SOUTH32

DENDROBIUM
LONGWALL 19

FEBRUARY 2021




LONGWALL 19

WATERCOURSE IMPACT, MONITORING, MANAGEMENT AND CONTINGENCY PLAN

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Review History

Revision	Description of Changes	Date	Approved
A	New Document-DRAFT	March 2020	GB
B	Updated for Longwall 19	February 2021	GB

Persons involved in the development of this document include:

Name	Title	Company
Billy Agland	Environmental Officer	Illawarra Metallurgical Coal
Cody Brady	Principal Approvals	Illawarra Metallurgical Coal
Gary Brassington	Manager Approvals	Illawarra Metallurgical Coal
Josh Carlon	Environmental Coordinator	Illawarra Metallurgical Coal

1 INTRODUCTION

1.1 Project Background

Illawarra Metallurgical Coal (IMC), a wholly owned subsidiary of South32 Pty Ltd (South32), operates the underground Dendrobium Mine, located in the Southern Coalfield of New South Wales. Longwalls from the Wongawilli Seam have been mined in Areas 1, 2 and 3A with current operations in Area 3B.

IMC was granted Development Consent by the NSW Minister for Planning for the Dendrobium Project on 20 November 2001. In 2007, IMC proposed to modify its underground coal mining operations and the NSW Department of Planning advised that the application for the modified Area 3 required a modification to the original consent. The application followed the process of s75W of the *Environmental Planning and Assessment Act 1979* (EP&A Act) and required the submission of a comprehensive Environmental Assessment (EA) (Cardno 2007). The EA described the environmental consequences likely from cracking and diversion of surface water as a result of the proposed mining. These impacts included diversion of flow, lowering of aquifers, changes to habitat for threatened species as well as other impacts and environmental consequences.

On 8 December 2008, the Minister for Planning approved a modification to DA_60-03-2001 for Dendrobium Underground Coal Mine and associated surface facilities and infrastructure under Section 75W of the EP&A Act.

Schedule 3, Condition 7 of the Development Consent requires the development of a Subsidence Management Plan (SMP) for approval prior to carrying out mining operations that could cause subsidence.

1.2 Scope

The Watercourse Impact Monitoring, Management and Contingency Plan (WIMMCP) has been prepared to comply with the Dendrobium Development Consent in respect to surface water management for Longwall 19 in Dendrobium Area 3A.

The Dendrobium Development Consent requires a WIMMCP subject to Schedule 3, Condition 4 as provided below.

4. Prior to carrying out any underground mining operations that could cause subsidence in either Area 3A, Area 3B or Area 3C, the Applicant shall prepare a Watercourse Impact Monitoring, Management and Contingency Plan to the satisfaction of the Secretary. Each such Plan must:

(a) demonstrate how the subsidence impact limits in conditions 1 - 3 are to be met;

(b) include a monitoring program and reporting mechanisms to enable close and ongoing review by the Department and DPI of the subsidence effects and impacts (individual and cumulative) on Wongawilli Creek, Sandy Creek and Sandy Creek Waterfall;

(c) include a general monitoring and reporting program addressing surface water levels, water flows, water quality, surface slope and gradient, erodibility, aquatic flora and fauna (including Macquarie Perch, any other threatened aquatic species and their habitats) and ecosystem function;

(d) include a management plan for avoiding, minimising, mitigating and remediating impacts on watercourses, which includes a tabular contingency plan (based on the Trigger Action Response Plan structure) focusing on measures for remediating both predicted and unpredicted impacts;

(e) address third and higher order streams individually but address first and second order streams collectively;

(f) be prepared in consultation with DECC, Water NSW and DPI;

(g) incorporate means of updating the plan based on experience gained as mining progresses;

(h) be approved prior to the carrying out of any underground mining operations that could cause subsidence impacts on watercourses in the relevant Area; and

(i) be implemented to the satisfaction of the Secretary.

1.3 Study Area

The Study Area is defined as the surface area that could be affected by the mining of the proposed Longwall 19. The extent of the Study Area has been calculated by combining the areas bounded by the following limits:

- The 35° angle of draw line from the extents of the proposed Longwall 19;
- The predicted limit of vertical subsidence, taken as the 20 millimetre (mm) subsidence contour, resulting from the extraction of the proposed longwall; and

- The natural features located within 600 metre (m) of the extent of the longwall mining area, in accordance with Schedule 3, Condition 8(d) of the Development Consent.

The depth of cover varies between 280 m and 370 m directly above the proposed Longwall 19. The 35° angle of draw line, therefore, has been determined by drawing a line that is a horizontal distance varying between 196 m and 259 m around the extents of the longwall void.

The predicted limit of vertical subsidence, taken as the predicted total 20 mm subsidence contour, has been determined using the calibrated Incremental Profile Method (IPM), which is described in MSEC (2020). The predicted incremental 20 mm subsidence contour extends beyond the 35° angle of draw above the existing Longwalls 6 to 8. Elsewhere, the contour is located inside the angle of draw.

The watercourses located outside the extent of longwall mining, which could experience far-field or valley related movements, and could be sensitive to these movements, have been identified and included in the assessments provided in this report. The WIMMCP also provides updated monitoring, management and contingency for the Longwall 19 Study Area. The location of the watercourses in respect of Dendrobium Area 3A is shown in **Figure 1-1**.

This WIMMCP addresses:

- Impact assessment and how the subsidence impact limits specified in the approval will be met;
- Monitoring and reporting;
- Trigger levels that initiate reporting and the development of management or remedial measures;
- Implementation of remedial measures should mining induced degradation to the watercourses be observed or measured (including contingency measures); and
- Access to watercourses and rehabilitation of access routes to watercourses.

The WIMMCP does not provide detailed reporting of monitoring data. These requirements are fulfilled by the EA (Cardno 2007), Area 3A SMP (Cardno 2012), End of Panel (EoP) Reports, Annual Environmental Management Reports (AEMRs) and other reports.

1.4 Objectives

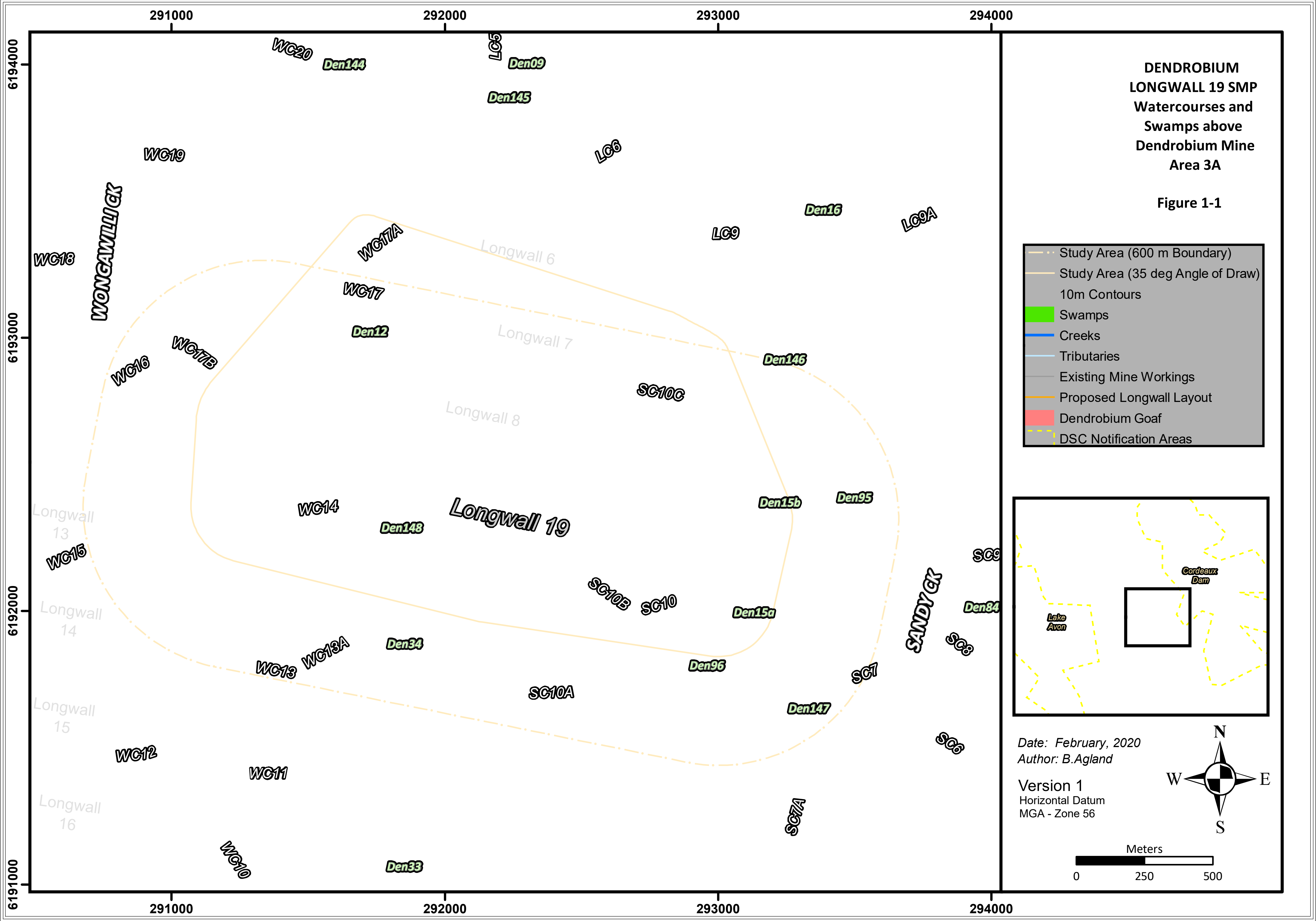
The objectives of this WIMMCP are to identify at risk watercourse features and characteristics within the Longwall 19 Study Area (**Figure 1-1**) and to monitor and manage potential impacts and/or environmental consequences of the proposed workings on watercourses. This Longwall 19 WIMMCP is intended to operate in parallel with the Area 3A WIMMCP (approved 28 June 2010).

1.5 Consultation

The WIMMCPs and other Management Plans have been developed by IMC, in consultation with:

- DPIE; the Biodiversity Conservation Division within the Department (BCD), DRG; and
- WaterNSW.

The WIMMCP and other relevant documentation are available on the IMC website (Condition 11 Schedule 8: DA 60-03-2001).



DENDROBIUM LONGWALL 19 SMP Watercourses and Swamps above Dendrobium Mine Area 3A
Figure 1-1
Study Area (600 m Boundary)
Study Area (35 deg Angle of Draw)
10m Contours
Swamps
Creeks
Tributaries
Existing Mine Workings
Proposed Longwall Layout
Dendrobium Goaf
DSC Notification Areas
Cordeaux Dam
Lake Avon
Date: February, 2020
Author: B.Agland
Version 1
Horizontal Datum
MGA - Zone 56
N
W
E
S
Meters
0
250
500
291000
292000
293000
294000
6194000
6193000
6192000
6191000
Longwall 19
Longwall 6
Longwall 7
Longwall 8
Longwall 13
Longwall 14
Longwall 15
Longwall 16
WONGAWILLI CK
SANDY CK
WC20
WC19
WC18
WC17A
WC17
WC17B
WC16
WC15
WC14
WC13
WC13A
WC12
WC11
WC10
LC5
LC6
LC9
LC9A
SC10C
SC10B
SC10
SC10A
SC9
SC8
SC7
SC7A
SC6
Den144
Den09
Den145
Den16
Den12
Den146
Den15b
Den95
Den148
Den84
Den15a
Den34
Den96
Den147
Den33

2 PLAN REQUIREMENTS

Extraction of coal from Longwall 19 will be in accordance with the conditions set out in the Dendrobium Development Consent and conditions attached to relevant mining leases.

Baseline studies have been completed within the Study Area and surrounds to record biophysical characteristics with further mapping activities ongoing to improve understanding of the environment. Monitoring is conducted in the area potentially affected by subsidence from the extraction of Longwall 19. The monitoring in these areas will be based on the Before After Control Impact (BACI) design criteria.

Details of surface water monitoring incorporating water quality and hydrographic monitoring and the interpretation of data are provided in Attachment A of the Surface Water Quality and Hydrology Assessment (HGEO 2019). The monitoring program is incorporated into this plan and the Longwall 19 SMP.

The Longwall 19 monitoring and assessment programs will provide ongoing water-related monitoring of the streams and sub-catchments potentially affected by the mining and allow assessment of the magnitude of any developing trends in overland and subsurface flow and water quality effects resulting from mining. The watercourse monitoring relevant to Longwall 19 is summarised in **Appendix A: Table 1.1**.

The Strahler stream classification system is commonly used to define the class of a watercourse and was used in the Southern Coalfield Inquiry (IEP, 2019a). Streams are classified based on the number of contributing tributaries, with headwater streams classed as first and second order streams and third and higher order streams being given the classification as 'streams of significance'. The Southern Coalfield Inquiry recommends that assessments should focus on these higher order streams. Within Area 3A, Sandy and Wongawilli Creeks are classed as third order streams. Other watercourses within Area 3A are first or second order streams.

The monitoring locations for watercourses within the Study Area will be reviewed as required and can be modified (with agreement) accordingly.

Should monitoring reveal impacts greater than what is authorised by the approval, modifications to the project and mitigation measures would be considered to minimise impacts.

2.1 Dendrobium Development Consent DA60-03-2001

The Dendrobium Underground Coal Mine (DA 60-03-2001) modification was approved under Section 75W of the EP&A Act on 8 December 2008. **Table 1** lists the Conditions of Consent relevant to the WIMMCP and where the conditions are addressed.

Table 1 Dendrobium Modified DA-60-03-2001 Development Consent Conditions

Dendrobium Development Consent Condition	Relevant WIMMCP Section
Condition 2 – Schedule 3 The Applicant shall ensure that underground mining operations do not cause subsidence impacts at Sandy Creek and Wongawilli Creek other than "minor impacts" (such as minor fracturing, gas release, iron staining and minor impacts on water flows, water levels and water quality) to the satisfaction of the Secretary.	Sections 3, 4 and 5
Condition 3 – Schedule 3 The Applicant shall ensure the development does not result in reduction (other than negligible reduction) in the quality or quantity of surface water or groundwater inflows to Lake Cordeaux or Lake Avon or surface water inflow to the Cordeaux River at its confluence with Wongawilli Creek, to the satisfaction of the Secretary.	Sections 3, 4 and 5

Dendrobium Development Consent Condition	Relevant WIMMCP Section
Condition 4 – Schedule 3 Prior to carrying out any underground mining operations that could cause subsidence in either Area 3A, Area 3B or Area 3C, the Applicant shall prepare a Watercourse Impact Monitoring, Management and Contingency Plan to the satisfaction of the Secretary. Each such Plan must:	
(a) demonstrate how the subsidence impact limits in conditions 1 - 3 are to be met;	Sections 3, 4 and 5
(b) include a monitoring program and reporting mechanisms to enable close and ongoing review by the Department and DPI of the subsidence effects and impacts (individual and cumulative) on Wongawilli Creek, Sandy Creek and Sandy Creek Waterfall;	Section 3 and **Appendix A**
(c) include a general monitoring and reporting program addressing surface water levels, water flows, water quality, surface slope and gradient, erodibility, aquatic flora and fauna (including Macquarie Perch, any other threatened aquatic species and their habitats) and ecosystem function;	Section 3 and **Appendix A**
(d) include a management plan for avoiding, minimising, mitigating and remediating impacts on watercourses; include a tabular contingency plan (based on the Trigger Action Response Plan structure) which focuses on measures for remediating both predicted and unpredicted impacts on watercourses;	Section 6 and **Appendix A**
(e) address third and higher order streams individually but address first and second order streams collectively;	Sections 5
(f) be prepared in consultation with DECC, Water NSW and DPI;	Section 1.4
(g) incorporate means of updating the plan based on experience gained as mining progresses;	Section 8
(h) be approved prior to the carrying out of any underground mining operations that could cause subsidence impacts on watercourses in the relevant Area; and	Section 2
(i) be implemented to the satisfaction of the Secretary.	

2.2 Leases and Licences

The following licences and permits may be applicable to IMC's operations in the Longwall 19 Study Area:

- Dendrobium Mining Lease as shown in **Table 2**;
- Environmental Protection Licence 3241 which applies to the Dendrobium Mine. A copy of the licence can be accessed at the Environment Protection Agency (EPA) website via the following link http://www.environment.nsw.gov.au/poeo;
- Dendrobium Mining Operations Plan FY 2016 to FY 2022;
- Relevant Occupational Health and Safety approvals; and
- Any additional leases, licences or approvals resulting from the Dendrobium Development Consent.

Table 2 Dendrobium Leases

Mining Lease - Document Number	Issue Date	Expiry Date/ Anniversary Date
CCL 768	7 May 1998	7 September 2026

3 MONITORING

3.1 Subsidence Monitoring

Survey monitoring techniques will be employed at upland swamps and watercourses throughout the Study Area to measure subsidence movements. Additionally, regional 3D Global Navigation Satellite System (GNSS) marks will be placed at strategic positions throughout the Study Area to monitor absolute surface movements.

Pending site access and approval, survey monitoring lines will be established across a selection of watercourses and upland swamps within the 20 mm predicted subsidence contour. The monitoring lines will target controlling rockbars and steps. Additionally, survey monitoring lines will be installed across the Wongawilli Creek valley to measure closure (or opening) of the valley. Installation of additional Wongawilli Creek monitoring lines will be subject to site access and any other constraints.

Watercourse and upland swamp monitoring lines will employ a series of marks along a transect at nominally 20 m intervals. If practical, upland swamp transects will be related to a GNSS control network to provide absolute 3D movements in addition to level, tilt and strain changes.

Nominal accuracy will be +/- 5 mm relative between marks and +/- 20 mm for horizontal and vertical accuracy if the swamp is related to a GNSS control network. Survey closure lines across the Wongawilli Creek valley will be measured for closure only; nominal accuracy will be +/- 5 mm.

Survey monitoring sites will be chosen for suitability and detailed in the Dendrobium Survey Monitoring Program. Baseline monitoring will be conducted prior to active subsidence.

3.2 Longwall 19 Study Area Watercourses

Extensive geomorphological mapping has been completed for a large portion of Dendrobium Area 3, including the location of significant features in the watercourses (**Figure 1-1**). In line with recommendations of IEP (2019a) and the 2016 Catchment Audit (Alluvium Consulting Australia 2017a) the locations and timing of monitoring for ecological aspects, water quality and stream flow is integrated and uses a BACI design (**Table 3**).

Table 3 Summary of Watercourses to be Monitored within 600 m of the Longwall 19

Watercourse	Catchment	Monitoring
Wongawilli Creek	Wongawilli	Observation, Water Chemistry, Water Flow, Water level, Water Quality Parameters
WC13	Wongawilli	Observation, Water Chemistry, Water level, Water Quality Parameters
WC14	Wongawilli	Observation, Water Chemistry, Water Flow, Water level, Water Quality Parameters
WC15	Wongawilli	Observation, Water Chemistry, Water Flow, Water Level, Water Quality Parameters
WC16	Wongawilli	Observation, Water Level, Water Quality Parameters
WC17	Wongawilli	Observation, Water Chemistry, Water level, Water Quality Parameters
WC17A	Wongawilli	Observation
WC17B	Wongawilli	Observation
Sandy Creek[1]	Lake Cordeaux	Observation, Water Chemistry, Water Flow, Water level, Water Quality Parameters
SC7	Lake Cordeaux	Observation, Water Chemistry, Water Level, Water Quality Parameters
SC10	Lake Cordeaux	Observation, Water Chemistry, Water Flow, Water Level Water Quality Parameters

[1] Not located within 600 m boundary of the longwall.

SC10C	Lake Cordeaux	Observation, Water Chemistry, Water Flow Water level, Water Quality Parameters

3.3 Observational Monitoring

IMC has conducted ongoing monitoring of watercourses in the Dendrobium area since 2001 (**Figure 3-1**). This monitoring builds upon the understanding of processes within the watercourses, along with identifying and assessing any episodic or temporal changes.

This monitoring (along with other monitoring programs described in the WIMMCP) is consistent with (in part) *Condition 4 Schedule 3* "*include a general monitoring and reporting program addressing surface water levels, water flows, water quality, surface slope and gradient, erodibility, aquatic flora and fauna (including Macquarie Perch, any other threatened aquatic species and their habitats) and ecosystem function*".

The IMC Environmental Field Team (IMCEFT) is continuing to undertake structured monitoring assessments, including:

- Water: location, volume and flow characteristics;
- Significant features: rockbars, pools flow channels, steps/waterfalls;
- Vegetation: location, species, and observed appearance; and
- Sediment: composition, depth and moisture.

Monitoring sites and frequencies are provided in **Table 1.1 (Appendix A)**. Additional monitoring within Dendrobium Area 3A will be installed ahead of longwall mining to achieve 2 years baseline data (subject to timing and approval timeframes of any request to install additional monitoring).

Observations of any surface water and vegetation health for prominent species are undertaken. Where surface water is present within a swamp or a watercourse the data collected includes water quality parameters (using a monitoring probe) and water levels from installed benchmarks established at the pool. Observations of any surface flow are also made during monitoring.

This data is used to compare differences in site conditions of swamps and watercourses before and after mining. Sites that will not be mined under are also monitored to provide a comparison of sites mined under and sites not mined under during different climatic conditions.

IMCEFT routinely make qualitative observations of flow conditions (e.g. surface flow/subsurface flow/not flowing) along watercourses in Area 3A and 3B. Area 3C will be monitored to achieve the two-year baseline monitoring period. Details on the assessment process and triggers for potential baseflow reductions on Wongawilli Creek are detailed in Watershed Hydrogeo (2019) and **Appendix A**.

This monitoring provides key data to assess the Sandy and Wongawilli Creeks Performance Measure; Minor impacts:

- minor fracturing;
- gas release;
- iron staining;
- water flows;

This monitoring also provides key data to assess the Sandy Creek Waterfall (SCWF-1) Performance Measure:

- no rock fall occurs at Sandy Creek Waterfall or from its overhang;
- the structural integrity of the waterfall, its overhang and its pool are not impacted;
- cracking in Sandy Creek within 30 m of the waterfall is of negligible environmental and hydrological consequence; and
- negligible diversion of water occurs from the lip of the waterfall

The following Area 3A sites along watercourses and swamps are included in the observational and photo point monitoring program:

- Monitoring sites:

  - Sandy and Wongawilli Creeks (commenced 2001);
  - WC14, WC15, WC16, WC17, WC17A, WC17B, SC7, SC10 and SC10C;
  - Swamps 12, 15a, 15b, 34, 95, 96, 146, 147 and 148.
- Reference sites:
  - Swamps 2, 7, 22, 24, 25, 33, 84, 85, 86, 87 and 88.
  - Wongawilli Creek, LC5, CR36, Sandy Creek, WC11 (Swamp 33), SC9A (Swamp 84), DC10 (Swamp 85), D10 and Gallahers Creek (Swamp 88).

The monitoring sites above are composed of both existing sites and proposed monitoring sites. Due to the steep terrain, dense vegetation and shallow sediment depth, proposed monitoring sites may be relocated to a more suitable site. Additionally, proposed monitoring site locations have not been assigned site identification numbers at this time, as they may be subject to change until sight suitability is determined. Proposed pool water level and observation monitoring sites will be finalised prior to commencement of the minimum two year baseline period.

3.4 Water Quality and Chemistry

Monitoring undertaken by IMC since 2003 (**Figure 3-2**) includes water quality monitoring of parameters such as pH, Electrical Conductivity (EC), Dissolved Oxygen (DO), Oxygen Reduction Potential (ORP) and temperature. Monitoring sites where these parameters are sampled are indicated as water quality sites.

Water quality is also monitored for analytes including DOC, Na, K, Ca, Mg, Filt. SO4, Cl, T. Alk., Total Fe, Mn, Al, Filt. Cu, Ni, Zn, Si. Water samples are retrieved from the monitoring sites and analytes are tested in a laboratory. Monitoring sites where water samples are taken for laboratory testing are indicated as water chemistry sites.

The key field parameters of DO, pH, EC and ORP for monitoring sites within the Longwall 19 Study Area will be analysed to identify any changes in water quality resulting from the mining. Pools and streams away from mining are monitored to allow for a comparison against sites not influenced by mining. Over time some water quality-specific site names have changed. These changes have been implemented to align monitoring site's names with mapped stream features. These changes are shown in **Table 4** below.

Table 4 Changes to Water Quality site names

Previous Site Name	Current Site Name	Watercourse
SCL	SCk_Rockbar 5	Sandy Creek
WWL2	Wongawilli Ck (FR6)	Wongawilli Creek
WWM1	WC_Pool 46	Wongawilli Creek
WWM3	WC_Pool 43b	Wongawilli Creek
DC_S2	DC_Pool 22	Donalds Castle Creek
DCU3	Donalds Castle Ck (FR6)	Donalds Castle Creek
WC15_S1	WC15_Pool 9	WC15
WC21_S1	WC21_Pool 5	WC21
DC13_S1	DC13_Pool 2b	DC13

Trigger values for water quality parameters are in detailed in the TARP (**Appendix A**). The TARPs are based on the field parameters pH, EC and DO due to the ability of these parameters to indicate potential mining impacts on water quality, the rapid and in situ nature in which they are determined, and the quantity of baseline data available, which for Donalds Castle, Sandy and Wongawilli Creeks is greater than 18 years (since August 2001).

A change of three standard deviations (enclosing approximately 99.7% of the baseline data assuming a normal distribution) from the respective parameter means resulting from mining, will be used for determining potential exceedances of water quality performance measures.

Statistical analysis of baseline and impact period data will be provided in EoP Reports, including clearly specifying the duration of the baseline monitoring period.

Any historical mining outside the project area (e.g. Wongawilli Creek mined beneath by Elouera) will be acknowledged and if required reflected in the baseline monitoring assessment. Exceedances of these levels have occurred occasionally in the baseline period.

This is to be expected assuming a normal statistical distribution of the data, in addition to random natural environmental effects on water quality such as storms (effects of decomposition of detrital organic matter), wildfires (ash wash off and dissolution effects), prolonged dry weather and drought (evaporative concentration effects).

As such, exceedance of the water quality performance measures will be quantitatively defined by "Mining results in two consecutive exceedances or three exceedances of the ±3 standard deviation level (positive for EC, negative for pH and DO) from the baseline mean within six months".

The water chemistry and level of water in Avon and Cordeaux Reservoirs will be monitored as a basis for comparison to the mine water. The locations of the samples and the testing procedure have been developed in consultation with the Dam Safety NSW and WaterNSW.

3.5 Groundwater

A Groundwater Assessment is provided in Attachment B of the SMP (SLR 2020). A peer review of the groundwater assessment was undertaken by Dr Franz Kalf and is provided in Attachment H of the SMP (KA 2020). An existing groundwater monitoring program is in place for Dendrobium, which includes Area 3A (**Figure 3-3**). The Dendrobium Long Term Groundwater Monitoring Program is available in **Appendix B**.

Groundwater monitoring is undertaken in:

- Surficial and shallow systems associated with upland swamps and the weathered near-surface bedrock.
- Consolidated rock strata comprising the deeper Hawkesbury Sandstone, the underlying Narrabeen Group and Illawarra Coal Measures.

Pre-mining and post-mining monitoring holes have been installed within Area 3 to investigate and monitor the highly connected fracture network above the goaf and the upwards migration of the phreatic surface.

Monitoring pore pressures at Dendrobium Mine uses vibrating wire piezometers installed at different depths within the same borehole, thereby creating a vertical array which can be used for 3D mapping and analysis of the pore pressure regime (IEP 2019a).

Before and after mining piezometers are routinely installed along the centreline of longwall panels to identify the maximum groundwater effects and the height of depressurisation within the subsidence zone.

3.6 Surface Water Flow and Pool Water Level

Existing surface water flow gauges and data loggers are installed at key stream flow monitoring sites; additional sites are proposed be installed to effectively monitor streams that may potentially experience influence from mining Longwall 19 (**Figure 3-4** and **Figure 3-5**). Water level data loggers are also installed at stream flow monitoring sites (**Figure 3-1**) along with manual benchmark water level monitoring sites. Data has been collected since 2003 and has been compiled within monitoring and field inspection reports (Illawarra Coal 2011), EoP Reports and regular impact update reports. Pool water level and flow monitoring sites have been established in Dendrobium Area 3A for monitoring before, during and after mining.

Pool water levels will be measured monthly before and after mining, on a weekly basis during active subsidence and in response to any identified impacts. Water level measurements will be undertaken relative to benchmarks installed on rocks or other stable features on the edge of the pools.

This data is used to compare differences in pool water levels within swamps and streams before and after mining. Sites that will not be mined under are also monitored to provide a comparison of mined and not mined under sites during different climatic conditions.

This monitoring provides key data to assess the Sandy and Wongawilli Creeks Performance Measure; "Minor impacts":

- water flows;
- water levels; and
- water quality.

Performance against this measure will be based on comparing pool water levels before mining with after mining. Pool water level data would also be used to determine the success of any pool/rockbar mitigation or rehabilitation.

Surface water flow data for the Dendrobium area is available from a series of flow gauges operated by IMC. These gauging stations provide estimates of stream flow via:

- A structure behind which water pools and flows over. The structures can be:
  - Natural, e.g. a rock bar, or
  - Engineered, e.g. a half-pipe flume.
- A sensor and logger that measure and record the water level ("stage") in the pool at 5-minute intervals.
- A "rating curve" which is a chart or graph of discharge (flow) versus stage for each gauging station. The rating curve is developed via periodic measurements of flow in the channel at a known water level.
- Estimates of mean daily flow are then provided.

IMC and an independent hydrologist are currently working to systematically identify and quantify the accuracy or error involved in each part of the process. The aim of the assessment is to document accuracy across the range of flows at all sites.

The flow monitoring sites are installed downstream of the mining area to assess any changes in surface flow from a catchment resulting from the mining. Sites have previously been installed using natural flow control features such as rockbars. However, in line with the recommendations of the IEP (2019a) and approval from WaterNSW, the installation of low-flow weirs has commenced, in order to gain high quality low-flow data. Flow monitoring sites are not installed directly over the longwalls as mining induced surface fracture networks typically result in recession flows being significantly or entirely diverted below the surface. The downstream monitoring sites are installed to measure catchment flow and monitor for reductions downstream of the mining area.

Flow gauges have been installed on Sandy Creek (Area 3A) and its tributaries, SC10, SC10C; Wongawilli Creek (Area 3B and 3A) and its tributaries WC21, WC15 and WC12 (Area 3B); Donalds Castle Creek and its tributary DC13 (Area 3B); Sandy Creek and Lake Avon tributaries LA2, LA3, LA4 and NDT1 (Area 3B). The historical flow record has been plotted alongside the record from a nearby 'control' gauge i.e. a gauge that was not mined under, either at all or not during the period of interest.

A review of the Area 3B WIMMCP Trigger Action Response Plan (TARP) was undertaken in consultation with WaterNSW and DPIE between 2018 and 2020 (**Appendix A**). The revised 3B TARP levels have been adapted for the Longwall 19 WIMMCP including the TARPs.

The review determined that two key flow reference sites were suitable:

- Wongawilli Creek at WWU (300024). This station is operated by IMC. Monitoring commenced more than 2 years prior to mining in Longwall 19, so has an appropriate pre-mining baseline record. This catchment is adjacent to Dendrobium Areas 3A and 3B and has the same geology and land use. The catchment size (3.2 sq.km) is slightly larger or similar in magnitude to many of the gauged sub-catchments to be assessed at Dendrobium. Despite proximity to Elouera Colliery, it is considered to be close to natural.
- O'Hares Creek at Wedderburn (#213200). This station has a long record, extending back to the late 1970s. The catchment is large (73 sq.km) compared to the area of mining but is considered to be appropriate as a control site. This gauging station is approximately 28 km north of Area 3B.

A third flow reference site was considered from three options at and more distant from Dendrobium (Woronora River, Sandy Creek and Bomaderry Creek), however a number of factors ruled out the use of those at this time. This decision might be revisited in the future if issues arise with the two selected reference sites (above), and also once a longer record is available at newer sites (e.g. sites LC5, CR36 at Dendrobium).

Surface water flow sites in the mining area will be assessed against the key flow reference sites during assessments for the EoP Report. The assessment comprises three checks of pre- versus post-mining behaviour for each assessment site.

Trigger values are proposed for water flow parameters in the TARP (**Appendix A**). The TARPs are based on the following parameters and assessments:

A. Change in flow exceedance (Q%ile) behaviour compared to key flow reference sites. In essence, this aims at quantifying an otherwise visual or qualitative assessment of flow behaviour (compared to normalised key flow reference site flow).

B. Relative change in the frequency of cease-to-flow days compared to key reference sites;

C. Relative change in Q50 (median flow) compared to key reference sites flows; and

D. Baseflow reduction along Wongawilli Creek, between Areas 3A and 3B.

A more detailed discussion of these assessments, developed and refined in consultation with agencies, is provided in Watershed HydroGeo (2019). If any of these indicate an impact is likely to have occurred, then the EoP Report will describe the impact as it relates to one or more of the broad hydrological behaviours, a reduction in the water resource indicator, or impact that could affect the ecological values of the stream. In the event that there is a reduction in Q50 median flow (Assessment C) or base flow reduction (Assessment D), and there is a Performance Measure related to that watercourse, then the reduction would be compared against the predicted losses from contemporary Groundwater and Surface Water Assessments to assess whether effects that cannot be explained by natural variability "exceed prediction". The assessment will determine if the impact is 'within Prediction' or 'exceeding Prediction', with further actions triggered by that outcome.

IMC commissioned the development of a regional-scale numerical groundwater flow model in support of mining at Dendrobium Colliery (Coffey Geotechnics 2012). IMC commissioned HydroSimulations (2014) to review and enhance the Model and this model has been updated and revised at regular intervals since then. Predictions from the groundwater model will be used to determine 'within Prediction' or 'exceeding Prediction' as stated above.

3.7 Near-Surface Groundwater and Soil Moisture

The surface area above the Longwall 19 Study Area is characterised by a series of drainage basins separated by steep ridges. The drainage basins drain to Wongawilli Creek, Sandy Creek and directly into Lake Cordeaux.

Monitoring of shallow groundwater levels allows for the indirect measurement of water storage and transmission parameters within the saturated part of hill-slope/upland swamp complexes. Shallow groundwater piezometers have been installed within and around several swamps and associated watercourses in Area 3 (**Figure 3-6**), including the hill-slope aquifers on the eastern side of Sandy Creek; within Swamp 15b (SC10C) and Swamp 12 (WC17).

Within Area 3A and 3B long-term piezometer records are available for Swamp 11 (LA4A1) as well as additional sites installed since 2011. Swamps 2 (Donalds Castle Creek), 7 (LC7B Lake Cordeaux tributary), 22, 24, 25, 33 (WC11), 84 (SC9A), 85 (DC10), 86, 87 and 88 (Gallahers Creek) have been selected as reference monitoring sites. This data is used to compare differences in shallow groundwater levels within swamps, streams and hill-slope aquifers before and after mining. Sites that will not be mined under are also monitored to provide a comparison of sites mined under and not mined under during different climatic conditions.

The piezometric monitoring directed at shallow groundwater levels is supplemented with monitoring of soil moisture profiles up to a maximum depth of 1.2 m. Key monitoring sites will be installed with loggers to provide a continuous soil moisture record.

The shallow groundwater piezometers and soil moisture probe data is compared with the Cumulative Monthly Rainfall Residuals (a key parameter for interpreting temporal soil and shallow groundwater data). Comparisons of the Cumulative Monthly Rainfall Residuals against mean monthly water heads in shallow groundwater piezometers and soil moisture profiles will take into account the known distribution of rainfall isohyets (contours of equal annual precipitation) in the local region (these being denser and less smooth closer to the Illawarra Escarpment and much wider proceeding northwest).

Several climate stations are available for analysis and modelling in Dendrobium Area 3 with the most appropriate data taking into account proximity, length of record and data quality (**Figure 3-2**).

A comprehensive array of multi-level piezometers have been installed on the centreline of panels at Dendrobium Mine in order to monitor pore pressure changes associated with subsidence. These monitoring holes include at least five transducers per borehole with installation at least 2 years prior to undermining, in line with the recommendations of the IEP (2019a and b). Where these monitoring sites are damaged as a result of undermining they are reinstalled after subsidence movements cease. Daily monitoring of local rainfall and mine water ingress from overlying and surrounding strata, and separation of rainfall correlated inflows for base flow volumetric analyses is also undertaken (IEP 2019a).

3.8 Slopes and Gradients

Slopes within the Longwall 19 Study Area have been mapped according to their gradients and are identified on Drawing 8 in MSEC (2020).

Monitoring of landscape features such as cliffs, slopes and rock outcrop was previously undertaken in Area 3A. Monitoring sites relevant to Longwall 19 are proposed to be reinstated, additional sites will be identified and monitored as required (**Figure 3-7**).

Monitoring of these sites allows for the measurement of any changes to the surface including soil cracking, erosion and/or sedimentation impacts resulting from subsidence.

The inspection and monitoring include the following:

- Monitoring sites based on an assessment of risk of impact where pre-mining measurements have been undertaken and reported;
- Areas of steep slopes that are en route or near monitoring sites;
- Rock outcrops that are en route or near monitoring sites;
- Any other sites where impacts have been previously observed that warrant follow-up inspection (i.e. rockfalls and soil cracking); and
- The general areas above the current mining location at the time of inspection.

The monitoring sites include comprehensive investigation as described below, and the wider area around the monitoring site is subject to inspection during monitoring events.

Observations on landform and land surface at the monitoring sites are recorded to account for the Australian Soil and Land Survey, Field Handbook, 2nd Edition (McDonald, Isbell, Speight, Walker and Hopkins 1990) as modified for subsidence monitoring.

Observations have been made of the landform elements in accordance with the Landform section of the Field Handbook. The landform element has generally been described in terms of the following attributes:

- Slope;
- Morphological type;
- Dimensions;
- Mode of geomorphological activity; and
- Geomorphological agent.

In addition, observation has been made of the land surface in accordance with the Land Surface section of the Field Handbook. The land surface has generally been described in terms of the following attributes:

- Aspect, elevation and drainage height;
- Disturbance at the site, including erosion and aggradations;
- Micro relief;
- Inundation;
- Coarse fragments and rock outcrop;
- Depth to free water; and
- Runoff.

A watercourse reach of between ten and twenty times the channel width is monitored to cover local geomorphological units (e.g. pool/riffle).

For each watercourse monitoring site, a range of measurements and observations of the watercourse characteristics are recorded along with established photo points. Measurements and observations incorporate the relevant parts of the Field Handbook, and relevant parts of the Riparian-Channel-Environmental Assessment (RCE) methodology (Petersen 1992).

While in most cases, impacts on steep slopes are likely to be restricted to surface cracks, there remains a low probability of large-scale downslope movements. Steep slopes are therefore monitored throughout the mining period and until any necessary rehabilitation is complete. Slopes and gradients are monitored prior to mining as well as monthly during active subsidence during mining. The monitoring is undertaken at six monthly intervals for two years following completion of mining.

3.9 Erodibility

Most of the surface of the Longwall 19 Study Area has been identified as highly weathered Hawkesbury Sandstone outcrops and Sandstone derived-soils. This soil landscape has been identified to have high to extreme erosion susceptibilities to concentrated flows. This results in potential flow on effects to slope stability and erosion from any cracking resulting from subsidence (Ecoengineers 2012). Landscape monitoring of slopes is undertaken in the Longwall 19 Study Area to identify any erosion of the surface (**Figure 3-7**).

An extensive survey network will be implemented, which includes relative and absolute horizontal and vertical movements. Additional sites will be added to the monitoring program prior to subsidence movements impacting the sites.

Due to terrain, vegetation and access restrictions, the primary method of identifying any erosion over the Longwall 19 Study Area will be Airborne Laser Scanning (ALS). This technique has proven to be successful in generating topographic models of subsidence over entire longwalls and mining domains and will also provide identification of any erosion. The maximum areas, length and depth of erosion will be measured by standard survey methods.

Base surveys over Area 3A using ALS were completed in December 2005. A verification base survey will be conducted prior to the commencement of mining of the proposed longwall. Subsidence landscape models using the same methodology after the completion of subsidence at each longwall will provide a new (subsided) baseline surface dataset. For a period of up to ten years after mining repeat ALS datasets and surface modelling will be completed to identify new or increases in existing erosion. Erosion will be quantified by comparison of the immediate post subsidence landscape model with the long-term monitoring model. Targeted ALS scans will be completed where erosion is observed via the observational and landscape monitoring programs or after significant events such as bushfire and flooding.

The nominal accuracy of ALS derived subsidence contours is in the order of +/- 0.10 m and effective algorithms have been developed to allow the use of ground strike data only within the assessment. This effectively allows the analysis to see through vegetation to the ground surface.

General observational inspections of the mining area will be undertaken at regular intervals, during active subsidence. In addition to erosion, these observations aim to identify any surface cracking, surface water loss, soil moisture changes, vegetation condition changes, and slope and gradient changes.

3.10 Flora, Fauna and Ecosystem Function

Terrestrial flora and vegetation communities in the Study Area are described in the Terrestrial Ecology Assessment (Niche 2020). Aquatic flora and fauna in the Study Area are described in the Aquatic Ecology Assessment (Cardno Ecology Lab 2020).

An aquatic ecology monitoring program has been established by Cardno for Area 3. The monitoring program includes sites within Donalds Castle, Sandy and Wongawilli Creeks.

A monitoring program designed to detect potential impacts to ecology and ecosystem function from subsidence has been implemented for Area 3. As recommended by the IEP (2019a), the monitoring program is based on a BACI design with sampling undertaken at impact and control locations prior to the commencement of extraction, during extraction and after extraction.

Over two years of baseline data is available for the Longwall 19 Study Area and this data indicates that the habitat in this area is relatively undisturbed. There is sufficient baseline data to enable the detection of changes to ecology associated with mining related impacts.

The study focuses on flora, fauna and ecosystem function of swamps and watercourses and is measured via the following attributes:

- The size of the swamps and the groundwater dependent communities contributing to the swamps;
- The composition and distribution of species within the swamps;
- RCE including a photographic record of each stream assessment site;
- Water quality, including pH, DO, ORP, temperature, turbidity and EC;
- Aquatic macrophytes, including presence, species composition and total area of coverage;
- Aquatic macroinvertebrates using the Australian River Assessment System (AUSRIVAS) sampling protocol and artificial aquatic macroinvertebrate collectors;

- Fish presence and numbers using backpack electro fisher and/or baited traps; and
- Presence of threatened species (including Macquarie Perch, Littlejohn's Tree Frog, Giant Burrowing Frog, Adams Emerald Dragonfly, Giant Dragonfly and Sydney Hawk Dragonfly).

Standardised transects in potential breeding habitat for the threatened frog species Littlejohn's tree frog and Giant burrowing frog have been established in Dendrobium Area 3A. These repeatable surveys enable direct comparison of the numbers of individuals recorded at each site from one year to the next.

Additional monitoring will commence in other streams two years prior to mining. Monitoring is also undertaken away from mining to act as control sites for the mining versus non-mining comparative assessment. Although there has been mining upstream of Sites SC6, SC8 and NDC, data to date indicates there are strong numbers of frogs in these areas for monitoring purposes.

Along each transect the monitoring includes: counts of frogs, an assessment of pools being used for breeding as well as counts of tadpoles and egg masses. This will enable a quantitative as well as qualitative assessment of breeding habitat for these species prior to, during and after mining.

Observations of the sites, photo points and pool water level data will also be collected as part of the frog and observational monitoring programs. Locations where significant changes have been observed (e.g. drainage of pools) will be mapped, documented and reported.

Aquatic ecology monitoring includes direct measures of aquatic flora and fauna as well as biophysical measures. Aquatic ecology monitoring sites for the Longwall 19 Study Area are shown in the Aquatic Ecology Assessment (Cardno 2020). These sites are located in watercourses that contain "significant" or "moderate" aquatic habitat and are suitable for AUSRIVAS assessment (i.e. are at least 100 m long).

During the baseline study the condition of the aquatic habitat at each site was assessed using a modified version of RCE (Chessman *et al*. 1997).

At each site where instream aquatic macrophytes are present, their species composition and total area of coverage is recorded. Features such as the presence of algae or flocculent on the surface of macrophytes would also be noted.

Two methods are used to sample aquatic macroinvertebrates: the AUSRIVAS protocol for NSW streams (Turak *et al*. 2004) and artificial aquatic macroinvertebrate collectors, a quantitative method developed by CEL for freshwater environmental impact assessment.

In consideration of the possible presence of threatened macroinvertebrate species within the SMP Area, all dragonfly larvae collected in invertebrate sampling will be identified to the taxonomic level of family. Any individuals of the genus Petalura, Austrocorduliidae and Gomphomacromiidae will be further identified to species level if possible, and if there is any confusion, specimens will be referred to a specialist taxonomist. The confirmed presence of a threatened species will trigger further investigation into the species and its habitats in relation to potential subsidence impacts.

Fish are sampled using a back-pack electrofisher (model LR-24 Smith-Root) and baited traps. At each site, eight baited traps are deployed in a variety of habitats such as amongst aquatic plants and snags, in deep holes and over bare substratum. The back-pack electrofisher is operated around the edge of pools and in riffles. At each site, four, two-minute shots are performed. Fish stunned by the current are collected in a scoop net, identified and measured. Native species are released unharmed while exotics are not returned to the water.

Ongoing monitoring uses the BACI design with two types of monitoring sites included in the program:

- Potential impact sites - these may be subject to mine subsidence impacts during and after longwall extraction; and
- Control sites - these will provide a measure of background environmental variability within the catchments as distinct from any mine subsidence impacts.

Monitoring site locations are detailed in **Attachment 1: Table 1** and in Aquatic Ecology Assessment (Cardno 2020).

Observation data will also be collected as part of the monitoring program. Locations where significant changes have been observed (e.g. drainage of pools) will be mapped, documented and reported.

3.11 Pools and Controlling Rockbars

Dendrobium Mine lies in the southern part of the Permo-Triassic Sydney Basin. The geology mainly comprises sedimentary sandstones, shales and claystones, which have been intruded by igneous sills.

The sandstone units vary in thickness from a few metres to as much as 120 m. The major sandstone units are interbedded with other rocks and, though shales and claystones are quite extensive in places, the sandstone predominates.

The major sedimentary units at Dendrobium are, from the top down:

- The Hawkesbury Sandstone.
- The Narrabeen Group (including the Bulgo Sandstone).
- The Eckersley Formation.

Extensive geomorphological mapping has been completed for a large portion of Dendrobium Area 3, including the location of significant features in the watercourses (**Figure 3-8**).

The eastern area is broadly sited on a plateau dissected by a number of relatively shallow sub-catchments draining either into Cordeaux River via Wongawilli Creek or Donalds Castle Creek or five un-named 1st and 2nd order streams draining directly to the southern end of Lake Avon.

The largest watercourse within the Study Area is Wongawilli Creek (**Figure 1-1**) which is located between Areas 3A and 3B. The headwaters of Wongawilli Creek are located along a drainage divide separating surface runoff and shallow groundwater outflow runoff from Native Dog Creek and Lake Avon to the west. Sandy Creek is a third order perennial stream with a small baseflow which is located to the east of the proposed Longwall 19. Sandy Creek flows into Lake Cordeaux and has a number of 1st and 2nd order tributaries reporting flows.

The geomorphology of tributary sub-catchments in Longwall 19 Study Area is typically characterised by upland plateau and a series of 'benches' comprised of catenary hill-slopes and swamps enclosed in roughly crescent-shaped cliff lines (**Figure 3-4**).

The upstream southern end of the catchment consists of a ridge containing a thin sandy soil profile accumulated on a generally dome shaped outcrop. This outcrop exhibits pronounced removal of the sandstone's kaolinite clay cement and is typically white and friable (Hazelton and Tille 1990).

Drainage is to the north east and south west down slopes, with little evidence of surface drainage channels. This is consistent with headwater hill-slope aquifer zones and overland sheet flow during extreme rainfall events.

Wongawilli, Sandy and Donalds Castle Creeks are perennial flowing streams with small base flows and increased flows for short periods of time after each significant rain event.

Beds of the creeks are typically formed within Bulgo Sandstone, which overlies the Stanwell Park Claystone; however, there are sections of the headwaters of these creeks which are formed within the Hawkesbury Sandstone.

Three distinct channel types may be recognised in the main channel uplands, and in the tributaries of Sandy and Wongawilli Creeks:

- Narrow indistinct channels associated with low sedge/heath type vegetation cover and a relatively thick sandy riparian soil profile. The streambed consists of weathered bedrock and/or sandy materials. This is the situation in which valley infill swamps may be found.
- Rock rockbars of variable width which are usually smooth except for minor depressions on joint planes and occasional potholes. These platforms normally grade to a thinly vegetated sandy soil on both sides and usually exhibit the effects of chemical deposition of hydrated iron oxides. This deposition ranges from a slight colouration of the surface strata to intense replacement of the rock fabric.
- Channels that are erosive into cross-bedded sandstone and exhibit a rough riffle like surface usually with accumulations of boulders and other sediments. These channels are usually bounded by solid rock outcrop.

A number of semi-permanent pools may be found within the channels of these drainage lines and creeks. The mechanisms of pool stability are variable and uniquely depend on local stratigraphy, structure and gradient. Pools range from:

- Water accumulations in depression of an impermeable bedrock shelf (analogous to a bathtub) that is fed by direct precipitation, seepage or flood events; to
- Pools within eroded sections of sandy sediment and a free water surface that is dependent on surface flows and the local groundwater regime for stability.

Pools within unconsolidated (sandy) sediments are in a state of equilibrium between water in (from a higher part of the phreatic groundwater surface either upstream or laterally) and water out (flowing down the phreatic surface).

Most bedrock pools and riffle complexes rely on equilibrium between excess water in compared to water out. If the water inflow is less than the outflow, then the pool water level declines. The nature of this equilibrium is ultimately dependent on the position of the pool on the overall stream gradient. Many pools in the streams naturally develop at rockbars and at sediment and debris accumulations.

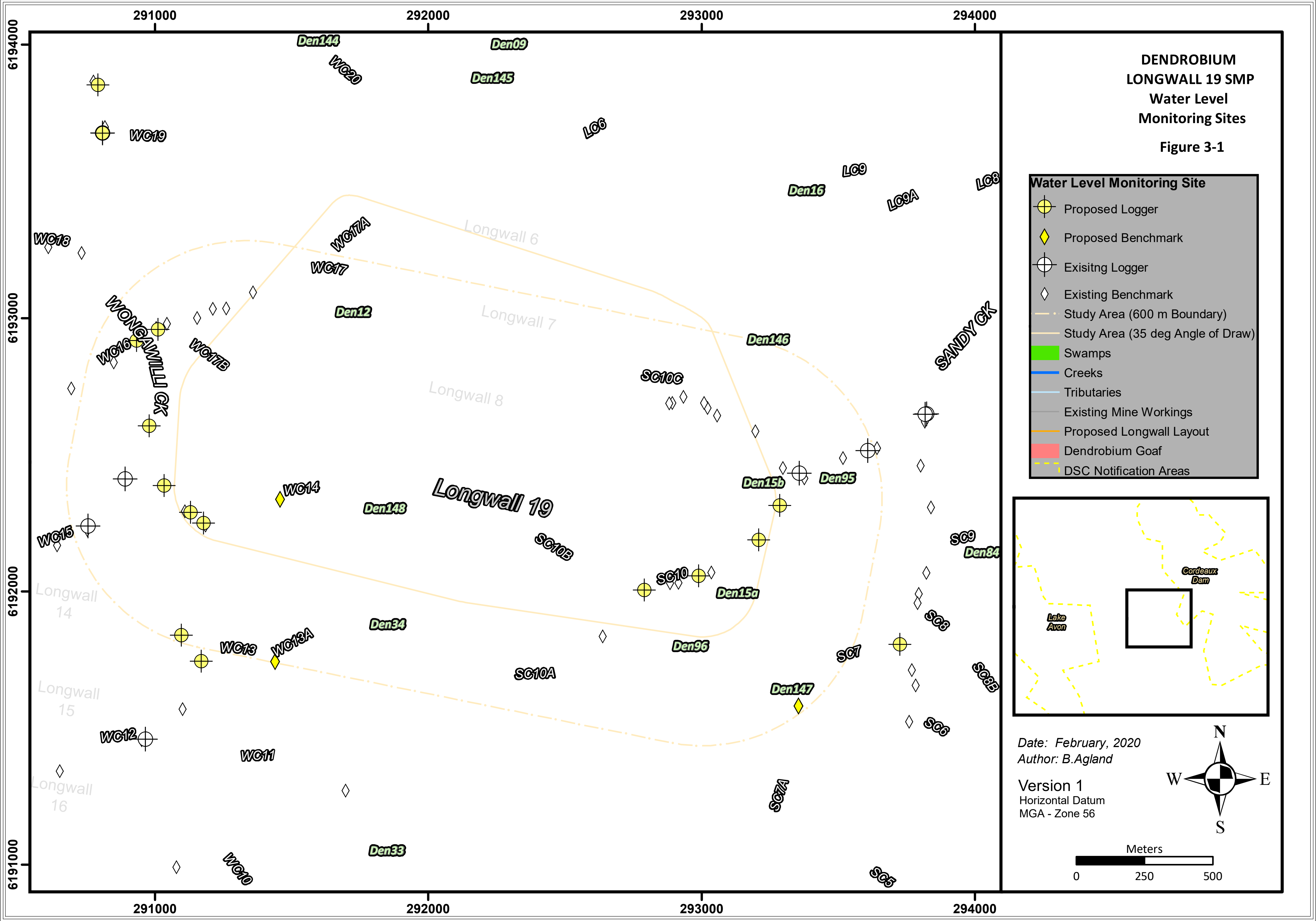
Rockbars and pools of Wongawilli Creek within the 600 m Study Area boundary (**Figure 3-8**) were mapped in February 2020 by IMCEFT. All mapped rockbar controlled pools in Sandy and Wongawilli Creeks are significant permanent pools.

3.12 Reporting

EoP Reports are prepared in accordance with Condition 9 Schedule 3 of the Dendrobium Development Consent. Results from the monitoring program are included in the EoP Report and in the AEMR. These reports detail the outcomes of monitoring undertaken; provide results of visual inspections and determine whether performance indicators have been exceeded.

Monitoring results will be reviewed monthly by the IMC Subsidence Management Committee. However, if the findings of monitoring are deemed to warrant an immediate response, the Principal Approvals will initiate the requirements of the TARPs (**Appendix A**).

Monitoring results are included in the Annual Reporting requirement under Condition 5 Schedule 8 in accordance with the Dendrobium Development Consent and are made publicly available in accordance with Condition 11, Schedule 8.


DENDROBIUM
LONGWALL 19 SMP
Water Level
Monitoring Sites
Figure 3-1
Water Level Monitoring Site
Proposed Logger
Proposed Benchmark
Exisitng Logger
Existing Benchmark
Study Area (600 m Boundary)
Study Area (35 deg Angle of Draw)
Swamps
Creeks
Tributaries
Existing Mine Workings
Proposed Longwall Layout
Dendrobium Goaf
DSC Notification Areas
Date: February, 2020
Author: B.Agland
Version 1
Horizontal Datum
MGA - Zone 56
Meters
0 250 500
N S E W
Cordeaux Dam
Lake Avon
291000 292000 293000 294000
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Longwall 16
WONGAWILLI CK
SANDY CK
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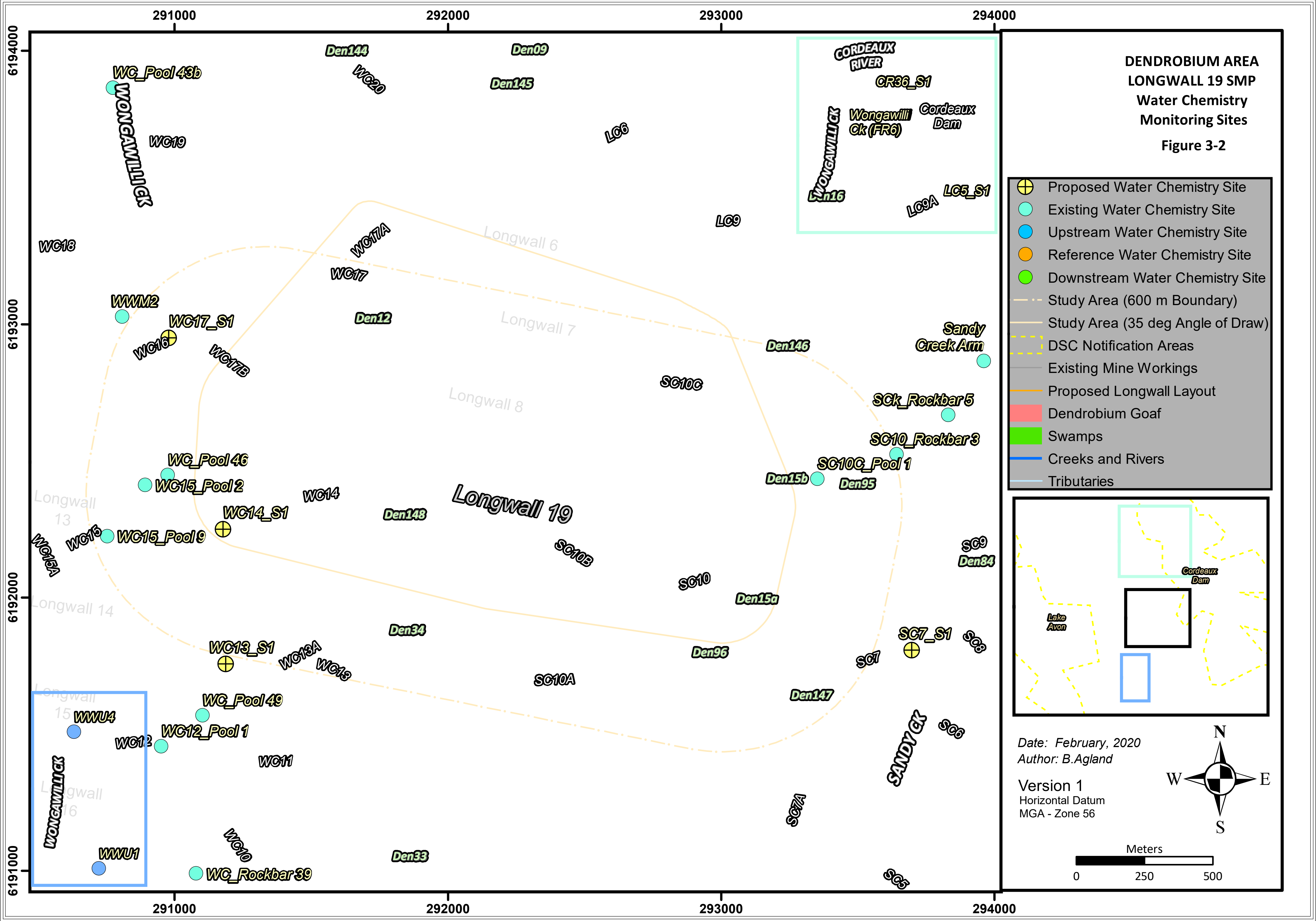

DENDROBIUM AREA
LONGWALL 19 SMP
Water Chemistry
Monitoring Sites
Figure 3-2
Proposed Water Chemistry Site
Existing Water Chemistry Site
Upstream Water Chemistry Site
Reference Water Chemistry Site
Downstream Water Chemistry Site
Study Area (600 m Boundary)
Study Area (35 deg Angle of Draw)
DSC Notification Areas
Existing Mine Workings
Proposed Longwall Layout
Dendrobium Goaf
Swamps
Creeks and Rivers
Tributaries
Date: February, 2020
Author: B.Agland
Version 1
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SANDY CK
Sandy Creek Arm
Cordeaux Dam
Lake Avon
Wongawilli Ck (FR6)
WC_Pool 43b
WC19
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WC17_S1
WC16
WC17B
WC17
WC17A
WC_Pool 46
WC15_Pool 2
WC14_S1
WC14
WC15
WC15_Pool 9
WC15A
WC13_S1
WC13A
WC13
WC_Pool 49
WWU4
WC12
WC12_Pool 1
WC11
WC10
WWU1
WC_Rockbar 39
Den144
WC20
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LC5_S1
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SC10_Rockbar 3
SC10C_Pool 1
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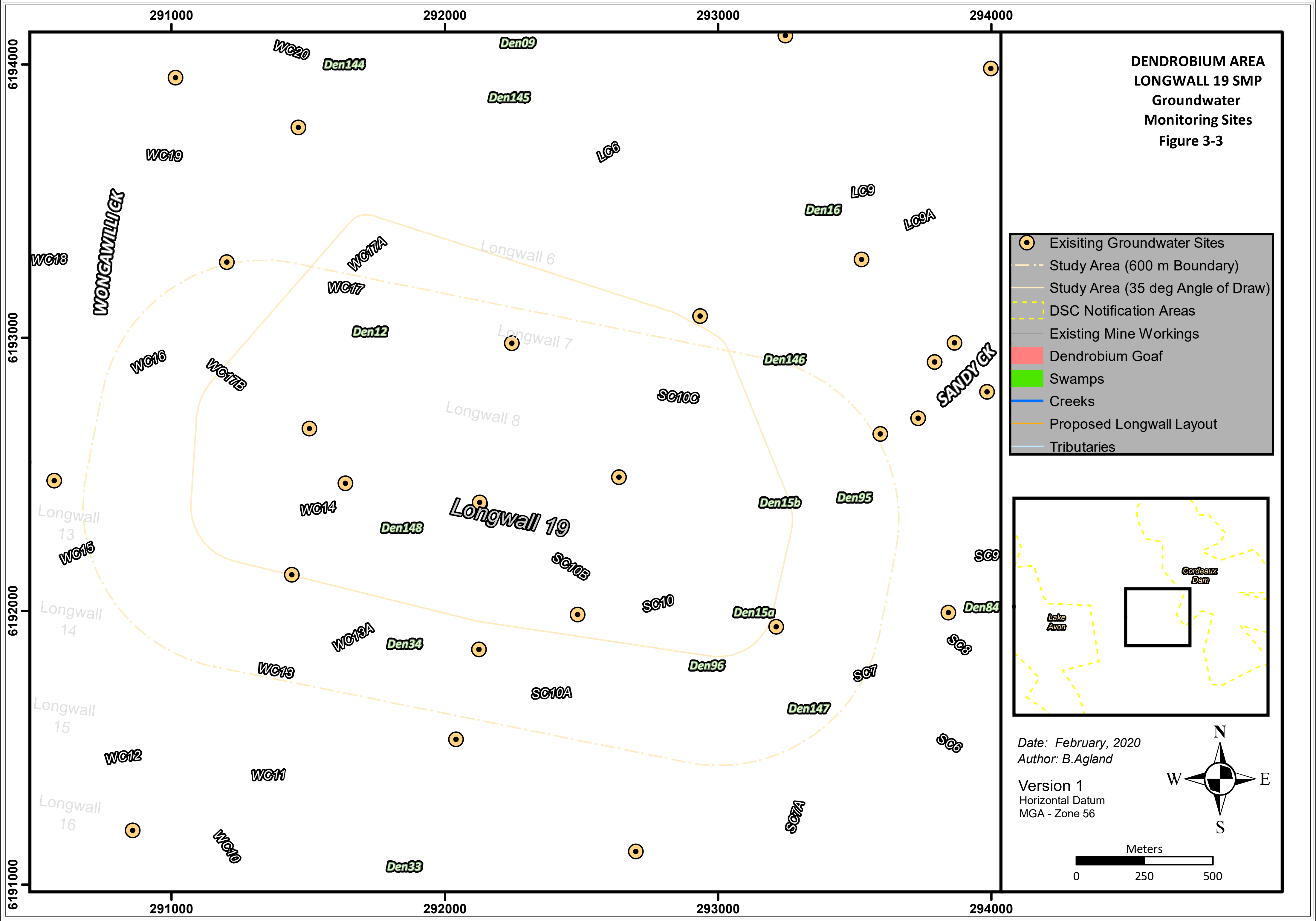
SC7A
SC5



DENDROBIUM AREA
LONGWALL 19 SMP
Groundwater
Monitoring Sites
Figure 3-3
Exisiting Groundwater Sites
Study Area (600 m Boundary)
Study Area (35 deg Angle of Draw)
DSC Notification Areas
Existing Mine Workings
Dendrobium Goaf
Swamps
Creeks
Proposed Longwall Layout
Tributaries
Date: February, 2020
Author: B.Agland
Version 1
Horizontal Datum
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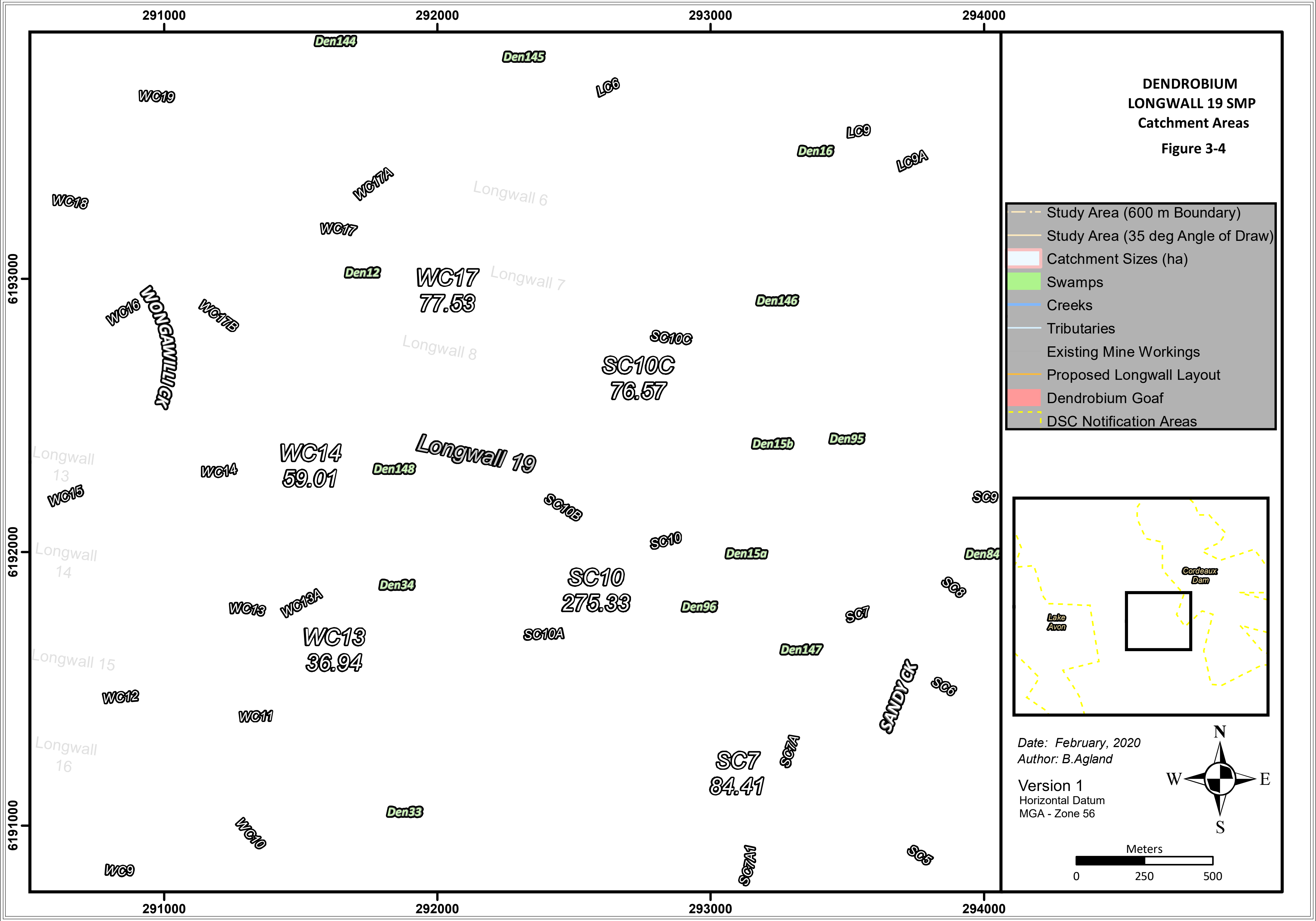

DENDROBIUM
LONGWALL 19 SMP
Catchment Areas
Figure 3-4
Study Area (600 m Boundary)
Study Area (35 deg Angle of Draw)
Catchment Sizes (ha)
Swamps
Creeks
Tributaries
Existing Mine Workings
Proposed Longwall Layout
Dendrobium Goaf
DSC Notification Areas
Cordeaux Dam
Lake Avon
Date: February, 2020
Author: B.Agland
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WC13A
WC12
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SC6
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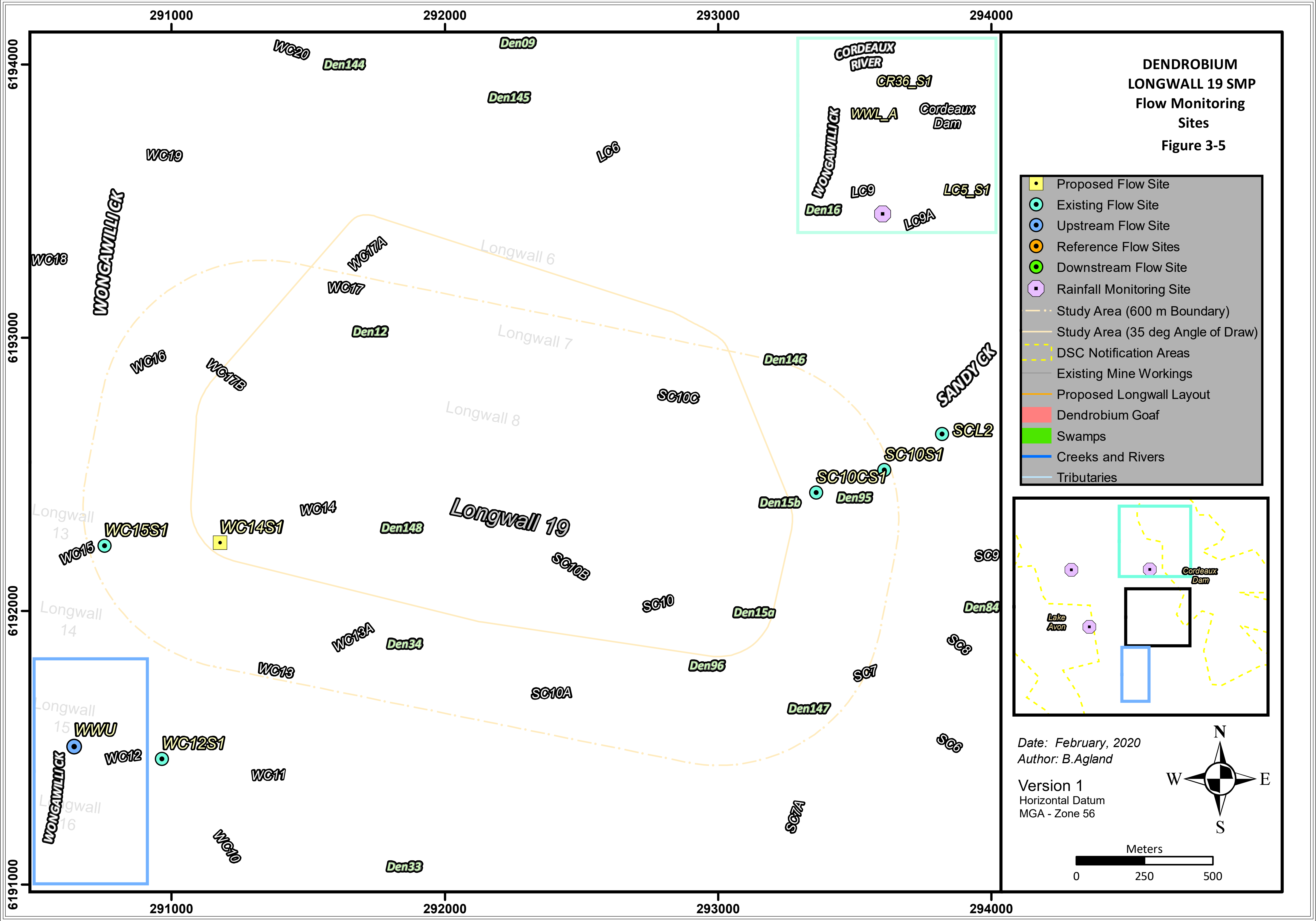
DENDROBIUM
LONGWALL 19 SMP
Flow Monitoring
Sites
Figure 3-5
Proposed Flow Site
Existing Flow Site
Upstream Flow Site
Reference Flow Sites
Downstream Flow Site
Rainfall Monitoring Site
Study Area (600 m Boundary)
Study Area (35 deg Angle of Draw)
DSC Notification Areas
Existing Mine Workings
Proposed Longwall Layout
Dendrobium Goaf
Swamps
Creeks and Rivers
Tributaries
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CORDEAUX RIVER
SANDY CK
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SC10S1
SC10CS1
Den15b
Den95
WC14
WC15S1
WC14S1
Den148
WC15
SC10B
SC9
SC10
Den15a
Den84
WC13A
Den34
WC13
Den96
SC8
SC7
SC10A
Den147
WWU
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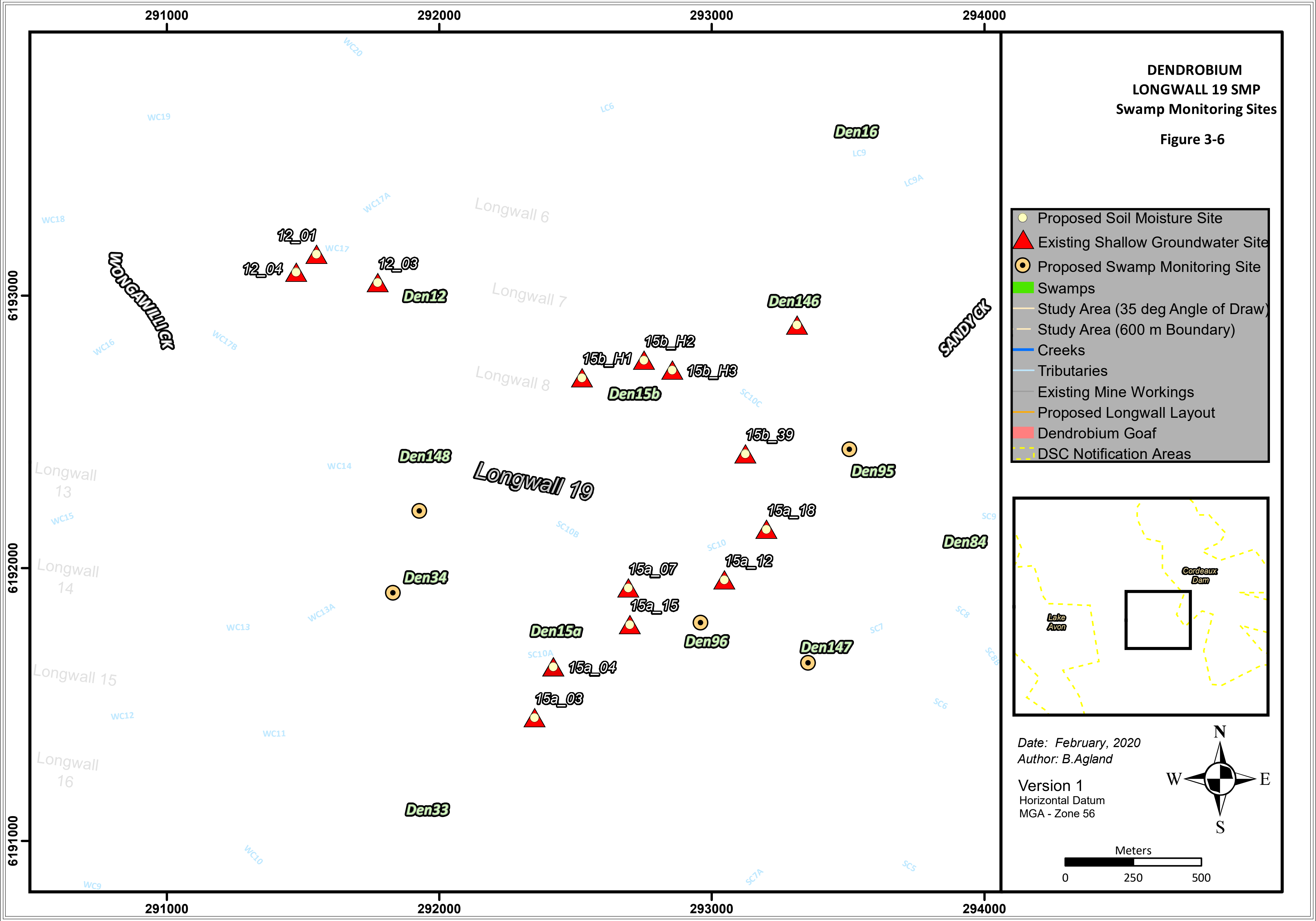
LC5_S1
Den16
LC9A


DENDROBIUM
LONGWALL 19 SMP
Swamp Monitoring Sites
Figure 3-6
Proposed Soil Moisture Site
Existing Shallow Groundwater Site
Proposed Swamp Monitoring Site
Swamps
Study Area (35 deg Angle of Draw)
Study Area (600 m Boundary)
Creeks
Tributaries
Existing Mine Workings
Proposed Longwall Layout
Dendrobium Goaf
DSC Notification Areas
Cordeaux Dam
Lake Avon
Date: February, 2020
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Longwall 15
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Longwall 19
WONGAWILLI CK
SANDY CK
Den16
Den12
Den146
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Den148
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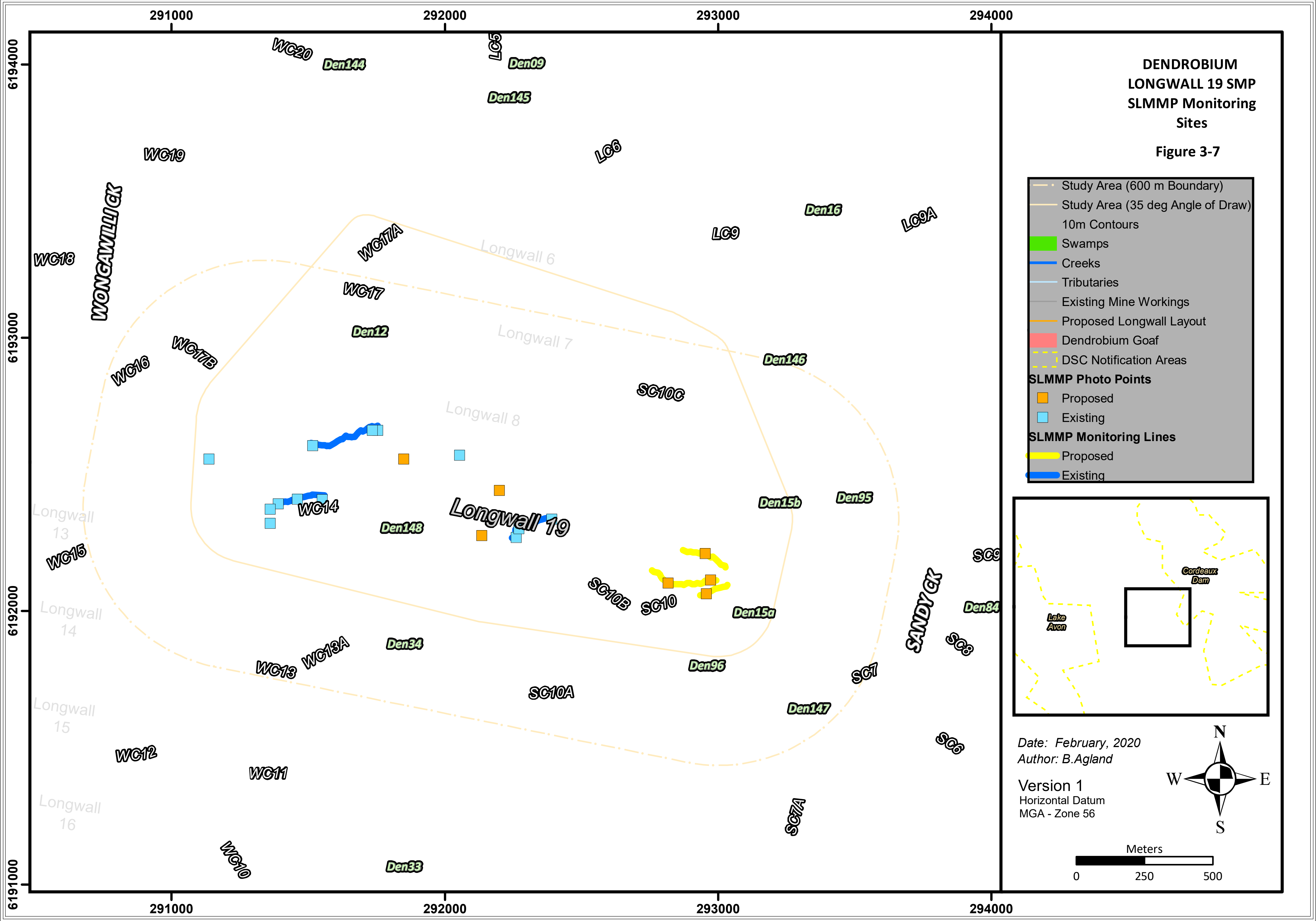
Den84
Den34
Den15a
Den96
Den147
Den33
12_01
12_04
12_03
15b_H1
15b_H2
15b_H3
15b_39
15a_18
15a_07
15a_12
15a_15
15a_04
15a_03
WC20
WC19
LC6
LC9
LC9A
WC18
WC17A
WC17
WC16
WC17B
SC10C
WC14
WC15
SC10B
SC9
SC10
WC13A
WC13
SC10A
SC8
SC7
SC8B
SC6
WC12
WC11
WC10
WC9
SC7A
SC5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Longwall 16
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WC10
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DENDROBIUM LONGWALL 19 SMP SLMMP Monitoring Sites
Figure 3-7
Study Area (600 m Boundary)
Study Area (35 deg Angle of Draw)
10m Contours
Swamps
Creeks
Tributaries
Existing Mine Workings
Proposed Longwall Layout
Dendrobium Goaf
DSC Notification Areas
SLMMP Photo Points
Proposed
Existing
SLMMP Monitoring Lines
Proposed
Existing
Cordeaux Dam
Lake Avon
Date: February, 2020
Author: B.Agland
Version 1
Horizontal Datum
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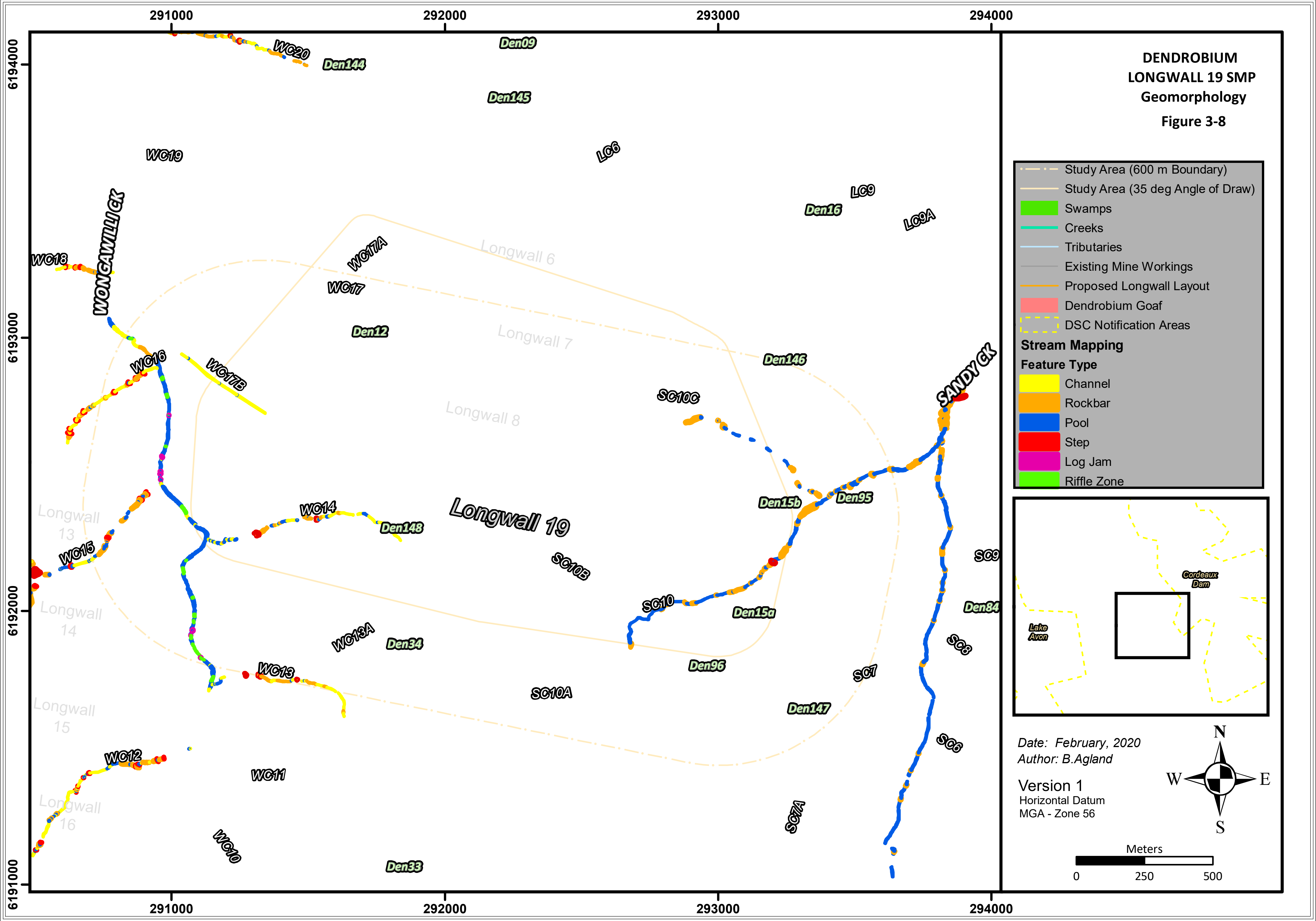
DENDROBIUM
LONGWALL 19 SMP
Geomorphology
Figure 3-8
Study Area (600 m Boundary)
Study Area (35 deg Angle of Draw)
Swamps
Creeks
Tributaries
Existing Mine Workings
Proposed Longwall Layout
Dendrobium Goaf
DSC Notification Areas
Stream Mapping
Feature Type
Channel
Rockbar
Pool
Step
Log Jam
Riffle Zone
Cordeaux Dam
Lake Avon
Date: February, 2020
Author: B.Agland
Version 1
Horizontal Datum
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4 PERFORMANCE MEASURES AND INDICATORS

Performance measures and indicators have been derived from the Dendrobium Development Consent. These performance measures are presented in **Table 5** and will be applied to the Dendrobium Area 3A mining area including the Longwall 19 Study Area.

Table 5 Subsidence Impact Performance Measures

Dendrobium Development Consent
• Operations shall not cause subsidence impacts at Sandy Creek and Wongawilli Creek other than "minor impacts" (such as minor fracturing, gas release, iron staining and minor impacts on water flows, water levels and water quality); • Operations will not result in reduction (other than negligible reduction) in the quality or quantity of surface water or groundwater inflows to Lake Cordeaux or Lake Avon or surface water inflow to the Cordeaux River at its confluence with Wongawilli Creek. • The Applicant must ensure that, as a result of the development: - no rock fall occurs at Sandy Creek Waterfall or from its overhang; - the structural integrity of the waterfall, its overhang and its pool are not impacted; - cracking in Sandy Creek within 30 m of the waterfall is of negligible environmental and hydrological consequence; and - negligible diversion of water occurs from the lip of the waterfall to the satisfaction of the Secretary. • The Applicant must ensure that subsidence does not cause erosion of the surface or changes in ecosystem functionality of Swamp 15a and that the structural integrity of its controlling rockbar is maintained or restored, to the satisfaction of the Secretary.

A detailed list of performance measures and triggers is included in the TARPs in **Appendix A**.

4.1 Impact Mechanisms

Subsidence is an unavoidable consequence of longwall mining and includes vertical and horizontal movement of the land surface. Subsidence effects include surface and sub-surface cracking, buckling, dilation and tilting. These effects can result in changes to the hydrology of watercourses.

Changes to watercourse hydrology and water quality can result in environmental consequences. The likelihood and timing of these consequences relate to the size and duration of the effect. The potential consequences of mining on groundwater and surface water in the Special Areas are (IEP 2019a and b):

- Groundwater depressurisation
    - The creation of an excavation below the water table can affect groundwater in a number of basic ways. In all cases, because the fluid pressure in an excavation is much lower than that of the fluid that originally occupied the space, a flow system is established with the excavation acting as a sink into which surrounding groundwater flows. The rate of flow and observed extent of depressurisation depend on the hydrogeological properties of the rock mass. If the excavated area is sufficiently large, the spatial extent and rate of flow into the sink can be enhanced by the formation of fractures.
- Surface water diversions
    - Diversions into a shallow, localised fracture network, where loss of flow from a surface water is likely to return to the system at some point downstream, which based on observations of the SCI (2008) may vary from 20 m for specific rockbars to more than 200 m.
- Surface water permanent losses
    - Diversions into deeper, dilated shear surfaces on bedding planes, where these form a conduit for lateral water flow, which may or may not report to the same catchment (i.e. it may become a permanent loss).
- Groundwater depressurisation

  - Groundwater within the Hawkesbury Sandstone and Narrabeen Group as well as the Permian coal measures is recharged from rainfall and water bodies where the lithologies occur at outcrop, as well as potential downward leakage from overlying strata (Hydrosimulations 2018).

- Water quality
  - Water quality within watercourses is affected by numerous factors including runoff from swamps and interactions between bedrock and water, with fracturing of bedrock due to mining causing local water quality impacts.

The environmental consequences which could relate to changes in hydrology and water quality include:

- Species composition change and/or changes in vegetation communities.
- Loss of aquatic ecology and/or changes in aquatic habitat resulting from a reduction of surface water quality and/or flows and standing pools.
- Water-borne inputs to Lake Avon, Lake Cordeaux and Cordeaux River such as erosive export of fine sands and clays and/or ferruginous precipitates.
- Reduced inflows into Lake Avon, Lake Cordeaux and Cordeaux River.

4.2 Potential for Connectivity to the Mine Workings

The fracture zone comprises in-situ material lying immediately above the caved zone which have sagged downwards and consequently suffered significant bending, fracturing, joint opening and bed separation (Singh and Kendorski, 1981; Forster, 1995). Where the panel width-to-depth ratio is high and the depth of cover is shallow, the fracture zone would extend from the seam to the surface. Where the panel width-to-depth ratio is low, and where the depth of cover is high, the fracture zone would not extend from the seam to the surface.

The possible height of the fracture zone is dependent upon the angle of break, the width of the panel, the thickness of seam extracted and the spanning capacity of a competent stratum at the top of the fracture zone (MSEC 2012). Based on mining geometry, the height of the fracture zone equals the panel width, minus the span, divided by twice the tangent of the angle of break.

It should be noted that the height of the fracture zone should be viewed in the context of fracturing only and should not necessarily be directly associated with an increase in vertical permeability. There are numerous models for the height of fracturing and height of depressurisation. A review of these matters was conducted for the Bulli Seam Operations Project Response to PAC deliberations (Hebblewhite 2010).

The Regional Groundwater Models at Dendrobium uses site specific data to determine the height of depressurisation. Dendrobium monitors in excess of 1,000 piezometers in ~100 boreholes (including a comprehensive array of piezometers above the centreline of longwall goafs) and has analysed many thousands of samples for field parameters, laboratory analysis, algae and isotopes.

The results of water analysis and the interpretation of the height of connective fracturing was peer reviewed by Parson Brinckerhoff (2012). The peer review states that "*the use of standard hydrogeochemical tools clearly demonstrated the geochemical difference between water from the Wongawilli Coal Seam and goaf, and the overlying sandstone formations and surface water from Lake Cordeaux*". Although the report acknowledged limitations of the available data, this review is based on one of the most comprehensive datasets available in the Southern Coalfield.

In January 2015 SRK Consulting conducted a detailed independent review of the Dendrobium water chemistry data to:

- Assess the level of detail, quality of science, depth and technical appropriateness of the water chemistry data.
- Evaluate associated interpretations in relation to underground operations of Dendrobium Mine, with specific focus on how these address the question of hydraulic connectivity between the mined areas and the reservoirs.

Based on the review SRK concluded that the observed geochemical trends are not consistent with a high degree of hydraulic connectivity between the underground workings and the surface water bodies.

As reported in Coffey (2012) most of the change in aquifer properties occurs within the collapsed zone.

Changes in aquifer properties above the collapsed zone are less severe and largely restricted to increases in storability. Groundwater drawdown due to sudden storativity increases will ultimately impact the surface, either directly (as seepage from watercourses or lakes to satisfy the drawdown), or by intercepting baseflow.

Predictions of fracture zone dimensions for Dendrobium (MSEC 2012 and Coffey 2012) refer to geotechnical fracturing behaviour and are not necessarily directly related to groundwater responses resulting from increased vertical permeability.

Parson Brinckerhoff and IMC have completed testing to characterise the pre- and post-mining permeability above Longwall 9, the first longwall in a new domain, not affected by previous mining. After Longwall 9 mined under the site it was tested to quantify the change to vertical and horizontal permeability of the strata, including the Bulgo and Hawkesbury Sandstones and the Bald Hill Claystone. The testing involved core, packer and borehole interference testing, groundwater flow and tracer testing.

Mining of Longwall 9 resulted in a significant increase in subsurface fracturing compared with pre-mining. Down-hole camera surveys identified a number of open horizontal and inclined fractures with apertures of several centimetres. Groundwater ingress was noted at several open fractures.

Most post-mining test bores showed decreases in groundwater level and strong downward hydraulic gradients, particularly in the lower Bulgo Sandstone. Significantly however, groundwater levels in the shallow Hawkesbury Sandstone remained perched at the study site.

Horizontal hydraulic conductivity increased between one to three orders of magnitude due to mine subsidence and strata fracturing. Increases in hydraulic conductivity are observed in every geological unit but are greatest below the base of the Hawkesbury Sandstone.

In contrast to pre-mining testing in which no breakthrough was observed, horizontal tracer testing after the passage of Longwall 9 resulted in breakthrough in about 40 minutes. This indicates a bulk hydraulic conductivity in the order of 10 m/day; at least two orders of magnitude higher than pre-mining conditions.

No breakthrough in tracer was observed in either the pre-mining or the post-mining tests of the Bald Hill Claystone and this indicates that the vertical conductance at the research site was below the detection limit of the test, estimated to be approximately 0.7 m/day.

Activated carbon samplers deployed in streams adjacent to the research site detected no breakthrough of tracer and therefore there is no evidence of preferential flow paths either existing or induced between the research site and adjacent streams.

Sampling of water from the underground mine detected no breakthrough of tracer and therefore there is no evidence of preferential flow paths induced between the research site and the workings.

Although current observations do not allow a precise definition of the height of intense fracturing using any criteria (and the boundaries are gradational in any case), most evidence suggests that the zone of most intense and vertically connected fracturing in Area 3B extends into the Bulgo Sandstone.

Estimates for the height of fracturing at Dendrobium based on published methods range from 122 m to 357 m. This range in estimates is large and presents a challenge to those wishing to model hydrogeological impacts of mining on a regional scale based on mine site data.

The pre- and post-mining investigations carried out in this research study provide important constraints on the extent of mining related disturbance and its effect on groundwater systems.

A review of methods for estimating the height of fracturing above longwall panels at Dendrobium Mine was commissioned by DPIE and carried out by geotechnical consultants Pells Sullivan Meynink (PSM). The PSM report was made available to South32 on 7 September 2017.

Recommendations by PSM regarding additional monitoring and research to add to our understanding of the catchment are generally supported and many of these have been acted on.

The IEP (2019b) Part 2 Report further considered mining operations within the special areas and reiterated its earlier position stated in IEP (2019a*):*

The Panel has given detailed consideration to the equations in the Part 1 Report and concluded that it cannot endorse either at this point in time. For a range of reasons, neither or either may ultimately prove to be sufficiently reliable. It recommended erring on the side of caution and deferring to the Tammetta equation until:

i. field investigations quantify the height of complete drainage at Metropolitan and Dendrobium mines; and/or

ii. *geomechanical modelling of rock fracturing and fluid flow are shown to be sufficiently reliable for informing the calibration of groundwater models at mine sites in the catchment.*

The Regional Groundwater Model for Dendrobium Mine has been revised to consider the findings of the PSM report and IEP Reports (2019a and b), including the use of the Tammetta model and modelling connectivity to the surface. HydroSimulations state that regardless of the method used to assess fracturing, they believe the current groundwater modelling approach is sound.

In accordance with Schedule 3, Condition 19(c) of the Area 3B SMP Approval, height of connective fracturing investigations across longwalls in Area 3B are undertaken and reported to the Department prior to each longwall extraction. The most recent report, Hebblewhite (2020) states:

… comments and conclusions are drawn in relation to the overall concept of height of depressurisation, and the status of predictive models:

- *…*
- *… mining-induced impacts are occurring above all panels throughout the overburden sequence, through to, or very close to the surface in all cases. This includes increased defect/fracture impacts; significant increases in permeability; and reduction to near-zero pressure head throughout the strata.*
- *There is some evidence of very localised retained groundwater in perched aquifers at some locations, and at different vertical horizons, but these are not extensive.*
- *On the basis of this evidence, it is reasonable to conclude that the height of depressurisation is close to, or equal to the total depth of overburden above the working coal seam, i.e. extending to the surface in each instance.*
- *In spite of the reduced longwall panel width in Area 3A (LW6 and LW7), the height of depressurisation has still effectively extended to the surface, albeit with a reduced strata fracture density above the mined panels. It is likely that a more significant panel width reduction and or mining height reduction would be necessary to cause a significant reduction in height of depressurisation in this particular mining region.*
- *The lack of significant differential in height of depressurisation with the reduced panel widths means that the range of the dataset available to assist with developing an improved prediction model remains inconsistent, and insufficient to enable any further model development based on empirical methods.*
- *There is strong evidence at all locations of significant depressurisation occurring ahead of under-mining, due to the effect of adjacent mining panels, and earlier mining development. These effects are evident at most of the strata horizons, extending towards the surface.*
- *… the Tammetta model is clearly the most appropriate one to continue using in the future. It provides a reasonably accurate prediction – given the variability of factors such as depth across any particular panel.*

4.3 Potential for Fracturing Beneath the Watercourses

Based on the predicted systematic and non-systematic subsidence movements (MSEC 2012, 2015, 2018 and 2020) the bedrock below the watercourses are likely to fracture as a consequence of subsidence induced strains.

Surface flows captured by the surface subsidence fracture network resulting from valley related movements which do not connect to a deeper storage, aquifer or the mine workings will re-emerge further downstream (see **Section 4.2**). This prediction is based on an assessment of the depth of valley closure induced vertical fracturing from the surface and measurements of water balance downstream of mining areas.

The depth of fracturing in the “surface zone” is addressed in the Bulli Seam Operations Environmental Assessment: Section 5.2.1, Appendix A, Appendix B and Appendix C as well as in the Response to Submissions and Response to the NSW Planning Assessment Commission. The BSO Independent Peer Review of strata deformation provided by Professor Bruce Hebblewhite concurs with the concept of the “surface zone” fracture network related to down-slope or valley movements. Several studies have determined the depth of these vertical fracture networks are restricted to approximately 15 to 20 m below the surface.

The depth and other attributes of the surface fracture zone have been comprehensively determined using the following instruments and techniques:

- Calliper logging;
- Straddle packer permeability testing;

- Overcore stress measurements;
- Core logging and geotechnical testing;
- Geophysical testing;
- Water level monitoring;
- Borehole cameras;
- Subsidence, extensometer monitoring and shear deformation monitoring;
- Stress change and fracture logging;
- Permeability testing and falling head tests; and
- Mapping of pressured air drilling fines.

The following sites have been comprehensively investigated to demonstrate the dimensions of the "surface fracture zone":

- Two rockbars on the Waratah Rivulet; and
- Four rockbars on Georges River.

Monitoring from Dendrobium Mine indicates the surface fracture network over the goaf connects to or is concurrent with the fracture network which propagates from the seam to the surface (IEP 2019a). In this instance the diversion of surface flow to deep strata storage or the mine relates to vertical permeability increases associated with this fracturing.

Prior to any remediation works within the Study Area that target surface/shallow fracture networks, the depth of the fracturing will be characterised by standard techniques such as drilling, down hole cameras and calliper measurements. The hydraulic conductance of these fracture networks will also be determined prior to implementing any rehabilitation.

The effects of mining on surface water flow following the completion of Longwall 14 was modelled and assessed in the Longwall 14 EoP Report (IMC 2019). This assessment has identified that mining-related effects on the flow regime have occurred in tributaries to Donalds Castle Creek (DCS2, DC13S1), Lake Avon tributary (LA4) and tributaries to Wongawilli Creek (WC15S1 and WC21S1). There is also a possible change to runoff characteristics at the downstream gauge of Donalds castle Creek (DCU) and Wongawilli Creek (WWL), although there is no clear causal link to Longwall 14 mining.

The water level in Pool 43a on Wongawilli Creek has declined since 2012, and water levels dropped below baseline on 20 November 2017. Assessment of the declining water levels in Pool 43 was hindered by the unusually dry conditions during the extraction of Longwall 13 which has affected pools outside the influence of mining. However, the steady decline in water levels at Pool 43a since 2012 appears independent of the rainfall trends and, combined with observations of drawdown in groundwater pressures in the sandstone substrate, suggests that water level trends at Pool 43a may be due to induced baseflow reduction. Rainfall-runoff modelling of flows at the downstream gauge (WWL) indicates that baseflow reduction is less than predicted by numerical modelling.

4.4 Potential for Erosion Within the Watercourses

Tilting, cracking, desiccation and/or changes in vegetation health could result in erosion within the watercourses. The likelihood and timing of these consequences relate to the size and duration of the effect.

Subsidence predictions were carried out to assess the potential impacts of longwall mining in the Study Area. The assessment indicated that the levels of impact on the natural features were likely to be similar to the impacts observed within Area 3A and Area 3B to date. A summary of the maximum predicted values of subsidence, tilt and strain at the watercourses is provided in **Section 5**.

Tilting of sufficient magnitude could change the catchment area of a watercourse or re-concentrate runoff leading to scour and erosion.

Changes in gradients predicted to occur following mining are shown in **Section 5**. These changes have been considered in relation to the likelihood of change in drainage line alignment by MSEC (2012, 2015, 2017, 2018 and 2020). The assessment takes into account the nature of the watercourse and whether the predicted tilt is significant when compared to the existing slopes.

Landscape monitoring commenced in 2004 for Dendrobium Area 1. This monitoring program has been continued and updated throughout the mining period for Areas 2, 3A and 3B. The monitoring includes inspections of watercourses at regular intervals prior to mining, during active subsidence and following the completion of subsidence movements. In addition to erosion (increased incision and/or widening), these observations target any surface cracking, surface water loss, soil moisture changes, vegetation condition changes, slope and gradient changes and the condition of rockbars.

The observed impacts on natural features above Area 3A to date are generally consistent with those predicted.

4.5 Potential for Aquatic Ecology Changes Within the Watercourses

Where there are changes to watercourse hydrology that are large and persistent there is likely to be an aquatic ecology response. Aquatic species which do not have life-cycles adapted to temporary loss of aquatic habitat are likely to be relatively susceptible to changes in pool water level. In comparison, riparian vegetation is likely to be relatively resilient to changes in groundwater level and soil moisture, demonstrated by the persistence of these vegetation communities during extended periods of drought.

Cardno undertakes a monitoring program designed to detect mining-related subsidence impacts to indicate the condition of aquatic ecology.

The monitoring program is based on a BACI design that provides a measure of natural spatial and temporal variability in key aquatic ecology indicators at potential impact and control sites before, during and after mining. This enables changes in the mining area to be distinguished from changes due to natural variability.

The monitoring program focuses on the following key indicators:

- Habitat condition assessed using the RCE Inventory method and by establishing a photographic record through time;
- Aquatic macroinvertebrates sampled in accordance with AUSRIVAS;
- Aquatic macroinvertebrates sampled quantitatively using artificial collectors;
- Sampling of fish using bait traps and backpack electrofishing; and
- Limited in situ water quality sampling is undertaken to assist with interpretation of trends in the above indicators.

Monitoring is undertaken within Wongawilli Creek and Sandy Creek, and at comparable Control sites established on Wongawilli, Sandy, Donalds Castle and Kentish creeks. Univariate and multivariate statistical analyses have been conducted on the AUSRIVAS sampling and artificial collectors. Surveys and reporting have been completed in 2010, 2011, 2013, 2014, 2015, 2017, 2018 and 2019. Further details of the aquatic ecology monitoring program are available in the Aquatic Ecology Assessment (Cardno 2020).

In the Southern Coalfield, impacts to riparian vegetation as a result of subsidence are minor in occurrence. Furthermore, no impacts to riparian vegetation have been observed in Dendrobium Mine to date (Niche 2012). Previous examples of impacts include: dieback of riparian vegetation as a result of subsidence of the Cataract River during the 1990s (Eco Logical Australia, 2004 in TEC 2997), and small localised changes to riparian vegetation along a section of the Waratah Rivulet (Helensburgh Coal 2007).

4.6 Potential for Raw Water Quality Changes

From several years of monitoring there has been no evidence of short or long-term impacts to water quality or drinking water quality in Lake Avon or Lake Cordeaux, despite tributaries of the lake being directly undermined by Elouera Colliery and Dendrobium Mine longwalls, causing bedrock fracturing.

Due to the standoffs from Wongawilli Creek of the Area 3A longwalls, it is not expected any significant fracturing and sub-bed flow diversions in Wongawilli Creek would alter flows or water quality other than minor impacts. Due to the substantial distance downstream, it is predicted there will be no reduction (other than negligible reduction) in the quality or quantity of surface water inflow to the Cordeaux River at its confluence with Wongawilli Creek.

Based on past experience from Wongawilli and Native Dog Creeks which were directly mined under by Elouera Colliery longwalls, it is also considered highly unlikely that there would be any adverse effect on bulk drinking water supply quality in the Lake Avon, Lake Cordeaux or Cordeaux River (into which Donalds Castle and Wongawilli Creeks discharge) systems.

Any water-borne inputs to Lake Avon, Lake Cordeaux and Cordeaux River would likely be restricted to a possible erosive export of fine sands and clays and/or ferruginous precipitates near the mouths of minor creeks designated WC13, WC14, WC15, WC16, WC17, SC7 and SC10 during mining of Longwall 19. It is predicted that these water-borne inputs will result in negligible environmental consequences.

These creeks are all remote from their respective dam off-takes and outflows. Such zones would be localised around the point of input to the Lake and would be unlikely to have any detrimental effect on local freshwater ecology and unable to affect bulk water supply quality.

4.7 Achievement of Performance Measures

Longwall mining can result in surface cracking, heaving, buckling and stepping at the surface. Surface deformations can also develop as the result of downslope movements where longwalls are extracted beneath steep slopes.

In these cases, the downslope movements can result in the development of tension cracks at the tops of the steep slopes and compression ridges at the bottoms of the steep slopes. Fracturing of bedrock can also occur in the bases of stream valleys due to the compressive strains associated with valley closure movements. The extent and severity of these mining induced ground deformations are dependent on a number of factors, including the mine geometry, depth of cover, overburden geology, geomorphology, locations of natural jointing in the bedrock and the presence of near surface geological structures.

A number of large surface cracks were observed at the commencing end of Longwall 3 in Area 2 at Dendrobium Mine. The depth of cover at the commencing end of Longwall 3 was as shallow as 145 m, which is less than that above Longwall 19 in Area 3A, which varies between 280 m and 370m. It is expected, therefore, that the widths of surface cracking resulting from the extraction in Area 3B would be generally less than that observed above the commencing end of Longwall 3.

The experience gained from mining in Dendrobium Areas 1, 2 and 3 indicate that mining-induced fracturing in bedrock and rockbars are commonly found in sections of streams that are located directly above extracted longwalls. However, minor fracturing has also been observed in some locations beyond extracted longwall goaf edges, the majority of which have been within the limit of conventional subsidence or associated with valley closure or bedding plane shear.

An empirical database has been developed of pool and rockbar sites in the Southern Coalfield that have experienced mining induced valley related movements. The upsidence and closure movements at these sites have been predicted, using the ACARP Method of predicting valley closure, at the time when the first pool impact occurred, or after this time, when pool water loss was first recorded.

An analysis of impact rates has been undertaken using the currently available database of pools and rockbar case studies. This database is being continually developed and, to date, research has mainly concentrated on collating knowledge on the known pool and rockbar impact sites, whilst less data has been included for sites that had no impacts as a result of mining. The current reference to the 200 mm predicted total closure value should therefore be viewed as an indication of low probability of impact (i.e. around 10 %).

It has been assessed, therefore, that it is unlikely that significant fracturing or surface water flow diversions would occur along Sandy or Wongawilli Creeks as a result of the extraction. This assessment has been based on limiting the predicted additional closure at the mapped rockbars and riffles to 210 mm.

During the Longwall 13 extraction period, low water levels in Pool 43a were observed.

Additionally, an approximately 1.5 km reach of Wongawilli Creek, extending from Pool 43a, was observed to be dry (Longwall 13 EoP Report). Although the fracture in the base of Pool 43a was caused by mine subsidence, water levels in the pool were declining prior to the fracture occurring, with no significant changes in pool water-level recession (Watershed HydroGeo 2018).

Investigation and analyses showed that reductions in baseflow to Wongawilli Creek, in-line with predictions, had occurred due to mining in Areas 3A and 3B and subsequent reductions in groundwater levels in the Upper Bulgo Sandstone and Lower Hawkesbury Sandstone (Watershed HydroGeo 2018). However, the dominant process contributing to the low pool water-levels was the severe rainfall deficit and depressed groundwater levels (Watershed HydroGeo 2018).

IEP (2019a) reviewed the valley closure impact model and made the following recommendation: *the concept of restricting predicted valley closure to a maximum of 200 mm to avoid significant environmental consequences should be revised for watercourses*.

As described above, the closure impact model has been successfully used at Dendrobium Mine to date, with the target value of 200 mm predicted closure resulting in a low-likelihood of impact (consistent with the model predictions). The valley closure impact model undergoes continuous review as part of the EoP Reporting process to determine the applicability of the predicted valley closure target for each stream.

IMC has adopted a 200 mm predicted closure as a key design constraint for the setback of longwall panels from named watercourses at Dendrobium Mine, where a setback is provided to reduce impacts to that stream. The empirical data used to develop the 200mm closure target includes only streams with a setback from mining. An alternative target would need to be developed for streams directly mined under.

When applied on a case-by-case basis, the closure impact model can be refined and continue to be used to achieve a specified level of impact likelihood. While ongoing review of data to refine the closure impact model and closure target is supported, monitoring data to date does not indicate that the target of 200 mm predicted closure for named streams at Dendrobium Mine requires significant change at this time.

4.7.1 Water Storages

Dendrobium Mine is located within the Metropolitan Special Area. There are two reservoirs located in the vicinity of the mining area. Cordeaux Reservoir is located 0.9 km east of the proposed Longwall 19, at its closest point. The Cordeaux Dam Wall is located more than 5 km north of the proposed longwall.

The Avon Reservoir is located 3.1 km west of the proposed Longwall 19, at its closest point. The existing longwalls in Area 3B are located between Longwall 19 and the reservoir. The Avon Dam Wall is located more than 5 km north-west of Longwall 19.

Longwall 19 is not located within the Avon or Cordeaux Dams Safety NSW Notification Areas.

5 PREDICTED IMPACTS

Subsidence has the potential to affect watercourses overlying and adjacent to the proposed longwall due to either transient or relatively permanent changes in porosity and permeability of the soil matrix and bedrock. Sandstone is likely to fracture as a result of the differential subsidence movements predicted.

If a watercourse overlies a longwall panel it is likely to undergo temporary extensional “face line” cracking (perpendicular to the long axis of the panel) as the panel retreats, followed by re-compression as the maximum subsidence occurs at any one location.

In addition, where a watercourse overlies a longwall, it is likely to undergo both longer-term extensional “rib line” cracking (parallel to the long axis of the panel) along the outer edge and compression within the central portion of the subsidence trough.

Predicted impacts were assessed for Sandy and Wongawilli Creeks (third order) and all other drainage lines (first and second order) within the Longwall 19 Study Area (MSEC 2020).

In accordance with the findings of the Southern Coalfield Inquiry and IEP (2019a):

- **Subsidence effects** are defined as the deformation of ground mass such as horizontal and vertical movement, curvature and strains.
- **Subsidence impacts** are the physical changes to the ground that are caused by subsidence effects, such as tensile and sheer cracking and buckling of strata.
- **Environmental consequences** are then identified, for example, as a loss of surface water flows and standing pools.

Impact predictions have been completed within the Study Area in order to record potential and likely impacts from the proposed mining. The predictions are based on mathematical and empirical models and utilise the best available information for the Southern Coalfield and in particular Dendrobium Mine conditions. The impact predictions have been compared with previous predictions for Dendrobium Mine and the Conditions of Consent to ensure compliance of the proposed mining.

Monitoring is conducted in the area potentially affected by subsidence and in reference areas. Data collected in the impact zone will be compared to baseline and reference sites to determine any impacts from subsidence.

5.1 Subsidence Effects

The maximum predicted subsidence parameters resulting from the extraction of Longwalls 9 to 18 are provided in MSEC (2012, 2015, 2017 and 2018). The predicted subsidence parameters including; vertical subsidence, tilt and curvature have been used in the impact assessment for the Longwall 19 Study Area.

The predicted strains were determined by analysing the strains measured at Dendrobium Mine and other NSW Collieries, where the longwall width-to depth ratios and extraction heights were similar to the proposed longwall. The prediction of strain is more difficult than the predictions of subsidence, tilt and curvature. The reason for this is that strain is affected by many factors, including ground curvature and horizontal movement, as well as local variations in the near surface geology, the locations of joints in bedrock, and the depth of bedrock. Survey tolerance can also represent a substantial portion of the measured strain, in cases where the strains are of a low order of magnitude. The profiles of observed strain, therefore, can be irregular even when the profiles of observed subsidence, tilt and curvature are relatively smooth.

Adopting a linear relationship between curvature and strain provides a reasonable prediction for the conventional tensile and compressive strains. The locations that are predicted to experience hogging or convex curvature are expected to be net tensile strain zones and locations that are predicted to experience sagging or concave curvature are expected to be net compressive strain zones. In the Southern Coalfield, it has been found that a factor of 15 provides a reasonable relationship between the predicted maximum curvatures and the predicted maximum conventional strains.

The maximum predicted conventional strains resulting from the extraction of Longwall 19, based on applying a factor of 15 to the maximum predicted curvatures, are 15 mm/m tensile and compressive. These predicted levels of strain are likely to result in fracturing of the surface bedrock.

5.2 Wongawilli Creek

5.2.1 Description

Wongawilli Creek is a third order perennial stream with a small base flow and increased flows for short periods of time after significant rain events. The creek generally flows in a northerly direction and drains into the Cordeaux River to the north of the proposed longwall. Pools in the creek naturally develop behind the rockbars and at the sediment and debris accumulations.

The thalweg (i.e. base or centreline) of Wongawilli Creek is located at a minimum distance of 175 m south-west of the finishing end of Longwall 19, at its closest point. The minimum distances between the thalweg of the creek and the completed longwalls are 110 m for Longwall 6 in Area 3A and 290 m for Longwall 9 in Area 3B.

The total length of Wongawilli Creek located within the Study Area based on the 600 m boundary is 1.4 km.

5.2.2 Subsidence Predictions

A summary of the maximum predicted values of total vertical subsidence, upsidence and closure for Wongawilli Creek due to the extraction of the proposed Longwall 19 is provided in **Table 6**. The values are the maximum predicted subsidence effects anywhere along the creek due to the mining in Areas 3A, 3B and 3C (MSEC 2020).

Table 6 Maximum Predicted Total Subsidence, Valley Related Upsidence and Closure for Wongawilli Creek

Longwall	Maximum Predicted Subsidence (mm)	Maximum Predicted Upsidence (mm)	Maximum Predicted Closure (mm)
Longwalls 6 to 18, Longwalls 20 and 21	<20	150	210
Longwall 19	<20	150	210

Wongawilli Creek is predicted to experience less than 20 mm vertical subsidence due to the mining in Areas 3A, 3B and 3C. Whilst the creek could experience very low levels of vertical subsidence, it is not expected to experience measurable conventional tilts, curvatures or strains.

The maximum predicted total valley related effects for Wongawilli Creek are 150 mm upsidence and 210 mm closure. The maximum predicted valley related effects within the Study Area occur along the section of creek located between Areas 3A and 3B.

The maximum predicted incremental valley related effects due to the mining of the proposed Longwall 19 only are 50 mm upsidence and 70 mm closure. The maximum predicted incremental valley related effects occur where Wongawilli Creek is located closest to the proposed Longwall 19.

Wongawilli Creek could experience compressive strains due to the valley closure effects. The predicted strains have been determined based on an analysis of ground monitoring lines for valleys with similar heights located at similar distances from previously extracted longwalls in the Southern Coalfield, as for Wongawilli Creek. The maximum predicted compressive strain for Wongawilli Creek due to the extraction of the proposed Longwall 19 is 7 mm/m based on the 95 % confidence level.

5.2.3 Impact Predictions/Environmental Consequences

Potential for increased levels of ponding, flooding and scouring due to the mining-induced tilts

The average natural grade of the section of Wongawilli Creek within the Study Area is approximately 3.6 mm/m (i.e. 0.36 %, or 1 in 278). The predicted changes in grade due to the mining of Longwall 19, therefore, are considerably less than the average natural grade. It is unlikely, therefore, that there would be adverse changes in the potential for ponding, flooding or scouring of the banks along the creek due to the mining-induced tilt.

It is possible, however, that there could be some localised changes in the levels of ponding or flooding where the maximum changes in grade coincide with existing pools, steps or cascades along the creek. It is not anticipated that these changes would result in adverse impacts on the creek, due to the mining-induced tilt, since the predicted changes in grade are less than 0.05 %.

Potential for fracturing of bedrock and surface water flow diversions

Diversions of surface water flows also occur naturally from erosion and weathering processes and from natural valley bulging movements. Mining-induced surface water flow diversions into the strata occur where there is an upwards thrust of bedrock, resulting in a redirection of some water flows into the dilated strata beneath the creek beds. At higher depths of cover, where a constrained zone exists or where the creek is not directly mined beneath, the water generally reappears further downstream of the fractured zone as the surface flow is only redirected below the creek bed where the fractured zone exists.

Wongawilli Creek is located at minimum distances of 110 m and 290 m from the existing longwalls in Areas 3A and 3B, respectively, and a minimum distance of 175 m from the proposed Longwall 19. While the creek could experience very low levels of vertical subsidence, it is not expected to experience measurable conventional strains. That is, the strains due to the conventional ground movements are expected to be less than 0.3 mm/m.

The maximum predicted incremental closure along Wongawilli Creek due to the mining of the proposed Longwall 19 only is 70 mm. The maximum predicted total closure along the creek is 210 mm which occurs downstream of Longwall 19. The maximum predicted compressive strain for the creek due to the valley closure effects is 7 mm/m based on the 95 % confidence level.

Fracturing in bedrock has been observed due to previous longwall mining where the tensile strains are greater than 0.5 mm/m or where the compressive strains are greater than 2 mm/m. It is possible, therefore, that fracturing could occur along Wongawilli Creek due to the valley related compressive strains. Fracturing has been observed up to approximately 400 m outside of previously extracted longwalls in the Southern Coalfield.

The maximum predicted total closure along Wongawilli Creek, after the extraction of the existing Longwalls 6 to 9 in Area 3A, the existing and future Longwalls 9 to 18 in Area 3B, the future Longwalls 20 and 21 in Area 3C and the proposed Longwall 19 in Area 3A is 210 mm. The predicted rate of impact for the rockbars along the creek after the extraction of the existing and future longwalls, therefore, is in the order of 7 % based on the maximum predicted closure.

It has been assessed that the likelihood of fracturing resulting in surface water flow diversions along Wongawilli Creek, due to the extraction of the proposed Longwall 19, is low, i.e. affecting less than 10 % of rockbars and other stream controlling features located within the Study Area. However, minor fracturing could still occur along the creek, at distances up to approximately 400 m from the proposed longwall.

Baseflow Reduction

Where stream flow is partly sustained by the discharge of groundwater from adjacent aquifers (baseflow), mining related groundwater drawdown may result in a reduction of the baseflow component. Conservative estimates based on a regional groundwater model by SLR (2020) indicate that the baseflow components of Wongawilli Creek and Sandy Creek may decline by up to 1.27 and 1.15 megalitres per day (ML/day) (cumulative / whole mine) and up to 0.01 ML/day and 0.06 ML/day (due to LW19 incrementally) following longwall extraction. This equates to approximately 8% and 29% of the mean flow at the downstream gauges (0.1% and 1.5% incremental). Baseflow reduction would occur along the reach of Wongawilli Creek between Areas 3A and 3B following mining of Longwalls 15 to 19. As a result, cease-to-flow events, similar to those observed during the recent severe drought, are likely to occur more frequently under similar weather conditions (HGEO 2020).

In relation to estimates of baseflow loss, the IEPMC (2019c) considered that: errors in modelled pressure heads and inconsistencies between predictions and observations continue to lead to little confidence in the groundwater model's ability to predict surface water flow losses. Recommendations relating to managing uncertainty in model predictions are covered in the Panel's Part 2 Report. The IEPMC Part 2 report (IEPMC, 2019b) recommends that uncertainty analysis of groundwater and surface water models should follow the uncertainty analysis workflow recommended by the IESC (2018); and that a precautionary approach should be taken that does not assume groundwater model outputs are accurate. Predictions should be conservatively high to allow for prediction uncertainty and where practicable the associated non-exceedance probability should be stated. Groundwater consultants SLR (2020) have taken the latter approach by applying conservative assumptions in deriving the baseflow loss estimates, including the assumed vertical connectivity between seam (mine workings) and surface, as suggested by PSM, 2017.

5.3 Sandy Creek

Sandy Creek is situated on the eastern side of the existing Longwalls 6 to 8 and the proposed Longwall 19 in Area 3A. The thalweg of the creek is located 750 m from the commencing end of Longwall 19, at its closest point. Sandy Creek is therefore located outside the Study Area based on the 600 m boundary.

The maximum predicted incremental vertical subsidence, upsidence and closure for Sandy Creek, due to the mining of Longwall 19, are all less than 20 mm. While the creek could experience very low levels of these subsidence effects, it is not expected to experience measurable tilts, curvatures or strains (MSEC 2020).

It is unlikely, therefore, that adverse impacts would occur along Sandy Creek due to the mining of Longwall 19 (MSEC 2020).

5.3.1 Sandy Creek Waterfall

Sandy Creek Waterfall (SC-WF1) has a length around 75 m long including the surrounding cliff line and an overall height of around 17 m.

The waterfall has an overhang of up to 20 m, which varies in thickness from a maximum around 6 m to less than 1 m at the edge. Sandy Creek Waterfall is situated where Sandy Creek flows into the Cordeaux Reservoir. The centreline of the waterfall is located 900 m north-east of the commencing end of Longwall 19. At this distance, the predicted incremental vertical subsidence, upsidence and closure for Sandy Creek Waterfall are negligible.

Dendrobium Longwalls 6 and 7 have been mined to within 350 m and 400 m, respectively, of the waterfall with no adverse impacts observed. The maximum measured total closure across Sandy Creek Waterfall due to the mining of Longwalls 6 to 8 was approximately 14 mm. The proposed Longwall 19 is located 900 m from the centreline of Sandy Creek Waterfall. This longwall is between 1.8 to 2.3 times the distances of Longwalls 6 to 8 from the centreline of the waterfall. Also, the eastern end of Longwall 8 extends beyond the eastern end of Longwall 19 and, therefore, it provides shadowing effects (MSEC 2020). On this basis, the predicted incremental closure for Sandy Creek Waterfall due to Longwall 19 is less than 5 mm. The predicted incremental movement therefore is in the order of the survey tolerance and environmental effects.

It is unlikely that Sandy Creek Waterfall would experience adverse impacts due to the mining of Longwall 19 (MSEC 2020).

A Sandy Creek Waterfall Management Plan has been developed to manage risk to the waterfall due to the mining of Longwall 19 (Appendix C).

5.3.2 Waterfall SC10-WF15

A waterfall (SC10-WF15) is situated along SC10 to the east of the proposed Longwall 19. The nearest edge of the waterfall is located 160 m from the commencing (i.e. eastern) end of Longwall 19. The waterfall is approximately 15 m wide, 5 m high and has an overhang of up to approximately 3 m. A summary of the maximum predicted values of total subsidence, upsidence and closure at SC10-WF15, after the extraction of the longwall is provided in **Table 7**.

Table 7 Maximum Predicted Total Subsidence, Valley Related Upsidence and Closure for SC10-WF15

Name	Maximum Predicted Subsidence (mm)	Maximum Predicted Upsidence (mm)	Maximum Predicted Closure (mm)
Waterfall SC10-WF15	<20	90	125

The waterfall is predicted to experience less than 20 mm vertical subsidence. While the waterfall could experience very low levels of vertical subsidence, it is not expected to experience measurable tilts, curvatures or conventional strains.

The maximum predicted total valley related effects at the waterfall are 90 mm upsidence and 125 mm closure. As described above, fracturing in the bed of SC10 could occur up to 400 m outside of the mining area and, hence, near the waterfall. The method of assessment for surface water flow diversions has been predominately based on the previous experience of mining near to and beneath relatively flat streams in the Southern Coalfield. The impact assessments for the pools immediately upstream of the waterfall, therefore, need to consider the steep gradient (i.e. the waterfall) immediately downstream.

Based on the previous experience of mining beneath a similar sized waterfall at Elouera Colliery and near to cliffs elsewhere in the Southern Coalfield, the likelihood of an instability at the waterfall SC10-WF15 is considered to be very low. It is possible, however, that rockfalls could occur at or near the waterfall due to mining, due to natural processes, or both (MSEC 2020).

5.4 Drainage Lines

5.4.1 Description

The unnamed drainage lines are located above and adjacent to Longwall 19. These drainage lines are first and second order streams. The beds generally comprise exposed bedrock containing rockbars with some standing pools. There are also steps and cascades along the steeper sections. Debris accumulations have formed along the flatter sections that include loose rocks and tree branches.

The natural gradients of the drainage lines typically vary between 50 mm/m (i.e. 5.0 %, or 1 in 20) and 200 mm/m (i.e. 20 %, or 1 in 5), with average natural gradients in the order of 100 mm/m (i.e. 10 %, or 1 in 10). The drainage lines have localised areas with natural grades greater than 500 mm/m where there are steps and cascades.

5.4.2 Subsidence Predictions

The drainage lines are located across the Study Area and therefore could experience the full range of predicted subsidence movements. A summary of the maximum predicted values of subsidence movements, after the extraction of the longwall is provided in **Table 8** (MSEC 2020).

Table 8 Maximum Predicted Total Subsidence, Tilt and Curvature for the Drainage Lines after Longwall 19

Location	Maximum Predicted Vertical Subsidence (mm)	Maximum Predicted Total Tilt (mm/m)	Maximum Predicted Total Hogging Curvature (km-1)	Maximum Predicted Total Sagging Curvature (km-1)
Drainage Lines	2750	30	1	0.8

The maximum predicted tilt for the drainage lines within the Study Area, based 35-degree angle of draw is 30 mm/m (i.e. 3.0 % or 1 in 33), which represents a change in grade of 1 in 33. The predicted mining-induced tilts are less than the natural gradients of the drainage lines that typically vary between 50 mm/m and 200 mm/m (i.e. 5 % to 20 %).

There are no predicted reversals of stream grade along drainage lines SC10, SC10C, WC14 and WC17. There are slight reductions in grades along drainage lines SC10C and WC17, upstream of the chain pillars and the edges of the mining area. There is potential for minor and localised increased ponding upstream of these locations. However, drainage lines SC10C and WC17 are located above the existing Longwalls 7 and 8 and, therefore, the potential for increased ponding occurs due to these existing longwalls rather than the proposed Longwall 19.

The maximum predicted conventional strains for the drainage lines, based on applying a factor of 15 to the maximum predicted conventional curvatures, are 15 mm/m tensile and 12 mm/m compressive. The predicted strains directly above the mining area are 8 mm/m tensile and compressive based on the 95 % confidence levels.

5.4.3 Impact Assessment

Potential for increased levels of ponding, flooding and scouring due to the mining-induced tilts

Mining can result in increased levels of ponding in locations where the mining-induced tilts oppose and are greater than the natural drainage line gradients that exist before mining. Mining can also potentially result in an increased likelihood of scouring of the banks in the locations where the mining-induced tilts considerably increase the natural drainage line gradients that exist before mining.

The maximum predicted tilt for the drainage lines within the Study Area is 30 mm/m (i.e. 3.0 % or 1 in 33). The predicted mining-induced tilts are less than the natural gradients of the drainage lines that typically vary between 50 mm/m and 200 mm/m (i.e. 5 % to 20 %).

There are no predicted reversals of stream grade along drainage lines SC7, SC10, SC10C, WC13, WC14 and WC17. There are slight reductions in grades along drainage lines SC10C and WC17, upstream of the chain pillars and the edges of the mining area. There is potential for minor and localised increased ponding upstream of these locations. However, drainage lines SC10C and WC17 are located above the existing Longwalls 7 and 8 and, therefore, the potential for increased ponding occurs due to these existing longwalls rather than the proposed Longwall 19.

Elsewhere, the predicted post-mining grades are similar to the natural grades. It is unlikely, therefore, that there would be large-scale adverse changes in the levels of ponding or scouring of the banks along these drainage lines due to the mining-induced tilt. It is possible that localised increased ponding could develop in some isolated locations, where the natural grades are small, and upstream of the chain pillars and the edges of the mining area.

The potential impacts of increased ponding and scouring of the drainage lines, therefore, are expected to be minor and localised. Impacts resulting from changes in surface water flows are expected to be small in comparison with those which occur during natural flooding conditions.

Potential for cracking in the creek bed and fracturing of bedrock

Impacts have been observed along the drainage lines above and adjacent to the previously extracted Longwall 9 to 14 in Area 3B, including fracturing in the rockbars and exposed bedrock, dilation and uplift of the bedrock, iron staining, surface water flow diversions and reduction in pool water levels. These impacts predominately occurred directly above the extracted longwalls. However, fracturing was also observed up to 300 m from the extracted longwalls in Area 3B.

The maximum predicted subsidence effects due to the proposed Longwall 19 are similar to but less than the maximum predicted values for the existing longwalls in Area 3B.

The potential impacts for the drainage lines within the Study Area, therefore, are expected to be similar to those observed above and adjacent to the existing longwalls in Area 3B.

It is expected that fracturing of the bedrock would occur along the sections of the drainage lines that are located directly above the proposed Longwall 19 and the adjacent existing Longwalls 7 and 8. Fracturing can also occur outside the extents of the longwall, with minor and isolated fracturing occurring at distances up to approximately 400 m.

The mining-induced compression due to valley closure effects can also result in dilation and the development of bed separation in the topmost bedrock, as it is less confined. This valley closure related dilation is expected to develop predominately within the top 10 m to 20 m of the bedrock. Compression can also result in buckling of the topmost bedrock resulting in heaving in the overlying surface soils.

Surface water flow diversions are likely to occur along the sections of drainage lines that are located directly above and adjacent to the longwall.

5.5 Water Quality

Longwall subsidence can result in fracturing of streambeds and this fracturing can lead to changes in stream water quality due to the following processes (HGEO 2020):

- Diversion of surface flows through shallow fractures resulting from valley closure and the unconfined nature of near-surface strata (to ~10 to 15 m depth);
- Oxidation and dissolution of minerals in the freshly fractured bedrock (notably marcasite [FeS_2], ankerite [$Ca(Mg,Fe_2^+,Mn)(CO_3)_2$] and siderite [Fe_2+CO_3]);
- Leaching of ions from the bedrock strata present within the surface fracturing zone; and
- Enhanced drainage and discharge of groundwater (with higher EC and dissolved iron and lower DO) to creeks via subsidence induced fractures.

Oxidation of Fe_2^+ in sulphide and carbonate minerals can result in a decrease in pH and release of Fe, Mn and Mg into solution. This can manifest as ferruginous springs, iron staining of stream beds and rock faces, and localised accumulation of ferruginous sediment. The release of hydrogen ions (decrease in pH) may be offset or buffered by pH increases caused by CO_2 outgassing from turbulent stream sections and by ankerite dissolution (HGEO 2020).

Due to the setback distance of the Longwall 19 from Sandy and Wongawilli Creeks, it is not expected that any significant fracturing and sub-bed flow diversions will occur in Sandy of Wongawilli Creeks to alter flows or water quality other than minor impacts. Due to the substantial distance downstream, it is predicted there will be no measurable reduction in the quality or quantity of surface water inflow to the Cordeaux River at its confluence with Wongawilli Creek.

Based on previous observations, it is expected that water quality influence due to mining would be minor in stream reaches within subsidence affected areas (SC10 and SC10C; upper reaches of WC14). Local discolouration of streambeds and rock faces by iron hydroxide precipitation can continue for a number of years but is a temporary impact. Water quality effects on stored waters of the reservoirs are expected to be negligible and undetectable (HGEO2020).

5.5.1 Water Supply Reservoirs and the Cordeaux River

For Avon Reservoir, the simulated incremental leakage from the reservoir storage due to extraction of Longwall 19 is effectively zero, which is logical given the distance between the panel and the reservoir (SLR 2020). Predicted losses due to Dendrobium Areas 1-3C, with and without Longwall 19, are less than Dams Safety NSW's prescribed tolerable limit.

For Cordeaux Reservoir, simulated incremental leakage is also predicted to be less than the prescribed tolerable limit, and the incremental rate due to Longwall 19 is also effectively zero (SLR 2020).

The Avon and Cordeaux Reservoirs are located at minimum distances of 0.9 km and 3.1 km, respectively, from the proposed Longwall 19. At these distances, the reservoirs are not predicted to experience measurable conventional or valley related effects (MSEC 2020).

6 MANAGEMENT AND CONTINGENCY PLAN

The potential impacts of mine subsidence to watercourses and associated features in Longwall 19 Study Area are provided below, together with a summary of the avoidance, minimising, mitigation and remediation measures proposed.

6.1 Objectives

The aims and objectives of the Plan include:

- Avoiding and minimising impacts to significant environmental values where possible.
- Implementing TARPs and reporting to identify, assess and responding to impacts to watercourses.
- Carrying out mitigation and remediation works in a manner that protects to the greatest practicable extent the environmental values of the area.
- Achieving the Performance Measures outlined in the Dendrobium Development Consent, to the satisfaction of the Secretary.
- Monitoring and reporting effectiveness of the Plan.

To achieve these aims, monitoring, management, mitigation, remediation and offsetting has been incorporated into the mining activity proposed by IMC.

6.2 Trigger Action Response Plan

The TARPs relate to identifying, reporting, assessing and responding to potential impacts to watercourses (including impacts greater than predicted) from subsidence impacts due to the mining of Longwall 19. These TARPs have been prepared using knowledge gained from previous mining in other areas of Dendrobium. The TARPs for any Longwall 19 impacts within the Study Area watercourses are included in **Appendix A: Table 1.2**. For impacts to watercourses from Longwalls 6 to 8, the Dendrobium Area 3A WIMMCP TARPs (approved 28 June 2010) will be applied.

The TARPs represent actions (including reporting) to be taken upon reaching each defined trigger level. If required, a Corrective Management Action (CMA) is developed in consultation with stakeholders to manage an observed impact in accordance with relevant approvals. The WIMMCP provides a basis for the design and implementation of any mitigation and remediation. Generic CMAs are developed as required, in consultation with WaterNSW, to provide for a prompt response to a specific impact that requires a specific CMA. If appropriate these discussions will consider whether pre-approvals for the CMA can be obtained where immediate implementation is required.

Monitoring of environmental aspects provides key data when determining any requirement for a CMA, including mitigation or rehabilitation. The triggers are based on comparison of baseline and impact monitoring results. Specific triggers will continue to be reviewed and developed in consultation with key stakeholders. Where required the triggers will be reviewed and changes proposed in impact assessment reports provided to government agencies or in EoP Reports. Any changes to the triggers would require approval of DPIE.

Level 1 TARPs typically relate to the routine impacts from mining and/or natural (non-mining) variability in the monitoring data. TARP level 1 impacts are reported to key stakeholders via a variety or mechanisms, including an Impact Update Report provided to Government Agencies.

Level 2 and 3 TARPs result in further investigations and reporting. Impact assessment reports include:

- Study scope and objectives;
- Consideration of relevant aspect from this Plan;
- Analysis of trends and assessment of any impacts compared to prediction;
- Root cause analysis of any change or impact;
- Assessment of the need for contingent measures and management options;
- Any recommended changes to this Plan; and
- Appropriate consultation.

The Level 2 and 3 TARPs may require the development of site-specific CMAs which include:

- A description of the impact to be managed;
- Results of specific investigations;
- Aims and objectives for any corrective actions;
- Specific actions required to mitigate/manage and timeframes for implementation;
- Environmental offsetting;
- Roles and responsibilities;
- Gaining appropriate approvals from landholders and government agencies; and
- Reporting, consultation and communication.

6.3 Avoiding and Minimising

Mine layouts for Dendrobium Area 3A have been developed using IMC's Integrated Mine Planning Process (IMPP). This process considers mining and surface impacts when designing mine layouts.

IMC has assessed mining layout options for Dendrobium Area 3A against the following criteria:

- Extent, duration and nature of any community, social and environmental impacts;
- Coal customer requirements;
- Roadway development and longwall continuity;
- Mine services such as ventilation;
- Recovery of the resource for the business and the State; and
- Gas drainage, geological and geotechnical issues.

Several layout alternatives for Area 3A were assessed by IMC using a multi-disciplinary team including environment, community, mining and exploration expertise. These included variations in the number of longwalls and orientations, lengths, and setbacks of the longwalls from key surface features. These options were reviewed, analysed and modified until an optimised longwall layout in Area 3A was achieved.

SMP Approval for the area of Longwall 19 was granted 9 July 2010, along with Longwalls 6 – 8. The width of the proposed Longwall 19 was set at 305 m in April of 2014 when the mains headings were established to allow for the gateroads of the longwall. Subsequent Area 3B Approval conditions required that Longwall 19 be further considered by DPIE. Due to these circumstances, consideration of a reduction in longwall width cannot be assessed as part of this SMP.

Area 3A is part of the overall mining schedule for Dendrobium Mine and has previously been mined, with Longwall 8 the most recently extracted in December 2012. A return to Area 3A to extract Longwall 19 has been designed to flow on from Areas 3B and 3C to provide a continuous mining operation.

There are a number of surface and subsurface constraints within the vicinity of Area 3A including major surface water features such as Cordeaux Reservoir, Sandy Creek, Wongawilli Creek; and a number of geological constraints such as dykes, faults, and particularly the Dendrobium Nepheline Syenite Intrusion, which has intruded into the Wongawilli Seam to the east of Longwall 19. The process of developing the layout for Area 3A has considered predicted impacts on natural features and aimed to minimise these impacts within geological and other mining constraints.

No contingent mining areas containing Wongawilli Seam Coal resources with the possibility for extraction are available to IMC.

The layouts at Dendrobium Mine have been modified to reduce the potential for impacts to surface features. Changes to a mine layout have significant flow-on impacts to mine planning and scheduling as well as economic viability. These issues need to be taken into account when optimising mine layouts. The process adopted in designing the Longwall 19 mine layout incorporated the hierarchy of avoid/minimise/mitigate as requested by the DPIE and BCD. Mine plan changes result in significant business and economic impact, including:

- Reduction in coal extracted;
- Reduction in royalties to the State;
- Additional costs to the business;

- Risks to longwall production due to additional roadway development requirements; and
- Constraints on blending which can disrupt the supply of coal to meet customer requirements.

The mining layout of the proposed longwall is designed to avoid Wongawilli Creek and the Nepheline Syenite Intrusion. A summary of the geology of Longwall 19 is available in Attachment H of the SMP.

Wongawilli Creek is located to the east of the proposed Longwall 19. The thalweg (i.e. base or centreline) of Wongawilli Creek is located at a minimum distance of 175 m south-west of the finishing end of Longwall 19, at its closest point. The minimum distances between the thalweg of the creek and the completed longwalls are 110 m for Longwall 6 in Area 3A and 290 m for Longwall 9 in Area 3B.

6.4 Mitigation and Rehabilitation

If the performance measures in the Development Consent are not met, then following consultation with BCD, WaterNSW and DRG, the Secretary of DPIE may issue a direction in writing to undertake actions or measures to mitigate or remediate subsidence impacts and/or associated environmental consequences. The direction must be implemented in accordance with its terms and requirements, in consultation with the Secretary and affected agencies.

As indicated in Schedule 2, Conditions 1 and 14 of the Development Consent, the mitigation and rehabilitation described in this Plan is required for the development and an integral component of the proposed mining activity. To the extent these activities are required for the development approved under the Dendrobium Mine Development Consent no other licence under the then *Threatened Species Conservation Act 1995* (TSC Act) (repealed by the *Biodiversity Conservation Act 2016*) is required in respect of those activities.

At the time of grant of the Dendrobium Development Consent there was no requirement for concurrence in respect of threatened species or ecological communities. The requirement for concurrence was, at that time, governed by section 79B of the EPA Act. At the time of grant of the Dendrobium Consent there was a requirement for consultation with the Minister administering the then TSC Act and this consultation was undertaken.

6.4.1 Sealing of Rock Fractures

Where the bedrock base of any significant permanent pool or controlling rockbar within Sandy or Wongawilli Creeks are impacted from subsidence and where there is limited ability for these fractures to seal naturally they will be sealed with an appropriate and approved cementitious (or alternative) grout. Grouting will be focused where fractures result in diversion of flow from pools or through the controlling rockbar. Significant success has been achieved in the remediation of the Georges River where four West Cliff longwalls directly mined under the river and pool water level loss was observed.

A number of grouts are available for use including cement and Poly-urethane Resin (PUR), with various additives. These grouts can be used with or without fillers such as clean sand. Grouts can be mixed on-site and injected into a fracture network or placed by hand. Hand-placed and injection grouting of large fractures were successfully implemented in the Georges River near Appin.

Such operations do have the potential to result in additional environmental impacts and are carefully planned to avoid contamination. Mixing areas will be restricted to cleared seismic lines or other open areas wherever possible. Bunds are used to contain any local spillage at mixing points. Temporary cofferdams can be built downstream of the grouting operations to collect any spillage or excess grouting materials for disposal off-site. The selection of grouting materials is based on demonstrated effectiveness and ensuring that there is no significant impact to water quality or ecology.

6.4.2 Injection Grouting

Injection grouting involves the delivery of grout through holes drilled into the bedrock targeted for rehabilitation. A variety of grouts and filler materials can be injected to fill the voids in the fractured strata intercepted by the drill holes. The intention of this grouting is to achieve a low permeability 'layer' below any affected pool as well as the full depth of any controlling rockbar.

Where alluvial materials overlie sandstone, grouts may be injected through grout rods to seal voids in or under the soil profile. This technique was successfully used at Pool 16 in the Georges River to rehabilitate surface flow by-pass to Pool 17. In this case 1-2m of loose sediment was grouted through using purpose built grouting pipes.

Grouting holes are drilled in a pattern, usually commencing at a grid spacing of 1m x 1m to 2m x 2m. The most efficient way to drill the holes taking into account potential environmental impact is by using handheld drills. The drills are powered by compressed air which is distributed to the work area from a compressor. The necessary equipment will be sited on cleared seismic lines or other clear areas wherever possible with hoses run out to target areas.

Grout is delivered from a small tank into the ground via mechanical packers installed at the surface. All equipment can be transported with vehicles capable of travelling on tracks similar to seismic lines. If necessary, equipment or materials can be flown to nearby tracks or open spaces by helicopter. Helicopter staging has previously occurred from Cordeaux Mine where there is appropriate logistical support. The grout is mixed and pumped according to a grout design. A grout of high viscosity will be used if vertical fracturing is believed to be present since it has a shorter setting time. A low viscosity grout will be used if cross-linking is noted during grouting. Once the grout has been installed the packers are removed and the area cleaned.

After sufficient time for the product to set the area may be in-filled with additional grouting holes that target areas of significant grout take from the previous pass. The grouting program can normally be completed with hand held equipment. Wherever possible the setup and mixing areas will be restricted to cleared seismic lines and other open areas. Bunds are used to contain any local spillage at mixing points.

Grouting volumes and locations are recorded and high-volume areas identified. Once the grout take in the area is reduced and the material has set, the grouted section of the pool is isolated and tested with local or imported clean water. The rate at which the water drains is measured and compared to pre-grouting results. The grouting process is iterative; relying on monitoring of grout injection quantities, grout backpressures and measurements of water holding capacity. In the Georges River the majority of pools were sealed with two to three grout passes.

If flow diversion through a large rockbar occurs, it may be more appropriate to implement alternative grouting techniques such as a deeper grout curtain which can be delivered via traditional or directional drilling technologies. Grouting should preferentially be undertaken at the completion of subsidence movements in the area to reduce the risk of the area being re-impacted. **Figure 6-1** shows grouting operations in progress within the Georges River.

(a) Drilling into the bedrock

(b) Grout pump station setup

(c) Injecting grout into bedrock via a specially designed packer system

Figure 6-1 Rockbar Grouting in the Georges River - (A) Drilling into the bedrock, (B) Grout pump station setup, (C) Injecting grout into bedrock via a specially designed packer system.

6.4.3 Erosion Control

Erosion can occur along preferred flow paths where subsidence induced tilts increase a catchment area. To arrest this type of erosion, 'coir log dams' are installed at knick points in the channelised flow paths or at the inception of tunnel/void spaces (**Figure 6-2**).

Figure 6-2 Square Coir Logs for Knick Point Control

As the coir log dams silt up they are regularly added to by the placement of additional layers of logs until the pooled water behind the 'dams' is at or above the level of the bank of the eroded channel. The coir logs are held in place by 50mm x 50mm wooden stakes and bound together with wire (**Figure 6-3**).

The coir log dam slows the flows in the eroding drainage line such that the drainage line will silt up.

Figure 6-3 Installation of Square Coir Logs

The most important aspect of these coir dams is the positioning of the first layer of coir logs. A trench is cut into the soil so the first layer sits on the underlying substrate or so the top of the first coir log is at ground level (**Figure 6-4**).

Figure 6-4 Trenching and Positioning of the First Layer of Coir Logs and Construction of a Small Dam in a Channel

The coir log dams are constructed at intervals down the eroding flow line, the intervals being calculated on the depth of erosion and predicted peak flows and added to until the pooled water behind the 'dams' is at or above the level of the bank of the erosion. Where increased filtering of flows is required the coir logs are wrapped in fibre matting (**Figure 6-5**).

Figure 6-5 Small Coir Log Dams with Fibre Matting

6.4.4 Surface Treatments

Where cracking develops in significant areas and natural infilling is not occurring, the cracks may require forking over and compacting to prevent erosion. Larger cracks may require more work to repair them, for example, mulch or other protection to prevent the development of erosion channels. Surface protection will remain in place until revegetation covers the disturbed area. In some cases, if the cracks are wider they may require gravel or sand filling up to surface level and revegetation using brush matting. Maintenance of moisture in rehabilitation areas can be enhanced by additional water spreading techniques, involving long lengths of coir logs and hessian 'sausages' linked together across the contour such that water flow builds up behind them and slowly seeps through the water spreaders (**Figure 6-6**).

Figure 6-6 Round Coir Logs Installed to Spread Water

Erosion control and water spreading involves soft-engineering materials that are biodegradable and become integrated into the soil profile. This approach is ecologically sustainable in that all the materials used can breakdown and become part of the organic component of the soil. This also removes the requirement for any post-rehabilitation removal of structures or materials. However, rehabilitation measures have the potential to cause impact through the materials used and the disturbance associated with access. Relevant approvals will be obtained to ensure the protection of the environment as works are implemented.

6.4.5 Gas Release

A typical driver of gas release at the surface is pressure changes, dilation and/or fracturing of the rock mass and associated release to the surface, with or without groundwater flows. Grouting techniques discussed above can reduce these associated gas flows at specific sites. In all identified circumstances in the Southern Coalfield the gas releases have diminished over time. Typically, this time is a number of months but it can be a number of years. Long running gas releases significantly reduce in quantity over time. Where vegetation is impacted by gas releases the areas affected will be revegetated once monitoring determines the gas releases have ceased or reduced to an extent that vegetation is no longer affected.

Very few gas releases have been observed within the Dendrobium mining area.

6.4.6 Water Quality

Ecoengineers (2012) outline mitigation measures that would be considered if unpredicted water quality impacts were detected. Any works on WaterNSW land requires prior approval from WaterNSW to access the land and there is a requirement for compliance with the Access Agreement between WaterNSW and IMC. These requirements ensure strict limits are placed on any impacts associated with undertaking rehabilitation works on WaterNSW land.

6.4.7 Alternative Remediation Approaches

IMC has successfully implemented a subsidence rehabilitation program in the Georges River where there were impacts associated with mining directly under streams. This rehabilitation focused on grouting of mining induced fractures and strata dilation to reinstate the structural integrity and water holding capacity of the bedrock. Metropolitan Colliery is currently undertaking work aimed at rehabilitating areas impacted by subsidence using PUR and other grouting materials. IMC is consulting with Metropolitan Colliery in relation to these technologies. Should rehabilitation be necessary in the Longwall 19 Study Area, the best option available at the time of the rehabilitation work will be identified and with appropriate approval, implemented by IMC.

Cracking due to subsidence will tend to seal as the natural processes of erosion and deposition act on them. The characteristics of the surface materials and the prevailing erosion and depositional processes of a specific area will determine the rate of infill of cracks and sealing of any fracture network.

6.4.8 Monitoring Remediation Success

Baseline studies have been completed within the Study Area to record biophysical characteristics of the mining area. Monitoring is constantly conducted in the area potentially affected by subsidence from Longwall 19 extraction as well as areas away from mining to act as control sites. The studies in these areas are based on the BACI design criteria.

A comprehensive monitoring program is in place for watercourses identified in this Plan. A summary of watercourse monitoring within Longwall 19 Study Area is provided in **Section 3**. In the event monitoring reveals impacts greater than what is authorised by the approval, modifications to the project, mitigation measures and environmental offsets would be considered to minimise impacts.

The monitoring program would remain in place prior to, during and following the implementation of any mitigation measures in the Longwall 19 Study Area. The monitoring program is based on the BACI design with sampling undertaken at impact and control locations prior to the commencement of mitigation, during mitigation and after the completion of the mitigation actions. The monitoring locations/points for watercourses within Longwall 19 Study Area will be reviewed as required and can be modified (with agreement) accordingly.

Data will be analysed according to the BACI design. Statistical analyses between control, impact and mitigation sites will be used to determine whether there are statistically significant differences between these sites. This analysis will assist in determining the success of any mitigation or natural reduction of mining impacts over time.

Observation data will also be collected as part of the monitoring program and be used to provide contextual information to the above assessment approach. Monitoring data and observations will be mapped, documented and reported.

6.5 Biodiversity Offset Strategy

Where impacts are greater than predicted or not within approved levels, compensatory measures will be considered. Any compensatory measure will consider the level of impact requiring compensation, the compensatory measures available and the practicality and cost of implementing the measure.

Subject to Condition 14 of Schedule 3 of the Development Consent:

- The Applicant shall provide suitable offsets for loss of water quality or loss of water flows to WaterNSW storages, clearing and other ground disturbance (including cliff falls) caused by its mining operations and/or surface activities within the mining area, unless otherwise addressed by the conditions of this consent, to the satisfaction of the Secretary. These offsets must:
  - (a) be submitted to the Secretary for approval by 30 April 2009;
  - (b) be prepared in consultation with WaterNSW;
  - (c) provide measures that result in a beneficial effect on water quality, water quantity, aquatic ecosystems and/or ecological integrity of WaterNSW's Special Areas or water catchments.

IMC transferred 33 ha of land adjacent to the Cataract River to WaterNSW to meet the above condition. A biodiversity offset strategy has been developed in consultation with BCD and WaterNSW for the approval of the Secretary of DPIE. The Secretary DPIE approved the Strategic Biodiversity Offset in accordance with Condition 15 of Schedule 2 of the Development Consent for the Dendrobium Coal Mine 16 December 2016. The Secretary also expressed satisfaction that the Strategy fulfils the requirements of the SMP for Area 3B and 3C. IMC has sought concurrence from the Secretary that the Strategy also satisfies the requirements of the SMP for Area 3A.

6.6 Research

To assist in further understanding the impacts of subsidence and rehabilitation of swamps IMC will undertake research to the satisfaction of the Secretary. The research will be directed to improving the prediction, assessment, remediation and/or avoidance of subsidence impacts and environmental consequences to swamps. The knowledge and techniques developed through this research will assist with any requirement for rehabilitation within watercourses.

6.7 Contingency and Response Plan

In the event the TARP parameters are considered to have been exceeded, or are likely to be exceeded, IMC will implement a Contingency Plan to manage any unpredicted impacts and their consequences.

This would involve the following actions:

- Identify and record the event.
- Notify government agencies and specialists as soon as practicable.
- Conduct site visits with stakeholders as required.
- Contract specialists to investigate and report on changes identified.
- Provide incident report to relevant agencies.
- Establish weekly monitoring frequency for the site until stabilised.
- Updates from specialists on investigation process.
- Inform relevant government agencies of investigation results.
- Develop site CMA in consultation with key stakeholders and seek approvals.
- Implement CMA as agreed with stakeholders following approvals.
- Conduct initial follow up monitoring and reporting following CMA completion.
- Provide any environmental offset required by the Consent.
- Review the WIMMCP in consultation with key government agencies and seek approval for any modifications.
- Report in EoP Report and AEMR.

A site-specific rehabilitation action plan detailing the location and specific works to be implemented will be prepared following the identification of mining induced degradation that exceeds the trigger levels specified in the TARPS.

The site-specific rehabilitation action plan will be developed in consultation with relevant stakeholders. Authority to access the land to conduct works and implement environmental controls requires approval of WaterNSW.

Table 9 provides a summary of the avoidance, mitigation and contingency measures proposed to manage impacts where predicted impacts are exceeded.

Table 9 Performance Measures, Predicted Impacts, Mitigation and Contingent Measures for Watercourses

Feature	Performance Measure	Predicted Impacts	How Monitored	How Managed	Exceeding Prediction	Contingent Measures
Wongawilli Creek	**Minor environmental consequences** including: minor fracturing, gas release and iron staining; and minor impacts on water flows, water levels and water quality	Minor environmental consequences including: minor fracturing, gas release and iron staining; and minor impacts on water flows, water levels and water quality	• Observation of Wongawilli Creek for fracturing, gas release and iron staining • Measurement of pool water levels • Measurement of surface water flow • Measurement of surface water quality	The longwall has been setback 175 m from Wongawilli Creek Grouting of fractures in rockbar and bedrock base of any significant pool where flow diversion results in pool water level lower than baseline period	Mining results in more than minor environmental consequences in Wongawilli Creek, including: • structural integrity of the bedrock base of any significant permanent pool or controlling rockbar cannot be restored i.e. pool water level within the pool after CMAs continues to be lower than baseline period • fracturing within Wongawilli Creek resulting in diversion of flow such that >10% of the pools have water levels lower than baseline period • measured surface water flow reduction, based on Assessment Methods C, D, to be compared against predictions made in contemporary groundwater modelling conducted (to the satisfaction of the Secretary) to assess whether effects that cannot be explained by natural variability[2] • gas release results in vegetation dieback that does not revegetate • gas release results in mortality of threatened species or ongoing loss of aquatic habitat • iron staining and associated increases in dissolved iron resulting from the mining is observed in water at	Grouting of fractures in rockbar and bedrock base of any significant pool where flow diversion results in pool water level lower than baseline period Provide residual environmental offset for any mining impact as required by Condition 14 Schedule 3 of the Development Consent

[2] See Section 3.6 for details on Assessments C and D.

Feature	Performance Measure	Predicted Impacts	How Monitored	How Managed	Exceeding Prediction	Contingent Measures
					Wongawilli Creek downstream monitoring site Wongawilli Ck (FR6) • mining results in two consecutive exceedances or three exceedances of the ±3 standard deviation level (positive for EC, negative for pH and DO) from the baseline mean within six months that cannot be attributed to natural variation	
Sandy Creek	**Minor environmental consequences** including: minor fracturing, gas release and iron staining; and minor impacts on water flows, water levels and water quality	Minor environmental consequences including: minor fracturing, gas release and iron staining; and minor impacts on water flows, water levels and water quality	• Observation of Sandy Creek for fracturing, gas release and iron staining • Measurement of pool water levels • Measurement of surface water flow • Measurement of surface water quality	The longwall has been setback 750 m from Wongawilli Creek Grouting of fractures in rockbar and bedrock base of any significant pool where flow diversion results in pool water level lower than baseline period	Mining results in more than minor environmental consequences in Sandy Creek, including: • structural integrity of the bedrock base of any significant permanent pool or controlling rockbar cannot be restored i.e. pool water level within the pool after CMAs continues to be lower than baseline period • fracturing within Sandy Creek resulting in diversion of flow such that >10% of the pools have water levels lower than baseline period • measured surface water flow reduction, based on Assessment Methods C, D, to be compared against predictions made in contemporary groundwater modelling conducted (to the satisfaction of the Secretary) to assess whether effects that cannot be explained by natural variability[3]	Grouting of fractures in rockbar and bedrock base of any significant pool where flow diversion results in pool water level lower than baseline period Provide residual environmental offset for any mining impact as required by Condition 14 Schedule 3 of the Development Consent

[3] See Section 3.6 for details on Assessments C and D.

Feature	Performance Measure	Predicted Impacts	How Monitored	How Managed	Exceeding Prediction	Contingent Measures
					• gas release results in vegetation dieback that does not revegetate • gas release results in mortality of threatened species or ongoing loss of aquatic habitat • iron staining and associated increases in dissolved iron resulting from the mining is observed in w ater at Sandy Creek dow nstream monitoring site SCk_Rockbar 5 Site • mining results in tw o consecutive exceedances or three exceedances of the ±3 standard deviation level (positive for EC, negative for pH and DO) from the baseline mean w ithin six months that cannot be attributed to natural variation	
Waterfall SC-WF1	Negligible environmental consequences including: • no rock fall occurs at Sandy Creek Waterfall or from its overhang; • the structural integrity of the w aterfall, its overhang and its pool are not impacted; • cracking in Sandy Creek w ithin 30 m of the w aterfall is of negligible environmental and	Negligible environmental consequences including: no rock fall occurs at the w aterfall or from its overhang; no impacts on the structural integrity of the w aterfall, its overhang and its pool; negligible cracking in Sandy Creek w ithin 30 m of the w aterfall; and negligible diversion of w ater from the lip of the w aterfall	• Observation of Waterfall SC-WF1 for rock falls, impacts on structural integrity and cracking • Measurement of pool w ater levels	Implementation of the Sandy Creek WF1 Management Plan	Mining results in more than negligible environmental consequences including: • rock fall at the w aterfall or its overhang • impacts on the structural integrity of the w aterfall, its overhang or its pool • cracking in Sandy Creek w ithin 30m of the w aterfall which results in observable flow diversion • cracking in Sandy Creek w hich results in observable flow diversion from the lip of the w aterfall	Grouting of fractures w ithin 30 m of the w aterfall where flow diversion is observed (w here it is safe to do so) Provide residual environmental offset for any mining impact as required by Condition 14 Schedule 3 of the Development Consent

Feature	Performance Measure	Predicted Impacts	How Monitored	How Managed	Exceeding Prediction	Contingent Measures
	hydrological consequence; and • negligible diversion of water occurs from the lip of the waterfall					
Lake Cordeaux	Operations do not result in reduction (other than **negligible reduction**) in the quality or quantity of surface water or groundwater inflows to Lake Cordeaux	Negligible reduction in the quality and quantity of surface water and groundwater inflows to Lake Cordeaux	• Measurement of surface water flow • Measurement of water quality • Groundwater model calibrated to groundwater levels, surface water flows and mine water budget	Longwalls do not mine directly under the reservoir. The proposed longwall has been setback 0.9 km from Lake Cordeaux	Mining results in more than negligible reduction in the quality or quantity of surface water or groundwater inflows to Lake Cordeaux, including: • measured surface water flow reduction, based on Assessment Methods C, D, to be compared against predictions made in contemporary groundwater modelling conducted (to the satisfaction of the Secretary) to assess whether effects that cannot be explained by natural variability[4 5] • mining results in two consecutive exceedances or three exceedances of the ±3 standard deviation level (positive for EC, negative for pH and DO) from the baseline mean within six months that cannot be attributed to natural variation	Grouting of fractures in rockbar and bedrock base of any significant pool where flow diversion results in pool water level lower than baseline period Provide residual environmental offset for any mining impact as required by Condition 14 Schedule 3 of the Development Consent
Cordeaux River	Operations do not result in reduction (other than **negligible reduction**) in the quality or quantity of surface	Negligible reduction in the quality and quantity of surface water inflow to the Cordeaux River at its	• Observation of Wongawilli Creek for iron staining	The longwall has been setback between 175 m from Wongawilli Creek	Mining results in more than negligible reduction in the quality or quantity of surface water inflows to the Cordeaux River	Grouting of fractures in rockbar and bedrock base of any significant pool where flow

[4] See Section 3.6 for details on Assessments C and D.

[5] Surface water inflows calculation = [Impacts at gauged catchments (SCL2) + LC5 + estimated impacts at ungauged but undermined catchments] / [total estimated inflow to LC].

Feature	Performance Measure	Predicted Impacts	How Monitored	How Managed	Exceeding Prediction	Contingent Measures
	water inflow to the Cordeaux River at its confluence with Wongawilli Creek	confluence with Wongawilli Creek	• Measurement of surface water flow • Measurement of surface water quality		at its confluence with Wongawilli Creek, including: • measured surface water flow reduction in Wongawilli Creek at its confluence with Cordeaux River is greater than predicted by modelling (to the satisfaction of the Secretary) that cannot be attributed to natural variation[6] • mining results in two consecutive exceedances or three exceedances of the ±3 standard deviation level (positive for EC, negative for pH and DO) from the baseline mean within six months that cannot be attributed to natural variation	diversion results in pool water level lower than baseline period Provide residual environmental offset for any mining impact as required by Condition 14 Schedule 3 of the Development Consent

Note: The mitigation measures will be assessed for appropriateness (in consultation with key stakeholders), as the need arises, on the individual watercourses being impacted to ensure significant additional impacts to the watercourses are not created by the carrying out of these mitigation measures. The provision of residual environmental offsets will be considered where the potential impacts of mitigation measures are greater than the impacts of mining or where the mitigation measures are not successful. Additional actions are required as per the TARPs, including informing stakeholders, review of monitoring and further assessments as required.

[6] Flow reduction as determined from measured at flow gauging station WWL_A.

7 INCIDENTS, COMPLAINTS, EXCEEDANCES AND NON-CONFORMANCES

7.1 Incidents

IMC will notify DPIE and other relevant agencies of any incident associated with Longwall 19 operations as soon as practicable after IMC becomes aware of the incident. IMC will provide DPIE and any relevant agencies with a report on the incident within seven days of confirmation of any event.

7.2 Complaints Handling

IMC will:

- Provide a readily accessible contact point through a 24-hour toll-free Community Call Line (1800 102 210). The number will be displayed prominently on IMC sites in a position visible by the public as well as on publications provided to the local community.
- Respond to complaints in accordance with the IMC Community Complaints and Enquiry Procedure.
- Maintain good communication lines between the community and IMC.
- Keep a register of any complaints, including the details of the complaint with information such as:
    - Time and date.
    - Person receiving the complaint.
    - Complainant's name and phone number.
    - Description of the complaint and where complaint relates to.
    - Details of any response where appropriate.
    - Details of any corrective actions.

7.3 Non-Conformance Protocol

The requirement to comply with all approvals, plans and procedures is the responsibility of all personnel (staff and contractors) employed on or in association with Dendrobium Mine operations. Regular inspections, internal audits and initiation of any remediation/rectification work in relation to this Plan will be undertaken by the Principal Approvals.

Non-conformities, corrective actions and preventative actions are managed in accordance with the following process:

- Identification and recording of non-conformance and/or non-compliance.
- Evaluation of the non-conformance and/or non-compliance to determine specific corrective and preventative actions.
- Corrective and preventative actions to be assigned to the responsible person.
- Management review of corrective actions to ensure the status and effectiveness of the actions.

An Annual Review will be undertaken to assess IMC's compliance with all conditions of the Dendrobium Development Consent, Mining Leases and other approvals and licenses.

An independent environmental audit will also be undertaken (Condition 6 Schedule 8) to review the adequacy of strategies, plans or programs under these approvals and if appropriate, recommend actions to improve environmental performance. The independent environmental audit will be undertaken by a suitably qualified, experienced and independent team of experts whose appointment has been endorsed by the Secretary of DPIE.

8 PLAN ADMINISTRATION

This WIMMCP will be administered in accordance with the requirements of the Dendrobium Environmental Management System (EMS) and the Dendrobium Development Consent Conditions. A summary of the administrative requirements is provided below.

8.1 Roles and Responsibilities

Statutory obligations applicable to Dendrobium operations are identified and managed via an online compliance management system (TICKIT). The online system can be accessed by the responsible IMC managers from the link below.

https://illawarracoal.tod.net.au/login.

The overall responsibility for the implementation of this WIMMCP resides with the Manager Approvals who shall be the WIMMCP's authorising officer.

Responsibilities for environmental management in Dendrobium Area 3 and the implementation of the WIMMCP include:

Manager Approvals

- Ensure that the requisite personnel and equipment are provided to enable this WIMMCP to be implemented effectively.
- Authorise the WIMMCP.

Principal Approvals

- Develop the WIMMCP and any amendments thereto.
- To document any approved changes to the WIMMCP.
- Provide regular updates to IMC on the results of the WIMMCP.
- Arrange information forums for key stakeholders as required.
- Prepare any report and maintain records required by the WIMMCP.
- Organise and participate in assessment meetings called to review mining impacts.
- Respond to any queries or complaints made by members of the public in relation to aspects of the WIMMCP.
- Organise audits and reviews of the WIMMCP.
- Address any identified non-conformances, assess improvement ideas and implement if appropriate.
- Arrange implementation of any agreed actions, responses or remedial measures.
- Ensure surveys required by this WIMMCP are conducted and record details of instances where circumstances prevent these from taking place.

Environmental Field Team Lead

- Instruct suitable person(s) in the required standards for inspections, recording and reporting and be satisfied that these standards are maintained.
- Investigate significant subsidence impacts.
- Identify and report any non-conformances with the WIMMCP.
- Participate in assessment meetings to review subsidence impacts.
- Bring to the attention of the Principal Approvals any findings indicating an immediate response may be warranted.
- Bring to the attention of the Principal Approvals any non-conformances identified with the WIMMCP provisions or ideas aimed at improving the WIMMCP.

Survey Team Coordinator

- Collate survey data and present in an acceptable form for review at assessment meetings.

- Bring to the attention of the Principal Approvals any findings indicating an immediate response may be warranted.
- Bring to the attention of the Principal Approvals any non-conformances identified with the Plan provisions or ideas aimed at improving the WIMMCP.

Technical Experts

- Conduct the roles assigned to them in a competent and timely manner to the satisfaction of the Principal Approvals and provide expert opinion.

Person(s) Performing Inspections

- Inform the Environmental Field Team Lead of any non-conformances identified with the Plan, or ideas aimed at improving the WIMMCP.
- Conduct inspections in a safe manner.

8.2 Resources Required

The Approvals Manager provides resources sufficient to implement this WIMMCP.

Equipment will be needed for the TARP provisions of this WIMMCP. Where this equipment is of a specialised nature, it will be provided by the supplier of the relevant service. All equipment is to be appropriately maintained, calibrated and serviced as required in operations manuals.

The Approvals Manager shall ensure personnel and equipment are provided as required to allow the provisions of this Plan to be implemented.

8.3 Training

All staff and contractors working on IMC sites are required to complete the IMC training program which includes:

- An initial site induction (including all relevant aspects of environment, health, safety and community).
- Safe Work Method Statements and Job Safety Analyses, Toolbox Talks and pre-shift communications.
- On-going job specific training and re-training (where required).

It is the responsibility of the Approvals Manager to ensure that all persons and organisations having responsibilities under this WIMMCP are trained and understand their responsibilities.

The person(s) performing regular inspections shall be under the supervision of the Environmental Field Team Lead and be trained in observation, measurement and reporting. The Environmental Field Team Lead shall be satisfied that the person(s) performing the inspections are capable of meeting and maintaining this standard.

8.4 Record Keeping and Control

Environmental Records are maintained in accordance with the IMC document control requirements.

IMC document control requirements include:

- Documents are approved for adequacy by authorised personnel prior to use.
- Obsolete documents are promptly removed from circulation.
- Documents are reissued, or made available, to relevant persons in a timely fashion after changes have been made and the authorisation process is complete.

The WIMMCP and other relevant documentation will be made available on the IMC website.

8.5 Management Plan Review

A review of the objectives and targets associated with the Dendrobium Area 3 operations is undertaken on an annual basis via the IMC planning process. These reviews, which include involvement from senior management and other key site personnel, assess the performance of the mine over the previous year and develop goals and targets for the following period.

An annual review of the environmental performance of Dendrobium Area 3 operations will also be undertaken in accordance with Condition 5 Schedule 8 of the Dendrobium Development Consent. More specifically this WIMMCP will be subject to review (and revision if necessary, to the satisfaction of the Secretary) following:

- The submission of an annual review under Condition 5 Schedule 8.
- The submission of an incident report under Condition 3 Schedule 8.
- The submission of an audit report under Condition 6 Schedule 8.
- Any modification to the conditions of the Dendrobium Development Consent.

If deficiencies in the EMS and/or WIMMCP are identified in the interim period, the plans will be modified as required. This process has been designed to ensure that all environmental documentation continues to meet current environmental requirements, including changes in technology and operational practice, and the expectations of stakeholders.

9 REFERENCES AND SUPPORTING DOCUMENTATION

ACARP, 2009. Damage Criteria and Practical Solutions for Protecting River Channels. Project Number C12016. Ken Mills SCT May 2009.

Axys, 2020. Review of Dendrobium Longwall 19 Subsidence Management Plan, Risk Assessment Report. AR2817 (Revision 3) March 2020.

BHP Billiton Illawarra Coal, 2006. Georges River Report: Assessment of Georges River Remediation Longwalls 5A1-4. November 2006.

BHP Billiton Illawarra Coal, 2011. Understanding Swamp Conditions - Field Inspection Report - September 2010 to November 2010. BHP Billiton Illawarra Coal, April, 2011.

Biosis Research 2007. Dendrobium Area 3 Species Impact Statement, Prepared for BHP Billiton Illawarra Coal, Biosis Research Pty Ltd.

Biosis Research 2007. Dendrobium Coal Mine and Elouera Colliery Flora and Fauna Environmental Management Program, Annual Monitoring Report – Spring 2003 to Winter 2006, Biosis Research Pty Ltd.

Biosis Research, 2009. Revision of the Dendrobium Coal Mine Flora and Fauna Monitoring Program. February 2009.

Biosis Research, 2012(a). Elouera and Dendrobium Ecological Monitoring Program. Annual Monitoring Report Financial Year 2010/2011. August 2012.

Biosis Research, 2012(b). Swamp 15b TARP Assessment – Ecology. Ref:15462, 10 October 2012.

Biosis, 2014. Dendrobium Ecological Monitoring Program, Annual Report for 2012/2013 Financial Year. February 2014. Prepared for Illawarra Coal.

Biosis, 2015. Dendrobium Terrestrial Ecology Monitoring Program, Annual Report for 2014. September 2015. Prepared for Illawarra Coal.

Biosis, 2019. Dendrobium Areas 2, 3A and 3B: Terrestrial Ecology Monitoring Program Annual Report 2018, Final Report, Prepared for Illawarra Coal, 21 June 2019.

Boughton W, 2004. The Australian water balance model. Environ Model Softw 19:943–956. doi: doi:10.1016/j.envsoft.2003.10.007.

Cardno, 2020. Aquatic Flora and Fauna Review, Longwall 19 Subsidence Management Plan. AWE200141. March 2020.

Cardno, 2019. Dendrobium Area 3B Aquatic Ecology Monitoring 2010 to 2017. 8 December 2019.

Cardno Ecology Lab, 2012. Aquatic Flora and Fauna Assessment. Prepared for BHPBIC, February 2012.

Cardno Ecology Lab, 2012. Swamp 15b and SC10C Aquatic Flora and Fauna Review. Ref: NA49913032, 5 October 2012.

Cardno Ecology Lab, 2013. Dendrobium Area 3A Aquatic Ecology Monitoring 2008-2012. Job Number: EL1112073 Prepared for BHP Billiton – Illawarra Coal, February 2013.

Cardno Ecology Lab, 2013. Review of Sandy Creek Pools Aquatic Flora and Fauna. 25 February 2013.

Cardno Ecology Lab, 2013. SC10C Level 3 Aquatic Ecology Trigger Assessment. 11 June 2013.

Cardno Ecology Lab, 2015. Dendrobium Area 3A Aquatic Ecology Monitoring 2008 to 2014. 30 March 2015.

Cardno Forbes Rigby, 2007. Landscape Impact Assessment and Monitoring Site Optimisation. Prepared for BHPBIC.

Cardno Forbes Rigby, 2007. Area 3A Subsidence Management Plan Longwalls 6 to 10. Prepared for BHPBIC.

Cardno Forbes Rigby, 2007. Dendrobium Area 3 Environmental Assessment. Prepared for BHPBIC.

Chafer, C., Noonan, M and Macnaught, E. 2004. The Post-Fire Measurement of Fire Severity and Intensity in the Christmas 2001 Sydney Wildfires. International Journal of Wildland Fire Vol. 13; pp. 227-240.

Chiew, F, Wang, Q. J., McConachy, F., James, R., Wright, W, and deHoedt, G. 2002. Evapotranspiration Maps for Australia. Hydrology and Water Resources Symposium, Melbourne, 20-23 May, 2002, Institution of Engineers, Australia.

Coffey, 2012. Groundwater Study Area 3B Dendrobium Coal Mine: Numerical Modelling. GEOTLCOV24507AA-AB2 2 October 2012.

Ditton, S., and Merrick, N.P. 2014. A new sub-surface fracture height prediction model for longwall mines in the NSW coalfields. Paper presented at the Australian Earth Science Convention, Newcastle, NSW.

Doherty, J. 2010. PEST: Model-Independent Parameter Estimation User Manual (5th ed.): Watermark Numerical Computing, Brisbane, Queensland, Australia.

EarthTech Engineering Pty Ltd, 2005. Thresholds for Swamp Stability. Prepared for BHPBIC, January 2005.

The Ecology Lab, 2007. Dendrobium Area 3 Assessment of Mine Subsidence Impacts on Aquatic Habitat and Biota. October 2007.

Ecoengineers, 2006. Assessment of Surface Water Chemical Effects of Mining by Elouera Colliery. January - December 2005. February 2006.

Ecoengineers, 2006. Assessment of Catchment Hydrological Effects by Mining by Elouera Colliery Stage 1: Establishment of a Practical and Theoretical Framework. August 2006.

EcoEngineers, 2007. Surface Water Quality and Hydrology Assessment to Support SMP Application for Dendrobium Area 3.

EcoEngineers, 2010. End of Panel Surface and Shallow Groundwater Impacts Assessment Dendrobium Area 2 Longwall 5. Document Reference No. 2010/01A. April 2010.

Ecoengineers, 2012. Surface Water Quality and Hydrological Assessment: Dendrobium Area 3B Subsidence Management Plan Surface and Shallow Groundwater Assessment.

Ecoengineers, 2012. Level 2 TARP Independent Review and Recommendations Swamp 15b Dendrobium Area 3A. 25 September 2012.

Ecoengineers, 2013. Level 3 TARP Independent Review and Recommendations Sandy Creek Catchment Pool 7 (Dendrobium Area 3A). 12 February 2013.

Ecoengineers, 2013. Level 2 TARP Specialist Review and Recommendations Donalds Castle Creek. 22 May 2013.

Ecoengineers, 2014. End of Panel Surface and Shallow Groundwater Impacts Assessment, Dendrobium Area 3B Longwall 9. June 2014.

Ecoengineers, 2015. End of Panel Surface and Shallow Groundwater Impacts Assessment, Dendrobium Area 3B Longwall 10. February 2015.

Eco Logical Australia, 2004. The Impacts of Longwall Mining on the Upper Georges River Catchment: Report to Total Environment Centre, 2004.

Forster, 1995. Impact of Underground Mining on the Hydrogeological Regime, Central Coast NSW. Engineering Geology of the Newcastle-Gosford Region. Australian Geomechanics Society. Newcastle, February 1995.

GHD, 2007. Dendrobium Area 3A Predicted Hydrogeologic Performance. Report for BHP Billiton, Illawarra Coal. November 2007.

GSS Environmental, 2013. Baseline and Pre-Mining Land Capability Survey. Dendrobium Mine, Area 3B. February 2013.

Hazelton P.A. and Tille P.J. 1990. Soil Landscapes of the Wollongong-Port Hacking 1:100,000 Sheet map and report, Soil Conservation Service of NSW, Sydney.

Hebblewhite, 2010. BHP Billiton Illawarra Coal: Bulli Seam Operations Project – Independent Review. 31 March 2010.

Helensburgh Coal Pty Ltd, 2007. Submission to: Independent Expert Panel - Inquiry into NSW Southern Coalfield July 2007, Helensburgh Coal Pty Ltd.

Heritage Computing, 2009. Dendrobium Colliery Groundwater Assessment: Mine Inflow Review, Conceptualisation and Preliminary Groundwater Modelling. Merrick, N.P., Heritage Computing Report HC2009/2, February 2009.

Heritage Computing, October 2011. Recalibration of the Dendrobium Local Area Groundwater Model after Completion of Longwall 6 (Area 3A). Report prepared for Illawarra Coal. Report HC2011/13.

HGEO 2020. Assessment of surface water flow and quality effects of proposed Dendrobium Longwall 19. J21495, March 2020.

HGEO, 2019. Dendrobium Mine End of Panel Surface Water and Shallow Groundwater Assessment: Longwall 14 (Area 3B), September 2019, Project number: J21474, Report: D19327.

HGEO, 2019. Dendrobium Mine Estimates of seepage from Lake Avon following redrilling of holes at AD3, AD4 and AD8. September 2019. Project number: J21476. Report: D19337.

HydroSimulations, 2014. Dendrobium Area 3B Groundwater Model Revision: Swamps, Stream Flows and Shallow Groundwater Sata. Report: HC2014/4 March 2014.

HydroSimulations, 2019. Dendrobium Area 3B Longwall 17 Groundwater Assessment. Report: HC2018 March 2019.

Illawarra Coal, 2014. Longwall 9 End of Panel Report.

Illawarra Coal, 2015. Longwall 10 End of Panel Report.

Illawarra Coal, 2016. Longwall 11 End of Panel Report.

Illawarra Coal, 2017. Longwall 12 End of Panel Report.

Illawarra Coal, 2018. Longwall 13 End of Panel Report.

Illawarra Metallurgical Coal, 2019. Longwall 14 End of Panel Report.

Independent Expert Panel for Mining in the Catchment, 2019a, Independent Expert Panel for Mining in the Catchment Report: Part 1. Coal Mining Impacts in the Special Areas of the Greater Sydney Water Catchment, Prepared for the NSW Department of Planning, Industry and Environment.

Independent Expert Panel for Mining in the Catchment, 2019b, Independent Expert Panel for Mining in the Catchment Report: Part 2. Coal Mining Impacts in the Special Areas of the Greater Sydney Water Catchment, Prepared for the NSW Department of Planning, Industry and Environment.

Kalf and Associates, 2020. South32 – Illawarra Coal Dendrobium Mine: KA Peer Review of SLR Groundwater Modelling Assessment of Longwall 19 extraction.

Kirchner, J. W. 2009. Catchments as simple dynamical systems: Catchment characterization, rainfall-runoff modelling, and doing hydrology backwards. Res., W02429.

Manly Hydraulics Laboratory, 2006. BHP Billiton Dendrobium Mine Area 2 Subsidence Environmental Management Plan Water Monitoring and Management Program. Prepared for BHPBIC. Version 1.4 January 2006.

McMahon, 2014. Dendrobium Community Consultative Committee Report: Review of Surface Water Study. An independent review of surface water hydrological modelling associated with Illawarra Coal's Dendrobium Area 3, conducted by Emeritus Professor Thomas McMahon, University of Melbourne. 4 June 2014.

MSEC, 2007. Dendrobium Mine Area 3A Longwalls 6 to 10. Report on The Prediction of Subsidence Parameters and the Assessment of Mine Subsidence Impacts on Natural Features and Surface Infrastructure Resulting from the Extraction of proposed Longwalls 6 to 10 in Area 3A at Dendrobium Mine in Support of the SMP and SEMP Applications. September 2007.

MSEC, 2012. Dendrobium Area 3B Subsidence Predictions and Assessments for Natural Features and Surface Infrastructure in Support of the SMP Application.

MSEC, 2015. Dendrobium Area 3B – Longwalls 12 to 18 Review of the Subsidence Predictions and Impact Assessments for Natural and Built Features in Dendrobium Area 3B based on Observed Movements and Impacts during Longwalls 9 and 10.

MSEC, 2017. Dendrobium mine – Area 3B. The Effects of the Proposed Modified Commencing Ends of Longwalls 15 to 18 in Area 3B at Dendrobium Mine on the Subsidence Predictions and Impact Assessments. MSEC914 August 2017.

MSEC, 2018. Dendrobium – Longwalls 17 and 18. Subsidence Predictions and Impact Assessments for the Natural and Built Features due to the Extraction of Longwalls 17 and 18 in Area 3B at Dendrobium Mine. MSEC992 November 2018.

MSEC, 2019. Report on the effects of surface lineaments on the measured ground movements at Dendrobium Area 3B based on the measured LiDAR contours. Report No. MSEC1034.

MSEC, 2020. Dendrobium – Longwall 19 Subsidence Predictions and Impact Assessments for the Natural and Built Features due to the Extraction of the Proposed Longwall 19 in Area 3A at Dendrobium Mine. MSEC1082 March 2020.

Niche Environment and Heritage, 2012. Terrestrial Ecological Assessment. Prepared for BHP Billiton Illawarra Coal. February 2012.

Niche, 2020. Dendrobium Longwall 19 Terrestrial Ecological Assessment - Accompanying Document to Dendrobium Longwall 19 Subsidence Management Plan. Prepared for South32 Illawarra Metallurgical Coal, March 2020.

NPWS, 2003. The Native Vegetation of the Woronora, O'Hares and Metropolitan Catchments. Central Conservation Programs and Planning Division NSW National Parks and Wildlife Service; August 2003.

OEC, 2001. Environmental Impact Statement Dendrobium Coal Project. Olsen Environmental Consulting, Figtree, N.S.W.

Parkhurst. D.L., and Appelo, C.A.J. 2012. Description of Input and Examples for PHREEQC Version 3 – A Computer Program for Speciation, Batch-Reaction, One- Dimensional Transport and Inverse Geochemical Calculations. US Department of Interior/US Geological Survey.

Parson Brinckerhoff, 2012. Independent Review of Dendrobium Area 2 and 3A Hydrochemical Data. August 20012.

Parsons Brinckerhoff, 2015. Connected fracturing above longwall mining operations, Part 2: Post-longwall investigation. For BHP Billiton Illawarra Coal. Document number 2172268F-WAT-REP-002 RevB. 6 March 2015.

Petersen, 1992. The RCE: a Riparian, Channel, and Environmental Inventory for small streams in the agricultural landscape. Freshwater Biology Vol 27, Issue 2, April 1992.

Resource Strategies, 2009. Bulli Seam Operations Environmental Assessment. Report in support of an application for the continued operations of the Appin and West Cliff Mines.

Singh & Kendorski, 1981. Strata Disturbance Prediction for Mining Beneath Surface Water and Waste Impoundments, Proc. First Conference on Ground Control in Mining, West Virginia University, PP 76-89.

SLR, 2020. Dendrobium Area 3A Longwall 19 Groundwater Assessment. Report: 665.10009-R02_v2.0. F. January 2020.

Tammetta, P. (2013). Estimation of the height of complete groundwater drainage above mined longwall panels. Groundwater, 51(5), 723-734.

Tomkins, K.M. and Humphries, G.S. 2006. Technical report 2: Upland Swamp development and erosion on the Woronora Plateau during the Holocene. January 2006. Sydney Catchment Authority – Macquarie Collaborative Research Project.

Tozer, M. et el 2002. Native Vegetation Maps of the Cumberland Plain Western Sydney. NSW National Parks and Wildlife Service 2002.

Waddington, A.A. and Kay, D.R. 2001. Research into the Impacts of Mine Subsidence on the Strata and Hydrology of River Valleys and Development of Management Guidelines for Undermining Cliffs. Gorges and River Systems. Final Report on ACARP Research Project C8005, March 2001.

Waddington, A.A. and Kay, D.R. 2002. Management Information handbook on the Undermining of Cliffs, Gorges and River Systems. ACARP Research Projects Nos. C8005 and C9067, September 2002.

Watershed HydroGeo, 2018. Analysis of low flow and pool levels on Wongawilli Creek. Report r003i2, October 2018.

Watershed HydroGeo, 2019. Discussion of Surface Water Flow TARPs. Report r011i5, December 2019.

Zhang, L. Dawes, W.R. and Walker, G.R. 1999. Predicting the effect of Vegetation Changes on Catchment Average Water Balance. Technical Report No. 99/12, Cooperative Research Centre for Catchment Hydrology.

Appendix A – Watercourse Monitoring and Trigger Action Response Plan

Table 1.1 – Dendrobium Area 3 Watercourse Monitoring

Watercourse monitoring within Dendrobium Area 3 will be installed ahead of mining to achieve 2 years baseline data (subject to timing and approval timeframes of any request to install additional monitoring). Monitoring will be conducted throughout the mining period and for at least 2 years following active subsidence. A review of the continuation and potentially extending post mining monitoring will be carried out in consultation with DPIE, WaterNSW and other relevant agencies where required. Where impacts are observed, the monitoring period will be extended and this will be reported in Impact Assessment Reports and End of Panel Reports. For Level 2 and 3 Triggers and for impacts exceeding prediction this review will be conducted in consultation with key agencies. The location of monitoring sites is indicated on Figures 2-1 to 2-57.

	MONITORING SITE	SITE TYPE	MONITORING FREQUENCY	PARAMETERS
OBSERVATIONAL MONITORING				
Area 3A	Sandy Creek and tributaries (including SC7 and SC10) Wongawilli Creek and tributaries *Refer to Figure 3-1 of Longwall 19 WIMMCP*	Observation and photo point monitoring: • Sites based on an assessment of risk • Streams and swamps • Pools and rockbars • Previously observed impacts that warrant follow-up inspection	• Monthly 2 years pre- and post-mining, weekly when longwall is within 400 m of monitoring site • Reference sites 6 monthly	Visual signs of impacts to creeks and drainage lines (i.e. cracking, vegetation changes, increased erosion, changes in water colour, soil moisture etc.) determined by comparing baseline photos with photos during the mining period Manual Field Testing: Key water quality parameters in pools analysed to identify any changes resulting from mining including pH, Temp, EC, DO and ORP Pool water levels to identify any changes resulting from mining. At suitable sites, pool water levels will be measured with a pressure transducer and continuous logger. A benchmark for manual readings will be installed at sites that are not suitable for a logger
AREA 3B	**Impact Sites** Native Dog, Wongawilli and Donalds Castle Creeks, WC21, WC18, WC16, WC15, WC12, WC9, WC8, WC7, WC6, LA5, LA4, LA3, LA2, ND1 and DC13 Swamps 5, 10, 11, 13, 14, 23, 35a, 35b, 1a, 1b, 8, 3 and 4 *Refer to Figures 2-2 to 2-11 and 2-25 to 2-32 of 3B WIMMCP* **Reference Sites** Wongawilli Creek, Sandy Creek, LC5[1], LC7B, WC11, SC9A, SC10A, NDC1, DC10 and D10 Swamps 2[1], 7[1], 15a, 22, 24, 25, 33, 84, 85, 86, 87 and 88 *Refer to Figures 2-12 to 2-25, 2-28 to 2-30 and 2-33 to 2-35*			
AREA 3C	**Impact Sites** [2,3] Wongawilli Creek, Donalds Castle Creek, DC13, WC20, WC21, WC22, WC23, WC24, WC25, WC26, WC27, WC29, LC5[1] Swamps 2[1], 5, 7[1], 9, 124, 140, 141, 142, 144 and 145 **Reference Sites** CR36 (Cordeaux River tributary)			
WATER CHEMISTRY				

<table>
<tr>
<td>Area 3A</td>
<td>Wongawilli Creek
WWU1, WWU4, WC_Pool 46, WWM2, WC_Pool 43b and Wongawilli Creek (FR6)
WC17_S1 (Wongawilli Creek tributary)
WC14_S1 (Wongawilli Creek tributary)
WC13_S1 (Wongawilli Creek tributary)
Sandy Creek
SCk_Rockbar 5 (Sandy Creek adjacent to LW7)
SC10_Rockbar 3 (Sandy Creek tributary)
SC10C_Pool 1 (SC10 tributary)
SC7_S1 (Sandy Creek tributary)
Lake Cordeaux
Sandy Creek Arm (lake site) Refer to Figure 3-1 of Longwall 19 WIMMCP</td>
<td rowspan="2">• Collect sample
• Field water quality</td>
<td rowspan="2">• Monthly monitoring pre, during and post mining for two years</td>
<td rowspan="2">Lab. Analytes:
• (incl. lab checks of pH, lab. check of EC, DOC, Na, K, Ca, Mg, Filt. SO4, Cl, T. Alk., Total Fe, Mn, Al, Filt. Cu, Ni, Zn, Si)</td>
</tr>
<tr>
<td>AREA 3B</td>
<td>Wongawilli Creek
WWU1 (Wongawilli Creek headwaters)
WWU4 (Wongawilli Creek upstream)
WC_Rockbar 39 (Wongawilli Creek adjacent to LW17)
WC Pool 49 (Wongawilli Creek adjacent to LW15)
WC_Pool 46 (Wongawilli Creek adjacent to LW12)
WWM2 (Wongawilli Creek adjacent to LW11)
WC_Pool 43b (Wongawilli Creek downstream of LW9)
Wongawilli Creek (FR6) (Wongawilli Creek downstream)
WC21_Pool 5 (Wongawilli Creek tributary downstream of mining)
WC21 Pools 30 and 53 (Wongawilli Creek tributaries over mining)
WC15_Pool 28 (Wongawilli Creek tributary downstream of mining)
WC15_Pool 9 (Wongawilli Creek tributary downstream of mining)
WC15_Pool 2 (Wongawilli Creek tributary downstream of mining)
WC7_Pool 1(Wongawilli Creek tributary downstream of mining)
WC12_Pool 1 (Wongawilli Creek tributary downstream of mining)
Lake Avon
LA4_S1, LA4_S2, LA5_S1, LA5_S2, LA3 Pool 4, LA2 Pool 5, LA1and LA_1 (Lake Avon tributaries downstream of mining)
NDC4 (Native Dog Creek downstream of mining)
NDC1 (Native Dog Creek upstream of Area 3B)</td>
</tr>
</table>

	NDT1 (tributary to Native Dog Creek downstream of mining) **Donalds Castle Creek** Donalds Castle Creek (FR6) (Donalds Castle Creek lower) DCL3 (Donalds Castle Creek Upstream approx. 1km from Cordeaux River) DC_Pool 22 (Donalds Castle Creek downstream of mining) DC13_Pool 2b (Donalds Castle Creek tributary downstream of mining) **Lake Cordeaux** *LC5_S1 (Reference Site)* *Refer to Figure 2-35* **Cordeaux River** CR36_S1 (Cordeaux River tributary Reference Site)			
AREA 3C	**Wongawilli Creek** WWU1 (headwaters; upstream of Area 3C) WWU4 (upstream of Area 3C) Wongawilli Ck (FR6) (Wongawilli Creek downstream) WC_Pool 43b (adjacent to Longwall 20) WC_S1 (downstream of Longwall 21) WC_Pool 20 (downstream of Longwalls 20 and 21) (4) WC20_S1 (downstream of Longwall 20) (4) WC24_S1 (downstream of Longwall 20) (4) WC26_S1 (downstream of Longwall 20) (4) **Donalds Castle Creek** Donalds Castle Ck (FR6) (Donalds Castle Creek lower) DCL3 (Donalds Castle Creek upstream of Cordeaux River confluence) **Lake Avon** NDC1 (Native Dog Creek upstream of Area 3B) **Lake Cordeaux** LC5_S1 (downstream of Longwall 20) **Cordeaux River** CR36_S1 (Reference site northeast of Area 3C)			
WATER FLOW				
Ref Sites	**O'Hares Creek** [NSW govt site] 213200 (O'Hares Creek @ Wedderburn) **Wongawilli Creek** WWU (Wongawilli Creek upstream)	• Some data (for reference sites) is provided by Water NSW		Other reference sites may be used depending on data availability and quality (e.g. Woronora River 2132101 and Bomaderry Creek 215016)

Area 3A	**Wongawilli Creek** WWU (Wongawilli Creek upstream) WWL_A (Wongawilli Creek downstream) WC14S1 (Wongawilli Creek tributary) **Sandy Creek** SCL2(Sandy Creek at downstream) SC10S1 and SC10CS1 (Sandy Creek tributary) *Refer to Figures 2-35 and 2-36*	• Pressure transducer with data logger • Flow gauging site (volumetric or flow meter). Low-profile weir or suitable natural rockbar control	• Continuous 1-hour logging intervals	Automatic pool water level measurements which are converted to flows by calculation of rating curves using measured creek cross sections/measured flows at the monitoring point. Hydrological changes are assessed by comparing pre- and post-mining observed flows from impact or assessment sites to flow data from similar reference sites (that are not impacted by mining).
AREA 3B	**Wongawilli Creek** WWU (Wongawilli Creek upstream) WWL_A (Wongawilli Creek downstream) WC21S1 (Wongawilli Creek tributary downstream of mining) WC15S1 (Wongawilli Creek tributary downstream of mining) WC12S1 (Wongawilli Creek tributary downstream of mining) **Donalds Castle Creek** DCU (Donalds Castle Creek @ FR6) DC13S1 (Donalds Castle Creek tributary downstream of mining) DCS2 (Donalds Castle Creek downstream of mining) **Lake Avon** LA4S1 (Lake Avon tributary downstream of mining) LA3S1 (Lake Avon tributary downstream of mining) LA2S1 (Lake Avon tributary downstream of mining) NDTS1 (Lake Avon Tributary downstream of mining) **Lake Cordeaux** LC5S1 (Reference Site) **Cordeaux River** CR36S1 (Cordeaux River tributary Reference Site) *Refer to Figures 2-35 and 2-36*			
AQUATIC ECOLOGY				
	Impact Sites: Sites 2, 3, 4, X4, X5 and X6 (Wongawilli Creek) Sites X2 and X3 (WC21) Site X1 (Donalds Castle Creek) Sites 8, 9, 11, 12 and 13 (Sandy Creek Catchment) *Refer to Figure 2-57 of 3B WIMMCP* **Reference Sites:** Site 1 (Wongawilli Creek – until LW15) Site 5 (Wongawilli Creek)	• Quantitative and observational monitoring	• Two baseline monitoring campaigns prior to mining during autumn and spring • Monitoring during mining in autumn and spring • Monitoring post mining for two years or as otherwise required • Monitoring targets sites as mining progresses through the domain	Macroinvertebrate sampling and assessment using the AUSRIVAS protocol and quantitative sampling using artificial collectors In consideration of Adams Emerald Dragonfly, Giant Dragonfly and Sydney Hawk Dragonfly, individuals of the genus Austrocorduliidae and Gomphomacromiidae, Petalura are identified to species level if possible

	Site 14 (Donalds Castle Creek) Site 6 (WC21) Site 7 (Sandy Creek) Sites 15 and 16 (Kentish Creek) *Refer to Figure 2-57 of 3B WIMMCP*			Fish are sampled by visual observations and dip netting in the Longwall 19 Study Area, and sampled using a back-pack electrofisher and baited traps in Area 3B
TERRESTRIAL ECOLOGY				
AREAS 3A, 3B, 3C	**Impact Sites:** DC13 (Donalds Castle Creek tributary) DC(1) (Donalds Castle Creek) WC15 and 21 (Wongawilli Creek tributaries) LA4A (Lake Avon tributary) ND1 (Native Dog Creek tributary) **Reference Sites:** WC10 and 11 (Wongawilli Creek tributaries) SC6, SC7-1, SC7-2, SC7A and SC8 (Sandy Creek tributaries) DC8 (Donalds Castle Creek tributary) NDC (Native Dog Creek)	• Standardised transects in potential breeding habitat for two threatened frog species, Littlejohn's Tree Frog and Giant Burrowing Frog	• Surveys are undertaken in optimal periods over the season (i.e. when frogs are calling and/or active at known sites)	Frog surveys are conducted along creeks with a focus on features susceptible to impacts e.g. breeding pools. Potential breeding habitat for Littlejohn's Tree Frog and Giant Burrowing Frog will be targeted. Standardised transects have been established to record numbers of individuals recorded at each site from one year to the next. Tadpole counts will also be undertaken as part of the breeding habitat monitoring transects. These transects are surveyed by walking down the creekline and counting all amphibians seen or heard on either side of the line

(1) *Reference site for Area 3B; impact site when mining commences in Area 3C.*

(2) *The proposed sites are designed to monitor each mapped pool/rockbar complex within the Study Area reach of Wongawilli Creek. Based on site inspections (August 2019), continuous monitoring will be implemented at suitable sites. A benchmark for manual readings will be installed at sites that are not suitable for continuous monitoring.*

(3) *Proposed sites within the Wongawilli Creek tributaries are subject to change based on further field inspections. The sites will target pool/rockbar complexes and steps.*

Table 1.2 – Longwall 19 Study Area Watercourse Impacts, Triggers and Response

OBSERVATIONAL MONITORING		
Sandy Creek and Wongawilli Creek **Relevant Performance Measure(s):** • Wongawilli Creek - minor environmental consequences • Sandy Creek - minor environmental consequences General observation of streams in active mining areas when longwall is within 400m	***Level 1*** • Crack or fracture up to 100mm width at its widest point with no observable loss of surface water or erosion • Crack or fracture up to 10m length with no observable loss of surface water or erosion • Erosion in a localised area (not associated with cracking or fracturing) which would be expected to naturally stabilise without CMA and within the period of monitoring • Observable release of strata gas at the surface • Observable increase in iron staining within the mining area • Observation that a pool on a subject Creek is dry • Observation that the subject Creek has ceased to flow	• Continue monitoring program • Submit an Impact Report to BCD, DPIE, DRG, Water NSW • Report in the End of Panel Report • Summarise actions and monitoring in AEMR
	Level 2 • Observation that a single pool on a subject Creek is dry in consecutive monitoring events • Observation that two or more pools on a subject Creek are dry in a single monitoring event • Observation that the subject Creek has ceased to flow in consecutive monitoring event	• *Actions as stated for Level 1* • Carry out Water Flow Assessment Method D • Review monitoring frequency • Submit letter report to DPIE, DRG and Water NSW and seek advice on any CMA required • Implement agreed CMAs as approved (subject to agency feedback)
	• Crack or fracture between 100 and 300mm width at its widest point or any fracture which results in observable loss of surface water or erosion • Crack or fracture between 10 and 50m length • Soil surface crack that causes erosion that is likely to stabilise within the monitoring period without intervention • Observable increase in iron staining within the mining area continues to outside the mining area i.e. 400m from the longwall	• *Actions as stated for Level 1* • Review monitoring frequency • Submit letter report to DPIE, DRG and Water NSW and seek advice on any CMA required • Implement agreed CMAs as approved (subject to agency feedback)
	Level 3 • Crack or fracture over 300mm width at its widest point • Crack or fracture over 50m length • Fracturing observed in the bedrock base of any significant permanent pool which results in observable loss of surface water • Soil surface crack that causes erosion that is unlikely to stabilise within the monitoring period without intervention	• *Actions as stated for Level 2* • Offer site visit with BCD, DPIE, DRG, Water NSW • Implement additional monitoring or increase frequency if required • Develop site CMA (subject to agency feedback). This may include: grouting of rockbar and bedrock base of any significant pool where it is appropriate to do so in consultation with BCD, DPIE, DRG, Water NSW • Completion of works following approvals and at a time agreed between S32, DPIE, DRG and Water NSW (i.e. may be after mining induced

	• Gas release results in vegetation dieback, mortality or loss of aquatic habitat • Observable increase in iron staining within the mining area continues more than 600m from the longwall	movements and impacts are complete), including monitoring and reporting on success • Review relevant TARP and Management Plan in consultation with key agencies
	Exceeding Prediction • Structural integrity of the bedrock base of any significant permanent pool or controlling rockbar cannot be restored i.e. pool water level within the pool after CMAs continues to be lower than baseline period • Gas release results in vegetation dieback that does not revegetate • Gas release results in mortality of threatened species or ongoing loss of aquatic habitat • Iron staining and associated increases in dissolved iron resulting from the mining is observed in water at Wongawilli Creek downstream monitoring site Wongawilli Creek (FR6) • Iron staining and associated increases in dissolved iron resulting from the mining is observed in water at the Sandy Creek downstream monitoring site Sandy Creek SCk_Rockbar 5 • Greater than negligible diversion of water occurs from the lip of the waterfall	• *Actions as stated for Level 3* • Investigate reasons for the exceedance • Update future predictions based on the outcomes of the investigation • Provide residual environmental offset for any mining impact where CMAs are unsuccessful as required by Condition 14 Schedule 3 of the Development Consent
WC13, WC14, WC15, WC16, WC17, WC17A, WC17B, SC7, SC10 and SC10C General observation of streams in active mining areas when longwall is within 400m	***Level 1*** • Crack or fracture up to 100mm width at its widest point with no observable loss of surface water or erosion • Crack or fracture up to 10m length with no observable loss of surface water or erosion • Erosion in a localised area (not associated with cracking or fracturing) which would be expected to naturally stabilise without CMA and within the period of monitoring • Observable release of strata gas at the surface • Observable increase in iron staining within the mining area	• Continue monitoring program • Submit an Impact Report to BCD, DPIE, DRG, Water NSW • Report in the End of Panel Report • Summarise actions and monitoring in AEMR

	Level 2 • Crack or fracture between 100 and 300mm width at its widest point or any fracture which results in observable loss of surface water or erosion • Crack or fracture between 10 and 50m length • Soil surface crack that causes erosion that is likely to stabilise within the monitoring period without intervention • Observable increase in iron staining within the mining area continues to outside the mining area i.e. 400m from the longwall	• *Actions as stated for Level 1* • Review monitoring frequency • Submit letter report to DPIE, DRG and Water NSW and seek advice on any CMA required • Implement agreed CMAs as approved (subject to agency feedback)
	Level 3 • Crack or fracture over 300mm width at its widest point • Crack or fracture over 50m length • Fracturing observed in the bedrock base of any significant permanent pool which results in observable loss of surface water • Soil surface crack that causes erosion that is unlikely to stabilise within the monitoring period without intervention • Gas release results in vegetation dieback, mortality or loss of aquatic habitat • Observable increase in iron staining within the mining area continues more than 600m from the longwall	• *Actions as stated for Level 2* • Offer site visit with BCD, DPIE, DRG, Water NSW • Implement additional monitoring or increase frequency if required • Develop site CMA (subject to agency feedback). This may include: grouting of rockbar and bedrock base of any significant pool where it is appropriate to do so in consultation with BCD, DPIE, DRG, Water NSW • Completion of works following approvals and at a time agreed between S32, DPIE, DRG and Water NSW (i.e. may be after mining induced movements and impacts are complete), including monitoring and reporting on success • Review relevant TARP and Management Plan in consultation with key agencies
WATER QUALITY		
Wongawilli Creek **Relevant Performance Measure(s):** • Wongawilli Creek - minor environmental consequences Wongawilli Creek (FR6) Baseline means: • pH 6.01 • EC 100.4 uS/cm • DO 89.5%	***Level 1*** • One exceedance of the ±3 standard deviation level (positive for EC, negative for pH and DO) from the baseline mean within six months: – pH 4.39 – EC 163.9 uS/cm – DO 49.1%	• Continue monitoring program • Submit an Impact Report to BCD, DPIE, DRG, Water NSW • Report in the End of Panel Report • Summarise actions and monitoring in AEMR
	Level 2 • Two non-consecutive exceedances of the ±3 standard deviation level (positive for EC, negative for pH and DO) from the baseline mean within six months: – pH 4.39 – EC 163.9 uS/cm – DO 49.1%	• *Actions as stated for Level 1* • Review monitoring frequency • Submit letter report to DPIE, DRG and Water NSW and seek advice on any CMA required • Implement agreed CMAs as approved (subject to agency feedback)

	Level 3 • Three exceedances of the ±3 standard deviation level (positive for EC, negative for pH and DO) from the baseline mean within six months: – pH 4.39 – EC 163.9 uS/cm – DO 49.1%	• *Actions as stated for Level 2* • Offer site visit with BCD, DPIE, DRG, Water NSW • Implement additional monitoring or increase frequency if required • Review relevant TARP and Management Plan in consultation with key agencies • Develop site CMA (subject to agency feedback). This may include: – Limestone emplacement to raise pH where it is appropriate to do so • Completion of works following approvals and at a time agreed between S32, DPIE, DRG and Water NSW (i.e. may be after mining induced movements and impacts are complete), including monitoring and reporting on success
	Exceeding Prediction • Mining results in two consecutive exceedances or three exceedances of the ±3 standard deviation level (positive for EC, negative for pH and DO) from the baseline mean within six months: – pH 4.39 – EC 163.9 uS/cm – DO 49.1%	• *Actions as stated for Level 3* • Investigate reasons for the exceedance • Update future predictions based on the outcomes of the investigation • Provide residual environmental offset for any mining impact where CMAs are unsuccessful as required by Condition 14 Schedule 3 of the Development Consent
Sandy Creek **Relevant Performance Measure(s):** • Sandy Creek - minor environmental consequences SCk_Rockbar 5 Site Baseline means: • pH 5.54 • EC 101.1 uS/cm • DO 74.8%	***Level 1*** • One exceedance of the ±3 standard deviation level (positive for EC, negative for pH and DO) from the baseline mean within six months: – pH 5.10 – EC 129.9 uS/cm – DO 17.9%	• Continue monitoring program • Submit an Impact Report to BCD, DPIE, DRG Water NSW • Report in the End of Panel Report • Summarise actions and monitoring in AEMR
	Level 2 • Two non-consecutive exceedances of the ±3 standard deviation level (positive for EC, negative for pH and DO) from the baseline mean within six months: – pH 5.10 – EC 129.9 uS/cm – DO 17.9%	• *Actions as stated for Level 1* • Review monitoring frequency • Submit letter report to DPIE, DRG and Water NSW and seek advice on any CMA required • Implement agreed CMAs as approved (subject to agency feedback)
	Level 3	• *Actions as stated for Level 2* • Offer site visit with BCD, DPIE, DRG, Water NSW • Implement additional monitoring or increase frequency if required

	• Three exceedances of the ±3 standard deviation level (positive for EC, negative for pH and DO) from the baseline mean within six months: – pH 5.10 – EC 129.9 uS/cm – DO 17.9%	• Review relevant TARP and Management Plan in consultation with key agencies • Collect laboratory samples and analyse for: – pH, EC, major cations, major anions, Total Fe, Mn & Al – Filterable suite of metals • Develop site CMA (subject to agency feedback). This may include: – Limestone emplacement to raise pH where it is appropriate to do so • Completion of works following approvals and at a time agreed between S32, DPIE, DRG and Water NSW (i.e. may be after mining induced movements and impacts are complete), including monitoring and reporting on success
	Exceeding Prediction • Mining results in two consecutive exceedances or three exceedances of the ±3 standard deviation level (positive for EC, negative for pH and DO) from the baseline mean within six months: – pH 5.10 – EC 129.9 uS/cm – DO 17.9%	• *Actions as stated for Level 3* • Investigate reasons for the exceedance • Update future predictions based on the outcomes of the investigation • Provide residual environmental offset for any mining impact where CMAs are unsuccessful as required by Condition 14 Schedule 3 of the Development Consent
Lake Cordeaux **Relevant Performance Measure(s):** • Lake Cordeaux - negligible reduction in the quality of surface water inflows to Lake Cordeaux Sandy Creek Arm Site Baseline means: • pH 6.11 • EC 93 uS/cm • DO 87.6%	***Level 1*** • One exceedance of the ±3 standard deviation level (positive for EC, negative for pH and DO) from the baseline mean within six months: – pH 3.96 – EC 137 uS/cm – DO 49.4%	• Continue monitoring program • Submit an Impact Report to BCD, DPIE, DRG, Water NSW • Report in the End of Panel Report • Summarise actions and monitoring in AEMR
	Level 2 • Two non-consecutive exceedances of the ±3 standard deviation level (positive for EC, negative for pH and DO) from the baseline mean within six months: – pH 3.96 – EC 137 uS/cm – DO 49.4%	• *Actions as stated for Level 1* • Review monitoring frequency • Submit letter report to DPIE, DRG and Water NSW and seek advice on any CMA required • Implement agreed CMAs as approved (subject to agency feedback)
	Level 3	• *Actions as stated for Level 2* • Offer site visit with BCD, DPIE, DRG, Water NSW • Implement additional monitoring or increase frequency if required

	• Three exceedances of the ±3 standard deviation level (positive for EC, negative for pH and DO) from the baseline mean within six months: – pH 3.96 – EC 137 uS/cm – DO 49.4%	• Review relevant TARP and Management Plan in consultation with key agencies • Collect laboratory samples and analyse for: – pH, EC, major cations, major anions, Total Fe, Mn & Al – Filterable suite of metals • Develop site CMA (subject to agency feedback). This may include: – Limestone emplacement to raise pH where it is appropriate to do so – Grouting of fractures in rockbar and bedrock base of any significant pool where flow diversion results in pool water level lower than baseline period • Completion of works following approvals and at a time agreed between S32, DPIE, DRG and Water NSW (i.e. may be after mining induced movements and impacts are complete), including monitoring and reporting on success
	Exceeding Prediction • Mining results in two consecutive exceedances or three exceedances of the ±3 standard deviation level (positive for EC, negative for pH and DO) from the baseline mean within six months: – pH 3.96 – EC 137 uS/cm – DO 49.4%	• *Actions as stated for Level 3* • Investigate reasons for the exceedance • Update future predictions based on the outcomes of the investigation • Provide residual environmental offset for any mining impact where CMAs are unsuccessful as required by Condition 14 Schedule 3 of the Development Consent
POOL WATER LEVEL		
Wongawilli Creek and Sandy Creek **Relevant Performance Measure(s):** • Wongawilli Creek - minor environmental consequences • Sandy Creek - minor environmental consequences	***Level 1*** • Single pool on a subject Creek is observed as dry	• Continue monitoring program • Carry out Water Flow Assessment Method D. • Submit letter report to DPIE, DRG and Water NSW • Report in the End of Panel Report • Summarise actions and monitoring in AEMR
	Level 2 • Single pool on a subject Creek is observed as dry in consecutive monitoring events • Two or more pools on a subject Creek are observed as dry in a single monitoring event	• *Actions as stated for Level 1* • Review monitoring frequency • Submit letter report to DPIE, DRG and Water NSW and seek advice on any CMA required • Implement agreed CMAs as approved (subject to agency feedback)

	Level 3 • Fracturing resulting in diversion of flow such that <10% of the pools have water levels lower than baseline period	• *Actions as stated for Level 2* • Offer site visit with BCD, DPIE, DRG, Water NSW • Implement additional monitoring or increase frequency if required • Review relevant TARP and Management Plan in consultation with key agencies • Develop site CMA (subject to agency feedback). This may include: grouting of rockbar and bedrock base of any significant pool where it is appropriate to do so in consultation with BD, DPIE, DRG, Water NSW • Completion of works following approvals and at a time agreed between S32, DPIE, DRG and Water NSW (i.e. may be after mining induced movements and impacts are complete), including monitoring and reporting on success
	Exceeding Prediction • Fracturing resulting in diversion of flow such that >10% of the pools have water levels lower than baseline period	• *Actions as stated for Level 3* • Investigate reasons for the exceedance • Update future predictions based on the outcomes of the investigation • Provide residual environmental offset for any mining impact where CMAs are unsuccessful as required by Condition 14 Schedule 3 of the Development Consent

Monitoring	Trigger	Action
SURFACE WATER FLOW		
Wongawilli Creek and Sandy Creek **Lake Cordeaux and Cordeaux River** **Relevant Performance Measure(s):** • Wongawilli Creek - minor environmental consequences • Sandy Creek - minor environmental consequences • Lake Cordeaux - negligible reduction in the quantity of surface water inflows to Lake Cordeaux[1] • Cordeaux River - negligible reduction in the quantity of surface water inflow to the Cordeaux River at its confluence with Wongawilli Creek[2]	***Level 1*** • A) Lower flow than expected (additional 10-15% of days where Q% lower than Reference Q%) • B) 5-10% increase in cease-to-flow frequency beyond natural) • C) Reduction in Q50 (10-15% beyond natural)	• Continue monitoring program. • Submit an Impact Report to BCD, DPIE, DRG, WaterNSW. • Report in the End of Panel Report. • Summarise actions and monitoring in AEMR.
	Level 2 • A) Lower flow than expected (additional 15-20% of days where Q% lower than Reference Q%). • B) 10-20% increase in cease-to-flow frequency (beyond natural) • C) 15-20% reduction in Q50 (beyond natural) • D) Observation that the subject Creek has ceased to flow at spatially consecutive monitoring sites.	• *Actions as stated for Level 1* • Review monitoring frequency. • D) → carry out Water Flow Assessment Method D. • Submit letter report to DPIE, DRG and WaterNSW and seek advice on any CMA required. • Implement agreed CMAs as approved (subject to agency feedback).
	Level 3	• *Actions as stated for Level 2*

[1] Surface water inflows calculation = [Impacts at gauged catchments (SCL2) + LC5 + estimated impacts at ungauged but undermined catchments] / [total estimated inflow to LC].
[2] Flow reduction as determined from measured at flow gauging station WWL_A.

Surface water flow Reference sites (as in Table 1.1): • Wongawilli Creek - WWU (Wongawilli Creek upstream); • O'Hares Creek at Wedderburn (213200); • (other such sites, if necessary, include Woronora River 2132101 and Bomaderry Creek 215016) NB. This section of the TARP contains four Water Flow Assessment Methods, labelled A, B, C and D, which are specified in detail in Watershed HydroGeo (2019). Hydrological changes are assessed by comparing pre- and post-mining observed flows from impact or assessment sites to flow data from the reference sites. *Natural variability ('NV') will be defined as the 'average' change at the selected reference sites. Triggers may occur when the apparent impact at a site (NV + x% change) could be less than maximum observed variability at one of the reference sites.*	• A) Lower flow than expected (additional >20% of days where Q% lower than Reference Q%) • B) >20% increase in cease-to-flow frequency (beyond natural) • C) >20% reduction in Q50 (beyond natural)	• Offer site visit with BCD, DPIE, DRG, WaterNSW. • Implement additional monitoring or increase frequency if required. • Develop site CMA (subject to agency feedback). This may include: grouting of rockbar and bedrock base of any significant pool where it is appropriate to do so in consultation with BCD, DPIE, DRG, WaterNSW. • Completion of works following approvals and at a time agreed between S32, DPIE, DRG and WaterNSW (i.e. may be after mining induced movements and impacts are complete), including monitoring and reporting on success. • Review relevant TARP and Management Plan in consultation with key agencies.
	Exceeding Prediction Measured surface water flow reduction, based on Assessment Methods C, D, to be compared against predictions made in contemporary groundwater modelling conducted to the satisfaction of the Secretary to assess whether effects that cannot be explained by natural variability "exceed prediction".	• *Actions as stated for Level 3* • Investigate reasons for the exceedance. • Update future predictions based on the outcomes of the investigation. • Provide residual environmental offset for any mining impact where CMAs are unsuccessful as required by Condition 14 Schedule 3 of the Development Consent.
Tributaries of Wongawilli Creek and Sandy Creek and other affected watercourses not subject to performance measures **Surface water flow Reference sites** (as in Table 1.1):	***Level 1*** • A) Lower flow than expected (additional 10-20% of days where Q% lower than Reference Q%) • B) 5-10% increase in cease-to-flow frequency (beyond natural) • C) 10-20% reduction in Q50 (beyond natural)	• Continue monitoring program. • Submit an Impact Report to BCD, DPIE, DRG, WaterNSW. • Report in the End of Panel Report. • Summarise actions and monitoring in AEMR.

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- <u>Wongawilli Creek - WWU</u> (Wongawilli Creek upstream);
- <u>O'Hares Creek and Wedderburn (213200);</u>
- (other such sites, if necessary, include Woronora River 2132101 and Bomaderry Creek 215016)

NB. This section of the TARP contains four Water Flow Assessment Methods, labelled A, B, C and D, which are specified in detail in Watershed HydroGeo (2019).

Hydrological changes are assessed by comparing pre- and post-mining observed flows from impact or assessment sites to flow data from the reference sites.

Natural variability ('NV') will be defined as the 'average' change at the selected reference sites. Triggers may occur when the apparent impact at a site (NV + x% change) could be less than maximum observed variability at one of the reference sites.
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Level 2

- A) Lower flow than expected (additional 20-30% of days where Q% lower than Reference Q%)
- B) 10-20% increase in cease-to-flow frequency (beyond natural)
- C) 20-30% reduction in Q50 (beyond natural)
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- *Actions as stated for Level 1*
- Review monitoring frequency.
- Submit letter report to DPIE, DRG and WaterNSW and seek advice on any CMA required.
- Implement agreed CMAs as approved (subject to agency feedback).
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Level 3

- A) Lower flow than expected (additional >30% of days where Q% lower than Reference Q%)
- B) >20% increase in cease-to-flow frequency (beyond natural)
- C) >30% reduction in Q50 (beyond natural)
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- *Actions as stated for Level 2*
- Offer site visit with BCD, DPIE, DRG, WaterNSW.
- Implement additional monitoring or increase frequency if required
- Develop site CMA (subject to agency feedback). This may include: grouting of rockbar and bedrock base of any significant pool where it is appropriate to do so in consultation with BCD, DPIE, DRG, WaterNSW.
- Completion of works following approvals and at a time agreed between S32, DPIE, DRG and WaterNSW (i.e. may be after mining induced movements and impacts are complete), including monitoring and reporting on success.
- Review relevant TARP and Management Plan in consultation with key agencies.
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AQUATIC ECOLOGY
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Pool water level, interconnectivity between pools and loss of connectivity, noticeable alteration of habitat

- Wongawilli Creek catchment – 8 sites
- Sandy Creek catchment – 2 sites

Relevant Performance Measure(s):

- Wongawilli Creek - minor environmental consequences
- Sandy Creek - minor environmental consequences
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Level 1

- Reduction in aquatic habitat for 1 year
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- Continue monitoring program
- Submit an Impact Report to BCD, DPIE, DRG, Water NSW
- Report in the End of Panel Report
- Summarise actions and monitoring in AEMR
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Level 2

- Reduction in aquatic habitat for 2 years following the active subsidence period
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- *Actions as stated for Level 1*
- Review monitoring frequency
- Submit letter report to DPIE, BCD, DRG and Water NSW and seek advice on any CMA required
- Implement agreed CMAs as approved (subject to agency feedback)
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Level 3

- Reduction in aquatic habitat for >2 years following the active subsidence period
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- *Actions as stated for Level 2*
- Offer site visit with BCD, DPIE, DRG, Water NSW
- Implement additional monitoring or increase frequency if required
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		• Review relevant TARP and Management Plan in consultation with key agencies • Develop site CMA (subject to agency feedback). This may include: grouting of rockbar and bedrock base of any significant pool where it is appropriate to do so in consultation with BCD, DPIE, DRG, Water NSW • Completion of works following approvals and at a time agreed between S32, DPIE, DRG and Water NSW (i.e. may be after mining induced movements and impacts are complete), including monitoring and reporting on success
TERRESTRIAL FAUNA – THREATENED FROG SPECIES		
Pool water level, interconnectivity between pools and loss of connectivity, noticeable alteration of habitat • Wongawilli Creek catchment – 2 sites • Sandy Creek catchment – 5 sites **Relevant Performance Measure(s):** • Wongawilli Creek - minor environmental consequences • Sandy Creek - minor environmental consequences	***Level 1*** • Reduction in habitat for 1 year	• Continue monitoring program • Submit an Impact Report to BCD, DPIE, DRG, Water NSW • Report in the End of Panel Report • Summarise actions and monitoring in AEMR
	Level 2 • Reduction in habitat for 2 years following the active subsidence period	• *Actions as stated for Level 1* • Review monitoring frequency • Submit letter report to DPIE, BCD, DRG and Water NSW and seek advice on any CMA required • Implement agreed CMAs as approved (subject to agency feedback)
	Level 3 • Reduction in habitat for > 2 years following the active subsidence period	• *Actions as stated for Level 2* • Offer site visit with BCD, DPIE, DRG, Water NSW • Implement additional monitoring or increase frequency if required • Review relevant TARP and Management Plan in consultation with key agencies • Develop site CMA (subject to agency feedback). This may include: grouting of rockbar and bedrock base of any significant pool where it is appropriate to do so in consultation with BCD, DPIE, DRG, Water NSW • Completion of works following approvals and at a time agreed between S32, DPIE, DRG and Water NSW (i.e. may be after mining induced movements and impacts are complete), including monitoring and reporting on success

Department of Planning, Industry and Environment (DPIE)

Biodiversity and Conservation Division (BCD) within DPIE

Division of Resources and Geoscience within the Department (DRG) within DPIE

WaterNSW

Appendix B – Dendrobium Long Term Groundwater Monitoring Program

Appendix C – Sandy Creek Waterfall Management Plan