LakeCoal

CHAIN VALLEY COLLIERY

EXTRACTION PLAN

MINIWALLS S2 and S3

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Company	LakeCoal Pty Ltd	
Mine	Chain Valley Colliery	
Development Consent	SSD-5465 MOD 2	
Mining Leases	ML1632	
Author(s)	David Hill, Tim Chisholm, Wade Covey, Chris Armit	
Document	Chain Valley Colliery Extraction Plan – Miniwalls S2 and S3	
Revision	0	Date: 06/03/19
Reviewed by:		Ben Smith Technical Services Manager
Authorised by:		Gary Cambourn General Manager

1.0 Introduction

1.1 Background

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[illegible] re[illegible]ed [illegible] within “Area A” [illegible] 2 [illegible] de[illegible]ig[illegible]ed [illegible] [illegible]ide [illegible] M[illegible] [illegible]ide[illegible] [illegible]rrier [illegible] M[illegible] [illegible] [illegible]rrier [illegible] **Figure 1** [illegible] de[illegible]ig[illegible] re[illegible]uire[illegible] [illegible]ide[illegible] [illegible] **Strata2, 2018** [illegible]ide[illegible] [illegible] [illegible]udie[illegible] **MSEC, 2018** [illegible]

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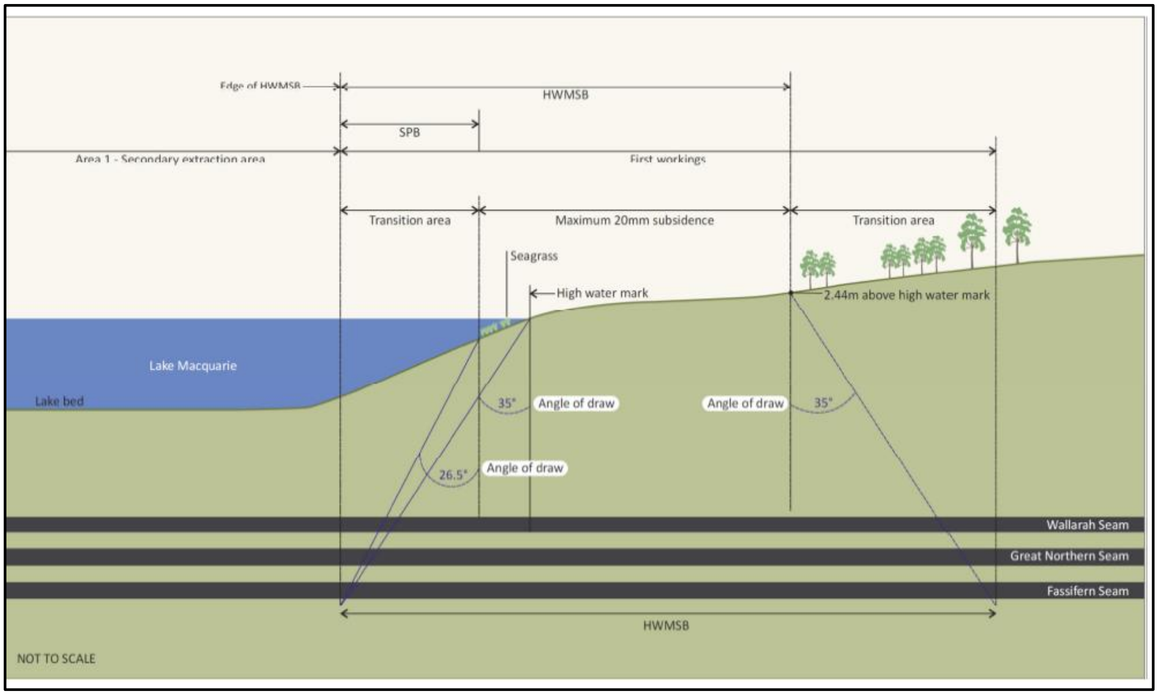

Figure 1- Protection Barrier Schematic

1.2 Scope

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“The Applicant shall prepare an Extraction Plan for all second workings on site, to the satisfaction of the Secretary.”

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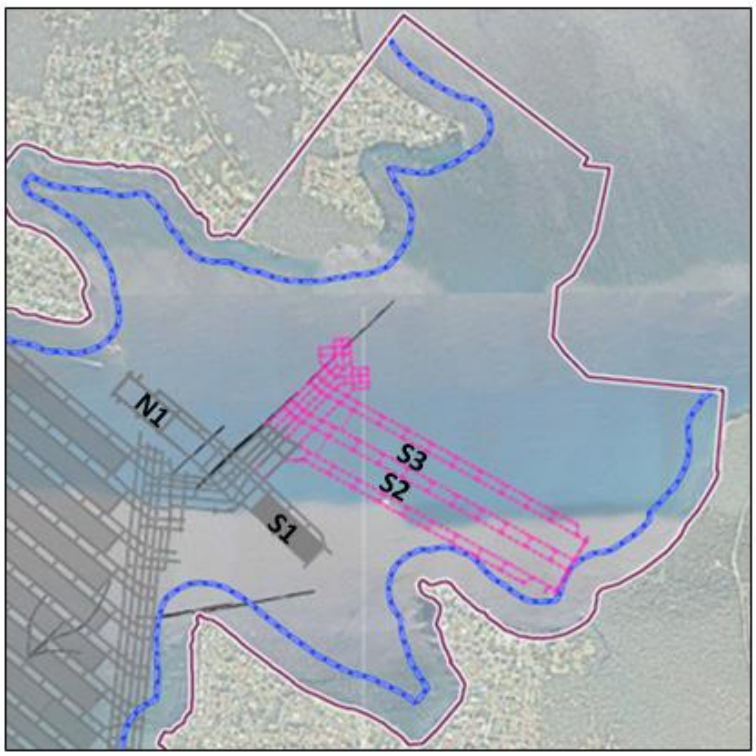

Figure 2- S2 and S3 Extraction Plan Locality

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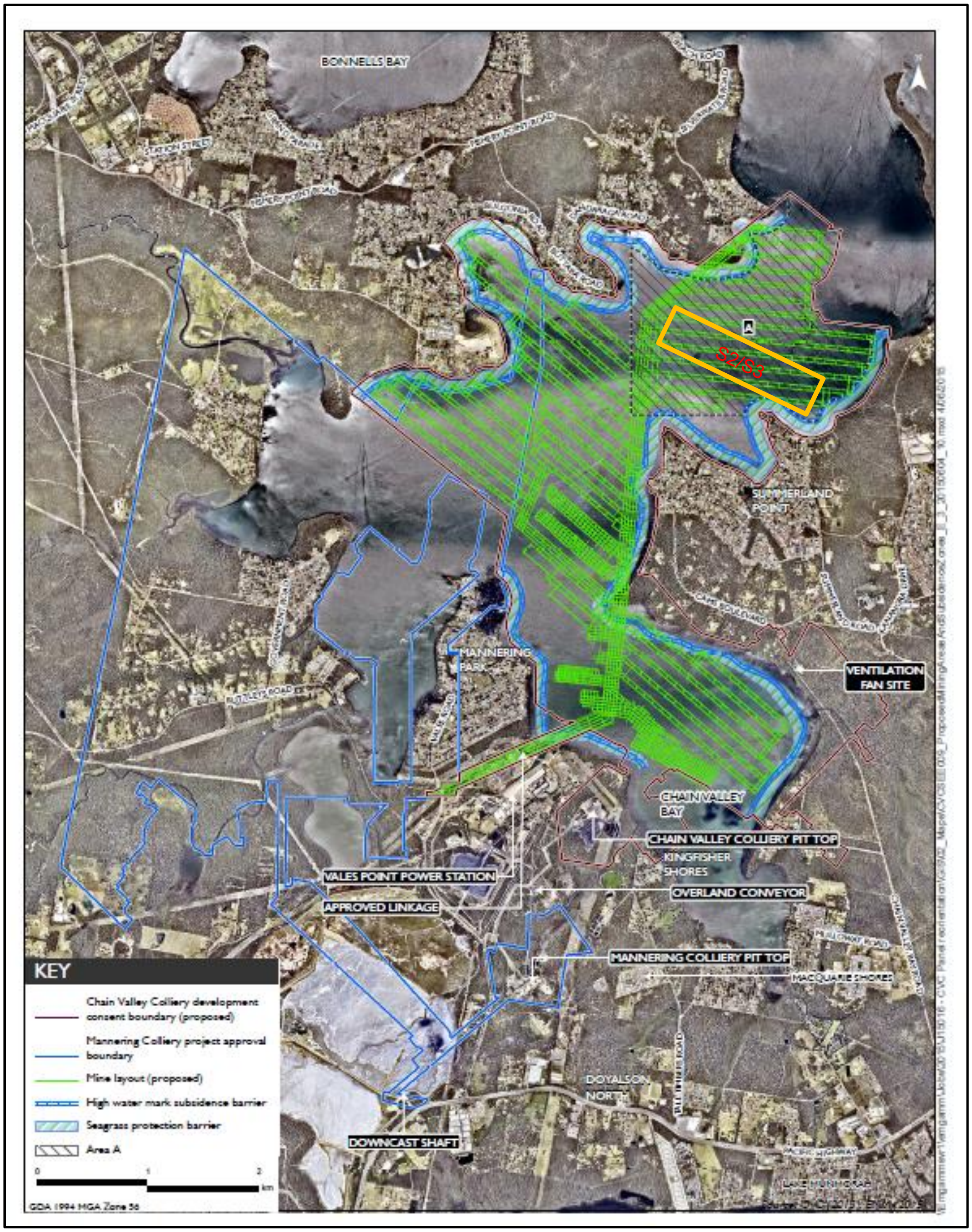

Figure 3- Approved Mining Extension Area including Proposed S2 and S3 Location within Area A

1.3 Development Consent Conditions

[illegible] **Table 1.**

Table 1 – Development Consent Conditions

Development Consent Condition - Condition 7 of Schedule 4	Document Reference
[illegible]	
a) [illegible]	[illegible]
b) [illegible]	[illegible]
c) [illegible]	[illegible]
d) [illegible]	[illegible]
e) [illegible]	[illegible]
f) [illegible]	[illegible]
g) [illegible] • [illegible] • [illegible] • [illegible]	[illegible]
• [illegible]	[illegible]

• [illegible]	
• [illegible] • [illegible] • [illegible] • [illegible]	
[illegible] • [illegible] • [illegible]	[illegible]
[illegible]	[illegible]
[illegible] • [illegible] • [illegible] • [illegible] • [illegible]	[illegible]
d [illegible]	[illegible] 2 [illegible]
e [illegible] 2 [illegible]	[illegible]
[illegible]	[illegible]

1.4 Objective

[illegible]

- [illegible] reduce identified [illegible]
- [illegible]

2.0 Extraction Plan Development

[illegible]

- [illegible] (**Strata2, 2018**); and
- [illegible] (**MSEC, 2018**)

[illegible] (**DGS Report CHV-002-10b**) [illegible] (**DGS Report CHV-002-11a**) [illegible]

2.1 Project Team

[illegible] **Table 2** [illegible]

Table 2- Project Team

Name	Company	Technical Area
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible] Mining Engineering
[illegible]	[illegible]	[illegible] Mine Design [illegible]
[illegible]	[illegible]	Mine [illegible]

[illegible]

[illegible] **Table 3.**

Table 3 - Specialist Consultants

Management Plan	Developed By	Associated Specialist Company	Specialist Name	Specialisation/Notes
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]			
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]			

Management Plan	Developed By	Associated Specialist Company	Specialist Name	Specialisation/Notes
[illegible]	[illegible]			
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

2.2 Agency Consultation

[illegible]

2.3 Landholder and Community Consultation

[illegible]

[illegible]

[illegible] subsidence monitoring and reporting [illegible]

2.4 Infrastructure Owner Consultation

[illegible] infrastructure identified within the [illegible]2 and [illegible] extraction plan area [illegible] during the development [illegible] referred the matter to the [illegible] resulting in [illegible] further immediate [illegible] required in regard [illegible]

[illegible]

2.5 Subsidence Predictions and Impact Review

[illegible] original subsidence [illegible] (**DGS, 2015**) [illegible] subsidence [illegible] reviewed [illegible] subsidence data [illegible] included updated subsidence data from Mine [illegible] existing [illegible] subsidence data from surrounding extracted [illegible] subsidence data [illegible] Mine [illegible]2 [illegible] subsidence [illegible] predicted [illegible] (**DGS CHV-002-10b**).

[illegible] subsidence [illegible] resulting in subsidence [illegible] original predictions [illegible] predicted [illegible] the data and [illegible] indicating [illegible] subsidence [illegible] driven [illegible]

(i) [illegible] increase in [illegible] Mudstone [illegible] and [illegible] in overburden [illegible]

(ii) [illegible] increased [illegible] developing [illegible] exceeded the bearing strength [illegible] moisture [illegible]

[illegible]2 and [illegible] design [illegible]

- [illegible] previously [illegible] and
- [illegible]2 [illegible] increased from [illegible]2 [illegible] (**Strata2, 2018**).

[illegible] subsidence predictions [illegible] developed for [illegible] revised [illegible] (**MSEC, 2018**).

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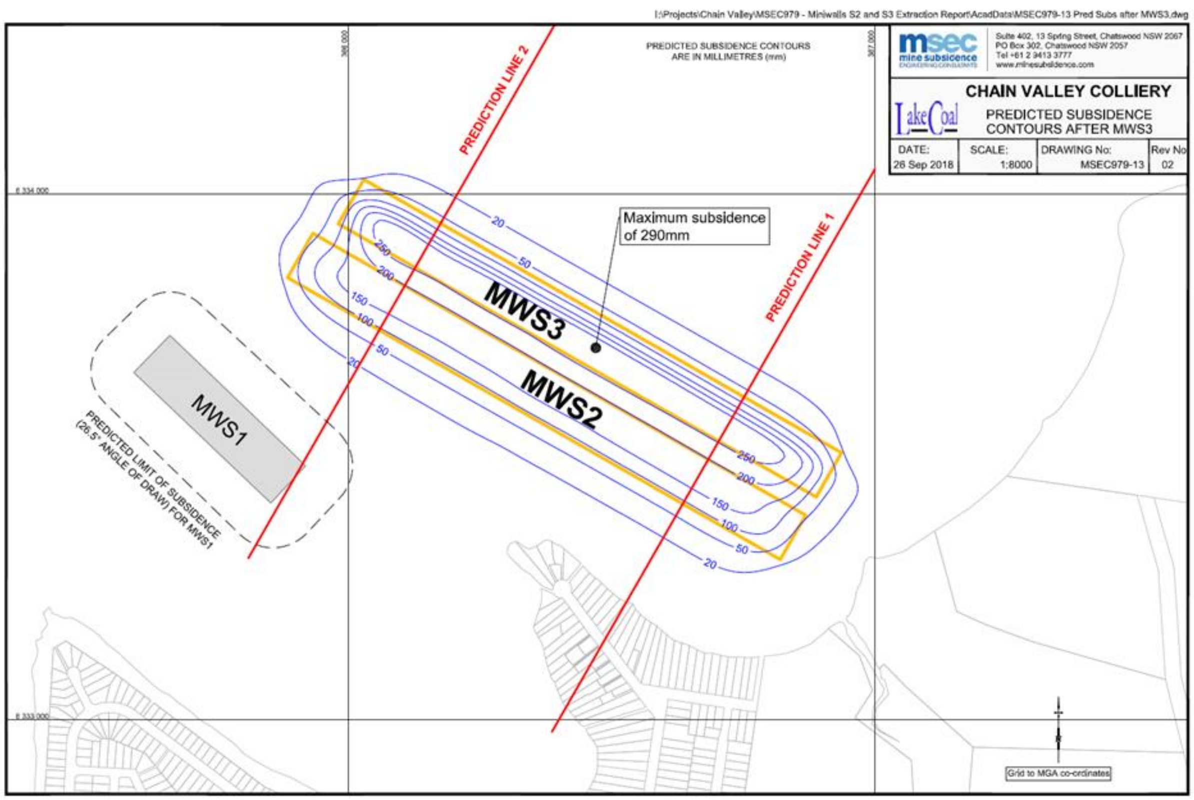

Figure 4: Predicted subsidence contours after S2 and S3

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3.0 Overview

3.1 Mine Planning and Design

3.1.1 Area covered by this Extraction Plan

[illegible] (see **Plan 4, Appendix 9**). [illegible]

[illegible] (see **Figure 5**). [illegible]

[illegible] (see **Figure 5**). [illegible]

3.1.2 Proposed mine layout

[illegible]

- [illegible] Section 2.5 [illegible]
- [illegible]
- [illegible]

[illegible]

Table 4: Mine Plan Change

Approved Layout Change	Justification for Modification
[illegible]	[illegible]
[illegible]	[illegible]

[illegible]

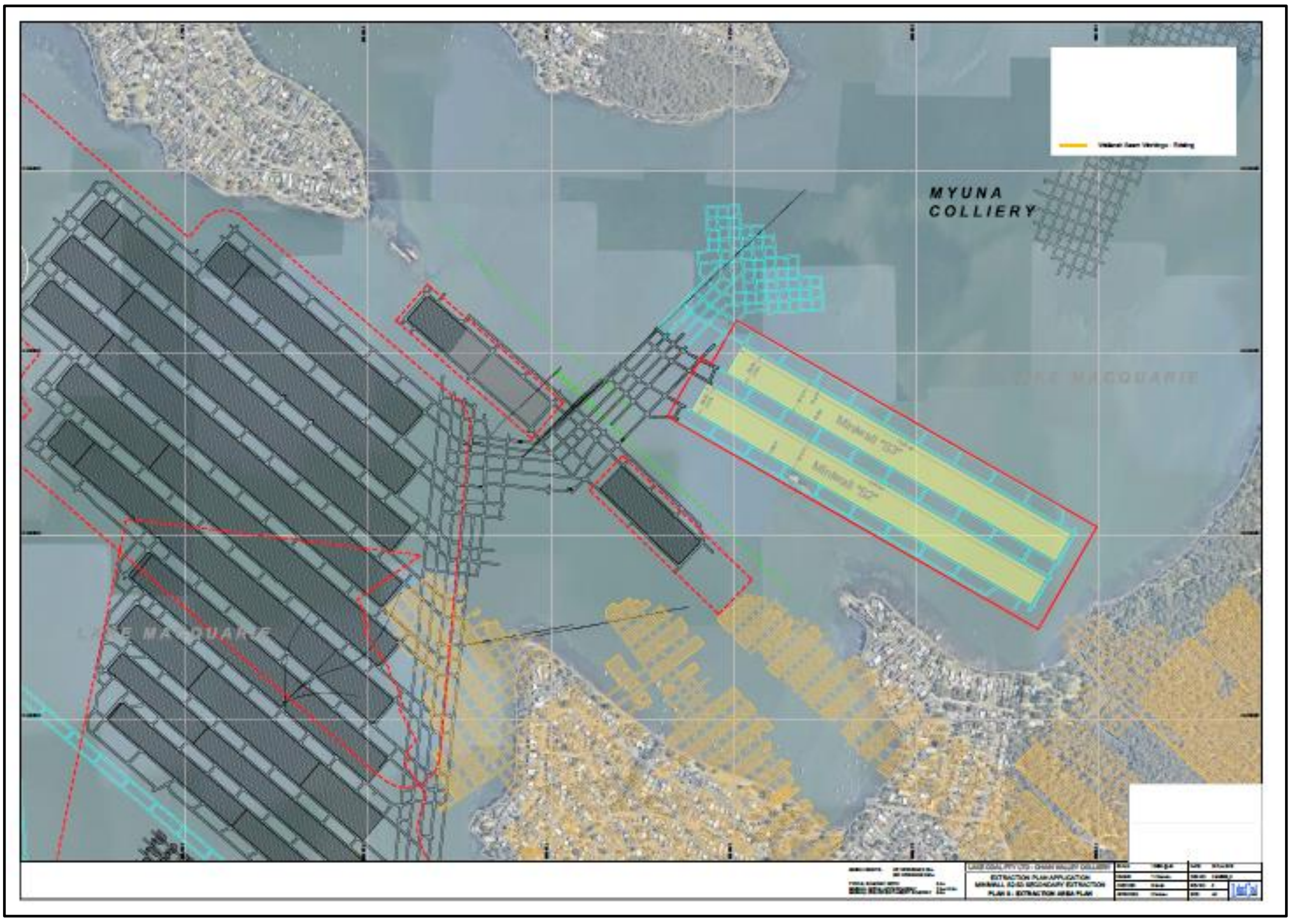

Figure 5- Aerial Photograph with mine plan overlay

3.1.3 Mining Domains □e□r□□□ed □□d □□□r□□ed□

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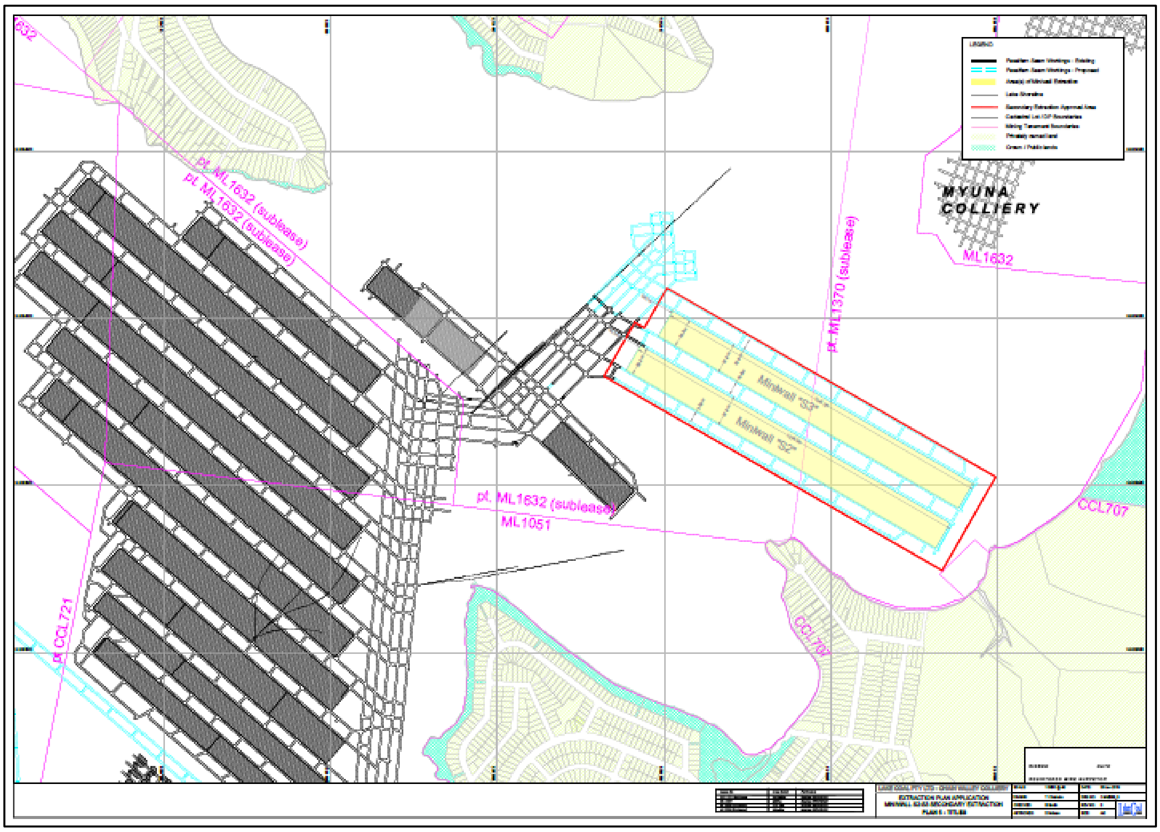

Figure 6- Chain Valley Bay Leases and Land Ownership

Overlying Wallarah Seam Workings

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Existing Chain Valley Colliery First Workings and Extraction

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Future Chain Valley Mining

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3.1.4 Mining parameters

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- [illegible] **Plan 1, Appendix 9** [illegible]

[illegible]

[illegible]

Tables 5 to 8 [illegible]

Table 5 - Coal Recovery within the Extraction Plan Area

Total Resource (Extraction Plan area 37.3ha)	**3.0Mt**
Total Development extraction	**0.21Mt**
Total Miniwall Extraction	**0.97Mt**
Total Reserves Extracted	**1.18Mt**
Percentage Recovery	**39%**

Table 6 - Miniwall Panel Geometry

Panel	Panel Length (m)	Void Width (m)	Extraction Height (m)	ROM Tonnes (Mt)
[illegible]2	[illegible]	[illegible]	[illegible]	[illegible] M[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible] M[illegible]

Table 7- Fassifern Seam Parameters and Development Roadway Geometry

Panel	Seam Thickness (m)	Depth of Cover (m)	Drivage Width (m)	Drivage Height (m)
[illegible]2	[illegible] – [illegible]	[illegible]	[illegible]	[illegible]2
[illegible]	[illegible] – [illegible]	[illegible]		

Table 8- Estimated Mining Schedule

Panel	Start Date	End Date	Estimated Duration (months)
[illegible]2	[illegible] 2[illegible]	[illegible]er 2[illegible]	[illegible]
[illegible]	[illegible]er 2[illegible]	M[illegible] 2[illegible]	[illegible]

3.1.5 Previous Wallarah Seam workings and multi-seam interactions

[illegible]

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- [illegible] carried [illegible] Mod 2 and Mod [illegible] 2 [illegible] ide [illegible] ed [illegible] M[illegible] 2 [illegible] eir [illegible] de[illegible] er [illegible] di[illegible] u[illegible] M[illegible] 2 and M[illegible] uld [illegible] ed [illegible] r [illegible] g[illegible]
- [illegible] carried [illegible] M[illegible] 2 and M[illegible] ed [illegible] ide [illegible] 2[illegible] and [illegible] g[illegible] dr[illegible] M[illegible] 2 and M[illegible] uld [illegible] ed [illegible] r [illegible] g[illegible]

3.1.6 Special subsidence management features

[illegible] ed [illegible] F[illegible] er [illegible] ed [illegible] under higher [illegible] ed [illegible] ed [illegible] er [illegible] ed [illegible] ed [illegible] er the **Strata2 Report CHV-006-Rev1** and **MSEC Report 979** [illegible] ed [illegible] F[illegible] ed [illegible] 2 [illegible] ed [illegible] d[illegible] er [illegible] irregular [illegible] ide[illegible] e[illegible]

[illegible] ed [illegible] 2 and [illegible] ed [illegible] erred [illegible] irregular [illegible] ide[illegible] e[illegible]

3.2 Subsidence Predictions

[illegible] ide[illegible] de[illegible] ed [illegible] Mi[illegible] e design [illegible] ier [illegible] ed [illegible] (**DGS, 2015**) [illegible] ed [illegible] ide[illegible] ed [illegible] **ACARP Project C10023 (ACARP, 2003)** [illegible] ide[illegible] d[illegible] ed M[illegible] ier[illegible] M[illegible] g [illegible] iery's LW17 to 23. [illegible] re[illegible] ed [illegible] M[illegible] 2 e[illegible] eed [illegible] (**DGS Report CHV-002-10b)** [illegible] ed [illegible] ide[illegible] (**DGS Report CHV-002-11a**)[illegible]

[illegible] g [illegible] ide[illegible] 2 and [illegible] ge[illegible] de[illegible] du[illegible] ed [illegible] 2 [illegible] g (**Strata2, 2018**) [illegible] d[illegible] ed [illegible] M[illegible] ide[illegible]

[illegible]

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- [illegible]
- [illegible]
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- [illegible]
- [illegible]

[illegible] **Table 9**[illegible]

Table 9 - Predicted Subsidence Effects (MSEC, 2018)

Panel	Subsidence (m)		Angle of Draw	Long-Term Tilt & Systematic Strain Maxima (mm/m)		
	Short-Term	Long-Term		Tilt	Tensile Strain	Compressive Strain
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

3.2.1 Lakebed fracturing

Ditton (2015) [illegible]

MSEC (2018) [illegible] of ≤ 10mm at the rock head extending to [illegible]

[illegible] that occur will be naturally ‘filled’ by lake bed sediments with no impact on [illegible]

3.2.2 Sub-surface Fracturing

[illegible] methods [illegible] been adopted for [illegible] the height [illegible] sub-surface fracturing [illegible]

i) [illegible] Ditton and Merrick (2014) [illegible]

ii) [illegible] 2012 [illegible]

[illegible] are addressed [illegible]

3.2.2.1 Ditton and Merrick (2014) Methodology

[illegible] Ditton and Merrick [illegible] Forster [illegible] Figure [illegible] sub-surface fracturing [illegible] predicted height [illegible] is termed the "A Horizon" ([illegible]) or "Fractured Zone" (Forster [illegible]).

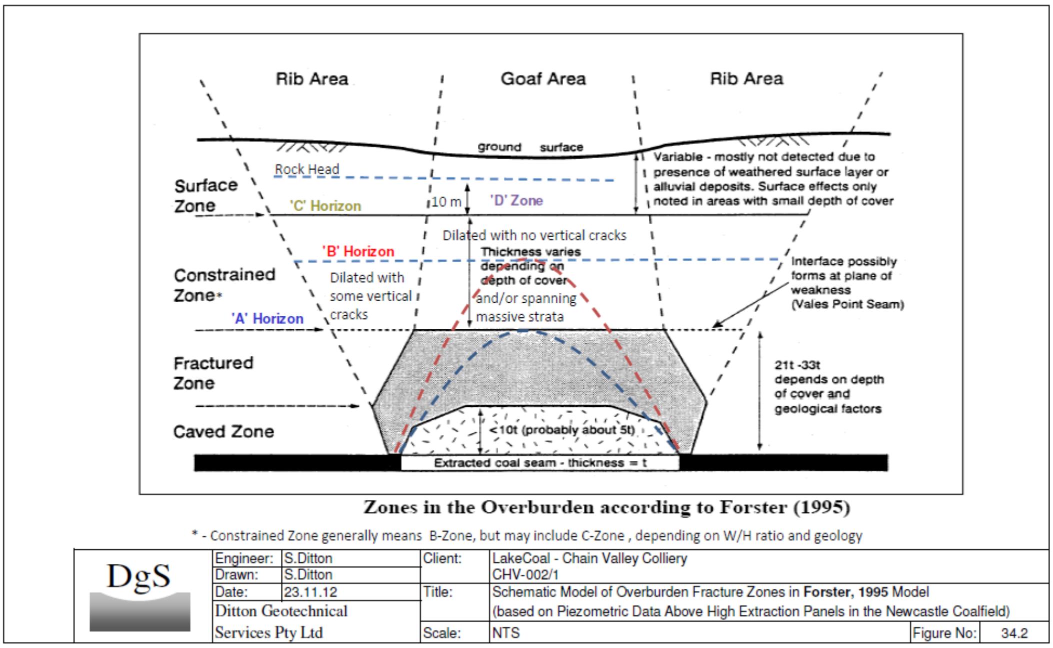

Figure 7- Overburden Fracture Zones (Ditton, 2013)

[illegible] **Ditton & Merrick (2014)** [illegible] the **Forster** [illegible] the original **Forster** [illegible] **DSG Report CHV-002-11a** [illegible] height [illegible] fracturing [illegible] height [illegible] fracturing prediction [illegible]

[illegible] results [illegible] height [illegible] are summarised in **Table 10**.

Table 10 - Predicted Heights of Fracturing Above Panels S2 and S3 (Strata2, 2018)

Panel (S=Start) (F=Finish)	Effective Cover Depth (m)	Rock Cover (m)	"A Zone" Height Range (Ditton and Merrick, 2014) (m)	Constrained Zone Thickness below Rock Head (m)	
				Predicted Minimum from Ditton and Merrick (m)	12T Criterion (m)
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[illegible] **Ditton and Merrick** [illegible] **(Forster, 1995)** [illegible] and haven't [illegible]

3.2.2.2 SCT (2008) Methodology

[illegible] (assuming a 'k' [illegible]

[illegible]

3.2.2.3 Conclusions regarding Sub-Surface Fracturing

[illegible]

3.2.3 Potential Environmental Consequences

[illegible] (**Appendix 2**).

- [illegible]
- [illegible]
- [illegible]
- [illegible]

[illegible] (**Section 3.1.2**) [illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

Table 13- Navigation Marker Predicted Subsidence Parameters

Location / ID	Predicted Subsidence (m)	Predicted Tilt (mm/m)
[illegible]	[illegible]	[illegible]

3.3 Performance Objectives

3.3.1 Development Consent Approval Requirements

[illegible]

"*The Applicant shall ensure that vertical subsidence within the High Water Mark Subsidence Barrier and within Seagrass beds is limited to a maximum of 20 millimetres (mm). If at any stage predicted subsidence levels are exceeded within these area, an ecological monitoring program shall be initiated to assess the impacts to ecological communities and threatened species and if appropriate, offsets are to be provided for any impacts detected"*

[illegible] **Section 3.4** [illegible]

[illegible]

"The Applicant shall ensure that the development does not cause any exceedance of the performance measures in Table 8 to the satisfaction of the Secretary."

[illegible] **Table 14**[illegible]

Table 14 - Performance Measures - Natural & Heritage Features

Biodiversity	
Threatened species or endangered communities	Negligible environmental consequences
Mangrove beds	Negligible environmental consequences including: • Negligible change in size and distribution of mangrove beds; • Negligible change in the function of mangrove beds; and • Negligible change to the composition or distribution of mangrove species within mangrove beds.
Benthic communities	Minor environmental consequences including minor changes to species composition and/or distribution.
Mine Workings	
First workings under an approved extraction plan beneath any feature where performance measures in this table require negligible environmental consequences	To remain long term stable and non-subsiding
Second workings	To be carried out only in accordance with an approved extraction plan

Notes:

• The Applicant will be required to define more detailed performance indicators (including impact assessment criteria) for each of these performance measures in the various management plans that are required under this consent (see Condition 7 below).

• Measurement and/or monitoring of compliance with performance measures and performance indicators is to be undertaken using generally accepted methods that are appropriate to the environment and circumstances in which the feature or characteristic is located. These methods are to be fully described in the relevant management plans. In the event of a dispute over the appropriateness of proposed methods, the Secretary will be the final arbiter.

• The requirements of this condition only apply to the impacts and consequences of mining operations, construction or demolition undertaken following the date of approval of this consent.

[illegible] first workings in the extraction plan area [illegible] beneath any feature outlined in **Table 14**, should a change to first workings be required, the first workings will be designed to be long term stable.

[illegible] Subsidence Management Plan will be implemented as outlined in **Section 3.4** of this management plan to determine [illegible] negligible/minor [illegible] includes more detailed performance indicators

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[illegible]

"The Applicant shall ensure that the development does not cause any exceedances of the performance measures in Table 9, to the satisfaction of the Secretary.

[illegible] **Table 15**[illegible]

Table 15 – Subsidence Impact Performance Measures – Built Features

[illegible]	
[illegible]	[illegible]
[illegible]	
[illegible]	[illegible]

Notes:

- *The Applicant will be required to define more detailed performance indicators (including impact assessment criteria) for each of these performance measures in measures in the Built Features Management Plans or Public Safety Management Plan (see Condition 7 below).*
- *Measurement and/or monitoring of compliance with performance measures and performance indicators is to be undertaken using generally accepted methods that are appropriate to the environment and circumstances in which the feature or characteristic is located. These methods are to be fully described in the relevant management plans. In the event of a dispute over the appropriateness of proposed methods, the Secretary will be the final arbiter.*
- *The requirements of this condition only apply to the impacts and consequences of mining operations, construction or demolition undertaken following the date of approval of this consent.*
- *Requirement's regarding safety or serviceability do not preclude preventative actions or mitigation being taken prior to or during mining in order to achieve or maintain these outcomes.*
- *Requirement's under this condition may be met by measures undertaken in accordance with the Mine Subsidence Compensation Act 1961.*

[illegible]

[illegible] **Section 3.4** [illegible]

3.3.2 Other Approval Requirements

[illegible]

- [illegible]

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3.4 Subsidence Management Strategies

3.4.1 Mine design elements

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3.4.2 Subsidence Monitoring and Management

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Figure 10- Subsidence Monitoring and Management Framework

[illegible] **Section 4** [illegible] **Appendix 2** [illegible]

3.4.3 Remediation strategies

[illegible] **Appendix 2** [illegible] **Appendix 8** [illegible]

3.4.4 Adaptive Management Strategy

[illegible]

3.4.5 Procedures for investigation of incidents

[illegible]

[illegible]

[illegible]

3.4.6 Procedures for quality assurance and review

[illegible]

[illegible]

- [illegible]
- [illegible]
- [illegible]

[illegible]

3.4.7 Complaints

[illegible]

4.0 Key Component Plans

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Table 16 –Key Component Plan Requirements

	Relevant to S2 and S3	Comments
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Groundwater Management Plan

[illegible] **Appendix 1** [illegible]

- [illegible]
- [illegible]
- [illegible]

[illegible]

Biodiversity Management Plan

[illegible] **Appendices 5 and 4** [illegible]

[illegible]

[illegible]

Public Safety and Built Features Management Plans

[illegible]

[illegible]ed on Chain Valley Colliery's approved mine design principles mining is not expected to result in [illegible]

[illegible]

LAST REVIEW DATE	NEXT REVIEW DATE	REVISION NO	DOCUMENT OWNER
		[illegible]	[illegible]

5.0 *Subsidence Effects and Environmental Monitoring Program*

5.1 Monitoring Program Summary

The proposed Subsidence Monitoring Program is included in **Appendix 7** of this document. Environmental monitoring programs are summarised within each of the relevant management plans. Effective subsidence management is achieved through a combination of conservative mine design and continuous monitoring of subsidence related effects and is [illegible] in the Subsidence Management Plan. [illegible] regular and routine monitoring [illegible] provide a means to verify and validate that predicted subsidence levels are not being exceeded and if the resultant levels of subsidence are resulting in effects [illegible] those predicted, the mine design can then be adjusted and revised as required if exceedances occur or are likely to occur.

[illegible] surveys of the [illegible] bed and surveys of the [illegible] will be used to validate and confirm the predicted vertical subsidence around the mining [illegible]. In addition, ongoing environmental monitoring in the form of [illegible] surveys will ensure that the resultant vertical subsidence levels are not resulting in a more significant impact than predicted. **Appendix 4 and 5** contain the mine's [illegible] Management Plans.

Monitoring [illegible] pressure heights [illegible] will [illegible] be recorded within the mining area to confirm the predictions [illegible] surface [illegible] due to the presence of the [illegible] heights [illegible] the proposed mining [illegible] due to the risks associated with the drilling [illegible] drilling rig [illegible] mining [illegible] monitoring [illegible] will be utilised to provide an indirect measure [illegible] between the [illegible] and mine workings.

LAST REVIEW DATE	NEXT REVIEW DATE	REVISION NO	DOCUMENT OWNER
		[illegible]	Mine Manager [illegible]
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[illegible]

[illegible]

[illegible] **Appendix 2** [illegible]

6.0 *Plan Implementation*

6.1 Reporting

Incident Reporting

[illegible] **Section 3.4.5** [illegible]

Regular Reporting

[illegible]

Annual Reporting

[illegible]

[illegible]

[illegible]

[illegible]

- [illegible]
- [illegible]
- [illegible]

[illegible]

[illegible]

[illegible]

[illegible]

6.2 Review

[illegible] February 2016 and on a 3 yearly basis after that, the mines' environmental management systems will [illegible]

6.3 Responsibilities

[illegible] **Table 17** [illegible]

Table 17 - Roles and Responsibilities

Role	Responsibilities
Manager – Mining Engineering	• Provide adequate resources for the activities required under this plan. • Ensure all operations are undertaken in accordance with this plan. • Ensure all mining is undertaken in accordance to approved mine plans.
Technical Services Manager	• Provide adequate resources for the activities required under this plan. • Provide technical review and assistance during the development of the extraction plan and its amendments. • Coordinate technical sub consultants used to work on this extraction plan.
Environmental and Community Coordinator	• Coordinate and undertake the environmental monitoring required under this document. • Ensure all reporting and monitoring is completed to an appropriate standard and in a timely manner. • Ensure that discrepancies between actual monitoring results and predicted outcomes are reported to appropriate stakeholders as soon as practicable. • Manage the implementation of the environmental management plans under this document. • Be responsible for all environmental reporting, management plans, community consultation and communication with stakeholders and government authorities.
Mine Surveyor	• Preparation of the subsidence monitoring program. • Coordinate and undertake all subsidence monitoring required under the Subsidence Monitoring Program. • Maintain plans and records of all subsidence monitoring. • Distribute survey data to the relevant stakeholders within agreed timeframes. • Report any discrepancies and/or exceedances of the survey results from expected/predicted data to the ECC Coordinator and Manager – Mining Engineering. • Prepare all subsidence related reporting to an appropriate standard.

7.0 References

[illegible]MM [illegible] **Chain Valley Colliery Mining Extension 1 Project, Environmental Impact Statement.** [illegible]

[illegible]MM [illegible] **Chain Valley Colliery Modification 2, Statement of Environmental Effects.** [illegible]

[illegible] **Subsidence Predictions and General Impact Assessment for the Chain Valley Colliery – Modification 2** [illegible]

[illegible] **Updated Investigation Report into the Maximum Subsidence Prediction Exceedances over the Miniwalls 1 to 12 at Chain Valley Colliery.** [illegible]

[illegible] **Subsidence Impact Assessment of the Proposed Northern Area Miniwalls (S1 and N1) at Chain Valley Colliery.** [illegible]

[illegible] Merri [illegible] **A New Sub-surface Fracture Height Prediction Model for Longwall Mines in the NSW Coalfields.** [illegible]

[illegible] **Impact of Underground Coal Mining on the Hydrogeological Regime, Central Coast, NSW** [illegible]

[illegible] **Subsidence Predictions and Impact Assessments for the Natural and Built Features due to the Extraction of the Proposed Miniwalls S2 and S3 in Support of the Extraction Plan** [illegible]

[illegible] **Aquifer Inflow Prediction above Longwall Panels** [illegible]

[illegible] **Geotechnical Aspects of S2 and S3 Panel Design** [illegible]

[illegible] **Subsidence: Occurrence, Prediction and Control** [illegible]

WRAC Risk Assessment

Workplace Risk Assessment & Control

RA 00278 - S2 and S3 Miniwall Extraction Plan Risk Assessment

Site: Chain Valley Colliery

Date: 25/02/2019

No:	RA 00278 - S2 and S3 Miniwall Extraction Plan Risk Assessment		
Topic	S2 and S3 Miniwall Extraction Plan Risk Assessment		
Venue	CVC Boardroom		
Requested by:	Wade Covey Environment and Community Coordinator	**Date:** 25/02/2019	**Time allowed:** ½ day
Facilitator	Wade Covey Environment and Community Coordinator		

Relevant Risk Assessment Documents/Procedures/Safety Alerts/Safety Bulletins

- MSEC (2018) Subsidence Assessment – S2/S3 Miniwall panels
- Strata2 Geotechnical Assessment – S2/S3 Miniwall panels

Persons participating in Risk Assessment

Name	Position	Years' Experience in Industry	Signature
Chris Armit	Environmental/Mining/Geotech.	19	
David Hill	Geotechnical Engineer	39	
Liam Kirk	Geotechnical Engineer	7	
Wade Covey	Environmental Coordinator	13	

Purpose

This risk assessment has been conducted to assess and document potential surface and sub-surface subsidence risks associated with mining of Northern Mining Domains (NMD) Miniwall's S2 to S3.

Objectives and Scope

The objectives of this risk assessment are to :

- Identify hazards and assess the risk associated with environmental, public safety and surface built feature impacts from extraction.
- Ensure compliance with the WHS (Mines) Regulation 2014 Clause 67 Subsidence:
  (1) In complying with clause 9, the mine operator of an underground coal mine must manage risks to health and safety associated with subsidence at the mine.
  (2) Without limiting subclause (1), the mine operator must ensure that:
    (a) So far as is reasonably practicable, the rate, method, layout, schedule and sequence of mining operations do not put the health and safety of any person at risk from subsidence, and
    (b) Monitoring of subsidence is conducted, including monitoring of its effects on relevant surface and subsurface features, and
    (c) Any investigation of subsidence and any interpretation of subsidence information is carried out only by a competent person, and
    (d) All subsidence monitoring data is provided to the regulator in the form and at the times required by the regulator, and
    (e) So far as reasonably practicable, procedures are implemented for the effective consultation, co-operation and co-ordination of action with respect to subsidence between the mine operator and relevant persons conducting any business or undertaking that is, or is likely to be, affected by subsidence.
- Meet (where applicable) the standards for assessing and managing risks of subsidence as outlined in the "Managing Risks of Subsidence Guideline", February 2017.
- Place a particular focus on recently updated subsidence predictions and recommendations for the area including a review of causal factors behind the exceedance of subsidence predictions over the MW 1 to 12 area.
- Identify the existing and potential controls to reduce the risk to a reasonable practicable level.

The scope of the risk assessment focuses on the extraction area defined by a 35 degree angle of draw or to the predicted 20mm subsidence contour of S2 to S3 (see **Figure 1**). The level of monitoring strategy required will be commensurate with the assessed level of risk (ie after controls are put in place) or potential consequence. The corresponding residual risk will determine if these controls are sufficiently acceptable.

The list of surface and sub-surface features outlined in Appendix B of the 2003 NSW Department of Mineral Resources Guidelines for Application for Subsidence Management Approvals, along with items outlined in the 2017 Managing Risks of Subsidence Guideline, have been used as a starting reference list of features for assessment. All features on the list were assessed as to whether they exist within the defined extraction plan area. Where a feature is not noted in the WRAC assessment, it has not been identified within the area of interest.

Figure 1- NMD S2 to S3 Extraction Impact area (area of change) due to Fassifern Miniwall Mining

Risk Assessment Process

1. Hazard identification
2. Identified hazards were evaluated with regard to consequence and then the Likelihood of that consequence outcome was assessed, assuming existing controls to be effectively implemented.
3. Risk rankings were derived.

4. Additional controls were proposed where possible for medium and high risks and the hazards were re-evaluated to arrive at the residual risk.
5. Likelihood and consequence were assessed in accordance AS/NZS ISO 31000:2009 Risk Management – Principles and guidelines.
6. This risk assessment was conducted in general compliance with MDG1010 and MDG1014.
7. As low as reasonably practicable (ALARP) is determined from WHS Act 2011, Section 18.
8. Hazardous Manual Tasks should be identified and controlled to a reasonable practicable level of risk using the Risk Assessment Worksheet for Hazardous Manual Tasks Form and actions recorded in this risk assessment.
9. Actions and outcomes from the risk assessment are recorded with a due date of action completion and responsible person.
10. Risk Assessments are monitored and reviewed as detailed by the LakeCoal Site Work Health and Safety Management System.

Risk Assessment Checklist based on Hazard / Energy Types

Energy Type	POTENTIAL HAZARDS			
	To People	**To Equipment**	**To Production**	**To The Environment**
Electrical	• Electric Shock • Burns • Smoke Inhalation	• Unplanned movement • Fire • Circuit Damage	• Supply fails causing shutdown • Inadequate supply causing process slowdown	• Fire
Mechanical	• Crushed • Struck by Moving or Flying Objects • Caught Between Moving Objects	• Collision • Breakdown • Unplanned Movement • Breakages • Vibration	• Fails & Causes Shutdown • Slows Down Production	• Physical Damage • Fire
Chemical	• Burns • Skin Irritation • Ingestion • Inhalation (Toxic atmospheres) • Explosion (Mixing incompatible)	• Fire • Internal Damage • Corrosion	• Causes Delays or Shutdowns (Not enough, wrong type to much)	• Spillage (Water contamination, soil contamination, air pollution, vegetation destroyed)
Pressure (Fluids/Gases)	• Fluid Injection • Crush • Respiratory Problems	• Unplanned Movement • Poor Performance • Breakdown	• Equipment Failure Shutdown (No fluids or to much fluids, no gases or to much gases)	• Contamination (Dust, fuel/oil, dirty water0
Radiation	• Burns • Eye Damage (welding flash) • Internal problems		• Source fails (Causing delays or shutdown)	• Contamination
Thermal	• Burns • Heat Exhaustion • Frostbite	• Overheating • Freezing	• Shutdown (Overheating or freezing)	
Biochemical	• Sprains • Strains		• Slowdown due to loss of staff	
Noise/Vibration	• Hearing damage	• Mechanical damage	• Slowdown due to people not accessing area	• Community complaints
Biological	• Illness • Disease		• Shutdown due to lack of people	
Gravitational	• Falling from Heights • Objects falling on Personnel	• Rollover • Collapse • Failure • Damage from fall • Damage from	• Objects falling causing slowdown or shutdown	• Contamination

		objects falling		

Risk Matrix

Hierarchy of Control		Likelihood			
Elimination	Do we still have to do this?	A	Almost certain to happen	FREQUENCY	1 per week to 1 per month
Substitution	Is there another way or product?	B	Likely to happen at some point		1 per month to 1 per year
Redesign/Engineer	Can the equipment or process be modified?	C	Moderate, possible; heard of so it might happen		1 per year to 1 per 10 years
Isolation/Guarding	Will guarding or some type of barrier help?	D	Unlikely, not likely to happen		1 per 10 years to 1 per 100 years
Administration	Will a written procedure and/or training help?	E	Rare, practically impossible		Less than 1 per 100 years
PPE	Is personal protective equipment adequate?				

Maximum Reasonable Consequence

Consequence	Injury (I)	Environmental (E)	Loss (L)
1 - Critical	Could kill, permanently disable	Regional environmental impact/ecosystem damage. Impact causing mine or business closure. E.g. Major release off site with long term detrimental effect	Could cause very major damage > $3M
2 - High	Could cause serious injury (major LTI)	Substantial environmental damage which could result in major financial loss and/or prosecution. E.g Off-site release resulting in local ecosystem damage	Could cause major damage $500K - $3M
3 - Medium	Could cause typical MTC/LTI	Substantial temporary or minor long term damage, release immediately contained with outside assistance eg. A minor water discharge or large hydrocarbon spill. Legal non-compliance.	Could cause moderate damage $100K - $500K
4 - Low	Could cause first aid injury	Temporary or minor damage, non-compliance with internal environmental target, no legal breach, eg. Minor spill	Could cause damage $20K - $100K
5 - Insignificant	Couldn't cause injury	No detrimental effect, low financial loss, negligible environmental impact	Couldn't cause damage, or <$20K damage

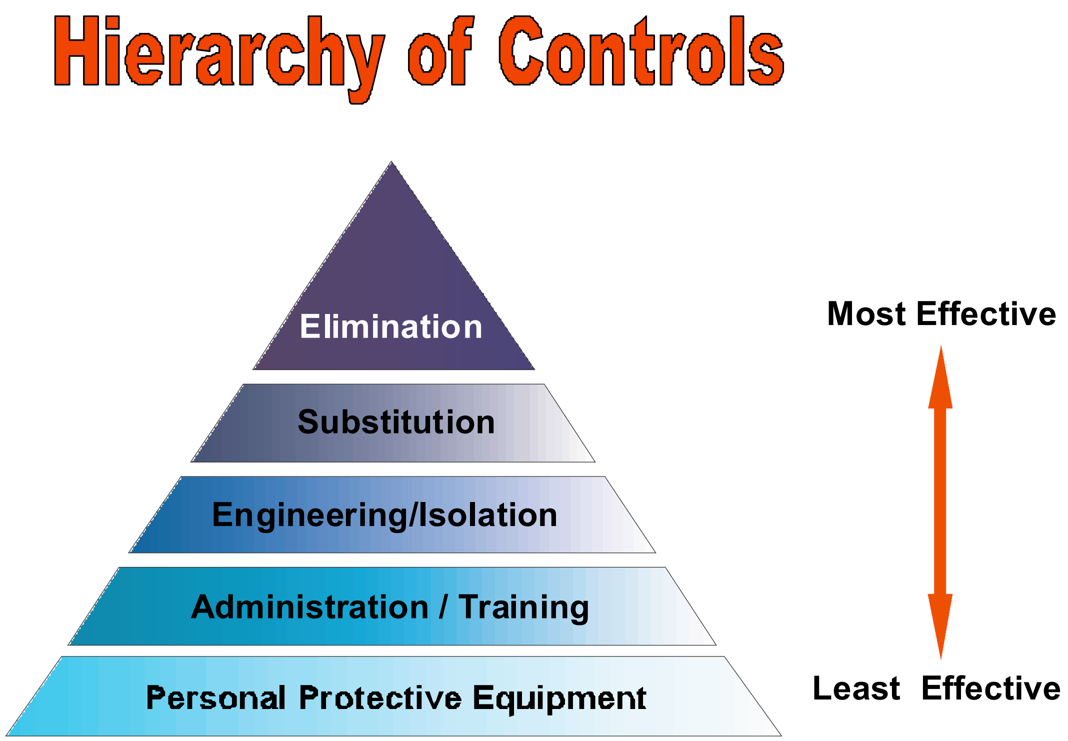
Risk Score Matrix

Risk Score	Risk	What should I do?
1 to 3	Critical	STOP WORK Immediate action required, inform senior management
4 to 10	High	Risk Assessment required. Action plan required, senior management attention needed
11 to 15	Medium	Specific monitoring of procedures required management responsibility must be specified
16 to 25	Low	Manage through routine procedures

Consequence \ Likelihood	A- Certain	B - Likely	C - Moderate	D - Unlikely	E - Rare
1 - Critical	1	2	4	7	11
2 - High	3	5	8	12	16
3 - Medium	6	9	13	17	20
4 - Low	10	14	18	21	23
5 - Insignificant	15	19	22	24	25

Least Effective ↕ Most Effective

Hierarchy of Controls (as per WHS Regulations 2011 Clause 36)



HIERARCHY OF CONTROLS 1-6 Descending Order(as per WHS Regulations 2011 Clause 36)	
Elimination	Remove the hazard from the workplace (Re-Design)
Substitution	Substituting (wholly or partly) the hazard giving rise to the risk with something that gives rise to a lesser risk. (Alternative product / plant)
Isolation	Isolating the hazard from any person exposed to it. Use barriers to shield or isolate the hazard (Guards on machines, enclosures for noises)
Engineering controls	Design & install equipment to counteract or lessen the hazard
Administrative controls	change to a system of work, a process or a procedure to lessen the hazard
Personal Protective Equipment	ensuring the provision and use of suitable personal protective equipment

Hazard Analysis and Risk Assessment

The risk management methodology as described in WHS Act 2011, WHS Regulations 2011, WHS Code of Practice WHS Act 2011, Section 274, Code of Practice –How to Manage Work, Health and Safety Risks 2011, MDG1010 and AS/NZS ISO 31000:2009 is used to identify the various processes and activities at LakeCoal sites.

Risk analyses shall be completed for each activity based on the following matrix. The subsequent risk ranking shall then determine the frequency of re-assessments.

Likelihood	Consequences
A. Almost certain to happen	1. Permanently disable.
B. Like to happen at some point	2. Could cause serious injury (Major LTI)
C. Moderate, possible, heard of so it might happen	3. Could cause Medical Treatment Case/ LTI
D. Unlikely, not likely to happen	4. Could cause First Aid Treatment
E. Rare, practically Impossible	5. Could not cause injury

Likelihood and Consequences are applicable to Table 1 below.

		LIKELIHOOD				
CONSEQUENCE		A – Certain	B – Likely	C – Moderate	D – Unlikely	E - Rare
	1 - Critical	1	2	4	7	11
	2 - High	3	5	8	12	16
	3 - Medium	6	9	13	17	20
	4 - Low	10	14	18	21	23
	5 - Insignificant	15	19	22	24	25

Facts

- Extraction is to occur in the Fassifern seam utilising miniwall extraction methods and solely beneath Lake Macquarie (ie outside the High Water Mark Subsidence Barrier and Seagrass Protection Barrier).
- S2 to S3 extraction depth of cover ranges between an effective depth of 142-165m. The panels are at >35^{0} angle of draw to the foreshore.
- Both miniwalls have a void width of 97m and an inter panel pillar width of 40m.
- No extraction is planned within the High Water Mark Subsidence Barrier (HWMSB) and Seagrass Protection Barrier (SPB)
- Updated predictions for subsidence over the MW1 to 12 area of 720mm were exceeded in the MW7 to 10 area with up to 1100mm recorded (a further 150mm of creep movement could be expected). The subsidence model has since been reviewed and amended to align with this increase, and to gain an understanding of the potential mechanisms behind the increase. This model and information has been utilised to develop a mine plan and updated predictions for the NMD such that predicted subsidence is planned to remain within the approved 780mm for the domain allowing for anticipated longer term creep.
- A detailed subsidence assessment has been undertaken for miniwalls S2 and S3 by Mine Subsidence Engineering Consultants (MSEC). The assessment has indicated that the subsidence results over the miniwalls will result in approximately 290mm of vertical subsidence and 6mm/m tilt. Predicted vertical subsidence at the sea grass beds/moorings and jetties is predicted to be less than 20mm. The expected subsidence at Pelican rock is expected to be in the order of 90mm.
- Strata2 Consulting has undertaken a detailed geotechnical design report for the miniwall layout which has formed the basis for the mine design used in the subsidence assessment.
- LakeCoal has successfully mined Miniwall S1 in the NMD with subsidence monitoring results at the foreshore well within predictions.
- LakeCoal has completed a rock head survey of the NMD which has formed the basis for the key assumptions used in the technical reports.
- The location of the maximum predicted subsidence is located beneath Lake Macquarie within the FAS working footprint (ie outside the foreshore and mapped seagrass areas) **Figure 1**.

Assumptions

- Employees are trained and assessed in relevant contents of the LakeCoal site WHSMS as a minimum.

- Compliance with the Environmental Protection Act 1994, Environmental Planning and Assessment Act 1979, Work Health and Safety Act 2011 and Work Health and Safety Regulations 2011, Code of Practice –How to Manage Work, Health and Safety Risks 2011, AS/NZS ISO 31000:2009 Risk Management – Principles and Guidelines.
- Compliance with the Lake Coal Environmental Management System
- Compliance with the Work Health and Safety Act 2011 and Work Health and Safety Regulations 2011, Code of Practice –How to Manage Work, Health and Safety Risks 2011, AS/NZS ISO 31000:2009 Risk Management – Principles and Guidelines.

Monitoring and Review

LakeCoal site monitoring and review processes should encompass all aspects of the risk management process for the purposes of:

- ensuring that controls are effective and efficient in both design and operation;
- obtaining further information to improve risk assessment;
- analyzing and learning lessons from events (including near-misses), changes, trends, successes and failures;
- Identifying emerging risks.

References

- AS/NZS ISO 31000:2009 Risk Management – Principles and Guidelines
- MDG1010 – Risk Management Handbook for the Mining Industry
- MDG1014 - Guideline to reviewing a risk assessment of mine equipment and operations
- Work Health and Safety Act 2011
- Work Health and Safety Regulations 2011
- Codes of Practice –WHS Act 2011, Section 274.
- Work Health and Safety Mines Act 2013
- Work Health and Safety Mines Regulations 2014
- AS/NZS ISO 31000:2009 Risk Management – Principles and Guidelines
- MDG1010 – Risk Management Handbook for the Mining Industry
- MDG1014 - Guideline to reviewing a risk assessment of mine equipment and operations

- Environmental Protection Act 1994
- Environmental Planning and Assessment Act 1979
- DGS, 2017. Multi-Seam Mining Feasibility Study for the Proposed Miniwalls CVB to CVB4 at Chain Valley Colliery
- EMM, 2015. Chain Valley Colliery- Modification 2- SoEE
- EMM, 2013. Chain Valley Colliery Mining Extension project 1- EIS
- Lake Coal, 2013. Chain Valley Colliery Extraction Plan MW7 to MW12
- NSW DMR, 2003. Guideline for Applications for Subsidence Management Approvals
- NSW DRE Mine Safety, 2017. Guideline Managing Risk of Subsidence
- PHMP 00021- Mannering and Chain Valley Collieries Principal Hazard Management Plans
- Subsidence PHMP Risk Assessment Dated 15/12/16
- Miniwall S1/N1 Extraction Plan and associated Risk Assessment

Definitions

Hazard

Means a situation or thing that has the potential to harm a person. Hazards at work may include: noisy machinery, a moving forklift, chemicals, electricity, working at heights, a repetitive job, bullying and violence at the workplace.(reference Code of Practice –How to Manage Work, Health and Safety Risks 2011)

Hazardous Manual Task

Defined in the WHS Regulations 2011, means a task that requires a person to lift, lower, push, pull, carry or otherwise move, hold or restrain any person, animal or thing involving one or more of the following:

- repetitive or sustained force
- high or sudden force
- repetitive movement
- sustained or awkward posture
- exposure to vibration.

Musculoskeletal disorder

Defined in the WHS Regulations 2011, means an injury to, or a disease of, the musculoskeletal system, whether occurring suddenly or over time. It does not include an injury caused by crushing, entrapment (such as fractures and dislocations) or cutting resulting from the mechanical operation of plant.

Risk Assessment
Risk management process applied to a scope of work, overall activities, equipment and machinery to determine how often specified events may occur and the magnitude of their consequence. When applied to a specific and sequential set of job steps/activities this may be referred to as a Job Safety Analysis.

Risk

Is the possibility that harm (death, injury or illness) might occur when exposed to a hazard. (Reference Code of Practice –How to Manage Work, Health and Safety Risks 2011)

Risk control

Means taking action to eliminate health and safety risks so far as is reasonably practicable, and if that is not possible, minimising the risks so far as is reasonably practicable. Eliminating a hazard will also eliminate any risks associated with that hazard. .(reference Code of Practice –How to Manage Work, Health and Safety Risks 2011)

WRAC
Workplace Risk Assessment & Control

Subsidence
Movement of the ground surface as a result of readjustments of the overburden due to collapse or failure of underground mine workings and/or compression of remnant pillars

Subsidence Effects
The term used to define the subsidence and differential subsidence parameters (i.e. subsidence, tilt, strain and horizontal displacement) that may or may not have an impact on natural or man-made surface and sub-surface features above a mining area

Subsidence Impacts
The impact that a subsidence effect has on natural or man-made surface and sub-surface features above a mining area

Tilt
The rate of change of subsidence between two points (A and B), measured at set distances apart (usually 10 m).

Strain
The change in horizontal distance between two points at the surface after mining, divided by the pre-mining distance between the points, may be tensile, compressive or shear.

Rock Head
The geological boundary in the overburden between competent rock and unconsolidated sediments and weathered rock

Abbreviations

ALARP	As low as reasonably practicable (ALARP) - determined from WHS Act 2011, Section 18.
CVC	Chain Valley Colliery
DISRD	Department of Industry, Skills and Regional Development
EMP	Environmental Management Plan
FOS	Factor of Safety
JSA	Job Safety Analysis
LTA	less than adequate
LAK	LakeCoal
MC	Mannering Colliery
MSD	Musculoskeletal Disorder
MSMFI	Multi-seam Mining Feasibility Investigation
PCP	Principle Control Plans
PMHMP	Principle Mining Hazard Management Plans
PPE	Personal protective Equipment
STD	Standard
STF	Slip/Trips/Falls
SMP	Safety Management Plan
SWP	Standard Work Procedure

Risk Table

The hazards were analysed and risks derived. The existing control mechanisms were identified prior to establishment of risk. Proposed risk reductions were discussed and agreed and a residual risk determined based on implementation of existing and proposed risk reductions. Consequences assessed through this risk assessment were taken as the reasonable practicable level of risk considering Injury to Personnel as a primary consideration and Environmental Impact and Financial Loss as a secondary consideration as defined in the Risk Assessment Matrix.

No	Activity	Potential Hazard	Existing Controls	Cons I,E,L	Likelihood	Consequence	Risk Rank	Proposed Controls	Likelihood	Consequence	Risk Rank	Risk Level	Responsible Person	Due Date
1.	**Natural Features**													
1.1a	Groundwater	Loss of groundwater from aquifers due to subsidence induced fracturing impacts users or dependant ecosystems	• Sub-critical Mine design (panel width, chain pillar width and extraction height to limit height of hydraulic fracturing) • Strata2 Mine Design Report • Existing extraction has already influenced groundwater levels (minimal further impact predicted) • Avg dewatering volume is within predictions. • Ground water assessment (SEE) • GWMP • Operational water management TARP and underground water make monitoring.	E	D	3	17	Update the GWMP for S2/S3 Extraction Plan application Review CVC operational water management TARP to include GWMP review outcomes				ALARP	E&C Coordinator Mine Surveyor	25/03/19 25/03/19

No	Activity	Potential Hazard	Existing Controls	Cons I,E,L	Likelihood	Consequence	Risk Rank	Proposed Controls	Likelihood	Consequence	Risk Rank	Risk Level	Responsible Person	Due Date
1.1b		Abnormal groundwater loss due to extraction of miniwall panels	• Strata2 Mine Design Report • Sub-critical Mine design (panel width, chain pillar width and extraction height to limit height of hydraulic fracturing) • S2 and S3 panels designed to exclude direct extraction and indirect interconnection with major fault plane/dip • Existing extraction has already influenced groundwater levels (minimal further impact predicted) • Avg dewatering volume is within predictions • Ground water assessment (SEE) • GWMP	E	D	3	17	Review and update subsidence and water management TARP based on recent NMD experience and GWMP update.				ALARP	Technical Services Manager	25/03/19

No	Activity	Potential Hazard	Existing Controls	Cons I,E,L	Likelihood	Consequence	Risk Rank	Proposed Controls	Likelihood	Consequence	Risk Rank	Risk Level	Responsible Person	Due Date
1.1c		Impact on registered groundwater bores in proximity to extraction effects their ongoing use (GW24575)	• Minimal impact based on assessment and existing mining (SEE) • Confirmed integrity and if in use • Sub-critical Mine design (panel width, chain pillar width and extraction height to limit height of hydraulic fracturing)	E	D	4	18	Monitor yields, saturated thickness and quality where access granted Provide alternative water supply until impacted bore recovers where proven to be related to mining impact or as required by the secretary	D	5	22	LOW	E&C Coordinator	If triggered

No	Activity	Potential Hazard	Existing Controls	Cons I,E,L	Likelihood	Consequence	Risk Rank	Proposed Controls	Likelihood	Consequence	Risk Rank	Risk Level	Responsible Person	Due Date
1.2a	Sea/Lake	Increased depth/lakebed cracking resulting in impacts outside predictions	• Sub-critical Mine design (panel width, chain pillar width and extraction height to limit height of hydraulic fracturing) • Geological mapping of known structures incorporated into the mine design and assessed. • Detailed subsidence assessment by MSEC. Predictions are significantly less than the EA approved limits. • Extensive subsidence model including bathymetric survey • Subsidence monitoring program • No previous evidence of significant irregularities around geological structures in previous MW areas	E	D	3	17					ALARP		
1.3a	Shoreline	Increased flooding risk due to subsidence	• HWMSB/Mine Design Report • Subsidence assessment (<20mm predicted) • Subsidence monitoring program • Contingency Plan	E	E	2	16					ALARP		

No	Activity	Potential Hazard	Existing Controls	Cons I,E,L	Likelihood	Consequence	Risk Rank	Proposed Controls	Likelihood	Consequence	Risk Rank	Risk Level	Responsible Person	Due Date
1.3b		Foreshore ecology impacted by increased flooding or erosion	• HWMSB/Mine Design • Subsidence assessment • Subsidence monitoring program including 6 monthly bathymetric surveys	E	E	3	20	Undertake remediation of any mining affected sections of foreshore in consultation with relevant authorities/landowners.				ALARP	E&C Coordinator	If triggered
1.3c		Changes in lakebed depth and wave climate result in increased erosion	• HWMSB/Mine Design • Low wave height environment (SEE) • Subsidence assessment • Subsidence monitoring program	E	E	4	23					ALARP		

No	Activity	Potential Hazard	Existing Controls	Cons I,E,L	Likelihood	Consequence	Risk Rank	Proposed Controls	Likelihood	Consequence	Risk Rank	Risk Level	Responsible Person	Due Date
1.4	Ecosystems (Seagrass)	Increased depth from subsidence reduces presence/health of seagrass beds	• Sub-critical Mine design (panel width, chain pillar width and extraction height to limit height of hydraulic fracturing) • Seagrass mapping (no threatened species identified in extraction plan area) • Seagrass Management Plan and monitoring program • SPB/Mine design report • Subsidence assessment (<20mm predicted) • Subsidence monitoring program	E	D	4	21					ALARP		
1.5	Ecosystems (Benthic Communities)	Increased depth from subsidence reduces colony numbers/health	• Benthic surveys (6 monthly) • Benthic Communities Management Plan • Subsidence assessment (<290mm predicted) • Subsidence monitoring program • Predictive modelling and assessment	E	D	4	21					ALARP		

No	Activity	Potential Hazard	Existing Controls	Cons I,E,L	Likelihood	Consequence	Risk Rank	Proposed Controls	Likelihood	Consequence	Risk Rank	Risk Level	Responsible Person	Due Date
1.6	Threatened and Protected Species (Loggerhead and Green Turtles)	Increased depth from subsidence results in reduction in food source (seagrass)	• Seagrass mapping • SPB/Mine Design Report • Subsidence Assessment (<20mm Predicted) • Mobile and no impact predicted to food source	E	E	5	25					ALARP		
1.7	Cliff/Steep Slope(Frying Pan Point)	Horizontal movements of cliff face results in rock failure	• Sub-critical Mine design (panel width, chain pillar width and extraction height to limit height of hydraulic fracturing) • Subsidence assessment (MSEC) • Subsidence monitoring program • HWMSB/Mine Design	E I	D D	3 2	17 12		(I)E	2	16	LOW		
1.8	Rock outcrops within lake (adjacent S2)	Change in depth results in public safety risk	• Subsidence assessment (<100mm predicted) • No direct undermining of the outcrop or marker • Subsidence monitoring program	I	E	2	16	RMS to undertake visual monitoring of marker during routine inspections.				ALARP	RMS	During Subsidence
2.	**Public Utilities**													

No	Activity	Potential Hazard	Existing Controls	Cons I,E,L	Likelihood	Consequence	Risk Rank	Proposed Controls	Likelihood	Consequence	Risk Rank	Risk Level	Responsible Person	Due Date
2.1	Telecommunication line	Nil. Outside extraction area	•											
2.2	Services	Services not identified within impact area during original SEE impacted by subsidence	• Dial before you dig has confirmed no services located within subsidence affectation area (>20mm). All services located landward from high water mark.	L	D	3	17		E	3	20			
3. Public Amenities														
	Nil		•											
4. Farm Land and Facilities														
	Nil		•											

No	Activity	Potential Hazard	Existing Controls	Cons I,E,L	Likelihood	Consequence	Risk Rank	Proposed Controls	Likelihood	Consequence	Risk Rank	Risk Level	Responsible Person	Due Date
5. Industrial, Commercial and Business Establishments														
	Nil													
6. Areas of Archaeological and/or Heritage Significance														

No	Activity	Potential Hazard	Existing Controls	Cons I,E,L	Likelihood	Consequence	Risk Rank	Proposed Controls	Likelihood	Consequence	Risk Rank	Risk Level	Responsible Person	Due Date
6.1	AHIMS sites (adjacent extraction plan area)	Arch sites near foreshore impacted by flooding or erosion increases due to subsidence	• Locations identified (approx.) via AHIMS register • No sites located adjacent to mining footprint on AHIMS register • Heritage Management Plan (EMP-D-16371) • HWMSB (no impact predicted) • Subsidence assessment • Subsidence monitoring program	E	E	4	23					ALARP		
7. Items of Architectural Significance														
	Nil													

No	Activity	Potential Hazard	Existing Controls	Cons I,E,L	Likelihood	Consequence	Risk Rank	Proposed Controls	Likelihood	Consequence	Risk Rank	Risk Level	Responsible Person	Due Date
8. Permanent Survey Control Marks														
8.1	State Survey Marks/Permanent Survey Marks	Survey marks near foreshore effected by horizontal/vertical movement	• HWMSB/Mine Design • Subsidence assessment • Subsidence monitoring program	E	C	4	18	Include existing marks and include in subsidence monitoring program for S2 and S3				ALARP	Mine Surveyor	15/2/19
9. Residential Establishments														
	Nil		•											

No	Activity	Potential Hazard	Existing Controls	Cons I,E,L	Likelihood	Consequence	Risk Rank	Proposed Controls	Likelihood	Consequence	Risk Rank	Risk Level	Responsible Person	Due Date
10. Other identified items requiring particular assessment														
10.1a	Public Safety	Shallow water buoy (or other markers including sailing markers) within extraction plan area impacted due to subsidence resulting public safety risk	• Subsidence assessment • Strata2 Mine Design Report. • Marker locations visually assessed and mapped. • RMS consulted as part of previous Extraction Plan.	I	C	3	13	RMS to undertake visual inspections of markers during subsidence. Keep CCC informed of actions taken in relation to public safety risks	E	3	20	LOW	RMS E&C Coordinator	During mining Quarterly
10.1b		Jetties within extraction plan area impacted due to subsidence	• Subsidence assessment (<20mm predicted) due to mine design principles • Consultation program / community notifications • Visual assessment undertaken • Subsidence monitoring program	E	D	4	21	Consultation with affected landholders - send out notification letters Keep CCC informed of actions taken and progress.				ALARP	Mine Surveyor E&C Coordinator	25/03/19 Quarterly

No	Activity	Potential Hazard	Existing Controls	Cons I,E,L	Likelihood	Consequence	Risk Rank	Proposed Controls	Likelihood	Consequence	Risk Rank	Risk Level	Responsible Person	Due Date
		Moorings within extraction plan area impacted due to subsidence	• Limited moorings adjacent the EP area • MSEC Subsidence assessment • Majority of moorings within seagrass boundary (<20mm subsidence).Negligible change • Subsidence monitoring program	E	D	4	21					ALARP		
10.2	Consultation	LTA community, stakeholder or agency consultation results in concerns over impact	• CCC • Website • Regular meetings with relevant authorities • Extraction Plan Guidelines • Landowner notifications to be sent out.	E	C	4	18					ALARP		

No	Activity	Potential Hazard	Existing Controls	Cons I,E,L	Likelihood	Consequence	Risk Rank	Proposed Controls	Likelihood	Consequence	Risk Rank	Risk Level	Responsible Person	Due Date
10.3a	Subsidence Impact (general)	Subsidence predictions exceeded results in increased impact/community concern/ breach of conditions	• Sub-critical Mine design (panel width, chain pillar width and extraction height to limit height of hydraulic fracturing) • MSEC Subsidence Assessment • Extensive subsidence model including bathymetric survey • Subsidence monitoring program	E	D	3	17	Extend Summerland Point foreshore monitoring where is access granted Organise appropriate land access to conduct monitoring Investigate potential for additional floor and roof cores to be undertaken in the NMD to improve understanding of geological conditions Review mine design and contingency plans/adaptive management measures in each management plan/TARP are adequate	E	3	20	Low	Mine Surveyor Mine Surveyor Technical Services Manager Technical Services Manager	25/03/19 25/03/19 25/03/19

No	Activity	Potential Hazard	Existing Controls	Cons I,E,L	Likelihood	Consequence	Risk Rank	Proposed Controls	Likelihood	Consequence	Risk Rank	Risk Level	Responsible Person	Due Date
10.3b	Subsidence Impact (general)	Known or unknown geological structures in the workings increases subsidence impact	• Geological database and mapping from old and existing workings • Strata2 Mine Design Report • Known major structures incorporated into the updated geological and subsidence model • All pillars squat pillars thus confinement not reduced by structures • Subsidence monitoring to date has not indicated significant variation in areas of geological structure • Subsidence monitoring program	E	D	3	17	Faults/dykes to be assessed case by case as to whether extraction barrier required				ALARP	Technical Services Manager	As required

No	Activity	Potential Hazard	Existing Controls	Cons I,E,L	Likelihood	Consequence	Risk Rank	Proposed Controls	Likelihood	Consequence	Risk Rank	Risk Level	Responsible Person	Due Date
10.3c	Subsidence Impacts (Height of Fracturing)	Height of fracturing exceeds predictions leading to impacts on groundwater/ingress into mine workings due to direct hydraulic connectivity with the Lake.	• Sub-critical mine design (panel width, chain pillar width and extraction height to limit height of hydraulic fracturing) • Lake Bed rock head survey undertaken and used to inform Mine Design and Subsidence Assessment report. • Constrained zone thickness is greater than or equal to 12T • Strata2 Mine Design Report • Experience from inbye end of Miniwall 12 at Chain Valley at similar rock head thickness did not result in increased water make or signs of direct connectivity at higher levels of subsidence • MSEC Subsidence Assessment Report • No overlying workings in the NMD • Geological mapping and site model • Subsidence monitoring program • Avg dewatering volume is within predictions • Ground water assessment (SEE) • GWMP • Operational water management TARP	E	D	3	17	Bathymetric survey to be undertaken at the end of S2 and end of S3 panel. Consider the potential for a cored uphole to confirm the geo mechanical properties of the above the workings to confirm mine design assumptions.				ALARP	Mine Surveyor Technical Services Manager	30/10/19 31/03/19

No	Activity	Potential Hazard	Existing Controls	Cons I,E,L	Likelihood	Consequence	Risk Rank	Proposed Controls	Likelihood	Consequence	Risk Rank	Risk Level	Responsible Person	Due Date
10.3d	Overall S2 to S3 Subsidence Risk (consideration of all risks and required controls)	Irregular subsidence due to Failure/yield of pillars or floor resulting in subsidence exceedance /impacts	• Mine design Report (panel width, pillar width and extraction height results in limited subsidence of <290mm) • Panels designed to exclude direct extraction and indirect interconnection with major fault plane/dip • Only two extraction panels separated by 40m wide pillar. • Subsidence assessment • Subsidence monitoring program • Subsidence management TARP • No previous evidence of significant subsidence irregularities around geological structures in previous MW areas	E L I	D D D	2 2 3	12 12 17	Consider taking floor cores along the north mains to determine claystone thickness/properties to confirm consistency with design assumptions. Review Subsidence Management TARP after S2 panel, if greater than normal triggered. Revise predictions and management strategies as required Apply further mine design and contingency plans/adaptive management measures in each management plan based on ongoing monitoring as mining progresses. Bathymetric survey to be undertaken at the end of S2 and end of S3 panel.	(E)D	2	12	Mod	Technical Services Manager Technical Services Manager Technical Services Manager Mine Surveyor	25/03/19 Post S2 (indicative 1/9/19) As required 30/10/19

Actions

No	Clause(s) No from RA Tables	Action	Person responsible for Action	Action timeframe	Comments	Database Action No	Responsible Person signature
1.	1.1a	Update the GWMP for S2/S3 Extraction Plan application	E&C Coordinator	28/2/19			
2	1.1a	Review CVC operational water management TARP to include GWMP review outcomes	Mine Surveyor	31/3/19			
3	1.1b	Review and update subsidence and water management TARP based on recent NMD experience and GWMP update.	Technical Services Manager	31/4/19			
4	1.1c	Monitor yields, saturated thickness and quality where access granted Provide alternative water supply until impacted bore recovers where proven to be related to mining impact or as required by the secretary	E&C Coordinator	If Triggered	Only required if triggered.	n/a	
5	1.3b	Undertake remediation of any mining affected sections of foreshore in consultation with relevant authorities/landowners.	E&C Coordinator	If Triggered	Only required if triggered.	n/a	
6	1.8, 10.1a	RMS to undertake visual monitoring of marker during routine inspections.	RMS Representative	During Subsidence	To be coordinated by RMS	n/a	
7	8.1	Search for existing State Survey marks and include in subsidence monitoring program for S2 and S3	Mine Surveyor	31/3/19			
8	10.1a	Keep CCC informed of actions taken in relation to public safety risks	E&C Coordinator	Quarterly	Only required if triggered.	n/a	

9	10.1b	Consultation with affected landholders - send out notification letters of subsidence monitoring program	Mine Surveyor	31/03/19			
10	10.3a	Extend and install Summerland Point foreshore monitoring points where access is granted	Mine Surveyor	30/04/19			
11	10.3a	Investigate potential for additional floor and roof cores to be undertaken in the NMD to improve understanding of geological conditions	Technical Services Manager	15/03/19			
12	10.3a	Review mine design and contingency plans/adaptive management measures in each management plan/TARP are adequate	Technical Services Manager	15/03/19			
13	10.3b	Faults/dykes to be assessed case by case as to whether extraction barriers are required	Technical Services Manager	If triggered	Only required if triggered.	n/a	
14	10.3c	Bathymetric survey to be undertaken at the end of S2 and end of S3 panel.	Mine Surveyor	30/10/19 (Indicative)			
15	10.3c	Consider the potential for a cored uphole to confirm geomechanical properties to confirm mine design assumptions.	Technical Services Manager	15/03/19			
16	10.3d	Consider taking floor cores along the north mains to determine claystone thickness/properties to confirm consistency with design assumptions.	Technical Services Manager	15/03/19			

17	10.3d	Review Subsidence Management TARP after S2 panel, if greater than normal triggered. Revise predictions and management strategies as required	Technical Services Manager	01/09/19			
18	10.3d	Apply further mine design and contingency plans/adaptive management measures in each management plan based on ongoing monitoring as mining progresses.	Technical Services Manager	If triggered	Only required if triggered.	n/a	

Wade Covey

Facilitator Name **Signed for Wade** **25/02/19**

Dave Mclean

(Manager of Mining Engineering Name)

MDG 1014 Review Checklist
RISK ASSESSMENT REVIEW CHECKLIST

Risk Assessment Title: S2 and S3 Miniwall Extraction Plan Risk Assessment ***Date:*** 20/12/19

Site: CVC

1. Report

[Circle or Highlight Yes or No for the following]

1.1	Is there a description of the operation or equipment being assessed?	Yes / No
1.2	Is there a summary of the strategic, corporate and risk management context?	Yes / No
1.3	Is there a list of the people involved in the risk identification step, together with their organizational roles and experience relevant to the risk assessment topic?	Yes / No
1.4	Is there an adequately detailed outline of the approach used to identify the risks?	Yes / No
1.5	Is there an outline of the method used for assessing the likelihood and consequences of the risks?	Yes / No
1.6	Is there, discussion of the basis for defining either the safety standard to be achieved, or the level of risk management expenditure?	Yes / No
1.7	Is there a list of the main actions to be taken to reduce risks and to manage risks?	Yes / No
1.8	Is there a timetable for implementing the main actions?	Yes / No
1.9	Does the report specify a requirement for a working audit requirement after completion of all stages?	Yes / No

2. Process

How do you rate the following? [Circle or Highlight Poor to Very Good]

		Poor/Very Good
2.1	The range of expertise of team which did the study.	**1 2 3 4 5**
2.2	The appropriateness of the degree of detail of the study.	**1 2 3 4 5**
2.3	The comprehensiveness of the systematic approach.	**1 2 3 4 5**
2.4	The identification of the key risk scenarios to be addressed.	**1 2 3 4 5**
2.5	The basis for deciding the required safety level or effort.	**1 2 3 4 5**
2.6	The method for assessing likelihood and consequences.	**1 2 3 4 5**
2.7	The thoroughness of consideration of planned risk reduction actions.	**1 2 3 4 5**
2.8	The thoroughness of consideration of existing or planned risk controls.	**1 2 3 4 5**
2.9	The objectivity and balance of the study (ie not unduly optimistic or pessimistic)	**1 2 3 4 5**

Signed:

Position: Environment and Community Coordinator Date: 25/02/2019

Version 1 - 30/01/19

CHAIN VALLEY COLLIERY- SUBSIDENCE MANAGEMENT TRIGGER ACTION RESPONSE PLAN (TARP)

SUBSIDENCE MANAGEMENT NORTHERN MINING DOMAIN S2 and S3

		DETAILED PERFORMANCE INDICATORS	MONITORING REQUIREMENTS	CONTAINMENT / REMEDIATION MEASURES	ADAPTIVE MANAGEMENT MEASURES	CONTINGENCY PLANS
Triggers	SUBSIDENCE PARAMETERS (Input Variable Validation)	**Normal** [illegible]	[illegible]			
		Trigger Level 1 [illegible]	[illegible] height is ≤ 3.5m			[illegible]
		Trigger Level 2 [illegible]		**Cease extraction and review**	[illegible]	[illegible]
	SUBSIDENCE PARAMETERS (Bathymetric Survey)	**Normal** Subsidence ≤ 300mm	[illegible]			
		Trigger Level 1 Subsidence > 300mm to ≤ 500mm	[illegible]		[illegible]	[illegible]
		Trigger Level 2 [illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	SUBSIDENCE PARAMETERS (Foreshore Survey over minimum of 2 adjacent pegs)	**Normal** [illegible]	[illegible]			
		Trigger Level 1 [illegible]	[illegible]		[illegible]	
		Trigger Level 2 [illegible]	[illegible]	**Cease extraction in panel in question until review conducted in consultation with DP&E and DRE** [illegible]	[illegible]	[illegible]
	BUILT FEATURES	**Normal** [illegible]	[illegible]			
		Trigger Level 1 [illegible]	[illegible]	[illegible]		[illegible]
		Trigger Level 2 [illegible]	[illegible]	**Cease extraction in panel in question until review conducted in consultation with DP&E and DRE** [illegible]	[illegible]	[illegible]

Version 1 - 13/04/18

CHAIN VALLEY COLLIERY- SUBSIDENCE MANAGEMENT TRIGGER ACTION RESPONSE PLAN (TARP)

SUBSIDENCE MANAGEMENT NORTHERN MINING DOMAIN S2 and S3

		DETAILED PERFORMANCE INDICATORS	MONITORING REQUIREMENTS	CONTAINMENT / REMEDIATION MEASURES	ADAPTIVE MANAGEMENT MEASURES	CONTINGENCY PLANS
Triggers	PUBLIC SAFETY (Foreshore area and steep slopes)	**Normal** [illegible]	[illegible]			
		Trigger Level 1 [illegible]	[illegible]		[illegible]	
		Trigger Level 2 [illegible]	[illegible]	**Cease extraction in panel in question until review conducted in consultation with DP&E and DRE** [illegible]	[illegible]	[illegible]
	BENTHIC COMMUNITIES	**Normal** [illegible]	[illegible]			
		Trigger Level 1 [illegible]	[illegible]			
		Trigger Level 2 [illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	SEAGRASS	**Normal** [illegible]	[illegible]			
		Trigger Level 1 [illegible]	[illegible]		[illegible]	
		Trigger Level 2 [illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	WATER INFLOW	[illegible]				
Responsibilities	ECC	[illegible]				
	Mine Surveyor	[illegible]				
	Mine Manager	[illegible]				

GeoTerra

LAKECOAL PTY LTD

CHAIN VALLEY COLLIERY
GROUNDWATER MANAGEMENT PLAN

Lake Macquarie, NSW

CVC3-R2B
27 FEBRUARY 2019

GeoTerra Pty Ltd ABN 82 117 674 941

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Authorised on behalf of GeoTerra Pty Ltd:	
Name:	Andrew Dawkins
Signature:	
Position:	Managing Geoscientist

Date	Rev.	Comments
17.01.2019		Initial Draft
29.01.2019	A	Incorporate review comments
27.02.2019	B	Incorporate new Figures

TABLE OF CONTENTS

FIGURES

TABLES

1. INTRODUCTION

This revised Groundwater Monitoring Program (GwMP) has been prepared in compliance with Schedule 3 (Condition 18D) of the LakeCoal Pty Ltd Chain Valley Colliery Extension Project Approval SSD 5465, as well as the addition of Miniwalls S2 and S3.

This report is to be read in conjunction with the Water Management Plan prepared for the Colliery (LakeCoal, 2019).

The plan includes:

- a groundwater water quality and quantity monitoring program,
- trigger levels for mining impacts on groundwater systems,
- procedures to be followed in the event that monitoring of groundwater indicates an exceedance of trigger levels,
- measures to mitigate, remediate and/or compensate for identified impacts,
- a protocol for the notification of trigger level exceedances, and;
- a contingency plan where, in the event of adverse effects on groundwater quality and/or quantity due to mining impacts, the Colliery will provide an equivalent supply until the affected supply is restored, or as agreed with the landowner and the NSW Office of Water (DIW).

Groundwater related operations at Chain Valley Colliery include the;

- historic Great Northern and Wallarah seams bord and pillar workings;
- current Fassifern Seam development as well as miniwall workings; and
- water storage and management facilities owned and operated by the Colliery.

Operation of the GwMP needs a high level of management input to operate the Colliery within the relevant requirements and various water licences, particularly to ensure compliance with the water discharges authorised by Environment Protection Licence 1770.

An essential part of the plan is monitoring of all groundwater inflows and extraction into and out of the underground with reliable flow meters, as well as monitoring of groundwater levels and water quality in private bores.

This information is necessary for periodical reviews of the groundwater management system and to support any updates/changes to licences.

The proposed mitigation measures minimise and manage the impacts of any potential adverse effects on local aquifers within the GwMP area.

The proposed mitigation measures minimise, where possible, the impacts of the proposed mining on the various groundwater sources, aquifers or groundwater dependent ecosystems that may be present in the Project Area.

1.1 Objectives

The objective of the GwMP is to operate the Colliery so that the subsurface mining operations will be conducted in a manner which minimises the potential impacts on groundwater flow and quality, aquifer integrity, groundwater dependent ecosystems and other off-site groundwater related impacts.

In order to achieve this goal, the GwMP will be used to establish procedures to:-

- measure, control, mitigate and repair potential impacts that could, or do, occur to the groundwater system overlying Chain Valley Colliery, and;
- identify, measure, minimise or where possible, avoid potential significant adverse impacts that can result from mining and subsidence on the groundwater systems within the Project Area.

In addition, the GwMP will be used to

- monitor groundwater system changes in relation to the leaseholder's mining activities;
- assess the pre and post-mining condition of groundwater systems in the lease area;
- ensure all relevant groundwater criteria are met;
- minimise and manage any impacts on the availability of groundwater to potentially impacted residents, landholders or other groundwater users;
- minimise adverse changes on groundwater dependent ecosystems, where present
- provide a forum to record and discuss mining impacts, and;
- provide an annual report on the monitoring, observations and actions conducted within the preceding 12 months to the Department of Industry – Water (DIW).

These objectives will be met by:

- monitoring groundwater seepage and groundwater quality in the workings during mining within the mine lease area;
- installation of water monitoring appliance(s) to measure pumped water volumes to and from the mine workings. These appliances will be maintained in good working order. If required the mine will supply a test certificate to certify the current accuracy of the appliance(s) furnished by the manufacturer or by some duly qualified person or organisation. The mine water pumping records will be maintained and supplied to DIW upon request;
- providing a plan of action in the event that the impacts of mining are greater than anticipated and initiate action to mitigate or remedy potential significant impacts that may occur;
- ensuring that any tailwater drainage will not be allowed to discharge onto adjoining roads, crown land or other lands, or into any unauthorised stream, or any aquifer, by surface or subsurface drains or pipes or any other means without appropriate approval;
- ensuring that any groundwater extracted from the works will not be discharged into any watercourse or source of groundwater except in compliance with the *Protection of the Environment Operations Act (1997);*
- any works used for the purpose of conveying, distributing or storing groundwater from the works will not be constructed or installed so as to obstruct the free passage of floodwaters flowing in, to or from a river or lake;
- all groundwater extracted from the works will be used or applied only on such land, and for such purposes, as approved by DIW, and;
- providing a forum to report, discuss and record impacts to the groundwater system that involves the Chain Valley Colliery, stakeholders, DIW as required.

1.2 Scope

The GwMP is to be used to protect, monitor and manage the condition of the groundwater system within the Chain Valley Colliery lease area that may potentially be impacted due to coal mining and mine subsidence within the lease area.

The GwMP also applies to persons employed or engaged by the Colliery when carrying out activities described by this plan.

This GwMP is to be read in conjunction with the current version of the Water Management Plan (EMP-D-16368) which outlines the monitoring and management of specific factors relating to surface water and groundwater issues due to the predicted subsidence.

All other water management components not directly related to the GwMP are contained as part of the Water Management Plan (EMP-D-16368).

The GwMP covers mining until completion of Domains 1 and 2, although the plan may be used beyond that benchmark with appropriate modification.

1.3 Definitions

For the purpose of this document, the GwMP area is defined as the groundwater systems within the Chain Valley Colliery Lease area. The main features in the GwMP area shown in **Figure 1** include the;

- current Chain Valley Colliery workings in the Fassifern Seam;
- the proposed extraction within Domains 1 and 2, and;
- the proposed extraction of Miniwalls S2 and S3

1.4 Limitations

This GwMP is based on current monitoring data and the proposed and approved operational aspects relating to Chain Valley Colliery. The relevant groundwater features have been identified from;

- existing studies;
- data supplied by Colliery representatives, and from;
- associated consultant's reports in the lake Macquarie area.

The impacts of mining on the groundwater system have been assessed in previous studies (see references). However, it is recognised that prediction and assessment of changes to, and effects from, operation of the colliery on the groundwater system can be relied upon only to a certain extent.

The environmental assessment groundwater study (GeoTerra, 2013) determined there is a low potential for the mine's impacts on the groundwater system to exceed the predictions and assessments. However, the possibility of impacts above predictions has been considered in this plan.

The GwMP will not necessarily prevent impacts from the proposed mining, but does identify appropriate procedures to manage the impacts within tolerable limits and identifies procedures that can be followed should evidence of increased impacts and unacceptable risk emerge.

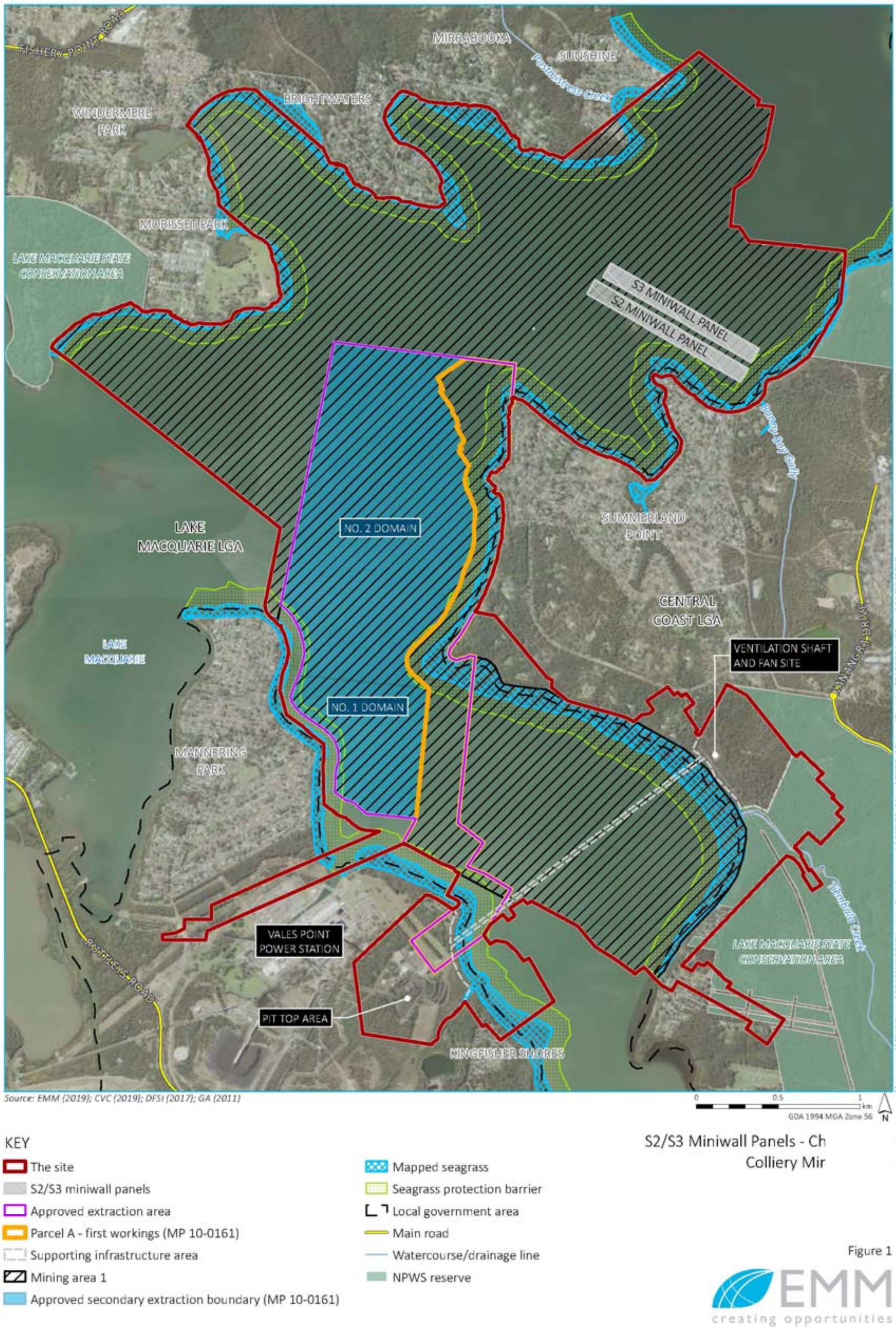

Figure 1 Chain Valley Colliery Mining Area

2. LEGISLATION

The following sub-sections outline New South Wales statutory requirements that apply to the proposed mining operation with respect to groundwater.

2.1 Water Management Act 2000

The key legislation for the management of water in the Project Area is *Water Management Act 2000*, which regulates water use for rivers and aquifers where water sharing plans have commenced.

The Project area is located in the *South Lake Macquarie Water Source* section of the Water Sharing Plan - Hunter unregulated water sources.

The object of the *Water Management Act 2000* is the sustainable and integrated management of the State's water for the benefit of both present and future generations. The Act provides arrangements for controlling land-based activities that affect the quality and quantity of the State's water resources. It provides for four types of approval:

- Water use approvals – authorise the use of water at a specified location for a particular purpose, for up to ten years;
- Water management work approvals;
- Controlled activity approvals; and
- Aquifer interference activity approvals – authorise the holder to conduct activities that affect the aquifer. This approval is for activities that intersect groundwater, other than water supply bores and may be issued for up to ten years.

For controlled activities and aquifer interference activities, the Act requires that the activities avoid or minimise impacts on the water resource and land degradation, and where possible the land must be rehabilitated.

Under the *Water Management Act 2000*, the NSW Office of Water has prepared a range of statutory water management plans covering aspects such as water sharing, water use, drainage management and floodplain management. In NSW, 36 water sharing plans have commenced, covering 80 percent of water currently extracted. The plans cover most of the regulated river systems (those controlled by major dams for rural water supplies), a number of unregulated river systems and the major inland alluvial aquifers.

2.2 State Groundwater Policy

The *NSW State Groundwater Policy* (Framework Document) was adopted in 1997 and aims to manage the State's groundwater resources to sustain their environmental, social and economic uses. The policy has three component parts:

- The *NSW Groundwater Quality Protection Policy*, adopted in December 1998;
- The *NSW State Groundwater Dependent Ecosystems Policy*, adopted in 2002; and
- The *NSW Groundwater Quantity Management Policy*.

2.2.1 Groundwater Quality Protection

The *NSW Groundwater Quality Protection Policy* (Department of Land and Water Conservation, 1998), states that the objectives of the policy will be achieved by applying the management principles listed below.

- All groundwater systems should be managed such that their most sensitive identified beneficial use (or environmental value) is maintained.
- Town water supplies should be afforded special protection against contamination.
- Groundwater pollution should be prevented so that future remediation is not required.
- For new developments, the scale and scope of work required to demonstrate adequate

groundwater protection shall be commensurate with the risk the development poses to a groundwater system and the value of the groundwater resource.

- A groundwater pumper shall bear the responsibility for environmental damage or degradation caused by using groundwater that is incompatible with soil, vegetation and receiving waters.
- Groundwater dependent ecosystems will be afforded protection.
- Groundwater quality protection should be integrated with the management of groundwater quality.
- The cumulative impacts of developments on groundwater quality should be recognised by all those who manage, use, or impact on the resource.
- Where possible and practical, environmentally degraded areas should be rehabilitated and their ecosystem support functions restored.

2.2.2 Groundwater Dependent Ecosystems

The *NSW State Groundwater Dependent Ecosystems Policy* (Department of Land and Water Conservation, 2002) is specifically designed to protect valuable ecosystems which rely on groundwater for survival so that, wherever possible, the ecological processes and biodiversity of these dependent ecosystems are maintained or restored for the benefit of present and future generations. The policy defines Groundwater Dependent Ecosystems (GDEs), as *"communities of plants, animals and other organisms whose extent and life processes are dependent on groundwater".*

Five management principles establish a framework by which groundwater is managed in ways that ensure, whenever possible, that ecological processes in dependent ecosystems are maintained or restored. A summary of the principles follows:

- GDEs can have important values. Threats should be identified and action taken to protect them;
- Groundwater extractions should be managed within the sustainable yield of aquifers;
- Priority should be given to ensure that sufficient groundwater is available at all time to identified GDEs;
- Where scientific knowledge is lacking, the precautionary principle should be applied to protect GDEs; and
- Planning, approval and management of developments should aim to minimise adverse effects on groundwater by maintaining natural patterns, not polluting or causing changes to groundwater quality and rehabilitating degraded groundwater systems.

2.2.3 Groundwater Quantity Protection

The objectives of managing groundwater quantity in New South Wales are to:

- achieve the efficient, equitable and sustainable use of the State's groundwater;
- prevent, halt and reverse degradation of the State's groundwater and/or its dependent ecosystems;
- provide opportunities for development which generate the most cultural, social and economic benefits to the community, region, state and nation, within the context of environmental sustainability; and to;
- involve the community in the management of groundwater resources.

3. CURRENT AND PROPOSED OPERATIONS

Chain Valley Colliery is an underground coal mine operated by LakeCoal Pty Ltd (LakeCoal).

The Colliery is located in the Newcastle Coalfields at the southern end of Lake Macquarie in NSW, and is approximately 60 kilometres south of Newcastle, within the Swansea-North Entrance Mine Subsidence District.

The Management Plan Area incorporates the relatively flat pit top area, existing ventilation shaft and fan site on Summerland Point, as well as foreshore areas and Lake Macquarie.

The terrestrial land within the GwMP Area is gently undulating and drains to Lake Macquarie.

Chain Valley commenced operation in the 1960's extracting coal from the Wallarah seam, the Great Northern seam and the Fassifern seam, and currently conducts mining within leases ML 1051, CCL 721 and ML 1632.

The current Fassifern Seam miniwalls are located underneath Lake Macquarie, within and to the north of Chain Valley Bay.

The mine has completed extraction of Miniwalls 1 to 12 (MW1 to MW12) and has an approved Extraction Plan for Miniwalls N1 and S1 in the Fassifern Seam. At the time of writing, the Chain Valley Colliery had recently completed MWS1 and most of MWN1.

No current or proposed secondary extraction underlies any terrestrial based surface water catchments, with all secondary extraction proposed to be underneath the saline, tidal region of Lake Macquarie.

The Colliery currently has Development Consent (SSD-5465 – as modified) for:

- extraction of up to a maximum of 2.1 million tonnes per annum until 31 December 2027 through continued mining via first workings and miniwall methods within the Fassifern Seam;
- continued coal transport for the surface facilities site;
- continued use of the existing surface facilities, and;
- continuation of passive underground activities within the old workings of the Wallarah seam, Great Northern seam and the Fassifern seam.

The proposed mining areas lie approximately 200m below the sediments of Lake Macquarie, within a boundary set to exclude secondary extraction within the High Water Mark Subsidence Barrier or the Seagrass Protection Barrier.

Bord and pillar mining was commenced in the Fassifern seam in 2006 and secondary extraction in the form of miniwall mining method in the Fassifern seam commenced in 2011.

The S2 and S3 miniwall panels will be 97m wide (rib to rib) with a 40m wide inter-panel pillar, with the panel widths being significantly less than those previously proposed for Chain Valley and adjacent mines – for example, at Wyee Colliery Longwalls 17 to 21 were up to 150m wide, and were extracted between 150m and 180m below surface.

The Development Consent (SSD-5465 – as modified) was approved on 23/12/2013 which permitted the above activities.

Historically, Chain Valley Colliery has mined within the Wallarah and Great Northern seams to the east with via bord and pillar methods, while to the south west and west Wyee State Mine (now named Mannering Colliery) has mined the Great Northern Seam and Fassifern using bord and pillar and longwall extraction.

Mining within the Wallarah and Great Northern Seams will not be undertaken as part of the Project.

The maximum water depth within the proposed mining areas is approximately 9m and the maximum depth to rock head is 20m. Directly above MWS2 and MWS3 the lake varies from 3 – 8m deep.

Sediment on the bottom of the lake varies from 9 – 23m deep over MWS2 and MWS3.

Overburden above the Fassifern Seam over Miniwalls S2 and S3, including the lake sediments, ranges from 164 – 172m.

3.1 Adjacent Workings

Chain Valley Mine is entirely surrounded by the existing Mannering, Myuna and Wallarah Collieries as well as by the historic Newvale and Moonee Collieries.

Mannering Colliery (formerly the Wyee State Mine), has conducted longwall mining in the Great Northern and Fassifern seams since the 1960s. Extraction continued until 2002, when mining became uneconomic. The mine was temporarily shut down until 2004 when it was reopened by Centennial Coal. Since 2004, mining progressed in the Fassifern Seam using bord and pillar methods.

The Myuna Colliery commenced operation in 1981 and is currently mining the Fassifern seam via bord and pillar techniques.

Wallarah Colliery operated from 1979 until 2002, when it was placed under care and maintenance.

Munmorah, Mandalong and Cooranbong Collieries are also nearby, but are not immediately adjacent to the Chain Valley Colliery holding boundary.

3.2 Predicted Subsidence

The maximum subsidence after completion of mining will be located under Lake Macquarie, with the 20mm subsidence line to be contained within the lake high water mark (Ditton Geotechnical Services, 2013) and (MSEC, 2018).

The maximum predicted subsidence, tilts and strains over the proposed workings (assuming a 200m depth of cover) are summarised in **Table 1**.

TABLE 1 Maximum Predicted Subsidence

Parameter	Miniwall Workings	Miniwalls S2 and S3
Vertical subsidence	620mm	<290mm
Tilt	17mm/m	<6mm/m
Strain (Compressive and Tensile)	6.0mm/m	3 / 1mm/m

To date, the maximum subsidence has been observed as summarised in **Table 2**.

TABLE 2 Maximum Observed Subsidence

Location	Maximum Subsidence (mm)
MW1 - MW3 and MW6 - MW12	750
MW7 – MW12 (western end)	1150
MW4 – MW5A (eastern end)	220 (after MW4) 350 (after MW5A)
MW5 and MW5A (western end)	460

It is predicted there will be no measureable subsidence at the lake foreshore (Ditton Geotechnical Services, 2013) and (MSEC, 2018).

3.3 Rainfall and Evaporation

Analysis of climatic data from the Bureau of Meteorology (BoM) weather station at Peats Ridge indicates the following rainfall data;

- Maximum 2186 mm/annum
- 90th percentile 1685 mm/annum
- 75th percentile 1418 mm/annum
- Median 1226 mm/annum
- 20th percentile 902 mm/annum
- Minimum 567 mm/annum

The annual evaporation patterns at Peats Ridge BoM Station indicate the following;

- Maximum 1420 mm/annum
- 90th %ile 1247 mm/annum
- 75th %ile 1210 mm/annum
- Median 1170 mm/annum
- 20th %ile 1090 mm/annum
- Minimum 410 mm/annum

4. LOCAL GROUNDWATER SYSTEM

For management purposes, groundwater within the GwMP area has been divided into the following classes;

(Mine water) groundwater and town water that is pumped into or out of the underground workings

(Groundwater) water contained within strata overlying the mine workings

(Seeps and springs) groundwater that discharges to surface water catchments within the Project Area.

Groundwater flows from the "terrestrial" recharge areas, outside of Lake Macquarie, as well as from the saline waters of Lake Macquarie into the overburden under a regional hydraulic gradient, with dominantly horizontal confined flow along discrete discontinuities and fractures within bedding planes, and / or above fine grained, relatively impermeable strata within the overburden sequence.

The overburden generally contains low yielding aquifers with low hydraulic conductivities.

A schematic of the stratigraphic sequence is shown in **Figure 2.**

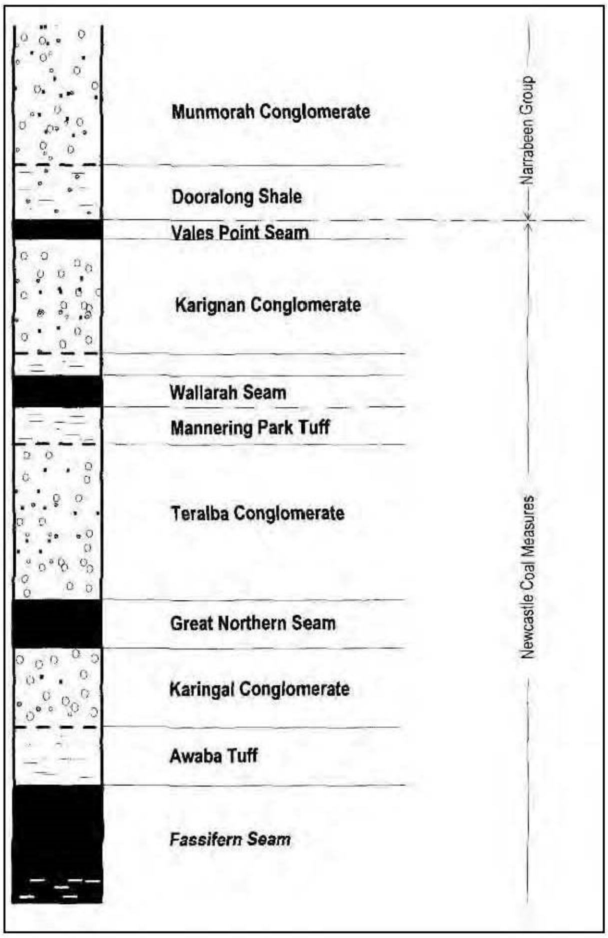

Figure 2 Local Area Stratigraphy

4.1 Alluvial Aquifers

Quaternary to recent alluvial terrestrial sediments comprising sand, gravel, clay and silt are associated with creeks and drainage channels in the local area, to the east, west and south the shores of Lake Macquarie.

Alluvium in the vicinity of the Project area is likely to be present associated with the drainage lines which discharge to Lake Macquarie.

No data is available for the thickness or lithology of alluvium within the Project area. However it is anticipated, if present, to be thin, with limited aerial extent, and no significant water storage or transmitting capacity.

Alluvial sediments within the "terrestrial" areas, outside of the Project Area, are generally too shallow and limited in extent to be used for groundwater supply.

4.2 Lake Macquarie Sediments

Sediments in the vicinity of MWS2 and MWS3 within Lake Macquarie consist of unconsolidated sands, clays, silts and gravels from 9 - 23m thick.

4.3 Shallow Bedrock

The shallow bedrock comprises weathered bedrock which potentially contains discontinuous perched aquifers developed at the interface between the soil and bedrock and along zones of locally increased permeabilities caused by weathering of bedrock and faulting.

The depth and permeability of any aquifers is likely to be dependent on the depth of weathering and the extent and frequency of any permeable fracture systems.

Recharge to the shallow bedrock aquifer is primarily through rainfall infiltration, with some infiltration into to the underlying basement through fractures, joints and faults.

4.4 Deep Bedrock

The Newcastle Coal Measures are overlain by the Munmorah Conglomerate and the Dooralong Shale of the Triassic Narrabeen Group which comprise the majority of the overburden.

The Munmorah Conglomerate extends to a depth of approximately 120m in the vicinity of the Project area and comprises mostly quartz-lithic sandstone interbedded with pebble conglomerate.

The Dooralong Shale is up 20m thick and comprises cross-bedded sandstone intercalated with siltstone and claystone (Forster and Enever, 1992).

Fractured bedrock aquifers would be present within the Narrabeen Group and the Newcastle Coal Measures with discrete water yielding horizons associated with zones of increased permeability i.e. faults and the coal seams.

The overburden and interburden is a low yielding sequence of essentially dry conglomerates and shales.

Joints and fractures associated with fractured bedrock systems tend to be laterally and vertically discontinuous, resulting in poor hydraulic connection and low groundwater yields.

Forster and Enever (1992) state that "*neither the Narrabeen Group nor the Newcastle Coal Measures contain any significant quantities of groundwater and their permeabilities are known to be generally low (<10-7 m/s).*

Any permeable zones which do occur are usually due to jointing, faulting and shearing on bedding planes.

Because of the extremely low permeability of the rock substance, groundwater flow through the overburden strata is almost exclusively by interconnecting defects such as joints and bedding.

For this reason, coal seams with their interconnecting cleat and joint patterns are often found to be 'aquifers' relative to the surrounding strata. Despite this, most underground coal mines on the Central Coast are quite dry, and rarely have any major groundwater problems."

Groundwater in the deep bedrock aquifer is of poor quality with salinity levels ranging from 3000 to 16,000 µS/cm.

Recharge to the deep bedrock aquifer is generally from infiltration of rainfall from overlying aquifers and the flow direction is expected to reflect the local topography.

4.5 Coal Seams

The coal deposits historically or currently mined in the area include the Wallarah, Great Northern and Fassifern seams of the Newcastle Coal Measures which are generally interbedded with tuffaceous claystone.

The coal seams generally have a low primary or inter-granular porosity and permeability, with bedding planes, joints, fractures and cleating imparting an enhanced secondary permeability.

The 4.5 – 5.5m thick Fassifern seam underlies the Wallarah and Great Northern seams within the Project area, and lies between 185m and 220m below surface, with a proposed mining height of up to 3.5m.

4.6 Structure and Intrusions

The overburden dips at approximately two degrees to the south-west.

Superimposed on the regional dip is the Macquarie Syncline, with an axis that runs through the Chain Valley Colliery holding, along with associated faulting and igneous intrusions.

Mapped and inferred geological structures in the Project Area include a number of faults and dykes, with two normal faults with throws of less than 10m located either side of MWS2 and MWS3 as shown in **Figure 3**.

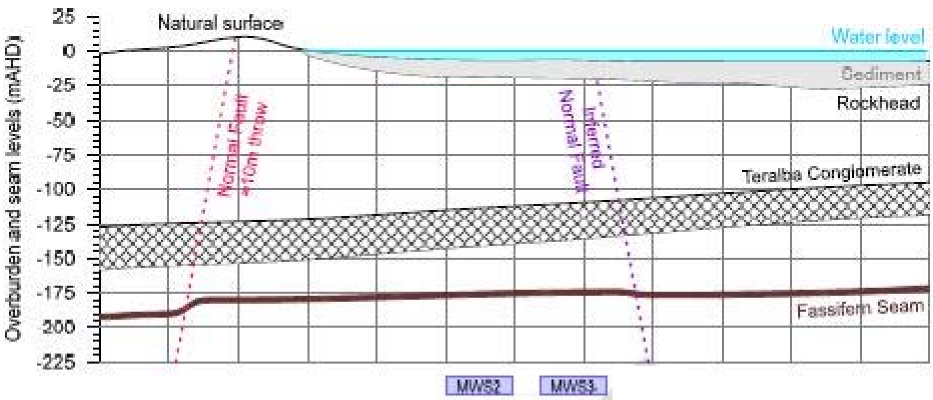

Figure 3 Faulting in the Vicinity of MWS2 and MWS3 (MSEC, 2018)

The Fassifern Seam workings have intersected numerous structures, however, no significant inflows have been observed to the workings (Strata2, 2018).

4.7 Private Bores Within or Adjacent to the Proposed Mining Area

Fifteen DIW registered bores are located within or near the GwMP area as shown in **Figure 4** and **Table 3**.

From the available data, the majority of bores are completed in shallow (<18.3mbgl) sandy alluvium with one coal exploration bore converted for use as a domestic water supply (GW31646)

All remaining private bores in the GwMP are potentially used for domestic garden or limited irrigation water supply.

Where the data is available from the DIW records, groundwater has been obtained from the shallow sandy alluvial / colluvial aquifers with low to moderate yields ranging from 0.13L/sec to 1.50L/sec.

Table 3 Registered Local Private Bores

GW	E	N	Drilled	Depth (m)	SWL (m)	Aquifer (mbgl)	YIELD (L/s)	Purpose	Bore Currency
11915	363007	6329604	-	5.4	-	-	-	Poultry	no response
24575	365969	6332788	1965	15.2	-	-	-	Domestic	no response
31646	366742	6329317	1960	277.5	3.0	3.0 – 10.6	0.13	Dom. / Coal Explore	not present
34560	364130	6330883	1970	18.3	5.5	5.5	-	Domestic	not present
34600	367678	6332873	1971	61.0	5.7	18.2	0.06	Waste disposal	-
80489	366441	6329674	2003	-	-	-	-	Domestic	no internal access
80830	363757	6330850	2004	-	-	-	-	Test bore	capped / covered
201149	367104	6329608	2006	4.0	1.0	1.0 – 4.0	1.50	Irrigation spear	no response
201150	366840	6329640	2006	4.0	1.0	1.0 – 4.0	1.50	Irrigation spear	no response
201977	363730	6331388	2008	7.1	6.0	6.0 – 7.0	-	Monitoring	-
202028	363872	6334034	2007	5.5	1.6	-	-	Test bore	not present
202098	363829	6334141	2007	4.0	0.8	-	-	Test bore	not present
202246	363834	6334174	2007	3.5	1.2	0.6 – 3.5	-	Test bore	not present
202247	363899	6333964	2007	5.0	3.6	2.0 – 5.1	-	Test bore	not present
202248	363918	6333881	2007	5.0	-	2.0 – 5.0	-	Test bore	not present

Note: - no data available

4.8 Regional Groundwater Use

Registered bores in the vicinity of the GwMP area are generally installed into the Munmorah Conglomerate to a maximum depth of 61m, with the majority of bores installed to less than 30m.

Groundwater yields are generally less than 1 L/s, with one bore reporting a yield of 5 L/s.

The authorised uses of the bores include:

- stock watering;
- poultry
- industrial;
- domestic, and;
- waste disposal.

While it is recognised that not all existing bores are likely to be registered, the database gives an indication of groundwater usage in the area.

Overall, it is concluded that the importance and reliance on groundwater by local landowners and residents is limited.

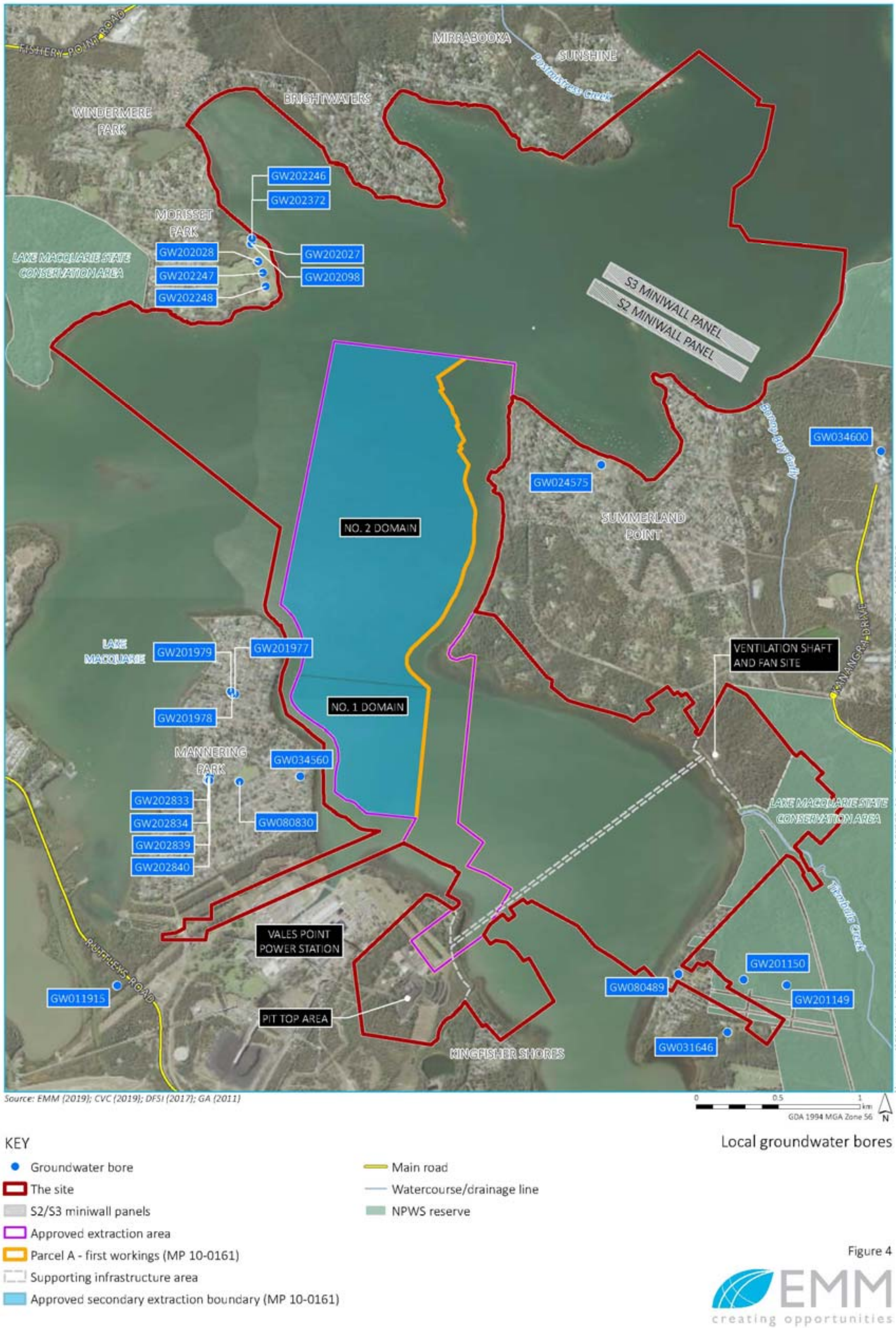

Figure 4 Local Groundwater Bores

5. GROUNDWATER IMPACTS FROM PREVIOUS MINING

The Chain Valley Mine is surrounded by other collieries which have been extracting coal from as early as the 1940s using both longwall and bord and pillar methods.

Historical and current mining operations have resulted in extensive dewatering and depressurisation within and overlying the extracted coal seams.

Water is pumped out of the mines which results in a lowering of the potentiometric surface within the overlying aquifers.

Due to the extent of mining in the region, the subsidence effects would have partly depressurised the overburden.

5.1 Wyee State Mine

An extensive study by (Forster and Enever, 1992) at the adjacent Wyee State Mine (now called Mannering Colliery) assessed the impact of 150m wide longwall mining on the hydrogeological properties of the overburden.

The study assessed that longwall mining of the Great Northern Seam resulted in measurable changes in the hydrogeological properties over a large proportion of the overburden as a result of the redistribution of stresses. The changes reported for the overburden were:

- **Upper Strata** (more than 115 m above the Great Northern Seam) - the hydrogeological properties of the strata after mining were generally similar to those measured prior to mining. Some strata reported a temporary drop in piezometric pressure which recovered soon after the completion of mining in that area.
- **Intermediate Strata** (65 to 115 m above the Great Northern Seam) – experienced significant permanent piezometric pressure increases after mining. The cause of the increase in pressure was uncertain, however it was concluded that *"since the intermediate strata have not lost piezometric pressure, it is certain that significant vertical drainage has not occurred from these strata and they have formed an effective barrier against vertical hydraulic connection between the surface and the mine."*
- **Lower Strata** (less than 65 m above the Great Northern Seam) – showed significant increased permeability and permanent decreases in piezometric pressure which indicated that significant cracking has occurred and allowed partial drainage into the workings.

Although measured changes in the lower strata indicate hydraulic connection was generated and groundwater seepage to the workings had occurred, the changes in the intermediate and upper strata was not significant, and were due to minor strata movements and the formation of fractures that were vertically discontinuous.

It was assessed that the intermediate and upper strata would form a barrier to vertical drainage and that aquifers from 65 - 115m above the workings should not be hydraulically vertically connected to the workings, and should not be drained as a result of subsidence.

Aquifers greater than 115m above the mine workings should not be impacted at all.

It should be noted that the subsidence studied over the Wyee mine related to 150m wide longwalls, whilst the maximum width of the proposed Chain Valley miniwalls is 97m, with 30.6m wide pillars. As a result, the predicted subsidence and the height of fracturing over the proposed workings will be significantly less than was observed over the Wyee longwalls.

5.2 Private Bores

No adverse changes to bore yields, pumping flow duration or groundwater quality have been observed or reported in private bores within the GwMP area.

5.3 Potable Mine Water Supply

The mine has a potable water supply connection from the Wyong Council town-water system.

Historically, a range of 132 - 162ML/year of potable water is supplied to the mine, of which approximately 15% is used for pit top operations and 85% is used for dust suppression in the underground.

As required by Schedule 3, Condition 18(b) of SSD-5465, practical measures to minimise potable water consumption and maximise recycled water use have been implemented and continue to be investigated by LakeCoal, as discussed in the associated WMP. However, the use of non-potable water in all operational activities is not possible due to its quality, work health and safety and equipment requirements.

5.4 Licensed Mine Water Discharges

The discharge of mine water from the sedimentation and pollution control ponds is licensed under the *Protection of the Environment Operations Act* 1997 by the Environment Protection Authority (EPA).

Under the Environmental Protection Licence (EPL) No. 1770 there is a single licensed discharge point for Chain Valley Mine (LDP1), which has a maximum discharge volume of 12,161 kL/day.

The Colliery obtained a 4,443 ML/year groundwater licence (20BL173107) on the 12th March 2013 under the *Water Act, 1912* to enable water to be pumped from the underground workings to the sedimentation and pollution control ponds at the pit top.

5.5 Mine Water Pumping and Mine Groundwater Inflow

Historic data indicates that 1,914 – 2,536.4 ML/year of mine water has been extracted via two pumps in the Great Northern Seam workings sump, with a reduction in extraction volumes being evident over the last 3 years as shown in **Figure 5**.

The net groundwater seepage into the workings is estimated from the difference between the annual potable water intake and the annual water volume extracted from the underground workings.

The latest annual groundwater make from the mine is estimated at 1,817ML/yr, or 4.98ML/day.

Temporary increases in groundwater inflows to the mine have been reported in the vicinity of faults and associated fractures. The increases in inflow are usually short lived as the structures associated with fractured bedrock systems tend to be laterally and vertically discontinuous, resulting in poor hydraulic connection and have low groundwater yields (GeoTerra, 2013).

In general, the Fassifern Seam has to date been the driest seam, whilst mining of the overlying Wallarah Seam has been conducted without major adverse impacts to the overlying aquifers or inflow of water from Lake Macquarie (GeoTerra, 2013).

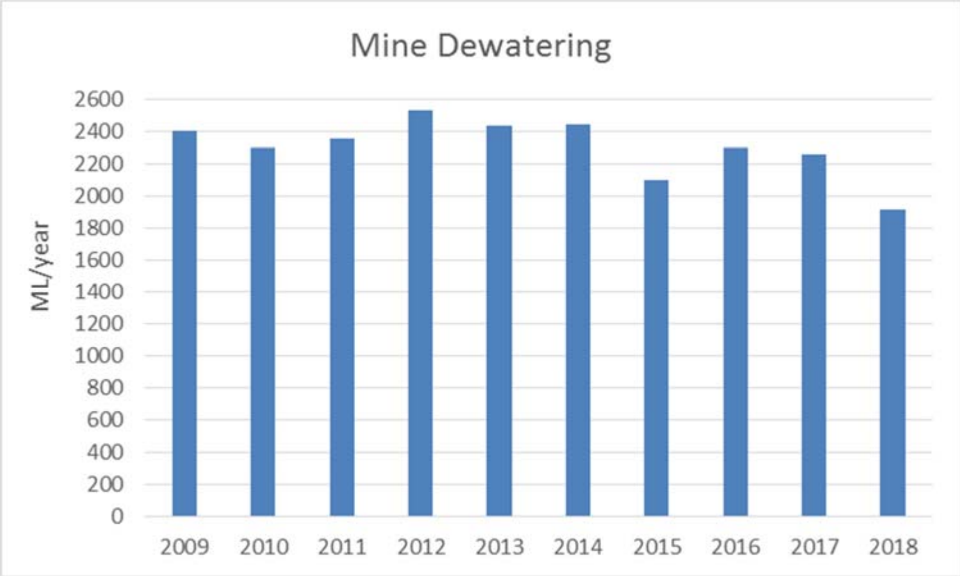

Figure 5 Annual Mine Dewatering Volumes

5.6 Mine Groundwater Quality

Groundwater monitored within the current and historic underground mining areas in the Chain Valley mine indicates the inflow water is brackish to relatively saline in subsided areas over the Great Northern Seam workings (11,800 – 28,200mg/L) with a circum-neutral to mildly alkaline pH (7.30 – 7.76).

Groundwater seepage from a dyke at the northern end of the current Fassifern seam workings, over the unsubsided main headings, had a brackish salinity of 2,390mg/L and an alkaline pH of 8.63 as shown in **Tables 4** and **5**.

The data indicates that groundwater within the underground is significantly above the ANZECC 2000 criteria (default trigger values for physical & chemical stressors in SE Aust. lowland rivers and 95% protection of freshwater species) for;

- pH (Fassifern dyke);
- electrolytical conductivity (all samples);
- total nitrogen (all samples);
- total phosphorous (Fassifern dyke), as well as,
- filterable copper (GNS sump , Fassifern dyke), and
- filterable zinc (all samples except GNS2)

The exceedance in the mine water seepage depends on the guideline applied for the end use of the water.

The groundwater seepage is not generally suitable for potable, livestock or irrigation use, but is suitable for discharge under the EPA licence to Lake Macquarie.

Table 4 Water Chemistry - Major Ions

	pH	EC (uS/cm)	TDS	Na	Ca	K	Mg	Cl	F	HCO3	SO4	Total P	Total N	DOC
ANZECC 2000	6.5 -8.0	2,200	-	-	-	-	-	-	-	-	-	0.05	0.5	-
Karignan Ck	6.93	185	100	29	2.2	2.3	3.5	54	0.10	10	6	**0.15**	**0.6**	17
Chain Valley Bay	7.64	47,300	36,100	10500	470	470	1100	19400	1.3	125	2200	**0.06**	0.4	<1
GNS SUMP	7.48	35,600	23,200	7640	590	125	690	13600	0.25	360	1200	0.04	**2.3**	2
GNS1 (roof)	7.30	40,400	28,200	7980	730	80	840	15600	0.47	435	1320	<0.01	**3.4**	<1
GNS2 (pond)	7.76	19,500	11,800	3950	140	38	230	6730	0.57	385	250	0.02	**0.6**	3
Fassifern dyke	**8.63**	3,500	2,390	925	1.9	9.1	2.1	310	5.6	2040	7	**0.65**	**4.1**	3

NOTE: all values in mg/L

samples collected 22/6/2012

Table 5 Water Chemistry - Metals

	Fe(T)	Fe	Mn(T)	Mn	Cu	Pb	Zn	Ni	Al	As	Li	Ba	Sr
ANZECC 2000	-	-	1.9	1.9	0.0014	0.0034	0.008	0.011	0.055	0.013 / 0.024	-	-	-
Karignan Ck	1.3	0.82	0.03	0.03	**0.003**	<0.001	**0.014**	<0.01	0.05	<0.01	<0.001	0.026	0.10
Chain Valley Bay	0.10	0.02	0.02	0.01	**0.003**	<0.001	**0.013**	<0.01	0.03	<0.01	0.38	0.041	4.8
GNS SUMP	0.18	0.07	0.06	0.04	**0.004**	<0.001	**0.018**	<0.01	0.04	<0.01	0.98	0.084	31
GNS1 (roof)	0.12	0.07	0.27	0.16	<0.001	<0.001	**0.010**	<0.01	0.03	<0.01	1.3	0.080	44
GNS2 (pond)	0.05	<0.01	<0.01	<0.01	<0.001	<0.001	0.003	<0.01	0.01	<0.01	0.59	0.17	11
Fassifern dyke	2.4	0.08	0.06	0.02	**0.004**	<0.001	**0.019**	<0.01	0.04	<0.01	0.28	0.37	1.0

NOTE: all values in mg/L

metals reported as acidified and 45um filtered samples except where Total (T) values are shown

samples collected 22/6/2012

6. POTENTIAL GROUNDWATER IMPACTS

It is anticipated that subsidence over the 164 - 172m deep proposed S2 and S3 miniwall workings may affect the overlying groundwater system through;

- surface cracking to approximately 20m below surface;
- goaf fracturing to less than 96m above the seam (Strata2, 2018), with partial loss of groundwater if fracturing extends into an overlying aquifer, which can cause minor groundwater inflow from the goaf to the workings;
- an exponential decrease in overburden permeability with height above the workings;
- connectivity between the mine workings and overlying aquifers within the fractured goaf, which can result in depressurisation of the aquifers;
- dewatering and depressurisation of the Great Northern and Fassifern seams as mining progresses;
- increased aquifer permeability, and potentially
- reduced groundwater quality in the overlying aquifers.

6.1 Hydraulic Connection to Lake Macquarie

The (Forster and Enever, 1992) study at Wyee, with 150m wide longwalls, indicated there was no hydraulic connection at heights over 115m above the extracted workings.

It should be noted that the proposed miniwalls have a maximum width of 97m, which means the height of fracturing would be less than that observed over the 150m wide Wyee longwalls.

As a result, hydraulic connection between the mine and Lake Macquarie over the proposed secondary extraction workings (Miniwalls S2 and S3) is not likely as the minimum depth of cover is at least 172m (including lake bed sediments) or from 142 – 165 of basement (excluding the sediments in Lake Macquarie) .

6.2 Aquifer / Aquitard Interconnection

Mining induced cracking and vertical subsidence of strata over the extraction area may potentially extend up to 20m below surface, with bedding dilation below from below the surface zone down to the upper goaf.

In the upper horizons, subsidence can alter the dominance of the pre-mining horizontal flow along or above aquitards to generate a combination of vertical and horizontal flow regimes as aquitards are breached and water drains to lower elevations in the strata.

Vertical flow continues down the strata until the drainage is restricted by intact aquitards, at which the depth the flow then resumes its horizontal dominance.

Below the surface cracked zone, an increase in horizontal flow component can occur due to dilation and bending of strata, even though the layers are not actually breached by vertical cracking. The increased horizontal permeability extends across the subsided area, gradually diminishing as the subsidence and dilation decreases out to the edge of the subsidence zone.

No adverse interconnection of aquifers and aquitards is anticipated within 20m of the lake bed as there are no recorded aquifers in this interval.

However, there may be an increased rate of recharge into the upper overburden from the lake waters due to the increased secondary porosity and permeability of the subsided, fractured overburden.

6.3 Regional Groundwater Depressurisation

Extensive mining of the Fassifern, Wallarah and Great Northern seams at Chain Valley and surrounding collieries for more than 60 years has significantly depressurised the overburden within the vicinity of the proposed workings.

Groundwater levels within the Fassifern seam has already been extensively impacted by mining in the area and therefore the proposed mining is likely to have little additional impact, if any.

The deeper basement lithologies have increased permeability in areas of partial or full extraction due to subsidence induced caving and fracturing over the workings which results in an increased groundwater storage capacity of the overburden through increased secondary porosity.

Groundwater flow rates within the deeper aquifers are likely to increase within the caved and fractured areas due to greater hydraulic connectivity between horizontal and vertical fractures.

A temporary lowering of the regional piezometric surface over the subsidence area of up to 1.0m due to horizontal dilation of strata may occur due to the increase in secondary porosity and permeability (GeoTerra, 2013). This effect will be more notable directly over the area of greatest subsidence and dilation, and will dissipate laterally out to the edge of the subsidence zone.

Based on similar observations in NSW with similar mining layouts, surficial and mid depth strata groundwater levels may reduce by up to 15m, and may stay at that reduced level until maximum subsidence develops at a specific location. The duration of the reduction depends on the time required to develop maximum subsidence, the time for subsidence effects to migrate away from a location as mining advances to subsequent panels, and the length of time required to recharge the secondary voids.

The degree of groundwater level decline under the lake due to subsidence is predominantly determined by the proximity to a mined panel, however it can also be significantly affected by the rate of lake water infiltration and terrestrial rainfall recharge to an aquifer, as well as changes in the rate or duration of groundwater extraction in any adjacent groundwater bores.

On the basis that the pre-mining circumstances of lake water and rainfall recharge as well as any local bore pumping remain the same, it is anticipated that groundwater levels will recover over a few months as the secondary void space is recharged by lake water and rainfall infiltration.

There is generally no permanent post mining reduction in groundwater levels under the lake, as no new hydraulically connected outflow paths from within the overburden develop.

6.4 Private Bore Yields and Serviceability

Although 6 registered bore sites are located within the predicted 1.0m groundwater depressurisation area, no private bore yields or serviceability have historically been reported to be, or are predicted to be affected by subsidence or regional groundwater depressurisation associated with the proposed workings, which are entirely located under Lake Macquarie.

No beneficial users of the deep bedrock/coal measures aquifers have been identified in the vicinity of the GwMP Area.

6.5 Groundwater Dependent Ecosystems

Cumulative impacts from the proposed mining are not anticipated to adversely impact on groundwater dependant ecosystems in the 20mm subsidence area.

This is primarily because no groundwater dependent ecosystems have been identified in the proposed subsidence area within or under Lake Macquarie

6.6 Groundwater Quality

Previous observations in NSW Coalfields indicates that groundwater quality within the subsided overburden is not generally adversely affected, however there may be increased iron hydroxide precipitation and a lowering of pH if the groundwater is exposed to “fresh” surfaces in the strata with dissolution of unweathered iron sulfide (marcasite) or iron carbonate (siderite).

The degree of iron hydroxide and pH change due to subsidence is difficult to predict, and can range from no observable effect to a distinct discolouration of water pumped out of bores.

The discolouration does not pose a health hazard, however it can cause clogging of pumping equipment and piping in extreme cases.

It should be noted that many bores in the local area can already have significant iron hydroxide levels, and a pre-mining survey of the active bores is required to assess the baseline water quality prior to undermining.

Acidity (pH) changes of up to 1 order of magnitude can occur, however the change can be reduced if the bore has sufficient bicarbonate levels.

The potential for groundwater contamination also exists from spills of fuels, oils and chemicals from both the surface and underground mine workings. Spills may result in the contamination of soil, while the infiltration of rainfall or direct migration of contaminants to the water table has the potential to contaminate shallow aquifers.

The potential for impacts can be minimised through the appropriate storage of fuels and hazardous chemicals, the implementation of appropriate work procedures and regular inspections and maintenance of equipment and plant.

Leaks and spills should be handled in accordance with the Environmental Management Plan prepared for the project, and remediated as required on a case by case basis.

Infiltration of potentially contaminated water from the sedimentation dams also has the potential to impact groundwater quality. As the dams receive all site runoff, amenities water and mine water, as well as workshop and wash down water after treatment by an oil separator, there is potential for the water within the dams to be contaminated by dissolved petroleum hydrocarbons and heavy metals. It is understood the dams are not lined with a low permeability layer, and as such, seepage of potentially contaminated water within the dams may be infiltrating alluvial or shallow aquifers.

6.7 Groundwater Seepage to or From Terrestrial Streams

No known springs or streams are present in the GwMP area that would be affected by subsidence and associated regional groundwater depressurisation with the existing and proposed workings.

Overall, the terrestrial streams within the GwMP area will be subjected to no or very low tensile and compressive strains and are not anticipated to be adversely affected by subsidence related stream bed cracking.

No loss of overall stream flow or regional change in stream water quality within the local streams is anticipated to occur.

6.8 Groundwater Inflow to Mine Workings

Loss of lake water or any significant loss of connate groundwater within the overburden to the underlying workings has not been observed in mines in the local area at similar depths of cover to the proposed workings.

Vertical hydraulic connection to the workings is anticipated to be restricted by the Dooralong Shale and the Mannering Park Tuff aquitards, which are not anticipated to be breached by subsidence over the proposed Fassifern seam workings and are both below the surficial and above the goaf, vertically connected, dilation zones.

The horizontal permeability above and between the aquitards may be enhanced after subsidence, however there is no additional vertical connectivity through or below them to the underlying workings.

Based on available records, the 2018 annual groundwater seepage into the workings was 1,817ML/yr, or 4.98ML/day.

No obvious relationship between expansion of the mine and increased groundwater inflow to the workings is evident in the current data, with a reduction in mine water pumping evident over the last three years.

Based on a groundwater modelling assessment (GeoTerra, 2013) the inflow may increase up to 10.5ML/day as the Colliery expands.

7. GROUNDWATER MONITORING PLAN

The groundwater monitoring program at locations shown in **Figure 3** is designed to provide a database that enables:

- comparison of anticipated vs observed impacts on the groundwater system through miniwall as well as bord and pillar extraction of the Fassifern seam at Chain Valley Colliery and any associated subsidence effects, and;
- procedures to assess, manage or rehabilitate any adverse effects that exceed specified trigger levels.

As the proposed workings, and the anticipated associated subsidence impacts, are wholly located underneath or within Lake Macquarie, the monitoring plan specifically deals with the following issues.

7.1 Mine Groundwater Inflow

The active underground mining area should be monitored by the underground supervisors to assess whether observable groundwater inflow is occurring to the active panels and to note if any changes are noted.

Water flow monitoring appliances have been installed in the mine to measure pumped water volumes to and from the mine workings. These appliances will be maintained in good working order, and if required, the mine will supply a test certificate to certify the current accuracy of the appliances furnished by the manufacturer or by some duly qualified person or organisation.

Daily total mine water pumping records will be maintained, plotted and interpreted annually and will be supplied to DIW annually within the AEMR.

7.2 Private Bore Water Levels

Where property access is granted and access inside a bore is possible, water levels within the private bores could be measured at least once before and once after mining is conducted in the GwMP Area to assess if any adverse effects due to subsidence have occurred as shown in **Table 6**.

Where monitoring of groundwater levels is not possible due to installed pump head-works, the mine will assess any reports from landowners in regard to adverse effects on bore water availability that may occur during or after extraction of the proposed workings.

Each property owner may be interviewed before and after the proposed mining to assess the bore's status, pumping rate, its general duration of pumping as well as the type and set up of the pump. The bore yield should also be measured, and water levels measured where access inside the bore is possible.

Where private bores are being occasionally or frequently pumped, and could thereby temporarily distort the static regional groundwater levels, the depth to groundwater, where accessible, should be monitored during pump resting periods to assess the regional piezometric surface across the area.

Table 6 Private Bore Water Level Monitoring

GW	Monitoring Frequency	Monitoring Method	Units
11915	Upon access / post mining	Dip meter	mbgl
24575	Upon access / post mining	Dip meter	mbgl
34600	Upon access / post mining	Dip meter	mbgl
201149	Upon access / post mining	Dip meter	mbgl
201150	Upon access / post mining	Dip meter	mbgl
201977	Upon access / post mining	Dip meter	mbgl

Note: mbgl = metres below ground level

7.3 Groundwater Quality

7.3.1 Inactive Private Bores

Where property access is granted and access inside a bore is possible, a pre-mining water sample collection and analysis will be conducted within one month of access being granted and available, and will be repeated at the end of mining in the Project Area to enable assessment of any subsidence related changes in groundwater quality.

Each bore will be purged prior to sampling until pH and salinity measurements stabilise, which usually involves removal of at least three bore volumes of water.

Samples will be collected, appropriately preserved, kept on ice and transported under chain of custody documentation to arrive at the laboratory within appropriate holding times.

In addition, each piezometer or inactive bore will be monitored in the field for bi-monthly salinity (µS/cm) and pH measurements.

7.3.2 Active Private Bores

Where property access is granted and access to the groundwater bore is possible, an initial water sample collection and analysis will be conducted within one month of access being granted and available, and will be repeated at the end of mining in the Project Area to enable assessment of any subsidence related changes in groundwater quality.

To date, access to one current bore has been granted (GW80489), however no sample could be obtained as the installed pump was not working.

The use, and any treatment, of the bore water should be ascertained and observations made on the quantum of iron hydroxide precipitating from the pumped water before and after mining.

Each bore will be purged prior to sampling until pH and salinity measurements stabilise, which usually involves removal of at least three bore volumes of water.

Samples will be collected from bores that are current and accessible as shown in **Table 7**, and will be appropriately preserved, kept on ice and transported under chain of custody documentation to arrive at the laboratory within appropriate holding times.

Table 7 Private Bore Water Quality Monitoring

GW	Monitoring Frequency	Monitoring Method	Units
11915	Upon access / post mining	In situ pump / bailer	pH EC mg/L (ions, metals, nutrients)
24575	Upon access / post mining	In situ pump / bailer	pH EC mg/L (ions, metals, nutrients)
34600	Upon access / post mining	In situ pump / bailer	pH EC mg/L (ions, metals, nutrients)
201149	Upon access / post mining	In situ pump / bailer	pH EC mg/L (ions, metals, nutrients)
201150	Upon access / post mining	In situ pump / bailer	pH EC mg/L (ions, metals, nutrients)
201977	Upon access / post mining	In situ pump / bailer	pH EC mg/L (ions, metals, nutrients)

During extraction within the GwMP area, the frequency of monitoring and the parameters to be monitored may be varied in consultation with DIW once the baseline groundwater quality and its response to mining (if any) is established.

The frequency of post mining monitoring will be reassessed after mining is complete in the GwMP Area as it may be possible, depending on results, to lengthen the intervals.

Table 8 presents the physical groundwater quality parameters to be measured.

Table 8 Groundwater Quality Monitoring Parameters

SUITE	ANALYTES
Initial monitoring / After mining is completed	Field EC, Eh, pH, temp TDS, Na, K, Ca, Mg, F, Cl, SO4, HCO3, NO3, Total N, Total P Cu, Pb, Zn, Ni, Fe, Mn, As, Se, Cd, Cr, Li, Ba, Cs, Rb, Sr (filtered)

7.4 Groundwater Contamination

In accordance with the sites' Environmental Protection Licence, surface water discharged from the dams is monitored monthly for a range of pollutants as specified in the site EPL and associated Water Management Plan.

The range of analysis for surface water also includes oil and grease, which allows the assessment of impact, if any, that these dams may be having on underlying aquifers.

8. GROUNDWATER ASSESSMENT CRITERIA AND TRIGGERS

Management of impacts within predictions follow standard assessment review and response protocols.

Contingent measures are included in this plan to ensure the timely and adequate management of the proposed extraction and subsidence impacts outside of anticipated levels.

Where and if required, specialist hydrogeological / hydrological investigations and reports may include:

- the study scope and objectives
- consideration of any relevant aspect from this plan
- analysis of trends
- assessment of any impacts against prediction
- assessment of the cause of a change or impact
- options for management and mitigation
- assessment for the need for contingency measures
- any recommended changes to this plan, and;
- appropriate consultation with DIW, DRE and EPA

Site specific mitigation / remediation action plans may include:

- a description of the impact to be managed
- results of the specialist investigations
- aims and objections for the plan
- specific actions required to mitigate/manage
- timeframes for implementation
- roles and responsibilities
- identification of and gaining appropriate approvals from landholders and government agencies, and;
- a consultation and communication plan.

Trigger values for further assessment of potential subsidence effects on groundwater systems within the plan area are discussed in the following sections.

The triggers have been developed to reflect the current variability in relevant parameters and to enable the identification of any changes that may be due to either subsidence effects, landowner impacts and/or natural causes.

If trigger values are exceeded, the cause and effect will be investigated and a management plan developed if it is directly related to mining.

The Manager Environment shall be responsible for the implementation of agreed actions and shall communicate such actions to the relevant landowners or authorities.

8.1 Mine Water Extraction and Discharge

Chain Valley Colliery holds a DIW license (20BL173107) to extract up to 4,443 ML/year from the workings, and currently holds EPL 1770 which permits volumetric discharge of up to 12,161 kL/day via its licensed discharge point into Lake Macquarie.

Mine water extraction will be measured daily and daily discharge volumes will be reported publically on a monthly basis via LakeCoal’s website.

As part of the AEMR the average monthly groundwater extraction rates will be determined by assessing the difference between the potable water pumped into the workings and the total water pumped out of the workings. This assumes no hydraulic conductivity with Lake Macquarie, surface potable water leaks, water theft or measurement error.

A trigger for the groundwater extraction will be where the monthly average extracted underground mine water exceeds **10.5ML/day** (75th percentile groundwater inflow – refer Table 3), and this average continues for at least 2 months.

8.2 Private Bore Groundwater Levels

It should be noted that landowners pumping their own bores, as well as the interference effect from other landholders pumped bores can significantly affect temporary standing water levels in a bore, without any influence from mining or subsidence.

On this basis, if the combined monitoring of the outlined private bores indicates a sustained drawdown of **greater than 2m over a 2 month period** in a private bore, or, if a landowner reports a lack of groundwater availability in a bore that cannot be accessed internally, then the cause of the exceedance will be investigated to assess whether the >2m drawdown or lack of supply is due to;

- lack of rainfall recharge, using comparison to the cumulative sum of daily rainfall,
- operation of landowner bores either within or outside an affected bores property,
- subsidence, or
- any or all of the above.

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The 2m drawdown trigger level has been derived through extrapolation of similar mining subsidence related effects in similar mining layouts and geomorphological areas in NSW and to be consistent with the minimal impact considerations of the NSW Aquifer Interference Policy.

8.3 Private Bore Groundwater Quality

If a landowner reports an increase in iron hydroxide precipitation or water salinity, as an initial default, the ANZECC 2000 irrigation and livestock guidelines shown in **Table 9** will be used as trigger levels to assess bore water quality.

As no bores are used for drinking water in the GwMP, drinking water quality criteria and triggers are not specified.

Table 9 Groundwater Chemistry Criteria (mg/L)

	pH	TDS	Hardness as CaCO3	Cu	Pb	Zn	Ni	Fe	Mn	As	Cd
Irrigation	*6 - 8.5*	-	*>60-350*	*5*	*5*	*5*	*2*	*10*	*10*	*2.0*	*0.05*
Livestock	-	*<4000/5000*	-	*1 / 0.4*	*0.1*	*20*	*1*	-	-	*0.5*	*0.01*

NOTE: all metals values are for filtered metals

irrigation criteria for short term trigger values (< 20 years)

Livestock criteria for beef / sheep

9. POTENTIAL GROUNDWATER AMELIORATIVE ACTIONS

9.1 Private Bore Yield

Although it is not anticipated due to the separation distance from the bores to the proposed subsidence area, should the accessibility, available drawdown or yield of a bore be impacted due to subsidence, the Colliery is required to provide an alternative water supply until the bore recovers.

If the level does not sufficiently recover and the effect is due to subsidence rather than regional climatic or anthropogenic factors, repairs or maintenance to a bore can be undertaken after maximum subsidence has developed. At this time the pump intake can be lowered, the bore extended to a greater depth or a new bore can be established.

With these mitigation measures in place it is unlikely that water supply to properties will be significantly impacted by the proposed mining.

In the event of a monitored or reported adverse impacts on the yield or saturated thickness of a private registered bore, the cause will be investigated.

If a groundwater level drop of over 2m for a period of over 2 months is recorded, and the reduction in bore yield is a consequence of subsidence, the mine will enter into negotiations with the affected landowners and the Mine Subsidence Board with the intent of formulating an agreement which provides for one, or a combination of;

- re-establishment of saturated thickness in the affected bore(s) through bore deepening;
- establishment of additional bores to provide a yield at least equivalent to the affected bore prior to mining;
- provision of access to alternative sources of water; and/or
- compensation to reflect increased water extraction costs, e.g. due to lowering pumps or installation of additional or alternative pumping equipment.

9.2 Private Bore Groundwater Quality

In the event of an adverse change in groundwater quality to a private bore, particularly in regard to salinity and / or iron levels, the mine will implement an investigation to determine if the cause is due to subsidence.

Although it is not anticipated due to the separation distance from the bores to the proposed subsidence area, if subsidence cracking has caused a notable increase in iron hydroxide precipitates or the landowner reports an adverse change in salinity, and that change that exceeds the trigger levels, the mine will enter into negotiations with the affected landowner with the intent of formulating an agreement which provides for one, or a combination of;

- re-establishment of the water supply from a new bore to provide water equivalent to the pre mining status of the bore (on the basis that the landholder has allowed for pre-mining status of the bore to be established);
- provide access to an alternative source of water, or;
- compensate the bore owner to reflect the economic costs incurred due to the subsidence effects on the water quality.

10. CONTINGENCIES

In the event that the proposed monitoring indicates that a trigger has been reached or is being approached, LakeCoal will commission a hydrogeologist or hydrologist to review the data, with the outcomes of that review, including any recommendations, being subject to consultation with DIW.

A trigger of pH or EC would initially lead to an increase in the analytes monitored and/or frequency of sampling to confirm the magnitude and extent of the change in groundwater chemistry and verify the change is a consequence of mining.

Should the standing water level trigger be achieved in any bore, the mine staff shall notify the affected landowner(s) and, if it is the hydrogeologist's opinion that the reduction is a consequence of mining, mitigation measures identified in previous sections will be initiated.

An independent authority may also be used where a dispute arises as to the cause of the change, given that groundwater supply and quality can be affected by non-mining related factors such as bore siltation, aquifer depletion by adjoining mining operations, agricultural users, bacterial infection, fertilizer contamination etc.

11. AUDIT AND REVIEW

This document shall be reviewed, and if necessary revised, within 3 months of the following;

- the submission of an Annual Environmental Management Report;
- the submission of an incident report;
- the submission of an independent environmental audit; and
- following any modification to the project approval.

Other factors that may require a review of the GwMP are;

- observation of greater impacts on surface features due to mine subsidence than was previously expected;
- observation of fewer impacts or no impacts on surface features due to mine subsidence than was previously expected, and/or;
- observation of significant variation between observed and predicted subsidence.

Internal and external audits of this document will be carried out as described below. If possible internal and external audits shall be objective and be conducted by a person or organisation independent of the document being audited.

Audits shall be carried out by personnel who have the necessary qualifications and experience to make an objective assessment of the issues. The extent of the audit, although pre-determined may be extended if a potentially serious deviation from this document is detected.

Any audit non-conformances and/or improvement opportunities will have corrective and preventative actions implemented to avoid recurrence, these actions will be loaded into the site Incident Database to ensure the actions are assigned to the relevant people and completed.

11.1 Internal Audits

Internal audits of this document and all other Environmental Management System documents are to be undertaken every three years. Improvements from the audit are to be incorporated in the site action database to ensure the actions are assigned to the relevant people and completed.

11.2 External Audits

External audits will be conducted utilising external specialists and will consider the document and related documents. External auditors shall be determined based on skills and experience and upon what is to be accomplished. External audits will be periodically at a frequency determined by the site General Manager, or in response to significant environmental incidents for which a systems failure has been determined as a contributor to the incident.

An Independent Environmental Audit will be undertaken every three years (or as otherwise required by the Department of Planning and Infrastructure) by an audit team whose appointment has been endorsed by the Director-General of the Department of Planning and Infrastructure.

Any actions arising from external audits will be loaded into the site actions database to ensure the actions are assigned to the relevant people and completed.

12. RECORDS

Generally, the site Environmental co-ordinator will maintain all Environmental Management System records, which are not of a confidential nature. Records that are maintained include:

- Monitoring data and equipment calibration;
- Environmental inspections and auditing results;
- Environmental incident reports;
- Complaint register; and
- Licenses and permits.

All records are stored so that they are legible, readily retrievable and protected against damage, deterioration and loss. Records are maintained for a minimum of 4 years.

13. RESPONSIBILITIES AND ACCOUNTABILITIES

13.1 General Manager

- Ensure that the requisite personnel and equipment are provided to enable this plan to be implemented effectively;

13.2 Environmental Coordinator

- Authorise the Plan and any amendments thereto;
- Ensure this plan is reviewed should any changes to the mine plan or if levels of subsidence are greater than predicted. Notify the relevant authorities of any triggers being exceeded;
- Reporting in the Annual Environmental Management Report
- Ensure that inspections are undertaken in accordance with the schedule;
- Ensure that persons conducting the inspection are appropriately trained, understand their obligations and the specific requirements of this plan;
- Review and assess monitoring results and inspection checklists;
- Promptly notify the General Manager of any identified environmental issue

13.3 Hydrogeologist / Hydrologist

- Assist in compiling and/or reviewing the monitoring to the standard and frequency as outlined in this plan;
- Promptly notify the Environment and Community Coordinator of any identified environmental issue

14. TRAINING

All personnel who conduct inspections will be trained in the requirements of the plan.

Training will be conducted on maintaining and downloading monitoring equipment, operation of the field testing equipment and sampling procedure for laboratory analysis identification of the various subsidence impacts detailed in this plan.

15. REPORTING

15.1 Annual Environmental Management Report

An Annual Environmental Management Report (AEMR) will be submitted to DIW each year. As part of the AEMR the groundwater section will include;

- groundwater related activities, and the level of compliance with the GwMP;
- all groundwater monitoring volumes and rates taken by the works;
- the volume groundwater extracted from the works that was discharged via the Licensed Discharge Point;
- all groundwater extraction data;
- the extent of groundwater depressurisation and any groundwater salinity impacts compared with predictions in the Environment Assessment;
- interpretation of the data, discussion of trends and their implications;
- an overall comparison of groundwater performance with predictions for the life of the mine provided in the Environmental Assessment, and;
- an outline of proposed adaptive or remediation actions if required.

Notification of the groundwater monitoring results and interpretations will be reported within the required annual period to outline the natural trends and any impacts from mining on the groundwater system.

16. REFERENCES

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Peabody LakeCoal Pty Ltd, 2008 Annual Environmental Management Report, Chain Valley Colliery, Year Ending 30 June 2008

Peabody LakeCoal Pty Ltd, 2009 Annual Environmental Management Report, Chain Valley Colliery, Year Ending 30 June 2009

Strata 2, 2018 Geotechnical Aspects of S2 and S3 panel Design

the site, GeoTerra reserve the right to review the report in the context of the additional information.

In preparing this report, GeoTerra has relied upon certain verbal information and documentation provided by the client and / or third parties. GeoTerra did not attempt to independently verify the accuracy or completeness of that information. To the extent that the conclusions and recommendations in this report are based in whole or in part on such information, they are contingent on its validity. GeoTerra assume no responsibility for any consequences arising from any information or condition that was concealed, withheld, misrepresented, or otherwise not fully disclosed or available to GeoTerra.

Interpretations and recommendations provided in this report are opinions provided for our Client's sole use in accordance with the specified brief. As such they do not necessarily address all aspects of water, soil or rock conditions on the subject site. The responsibility of GeoTerra is solely to its client and it is not intended that this report be relied upon by any third party, who should make their own enquiries.

The advice herein relates only to this project and all results, conclusions and recommendations made should be reviewed by a competent and experienced person with experience in environmental and / or hydrological investigations before being used for any other purpose. The client should rely on its own knowledge and experience of local conditions in applying the interpretations contained herein.

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Delta coal	Doc Owner: **Environment and Community Coordinator**
	Doc No: ENV 00021 - Benthic Communities Management Plan

CHAIN VALLEY COLLIERY

Benthic Communities Management Plan

ENVIRONMENTAL MANAGEMENT PLAN

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Date:	17/06/2019

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1 Introduction

Chain Valley Colliery is an underground coal mine located on the southern end of Lake Macquarie, approximately 100km north of Sydney and 60km south of Newcastle, adjacent to the Vales Point Power Station, producing thermal coal for the domestic and export markets.

A formal Environmental Management System (EMS) has been developed as a systematic and structured approach to managing environmental issues at the operation. This has been developed in general accordance with the requirements of the international standard ISO 14001.

This Benthic Communities Management Plan (BCMP) is an element of the Chain Valley Colliery Environmental Management System.

This Benthic Communities Management Plan has also been completed to satisfy the requirement of Condition 7(h), Schedule 4 of Development Consent SSD-5465 (Modification 2), which states:

"The Applicant shall prepare an Extraction Plan for all second workings on site, to the satisfaction of the Secretary. Each Extraction Plan must:

(h) include a Benthic Communities Management Plan, which has been prepared in consultation with OEH, LMCC, and DPI Fisheries, which provides for the management of the potential impacts and/or environmental consequences of the proposed second workings on benthic communities, and which includes:

- surveys of the lake bed to enable contours to be produced and changes in depth following subsidence to be accurately measured;
- benthic species surveys within the area subject to second workings, as well as control sites outside the area subject to second workings (at similar depths) to establish baseline data on species number and composition within the communities;
- a program of ongoing seasonal monitoring of benthic species in both control and impact sites;
- development of a model to predict likely impact of increased depth and associated subsidence impacts and effects, including but not limited to light reduction and sediment disturbance, on benthic species number and benthic communities composition, incorporating the monitoring and survey data collected; and
- updating the model every 2 years using the most recent monitoring and survey data;

The relevant requirements from Table 8 within Condition 2, Schedule 4 of SSD-5465 (Modification 2), including the relevant notes, are recreated in **Table 1**.

Table 1: Subsidence Impact Performance Measures

Biodiversity	
Benthic Communities	Minor environmental consequences, including minor changes to species composition and/or distribution

Notes:

- *The Applicant will be required to define more detailed performance indicators (including impact assessment criteria) for each of these performance measures in the various management plans that are required under this consent (see Condition 7 below).*
- *Measurement and/or monitoring of compliance with performance measures and performance indicators is to be undertaken using generally accepted methods that are appropriate to the environment and circumstances in which the feature or characteristic is located. These methods are to be fully described in the relevant management plans. In the event of a dispute over the appropriateness of proposed methods, the Secretary will be the final arbiter.*
- *The requirements of this condition only apply to the impacts and consequences of mining operations, construction or demolition undertaken following the date of approval of this consent.*

2 Purpose

The purpose of this Benthic Communities Management Plan is to:

- outline details of the benthic communities monitoring data collected;
- outline existing and predicted subsidence levels;
- outline the methodology to be used to identify depth changes at monitoring locations;
- identify benthic community monitoring locations;
- identify reporting requirements;
- detail benthic community management measures;
- identify the requirements for incident or exceedances reporting and reviews of the document; and
- identify persons responsible for implementation of requirements.

3 Background

3.1 Baseline Data on Benthic Communities

Both species diversity and abundance are recorded as part of the 6 monthly seasonal (autumn and spring) benthic communities monitoring, which commenced in 2012.

The mud basin off Summerland Point, in Chain Valley Bay and Bardens Bay, was found to be inhabited by 21 species of organisms greater than 1mm in size. Polychaete worms and bivalve molluscs were the most frequently encountered animals.

Bottom sediment in the study area was composed of a small fraction of black sand and shell fragments of various sizes. Most of the sediment was fine black or grey mud.

The sampling results of the benthos undertaken at six monthly intervals between February 2012 and September 2017 revealed the following:

- The similar suite of organisms dominated each of the 19 sample stations. These were polychaete worms and bivalves.
- Stations were distinguished by the relative abundance of the dominant species.
- Water depth was not the key parameter in determining the species composition at a station.
- Physical variables such as salinity (conductivity), dissolved oxygen concentration and turbidity of the bottom water, measured only on the day the benthos was sampled, had little influence on the species composition of the benthos over the period sampled.

The results collated to date appear to support the notion that increasing the water depth by the predicted levels of subsidence has, to date, had no discernible effect on the composition and abundance of organisms making up the benthos of the mud basin.

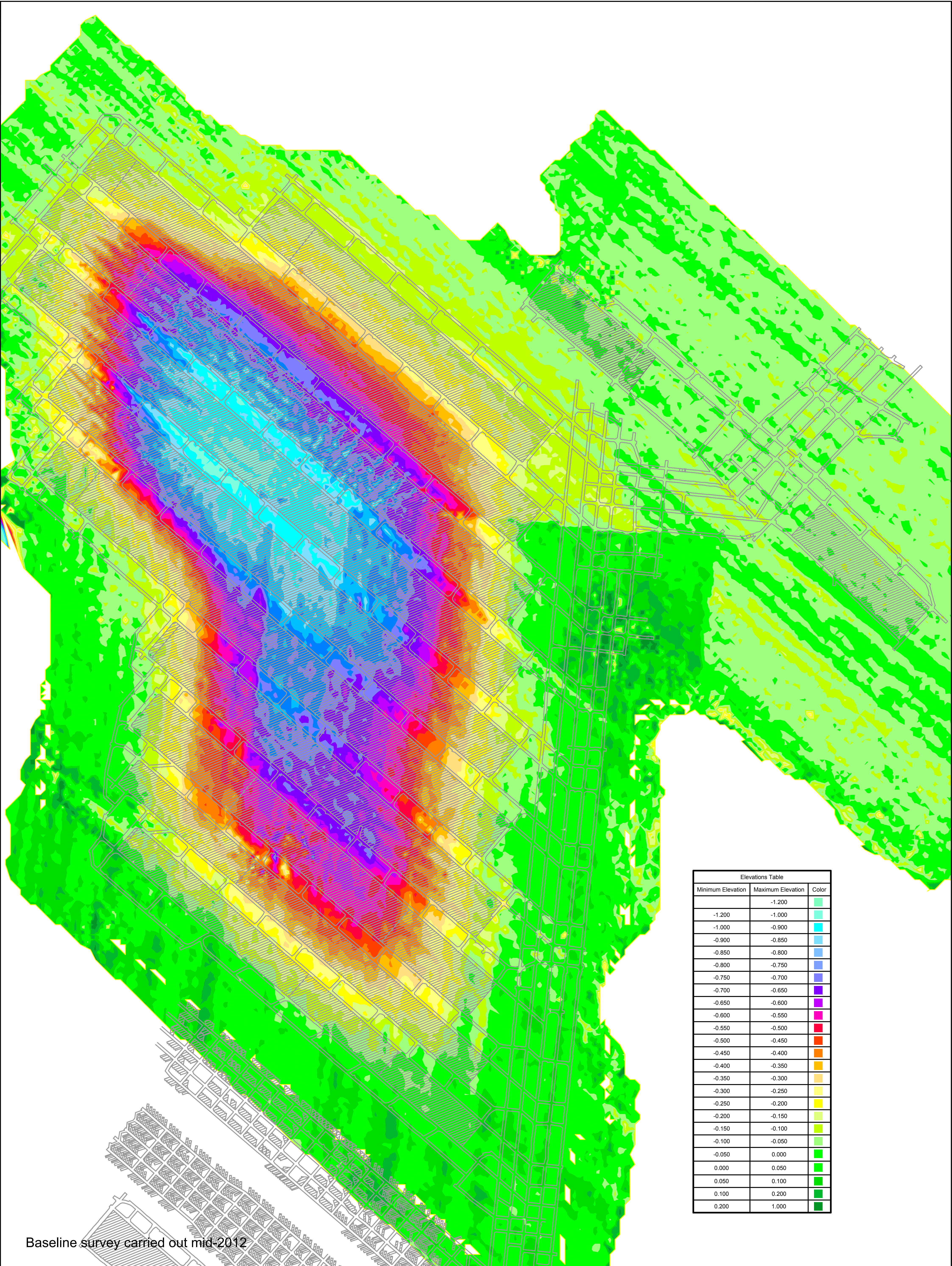
3.2 Bathymetric Surveys

Bathymetric data from the NSW Office of Environment and Heritage (OEH) was obtained in draft format during 2012. Delta Coal was granted a license to use this OEH data for the purposes of monitoring changes in the bed of Lake Macquarie, and acknowledges the OEH's data which has enabled the subsidence comparison to be undertaken based on this 2010 data and data subsequently obtained in 2012 by Delta Coal. OEH notes that the data was obtained via use of differential GPS and a 200 kHz echosounder, which is noted to provide a general data accuracy of 0.1m.

Delta Coal commissioned Astute Surveying in March 2012 to undertake a bathymetric survey over the areas of current and proposed workings. The primary purpose of this survey was to obtain accurate baseline data for future subsidence assessments and to enable comparison with the draft OEH data from 2010. Importantly, the 2012 survey provided accurate details of the Lake depth within the proposed mining areas, which would enable future surveys to use as baseline data to monitor the future subsidence levels as a result of mining activities. Prior to 2018 bathymetric surveys have been conducted annually.

Following an exceedance of the subsidence predictions over Chain Valley Colliery's MW7-12 mining area in 2017 Delta Coal has committed to undertaking future bathymetric surveys at 6 monthly intervals to further understand the behavior of subsidence over the active mining areas. The latest January 2019 bathymetric survey results for Chain Valley Colliery are shown on **Figure 1**.

The surveys have shown that subsidence from the miniwall mining can be monitored with a useful level of accuracy and the surveys will be continued bi-annually to cover future mining areas and areas where mining has been completed.



Elevations Table

Minimum Elevation	Maximum Elevation	Color
	-1.200	
-1.200	-1.000	
-1.000	-0.900	
-0.900	-0.850	
-0.850	-0.800	
-0.800	-0.750	
-0.750	-0.700	
-0.700	-0.650	
-0.650	-0.600	
-0.600	-0.550	
-0.550	-0.500	
-0.500	-0.450	
-0.450	-0.400	
-0.400	-0.350	
-0.350	-0.300	
-0.300	-0.250	
-0.250	-0.200	
-0.200	-0.150	
-0.150	-0.100	
-0.100	-0.050	
-0.050	0.000	
0.000	0.050	
0.050	0.100	
0.100	0.200	
0.200	1.000	

Figure

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CHAIN VALLEY COLLIERY

Bathymetric Survey 20.1.19
Miniwall 1-3,6-12 (Post Extraction)

SCALE:	AS SHOWN	DATE:	25 Jan 2019
DRAWN:	T Chisholm	DRG NO:	C1S0127_1
CHECKED:	-	REV NO:	10
SIGNED:	-	SIZE:	A3

LakeCoal

3.3 Subsidence Predictions and Management

Subsidence modelling has predicted up to approximately 1.23 metres of subsidence to the Lake floor associated with the planned miniwall mining where there is overlying workings, and 780mm where only single seam extraction is undertaken.

As outlined in **Section 3.2** Delta Coal recorded a subsidence exceedance over its Miniwall 7-12 area during the 2017 bathymetric survey where 1100mm of subsidence occurred. As a result of the exceedance Delta Coal has re-designed its future mining its future mining areas to ensure that subsidence values are within the approved predictions.

3.4 Consultation

The Benthic Communities Management Plan is required to be prepared in consultation with the OEH, LMCC and DPI Fisheries.

The original Benthic Communities Management Plan was developed in consultation with the OEH, DPI Fisheries and LMCC. These agencies were contacted on the 28 March 2012, and at this time a face-to-face meeting was offered to discuss the development of the methodologies and management plan, however all stakeholders requested information be provided for comment due to resource constraints. As a result each stakeholder was provided a summary of the survey methods for comment on the 11 April 2012. A response was received from LMCC on the 23 May 2012 regarding mitigation measures and these comments were addressed in the BCMP. No comments were received from OEH or DPI Fisheries.

Copies of the draft Benthic Communities Management Plan (Revision 1) were distributed to the OEH, LMCC and DPI Fisheries on the 13th March 2014 with comments requested back by the 1st April 2014, as of the 7th April 2014 only one response from the OEH had been received, dated the 21st March 2014. The OEH noted that while they encourage the development of such plans, they do not approve or endorse these documents and accordingly no comments were provided.

The previous version of the Benthic Communities Management Plan was sent to OEH, DPI Fisheries and LMCC on 4 November 2016 for review and comment. All three agencies provided comments on the revised Plan. LMCC and DPI Fisheries confirmed that the document was acceptable in its revised form while OEH noted that while they encourage the development of such plans, they do not approve or endorse these documents and accordingly no comments were provided on the content of the Plan.

A further review to the management plan was conducted in 2019 in consultation with DPE-resource assessments, OEH, LMCC and DPI Fisheries. Feedback from Department of Planning-resource assessments requested; the inclusion of the most recent bathymetric survey in January 2019 and an update of the latest mine plan in the monitoring. DPI Fisheries gave confirmation that this plan was adequate on the 05/06/2019. OEH remitted advice on the 05/06/2019 that they were not able to provide comment on plans. LMCC were requested on several occasions for comment on this Management Plan without comment received. A considerable amount of detailed consultation between the former Lake Coal and LMCC occurred in May 2018 for the earlier version of the BCMP.

4 Benthic Communities Monitoring Program

Based on contour mapping of Lake Macquarie and Delta Coal hydrographic surveys, it was identified that the mining operations are largely proposed to occur beneath areas of the Lake at water depths between 4-6m which represent the general Lake depths where subsidence is proposed and under which mining activities have been, will be or are proposed to occur. Accordingly, the monitoring program was designed to sample benthic invertebrate communities from these depths and to provide ongoing monitoring of the potential effects of subsidence. The methodology and monitoring details are presented in the following sections.

4.1 Sampling Locations

In order to analyse the community assemblages and determine potential impacts of subsidence over time, sampling was, and will continue to be undertaken across two depth intervals from numerous site locations within three site types. The site types consist of;

- Impacted (site prefix "IM"): Sites which are currently, or were historically impacted upon by subsidence;
- Reference (site prefix "R"): Sites which are not currently impacted by subsidence but fall within the proposed future mining footprint. Following undermining, Reference sites are designated as Impacted sites; and
- Control (site prefix "C"): Sites which will not be impacted upon by subsidence.

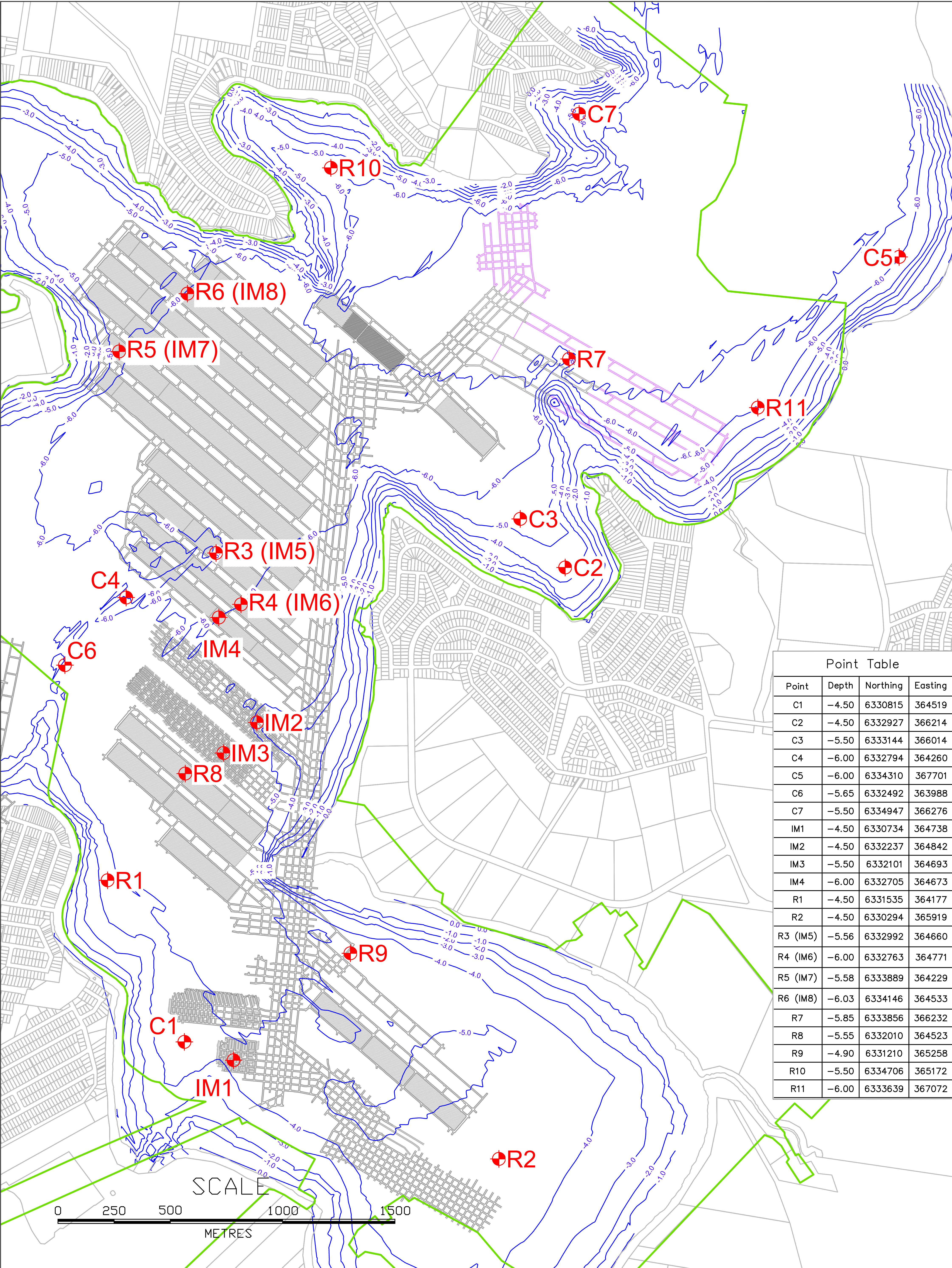
The sampling locations are identified in **Table 2** and **Figure 2**.

Table 2: Benthic Community Sampling Locations

Site Name	Sample Depth (m)	Easting	Northing
C1	-4.5	364519	6330815
C2	-4.5	366214	6332927
C3	-5.5	366014	6333144
C4	-6	364260	6332794
C5	-6.0	367701	6334310
C6	-5.5	363988	6332492
C7	-5.5	366276	6334947
R1	-4.5	364177	6331535
R7	-6.0	366232	6333856
R9	-4.5	365258	6331210
R10	-5.5	365172	6334706
R11	-6.0	367072	6333639
IM1	-4.5	364738	6330734
IM2	-4.5	364842	6332237
IM3	-5.5	364693	6332101
IM4	-6	364673	6332705
IM5 (previously R3)	-6	364771	6332763
IM6 (previously R4)	-5.5	364660	6332992
IM7 (previously R5)	-5.5	364229	6333889
IM8 (previously R6)	-6.0	364533	6334146
IM9 (Previously R8)	-5.5	364523	6332010
IM10 (Previously R2)	-4.5	365919	6330294

4.2 Sampling Methods

Each of the sites will be surveyed for biotic (benthic invertebrates) and environmental (water quality, benthic sediment) variables. The surveys will be undertaken during spring and autumn.



Point Table			
Point	Depth	Northing	Easting
C1	−4.50	6330815	364519
C2	−4.50	6332927	366214
C3	−5.50	6333144	366014
C4	−6.00	6332794	364260
C5	−6.00	6334310	367701
C6	−5.65	6332492	363988
C7	−5.50	6334947	366276
IM1	−4.50	6330734	364738
IM2	−4.50	6332237	364842
IM3	−5.50	6332101	364693
IM4	−6.00	6332705	364673
R1	−4.50	6331535	364177
R2	−4.50	6330294	365919
R3 (IM5)	−5.56	6332992	364660
R4 (IM6)	−6.00	6332763	364771
R5 (IM7)	−5.58	6333889	364229
R6 (IM8)	−6.03	6334146	364533
R7	−5.85	6333856	366232
R8	−5.55	6332010	364523
R9	−4.90	6331210	365258
R10	−5.50	6334706	365172
R11	−6.00	6333639	367072

Legend
- Fassifern Seam CVC Workings (December 2015)
- Proposed Fassifern Seam Workings
- Other Existing Workings (Fassifern Seam)
- Project Boundary - Chain Valley Mining Extension 1

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BENTHIC MONITORING POINTS
LAKE MACQUARIE

SCALE:	1:15000	DATE:	28 May 2019
DRAWN:	T Chisholm	DRG NO:	C1S0120_1
CHECKED:	C Armit	REV NO:	13
Figure 2		SIZE:	A3

Lake Coal

4.2.1 Water Quality

General physico-chemical water quality variables will be measured at the sites during sampling. The water quality parameters will be measured at 0.5m below the surface and 0.5m above the Lake bed. The variables measured will include temperature (^{o}C), pH, turbidity (NTU), conductivity (µS/cm), dissolved oxygen (mg/L and % saturation) and oxygen reduction potential (ORP) or photosynthetically active radiation (PAR).

4.2.2 Benthic Sediment

Sediment samples will be collected to a depth of 20cm at each of the sites using 250mL jars. The jars will be labelled and transported to the laboratory for analysis via settlement method.

4.2.3 Benthic Invertebrates

At each site, five replicate samples of benthic sediment will be collected by a diver using 200x200x100mm sieve boxes with 1mm mesh.

The samples will be sieved to remove sediment particles less than 1mm in diameter. The residual material will then be transferred to a labelled 250mL plastic jar and preserved with formaldehyde. Large fragments of shell will be removed from the sample at this time to ensure that the sample volume did not exceed 250mL and the samples are retained for later inspection at the laboratory.

4.3 Laboratory Analysis

4.3.1 Benthic Sediment

The 250mL sample of the entire sediment from each site will be transferred into a 500mL clear glass measuring cylinder and the volume made up to 500mL with seawater. The cylinder is then to be stoppered and shaken vigorously to suspend the sediment in the seawater. The sample will then be allowed to settle and the volumes of each fraction (shell and coarse sand, fine sand, mud and fine silt) calculated and recorded. Results are then determined relative to the initial volume of sediment collected in the 250mL jar.

4.3.2 Benthic Invertebrate Identification

The contents of each jar is run through a 1mm mesh sieve and washed free of formalin and any remaining mud.

The washed material is then placed into two enamel dishes and portions of each sample placed in a 100mm diameter petri dish for examination under a stereoscopic binocular microscope to detect and recover small organisms. Organisms and parts of organisms are removed, counted, identified and the results entered into a spreadsheet. The benthic invertebrates are identified to genera and species where possible. This process is repeated until the debris of the entire sample had been examined. The results for each site are then entered into an excel spreadsheet for summary and analysis. All shell remaining in the sample is kept for later examination.

4.4 Data Analysis

The biotic and environmental data will be analysed using a variety of univariate and multivariate analysis (**Table 3**). The statistical methods used to analyse the data were determined based on earlier monitoring data to provide the most statistically robust assessment of comparison between impacted and reference and control sites and environmental data. It must be noted that control and reference sites are the same until undermined.

Table 3: Data Analysis

Variable Type	Analysis	Description
Environmental: Water quality	ANZECC/ARMCANZ Guidelines (ANZECC Guidelines)	Trigger values for slightly – moderately disturbed ecosystems: Estuaries.
Biotic and Environmental	Univariate	Descriptive graphical statistics. Analysis of Variance and Similarity (2 way nested)
Biotic and Environmental	Multivariate	A square-root transformation was performed on the data and Bray-Curtis Similarity matrices created. Cluster analysis was then performed for each site and dendrogram plots produced.
	Multidimensional Scaling Ordination	The analysis represents the sites as points in space so the relative distances between samples show similarities in community structure. Samples that are placed closer together are more similar than samples further apart.
	BIOENV	The analysis matches environmental variables against biotic data which have been measured at the same sites. This analysis enables analysis of the extent to which the physio-chemical data is related to the observed biological patterns. Correlations were performed for each site between the biotic and environmental factors using the BIOENV function in PRIMER5.

4.5 Monitoring Frequency

The baseline sampling program methods outlined in **Section 4** will form the basis for a seasonal monitoring program that will be undertaken during spring and autumn each year to survey biotic (benthic invertebrates) and environmental variables (water quality and sediment). The program has been designed to enable analysis and reporting of the data to monitor the impacts of subsidence and effects, including but not limited to light reduction and sediment disturbance, on benthic species number and benthic communities composition and distribution.

In addition to the above, annual lake bed bathymetric surveys will be undertaken prior to each autumn survey. The annual bathymetric surveys will enable any change to the lake floor to be identified and addressed during the data analysis process.

4.6 Program Refinement

The survey methods will be reviewed every two years of seasonal sampling to refine the sampling program if required. Prior to each seasonal sampling event the sites will be reviewed against the mine plans to ensure that any reference sites that have become impacted upon by mining are reclassified as impact sites, and replacement reference sites are identified and sampled. This will result in additional reference sites being added to the program during the monitoring period.

5 Modelling to Monitor Potential Impacts

5.1 Model Background

Maximum subsidence for the proposed future mining activities is predicted to be 1230mm, or 780mm where no overlying workings exist. The analysis undertaken on the baseline data provides an initial assessment of biotic and environmental variables associated with the study area and forms the basis of the formation of the predictive modelling (JSA 2012). The results will be reported in biannual monitoring reports and the Annual Review.

The aim of the predictive modelling is to compare the condition of the baseline benthic community assemblages prior to mining to the benthic community assemblages after mining has occurred, to ensure that only minor environmental consequences occur due to mining activities. The effects of subsidence are required to result in only minor changes to species composition and/or distribution. As the environmental variables which affect benthic communities are complex, in order to determine whether community dynamics at reference sites are related to subsidence, seasonal biotic survey data will be analysed against environmental data and between impacted types. The analysis and modelling will be undertaken to determine whether:

- Overall community dynamics are related to seasonal and environmental variables and/or subsidence impacts;
- Abundance and diversity changes to community composition at reference sites that have been undermined are related to seasonal and environmental variables or subsidence impacts; and
- Changes identified in reference sites that have been undermined are considered minor.

5.2 Analysis

In order for the model to identify whether the environmental consequences of subsidence are considered minor (and therefore whether mitigation measures will be required) a series of statistical analysis will be undertaken and reported seasonally and annually. Based on the expected timing of subsidence impacts, the analysis will model scenarios to determine:

- Changes in undermined reference sites with the baseline conditions at the same sites; and
- Similarity of impacted sites to control and reference sites at similar depths.

The modelling will be based on Multi-dimensional Scaling (MDS) Ordination, two way ANOVAs (analysis of variation) and ANOSIM (analysis of similarity) techniques to identify any links in community structure between sites at the same depth profiles. The modelling will be based on the existing benthic community structure, actual subsidence levels (determined from annual bathymetric surveys), predicted levels of increased subsidence and collection of seasonal data.

Figure 2 identifies the reference sites applicable to the project. The communities at the reference sites will be compared against control and reference sites at a similar depth profile. The determination of the level of impact of subsidence, once other environmental variables have been discounted by the model will be based on ANOVA/ANOSIM techniques.

Essentially, if ANOVA/ANOSIM results indicate that undermined reference site communities are changing at a rate of ANOVA/ANOSIM test of significance <5 % then the impacts will be considered to be moderate or major mitigation measures to manage impacts will be required. The use of 5% (the p significance level of 0.05) is a standard statistical method of determining level of significance, another is p= 0.01. Because the data set used in the initial analysis represents a single sampling event the use of the conservative 5% significance rule has been applied to determine minor impacts(other methods such as ranking and scaling were applied to the data but did not provide adequate measurable results). The 5% significance will be applied to seasonal data and revisited with regard to suitability based on data outcomes.

The options for mitigation measures to manage subsidence on the lake floor are largely limited to changes to mine design. If impacts are determined to be moderate or major, mine planning will be required to modify mine plans.

The benthic community results of surveys and annual monitoring undertaken have identified that while communities at some sites were defined by dominant species, the abundance and diversity of the communities did not identify clear links to location or impact type. Rather the analysis identified that natural environmental fluctuations in water quality, benthic substrate composition and natural depth intervals were influencing the communities (JSA 2013).

The results of sampling between February 2012 and September 2017 appear to support the notion that increasing the water depth by the predicted subsidence will have no discernible effect on the composition and abundance of organisms making up the benthos of the mud basin (Laxton & Laxton, 2017). This is supported by the statistical modelling of results which is undertaken every 3 years.

In January 2018 Delta Coal engaged JSA environmental to undertake the 3 yearly statistical modelling of the sites Benthos data set. Detailed ANOSIM analysis of the benthic community data between un-impacted and impacted sites between 2012 – 2017 identified a significance p value of 24.1%. This value indicates that there had been no significant differences between the un-impacted and impacted sites over the last 5 years.

If the assessment of results from future analysis indicate that impacts are outside the defined trigger level Delta Coal will investigate the cause of incident and implement corrective actions where required as outlined in Section 6.

6 Incident & Compliance Management

6.1 Introduction

The benthic community monitoring results will be reviewed on a biannual basis as survey reports are received to confirm compliance with the conditions specified in the *Subsidence Impact Performance Measures* found in **Table 1**.

The Annual Review will also include a summary of monitoring results during the past year, discussion with reference to the impact assessment criteria, and any relevant details related to comparisons between actual results and predictions in the Environmental Impact Statement. The Annual Review will be forwarded to the relevant authorities including Department of Planning and Environment, and Environment Protection Authority. The Annual Review will also be forwarded to members of the Community Consultative Committee and local Councils (Central Coast and Lake Macquarie). It will also be placed on the company's website along with a summary of environmental monitoring results.

6.2 Incident or Non Compliance Reporting

If monitoring reveals that, as a result of mining activities, greater than minor impacts have occurred, then Delta Coal will conduct an investigation into the cause of the non-compliance. The investigation will consider any activities or other factors that may have generated the non-compliance. The report will be provided to OEH, LMCC and Department of Planning and Environment.

The report will:

a) describe the date, time and nature of the exceedance / incident;
b) identify the cause (or likely cause) of the exceedance / incident;
c) describe what action has been taken to date; and
d) describe the proposed measures to address the exceedance / incident.

Delta Coal would implement the recommendations of the investigation in order to address any future non-compliance issues.

Additional details of the incident reporting process are provided in the Environmental Management Strategy.

7 Stakeholder Management and Response

7.1 Complaint Protocol

Delta Coal has a 24-hour telephone hotline (1800 687 557) for members of the public to lodge complaints, concerns, or to raise issues associated with the operation. This service aims to promptly and effectively address community concerns and environmental matters.

The full details of the complaints line are covered in the Environmental Management Strategy, but in summary, all complaints are recorded and responded to, if for some reason no action is taken then the reason why is recorded. The information recorded in the complaint register includes;

- date and time the complaint was lodged;
- personal details provided by the complainant;

- nature of the complaint;
- action taken or if no action was taken, the reason why; and
- follow up contact with the complainant.

7.2 Dispute Resolution

If any disputes are not adequately addressed by the complaints handling process then they will be handled by the site Environment and Community Coordinator, if the response of Delta Coal is not considered to satisfactorily address the concern of the complainant, a meeting will be convened with the Mine Manager together with the Environment and Community Coordinator.

The complainant will be advised of the outcomes from the meeting and the actions to be implemented as a result.

After implementation of the proposed actions, the complainant will be contacted and advice sought as to the satisfaction or otherwise with the measures taken.

If no agreed outcome is determined or the complainant is still not satisfied by the action taken, then an Independent Review may be requested by the complainant. If determined to be warranted by the Secretary, an Independent Review will be undertaken in accordance with the requirements of the project approval to achieve an outcome to the satisfaction of the Secretary.

8 Roles and Responsibilities

Roles, responsibilities specific to completing the requirements of Benthic Communities Management Plan are identified in **Table 4**.

Table 4: Roles and Responsibilities

Role	Responsibilities
Mine Manager	• Ensure that adequate financial and personnel resources are made available for the implementation of the Benthic Communities Management Plan.
Environment and Community Coordinator	• Co-ordinate benthic community monitoring. • Review benthic community monitoring results on a seasonal and annual basis. • Develop management actions in consultation with regulatory agencies as/if required from the monitoring results. • Compile the Annual Review (including a summary of the benthic community monitoring). • Respond to any potential or actual non-compliance and report these as required to regulatory bodies and other stakeholders. • Undertake reviews of this document as per **Section 9.** • Undertake or coordinate the required audits of this document, in accordance with **Section 9.2**. • Notify DPI Fisheries, Department of Industry – Resources and Energy and Department of Planning and Environment if there are any exceedances in impact thresholds outlined in **Section 1**. • Ensure complaint handling and response is undertaken, including determination of sources and potential remedial action to avoid recurrence.

8.1 Training, Awareness and Competence

Training is an essential component of the implementation phase of this Benthic Communities Management Plan. Any person or position that has a role or responsibility under this document will be provided with a copy of the document and be advised verbally regarding their requirements by the Environment and Community Coordinator.

As the document owner, the Environment and Community Coordinator is the contact point for any person that does not understand this document or their specific requirements, and will provide guidance and training to any person that requires additional training regarding this management plan.

9 Audit and Review

9.1 Overview

This document shall be reviewed, and if necessary revised, within 3 months of the following:

- The submission of an Annual Review;
- The submission of an incident report under **Section 6.2**;
- The submission of an independent environmental audit; and
- Following any modification to the development consent.

As outlined in **Section 6.1**, the annual review will include a review of the seasonal monitoring program and mine plans to ensure that any reference sites that have been impacted by mining reclassified as impacted impact sites, and replacement reference sites identified and sampled. Survey methods will be reviewed every two years to refine the sampling program if required. Improvements identified during reviews or audits will be incorporated into the Benthic Communities Management Plan.

9.2 External Audits

An Independent Environmental Audit of the Chain Valley Colliery development consent will be undertaken every three years (or as otherwise required by Department of Planning and Environment) by an audit team whose appointment has been endorsed by the Secretary. This audit will review the relevant management plans that apply to the operation.

Any actions arising from external audits will be loaded into the site action management database to ensure the actions are assigned to the relevant people and completed.

10 Records

Generally the Environment and Community Coordinator will maintain all Environmental Management System records, which are not of a confidential nature. Records that are maintained include:

- monitoring data and equipment calibration;
- environmental inspections and auditing results;
- environmental incident reports;
- complaint register; and
- licenses and permits.

All records are stored so that they are legible, readily retrievable and protected against damage, deterioration and loss. Records are maintained for a minimum of 4 years.

11 Document Control

This document and all others associated with the Environmental Management System shall be maintained in a document control system which is in compliance with AS/NZS 4804; section 4.3.3.4 (Document Control) and in compliance with the site Document Control Standard which is available to all personnel.

Any proposed change to this document shall be via the document control administrator who is the only person able to access the controlled documents.

12 References & Associated Documents

AS/NZS ISO 14001:2004	Environmental management systems – Requirements with guidance for use
AS/NZS ISO 14004:2004	Environmental management systems – General guidelines on principles, systems and support techniques
ANZECC (2000)	Australian and New Zealand Guidelines for Fresh and Marine Water Quality.
SSD-5465	Development Consent SSD-5465 (Modification 2), 16 December 2015
JSA Environmental 2013	Chain Valley Colliery Mining Extension 1 Project Marine Ecology Assessment Delta Coal
JSA Environmental 2015	Chain Valley Colliery Modification 2 Marine Ecology Assessment Delta Coal
Laxton & Laxton, 2013	Lake Macquarie Benthos Survey Results of Sampling No. 4. September 2013.
Laxton and Laxton 2015	Benthic Communities Survey of Chain Valley Bay, Summerland Point and Crangan Bay, Lake Macquarie, NSW
Laxton and Laxton 2016	Lake Macquarie Benthos Survey Results No.10 September 2016. J.H. & E.S. Laxton - Environmental Consultants P/L. Report for Lake Coal Pty Ltd Chain Valley Colliery.

13 Definitions

CVC
Delta Coal - Chain Valley Colliery

DTIRIS – Resources and Energy
Department of Trade, Investment, Regional Infrastructure and Services – Resources and Energy

DPI Fisheries
Department of Primary Industries – Fisheries NSW

EMS
Environmental Management System

LMCC
Lake Macquarie City Council

OEH
Office of Environment and Heritage

Secretary
Secretary of the Department of Planning and Environment, or nominee

SSD-5465
Development Consent SSD-5465 (for the Chain Valley Colliery Mining Extension 1 Project)

Doc Owner:	**Environment and Community Coordinator**
Doc No:	ENV 00020 - Seagrass Management Plan

CHAIN VALLEY COLLIERY

Seagrass Management Plan

ENVIRONMENTAL MANAGEMENT PLAN

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	Mine Manager
Date:	17/06/2019

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1 Introduction

Chain Valley Colliery is an underground coal mine located on the southern end of Lake Macquarie, approximately 100km north of Sydney and 60km south of Newcastle, adjacent to the Vales Point Power Station, producing thermal coal for the domestic and export markets.

A formal Environmental Management System (EMS) has been developed as a systematic and structured approach to managing environmental issues at the operation. This has been developed in general accordance with the requirements of the international standard ISO 14001.

This Seagrass Management Plan is an element of the Chain Valley Colliery Environmental Management System.

This Seagrass Management Plan has also been completed to satisfy the requirements of Development Consent SSD–5465 (Modification 2), Schedule 4 Condition 7(i) and Schedule 4 Table 8, which states:

"7. The Applicant shall prepare an Extraction Plan for all second workings on site, to the satisfaction of the Secretary. Each Extraction Plan must:

> (i) include a Seagrass Management Plan, which has been prepared in consultation with OEH, LMCC, and DPI Fisheries, which provides for the management of the potential impacts and/or environmental consequences of the proposed second workings on seagrass beds, and which includes:
>
> - a program of ongoing monitoring of seagrasses in both control and impact sites; and
> - a program to predict and manage subsidence impacts and environmental consequences to seagrass beds to ensure the performance measures in Table 8 are met."

In addition to the above, Condition 2 within Schedule 4 of SSD-5465 (Modification 2) also requires that:

"The Applicant shall ensure that the development does not cause any exceedance of the performance measures in Table 8 to the satisfaction of the Secretary."

The relevant seagrass requirements from Table 8 within Schedule 4 of the Development Consent, including the relevant notes, are recreated in **Table 1**.

Table 1: Subsidence Impact Performance Measures - Natural and Heritage Features

Biodiversity	
Seagrass beds	Negligible environmental consequences including: • *negligible* change in the size and distribution of seagrass beds; • *negligible* change in the functioning of seagrass beds; and • *negligible* change to the composition or distribution of seagrass species within seagrass beds.

Notes:

- *The Applicant will be required to define more detailed performance indicators (including impact assessment criteria) for each of these performance measures in the various management plans that are required under this consent (see Condition 7 below).*
- *Measurement and/or monitoring of compliance with performance measures and performance indicators is to be undertaken using generally accepted methods that are appropriate to the environment and circumstances in which the feature or characteristic is located. These methods are to be fully described in the relevant management plans. In the event of a dispute over the appropriateness of proposed methods, the Secretary will be the final arbiter.*
- *The requirements of this condition only apply to the impacts and consequences of mining operations, construction or demolition undertaken following the date of approval of this consent.*

2 Purpose

The purpose of this Seagrass Management Plan is to:

- outline details of the seagrass monitoring data collected;
- outline subsidence prediction methodology;
- outline the methodology to be used to identify depth changes at monitoring locations;
- identify seagrass monitoring locations;
- identify reporting requirements;
- detail seagrass management measures;
- identify the requirements for incident or exceedances reporting and reviews of the document; and
- identify persons responsible for implementation of requirements.

3 Background

3.1 Operations

Chain Valley Colliery is an underground coal mine with current coal mining methods including development of roadways in the coal seam known as first workings and secondary extraction. These first workings develop panels to support the installation of a miniwall, a modern secondary coal extraction method.

Lake Macquarie is the largest saline lake in New South Wales. It lies on the central coast between Sydney and Newcastle within the local government areas of Central Coast and Lake Macquarie Council's. Lake Macquarie has a catchment of 700 square kilometres and a water surface area of 125 square kilometres (Bell & Edwards, 1980). The lake has a permanent entrance to coastal waters at Swansea and has an average depth of around 6 meters (Laxton, 2005).

The catchment of Lake Macquarie is largely rural with large areas of bush land and grazing land. The shoreline of Lake Macquarie is heavily urbanised, especially the eastern, western and northern shorelines. The region has a relatively long history of coal mining and power generation, with mining occurring since the late 1800s and the first power station at Lake Macquarie commencing operations in 1958.

The Chain Valley Colliery is situated on the southern shores of Lake Macquarie near Mannering Park, NSW. The mine has been operating since 1962. Mining is currently undertaken using miniwall methods with first workings to support the development in advance of each miniwall panel. All secondary extraction is currently occurring in the Fassifern seam, in line with Development Consent SSD–5465 (Modification 2). The general layout of the Chain Valley Extension Project in respect to Lake Macquarie is shown on **Figure 1**.

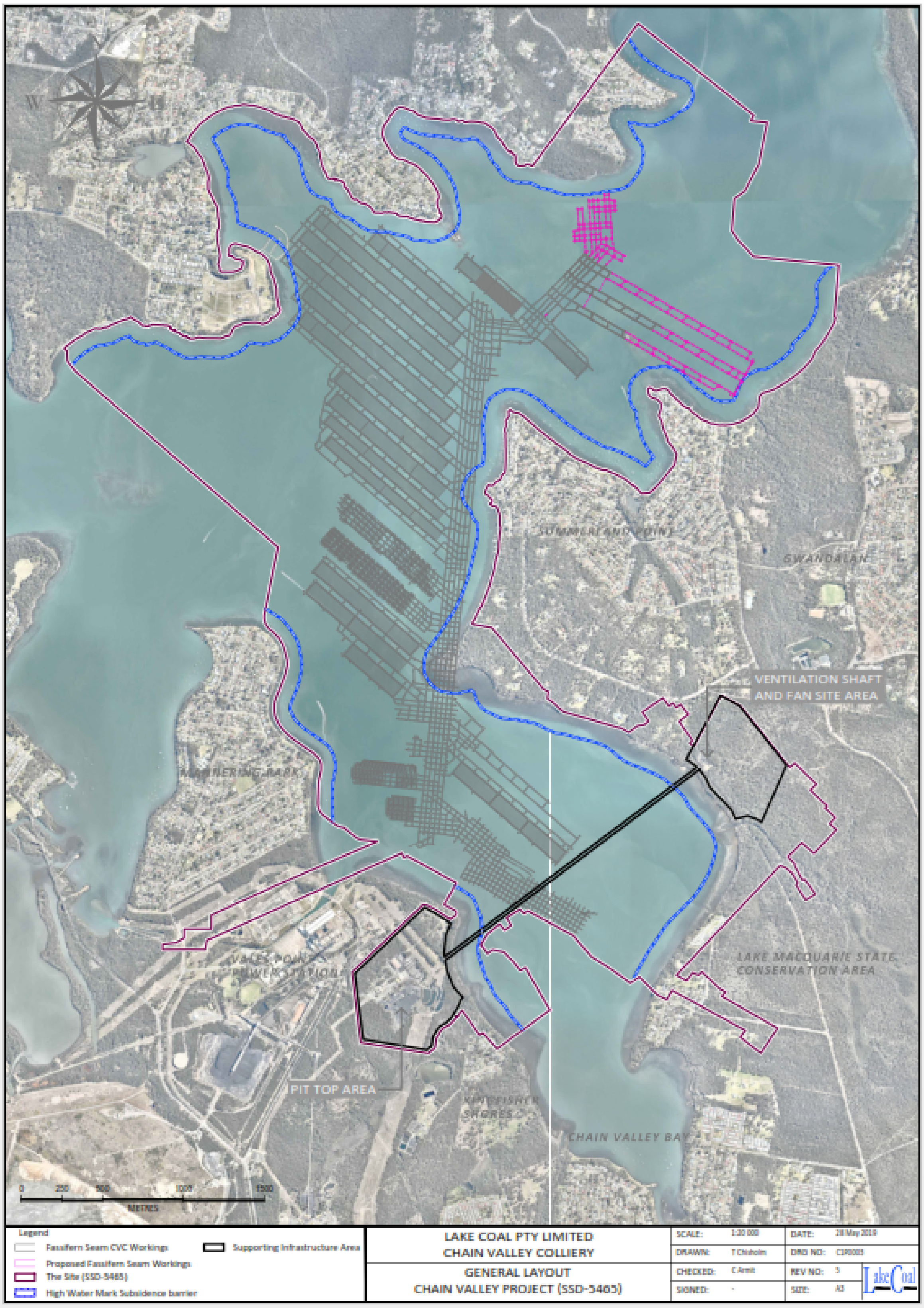

Figure 1: General Layout of the Chain Valley

3.2 Seagrass Communities

Lake Macquarie contains approximately 10% of the total area of seagrass beds in NSW (DPI 2007). Four species of seagrass occur in Lake Macquarie: eel grass (*Zostera capricorni*); paddle weed (*Halophila ovalis*); *Ruppia sp.*; and strapweed (*Posidonia Australia*) which is listed as an endangered species under the Fisheries Management Act, 1994.

Seagrass distribution within estuaries is naturally influenced by light penetration, depth, salinity, nutrient status, bed stability, wave energy, estuary type, and the evolutionary stage of the estuary. Light is a major limiting factor for the growth of seagrasses and the effects of shading either by artificial structures or increased turbidity associated with sediment re-suspension are common light reducing factors in estuaries (BioAnalysis 2008).

Seagrass communities in Lake Macquarie appear to have declined since 1953, though there was a general increase in the cover of seagrass in Lake Macquarie between 2000 and 2004 due to a change in light penetration following a period of lower freshwater inputs (King and Barclay 1986; Wellington 2000; Gray and Wellington 2004).

Annual surveys of seagrass communities in Summerland Point, Chain Valley and Crangan Bay (i.e. within and adjacent to the current mining areas) have been undertaken on behalf of Delta Coal since 2008 by J.H. & E.S. Laxton - Environmental Consultants Pty Ltd. Additional survey locations in Bardens Bay were added in 2014. Two species of seagrass are present in these areas, namely, eel grass and paddle weed. The 2017 survey report *Seagrass Survey of Chain Valley Bay, Summerland Point, Bardens Bay and Crangan Bay, Lake Macquarie, NSW (Results for 2008 to 2017)* (JH & ES Laxton - Environmental Consultants, June 2017) reported seagrass cover along the transects ranged from 90.44 to 100% of the substratum in 2017. Since 2011 seagrass cover has generally increased progressively. This annual increases in seagrass cover is most likely attributable to the cessation of commercial fishing in Lake Macquarie which were known to impact on the seagrass beds through land based netting practices.

In 2018 there were no changes in sea bed height across transects greater than 0.10m (0.15m trigger level) compared with the datum from previous years.

Several studies have been conducted on the seagrass beds in Chain Valley Bay and Summerland Point that are relevant to this Seagrass Management Plan.

In July and August 2007, Delta Coal engaged JH & ES Laxton – Environmental Consultants to identify the environmental factors that included seagrasses, benthic fauna and bathymetry. The study area was the area east of Mannering Park. It was found that the seagrass beds were composed of *Zostera capricorni* (Eel grass) only.

It was concluded that seagrasses in Chain Valley Bay commenced along the lake edge and appeared to have a depth limit of less than 2m, and that any mining beneath the beds could lead to subsidence which would cause a decline of seagrasses along the outer edge of the seagrass beds. It was also concluded that the distribution and density of seagrass beds in Chain Valley Bay could change due to events unrelated to underground coal mining.

In July 2008, the seagrass survey was conducted to the west of Summerland Point (see **Figure 1**), from Frying Pan Point to Sandy Beach Reserve, Summerland Point, Lake Macquarie. The 2008 seagrass survey provided the baseline data for seagrass distribution, density and condition to which annual surveys are compared. It was determined that seagrass densities in Chain Valley Bay and Crangan Bay ranged from 17.74 to 99.32% of the substratum in the -0.19 to -2.34 A.H.D zone around the shore. Two forms of the seagrass *Zostera capricorni* were present; short leaved and long leaved forms. In Lake Macquarie, the distinction between these two forms of *Zostera capricorni* appeared to be arbitrary. In 2010 a second species of seagrass, *Halophila ovalis* (paddle weed), was discovered for the first time at transect E6 in Chain Valley Bay on 12th June 2010.

Subsequent annual seagrass surveys discovered large and unexplained changes in seagrass cover which were unrelated to underground coal mining, as no mining had impacted seagrass beds since commencement of monitoring. The precise reasons for these longer term changes in seagrass distribution are not always obvious but may be related to changes in water transparency, salinity, nutrient concentrations and the proliferation of epiphytic algae. Migration of sediment may also change the distribution of seagrasses over time. It is also thought that the cessation of commercial fishing in Lake Macquarie has positively contributed to the regrowth of seagrass beds around the Lake.

Seagrass is a vital component of Lake Macquarie's marine ecosystem. It captures the sun's energy and converts it into organic matter that may be utilised by the whole food chain. Destruction of seagrass beds could lead to a reduction in available organic matter for marine flora and faunal species. Seagrass also improves water quality as it decreases sediment within the water column and takes in many nutrients and heavy metals entering the waterway. Hence a reduction in seagrass population may also result in decreased water quality.

3.3 Seagrass Mapping

The seagrass bed assessment completed for Chain Valley Colliery by JH & ES Laxton – Environmental Consultants P/L found that two forms of the seagrass *Zostera capricorni* were present adjacent to the proposed mining operations. These were short leaved and long leaved forms of *Zostera capricorni*. It observed the seagrass beds commenced along the lake edge and terminated when water depths approached 2m.

Further mapping undertaken as part of the Chain Valley Mining Extension 1 Project in 2011/2012, enabled the maximum depths and locations of seagrass to be considered in the mine design for the Mining Extension 1 Project. This resulted in the generation of a broader seagrass protection barrier, extending to the proposed mining areas, which was then used to refine the mine design and ensure subsidence impacts to seagrass communities could be avoided. This study found that the communities were dominated by *Zostera capricorni* and that in general, the areas were characterised by patchy individuals of *Zostera*. The seagrass beds were found to exist to a maximum depth of 1.9m.

Further visual assessments and remapping of seagrass beds within the areas of Sugar Bay, Frying Pan Bay and Point Wolstoncroft was undertaken by Delta Coal, JH & ES Laxton – Environmental Consultants P/L and Daly Smith Surveyors in February 2018. The mapping was commissioned by Delta Coal as part of the development of it's next extraction plan for its Northern Mining Area (NMA).

Details from these studies have been combined to produce the mapping of seagrass over the entirety of the historic, current and future mining areas, and enabled the seagrass protection barrier to be further defined. The current seagrass mapping is shown on **Figure 2**.

3.4 Subsidence Predictions and Management

Subsidence modelling has predicted up to approximately 1.23 metres of subsidence to the Lake floor associated with the planned miniwall mining where there is overlying workings, and 780mm where only single seam extraction is undertaken.

Delta Coal recorded a subsidence exceedance over its Miniwall 7-12 area during the 2017 annual bathymetric survey where 1100mm of subsidence was identified. As a result of the exceedance Delta Coal has re-designed its future mining areas to ensure that subsidence values are within the approved predictions in accordance with SSD 5465.

The seagrass communities within the entirety of the proposed mining areas have been mapped and the majority of the seagrass beds appear to extend to depths around 2 – 2.5m. As a result, if mining takes place beneath the seagrass beds, and subsidence takes place, it could be expected that the lower areas of the seagrass beds will potentially retreat with increased depth as a result of reduced light available for photosynthesis.

In light of Condition 7 (i) Schedule 4 and to ensure the performance measures in **Table 1** are met an essential component of this Seagrass Management Plan is the Seagrass Protection Barrier to ensure that any impacts associated with its mining operations are negligible. This barrier is further described in **Section 4.1**.

3.5 Consultation

The original version of this Seagrass Management Plan was provided to OEH, LMCC and DPI Fisheries for comment. Both LMCC and DPI Fisheries reviewed the Seagrass Management Plan, with comments from DPI Fisheries provided on the 28th June 2013. At that time DPI Fisheries had no objection to the plan being implemented as written. Comments from Lake Macquarie City Council were received on the 19th July 2013, which were addressed and incorporated into the document, this final version was then sent back to Council who confirmed on the 19th August 2013 that the changes had addressed their comments. The changes made previously to address Council's comments remain in the current version.

Revision 2 of the draft Seagrass Management Plan was provided to OEH, DPI Fisheries and LMCC on the 12th March 2014, with comments on the draft plan requested back by the 1st April 2014. The only response received was from OEH, dated the 21st March 2014. The OEH noted that while they encourage the development of such plans, they do not approve or endorse these documents and accordingly no comments were provided.

Revision 3 of the Seagrass Management Plan was sent to OEH, DPI Fisheries and LMCC on 4 November 2016 for review and comment. All three agencies provided comments on the revised Plan. LMCC and DPI Fisheries confirmed that the document was acceptable in its revised form while OEH noted that while they encourage the development of such plans, they do not approve or endorse these documents and accordingly no comments were provided on the content of the Plan.

Revision 4 of the Seagrass Management Plan was provided to OEH, DPI Fisheries and LMCC on 26 February 2018 with the Extraction Plan application for Chain Valley Colliery's Northern Mining Area (NMA).

Revision 5 of the Seagrass Management Plan was sent to OEH, DPI Fisheries and LMCC in May 2019. On the 5 June 2019 DPI Fisheries responded that the Seagrass Management Plan was adequate. On 5 June 2019 OEH noted that they do not approve or endorse these documents and accordingly no comments were provided on the content of the Plan. No comments have been provided by LMCC.

4 Seagrass Management

No secondary extraction is being undertaken, nor is it planned to be undertaken beneath seagrass beds.

In addition, to achieve negligible impact on seagrass beds due to subsidence effects, a seagrass protection barrier has been established. This barrier is based on the seagrass mapping and the application of an "angle of draw" of 26.5° from the seagrass area to the coal seam being mined, as depicted in **Figure 2** and **Figure 3**.

Only first workings are to be undertaken within the seagrass protection barrier. In these areas subsidence will be limited to less than 20mm which is considered to be negligible.

The purpose of this plan is to monitor and report on any changes in seagrass communities over time. The monitoring program also includes physical surveys to detect if there is any vertical movement that could attributable to mine subsidence and if identified, determine if subsidence has caused anything other than a negligible impact. To achieve this, the following will be undertaken:

- an annual survey of the study area with 50 seagrass transects using differential GPS survey methods. These differential GPS survey methods will establish the precise location and height of the lake bed at inner and outer ends of each transect and compare these values against those of previous years and the baseline survey;
- a survey to determine the maximum seaward extent of the seagrass beds and the maximum depth at which they occurred;
- photographic survey of seagrass distribution, density and condition along each transect to be recorded using a video camera enclosed within a waterproof housing and mounted on a floating platform;
- conduct annual seagrass surveys while mining operations have the potential to impact seagrass communities. Reports of annual surveys will be sent to the Department of Primary Industries – Fisheries and Lake Macquarie City Council.
- a summary of the annual seagrass survey will be included in the Annual Review;
- responding to any potential or actual non-compliances and reporting as required to regulatory bodies and other stakeholders; and
- all complaints will be recorded in the complaints register with actions taken also noted.

The personnel responsible for the above management measures are detailed in **Section 8** (Roles and Responsibilities).

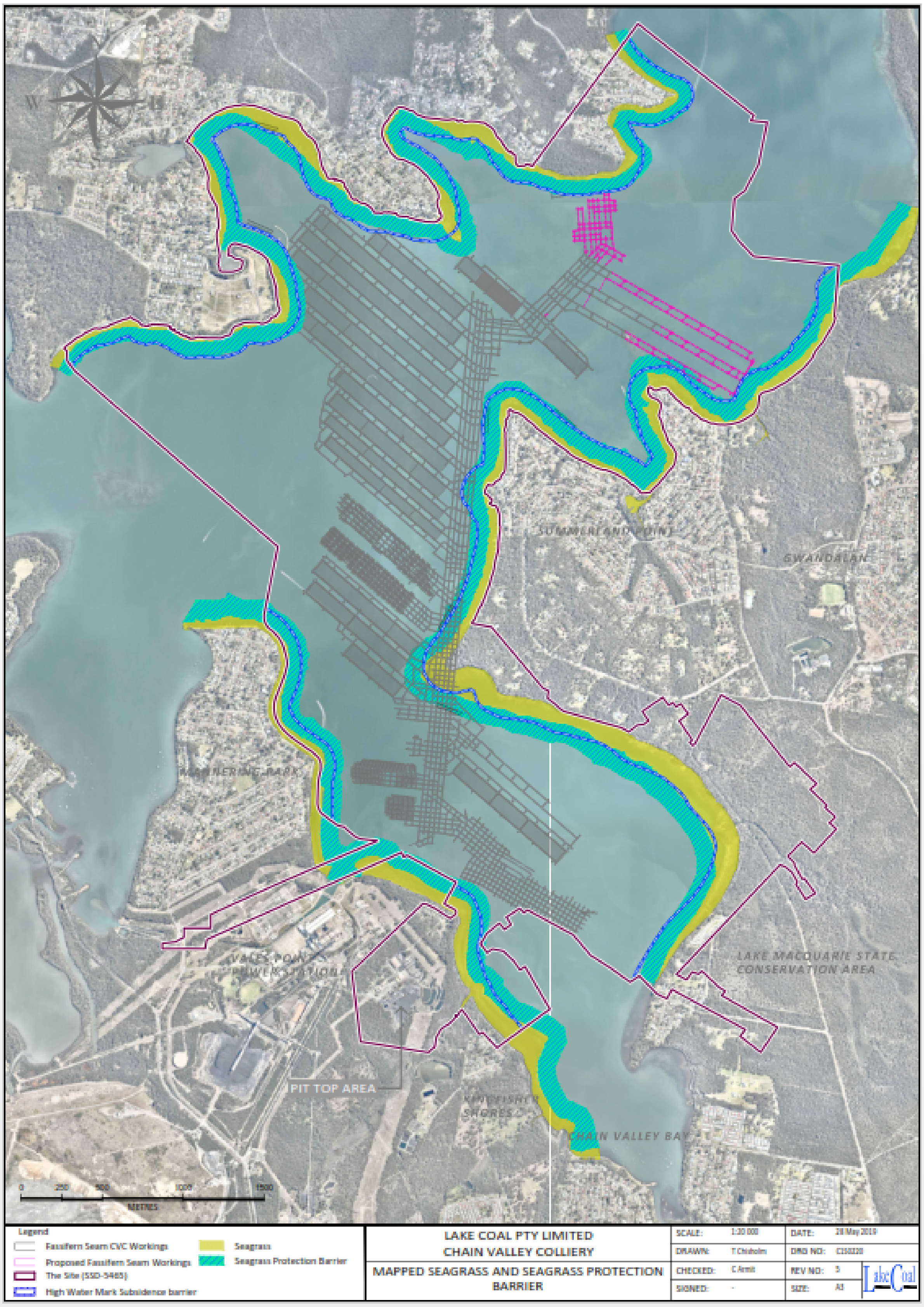

Figure 2: Mapped Seagrass and Seagrass Protection Barrier

4.1 Seagrass Protection/Limits

As part of the protection of the lake foreshore, the Colliery holding mining leases require a protection barrier around the foreshore. This is known as the High Water Mark (HWM) Subsidence Barrier and is shown on **Figure 1**. The barrier is approximately 130 metres wide, but varies based on the depth of cover, and no secondary extraction occurs within this zone. Although similar in some locations, the HWM Subsidence Barrier and the Seagrass Protection Barrier are separate barriers, with the mine layout limited (among other factors) by either barrier at any specific location. The application of the HWM Subsidence Barrier and Seagrass Protection Barrier is depicted on **Figure 3**.

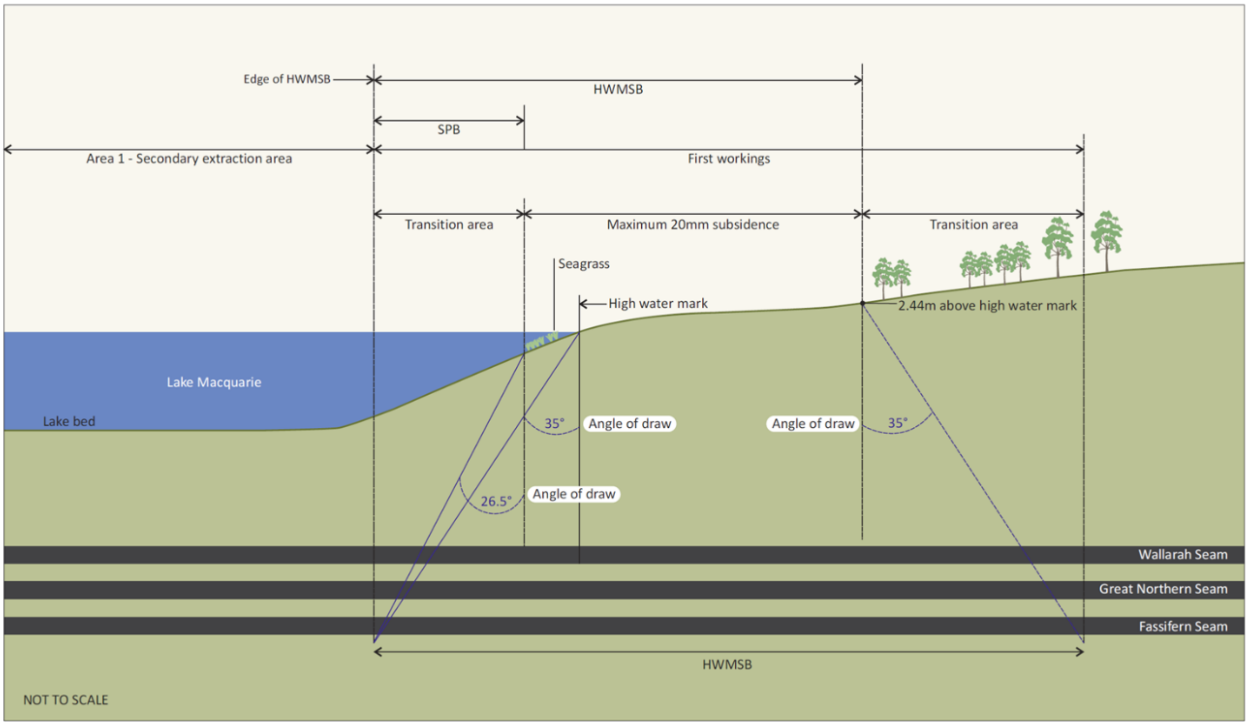

Figure 3: Protection Barrier Schematic

Despite the above barriers which are in place to protect the seagrass and foreshore areas, monitoring thresholds have been established based on observable change to seagrass beds or bed height, the following triggers have been set:

1. 20% decline in condition from the base year survey (i.e. earliest survey prior to mining occurring nearby).
2. Mining induced subsidence of 150mm or greater being recorded at one of the monitoring sites.

The Delta Coal Environment and Community Coordinator will notify DPI Fisheries, Lake Macquarie City Council and the Department of Planning and Environment if either of the above impact thresholds are exceeded, if deemed necessary by any of the parties, a meeting will be convened to discuss the results and determine any required future action.

It is noted that in prior years the 20% decline in baseline condition has been seen at a number of seagrass monitoring sites in the absence of any subsidence, as such, reaching a threshold may not in itself warrant the convening of a meeting or the requirement for further actions.

4.2 Seagrass Impact Mitigation

If, through the monitoring program (refer **Section 5**), subsidence is found to occur in areas known to contain seagrass beds (as identified in **Figure 2**) and loss of seagrass habitat has been determined to have occurred as a direct result of this subsidence, then Delta Coal would commit to undertaking remediation strategies to replace an equal area of any loss of seagrass habitat that has occurred.

While Delta Coal's approach to manage seagrass is aimed at protection, if an investigation were to identify that an exceedance / incident has occurred that was a direct result of the mining activities and associated subsidence, then Delta Coal would develop a remediation plan, which would be submitted to DPI Fisheries, identifying the proposed remediation strategy. The strategy would identify proposed remediation measures which could include:

- Transplanting existing communities with additional fast growing locally occurring seagrass plants;
- Regrading: topographical restoration; and/or
- Fertilising: to stimulate lateral ingrowth of seagrass communities.

The exact method of remediation would be determined based on the existing integrity of the seagrass beds, existing species and specific impacts that have occurred, that is, the remediation strategy would be "site specific" to ensure the most appropriate remediation methodology is implemented in consultation with DPI Fisheries.

Should remediation on-site not be viable, mitigation could be undertaken at other sites within Lake Macquarie in consultation with DPI Fisheries and LMCC, that is, work would be completed to offset the impact arising as a result of mining activities.

5 Seagrass Monitoring

5.1 General Requirements

The detailed methods used to conduct the surveys to determine subsidence of the lake bed and the photographic surveys of seagrass distribution, density and conditions are described below. The same or similar methods should be used in future seagrass surveys to ensure consistency of results.

Seagrass photography

A video camera, fitted with a wide conversion lens and enclosed in an underwater housing is used to capture the video footage.

The camera in the underwater housing is mounted vertically in the centre of a 1m long surfboard. This rig is towed alongside a workboat. Experimentation revealed that the best photographic results are obtained when the boat and photographic rig were poled very slowly along the transect line on windless days. Good quality photographs were obtained both in boat shadow and full sunlight although half shadow sequences could still be evaluated satisfactorily.

The water depth along most of the transect lines ranges from around 0.5 to 2m (depending on the lake level). At the end of the transect line the water depth could be around 2m. Transect lines are photographed from the outer end to the inner end. The beginning of each transect is marked by photographing a plate with the transect number printed in large type.

At the end of the each day's photography, the hard drive of the video camera is downloaded, the film is paused at around 1m intervals along the transect line. Each still frame is examined and the following information is recorded on a data sheet:

1. The file name and number of the video segment being examined.
2. The transect number and date the video was taken.
3. The percentage areas occupied by the following organisms in each still or quadrat was determined:
   (a) % area occupied by long leaved seagrass (*Zostera capricorni*)
   (b) % area occupied by short leaved seagrass (*Zostera capricorni*)
   (c) % area occupied by the small seagrass (*Halophila ovalis*)
   (d) degree of fouling of the seagrass leaves by algae 1=no fouling, 2=light fouling, 3=heavy fouling.
   (e) % area occupied by the large brown alga (*Sargassum* sp., *Hormosira banksii* or *Cystoseira trinodis*)
   (f) % area occupied by filamentous and thallous algae (green or brown algae)
   (g) Number of the large bivalve *Pinna bicolor*
   (h) % area of uncolonised (by macroscopic epibenthos) ground (bare ground).

At the end of the analysis of the photographs, the results are entered into a work sheet and mean values for each category of organism are calculated.

Surveying Methods

Surveyors have established base stations with their differential GPS equipment along the shore of Chain Valley Bay. A carbon fibre staff fitted with a 110mm diameter aluminium base plate (to prevent penetration into the sediment) is used to take the readings. Survey data (x, y & z coordinates) are recorded on a separate hand piece. Communication between the GPS receiver, the base stations and the hand piece is by coded radio signals.

The boat is maneuvered into position at the inshore end of each transect. The staff is placed on the lakebed and held vertically until the observation is made and recorded. The boat is then moved outwards from the shore where intermediate points along the transect were established and recorded. When the outer end of the transect is reached, the staff is placed alongside the concrete marker and the position and height of the lake bed was recorded.

The memory of the hand held gps is downloaded and the following plots made:

- A map of the position of transects in Chain Valley Bay, Summerland Point and Bardens Bay.
- A table of the coordinates of inner and outer ends of each transect and the coordinates of the base stations are made.
- The elevations of the seabed at the inner and outer ends of each transect, relative to AHD, are established and tabulated.

The results from the seagrass monitoring, including determination of compliance with seagrass impact thresholds, is undertaken and reported back to Delta Coal in a formal report to be provided annually following the completion of each annual seagrass survey.

5.2 Monitoring Locations

Monitoring locations have been chosen based on the proposed mining activities that will be covered by the Seagrass Management Plan, over time, as this management plan is updated to reflect future mining locations, it is anticipated that additional monitoring transects will be incorporated and others removed from the monitoring regime as time progresses. More specifically, the monitoring locations proposed to be monitored are those that are adjacent to past, current and proposed mining activities that are within the review period of this management plan.

The monitoring locations are substantially derived from the original experimental and control transects selected by JH & ES Laxton – Environmental Consultants Pty Ltd and JSA Environmental Pty Ltd who completed the Marine Ecology assessment that supported the Environmental Assessment for the Mining Extension 1 Project. An additional 15 transects were added to the seagrass monitoring program as part of the latest revision to this plan to obtain baseline information within the areas of Frying Pan Bay, Sugar Bay and the Northern side of Point Wolstoncroft. Two additional Control Points (C5 and C6) were also added to the monitoring program in 2018.

The current monitoring locations are;

- Transects E1 to E16 Transects primarily in Chain Valley Bay and adjacent Summerland Point
- Transects T1 to T8 Transects adjacent Summerland Point
- Transects C1 to C6 Control stations in Crangan Bay and Frying Pan Bay
- Transects A1 to A6 Transects primarily in Bardens Bay
- Transect L1 Transect above potential future first workings in Chain Valley Bay
- Transects S1 to S6 Transect adjacent Sugar Bay
- Transects F1 to F7 Transects adjacent Frying Pan Bay and along Point Wolstoncroft.

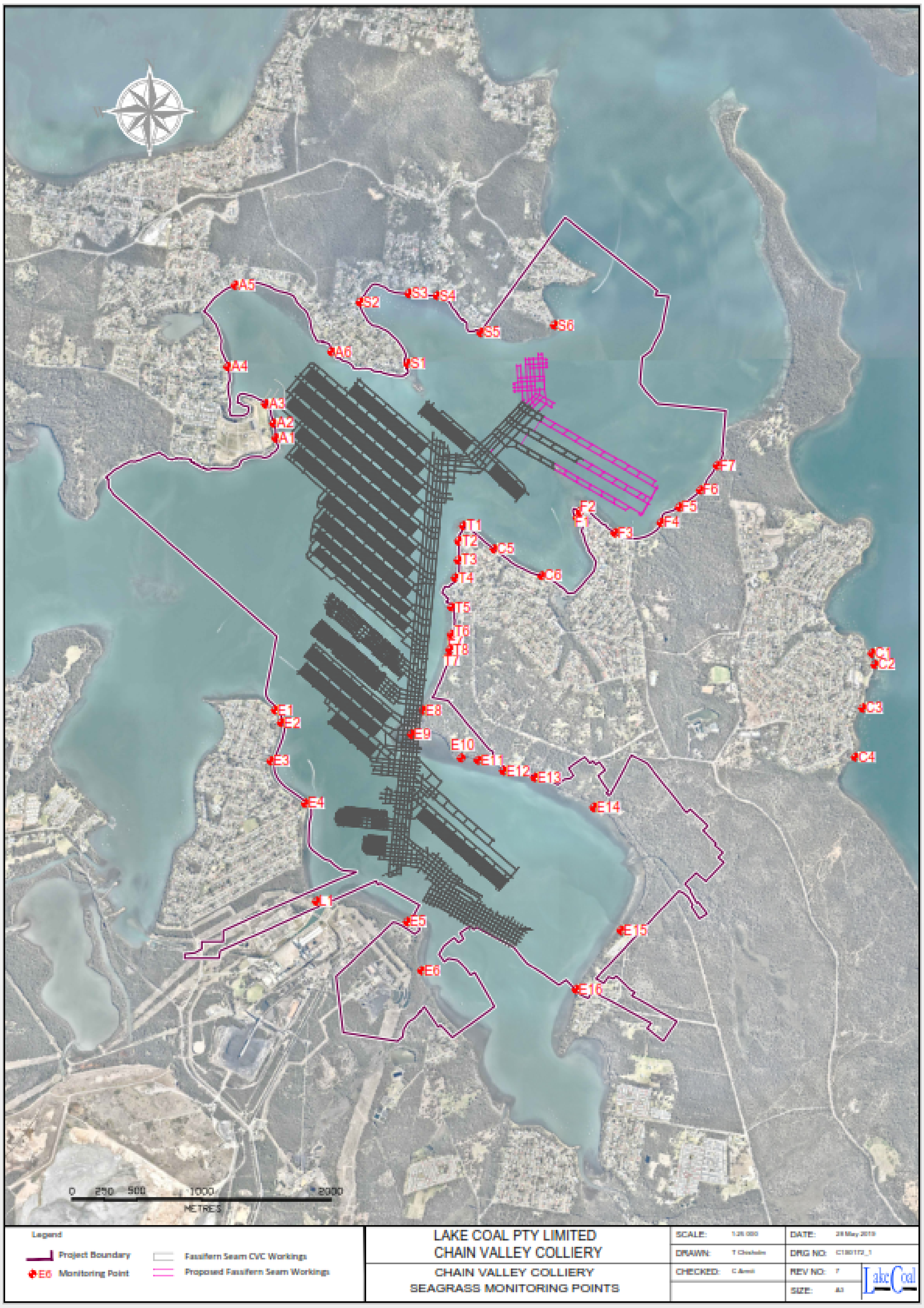

Figure 4: Locations of Seagrass Monitoring Transects

Table 2 shows the GPS locations of the inner ends of the seagrass monitoring transects. Where available, reduced levels of the lakebed measured historically are presented. For sites that have not yet been surveyed by differential GPS, baseline depth levels will be obtained prior to any secondary extraction undertaken in the vicinity of the site. Transects in Crangan Bay were for control purposes only, i.e. no mining or subsidence impact potential, and accordingly no differential GPS depths/locations are required. Relocation of the control stations is done with hand held GPS.

Table 2: Seagrass Monitoring Transect Coordinates

Site	Easting	Northing	Reduced Level (m) – inner transect	Reduced Level (m) – outer transect
E1	363986	6331797	-0.68	-1.00
E2	364035	6331701	-0.64	-1.78
E3	363953	6331405	-0.32	-2.34
E4	364220	6331078	-0.46	-1.69
E5	365006	6330164	-0.46	-1.68
E6	365118	6329788	-0.48	-1.21
E7	365351	6332350	-0.24	-1.68
E8	365128	6331796	-0.27	-0.99
E9	365040	6331608	-0.19	-1.07
E10	365423	6331427	-0.41	-1.74
E11	365554	6331410	-0.40	-1.09
E12	365750	6331329	-0.59	-1.50
E13	365991	6331278	-0.59	-1.44
E14	366447	6331047	-0.52	-1.34
E15	366657	6330098	-0.39	-1.22
E16	366310	6329644	-0.55	-1.08
T1	365440	6333217	-0.40	-1.15
T2	365403	6333101	-0.70	-1.31
T3	365400	6332952	-0.29	-1.01
T4	365377	6332817	-0.46	-1.12
T5	365350	6332590	-0.42	-1.38
T6	365348	6332380	-0.47	-1.61
T7	365321	6332207	-0.17	-1.64
T8	365337	6332262	-0.20	-1.14
C1	368596	6332235	N/A	N/A
C2	368619	6332147	N/A	N/A
C3	368524	6331811	N/A	N/A
C4	368467	6331435	N/A	N/A
C5	365676	6333038	N/A	N/A
C6	366045	6332831	N/A	N/A
A1	363991	6333894	-0.51	-1.19
A2	363974	6334009	-0.39	-0.81
A3	363912	6334156	-0.33	-1.44
A4	363621	6334445	-0.16	-0.72
A5	363678	6335072	-0.30	-0.96
A6	364423	6334560	-0.14	-0.68
L1	364306	6330322	-1.12	-1.63
S1	365009	6334470	-0.64	-1.78
S2	364642	6334943	-0.28	-1.59
S3	365017	6335008	-0.11	-1.87

Site	Easting	Northing	Reduced Level (m) – inner transect	Reduced Level (m) – outer transect
S4	365235	6334992	-0.11	-1.73
S5	365575	6334709	-0.69	-1.39
S6	366144	6334765	-0.1	-0.92
F1	366321	6333281	-0.25	-1.31
F2	366342	6333330	-0.24	-1.98
F3	366611	6333163	-0.11	-1.88
F4	366968	6333242	-0.11	-2.45
F5	367106	6333361	-0.33	-2.46
F6	367271	6333493	-0.3	-2.81
F7	367402	6333682	-0.48	-1.4

6 Incident & Compliance Management

6.1 Introduction

The seagrass monitoring results will be reviewed on an annual basis as survey reports are received to confirm compliance with the conditions specified in the *Subsidence Impact Performance Measures - Natural and Heritage Features* found in **Table 1** and the criteria outlined in **Section 4.1**.

The Annual Review will also include a summary of monitoring results during the past year, discussion with reference to the impact assessment criteria, and any relevant details related to comparisons between actual results and predictions in the Environmental Impact Statement. The Annual Review will be forwarded to the relevant authorities including Department of Planning and Environment, and Environment Protection Authority. The Annual Review will also be forwarded to members of the Community Consultative Committee and local Councils (Central Coast and Lake Macquarie). It will also be placed on the company's website along with a summary of environmental monitoring results.

6.2 Incident or Non Compliance Reporting

If seagrass monitoring reveals that, as a result of mining activities, the criterion outlined in **Section 4.1** have been exceeded, then Delta Coal will conduct an investigation into the cause of the non-compliance. The investigation will consider any mining activities or other factors that may have generated the non-compliance. The report will be provided to DPI Fisheries and the Department of Planning and Environment.

The report will:

a) describe the date, time and nature of the exceedance / incident;
b) identify the cause (or likely cause) of the exceedance / incident;
c) describe what action has been taken to date; and
d) describe the proposed measures to address the exceedance / incident.

Delta Coal would implement the recommendations of the investigation in order to address any future non-compliance issues.

Additional details of the incident reporting process are provided in the Environmental Management Strategy.

7 Stakeholder Management and Response

7.1 Complaint Protocol

Delta Coal has a 24-hour telephone hotline (1800 687 557) for members of the public to lodge complaints, concerns, or to raise issues associated with the operation. This service aims to promptly and effectively address community concerns and environmental matters.

The full details of the complaints line are covered in the Environmental Management Strategy, but in summary, all complaints are recorded and responded to, if for some reason no action is taken then the reason why is recorded. The information recorded in the complaint register includes;

- date and time the complaint was lodged;
- personal details provided by the complainant;
- nature of the complaint;
- action taken or if no action was taken, the reason why; and
- follow up contact with the complainant.

7.2 Dispute Resolution

If any disputes are not adequately addressed by the complaints handling process then they will be handled by the site Environment and Community Coordinator, if the response of Delta Coal is not considered to satisfactorily address the concern of the complainant, a meeting will be convened with the Mine Manager together with the Environment and Community Coordinator.

The complainant will be advised of the outcomes from the meeting and the actions to be implemented as a result.

After implementation of the proposed actions, the complainant will be contacted and advice sought as to the satisfaction or otherwise with the measures taken.

If no agreed outcome is determined or the complainant is still not satisfied by the action taken, then an Independent Review may be requested by the complainant. If determined to be warranted by the Secretary, an Independent Review will be undertaken in accordance with the requirements of the development consent to achieve an outcome to the satisfaction of the Secretary.

8 Roles and Responsibilities

Roles and responsibilities specific to completing the requirements of the Seagrass Management Plan are identified in **Table 3**.

Table 3: Seagrass Management Roles and Responsibilities

Role	Responsibilities
Mine Manager	• Ensure that adequate financial and personnel resources are made available for the implementation of the Seagrass Management Plan.
Environment and Community Coordinator	• Co-ordinate seagrass monitoring, through the use of differential GPS surveying and photographic monitoring of seagrass beds. • Develop management actions in consultation with regulatory agencies as/if required from the monitoring results. • Review seagrass monitoring results on an annual basis. • Send Annual Seagrass Monitoring reports to DPI Fisheries and • Compile the Annual Review (including a summary of the annual seagrass survey). • Respond to any potential or actual non-compliance and report these as required to regulatory bodies and other stakeholders. • Undertake reviews of this document as per **Section 9** • Undertake or coordinate the required audits of this document, in accordance with **Section 9**. • Notify the DPI Fisheries, Department of Industry – Resources and Energy and Department of Planning and Environment if there are any exceedances in impact thresholds outlined in **Section 4.1** • Ensure complaint handling and response is undertaken, including determination of sources and potential remedial action to avoid recurrence.

8.1 Training, Awareness and Competence

Training is an essential component of the implementation phase of this Seagrass Management Plan. Any person or position that has a role or responsibility under this document will be provided with a copy of the document and be advised verbally regarding their requirements by the Environment and Community Coordinator.

As the document owner, the Environment and Community Coordinator is the contact point for any person that does not understand this document or their specific requirements, and will provide guidance and training to any person that requires additional training regarding this management plan.

9 Audit and Review

9.1 Overview

This document shall be reviewed, and if necessary revised, within 3 months of the following:

- The submission of an Annual Review;
- The submission of an incident report under **Section 6.2**;
- The submission of an independent environmental audit; and
- Following any modification to the development consent

9.2 External Audits

An Independent Environmental Audit will be undertaken every three years (or as otherwise required by Department of Planning and Environment) by an audit team whose appointment has been endorsed by the Secretary.

Any actions arising from external audits will be loaded into the site Incident Database to ensure the actions are assigned to the relevant people and completed.

10 Records

Generally the Environment and Community Coordinator will maintain all Environmental Management System records, which are not of a confidential nature. Records that are maintained include:

- monitoring data and equipment calibration;
- environmental inspections and auditing results;
- environmental incident reports;
- complaint register; and
- Licenses and permits.

All records are stored so that they are legible, readily retrievable and protected against damage, deterioration and loss. Records are maintained for a minimum of 4 years.

11 Document Control

This document and all others associated with the Environmental Management System shall be maintained in a document control system which is in compliance with AS/NZS 4804; section 4.3.3.4 (Document Control) and in compliance with the site Document Control Standard which is available to all personnel.

Any proposed change to this document shall be via the document control administrator who is the only person able to access the controlled documents.

12 References & Associated Documents

AS/NZS ISO 14001:2004	Environmental management systems – Requirements with guidance for use
AS/NZS ISO 14004:2004	Environmental management systems – General guidelines on principles, systems and support techniques
EPL 1770	Environment Protection License 1770
EIS	**Error! Unknown document property name. Error! Unknown document property name. Error! Unknown document property name.**
SSD–5465	Development Consent SSD-5465 (Modification 2) dated 16 December 2015 for the Mining Extension 1 Project
POEO Act 1997	Protection of the Environment Operations Act, 1997

Bell, F.C. and Edwards, A.R. (1980) *An Environmental Inventory of Estuaries and Coastal Lagoons in New South Wales*. Total Environment Centre.

BioAnalysis (2008) assessment of seagrasses associated with proposal to expand the Lake Macquarie yacht club in Belmont Bay.

EMM (June 2015) *Chain Valley Colliery Modification 2 Statement of Environmental Effects*, prepared by EMGA Mitchell McLennan (EMM) dated 29 June 2015.

NSW DPI (2007) PrimeFacts 629 - Seagrasses.

Laxton, J.H. (2005) *Water Quality of Lake Macquarie*. J.H. & E.S. Laxton – Environmental Consultants P/L. Unpublished Report.

Laxton, E. and Laxton, J.H. (August 2007) Aquatic Biology of Chain Valley Bay Lake Macquarie, NSW. J.H. & E.S. Laxton – Environmental Consultants P/L. Unpublished report prepared for Chain Valley Colliery.

Laxton, J.H. and Laxton, E. (July 2008) Seagrass Survey of Chain Valley Bay Lake Macquarie, NSW. J.H. & E.S. Laxton – Environmental Consultants P/L. Unpublished report prepared for Chain Valley Colliery.

Laxton, J.H. and Laxton, E. (2009). Peabody Energy – Chain Valley Colliery. *Aquatic Biology of Domain No. 2 off Summerland Point, Lake Macquarie, NSW.* Emma and John H. Laxton. July 2009

Laxton, J.H. and Laxton, E. (2011). Seagrass Survey of Chain Valley Bay, Summerland Point and Crangan Bay, Lake Macquarie, NSW (Results from 2008, 2010 and 2011) J.H. & E.S. Laxton – Environmental Consultants P/L. Unpublished report prepared for Chain Valley Colliery.

Laxton, J.H. and Laxton, E. (2012). Seagrass Survey of Chain Valley Bay, Summerland Point and Crangan Bay, Lake Macquarie, NSW (Results from 2008, 2010, 2011 and 2012) J.H. & E.S. Laxton – Environmental Consultants P/L. Unpublished report prepared for Chain Valley Colliery.

Laxton, J.H. and Laxton, E. (2013). Seagrass Survey of Chain Valley Bay, Summerland Point and Crangan Bay, Lake Macquarie, NSW. (Results for 2008, 2010, 2011, 2012 and 2013). J.H. & E.S. Laxton – Environmental Consultants P/L. Unpublished report prepared for Chain Valley Colliery.

Laxton, J.H. and Laxton, E.S. (2014) Seagrass Survey of Chain Valley Bay, Summerland Point and Crangan Bay, Lake Macquarie, NSW (Results for 2008 to 2014). J.H. & E.S. Laxton – Environmental Consultants P/L. Unpublished report prepared for Chain Valley Colliery.

Laxton, J.H. and Laxton, E.S. (2015) Seagrass Survey of Chain Valley Bay, Summerland Point and Crangan Bay, Lake Macquarie, NSW (Results for 2008 to 2015). J.H. & E.S. Laxton – Environmental Consultants P/L. Unpublished report prepared for Chain Valley Colliery.

Laxton, J.H. and Laxton, E.S. (2016) Seagrass Survey of Chain Valley Bay, Summerland Point, Bardens Bay and Crangan Bay, Lake Macquarie, NSW (Results for 2008 to 2016). J.H. & E.S. Laxton – Environmental Consultants P/L. Unpublished report prepared for Chain Valley Colliery.

Laxton, J.H. and Laxton, E.S. (2017) Seagrass Survey of Chain Valley Bay, Summerland Point, Bardens Bay and Crangan Bay, Lake Macquarie, NSW (Results for 2008 to 2017). J.H. & E.S. Laxton – Environmental Consultants P/L. Unpublished report prepared for Chain Valley Colliery.

13 Definitions

CVC
Delta Coal - Chain Valley Colliery

DPI Fisheries
NSW Department of Primary Industries – Fisheries

EMS
Environmental Management System

HWM
High Water Mark

LMCC
Lake Macquarie City Council

OEH
Office of Environment and Heritage

Secretary
Secretary of the Department of Planning and Environment, or nominee

Safety Management Plan

Public Safety Management Plan
S2/S3 Miniwall Panels

Author	[illegible]
	[illegible] – [illegible]
Authorised By	[illegible]
	Operations Manager
[illegible]	[illegible]

1 Table of Contents

2 Introduction

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Notes:

• *The Applicant will be required to define more detailed performance indicators (including impact assessment criteria) for each of these performance measures in the Built Features Management Plans or Public Safety Management Plan (see Condition 7 below).*

• *Measurement and/or monitoring of compliance with performance measures and performance indicators is to be undertaken using generally accepted methods that are appropriate to the environment and circumstances in which the feature or characteristic is located. These methods are to be fully described in the relevant management plans. In the event of a dispute over the appropriateness of proposed methods, the Secretary will be the final arbiter.*

• *The requirements of this condition only apply to the impacts and consequences of mining operations, construction or demolition undertaken following the date of approval of this consent.*

- *Requirement's regarding safety or serviceability do not preclude preventative actions or mitigation being taken prior to or during mining in order to achieve or maintain these outcomes.*
- *Requirement's under this condition may be met by measures undertaken in accordance with the Mine Subsidence Compensation Act 1961.*

3 Purpose and Scope

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4 Background

4.1 Operations

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[illegible] **Figure 1**[illegible]

4.2 Subsidence Predictions

[illegible] **Figure 2),** [illegible] **Figure 1** [illegible]

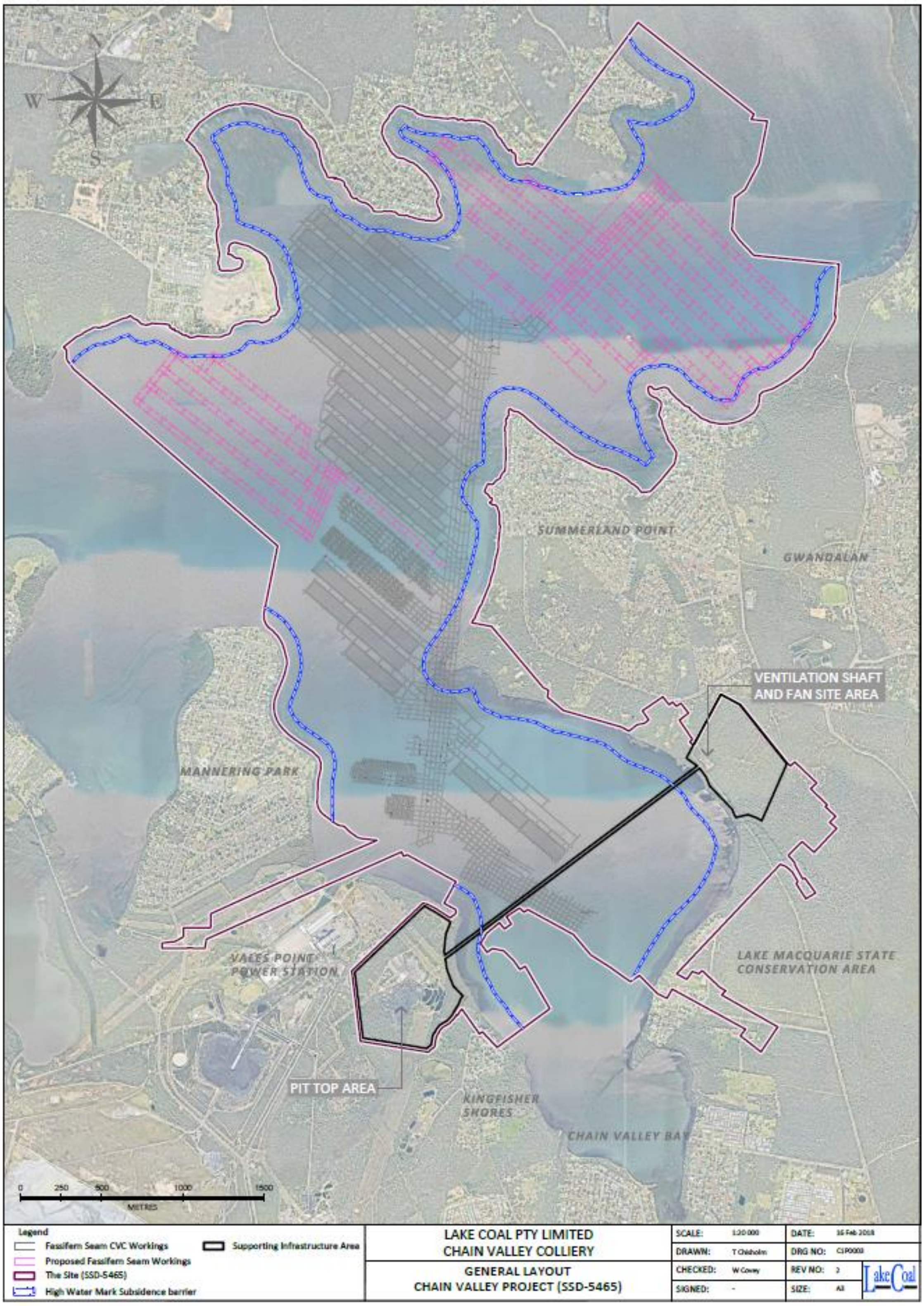

Figure 1: General Layout of the Chain Valley Northern Mining Domain

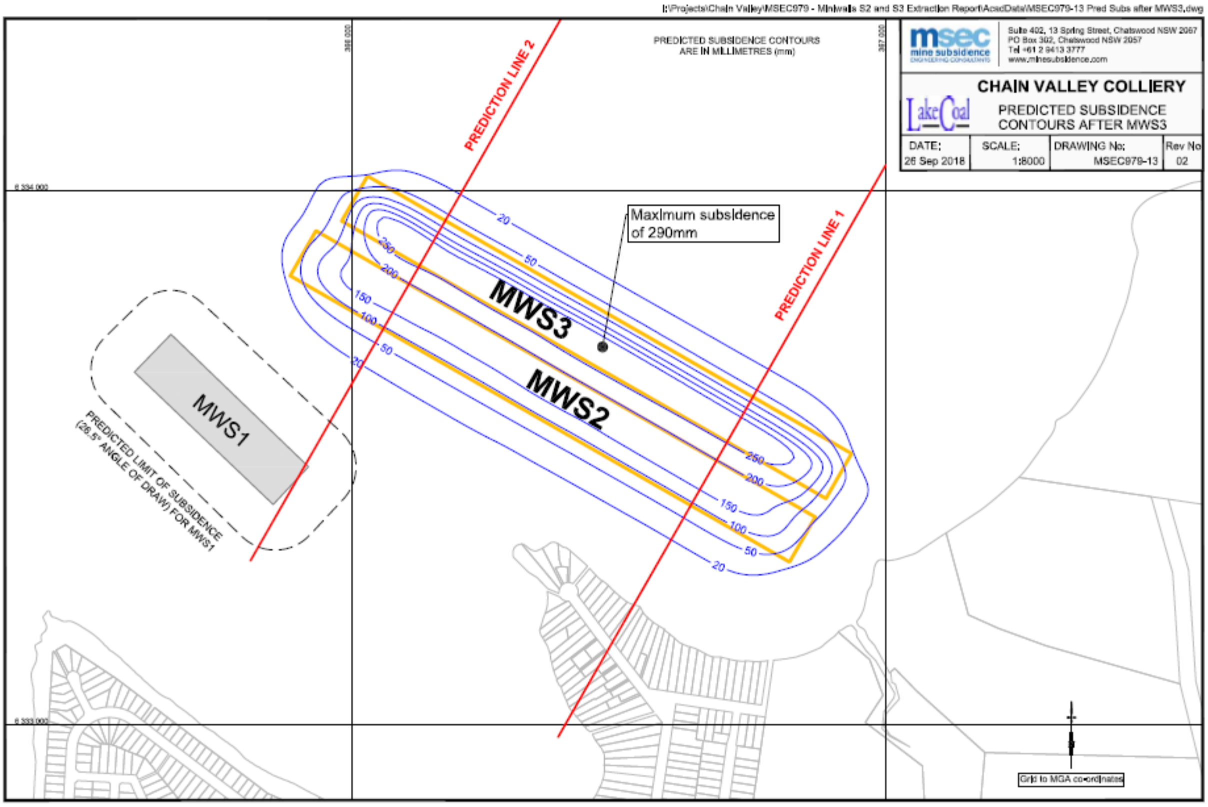

Figure 2: Predicted Subsidence Associated with Panels S2 and S3.

4.3 Public Safety Management - Scope

4.3.1 Identified Features

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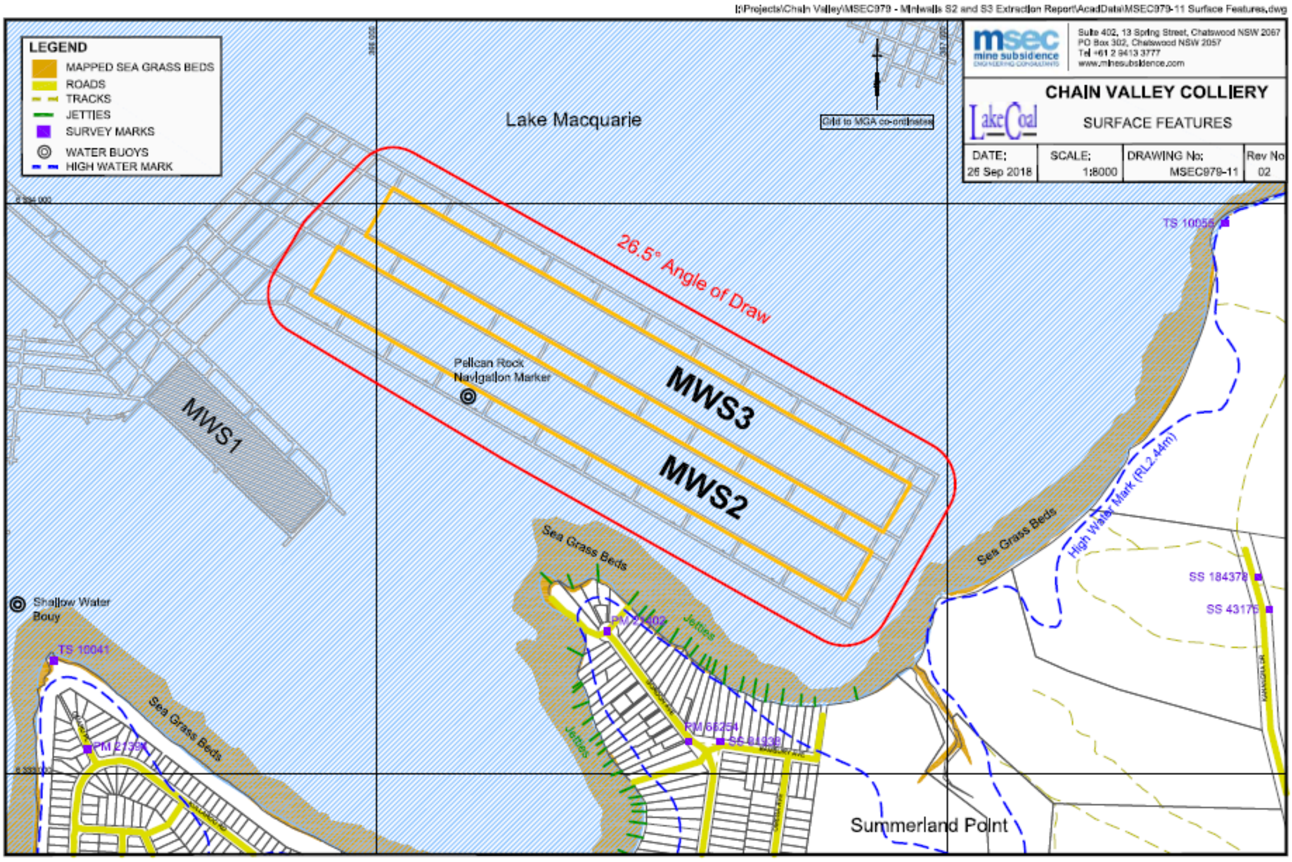

Figure 3: Chain Valley Colliery Surface Features

5 Public Safety Monitoring

5.1 Subsidence Monitoring Methods

5.1.1 Bathymetric Surveys

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5.1.2 Foreshore Monitoring

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Figure 4: Example subsidence monitoring point with safety cap.

6 Public Safety Management

6.1 Management Practices

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6.2 Consultation

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7 Roles and Responsibilities

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LakeCoal	Doc Owner: Mine Surveyor

CHAIN VALLEY COLLIERY

ENV 00029

Subsidence Monitoring Program

MINIWALLS S2 – S3

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Authorised by:	David Mclean Manager Mining Engineering LakeCoal – Chain Valley Colliery
Date:	25/01/2019

1 Table of Contents

List of Figures / Tables

2 Introduction

Chain Valley Colliery is an underground coal mine located on the southern end of Lake Macquarie, approximately 100km north of Sydney and 60km south of Newcastle, adjacent to the Vales Point Power Station, producing thermal coal for the domestic and export markets.

A formal Extraction Management Plan has been developed in order to manage the process of mining layout design and mitigate any subsidence impacts on surface infrastructure and/or stakeholders.

The Subsidence Monitoring Program is an element of the Chain Valley Colliery Extraction Management Plan, and has been developed to satisfy the requirements of Development Consent SSD-5465, condition 7(k) and Tables 8-9 in Schedule 4, which states:

"7. The Applicant shall prepare and implement an Extraction Plan for all second workings on site, to the satisfaction of the Director-General. Each Extraction Plan must:

(k) include a Subsidence Monitoring Program which has been prepared in consultation with DRE, which:

- Provides data to assist with the management of the risks associated with subsidence;
- Validates the subsidence predictions
- Analyses the relationship between the predicted and resulting subsidence effects and predicted and resulting impacts under the plan and any ensuing environmental consequences; and
- Informs the contingency plan and adaptive management process;

Condition 1, Schedule 4 of SSD5465 states:

"The Proponent shall ensure that vertical subsidence within the High Water Mark Subsidence Barrier and within Seagrass beds is limited to a maximum of 20 millimeters (mm)."

In addition to the above, Condition 2 within Schedule 4 of SSD-5465 also requires that:

"The Applicant shall ensure that the development does not cause any exceedance of the performance measures in Table 8 to the satisfaction of the Director-General."

The relevant subsidence monitoring requirements from Table 8 within Schedule 4 of the Development Consent, including the relevant notes, are recreated in **Table 1.**

Table 1 - Subsidence Impact Performance Measures - Natural and Heritage Features

Biodiversity	
Threatened species or endangered populations	Negligible environmental consequences
Seagrass beds	Negligible environmental consequences including: • Negligible changes in size and distribution of seagrass beds; • Negligible change in the function of seagrass beds; and • Negligible change to the composition or distribution of seagrass species within seagrass beds.
Benthic communities	Minor environmental consequences, including minor changes to species composition and/or distribution

Mine Workings	
First Workings under an approved Extraction Plan beneath any feature where performance measures in this table require negligible environmental consequences	To remain long term stable and non-subsiding
Second Workings	To be carried out only in accordance with and approved Extraction Plan.

Notes:

• The Applicant will be required to define more detailed performance indicators (including impact assessment criteria) for each of these performance measures in the various management plans that are required under this consent (see Condition 7 below).

• Measurement and/or monitoring of compliance with performance measures and performance indicators is to be undertaken using generally accepted methods that are appropriate to the environment and circumstances in which the feature or characteristic is located. These methods are to be fully described in the relevant management plans. In the event of a dispute over the appropriateness of proposed methods, the Secretary will be the final arbiter.

• The requirements of this condition only apply to the impacts and consequences of mining operations, construction or demolition undertaken following the date of approval of this consent

Condition 4 within Schedule 4 of SSD-5465 also requires that:

"The Applicant shall ensure that the development does not cause any exceedances of the performance measures in Table 9, to the satisfaction of the Director-General.

The relevant subsidence monitoring requirements from Table 9 within Schedule 4 of the Development Consent, including the relevant notes, are recreated in **Table 2**

Table 2 - Subsidence Impact Performance Measures – Built Features

Built Features	
Trinity Point Marina Development Other built features	• Always safe • Serviceability should be maintained wherever practicable. Loss of serviceability must be fully compensated • Damage must be fully compensated
Public Safety	
Public Safety	Negligible additional risk

Notes:

• The Applicant will be required to define more detailed performance indicators (including impact assessment criteria) for each of these performance measures in the various management plans that are required under this consent (see Condition 7 below).

• Measurement and/or monitoring of compliance with performance measures and performance indicators is to be undertaken using generally accepted methods that are appropriate to the environment and circumstances in which the feature or characteristic is located. These methods are to be fully described in the relevant management plans. In the event of a dispute over the appropriateness of proposed methods, the Secretary will be the final arbiter.

- *The requirements of this condition only apply to the impacts and consequences of mining operations, construction or demolition undertaken following the date of approval of this consent.*
- *Requirement's regarding safety or serviceability do not preclude preventative actions or mitigation being taken prior to or during mining in order to achieve or maintain these outcomes.*
- *Requirement's under this condition may be met by measures undertaken in accordance with the Mine Subsidence Compensation Act 1961.*

3 Purpose

The purpose of this Subsidence Monitoring Program is to:

- define the subsidence monitoring scope;
- outline subsidence predictions;
- outline the methodology to be used to monitor subsidence impacts
- identify subsidence monitoring locations;
- identify reporting requirements;
- analyse the relationship between predicted and resulting subsidence effects;
- identify the requirements for incident or exceedances reporting.

4 Background

4.1 Operations

Chain Valley Colliery is an underground coal mine with current coal mining methods including development of roadways in the coal seam known as first workings and secondary extraction. These first workings develop panels to support the installation of a miniwall, a modern secondary coal extraction method.

Lake Macquarie is the largest saline lake in New South Wales. It lies on the central coast between Sydney and Newcastle within the local government areas of Wyong and Lake Macquarie. Lake Macquarie has a catchment of 700 square kilometers and a water surface area of 125 square kilometers (Bell & Edwards, 1980). The lake has a permanent entrance to coastal waters at Swansea and has an average depth of around 6 meters (Laxton, 2005).

The catchment of Lake Macquarie is largely rural with large areas of bush land and grazing land. The shoreline of Lake Macquarie is heavily urbanised, especially the eastern, western and northern shorelines. The region has a relatively long history of coal mining and power generation, with mining occurring since the late 1800s and the first power station at Lake Macquarie commencing operations in 1958.

The Chain Valley Colliery is situated on the southern shores of Lake Macquarie near Mannering Park, NSW. The mine has been operating since 1962. Mining is currently undertaken using miniwall methods with first workings to support the development in advance of each miniwall panel. All secondary extraction is currently occurring in the Fassifern seam, in line with Development Consent SSD–5465. The general layout of the Chain Valley Extension Project in respect to Lake Macquarie is shown in Error! Reference source not found..

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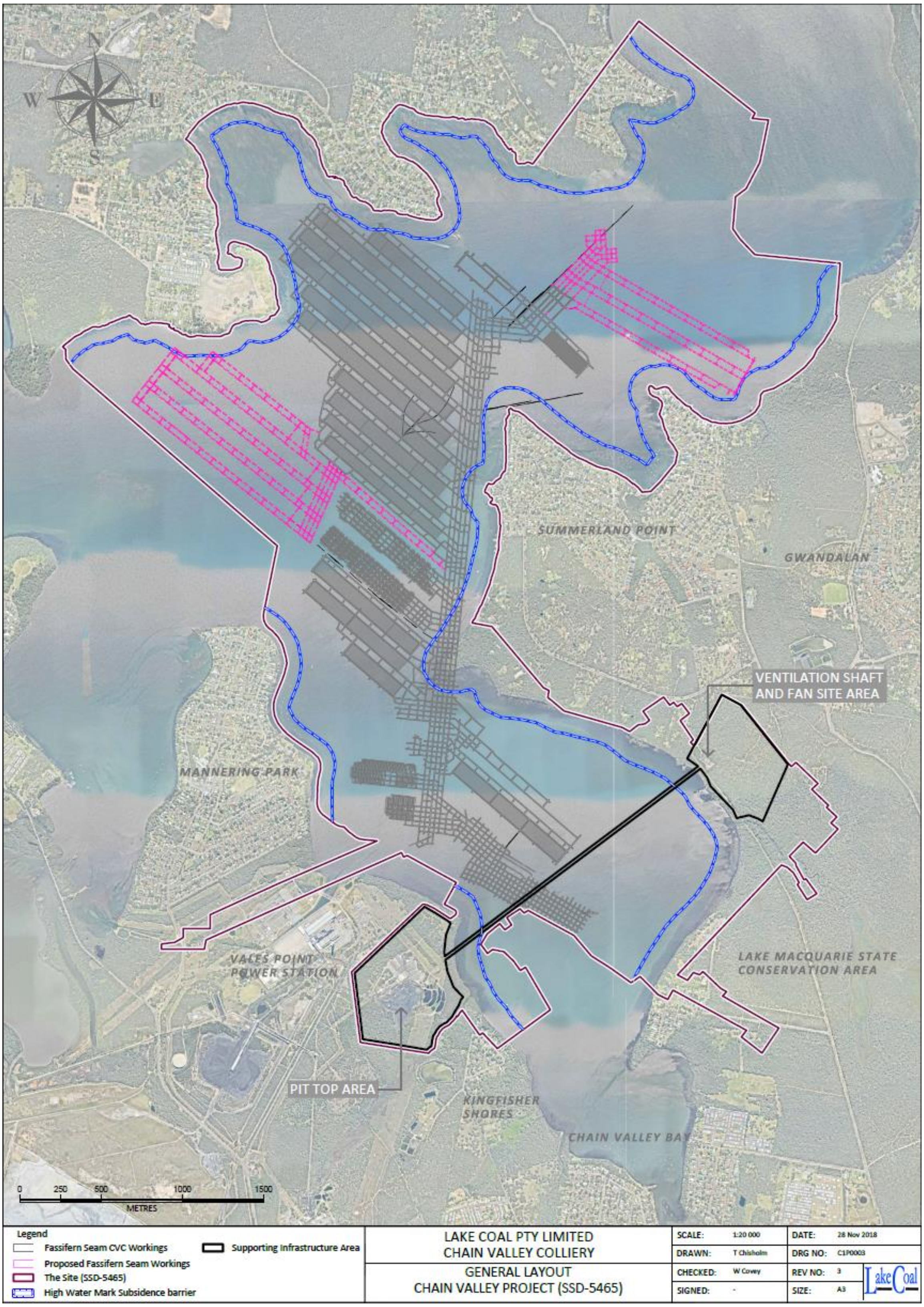

Figure 1 - General Layout of the Chain Valley Project

4.2 Subsidence Predictions

Subsidence modelling has predicted up to approximately 290mm of subsidence to the Lake floor associated with the planned miniwall mining in S2 and S3 **(Figure 2),** against an approved maximum of 780mm (SSD 5465). No additional subsidence is expected to occur within the seagrass or foreshore areas as a result of Fassifern extraction.

The subsidence parameters beneath the lake, after each panel are included in **Table 3 and 4** for reference of monitoring results against. Respective triggers points for additional monitoring and response are included in the Subsidence Management TARP.

Table 3 – Miniwall S2-S3 Subsidence Predictions (MSEC, September 2018 "MSEC979 Revision 2"

Method	Predicted vertical subsidence (mm)	Notes
Monitoring data for MW1 to MW12	200	Includes a component of sag subsidence
Mills and Edwards (1997)	210	
ACARP (2003)	150 mm (mean)	315 mm (upper 95 % confidence level)
Elastic model (Das, 1986)	260	Pillar, roof and floor compression

Table 4 - Miniwall S2-S3 Subsidence Predictions - Post Extraction (MSEC, September 2018 "MSEC979 Revision 2")

Due to miniwall	Maximum predicted incremental vertical subsidence (mm)	Maximum predicted incremental tilt (mm/m)	Maximum predicted incremental hogging curvature (km^{-1})	Maximum predicted incremental sagging curvature (km^{-1})
MWS2	130	2	0.03	0.07
MWS3	260	5	0.14	0.30

Miniwalls	Maximum predicted total vertical subsidence (mm)	Maximum predicted total tilt (mm/m)	Maximum predicted total hogging curvature (km^{-1})	Maximum predicted total sagging curvature (km^{-1})
MWS2 and MWS3	290	6	0.10	0.30

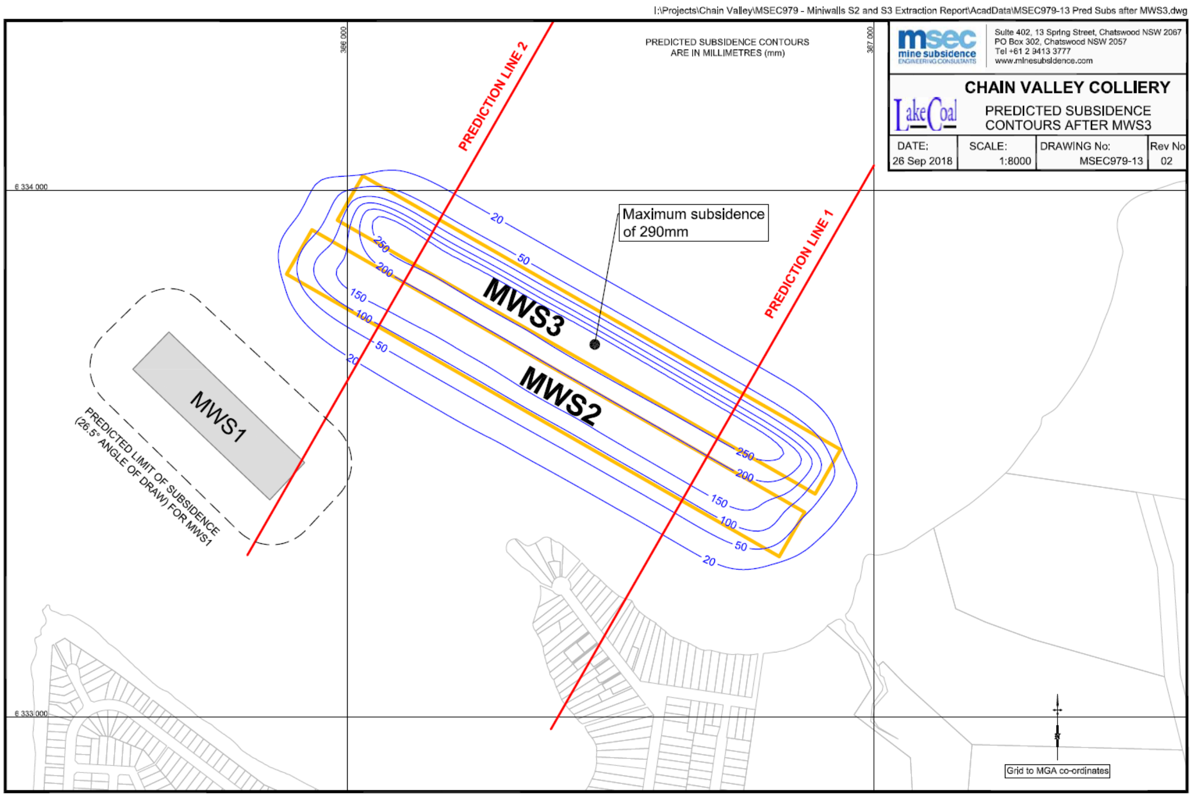

Figure 2 - Predicted Subsidence After S2 & S3

4.3 Subsidence Monitoring - Scope

4.3.1 Shoreline (High Water Mark)

The shoreline of Lake Macquarie is protected under Mining Lease Conditions requiring Ministerial Approval to carry out mining operations within the High Water Mark Subsidence Barrier (HWMSB). The HWMSB is defined in the seam by a line defined by an angle of draw of 35° drawn lakewards from the high water level of Lake Macquarie, and on the land side, a line drawn from the 2.44m contour at 35° towards the land (refer to Figure 3).

Condition 1, Schedule 4 of SSD5465 states:

"The Proponent shall ensure that vertical subsidence within the High Water Mark Subsidence Barrier and within Seagrass beds is limited to a maximum of 20 millimeters(mm)…."

A key objective of the mine design is to minimise vertical subsidence within the HWMSB and prevent additional subsidence above the high water mark. To ensure effectiveness of the mine design, monitoring of the shoreline is proposed via the installation and monitoring of fixed reference marks surveyed at regular intervals.

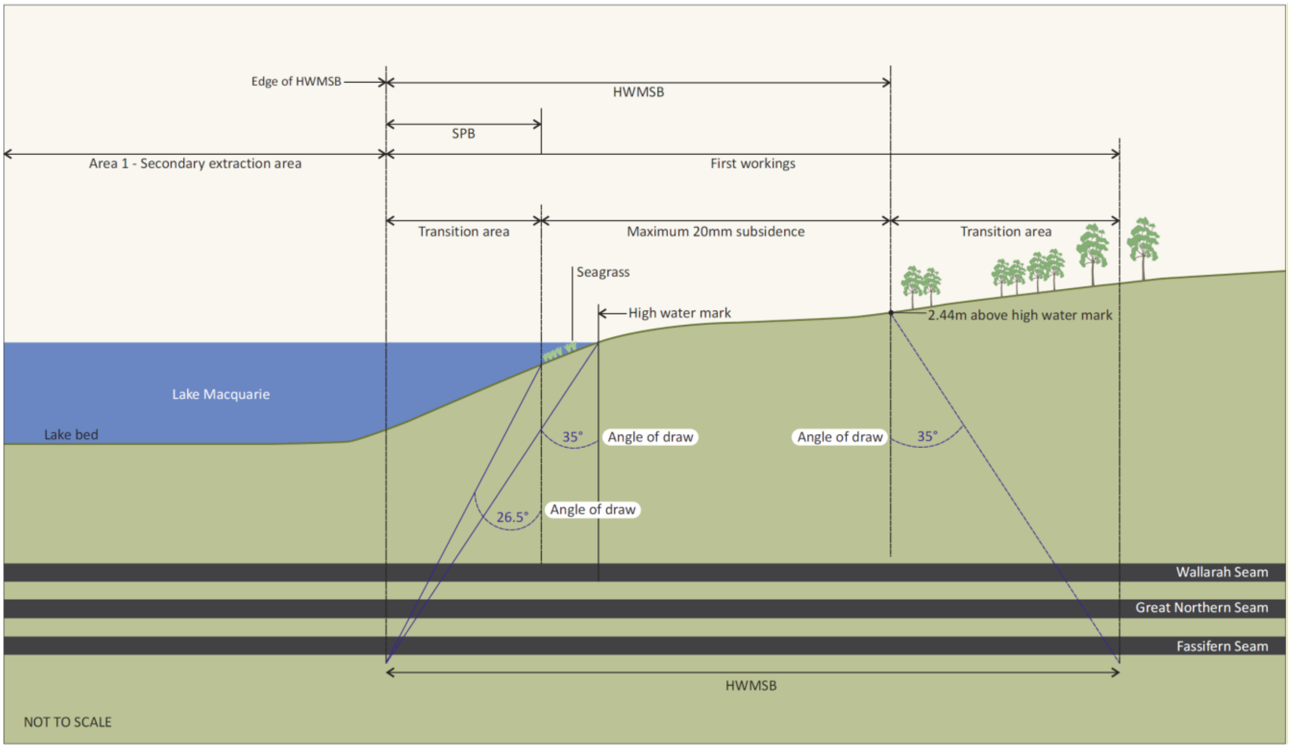

Figure 3 - High Water Mark Subsidence Barrier Typical Diagram

4.3.2 Seagrass

Condition 2, Schedule 4 of SSD-5465 specifies negligible environmental impacts on the species of seagrass found within the current area of mining operations as a condition of approval.

Seagrass distribution within estuaries is naturally influenced by light penetration, depth, salinity, nutrient status, bed stability, wave energy, estuary type, and the evolutionary stage of the estuary.

Regular surveys of the seagrass extents are undertaken in order to monitor impacts on the seagrass population. Lakecoal's Seagrass Management Plan ENV 00009 outlines the methodology used to determine changes to composition and quantity of seagrass populations in Lake Macquarie.

A 26.5° line taken from the lake side of the mapped seagrass location projected to the Fassifern Seam has been defined as a protection barrier, and no miniwall extraction is to take place within this barrier.

Subsidence Monitoring of the lakebed is also proposed via bathymetric survey over the current mining area in order to validate the subsidence prediction model.

4.3.3 Benthic Communities

The mud basin is inhabited by a diverse number of marine organisms. Condition 2, Schedule 4 of SSD-5465 specifies minor environmental consequences on the Benthic communities, including minor changes to species composition and/or distribution as a condition of approval.

Regular surveys of the lake bed are undertaken in order to monitor variations in the composition and density of benthos due to mining, environmental and/or other seasonal factors. Lakecoal's Benthic Communities

Management Plan ENV 00006 outlines the methodology used to determine changes to species diversity and abundance.

Subsidence Monitoring of the lakebed is also proposed via bathymetric survey over the current mining area in order to validate the subsidence prediction model, and to determine approximate levels of subsidence on specific benthic sample locations.

5 Subsidence Monitoring

5.1 Subsidence Monitoring Methods

5.1.1 Bathymetric Surveys

Bathymetric data from the NSW Office of Environment and Heritage (OEH) was obtained in draft format during 2012. LakeCoal was granted a license to use this OEH data for the purposes of monitoring changes in the bed of Lake Macquarie, and acknowledges the OEH's data which has enabled the subsidence comparison to be undertaken based on this 2010 data and data subsequently obtained in 2012 by LakeCoal. OEH notes that the data was obtained via use of differential GPS and a 200 kHz echosounder, which is noted to provide general data accuracy of 0.1m.

LakeCoal commissioned Astute Surveying in 2012 to undertake a bathymetric survey annually over the areas of current and proposed workings. The primary purpose of this survey was to obtain accurate baseline data for future subsidence assessments and to enable comparison with the draft OEH data from 2010. Importantly, the ongoing surveys provided accurate details of the Lake depth within the proposed mining areas, which would enable future surveys to use as baseline data to monitor the future subsidence levels as a result of mining activities. Bathymetric surveys are currently to be conducted at least six monthly intervals subsequent to this baseline survey.

Comparative analysis of the surveys highlights some elevation changes which are unrelated to mining, generally however these appear to be minor movements, perhaps related to movement of sediment as a result of the wave climate in the Lake. The surveys have shown that subsidence from the miniwall mining can be monitored with a useful level of accuracy and the surveys will be continued to cover future mining areas and areas where mining has been completed.

5.1.2 Foreshore Monitoring

Subsidence monitoring around Summerland Point and into Frying Plan Bay has already been established due to previous mining operations to the immediate southwest of the extraction area. Each line will be extended past the area of effect prior extraction (**Figure 4**)

Monitoring points will be established along the foreshore at approximately 20-30m intervals and will be reestablished where missing. New monitoring locations will be subject to landholder access arrangements and permission.

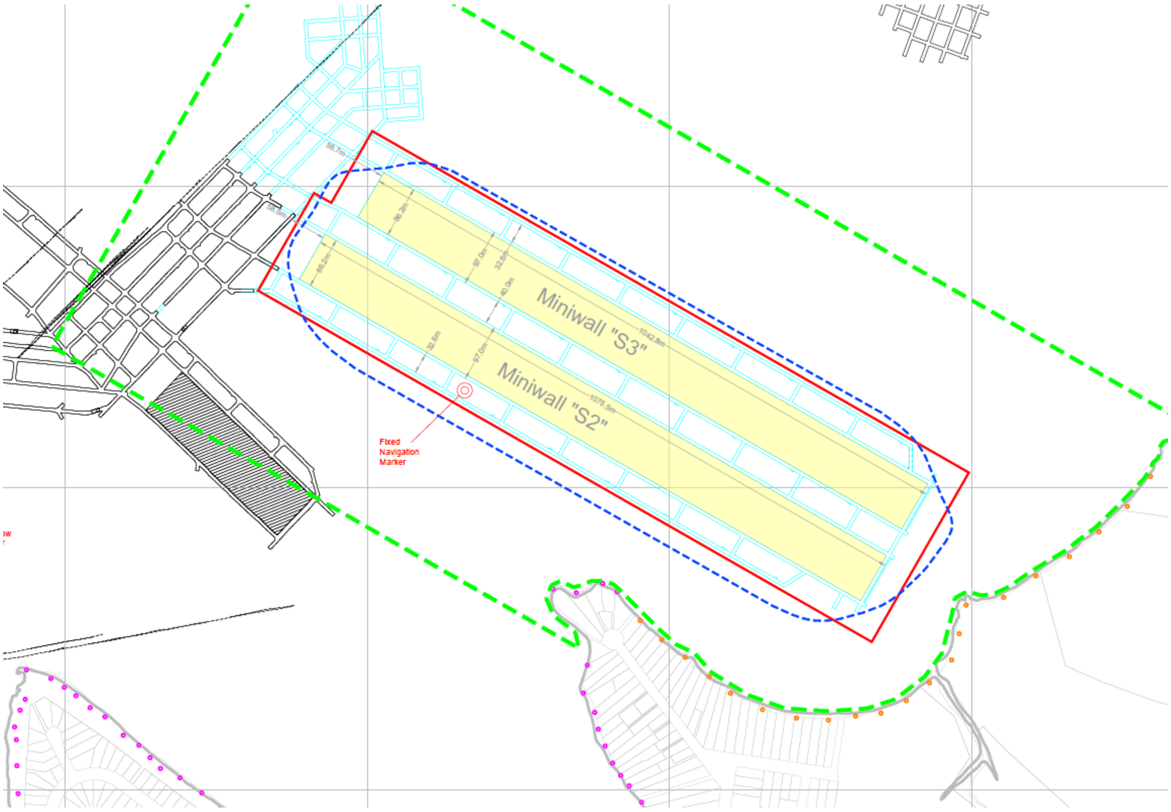

Figure 4 - Proposed Shoreline Subsidence Monitoring Locations, Summerland Point

The foreshore monitoring points will be monitored as follows:

- The points are to be established as per S2 to S3 Extraction Plan- Plan 7.
- X and Y locations will be measured using GPS equipment for plotting purposes (±0.050m)
- AHD RL (Z) component will be leveled using Automatic or Digital levelling equipment to an accuracy of 5mm/km.
- Surveys are to be conducted at intervals prescribed in **Table 5**, during mining operations and after completion of a panel.
- The results are uploaded to DRE's online subsidence web portal within 14 days of survey.

Additional as a part of the foreshore survey monitoring, observations will be made for visual impact or changes to public safety risk. A Subsidence Inspection Proforma will be completed with each survey. The proforma includes visual inspection of steep slopes, boulder or tree instability, ponding and other potential effects of mine subsidence.

Navigation markers will continue to be monitored by Roads and Maritime Services, who will inform LakeCoal of any abnormal changes potentially attributable to mine subsidence.

5.2 Subsidence Monitoring Frequency Requirements

Based on the monitoring program outlined above, the following monitoring frequencies are to be established to validate model outcomes, enable early detection of subsidence trending to increased impact levels over that predicted, allow early application of containment, adaptive and contingency measures to prevent impact outside approved and particularly increased impact to the foreshore.

All evaluations are to be made against the criteria outlined in the Subsidence Monitoring TARP.

Table 5 - Subsidence Monitoring Frequencies

	Pre-Extraction	During Extraction	Post Extraction
Bathymetric surveys	Single baseline survey prior to extraction (June 2019)	End of panel for S2 End of panel survey for S3	Annual for 3 years unless TARP triggered
Foreshore Level Monitoring	Baseline survey prior to commencement of extraction	Monthly intervals	Annual for 3 years unless TARP triggered

5.3 Subsidence Monitoring Review

Chain Valley Colliery will undertake a review of available subsidence monitoring data against predictions and expected outcomes annually within its Annual Review as required by SSD-5465.

5.4 Consultation

The Subsidence Monitoring Plan is required to be prepared in consultation with DRE. DRE have been consulted during the submission of the Extraction Plan and also as a part of the High Risk Activity Notification.

Roads and Maritime Services Project Officer (North Area) has been contacted during the development of the Extraction Plan and referred the matter to the RMS asset team, resulting in no further immediate actions required in regard to management of the navigation markers.

The Community Consultative Committee (CCC) for the mine will be routinely updated on subsidence monitoring results and any change in impact or public safety concern.

6 Roles and Responsibilities

Roles, responsibilities specific to completing the requirements of this Subsidence Monitoring Program are identified in **Table 6**.

Table 6: Subsidence Monitoring Program Roles and Responsibilities

Role	Responsibilities
Mine Manager	• Ensure that adequate financial and personnel resources are made available for the implementation of the Subsidence Monitoring Program
Mine Surveyor	• Co-ordinate subsidence monitoring, through the use of bathymetric surveys, conventional surveys along foreshore and underground data collection. • Review subsidence monitoring results against Subsidence Management TARP triggers • Inform relevant stakeholders as to the subsidence monitoring results • Review, and if necessary revise this document: ○ In the event of any exceedance in impact thresholds ○ Following any modification to the development consent
Environment and Community Coordinator	• Develop management actions in consultation with regulatory agencies as/if required from the monitoring results. • Respond to any potential or actual non-compliance and report these as required to regulatory bodies and other stakeholders. • Notify the relevant Government Agencies and other affected parties of any exceedances of the performance measures • Coordinate the meeting of the Subsidence Review Committee • Ensure complaint handling and response is undertaken, including determination of sources and potential remedial action to avoid recurrence.

Lake Coal	[illegible] Environment and Community Coordinator
	[illegible]

CHAIN VALLEY COLLIERY

Rehabilitation Management Plan

ENVIRONMENTAL MANAGEMENT PLAN

Authors	[illegible]
	[illegible]
	[illegible]
	[illegible]
Authorised by:	
	Chris Armit
	[illegible]
Date:	[illegible]

Review Date	Next Review Date	Revision No	Document Owner	Page
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1 Introduction

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Note: The Rehabilitation Management Plan should address all land impacted by the development whether prior to, or following, the date of this consent."

[illegible] addition to the above requirements, Condition 26, within Schedule 3 also requires that "the Applicant shall [illegible] disturbance" [illegible]

2 Purpose

[illegible]

- [illegible]
- [illegible]
- [illegible]

3 Background

[illegible] **Figure 3.1** [illegible]

3.1 Site History

[illegible] with the first delivery to the adjacent Delta Electricity's Vales Point [illegible]

LakeCoal was formed in 2001 to acquire BHP Billiton's 80% [illegible]

[illegible]

[illegible]

[illegible] Hill Bay Coal Preparation Plant, all located at the southern end of Lake Macquarie. At the time of LakeCoal's [illegible]

[illegible]

Chain Valley Colliery peaked with a workforce of approximately 380 men in the mid 1980's. [illegible]

[illegible]

Mi[illegible] 1990's. There is still some remaining resource within the Great Northern seam, however the focus of [illegible]

LAKE COAL PTY LIMITED CHAIN VALLEY COLLIERY	SCALE:	1:2000	DATE:	13 Nov 2014
	DRAWN:	T Chisholm	DRG NO:	C1S0154_1
REHABILITATION MANAGEMENT PLAN FIGURE 3.1 - SURFACE FACILITIES	CHECKED:	C Ellis	REV NO:	1
	REVISION:	1	SIZE:	A3

Lake Coal

3.2 Land Tenure and Use

[illegible] Table 3.1 [illegible] Figure 3.2.

Table 3.1: Land ownership details

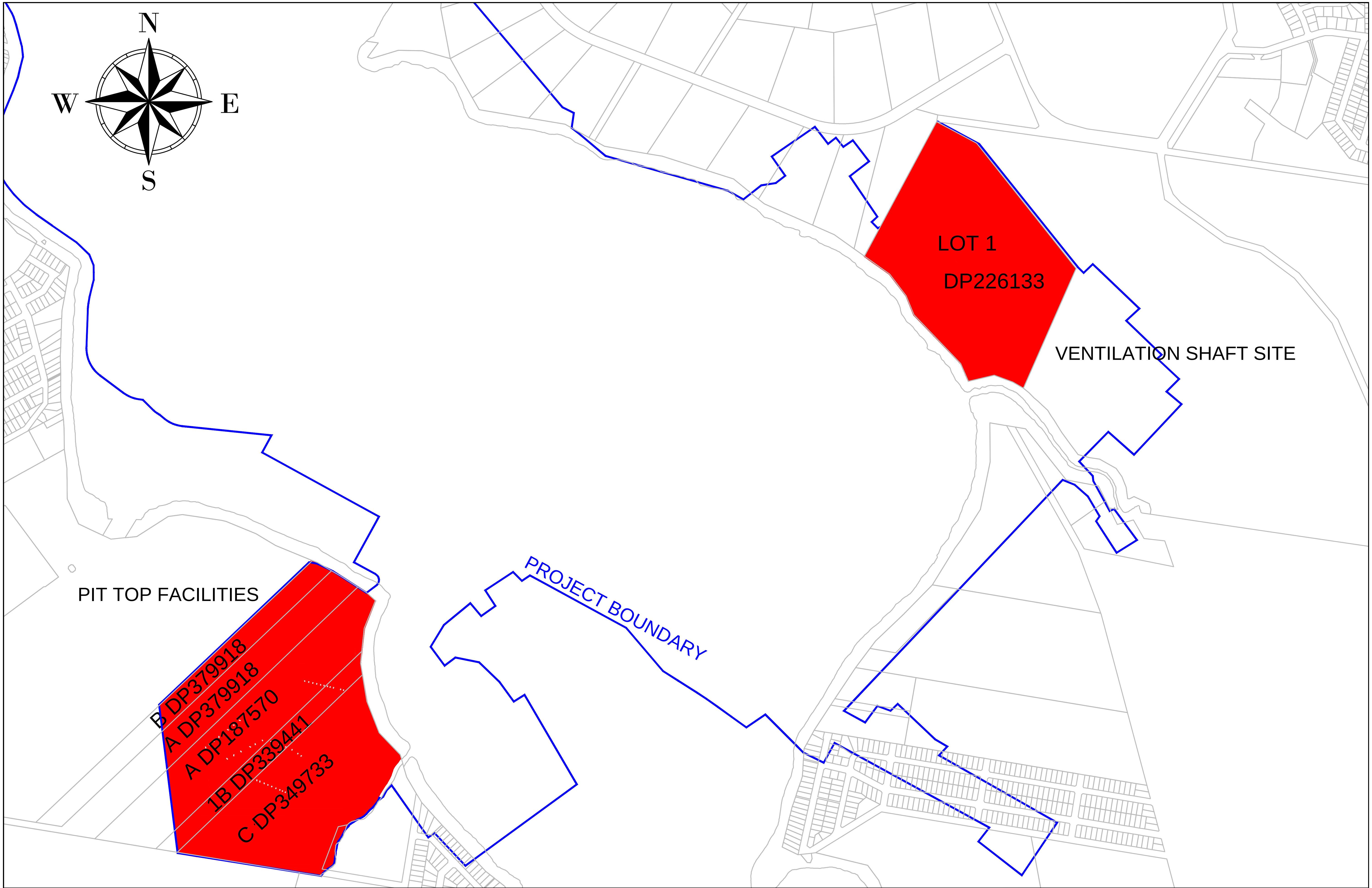
Site	Owner	Lot	Deposited Plan
[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]
		[illegible]	[illegible]
		[illegible]	[illegible]
		[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	22[illegible]

3.3 Mining methods

[illegible]

[illegible]

[illegible]



LAKE COAL PTY LIMITED CHAIN VALLEY COLLIERY	SCALE: 1:10000	DATE: 13 Nov 2014	
	DRAWN: T Chisholm	DRG NO: C1S0154_2	
REHABILITATION MANAGEMENT PLAN FIGURE 3.2 - SURFACE FACILITY AREAS	CHECKED: C Ellis	REV NO: 1	LakeCoal
	REVISION: 1	SIZE: A3	

3.4 Coal processing

[illegible]

3.5 Waste management

[illegible]

[illegible]

[illegible]

[illegible]

3.6 Coal stockpiles

[illegible] Figure 3.1 [illegible]

3.7 Water management

[illegible]

[illegible]

3.8 Hydrocarbon Management

[illegible]

4 Consultation

[illegible] **Table 4.1**. **Table 4.1** [illegible]

Table 4.1 Consultation Summary

Stakeholder	Comments	Response/Action
[illegible]	• [illegible]	• [illegible]
Fisheries [illegible]	• [illegible] Macquarie	• [illegible]
[illegible]	• [illegible]	• [illegible]
	• [illegible]	• [illegible]
[illegible]	• [illegible]	• [illegible]
	• [illegible] criteria of a ‘clear trend of increasing species diversity’ may not equate to the objective of a ‘self[illegible] stem’ [illegible]	• [illegible]

Table 4.1 Consultation Summary

Stakeholder	Comments	Response/Action
		[illegible]
	• [illegible]	• [illegible]
[illegible]	• [illegible]	• [illegible]
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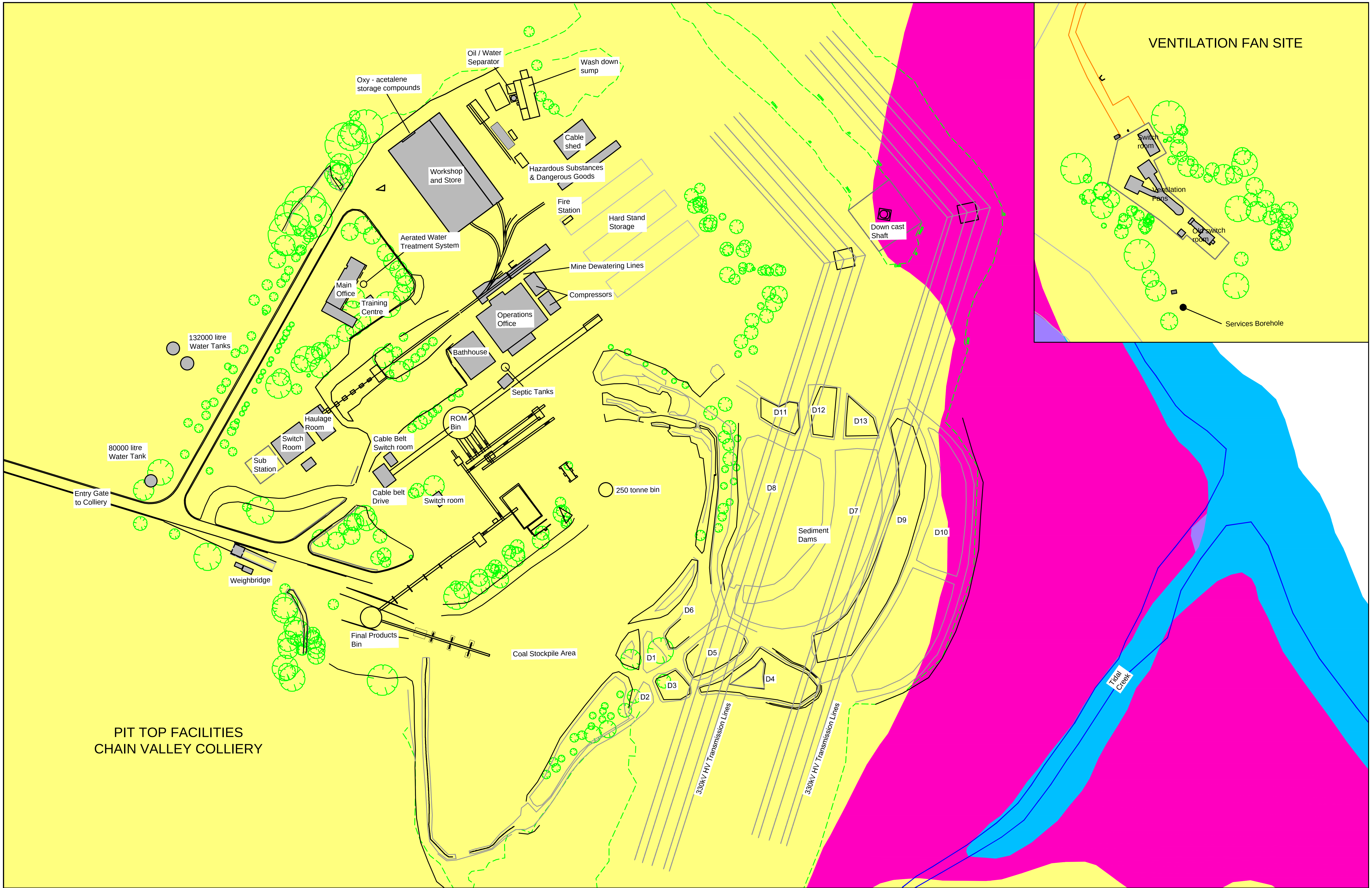
[illegible]	• [illegible]	• [illegible]
[illegible]	• [illegible]	• [illegible]
[illegible]	• [illegible]	• Noted
	• [illegible]	• [illegible]

5 Environmental Characterisation

5.1 Physical Environment

[illegible]

[illegible] *NSW Acid Sulfate Soil Risk Maps* [illegible] **Figure 4.1.**



CLASS 1 - ALL WORKS

CLASS 2 - WORKS BELOW GROUND SURFACE

CLASS 4 - WORKS BEYOND 2m BELOW GROUND SURFACE

CLASS 5 - WORKS WITHIN 500m OF ADJACENT CLASSES 1 - 4

LAKE COAL PTY LIMITED
CHAIN VALLEY COLLIERY

FIGURE 4.1 - ACID SULFATE SOILS WITHIN PROPOSED REHABILITATION AREAS

SCALE:	1: 2000	DATE:	13 Nov 2014
DRAWN:	T Chisholm	DRG NO:	C1S0154_3
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REVISION:	1	SIZE:	A3

5.2 Hydrology

5.2.1 Surface water

[illegible] **Figure 3.1** [illegible]

[illegible]

[illegible] Water Management Plan [illegible]

5.2.2 Groundwater

[illegible]

[illegible] migrates into the Colliery's underground workings [illegible]

[illegible]

[illegible] Water Management Plan [illegible]

5.3 Natural Environment

5.3.1 Geology

[illegible]

[illegible]

[illegible]

Figure 5.1 [illegible]

F[illegible]

5.3.2 Aquatic Ecology

[illegible] M[illegible] [illegible] [illegible] *et al.* 2011[illegible] However, in areas removed from the Lake's en[illegible] [illegible]

[illegible]

[illegible]

[illegible]

5.3.3 Terrestrial Ecology

[illegible] 2[illegible]2 [illegible]

Fr[illegible] [illegible]

[illegible] *Petaurus norfolcensis* [illegible] *Anthochaera phrygia* [illegible] *Lathamus discolor* [illegible] F[illegible] *Pteropus poliocephalus* [illegible]

[illegible]

[illegible]

Figure 5.1: Typical Stratigraphy at Chain Valley Colliery

6 Socio-economic and Cultural Environment

6.1 Workforce Profile

[illegible]

[illegible]

6.1.1 Demographics

- [illegible]
- [illegible]
- [illegible]

6.1.2 Residential location

- [illegible]
- [illegible]
- [illegible]

6.1.3 Housing and household composition

- [illegible]
- [illegible]
- [illegible]
- [illegible]
- [illegible]

6.1.4 Household expenditure and service usage

- [illegible]
- [illegible]

- [illegible]

6.1.5 Charitable contributions

- [illegible]
- [illegible]

6.2 Cultural Environment

[illegible]

6.2.1 Aboriginal heritage

[illegible] group (also spelt Awabagal), a language name derived from the 'Awaba' place name for Lake Macquarie [illegible]

[illegible]

[illegible]

6.2.2 Historic heritage

[illegible] 2004 identifies the "Wyee Coal Conveyor Railway Loop" as an item of local [illegible] address of the "Wyee [illegible] identified in the Lake Macquarie LEP as "North of Wyee to Vales Point Power Station" which indicates that the conveyor linking the Wyee rail loop and power station form part of the [illegible]

[illegible]

[illegible]

[illegible]

7 Rehabilitation Management

7.1 Proposed rehabilitation during life of the current MOP

[illegible]

[illegible]

7.2 Mine closure planning

[illegible]

[illegible]

7.3 Mine closure and final rehabilitation objectives

The current MOP describes LakeCoal's objectives for closure of the Colliery which are:

- [illegible]
- [illegible]
- [illegible]
- [illegible]
- [illegible]
- [illegible]

[illegible]

[illegible]

Table 7.1 Rehabilitation objectives

Feature	Objective
Mine site [illegible]	• [illegible] • [illegible]
[illegible]	• [illegible]
[illegible]	• [illegible] • [illegible]
[illegible]	• [illegible]
[illegible]	• [illegible] *Mine Subsidence Compensation Act 1961.*
[illegible]	• [illegible] • [illegible]

Notes:

- *These rehabilitation objectives apply to all subsidence impacts and environmental consequences caused by mining taking place after the granting of project approval MP 10_0161, and to all development surface infrastructure part of the development, whether constructed prior to or following the date of this consent.*
- *Rehabilitation of subsidence impacts and environmental consequences caused by mining which took place prior to the date of project approval (MP 10_0161) may be subject to the requirements of other approvals (eg under a mining lease or an Subsidence Management Plan approval).*

7.4 Final rehabilitation planning criteria & performance measures

[illegible]

- [illegible]
- [illegible]
- [illegible]
- [illegible]
- [illegible] *Lantana camara* [illegible] *Chrysanthemoides monilifera* [illegible]
- [illegible]
- [illegible]
- [illegible]
- [illegible]
- suitable locations for the burial of “clean” material;
- [illegible]
- [illegible]
- [illegible]

- [illegible]

Table 7.2 [illegible]

Table 7.2 Rehabilitation Completion Criteria and Performance Measures

Phase	Objective	Completion criteria	Performance measures
[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]

Table 7.2 Rehabilitation Completion Criteria and Performance Measures

Phase	Objective	Completion criteria	Performance measures
			[illegible]
	[illegible]	[illegible] ≥ 0.[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
		[illegible] surface area cover ≤ [illegible]	[illegible]
		[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]

Table 7.2 Rehabilitation Completion Criteria and Performance Measures

Phase	Objective	Completion criteria	Performance measures
	[illegible]urr[illegible]u[illegible]di[illegible]g [illegible]d[illegible]e [illegible]d i[illegible] [illegible]e	[illegible]d[illegible]e [illegible]u[illegible] [illegible]er [illegible]e[illegible]d[illegible]g [illegible] [illegible]i[illegible]ued e[illegible]e[illegible] [illegible]u[illegible] i[illegible] [illegible]r[illegible]e[illegible]e[illegible]	M[illegible]i[illegible]ri[illegible]g [illegible]d de[illegible] [illegible]i[illegible]ri[illegible]g i[illegible]uded [illegible]i[illegible]i[illegible] [illegible]ure [illegible]e[illegible]r[illegible]
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7.5 Interaction with other environmental management plans

[illegible]i[illegible]di[illegible]ed i[illegible] **Section 1** [illegible]i[illegible] [illegible]M[illegible] i[illegible] [illegible]u[illegible]e [illegible]i[illegible] [illegible]erie[illegible] [illegible] that sit under the Colliery's EMS. Like [illegible]i[illegible] [illegible]e[illegible]e [illegible]e [illegible]ree [illegible]e[illegible]r re[illegible]ie[illegible] [illegible]eri[illegible]d [illegible]i[illegible]e [illegible]e[illegible]i[illegible]e re[illegible]i[illegible]ed [illegible]d u[illegible]d[illegible]ed[illegible] [illegible]e [illegible]i[illegible]e [illegible]r[illegible]e[illegible] [illegible]re[illegible]re [illegible]e [illegible]i[illegible]e [illegible]ure [illegible]e [illegible]e[illegible]er[illegible] [illegible]e [illegible]M[illegible] i[illegible]e[illegible]e[illegible]ed [illegible]i[illegible]r [illegible]e [illegible]i[illegible]e [illegible]ure [illegible]ddi[illegible]e [illegible]e [illegible]er e[illegible]ir[illegible]e[illegible] [illegible]ge[illegible]e[illegible]e[illegible]i[illegible]e [illegible]i[illegible]di[illegible]er[illegible]i[illegible] M[illegible]ge[illegible]e[illegible] [illegible]er M[illegible]ge[illegible]e[illegible]e[illegible]i[illegible] [illegible]u[illegible]ie[illegible] M[illegible]ge[illegible]e[illegible] [illegible]e[illegible]gr[illegible]M[illegible]ge[illegible]e[illegible] [illegible]d [illegible]eri[illegible]ge M[illegible]ge[illegible]e[illegible] [illegible]u[illegible]d [illegible]e u[illegible]ed [illegible]i[illegible]r[illegible] [illegible]e [illegible]M[illegible]F[illegible]r e[illegible]e [illegible]e [illegible]i[illegible]di[illegible]er[illegible]i[illegible]M[illegible]ge[illegible]e[illegible] [illegible]ig[illegible]i[illegible]di[illegible]e [illegible]e[illegible]de[illegible]i[illegible]e[illegible]ie[illegible] [illegible]e u[illegible]ed i[illegible] [illegible]e re[illegible]i[illegible]i[illegible] [illegible]eed [illegible]i[illegible]u[illegible]e [illegible]ee[illegible]e [illegible]eed[illegible]urr[illegible]u[illegible]di[illegible]g [illegible]u[illegible] [illegible]u[illegible]ie[illegible] [illegible]d [illegible]eed[illegible] [illegible]e [illegible]rge[illegible]ed duri[illegible]g [illegible]ure [illegible]r[illegible]e [illegible]er M[illegible]ge[illegible]e[illegible] [illegible]ig[illegible]gi[illegible]e dire[illegible]i[illegible] [illegible]eri[illegible]g [illegible]eed[illegible] [illegible]r re[illegible]i[illegible]i[illegible] [illegible]ig[illegible]e [illegible]e[illegible]ure[illegible]u[illegible] [illegible]e re[illegible]e[illegible]i[illegible] [illegible]e [illegible]e [illegible]er [illegible]u[illegible]u[illegible]i[illegible]ege[illegible]i[illegible] e[illegible]i[illegible]e[illegible]i[illegible] [illegible]e[illegible]e[illegible]

7.6 Progressive rehabilitation

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7.7 Final rehabilitation proposals

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7.7.1 Disturbed land

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7.7.2 Water management

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[illegible]

7.7.3 Rehabilitation trials and research

[illegible]

7.7.4 Community

[illegible]

- [illegible]
- [illegible]
- [illegible]
- [illegible] compromised; the community's resilience to the adverse impacts of mine closure is strengthened; and [illegible]

7.7.5 Remaining features

[illegible]

- [illegible]
- [illegible] *AS 2601-2001: The Demolition of Structures* [illegible]
- [illegible]
- [illegible]
- [illegible]

[illegible]

7.7.6 Other infrastructure and services

[illegible]

7.8 Conceptual site land works

Figure 7.1 [illegible]

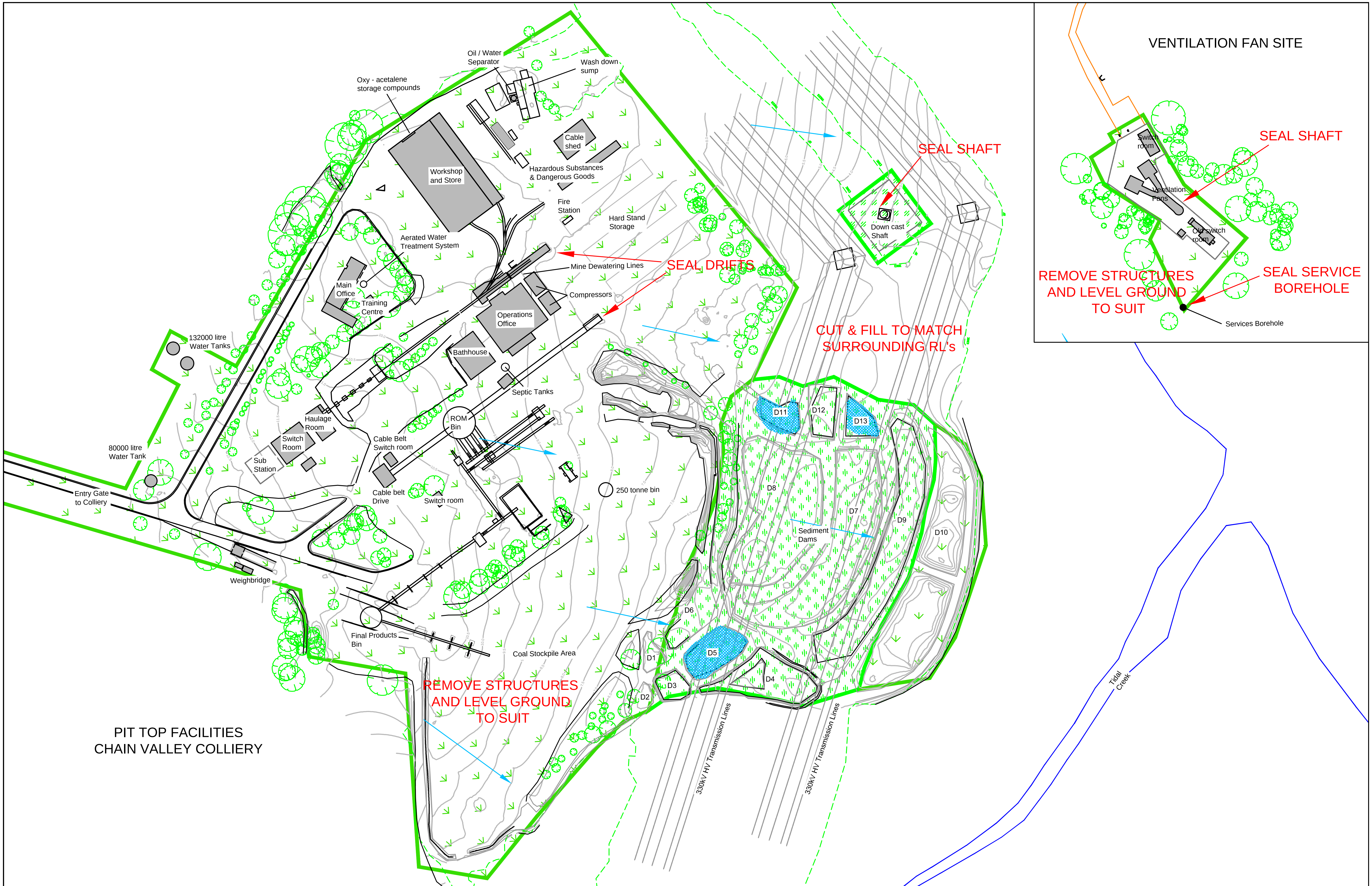
8 Rehabilitation Monitoring

[illegible]

[illegible]

- [illegible]
- [illegible]
- [illegible]
- [illegible]
- [illegible]
- [illegible]
- [illegible]
- [illegible]
- [illegible]
- [illegible]

[illegible]



LAKE COAL PTY LIMITED CHAIN VALLEY COLLIERY	SCALE: 1:2000	DATE: 13 Nov 2014
	DRAWN: T Chisholm	DRG NO: C1S0154_4
FIGURE 7.1 CONCEPTUAL FINAL REHABILITATION	CHECKED: C Ellis	REV NO: 1
	REVISION: 1	SIZE: A3

9 Financial provisioning

[illegible]

[illegible]

[illegible]

9.1 Planned Mine Closure

[illegible]

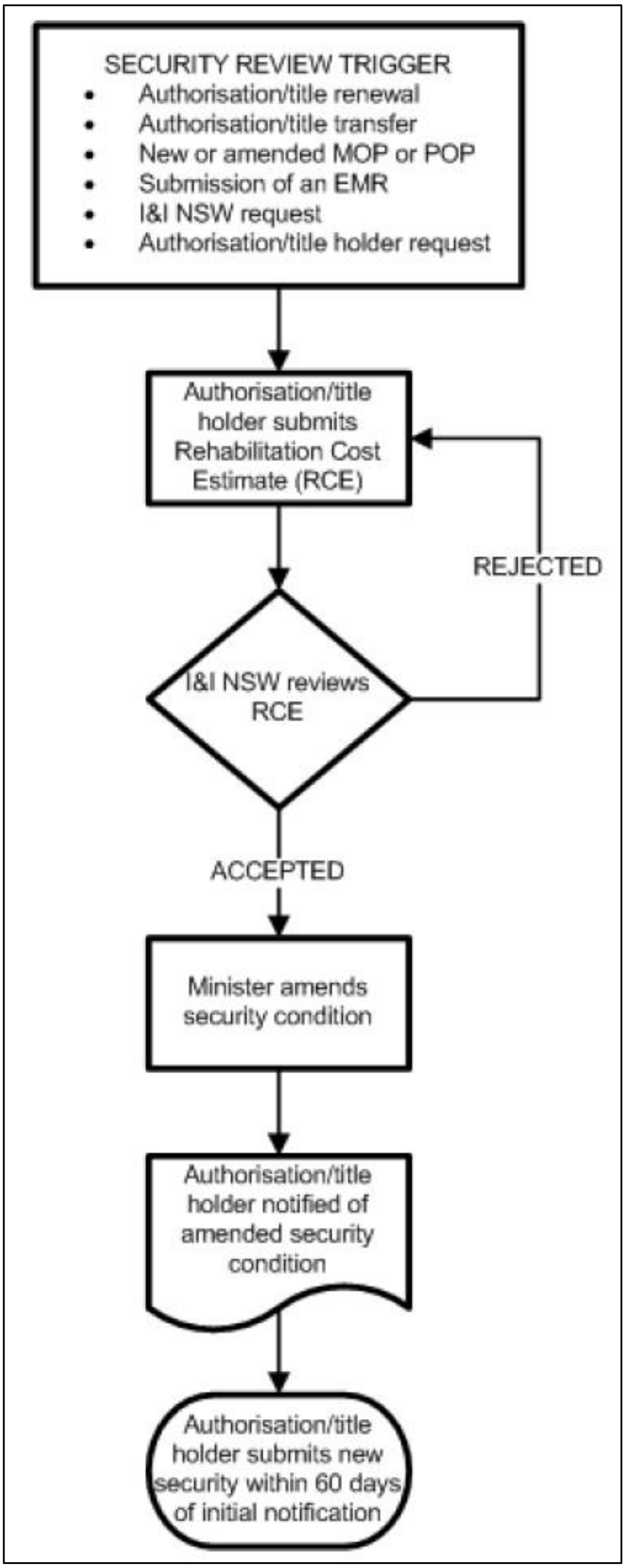
[illegible] lculate (and recalculate) mine closure costs is DRE’s Rehabilitation Cost [illegible]

[illegible] rejects the calculation it needs to be recompleted until it is accepted. In line with DRE’s [illegible]

9.2 Unplanned Closure

[illegible] *Mining Act (1992)* [illegible]

[illegible] security deposit must cover the Government’s full costs in undertaking [illegible] **Figure 9.1**[illegible]



[illegible]

Figure 9.1: Security review process

9.3 Temporary Closure (care and maintenance)

[illegible]

10 Risk Management

[illegible]

[illegible]

- [illegible]
- [illegible]
- [illegible]
- [illegible]
- [illegible]
- [illegible]
- [illegible]
- [illegible]
- [illegible]
- [illegible]
- [illegible]
- [illegible]
- [illegible]
- [illegible]

10.1 Residual Risk Register

[illegible]

11 Incident and Compliance Management

[illegible]

[illegible]

[illegible]

12 Stakeholder Management and Response

[illegible]

12.1 Mine Closure and Rehabilitation Stakeholders

[illegible]

- [illegible]
  - [illegible]
  - [illegible]
  - [illegible]
  - [illegible]

- [illegible]
  - [illegible]
  - [illegible]
  - [illegible]
  - [illegible]
  - [illegible]

- [illegible]
  - [illegible]
  - [illegible]

- [illegible]
  - [illegible]
    - [illegible]
    - [illegible]
      - [illegible]
      - [illegible]
  - [illegible]
    - [illegible]
      - [illegible]
      - [illegible]
    - [illegible]
    - [illegible]
  - [illegible]
    - [illegible]

12.2 Complaints Handling / Community Hotline

[illegible]

[illegible]

- [illegible]
- [illegible]
- [illegible]
- [illegible]
- [illegible]

[illegible]

12.3 Dispute Resolution

[illegible]

[illegible]

[illegible]

13 Roles and Responsibilities

[illegible] **Table 12.1**.

Table 12.1 Roles and responsibilities for rehabilitation management

Role	Responsibilities
[illegible]	• [illegible]

Role	Responsibilities
[illegible]	• [illegible] • [illegible] • [illegible] • [illegible] on the company's website. • [illegible] • [illegible] • [illegible] • [illegible] • [illegible] • [illegible] • [illegible] • [illegible] • [illegible] • [illegible] • [illegible] • [illegible] • [illegible] • [illegible]

14 Audit and Review

The RMP will be kept up to date through LakeCoal's standard audit and review process, however it is noted [illegible]

14.1 Overview

[illegible]

- [illegible]
- [illegible]
- [illegible]

- [illegible]

[illegible]

[illegible]

[illegible]

14.2 Internal audits

[illegible]

14.3 External audits

[illegible]

[illegible]

[illegible]

15 Records and Document Control

[illegible]

[illegible]

- [illegible]
- [illegible]
- [illegible]
- [illegible]
- [illegible]

[illegible]

[illegible]

[illegible]

[illegible]

16 References and Associated Documents

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

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[illegible]

[illegible]

[illegible] *Mine Operation Plan Chain Valley Colliery and Mannering Colliery 2018 - 2020*

[illegible]

[illegible] *EDG01: Borehole Sealing Requirements on Land*

[illegible] *ESG3 Mining Operations Plan (MOP) Guidelines, September 2013.*

[illegible] *Strategic Framework for Mine Closure* [illegible] *The hydraulic and morphological response of a large coastal lake to rising sea levels* [illegible]

[illegible]

17 Definitions

[illegible]

SIGNED DATE

MANAGER OF MINING ENGINEERING

SIGNED DATE

REGISTERED MINE SURVEYOR

MINING HEIGHTS - 1ST WORKINGS 3.20m
2ND WORKINGS 3.50m

TYPICAL ROADWAY WIDTH	5.4m
MINIWALL INSTALLATION ROADWAY	7.9m-10.0m
MINIWALL PRE-DRIVEN TAKEOFF ROADWAY	6.5m

LAKE COAL PTY LTD - CHAIN VALLEY COLLIERY

EXTRACTION PLAN APPLICATION
MINIWALL S2-S3 SECONDARY EXTRACTION

PLAN 1 - EXISTING & PROPOSED WORKINGS

SCALE:	1:3000 @ A0	DATE:	25 Feb 2019
DRAWN:	T Chisholm	DRG NO:	C4A0086_1
CHECKED:	B Smith	REV NO:	0
APPROVED:	D Mclean	SIZE:	A0

LAKE COAL PTY LTD - CHAIN VALLEY COLLIERY	SCALE: 1:3000 @ A0	DATE: 25 Feb 2019
EXTRACTION PLAN APPLICATION MINIWALL S2-S3 SECONDARY EXTRACTION **PLAN 2 - SURFACE FEATURES**	DRAWN: T Chisholm	DRG NO: C4A0086_2
	CHECKED: B Smith	REV NO: 0
	APPROVED: D Mclean	SIZE: A0

LAKE COAL PTY LTD - CHAIN VALLEY COLLIERY	SCALE: 1:3000 @ A0	DATE: 25 Feb 2019
EXTRACTION PLAN APPLICATION MINIWALL S2-S3 SECONDARY EXTRACTION	DRAWN: T Chisholm	DRG NO: C4A0086_3
	CHECKED: B Smith	REV NO: 0
PLAN 3 - GEOLOGICAL FEATURES	APPROVED: D Mclean	SIZE: A0

Lake Coal

LAKE COAL PTY LTD - CHAIN VALLEY COLLIERY	SCALE: 1:3000 @ A0	DATE: 25 Feb 2019
EXTRACTION PLAN APPLICATION MINIWALL S2-S3 SECONDARY EXTRACTION	DRAWN: T Chisholm	DRG NO: C4A0086_4
	CHECKED: B Smith	REV NO: 0
PLAN 4 - OVERLYING WORKINGS	APPROVED: D Mclean	SIZE: A0

Lease No	Area (total)	Particulars
CCL 721 (Sublease	2405.8ha	Expires 30/06/2022
ML 1051	259ha	Expires 07/07/2022
ML1370 (Sublease)	112.7ha	Expires 30/06/2022
ML1632 (Sublease)	494.9ha	Expires 30/06/2022

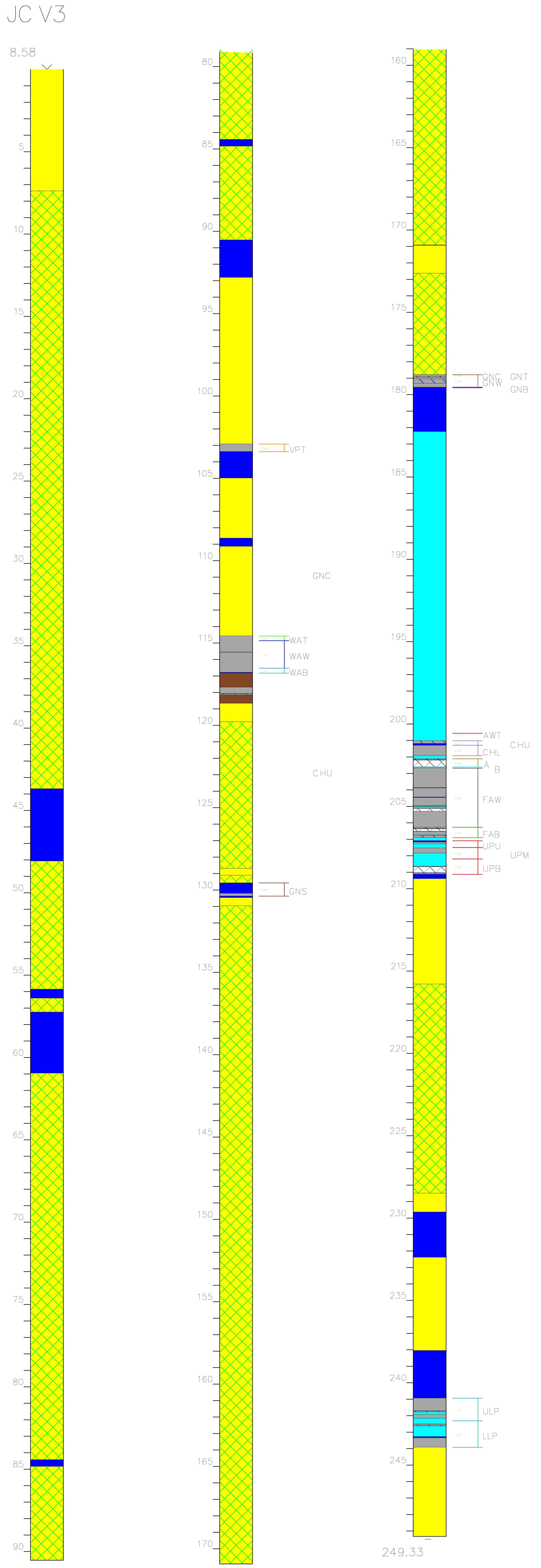
LAKE COAL PTY LTD - CHAIN VALLEY COLLIERY

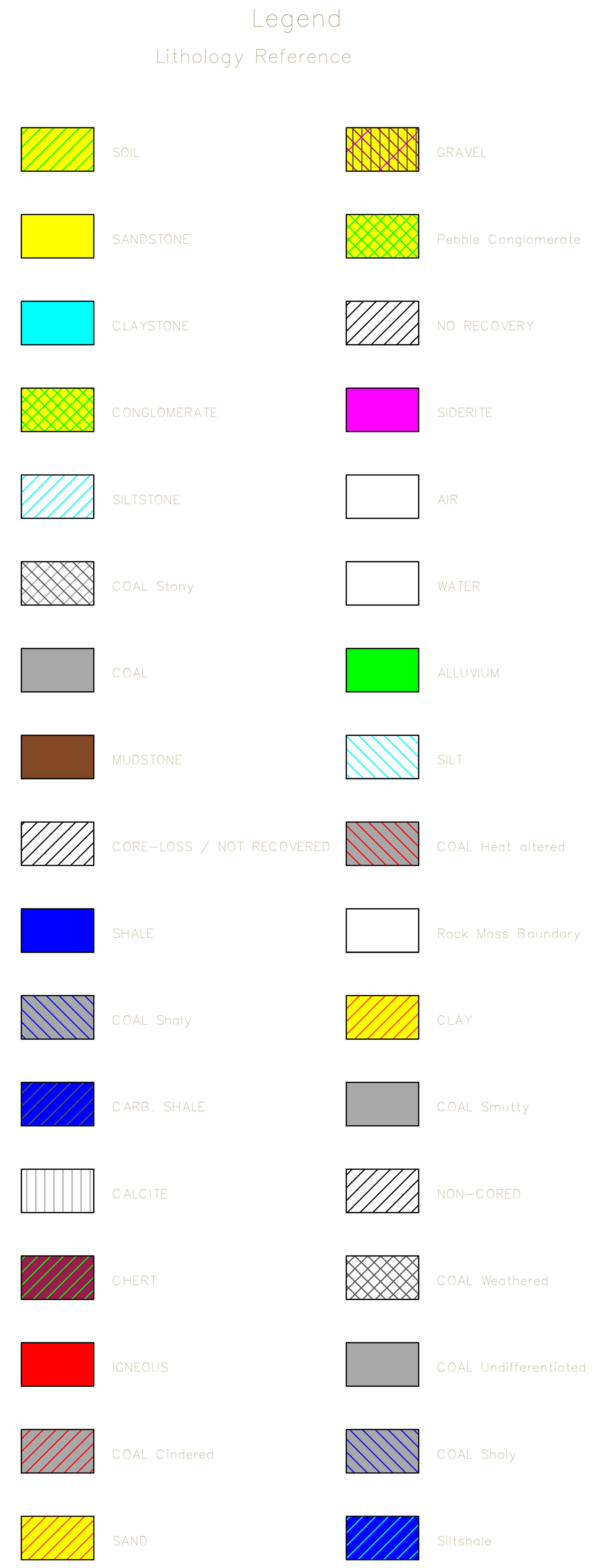
EXTRACTION PLAN APPLICATION
MINIWALL S2-S3 SECONDARY EXTRACTION

PLAN 5 - TITLES

SCALE:	1:3000 @ A0	DATE:	25 Feb 2019
DRAWN:	T Chisholm	DRG NO:	C4A0086_5
CHECKED:	B Smith	REV NO:	0
APPROVED:	D Mclean	SIZE:	A0

LakeCoal





Seam Legend

Seam Expansion Reference

VPT – Vales Point
WAT – Wallarah – tops
WAW – Wallarah – working secti
WAB – Wallarah – bottoms
LWA – Wallarah Lower / Toukley
TBC – Great Northern – conglom
GNN – Great Northern – non–con
GNS – Great Northern – Split
GNC – Claystone
GNT – Great Northern – Tops
GNW – Great Northern – Working
GNB – Great Northern – Bottoms
AWT – Awaba Tuff
CHU – Chain Valley Upper
CHL – Chain Valley Lower
FAT – Fassifern – Tops
A – Fassifern – A ply
B – Fassifern – B ply Clayst
FAW – Fassifern – Working Sect
FAB – Fassifern – Bottoms
UPU – Upper Pilot Upper
UPM – Upper Pilot Middle
UPB – Upper Pilot Lower
ULP – Lower Pilot Upper
LLP – Lower Pilot Lower

LAKE COAL PTY LTD - CHAIN VALLEY COLLIERY	SCALE: 1:3000 @ A0	DATE: 25 Feb 2019	
EXTRACTION PLAN APPLICATION	DRAWN: T Chisholm	DRG NO: C4A0086_6	
MINIWALL S2-S3 SECONDARY EXTRACTION	CHECKED: B Smith	REV NO: 0	LakeCoal
PLAN 6 - GEOLOGICAL INFORMATION	APPROVED: D Mclean	SIZE: A0	

LAKE COAL PTY LTD - CHAIN VALLEY COLLIERY

EXTRACTION PLAN APPLICATION
MINIWALL S2-S3 SECONDARY EXTRACTION

PLAN 7 - SUBSIDENCE MONITORING PLAN

SCALE:	1:3000 @ A0	DATE:	25 Feb 2019
DRAWN:	T Chisholm	DRG NO:	C4A0086_7
CHECKED:	B Smith	REV NO:	0
APPROVED:	D Mclean	SIZE:	A0

LakeCoal

MINING HEIGHTS - 1ST WORKINGS 3.20m
2ND WORKINGS 3.50m

TYPICAL ROADWAY WIDTH 5.4m
MINIWALL INSTALLATION ROADWAY 7.9m-10.0m
MINIWALL PRE-DRIVEN TAKEOFF ROADWAY 6.5m

LAKE COAL PTY LTD - CHAIN VALLEY COLLIERY	SCALE: 1:3000 @ A0	DATE: 25 Feb 2019
EXTRACTION PLAN APPLICATION MINIWALL S2-S3 SECONDARY EXTRACTION	DRAWN: T Chisholm	DRG NO: C4A0086_8
	CHECKED: B Smith	REV NO: 0
PLAN 8 - EXTRACTION AREA PLAN	APPROVED: D Mclean	SIZE: A0

mine subsidence
ENGINEERING CONSULTANTS

LAKE COAL:

Miniwalls S2 and S3

Subsidence Predictions and Impact Assessments for the Natural and Built Features due to the Extraction of the Proposed Miniwalls S2 and S3 in Support of the Extraction Plan

DOCUMENT REGISTER

Revision	Description	Author	Checker	Date
01	Draft Issue	JB	BM	03 Sep 18
02	Draft Issue	JB	BM/DJK	26 Sep 18
A	Final Issue	JB	BM/DJK	7 Feb 19

Report produced to: Support the Extraction Plan Application for the proposed Miniwalls S2 and S3 at to be issued to the Department of Planning and Environment.

Background reports available at *www.minesubsidence.com*[1]:

Introduction to Longwall Mining and Subsidence (Revision A)

General Discussion of Mine Subsidence Ground Movements (Revision A)

Mine Subsidence Damage to Building Structures (Revision A)

[1] Direct link: http://www.minesubsidence.com/index_files/page0004.htm

Lake Coal Pty Ltd operates Chain Valley Colliery (CVC) which is located in the Newcastle Coalfield of New South Wales. The colliery is currently extracting miniwalls in the Fassifern Seam beneath the southern end of Lake Macquarie pursuant to their Development Consent (SSD 12_5465, as modified).

CVC proposes to extract Miniwalls S2 and S3 (MWS2 and MWS3) in the Fassifern Seam beneath Lake Macquarie. These two miniwalls are located north-east of the completed MWS1, at a minimum distance of 235 m. The two miniwalls each have a void width (including first workings) of 97 m and an inter-panel pillar width of 40 m. The depth of the Fassifern Seam below rockhead (i.e. excluding the lake bed sediment) varies between 142 m and 165 m and the working height is 3.5 m.

CVC has previously completed the extraction of Miniwalls 1 to 12 (MW1 to MW12) and Miniwall S1 (MWS1). The vertical subsidence measured above MW1 to MW6 and above the eastern ends of MW7 to MW12 were within predictions. However, increased vertical subsidence was observed above the western ends of MW7 to MW12. A detailed review was carried out by Ditton Geotechnical Services that found that the subsidence exceedance was caused by overloading the chain pillars due to the progressive widening of the overall mined-out area and gradual increase in the overall thickness of the claystone units in the seam floor. The vertical subsidence above MWS1 was not discernible outside the accuracy of the bathymetric survey.

Increased vertical subsidence is not anticipated for MWS2 and MWS3 due to the narrow overall mining void width (i.e. only two miniwalls in the series), shallower depth of cover (i.e. reduced load on the chain pillar) and wider chain pillar width (i.e. 40 m rather than 30 m to 33 m, with stability index greater than 2.7). The subsidence behaviour for MWS2 and MWS3 is therefore expected to be similar to that observed above MW1 to MW6 and above the eastern ends of MW7 to MW12.

The predicted subsidence parameters for MWS2 and MWS3 have been obtained using the Incremental Profile Method (IPM). The IPM has been calibrated for the local conditions using the locally available monitoring and geotechnical data at CVC and using other empirical and mechanistic methods. The maximum predicted subsidence parameters are: 290 mm vertical subsidence, 6 mm/m tilt (i.e. 6 %, or 1 in 167), 0.10 km^{-1} hogging curvature (i.e. 10 km minimum radius) and 0.30 km^{-1} sagging curvature (i.e. 3.3 km minimum radius).

The natural and built features located near MWS2 and MWS3 include the: lake bed sediment, sea grass beds and benthic communities on the lake bed, lake foreshore high-water mark (RL 2.44 mAHD), a navigation marker, jetties, moorings, residential buildings and other associated structures and services along the lake foreshore, and survey control marks.

The predicted changes in the levels of the lake bed directly above MWS2 and MWS3 are less than 0.3 m. These changes are small when compared with the overall depth of the lake which is typically greater than 5 m above the proposed mining area.

The Pelican Rock Navigation Marker is located on the rock outcrop that extends into Lake Macquarie from Summerland Point. The marker is outside but immediately adjacent to the tailgate of MWS2. The predicted vertical subsidence for the navigation marker is 90 mm. The predicted subsidence should be provided to Roads and Maritime Services so that management strategies can be developed for the marker, if required.

MWS2 and MWS3 are located outside the Sea Grass Protection Barrier, defined by a 26.5° angle of draw from the mapped extents of the sea grass beds. The predicted vertical subsidence at the mapped sea grass beds due to the proposed mining is less than 20 mm.

MWS2 and MWS3 are also located outside the High Water Mark Protection Barrier, defined by a 35° angle of draw from the high-water mark of RL2.44 mAHD. The predicted vertical subsidence at the high-water mark due to the proposed mining is also less than 20 mm. It is unlikely, therefore, that there would be measurable changes in the high-water mark due to the extraction of MWS2 and MWS3.

The predicted vertical subsidence at the mapped sea grass beds and, hence, at the lake foreshore is less than 20 mm. It is unlikely, therefore, that there would be adverse impacts on the surface features located above the sea grass beds (i.e. jetties and moorings) or along the lake foreshore, including houses, other associated structures, roads and services.

The state survey control marks located near to MWS2 and MWS3 could experience low-level horizontal movements. NSW Spatial Services should be notified so that the affected state survey marks can be managed and re-established after active subsidence, as required.

The assessments provided in this report indicate that the levels of impact due to mine subsidence on the natural and built features can be managed by the preparation and implementation of appropriate management strategies. The discussions provided in this report should be read in conjunction with the relevant management plans associated with this application.

CONTENTS

LIST OF TABLES, FIGURES AND DRAWINGS

Tables

Table numbers are prefixed by the number of the chapter in which they are presented.

Figures

Figure numbers are prefixed by the number of the chapter or the letter of the appendix in which they are presented.

Drawings

Drawings referred to in this report are included in Appendix D at the end of this report.

1.1. Background

Lake Coal Pty Ltd (LC) operates Chain Valley Colliery (CVC) which is located in the Newcastle Coalfield of New South Wales (NSW). The colliery is currently extracting miniwalls in the Fassifern Seam beneath the southern end of Lake Macquarie pursuant to their Development Consent (SSD 12_5465, as modified).

CVC has completed the extraction of Miniwalls 1 to 12 (MW1 to MW12). The colliery has an approved Extraction Plan for Miniwalls S1 and N1 (MWS1 and MWN1) in the Fassifern Seam. At the time of this report, CVC had completed MWS1 and was in the process of mining MWN1.

CVC proposes to extract Miniwalls S2 and S3 (MWS2 and MWS3) in the Fassifern Seam. These two miniwalls are located north-east of the completed MWS1, at a minimum distance of 235 m.

The locations of the existing and proposed miniwalls are shown in Drawings Nos. MSEC979-01 and MSEC979-02, in Appendix D. MWS2 and MWS3 have also been overlaid on an aerial photograph in Fig. 1.1. These two miniwalls are located north of the suburb of Summerland Point.

Courtesy of Nearmap

Fig. 1.1 Aerial photograph and MWS2 and MWS3

LC is currently preparing an Extraction Plan Application for MWS2 and MWS3. Mine Subsidence Engineering Consultants (MSEC) has been commissioned by LC to:

- prepare subsidence predictions for MWS2 and MWS3, including the cumulative movements due to the previously extracted and approved miniwalls;
- identify the natural and built features near the miniwalls;
- provide subsidence predictions for each of these surface features;
- prepare impact assessments for each of the natural and built features; and
- recommend management strategies and monitoring.

This report has been prepared to support the Extraction Plan Application for MWS2 and MWS3 that will be submitted to the Department of Planning and Environment. The discussions provided in this report should be read in conjunction with the relevant management plans associated with this application.

Chapter 1 provides background information on the study, including the mining geometry, surface and seam levels and the overburden lithology.

Chapter 2 defines the Study Area and provides a summary of the natural and built features that have been identified within this area.

Chapter 3 provides an overview and the calibration of the methods that have been used to predict the mine subsidence movements due to the extraction of the miniwalls.

Chapter 4 provides the maximum predicted subsidence parameters resulting from the extraction of the miniwalls. This chapter also provides the predicted fracture widths at rockhead and the predicted deformations deeper within the overburden.

Chapter 5 provides the descriptions, predictions and impact assessments for each of the natural and built features that could be affected by subsidence. Recommendations for each of these features are also provided, which have been based on the predictions and impact assessments.

1.2. Mining geometry

The locations of MWS2 and MWS3 are shown in Drawings Nos. MSEC979-01 and MSEC979-02. A summary of the dimensions of these miniwalls is provided in Table 1.1. The miniwalls will be extracted in the Fassifern Seam.

Table 1.1 Geometry of the miniwalls

Miniwall	Overall void length including installation heading (m)	Overall void width including the first workings (m)	Tailgate pillar width (m)
MWS2	1078	97	-
MWS3	1045	97	40

The lengths of miniwall (i.e. secondary) extraction excluding the installation headings are 1070 m for MWS2 and 1037 m for MWS3. The miniwall face widths excluding the first workings are 86 m. The miniwalls will be extracted towards the main headings (i.e. retreat mining) from the south-east to the north-west.

The development headings are 5.4 m wide and 3.2 m high. The cut-throughs are at 100 m centres. The solid pillars between MWS2 and MWS3, therefore, are 95 m long by 40 m wide and 3.2 m high. The solid pillars on the tailgate side of MWS2 are 105 m long by 32.6 m wide and 3.2 m high and the solid pillars on the maingate of MWS3 are 105 m long by 40 m wide and 3.2 m high.

1.3. Surface, overburden and seam levels

The levels of the lake bed, rockhead, Teralba Conglomerate and Fassifern Seam based on the geological model were provided by Coal Resource Consulting (CRC, 2018). The natural surface level, thickness of the claystone floor of the Fassifern Seam and the graphical borehole logs were provided by CVC (2018). The approximate levels and thicknesses of the Munmorah, Karignan and Karingal Conglomerate members and the Awaba Tuff have been determined from the borehole logs.

Two cross-sections and one long-section have been taken through MWS2 and MWS3, as shown in Drawings Nos. MSEC979-03 to MSEC979-09. The levels of the natural surface, lake bed floor, rockhead, Teralba Conglomerate and Fassifern Seam along Cross-sections 1 and 2 and Long-section 1 are illustrated in Fig. 1.2 to Fig. 1.4, respectively. Cross-section 1 is located near the commencing (i.e. south-eastern) ends of the miniwalls and Cross-section 2 is located near the finishing (i.e. north-western) ends of the miniwalls. Long-section 1 has been taken through the centreline of MWS2.

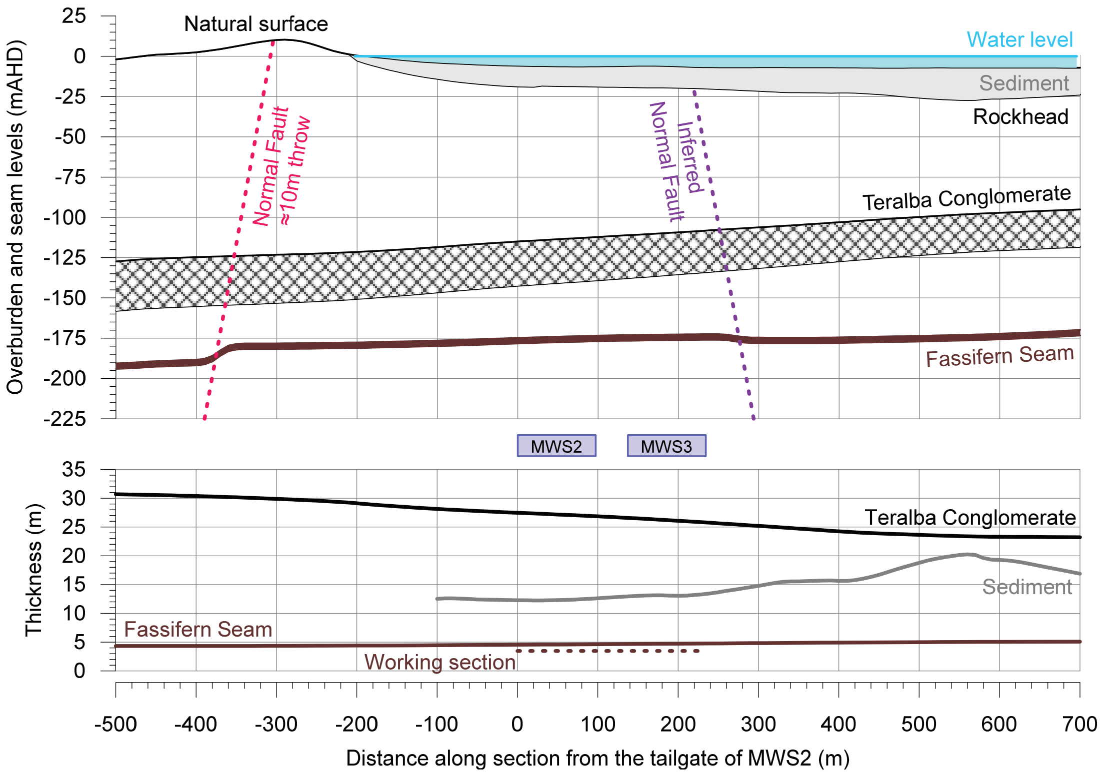


Fig. 1.2 Surface and seam levels along Cross-section 1 (near commencing ends)

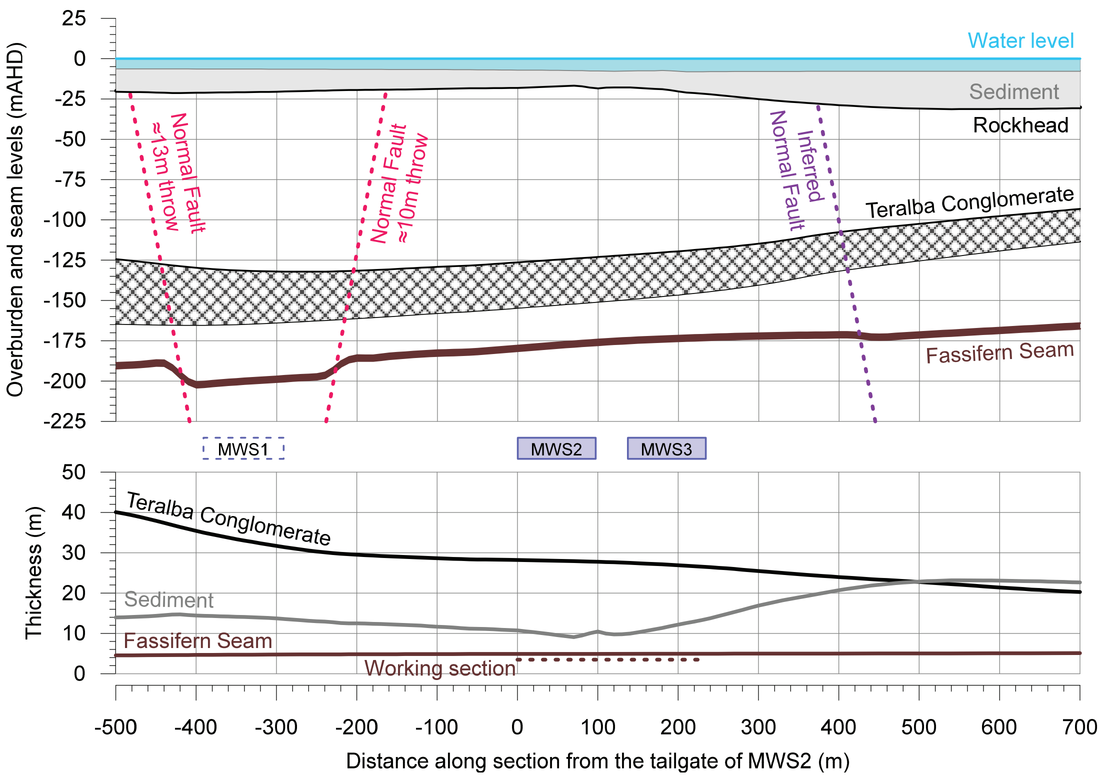


Fig. 1.3 Surface and seam levels along Cross-section 2 (near finishing ends)

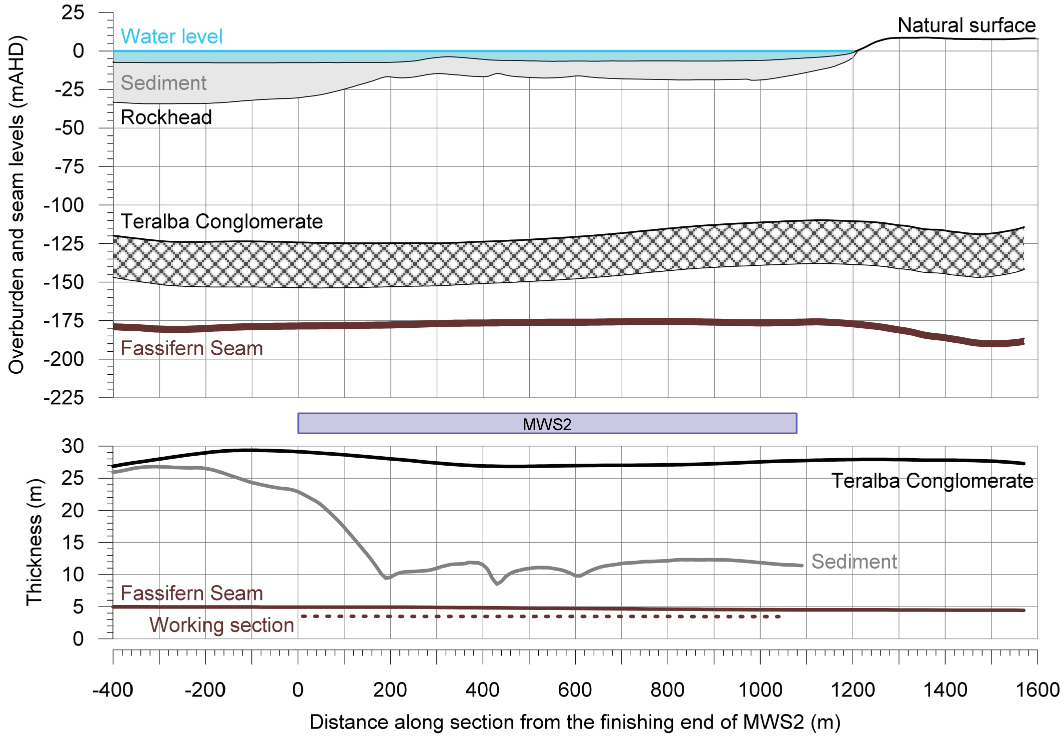


Fig. 1.4 Surface and seam levels along Long-section 1 (centreline of MWS2)

The natural surface and the lake bed contours are shown in Drawing No. MSEC979-03. MWS2 and MWS3 are located directly beneath Lake Macquarie. These two miniwalls are situated at a minimum distance of approximately 130 m from the lake foreshore based on the 0 m Australian Height Datum (mAHD) surface level contour.

The depth of the lake bed beneath the mean water level (i.e. 0 mAHD) varies between approximately 3 m and 8 m directly above MWS2 and MWS3. The thickness of the lake bed sediment is illustrated in Drawing No. MSEC979-08. The sediment thickness varies between approximately 9 m and 23 m directly above MWS2 and MWS3.

The rockhead level, Fassifern Seam floor level, Fassifern Seam thickness and depth of the Fassifern Seam below rockhead contours are shown in Drawings Nos. MSEC979-04 to MSEC979-07, respectively. It is noted that, in this report, the *depth of seam* contours refers to the distance between the top of the working section within the Fassifern Seam and rockhead, i.e. excluding the lake bed sediment. The working section (i.e. underside of C Ply) is located approximately 1.8 m below the roof of the Fassifern Seam.

The depth of the top of the working section in the Fassifern Seam below rockhead varies between 142 m at the finishing (i.e. north-western) end of MWS3 and 165 m above the tailgate of MWS2. The total depth of cover including the lake bed sediment varies between approximately 164 m and 172 m.

The Fassifern Seam dips from the north-east towards the south-west. The average seam dip across the width of the mining area is approximately 1 % to 2 %.

The thickness of the Fassifern Seam varies between 4.5 m and 5 m within the proposed mining area. The miniwalls will extract a height of 3.5 m within this seam. The top of the working section is at the underside of the C Ply which is approximately 1.8 m below the roof of the Fassifern Seam (refer to Fig. 1.5).

A summary of the mining geometry of MWS2 and MWS3 is provided in Table 1.2.

Table 1.2 Mining geometry of MWS2 and MWS3

Miniwall	Overall void length (m)	Void width (m)	Tailgate pillar width (m)	Depth below rockhead (m)	W/H ratio of miniwall void	W/H ratio of overall mining void	Working section height (m)
MWS2	1078	97	-	146 ~ 165	0.59 ~ 0.66	0.59 ~ 0.66	3.5
MWS3	1045	97	40	142 ~ 156	0.62 ~ 0.68	1.50 ~ 1.65	3.5

The width-to-depth ratios for each of the miniwall voids vary between 0.59 and 0.68. The void widths of MWS2 and MWS3 are therefore subcritical. The width-to-depth ratios of the overall mining width vary between 1.50 and 1.65 at the completion of MWS3.

1.4. Geological details

CVC is located in the Newcastle Coalfield in the northern part of the Sydney Basin. The stratigraphy comprises the upper sequences of the Permian Newcastle Coal Measures overlain by the Triassic Narrabeen Group. The bedrock is then overlain by sediment in the bed of Lake Macquarie. The stratigraphy of the area is illustrated in Table 1.3.

Table 1.3 Stratigraphy of the Lake Macquarie area of the Newcastle Coalfield

Period	Group	Subgroup	Lithology
Triassic	Narrabeen Group	Clifton	Munmorah Group (Conglomerate)
			Dooralong Shale
Permian	Newcastle Coal Measures	Moon Island Beach	Vales Points Coal
			Karignan Conglomerate
			Tuff
			Wallarah Coal
			Mannering Park Tuff
			Teralba Conglomerate
			Great Northern Coal
		Boolaroo	Karingal Conglomerate
			Awaba Tuff
			Fassifern Coal
			Claystone and Pilot Coal
			Croudace Bay Conglomerate

The thickness of the Fassifern Seam varies between 4.5 m and 5 m within the extents of MWS2 and MWS3. The floor of the seam comprises interbedded coal and carbonaceous shale and moisture sensitive claystone (Strata[2], 2019). The bedding thicknesses vary between 50 mm and 300 mm with a total thickness of less than 2 m within the mining area. The claystone floor then overlies interbedded conglomerate, sandstone and shale units.

The Fassifern Seam is overlain by the Awaba Tuff which comprises a variable sequence of tuffaceous claystone, sandstone and siltstone, with the beds usually sandwiched between stronger shaley coal units (DgS, 2013). This unit has a thickness of approximately 20 m directly above MWS2 and MWS3. The Awaba Tuff tends to swell and degrade in the presence of moisture (Strata[2], 2019).

The overburden consists of interbedded conglomerate, sandstone, carbonaceous shale, coal and tuffaceous claystone and sandstone. There are several massive conglomerate units above the Fassifern Seam comprising (from bottommost to topmost) the Karingal, Teralba, Karignan and Munmorah (lower and upper) members.

The largest unit in the overburden is the Teralba Conglomerate. This unit is located between 25 m and 40 m above the Fassifern Seam. The overall thickness of the Teralba Conglomerate is illustrated in MSEC979-09 and it ranges between 26 m and 29 m directly above MWS2 and MWS3.

The approximate thicknesses of other conglomerate members, based on the drillholes near MWS2 and MWS3, are 6 m to 8 m for the Karingal Conglomerate, 20 m to 25 m for the Karignan Conglomerate and 20 m to 25 m for the Munmorah Conglomerate.

The rock is overlain with sediment on the bed of Lake Macquarie. The thickness of the lake bed sediment is shown in Drawing No. MSEC979-08 and it varies between 9 m and 23 m directly above MWS2 and MWS3.

The stratigraphy at CVC based on drillhole JCV3 is illustrated in Fig. 1.5. This drillhole is located on the headland to the south-west of MWS2 and MWS3, as shown in Drawing No. MSEC979-01.

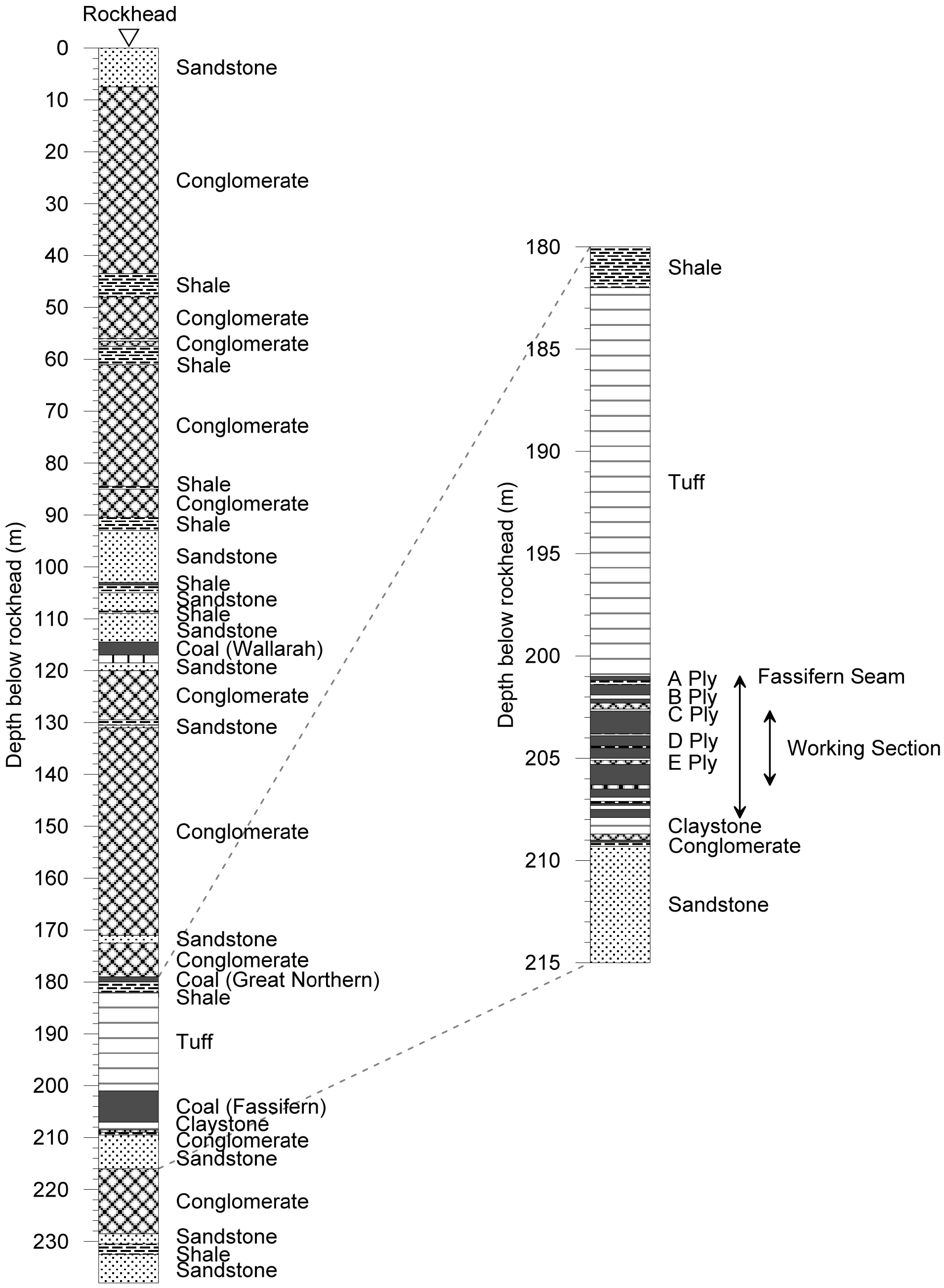


Fig. 1.5 Stratigraphy at CVC based on Drillhole JCV3

CVC is located to the west of the Macquarie Syncline. Regional structure comprises west-northwest to east-southeast orientated normal faults. The mapped and inferred geological structures near MWS2 and MWS3 are shown in MSEC979-10. The faults are also illustrated in the cross-sections in Fig. 1.2 and Fig. 1.3.

A fault zone is located on the south-western side of MWS2. The zone comprises normal faults with a strike of approximately 131°. The largest fault has a throw of 10 m and other faults in this zone have throws of less than 2 m. The faults dip towards the south-west with angles between 50° and 75° (DgS, 2018b).

The fault zone is located closest to MWS2 at its finishing end. The largest fault in this zone (i.e. 10 m throw) is located at a minimum distance of 175 m from this miniwall at seam level. It is not anticipated that this fault zone would affect the subsidence that develops from MWS2 and MWS3 due to its distance from the mining area (i.e. more than one depth of cover from the miniwalls).

A normal fault is located further to the south-west on the far-side of MWS1. This fault has a throw of approximately 13 m and dips towards the north-east. MWS1 is located within a horst bounded by the faults on the maingate and tailgate sides, as shown in Fig. 1.3.

An inferred normal fault is located on the north-eastern side of MWS3. This inferred normal fault has a west-northwest to east-southeast orientation and it has a throw of approximately 2 m. The inferred fault dips towards the north-east at an angle of approximately 60° (Strata[2], 2019).

The inferred normal fault is located adjacent to the maingate of MWS3 at its commencing end. The distance of the fault increases along the length of this miniwall. It is located approximately 220 m north-west of MWS3 at its finishing end. MWS2 and MWS3 are located within a graben bounded by the faults on the south-western and north-eastern sides, as shown in Fig. 1.3.

The effect of the inferred fault on the predicted subsidence for MWS2 and MWS3 was reviewed using a numerical model (refer to Section 3.5.6). The numerical analysis indicates that slightly increased vertical subsidence (i.e. less than 10 % of the maximum predicted value) could occur when mining immediately adjacent to a normal fault. Only low-level additional subsidence is anticipated due to the relatively high dip (i.e. 60°) and relatively small throw (i.e. approximately 2 m).

It is not expected, therefore, that the inferred normal fault would result in a significant increase in the vertical subsidence due to the extraction of MWS2 and MWS3. This is supported by the fact that there was no obvious relationship between vertical subsidence and the presence or absence of major geological structures for the existing MW1 to MW12 (Strata[2], 2019).

The surface expression (i.e. at rockhead) for the inferred fault is projected above MWS3 near its commencing end. It is possible that locally increased compressive strain could develop in this location due to the extraction of this miniwall. The numerical analysis did not show a significant change in the horizontal movements at rockhead. The lake bed sediment is more than 10 m thick at the commencing end of MWS3. It is unlikely that there would be measurable strain at the lake bed due to the thickness of the sediment.

The major principal stress direction is orientated north-northeast to north-east (DgS, 2018b). The in situ stress at rockhead is approximately 6.5 MPa and it increases by approximately 0.1 MPa per metre depth. The minor principal stress is near-zero at rockhead and it increases by approximately 0.06 MPa per metre depth (DgS, 2018b).

2.1. Definition of the Study Area

The *Study Area* is defined as the surface area that could be affected by the mining of MWS2 and MWS3. The extent of the Study Area has been calculated by combining the areas bounded by the following limits:

- the 26.5° angle of draw line from the extents of MWS2 and MWS3; and
- the predicted limit of vertical subsidence, taken as the 20 mm subsidence contour, resulting from the extraction of the miniwalls.

The depth of the Fassifern Seam below rockhead contours are shown in Drawing No. MSEC979-06. The depth of the seam below rockhead varies between 142 m and 165 m directly above MWS2 and MWS3. The 26.5° angle of draw line, therefore, has been determined by drawing a line that is a horizontal distance varying between 71 m and 83 m around the extents of the miniwall voids.

The predicted limit of vertical subsidence, taken as the predicted total 20 mm subsidence contour, has been determined using the Incremental Profile Method (IPM). The description and calibration of the IPM are provided in Chapter 3. The predicted total subsidence contours, including the 20 mm subsidence contour, are shown in Drawing No. MSEC979-13. The predicted 20 mm subsidence contour is located entirely within the 26.5° angle of draw line.

The 26.5° angle of draw line for MWS2 and MWS3 is shown in Drawings Nos. MSEC979-01 and MSEC979-02. The features located outside the 26.5° angle of draw, that are predicted to experience far-field movements and could be sensitive to these movements, have been included in the assessments provided in this report. The features near MWS2 and MWS3 that are sensitive to far-field horizontal movements are the survey control marks.

2.2. Natural and built features within the Study Area

MWS2 and MWS3 are located directly beneath the southern part of Lake Macquarie. The miniwalls are north of the suburb of Summerland Point. Photographs of the lake foreshore near MWS2 and MWS3 are provided in Fig. 2.1.

Fig. 2.1 Lake foreshore at Summerland Point

A summary of the natural and built features located within or in the immediate vicinity of the Study Area is provided below:

- lake bed sediment;
- sea grass beds and benthic communities on the lake bed;
- lake foreshore high-water mark (RL 2.44 mAHD);
- a navigation marker;
- jetties and moorings;
- residential buildings and other structures along the lake foreshore; and
- survey control marks.

The locations of these features are shown in Drawing No. MSEC979-11. The descriptions, predictions and impact assessments for the natural and built features are provided in Chapter 5.

3.0 OVERVIEW OF MINE SUBSIDENCE AND THE METHODS USED TO PREDICT THE MINE SUBSIDENCE PARAMETERS FOR THE MINIWALLS

3.1. Introduction

The following sections provide overviews of mine subsidence parameters and the methods that have been used to predict these movements. Further information is also provided in the background reports entitled *Introduction to Longwall Mining and Subsidence* and *General Discussion on Mine Subsidence Ground Movements* which can be obtained from *www.minesubsidence.com*.

3.2. Overview of conventional subsidence parameters

The normal ground movements resulting from the extraction of underground panels are referred to as conventional or systematic subsidence movements. These movements are described by the following parameters:

- **Subsidence** usually refers to vertical displacement of a point, but subsidence of the ground actually includes both vertical and horizontal displacements. These horizontal displacements in some cases, where the subsidence is small beyond the panel goaf edges, can be greater than the vertical subsidence. Subsidence is usually expressed in units of *millimetres (mm)*.
- **Tilt** is the change in the slope of the ground as a result of differential subsidence and it is calculated as the change in subsidence between two points divided by the distance between those points. Tilt is, therefore, the first derivative of the subsidence profile. Tilt is usually expressed in units of *millimetres per metre (mm/m)*. A tilt of 1 mm/m is equivalent to a change in grade of 0.1 %, or 1 in 1000.
- **Curvature** is the second derivative of subsidence, or the rate of change of tilt, and is calculated as the change in tilt between two adjacent sections of the tilt profile divided by the average length of those sections. Curvature is usually expressed as the inverse of the **Radius of Curvature** with the units of *1/kilometres (km^{-1})*, but the values of curvature can be inverted, if required, to obtain the radius of curvature, which is usually expressed in *kilometres (km)*.
- **Strain** is the relative differential horizontal movements of the ground. **Normal strain** is calculated as the change in horizontal distance between two points on the ground, divided by the original horizontal distance between them. Strain is typically expressed in units of *millimetres per metre (mm/m)*. **Tensile Strains** occur where the distances between two points increase and **Compressive Strains** occur when the distances between two points decrease. So that ground strains can be compared between different locations, they are typically measured over bay lengths that are equal to the depth of cover between the surface and seam divided by 20.

  Whilst mining induced normal strains are measured along monitoring lines, ground shearing can also occur both vertically and horizontally across the directions of monitoring lines. Most of the published mine subsidence literature discusses the differential ground movements that are measured along subsidence monitoring lines, however, differential ground movements can also be measured across monitoring lines using 3D survey monitoring techniques.
- **Horizontal shear deformation** across monitoring lines can be described by various parameters including horizontal tilt, horizontal curvature, mid-ordinate deviation, angular distortion and shear index. It is not possible, however, to determine the horizontal shear strain across a monitoring line using 2D or 3D monitoring techniques. High deformations along monitoring lines (i.e. normal strains) are generally measured where high deformations have been measured across the monitoring line (i.e. shear deformations), and vice versa.

The **incremental** subsidence, tilts, curvatures and strains are the additional parameters that result from the extraction of each panel. The **cumulative** subsidence, tilts, curvatures and strains are the accumulated parameters that result from the extraction of a series of panels. The **total** subsidence, tilts, curvatures and strains are the final parameters at the completion of a series of panels. The **travelling** tilts, curvatures and strains are the transient movements as the panel extraction face mines directly beneath a given point.

The measured horizontal movements at survey marks that are located beyond the panel goaf edges and over solid unmined coal areas are often much greater than the observed vertical movements at those marks. These movements are often referred to as *far-field movements*.

Far-field horizontal movements tend to be bodily movements towards the extracted goaf area and are accompanied by very low-levels of strain. These movements generally do not result in impacts on natural features or built environments, except where they are experienced by large structures that are very sensitive to differential horizontal movements.

In some cases, higher levels of far-field horizontal movements have been observed where steep slopes or surface incisions exist nearby, as these features influence both the magnitude and the direction of ground movement patterns. Similarly, increased horizontal movements are often observed around sudden changes in geology or where blocks of coal are left between panels or near other previously extracted series of panels. In these cases, the levels of observed subsidence can be slightly higher than normally predicted, but these increased movements are generally accompanied by very low-levels of tilt and strain.

3.3. Review of the monitoring data for MW1 to MW12

CVC has completed the extraction of MW1 to MW12 in the Fassifern Seam. The locations of these miniwalls are shown in Drawing No. MSEC979-01. The northern series comprises MW1 to MW3 and MW6 to MW12. The southern series comprises MW4, MW5 and MW5A.

A summary of the mining geometries of the existing miniwalls is provided in Table 3.1.

Table 3.1 Mining geometries of the existing MW1 to MW12

Miniwall	Overall void length (m)	Void width (m)	Tailgate pillar width (m)	Depth of seam below rockhead (m)	W/H ratio of miniwall void	W/H ratio of the overall mining void (eastern ends)	W/H ratio of the overall mining void (western ends)
MW1	920	71	-	185 ~ 190	0.37 ~ 0.39	0.37 ~ 0.39	-
MW2	930	74	30	185 ~ 190	0.39 ~ 0.40	0.92 ~ 0.95	-
MW3	900	97	30	185 ~ 190	0.52 ~ 0.53	1.60 ~ 1.63	-
MW6	880	97	33	185 ~ 190	0.51 ~ 0.53	2.28 ~ 2.35	-
MW7	1190	98	33	180 ~ 190	0.52 ~ 0.54	2.99 ~ 3.09	0.52 ~ 0.54
MW8	1185	97	33	180 ~ 190	0.52 ~ 0.54	3.68 ~ 3.84	1.21 ~ 1.27
MW9	1285	98	33	175 ~ 190	0.52 ~ 0.56	4.35 ~ 4.72	1.90 ~ 2.06
MW10	1245	97	33	170 ~ 190	0.52 ~ 0.57	5.06 ~ 5.55	2.59 ~ 2.84
MW11	1150	97	33	165 ~ 185	0.53 ~ 0.59	5.89 ~ 6.51	3.36 ~ 3.72
MW12	730	97	33	175 ~ 180	0.54 ~ 0.56	6.76 ~ 6.97	4.18 ~ 4.31
MW4	410	97	-	175 ~ 180	0.53 ~ 0.56	0.53 ~ 0.56	-
MW5	760	97	40	175 ~ 190	0.51 ~ 0.55	1.23 ~ 1.33	0.51 ~ 0.55
MW5A	805	98	30	180 ~ 190	0.51 ~ 0.55	1.89 ~ 2.04	1.17 ~ 1.26

The miniwalls were extracted from the Fassifern Seam. The seam has an overall thickness ranging between 5 m and 6 m. The working section was in the middle part of the seam (at the underside of C Ply). The mining height was 3.4 m for MW1 to MW7 and 3.5 m for MW8 to MW12 (Strata[2], 2019).

The subsidence of the lake bed has been measured annually since 2012 using bathymetric surveys. These surveys measure the depth to the lake bed and have an accuracy in the order ±100 mm. The base surveys of the lake floor were carried out between 2012 and 2016. The vertical subsidence has been determined by taking the difference between the base surveys and subsequent surveys carried out in August 2017 (MW4 to MW5A) and April 2018 (MW1 to MW3 and MW6 to MW12). The latest bathymetric survey was carried out in January 2019 and there was no appreciable change above MW1 to MW12 from the previous survey carried out in April 2018.

The measured vertical subsidence contours for MW1 to MW12 based on the bathymetric surveys are shown in Fig. 3.1. The contours outside of the mining areas have been cropped for clarity.

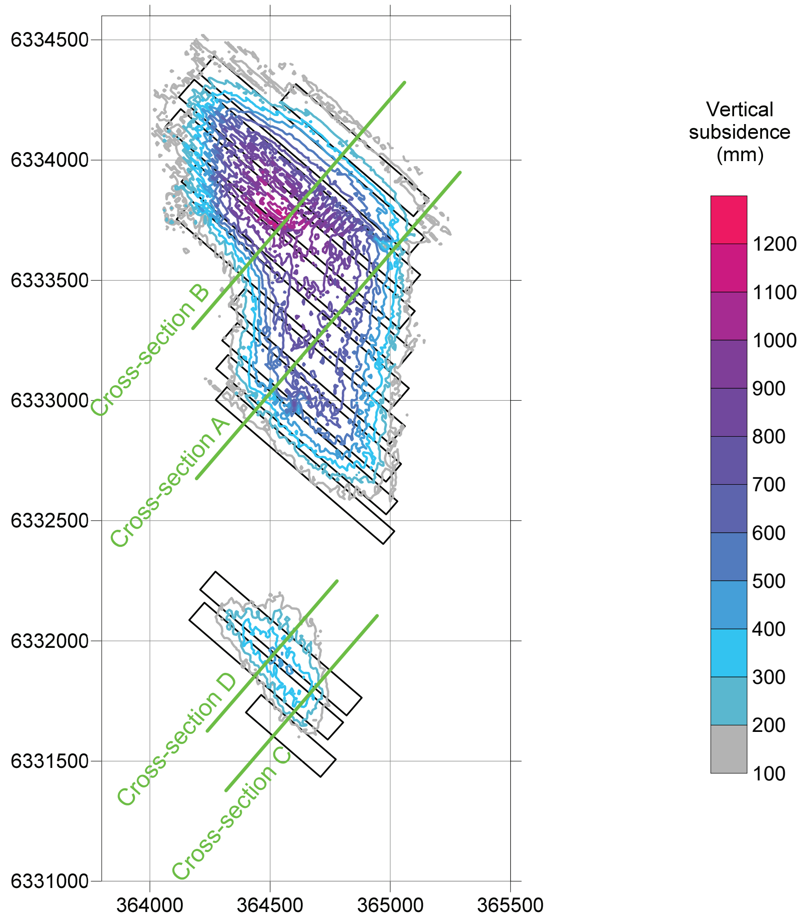


Fig. 3.1 Measured vertical subsidence contours for MW1 to MW12

The profiles of the measured vertical subsidence along Cross-sections A to D are shown in Fig. 3.2 to Fig. 3.5, respectively. The locations of these cross-sections are shown in Fig. 3.1.

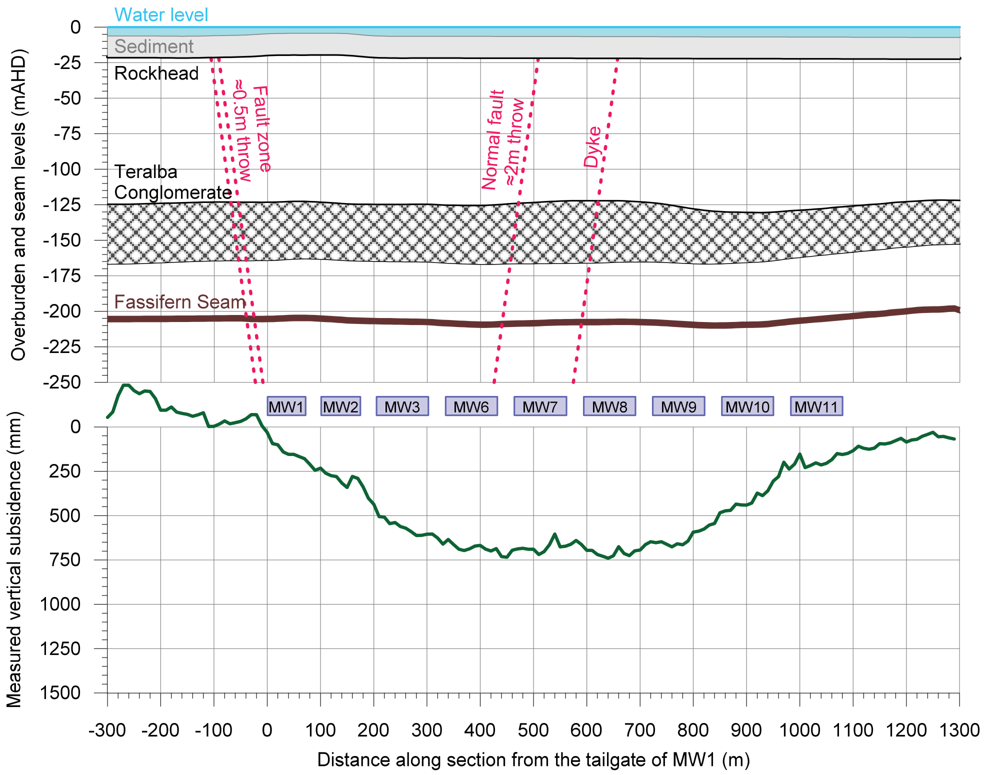


Fig. 3.2 Measured vertical subsidence along Cross-section A due to MW1 to MW11 (east)

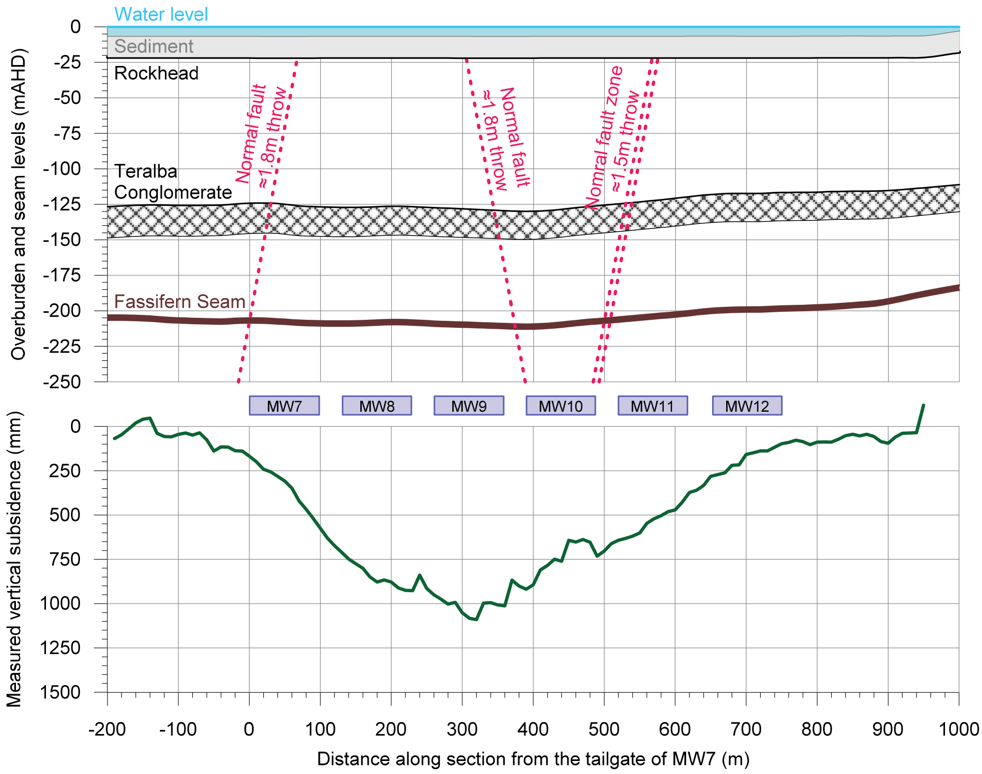


Fig. 3.3 Measured vertical subsidence along Cross-section B due to MW7 to MW12 (west)

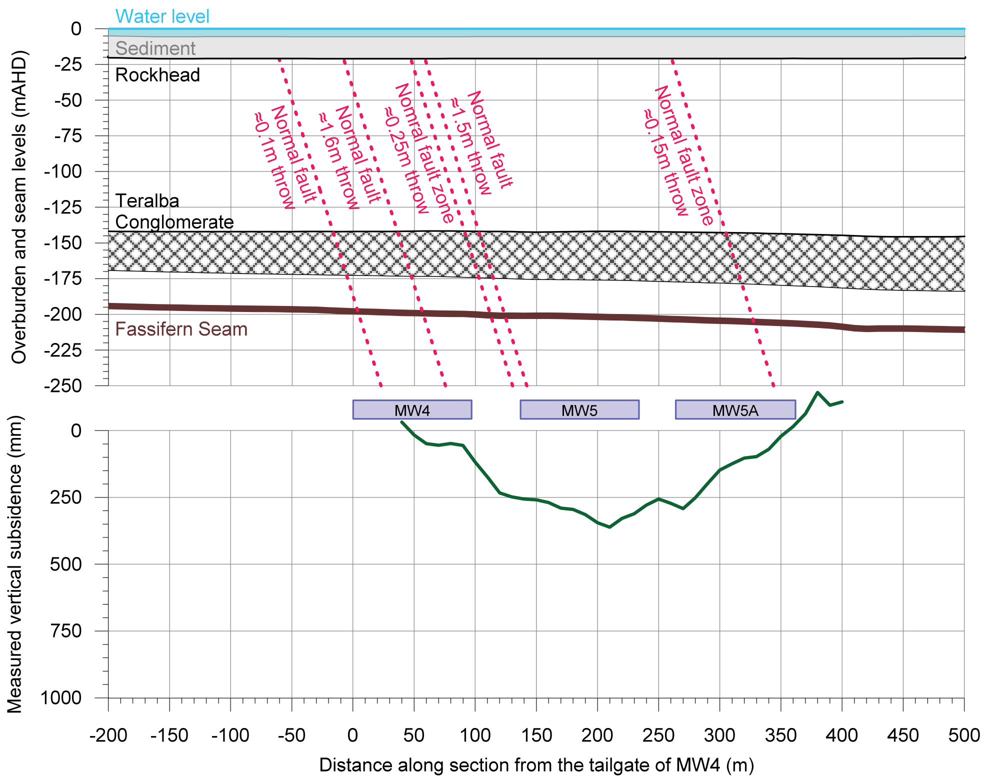


Fig. 3.4 Measured vertical subsidence along Cross-section C due to MW4 to MW5A (east)

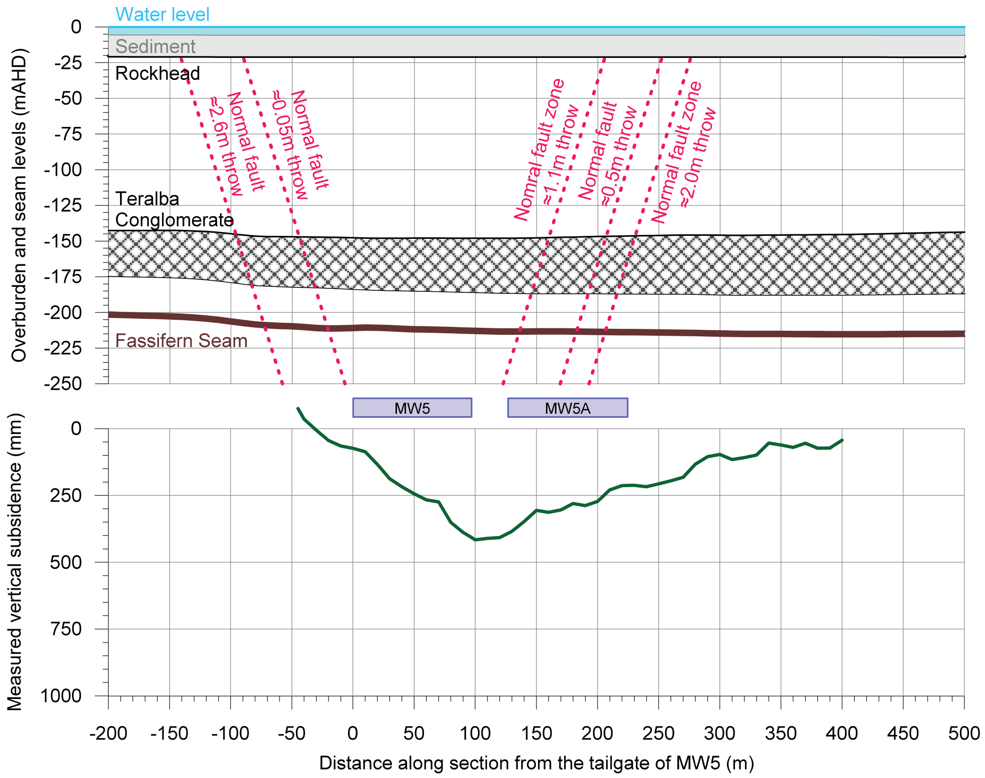


Fig. 3.5 Measured vertical subsidence along Cross-section D due to MW4 to MW5A (west)

A summary of the maximum measured vertical subsidence for MW1 to MW12 is provided in Table 3.2.

Table 3.2 Maximum measured vertical subsidence for MW1 to MW12

Miniwalls	Location	Maximum measured vertical subsidence (mm)
MW1 to MW3 and MW6 to MW12 (eastern ends)	Near Cross-section A (refer to Fig. 3.2)	750
MW7 to MW12 (western ends)	Near Cross-section B (refer to Fig. 3.3)	1150
MW4 to MW5A (eastern ends)	Near Cross-section C (refer to Fig. 3.4)	220 (after LW4) 350 (after LW5A)
MW5 and MW5A (western ends)	Near Cross-section D (refer to Fig. 3.5)	460

The maximum measured vertical subsidence for the existing MW1 to MW12 was 1150 mm and it occurred above the western part of MW9 (refer to Fig. 3.3). The maximum measured vertical subsidence above the eastern part of this existing series (i.e. MW1 to MW3 and MW6 to MW12) was 750 mm (refer to Fig. 3.2).

The maximum measured total vertical subsidence divided by the mining height versus the overall mining void width-to-depth ratio for MW1 to MW12 is illustrated in Fig. 3.6. The overall mining void width-to-depth ratios are based on the depth of rock (i.e. Fassifern Seam roof to rockhead). The results for Wyee LW17 to LW21 are also shown in this figure for comparison (Source: DgS, 2018b and Strata[2], 2019).

Wyee LW17 to LW23 had void widths ranging between 130 m and 150 m and chain pillar widths of 45 m. The longwalls were extracted in the Fassifern Seam with a working height of 3.2 m. The depths of cover vary between 170 m and 195 m. The width-to-depth ratios for the longwalls, therefore, vary between 0.75 and 0.81.

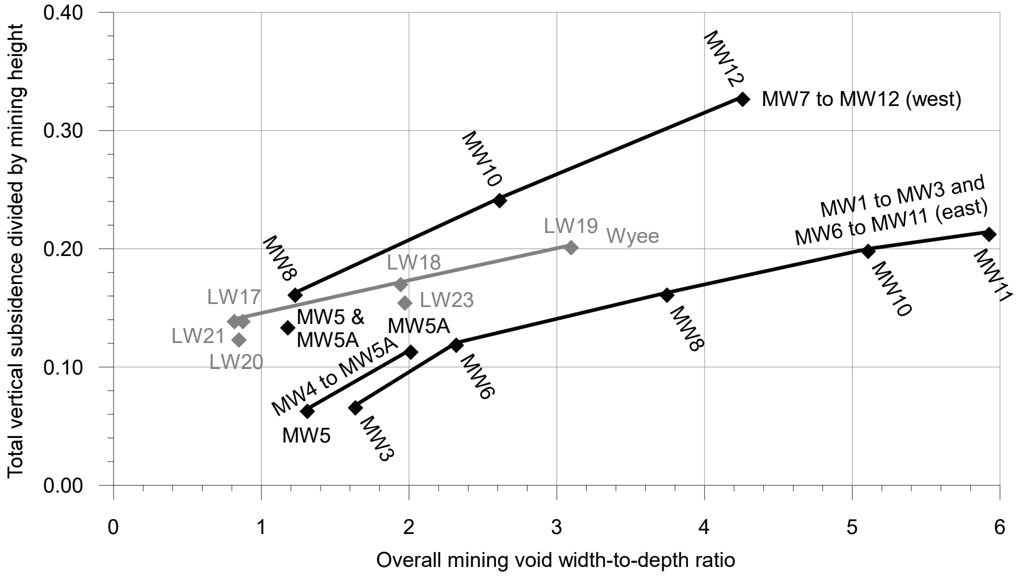


Fig. 3.6 Maximum measured total vertical subsidence divided by mining height versus overall mining void width-to-depth ratio

The subsidence predictions for MW1 to MW12 were provided by Ditton Geotechnical Services (DgS). The original predictions are outlined in Report. No. CHS-002/1 (DgS, 2013) which supported the Extraction Plan Application for MW7 to MW12.

The predictions were obtained using two empirical models (ACARP, 2003 and SDPS, 2007) and an analytical model (after Das, 1998). The maximum predicted vertical subsidence for MW7 to MW12 was 720 mm (DgS, 2013).

The vertical subsidence above the western ends of MW7 to MW12 exceeded the original predictions. An extensive review and assessment of the subsidence exceedance was carried out by DgS (2018a). It was concluded that the:

> "*…subsidence exceedance over MW1-12 was caused by over-loading of the chain pillars. This was in turn primarily a result of:*
>
> *(i) reducing overburden stiffness due to the progressive widening of the overall mined-out area, and*
>
> *(ii) reducing pillar system strength due to a gradual increase in the overall thickness of the claystone units in the Fassifern Seam floor northwards towards MW12.*" (DgS, 2018a)

The review by DgS (2018a) found that the subsidence above the initial mined panels was limited by spanning conglomerate units in the overburden. The maximum measured subsidence for the first two panels in the series was less than 300 mm (i.e. less than 0.09 times the mining height). After the extraction of additional miniwalls, the conglomerate units in the overburden were less capable of spanning the overall mining void width when the width-to-depth was greater than the supercritical width (DgS, 2018a).

The reduced spanning capacities increased load on the chain pillars where the "*average chain pillar stress is estimated at 15 to 20 MPa. This is of the same order as the bearing capacity of the claystone floor (15 to 21 MPa).*" (DgS, 2018a). Hence, the "*softened claystone at the pillar periphery would tend to deform laterally, reducing confinement and reducing the pillar core width. As pillar stiffness reduces, overburden deformation increases and more load sheds to the goaf.*" (DgS, 2018a).

At that point the "*goaf strain-hardens under load produced by increasing overburden deflection. This provides support and assists the Munmorah Conglomerate to behave elastically and span until a late stage in the process*" and that "*subsidence then becomes simply a function of the resistance offered by the failed pillars and goaf*" (DgS, 2018a). In the long-term it was "*estimated that goaf consolidation could result in up to 300 mm of additional subsidence in the next two or more years, resulting in final subsidence of up to 1.45 m*" (DgS, 2018a).

The increased vertical subsidence above the western ends of MW7 to MW12 appears to be the result of the wide overall mining void width (i.e. more than three miniwalls in the series) combined with narrower chain pillars (i.e. low stability index). This behaviour is not expected for MWS2 and MWS3 due to the narrow overall mining void width (i.e. only two miniwalls in the series), shallower depth of cover (i.e. reduced load on the chain pillar) and wider chain pillar width (i.e. higher stability index). The subsidence behaviour for MWS2 and MWS3 is therefore expected to be similar to that observed above MW1 to MW6 and above the eastern ends of MW7 to MW12.

3.4. Review of the monitoring data for MWS1

CVC has completed the extraction of MWS1 in the Fassifern Seam. A bathymetric survey was carried out in January 2019. The vertical subsidence above MWS1 was not discernible outside the accuracy of the bathymetric survey.

The subsidence along the foreshore of Frying Pan Bay was also measured using 2D survey marks fixed to structures including seawalls and jetties. The measured vertical subsidence along the lake foreshore is illustrated in Fig. 3.7. The latest survey was carried out on the 21 December 2018.

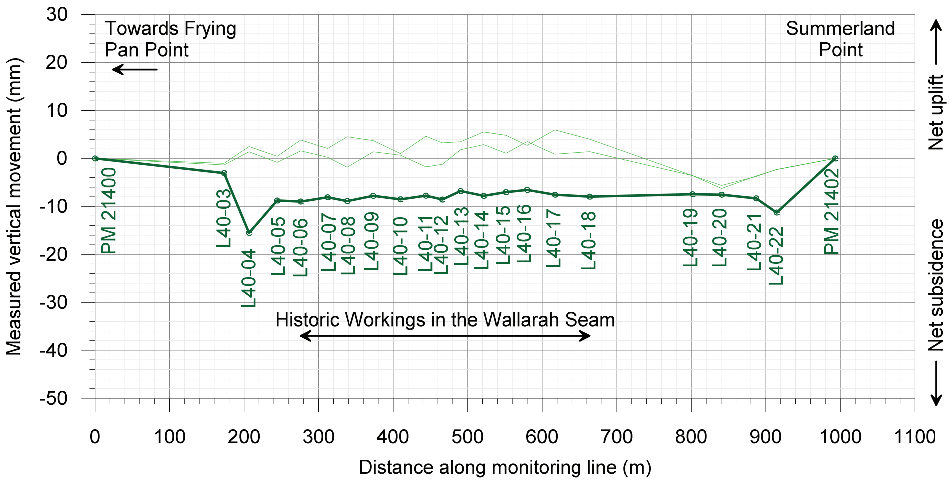


Fig. 3.7 Measured vertical subsidence along the foreshore of Frying Pan Bay

The vertical subsidence measured at the lake foreshore was typically less than 10 mm. Slightly higher values were measured at Marks L40-04 and L40-22; however, these marks could have been disturbed as they differ from the adjacent marks. The measurements were relatively uniform along the length of the monitoring line and, therefore, these could comprise a reasonable proportion of survey tolerance.

3.5. Subsidence model for MWS2 and MWS3

The void widths of MWS2 and MWS3 of 97 m are the same as the void widths for the existing MW3 to MW12, but are greater than the void widths of MW1 and MW2 of 72 m. The pillar width of 40 m is greater than the pillar widths for MW2, MW3, MW5A and MW6 to MW12 of 30 m to 33 m. The existing MW5 has a tailgate chain pillar width of 40 m and therefore it is the same width as the pillar between MWS2 and MWS3.

The overall mining void width for MWS2 and MWS3 of 234 m is less than the overall mining void widths of MW1 to MW3 plus MW6 to MW12 of 1215 m at their eastern ends and 750 m at their western ends. The overall mining void width of MWS2 and MWS3 is also less than that for the eastern ends of MW4 to MW5A of 360 m but it is similar to that for the western ends of MW5 and MW5A of 224 m.

The depth of the Fassifern Seam below rockhead for MWS2 and MWS3 varies between 142 m and 165 m. The depth of the seam below rockhead for the existing MW1 to MW12 varies between approximately 160 m and 190 m. The thickness of the Teralba Conglomerate above MWS2 and MWS3 of 26 m to 29 m is generally less than that above the existing miniwalls that varies between approximately 30 m to 40 m.

The vertical subsidence for MWS2 and MWS3 will therefore differ from that above the existing MW1 to MW12 due to the smaller overall mining void width, larger chain pillar width, shallower depth of cover and the thinner conglomerate units in the overburden.

The predictions for MWS2 and MWS3 have been obtained using the Incremental Profile Method (IPM). The method is an empirical model based on a large database of observed monitoring data from previous mining within the Southern, Newcastle, Hunter and Western Coalfields of New South Wales. The IPM has been calibrated using the locally available monitoring and geotechnical data at CVC and using other empirical and mechanistic methods.

The database consists of detailed subsidence monitoring data from collieries in NSW including: Angus Place, Appin, Baal Bone, Bellambi, Beltana, Blakefield South, Bulli, Chain Valley, Clarence, Coal Cliff, Cooranbong, Cordeaux, Corrimal, Cumnock, Dartbrook, Delta, Dendrobium, Eastern Main, Ellalong, Fernbrook, Glennies Creek, Gretley, Invincible, John Darling, Kemira, Lambton, Liddell, Mandalong, Metropolitan, Mt. Kembla, Munmorah, Nardell, Newpac, Newstan, Newvale, Newvale 2, South Bulga, South Bulli, Springvale, Stockton Borehole, Teralba, Tahmoor, Tower, Wambo, Wallarah, Western Main, Ulan, United, West Cliff, West Wallsend and Wyee.

The database consists of the observed incremental subsidence profiles, which are the additional subsidence profiles resulting from the extraction of each panel within a series of panels. It can be derived from the normalised incremental subsidence profiles within the database, that the observed shapes and magnitudes are reasonably consistent where the mining geometry and local geology are similar.

Subsidence predictions made using the IPM use the database of observed incremental subsidence profiles, the panel geometries, local surface and seam information and geology. The method tends to over-predict the conventional subsidence parameters (i.e. is slightly conservative) where the mining geometry and geology are within the range of the empirical database. The predictions can be further tailored to local conditions where observed monitoring data is available close to the mining area.

Further details on the IPM are provided in the background report entitled *General Discussion on Mine Subsidence Ground Movements* which can be obtained from *www.minesubsidence.com*. The calibration of the IPM for the local conditions at CVC is discussed in the following sections.

3.5.1. Conceptual subsidence model

The miniwalls at CVC are located within the Fassifern Seam. The caving zone extends between approximately 5 and 10 times the mining height above the top of the working section. The top of the caving zone, therefore, is between 18 m and 35 m above C Ply in the Fassifern Seam.

The base of the Karingal Conglomerate is located approximately 15 m to 20 m above the Fassifern Seam within the mining area. The base of the Teralba Conglomerate is located approximately 25 m to 40 m above the seam. The caving zone, therefore, extends between the Karingal and Teralba Conglomerate members, depending on their spanning capacities.

The Subsidence Reduction Potentials (SRP) of the Karingal, Teralba, Karignan and Munmorah Conglomerate members have been determined using the method outlined in Australian Coal Association Research Program (ACARP) Project No. C10023 (ACARP, 2003). A summary of the SRP for these members (based on Figure 6.8 of ACARP, 2003) is provided in Table 3.3. The height above the seam and thickness of the Teralba Conglomerate have been determined from the geological model. The heights and thicknesses of the other members have been interpreted from the drillhole logs.

Table 3.3 Subsidence Reduction Potential for the conglomerate members

Member	Panel spanning width (m)	Average depth of seam below rockhead (m)	Height above the seam (m)	Thickness (m)	Height above seam divided by the depth below rockhead (y/H)	SRP
Munmorah	97	150	≈ 120	≈ 20 to 25	≈ 0.80	High
Karignan	97	150	≈ 80	≈ 20 to 25	≈ 0.53	High
Teralba	97	150	25 to 40	26 to 29	0.17 ~ 0.27	High
Karingal	97	150	15 to 20	6 to 8	0.10 ~ 0.13	Low

The Teralba, Karignan and Munmorah Conglomerate members are considered to have High SRP based on the 2003 ACARP method. The Karingal Conglomerate is considered to have Low SRP due to its smaller interburden with the Fassifern Seam and smaller thickness (i.e. less than 10 m). It has been assumed, therefore, that the Karingal Conglomerate cannot span the voids of the miniwalls.

The overburden between rockhead and the base of the Teralba Conglomerate spans the caving zones that develop above each of the miniwalls. The overburden is supported by the chain pillars and the strata beneath the Teralba Conglomerate within the angle of break of the chain pillars. On the perimeter of the mining area, the overburden is supported by the abutments.

The vertical subsidence develops from the combination of the:

- pillar component comprising compression of the chain pillar and the immediate floor and roof;
- abutment component comprising compression of the abutment adjacent to the mining area including the compression of the immediate floor and roof; and
- sagging component due to vertical deformation (i.e. “bending”) of the overburden above the miniwall voids combined with horizontal shear through the overburden.

A cross-section showing the overburden above a generic series of miniwalls at CVC is illustrated in Fig. 3.8. The conceptual subsidence model comprising the pillar, abutment and sagging components of vertical subsidence is illustrated in Fig. 3.9.

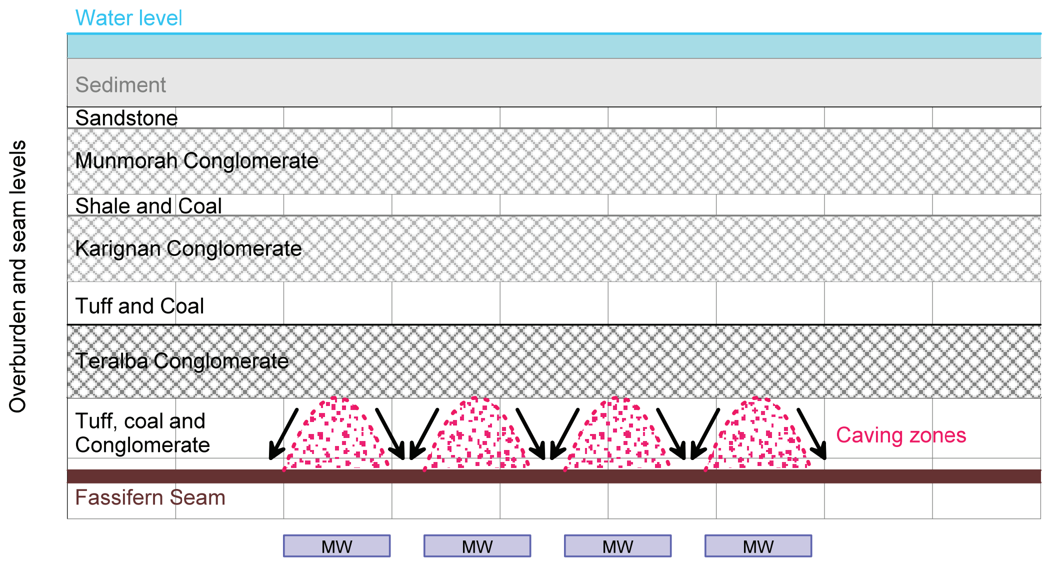


Fig. 3.8 Overburden above a generic series of miniwalls

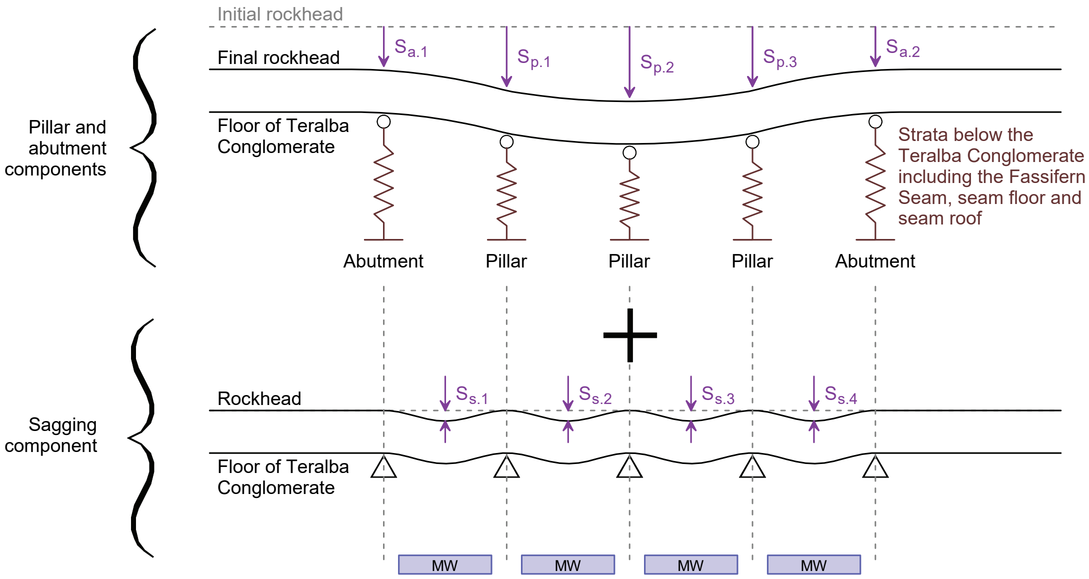


Fig. 3.9 Conceptual subsidence model

The total vertical subsidence for a series of miniwalls is equal to the combination of the pillar component (S_p), abutment component (S_a) and the sagging component (S_s). The ongoing extraction of miniwalls in the series increases the overall mining void. This reduces the spanning capacity of the overburden that in turn increases the load on the pillars which then may ultimately fail. The pillar component and sagging component of vertical subsidence increase, therefore, as additional miniwalls are mined within the series. This increased vertical subsidence was observed above the western ends of MW7 to MW12.

However, MWS2 and MWS3 have an overall mining void width of 234 m, which is less than the critical width that develops after the extraction of three or more miniwalls. The subsidence behaviour of MWS2 and MWS3 is expected to be similar to that for MW1 to MW6 and for the eastern ends of MW7 to MW12 where the pillars are believed to have remained intact.

There is a complex interaction between the pillar, abutment and sagging components of vertical subsidence. However, these components can be separated for MWS2 and MWS3 due to the: narrow miniwall void widths (i.e. subcritical width), the small overall mining void width (i.e. only two miniwalls in the series) and the wider pillar width (i.e. high stability index).

The overburden above MWS2 and MWS3 is supported by the chain pillar on one side and by an abutment on the other side. The total vertical subsidence (S_{max}), therefore, is the average of the pillar component (S_p) and the abutment component (S_a) plus the sagging component (S_s), as follows:

Equation 1 $S_{max} = (S_p + S_a)/2 + S_s$

The pillar, abutment and sagging components of vertical subsidence are described in the following sections.

3.5.2. Pillar component

There are various methods that can be used to predict the pillar component of vertical subsidence for subcritical panels. Four empirical methods have been used and these are described below.

Monitoring data for MW1 to MW12:

The predicted vertical subsidence due to MWS2 and MWS3 can be determined using the monitoring data from the existing miniwalls at CVC. The relationship between the maximum vertical subsidence divided by mining height versus the overall mining void width-to-depth ratio is illustrated in Fig. 3.6.

The pillar between MWS2 and MWS3 has a Stability Index greater than 2.7 (refer to the following section) and, therefore, it is expected to remain intact. The overall mining void width for MWS2 and MWS3 is 234 m (i.e. two times 97 m miniwalls plus 40 m pillar) which is less than the critical width that develops after the extraction of three or more miniwalls. It is expected, therefore, that the pillar will remain intact. The relationship between vertical subsidence and overall mining void width for MWS2 and MWS3 is expected to follow similar behaviours as for MW1 to MW6 and for the eastern ends of MW7 to MW12.

The panel width (97 m) and pillar width (40 m) and mining height (3.5 m) for MWS2 and MWS3 are similar to those for MW4 and MW5. The maximum measured vertical subsidence for these two existing miniwalls of 220 mm, therefore, provides a good indication of the subsidence for the proposed miniwalls.

The overall mining void width for MWS2 and MWS3 is 234 m (i.e. 97 m + 40 m + 97 m). The average depth of the Fassifern Seam below rockhead for these miniwalls is 150 m. The overall mining void width-to-depth ratio for MWS2 and MWS3 of 1.56 is similar to that for the existing MW1 to MW3 of 1.64 (i.e. 302 m overall mining void divided by 184 m rock cover). The measured vertical subsidence for MW1 to MW3 of 230 mm, therefore, also provides a good indication of the subsidence for the proposed miniwalls.

However, the overall depth of cover (including the lake bed sediment) of 170 m for MWS2 and MWS3 is less than that for MW4 and MW5 of 210 m and for MW1 to MW3 of 200 m. Also, the mining height for MWS2 and MWS3 of 3.5 m is slightly greater than that for MW1 to MW5A of 3.4 m.

The pillar load and, hence, the pillar component of vertical subsidence for MWS2 and MWS3 is reduced due to the shallower depth of cover but it is slightly increased due to the mining height. The maximum predicted vertical subsidence for MWS2 and MWS3 therefore is:

Equation 2 $S_p = 220\text{ mm} \times (170/210) \times (3.5/3.4) = 185\text{ mm}$ based on MW4 and MW5

Equation 3 $S_p = 230\text{ mm} \times (170/200) \times (3.5/3.4) = 200\text{ mm}$ based on MW1 to MW3

The maximum predicted value of 185 mm to 200 mm includes both the pillar component and the sagging component of vertical subsidence. The numerical analysis of the existing miniwalls (refer to Section 3.5.4) indicates that the sagging component for the existing miniwalls represents around 15 % of the overall vertical subsidence. It has been conservatively assumed, therefore, that the pillar component for MWS2 and MWS3 is 200 mm based on the monitoring data from the existing miniwalls.

Mills and Edwards (1997):

The pillar component of vertical subsidence is dependent on whether the chain pillars remain intact or fail. The pillar Stability Index (SI) is the ratio of the pillar stress to pillar strength. The pillar strength can be predicted using the formula provided by Mills and Edwards (1997):

Equation 4 $Q_p = 8(0.64 + 0.36\,w/h)$

where w = pillar width (m)
h = pillar height (m)

The relationship between surface subsidence and Stability Index is illustrated on the left side of Fig. 3.10 (Mills and Edwards, 1997). These data are based on mining in the Great Northern and Wallarah Seams in the Lake Macquarie area. Pillars with a Stability Index greater than approximately 2.7 can generally be considered to remain intact. Pillars with a Stability Index less than 2.0 have been typically observed to fail.

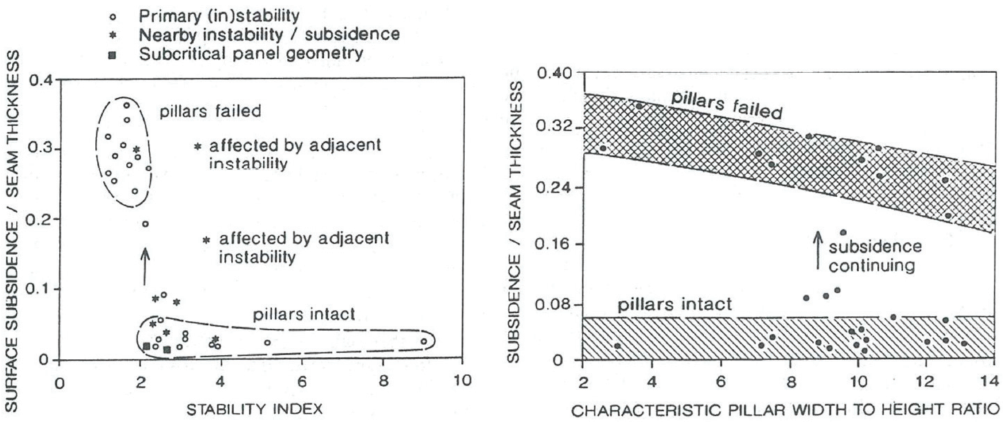


Fig. 3.10 Vertical subsidence versus Stability Index (left side) and versus pillar width-to-height ratio (right side) (Mills and Edwards, 1997)

The vertical subsidence versus the pillar width-to-height ratio is illustrated on the right side of Fig. 3.10 (Mills and Edwards, 1997). The vertical subsidence for intact pillars is less than 0.06 times the seam thickness (i.e. mining height). The vertical subsidence for failed pillars varies between 0.25 and 0.35 times the seam thickness (i.e. mining height), depending on the pillar width-to-height ratio.

The pillar between MWS2 and MWS3 has a width (w) of 40 m and a height (h) of 3.2 m. The pillar strength based on Mills and Edwards (1997) is as follows:

Equation 5 $Q_p = 8(0.64 + 0.36 \times 40/3.2) = 41$ MPa

The pillar stress is determined from the weight of the overburden within its tributary area divided by the pillar area. The weights of the water, sediment and rock on the chain pillar between MWS2 and MWS3 are summarised in Table 3.4. The tributary width is equal to the miniwall width (97 m) plus the pillar width (40 m) down to the base of the Teralba Conglomerate. The tributary width beneath the Teralba Conglomerate is based on an angle of break of 20° on either side of the pillar. The tributary length is equal to the average pillar length (95 m) plus the cut-through width (5 m).

Table 3.4 Weight of the overburden on the chain pillar between MWS2 and MWS3

Unit	Unit weight (kg/m^3)	Depth to base (m)	Thickness (m)	Tributary width (m)	Tributary length (m)	Weight (MN)
Water	1000	-7.4	7	137.0	100.0	1019
Sediment	1500	-17.4	10	137.0	100.0	2044
Rockhead to the base of the Teralba Conglomerate	2500	-150.4	133	137.0	100.0	45,544
Base of the Teralba Conglomerate to the roof of the Fassifern Seam	2500	-173.9	24	48.6	100.0	2863
					Total	**51,470**

The total stress in the pillar is equal to the weight on the pillar divided by its area:

Equation 6 $\sigma_p = 51{,}470$ MN / (95m x 40m) = 13.5 MPa

The pillar Stability Index (SI), therefore, is:

Equation 7 SI = 41 MPa / 13.5 MPa = 3.0

The SI is greater than 2.7 and, therefore, the pillar is considered to remain intact with minimal long-term creep. The vertical subsidence for an intact pillar (refer to the right side of Fig. 3.10) is 0.06h (i.e. 0.06 times the mining height of 3.5 m). The vertical subsidence based on Mills and Edwards (1997), therefore, is:

Equation 8 $S_p = 0.06 \times 3.5$ m = 0.21 mm (i.e. 210 mm)

It is noted that the predicted vertical subsidence of 210 mm includes both the pillar component and sagging component of vertical subsidence.

ACARP (2003):

The original predictions for MW1 to MW12 (DgS, 2013) were determined using the method outlined in ACARP Project No. C10023 (ACARP, 2003). The exceedance above MW7 to MW12 has been considered to be the result of the supercritical mining width reducing the spanning capacity of the overburden which then in turn overloaded the chain pillars. This behaviour occurred after the overall mining void width was greater than the critical width that develops after the extraction of three or more miniwalls.

The overall mining void width for MWS2 and MWS3 is 234 m (i.e. two times 97 m miniwalls plus 40 m pillar) and it is less than the critical width. It is considered, therefore, that the 2003 ACARP should provide a reasonable indication of the vertical subsidence for the first two miniwalls in the current series (i.e. MWS2 and MWS3).

The relationship between the pillar component of vertical subsidence divided by mining height (S_p/T) versus the pillar stress (σ_p) is illustrated in Fig. 3.11 (Source: DgS, 2013 after ACARP, 2003).

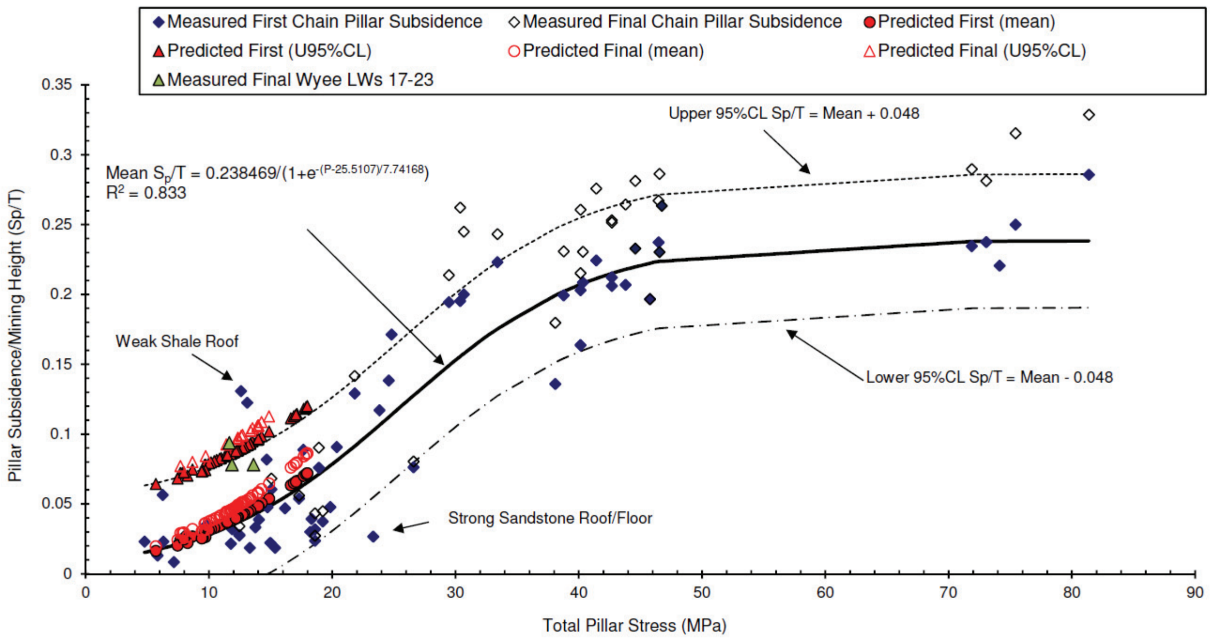


Fig. 3.11 Pillar component of vertical subsidence divided by mining height (S_p/T) versus total pillar stress (DgS, 2013 after ACARP, 2003)

The predicted mean pillar subsidence divided by mining height for a pillar stress is 13.5 MPa, therefore, is:

Equation 9 $S_p/T = 0.238469/(1+e^{\wedge}(-13.5-25.5107)/7.74168) = 0.042$

The predicted mean pillar subsidence based on a mining height of 3.5 m is:

Equation 10 $S_{p.mean} = 0.042 \times 3.5\ m = 0.150\ m$ (i.e. 150 mm)

The upper 95 % confidence level based on a mining height of 3.5 m is:

Equation 11 $S_{p.95\%} = (0.042 + 0.048) \times 3.5\ m = 0.315\ m$ (i.e. 315 mm)

The predicted pillar component of vertical subsidence obtained using the 2003 ACARP method therefore is 150 mm. The predicted upperbound vertical subsidence based on the 95 % confidence level is 315 mm.

Elastic model:

The chain pillar between MWS2 and MWS3 has an SI greater than 2.7 and a width-to-height (w/h) ratio greater than 5. It is expected that the pillar will remain intact with minimal long-term creep. The predicted pillar component of vertical subsidence therefore can be determined from the predicted elastic compression of the pillar, roof and floor. The methodology has been based on that outlined by Das (1986).

The pillar component of vertical subsidence is the sum of the compression of the pillar (P_p), the roof strata (P_r) and floor strata (P_f) as follows:

Equation 12 $S_p = P_p + P_r + P_f$

The compression of the pillar is provided by:

Equation 13 $P_p = \sigma_{net}\, h/E_c$

where σ_{net} = change in vertical stress (MPa)
h = height of the pillar (m)
E_c = elastic modulus of coal (MPa)

The compression of the roof and floor is provided by:

Equation 14 $P_{r/f} = \sigma_{net}\, w(1\text{-}v^2)/E_{r/f}$

where w = width of the pillar (m)
$E_{r/f}$ = elastic modulus of roof / floor strata (MPa)
v = Poisson's ratio

The roof and floor comprise interbedded strata of varying stiffnesses. The compression of multi-layered strata in the roof and floor is determined by summing the components from the strata within a distance of one pillar width (w) of the working section:

Equation 15 $P_{r/f} = \sigma_{net}\, \Sigma\, t_i(1\text{-}v_i^2)/E_i$

where t_i = thickness of the 'ith' unit (m) located within a distance of one pillar width (w) of the working section, i.e. $\Sigma\, t_i = w$
E_i = elastic modulus of the 'ith' unit (MPa)
v_i = Poisson's ratio of the 'ith' unit

The initial stress on the pillar (i.e. prior to secondary extraction) due to the weight of the water, sediment and rock in the overburden is 4.1 MPa. The final stress on the pillar (i.e. after secondary extraction) is 13.5 MPa, as shown in Equation 6. The change in stress (σ_{net}) due to secondary extraction, therefore, is 9.4 MPa.

A summary of the strata that are located within a distance of one pillar width (w, i.e. 40 m) of the working section and their thicknesses is provided in Table 3.5. The elastic modulus and Poisson's ratio for the coal seam, roof strata and floor strata (after DgS, 2013) are also provided in this table. These values represent the averages for each member and, therefore, are suitable for the elastic compression analysis.

Table 3.5 Properties of the roof, seam and floor (properties after DgS, 2013)

Location	Units	Thickness (m)	Elastic modulus (GPa)	Poisson's ratio
Roof	Teralba Conglomerate	> 10	5.0	0.25
	Sandstone	2	5.0	0.25
	Karingal Conglomerate	8	5.0	0.25
	Awaba tuff and shale	20	1.5	0.25
Fassifern Seam	Working section	3.5*	1.5	0.25
	Basal section	2	1.5	0.25
Floor	Claystone and shaley coal	2	1.5	0.35
	Conglomerate, sandstone and shale	> 36	5.0	0.25

Note: * denotes that the full working thickness of 3.5 m has been adopted rather than the pillar height of 3.2 m.

The predicted component of vertical subsidence due to the pillar component (comprising compression of the pillar, roof and floor strata) is provided by:

Equation 16 $S_p = 20 + 155 + 85 = 260$ mm

The predicted pillar component of vertical subsidence obtained using the elastic model therefore is 260 mm.

Summary:

A summary of the predictions for the pillar component of vertical subsidence is provided in Table 3.6.

Table 3.6 Predictions for the pillar component of vertical subsidence for MWS2 and MWS3

Method	Predicted vertical subsidence (mm)	Notes
Monitoring data for MW1 to MW12	200	Includes a component of sag subsidence
Mills and Edwards (1997)	210	
ACARP (2003)	150 mm (mean)	315 mm (upper 95 % confidence level)
Elastic model (Das, 1986)	260	Pillar, roof and floor compression

The predicted pillar component of vertical subsidence (S_p) has therefore been conservatively taken as 260 mm, being the maximum value derived from the four empirical methods.

3.5.3. Abutment component

The abutment on the tailgate side of MWS2 comprise 105 m by 32.6 m pillars separated by 5 m wide cut-throughs and the abutment on the maingate side of MWS3 comprise 105 m by 40 m pillars separated by 5 m wide cut-throughs. The minimum abutment pillar strength based on Mills and Edwards (1997) is as follows:

Equation 17 $Q_p = 8(0.64 + 0.36 \times 32.6/3.2) = 34$ MPa

The abutment pillars support the overburden on one side only (i.e. miniwall on one side and solid coal on the other side). It is predicted that the pillars support three-quarters of the abutment load and the adjacent solid coal supports the remaining one-quarter of the abutment load. The total stress in each of the abutment pillars is equal to the load on each pillar divided by its area:

Equation 18 $\sigma_p = 23{,}335$ MN / (105m x 32.6m) = 6.8 MPa

The pillar Stability Index (SI), therefore, is:

Equation 19 SI = 34 MPa / 6.8 MPa = 5.0

The Stability Index is greater than 2.7 and, therefore, the abutment pillars are considered to remain intact with minimal long-term creep. The predicted abutment component of vertical subsidence based on the elastic model (after Das, 1986) therefore is:

Equation 20 $S_a = 10 + 60 + 30 = 100$ mm

The predicted abutment component of vertical subsidence (S_a) is 100 mm.

3.5.4. Sagging component

The strata between the base of the Teralba Conglomerate and rockhead span across the miniwall voids. The spanning capacities of these units are dependent on the many factors including the: miniwall void width, the overall mining void width, depth of cover, thickness and strength of the units, and the surcharge.

The sagging component of vertical subsidence has been determined using a numerical model based on Universal Distinct Element Code (UDEC). This method is a two-dimensional Discrete Element Method (DEM) comprising deformable elements that interact via compliant contacts (Itasca, 2015).

The numerical model has not been designed to analyse the complex interaction between the chain pillar, claystone floor and the immediate roof. The model has been designed to assess the sagging of the strata from rockhead down to the base of the Teralba Conglomerate (i.e. above the caving zone) across the miniwall voids. Whilst the chain pillars, seam floor and seam roof have been modelled, the deformations have only been assessed above the base of the Teralba Conglomerate.

The UDEC model has been derived from the *base model* that was originally developed for the Southern Coalfield (Barbato, 2017). The numerical model has been updated for the local stratigraphy at CVC and for the geometry of the miniwalls.

The void widths of MWS2 and MWS3 are 97 m and the chain pillar width is 40 m. The average depth of the Fassifern seam below rockhead within the mining area is 150 m. The edges of the numerical model have been taken as four times the average depth of the seam (i.e. 600 m) from the outsides of the miniwall edges. The overall width of the model therefore is 1434 m.

A summary of the stratigraphy adopted in the UDEC model is provided in Table 3.7. The overall depth of the numerical model is 258 m. The depths of the modelled element (i.e. blocks) have been taken as 5 m for the conglomerate and sandstone units, 3 m to 4 m for the shale and tuff units and 1 m for the coal and claystone units. The aspect ratio for the elements has been taken as 1.5 wide to 1.0 high.

Table 3.7 Stratigraphy adopted in the UDEC model

Unit	Thickness (m)	Depth below rockhead to base of unit (m)	Element size (H x V, m x m)
Sandstone	10	10	7.5 x 5
Conglomerate	20	30	7.5 x 5
Shale	20	50	6 x 4
Conglomerate	20	70	7.5 x 5
Sandstone	20	90	7.5 x 5
Conglomerate	30	120	7.5 x 5
Tuff	30	150	4.5 x 3
Coal (working section)	3*	153	1.5 x 1
Coal (basal section)	3	156	1.5 x 1
Claystone	2	158	1.5 x 1
Sub-floor	100	258	15 x 10

Note: * denotes that the working section has been modelled as 3 m thick. The results have been scaled by a factor of 1.17 to provide an equivalent mining height of 3.5 m.

The material properties for the UDEC model have been based on those outlined in the reports by DgS (2013 and 2018b). A summary of the properties for the conglomerate, sandstone/siltstone, shale, tuff and coal units is provided in Table 3.8. These values represent the latest and specific properties for each unit.

Table 3.8 Material properties adopted in the UDEC model (based on DgS, 2013 and 2018b)

Unit	Unit weight (kg/m^3)	UCS (MPa)	Elastic modulus (GPa)	Poisson's ratio
Conglomerate	2500	40 to 60	5 to 15	0.25
Sandstone/Siltstone	2500	20 to 30	3 to 5	0.25
Shale	2500	12 to 15	1.5 to 2.25	0.25
Tuff	2500	1.65 to 2.15	1.5 to 3.0	0.25
Coal	1400	15 to 20	1.5 to 2.0	0.25

A parametric analysis has identified that the material strength properties (i.e. cohesion and friction angle) have little influence, if any, on the maximum modelled vertical subsidence (Barbato, 2017). The cohesion and friction angle for the block elements therefore have adopted the *base model* values. The parametric analysis also showed that the material stiffness properties (i.e. elastic modulus and Poisson's ratio) have a lesser influence on the sagging component of vertical subsidence when compared with that for the joint strength properties.

A Coulomb slip with residual strength model has been adopted for the horizontal and vertical discontinuities in the numerical model. The joint properties have been taken as the values calibrated in the *base model* for each of the member types. A parametric analysis identified that the joint stiffness properties (i.e. normal and shear) have little influence, if any, on the maximum modelled vertical subsidence (Barbato, 2017).

The numerical model was initially reviewed using the monitoring data for the existing MW1 to MW12. Four additional models were established comprising: five miniwalls with 97 m void widths and 33 m pillar widths; depths of the seam below rockhead ranging between 180 m and 200 m; and thicknesses of the Teralba Conglomerate ranging between 20 m and 40 m.

The modelled sagging component of vertical subsidence for these four numerical models ranged between 30 mm and 40 mm. It is not possible to compare these low-level movements with those measured above the existing MW1 to MW12 since they are less than the order of tolerance for the bathymetric surveys. The sagging component of vertical subsidence is not apparent in the monitoring data above MW1 to MW3 and MW6 and above the eastern ends of MW7 to MW12 (refer to Fig. 3.2) indicating that this component is considerably less than the pillar component.

The modelled profiles of incremental vertical subsidence obtained from the UDEC model for MWS2 and MWS3 are illustrated in Fig. 3.12. The incremental profiles represent the additional movements due to the extraction of each miniwall. The sagging component of vertical subsidence (S_s) is equal to the maximum modelled vertical subsidence minus the average vertical subsidence due to the pillar component (S_p) and abutment component (S_a).

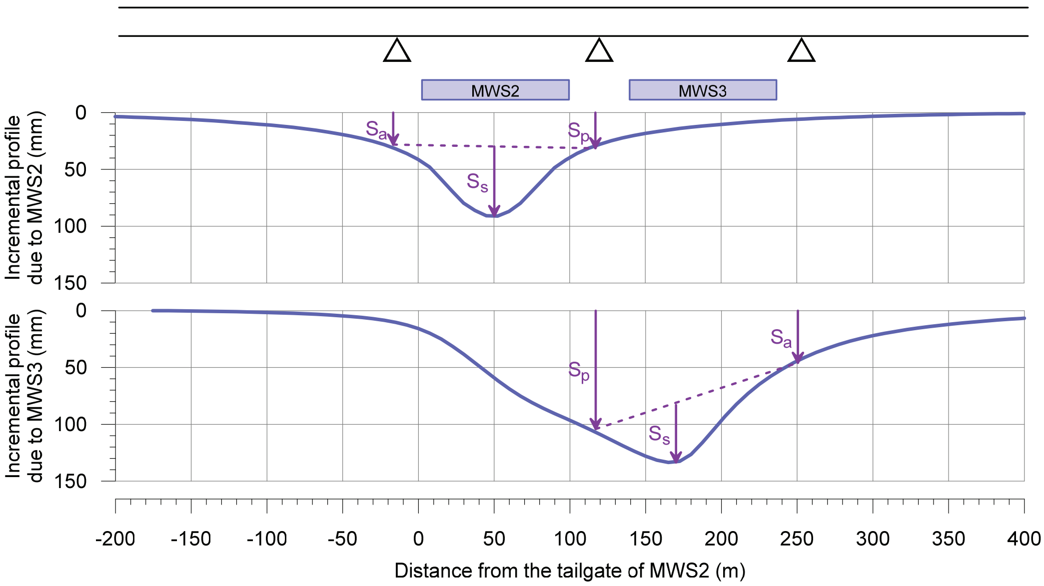


Fig. 3.12 Modelled profiles of vertical subsidence for MWS2 and MWS3

The predicted sagging component of vertical subsidence for MWS2 and MWS3 obtained from the numerical model is between 50 mm and 60 mm. This component is small when compared with the predicted pillar component of vertical subsidence of 260 mm. The lower-level sagging component of vertical subsidence indicates that the strata in the upper parts of the overburden arch over the extracted voids.

The sagging component of vertical subsidence for MWS2 and MWS3 has been taken as 60 mm.

3.5.5. Maximum predicted vertical subsidence

The IPM has been calibrated based on each of the predicted components of vertical subsidence. The model has adopted a pillar component of 260 mm, an abutment component of 100 mm and a sagging component of 60 mm. The IPM also includes an additional component due to long-term residual movements of approximately 10 % to 20 %.

The maximum predicted vertical subsidence due to the extraction of MWS2 and MWS3 obtained using the calibrated IPM therefore is 290 mm. The maximum predicted vertical subsidence, tilt, curvature and strain for the miniwalls are summarised in Chapter 4.

3.5.6. Effects of geological structures

An inferred normal fault is located on the north-eastern side of MWS3. The fault is adjacent to the maingate of MWS3 at its commencing end. The distance of the fault increases along the length of this miniwall. It is located approximately 220 m north-west of MWS3 at its finishing end. The throw of this fault is approximately 2 m and it dips towards the north-east at approximately 60° (Strata[2], 2019). It is also possible that other minor faults could be present within the mining area.

The effect of the inferred fault or other unidentified minor faults on the predicted subsidence for MWS2 and MWS3 was reviewed using the UDEC model. Several numerical models were analysed comprising a series of miniwalls with the depths of the seam below rockhead ranging between 150 m and 200 m and the thicknesses of the Teralba Conglomerate ranging between 20 m and 40 m. These ranges were selected to cover those for MWS2 and MWS3 as well as for the existing MW1 to MW12.

The modelled vertical subsidence for the base models were compared with those determined when normal faults (i.e. discontinuities) were introduced. These discontinuities were modelled with a 60° to 70° dip adjacent to the chain pillar midway through the series. The faults were modelled with dips towards and away from the direction of the mining sequence.

The numerical analyses found that there was slightly increased vertical subsidence of 10 mm to 20 mm due to the miniwall located immediately adjacent to the normal fault and within the hanging wall block (i.e. on the down-throw side). There was little to no increase in vertical subsidence for the miniwall located immediately adjacent to the normal fault and within the foot wall block (i.e. on the up-throw side). Similarly, there was no increase in vertical subsidence for the miniwalls located more than one panel width from the modelled faults.

It is not expected, therefore, that the inferred normal fault or other unidentified minor faults would result in a significant increase in the vertical subsidence due to the extraction of MWS2 and MWS3. This is supported by the fact that there was no obvious relationship between vertical subsidence and the presence or absence of major geological structures for the existing MW1 to MW12 (Strata[2], 2019).

The surface expression (i.e. at rockhead) of the inferred fault adjacent to the maingate of MWS3 could result in localised increased compressive strain. However, the numerical analyses did not show any significant change in the horizontal movements at rockhead. The lake bed sediment is more than 10 m thick at the commencing end of MWS3. It is unlikely, therefore, that there would be measurable strain at the lake bed due to the thickness of the sediment.

3.6. Historic workings in the Wallarah Seam

There are historic workings in the Wallarah Seam located to the south-west and to the south-east of MWS2 and MWS3. These historic workings are shown in Drawing No. MSEC979-01.

Historic partial extraction has been carried out in the panel located south-west of MWS2 and MWS3. The workings comprise 42 m wide goafs (i.e. extracted pillars) between 18 m by 18 m remnant pillars. These historic workings are located 300 m from MWS2 at their closest point, i.e. two times the depth of cover from the miniwalls. At this distance, it is very unlikely that the extraction of MWS2 and MWS3 would affect the load on or the stability of these historic workings.

Historic first workings only have been carried out to the south-east of MWS2 and MWS3 and beneath the foreshore. These historic workings are located outside the 26.5° and 35° angles of draw. It is unlikely that the extraction of MWS2 and MWS3 would affect the load on or the stability of these historic first workings.

4.1. Introduction

The following sections provide the maximum predicted conventional subsidence parameters resulting from the extraction of MWS2 and MWS3. The predicted subsidence parameters and the impact assessments for the natural and built features are provided in Chapter 5.

The predicted vertical subsidence, tilt, curvature and strain for MWS2 and MWS3 have been obtained using the IPM. The subsidence model has been calibrated using the locally available monitoring and geotechnical data at CVC and using other empirical and mechanistic methods, as described in Chapter 3.

4.2. Maximum predicted conventional vertical subsidence, tilt and curvature

A summary of the maximum predicted values of incremental conventional vertical subsidence, tilt and curvature due to the extraction of each of MWS2 and MWS3 is provided in Table 4.1. The incremental values are the additional movements due to each miniwall.

Table 4.1 Maximum predicted incremental conventional vertical subsidence, tilt and curvature due to the extraction of each of the miniwalls

Due to miniwall	Maximum predicted incremental vertical subsidence (mm)	Maximum predicted incremental tilt (mm/m)	Maximum predicted incremental hogging curvature (km^{-1})	Maximum predicted incremental sagging curvature (km^{-1})
MWS2	130	2	0.03	0.07
MWS3	260	5	0.14	0.30

The predicted total vertical subsidence contours after the extraction of MWS2 and MWS3 are shown in Drawings Nos. MSEC979-12 and MSEC979-13, respectively. The predicted limit of vertical subsidence (i.e. the 26.5° angle of draw line) for MWS1 is also shown in these drawings. The predicted limit of vertical subsidence for MWS1 is located outside the predicted 20 mm subsidence contour for MWS2 and MWS3. The additional vertical subsidence due to MWS1, within the predicted limit of vertical subsidence for MWS2 and MWS3, therefore, is considered to be negligible.

A summary of the maximum predicted values of total vertical subsidence, tilt and curvature after the extraction of MWS2 and MWS3 is provided in Table 4.2. The total parameters represent the accumulated movements within the 26.5° angle of draw for MWS2 and MWS3.

Table 4.2 Maximum predicted total conventional subsidence, tilt and curvature

Miniwalls	Maximum predicted total vertical subsidence (mm)	Maximum predicted total tilt (mm/m)	Maximum predicted total hogging curvature (km^{-1})	Maximum predicted total sagging curvature (km^{-1})
MWS2 and MWS3	290	6	0.10	0.30

The maximum predicted total vertical subsidence of 290 mm represents 8 % of the proposed extraction height of 3.5 m. The greatest vertical subsidence occurs directly above MWS3.

The maximum predicted total tilt is 6 mm/m (i.e. 0.6 %, or 1 in 167) and it occurs adjacent to the maingate of MWS3. The maximum predicted total conventional curvatures are 0.10 km^{-1} hogging and 0.30 km^{-1} sagging, which represent minimum radii of curvatures of 10 km and 3.3 km, respectively.

The predicted conventional subsidence parameters vary across the mining area. To illustrate this variation, the predicted profiles of vertical subsidence, tilt and curvature have been determined along two prediction lines. The predicted profiles of total vertical subsidence, tilt and curvature along Prediction Lines 1 and 2 are shown in Figs. C.01 and C.02, respectively, in Appendix C. The locations of these prediction lines are shown in Drawings Nos. MSEC979-12 and MSEC979-13.

4.3. Predicted strains

The prediction of strain is more difficult than the predictions of subsidence, tilt and curvature. The reason for this is that strain is affected by many factors, including curvature and horizontal movement, as well as local variations in the near surface geology, the locations of pre-existing natural joints at bedrock, and the depth of bedrock. Survey tolerance can also represent a substantial portion of the measured strain, in cases where the strains are of a low order of magnitude. The profiles of observed strain, therefore, can be irregular even when the profiles of observed subsidence, tilt and curvature are relatively smooth.

The conventional (i.e. classical or systematic) strains can be determined based on the average relationship between curvature and strain. Similar relationships have been proposed by various authors. Adopting a linear relationship between curvature and strain provides a reasonable prediction for the conventional tensile and compressive strains.

The locations that are predicted to experience hogging or convex curvature are expected to be net tensile strain zones and locations that are predicted to experience sagging or concave curvature are expected to be net compressive strain zones. In the Newcastle and Hunter Coalfields, it has been found that a factor of 10 provides a reasonable relationship between the predicted maximum curvatures and the predicted maximum conventional strains.

The maximum predicted conventional strains at rockhead due to MWS2 and MWS3, based on applying a factor of 10 to the maximum predicted curvatures, are 1 mm/m tensile and 3 mm/m compressive. These strains represent typical values when the ground subsides regularly with no localised, elevated or irregular strains. The maximum strains can be greater than these typical values, especially in the locations of near-surface geological structures.

At a point, however, there can be considerable variation from the linear relationship, resulting from non-conventional movements or from the normal scatters that are observed in strain profiles. When expressed as a percentage, observed strains can be many times greater than the predicted conventional strain for low magnitudes of curvature.

There is limited ground monitoring data available for panels with widths and depths of cover similar to those for MWS2 and MWS3. Newstan LW6 and LW7 had void widths of 100 m and were extracted from the West Borehole Seam at a depth of cover of 200 m. The strains measured along the LW5XL-Line were less than 0.5 mm/m. The experience at Newstan may indicate that the actual strains at rockhead for MWS2 and MWS3 could be less than those predicted using the linear relationship with curvature.

The bedrock is overlain by 9 m and 23 m of sediment directly above MWS2 and MWS3. The sediment will smooth out the localised strains at rockhead. It is expected that the strains at the top of the sediment (i.e. lake bed) will be less than 0.5 mm/m.

The extraction of MWS2 and MWS3 could result in fracturing at rockhead. Also, localised compressive strains could develop at the surface expression of the inferred fault adjacent to the maingate of MWS3. It is unlikely that surface deformations at rockhead would be visible in the lake bed due to the considerable depth of the overlying sediment.

The maximum predicted conventional tensile strain due to MWS2 and MWS3 is 1 mm/m. The estimated fracture width, based on a typical joint spacing of 10 m, is in the order of 10 mm. However, it is more likely that a number of smaller fractures (i.e. widths of less than 10 mm) would develop rather than a single larger fracture.

The fractures at rockhead extend between 1 m to 3 m into the bedrock. The larger fractures would be infilled with the sediment on the lake bed. Further discussions on discontinuous and continuous fracturing and changes in the overburden permeability are provided in the report by Strata[2] (2019).

4.4. Predicted horizontal movements

The predicted conventional horizontal movements over the miniwalls are calculated by applying a factor to the predicted conventional tilt values. In the Newcastle and Hunter Coalfields a factor of 10 is generally adopted, being the same factor as that used to determine the conventional strains from the conventional curvatures, and this has been found to give a reasonable correlation with measured data. This factor will vary and will be higher at low tilt values and lower at high tilt values. The application of this factor will therefore lead to over-prediction of horizontal movements where the tilts are high and under-prediction of the movements where the tilts are low.

The maximum predicted conventional tilt for MWS2 and MWS3 is 6 mm/m. The maximum predicted conventional horizontal movement, therefore, is approximately 60 mm, i.e. 6 mm/m multiplied by a factor of 10. The horizontal movements are oriented towards the middle of the mining area.

The maximum modelled horizontal movement obtained from the numerical model (refer to Section 3.5.4) is 40 mm. This is a similar order to that obtained from the empirical relationship considering that it does not include the horizontal movement due to the pillar and abutment components.

The mining-induced horizontal movements can extend outside the 26.5° angle of draw line. These low-level horizontal movements tend to be bodily movements, towards the mining area, that are accompanied by very low-levels of strain, generally less than survey tolerance.

It is very unlikely that natural and built features near MWS2 and MWS3 would experience adverse impacts due to the far-field horizontal movements. However, features that could be sensitive to these low-level movements need to be considered. The features near MWS2 and MWS3 that are sensitive to far-field horizontal movements are the survey control marks.

4.5. Predicted deformations through the overburden

The deformations through the overburden have been determined from the UDEC model. The modelled profiles of vertical subsidence and horizontal movement through the overburden strata are illustrated in Fig. 4.1. The profiles have been taken through the centreline of MWS3, midway between the centreline and tailgate (referred to as the quarter point) and at the tailgate of this miniwall. The modelled profiles through MWS2 are similar to those presented below but with smaller magnitudes.

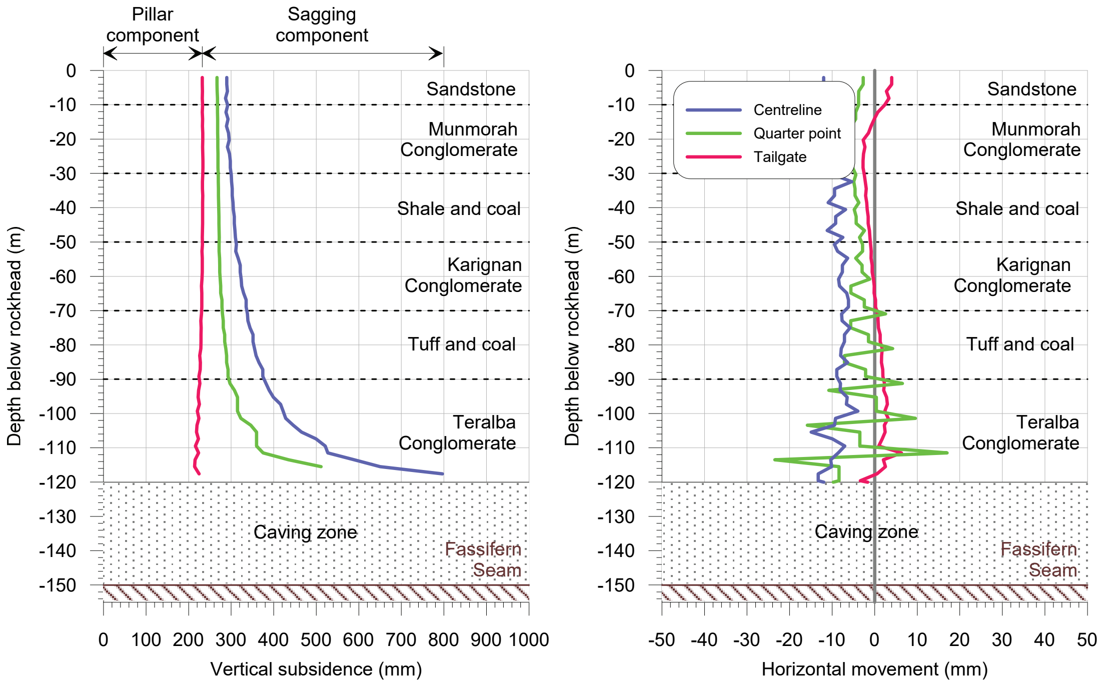


Fig. 4.1 Modelled profiles of vertical subsidence and horizontal movement through the overburden at the centreline, quarter point and tailgate of MWS3

The vertical subsidence at the miniwall centreline varies from 290 mm (i.e. 8 % of the mining height) at rockhead to approximately 380 mm (i.e. 11 % of the mining height) near the top of the Teralba Conglomerate. The vertical subsidence increases more rapidly within the Teralba Conglomerate, with values exceeding 500 mm within the basal section. The vertical subsidence adjacent to the tailgate is approximately 260 mm (7 % of the mining height) from rockhead to the base of the Teralba Conglomerate.

The vertical strain (over a 20 m height) varies from 0.5 mm/m at rockhead to 1.5 mm/m at the base of the Karignan Conglomerate. The vertical strain within the Teralba Conglomerate varies from approximately 3.5 mm/m at the top to approximately 10 mm/m at the base of the unit. The vertical strain is greatest near the centreline of the miniwall and reduces towards the maingate and tailgate.

The horizontal shear on the bedding plane partings is small (i.e. less than 10 mm) between rockhead and the top of the Teralba Conglomerate. The horizontal shear within the Teralba Conglomerate varies from approximately 10 mm at the top to approximately 25 mm at the base of this unit. It is noted that the magnitudes of the horizontal shears are dependent on their spacings. Hence, fewer but larger horizontal shears, or more but smaller horizontal shears, could develop compared with those predicted, depending on their actual spacing.

Further discussions on discontinuous and continuous fracturing and changes in the overburden permeability are provided in the report by Strata[2] (2019).

The following sections provide the descriptions, predictions and impact assessments for the natural and built features located within the Study Area. The features located outside the Study Area, that are predicted to experience far-field movements and could be sensitive to these movements, have been included in these assessments, i.e. the survey control marks.

5.1. Lake bed

The existing and the predicted post-mining lake bed level contours are illustrated in Fig. 5.1. The existing contours have been derived from the base bathymetric surveys carried out between 2012 and 2016. These surveys measure the depth of the lake bed and have an accuracy in the order ±100 mm.

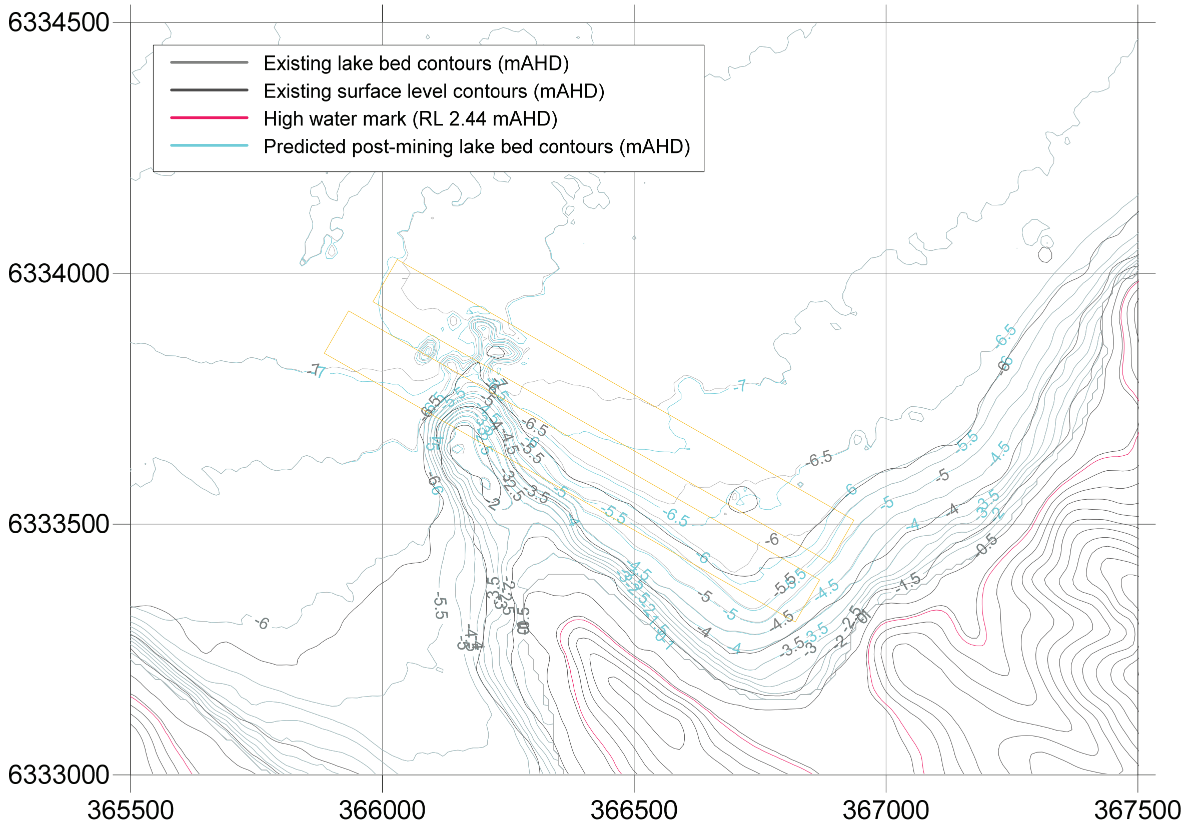


Fig. 5.1 Existing and predicted post-mining lake bed level contours

The predicted changes in the levels of the lake bed directly above the miniwalls are less than 0.3 m. These changes are small when compared with the overall depth of the lake which is typically greater than 5 m above the proposed mining area. It is considered unlikely, therefore, that there would be adverse impacts on the lake bed sediment due to these predicted low-level movements.

Further details on the benthic communities are provided in the Benthic Communities Management Plan which is included as part of the Extraction Plan.

5.2. Sea grass beds

The sea grass beds are located along the lake foreshore below the low-water mark. The mapped extents of the sea grass beds are shown in Drawing No. MSEC979-11. Photographs of these sea grass beds are also provided in Fig. 5.2.

Fig. 5.2 Sea grass beds along the lake foreshore

The Sea Grass Protection Barrier (SGPB) is defined by a 26.5° angle of draw from the mapped extents of the sea grass beds. It can be seen in Drawing No. MSEC979-02 and in Fig. 5.3 and Fig. 5.4 that MWS2 and MWS3 are located outside of the SGPB.

The predicted vertical subsidence at the mapped sea grass beds due to the proposed mining is less than 20 mm. Only low-level vertical subsidence is therefore expected at the sea grass beds due to the extraction of MWS2 and MWS3.

The monitoring and management strategies associated with the sea grass beds are undertaken in accordance with the Sea Grass Management Plan which is included as part of the Extraction Plan.

5.3. Lake foreshore

The lake foreshore is shown in Drawing No. MSEC979-11. The high-water mark, defined by the RL2.44 mAHD surface level contour, is also shown in that drawing.

The foreshore of Lake Macquarie at Summerland Point is located to the south and to the east of MWS2 and MWS3. Cross-section 1 and Long-section 1 have been taken near the commencing (i.e. south-eastern) ends of MWS2 and MWS3, where the miniwalls are closest to the lake foreshore. The locations of these sections are shown in Drawings Nos. MSEC979-03 to MSEC979-09. The natural surface, lake bed and seam level along Cross-section 1 and Long-section 1 near the commencing ends of the miniwalls are shown in Fig. 5.3 and Fig. 5.4, respectively.

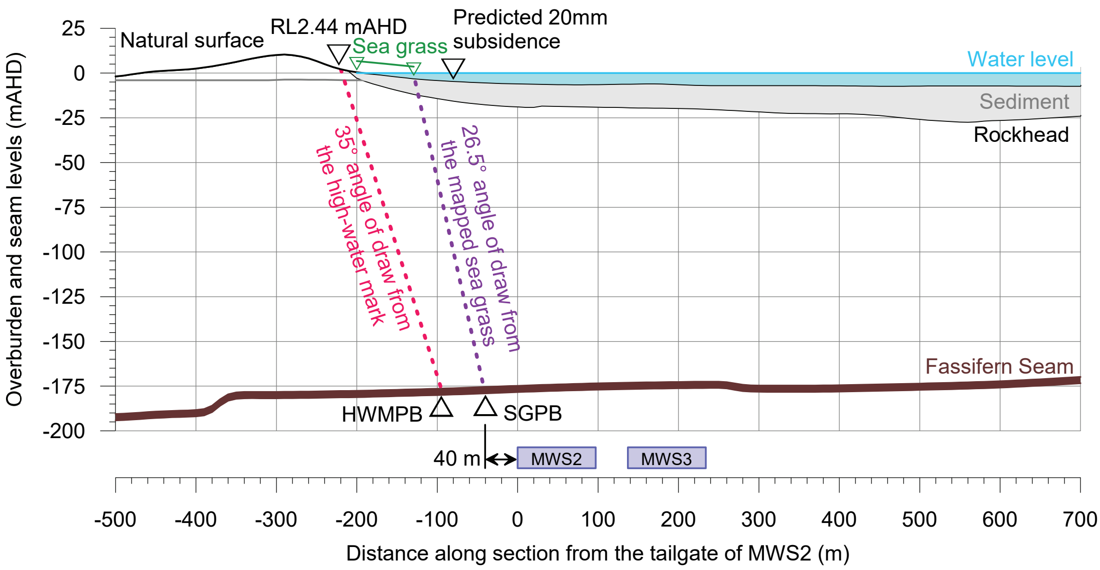


Fig. 5.3 Cross-section 1 near the commencing ends of MWS2 and MWS3

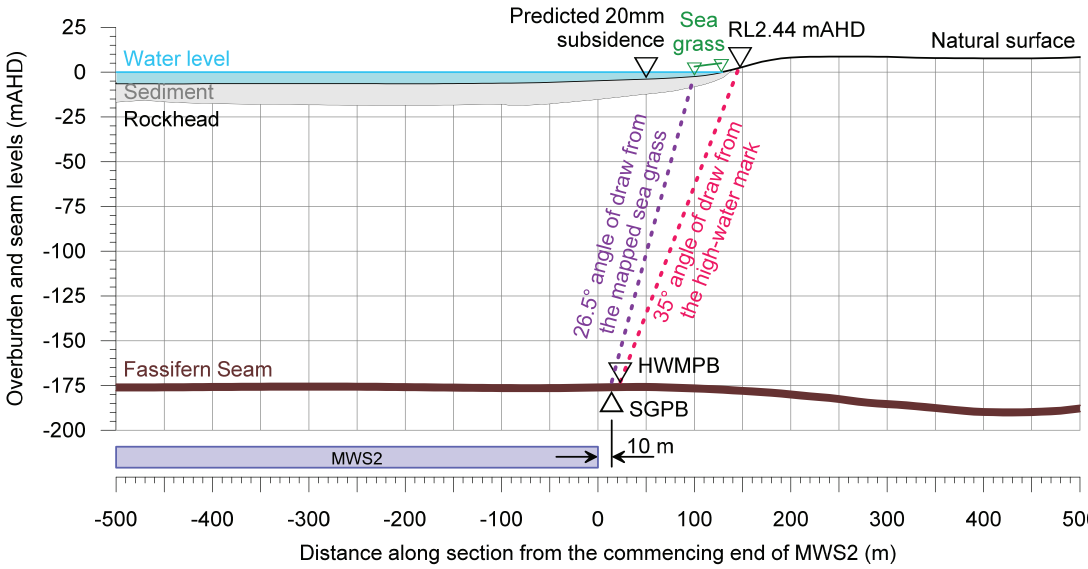


Fig. 5.4 Long-section 1 at the commencing end of MWS2

The High Water Mark Protection Barrier (HWMPB), defined by a 35° angle of draw from the high-water mark, is shown in Drawing No. MSEC979-02. It can be seen from that drawing and from Fig. 5.3 and Fig. 5.4 that MWS2 and MWS3 are located outside of the HWMPB. It can also be seen from the drawing and figures that MWS2 and MWS3 are also located outside the SGPB.

The predicted vertical subsidence at the high-water mark (i.e. RL2.44 mAHD) is less than 20 mm. It is unlikely, therefore, that there would be measurable changes in the high-water mark due to the extraction of MWS2 and MWS3.

5.4. Built features

The built features near MWS2 and MWS3 are shown in Drawing No. MSEC979-11.

The Pelican Rock Navigation Marker is located on the rock outcrop that extends into Lake Macquarie from Summerland Point. The marker is located outside but immediately adjacent to the tailgate of MWS2. A photograph of this navigation mark is provided in Fig. 5.5.

Fig. 5.5 Pelican Rock Navigation Marker

The predicted vertical subsidence for the navigation marker due to MWS2 and MWS3 is 90 mm. The predicted subsidence should be provided to Roads and Maritime Services (RMS) so that management strategies can be developed for the marker, if required.

Many of the built features located along the foreshore can be seen Fig. 5.6. These features include houses, other associated structures, jetties, moorings, roads and services.

Fig. 5.6 Built features along the foreshore at Summerland Point

The predicted vertical subsidence at the mapped sea grass beds and, hence, at the lake foreshore is less than 20 mm. It is unlikely, therefore, that there would be adverse impacts on the surface features located above the sea grass beds (i.e. jetties and moorings) or along the lake foreshore, including houses, other associated structures, roads and services.

The state survey control marks located near to MWS2 and MWS3 could experience low-level horizontal movements. NSW Spatial Services should be notified so that the affected state survey marks can be managed and re-established after active subsidence, as required.

APPENDIX A. GLOSSARY OF TERMS AND DEFINITIONS

Glossary of terms and definitions

Some of the more common mining terms used in the report are defined below:

Angle of draw	The angle of inclination from the vertical of the line connecting the goaf edge of the workings and the limit of subsidence (which is usually taken as 20 mm of subsidence).
Chain pillar	A block of coal left unmined between the extraction panels.
Cover depth (H)	The depth from the surface to the top of the seam. Cover depth is normally provided as an average over the area of the panel.
Closure	The reduction in the horizontal distance between the valley sides. The magnitude of closure, which is typically expressed in the units of *millimetres (mm)*, is the greatest reduction in distance between any two points on the opposing valley sides. It should be noted that the observed closure movement across a valley is the total movement resulting from various mechanisms, including conventional mining induced movements, valley closure movements, far-field effects, downhill movements and other possible strata mechanisms.
Critical area	The area of extraction at which the maximum possible subsidence of one point on the surface occurs.
Curvature	The change in tilt between two adjacent sections of the tilt profile divided by the average horizontal length of those sections, i.e. curvature is the second derivative of subsidence. Curvature is usually expressed as the inverse of the **Radius of Curvature** with the units of *1/kilometres (km-1)*, but the value of curvature can be inverted, if required, to obtain the radius of curvature, which is usually expressed in *kilometres (km)*. Curvature can be either **hogging** (i.e. convex) or **sagging** (i.e. concave).
Extracted seam	The thickness of coal that is extracted. The extracted seam thickness is thickness normally given as an average over the area of the panel.
Effective extracted seam thickness (T)	The extracted seam thickness modified to account for the percentage of coal left as pillars within the panel.
Face length	The width of the coalface measured across the panel.
Far-field movements	The measured horizontal movements at pegs that are located beyond the panel edges and over solid unmined coal areas. Far-field horizontal movements tend to be bodily movements towards the extracted goaf area and are accompanied by very low-levels of strain.
Goaf	The void created by the extraction of the coal into which the immediate roof layers collapse.
Goaf end factor	A factor applied to reduce the predicted incremental subsidence at points lying close to the commencing or finishing ribs of a panel.
Horizontal displacement	The horizontal movement of a point on the surface of the ground as it settles above an extracted panel.
Inflection point	The point on the subsidence profile where the profile changes from a convex curvature to a concave curvature. At this point the strain changes sign and subsidence is approximately one half of S max.
Incremental subsidence	The difference between the subsidence at a point before and after a panel is mined. It is therefore the additional subsidence at a point resulting from the excavation of a panel.
Panel	The plan area of coal extraction.
Panel length (L)	The longitudinal distance along a panel measured in the direction of (mining from the commencing rib to the finishing rib.
Panel width (Wv)	The transverse distance across a panel, usually equal to the face length plus the widths of the roadways on each side.
Panel centre line	An imaginary line drawn down the middle of the panel.
Pillar	A block of coal left unmined.
Pillar width (Wpi)	The shortest dimension of a pillar measured from the vertical edges of the coal pillar, i.e. from rib to rib.

Shear deformations	The horizontal displacements that are measured across monitoring lines and these can be described by various parameters including; horizontal tilt, horizontal curvature, mid-ordinate deviation, angular distortion and shear index.
Strain	The change in the horizontal distance between two points divided by the original horizontal distance between the points, i.e. strain is the relative differential displacement of the ground along or across a subsidence monitoring line. Strain is dimensionless and can be expressed as a decimal, a percentage or in parts per notation. **Tensile Strains** are measured where the distance between two points or survey pegs increases and **Compressive Strains** where the distance between two points decreases. Whilst mining induced **strains** are measured **along** monitoring lines, ground **shearing** can occur both vertically, and horizontally **across** the directions of the monitoring lines.
Sub-critical area	An area of panel smaller than the critical area.
Subsidence	The vertical movement of a point on the surface of the ground as it settles above an extracted panel, but, 'subsidence of the ground' in some references can include both a vertical and horizontal movement component. The vertical component of subsidence is measured by determining the change in surface level of a peg that is fixed in the ground before mining commenced and this vertical subsidence is usually expressed in units of *millimetres (mm)*. Sometimes the horizontal component of a peg's movement is not measured, but in these cases, the horizontal distances between a particular peg and the adjacent pegs are measured.
Super-critical area	An area of panel greater than the critical area.
Tilt	The change in the slope of the ground as a result of differential subsidence, and is calculated as the change in subsidence between two points divided by the horizontal distance between those points. Tilt is, therefore, the first derivative of the subsidence profile. Tilt is usually expressed in units of *millimetres per metre (mm/m)*. A tilt of 1 mm/m is equivalent to a change in grade of 0.1 %, or 1 in 1000.
Uplift	An increase in the level of a point relative to its original position.
Upsidence	Upsidence results from the dilation or buckling of near surface strata at or near the base of the valley. The magnitude of upsidence, which is typically expressed in the units of *millimetres (mm)*, is the difference between the observed subsidence profile within the valley and the conventional subsidence profile which would have otherwise been expected in flat terrain.

APPENDIX B. REFERENCES

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APPENDIX C. FIGURES

Predicted profiles of vertical subsidence, tilt and curvature along Prediction Line 1 due to the extraction of MWS2 and MWS3

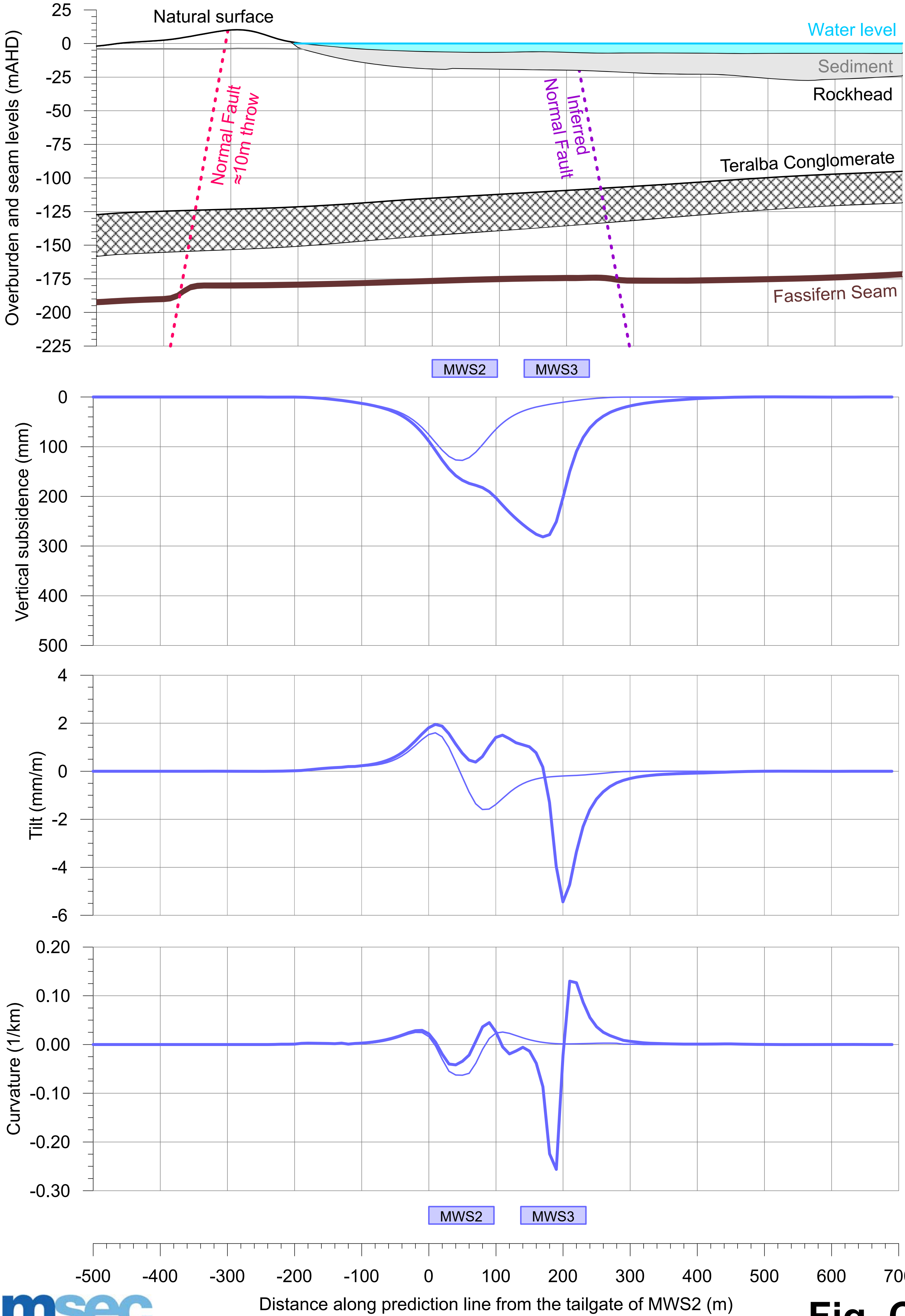

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Fig. C.01

Predicted profiles of vertical subsidence, tilt and curvature along Prediction Line 2 due to the extraction of MWS2 and MWS3

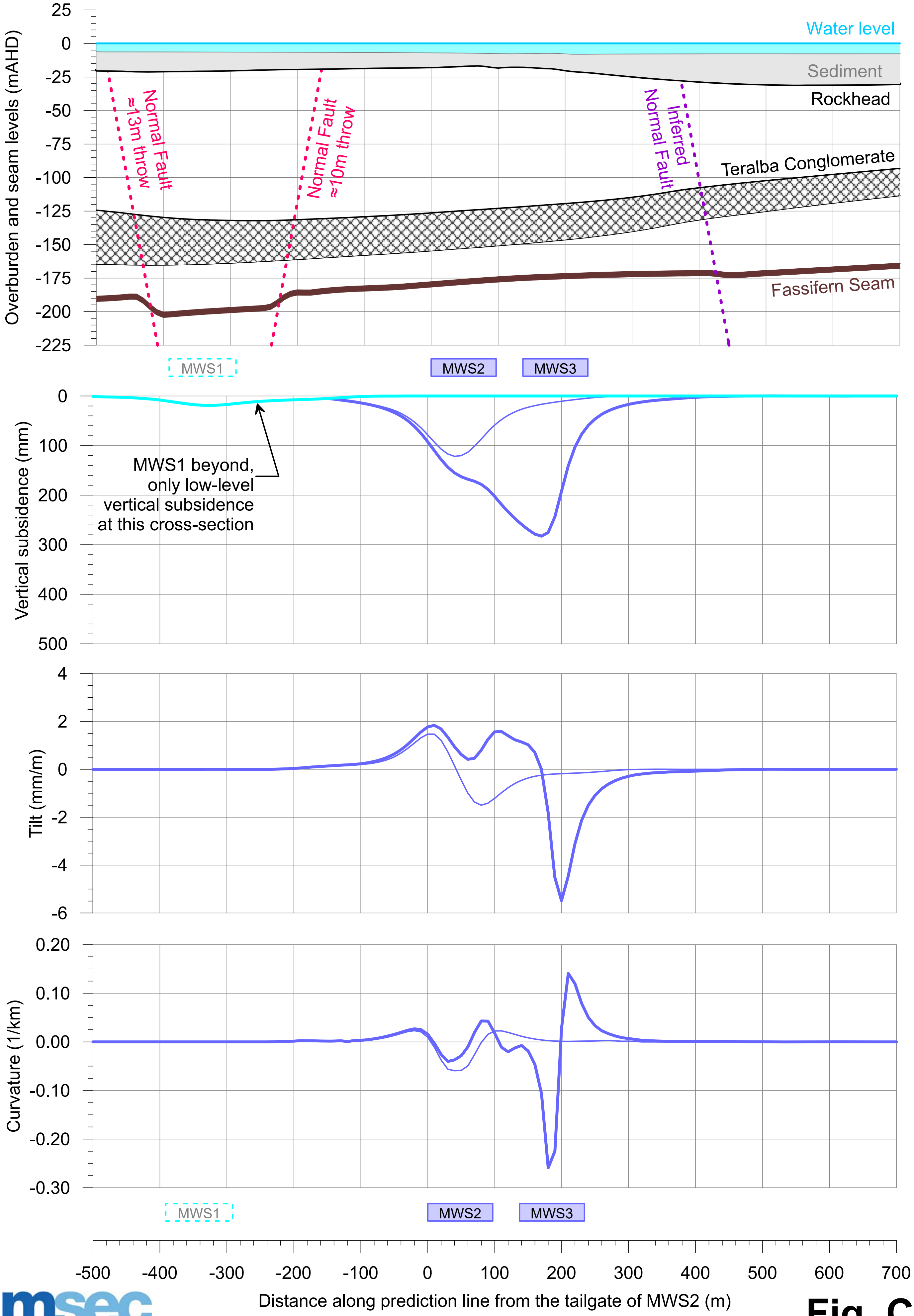

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Fig. C.02

APPENDIX D. DRAWINGS

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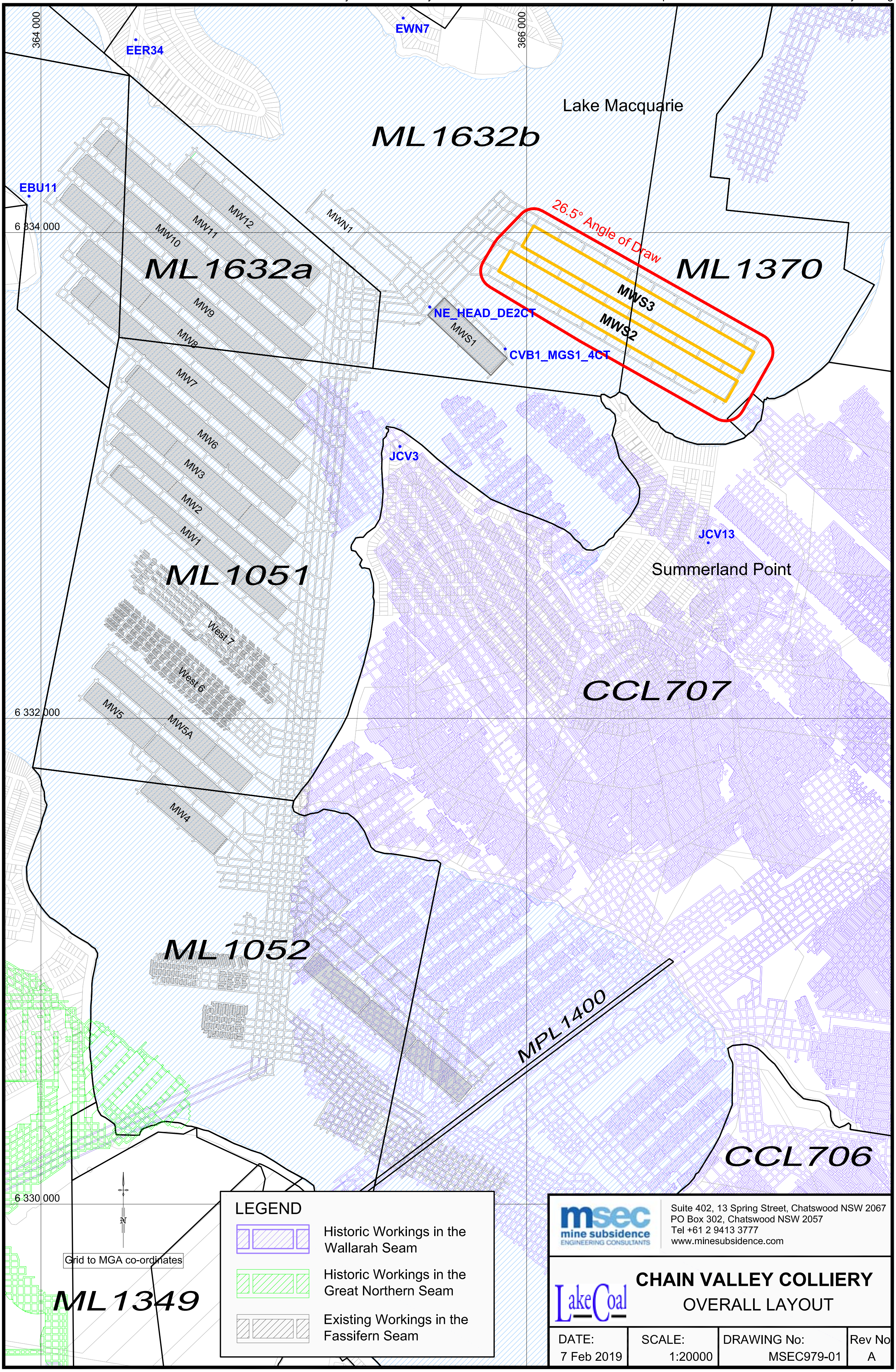

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OVERALL LAYOUT

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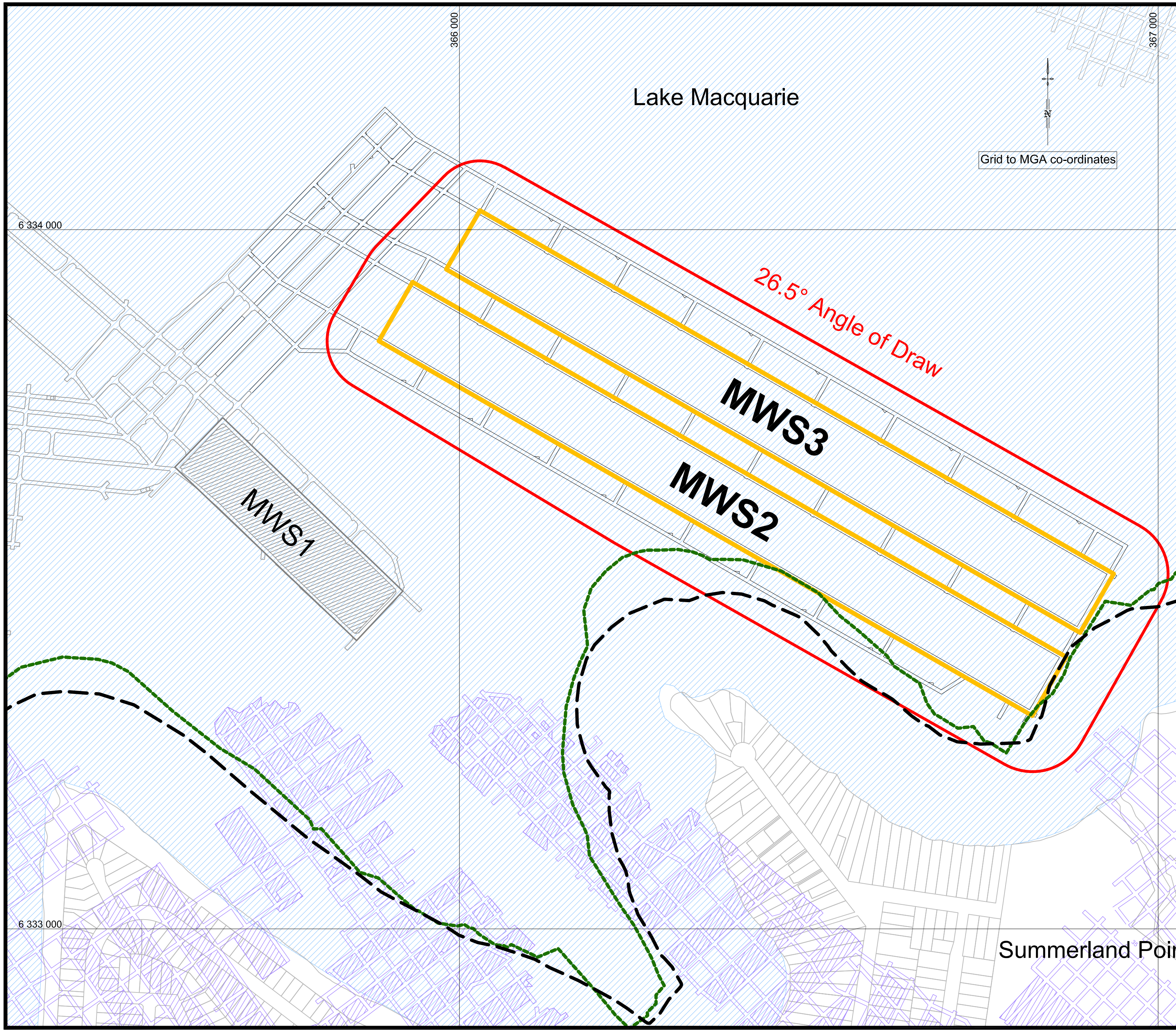

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LAYOUT OF
MWS2 AND MWS3

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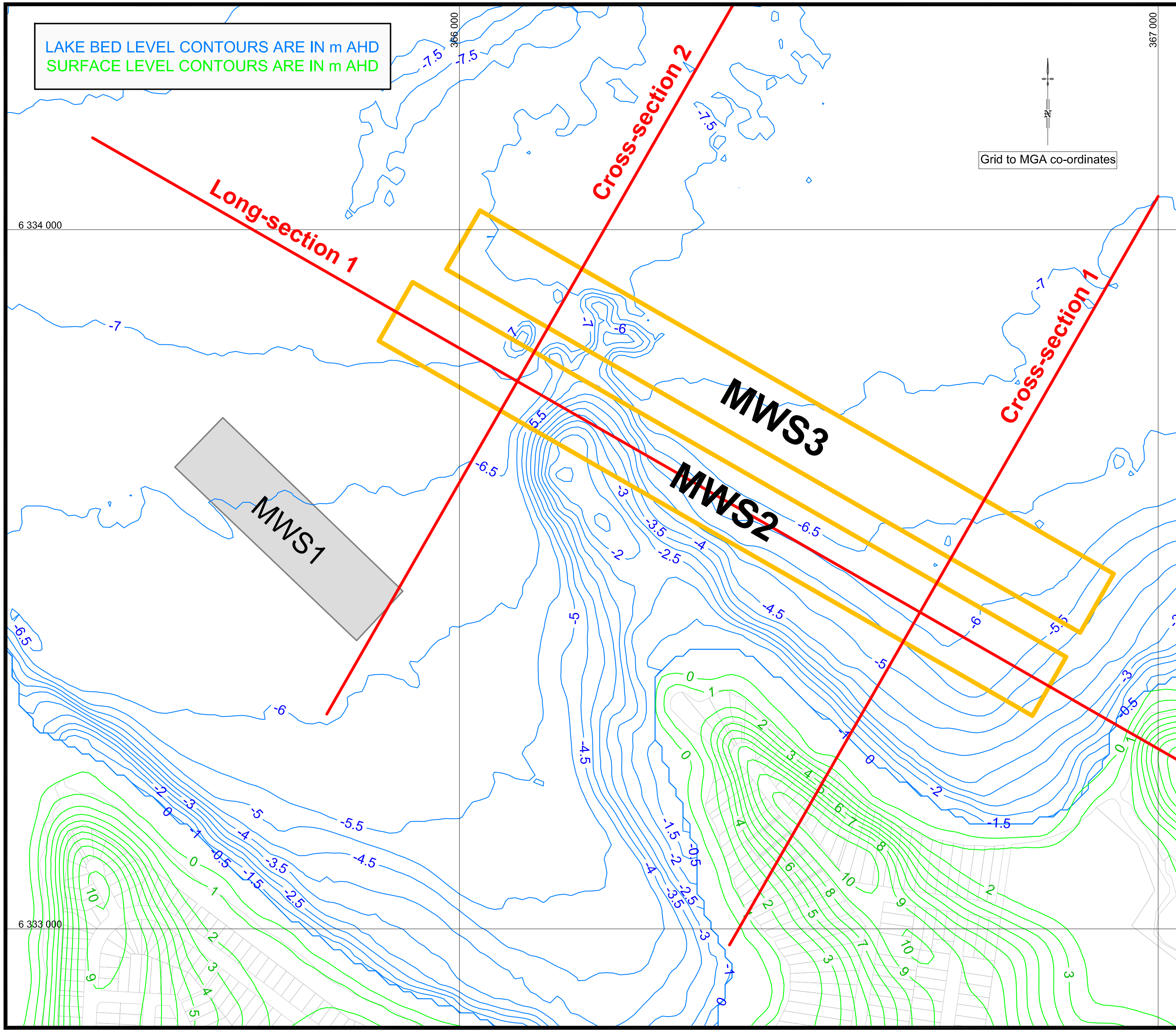

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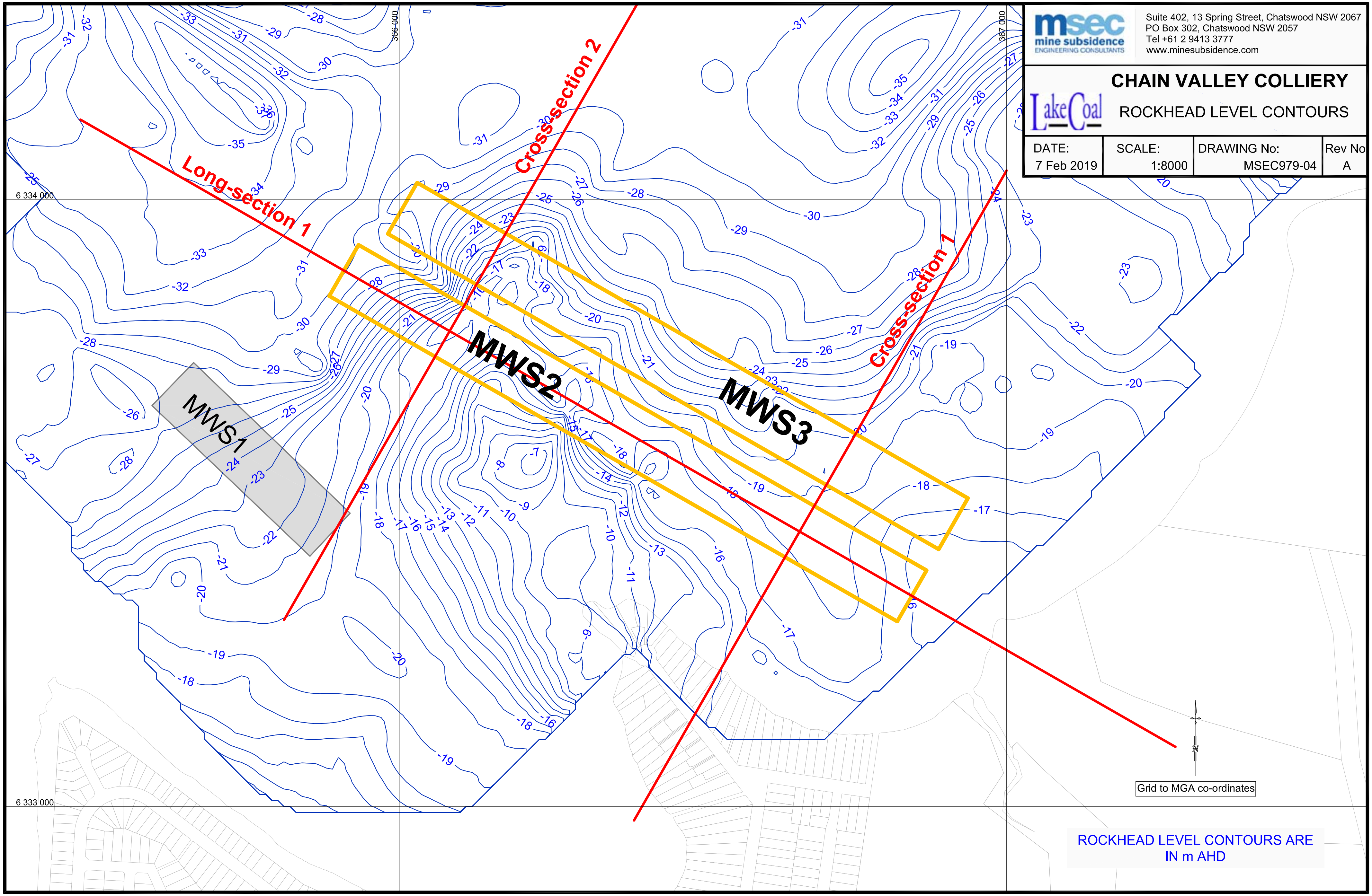

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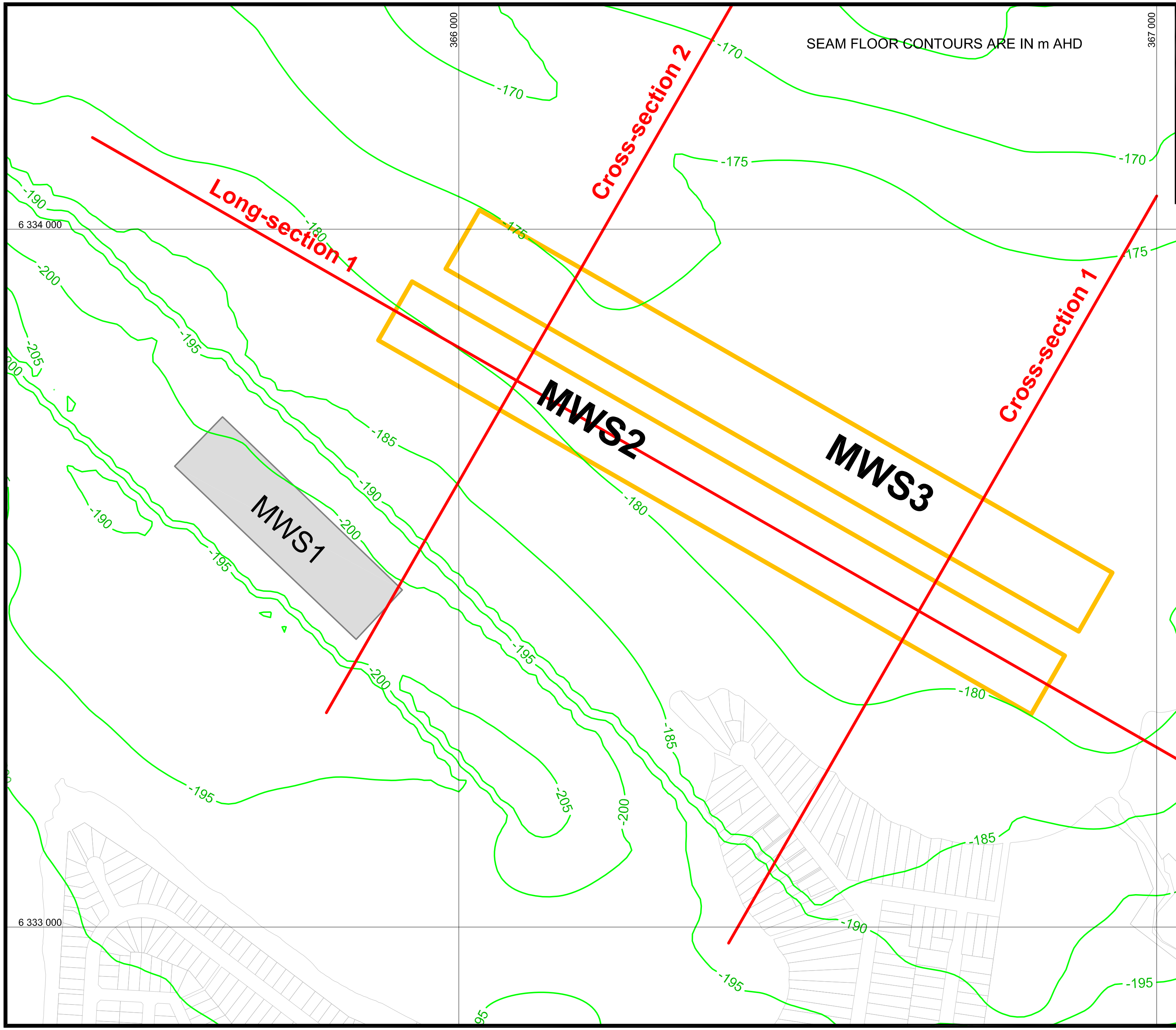

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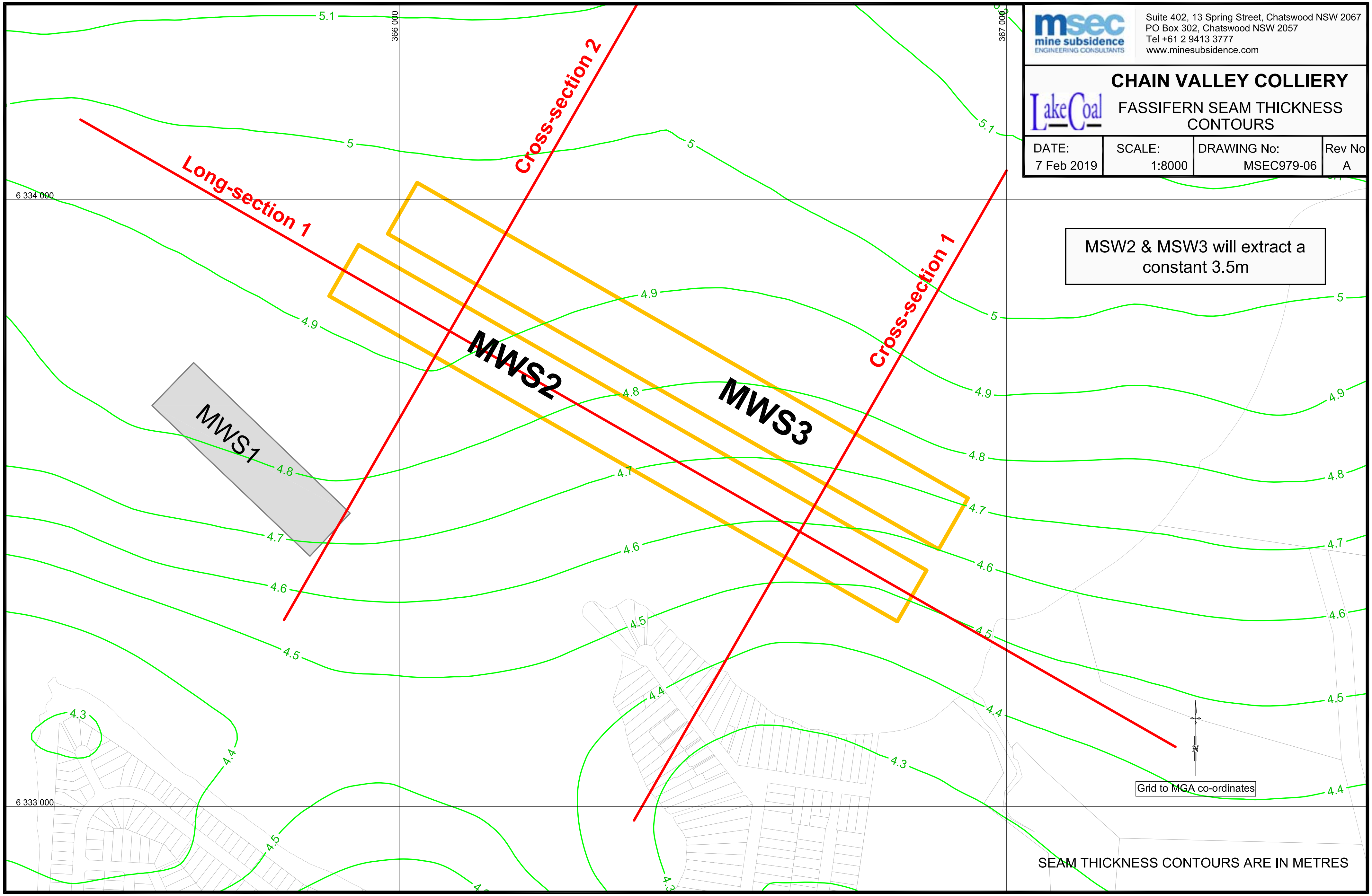

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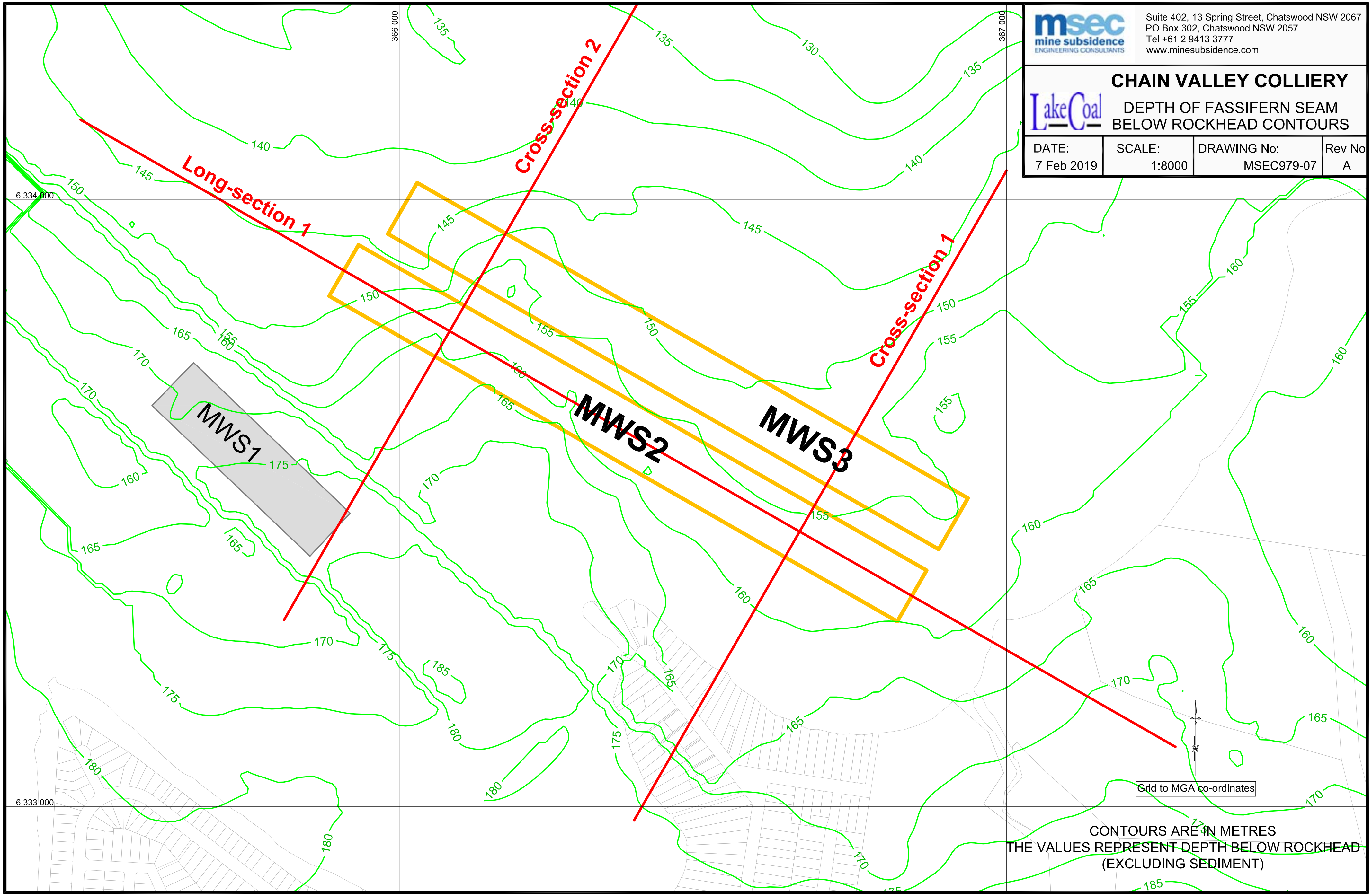

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DEPTH OF FASSIFERN SEAM BELOW ROCKHEAD CONTOURS

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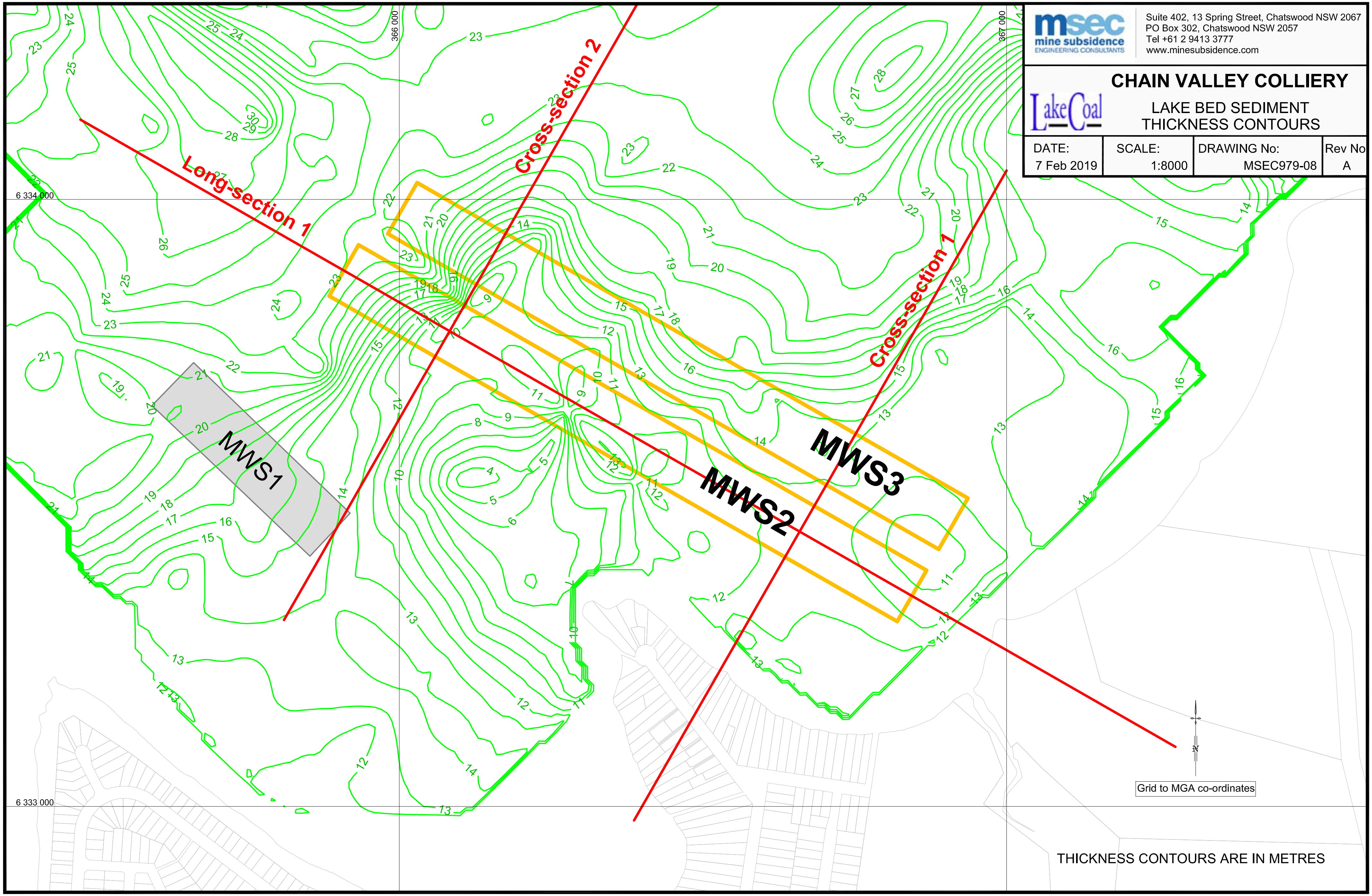

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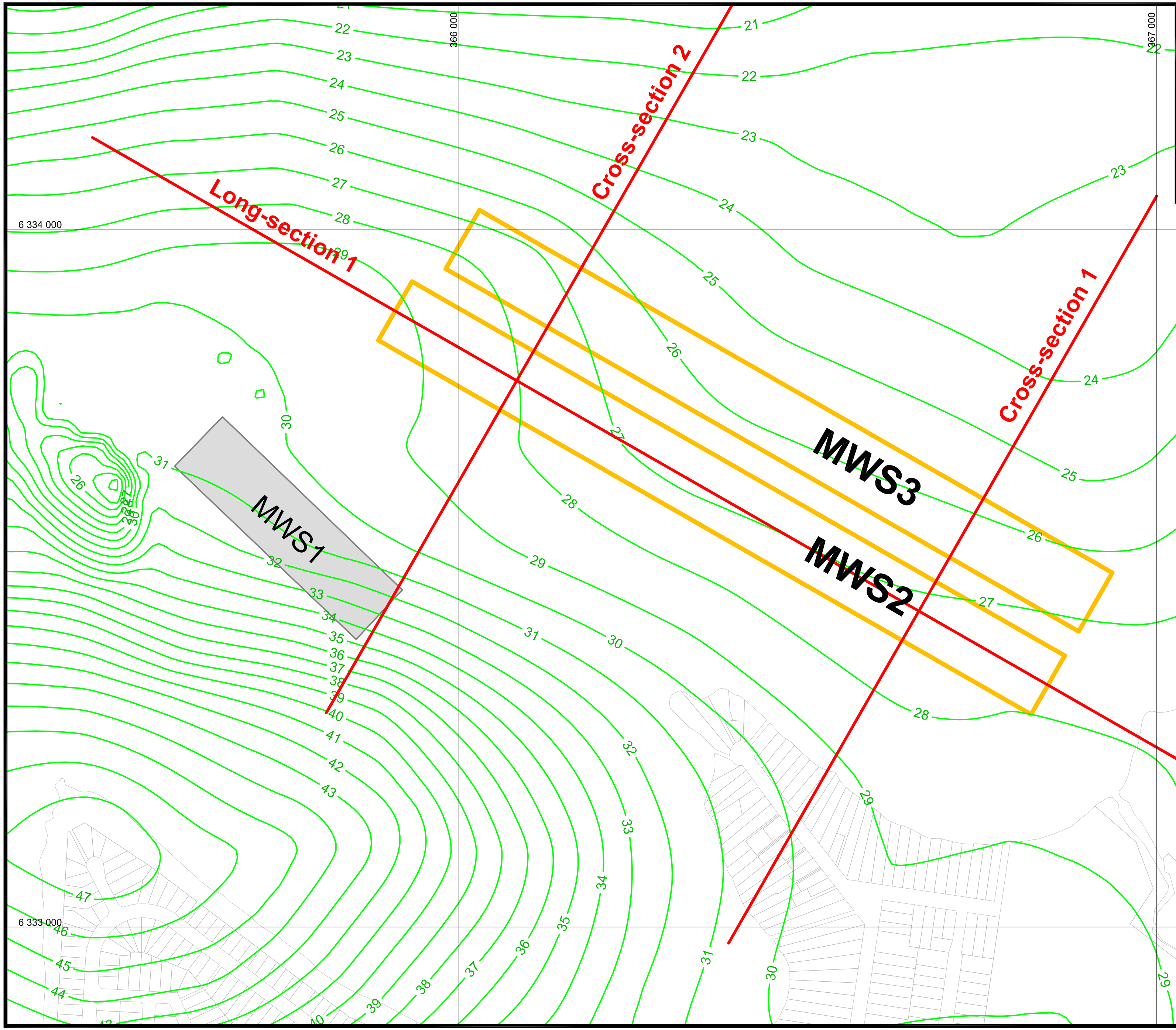

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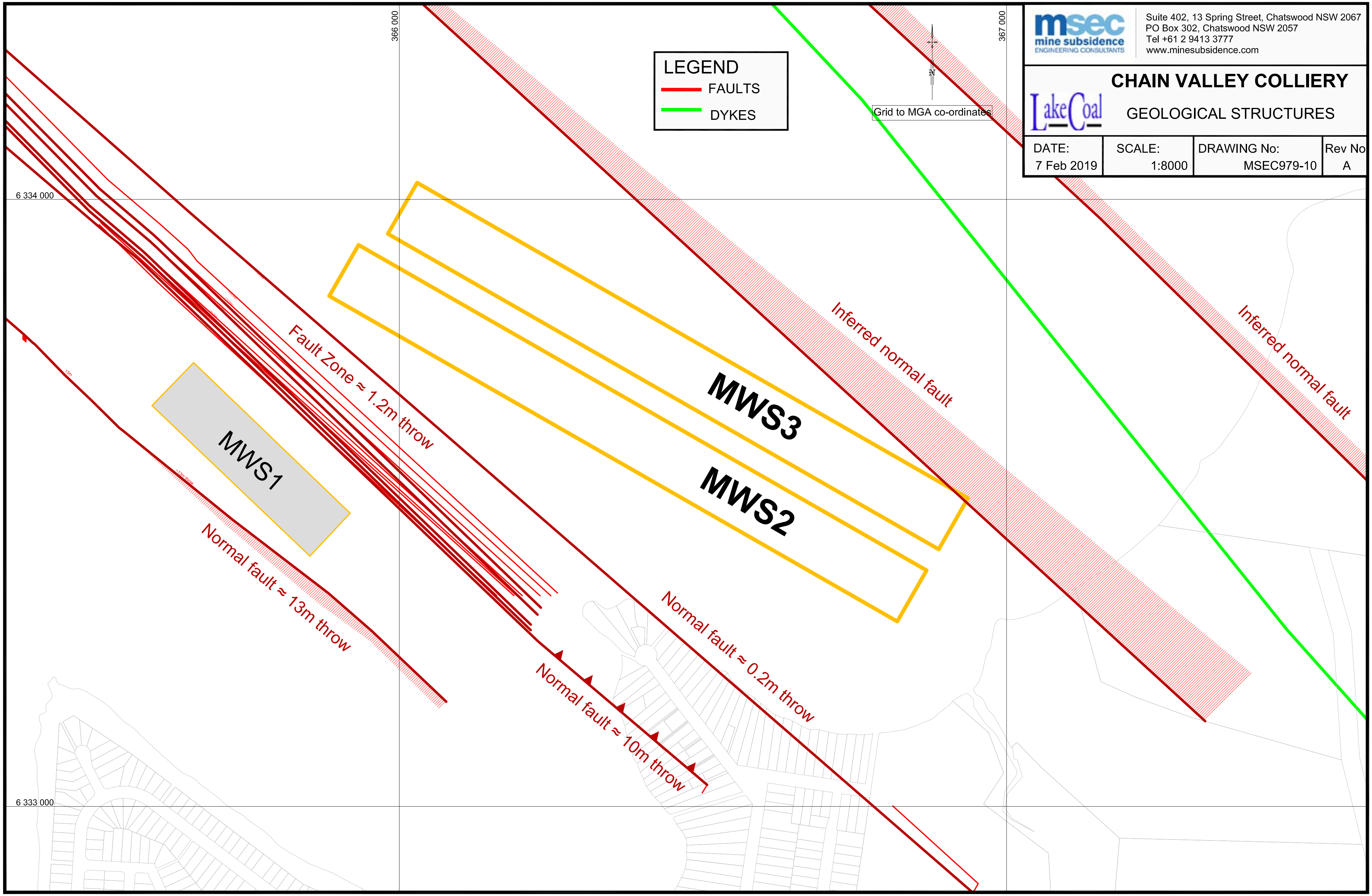

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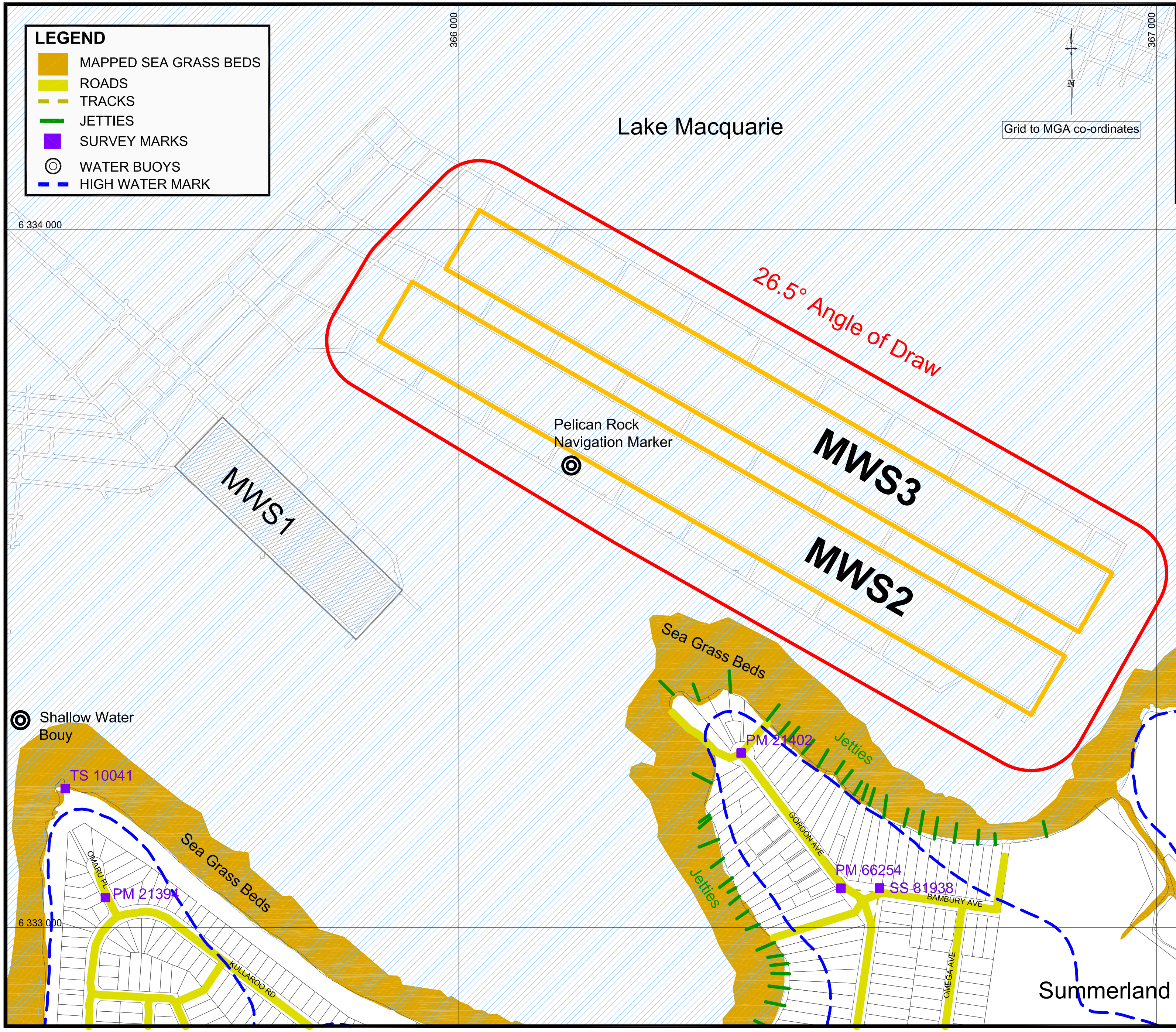

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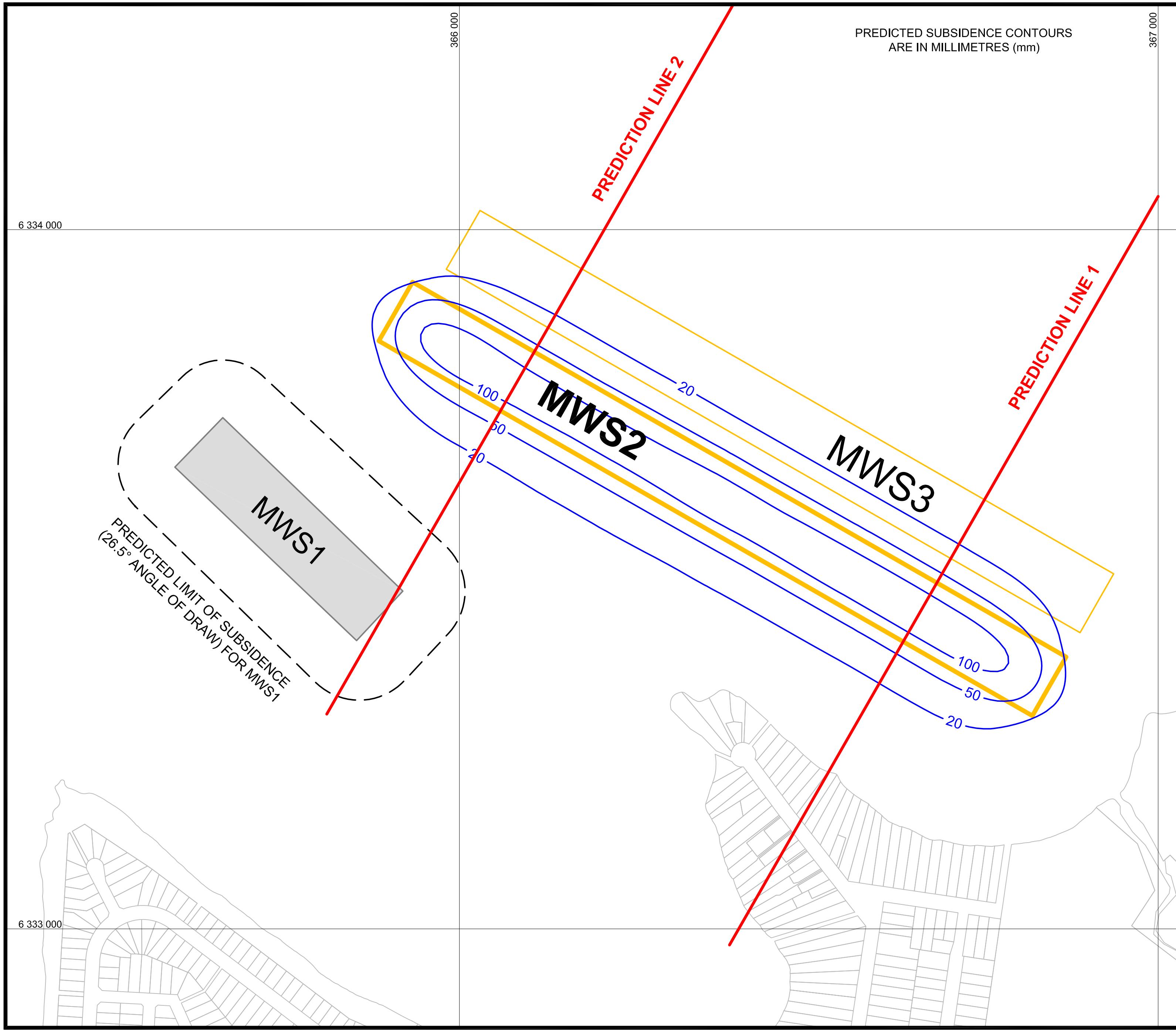

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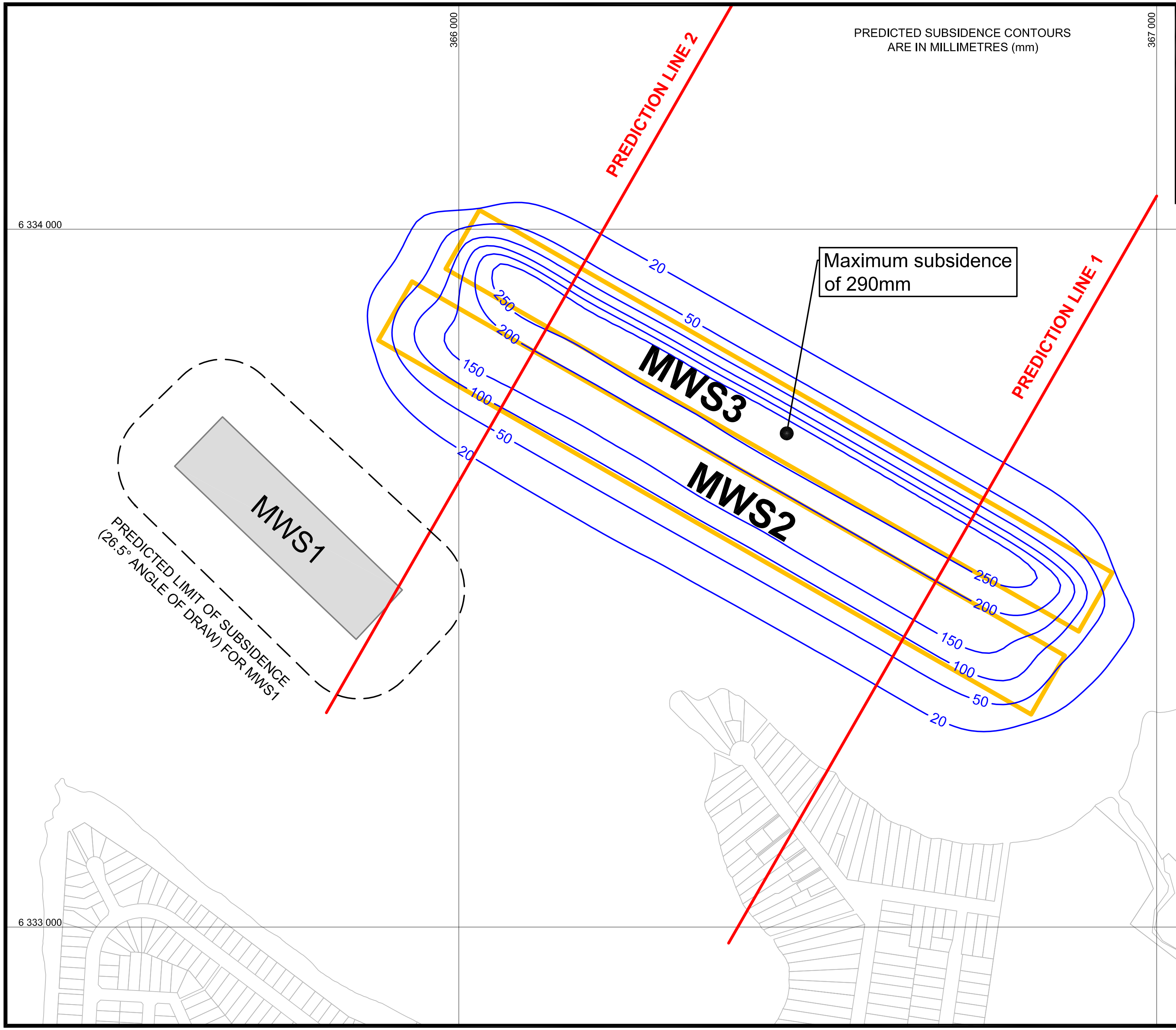

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