UG1 LONGWALLS 101 TO 103
WATER MANAGEMENT PLAN

<table>
<thead>
<tr>
<th>Version</th>
<th>Issue Date</th>
<th>Section Revised</th>
<th>Description</th>
<th>Review Team</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>September 2017</td>
<td>All</td>
<td>Approved</td>
<td>MCO</td>
</tr>
<tr>
<td>2</td>
<td>March 2019</td>
<td>Sections 1, 4, 13 and Figures</td>
<td>Amended 103 Layout</td>
<td>MCO</td>
</tr>
</tbody>
</table>

Approved: S.J. Archinal Date: 28/03/2014
# TABLE OF CONTENTS

1.0 **INTRODUCTION** .................................................................................1  
1.1 PURPOSE AND SCOPE .......................................................................1  
1.2 STRUCTURE OF THE LONGWALLS 101-103 WATER MANAGEMENT PLAN ...2  

2.0 **WATER MANAGEMENT PLAN REVIEW AND UPDATE** ......................8  
2.1 ACCESS TO INFORMATION ....................................................................8  

3.0 **STATUTORY REQUIREMENTS** ..........................................................9  
3.1 EP&A ACT APPROVAL .........................................................................9  
3.2 OTHER LEGISLATION ...........................................................................11  

4.0 **PREDICTED SUBSIDENCE IMPACTS AND ENVIRONMENTAL CONSEQUENCES** ........................................................................12  
4.1 LONGWALLS 101-103 EXTRACTION SCHEDULE ....................................12  
4.2 PREDICTED SUBSIDENCE IMPACTS AND ENVIRONMENTAL CONSEQUENCES ....13  
4.3 ENVIRONMENTAL RISK ASSESSMENT ..................................................14  
4.4 SURFACE WATER ..............................................................................14  
4.4.1 Baseline Data ..................................................................................14  
4.4.2 Summary of Subsidence Impacts to Drainage Lines ................................15  
4.5 GROUNDWATER ...............................................................................16  
4.5.1 Baseline Data ..................................................................................16  
4.5.2 Hydrogeological Regime ...................................................................17  
4.5.3 Alluvial Aquifers .............................................................................17  
4.5.4 Tertiary Palaeochannel Deposits .......................................................17  
4.5.5 Porous Rock Groundwater Systems ................................................18  
4.5.6 Groundwater Use ...........................................................................18  
4.5.7 Private Bores ..................................................................................18  
4.5.8 Predicted Impacts ...........................................................................19  

5.0 **PERFORMANCE MEASURES, PERFORMANCE INDICATORS AND INVESTIGATION TRIGGER LEVELS** ................................................21  
5.1 SUBSIDENCE IMPACT PERFORMANCE MEASURES ..............................21  
5.2 SURFACE WATER QUALITY TRIGGER INVESTIGATION LEVELS ............22  
5.3 GROUNDWATER TRIGGER INVESTIGATION LEVELS ............................23  

6.0 **MONITORING** ...............................................................................28  
6.1 POTENTIAL SUBSIDENCE IMPACTS ...................................................28  
6.2 SURFACE WATER FLOW AND QUALITY ............................................28  
6.3 GROUNDWATER ..............................................................................29  
6.4 SUBSIDENCE – ENVIRONMENTAL CONSEQUENCES .............................29  

7.0 **MANAGEMENT MEASURES** ...........................................................31  
7.1 SURFACE WATER .............................................................................31  
7.2 GROUNDWATER ..............................................................................32  

8.0 **CONTINGENCY PLAN** .......................................................................33  
8.1 TRIGGER ACTION RESPONSE PLAN ................................................34  

9.0 **REVIEW AND IMPROVEMENT OF ENVIRONMENTAL PERFORMANCE** ...35  
9.1 ANNUAL REVIEW ................................................................................35  

<table>
<thead>
<tr>
<th>Document</th>
<th>Version</th>
<th>Issue</th>
<th>Effective</th>
<th>Review</th>
<th>Author</th>
<th>Approved</th>
</tr>
</thead>
<tbody>
<tr>
<td>MCO_UG1_LW101-103_WMP</td>
<td>2</td>
<td>March 2019</td>
<td>March 2019</td>
<td>March 2020</td>
<td>MCO</td>
<td>S. Archinal</td>
</tr>
<tr>
<td>9.2 AUDITS</td>
<td>36</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9.3 FUTURE EXTRACTION PLANS</td>
<td>36</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**10.0 INCIDENTS** ............................................................................................................37

**11.0 COMPLAINTS** ................................................................................................................38

**12.0 NON COMPLIANCE WITH STATUTORY REQUIREMENTS** .............................................39

**13.0 REFERENCES** .............................................................................................................40

<table>
<thead>
<tr>
<th>Document</th>
<th>Version</th>
<th>Issue</th>
<th>Effective</th>
<th>Review</th>
<th>Author</th>
<th>Approved</th>
</tr>
</thead>
<tbody>
<tr>
<td>MCO_U1G1_LW101-103_WMP</td>
<td>2</td>
<td>March 2019</td>
<td>March 2019</td>
<td>March 2020</td>
<td>MCO</td>
<td>S. Archinal</td>
</tr>
</tbody>
</table>
LIST OF TABLES

Table 1  Water Management Plan Requirements
Table 2  Provisional Extraction Schedule
Table 3  Comparison of Maximum Predicted Conventional Subsidence Parameters for Drainage Line 7 based on the Approved Layout and the Extraction Plan Layout
Table 4  Maximum Predicted Total Conventional Subsidence, Tilt and Curvature for Drainage Line 7 Resulting from the Extraction of Longwalls 101, 102 and 103
Table 5  Water Subsidence Impact Performance Measure
Table 6  Surface Water Subsidence Management Objectives and Performance Indicators
Table 7  Surface Water Quality Trigger Investigation Levels
Table 8  Salinity and pH Trigger Levels
Table 9  Trigger Groundwater Levels – Alluvium Bores
Table 10 Water Monitoring Program Overview
Table 11 Groundwater Bores Relevant to Longwalls 101-103
Table 12 Potential Surface Water Management Measures

LIST OF FIGURES

Figure 1  Regional Location
Figure 2  Moolarben Coal Complex Layout
Figure 3  Underground Mine 1 Longwalls 101 to 103 Layout
Figure 4  Drainage Lines and Surface Water Quality Monitoring Locations Relevant to Longwalls 101 to 103
Figure 5  Relevant Mapped Groundwater Sources
Figure 6  Groundwater Monitoring and Investigation Locations Relevant to Longwalls 101 to 103

LIST OF ATTACHMENTS

Attachment 1  UG1 Longwalls 101 to 103 Water Management Plan Subsidence Impact Register
Attachment 2  UG1 Longwalls 101 to 103 Water Management Plan Trigger Action Response Plan
Attachment 3  Groundwater Technical Report
1.0 INTRODUCTION

The Moolarben Coal Complex is an open cut and underground coal mining operation located approximately 40 kilometres (km) north of Mudgee in the Western Coalfield of New South Wales (NSW) (Figure 1).

Moolarben Coal Operations Pty Ltd (MCO) is the operator of the Moolarben Coal Complex on behalf of the Moolarben Joint Venture (Moolarben Coal Mines Pty Ltd [MCM], Sojitz Moolarben Resources Pty Ltd and a consortium of Korean power companies). MCO and MCM are wholly owned subsidiaries of Yancoal Australia Limited.

Stage 1 at the Moolarben Coal Complex has been operating for several years and at full development will comprise three open cut mines (OC1, OC2 and OC3), a longwall underground mine (UG4), and mining related infrastructure (including coal processing and transport facilities) (Figure 2). Stage 2 at the Moolarben Coal Complex has commenced and at full development will comprise one open cut mine (OC4), two longwall underground mines (UG1 and UG2) and mining related infrastructure (Figure 2).

The UG1 Underground Mine is a component of the approved Moolarben Coal Complex (Figure 2). The UG1 Underground Mine commenced first workings in April 2016 and commenced secondary workings (longwall extraction) in October 2017 by longwall mining methods from the Ulan Seam within Mining Lease (ML) 1605, ML 1606, ML 1628, ML 1691 and ML 1715 (Figure 3).

Mining operations at the Moolarben Coal Complex are currently approved until 31 December 2038 and would continue to be carried out in accordance with Project Approval (05_0117) (Moolarben Coal Project Stage 1) as modified and Project Approval (08_0135) (Moolarben Coal Project Stage 2) as modified, granted under the NSW Environmental Planning and Assessment Act, 1979 (EP&A Act).

1.1 PURPOSE AND SCOPE

This UG1 Longwalls 101 to 103 Water Management Plan (LW101-103 WMP) has been prepared to satisfy the requirements of Schedule 4, Condition 5(h) of Project Approval (08_0135) for the management of potential impacts to watercourses and aquifers due to secondary extraction of Longwalls 101 to 103.

The approved complex-wide Water Management Plan (WMP) (dated 31 July 2015), developed in consultation with the Department of Primary Industries (DPI) Water, is implemented to manage surface water and groundwater related impacts across the Moolarben Coal Complex (including the Longwalls 101-103 Study Area). To avoid duplication of existing Environmental Management Plans, this LW101-103 WMP references components of the approved complex-wide WMP.
This LW101-103 WMP has been prepared by MCO with input from suitably qualified experts (WRM Water & Environment [WRM] [surface water], HydroSimulations [groundwater], Mine Advice Pty Ltd and Mine Subsidence Engineering Consultants [MSEC]). The appointment of the team of suitably qualified and experienced persons (which includes representatives of MCO, WRM, HydroSimulations and MSEC) was endorsed by the Secretary of the DP&E.

In summary:

**Purpose:** This LW101-103 WMP outlines the management of potential environmental consequences on watercourses and aquifers resulting from the extraction of Longwalls 101-103.

**Scope:** This LW101-103 WMP covers watercourses and aquifers within the Longwalls 101-103 Study Area (Figure 4).

Longwalls 101-103 are a subset of Longwalls 101-105, which together form the UG1 Underground Mine at the Moolarben Coal Complex. A separate Extraction Plan will be prepared for Longwalls 104 and 105 prior to secondary extraction of these longwalls commencing.

Since the Extraction Plan approval on the 21 September 2017, MCO has revised the mine plan to relocated Longwall 103 installation position to avoid an igneous intrusion and a mining First-Workings Plunge Panel where Longwall extraction is not viable. These changes are included in this Water Management Plan amendment. MSEC (2019) assessed the revised layout and concluded that “No revisions are recommended for the approved Extraction Plan or the approved Subsidence Monitoring Program.”

### 1.2 STRUCTURE OF THE LONGWALLS 101-103 WATER MANAGEMENT PLAN

The remainder of the LW101-103 WMP is structured as follows:

- **Section 2** Describes the review and update of the LW101-103 WMP.
- **Section 3** Outlines the statutory requirements applicable to the LW101-103 WMP.
- **Section 4** Summarises the predicted subsidence impacts and environmental consequences resulting from the secondary extraction of Longwalls 101-103.
- **Section 5** Details the performance measures and indicators that will be used to assess environmental performance in relation to watercourses and aquifers.

---

1. Longwalls 101-103 and the area of land within the furthest extent of the 26.5 degree (°) angle of draw and 20 millimetre (mm) predicted subsidence contour.
**Section 6**  Describes the monitoring program.

**Section 7**  Describes the potential management measures that could be implemented to remediate any identified impacts to watercourses and aquifers.

**Section 8**  Provides a Contingency Plan to manage any unpredicted impacts and their consequences and describes the Trigger Action Response Plan (TARP) management tool.

**Section 9**  Describes the Annual Review requirements, audits, improvement of environmental performance and preparation for future Extraction Plans.

**Section 10**  Outlines the management and reporting of incidents.

**Section 11**  Outlines the management and reporting of complaints.

**Section 12**  Outlines the management and reporting of any non-compliance with statutory requirements.

**Section 13**  Lists the documents referred to in Sections 1 to 12 of this LW101-103 WMP.
Figure 3

Legend:
- Exploration Licence Boundary
- Mining Lease Boundary
- Haul Road
- Existing/Approved Development
- Open Cut Mining Area
- Out-of-pit Emplacement
- Surface Infrastructure Area
- Underground Longwall Layout
- Longwalls 101 to 103 Study Area

Source: MCO (June 2019); NSW Dept of Industry (2019)
Drainage Lines and Surface Water Quality Monitoring Locations Relevant to Longwalls 101 to 103

Figure 4
2.0 WATER MANAGEMENT PLAN REVIEW AND UPDATE

In accordance with Condition 5, Schedule 6 of Project Approval (08_0135), this LW101-103 WMP will be reviewed within three months of the submission of:

- an Annual Review under Condition 4, Schedule 6;
- an incident report under Condition 7, Schedule 6; and
- an audit under Condition 9, Schedule 6;

if necessary, revised to the satisfaction of the Secretary of the DP&E to ensure the plan is updated on a regular basis and to incorporate any recommended measures to improve environmental performance. Where this review leads to revisions to the LW101-103 WMP, then within four weeks of the review, the revised LW101-103 WMP will be submitted to the Secretary of the DP&E for approval.

2.1 ACCESS TO INFORMATION

In accordance with Condition 11, Schedule 6 of Project Approval (08_0135), MCO will make the approved LW101-103 WMP publicly available on the MCO website.
3.0 STATUTORY REQUIREMENTS

MCO’s statutory obligations are contained in:

- the conditions of the NSW Project Approval (05_0117) (as modified) and NSW Project Approval (08_0135) (as modified);
- the conditions of Commonwealth Approvals (EPBC 2007/3297, EPBC 2013/6926 and EPBC 2008/4444);
- relevant licences and permits, including conditions attached to the Environment Protection Licence (EPL) No. 12932 and MLs (i.e. ML 1605, ML 1606, ML 1628, ML 1691 and ML 1715);
- water access licences (WALs) under the NSW Water Management Act, 2000 (WAL36340, WAL37582 and WAL37583);
- water licences under the NSW Water Act, 1912 (20BL172002, 20BL173923 and 20BL173935) which are in the process of being converted to WALs by DPI Water; and
- other relevant legislation.

Obligations relevant to this LW101-103 WMP are described below.

3.1 EP&A ACT APPROVAL

Condition 5(h), Schedule 4 of Project Approval (08_0135) requires the preparation of a Water Management Plan (i.e. this LW101-103 WMP) as a component of the Extraction Plan. In addition, Conditions 5(n), 5(p) and 6, Schedule 4 and Condition 3, Schedule 6 of Project Approval (08_0135) outline general management plan requirements that are applicable to the preparation of this LW101-103 WMP. Table 1 presents these requirements and indicates where they are addressed within this LW101-103 WMP.

Table 1: Water Management Plan Requirements

<table>
<thead>
<tr>
<th>Project Approval (08_0135) Condition</th>
<th>LW101-103 WMP Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>Condition 5, Schedule 4</td>
<td></td>
</tr>
<tr>
<td>5. The Proponent shall prepare and implement an Extraction Plan for all second workings on site to the satisfaction of the Secretary. Each extraction plan must:</td>
<td></td>
</tr>
<tr>
<td>...</td>
<td>This document</td>
</tr>
<tr>
<td>(h) include a Water Management Plan, which has been prepared in consultation with EPA and DPI Water, which provides for the management of the potential impacts and/or environmental consequences of the proposed second workings on watercourses and aquifers, including:</td>
<td></td>
</tr>
<tr>
<td>• surface and groundwater impact assessment criteria, including trigger levels for investigating any potentially adverse impacts on water resources or water quality;</td>
<td>Section 5</td>
</tr>
<tr>
<td>• a program to monitor and report stream flows, assess any changes resulting from subsidence impacts and remediate and improve stream stability;</td>
<td>Sections 6 and 9</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Document</th>
<th>Version</th>
<th>Issue</th>
<th>Effective</th>
<th>Review</th>
<th>Author</th>
<th>Approved</th>
</tr>
</thead>
<tbody>
<tr>
<td>MCO_UG1_LW101-103_WMP</td>
<td>2</td>
<td>March 2019</td>
<td>March 2019</td>
<td>March 2020</td>
<td>MCO</td>
<td>S. Archinal</td>
</tr>
<tr>
<td>Project Approval (08_0135) Condition</td>
<td>LW101-103 WMP Section</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>--------------------------------------</td>
<td>-----------------------</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• a program to monitor and report groundwater inflows to underground workings;</td>
<td>Sections 6 and 9</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• a program to predict, manage and monitor impacts on groundwater bores on privately-owned land;</td>
<td>Sections 6 and 9</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• a program to:</td>
<td>Attachment 3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>− confirm the location and saturated extent of the palaeochannel adjacent to the extents of underground 1 second workings, including drilling of additional investigation bores;</td>
<td>Sections 4 and 6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>− validate, and if necessary revise, the groundwater model for the palaeochannel; and</td>
<td>Sections 4 and 7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>− monitor and report on the groundwater impacts of underground 1 second workings on the palaeochannel; and</td>
<td>Sections 6 and 9</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a program to monitor and report on the predicted groundwater impacts on the palaeochannel adjacent to underground 1 boundary; and</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>...</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(n) include a contingency plan that expressly provides for adaptive management where monitoring indicates that there has been an exceedance of any performance measure in Table 18 and 19, or where such exceedances seem likely;</td>
<td>Section 8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>...</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(p) include a program to collect sufficient baseline data for future Extraction Plans.</td>
<td>Section 9.3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Condition 6, Schedule 4**

6. The Proponent shall ensure that the management plans required under conditions 5(g)-(l) above include:

(a) an assessment of the potential environmental consequences of the Extraction Plan incorporating any relevant information that has been obtained since this approval; and Sections 4 and 6.4

(b) a detailed description of the measures that would be implemented to remediate predicted impacts. Section 7

**Condition 3, Schedule 6**

3. The Proponent shall ensure that the management plans required under this approval are prepared in accordance with any relevant guidelines, and include:

(a) detailed baseline data Sections 4.4.1 and 4.5.1

(b) a description of:

• the relevant statutory requirements (including any relevant approval, licence or lease conditions); Section 3

• any relevant limits or performance measures/criteria; Section 5

• the specific performance indicators that are proposed to be used to judge the performance of, or guide the implementation of, the project or any management measures; Section 5

(c) a description of the measures that would be implemented to comply with the relevant statutory requirements, limits, or performance measures/criteria; Sections 7 and 8

(d) a program to monitor and report on the:

• impacts and environmental performance of the project; Sections 6 and 9

• effectiveness of any management measures (see c above); Section 8

(e) a contingency plan to manage any unpredicted impacts and their consequences; Sections 6 and 9

(f) a program to investigate and implement ways to improve the environmental performance of the project over time;
Table 1 (Continued): Water Management Plan Requirements

<table>
<thead>
<tr>
<th>Project Approval (08_0135) Condition</th>
<th>LW101-103 WMP Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>(g) a protocol for managing and reporting any:</td>
<td></td>
</tr>
<tr>
<td>• incidents;</td>
<td>Section 10</td>
</tr>
<tr>
<td>• complaints;</td>
<td>Section 11</td>
</tr>
<tr>
<td>• non-compliances with statutory requirements; and</td>
<td>Section 12</td>
</tr>
<tr>
<td>• exceedences of the impact assessment criteria and/or performance criteria; and</td>
<td>Section 8</td>
</tr>
<tr>
<td>(h) a protocol for periodic review of the plan.</td>
<td>Section 2</td>
</tr>
</tbody>
</table>

3.2 OTHER LEGISLATION

MCO will operate the Moolarben Coal Complex consistent with Project Approval (08_0135) and any other legislation that is applicable to an approved Part 3A Project under the EP&A Act.

The following Acts may be applicable to, but are not limited to, the conduct of the Moolarben Coal Complex:

- Crown Lands Act, 1989;
- Fisheries Management Act, 1994;
- Heritage Act, 1977;
- Mine Subsidence Compensation Act, 1961;
- Mining Act, 1992;
- National Parks and Wildlife Act, 1974;
- Biodiversity Conservation Act, 2016;
- Protection of the Environment Operations Act, 1997;
- Roads Act, 1993;
- Water Act, 1912;
- Water Management Act, 2000;
- Work Health and Safety Act, 2011; and

Relevant licences or approvals required under these Acts will be obtained as required.
4.0 PREDICTED SUBSIDENCE IMPACTS AND ENVIRONMENTAL CONSEQUENCES

4.1 LONGWALLS 101-103 EXTRACTION SCHEDULE

Longwalls 101-103, 103 Plunge Panel and the area of land within the furthest extent of the 26.5° angle of draw and 20 mm predicted subsidence contour (i.e. the Longwalls 101-103 Study Area) are shown on Figures 3 and 4. Longwall extraction will occur from the west to the east. The longwall layout includes approximately 311 metre (m) panel widths (void) with 20 m pillars (solid).

The provisional extraction schedule for Longwalls 101-103 is provided in Table 2.

<table>
<thead>
<tr>
<th>Longwall</th>
<th>Estimated Start Date</th>
<th>Estimated Duration</th>
<th>Estimated Completion Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>101</td>
<td>October 2017</td>
<td>8 months</td>
<td>June 2018</td>
</tr>
<tr>
<td>102 (A+B)</td>
<td>August 2018</td>
<td>12 months</td>
<td>August 2019</td>
</tr>
<tr>
<td>103</td>
<td>October 2019</td>
<td>10 months</td>
<td>July 2020</td>
</tr>
<tr>
<td>103 Plunge</td>
<td>March 2019</td>
<td>3 Months</td>
<td>May 2019</td>
</tr>
</tbody>
</table>

Following approval of the UG1 Optimisation Modification in April 2016, MCO has delineated a geological feature in Longwall 102 that prevents economic mining of this section, and has subsequently revised the longwall layout to incorporate a barrier pillar around this feature. The barrier pillar separating Longwalls 102A and 102B is approximately 140 m in length. In addition, following further detailed design, Longwalls 101-103 have been shortened by approximately 70 m to provide safe operational conveyor distance between the end of the longwalls and main headings.

A second geological intrusion has been located at the commencing end of LW103 preventing viable extraction by longwall mining methods in this area. As a consequence, the LW103 commencing position has been moved outbye of the influence of this structure, and a first workings plunge panel has been established to partially extract the remanent coal that would otherwise become sterilised.

With the exception of these changes, the longwall geometry is the same as that for the approved UG1 Optimisation Modification, and MSEC (2017) and MSEC (2019) concludes that the overall impact assessments for the natural and built features are unchanged or reduced.
4.2 PREDICTED SUBSIDENCE IMPACTS AND ENVIRONMENTAL CONSEQUENCES

Subsidence impact predictions for the drainage lines in the Longwalls 101-103 Study Area were conducted in 2015 for the UG1 Optimisation Modification (the Approved Layout) and have been revised to reflect the latest longwall layout (the Extraction Plan Layout) (MSEC, 2017 and 2019).

No rivers, creeks or watercourses are impacted by subsidence from Longwalls 101-103. The only drainage line predicted to be impacted by subsidence from Longwalls 101-103 is ephemeral drainage line DL7, which is predicted to experience subsidence from Longwalls 102 and 103 only.

The head of drainage line DL6 (Figure 4) is just within the Study Area, but is located outside the extent of 20 mm subsidence from Longwalls 101-103 and therefore will experience negligible subsidence movements (MSEC, 2017).

MSEC (2017) compared the maximum predicted subsidence impacts on DL7 due to the extraction of Longwalls 101-103 based on the Extraction Plan Layout, with the maximum predictions due to the extraction of Longwalls 101-103 based on the Approved Layout. This comparison is provided in Table 3.

Table 3: Comparison of Maximum Predicted Conventional Subsidence Parameters for Drainage Line 7 based on the Approved Layout and the Extraction Plan Layout

<table>
<thead>
<tr>
<th>Layout</th>
<th>Subsidence (mm)</th>
<th>Tilt (mm/m)</th>
<th>Hogging Curvature (km⁻¹)</th>
<th>Sagging Curvature (km⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Approved Layout (LW101-103)</td>
<td>2100</td>
<td>45</td>
<td>2.3</td>
<td>1.8</td>
</tr>
<tr>
<td>Extraction Plan Layout</td>
<td>2100</td>
<td>45</td>
<td>2.3</td>
<td>1.8</td>
</tr>
</tbody>
</table>


mm/m = millimetres per metre, km⁻¹ = 1/kilometres.

1 Subsidence refers to vertical displacements of the ground.

2 Tilt is 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 distance between those two points.

3 Curvature is the second derivative of subsidence, 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.

The maximum predicted total subsidence parameters for DL7 based on the Approved Layout are the same as those for the Extraction Plan Layout for Longwalls 101 to 103 (MSEC, 2017).

The maximum predicted total conventional subsidence, tilt and curvature for drainage line DL7 resulting from the extraction of Longwalls 102 and 103, based on the Extraction Plan Layout, are provided in Table 4.
### 4.3 ENVIRONMENTAL RISK ASSESSMENT

An Environmental Risk Assessment (ERA) was conducted for the Longwall 101-103 Extraction Plan to provide appropriate consideration to risk assessment and risk management in accordance with the DP&E and DRE (2015) *Guidelines for the Preparation of Extraction Plans*. The suitably qualified and experienced experts endorsed by the Secretary of the DP&E for the preparation of the UG1 Longwalls 101-103 Extraction Plan participated in the ERA.

The ERA indicated that risks relevant to surface water and groundwater in the Longwalls 101-103 Study Area were in the “Low” or “Medium” category, and it was expected that the risks could be managed with implementation of the appropriate mitigation, management and/or control measures.

The ERA was reviewed in March 2019 to support the Longwalls 101-103 Extraction Plan Amendment and in consideration of the Revised Extraction Plan Layout. No changes to the ERA were required.

### 4.4 SURFACE WATER

#### 4.4.1 Baseline Data

The Moolarben Coal Complex is located in the Upper Goulburn River and Wollar Creek catchments (both sub-catchments to the larger Goulburn River and Hunter River catchments), which have catchment areas of approximately 2,455 square kilometres (km²) and 532 km², respectively. Both catchments drain to the Goulburn River which flows in an easterly direction, eventually joining the Hunter River approximately 150 km downstream of the Moolarben Coal Complex.

Moolarben Creek is a tributary of the Upper Goulburn River sub-catchment and flows along the western boundary of the Moolarben Coal Complex. Wilpinjong Creek is a tributary of Wollar Creek sub-catchment and flows along the east and north-east of the Moolarben Coal Complex into Wollar Creek, before joining the Goulburn River approximately 26 km downstream of the Moolarben Coal Complex.

<table>
<thead>
<tr>
<th>Location</th>
<th>Subsidence (mm)</th>
<th>Tilt (mm/m)</th>
<th>Hogging Curvature (km⁻¹)</th>
<th>Sagging Curvature (km⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Longwall 102</td>
<td>45</td>
<td>2.5</td>
<td>0.1</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>Longwall 103</td>
<td>2100</td>
<td>45</td>
<td>2.3</td>
<td>1.8</td>
</tr>
</tbody>
</table>

Source: after MSEC (2017)
Four minor drainage lines were identified by MSEC (2015) within the UG1 Study Area (i.e. associated with Longwalls 101-105) as part of the Subsidence Assessment for the *UG1 Optimisation Modification Environmental Assessment* (UG1 Optimisation Modification). All drainage lines identified in the vicinity of the Longwalls 101-103 Study Area are ephemeral as water only flows during, and for short periods after, each rain event (MSEC, 2015).

Of the drainage lines identified within the UG1 Study Area, only a section of drainage line DL7 is impacted by Longwalls 102 and 103 (Figure 4). DL7 is a tributary of Murrugamba Creek, which flows into Wilpinjong Creek.

DL6 is located within the Study Area however subsidence impacts are predicted to be negligible. DL4 and DL5 are located within the approved out-of-pit emplacement and no longer exist and DL6 is not predicted to be impacted by subsidence caused by the extraction of Longwalls 101-103.

### 4.4.2 Summary of Subsidence Impacts to Drainage Lines

MSEC (2017) concluded the maximum predicted total subsidence parameters for the drainage lines based on the Approved Layout are the same as those for the Extraction Plan Layout for Longwalls 101 to 103. Therefore, the potential impacts on the drainage lines are the same as those assessed based on the Approval Layout. In summary (MSEC, 2017):

- The drainage lines within the Study Area are top of catchment ephemeral drainage features as water only flows during and for short periods after each rain event. Small residual ponded areas may occur for short periods of time immediately after major rain events along the shorter flatter grade sections of the drainage lines. Additional ponding may occur along the drainage lines resulting from the extraction of Longwalls 101 to 103.

- Sections of beds downstream of the additional ponding areas, may erode during subsequent rain events, especially during times of high flow. It is expected that, over time, the gradients along the drainage lines would approach grades similar to those that existed before mining. The extent of additional ponding along the drainage lines would, therefore, be expected to decrease with time.

- Fracturing and dilation of the bedrock would occur as a result of the extraction of these longwalls.

- In times of heavy rainfall, the majority of the surface water runoff would be expected to flow over the surface cracking in the beds and only a small proportion of the flow would be diverted into the fractured and dilated strata below. In times of low flow, however, a larger proportion of the surface water flow could be diverted into the strata below the beds and this could affect the quality and quantity of this water flowing through the cracked strata beds. Nevertheless,
during high flow or low flow times, this small quantity is expected to have little impact on the overall quality of water flowing out of the drainage lines.

WRM (2017) considered the potential impacts to drainage line DL7 as a result of the extraction of Longwalls 101-103 and concluded that, consistent with predicted impacts for the Approved Layout:

- The predicted changes in grade are expected to increase the risk of erosion over a reach length of about 100 m immediately downstream of the chain pillar.
- The predicted changes in grade are expected to increase the risk of ponding over a reach length of about 100 m immediately upstream of the chain pillar.
- It is expected that over time, the gradients along the drainage lines would approach grades similar to those which existed before mining. The extent of additional ponding along the drainage lines would therefore be expected to decrease with time.
- It is also expected that, with time, the fracturing in the bedrock would be filled with alluvial and colluvial materials during subsequent flow events, reducing the diversion of surface water flows into subsurface flows.
- It may be necessary, however, that some remediation of the beds of the drainage line would be required, such as infilling of surface cracks with materials comprising a high clay content, or by locally regrading and re-compacting the surface.

4.5 GROUNDWATER

4.5.1 Baseline Data

Previous groundwater assessments have extensively detailed the hydrogeological regime and groundwater quality within and surrounding the Moolarben Coal Complex. Previous assessments include:

- Moolarben Coal Project – Groundwater Assessment (Peter Dundon and Associates Pty Ltd, 2006);
- Moolarben Stage 2 Groundwater Assessment (Aquaterra Consulting Pty Ltd, 2008);
- Moolarben Complex Stage 2 – Preferred Project Report – Groundwater Impact Assessment (RPS Aquaterra, 2011);
- Moolarben Coal Complex Stage 1 Optimisation Modification Groundwater Assessment (Australasian Groundwater & Environmental Consultants Pty Ltd, 2013);
- Moolarben Coal Complex UG1 Optimisation Modification – Environmental Assessment – Groundwater Assessment (Dundon Consulting Pty Limited, 2015); and
LONGWALLS 101-103 WATER MANAGEMENT PLAN
Moolarben Coal Operations

- Moolarben Coal Complex UG1 Optimisation Modification Groundwater Modelling Assessment (HydroSimulations, 2015).

4.5.2 Hydrogeological Regime

The Moolarben Coal Complex area is located in the Western Coalfield on the north-western edge of the Sydney-Gunnedah Basin, which contains sedimentary rocks, including coal measures, of Permian and Triassic age. The dominant outcropping lithologies over the Moolarben Coal Complex are the Triassic Narrabeen Group (Wollar Sandstone) and the Permian Illawarra Coal Measures. The siltstones and sandstones of the Triassic Narrabeen Group form elevated, mesa-like incised plateaus associated with the Goulburn River National Park and the Munghorn Gap Nature Reserve.

4.5.3 Alluvial Aquifers

Quaternary alluvial deposits in the vicinity of the Moolarben Coal Complex are associated with Lagoon Creek, Goulburn River, Moolarben Creek and Wilpinjong Creek.

There is no ‘highly productive’ groundwater, as defined under the NSW Aquifer Interference Policy, mapped in the vicinity of the Moolarben Coal Complex. The nearest ‘highly productive’ groundwater is a portion of the alluvial aquifer associated with Wilpinjong Creek downstream of the Wilpinjong Coal Mine.

4.5.4 Tertiary Palaeochannel Deposits

Tertiary palaeochannel deposits have been recognised in the Goulburn River diversion (at Ulan) and in the Murragamba and Wilpinjong creek valleys, with a maximum thickness of 40 m to 50 m. Palaeochannels are remnants of inactive river or stream channels that have been later filled in or buried by younger sediment. The infill sediments consist of poorly-sorted semi-consolidated quartzose sands and gravels in a clayey matrix.

Transient Electro-Magnetic (TEM) and Direct Current (DC) electrical resistivity surveys have been conducted to better define the thickness and the extent of the palaeochannel to the north-east of UG1. Following a subsequent program of targeted drilling, HydroSimulations has determined that the UG1 mine layout for Longwalls 101-103 would not pass beneath water bearing palaeochannel sediments, as was considered in HydroSimulations (2015).

An extensive description of the location and saturated extent of the palaeochannel is provided by HydroSimulations (2017), which includes analysis of additional investigation bores drilled after the UG1 Optimisation Modification Environmental Assessment to confirm the location and saturated extent of the palaeochannel adjacent to the extents of Longwalls 101 to 103 in fulfilment of Condition 5(h), Schedule 4 of Project Approval 08_0135.
HydroSimulations (2017) (Attachment 3) confirms Longwalls 101 to 103 do not directly underlie saturated palaeochannel. On this basis, HydroSimulations (2017) concludes the assumptions of the groundwater modelling conducted for the Approved Layout (as part of the UG1 Optimisation Modification by HydroSimulations [2015]) remain valid for the Extraction Plan Layout.

4.5.5 Porous Rock Groundwater Systems

The porous rock groundwater systems consist of the Narrabeen Group sandstones and the Illawarra Coal Measures, consisting of coal seams, conglomerate, mudstones and siltstones.

4.5.6 Groundwater Use

None of the identified groundwater systems is a significant aquifer. The most permeable units are the Ulan Seam and Marrangaroo Conglomerate, while the sandstones of the Narrabeen Group are of lower permeability and are elevated above the Moolarben Coal Complex. The Illawarra Coal Measures also include low permeability mudstones and siltstones.

Recharge to the groundwater systems would occur primarily from direct rainfall and runoff infiltration. The Permian and Triassic groundwater systems in the vicinity of the Moolarben Coal Complex are primarily recharged at outcrops and subcrops. Where the Triassic and/or Permian strata are overlain by alluvium, colluvium or highly weathered bedrock, additional recharge may occur from these unconsolidated surficial materials.

There are no high priority culturally significant sites listed in the Water Sharing Plan for the Hunter Unregulated and Alluvial Water Sources 2009. However, a spring known as The Drip is a groundwater dependent ecosystem (GDE) with local cultural significance. This water feature is likely to be fed from perched water in the Wollar Sandstone and is not considered relevant to this Extraction Plan as there is no credible mechanism for impact from the extraction of Longwalls 101-103.

4.5.7 Private Bores

No private bores are predicted to experience greater than minimal impact (i.e. drawdown greater than 2 m, as defined in the NSW Aquifer Interference Policy) due to the Moolarben Coal Complex.

A bore census has been undertaken to identify private groundwater use in the vicinity of the Moolarben Coal Complex. Only three private bores were identified during the census survey that are relevant to the assessment of potential Moolarben Coal Complex mining effects².

² This does not include bores located on private properties to the west of the Moolarben Coal Complex that are developed in the outcropping basement rocks or associated regolith that underlie the Sydney Basin and that are
Two of these bores (census points SP39 and SP42) are shallow low-yielding bores located more than 7 km up-dip and south-west of UG1 Longwalls 101-103 and as a result these bores would not be impacted.

The remaining private bore (census point SP49) is located more than 6 km to the north of UG1 Longwalls 101-103 and is a relatively shallow bore (24 m) developed in Triassic strata. Negligible drawdown impact due to the Moolarben Coal Complex mining has been predicted at this bore.

### 4.5.8 Predicted Impacts

Potential groundwater impacts due to the extraction of Longwalls 101-103 were assessed in 2015 as part of the UG1 Optimisation Modification (the Approved Layout). These predicted impacts have been reviewed by HydroSimulations (2017) for the Extraction Plan Layout.

The Extraction Plan Layout would result in the same, or lower, potential impacts in comparison to the Approved Layout (as assessed and approved for the UG1 Optimisation Modification), given:

- The lengths of Longwalls 101-103 have been reduced from those that were simulated by approximately 70 m.
- MSEC (2017) predicts potential subsidence impacts for the Extraction Plan Layout would be the same or lower than those for the Approved Layout.
- Additional drilling investigation has confirmed the assumptions of the HydroSimulations (2015) modelling with respect to Longwalls 101-103 not directly underlying the saturated palaeochannel.

In summary, the approved potential groundwater impacts of the Moolarben Coal Complex are predicted to remain unchanged for the minor changes in the layout of Longwalls 101 to 103 for the Extraction Plan.

Key outcomes of previous groundwater assessments for the approved Moolarben Coal Complex are (HydroSimulations, 2017):

- Less than 2 m drawdown in the alluvium/regolith adjacent to the northern edge of the UG1 longwall panels (layer 1 of the HydroSimulations [2015] groundwater model).
• Drawdowns greater than 2 m in alluvium/regolith to the north-west of UG1, and to the east of UG1 in Murragamba Valley (layer 1 of the HydroSimulations [2015] groundwater model).

• No private bores are likely to be affected by 2 m drawdown or more due to the Moolarben Coal Complex, including UG1.

• No drawdown is anticipated in the Upper Triassic (or Lower Triassic) as these sediments are inherently dry.

• Drawdown in the Ulan Seam; however, as the Ulan Seam has no productive water use other than for mining purposes, no change to beneficial use category is anticipated.
5.0 PERFORMANCE MEASURES, PERFORMANCE INDICATORS AND INVESTIGATION TRIGGER LEVELS

5.1 SUBSIDENCE IMPACT PERFORMANCE MEASURES

This LW101-103 WMP has been developed to manage the potential environmental consequences of the secondary extraction of Longwalls 101-103 on drainage lines and aquifers in accordance with Condition 5(h), Schedule 4 of Project Approval (08_0135).

In accordance with Condition 1, Schedule 4 of Project Approval (08_0135), MCO must ensure that there is no exceedance of the subsidence impact performance measures listed in Table 18 of Condition 1, Schedule 4 and Table 19 of Condition 3, Schedule 4 of Project Approval (08_0135).

The subsidence impact performance measure relevant to water resources in the Longwalls 101-103 Study Area is listed in Table 5.

Table 5: Water Subsidence Impact Performance Measure

<table>
<thead>
<tr>
<th>Feature</th>
<th>Subsidence Impact Performance Measure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drainage Lines (DL1 – DL7)</td>
<td>No greater subsidence impacts or environmental consequences than predicted in the EA.</td>
</tr>
</tbody>
</table>

Source: Table 18 of Condition 1, Schedule 4 of Project Approval (08_0135).

Notes:
- MCO is 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 approval.
- 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 of the DP&E will be the final arbiter.

The performance measure ‘No greater subsidence impacts or environmental consequences than predicted in the EA’ for Drainage Lines (DL1-DL7) reflects the predictions by MSEC (2015), which are summarised in Section 4.4.2.

WRM (2017) has developed objectives and performance indicators to assess whether potential subsidence impacts on surface drainage are not greater than those predicted. Table 6 details the objectives and performance indicators for DL7.
**Table 6: Surface Water Subsidence Management Objectives and Performance Indicators**

<table>
<thead>
<tr>
<th>Objective</th>
<th>Performance Indicator</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Drainage Lines</strong></td>
<td></td>
</tr>
</tbody>
</table>
| No significant increase in active erosion in DL7. | • Change in visible erosion.  
• Development of, or change in, headcut erosion along DL7. |
| No change in stream character for DL7 beyond approved. | • Change in character, such as increased erosion or change in vegetation along drainage line.  
• Extensive duration of water ponding. |
| No measurable change in downstream water quality. | • Downstream water quality (consistent with approved complex-wide Surface Water Management Plan [SWMP]). |
| Minimise change in surface flow when cracks appear (as is predicted to occur) | • Appearance of unsealed surface cracking across the bed of DL7. |

**5.2 SURFACE WATER QUALITY TRIGGER INVESTIGATION LEVELS**

The approved complex-wide SWMP includes water quality investigation trigger levels. As DL7 is a (minor drainage line) tributary of Murragamba Creek (which flows into Wilpinjong Creek), the water quality investigation trigger levels established for Murragamba Creek at monitoring site SW04 and Wilpinjong Creek at monitoring site SW16 (Figure 4 and Table 7) (based on analysis of surface water quality monitoring data) are relevant to this LW101-103 WMP, to confirm subsidence impacts from Longwalls 101-103 do not result in adverse water quality impacts to the downstream environment.

**Table 7: Surface Water Quality Trigger Investigation Levels**

<table>
<thead>
<tr>
<th>Waterway</th>
<th>Monitoring Site</th>
<th>pH</th>
<th>EC (µs/cm)</th>
<th>Turbidity (NTU)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>20th/80th</td>
<td>ANZECC</td>
<td>80th %ile</td>
</tr>
<tr>
<td></td>
<td></td>
<td>%ile Trigger Values</td>
<td>Guideline</td>
<td>Trigger Value</td>
</tr>
<tr>
<td>Murragamba Creek</td>
<td>SW04</td>
<td>6.1 – 7.7</td>
<td>6.5 – 8.0</td>
<td>1,622</td>
</tr>
<tr>
<td>Wilpinjong Creek</td>
<td>SW16</td>
<td>6.5 – 7.4</td>
<td>6.5 – 8.0</td>
<td>800</td>
</tr>
</tbody>
</table>

*Note: The shaded cells indicate the adopted water quality trigger level. ND = No data (i.e. less than 24 monitoring points), %ile = percentile, EC = electrical conductivity, µS/cm = microSiemens per centimetre and NTU = Nephelometric Turbidity Units.*
5.3 GROUNDWATER TRIGGER INVESTIGATION LEVELS

There are no subsidence performance measures relevant to groundwater. Notwithstanding, a summary of groundwater levels and quality investigation triggers relevant to Longwalls 101-103 is provided below.

**Salinity and pH Triggers**

Salinity and pH investigation trigger levels are defined in Table 8. The bores in Table 8 (a sub-set of those in the approved complex-wide Groundwater Management Plan [GWMP]) are considered by HydroSimulations (2017) to be those relevant for investigating potential changes in groundwater quality due to longwall mining in Longwalls 101-103. The recommended salinity and pH triggers for each relevant bore are presented in Table 8.

Salinity triggers have been developed based on the 95th percentile baseline salinity level recorded at relevant bore locations. Should a measured salinity level exceed the trigger for two consecutive monitoring events, and the measured salinity is in a lower beneficial use category than the trigger level, then the groundwater investigation protocol described in the complex-wide GWMP will be initiated.

pH triggers have been developed from the 5th and 95th percentile baseline pH levels recorded at each bore location considered relevant to Longwalls 101-103. Should a measured pH level exceed the trigger for two consecutive monitoring events, then the groundwater investigation protocol described in the complex-wide GWMP will be initiated.

**Table 8: Salinity and pH Trigger levels**

<table>
<thead>
<tr>
<th>Bore</th>
<th>Depth (m)</th>
<th>Lithology Screened</th>
<th>Historical lab EC (5th to 95th percentile) (µS/cm)</th>
<th>EC Trigger Level (µS/cm)</th>
<th>Beneficial Use Category Based on Lab EC 95th Percentile</th>
<th>pH Trigger Level (5th to 95th percentile)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PZ186</td>
<td>114</td>
<td>Permian Overburden</td>
<td>336-465 (370)</td>
<td>465</td>
<td>Potable</td>
<td>5.9 – 7.8 (6.4)</td>
</tr>
<tr>
<td>PZ187</td>
<td>22</td>
<td>Palaeochannel Alluvium</td>
<td>170-656 (201)</td>
<td>656</td>
<td>Potable</td>
<td>5.4 – 7.1 (5.8)</td>
</tr>
<tr>
<td>PZ188</td>
<td>18.5</td>
<td>Palaeochannel Alluvium</td>
<td>198-394 (245)</td>
<td>394</td>
<td>Potable</td>
<td>4.7 – 6.9 (5.5)</td>
</tr>
<tr>
<td>PZ189</td>
<td>65</td>
<td>Permian Overburden</td>
<td>311-408 (375)</td>
<td>408</td>
<td>Potable</td>
<td>5.6 – 6.8 (6.1)</td>
</tr>
</tbody>
</table>

1 Historical values in brackets are median values.
Groundwater Level Triggers

Triggers for measured groundwater levels have been developed based on the minimal impact considerations in the NSW Aquifer Interference Policy.

There is no ‘highly productive’ groundwater, as defined under the NSW Aquifer Interference Policy, mapped in the vicinity of the Moolarben Coal Complex. The nearest ‘highly productive’ groundwater is a portion of the alluvial aquifer associated with Wilpinjong Creek downstream of the Wilpinjong Coal Mine.

The NSW Aquifer Interference Policy describes the following minimal impact considerations for less productive groundwater sources:

- Less than or equal to 10% cumulative variation in the water table, allowing for typical climatic “post-water sharing plan” variations, 40m from any:
  
  (a) high priority groundwater dependent ecosystem; or
  (b) high priority culturally significant site; listed in the schedule of the relevant water sharing plan.

  A maximum of a 2m decline cumulatively at any water supply work.

There are no high priority groundwater dependent ecosystems or high priority culturally significant sites identified in the Water Sharing Plan for the Hunter Unregulated and Alluvial Water Sources 2009 or Water Sharing Plan for the North Coast Fractured and Porous Rock Groundwater Sources 2016 in the vicinity of the Moolarben Coal Complex (Figure 5).

The groundwater investigation protocol detailed in the approved complex-wide GWMP would be initiated in cases where groundwater monitoring identifies the potential for a greater than 2 m reduction in the groundwater level at a private bore, determined against groundwater level hydrograph trends.

Water level triggers have been developed for alluvium monitoring bores listed in Table 9. The bores in Table 9 (which are a sub-set of those in the approved complex-wide GWMP) have been selected as investigation triggers for potential changes in groundwater levels due to underground mining in Longwalls 101-103. The investigation trigger levels (developed from an analysis of historical groundwater levels) are also provided in Table 9 and have been set at 2 m below the minimum water level reported during the baseline monitoring period.
Figure 5

Source: MCO (June 2016); NSW Dept of Industry (2016); NOW (2016)

Relevant Mapped Groundwater Sources

LEGEND
- Exploration Licence Boundary
- Mining Lease Boundary

Water Sharing Plan for the NSW Murray Darling Basin Fractured Rock Groundwater Sources 2011
- Lachlan Fold Belt MDB Groundwater Source

Water Sharing Plan for the NSW Murray Darling Basin Porous Rock Groundwater Sources 2011
- Sydney Basin MDB Groundwater Source

Water Sharing Plan for the North Coast Fractured and Porous Rock Groundwater Sources 2016
- Sydney Basin - North Coast Groundwater Source

Water Sharing Plan for the Hunter Unregulated and Alluvial Water Sources 2009
- Unnamed Alluvial in Wollar Creek Water Source
- Unnamed Alluvial in Goulburn River Water Source

Figure 5

Moolarben Coal Complex

SYDNEY BASIN - NORTH COAST GROUNDWATER SOURCE

UNNAMED ALLUVIAL IN WOLLAR CREEK WATER SOURCE

UNNAMED ALLUVIAL IN GOULBURN RIVER WATER SOURCE
Table 9: Trigger Groundwater Levels – Alluvium Bores

<table>
<thead>
<tr>
<th>Alluvium Piezometer Number</th>
<th>Base of Alluvium/Tertiary Palaeochannel (m AHD)</th>
<th>Interval/Level Monitored (mbgl)</th>
<th>Minimum Observed Groundwater Level/Pressure (mbgl)</th>
<th>Minimum Observed Groundwater Level/Pressure (m AHD)</th>
<th>Trigger Level (m AHD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PZ187</td>
<td>&lt;396.5</td>
<td>15-21</td>
<td>2.9</td>
<td>415.7</td>
<td>413.7</td>
</tr>
<tr>
<td>PZ188</td>
<td>403.6</td>
<td>12-18</td>
<td>8.4</td>
<td>415.2</td>
<td>413.2</td>
</tr>
</tbody>
</table>

m AHD = metres Australian Height Datum, mbgl = metres below ground level.

The above trigger levels are intended to trigger an investigation to determine whether the cause of the water level/pressure decline is caused by MCO’s mining activity, excluding borefield pumping, and to recommend an appropriate response action. Prior to initiating a response action, an exceedance of a trigger level would need to occur for at least two successive monthly monitoring rounds, to eliminate possible anomalous readings.

**Additional Monitoring Bores**

As recommended by HydroSimulations (2017), an additional groundwater monitoring bore (standpipe) has been installed, located at the northern end of Longwall 101 (Bore A, PZ211) (Figure 6) to monitor groundwater levels in the palaeochannel. A second monitoring bore (Bore B, PZ213) has been installed at the northern end of LW105. A third monitoring bore (Bore C, PZ214) has been installed at the northern end of LW103.

The trigger for investigation for the piezometer north of LW101 (Bore A, PZ211) (Figure 6) would be a drawdown of greater than 2 m (based on a baseline level established from approximately three months of monitoring data). As above, the trigger level established for Bore A, PZ211 would need to have been exceeded for at least two successive monthly monitoring rounds, to eliminate possible anomalous readings prior to initiating a response action.
Figure 6

Groundwater Monitoring
and Investigation Locations
Relevant to Longwalls 101 to 103

Source: MLC (June 2019); NSW Dept of Industry (2019);
HydroSimulations (2017)
6.0 MONITORING

6.1 POTENTIAL SUBSIDENCE IMPACTS

A monitoring program has commenced to monitor the impact of the secondary extraction of Longwalls 101-103 on DL7, which is the only watercourse predicted to be impacted by subsidence from Longwalls 101-103. The key components of the monitoring program are summarised in Table 10.

Table 10: Water Monitoring Program Overview

<table>
<thead>
<tr>
<th>Monitoring Component</th>
<th>Parameter</th>
<th>Timing/Frequency</th>
<th>Responsibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-mining</td>
<td>Baseline photographic record.</td>
<td>Prior to undermining</td>
<td>Environmental and Community Manager</td>
</tr>
<tr>
<td>Visual inspection and photographic record of drainage line DL7</td>
<td>Visual inspection and photographic record of drainage line DL7</td>
<td>Environmental and Community Manager</td>
<td></td>
</tr>
<tr>
<td>During Mining</td>
<td>Walk the length of drainage line DL7 over Longwall 103 and note any areas of active erosion, sediment deposition, water ponding or streambed cracking.</td>
<td>Within 3 months of undermining drainage line DL7</td>
<td>Environmental and Community Manager</td>
</tr>
<tr>
<td>Post Mining</td>
<td>Walk the length of drainage line DL7 over Longwall 103 and note any areas of active erosion, sediment deposition, water ponding or streambed cracking.</td>
<td>Ongoing inspections every 6 months for 1 year after undermining drainage line DL7</td>
<td>Environmental and Community Manager</td>
</tr>
</tbody>
</table>

Subsidence parameters will be measured in accordance with the Longwalls 101 to 103 Subsidence Monitoring Program.

6.2 SURFACE WATER FLOW AND QUALITY

Surface water monitoring for receiving watercourses is undertaken for flow, water quality, stream health and channel stability as described in the approved complex-wide SWMP.

Water quality sampling of receiving streams will continue to be undertaken in accordance with the approved complex-wide SWMP. Appropriate water quality monitoring at locations downstream of DL7 on Murragamba Creek (SW04) and Wilpinjong Creek (SW16) are shown on Figure 4.
6.3 GROUNDWATER

Groundwater monitoring is undertaken for groundwater extraction, groundwater levels, groundwater quality and leachate/seepage losses from water and water storages as described in section 6.0 of the approved complex-wide GWMP. Groundwater monitoring bores considered by HydroSimulations (2017) to be relevant to Longwalls 101-103 are provided in Table 11. The locations of these groundwater monitoring bores are shown on Figure 6.

Additional Palaeochannel Monitoring Bore

Additional palaeochannel monitoring bores (standpipe) have been established to the north-east of Longwall 101 and Longwall 103 to monitor groundwater levels in the palaeochannel, as recommended by HydroSimulations (2017) (Figure 6).

The new monitoring bores were installed prior to the commencement of longwall mining in Longwall 101.

Groundwater Inflows

Groundwater inflows are determined by monitoring of dewatering (with flow meters), less metered supply inflows, estimated water stored underground, water loss in workings, and calculated recirculation from adjacent Open Cut workings. Groundwater take will be partitioned into the various water sharing plan sources using the relative proportions predicted in the groundwater model. Partitioning may be adjusted based on monitoring data, water geochemistry or expert input.

6.4 SUBSIDENCE – ENVIRONMENTAL CONSEQUENCES

MCO will compare the results of the subsidence impact monitoring against the water performance measure and indicators (Section 5.1). In the event that any observed subsidence impact exceeds a performance indicator, additional monitoring and assessment will be undertaken (Section 7). In the event that any observed subsidence impacts exceed the performance measure, MCO will assess the consequences of the exceedance in accordance with the Contingency Plan described in Section 8.
Table 11: Groundwater Bores Relevant to Longwalls 101-103

<table>
<thead>
<tr>
<th>Bore</th>
<th>Type</th>
<th>Depth (m)</th>
<th>Screened Interval (mbgl)</th>
<th>Lithology Screened</th>
<th>Water Level Monitoring Frequency</th>
<th>Historical Water Level Range (mbgl)</th>
<th>Water Quality Monitoring Frequency</th>
<th>Date Established</th>
<th>Licence No.</th>
<th>Easting (m)</th>
<th>Northing (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PZ127*</td>
<td>VWP</td>
<td>152</td>
<td>43</td>
<td>Triassic</td>
<td>Datalog - Reported monthly</td>
<td>Dry</td>
<td>N/A</td>
<td>23/11/2007</td>
<td>20BL173935</td>
<td>762799</td>
<td>6424948</td>
</tr>
<tr>
<td>PZ127</td>
<td>VWP</td>
<td>68</td>
<td>Permian overburden</td>
<td></td>
<td>Datalog - Reported monthly</td>
<td>47.2 - 52.1</td>
<td>N/A</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PZ127</td>
<td>VWP</td>
<td>112</td>
<td>Permian overburden</td>
<td></td>
<td>Datalog - Reported monthly</td>
<td>84.7 - 101.3</td>
<td>N/A</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PZ127</td>
<td>VWP</td>
<td>141</td>
<td>Ulan seam</td>
<td></td>
<td>Datalog - Reported monthly</td>
<td>103.4 - 126.1</td>
<td>N/A</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PZ130</td>
<td>VWP</td>
<td>111</td>
<td>38.5</td>
<td>Permian overburden</td>
<td>Datalog - Reported monthly</td>
<td>37.7 - 40.4</td>
<td>N/A</td>
<td>29/11/2007</td>
<td>20BL173935</td>
<td>760940</td>
<td>6422438</td>
</tr>
<tr>
<td>PZ130</td>
<td>VWP</td>
<td>64</td>
<td>Permian overburden</td>
<td></td>
<td>Datalog - Reported monthly</td>
<td>51.6 - 58.9</td>
<td>N/A</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PZ130</td>
<td>VWP</td>
<td>97</td>
<td>Ulan seam</td>
<td></td>
<td>Datalog - Reported monthly</td>
<td>79.3 - 88.2</td>
<td>N/A</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PZ157*</td>
<td>SP</td>
<td>122</td>
<td>116 - 122</td>
<td>Ulan seam</td>
<td>Manual monthly</td>
<td>63.52 - 73.40</td>
<td>6-months</td>
<td>6/03/2008</td>
<td>20BL173935</td>
<td>763825</td>
<td>6425391</td>
</tr>
<tr>
<td>PZ186</td>
<td>SP</td>
<td>114</td>
<td>108 - 114</td>
<td>Permian overburden</td>
<td>Datalog - Reported monthly</td>
<td>8.47 - 17.21</td>
<td>6 months</td>
<td>6/05/2009</td>
<td>20BL173935</td>
<td>764788</td>
<td>6425865</td>
</tr>
<tr>
<td>PZ187</td>
<td>SP</td>
<td>22</td>
<td>15 - 21</td>
<td>Palaeochannel Alluvium</td>
<td>Datalog - Reported monthly</td>
<td>0.78 - 2.88</td>
<td>6 months</td>
<td>7/05/2009</td>
<td>20BL173935</td>
<td>764784</td>
<td>6425871</td>
</tr>
<tr>
<td>PZ188</td>
<td>SP</td>
<td>18.5</td>
<td>12 - 18</td>
<td>Palaeochannel Alluvium</td>
<td>Datalog - Reported monthly</td>
<td>7.29 - 8.40</td>
<td>6 months</td>
<td>14/05/2009</td>
<td>20BL173935</td>
<td>764478</td>
<td>6426084</td>
</tr>
<tr>
<td>PZ189</td>
<td>SP</td>
<td>65</td>
<td>59 - 95</td>
<td>Permian overburden</td>
<td>Datalog - Reported monthly</td>
<td>10.41 - 14.90</td>
<td>6 months</td>
<td>20/05/2009</td>
<td>20BL173935</td>
<td>764503</td>
<td>6426089</td>
</tr>
<tr>
<td>PZ179</td>
<td>VWP</td>
<td>145</td>
<td>29</td>
<td>Triassic</td>
<td>Datalog - Reported monthly</td>
<td>24.6 - 28.0</td>
<td>N/A</td>
<td>4/07/2008</td>
<td>20BL173935</td>
<td>764688</td>
<td>6426599</td>
</tr>
<tr>
<td>PZ179</td>
<td>VWP</td>
<td>33</td>
<td>Permian overburden</td>
<td></td>
<td>Datalog - Reported monthly</td>
<td>25.8 - 32.7</td>
<td>N/A</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PZ179</td>
<td>VWP</td>
<td>145</td>
<td>Ulan seam</td>
<td></td>
<td>Datalog - Reported monthly</td>
<td>28.9 - 71.4</td>
<td>N/A</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bore A, PZ211</td>
<td>SP</td>
<td>20</td>
<td>17-20</td>
<td>Palaeochannel Alluvium</td>
<td>Manual monthly</td>
<td>TBC</td>
<td>6-months</td>
<td>24/07/2017</td>
<td>20BL173935</td>
<td>763442</td>
<td>6426146</td>
</tr>
<tr>
<td>Bore B, 213</td>
<td>SP</td>
<td>22</td>
<td>20-22</td>
<td>Palaeochannel Alluvium</td>
<td>Manual monthly</td>
<td>TBC</td>
<td>6-months</td>
<td>25/07/2017</td>
<td>20BL173935</td>
<td>764341</td>
<td>6425229</td>
</tr>
</tbody>
</table>

VWP = Vibrating Wire Piezometer, SP = Standpipe Piezometer, N/A = not applicable, * to be monitored until impacted by mining, TBC = To be completed (i.e. following installation).
7.0 MANAGEMENT MEASURES

Water management at the Moolarben Coal Complex is currently undertaken in accordance with the approved complex-wide WMP and associated subplans (Site Water Balance, SWMP and GWMP). Sections 4.0 and 8.0 of the approved complex-wide SWMP provide details of the management system and management measures for surface water, respectively. Section 8.0 of the approved complex-wide GWMP describes management measures for groundwater systems.

In addition to the management systems and measures detailed in the approved complex-wide SWMP and GWMP, WRM (2017) and HydroSimulations (2017) have recommended measures which are specific to Longwalls 101-103 that will be implemented, where appropriate.

7.1 SURFACE WATER

Potential management measures to mitigate/remediate environmental consequences are provided in Table 12. The implementation of these management measures will be considered with regard to the specific circumstances of the subsidence impact (e.g. the location, nature and extent of the impact) and the assessment of environmental consequences. The implementation of management measures will be related to the scale of impact and the ability to, and value in, undertaking mitigation measures on a case by case basis.

The requirement and methodology for any subsidence remediation techniques will be determined in consideration of:

- Potential impacts of the unmitigated impact, including potential risks to public safety and the potential for self-healing or long-term degradation.
- Potential impacts of the remediation technique, including site accessibility.

<table>
<thead>
<tr>
<th>Measure</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drainage Line 7</td>
<td>• Obtain specialist advice on appropriate remediation works.</td>
</tr>
<tr>
<td>Erosion Management</td>
<td>• Obtain specialist advice on likely cause of vegetation change and remediation strategy.</td>
</tr>
<tr>
<td>Remediation of vegetation impacted by erosion and ponding</td>
<td>• Obtain survey of ponded area to identify ponding depth and extent.</td>
</tr>
<tr>
<td>Water ponding management</td>
<td>• Investigate potential drainage works to restore existing drainage characteristics.</td>
</tr>
<tr>
<td>Downstream water quality management</td>
<td>• Manage in accordance with section 8.0 of the approved complex-wide SWMP.</td>
</tr>
</tbody>
</table>

Table 12: Potential Surface Water Management Measures
7.2 GROUNDWATER

An investigation will be initiated where the groundwater monitoring identifies results outside the trigger levels (or ranges) described in Section 5.3 and consistent with the approved complex-wide GWMP will include (where applicable):

- comparing results with background trends for that location;
- reviewing influences from rainfall or drought conditions;
- reviewing non-MCO land-use activities in the area;
- re-testing the sample or a review of the quality sample result in the event of an apparently anomalous result; and
- liaising with Ulan Coal Mines Limited and Wilpinjong Coal Mine at the time of the investigation to review mining activities in the area where cumulative impacts are considered likely.

When a groundwater quality or groundwater level measurement has been investigated the findings of the investigation will be reported in the Annual Review.

In the event that groundwater levels are lowered at a privately-owned supply bore or well by an amount that exceeds the minimum harm criteria of 2 m as specified in the NSW Aquifer Interference Policy, and that leads to a continued loss or reduction of supply to the local groundwater user, MCO will investigate appropriate remedial measures which may include bore-reconditioning or provision of an alternative water supply.

**Review of Groundwater Model**

Consistent with the commitments within Project Approval 08_0135, a groundwater modelling review and model recalibration (where required) will be conducted 2 years (and 5 yearly thereafter) after commencing Stage 2 coal extraction.
8.0 CONTINGENCY PLAN

Subsidence Performance Measures

In the event the subsidence impact performance measure relevant to water (Table 5) is considered to have been exceeded or is likely to be exceeded (i.e. in consideration of the performance indicators and triggers identified Section 5), MCO will implement the following Contingency Plan:

- The observation will be reported to the Underground Technical Manager and/or the Environmental and Community Manager within 24 hours.
- The observation will be recorded in the Subsidence Impact Register (Attachment 1).
- Any exceedance of a subsidence impact performance measure relevant to water will be reported to the DP&E as soon as practicable after MCO becomes aware of the exceedance.
- MCO will conduct an investigation to evaluate the potential contributing factors with input from appropriately qualified and experience specialists where required. The investigation will:
  - include the re-survey of relevant subsidence monitoring lines;
  - compare and critically analyse measured versus predicted subsidence parameters;
  - review measured subsidence parameters against the observed impact; and
  - review the UG1 Longwalls 101 to 103 Subsidence Monitoring Program and update where appropriate.
- MCO will identify an appropriate course of action with respect to the identified impact(s), in consultation with specialists and relevant agencies, as necessary. For example:
  - proposed contingency measures;
  - a program to review the effectiveness of the contingency measures; and
  - consideration of adaptive management.

Contingency measures will be developed in consideration of the specific circumstances of the impact (e.g. location, nature and extent) and the assessment of environmental consequences. Potential contingency measures would include management measures similar to those described in Table 12.

The proposed course of action will consider the nature and extent/scale of all recorded impacts. It may, for example, be more appropriate to remediate previously impacted areas as opposed to the specific impact that initiated the implementation of the Contingency Plan.

- MCO will submit the proposed course of action to the DP&E for approval.
- MCO will implement the approved course of action to the satisfaction of the DP&E.
**Surface Water Quality**

Contingency measures for exceedances of the investigation trigger levels described in Section 5.2 for surface water quality will be consistent with the process described in section 6 of the approved complex-wide SWMP.

**Groundwater Levels and Quality**

Contingency measures for exceedances of the investigation trigger levels described in Section 5.3 for groundwater levels and quality will be consistent with the process described in section 8.3 of the approved complex-wide GWMP.

### 8.1 TRIGGER ACTION RESPONSE PLAN

The framework for the various components of this LW101-103 WMP are summarised in the TARP shown in Attachment 2. The TARP illustrates how the various predicted subsidence impacts, monitoring components, performance measures, and responsibilities are structured to achieve compliance with the relevant statutory requirements, and the framework for management and contingency actions.

The TARP provides a simple and transparent summary of the monitoring of environmental performance and the implementation of management and/or contingency measures.
9.0 REVIEW AND IMPROVEMENT OF ENVIRONMENTAL PERFORMANCE

9.1 ANNUAL REVIEW

In accordance with Condition 4, Schedule 6 of Project Approval (08_0135), MCO will conduct an annual review of operations conducted at the Moolarben Coal Complex (including the performance of this LW101-103 WMP) prior to 31 March for the preceding calendar year.

The Annual Review will:

- describe the works carried out in the previous calendar year, and the development proposed to be carried out over the current calendar year;
- include a comprehensive review of the monitoring results and complaints records of the Moolarben Coal Complex over the previous calendar year, including a comparison of these results against the:
  - relevant statutory requirements, limits or performance measures/criteria;
  - monitoring results of previous years; and
  - relevant predictions in the EA;
- identify any non-compliance over the last year, and describe what actions were (or are being) taken to ensure compliance;
- identify any trends in the monitoring data over the life of the Moolarben Coal Complex;
- identify any discrepancies between the predicted and actual impacts of the Moolarben Coal Complex, and analyse the potential cause of any significant discrepancies; and
- describe what measures will be implemented over the next year to improve the environmental performance of the Moolarben Coal Complex.

In accordance with Condition 11, Schedule 6 of Project Approval (08_0135), the Annual Review will be made available on the MCO website.

As described in Section 2, this LW101-103 WMP will be reviewed within three months of the submission of an Annual Review, and, if necessary, revised to ensure the plan is updated on a regular basis and to incorporate any recommended measures to improve environmental performance.
9.2 AUDITS

In accordance with Condition 9, Schedule 6 of Project Approval (08_0135), an independent environmental audit was conducted by the end of December 2015, and will be undertaken every three years thereafter. A copy of the independent environmental audit report will be submitted to the Secretary of the DP&E and made publicly available on the MCO website.

The independent environmental audit will be conducted by a suitably qualified, experienced and independent team of experts whose appointment has been endorsed by the Secretary of the DP&E.

The independent environmental audit will assess the environmental performance of the Moolarben Coal Complex and assess whether it is complying with the requirements of Project Approval (08_0135), and any other relevant approvals, and recommend measures or actions to improve the environmental performance of the Moolarben Coal Complex.

As described in Section 2, this LW101-103 WMP will be reviewed within three months of the submission of an independent environmental audit, and, if necessary, revised to ensure the plan is updated on a regular basis and to incorporate any practicable recommended measures to improve environmental performance.

9.3 FUTURE EXTRACTION PLANS

In accordance with Condition 5(p), Schedule 4 of Project Approval (08_0135), MCO will collect baseline data for future Extraction Plans (e.g. for the next mining domain in the UG1 Underground Mine).

Consideration of environmental performance and management measures, in accordance with the review(s) conducted as part of this LW101-103 WMP, will inform the appropriate type and frequency of monitoring and management/mitigation for future Extraction Plans.

In regard to groundwater, this includes the installation of an additional groundwater monitoring bore located at the northern end of Longwall 105 (Figure 6) to collect data in regard to the palaeochannel.
10.0 INCIDENTS

An incident is defined in Project Approval (08_0135) as a set of circumstances that:

- causes or threatens to cause material harm to the environment; and/or
- breaches or exceeds the limits or performance measures/criteria in Project Approval (08_0135).

The reporting of incidents will be conducted in accordance with Condition 7, Schedule 6 of Project Approval (08_0135).

MCO will notify the Secretary of the DP&E and any other relevant agencies of any incident associated with the UG1 Underground Mine immediately after MCO confirms that an incident has occurred. Within seven days of the date of the incident, MCO will provide the Secretary of the DP&E and any relevant agencies with a detailed report on the incident. The report will:

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

MCO maintains a Community Complaints Line (Phone Number: 1800 556 484) that is dedicated to the receipt of community complaints. The Community Complaints Line is publicly advertised and operates 24 hours per day, seven days a week, to receive any complaints from neighbouring residents or other stakeholders.

MCO has developed a Community Complaints Procedure which details the process to be followed when receiving, responding to and recording community complaints. The Community Complaints Procedure is supported by a Complaints Database.

The Community Complaints Procedure is a component of the MCO Environmental Management Strategy which requires the recording of relevant information including:

- the nature of the complaint;
- method of the complaint;
- relevant monitoring results and meteorological data at the time of the complaint;
- site investigation outcomes;
- any necessary site activity and activity changes;
- any necessary actions assigned; and
- communication of the investigation outcome(s) to the complainant.

In accordance with Condition 11, Schedule 6 of Project Approval (08_0135), the complaints register will be updated monthly and made available on the MCO website.
12.0 NON COMPLIANCE WITH STATUTORY REQUIREMENTS

A protocol for the managing and reporting of non-compliances with statutory requirements has been developed as a component of MCO’s Environmental Management Strategy and is described below.

Compliance with all approvals, plans and procedures will be the responsibility of all personnel (staff and contractors) employed on or in association with the Moolarben Coal Complex.

The Environmental and Community Manager (or delegate) will undertake regular inspections, internal audits and initiate directions identifying any remediation/rectification work required.

As described in Section 10, MCO will notify the Secretary of the DP&E, and any other relevant agencies, of any incident associated with MCO as soon as practicable after MCO becomes aware of the incident. Within seven days of the date of the incident, MCO will provide the Secretary of the DP&E, and any relevant agencies, with a detailed report on the incident.

A report of MCO’s compliance with all conditions of Project Approval (08_0135), MLs and relevant licenses will be included in each Annual Review. The Annual Review will be made publicly available on the MCO website.

As described in Section 9.2, an independent environmental audit was conducted by the end of December 2015, and will be undertaken every three years thereafter. A copy of the independent environmental audit report will be submitted to the Secretary of the DP&E and made publicly available on the MCO website.
13.0 REFERENCES


Mine Advice (2019), *SUBJECT: Geotechnical Evaluation of Proposed Taking of Unsupported Plunges in LW103A Block*


ATTACHMENT 1

UG1 LONGWALLS 101 TO 103 WATER MANAGEMENT PLAN
SUBSIDENCE IMPACT REGISTER
### UG1 Longwalls 101 to 103 Water Management Plan – Subsidence Impact Register

<table>
<thead>
<tr>
<th>Impact Register Number</th>
<th>Impacted Water Feature</th>
<th>Impact Description</th>
<th>Does Impact Exceed the Land Performance Measure/Indicators? (Yes/No)</th>
<th>Were Management Measures Implemented? (Yes/No)</th>
<th>Were Management Measures Effective? (Yes/No)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Document Details

<table>
<thead>
<tr>
<th>Document</th>
<th>Version</th>
<th>Issue</th>
<th>Effective</th>
<th>Review</th>
<th>Author</th>
<th>Approved</th>
</tr>
</thead>
<tbody>
<tr>
<td>MCO_U1G1_LW101-103_WMP</td>
<td>2</td>
<td>March 2019</td>
<td>March 2019</td>
<td>March 2019</td>
<td>MCO</td>
<td>S. Archinal</td>
</tr>
</tbody>
</table>
ATTACHMENT 2

UG1 LONGWALLS 101 TO 103 WATER MANAGEMENT PLAN
TRIGGER ACTION RESPONSE PLAN

<table>
<thead>
<tr>
<th>Document</th>
<th>Version</th>
<th>Issue</th>
<th>Effective</th>
<th>Review</th>
<th>Author</th>
<th>Approved</th>
</tr>
</thead>
<tbody>
<tr>
<td>MCO_UG1_LW101-103_WMP</td>
<td>2</td>
<td>March 2019</td>
<td>March 2019</td>
<td>March 2020</td>
<td>MCO</td>
<td>S. Archinal</td>
</tr>
<tr>
<td>Condition</td>
<td>Normal</td>
<td>Predicted Impacts</td>
<td>Level 1</td>
<td>Level 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-----------</td>
<td>--------</td>
<td>------------------</td>
<td>---------</td>
<td>---------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trigger</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Surface Water:</td>
<td>• Photographic record of Drainage Line 7.</td>
<td>Predicted impacts to drainage lines as per MSEC (2015) due to Longwalls 101 to 103, namely subsidence up to 2100 mm along DL7 with associated impacts and environment consequences, and negligible subsidence along other drainage lines (DL1 to DL6). Predicted groundwater impacts as per HydroSimulations (2015).</td>
<td>If performance indicators/triggers are exceeded for: • Subsidence impacts to drainage lines (Section 5.1). • Downstream surface water quality (Section 5.2). • Groundwater level and quality (Section 5.3).</td>
<td>If the subsidence impact performance measure for water resources (Table 5) has been exceeded, or is likely to be exceeded (e.g. greater than predicted impacts to drainage lines).</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Groundwater:</td>
<td>• Groundwater levels and quality as described in Section 4.5 and complex-wide Groundwater Monitoring Program.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Action</th>
<th></th>
<th>Implement Management Measures</th>
<th>Restoration/Contingency Phase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Establish baseline data. Includes:</td>
<td>• Conduct monitoring, consistent with Section 6 and the UG1 Longwalls 101 to 103 Subsidence Monitoring Program.</td>
<td>Implement management measures, as required, in accordance with Section 7.</td>
<td>Implement Contingency Plan, including notifications, as described in Section 8.</td>
</tr>
<tr>
<td>• Photographic record of Drainage Line 7.</td>
<td>• Implement management measures, as required, in accordance with Section 7.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Installation of recommended groundwater bore (standpipe) to the north of Longwall 101.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Frequency</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>• Photographic record of Drainage Line 7 prior to the commencement of Longwall 101.</td>
<td>Monitoring frequency consistent with Section 6.</td>
<td>As required, in accordance with Section 7.</td>
<td>As required, in accordance with Section 8.</td>
</tr>
<tr>
<td>• Installation of recommended groundwater bore (standpipe) to the north of Longwall 101 three months prior to the commencement of Longwall 101.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Position of Decision Making</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Environmental and Community Manager.</td>
<td>Environmental and Community Manager.</td>
<td>Environmental and Community Manager.</td>
<td>Environmental and Community Manager.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Document</th>
<th>Version</th>
<th>Issue</th>
<th>Effective</th>
<th>Review</th>
<th>Author</th>
<th>Approved</th>
</tr>
</thead>
<tbody>
<tr>
<td>MCO_UG1_LW101-103_WMP</td>
<td>2</td>
<td>March 2019</td>
<td>March 2019</td>
<td>March 2020</td>
<td>MCO</td>
<td>S. Archinal</td>
</tr>
</tbody>
</table>
ATTACHMENT 3

GROUNDWATER TECHNICAL REPORT
1. **INTRODUCTION**

The Moolarben Coal Complex is an open cut and underground coal mining operation located approximately 40 kilometres (km) north of Mudgee in the Western Coalfield of New South Wales (NSW) (Figure 1).

Moolarben Coal Operations Pty Ltd (MCO) has approval under Project Approval (08_0135) for the extraction of Longwalls 101-105 as part of the Underground Mine 1 (UG1) of the Moolarben Coal Complex. MCO is preparing the Extraction Plan covering Longwalls 101-103, which will outline the proposed management, mitigation, monitoring and reporting of potential subsidence impacts and environmental consequences from the secondary extraction of Longwalls 101-103. Additional information on the Moolarben Coal Complex and UG1 is provided in the main text of the Extraction Plan.

This report responds to a request from MCO for a groundwater assessment review of the Extraction Plan for UG1 Longwalls 101-103 of the Moolarben Coal Complex (Figure 1). The report will support the Water Management Plan component of the Longwalls 101-103 Extraction Plan and addresses relevant aspects of Project Approval (08_0135) Schedule 4 Condition 5 (h).
2. SCOPE OF WORK

This report pertains to Longwalls 101-103. It:

- provides a summary of outcomes of previous studies including hydrogeology, subsidence and potential groundwater impacts;
- proposes a monitoring program for monitoring the impacts of Longwalls 101-103 extraction;
- proposes trigger levels and management responses for the impacts of Longwalls 101-103 extraction;
- provides data analysis of key bores with respect to observed groundwater levels to date;
- confirms the location and saturated extent of the Tertiary Palaeochannel definition in the vicinity of Longwalls 101-103 following analysis of additional investigation bores; and
- provides conclusions in regard to how the analysis in this report supports the findings of previous groundwater modelling assessments.

3. PREVIOUS STUDIES

3.1 Background

Stage 1 at the Moolarben Coal Complex has been operating for several years and at full development will comprise three open cut mines (OC1, OC2 and OC3), a longwall underground mine (UG4), and mining related infrastructure (including coal processing and transport facilities) (Figure 2).

Stage 2 at the Moolarben Coal Complex has commenced and at full development will comprise one open cut mine (OC4), two longwall underground mines (UG1 and UG2) and mining related infrastructure (Figure 2).

The UG1 Underground Mine is a component of the approved Moolarben Coal Complex (Figure 2). The UG1 Underground Mine commenced first workings in April 2016 and is scheduled to commence secondary workings (longwall extraction) in October 2017 by longwall mining methods from the Ulan Seam within Mining Lease (ML) 1605, ML 1606, ML 1628, ML 1691 and ML 1715 (Figure 3).

The most recent assessment and approval for UG1 was the UG1 Optimisation Modification (Project Approval 08_0135 [Stage 2] Mod 2), which assessed the currently approved layout for UG1 (Longwalls 101-105) (Figure 3).

3.2 Hydrogeology

Several groundwater investigations, assessments and reviews have been undertaken since 2006 to assess the potential impacts of the approved Moolarben Coal Complex. Recent groundwater assessments undertaken for the approved Moolarben Coal Complex include:

- Moolarben Coal Complex Stage 2 PPR Groundwater Impact Assessment, November 2011 (RPS Aquaterra, 2011);
- Moolarben Coal Project Stage 1 Optimisation Modification Groundwater Assessment (AGE, 2013);
- Moolarben Coal Complex Stage 2 PPR Response to Submissions Additional Groundwater Impact Assessment (RPS Aquaterra, 2012); and
- Moolarben Coal Complex Optimisation Modification Groundwater Modelling Assessment (HydroSimulations, 2015).

RPS Aquaterra (2011) predicted that drawdown impacts on privately-owned bores from the approved Moolarben Coal Complex would not exceed 0.6 m and therefore would have negligible effect on groundwater users.

Groundwater monitoring and management at the Moolarben Coal Complex is conducted in accordance with the Water Management Plan, including the approved subcomponent Groundwater Management Plan (Appendix 3).
3.2.1 Hydrogeological Regime

The Moolarben Coal Complex area is located in the Western Coalfield on the north-western edge of the Sydney-Gunnedah Basin, which contains sedimentary rocks, including coal measures, of Permian and Triassic age. The dominant outcropping lithologies over the Moolarben Coal Complex are the Triassic Narrabeen Group (Wollar Sandstone) and the Permian Illawarra Coal Measures. The siltstones and sandstones of the Triassic Narrabeen Group form elevated, mesa-like incised plateaus associated with the Goulburn River National Park and the Munghorn Gap Nature Reserve.

3.2.2 Alluvial Aquifers

Quaternary alluvial deposits in the vicinity of the Moolarben Coal Complex are associated with Lagoon Creek, Goulburn River, Moolarben Creek and Wilpinjong Creek.

There is no ‘highly productive’ groundwater, as defined under the Aquifer Interference Policy (NSW Government, 2012), mapped in the vicinity of the Moolarben Coal Complex. The nearest ‘highly productive’ groundwater is a portion of the alluvial aquifer associated with Wilpinjong Creek downstream of the Wilpinjong Coal Mine.

3.2.3 Tertiary Palaeochannel Deposits

Tertiary palaeochannel deposits have been recognised in the Goulburn River diversion (at Ulan) and in the Murragamba and Wilpinjong creek valleys, with a maximum thickness of 40 m to 50 m. Palaeochannels are remnants of inactive river or stream channels that have been later filled in or buried by younger sediment. The infill sediments consist of poorly-sorted semi-consolidated quartzose sands and gravels in a clayey matrix.

Transient Electro-Magnetic (TEM) and Direct Current (DC) electrical resistivity surveys have been conducted to better define the thickness and the extent of the palaeochannel to the north-east of UG1. Following a subsequent program of targeted drilling, HydroSimulations has determined that the modified UG1 mine layout for Longwalls 101-103 would not pass beneath any water bearing palaeochannel sediments, as was considered in HydroSimulations (2015). A summary of the recent investigation into further definition of the palaeochannel is provided in Section 7.

3.2.4 Porous Rock Groundwater Systems

The porous rock groundwater systems consist of the Narrabeen Group sandstones and the Illawarra Coal Measures, consisting of coal seams, conglomerate, mudstones and siltstones.

None of the identified groundwater systems is a significant aquifer. The most permeable units are the Ulan Seam and Marrangaroo Conglomerate, while the sandstones of the Narrabeen Group are of lower permeability and are elevated above the Moolarben Coal Complex. The Illawarra Coal Measures also include low permeability mudstones and siltstones.

Recharge to the groundwater systems would occur primarily from direct rainfall and runoff infiltration. The Permian and Triassic groundwater systems in the vicinity of the Moolarben Coal Complex are primarily recharged at outcrops and subcrops. Where the Triassic and/or Permian strata are overlain by alluvium, colluvium or highly weathered bedrock, additional recharge may occur from these unconsolidated surficial materials.

There are no high priority culturally significant sites listed in the Water Sharing Plan for the Hunter Unregulated and Alluvial Water Sources 2009. However, a spring known as The Drip is a groundwater dependent ecosystem (GDE) with local cultural significance. This water feature is likely to be fed from perched water in the Wollar Sandstone and is not considered relevant to this Extraction Plan as it is located more than 6 km to the north of the UG1 mine and there is no credible mechanism for impact from the extraction of Longwalls 101-103.
3.3 Subsidence

Potential subsidence impacts for the Approved Layout for the UG1 longwalls (Longwalls 101-105) were assessed by MSEC (2015), and subsequently approved (subject to conditions), as part of the approved UG1 Optimisation Modification.

During the preparation of the Extraction Plan, MCO introduced a barrier pillar separating Longwalls 102A and 102B with a total length of approximately 300 m along the alignment of Longwall 102. In addition, for operational reasons MCO has reduced the length of Longwalls 101-103 by approximately 70 m to maintain a safe operating distance between the end of the longwall panels and the infrastructure (e.g. conveyors and associated electrical infrastructure) within the Main Headings.

MSEC (2017) reviewed the layout for Longwalls 101-103 for the Extraction Plan (referred to as the Extraction Plan Layout) and concluded:

“...the overall impact assessments for the natural and built features based on the Extraction Plan Layout are unchanged, or reduce compared to those based on the Approved Layout.”

The comparison of the maximum predicted subsidence parameters resulting from the extraction of Longwalls 101-103, based on the Extraction Plan Layout, with those based on the Approved Layout is provided in Table 1. The values are the maxima anywhere above longwall layouts.

It can be seen that the maximum predicted total subsidence parameters based on the Approved Layout are the same as those for the Extraction Plan Layout for Longwalls 101-103. Whilst the specific values of the maximum tilt and curvatures are not shown, due to these representing the localised irregular movements rather than the macro (i.e. overall) movements, these parameters do not change (MSEC, 2017).

Table 1. Comparison of Maximum Predicted Conventional Subsidence Parameters based on the Approved Layout and the Extraction Plan Layout

<table>
<thead>
<tr>
<th>Layout</th>
<th>Maximum Predicted Total Conventional Subsidence (mm)</th>
<th>Maximum Predicted Total Conventional Tilt (mm/m)</th>
<th>Maximum Predicted Total Conventional Hogging Curvature (km⁻¹)</th>
<th>Maximum Predicted Total Conventional Sagging Curvature (km⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Approved Layout (LW101-103)</td>
<td>2400</td>
<td>&gt; 100</td>
<td>&gt; 3</td>
<td>&gt; 3</td>
</tr>
<tr>
<td>Extraction Plan Layout</td>
<td>2400</td>
<td>&gt; 100</td>
<td>&gt; 3</td>
<td>&gt; 3</td>
</tr>
</tbody>
</table>

Source: MSEC (2017)

In regard to potential for subsidence-related surface cracking, MSEC (2017) states:

“The depths of cover over the underground mining areas vary from 47 m to 165 m. Where the depths of cover above Longwalls 101 to 103 are less than 100 m, surface cracking is expected to be typically in the order of 150 to 200 mm wide, but could be as large as 500 mm wide where the depths of cover are the shallowest. The surface crack widths are likely to be smaller where the depths of cover are greater, or where the surface cracks result from the travelling wave. Where the depths of cover above Longwalls 101 to 103 are 100 to 150 m, the surface crack widths are expected to be typically in the order of 100 to 150 mm wide.”

The extent of potential cracking predicted by MSEC (2017) for the Extraction Plan Layout is consistent with the Approved Layout.
3.4 Summary of Potential Groundwater Impacts

HydroSimulations (2015) presents potential impacts associated with the Approved Layout. The Extraction Plan Layout would result in the same, or lower, potential impacts in comparison to the Approved Layout (as assessed and approved for the UG1 Optimisation Modification), given:

- The Longwalls 101-103 lengths have been reduced from those that were simulated by approximately 70 m.
- MSEC (2017) predicts potential subsidence impacts for the Extraction Plan Layout would be the same or lower than those for the Approved Layout.
- Additional drilling investigation has confirmed the assumptions of the HydroSimulations (2015) modelling with respect to the extent and saturation of the palaeochannel.

A summary of potential groundwater impacts is provided below, with focus on Longwalls 101-103 where possible (i.e. it is difficult to isolate impacts from the approved cumulative impacts of the Moolarben Coal Complex open cuts and Wilpinjong and Ulan Coal Mines).

3.4.1 Risk Assessment

On 8 December 2016, a team consisting of MCO operational, technical and environmental staff and specialist consultants participated in a facilitated risk assessment workshop on the UG1 Longwalls 101-103 inclusive.

No follow-up actions that were not already completed, relevant to groundwater, were identified. The risks identified by the Risk Assessment team were considered to be as low as reasonably practicable (ALARP).

3.4.2 Privately Owned Bores

A bore census has been undertaken to identify private groundwater use in the vicinity of the Moolarben Coal Complex.

Only three bores were identified during the census survey that are located on private property relevant to the assessment of Moolarben Coal Complex mining effects. Two of these bores (census points SP39 and SP42) are shallow low-yielding bores located more than 7 km up-dip and south-west of UG1 Longwalls 101-103 and as a result these bores would not be impacted. The remaining private bore (census point SP49) is located more than 6 km to the north of UG1 Longwalls 101-103 and is a relatively shallow bore (24 m) developed in Triassic strata. Negligible drawdown impact due to the Moolarben Coal Complex mining has been predicted at this bore.

A further private bore developed in Triassic strata is located over 12 km north of the UG1 (Work ID GW064580). A negligible drawdown is predicted at this bore from Moolarben Coal Complex mining related effects (i.e. all approved mining operations, not UG1 in isolation). This bore is 70 m deep and is predicted to have an additional drawdown impact of up to 5 m as a result of mining at the Ulan Mine Complex (Mackie Environmental Research, 2009).

Predicted drawdown impacts from the approved Moolarben Coal Complex on privately owned bores within 10 km of the Moolarben Coal Complex would not exceed 0.6 m and therefore the Moolarben Coal Complex would have negligible effect on groundwater users. The predicted maximum drawdown impact of 0.6 m is less than the 2 m minimal impact consideration for drawdown impacts at an existing bore specified in the NSW Aquifer Interference Policy.

The location and baseline condition of each of the privately owned bores are summarised in Table 2.

---

1 This does not include bores located on private properties to the west of the Moolarben Coal Complex that are developed in the outcropping basement rocks or associated regolith that underlie the Sydney Basin and that are hydraulically disconnected from the hydrogeological regime of the Sydney Basin sedimentary strata and its associated alluvial sediments.
### Table 2. Baseline Condition of Privately Owned Bores

<table>
<thead>
<tr>
<th>Census Point ID</th>
<th>Easting</th>
<th>Northing</th>
<th>Bore Type</th>
<th>Licence No.</th>
<th>Work ID</th>
<th>Hydrogeological Unit</th>
<th>Water Level (m AHD)</th>
<th>EC (µS/cm)</th>
<th>pH</th>
<th>Yield (L/s)</th>
<th>Distance to LW101-103</th>
</tr>
</thead>
<tbody>
<tr>
<td>SP39-40</td>
<td>760393</td>
<td>6414282</td>
<td>Stock</td>
<td></td>
<td>-</td>
<td>Permian coal measures</td>
<td>526</td>
<td>1020 – 1598</td>
<td>6.9 – 8.0</td>
<td>-</td>
<td>&gt; 7 km</td>
</tr>
<tr>
<td>SP42-43</td>
<td>761294</td>
<td>6414948</td>
<td>Stock</td>
<td></td>
<td>-</td>
<td>Permian coal measures</td>
<td>516</td>
<td>1450 – 1990</td>
<td>6.3 – 7.4</td>
<td>-</td>
<td>&gt; 7.9 km</td>
</tr>
<tr>
<td>SP49</td>
<td>765308</td>
<td>6451971</td>
<td>Domestic</td>
<td>80BL236762</td>
<td>GW800279</td>
<td>Triassic Narrabeen Group</td>
<td>375.1</td>
<td>730</td>
<td>6.0</td>
<td>-</td>
<td>&gt; 6 km</td>
</tr>
<tr>
<td>-</td>
<td>764120</td>
<td>6438504</td>
<td>Stock &amp; Domestic</td>
<td>20BL137225</td>
<td>GW064580</td>
<td>Triassic Narrabeen Group</td>
<td>-</td>
<td>-</td>
<td>0.63</td>
<td>&gt; 12 km</td>
<td></td>
</tr>
</tbody>
</table>

EC = electrical conductivity; µS/cm = microSiemens per centimetre; m AHD = metres Australian Height Datum

#### 3.4.3 Groundwater Modelling

The groundwater assessment by HydroSimulations (2015) used MODFLOW-SURFACT groundwater modelling software to assess the potential cumulative impacts on groundwater resources of Moolarben Coal Complex open cut mining and UG1 underground mining for Longwalls 101-105, as well as adjacent mining operations (Ulan Mine Complex and Wilpinjong Coal Mine).

The model domain is discretised into 1,166,592 cells comprising 434 rows, 336 columns and 8 layers. The dimensions of the model cells are varied from 100 m in the mining areas to 500 m near the boundaries. The model extent is 49.8 km from west to east (Eastings 740000-789800) and 54.7 km from south to north (Northings 6405300-6460000), covering an area of approximately 2,725 km².

Based on the conceptual hydrogeology described in the PPR report (RPS Aquaterra, 2011), the following layers were defined for the model:

- Layer 1: Quaternary alluvium, Tertiary palaeochannel and Weathered bedrock/ regolith.
- Layer 2: Triassic (upper) or Permian where Triassic is eroded.
- Layer 3: Triassic (lower) or Permian where Triassic is eroded.
- Layer 4: Permian (upper).
- Layer 5: Permian (middle).
- Layer 6: Permian (lower).
- Layer 7: Ulan Seam.
- Layer 8: Marrangaroo Formation, Ulan Granite and Volcanics.

As determined by RPS Aquaterra (2011), Layers 5-7 for the mid-Permian, lower-Permian and the Ulan Seam were taken to be fractured in the model across UG1.

Calibration was carried out in a transient mode (using time slices) to achieve a history match to the reported observed groundwater levels during the period 1987 to 2008 (RPS Aquaterra, 2011). The calibration was done against 1,227 target water levels, using a combination of auto-sensitivity analysis and manual modification of zones and model parameters. These targets were distributed throughout the model layers in the form of 145 groundwater hydrographs. Calibration achieved a satisfactory Scaled Root Mean Square (SRMS) performance measure of about 8%, and the mass balance error was less than 0.1%.

The prediction period ran from July 2008 to June 2042 to simulate extraction for the full duration of approved Moolarben Coal Complex mining.

#### 3.4.4 Groundwater Modelling Results

A summary of groundwater impacts is provided below.

The groundwater model developed using MODFLOW-SURFACT software (HydroSimulations, 2015) has been used to predict responses to UG1 longwall extraction of coal from the Ulan Seam for Longwalls 101-105 over a period of nine years. Each model simulation included the cumulative effects of Moolarben open cut mining as well as Ulan and Wilpinjong operations.
Predicted drawdowns in model Layer 1 for the alluvium/regolith and the Tertiary palaeochannel at the end of Longwall 105 are shown in Figure 4. The model predicts less than 0.5 m drawdown in Layer 1 adjacent to the northern edge of the UG1 longwall panels. Given the drawdown minimal impact consideration of 2 m in the Aquifer Interference Policy, the effect on alluvial and regolith water levels due to UG1 mining is expected to be negligible. Drawdowns greater than 2 m are predicted in Layer 1 to the north-west of UG1, and to the east of UG1 in Murragamba Valley. However, these approved drawdowns are due to approved OC1 and OC4 mining and should not be attributed to UG1.

In summary, and consistent with previously approved impacts:

- No private bores are likely to be affected by 2 m drawdown or more.
- No drawdown is anticipated in the Upper Triassic (or Lower Triassic) as these sediments are inherently dry.
- With the exception of drawdown at the level of the Ulan Seam in the north-eastern extents of UG1, there would be no discernible change in drawdown resulting from UG1 extraction.
- The Ulan Seam has no productive water use other than for mining purposes. No change to beneficial use category is anticipated.
4. MONITORING PROGRAM

4.1 Groundwater Monitoring

Groundwater monitoring at the Moolarben Coal Complex is currently undertaken in accordance with the complex-wide Groundwater Management Plan (GMP) (MCO, 2015). The objectives of the GMP are to establish baseline groundwater quality and water level data and to implement a program of data collection that can be utilised to assess potential impacts of mining activities on the groundwater resources of the area.

In October 2016 a revised version of the GMP was provided by MCO to DPI Water and the Department of Planning and Environment, which describes MCO’s proposed improvements to the current GMP. The description of monitoring and management below is consistent with the revised GMP dated October 2016.

The groundwater monitoring network currently consists of 51 monitoring sites distributed across all major hydrogeological units, comprising 41 standpipe (SP) sites and 10 multi-level vibrating wire piezometer (VWP) sites. The standpipe piezometers can be used for monitoring water level either manually or with an automated datalogger, as well as for collection of water samples for groundwater quality monitoring purposes. The VWPs are grouted and therefore can only be used for monitoring groundwater pressures.

A sub-set of the monitoring network which is most relevant to UG1 Longwalls 101-103 is detailed in Table 3, with bore locations provided in Figure 5. PZ156 and PZ157 will require grouting prior to mining and will be removed from the monitoring program.

The assessment of riparian vegetation undertaken by Ecovision Consulting for the Stage 2 EA did not indicate any specific riparian plant communities that could be considered groundwater dependent ecosystems (GDEs) and therefore no specific groundwater monitoring for riparian vegetation communities is required.

4.2 Groundwater Inflows

Since commencement of UG1 first workings in April 2016, groundwater inflows have been monitored by means of flowmeters on dewatering lines along the headings either side of Longwall 101 (Figure 5).

Water supply to the underground workings is also monitored and will be considered when quantifying groundwater inflows.

4.3 Groundwater Levels

Table 3 details the monitoring program for groundwater levels at monitoring bores relevant to UG1 Longwalls 101-103. The piezometers will be monitored manually on a monthly basis, or continuously by means of automatic dataloggers, as detailed in Table 3.

As monitoring sites PZ127 and PZ157 within the UG1 Longwalls 101-103 area have piezometers in the Ulan Seam, monitoring might be disrupted as mining progresses in these areas. The more elevated piezometers in P127 have more chance of survival.
Table 3. Groundwater Bores Relevant to UG1 Longwalls 101-103

<table>
<thead>
<tr>
<th>Bore</th>
<th>Type</th>
<th>Depth (m)</th>
<th>Screened Interval (m)</th>
<th>Lithology Screened</th>
<th>Water Level Monitoring Frequency</th>
<th>Historical Water Level Range (m)</th>
<th>Water Quality Monitoring Frequency</th>
<th>Date Established</th>
<th>Licence No.</th>
<th>Easting (m)</th>
<th>Northing (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PZ 127</td>
<td>VWP</td>
<td>152</td>
<td>43</td>
<td>Triassic</td>
<td>Datalog Reported monthly</td>
<td>Dry</td>
<td>N/A</td>
<td>23/11/2007</td>
<td>20BL173935</td>
<td>762 799</td>
<td>6424948</td>
</tr>
<tr>
<td></td>
<td>VWP</td>
<td>68</td>
<td>Permian overburden</td>
<td></td>
<td>Datalog Reported monthly</td>
<td>47.2 - 52.1</td>
<td>N/A</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>VWP</td>
<td>112</td>
<td>Permian overburden</td>
<td></td>
<td>Datalog Reported monthly</td>
<td>84.7 - 101.3</td>
<td>N/A</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>VWP</td>
<td>141</td>
<td>Ulan seam</td>
<td></td>
<td>Datalog Reported monthly</td>
<td>103.4 - 126.1</td>
<td>N/A</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PZ 130</td>
<td>VWP</td>
<td>111</td>
<td>38.5</td>
<td>Permian overburden</td>
<td>Datalog Reported monthly</td>
<td>37.7 - 40.4</td>
<td>N/A</td>
<td>29/11/2007</td>
<td>20BL173935</td>
<td>760 940</td>
<td>6422438</td>
</tr>
<tr>
<td></td>
<td>VWP</td>
<td>64</td>
<td>Permian overburden</td>
<td></td>
<td>Datalog Reported monthly</td>
<td>51.6 - 58.9</td>
<td>N/A</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>VWP</td>
<td>97</td>
<td>Ulan seam</td>
<td></td>
<td>Datalog Reported monthly</td>
<td>79.3 - 88.2</td>
<td>N/A</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PZ 186</td>
<td>SP</td>
<td>114</td>
<td>108 - 114</td>
<td>Permian overburden</td>
<td>Datalog Reported monthly</td>
<td>8.47 - 17.21</td>
<td>6 months</td>
<td>6/05/2009</td>
<td>20BL173935</td>
<td>764 788</td>
<td>6425865</td>
</tr>
<tr>
<td>PZ 187</td>
<td>SP</td>
<td>22</td>
<td>15 - 21</td>
<td>Palaeochannel Alluvium</td>
<td>Datalog Reported monthly</td>
<td>0.78 - 2.88</td>
<td>6 months</td>
<td>7/05/2009</td>
<td>20BL173935</td>
<td>764 784</td>
<td>6425871</td>
</tr>
<tr>
<td>PZ 188</td>
<td>SP</td>
<td>18.5</td>
<td>12 - 18</td>
<td>Palaeochannel Alluvium</td>
<td>Datalog Reported monthly</td>
<td>7.29 - 8.40</td>
<td>6 months</td>
<td>14/05/2009</td>
<td>20BL173935</td>
<td>764 478</td>
<td>6426084</td>
</tr>
<tr>
<td>PZ 189</td>
<td>SP</td>
<td>65</td>
<td>59 - 95</td>
<td>Permian overburden</td>
<td>Datalog Reported monthly</td>
<td>10.41 - 14.90</td>
<td>6 months</td>
<td>20/05/2009</td>
<td>20BL173935</td>
<td>764 503</td>
<td>6426089</td>
</tr>
<tr>
<td>PZ 179</td>
<td>VWP</td>
<td>145</td>
<td>29</td>
<td>Triassic</td>
<td>Datalog Reported monthly</td>
<td>24.6 - 28.0</td>
<td>N/A</td>
<td>4/07/2008</td>
<td>20BL173935</td>
<td>764 688</td>
<td>6426599</td>
</tr>
<tr>
<td></td>
<td>VWP</td>
<td>33</td>
<td>Permian overburden</td>
<td></td>
<td>Datalog Reported monthly</td>
<td>25.8 - 32.7</td>
<td>N/A</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>VWP</td>
<td>145</td>
<td>Ulan seam</td>
<td></td>
<td>Datalog Reported monthly</td>
<td>28.9 - 71.4</td>
<td>N/A</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
4.4 Groundwater Quality

Table 4 details the monitoring program for groundwater quality at monitoring bores relevant to UG1 Longwalls 101-103. Samples are taken six-monthly and sent for laboratory analysis of key parameters (Table 4).

Field measurements of EC and pH are recorded at the time of water quality sampling conducted for relevant bores. No change is required for the Longwalls 101-103 Extraction Plan.

Table 4. Groundwater Quality Monitoring Program

<table>
<thead>
<tr>
<th>Class</th>
<th>Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical parameters</td>
<td>EC, Total Dissolved Solids (TDS), Total Suspended Solids (TSS) and pH</td>
</tr>
<tr>
<td>Major cations</td>
<td>calcium, magnesium, sodium, potassium</td>
</tr>
<tr>
<td>Major anions</td>
<td>carbonate, bicarbonate, chloride and sulphate</td>
</tr>
<tr>
<td>Dissolved metals</td>
<td>aluminium, arsenic, boron, cobalt, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, selenium, silver and zinc</td>
</tr>
<tr>
<td>Nutrients</td>
<td>ammonia, nitrate, phosphorus, reactive phosphorus</td>
</tr>
<tr>
<td>Other</td>
<td>fluoride</td>
</tr>
</tbody>
</table>

4.5 Streamflow

Streamflow monitoring forms part of the surface water monitoring regime. A data sharing agreement has been established between MCO, Ulan Coal Mines Limited and Wilpinjong Coal Pty Limited. The streamflow data from this program will inform the monitoring of stream baseflows (i.e. net groundwater discharge to the stream system) throughout the life of the Moolarben Coal Complex. Streamflow monitoring is discussed further in the existing complex-wide Surface Water Management Plan.

4.6 Climate Monitoring

Climate monitoring data are collected from an automatic weather station on site.

The recorded rainfall data are used to differentiate between natural groundwater level variations caused by rainfall induced recharge, and abstraction induced variations due to mining or groundwater pumping\(^2\). For shallow unconfined aquifers there is a direct and often immediate relationship between rainfall and groundwater level. For deeper aquifers this relationship often holds but with a time-lagged and muted response.

\(^2\) By calculation of rainfall residual mass (cumulative deviation from the mean), and observation of abstraction timing.
5. TRIGGER LEVELS AND MANAGEMENT RESPONSES

MCO evaluates the environmental performance of the Moolarben Coal Complex against the predictions of impact made in the Stage 1 and Stage 2 Environmental Assessment documents and the performance measures described in the complex-wide GMP dated October 2016.

Periodic review of performance is undertaken by comparison of observed monitoring results against model predictions. The performance is assessed in terms of specific parameters by the application of trigger levels which are used to initiate a response action, as detailed in the following sections.

MCO has established trigger values to determine the need for investigation and possible response actions for potential impacts to groundwater levels and quality in the alluvial and Triassic groundwater systems.

The Permian strata are already extensively affected by past mining, are predicted to undergo significant further impact from ongoing mining at the Moolarben Coal Complex, the Ulan Mine Complex and the Wilpinjong Coal Mine, and contain groundwater of generally poor quality. Accordingly, trigger levels have not been set for the monitoring piezometers screened in the Permian.

5.1 Groundwater Quality Triggers

The ANZECC (2000) guidelines for Fresh and Marine Water Quality apply to the quality of both surface waters and groundwaters as they have been developed to protect environmental values relating to above-ground uses such as irrigation and stock use.

ANZECC (2000) recommends that wherever possible site-specific data be used to define trigger values for physical and chemical factors which can adversely impact the environment, rather than using ANZECC guideline values.

Groundwater monitoring results indicate that baseline values of pH and EC in the vicinity of the Moolarben Coal Complex vary across a wide range and can be outside the ANZECC (2000) guideline values for ecosystem protection. Therefore, site specific trigger levels based on the baseline data have been developed for monitoring the impact of the Moolarben Coal Complex.

5.1.1 Salinity Triggers

Table 1 of the NSW Aquifer Interference Policy sets out the minimal impact considerations for aquifer interference activities for less productive groundwater sources, including (inter alia):

Any change in the groundwater quality should not lower the beneficial use category of the groundwater source beyond 40m from the activity.

The Water Sharing Plan for the Hunter Unregulated and Alluvial Water Sources 2009 which regulates the alluvial water sources does not designate beneficial uses for the alluvial aquifers in the vicinity of the Moolarben Coal Complex. The Water Sharing Plan for the North Coast Fractured and Porous Rock Groundwater Sources does not designate beneficial uses for the non-alluvial groundwater (i.e. groundwater within the porous rock water groundwater system) in the vicinity of the Moolarben Coal Complex.

The following beneficial uses were recommended by the National Water Quality Management Strategy Guidelines for Groundwater Protection in Australia for major (or significant) aquifers and have been adopted by the DPI Water in its Groundwater Quality Protection Policy (Department of Land and Water Conservation, 1998):

- ecosystem protection;
- recreation and aesthetics;
- raw water for drinking water supply; and
- agricultural water and industrial water.
The *National Land and Water Resources Audit* (Murray Darling Basin Commission, 2005) specified groundwater quality ranges for beneficial use categories based on salinity (Table 5). These salinity-based categories generally align with the beneficial uses within the NSW *Groundwater Quality Protection Policy*.

### Table 5. Groundwater Quality Categories: Electrical Conductivity

<table>
<thead>
<tr>
<th>Beneficial Use</th>
<th>Quality Range</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potable</td>
<td>Up to 800 µS/cm (500 mg/L TDS)*</td>
<td>Suitable for all drinking water and uses.</td>
</tr>
<tr>
<td>Marginal Potable</td>
<td>800-2,350 µS/cm (500-1,500 mg/L TDS)*</td>
<td>At the upper level this water is at the limit of potable water, but is suitable for watering of livestock, irrigation and other general uses.</td>
</tr>
<tr>
<td>Irrigation</td>
<td>2,350-7,800 µS/cm (1,500-5,000 mg/L TDS)*</td>
<td>At the upper level, this water requires shandying for use as irrigation water or to be suitable for selective irrigation and watering of livestock.</td>
</tr>
<tr>
<td>Saline</td>
<td>7,800-22,000 µS/cm (5,000-14,000 mg/L TDS)*</td>
<td>Generally unsuitable for most uses. It may be suitable for a diminishing range of salt-tolerant livestock up to about 6,500mg/L [~10,150 µS/cm] and some industrial uses.</td>
</tr>
<tr>
<td>Highly Saline</td>
<td>&gt; 22,000 µS/cm (14,000 mg/L TDS)*</td>
<td>Suitable for coarse industrial processes up to about 20,000 mg/L [~31,000 µS/cm].</td>
</tr>
</tbody>
</table>


Salinity triggers have been developed based on the 95th percentile baseline salinity level recorded at each relevant bore location. Should a measured salinity level exceed the trigger for two consecutive monitoring events, and the measured salinity is in a lower beneficial use category (Table 5) than the trigger level, then the groundwater investigation protocol described in the complex-wide GMP will be initiated.

The bores in Table 6 (a sub-set of those in the complex-wide GMP) are considered to be those relevant for investigating potential changes in groundwater quality due to longwall mining in Longwalls 101-103. The recommended salinity triggers (from the revised GMP dated October 2016) for each relevant bore are presented in Table 6. These values are lower than the current GMP (2015) trigger values.

### Table 6. Salinity and pH Trigger levels

<table>
<thead>
<tr>
<th>Bore</th>
<th>Depth (m)</th>
<th>Lithology Screened</th>
<th>Historical lab EC (5th to 95th percentile) (µS/cm)*</th>
<th>EC Trigger Level (µS/cm)</th>
<th>Beneficial Use Category Based on Lab EC 95th Percentile</th>
<th>pH Trigger Level (5th to 95th percentile)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>PZ186</td>
<td>114</td>
<td>Permian Overburden</td>
<td>336-465 (370)</td>
<td>465</td>
<td>Potable</td>
<td>5.9 – 7.8 (6.4)</td>
</tr>
<tr>
<td>PZ187</td>
<td>22</td>
<td>Palaeochannel Alluvium</td>
<td>170-656 (201)</td>
<td>656</td>
<td>Potable</td>
<td>5.4 – 7.1 (5.8)</td>
</tr>
<tr>
<td>PZ188</td>
<td>18.5</td>
<td>Palaeochannel Alluvium</td>
<td>198-394 (245)</td>
<td>394</td>
<td>Potable</td>
<td>4.7 – 6.9 (5.5)</td>
</tr>
<tr>
<td>PZ189</td>
<td>65</td>
<td>Permian Overburden</td>
<td>311-408 (375)</td>
<td>408</td>
<td>Potable</td>
<td>5.6 – 6.8 (6.1)</td>
</tr>
</tbody>
</table>

*NB. Historical values in brackets are median values

#### 5.1.2 pH Triggers

pH triggers have been developed from the 5th and 95th percentile baseline pH levels recorded at each bore location considered relevant to Longwalls 101-103. Should a measured pH level exceed the trigger for two consecutive monitoring events, then the groundwater investigation protocol described in the complex-wide GMP will be initiated. Recommended trigger values (from the revised GMP dated October 2016) are in Table 6.
5.2 Groundwater Level Triggers

Triggers for measured groundwater levels have been developed based on the minimal impact considerations in the NSW Aquifer Interference Policy.

There is no ‘highly productive’ groundwater, as defined under the Aquifer Interference Policy, mapped in the vicinity of the Moolarben Coal Complex. The nearest ‘highly productive’ groundwater is a portion of the alluvial aquifer associated with Wilpinjong Creek downstream of the Wilpinjong Coal Mine.

The NSW Aquifer Interference Policy describes the following minimal impact considerations for less productive groundwater sources:

- Less than or equal to 10% cumulative variation in the water table, allowing for typical climatic “post-water sharing plan” variations, 40m from any:
  - (a) high priority groundwater dependent ecosystem; or
  - (b) high priority culturally significant site;
  - listed in the schedule of the relevant water sharing plan.

- A maximum of a 2m decline cumulatively at any water supply work.

There are no high priority groundwater dependent ecosystems or high priority culturally significant sites identified in the Water Sharing Plan for the Hunter Unregulated and Alluvial Water Sources 2009 or Water Sharing Plan for the North Coast Fractured and Porous Rock Groundwater Sources in the vicinity of the Moolarben Coal Complex.

The groundwater investigation protocol detailed in the complex-wide GMP would be initiated in cases where the groundwater monitoring program identifies the potential for a greater than 2 m reduction in the groundwater level at a private bore, determined against groundwater level hydrograph trends, so that a 2 m drawdown attributable to the cumulative impact of mining at the Moolarben Coal Complex, Ulan Mine Complex and/or Wilpinjong Coal Mine will be an effect superimposed on trends due to either climatic effects and/or other external cause.

Water level triggers have been developed for alluvium monitoring bores listed in Table 7. The bores in Table 7 (which are a sub-set of those in the complex-wide GMP) have been selected as investigation triggers for potential changes in groundwater levels due to underground mining in Longwalls 101-103. The investigation trigger levels (developed from an analysis of historical groundwater levels) are also provided in Table 7 and have been set at 2 m below the minimum water level reported during the baseline monitoring period.

<table>
<thead>
<tr>
<th>Alluvium Piezometer Number</th>
<th>Base of Alluvium/Tertiary Palaeochannel (m AHD)</th>
<th>Interval/Level Monitored (mbgl)</th>
<th>Minimum Observed Groundwater Level/Pressure (mbgl)</th>
<th>Trigger Level (m AHD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PZ187</td>
<td>&lt;396.5</td>
<td>15-21</td>
<td>2.9</td>
<td>415.7</td>
</tr>
<tr>
<td>PZ188</td>
<td>403.6</td>
<td>12-18</td>
<td>8.4</td>
<td>415.2</td>
</tr>
</tbody>
</table>

The above trigger levels are intended to trigger an investigation to determine whether the cause of the water level/pressure decline is caused by MCO’s mining activity, excluding borefield pumping, and to recommend an appropriate response action. Prior to initiating a response action, an exceedance of a trigger level will need to occur for at least two successive monthly monitoring rounds, to eliminate possible anomalous readings.
6. DATA ANALYSIS

6.1 Key Alluvial Bores

The key alluvium monitoring bores pertinent to Longwalls 101-103 are:

- PZ187 – 1.0 km from the takeoff line for Longwall 103; and
- PZ188 – 0.8 km from the takeoff line for Longwall 103.

Time-series graphs of groundwater level, EC and pH are provided in Figure 6 and Figure 7.

PZ187 and PZ188 have similar groundwater level response which correlates well with the rainfall trend represented by the “Moolarben CRD” on the figures, without any significant time lag. This suggests that the water levels are controlled by direct vertical infiltration of rain water, with possible contributions from coincident streamflow down Wilpinjong Creek.

The groundwater quality is fresh at both sites.

6.2 Key Permian Overburden Bores

The key Permian overburden monitoring bores pertinent to Longwalls 101-103 are:

- PZ186 – 1.0 km from the takeoff line for Longwall 103;
- PZ189 – 0.8 km from the takeoff line for Longwall 103.

Time-series graphs of groundwater level, EC and pH are provided in Figure 8 and Figure 9.

PZ186 and PZ189 have similar groundwater level patterns. The responses correlate well with the rainfall trend with a time lag of about 8 months. The peak water level at PZ186 is about 8 m lower than the peak in the overlying alluvium bore (PZ187). The peak water level at PZ189 is about 3 m lower than the peak in the overlying alluvium bore (PZ188). This suggests that the water levels are controlled by direct vertical infiltration of rain water through the alluvium.

In late 2016, there was an abrupt decline in groundwater level by about 1 m. This could be due to the UG1 first workings, but the event coincided with a similarly abrupt change in the rainfall trend.

The groundwater quality is fresh at both sites. At PZ186, the EC is about the same as in the overlying alluvium. At PZ189, the EC is about double that in the overlying alluvium.

6.2 Key Ulan Seam Bores

The key Ulan Seam monitoring bores pertinent to Longwalls 101-103 are:

- PZ156 – about 7 m north of the takeoff line for Longwall 101;
- PZ157 – about 115 m south of the takeoff line for Longwall 103.

Time-series graphs of groundwater level, EC and pH are provided in Figure 10 and Figure 11.

PZ156 and PZ157 have almost identical groundwater level responses, with a head difference of only 1 m. The responses correlate very well with the rainfall trend with a time lag of about 12-18 months. This suggests that the water levels are controlled by vertical infiltration of rain water into the coal seam at outcrop/subcrop, with lateral migration of a pressure response through the seam.

In late 2016, there was an abrupt decline in groundwater level by about 5 m. This was due to the UG1 first workings, and preceded a smaller abrupt change in the rainfall trend.

The groundwater EC has tended to increase with rising groundwater level, with recent measurements at the boundary between “potable” and “marginal potable” quality (800 µS/cm).
Both these bores will be unserviceable following mining.

6.2 Key VWP Bores

The key multi-level VWP monitoring bores pertinent to Longwalls 101-103 are:

- PZ127 – over the pillar between Longwalls 102 and 103;
- PZ130 – over the pillar between Longwalls 104 and 105;
- PZ179 – 1.3 km from the takeoff line for Longwall 102.

Time-series graphs of groundwater level, EC and pH are provided in Figures 12-14.

At each site there is a fairly consistent vertical gradient indicative of downwards groundwater movement.

At PZ127, only the Ulan Seam VWP shows any correlation with rainfall trend, and it appears considerably lagged in time. A probable drawdown of about 1 m due to UG1 first workings is evident in the lower Permian in late 2016.

PZ130 ought to be affected by OC2 mining, but there is no evidence of a mining effect in the groundwater responses. In addition, the head in the Ulan Seam (about 450 mAHDb) appears anomalously high.

PZ179 has a lagged rainfall response in the Ulan Seam, and has a probable UG1 mining effect of about 3 m drawdown in late 2016. A smaller drawdown at the same time is apparent in the upper Permian. The middle Permian sensor appears anomalous as its head is out of sequence with neighbouring sensors and should be removed from the monitoring program.
7. TERTIARY PALAEOCHANNEL DEFINITION

7.1 Objective

Further investigation into the extent and saturation status of the Tertiary palaeochannel has been undertaken to address an additional condition placed on the approval of the UG1 Extraction Plan Water Management Plan, which requires a program to:

1. confirm the location and saturated extent of the palaeochannel adjacent to the extents of underground 1 second workings, including drilling of additional investigation bores;
2. validate, and if necessary revise, the groundwater model for the palaeochannel; and
3. monitor and report on the groundwater impacts of underground 1 second workings on the palaeochannel; and a program to monitor and report on the predicted groundwater impacts on the palaeochannel adjacent to underground 1 boundary.

7.2 Field Investigations

The palaeochannel extent, sediment thickness and relative permeabilities in the UG1 Optimisation Modification groundwater model were inferred from a geophysical survey comprising transient electromagnetic (TEM) and direct current (DC) electrical resistivity profiling (Groundwater Imaging, 2014) and available exploration records. Both geophysical methods give estimates of the true electrical resistivity of the subsurface, generally to limiting depths of 50-70 m. The resistivity of a material is determined primarily by water content, water quality and lithology. High resistivity (>100 ohm metres) is indicative of freshwater sand, unsaturated sand or arenaceous rock (e.g. sandstone). Low resistivity (<10 ohm metres) is indicative of saltwater sand, clay, or argillaceous rock (e.g. shale). Accordingly, the interpretation of TEM or DC surveys is ambiguous in terms of the causative factors.

Figure 15 shows the TEM true resistivity pattern (at approximate depth 12 m) in relation to three DC resistivity survey lines (DC 1, DC 2 and DC 3) and Longwalls 101-105. The DC lines were located in areas of potential palaeochannel sediments at the northern ends of Longwalls 101-105.

The revised outline of the palaeochannel (HydroSimulations, 2015) at that time is shown in Figure 16 in relation to the 12 m depth TEM resistivity pattern and two pre-TEM key bores. Three discontinuous zones of potentially good quality palaeochannel sediments were interpreted. One of the isolated pockets of sediments occurs at the north-eastern end of Longwalls 101-102. No palaeochannel was detected at the north-eastern end of Longwall 103, but the palaeochannel was detected above the proposed mains at the north-eastern end of Longwalls 104-105 and in the vicinity of the takeoff lines there. Overall, HydroSimulations (2015) considered that the extended longwall panels would not pass beneath any water-bearing palaeochannel sediments.

To support the interpretation of the revised extent of the palaeochannel, a drilling program was undertaken at 7 sites at so-called post-TEM bores at the ends of Longwalls 101-103. The post-TEM bores relevant to Longwalls 101-103 are shown in Figure 16. The bores are aligned along Transects A and B as marked on Figure 16.

Figure 17 and Figure 18 show detailed comparisons of bore logs and downhole geophysical logs (primarily gamma and resistivity) for Transect A and Transect B, respectively. While there can be ambiguity in the physical description of cuttings, the geophysical logs are usually more diagnostic. Gamma logs, which indicate relative potassium content, show a consistent sharp increase from low to high counts at or near the base of the palaeochannel. This is marked by a green circle on each plot. Gamma counts are usually good indicators of relative sand/clay content, with higher counts for higher clay content. However, in these logs, the gamma counts are consistently low in palaeochannel sediments even though clay is often recorded as the dominant lithology, or the sands and gravels are recorded as being in a clayey matrix. This observation suggests that the type of clay is low in potassium (as is known to occur in the Namoi Valley).
Resistivity logs are particularly useful indicators of saturation, as no reading can be taken until the sensor is immersed in water. The commencement of each resistivity log, therefore, gives the groundwater level at the time of logging. In combination with gamma logs, the resistivity log can often be used to discriminate between saline water and clay as the causes of low resistivity readings. Taken together, the resistivity and gamma logs provide a reliable means of measuring the saturated thickness of palaeochannel sediments. Two holes on Transect B were found to be completely dry within the palaeochannel sediments: MCOL396 and MCOL398 (Figure 18).

Visual impressions of the subsurface geology (to a maximum depth of 40 m) are provided in Figure 19 and Figure 20, respectively, for Transect A and Transect B. The palaeochannel is interpreted to comprise gravel, coarse sand, sand and clay lithologies. On each figure is marked the saturated thickness derived from the resistivity log. The degree of saturation is variable, with several holes being almost or completely dry, and all with a low saturated thickness fraction. On both sections is a superficial clay zone of about 10 m thickness.

The interpreted saturated thickness of palaeochannel sediments is given in Figure 21. Of particular interest are the values of zero and 2 m near the northern ends of Longwalls 101 and 102, in agreement with earlier conclusions by RPS Aquaterra (2011) and HydroSimulations (2015) that the palaeochannel here is essentially unsaturated. Near the takeoff line of Longwall 101, approximately 2 m of water has been recorded, which is about 7 percent of the palaeochannel thickness. For the seven sites near the end of Longwalls 101-102, the statistics for the saturated thickness fraction (i.e. percentage of water compared to total thickness of palaeochannel) are: range 0% to 31%; mean 9%; median 4%.

7.3 Summary of Findings – Palaeochannel Definition

With respect to Item [1] in Section 7.1 [Objectives], it is proposed that a reasonable definition of “saturated extent” be that volume of the palaeochannel where the Tertiary sediments are saturated to more than 10 percent of the alluvial thickness.

The additional investigation bores at the northern end of Longwalls 101-102 have confirmed the palaeochannel extent and the lack of saturation of the palaeochannel sediments, with saturated thickness fraction less than 10%. No palaeochannel deposits have been observed above Longwall 103.

No further drilling is required at Longwalls 101-103, as the additional drilling has successfully confirmed the location and saturated extent of the palaeochannel there.

With respect to Item [2] in Section 7.1 [Objectives], the additional drilling and downhole geophysics has successfully validated the assumptions in the groundwater model.

With respect to Item [3] in Section 7.1 [Objectives], it is recommended that a monitoring site (Site A) be established near bore MCOL394 to the north-east of Longwall 101, about 85 m from the takeoff line (Figure 22). At this location there is expected to be about 9 m of saturated gravel below about 16 m of dry clay and sand. An additional monitoring site (Site B) is recommended near MCOL406 in the axis of the palaeochannel about 200 m north of the Longwall 105 takeoff line, where the palaeochannel thickness is about 24 m (Figure 22).

---

3 The ratio of water thickness to palaeochannel thickness
8. CONCLUSION

The key findings of this Longwalls 101-103 Extraction Plan groundwater assessment review are:

1. Since the publication of the Groundwater Modelling Assessment for the Moolarben Coal Complex UG1 Optimisation Modification (HydroSimulations, 2015), additional field investigations have been undertaken to confirm the location and saturated extent of the palaeochannel adjacent to the extents of UG1 second workings.

2. The additional investigation bores at the northern end of Longwalls 101-102 have confirmed the palaeochannel extent and the lack of saturation of the palaeochannel sediments. No palaeochannel sediments have been observed above Longwall 103.

3. The additional drilling and downhole geophysics have successfully validated the assumptions in the groundwater model.

4. Given the robustness of the model with respect to palaeochannel morphology adjacent to UG1, the model predictions remain applicable.

5. The model predicts negligible drawdown in alluvium and regolith for UG1 extraction.

6. No private bores are likely to be affected by 2 m drawdown or more. No drawdown is anticipated in the Upper Triassic (or Lower Triassic) as these sediments are inherently dry. With the exception of drawdown at the level of the Ulan Seam in the north-eastern extents of UG1, there would be no discernible change in drawdown resulting from UG1 extraction.

7. Monitoring bores from the existing monitoring network located in close proximity to Longwalls 101-103 are suitable to monitor groundwater levels and quality and confirm potential impacts are consistent with those previously assessed and approved.

8. Groundwater level and quality trigger levels established for these bores (as per the GMP dated October 2016) with investigation protocols to be implemented should triggers be exceeded (as identified by monitoring) are suitable for the UG1 Longwalls 101-103 Extraction Plan.

9. Additional palaeochannel monitoring bores are recommended to be installed to the north-east of UG1 longwalls 101 and 105 prior to the commencement of secondary extraction of LW101 and LW104 respectively.

This review, based on currently available records, indicates no material groundwater impacts are expected from mining of Longwalls 101-103 beyond what was assessed and approved in the Moolarben Coal Complex UG1 Optimisation Modification Groundwater Modelling Assessment (HydroSimulations, 2015).
9. References


MSEC (2015) Moolarben Coal Project (Stage 2) Subsidence Predictions and Impact Assessments for Natural Features and Items of Surface Infrastructure due to Proposed Extraction of Mining Longwalls 1 to 13.


FIGURES
Figure 1

Source: NSW Land & Property Information (2015); NSW Department of Industry (2016); Office of Environment and Heritage NSW (2016)
Figure 2

Source: MCD (June 2016); NSW Dept of Industry (2016)
Figure 4. Total Drawdown (m) in Alluvium / Regolith (model layer 1) at the end of UG1 Mining
Figure 5. Groundwater Monitoring Bores Most Relevant to UG1 Longwalls 101-103
Figure 6. Groundwater Hydrographs for Alluvium Monitoring Bore PZ187

Figure 7. Groundwater Hydrographs for Alluvium Monitoring Bore PZ188
Figure 8. Groundwater Hydrographs for Permian Overburden Monitoring Bore PZ186

Figure 9. Groundwater Hydrographs for Permian Overburden Monitoring Bore PZ189
Figure 10. Groundwater Hydrographs for Ulan Seam Monitoring Bore PZ156

Figure 11. Groundwater Hydrographs for Ulan Seam Monitoring Bore PZ157
Figure 12. Groundwater Hydrographs for VWP Bore PZ127

Figure 13. Groundwater Hydrographs for VWP Bore PZ130
Figure 14. Groundwater Hydrographs for VWP Bore PZ179
Figure 15. Longwall Locations, DC Resistivity Lines and TEM True Resistivity at 12m Depth
Figure 16. Post-TEM Investigation Bore Names and Locations with TEM Resistivity (at 12m Depth)
Figure 17. Transect A Geophysical and Lithological Logs

- Gamma marker at base of palaeochannel
Figure 18. Transect B Geophysical and Lithological Logs

- Gamma marker at base of palaeochannel
Figure 19. Transect A Geological Section Showing Tertiary Palaeochannel (Gravel and Sand) Profile and Degree of Saturation
Figure 20. Transect B Geological Section Showing Tertiary Palaeochannel (Gravel and Sand) Profile and Degree of Saturation
Figure 21. Interpreted Saturated Thickness of Tertiary Palaeochannel Sediments (m)
Figure 22. Proposed Monitoring Bore Locations