Attachment D – Risk Assessment

South32 - Illawarra Metallurgical Coal

Review of Dendrobium Longwalls 22 and 23 Subsidence Management Plan

Risk Assessment Report

AR3122

Revision 2

Tuesday, 29 June 2021

Assessment and report completed by;
AXYS Consulting Pty Ltd
PO Box 1011, Wilton, 2571
NSW, Australia
+61417281115

1. Revisions

Rev No	Date	Description
1	17 June 2021	Initial Release
2	29 June 2021	Updates following document review by Professor Bruce Hebblewhite

TABLE OF CONTENTS

2. Participants

Name	Position	Relevant Years' Experience
Daniel Pygas	Cardno Principal Aquatic Ecology	14 Years
Will Minchin	Watershed HydroGeo Hydrogeologist	16 Years
Sian Griffiths	Niche Environment and Heritage Senior Ecologist	Years
Dr Stuart Brown	HydroGeo Principal Hydrogeologist	25 Years
James Barbato	Mine Subsidence Engineering Consultants (MSEC) Subsidence Engineer	16 Years
Hugo Kaag	South32 Principal Geologist	26 Years
Cody Brady	South32 Principal Approvals	5 Years

The following participants were not in attendance at the risk assessment held on 3 June though have reviewed this risk assessment report and provided feedback which has been incorporated. Professor Bruce Hebblewhite was engaged by Illawarra Metallurgical Coal (IMC) to provide a peer review of the document. Professor Hebblewhite reviewed Revision 1 of the document. Revision 2 has been updated to incorporate the feedback of the peer review.

Name	Position	Relevant Years' Experience
Prof. Bruce Hebblewhite	B K Hebblewhite Consulting Peer Reviewer	45+ Years

3. Introduction

IMC carried out a risk assessment for the Dendrobium Longwalls 22 and 23 Subsidence Management Plan (SMP) application in accordance with the recommendation from the Independent Expert Panel (Panel) that SMP applications consider the potential implications of mining within a risk assessment context, and in particular any implications for water quantity as a result of faulting, basal shear planes and lineaments.

Upon receiving feedback from the Panel regarding risk assessments undertaken to support recent SMP applications, this risk assessment has incorporated the feedback where appropriate.

The risk assessment identifies the existing controls associated with mining operations at Dendrobium. Several recommendations and actions for further controls have been identified through the risk assessment process.

4. System Description

Dendrobium Mine is an underground coal mine which commenced construction in January 2002 following approval from the Minister of the then Department of Urban Affairs and Planning on 20 November 2001. Longwall mining commenced at Dendrobium in April 2005 with longwalls currently being extracted in Area 3B.

The mine is owned and operated by IMC, a wholly owned subsidiary of South32 Ltd. The mine operates on a continuous basis, 24 hours a day and 7 days a week. The mine operates one longwall production panel and development units.

The Panel Report Part 1 (2019) on specific mining activities at Metropolitan and Dendrobium Mines recommended *that "all applications to extract coal within Special Areas should be supported by independently facilitated and robust risk assessments that conform to ISO 31000 (the international standard for risk management subscribed to Australia)"*. The Panel also recommended that the potential implications for water quantity of faulting, bedding plane shears and lineaments need to be very carefully considered and risk assessed at all mining operations in the Special Areas.

The Department of Planning, Industry and Environment (DPIE) have previously provided correspondence to IMC that the Panel have raised concerns regarding mining operations near or under lineaments in special areas of the catchment of the Southern Coalfield. The Panel stated, "*specific regard to the potential impacts on surface water features, including swamps and waterfalls, of mining near and under lineaments".*

Therefore, this risk assessment has been carried out to identify the existing controls associated with mining operations of Dendrobium's Longwalls 22 and 23 in Special Areas of the catchment and to make recommendations for further controls where appropriate.

The main consideration is for compliance with the Dendrobium mine Development Consent, however safety, business interruption, community concerns, reputational damage and environmental issues have been considered where relevant.

The assessment uses the "Workplace Risk Assessment and Control" (WRAC) format as it provides for a more detailed description of any perceived hazards and their identified controls. It was considered that this assessment type provides for easier reading by non-technical persons.

4.1 Longwalls 22 and 23 - Background

IMC commenced longwall extraction in Dendrobium Area 3B in 2013 with Longwall 9 the first in the series. Longwall 16 is currently being extracted. IMC proposes to extract Longwalls 22 and 23 within the Wongawilli Seam, which are the second and third longwalls in the Area 3C series. The longwall will be extracted towards the main headings (i.e. retreat mining from the west towards the east) with a maximum cutting height of 3.9m. Longwall 22 will be extracted after Longwall 21 in Area 3C with Longwall 23 to follow.

The Study Area (Drawing 1104-02 MSEC2020 [Attachment 6]) has been defined, as a minimum, as the surface area enclosed by the: 35° angle of draw line from the extents of Longwalls 22 and 23; and the predicted incremental 20 mm subsidence contour due to the extraction of the proposed longwall. The natural features located within 600 m of the extent of the longwall mining area have also been included in the assessments, in accordance with Condition 8(d), Schedule 3, of the Development Consent (DA 60-03-2001); and features that are expected to experience either far-field horizontal movements, or valley related effects, and which could be sensitive to these movements. Specialist assessments submitted as part of the Longwall 22 and 23 SMP application should be read in conjunction with this risk assessment.

Natural and built features considered in the risk assessment:

- Wongawilli Creek is located west of Longwalls 22 and 23 and are 345 m and 320 m from the finishing ends of Longwalls 22 and 23, at its closest points. At this distance, the maximum predicted additional vertical subsidence is less than 20 mm, 500 mm upsidence and 80 mm closure. Fracturing could occur along the section of Wongawilli Creek that is located within a distance of approximately 400 m from the proposed longwalls. The rate of Type 3 impacts (i.e. fracturing resulting in surface water flow diversions) for the rockbars located within the Study Area has been assessed as low, i.e. less than 10%.
- Drainage lines are located directly above and adjacent to the proposed longwalls. These drainage lines are first and second-order streams that form tributaries to Lake Cordeaux in the eastern part of the Study Area and to Wongawilli Creek in the western part of the Study Area. The drainage lines could experience the full range of predicted subsidence effects.
- It is expected that fracturing would occur along the sections of the drainage lines that are located directly above the proposed Longwalls 22 and 23. Fracturing can also occur outside the extents of the proposed longwalls at distances up to approximately 400 m. Surface water flow diversions are also likely to occur along the sections of drainage lines that are located directly above and adjacent to the proposed longwalls.
- There are two swamps (Den07 and Den153) that have been identified directly above the proposed longwalls. There are four additional swamps located wholly or partially within the Study Area based on the 35° angle of draw line and a further eight swamps located wholly or partially within the Study Area based on the 600 m boundary. (Drawing 1104-09 MSEC2020 [Attachment 6]).
- The Cordeaux Reservoir is located east of the proposed longwalls. The Full Supply Level is at a distance of 300 m from each of the proposed Longwalls 22 and 23, at the closest points. Minor and isolated fracturing could occur in the bedrock beneath the Cordeaux Reservoir within a distance of approximately 400 m from the proposed mining.
- The Avon Reservoir is located more than 3 km from the proposed longwalls.
- The Cordeaux Dam Wall is located approximately 2.8 km north the proposed Longwall 23 and the Avon Dam Wall is located more than 8 km west of the proposed longwalls. At these distances, the dam walls are not expected to experience measurable differential horizontal movements over their lengths. It is not anticipated that adverse impacts would occur to the dam walls due to the proposed mining.

- Geological features at both inseam and surface levels were considered as part of the risk assessment and are shown on (Drawing 1104-07 MSEC2021 [Attachment 6]).

5. Context Summary

5.1 Strategic Context

IMC is committed to ensuring safety and environmental compliance within its operation. When new equipment or processes are implemented, IMC insist that risk assessment techniques are used to reduce the risks to people, equipment, environment and operations.

5.2 Corporate Context

As IMC is committed to safety and environmental compliance, when a change to systems or new equipment or systems are introduced into the operation, management insist that risk assessment techniques are used to identify and minimising exposure to its people and the operations. IMC is also committed to implementing risk assessment techniques to identify risk when required by external sources.

5.3 Risk Management Context

Due to correspondence received from the DPIE in relation to advice received from the Panel, the management of IMC have conducted a formal risk assessment to address the concerns of mining in the catchment that may be affected by the extraction of Longwalls 22 and 23.

There are a number of considerations during each risk assessment, being personal safety, equipment damage, operational loss, reputation or environmental issues. This assessment specifically addressed the risks associated to legal compliance that may result from the extraction of Longwalls 22 and 23.

6. Objectives and Scope

The objective of this risk assessment was to support the Longwall 22 and 23 SMP application and to address recommendations raised by the Panel. This risk assessment addressed the risks associated to legal compliance that may result from the extraction of Longwalls 22 and 23.

A scoping session was carried out with the assessment team and the following items were agreed to be assessed:

- Cordeaux Reservoir
- Groundwater
- Wongawilli Creek
- Swamps, tributaries to Cordeaux Reservoir and Wongawilli Creek

For each of the items above the following concerns (where relevant) were reviewed and assessed:

- Surface subsidence
- Sub-surface ground movements
- Valley closure and upsidence
- Lineaments
- Faults
- Dykes
- Groundwater drawdown

7. Assumptions and Constraints

The following assumptions and limitations were applied to this risk assessment:

- iPick Document Kiosks and the South32 web site are available and provide access to site documentation
- South32 have a team addressing mining approvals and compliance
- Detailed subsidence predictions and other analysis have been developed to understand the potential impact from Longwalls 22 and 23
- Reliable subsidence measurement is available and used
- A detailed understanding of prior experience from mining under the catchment areas and the effect on those areas in the Southern Coalfield are well documented and understood
- Extensive monitoring will be conducted both electronically and physically to identify any adverse impact to areas prior, during and after mining activities associated with the current extraction application
- IMC have undertaken several risk assessments of this kind to support SMP applications. A number of investigations and technical studies which were “Treatment Options” of previous risk assessment have now been completed. These studies e.g. SRK 2020, provide valuable information understanding of the hazards being assessed. Whilst these investigations are not strict controls in themselves, they are included as they inform the hazard and related controls.

Related and referenced documents include:

- AS NZS ISO 31000-2009: Risk Management - Principles and guidelines
- MDG1010 - Risk Management Handbook for the Mining Industry
- MDG1014 - Guide to Reviewing a Risk Assessment of Mine Equipment and Operations
- *Work Health and Safety Act 2011*
- Work Health and Safety Regulation 2011
- *Work Health and Safety (Mines and Petroleum Sites) Act 2013*
- Work Health and Safety (Mines and Petroleum Sites) Regulation 2014
- Doyle J, 2007. Review of Permeability of Geological Structures in the Dendrobium Area.
- HGEO, 2020. Dendrobium Mine Spatial analysis of mine inflow chemistry, Dendrobium Areas 1, 2 and 3. April 2020. Report D20357.
- HGEO, 2021. Dendrobium Mine Reporting trends in water quality and metal loads in streams. May 2021. Report D21143.
- HGEO, 2020. Dendrobium Mine Spatial analysis of piezometric responses to mining, Dendrobium Area 3A and 3B. December 2020. Report D20373.
- HGEO, 2020. Dendrobium Mine Effects of Longwall 16 extraction on overlying strata and groundwater conditions, Dendrobium Area 3B. November 2020. Report D20374.
- Independent Expert Panel for Mining in the Catchment (IEPMC), 2019, 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
- B K Hebblewhite Consulting, 2020. Dendrobium Mine – Longwalls 14-18 Independent Review – Height of Fracturing (Stage 4). File Name: 2010/01.1. 5 November. November 2020.
- Letter from Department of Planning and Environment titled: Independent Expert Panel for Mining in the Catchment, Advice Regarding Lineaments
  File Name: 20190219_ltr to South32 Re: lineaments.
- Letter form Emeritus Professor Jim Galvin titled Re: IEPMC advice to Department of Planning and Environment Emerging knowledge regarding lineaments. File Name: IEPMC advice to DPE re-emerging knowledge lineaments.
- Mine Subsidence Engineering Consulting, 2021. Subsidence Predictions and Impact Assessments for the Natural and Built Features due to the Extraction of the Proposed Longwall 22 and 23 in Area 3C at Dendrobium Mine. Report No. MSEC1104, Rev A. dated 21 March 2021.
- SCT, 2020. Review of HGEO Report D19341: Investigation Into the Height of Fracturing above extracted longwalls in Area 3, Dendrobium. DEN4968A.
- SRK Consulting, 2020. Geological Structure Comparison Investigation. STH055.
- Tonkin, C., & Timms, W. 2015). Geological Structures and Fault infill in the Southern Coalfields and Implications for Groundwater Flow. Journal of Research Projects Review, 4, 49 - 58.
- Watershed HydroGeo, 2019. Dendrobium Area 3B Discussion of Surface Water Flow TARPs. December 2019.
- Watershed HydroGeo, 2021. Avon Reservoir catchment - catchment and reservoir water balance. January 2021. Report R012i4.

8. Risk Treatment

The group was introduced to the risk assessment process at the commencement of the session by the facilitator. The various steps were explained, and the group reviewed the likelihood, consequence and risk ranking matrix.

The risk ranking was undertaken with consideration to existing controls being in place.

Risk ranking was undertaken by the risk assessment team with consideration to the consequence of an event occurring and the likelihood of that hazard (event) occurring that leads to the level of consequence identified. The consequence ranking may be one of six identified types i.e. Health and Safety, Natural Environment, Community, Reputation, Legal and Financial. The scales for these consequences are shown in Section 13 “Risk Rank Method”.

It is noted that different types of consequences may/will have a different likelihood of occurrence, this equates to a different risk ranking being realised. For example, the ‘Natural Environment’ consequence of an event occurring may be low but with a high likelihood. However, a ‘Legal’ consequence of an event occurring may be high, but with a low likelihood. For any event, the combination of consequence and likelihood which results in the highest risk is documented.

During this assessment the group considered, as far as practicable, all consequences shown in Section 13, however, to reduce the complexity and volume of reporting, only the worst case ‘risk ranking’ for each hazard is documented in the risk assessment. Using this process some consequences that are high may have an overall low ‘risk rank’ because the probability of the event (leading to the consequence level identified) is very low, whereby a consequence may have a high ‘risk rank’ because the probability of the event (leading to the consequence level identified) is higher.

Controls were developed using the following forms:

- Avoidance – avoid the risk by deciding not to proceed with the activity likely to generate the risk (where this is practicable).
- Reduction – reduce the likelihood of the event.
- Reduction – reduce the consequences of the event.
- Accept – accept the risk within the organisation and establish an appropriate plan to manage the consequences of these risk if they are to occur.

The above risk control options were applied by reference to the following control methodologies in a hierarchical sequence.

- Design – to the extent reasonable and practicable ensure that hazards are designed out of the proposal.
- Remove the hazard or substitute a less hazardous proposal.
- Adopt a safer process – alter the process, equipment or work practices.
- Enclose or isolate the hazard – provide barriers or other techniques.
- Establish appropriate administrative procedures. Set up, document and implement new procedures that provide for:
  - Scheduling of the proposal to reduce exposure.
  - Routine maintenance and housekeeping procedures
  - Training on hazards associated with the proposal.
- Mitigate, rehabilitate or provide offsets for impacts from the proposal.

9. Facilitator

Shane Chiddy holds an Associate Diploma in Engineering (Electrical), is an Officer of the Institution of Engineers (Australia) and is a member of the Asset Management Council of Australia (AMC) and the Mining Electrical and Mining Mechanical Engineering Society (MEMMES). He has also completed Contract Law through Macquarie University, G2 and Establish the Risk Management Systems (Mine 7033 - G3) through Queensland University and is certified as a Functional Safety Engineer by TÜV Rheinland for both Safety Instrumented Systems and Machine Safety.

Prior to commencing his consulting career, Shane Chiddy qualified as an electrician and worked underground for 15 years. He then occupied a number of engineering roles within Rio Tinto, including such roles as electrical supervisor, development engineer and senior production engineer. This latest role was responsible for the longwall, underground diesel equipment and conveyors.

Additionally, Shane Chiddy has been trained and accredited by John Moubray in the UK as a certified RCM II practitioner, and has conducted a number of extensive Reliability-centred Maintenance II analyses including underground and surface equipment such as longwalls, continuous miners and conveying systems. He has facilitated RCM II analysis and delivered training in the mining, defence and telecommunications industries.

His consulting experience includes the application of Reliability-centred Maintenance II and extensive risk management and project management assignments.

10. Sub-Systems Considered in the Assessment

Sub-System		STEP IN PROCESS	
1	Review Dendrobium Longwalls 22 and 23 Subsidence Management Plan	A	Cordeaux Reservoir
		B	Groundwater
		C	Wongawilli Creek
		D	Swamps, Tributaries to Cordeaux Reservoir, Wongawilli Creek and Cordeaux River

11. Risk Assessment Methodology

11.1 Qualitative Risk Analysis

This risk assessment has been performed using Qualitative Risk Analysis techniques and has been performed to align with the principles of the Australian Standard AS31000 - Risk Management Principles and Guidelines and the Department of Mineral Resource Guideline MDG1010.

The risk assessment has followed the WRAC (Workplace Risk Assessment and Control) principles as outlined in the guideline.

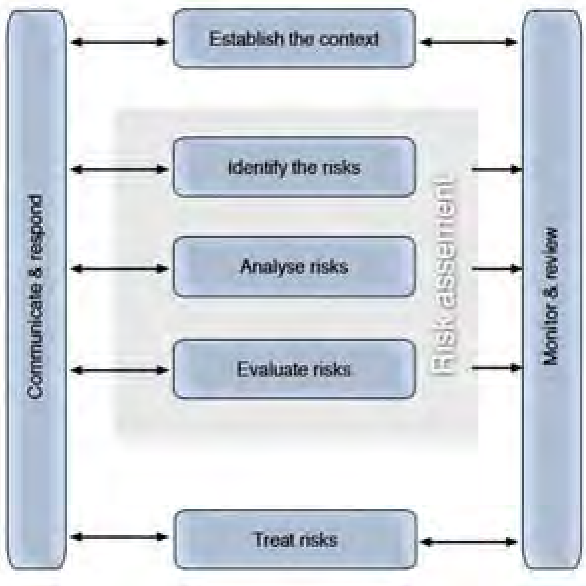
The qualitative approach succeeds by using local expert knowledge and relevant historical data.

This system of analysis uses a participative approach which is very powerful for identifying potential hazard scenarios.

The following steps outline the systematic identification of hazards, ranking of risks, and identification of new and/or improved controls that were used in the risk assessment session:

1. Introduce team to the risk assessment process and the context of the risk assessment. This includes the scope and method of the risk assessment
2. Identify discrete components, or elements, of the Project
3. Identify and add potential deviation steps
4. Review each sub-system and identify loss scenarios - (Potential Incidents and Accidents)
5. For those hazards evaluate the risk using the risk rank method by determining the probability, consequence, and risk rank of each loss scenario
6. Identify existing controls for each hazard
7. Specify additional controls required to control the hazard(s)
8. Close the risk assessment
9. Document and distribute to the team for proof reading
10. Undertake verification of the assessment by a nominated person

The available Standards on Risk Management (including MDG1010) define the Risk Management process as that shown below.



11.2 Establish the Context

This risk analysis has been performed using Qualitative Risk Analysis techniques and is performed in compliance with the Department of Mineral Resources (now the Resources Regulator) Guideline MDG1010.

11.3 Identify Hazards

This step involves identification of all the hazards to be managed. To correctly apply this step a well-structured systematic process must be used, because controls may not be able to be implemented to reduce or eliminate any hazards missed at this point in the analysis.

For each hazard, the team identifies:

1. What Can Happen; and
2. How and Why it Can Happen

Checklists, Flowcharts and Brainstorming are used to identify hazards.

11.4 Analyse Risks

The main objectives of an analysis is to separate minor risks from major risks and to provide data to assist in the evaluation and treatment of hazards.

Risk Analysis involves considering the following:

1. Likelihood of the hazard occurring (identified as 'L' within the worksheets)
2. Consequences if the hazard does occur (identified as 'C' in the worksheets)
3. Determining any existing controls

The combination of the likelihood and the consequence determines the level of the risk involved. The likelihood and consequence categories used are outlined in Section 13.

During the assessment the consequences are categorised as either hazards to personnel, the environment or to the site operations. Reputation, legal compliance and community are also considered where appropriate.

The consequence category is identified on the Analysis Worksheets in the Column labelled 'T' for Type.

11.5 Evaluate Risks

Evaluation involves comparing the level of risk found during the analysis with previously established risk criteria. The output of this part of the process is a list of prioritised hazards for further action.

If the resulting hazards fall into the low or tolerable risk categories, they may be accepted with minimal further treatment. Although, low and tolerable hazards should be monitored and periodically reviewed to ensure that they remain tolerable.

If hazards do not fall into the low or tolerable risk category, then they should be treated using other options.

11.6 Treat Risks

Risk treatment involves identifying the range of options for treating risks, assessing the options and preparing risk treatment plans and implementing them.

Risk treatment may be in one of the following forms:

1. Risk avoidance. Decide not to proceed with the activity
2. Reduce likelihood. Reduce the chance of the risk occurring
3. Reduce the risk consequences. Reduce the consequence if the risk occurs
4. Retain (or accept) the risk. Plans should be put in place to mitigate the consequences of these risks in the event that they occur

Risk treatment options are assessed on the extent of any additional benefits or opportunities created. A number of options may be considered and applied either individually or in a combination.

Risk treatment plans are developed to identify responsibilities, schedules, budgets and performance measures and the review process that is to be established.

11.7 Monitor and Review

It is essential to monitor the effectiveness of the risk management system and the risk treatment implementation.

Risks and the effectiveness of control measures need to be monitored to ensure that the changing environments do not alter risk priorities. Few risks remain static.

Factors affecting likelihood and/or consequence change as do factors regarding suitability of controls.

11.8 Communications and Consultation

Communication and consultation are important during the entire risk management process. It is important to develop a communication plan for both internal and external stakeholders.

This should be a two-way consultation not a one-way flow of information.

Effectiveness of internal and external communications is important to ensure that those responsible for implementing risk management understand the basis on which all decisions have been made, and why particular actions are required.

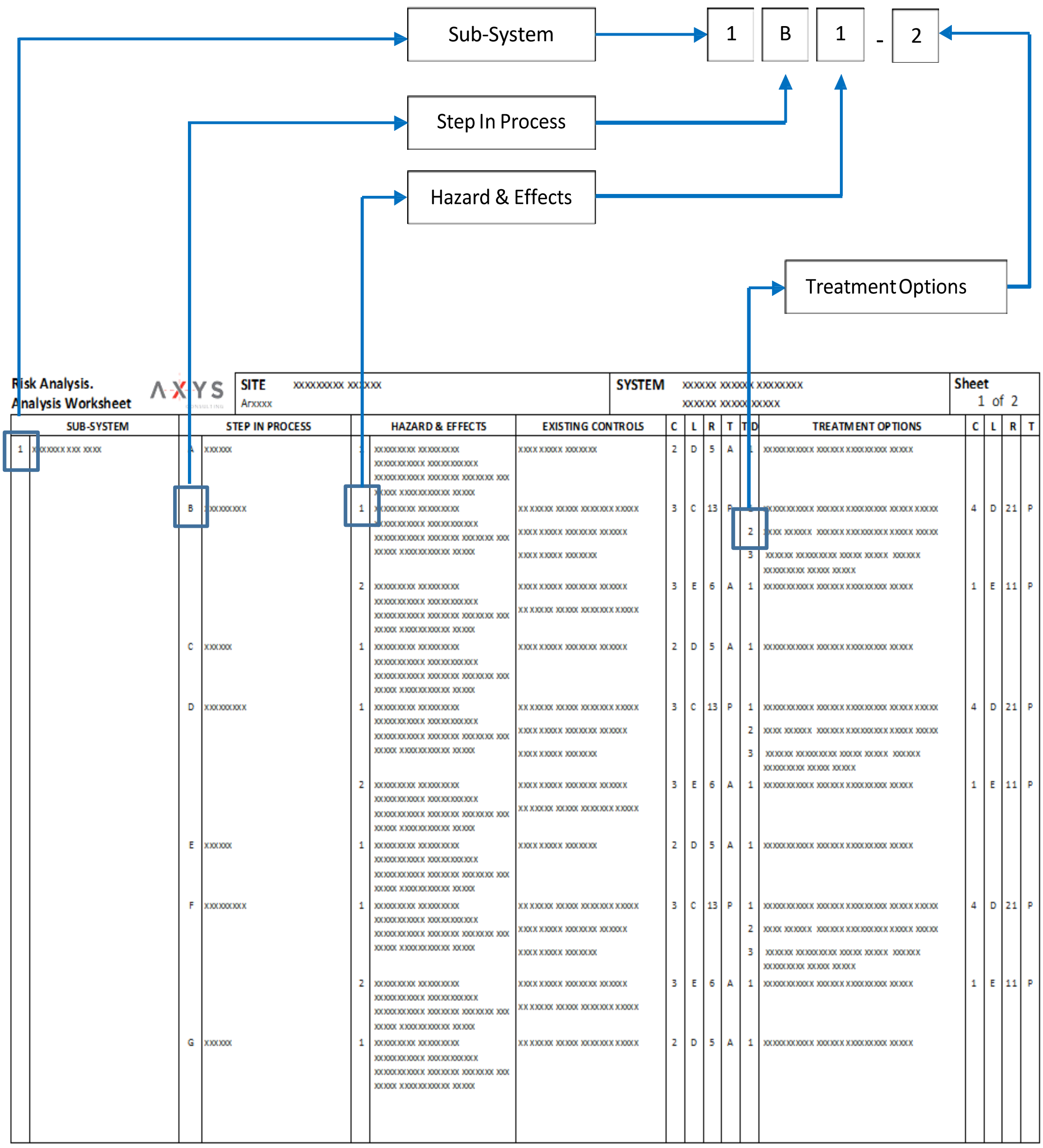
12. Risk Assessment Numbering

The assessment uses an alphanumeric numbering system to differentiate each component, the step in the process, the hazard and the treatment options.

The sub system number is found in the first column of the worksheets, the step is identified as a letter and is found in the third column, the hazard number in the fifth column and the treatment options in the TID (Treatment ID) column.

Using this method each hazard and treatment option throughout the analysis has a distinct identifier. This identifier then flows through all of the worksheets and can be referenced back to the Analysis Worksheets.

The example below shows the distinct identifier for the hazard is 1B1, the treatment option identified below would be identified as 1B1-2.



13. Risk Rank Method

For each event, the Likelihood and Consequence is determined and selected. If an event affects more than one area of consequence (e.g. affects people and operations), the highest rank number is always selected.

Risk Matrix								
Likelihood		**Consequence**						
		Low 1	**Minor 3**	**Moderate 10**	**Significant 30**	**Major 100**	**Catastrophic 300**	
10 Almost Certain	Could be expected to occur more than once during the study or project. Could occur once per year.	10	30	100	300	1000	3000	
3 Likely	Could easily be incurred and has generally occurred in similar studies or projects Could be incurred 1 - 2 Years	3	9	30	90	300	900	
1 Possible	Incurred in a minority of similar studies or projects. Could be incurred within a 5-year strategic budget period	1	3	10	30	100	300	
0.3 Unlikely	Known to happen, but only rarely. Could be incurred within a 5 -20-year time frame	0.3	0.9	3	9	30	90	
0.1 Rare	Has not occurred in similar studies or projects, but could Could be incurred 20 – 50 years	0.1	0.3	1	3	10	30	
0,03 Very Rare	Conceivable, but only in extreme circumstances. Has not happened in industry in the last 50 years	0.03	0.09	0.3	0.9	3	9	

Area of Effect	Estimated Level of Consequence					
	1	3	10	30	100	300
Harm to People (P)	Low level short term subjective symptoms or inconvenience. No medical treatment	Objective but reversible impairment. Medical treatment injury or illness	Permanent impairment <30% of body to one or more persons	Single fatality. Permanent impairment >30% of body to one or more persons	2-20 fatalities Permanent impairment >3-% of body more than 10 persons	>20 fatalities. Permanent impairment >30% of body to more than 100 persons
Environmental (E)	Low level impact to land, biodiversity, ecosystem services, water resources or air	Minor Impacts (<3 months) to land, biodiversity, ecosystem services, water resources or air	Moderate impacts. (<1 year) to land, biodiversity, ecosystem services, water resources or air	Major impacts (<5 years) to land, biodiversity, ecosystem services, water resources or air	Serious or extensive impacts (<20 years) to land, biodiversity, ecosystem services, water resources or air	Severe impacts (>20 years) to land, biodiversity, ecosystem services, water resources or air
Community (C)	Single low-level community health, safety or security impact, low level inconvenience <2 weeks, minor, low level disturbance to a single house or structure.	Minor community health, safety or security impacts (<10 households) or human rights infringements, inconvenience to livelihoods <6 months, moderate damage to <50 houses or community infrastructure	Moderate community health, safety or security impacts (<50 households). Single allegation of human rights violations, moderate disruption to people's lives (<50 households)	Serious community health, safety or security impacts (<50 households). Multiple allegations of human rights violations, extended disruption to people's lives (>50 households)	Serious community health, safety or security impacts (>50 households) or human rights violation, extended disruption to people's lives (>200 households)	Extensive community health, safety or security impacts (>200 households) or human rights violations, extended serious disruption to people's lives (>1000 households)
Reputation (R)	Public concern restricted to local complaints. Low level interest from local media and/or regulator	Adverse local public or media attention and complaints. Heightened scrutiny from regulator. Asset reputation is adversely affected with a small number of people	Attention from regional media and/or heightened concern by local community. Criticism by community, NGOs or activists. Asset reputation adversely affected.	Adverse national media attention. General public and NGO adverse reaction with interest from regulators with no material outcome. Structured campaigning from employees.	Serious national and international negative media attention. General public and NGO adverse reaction with interest from regulators (<3 months). Structured campaigning from employees.	Crisis event or publication of confidential material information resulting in international media, government, regulator, NGO campaigning and employee condemnation of the company (<6 months)
Legal (L)	Low level legal issue	Minor legal issues and non- compliance with commitments	Breach of regulation. Lack of valid exploration title	Significant civil litigation	Prosecutions for criminal breaches resulting in gaol terms for employees or agents or defendant to major civil litigation	Lack of valid operating title, forced closure of an operation, competition, anti-corruption, international trade law or tax breach
Financial (F)	<US$500,000	US$5,000,000 to >US$500,000	US$25,000,000 to >US$5,000,000	US$100,000,000 to >US$25,000,000	US$250,000,000 to >US$100,000,000	>$250,000,000

Attachment 1

Analysis Worksheets

Risk Analysis. Analysis Worksheet	SITE South32 - Illawarra Metallurgical Coal AR3122	SYSTEM Dendrobium Longwall 22 and 23 Subsidence Management Plan	Sheet Page 19

SUB-SYSTEM		STEP IN PROCESS		HAZARD & EFFECTS		EXISTING CONTROLS	C	L	R	T	TID	TREATMENT OPTIONS	C	L	R	T
1	Review Dendrobium Longwalls 22 and 23 Subsidence Management Plan	A	Cordeaux Reservoir	1	Surface subsidence and sub-surface ground movements results in impacts in excess of Development Consent (no more than negligible impacts as defined by the regional groundwater model) and/or Dams Safety NSW conditions (policy of no more than 1ML per day cumulative leakage from Cordeaux Reservoir) in addition to Groundwater Licences, Aquifer Interference Policy and minimal harm criteria	Groundwater Licence with sufficient groundwater Groundwater and surface water monitoring (piezometers, mine water balance and water chemistry) data are analysed in independent studies, results inform surface and groundwater models and analysis. These models are used to ensure compliance with approval conditions and to demonstrate compliance. Longwall panels are set back a minimum of 300 metres from Cordeaux Reservoir full supply level Mine design limiting extraction height to 3.9 metres Height of Fracturing Investigation (HGEO 2020 and Hebblewhite Report 2010/01.1) Discussion paper on "Catchment Water Budget and Processes" completed (Watershed Hydrogeo Report R012i4 - 2021)	10	0.3	3	L	1	Continue to periodically review and constrain the model using new field data (e.g. permeability data, defect logging) and calibrate the groundwater model against monitoring results including peer review at appropriate intervals				

	SUB-SYSTEM		STEP IN PROCESS		HAZARD & EFFECTS	EXISTING CONTROLS	C	L	R	T	TID	TREATMENT OPTIONS	C	L	R	T
1	Review Dendrobium Longwalls 22 and 23 Subsidence Management Plan	A	Cordeaux Reservoir	2	Lineaments concentrate subsidence or groundwater in excess of Development Consent (no more than negligible impacts as defined by the regional groundwater model) and/or Dams Safety NSW conditions (policy of no more than 1ML per day cumulative leakage from Avon Reservoir) in addition to Groundwater Licences, Aquifer Interference Policy and minimal harm criteria	Lineaments are mapped and recorded Lineaments are assessed for correlation with known geological conditions Surface mapping around lineaments to understand if there is an associated geological feature Drilling from both surface and underground targeting known and inferred geology completed The IEP Part 1 Report has been reviewed with the key recommendations of Section 3.6 [Recommendation 1] implemented to determine mine design constraints to achieve compliance with consent conditions Groundwater licence with sufficient groundwater Ground and surface water monitoring (e.g. piezometers, mine water balance and water chemistry) data are analysed in independent studies, results inform surface and groundwater models and analysis. These models are used to ensure compliance with approval conditions and to demonstrate compliance. Mine design limiting extraction height to 3.9 metres Measured subsidence has been reviewed in locations of mapped lineaments and other geological structures (MSEC Report MSEC1034 - 2019 and SRK Report STH055 - 2020) No correlation has been found between mine inflow chemistry and lineaments (HGEO Report D20357 2020)	10	0.3	3	L	1	Continue to periodically review and calibrate the groundwater model against monitoring results including peer review at appropriate intervals				
											2	In the event that an anomalous, unmapped geological structure is encountered: 1. Assess the significance of the structure to increase understanding 2. If necessary, conduct surveys and testing e.g. radio imaging method, seismic, inseam and/or surface drilling 3. If the structure is deemed significant, revise mine plan accordingly to avoid/manage the geological structure				

SUB-SYSTEM	STEP IN PROCESS	HAZARD & EFFECTS	EXISTING CONTROLS	C	L	R	T	TID	TREATMENT OPTIONS	C	L	R	T
			No correlation has been found between groundwater drawdown (piezometric response) and lineaments (HGEO Report D20373 - 2020) Groundwater models are informed by recent and ongoing investigations into changes to permeability around other parts of Dendrobium Mine to assess possible interaction with the reservoir. Mine headings in Dendrobium Area 3A mined through a dyke under Cordeaux Reservoir which does not produce groundwater. This informs groundwater assessments and mine design. Mine headings in Corrimal Mains mined through multiple dykes near to Longwalls 22 and 21 none of which produced significant water										

Risk Analysis. Analysis Worksheet	SITE South32 - Illawarra Metallurgical Coal AR3122	SYSTEM Dendrobium Longwall 22 and 23 Subsidence Management Plan	Sheet Page 22

SUB-SYSTEM		STEP IN PROCESS		HAZARD & EFFECTS		EXISTING CONTROLS	C	L	R	T	TID	TREATMENT OPTIONS	C	L	R	T
1	Review Dendrobium Longwalls 22 and 23 Subsidence Management Plan	A	Cordeaux Reservoir	3	Unnamed faults and dykes result in impacts in excess of Development Consent (no more than negligible impacts as defined by the regional groundwater model) and/or Dams Safety NSW conditions (policy of no more than 1ML per day cumulative leakage from Cordeaux Reservoir) in addition to Groundwater Licences, Aquifer Interference Policy and minimal harm criteria	Faults and dykes are mapped and recorded Surface geological mapping around faults and dykes Drilling from both surface and underground targeting known and inferred geology completed Extensive exploration program undertaken to identify location of faults and dykes Review of Permeability of Geological Structures in the Dendrobium Area J DOYLE 2007 Tonkin, C., & Timms, W. (2015). Geological Structures and Fault-infill in the Southern Coalfields and Implications for Groundwater Flow. Journal of Research Projects Review, 4, 49-58 No correlation has been found between mine inflow chemistry and lineaments (HGEO Report D20357 2020) No correlation has been found between groundwater drawdown (piezometric response) and lineaments (HGEO Report D20373 - 2020)	10	0.3	3	L	1 2 3	Review geological features relevant to Longwalls 22 and 23 to determine if further investigatory actions such as inseam and or surface drilling are required Continue to periodically review and calibrate the groundwater model against monitoring results including peer review at appropriate intervals In the event that an anomalous, unmapped geological structure is encountered: 1. Assess the significance of the structure to increase understanding 2. If necessary, conduct surveys and testing e.g. radio imaging method, seismic, inseam and/or surface drilling 3. If the structure is deemed significant, revise mine plan accordingly to avoid/manage the geological structure				

Risk Analysis. Analysis Worksheet	SITE South32 - Illawarra Metallurgical Coal AR3122	SYSTEM Dendrobium Longwall 22 and 23 Subsidence Management Plan	Sheet Page 23

SUB-SYSTEM		STEP IN PROCESS		HAZARD & EFFECTS		EXISTING CONTROLS	C	L	R	T	TID	TREATMENT OPTIONS	C	L	R	T
1	Review Dendrobium Longwalls 22 and 23 Subsidence Management Plan	A	Cordeaux Reservoir	4	Shear planes (including basal shear planes) transmits groundwater in excess of Development Consent Conditions (no more than negligible impacts as defined by the regional groundwater model) and/or Dams Safety NSW conditions (policy of no more than 1ML per day cumulative leakage from Cordeaux Reservoir) in addition to Groundwater Licence, Aquifer Interference Policy and minimal harm criteria.	Shear planes (including basal shear planes) have been extensively drilled and characterised (including extent, depth and permeability) (SCT Reports 2015-2019) Mining is planned to avoid the Cordeaux Reservoir Full Supply Level (FSL) by a minimum of 300 metres Extensive geological and hydrogeological testing of surface boreholes through the basal shear horizons including lithology, defect logging, geophysical logging, Lugeon testing and geotechnical analysis The IEP Part 1 Report has been reviewed with the key recommendations of Section 3.6 [Recommendation 1] implemented to determine mine design constraints to achieve compliance with consent conditions Groundwater licence with sufficient groundwater Ground and surface water monitoring (e.g. piezometers, mine water balance and water chemistry) data are analysed in independent studies, results inform surface and groundwater models and analysis. These models are used to ensure compliance with approval conditions and to demonstrate compliance. Groundwater modelling indicates that the maximum of 1 ML per day additional seepage from Dams Safety NSW is not likely to be exceeded	10	0.3	3	L	1 2	Continue to periodically review and calibrate the groundwater model against monitoring results including peer review at appropriate intervals In the event that a shear plane is encountered that transmits an anomalous amount groundwater, investigations to understand the change in horizontal permeability due to mining will take place				

SUB-SYSTEM		STEP IN PROCESS		HAZARD & EFFECTS		EXISTING CONTROLS	C	L	R	T	TID	TREATMENT OPTIONS	C	L	R	T
1		B	Groundwater	1	Surface subsidence and sub-surface ground movements results in impacts excess of Development Consent (no more than negligible impacts as defined by the regional groundwater model) and/or Dams Safety NSW conditions (policy of no more than 1ML per day cumulative leakage from Cordeaux Reservoir) in addition to Groundwater Licence, Aquifer Interference Policy and minimal harm criteria.	Reviews undertaken on basal shear adjacent to Area 3B. Shear planes below the surface showed no significant change in strata permeability (ref. SCT DEN5035, HGEO D20370). Discussion paper on "Catchment Water Budget and Processes" completed (Watershed Hydrogeo Report R012i4 - 2021) Groundwater Licence with sufficient Groundwater allocation Ground and surface water monitoring (piezometers, mine water balance and water chemistry) data are analysed in independent studies, results inform surface and groundwater models and analysis. These models are used to ensure compliance with approval conditions and to demonstrate compliance Mine design limiting extraction height to 3.9 metres Height of Fracturing Investigation (HGEO 2020 and Hebblewhite Report 2010/01.1)	10	0.3	3	L	1	Continue to periodically review and calibrate the groundwater model against monitoring results including peer review at appropriate intervals				

Risk Analysis.
Analysis Worksheet

SITE South32 - Illawarra Metallurgical Coal
AR3122

SYSTEM Dendrobium Longwall 22 and 23 Subsidence Management Plan

Sheet

SUB-SYSTEM		STEP IN PROCESS		HAZARD & EFFECTS		EXISTING CONTROLS	C	L	R	T	TID	TREATMENT OPTIONS	C	L	R	T
1	Review Dendrobium Longwalls 22 and 23 Subsidence Management Plan	B	Groundwater	2	Lineaments concentrate subsidence or groundwater impacts in excess of development consent conditions (and Groundwater Licence, Aquifer Interference policy, minimal harm criteria).	Lineaments are mapped and recorded Lineaments are assessed for correlation with known geological conditions Surface mapping around lineaments to understand if there is an associated geological feature Drilling from both surface and underground targeting known and inferred geology completed The IEP Part 1 Report has been reviewed with the key recommendations of Section 3.6 [Recommendation 1] implemented to determine mine design constraints to achieve compliance with consent conditions Groundwater licence with sufficient groundwater Ground and surface water monitoring (e.g. piezometers, mine water balance and water chemistry) data are analysed in independent studies, results inform surface and groundwater models and analysis. These models are used to ensure compliance with approval conditions and to demonstrate compliance. Mine design limiting extraction height to 3.9 metres Measured subsidence has been reviewed in locations of mapped lineaments and other geological structures (MSEC Report MSEC1034 - 2019 and SRK Report STH055 - 2020) No correlation has been found between mine inflow chemistry and lineaments (HGEO Report D20357 2020)	10	0.3	3	L	1 2 3	Review Reporting of Geological Features relevant to Longwalls 22 & 23 to determine if further investigatory actions such as inseam and or surface drilling are required to define geological features Continue to periodically review and calibrate the groundwater model against monitoring results including peer review at appropriate intervals In the event that an anomalous, unmapped geological structure is encountered: 1. Assess the significance of the structure to increase understanding 2. If necessary, conduct surveys and testing e.g. radio imaging method, seismic, inseam and/or surface drilling 3. If the structure is deemed significant, revise mine plan accordingly to avoid/manage the geological structure				

Risk Analysis. Analysis Worksheet	SITE South32 - Illawarra Metallurgical Coal AR3122	SYSTEM Dendrobium Longwall 22 and 23 Subsidence Management Plan	Sheet Page 26

SUB-SYSTEM		STEP IN PROCESS		HAZARD & EFFECTS		EXISTING CONTROLS	C	L	R	T	TID	TREATMENT OPTIONS	C	L	R	T
1		B		3	Unnamed faults and dykes result in impacts in excess of development consent conditions (and Groundwater Licence, Aquifer Interference Policy and associated minimal harm criteria) on groundwater quantity	No correlation has been found between groundwater drawdown (piezometric response) and lineaments (HGEO Report D20373 - 2020) Faults and dykes are mapped and recorded Surface geological mapping around faults and dykes Drilling from both surface and underground targeting known and inferred geology completed Extensive exploration program undertaken to identify location of faults and dykes Review of Permeability of Geological Structures in the Dendrobium Area J DOYLE 2007 Tonkin, C., & Timms, W. (2015). Geological Structures and Fault-infill in the Southern Coalfields and Implications for Groundwater Flow. Journal of Research Projects Review, 4, 49 - 58. No correlation has been found between groundwater drawdown (piezometric response) and lineaments (HGEO Report D20373 - 2020) No correlation has been found between mine inflow chemistry and lineaments (HGEO Report D20357 2020)	10	0.3	3	L	1 2	Continue to periodically review and calibrate the groundwater model against monitoring results including peer review at appropriate intervals In the event that an anomalous, unmapped geological structure is encountered: 1. Assess the significance of the structure to increase understanding 2. If necessary, conduct surveys and testing e.g. radio imaging method, seismic, inseam and/or surface drilling 3. If the structure is deemed significant, revise mine plan accordingly to avoid/manage the geological structure				

Risk Analysis. Analysis Worksheet	SITE South32 - Illawarra Metallurgical Coal AR3122	SYSTEM Dendrobium Longwall 22 and 23 Subsidence Management Plan	Sheet Page 27

SUB-SYSTEM		STEP IN PROCESS		HAZARD & EFFECTS		EXISTING CONTROLS	C	L	R	T	TID	TREATMENT OPTIONS	C	L	R	T
1	Review Dendrobium Longwalls 22 and 23 Subsidence Management Plan	B	Groundwater	4	Shear planes (including basal shear planes) transmits groundwater in excess of Development Consent Conditions (no more than negligible impacts as defined by the regional groundwater model) and/or Dams Safety NSW conditions (policy of no more than 1ML per day cumulative leakage from Cordeaux Reservoir) in addition to Groundwater Licence, Aquifer Interference Policy and minimal harm criteria.	Shear planes (including basal shear planes) have been extensively drilled and characterised (including extent, depth and permeability) (SCT Reports 2015-2019) Mining is planned to avoid the Cordeaux Reservoir FSL by a minimum of 300 metres Extensive geological and hydrogeological testing of surface boreholes through the basal shear horizons including lithology, defect logging, geophysical logging, Lugeon testing and geotechnical analysis Standing water levels in boreholes that intersect basal shear planes provide an indication of hydraulic gradient towards the mine, which is a key input to the local model used to calculate inflow rates The IEP Part 1 Report has been reviewed with the key recommendations of Section 3.6 [Recommendation 1] implemented to determine mine design constraints to achieve compliance with consent conditions Groundwater licence with sufficient groundwater Ground and surface water monitoring (e.g. piezometers, mine water balance and water chemistry) data are analysed in independent studies, results inform surface and groundwater models and analysis. These models are used to ensure compliance with approval conditions and to demonstrate compliance.	10	0.3	3	L	1 2	Continue to periodically review and calibrate the groundwater model against monitoring results including peer review at appropriate intervals In the event that a shear plane is encountered that transmits an anomalous amount groundwater, investigations to understand the change in horizontal permeability due to mining will take place				

	SUB-SYSTEM		STEP IN PROCESS		HAZARD & EFFECTS	EXISTING CONTROLS	C	L	R	T	TID	TREATMENT OPTIONS	C	L	R	T
1	Review Dendrobium Longwalls 22 and 23 Subsidence Management Plan	C	Wongawilli Creek	1	Valley closure results in impacts in excess of development consent conditions for Wongawilli Creek (including no more than minor environmental consequences)	Longwall panels setback from Wongawilli Creek considering cumulative movements from Areas 3A, 3B and 3C Calibrated subsidence model is used to assess longwall setback options from Wongawilli Creek to achieve performance measures. Subsidence monitoring data is analysed and interrogated against predictions to verify modelling. Ground and surface water monitoring (surface water gauging, piezometers, mine water balance and water chemistry) data are analysed in independent studies, results inform surface and groundwater models. These models are used to design mining parameters to ensure compliance with approval conditions and to demonstrate compliance. Environmental monitoring including visual inspections and aquatic ecology monitoring Experience with mining next to Wongawilli Creek for Longwall Area 3A and 3B. Impact levels from these activities influence setbacks. Impacts to date have been in-line with modelling Subsidence Management Plan - including End of Panel reporting and auditing against Performance Measures Revised WIMMCP including surface water flow TARPS for Wongawilli Creek (Watershed Hydrogeo 2019) (IMC 2020)	10	0.1	1	F	1	Submit the Subsidence Management Plan for Longwalls 22 and 23				

Risk Analysis. Analysis Worksheet	SITE AR3122	South32 - Illawarra Metallurgical Coal	SYSTEM	Dendrobium Longwall 22 and 23 Subsidence Management Plan	Sheet Page 29

SUB-SYSTEM		STEP IN PROCESS		HAZARD & EFFECTS		EXISTING CONTROLS	C	L	R	T	TID	TREATMENT OPTIONS	C	L	R	T
1	Review Dendrobium Longwalls 22 and 23 Subsidence Management Plan	C	Wongawilli Creek	2	Lineaments, faults, dykes and intrusions result in impacts in excess of development consent conditions for Wongawilli Creek (including no more than minor environmental consequences)	Lineaments are mapped and recorded Lineaments are assessed for correlation with known geological conditions Surface mapping around lineaments to understand if there is a geological feature associated Targeted exploration drilling from both surface and underground Subsidence Management Plan - including end of panel reporting and auditing against Performance Measures Review of Permeability of Geological Structures in the Dendrobium Area J DOYLE 2007	10	1	10	F	1	In the event that an anomalous, unmapped geological structure is encountered: 1. Assess the significance of the structure to increase understanding 2. If necessary, conduct surveys and testing e.g. radio imaging method, seismic, inseam and/or surface drilling 3. If the structure is deemed significant, revise mine plan accordingly to avoid/manage the geological structure				

SUB-SYSTEM		STEP IN PROCESS		HAZARD & EFFECTS		EXISTING CONTROLS	C	L	R	T	TID	TREATMENT OPTIONS	C	L	R	T
1	Review Dendrobium Longwalls 22 and 23 Subsidence Management Plan	C	Wongawilli Creek	3	Groundwater drawdown results in impacts in excess of development consent conditions for Wongawilli Creek (including no more than minor environmental consequences)	Longwall panels setback from Wongawilli Creek considering cumulative movements from Areas 3A, 3B and 3C Revised WIMMCP including surface water flow TARPS for Wongawilli Creek (Watershed Hydrogeo 2019) (IMC 2020) Subsidence Management Plan - including end of panel reporting and auditing against Performance Measures Ground and surface water monitoring (e.g. piezometers, mine water balance and water chemistry) data are analysed in independent studies, results inform surface and groundwater models and analysis. These models are used to ensure compliance with approval conditions and to demonstrate compliance. An inclined groundwater monitoring boreholes was established between Longwall 22 and Wongawilli Creek to monitor groundwater depressurisation	10	1	10	F	1	Nil Required				

Risk Analysis. Analysis Worksheet	SITE South32 - Illawarra Metallurgical Coal AR3122	SYSTEM Dendrobium Longwall 22 and 23 Subsidence Management Plan	Sheet Page 31

	SUB-SYSTEM		STEP IN PROCESS		HAZARD & EFFECTS	EXISTING CONTROLS	C	L	R	T	TID	TREATMENT OPTIONS	C	L	R	T
1	Review Dendrobium Longwalls 22 and 23 Subsidence Management Plan	D	Swamps, Tributaries to Cordeaux Reservoir, Wongawilli Creek and Cordeaux River	1	Surface subsidence, sub-surface movements or valley closure result in impacts to Swamps, Tributaries to Wongawilli Creek, Cordeaux Reservoir and Cordeaux River in excess of development consent conditions	Subsidence monitoring data are analysed and interrogated against predictions to verify modelling Ground and surface water monitoring (e.g. piezometers, mine water balance and water chemistry) data are analysed in independent studies, results inform surface and groundwater models. The analysis is used to assess impacts and demonstrate compliance Subsidence Management Plan - including end of panel reporting and auditing against Performance Measures Environmental monitoring including terrestrial and aquatic ecology monitoring programs - (e.g. LiDAR or other methods for the mapping of swamp boundaries, floristic monitoring of swamps) Research programs e.g. Littlejohns Tree Frog, Giant Dragon Fly and Swamp Research Plans Maddens Plains biodiversity offset	10	0.3	3	L	1	Submit the Subsidence Management Plan for Longwalls 22 and 23				

SUB-SYSTEM		STEP IN PROCESS		HAZARD & EFFECTS		EXISTING CONTROLS	C	L	R	T	TID	TREATMENT OPTIONS	C	L	R	T
1	Review Dendrobium Longwalls 22 and 23 Subsidence Management Plan	D	Swamps, Tributaries to Cordeaux Reservoir, Wongawilli Creek and Cordeaux River	2	Lineaments, faults and dykes result in impacts in excess of development consent conditions for Swamps, Tributaries to Wongawilli Creek, Cordeaux Reservoir and Cordeaux River	Lineaments are mapped and recorded Lineaments are assessed for correlation with know geological conditions Surface mapping around lineaments to understand if there is an associated geological feature Targeted exploration drilling from both surface and underground Ground and surface water monitoring (e.g. piezometers, mine water balance and water chemistry) data are analysed in independent studies, results inform surface and groundwater models. The analysis is used to assess impacts and demonstrate compliance Mine design avoids major geological structures Subsidence Management Plan - including end of panel reporting and auditing against Performance Measures Environmental monitoring including terrestrial and aquatic ecology monitoring programs - (e.g. LiDAR or other methods for the mapping of swamp boundaries, floristic monitoring of swamps) Subsidence monitoring - (closure lines, vertical subsidence, 3D far-field, ALS, visual inspection) data are analysed in independent studies, results inform the calibrated subsidence model and mine planning decisions	10	0.3	3	L	1	In the event that an anomalous, unmapped geological structure is encountered: 1. Assess the significance of the structure to increase understanding 2. If necessary, conduct surveys and testing e.g. radio imaging method, seismic, inseam and/or surface drilling 3. If the structure is deemed significant, revise mine plan accordingly to avoid/manage the geological structure				

SUB-SYSTEM	STEP IN PROCESS	HAZARD & EFFECTS	EXISTING CONTROLS	C	L	R	T	TID	TREATMENT OPTIONS	C	L	R	T
			Investigation completed comparing the impacts on lineaments from mining in the Western Coalfield (Springvale) and the Southern Coalfield. Outcomes of this investigation informed lineament consideration in mine planning Research programs e.g. Littlejohns Tree Frog, Giant Dragon Fly and Swamp Research Plans Maddens Plains biodiversity offset Development of methodology for assessment of water quality trends and solute loads (ref. HGEO D21143) WatershedHG, 2019 (report R08i5) which determined groundwater impacts are observed in swamps at a distance of ~60m from longwalls										

	SUB-SYSTEM		STEP IN PROCESS		HAZARD & EFFECTS	EXISTING CONTROLS	C	L	R	T	TID	TREATMENT OPTIONS	C	L	R	T
1	Review Dendrobium Longwalls 22 and 23 Subsidence Management Plan	D	Swamps, Tributaries to Cordeaux Reservoir, Wongawilli Creek and Cordeaux River	3	Cumulative impacts, including the impacts of cracking of first and second order watercourses. Leading to effects on aquatic and terrestrial ecology greater than those predicted in the EIS, WIMMCP and SMP (Schedule 2, Condition 2 and Schedule 3, Conditions 4 and 7 of the Development Consent)	Surface water monitoring data are analysed in independent studies, results inform surface data analysis and TARPs. These are used to ensure compliance with approval conditions and to demonstrate compliance. Environmental monitoring including terrestrial and aquatic ecology monitoring programs - (e.g. Littlejohns Tree Frog Monitoring Programme, upland swamps and other aquatic flora and fauna monitoring) Longwall panels setback from Wongawilli Creek considering cumulative movements from Areas 3A, 3B and 3C Existing monitoring at numerous sites on Wongawilli Creek, Cordeaux Reservoir and Cordeaux River and tributaries. Monitoring frequency at these sites would be increased during and after extraction of Longwalls 22 and 23 in line with existing management plans. Development of methodology for assessment of water quality trends and solute loads (ref. HGEO D21143) Research programs e.g. Littlejohns Tree Frog, Giant Dragon Fly and Swamp Research Plans Maddens Plains biodiversity offset	10	1	10	E	1	Continue to consider cumulative impacts to aquatic ecology due to any reductions in availability of habitat in first and second order watercourses.				

Attachment 2

Assessment Worksheets
(Risk Rank Order)

Risk Analysis Risk Order

REF	Risk	HAZARD	TID	TREATMENT OPTIONS
1C2	10	Lineaments, faults, dykes and intrusions result in impacts in excess of development consent conditions for Wongawilli Creek (including no more than minor environmental consequences)	1	In the event that an anomalous, unmapped geological structure is encountered: 1. Assess the significance of the structure to increase understanding 2. If necessary, conduct surveys and testing e.g. radio imaging method, seismic, inseam and/or surface drilling 3. If the structure is deemed significant, revise mine plan accordingly to avoid/manage the geological structure
1C3	10	Groundwater drawdown results in impacts in excess of development consent conditions for Wongawilli Creek (including no more than minor environmental consequences)	1	Nil Required
1D3	10	Cumulative impacts, including the impacts of cracking of first and second order watercourses. Leading to effects on aquatic and terrestrial ecology greater than those predicted in the EIS, WIMMCP and SMP (Schedule 2, Condition 2 and Schedule 3, Conditions 4 and 7 of the Development Consent)	1	Continue to consider cumulative impacts to aquatic ecology due to any reductions in availability of habitat in first and second order watercourses.
1A1	3	Surface subsidence and sub-surface ground movements results in impacts in excess of Development Consent (no more than negligible impacts as defined by the regional groundwater model) and/or Dams Safety NSW conditions (policy of no more than 1ML per day cumulative leakage from Cordeaux Reservoir) in addition to Groundwater Licences, Aquifer Interference Policy and minimal harm criteria	1	Continue to periodically review and constrain the model using new field data (e.g. permeability data, defect logging) and calibrate the groundwater model against monitoring results including peer review at appropriate intervals
1A2	3	Lineaments concentrate subsidence or groundwater in excess of Development Consent (no more than negligible impacts as defined by the regional groundwater model) and/or Dams Safety NSW conditions (policy of no more than 1ML per day cumulative leakage from Avon Reservoir) in addition to Groundwater Licences, Aquifer Interference Policy and minimal harm criteria	1	Continue to periodically review and calibrate the groundwater model against monitoring results including peer review at appropriate intervals
			2	In the event that an anomalous, unmapped geological structure is encountered: 1. Assess the significance of the structure to increase understanding 2. If necessary, conduct surveys and testing e.g. radio imaging method, seismic, inseam and/or surface drilling 3. If the structure is deemed significant, revise mine plan accordingly to avoid/manage the geological structure
1A3	3	Unnamed faults and dykes result in impacts in excess of Development Consent (no more than negligible impacts as defined by the regional groundwater model) and/or Dams Safety NSW conditions (policy of no more than 1ML per day cumulative leakage from Cordeaux Reservoir) in addition to Groundwater Licences, Aquifer Interference Policy and minimal harm criteria	1	Review geological features relevant to Longwalls 22 and 23 to determine if further investigatory actions such as inseam and or surface drilling are required
			2	Continue to periodically review and calibrate the groundwater model against monitoring results including peer review at appropriate intervals
			3	In the event that an anomalous, unmapped geological structure is encountered: 1. Assess the significance of the structure to increase understanding 2. If necessary, conduct surveys and testing e.g. radio imaging method, seismic, inseam and/or surface drilling 3. If the structure is deemed significant, revise mine plan accordingly to avoid/manage the geological structure
1A4	3	Shear planes (including basal shear planes) transmits groundwater in excess of Development Consent Conditions (no more than negligible impacts as defined by the regional groundwater model) and/or Dams Safety NSW conditions (policy of no more than 1ML per day cumulative leakage from Cordeaux Reservoir) in addition to Groundwater Licence, Aquifer Interference Policy and minimal harm criteria.	1	Continue to periodically review and calibrate the groundwater model against monitoring results including peer review at appropriate intervals
			2	In the event that a shear plane is encountered that transmits an anomalous amount groundwater, investigations to understand the change in horizontal permeability due to mining will take place

REF	Risk	HAZARD	TID	TREATMENT OPTIONS
1B1	3	Surface subsidence and sub-surface ground movements results in impacts excess of Development Consent (no more than negligible impacts as defined by the regional groundwater model) and/or Dams Safety NSW conditions (policy of no more than 1ML per day cumulative leakage from Cordeaux Reservoir) in addition to Groundwater Licence, Aquifer Interference Policy and minimal harm criteria.	1	Continue to periodically review and calibrate the groundwater model against monitoring results including peer review at appropriate intervals
1B2	3	Lineaments concentrate subsidence or groundwater impacts in excess of development consent conditions (and Groundwater Licence, Aquifer Interference policy, minimal harm criteria).	1	Review Reporting of Geological Features relevant to Longwalls 22 & 23 to determine if further investigatory actions such as inseam and or surface drilling are required to define geological features
			2	Continue to periodically review and calibrate the groundwater model against monitoring results including peer review at appropriate intervals
			3	In the event that an anomalous, unmapped geological structure is encountered: 1. Assess the significance of the structure to increase understanding 2. If necessary, conduct surveys and testing e.g. radio imaging method, seismic, inseam and/or surface drilling 3. If the structure is deemed significant, revise mine plan accordingly to avoid/manage the geological structure
1B3	3	Unnamed faults and dykes result in impacts in excess of development consent conditions (and Groundwater Licence, Aquifer Interference Policy and associated minimal harm criteria) on groundwater quantity	1	Continue to periodically review and calibrate the groundwater model against monitoring results including peer review at appropriate intervals
			2	In the event that an anomalous, unmapped geological structure is encountered: 1. Assess the significance of the structure to increase understanding 2. If necessary, conduct surveys and testing e.g. radio imaging method, seismic, inseam and/or surface drilling 3. If the structure is deemed significant, revise mine plan accordingly to avoid/manage the geological structure
1B4	3	Shear planes (including basal shear planes) transmits groundwater in excess of Development Consent Conditions (no more than negligible impacts as defined by the regional groundwater model) and/or Dams Safety NSW conditions (policy of no more than 1ML per day cumulative leakage from Cordeaux Reservoir) in addition to Groundwater Licence, Aquifer Interference Policy and minimal harm criteria.	1	Continue to periodically review and calibrate the groundwater model against monitoring results including peer review at appropriate intervals
			2	In the event that a shear plane is encountered that transmits an anomalous amount groundwater, investigations to understand the change in horizontal permeability due to mining will take place
1D1	3	Surface subsidence, sub-surface movements or valley closure result in impacts to Swamps, Tributaries to Wongawilli Creek, Cordeaux Reservoir and Cordeaux River in excess of development consent conditions	1	Submit the Subsidence Management Plan for Longwalls 22 and 23
1D2	3	Lineaments, faults and dykes result in impacts in excess of development consent conditions for Swamps, Tributaries to Wongawilli Creek, Cordeaux Reservoir and Cordeaux River	1	In the event that an anomalous, unmapped geological structure is encountered: 1. Assess the significance of the structure to increase understanding 2. If necessary, conduct surveys and testing e.g. radio imaging method, seismic, inseam and/or surface drilling 3. If the structure is deemed significant, revise mine plan accordingly to avoid/manage the geological structure
1C1	1	Valley closure results in impacts in excess of development consent conditions for Wongawilli Creek (including no more than minor environmental consequences).	1	Submit the Subsidence Management Plan for Longwalls 22 and 23

Attachment 3

Assessment Worksheets
(Consequence Order)

Risk Analysis Consequence Order

REF	Con	HAZARD	TID	TREATMENT OPTIONS
1A1	10	Surface subsidence and sub-surface ground movements results in impacts in excess of Development Consent (no more than negligible impacts as defined by the regional groundwater model) and/or Dams Safety NSW conditions (policy of no more than 1ML per day cumulative leakage from Cordeaux Reservoir) in addition to Groundwater Licences, Aquifer Interference Policy and minimal harm criteria	1	Continue to periodically review and constrain the model using new field data (e.g. permeability data, defect logging) and calibrate the groundwater model against monitoring results including peer review at appropriate intervals
1A2	10	Lineaments concentrate subsidence i.e. groundwater effects in excess of Development Consent (no more than negligible impacts as defined by the regional groundwater model) and/or Dams Safety NSW conditions (policy of no more than 1ML per day cumulative leakage from Cordeaux Reservoir) in addition to Groundwater Licences, Aquifer Interference Policy and minimal harm criteria	1	Continue to periodically review and calibrate the groundwater model against monitoring results including peer review at appropriate intervals
			2	In the event that an anomalous, unmapped geological structure is encountered: 1. Assess the significance of the structure to increase understanding 2. If necessary, conduct surveys and testing e.g. radio imaging method, seismic, inseam and/or surface drilling 3. If the structure is deemed significant, revise mine plan accordingly to avoid/manage the geological structure
1A3	10	Unnamed faults and dykes result in impacts in excess of Development Consent (no more than negligible impacts as defined by the regional groundwater model) and/or Dams Safety NSW conditions (policy of no more than 1ML per day cumulative leakage from Cordeaux Reservoir) in addition to Groundwater Licences, Aquifer Interference Policy and minimal harm criteria	1	Review geological features relevant to Longwalls 22 and 23 to determine if further investigatory actions such as inseam and or surface drilling are required
			2	Continue to periodically review and calibrate the groundwater model against monitoring results including peer review at appropriate intervals
			3	In the event that an anomalous, unmapped geological structure is encountered: 1. Assess the significance of the structure to increase understanding 2. If necessary, conduct surveys and testing e.g. radio imaging method, seismic, inseam and/or surface drilling 3. If the structure is deemed significant, revise mine plan accordingly to avoid/manage the geological structure
1A4	10	Shear planes (including basal shear planes) transmits groundwater in excess of Development Consent Conditions (no more than negligible impacts as defined by the regional groundwater model) and/or Dams Safety NSW conditions (policy of no more than 1ML per day cumulative leakage from Cordeaux Reservoir) in addition to Groundwater Licence, Aquifer Interference Policy and minimal harm criteria.	1	Continue to periodically review and calibrate the groundwater model against monitoring results including peer review at appropriate intervals
			2	In the event that a shear plane is encountered that transmits an anomalous amount groundwater, investigations to understand the change in horizontal permeability due to mining will take place
1B1	10	Surface subsidence and sub-surface ground movements results in impacts excess of Development Consent (no more than negligible impacts as defined by the regional groundwater model) and/or Dams Safety NSW conditions (policy of no more than 1ML per day cumulative leakage from Cordeaux Reservoir) in addition to Groundwater Licence, Aquifer Interference Policy and minimal harm criteria.	1	Continue to periodically review and calibrate the groundwater model against monitoring results including peer review at appropriate intervals
1B2	10	Lineaments concentrate subsidence or groundwater impacts in excess of development consent conditions (and Groundwater Licence, Aquifer Interference policy, minimal harm criteria).	1	Review Reporting of Geological Features relevant to Longwalls 22 & 23 to determine if further investigatory actions such as inseam and or surface drilling are required to define geological features
			2	Continue to periodically review and calibrate the groundwater model against monitoring results including peer review at appropriate intervals
			3	In the event that an anomalous, unmapped geological structure is encountered: 1. Assess the significance of the structure to increase understanding 2. If necessary, conduct surveys and testing e.g. radio imaging method, seismic, inseam and/or surface drilling 3. If the structure is deemed significant, revise mine plan accordingly to avoid/manage the geological structure
1B3	10	Unnamed faults and dykes result in impacts in excess of development consent conditions (and Groundwater	1	Continue to periodically review and calibrate the groundwater model against monitoring results including peer review at appropriate intervals

REF	Con	HAZARD	TID	TREATMENT OPTIONS
		Licence, Aquifer Interference Policy and associated minimal harm criteria) on groundwater quantity	2	In the event that an anomalous, unmapped geological structure is encountered: 1. Assess the significance of the structure to increase understanding 2. If necessary, conduct surveys and testing e.g. radio imaging method, seismic, inseam and/or surface drilling 3. If the structure is deemed significant, revise mine plan accordingly to avoid/manage the geological structure
1B4	10	Shear planes (including basal shear planes) transmits groundwater in excess of Development Consent Conditions (no more than negligible impacts as defined by the regional groundwater model) and/or Dams Safety NSW conditions (policy of no more than 1ML per day cumulative leakage from Cordeaux Reservoir) in addition to Groundwater Licence, Aquifer Interference Policy and minimal harm criteria.	1	Continue to periodically review and calibrate the groundwater model against monitoring results including peer review at appropriate intervals
			2	In the event that a shear plane is encountered that transmits an anomalous amount groundwater, investigations to understand the change in horizontal permeability due to mining will take place
1C1	10	Valley closure results in impacts in excess of development consent conditions for Wongawilli Creek (including no more than minor environmental consequences).	1	Submit the Subsidence Management Plan for Longwalls 22 and 23
1C2	10	Lineaments, faults, dykes and intrusions result in impacts in excess of development consent conditions for Wongawilli Creek (including no more than minor environmental consequences)	1	In the event that an anomalous, unmapped geological structure is encountered: 1. Assess the significance of the structure to increase understanding 2. If necessary, conduct surveys and testing e.g. radio imaging method, seismic, inseam and/or surface drilling 3. If the structure is deemed significant, revise mine plan accordingly to avoid/manage the geological structure
1C3	10	Groundwater drawdown results in impacts in excess of development consent conditions for Wongawilli Creek (including no more than minor environmental consequences)	1	Nil Required
1D1	10	Surface subsidence, sub-surface movements or valley closure result in impacts to Swamps, Tributaries to Wongawilli Creek, Cordeaux Reservoir and Cordeaux River in excess of development consent conditions	1	Submit the Subsidence Management Plan for Longwalls 22 and 23
1D2	10	Lineaments, faults and dykes result in impacts in excess of development consent conditions for Swamps, Tributaries to Wongawilli Creek, Cordeaux Reservoir and Cordeaux River	1	In the event that an anomalous, unmapped geological structure is encountered: 1. Assess the significance of the structure to increase understanding 2. If necessary, conduct surveys and testing e.g. radio imaging method, seismic, inseam and/or surface drilling 3. If the structure is deemed significant, revise mine plan accordingly to avoid/manage the geological structure
1D3	10	Cumulative impacts, including the impacts of cracking of first and second order watercourses. Leading to effects on aquatic and terrestrial ecology greater than those predicted in the EIS, WIMMCP and SMP (Schedule 2, Condition 2 and Schedule 3, Conditions 4 and 7 of the Development Consent)	1	Continue to consider cumulative impacts to aquatic ecology due to any reductions in availability of habitat in first and second order watercourses.

Attachment 4

Risk Treatment Schedule and Action Plan

ID	HAZARD	TID	TREATMENT OPTIONS	RESPONSIBILITY	IMPLEMENTATION	COMMENTS	COMPLETED (Sign Off)
1A1	Surface subsidence and sub-surface ground movements results in impacts in excess of Development Consent (no more than negligible impacts as defined by the regional groundwater model) and/or Dams Safety NSW conditions (policy of no more than 1ML per day cumulative leakage from Cordeaux Reservoir) in addition to Groundwater Licences, Aquifer Interference Policy and minimal harm criteria	1	Continue to periodically review and constrain the model using new field data (e.g. permeability data, defect logging) and calibrate the groundwater model against monitoring results including peer review at appropriate intervals	Cody Brady	Friday, 30 July 2021		
1A2	Lineaments concentrate subsidence or groundwater in excess of Development Consent (no more than negligible impacts as defined by the regional groundwater model) and/or Dams Safety NSW conditions (policy of no more than 1ML per day cumulative leakage from Avon Reservoir) in addition to Groundwater Licences, Aquifer Interference Policy and minimal harm criteria	1	Continue to periodically review and calibrate the groundwater model against monitoring results including peer review at appropriate intervals	Cody Brady (Assessment by Watershed Hydrogeo)	Friday, 30 July 2021		
		2	In the event that an anomalous, unmapped geological structure is encountered: 1. Assess the significance of the structure to increase understanding 2. If necessary, conduct surveys and testing e.g. radio imaging method, seismic, inseam and/or surface drilling 3. If the structure is deemed significant, revise mine plan accordingly to avoid/manage the geological structure	Cody Brady (IMC Technical Services)	Friday, 30 July 2021		
1A3	Unnamed faults and dykes result in impacts in excess of Development Consent (no more than negligible impacts as defined by the regional groundwater model) and/or Dams Safety NSW conditions (policy of no more than 1ML per day cumulative leakage from Cordeaux Reservoir) in addition to Groundwater Licences, Aquifer Interference Policy and minimal harm criteria	1	Review geological features relevant to Longwalls 22 and 23 to determine if further investigatory actions such as inseam and or surface drilling are required	Cody Brady (IMC Technical Services)	Friday, 30 July 2021		
		2	Continue to periodically review and calibrate the groundwater model against monitoring results including peer review at appropriate intervals	Cody Brady (Assessment by Watershed Hydrogeo)	Friday, 30 July 2021		
		3	In the event that an anomalous, unmapped geological structure is encountered: 1. Assess the significance of the structure to increase understanding 2. If necessary, conduct surveys and testing e.g. radio imaging method, seismic, inseam and/or surface drilling 3. If the structure is deemed significant, revise mine plan accordingly to avoid/manage the geological structure	Cody Brady (IMC Technical Services)	Friday, 30 July 2021		

ID	HAZARD	TID	TREATMENT OPTIONS	RESPONSIBILITY	IMPLEMENTATION	COMMENTS	COMPLETED (Sign Off)
1A4	Shear planes (including basal shear planes) transmits groundwater in excess of Development Consent Conditions (no more than negligible impacts as defined by the regional groundwater model) and/or Dams Safety NSW conditions (policy of no more than 1ML per day cumulative leakage from Cordeaux Reservoir) in addition to Groundwater Licence, Aquifer Interference Policy and minimal harm criteria.	1	Continue to periodically review and calibrate the groundwater model against monitoring results including peer review at appropriate intervals	Cody Brady (Assessment by Watershed Hydrogeo)	Friday, 30 July 2021		
		2	In the event that a shear plane is encountered that transmits an anomalous amount groundwater, investigations to understand the change in horizontal permeability due to mining will take place	Cody Brady	Friday, 30 July 2021		
1B1	Surface subsidence and sub-surface ground movements results in impacts excess of Development Consent (no more than negligible impacts as defined by the regional groundwater model) and/or Dams Safety NSW conditions (policy of no more than 1ML per day cumulative leakage from Cordeaux Reservoir) in addition to Groundwater Licence, Aquifer Interference Policy and minimal harm criteria.	1	Continue to periodically review and calibrate the groundwater model against monitoring results including peer review at appropriate intervals	Cody Brady	Friday, 30 July 2021		
1B2	Lineaments concentrate subsidence or groundwater impacts in excess of development consent conditions (and Groundwater Licence, Aquifer Interference policy, minimal harm criteria).	1	Review Reporting of Geological Features relevant to Longwalls 22 & 23 to determine if further investigatory actions such as inseam and or surface drilling are required to define geological features	Cody Brady (IMC Technical Services)	Friday, 30 July 2021		
		2	Continue to periodically review and calibrate the groundwater model against monitoring results including peer review at appropriate intervals	Cody Brady (Assessment by Watershed Hydrogeo)	Friday, 30 July 2021		
		3	In the event that an anomalous, unmapped geological structure is encountered: 1. Assess the significance of the structure to increase understanding 2. If necessary, conduct surveys and testing e.g. radio imaging method, seismic, inseam and/or surface drilling 3. If the structure is deemed significant, revise mine plan accordingly to avoid/manage the geological structure	Cody Brady (IMC Technical Services)	Friday, 30 July 2021		

ID	HAZARD	TID	TREATMENT OPTIONS	RESPONSIBILITY	IMPLEMENTATION	COMMENTS	COMPLETED (Sign Off)
1B3	Unnamed faults and dykes result in impacts in excess of development consent conditions (and Groundwater Licence, Aquifer Interference Policy and associated minimal harm criteria) on groundwater quantity	1	Continue to periodically review and calibrate the groundwater model against monitoring results including peer review at appropriate intervals	Cody Brady (Assessment by Watershed Hydrogeo)	Friday, 30 July 2021		
		2	In the event that an anomalous, unmapped geological structure is encountered: 1. Assess the significance of the structure to increase understanding 2. If necessary, conduct surveys and testing e.g. radio imaging method, seismic, inseam and/or surface drilling 3. If the structure is deemed significant, revise mine plan accordingly to avoid/manage the geological structure	Cody Brady (IMC Technical Services)	Friday, 30 July 2021		
1B4	Shear planes (including basal shear planes) transmits groundwater in excess of Development Consent Conditions (no more than negligible impacts as defined by the regional groundwater model) and/or Dams Safety NSW conditions (policy of no more than 1ML per day cumulative leakage from Cordeaux Reservoir) in addition to Groundwater Licence, Aquifer Interference Policy and minimal harm criteria.	1	Continue to periodically review and calibrate the groundwater model against monitoring results including peer review at appropriate intervals	Cody Brady (Assessment by Watershed Hydrogeo)	Friday, 30 July 2021		
		2	In the event that a shear plane is encountered that transmits an anomalous amount groundwater, investigations to understand the change in horizontal permeability due to mining will take place	Cody Brady	Friday, 30 July 2021		
1C1	Valley closure results in impacts in excess of development consent conditions for Wongawilli Creek (including no more than minor environmental consequences)	1	Submit the Subsidence Management Plan for Longwalls 22 and 23	Cody Brady	Friday, 30 July 2021		
1C2	Lineaments, faults, dykes and intrusions result in impacts in excess of development consent conditions for Wongawilli Creek (including no more than minor environmental consequences)	1	In the event that an anomalous, unmapped geological structure is encountered: 1. Assess the significance of the structure to increase understanding 2. If necessary, conduct surveys and testing e.g. radio imaging method, seismic, inseam and/or surface drilling 3. If the structure is deemed significant, revise mine plan accordingly to avoid/manage the geological structure	Cody Brady (IMC Technical Services)	Friday, 30 July 2021		

ID	HAZARD	TID	TREATMENT OPTIONS	RESPONSIBILITY	IMPLEMENTATION	COMMENTS	COMPLETED (Sign Off)
1C3	Groundwater drawdown results in impacts in excess of development consent conditions for Wongawilli Creek (including no more than minor environmental consequences)	1	Nil Required				
1D1	Surface subsidence, sub-surface movements or valley closure result in impacts to Swamps, Tributaries to Wongawilli Creek, Cordeaux Reservoir and Cordeaux River in excess of development consent conditions	1	Submit the Subsidence Management Plan for Longwalls 22 and 23	Cody Brady	Friday, 30 July 2021		
1D2	Lineaments, faults and dykes result in impacts in excess of development consent conditions for Swamps, Tributaries to Wongawilli Creek, Cordeaux Reservoir and Cordeaux River	1	In the event that an anomalous, unmapped geological structure is encountered: 1. Assess the significance of the structure to increase understanding 2. If necessary, conduct surveys and testing e.g. radio imaging method, seismic, inseam and/or surface drilling 3. If the structure is deemed significant, revise mine plan accordingly to avoid/manage the geological structure	Cody Brady (IMC Technical Services)	Friday, 30 July 2021		
1D3	Cumulative impacts, including the impacts of cracking of first and second order watercourses. Leading to effects on aquatic and terrestrial ecology greater than those predicted in the EIS, WIMMCP and SMP (Schedule 2, Condition 2 and Schedule 3, Conditions 4 and 7 of the Development Consent)	1	Continue to consider cumulative impacts to aquatic ecology due to any reductions in availability of habitat in first and second order watercourses.	Cody Brady (Assessment by Cardno)	Friday, 30 July 2021		

Attachment 5

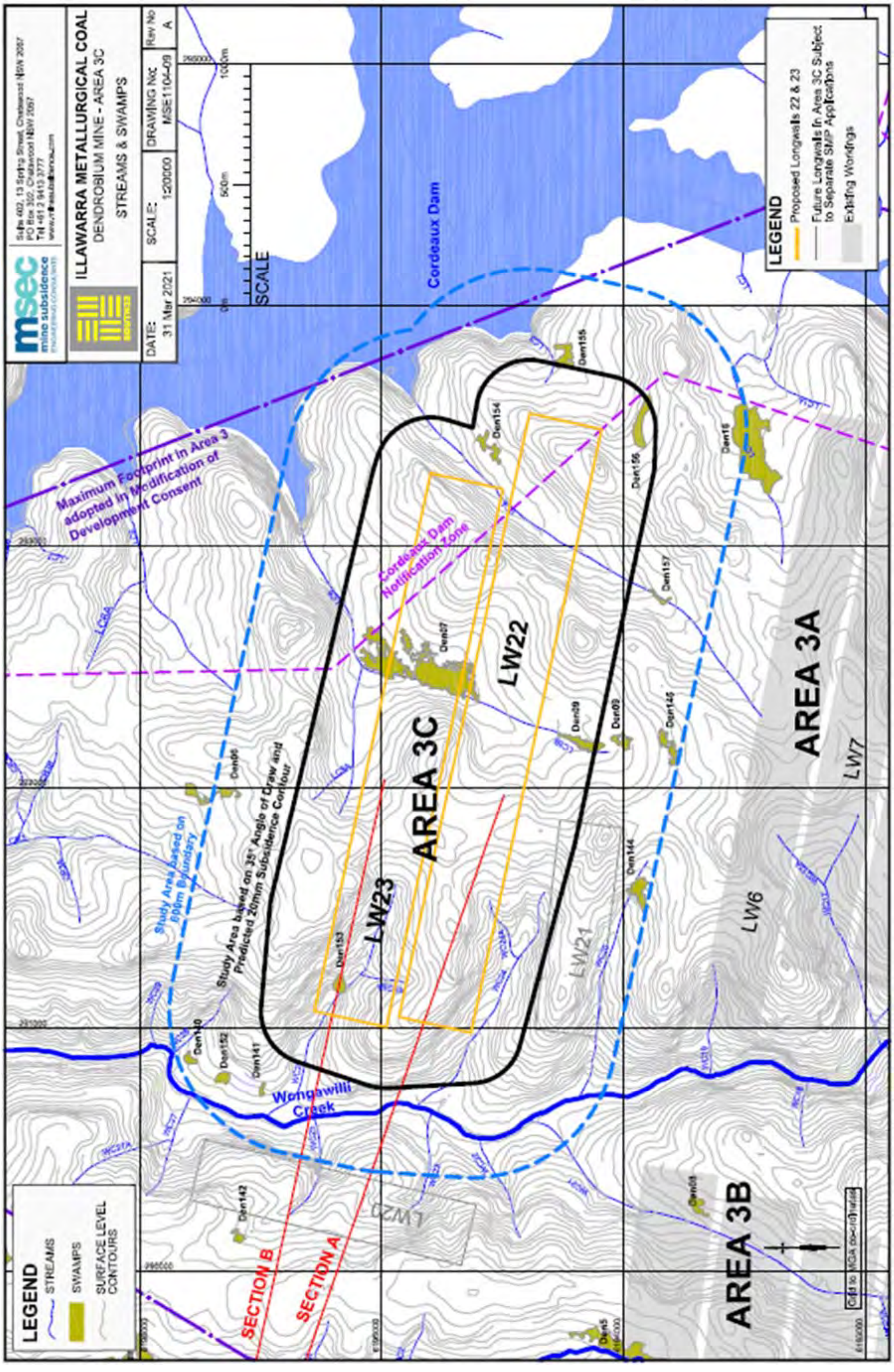
Risk Rank Order
Associated with Lineaments

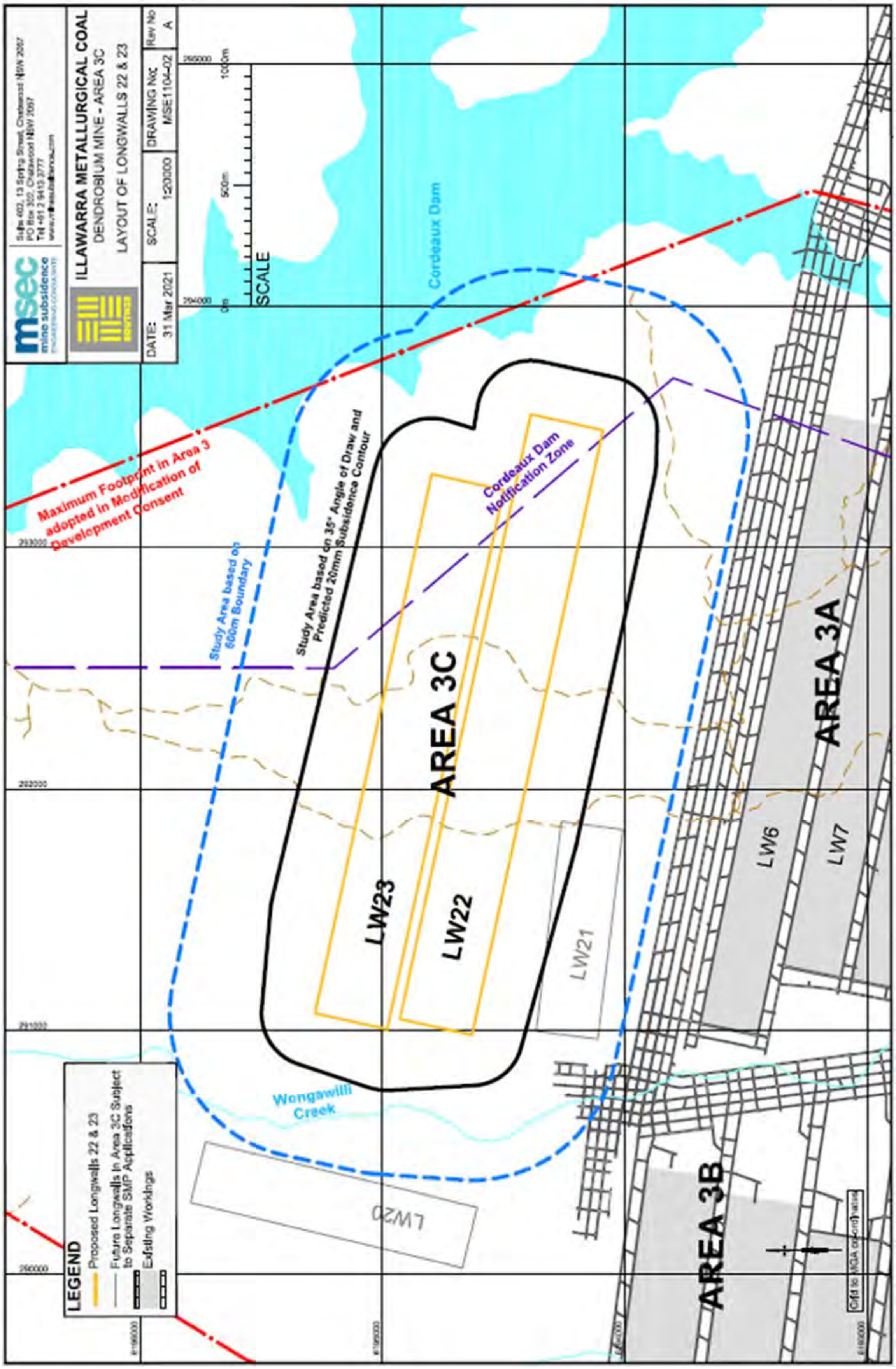
Risk Analysis Risk Order (Associated with Lineaments)

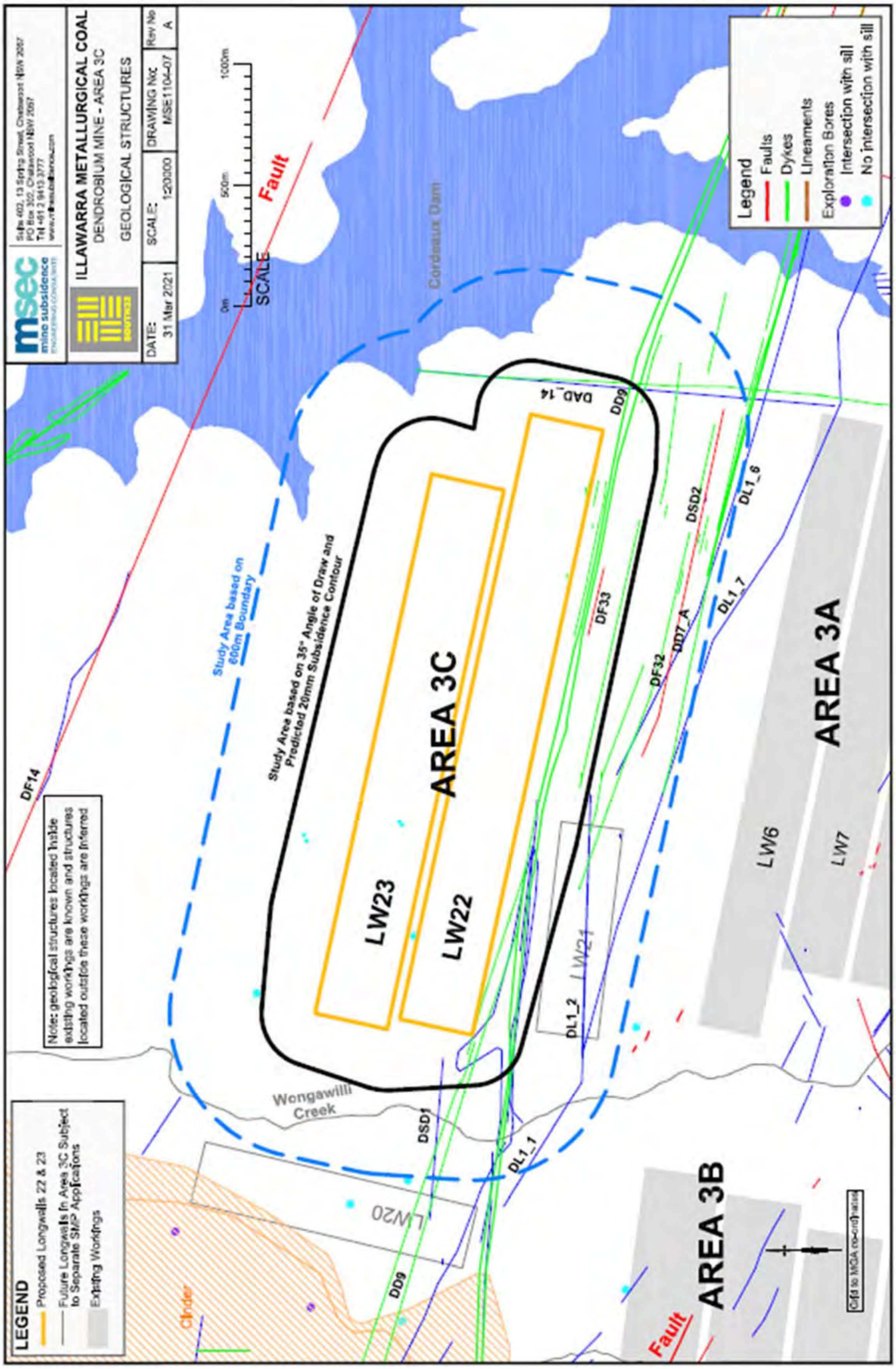
REF	Risk	HAZARD	TID	TREATMENT OPTIONS
1C2	10	Lineaments, faults, dykes and intrusions result in impacts in excess of development consent conditions for Wongawilli Creek (including no more than minor environmental consequences)	1	In the event that an anomalous, unmapped geological structure is encountered: 1. Assess the significance of the structure to increase understanding 2. If necessary, conduct surveys and testing e.g. radio imaging method, seismic, inseam and/or surface drilling 3. If the structure is deemed significant, revise mine plan accordingly to avoid/manage the geological structure
1A2	3	Lineaments concentrate subsidence i.e. groundwater effects in excess of Development Consent (no more than negligible impacts as defined by the regional groundwater model) and/or Dams Safety NSW conditions (policy of no more than 1ML per day cumulative leakage from Cordeaux Reservoir) in addition to Groundwater Licences, Aquifer Interference Policy and minimal harm criteria	1	Continue to periodically review and calibrate the groundwater model against monitoring results including peer review at appropriate intervals
			2	In the event that an anomalous, unmapped geological structure is encountered: 1. Assess the significance of the structure to increase understanding 2. If necessary, conduct surveys and testing e.g. radio imaging method, seismic, inseam and/or surface drilling 3. If the structure is deemed significant, revise mine plan accordingly to avoid/manage the geological structure
1B2	3	Lineaments concentrate subsidence or groundwater impacts in excess of development consent conditions (and Groundwater Licence, Aquifer Interference policy, minimal harm criteria).	1	Review Reporting of Geological Features relevant to Longwalls 22 & 23 to determine if further investigatory actions such as inseam and or surface drilling are required to define geological features
			2	Continue to periodically review and calibrate the groundwater model against monitoring results including peer review at appropriate intervals
			3	In the event that an anomalous, unmapped geological structure is encountered: 1. Assess the significance of the structure to increase understanding 2. If necessary, conduct surveys and testing e.g. radio imaging method, seismic, inseam and/or surface drilling 3. If the structure is deemed significant, revise mine plan accordingly to avoid/manage the geological structure
1D2	3	Lineaments, faults and dykes result in impacts in excess of development consent conditions for Swamps, Tributaries to Wongawilli Creek, Cordeaux Reservoir and Cordeaux River	1	In the event that an anomalous, unmapped geological structure is encountered: 1. Assess the significance of the structure to increase understanding 2. If necessary, conduct surveys and testing e.g. radio imaging method, seismic, inseam and/or surface drilling 3. If the structure is deemed significant, revise mine plan accordingly to avoid/manage the geological structure

Attachment 6

Area 3C – Longwall 22 and 23 Plan


ILLAWARRA METALLURGICAL COAL
DENDROBIUM MINE - AREA 3C
STREAMS & SWAMPS
DATE:
31 Mar 2021
SCALE:
1:20000
DRAWING No:
MSE1104-09
Rev No
A
SCALE
Cordeaux Dam
LEGEND
Proposed Longwalls 22 & 23
Future Longwalls in Area 3C Subject to Separate SMP Applications
Existing Workings
Maximum Footprint in Area 3 adopted in Modification of Development Consent
Cordeaux Dam Notification Zone
Study Area based on 35° Angle of Draw and Predicted 20mm Subsidence Contour
Study Area based on 600m Boundary
AREA 3C
AREA 3A
AREA 3B
LW22
LW23
LW21
LW20
LW6
LW7
Wongawilli Creek
SECTION A
SECTION B
LEGEND
STREAMS
SWAMPS
SURFACE LEVEL CONTOURS


msec
mine subsidence
ILLAWARRA METALLURGICAL COAL
DENDROBIUM MINE - AREA 3C
LAYOUT OF LONGWALLS 22 & 23
DATE:
31 Mar 2021
SCALE:
1:20000
DRAWING No:
MSE1104-02
Rev No
A
SCALE
0m
500m
1000m
Cordeaux Dam
Maximum Footprint in Area 3 adopted in Modification of Development Consent
Study Area based on 35° Angle of Draw and Predicted 20mm Subsidence Contour
Study Area based on 600m Boundary
Cordeaux Dam Notification Zone
AREA 3C
AREA 3A
AREA 3B
LW23
LW22
LW21
LW20
LW6
LW7
Wongawilli Creek
LEGEND
Proposed Longwalls 22 & 23
Future Longwalls in Area 3C Subject to Separate SMP Applications
Existing Workings


msec mine subsidence
ILLAWARRA METALLURGICAL COAL
DENDROBIUM MINE - AREA 3C
GEOLOGICAL STRUCTURES
DATE: 31 Mar 2021
SCALE: 1:20000
DRAWING No: MSE1104-07
Rev No: A
SCALE
0m
500m
1000m
Fault
Cordeaux Dam
Legend
Faults
Dykes
Lineaments
Exploration Bores
Intersection with sill
No intersection with sill
Study Area based on 600m Boundary
Study Area based on 35° Angle of Draw and Predicted 20mm Subsidence Contour
AREA 3C
LW23
LW22
LW21
AREA 3A
LW6
LW7
AREA 3B
LW20
Wongawilli Creek
DF14
DF33
DF32
DSD2
DSD1
DL1_6
DL1_7
DL1_2
DL1_1
DD9
DAD_14
DD7_A
Note: geological structures located inside existing workings are known and structures located outside these workings are inferred
LEGEND
Proposed Longwalls 22 & 23
Future Longwalls in Area 3C Subject to Separate SMP Applications
Existing Workings
Fault

Attachment E – Surface Water Assessment

Illawarra Metallurgical Coal

Dendrobium Mine

Assessment of surface water and shallow groundwater effects of proposed Longwalls 22 & 23, Area 3C

HGEO Pty Ltd
Date: June 2021
Project number: J21498
Report: D20368

DOCUMENT REGISTER

Revision	Description	Date	Comments
01	1st Draft	18/5/2021	MS Word
06	Final report	7/6/2021	pdf

FILE

Https://hgeocomau.sharepoint.com/sites/HGEO/Shared Documents/Files/Client_Site/Dendrobium/04_Projects/J21498_LW21_23_SMP_SW/D20368_Dendrobium_LW22_23_SW_Impact_Assessment_V07.docx

Cover photo: Wongawilli Creek, looking upstream from Fire Road 6 on 28 June 2017

QUALITY CONTROL

Process	Staff	Signature	Date
Authors	Stuart Brown, Will Minchin		
Approved	Stuart Brown	[signature]	7/6/2021

COPYRIGHT

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABBREVIATIONS

Abbreviation/Term	Meaning
AHD	Australian Height Datum (Mean Sea Level 1966-1968)
BACS	Bald Hill Claystone
bgl	Below ground level
BGSS	Bulgo Sandstone
CVSS	Colo Vale Sandstone
DPIE	Department of Planning, Industry and Environment
EOP	End of Panel (monitoring review report)
HBSS	Hawkesbury Sandstone
IAPUM	Independent Advisory Panel for Underground Mining
IEPMC	Independent Expert Panel for Mining in the Catchment (now succeeded by IAPUM)
IESC	Independent Expert Scientific Committee
IMC	Illawarra Metallurgical Coal
IMCEFT	Illawarra Metallurgical Coal Environmental Field Team
NDC	Native Dog Creek (tributary to Lake Avon)
SIMMCP	Swamp Impact Monitoring Management and Contingency Plan
SMP	Subsidence Management Plan
TARP	Trigger Action Response Plan
WIMMCP	Watercourse Impact Monitoring Management and Contingency Plan

EXECUTIVE SUMMARY

Illawarra Metallurgical Coal (IMC), a wholly owned subsidiary of South32 Limited (South32), operates the underground Dendrobium Mine in the Southern Coalfield of New South Wales (NSW). IMC proposes to extract Longwalls 22 and 23 in Area 3C, located immediately to the north of active mining Area 3B, between Lake Cordeaux and Wongawilli Creek.

Dendrobium Mine is located within the catchment of the Upper Nepean River on the Woronora Plateau inland of the Illawarra Escarpment. Drainage is to the north-northwest, towards the Nepean River, with most of the local surface runoff initially captured in Lakes Cordeaux and Avon before eventually flowing into the Nepean River. The study area is nominally defined by the area within 600 m of the edge of the proposed longwalls. Within the study area, surface runoff drains into Wongawilli Creek, Lake Cordeaux and Cordeaux River via a number of tributaries.

The main third-order channel of Wongawilli Creek is approximately 345 m from Longwall 22 at its closest approach and 320 m from Longwall 23. Adverse effects associated with Longwalls 22 and 23 such as creek bed fracturing and flow diversion is possible in Wongawilli Creek and its tributaries within 400 m of longwalls. Creeks that flow above longwall panels will likely be affected by subsidence and surface cracking associated with those longwalls. Wongawilli Creek tributaries WC24A and WC26 flow over the footprint of Longwalls 22 and 23. Lake Cordeaux tributaries LC5 and LC6 cross directly above Longwalls 22 and 23. Valley-related closure could result in minor and localised fracturing of the WC24 creek bed and potential flow diversion.

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. Groundwater modelling (Watershed Hydrogeo, 2021) indicates that the incremental effect on stream flow along Wongawilli Creek due to extraction of Longwalls 22 and 23 would be in the range 0.025-0.09 and 0.043-0.15 ML/day respectively. The cumulative effect on flows due to the extraction of Longwall 6 to 23 is estimated to be approximately 0.6-2.2 ML/day along Wongawilli Creek with the effects peaking around 2031-2035, and declining thereafter. The cumulative effects are likely to increase the number of cease-to-flow days in the middle to lower reach of Wongawilli Creek (adjacent to Areas 3A, 3B and 3C), and an increase in cease-to-flow days (from 6% of the time to 17% on average) and being most obvious during extended dry conditions in Wongawilli Creek. An increase in cease-to-flow frequency and reduction in flow is predicted by groundwater modelling at the WWL gauging station at the bottom of Wongawilli Creek. However, this is considered unlikely based on monitoring data gathered and analysed to date, which indicate mining effects are difficult to discern from natural variation. However, as longwall operations move from Area 3A and 3B to the north into Area 3C, discernible effects at the WWL gauging station become more likely.

Loss of flow due to Longwalls 22 and 23 is also predicted in LC5, LC6 (tributaries to Lake Cordeaux) and WC26 and WC24 (tributaries to Wongawilli Creek), as well as very minor loss of baseflow at CR36 (tributary to Cordeaux River). The losses in the first four of these will be due to both subsidence cracking and groundwater depressurisation or drawdown, while drawdown effects alone will be the cause of reduced flow in CR36. Groundwater modelling indicates that Longwalls 22 and 23 may result in an incremental seepage loss from Lake Cordeaux of approximately 0.08 and 0.05 ML/day, respectively, and lead to a cumulative loss from that reservoir, due to Dendrobium Mine, of up to 0.36 ML/d.

Based on previous observations, it is expected that water quality impacts, including localised iron staining, may be observed in tributaries that cross the longwall footprints (WC24, WC26, LC5 and LC6), and possibly in LC7 which is entirely within 400 m of Longwall 22; however, those impacts are

not expected to significantly influence water quality at downstream locations on Wongawilli Creek. Local discolouration of streambeds and rock faces by iron hydroxide precipitation can continue for a number of years. Water quality effects on stored waters of the reservoirs are expected to be negligible and undetectable.

There are fourteen areas of Coastal Upland Swamp vegetation located entirely or partially within the study area. Based on previous experience at Area 3B and subsidence predictions, it is likely that shallow groundwater levels will be affected in Swamps 7 and Den 153 which substantially overlap the longwall footprint. The remaining swamps are unlikely to be impacted, though minor and isolated fracturing could occur at distances up to 400 m outside the mining area.

1. INTRODUCTION

1.1 Project background

Illawarra Metallurgical Coal (IMC), a wholly owned subsidiary of South32 Limited (South32), operates the underground Dendrobium Mine in the Southern Coalfield of New South Wales (NSW). The mine is located about 12 kilometres (km) west of Wollongong and within the Metropolitan Special Catchment Area managed by WaterNSW.

Since approval in 2001, underground mining has been carried out at Dendrobium Mine, with longwall extraction commencing within Area 1 in 2005. Longwall extraction has continued in Areas 2 3A and Area 3B to present. IMC proposes to extract Longwalls 22 and 23 in Area 3C, located to the north of Area 3A (Figure 1). Extraction of Longwalls 22 and 23 is scheduled to follow extraction of Longwall 19 in Area 3A and Longwall 21 in Area 3C.

Previous workings in the Wongawilli Seam are located to the south of the mine at Elouera and Nebo, and to the east at Kemira. The overlying Bulli Seam was mined previously at Mt Kembla to the east of Area 1. IMC is preparing a Subsidence Management Plan (SMP) as part of the approvals process for Longwalls 22 and 23. HGEO was engaged to carry out an assessment of the potential effects of mining on surface water and shallow groundwater systems. This assessment is to form part of the SMP and should be read in conjunction with that document and other specialist reports referred to in the SMP.

1.2 Study area

The study area is nominally defined by the area within 600 m of the edge of the longwall (Development Consent Schedule 3, Condition 8(d)), being the minimum extent of the assessments for the valley related subsidence effects (MSEC, 2021). MSEC (2021) also considers a study area based on the 35° angle of draw and predicted 20 mm subsidence contour. Study areas defined by both criteria are shown in Figure 1. This assessment considers reaches of Wongawilli Creek that extend upstream and downstream of the 600 m envelope, as appropriate for the definition of baseline characteristics and impact monitoring.

1.3 Scope

The scope of this assessment is to provide supporting information for the SMP for Area 3C which is required under Schedule 3 of the Dendrobium Development Consent. The assessment is to include:

- Description of surface water hydrology within the study area.
- Summary of existing monitoring sites.
- Summary of baseline monitoring data.
- Assessment of potential impacts to surface water systems as a result of subsidence related to Longwalls 22 and 23, with emphasis on the quantity and quality of flows to Lake Avon, Lake Cordeaux and the Cordeaux River.
- Assessment of the potential impact to the hydrological function of swamps as a result of subsidence related to longwall extraction.
- Provide assessment and recommendations to allow for an update to relevant elements of the Watercourse Impact Monitoring, Management and Contingency Plan (WIMMCP) and Swamp Impact Monitoring, Management and Contingency Plan (SIMMCP).

1.4 Relevant approval conditions

Table 1. Dendrobium Development Consent conditions relevant to this surface water assessment

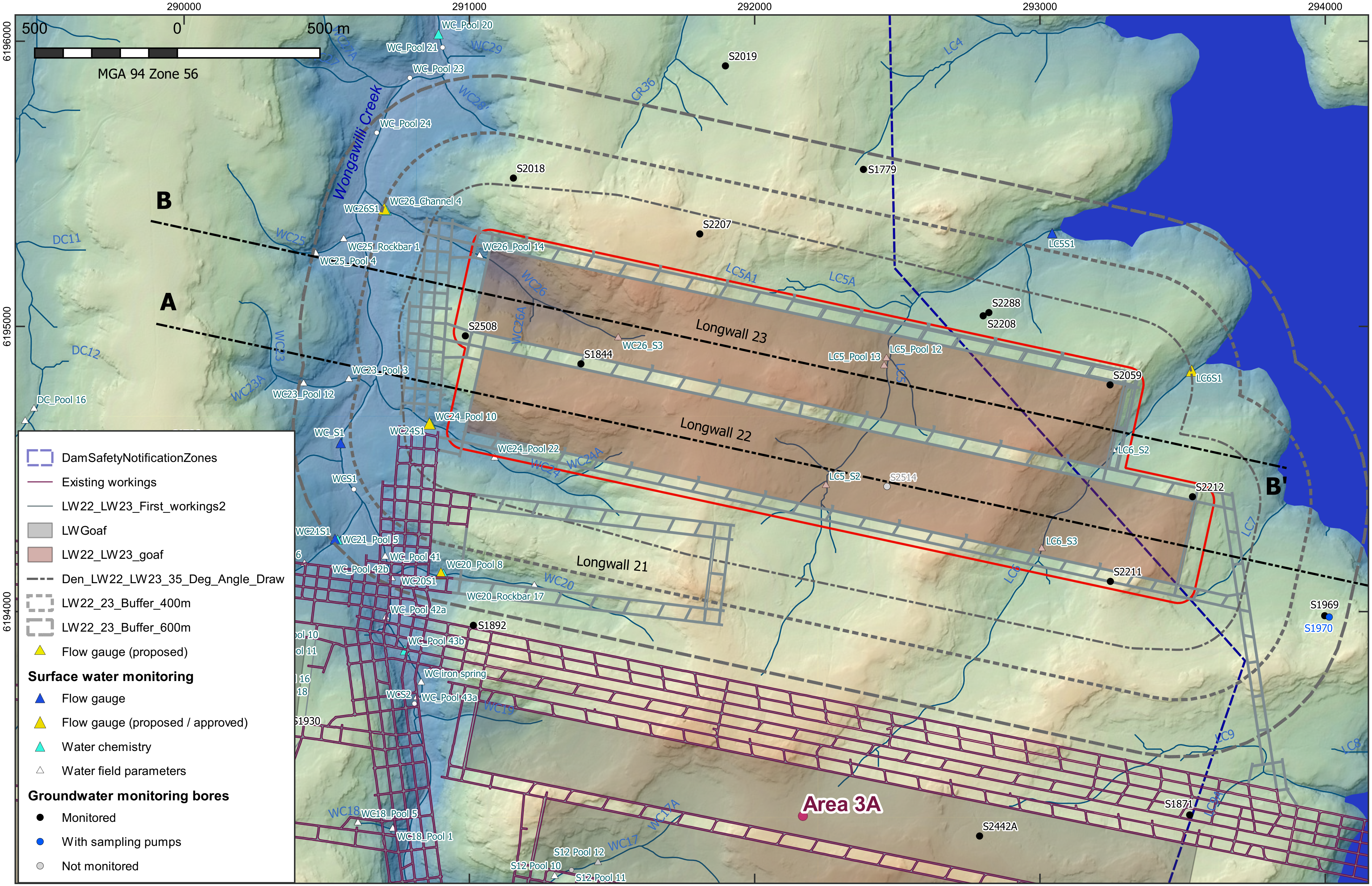
Condition		Where addressed
Schedule 3 – Specific Environmental Conditions		
2	The Applicant shall ensure that underground mining operations do not cause subsidence impacts at Sandy Creek and Wongawilli Creek other than "minor impacts" (such as minor fracturing, gas release, iron staining and minor impacts on water flows, water levels and water quality) to the satisfaction of the Secretary.	Section 4 (this report)
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.	Section 4 (this report)

1.5 IEPMC Recommendations

The Independent Expert Panel for Mining in the Catchment (IEPMC) was established in February 2018 to provide expert advice to the Department of Planning, Industry and Environment (DPIE) on the impact of mining activities in the Greater Sydney Water Catchment Special Areas, with a focus on risks to quantity of water.

The findings of the panel were released in a two-part report in October 2019. Part 1 focusses on modelling and monitoring used in the assessment and management of subsidence-induced effects and impacts on groundwater and surface water at Dendrobium Mine and Metropolitan Mine (IEPMC, 2019a). Recommendations were directed to informing mine design and approvals, monitoring and performance. Part 2 focusses on the impacts of mining in the Greater Sydney Water Catchment Special Areas on water quantity and swamps, including cumulative impacts, and a requirement to review and update relevant findings of the 2008 Southern Coalfield Inquiry (IEPMC, 2019b).

Subsequent to the release of the main findings in Parts 1 and 2, the IEPMC provided advice to the DPIE on the SMP for Dendrobium Mine Longwall 21 (IEPMC, 2019c). Recommendations from the IEPMC reports are referred to throughout this assessment.



Dendrobium Longwalls 22 & 23 Surface water assessment

Location map and surface water monitoring sites

Figure 1

file: Dendrobium5.qgz

1.6 Mining geometry

The layout of the proposed Longwalls 22 and 23 are shown in Figure 1. Both longwalls will be extracted from the Wongawilli seam, with mining dimensions as shown in Table 2.

Table 2. Mining parameters for Longwalls 22 and 23

Longwall	Length (m)	Width (m) (incl first workings)	Mining height (max)	Depth of cover (m)	
				Range	Mean
22	2561	305	3.9	289 – 372	332
23	2283	305	3.9	287 – 386	333

Longwalls will be extracted towards the main headings (from west to east). The extent of Longwall 22 within the Wongawilli Coal Seam is shown in an east-west geological cross-section A-A' in Figure 2 and Longwall 23 is shown in cross-section B-B' in Figure 3.

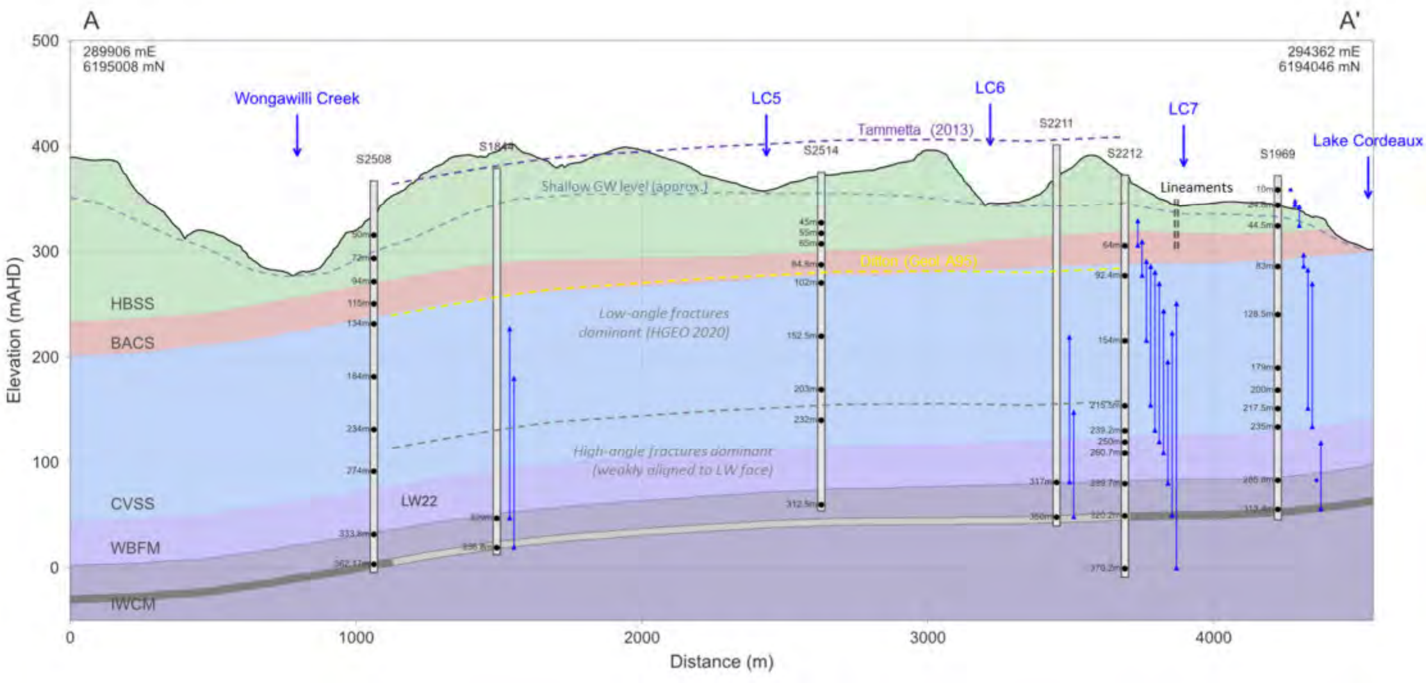


Figure 2. Hydrogeological cross section A-A' through Longwall 22 (east-west)

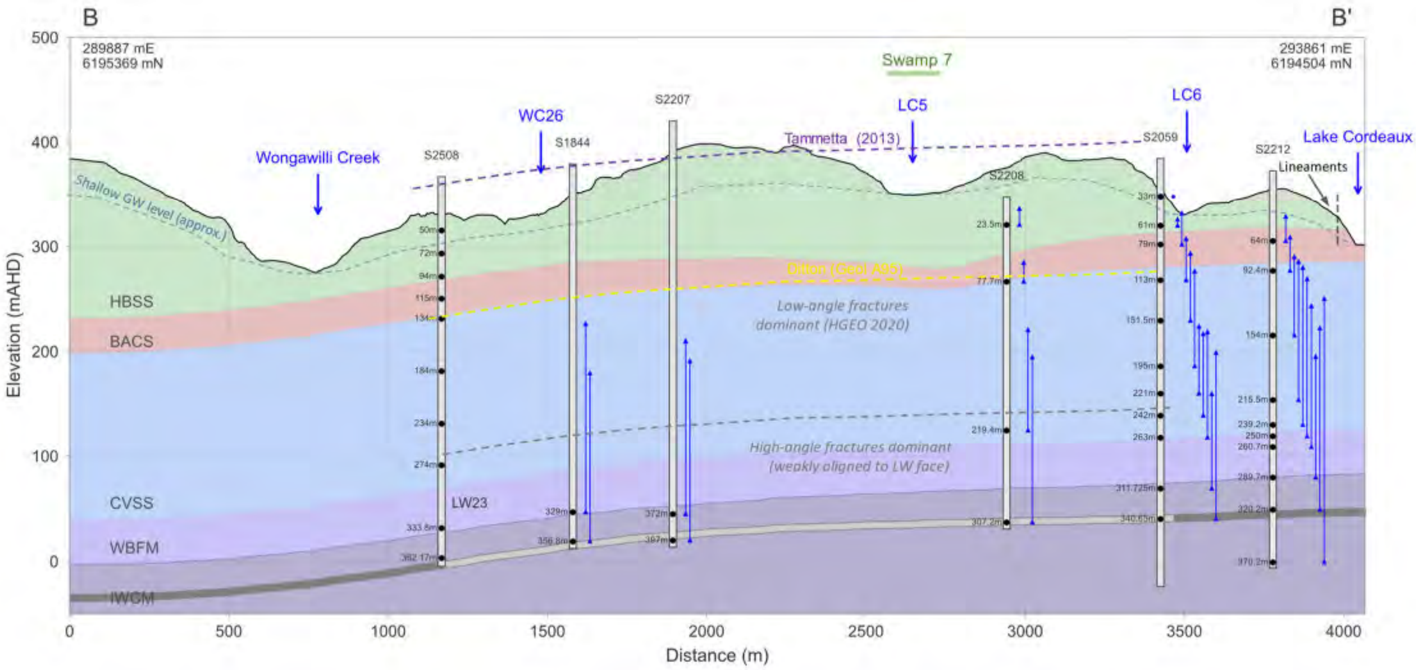


Figure 3. Hydrogeological cross section B-B' through Longwall 23 (east-west)

2. BACKGROUND

2.1 Topography

Dendrobium Mine is located on the Woronora Plateau inland of the Illawarra Escarpment. The escarpment rises from the coastal plain to elevations in excess of 400 mAHD around Dendrobium. The plateau generally slopes to the north or northwest, toward the centre of the Sydney Basin. Dendrobium Area 3 is characterised by broad sandstone ridges and plateaus rising to approximately 410 m AHD, incised by relatively steep and rugged gullies. The proposed longwalls are aligned approximately west-east and located immediately to the north of active mining Area 3B and between Wongawilli Creek and Lake Cordeaux.

2.2 Climate

Weather data have been collected at the Dendrobium Mine since 2003. Mean annual rainfall between 2002 and 2020 was 1028 mm (2.82 mm per day on average). Rainfall decreases westward away from the Illawarra escarpment. Picton, located 20 km to the northwest of Dendrobium, records an average annual rainfall of 814 mm (1886-2020). At Dendrobium, rainfall tends to be higher in the summer and early autumn months. It is common for a substantial proportion of the annual rainfall to be delivered in one or two large rainfall events (>150 mm), during which significant surface water runoff and groundwater recharge are generated.

Maximum daily temperature varies seasonally from approximately 20°C in the winter months (June – August) to 40°C or higher in the summer (December – February). Evapotranspiration also varies seasonally in line with temperature and solar radiation, peaking during the summer months. Potential evapotranspiration calculated using the Penman-Monteith formula is typically between 1 and 3 mm/day in the winter months and between 3 and 6 mm/day in the summer months.

Figure 4 shows rainfall trends at Dendrobium as derived from SILO rainfall data as shown by the Cumulative Rainfall Residual curve (CRR). This figure shows the occurrence of significant dry and wet periods from 1900 (where the CRR curve trends downwards and upwards, respectively), including the Millennium Drought and the more recent 2017-2019 drought. Rainfall in 2020 was the highest recorded on site at Dendrobium since 2002, resulting in significant recovery of surface water flows and soil moisture storage.

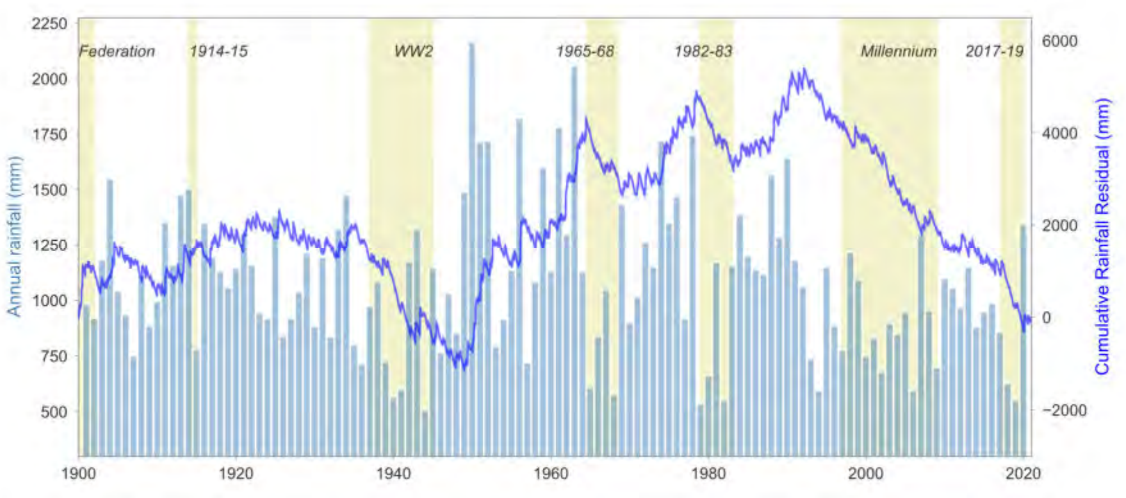


Figure 4. Long-term rainfall trends and significant droughts (SILO data at Dendrobium)

2.3 Hydrology

Dendrobium Mine is located within the catchments of the Avon and Cordeaux Rivers, which are tributaries of the Upper Nepean River. Drainage is generally to the north-northwest, towards the Nepean River, with most of the local surface runoff initially captured in Cordeaux, Avon, Nepean and Cataract lakes, before eventually flowing into the Nepean River. These lakes are reservoirs operated by WaterNSW as part of the water supply network for Sydney. Lake levels are regulated by controlled releases and overflow at the reservoir dams.

Longwalls 22 and 23 are oriented broadly east-west, spanning the ridgeline between Wongawilli Creek and Lake Cordeaux. Approximately 30 % of the longwall area sits within the Wongawilli Creek catchment and ~70 % within the Lake Cordeaux catchment. The study area as defined by the 600 m distance buffer overlaps with several sub-catchments Wongawilli Creek and Lake Cordeaux as listed in Table 3. Of these, tributaries LC5, LC6, WC26 and WC24A cross the proposed longwall footprint over part of their length.

Table 3. Sub-catchments overlapping the Longwall 22 and 23 study area.

Catchment	Sub-catchment	Area (Ha)	Catchment Area over LW (Ha)	Catchment Area within 400 m (Ha)	Stream order (Strahler)	Length (m) within 400m
Lake Cordeaux	Lake Cordeaux	7982.3	99.1 (1.2%)	291.9 (3.7 %)	n/a	595 (shoreline)
	LC4	83.6		2.3 (2.8 %)	2	
	LC5	193.3	73.4 (38.0 %)	162.8 (84.2 %)	2	1708 (82%)
	LC6	117.4	22.5 (19.2 %)	65.8 (56.1 %)	1	1360 (67%)
	LC7	35.4	2.9 (8.2 %)	34.9 (98.6 %)	1	487 (100%)
	LC8	13.7			1	
	LC9	72.0		2.4 (3.4 %)	2	
Cordeaux River	CR36	175.1		15.4 (8.3 %)	2	
Wongawilli Creek	Wongawilli Creek	2030.2	48.8 (2.4 %)	153.9 (7.6 %)	3	555 (5%)
	WC20	45.0		5.3 (11.7 %)	1	
	WC21	238.6			2	
	WC22	15.6			1	
	WC23	29.7		0.2 (0.5 %)	1	52 (7%)
	WC24	55.8	16.9 (30.2 %)	55.8 (100%)	2	1028 (100%)
	WC25	24.8			1	
	WC26	56.4	32.1 (56.9 %)	56.0 (99.3 %)	2	1046 (91%)
	WC28	18.3		7.1 (38.7 %)	1	

2.3.1 Wongawilli Creek

Wongawilli Creek is a third-order perennial stream that flows north to join the Cordeaux River approximately 4 km north of Area 3B (Longwall 9) or 3 km north of Area 3C Longwall 23. Wongawilli Creek has two gauging stations along its main third-order watercourse (WWU upstream and WWL downstream of mining operations) and three gauging stations in the lower reaches of major tributaries WC12, WC15 and WC21. Prior to the 2017-2019 drought, Wongawilli Creek (WWL) typically recorded flow on more than 95% of days. Baseflows in Wongawilli Creek are sustained by groundwater discharge from the Hawkesbury Sandstone (HBSS) and to a much lesser extent from formations underlying the HBSS that are exposed in the valley floor upstream of the study area near Area 3B (Bald Hill Claystone [BACS] and Colo Vale Sandstone [CVSS]). During the 2017-2019 drought the number of days with recorded flow (> 0.01 ML/d) dropped to 21 % in 2018 before recovering to 90 % in 2020.

The main third-order channel of Wongawilli Creek is approximately 345 m and 320 m from Longwalls 22 and 23 at its closest approach and is within 400 m of the proposed longwalls over 555 m of stream length. Tributaries WC24A, WC26A and WC26 cross the longwall footprint; tributaries WC24 and WC23 which is on the western side of Wongawilli Creek is within 400 m of the longwalls to a distance of 52 m above the confluence. Other Wongawilli Creek tributaries are beyond 400 m from the longwalls.

2.3.2 Lake Cordeaux

Longwalls 22 and 23 are both offset from Lake Cordeaux Full Supply Level (FSL) by 300 m; a total of 595 m of shoreline is within 400 m of the longwall footprints. The Avon Dam structure is located 2.7 km to the north-northeast of Longwall 23.

Tributaries LC5 and LC6 cross the longwall footprint of both proposed panels, with reaches of length 1,708 and 1,360 m within 400 m. LC7 does not cross the longwall footprint directly; however, the tributary is entirely within 400 m of the longwalls (487 m of its length). Other tributaries to Lake Cordeaux are beyond 400 m from the proposed longwalls.

2.3.3 Cordeaux River

Tributary CR36 flows northward, parallel to Wongawilli Creek, to join the Cordeaux River approximately 100 m upstream of the Wongawilli Creek confluence and approximately 2.4 km downstream of Cordeaux Dam. The upper reaches of CR36 are 437 m from Longwall 23 at its closest point. Gauging station CR36S1 is located on Fire Road 6 and was installed in September 2019. The gauge recorded flow on 80 % of days in 2020.

2.4 Hydrogeology

Dendrobium Mine is located within the Southern Coalfield which is one of the five major coalfields that lie within the Sydney Geological Basin. The stratigraphy of the Southern Sydney Basin is shown in Figure 5. The Basin is primarily a Permo-Triassic sedimentary rock sequence, underlain by undifferentiated sediments of Carboniferous and Devonian age. The Bulli and Wongawilli Coal Seams are the primary target seams in the top part of the Illawarra Coal Measures and, like previous longwalls at Dendrobium, the Wongawilli Coal seam is the target for Longwalls 22 and 23.

The Coal Measures are overlain by Triassic sandstones, siltstones and claystones of the Narrabeen Group and the HBSS. The HBSS is the dominant outcropping formation across the mine area, but lower stratigraphic units (BACS, Narrabeen Group) are exposed in deeply incised parts of Wongawilli Creek and along the south-eastern shores of Lake Cordeaux. The Bulgo Sandstone is exposed along the Lake Cordeaux shoreline near Area 2, to the southeast of Longwall 22, and is inferred to subcrop to the east of Longwalls 22 and 23 along the axis or thalweg of the flooded valley that is now Lake Cordeaux.

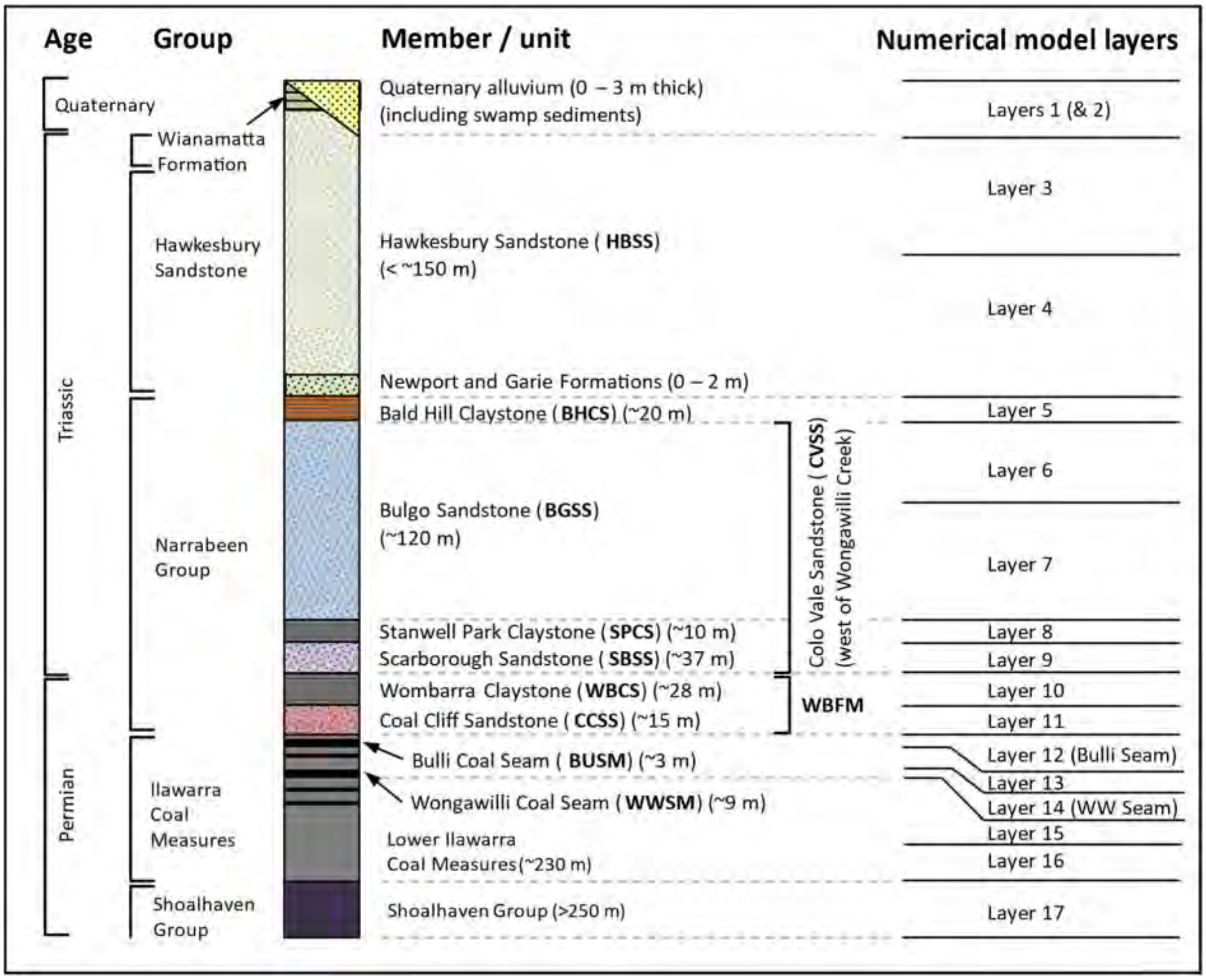


Figure 5. Stratigraphy of the Southern Coalfield and groundwater model layers

Three main groundwater systems are recognised:

1. Perched groundwater systems associated with swamps and shallow sandstone. These may be ephemeral and/or disconnected from the deeper groundwater systems;
2. Shallow groundwater systems: layered water-bearing zones within the saturated HBSS; and
3. Deeper groundwater systems within the Narrabeen Group and the Illawarra Coal Measures.

Recharge to the aquifer systems comes primarily from rainfall infiltration through outcropping formations, generally the HBSS in the western half of the Dendrobium Mine area and the Bulgo Sandstone in the eastern half. There will be some recharge from the Reservoirs and streams to host formations at times of high water level and creek flooding. In the western part of Area 3B, the Stanwell Park Claystone pinches out such that the Bulgo and Scarborough Sandstones form a single unit, the CVSS.

Strong topographic relief and recharge drive vertical groundwater flow near the ground surface, but at depth the alternation of aquifers and aquitards promotes horizontal groundwater flow at the base of permeable units. In general, groundwater flow in shallow systems is strongly influenced by local topographical features such as streams and lakes, whereas deeper groundwater systems are influenced by regional topographic and drainage patterns (Toth, 2009). Regional groundwater flow in the deeper sandstone units (pre-development) is predominantly northwest, towards the Nepean River system and away from the Illawarra escarpment.

Discharge from the groundwater systems occurs naturally at the surface to creeks (contributing to stream baseflow) and to the reservoirs as baseflow and seeps, and as evapotranspiration. Along the escarpment to the south-east of Dendrobium Mine, groundwater discharge appears as seeps in cliff faces at the junction of formations with contrasting permeability.

Groundwater piezometric levels are shown on Figure 3 for monitoring bores located near the cross section, including water level observations in the recently drilled Elouera Fault investigation holes, and estimates of the water level within the abandoned Elouera Mine workings.

2.4.1 Faults and lineaments

Major faults and lineaments that cross the study area are shown in Figure 1. Most mapped faults are known from underground workings and therefore relate to the Wongawilli coal seam. Lineaments (shown in purple) are linear features identified from aerial photography, Lidar or geophysics. Lineaments typically relate to prominent rock joints, fracture zones, faults or dykes that are preferentially eroded or which control the course of a creek or river. Such geological features may represent linear or planar zones of enhanced permeability and therefore have the potential to propagate groundwater drawdown impacts to a greater distance from the mine footprint than otherwise would have been the case.

SRK (2020) assessed the presence of surface structures, including lineaments, and the role these might play in increasing subsidence and environmental impacts around mining areas at Dendrobium. SRK noted that the conditions at Dendrobium (Southern Coalfield) are different to those in the Western Coalfield (e.g. at Springvale Mine) where lineaments around mining areas increased subsidence effects to significant distances, leading to the transmission of effects out to hundreds of metres or a kilometre or so from Springvale workings. Based on analysis of repeated Lidar surveys, SRK concluded that "*longwall mining activities to date at Dendrobium appear to have had little or no effect in the reactivation of surface lineaments*" and "*minor [apparent] movement is mostly restricted to areas above individual longwall panels*. The potential for reactivation of surface lineaments extending outside the planned longwall areas was assessed as low.

The following mapped structural features pass within 400 m of Longwalls 22 and 23:

- A zone of igneous dykes and associated surface lineaments passes between Longwalls 21 and 22, oriented broadly parallel to Longwall 22. The features pass within 100 m of the Longwall 22 footprint and intersect Wongawilli Creek, WC24, LC5, LC6 and Lake Cordeaux.
- A north-south oriented surface lineament passes within 160 m of Longwall 22 and intersects tributaries LC7, LC9, possibly extending to the shoreline of Lake Cordeaux. The mapped features are underlain, and potentially intersected by, first workings for Longwall 22 (Pioneer Mains).

These features and their potential influence on groundwater impacts are discussed in the groundwater assessment report by Watershed Hydrogeo (2021).

2.5 Upland Swamps

Coastal Upland Swamps are endemic to the eastern part of the Sydney Basin and have a significant role in catchment hydrology. They are listed as an endangered ecological community under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*, and the NSW *Biodiversity Conservation Act 2016*. Upland Swamps are typically located at the headwaters of low order streams, on low relief plateaus on low permeability HBSS. Swamp vegetation is highly variable, ranging from open graminoid (grassy) heaths and sedgelands to fernlands and scrub (Threatened Species Scientific Committee (TSSC), 2014).

The location and extent of mapped swamps is shown in Figure 6 and is derived from a combination of mapping by the NSW Office of Environment and Heritage (OEH), ecological consultants and the Illawarra Metallurgical Coal Environmental Field Team (IMCEFT). There are fourteen swamps located entirely or partially within the study area based on the 600 m buffer and the 35° angle of draw line for Longwalls 22 and 23. Those swamps are listed in Table 4, which lists swamp position in relation to the landscape and the dominant vegetation communities. Two swamps (Swamp 7 and Den 153) partially or entirely overlie the longwall footprints and a further six swamps extend within 400 m of the longwall footprints.

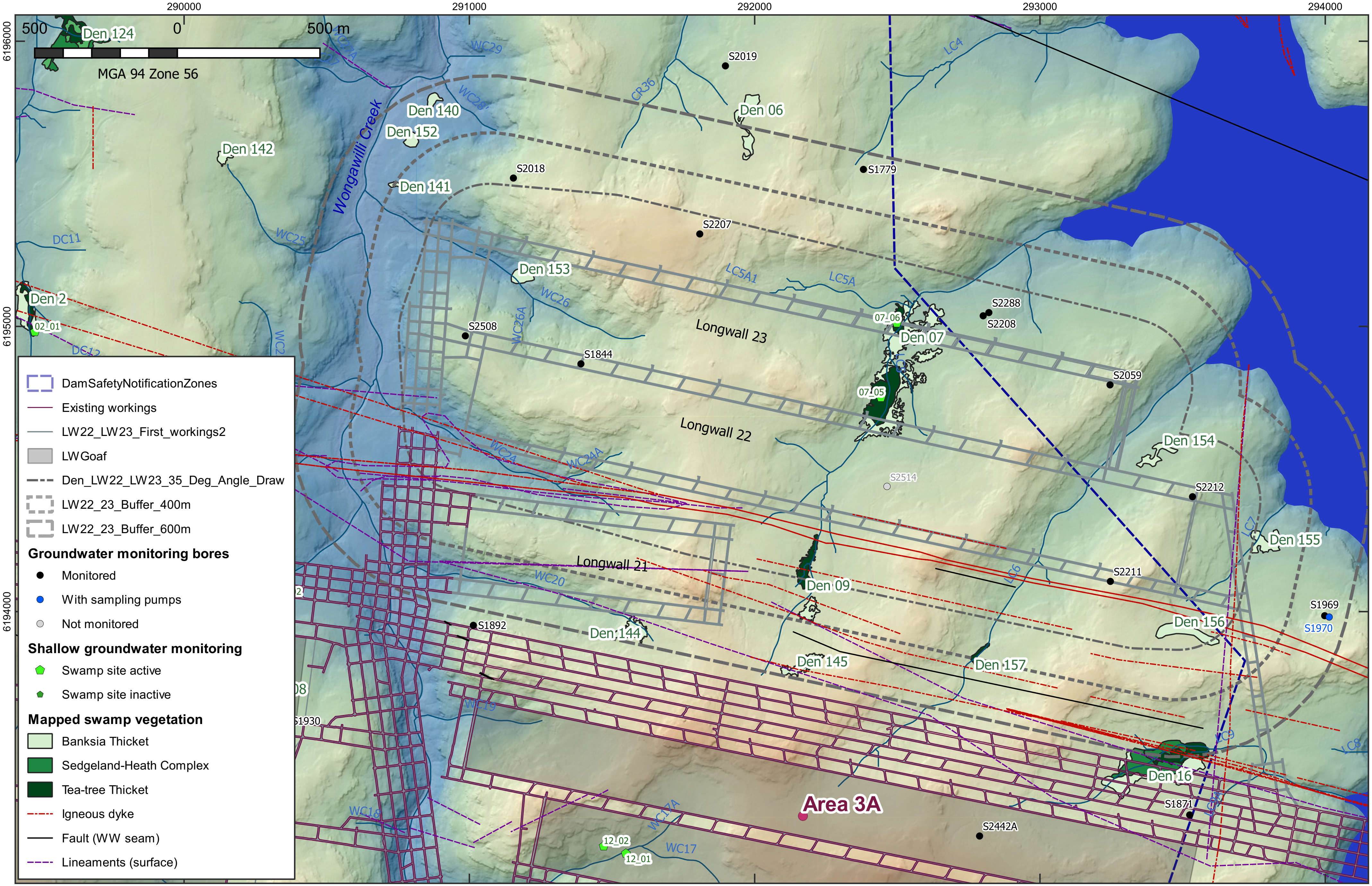
Table 4. Swamp vegetation communities within the study area

Swamp	Area (ha)	Position	Vegetation communities	Minimum Distance from LW (m)	Monitoring	
					Shallow GW	Soil Moisture
Den06	0.57	Valley side (CR36)	Banksia Thicket	488		
Swamp 7	4.87	Valley floor (LC5)	Banksia Thicket, Tea Tree Thicket	0	07_05, 07_06	S07_S05, S07_S06
Swamp 9	0.79	Valley floor (LC5)	Banksia Thicket, Tea Tree Thicket	90		
Den16	3.75	Valley floor LC9	Banksia, Tea Tree Thicket, Sedgeland-Heath Complex	542		
Den140	0.16	Valley side (WWC)	Banksia Thicket	527		
Den141	0.08	Valley side (WWC)	Banksia Thicket	360		
Den144	0.54	Valley floor (WC20)	Banksia Thicket	503		
Den145	0.41	Valley side (LC5)	Banksia Thicket	498		
Den152	0.22	Valley side (WWC)	Banksia Thicket	436		
Den153	0.29	Valley floor (WC26)	Banksia Thicket	0		
Den154	0.40	Valley side (LC6)	Banksia Thicket	73		
Den155	0.50	Valley floor (LC7)	Banksia Thicket	209		
Den156	0.71	Valley side (LC7)	Banksia Thicket	130		
Den157	0.12	Valley floor (LC6)	Tea Tree Thicket	336		

The structure and hydrological function of Coastal Upland Swamps has been well studied by Young (1982), Tomkins and Humphreys (2006), Cowley *et al*. (2016), Fryirs *et al*. (2014), and others. Upland

Swamps form on accumulations of sandy and silty sediments on the broad and gently sloping headwater valleys. Measured cross-sections indicate a reasonably consistent structure: A basal layer of grey-brown, medium to coarse sand is overlain by increasingly organic rich sands and organic fines. There is commonly a lateral variation in facies caused by the fractionation of sediments during overland flow such that grey-brown sands accumulate at the swamp margins, whereas finer-grained sediments (silt, mud) and organic material accumulate towards the swamp axis (Young, 1982). Fibric mats of live and dead organic matter occur at the swamp surface, up to a depth of approximately 50 cm, providing some protection from erosion during runoff events. Episodes of scouring and erosion occur naturally with a periodicity of several thousand years (Tomkins and Humphreys, 2006) and are thought to be caused by high intensity rainfall-runoff events, possibly following wildfires.

Ground subsidence and near-surface fracturing related to longwall mining can impact swamp hydrology as has been observed during mining at Dendrobium Areas 3A and 3B. Those effects are discussed further in Section 4.

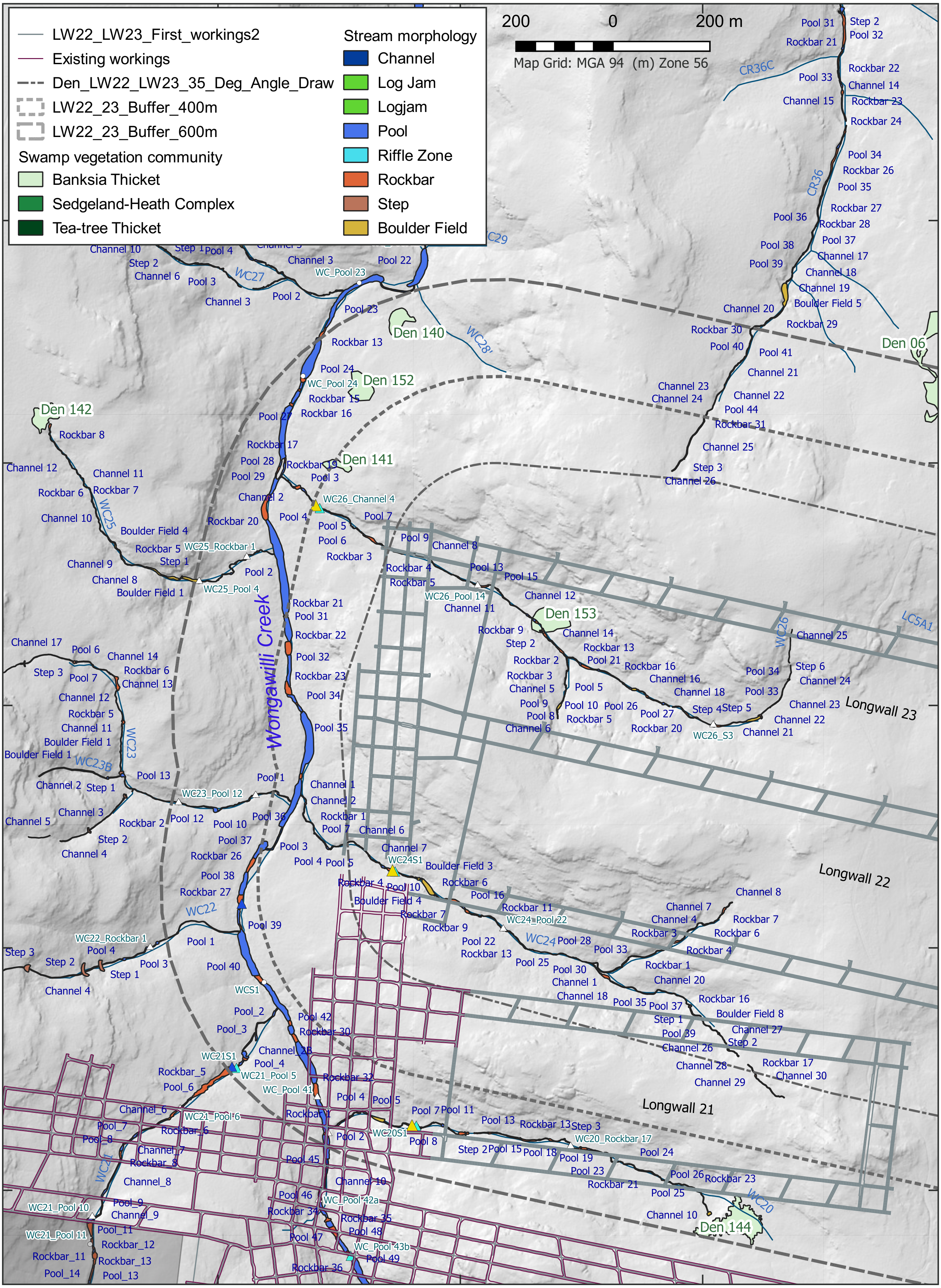


Dendrobium Longwalls 22 & 23 Surface water assessment

Mapped swamp vegetation, groundwater monitoring and geological structure

Figure 6

file: Dendrobium5.qgz

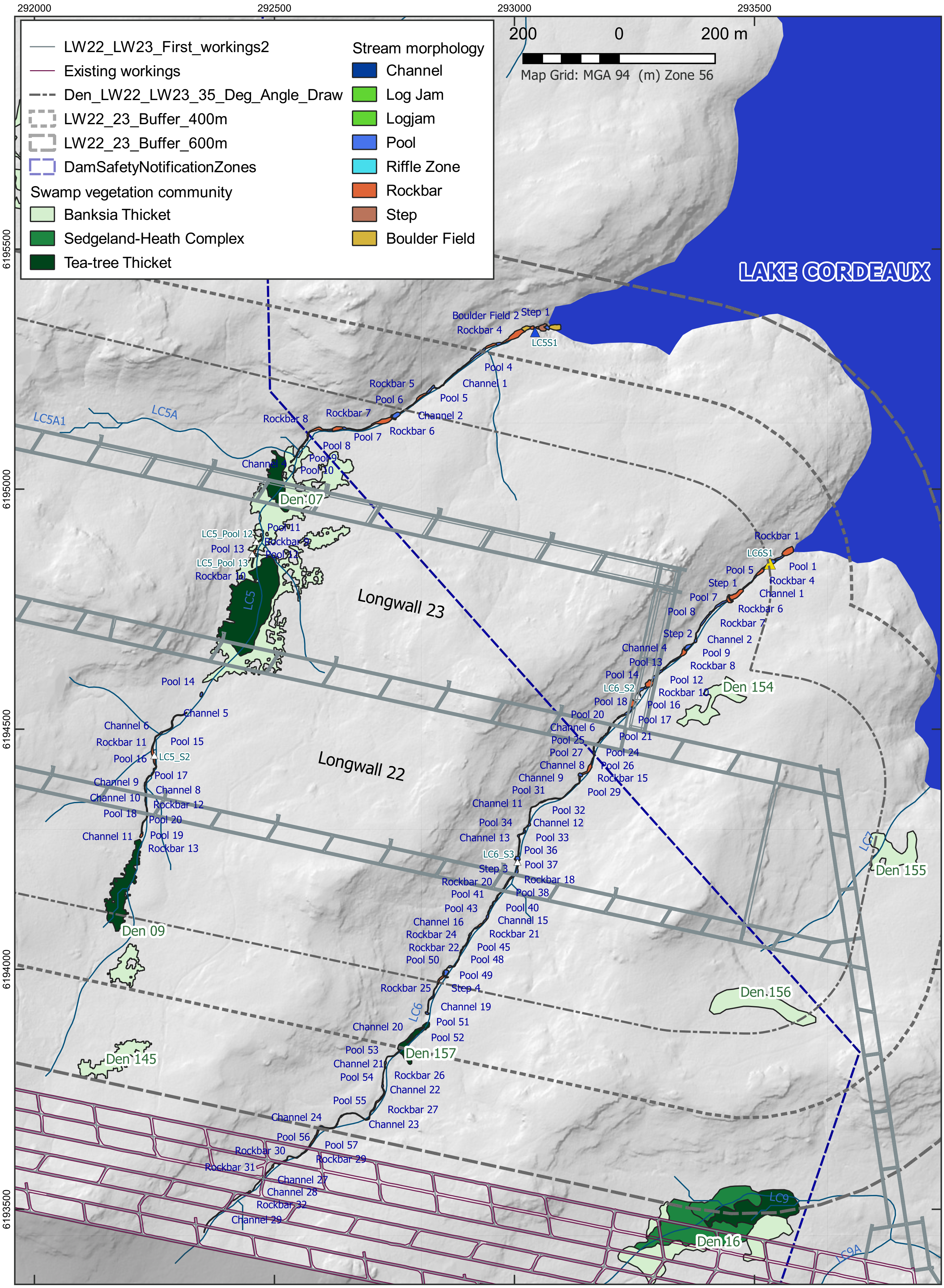


Dendrobium Longwalls 22 & 23 Surface water assessment

Figure 7

Stream morphology mapping (Wongawilli Creek)

file: Dendrobium5.qgz

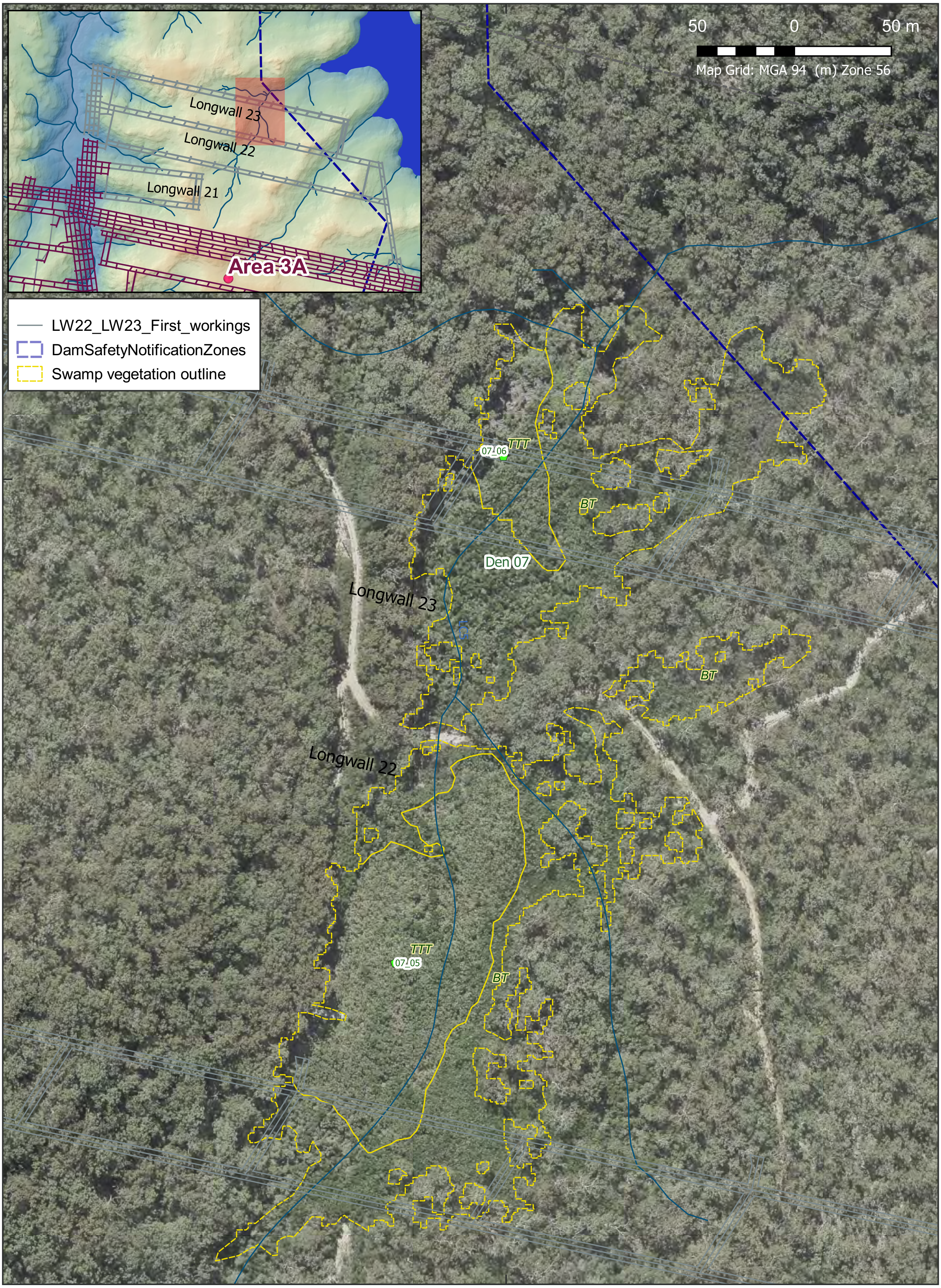


Dendrobium Longwalls 22 & 23 Surface water assessment

Stream morphology mapping (LC5 and LC6)

Figure 8

file: Dendrobium5.qgz

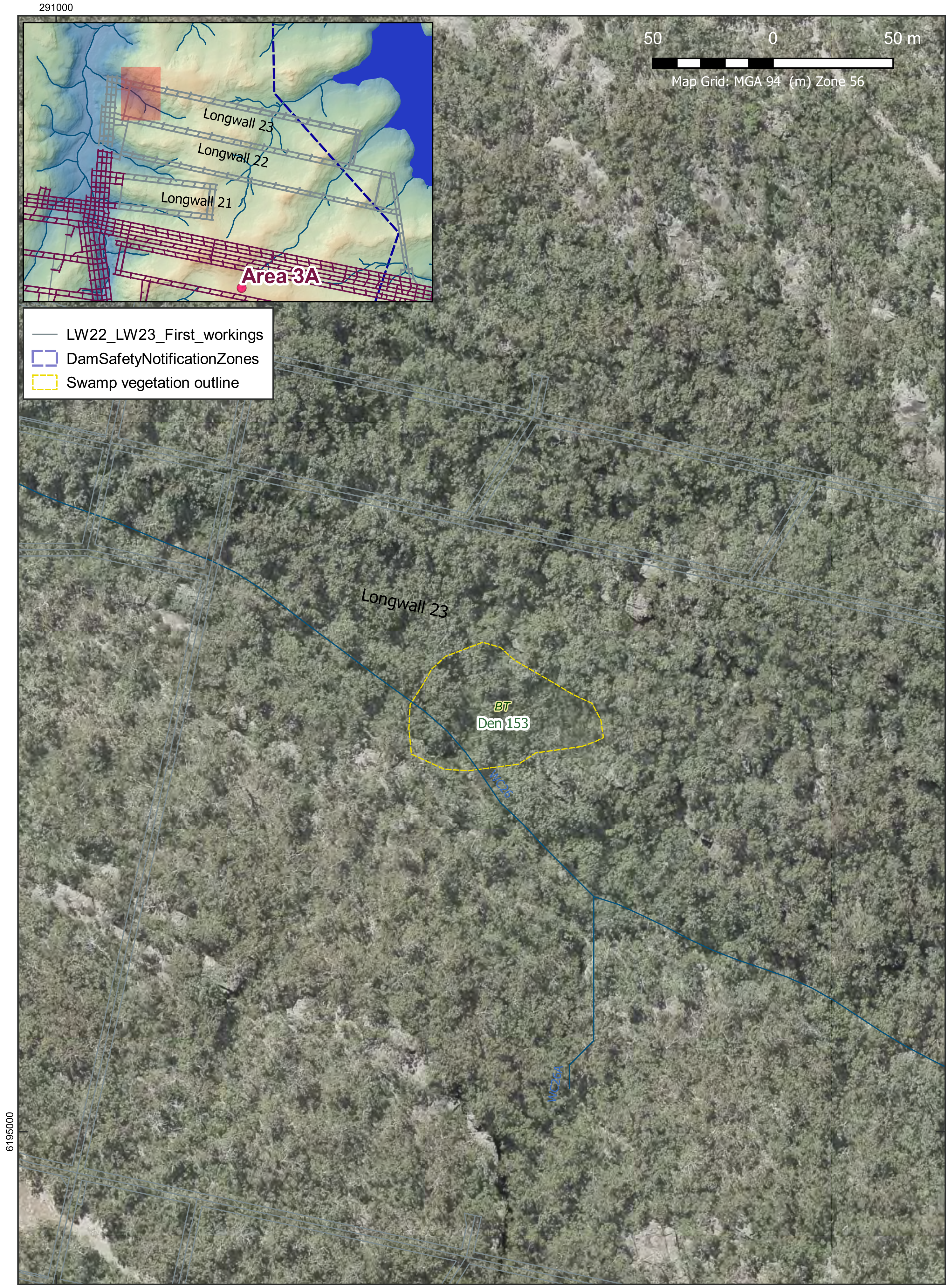


Dendrobium Longwalls 22 & 23 Surface water assessment

Swamp 7 Air photo (April 2020)

Figure 9

file: Dendrobium5.qgz



hgeo.com.au

Dendrobium Longwalls 22 & 23 Surface water assessment

Swamp Den 153 Air photo (April 2020)

Figure 10

file: Dendrobium5.qgz

3. BASELINE ASSESSMENT

3.1 Monitoring

This section outlines the network of monitoring infrastructure and sites operated by IMC that are relevant to the study area. Further details of monitoring sites and procedures are outlined in the Dendrobium Area 3B WIMMCP (South32, 2020a).

3.1.1 Geomorphological mapping

Stream bed morphology has been mapped in detail by the IMCEFT to provide baseline observations in all active and proposed mining areas. Mapping involved characterisation of the watercourse in terms of its bed characteristics (e.g. channel, pool, riffle, rockbar, etc.), sediment type and vegetation. Key features are mapped and photographed for comparison during and after mining. Major streams and tributaries to Lake Avon and Wongawilli Creek adjacent to proposed Longwalls 22 and 23 have been mapped as part of previous assessments for mining at Dendrobium Mine (Figure 7 and Figure 8). Each feature is photographed, and changes noted during regular monitoring events.

3.1.2 Surface Water Monitoring

Monitoring of surface water is carried out at numerous sites across the Dendrobium Mine lease by the IMCEFT on a monthly basis prior to mining and on a weekly basis during mining, as part of the Area 3B WIMMCP (South32, 2020a). There are 18 active monitoring sites on tributaries to Lake Cordeaux and Wongawilli Creek (and their sub-tributaries) within 600 m of the proposed longwalls. Stream monitoring sites within the study area are shown in Figure 1. Those sites at which flow conditions are recorded and/or water chemistry data is collected are listed in Table 5 (monitoring dates shown). Flow observations consist of records ranging from “no flow observed” through “trickle observed” to “surface flow observed”. The list includes selected gauging sites beyond the study area that provide down-gradient impact monitoring (green shading) and up-gradient control points (blue shading).

Table 5. Surface water monitoring sites relevant to Longwalls 22 and 23

Catchment	Site	East (MGA94)	North (MGA94)	Field obs. from	Chemistry sampling	Flow gauge
Wongawilli Creek	WWU1	291131	6188146	15/08/2001	WWU1	
	WWU	290808	6189716	1/01/2008		WWU
	WWU4	290798	6189962	17/07/2002	WWU4	
	WC_Pool 43b	290774	6193865	17/04/2008	Yes	Level logger
	WC20S1 (approved)	290890	6194130	N/A		
	WC_S1	290549	6194591	28/02/2012	WC_S1	Level logger
	WC24S1 (approved)	290870	6194650	N/A		
	WC24_Pool 10	290866	6194658		Yes	
	WC26S1 (approved)	290725	6195400	N/A		
	Wongawilli Ck (FR6)	290960	6197376	15/05/2001	WC_FR6	WWL_A
	WWL	290975	6197526	2/11/2007		WWL
Cordeaux River	CR36S1	291482	6197652	12/09/2019	CR36_S1	CR36S1
	CR_S1	291673	6197592	28/10/2016	CR_S1	

Catchment	Site	East (MGA94)	North (MGA94)	Field obs. from	Chemistry sampling	Flow gauge
	CR_S2	289575	6202472	1/11/2016	CR_S2	
Lake Cordeaux	Sandy Creek Arm	293960	6192865	11/02/2006	Yes	
	LC5S1	293043	6195327	28/03/2019	LC5_S1	LC5S1
	LC6S1 (proposed)	293495	6194813	N/A	LC6_S1	LC6S1

The monitoring of water quality parameters provides a means of detecting and assessing the effects of streambed fracturing or the emergence of ferruginous springs. Monitoring includes measurement of field parameters (pH, Electrical Conductivity (EC), Dissolved Oxygen (DO), Oxygen Reduction Potential (ORP) and laboratory tested analytes (DOC, Na, K, Ca, Mg, Filt. SO4, Cl, T. Alk., Total Fe, Mn, Al, Filt. Cu, Ni, Zn, Si). Stable isotopes ($\delta^{18}O$, $\delta^{2}H$, ^{13}C) and tritium are analysed at selected locations to provide baseline data for environmental tracer studies.

3.1.3 Shallow Groundwater Monitoring

Figure 6 shows areas of swamp vegetation as mapped by ecological consultants Niche and IMC. Hydrological baseline characteristics and mining effects at swamps are monitored using shallow (1 to 3 m) piezometers and soil moisture sensors. Figure 6 shows the locations of shallow groundwater monitoring sites in the vicinity of Longwalls 22 and 23.

The Trigger Action Response Plan (TARP) related assessments carried out as part of the SMP relate to those piezometers located within Upland Swamp sub-community areas mapped as Banksia Thicket, Sedgeland-heath complex and Tea Tree Thicket; being listed as Costal Upland Swamp Endangered Ecological Community (EEC). Piezometers located within fringing Eucalypt Woodland are excluded from the TARP related assessment as per the advice from OEH (dated 17/01/2014).

3.1.4 Soil moisture monitoring

Soil moisture profiles are monitored at most swamps, with sensor arrays typically positioned near shallow piezometers (where possible). Where possible the monitoring arrays are numbered according to the corresponding piezometer (if present) with an 'S' prefix. At most locations, five sensors are installed at 20 cm depth intervals to a total depth of 1 m.

Soil moisture is measured using Sentek sensors which monitor changes in the dielectric constant within a cylinder of soil extending to a radial distance of 10 cm from the access tube. Soil moisture is reported as mm water per 100 mm soil depth (or volumetric % water) at each monitored depth (Sentek, 2017). The most recent installations are equipped with automated data loggers set to record moisture levels every hour, whereas previous installations are recorded manually during scheduled site visits.

3.2 Baseline conditions

3.2.1 Stream flow and catchment yield

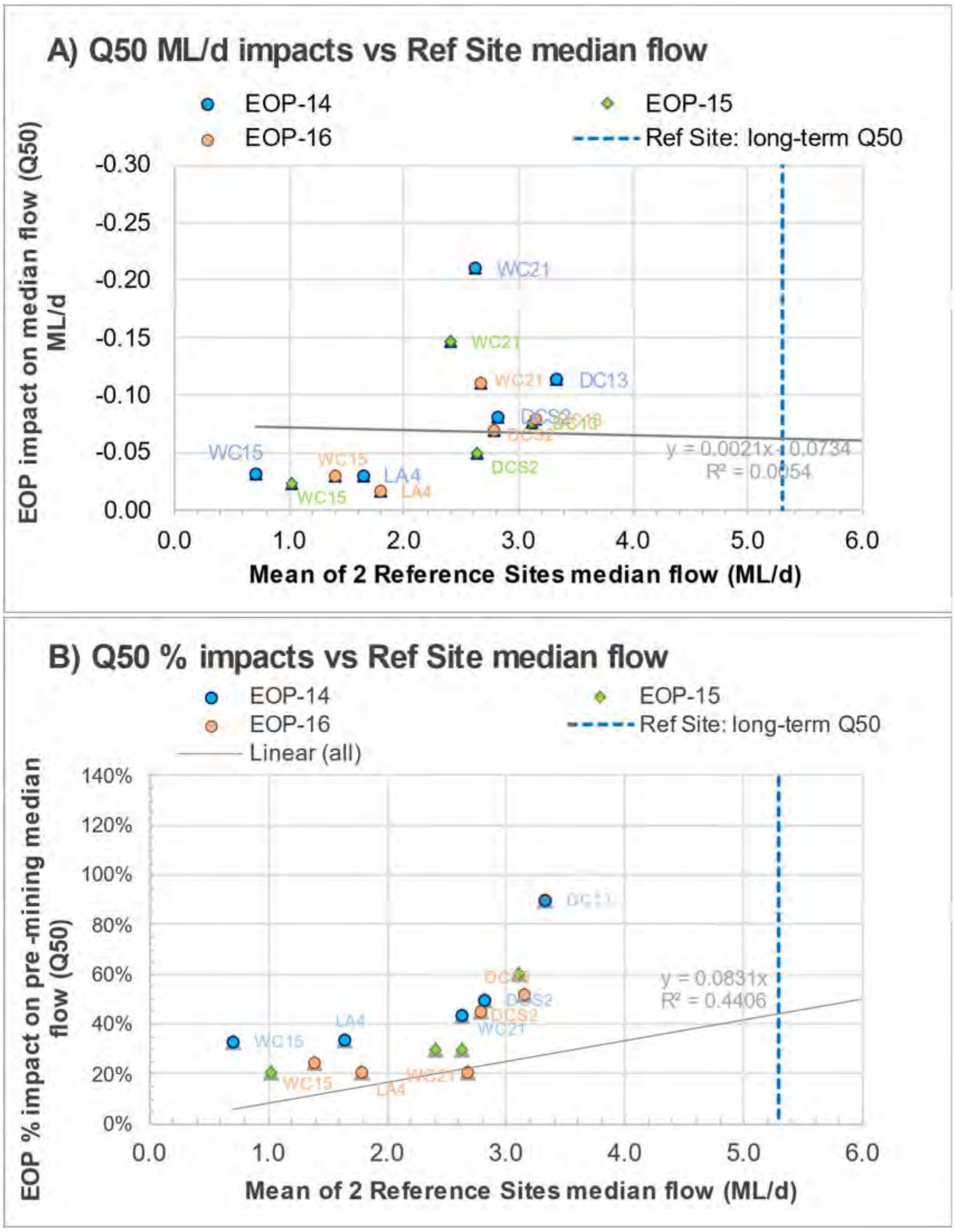
Table 6 lists stream flow gauging stations relevant to the study area, including those located outside the study area that will be used as downstream monitoring sites. The baseline period to 2020 includes data collected over the severe drought of 2018-2019. The last column of Table 6 summarises the effects on stream flow that are attributed to mining in previous reports.

Based on 13 complete years of data at WWL on Wongawilli Creek, average flow in Wongawilli Creek is approximately 14.8 ML/d, while the long-term median flow (Q50) is approximately 3.6 ML/d. Within the monitoring period, 'wet' years have an average of approximately 22 ML/d and Q50 of 6 ML/d, based on the four wettest years. 'Dry' years have an average of approximately 8 ML/d and Q50 of 0.9 ML/d, noting that during 2018 (in the middle of the recent drought), Q50 at WWL was <0.01 ML/d.

The assessment of mining effects on surface water flow or yield around Area 3B is carried out for End of Panel (EoP) reports using recently agreed TARP methods (Watershed HydroGeo, 2019a and South 32, 2020). The new assessment analyses median flow (Q50), cease-to-flow frequency, and general hydrological behaviour, using a comparison against flow at two Reference Sites for the corresponding pre- and post-mining periods. A trial of these assessments was conducted for the Longwall 14 assessment period (Watershed Hydrogeo, 2019a) and then the first formal assessment using the new TARP methods was carried out in HGEO (2020a). A summary of the mining effects based on the most recent EOP report for Longwall 16 is in Table 7.

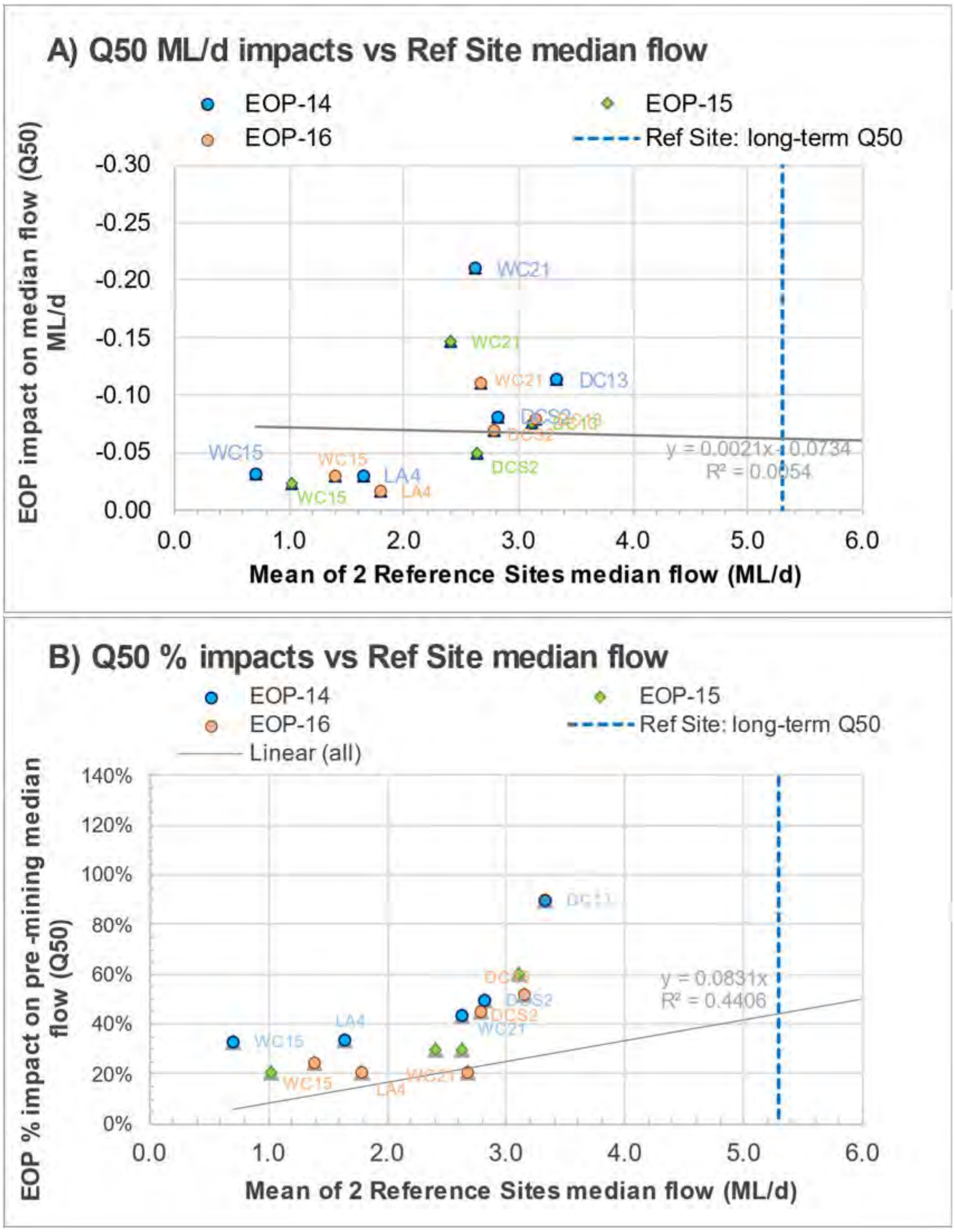
Effects on surface flow were evident at all headwater subcatchments that have been mined under, e.g. DC13, DCS2, WC21, WC15, LA4. The impacts are evident in all three assessments relevant to these sites, most significantly an increase in the frequency of cease-to-flow conditions and a reduction in Q50. As reported in HGEO (2020a, 2021), impacts on Q50 at the sites listed here, when compared to gauged pre-mining Q50, were equivalent to reductions of 20-60% of median flow.

The results of the assessment of impacts on Q50 from the two recent assessments is summarised on the following charts. The x-axis shows the average of the median at the two Reference Sites for the relevant post-mining periods (these periods are different for different 'Assessment Sites due to their position above or near different longwalls). This Reference Site median flow is a measure of the 'wetness' or availability of flow in each period.



On

- Figure 11A, this is compared to the estimated surface water loss, expressed as a percentage of the pre-mining median flow at each site.



On

- Figure 11B, this is compared to estimated surface water loss, expressed as a percentage of the estimated 'expected flow' at each site during that period. The expected flow is based on the 'un-impacted' Reference Sites.

In both Figures, the trend is that the impact increases (on the Y-axis) with increasing Reference Site flow (x-axis). Reference Site flow or 'wetness' is not the only factor that will affect the magnitude of impact; that will be influenced by the fraction of the sub-catchment that is affected by mining, the period for which mining has occurred in that catchment, as well as depth of cover and topographic effects.

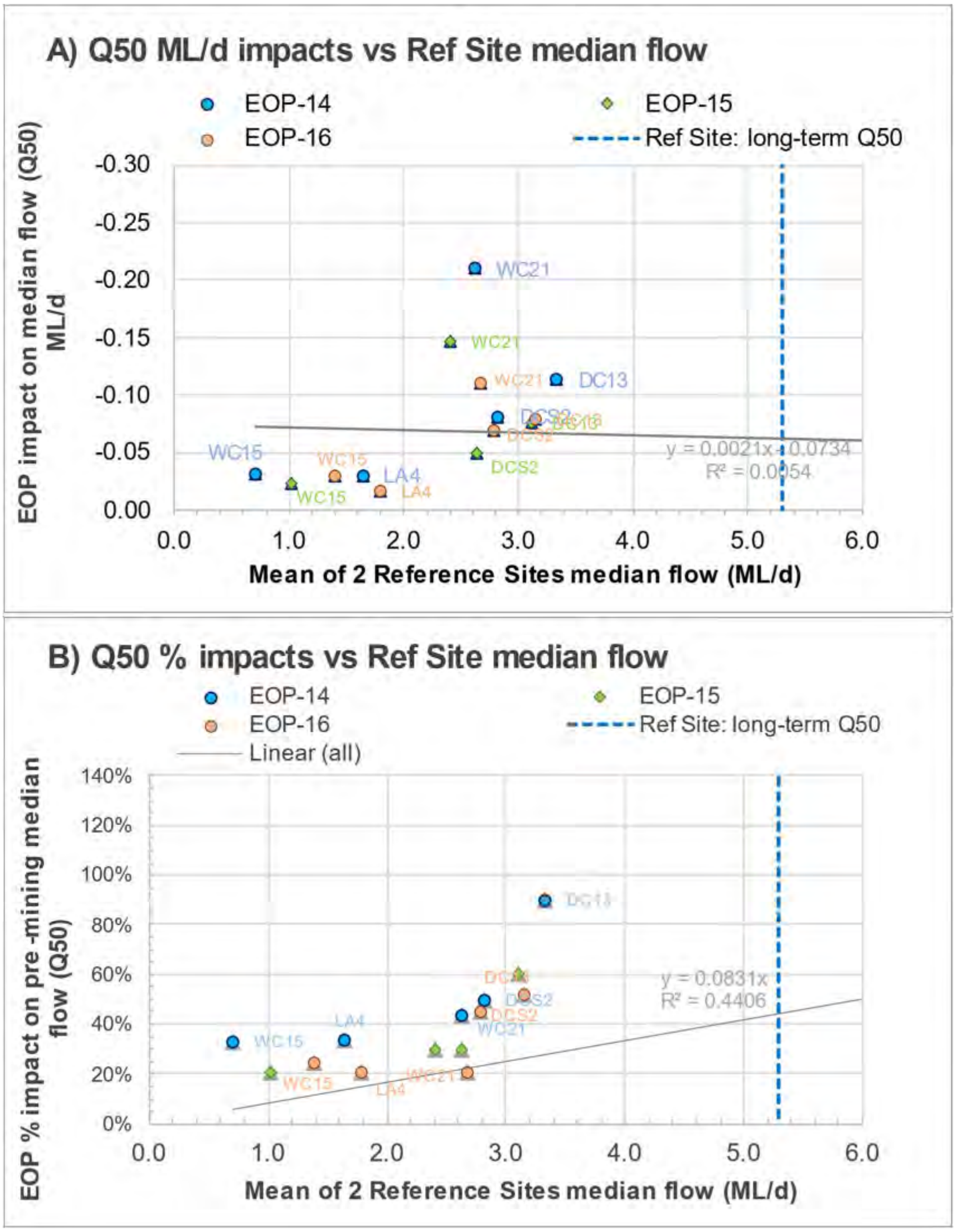


Figure 11. Historical flow impacts compared to Reference Site flows

Between EOP14, EOP15 and EOP16, the mined area of catchment for DC13, DCS2, and LA4 did not change, and barely changed in WC21. The other parameters (depth of cover and topographic effects) were also constant, and the assessed impacts generally declined from EOP14 through EOP15 to EOP16, although some subcatchments are variable (e.g. losses in ML/d at DCS2 were estimated to be lower in EOP15 than in both EOP14 and EOP16). As a result, the data does suggest that ‘wetness’ may lead to greater impact, i.e. the concept that if there is more rainfall and flow, then there is more surface water flow that can be lost to fracturing and drawdown. If there is no rainfall and no flow or little flow, then there is less flow that can be lost.

The estimated losses (Watershed 2019a and HGEO, 2021) appear reliable and consistent with field observations. However, both these periods are limited to periods dominated by drought conditions. This is shown by comparing the Reference Site median flow for the EoP periods shown on the x-axis of these charts against the long-term Reference Site median flow (the dashed blue line on Figure 11). This confirms that flow averaged over recent years is low (30-50%) compared to long-term average conditions, although higher rainfall in 2020 and continuing into 2021 (Section 2.2) is causing that recent average to increase toward the long-term average.

The implication is that if rainfall and flow revert to average conditions (and conditions thus far in 2020-2021 point to higher than average rainfall and flow), then reductions to stream flow may rise – not because of changes to the physical mining effects (fracturing and drawdown), but due to the increased availability of surface water flow. There is not historical data to indicate how much the reductions may rise, but the trends on Figure 11 and the ratio of recent Reference Site median flow compared to the long-term average suggests that an increase in overall reductions by 2-3 times, and potentially more, compared to that assessed in the recent EoP reports is plausible.

Table 6. Stream flow gauging stations relevant to the study area

Water-course	Gauge	Catch-ment Area (km^2)	Pre-mining gauged record			Representative* pre-mining baseline 2008-2020			Post-mining record		Annual no-flow days	Observed mining effects
			Period	Median flow (ML/day)	Mean flow (ML/day)	Median flow (ML/day)	Mean flow (ML/day)	Yield (%rain)	Median flow (ML/day)	Mean flow (ML/day)		
Wongawilli Creek	WWU	3.21	02/11/2007-12/06/2020	0.27	3.29	0.27	3.29	33%	n/a	n/a	20 (5.5%)	Although Elouera Colliery did mine in this catchment, it is considered to be an upstream control site. There is no impact from Dendrobium mining.
Wongawilli Creek	WWL	20.08	02/11/2007-09/02/2010	3.66	11.70	3.08	14.78	26%	2.90	15.45	Pre→ Post 30 → 17 (8→4%)	No evidence for change of flow characteristics at downstream gauge compared to reference sites**
LC5	LC5S1	1.86	04/04/2019-01/02/2021	0.12	0.74	0.13	0.8	30%	n/a	n/a	12%	
LC6	LC6S1	1.16	(proposed)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	Proposed, not yet installed
Cordeaux River tributary	CR36S1	1.75	05/09/2019-01/02/2021	0.03	2.68	0.05	1.8	30%	n/a	n/a	25%	
WWC tributaries	WC20	0.44	(approved)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	Approved, not yet installed
	WC24	0.50	(approved)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	Approved, not yet installed
	WC26	0.55	(approved)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	Approved, not yet installed

Statistics are based on the full flow record, accounting for QA assessment by ALS hydrographers. Pre-mining and post-mining are in reference to Dendrobium mining (not Elouera).
**Representative pre-mining* flow statistics based on synthetic series via comparison against reference site (WWU). These are used for subsequent impact assessment, and are used so as not to skew predictions to recent drought conditions (Mar-2017 to Feb-2020).
** Qualitative monitoring of flow condition by IMCEFT between WWU and WWL has shown that baseflow losses are evident at very low flows in reaches close to extracted Area 3A and 3B longwalls, even if effects are not clear at the WWL downstream gauge.

Table 7. Summary of historical effects on stream flow from Longwall 16 EOP report

Site	Watercourse	Area	Date mining occurred under sub-catchment	A) Low flow Q%ile outside Reference Site Q%ile		B) Change in cease-to-flow frequency (beyond natural)		C) Change Q50 (beyond natural) as % of pre-mining Q50			Rainfall-runoff model comparison	Comment
				Change %	TARP Level	Change %	TARP Level	Change ML/d	Change %	TARP Level		
DC13S1	DC13	A3B	9/02/2013	59%	Level 3	20%	Level 2	-0.08	-62%	Level 3	n/a	Effects are similar to those in LW14,15
DCS2	Donalds Castle Creek	A3B	10/07/2013	54%	Level 3	40%	Level 3	-0.07	-45%	Level 3	n/a	Effects are similar to those in LW14,15
DCU	Donalds Castle Creek	A3B	9/02/2013	-6%	Not triggered	8%	Level 1	0.11	30%	Not triggered	Not triggered	Effects are similar to those in LW14,15. This is consistent with findings from rainfall-runoff model.
WC21S1	WC21	A3B	5/10/2013	30%	Level 3	12%	Level 2	-0.10	-21%	Level 3	n/a	Effects are similar to those in LW14,15
WC15S1	WC15	A3B	28/01/2017	20%	Level 3	7%	Not triggered* **(Level 1)**	-0.03	-25%	Level 3	n/a	Similar to LW15. * However, changes to low flow accuracy means that Method B not completely reliable. Level 1 is likely.
WC12S1	WC12	A3B	18/10/2020	-9.9%	Not triggered	-9%	Not triggered	0.012	139%	Not triggered	Not triggered	First panel under catchment. No discernible effect This is consistent with findings from rainfall-runoff model.
WWL	Wongawilli Creek	d/s A3B	9/02/2010	-1%	Not triggered	-1%	Not triggered	0.18	5%	Not triggered	Not triggered	Effects are similar to those in LW14,15. Rainfall-runoff model suggests possible small effect, but insufficient to trigger former TARP – in agreement.
WWLA	Wongawilli Creek	d/s A3B	9/02/2010									No pre-mining baseline record. To be assessed in future EoP report.
LA4S1	LA4	A3B	1/04/2015	11%	Level 1	-10%	Not triggered* **(Level 3)**	-0.02	-31%	Level 3	n/a	Logger failed, not yet replaced. Effects considered to be the same as for Longwall 15. *.Low flows are reported to greater accuracy in post-mining period, so Method B not treated as completely reliable →Level 3 is likely.
LA3S1	LA3	A3B	28/04/2019	38%	Level 3	39%	Level 3	-0.04	-292%	Level 3	n/a	Effects are similar to those following LW15, Similar to LW15, but increase in CTF frequency.
LA2S1	LA2	A3B	01/03/2020	-15%	Not triggered	-23%	Not triggered	-0.006	-294%	Level 3	n/a	LW16 mined under upper part of watercourse. Reduction in Q50.
NDS1	ND1	A3B	Not yet (LW17 or LW18)									To be assessed in future EoP report.

3.2.2 Surface water quality

Water chemistry is monitored at sites on Wongawilli Creek, and tributaries to Lake Cordeaux providing baseline data for those watercourses in relation to Longwalls 22 and 23 (Table 5; Figure 1). Regular sampling and analysis have been carried out at the furthest downstream sites on Wongawilli Creek (at FR6) since 2001. Therefore, there is 12 years of baseline water quality data prior to the development of Area 3B, and >20 years of baseline data for Longwalls 22 and 23. Water chemistry at LC5_S1 and CR36_S1 have been monitored since 2019, providing >2 years of baseline data for Longwalls 22 and 23.

ANZECC (2000) provides a framework for conserving the ambient water quality of streams and lakes through the development of Water Quality Objectives (WQO) based on their agreed environmental values. The approach has been adopted by the NSW Government in the management of the Hawkesbury-Nepean River system (HNCMA, 2008; HRC, 1998). Baseline water quality data (pre-Longwall 9) are summarised and compared against guideline levels for the protection of 95% of freshwater aquatic species (Table 8).

Table 8. Baseline water quality field parameters

Median values (mg/L)	Wongawilli Creek catchment			Lake Cordeaux catchment			ANZECC (2000)# Freshwater 95%
	WWU4	WC_Pool 43B	WC_FR6	LC5_S1	CR36_S1	Lake Cordeaux	
Samples	186	224	859	13	9	173	
Start date	16/09/2002	17/04/2008	15/08/2001	28/03/2019	12/09/2019	11/02/2006	
EC (µs/cm)	84.5	91.0	96.0	114.5	127.0	91.0	30-350[a]
pH (pH units)	**5.4**	**5.6**	**6.1**	**5.4**	**6.0**	6.6	6.5-7.5 [a]
DO (%)	92.9	**68.6**	90.5	96.1	**86.2**	**84.9**	90-110
Temp (°C)	17.3	14.3	17.7	14.5	13.9	18.2	
TDS (mg/L)	62	61	64	78	71	59	
TSS (mg/L)	5	5	5	5	5	5	
Total Alk	1	4	2	1	2	10	-
Cl	19	22	23.6	33	33	18	-
SO4	5	4	3	4	2	3	-
Na	10	12	12	17	17	11	-
K	0.5	1	0.5	1	1	1	-
Ca	0.5	1	0.5	1	1	2	-
Mg	2	3	2	3	2	2	-
Al	0.05	0.03	0.04	**0.09**	**0.06**	0.02	0.055[b]
Fe	0.07	0.29	0.22	0.05	0.15	0.12	-
Mn	0.062	0.112	0.04	0.03	0.029	0.017	1.9
Ni	0.005	0.002	0.001	0.001	0.001	0.001	0.011
Si	1.7	2.1	1.8	2.1	1.9	0.6	-
Zn	**0.024**	**0.013**	0.006	0.005	0.006	0.003	0.008
Total N	0.1	0.1	0.1			**0.35**	0.25 [a]
Total P	0.01	0.01	0.01	0.01	0.01	0.01	0.02 [a]

Guideline trigger vales for protection of 95% of species; (a) Default trigger levels for Upland river systems in south-east Australia. (b) Trigger for Al in water with pH >6.5.

While the ANZECC (2000) guideline provides default trigger values for the protection of aquatic species, its preferred approach is to use local (site) reference data when sufficient baseline data are available. Accordingly, the WIMMCP for Dendrobium Mine Area 3B (South32, 2020a) adopts location-specific trigger levels determined from baseline monitoring data. The TARP levels are set for key water quality parameters (pH, EC and DO; see Section 5).

Streams draining the Dendrobium area contain relatively fresh water (<150 µS/cm) dominated by sodium and chloride ions, reflecting mostly direct rainfall runoff. Water pH is typically mildly acidic (pH 5.4 to 6.6), likely due to drainage from swamps and organic-rich soils. Dissolved trace metals are present in very low concentrations, mostly below the ANZECC guidelines for protection of 95% of freshwater species (where trigger levels are set). An exception is dissolved aluminium and zinc in some locations. Elevated concentrations of zinc in WWU4 may be related to previous mining at Elouera (1994 – 2007) which passed beneath the upper catchment. The slightly elevated aluminium concentrations are to be expected since aluminium (and most metals) are more soluble in waters of low pH, with aluminium being derived from the weathering of aluminosilicate minerals. Median DO levels are variable and typically between 85 and 96% saturation, but as low as 44 % in some frequently isolated pools. Time series plots of field parameters and selected dissolved metals for stream sampling sites relevant to this assessment are shown in Appendix 1.

3.2.3 Shallow groundwater

Swamp groundwater levels in the Dendrobium Mine area have been monitored since 2010, providing baseline data with which to assess the natural hydrological characteristics of swamps, and also the impacts of mine-related subsidence on swamp hydrology. Monitoring of shallow groundwater levels and soil moisture content in Coastal Upland Swamps is prescribed in the Area 3B SIMMCP (South32, 2020b).

Hydrographs for shallow piezometers located at swamps within 600 m of Longwalls 22 and 23 are presented in Appendix 2 (noting that only one swamp is currently monitored – Swamp 7) including reference swamps. Note that prior to Longwalls 22 and 23, Swamp 7 was considered a reference swamp with respect to Areas 3A and 3B. Each hydrograph is plotted relative to ground elevation and the elevation of the piezometer base, longwall timing, rainfall, and the dates that previous longwalls pass under (or within 400 m of) a piezometer. Also plotted on the hydrographs in red is the groundwater level recession rate in mm/day.

Swamp hydrographs display a range of responses reflecting varying hydrological regimes at each swamp and at different locations within each swamp. At most locations, the shallow groundwater level rises sharply to within centimetres of the ground surface after a significant rainfall event (>75 mm in one day), particularly if the event is preceded by rainy days. The shape of the recession curve is characteristic of each swamp and location, with the following responses being common:

- In some swamps, a sharp peak lasting several days following a significant rainfall event, followed by a rapid recession as described below. The sharp peaks represent input from rainfall and subsequent runoff events. An example is at Swamp 87, piezometer 87_01.
- In other swamps, a flat-topped or gently sloping peak with a duration of several weeks, indicating that groundwater levels are sustained near the ground surface following the rainfall event or that there is sufficient water entering the swamp (from rainfall or run-on from up-catchment) and the level of water in the swamp is maintained at a constant elevation by surface drainage. An example is Swamp 85, piezometer 85_02.
- A concave downward recession (seen in Swamp 1b at piezometer 01b_01, prior to mining).
- A concave upward recession (seen in Swamp 23, piezometer 23_02).

In many cases swamp hydrographs display characteristic combinations of the above responses, suggesting that each is indicative of a hydrological (or hydrogeological) control that becomes dominant as the water supply declines after the rainfall event.

The relationship between the swamp shallow groundwater system and the regional (e.g. HBSS) groundwater system is determined through comparison of swamp groundwater levels with piezometric data from the deeper groundwater monitoring network. Swamps that display continuous or near continuous saturation typically have a connection with the regional groundwater table and are therefore partially dependent on groundwater (e.g. Swamps 7). Other swamps are saturated for periods of weeks or months following large rainfall events but remain largely unsaturated during dry periods. Such swamps are typically associated with perching above the interface between the sandstone or claystone substrate and therefore disconnected from the regional groundwater system.

Swamps that have been undermined commonly display hydrological changes shortly following the passage of the longwall beneath the monitoring site. Those hydrological changes are described in Section 4.7.

4. POTENTIAL MINING EFFECTS

Ground subsidence and depressurisation of groundwater systems associated with underground mining can result in a range of effects on surface water and shallow groundwater systems. In this section, potential impacts are identified, and their likelihood and severity assessed in relation to the proposed mining activities.

In relation to Longwalls 22 and 23 the most likely effects are:

1. **Altered drainage and flooding**. Mine subsidence can lead to changes in gradient within watercourses and the general landscape which in turn may lead to a change in the likelihood of ponding, flooding and erosion.
2. **Flow diversions**. The development of fractures in a stream bed may result in diversion of flow from the stream channel to the sub-surface and a measurable reduction in stream flow at monitoring gauges. This effect has the potential to be long-lasting or permanent.
3. **Groundwater drawdown and reduction in baseflow**. Where stream flow is partly sustained by the discharge of groundwater from adjacent aquifers (baseflow), groundwater drawdown or depressurisation due to mining can lead to a reduction in baseflow and additional cease to flow/pool dry days. This effect is likely to be long-lasting (i.e. decades), but not permanent.
4. **Altered surface water quality**. Fracturing of the stream substrate can result in the development of ferruginous springs (iron staining), alteration of water quality parameters and the mobilisation of trace metals which may in turn affect the health of aquatic ecosystems.
5. **Altered swamp hydrology**. Near-surface fracturing can result in a decline in shallow groundwater levels which may in turn affect soil moisture content, swamp vegetation and dependent ecosystems. Effects on swamp hydrology (water retention and groundwater drainage rates) can be long-lasting and possibly permanent. Potential effects on swamp vegetation is described in the ecological assessment (Niche, 2021) accompanying the SMP.

4.1 Mine subsidence

Most surface water and shallow groundwater impacts are associated with ground subsidence and near-surface fracturing. It is therefore relevant to review predictions of subsidence and surface cracking associated with the extraction of Longwalls 22 and 23 by mine subsidence consultants MSEC (2021). The MSEC assessment used the Incremental Profile Method (IPM) calibrated to observations and measurements above previously mined longwalls at Dendrobium. The main findings from the MSEC report are listed in Table 9. The reader is referred to the subsidence assessment by MSEC (2021) for further detail.

Table 9. Summary of predicted subsidence effects (from MSEC 2021)

Location / feature	Predicted subsidence effects
Within longwall footprint	**Incremental movement**: Up to 2550 mm subsidence, 35 mm/m incremental tilt, 0.9 km^{-1} incremental hogging and sagging curvatures. The maximum predicted strains are 8 mm/m tensile and compressive based on the 95 %confidence levels. **Cumulative movement**: 3000 mm subsidence; 40 m/m tilt; 1.0 km^{-1} curvature
Wongawilli Creek	Wongawilli Creek is located ~320 m west of the proposed longwalls, at its closest point. At this distance, the predicted incremental vertical subsidence is less than 20 mm, whereas predicted upsidence ranges between 40 mm and 80 mm, highest at rock bars 21, 22 and 25. Total valley closure is expected to range up to 190 mm. MSEC estimates that the likelihood of fracturing resulting in surface water flow

Location / feature	Predicted subsidence effects
	diversions along Wongawilli Creek, due to the extraction of the proposed LW22 and LW23, is low (affecting ~ 6 % of rockbars in the Study Area). However, minor fracturing could still occur elsewhere along the creek, at distances up to approximately 400 m from the proposed longwalls.
Lake Cordeaux	Minor and isolated fracturing could occur in the bedrock beneath the Lake Cordeaux within approximately 400 m of the proposed mining. However, the fracturing is unlikely to be visible at the surface due to the alluvial deposits.
Tributaries	Drainage lines located directly above the mining area (**LC5, LC6, WC24 and WC26**) are likely to experience the full range of predicted subsidence effects including fracturing, uplift of the bedrock, iron staining, flow diversions and reduction in pool water levels. Localised ponding due to mining-induced tilt could develop along some sections of the drainage lines where the natural stream gradients are relatively low. Fracturing can also occur outside the extents of the proposed longwalls, with minor and isolated fracturing occurring at distances up to approximately 400 m (**LC7**).
Swamps	Fourteen swamps are located within the Study Area as defined by the 600m buffer. **Swamps 7 and Den 153** overlap with the longwall footprints. Strata fracturing and dilation are expected to occur in the substrate of those swamps which may result in the diversion of some surface water flows. Those diverted flows may re-emerge at the limits of fracturing and dilation. The remaining swamps are located outside the proposed mining area at distances ranging between 70 m and 540 m. Fracturing could occur along the streams within the swamps located closest to the proposed longwalls and isolated fracturing could occur at distances up to 400 m outside the mining area.

4.2 Subsurface fracturing

Extraction of coal using longwall methods commonly results in ground subsidence and associated deformation and fracturing of overlying strata (Peng and Chiang, 1984; Whittaker and Reddish, 1989). While authors differ in their terminology, there is general agreement on the overall fracture zonation patterns. Fracturing is most intense and vertically connected immediately above the collapsed longwall (goaf), and grades upwards through zones of less fractured strata (Booth, 2002). Fracturing of the overburden can cause significant changes in aquifer characteristics such as permeability and storage, and potentially can provide pathways for vertical groundwater movement between shallow groundwater and surface water systems and underground mines (Advisian, 2016; McNally and Evans, 2007). The height to which vertically connected (and free-draining) fracture networks extend above the mined seam is therefore important in assessing potential impacts of longwall mining on groundwater and surface water systems.

Several authors have developed empirical approaches to estimating the height of connected fracturing or complete groundwater drainage above longwalls (e.g. Ditton and Merrick, 2014; Forster, 1995; Guo *et al.*, 2007; Mills, 2011; Tammetta, 2013). These methods have been used at numerous coal mines in NSW to provide guidance on the height of fracturing for the development of numerical groundwater impact models. At Dendrobium, the methods of Ditton and Merrick (2014) and Tammetta (2013) yield estimates that are significantly different from each other. A review of longwall subsidence fracturing at Dendrobium was commissioned by the then NSW Department of Planning and Environment (DPE). The review by consultants PSM (2017) concluded that such empirical approaches carry significant uncertainty and limitations related to the data on which they were based, and that fracturing above the (305 m wide) panels in Area 3B likely extends to the surface (Galvin, 2017; PSM, 2017). The IEPMC similarly recommended "*erring on the side of caution and deferring to the Tammetta equation*" until the height of fracturing can be confirmed through field investigations and/or geotechnical modelling (IEPMC, 2018).

Such investigations were carried out by IMC between 2018 and 2019 above extracted longwalls in Areas 3A and 3B (HGEO, 2020b) and are ongoing. The initial study concluded that mining-induced fracturing, including high -angle fracturing, is highly variable but appears to extend to the surface above longwalls of width 249 m in Area 3A and 305 m in Area 3B. The density of fracturing decreases with height above the goaf, with anomalous fracturing within the BACS and below 120 m above the goaf. Packer tests indicate an increase in permeability of 2 to 3 orders of magnitude relative to pre-mining conditions throughout most strata above the longwall goaf. Vibrating wire piezometers (VWP) installed after longwall extraction indicate significant depressurisation throughout all strata, with near-zero pressure heads recorded in most piezometers. Complete depressurisation is recorded throughout the HBSS in most holes drilled above goaf. Subsequent monitoring indicates that groundwater pressures start to recover in some strata (upper BGSS, lower HBSS) several years after mining (2020c, 2021).

The findings of the drilling investigation can be applied directly to Longwalls 22 and 23. It is expected that fracturing will extend to the surface over at least part of the longwall footprint, resulting in depressurisation of the HBSS and potential for surface-to-seam connectivity above the goaf. Over-goaf investigation holes have recently been installed above proposed Longwalls 22 and 23 for baseline monitoring (S2514 an S2526). Those holes will be redrilled and replaced following extraction of the longwalls to assess fracturing extent and groundwater conditions.

4.3 Altered drainage and flooding

Changes in stream bed gradient due to mining can result in increased ponding where the ground tilt opposes the natural gradient or can result in increased flow velocity and bed scouring where mine-induced tilt increases the natural stream gradient. Potential for increased ponding and scouring due to mine-induced changes in stream gradient is assessed by MSEC (2021). The main conclusions in relation to the MSEC assessment of changes in stream-bed gradient are as follows:

- There are predicted reductions in grade along Stream LC5B and within the extent of Swamp 7. There is potential for minor and localised increased ponding upstream of these locations and within this swamp due to mining-induced tilt. The areas of the swamp further up the valley sides have higher natural grades and there are no predicted reductions in grade away from the valley base.
- There are no predicted reductions in grade along the remaining streams or within the remaining swamps within the Study Area. It is unlikely, therefore, that these swamps would experience adverse changes in ponding or scouring due to the mining-induced tilt or vertical subsidence.
- The predicted changes in grade along Wongawilli Creek are considerably less than the average natural grade. Therefore, it is unlikely that there will be adverse changes in the potential for ponding, flooding or scouring of the banks along the creek due to the mining-induced tilt. However, it is possible that some localised changes in the levels of ponding or flooding could occur where the maximum changes in grade coincide with existing pools, steps or cascades along Wongawilli 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 %.

4.4 Changes in stream flow characteristics

4.4.1 Fracturing and flow diversion

Mining directly under or close to surface watercourses can result in diversion of flow from the watercourse and/or loss of surface flow from the catchment. Water diverted from surface channels can be directed through fracture networks to the water table and may re-emerge downstream, as is commonly observed in the Southern Coalfield. If surface fractures intersect deeper (vertically connected) mining induced fracture networks, there is potential for water to be directed into those deeper fracture storages, or to the mine itself. In the latter case, surface flow would be lost from the catchment. Significant losses would be detected as a decrease in flow (and catchment yield) at downstream gauges.

Based on the subsidence assessment by MSEC (2021), summarised in Table 9, and previous experience at Dendrobium summarised in Section 3.2.1, the following effects are expected as a result of Longwalls 22 and 23 extraction:

- Wongawilli Creek: Passing within 320 m of the longwalls, the probability of impacts such as fracturing and flow diversion is considered low, but possible. A fracture and low pool water levels were noted in Pool 43a after the completion of LW9. Pool 43a is located 200 m west of LW6 in Area 3A and 410 m east of LW9 in Area 3B.
- Tributaries LC5, LC6, WC24 and WC26 will be directly mined under by Longwalls 22 and 23. Those tributaries will likely experience stream bed fracturing and flow diversions associated with longwall subsidence. Flow reductions will likely be observed at the downstream gauge LC5S1 and at the proposed gauge LC6S1. Water levels in individual pools may be reduced along reaches that overlay or are closely adjacent to the longwall footprint.
- Tributary LC7 is entirely within 400 m of Longwall 22 and within 60 m at its closest approach. Based on observations in tributary WC 15 in Area 3B, it is possible that fracturing and flow diversion will occur along LC7.
- The lower reaches of tributary WC23 (west of Wongawilli Creek) are within 400 m of the longwall footprints (360 m at its closest). Fracturing and flow diversion is considered possible but unlikely in this tributary.
- Other watercourses (WC20, WC21, WC22, WC25, WC28, CR36, LC4, LC9) are located more than 400 m from the proposed longwall. It is unlikely that those watercourses will experience significant fracturing and flow diversion.

4.4.2 Baseflow loss due to groundwater depressurisation

Where stream flow is partly sustained by the discharge of groundwater from adjacent aquifers (baseflow), groundwater drawdown or depressurisation due to mining can lead to a reduction in the baseflow component. This effect is typically the dominant mechanism for flow loss in reaches where the longwall panels have been set-back from streams and fracturing is avoided or reduced. This effect combines with the effect of fracturing to result in the more significant losses experience directly above longwalls.

4.4.3 Total loss of surface water flow

The potential reduction in groundwater levels and baseflow in watercourses and the likely effects of fracturing were assessed using a regional numerical groundwater model (Watershed Hydrogeo, 2021). A summary of the estimated incremental loss of surface water flow due to Longwalls 22 and 23 is shown in Table 10 and the reader is referred to the groundwater assessment report for further details.

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.

Incremental and cumulative flow reductions as ML/d are tabulated in Tables 7-5, 7-6 and 7-7 and Appendix H of Watershed HydroGeo, 2021), and are presented for 5-year periods as previously requested in DPIE's conditions. Groundwater consultants Watershed HydroGeo (2021) has taken the latter approach identified above by applying conservative assumptions in deriving the estimates in Tables 7-5, 7-6 and 7-7 and Appendix H of Watershed HydroGeo (2021). Estimates are presented as the "most likely' value followed by the possible uncertainty range (accounting for uncertainty in modelled hydrogeological parameters, mining effects and also variability in rainfall and flow). The most likely estimate for 2016-2020 is consistent with estimates of observed cumulative impacts as of Longwalls 14, 15 and 16, as described in Watershed HydroGeo (2021).

Rather than duplicating all that detail here, and to communicate what the likely worst-case effects would be, Table 10 presents a summary of the 'most likely' and range in reduction in flow at each watercourse or catchment for the 5-year period with the greatest reduction.

Table 10. Estimated cumulative and incremental change in surface water flow

Watercourse / subcatchment	Longwall 22 incremental	Longwall 23 incremental	Cumulative effect
CR36	-0.004 (-0.002 - -0.008)	-0.005 (-0.003 - -0.010)	-0.12 (-0.006 - -0.023)
LC5	-0.040 (-0.022 - -0.074)	-0.032 (-0.017 - -0.061)	-0.078 (-0.078 - -0.235)
LC6	-0.037 (-0.021 - -0.070)	-0.018 (-0.010 - -0.035)	-0.069 (-0.069 - -0.208)
WC24	-0.026 (-0.014 - -0.050)	-0.007 (-0.004 - -0.014)	-0.049 (-0.033 - -0.114)
WC26	-0.021 (-0.010 - -0.042)	-0.072 (-0.039 - -0.138)	-0.098 (-0.033 - -0.228)
lower Wongawilli Creek	-0.110 (-0.006 - -0.022)	-0.070 (-0.007 - -0.196)	-0.184 (-0.131 - -0.458)
Wongawilli Creek WWL	-0.046 (-0.025 - -0.089)	-0.078 (-0.043 - -0.149)	-0.63 (-0.63 - -2.22)

Results are provided as: 'most likely' (predicted range)
* Incremental flow reductions as ML/d from those shown in Tables 7-5, 7-6 and 7-7 of Watershed HydroGeo, 2021)

The potential incremental decrease in stream flow as a result of Longwall 22 and Longwall 23 extraction equates to approximately 4% and 7% respectively of the whole of mine losses over the period 2025-2035 for Wongawilli Creek (including tributaries). At the time of the maximum expected loss (approximately within 5 years and possibly out to 10 years post-extraction) the peak cumulative losses are estimated at up 10% of 'wet' year average flow[1] and 7-30% of 'dry' year average flow. Incremental losses are predicted to be 1-3% and 1-2% for Longwall 22 and 23 respectively.

After 2035 both the cumulative and incremental losses are expected to decline, although the conservative predictions in Table 10 and Watershed HydroGeo (2021) account for potential permanency of effects.

The sum of incremental losses on LC5 and LC6, due to each of Longwalls 22 and 23, are predicted to be approximately 30-35% and 20-25% of cumulative Dendrobium effects on these watercourses. In terms of average flow, Longwalls 22 and 23 are estimated to result in a reduction of 6-19% and 6-17% respectively, with 'best' estimates of approximately 11% and 9% of average flow. Cumulative effects on due to Dendrobium Mine are estimated to be 15-44% of average flow [2], with the most likely effect based on experience in Area 3B considered to be 15-25% of estimated long-term average (i.e. 0.07-0.120 ML/d on each of LC5 and LC6), but likely to be up to approximately 40% of 'dry' year average flow.

Decreases in flow will be most apparent during periods of low rainfall and low-flow in the catchments and are likely to manifest as a reduction or cessation of baseflow leading to an increase in no-flow days compared with baseline conditions, as illustrated in Section 4.4.4.

4.4.4 Predicted effects on stream flow characteristics

Detailed assessment of the three watercourses most likely to be affected by Longwalls 22 and 23, LC5, CR36 and Wongawilli Creek is provided below. LC6, WC24 and WC26 are also discussed below, although the current lack of monitoring data limits the discussion.

The predicted effects of flow depletion on stream flow characteristics are well-illustrated using flow duration curves. A flow duration curve shows the percentage of time that a stream carries flow exceeding a given rate, and it is useful for defining low-flow and no-flow characteristics. Flow duration curves for the gauged site LC5S1 on LC5 are presented on Figure 12.

On each plot, the baseline flow duration curve is presented. The flow duration curves and associated discussion are based on gauged data, rather than on rainfall-runoff modelling as was used in previous SMP assessments. Where possible, the baseline is derived from data from 2008-2021 to provide a representative assessment. This baseline is presented as a heavy green line.

The range in predicted impacts from the groundwater modelling (Table 10) for selected sites has then been applied for three cases:

- the predicted "cumulative" impacts as for Dendrobium Mine, simulated as all 'approved/proposed' longwalls [all historical Longwalls 1-16 plus Longwalls 17-23] (red/orange lines) and
- the simulated incremental effects of proposed Longwall 22 and Longwall 23 (blue lines).

The difference between one of the blue or red lines and the solid green line indicates the predicted impact or flow depletion at each site, based on the range in the groundwater modelling predictions.

---

[1] With reference to future assessment against the agreed TARPs, the predicted impact is 10-35% of 'wet' year median flow (Q50), and 70-100% of 'dry' year Q50 at WWL.
[2] With reference to future assessment against the agreed TARPs, the predicted impact is 6-20% of estimated 'wet' year median flow, and up to approximately 70% of estimated 'dry' year median flow at LC5 and LC6, noting that monitoring started in 2019 at LC5 and has not commenced at LC6.

Tributary LC5 (LC51S1)

Flow gauging has occurred at LC5 since April-2019, with currently available data until April-2021. The pre-mining data record is for 24 months. The flow duration curve for this period is shown on Figure 12A (blue series). In order to make subsequent impact assessment more representative of long-term conditions, a synthetic series has been calculated from a reference site for the longer period 2008-2021 (green series). This synthetic series is less skewed towards the severe drought conditions that persisted for much of the LC5 gauged record.

Impact assessment for this tributary has been conducted by using the synthetic series to represent 'baseline' conditions (Figure 12B,C). The groundwater model predictions (Watershed Hydrogeo, 2021) of flow reduction for this watercourse are then applied to the baseline to illustrate potential effects of Longwall 22 (incremental - Figure 12B), Longwall 23 (incremental - Figure 12C) and Dendrobium as a whole.

The flow duration curves for LC5 (Figure 12B,C) indicate that:

- The groundwater model predicts that the effect of Longwall 22 (light and dark blue lines) would result in a decline in low-flows of between 0.02 and 0.07 ML/d, and 0.02-0.06 ML/d for Longwall 23. This would lead to an increase in the number of days with no-flows at LC5 (from approximately 6% of the time to approximately 21-39%), which is an additional 16-23% of the time. Based on recent analysis for EoP assessments, the lower end of these increases in cease-to-flow frequency are considered more likely than a 40% increase.

- The predicted effects of Dendrobium as a whole on LC5 (mostly due to Area 3A and 3C) is approximately 0.08-0.24 ML/d (orange-red lines on Figure 12B,C). This could result in cease-to-flow conditions up to 30-46% of the time on LC5. An increase of approximately 24-27% (to about 30-33% of the time) is considered more likely based on analysis of field data in EoP assessments. The discrepancy is related to the conservatism imposed in the groundwater model configuration and predictions, as described in Section 3.2.

Tributary LC6 (LC61S1)

In the absence of gauged data (Section **Error! Reference source not found.**, Table 5 and Table 6) the best estimates of impacts on LC6 is to assume that the effects on LC5 would be similar to those on LC6, noting that Longwall 22 mines beneath a similar length of LC5 and LC6, while Longwall 23 should have a smaller effect on LC6 than it would on LC5 due to the creek only crossing the southeastern corner of the panel. As a result, cracking and baseflow loss effects on LC6 will be similar to those on LC5 for Longwall 22, while there would be similar drawdown effects from Longwall 23 but with a lower probability of cracking effects on LC6 due to Longwall 23.

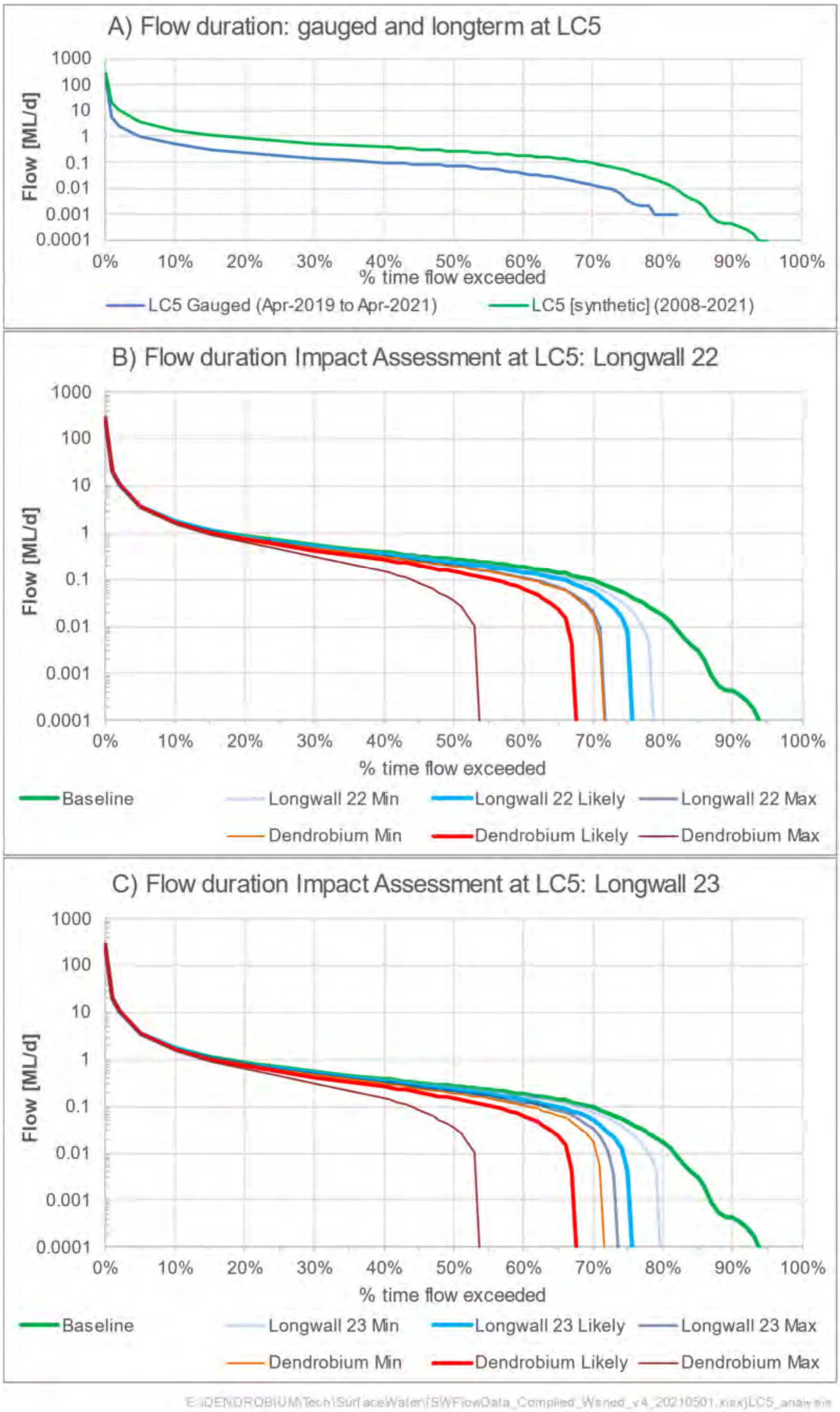


Figure 12 Flow duration curve and estimated mining effects at LC5S1

Tributaries WC24 and WC26

In the absence of gauged data (Section **Error! Reference source not found.**, Table 5 and Table 6) the best estimates of impacts on WC24 and WC26 is to assume that the effects on LC5 would be similar to those on these creeks, noting that Longwall 24 mines beneath a greater length of WC26 than LC5, while Longwall 22 should have a smaller effect on WC24 than it would on LC5 due to the creek WC24A only crossing a small section of the panel and then mainly flowing just outside (approximately 100m) the panel footprint. As a result, cracking and baseflow loss effects on WC26 will be similar to those on LC5 for Longwall 23, while there would be similar drawdown effects from Longwall 22 but with a lower probability of cracking effects on WC24 due to Longwall 22.

Tributary CR36 to Cordeaux River

Flow gauging has occurred at CR36 since September-2019, with currently available data until April-2021. The current pre-mining data record is for 20 months. The flow duration curve for this period is shown on Figure 13A (blue series). In order to make subsequent impact assessment more representative of long-term conditions, a synthetic series has been calculated from a reference site for the longer period 2008-2021 (green series). This synthetic series is less skewed towards the drought conditions that persisted for the early half of the CR36 gauged record.

The predicted effects of flow depletion on stream flow characteristics at CR36 are illustrated using flow duration curves on Figure 13. The format of the figure is the same as for Figure 12, above. The range in predicted impacts from the groundwater modelling (Table 10) for CR36 has been applied to the baseline for three cases:

- the predicted “cumulative” impacts as for Dendrobium Mine, simulated as all ‘approved/proposed’ longwalls [all historical Longwalls 1-16 plus Longwalls 17-23] (red/orange lines), and
- the simulated incremental effects of proposed Longwall 22 and Longwall 23 (blue lines).

The difference between one of the blue or red lines and the solid green line indicates the predicted impact or flow depletion at each site, based on the range in the groundwater modelling predictions.

The flow duration curves for CR36 (Figure 13B,C) indicate that:

- The groundwater model predicts that the effect of Longwall 22 (light and dark blue lines) would result in a decline in low-flows of between 0.002 and 0.008 ML/d, and 0.003-0.01 ML/d for Longwall 23. This would lead to an increase in the number of days with no-flows at CR36 (from approximately 11% of the time to approximately 18-24%), which is an additional 7-12% (Longwall 22) or 8-13% (Longwall 23) of the time. Given the distance from Longwalls 22 and 23 to CR36 (Table 3), this effect seems conservative.
- The predicted effects of Dendrobium as a whole on CR35 (due to mining in Area 3C) is approximately 0.006-0.023 ML/d (orange-red lines on Figure 13B,C). This could result in cease-to-flow conditions up to 22-31% of the time on CR36 from a baseline of approximately 11%. Based on the distance from the proposed longwalls and experience elsewhere at Dendrobium, this magnitude of flow reduction and increase in low-flow frequency is considered to be conservative.

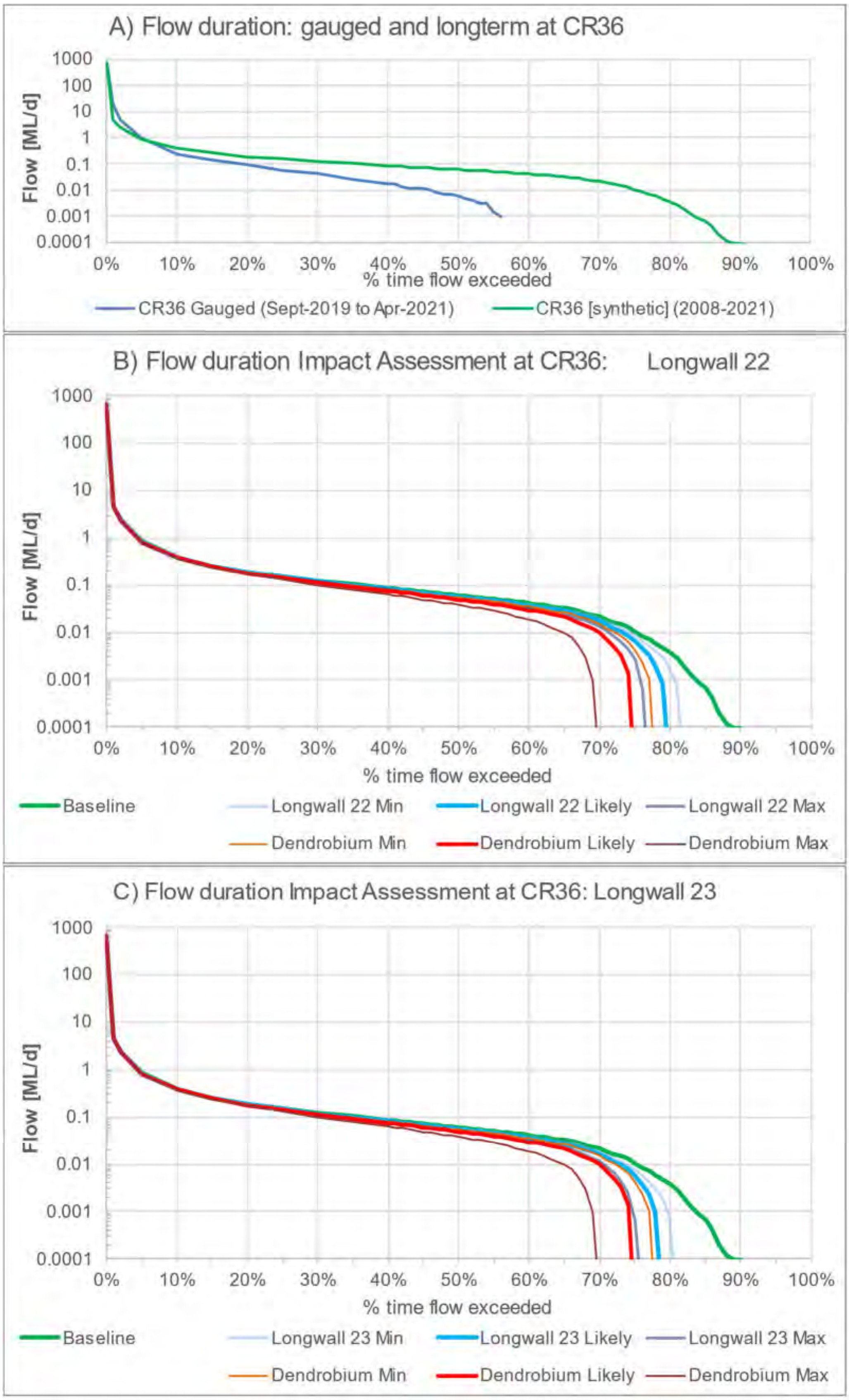


Figure 13 Flow duration curve and estimated mining effects at CR36S1

Wongawilli Creek (WWL)

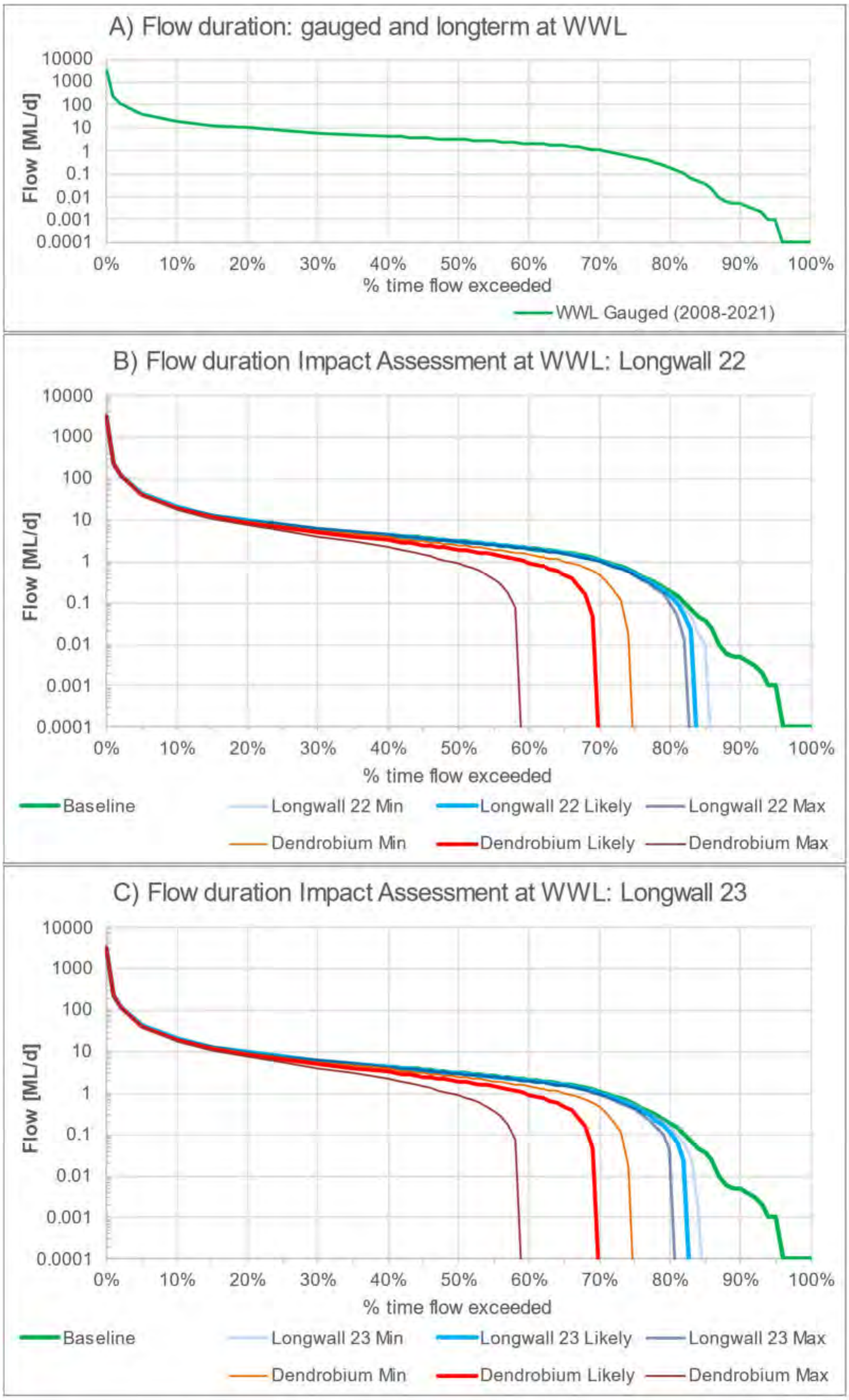
The flow duration curves for WWL (Figure 14) indicate that:

- Baseline cease-to-flow frequency is approximately 4%, based on the green line on Figure 14 and the statistics in Table 6. Based on the analysis presented using recently-updated TARP assessments (HGEO, 2021; Watershed Hydrogeo, 2019a), the effects of the historical Dendrobium mining at WWL have been less than predicted in previous groundwater modelling studies, and are within the scale of natural variability.

- The predicted maximum incremental effect of Longwall 22 is up to 0.09 ML/d (Figure 14B). This alone would result in cease-to-flow conditions occurring 14-17% of the time, although such an increase is again considered highly unlikely based on analysis of historical field data. The maximum predicted incremental effect of Longwall 23 is greater (up to 0.15 ML/d), and that could result in a similar change in cease-to-flow frequency from approximately 4% to 15-19% (Figure 14C).

- The conservative groundwater model predicts that the effect of all Dendrobium longwalls would result in a significant decline in low-flows (red/orange lines on Figure 14C) and a significant increase in the number of days with no-flows at WWL (from about 4% of the time to 25-41%). As noted above, such a decline in flow or change in cease-to-flow frequency has not been observed to date.

Effects on flows at WWL have not yet been identified in the EoP Reports (using comparison against AWBM rainfall-runoff modelling) or in more recent analysis using comparison against reference gauge records (HGEO, 2020a, 2021; Watershed Hydrogeo, 2019a). This is despite several upstream gauging sites in Area 3B showing flow reductions or pool level decline (e.g. Pool 43a, Wongawilli Creek, located between Area 3A and 3B; HGEO, 2018a; Watershed Hydrogeo, 2018 and 2019). Therefore, it is possible that effects upstream of, or between, gauging stations may be more significant than those observed at downstream gauging stations.



F:\DENDROBIUM\Tech\SurfaceWater\SWFlowData_Compiled_Wshed_v4_20210301.xlsx|WWL_analysis

Figure 14. Flow duration curve for WWL on Wongawilli Creek

Wongawilli Creek adjacent to Area 3C

The previous point is pertinent to the position or distance of Area 3C longwalls to the ‘lower’ reach of Wongawilli Creek, as well as that of earlier longwalls in Area 3A and 3B longwalls along each side of the ‘middle’ reach. Along the section of the creek between Area 3A and 3B, reductions in baseflow due to groundwater drawdown in the near-surface strata (HBSS and CVSS or Bulgo Sandstone) have caused reductions in baseflow which, while small in absolute magnitude, can be a significant portion or all of the flow down this reach of Wongawilli Creek in extreme drought periods, as have been experienced 2017 into early 2020.

Figure 15 shows a comparison of distance from each longwall to Wongawilli Creek and the ‘frontage’, which is a measure of the length of the nearest longwall edge to the creek. Comparing these two parameters, Longwalls 22 and 23 are likely to have effects on Wongawilli Creek that are similar to those of previous longwalls in Area 3A and 3B longwalls, noting the earlier comment and assessment by MSEC (2021) regarding surface fracturing. A comparison of the panel width/depth of cover (W/D) relationship indicates that same concept, although indicates that the W/D ratio is greater than for most of the previous Area 3A panels.

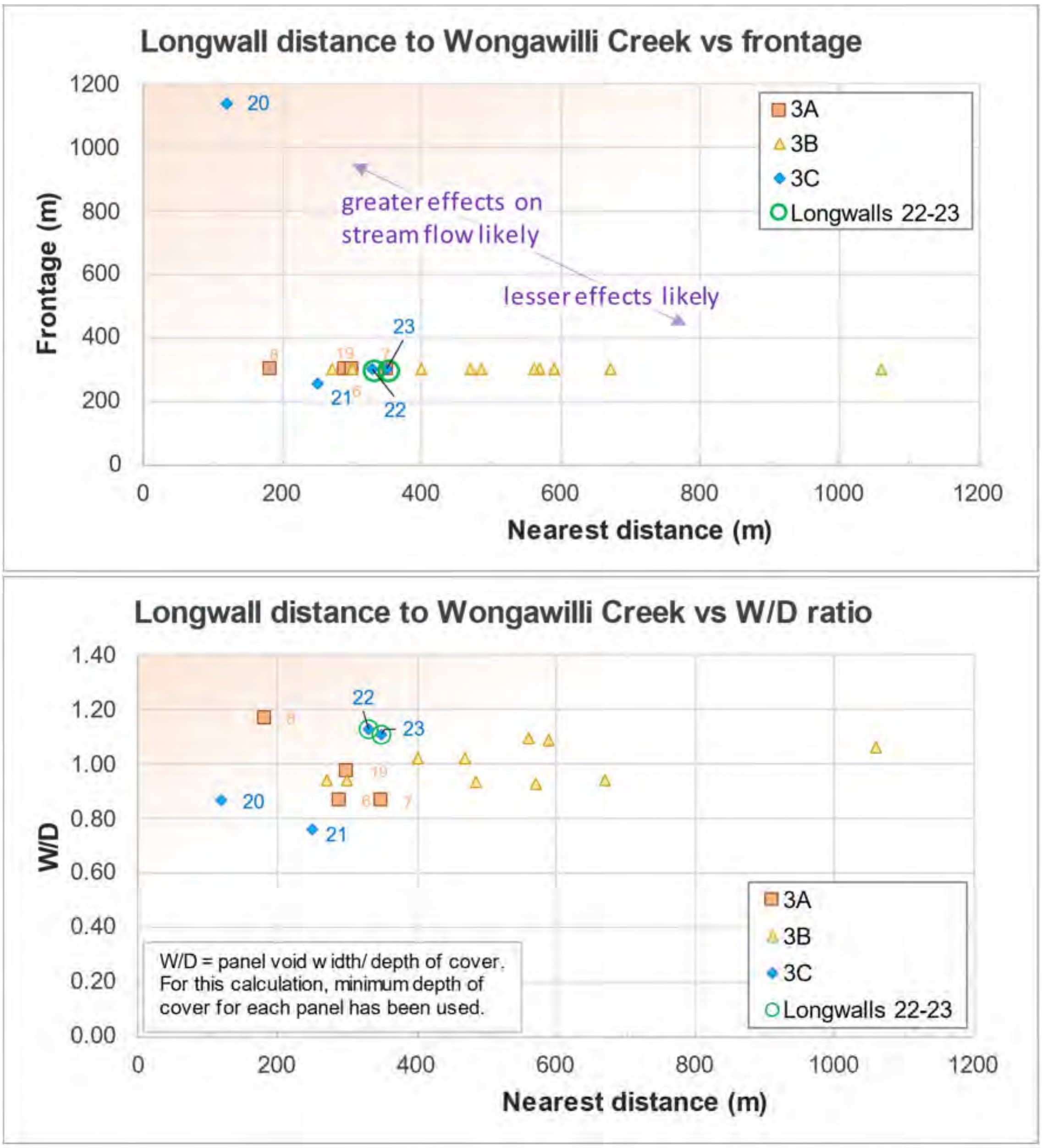


Figure 15. Relative impact risk to Wongawilli Creek

As noted in Table 10, groundwater modelling suggests that the cumulative flow reduction due to all Dendrobium longwalls in this reach would be in the order of 0.13-0.46 ML/d (moderate estimate of 0.18 ML/d) (more detail presented in Watershed HydroGeo, 2021). The predicted incremental effect of Longwall 22 is 0.06-0.022 ML/d and would be 0.007-0.026 ML/d for Longwall 23. Through time, the effect of these longwalls would be a significant amount of the predicted effect on this reach of the cumulative effect of all Dendrobium longwalls. The groundwater model results are consistent with the analysis of depth and frontage and W/D presented above.

As a result, it is expected that Longwall 22 would cause an effectively negligible (1%) increase in the duration and length over which cease-to-flow conditions can occur in the lower Wongawilli Creek during drought periods. The effect of Longwall 23 is predicted to be up to a 2% increase (from approximately 6% of the time to 8%). The effect of these longwalls would likely not be discernible from natural variability or from the effects of other historical, approved and proposed longwalls. The cumulative effect of Dendrobium longwalls, based on the groundwater modelling, could result in an increase in cease-to-flow days from approximately 6% of the time (baseline, on average) to 17% of the time in this reach of Wongawilli Creek near Area 3C.

4.5 Leakage from reservoirs

Watershed HydroGeo (2021) carried out several numerical modelling scenarios in which the permeability of strata between Area 3B and Lake Avon (and other incised valleys) were enhanced to reflect changes due to subsidence movements such as valley closure. The estimated total leakage losses from Lakes Avon and Cordeaux, and incremental losses due to the extraction of Longwalls 22 and 23 are shown in Table 11.

The estimated incremental leakage losses from Avon Reservoir as a result of extraction of Longwalls 22 and 23 is estimated to be nil, due to the distance from that reservoir. The incremental effect of Longwall 22 and 23 on leakage from Lake Cordeaux is 0.08 and 0.05 ML/d (Table 11).

Table 11. Estimated leakage from reservoirs (Watershed HydroGeo, 2021)

Reservoir	Whole mine cumulative loss (ML/day)	Incremental loss (ML/day)	
		Longwall 22	Longwall 23
Lake Avon	0.09 – 0.45 (mean 0.18)	<0.01	<0.01
Lake Cordeaux	0.11 – 0.36 (mean 0.23)	0.08	0.05

4.6 Stream 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:

- 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.

Observed impacts to water quality from previous mining are summarised in Table 12, based on EoP monitoring reports.

Table 12. Previous impacts to steam water quality

Water-course	Monitoring sites	Observations	Water quality effects
Wongawilli Creek	Pool 43a	Decline in water level at Pool 43a is apparent from 2013 following extraction of Longwalls 6 to 8 in Area 3A.	No adverse trends in EC or pH associated with the water level decline. Increases in EC in some pools during 2017-2019 likely related to drought conditions.
	WWU4	Site is upstream of Dendrobium operations but downstream of Elouera Mine longwalls. Elouera Longwalls mined directly under the upper reaches of Wongawilli Creek from 1994 to 2001, and in 2007.	Increase in sulfate, Mn and Zn during 2007 following extraction of Elouera longwall Delta Longwall 17 (end 5/4/2007). Concentrations declined over following 10 years but remain slightly elevated as of 2020
WC15	WC15 Pool 2 and 9	WC15 mined under by Longwall 15 in late 2019 and approached within 35 m by Longwall 13 and 14 in April 2018, and Feb 2019. Resulted in reduction in stream flow and pool water levels	No obvious change in EC in downstream pools 2 and 9; Slight increase in Zn during Longwalls 14 and 15.
WC17	S12 Pools 9, 10, 11, 12	Tributary crosses previously extracted Longwalls 7 and 7. Evidence for declining pool levels along the watercourse during extraction of Longwalls 7 and/or 8.	Iron staining in creek bed. Increase in pool water pH during Longwall 7 from ~pH 5 to pH ~6 to 7. Fluctuating EC in some pools.
WC21	WC21 Pool 5	Watercourse and catchment mined under by Longwalls 9 to 15 (2013-2019). Reduction in stream low and drying of reaches directly mined under.	Increase in water pH and gradually increasing EC trend in downstream Pool 5 following Longwall 10 extraction. Transient increase in sulfate, Fe, Mn and Zn (longwalls 10 - 13)
Donalds Castle Creek	DCC Pool 19	Upper reaches of Donalds Castle Creek including Swamps 1b and 5 mined under by Longwalls 9, 10 and 11. Reduction in flow at DCS2 and DC13S1; reduction in pool levels.	Elevated EC conditions were observed in the upper tributaries of Donalds Castle Creek during 2018 and 2019. Accompanied by low DO and elevated sulfate, Zn and Mn.
SC10C	Pools 0, 1, 3, 4, 5, 7, 8, 9, 10, 11	Tributary crosses previously extracted Longwall 8. Decline in pool levels and/or drying of pool during or following Longwall 8.	Iron staining and local accumulation of ferruginous sediment. Increase in pool water pH during Longwalls 6 – 8 from ~pH 5 to pH ~6 to 7. Decline in EC in some pools, similar to trends in Sandy Creek. Increase in EC to ~300+ µS/cm (Pools 0, 3 10) from 2014. Increase in dissolved Fe, Mn, Al, Zn following mining in Area 3A.
SC10	Rockbar 3	Tributary crosses the south east corner of Longwall 8. Data too sparse to identify water level effects with certainty.	No adverse water quality effects noted; Increase in EC at Rockbar 3 associated with dry conditions in 2017-2018.
Native Dog Creek	NDC; several pools	Elouera Longwalls mined directly under NDC from 1994 to 2003 resulting in watercourse fracturing and flow diversion.	Iron staining in the creek bed and pools, most evident from above Elouera Longwall 7 (NDC_Pool25). Sharp transient increase in EC accompanied by low pH and DO in Pools 13, 20, 22 and 25 following Elouera Longwall 7 extraction. Effects including low pH (<4) appear to have recovered as of 2018 when monitoring resumed.

In summary, watercourses that have been directly mined under typically show one or more of the following water quality effects compared with baseline conditions:

- A transient increase in EC, evident at one or more monitoring sites, but not always detectable at downstream locations.
- An increase in water pH from baseline mildly acidic conditions to near neutral conditions; or, more rarely, a decrease in water pH (e.g. Native Dog Creek associated with Elouera Mine).
- Transient increases in dissolved Fe and Mn (+/- Zn and Al) at sampling locations immediately down-stream of the affected area.
- Iron staining is typically localised to reaches overlying and immediately downstream of a longwall footprint. In the case of SC10C, iron staining increased in 2020 some 7 years after mining due to recovery of groundwater levels within fracture networks above extracted longwall (HGEO, 2020c).

Water quality impacts have not been detected in watercourses that are not directly mined under.

Based on previous observations, it is expected that water quality influence due to the extraction of Longwalls 22 and 23 would be minor or undetectable in stream reaches within most subsidence affected areas. Transient water quality impacts, including localised iron staining, may be observed in in tributaries that cross the longwall footprints (WC24, WC26, LC5 and LC6), and possibly in LC7 which is entirely within 400 m of Longwall 22; however, those impacts are not expected to significantly influence water quality at downstream locations on Wongawilli Creek. Local discolouration of streambeds and rock faces by iron hydroxide precipitation can continue for a number of years but is expected to be a temporary impact. Water quality effects on stored waters of the reservoirs are expected to be negligible and undetectable.

4.7 Swamp hydrology

Swamps that have been undermined commonly display hydrological changes shortly following the passage of the longwall beneath the monitoring site. Hydrographs of piezometers at affected locations may show one or more of the following:

- a decrease in the average shallow groundwater elevation;
- a decrease in the duration of saturation of the swamp sediments following a significant rainfall event; or
- a change in the shape of saturation peak and recession curves (and recession rate) in response to significant rainfall events.

Hydrological changes at swamps are most likely due to the development of surface fracturing and bedding plane openings in the sandstone substrate of the swamp and/or a rockbar at the swamp outlet. The formation of fractures in the substrate may change the swamp from a perched system to a connected system. The impact on the swamp will be dependent on the head difference between the swamp sediments and the sandstone substrate. Where the hydraulic gradient is downwards (into the sandstone, which is common) then the fracturing will lead to greater flows of water from the swamp and a decline in average swamp groundwater levels (and increase in recession rate). It is not yet known whether the hydrological characteristics recover to some degree as fractures are filled with fine sediments and on-going monitoring is required to assess longer-term impacts.

Drying of upland swamps can result in further impacts, including:

- Reduction of soil moisture levels and loss of cohesiveness of the swamp sediments.

- Decline of groundwater-dependent plant species and consequent changes in vegetation structure.

- Decline of groundwater-dependent fauna including macroinvertebrates and stygofauna.
- Oxidation of peaty sediments resulting in increased hydrophobicity, lower water holding capacity, potential changes in nutrient cycling, and changes in water quality.
- Increased risk of channelization and gully erosion.
- Reduced resilience to bushfires.

A recent assessment of shallow groundwater impacts due to mining at Dendrobium was carried out by Watershed Hydrogeo (2019b). The assessment concluded that almost all shallow piezometers that are directly mined under by longwalls extracted in Dendrobium Area 3A and 3B show responses to mining. Changes in shallow groundwater levels or groundwater fluctuation characteristics are not evident in shallow piezometers located in swamp sediments more than 60 m from the extracted longwall margin.

Observations at the Springvale Mine in the Western Coalfield show that hydrological impacts can occur in swamps overlying connected geological structures (faults or other lineaments) at distances greater than 1200 m from the longwall (Galvin et al., 2016). The same effect is not apparent at Dendrobium. Recent studies have identified no anomalous subsidence specifically related to mapped lineaments (MSEC, 2019), and no hydrological impacts at swamp piezometers located near mapped lineaments that are greater than 60 m from the goaf (Watershed HydroGeo, 2019b). However, it is prudent to consider the possibility of distant impacts where swamps overlie mapped lineaments that intersect the mine footprint.

The locations of mapped swamp vegetation communities relative to the planned longwalls are shown in Figure 1. Swamps located within 600 m of the planned longwalls are listed in Table 13, with a qualitative assessment of the likelihood that the shallow groundwater regime will be affected by subsidence related ground movements associated with Longwalls 22 and 23 (as described above). The likelihood is based on observations at swamps in Area 3B during and after longwall extraction (HGEO, 2021; Watershed Hydrogeo, 2019b) and predictions of subsidence related to longwall extraction and other ground movement related to valley closure (MSEC, 2021).

Swamps that significantly overlap Longwalls 22 and 23 (Swamp 7 and Den 153) will likely be impacted by subsidence and fracturing of the sandstone substrate. Impacts are likely to include a decline in mean shallow groundwater levels and less frequent wetting of swamp sediments following rainfall. Soil moisture levels will likely decline (on average) relative to pre-mining conditions.

Isolated fracturing may occur beneath swamps that extend within 400 m of the longwalls, with the likelihood decreasing with distance (Den 154, 9, 156, 155, 157, 141). Experience at Dendrobium suggests that noticeable shallow groundwater impacts beyond 60 m are unlikely, but possible. The remaining swamps are unlikely to be impacted since they are located more than 400 m from the proposed goaf and/or are predicted to experience negligible ground movement related to mine subsidence (<60 mm) and valley closure.

There are no mapped lineaments or other structural features that represent a direct pathway between the longwall footprints and swamps.

Table 13. Summary of predicted impacts to Upland Swamps

Swamp	Area (ha)	Distance from Longwall (m)	% Area within 60 m of Longwall	Maximum predicted vertical ground movement (mm; MSEC, 2021)			Likelihood of shallow groundwater effects
				Subsidence	Valley related closure	Tilt (mm/m)	
Den06	0.57	488		<20		<0.5	Unlikely
Swamp 7	4.87	0	87.7%	2650	475	35	Likely
Swamp 9	0.79	90		<20	200	<0.5	Possible
Den16	3.75	542		30	60	<0.5	Unlikely
Den140	0.16	527		<20		<0.5	Unlikely
Den141	0.08	360		<20		<0.5	Possible
Den144	0.54	503		<20	225	<0.5	Unlikely
Den145	0.41	498		<20		<0.5	Unlikely
Den152	0.22	436		<20		<0.5	Unlikely
Den153	0.29	0	100.0%	2100	400	30	Likely
Den154	0.40	73		<20		<0.5	Possible
Den155	0.50	209		<20		<0.5	Possible
Den156	0.71	130		<20		<0.5	Possible
Den157	0.12	336		<20	150	<0.5	Possible

5. PERFORMANCE MEASURES

The performance measures and monitoring of surface water and shallow groundwater in relation to mining at Area 3C are defined in the Area 3C SMP (South32, 2019). The TARP (Appendix A of the SMP) specifies trigger levels and a three-tiered management response for assessing and responding to impacts from mining. The triggers are based on environmental data collected before mining commenced (baseline period).

Stream monitoring sites reviewed as part of this assessment are included in the Area 3C SMP, including sites upstream and downstream of the proposed Longwalls 22 and 23. Therefore, the existing TARPs are considered generally applicable to future monitoring and management of mining effects related to Longwalls 22 and 23. The existing TARPs for surface water flow, water chemistry and shallow groundwater is reproduced in Appendix 4. Specific recommendations for revision of the monitoring program and trigger levels are given below.

5.1 Surface water monitoring

Watercourses within the study area are (or have been) monitored at multiple sites as part of the current SMP for Area 3C. Monitoring should continue at existing sites as specified in the Area 3C SMP.

The monitoring network was recently extended to include additional monitoring locations along WC20, WC24, WC26 and LC6. Those locations are included in Figure 1.

5.2 Swamp monitoring

Swamps are groundwater dependent features. Piezometric levels within the swamps, and in the substrate to the swamps, provide a key early indicator of change (IEPMC, 2019b). Piezometric levels therefore form an important component of TARPs for the management of impacts to upland swamps. Shallow groundwater and soil moisture monitoring within Swamp 7 is part of the existing Area 3C SMP.

6. REFERENCES

Advisian, 2016. Literature review of underground mining beneath catchments and water bodies (No. A26324), Report commissioned by WaterNSW.

ANZECC, 2000. Australian water quality guidelines for fresh and marine waters, National Water Quality Management Strategy Paper No 4. Australian and New Zealand Environment and Conservation Council, Canberra.

Booth, C.J., 2002. The Effects of Longwall Coal Mining on Overlying Aquifers, in: Younger, P., Robins, N. (Eds.), Mine Water Hydrogeology and Geochemistry, Geological Society, London Special Publications. pp. 17–45.

Cowley, K.L., Fryirs, K.A., Hose, G.C., 2016. Identifying key sedimentary indicators of geomorphic structure and function of upland swamps in the Blue Mountains for use in condition assessment and monitoring. Catena 147, 564–577.

Ditton, S., Merrick, N., 2014. A new sub-surface fracture height prediction model for longwall mines in the NSW coalfields, in: Australian Earth Science Convention 2014, Abstracts No. 110. Presented at the Australian Earth Science Convention, 7-10 July 2014, Geological Society of Australia, Newcastle, NSW, pp. 135–136.

Forster, I., 1995. Impact of underground mining on the hydrogeological regime, Central Coast, NSW, in: Sloan, S. (Ed.), . Presented at the Engineering Geology of Newcastle - Gosford Region, Australian Geomechnics Society.

Fryirs, K.A., Gough, J., Hose, G.C., 2014. The geomorphic character and hydrological function of an upland swamp, Budderoo plateau, southern highlands, NSW, Australia. Phys. Geogr. 35, 313–334.

Galvin, J.R., 2017. Review of PSM report on height of fracturing - Dendrobium Area 3B, Review commissioned by the NSW Department of Planning and Environment.

Galvin, J.R., Timms, W., Mactaggart, B., 2016. Springvale Mine Extension Project - Extraction Plan for Longwall 419, Report for NSW Department of Planning and Environment. Sydney.

Guo, H., Adhikary, D., Gaveva, D., 2007. Hydrogeological response to longwall mining, ACARP Report C14033, CSIRO Exploration and Mining. Australian Coal Industry's Research Program (ACARP).

HGEO, 2021. Dendrobium Mine End of Panel surface water and shallow groundwater assessment: Longwall 16 (Area 3B) (No. D21132), Report by HGEO Pty Ltd for South32 Illawarra Coal.

HGEO, 2020a. Dendrobium Mine End of Panel surface water and shallow groundwater assessment: Longwall 15 (Area 3B) (No. D20358), Report by HGEO Pty Ltd for South32 Illawarra Coal.

HGEO, 2020b. Investigation into the height of fracturing above extracted longwalls in Area 3, Dendrobium (No. D19341), Report by HGEO Pty Ltd for Illawarra Metallurgical Coal.

HGEO, 2020c. Effects of Longwall 16 extraction on overlying strata and groundwater conditions, Dendrobium Area 3B (No. D20374), Report by HGEO Pty Ltd for South32 Illawarra Metallurgical Coal.

HGEO, 2018. Assessment of water level, stream flow and water chemistry trends at Wongawilli Creek (No. D18295), Report by HGEO Pty Ltd for South32 Illawarra Coal.

HNCMA, 2008. Hawkesbury-Nepean Catchment Action Plan 2007-2016. Hawkesbury-Nepean Catchment Management Authority, Goulburn, NSW.

HRC, 1998. Independent Inquiry into the Hawkesbury Nepean River System: Final Report. Healthy Rivers Commission of NSW, Sydney.

IEPMC, 2019a. Independent Expert Panel for Mining in the Catchment Report: Part 1. Review of specific mining activities at the Metropolitan and Dendrobium coal mines, Report by the Independent Expert Panel for Mining in the Catchment for the NSW Department of Planning, Industry and Environment.

IEPMC, 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, Report by the Independent Expert Panel for Mining in the Catchment for the NSW Department of Planning, Industry and Environment.

IEPMC, 2019c. Advice to Energy and Resource Assessments: Dendrobium Coal Mine Longwall 21 Subsidence Management Plan (No. IEPMC 2019-04), Report by the Independent Expert

Panel for Mining in the Catchment for the NSW Department of Planning, Industry and Environment.

IEPMC, 2018. Initial report on specific mining activities at the Metropolitan and Dendrobium coal mines, Report by the Independent Expert Panel for Mining in the Catchment for the NSW Department of Planning and Environment.

McNally, G., Evans, R., 2007. Impacts of longwall mining on surface water and groundwater, Southern Coalfield, NSW, Report prepared for NSW Department of Environment and Climate Change. eWater Cooperative Research Centre, Canberra.

Mills, K.W., 2011. Developments in understanding subsidence with improved monitoring, in: Proceedings of the Eighth Triennial Conference on Management of Subsidence, 2011. Presented at the Mine Subsidence 2011, Mine Subsidence Technological Society, Pokolbin, NSW, pp. 25–41.

MSEC, 2021. Subsidence Predictions and Impact Assessments for the Natural and Built Features due to the Extraction of the Proposed Longwalls 22 and 23 in Area 3C at Dendrobium Mine (No. MSEC1104 Rev03). Report by Mine Subsidence Engineering Consultants for Illawarra Metallurgical Coal.

MSEC, 2019. Review of the effects of lineaments and geological structures on the measured surface subsidence in Area 3B at Dendrobium Mine (No. MSEC1034). Report by Mine Subsidence Engineering Consultants for South32 Illawarra Coal.

Niche, 2021. Dendrobium Area 3C Longwalls 22 and 23 Terrestrial Ecological Assessment, Report for South32 Illawarra Metallurgical Coal.

Peng, S.S., Chiang, H.S., 1984. Longwall mining. Wiley, New York.

PSM, 2017. Height of cracking - Dendrobium Area 3B, Dendrobium Mine (No. PSM3021- 002R), Report commissioned by the NSW Department of Planning and Environment.

Sentek, 2017. Soil Moisture Measuring, Soil Moisture Measurement – Sentek [WWW Document]. URL http://www.sentek.com.au/products/soil-moisture-triscan-sensors.asp (accessed 4.28.17).

South32, 2020a. Dendrobium Area 3B Watercourse impact monitoring management and contingency plan (Management Plan No. Rev 1.5). South32 Illawarra Coal.

South32, 2020b. Dendrobium Area 3B Swamp impact monitoring management and contingency plan (Management Plan No. Rev 1.5). South32 Illawarra Coal.

South32, 2019. Dendrobium Area 3C Watercourse impact monitoring management and contingency plan (Management Plan No. B). South32 Illawarra Coal.

SRK, 2020. Geological structures comparison investigation (No. STH055), Report by SRK Consulting for Illawarra Metallurgical Coal.

Tammetta, P., 2013. Estimation of the height of complete groundwater drainage above mined longwall panels. Groundwater 52, 826–826. https://doi.org/10.1111/gwat.12253

Threatened Species Scientific Committee (TSSC), 2014. Conservation Advice (including listing advice) for Coastal Upland Swamps in the Sydney Basin Bioregion. Department of the Environment, Canberra.

Tomkins, K.M., Humphreys, G.S., 2006. Evaluating the Effects of Fire and Other Catastrophic Events on the Sediment and Nutrient Transfer Within SCA Special Areas. Technical Report 2: Upland swamp development and erosion on the Woronora Plateau during the Holocene, Report commissioned by the Sydney Catchment Authority. Macquarie University. Dept. of Environment and Geography.

Toth, J., 2009. Gravitational systems of groundwater flow: Theory, evaluation, utilization. Cambridge University Press, Cambridge, UK.

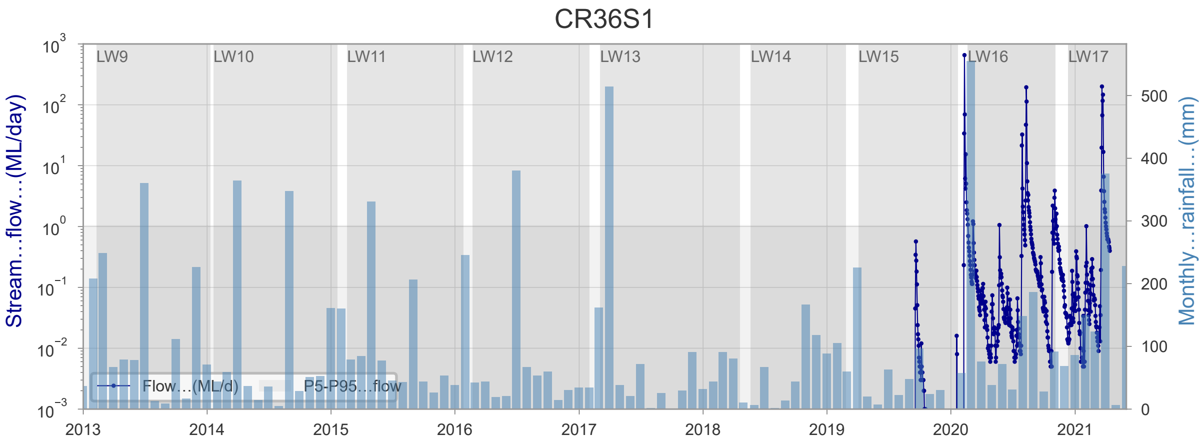
Watershed Hydrogeo, 2021. Dendrobium Area 3C Longwall 22 and 23 groundwater assessment (No. R016i7), Report for South32 Illawarra Metallurgical Coal.

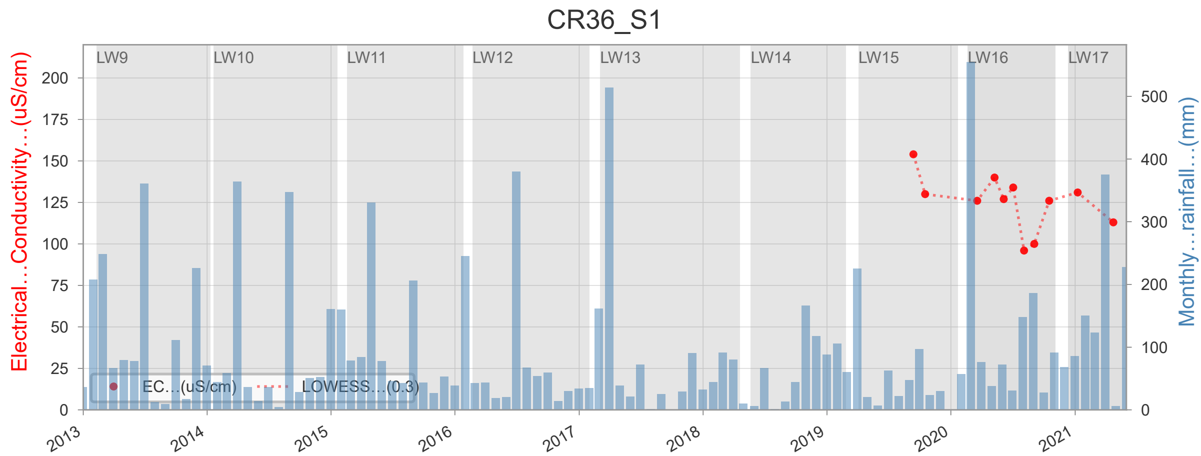
Watershed Hydrogeo, 2019a. Discussion of surface water flow TARPs (No. R011i5), Report for South32 Illawarra Metallurgical Coal.

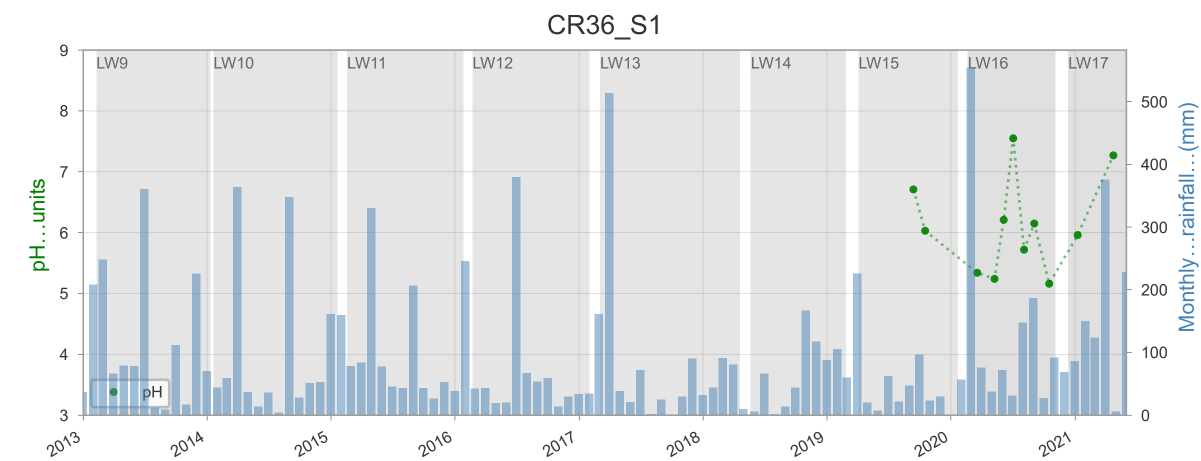
Watershed Hydrogeo, 2019b. Geographic review of mining effects on Upland Swamps at Dendrobium (No. R008i5), Report for South32 Illawarra Metallurgical Coal.

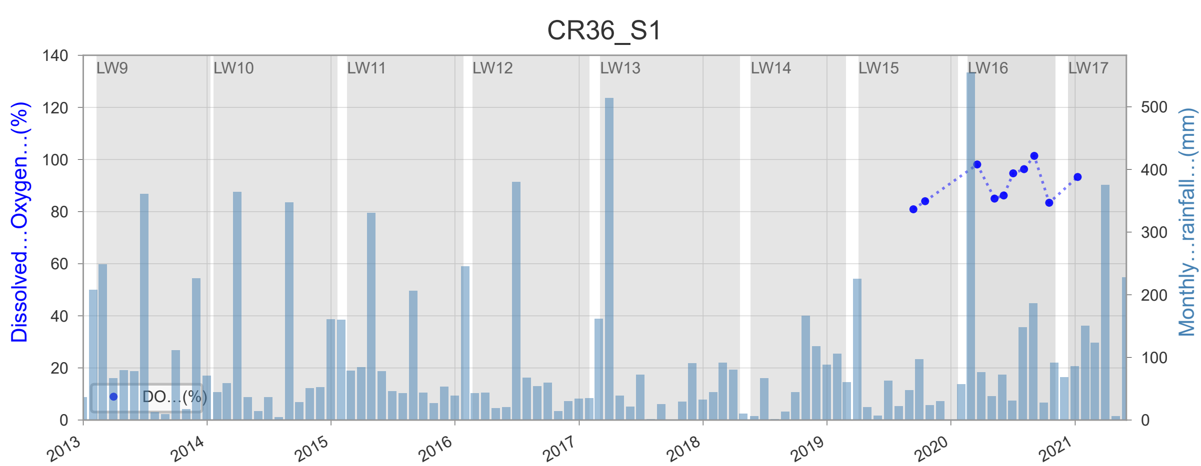
Watershed Hydrogeo, 2018. Dendrobium Area 3B Analysis of low-flow and pool levels on Wongawilli Creek (No. R003i2), Report for South32 Illawarra Metallurgical Coal.

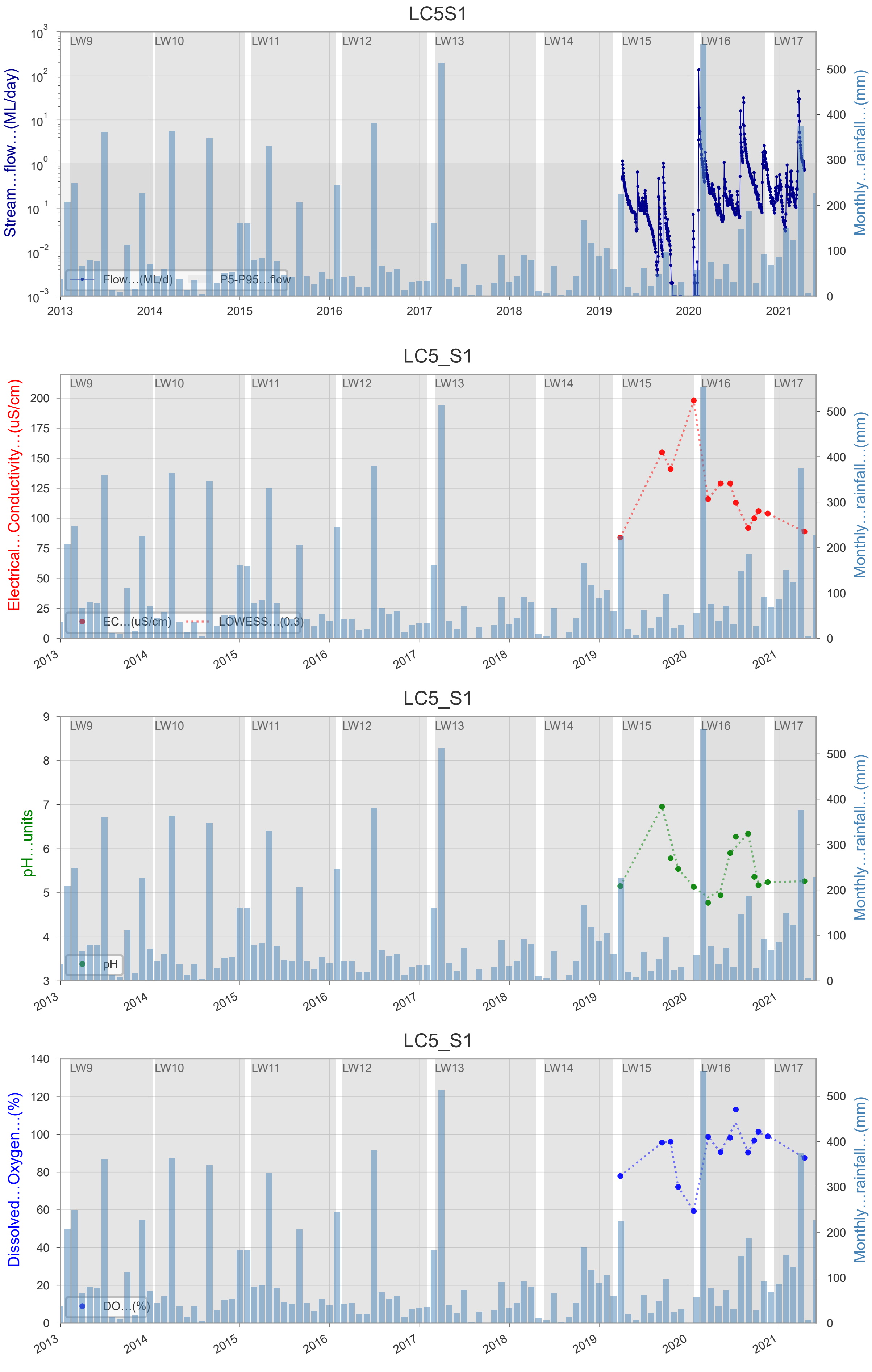
Whittaker, B., Reddish, D., 1989. Subsidence: occurrence, prediction and control. Elsevier, Amsterdam.
Young, A.R.M., 1982. Upland swamps (dells) on the Woronora Plateau, NSW. University of Wollongong.

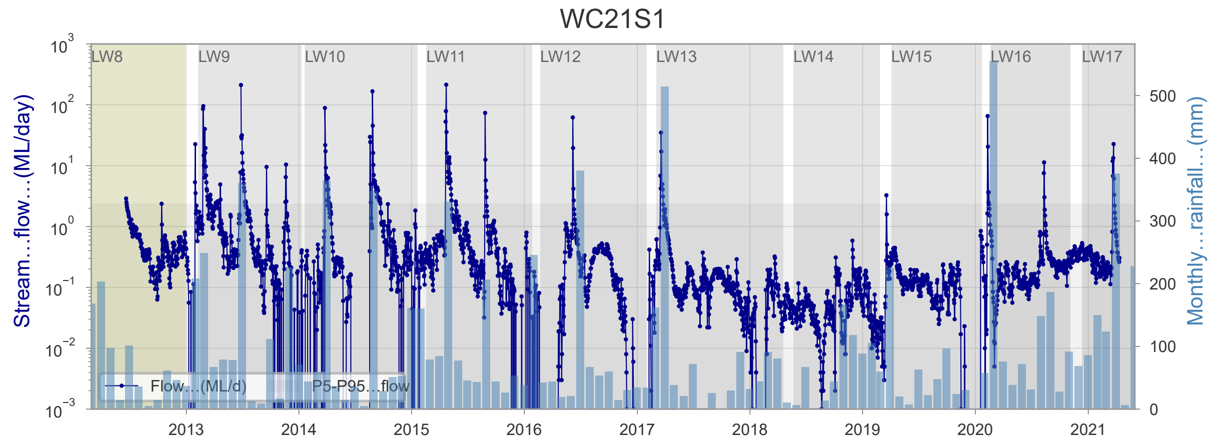

CR36S1
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
Stream...flow...(ML/day)
Monthly...rainfall...(mm)
Flow...(ML/d)
P5-P95...flow

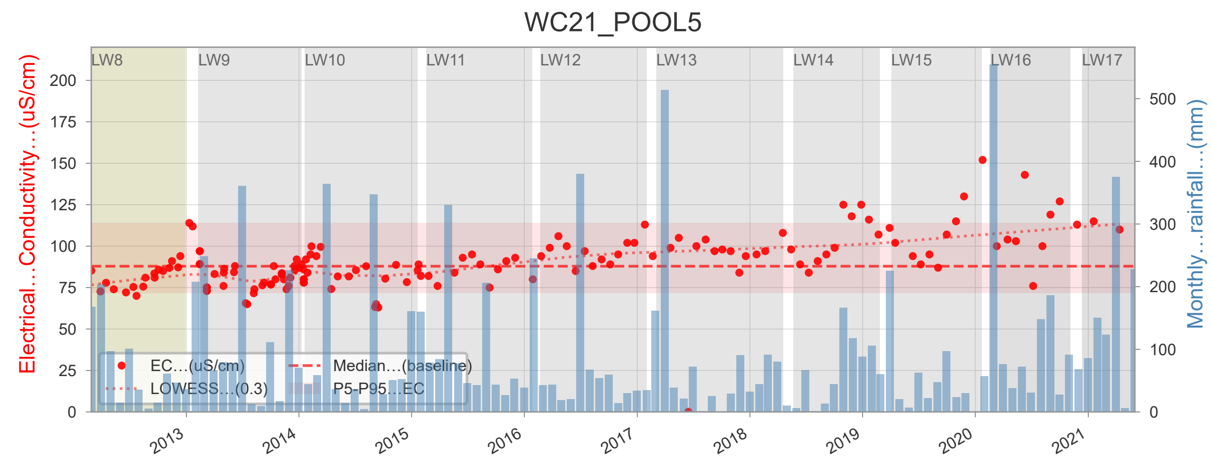

CR36_S1
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
Electrical...Conductivity...(uS/cm)
Monthly...rainfall...(mm)
EC...(uS/cm)
LOWESS...(0.3)

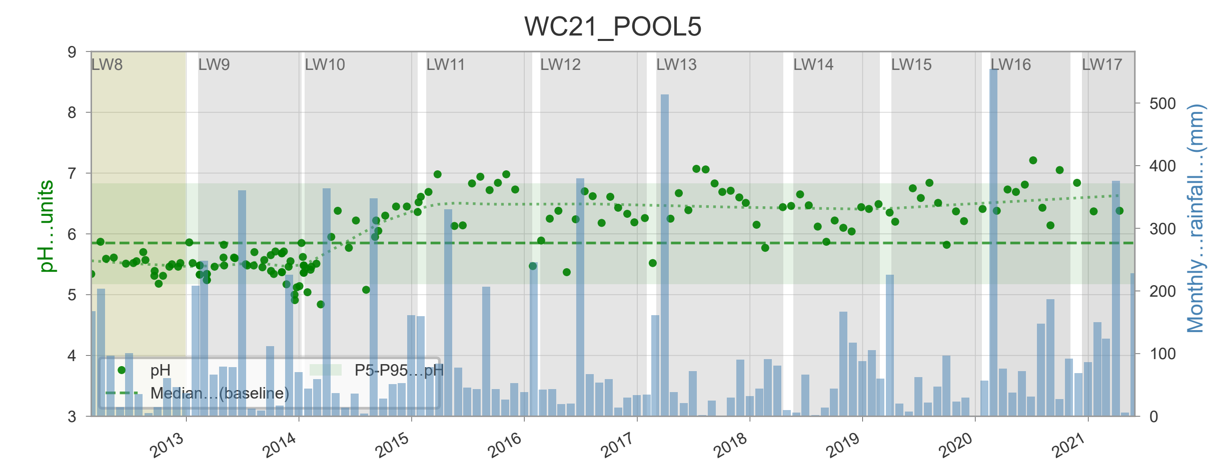

CR36_S1
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
pH...units
Monthly...rainfall...(mm)
pH

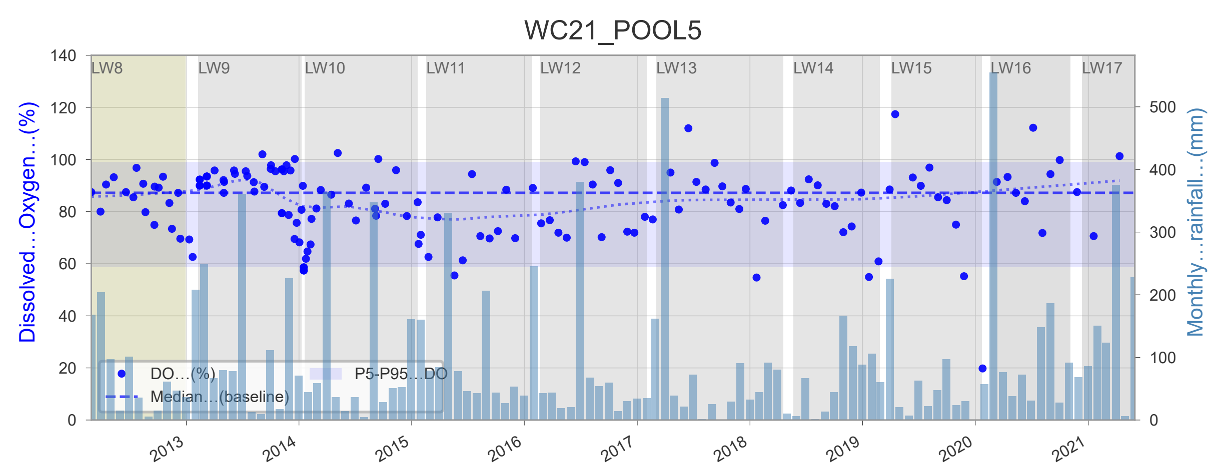

CR36_S1
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
Dissolved...Oxygen...(%)
Monthly...rainfall...(mm)
DO...(%)

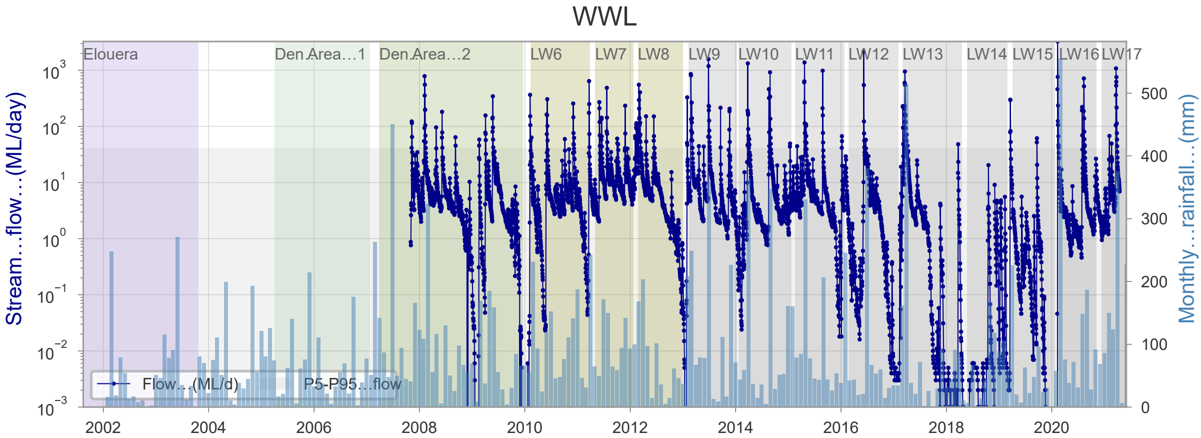
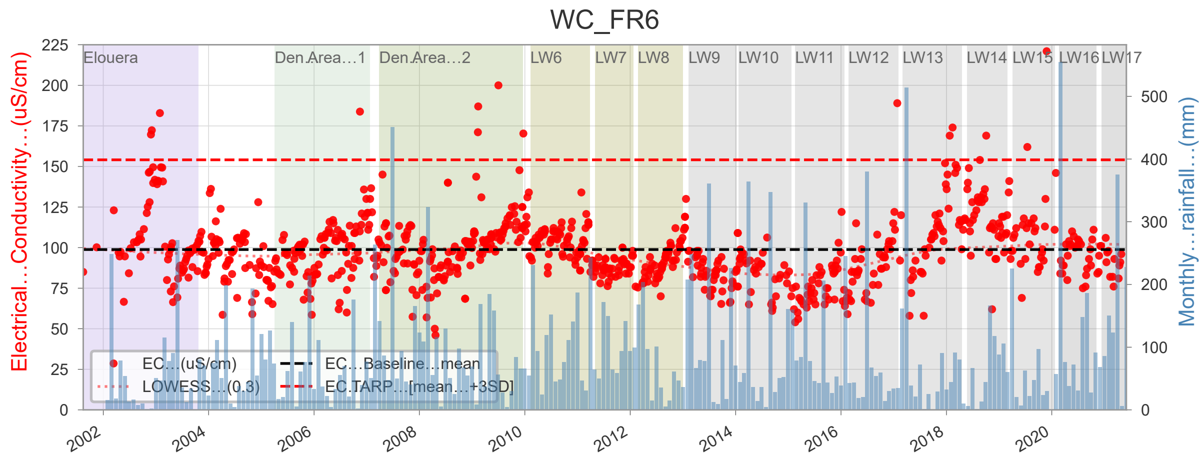
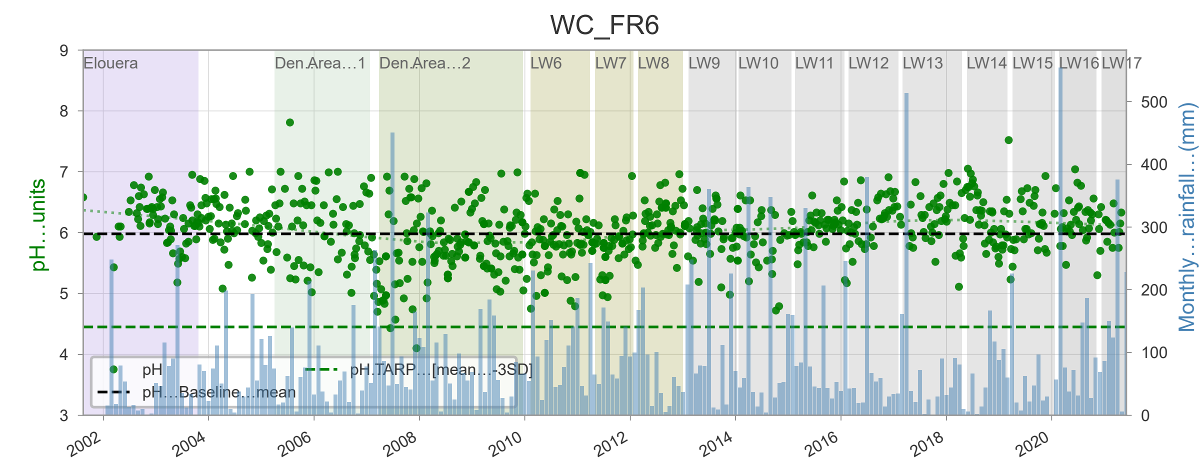
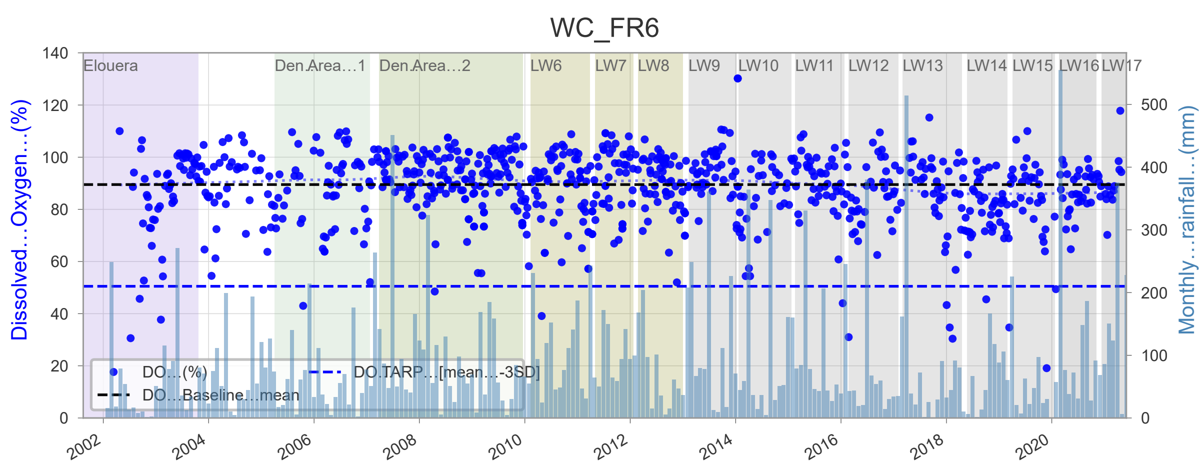

LC5S1
Stream…flow…(ML/day)
Monthly…rainfall…(mm)
Flow…(ML/d)
P5-P95…flow
LC5_S1
Electrical…Conductivity…(uS/cm)
EC…(uS/cm)
LOWESS…(0.3)
LC5_S1
pH…units
pH
LC5_S1
Dissolved…Oxygen…(%)
DO…(%)
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
2013
2014
2015
2016
2017
2018
2019
2020
2021

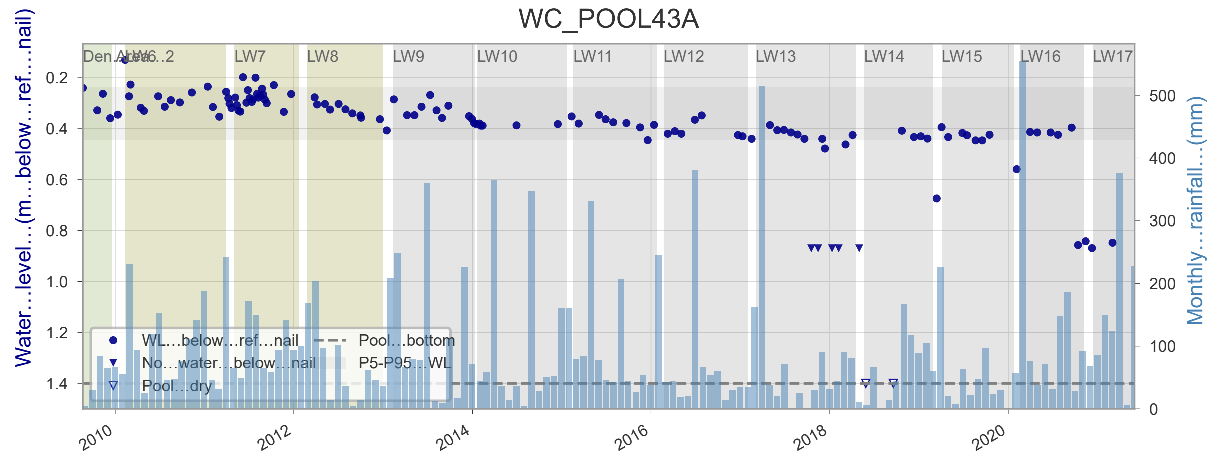

WC21S1
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
Stream...flow...(ML/day)
Monthly...rainfall...(mm)
Flow...(ML/d)
P5-P95...flow

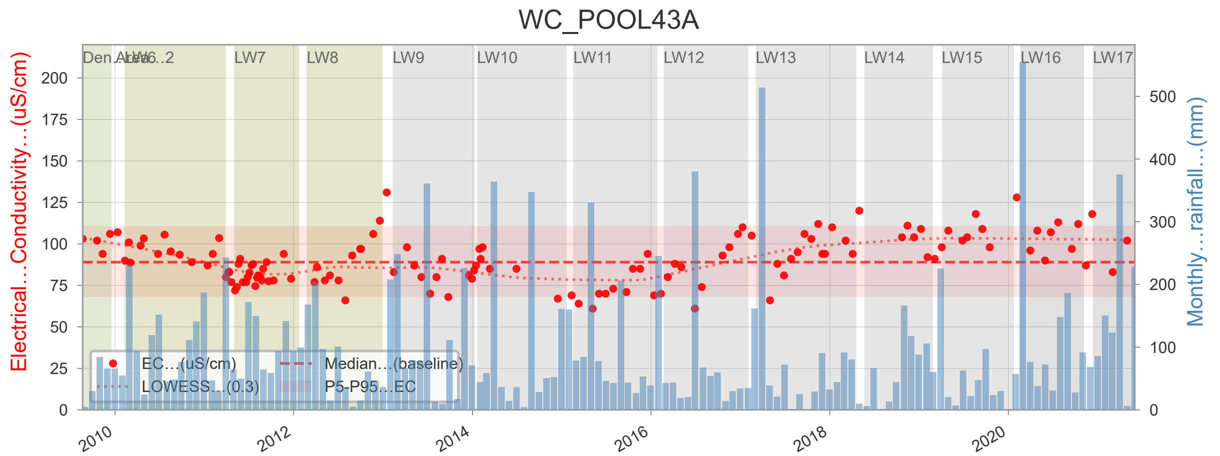

WC21_POOL5
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
Electrical...Conductivity...(uS/cm)
Monthly...rainfall...(mm)
EC...(uS/cm)
LOWESS...(0.3)
Median...(baseline)
P5-P95...EC

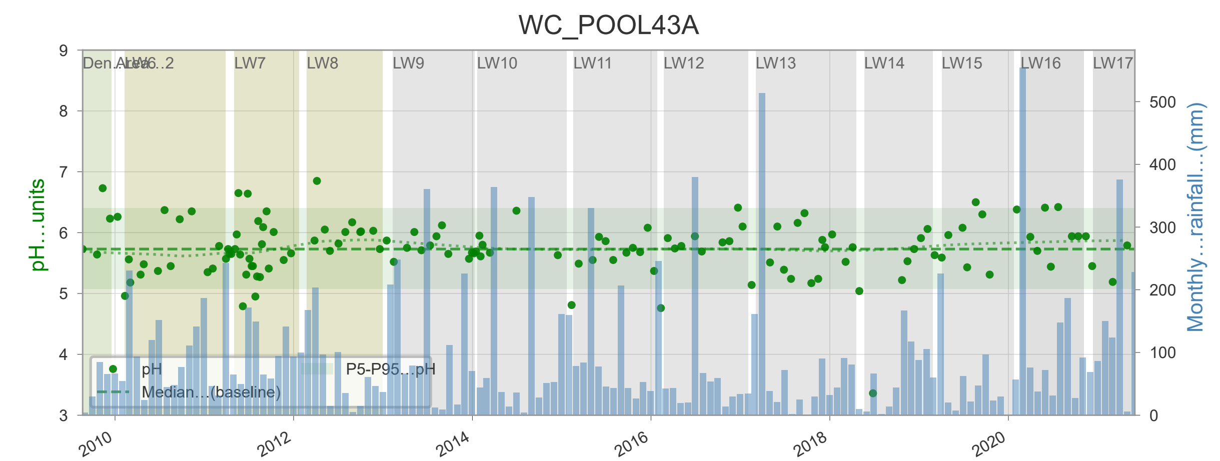

WC21_POOL5
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
pH...units
Monthly...rainfall...(mm)
pH
Median...(baseline)
P5-P95...pH

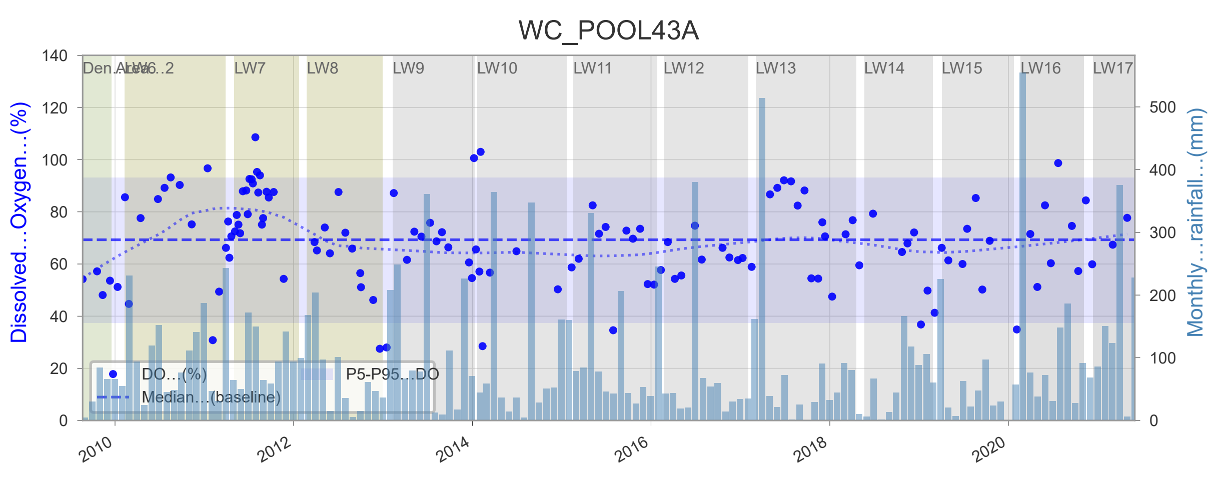

WC21_POOL5
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
Dissolved...Oxygen...(%)
Monthly...rainfall...(mm)
DO...(%)
Median...(baseline)
P5-P95...DO

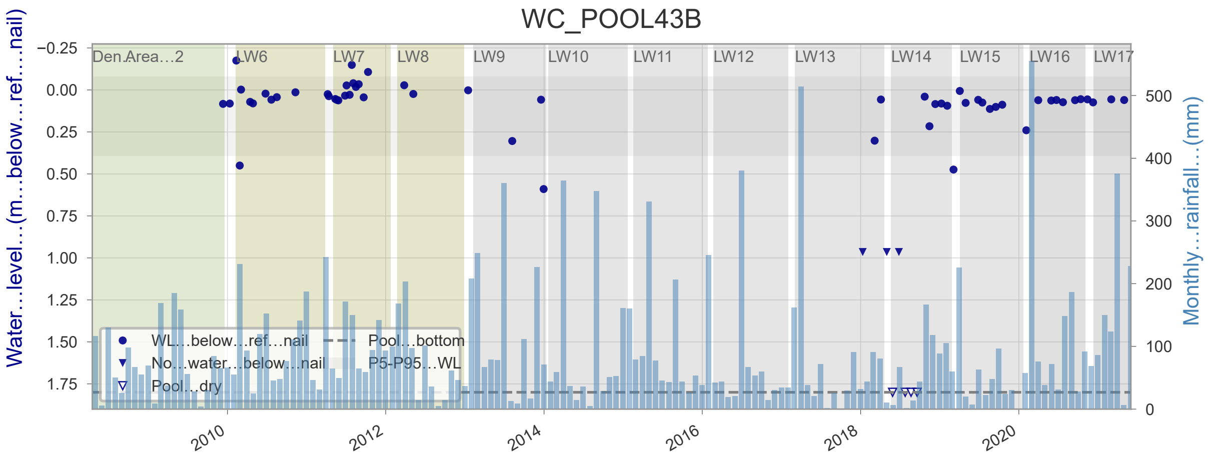

WWL
Stream...flow...(ML/day)
Monthly...rainfall...(mm)
Elouera
Den.Area...1
Den.Area...2
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
Flow...(ML/d)
P5-P95...flow

WC_FR6
Electrical...Conductivity...(uS/cm)
Monthly...rainfall...(mm)
Elouera
Den.Area...1
Den.Area...2
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
EC...(uS/cm)
LOWESS...(0.3)
EC...Baseline...mean
EC.TARP...[mean...+3SD]

WC_FR6
pH...units
Monthly...rainfall...(mm)
Elouera
Den.Area...1
Den.Area...2
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
pH
pH...Baseline...mean
pH.TARP...[mean...-3SD]

WC_FR6
Dissolved...Oxygen...(%)
Monthly...rainfall...(mm)
Elouera
Den.Area...1
Den.Area...2
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
DO...(%)
DO...Baseline...mean
DO.TARP...[mean...-3SD]

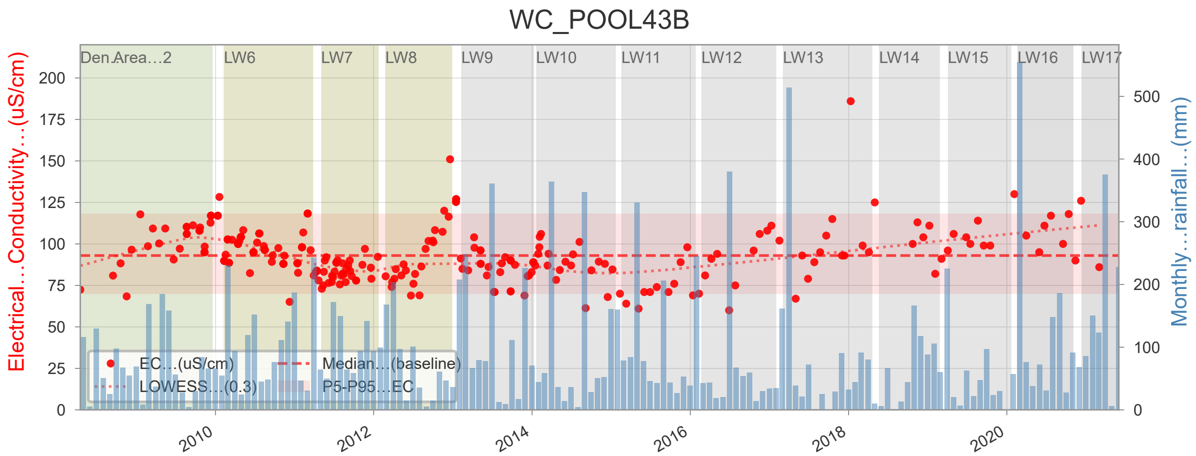

WC_POOL43A
Water...level...(m...below...ref....nail)
Monthly...rainfall...(mm)
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
WL...below...ref...nail
No...water...below...nail
Pool...dry
Pool...bottom
P5-P95...WL

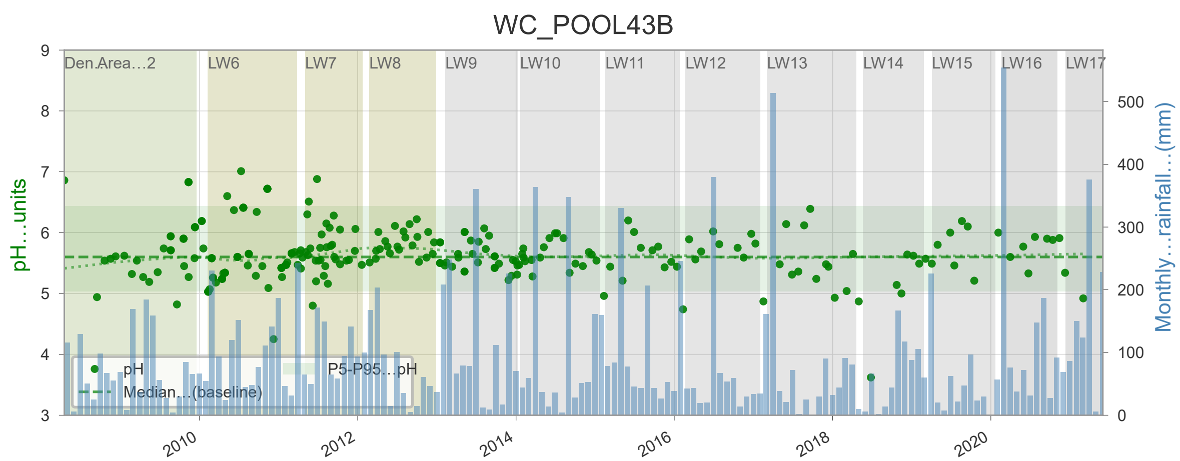

WC_POOL43A
Electrical...Conductivity...(uS/cm)
Monthly...rainfall...(mm)
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
EC...(uS/cm)
LOWESS...(0.3)
Median...(baseline)
P5-P95...EC

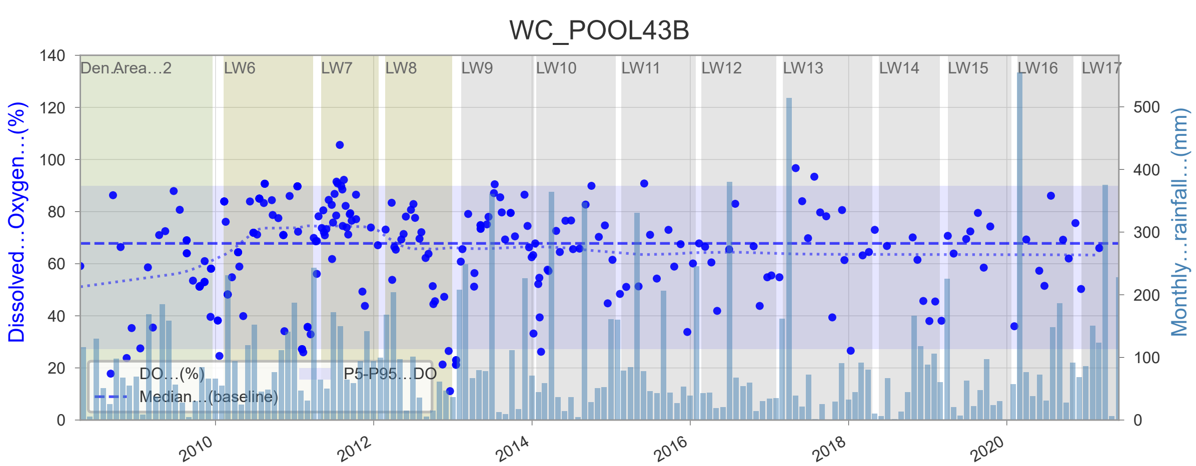

WC_POOL43A
pH...units
Monthly...rainfall...(mm)
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
pH
Median...(baseline)
P5-P95...pH

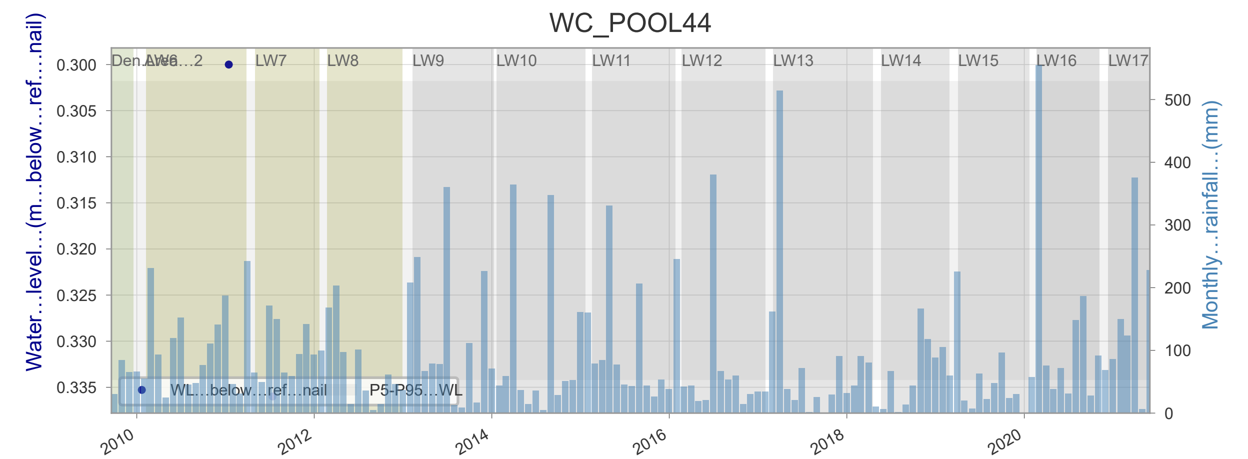

WC_POOL43A
Dissolved...Oxygen...(%)
Monthly...rainfall...(mm)
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
DO...(%)
Median...(baseline)
P5-P95...DO

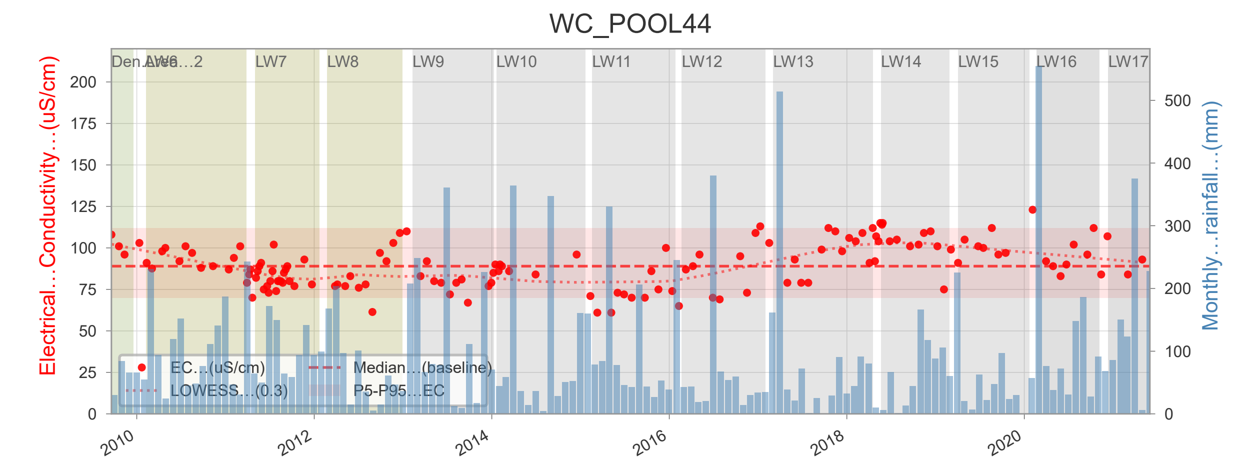

WC_POOL43B
Water...level...(m...below...ref...nail)
Monthly...rainfall...(mm)
Den.Area...2
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
WL...below...ref...nail
No...water...below...nail
Pool...dry
Pool...bottom
P5-P95...WL

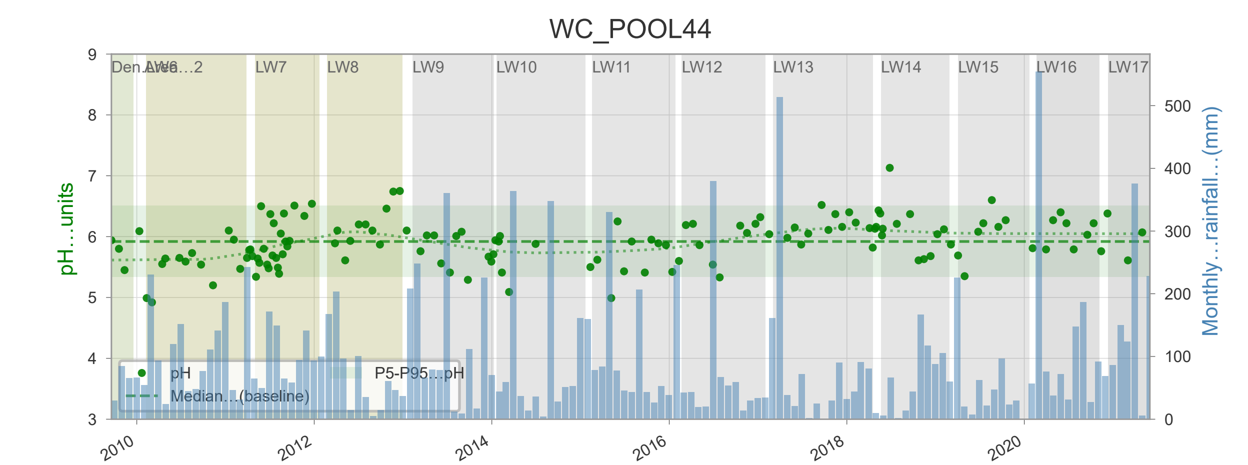

WC_POOL43B
Electrical...Conductivity...(uS/cm)
Monthly...rainfall...(mm)
Den.Area...2
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
EC...(uS/cm)
LOWESS...(0.3)
Median...(baseline)
P5-P95...EC

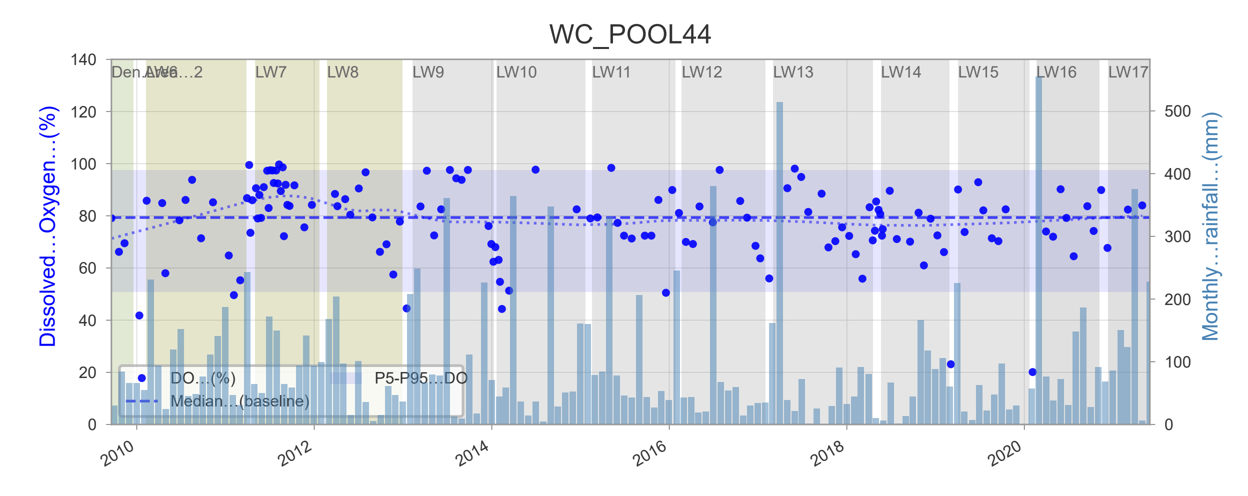

WC_POOL43B
pH...units
Monthly...rainfall...(mm)
Den.Area...2
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
pH
Median...(baseline)
P5-P95...pH


WC_POOL43B
Dissolved...Oxygen...(%)
Monthly...rainfall...(mm)
Den.Area...2
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
DO...(%)
Median...(baseline)
P5-P95...DO

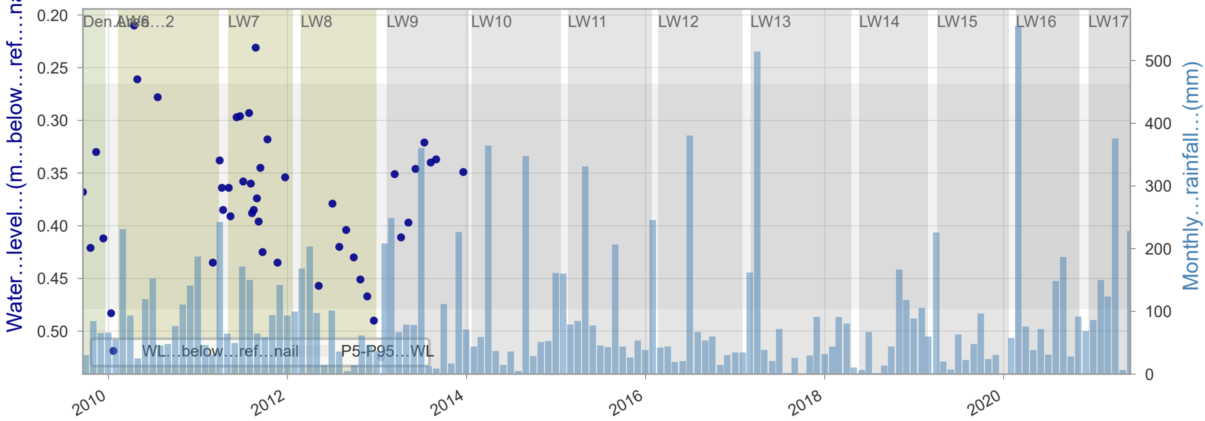

WC_POOL44
Water...level...(m...below...ref...nail)
Monthly...rainfall...(mm)
Den.Area...2
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
WL...below...ref...nail
P5-P95...WL
0.300
0.305
0.310
0.315
0.320
0.325
0.330
0.335
0
100
200
300
400
500
2010
2012
2014
2016
2018
2020


WC_POOL44
Electrical...Conductivity...(uS/cm)
Monthly...rainfall...(mm)
Den.Area...2
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
EC...(uS/cm)
LOWESS...(0.3)
Median...(baseline)
P5-P95...EC
0
25
50
75
100
125
150
175
200
0
100
200
300
400
500
2010
2012
2014
2016
2018
2020

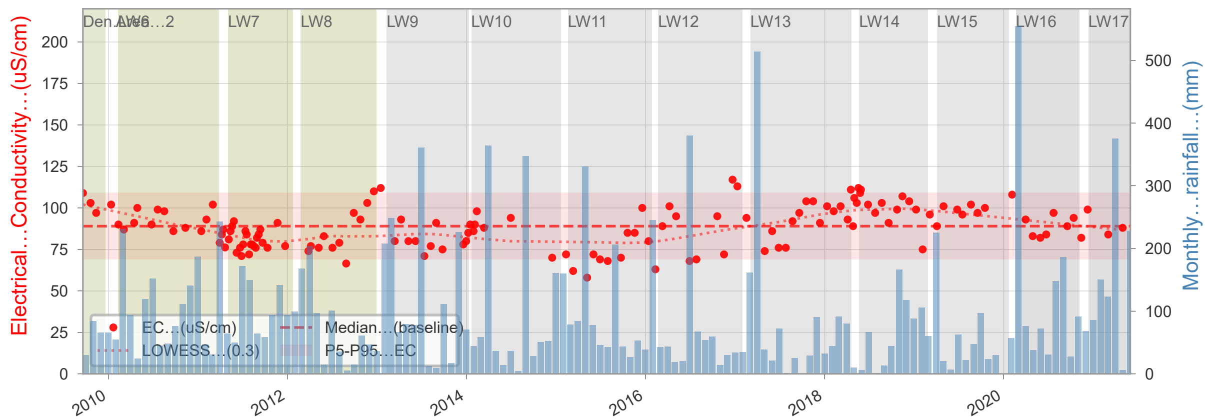

WC_POOL44
pH...units
Monthly...rainfall...(mm)
Den.Area...2
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
pH
Median...(baseline)
P5-P95...pH
3
4
5
6
7
8
9
0
100
200
300
400
500
2010
2012
2014
2016
2018
2020


WC_POOL44
Dissolved...Oxygen...(%)
Monthly...rainfall...(mm)
Den.Area...2
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
DO...(%)
Median...(baseline)
P5-P95...DO
0
20
40
60
80
100
120
140
0
100
200
300
400
500
2010
2012
2014
2016
2018
2020

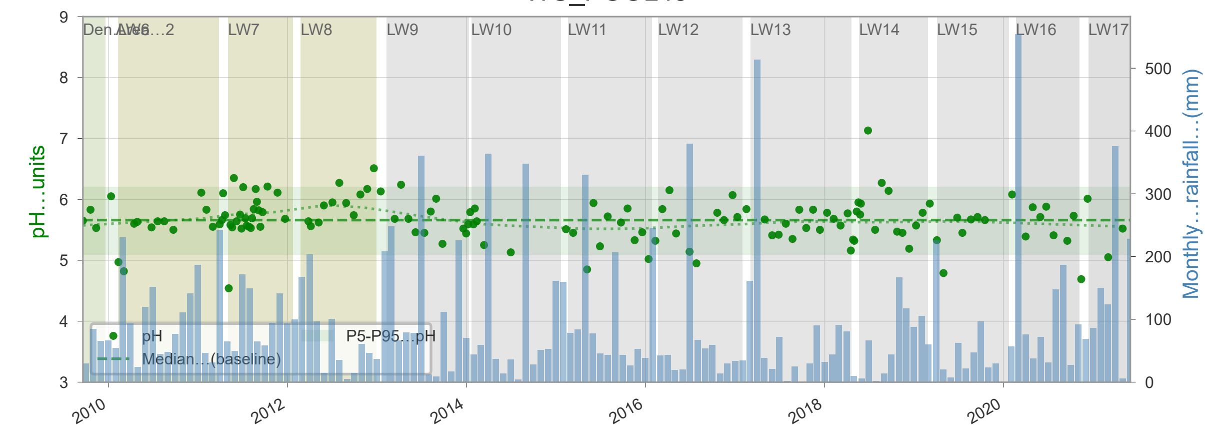
WC_POOL45



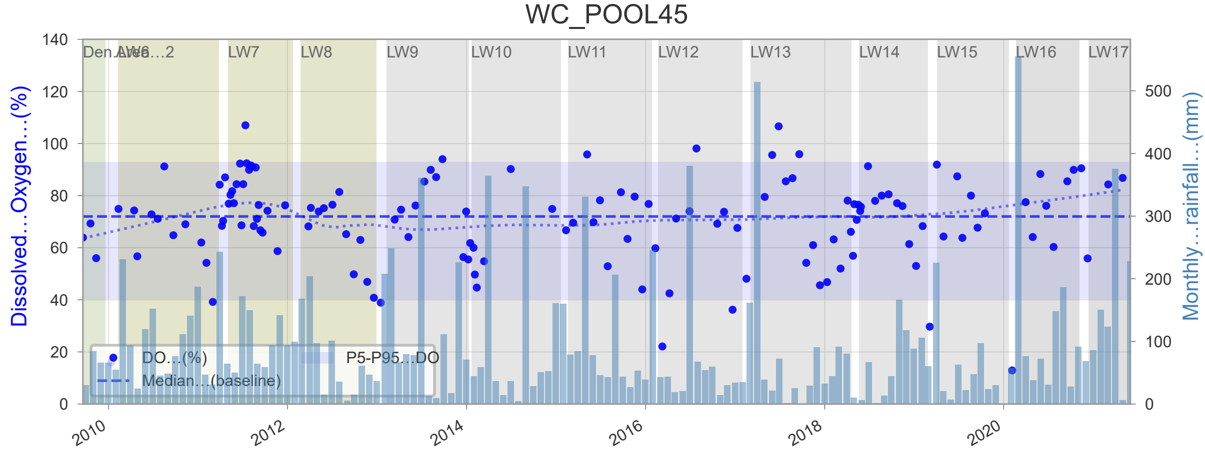
WC_POOL45

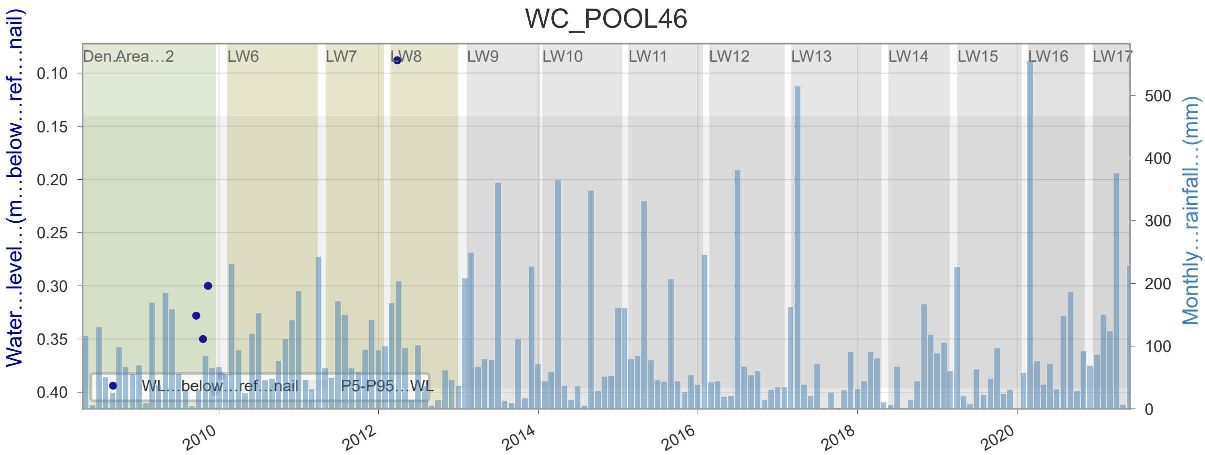


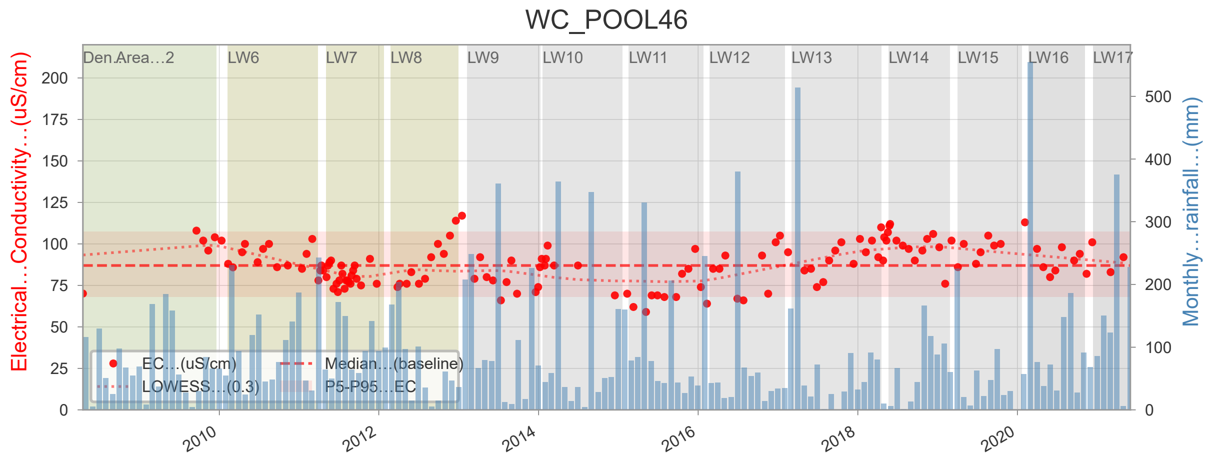
WC_POOL45

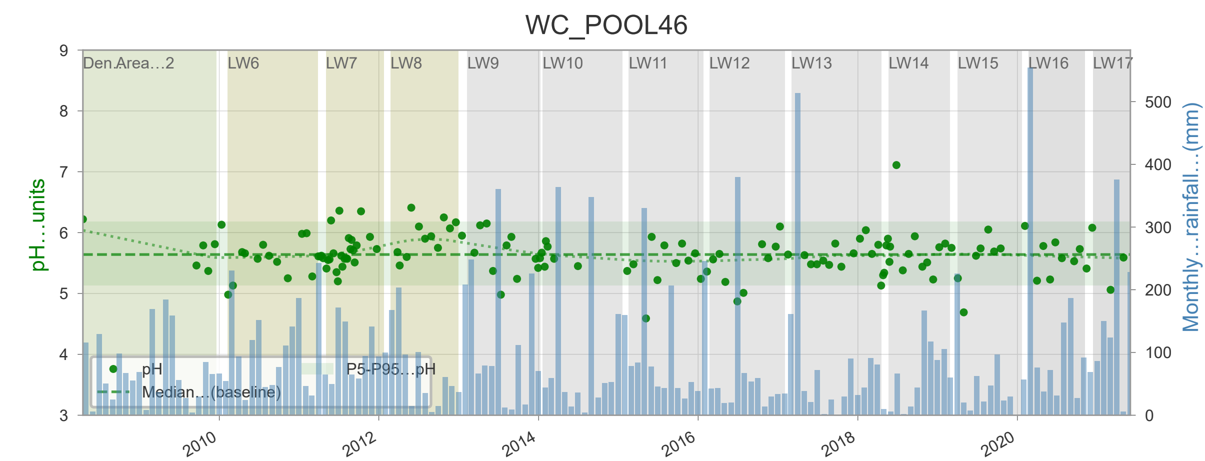


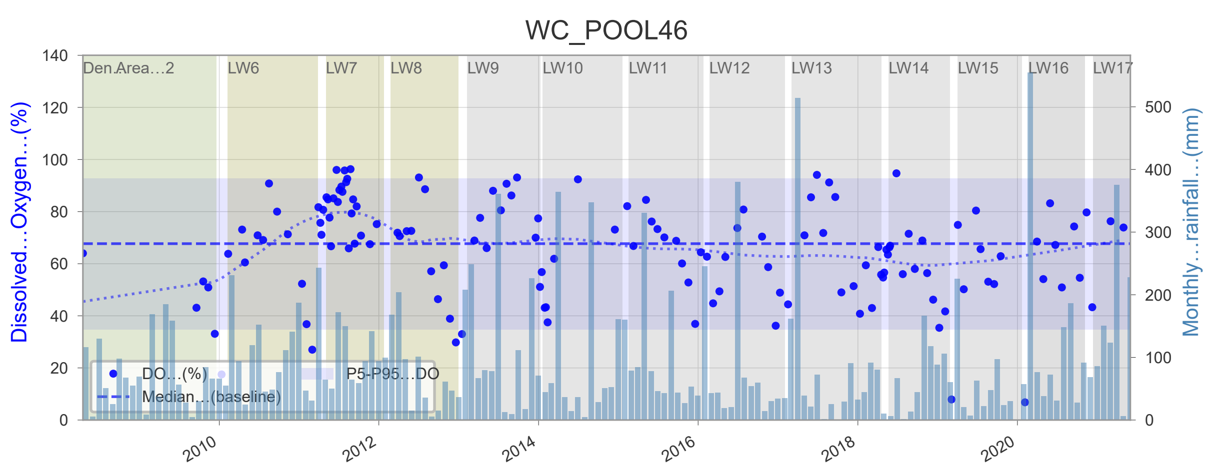
WC_POOL45

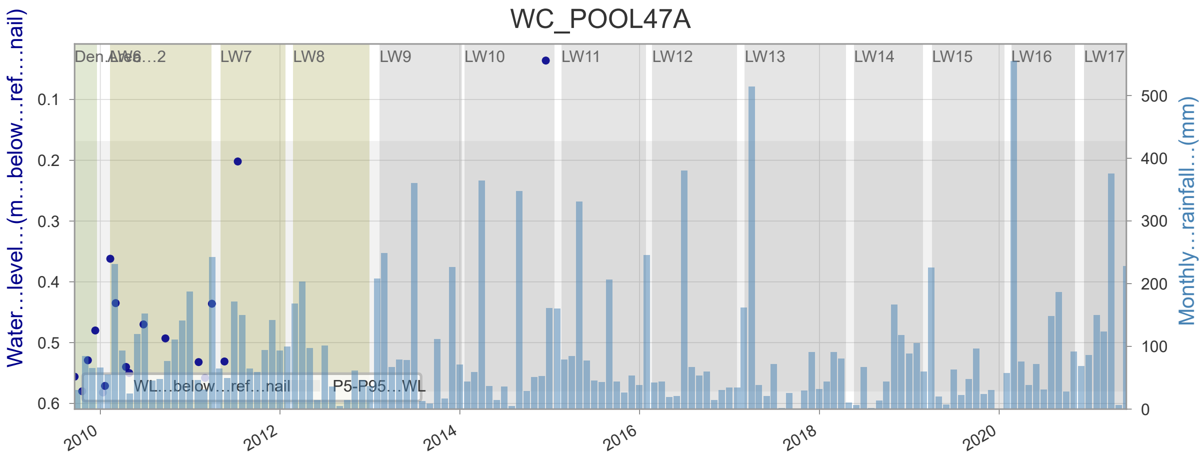


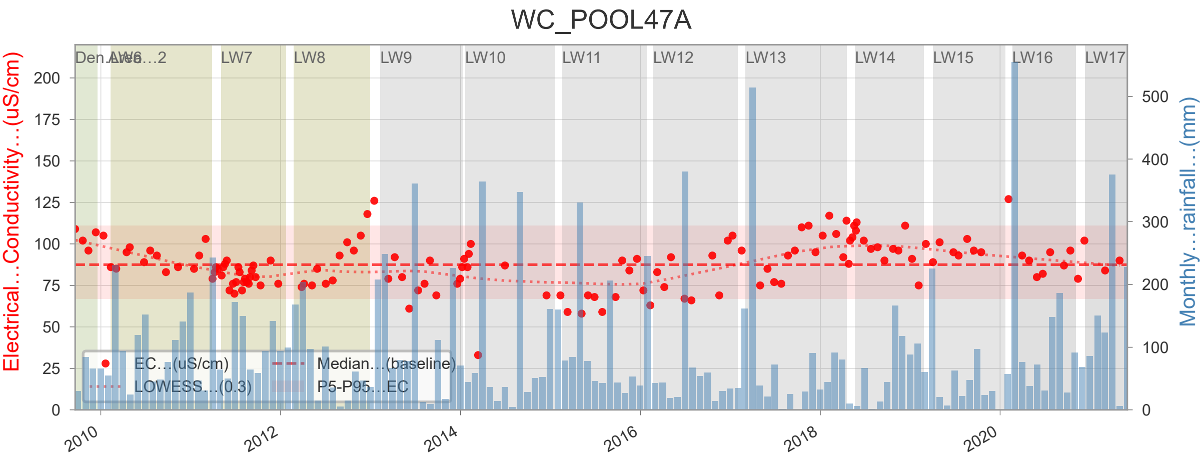

WC_POOL46
Den.Area...2
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
Water...level...(m...below...ref...nail)
Monthly...rainfall...(mm)
WL...below...ref...nail
P5-P95...WL

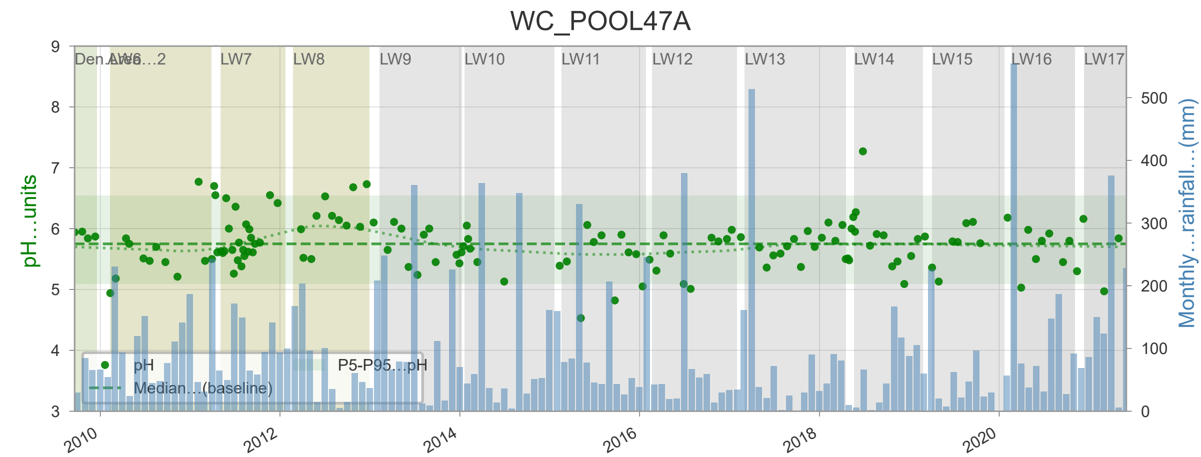

WC_POOL46
Electrical...Conductivity...(uS/cm)
Monthly...rainfall...(mm)
EC...(uS/cm)
LOWESS...(0.3)
Median...(baseline)
P5-P95...EC

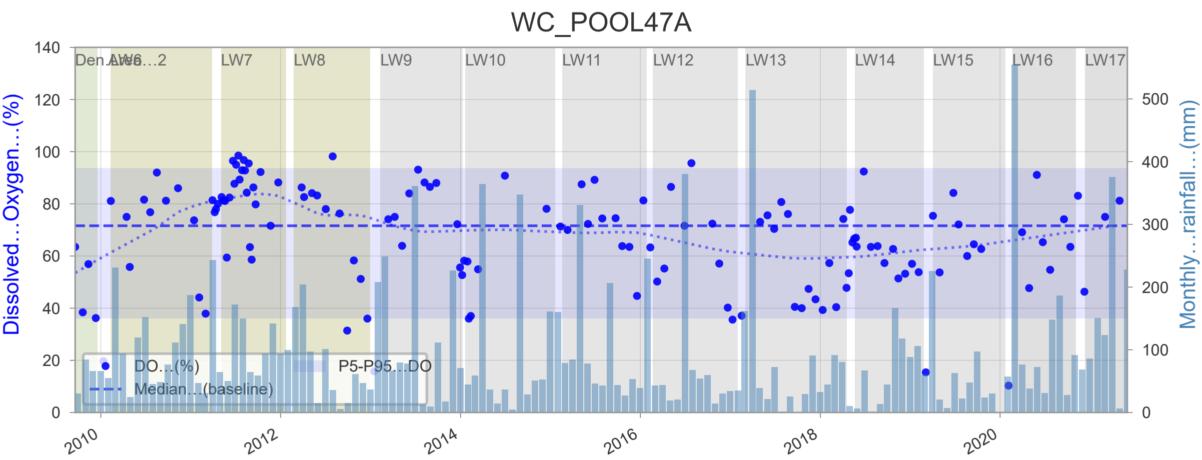

WC_POOL46
pH...units
Monthly...rainfall...(mm)
pH
Median...(baseline)
P5-P95...pH

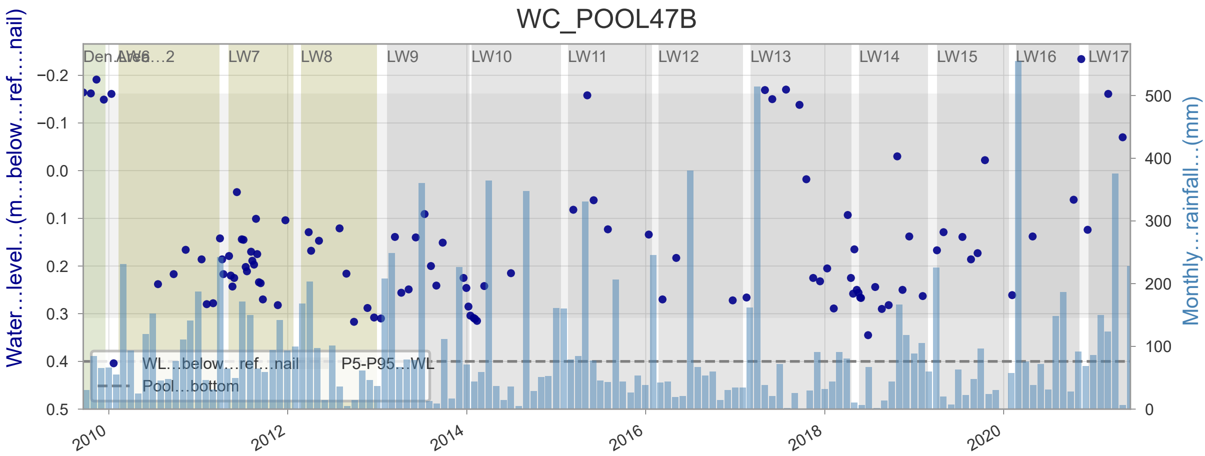

WC_POOL46
Dissolved...Oxygen...(%)
Monthly...rainfall...(mm)
DO...(%)
Median...(baseline)
P5-P95...DO


WC_POOL47A
Water...level...(m...below...ref...nail)
Monthly...rainfall...(mm)
Den Awe...2
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
WL...below...ref...nail
P5-P95...WL

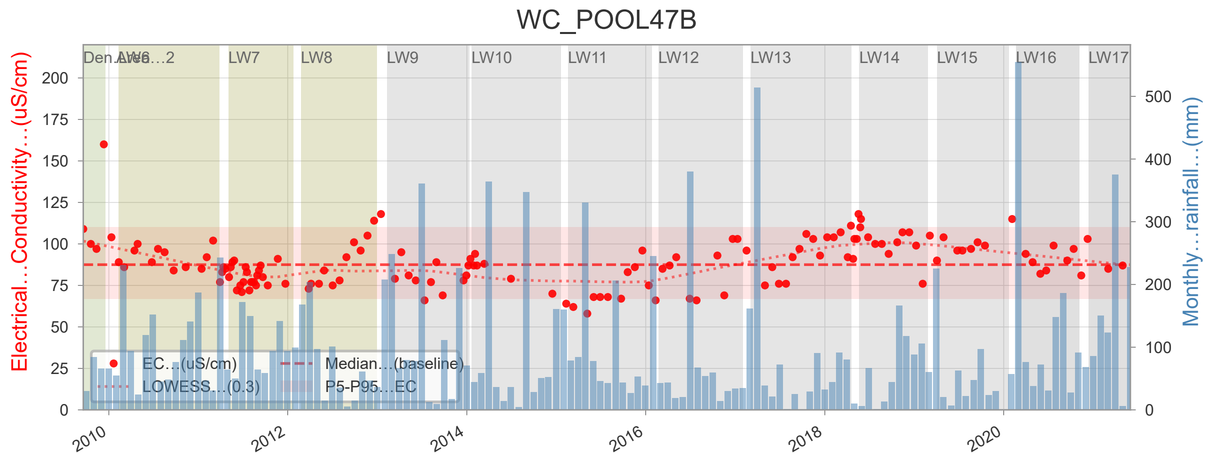

WC_POOL47A
Electrical...Conductivity...(uS/cm)
Monthly...rainfall...(mm)
EC...(uS/cm)
LOWESS...(0.3)
Median...(baseline)
P5-P95...EC


WC_POOL47A
pH...units
Monthly...rainfall...(mm)
pH
Median...(baseline)
P5-P95...pH

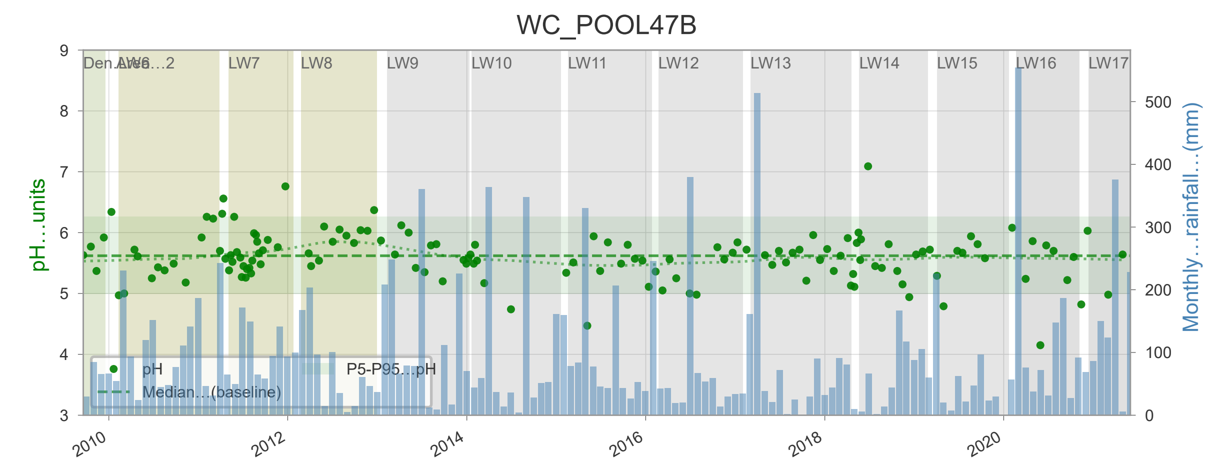

WC_POOL47A
Dissolved...Oxygen...(%)
Monthly...rainfall...(mm)
DO...(%)
Median...(baseline)
P5-P95...DO



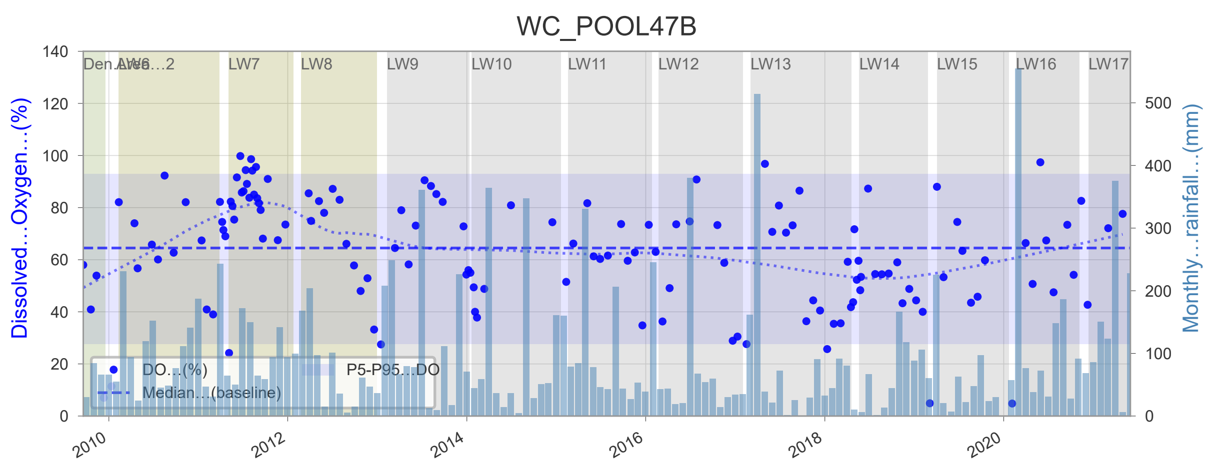
WC_POOL47B
Den.Area...2
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
Water...level...(m...below...ref...nail)
Monthly...rainfall...(mm)
WL...below...ref...nail
Pool...bottom
P5-P95...WL



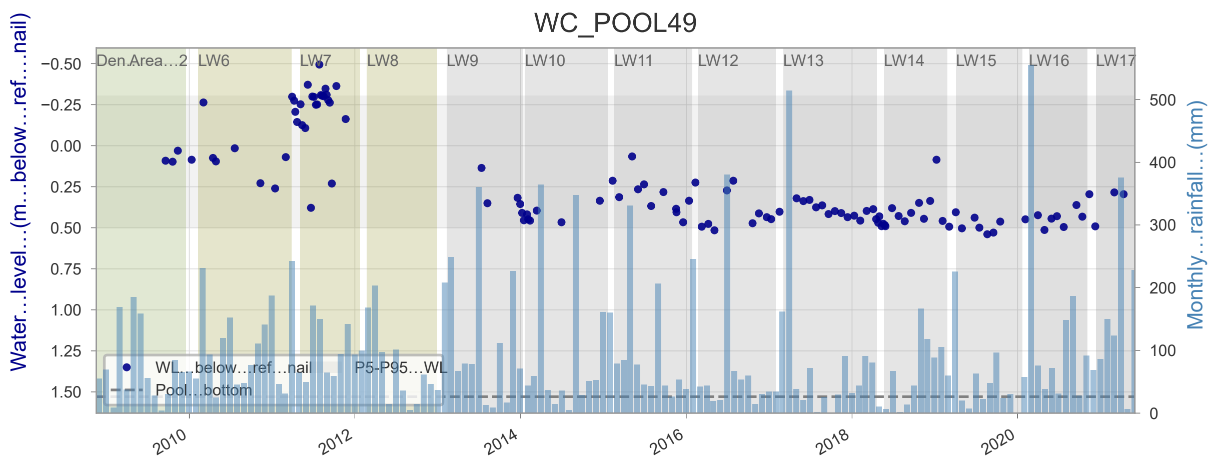
WC_POOL47B
Den.Area...2
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
Electrical...Conductivity...(uS/cm)
Monthly...rainfall...(mm)
EC...(uS/cm)
LOWESS...(0.3)
Median...(baseline)
P5-P95...EC

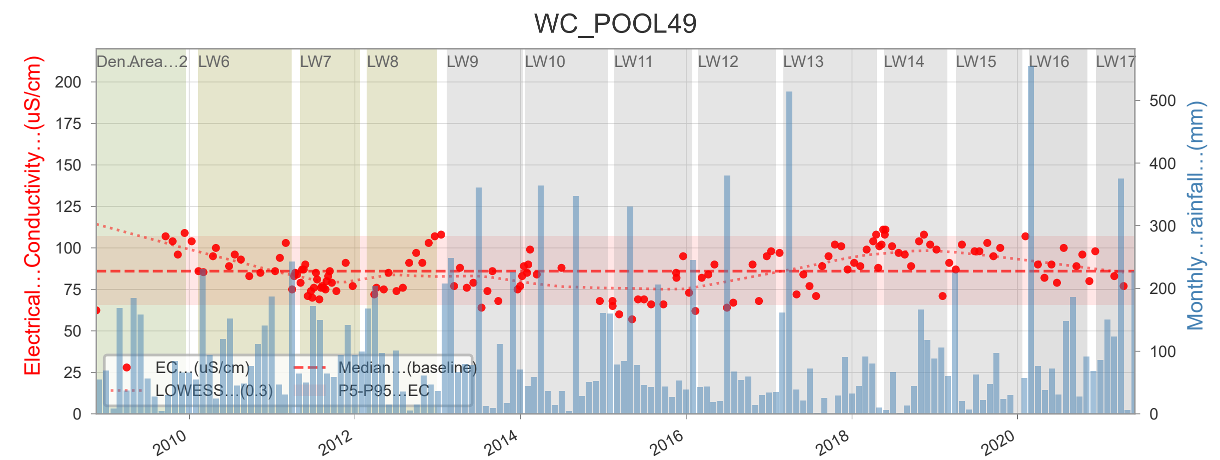


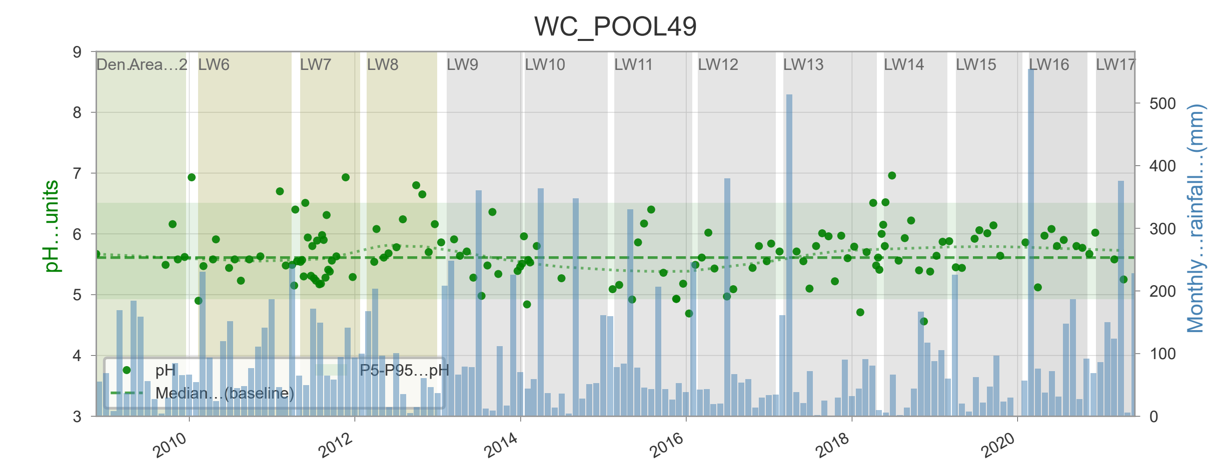
WC_POOL47B
Den.Area...2
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
pH...units
Monthly...rainfall...(mm)
pH
Median...(baseline)
P5-P95...pH

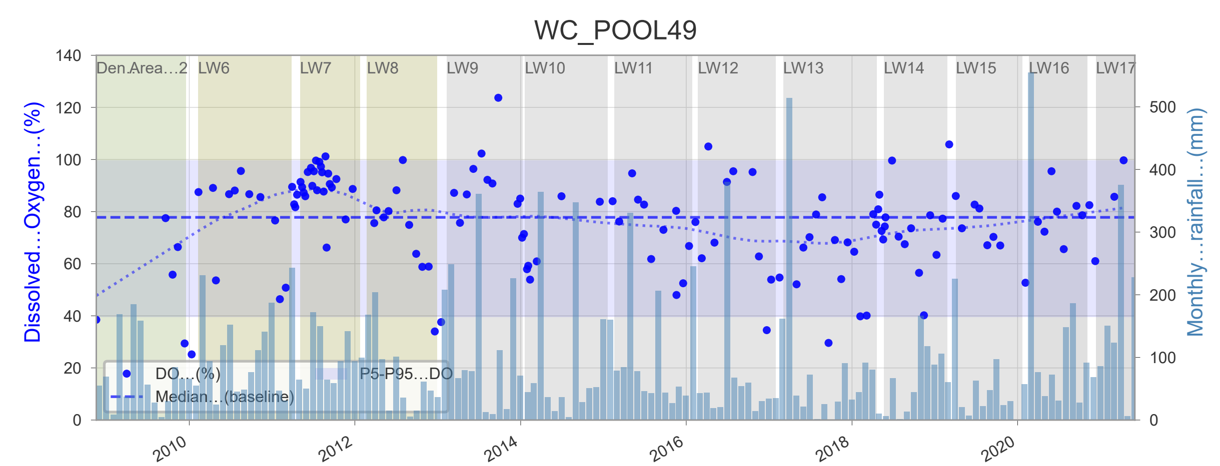


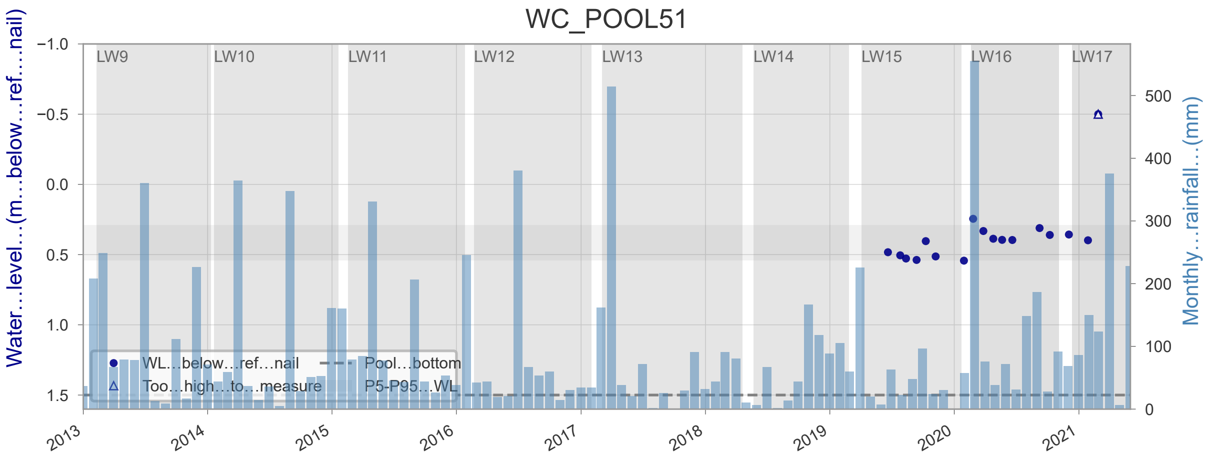
WC_POOL47B
Den.Area...2
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
Dissolved...Oxygen...(%)
Monthly...rainfall...(mm)
DO...(%)
Median...(baseline)
P5-P95...DO

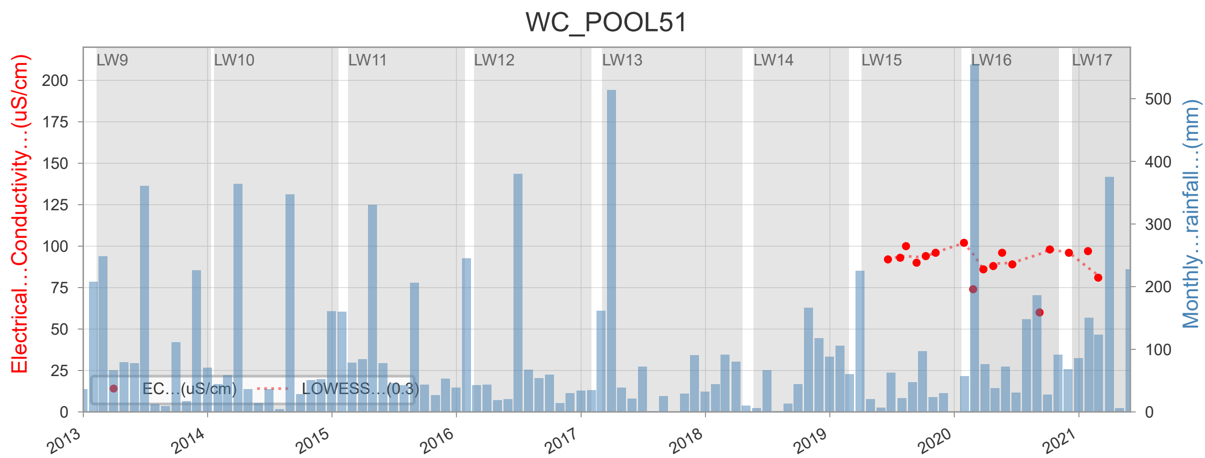

WC_POOL49
Water...level...(m...below...ref...nail)
Monthly...rainfall...(mm)
Den.Area...2
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
WL...below...ref...nail
Pool...bottom
P5-P95...WL
-0.50
-0.25
0.00
0.25
0.50
0.75
1.00
1.25
1.50
500
400
300
200
100
0
2010
2012
2014
2016
2018
2020

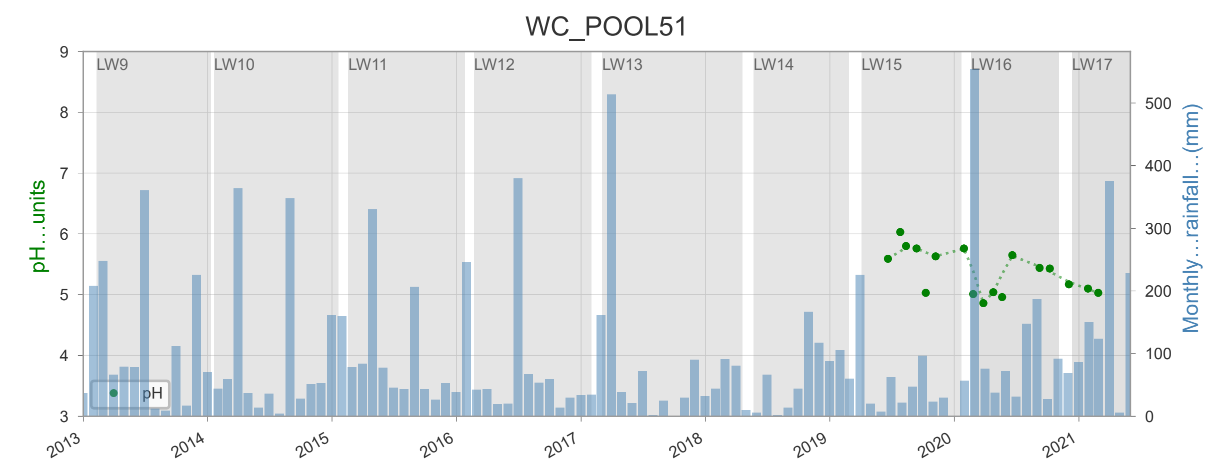

WC_POOL49
Electrical...Conductivity...(uS/cm)
Monthly...rainfall...(mm)
Den.Area...2
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
EC...(uS/cm)
LOWESS...(0.3)
Median...(baseline)
P5-P95...EC
200
175
150
125
100
75
50
25
0
500
400
300
200
100
0
2010
2012
2014
2016
2018
2020

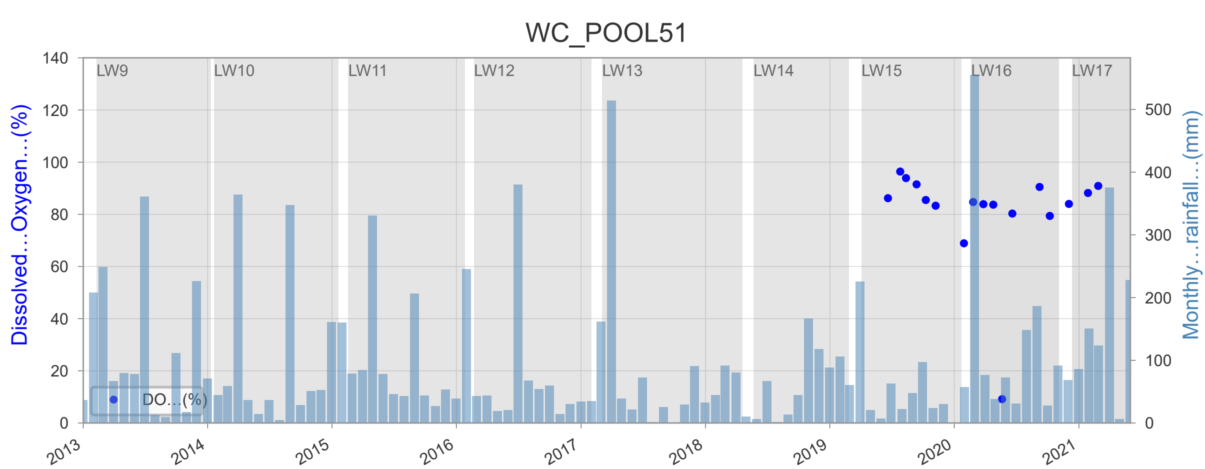

WC_POOL49
pH...units
Monthly...rainfall...(mm)
Den.Area...2
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
pH
Median...(baseline)
P5-P95...pH
9
8
7
6
5
4
3
500
400
300
200
100
0
2010
2012
2014
2016
2018
2020

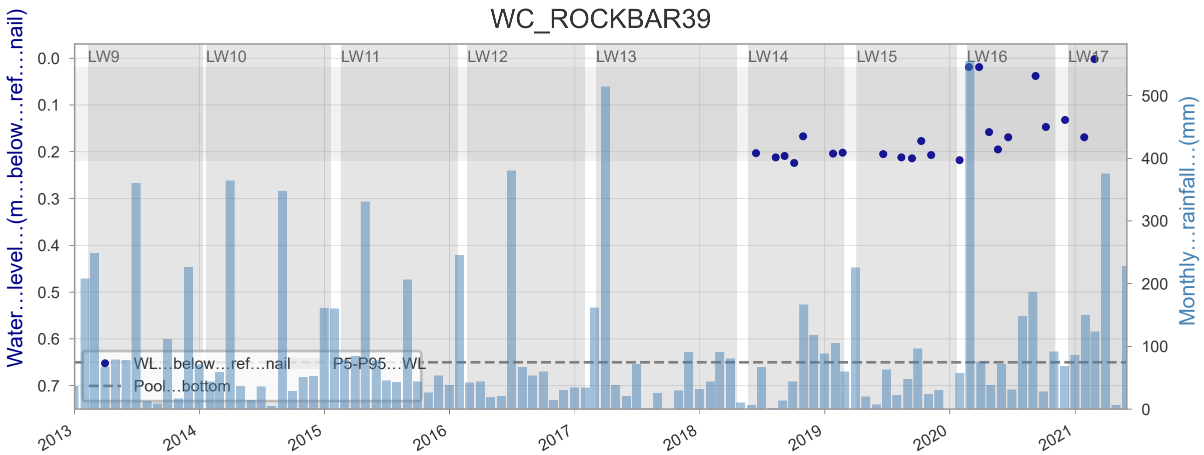

WC_POOL49
Dissolved...Oxygen...(%)
Monthly...rainfall...(mm)
Den.Area...2
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
DO...(%)
Median...(baseline)
P5-P95...DO
140
120
100
80
60
40
20
0
500
400
300
200
100
0
2010
2012
2014
2016
2018
2020

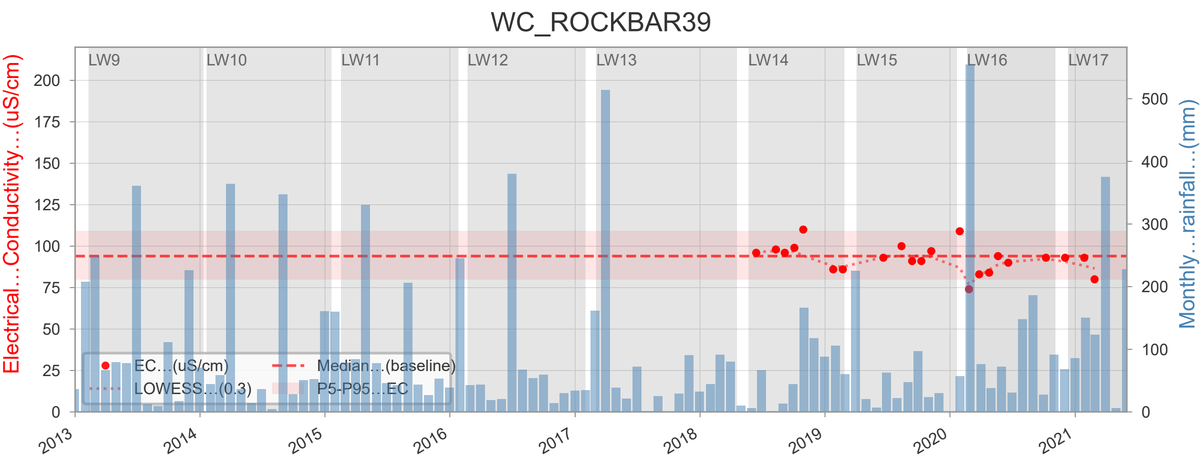

WC_POOL51
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
Water...level...(m...below...ref...nail)
Monthly...rainfall...(mm)
WL...below...ref...nail
Too...high...to...measure
Pool...bottom
P5-P95...WL
2013
2014
2015
2016
2017
2018
2019
2020
2021

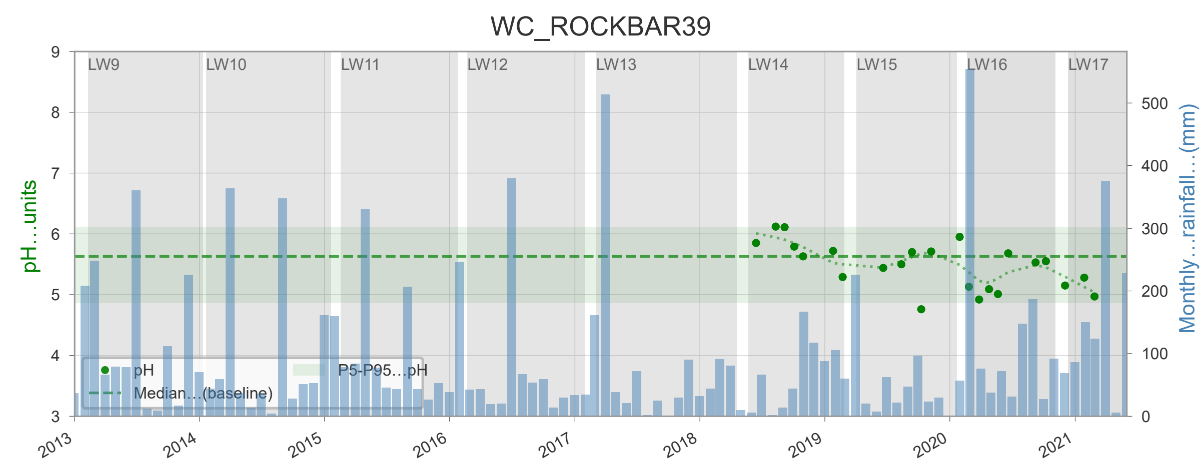

WC_POOL51
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
Electrical...Conductivity...(uS/cm)
Monthly...rainfall...(mm)
EC...(uS/cm)
LOWESS...(0.3)
2013
2014
2015
2016
2017
2018
2019
2020
2021

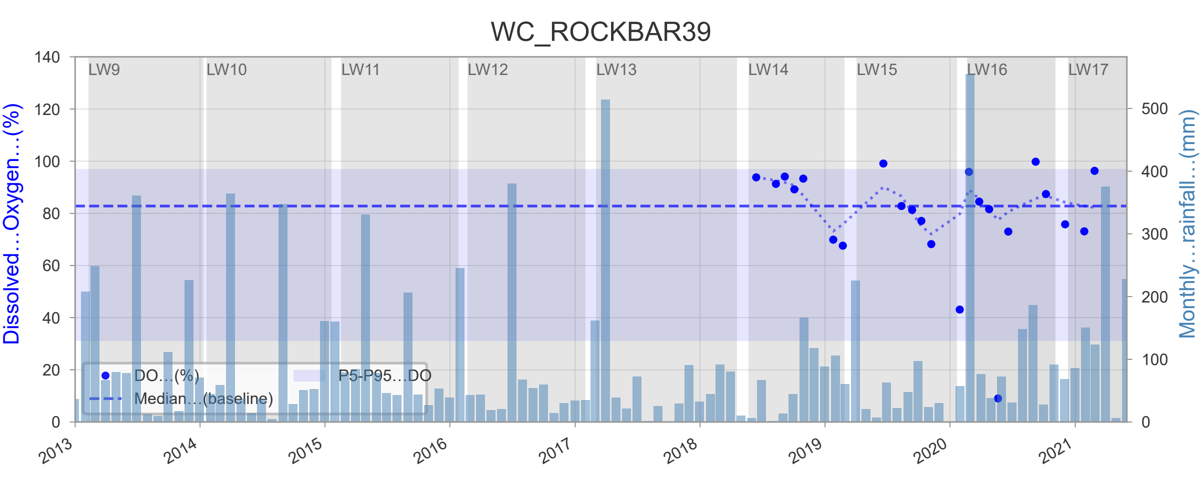

WC_POOL51
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
pH...units
Monthly...rainfall...(mm)
pH
2013
2014
2015
2016
2017
2018
2019
2020
2021

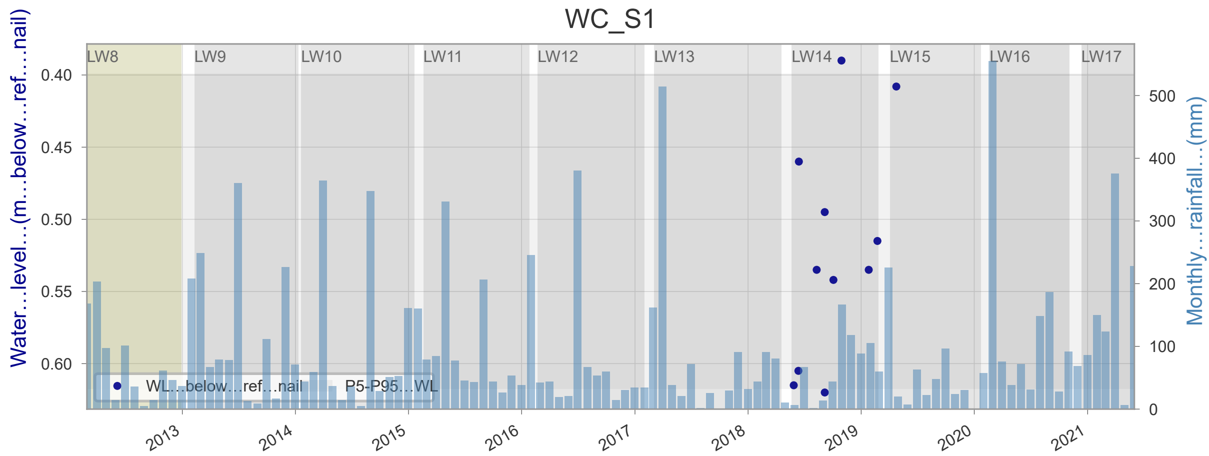

WC_POOL51
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
Dissolved...Oxygen...(%)
Monthly...rainfall...(mm)
DO...(%)
2013
2014
2015
2016
2017
2018
2019
2020
2021


WC_ROCKBAR39
Water...level...(m...below...ref....nail)
Monthly...rainfall...(mm)
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
WL...below...ref...nail
P5-P95...WL
Pool...bottom

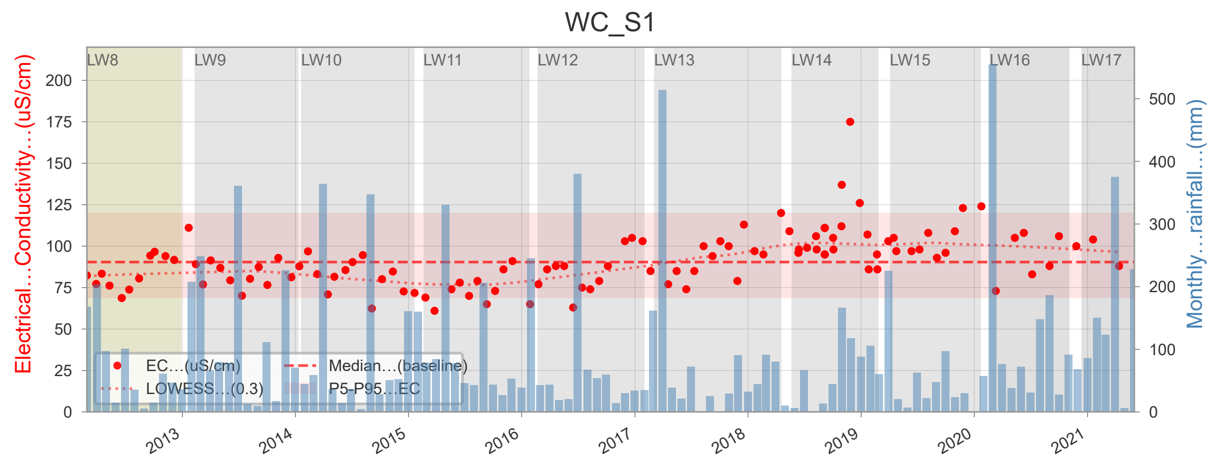

WC_ROCKBAR39
Electrical...Conductivity...(uS/cm)
Monthly...rainfall...(mm)
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
EC...(uS/cm)
Median...(baseline)
LOWESS...(0.3)
P5-P95...EC


WC_ROCKBAR39
pH...units
Monthly...rainfall...(mm)
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
pH
P5-P95...pH
Median...(baseline)

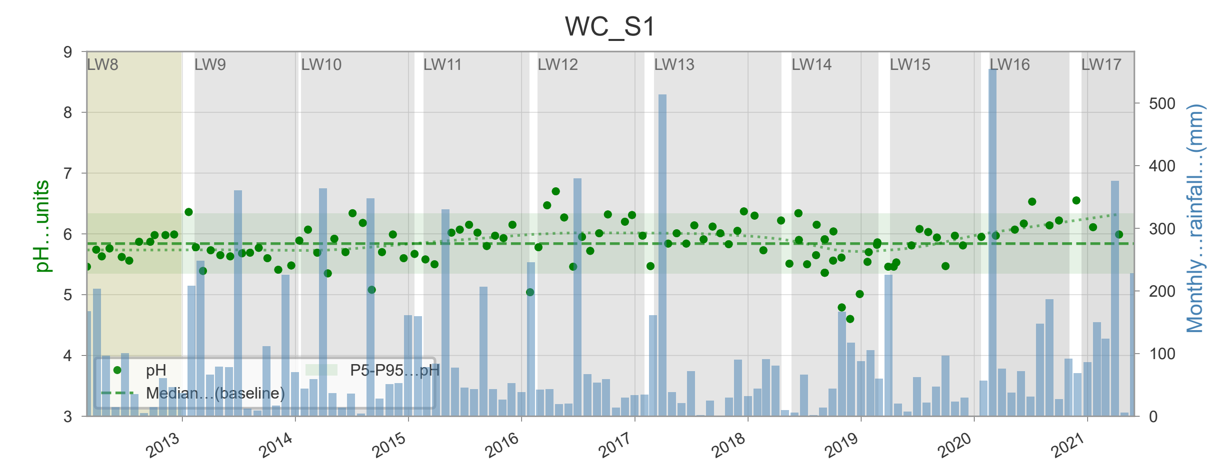

WC_ROCKBAR39
Dissolved...Oxygen...(%)
Monthly...rainfall...(mm)
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
DO...(%)
P5-P95...DO
Median...(baseline)



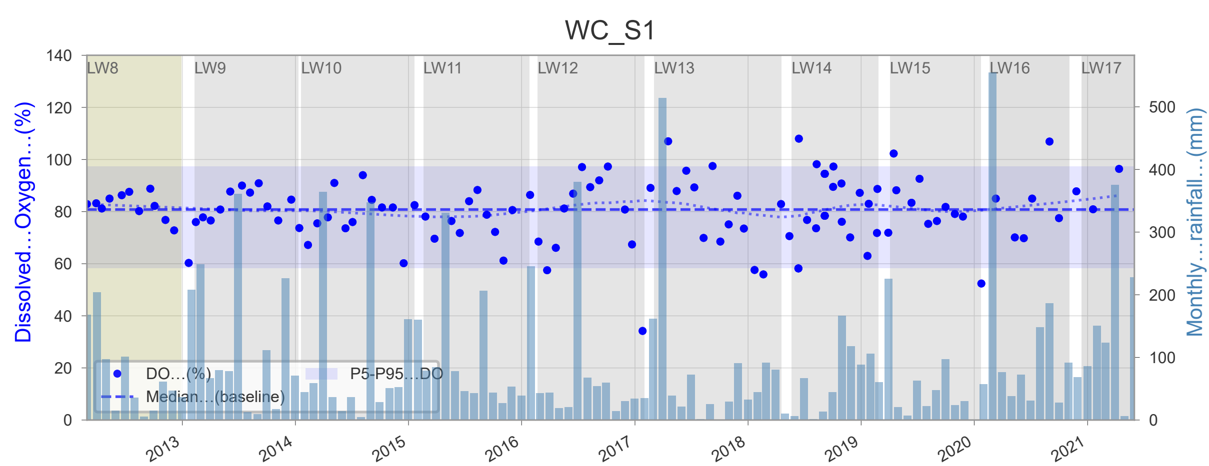
WC_S1
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
Water...level...(m...below...ref...nail)
Monthly...rainfall...(mm)
WL...below...ref...nail
P5-P95...WL



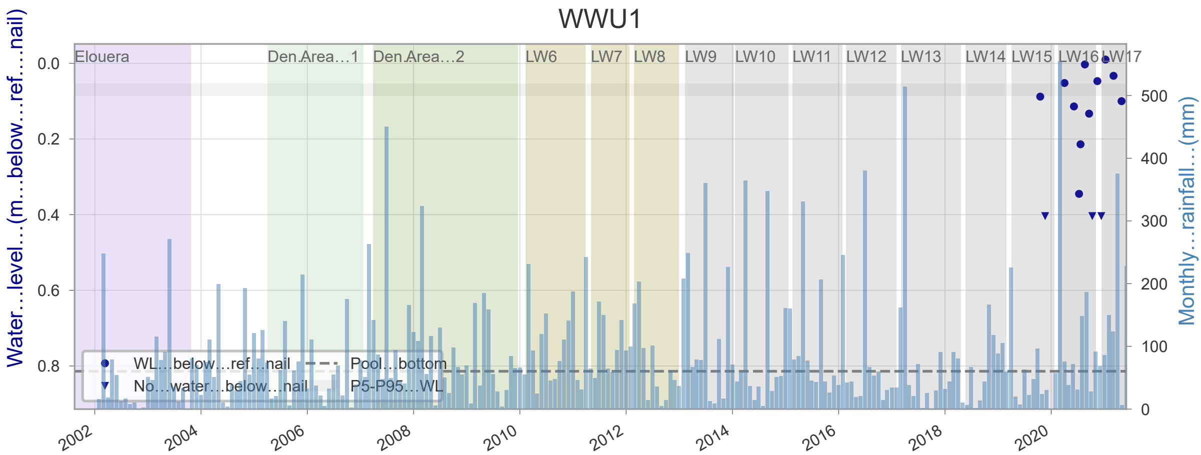
WC_S1
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
Electrical...Conductivity...(uS/cm)
Monthly...rainfall...(mm)
EC...(uS/cm)
LOWESS...(0.3)
Median...(baseline)
P5-P95...EC



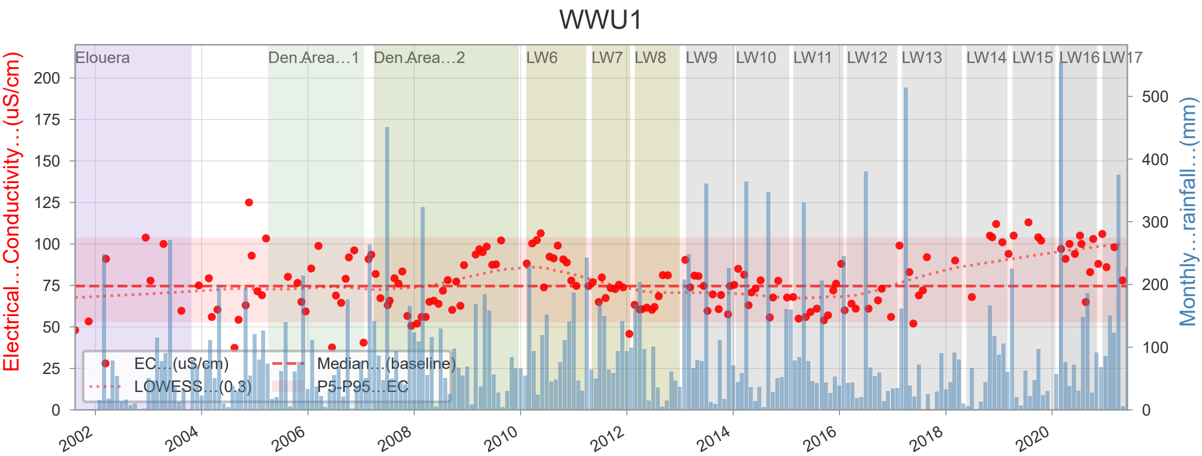
WC_S1
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
pH...units
Monthly...rainfall...(mm)
pH
Median...(baseline)
P5-P95...pH



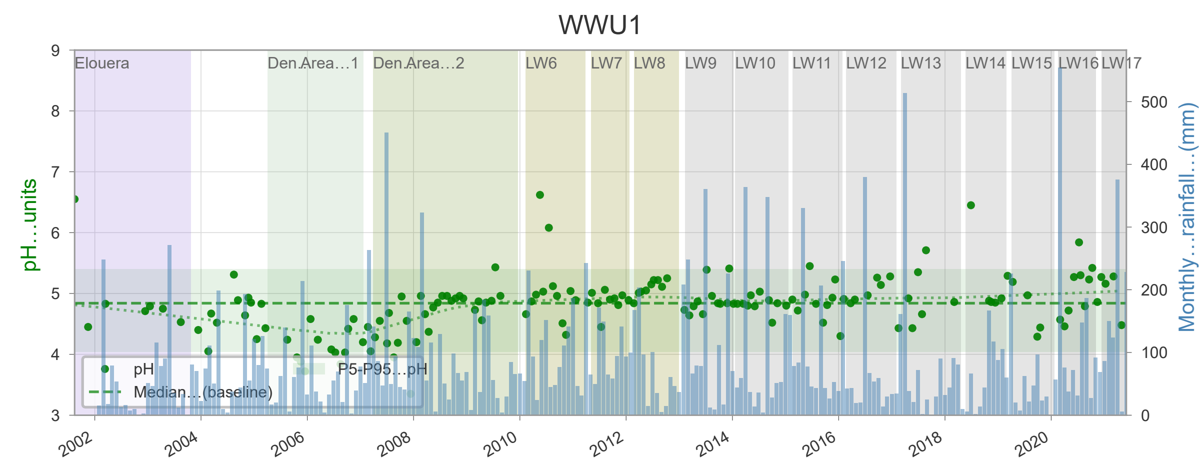
WC_S1
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
Dissolved...Oxygen...(%)
Monthly...rainfall...(mm)
DO...(%)
Median...(baseline)
P5-P95...DO



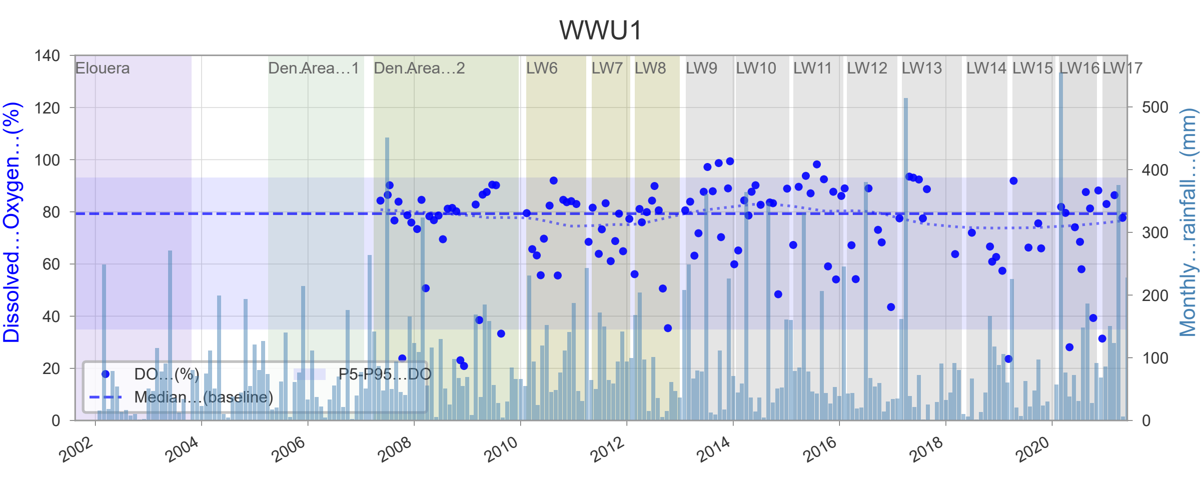
WWU1
Elouera
Den.Area...1
Den.Area...2
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
Water...level...(m...below...ref...nail)
Monthly...rainfall...(mm)
WL...below...ref...nail
No...water...below...nail
Pool...bottom
P5-P95...WL



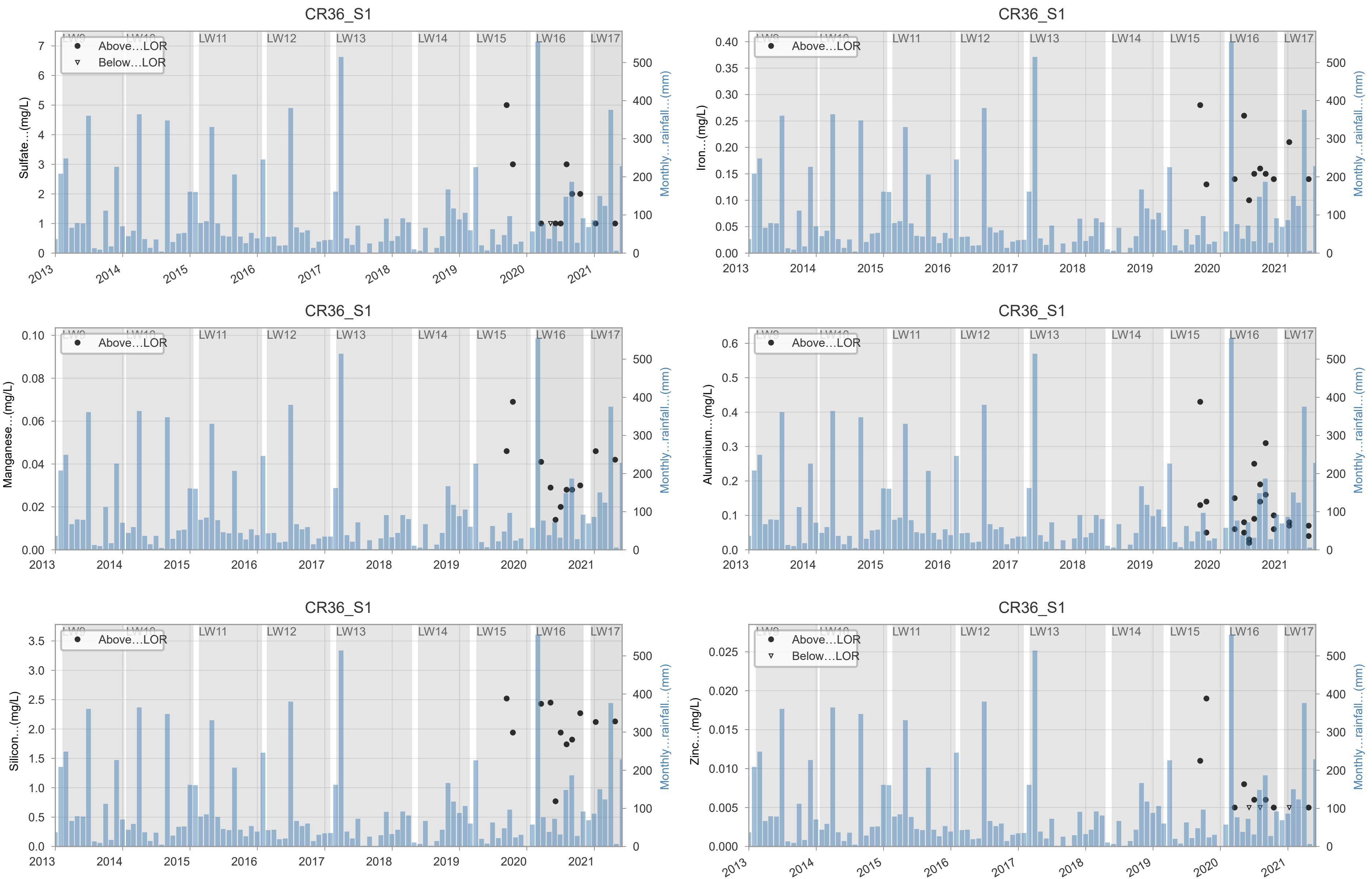
WWU1
Elouera
Den.Area...1
Den.Area...2
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
Electrical...Conductivity...(uS/cm)
Monthly...rainfall...(mm)
EC...(uS/cm)
LOWESS...(0.3)
Median...(baseline)
P5-P95...EC



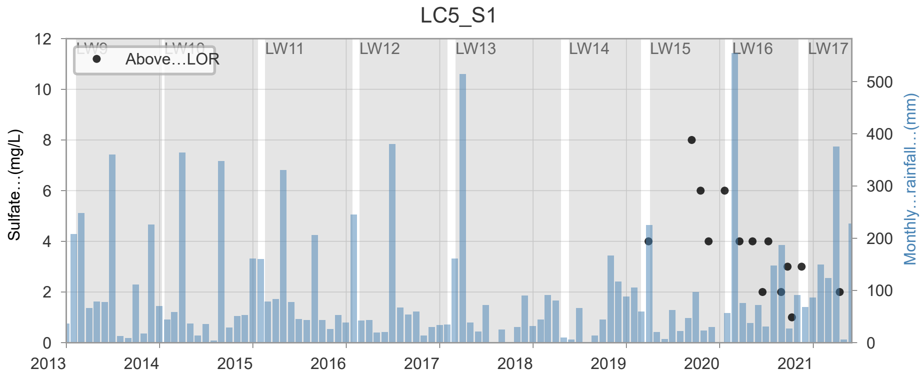
WWU1
Elouera
Den.Area...1
Den.Area...2
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
pH...units
Monthly...rainfall...(mm)
pH
Median...(baseline)
P5-P95...pH

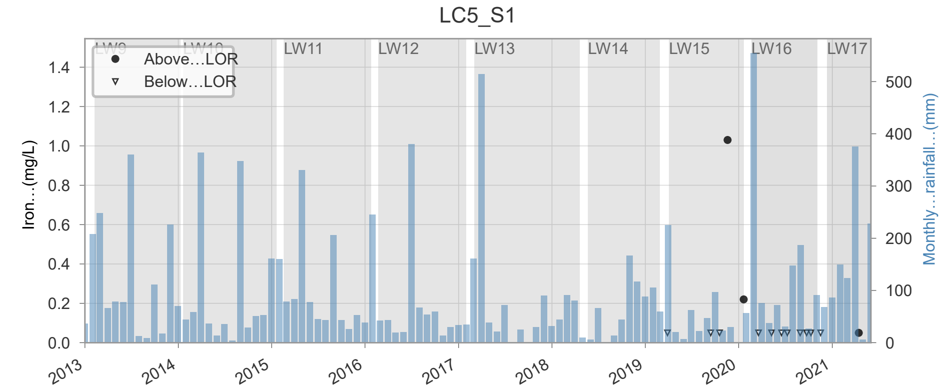


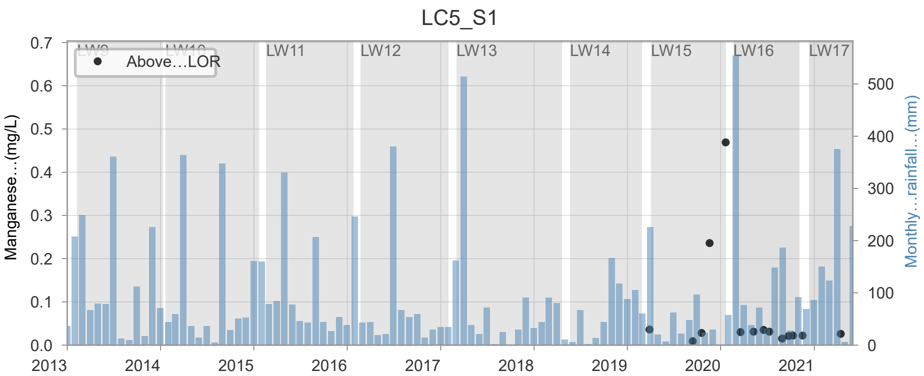
WWU1
Elouera
Den.Area...1
Den.Area...2
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
Dissolved...Oxygen...(%)
Monthly...rainfall...(mm)
DO...(%)
Median...(baseline)
P5-P95...DO

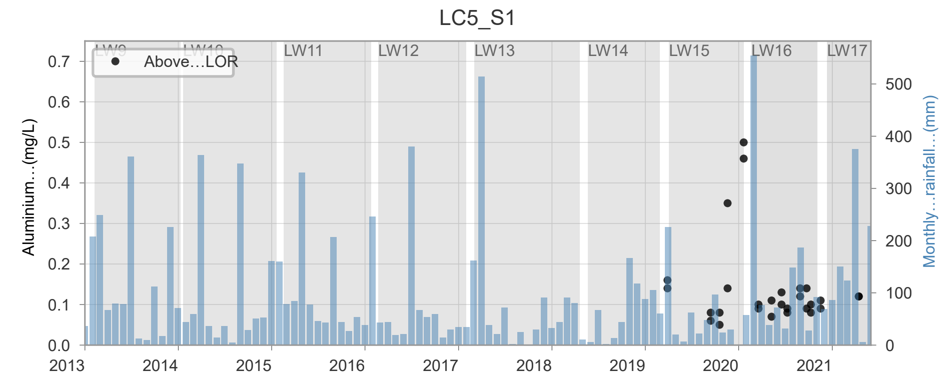


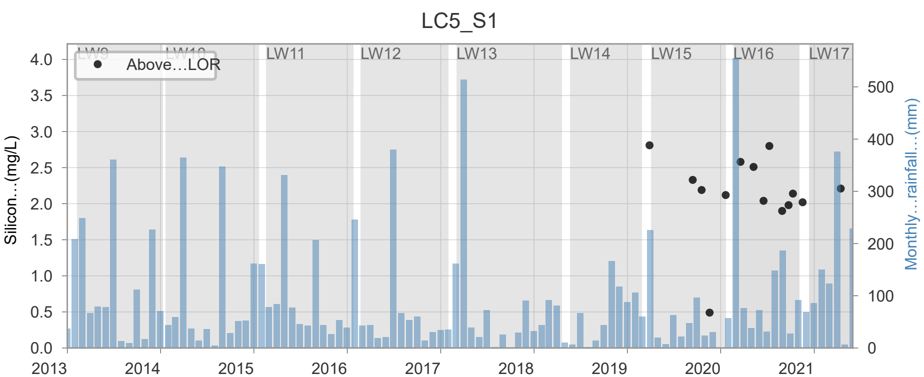
CR36_S1
Sulfate...(mg/L)
Iron...(mg/L)
Manganese...(mg/L)
Aluminium...(mg/L)
Silicon...(mg/L)
Zinc...(mg/L)
Monthly...rainfall...(mm)
Above...LOR
Below...LOR
LW11
LW12
LW13
LW14
LW15
LW16
LW17

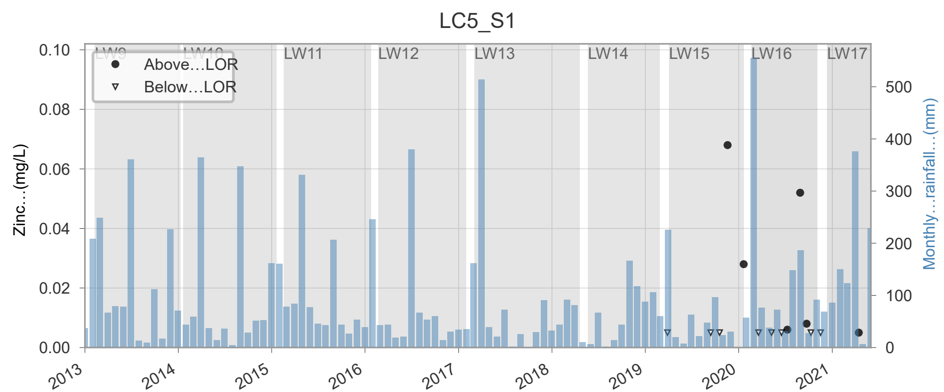

LC5_S1
Above…LOR
LW11
LW12
LW13
LW14
LW15
LW16
LW17
Sulfate…(mg/L)
Monthly…rainfall…(mm)

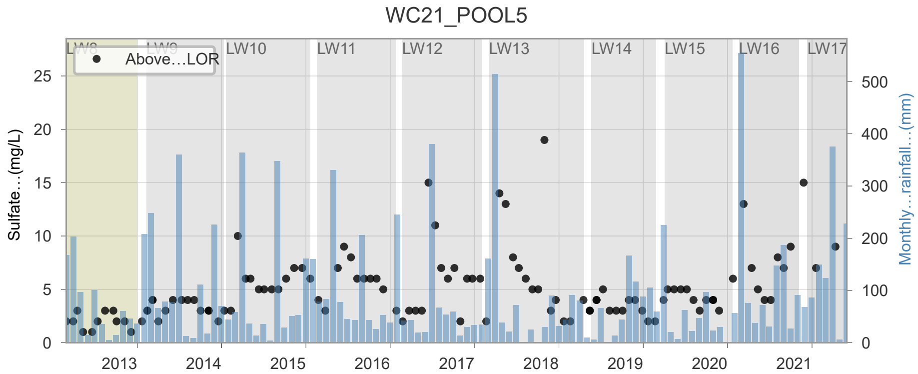

LC5_S1
Above…LOR
Below…LOR
LW11
LW12
LW13
LW14
LW15
LW16
LW17
Iron…(mg/L)
Monthly…rainfall…(mm)

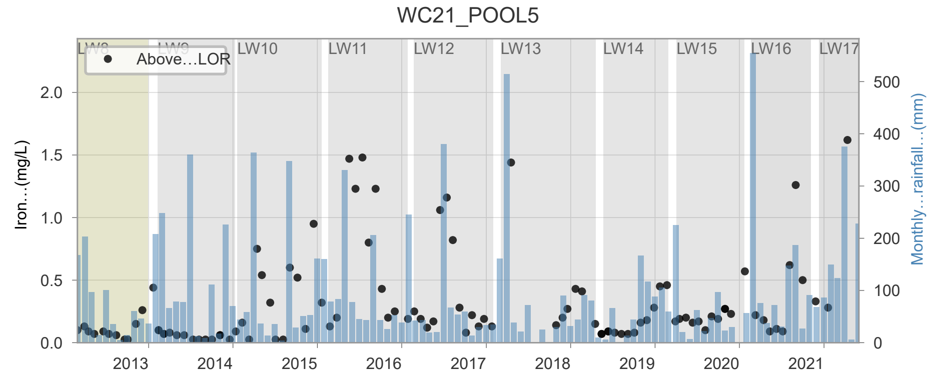

LC5_S1
Above…LOR
LW11
LW12
LW13
LW14
LW15
LW16
LW17
Manganese…(mg/L)
Monthly…rainfall…(mm)

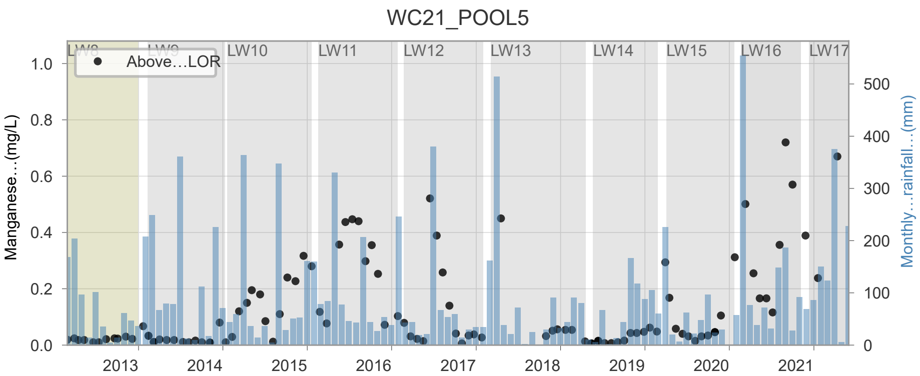

LC5_S1
Above…LOR
LW11
LW12
LW13
LW14
LW15
LW16
LW17
Aluminium…(mg/L)
Monthly…rainfall…(mm)

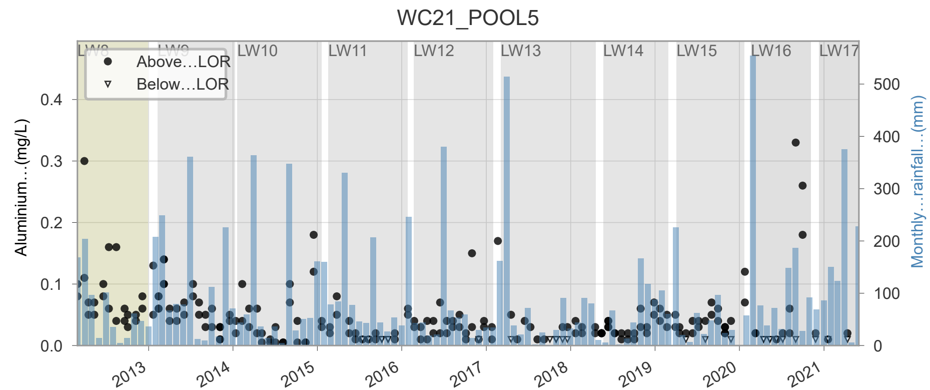

LC5_S1
Above…LOR
LW11
LW12
LW13
LW14
LW15
LW16
LW17
Silicon…(mg/L)
Monthly…rainfall…(mm)

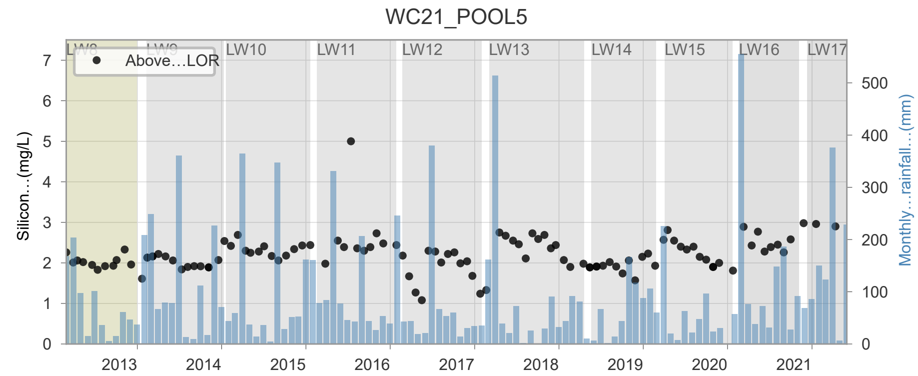

LC5_S1
Above…LOR
Below…LOR
LW11
LW12
LW13
LW14
LW15
LW16
LW17
Zinc…(mg/L)
Monthly…rainfall…(mm)

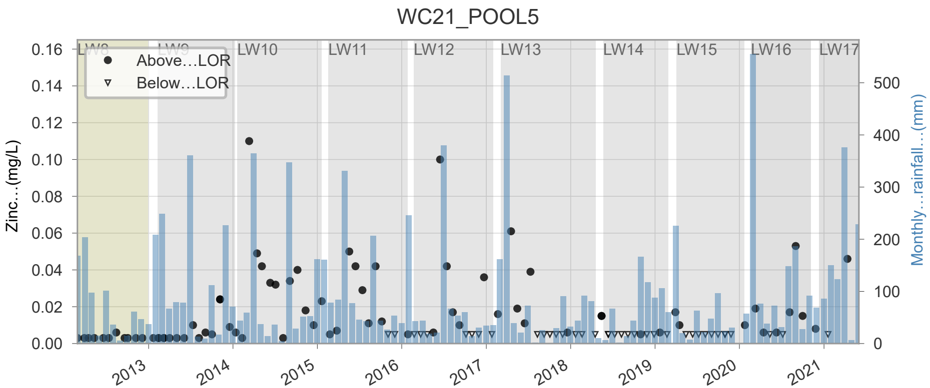

WC21_POOL5
Above…LOR
LW8 LW9 LW10 LW11 LW12 LW13 LW14 LW15 LW16 LW17
Sulfate…(mg/L)
Monthly…rainfall…(mm)
2013 2014 2015 2016 2017 2018 2019 2020 2021

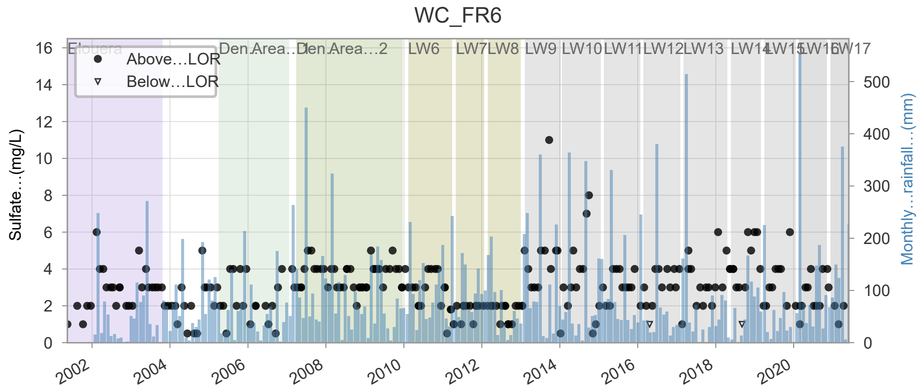

WC21_POOL5
Above…LOR
LW8 LW9 LW10 LW11 LW12 LW13 LW14 LW15 LW16 LW17
Iron…(mg/L)
Monthly…rainfall…(mm)
2013 2014 2015 2016 2017 2018 2019 2020 2021


WC21_POOL5
Above…LOR
LW8 LW9 LW10 LW11 LW12 LW13 LW14 LW15 LW16 LW17
Manganese…(mg/L)
Monthly…rainfall…(mm)
2013 2014 2015 2016 2017 2018 2019 2020 2021

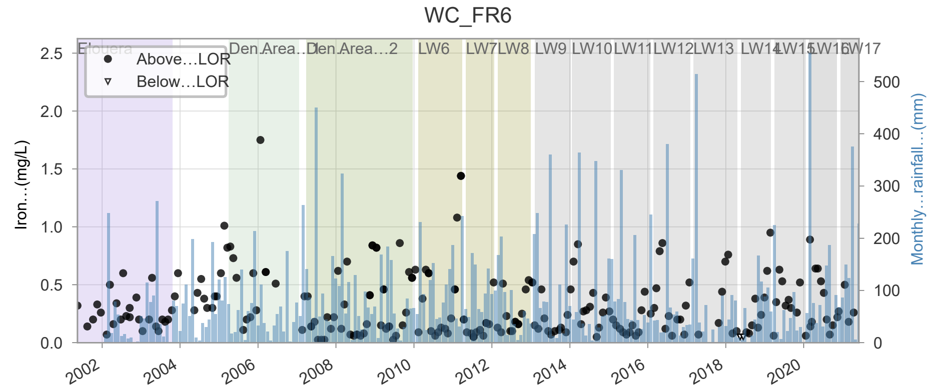

WC21_POOL5
Above…LOR
Below…LOR
LW8 LW9 LW10 LW11 LW12 LW13 LW14 LW15 LW16 LW17
Aluminium…(mg/L)
Monthly…rainfall…(mm)
2013 2014 2015 2016 2017 2018 2019 2020 2021


WC21_POOL5
Above…LOR
LW8 LW9 LW10 LW11 LW12 LW13 LW14 LW15 LW16 LW17
Silicon…(mg/L)
Monthly…rainfall…(mm)
2013 2014 2015 2016 2017 2018 2019 2020 2021

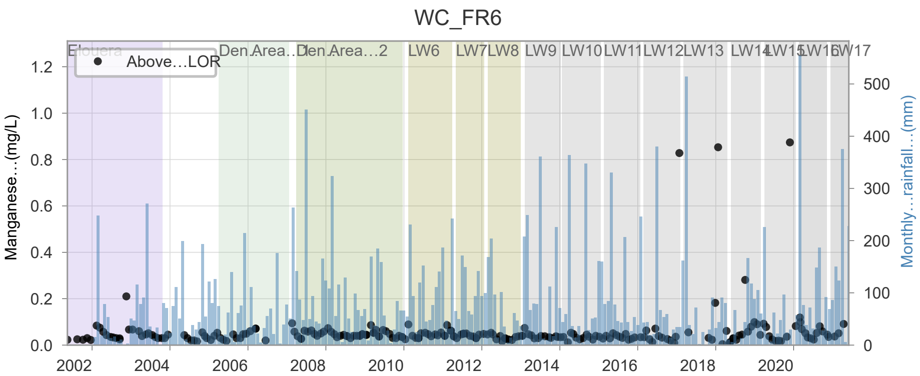

WC21_POOL5
Above…LOR
Below…LOR
LW8 LW9 LW10 LW11 LW12 LW13 LW14 LW15 LW16 LW17
Zinc…(mg/L)
Monthly…rainfall…(mm)
2013 2014 2015 2016 2017 2018 2019 2020 2021



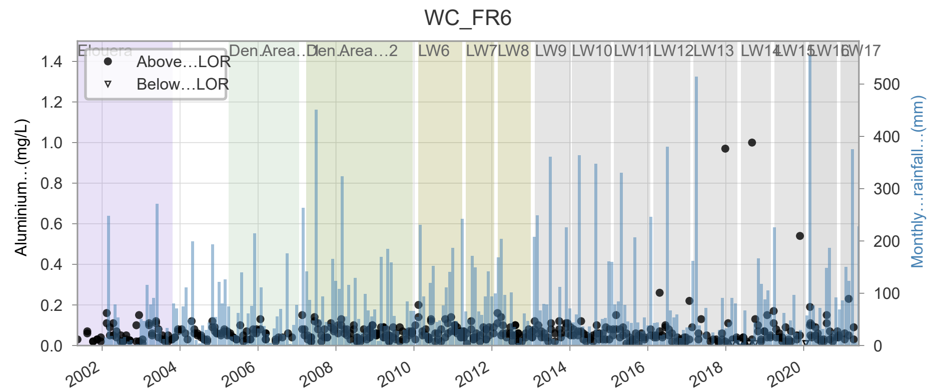
WC_FR6
Sulfate...(mg/L)
Monthly...rainfall...(mm)
Above...LOR
Below...LOR
Den.Area...1
Den.Area...2
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17



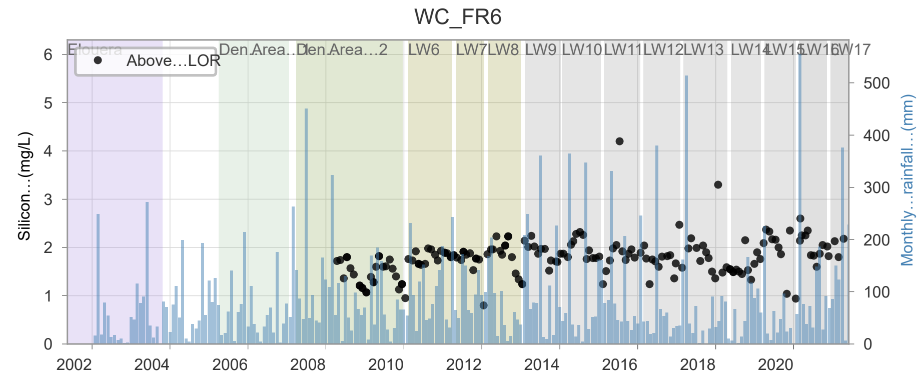
WC_FR6
Iron...(mg/L)
Monthly...rainfall...(mm)
Above...LOR
Below...LOR



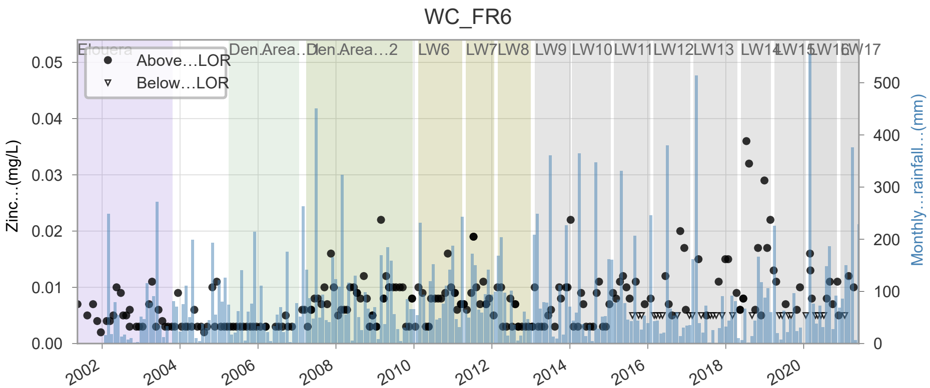
WC_FR6
Manganese...(mg/L)
Monthly...rainfall...(mm)
Above...LOR



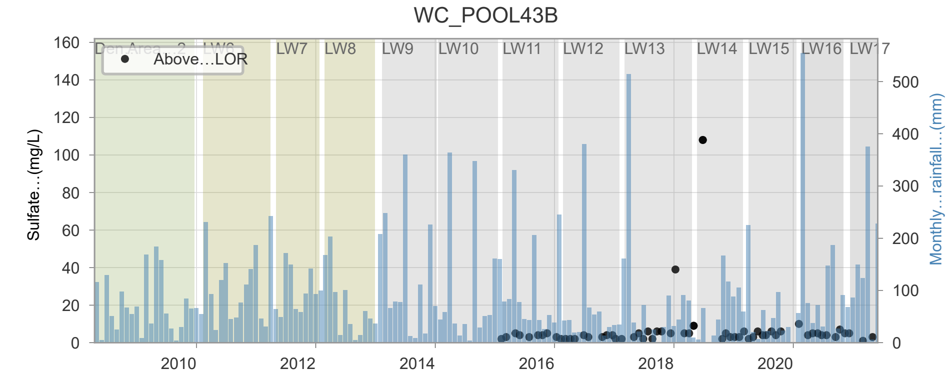
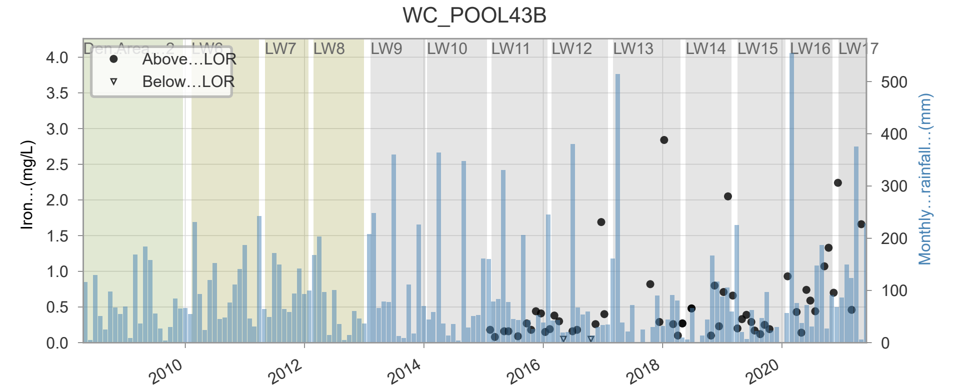
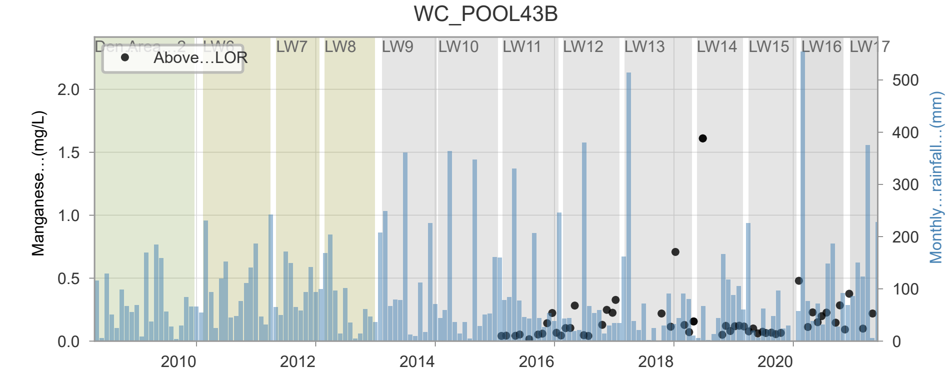
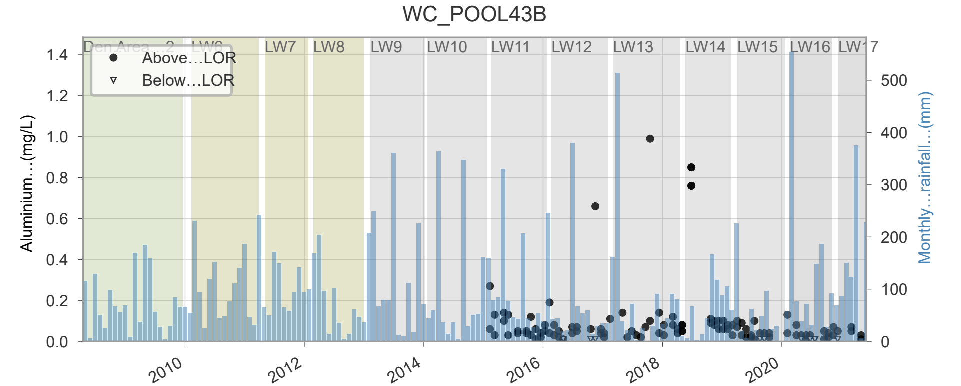
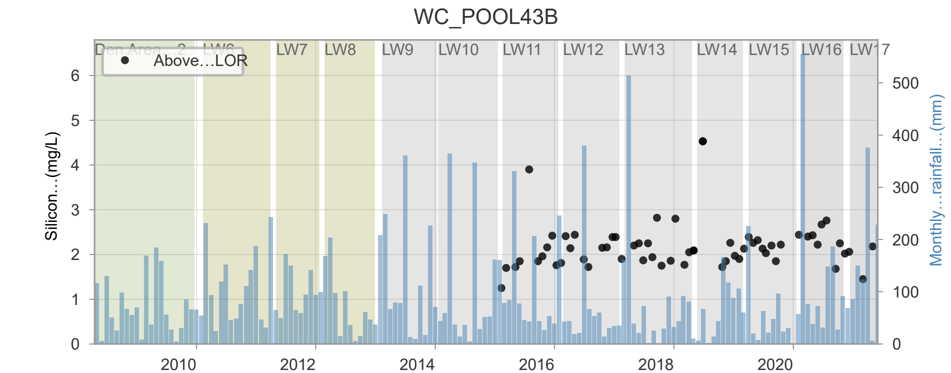
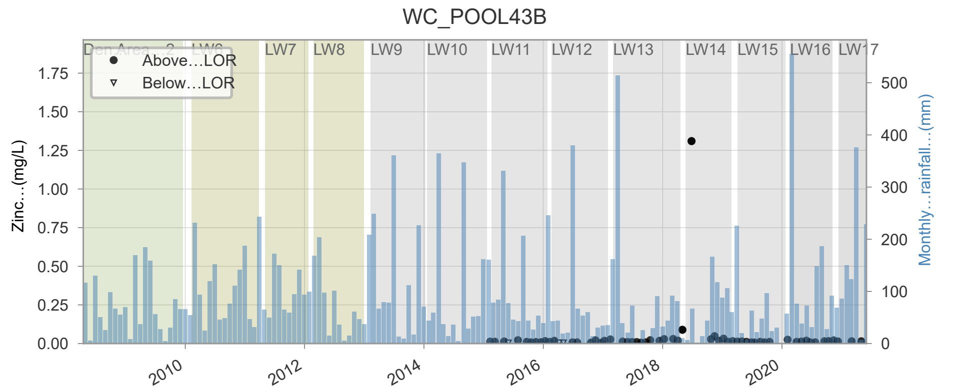
WC_FR6
Aluminium...(mg/L)
Monthly...rainfall...(mm)
Above...LOR
Below...LOR

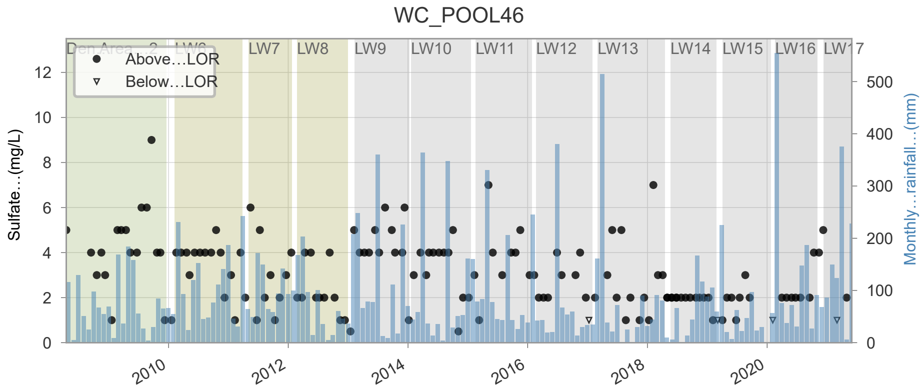


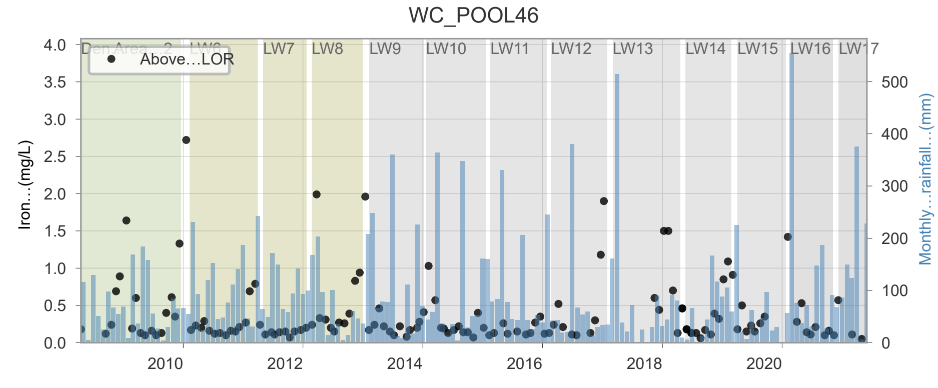
WC_FR6
Silicon...(mg/L)
Monthly...rainfall...(mm)
Above...LOR

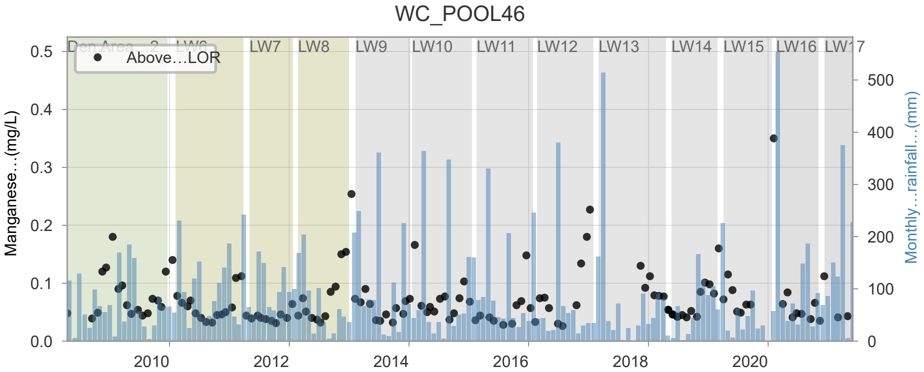


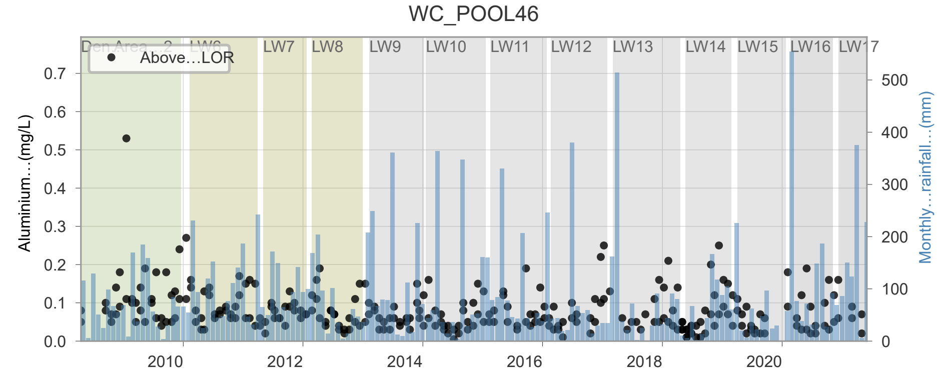
WC_FR6
Zinc...(mg/L)
Monthly...rainfall...(mm)
Above...LOR
Below...LOR

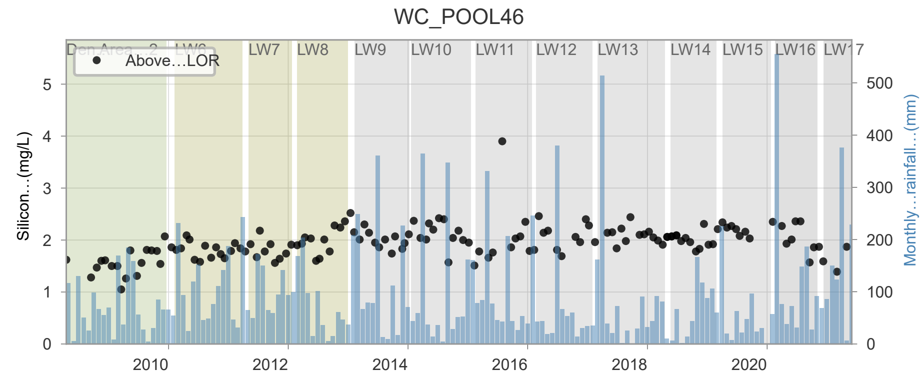

WC_POOL43B
Above…LOR
Sulfate…(mg/L)
Monthly…rainfall…(mm)
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16

WC_POOL43B
Above…LOR
Below…LOR
Iron…(mg/L)
Monthly…rainfall…(mm)
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16

WC_POOL43B
Above…LOR
Manganese…(mg/L)
Monthly…rainfall…(mm)
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16

WC_POOL43B
Above…LOR
Below…LOR
Aluminium…(mg/L)
Monthly…rainfall…(mm)
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16

WC_POOL43B
Above…LOR
Silicon…(mg/L)
Monthly…rainfall…(mm)
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16

WC_POOL43B
Above…LOR
Below…LOR
Zinc…(mg/L)
Monthly…rainfall…(mm)
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16

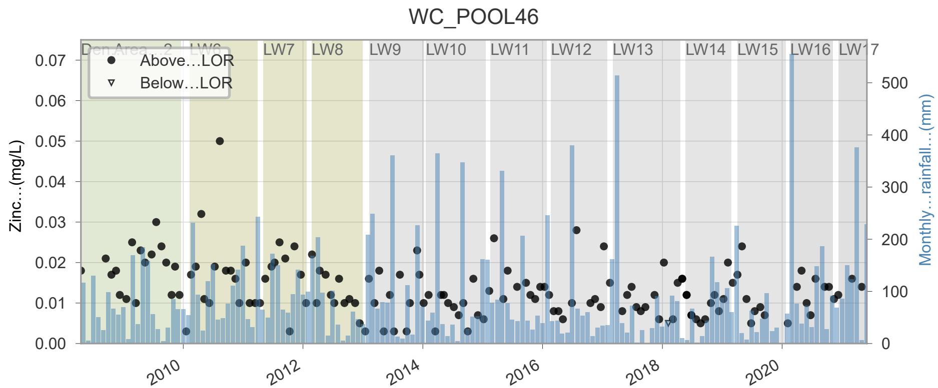

WC_POOL46
Above...LOR
Below...LOR
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
Sulfate...(mg/L)
Monthly...rainfall...(mm)
2010
2012
2014
2016
2018
2020

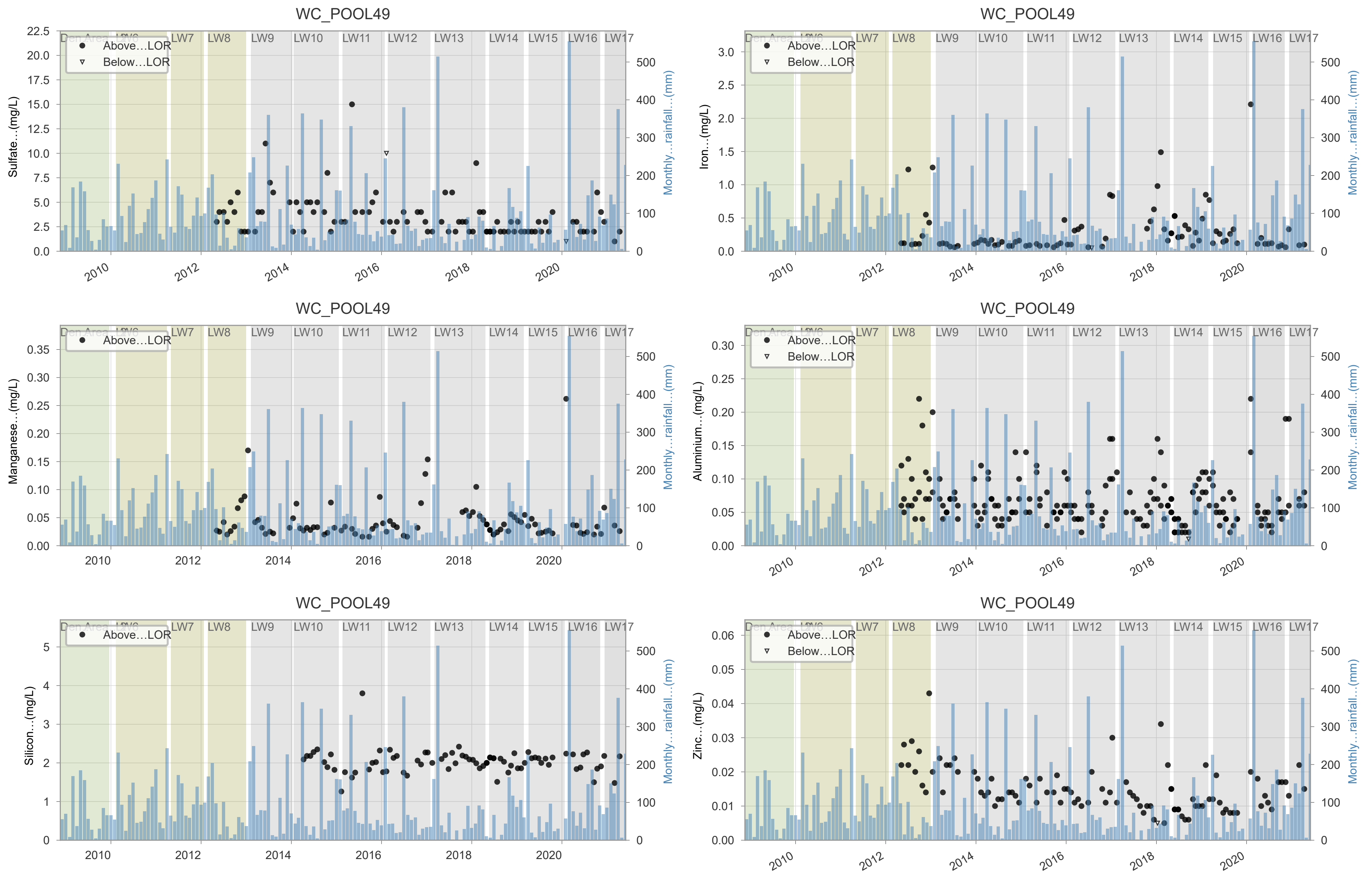

WC_POOL46
Above...LOR
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
Iron...(mg/L)
Monthly...rainfall...(mm)
2010
2012
2014
2016
2018
2020


WC_POOL46
Above...LOR
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
Manganese...(mg/L)
Monthly...rainfall...(mm)
2010
2012
2014
2016
2018
2020

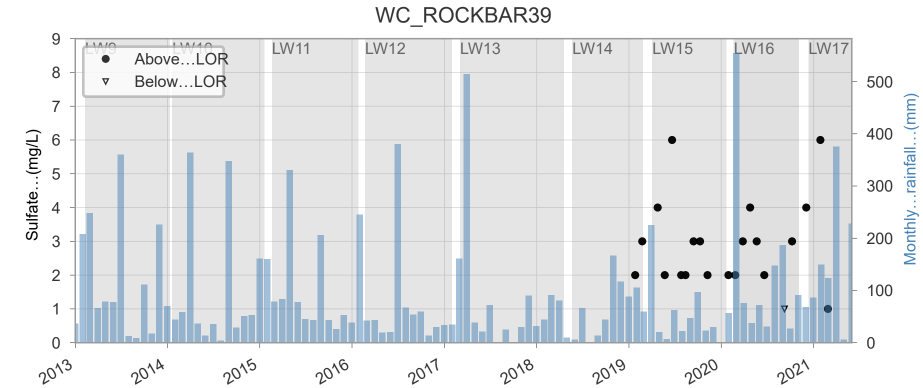

WC_POOL46
Above...LOR
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
Aluminium...(mg/L)
Monthly...rainfall...(mm)
2010
2012
2014
2016
2018
2020

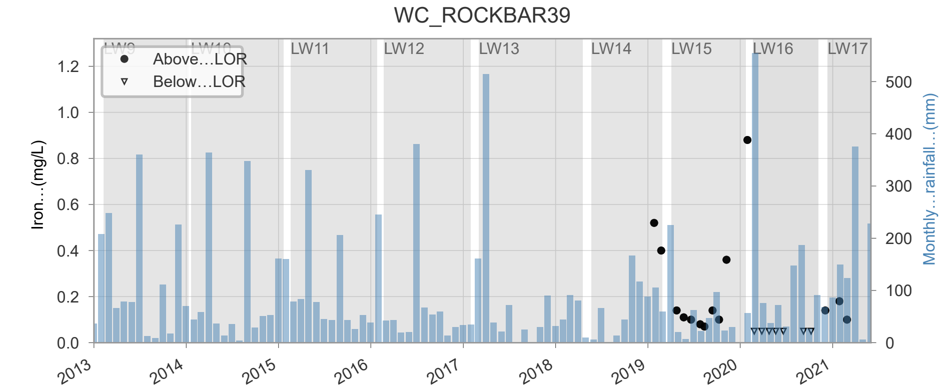

WC_POOL46
Above...LOR
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
Silicon...(mg/L)
Monthly...rainfall...(mm)
2010
2012
2014
2016
2018
2020

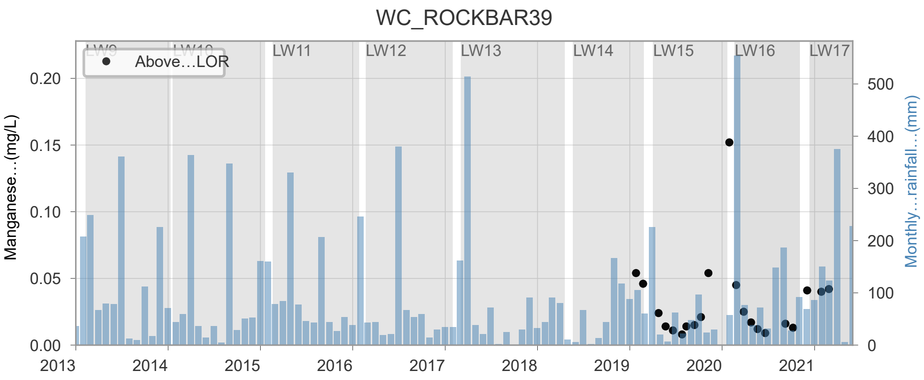

WC_POOL46
Above...LOR
Below...LOR
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
Zinc...(mg/L)
Monthly...rainfall...(mm)
2010
2012
2014
2016
2018
2020

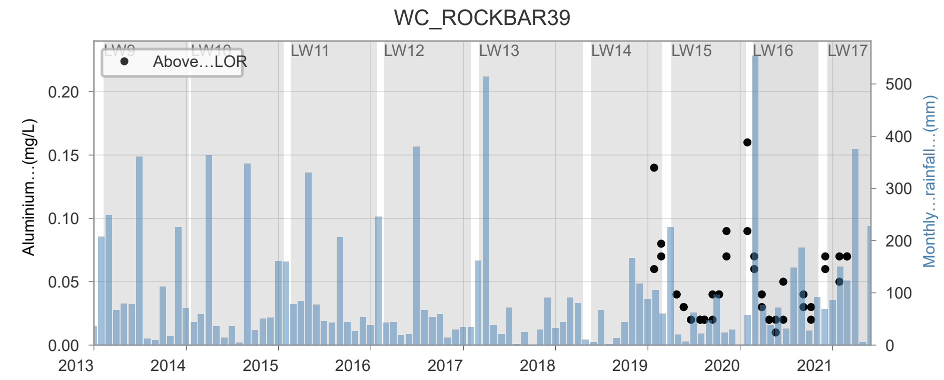


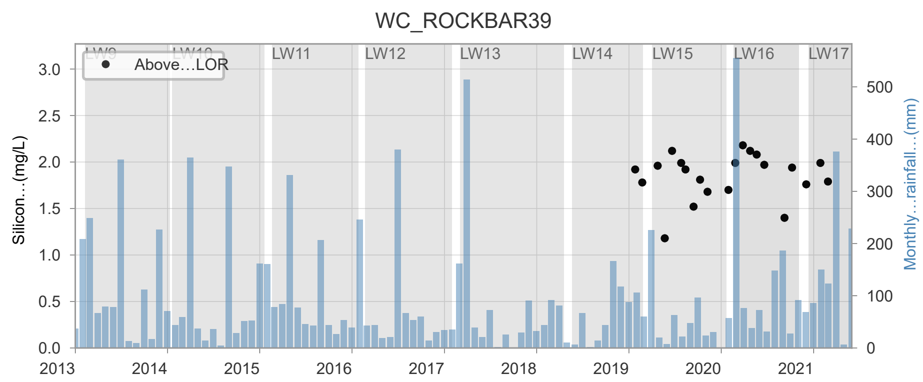
WC_POOL49
Sulfate...(mg/L)
Iron...(mg/L)
Manganese...(mg/L)
Aluminium...(mg/L)
Silicon...(mg/L)
Zinc...(mg/L)
Monthly...rainfall...(mm)
Above...LOR
Below...LOR
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
2010
2012
2014
2016
2018
2020

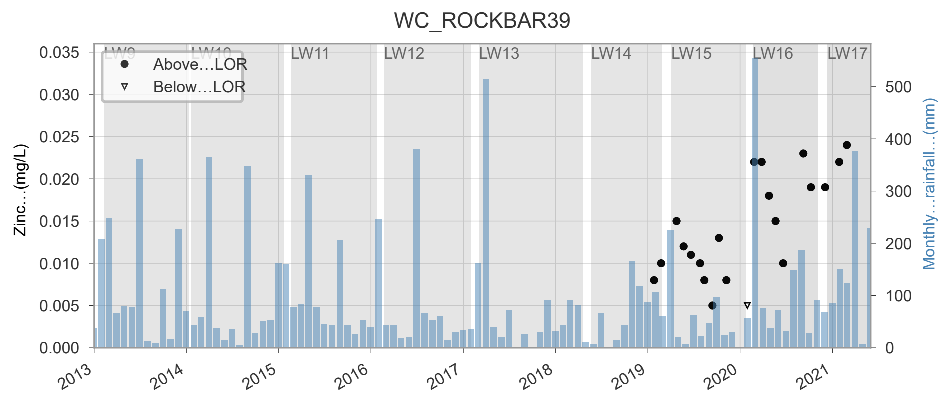

WC_ROCKBAR39
Above…LOR
Below…LOR
LW11
LW12
LW13
LW14
LW15
LW16
LW17
Sulfate…(mg/L)
Monthly…rainfall…(mm)

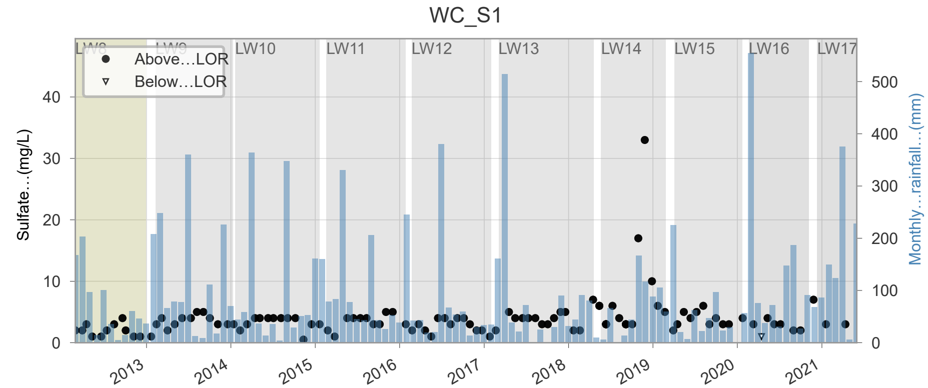

WC_ROCKBAR39
Above…LOR
Below…LOR
LW11
LW12
LW13
LW14
LW15
LW16
LW17
Iron…(mg/L)
Monthly…rainfall…(mm)

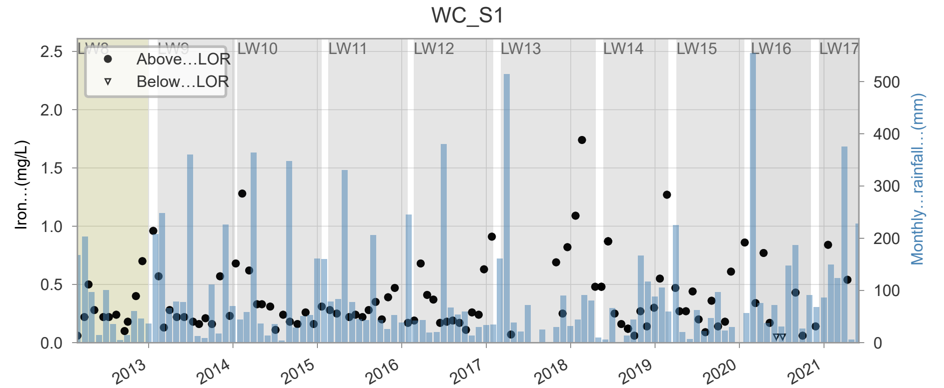

WC_ROCKBAR39
Above…LOR
LW11
LW12
LW13
LW14
LW15
LW16
LW17
Manganese…(mg/L)
Monthly…rainfall…(mm)

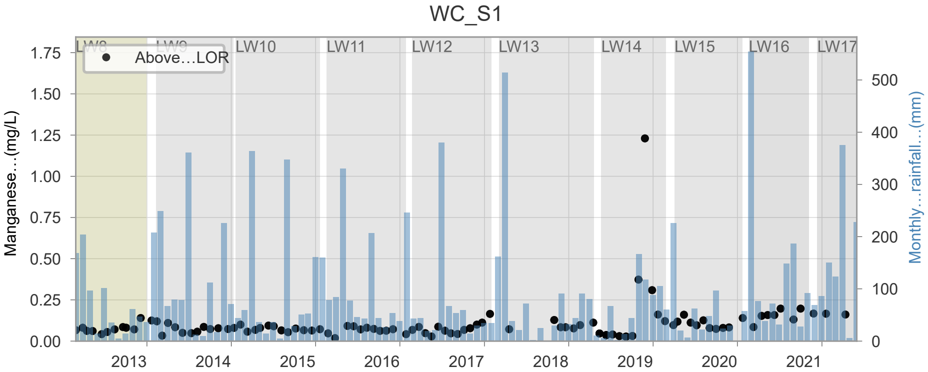

WC_ROCKBAR39
Above…LOR
LW11
LW12
LW13
LW14
LW15
LW16
LW17
Aluminium…(mg/L)
Monthly…rainfall…(mm)

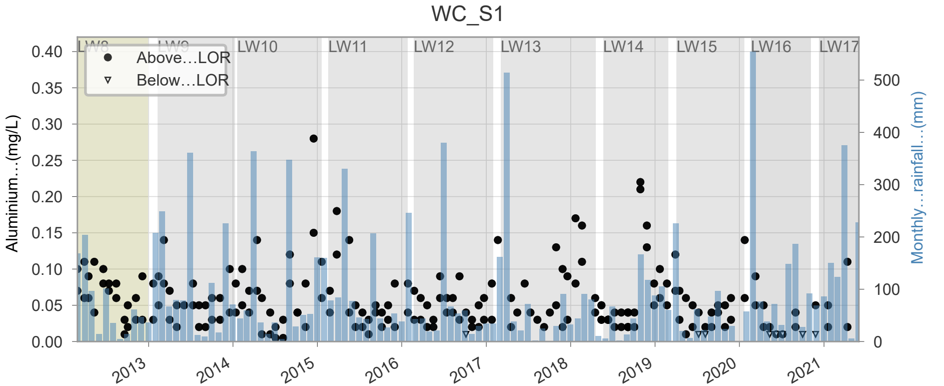

WC_ROCKBAR39
Above…LOR
LW11
LW12
LW13
LW14
LW15
LW16
LW17
Silicon…(mg/L)
Monthly…rainfall…(mm)

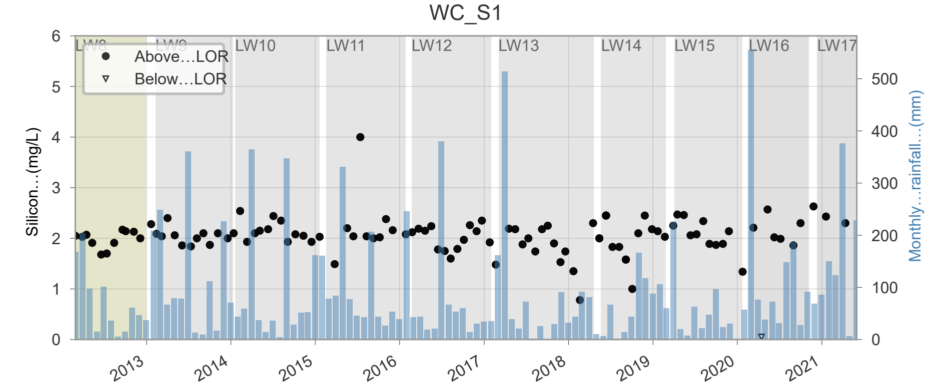

WC_ROCKBAR39
Above…LOR
Below…LOR
LW11
LW12
LW13
LW14
LW15
LW16
LW17
Zinc…(mg/L)
Monthly…rainfall…(mm)

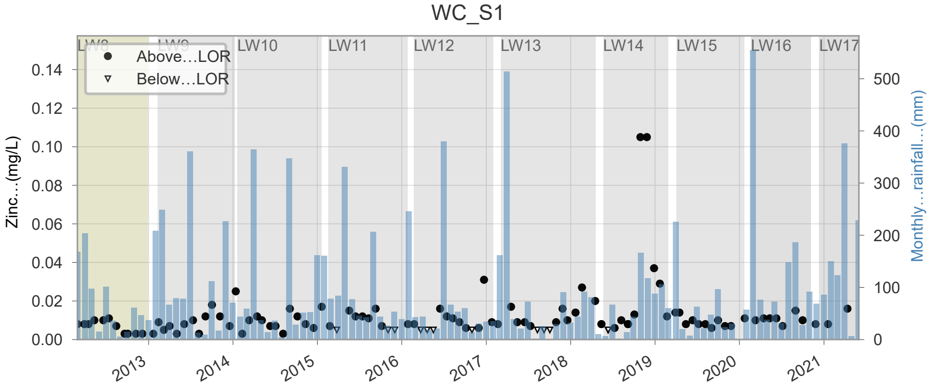

WC_S1
Sulfate...(mg/L)
Monthly...rainfall...(mm)
Above...LOR
Below...LOR
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
0
10
20
30
40
0
100
200
300
400
500
2013
2014
2015
2016
2017
2018
2019
2020
2021


WC_S1
Iron...(mg/L)
Monthly...rainfall...(mm)
Above...LOR
Below...LOR
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
0.0
0.5
1.0
1.5
2.0
2.5
0
100
200
300
400
500
2013
2014
2015
2016
2017
2018
2019
2020
2021


WC_S1
Manganese...(mg/L)
Monthly...rainfall...(mm)
Above...LOR
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
0.00
0.25
0.50
0.75
1.00
1.25
1.50
1.75
0
100
200
300
400
500
2013
2014
2015
2016
2017
2018
2019
2020
2021


WC_S1
Aluminium...(mg/L)
Monthly...rainfall...(mm)
Above...LOR
Below...LOR
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0
100
200
300
400
500
2013
2014
2015
2016
2017
2018
2019
2020
2021


WC_S1
Silicon...(mg/L)
Monthly...rainfall...(mm)
Above...LOR
Below...LOR
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
0
1
2
3
4
5
6
0
100
200
300
400
500
2013
2014
2015
2016
2017
2018
2019
2020
2021


WC_S1
Zinc...(mg/L)
Monthly...rainfall...(mm)
Above...LOR
Below...LOR
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0
100
200
300
400
500
2013
2014
2015
2016
2017
2018
2019
2020
2021

APPENDIX 1 – Surface water chemistry time-series

APPENDIX 2 – Surface flow observations on Wongawilli Ck

Figure A2-1

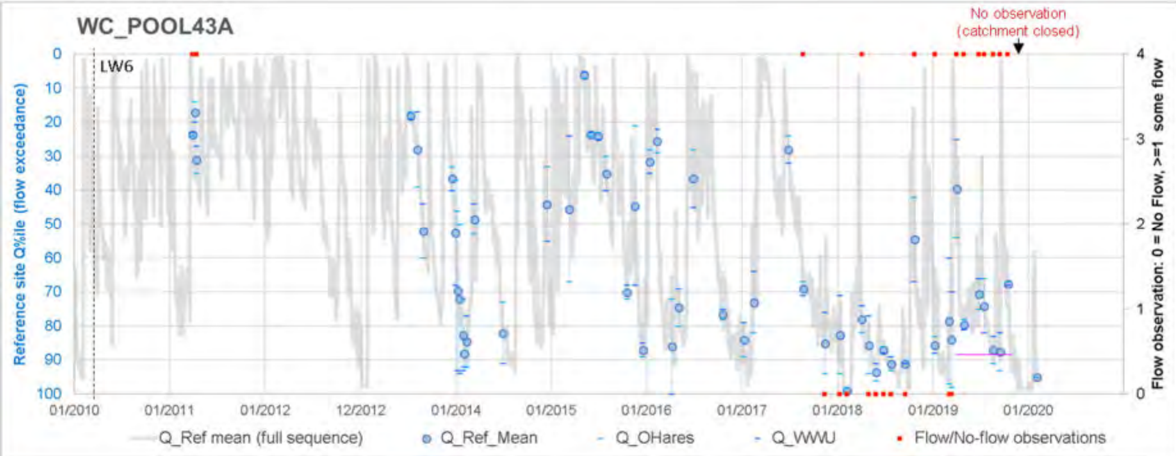


Figure A2-2

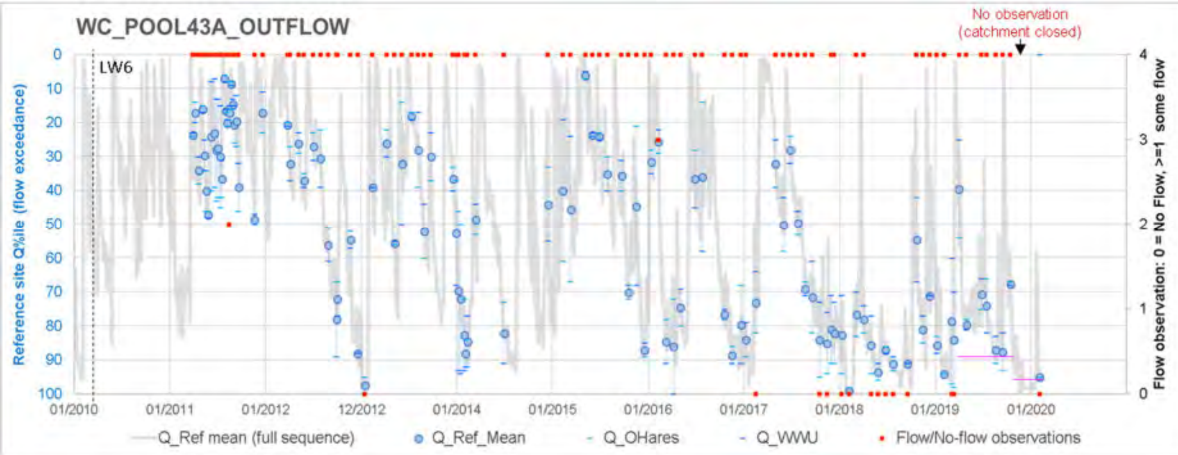
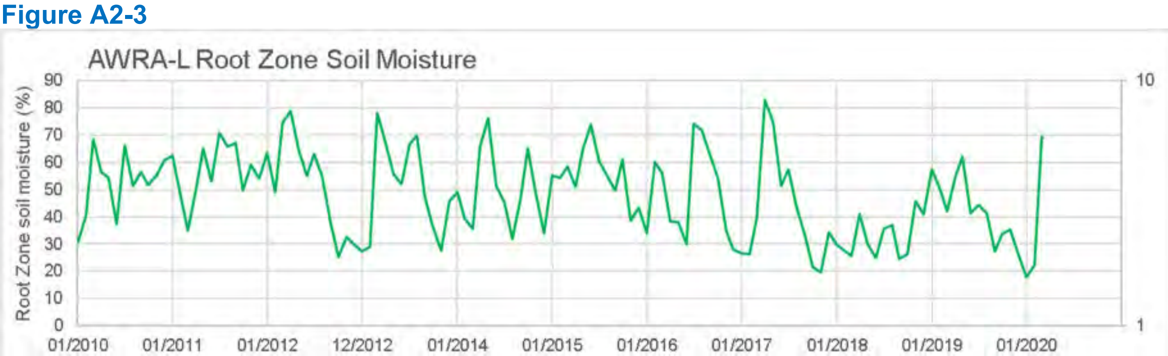


Figure A2-3



These inflow and outflow sites at Pool 43A, which is near to Longwalls 6 and 9, have relatively long post-mining records but no pre-mining baseline records.

E:\DENDROBIUM\Reports\HGE009\WongaCk_MiddleReach_v3.pptx

E:\DENDROBIUM\Tech\SurfaceWater\Observations\DA3A_DA3B_Inflow&Outflow_Obs.xlsx

Figure A2-4

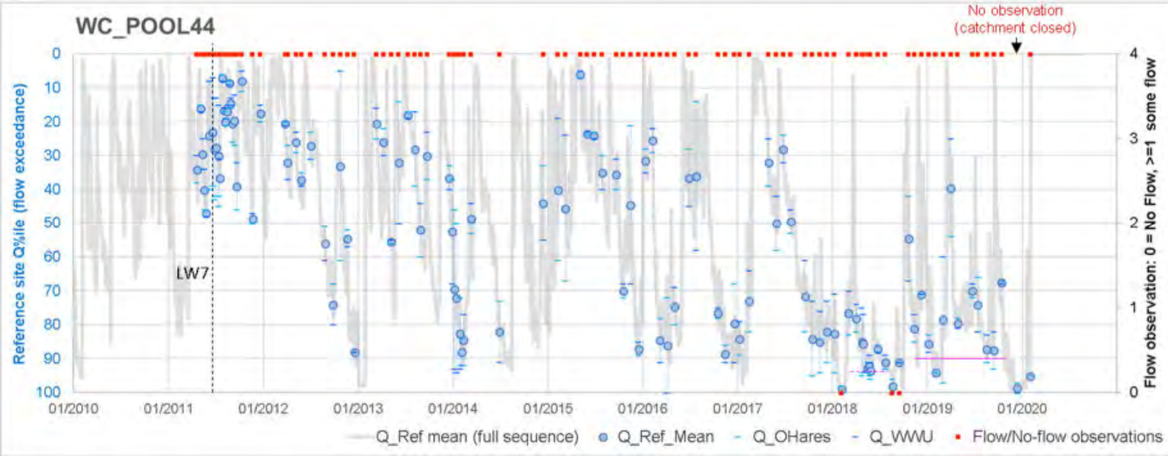


Figure A2-5

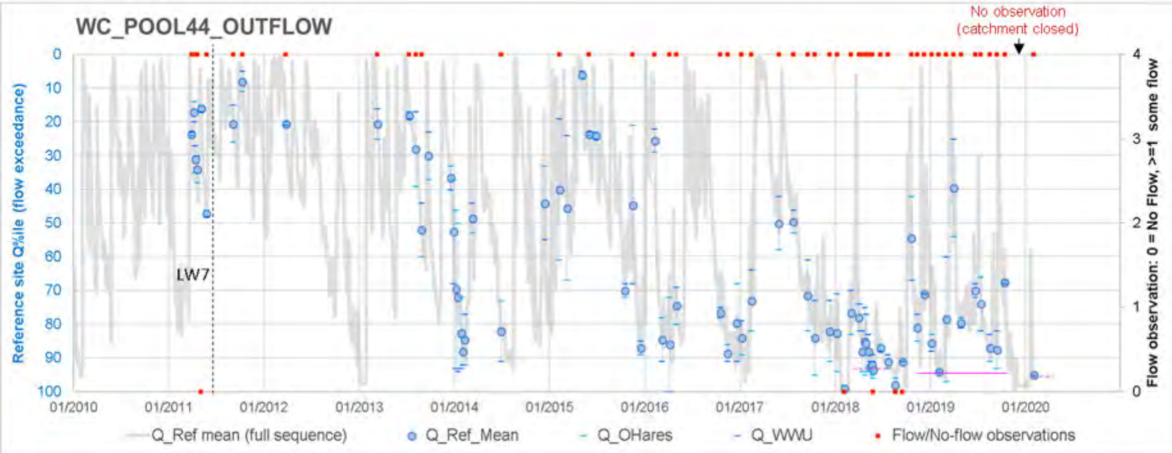
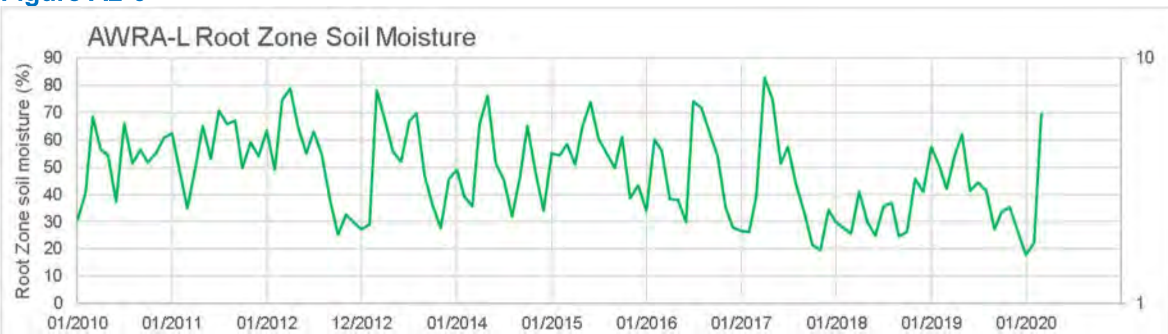


Figure A2-6



These inflow and outflow sites at Pool 44, which is near to Longwalls 7 and 10, have relatively long post-mining records but limited pre-mining baseline records.

Figure A2-7

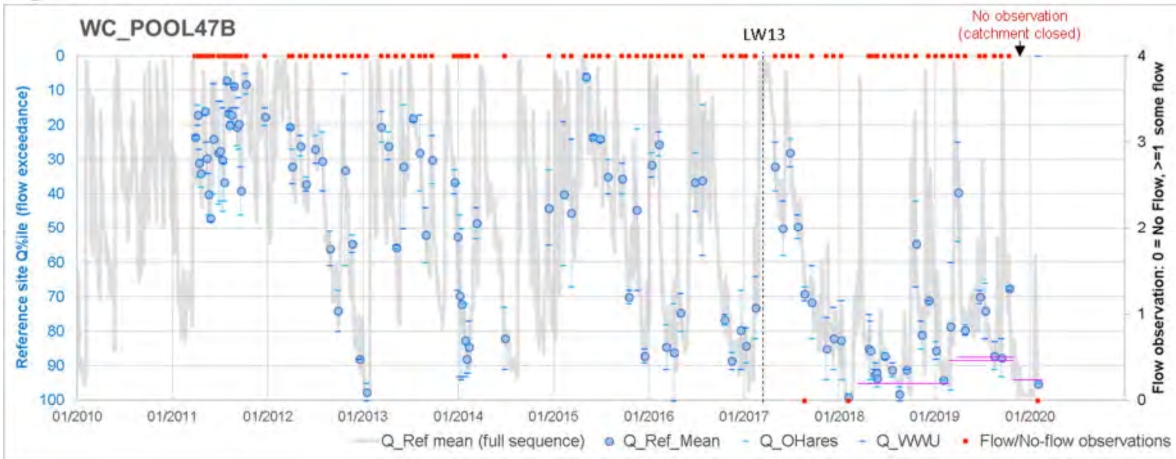


Figure A2-8

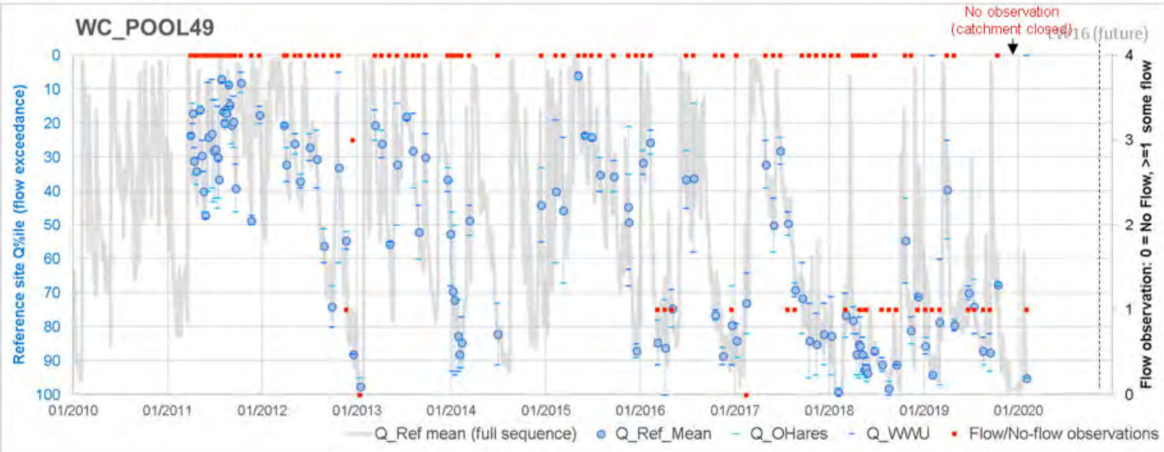
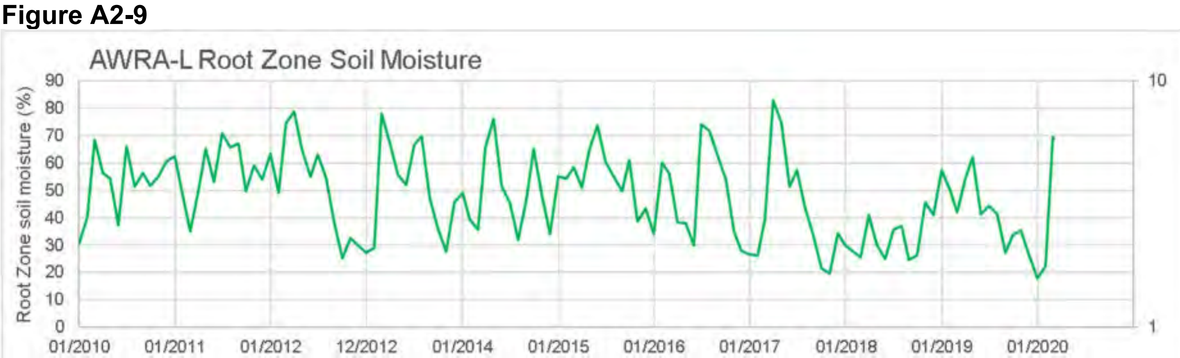


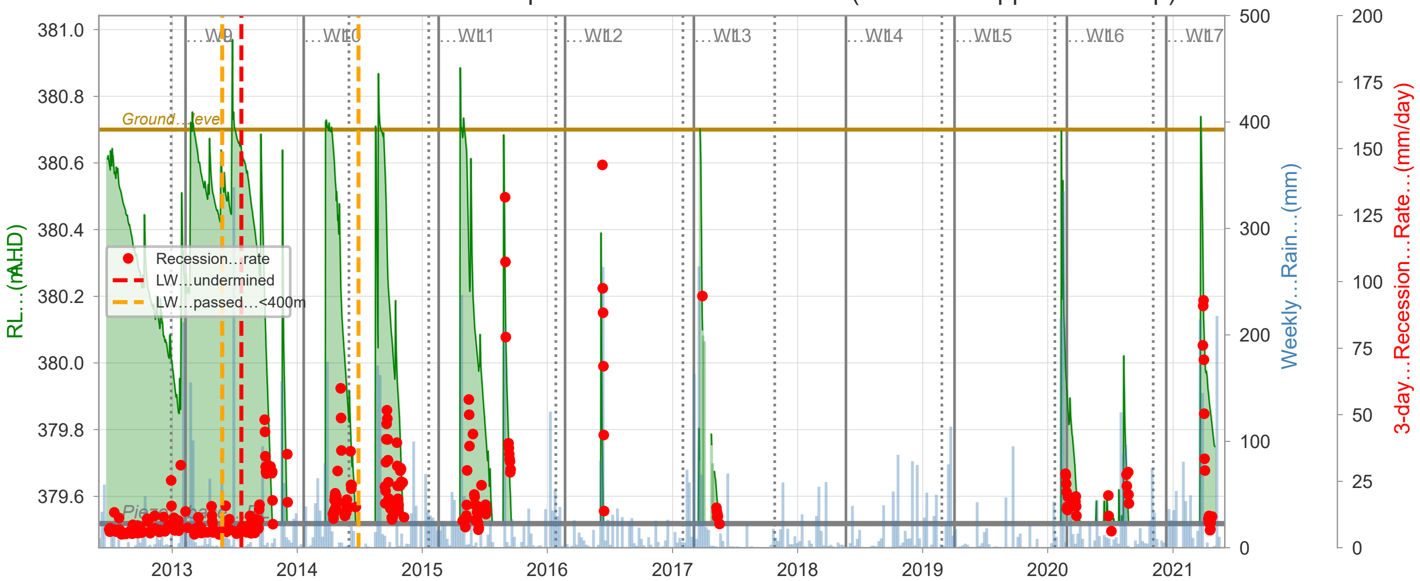
Figure A2-9



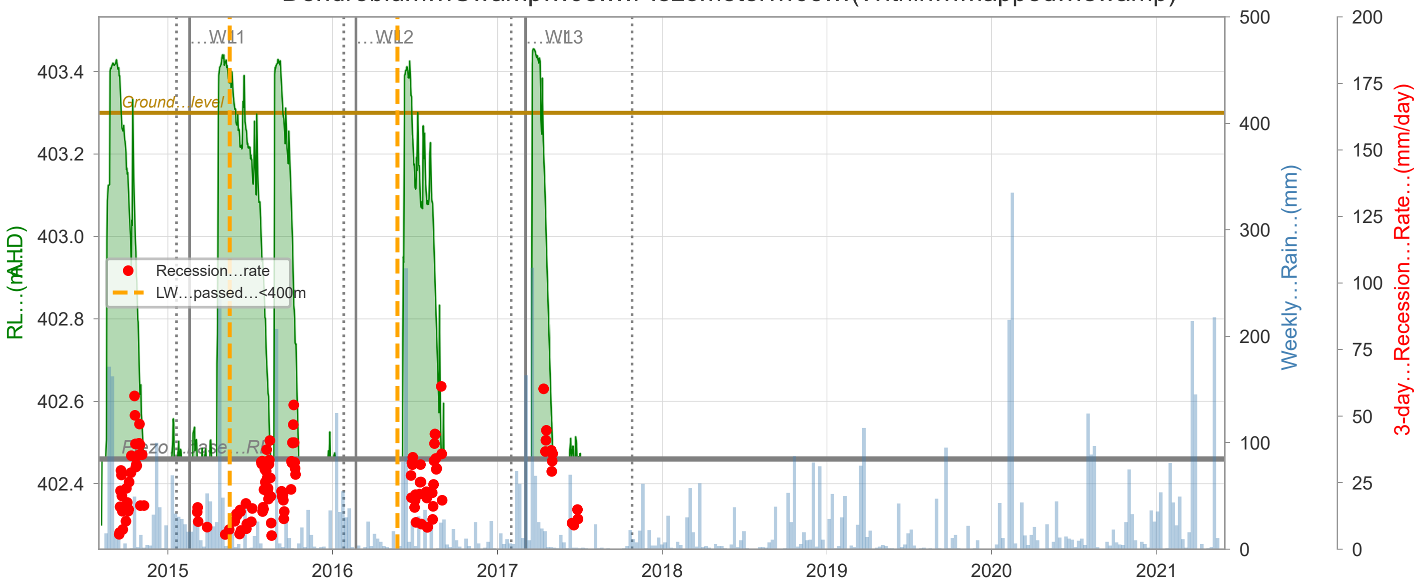
These two sites (Pool 47B and Pool 49) are further upgradient along Wongawilli Creek, near to Longwalls 13 and 16 (which is yet to be extracted). They have relatively longer pre-mining records than the other sites (Pools 43A and 44).

APPENDIX 3 – Swamp shallow groundwater hydrographs

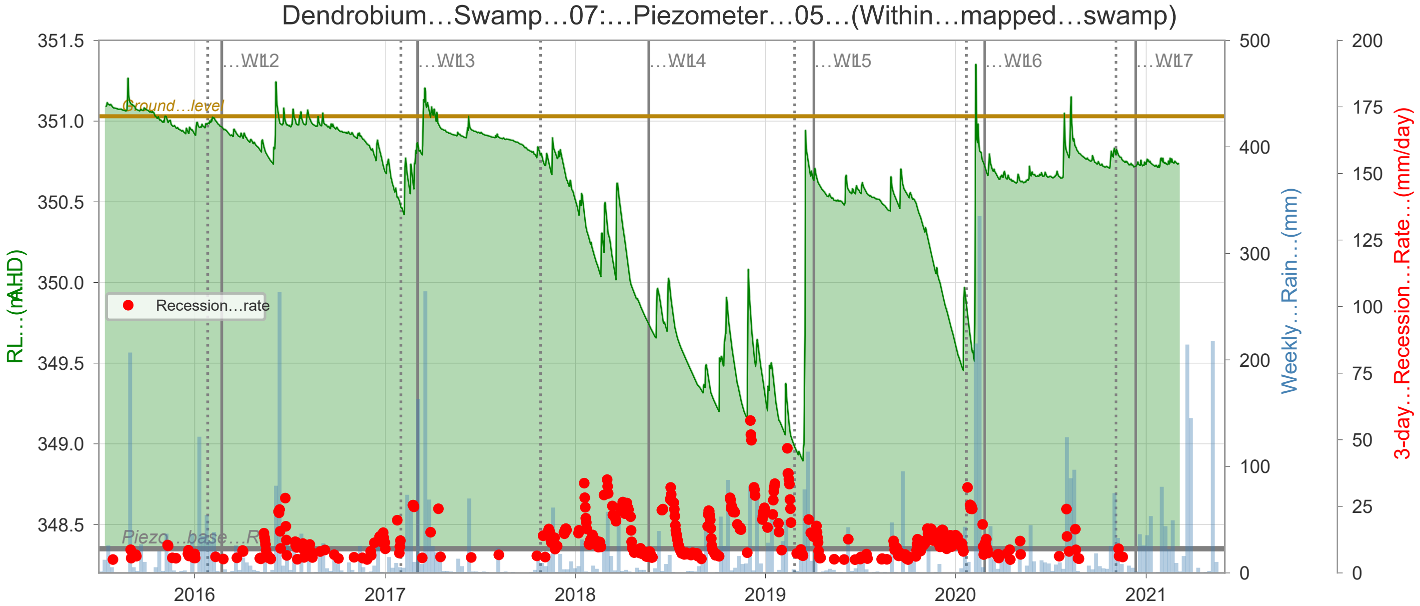
Dendrobium Swamp 05: Piezometer 04 (Within mapped swamp)

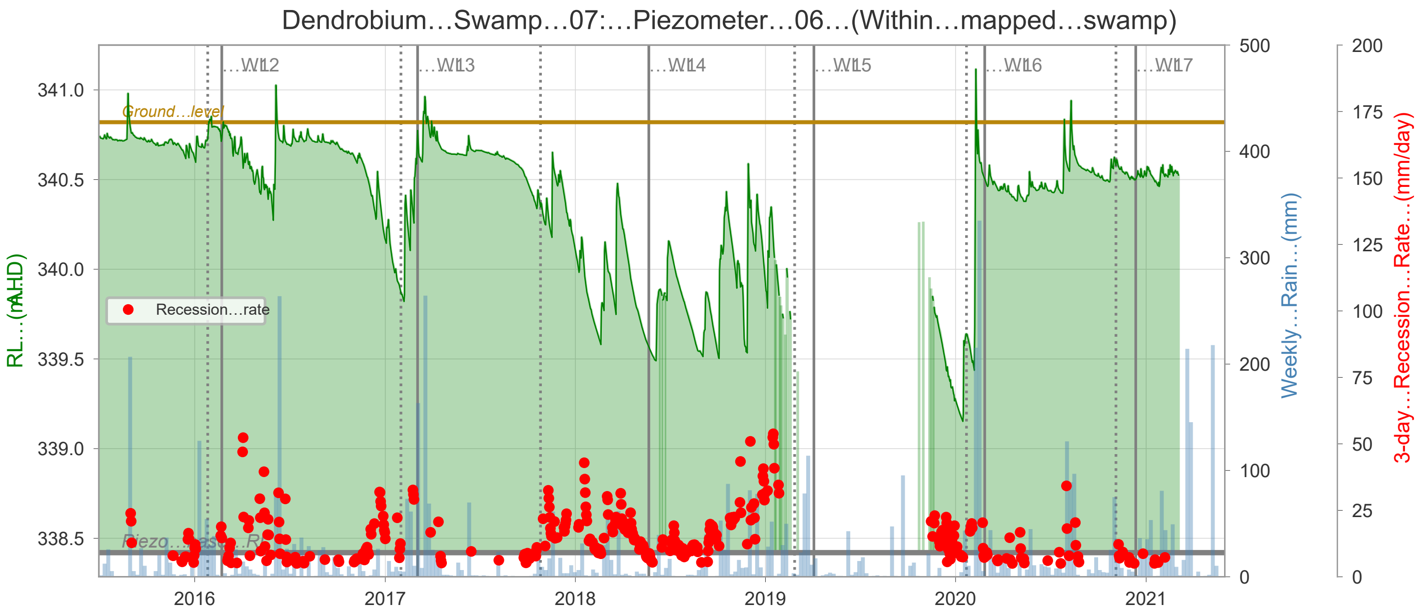


Dendrobium Swamp 05: Piezometer 05 (Within mapped swamp)

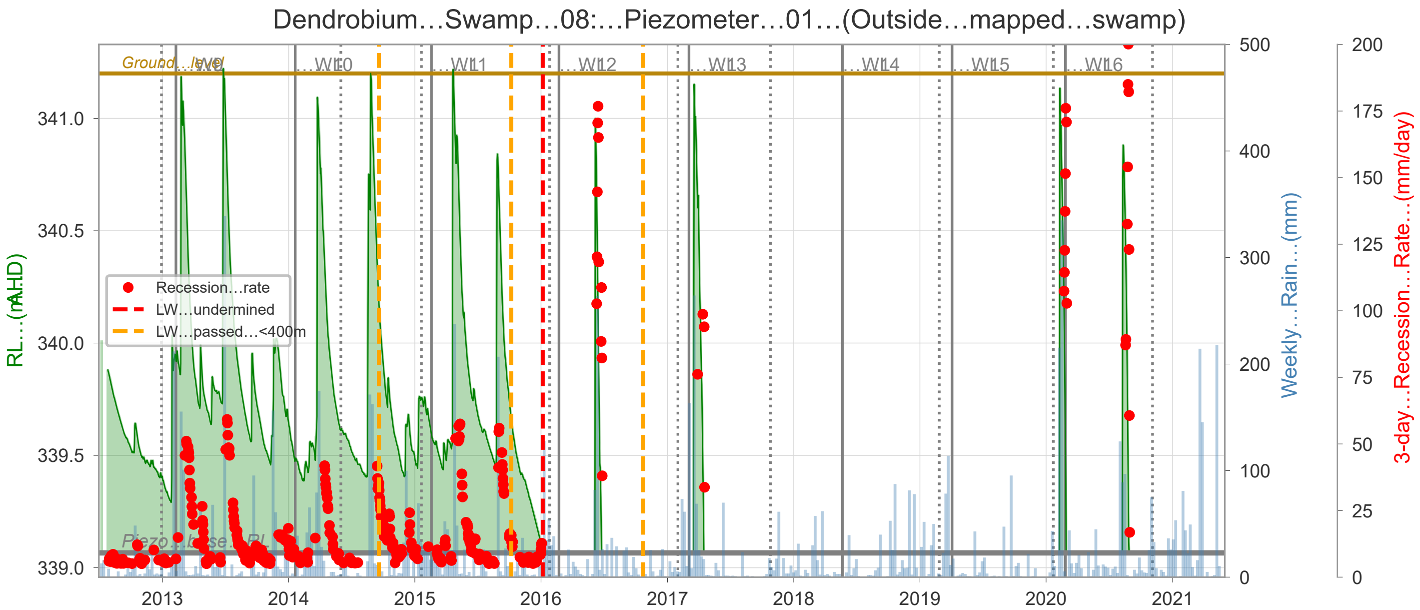


Dendrobium Swamp 07: Piezometer 05 (Within mapped swamp)

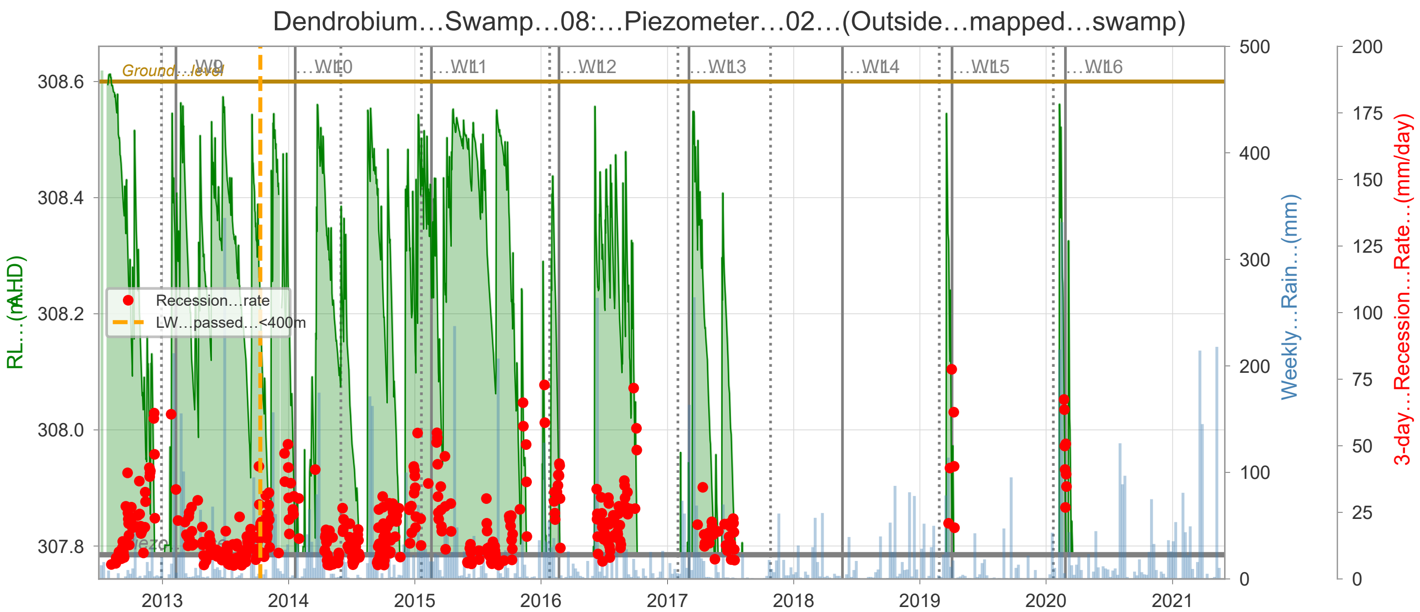




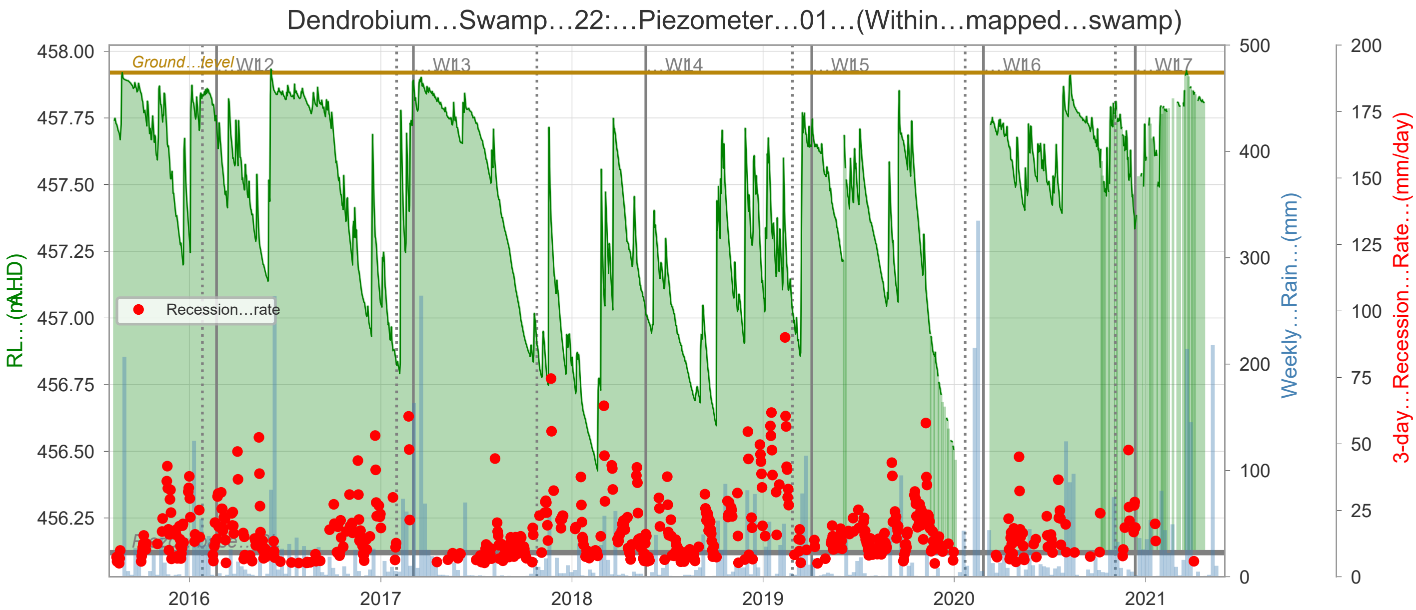
Dendrobium…Swamp…07:…Piezometer…06…(Within…mapped…swamp)
Ground…level
Recession…rate
RL…(mAHD)
Weekly…Rain…(mm)
3-day…Recession…Rate…(mm/day)



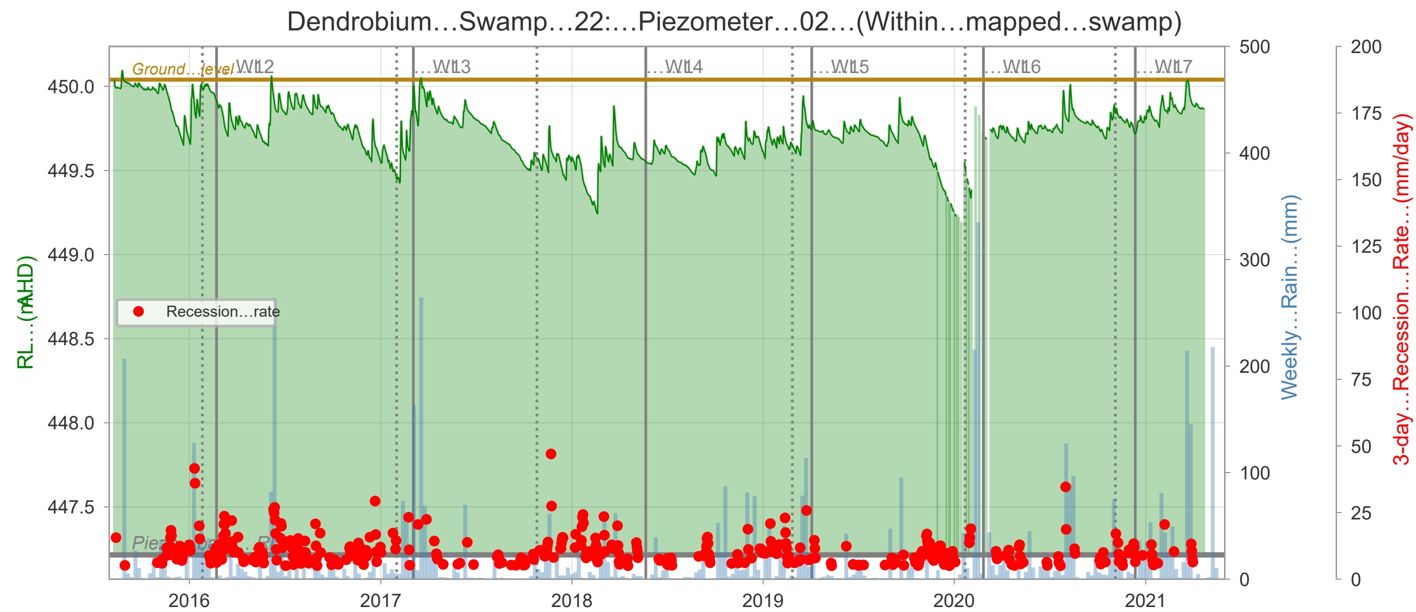
Dendrobium…Swamp…08:…Piezometer…01…(Outside…mapped…swamp)
Ground…level
Recession…rate
LW…undermined
LW…passed…<400m
RL…(mAHD)
Weekly…Rain…(mm)
3-day…Recession…Rate…(mm/day)



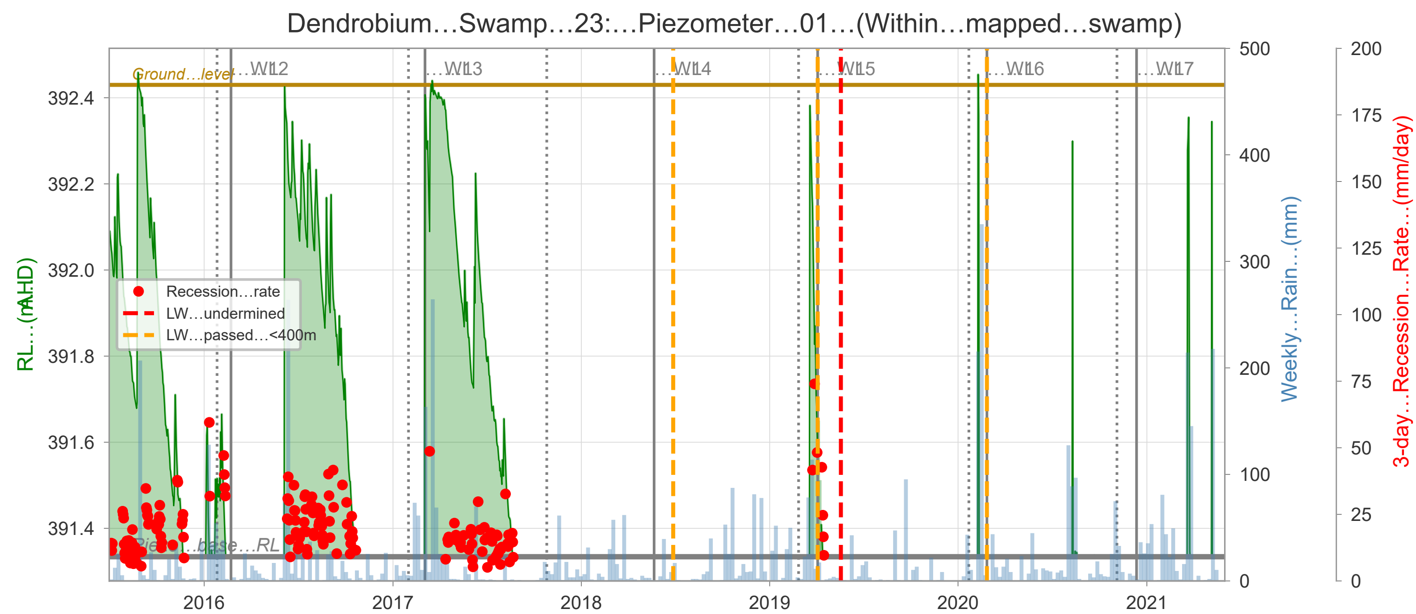
Dendrobium…Swamp…08:…Piezometer…02…(Outside…mapped…swamp)
Ground…level
Recession…rate
LW…passed…<400m
RL…(mAHD)
Weekly…Rain…(mm)
3-day…Recession…Rate…(mm/day)



Dendrobium…Swamp…22:…Piezometer…01…(Within…mapped…swamp)
Ground…level
Recession…rate
RL…(mAHD)
Weekly…Rain…(mm)
3-day…Recession…Rate…(mm/day)
WL12
WL13
WL14
WL15
WL16
WL17

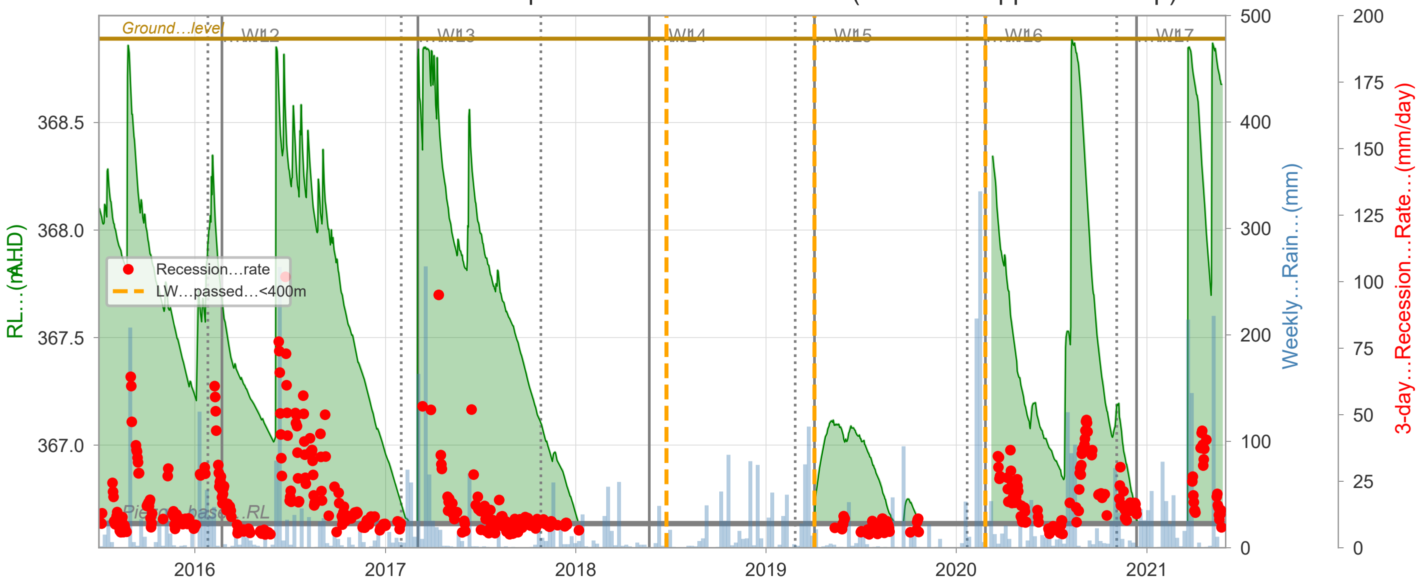


Dendrobium…Swamp…22:…Piezometer…02…(Within…mapped…swamp)
Ground…level
Recession…rate
RL…(mAHD)
Weekly…Rain…(mm)
3-day…Recession…Rate…(mm/day)
WL12
WL13
WL14
WL15
WL16
WL17

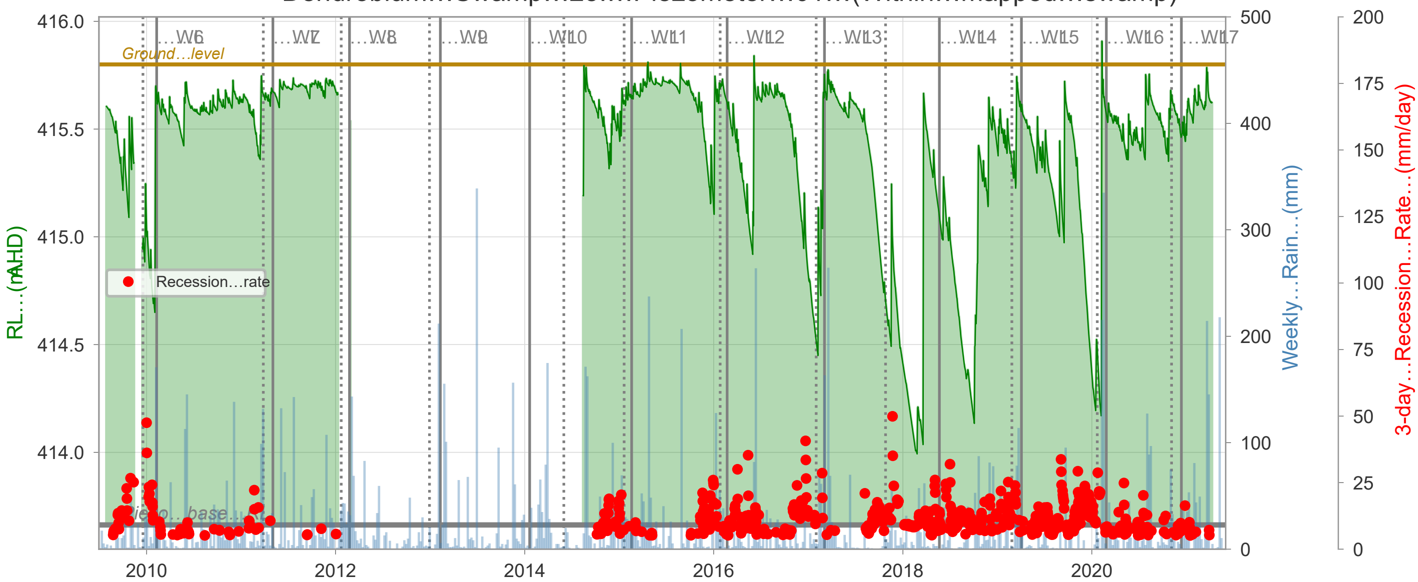


Dendrobium…Swamp…23:…Piezometer…01…(Within…mapped…swamp)
Ground…level
Recession…rate
LW…undermined
LW…passed…<400m
RL…(mAHD)
Weekly…Rain…(mm)
3-day…Recession…Rate…(mm/day)
WL12
WL13
WL14
WL15
WL16
WL17

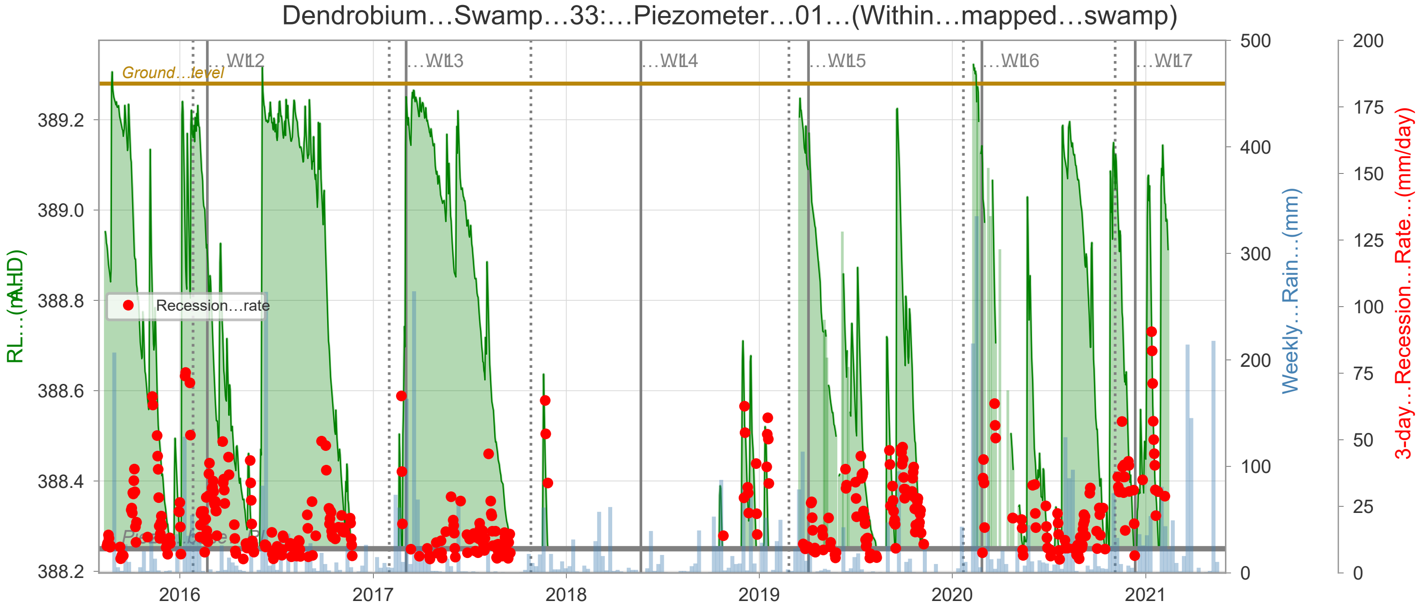
Dendrobium Swamp 23: Piezometer 02 (Within mapped swamp)



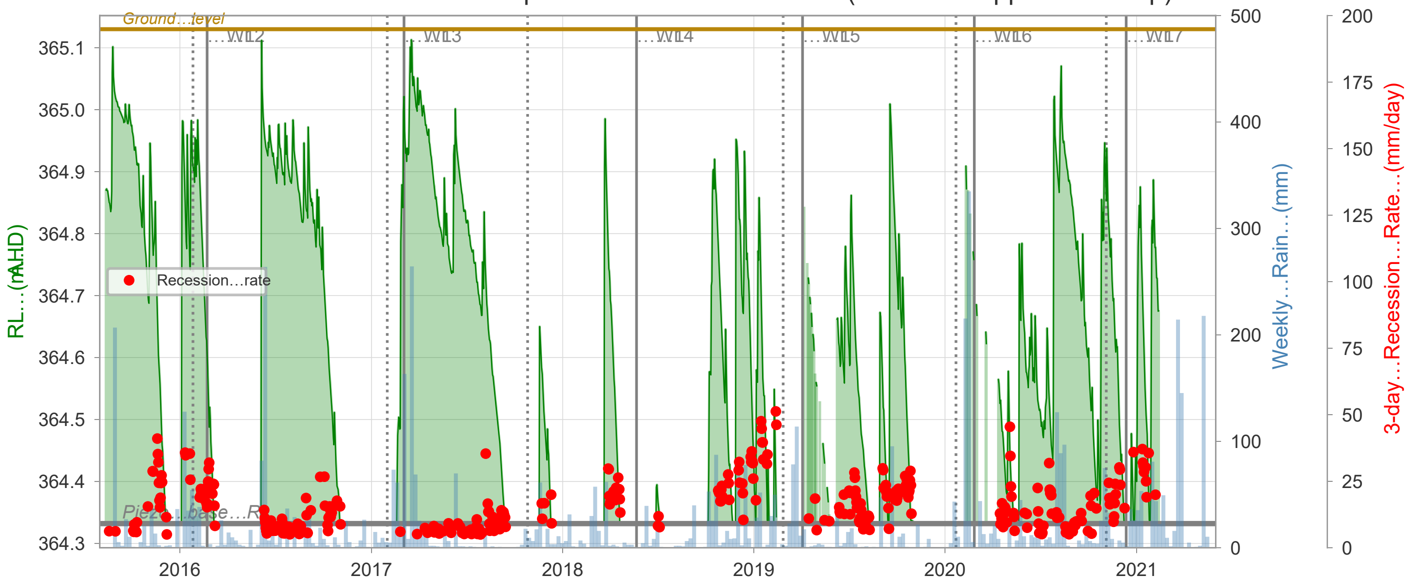
Dendrobium Swamp 25: Piezometer 01 (Within mapped swamp)



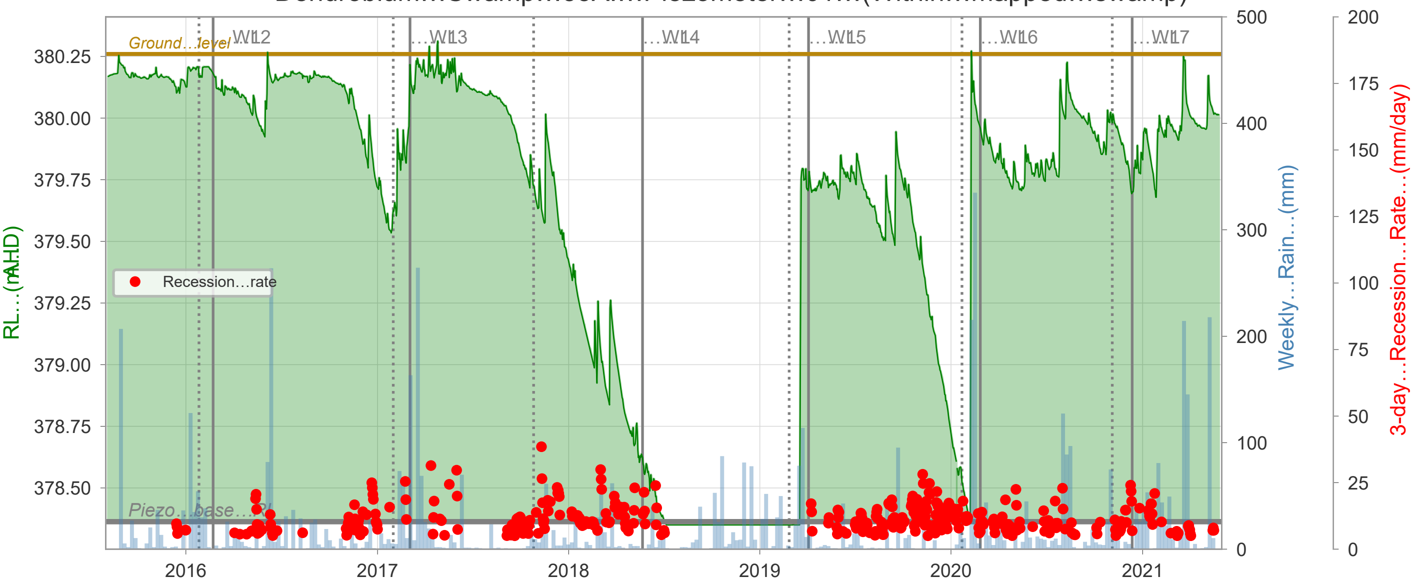
Dendrobium Swamp 33: Piezometer 01 (Within mapped swamp)



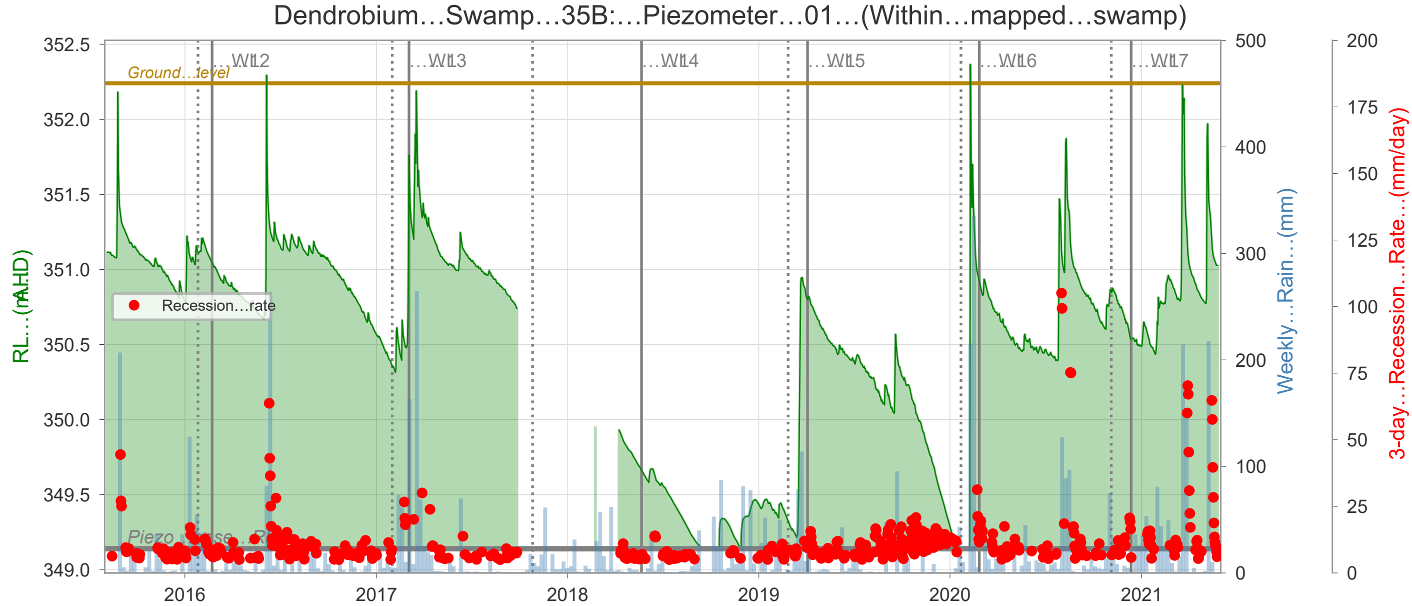
Dendrobium Swamp 33: Piezometer 03 (Within mapped swamp)



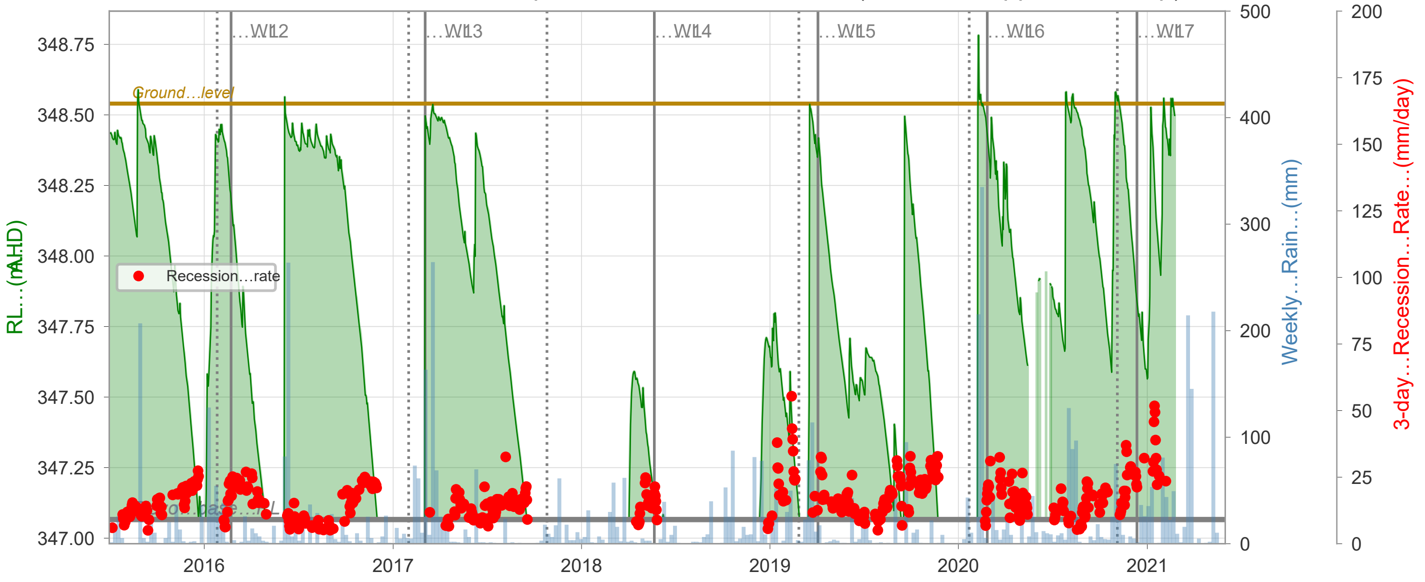
Dendrobium Swamp 35A: Piezometer 01 (Within mapped swamp)



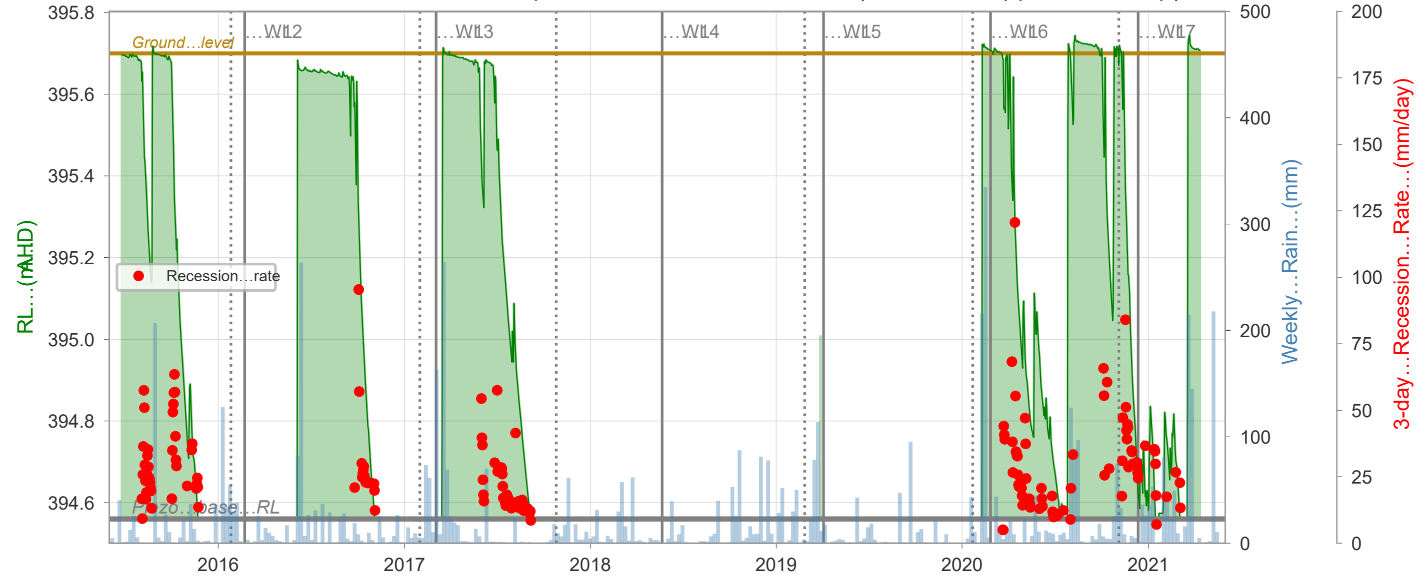
Dendrobium Swamp 35B: Piezometer 01 (Within mapped swamp)



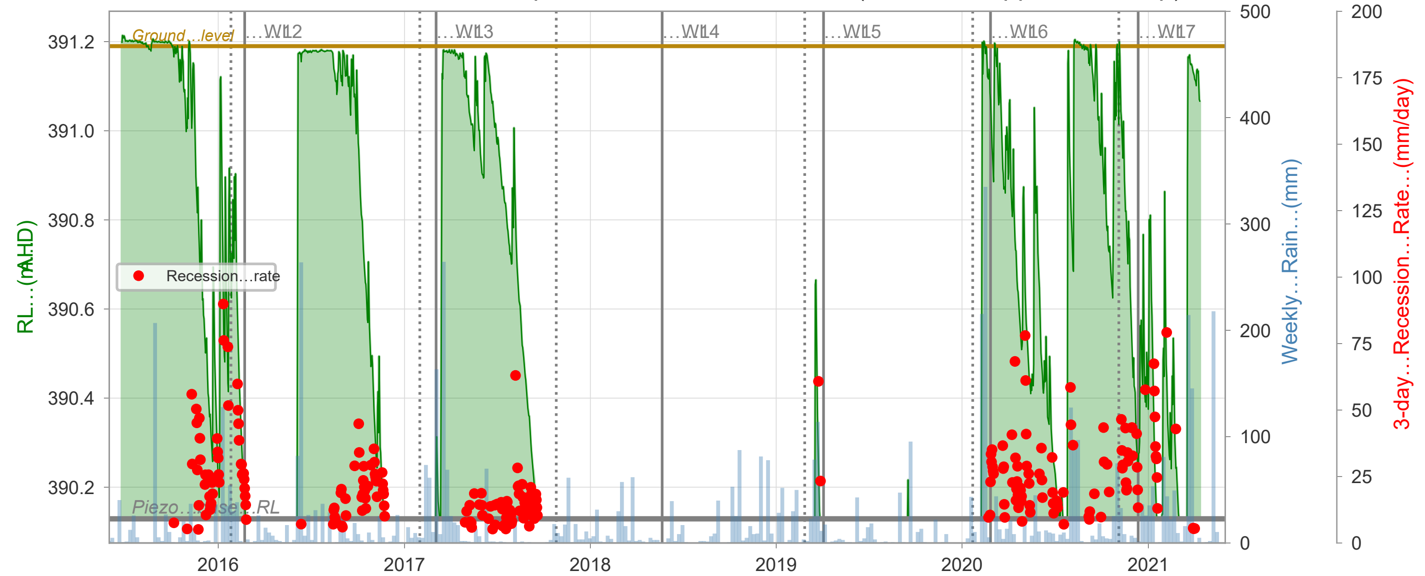
Dendrobium…Swamp…84:…Piezometer…01…(Within…mapped…swamp)

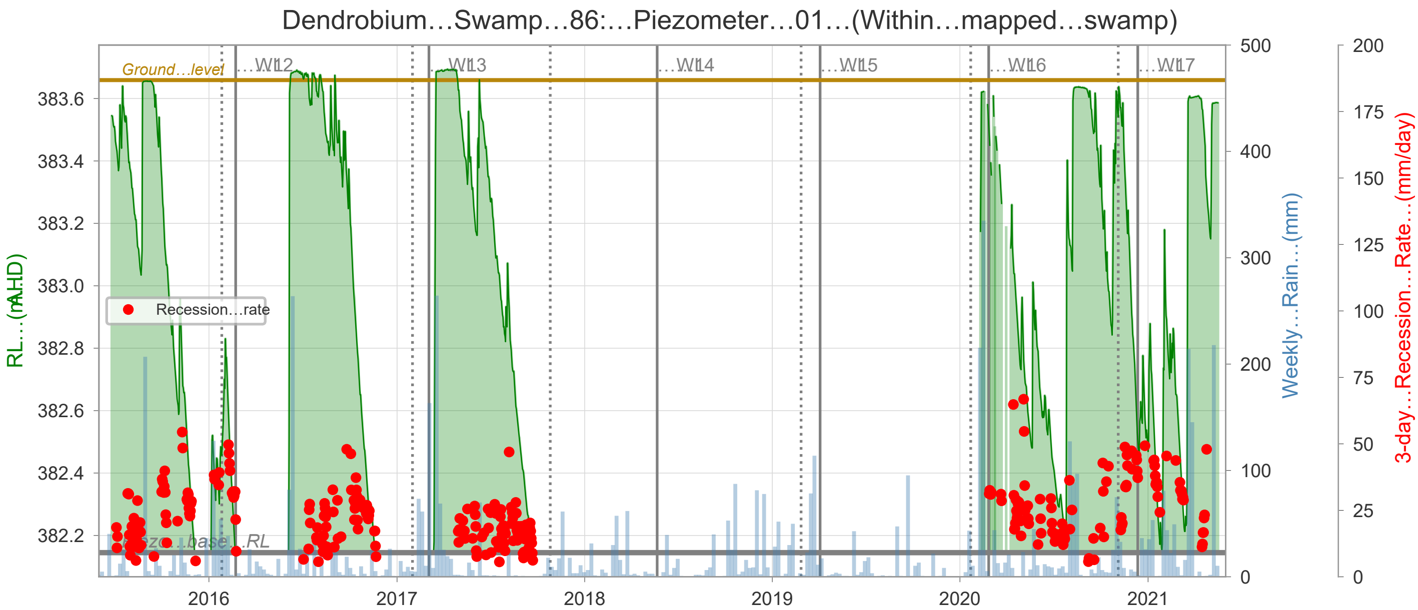


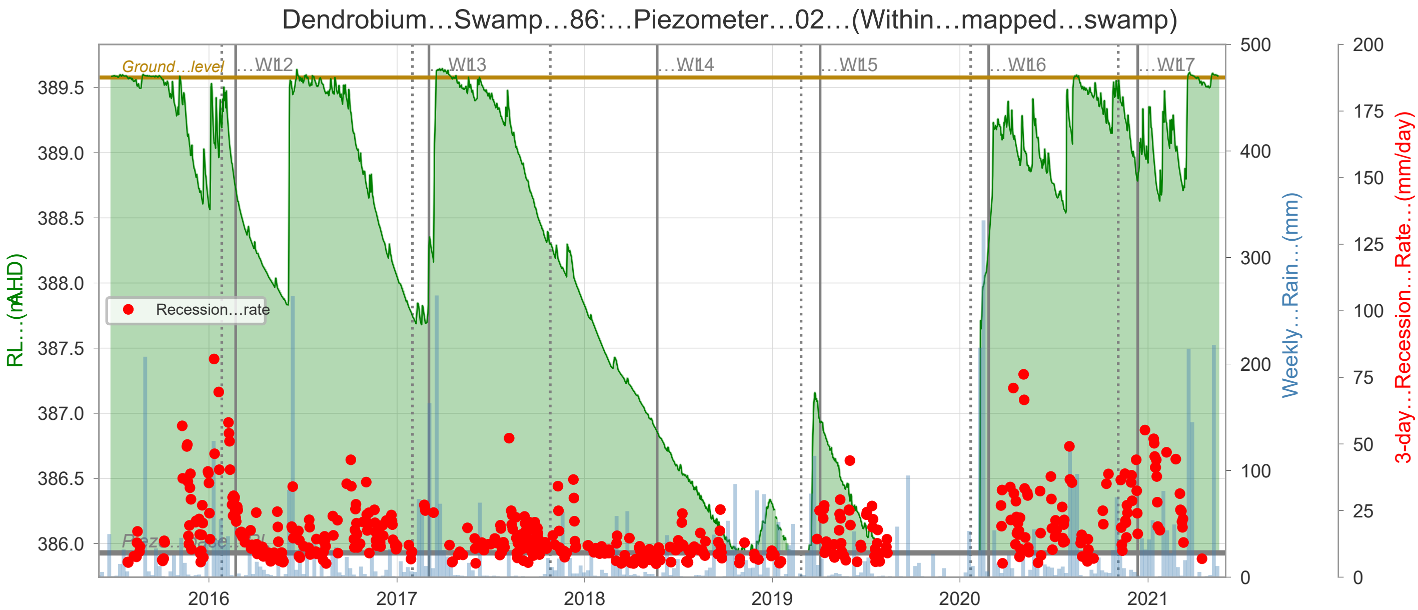
Dendrobium…Swamp…85:…Piezometer…01…(Within…mapped…swamp)

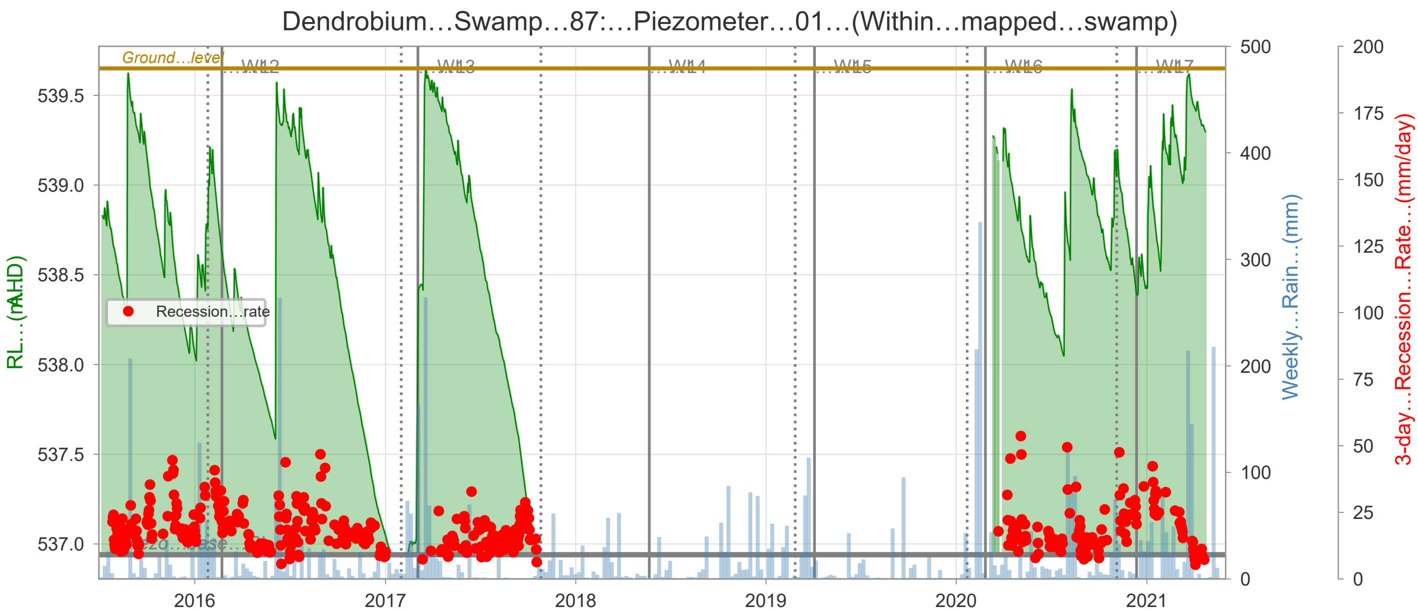


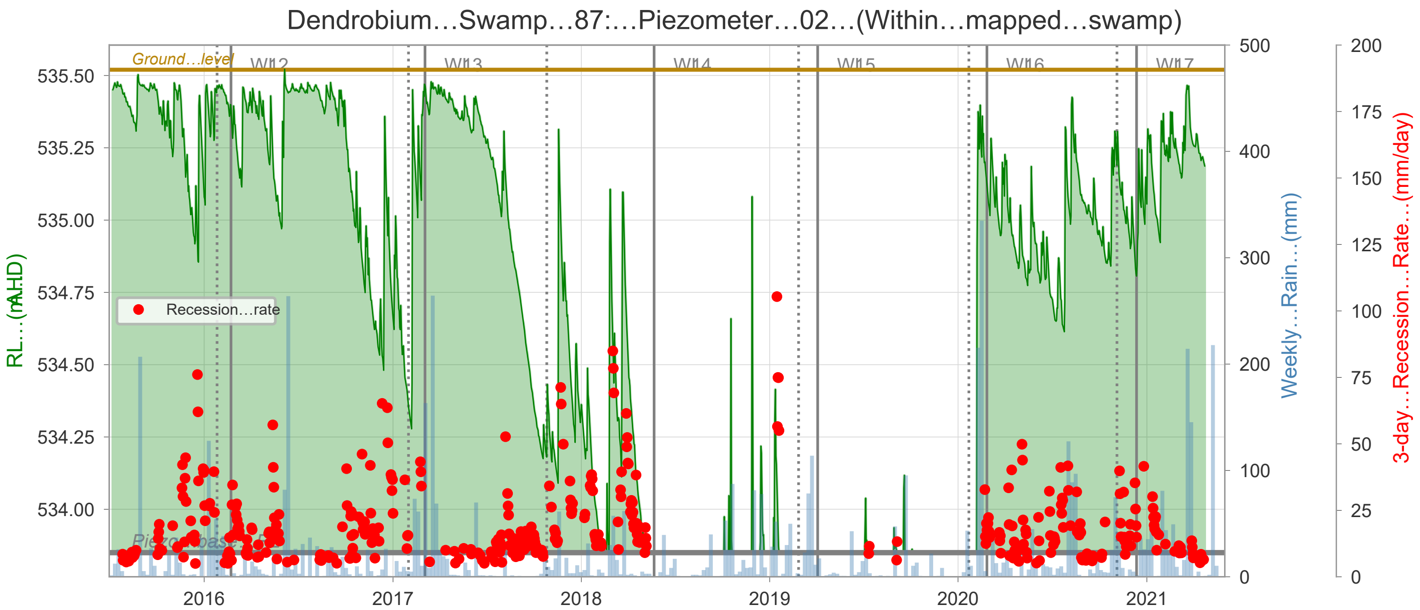
Dendrobium…Swamp…85:…Piezometer…02…(Within…mapped…swamp)

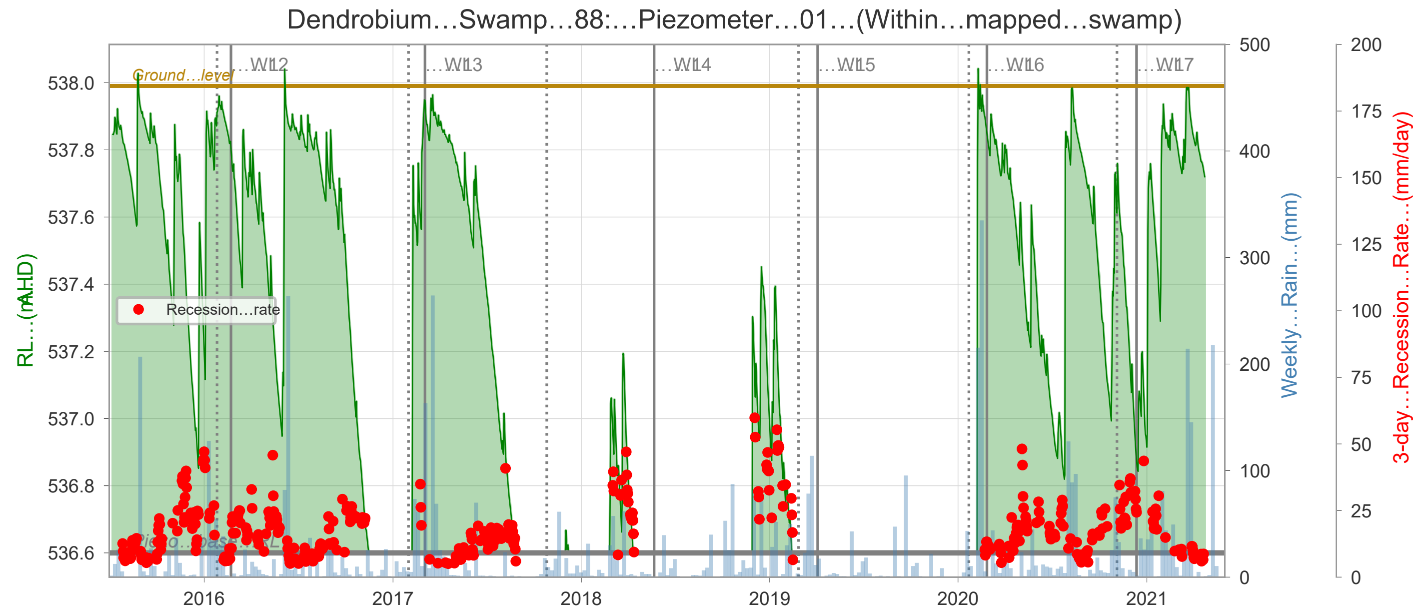


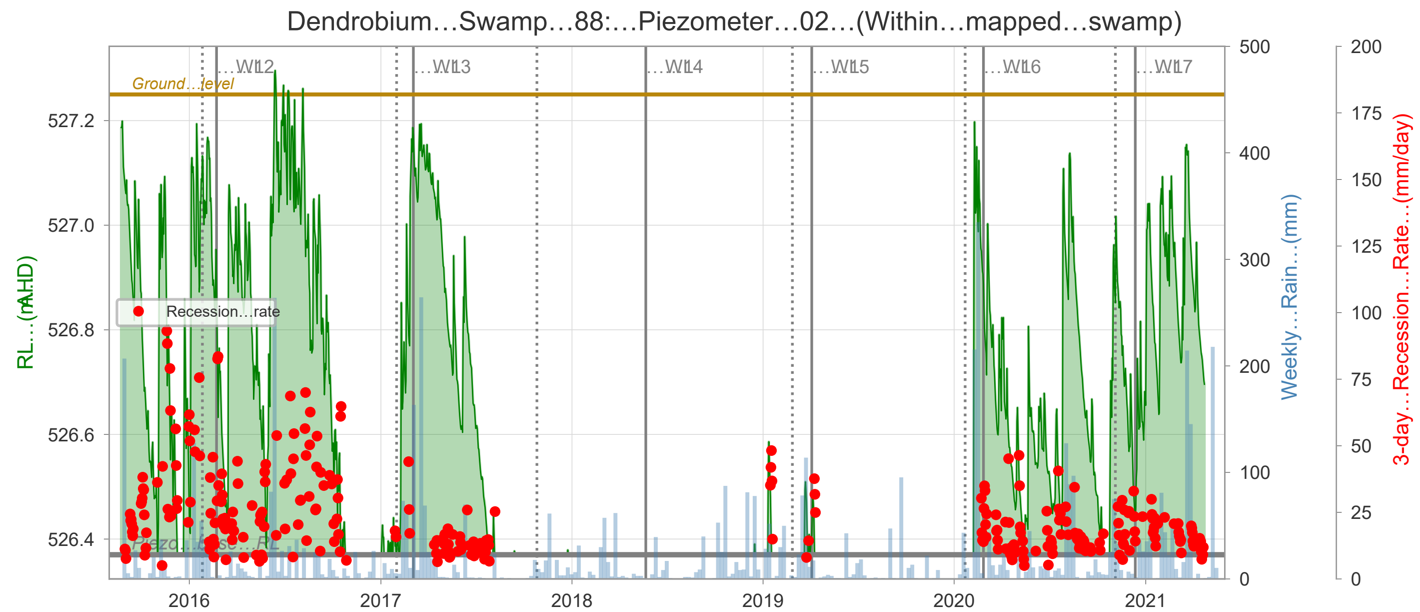

Dendrobium…Swamp…86:…Piezometer…01…(Within…mapped…swamp)
Ground…level
Recession…rate
RL…(mAHD)
Weekly…Rain…(mm)
3-day…Recession…Rate…(mm/day)
2016
2017
2018
2019
2020
2021


Dendrobium…Swamp…86:…Piezometer…02…(Within…mapped…swamp)
Ground…level
Recession…rate
RL…(mAHD)
Weekly…Rain…(mm)
3-day…Recession…Rate…(mm/day)
2016
2017
2018
2019
2020
2021


Dendrobium…Swamp…87:…Piezometer…01…(Within…mapped…swamp)
Ground…level
Recession…rate
RL…(mAHD)
Weekly…Rain…(mm)
3-day…Recession…Rate…(mm/day)
2016
2017
2018
2019
2020
2021


Dendrobium…Swamp…87:…Piezometer…02…(Within…mapped…swamp)
Ground…level
Wl12
Wl13
Wl14
Wl15
Wl16
Wl17
Recession…rate
RL…(mAHD)
Weekly…Rain…(mm)
3-day…Recession…Rate…(mm/day)
535.50
535.25
535.00
534.75
534.50
534.25
534.00
2016
2017
2018
2019
2020
2021


Dendrobium…Swamp…88:…Piezometer…01…(Within…mapped…swamp)
Ground…level
…Wl12
…Wl13
…Wl14
…Wl15
…Wl16
…Wl17
Recession…rate
RL…(mAHD)
Weekly…Rain…(mm)
3-day…Recession…Rate…(mm/day)
538.0
537.8
537.6
537.4
537.2
537.0
536.8
536.6
2016
2017
2018
2019
2020
2021


Dendrobium…Swamp…88:…Piezometer…02…(Within…mapped…swamp)
Ground…level
…Wl12
…Wl13
…Wl14
…Wl15
…Wl16
…Wl17
Recession…rate
RL…(mAHD)
Weekly…Rain…(mm)
3-day…Recession…Rate…(mm/day)
527.2
527.0
526.8
526.6
526.4
2016
2017
2018
2019
2020
2021

APPENDIX 4 – Trigger Action Response Plan (Area 3C)

Appendix A – Watercourse Monitoring and Trigger Action Response Plan

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 or until the consequences of mining have stabilised. A review of 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 the figures of the relevant areas WIMMCP.

Table 1.1 – Dendrobium Area 3 Watercourse Monitoring

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 3A 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, WC7, LA5, LA4, LA3, LA2, LA1, ND1, ND2 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, Gallaghers Creek, LC5[1], WC11, DC10, SC9A, CR36 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, WC20, WC24, WC26, LC5[1] Swamps 7, 9, 144 and 145 **Reference Sites** CR36 (Cordeaux River tributary)			
WATER CHEMISTRY				
AREA 3A	**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**	• Collect sample • Field water quality	• Monthly monitoring pre, during and post mining for two years	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)

	Sandy Creek Arm (lake site) *Refer to Figure 3-2 of 3A WIMMCP*			
AREA 3B	**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, LA1 and LA_1 (Lake Avon tributaries downstream of mining) NDC_Pool 1 (Native Dog Creek downstream of mining) NDC_Pool 3 (Native Dog Creek downstream of mining)NDC1 (Native Dog Creek upstream of Area 3B) ND1_Pool 2 (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 Creek (FR6) (Wongawilli Creek downstream) WC_Pool 43b (adjacent to Longwall 20) WC_S1 (downstream of Longwall 21) WC20_S1 (downstream of Longwall 21) [4] WC24_S1 (downstream of Longwall 21) [4] WC26_S1 (downstream of Longwall 21) [4] **Donalds Castle Creek** Donalds Castle Creek (FR6) (Donalds Castle Creek lower) DC_Pool 22 DCL3 (Donalds Castle Creek upstream of Cordeaux River confluence) **Lake Cordeaux** LC5_S1[1] (downstream of Longwall 21) **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 WaterNSW		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 3-5 of 3A WIMMCP*	• 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 (Native Dog Creek tributary downstream of mining) NDCS1 (Lake Avon tributary downstream of mining) NDTS1 (Native Dog Tributary downstream of mining) **Lake Cordeaux** LC5S1 (Reference Site) **Cordeaux River** CR36S1 (Cordeaux River tributary Reference Site) *Refer to Figure 2-36 of 3B WIMMCP*			
AREA 3C	**Wongawilli Creek** WWU (Wongawilli Creek upstream) WWL_A (Wongawilli Creek downstream) WWL (Wongawilli Creek downstream) WCS1 (Wongawilli Creek downstream) WC20S1 (Wongawilli Creek tributary downstream of mining) WC24S1 (Wongawilli Creek tributary downstream of mining) WC26S1 (Wongawilli Creek tributary within the study area) **Donalds Castle Creek** DCU (Donalds Castle Creek downstream of mining) DCS2 (Donalds Castle Creek within study area) **Lake Cordeaux** LC5S1[1] (Downstream of LW20) **Cordeaux River** CR36S1 (Cordeaux River tributary Reference Site)			
AQUATIC ECOLOGY				
AREAS 3A, 3B and 3C	**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) 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*	• Quantitative and observational monitoring	• Two baseline monitoring campaigns prior to mining during autumn and spring • Biennial monitoring during mining in autumn and spring • Biennial monitoring post mining for two years or as otherwise required • Biennial 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 Fish are sampled by visual observations and dip netting in Area 3A, and sampled using baited traps in Area 3B
TERRESTRIAL ECOLOGY				

AREAS 3A, 3B and 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 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.*

(4) *The proposed water chemistry monitoring sites are designed to detect changes to water quality, due to mining in Area 3C, within Wongawilli Creek. The proposed tributary sites (WC26, WC24 and WC20) aim to detect surface water inputs into Wongawilli Creek. Based on field observations, the Wongawilli Creek tributaries WC28, WC27, WC25, WC23 and WC22 were deemed as unsuitable for water chemistry sites due to a lack of site flows and the morphology of the tributaries.*

Table 1.2 – Dendrobium Area 3C Watercourse Impacts, Triggers and Response

OBSERVATIONAL MONITORING		
Donalds Castle Creek and Wongawilli Creek **Relevant Performance Measure(s):** • Donalds Castle Creek - minor environmental consequences • Wongawilli 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, MEG, WaterNSW • 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, MEG and WaterNSW 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, MEG and WaterNSW 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, MEG, 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, MEG, WaterNSW • Completion of works following approvals and at a time agreed between S32, DPIE, MEG and WaterNSW (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 the Donalds Castle Creek downstream monitoring site Donalds Castle Creek (FR6) • 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)	• *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
DC13, LC5, WC20, WC21, WC22, WC23, WC24, WC25, WC26, WC27 and WC29 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, MEG, WaterNSW • 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, MEG and WaterNSW 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	• *Actions as stated for Level 2* • Offer site visit with BCD, DPIE, MEG, WaterNSW

	• 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	• 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, MEG, WaterNSW • Completion of works following approvals and at a time agreed between S32, DPIE, MEG 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
WATER QUALITY		
Wongawilli Creek **Relevant Performance Measure(s):** • Wongawilli Creek - minor environmental consequences Wongawilli Creek (FR6) Baseline means: • pH 5.98 • EC 98.8 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 4.45 – EC 154.1 uS/cm – DO 50.5%	• Continue monitoring program • Submit an Impact Report to BCD, DPIE, MEG, WaterNSW • 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 4.45 – EC 154.1 uS/cm – DO 50.5%	• *Actions as stated for Level 1* • Review monitoring frequency • Submit letter report to DPIE, MEG and WaterNSW 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 4.45 – EC 154.1 uS/cm – DO 50.5%	• *Actions as stated for Level 2* • Offer site visit with BCD, DPIE, MEG, WaterNSW • 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, MEG and WaterNSW (i.e. may be after mining induced movements and impacts are complete), including monitoring and reporting on success
	Exceeding Prediction	• *Actions as stated for Level 3*

	• 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 4.45 – EC 154.1 uS/cm – DO 50.5%	• 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
Donalds Castle Creek **Relevant Performance Measure(s):** • Donalds Castle Creek - minor environmental consequences Donalds Castle Creek (FR6) Baseline means: • pH 5.41 • EC 116 uS/cm • DO 85.6%	***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 3.60 – EC 185.8 uS/cm – DO 40.1%	• Continue monitoring program • Submit an Impact Report to BCD, DPIE, MEG WaterNSW • 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 3.60 – EC 185.8 uS/cm – DO 40.1%	• *Actions as stated for Level 1* • Review monitoring frequency • Submit letter report to DPIE, MEG and WaterNSW 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 3.60 – EC 185.8 uS/cm – DO 40.1%	• *Actions as stated for Level 2* • Offer site visit with BCD, DPIE, MEG, WaterNSW • Implement additional monitoring or increase frequency if required • 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, MEG and WaterNSW (i.e. may be after mining induced movements and impacts are complete), including monitoring and reporting on success
	Exceeding Prediction	• *Actions as stated for Level 3* • Investigate reasons for the exceedance

	• 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 3.60 – EC 185.8 uS/cm – DO 40.1%	• 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 LC5_S1 Site[1] 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, MEG, WaterNSW • 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, MEG and WaterNSW 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 3.96 – EC 137 uS/cm – DO 49.4%	• *Actions as stated for Level 2* • Offer site visit with BCD, DPIE, MEG, WaterNSW • Implement additional monitoring or increase frequency if required • 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

[1] Monitoring site was established 28 March 2019, less than 24 months baseline monitoring at the time of submission. Monitoring site Sandy Creek Arm is located on Lake Cordeaux and has a substantial baseline monitoring dataset. Therefore, the baseline and trigger level values shown in the table are those of Sandy Creek Arm site as a proxy. This will be updated with LC5_S1 baseline data once this is available prior to commencement of mining Longwalls 20 or 21.

		• Completion of works following approvals and at a time agreed between S32, DPIE, MEG and WaterNSW (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		
Donalds Castle Creek and Wongawilli Creek **Relevant Performance Measure(s):** • Donalds Castle Creek - minor environmental consequences • Wongawilli 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, MEG and WaterNSW • 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, MEG and WaterNSW 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, MEG, WaterNSW • 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, MEG, WaterNSW • Completion of works following approvals and at a time agreed between S32, DPIE, MEG and WaterNSW (i.e. may be after mining induced movements and impacts are complete), including monitoring and reporting on success
	Exceeding Prediction	• *Actions as stated for Level 3* • Investigate reasons for the exceedance

	• Fracturing resulting in diversion of flow such that >10% of the pools have water levels lower than baseline period	• 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
SURFACE WATER FLOW		
Donalds Castle Creek, Wongawilli Creek, Lake Cordeaux and Cordeaux River **Relevant Performance Measure(s):** • Donalds Castle Creek - minor environmental consequences • Wongawilli Creek - minor environmental consequences • Lake Cordeaux - negligible reduction in the quantity of surface water inflows to Lake Cordeaux[2] • Cordeaux River - negligible reduction in the quantity of surface water inflow to the Cordeaux River at its confluence with Wongawilli Creek[3] **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	***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, MEG, 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, MEG and WaterNSW and seek advice on any CMA required. • Implement agreed CMAs as approved (subject to agency feedback).
	Level 3 • 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)	• *Actions as stated for Level 2* • Offer site visit with BCD, DPIE, MEG, 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, MEG, WaterNSW. • Completion of works following approvals and at a time agreed between S32, DPIE, MEG 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.

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

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.*		• 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 Donalds Castle Creek and Wongawilli Creek and other affected watercourses not subject to performance measures **Surface water flow Reference sites** (as in Table 1.1)**:** • Wongawilli Creek - WWU (Wongawilli Creek upstream); • O'Hares Creek and 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.*	***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, MEG, WaterNSW. • Report in the End of Panel Report. • Summarise actions and monitoring in AEMR.
	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)	• Actions as stated for Level 1 • Review monitoring frequency. • Submit letter report to DPIE, MEG and WaterNSW and seek advice on any CMA required. • Implement agreed CMAs as approved (subject to agency feedback).
	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)	• *Actions as stated for Level 2* • Offer site visit with BCD, DPIE, MEG, 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, MEG, WaterNSW. • Completion of works following approvals and at a time agreed between S32, DPIE, MEG 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.
AQUATIC ECOLOGY		
	Level 1	• Continue monitoring program

Pool water level, interconnectivity between pools and loss of connectivity, noticeable alteration of habitat • Donalds Castle Creek catchment – 1 site • Wongawilli Creek catchment – 8 sites	• Reduction in aquatic habitat for 1 year	• Submit an Impact Report to BCD, DPIE, MEG, WaterNSW • Report in the End of Panel Report • Summarise actions and monitoring in AEMR
	Level 2 • Reduction in aquatic habitat for 2 years following the active subsidence period	• *Actions as stated for Level 1* • Review monitoring frequency • Submit letter report to DPIE, BCD, MEG and WaterNSW and seek advice on any CMA required • Implement agreed CMAs as approved (subject to agency feedback)
	Level 3 • Reduction in aquatic habitat for >2 years following the active subsidence period	• *Actions as stated for Level 2* • Offer site visit with BCD, DPIE, MEG, WaterNSW • 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, MEG, WaterNSW • Completion of works following approvals and at a time agreed between S32, DPIE, MEG and WaterNSW (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 • Donalds Castle Creek catchment – 2 site • Wongawilli Creek catchment – 2 sites	***Level 1*** • Reduction in habitat for 1 year	• Continue monitoring program • Submit an Impact Report to BCD, DPIE, MEG, WaterNSW • 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, MEG and WaterNSW 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, MEG, WaterNSW • 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, MEG, WaterNSW • Completion of works following approvals and at a time agreed between S32, DPIE, MEG and WaterNSW (i.e. may be after mining induced movements and impacts are complete), including monitoring and reporting on success

Regulatory Agency Acronyms

- Department of Planning, Industry and Environment (DPIE)
- Biodiversity and Conservation Division (BCD)
- Department of Mining, Exploration and Geosciences (MEG)
- WaterNSW

Attachment F – Terrestrial Ecology Assessment

Excellence in your environment

niche Environment and Heritage

DENDROBIUM Area 3C
LONGWALLS 22 and 23 TERRESTRIAL ECOLOGICAL ASSESSMENT

ACCOMPANYING DOCUMENT TO DENDROBIUM LONGWALLS 22 and 23 SUBSIDENCE MANAGEMENT PLAN

Prepared for SOUTH32 ILLAWARRA METALLURGICAL COAL | 27 August 2021

niche-eh.com

Excellence in your environment

Document control

Project number	Client	Project manager	LGA
5804	South32 Illawarra Metallurgical Coal (IMC)	Sian Griffiths	Wollongong

Version	Author	Review	Status	Date
R0	Sian Griffiths and Sarah Hart	Freya Gordon	Draft	09 June 2021
R1	Sian Griffiths	South32	Final	25 June 2021
R2	Sian Griffiths and Sarah Hart	South32	Final	25 August 2021
R3	Sian Griffiths and Sarah Hart	-	Final	27/08/2021

Enquiries should be addressed to:

Sydney Head Office
Niche Environment and Heritage
02 9630 5658
info@niche-eh.com
PO Box 2443 North Parramatta
NSW 1750 Australia

Executive Summary

Project outline

Niche Environment and Heritage Pty Ltd (Niche) was commissioned by South32 Illawarra Metallurgical Coal (IMC) to prepare a Terrestrial Ecological Assessment for the extraction of Longwalls 22 and 23 within Dendrobium Area 3C (DA3C). Initial approval to mine Dendrobium Area 3 (DA3) was granted in 2001 (DA 60-03-2001) and a modification to the Consent was granted in 2008. Development Consent was granted following the completion of a number of assessments specific to DA3 including a Species Impact Statement (SIS), which was completed in 2007 (Biosis 2007) as part of the modification.

Further to the 2008 approval, a Subsidence Management Plan (SMP), specific to Longwalls 22 and 23 within DA3C is required to be approved by the New South Wales Department of Planning, Industry and Environment (DPIE) prior to any mining of the proposed longwalls. The SMP must be accompanied by a revised terrestrial ecological assessment to address any recent legislative changes, guidelines and research regarding subsidence associated with longwall mining. This report constitutes the revised terrestrial ecological assessment and is specific to Longwalls 22 and 23 having regard to the proposed mine design and longwall layout as defined by the Mine Subsidence Engineering Consultants (MSEC) subsidence impact assessment (MSEC 2021).

The SMP involved flora and fauna surveys within DA3C and focused on landscape features and associated biodiversity which may be sensitive to the impacts of subsidence from longwall extraction. The study area was defined by the limit of subsidence associated with proposed Longwalls 22 and 23.

Natural areas and features sensitive to subsidence within the DA3C study area include: watercourses, cliffs, rock outcrops, steep slopes and upland swamps. Significant conclusions from the MSEC (2021) report, relevant to this study include the following:

Wongawilli Creek and drainage lines

- It is possible that there could be some localised changes in the levels of ponding or flooding as a result of subsidence induced tilt where the maximum changes in grade coincide with existing pools, steps or cascades along Wongawilli Creek. It is not anticipated that these changes would result in adverse impacts on the creek.
- It is possible that fracturing could occur along Wongawilli Creek due to the valley-related compressive strains. The likelihood of fracturing resulting in surface water flow diversions along Wongawilli Creek, due to the extraction of the proposed Longwalls 22 and 23, is low.
- The potential impacts of increased ponding and scouring of drainage lines as a result of subsidence induced tilt are expected to be minor and localised. There is potential for a reduction in stream grade and increased ponding at two locations along LC5, in the vicinity of Swamp Den07. The impacts resulting from the changes in surface water flows due to the mining-induced tilt are expected to be small in comparison with those which occur during natural flooding conditions. Fracturing of the bedrock is expected to occur along the sections of the drainage lines that are located directly above the proposed longwalls. Fracturing can also occur outside the extents of the proposed longwalls, with minor and isolated fracturing previously observed 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. 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 proposed longwalls.

Cliffs, rock outcrops and steep slopes

- The cliffs in the study area could be impacted due to the proposed mining directly beneath or adjacent to them. The potential impacts include fracturing in the exposed rockface and, if it is marginally stable, this could then result in cliff instabilities. It has been estimated that between 7 % and 10 % of the total length, or between 3 % and 5 % of the total face area of the cliffs located directly above or adjacent to the proposed longwalls would be impacted. It is unlikely that other cliffs located outside the Study Area based on the 35 degree angle of draw would experience adverse impacts due to their distances from the proposed longwalls.
- The downslope movement of the ground would be expected to occur along rock outcrops and steep slopes within the Study Area. The steep slopes are heavily vegetated and erosion due to soil instability (i.e. downslope movements) was not readily apparent from the site investigations undertaken. If tension cracks were to develop, due to the extraction of the proposed longwalls, it is possible that soil erosion could occur and require treatment.

Upland Swamps

- It is unlikely that the swamps would experience adverse changes in the levels of ponding or scouring based on the predicted subsidence induced tilt.
- As swamps Den07 and Den153 occur directly above the proposed longwalls, fracturing is likely to occur in the bedrock and the dilated strata beneath the drainage lines and within these swamps could result in the diversion of surface water flows beneath these swamps. The drainage lines upstream of these swamps flow during and shortly after rainfall events. Where there is no connective fracturing to any deeper storage, it is likely that surface water flows will re-emerge at the limits of fracturing and dilation.
- The remaining swamps are located outside the mining area, at minimum distances ranging between 70 m and 540 m from the proposed longwalls. Fracturing has been observed in streams located outside the extents of previously extracted longwalls at distances of up to 290 m. Minor and isolated fracturing has also been observed up to 400 m outside of longwalls.
- Swamp Den09 is located near the base of tributary LC5 and it is at a minimum distance of 90 m from the proposed longwalls. Fracturing could occur in the base of the valley and within this swamp. Fracture widths in the order of 20 mm to 50 mm have been observed due to valley-related effects at similar distances from previous longwall mining.
- Swamp Den157 is located near the base of tributary LC6 and it is at a minimum distance of 335 m from the proposed longwalls. It is possible, but unlikely, that fracturing could occur in the base of the valley and within this swamp.
- The remaining swamps within the Study Area are either located on the valley sides or are more than 400 m outside the proposed mining area. It is unlikely therefore that fracturing would develop in the bedrock beneath these remaining swamps.

Surface water

- Baseflow components of Wongawilli Creek are predicted to decline following longwall extraction. These reductions in baseflow can result in an increased number of cease to flow days.

- Loss of flow is also predicted in LC5, LC6 (tributaries to Lake Cordeaux) and WC26 and WC24 (tributaries to Wongawilli Creek), as well as very minor loss of baseflow at CR36 (tributary to Cordeaux River). The losses will be due to subsidence cracking and/or groundwater depressurisation or drawdown.
- Water quality impacts, including localised iron staining, may be observed in tributaries that cross the longwall footprints (WC24, WC26, LC5 and LC6), and possibly in LC7 which is entirely within 400 m of Longwall 22; however, those impacts are not expected to significantly influence water quality at downstream locations on Wongawilli Creek. Local discolouration of streambeds and rock faces by iron hydroxide precipitation can continue for a number of years.
- It is likely that shallow groundwater levels will be affected in Swamps Den 7 and Den 153 which substantially overlap the longwall footprint. The remaining swamps are unlikely to be impacted.

Literature review

The findings from the MSEC (2021) report form the basis to which the impact assessments for threatened flora, fauna and ecological communities have been assessed in this report.

A significant body of other work relating to previous approvals and monitoring for underground mining within DA3 was reviewed as part of this report with major reports listed below:

- SIS completed for the 2008 modification (Biosis 2007);
- *Dendrobium Area 3A Terrestrial Ecology Assessment* (Niche 2020);
- *Dendrobium Area 3C Terrestrial Ecology Assessment* (Niche 2019);
- *Dendrobium Area 3B Terrestrial Ecology Assessment* (Niche 2012);
- Monitoring as part of previous SMPs for longwalls within Areas 3A and 3B including annual and end of panel reporting (e.g. Biosis 2020; HGeo 2017);
- Statutory reviews and policy guidelines including;
    - *Southern Coalfields Inquiry* (DOP 2008);
    - *Upland Swamps Environmental Assessment Guidelines – Draft* (OEH 2012); and
    - *Independent Expert Panel for Mining in the Catchment Report: Part 2. Coal Mining Impacts in the Special Areas of the Greater Sydney Water Catchment* (IEPMC 2019).

Summary of methods

Literature review was supplemented with field survey concentrating on landscape features and associated biodiversity which may be sensitive to impacts of subsidence from longwall extraction such as swamps, watercourses and rocky areas. Survey was conducted in May and June 2020.

Survey activities included vegetation validation of upland swamps, and diurnal and nocturnal frog and tadpole searches. A likelihood of occurrence and impact analysis was conducted for threatened species after considering the literature review and survey results.

Summary of results and impact assessment

Ground-truthing of upland swamp community mapping resulted in changes to upland swamp sub-community patterns, swamp boundaries and changes in vegetation communities. Fourteen upland swamps, that meet the definition of the Threatened Ecological Community (TEC) under the *Biodiversity Conservation Act 2016* (BC Act) and *Environment Protection and Biodiversity Conservation Act* (EPBC Act), occur within the wider study area with complexity of swamps generally increasing with overall size. One complex larger Swamp (Den07) occurs within the predicted area of subsidence impacts (35 degree angle of draw study area). Based on previous subsidence monitoring, a maximum impact area for swamps was calculated at 4.54 hectares constituting the upland swamps within the groundwater impact zone (60 m buffer from extent of longwalls).

Habitats such as pools are likely to experience some level of subsidence impacts (comprising both direct and indirect impacts). Subsidence impacts to features such as cliffs, overhangs and rocky outcrops have the potential to occur but are likely to have limited impacts on threatened biodiversity within the study area due to the small area of predicted impacts.

One threatened plant species was recorded within upland swamps of the study area: *Leucopogon exolasius.* Three additional threatened plant species (*Epacris purpurascens var. purpurascens, Cryptostylis hunteriana* and *Pultenaea aristata)* were deemed to have habitat in the study area that may be potentially impacted by subsidence. However, impacts for these species are likely to be minimal.

Nine threatened fauna species are considered to be potentially impacted by subsidence impacts resulting from the proposal comprising:

- Frogs: Littlejohn's Tree Frog, Giant Burrowing Frog, Red-crowned Toadlet.
- Reptiles: Broad-headed Snake, Rosenberg's Goanna.
- Mammals: Large Bent-wing Bat, Little Bentwing Bat, Southern Myotis.
- Invertebrates: Giant Dragonfly.

From the above species, it is considered that potentially significant impacts could occur for the three frog species and the Giant Dragonfly.

Ongoing monitoring requirements for biodiversity are provided within the recommendations section of the report. Recommendations are focussed around swamp and frog monitoring along watercourses in concert with established programs for measuring physical impacts of subsidence.

Glossary and list of abbreviations

Term or abbreviation	Definition
BC Act	NSW *Biodiversity Conservation Act 2016*
BCD	Biodiversity Conservation Division of DPIE
DA3C	Dendrobium Area 3C
DA3	Dendrobium Area 3
DoEE	Commonwealth Department of Environment and Energy
DPIE	NSW Department of Planning, Industry and Environment (formerly OEH)
EEC	Endangered Ecological Community
EP&A Act	NSW *Environmental Planning and Assessment Act 1979*
EPBC Act	Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*
ESSGW	Exposed Sandstone Scribbly Gum Woodland
ha	Hectares
KTP	Key Threatening Process
IMC	South32 Illawarra Metallurgical Coal
Locality	The area within a 10 kilometre radius of the study area
Longwall	Longwall
MNES	Matters of National Environmental Significance listed on the EPBC Act
NPWS	National Parks and Wildlife Service
OEH	NSW Office of Environment and Heritage (now DPIE)
Proposal	The development, activity or proposed action, Longwalls 22 and 23
SGPF	Sandstone Gully Peppermint Forest
SIS	Species Impact Statement
SMP	Subsidence Management Plan
Study area	Area potentially directly or indirectly impacted by the proposal
TARP	Trigger Action Response Plan
THPS	Temperate Highland Peat Swamps
TSC Act	NSW *Threatened Species Conservation Act 1995* (repealed by the *BC Act*)
USBT	Upland Swamp: Banksia Thicket
USTTT	Upland Swamp: Tea Tree Thicket
USSHC	Upland Swamp: Sedgeland Heath Complex
USFEW	Upland Swamp: Fringing Eucalypt Woodland

Table of Contents

List of Figures

List of Tables

1 Introduction

1.1 Background and need for the project

Niche Environment and Heritage Pty Ltd (Niche) was commissioned by South32 Illawarra Metallurgical Coal (IMC) to prepare a Terrestrial Ecological Assessment for the extraction of Longwalls 22 and 23 within Dendrobium Area 3C (DA3C) (Figure 1, Figure 2). Initial approval to mine Dendrobium Area 3 (DA3) was granted in 2001 (DA 60-03-2001) and a modification to the Consent was granted in 2008. Development Consent was granted following the completion of a number of assessments specific to DA3 including a Species Impact Statement (SIS), which was completed in 2007 (Biosis 2007) as part of the modification.

Further to the 2008 approval, a Subsidence Management Plan (SMP) for Longwalls 22 and 23 within DA3C (Figure 2) is required to be approved by the New South Wales (NSW) Department of Planning, Industry and Environment (DPIE) prior to any mining of the proposed longwalls. The SMP must be accompanied by a revised terrestrial ecological assessment to address any recent legislative changes, guidelines and research regarding subsidence associated with longwall mining. This report constitutes the revised terrestrial ecological assessment and is specific to proposed Longwalls 22 and 23 in DA3C having regard to the proposed mine design as defined by Mine Subsidence Engineering Consultants (MSEC) subsidence impact assessment (MSEC 2021).

This ecological report has been prepared to meet the relevant sections of the *NSW Department of Primary Industries Guideline for Applications for Subsidence Management Approvals December 2003*.

1.2 Statutory and other approvals

1.2.1 Landscape approval

Approval to mine DA3 was granted by the Department of Planning (now Department of Planning, Industry and Environment (DPIE)) in 2001. In 2007, IMC applied to modify the approval for Dendrobium Mine pursuant to section 75W of the *Environmental Planning and Assessment Act 1979* (EP&A Act). A SIS was conducted, and an environmental assessment completed to support the proposal to modify the footprint of Area 3.

Since the Dendrobium mine was approved by the Commonwealth of Australia as a controlled action under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) in December 2001, approval within this assessment is not required under the EPBC Act. Threatened species and threatened ecological communities (TECs) listed under the EPBC Act have been considered within this report, however revised impact assessments for species listed under the EPBC Act are not required.

1.3 Timeline and project justification

Longwalls 22 and 23 are scheduled to be extracted between February 2023 – September 2023.

Mine layouts for DA3C 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 DA3C 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 DA3C 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 DA3C was achieved. DA3C is part of the overall mining schedule for Dendrobium Mine and has been designed to flow on from (and return to) Areas 1, 2, 3A, 3B and 3C to provide a continuous mining operation. There are a number of surface and subsurface constraints within the vicinity of DA3C including major surface water features such as Lake Cordeaux and Wongawilli Creek; and a number of geological constraints such as dykes and faults. The process of developing the layout for DA3C has considered predicted impacts on major natural features and aimed to minimise these impacts within geological and other mining constraints. The layouts at Dendrobium Mine have been modified to reduce the potential for impacts to surface features. The process adopted in designing the DA3C mine layout incorporated the hierarchy of avoid/minimise/mitigate as requested by the DPIE and its incorporated Biodiversity Conservation Division (BCD).

2 Description of the study area and subsidence predictions

2.1 Study area

Two longwalls (Longwalls 22 and 23) (hereafter referred to as 'the proposal') have been proposed in the study area. The study area considered within this report (Figure 2) is consistent with the area described in MSEC 2021 as the surface area that could be affected by the mining of the proposed longwalls consisting of:

- The 35 degree angle of draw line from the extents of the proposed Longwalls 22 and 23;
- The predicted limit of vertical subsidence, taken as the 20 millimetres (mm) subsidence contour, resulting from the extraction of the proposed longwalls; and
- The natural features located within 600 metres (m) of the extent of the longwall mining area, in accordance with Condition 8(d) of the Development Consent DA 60-03-2001.

The study area at its largest (Figure 2) constitutes approximately 638 ha of largely undisturbed bushland and watercourses of the Cordeaux River Catchment inside the WaterNSW Metropolitan Special Area. The Cordeaux River is part of the Hawkesbury-Nepean Catchment.

Fire roads, easements, active and rehabilitating trails, as well as exploration drilling sites occur within the study area and are the primary sources of disturbance. The study area is in WaterNSW controlled land and is contiguous with a large reserve system which includes the Upper Nepean State Conservation Area to the west and the Illawarra Escarpment Area to the east (Figure 1).

2.1.1 Rivers, creeks and drainage lines

There is one third order perennial stream (Wongawilli Creek) located outside the study area based on the 35 degree angle of draw line; however, it is partially located within the study area based on the 600 m boundary (Figure 3). The total length of the creek within the 600 m boundary is approximately 1.8 km (MSEC 2021).

Wongawilli Creek has 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 approximately 2.7 km to the north of the proposed longwalls (MSEC 2021). Pools and riffle zones in Wongawilli Creek are permanent and naturally develop upstream of rockbars and at areas of sediment and debris accumulations (Figure 3).

The drainage lines that are located directly or partially above Longwalls 22 and 23 include LC6, LC5, WC24A, WC26 and WC26A (Figure 3) (MSEC 2021). These drainage lines are first and second-order streams that form tributaries to Lake Cordeaux in the eastern part of the study area and to Wongawilli Creek in the western part of the study area (MSEC 2021). The beds of the drainage lines 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 sand deposits or islands, loose rocks and tree branches. (MSEC 2021).

2.1.2 Cliffs

Four cliffs have been identified within the study area. Two cliffs are located directly above the proposed Longwall 23 and the other two cliffs are located outside and adjacent to this longwall. The cliffs have overall lengths ranging between 25 m and 60 m and heights of approximately 11 m or 12 m (MSEC 2021). The cliffs have formed from Hawkesbury Sandstone, with the faces being at various stages of weathering and erosion. The cliffs have many overhangs and undercuts that are generally less than 6 m in depth (MSEC 2021).

2.1.3 Rock outcrops and steep slopes

Rock outcrops and steep slopes are located across the study area (MSEC 2021).

The steep slopes within the study area have been identified within the valleys of Lake Cordeaux, Wongawilli Creek and their tributaries. The natural grades of the steep slopes typically vary up to approximately 1 in 2 (i.e. 27°, or 50 %), with isolated areas with natural grades up to 1 in 1 (i.e. 45° or 100 %) (MSEC 2021).

2.1.4 Upland swamps

There are two swamps (Den07 and Den153, Figure 3) that have been identified directly above the proposed longwalls. There are four additional swamps located wholly or partially within the study area based on the 35 degree angle of draw line and a further eight swamps located wholly or partially within the study area based on the 600 m boundary (Figure 3) (MSEC 2021).

The upland swamps can be categorised into two types, the valley infill swamps that form within the drainage lines, and headwater swamps that form within relatively low sloped areas of weathered Hawkesbury Sandstone where hillslope aquifers exist (MSEC 2021).

The term 'upland swamp' here refers to those that meet the NSW and Commonwealth final determination descriptions of Coastal Upland Swamps in the Sydney Basin Bioregion, which is listed as an Endangered Ecological Community (EEC) under the NSW BC Act and the Commonwealth EPBC Act.

2.2 Predicted mine subsidence for natural features

Subsidence predictions for Longwalls 22 and 23 within DA3C were investigated and reported by MSEC (2021). Subsidence impacts for natural features prone to subsidence impacts were examined including:

- Major creeks and associated drainage features;
- Upland swamps; and
- Cliffs, rock outcrops and steep slopes.

These natural features may provide important habitat for threatened species or constitute TECs and are the focus of this assessment. A summary of the predicted impacts that the proposal will have on these features is described below (Table 1), as documented in MSEC (2021).

Table 1: Predicted subsidence impacts to natural features and potential biodiversity impacts for Longwalls 22 and 23 (MSEC 2021; HGeo 2021)

Feature	Description of natural feature	Predicted subsidence or surface water impact	Previously observed impacts in other areas
Wongawilli Creek	Wongawilli Creek is a third order perennial stream with a small base flow and increased flows for short periods of time after each significant rain event. The creek generally flows in a northerly direction and drains into the Cordeaux River. Pools in the creek naturally develop behind the rockbars and at sediment and debris accumulations (MSEC 2021). Wongawilli Creek is located on the western side of the proposed longwalls. The thalweg (i.e. base or centreline) of the creek is 345 m and 320 m from the finishing ends of Longwalls 22 and 23, respectively, at its closest points. Further upstream, the creek is located between the completed longwalls in Areas 3A and 3B. The minimum distances between the thalweg of the creek and the completed longwalls are 110 m for Area 3A and 260 m for Area 3B (MSEC 2021).	While the creek could experience very low levels of vertical subsidence, it is not expected to experience measurable conventional tilts, curvatures or strains. Wongawilli Creek could experience compressive strains due to the valley closure movements (MSEC 2021). It is unlikely 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 Wongawilli 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 % (MSEC 2021). It is possible that fracturing could occur along Wongawilli Creek due to the valley-related compressive strains (MSEC 2021). The likelihood of fracturing resulting in surface water flow diversions along Wongawilli Creek, due to the extraction of the proposed Longwalls 22 and 23, is low, i.e. affecting approximately 6 % of rockbars located within the Study Area. However, minor fracturing could still occur elsewhere along the creek, at distances up to approximately 400 m from the proposed longwalls (MSEC 2021).	Fracturing has been observed up to approximately 400 m outside of previously extracted longwalls in the Southern Coalfield. Fracturing has been observed at distances up to 300 m from the completed longwalls in Area 3B (MSEC 2021). The extraction of Longwall 6 to Longwall 16 has resulted in one Type 3 impact along Wongawilli Creek. A Type 3 impact is defined as *fracturing in a rockbar or upstream pool resulting in a reduction in standing water level based on current rainfall and surface water flow* (MSEC 2021). Fracturing was first observed in the bed of Pool 43a after the completion of Longwall 9. This pool is located at distances of 200 m west of Longwall 6 in Area 3A and 410 m east of Longwall 9 in Area 3B. Pool water levels below baseline conditions were observed in this pool during low flow conditions (i.e. Type 3 impact) after the completion of Longwall 13. No other fractures have been observed along Wongawilli Creek due to the longwalls extracted in Areas 3A and 3B (MSEC 2021). The longwalls in Areas 3A and 3B were setback from Wongawilli Creek so that the predicted closure is less than 200 mm at the mapped rockbars. It was assessed that the likelihood of significant fracturing resulting in surface water flow diversions along Wongawilli Creek would be low, i.e. affecting less than 10 % of the pools and channels. It is considered that the observed rate of impact is low (i.e. one Type 3 impact along the 2 km length of Wongawilli Creek) (MSEC 2021).
Drainage Lines	There are unnamed drainage lines that are located directly above and adjacent to the proposed Longwalls 22 and 23. These drainage lines are first and second-order tributaries	The potential impacts of increased ponding and scouring of the drainage lines as a result of subsidence induced tilt are expected to be minor and localised. There is potential for a reduction in stream grade and increased ponding at	Impacts have been observed along the drainage lines above and adjacent to the previously extracted Longwall 9 to Longwall 16 in DA3B,

	to Lake Cordeaux in the eastern part of the Study Area and to Wongawilli Creek in the western part of the Study Area (MSEC 2021). The beds of the drainage lines 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 sand deposits or islands, loose rocks and tree branches (MSEC 2021). The natural gradients of the drainage lines vary between 20 mm/m (i.e. 2.0 %, or 1 in 50) and 500 mm/m (i.e. 50 %, or 1 in 2), with average natural gradients typically ranging between 50 mm/m (i.e. 5 %, or 1 in 20) and 200 mm/m (i.e. 20 %, or 1 in 5). The drainage lines have localised areas with natural grades greater than 500 mm/m where there are steps and cascades (MSEC 2021).	two locations along LC5, in the vicinity of Swamp Den07. The impacts resulting from the changes in surface water flows due to the mining-induced tilt are expected to be small in comparison with those which occur during natural flooding conditions (MSEC 2021). Fracturing of the bedrock is expected to occur along the sections of the drainage lines that are located directly above the proposed longwalls. Fracturing can also occur outside the extents of the proposed longwalls, with minor and isolated fracturing previously observed at distances up to approximately 400 m (MSEC 2021). 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-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 (MSEC 2021). Surface water flow diversions are likely to occur along the sections of drainage lines that are located directly above and adjacent to the proposed longwalls (MSEC 2021).	including change in water appearance (orange precipitate); fracturing upstream of pools, in rockbars and exposed bedrock; dilation, uplift and displacement of the bedrock; iron staining; soil cracking; surface water flow loss and 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 DA3B and assessed as potentially occurring up to 400 m from the mining area (MSEC 2021).
Cliffs	Cliffs are defined as ‘continuous rock face, including overhangs, having a minimum length of 20 metres, a minimum height of 10 metres and a minimum slope of 2 to 1 (>63.4º)’. A minor cliff is defined as ‘A continuous rock face, including overhangs, having a minimum length of 20 metres, heights between 5 metres and 10 metres and a minimum slope of 2 to 1 (>63.4º); or a rock face having a maximum length of 20 metres and a minimum height of 10 metres’ (MSEC 2021). There are four cliffs that have been identified within the Study Area based on the 35 degree angle of draw line. These cliffs are located along the valley sides of LC6, WC26 and their tributaries (MSEC 2021). The minor cliffs within the Study Area are located within the valleys of Lake Cordeaux, Wongawilli Creek and their tributaries. The lengths of each of the minor cliffs typically range between 20 m and 50 m and have heights up to 10 m (MSEC 2021).	The cliffs in the study area could be impacted due to the proposed mining directly beneath or adjacent to them. The potential impacts include fracturing in the exposed rockface and, if it is marginally stable, this could then result in cliff instabilities (MSEC 2021). It has been estimated that between 7 % and 10 % of the total length, or between 3 % and 5 % of the total face area of the cliffs located directly above or adjacent longwalls could be impacted. The actual impacts for the proposed longwalls could be greater or lesser than these ranges, as it is more difficult to predict the extents of impact due to the relatively short lengths of cliffs located above and adjacent to the proposed longwalls (MSEC 2021). It is unlikely that other cliffs located outside the Study Area based on the 35 degree angle of draw would experience adverse impacts due to their distances from the proposed longwalls. This is based on the extensive experience of mining near to but not directly beneath cliffs in the NSW coalfields, where no large cliff falls have	The cliffs that were located above the previously extracted longwalls in Area 1 are considered to be a relevant case study for previous impacts to cliffs in Dendrobium mining area. The longwalls were extracted directly beneath a ridgeline and rockfalls were observed in eight locations directly above the mining area. The length of ridgeline disturbed due to the extraction of Longwalls 1 and 2 is estimated to be between 7 % and 10 % of the total plan length of ridgeline directly above the longwalls. The length of rockfalls that occurred due to the extraction of Longwalls 1 and 2; however, is less than the length of the disturbed ridgeline (MSEC 2021).

		occurred when the cliffs are located completely outside the angle of draw from mining. It is still possible, but unlikely, that isolated rockfalls could occur due to mining, natural processes, or both (MSEC 2021).	
Rock outcrops/ steep slopes	Steep slopes are defined as an area of land having a gradient between 1 in 3 (33% or 18.3º) and 2 in 1 (200% or 63.4º)". The steep slopes within the Study Area have been identified within the valleys of Lake Cordeaux, Wongawilli Creek and their tributaries. The natural grades of the steep slopes typically vary up to approximately 1 in 2 (i.e. 27°, or 50 %), with isolated areas with natural grades up to 1 in 1 (i.e. 45° or 100 %) (MSEC 2021). Rock outcrops are defined as exposed rockfaces with heights of less than 10 m or slopes of less than 2 in 1. There are rock outcrops located across the Study Area, primarily within the valleys of Lake Cordeaux, Wongawilli Creek and their tributaries (MSEC 2021).	The downslope movement of the ground would be expected to occur along rock outcrops and steep slopes within the Study Area (MSEC 2021). The steep slopes are heavily vegetated and erosion due to soil instability (i.e. downslope movements) was not readily apparent from the site investigations undertaken. If tension cracks were to develop, due to the extraction of the proposed longwalls, it is possible that soil erosion could occur and require treatment (MSEC 2021).	Within DA1, cracks up to approximately 400 mm in width were observed along the top of the ridgeline, with other surface cracks, typically in the order of 100 mm to 150 mm in width, observed further down the ridgeline and the steep slopes (MSEC 2021).
Upland swamps	Two swamps (Den07 and Den153) occur directly above the proposed longwalls and within the groundwater impact zone (60 m buffer to the longwalls) (a total of 4.54 ha of swamp). There are four additional swamps (Den09, Den154, Den155 and Den156) located wholly or partially within the Study Area based on the 35 degree angle of draw line and a further eight swamps (Den06, Den16, Den140, Den141, Den144, Den145, Den152 and Den157) located wholly or partially within the Study Area based on the 600 m boundary (MSEC 2021). The upland swamps can be categorised into two types, the valley infill swamps that form within the drainage lines, and headwater swamps that form within relatively low sloped areas of weathered Hawkesbury Sandstone where hillslope aquifers exist (MSEC 2021).	It is unlikely that the swamps would experience adverse changes in the levels of ponding or scouring based on the predicted subsidence induced tilt (MSEC 2021). As swamps Den07 and Den153 occur directly above the proposed longwalls, fracturing is likely to occur in the bedrock and the dilated strata beneath the drainage lines and within these Swamps could result in the diversion of surface water flows beneath parts of these swamps. The drainage lines upstream of these swamps flow during and shortly after rainfall events. Where there is no connective fracturing to any deeper storage, it is likely that surface water flows will re-emerge at the limits of fracturing and dilation (MSEC 2021). The remaining swamps are located outside the mining area, at minimum distances ranging between 70 m and 540 m from the proposed longwalls. Fracturing has been observed in streams located outside the extents of previously extracted longwalls at distances of up to 290 m. Minor and isolated fracturing has also been observed up to 400 m outside of longwalls (MSEC 2021).	The mining of Longwall9 in DA3B, located directly above upland swamp Den05, resulted in multiple fractures and uplifting at its basal step. Reduction in groundwater levels were also noted (MSEC 2021). Impacts were observed to swamps due to the extraction of Longwalls 10 to 16. Groundwater levels were lower than baseline and recession rates greater than baseline for Swamps Den03, Den05, Den10, Den11, Den13, Den14 and Den23. Soil moisture levels below baseline were also reported in Swamps Den05, Den11, Den14 and Den23 (MSEC 2021). Longwall 4 and Longwall 5 in Area 2 were extracted directly beneath Swamp Den01, which contains both a headwater and valley infill swamp areas located along Drainage Line A2-14. Cracking was observed within the extent of the swamp in three locations and fracturing was observed in the downstream rockbar. Whilst reductions in groundwater levels in the soil were observed in the

		Swamp Den09 is located near the base of Stream LC5 and it is at a minimum distance of 90 m from the proposed longwalls. Fracturing could occur in the base of the valley and within this swamp. Fracture widths in the order of 20 mm to 50 mm have been observed due to valley-related effects at similar distances from previous longwall mining (MSEC 2021). Swamp Den157 is located near the base of Stream LC6 and it is at a minimum distance of 335 m from the proposed longwalls. It is possible, but unlikely, that fracturing could occur in the base of the valley and within this swamp. Fracture widths less than 20 mm have been observed due to valley-related effects at similar distances from previous longwall mining (MSEC 2021). The remaining swamps within the Study Area are either located on the valley sides or are more than 400 m outside the proposed mining area. It is unlikely therefore that fracturing would develop in the bedrock beneath these remaining swamps (MSEC 2021).	swamp and the upstream hillslope aquifer, the groundwater levels respond to significant recharge events. Based on the observations to date, there has been no erosion or other physical changes observed within Swamp Den01 resulting from the mining in Area 2 (MSEC 2021). Longwall 7 in DA3A was extracted directly beneath Swamp Den12, which is a headwater swamp located on the valley side of Drainage Line WC17. One fracture was identified in a rock outcrop after mining beneath this swamp. Piezometer data (one of four monitoring station) shows a reduction in groundwater levels (MSEC 2021).
Water quality and surface water	• Wongawilli Creek • Drainage lines	The incremental effect on stream flow along Wongawilli Creek due to extraction of Longwalls 22 and 23 would likely be in the range 0.025-0.09 and 0.043-0.15 ML/day respectively. The cumulative effect on flows due to the extraction of Longwall 6 to 23 is estimated to be approximately 0.6-2.2 ML/day along Wongawilli Creek with the effects peaking around 2031-2035, and declining thereafter. The cumulative effects are likely to increase the number of cease-to-flow days in the middle to lower reach of Wongawilli Creek (adjacent to Areas 3A, 3B and 3C), from 6% of the time to 17% on average, being most obvious during extended dry conditions in Wongawilli Creek. An increase in cease-to-flow frequency and reduction in flow is predicted, but considered unlikely based on monitoring data, which indicate mining effects are difficult to discern from natural variation (HGeo 2021). Loss of flow is also predicted in LC5, LC6 (tributaries to Lake Cordeaux) and WC26 and WC24 (tributaries to Wongawilli Creek), as well as very minor loss of baseflow at CR36 (tributary to Cordeaux River). The losses will be due to subsidence cracking and/or groundwater depressurisation or drawdown (HGeo 2021).	Effects on surface flow were evident at all headwater subcatchments that have been mined under (e.g. DC13, DCS2, WC21, WC15, LA4), with an increase in the frequency of cease-to-flow conditions and a reduction in long-term median flow (equivalent to reductions of 20-60% of median flow).

	• Water quality	Water quality impacts, including localised iron staining, may be observed in tributaries that cross the longwall footprints (WC24, WC26, LC5 and LC6), and possibly in LC7 which is entirely within 400 m of Longwall 22; however, those impacts are not expected to significantly influence water quality at downstream locations on Wongawilli Creek. Local discolouration of streambeds and rock faces by iron hydroxide precipitation can continue for a number of years (HGeo 2021).	Watercourses that have been directly mined under typically show one or more of the following water quality effects compared with baseline conditions (HGeo 2021): • A transient increase in electrical conductivity, evident at one or more monitoring sites, but not always detectable at downstream locations. • An increase in water pH from baseline mildly acidic conditions to near neutral conditions; or, more rarely, a decrease in water pH (e.g. Native Dog Creek associated with Elouera Mine). • Transient increases in dissolved Fe and Mn (+/- Zn and Al) at sampling locations immediately down-stream of the affected area. • Iron staining is typically localised to reaches overlying and immediately downstream of a longwall footprint. In the case of SC10C, iron staining increased in 2020 some 7 years after mining due to recovery of groundwater levels within fracture networks above extracted longwall. Water quality impacts have not been detected in watercourses that are not directly mined under (HGeo 2021). Local discolouration of streambeds and rock faces by iron hydroxide precipitation can continue for a number of years but is a temporary impact (HGeo 2021).
	Swamps	It is likely that shallow groundwater levels will be affected in Swamps Den07 and Den 153 which substantially overlap the longwall footprint. The remaining swamps are unlikely to be impacted, though minor and isolated fracturing could occur at distances up to 400 m outside the mining area (HGeo 2021). A review of piezometer data used for detection of impacts to swamps throughout the Dendrobium Area concluded that a reduction in the water table to below pre-mining levels and/or increased recession (drainage) rate is likely	Swamps that have been undermined commonly display hydrological changes shortly following the passage of the longwall beneath the monitoring site. Hydrographs of piezometers at affected locations may show one or more of the following (HGeo 2021): • a decrease in the average shallow groundwater elevation;

		to occur in swamps within 60 m of a longwall panel as a result of mining. Effects on swamp water tables have not been observed at distances greater than 60 m from a longwall panel (Watershed HydroGeo 2019).	• a decrease in the duration of saturation of the swamp sediments following a significant rainfall event; or • a change in the shape of saturation peak and recession curves (and recession rate) in response to significant rainfall events.

2.3 Approach

The approach to this assessment has been informed by previous ecological survey work and impact assessment for the study area and surrounds, field survey of the study area, current knowledge of subsidence impacts on the landscape, legislative guidelines and consultation.

While impact assessment for the entire DA3 study area has already been completed in the form of a SIS (Biosis 2007), the current assessment is required to ensure that the findings of the SIS remain relevant to Longwalls 22 and 23 within DA3C, given the following:

- Updates to schedules of relevant legislation concerning threatened species (which may confer a different conservation status for certain species or community).
- New information regarding predicted subsidence impacts, the accuracy of previous subsidence predictions and results from monitoring of impacts to ecological features and threatened species.

The SIS for DA3, which incorporated the current study area, was completed in 2007 (Biosis 2007). Some data gaps within the SIS have been identified in this study, and appropriate surveys completed to fill these gaps.

The target of the current survey and assessment has been to focus on the ecological values sensitive to the effects of subsidence, as identified in MSEC (2021) and Section 2.2.

3 Literature review

A significant body of work has been conducted within the DA3 study area for previous approvals for underground mining and to satisfy consent conditions in regard to monitoring. The main relevant documentation was reviewed as part of this SMP with details provided in preceding sections of this report.

In addition, relevant statutory reviews and policy guidelines have been reviewed (see section 3.8) including;

- Southern Coalfields Inquiry;
- Upland Swamps Environmental Assessment Guidelines (Draft); and
- Independent Expert Panel for Mining in the Catchment Report: Part 2. Coal Mining Impacts in the Special Areas of the Greater Sydney Water Catchment.

3.1 Previous surveys and ongoing monitoring

The DA3 study area has been included within ecological assessments commissioned by IMC for over 15 years which have been used to support development applications and exploration activities within the area. The results of select key relevant assessments have been referred to or summarised in this report (see sections 3.2 to 3.6 below). Threatened species previously recorded in previous assessments have generally been supplied to BCD (and its predecessors) for inclusion in the Bionet Atlas of NSW Wildlife threatened species database which has been consulted for this assessment. Relevant assessments conducted within the Dendrobium Area include:

- *Dendrobium Coal Project SIS* (Biosis 2001a) and the SIS completed for the 2008 modification (Biosis 2007);
- *Dendrobium Coal Project: Terrestrial and Aquatic Habitat Assessment* (Biosis 2001b);
- *Dendrobium Coal Project: Likely Impacts of Subsidence on Terrestrial Ecology* (Biosis 2001c);
- Terrestrial Flora and Fauna Habitat Assessments accompanying coal exploration activities within DA3B (various companies approximately 1996 – 2011);
- *Dendrobium Coal Mine and Elouera Colliery Flora and Fauna Environmental Management Program, Annual Monitoring Report – Spring 2003 to Winter 2006* (Biosis 2007a);
- *DA2 Longwalls 3-5a Impacts of Subsidence on Terrestrial Flora and Fauna* (Biosis 2007b);
- *DA3B: Terrestrial Ecological Assessment* (Niche 2012);
- *DA3C: Terrestrial Ecological Assessment* (Niche 2019b);
- *DA3A Terrestrial Ecology Assessment* (Niche 2020b);
- *DA3B Longwall 18 Terrestrial Ecological Assessment* (Niche 2020a);
- Monitoring as part of previous SMPs for longwalls within areas 3A and 3B, including annual and end of panel reporting;
- *Geographic review of mining effects on Upland Swamps at Dendrobium Mine* (Watershed HydroGeo 2019); and

- *Dendrobium Next Domain - Biodiversity Assessment Report and Biodiversity Offset Strategy* (Niche 2019a).

Long-term monitoring of vegetation and fauna populations has been undertaken in Dendrobium Areas 1, 2 and 3, which began in 2003. Ecological monitoring has targeted both flora and fauna, and has involved vegetation quadrats and transects, and bird, frog and reptile surveys. Five years of data and records from the monitoring locations were utilised in the SIS (Biosis 2007). A review of the findings of the long-term monitoring is provided in Section 3.7.

3.2 Dendrobium Area 3 Species Impact Statement

Biosis prepared a SIS in 2007 (Biosis 2007), to support the application to modify the Dendrobium Mine Consent (DA-60-03-2001) to incorporate a revised DA3 footprint and longwall layout. The SIS involved an extensive survey and impact assessment of Areas 3A, 3B and 3C.

To assess the impacts of mining in DA3, the maximum subsidence parameters determined from MSEC for DA3A were extrapolated to the entire Dendrobium Area 3 footprint (Biosis 2007).

As such, the consent required that once the mine plans for these areas were finalised any impacts in areas DA3B and DA3C greater than those specified in the SIS, would require a review of the SIS outcomes. The SIS therefore provides the basis against which the proposal should be assessed.

A comparison of the relevant DA3 subsidence parameters used in the SIS (Biosis 2007), against the current MSEC (2021) report is provided below in Table 2. Both MSEC reports concluded similar potential subsidence impacts. The impact assessments for threatened species in the SIS are similar to those within this report.

Table 2: Subsidence predictions from the Area 3 SIS (Biosis 2007) compared to MSEC (2021) report for current study area

Subsidence Parameters	Dendrobium Area 3 SIS (Biosis 2007)	MSEC (2021) report for DA3C Longwalls 22 and 23
Wongawilli Creek	Longwalls set back from Wongawilli Creek. Wongawilli Creek is unlikely to incur any significant impacts as a result of the extraction of the proposed longwalls. Some minor fracturing could occur. Localised ponding changes may occur due to subsidence induced tilt.	Longwalls set back from Wongawilli Creek. The creek could experience very low levels of vertical subsidence, however is not expected to experience measurable conventional tilts, curvatures or strains. Wongawilli Creek could experience compressive strains due to the valley closure movements (MSEC 2021). It is unlikely 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 that fracturing could occur along Wongawilli Creek due to the valley-related compressive strains (MSEC 2021). The likelihood of fracturing resulting in surface water flow diversions along Wongawilli Creek, due to the extraction of the proposed longwalls, is low. However, minor fracturing could still occur elsewhere along the creek, at distances up to approximately 400 m from the proposed longwalls (MSEC 2021).
Drainage lines	No specific predictions for the drainage lines in the study area in the SIS.	The potential impacts of increased ponding and scouring of the drainage lines due to mining induced tilt are expected to be minor and localised. The impacts resulting from the changes in surface water flows due to the mining-induced tilt are expected to be small in comparison with those which occur during natural flooding conditions (MSEC 2021). Fracturing of the bedrock is expected to occur along the sections of the drainage lines that are located directly above the longwalls. Fracturing can also occur outside the extents of the proposed longwalls, with fracturing previously observed at distances up to approximately 400 m (MSEC 2021). The mining-induced compression due to valley closure effects can also result in dilation and the development of bed separation in the top 10 m to 20 m of the bedrock, as it is less confined. Compression can also result in buckling of the topmost bedrock resulting in heaving in the overlying surface soils (MSEC 2021). Surface water flow diversions are likely to occur along the sections of drainage lines that are located directly above and adjacent to the proposed longwalls (MSEC 2021).
Cliffs	Predicted to be some impact to between 7% and 10% of the cliff lines that will be directly mined beneath. Cliff lines that will not be directly mined beneath are unlikely to exhibit any significant impacts.	Between 7 % and 10 % of the total length, or between 3 % and 5 % of the total face area of the cliffs located directly above or adjacent to longwalls would be impacted by fracturing in the exposed rockface and, if it is marginally stable, this could then result in cliff instabilities (MSEC 2021). It is unlikely that other cliffs located outside the Study Area based on the 35 degree angle of draw would experience adverse impacts due to their distances from the proposed longwalls. It is still possible, but unlikely, that isolated rockfalls could occur due to mining, natural processes, or both (MSEC 2021).

Subsidence Parameters	Dendrobium Area 3 SIS (Biosis 2007)	MSEC (2021) report for DA3C Longwalls 22 and 23
Rock outcrops	Percentage of rock outcrops that are likely to be impacted by mining is small – much less than 7% to 10% of the total length of rock outcrops directly mined beneath.	Downslope movement of the ground would be expected to occur along rock outcrops within the Study Area (MSEC 2021).
Steep slopes	DA3 steep slopes are expected to result in cracking of the surface soils and possible downhill movements, similar to Dendrobium Areas 1 and 2. The greatest surface cracking and downhill movements are expected to occur along the steep slopes directly mined beneath and adjacent to ridgelines.	Downslope movement of the ground would be expected to occur along steep slopes within the Study Area (MSEC 2021). The steep slopes are heavily vegetated and erosion due to soil instability (i.e. downslope movements) was not readily apparent from the site investigations undertaken. If tension cracks were to develop, due to the extraction of the proposed longwalls, it is possible that soil erosion could occur and require treatment (MSEC 2021).
Upland Swamps	Swamps directly mined beneath are expected to experience the full range of predicted subsidence and valley related movements. It is unlikely that mine subsidence induced scour effects would affect the swamps in Area 3. It is possible that the changes in water level within the swamps could impact on the distribution of local vegetation within the swamps. The surfaces of the swamps are free draining, and it is not anticipated that significant changes in water levels would occur as a result of subsidence induced tilt.	It is unlikely that the swamps would experience adverse changes in the levels of ponding or scouring based on the predicted subsidence induced tilt (MSEC 2021). As swamps Den07 and Den153 occur directly above the proposed longwalls, the dilated strata beneath the drainage lines and within these Swamps could result in the diversion of surface water flows beneath parts of these swamps. The drainage lines upstream of these swamps flow during and shortly after rainfall events. Where there is no connective fracturing to any deeper storage, it is likely that surface water flows will re-emerge at the limits of fracturing and dilation (MSEC 2021). The remaining swamps are located outside the mining area, at minimum distances ranging between 70 m and 540 m from the proposed longwalls. Fracturing has been observed in streams located outside the extents of previously extracted longwalls at distances of up to 290 m. Minor and isolated fracturing has also been observed up to 400 m outside of longwalls (MSEC 2021). Swamp Den09 is located near the base of LC5 and it is at a minimum distance of 90 m from the proposed longwalls. Fracturing could occur in the base of the valley and within Swamp Den09 (located near the base of LC5 and at a minimum distance of 90 m from the proposed longwalls) (MSEC 2021). It is possible, but unlikely, that fracturing could occur in the base of the valley and within Swamp Den157 (located near the base of LC6 and at a minimum distance of 335 m from the proposed longwalls) (MSEC 2021).

Subsidence Parameters	Dendrobium Area 3 SIS (Biosis 2007)	MSEC (2021) report for DA3C Longwalls 22 and 23
		The remaining swamps within the Study Area are either located on the valley sides or are more than 400 m outside the proposed mining area. It is unlikely therefore that fracturing would develop in the bedrock beneath these remaining swamps (MSEC 2021).

The results of the SIS in regard to ecological impacts, specifically threatened species, included the following:

- Fourteen threatened flora species were considered in the SIS. Two threatened flora species, *Acacia bynoeana* and *Pultenaea aristata* were recorded within DA3. A further nine species were regarded as having potential habitat. Seven-part tests under the *Threatened Species Conservation Act 1995* (TSC Act) (equivalent to the current five-part test under the *Biodiversity Conservation Act 2016* [BC Act]) concluded that the proposed longwall mining activities in Area 3 were unlikely to have a significant impact on any threatened flora within the study area.
- Sixty-three threatened fauna were considered in the SIS. Sixteen species were recorded in the DA3 study area including:
    - Littlejohn's Tree Frog (*Litoria Littlejohni*);
    - Giant burrowing Frog (*Heleioporus australiacus*);
    - Red-crowned Toadlet (*Pseudophryne australis*);
    - Gang-gang cockatoo (*Callocephalon fimbriatum*);
    - Glossy black cockatoo (*Calyptorhynchus lathami*);
    - Olive Whistler (*Pachycephala olivacea*);
    - Barking Owl (*Ninox connivens*);
    - Powerful Owl (*Ninox strenua*);
    - Eastern Pygmy-possum (*Cercartetus nanus*);
    - Eastern Freetail Bat (*Mormopterus norfolkensis*);
    - Koala (*Phascolarctos cinereus*);
    - Grey-headed Flying-fox (*Pteropus poliocephalus*);
    - Large Bent-winged Bat (*Miniopterus orianae oceanensis*);
    - Large-eared Pied Bat (*Chalinolobus dwyeri*);
    - Southern Myotis (*Myotis macropus*); and
    - Rosenberg's Goanna (*Varanus rosenbergi*).
- Seven-part tests concluded that the DA3 mining operations would likely cause a significant impact to local populations of Littlejohn's Tree Frog, Giant Burrowing Frog, Red-crowned Toadlet, Stuttering Frog (*Mixophyes balbus*) and Giant Dragonfly (*Petalura gigantea*). The possible mechanisms of subsidence and physical effects of subsidence were determined to have a direct impact on known and potential habitat for these threatened fauna, which included waterways, upland swamps, riparian vegetation, ridge lines and rock overhangs.
- One EEC: Shale Sandstone Transition Forest, which was listed on the TSC Act (now the BC Act) and EPBC Act was recorded within the study area, however, was considered unlikely to be significantly impacted by the Area 3 mining operations. Shale Sandstone Transition Forest (SSTF) is now listed as a Critically Endangered Ecological Community (CEEC).

It is noted that upland swamps within the study area were not a listed TEC at the time of the SIS under either the TSC Act (gazetted in 2012) or EPBC Act (gazetted in 2014). The community has since been added to the relevant schedules as an EEC under the TSC/BC Act and EPBC Act.

The survey effort and outcomes of the SIS have been summarised in Section 4.1.

3.3 Dendrobium Area 3C: Longwalls 20-21 Terrestrial Ecological Assessment

Niche was commissioned by IMC to prepare a Terrestrial Ecological Assessment for proposed Longwalls 20 and 21 within DA3C (DA3C) (Niche 2019a).

The assessment involved flora and fauna survey within DA3C which focused on landscape features and threatened species sensitive to the impacts of subsidence from extraction of proposed Longwalls 20 and 21. Natural areas sensitive to subsidence within the DA3C study area included: Wongawilli Creek, Donalds Castle Creek, drainage lines, cliffs, rock outcrops, steep slopes, and upland swamps.

Four threatened plant species (*Epacris purpurascens* var. *purpurascens, Pultenaea aristata, Cryptostylis hunteriana* and *Leucopogon exolasius*) were considered to have habitat in the study area for Longwalls 20 and 21. Impacts on these species were assessed within the Area 3 mining operation's SIS (Biosis 2007) and were considered likely to be minimal as a result of DA3C.

Nine threatened fauna species were considered to be potentially impacted by subsidence impacts resulting from the proposed Longwalls 20 and 21 comprising:

- Frogs: Littlejohn's Tree Frog, Giant Burrowing Frog, Red-crowned Toadlet;
- Reptiles: Broad-headed Snake, Rosenberg's Goanna;
- Mammals: Large Bent-winged Bat, Little Bentwing Bat, Southern Myotis; and
- Invertebrates: Giant Dragonfly.

The findings of the SIS were determined to be accurate in relation to Longwalls 20 and 21 impact on local populations of the three frog species and the Giant Dragonfly. Subsidence impacts were determined as likely for known and potential habitat for these species, as they are reliant upon drainage lines, upland swamps, ridgelines and rock outcrops. The same conclusion was reached in the SIS impact assessments for these species, however the Stuttering Frog was considered to be significantly impacted within the initial SIS whereas it was considered unlikely to occur within the DA3C Terrestrial Ecological Assessment.

Ten upland swamps were recorded within the Longwalls 20 and 21 study area within DA3C. The upland swamps in the study area fit the description of Coastal Upland Swamps in the Sydney Basin Bioregion, which has been listed as an EEC under the TSC/BC Act and EPBC Act since the 2007 SIS.

A number of recommendations were proposed in relation to terrestrial ecological values, and included the following:

- On-going monitoring which is currently being undertaken within DA3 should continue. Monitoring of impacts due to Longwalls 20 and 21 to follow pre-existing methodology. Monitoring to continue targeted surveys for Littlejohn's Tree Frog and Red-crowned Toadlet. Upland swamp monitoring transects should continue. If monitoring reveals impacts greater than predicted or authorised by the approval, modifications to the project and mitigation measures should be considered to minimise impacts.
- Visual comparison of photo point monitoring undertaken at each upland swamp site should also continue from marked monitoring points.
- Mapping of microhabitats such as pools along streams, as currently performed by IMC for DA3B, should be extended to DA3C prior to baseline frog surveys.

- All remediation works should include appropriate measures to minimise environmental impacts. This includes avoiding the spread of Chytrid Fungus following the NPWS guidelines (Department of Environment and Climate Change [DECC] 2008).
- The implementation of any mitigation measures should include monitoring to confirm the success of any implemented measures.
- Surface cracking within woodland or forested areas where significant fauna entrapment is likely should be mitigated in order to minimise fauna entrapment.

3.4 Dendrobium Area 3B: Longwalls 9 to 18 Terrestrial Ecology Assessment

Niche was commissioned by IMC in 2011 to prepare a Terrestrial Ecological Assessment for Dendrobium Area 3B (DA3B) (Niche 2012).

The assessment involved a flora and fauna survey within DA3B which focused on landscape features sensitive to the impacts of subsidence from extraction of proposed Longwalls 9 to 18. Natural areas sensitive to subsidence within the DA3B study area included: Wongawilli Creek, Donalds Castle Creek, drainage lines, cliffs, rock outcrops, steep slopes, and upland swamps.

A population of the threatened flora species, *Pultenaea aristata,* was recorded in an upland swamp in the DA3B study area. The population estimate was greater than a thousand individuals. The SIS also identified a population of *Acacia bynoeana* consisting of approximately 30 individuals within the DA3B study area.

Four threatened plant species (*Epacris purpurascens* var. *purpurascens, Pultenaea aristata, Cryptostylis hunteriana* and *Leucopogon exolasius*) were considered to have habitat in the study area that may be potentially impacted by subsidence. Seven-Part Tests were carried out for each of these species which concluded that a significant impact was unlikely. The same conclusion was reached in the 2007 SIS (Biosis 2007).

Threatened fauna recorded during the DA3B survey included Red-crowned Toadlet, Littlejohn's Tree Frog, Gang-gang Cockatoo, and Grey-headed Flying Fox. Fauna impact assessments were conducted for 31 threatened fauna, including:

- Amphibians: Littlejohn's Tree Frog, Giant Burrowing Frog and Red-crowned Toadlet;
- Birds: Barking Owl, Black Bittern (*Ixobrychus flavicollis*), Eastern Bristle Bird (*Dasyornis brachypterus*), Eastern Ground Parrot (*Pezoporus wallicus wallicus*), Grass Owl (*Tyto longimembris*), Gang-gang Cockatoo, Glossy Black Cockatoo, Masked Owl (*Tyto novaehollandiae*), Sooty Owl (*Tyto tenebricosa*), and Powerful Owl;
- Mammals: Brush-tailed Rock Wallaby (*Petrogale penicillata*), Eastern Pygmy Possum, Long nosed Potoroo (*Potorous tridactylus tridactylus*), Southern Brown Bandicoot (*Isoodon obesulus*), Spotted tail Quoll (*Dasyurus maculatus*), Squirrel Glider (*Petaurus norfolcensis*), Large Bent-winged Bat, Little Bentwing-bat (*Miniopterus australis*), Large-eared Pied Bat, Eastern Cave Bat (*Vespadelus troughtoni*), Eastern False Pipistrelle (*Falsistrellus tasmaniensis*), Golden-tipped Bat (*Kerivoula papuensis*), Southern Myotis, Greater Broad-nosed Bat (*Scoteanax rueppellii*) and Yellow-bellied Sheathtail-bat (*Saccolaimus flaviventris*);
- Reptiles: Broad-headed Snake (*Hoplocephalus bungaroides*) and Rosenberg's Goanna; and
- Giant Dragonfly.

Seven-Part Tests concluded that the proposed Longwalls 9 to 18 were likely to have a significant impact on local populations of Littlejohn's Tree Frog, Giant Burrowing Frog, Red-crowned Toadlet and Giant Dragonfly. Subsidence impacts were determined as likely for known and potential habitat for these species, as they are reliant upon Donalds Castle Creek and drainage lines, upland swamps, ridgelines and rock outcrops. The same conclusion was reached in the SIS impact assessments for these species, however the Stuttering Frog was considered to be significantly impacted within the initial SIS whereas it was considered unlikely to occur within the DA3B Terrestrial Ecological Assessment.

SSTF which was listed as a CEEC under the EPBC Act and TSC Act (repealed and replaced by the BC Act), occurs within the DA3B study area. Mining in DA3B was considered unlikely to result in any physical landscape changes which may impact this community. The assessment concluded that SSTF is unlikely to be significantly impacted by the mining Longwalls 9 to 18.

Thirteen large upland swamps were recorded within the DA3B study area. The upland swamps in the study area fit the description of Coastal Upland Swamps in the Sydney Basin Bioregion, which has been listed as an EEC under the BC Act and EPBC Act since the 2007 SIS. The potential for DA3B to impact upland swamps was considered to be low. A Seven-Part Test for Coastal Upland Swamps in the Sydney Basin Bioregion was conducted and concluded that a significant impact on this community was unlikely, primarily due to the proportion of swamps likely to be impacted compared with swamps within the locality and the severity of impacts predicted.

A number of recommendations were proposed in relation to terrestrial ecological values, and included the following:

- On-going monitoring which is currently being undertaken within DA3 should continue. Monitoring of DA3B to follow pre-existing methodology. Monitoring to continue targeted surveys for Littlejohn's Tree Frog, Red-crowned Toadlet and Giant Dragonfly. Upland swamp monitoring transects should continue. Transect and photo point monitoring to be included within upland Swamp 35A as this swamp contains a population of *Pultenaea aristata*. In the event that monitoring reveals impacts greater than predicted or authorised by the approval, modifications to the project and mitigation measures should be considered to minimise impacts.
- The implementation of any mitigation measures should include monitoring to confirm the success of any implemented measures.
- All remediation works should include appropriate measures to minimise environmental impacts. This includes avoiding the spread of Chytrid Fungus following the NPWS guidelines (DECC 2008).
- Surface cracking within woodland or forested areas where significant fauna entrapment is likely should be mitigated in order to minimise fauna entrapment.

It is noted that the *P.aristata* population referred to in the DA3B terrestrial ecology report were referenced from the project SIS, however no records of the species have been found to occur at Swamp Den35a within the Atlas of NSW Wildlife, mapping of literature reviewed or during recent field survey. Additionally, the reference states that the population occurs directly above Longwall 17. The reference is therefore considered to be incorrect. The closest known population of *P. aristata* is on the edge of Swamp Den149, which coincides with quadrat locations from the 2007 SIS and is above Longwall 17. Recommendations for monitoring of *P. aristata* have therefore been updated to reflect the actual location of the records.

3.5 Dendrobium Area 3A: Longwall 19 Terrestrial Ecological Assessment

Niche was commissioned by IMC in 2019 to prepare a Terrestrial Ecological Assessment for the extraction of Longwall 19 within DA3A (Niche 2020b).

Natural areas and features sensitive to subsidence within the DA3A study area include Wongawilli Creek, watercourses, cliffs, rock outcrops, steep slopes and upland swamps.

Nine upland swamps occur within the wider study area with complexity of swamps generally increasing with overall size. Based on previous subsidence monitoring, a maximum impact area for swamps was calculated at 18.12 hectares constituting the upland swamps within or along the 35 degree angle of draw study area.

Habitats such as pools, primarily located on Wongawilli Creek of which 1.4 km crosses the 600 m study area for Longwall 19, are likely to experience some level of subsidence impacts (comprising both direct and indirect impacts). Subsidence impacts to features such as cliffs, overhangs and rocky outcrops have the potential to occur but are likely to have limited impacts on threatened biodiversity within the study area due to the small area of predicted impacts.

Four threatened plant species (*Epacris purpurascens var. purpurascens, Pultenaea aristata, Cryptostylis hunteriana* and *Leucopogon exolasius)* were deemed to have habitat in the study area that may be potentially impacted by subsidence, however impacts for these species are likely to be minimal.

Nine threatened fauna species are considered to be potentially impacted by subsidence impacts resulting from the proposal comprising:

- Frogs: Littlejohn's Tree Frog, Giant Burrowing Frog, Red-crowned Toadlet;
- Reptiles: Broad-headed Snake, Rosenberg's Goanna;
- Mammals: Large Bent-winged Bat, Little Bentwing Bat, Southern Myotis; and
- Invertebrates: Giant Dragonfly.

From the above species, it is considered that potentially significant impacts could occur for the three frog species and the Giant Dragonfly. The same conclusion was reached in the DA3 SIS impact assessments for these species.

Recommendations are focussed around swamp and frog monitoring along watercourses in concert with established programs for measuring physical impacts of subsidence.

3.6 Dendrobium Area 3B Longwall 18 Terrestrial Ecological Assessment

Niche was commissioned by IMC to prepare a terrestrial ecological assessment for the extraction of Longwall 18 within DA3B (Niche 2020a).

Natural areas and features sensitive to subsidence within the study area included watercourses, cliffs, rock outcrops, steep slopes and upland swamps.

Six upland swamps occur within the wider study area with complexity of swamps generally increasing with overall size. One complex larger swamp (Den14) partially occurs within the predicted area of subsidence impacts (35 degree angle of draw study area). Based on previous subsidence monitoring, a maximum impact area for swamps was calculated at 3.94 hectares constituting the upland swamps or portion of swamp within or up to the 35 degree angle of draw study area.

Habitats such as pools which are potential breeding or nursery habitat for threatened frogs are likely to experience some level of subsidence impacts (comprising both direct and indirect impacts). Subsidence impacts to features such as cliffs, overhangs and rocky outcrops have the potential to occur but are likely to have limited impacts on threatened biodiversity within the study area due to the small area of predicted impacts.

One threatened plant species was recorded within upland swamps of the study area: *Pultenaea aristata.* Three additional threatened plant species (*Epacris purpurascens var. purpurascens, Cryptostylis hunteriana* and *Leucopogon exolasius)* were deemed to have habitat in the study area that may be potentially impacted by subsidence. However, impacts for these species are likely to be minimal.

Nine threatened fauna species are considered to be potentially impacted by subsidence impacts resulting from the proposal comprising:

- Frogs: Littlejohn's Tree Frog, Giant Burrowing Frog, Red-crowned Toadlet.
- Reptiles: Broad-headed Snake, Rosenberg's Goanna.
- Mammals: Eastern Bentwing Bat, Little Bentwing Bat, Southern Myotis.
- Invertebrates: Giant Dragonfly.

From the above species, it is considered that significant cumulative impacts (due to mining of Longwall 18 and other longwalls within area DA3B) could occur for the three frog species and the Giant Dragonfly.

Ongoing monitoring requirements for biodiversity are provided within the recommendations section of the report. Recommendations are focussed around swamp and frog monitoring along watercourses in concert with established programs for measuring physical impacts of subsidence.

3.7 Dendrobium Terrestrial Ecology Monitoring Program

Annual reporting (Biosis 2016, Biosis 2017, Biosis 2018, Biosis 2019, Biosis 2020, Niche 2021) documents the ecological monitoring program undertaken within DA2, DA3A and DA3B since 2003. Subsidence related impacts following mining in these areas include lowering of shallow groundwater in upland swamps and loss or alteration in the quality of pool water for first and second order streams.

The following ecological features are monitored as part of the terrestrial ecology program (Biosis 2020):

- Vegetation within upland swamps in DA2, DA3A and DA3B; and
- Littlejohn's Tree Frog *Litoria littlejohni* along selected streams providing suitable habitat in Area 3A and Area 3B.

LIDAR mapping of the upland swamp extents is also undertaken as part of the monitoring program. This detailed mapping of the upland swamp boundaries was used in the current assessment.

The following summarises the findings of the most recent Dendrobium monitoring (Niche 2021):

- Visual trends of drying (or areas of die-back) were observed at Impact swamps that have been directly mined beneath. The drying of the Impact Upland Swamps over time since impact may be exacerbated by the effect of the recent drought, though the correlation between impact of mining and drying of the Impact Upland Swamps is evidenced by the significant difference between Control and Impact Upland Swamps over this drought period.
- Cumulative impacts have been observed at a number of Impact Upland Swamps, which show stronger trends of significant decline in Total Species Richness (TSR) over time and significant changes to composition, with 'wetter' species becoming less common post impact, suggesting a loss of species that prefer moist soils. Some swamps show species dying out over time, with limited recruitment of new species, suggestive of dieback.
- It is likely that mining is having an impact on frog reproduction due to decreased tadpole survivorship and a reduction in the extent of preferred habitats.
- The 2020 analysis of impacts to Upland Swamps and Creeks found that an ecological response had been detected at several Impact sites within DA3A and DA3B where decline in ecological values has been observed.
- Long term declines have been identified through this monitoring program and potential resilience may be observed after a healthy 2020 rainfall season, the Upland Swamps and Creeks may respond and retain the necessary water to sustain the vegetation and Littlejohn Tree Frog breeding cycles.

The monitoring program will continue to achieve the following key objectives:

- Ongoing monitoring of Upland Swamps and amphibians within DA3A and DA3B.
- Determine if mining results in changes to the Upland Swamps or LJTF populations of the Dendrobium mining area through comparison of baseline and control data with that collected through ongoing monitoring.

3.8 Geographic review of mining effects on Upland Swamps at Dendrobium Mine

A review of piezometer data used for detection of impacts to swamps throughout the Dendrobium Area has been conducted (Watershed HydroGeo 2019) which concluded: "*Based on assessments of water levels and recession rates around past mining in Areas 2, 3A and 3B, hydrographs from swamp piezometers within 60 m are likely to exhibit a mining effect and almost certain to exhibit a mining effect when directly mined under, be that through a reduction in the water table to below pre-mining levels and/or increased recession (drainage) rate. Effects on swamp water tables have not been observed at distances greater than 60 m from a longwall panel*'.

When considering piezometers that are lithologically similar, but lying outside of mapped swamp communities, impacts have been observed at 95 and 125 m in two piezometers in DA3B. Some piezometers within that distance (125 m) have recorded no mining effects."

The above findings are important with regard to assessing the likely extent of impacts to swamp communities.

3.9 Relevant reviews considered in this report

The following reviews have been considered in the current study:

- Impacts of Underground Coal Mining on Natural Features in the Southern Coalfield (Southern Coalfield Inquiry) (DOP 2008);
- The Draft Upland Swamp Environmental Assessment Guidelines, Guidance for the Underground Mining Industry Operating in the Southern and Western Coalfields (DECCW 2011); and
- Independent Expert Panel for Mining in the Catchment Report: Part 2. Coal Mining Impacts in the Special Areas of the Greater Sydney Water Catchment (IEPMC 2019).

Key findings of the above reviews (as relevant to this assessment) are shown in Table 3.

Table 3: Key findings of relevant reviews

Southern Coalfield Inquiry
Environmental assessments should include a minimum of 2 years of baseline data, collected at an appropriate frequency and scale provided for significant natural features.
Development of improved regional and cumulative data sets for the natural features of the Southern Coalfield.
Before After Control Impact (BACI) study is considered the most appropriate design for many impact studies. Appropriate replication in both impact (directly above the mine) and control (outside direct impact zone) sites is required in monitoring programs so natural variability can be determined.
Environmental assessments should include identification and assessment of significance for all natural features located within 600 m of the edge of secondary extraction.
Risk Management Zones should be identified for all significant natural features, which are sensitive to valley closure and upsidence, including rivers, significant streams (3rd order or above in the Strahler stream classification), significant cliff lines, significant overhangs and valley infill swamps.
Approved mining within identified Risk Management Zones (and particularly in proximity to highly significant natural features) should be subject to increased monitoring and assessment requirements which address subsidence effects, subsidence impacts and environmental consequences.
The requirements should also address reporting procedures for back analysis and comparison of actual versus predicted effects and impacts, in order to review the accuracy and confidence levels of the prediction techniques used.
Upland Swamps Environmental Assessment Guidelines (Draft)
All underground mining proposals and operations that have the potential to impact on Upland Swamps demonstrate how they have applied the Upland Swamp Environmental Assessment Guideline.
Impacts to swamps of 'special significance status' are avoided.
Impacts on Upland Swamps (not of special significance status) are minimised as far as possible.
Monitoring undertaken by the underground mining industry to understand subsidence effects, impacts and environmental consequences is greatly improved.
Adaptive management should be implemented to provide a systematic process for continually detecting impacts, validating predictions and improving mining operations to prevent further impacts. Active adaptive management usually involves a comparison of management options and a conscious investment in learning by experimentation.
Effective and rigorous monitoring, evaluation, and reporting on management performance and ecological and hydrological impacts are required to inform the adaptive management process and should be integrated into core management systems in a consistent way across industry.
Management measures are to include contingency plans that allow for any unforeseen circumstances, particularly given the uncertainty inherent in the assessment of subsidence impacts, such as non-systematic subsidence (valley closure and upsidence).
Prior to underground mining proponents preparing an environmental assessment there is a need to gather baseline data. Initial steps in the collection of baseline data on Upland Swamps may include desktop studies to identify the location of the

Upland Swamps (e.g. through vegetation mapping) and the identification of key threatening processes and Upland Swamps listed under national and state legislation.
Independent Expert Panel for Mining in the Catchment Report: Part 2. Coal Mining Impacts in the Special Areas of the Greater Sydney Water Catchment (IEPMC 2019)
Longwall mining directly under swamps in the Southern Coalfield can result in significant changes to swamp hydrology and redirection of surface runoff, which the Panel considers are very likely irreversible.
Despite decades of monitoring, mining-induced changes to upland swamp vegetation communities are still not able to be clearly differentiated from natural changes. Vegetation change assessment to date does not provide a clear and timely measure of possible changes in ecosystem functionality of the upland swamps. This means that it has been of limited value as a performance indicator. This may be resolved in part by changes in methodology. Quantitative monitoring data should be supplemented by an overview of the whole swamp and assessment of changes in biomass. Use of targeted obligate swamp-dependent species (either plants or animals) may be a more reliable and timely indicator of ecological consequences than measures such as total species richness of vegetation. However, the decadal nature of many changes still remains a barrier to distinguishing between mining induced variations and natural variations.
Existing TARPs define ecosystem functionality predominantly by consequences (vegetation change and erosion) that may take years or decades to be measurable and clearly separable from natural variation. Swamps are groundwater-dependent ecosystems. Therefore, a change in piezometric levels should be the primary gauge of impacts on the ecosystem. If maintenance of ecosystem functionality is to be mandated for any swamp, then piezometric variation must be used not only in TARPs but also in performance measures.
Future swamp monitoring and modelling programs should be designed to: • Provide a hydrological balance for representative swamps, sufficient to identify any mining-induced changes in soil moisture and in baseflow down the exit stream; and to provide vertical leakage rates as inputs to groundwater models, in order to quantify how much of the leakage is diverted back into the catchment or elsewhere. • Link any changes in swamp vegetation to changes in water table position, soil moisture content and soil organic carbon content. • Identify the presence of and any changes in obligate swamp fauna such as the Giant Dragonfly (*Petalura gigantea*).
Annual performance reports, end-of-panel reports and reports on studies required by development consent conditions, should: • integrate hydrological and ecological impact and consequence assessments; • include discussion of the inter-related changes in hydrological and ecological consequences for swamps, rather than having only discrete chapters on each; • include results for the entire period of monitoring, rather than just the previous year, that should be assessed, not only for the current mining area but for previous mining domains.
Remediation should not be relied upon for features, including watercourses and swamps, that are highly significant or of special significance (as per the guidance provided by the Planning Assessment Commission Panels for the Metropolitan Coal Project and the Bulli Seam Operations Project).
Consent conditions for Dendrobium Mine issued in 2008 in relation to offsetting impacts on swamps do not appear to have foreseen the scale of impacts occurring today but have been subsequently addressed by a Strategic Biodiversity Offset approved in 2016.
There is very limited, if any, scope for remediating fracture networks beneath swamps. Therefore, in circumstances where it is difficult, if not impossible, to design a viable mining layout that avoids impacting swamps and mining is to proceed, there is little option other than to consider offsets as compensation for the consequences of negative environmental impacts on swamps.
All future mine approvals in the Special Areas should include performance measures related to measured changes in groundwater pressure and/or pressure gradients where these have the potential to impact on surface water diversions or losses.

The proposed mining is consistent with the recommendations of these reports due to the following proposed actions:

- Subsidence prediction reports and environmental studies have been used to determine potential impacts for DA3C;
- Potential impacts to upland swamps have been determined;
- Long-term monitoring of natural features in DA3 is currently being undertaken including upland swamps, piezometric variation and targeted surveys of Littlejohns Tree Frog and Giant Dragonfly. It is recommended these programs continue and are expanded to DA3C; and
- Additional management and mitigation measures have been recommended in this report and the SIS.

3.10 Databases

Databases used in the preparation of this report include:

- DPIE Bionet Atlas of NSW Wildlife (DPIE 2020) (accessed April 2021); and
- EPBC Act Protected Matters Search Tool (Department of the Environment and Energy (DoEE) 2020) (accessed April 2021).

Further records of threatened species were obtained from the SIS (Biosis 2007), and from the previous studies listed in Section 3.

4 Methods

4.1 Previous survey effort

This section identifies the extensive surveys which have been conducted within DA3 and surrounds. The survey effort from the SIS (Biosis 2007) and previous surveys within DA3 has been summarised in Table 4.

Table 4: Approximate total hours of SIS survey effort and other previous surveys in Area 3

Survey method	Total hours
Vegetation quadrats and transects	44 person hours in SIS, and 373.5 person hours in previous surveys
Vegetation validation and Targeted surveys for threatened plant species	244.5 person hours in SIS and 95 hours in previous surveys
Plot based surveys for *Pultenaea aristata* population count	14 person hours in SIS
Diurnal bird survey	288.5 person hours in previous survey
Nocturnal frog survey	274.8 person hours in previous survey
Bat Detection	68 Trap nights in previous survey
Harp Trap	24 Trap nights in previous survey
Arboreal Elliot Traps (Small)	72 Trap nights in previous survey
Arboreal Elliot Traps (Large)	72 Trap nights in previous survey
Arboreal hair tubes	303 Trap nights in previous survey
Cage traps	360 Trap nights in previous survey
Diurnal bird surveys	13.88 person hours in previous survey
Diurnal herpetofauna Search	44.03 person hours
Diurnal call playback	2.05 person hours in previous survey
Frog habitat search	23.9 person hours
Nocturnal watercourse search	49 person hours in previous survey
Spotlighting	64 person hours in previous survey
Nocturnal call playback	52 person hours in previous survey
Frog call/Song Meter	225 trap nights

Areas previously surveyed within the current study area as part of the SIS (Biosis 2007), ongoing monitoring (Biosis 2018) and other previous assessments (Niche 2019a), have been identified in Table 5 and 6. The data from these previous surveys has supplemented the data collected as part of the current assessment.

Table 5: Previous survey effort of swamps in study area

Swamp	Swamp characteristics	Position of highest impact area	Previous vegetation survey	Previous fauna survey
Den06	Small simple swamp	600 m buffer area	-	-
Den07	Large complex swamp	Mined beneath	1 x vegetation surveys sites (vegetation validation and dominant species observations) (Biosis 2007). Rapid data point, vegetation/habitat observation, vegetation boundary (Niche 2019a).	Scat collection, nocturnal call playback (frogs, mammals and owls), nocturnal herpetofauna search, diurnal bird survey, spotlighting (mammals, reptiles, birds), arboreal elliots/hair tubes (Biosis 2007). Diurnal frog and tadpole searches, nocturnal frog searches, songmeter, call playback (Niche 2019a).
Den09	Small simple swamp	Angle of Draw	1 x vegetation transect (Biosis 2007). Rapid data point (Niche 2019a).	-
Den140	Small simple swamp	600 m buffer area	Rapid data point (Niche 2019a).	-
Den141	Small simple swamp	600 m buffer area	Rapid data point (Niche 2019a).	-
Den144	Small simple swamp	600 m buffer area	Rapid data point (Niche 2019a).	-
Den145	Small simple swamp	600 m buffer area	Rapid data point (Niche 2019a).	-
Den16	Small complex swamp	600 m buffer area	1 x vegetation transect (Biosis 2007).	-
Den152	Small simple swamp	600 m buffer area	-	-
Den153	Small simple swamp	Mined beneath	-	-
Den154	Small simple swamp	Angle of Draw	-	-
Den155	Small simple swamp	600 m buffer area	-	-
Den156	Small simple swamp	Angle of Draw	-	-
Den157	Small simple swamp	600 m buffer area	-	-

Table 6: Previous survey effort of natural features in study area

Stream	Stream order	Position of highest impact area	Previous vegetation survey	Previous fauna survey
Wongawilli Creek	3rd order	600 m buffer area	2 x floristic plots (Biosis 2007). 1 x vegetation surveys sites (vegetation validation and dominant species observations) (Biosis 2007). 2 x vegetation/habitat observation (Niche (2019a).	Diurnal herpetofauna search, habitat assessment, diurnal bird survey, nocturnal call playback (frogs), anabat, scat collection (Biosis 2007). Diurnal frog and tadpole searches, nocturnal frog searches, songmeter (Niche 2019a).
WC20	1st order	600 m buffer area	3 x vegetation/habitat observation (Niche (2019a).	Diurnal frog and tadpole searches, songmeter call playback (Niche 2019a).
WC24	2nd order	Angle of Draw	-	Diurnal frog and tadpole searches, songmeter (Niche 2019a).
WC24A	1st order	Mined beneath	-	-
WC26	2nd order	Mined beneath	1 x vegetation/habitat observation (Niche (2019a).	Nocturnal frog searches (Niche 2019a).
LC5	2nd order	Mined beneath	1 x vegetation surveys sites (vegetation validation and dominant species observations) (Biosis 2007). Rapid data point, vegetation/habitat observation, vegetation boundary (Niche 2019a).	Scat collection, nocturnal call playback (frogs, mammals and owls), nocturnal herpetofauna search, diurnal bird survey, spotlighting (mammals, reptiles, birds), arboreal elliots/hair tubes (Biosis 2007). Diurnal frog and tadpole searches, call playback (Niche 2019a).
LC6	1st order	Mined beneath	-	-

4.2 Current survey

4.2.1 Survey timing

The current project involved flora and fauna surveys within the study area and focused on landscape features and associated biodiversity which may be sensitive to the impacts of subsidence from longwall extraction such as swamps, waterways and rocky areas. Survey effort focussed on areas within the study area which had not been subject to previous survey or had limited survey coverage (Figure 5 and Figure 6).

Survey was conducted throughout the study area over the following days: 20, 29 May and 3, 24, 25 June 2020, with two additional nights of survey along LC5 and LC6 on the 11 and 12 August 2021. Field survey effort from previous nearby longwalls was also utilised to supplement the survey data from the current survey:

- Longwalls 20 and 21 (Niche 2019a): survey dates: 2, 14 August 2017, 5 October 2017, 17, 28 August – 19 September 2018 (songmeter), 4 December 2018.
- Longwall19 (Niche 2020): survey dates: 12 December 2019.

Field survey activities are detailed in the following sections.

4.2.2 Flora and vegetation survey

Flora surveys were undertaken on 14 August 2017, 17 and 28 August 2018, 20 and 29 May 2020, and 3 June 2020.

Flora survey focused on vegetation validation of Upland Swamps within the study area (Figure 3, Figure 4). A sample of swamps mapped within the Woronora vegetation mapping project (NPWS 2003), Biosis (2019) swamp mapping or identified via aerial photography analysis were visited to confirm the vegetation present and update mapping of swamp boundaries including the swamp unit and sub-unit as per NPWS 2003. This process was completed by performing rapid data points to record the following (Figure 4):

- Dominant species present at all strata levels; and
- Total projective foliage cover and height at all strata levels.

Species composition and characteristics were then compared with vegetation descriptions. Boundaries between units and sub-units were captured in the field by collecting waypoints and tracks along identified boundaries. Where possible, vegetation patterns within swamps were also observed from surrounding vantage points using binoculars to aid with identifying consistency of vegetation or otherwise across the swamp.

Field GPS data was later overlaid onto aerial imagery and boundary mapping was completed with adjustments made if necessary, according to observable colour and texture patterns of vegetation as well as observations of tree canopies, which were used to define the outer-boundaries of the swamps.

Limitations associated with the selected method include reliance on correct positioning of aerial imagery as well as correct interpretation of canopy shadows. Boundaries between swamp communities and sub-communities are frequently not discrete, rather these communities' grade into one another. Therefore, there is an element of subjectivity regarding the exact positioning of boundaries dependent upon the observer.

The flora survey included opportunistic threatened plant species search within upland swamps in the study area.

4.2.3 Fauna survey

Fauna survey effort focused on areas susceptible to subsidence impacts and associated fauna. Areas targeted included upland swamps and creek lines (Figure 6). A summary of the survey effort is shown in Table 7.

Table 7: Survey effort

Survey Technique	Habitat	Estimated Survey Effort (person hours)	Date
Diurnal frog and tadpole searches	Wongawilli Creek, WC24, WC20, LC5, LC6, Swamp Den07	7.5 hr	2 August 2017, 5 October 2017, 28 August 2018, 4 December 2018, 12 December 2019, 3 June 2020, 24 June 2020.

Survey Technique	Habitat	Estimated Survey Effort (person hours)	Date
Nocturnal frog searches	WC26, Wongawilli Creek, Swamp Den07	22	2 August 2017, 5 October 2017, 25 June 2020, 11, 12 August 2021.
Songmeter	Wongawilli Creek, WC24, WC20, Swamp Den07	22 nights x 3 songmeters	28 August 2018- 19 September 2018
Call playback	WC20, downstream of swamp, LC5, Swamp Den07	1 hr	28 August 2018, 4 December 2018, 20 May 2020
Reptile Search	Ridge above W26, WC26, above L6 on ridge plateau	2	2 August 2017, 24, 25 June 2020

4.2.4 Limitations

The majority of the fauna survey was conducted during the cooler months of May, June, August, then in early December. Survey focused on biodiversity that could potentially be impacted by subsidence, such as swamps and frogs. Other biodiversity and habitat features of the study area were not targeted in the field assessment.

4.3 Upland swamp mapping

A number of smaller swamps or swamp-like vegetation are scattered throughout the study area. These small patches of swamp like vegetation are often too small to map as discrete swamps and occur in small areas of impeded drainage that contain a mix of plant species common to the upland swamps and fringing eucalypt woodlands of the region. These patches of vegetation have not been identified in the existing swamp mapping of the study area and field observations indicate that these patches of vegetation occur randomly in the landscape, are not typically restrained by sandstone rock bars and are unlikely to be sustained by groundwater seeps.

The Swamp Impact Monitoring, Management and Contingency Plan addresses the small areas of swamp vegetation communities and deals with them as a whole. Therefore, the small and less significant swamps (less than 1500 m^2 in area) have not been named and mapped as part of this assessment, with monitoring efforts focused on larger representative swamps. Two exceptions for the current study area include Swamp 141 and Swamp 157, both included despite their small size due to being incorporated in previous mapping for adjoining longwalls and/or regional mapping (NPWS 2003).

4.4 Likelihood of occurrence assessment for threatened species

A list of threatened species within the locality (5 km radius) was derived from database searches (DPIE Bionet Atlas of NSW Wildlife and EPBC Act Protected Matters Search Tool) (Appendix 1). The list of potentially impacted species is determined from consideration of this list. In order to adequately determine the relevant level of assessment for each species, further analysis of the likelihood of those species occurring within the study area was undertaken.

Five categories for 'likelihood of occurrence' (Table 8) were attributed to species after consideration of criteria such as known records, presence or absence of important habitat features on the subject site, results of the field surveys and professional judgement. This process was completed for each individual species.

Species considered further were those in the 'Known' to 'Moderate' categories and where impacts for the species could reasonably occur from the development (Appendix 1).

Table 8: Likelihood of occurrence methodology

Likelihood rating	Threatened Flora/EEC Criteria	Threatened and Migratory Fauna Criteria
Known	The species/EEC was observed within the study area.	The species was observed within the study area.
High	It is likely that a species/EEC inhabits or utilises habitat within the study area.	It is likely that a species inhabits or utilises habitat within the study area.
Moderate	Potential habitat for a species/EEC occurs on the site. Adequate field survey would determine if there is a 'high' or 'low' likelihood of occurrence for the species within the study area.	Potential habitat for a species occurs on the site and the species may occasionally utilise that habitat. Species unlikely to be wholly dependent on the habitat present within the study area.
Low	It is unlikely that the species/EEC inhabits the study area.	It is unlikely that the species inhabits the study area. If present at the site, the species would likely be a transient visitor. The site contains only very common habitat for this species which the species would not rely on for its on-going local existence.
None	The habitat within the study area is unsuitable for the species/EEC.	The habitat within the study area is unsuitable for the species.

5 Results

5.1 Vegetation communities

Seven vegetation communities or sub-communities have been mapped as occurring within the study area by NPWS (2003) and Niche during the current project, after confirmation of swamp mapping (Table 9).

Ground-truthing of upland swamp community mapping resulted in changes to upland swamp sub-community patterns, swamp boundaries and changes in vegetation communities (Figure 3, Figure 4, Figure 5).

A number of small swamps were added to vegetation mapping after field observations. Conversely, sections of previously mapped swamps were reclassified as other community types. These areas corresponded with woodland or forest communities with thick understories of banksia thicket. These changes are to be expected since the base mapping of the Upland Swamp Banksia Thicket community unit did not attempt to remove areas of banksia thicket that may occur in other communities such as Exposed Sandstone Scribbly Gum Woodland (see page 200 of NPWS 2003).

Banksia thickets are moderately frequent throughout the study area in the range of communities present. Often these areas share floristic similarities with simpler swamp types such as areas of banksia thicket (typically dominated by *Banksia marginata*). However, the presence of other diagnostic swamp species that are more reliant on frequently waterlogged soils is lacking or poorly represented in these areas.

Table 9: Area of vegetation communities within the study area (including adjacent swamp areas)

Map Unit (NPWS 2003)	Vegetation Community (NPWS 2003)	PCT	Keith Formation	Keith Class	Corresponding TEC	Area in study area * (ha)
MU4	Sandstone Riparian Scrub	1292 Water Gum - Coachwood riparian scrub along sandstone streams, Sydney Basin Bioregion	Dry Sclerophyll Forests (Shrub/grass sub-formation)	Cumberland Dry Sclerophyll Forests	Not listed	3.01
MU26	Sandstone Gully Peppermint Forest (SGPF)	1250 Sydney Peppermint - Smooth-barked Apple - Red Bloodwood shrubby open forest on slopes of moist sandstone gullies, eastern Sydney Basin Bioregion	Dry Sclerophyll Forests (Shrubby sub-formation)	Sydney Coastal Dry Sclerophyll Forests	Not listed	228.2
MU29	Exposed Sandstone Scribbly Gum Woodland (ESSGW)	1083 Red Bloodwood - scribbly gum heathy woodland on sandstone plateaux, Sydney Basin Bioregion	Dry Sclerophyll Forests (Shrubby sub-formation)	Sydney Coastal Dry Sclerophyll Forests	Not listed	365.5
MU39	Rock Plate Heath Mallee	881 Hairpin Banksia - Kunzea ambigua - Allocasuarina distyla heath on coastal sandstone plateaux, Sydney Basin Bioregion	Heathlands	Sydney Coastal Heaths	Not listed	1.7

Map Unit (NPWS 2003)	Vegetation Community (NPWS 2003)	PCT	Keith Formation	Keith Class	Corresponding TEC	Area in study area * (ha)
MU42	Upland Swamps: Banksia Thicket (USBT)	1803 Needlebush - banksia wet heath on sandstone plateaux of the Sydney Basin Bioregion	Freshwater Wetlands	Coastal Heath Swamps	Coastal Upland Swamps of the Sydney Basin Bioregion (BC Act and EPBC Act)	18.2
MU43	Upland Swamps: Tea-Tree Thicket (USTTT)	1804 Banksia - Needlebush - Tea-tree damp heath swamps on coastal sandstone plateaus of the Sydney basin	Freshwater Wetlands	Coastal Heath Swamps	Coastal Upland Swamps of the Sydney Basin Bioregion (BC Act and EPBC Act)	0 .6
MU44	Coastal Upland Swamps: Sedgeland-Heath Complex (Cyperoid Heath)	1804 Needlebush - banksia wet heath swamps on coastal sandstone plateaus of the Sydney Basin	Freshwater Wetlands	Coastal Heath Swamps	Coastal Upland Swamps of the Sydney Basin Bioregion (BC Act and EPBC Act)	0.5

*note that figures for swamp communities include areas of swamps beyond the study area boundary where any part of the swamp occurs within the boundary. Vegetation calculations are a combination of NPWS (2003) mapped areas and Niche validated mapping for swamp communities. There may be some discrepancies where NPWS (2003) has mapped upland swamp communities and the swamp boundaries have been adjusted as part of the validated swamp mapping undertaken as part of this assessment.

5.2 Upland swamps within the study area

There are 14 Upland swamps (meeting the definition of the Commonwealth and State listed TEC as in Table 9) that occur within the study area based on the 600 m boundary (Table 10) (Figure 3 and Figure 4). The majority of swamps are smaller swamps with single sub-communities, which tend to be drier swamp types (Banksia Thicket). Complexity of swamps generally increased with overall size of the swamp complex. This is likely due to larger swamps having more variable groundwater conditions across the swamp from more frequently waterlogged areas with heavy peat development to less frequently waterlogged areas with less peat development.

One complex large Upland Swamp (Swamp Den07) is located within the predicted area of subsidence impacts (35 degree angle of draw study area) (Figure 3 and Figure 4). There are also four smaller swamps occurring within the predicted area of subsidence impacts (35 degree angle of draw study area). The swamps (Den07 and Den153) are directly above the proposed Longwalls (Figure 3).

Table 10: Upland Swamps within the study area

Swamp No.	Valley infill or headwater	Swamp Community/sub-community	Area (ha)					
			Total Swamp[1]	600 m boundary	Angle of draw	Groundwater impact zone (60 m buffer)	Above Longwall 22	Above Longwall 23
Den 06	Headwater	Upland Swamps: Banksia Thicket	0.57	0.24	-	-	-	-
Den 07	Valley Infill	Upland Swamps: Banksia Thicket	3.18	3.18	3.18	2.67	0.13	1.65
		Upland Swamps: Tea-tree Thicket	1.69	1.69	1.69	1.58	-	1.31
Den 09	Valley Infill	Upland Swamps: Banksia Thicket	0.29	0.29	-	-	-	-
		Upland Swamps: Tea-tree Thicket	0.50	0.50	0.42	-	-	-
Den 16	Valley Infill	Upland Swamps: Banksia Thicket	1.28	-	-	-	-	-
		Upland Swamps: Tea-tree Thicket	0.78	0.51	-	-	-	-
		Upland Swamps: Sedgeland-Heath Complex (Cyperoid Heath)	1.69	0.47	-	--	-	
Den 140	Headwater	Upland Swamps: Banksia Thicket	0.16	0.16	-	-	-	-
Den 141	Headwater	Upland Swamps: Banksia Thicket	0.08	0.08	-	-	-	-
Den 144	Headwater	Upland Swamps: Banksia Thicket	0.54	0.54	-	-	-	-
Den 145	Headwater	Upland Swamps: Banksia Thicket	0.41	0.41	-	-	-	-
Den 152	Headwater	Upland Swamps: Banksia Thicket	0.22	0.22	-	-	-	-
Den 153	Valley infill	Upland Swamps: Banksia Thicket	0.29	0.29	0.29	0.29	-	0.29
Den 154	Headwater	Upland Swamps: Banksia Thicket	0.40	0.40	0.40	-	-	-
Den 155	Headwater	Upland Swamps: Banksia Thicket	0.50	0.50	0.03	-	-	-
Den 156	Headwater	Upland Swamps: Banksia Thicket	0.71	0.71	0.65	-	-	-
Den 157	Valley infill	Upland Swamps: Tea-tree Thicket	0.12	0.12	-	-	-	-
Total		**-**	**13.41**	**10.31**	**6.66**	**4.54**	**0.13**	**3.25**

[1] Includes all swamps that are located wholly or partially within the 600 m study area boundary.

5.3 Upland swamp community descriptions

5.3.1 MU42: Upland Swamps: Banksia Thicket (BT)

Banksia Thicket occurs as small swamps or on the drier edges of larger more complex swamps within the study area. Within the study area the community typically grades into adjoining areas of the drier MU26: Sandstone Gully Peppermint Forest and MU29 Exposed Sandstone Scribbly Gum Woodland.

In some swamps, a sparse canopy layer exists. Where this occurs, the canopy has a low projective foliage cover (e.g. 5%). Trees included *Eucalyptus racemosa* or *E. sieberi* with a canopy height to approximately 15 m.

The shrub layer reached a height of approximately 4 - 5 m, and a high projective foliage cover of 60 to 90%. The shrub layer primarily consisted of *Banksia ericifolia* with associate species including *Acacia terminalis, Hakea teretifolia, Leptospermum polygalifolium, L. juniperinum, L. squarrosum, Petrophile pulchella.*

Ground layer species include: *Bauera rubioides, Baeckea imbricata, Epacris microphylla, Empodisma minus, Cyathochaeta diandra, Hibbertia riparia, Lepidosperma limicola, Sprengelia incarnata, Schoenus brevifolius* and *Dillwynia floribunda.*

5.3.2 MU43: Upland Swamps: Tea Tree Thicket (TTT)

Tea Tree Thicket occurs in areas of impeded drainage within upland swamps in the study area.

The community has been classified as a closed scrub, with a small tree and shrub layer reaching a height of approximately 5 m and project foliage cover of up to 80%. Canopy trees include *Eucalyptus piperita and E. racemosa.*

The midstorey and shrub layers include: *Acacia rubida, Banksia robur, Melaleuca linearifolia, Leptospermum juniperinum, L polygalifolium, L lanigerum* and *Petrophile pulchella.*

Ground layer species include: *Gahnia sieberi, Baumea teretifolia, Dillwynia floribunda, Empodisma minus, Leptocarpus tenax* and *Lepidosperma limicola*.

5.3.3 MU44: Upland Swamps: Sedgeland Heath Complex

a) Sedgeland

The sedgeland community occurs within minor depressions in upland swamp Den14 in the study area.

The shrub layer reached a height of approximately 1 m with a project foliage cover of up to 30%. Shrubs included: *Baeckea imbricata, Epacris obtusifolia, Sprengelia incarnata, Symphionema paludosum, Boronia parviflora, Hakea teretifolia* and *Banksia ericifolia* subsp*. ericifolia*

The Ground layer has a projected foliage cover of approximately 30 to 60%. Species include: *Leptocarpus tenax, Schoenus brevifolius, Schoenus paludosus, Lepyrodia scariosa, Ptilothrix deusta, Dampiera stricta* and *Stylidium graminifolium.*

b) Restioid Heath

The restioid heath, like that of sedgeland, usually occurs within minor depressions in upland swamps, though none was recorded in the study area.

A low shrub layer of *Banksia oblongifolia*, *Hakea teretifolia* and *Epacris obtusifolia* consistently occur with occasional *B. robur*, *Melaleuca thymifolia* and *M. squarrosa*. The project foliage cover is approximately 40% to a height of 1 m.

The ground cover consists of a combination of rushes, herbs and grasses forming a dense ground cover. Species present include *Empodisma minus*, *Lepyrodia scariosa*, *Leptocarpus tenax*, *Lindsaea linearis*, *Xanthorrhoea resinifera*, *Stackhousia nuda*, *Mitrasacme polymorpha* and *Schoenus brevifolius*.

c) Cyperoid heath

The cyperoid heath occurs within the minor depressions in upland swamp Den14 in the study area.

A low shrub layer of *Banksia robur, Melaleuca squarrosa, Hakea teretifolia, Leptospermum juniperinum, Banksia ericifolia* subsp. *ericifolia, Pultenaea divaricata* and *Baeckea linifolia*. The project foliage cover is approximately 35% to a height of 1.5 m.

The ground cover consists of a combination of sedges and rushes up to 1 m in height and 90% projected foliage cover. Species present include *Lepidosperma limicola, Gymnoschoenus sphaerocephalus, Chorizandra sphaerocephala, Baumea rubiginosa, Empodisma minus, Leptocarpus tenax, Mitrasacme polymorpha* and *Xyris operculata*.

5.4 Upland swamp – TEC classification

5.4.1 BC Act/TSC Act/EPBC Act

The majority of upland swamps within the study area are considered to fit the NSW and Commonwealth determination descriptions of Coastal Upland Swamps in the Sydney Basin Bioregion, which is listed as an EEC under the NSW BC Act and the Commonwealth EPBC Act. Point 7 of the Final Determination (NSW Scientific Committee 2012) states Coastal Upland Swamp in the Sydney Basin bioregion includes mapping units: Upland Swamps Banksia Thicket (MU42), Upland Swamps Tea-tree Thicket (MU43) and Upland Swamps Sedgeland-Heath Complex (MU44) of NPWS (2003). All three of these communities occur within the upland swamps in the study area (Figure 3).

The approximate area of EEC Coastal Upland Swamps within the wider study area, which includes the totality of a swamp where any part of the swamp is within 600 m of the proposed longwalls is 13.41 ha (Table 10).

5.5 Threatened flora

A total of 33 threatened plant species listed on the EPBC Act and or BC Act have been previously recorded, or have potential habitat within a 5 km radius of the study area (Appendix 1 and Figure 6). Of the 33 threatened species obtained in the database searches, ten species (*Acacia bynoeana, Cryptostylis hunteriana, Epacris purpurascens* var. *purpurascens, Grevillea parviflora* subsp. *parviflora, Grevillea raybrownii, Leucopogon exolasius, Melaleuca deanei, Persoonia acerosa, Persoonia hirsuta* and *Pultenaea aristata*) were considered to have a Moderate to High likelihood of occurrence in the study area.

Leucopogon exolasius was observed at three locations within the study area during surveys in 2018 (Figure 4). Small numbers of the species were recorded at each location (between one and five plants). The species was recorded along the powerline easement that runs north to south through the centre of the study area, within Exposed Sandstone Scribbly Gum Woodland and Sandstone Gully Peppermint Forest (Figure 4). No other threatened flora was recorded within the study area.

Potential impacts to threatened flora are discussed in Section 6.3.

5.6 Threatened fauna

A total of 68 threatened fauna species listed on the EPBC Act and or BC Act have been previously recorded, or have potential habitat within a 5 km radius of the study area (Appendix 1 and Figure 8). Forty of these species were determined to have a moderate or high likelihood of occurrence within the study area (Appendix 1).

The previous SIS survey recorded 139 fauna, including 32 threatened fauna within DA3. The threatened fauna recorded during the current survey are detailed in Table 11 (Figure 5).

Table 11: Threatened fauna recorded during current survey and previous nearby recent surveys (See section 4.2.1).

Threatened species	Observation details	Date
Littlejohn's Tree Frog	Observations of tadpoles and adults (heard call) were made from the following locations: • LC5 and Swamp Den07 (approximately 163 individuals across multiple pools. • LC5 – approximately 394 individuals across multiple pools. • LC6 – approximately 836 individuals across multiple pools and in varying stages of development.	12/12/2019 20/05/5020 29/05/2020 24/06/2020 25/06/2020
Red-crowned Toadlet	Recorded along WC20 downstream of upland swamp Den 144	4/12/2018
Koala	Recorded on the way into LC6	12/08/2021

In additional to those threatened species listed in Table 11, the following threatened fauna are previously known from the study area (Bionet records on Figure 5 and Figure 7):

- Frogs: Giant Burrowing Frog.
- Birds: Dusky Woodswallow.
- Mammals: Large Bent-wing bat, Southern Myotis, Eastern Coastal Free-tailed Bat, Eastern Pygmy-possum.

5.7 Fauna habitat

Fauna habitat within the study area considered prone to subsidence impacts is described below.

5.7.1 Upland swamps

Upland swamps range in character from relatively dry swamps supporting Banksia Thicket to more permanently inundated swamps with abundant sedges and herbs (see section 5.2). Upland swamps may provide habitat to a wide variety of birds, mammals, amphibians, reptiles and invertebrate species, with particular species performing strong associations with swamps (e.g. the Giant Dragonfly).

Upland swamps within the study area also provide an important role in regulating flows along particular watercourses within the study area.

5.7.2 Creeks and drainage lines

Major watercourses within and adjoining the DA3C study area include: Wongawilli Creek and Lake Cordeaux. Various drainage lines and tributaries of these watercourses occur throughout the study area. All creeks and drainage lines within the study area are considered to be generally in good condition, and they provide a range of habitat features including: emergent vegetation, riffles, pools, sandy substrate and rocks.

Creek lines are important to particular frog and reptile species including threatened species, with water facilitating the breeding cycle and other lifecycle components of most frogs. The character of drainage lines depends on their size, slope and catchment area with small ephemeral streams offering important breeding and sheltering habitat for some species while larger permanent streams are preferred by others. Habitat features along the streams include rock pools, riffle zones, gravel beds, woody debris, boulders and aquatic vegetation.

5.7.3 Sandstone outcrops, overhangs and caves

Sandstone outcrops, overhangs and caves are typically important to reptile and bat species. Threatened reptiles that may utilise such features include the threatened Broad-headed Snake.

Caves and overhangs within the study area may provide habitat for micro-bats, including threatened species: Large Bent-winged Bat, Little Bentwing-bat and Southern Myotis. Cave development within the study area is poor however, so roosting is likely to be confined to limited areas. No large breeding colonies of cave dependant bats are expected to occur within the study area.

5.8 Key threatening processes

Key-threatening processes (KTP) relevant to the project include:

1. Alteration of habitat following subsidence due to longwall mining; and
2. Alteration of the natural flow regimes of rivers, stream, floodplains and wetlands.

5.8.1 Alteration of habitat following subsidence due to Longwall mining

Alteration of habitat following subsidence due to longwall mining is listed as a KTP under Schedule 4 of the NSW BC Act. This is the most relevant KTP associated with the proposal.

Subsidence due to longwall mining has been recognised as causing habitat alteration, with species and ecological communities that depend on aquatic and semi-aquatic habitats being particularly susceptible to the impacts of subsidence. Consequently, alteration of habitat following subsidence due to longwall mining has been determined by the NSW Scientific Committee to constitute a KTP (NSW Scientific Committee 2005).

A list of threatened species, populations and TECs potentially impacted by longwall mining is provided in the NSW Scientific Committee Final Determination for this KTP (NSW Scientific Committee 2005). Flora of relevance to this assessment include: *Epacris purpurascens* var*. purpurascens, Leucopogon exolasius, Melaleuca deanei, Persoonia acerosa* and *Pultenaea aristata.* Fauna include: Eastern Pygmy Possum, Southern Brown Bandicoot, Giant Burrowing Frog, Black Bittern, Littlejohn's Tree Frog, Stuttering Frog, Southern Myotis, Red-crowned Toadlet, Grey-headed Flying Fox, Giant Dragonfly, Broad-headed Snake and Rosenberg's Goanna.

5.8.2 Alteration of the natural flow regimes of rivers, stream, floodplains and wetlands

Alteration of the natural flow regimes of rivers, stream, floodplains and wetlands is listed as a KTP under Schedule 4 of the BC Act. This is a relevant KTP associated with the proposal, which is caused by subsidence.

Alteration to natural flow regimes can occur through reducing or increasing flows, altering seasonality of flows, changing the frequency, duration, magnitude, timing, predictability and variability of flow events, altering surface and subsurface water levels and changing the rate of rise or fall of water levels.

5.9 Critical habitat or Areas of Outstanding Biodiversity Value (AOBV)

Areas of Critical Habitat under the TSC Act have been replaced by AOBVs with the introduction of the BC Act. No AOBVs have been declared for any ecological values within the study area. No AOBVs will be impacted by the proposal.

6 Impact assessment

6.1 Potential impacts to vegetation

Vegetation communities which are not dependent on groundwater are unlikely to be impacted by subsidence due to underground mining. This accounts for most of the woodland and forest communities in Table 9.

Groundwater dependant and riparian vegetation may experience some floristic changes in response to changed groundwater conditions, as a result of subsidence.

Riparian vegetation is generally not mapped as discrete vegetation communities, rather these areas display structural and floristic variation within their composite community in response to more frequent contact with shallow groundwater. Riparian vegetation may be potentially impacted by subsidence through water diversion or cracking of bedrock.

In the Southern Coalfield, observed impacts to riparian vegetation as a result of subsidence are minor in occurrence. Furthermore, limited impacts to riparian vegetation have been observed in Dendrobium Mine to date (Biosis 2016). Previous examples of impacts include: dieback of riparian vegetation as a result of methane releases which occurred nearby Cataract River during the 1990s (Eco Logical Australia 2004), and small localised changes to riparian vegetation along a section of the Waratah Rivulet.

Impacts to riparian vegetation associated with the proposal are predicted to be minor in occurrence, being localised if they occurred.

Groundwater dependant ecosystems (typically comprising upland swamps within the locality) on the other hand are prone to groundwater changes as a result of subsidence. Potential impacts are discussed below.

6.2 Potential impacts to upland swamps

The study area contains a mixture of headwater swamps and valley infill swamps. A total of 13.41 ha across 14 upland swamps (including complex swamps with wetter sub-units) occur within and adjacent to the 600 m study area. However, the areas bounded by 600 m (especially if adjacent swamp areas are included) is considered a conservative approach to determining areas of potential impacts.

The majority of impacts to upland swamps will take place where they occur above the proposed longwall (3.38 ha of upland swamps) and within the groundwater impact zone (60 m buffer) (4.54 ha of upland swamps). The severity and risk of impacts will reduce with distance from longwalls up to the 35 degree angle of draw study area, which includes the 20 mm subsidence contour (6.66 ha of upland swamp within 35 degree angle of draw study area). Beyond the 35 degree angle of draw study area, impacts to features such as swamps and watercourses are expected to be minor or negligible. A recent assessment at Dendrobium Mine concluded that hydrological change in upland swamps is not evident in shallow groundwater piezometers located more than 60 m from the extracted longwall margin (Watershed Hydrogeo, 2019). Where streams flowing into swamps are located above or in close proximity to longwalls this may have impacts on swamps downstream of impacted streams.

Den 07 and Den 153 are located partially above Longwalls 22 and 23, a total of 0.13 ha are above Longwall 22 and 3.25 ha above Longwall 23 (Figure 3). Approximately 6.66 ha of upland swamps from

Den07, 09, 153, 154, 155 and 156 occur within the 35 degree angle of draw study area. These areas are likely to experience a range of subsidence impacts (see Table 12). Additional swamps located within the study area based on the 600 m boundary (Figure 3) equate to an additional 10.31 ha of upland swamps within the wider study area which may experience some minor or negligible impacts depending on the distance from the proposed longwall.

To assess the potential impacts of subsidence on upland swamps, a review of MSEC (2021) subsidence predictions and previous literature on monitoring of swamp subsidence impacts from the locality has been completed, with a summary provided in Table 12.

Table 12: Impact predictions for Upland Swamps within and adjacent to the study area

Swamp	Swamp characteristics	Location	Position of highest impact area	Subsidence predictions (MSEC 2021)	Potential impacts
Den 06	Small simple swamp	490 m north of Longwall 23	600 m buffer area	Unlikely to experience adverse changes in the levels of ponding or scouring based on the predicted subsidence induced tilt. It is unlikely that fracturing would develop in the bedrock beneath this swamp.	Unlikely to be measurable impacts, given the distance from the longwall and that subsidence effects are generally only experienced up to 400 m from a longwall.
Den 07	Large complex swamp	Partially above Longwall 22 and directly above Longwall 23	Mined beneath	There is potential for minor and localised increased ponding and scouring within this swamp due to subsidence induced tilt. Fracturing of the bedrock is likely to occur and result in the dilation of the strata beneath the swamp. The dilated strata beneath the drainage lines and within Swamp Den07 is likely result in the diversion of some surface water flows beneath parts of these swamps. The drainage lines upstream of this swamp flow during and shortly after rainfall events. Where there is no connective fracturing to any deeper storage, it is likely that surface water flows will re-emerge at the limits of fracturing and dilation.	Possible ecological impacts including changes in vegetation and threatened species habitat (predominantly for Littlejohn's Tree Frog, which is known to occur within Swamp Den07, and downstream along watercourse LC5). Potential breeding habitat for this population may be impacted through reductions in water retention from pools after fracturing. Wetter Swamp types (such as Tea-tree Thicket) may trend towards Banksia Thicket or Fringing Eucalypt Woodland if changes are long-term. Vegetative dieback may be experienced due to reduction in water holding capacity of the swamp.
Den 09	Small simple swamp	90 m south of Longwall 22	Angle of Draw	Unlikely to experience adverse changes in the levels of ponding or scouring based on the predicted subsidence induced tilt. Fracturing could occur in the base of the valley and within this swamp.	Possible ecological impacts including changes in vegetation, with areas trending towards Banksia Thicket or Fringing Eucalypt Woodland if changes are long-term. A population of Littlejohn's Tree Frog is known to occur downstream of this swamp. Potential breeding habitat for this population may be impacted through reductions in water retention from pools after fracturing.
Den 16	Small simple swamp	540 m south of Longwall 22	600 m buffer area	Unlikely to experience adverse changes in the levels of ponding or scouring based on the predicted subsidence induced tilt. It is unlikely that fracturing would develop in the bedrock beneath this swamp.	Unlikely to be measurable impacts, given the distance from the longwall and that subsidence effects are generally only experienced up to 400 m from a longwall.
Den 140	Small simple swamp	525 m north-west of Longwall 23	600 m buffer area	Unlikely to experience adverse changes in the levels of ponding or scouring based on the predicted subsidence induced tilt.	Unlikely to be measurable impacts, given the distance from the longwall and that subsidence effects are generally only experienced up to 400 m from a longwall.

Swamp	Swamp characteristics	Location	Position of highest impact area	Subsidence predictions (MSEC 2021)	Potential impacts
				It is unlikely that fracturing would develop in the bedrock beneath this swamp.	
Den 141	Small simple swamp	360 m west of Longwall 23	600 m buffer area	Unlikely to experience adverse changes in the levels of ponding or scouring based on the predicted subsidence induced tilt. It is unlikely that fracturing would develop in the bedrock beneath this swamp.	Unlikely to be measurable impacts, given the distance from the longwall and that subsidence effects are generally only experienced up to 400 m from a longwall, the MSEC (2021) predictions, the small size of the swamp and the fact that it supports one of the drier swamp types (Banksia Thicket).
Den 144	Small simple swamp	500 m south of Longwall 22	600 m buffer area	Unlikely to experience adverse changes in the levels of ponding or scouring based on the predicted subsidence induced tilt. It is unlikely that fracturing would develop in the bedrock beneath this swamp.	Unlikely to be measurable impacts, given the distance from the longwall and that subsidence effects are generally only experienced up to 400 m from a longwall.
Den 145	Small complex swamp	500 m south of Longwall 22	600 m buffer area	Unlikely to experience adverse changes in the levels of ponding or scouring based on the predicted subsidence induced tilt. It is unlikely that fracturing would develop in the bedrock beneath this swamp.	Unlikely to be measurable impacts, given the distance from the longwall and that subsidence effects are generally only experienced up to 400 m from a longwall.
Den 152	Small simple swamp	435 m north-west of Longwall 23	600 m buffer area	Unlikely to experience adverse changes in the levels of ponding or scouring based on the predicted subsidence induced tilt. It is unlikely that fracturing would develop in the bedrock beneath this swamp.	Unlikely to be measurable impacts, given the distance from the longwall and that subsidence effects are generally only experienced up to 400 m from a longwall.
Den 153	Small simple swamp	Directly above Longwall 23	Mined beneath	There is potential for minor and localised increased ponding and scouring within this swamp due to subsidence induced tilt. Fracturing of the bedrock is likely to occur and result in the dilation of the strata beneath the swamp. The dilated strata beneath the drainage lines and within Swamp Den153 is likely to result in the diversion of some surface water flows beneath parts of these swamps. The drainage lines	Possible ecological impacts including changes in vegetation, trending towards Fringing Eucalypt Woodland. Vegetative dieback may be experienced due to reduction in water holding capacity of the swamp.

Swamp	Swamp characteristics	Location	Position of highest impact area	Subsidence predictions (MSEC 2021)	Potential impacts
				upstream of this swamp flow during and shortly after rainfall events. Where there is no connective fracturing to any deeper storage, it is likely that surface water flows will re-emerge at the limits of fracturing and dilation.	
Den 154	Small simple swamp	70 m north of Longwall 22 and 95 m east of Longwall 23	Angle of Draw	Unlikely to experience adverse changes in the levels of ponding or scouring based on the predicted subsidence induced tilt. It is unlikely that fracturing would develop in the bedrock beneath this swamp.	Unlikely to be measurable impacts, given the MSEC (2021) predictions, the small size of the swamp and the fact that it supports one of the drier swamp types (Banksia Thicket).
Den 155	Small simple swamp	210 m east of Longwall 22	600 m buffer area	Unlikely to experience adverse changes in the levels of ponding or scouring based on the predicted subsidence induced tilt. It is unlikely that fracturing would develop in the bedrock beneath this swamp.	Unlikely to be measurable impacts, given the distance from the longwall, the MSEC (2021) predictions, the small size of the swamp and the fact that it supports one of the drier swamp types (Banksia Thicket).
Den 156	Small simple swamp	130 m south-east of Longwall 22	Angle of Draw	Unlikely to experience adverse changes in the levels of ponding or scouring based on the predicted subsidence induced tilt. It is unlikely that fracturing would develop in the bedrock beneath this swamp.	Unlikely to be measurable impacts, given the MSEC (2021) predictions, the small size of the swamp and the fact that it supports one of the drier swamp types (Banksia Thicket).
Den 157	Small simple swamp	335 m south of Longwall 22	600 m buffer area	Unlikely to experience adverse changes in the levels of ponding or scouring based on the predicted subsidence induced tilt. It is possible, but unlikely, that fracturing could occur in the base of the valley and within this swamp.	Possible ecological impacts including changes in vegetation, trending towards Banksia Thicket and Fringing Eucalypt Woodland. Vegetative dieback may be experienced If fracturing occurs due to reduction in water holding capacity of the swamp. A population of Littlejohn's Tree Frog is known to occur downstream of this swamp. Potential breeding habitat for this population may be impacted through reductions in water retention from pools if fracturing occurs.

The MSEC (2021) report has predicted potential subsidence impacts within four upland swamps located within the study area: swamps Den07 and Den153 (mined beneath by Longwall 22 or 23) and swamps Den09 and Den157.

Should changes in groundwater levels within the upland swamps occur, this may impact on the distribution of local vegetation within the swamps (potentially resulting in dieback where water holding capacity is reduced) as well as potential for downstream impacts to associated watercourses and threatened frog habitat.

6.3 Potential impacts to threatened flora

Ten threatened flora species have been determined to have a moderate to high likelihood of occurring within the study area (Appendix 1). However, a limited number have potential habitat likely to be impacted by subsidence.

Threatened flora likely to be impacted by subsidence (Table 13) include those associated with ground water dependent habitats, such as upland swamps and riparian vegetation. Ridgeline and woodland dependent threatened flora are unlikely to be significantly impacted by subsidence.

One threatened plant species is known to occur in the study area, *Leucopgon exolasius* (Figure 4). Three additional species (*Epacris purpurascens* var*. purpurascens, Cryptostylis hunteriana* and *Pultenaea aristata*) are considered to have habitat within the study area that may be potentially impacted by subsidence. Each of these species has potential habitat within upland swamps or creek line vegetation communities, however none of these species are reliant on such habitat and occur throughout a range of other habitats within the study area.

Impacts from the proposed mining on threatened flora have been assessed within the Dendrobium SIS and are likely to be minimal (Table 13).

Table 13: Threatened flora with potential to be impacted within the study area

Botanical Name	Potential Habitat in study area	Potential to be Impacted by subsidence	Seven-Part Test undertaken in SIS (Biosis 2007)
Cryptostylis hunteriana	Not previously recorded in study area. Potential habitat includes upland swamps, creek lines and ridge lines.	Yes. Upland swamps and creek line habitat may be impacted by subsidence.	Yes. No significant impact concluded.
Epacris purpurascens var. *purpurascens*	Not previously recorded in study area. Potential habitat includes upland swamps, creek lines and ridge lines.	Yes. Upland swamps and creek line habitat may be impacted by subsidence.	Yes. No significant impact concluded.
Leucopogon exolasius	Previously recorded in the study area (see Figure 4). Potential habitat includes creek lines. Vegetation communities include SGPF and SRS.	Yes. Creek line habitat may be impacted by subsidence.	Yes. No significant impact concluded.

Botanical Name	Potential Habitat in study area	Potential to be Impacted by subsidence	Seven-Part Test undertaken in SIS (Biosis 2007)
Pultenaea aristata	Not previously recorded in the study area. Potential habitat includes upland swamps and creek lines.	Yes. Upland swamps and creek line habitat may be impacted by subsidence.	Yes. No significant impact concluded.

6.4 Potential impacts to fauna

Subsidence may have a direct impact on known and potential habitat for threatened fauna such as watercourses, upland swamps, riparian vegetation, rock overhangs, rocky outcrops, cliffs and crevices. Predicted impacts to these habitats are documented in Table 1.

Woodland and forest habitat types make up the majority of the study area. These habitat types which are not dependent on groundwater are unlikely to be impacted by subsidence. Microhabitat features such as tree hollows and exfoliating bark are also unlikely to be impacted.

The proposed longwall layout has been set back from major watercourses within the study area including Wongawilli Creek and Lake Cordeaux, and as such, subsidence impacts within these areas would be limited (MSEC 2021).

Watercourses that are directly mined beneath and those within the 35 degree angle of draw, are likely to have bedrock fracturing with associated impacts such as diversion of surface water flows, reduction of baseflows, loss of flow and/or draining of pooled water. In addition to hydrological impacts, secondary impacts on water quality, such as increased concentrations of iron and manganese precipitates and increased iron staining are likely to occur as a result of bedrock fracturing and increased groundwater input to the streams. The iron and manganese precipitates form an organic flocculant which decomposes and decreases dissolved oxygen, which may impact aquatic fauna and insects. Both such impacts (hydrological and water quality) may extend some distance downstream from the zone of fracturing, with the severity of impacts reducing with distance from the zone of fracturing as a result of dilution, particularly in partially groundwater-fed systems. Mapped watercourses within the 35 degree angle of draw study area are susceptible to subsidence impacts (both direct and indirect), however impacts are likely to be confined to features such as standing pools, which make up a small but important proportion of the overall watercourse.

Within the Dendrobium mining domain, the above-mentioned aquatic impacts are considered the most significant impact to fauna. In regard to terrestrial fauna, such impacts are of particular relevance to frog species including the threatened species Red-crowned Toadlet, Littlejohn's Tree Frog and Giant Burrowing Frog, which are discussed in detail in Section 6.5.

Impacts on cliff lines, rock outcrops and other rocky habitats within the study area are likely to be minor, as observed in previous mining areas. No large-scale cliff collapses or slope failures are predicted, though tension cracks may appear in steep slopes, resulting in erosion and requiring remediation. The rock outcrops located directly above the proposed longwall would experience fracturing and, where the rock is marginally stable, this could then result in instabilities. Previous experience shows percentage of cliffs/rock outcrops that experience adverse impacts is small, representing between 3 % and 5 % of the total surface area. Such impacts, while having some potential to alter available roosting or sheltering habitat for a range of species, have limited potential to harm or cause widespread mortality to species given the minimal occurrence of rock falls and collapses predicted, as well as the limited importance of any given area of such habitat (i.e. there is no one area considered to be particularly important for the survival of species within the study area, such as roosting bats).

6.5 Potential impacts to threatened fauna

A total of 68 threatened fauna were considered during the likelihood of occurrence assessment (Appendix 1). Thirty-nine of these species were determined to have a moderate or high likelihood of occurrence within the study area. Subsidence impacts from the proposed longwalls are likely to be negligible for the majority of these species. Nine threatened species are considered to be potentially impacted by subsidence impacts resulting from the proposal (Table 14).

Assessments of significance under the TSC Act were carried out for 30 threatened species during the project SIS, with significant impacts considered to potentially occur for six species comprising:

- Frogs: Littlejohn’s Tree Frog, Giant Burrowing Frog, Red-crowned Toadlet and Stuttering Frog;
- Reptiles: Broad-headed Snake; and
- Invertebrates: Giant Dragonfly.

The results of the assessments of significance are considered relevant to the proposed mining, with the exception of the Stuttering Frog. The Stuttering Frog is not likely to be present in the study area as it has not been recorded during the present study or during extensive survey programs targeting threatened frog species conducted in adjacent areas with the same habitats (Biosis 2020). The very few recent records of the Stuttering Frog located from the Sydney Basin and southwards have all been associated with large permanent streams lined by wet sclerophyll or rainforest vegetation that tends to form a dense enclosing canopy over the stream area. This habitat is very limited or absent from the study area and surrounds.

An assessment of potential impacts from the current proposal for each of the identified threatened species likely to be impacted is provided below in Table 14.

Table 14: Threatened fauna of the study area with moderate to high potential for impacts due to the proposal

Species	Recent records and habitat in study area	Potential impact to species or potential habitat in study area	Assessment of significance undertaken in SIS and result (Biosis 2007)	Current conservation and impact status
Amphibians				
Heleioporus australiacus Giant Burrowing Frog	Species has been recorded during SIS and subsequent monitoring surveys in DA3A and DA3B (Biosis 2020; Figure 7). Records are sporadic due to difficulty of detection. Previously recorded in study area (Bionet records, Figure 5). Not recorded during current survey but assumed to be present due to difficulty of detection.	Potential impacts include: changes to flow regimes, loss of surface flow and water retention within breeding pools. Changes in upland swamps are likely to impact the species via influencing downstream pool availability or permanency or through changes in sheltering habitat within swamps.	Yes. Significant impact determined.	Conservation listing status of species has not changed since original SIS. Habitat has been shown to be impacted during monitoring of subsidence impacts within DA3A and DA3B as predicted within SIS. Access constraints and detectability make it difficult to judge severity of impacts on population via monitoring. Impacts detected for Littlejohn's Tree Frog for permanent pools are likely relevant for Giant Burrowing Frog.
Litoria littlejohni Littlejohn's Tree Frog	Recorded throughout DA3 during SIS (Bionet records on Figure 5). Recorded within current study in several watercourses and downstream of upland swamps (Figure 5). Likely to be present in other watercourses throughout study area where appropriate breeding habitat is present. Within the study area, the species relies upon semi-permanent pools for tadpole development. Maturation times for tadpoles have been observed to take around four months (Anstis 2002), although this is variable in the field depending on factors such as weather. Pools of	Potential impacts include: changes to flow regimes, loss of surface flow and water retention within breeding pools. Changes in upland swamps are likely to impact the species via influencing downstream pool availability or permanency or through changes in sheltering habitat within swamps.	Yes. Significant impact determined.	Conservation listing status of species has not changed since original SIS. Habitat has been shown to be impacted during monitoring of subsidence impacts within DA3A and DA3B as predicted within SIS. Monitoring within DA3B indicates that abundance of species is likely to have declined due to subsidence impacts such as reduced water retention in pools (Biosis 2016). In 2016 a declining trend in Littlejohn's Tree Frogs was recorded at post-mining site WC17, with no tadpoles or egg masses recorded from 2014 – 2016 (Biosis 2019). However, in 2017 120 tadpoles were recorded at the site, indicating a return to pre-mining

Species	Recent records and habitat in study area	Potential impact to species or potential habitat in study area	Assessment of significance undertaken in SIS and result (Biosis 2007)	Current conservation and impact status
	sufficient depth and hydroperiod within the catchment area were almost exclusively located along second order or higher streams or else first order streams where headwater swamps are positioned upstream. Larger, faster flowing streams such as Wongawilli Creek are less likely to support breeding.			recruitment conditions (Biosis 2019). In 2018, no individuals at any life stage were recorded within the breeding pools. This is consistent with the trends observed at the control sites and was attributed to the dry conditions at the time of survey (Biosis 2019). The 2019 results recorded marked increase in detection of adult and tadpole life stages of Littlejohn's Tree Frog, but a decrease in the detection of egg mass, despite the relatively similar environmental conditions between the 2018 and 2019 (Biosis 2020). The 2021 monitoring program (Niche 2021) found that it is likely that mining is having an impact on frog reproduction due to decreased tadpole survivorship and a reduction in the extent of preferred habitats.
Pseudophryne australis Red-crowned Toadlet	Recorded during the SIS at five sites in DA3 including Upland Swamp 10, and a drainage line near Upland Swamp Den15b. Recorded in DA3B in 2011 surveys (Niche 2012) and during follow-up monitoring (e.g. Biosis 2016). Recorded in DA3C along WC20 in 2018 (Figure 5).	Given its habitat preferences appear to be largely dependent upon surface water runoff and seepage rather than groundwater and requirements for semi-permanent pools, it is considered that this species is less sensitive to impacts from subsidence in comparison with other species such as Littlejohn's Tree Frog. Nonetheless, changes in hydrology related to cracking of bedrock underlying streams providing habitat for the Red-crowned Toadlet have the potential to influence moisture levels and retention of moisture within small pools, soaks and leaf litter environments on which Red-	Yes. Significant impact determined.	Conservation listing status of species has not changed since original SIS. There has been limited monitoring to specifically assess impacts to Red-crowned Toadlet due to subsidence within the Dendrobium Area. Monitoring has focussed upon the Littlejohn's Tree Frog which is likely to be more prone to subsidence impacts and more effectively monitored due to a conspicuous, relatively lengthy tadpole phase. Impacts detected for Littlejohn's Tree Frog along smaller streams are likely relevant for Red-crowned Toadlet.

Species	Recent records and habitat in study area	Potential impact to species or potential habitat in study area	Assessment of significance undertaken in SIS and result (Biosis 2007)	Current conservation and impact status
		crowned Toadlets rely to complete their lifecycle. While some records of the species in the local area are adjacent to swamps, it is not considered that swamps play a particularly important role in providing appropriate breeding or sheltering habitat.		
Reptiles				
Hoplocephalus bungaroides Broad-headed Snake	Potential habitat includes ridgeline and creek lines. Vegetation communities include SGPF and ESSGW.	Impacts to any potential habitat is likely to be limited, based on previous observations of subsidence within adjacent mined areas and predictions of subsidence for the current proposal. That is, predictions of subsidence impacts such as rock-falls are limited in their extent (MSEC 2021). This factor, coupled with the requirement that subsidence would need to be coincident with sheltering habitat for the Broad-headed Snake which is quite limited, and that deleterious impacts would need to then result, leads to a prediction of minimal impacts for this species.	Yes. No significant impact determined.	Conservation listing status of species has not changed since original SIS. Limited monitoring has been done for this species. The species is difficult to detect and monitoring which includes lifting of preferred rock plates is potentially harmful to the species. It is not known if this species has been impacted by subsidence from mining within the Dendrobium Area, however given the limited extent of reported rock-falls, impacts are likely to be minimal and difficult to detect.
Varanus rosenbergi Rosenberg's Goanna	Previously recorded by Biosis (2007) within DA3. Potential habitat includes upland swamps, ridgelines and creek lines. Vegetation communities include: SGPF and upland swamp communities.	Potential impacts include death or injury resulting from rock fall or collapse. Impacts to any potential habitat is likely to be limited, based on previous observations of subsidence within adjacent mined areas and	Yes. No significant impact determined.	Conservation listing status of species has not changed since original SIS. Limited monitoring has been done for this species.

Species	Recent records and habitat in study area	Potential impact to species or potential habitat in study area	Assessment of significance undertaken in SIS and result (Biosis 2007)	Current conservation and impact status
		subsidence predictions for the current proposal. That is, predictions of subsidence impacts such as rock-falls are limited in their extent (MSEC 2021). This factor, coupled with the requirement that subsidence would need to be coincident with sheltering habitat for the Rosenberg's Goanna and that deleterious impacts would need to then result, leads to a prediction of minimal impacts for this species.		It is not known if this species has been impacted by subsidence from mining within the Dendrobium Area, however given the limited extent of reported rock-falls, impacts are likely to be minimal and difficult to detect.
Mammals				
Miniopterus orianae oceanensis Large Bent-winged Bat	Recorded in study area with probable certainty during the SIS. Previously recorded in DA3C study area (Bionet records in Figure 5). Potential habitat includes the entire study area, however only specific features likely to be impacted (such as caves).	Potential impacts include death or injury resulting from rock fall or collapse, possible changes in availability of breeding and roosting habitat. Maternity caves would not occur within the study area. If roosting occurs within the study area, it is unlikely to be widespread or significant. Minimal impacts (from subsidence of features such as cliffs and overhangs) are expected to occur given the limited propensity of roosting within the study area and the limited area of impact predicted to occur for possible roost habitats.	Yes. No significant impact determined.	Conservation listing status of species has not changed since original SIS. Monitoring has not been undertaken for this species. It is not known if this species has been impacted by subsidence from mining within the Dendrobium Area, however given the limited extent of reported rock-falls and cliff failures, impacts are likely to be minimal and difficult to detect.
Minipoterus australis	Recorded in study area with probable certainty during the SIS.	Potential impacts include death or injury as result of rock fall or collapse, possible changes in availability of breeding and roosting habitat.	Yes.	Conservation listing status of species has not changed since original SIS.

Species	Recent records and habitat in study area	Potential impact to species or potential habitat in study area	Assessment of significance undertaken in SIS and result (Biosis 2007)	Current conservation and impact status
Little Bent-wing Bat	Potential habitat includes the entire study area, however only specific features likely to be impacted (such as caves).		No significant impact determined.	Monitoring has not been undertaken for this species. It is not known if this species has been impacted by subsidence from mining within the Dendrobium Area, however given the limited extent of reported rock-falls and cliff failures, impacts are likely to be minimal and difficult to detect.
Myotis macropus Southern Myotis	Recorded in study area during the SIS. Previously recorded in DA3C study area (Bionet records in Figure 5). Potential foraging habitat includes larger watercourses with pools and standing water and adjacent vegetation. Roosting habitat includes hollow-bearing trees and caves.	Potential impacts include death or injury as result of rock fall or collapse and impacts on prey availability due to drying of pools.	Yes. No significant impact determined.	Conservation listing status of species has not changed since original SIS. Monitoring has not been undertaken for this species. It is not known if this species has been impacted by subsidence from mining within the Dendrobium Area, however given the limited extent of reported rock-falls and cliff failures, impacts are likely to be minimal and difficult to detect. Drying of pools may impact on prey availability, but this impact is considered likely to be minimal given that the larger watercourses in the study area (such as Wongawilli Creek) are unlikely to be impacted by Longwalls 22 and 23.
Invertebrates				
Petalura gigantea Giant Dragonfly	No previous record in the study area, however suitable habitat identified in Swamp Den07 (Invertebrate Identification Australasia 2019). No	Potential impacts include loss of upland swamp habitat as a result of subsidence. The critical factor governing the presence of *P. gigantea* is	Yes. Significant impact determined.	Conservation listing status of species has not changed since original SIS.

Species	Recent records and habitat in study area	Potential impact to species or potential habitat in study area	Assessment of significance undertaken in SIS and result (Biosis 2007)	Current conservation and impact status
	swamps within the study area have known sightings of the species (Invertebrate Identification Australasia 2019). It should be noted that the species has been confirmed within DA3B and 3A and adjacent to DA6. Potential habitat includes upland swamps. Swamps that were recorded as being suitable habitat for *P. gigantea* were those swamps that had a high groundwater level with permanent wet areas that could include active soaks/seepage zones, exposed pools and streams evident during the dry periods and a deep peat layer (Invertebrate Identification Australasia 2019). The swamps also usually contained characteristic saturated soil vegetation such as *Banksia robur*, *Melaleuca sp*, *Gahnia sp*. *Lomandra sp* and the pouched Coral Fern (*Gleichenia dicarpa*) (Invertebrate Identification Australasia 2019).	the permanent shallow groundwater level (Invertebrate Identification Australasia 2019). Once the groundwater level drops below the depth of the larval burrows (> 70cm) and the peat dries the habitat, potentially a population in a specific swamp is lost (Invertebrate Identification Australasia 2019).		Swamps with preferred breeding habitat for this species, based on the presence of moist swamp subcommunities (Den07 identified as suitable habitat within Invertebrate Identification Australasia 2019) occur within the angle of draw and may be impacted by subsidence as a result of Longwalls 22 and 23. Additional swamps with preferred foraging habitat (i.e. within 500 m of a swamp with breeding habitat) for this species occur within the angle of draw study area and the 600 m study area. Minimal impacts are expected to occur for foraging habitat within dryer swamp types.

7 Monitoring and recommendations

7.1 Existing monitoring and requirements

A terrestrial ecology monitoring program within Dendrobium began in 2003. Details of the current monitoring program for DA3B are contained in Biosis (2020) *Dendrobium Terrestrial Ecological Monitoring Program Annual Report for 2019*. Findings from each year of terrestrial ecology monitoring are reported in Annual Environmental Management Reports and End of Panel Reports.

Related monitoring programs include monitoring of abiotic parameters which are key predictors of biodiversity impacts, such as soil moisture, shallow groundwater levels and recharge rates, rainfall and temperature.

Prior to the proposed mining, a Swamp Impact Monitoring Management and Contingency Plan and Watercourse Impacts Monitoring Management and Contingency Plan is to be implemented to the satisfaction of the Secretary as per Schedule 3 Condition 6 of the Development Consent. It is to be prepared in consultation with BCD, WaterNSW and DPIE.

7.2 Recommendations for future monitoring

Terrestrial ecology monitoring for DA3C should continue to be based on existing methodologies within Biosis (2020) to ensure consistency of data capture to allow for ongoing comparisons with monitoring conducted to date. However, improvements and additions to these programs are recommended.

It is recommended the following be continued or included in the terrestrial ecology monitoring program for DA3C:

- Monitoring of upland swamps should continue to follow the methodology outlined in Biosis (2016).
- Visual comparison of photo point monitoring undertaken at each upland swamp site should continue from marked monitoring points.
- Mapping of upland swamp boundaries within DA3C should be refined prior to baseline surveys. Recent methods including the use of drones is likely to achieve better accuracy and consistency for mapping of swamp boundaries.
- Mapping of microhabitats such as pools along streams, as currently performed by IMC for DA3, should be extended to DA3C study area prior to baseline frog surveys.
- Frog monitoring in DA3C (and other areas) should include rainfall or hydrometric trigger values for surveys to allow for greater consistency between years which would aid in comparison of results (pre versus post mining and impact versus control). However, this may not be feasible given catchment closures after rain.
- A baseline survey focussed on tadpole survey for Littlejohn's Tree Frog and aural detection of Red-crowned Toadlet should be conducted after sufficient rainfall and within the appropriate season.
- Analysis of swamp monitoring data should incorporate any changes in piezometric levels at or near the swamps.
- Monitoring programs should continue to be based on BACI design.

- Swamp and watercourse monitoring should categorise impact sites based on their distance from longwalls, distinguishing between sites above longwalls, sites less than 60 m from longwalls and sites outside the 35 degree angle of draw.
- All remediation works that are undertaken near waterways, must take appropriate measures to minimise environmental impacts. This includes avoiding the spread of Chytrid Fungus following the NPWS guidelines.
- The implementation of mitigation measures should also be followed by monitoring to confirm the success or otherwise of any implemented measures.
- Methods should seek to identify any significant (e.g. greater than 10 mm) surface cracking within the study area so that monitoring and mitigation measures to minimise fauna entrapment (if identified as occurring) can be undertaken.

8 Conclusion

Impacts on features from subsidence caused by longwall mining within the Dendrobium domain are largely predictable given a particular longwall mine layout. This is evidenced through identification of reasonably consistent patterns during monitoring of subsidence impacts undertaken for DA2, DA3A and DA3B (e.g. MSEC 2021; Watershed HydroGeo 2019). Subsidence predictions for the proposed Longwalls 22 and 23 within DA3C are consistent with previous subsidence predictions for DA3 in their nature.

Monitoring of impacts to natural features such as swamps, watercourses and cliffs in DA3A and DA3B (e.g. Biosis 2016; HGEO 2017) supports past subsidence predictions. Monitoring results have highlighted a high likelihood of impact to watercourses and swamps through a reduced capacity for water recharge and permanency within the shallow groundwater table and within features such as pools along watercourses. Such impacts can be confidently predicted above and in close proximity to longwalls but become less apparent with distance from longwalls. For example, a recent review of monitoring (Watershed HydroGeo 2019) indicates that hydrographs from swamp piezometers within 60 m of longwalls at Dendrobium are likely to exhibit a mining effect and are almost certain to exhibit a mining effect when directly mined under, be that through a reduction in the water table to below pre-mining levels and/or increased recession (drainage) rate. Conversely, effects on swamp groundwater levels have not been observed at distances greater than 60 m from a longwall panel.

Where subsidence impacts do occur, deleterious effects to particular threatened species such as Littlejohn's Tree Frog have been highlighted as highly likely or definitive in some areas. However, clear patterns regarding the significance and severity of impacts to biodiversity values such as swamps and target threatened species have at times been difficult to illustrate confidently due to other impacts such as drought operating concurrently with subsidence impacts (e.g. Biosis 2016).

Review of the SIS predictions with regard to subsidence impacts on threatened biodiversity along with other relevant studies and surveys conducted as part of the current project support the findings of the *Dendrobium Area 3 Species Impact Statement* (Biosis 2007) with few departures. Since the SIS (2007), upland swamps of the study area have been listed as an EEC within NSW under the BC Act and nationally under the EPBC Act. In addition, whereas the original SIS highlighted significant impacts for the Stuttering Frog (on a precautionary basis) sufficient data now exists to assess with relatively high confidence that the species does not occur within the study area.

Fourteen upland swamps that meet the definition of the EEC listed under the BC Act and EPBC Act occur within the 600 m study area boundary. Approximately 4.54 ha of swamps within the study area may be impacted via subsidence from the proposal, as they occur within the groundwater impact zone (60 m buffer from longwall extent). In addition, habitats such as pools, along the watercourses within the 35 degree angle of draw study area, are likely to experience subsidence impacts (comprising both direct and indirect impacts). Subsidence impacts to features such as cliffs, overhangs and rocky outcrops have the potential to occur but are likely to have limited impacts on threatened biodiversity within the study area due to the small area of predicted impacts.

It is recommended that subsidence monitoring programs including biodiversity monitoring continue. Recommendations in regard to biodiversity monitoring have been included in Section 7.2 of this report.

9 References

Augee, M. L., & Ford, D. (1999). Radio-tracking studies of grey-headed flying-foxes, *Pteropus poliocephalus*, from the Gordon colony, Sydney. In Proceedings-Linnean Society of New South Wales (vol. 121, pp. 61-70). Linnean Society of New South Wales.

Allison, F. R., & Hoye, G. A. (1995). Eastern Freetail-bat. The Mammals of Australia, Reed New Holland, Sydney, 484-485.

Barker J., Clifford Grigg G. and Tyler M.J. (1995) 'A Field Guide to Australian Frogs.' Surrey Beatty and Sons, Sydney.

Biosis (2001a) Dendrobium Coal Project Species Impact Statement, Report for BHP Billiton, Biosis Pty Ltd.

Biosis (2001b) Dendrobium Coal Project: Terrestrial and Aquatic Habitat Assessment, Report for Olsen Environment and Consulting Pty Ltd, Biosis Pty Ltd.

Biosis (2001c) Dendrobium Coal Project: Likely Impacts of Subsidence on Terrestrial Ecology, Report for BHP Billiton, Biosis Pty Ltd.

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

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

Biosis (2007b) Dendrobium Area 2 Longwalls 3-5a Impacts of Subsidence on Terrestrial Flora and Fauna, Biosis Pty Ltd.

Biosis (2016) Dendrobium Terrestrial Ecological Monitoring Program Annual Report for 2015. Prepared for Illawarra Coal. Dated 6 May 2016.

Biosis (2017) Dendrobium Terrestrial Ecological Monitoring Program Annual Report for 2016. Prepared for Illawarra Coal.

Biosis (2018) Dendrobium Terrestrial Ecological Monitoring Program Annual Report for 2017. Prepared for Illawarra Coal.

Biosis (2019) Dendrobium Terrestrial Ecological Monitoring Program Annual Report for 2018. Prepared for Illawarra Coal. Dated 21 June 2019.

Biosis (2020) Dendrobium Terrestrial Ecological Monitoring Program Annual Report for 2019. Prepared for Illawarra Coal. Dated 8 July 2020.

Churchill, S. (1998). Australian bats. New Holland.

Cogger HG (1992) 'Reptiles and Amphibians of Australia.' Reed Books, Sydney.

Daly G (1996) Observations of the Eastern Owl Frog *Heleioporus australiacus* (Anura: Myobatrachidae) in Southern NSW. *Herpetofauna* 26, 33-42.

Debus S and Chafer C (1994a) The Powerful Owl *Ninox strenua* in New South Wales. Australian Birds 28, 21-39.

Debus S and Chafer C (1994b) The Sooty Owl, *Tyto tenebricosa* & Powerful Owl, *Ninox strenua* in NSW. Australian Birds 28 Supplement, 2.

DECC (2008) Hygiene protocol for the control of disease in frogs. Information Circular Number 6. Department of Environment and Climate Change (NSW), Sydney South.

DECCW (2011) Upland Swamp Environmental Assessment Guidelines, Guidance for the underground mining industry operating in the southern and western coalfields Draft Version: V0.9.

DoEE (2020) EPBC Act Protected Matters Report. Commonwealth Department of Energy and the Environment. Report created July 2020.

DOP (2008) Impacts of underground coal mining on natural features in the Southern Coalfield: strategic review. State of New South Wales through the NSW Department of Planning, 2008

DPIE (2020) BioNet Atlas, Department of Planning, Industry and Environment (DPIE), Goulburn St, Sydney. Accessed July 2020.

Forshaw JM and Cooper WT (1981) 'Australian Parrots (2nd Ed).' Lansdowne Press, Melbourne.

Gibbons, P., & Lindenmayer, D. B. (1997). Developing tree retention strategies for hollow-dependent arboreal marsupials in the wood production eucalypt forests of eastern Australia. *Australian Forestry*, 60(1), 29-45.

HGEO (2017) South32 - Illawarra Coal DENDROBIUM MINE End of Panel Surface Water and Shallow Groundwater Assessment: Longwall 12 (DA3B)

HGEO (2021) Illawarra Metallurgical Coal Dendrobium Mine, Assessment of surface water and shallow groundwater effects of proposed Longwall 22 & 23, Area 3C. June 2021.

Higgins PJ (1999) 'Handbook of Australian, New Zealand and Antarctic Birds. Oxford University Press, Melbourne. Higgins PJ and Davies SJJF (1996).

Higgins PJ and Peter JM (2002) 'Handbook of Australian, New Zealand & Antarctic Birds.

Hoye, G. A., & Richards, G. C. (1995) Greater broad-nosed bat *Scoteanax rueppellii*. The Mammals of Australia, 527-8.

Independent Expert Panel for Mining in the Catchment (IEPMC) (2019). 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.

Invertebrate Identification Australasia (2019) South 32 Illawarra Coal - Dendrobium Mine, Giant Dragonfly (*Petalura gigantea* Leach, 1815). Impact Assessment Project - Study 1, Progress Report 1. Dated 28 July, 2019.

Menkhorst, P. W., & Lumsden, L. F. (1995). Eastern False Pipistrelle. Mammals of Victoria, Oxford University Press, Melbourne.

MSEC (2021) Dendrobium – Longwalls 22 and 23 Subsidence Predictions and Impact Assessments for the Natural and Built Features due to the Extraction of the Proposed Longwalls 22 and 23 in Area 3C at Dendrobium Mine. March 2021. Revision A. Report Number MSEC1104.

Niche (2012). Dendrobium Area 3B Terrestrial Ecological Assessment: Accompanying Document to the Dendrobium Area 3B Subsidence Management Plan.

Niche (2019a) Dendrobium Longwalls 20-21 Terrestrial Ecological Assessment. Accompanying document to Dendrobium Longwalls 20-21 Subsidence Management Plan. Prepared for South32 Illawarra Coal. Dated 16 August 2019.

Niche (2019b) Dendrobium Mine – Plan for the Future: Coal for Steelmaking, Biodiversity Assessment Report. Prepared for Illawarra Coal Holdings Pty Ltd (Illawarra Coal) – South32 Limited. Dated May 2019.

Niche (2020a) Dendrobium Longwall 18 Terrestrial Ecological Assessment. Accompanying document to Dendrobium Longwall 18 Subsidence Management Plan. Prepared for South32 Illawarra Metallurgical Coal. Dated 12 August 2020.

Niche (2020b) Dendrobium Longwall 19 Terrestrial Ecological Assessment. Accompanying document to Dendrobium Longwall 19 Subsidence Management Plan. Prepared for South32 Illawarra Coal. Dated 11 March 2020.

Niche (2021) Dendrobium Areas 3A and 3B: Terrestrial Ecology Monitoring Program. Annual Report 2020. Prepared for South32 Illawarra Metallurgical Coal. Dated 29 April 2021.

NPWS (2003) Native Vegetation of the Woronora, O'Hares and Metropolitan Catchments. Conservation Assessment and Data Unit Central Conservation Programs and Planning Division.

NSW Department of Planning (DOP) (2008). Impacts of underground coal mining on natural features in the Southern coalfield: strategic review., NSW Department of Planning, Sydney, NSW Australia.

NSW Scientific Committee (2005), Final Determination Alteration of habitat following subsidence due to Longwall mining: http://www.environment.nsw.gov.au/determinations/LongwallMiningKtp.htm. last updated Feb 2011.

NSW Scientific Committee (2012) Coastal Upland Swamp in the Sydney Basin Bioregion - endangered ecological community listing. Proposed Gazettal date: 09/03/12.

Phillips, W. (1995). Eastern False Pipistrelle *Falsistrellus tasmaniensis*. The Mammals of Australia, 520-1.

Pizzey G and Knight F (1997) 'The Field Guide to the Birds of Australia.' Angus and Robertson, Sydney.

Recsei J (1996) Eastern Owl Frog, *Heleioporus australiacus*. Pp. 55-64 In 'Threatened Frogs of New South Wales: Habitats, Status and Conservation.' (Ed. H Ehmann). Frog and Tadpole Study Group of NSW, Sydney South.

Shields J and Crome F (1992) 'Parrots and Pigeons of Australia.' Angus and Robertson, Sydney.

Thumm K and Mahony M (1997) Red-crowned Toadlet *Pseudophryne australis*. Pp. 125-135 In 'Threatened Frogs of New South Wales: Habitats, Status and Conservation' (Ed. H Ehmann). Frog and Tadpole Study Group of NSW, Sydney South.

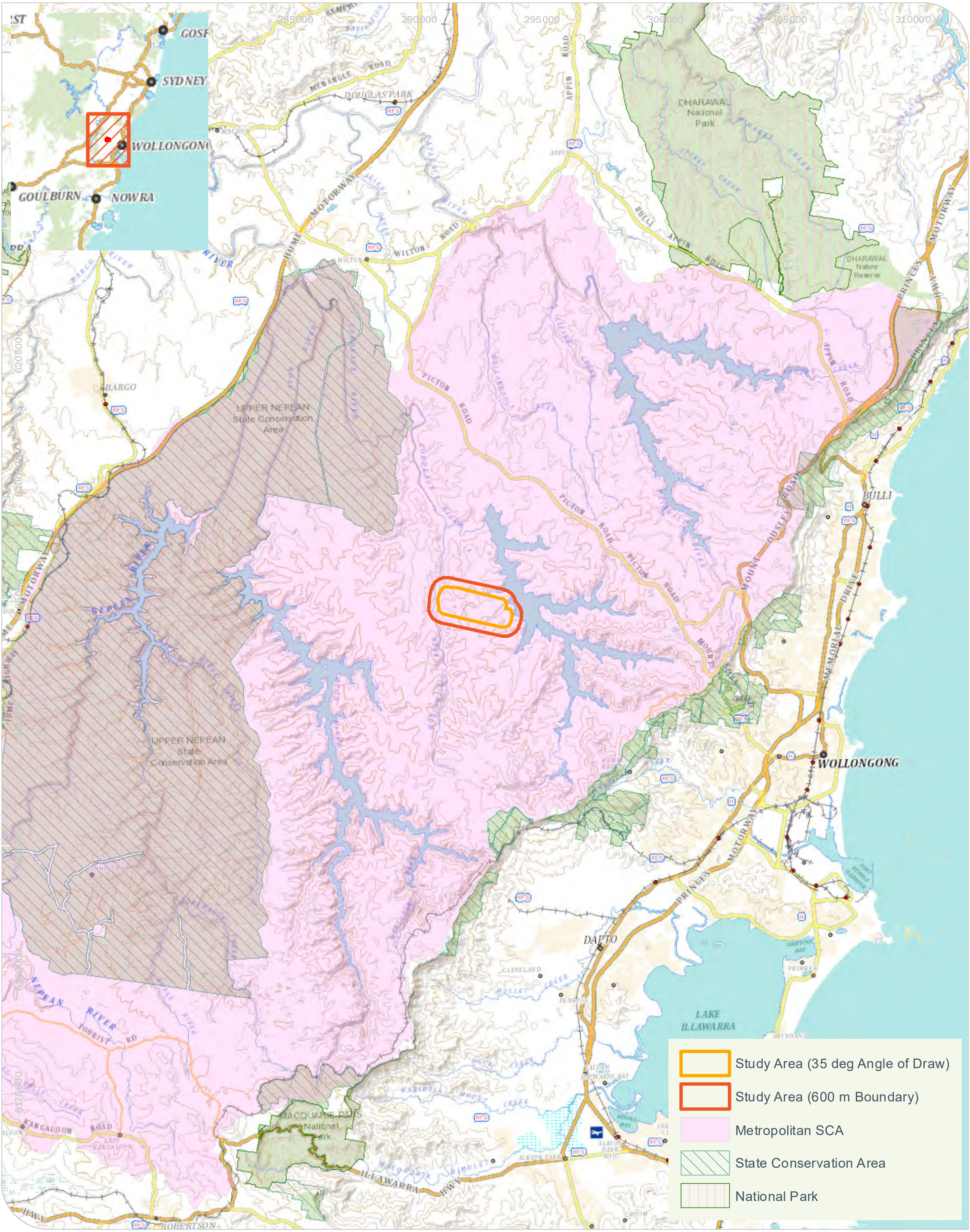
Turner V and Ward SJ (1995) Eastern Pygmy-possum. Pp. 217-218 In 'The Mammals of Australia' (Ed. R Strahan). Reed New Holland, Sydney.

Watershed HydroGeo (2019). Dendrobium Mine Geographic review of mining effects on Upland Swamps at Dendrobium Mine. Unpublished Report for Illawarra Coal.

Webb JK and Shine R (1998) Ecological characteristic of an endangered snake species *Hoplocephalus bungeroides* (Sepentes: Elapidae). Animal Conservation 1, 185-193.

Figures

Figure 1: Location Map



0 4 km

GDA 1994 MGA Zone 56

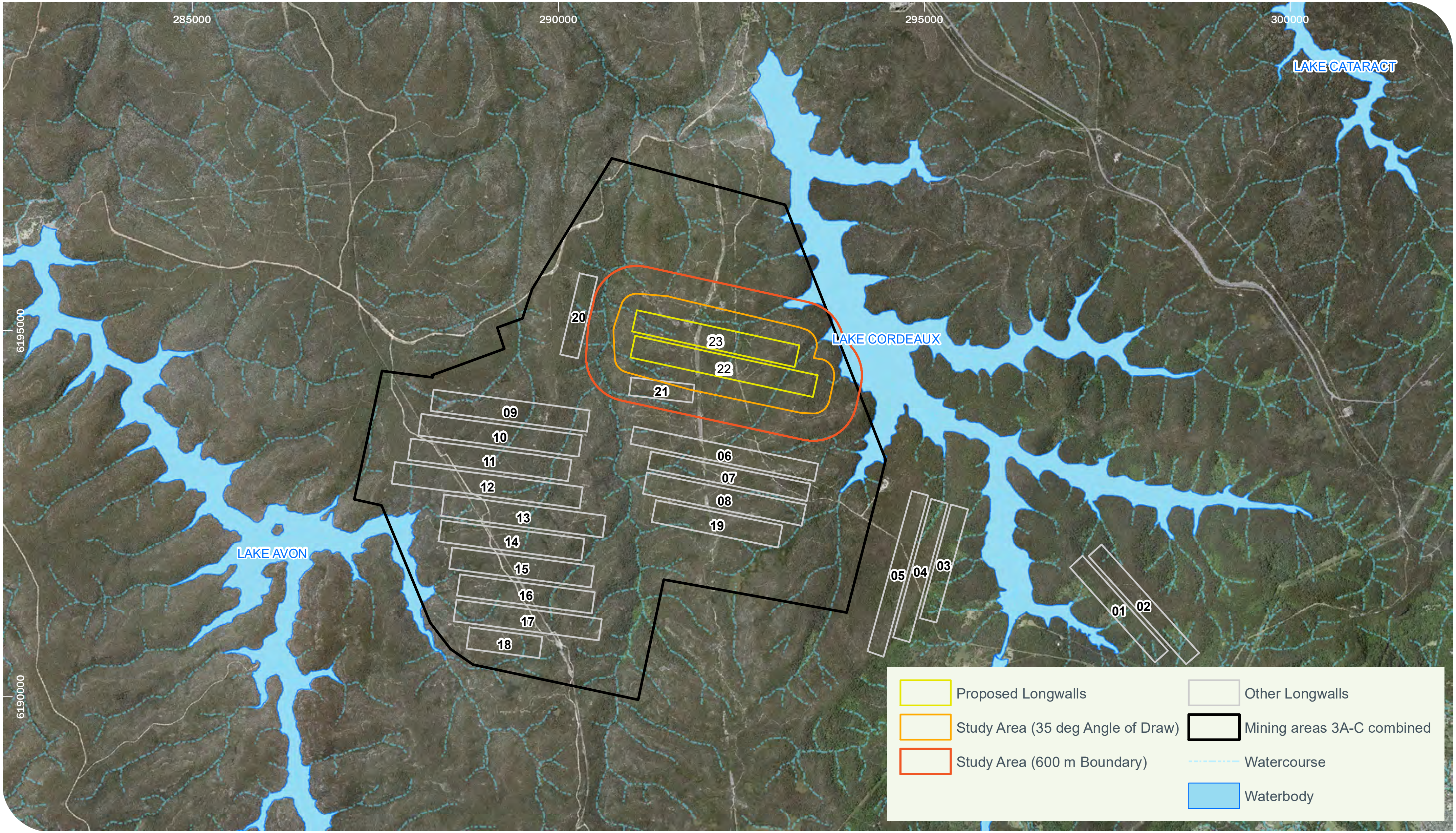
Location Map

Dendrobium Area 3A Longwall 22, 23 - Terrestrial Flora and Fauna Assessment

Niche PM: Sian Griffiths
Niche Proj. #: 5804
Client: South32 Illawarra Metallurgical Coal

Figure 1

Figure 2: Site Map



Environment and Heritage

0 1,000
m
GDA 1994 MGA Zone 56

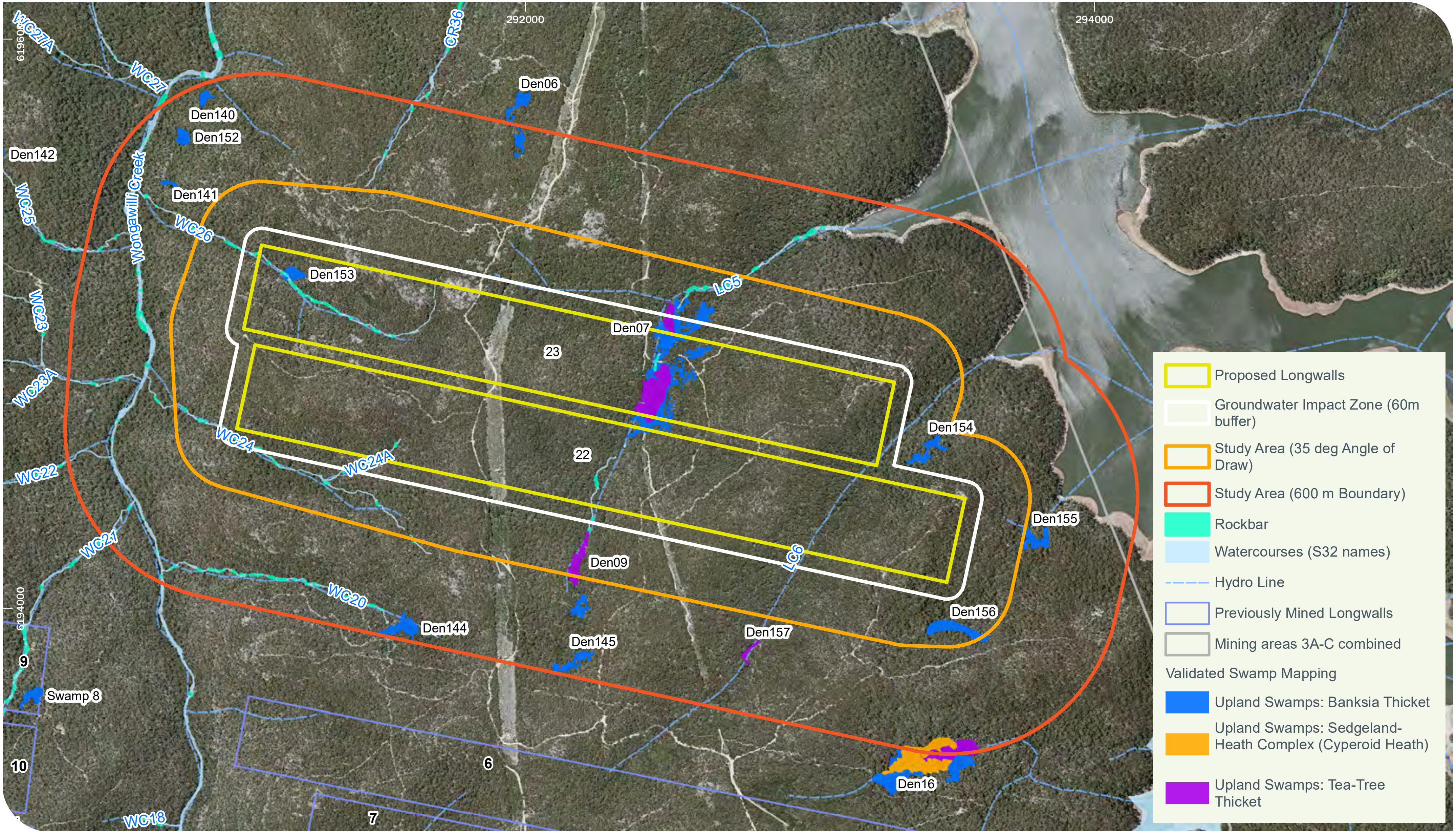
Site map

Dendrobium Area 3A Longwall 22, 23 - Terrestrial Flora and Fauna Assessment

Niche PM: Sian Griffiths
Niche Proj. #: 5804
Client: South32 Illawarra Metallurgical Coal

Figure 2

Figure 3: Watercourses and Confirmed Swamps within the Study Area and Surround



niche Environment and Heritage

N
0 300
m
GDA 1994 MGA Zone 56

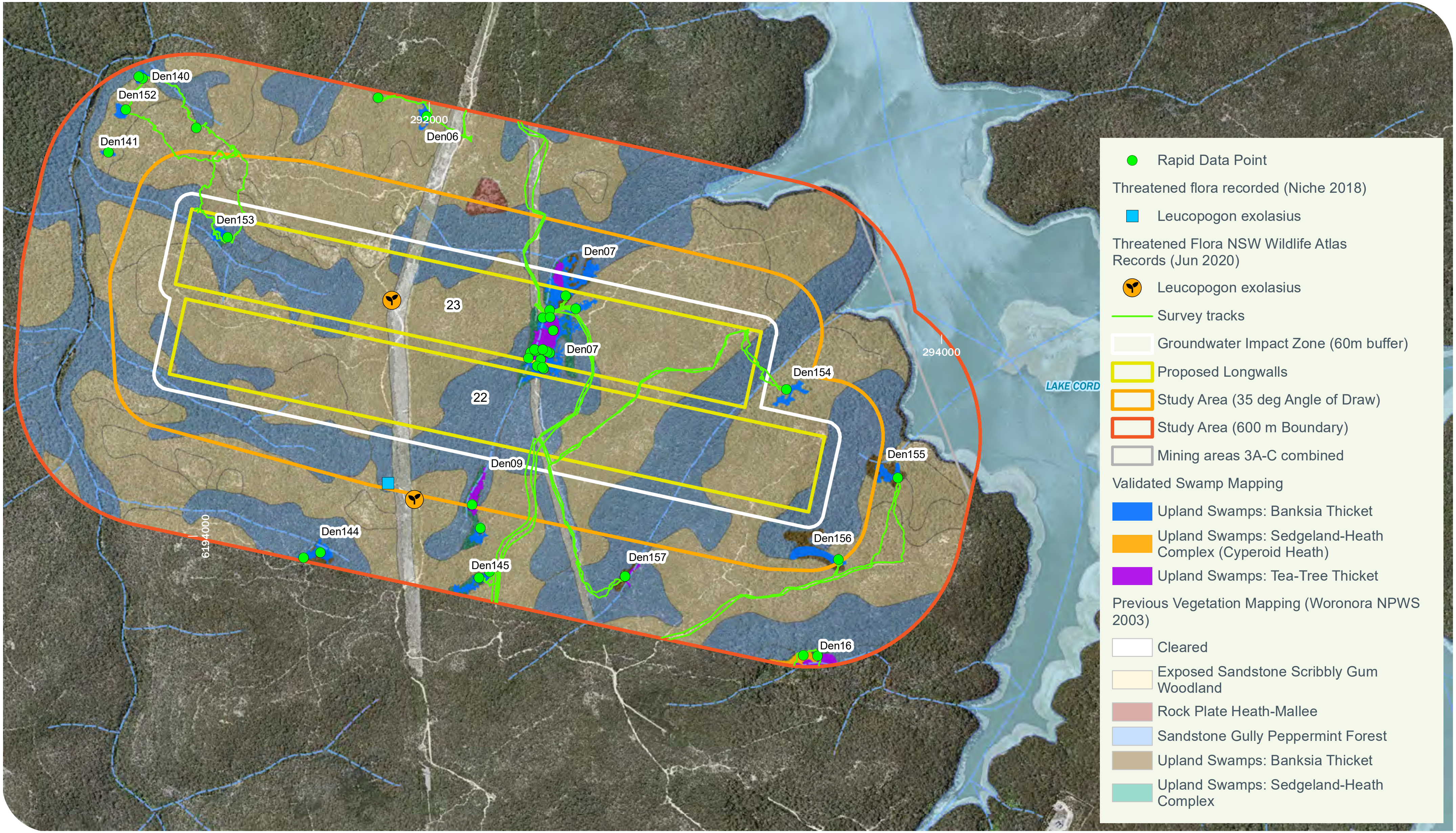
Watercourses and Confirmed Swamps within the Study Area and Surrounds

Dendrobium Area 3A Longwall 22, 23 - Terrestrial Flora and Fauna Assessment

Niche PM: Sian Griffiths
Niche Proj. #: 5804
Client: South32 Illawarra Metallurgical Coal

Figure 3

Figure 4: Flora Survey Effort, Vegetation Mapping and Threatened Flora Records



Drawn by: GT/YH Last updated: 8/20/2021 10:16:53 AM File: T:\spatial\projects\a5800\a5804_Dendrobium_LW22_23_FFA\Maps\report\LW22_23_FFA\5804_Figure_4_Rev_01_Flora.mxd

niche Environment and Heritage

N

0 400

m

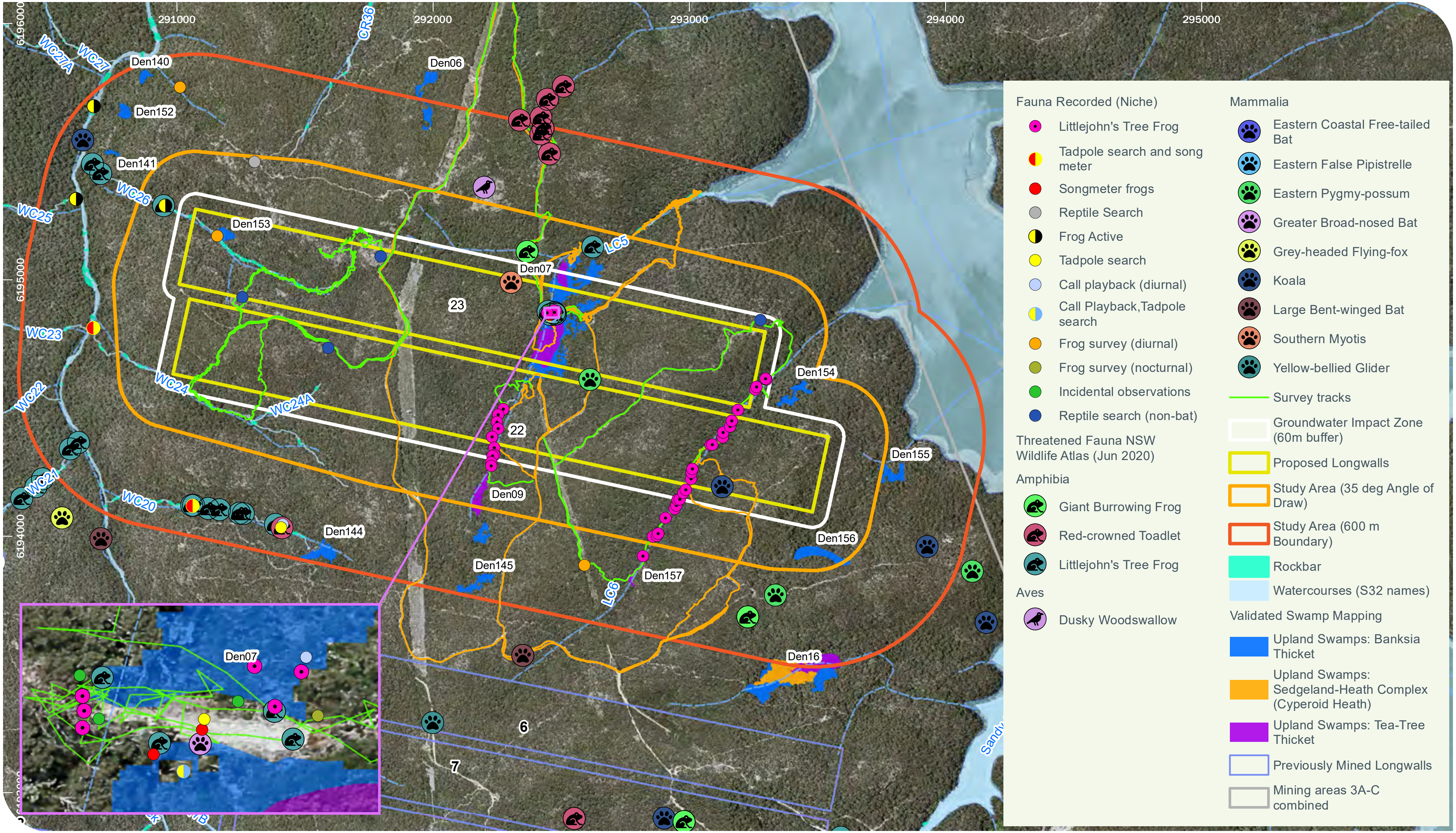
GDA 1994 MGA Zone 56

Flora Survey Effort, Results and Threatened Flora Records
Dendrobium Area 3A Longwall 22, 23 - Terrestrial Flora and Fauna Assessment

Niche PM: Sian Griffiths
Niche Proj. #: 5804
Client: South32 Illawarra Metallurgical Coal

Figure 4

Figure 5: Fauna Survey Effort, Results and Threatened Fauna Records



Drawn by: GT/YH Last updated: 8/20/2021 10:42:01 AM File: T:\spatial\projects\a5800\a5804_Dendrobium_LW22_23_FFA\Maps\report\LW22_23_FFA\5804_Figure_5_Rev_01_Fauna.mxd

niche Environment and Heritage

0 400
m
GDA 1994 MGA Zone 56

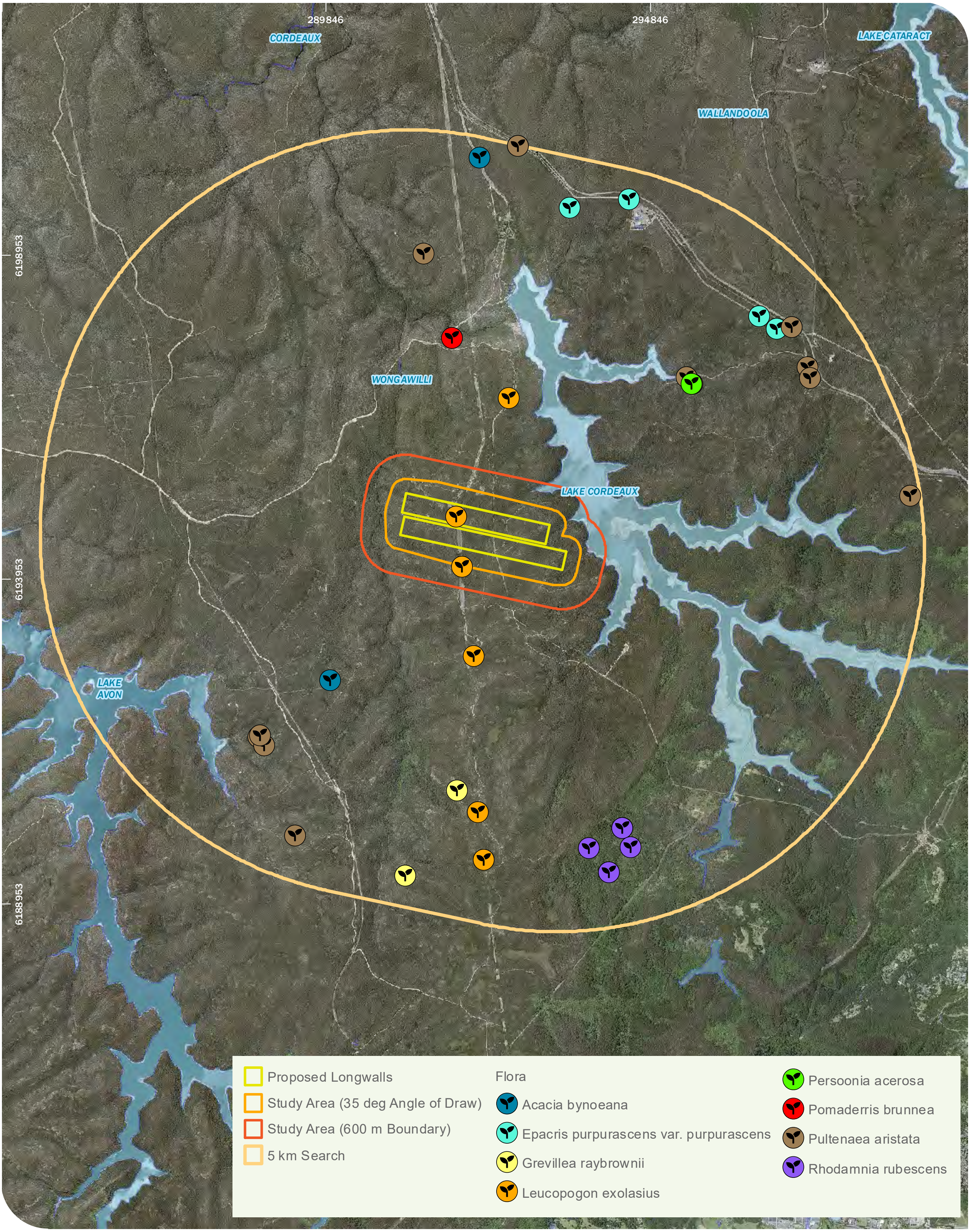
Fauna Survey Effort, Results and Threatened Fauna Records

Dendrobium Area 3A Longwall 22, 23 - Terrestrial Flora and Fauna Assessment

Niche PM: Sian Griffiths
Niche Proj. #: 5804
Client: South32 Illawarra Metallurgical Coal

Figure 5

Figure 6: NSW Bionet Atlas Threatened Species 5km Search - Flora



0 1,000

m

GDA 1994 MGA Zone 56

NSW Bionet Atlas Threatened Species 5km Search – Flora

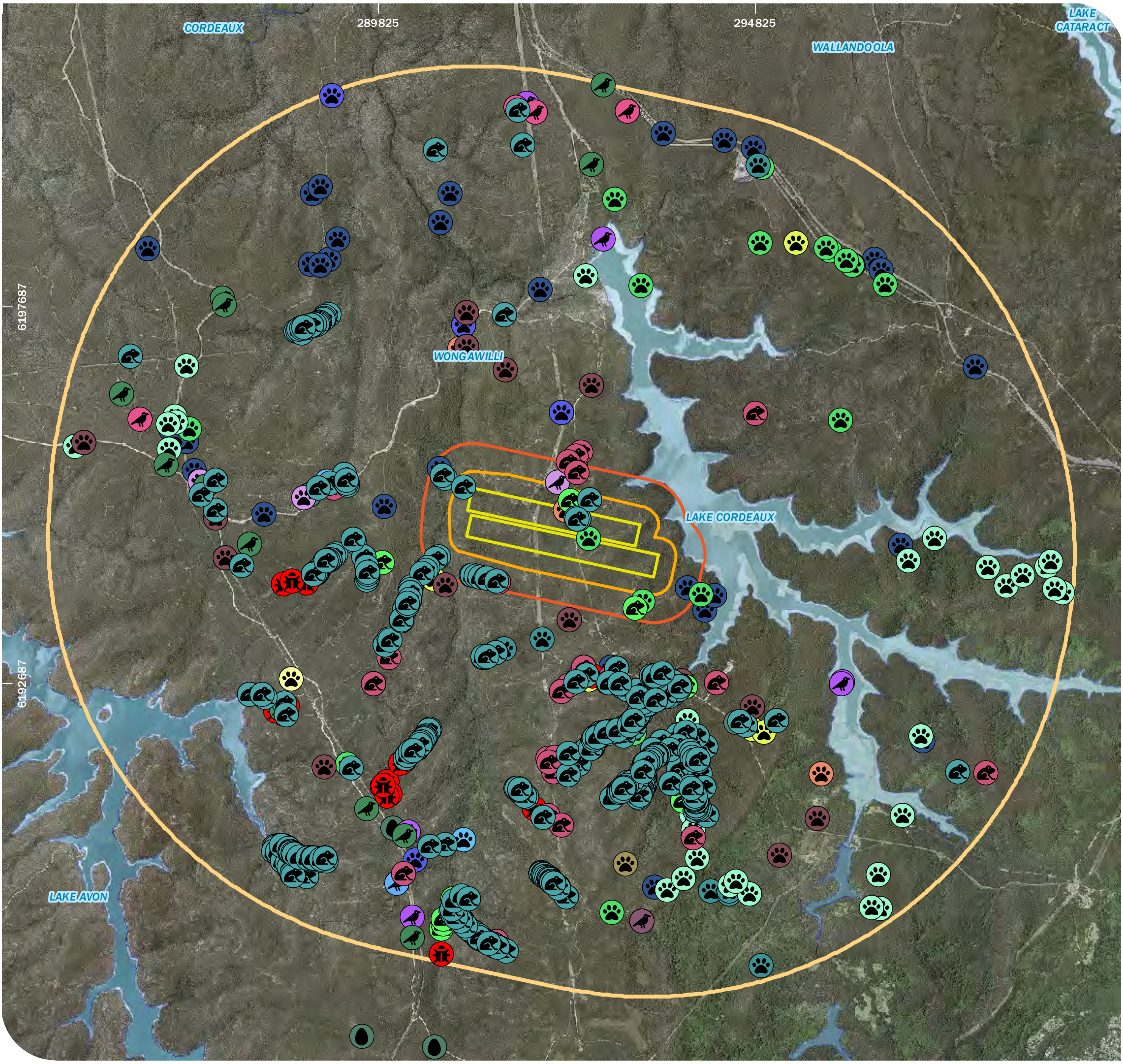
Dendrobium Area 3A Longwall 22, 23 - Terrestrial Flora and Fauna Assessment

Niche PM: Sian Griffiths
Niche Proj. #: 5804
Client: South32 Illawarra Metallurgical Coal

Figure 6

NSW Office of Environment and Heritage's BioNet Atlas, which holds the data from a number of custodians. Data Obtained 05/06/2020.

Figure 7: NSW Bionet Atlas Threatened Species 5km Search - Fauna



Threatened Fauna NSW Wildlife Atlas (Jun 2020)

- Giant Burrowing Frog
- Littlejohn's Tree Frog
- Red-crowned Toadlet

Aves

- Black Bittern
- Dusky Woodswallow
- Eastern Curlew
- Flame Robin
- Freckled Duck
- Little Eagle
- Little Lorikeet
- Scarlet Robin
- Varied Sittella
- White-bellied Sea-Eagle
- White-fronted Chat
- White-throated Needletail

Insecta

- Giant Dragonfly

Mammalia

- Brush-tailed Rock-wallaby
- Eastern Coastal Free-tailed Bat
- Eastern False Pipistrelle
- Eastern Pygmy-possum
- Golden-tipped Bat
- Greater Broad-nosed Bat
- Greater Glider
- Grey-headed Flying-fox
- Koala
- Large Bent-winged Bat
- Large-eared Pied Bat
- Little Bent-winged Bat
- Southern Brown Bandicoot (eastern)
- Southern Myotis
- Yellow-bellied Glider
- Yellow-bellied Sheathtail-bat

Reptilia

- Rosenberg's Goanna
- Proposed Longwalls
- Study Area (35 deg Angle of Draw)
- Study Area (600 m Boundary)
- 5 km Search

Drawn by: YH File: T:\spatial\projects\a5800\a5804_Dendrobium_LW22_23_FFA\Maps\report\LW22_23_FFA5804_Figure_7_ThreatenedFauna.mxd Last updated: 17-Mar-21 7:03:46 PM

niche Environment and Heritage

0 1,000
m
GDA 1994 MGA Zone 56

NSW Bionet Atlas Threatened Species 5km Search – Fauna

Dendrobium Area 3A Longwall 22, 23 - Terrestrial Flora and Fauna Assessment

Niche PM: Sian Griffiths
Niche Proj. #: 5804
Client: South32 Illawarra Metallurgical Coal

Figure 7

NSW Office of Environment and Heritage's BioNet Atlas, which holds the data from a number of custodians. Data Obtained 05/06/2020.

v2.0

Appendices

Appendix 1: Threatened species likelihood of occurrence tables

Scientific Name	Common Name	BC Act	EPBC Act	Habitat	Likelihood of Occurrence	Potential for Impact
Amphibians						
Heleioporus australiacus	Giant Burrowing Frog	V	V	Prefers hanging swamps on sandstone shelves adjacent to perennial non-flooding creeks (Daly 1996, Recsei 1996). Can also occur within shale outcrops within sandstone formations. In the southern part of its range can occur in wet and dry forests, montane sclerophyll woodland and montane riparian woodland (Daly 1996). Individuals can be found around sandy creek banks or foraging along ridge-tops during or directly after heavy rain. Males often call from burrows located in sandy banks next to water (Barker et. al.1995).	High. Previous records in study area in Bionet Atlas.	High
Litoria aurea	Green and Golden Bell Frog	E	V	Inhabits marshes, dams and stream-sides, particularly those containing bullrushes (Typha spp.) or spikerushes (Eleocharis spp.). Optimum habitat includes water-bodies that are un-shaded, free of predatory fish such as Plague Minnow (*Gambusia holbrooki*), have a grassy area nearby and diurnal sheltering sites available.	None	None
Litoria littlejohni	Littlejohn's Tree Frog	V	V	Occurs in wet and dry sclerophyll forests associated with sandstone outcrops between 280 and 1000 m on the eastern slopes of the Great Dividing Range (Barker et. al. 1995). Prefers rock flowing streams, but individuals have also been collected from semi-permanent dams with some emergent vegetation (Barker et. al.1995). Forages both in the tree canopy and on the ground, and has been observed sheltering under rocks on high exposed ridges during summer. It is not known from coastal habitats.	Known. Recorded during current survey and previously recorded in the study area.	High
Pseudophryne australis	Red-crowned Toadlet	V	-	Occurs on wetter ridge tops and upper slopes of sandstone formations on which the predominant vegetation is dry open forests and heaths. This species typically breeds within small ephemeral creeks that feed into larger semi-perennial streams. After rainfall these creeks are characterised by a series of shallow pools lined by dense grasses, ferns and low shrubs (Thumm & Mahony 1997).	High. Previous records in study area in Bionet Atlas.	High
Mixophyes balbus	Stuttering Frog	E	V	This species is usually associated with mountain streams, wet mountain forests and rainforests (Barker et. al.1995). It rarely wanders very far from the banks of permanent forest streams, although it will forage on nearby forest floors. Eggs are deposited in leaf litter on the banks of streams and are washed into the water during heavy rains (Barker et. al.1995).	Low	Low

Scientific Name	Common Name	BC Act	EPBC Act	Habitat	Likelihood of Occurrence	Potential for Impact
Birds						
Anthochaera phrygia	Regent Honeyeater	CE	CE	The Regent Honeyeater mainly inhabits temperate woodlands and open forests of the inland slopes of south-east Australia. Birds are also found in drier coastal woodlands and forests in some years. has contracted dramatically in the last 30 years to between north-eastern Victoria and south-eastern Queensland. There are only three known key breeding regions remaining: north-east Victoria (Chiltern-Albury), and in NSW at Capertee Valley and the Bundarra-Barraba region. In NSW the distribution is very patchy and mainly confined to the two main breeding areas and surrounding fragmented woodlands. In some years flocks converge on flowering coastal woodlands and forests.	Moderate	Low
Apus pacificus	Fork tailed Swift	-	M	The Fork-tailed Swift is almost exclusively aerial, flying from less than 1 m to at least 300 m above ground and probably much higher.	Low- overfly habitat only.	Low
Ardea alba	Great Egret	-	M	Great Egrets prefer shallow water, particularly when flowing, but may be seen on any watered area, including damp grasslands.	Low	Low
Ardea ibis	Cattle Egret	-	M	The Cattle Egret is found in grasslands, woodlands and wetlands, and is not common in arid areas. It also uses pastures and croplands, especially where drainage is poor.	Low	Low
Artamus cyanopterus cyanopterus	Dusky Woodswallow	V	-	Often reported in woodlands and dry open sclerophyll forests, usually dominated by eucalypts, including mallee associations. It has also been recorded in shrublands and heathlands and various modified habitats, including regenerating forests; very occasionally in moist forests or rainforests.	High. Previous records in study area in Bionet Atlas.	Low
Botaurus poiciloptilus	Australasian Bittern	E	E	The Australasian Bitterns is widespread but uncommon over south-eastern Australia. In NSW they may be found over most of the state except for the far north-west. Favours permanent freshwater wetlands with tall, dense vegetation, particularly bullrushes (Typha spp.) and spikerushes (Eleoacharis spp.).	Low	Low
Callocephalon fimbriatum	Gang-gang Cockatoo	V	-	In summer, occupies tall montane forests and woodlands, particularly in heavily timbered and mature wet sclerophyll forests (Higgins 1999). Also occur in subalpine Snow Gum woodland and occasionally in temperate or regenerating forest (Forshaw & Cooper 1981). In winter, occurs at lower altitudes in drier, more open eucalypt forests and woodlands, particularly in	High	Low

Scientific Name	Common Name	BC Act	EPBC Act	Habitat	Likelihood of Occurrence	Potential for Impact
				box-ironbark assemblages, or in dry forest in coastal areas (Shields & Crome 1992). It requires tree hollows in which to breed (Gibbons & Lindenmayer 1997).		
Calyptorhynchus lathami	Glossy Black-Cockatoo	V	-	Inhabits forest with low nutrients, characteristically with key Allocasuarina spp. Tends to prefer drier forest types (NPWS 1999) with a middle stratum of Allocasuarina below Eucalyptus or Angophora. Often confined to remnant patches in hills and gullies (Higgins 1999). Breed in hollows stumps or limbs, either living or dead.	High	Low
Chrysococcyx osculans	Black-eared Cuckoo		M	The Black-eared Cuckoo is widespread on mainland Australia, but avoids the wet, heavily forested areas on the east coast and the south-west corner of Western Australia. The Black-eared Cuckoo is found in drier country where species such as mulga and mallee form open woodlands and shrublands. It is often found in vegetation along creek beds.	Low	Low
Cuculus optatus, Cuculus saturatus	Oriental Cuckoo	-	M, MA	Mainly inhabits coniferous, deciduous and mixed forests. Breeds in northern hemisphere. Brood parasite, laying eggs in nests of other birds.	Low	Low
Daphoenositta chrysoptera	Varied Sittella	V	-	Inhabits wide variety of dry eucalypt forests and woodlands, usually with either shrubby under storey or grassy ground cover or both, in all climatic zones of Australia (Higgins and Peter 2002). Usually in areas with rough-barked trees, such as stringybarks or ironbarks, but also in paperbarks or mature Eucalypts with hollows.	High	Low
Dasyornis brachypterus	Eastern Bristlebird	E	E	Found in coastal woodlands, dense scrub and heathlands, particularly where it borders taller woodlands (Pizzey and Knight 1997).	Low	Low
Epthianura albifrons	White-fronted Chat	V	-	Low vegetation in salty coastal and inland areas and crops. Runs along ground and is found in local flocks in Winter.	Low	Low
Falco hypoleucos	Grey Falcon	E	-	Usually restricted to shrubland, grassland and wooded watercourses of arid and semi-arid regions, although it is occasionally found in open woodlands near the coast. Also occurs near wetlands where surface water attracts prey.	Low	Low
Gallinago hardwickii	Latham's Snipe	-	M	Latham's Snipe is a non-breeding migrant to the south east of Australia including Tasmania, passing through the north and New Guinea on passage. Latham's Snipe breed in Japan and on the east Asian mainland. seen in small groups or singly in freshwater wetlands on or near the coast, generally among dense cover. They are found in any vegetation around wetlands, in sedges,	Low	Low

Scientific Name	Common Name	BC Act	EPBC Act	Habitat	Likelihood of Occurrence	Potential for Impact
				grasses, lignum, reeds and rushes and also in saltmarsh and creek edges on migration.		
Grantiella picta	Painted Honeyeater	V	V	Inhabits Boree/ Weeping Myall (*Acacia pendula*), Brigalow (*A. harpophylla*) and Box-Gum Woodlands and Box-Ironbark Forests. A specialist feeder on the fruits of mistletoes growing on woodland eucalypts and acacias. Prefers mistletoes of the genus Amyema.	Low	Low
Haliaeetus leucogaster	White-bellied Sea-Eagle	V	MA	Inhabits coastal and near coastal areas, building large stick nests, and feeding mostly on marine and estuarine fish and aquatic fauna.	Low	Low
Hieraaetus morphnoides	Little Eagle	V	-	Most abundant in lightly timbered areas with open areas nearby. Often recorded foraging in grasslands, crops, treeless dune fields, and recently logged areas. May nest in farmland, woodland and forest in tall trees.	High.	Low
Thinornis rubricollis	Hooded Plover	CE	V, MA	The Hooded Plover occurs on sandy beaches and inland saltlakes of south-eastern and south-western Australia. Within NSW, the Hooded Plover occurs along the southern coast, north to Jervis Bay. In souther-eastern Australian, the Hooded Plover is found mostly on long stretches of sandy shore, backed by tussock and creeper covered dunes with nearby inland lakes.	Low	Low
Hirundapus caudacutus	White-throated Needletail	-	V	An aerial species found in feeding concentrations over cities, hilltops and timbered ranges.	Low - overfly habitat only.	Low
Ixobrychus flavicollis	Black Bittern	V	-	Usually found on coastal plains below 200 m. Often found along timbered watercourses, in wetlands with fringing trees and shrub vegetation. The sites where they occur are characterized by dense waterside vegetation.	Moderate	Low
Lathamus discolor	Swift Parrot	E	CE	The Swift Parrot occurs in woodlands and forests of NSW from May to August, where it feeds on eucalypt nectar, pollen and associated insects. The Swift Parrot is dependent on flowering resources across a wide range of habitats in its wintering grounds in NSW. This species is migratory, breeding in Tasmania and also nomadic, moving about in response to changing food availability.	High	Low
lossopsitta pusilla	Little Lorikeet	V	-	Distributed in forests and woodlands from the coast to the western slopes of the Great Dividing Range in NSW, extending westwards to the vicinity of Albury, Parkes, Dubbo and Narrabri. Mostly occur in dry, open eucalypt forests and woodlands. They feed primarily on nectar and pollen in the tree canopy. Nest hollows are located at heights of between 2 m and 15 m, mostly	Moderate	Low

Scientific Name	Common Name	BC Act	EPBC Act	Habitat	Likelihood of Occurrence	Potential for Impact
				in living, smooth-barked eucalypts. Most breeding records come from the western slopes.		
Merops ornatus	Rainbow bee-eater	-	M	Found throughout mainland Australia most often in open forests, woodlands and shrublands, and cleared areas, usually near water. It will be found on farmland with remnant vegetation and in orchards and vineyards. It will use disturbed sites such as quarries, cuttings and mines to build its nesting tunnels.	Low	Low
Monarcha melanopsis	Black-faced Monarch	-	M	A migratory species found during the breeding season in damp gullies in temperate rainforests. Disperses after breeding into more open woodland (Pizzey & Knight 1997).	Moderate	Low
Monarcha trivirgatus	Spectacled Monarch	-	M	Coastal north-eastern and eastern Australia, including coastal islands, from Cape York, Queensland to Port Stephens, New South Wales. Prefers thick understorey in rainforests, wet gullies and waterside vegetation, as well as mangroves.	Moderate	Low
Motacilla flava	Yellow Wagtail	-	M	Breeds in temperate Europe and Asia. The Yellow Wagtail is a regular wet season visitor to northern Australia. Increasing records in NSW suggest this species is an occasional but regular summer visitor to the Hunter River region. The species is considered a vagrant to Victoria, South Australia and southern Western Australia. Habitat requirements for the Yellow Wagtail are highly variable, but typically include open grassy flats near water. Habitats include open areas with low vegetation such as grasslands, airstrips, pastures, sports fields; damp open areas such as muddy or grassy edges of wetlands, rivers, irrigated farmland, dams, waterholes; sewage farms, sometimes utilise tidal mudflats and edges of mangroves.	Low	Low
Myiagra cyanoleuca	Satin Flycatcher	-	M	Migratory species that occurs in coastal forests, woodlands and scrubs during migration. Breeds in heavily vegetated gullies (Pizzey & Knight 1997).	High	Low
Neophema chrysogaster	Orange-bellied Parrot	CE	CE, M	The Orange-bellied Parrot breeds in the south-west of Tasmania and migrates in autumn to spend the winter on the mainland coast of south-eastern South Australia and southern Victoria. There are occasional reports from NSW, with the most recent records from Shellharbour and Maroubra in May 2003. NSW habitats may be more frequently utilised than observations suggest. Typical winter habitat is saltmarsh and strandline-foredune vegetation communities either on coastlines or coastal lagoons. Spits and islands are favoured but they will turn up anywhere within these coastal regions. The species can be found	Low	Low

Scientific Name	Common Name	BC Act	EPBC Act	Habitat	Likelihood of Occurrence	Potential for Impact
				foraging in weedy areas associated with these coastal habitats or even in totally modified landscapes such as pastures, seed crops and golf courses.		
Ninox connivens	Barking Owl	V	-	Generally found in open forests, woodlands, swamp woodlands and dense scrub. Can also be found in the foothills and timber along watercourses in otherwise open country (Pizzey & Knight 1997).	Moderate	Low
Ninox strenua	Powerful Owl	V	-	Occupies wet and dry eucalypt forests and rainforests. Can occupy both un-logged and lightly logged forests as well as undisturbed forests where it usually roosts on the limbs of dense trees in gully areas. It is most commonly recorded within Red Turpentine in tall open forests and Black She-oak within open forests (Debus 1994a;Debus 1994b). Large mature trees with hollows at least 0.5 m deep are required for nesting (Garnett, 1992). Tree hollows are particularly important for the Powerful Owl because a large proportion of the diet is made up of hollow-dependent arboreal marsupials (Gibbons & Lindenmayer 1997). Nest trees for this species are usually emergent with a diameter at breast height of at least 100 cm (Gibbons & Lindenmayer 1997).	High.	Low
Numenius madagascariensis	Eastern Curlew	-	CE, MA, M	A primarily coastal distribution. Found in all states, particularly the north, east, and south-east regions including Tasmania. Rarely recorded inland. Mainly forages on soft sheltered intertidal sand flats or mudflats, open and without vegetation or cover. Breeds in the northern hemisphere.	Low	Low
Pandion cristatus	Eastern Osprey	V	M, MA	Found right around the Australian coast line, except for Victoria and Tasmania. They are common around the northern coast, especially on rocky shorelines, islands and reefs. The species is uncommon to rare or absent from closely settled parts of south-eastern Australia. Favour coastal areas, especially the mouths of large rivers, lagoons and lakes. Feed on fish over clear, open water.	Low	Low
Petroica boodang	Scarlet Robin	V	-	In NSW Scarlet Robin occur from the coast to the inland slopes. After breeding, some Scarlet Robins disperse to the lower valleys and plains of the tablelands and slopes. Some birds may appear as far west as the eastern edges of the inland plains in autumn and winter.	High.	Low
Petroica phoenicea	Flame Robin	V	-	Flame Robins are found in a broad coastal band from southern Queensland to just west of the South Australian border. The species is also found in Tasmania. The preferred habitat in summer includes eucalyptus forests and	Moderate	Low

Scientific Name	Common Name	BC Act	EPBC Act	Habitat	Likelihood of Occurrence	Potential for Impact
				woodland, whilst in winter prefers open woodlands and farmlands. It is considered migratory. The Flame Robin breeds from about August to January.		
Rhipidura rufifrons	Rufous Fantail	-	M	Migratory species that prefers dense, moist undergrowth of tropical rainforests and scrubs. During migration it can stray into gardens and more open areas (Pizzey & Knight 1997).	Low	Low
Rostratula benghalensis	Painted Snipe (Australian subspecies)	E	-	In NSW, this species has been recorded at the Paroo wetlands, Lake Cowell, Macquarie Marshes and Hexham Swamp. Most common in the Murray-Darling Basin. Prefers fringes of swamps, dams and nearby marshy areas where there is a cover of grasses, lignum, low scrub or open timber. Nests on the ground amongst tall vegetation, such as grasses, tussocks or reeds.	None	None
Stictonetta naevosa	Freckled Duck	V	-	The freckled duck breeds in permanent fresh swamps that are heavily vegetated. Found in fresh or salty permanent open lakes, especially during drought. Often seen in groups on fallen trees and sand spits.	Low	Low
Tyto novaehollandiae	Masked Owl	V	-	Inhabits a diverse range of wooded habitat that provide tall or dense mature trees with hollows suitable for nesting and roosting (Higgins, 1999). Mostly recorded in open forest and woodlands adjacent to cleared lands. Nest in hollows, in trunks and in near vertical spouts or large trees, usually living but sometimes dead (Higgins 1999). Nest hollows are usually located within dense forests or woodlands (Gibbons & Lindenmayer 1997). Masked owls prey upon hollow-dependent arboreal marsupials, but terrestrial mammals make up the largest proportion of the diet (Gibbons & Lindenmayer 1997, Higgins 1999).	High	Low
Tyto tenebricosa	Sooty Owl	V	-	Often found in tall old-growth forests, including temperate and subtropical rainforests. In NSW mostly found on escarpments with a mean altitude less than 500 metres. Nests and roosts in hollows of tall emergent trees, mainly eucalypts often located in gullies. Nests have been located in trees 125 to 161 centimetres in diameter.	Moderate	Low
Invertebrates						
Petalura gigantea	Giant Dragonfly	E	-	The Giant Dragonfly is found along the east coast of NSW from the Victorian border to northern NSW. It is not found west of the Great Dividing Range. There are known occurrences in the Blue Mountains and Southern Highlands, in the Clarence River catchment, and on a few coastal swamps from north of Coffs Harbour to Nadgee in the south (DECCW undated b). Live in permanent swamps and bogs with some free water and open vegetation. Adults emerge	High.	High – Numerous records within the locality and habitat present within the swamps of the study area. The species has been confirmed within Dendrobium Area 3B

Scientific Name	Common Name	BC Act	EPBC Act	Habitat	Likelihood of Occurrence	Potential for Impact
				from late October and are short-lived, surviving for one summer after emergence.		and 3A and adjacent to Dendrobium Area 6.
Synemon plana	Golden Sun Moth	E	CE	The Golden Sun Moth's NSW populations are found in the area between Queanbeyan, Gunning, Young and Tumut. Occurs in natural temperate grasslands and grassy box-gum woodlands in which groundlayer is dominated by wallaby grasses Austrodanthonia spp.	Low	Low
Mammals						
Petrogale penicillata	Brush-tailed Rock-wallaby	E	V	Found in rocky areas in a wide variety of habitats including rainforest gullies, wet and dry sclerophyll forest, open woodland and rocky outcrops in semi-arid country. Commonly sites have a northerly aspect with numerous ledges, caves and crevices (Eldridge 1995).	Low	Low
Mormopterus norfolkensis	Eastern Coastal Freetailed-bat	V	-	Most records are from dry eucalypt forests and woodlands to the east of the Great Dividing Range. Appears to roost in trees, but little is known of this species' habits (Allison & Hoye 1995, Churchill 1998).	High. Previous records in study area in Bionet Atlas.	Low
Falsistrellus tasmaniensis	Eastern False Pipistrelle	V	-	Inhabit sclerophyll forests, preferring wet habitats where trees are more than 20 m high (Churchill 1998). Two observations have been made of roosts in stem holes of living eucalypts (Phillips 1995). There is debate about whether or not this species moves to lower altitudes during winter, or whether they remain sedentary but enter torpor (Menkhorst & Lumsden 1995). This species also appears to be highly mobile and records showing movements of up to 12 km between roosting and foraging sites (Menkhorst & Lumsden 1995).	High	Low
Cercartetus nanus	Eastern Pygmy-possum	V	-	Inhabits rainforest through to sclerophyll forest and tree heath. Banksias and myrtaceous shrubs and trees are a favoured food source. Will often nest in tree hollows, but can also construct its own nest (Turner & Ward 1995). Because of its small size it is able to utilise a range of hollow sizes including very small hollows (Gibbons & Lindenmayer 1997). Individuals will use a number of different hollows and an individual has been recorded using up to 9 nest sites within a 0.5 ha area over a 5 month period (Ward 1990).	High. Previous records in study area in Bionet Atlas.	Low
Kerivoula papuensis	Golden tipped bat	V	-	The Golden-tipped Bat is distributed along the east coast of Australia in scattered locations from Cape York Peninsula in Queensland to south of Eden in southern NSW. Also occurs in New Guinea. Found in rainforest and adjacent wet and dry sclerophyll forest up to 1000 m. Also recorded in tall open forest, Casuarina-dominated riparian forest and coastal Melaleuca forests.	High	Low

Scientific Name	Common Name	BC Act	EPBC Act	Habitat	Likelihood of Occurrence	Potential for Impact
Scoteanax rueppellii	Greater Broad-nosed Bat	V	-	Prefer moist gullies in mature coastal forests and rainforests, between the Great Dividing Range and the coast. They are only found at low altitudes below 500 m (Churchill, 1998). In dense environments they utilise natural and human-made opening in the forest for flight paths. Creeks and small rivers are favoured foraging habitat (Hoye & Richards 1995). This species roosts in hollow tree trunks and branches (Churchill, 1998).	High	Low
Petauroides volans	Greater Glider	-	V	The Greater Glider is restricted to eastern Australia, occurring from the Windsor Tableland in north Queensland through to central Victoria. It is typically found in highest abundance in taller, montane, moist eucalypt forests with relatively old trees and abundant hollows.	Moderate	Low
Pteropus poliocephalus	Grey-headed Flying-fox	V	V	This species is a canopy-feeding frugivore and nectarivore of rainforests, open forests, woodlands, melaleuca swamps and banksia woodlands. Bats commute daily to foraging areas, usually within 15 km of the day roost (Tidemann 1995) although some individuals may travel up to 70 km (Augee & Ford 1999).	High	Low
Phascolarctos cinereus	Koala	V	-	Inhabits eucalypt forests and woodlands. The suitability of these forests for habitation depends on the size and species of trees present, soil nutrients, climate and rainfall (Reed 1990).	High. Previous records in study area in Bionet Atlas.	Low
Miniopterus orianae oceanensis	Large bent-winged bat	V	-	Eastern Bent-wing Bats occur along the east and north-west coasts of Australia. Caves are the primary roosting habitat, but also use derelict mines, storm-water tunnels, buildings and other man-made structures.	High. Previous records in study area in Bionet Atlas.	Moderate, however limited significance. Maternity caves would not occur within the study area. If roosting occurs it is unlikely to be widespread or significant and minimal impacts from subsidence of features such as cliffs are expected to occur given the limited propensity of roosting. No further assessment is considered required.
Chalinolobus dwyeri	Large-eared Pied Bat	V	V	Located in a variety of drier habitats, including the dry sclerophyll forests and woodlands to the east and west of the Great Dividing Range (Hoye & Richards 1995). Can also be found on the edges of rainforests and in wet sclerophyll forests (Churchill 1998). This species roosts in caves and mines in groups of between 3 and 37 individuals (Churchill 1998).	High	Low

Scientific Name	Common Name	BC Act	EPBC Act	Habitat	Likelihood of Occurrence	Potential for Impact
Miniopterus australis	Little bent-wing Bat	V	-	East coast and ranges of Australia from Cape York in Queensland to Wollongong in NSW. Moist eucalypt forest, rainforest, vine thicket, wet and dry sclerophyll forest, Melaleuca swamps, dense coastal forests and banksia scrub. Generally found in well-timbered areas.	High	Moderate, however limited significance. Maternity caves would not occur within the study area. If roosting occurs it is unlikely to be widespread or significant and minimal impacts from subsidence of features such as cliffs are expected to occur given the limited propensity of roosting. No further assessment is considered to be required.
Potorous tridactylus tridactylus	Long-nosed Potoroo	V	V	Inhabits coastal heath and wet and dry sclerophyll forests. Generally found in areas with rainfall greater than 760 mm. Requires relatively thick ground cover where the soil is light and sandy.	Moderate	Low
Pseudomys novaehollandiae	New Holland Mouse	V		Known to inhabit open heathlands, woodlands and forests with a heathland understorey and vegetated sand dunes. It is a social animal, living predominantly in burrows shared with other individuals. Distribution is patchy in time and space, with peaks in abundance during early to mid stages of vegetation succession typically induced by fire.	Low	Low
Isoodon obesulus	Southern Brown Bandicoot (eastern)	E	-	Prefers sandy soils with scrubby vegetation and/or areas with low ground cover that are burn from time to time (Braithwaite 1995). A mosaic of post fire vegetation is important for this species (Maxwell 1996).	High	Low
Myotis macropus	Southern Myotis	V	-	The Large-footed Myotis is found in the coastal band from the north-west of Australia, across the top-end and south to western Victoria. Generally roost in groups of 10 - 15 close to water in caves, mine shafts, hollow-bearing trees, storm water channels, buildings, under bridges and in dense foliage.	High. Previous records in study area in Bionet Atlas.	Moderate
Dasyurus maculatus	Spotted-tailed Quoll	V	-	Spotted-tailed Quoll is found on the east coast of NSW, Tasmania, eastern Victoria and north-eastern Queensland.	Moderate	Low
Petaurus australis	Yellow-bellied Glider	V	-	Occur in tall mature eucalypt forest generally in areas with high rainfall and nutrient rich soils. Forest type preferences vary with latitude and elevation; mixed coastal forests to dry escarpment forests in the north; moist coastal gullies and creek flats to tall montane forests in the south. Found along the	Low	Low

Scientific Name	Common Name	BC Act	EPBC Act	Habitat	Likelihood of Occurrence	Potential for Impact
				eastern coast to the western slopes of the Great Dividing Range, from southern Queensland to Victoria.		
Saccolaimus flaviventris	Yellow-bellied sheathtail Bat	V	-	The Yellow-bellied Sheathtail-bat is a wide-ranging species found across northern and eastern Australia. In the most southerly part of its range - most of Victoria, south-western NSW and adjacent South Australia - it is a rare visitor in late summer and autumn. There are scattered records of this species across the New England Tablelands and North West Slopes. Roosts singly or in groups of up to six, in tree hollows and buildings; in treeless areas they are known to utilise mammal burrows.	High.	Low
Reptiles						
Hoplocephalus bungaroides	Broad-headed Snake	E	V	Mainly occurs in association with communities occurring on Triassic sandstone within the Sydney Basin. Typically found among exposed sandstone outcrops with vegetation types ranging from woodland to heath. Within these habitats they generally use rock crevices and exfoliating rock during the cooler months and tree hollows during summer (Webb & Shine 1998).	High.	Moderate
Varanus rosenbergi	Rosenberg's Goanna	V	-	This species is a Hawkesbury/Narrabeen sandstone outcrop specialist (Wellington 1985). Occurs in coastal heaths, humid woodlands and both wet and dry sclerophyll forests (Cogger 1992).	High.	Moderate
Plants						
Acacia bynoeana	Bynoe's Wattle	V	E1	Grows mainly in heath and dry sclerophyll forest in sandy soils. Mainly south of Dora Creek-Morisset area to Berrima and the Illawarra region, west to the Blue Mountains, also recorded from near Kurri Kurri in the Hunter Valley and from Morton National Park. ROTAP: 3VC-	High. Previously recorded in Area 3C in the Biosis (2007) SIS along Fire Road 6.	Low
Allocasuarina glareicola		E	E	Primarily restricted to the Richmond (NW Cumberland Plain) district, but with an outlier population found at Voyager Point, Liverpool. Grows in Castlereagh woodland on lateritic soil. Found in open woodland with Parramatta Red Gum, Broad-leaved Ironbark, Narrow-leaved Apple, Scribbly Gum and Paperbarks.	Low	Low
Caladenia tessellata	Tessellated Spider Orchid	V	E1	The Tessellated Spider Orchid is found in grassy sclerophyll woodland on clay loam or sandy soils, though the population near Braidwood is in low woodland with stony soil. Known from the Sydney area (old records), Wyong, Ulladulla	Low	Low

Scientific Name	Common Name	BC Act	EPBC Act	Habitat	Likelihood of Occurrence	Potential for Impact
				and Braidwood in NSW. Populations in Kiama and Queanbeyan are presumed extinct. ROTAP: 3V		
Commersonia prostrata	Dwarf Kerrawang	E	E	Occurs on sandy, sometimes peaty soils in a wide variety of habitats: snow gum woodland at Rose Lagoon; blue leaved stringybark open forest at Tallong; and in brittle gum low open woodland at Penrose; scribbly gum - swamp mahogany ecotonal forest at Tomago.	Low	Low
Cryptostylis hunteriana	Leafless Tongue Orchid	V	V	Grows in swamp-heath on sandy soils, chiefly in coastal districts, south from the Gibraltar Range. ROTAP: 3VC-	Moderate	Moderate
Cynanchum elegans	White-flowered Wax Plant	E	E	Recorded from rainforest gullies scrub and steep slopes from the Gloucester district to the Wollongong area and inland to Mt Dangar. ROTAP: 3ECi	Low	Low
Epacris purpurascens var. purpurascens		V	-	Recorded from Gosford in the north, to Narrabeen in the east, Silverdale in the west and Avon Dam vicinity in the South. Found in a range of habitat types, most of which have a strong shale soil influence.	Moderate	Moderate
Genoplesium baueri	Bauer's Midge Orchid	E	E	Grows in dry sclerophyll forest and moss gardens over sandstone. Flowers February to March. Has been recorded between Ulladulla and Port Stephens. Currently the species is known from just over 200 plants across 13 sites. The species has been recorded in Berowra Valley Regional Park, Royal National Park and Lane Cove National Park and may also occur in the Woronora, O'Hares, Metropolitan and Warragamba Catchments.	Low	Low
Grevillea parviflora ssp. parviflora	Small-flower Grevillea	V	V	Grows in heathy associations or shrubby woodland, in sandy or light clay soils usually over shale substrates. Occurs west and south of Sydney from west of Prospect (where now almost certainly extinct), Kemps Creek and lower Georges River south to Camden, Appin and Cordeaux Dam, with disjunct northern populations south of Putty and near Cessnock and Cooranbong, possibly also south of Moss Vale.	Moderate	Low
Grevillea raybrownii		V		It occurs in Eucalyptus open forest and woodland with a shrubby understorey on sandy, gravelly loam soils derived from sandstone that are low in nutrients. Generally occurs on ridgetops and, less often, slopes and benches of Hawkesbury Sandstone and Mittagong Formation. restricted to an area bounded by Dapto, Robertson and Berrima, possibly also Bungonia.	High	Low

Scientific Name	Common Name	BC Act	EPBC Act	Habitat	Likelihood of Occurrence	Potential for Impact
Haloragis exalata subsp. exalata	Square Raspwort	V	V	Occurs in 4 widely scattered localities in eastern NSW. It is disjunctly distributed in the central coast, south coast and north-western slopes botanical subdivisions of NSW. The species appears to require protected and shaded damp situations in riparian habitats.	Low	Low
Leucopogon exolasius	Woronora Beard-heath	V	V	Grows in woodland on sandstone. Restricted to the Woronora and Grose Rivers and Stokes Creek, Royal National Park. ROTAP: 2VC-	High. Recorded by Niche in study area in 2018 and previous records in study area in Bionet Atlas.	Moderate
Melaleuca biconvexa	Biconvex Paperbark	V	V	Biconvex Paperbark generally grows in damp places, often near streams or low-lying areas on alluvial soils of low slopes or sheltered aspects. Scattered and dispersed populations found in the Jervis Bay area in the south and the Gosford-Wyong area in the north.	Low	Low
Melaleuca deanei	Dean's Low Melaleuca	V	V	Grows in wet heath on sandstone in coastal districts from Berowra to Nowra. ROTAP: 3RC-	Moderate	Low
Persicaria elatior	Tall Knotweed	V	V	This species normally grows in damp places, especially beside streams and lakes. Occasionally in swamp forest or associated with disturbance.	Low	Low
Persoonia acerosa	Mossy Geebung	V	V	Occurs in heath or dry sclerophyll forest on sandstone, from central Blue Mountains south to Hill Top. ROTAP: 2VC-	Moderate	Low
Persoonia bargoensis	Bargo Geebung	E	V	The Bargo Geebung occurs in woodland or dry sclerophyll forest on sandstone and on heavier, well drained, loamy, gravely soils.	Low	Low
Persoonia hirsuta	Hairy Geebung	E	E	The Hairy Geebung is found in sandy soils in dry sclerophyll open forest, woodland and heath on sandstone.	Moderate	Low
Persoonia nutans	Nodding Geebung	E	E	Confined to aeolian and alluvial sediments and occurs in a range of sclerophyll forest and woodland vegetation communities, with the majority of individuals occurring within Agnes Banks woodland or Castlereagh Scribbly Gum woodland. Restricted to the Cumberland Plain in western Sydney, between Richmond in the north and Macquarie Fields in the south.	Low	Low
Pimelea spicata	Spiked Rice-flower	E	E	In both the Cumberland Plain and Illawarra environments this species is found on well-structured clay soils.	Low	Low

Scientific Name	Common Name	BC Act	EPBC Act	Habitat	Likelihood of Occurrence	Potential for Impact
Pomaderris brunnea	Rufous Pomaderris	V	V	Brown Pomaderris grows in moist woodland or forest on clay and alluvial soils of flood plains and creek lines in association with *Eucalyptus amplifolia*, *Angophora floribunda*, *Acacia parramattensis, Bursaria spinosa* and *Kunzea ambigua*. ROTAP: 2VC-	Low	Low
Pomaderris cotoneaster	Cotoneaster Pomaderris	E	E	Cotoneaster Pomaderris has a very disjunct distribution and has been recorded in a range of habitats in predominantly forested country. The habitats include forest with deep, friable soil, amongst rock beside a creek, on rocky forested slopes and in steep gullies between sandstone cliffs.	Low	Low
Prasophyllum affine		E	E	Jervis Bay Leek Orchid is currently known from three areas south-east of Nowra on South Coast. These are Kinghorne Point, Wowly Gully near the town of Callala Bay, and near the township of Vincentia. Grows on poorly drained grey clay soils that support low heathland and sedgeland communities.	Low. Not previously recorded within 10 km of the study area.	Low
Pterostylis gibbosa	Illawarra Greenhood	E	E	Grows in open forest or woodland, on flat or gently sloping land with poor drainage. Known from a small number of populations in the Hunter region (Milbrodale), the Illawarra region (Albion Park and Yallah) and the Shoalhaven region (near Nowra)	Low	Low
Pterostylis saxicola	Sydney Plains Greenhood	E	E	Restricted to western Sydney between Freemans Reach in the north and Picton in the south. Most commonly found growing in small pockets of shallow soil in depressions on sandstone rock shelves above cliff lines. The vegetation communities above the shelves where *Pterostylis saxicola* occurs are sclerophyll forest or woodland on shale/sandstone transition soils or shale soils.	Low	Low
Pultenaea aristata	Prickly Bush-pea	V	V	Grows in moist, dry sclerophyll woodland to heath on sandstone, specifically the drier areas of Upland Swamps. Restricted to the Woronora Plateau, a small area between Helensburgh, south of Sydney, and Mt Keira above Wollongong. ROTAP: 2V	High.	Moderate
Rhizanthella slateri	Eastern Australian Underground Orchid	V, EP (Great Lakes)	E	Habitat requirements are poorly understood and no particular vegetation type has been associated with the species, although it is known to occur in sclerophyll forest. Highly cryptic given that it grows almost completely below the soil surface, with flowers being the only part of the plant that can occur above ground. Therefore usually located only when the soil is disturbed. In NSW, currently known from fewer than 10 locations, including near Bulahdelah, the Watagan Mountains, the Blue Mountains, Wiseman's Ferry area, Agnes Banks and near Nowra.	Low. Not previously recorded within 10 km of the study area.	

Scientific Name	Common Name	BC Act	EPBC Act	Habitat	Likelihood of Occurrence	Potential for Impact
Rhodamnia rubescens	Scrub Turpentine	CE	-	Occurs in coastal districts north from Batemans Bay in New South Wales, approximately 280 km south of Sydney, to areas inland of Bundaberg in Queensland. Populations of R. rubescens typically occur in coastal regions and occasionally extend inland onto escarpments up to 600 m a.s.l. in areas with rainfall of 1,000-1,600 mm. Found in littoral, warm temperate and subtropical rainforest and wet sclerophyll forest usually on volcanic and sedimentary soils.	Low	Low
Rhodomyrtus psidioides	Native Guava	CE	-	Pioneer species found in littoral, warm temperate and subtropical rainforest and wet sclerophyll forest often near creeks and drainage lines.	Low	Low
Syzygium paniculatum	Magenta Lilly Pilly	E	V	Found only in NSW, in a narrow, linear coastal strip from Bulahdelah to Conjola State forest. On the south coast the species occurs on grey soils over sandstone, restricted mainly to remnant stands of littoral rainforest. On the central coast it occurs on gravels, sands, silts and clays in riverside gallery rainforests and remnant littoral rainforest communities.	Low	Low
Thelymitra kangaloonica	Kangaloon Sun-orchid	CE	CE	Recorded from shallow black peaty soil in coastal heath on sandstone. *Thelymitra sp. Kangaloon* is a terrestrial orchid endemic to New South Wales, and is known from three locations near Robertson in the Southern Highlands.	Low	Low
Thesium australe	Austral Toadflax	V	V	Grows in very small populations scattered across eastern NSW, along the coast, and from the Northern to Southern Tablelands. It is also found in Tasmania and Queensland and in eastern Asia. Occurs in grassland or grassy woodland. Grows on Kangaroo Grass tussocks but has also been recorded within the exotic Coolatai Grass.	Low	Low
Xerochrysum palustre	Swamp Everlasting	-	V	Found in Kosciuszko National Park and the eastern escarpment south of Badja. Also found in eastern Victoria. Grows in swamps and bogs which are often dominated by heaths. Also grows at the edges of bog margins on peaty soils with a cover of shrubs or grasses.	Low	Low

Key: CE = Critically Endangered; E, E1 = Endangered; EP = Endangered Population; V = Vulnerable; M = Migratory.

Fauna that are exclusively dependant on marine environments, including near shore environments, were not included in the assessment due to lack of suitable habitat.

Habitat descriptions taken from the relevant profiles on the OEH Threatened Species website unless otherwise stated.

Appendix 2: Fauna recorded from targeted survey

Scientific Name	Common Name	Status NSW	Status Commonwealth	Quantity	Latitude	Longitude
Litoria littlejohni	Littlejohn's Tree Frog	V	V	4	-34.3667709	150.742933
Litoria littlejohni	Littlejohn's Tree Frog	V	V	20	-34.37009598	150.7409743
Litoria littlejohni	Littlejohn's Tree Frog	V	V	30	-34.37028251	150.7407489
Litoria littlejohni	Littlejohn's Tree Frog	V	V	50	-34.37054235	150.7407022
Litoria littlejohni	Littlejohn's Tree Frog	V	V	20	-34.3707777	150.7407411
Litoria littlejohni	Littlejohn's Tree Frog	V	V	5	-34.3710659	150.7404786
Litoria littlejohni	Littlejohn's Tree Frog	V	V	20	-34.37143425	150.740556
Litoria littlejohni	Littlejohn's Tree Frog	V	V	25	-34.37170206	150.7405557
Litoria littlejohni	Littlejohn's Tree Frog	V	V	40	-34.37172694	150.7404773
Litoria littlejohni	Littlejohn's Tree Frog	V	V	120	-34.37196159	150.7404197
Litoria littlejohni	Littlejohn's Tree Frog	V	V	60	-34.37208375	150.7404181
Litoria littlejohni	Littlejohn's Tree Frog	V	V	20	-34.37536575	150.7467765
Litoria littlejohni	Littlejohn's Tree Frog	V	V	60	-34.37468854	150.7472049
Litoria littlejohni	Littlejohn's Tree Frog	V	V	3	-34.37466225	150.7473703
Litoria littlejohni	Littlejohn's Tree Frog	V	V	4	-34.37459423	150.7474361
Litoria littlejohni	Littlejohn's Tree Frog	V	V	35	-34.37403872	150.7477533
Litoria littlejohni	Littlejohn's Tree Frog	V	V	60	-34.37374069	150.748152
Litoria littlejohni	Littlejohn's Tree Frog	V	V	25	-34.37361875	150.7482271
Litoria littlejohni	Littlejohn's Tree Frog	V	V	30	-34.37341027	150.7482935
Litoria littlejohni	Littlejohn's Tree Frog	V	V	10	-34.37340576	150.748385
Litoria littlejohni	Littlejohn's Tree Frog	V	V	100	-34.37317706	150.7485305
Litoria littlejohni	Littlejohn's Tree Frog	V	V	300	-34.3730708	150.7486515
Litoria littlejohni	Littlejohn's Tree Frog	V	V	65	-34.37268635	150.7488797
Litoria littlejohni	Littlejohn's Tree Frog	V	V	5	-34.37246545	150.7489004
Litoria littlejohni	Littlejohn's Tree Frog	V	V	10	-34.37233773	150.7489389
Litoria littlejohni	Littlejohn's Tree Frog	V	V	2	-34.37151335	150.7497374
Litoria littlejohni	Littlejohn's Tree Frog	V	V	5	-34.37150874	150.74981
Litoria littlejohni	Littlejohn's Tree Frog	V	V	12	-34.37126003	150.7502593
Litoria littlejohni	Littlejohn's Tree Frog	V	V	2	-34.37109381	150.7502837
Litoria littlejohni	Littlejohn's Tree Frog	V	V	5	-34.37088354	150.7505807
Litoria littlejohni	Littlejohn's Tree Frog	V	V	3	-34.37067609	150.7506667
Litoria littlejohni	Littlejohn's Tree Frog	V	V	6	-34.37031125	150.7509357
Litoria littlejohni	Littlejohn's Tree Frog	V	V	40	-34.36960088	150.7516941
Litoria littlejohni	Littlejohn's Tree Frog	V	V	30	-34.36951014	150.751746
Litoria littlejohni	Littlejohn's Tree Frog	V	V	4	-34.36926348	150.7521756
Litoria littlejohni	Littlejohn's Tree Frog	V	V	15	-34.36922915	150.7521481
Litoria littlejohni	Littlejohn's Tree Frog	V	V	1	-34.3666787	150.743294
Litoria littlejohni	Littlejohn's Tree Frog	V	V	17	-34.3666692	150.7432172
Litoria littlejohni	Littlejohn's Tree Frog	V	V	50	-34.36671875	150.7429331
Litoria littlejohni	Littlejohn's Tree Frog	V	V	50	-34.36673574	150.743251
Litoria littlejohni	Littlejohn's Tree Frog	V	V	30	-34.36674295	150.7429358
Pseudophryne australis	Red-crowned Toadlet	V	-	1	-34.3739798265	150.731509924

Additional subsection example of habitats and pool data for LC5 and LC6.

Latitude	longitude	Transect Name	Habitat notes	Size of pool	substrate	Water
-34.3631	150.7485	LC5	LC5	Shallow 50-25cm	Bedrock	100%
-34.3629	150.7485		Riparian fringing veg, deep	Moderate 100-50cm	Bedrock	100%
-34.363	150.7487		Very large pool, 8 m by 18 m	Moderate 100-50cm	Bedrock	100%
-34.3629	150.7488		Shallow broad pool, fringing riparian veg and egg mass observed	Shallow 50-25cm	Bedrock	100%
-34.3627	150.7493		Boulders and cobbles on the edge of the pool and bedrock and silt	Moderate 100-50cm	Boulders/large sandstone rocks	80%
-34.3632	150.7482		Gahnia, rock and cobble substrate, lots of riparian veg	Moderate 100-50cm	Boulders/large sandstone rocks	95%
-34.3637	150.7471		Very large pool, gahnia, riparian veg	Deep >100cm	Sand, Pebbles	90%
-34.3639	150.7468		Broad bedrock shallow	Very Shallow <25cm	Bedrock	0%
-34.3643	150.7464		Large pool with Sandy banks, sandstone cliffs surrounding the pool with fringing riparian veg and fallen woody debris. Good potential Giant Burrowing Frog habitat.	Moderate 100-50cm	Sand, Pebbles	100%
-34.3645	150.7459		Sandy, bedrock substrate with teatree, gahnia and ferns. Woody debris, siltation.	Shallow 50-25cm	Sand, Bedrock	80%
-34.3645	150.745		Sandy creek bed, bedrock, leaf packs and riparian veg	Deep >100cm	Bedrock, Pebbles	80%
-34.3645	150.7444		Sandy substrate, fringing riparian veg - potentially good Giant Burrowing Frog habitat	Moderate 100-50cm	Sand	85%
-34.3647	150.7442		Silty substrate on bedrock with fringing riparian veg	Very Shallow <25cm	Bedrock	
-34.3667	150.743		Over 100 *Crinia signifera* tadpoles, sandstone substrate, on trail, depth between 25 - 50 cm	Shallow 50-25cm	Bedrock	20%

Latitude	longitude	Transect Name	Habitat notes	Size of pool	substrate	Water
-34.3667	150.7432		Moderate deep but small bedrock pool with Littlejohn eggmass	Shallow 50-25cm	Bedrock	85%
-34.3669	150.7432		Shallow bedrock pool	Very Shallow <25cm	Bedrock	
-34.3694	150.742		Melaleuca Swamp, fringing riparian veg, 0.6 m deep, silty substrate	Moderate 100-50cm	Sand	80%
-34.37	150.7411		Sandy substrate, melaleuca Swamp, moderately deep long and narrow pooling habitat - suitable Giant Burrowing Frog. Leaf packs also: 30 Littlejohn tadpoles	Shallow 50-25cm	Sand	80%
-34.3706	150.7407		Bedrock substrate with riffles and riparian overhang.	Shallow 50-25cm	Bedrock, Pebbles, Boulders/large sandstone rocks	80%
-34.3709	150.7407		Bedrock substrate, shallow and long pool with fringing sedges and eucalyptus canopy. 80 % capacity.	Shallow 50-25cm	Bedrock	80%
-34.3712	150.7405		Sandy bottom, running riffle, fringing riparian vegetation and moderate deep, Littlejohn tadpoles >10.	Moderate 100-50cm	Sand, Pebbles	85%
-34.3716	150.7404		Cobbles substrate, silted bottom, riffles, leaf packs. Dry beyond this point towards the end	Shallow 50-25cm	Sand, Pebbles	95%
-34.372	150.7491	LC6	Shallow Sandy substrate pool. With gradual banks and fringing riparian vegetation on meander.	Shallow 50-25cm	Sand	95%
-34.372	150.7492		Moderate deep with fringing veg, riparian vegetation with fallen woody debris and cobbles	Moderate 100-50cm	Sand, Pebbles	95%
-34.3716	150.7493		Continuous shallow water, raised banks and Sandy banks!	Shallow 50-25cm	Sand, Pebbles	80%
-34.3715	150.7496		Continuous elongated pool 85% full, cobbles and silt substrate no tadpoles	Shallow 50-25cm	Sand, Pebbles	85%

Latitude	longitude	Transect Name	Habitat notes	Size of pool	substrate	Water
-34.3715	150.7498		Sandy, leaf packs and rock cobbles-	Very Shallow <25cm	Pebbles, Sand	85%
-34.3715	150.7499		On meander and sandy substrate with riparian veg and no tadpoles	Moderate 100-50cm	Sand, Pebbles	85%
-34.3713	150.7501		Long and narrow shallow pool with ferns and sedges and no tadpoles	Shallow 50-25cm	Sand, Pebbles	95%
-34.3713	150.7502			Shallow 50-25cm		
-34.3712	150.7502			Shallow 50-25cm		
-34.3711	150.7504		Sandstone influence and Sandy substrate and running riffles	Very Shallow <25cm	Sand, Bedrock	95%
-34.3719	150.7491		Continuous pool	Moderate 100-50cm	Sand	95%
-34.3722	150.749		Lots of fallen woody debris and silted	Shallow 50-25cm	Sand	95%
-34.3724	150.7489		Long moderate deep Sandy pool	Moderate 100-50cm	Sand	95%
-34.3726	150.7488		Very large deep pool with running riffles/cascade. Sandy and sandstone cobbles substrate	Deep >100cm	Sand, Pebbles	100%
-34.3727	150.7488		35 Littlejohns tadpoles and 1 egg mass on sandstone perch above large pool. Shallow broad pool with medium to deep holes	Moderate 100-50cm	Bedrock	100%

Appendix 3: Weather data from the survey period

Daily Rainfall (millimetres)

CAMPBELLTOWN (MOUNT ANNAN)

Station Number: 068257 · State: NSW · Opened: 2006 · Status: Open · Latitude: 34.06°S · Longitude: 150.77°E · Elevation: 112 m

2017	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1st	0	0	20.6	0.2	0	0	0	10.0	0	0	0	0.2
2nd	1.4	3.6	5.2	0	0	0	0	0.2	0	0	0	0
3rd	0	0	19.6	3.0	0	0	0.2	0	0	0	0	10.6
4th	1.4	0	33.8	2.0	1.4	0	0.4	11.0	0	0	3.2	4.4
5th	0	0	0.8	4.8	0	0	0.2	0	0	0	1.0	3.4
6th	15.0	0	1.4	0.2	0	0	0	0	0	0	7.0	0
7th	15.4	0	0.2	0	0	22.4	0	0	0	0	6.8	2.2
8th	0	30.2	2.2	0	0	17.8	0	0	0	0	0	0
9th	0	5.2	1.0	0	0	0.4	0	0	0	0	0	0.6
10th	4.6	0	0	10.6	0	29.4	0.2	0	0	0	0	0
11th	1.6	0	0	0	0	4.0	0.2	0	0	0.2	0	0
12th	0	0	0	0	0	0.2	0	0	0	0.2	0	0
13th	0	0	0	0.2	0	0.4	0	0	0	0.2	0	0
14th	1.6	0	0.4	0	0	0	0	0	0	0	0	0
15th	0	0	17.6	0	0.2	0.2	0	0	0	0	0	0
16th	0	0	10.2	0	0	0	0	0.2	0	0	0	0.6
17th	0	0	16.2	0	0	0	0	0	0	0	0.4	2.4
18th	0	2.4	6.4	0	0	0	0	0	0	0	0.2	0.4
19th	0	0.6	11.0	0	0	0	0	0	0	0	3.4	0
20th	0.2	4.8	1.4	0.2	6.0	0	0	0	0	9.0	0	0
21st	4.0	0	0	0	0	0	0	0	0	7.8	0.4	2.6
22nd	0	0	16.0	0	0	0	0	0.2	0	0.2	0	0.2
23rd	0	0	24.8	0	0	0.2	0.2	0	0	2.6	0.2	3.0
24th	0.2	0	6.8	0	7.6	0	0	0	0	0	0	0
25th	2.2	0	0	0.2	0	0.2	0	0	0	0	0	0
26th	0	32.0	0	0	0	0	0	0	0	0.4	0	0
27th	0	3.6	0	0.6	0	0	0	0	0	25.6	0.2	0.2
28th	0	4.4	0	0	0.2	0	0	0.6	0	0.2	6.8	0
29th	0		0	0	0.2	0.6	0	0.2	0	0	0.2	0
30th	0		0.4	0	0	0	0	0	0	0.2	0.4	1.2
31st	0		29.6		0		0	0.2		0.2		0.2
Highest daily	15.4	32.0	33.8	10.6	7.6	29.4	0.4	11.0	0	25.6	7.0	10.6
Monthly Total	47.6	86.8	225.6	22.0	15.6	75.8	1.4	22.6	0	46.8	30.2	32.2

Annual total for 2017 = 606.6mm

↓ This day is part of an accumulated total
Quality control: 12.3 Done & acceptable, *12.3* Not completed or unknown

Product code: IDCJAC0009 reference: 75919870

Australian Government
Bureau of Meteorology

Daily Rainfall (millimetres)

CAMPBELLTOWN (MOUNT ANNAN)

Station Number: 068257 · State: NSW · Opened: 2006 · Status: Open · Latitude: 34.06°S · Longitude: 150.77°E · Elevation: 112 m

Statistics for this station calculated over all years of data

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Highest daily	*118.8*	*172.4*	*85.4*	*83.4*	*46.0*	*146.6*	*51.6*	*52.6*	*35.2*	*27.6*	*64.4*	*38.8*
Date of highest daily	29th 2013	10th 2020	21st 2021	21st 2015	24th 2013	6th 2016	27th 2020	10th 2020	15th 2010	15th 2014	2nd 2010	14th 2018

1) Calculation of statistics

Summary statistics, other than the Highest and Lowest values, are only calculated if there are at least 20 years of data available.

2) Gaps and missing data

Gaps may be caused by a damaged instrument, a temporary change to the site operation, or due to the absence or illness of an observer.

3) Further information

http://www.bom.gov.au/climate/cdo/about/about-rain-data.shtml.

Product code: IDCJAC0009 reference: 75919870 Created on Fri 11 Jun 2021 14:05:52 PM AEST

Daily Rainfall (millimetres)

CAMPBELLTOWN (MOUNT ANNAN)

Station Number: 068257 · State: NSW · Opened: 2006 · Status: Open · Latitude: 34.06°S · Longitude: 150.77°E · Elevation: 112 m

2018	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1st	0	0	0	0	0	0.2	0	0	1.2	0	0	0
2nd	0	0	0	0	0	0	0	0	0	0	0.2	0
3rd	2.2	0.2	0	0	0	0	1.2	0	0	0	3.8	0
4th	0.2	0	0	0	0	0	0.2	0	6.0	5.6	0	0
5th	0	0	0	0	0	0	0.2	0	1.4	25.4	0	1.0
6th	0	0	2.6	0	0	23.4	0	0	0.4	0.2	0	1.0
7th	0	0	2.6	0	0	10.2	0	1.0	3.0	0.6	0	0
8th	0	0	0.6	0	0	0.2	0	0	9.2	0.2	11.0	0
9th	24.4	0	0	0	0	8.2	0	0	0.4	0	0	0
10th	1.4	2.4	0	0	0	0.4	0	0	0.2	0	0	0
11th	0	2.4	0	0	0	0	0	0	0	3.0	0	0
12th	0.2	0.2	0	0	0	0.2	0	0	0	0.4	0	0
13th	0	0	0	0	0.6	0	0.2	0	0	0.6	0	1.0
14th	0	0	1.2	0	0	0	0	0	0	15.4	0	38.8
15th	0	0	0	0	0	0	0.2	0	0	1.8	0.6	27.8
16th	0	0	0	0	0	0	0	0	0	1.4	4.6	23.2
17th	0	0	0	0	0	0	0	0	0	0.2	0	25.6
18th	0	0	0	0	0	0	0	0	0	27.4	0	0
19th	0	0	0	0	0	2.4	0	0	0	3.2	0	0
20th	0	11.2	0	0	0	5.6	0	0	0.2	0.2	0	1.2
21st	0	0.2	11.6	0	0	0	0	0	0	0.6	0.4	17.0
22nd	0	0	5.4	0	0	0	0	0	0	0.2	3.2	1.0
23rd	0	0		0	0	0	0	0	0	0	0	0.6
24th	0.2	0	0	0	0	0.2	0	0.6	0	0	0	0
25th	0	0.2	0.2	0	0	0	0	0	0	0	0	0
26th	0	33.2	2.6	0	0	0	0	0.4	3.2	0	0	0
27th	0	1.0	0	0	0	0.2	0	1.6	0.8	0	0	0
28th	0	0.2	0	0	0	3.2	0	0.2	0	0	11.2	0
29th	0		0	0	0.2	8.2	0.2	0.2	0	0	53.4	0
30th	0		0	9.8	4.0	0.2	0	0	0	0	0.2	0
31st	0		0		0		0	0		0		0
Highest daily	24.4	33.2	11.6	9.8	4.0	23.4	1.2	1.6	9.2	27.4	53.4	38.8
Monthly Total	28.6	51.2	26.8	9.8	4.8	62.8	2.2	4.0	26.0	86.4	88.6	138.2

Annual total for 2018 = 529.4mm

↓ This day is part of an accumulated total
Quality control: 12.3 Done & acceptable, *12.3* Not completed or unknown

Product code: IDCJAC0009 reference: 75919847

Daily Rainfall (millimetres)

CAMPBELLTOWN (MOUNT ANNAN)

Station Number: 068257 · State: NSW · Opened: 2006 · Status: Open · Latitude: 34.06°S · Longitude: 150.77°E · Elevation: 112 m

Statistics for this station calculated over all years of data

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Highest daily	*118.8*	*172.4*	*85.4*	*83.4*	*46.0*	*146.6*	*51.6*	*52.6*	*35.2*	*27.6*	*64.4*	*38.8*
Date of highest daily	29th 2013	10th 2020	21st 2021	21st 2015	24th 2013	6th 2016	27th 2020	10th 2020	15th 2010	15th 2014	2nd 2010	14th 2018

1) Calculation of statistics

Summary statistics, other than the Highest and Lowest values, are only calculated if there are at least 20 years of data available.

2) Gaps and missing data

Gaps may be caused by a damaged instrument, a temporary change to the site operation, or due to the absence or illness of an observer.

3) Further information

http://www.bom.gov.au/climate/cdo/about/about-rain-data.shtml.

Product code: IDCJAC0009 reference: 75919847 Created on Fri 11 Jun 2021 14:05:38 PM AEST

Australian Government
Bureau of Meteorology

Daily Rainfall (millimetres)

CAMPBELLTOWN (MOUNT ANNAN)

Station Number: 068257 · State: NSW · Opened: 2006 · Status: Open · Latitude: 34.06°S · Longitude: 150.77°E · Elevation: 112 m

2019	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1st	4.0	0	0	0	0	0	0	0	0	0	0	0
2nd	0	1.2	0.2	0	0	0	0	0	0	0	0	0
3rd	0	0.4	0.2	0.6	0	2.0	0	0	0	0	0	0
4th	0	0.2	0	0	7.4	18.6	0.2	0	0	0	14.8	0
5th	0	0	0	1.8	0	5.8	5.8	0	0	9.2	0.2	0
6th	13.4	0	0	0.4	0.2	0.8	2.8	0	0	0.8	0	0
7th	0	0	0	0	0	0	1.8	0	0	0	0	0
8th	0	0.2	0	0.2	0	0	0.8	0	0	0	0	0
9th	6.2	13.0	0	0	0	0	0.2	0	0	0	0	0
10th	0	0.2	0	0	0	0.2	0	0	0.2	0	0	0
11th	3.8	0	0	0	0.4	0	0	0	0	0	0	0
12th	10.6	0	0	0	0	0	0	0	0	1.0	0	0
13th	0	0	0	0	0	0	0	0	0	1.6	0	1.0
14th	0	0	1.0	0	0	0	0	0	0	0	0	0
15th	0	0	26.6	0	0	0	0	0	0	0	0	0
16th	0	0	3.4	0	0.2	2.0	0	0	0	0	0	0
17th	0	0	29.8	0	0	16.2	0	0	18.0	0	0	0
18th	0	0	34.2	0.4	0	0	0	0	25.0	0	0	0
19th	0	0	0.8	0	0	0	0	0	4.6	0	0	0
20th	0	0	1.0	0	0	0	0	0	4.2	0	0	0
21st	1.2	0.2	0	0	0	0.8	0	0	0.2	0	0	0
22nd	10.4	0.8	0	0	0	0.2	0.2	0	0	0	0	0
23rd	0.6	0	0.2	0	0	0	0.2	0	0	0	1.6	0
24th	0	0.6	0.6	0	0	8.8	0	0	0	0	0.2	0.2
25th	0	0	3.4	0	0.2	0.4	0	0	0	0	0	0.6
26th	0	0	0.2	0	0	0.2	0	0	0	0	3.8	0
27th	0	0	0	0	0	0.2	0	3.4	0	0	2.0	0
28th	24.4	0	0	0	0	0	0	0	0	0	0	0
29th	0.4		0	0	0	0.2	0	0	0	0	0	0
30th	0		19.4	0	0	0	0.8	14.6	0	0	0	0
31st	0		0.4		0		0	0		0		0
Highest daily	24.4	13.0	34.2	1.8	7.4	18.6	5.8	14.6	25.0	9.2	14.8	1.0
Monthly Total	75.0	16.8	121.4	3.4	8.4	56.4	12.8	18.0	52.2	12.6	22.6	1.8

Annual total for 2019 = 401.4mm

↓ This day is part of an accumulated total
Quality control: 12.3 Done & acceptable, *12.3* Not completed or unknown

Product code: IDCJAC0009 reference: 75919711

Australian Government
Bureau of Meteorology

Daily Rainfall (millimetres)

CAMPBELLTOWN (MOUNT ANNAN)

Station Number: 068257 · State: NSW · Opened: 2006 · Status: Open · Latitude: 34.06°S · Longitude: 150.77°E · Elevation: 112 m

Statistics for this station calculated over all years of data

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Highest daily	*118.8*	*172.4*	*85.4*	*83.4*	*46.0*	*146.6*	*51.6*	*52.6*	*35.2*	*27.6*	*64.4*	*38.8*
Date of highest daily	29th 2013	10th 2020	21st 2021	21st 2015	24th 2013	6th 2016	27th 2020	10th 2020	15th 2010	15th 2014	2nd 2010	14th 2018

1) Calculation of statistics

Summary statistics, other than the Highest and Lowest values, are only calculated if there are at least 20 years of data available.

2) Gaps and missing data

Gaps may be caused by a damaged instrument, a temporary change to the site operation, or due to the absence or illness of an observer.

3) Further information

http://www.bom.gov.au/climate/cdo/about/about-rain-data.shtml.

Product code: IDCJAC0009 reference: 75919711 Created on Fri 11 Jun 2021 14:03:06 PM AEST

Australian Government
Bureau of Meteorology

Daily Rainfall (millimetres)

CAMPBELLTOWN (MOUNT ANNAN)

Station Number: 068257 · State: NSW · Opened: 2006 · Status: Open · Latitude: 34.06°S · Longitude: 150.77°E · Elevation: 112 m

2020	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1st	0	0	0	0	10.0	0	0	0	0	3.4	26.8	0
2nd	0	0	0	2.4	0.2	0.4	0.2	0	0	0.2	2.0	6.8
3rd	0	6.6	0	6.2	0	0	0	0.2	0	0	0	2.0
4th	0	0	5.6	3.0	0	0	0	0.2	0	0	0	0
5th	0	0	8.2	0.2	0	0	0	0	3.2	0	6.0	0
6th	0	1.2	22.8	0	0	0	0	0	0	0	16.2	1.8
7th	1.2	35.8	0.2	0	0	0	0	0	0	0	0	0
8th	11.0	46.2	1.6	0	0	2.6	0	25.0	0	1.2	0	0
9th	0	43.6	0	0	0	0.8	0	0.4	1.6	0.2	0	0
10th	0	172.4	0	1.6	0	1.0	0	52.6	5.2	0	0	0
11th	0.2	0	0	9.6	0	0.6	5.2	1.4	0.2	0	0	0
12th	0.4	0	1.2	0	0	1.8	0.2	0	0.2	0	0	0
13th	7.6	6.8	0.2	0	0	0.6	0.4	3.2	0	0	1.2	0
14th	0	1.6	0.4	0	0	9.0	3.0	0.2	0.2	0	16.4	1.2
15th	0	0	8.0	0	0	0	0	6.6	0.2	0	0	2.8
16th	10.4	0.8	3.2	0	2.6	0	0	0	0	0	0	9.8
17th	32.0	0.8	9.4	0	0.2	0	0	0	0	0	0	1.4
18th	7.6	0.6	0.8	0	0	0.4	0	0	0	0	0	3.6
19th	3.2		0.2	0	1.0	0	0	0	0	0.2	0	1.4
20th	1.8		0	0	0	0.2	0	0	7.4	0	0	0.4
21st	16.6		0	0	0.6	11.0	0	0	7.0	0	0	0
22nd	0	0	0	0	35.8	0	0	0.2	5.2	0	0	25.2
23rd	0	1.4	0	0	0.8	0	0.2	0.2	0	0	2.6	0
24th	2.4	0.4	0	0	0.6	0.2	0	0	0	7.6	0	0
25th	5.6	0	0	0	0	0	0	0	0	19.0	0.2	0
26th	0	0	13.2	0	0.2	0	5.2	0	1.0	18.0	0	1.0
27th	0	0.4	1.6	0	2.0	0	51.6	0	0	5.8	0	0.4
28th	0	0	0.2	0	0	0	17.4	0.2	0	0	0	0
29th	0	0	2.8	0	0	0	0	0	0	11.2	0	11.2
30th	0		2.6	17.4	0	3.0	0.2	0	0	0.6	0	0.8
31st	0		0		0		0	0		16.6		0
Highest daily	32.0	172.4	22.8	17.4	35.8	11.0	51.6	52.6	7.4	19.0	26.8	25.2
Monthly Total	100.0		82.2	40.4	54.0	31.6	83.6	90.4	31.4	84.0	71.4	69.8

↓ This day is part of an accumulated total
Quality control: 12.3 Done & acceptable, *12.3* Not completed or unknown

Product code: IDCJAC0009 reference: 75919701

Australian Government
Bureau of Meteorology

Daily Rainfall (millimetres)

CAMPBELLTOWN (MOUNT ANNAN)

Station Number: 068257 · State: NSW · Opened: 2006 · Status: Open · Latitude: 34.06°S · Longitude: 150.77°E · Elevation: 112 m

Statistics for this station calculated over all years of data

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Highest daily	*118.8*	*172.4*	*85.4*	*83.4*	*46.0*	*146.6*	*51.6*	*52.6*	*35.2*	*27.6*	*64.4*	*38.8*
Date of highest daily	29th 2013	10th 2020	21st 2021	21st 2015	24th 2013	6th 2016	27th 2020	10th 2020	15th 2010	15th 2014	2nd 2010	14th 2018

1) Calculation of statistics

Summary statistics, other than the Highest and Lowest values, are only calculated if there are at least 20 years of data available.

2) Gaps and missing data

Gaps may be caused by a damaged instrument, a temporary change to the site operation, or due to the absence or illness of an observer.

3) Further information

http://www.bom.gov.au/climate/cdo/about/about-rain-data.shtml.

Product code: IDCJAC0009 reference: 75919701 Created on Fri 11 Jun 2021 14:02:05 PM AEST

Daily Rainfall (millimetres)

CAMPBELLTOWN (MOUNT ANNAN)

Station Number: 068257 · State: NSW · Opened: 2006 · Status: Open · Latitude: 34.06°S · Longitude: 150.77°E · Elevation: 112 m

2021	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1st	0	0.4	0	0	0	0	1.0	0.2				
2nd	1.8	37.4	0	0	0	0	3.2	0				
3rd	12.6	0	0	0	0	0	0	1.0				
4th	0.2	0	0	0	0.2	11.8	0.2	0.2				
5th	6.6	0	0	0	17.2	0	0	0				
6th	1.6	0	0	0	20.0	0	0	0				
7th	0	3.8	0	0	33.0	0	0	0				
8th	0.6	0.2	0	0.2	1.6	0	0.2	0				
9th	0.2	0	0	0.2	0	4.6	0	0				
10th	0	0	0	0	0	0.2	5.8	0				
11th	0	0	0	0	1.4	6.4	0.6	0				
12th	0	0	2.2	0	0.4	0	0.2	0				
13th	0	27.0	1.6	0	4.8	0	0.2	0				
14th	0	3.0	11.0	0	0	0	0	0				
15th	0	0	5.8	0	0	0	0	0				
16th	0	0.6	0	0	0	0	2.2	0				
17th	0	4.6	5.4	0	0	9.6	0.4	0				
18th	0	0.8	3.0	0	0	0	0	0				
19th	0	5.0	29.4	0	0	2.2	0	0				
20th	0.8	1.0	28.2	0	0	0.4	0	0				
21st	0	0	85.4	0	0	0.4	0	0				
22nd	0	0	29.8	0	0.2	0	0.2	0				
23rd	0	0	47.0	0	0.2	0	1.0	0				
24th	0	0	28.6	0	3.0	0.2	1.0	23.8				
25th	0	0.8		0	0	0.8	0	22.0				
26th	0	13.8		0	0	0	0					
27th	0.2	0.2		0	0	0.2	0					
28th	7.0	0		0	0	0	0					
29th	3.4			0	0	0.2	0					
30th	17.8			0	0	9.2	0					
31st	15.4				0		0					
Highest daily	17.8	37.4	85.4	0.2	33.0	11.8	5.8	23.8				
Monthly Total	68.2	98.6	277.4	0.4	82.0	46.2	16.2					

↓ This day is part of an accumulated total
Quality control: 12.3 Done & acceptable, *12.3* Not completed or unknown

Product code: IDCJAC0009 reference: 77847094

Daily Rainfall (millimetres)

CAMPBELLTOWN (MOUNT ANNAN)

Station Number: 068257 · State: NSW · Opened: 2006 · Status: Open · Latitude: 34.06°S · Longitude: 150.77°E · Elevation: 112 m

Statistics for this station calculated over all years of data

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Highest daily	*118.8*	*172.4*	*85.4*	*83.4*	*46.0*	*146.6*	*51.6*	*52.6*	*35.2*	*27.6*	*64.4*	*38.8*
Date of highest daily	29th 2013	10th 2020	21st 2021	21st 2015	24th 2013	6th 2016	27th 2020	10th 2020	15th 2010	15th 2014	2nd 2010	14th 2018

1) Calculation of statistics

Summary statistics, other than the Highest and Lowest values, are only calculated if there are at least 20 years of data available.

2) Gaps and missing data

Gaps may be caused by a damaged instrument, a temporary change to the site operation, or due to the absence or illness of an observer.

3) Further information

http://www.bom.gov.au/climate/cdo/about/about-rain-data.shtml.

Product code: IDCJAC0009 reference: 77847094 Created on Wed 25 Aug 2021 11:45:00 AM AEST

Daily Maximum Temperature (degrees Celsius)

CAMPBELLTOWN (MOUNT ANNAN)

Station Number: 068257 · State: NSW · Opened: 2006 · Status: Open · Latitude: 34.06°S · Longitude: 150.77°E · Elevation: 112 m

2017	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1st	28.0	*25.1*	28.0	*25.7*	23.9	17.7	16.4	*18.0*	19.3	25.9	24.7	33.1
2nd	26.9	*27.8*	27.2	*22.6*	22.6	18.2	16.0	*18.2*	21.8	26.0	24.2	28.9
3rd	29.6	*26.8*	24.2	*20.4*	18.7	18.1	13.8	*17.6*	28.7	25.2	29.9	28.2
4th	27.1	*34.8*	24.6	*20.8*	18.9	19.8	21.4	*16.6*	21.1	26.3	16.9	20.5
5th	23.1	*39.7*	24.6	*22.5*	22.2	18.8	20.0	*19.2*	17.8	30.2	17.2	25.3
6th	26.0	*36.8*	26.6	*23.3*	24.3	17.2	17.6	*20.4*	17.7	24.1	24.2	26.0
7th	29.6	*26.0*	25.4	*24.2*	20.8	14.8	18.2	*17.2*	19.6	22.9	22.6	31.9
8th	34.3	*26.2*	22.9	*24.9*	19.0	19.0	17.1	*18.1*	19.2	20.7	21.2	30.3
9th	34.5	*35.0*	23.8	*27.2*	21.3	19.4	17.0	*19.9*	19.9	33.2	24.6	26.9
10th	35.5	*44.1*	26.6	*18.8*	21.2	16.0	17.0	*22.6*	20.2	23.5	25.4	29.2
11th	40.8	*45.6*	27.6	23.9	21.3	18.1	18.0	*23.1*	25.0	25.8	24.7	31.5
12th	30.8	*35.5*	31.1	*21.9*	20.0	21.3	17.0	*21.0*	28.4	28.2	24.3	30.9
13th	39.9	*29.5*	29.5	*23.5*	21.9	20.0	17.1	*21.1*	33.0	27.6	24.0	35.7
14th	38.3	*25.0*	24.4	*25.5*	20.1	20.3	18.6	*23.4*	16.8	19.7	25.4	41.5
15th	28.5	*28.8*	26.5	*24.8*	20.9	19.6	18.4	*22.5*	20.7	22.6	27.6	26.4
16th	33.0	*37.8*	24.1	*25.5*	21.2	16.2	16.6	*19.8*	22.5	26.0	26.8	37.6
17th	41.8	*37.5*	21.6	*24.3*	20.4	18.6	17.9	*21.6*	19.6	26.4	27.2	29.0
18th	42.7	*31.0*	24.8	*25.3*	22.3	18.1	22.3	*15.7*	26.6	26.6	24.0	34.6
19th	22.4	*28.4*	27.2	*24.0*	18.4	19.7	16.3	*16.6*	22.1	31.5	26.3	40.0
20th	30.6	*27.6*	29.5	*24.4*	22.9	20.2	15.3	*17.5*	21.1	19.5	23.7	39.8
21st	28.0	*28.6*	26.4	*23.9*	22.4	19.2	16.9	*15.0*	26.7	20.0	25.4	25.8
22nd	29.2	*31.3*	32.3	*24.4*	21.6	18.4	17.8	*20.3*	29.9	23.0	25.0	28.5
23rd	36.7	*35.5*	22.2	*26.4*	22.9	17.1	21.5	*21.9*	35.7	23.2	29.2	37.3
24th	37.1	*29.9*	24.8	*25.0*	21.4	18.6	19.6	*18.5*	28.9	29.5	33.6	39.3
25th	24.7	*22.0*	24.1	*23.5*	20.4	17.8	20.6	*18.7*	25.8	31.9	30.7	21.2
26th	25.2	*25.0*	29.3	*22.7*	20.5	18.0	20.0	*20.0*	23.6	24.8	30.8	22.5
27th	27.7	*26.9*	29.5	*19.2*	21.0	15.7	18.1	*18.8*	25.1	26.4	28.5	29.1
28th	38.2	*27.2*	23.7	*20.6*	22.0	14.4	18.3	*16.9*	25.6	28.7	28.0	34.0
29th	33.0		32.3	*22.7*	16.5	17.1	19.3	*17.9*	25.7	32.3	27.1	38.4
30th	43.3		22.1	*22.0*	17.8	15.5	27.1	*19.1*	23.6	35.0	29.4	36.6
31st	37.3		23.4		15.9		14.8	*18.1*		22.4		29.1
Highest daily	43.3	*45.6*	32.3	*27.2*	24.3	21.3	27.1	*23.4*	35.7	35.0	33.6	41.5
Lowest daily	22.4	*22.0*	21.6	*18.8*	15.9	14.4	13.8	*15.0*	16.8	19.5	16.9	20.5
Monthly mean	32.4	31.3	26.1	23.5	20.8	18.1	18.3	19.2	23.7	26.1	25.8	31.3

Quality control: 12.3 Done & acceptable, *12.3* Not quality controlled or uncertain, *12.3* Precise date unknown

Product code: IDCJAC0010 reference: 75919988

Australian Government
Bureau of Meteorology

Daily Maximum Temperature (degrees Celsius)

CAMPBELLTOWN (MOUNT ANNAN)

Station Number: 068257 · State: NSW · Opened: 2006 · Status: Open · Latitude: 34.06°S · Longitude: 150.77°E · Elevation: 112 m

Statistics for this station calculated over all years of data

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean	30.4	28.5	26.9	24.2	21.2	17.8	17.8	19.2	22.5	25.1	27.3	28.4
Highest monthly mean	33.0	31.3	29.2	28.1	23.0	18.6	19.4	20.9	25.0	27.1	30.1	31.3
Lowest monthly mean	27.6	25.4	24.8	22.1	19.7	16.3	16.4	17.4	21.2	22.6	25.2	23.9
Highest daily	45.5	45.6	39.7	36.1	28.8	24.8	27.1	28.9	35.7	37.0	42.1	43.1
Date of highest daily	4th 2020	11th 2017	18th 2018	9th 2018	1st 2016	11th 2019	30th 2017	23rd 2012	23rd 2017	25th 2019	20th 2009	31st 2019
Lowest daily	20.2	18.0	16.3	15.0	13.9	12.0	10.2	11.1	13.6	15.0	16.1	17.5
Date of lowest daily	12th 2020	2nd 2012	14th 2020	30th 2020	31st 2015	27th 2016	16th 2015	22nd 2008	17th 2019	3rd 2009	5th 2020	15th 2006

1) Calculation of statistics

Summary statistics, other than the Highest and Lowest values, are only calculated if there are at least 10 years of data available.

2) Gaps and missing data

Gaps may be caused by a damaged instrument, a temporary change to the site operation, or due to the absence or illness of an observer.

3) Further information

http://www.bom.gov.au/climate/cdo/about/about-airtemp-data.shtml.

Product code: IDCJAC0010 reference: 75919988 Created on Fri 11 Jun 2021 14:07:35 PM AEST

Daily Maximum Temperature (degrees Celsius)

CAMPBELLTOWN (MOUNT ANNAN)

Station Number: 068257 · State: NSW · Opened: 2006 · Status: Open · Latitude: 34.06°S · Longitude: 150.77°E · Elevation: 112 m

2018	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1st	32.4	25.4	27.0	34.3	25.4	18.2	18.2	20.3	20.2	24.0	33.2	31.4
2nd	31.9	25.3	27.0	34.7	21.8	16.5	17.5	18.9	17.1	27.2	37.2	33.7
3rd	26.5	27.3	32.2	23.2	27.8	19.7	18.4	23.6	14.1	25.6	33.5	30.3
4th	26.9	28.4	28.2	27.0	27.2	19.1	19.4	18.7	18.1	16.2	28.8	25.5
5th	33.2	31.3	23.8	30.7	24.0	17.6	23.9	20.4	17.3	16.4	29.1	20.8
6th	38.4	30.6	25.4	29.7	23.8	19.1	24.9	18.3	20.9	19.5	32.9	26.9
7th	45.1	31.3	25.3	30.8	25.2	20.1	17.3	16.2	23.4	18.7	24.7	29.0
8th	38.6	36.0	26.1	31.6	26.1	14.0	16.7	19.4	16.8	22.9	20.2	32.0
9th	30.7	36.2	27.1	36.1	26.0	15.2	17.2	20.3	22.2	27.0	23.7	32.5
10th	23.9	34.7	27.2	26.5	24.8	18.3	17.5	23.0	23.2	16.4	24.7	27.9
11th	26.8	32.2	31.2	31.8	16.6	19.6	17.2	26.3	25.1	18.6	27.0	24.3
12th	33.3	33.3	29.2	34.9	16.5	16.6	18.2	15.9	30.1	18.8	27.1	23.9
13th	33.5	31.5	20.4	35.2	19.8	19.0	17.0	18.5	23.7	23.2	29.1	29.3
14th	26.0	38.6	28.8	30.6	20.9	18.3	18.2	23.7	27.9	20.9	23.6	24.0
15th	28.8	33.4	35.7	24.0	21.6	19.3	17.2	25.1	32.2	22.8	25.8	30.6
16th	25.5	31.9	27.0	28.6	20.0	17.6	17.9	20.1	19.3	25.0	20.7	33.3
17th	27.9	31.1	36.8	24.9	20.4	14.7	22.1	18.9	20.1	23.5	23.9	31.8
18th	34.9	34.0	39.7	23.9	22.3	17.6	20.4	21.8	26.8	26.7	23.5	27.8
19th	38.7	30.4	35.4	28.2	21.5	15.4	18.9	15.2	28.8	30.0	25.2	24.3
20th	38.3	23.8	30.5	28.1	22.8	18.4	17.6	16.7	18.7	30.2	29.6	33.7
21st	37.2	26.3	19.5	24.1	21.5	18.9	17.7	16.7	22.5	20.4	28.2	21.9
22nd	41.8	28.2	21.9	25.9	23.5	18.5	16.8	18.3	25.1	25.7	24.2	22.1
23rd	32.5	30.6	22.4	26.7	22.7	20.4	18.2	16.6	22.0	30.9	23.0	24.2
24th	38.2	35.6	27.8	27.4	21.6	18.6	23.4	19.2	17.9	19.9	25.2	28.2
25th	31.0	21.0	32.8	26.8	19.7	17.4	22.1	18.4	19.7	24.6	27.4	33.5
26th	33.1	22.3	25.3	27.1	22.2	18.4	20.4	17.0	19.1	23.5	25.5	34.3
27th	34.0	26.7	25.8	22.6	21.9	17.3	20.8	13.3	22.9	28.1	28.5	37.4
28th	32.9	33.7	30.0	22.1	21.7	15.4	21.1	16.2	31.2	20.6	18.7	39.2
29th	32.4		31.0	22.8	24.5	15.3	24.1	17.9	21.4	20.9	24.3	39.0
30th	36.2		35.0	22.7	18.1	18.9	18.7	19.5	20.8	30.5	26.6	37.4
31st	23.6		26.6		18.3		21.0	17.1		32.5		36.3
Highest daily	45.1	38.6	39.7	36.1	27.8	20.4	24.9	26.3	32.2	32.5	37.2	39.2
Lowest daily	23.6	21.0	19.5	22.1	16.5	14.0	16.7	13.3	14.1	16.2	18.7	20.8
Monthly mean	32.7	30.4	28.5	28.1	22.3	17.8	19.4	19.1	22.3	23.6	26.5	29.9

Quality control: 12.3 Done & acceptable, *12.3* Not quality controlled or uncertain, *12.3* Precise date unknown

Product code: IDCJAC0010 reference: 75919981

Australian Government
Bureau of Meteorology

Daily Maximum Temperature (degrees Celsius)

CAMPBELLTOWN (MOUNT ANNAN)

Station Number: 068257 · State: NSW · Opened: 2006 · Status: Open · Latitude: 34.06°S · Longitude: 150.77°E · Elevation: 112 m

Statistics for this station calculated over all years of data

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean	30.4	28.5	26.9	24.2	21.2	17.8	17.8	19.2	22.5	25.1	27.3	28.4
Highest monthly mean	33.0	31.3	29.2	28.1	23.0	18.6	19.4	20.9	25.0	27.1	30.1	31.3
Lowest monthly mean	27.6	25.4	24.8	22.1	19.7	16.3	16.4	17.4	21.2	22.6	25.2	23.9
Highest daily	45.5	45.6	39.7	36.1	28.8	24.8	27.1	28.9	35.7	37.0	42.1	43.1
Date of highest daily	4th 2020	11th 2017	18th 2018	9th 2018	1st 2016	11th 2019	30th 2017	23rd 2012	23rd 2017	25th 2019	20th 2009	31st 2019
Lowest daily	20.2	18.0	16.3	15.0	13.9	12.0	10.2	11.1	13.6	15.0	16.1	17.5
Date of lowest daily	12th 2020	2nd 2012	14th 2020	30th 2020	31st 2015	27th 2016	16th 2015	22nd 2008	17th 2019	3rd 2009	5th 2020	15th 2006

1) Calculation of statistics

Summary statistics, other than the Highest and Lowest values, are only calculated if there are at least 10 years of data available.

2) Gaps and missing data

Gaps may be caused by a damaged instrument, a temporary change to the site operation, or due to the absence or illness of an observer.

3) Further information

http://www.bom.gov.au/climate/cdo/about/about-airtemp-data.shtml.

Product code: IDCJAC0010 reference: 75919981 Created on Fri 11 Jun 2021 14:07:20 PM AEST

Daily Maximum Temperature (degrees Celsius)

CAMPBELLTOWN (MOUNT ANNAN)

Station Number: 068257 · State: NSW · Opened: 2006 · Status: Open · Latitude: 34.06°S · Longitude: 150.77°E · Elevation: 112 m

2019	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1st	35.0	21.8	*30.7*	*22.4*	25.3	20.3	17.2	*20.6*	*24.1*	22.3	*31.8*	*26.4*
2nd	33.9	25.9	*30.9*	*22.2*	24.3	20.7	21.1	*19.2*	*22.5*	28.2	*33.2*	*21.3*
3rd	31.9	34.0	*31.4*	*26.5*	18.9	17.9	19.1	*22.6*	*26.1*	31.1	*32.6*	*28.2*
4th	35.3	35.6	*34.6*	*22.5*	22.6	13.8	16.8	*19.6*	*28.2*	33.5	*27.8*	*30.5*
5th	40.1	27.0	*34.4*	*22.7*	20.7	16.5	15.9	*20.6*	*24.8*	17.7	*21.7*	*32.8*
6th	21.4	31.7	*36.7*	*27.7*	21.5	19.3	19.2	21.4	*30.0*	26.1	*30.4*	*32.6*
7th	25.3	32.2	*23.2*	*29.6*	22.7	19.4	19.1	*23.0*	*17.6*	25.5	*30.7*	*30.4*
8th	32.3	34.7	*32.1*	*32.4*	19.8	14.3	19.1	*20.3*	*18.8*	23.0	*30.0*	*27.6*
9th	32.0	31.7	*26.1*	*27.5*	20.8	21.0	17.6	*16.0*	*17.7*	20.5	*21.8*	*31.1*
10th	23.7	27.2	*33.7*	*21.2*	18.6	22.2	16.9	*14.6*	*19.0*	21.1	*27.1*	*38.3*
11th	28.9	32.8	*30.4*	*19.9*	21.1	24.8	18.6	*15.5*	*22.2*	18.4	*30.7*	*26.8*
12th	35.5	36.4	*35.0*	*22.7*	22.2	21.5	19.9	*19.0*	*25.7*	18.5	*36.7*	*25.1*
13th	28.2	28.3	*22.2*	*26.8*	22.5	23.1	14.1	*19.1*	*23.6*	20.8	*27.2*	*25.8*
14th	31.9	27.1	*27.8*	*23.8*	24.3	19.6	15.3	*19.2*	*23.2*	26.2	*30.0*	*30.6*
15th	36.8	29.3	*24.0*	*24.3*	22.9	19.5	17.7	*20.8*	*30.0*	29.1	*33.5*	*32.2*
16th	38.0	29.8	*24.6*	*25.7*	22.4	13.9	20.1	*24.9*	*29.7*	25.9	*24.5*	*25.0*
17th	39.4	34.5	*19.4*		23.8	18.0	18.8	*20.2*	*13.6*	27.0	*24.0*	*28.3*
18th	39.3	38.1	*21.9*	*27.6*	24.1	18.4	20.0	*23.3*	*16.6*	26.8	*30.9*	*34.5*
19th	29.2	32.7	*26.9*	*26.0*	23.6	16.8	19.6	*15.9*	*21.5*	28.3	*38.0*	*40.0*
20th	27.8	25.8	*28.1*	*26.3*	23.2	14.9	19.1	*20.3*	*23.5*	24.0	*27.0*	*29.6*
21st	25.6	24.7	*28.2*	*26.2*	26.5	15.0	23.3	*20.8*	*26.5*	26.1	*34.8*	*41.2*
22nd	35.2	25.9	*27.6*	*27.0*	26.5	16.1	23.4	*19.8*	*25.4*	29.4	*29.4*	*24.2*
23rd	33.9	26.5	*28.7*	*25.3*	23.8	16.8	23.2	*18.5*	*21.8*	31.2	*25.0*	*27.6*
24th	30.2	26.0	*31.8*	*26.4*	23.7	17.2	19.9	*25.0*	*22.4*	33.1	*24.6*	*28.3*
25th	37.2	27.4	*25.7*	*29.3*	25.8	17.2	19.5	*23.4*	*20.9*	37.0	*35.7*	*29.7*
26th	39.8	30.7	*25.4*	*27.7*	22.2	18.6	19.3	*14.6*	*23.3*	30.3	*34.7*	*32.7*
27th	38.2	28.1	*22.8*	*20.4*	19.0	19.9	20.4	*18.3*	*26.6*	26.0	*27.7*	*32.9*
28th	30.7	31.3	*26.6*	*26.3*	17.4	20.0	19.7	*22.0*	*21.8*	23.4	*31.9*	*37.9*
29th	34.4		*27.9*	*23.2*	20.0	20.8	21.1	*13.7*	*24.3*	29.9	*33.2*	*35.1*
30th	32.8		*24.9*	*23.9*	15.7	17.4	18.5	*16.4*	*20.3*	33.0	*26.9*	*38.9*
31st	39.3		*21.1*		19.9		19.2	*19.5*		32.9		*43.1*
Highest daily	40.1	38.1	*36.7*	*32.4*	26.5	24.8	23.4	*25.0*	*30.0*	37.0	*38.0*	*43.1*
Lowest daily	21.4	21.8	*19.4*	*19.9*	15.7	13.8	14.1	*13.7*	*13.6*	17.7	*21.7*	*21.3*
Monthly mean	33.0	29.9	27.9	25.3	22.1	18.5	19.1	19.6	23.1	26.7	29.8	31.2

Quality control: 12.3 Done & acceptable, *12.3* Not quality controlled or uncertain, *12.3* Precise date unknown

Product code: IDCJAC0010 reference: 75919977

Daily Maximum Temperature (degrees Celsius)

CAMPBELLTOWN (MOUNT ANNAN)

Station Number: 068257 · State: NSW · Opened: 2006 · Status: Open · Latitude: 34.06°S · Longitude: 150.77°E · Elevation: 112 m

Statistics for this station calculated over all years of data

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean	30.4	28.5	26.9	24.2	21.2	17.8	17.8	19.2	22.5	25.1	27.3	28.4
Highest monthly mean	33.0	31.3	29.2	28.1	23.0	18.6	19.4	20.9	25.0	27.1	30.1	31.3
Lowest monthly mean	27.6	25.4	24.8	22.1	19.7	16.3	16.4	17.4	21.2	22.6	25.2	23.9
Highest daily	45.5	45.6	39.7	36.1	28.8	24.8	27.1	28.9	35.7	37.0	42.1	43.1
Date of highest daily	4th 2020	11th 2017	18th 2018	9th 2018	1st 2016	11th 2019	30th 2017	23rd 2012	23rd 2017	25th 2019	20th 2009	31st 2019
Lowest daily	20.2	18.0	16.3	15.0	13.9	12.0	10.2	11.1	13.6	15.0	16.1	17.5
Date of lowest daily	12th 2020	2nd 2012	14th 2020	30th 2020	31st 2015	27th 2016	16th 2015	22nd 2008	17th 2019	3rd 2009	5th 2020	15th 2006

1) Calculation of statistics

Summary statistics, other than the Highest and Lowest values, are only calculated if there are at least 10 years of data available.

2) Gaps and missing data

Gaps may be caused by a damaged instrument, a temporary change to the site operation, or due to the absence or illness of an observer.

3) Further information

http://www.bom.gov.au/climate/cdo/about/about-airtemp-data.shtml.

Product code: IDCJAC0010 reference: 75919977 Created on Fri 11 Jun 2021 14:07:01 PM AEST

Daily Maximum Temperature (degrees Celsius)

CAMPBELLTOWN (MOUNT ANNAN)

Station Number: 068257 · State: NSW · Opened: 2006 · Status: Open · Latitude: 34.06°S · Longitude: 150.77°E · Elevation: 112 m

2020	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1st	30.6	*45.3*	31.9	*23.3*	16.6	22.5	20.4	*18.9*	18.6	24.6	20.1	33.9
2nd	27.4	*38.2*	36.9	*22.6*	17.6	16.7	23.2	*21.1*	24.0	28.5	22.6	24.5
3rd	34.4	*34.4*	20.6	*24.9*	20.0	18.7	17.4	*20.5*	29.5	30.4	25.0	23.5
4th	45.5	*23.2*	22.4	*25.6*	20.0	17.9	16.4	*21.7*	17.9	31.9	29.7	34.3
5th	27.4	*26.9*	21.8	*23.7*	21.4	18.5	18.4	*16.5*	22.8	32.5	16.1	24.3
6th	25.3	*23.3*	27.5	*23.6*	22.3	18.6	18.9	*17.3*	20.1	21.3	22.5	29.7
7th	34.6	*20.9*	25.0	*21.0*	22.5	18.1	16.6	*13.4*	23.4	20.8	21.8	29.6
8th	27.4	*22.5*	23.1	*20.1*	26.6	17.8	16.9	*18.0*	25.3	26.8	21.6	25.0
9th	26.1	*21.1*	23.2	*23.1*	26.2	20.3	18.0	*14.6*	14.3	22.3	22.9	28.3
10th	36.1	*29.3*	24.2	*23.1*	17.9	16.6	16.3	*16.4*	18.6	25.4	25.3	29.4
11th	22.2	*31.2*	25.4	*25.6*	19.5	21.6	16.2	*17.6*	21.0	28.5	28.8	23.4
12th	20.2	*27.8*	25.9	*22.2*	20.0	17.0	19.0	*16.9*	23.9	26.4	31.1	24.4
13th	26.5	*27.4*	26.8	*22.9*	17.7	19.3	17.7	*22.7*	24.9	30.8	28.9	26.4
14th	30.2	*27.8*	16.3	*26.2*	18.3	19.8	16.6	*18.3*	23.8	23.4	28.6	26.2
15th	30.8	*29.4*	21.5	*28.9*	18.2	20.0	16.7	*18.7*	24.2	29.8	32.0	25.7
16th	29.7	*26.5*	21.8	*23.8*	20.6	20.8	17.0	*19.5*	27.8	20.7	36.6	31.2
17th	21.9	*24.7*	22.7	*26.2*	20.4	16.0	17.4	*18.7*	30.6	28.8	25.0	34.4
18th	24.0	*32.5*	27.0	*25.1*	21.3	19.1	18.2	*20.4*	18.2	26.4	25.5	32.5
19th	24.5	*27.4*	32.1	*23.8*	21.4	19.1	20.1	*20.3*	23.2	22.2	28.4	19.5
20th	31.2		34.9	*18.8*	24.3	18.7	18.2	*17.2*	22.0	23.4	37.4	25.1
21st	32.8	*26.4*	25.6	*25.3*	18.3	18.1	17.6	*17.9*	30.0	27.3	26.6	24.4
22nd	34.8	*24.0*	30.1	*25.1*	15.8	15.9	18.7	*14.9*	26.1	26.9	28.1	26.6
23rd	40.9	*24.0*	22.8	*24.7*	17.3	16.3	19.8	*15.9*	23.1	29.4	26.2	27.3
24th	26.9	*29.1*	23.3	*27.6*	18.2	18.9	18.7	*17.5*	21.4	25.5	24.6	29.7
25th	30.5	*31.4*	25.6	*27.4*	17.9	18.1	20.2	*17.5*	23.1	15.4	26.1	20.8
26th	37.7	*32.9*	22.4	*26.3*	19.8	19.3	15.5	*19.4*	16.7	18.4	35.4	25.1
27th	33.0	*26.6*	21.7	*22.8*	20.9	16.3	16.4	*21.8*	19.3	20.8	30.0	33.4
28th	34.2	*26.6*	24.4	*22.8*	22.7	17.6	18.8	*19.7*	20.5	21.9	40.2	30.1
29th	29.9	*27.4*	25.4	*26.0*	18.8	17.2	20.5	*22.6*	21.5	22.7	39.0	20.6
30th	33.3		24.6	*15.0*	20.1	17.9	19.0	*25.4*	19.8	23.9	25.2	22.6
31st	37.9		27.6		20.7		17.7	*21.5*		22.8		23.5
Highest daily	45.5	*45.3*	36.9	*28.9*	26.6	22.5	23.2	*25.4*	30.6	32.5	40.2	34.4
Lowest daily	20.2	*20.9*	16.3	*15.0*	15.8	15.9	15.5	*13.4*	14.3	15.4	16.1	19.5
Monthly mean	30.6	28.2	25.3	23.9	20.1	18.4	18.1	18.8	22.5	25.2	27.7	26.9

Quality control: 12.3 Done & acceptable, *12.3* Not quality controlled or uncertain, *12.3* Precise date unknown

Product code: IDCJAC0010 reference: 75919959

Australian Government
Bureau of Meteorology

Daily Maximum Temperature (degrees Celsius)

CAMPBELLTOWN (MOUNT ANNAN)

Station Number: 068257 · State: NSW · Opened: 2006 · Status: Open · Latitude: 34.06°S · Longitude: 150.77°E · Elevation: 112 m

Statistics for this station calculated over all years of data

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean	30.4	28.5	26.9	24.2	21.2	17.8	17.8	19.2	22.5	25.1	27.3	28.4
Highest monthly mean	33.0	31.3	29.2	28.1	23.0	18.6	19.4	20.9	25.0	27.1	30.1	31.3
Lowest monthly mean	27.6	25.4	24.8	22.1	19.7	16.3	16.4	17.4	21.2	22.6	25.2	23.9
Highest daily	45.5	45.6	39.7	36.1	28.8	24.8	27.1	28.9	35.7	37.0	42.1	43.1
Date of highest daily	4th 2020	11th 2017	18th 2018	9th 2018	1st 2016	11th 2019	30th 2017	23rd 2012	23rd 2017	25th 2019	20th 2009	31st 2019
Lowest daily	20.2	18.0	16.3	15.0	13.9	12.0	10.2	11.1	13.6	15.0	16.1	17.5
Date of lowest daily	12th 2020	2nd 2012	14th 2020	30th 2020	31st 2015	27th 2016	16th 2015	22nd 2008	17th 2019	3rd 2009	5th 2020	15th 2006

1) Calculation of statistics

Summary statistics, other than the Highest and Lowest values, are only calculated if there are at least 10 years of data available.

2) Gaps and missing data

Gaps may be caused by a damaged instrument, a temporary change to the site operation, or due to the absence or illness of an observer.

3) Further information

http://www.bom.gov.au/climate/cdo/about/about-airtemp-data.shtml.

Product code: IDCJAC0010 reference: 75919959 Created on Fri 11 Jun 2021 14:06:46 PM AEST

Daily Maximum Temperature (degrees Celsius)

CAMPBELLTOWN (MOUNT ANNAN)

Station Number: 068257 · State: NSW · Opened: 2006 · Status: Open · Latitude: 34.06°S · Longitude: 150.77°E · Elevation: 112 m

2021	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1st	22.6	30.1	*34.8*	26.2	24.3	19.0	18.0	*22.8*				
2nd	22.0	26.2	*24.4*	*27.6*	24.6	22.5	18.4	*19.0*				
3rd	26.5	27.6	*24.7*	*27.6*	26.1	13.5	18.5	*20.1*				
4th	29.4	30.4	*29.3*	*30.9*	15.3	19.4	16.1	*15.4*				
5th	30.5	31.0	*24.8*	*28.3*	18.9	17.4	16.8	*19.4*				
6th	25.2	27.0	*25.1*	*27.4*	21.9	20.2	16.4	*21.0*				
7th	23.2	29.6	*28.0*	*27.0*	21.2	19.3	16.6	*19.7*				
8th	24.9	24.6	*29.2*	*26.9*	25.7	19.2	17.5	*15.8*				
9th	27.1	25.0	*31.7*	*29.4*	22.3	15.7	12.9	*19.8*				
10th	30.2	25.5	*26.6*	*22.5*	24.7	8.6	15.5	*22.2*				
11th	30.7	29.7	*26.5*	*18.3*	21.6	15.3	18.0	*24.7*				
12th	34.8	32.3	*24.5*	*21.3*	22.9	17.3	18.4	*20.8*				
13th	31.9	20.8	*33.0*	*23.0*	24.0	18.1	19.0	*20.3*				
14th	38.9	25.6	*18.2*	*27.8*	19.6	18.1	15.0	*20.8*				
15th	32.7	25.8	*24.3*	*25.9*	16.8	18.7	21.5	*21.0*				
16th	28.8	26.2	*20.0*	*22.3*	18.4	19.8	17.5	*21.7*				
17th	27.6	24.5	*24.2*	*20.0*	20.5	16.9	14.0	*19.7*				
18th	33.8	25.6	*20.2*	*23.9*	20.2	18.7	18.1	*19.2*				
19th	25.5	28.8	*24.6*	*24.9*	20.8	15.2	15.5	*22.0*				
20th	21.7	30.3	*20.2*	*23.0*	22.1	16.9	16.0	*23.8*				
21st	29.8	30.5	*19.5*	*21.3*	18.2	17.7	15.9	*23.7*				
22nd	37.3	30.8	*19.1*	*19.8*	21.2	18.4	16.7	*27.9*				
23rd	36.0	20.3	*19.7*	*22.6*	21.0	17.1	14.7	*25.8*				
24th	40.0	23.0		*23.5*	20.8	21.9	17.7	*11.1*				
25th	38.7	23.5		*22.2*	21.9	18.9	14.9					
26th	39.6	30.5		*23.8*	21.3	18.0	19.8					
27th	22.3	24.8		*23.9*	18.7	18.8	20.0					
28th	22.9	30.5		*23.0*	17.0	17.0	24.6					
29th	21.6			*24.3*	16.4	16.4	17.8					
30th	30.4			*24.6*	16.5	19.0	18.7					
31st	22.9		25.6		19.5		21.6					
Highest daily	40.0	32.3	*34.8*	*30.9*	26.1	22.5	24.6	*27.9*				
Lowest daily	21.6	20.3	*18.2*	*18.3*	15.3	8.6	12.9	*11.1*				
Monthly mean	29.3	27.2	24.9	24.4	20.8	17.8	17.5					

Quality control: 12.3 Done & acceptable, *12.3* Not quality controlled or uncertain, *12.3* Precise date unknown

Product code: IDCJAC0010 reference: 77847110

Australian Government
Bureau of Meteorology

Daily Maximum Temperature (degrees Celsius)

CAMPBELLTOWN (MOUNT ANNAN)

Station Number: 068257 · State: NSW · Opened: 2006 · Status: Open · Latitude: 34.06°S · Longitude: 150.77°E · Elevation: 112 m

Statistics for this station calculated over all years of data

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean	30.4	28.5	26.9	24.2	21.2	17.8	17.8	19.2	22.5	25.1	27.3	28.4
Highest monthly mean	33.0	31.3	29.2	28.1	23.0	18.6	19.4	20.9	25.0	27.1	30.1	31.3
Lowest monthly mean	27.6	25.4	24.8	22.1	19.7	16.3	16.4	17.4	21.2	22.6	25.2	23.9
Highest daily	45.5	45.6	39.7	36.1	28.8	24.8	27.1	28.9	35.7	37.0	42.1	43.1
Date of highest daily	4th 2020	11th 2017	18th 2018	9th 2018	1st 2016	11th 2019	30th 2017	23rd 2012	23rd 2017	25th 2019	20th 2009	31st 2019
Lowest daily	20.2	18.0	16.3	15.0	13.9	8.6	10.2	11.1	13.6	15.0	16.1	17.5
Date of lowest daily	12th 2020	2nd 2012	14th 2020	30th 2020	31st 2015	10th 2021	16th 2015	22nd 2008	17th 2019	3rd 2009	5th 2020	15th 2006

1) Calculation of statistics

Summary statistics, other than the Highest and Lowest values, are only calculated if there are at least 10 years of data available.

2) Gaps and missing data

Gaps may be caused by a damaged instrument, a temporary change to the site operation, or due to the absence or illness of an observer.

3) Further information

http://www.bom.gov.au/climate/cdo/about/about-airtemp-data.shtml.

Product code: IDCJAC0010 reference: 77847110 Created on Wed 25 Aug 2021 11:47:20 AM AEST

niche Environment and Heritage

niche-eh.com

Excellence in your environment

Contact Us

Niche Environment and Heritage
02 9630 5658
info@niche-eh.com

NSW Head Office – Sydney
PO Box 2443 North Parramatta
NSW 1750 Australia

QLD Head Office – Brisbane
PO Box 540 Sandgate
QLD 4017 Australia

Sydney
Illawarra
Central Coast
Newcastle
Mudgee
Port Macquarie
Brisbane
Cairns

Our services

Ecology and biodiversity
Terrestrial
Freshwater
Marine and coastal
Research and monitoring
Wildlife Schools and training

Heritage management
Aboriginal heritage
Historical heritage
Conservation management
Community consultation
Archaeological, built and landscape values

Environmental management and approvals
Impact assessments
Development and activity approvals
Rehabilitation
Stakeholder consultation and facilitation
Project management

Environmental offsetting
Offset strategy and assessment (NSW, QLD, Commonwealth)
Accredited BAM assessors (NSW)
Biodiversity Stewardship Site Agreements (NSW)
Offset site establishment and management
Offset brokerage
Advanced Offset establishment (QLD)

Attachment G – Aboriginal Cultural Heritage Assessment