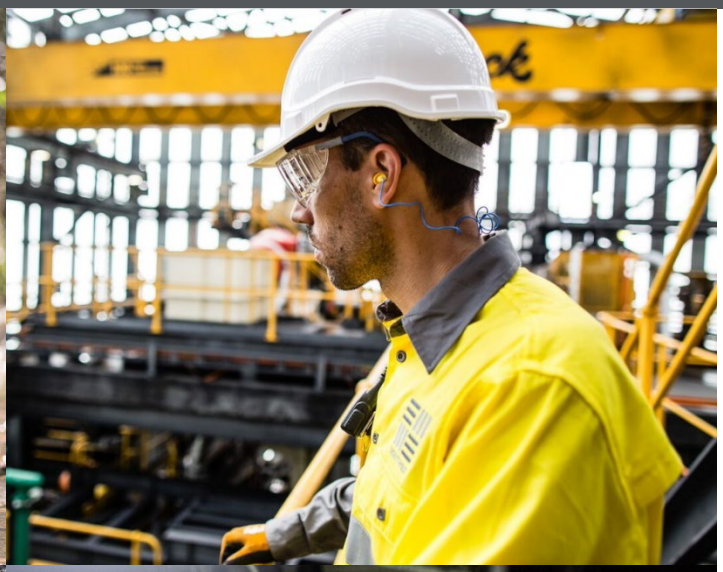
SOUTH32

DENDROBIUM
AREA 3C

JUNE 2024



AREA 3C

WATERCOURSE IMPACT, MONITORING, MANAGEMENT AND CONTINGENCY PLAN

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Review History

Revision	Description of Changes	Date	Approved
A	New Document	May 2019	GB
B	Minor updates	September 2019	GB
C	Figure updates	November 2019	GB
D	Updates to address Conditions 10 of the 3C SMP Approval (granted 19 December 2019)	June 2020	GB
E	Updated to address BCD and WaterNSW Feedback	August 2020	GB
F	Updated for Longwalls 22 and 23	June 2021	GB
G	Updated with Agency feedback	September 2021	GB
H	Updates to address Condition 10 of the 3C SMP Approval (granted 20 December 2022)	March 2023	GB
I	Updated to address DPE Feedback	May 2023	GB
I.1	Updated to address recommendations in the Area 3C Independent Monitoring Review and related comments from WaterNSW	May 2024	GB
1.2	Appendix F Updated	June 2024	GB

Persons involved in the development of this document

Name	Title	Company
Cody Brady	Principal Approvals	Illawarra Metallurgical Coal
Gary Brassington	Manager Approvals	Illawarra Metallurgical Coal
Josh Carlon	Coordinator Environment	Illawarra Metallurgical Coal
Linda Zanotto	Principal Approvals	Illawarra Metallurgical Coal

1 INTRODUCTION

1.1 Project Background

Illawarra Metallurgical Coal (IMC) operates underground coal mining operations at Dendrobium Mine, located in the Southern Coalfield of New South Wales. Longwalls from the Wongawilli Seam have been mined in Areas 1, 2, 3A and 3B. Longwall 21 in Area 3C has recently been extracted and was completed on 6 August 2023. Longwall 19A in Area 3A is currently being extracted.

IMC was granted Development Consent by the NSW Minister for Planning for the Dendrobium Project on 20 November 2001. In 2007, IMC proposed to modify its underground coal mining operations and the NSW Department of Planning advised that the application for the modified Area 3 required a modification to the original consent. The application followed the process of section 75W of the *Environmental Planning and Assessment Act 1979* (EP&A Act) and required the submission of a comprehensive Environmental Assessment (Cardno 2007). The Environmental Assessment (EA) described the environmental consequences likely from cracking and diversion of surface water as a result of the proposed mining. These impacts included diversion of flow, lowering of aquifers, changes to habitat for threatened species as well as other impacts and environmental consequences.

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

Schedule 3, Condition 7 of the Development Consent requires the development of a Subsidence Management Plan (SMP) for approval prior to carrying out mining operations in Area 3C.

This document satisfies Schedule 3, Condition 4 of the Development Consent, which requires the development of a Watercourse Impact Monitoring, Management and Contingency Plan (WIMMCP) for approval prior to carrying out mining operations in Area 3C.

There are two commitments by IMC pertaining to work which has been undertaken by an independent hydrographer to improve monitoring accuracy in Area 3C. The WIMMCP includes:

1. Minimum flow measurement accuracy on gauging stations; and
2. Assessment of flow monitoring procedures, their accuracy and implications for confidence in compliance.

This Revision has been revised to include IMC commitments made in relation to recommendations within the Area 3C Independent Monitoring Review (AGE, 2024) which are summarised as follows:

- Install proposed groundwater monitoring locations (DE-A1-04 and DE-A1-03) prior to July 2024;
- Include additional suitable unimpacted groundwater control sites in the lower Hawkesbury Sandstone (HBSS) and upper Bulgo Sandstone (BGSS) for BACI analysis;
- Undertake quarterly quality sampling (rather than annual sampling) at all Area 3C deep groundwater monitoring points for the first year (where access permits) and then review sampling frequency for future years;
- Investigate the feasibility of including an additional upper BGSS sampling point at S2659;
- Continue monitoring frequencies in relation to surface water level and water quality monitoring.
- Install proposed flow monitoring points LC7S1 and LC9S1 prior to July 2024 and August 2025 respectively.

There is no current plan to extract Longwall 20 as previously proposed and therefore this longwall has been removed from this document.

1.2 Scope

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

> 4. Prior to carrying out any underground mining operations that could cause subsidence in either Area 3A, Area 3B or Area 3C, the Applicant must prepare a Watercourse Impact Monitoring, Management and Contingency Plan to the satisfaction of the Secretary. Each such Plan must:
>
> (a) demonstrate how the subsidence impact limits in conditions 1 - 3 are to be met;

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

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

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

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

(f) be prepared in consultation with BCS, WaterNSW and Resources Regulator;

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

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

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

1.3 Study Area

The Study Area is defined as the surface area that could be affected by the mining of Longwalls 21, 22 and 23 (Longwalls 21 to 23) (**Figure 1-1**). The extent of the Study Area has been calculated by combining the areas bounded by the following limits:

- The 35° angle of draw line from the extents of Longwalls 21 to 23;
- The predicted limit of vertical subsidence, taken as the 20 mm subsidence contour, resulting from the extraction of the Longwalls 21 to 23; and
- The natural features located within 600 m of the extent of the longwall mining area, in accordance with Condition 8(d) of the Development Consent.

The depth of cover varies between 290 m and 420 m directly above the proposed Longwalls 21 to 23. The 35° angle of draw line, therefore, has been determined by drawing a line that is a horizontal distance varying between 200 m and 290 m around the extents of the longwall voids.

The predicted limit of vertical subsidence, taken as the predicted total 20 mm subsidence contour, has been determined using the calibrated Incremental Profile Method (IPM), which is described in MSEC (2021).

The features that are located within the 600 m boundary that are predicted to experience valley related movements and could be sensitive to these movements have been included in the assessments provided in this report. These features include streams and upland swamps.

There are additional features that are located outside the 600 m boundary that could experience either far field horizontal movements or valley related movements. The surface features that could be sensitive to such movements have been identified and have also been included in the assessments provided in this report.

1.4 Objectives

The objectives of this WIMMCP are to identify watercourse features and characteristics within the Dendrobium Longwalls 21 to 23 Study Area (**Figure 1-1**) and to monitor and manage potential impacts and/or environmental consequences of the proposed workings on watercourses.

1.5 Consultation

The Dendrobium WIMMCP has been developed by IMC in consultation with:

- Department of Planning, Housing and Infrastructure (DPHI or “the Department”, previously known as DPE);
- Resources Regulator;
- Biodiversity Conservation Division (BCD) now known as Biodiversity Conservation and Science (BCS) within the Department of Climate Change, Energy, the Environment and Water (DCCEEW); and
- WaterNSW.

In accordance with Condition 10(a), Schedule 3 of the Area 3C SMP Approval (20 December 2022), WaterNSW has been consulted on proposed changes to the WIMMCP. Consultation is detailed in Appendix D of this document.

The WIMMCP and other relevant documentation are available on the IMC website (Schedule 8, Condition 11 of the Development Consent).

1.5.1 Longwall 21 SMP Approval

In accordance with the Area 3C SMP Approval (19 December 2019) Condition 10a, Schedule 3, the WIMMCP was provided to WaterNSW in June 2020 for consultation. Agency feedback was received with **Table 9-1** providing details of feedback and associated responses. The Longwalls 20 and 21 WIMMCP (Revision E) was provided to the Department for consideration. The Department provided comments and recommendations in writing to IMC in July 2021. The WIMMCP was subsequently updated to address these comments (Revision G of this document).

1.5.2 Longwalls 22 and 23 SMP Approval

Revision G of the WIMMCP was submitted with the SMP application for Area 3C Longwalls 22 and 23 and approval was received on 20 December 2022. Table 9-2 provides details of agency feedback and associated responses. The WIMMCP has been updated to address these comments (Revision H). Further revisions were provided in response to requests for information from DPHI dated 14 April 2023 (Revision I), 17 May 2024 (Revision I.1) and 4 June 2024 (Revision I.2).

DENDROBIUM LONGWALLS 21 to 23 SMP Overview

Figure 1-1

SOUTH32

291000 292000 293000 294000

6196000 6195000 6194000 6193000

Lake Cordeaux

FIRE ROAD NO 6E

FIRE ROAD NO 6K

FIRE ROAD NO 6C

WONGAWILLI CK

Longwall 23

Longwall 22

Longwall 21

Longwall 9

Longwall 10

Longwall 6

Longwall 7

Longwall 8

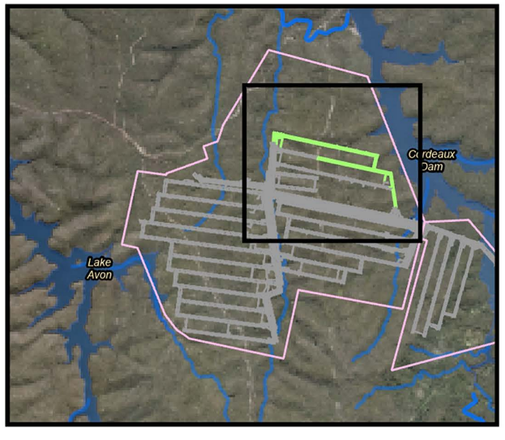
Swamp 140 Swamp 152 Swamp 142 Swamp 141 Swamp 153 Swamp 6 Swamp 7 Swamp 154 Swamp 155 Swamp 9 Swamp 89 Swamp 144 Swamp 145 Swamp 157 Swamp 156 Swamp 8 Swamp 16 Swamp 12 Swamp 146 Swamp 90 Swamp 15b

WC27A WC27 WC29 WC28 WC25 WC26 WC26A WC23B WC23A WC23 WC22 WC24 WC24A WC21 WC20 WC19 WC18 WC17A WC17 WC17B WC16

CR36C CR36B1 CR36

LC3 LC4A LC4 LC5A1 LC5A LC5B LC5B1 LC5 LC6 LC7 LC8 LC9 LC9A LC11 LC10

- Fire Roads
- 10m Contours
- Study Area (35 deg Angle of Draw)
- Study Area (600m Boundary)
- Existing Mine Workings
- Approved Mine Layout
- Dendrobium Goaf
- Rivers
- Creeks
- Tributaries
- Swamp
- Dendrobium Mining Areas



Date: February, 2024

Version 1
Horizontal Datum
MGA - Zone 56

N W E S

Meters
0 500 1,000

2 PLAN REQUIREMENTS

Extraction of coal from longwalls Area 3C will be in accordance with the conditions set out in the Dendrobium Development Consent, the Area 3C SMP Approval as well as conditions attached to relevant mining leases.

Baseline studies have been completed within the Study Area and surrounds to record biophysical characteristics. Monitoring is conducted in the area potentially affected by subsidence from Longwalls 22 to 23 extraction. The baseline studies have identified monitoring sites in these areas based on the Before After Control Impact (BACI) design criteria.

Details of surface water monitoring incorporating water quality and hydrographic monitoring and the interpretation of data are provided in Appendix A of HGEO (2021a). The monitoring program is incorporated into this Plan and the Longwalls 22 and 23 SMP.

The monitoring and assessment programs will provide ongoing water-related monitoring of the streams and sub-catchments potentially affected by the mining of Dendrobium Area 3C and allow assessment of the magnitude of any developing trends in overland and subsurface flow and water quality effects resulting from mining. The Dendrobium Area 3C watercourse monitoring is summarised as **Appendix A: Table 1.1**.

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

The monitoring locations for watercourses within Dendrobium Area 3C will be reviewed as required and can be modified (with agreement) accordingly. Monitoring locations have been updated based on commitments made in the Area 3C Independent Monitoring Review (AGE, 2024) as requested by DPHI.

2.1 Dendrobium Development Consent

The Dendrobium Underground Coal Mine (DA 60-03-2001) modification was approved under section 75W of the EP&A Act 1979 on 8 December 2008. **Table 2-1** lists the Conditions of Consent relevant to the WIMMCP and where the conditions are addressed.

Table 2-1 Dendrobium Development Consent DA-60-03-2001 Conditions

Dendrobium Development Consent Condition	Relevant WIMMCP Section
Condition 2 – Schedule 3 The Applicant must ensure that underground mining operations do not cause subsidence impacts at Sandy Creek and Wongawilli Creek other than “minor impacts” (such as minor fracturing, gas release, iron staining and minor impacts on water flows, water levels and water quality) to the satisfaction of the Secretary.	**Sections 3**, **4** and **5** (Sandy Creek not within the Study Area)
Condition 3 – Schedule 3 The Applicant must ensure the development does not result in reduction (other than negligible reduction) in the quality or quantity of surface water or groundwater inflows to Lake Cordeaux or Lake Avon or surface water inflow to the Cordeaux River at its confluence with Wongawilli Creek, to the satisfaction of the Secretary.	**Sections 3**, **4** and **5**
Condition 4 – Schedule 3 Prior to carrying out any underground mining operations that could cause subsidence in either Area 3A, Area 3B or Area 3C, the Applicant must prepare a Watercourse Impact Monitoring, Management and Contingency Plan to the satisfaction of the Secretary. Each such Plan must: (a) demonstrate how the subsidence impact limits in conditions 1 - 3 are to be met;	**Sections 3**, **4** and **5**

Dendrobium Development Consent Condition	Relevant WIMMCP Section
(b) include a monitoring program and reporting mechanisms to enable close and ongoing review by the Department and Resources Regulator of the subsidence effects and impacts (individual and cumulative) on Wongawilli Creek, Sandy Creek and Sandy Creek Waterfall;	**Section 2** and **Appendix A** (Sandy Creek and Sandy Creek Waterfall not within the Study Area)
(c) include a general monitoring and reporting program addressing surface water levels, water flows, water quality, surface slope and gradient, erodibility, aquatic flora and fauna (including Macquarie Perch, any other threatened aquatic species and their habitats) and ecosystem function;	**Section 3** and **Appendix A**
(d) include a management plan for avoiding, minimising, mitigating and remediating impacts on watercourses; include a tabular contingency plan (based on the Trigger Action Response Plan structure) which focuses on measures for remediating both predicted and unpredicted impacts on watercourses;	**Section 6** and **Appendix A**
(e) address third and higher order streams individually but address first and second order streams collectively;	**Sections 5**
(f) be prepared in consultation with BCS, WaterNSW and Resources Regulator;	**Section 1.5**
(g) incorporate means of updating the plan based on experience gained as mining progresses;	**Section 8.5**
(h) be approved prior to the carrying out of any underground mining operations that could cause subsidence impacts on watercourses in the relevant Area; and	**Section 1.4**
(i) be implemented to the satisfaction of the Secretary.	

2.2 Subsidence Management Plan Approval

The Dendrobium Area 3C SMP Approval was granted by the Director, Energy & Resource Assessments (Underground) of DPE on 20 December 2022 for Longwalls 21, 22 and 23. The approval does not include Longwall 20 as per Condition 1 of Schedule 4 which states "*The Applicant must not extract Longwall 20 as presented in Subsidence Management Plan 2019.*"

Table 2-2 lists the Conditions of the Approval relevant to revising the WIMMCP and where the conditions are addressed.

Table 2-2 Dendrobium Area 3C SMP Approval Conditions

Dendrobium Area 3C SMP Approval Condition	Relevant WIMMCP Section
Condition 10 – Schedule 3 The Applicant must submit a revised Area 3C WIMMCP (including its associated TARP) to the Secretary by 30 March 2023 for approval. The revised Area 3C WIMMCP must:	
(a) be prepared in consultation with WaterNSW;	**Section 1.5**
(b) include a TARP which contains quantitative triggers which support adaptive management measures directed to avoiding exceedances of the performance measures for Wongawilli Creek set out in in Table 1;	**Section 3.6, Section 6.3** and **Table 6-1**
(c) fully reflect the recommendations of the Independent Expert Panel which directly relate to impact monitoring, management, remediation and contingency planning in respect of watercourses;	**Section 2.2.1** **Section 2.2.2**

Dendrobium Area 3C SMP Approval Condition	Relevant WIMMCP Section
(d) reflect the nine monitoring program recommendations included in *Height of Cracking - Dendrobium Area 3B* (PSM, 2018); (e) include a methodology for developing a rating curve and establishing the relationship between the existing WWL gauge and the new gauge required to be constructed under condition 13 below; and (f) fully reflect the advice of the Independent Expert Panel dated March 2022 on the Subsidence Management Plan 2021 relating to improving performance measures for watercourses.	**Appendix C** **Section 2.2.1**

2.2.1 Condition 10(c), Schedule 3 – Independent Expert Panel's Recommendations

The IEP's Part 1 Report (i.e. IEP (2019a)) considered a previous (i.e. 2017) version of the Area 3B WIMMCP. Following input from WaterNSW and DPE, IMC developed substantially revised TARP triggers for the Area 3B WIMMCP between 2019 and 2020. The TARPs presented in Appendix A closely reflect these revised triggers. Consequently, many of the IEP's observations, conclusions and recommendations relevant to the WIMMCP and its TARP no longer have direct bearing. However, IMC has considered all relevant IEP observations and conclusions (as well as its recommendations set out below) and made appropriate changes to the WIMMCP.

In accordance with Condition 10(c), Schedule 3 of the Area 3C SMP Approval, the WIMMCP has been updated to fully reflect the recommendations of the Independent Expert Panel which directly relate to impact monitoring, management, remediation and contingency planning in respect of watercourses. **Table 2-3** details how the recommendations have been addressed or where the recommendations are addressed in the WIMMCP. The Longwalls 20 and 21 WIMMCP (Revision E) was provided to the Department for consideration. The Department provided comments and recommendations in writing to IMC in July 2021. The WIMMCP was updated to address these comments in Revision G of this document which was approved with the Longwalls 22 and 23 SMP. Table 2-3 has been updated most recent installations in line with IEP recommendations where relevant.

Table 2-3 IEP (2019) recommendations

IEP Recommendation	Relevant WIMMCP Section
14. In future, surface water monitoring requirements should include: i. a distinction between primary watercourse monitoring sites, which are the sites at which performance measures are specified; and secondary watercourse monitoring sites, which will provide additional information identified as necessary as the mine plan evolves	Primary watercourse monitoring site are the sites which specific performance measures are specified in the Consent or SMP Approval. The identification and the installation of flow monitoring at these sites is required at least four years in advance of mining activities. Secondary watercourse monitoring site provide additional information identified as necessary as the mine plan evolves. Distinction between primary and secondary monitoring sites is displayed on Figure 3-1, Figure 3-2 and Figure 3-3. Additionally, primary and secondary monitoring sites are detailed in **Table 1.2** of **Appendix A**. Watercourse and monitoring sites where performance measures are applicable (primary watercourse monitoring sites) are separated from those where performance measures are not applicable (secondary watercourse monitoring sites).
ii. a specification of the minimum flow measurement accuracy required at the primary and secondary sites	IMC in consultation with WaterNSW, have upgraded a number of flow monitoring sites across Dendrobium to increase the flow measurement accuracy. IMC will continue to upgrade and improve flow accuracy where possible and practical to do so. This includes using the half-pipe flumes as recommended by WaterNSW. Details of these flow gauges is presented in Section 3.6.1. IMC commissioned an independent hydrologist (Enviromon) to systematically identify and quantify the accuracy or error involved in each part of the flow monitoring process (Enviromon,

IEP Recommendation	Relevant WIMMCP Section
	2019 and Enviromon, 2020). This process has been carried out for a selection of gauging sites in Area 3A/B/C and is currently being applied to the remaining gauging sites, with some fine-tuning of the method for gauging sites where 'underflow' occurs (i.e. flow beneath the monitoring structure). The objective is to re-assess each gauging station for each future End of Panel report and to use the results to reduce the uncertainty where practicable. (i.e. additional data-gathering and improved measurement methods. Recent results are included in the Longwall 21 End of Panel Report.
iii. the identification of the primary sites in proposed future mining areas and the installation of flow monitoring at these sites at least four years in advance of mining activities	The Area 3C Independent Monitoring Review (AGE, 2024) identifies primary flow monitoring or performance measure sites specifying a four year baseline monitoring period as WWL_A, LC5S1 and LC6S1. The review confirmed that flow data will be available more than four years prior to the scheduled commencement of mining of the nearest longwall panel. Capturing a minimum four years of baseline data is not always possible at all Area 3C primary flow monitoring sites due to insufficient time to currently scheduled mining. Primary monitoring sites are those subject to specific performance measures. As monitoring progresses into new areas there may be watercourses that do not have specific performance measures associated with them in the Consent or SMP Approval. Capturing four years of baseline data for such sites will not be possible in all cases.
iv. the identification of the secondary sites as the mine plan evolves and the installation of flow monitoring at these sites at least two years in advance of mining activities or a shorter time if approved as part of the mine plan approval	Watercourse monitoring within Dendrobium Area 3C 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). AGE, 2024 confirmed that four of the six secondary flow monitoring sites would have more than two years of baseline data prior to the scheduled commencement of mining at the nearby longwall panel. The two exceptions are WC20S1 and WC20S2 where flow monitoring commenced between December 2021 and September 2022, less than two years prior to the commencement of mining of Longwall 21. The completion of flow monitoring installation at WC20S1 was delayed following multiple catchment closures due to flooding events in 2020-2022. WC20S2 was installed at the request of WaterNSW, however the timing of this request meant that the installation could not be completed more than two years prior to the commencement of Longwall 21. Monitoring will be conducted throughout the mining period and for at least 2 years following active subsidence. A review of the continuation of post mining monitoring will be carried out in consultation with DPE, WaterNSW and other relevant agencies.
v. paired piezometers in swamp sediments and nearby bedrock, and flow gauges at the swamp exit stream, at minimum for representative large valley infill swamps, and complemented by soil moisture sensors at selected sites	Monitoring the hydrogeological balance of representative swamps with flow gauges at the downstream exit stream is underway for ten swamps (Swamps 7, 9, 16, 144, 145, 153, 154, 155, 156 and 157) in Area 3C (**Section 3.6.1** and **Figure 3-3)**: • Swamp 7 is a large and "complex" valley infill swamp. Note it is the only swamp considered "complex" in the Longwalls 21 to 23 Study Area. A gauging station (LC5S2) has been established on the exit stream for Swamp 7.

IEP Recommendation	Relevant WIMMCP Section
	• Swamp 153 is a small and "simple" headwater swamp. A gauging station (WC26S2) was installed in late 2022 immediately downstream of Swamp 153 to monitor swamp outflow. • Swamp 144 is a small and "simple" headwater swamp. A gauging station (WC20S2) was installed in late 2022 immediately downstream of Swamp 144 to monitor swamp outflow. Piezometers paired with soil moisture probes are installed within these swamps to compliment the water flow monitoring.
vi. consistent use of inter-site comparisons using suitable control sites to complement rainfall-runoff modelling.	IMC now use inter-site comparisons using suitable control sites as the primary method of assessment and employ rainfall-runoff modelling as a secondary or complementary assessment. This assessment methodology and reasoning for the changes is detailed in Watershed HydroGeo 2019b and was developed in consultation with WaterNSW and DPE.
15. Surface flow monitoring associated with mining should be required to be continued until the consequences of mining (including any rehabilitation) have stabilised and/or the mine is considered by the relevant regulatory authorities to have been rehabilitated. This requires clear metrics of stabilisation.	Watercourse monitoring within Dendrobium Area 3C 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 the continuation of post mining monitoring will be carried out in consultation with DPE, WaterNSW and other relevant agencies.
16. To ensure confidence in the accuracy and validation of surface water models and conclusions and to support transparency in decision-making: i. a statement is provided on all relevant modelling assumptions and which good practice guides have been followed and how they have been followed, with justification of any departures from good practice	As noted in response to 14vi, inter-site comparisons using suitable control sites are used as the primary assessment method, with surface water modelling a secondary explanatory method. Where surface water modelling is used, the recommendations of the IEP (2019a) and McMahon (2014) would be adopted (e.g. presentation of model verification, discussion of data sources). The Hydrosimulations (2019) Longwalls 20 and 21 Groundwater Assessment and Watershed HydroGeo (2021) Groundwater Assessment discuss and state assumptions and accuracy of the groundwater model.
ii. updated peer reviews of rainfall-runoff modelling and reporting be undertaken by suitable independent experts and published	See **Section 3.6** and recommendation 16i above. Rainfall-runoff modelling, when it is required, is undertaken by Watershed HydroGeo, who have over 15 years' experience in 1D and 2D rainfall-runoff modelling, groundwater recharge estimation and groundwater modelling. Dendrobium surface water modelling has been reviewed by Emeritus Professor Thomas McMahon (2014). Modelling reports are published on the IMC web page in accordance with Condition 11, Schedule 8 of the Dendrobium Development Consent.
17. Monitoring requirements at the Dendrobium Mine should include: i. an assessment of flow monitoring procedures, their accuracy and implications for confidence in	IMC engaged an independent expert hydrographer (Enviromon) to review flow monitoring procedures and the accuracy of the installed equipment. The review aimed to characterise and compare the discharge measurement uncertainty reduction which can be achieved using half-pipe weir structures requested by WaterNSW, and Orpheus level sensors versus the existing

IEP Recommendation	Relevant WIMMCP Section
compliance is undertaken by a suitable independent expert and published	natural rock bar control arrangements and diver level sensors. This work continues with the latest update included in the LW21 EoP Report.
ii. installation of weirs and/or flumes at selected sites agreed by WaterNSW and the Dendrobium Mine, having regard to the observations made in this report. The selection of sites should consider the benefits in terms of assessing compliance within the remainder of the Area 3B operations and include at least one site representing the catchments draining to Lake Avon potentially affected by LW 16 to LW 18. The mine is currently in process of installing new weirs and/or flumes	IMC have upgraded of number of existing site and constructed a number of new weirs as requested by WaterNSW. These are detailed in Appendix E.
iii. publishing of rating curve data (including the manually gauged reference data) and photographs of flow gauges, so that accuracy can be judged when interpreting performance reports	See Appendix E for details.
19. In the future: ii. TARP triggers should be based on meaningful surface water loss indicators developed in consultation with relevant agencies with oversight and regulatory responsibilities for mining	See **Section 3.6**. IMC developed revised TARP triggers in consultation with WaterNSW and DPE between 2019 and 2020 for Area 3B. The Area 3C TARPs presented in Appendix A have been adapted from these.
iii. TARPs should be related to the desired outcomes (such as maintenance of water flows) and be consistent both within and between mine domains. TARP triggers for surface and groundwater should be based on meaningful flow loss indicators developed in consultation with relevant agencies and authorities with oversight and regulatory responsibilities for mining	See above. Additionally, refer to the Area 3C Swamp TARP Table 1.2 in Appendix A of the SIMMCP for groundwater trigger levels. TARPs (including groundwater triggers) have been developed in consultation with BCS and WaterNSW.
iv. In situations where performance measures of negligible or minor environmental consequences are set by government, mine planning should incorporate appropriate factors of safety to avoid marginal situations associated with gaps in the current knowledge base	See **Section 6.3**. Additionally, subsidence modelling used to determine appropriate setbacks from sensitive environmental features such as Wongawilli Creek is conservative in the predictions generated.
v. Consideration should be given to whether a performance measure of 'minimal iron staining' over a specified length of a watercourse is practically	The most recent observations of iron staining in Wongawilli Creek were evident from Pool 50 to Pool 20 and indicate the extent of iron staining fluctuates but is currently less extensive than when first reported in August 2023. The main source of the iron is a slope spring adjacent to Pool 50 with elevated

IEP Recommendation	Relevant WIMMCP Section
achievable if mining that results in iron staining is approved upstream of that designated area.	concentrations of dissolved iron which flows into Wongawilli Creek. IMC have commissioned independent experts to undertake assessments of the ecotoxic effects on aquatic flora and fauna due to elevated dissolved iron concentrations and associated iron precipitates in Wongawilli Creek. Condition 6 of the Area 3C SMP Approval provides the performance measures for mining in Area 3C, including no more than minor iron staining on Wongawilli Creek. In response to the Longwall 21 End of Panel Report, the Department has requested that IMC review the adequacy of the 'Exceeding Predictions' TARP trigger for iron staining in Wongawilli Creek in future subsidence management plan applications.

2.2.2 Condition 10(d), Schedule 3 – PSM (2018) Recommendations

In accordance with Condition 10(d), Schedule 3 of the Area 3C SMP Approval, the current revision of the WIMMCP reflects the nine monitoring program recommendations included in *Height of Cracking - Dendrobium Area 3B* (PSM, 2018). **Table 2-4** details how the recommendations were addressed or where the recommendations are addressed in the WIMMCP.

Table 2-4 PSM (2018) recommendations

PSM (2018) Recommendation	Relevant WIMMCP Section
1. The monitoring must be holistic and conceptualised from sound models including: a) Geological; b) Geotechnical; c) Groundwater; and d) Surface water.	IMC and consultant experts maintain and manage sophisticated models for geology, geotechnical, groundwater and surface water. Mine layouts for Dendrobium Area 3C have been developed using IMCs Integrated Mine Planning Process (IMPP) . This process considers mining and surface impacts when designing mine layouts. During this process, monitoring programs required to safely, efficiently and responsibly operate are developed. IMC and consultant experts participate in the IMMP. Additionally, the SMP Applications for longwalls in Area 3C include an independent consultant facilitated risk assessment in accordance with the IEP's recommendation (2019a). This risk assessment was attended by experts in the fields of; aquatic ecology, terrestrial ecology, subsidence, groundwater and surface water. These risk assessment was reviewed by an independent expert, Professor Bruce Hebblewhite.
2. All the natural and man-made infrastructure must be identified, characterised and the sensitivities identified.	Natural features such as swamps and watercourse are described and characterised in **Section 3** of the SIMMCP and WIMMCP. The sensitivities of mining to each of these are assessed in the specialist assessments attached to the SMP. Man-made features are characterised and detailed in the SMP and MSEC (2019, 2021 and 2023).
3. Hence the monitoring program is objective driven by the characteristics of the site conditions and the demands of the infrastructure that need to be protected and/or managed.	The Area 3C monitoring program has been designed for the natural features located with the Study Area and addresses the sensitivities of the natural features e.g. Wongawilli Creek has a number of parameters monitored including observational monitoring, water quality and chemistry, surface water flow and pool water levels.
4. The monitoring must be installed early enough to give an effective baseline.	Watercourse monitoring within Area 3C has been installed to provide a minimum of 2 years of baseline data (where timing and approval timeframes of any request to install additional monitoring can be reasonably met).

PSM (2018) Recommendation	Relevant WIMMCP Section
5. The monitoring must continue throughout and after the mining has been completed.	Watercourse monitoring within Area 3C will be conducted throughout the mining period and for at least 2 years following active subsidence. A review of the continuation of post mining monitoring will be carried out in consultation with DPE, WaterNSW and other relevant agencies. Where impacts are observed, the monitoring period will be extended and this will be reported in Impact Assessment Reports and EoP Reports.
6. The monitoring must be cognisant of potential interactions between the mining areas.	Impacts to watercourses along with monitoring sites for Areas 3A, 3B and 3C will be reviewed to ensure monitoring sites, particularly control sites are not influenced by interactions between these mining areas. This will occur on a periodic basis as detailed in **Section 8.5.** EoP assessments will identify any monitoring site which has experienced influence from other mining areas. This will be taken into consideration and an alternate site will be established where appropriate.
7. There must be sufficient monitoring remote from the mining to define the extent of the effects and impacts.	As detailed in **Section 3.6**, a review of the Area 3B WIMMCP TARPs was undertaken in consultation with WaterNSW and DPE between 2018 and 2020. The revised 3B TARP levels have been adapted for the Area 3C WIMMCP including the TARPs. The review determined that two key flow reference sites were suitable. These sites are located at significant distances from mining and would not experience the influences of mining at Dendrobium.
8. Each new mine or area will require a specific monitoring program.	There is a WIMMCP for each of the three Dendrobium mining areas: Dendrobium Area 3A WIMMCP (2020), Dendrobium Area 3B WIMMCP (2020) and Dendrobium Area 3C WIMMCP (this document). Each of these plans have been specifically developed in consideration of the natural features within each of the mining areas.
9. The monitoring program must be flexible and may require a number of cycles of design in order to ensure all the aspects of the “complex system” are captured.	A review of the objectives and targets associated with the Dendrobium Area 3 operations is undertaken on an annual basis via the IMC planning process. These reviews, which include involvement from senior management and other key site personnel, assess the performance of the mine over the previous year and develop goals and targets for the following period (**Section 8.5**). The IMC Subsidence Review Meeting is held monthly and attended by various specialists within IMC. As part of this meeting, environmental impacts and the current monitoring program is presented and reviewed by the attendees, allowing for adjustments to monitoring practices and regimes where necessary. Where a Level 2 or 3 TARP is reached a specialist consultant reviews the monitoring data and assesses whether the monitoring program needs to be modified (**Section 6.2**). The EoP Reporting process includes an assessment of the adequacy of the monitoring program and recommends any changes required (**Section 6.2**).

2.2.3 Condition 10(f), Schedule 3 – IEP Advice dated March 2022

In accordance with Condition 10(f), Schedule 3 of the Area 3C SMP Approval, the WIMMCP has been updated to fully reflect the advice of the Independent Expert Panel dated March 2022 relating to improving performance measures for watercourses. **Table 2-4** details how the recommendations have been addressed or where the recommendations are addressed in the WIMMCP.

Table 2-5 IEP Advice (March 2022) – Improving Performance Measures for Watercourses

IEP Recommendation	Relevant WIMMCP Section
2. The Watercourse Impact Monitoring Management and Contingency Plan should clarify the primary monitoring sites for the performance measures related to pool water levels.	Figure 3-1 of the WIMMCP shows the pool water level monitoring sites across the Study Area. Pool water level sites where performance measures are applicable are symbolised differently to non-performance measure sites.
3. For the application of Method D to pool water level reductions or increases in cease to flow days, an appropriate threshold for changes in cease-to-flow days should be specified as well as associated trigger levels for pool water or flow loss.	TARP assessment Method D relies on a review of qualitative observations of flow through pools along Wongawilli Creek. These observations are reduced to binary values; “flowing” versus “not flowing”. If consecutive pools are not flowing, this triggers a further assessment comparing observed flows along and into Wongawilli Creek (WWU and tributaries) against modelled predictions of flow loss to review whether the flow behaviour (performance) is within prediction. The aim of this is to assess whether there is broad reduction in flow in Wongawilli Creek, be that caused or enhanced by fracturing and/or baseflow reduction, and whether that is within the predictions made by the groundwater modelling. The threshold levels of 5%,10% and 20% levels are applied to Method B “change in cease-to-flow frequency beyond natural”, which are applied at gauging station sites.
The WIMMCP is missing ”a clear explanation of the Water Flow Assessment Methods A-D and associated triggers (which are only summarised in Section 3.6).”	**Appendix F** has been added to include step-by-step documentation of the calculation procedure used for Assessments A, B, C and D.

2.3 Leases and Licences

The following licences and permits may be applicable to IMC’s operations in Dendrobium Area 3C:

- Dendrobium Mining Lease as shown in **Table 2-5**;
- Environmental Protection Licence 3241 which applies to the Dendrobium Mine. A copy of the licence can be accessed at the EPA website via the following link http://www.environment.nsw.gov.au/poeo;
- Relevant occupational health and safety approvals; and
- Any additional leases, licences or approvals resulting from the Dendrobium Approval.

Table 2-6 Dendrobium leases

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

3 MONITORING

3.1 Subsidence Monitoring

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

Pending site access and approval, survey monitoring lines will be established across watercourses and representative large Upland Swamps within the 20 mm predicted subsidence contour. The monitoring lines will target controlling rockbars and steps. Additionally, survey monitoring lines will be installed across the Wongawilli Creek valley to measure closure (or opening) of the valley. Wongawilli Creek monitoring lines will be subject to site constraints.

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

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

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

3.2 Area 3C Watercourses

Extensive geomorphological mapping has been completed for Dendrobium Area 3, including the location of significant features in the watercourses (**Figure 1-1**).

In line with recommendations of IEP (2019a) and the 2016 Catchment Audit (Alluvium Consulting Australia 2017a) the locations and timing of monitoring for ecological aspects, water quality and stream flow is integrated and uses a BACI design **Table 3-1**.

Table 3-1 Summary of watercourses to be monitored within the Study Area

Watercourse	Catchment	Monitoring
CR36	Cordeaux River	Water Chemistry, Observations, Photo, Water Level, Flow
LC5	Lake Cordeaux	Water Chemistry, Observations, Photo, Water Level, Flow
LC5A	Lake Cordeaux	Water Level, Photo and Observations
LC5B	Lake Cordeaux	Water Level, Photo and Observations
LC6	Lake Cordeaux	Water Chemistry, Observations, Photo, Water Level, Flow
LC7	Lake Cordeaux	Water Chemistry, Water Level, Photo and Observations, Flow
LC8*	Lake Cordeaux	Water Level, Photo and Observations
LC9*	Lake Cordeaux	Water Chemistry, Observations, Photo, Water Level, Flow
LC9A*	Lake Cordeaux	Water Level, Photo and Observations
Lake Cordeaux	Lake Cordeaux	Water Chemistry, Photo, Observations
Wongawilli Creek	Wongawilli Creek	Water Chemistry, Observations, Photo, Water Level, Flow, Aquatic Ecology
WC20	Wongawilli Creek	Water Chemistry, Observations, Photo, Water Level, Flow
WC21	Wongawilli Creek	Water Chemistry, Observations, Photo, Water Level, Flow

Watercourse	Catchment	Monitoring
WC24	Wongawilli Creek	Water Chemistry, Observations, Photo, Water Level, Flow
WC24A	Wongawilli Creek	Water Level, Photo and Observations.
WC26	Wongawilli Creek	Water Chemistry, Observations, Photo, Water Level, Flow
WC26A	Wongawilli Creek	Water Level, Photo and Observations.
WC28	Wongawilli Creek	Observations, Water Level, Photo

*Monitoring sites installed/proposed for LW21A. Limited baseline data will be available for LW 22 and 23.

3.3 Observational Monitoring

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

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

The IMC Environmental Field Team (IMCEFT) undertakes structured monitoring assessments, including:

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

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

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

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

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

This monitoring provides key data to assess the Wongawilli Creek Performance Measure of Minor impacts: such as minor fracturing, gas release, iron staining and minor impacts on water flows, water levels and water quality.

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

- Monitoring sites:
    - CR36;
    - Wongawilli Creek (commenced 2001);
    - WC20, WC21, WC24, WC24A, WC26, WC26A, WC28; and
    - LC5, LC5A, LC5B, LC6, LC7, LC8*, LC9* and LC9A*.

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

**Sites installed/proposed for LW21A. Limited baseline data will be available for LW 22 and 23.*

3.4 Water Quality and Chemistry

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

The key field parameters of DO, pH, EC and ORP for monitoring sites within Dendrobium Area 3C will be analysed to identify any changes in water quality resulting from the mining. Pools and streams away from mining are monitored to allow for a comparison against sites not influenced by mining.

Over time, some water quality-specific site names have changed. These changes have been implemented to align monitoring site's names with mapped stream features. These changes are shown in **Table 3-2** below.

Table 3-2 Changes to water quality monitoring site names

Previous Site Name	Current Site Name	Watercourse
SCL	SCk_Rockbar 5	Sandy Creek
WWL2	Wongawilli Ck (FR6)	Wongawilli Creek
WWM1	WC_Pool 46	Wongawilli Creek
WWM3	WC_Pool 43b	Wongawilli Creek
DC_S2	DC_Pool 22	Donalds Castle Creek
DCU3	Donalds Castle Ck (FR6)	Donalds Castle Creek
WC15_S1	WC15_Pool 9	WC15
WC21_S1	WC21_Pool 5	WC21
DC13_S1	DC13_Pool 2b	DC13
WC_Iron Pool	WC_Channel 10	Wongawilli Creek
WWM2	WC_Channel 14	Wongawilli Creek
WC_Rockbar 39	WC_Pool 104	Wongawilli Creek
WC_Pool 51	WC_Pool 119	Wongawilli Creek
WC_Pool 55	WC_Pool 122	Wongawilli Creek
WC_S1	WC_Pool 38	Wongawilli Creek
WCS1	WC_Pool 41	Wongawilli Creek
WC_Pool 41	WC_Pool 44	Wongawilli Creek
WC_Pool 42b	WC_Pool 45	Wongawilli Creek
WC_Pool 42A	WC_Pool 46	Wongawilli Creek

Previous Site Name	Current Site Name	Watercourse
WWM3	WC_Pool 48	Wongawilli Creek
WC_Pool 43b	WC_Pool 49	Wongawilli Creek
WC_Pool 43A	WC_Pool 50	Wongawilli Creek
WCS2	WC_Pool 50	Wongawilli Creek
WC_Pool 44	WC_Pool 53	Wongawilli Creek
WC_Pool 45	WC_Pool 55	Wongawilli Creek
WC_Pool 46	WC_Pool 69	Wongawilli Creek
WC_Pool 47A	WC_Pool 72A	Wongawilli Creek
WC_Pool 47B	WC_Pool 72B	Wongawilli Creek
WC_Pool 49	WC_Pool 87	Wongawilli Creek

Trigger values are proposed for water quality parameters in the TARP (**Appendix A: Table 1.2**). The TARPs are based on the field parameters pH, EC and DO due to the ability of these parameters to indicate potential mining impacts on water quality, the rapid and in situ nature in which they are determined, and the quantity of baseline data available, which for Donalds Castle, Sandy and Wongawilli Creeks is greater than 18 years (since August 2001).

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

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

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

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

As such, exceedance of the water quality performance measures will be quantitatively defined by “Mining results in two consecutive exceedances or three exceedances of the ±3 standard deviation level (positive for EC, negative for pH and DO) from the baseline mean within six months”. The performance measure is applied at the FR6 monitoring sites on Wongawilli Creek. For Lake Cordeaux, the performance measure is applicable to monitoring site LC5_S1, LC_1 and LC_2.

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

3.5 Groundwater

A specialist Groundwater Assessment is provided in Attachment B of the SMP (Watershed HydroGeo 2021). An existing groundwater monitoring program is in place for Dendrobium, which includes Area 3C (**Figure 3-5**). The Dendrobium Long Term Groundwater Monitoring Program is available in **Appendix B**.

Groundwater monitoring is undertaken in:

- Surficial and shallow systems associated with upland swamps and the weathered near-surface bedrock.

- Consolidated rock strata comprising the deeper Hawkesbury Sandstone, the underlying Narrabeen Group and Illawarra Coal Measures.

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

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

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

To investigate groundwater-surface water dynamics in Wongawilli Creek, IMC installed a borehole in consultation with WaterNSW between Wongawilli Creek and the Longwalls 22 and 23. S2508 is an angled bore, inclined 40-degree to the west, with piezometers monitoring the lower HBSS, close to and essentially at the level of Wongawilli Creek.

The adequacy of the groundwater monitoring network was assessed by AGE, 2024 and IMC committed to implementing the following recommendations:

- Installation of groundwater monitoring locations (DE-A1-04 and DE-A1-03) prior to July 2024.
- Addition of suitable unimpacted groundwater quality and level control sites in the lower Hawkesbury Sandstone (HBSS) and upper Bulgo Sandstone (BGSS) by July 2024. Other piezometers around Dendrobium are already installed and monitoring groundwater unimpacted by Area 3 (other than possible far field effects). Therefore, for this purpose, multi-VWP bores operated by IMC on the western edge of Dendrobium Area 5 represent suitable options, i.e. bores S2324 and S2325, which have records back to 2016. There are others in Area 5 that may also serve as reference sites – the performance or reliability of individual piezometers may vary. Additionally, NSW government has monitored bores to the northwest of Dendrobium Area 5 since late 2021. IMC has already received access to these data sets and these sites will also be considered as Reference Sites.
- Quarterly sampling of groundwater quality monitoring sites for the first year (where access permits) and review whether to continue quarterly sampling or return to less frequent sampling for subsequent years.
- Investigation into the feasibility of inclusion of an additional upper BGSS sampling point at S2659. An adjacent hole at the same site (S1969) contains a sample pump at 43 m which provides sampling points at 43 m, 55 m, 109 m (BGSS) and 219 m (SBSS) at this site.

The status of the proposed and installed groundwater monitoring points is provided in the following tables:

Table 3-3 Area 3C Groundwater Level Monitoring

Bore ID	Status[1]	Location	Monitoring start date
S1390 S2514	Terminated Active	Longwall 22	21/05/2005
S1844	Active	Road between Longwalls 22 and 23	21/08/2006
S2059 DE-A1-03	Active Installed	Longwall 23	15/08/2011
S2211	Active	South of Longwall 22	30/09/2013
S2212	Active	Road between Longwalls 22 and 23	7/10/2013
S2508 DE-A1-06	Active Proposed	Road between Longwalls 22 and 23	23/04/2021
S2518 S2518B	Active	Longwall 23	20/12/2021
S2545 S2545A	Terminated Active	Longwall 21	11/08/2021

[1] Status as at May 2024

Bore ID	Status[1]	Location	Monitoring start date
S2655 S2656A	Proposed Active	Southeast of Longwall 22	24/11/2023
S1779	Active	North of Longwall 23	3/04/2006
S1845	Terminated	South of Longwall 21	29/11/2006
S1871	Active	South of Longwall 22	12/02/2007
S1892	Active	South of Longwall 21	4/08/2008
S2018	Active	North of Longwall 23	14/09/2009
S2207	Active	North of Longwall 23	5/08/2013
S2208 S2288	Active	North of Longwall 23	19/12/2013
S2659 S2659A S2659B	Active	East of Longwall 22	10/08/2009
S2658 S2658A S2658B	Active	East of Longwall 23	13/10/2023
S2669	Installed	North of Longwall 23	TBC
DE-A1-04	Proposed – To be installed before July 2024	Northeast of Longwall 23	TBC

Table 3-4 Area 3C Groundwater Quality Monitoring

Monitoring Site ID	Status[2]	Location	Sampling start date
S2659	Installed	East of Longwall 22	20/03/2024
S2658	Installed	East of Longwall 23	TBC – July 2024
DE-A1-03	Installed	Longwall 23	TBC – July 2024
DE-A1-04	To be installed before July 2024	Northeast of Longwall 23	TBC – July 2024

3.6 Surface Water Flow and Pool Water Level

Existing surface water flow gauges and data loggers are installed at key stream flow monitoring sites; additional sites are proposed to be installed to effectively monitor streams that may potentially experience influence from mining the proposed longwalls (**Figure 3-3**). A recommendation of the Area 3C Independent Monitoring Review was for installation of monitoring sites LC7S1 and LC9S1 to be before July 2024 and August 2025 respectively, to achieve more than two years of baseline monitoring data. At the time of writing, installation of these sites was scheduled for July 2024. Water level data loggers are also installed at stream flow monitoring sites along with manual benchmark water level monitoring sites. Data has been collected since 2003 and has been compiled within monitoring and field inspection reports, EoP Reports and regular impact update reports. Pool water level and flow monitoring sites have been established in Dendrobium Area 3C for monitoring before, during and after mining.

[2] Status as at May 2024

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

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

Pool water levels in swamps and streams are measured using installed benchmarks in impact sites and reference sites (**Figure 3-1)**.

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

This monitoring provides key data to assess the Wongawilli Creek Performance Measure of Minor impacts: such as minor fracturing, gas release, iron staining and minor impacts on water flows, water levels and water quality.

Performance against this measure will be based on comparing pool water levels before mining with after mining. Exceeding prediction is defined as fracturing resulting in diversion of flow such that >10% of the pools have water levels lower than baseline period along Wongawilli Creek. Pool water level data would also be used to determine the success of any pool/rockbar mitigation or rehabilitation.

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

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

The flow monitoring sites are installed downstream of the mining area to assess any changes in surface flow from a catchment resulting from the mining, see Section 3.6.1. Sites have previously been installed using natural flow control features such as rockbars. However, in line with the recommendations of the IEP (2019a) and approval from WaterNSW, the installation of low-flow structures (half pipes) has commenced, in order to gain high quality low-flow data. Flow monitoring sites are not installed directly over the longwalls as mining induced surface fracture networks typically result in recession flows being significantly or entirely diverted below the surface. The downstream monitoring sites are installed to measure catchment flow and monitor for reductions downstream of the mining area.

Flow gauges have been installed on Sandy Creek (Area 3A) and its tributaries, SC10, SC10C; Wongawilli Creek (Area 3B and 3A) and its tributaries WC21, WC15 and WC12 (Area 3B), WC20, WC24, WC26; Donalds Castle Creek and its tributaries DC13 (Area 3B), DC8; and Lake Avon tributaries LA2, LA3, LA4, Native Dog Creek and tributary NDT1 (Area 3B), AR19, CR36 and Lake Cordeaux tributaries LC5, LC6, LC7* and LC9*. The historical flow record has been plotted alongside the record from a nearby ‘control’ gauge i.e. a gauge that was not mined under, either at all or not during the period of interest.

**Sites not installed at time of writing; however are scheduled to be installed prior to July 2024.*

A review of the Area 3B WIMMCP Trigger Action Response Plan (TARP) was undertaken in consultation with WaterNSW and DPE between 2018 and 2020 (**Appendix A**). Key features of the updated TARPs are:

- Inclusion of a comparison of flows recorded at relevant sub-catchment monitoring sites around the Dendrobium mining area against reference sites, supplemented by rainfall-runoff modelling.
- Assessment of sub-catchment hydrology against indicators appropriate to identifying and quantifying potential effects on the broad hydrological behaviour within each sub-catchment; including effects on cease-to-flow conditions that may be significant to ecological values, and effects on median flow which is significant for the water resource potential.

A further assessment has been implemented to analyse the mining effects on low-flows that are known to occur along the “middle reach” of Wongawilli Creek, between Area 3A and 3B. The revised 3B TARP levels have been adapted for the Area 3C WIMMCP including the TARPs.

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

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

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

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

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

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

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

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

The step-by-step procedure used in calculations for these assessments is presented in **Appendix F**. The TARP Trigger Levels used in Assessment Method C have been updated to be based on the ‘Expected Flow’. This is considered more appropriate due to some sites having short baseline periods which can skew the pre-mining Q50 toward wet or dry periods. More detailed discussion of the approach is provided in Watershed HydroGeo (2019b), which was used to consult with agencies during 2019-20. If any of these indicate an impact is likely to have occurred, then the EoP Report will describe the impact as it relates to one or more of the broad hydrological behaviours, a reduction in the water resource indicator, or impact that could affect the ecological values of the stream. In the event that there is a reduction in Q50 median flow (Assessment C) or base flow reduction (Assessment D), and there is a Performance Measure related to that watercourse, then the reduction would be compared against the predicted losses from contemporary Groundwater and Surface Water Assessments to assess whether effects that cannot be explained by natural variability "exceed prediction". The assessment will determine if the impact is ‘within Prediction’ or ‘exceeding Prediction’, with further actions triggered by that outcome.

IMC commissioned the development of a regional-scale numerical groundwater flow model in support of mining at Dendrobium Colliery (Coffey Geotechnics 2012). IMC commissioned HydroSimulations (2014) to review and enhance the model at regular intervals. Predictions from the latest approved groundwater model will be used to determine ‘within Prediction’ or ‘exceeding Prediction’ as stated above.

3.6.1 Flow Gauges

IMC in consultation with WaterNSW, have upgraded a number of flow monitoring sites across Dendrobium to increase the flow measurement accuracy. IMC will continue to upgrade and improve flow accuracy where possible and practical to do so. This includes using the half-pipe flumes as recommended by WaterNSW. Table 3-3 details flow gauges in Area 3C. **Appendix E** contains further detailed information of the Area 3C flow monitoring stations including; location (easting and northings), elevation, photos of the site, type of structure and installation dates.

Table 3-5 Flow guages in Area 3C

Watercourse	Site	Status
WC20	WC20S1	Installed
WC20	WC20S2	Installed

WC21	WC21S1	Installed. Note this is a natural rockbar flow site.
WC24	WC24S1	Installed
WC26	WC26S1	Installed
WC26	WC26S2	Installed
LC5	LC5S1	Installed
LC5	LC5S2	Installed
LC6	LC6S1	Installed
CR36	CR36S1	Installed
LC7	LC7S1	Proposed site – scheduled to be installed prior to July 2024
LC9	LC9S1	Proposed site – scheduled to be installed prior to July 2024

3.6.2 WWL_A Flow Rating Curve

In accordance with Condition 10(e), Schedule 3 of the Area 3C SMP Approval, a methodology for developing a rating curve between WWL and WWL_A is detailed **Appendix C**.

Findings from this report indicate further investigation and steps are required to confidently transition from WWL to WWL_A. When documenting recommendations for further work, Enviromon (2020) noted the requirement for more gaugings across the range of flows, as well as some additional data from the hydrographers. Some new gaugings are now available that would allow this work to commence. However IMC are now investigating the potential for camera-based (image velocimetry) gauging methods to improve the rating curve at all sites at Dendrobium. The use of this equipment/method would assist the development of a more confident WWL:WWL_A relationship. A trial image velocimetry site was installed at CR36S1 in late 2023. As of the time of writing, data and images were still being recorded at the site to cover the required range of flow conditions. Once the full range of flows was collected at CR36S1 the equipment will be moved to the next flow monitoring site, with the aim of rolling it out across all sites over the next few years. As a result of this, the development of the WWL:WWL_A relationship will incorporate the velocimetry findings.

In the short to medium term, IMC will continue to monitor both WWL and WWL_A gauging sites.

3.6.3 Flow measurement accuracy at gauging stations

At Dendrobium Mine, IMC began installing flow gauging infrastructure in 2007. At the request of the landholder (WaterNSW) most of these sites relied on ‘natural’ controls, rather than artificial weirs/controls, to form pools at which stream level could be measured and then converted to an estimate of stream flow via a rating curve.

Since that time, IMC have made progress in improving surface water flow monitoring with respect to:

- Improving and replacing gauging infrastructure (e.g. installation and use of artificial weirs, as now agreed by WaterNSW);
- Improved (more accurate) water level sensors at pools;
- In limited circumstances obtaining special access to the WaterNSW catchment during and following moderate/high rainfall periods (when access is normally restricted) to improve level to flow conversion (the “rating curve”);
- Understanding and quantifying level and flow measurement uncertainty; and
- Semi-quantitative flow observations at all watercourse sites, where more quantitative flow gauging is not practical.

IMC engaged a specialist hydrologist (Enviromon) to review hydrographic methods and procedures to reduce uncertainty and improve level and flow measurement and estimation. Changes to equipment and procedure such as those listed above, have resulted in some improvement in flow measurement, especially so at sites that now rely

on artificial flumes and weirs (and a natural rockbar control). Reporting of flow gauge uncertainty using the tools developed by Enviromon has been provided in recent End of Panel Reports (e.g. for Longwalls 17 and 18). This shows that uncertainty in ML/d is small (i.e. higher reliability) at low to medium flows, increasing at high flows due to few or no check gaugings, plus flow occurring above the rockbar or engineered structure. Flow gauging has the lowest uncertainty at medium flows (often +/- 20 to 40%) at the flow gauges at Dendrobium, but higher at sites with natural controls (e.g. DCU, WWL).

Despite these improvements, estimation of flow during and after high rainfall events is difficult, primarily due to technology limitations, access and safety. This has consequences for reliably estimating flow statistics, especially monthly/annual average (arithmetic mean) flow (or the average across other similar periods). This is because the average is strongly influenced by the highest flows that typically occur over 3-10 days per year, and uncertainty in measuring those high flows propagates large errors through to estimates of the change in average flow between different periods.

IMC has become aware of technology that would remove the need to manually measure high flows, and so remove the safety risk, has been developed in recent years. This technique, Image Velocimetry, uses cameras and software to monitor stream flow and estimate flow velocity. This could be done from fixed positions or from drones or using hand-held devices. A fixed installation, that does not need to be permanent, is preferable.

Estimating volumetric flow still requires the use of assumptions and calculations from the measured flow velocities, but the method also allows for essentially continuous monitoring of sites, rather than relying on periodic visits by field staff. This should improve the quantification of the rating curve across more of the range of flow conditions.

A trial of image velocimetry began in late 2023, which will continue to occur in parallel with further data acquisition to improve the current (standard) methods for measuring stream water level and estimating stream flow, i.e. including expanding on the database of measured flow and improving the level-flow relationship (the rating curve) for each of the monitoring sites in Area 3C.

3.6.4 Assessment of flow monitoring procedures

A review of ALS Hydrographics' surface flow monitoring methods, data analysis and reporting was undertaken by Enviromon. The review recommended a series of improvement opportunities for the flow contractor. Key improvement opportunities were selected to focus on, which have been implemented. A follow-up review by Enviromon was completed in June 2023 to assess the improvements implemented by ALS to date. Flow results incorporating the improvement opportunities will be included in the next End of Panel Report for Dendrobium.

3.7 Near-Surface Groundwater and Soil Moisture

The surface area above Dendrobium Area 3C is characterised by a series of drainage basins separated by steep ridges. The drainage basins drain to Wongawilli Creek, Donalds Castle Creek and directly into Lake Cordeaux.

Monitoring of shallow groundwater levels allows for the indirect measurement of water storage and transmission parameters within the saturated part of hill-slope/upland swamp complexes. Shallow groundwater piezometers have been installed within Swamps 7 (three sites), 9 (two sites), 16 (two sites), 144, 145, 153,154, 155, 156 and 157 in Area 3C (**Figure 3-4**). Reference swamps are detailed in the Area 3C SIMMCP. This data is used to compare differences in shallow groundwater levels within swamps, streams and hill-slope aquifers before and after mining. Reference sites are monitored to provide a comparison of sites mined under and not mined under during different climatic conditions.

The piezometric monitoring directed at shallow groundwater levels is supplemented with monitoring of soil moisture profiles up to a maximum depth of 1.2 m (**Figure 3-4**). Key monitoring sites will be installed with loggers to provide a continuous soil moisture record.

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

Several climate stations are available for analysis and modelling across Dendrobium mining area with the most appropriate data taking into account proximity, length of record and data quality.

A comprehensive array of multi-level piezometers have been installed on the centreline of panels at Dendrobium Mine in order to monitor pore pressure changes associated with subsidence. These monitoring holes include at

least five transducers per borehole with installation at least 2 years prior to undermining, in line with the recommendations of the IEP (2019a and b). Where these monitoring sites are damaged as a result of undermining they are reinstalled after subsidence movements cease. Daily monitoring of local rainfall and mine water ingress from overlying and surrounding strata, and separation of rainfall correlated inflows for base flow volumetric analyses is also undertaken (IEP 2019a).

3.8 Pools and Controlling Rockbars

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

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

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

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

Extensive geomorphological mapping has been completed for Dendrobium Area 3, including the location of pools and rockbars (**Figure 3-6**).

Area 3C is broadly sited on a plateau dissected by a number of relatively deep sub-catchments draining either into Cordeaux River via Wongawilli Creek or Donalds Castle Creek or five un-named 1st and 2nd order streams draining directly to Lake Cordeaux.

The largest watercourse within the Study Area is Wongawilli Creek, which is located between Areas 3A and 3B. The headwaters of Wongawilli Creek are located along a drainage divide separating surface runoff and shallow groundwater outflow runoff from Native Dog Creek and Lake Avon to the west.

Donalds Castle Creek and its tributaries also drain the north-western part of Area 3B through a weakly incised plateau. Donalds Castle Creek catchment on this plateau is characterised by low topography, upland swamps and numerous unconfined shallow hillslope aquifers. Much of the soil is derived from weathering of shale-rich Mittagong Formation and is more clayey and of lower permeability than residual soils developed purely on Hawkesbury Sandstone outcrop.

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

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

Rockbars and pools in Donalds Castle and Wongawilli Creeks have been mapped (**Figure 3-6**). All mapped rockbar controlled pools in Wongawilli Creek are significant permanent pools.

3.9 Slopes and Gradients

Slopes within Area 3C have been mapped according to their gradients and are identified on Drawing 8 in MSEC (2021). Monitoring of landscape features such as cliffs, slopes and rock outcrops (Figure 3-7) will be undertaken in Area 3C in accordance with the Landscape Monitoring Program in Appendix G.

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

The inspection and monitoring include the following:

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

- The general areas above the current mining location at the time of inspection.

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

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

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

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

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

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

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

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

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

3.10 Erodibility

Most of the surface of Area 3C has been identified as highly weathered Hawkesbury Sandstone outcrops and Sandstone derived-soils. This soil landscape has been identified to have high to extreme erosion susceptibilities to concentrated flows. This results in potential flow on effects to slope stability and erosion from any cracking resulting from subsidence (Ecoengineers 2012).

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

Due to terrain, vegetation and access restrictions, the primary method of identifying any erosion over Area 3C will be Airborne Laser Scanning (ALS). This technique has proven to be successful in generating topographic models of subsidence over entire longwalls and mining domains and will also provide identification of any erosion. The maximum areas, length and depth of erosion will be measured by standard survey methods.

Base surveys over Area 3C using ALS were completed in December 2005. A verification base survey will be conducted prior to the commencement of mining of the proposed longwalls. Subsidence landscape models using the same methodology after the completion of subsidence at each longwall will provide a new (subsided) baseline surface dataset. For a period of up to ten years after mining repeat ALS datasets and surface modelling will be completed to identify new or increases in existing erosion.

Erosion will be quantified by comparison of the immediate post subsidence landscape model with the long-term monitoring model. Targeted ALS scans will be completed where erosion is observed via the observational and landscape monitoring programs or after significant events such as bushfire and flooding.

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

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

3.11 Flora and Fauna

Aquatic flora and fauna in the Study Area are described in Attachment A of the SMP, the Area 3C Aquatic Ecology Assessment (Cardno 2021). Terrestrial flora and vegetation communities in the Study Area are described in Attachment B of the SMP, the Terrestrial Ecology Assessment (Niche 2021).

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

A monitoring program designed to detect potential impacts to terrestrial ecology from subsidence has been implemented for Area 3. The monitoring program is based on a BACI design with sampling undertaken at impact and control locations prior to the commencement of extraction, during extraction and after extraction (**Figure 3-1**).

The existing aquatic ecology monitoring program uses a BACI approach in the data analysis to identify whether there has been any change in life stage detection pre-post impact, or between the control (reference sites) and impact sites. Identification of habitat loss due to mining induced change (e.g. pool water loss due to bedrock fracturing, or flocculant) is also completed to identify impacts.

Monitoring in Area 3C indicates that the habitat in this area is relatively undisturbed. There is sufficient baseline data to enable the detection of changes to ecology associated with mining related impacts.

Monitoring of flora and fauna in watercourses in the study area focuses on:

- Water quality, including pH, DO, ORP, temperature and EC;
- Aquatic macrophytes, including presence, species composition and total area of coverage;
- Aquatic macroinvertebrates using the Australian River Assessment System (AUSRIVAS) sampling protocol and artificial aquatic macroinvertebrate collectors;
- Fish presence and numbers using backpack electro fisher and/or baited traps;
- Presence of threatened species (including Macquarie perch, Littlejohn's tree frog, Giant burrowing frog, Adams emerald dragonfly, Giant dragonfly and Sydney hawk dragonfly); and
- Frog monitoring – frog surveys using standardised transects focussing on Littlejohn’s Tree Frog and Giant Burrowing Frog.

Standardised transects in potential breeding habitat for the threatened frog species Littlejohn's Tree Frog and Giant Burrowing Frog have been established in Dendrobium Area 3C. These repeatable surveys enable direct comparison of the numbers of individuals recorded at each site from one year to the next. The sites have been established within creeks associated with and/or downstream of swamps. Sites will be established on LC5, LC6, WC20, WC24 and WC26 in Area 3C (**Figure 3-9**)

Along each transect the monitoring includes: counts of frogs, an assessment of pools being used for breeding as well as counts of tadpoles and egg masses. This will enable a quantitative as well as qualitative assessment of breeding habitat for these species prior to, during and after mining. Monitoring is also undertaken away from mining at control (reference) sites for the mining versus non-mining comparative assessment.

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

Aquatic ecology monitoring includes direct measures of aquatic flora and fauna as well as biophysical measures.

Aquatic ecology monitoring sites for Area 3C are shown in Attachment A of the SMP, the Aquatic Ecology Assessment (Cardno 2021). These sites are located in watercourses that contain “significant” or “moderate” aquatic habitat and are suitable for AUSRIVAS assessment (i.e. are at least 100 m long).

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

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

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

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

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

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

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

Monitoring site locations are detailed in **Appendix A: Table 1.1** and (**Figure 3-8**).

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

3.12 Reporting

Trigger and impact reporting will be undertaken in accordance with the Watercourse TARP in Appendix A and the Landscape TARP in Appendix G.

Summary reports are required to be submitted to the Secretary every four months during the extraction of longwalls in Area 3C. This regular reporting includes details of monitoring results, an assessment of compliance with performance measures, an assessment of any exceedances of predictions and any level 2 or 3 TARP triggers, actions taken or measures implemented and the seam mining height during the period.

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

Monitoring results will be reviewed monthly by the IC Subsidence Management Committee. However, if the findings of monitoring are deemed to warrant an immediate response, the Principal Approvals will initiate the requirements of the TARPs (**Appendix A: Table 1.2**).

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

DENDROBIUM LONGWALLS 21 to 23 SMP Water Level Monitoring Sites

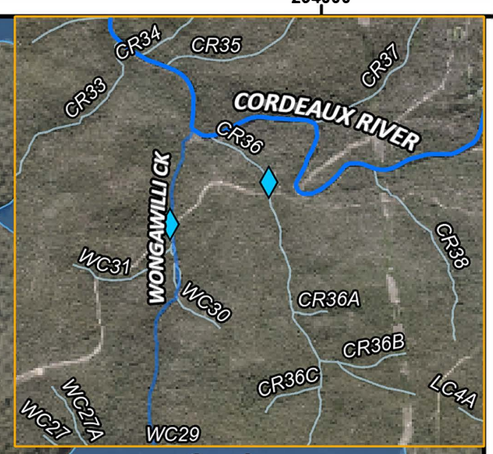
Figure 3-1

SOUTH32

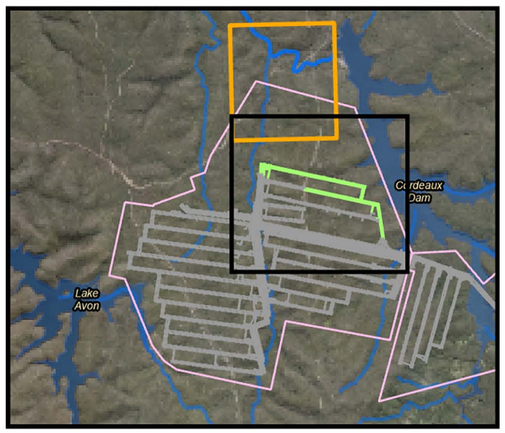
291000 292000 293000 294000

6196000 6195000 6194000 6193000

CR36B1 CR36C LC3 LC4A LC4 CR36 WC27A WC27 WC29 WC28' Swamp 6 Swamp 140 Swamp 152 Swamp 142 Swamp 141 WC25 WC26 Swamp 153 LC5A1 LC5A LC5B LC5B1 WC26A WC23B WC23A WC23 WC22 WONGAWILLI CK WC24 WC24A LC5 Swamp 7 Longwall 23 Longwall 22 Swamp 154 Swamp 89 WC21 WC20 Longwall 21 Swamp 9 LC6 LC7 Swamp 155 Swamp 144 Swamp 145 Swamp 157 Swamp 156 Longwall 9 Swamp 8 WC19 Longwall 10 WC18 WC17A WC17 Longwall 6 Longwall 7 Swamp 90 WC16 WC17B Longwall 8 Swamp 12 Swamp 15b Swamp 146 LC9 LC8 LC9A Swamp 16 LC11 LC10



- Performance Measure Water Level Logger Site
- Water Level Logger
- Manual Water Level Benchmark
- Study Area (35 deg Angle of Draw)
- Study Area (600m Boundary)
- Existing Mine Workings
- Approved Mine Layout
- Dendrobium Goaf
- Rivers
- Creeks
- Tributaries
- Swamp
- Dendrobium Mining Areas



Date: February, 2024

Version 1
Horizontal Datum
MGA - Zone 56

N W E S

Meters
0 500 1,000

DENDROBIUM LONGWALLS 21 to 23 SMP Water Quality and Observation Monitoring Sites

Figure 3-2

SOUTH32

291000 292000 293000 294000

6196000 6195000 6194000 6193000

Swamp 139 WONGAWILLI CK CR36B CR36B1 CR36C LC2 LC3 LC4A LC4 CR36 WC27A WC27 WC_Pool 20 WC29 Swamp 140 Swamp 152 WC28' Swamp 6 Swamp 141 WC26_Channel 4 WC25 Swamp 153 WC26 WC26A LC5A1 LC5A LC5_S2 LC5_S1 LC_1 LC5B LC5B1 LC5_Pool 13 Longwall 23 Swamp 7 LC6_Rockbar 1 LC_2 WC23A WC23 WC_Pool 38 WC24_Pool 10 WC22 WC24 WC24A LC5 Longwall 22 Swamp 154 LC7_Pool 2 Swamp 155 WC21_Pool 5 Swamp 89 WC20_Pool 8 Longwall 21 WC20 Swamp 144 Swamp 9 LC6 LC7 Swamp 156 WC21 WC_Pool 49 Swamp 145 Swamp 157 Longwall 9 Swamp 8 WC19 Swamp 16 LC9 LC8 LC9A LC9_Pool 2 WC18 WC17A WC17 Swamp 12 Longwall 7 Longwall 6 WC17B Swamp 146 LC11

Lake Cordeaux

CR34 CR35 CR37 CR33 CORDEAUX RIVER WONGAWILLI CK Wongawilli Ck (FR6) CR36_S1 CR36 CR38 WC31 WC30 CR36A CR36B CR36C LC4A WC27A WC27 WC29

Lake Avon

Performance Measure Water Quality Site
Water Chemistry and Observation SIte
Water Observation Site
Existing Mine Workings
Approved Mine Layout
Dendrobium Goaf
Rivers
Creeks
Tributaries
Swamp
Dendrobium Mining Areas
Study Area (35 deg Angle of Draw)_line
Study Area (600 m Boundary)_line

Date: May, 2024

Version 1
Horizontal Datum
MGA - Zone 56

N W E S

Meters
0 500 1,000

DENDROBIUM LONGWALLS 21 to 23 SMP Flow Monitoring Sites

Figure 3-3

SOUTH32

291000 292000 293000 294000

6196000 6195000 6194000 6193000

WC27A WC27 WC29 WC28 WC28.1 WC25 WC26 WC23B WC23 WC23A WC22 WC24 WC24A WC21 WC20 WC19 WC18 WC17A WC17 WC17B WC16 WC26A

CR36C CR36B1 CR36 CR36 184.45 LC3 LC4A LC4 LC4 81.78 LC5A1 LC5A LC5B LC5B1 LC5 LC5 187.59 LC6 LC6 117.89 LC7 LC7 33.86 LC8 7.73 LC9 LC9 71.99 LC9A LC11 LC10

WC28 15.67 WC26 56.34 WC24 56.12 WC20 46.7 WC21 239.54 WC19 25.24

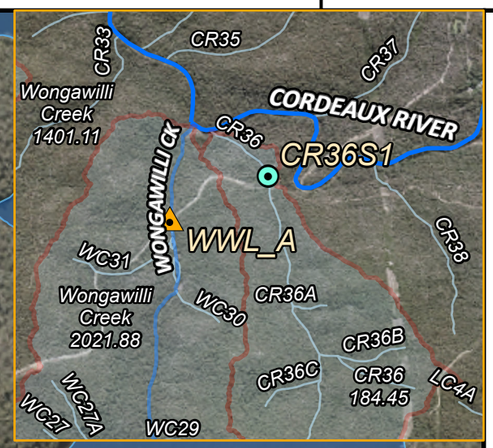
Swamp 6 Swamp 140 Swamp 152 Swamp 142 Swamp 141 Swamp 153 Swamp 7 Swamp 154 Swamp 155 Swamp 9 Swamp 144 Swamp 156 Swamp 145 Swamp 157 Swamp 8 Swamp 89 Swamp 16 Swamp 90 Swamp 12 Swamp 15b Swamp 146

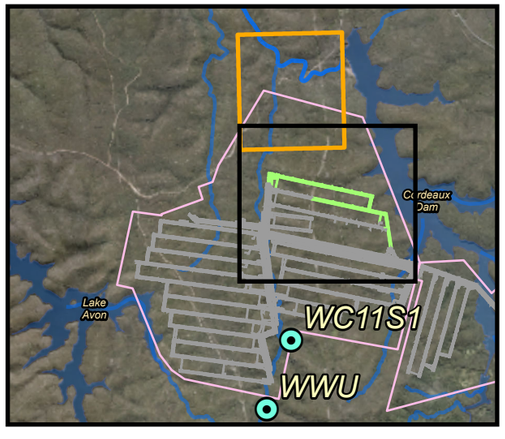
Longwall 23 Longwall 22 Longwall 21 Longwall 10 Longwall 6 Longwall 7 Longwall 8

WC26S1 WC26S2 WC24S1 WC21S1 WC20S1 WC20S2 LC5S1 LC5S2 LC6S1 LC7S1 LC9S1

Lake Cordeaux

WONGAWILLI CK





- Performance Measure Flow Site
- Flow Site
- Catchment Sizes (ha)
- Study Area (35 deg Angle of Draw)
- Study Area (600m Boundary)
- Existing Mine Workings
- Approved Mine Layout
- Dendrobium Goaf
- Rivers
- Creeks
- Tributaries
- Swamp
- Dendrobium Mining Areas
- SDWC Water Storage
- Longwall Labels
- Approved Longwall Labels

Date: February, 2024

Version 1
Horizontal Datum
MGA - Zone 56

N W E S

Meters
0 500 1,000

DENDROBIUM LONGWALLS 21 to 23 SMP Swamp Monitoring

Figure 3-4

SOUTH32

291000 292000 293000 294000

6196000 6195000 6194000 6193000

Lake Cordeaux

Swamp 140 Swamp 152 Swamp 142 Swamp 141 Swamp 6 Swamp 153 Swamp 7 Swamp 154 Swamp 155 Swamp 89 Swamp 9 Swamp 144 Swamp 145 Swamp 157 Swamp 156 Swamp 8 Swamp 16 Swamp 12 Swamp 146 Swamp 90 Swamp 15b

WC27A WC27 WC29 WC28 WC25 WC23B WC23A WC23 WC22 WC24 WC24A WC21 WC20 WC19 WC18 WC17A WC17 WC16 WC17B

CR36C CR36B1 CR36

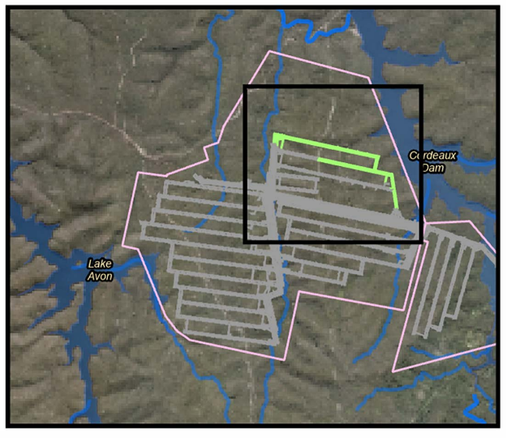
LC3 LC4A LC4 LC5A1 LC5A LC5B LC5B1 LC5 LC6 LC7 LC8 LC9 LC9A LC11 LC10

WC26S2 153_01 LC5S2 07_06 07_05 07_07 154_01 155_01 09_02 09_01 WC20S2 144_01 145_01 157_01 156_01 16_01 16_03

WONGAWILLI CK

Longwall 23 Longwall 22 Longwall 21 Longwall 9 Longwall 10 Longwall 6 Longwall 7 Longwall 8

- Shallow Groundwater and Soil Moisture Site
- Swamp Flow Site
- Study Area (35 deg Angle of Draw)
- Study Area (600m Boundary)
- Existing Mine Workings
- Approved Mine Layout
- Dendrobium Goaf
- Rivers
- Creeks
- Tributaries
- Swamp
- Dendrobium Mining Areas



Date: February, 2024

Version 1
Horizontal Datum
MGA - Zone 56

N W E S

Meters
0 500 1,000

DENDROBIUM LONGWALLS 21 to 23 SMP Groundwater Monitoring

Figure **3-5**

SOUTH32

291000 292000 293000 294000

6196000 6195000 6194000 6193000

Lake Cordeaux

Longwall 23 Longwall 22 Longwall 21 Longwall 10 Longwall 9 Longwall 8 Longwall 7 Longwall 6

S2669 S1779 S2018 S2207 S2288 S2208 S2508 DE-A1-06 S2518 S1844 S2059 DE-A1-03A DE-A1-03B DE-A1-03 S2658B S2658A S2658 S2514 S1390 S2212 S2545A S2545 S2211 S1892 S2659B S2659 S2656A S2655 S2659A S1845 S1871

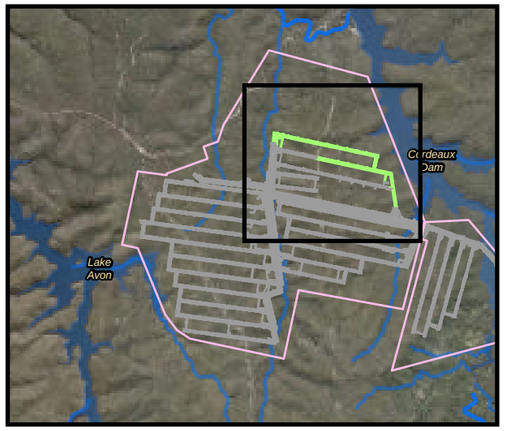
DE-A1-04 DE-A1-04B DE-A1-04A

CR36B1 CR36C CR36 LC3 LC4A LC4 LC5B LC5B1 LC5A1 LC5A LC5 LC6 LC7 LC8 LC9 LC9A LC10 LC11

WC27A WC27 WC29 WC28' WC25 WC26 WC26A WC23B WC23A WC23 WC22 WC24 WC24A WC21 WC20 WC19 WC18 WC17A WC17 WC16 WC17B

WONGAWILLI CK

Swamp 140 Swamp 152 Swamp 142 Swamp 141 Swamp 6 Swamp 153 Swamp 7 Swamp 154 Swamp 155 Swamp 89 Swamp 144 Swamp 156 Swamp 157 Swamp 145 Swamp 9 Swamp 8 Swamp 16 Swamp 12 Swamp 146 Swamp 90 Swamp 15b



Groundwater Monitoring
Proposed Groundwater Monitoring
Terminated Groundwater Monitoring
Study Area (35 deg Angle of Draw)
Study Area (600m Boundary)
Existing Mine Workings
Approved Mine Layout
Dendrobium Goaf
Rivers
Creeks
Tributaries
Swamp
Dendrobium Mining Areas

Date: March, 2024

Version 1
Horizontal Datum
MGA - Zone 56

Meters
0 500 1,000

DENDROBIUM LONGWALLS 21 to 23 SMP Geomorphology

Figure 3-6

SOUTH32

291000 292000 293000 294000

6196000 6195000 6194000 6193000

Lake Cordeaux

Longwall 23 Longwall 22 Longwall 21 Longwall 10 Longwall 9 Longwall 8 Longwall 7 Longwall 6

WONGAWILLI CK

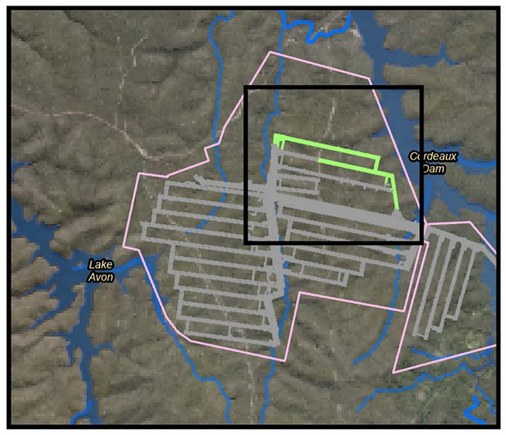
CR36B1 CR36C CR36 LC3 LC4A LC4 LC5A1 LC5A LC5B LC5B1 LC5 LC6 LC7 LC8 LC9 LC9A LC10 LC11

WC27A WC27 WC29 WC28 WC25 WC26 WC26A WC23B WC23 WC23A WC22 WC24 WC24A WC21 WC20 WC19 WC18 WC17A WC17 WC17B WC16

Swamp 140 Swamp 152 Swamp 142 Swamp 141 Swamp 6 Swamp 153 Swamp 7 Swamp 154 Swamp 155 Swamp 89 Swamp 9 Swamp 144 Swamp 145 Swamp 156 Swamp 157 Swamp 8 Swamp 16 Swamp 12 Swamp 146 Swamp 90 Swamp 15b

Stream Mapping Geomorphology

- Step/Waterfall
- Pool
- Rockbar
- Channel
- Boulder Field
- Cascade
- Study Area (35 deg Angle of Draw)
- Study Area (600m Boundary)
- Existing Mine Workings
- Approved Mine Layout
- Dendrobium Goaf
- Rivers
- Creeks
- Tributaries
- Swamp
- Dendrobium Mining Areas



Date: February, 2024

Version 1
Horizontal Datum
MGA - Zone 56

N W E S

Meters
0 500 1,000

DENDROBIUM LONGWALLS 21 to 23 SMP Landscape Monitoring Sites

Figure 3-7

SOUTH32

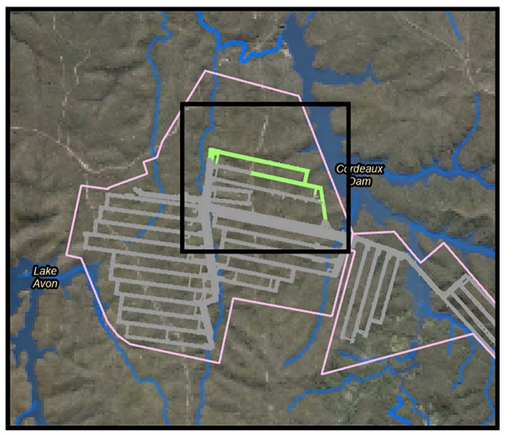
291000 292000 293000 294000

6196000 6195000 6194000 6193000

CR36B1 CR36C LC3 LC4A LC4 CR36 WC27A WC27 WC29 Swamp 140 Swamp 6 WC28' Swamp 152 Swamp 142 Swamp 141 WC25 Swamp 153 WC26 WC26A LC5A1 LC5A LC5B LC5B1 Swamp 7 Longwall 23 WC23B WC23 WC23A LC5 Swamp 154 WC22 WONGAWILLI CK WC24 WC24A Longwall 22 Swamp 9 Swamp 155 Swamp 89 Longwall 21 WC20 WC21 LC7 LC6 Swamp 144 Swamp 156 Swamp 145 Swamp 157 Longwall 9 Swamp 8 WC19 Swamp 16 LC9 LC8 Longwall 10 LC9A WC18 WC17A Longwall 6 WC17 Swamp 12 Longwall 7 Swamp 146 LC11 Swamp 90 WC16 WC17B Longwall 8 Swamp 15b LC10

Lake Cordeaux

- Landscape Monitoring Sites
- Study Area (35 deg Angle of Draw)
- Study Area (600m Boundary)
- Existing Mine Workings
- Approved Mine Layout
- Dendrobium Goaf
- Rivers
- Creeks
- Tributaries
- Swamp
- Dendrobium Mining Areas



Date: February, 2024

Version 1
Horizontal Datum
MGA - Zone 56

N W E S

Meters
0 500 1,000

DENDROBIUM LONGWALLS 21 to 23 SMP Aquatic Ecology Monitoring Sites

SOUTH32

Figure 3-8

291000 292000 293000 294000

6196000 6195000 6194000 6193000

Lake Cordeaux

Longwall 23 Longwall 22 Longwall 21 Longwall 9 Longwall 10 Longwall 6 Longwall 7 Longwall 8

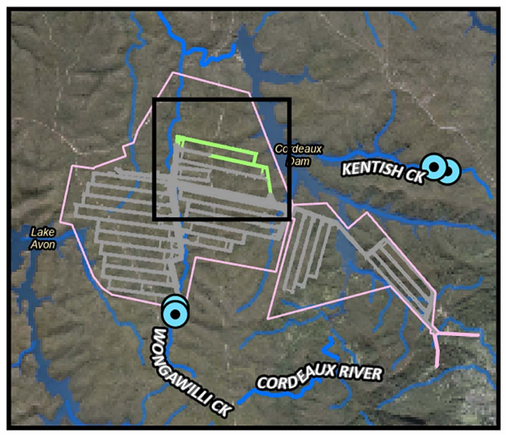
CR36B1 CR36C CR36 LC3 LC4A LC4 LC5A1 LC5A LC5B LC5B1 LC5 LC6 LC7 LC8 LC9 LC9A LC10 LC11

WC27A WC27 WC29 WC28 WC25 WC26 WC26A WC23B WC23A WC23 WC22 WC24 WC24A WC21 WC20 WC19 WC18 WC17A WC17 WC17B WC16

WONGAWILLI CK

Swamp 140 Swamp 152 Swamp 142 Swamp 141 Swamp 6 Swamp 153 Swamp 7 Swamp 154 Swamp 155 Swamp 89 Swamp 9 Swamp 144 Swamp 145 Swamp 157 Swamp 156 Swamp 8 Swamp 16 Swamp 12 Swamp 146 Swamp 90 Swamp 15b

- Reference Aquatic Ecology Site
- Aquatic Ecology Site
- Study Area (35 deg Angle of Draw)
- Study Area (600m Boundary)
- Existing Mine Workings
- Approved Mine Layout
- Dendrobium Goaf
- Rivers
- Creeks
- Tributaries
- Swamp
- Dendrobium Mining Areas



Date: February, 2024

Version 1
Horizontal Datum
MGA - Zone 56

N W E S

Meters
0 500 1,000

291000 292000 293000 294000

6196000 6195000 6194000 6193000

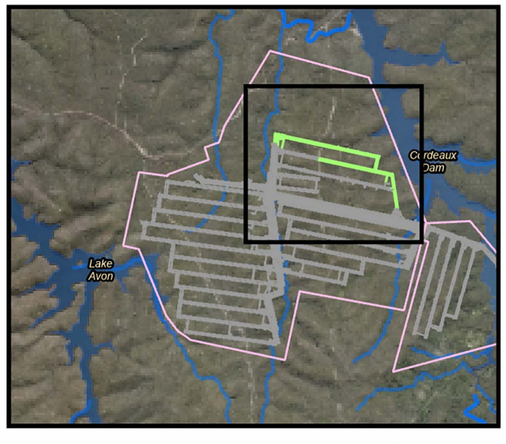
CR36B1 CR36C CR36 LC3 LC4A LC4 WC27A WC27 WC29 WC28 Swamp 140 Swamp 152 Swamp 142 Swamp 141 Swamp 6 Lake Cordeaux WC25 Swamp 153 WC26 WC26A LC5A1 LC5A LC5 LC5B LC5B1 Swamp 7 Longwall 23 WC23B WC23 WC23A WC24 WC24A LC5 Longwall 22 Swamp 154 WC22 WONGAWILLICK Swamp 89 WC20 Longwall 21 Swamp 9 Swamp 155 WC21 WC20 Swamp 144 LC7 LC6 Swamp 156 Swamp 145 Swamp 157 Longwall 9 Swamp 8 WC19 LC6 Swamp 16 LC9 LC8 Longwall 10 LC9A WC18 WC17A Longwall 6 WC17 Swamp 12 Longwall 7 Swamp 146 LC11 Swamp 90 WC16 WC17B Longwall 8 Swamp 15b LC10

DENDROBIUM LONGWALLS 21 to 23 SMP Frog Monitoring Tributaries

SOUTH32

Figure 3-9

- Frog Monitoring Tributaries
- Study Area (35 deg Angle of Draw)
- Study Area (600m Boundary)
- Existing Mine Workings
- Approved Mine Layout
- Dendrobium Goaf
- Rivers
- Creeks
- Tributaries
- Swamp
- Dendrobium Mining Areas



Date: February, 2024

Version 1
Horizontal Datum
MGA - Zone 56

N W E S

Meters
0 500 1,000

4 PERFORMANCE MEASURES AND INDICATORS

Subsidence impact performance measures for Wongawilli Creek are included within Condition 6, Schedule 3 of the Area 3C SMP Approval, Condition 9 of Schedule 2 and Condition 3 of Schedule 3 of the development consent. Under the requirements of this approval and the mine's development consent, these performance measures must be applied to the extraction of Longwalls 21, 22 and 23. These performance measures are presented in **Table 4-1** and will be applied to the Dendrobium Area 3C mining area.

Table 4-1 Subsidence impact performance measures

Dendrobium Development Consent
Condition 2, Schedule 3: • *The Applicant must 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*. Condition 3, Schedule 3: • *The Applicant must 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*.
Area 3C SMP Approval
Condition 6, Schedule 3: *The Applicant must ensure that the development does not cause any exceedance of the performance measures in Table 1, to the satisfaction of the Secretary*. Excerpt from Table 1: Subsidence Impact Performance Measures *Wongawilli Creek* • *Minor environmental consequences including:* *- minor fracturing, gas releases and iron staining; and* *- minor impacts on water flows, water levels and water quality*.

A detailed list of performance measures and triggers is included in the TARPs in **Appendix A: Table 1.2**. It is noted that in response to the Longwall 21 End of Panel Report, the Department has requested that IMC review the adequacy of the 'Exceeding Predictions' TARP trigger for iron staining in Wongawilli Creek in future subsidence management plan applications.

4.1 Impact Mechanisms

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

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

- Groundwater depressurisation
  - The creation of an excavation below the water table can affect groundwater in a number of basic ways. In all cases, because the fluid pressure in an excavation is much lower than that of the fluid that originally occupied the space, a flow system is established with the excavation acting as a sink into which surrounding groundwater flows. The rate of flow and observed extent of depressurisation depend on the hydrogeological properties of the rock mass. If the excavated area is sufficiently large, the spatial extent and rate of flow into the sink can be enhanced by the formation of fractures.

- Surface water diversions
  - Diversions into a shallow, localised fracture network, where loss of flow from a surface water is likely to return to the system at some point downstream, which based on observations of the SCI (2008) may vary from 20 m for specific rockbars to more than 200 m.
- Surface water permanent losses
  - Diversions into deeper, dilated shear surfaces on bedding planes, where these form a conduit for lateral water flow, which may or may not report to the same catchment (i.e. it may become a permanent loss).
- Groundwater depressurisation
  - Groundwater within the Hawkesbury Sandstone and Narrabeen Group as well as the Permian coal measures is recharged from rainfall and water bodies where the lithologies occur at outcrop, as well as potential downward leakage from overlying strata (Hydrosimulations 2018).
- Water quality
  - Water quality within watercourses is affected by numerous factors including runoff from swamps and interactions between bedrock and water, with fracturing of bedrock due to mining causing local water quality impacts.

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

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

4.2 Potential for Connectivity to the Mine Workings

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

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

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

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

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

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

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

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

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

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

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

Parson Brinckerhoff and IMC have completed testing to characterise the pre- and post-mining permeability above Longwall 9, the first longwall in a new domain, not affected by previous mining.

After Longwall 9 mined under the site it was tested to quantify the change to vertical and horizontal permeability of the strata, including the Bulgo and Hawkesbury Sandstones and the Bald Hill Claystone. The testing involved core, packer and borehole interference testing, groundwater flow and tracer testing.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

4.3 Potential for Fracturing Beneath the Watercourses

Based on the predicted systematic and non-systematic subsidence movements (MSEC 2021) the bedrock below the watercourses directly above the longwall are likely to fracture as a consequence of subsidence induced strains. The predicted strains decrease where the surface is not directly mined beneath, and generally reduce with distance from the longwall panel.

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

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

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

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

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

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

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

Prior to any remediation works within Area 3C that target surface/shallow fracture networks the depth of the fracturing will be characterised by standard techniques such as drilling, down hole cameras and calliper measurements. The hydraulic conductivity of these fracture networks will also be determined prior to implementing any rehabilitation.

Assessment of stream flow gauging records (Table 1, HGEO 2023b) indicates that most headwater sites located above longwalls are affected by subsidence, with many sites showing Level 3 impacts and a mix of Level 1-2 impacts. Sites located downstream or offset from longwalls have lower levels of impact, with many of these sites not triggering the various assessments. As in previous assessments, sites without Level 3 for Assessment C are also subject to comparison against rainfall-runoff modelling (the old TARP method) and these are consistent with the comparison against reference sites (Assessment C) with the exception of Level 1 at WC12S1 and Level 2 at ND1S1. HGEO (2023b).No change to catchment flow characteristics was identified at the Wongawilli Creek gauge downstream of Areas 3A and 3B (WWL). The TARP assessment methods indicate a continuation of modified low-flow characteristics at the downstream gauge of Donalds Castle Creek (DCU), which remains at TARP Level 1. Reductions in median flow (Q50) at sites upstream of DCU are obvious, and total approximately 40-60% of median flow at DCU, and so should be able to be detected at DCU, but no reduction in Q50 is apparent.

While noting ‘no change’ was detected, it is acknowledged that the scale of impacts in headwater streams overlying longwalls (e.g. WC21, DC13) may be impossible to detect further downstream given natural variability, larger contributing (and un-mined) catchments downstream at WWL, as well as the inherent uncertainties of the assessment methods. However, the assessments of WWL and DCU appear to indicate that there is clear potential for returned or re-emergent flow that has been identified as lost from upstream headwater catchments.

The assessment against the Performance Measures for Donalds Castle Creek, Wongawilli Creek, Lake Avon and Cordeaux River were all met (HGEO 2021b and 2023b).

4.4 Potential for Erosion Within the Watercourses

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

Subsidence predictions were carried out to assess the potential impacts of longwall mining in Area 3C (MSEC 2021). The assessment indicated that the levels of impact on the natural features were likely to be similar to the impacts observed within Area 3A and Area 3B to date. A summary of the maximum predicted values of subsidence, tilt and strain at the watercourses is provided in **Section 5**.

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

Changes in gradients predicted to occur following mining are shown in **Section 5**. These changes have been considered in relation to the likelihood of change in drainage line alignment by MSEC (2021). The assessment takes into account the nature of the drainage channel and whether the predicted tilt is significant when compared to the existing slopes.

Landscape monitoring commenced in 2004 for Dendrobium Area 1. This monitoring program has been continued and updated throughout the mining period for Areas 2, 3A and 3B.

The monitoring includes inspections of watercourses at regular intervals prior to mining, during active subsidence and following the completion of subsidence movements. In addition to erosion (increased incision and/or widening), these observations target any surface cracking, surface water loss, soil moisture changes, vegetation condition changes, slope and gradient changes and the condition of rockbars.

The observed impacts on natural features above Area 3B to date are generally consistent with those predicted in the assessments undertaken prior to mining.

4.5 Potential for Aquatic Ecology Changes Within the Watercourses

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

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

The monitoring program focuses on the following key indicators:

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

Monitoring is undertaken within Wongawilli Creek, WC21 (a tributary of Wongawilli Creek) and Donalds Castle Creek, and at comparable Control sites established on Wongawilli, Sandy, Donalds Castle and Kentish creeks. Univariate and multivariate statistical analyses have been conducted on the AUSRIVAS sampling and artificial collectors.

Physical impacts in Lake Avon tributary LA4B, including fracturing and flow diversion has resulted in a reduction in aquatic habitat. Fracturing of bedrock and diversion of flows in Lake Avon tributaries is likely to have resulted in some minor reduction in quantity and connectivity of aquatic habitat.

In the Southern Coalfield, impacts to riparian vegetation as a result of subsidence are minor in occurrence. Furthermore, no impacts to riparian vegetation have been observed in Dendrobium Mine to date (Niche 2012). Previous examples of impacts include: dieback of riparian vegetation as a result of subsidence of the Cataract River

during the 1990s (Eco Logical Australia, 2004 in TEC 1997), and small localised changes to riparian vegetation along a section of the Waratah Rivulet (Helensburgh Coal 2007).

4.6 Potential for Raw Water Quality Changes

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

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

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

Any water-borne inputs to Lake Cordeaux and Cordeaux River would likely be restricted to a possible erosive export of fine sands and clays and/or ferruginous precipitates near the mouths of minor tributaries designated WC20, WC21, WC24, WC24A, WC26, WC26A, WC28, LC5, LC5A, LC5B, LC6, LC7, LC8, LC9, LC9A and CR36 during mining of Area 3C. It is predicted that these water-borne inputs will result in negligible environmental consequences.

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

4.7 Water Storages

Dendrobium Mine is located within the Metropolitan Special Area. There are two reservoirs located in the vicinity of the mining area. The Longwalls 22 and 23 are located to the west of Lake Cordeaux. The longwalls are located at a minimum distance of 300 m from the Full Supply Level (FSL) of the reservoir. The Cordeaux Dam Wall is located at the northern end of the reservoir and it is at a distance of approximately 2.8 km from Longwall 23.

The FSL of the Cordeaux Reservoir is located outside the 35° angle of draw for the proposed longwalls. At this distance, the reservoir is predicted to experience less than 20 mm vertical subsidence. While the reservoir could experience very low levels of vertical subsidence, it is not expected to experience measurable conventional tilts, curvatures or strains (MSEC 2021).

Whilst the predicted valley related effects are small, it is possible that minor cracking could occur in the bedrock, as has been observed in the Southern Coalfield up to 400 m from previously extracted longwalls. It is possible that fracturing could occur in the bedrock beneath the Cordeaux Reservoir where it is located within approximately 400 m of the proposed longwalls. However, it is unlikely that fracturing would be visible in the bed of the reservoir due to the alluvial deposits (MSEC 2021).

The Avon Dam wall is located more than 8 km west of the proposed longwalls. At this distance, the dam wall is unlikely to experience measurable movements and, therefore, it is not expected to experience adverse impacts. The previous mining has not resulted in adverse impacts on these structures.

4.8 Achievement of Performance Measures

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

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

A number of large surface cracks were observed at the commencing end of Longwall 3 in Area 2 at Dendrobium Mine. The depth of cover at the commencing end of Longwall 3 was as shallow as 145 m, which is less than that

above Longwalls 22 and 23 in Area 3C. It is expected, therefore, that the widths of surface cracking resulting from the extraction in Area 3B would be generally less than that observed above the commencing end of Longwall 3.

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

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

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

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

The EoP Report for Longwall 19, submitted to the Department in September 2023, found that the Performance Measures for Donalds Castle Creek, Wongawilli Creek, Lake Avon and Cordeaux River were all met (HGEO 2023b).

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

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

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

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

The maximum predicted closure for Wongawilli Creek, due to the extraction of Longwalls 22 and 23 is 80 mm closure. The maximum predicted total closure along the section of the creek within the Study Area, including the movements from the existing and approved longwalls in Areas 3A, 3B and 3C is 190 mm (MSEC 2021).

5 PREDICTED IMPACTS FOR NATURAL FEATURES

Subsidence has the potential to affect watercourses overlying and adjacent to the proposed longwalls due to either transient or relatively permanent changes in porosity and permeability of the soil matrix and bedrock. Sandstone is likely to fracture as a result of the maximum differential subsidence movements predicted. The likelihood of these impacts occurring reduces where mining is setback from surface features.

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

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

Predicted impacts were assessed for Wongawilli Creek (third order) and all other drainage lines (first and second order) within Area 3C in Attachment C of the SMP (MSEC 2021). Subsidence predictions discussed in this Plan are focused on Longwalls 22 and 23. Where watercourses may be influenced by multiple longwalls, maximum predictions include cumulative predictions from multiple longwalls.

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

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

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

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

5.1 Subsidence Effects

The maximum predicted subsidence parameters resulting from the extraction of Longwalls 22 and 23 are provided in MSEC (2021). The predicted subsidence parameters including; vertical subsidence, tilt and curvature have been used in the impact assessment for Dendrobium Area 3C.

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

Adopting a linear relationship between curvature and strain provides a reasonable prediction for the conventional tensile and compressive strains. The locations that are predicted to experience hogging or convex curvature are expected to be net tensile strain zones and locations that are predicted to experience sagging or concave curvature are expected to be net compressive strain zones. In the Southern Coalfield, it has been found that a factor of 15 provides a reasonable relationship between the predicted maximum curvatures and the predicted maximum conventional strains. The maximum strains can be much greater than these typical values, especially in the locations of near-surface geological structures and in the bases of valleys.

5.2 Wongawilli Creek

5.2.1 Description

Wongawilli Creek is a third order perennial stream with a small base flow and increased flows for short periods of time after significant rain events. The creek generally flows in a northerly direction and drains into the Cordeaux River approximately 2 km to the north of the proposed longwalls. Pools in the creek naturally develop behind the rockbars and at the sediment and debris accumulations.

Wongawilli Creek is located west of the proposed Longwalls 22 and 23. The 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.

The total length of the creek within the 600 m boundary is approximately 1.8 km.

5.2.2 Subsidence Predictions

A summary of the maximum predicted values of total vertical subsidence, upsidence and closure for Wongawilli Creek is provided in **Table 5-1**. The values are the maxima anywhere along the section of the creek located within the Study Area based on the 600 m boundary.

Table 5-1 Maximum predicted total vertical subsidence, upsidence and closure for Wongawilli Creek

Location	Area or Longwall	Maximum predicted total vertical subsidence (mm)	Maximum predicted total upsidence (mm)	Maximum predicted total closure (mm)
Wongawilli Creek	Longwalls 19 to 21	< 20	60	150
	Longwall 22	< 20	70	160
	Longwall 23	< 20	90	190

The section of Wongawilli Creek located within the Study Area is predicted to experience less than 20 mm vertical subsidence. Whilst the creek could experience very low-levels of vertical subsidence, it is not expected to experience measurable conventional tilts, curvatures or strains.

The maximum predicted total valley related movements for the section of creek located within the Study Area are 90 mm upsidence and 190 mm closure. The predicted valley related effects within the Study Area are less than the maximum values further upstream, adjacent to Areas 3A and 3B, of 150 mm upsidence and 210 mm closure.

The maximum predicted additional valley-related effects for Wongawilli Creek, due to the mining of the proposed Longwalls 22 and 23 only, are 50 mm upsidence and 80 mm closure. The remaining valley-related effects within the Study Area predominantly occur due to Longwall 20 on the western side of the creek.

Wongawilli Creek could experience compressive strains due to the valley closure movements. The predicted strains have been determined based on an analysis of ground monitoring lines for valleys with similar heights located at similar distances from previously extracted longwalls in the Southern Coalfield, as for Wongawilli Creek. The maximum predicted compressive strain for Wongawilli Creek due to the extraction of Longwalls 20 to 23 is 8 mm/m based on the 95 % confidence level.

5.2.3 Impact Predictions/Environmental Consequences

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

The average natural grade of the section of Wongawilli Creek within the Study Area is approximately 4.5 mm/m (i.e. 0.45 %, or 1 in 222). The predicted changes in grade due to the mining of Longwalls 22 and 23, therefore, are considerably less than the average natural grade. It is unlikely, therefore, that there would be adverse changes in the potential for ponding, flooding or scouring of the banks along the creek due to the mining-induced tilt.

It is possible, however, that there could be some localised changes in the levels of ponding or flooding where the maximum changes in grade coincide with existing pools, steps or cascades along 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 %.

Potential for fracturing of bedrock and surface water flow diversions

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

Fracturing in bedrock has been observed due to previous longwall mining where the tensile strains are greater than 0.5 mm/m or where the compressive strains are greater than 2 mm/m. Therefore, it is possible that fracturing could occur along Wongawilli Creek due to the valley-related compressive strains. Fracturing has been observed up to approximately 400 m outside of previously extracted longwalls in the Southern Coalfield. Fracturing has been observed at distances up to 300 m from the completed longwalls in Area 3B.

The maximum predicted total closure along Wongawilli Creek within the Study Area, following the extraction of the proposed Longwalls 22 and 23, is 190 mm. The predicted rate of impact for the rockbars along this creek after the extraction of the proposed longwalls, therefore, is in the order of 7 % based on the maximum predicted closure.

It has been assessed that the likelihood of fracturing resulting in surface water flow diversions along Wongawilli Creek, due to the extraction of the proposed Longwalls 22 and 23, is low, i.e. affecting less than 6 % of rockbars located within the Study Area. However, minor fracturing could still occur along the creek, at distances up to approximately 400 m from the proposed longwalls.

Baseflow Reduction

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 longwall (HGEO 2021a).

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 flow1 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 Watershed HydroGeo (2021) accounts for potential permanency of effects (HGEO 2021a).

In relation to estimates of baseflow loss, the IEP (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 IEP Part 2 report (IEP, 2019b) recommends that uncertainty analysis of groundwater and surface water models should follow the uncertainty analysis workflow recommended by the IESC (2018); and that a precautionary approach should be taken that does not assume groundwater model outputs are accurate. Predictions should be conservatively high to allow for prediction uncertainty and where practicable the associated non-exceedance probability should be stated. Groundwater consultants Watershed HydroGeo (2021) have taken the latter approach by applying conservative assumptions in deriving the baseflow loss estimates, including the assumed vertical connectivity between seam (mine workings) and surface, as suggested by PSM, 2017.

Basal Shear Planes

Basal shear planes are lateral planar features that can extend laterally in strata (e.g. Bald Hill and Stanwell Park Claystones) at an elevation of, or just beneath, the base of incised valleys.

Basal shears and the likely distance over which these may act as conduits to groundwater flow should be considered in the context of the distances between the proposed longwalls and various hydrological features. Basal shears are unlikely to cause or increase connection between these longwalls for either Cordeaux or Avon Reservoirs. The shorter distance from these longwalls to nearby watercourses, including Wongawilli Creek, means that shear planes may increase connection to these features (HydroSimulations 2019).

5.3 Drainage Lines

5.3.1 Description

The unnamed drainage lines are located above and adjacent to Longwalls 22 and 23. 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 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 loose rocks and tree branches.

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 100 mm/m (i.e. 10 %, or 1 in 10) 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.

5.3.2 Subsidence Predictions

The drainage lines are located across the Study Area and, therefore, could experience the full range of predicted subsidence movements. A summary of the maximum predicted values of total vertical subsidence, tilt and curvature for the drainage lines is provided in **Table 5-2**. The total parameters represent the accumulated movements within the Study Area due to the extraction of the existing and proposed longwalls.

Table 5-2 Maximum predicted total subsidence, tilt and curvature for the drainage lines

Drainage Line	Maximum predicted total vertical subsidence (mm)	Maximum predicted total tilt (mm/m)	Maximum predicted total hogging curvature (km^{-1})	Maximum predicted total sagging curvature (km^{-1})
LC5	3000	35	0.90	0.70
LC6	2800	35	0.90	0.60
LC7	< 20	< 0.5	< 0.01	< 0.01
WC24	150	4	0.08	< 0.01
WC26	2500	25	0.40	0.60
Other	3000	40	1.0	1.0

The maximum predicted total tilt for the drainage lines is 40 mm/m (i.e. 4.0 %, or 1 in 25). The maximum predicted total conventional curvatures are 1.0 km^{-1} hogging and sagging, which represent minimum radius of curvatures of 1 km.

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

5.3.3 Impact Assessment

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

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

The maximum predicted tilt for the drainage lines within the Study Area is 40 mm/m (i.e. 5.0 % or 1 in 25). The predicted mining-induced tilts are less than the natural gradients of the drainage lines that typically vary between 50 mm/m and 200 mm/m (i.e. 5 % to 20 %).

It is unlikely, therefore, that there would be large-scale adverse changes in the levels of ponding or scouring of the banks along these drainage lines due to the mining-induced tilt. It is possible that localised increased ponding could develop in some isolated locations, where the natural grades are small and where the drainage lines exit the mining area. It is also possible, that there could be localised areas that experience increased scouring of the banks, in the locations of the predicted maximum increasing tilts, such as downstream of the longwall chain pillars.

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

Potential for cracking in the creek bed and fracturing of bedrock

Impacts have been observed along the drainage lines above and adjacent to the previously extracted Longwalls 9 to 16 in Area 3B, including fracturing in the rockbars and exposed bedrock, dilation and uplift of the bedrock, iron staining, surface water flow diversions and reduction in pool water levels. These impacts predominately occurred directly above the extracted longwalls. However, fracturing was also observed up to 290 m from the extracted longwalls.

The predicted subsidence parameters for the proposed longwalls are less than the maxima predicted for the existing and approved longwalls due to their narrower longwall void widths.

It is expected that fracturing of the bedrock 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, with minor and isolated fracturing occurring at distances up to approximately 400 m.

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

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

6 MANAGEMENT AND CONTINGENCY PLAN

The potential impacts of mine subsidence to watercourses and associated features in Area 3C are provided below, together with a summary of the avoidance, minimising, mitigation and remediation measures proposed.

6.1 Objectives

The aims and objectives of the Plan include:

- Avoiding and minimising impacts to significant environmental values where possible.
- Implementing TARPs and reporting to identify, assess and responding to impacts to watercourses.
- Carrying out mitigation and remediation works in a manner that protects to the greatest practicable extent the environmental values of the area.
- Achieving the Performance Measures outlined in the Dendrobium Development Consent and Area 3C SMP Approval, to the satisfaction of the Secretary.
- Monitoring and reporting effectiveness of the Plan.

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

6.2 Trigger Action Response Plan

The TARPs relate to identifying, assessing and responding to potential impacts to watercourses (including impacts greater than predicted) from subsidence in Dendrobium Area 3C. These TARPs have been prepared using knowledge gained from previous mining in other areas of Dendrobium, advice from the Panel (2023) and in consultation with DPHI, WaterNSW and BCS. The TARPs for Area 3C watercourses are included in **Appendix A: Table 1.2** and for Landscape features in **Appendix G**.

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

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

Level 2 and 3 TARPs result in further investigations and reporting by appropriately qualified specialists. Impact assessment reports will include:

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

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

- A description of the impact to be managed;
- Results of specific investigations;
- Aims and objectives for any corrective actions;
- Specific actions required to mitigate/manage and timeframes for implementation;

- Roles and responsibilities;
- Gaining appropriate approvals from landholders and government agencies; and
- Reporting, consultation and communication.

Performance indicators provide a measure for the performance measures. Where a performance indicator is exceeded, actions detailed in Section 6.4 will be undertaken.

6.3 Avoiding and Minimising

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

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

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

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

Area 3C is part of the overall mining schedule for Dendrobium Mine and has been designed to flow on from Areas 1, 2, 3A and 3B to provide a continuous mining operation. There are a number of surface and subsurface constraints within the vicinity of Area 3C 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 Area 3C 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. Changes to a mine layout have significant flow-on impacts to mine planning and scheduling as well as economic viability. These issues need to be taken into account when optimising mine layouts. The process adopted in designing the Dendrobium Area 3C mine layout incorporated the hierarchy of avoid/minimise/mitigate as requested by the DPE and BCD during the consultation process. Mine plan changes result in significant business and economic impact, including:

- Reduction in coal extracted;
- Reduction in royalties to the State;
- Additional costs to the business;
- Risks to longwall production due to additional roadway development requirements; and
- Constraints on blending which can disrupt the supply of coal to meet customer requirements.

Restricting mine layout flexibility can also have the following consequences:

- Additional energy used to ventilate the mine;
- Increased safety risks such as risk of frictional ignition on the longwall due to less than optimal ventilation;
- Increased power usage, reduced fan lifespan and a requirement to install booster fans;
- Requirement for heavy secondary support density;
- Potential for horizontal stress and vertical abutment concentrations;
- The risk of strata control associated with increased roadway development and longwall install and take-off faces;

- Exposes the workforce to higher risk environments more frequently;
- Results in a large number of equipment movements and interaction with workers and infrastructure; and
- Requires specialised equipment and skilled personnel with limited availability.

Longwalls 22 and 23 have been setback 345 and 320 m respectively from Wongawilli Creek and minimum of 300 m from Lake Cordeaux. This reduction in extraction also reduces subsidence movements at surface features in proximity to Wongawilli Creek and Lake Cordeaux, including the WC26, WC24, LC6, LC7 and CR36, and Swamps 141, 152,154,155 and 156.

The mining layout of Longwalls 22 and 23 is designed to avoid Lake Cordeaux, Wongawilli Creek and geological constraints.

Wongawilli Creek is situated on the western side of the longwalls in Area 3C. The thalweg (i.e. base or centreline) of the creek is 320 m from the finishing (i.e. western) end of Longwall 23, at its closest point. The minimum distances between the thalweg of the creek and the completed longwalls are 110 m for Longwall 6 in Area 3A and 290 m for Longwall 9 in Area 3B.

6.4 Mitigation and Rehabilitation

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

As indicated in Schedule 2, Conditions 1 and 14 of the Development Consent and Condition 7 of the Area 3C SMP Approval, the mitigation and rehabilitation described in this Plan is required for the development and an integral component of the proposed mining activity. To the extent these activities are required for the development approved under the Dendrobium Mine Development Consent no other licence under the then *Threatened Species Conservation Act 1995* (TSC Act) (repealed by the *Biodiversity Conservation Act 2016*) is required in respect of those activities.

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

6.4.1 Sealing of Rock Fractures

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

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

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

6.4.2 Injection Grouting

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

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

Grouting holes are drilled in a pattern, usually commencing at a grid spacing of 1 m x 1 m to 2 m x 2 m. The most efficient way to drill the holes taking into account potential environmental impact is by using handheld drills.

The drills are powered by compressed air which is distributed to the work area from a compressor. The necessary equipment will be sited on cleared seismic lines or other clear areas wherever possible with hoses run out to target areas.

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

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

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

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



(a) Drilling into the bedrock



(b) Grout pump station setup



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

Figure 6-1: Rockbar grouting in the Georges River

6.4.3 Erosion Control

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



Figure 6-2 Square coir logs for knick point control

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



Figure 6-3 Installation of square coir logs

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



Figure 6-4 Trenching and positioning of the first layer of coir logs and construction of a small dam in a channel

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



Figure 6-5 Small coir log dams with fibre matting

6.4.4 Surface Treatments

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



Figure 6-6 Round coir logs installed to spread water

Erosion control and water spreading involves soft-engineering materials that are biodegradable and become integrated into the soil profile. This approach is ecologically sustainable in that all the materials used can breakdown and become part of the organic component of the soil.

This also removes the requirement for any post-rehabilitation removal of structures or materials. However, rehabilitation measures have the potential to cause impact through the materials used and the disturbance associated with access. Relevant approvals will be obtained to ensure the protection of the environment as works are implemented.

6.4.5 Gas Release

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

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

6.4.6 Water Quality

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

6.4.7 Alternative Remediation Approaches

IMC has successfully implemented a subsidence rehabilitation program in the Georges River where there were impacts associated with mining directly under streams. This rehabilitation focused on grouting of mining induced fractures and strata dilation to reinstate the structural integrity and water holding capacity of the bedrock. Metropolitan Colliery is currently undertaking work aimed at rehabilitating areas impacted by subsidence using Poly-urethane Resin (PUR) and other grouting materials. IMC is consulting with Metropolitan Colliery in relation to these new and emerging technologies. Should rehabilitation be necessary in Dendrobium Area 3C, the best option available at the time of the rehabilitation work will be identified and with appropriate approval, implemented by IMC.

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

6.4.8 Monitoring Remediation Success

Baseline studies have been completed within the Study Area in order to record biophysical characteristics of the mining area. Monitoring is conducted in the area potentially affected by subsidence from the Area 3C extraction as well as areas away from mining to act as control sites. The studies in these areas are based on the BACI design criteria.

A comprehensive monitoring program is in place for watercourses identified in this Plan. A summary of watercourse monitoring within Dendrobium Area 3C is provided in **Section 3**. In the event that monitoring reveals impacts greater than what is authorised by the approval, modifications to the project, mitigation measures including remediation, offsets or other appropriate actions determined in consultation with the consent authority will be implemented

The monitoring program would remain in place prior to, during and following the implementation of any remediation measures in Area 3C. The monitoring program is based on the BACI design with sampling undertaken at impact and control locations prior to the commencement of remediation, during remediation and after the completion of the remediation actions. The monitoring locations/points for watercourses within Dendrobium Area 3C will be reviewed as required and can be modified (with agreement) accordingly.

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

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

6.5 Biodiversity Offset Strategy

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

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

The Applicant must provide suitable offsets for loss of water quality or loss of water flows to WaterNSW storages, clearing and other ground disturbance (including cliff falls) caused by its mining operations and/or surface activities within the mining area, unless otherwise addressed by the conditions of this consent, to the satisfaction of the Secretary. These offsets must:

(a) be submitted to the Secretary for approval by 30 April 2009;

(b) be prepared in consultation with WaterNSW; and

(c) provide measures that result in a beneficial effect on water quality, water quantity, aquatic ecosystems and/or ecological integrity of WaterNSW's Special Areas or water catchments.

IMC transferred 33 ha of land adjacent to the Cataract River to WaterNSW to meet the above condition.

A Strategic Biodiversity Offset (SBO) has been developed in consultation with BCS and WaterNSW for the approval of the Secretary of DPE. The Secretary DPE approved the SBO in accordance with Condition 15 of Schedule 2 of the Development Consent for the Dendrobium Coal Mine 16 December 2016. Following ongoing consultation with DPE, a revised SBO (October 2023) has been approved. The revised SBO confirms the Maddens Plains land satisfies offset requirements for upland swamps located in:

- Dendrobium Areas 3B and 3C identified in Table 3-1; and
- Dendrobium Areas 3A, 3B and 3C mapped on Figure 1 which cover swamps mapped at the time the SBO was prepared in 2016 and impacts on Swamp 15a which do not exceed performance measures under Condition 3 of Schedule 3 of the Consent.

6.6 Research

To assist in further understanding the impacts of subsidence and rehabilitation of swamps, IMC will undertake research to the satisfaction of the Secretary. The research will be directed to improving the prediction, assessment,

remediation and/or avoidance of subsidence impacts and environmental consequences to swamps. The Swamp Rehabilitation Research Program (SRRP) is currently being undertaken across Dendrobium Area 3.

6.7 Contingency and Response Plan

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

This would involve the following actions:

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

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

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

Table 6-1 provides a summary of the avoidance, mitigation and contingency measures proposed to manage impacts where predicted impacts are exceeded.

Table 6-1 Performance measures, predicted impacts, mitigation and contingency measures for watercourses

Feature	Performance Measure	Predicted Impacts	How Monitored	How Managed	Exceeding Prediction	Contingent Measures
Wongawilli Creek	**Minor environmental consequences** including: minor fracturing, gas release and iron staining; and minor impacts on water flows, water levels and water quality	Minor environmental consequences including: minor fracturing, gas release and iron staining; and minor impacts on water flows, water levels and water quality	• Observation of Wongawilli Creek for fracturing, gas release and iron staining • Measurement of pool water levels • Measurement of surface water flow • Measurement of surface water quality	The longwalls have been setback 320 m and 345 m from Wongawilli Creek Grouting of fractures in rockbar and bedrock base of any significant pool where flow diversion results in pool water level lower than baseline period	Mining results in more than minor environmental consequences in Wongawilli Creek, including: • structural integrity of the bedrock base of any significant permanent pool or controlling rockbar cannot be restored i.e. pool water level within the pool after CMAs continues to be lower than baseline period • fracturing within Wongawilli Creek resulting in diversion of surface flow such that >10% of the pools have water levels lower than baseline period • measured surface water flow reduction, based on Assessment Methods C and D, to be compared against predictions made in contemporary groundwater modelling conducted (to the satisfaction of the Secretary) to assess whether effects that cannot be explained by natural variability[3] • gas release results in vegetation dieback that does not revegetate • gas release results in mortality of threatened species or ongoing loss of aquatic habitat • iron staining and associated increases in dissolved iron resulting from the mining is observed in water at Wongawilli Creek downstream monitoring site Wongawilli Ck (FR6)	Grouting of fractures in rockbar and bedrock base of any significant pool where flow diversion results in pool water level lower than baseline period Provide residual environmental offset for any mining impact as required by Condition 14 Schedule 3 of the Development Consent

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

Feature	Performance Measure	Predicted Impacts	How Monitored	How Managed	Exceeding Prediction	Contingent Measures
					• mining results in two consecutive exceedances or three exceedances of the ±3 standard deviation level (positive for EC, negative for pH and DO) from the baseline mean within six months that cannot be attributed to natural variation	
Lake Cordeaux	**Operations do not result in reduction (other than negligible reduction) in the quality or quantity of surface water or groundwater inflows to Lake Cordeaux**	Negligible reduction in the quality and quantity of surface water and groundwater inflows to Lake Cordeaux	• Measurement of surface water flow • Measurement of water quality • Groundwater model calibrated to groundwater levels, surface water flows and mine water budget	Longwalls do not mine directly under the reservoir. The proposed longwalls are setback 300 m form the FSL.	Mining results in more than negligible reduction in the quality or quantity of surface water or groundwater inflows to Lake Cordeaux, including: • measured surface water flow reduction, based on Assessment Methods C, D, to be compared against predictions made in contemporary groundwater modelling conducted (to the satisfaction of the Secretary) to assess whether effects that cannot be explained by natural variability[4] [5] • mining results in two consecutive exceedances or three exceedances of the ±3 standard deviation level (positive for EC, negative for pH and DO) from the baseline mean within six months that cannot be attributed to natural variation	Provide residual environmental offset for any mining impact as required by Condition 14 Schedule 3 of the Development Consent
Cordeaux River	Operations do not result in reduction (other than **negligible reduction**) in the quality or quantity of surface water inflow to the Cordeaux River at its confluence with Wongawilli Creek	Negligible reduction in the quality and quantity of surface water inflow to the Cordeaux River at its confluence with Wongawilli Creek	• Observation of Wongawilli Creek for iron staining • Measurement of surface water flow • Measurement of surface water quality	The longwalls have been setback 320 and 345 m from Wongawilli Creek	Mining results in more than negligible reduction in the quality or quantity of surface water inflows to the Cordeaux River at its confluence with Wongawilli Creek, including: • measured surface water flow reduction in Wongawilli Creek at its confluence with Cordeaux River is greater than predicted by modelling (to the satisfaction of the	Provide residual environmental offset for any mining impact as required by Condition 14 Schedule 3 of the Development Consent

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

[5] Surface water inflows calculation = [Impacts at gauged catchments (SCL2) + LC5 + LC6 + estimated impacts at ungauged but undermined catchments] / [total estimated inflow to LC].

Feature	Performance Measure	Predicted Impacts	How Monitored	How Managed	Exceeding Prediction	Contingent Measures
					Secretary) that cannot be attributed to natural variation[6] • mining results in two consecutive exceedances or three exceedances of the ±3 standard deviation level (positive for EC, negative for pH and DO) from the baseline mean within six months that cannot be attributed to natural variation	

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

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

7 INCIDENTS, COMPLAINTS, EXCEEDANCES AND NON-CONFORMANCES

7.1 Incidents

IMC will notify DPHI and other relevant agencies of any incident associated with Area 3C operations as soon as practicable after IMC becomes aware of the incident. IMC will provide DPHI and any relevant agencies with a report on the incident within seven days of confirmation of any event.

7.2 Complaints Handling

IMC will:

- Provide a readily accessible contact point through a 24-hour toll-free Community Call Line (1800 102 210) and email address (illawarracommunity@south32.net). The number will be displayed prominently on IMC Projects and Mine sites in a position visible by the public as well as on publications, letters and other correspondence provided to the local community.
- Respond to complaints in accordance with the IMC Handling Community Complaints, Enquiries and Disputes Procedure.
- Maintain good communication lines between the community and IMC.
- Keep a register of any complaints, including the details of the complaint with information such as:
    - Time and date.
    - Person receiving the complaint.
    - Complainant's name and phone number.
    - Description of the complaint and where complaint relates to.
    - Details of any response where appropriate.
    - Details of any corrective actions.

7.3 Non-Conformance Protocol

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

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

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

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

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

8 PLAN ADMINISTRATION

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

8.1 Roles and Responsibilities

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

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

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

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

Manager Approvals

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

Principal Approvals

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

Coordinator Environment

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

Survey Team Coordinator

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

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

Technical Experts

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

Person(s) Performing Inspections

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

8.2 Resources Required

The Approvals Manager provides resources sufficient to implement this WIMMCP.

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

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

8.3 Training

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

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

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

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

8.4 Record Keeping and Control

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

IMC document control requirements include:

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

The WIMMCP and other relevant documentation will be made available on the IMC website in accordance with Condition 11, Schedule 2 of the Development Consent.

8.5 Management Plan Review

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

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

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

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

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Appendix A – Watercourse Monitoring and Trigger Action Response Plan

Appendix A – Dendrobium Area 3 Watercourse Monitoring and Trigger Action Response Plan

Watercourse monitoring within Dendrobium Area 3C 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). Primary flow monitoring sites in future mining areas will be established at least four years prior to any mining impacts. 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 key stakeholders 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 Program

MONITORING SITE		SITE TYPE	MONITORING FREQUENCY	PARAMETERS
OBSERVATIONAL MONITORING				
Area 3A	**Primary Monitoring Site** Sandy Creek Wongawilli Creek	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
	Secondary Monitoring Sites Sandy Creek tributaries (including SC7 and SC10) Wongawilli Creek tributaries			
AREA 3B	**Primary Monitoring Site** Wongawilli Creek Donalds Castle Creek			
	Secondary Monitoring Sites Native Dog, WC21, WC18, WC16, WC15, WC12, WC9, WC8, WC7, WC6, LA5, LA4, LA3, LA2, ND1 and DC13 **Reference Sites** Wongawilli Creek, Sandy Creek,, LC7B, WC11, SC9A, SC10A, NDC1, DC10 and D10			
AREA 3C	**Primary Monitoring Sites** Wongawilli Creek			
	Secondary Monitoring Site WC20, WC21, WC24, WC24A, WC26, WC26A, WC28, LC5, LC5A, LC5B, LC6, LC7, LC8, LC9, LC9A and CR36			

WATER CHEMISTRY				
Area 3A	**Primary Monitoring Site** **Wongawilli Creek** Wongawilli Creek (FR6) **Sandy Creek** Sandy Creek (SCk_Rockbar 5 (Sandy Creek adjacent to LW7) **Lake Cordeaux** Sandy Creek Arm (lake site)	• 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., SS, TDS, Total Fe, Mn, Al, Filt. Cu, Ni, Zn, Si)
	Secondary Monitoring Site **Wongawilli Creek** WWU1, WWU4, WC_Pool 46, WWM2 and WC_Pool 43b WC17_S1 (Wongawilli Creek tributary) WC14_S1 (Wongawilli Creek tributary) WC13_S1 (Wongawilli Creek tributary) **Sandy Creek** SC10_Rockbar 3 (Sandy Creek tributary) SC10C_Pool 1 (SC10 tributary) SC7_S1 (Sandy Creek tributary)			
AREA 3B	**Primary Monitoring Site** **Wongawilli Creek** Wongawilli Creek (FR6) (Wongawilli Creek downstream) **Lake Avon** Lake Avon (LA4_S1) **Donalds Castle Creek** Donalds Castle Creek (FR6) **Secondary Monitoring Site** **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) WC_Channel 14 (Wongawilli Creek adjacent to LW11) WC_Pool 43b (Wongawilli Creek downstream of LW9) 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_S2, LA5_S1, LA5_S2, LA3 Pool 4, LA2 Pool 5, LA1 and LA_1 (Lake Avon tributaries downstream of mining) **Donalds Castle Creek** 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) **Native Dog Creek** NDC4 (Native Dog Creek downstream of mining) NDC1 (Native Dog Creek upstream of Area 3B) NDT1 (tributary to Native Dog Creek downstream of mining)			
AREA 3C	**Primary Monitoring Site** **Wongawilli Creek** Wongawilli Creek (FR6) (Wongawilli Creek downstream) **Lake Cordeaux Tributaries** LC5_S1LC6_Rockbar 1			
	Secondary Monitoring Site **Wongawilli Creek and Wongawilli Creek Tributaries** WC_Pool 20 WC_Pool 38 WC_Pool 49 WC20_Pool 8 WC21_Pool 5 WC24_Pool 10 WC26_Channel 4 **Lake Cordeaux Tributaries** LC5_S2 LC5_Pool 13 LC7_Pool 2 LC9_Pool 2 **Lake Cordeaux** LC_S1 LC_S2 **Cordeaux River Tributary** CR36_S1			

WATER FLOW				
Ref Sites	**O'Hares Creek** [NSW govt site] 213200 (O'Hares Creek @ Wedderburn) **Wongawilli Creek** WWU (Wongawilli Creek upstream) WC11S1 (Wongawilli Creek tributary, south of DA3A)	• Some data (for reference sites) is provided by Water NSW		Other reference sites may be used depending on data availability and quality (e.g. Woronora River 2132101 and Bomaderry Creek 215016)
Area 3A	**Primary Monitoring Site** **Wongawilli Creek** WWL_A (Wongawilli Creek downstream) **Sandy Creek** SCL2 (Sandy Creek at downstream)	• 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).
	Secondary Monitoring Site **Sandy Creek Tributary** SC10S1 and SC10CS1			
AREA 3B	**Primary Monitoring Site** **Wongawilli Creek** WWU (Wongawilli Creek upstream) WWL_A (Wongawilli Creek downstream) downstream of mining) **Donalds Castle Creek** DCU (Donalds Castle Creek FR6) **Lake Avon** LA4S1 (Lake Avon tributary downstream of mining) LA3S1 (Lake Avon tributary downstream of mining) LA2S1 (Lake Avon tributary downstream of mining) NDTS1 (Lake Avon Tributary downstream of mining)			
	Secondary Monitoring Site **Wongawilli Creek** WC21S1 (Wongawilli Creek tributary downstream of mining) WC15S1 (Wongawilli Creek tributary downstream of mining) WC12S1 (Wongawilli Creek tributary downstream of mining) **Donalds Castle Creek** DC13S1 (Donalds Castle Creek tributary downstream of mining) DCS2 (Donalds Castle Creek downstream of mining)			
AREA 3C	**Primary Monitoring Site** **Wongawilli Creek** WWL_A (Wongawilli Creek downstream) **Lake Cordeaux Tributaries** LC5S1 LC6S1			
	Secondary Monitoring Site **Wongawilli Creek** WC20S1 WC20S2 WC21S1 WC24S1 WC26S1 WC26S2 **Lake Cordeaux Tributaries** LC5S2 LC7S1 LC9S1 **Cordeaux River Tributary** CR36S1			

TERRESTRIAL FAUNA – THREATENED FROG SPECIES				
AREA 3A	SC10C, SC10(1), SC10(2), 6CDL and WC17 *Reference Sites* WC10, WC11, SC7(1), SC7(2), SC7A, SC8, DC8, CR92, CR29D	Frog monitoring	Surveys are undertaken in winter each year to target active breeding periods (these can be variable depending on prevailing conditions) To address recommendation from Niche (2019), rainfall or hydrometric trigger values for surveys will be developed for surveys to allow for greater consistency between years which would aid in comparison of results (pre- versus post- mining and impact versus control).	For swamps frog surveys are conducted along associated creeks with a focus on features susceptible to impacts e.g. breeding pools. Potential breeding habitat for Littlejohn's Tree Frog and Giant Burrowing Frog will be targeted. Standardised transects have been established to record numbers of individuals recorded at each site from one year to the next. Tadpole counts will also be undertaken as part of the breeding habitat monitoring transects. These transects are surveyed by walking down the creekline and counting all amphibians seen or heard on either side of the line
AREA 3B	DC13, DC1, WC21, LA4A, LA2, ND1 NDC, ND2 and WC15 *Reference Sites* WC10, WC11, SC7(1), SC7(2), SC7A, SC8, DC8, CR92, CR29D			
AREA 3C	LC5, LC6, WC20, WC24 and WC26 – sites to be established *Reference Sites* WC10, WC11, SC7(1), SC7(2), SC7A, SC8, DC8, CR92, CR29D			
AQUATIC ECOLOGY				
AREAS 3A, 3B, 3C	**Sandy Creek Catchment** Site 11 and 12 (SC10) Site 13 (SC10C) Site 9 (Sandy Creek) **Wongawilli Creek Catchment** Sites 6, X2 and X3 (WC21) Sites 1, 2, 3, 4, 5, 21, 22, X4, X5 and X6 (Wongawilli Creek) **Donalds Castle Creek Catchment** Site 14, X1 (Donalds Castle Creek) **Reference Sites** Sites X7 and X8 Sites 15 and 16 (Kentish Creek)	• Quantitative and observational monitoring	Two annual baseline monitoring campaigns prior to mining during autumn and spring (providing 2 years of baseline data) Monitoring during mining in autumn and spring Monitoring post mining for two years or as otherwise required Monitoring targets sites as mining progresses through the domain	Macroinvertebrate sampling and assessment using the AUSRIVAS protocol and quantitative sampling using artificial collectors. In consideration of Adams Emerald Dragonfly and Sydney Hawk Dragonfly, individuals of the genus *Austrocorduliidae* and *Gomphomacromiidae* are identified to species level to confirm any potential identifications, as required. General fish surveys undertaken during each survey using dip nets, baited traps and visual observations. Targeted surveys for Macquarie perch undertaken using backpack electrofishing, as required.

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

OBSERVATIONAL MONITORING		
Wongawilli Creek *Primary Monitoring Site* **Relevant Performance Measure(s):** • 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 key stakeholders • Report in the End of Panel Report • Summarise actions and monitoring in Annual Review
	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 • 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* • Carry out Water Flow Assessment Method D • Review monitoring frequency • Seek advice from key stakeholders 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 key stakeholders • 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 key stakeholders

	• 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	• Completion of works following approvals and at a time agreed between IMC, DPE 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 • 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
WC20, WC21, WC24, WC24A, WC26, WC26A, WC28, LC5, LC5A, LC5B, LC6, LC7, LC8, LC9 and CR36 *Secondary Monitoring Sites* 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 key stakeholders • Report in the End of Panel Report • Summarise actions and monitoring in Annual Review
	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 • Seek advice from key stakeholders on any CMA required • Implement agreed CMAs as approved (subject to agency feedback)
	Level 3	• *Actions as stated for Level 2*

	• Crack or fracture over 300mm width at its widest point • Crack or fracture over 50m length • Fracturing observed in the bedrock base of any significant permanent pool which results in observable loss of surface water • Soil surface crack that causes erosion that is unlikely to stabilise within the monitoring period without intervention • Gas release results in vegetation dieback, mortality or loss of aquatic habitat • Observable increase in iron staining within the mining area continues more than 600m from the longwall	• Offer site visit with key stakeholders • 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, DPE, Resources Regulator and WaterNSW • Completion of works following approvals and at a time agreed between IMC and relevant stakeholders (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 *Primary Monitoring Site* **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 key stakeholders • Report in the End of Panel Report • Summarise actions and monitoring in Annual Review
	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 • Seek advice from key stakeholders 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 key stakeholders • 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 IMC and relevant stakeholders (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
Lake Cordeaux *Primary Monitoring Site* **Relevant Consent Condition(s):** • Lake Cordeaux - negligible reduction in the quality of surface water inflows to Lake Cordeaux LC5_S1 LC6_Rockbar 1 Baseline means*: *LC5_S1* • pH 5.54 • EC 102.4 uS/cm • DO 93.6% *LC6_Rockbar 1* • pH 5.1 • EC 97.2 uS/cm • DO 94.1% * *Baseline end date for LC5_S1 is 24/04/2023. LC6_Rockbar 1 is still in the baseline period at time of writing. The baseline mean values for LC6_Rockbar 1 may be recalculated prior to mining to capture additional data.*	***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: **LC5_S1** – pH 4.16 – EC 254.9 uS/cm – DO 61.2% **LC6_Rockbar 1** – pH 4.3 – EC 161.8 uS/cm – DO 36.2%	• Continue monitoring program • Submit an Impact Report to key stakeholders • Report in the End of Panel Report • Summarise actions and monitoring in Annual Review
	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: **LC5_S1** – pH 4.16 – EC 254.9 uS/cm – DO 61.2% **LC6_Rockbar 1** – pH 4.30 – EC 161.8 uS/cm – DO 36.2%	• *Actions as stated for Level 1* • Review monitoring frequency • Seek advice from key stakeholders 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:	• *Actions as stated for Level 2* • Offer site visit with key stakeholders • Implement additional monitoring or increase frequency if required

	LC5_S1 – pH 4.16 – EC 254.9 uS/cm – DO 61.2% **LC6_Rockbar 1** – pH 4.30 – EC 161.8 uS/cm – DO 36.2%	• Review relevant TARP and Management Plan in consultation with key agencies • Collect laboratory samples and analyse for: – pH, EC, major cations, major anions, Total Fe, Mn & Al – Filterable suite of metals • Develop site CMA (subject to agency feedback). This may include: – Limestone emplacement to raise pH where it is appropriate to do so – Grouting of fractures in rockbar and bedrock base of any significant pool where flow diversion results in pool water level lower than baseline period • Completion of works following approvals and at a time agreed between IMC and relevant stakeholders (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 (noting that LC5_S1 and LC6_Rockbar 1 are upstream of the confluence of the dam as safe access to the confluence is not available and therefore supplementary sampling will be conducted in the dam within proximity to the confluence): **LC5_S1** – pH 4.16 – EC 254.9 uS/cm – DO 61.2% **LC6_Rockbar 1** – pH 4.30 – EC 161.8 uS/cm – DO 36.2%	• *Actions as stated for Level 3* • Investigate reasons for the exceedance • Update future predictions based on the outcomes of the investigation • Provide residual environmental offset for any mining impact where CMAs are unsuccessful as required by Condition 14 Schedule 3 of the Development Consent
POOL WATER LEVEL		
Wongawilli Creek *Primary Monitoring Sites*	***Level 1*** • Single pool on a subject Creek is observed as dry. • End of Panel assessment indicates that up to three (i.e. 1-3) Subject Pools exhibit one or more of the following effects:	• Continue monitoring program • Carry out Water Flow Assessment Method D (i.e. comparison of apparent flow losses vs groundwater modelling) • Submit Impact Report to key stakeholders

Relevant Performance Measure(s): • Wongawilli Creek - minor environmental consequences "Subject Pools" = Area 3C Wongawilli Ck Pool sites with a level logger and within 600 m of an Area 3C longwall (this deliberately includes two sites closer to Areas 3A/3B). These are symbolised as 'Performance Measure Water Level Logger Site' on Figure 3.1 in the WIMMCP.	○ **1)** Pool water level below lowest baseline level; or ○ **2)** Pool level ratio, comparing Assessment site level each day with that at each nominated Reference Pool, is significantly different between pre- and post-mining periods; or ○ **3)** Pool level is at or below baseline level for increased duration (+5% of the relevant period) compared to Reference Pool(s); or ○ **4)** Rate of pool level recession (outside initial flood peak#) exceeds rate of pool level recession during baseline period (measured as average mm/day during the recession curve).	• Report in the End of Panel Report • Summarise actions and monitoring in Annual Review
	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 • End of Panel assessment indicates that up to six (i.e. 4-6) Subject Pools exhibit one or more of the following effects: ○ **1)** Pool water level below lowest baseline level; or ○ **2)** Pool level ratio, when compared with Reference Pool(s), is significantly* different between pre- and post-mining periods; or ○ **3)** Pool level is at or below baseline level for increased duration (+5% of the relevant period) compared to Reference Pool(s); or ○ **4)** Rate of pool level recession (outside initial flood peak#) exceeds rate of pool level recession during baseline period (measured as average mm/day during the recession curve).	• *Actions as stated for Level 1* • Review monitoring frequency • Seek advice from key stakeholders 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 • End of Panel assessment indicates that 7 or more Subject Pools exhibit one or more of the following effects: ○ Effects 1, 2, 3, 4, as per Level 1 and 2 (above).	• *Actions as stated for Level 2* • Offer site visit with key stakeholders • 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 key stakeholders • Completion of works following approvals and at a time agreed between IMC and relevant stakeholders (i.e. may be after mining induced

		movements and impacts are complete), including monitoring and reporting on success
	Exceeding Prediction • Fracturing resulting in diversion of flow such that >10% of the pools have water levels lower than baseline period • Result of **Assessment D** indicates that actual flow losses on Subject Creek exceed those simulated by contemporary groundwater modelling.	• *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
SURFACE WATER FLOW		
Wongawilli Creek, Lake Cordeaux and Cordeaux River *Primary Monitoring Sites* **Relevant Performance Measure(s):** • Wongawilli Creek - minor environmental consequences **Relevant Consent Condition(s)** • Lake Cordeaux - negligible reduction in the quantity of surface water inflows to Lake Cordeaux[1] • Cordeaux River - negligible reduction in the quantity of surface water inflow to the Cordeaux River at its confluence with Wongawilli Creek[2] **Surface Water Flow Reference Sites** (as in Table 1.1)**:** • Wongawilli Creek - WWU (Wongawilli Creek upstream); • WC11S1 • O'Hares Creek at Wedderburn (213200); • (other such sites, if necessary, include Woronora River 2132101 and Bomaderry Creek 215016)	***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 key stakeholders • Report in the End of Panel Report • Summarise actions and monitoring in Annual Review
	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 • Seek advice from key stakeholders 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 key stakeholders • 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 key stakeholders • Completion of works following approvals and at a time agreed between IMC and relevant stakeholders (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	• *Actions as stated for Level 3*

[1] Surface water inflows calculation = [Impacts at gauged catchments (SCL2) + LC5 + LC6 + estimated impacts at ungauged but undermined catchments] / [total estimated inflow to LC].
[2] Flow reduction as determined from measured at flow gauging station WWL_A.

NB. This section of the TARP contains four Water Flow Assessment Methods A-D. A step by step calculation procedure is detailed in Appendix F of the WIMMCP. 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.*	• 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".	• 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
Wongawilli Creek and other affected watercourses not subject to performance measures *Secondary Monitoring Sites* **Surface water flow Reference sites** (as in Table 1.1)**:** • Wongawilli Creek - WWU (Wongawilli Creek upstream); • WC11S1 (Wongawilli Creek tributary site, south of DA3A) • 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 A-D, Refer to Appendix F. 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*	***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 key stakeholders • Report in the End of Panel Report • Summarise actions and monitoring in Annual Review
	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 • Seek advice from key stakeholders 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 key stakeholders • 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 key stakeholders • Completion of works following approvals and at a time agreed between IMC and relevant stakeholders (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

site (NV + x% change) could be less than maximum observed variability at one of the reference sites.		
AQUATIC ECOLOGY		
Pool water level, interconnectivity between pools and loss of connectivity, noticeable alteration of habitat	***Level 1*** • Reduction in aquatic habitat for 1 year	• Continue monitoring program • Submit an Impact Report to key stakeholders • Report in the End of Panel Report • Summarise actions and monitoring in Annual Review
	Level 2 • Reduction in aquatic habitat for 2 years following the active subsidence period	• *Actions as stated for Level 1* • Review monitoring frequency • Seek advice from key stakeholders 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 key stakeholders • 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 key stakeholders • Completion of works following approvals and at a time agreed between IMC and relevant stakeholders (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 • Frog monitoring tributaries	***Level 1*** • Reduction in habitat for 1 year	• Continue monitoring program • Submit an Impact Report to key stakeholders • Report in the End of Panel Report • Summarise actions and monitoring in Annual Review
	Level 2 • Reduction in habitat for 2 years following the active subsidence period	• *Actions as stated for Level 1* • Review monitoring frequency • Seek advice from key stakeholders 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 key stakeholders • 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 key stakeholders • Completion of works following approvals and at a time agreed between IMC and relevant stakeholders (i.e. may be after mining induced movements and impacts are complete), including monitoring and reporting on success

Key Stakeholders/Agencies include the following and their successor agencies:

- Department of Planning and Environment (DPE)
- Biodiversity and Conservation Division (BCD)
- Resources Regulator
- WaterNSW

Appendix B – Dendrobium Long Term Groundwater Monitoring Program

DENDROBIUM LONG-TERM GROUNDWATER MONITORING PROGRAM

Areas 3A, 3B and 3C

Prepared for:

South32
Illawarra Metallurgical Coal
Innovation Campus Enterprise 1 Building
Level 3 Squires Way
North Wollongong, NSW 2500
Australia

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PREPARED BY

SLR Consulting Australia Pty Ltd
ABN 29 001 584 612
Level 1, The Central Building, UoW Innovation Campus
North Wollongong NSW 2500 Australia

T: +61 404 939 922
E: wollongong@slrconsulting.com www.slrconsulting.com

BASIS OF REPORT

This report has been prepared by SLR Consulting Australia Pty Ltd (SLR) with all reasonable skill, care and diligence, and taking account of the timescale and resources allocated to it by agreement with South32 (the Client). Information reported herein is based on the interpretation of data collected, which has been accepted in good faith as being accurate and valid.

This report is for the exclusive use of the Client. No warranties or guarantees are expressed or should be inferred by any third parties. This report may not be relied upon by other parties without written consent from SLR.

SLR disclaims any responsibility to the Client and others in respect of any matters outside the agreed scope of the work.

DOCUMENT CONTROL

Reference	Date	Prepared	Checked	Authorised
665.10009-R03-v4.0	4 February 2020	Braiya White, Claire Stephenson	Angus McFarlane	Angus McFarlane
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APPENDICES

Appendix A Groundwater Level Hydrographs – Long-Term Monitoring Locations

1 Introduction

Dendrobium mine is located approximately 12 kilometres (km) west of Wollongong (NSW) in the Southern Coalfield, and within the Metropolitan Special Catchment Area managed by WaterNSW. Longwall mining has been undertaken at Dendrobium since 2005 (IEPMC, 2019a) with the earliest multilevel piezometers installed in 2003 in Area 1 and from 2007 for Area 3. Dendrobium Mine is divided into six mining domains with Area 3 being further divided into Areas A, B and C.

SLR Consulting Pty Ltd (SLR) has been engaged to develop a long-term groundwater monitoring program for Areas 3A, 3B, and Longwall (LW) 20 – 21 (Area 3C) for the Dendrobium Mine operated by Illawarra Metallurgical Coal (IMC), a subsidiary of South32.

A long-term groundwater monitoring network is required to be developed to satisfy Condition 5(a), Schedule 4 of the Subsidence Management Plan Approval, granted 11th July 2019 (Development Consent DA 60-03-2001). This condition states that prior to the extraction of Longwall 16 (extraction proposed to commence in February 2020) the applicant must review and revise the Watercourse Impact Monitoring, Management and Contingency Plan for Area 3B to include a *"program of long-term groundwater monitoring, to be developed in consultation with WaterNSW, to monitor **groundwater levels** at specific locations and depths until post-mining groundwater levels have stabilised"*.

A recent investigation conducted by the Independent Expert Panel on Mining in the Catchment (IEPMC 2019a) has recommended that monitoring is increased at mine sites within the Greater Sydney Water Catchment Special Areas, to improve early identification of negative effects to features of environmental value. The IEPMC identified that large investigative efforts and monitoring programs have been undertaken at Dendrobium (and other mines within the Greater Sydney Water Catchment Special Areas). However, the IEPMC concluded the 'scale and complexity' of groundwater responses to mining in the region required more extensive monitoring to be undertaken by mines (IEPMC, 2019a).

This report presents a synthesis of the existing groundwater monitoring network and provides details of a recommended long-term groundwater monitoring program for Dendrobium mine areas 3A, 3B and 3C. This includes recommendations on monitoring frequency, annual reporting and data management requirements, along with groundwater model review requirements.

2 Existing Groundwater Monitoring Network

The following sections outline the various components and details of the current site groundwater monitoring network installed for Areas 3A, 3B and 3C. The monitoring network comprises a substantial number of multilevel vibrating wire piezometers (VWPs) positioned in various geologic units. Groundwater quality measurements are taken using pumps installed at selected VWP sites.

2.1 Groundwater Levels -VWPs

Groundwater levels are measured at Dendrobium using the extensive network of VWPs. These VWPs are positioned over the longwall footprint (including along longwall panel centrelines), within the off-goaf area and adjacent to major reservoirs (i.e. Lake Avon and Lake Cordeaux) in order to assess the impacts of depressurisation on the regional groundwater system. In all, 149 VWPs with 615 sensors have been installed as part of the monitoring network for Areas 3A, 3B and 3C. From this, a total of 101 VWPs with 394 individual sensors remain active. The Hawkesbury Sandstone is the most intensely monitored geologic unit, with 241 sensors positioned within 85 active VWPs.

Currently, measurements are collected at the VWPs on a daily to sub-daily basis and downloaded by field staff periodically for reporting. This data is collected and collated by Dendrobium Mine and uploaded and managed in an online database controlled by Geosensing Solutions.

The construction details of the VWPs and the monitored geology are shown in **Table 2-1** and locations shown in **Figure 1**.

Table 2-1 Groundwater Monitoring Network – VWPs

Area	S-Index	Status	Bore Name	Easting	Northing	Collar RL (mAHD)	Total depth (mbgl)	No. Sensors	No. Piezometers by Geology								
									HBSS	BHCS/ BACS	BGSS	SBSS	WBCS	CCSS	BUSM	WWSM	TGSM
3A	S1096	AD	AIS Kemira DDH 19	292699.6	6191120.9	435.1		1								1	
3A	S1099	AD	AIS Kemira DDH 22	292040.9	6191530.9	429.9		1								1	
3A	S1106	AD	AIS Kemira DDH 24	293904.7	6192602.4	335.2		1								1	
3A	S1388	AD	AIS Dend. DDH 29	292128.9	6192392.9	427.6		1								1	
3A	S1587	AD	DC Dend.DDH 41	292934.4	6193080.4	412.0		1								1	
3A	S1719	AD	DC Dend. DDH 56	291202.0	6193277.0	413.6	429.0	1								1	
3A	S1720	AD	DC Dend. DDH 57	291636.7	6192468.7	373.4	369.1	1								1	
3A	S1738	AD	DC Dend. DDH 61	292124.2	6191861.0	421.7	361.8	1								1	
3A	S1845	AD	Dend. DDH 77	291464.0	6193770.0	399.7		2							1	1	
3A	S1867	EX	ED Dend. DDH 84	293792.6	6192912.5	346.0		11	2		3	2	1	1	1	1	
3A	S1870	EX	ED Dend. DDH 85	293593.2	6192648.2	351.5	159.5	12	3		3	2	1	1	1	1	
3A	S1871	AD	ED Dend. DDH 86	293525.0	6193287.1	375.6		12	3		3	2	1	1	1	1	
3A	S1878	EXP	ED Dend. DDH 91	293842.3	6191994.3	337.1	309.3	11		1	3	3	1	1	1	1	
3A	S1879	EX	ED Dend. DDH 92	291440.3	6192133.4	379.7	368.5	12	3		3	3	1		1	1	
3A	S1885	EX	ED Dend. DDH 93	291504.4	6192667.9	420.0	420.4	12	3		3	3	1		1	1	
3A	S1888	EX	ED Dend. DDH 96	292486.5	6191987.4	381.3	320.5	8	2		2	2			1	1	
3A	S1889	AD	ED Dend. DDH 97	292244.8	6192980.4	435.4	386.3	8	2		2	2			1	1	
3A	S1890	AD	ED Dend. DDH 98	292637.3	6192490.5	407.1	347.5	8	2		2	2			1	1	
3A	S1892	EX	ED Dend. DDH 99	291014.1	6193952.0	356.1	389.2	8	2		2	2			1	1	
3A	S1907	EXP	ED Dend. DDH 103	293212.2	6191943.1	371.9	371.9	8	2		2	2			1	1	
3A	S1934	AD	ED Dend. DDH 115	292128.0	6192398.0	427.5	114.2	4	2		2						
3A	S1992	EX	EDEN119	293732.1	6192706.8	339.1	250.0	8	1		4	2			1		
3A	S1994	EX	EDEN120	293865.2	6192982.4	345.5	258.0	8	1		3	3			1		
3A	S2143C	AD	S2143C	293984.0	6192803.4	335.8		1	1								
3A	S2442A	EX	SC1-A	292788.5	6193213.2	407.6		6	3	1	2						
3A	S2443	EX	SC4	292176.0	6193027.4	426.7	227.0	6	3	1	2						
3B	S1579	EX	Dend. DDH 40	289061.3	6192056.3	423.1	446.4	1								1	
3B	S1739	AD	DC Dend. DDH 62	289683.6	6191798.7	423.7	438.4	1								1	
3B	S1755	EX	DC Dend. DDH64	289475.4	6191380.2	433.3		2							1	1	
3B	S1758	AD	Dend. DDH 65	288586.6	6193106.9	408.8		2							1	1	
3B	S1796	EX	Dend. DDH 69	289946.6	6194587.4	398.6	471.3	2							1	1	

Area	S-Index	Status	Bore Name	Easting	Northing	Collar RL (mAHD)	Total depth (mbgl)	No. Sensors	No. Piezometers by Geology								
									HBSS	BHCS/ BACS	BGSS	SBSS	WBCS	CCSS	BUSM	WWSM	TGSM
3B	S1800	AD	Dend. DDH 70	289933.4	6193996.5	392.5	452.8	2							1	1	
3B	S1855	EX	Dend. DDH 82	289746.5	6192833.2	366.6		2							1	1	
3B	S1908	AD	ED Dend. DDH 104	288925.9	6193601.4	405.7	460.5	8	2		3	1			1	1	
3B	S1910	EXP	EDEN105	289387.4	6194176.3	377.2		8	2		2	2			1	1	
3B	S1911	AD	EDEN106	288802.8	6192549.4	405.2	437.4	12	3		3	2	1	2		1	
3B	S1914	AD	EDEN107	289370.0	6192511.9	414.5	442.7	8	2		2	2			1	1	
3B	S1925	EXP	ED Dend. DDH 108	289251.6	6193041.1	416.7	463.6	8	2		2	2			1	1	
3B	S1926	AD	ED Dend. DDH 109	289660.4	6193444.9	409.0	458.0	8	2		2	2			1	1	
3B	S1927	EXP	ED Dend. DDH 110	290066.0	6192211.0	414.8	437.2	8	2		2	2			1	1	
3B	S1929	AD	ED Dend. DDH 111	290010.6	6193398.1	337.7	381.0	8	2		2	2			1	1	
3B	S1930	EXP	ED Dend. DDH 112	290367.3	6193582.9	353.1	401.4	12	3		3	3	1		1	1	
3B	S1931	EXP	ED Dend. DDH 113	290335.6	6192889.9	396.4		10	2	1	3	2			1	1	
3B	S1932	EXP	ED Dend. DDH 114	288863.3	6191505.4	396.1	400.2	12	4		3	3		1		1	
3B	S1995	AD	EDEN121	288212.4	6193662.3	404.5		2							1	1	
3B	S1998	EX	EDEN122	287750.6	6194273.1	410.5	479.3	2							1	1	
3B	S1999	EX	EDEN123	289232.8	6190843.7	406.4		2							1	1	
3B	S2000	EX	EDEN124	290161.4	6191011.2	442.0		2							1	1	
3B	S2001	EX	EDEN125	288462.6	6192020.0	413.9	431.2	10	3		3	2			1	1	
3B	S2002	AD	EDEN126	288633.4	6194222.1	400.0	466.0	2							1	1	
3B	S2003	AD	EDEN127	290571.1	6192478.0	409.4		2							1	1	
3B	S2004	EX	EDEN128	290538.5	6190794.8	443.5		2							1	1	
3B	S2006	EX	EDEN129	287263.2	6194204.3	409.1	464.0	10	3		3	2			1	1	
3B	S2007	EX	EDEN130	287590.8	6193718.9	405.8		2							1	1	
3B	S2009	AD	EDEN131	287828.2	6193092.0	402.5		10	3		3	2			1	1	
3B	S2013	EX	EDEN134	290857.7	6191198.2	399.7		2							1	1	
3B	S2070	EX	EDEN150	287619.3	6192813.2	414.7		2							1	1	
3B	S2071	AD	EDEN151	287027.2	6193200.9	443.1		2							1	1	
3B	S2078	AD	EDEN154	288190.0	6192451.9	342.0		2							1	1	
3B	S2126	AD	S2126	288536.6	6193897.9	397.6		2							1	1	
3B	S2192	AD	S2192	289826.7	6193848.7	389.3	288.0	6	3		3						
3B	S2193	EX	S2193	288523.4	6190985.9	370.8		2							1	1	
3B	S2194	EX	S2194	288514.9	6190978.8	371.1		11	3		3	2			1	1	1
3B	S2220	EXP	S2220 (AQ5)	289827.2	6193830.7	388.1	287.5	6	3		3						
3B	S2288	EX	Dend S2288 and S2208	292821.1	6195048.6	343.8		1								1	

Area	S-Index	Status	Bore Name	Easting	Northing	Collar RL (mAHD)	Total depth (mbgl)	No. Sensors	No. Piezometers by Geology								
									HBSS	BHCS/ BACS	BGSS	SBSS	WBCS	CCSS	BUSM	WWSM	TGSM
3B	S2303	EXP	Dend S2303	287109.8	6196268.1	411.7		9	3		3	1			1	1	
3B	S2306	EX	Swamp Bore 3 (adjacent)	288643.3	6192483.7	395.5	70.0	4	4								
3B	S2307	EX	Swamp Bore 4	288665.9	6192424.6	394.5	50.0	4	4								
3B	S2313	EX	Avon 1	287609.0	6192815.5	415.3		3	2		1						
3B	S2314	EX	Avon 2	288193.5	6192470.3	342.4		1	1								
3B	S2314A	EX	Avon 2 Redrill	288194.6	6192455.6	342.6		3	2		1						
3B	S2335	EX	WC21Project Hole1Site 2	289725.4	6192748.7	372.6	51.0	6	6								
3B	S2335A	EX	WC21Project Hole1Site 2	289727.0	6192755.0	370.1		6	6								
3B	S2336	EX	WC21Hole2,Site2	289721.9	6192758.1	372.4	35.0	1	1								
3B	S2337	EX	WC21Project Hole1Site 5	290021.0	6193411.9	336.1	51.0	4	4								
3B	S2338	EX	WC21Hole2,Site5	290012.2	6193406.7	336.1	51.0	3	3								
3B	S2351	EX	S14-04	290049.6	6191178.2	402.8		1	1								
3B	S2351A	EX	S14-03	290054.3	6191175.2	403.6		1	1								
3B	S2354	EX	S14-05	289730.9	6191413.7	424.6		1	1								
3B	S2376	EX	Avon6	288400.4	6192527.0	367.8		3	2		1						
3B	S2377	EX	Avon3	288333.4	6192020.4	408.2		3	2		1						
3B	S2378	EX	Avon4	288407.4	6191770.9	379.3		3	2		1						
3B	S2379	EX	Avon5	288312.9	6191140.5	356.6		3	2		1						
3B	S2398	EX	LW14-1	289073.2	6192164.3	420.2	335.0	7	4	1	2						
3B	S2398A	EX	LW14-1A	289072.9	6192156.9	420.5	11.0	1	1								
3B	S2398B	EX	LW14-1 post extraction Redrill	289070.9	6192172.6	418.0	335.5	7	4	1	2						
3B	S2399	EX	LW12-1	289810.5	6192965.1	355.1	350.0	6	3	1	2						
3B	S2399A	EX	S2399A	289815.6	6192967.8	354.6		2	2								
3B	S2401	EX	Den01b_R1	287752.2	6194264.9	411.1	119.0	6	6								
3B	S2402	EX	Den01b_R2	288207.8	6193666.6	403.4	92.0	6	6								
3B	S2403	EX	Den01b_R3	288345.1	6193761.1	400.7	60.0	6	6								
3B	S2404	EX	Den01b_R4	288528.6	6193896.8	396.2	59.0	6	6								
3B	S2405	EX	Den01b_R5	288729.5	6194087.6	386.1	71.0	6	6								
3B	S2406	EX	Den01b_R6	288669.1	6194176.5	396.6	86.0	6	6								
3B	S2408	EX	GW14-2	289552.1	6192193.4	398.1		7	7								
3B	S2409	EX	GW14-3	289546.1	6192269.7	394.6	120.0	6	6								
3B	S2409A	EX	GW14-3	289546.1	6192269.7	394.6	11.0	1	1								
3B	S2411	EX	LW12-2	289761.1	6192837.7	364.0	285.0	7	4	1	2						
3B	S2411A	EX	LW12-2a	289761.6	6192839.3	363.8	12.0	1	1								

Area	S-Index	Status	Bore Name	Easting	Northing	Collar RL (mAHD)	Total depth (mbgl)	No. Sensors	No. Piezometers by Geology								
									HBSS	BHCS/ BACS	BGSS	SBSS	WBCS	CCSS	BUSM	WWSM	TGSM
3B	S2412	AD	LW15-1	289201.1	6191807.4	427.3	341.4	7	4	1	2						
3B	S2412A	AD	LW15-1A	289201.1	6191807.4	427.3	12.0	1	1								
3B	S2420	EX	LW12-3	289738.4	6192780.0	367.8	272.8	7	4	1	2						
3B	S2420A	EX	LW12-3A	289738.4	6192780.0		272.8	1	1								
3B	S2421	EX	LW13-1	289590.4	6192492.2	381.8		7	4	1	2						
3B	S2421A	EX	LW13-1A	289590.4	6192492.2			1	1								
3B	S2433	EX	Elouera2-1	289082.0	6190172.9	375.7		1	1								
3B	S2435	EX	AD7	288080.8	6192411.6	328.2	108.2	3	2		1						
3B	S2436	EX	AD8	288313.8	6191499.7	320.3	108.2	3	1	1	1						
3B	S2436B	EX	AD8B	288313.8	6191499.7	320.5	39.3	1	1								
3B	S2436C	EX	AD8C (angle hole)	288319.6	6191500.8	320.7	70.0	1	1								
3B	S2441	EX	Elouera1-1	288752.5	6190268.4	347.6		1	1								
3B	S2441A	EX	Elouera1-2	288754.5	6190253.8	349.0		1	1								
3B	S2441B	EX	Elouera1-3	288760.7	6190260.9	348.4		1	1								
3B	S2444	EX	Elouera2-2	289077.9	6190167.7	376.3	324.8	1	1								
3C	S1390	EX	AIS Dend. DDH 31	292469.3	6194395.7	375.2		1								1	
3C	S1779	AD	Dend. DDH 67	292381.4	6195550.6	368.7	403.0	2							1	1	
3C	S1844	EX	Dend. DDH 76	291391.1	6194868.8	375.6	408.6	2							1	1	
3C	S1969	AD	EDEN118	293998.1	6193985.7	368.5		11	3		3	3			1	1	
3C	S2010	AD	EDEN132	292273.2	6196658.1	374.2	441.8	1								1	
3C	S2011	AD	EDEN133	292055.1	6197166.1	371.7		2							1	1	
3C	S2017	AD	EDEN136	291384.8	6196706.4	351.3		2							1	1	
3C	S2018	AD	EDEN137	291154.4	6195520.3	369.0		2							1	1	
3C	S2019	EX	EDEN138	291897.6	6195913.7	361.8		2							1	1	
3C	S2059	EXP	EDEN148	293245.7	6194795.1	380.8	401.3	12	3	1	3	3			1	1	
3C	S2207	EX	S2207	291807.6	6195324.3	416.8		2							1	1	
3C	S2208	AD	S2208	292801.1	6195037.3	344.1		7	2		2	2				1	
3C	S2211	AD	S2211	293247.0	6194106.0	397.7		2							1	1	
3C	S2212	AD	S2212	293534.8	6194402.9	369.2		10	1		3	3			1	1	1
3C	S2333	EX	D-A3C-14-12	290697.1	6197087.4	310.9		10	3		3	2			1	1	
3C	S2333A	AD	D-A3C-14-12A	290688.1	6197088.0	311.2		10	3		3	2			1	1	
3C	S2341A	EX	D-A5-28A	287489.0	6195138.2	402.6		4	4								
3C	S2352	EX	D-A5-6	286264.6	6195393.3	408.8	425.8	10	3		3	2			1	1	
3C	S2355	EX	A5_S85_DBH	288136.2	6194877.8	396.6	70.6	4	4								

Area	S-Index	Status	Bore Name	Easting	Northing	Collar RL (mAHD)	Total depth (mbgl)	No. Sensors	No. Piezometers by Geology								
									HBSS	BHCS/ BACS	BGSS	SBSS	WBCS	CCSS	BUSM	WWSM	TGSM
3C	S2355A	EX		288135.3	6194879.2	396.5	10.5	1	1								
3C	S2357	EX	A5-S100_DBH	286809.6	6196991.8	394.0	71.0	4	4								
3C	S2358	EX	A5-S97_DBH	286859.6	6197664.4	385.7	71.0	4	4								
3C	S2359	EX	D-A5-5	285354.6	6195547.7	403.6		10	3		3	2			1	1	
3C	S2361	EX	A5_S109_DBH	286277.9	6195810.7	402.4	70.0	4	4								
3C	S2362	EX	A5_S110_DBH	285772.9	6195823.0	399.9	70.0	4	4								
3C	S2364	EX	A5_S103_DBH	285982.8	6196782.1	395.0	70.0	4	4								
3C	S2365	EX	A5_101/102_DBH	286042.3	6196448.9	399.2	75.0	4	4								
3C	S2365A	EX		286041.9	6196442.6	399.1	70.0	1	1								
3C	S2370	EX	D-A5-2	285554.8	6196642.7	375.6		10	3		3	2			1	1	
3C	S2371	EX	A6_S116_DBH	291977.5	6199135.2	351.2	70.0	4	4								
3C	S2372	EX	A6_S115_DBH	291576.9	6198891.4	373.5	70.0	4	4								
3C	S2372A	EX		291572.2	6198894.4	373.6	17.0	1	1								
3C	S2373	EX	A6_S112_DBH	292043.2	6200899.2	359.0	70.0	4	4								
3C	S2374	EX	A6_S83_DBH	291114.8	6201461.1	324.4	70.0	4	4								
3C	S2438	EXP		287944.9	6197535.1	399.3	444.3	9	3		3	2			1		

Note: mbgl – metres below ground level
Coordinates are for GDA94 MGA56
HBSS – Hawkesbury Sandstone
BHCS/BACS – Bald Hill Claystone
BGSS – Bulgo Sandstone
SBSS – Scarborough Sandstone
WBCS – Wombarra Shale
CCSS – Coalcliff Sandstone
BUSM – Bulli Coal Seam
WWSM – Wongawilli Coal Seam
TGSM – Tongarra Coal Seam
Dend. – Dendrobium
EX – Existing
AD – Currently abandoned and destroyed
EXP – Existing – but with only a subset of original sensors

2.2 Water Quality

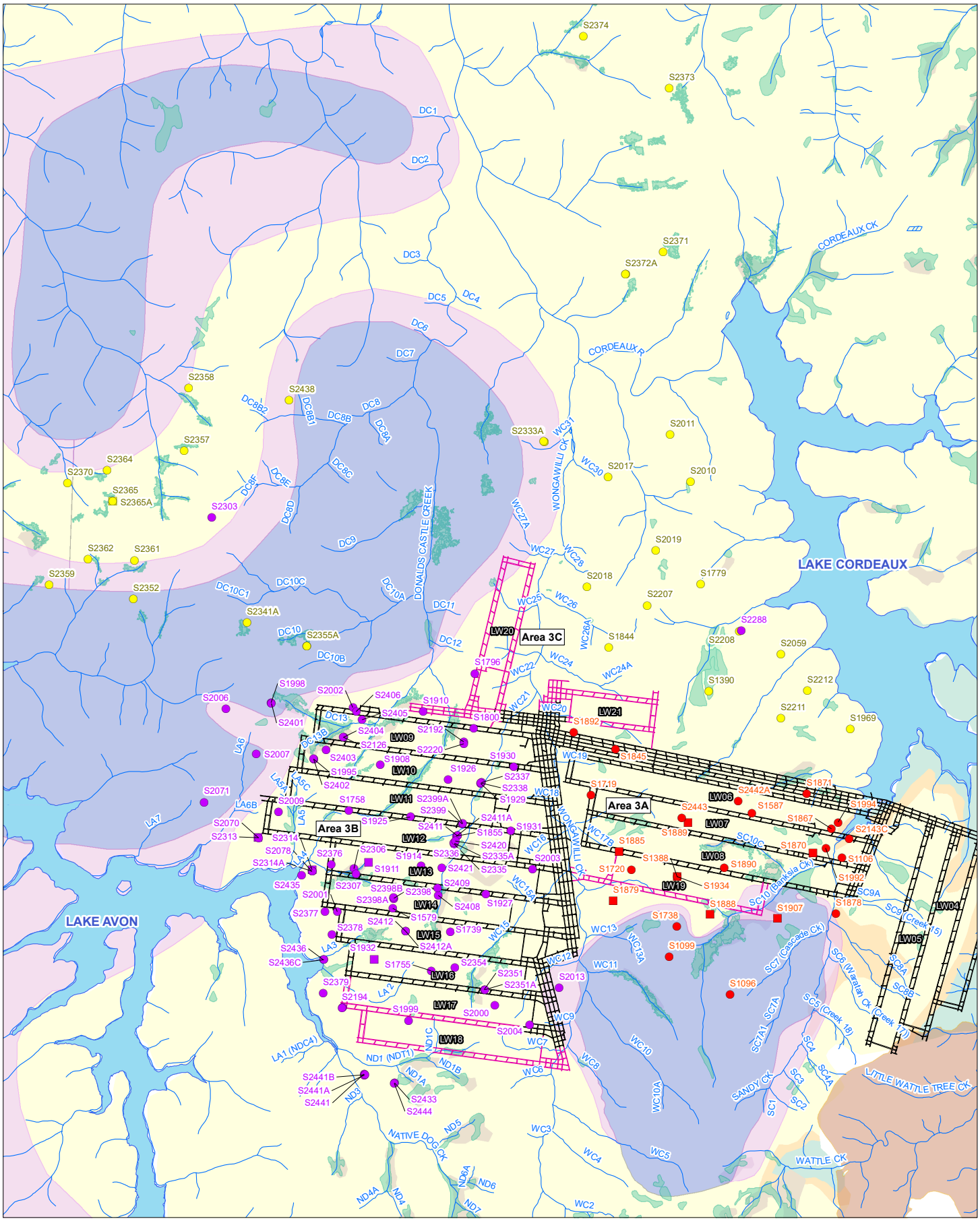
Groundwater quality is sampled at selected VWPs in Areas 3A, 3B and 3C via pumps fixed within the VWP borehole. Currently, 22 of the site VWPs are equipped for water quality sampling at multiple vertical intervals. Each borehole has up to three pumps, with the Hawkesbury Sandstone, Bulgo Sandstone or Scarborough Sandstone being the key lithologies monitored at Areas 3A, 3B and 3C. Details of these bores and the number of pumps per geologic unit are outlined in **Table 2-2**, and also presented on **Figure 1**.

Groundwater quality measurements are taken from the in-built pumps. Groundwater is currently assessed for salinity (as EC), pH, major ion compositions (e.g. HCO_3, Na), minor ion composition, and metals (e.g. Ba, Sr, Li) as well as a range of isotopes (e.g. tritium). Sampling of water quality has been undertaken at the mine since 2004.

Table 2-2 Groundwater Monitoring Network – water quality

Area	S-Index	Bore Name	Easting	Northing	Collar RL (mAHD)	Total depth (mbgl)	No. Pumps	No. Pumps by Geology		
								HBSS	BGSS	SBSS
3A	S1870	ED Dendrobium DDH 85	293593.2	6192648.2	351.5	159.5	2	2	1	
3A	S1879	ED Dendrobium DDH 92	291440.3	6192133.4	379.7	368.5	2	2	1	
3A	S1885	ED Dendrobium DDH 93	291504.4	6192667.9	420.0	420.4	2	2	1	
3A	S1888	ED Dendrobium DDH 96	292486.5	6191987.4	381.3	320.5	2	2	1	
3A	S1889	ED Dendrobium DDH 97	292244.8	6192980.4	435.4	386.3	2	2	1	
3A	S1907	ED Dendrobium DDH 103	293212.2	6191943.1	371.9	371.9	3	2	1	
3A	S1934	ED Dendrobium DDH 115	292128.0	6192398.0	427.5	114.2	2	2		
3B	S1911	EDEN106	288802.8	6192549.4	405.2	437.4	3	2	1	
3B	S1932	ED Dendrobium DDH 114	288863.3	6191505.4	396.1	400.2	2	3		
3B	S2001a	EDEN125a	288358.0	6191952.0	-	466.0	3	2	1	
3B	S2313	Avon 1	287609.0	6192815.5	415.3		3	2	1	
3B	S2314	Avon 2	288193.5	6192470.3	342.4		3	2	1	
3B	S2376A	Avon6A	288395.1	6192516.8	367.6		3	2	1	
3B	S2377A	Avon3A	288342.0	6192013.1	408.1		3			
3B	S2378A	Avon4A	288416.5	6191767.5	379.2		3	2	1	
3B	S2379A	Avon5A	288306.5	6191149.3	356.2		3	2	1	
3B	S2436A	AD8A	288313.8	6191499.7	320.3	90.0	2	1	1	
3C	S1970	EDEN118a	294014.0	6193981.0	-		3	1	1	1
3C	S2332A		290404.9	6196320.3	366.9		3	2	1	
3C	S2341B	D-A5-28B	287489.0	6195138.2	-		1	2	1	
3C	S2361A		286277.9	6195810.7	402.4	70.0	1	1		
3C	S2365A		286041.9	6196442.6	399.1	70.0	1	1		

Note: mbgl – metres below ground level
Coordinates are for GDA94 MGA56
HBSS – Hawkesbury Sandstone
BGSS – Bulgo Sandstone
SBSS – Scarborough Sandstone



0 1 km

Projection: GDA 1994 MGA Zone 56
Scale: 1:55,000

Project No.:	665.10009
Date:	22-Jan-2020
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Monitoring bore area (VWP)
- 3A
- 3B
- 3C

Monitoring bore area (VWP & WQ)
- 3A
- 3B
- 3C

- Proposed mine workings
- Current/Completed mine workings
- Watercourses
- Lakes
- Upland swamp (IC/OEH)
- Cinder above seam
- Cinder in seam

- Qs/Qal – alluvium
- Qs – swamp sediments
- Qt – talus
- Rh – HBSS
- Rnz – BHCS (BACS)
- Rnbu – BUSS/CVSS

DENDROBIUM LONG-TERM GROUNDWATER MONITORING PLAN

FIGURE 1

Existing Groundwater Monitoring Network

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3 Long-Term Groundwater Monitoring Program

3.1 Groundwater Levels

In order to identify bores within the existing network to be maintained as part of the long-term groundwater monitoring program, a series of criteria were set to identify bores that will provide beneficial data and insights into the behaviour over the life of the mine and post closure.

Four categories defining features of importance and areas of interest were used to select bores from the existing groundwater monitoring network that should be used as part of the long-term monitoring program. These categories are:

- longwall panel monitoring locations;
- Lake Avon shoreline monitoring locations;
- Lake Cordeaux monitoring locations; and
- locations associated with watercourses of interest (i.e. Wongawilli Creek, Donalds Castle Creek and Sandy Creek. See **Figure 1** for locations).

From these categories, a total of 48 existing bores have been identified to be retained as part of the long-term monitoring program for Dendrobium Areas 3A, 3B and 3C. Each of these bores is currently utilised to monitor groundwater level in several geologic units at various locations around the mine. Nine open standpipe bores have also been selected based on available information. Further verification of the construction and condition of the bores may be required prior to establishing the network, where issues are identified alternative locations will be proposed.

Table 3-1 provides a summary of these bores based on mine area and the monitoring groups identified above. A map of the location of each bore defined by monitoring group is provided on **Figure 2**. Several recommendations have been made for the modification of existing monitoring locations to enhance the monitoring network.

The proposed updates to the existing network include:

- The installation of sensors in the shallow geologic units (i.e. Hawkesbury Sandstone and Bald Hill Claystone) at monitoring bore S1796. This bore is adjacent to the western margin of Longwall 20 and currently has sensors in the Bulli and Wongawilli Coal Seams. The addition of shallow sensors at this location would provide a mining-affected dataset to compare to other bores that monitor groundwater levels adjacent to Donalds Castle and Wongawilli Creek (located either side of this longwall panel).
- The installation of sensors in the shallow geologic units (i.e. Hawkesbury Sandstone and Bald Hill Claystone) at monitoring bores S2013 and S2019 to monitor shallow groundwater levels adjacent to Donalds Castle Creek and Wongawilli Creek. It is also proposed that the abandoned bore S2018 be reinstated for this purpose.

Further discussion on the long-term monitoring network is included in **Section 3.1.1** to **Section 3.1.4**.

Table 3-1 Bores to be included in Long-term Monitoring Program

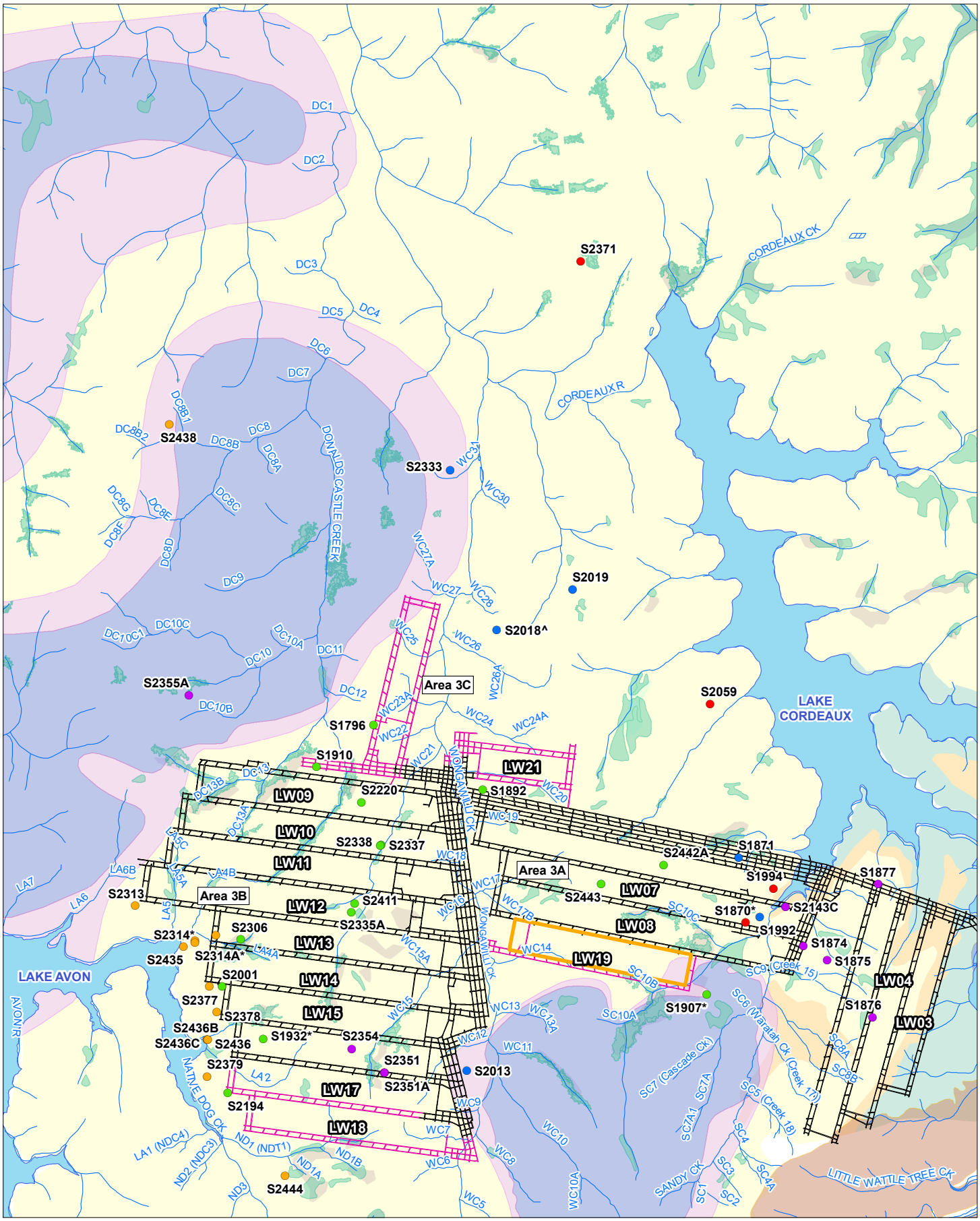
Monitoring Group	Area	S-Index	Bore Name	Easting	Northing	Collar RL (mAHD)	Total depth (mbgl)	No. Sensors	No. Piezometers by Geology								
									HBSS	BHCS/BACS	BGSS	SBSS	WBCS	CCSS	BUSM	WWSM	TGSM
Longwall	3A	S1892	ED Dendrobium DDH 99	291014.1	6193952.0	356.1	389.2	8	2		2	2			1	1	
	3A	S1907	ED Dendrobium DDH 103	293212.2	6191943.1	371.9	371.9	8	2*		2*	2			1	1	
	3A	S2442A	SC1-A	292788.5	6193213.2	407.6	-	6	3	1	2						
	3A	S2443	SC4	292176.0	6193027.4	426.7	227.0	6	3	1	2						
	3B	S1910	EDEN105	289387.4	6194176.3	377.2	-	8	2		2	2			1	1	
	3B	S1932	ED Dendrobium DDH 114	288863.3	6191505.4	396.1	400.2	12	4*		3	3		1		1	
	3B	S2001	EDEN125	288462.6	6192020.0	413.9	431.2	10	3		3	2			1	1	
	3B	S2194	S2194	288514.9	6190978.8	371.1	-	11	3		3	2			1	1	1
	3B	S2220	S2220 (AQ5)	289827.2	6193830.7	388.1	287.5	6	3		3						
	3B	S2306	Swamp Bore 3 (adjacent)	288643.3	6192483.7	395.5	70.0	4	4								
	3B	S2335A	WC21Project Hole1Site 2	289727.0	6192755.0	370.1	-	6	6								
	3B	S2337	WC21Project Hole1Site 5	290021.0	6193411.9	336.1	51.0	4	4								
	3B	S2338	WC21Hole2,Site5	290012.2	6193406.7	336.1	51.0	3	3								
	3B	S2411	LW12-2	289761.1	6192837.7	364.0	285.0	7	4	1	2						
	3B	S1796	Dend. DDH 69	289946.6	6194587.4	398.6	471.3	2	P	P					1	1	
	3B	S2351#	-	290049.6	6191178.2		15.0	OSP	1								
	3B	S2351A#	-	290054.3	6191175.2	-	30.1	OSP	1								
	3B	S2354#	-	289730.9	6191413.7	-	50.0	OSP	1								
Avon	3B	S2313	Avon 1	287609.0	6192815.5	415.3	-	3	2		1						
	3B	S2314	Avon 2	288193.5	6192470.3	342.4	-	1	1								
	3B	S2314A	Avon 2 Redrill	288194.6	6192455.6	342.6	-	3	2		1						
	3B	S2376	Avon6	288400.4	6192527.0	367.8	-	3	2		1						
	3B	S2377	Avon3	288333.4	6192020.4	408.2	-	3	2		1						
	3B	S2378	Avon4	288407.4	6191770.9	379.3	-	3	2		1						
	3B	S2379	Avon5	288312.9	6191140.5	356.6	-	3	2		1						
	3B	S2435	AD7	288080.8	6192411.6	328.2	108.2	3	2		1						
	3B	S2436	AD8	288313.8	6191499.7	320.3	108.2	3	1	1	1						
	3B	S2436B	AD8B	288313.8	6191499.7	320.5	39.3	1	1								
	3B	S2436C	AD8C (angle hole)	288319.6	6191500.8	320.7	70.0	1	1								
	3B	S2444	Elouera2-2	289077.9	6190167.7	376.3	324.8	1	1								
	3C	S2438	-	287944.9	6197535.1	399.3	444.3	9	3		3	2			1		
Cordeaux	3A	S1870	ED Dendrobium DDH 85	293593.2	6192648.2	351.5	159.5	12	3		3	2	1	1	1	1	
	3A	S1994	EDEN120	293865.2	6192982.4	345.5	258.0	8	1		3	3			1		
	3C	S2059	EDEN148	293245.7	6194795.1	380.8	401.3	12	3	1	3	3			1	1	

Monitoring Group	Area	S-Index	Bore Name	Easting	Northing	Collar RL (mAHD)	Total depth (mbgl)	No. Sensors	No. Piezometers by Geology								
									HBSS	BHCS/BACS	BGSS	SBSS	WBCS	CCSS	BUSM	WWSM	TGSM
	3C	S2371	A6_S116_DBH	291977.5	6199135.2	351.2	70.0	4	4								
	3A	S2143C#	-	293984.0	6192803.4	-	12.5	OSP	1								
	3A	S1874#	EDEN87b	294158.5	6192420.5	-	26.0	OSP	1								
	3A	S1875#	EDEN88b	294392.2	6192279.2	-	28.0	OSP	1								
	2	S1876#	EDEN89b	294836.8	6191719.2	-	41.5	OSP	1								
	2	S1877#	EDEN90b	294891.3	6193024.3	-	11.0	OSP	1								
Watercourses	3A	S1871	ED Dendrobium DDH 86	293525.0	6193287.1	375.6	-	12	3		3	2	1	1	1	1	
	3A	S1992	EDEN119	293732.1	6192706.8	339.1	250.0	8	1		4	2			1		
	3C	S2333	D-A3C-14-12	290697.1	6197087.4	310.9	-	10	3		3	2			1	1	
	3B	S2013	EDEN134	290857.7	6191198.2	399.7	-	4	P	P					1	1	
	3C	S2018^	EDEN137	291154.4	6195520.3	369.0	-	4	P	P					1	1	
	3B	S2019	EDEN138	291897.6	6195913.7	361.8	-	4	P	P					1	1	
	3B	S2355	A5_S85_DBH	288136.2	6194877.8	396.6	70.6	4	4								
	3B	S2355A#	-	288135.3	6194879.2	-	18.0	OSP	1								

OSP – Open Standpipe (bore constructed as PVC monitoring bore with one screened interval to enable manual groundwater monitoring)

- bore condition and construction to be verified

^ - currently abandoned, proposed to be re-established for monitoring purposes.



H:\Projects-SLR\620-BNE\665-WOL\665.10009\arcGIS\665.10009_00007 Proposed Monitoring Locations.mxd

0 1 km

Projection: GDA 1994 MGA Zone 56
Scale: 1:50,000

Project No.:	665.10009
Date:	31-Jan-2020
Drawn by:	JG
Sheet Size:	A4

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Monitoring Group

- Lake Avon monitoring locations
- Lake Cordeaux monitoring locations
- Longwall panel monitoring locations
- Watercourse monitoring locations
- Open standpipe locations
- LW19 longwall panel

- Proposed mine workings
- Current/Completed mine workings
- Watercourses
- Lakes
- Upland swamp (IC/OEH)
- Cinder above seam
- Cinder in seam

- Qs/Qal – alluvium
- Qs – swamp sediments
- Qt – talus
- Rh – HBSS
- Rnz – BHCS (BACS)
- Rnbu – BUSS/CVSS

DENDROBIUM LONG-TERM GROUNDWATER MONITORING PLAN

FIGURE 2

Proposed Monitoring Locations

3.1.1 Longwall Panel Monitoring Locations

As part of current monitoring, several bores have been installed above and around longwall panels to monitor changes in permeability before and after mining has occurred in the area. As described in the LW14 End of Panel Report (HGEO, 2019a), bores installed above longwall panels are often destroyed due to shearing after the longwall passes. Therefore, bores installed over the longwall panel are either discretely collecting data prior to or following mining. As part of the long-term monitoring program, the latter will be required to assess the change in groundwater levels over the mine workings to understand the response to goaf properties and subsidence with time after mining.

Based on this, 16 existing VWPs were proposed to be included in the long-term monitoring program to monitor groundwater levels in the strata above the longwall panels. If any of these bores are destroyed or removed during the course of mining, it is recommended that a new bore be redrilled to replace the lost bore once ground conditions have stabilised to allow data continuity.

Three existing OSP bores have also been included in the monitoring network. S2351 and S2351A are located adjacent to one another and monitor the Hawkesbury Sandstone at depths of 14 m and 29 m respectively. S2354 is also located in the Hawkesbury Sandstone at 42 m depth. Each of these bores overly the footprint of Longwall 16. It is recommended that manual groundwater levels be recorded for comparison to nearby VWP's (e.g. 1932) to verify sensor data.

A hydrograph of modelled groundwater levels, based on the results presented in SLR (2020), is presented for a representative location in **Figure 3**. A full set of recorded and simulated hydrographs is included in **Appendix A**.

S2443 is located above Longwall 7 (Area 3A) which was mined between 2011 and 2012. During active mining, aquifers overlying the mined coal seam experience depressurisation. Such an event can be observed at S2443 in sensors monitoring the lower Hawkesbury Sandstone aquifer (113.5 HBSS) and down to the lower Bulgo Sandstone (225 BGSS) following the start of mining in Area 3A (Longwall 6 in early 2010). As mining moves away from this location and into Area 3B (2015-2022), mining related drawdown and depressurisation is observed. Drawdown in the range of 5-10 m is typically observed in the upper Hawkesbury Sandstone aquifer, with recovery generally occurring faster (stabilisation of groundwater levels within 15 to 30 years post-mining). The lower units (Bulgo Sandstone, Scarborough Sandstone and coal seams) experience the greatest drawdown and may take a period of longer than 50 years for groundwater levels to stabilise post-mining.

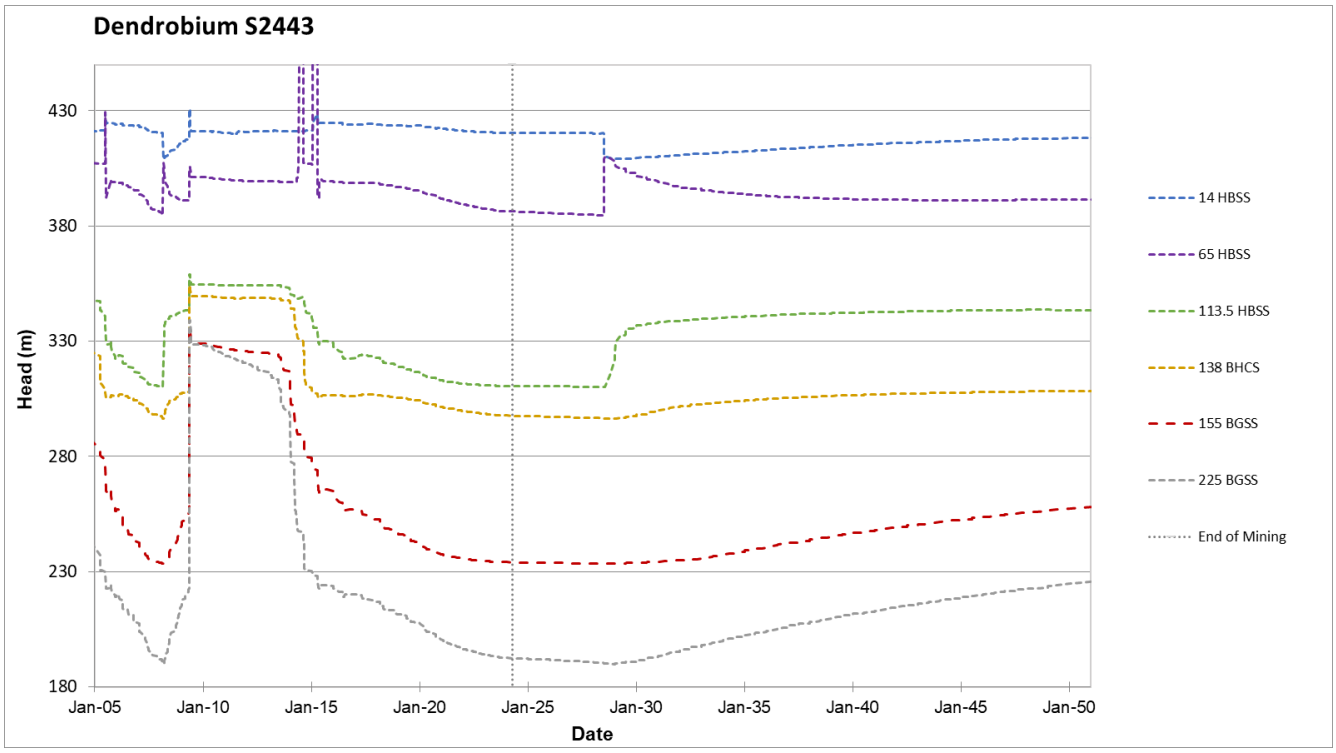


Figure 3 Modelled Groundwater Levels for Bore S2443

3.1.2 Lake Avon Shoreline Monitoring Locations

As tabulated in **Table 3-1**, 13 existing bores have been proposed to monitor groundwater levels adjacent to Lake Avon as part of the long-term monitoring program. These bores are located on the western margin of the Area 3B between the longwall panel and the eastern arm of Lake Avon that is fed by Native Dog Creek (see **Figure 2**).

Monitoring at these locations is primarily concentrated in the upper stratigraphic units (i.e. Hawkesbury Sandstone and Bald Hill Claystone) as Lake Avon is set within this geology. In addition to being used for groundwater level monitoring, these bores have recently been assessed for changes in strata permeability that have resulted from mining activity as part of a recent investigation undertaken by HGEO (2019b).

A hydrograph of modelled groundwater levels, based on the results presented in SLR (2020), is presented for a representative location in **Figure 4**.

S2314 is located approximately 140 m from the Lake Avon Shoreline and 160 m from the western end of Longwall 13. Monitoring is undertaken at three depths within the Hawkesbury Sandstone and Bulgo Sandstone aquifers, which is typical of the other Lake Avon monitoring bores. The lower stratigraphic units experience the greatest drawdown due to their proximity to the coal seam. At S2314, approximately 90 m of mining related drawdown is predicted to occur in the Bulgo Sandstone aquifer, with recovery predicted to begin approximately 65 years after mining is completed. Mining related impacts are less for the Hawkesbury Sandstone with the lower sensor predicted to experience a water level reduction of ~25 m, and the upper sensor ~5 m. Groundwater levels are predicted to stabilise within 5 years and 15 years of the completion of mining, in the upper and lower Hawkesbury Sandstone respectively.

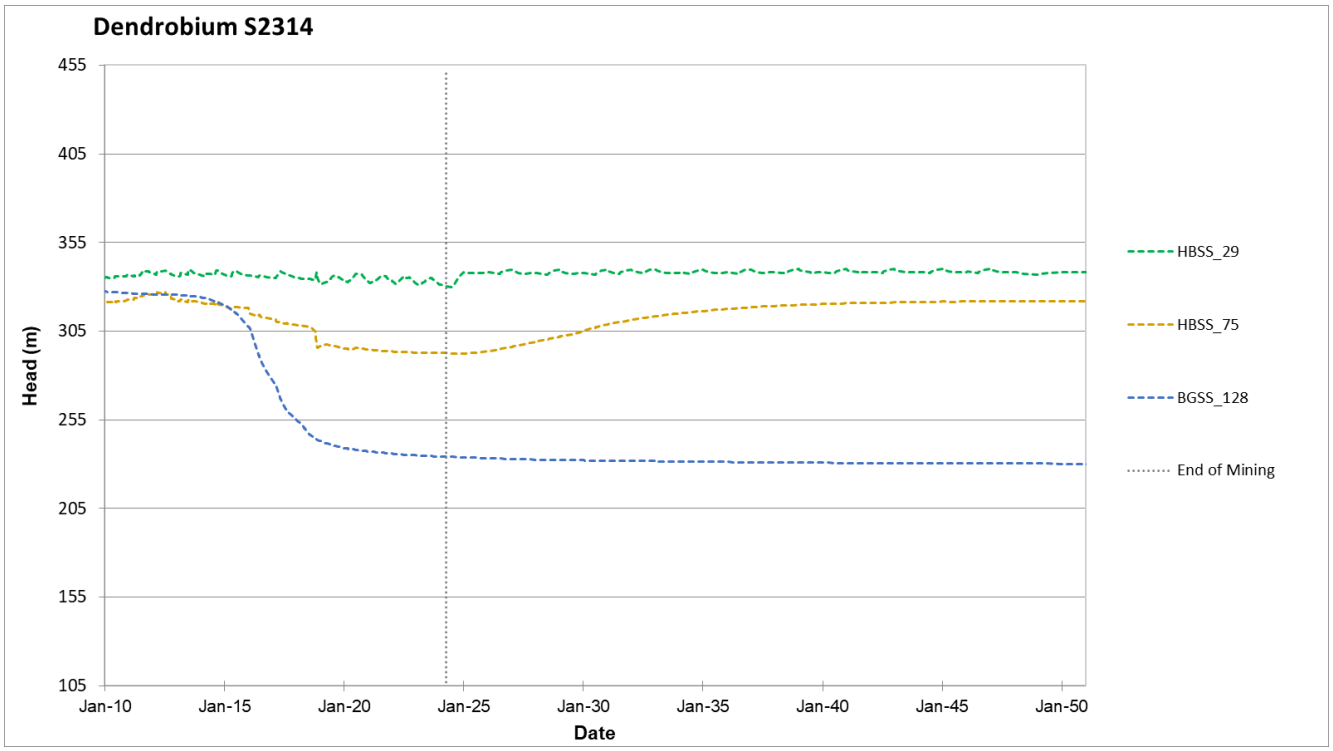


Figure 4 Modelled Groundwater Levels for Bore S2314

3.1.3 Lake Cordeaux Monitoring Locations

Three bores from the existing monitoring network have been proposed to be included as part of the long-term monitoring program (see **Figure 2** for locations) to monitor groundwater levels at Lake Cordeaux. S1994 and S1870 overlie Longwalls 6 and 7 (Area 3A) and are adjacent to Sandy Creek which flows into Lake Cordeaux. S1870 also has groundwater quality sampling capabilities. S2059 is located approximately 1.3 km north of Area 3A and approximately 345 m from the nearest point of Lake Cordeaux. S2371 is located to the north a further 4.5 km from bore S2059 and is approximately 900 m Lake Cordeaux. This location has been included as a far-field reference point for comparison against the monitoring bores positioned closer to the mine.

As with the Lake Avon bores, these bores have sensors primarily located in the upper stratigraphic units (i.e. Hawkesbury Sandstone and Bald Hill Claystone) in order to monitor any mining related impacts that may occur within these aquifers.

The following five existing OSP bores have also been included in the monitoring network, S2143C, S1874, S1875, S1876, S1877. Monitoring at these locations has not occurred since approximately 2012-2013, however, it is recommended that they be reinstated in order to monitor groundwater level recovery of the shallow aquifer adjacent to Lake Cordeaux. This includes review of the condition of the bores to ensure they are suitable to collect representative data. These bores are positioned within the Hawkesbury Sandstone at depths between 11 m and 42 m. It is recommended that manual groundwater level readings be taken from these bores and the data collected be used to verify water levels collected at shallow sensors in the adjacent VWPs S1870, S1992 and S1994.

A hydrograph of modelled groundwater levels, based on the results presented in SLR (2020), is presented for a representative location in **Figure 5**.

S1870 is located over the footprint of Longwall 7 (Area 3A) and adjacent to Sandy Creek and Lake Cordeaux. As with the hydrographs presented in **Sections 3.1.1** and **3.1.2**, the greatest mining related effects take place in the lower aquifers, with the degree of drawdown increasing with depth from the surface and proximity to the mined coal seam. Drawdown of 5-10 m is predicted to occur in the shallow Hawkesbury Sandstone aquifers with stabilisation of groundwater levels expected to occur within 5 years after the completion of mining. Drawdown of the Bulgo Sandstone aquifer is predicted to be in the range of 50-70 m, with recovery commencing around 5 years after the completion of mining. Groundwater levels are predicted to stabilise around 10 m lower than pre-mining groundwater levels approximately 100 to 150 years after the completion of mining.

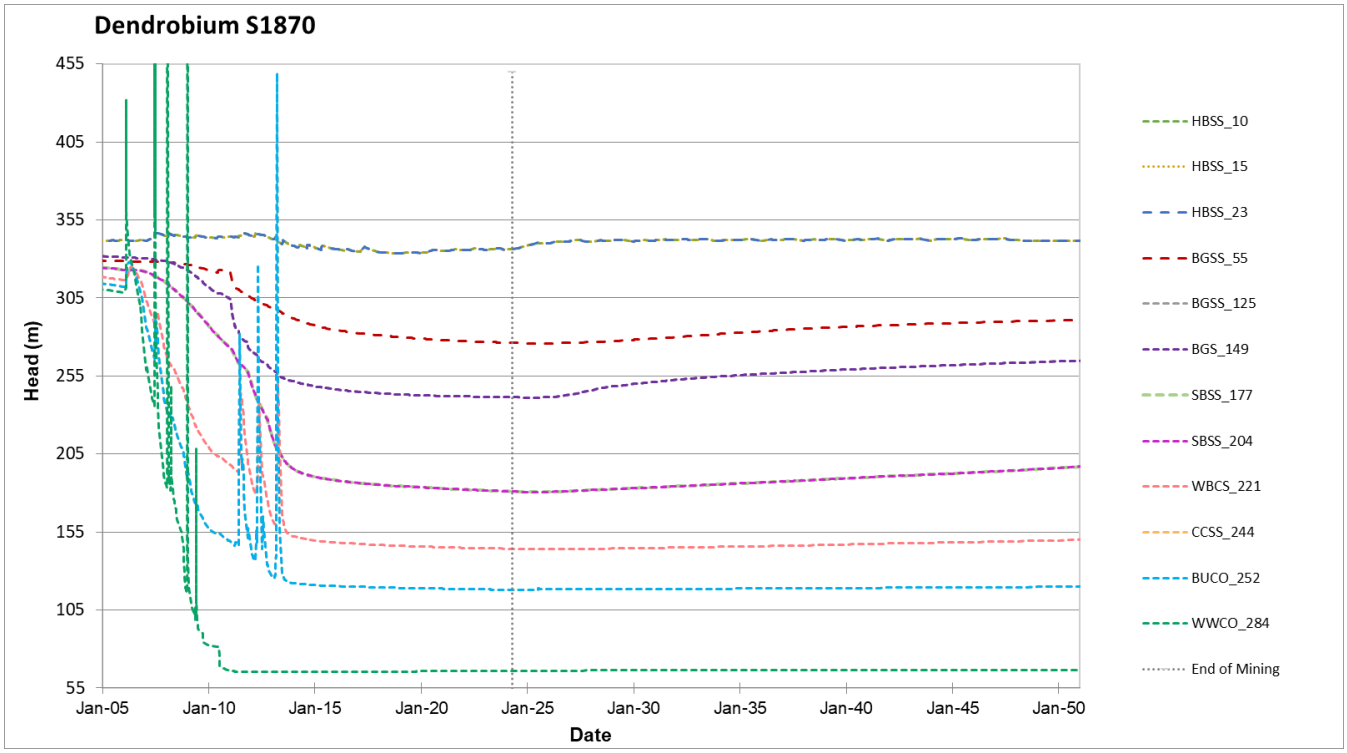


Figure 5 Modelled Groundwater Levels for Bore S1870

3.1.4 Monitoring Locations Associated with Watercourses

Seven bores from the existing monitoring network have been proposed to be included as part of the long-term monitoring program (see **Figure 2** for locations) to monitor groundwater levels along several watercourses associated with the mine. The watercourses of greatest interest are Donalds Castle Creek, Wongawilli Creek and Sandy Creek. Bores S1871 and S1992 are located adjacent to Sandy Creek and overlie the roadways and longwall panels (6 and 7) in Area 3A. The data provided by these bores will also support the data collected for S1870 and S1994 as part of the Lake Cordeaux Monitoring Group. Bore S2333/2333A is positioned to the north between Donalds Castle Creek and Wongawilli Creek at approximate distances of 1 km and 300 m respectively. S2355 is positioned within two tributaries, DC10 and DC10B, which flow into Donalds Castle Creek.

Bores S2013, S2018, and S2019 have been recommended to monitor groundwater levels near Wongawilli Creek. To do this, additional sensors have been recommended to be installed in the shallow geologic units (i.e. Hawkesbury Sandstone and Bald Hill Claystone) at these locations.

An existing OSP bore, S2355A, has been included in the monitoring network. It is positioned within two tributaries, DC10 and DC10B, which flow into Donalds Castle Creek. S2355A monitors the Hawkesbury Sandstone at a depth of 10.5 m. This open standpipe bore is adjacent to the VWP S2355, which also has a sensor positioned at 10.5 m depth. It is recommended that manual groundwater level measurements be taken from the OSP to verify VWP sensor readings.

A hydrograph of modelled groundwater levels, based on the results presented in SLR (2020), is presented for a representative location in **Figure 6**.

S2333 is located approximately 1.3 km from the northern end of Longwall 20, and approximately 300 m from Wongawilli Creek. At this location, mining related drawdown is not predicted to occur in the Hawkesbury Sandstone aquifer. Groundwater levels from the Bulgo Sandstone down to the Wongawilli Coal Seam are predicted to experience depressurisation in response to mining activities. The recovery of groundwater levels to pre-mining conditions is predicted to take more than 150 years to occur for these aquifers.

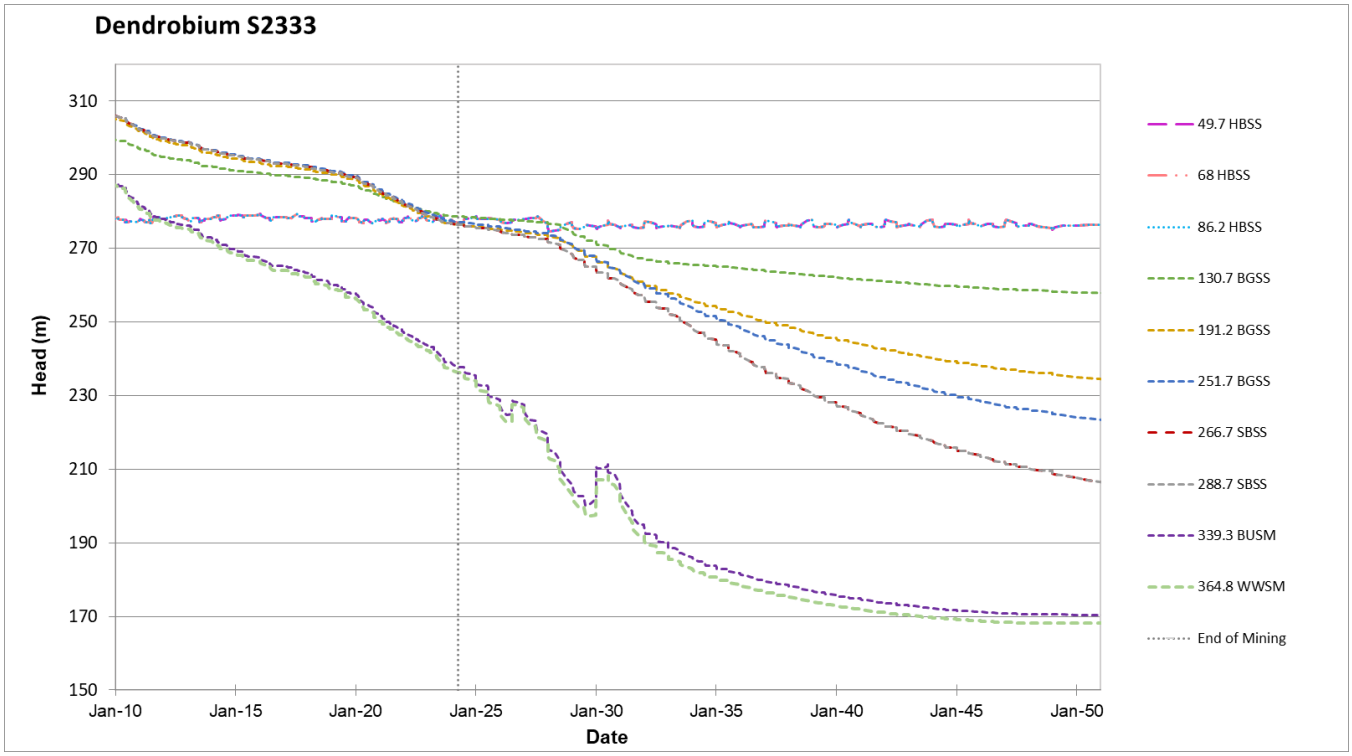


Figure 6 Modelled Groundwater Levels for Bore S2333

3.2 Groundwater Level Monitoring

3.2.1 Groundwater Levels

Consistent with the current monitoring program, groundwater level data should continue to be recorded at the VWPs on a daily basis. During active mining, data should be downloaded by field staff on a quarterly basis and stored on a central database. For the open standpipes, it is recommended that they be equipped with timeseries groundwater level loggers to obtain to assist with comparison to VWPs and for capturing seasonal responses. Post-closure groundwater level data should continue to be measured on a daily basis and downloaded on quarterly basis for a period of six years post-closure. After this time the monitoring frequency should be reviewed.

For OSP monitoring locations, groundwater levels should be manually dipped on a quarterly basis for comparison to trends recorded at nearby VWPs. This will allow for the identification of any potential deviations in measurements at these instruments. Dataloggers are also recommended to be installed at four locations (S1876, S2351A, S2354, and S2355A) to allow timeseries water level data to be collected at these locations.

3.3 Data Management and Reporting

During active mining, groundwater level data should be uploaded to the central database on a quarterly basis and QA/QC procedures put in place to ensure the accuracy of data entries. For the initial six years post closure data should be downloaded on a quarterly basis. Groundwater level data should be reviewed by a suitably qualified person on an annual basis, and analysis of the data assessment of potential for impacts reported in an annual review. After six years post closure data management and reporting requirements should be reviewed.

Groundwater trends should be compared to predicted groundwater trends based on current numerical groundwater model predictions. An assessment of observed groundwater levels against modelled predictions should be carried out during annual reporting by a suitably qualified person. This assessment should determine whether the observed data is consistent with observed and predicted trends and make recommendations for further investigations if a significant discrepancy is identified.

3.4 Future Modelling

It is recommended that the validity of model predictions be re-assessed regularly to ensure that estimates reflect observed environmental conditions and are capable of providing reliable predictions to allow for planning. This assessment should include, but not be limited to:

- Comparison of modelled and observed groundwater levels for the bores proposed to be monitored as part of the long-term monitoring program.
- Comparison of modelled and observed mine inflows.
- Comparison of modelled and observed vertical pressure head, particularly for longwall panel monitoring locations identified in **Section 3.1.1**.

As per **Section 3.2.1**, observed groundwater level trends should be compared to predicted levels from the current numerical groundwater model on an annual basis during active operations. This will enable early identification of any deviations in predictions and initiate review into the reasons for differences. In addition, in line with development consent conditions, a three-yearly independent review of the numerical groundwater model should be conducted.

4 Closing

SLR was engaged to review available information on the existing site groundwater monitoring network in consideration of predicted changes in groundwater conditions over the life of the mine. Based on the available information, a selection of key monitoring locations have been identified to be used in the long-term groundwater monitoring program for Areas 3A, 3B and 3C (LW20 – 21). The proposed network utilises existing monitoring points and includes nine open standpipe monitoring bores to assist in verifying VWP sensor trends.

Groundwater levels should continue to be recorded on a daily basis and downloaded quarterly during mining and post mining. Groundwater level trends should be compared to predicted and observed trends and reviewed and reported annually by a suitably qualified person. In addition to three-yearly independent reviews of the groundwater model, these assessments will enable regular review of the performance of the numerical groundwater model to replicate observed response to mining and recovery.

5 References

HGEO, 2019a. *Dendrobium Mine End of Panel Groundwater Assessment for Longwall 14 (Area 3B).* Report D19326, June 2019.

HGEO, 2019b. *Estimates of seepage from Lake Avon following redrilling of holes at AD3, AD4 and AD8.* Report D19337, September 2019.

IEPMC, 2019a. *Part 1 - Review of specific mining activities at the Metropolitan and Dendrobium coal mines*. https://www.chiefscientist.nsw.gov.au/__data/assets/pdf_file/0004/281731/IEPMC-Part-1-Report.pdf

IEPMC, 2019b. *Part 2 - Coal mining impacts in the Special Areas of the Greater Sydney Water Catchment*. https://www.chiefscientist.nsw.gov.au/__data/assets/pdf_file/0005/281732/IEPMC-Part-2-Report.pdf

SLR, 2020. *Dendrobium Mine Longwall 19 Groundwater Assessment*. Prepared for South32, report 665.10009.R02, v2.0, January 2020.

APPENDIX A

Groundwater Level Hydrographs – Long-term monitoring locations

Longwall Panel Monitoring Locations

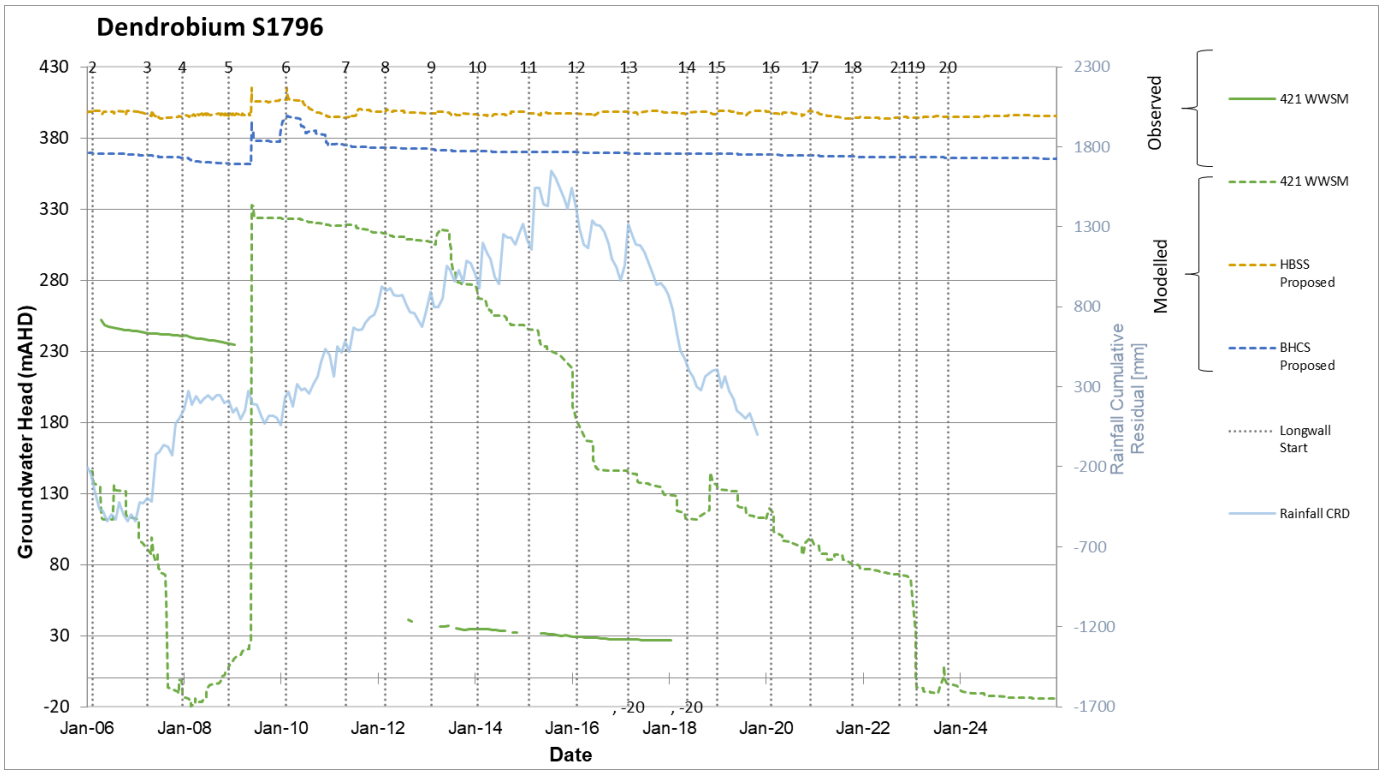


Figure A-1 Modelled and Observed Groundwater levels – S1796

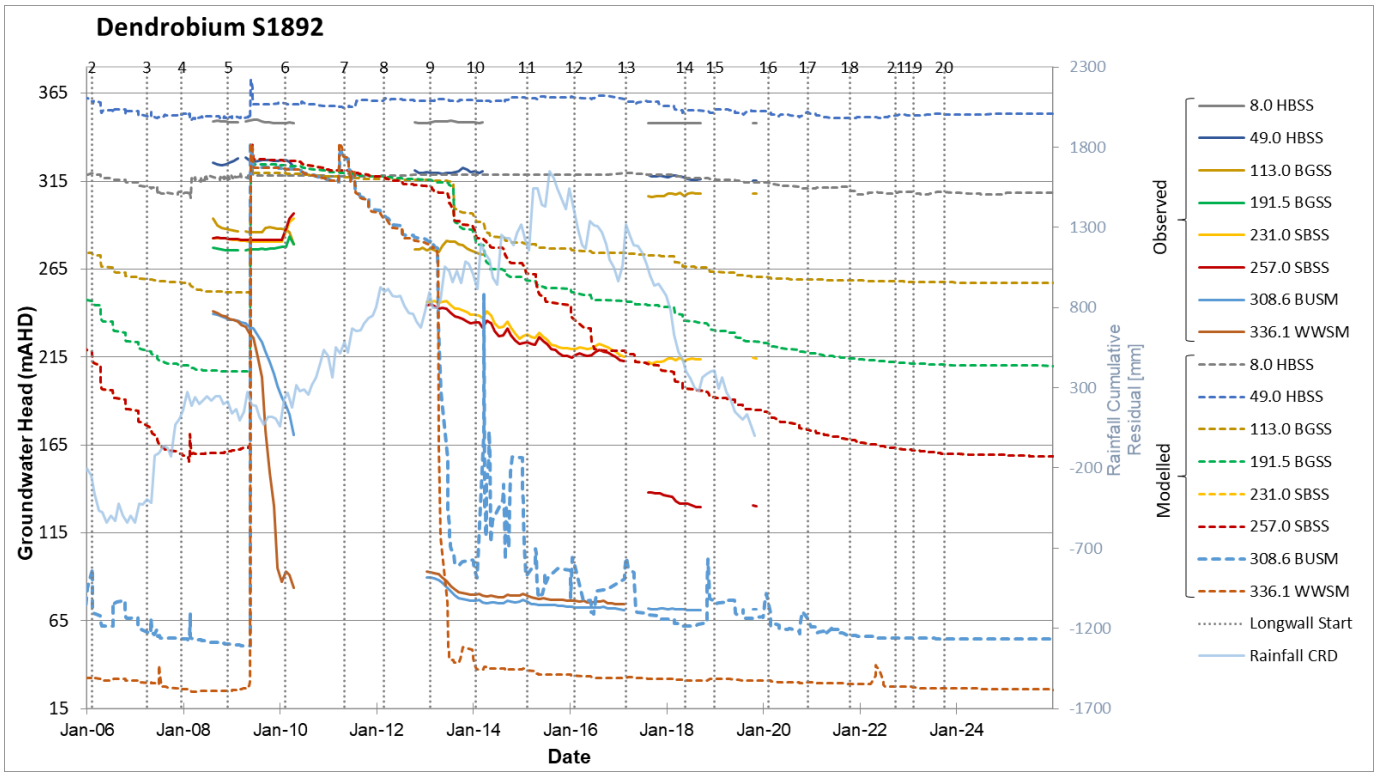


Figure A-2 Modelled and Observed Groundwater levels – S1892

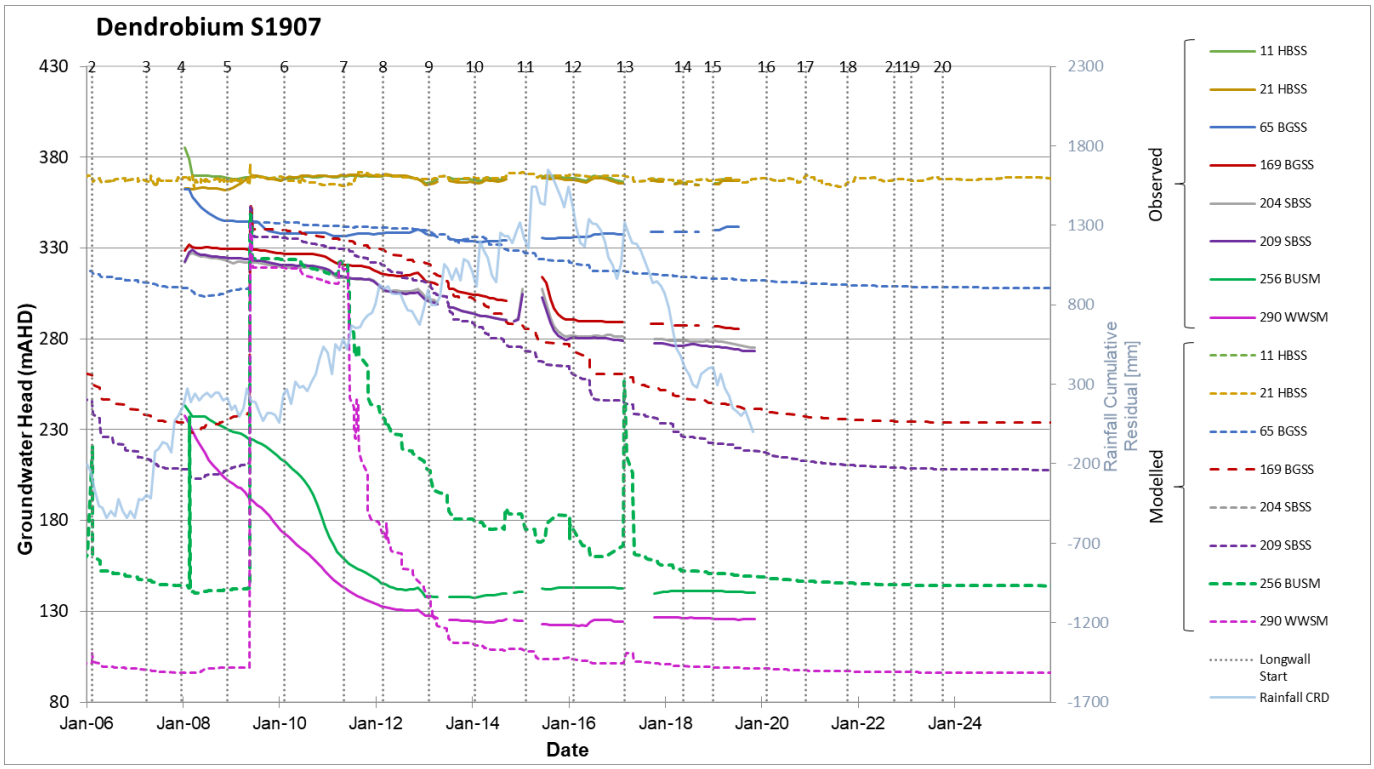


Figure A-3 Modelled and Observed Groundwater levels – S1907

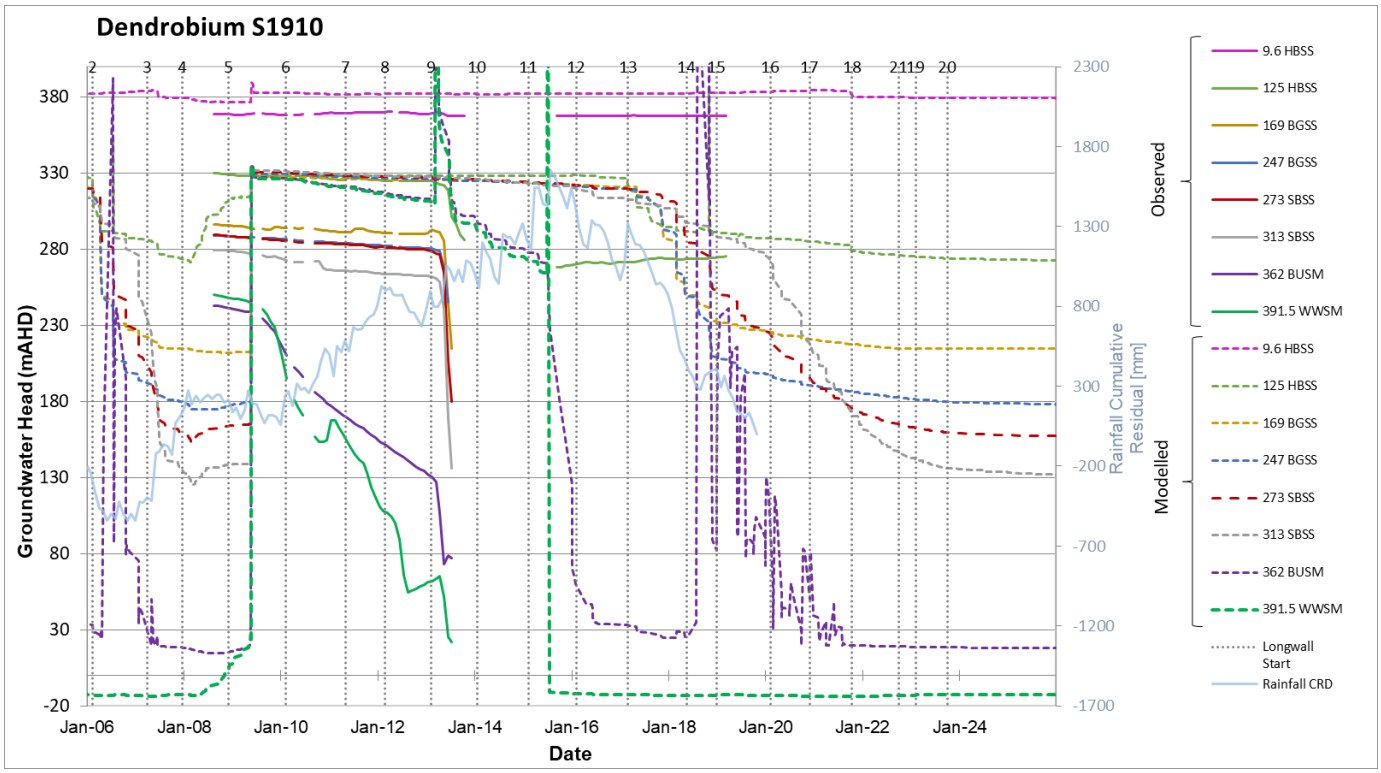


Figure A-4 Modelled and Observed Groundwater levels – S1910

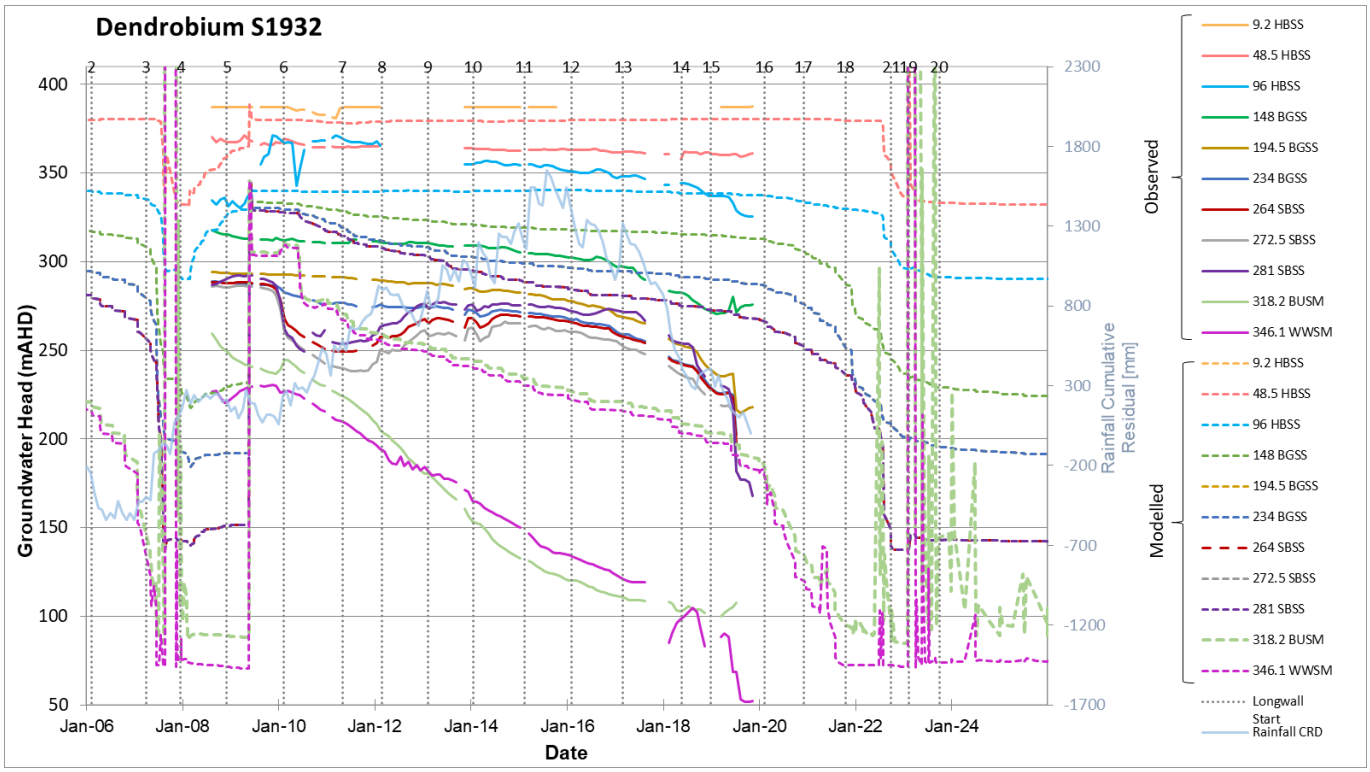


Figure A-5 Modelled and Observed Groundwater levels – S1932

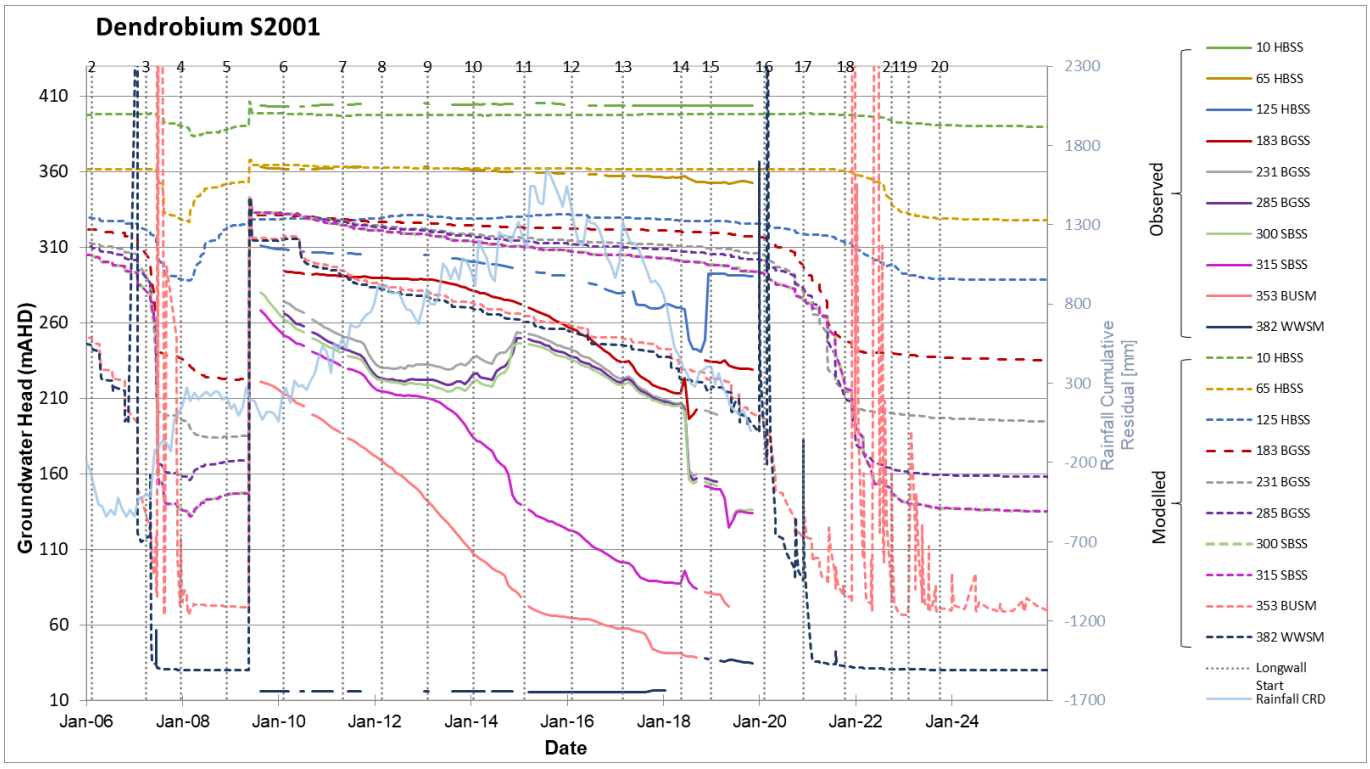


Figure A-6 Modelled and Observed Groundwater levels – S2001

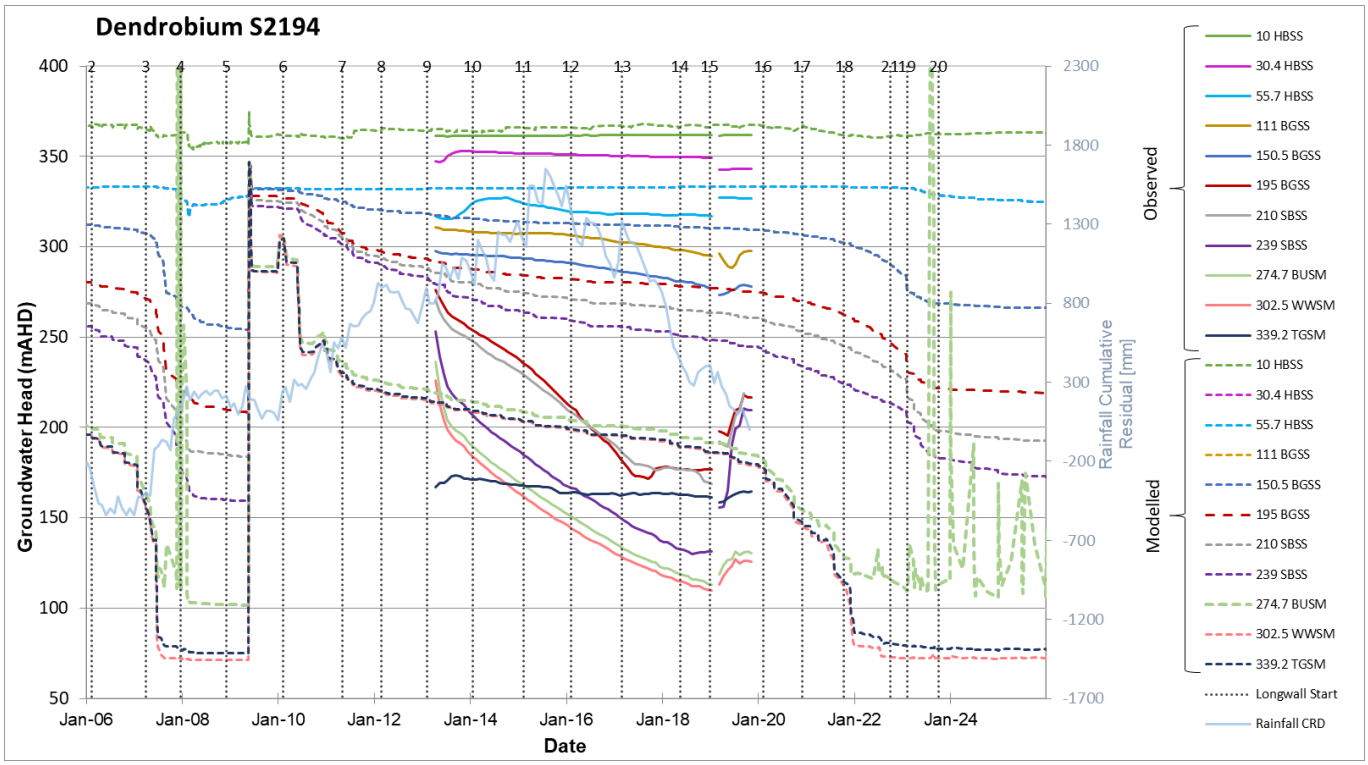


Figure A-7 Modelled and Observed Groundwater levels – S2194

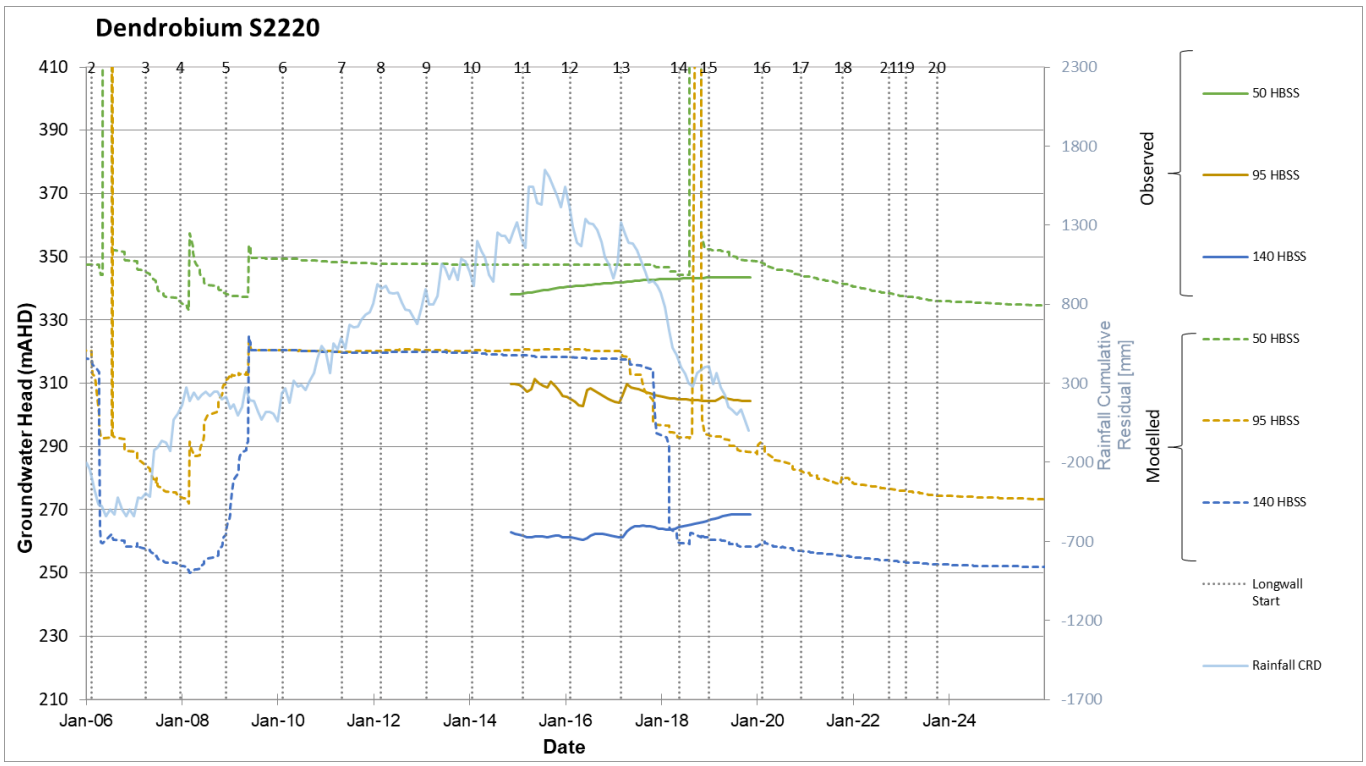


Figure A-8 Modelled and Observed Groundwater levels – S2220

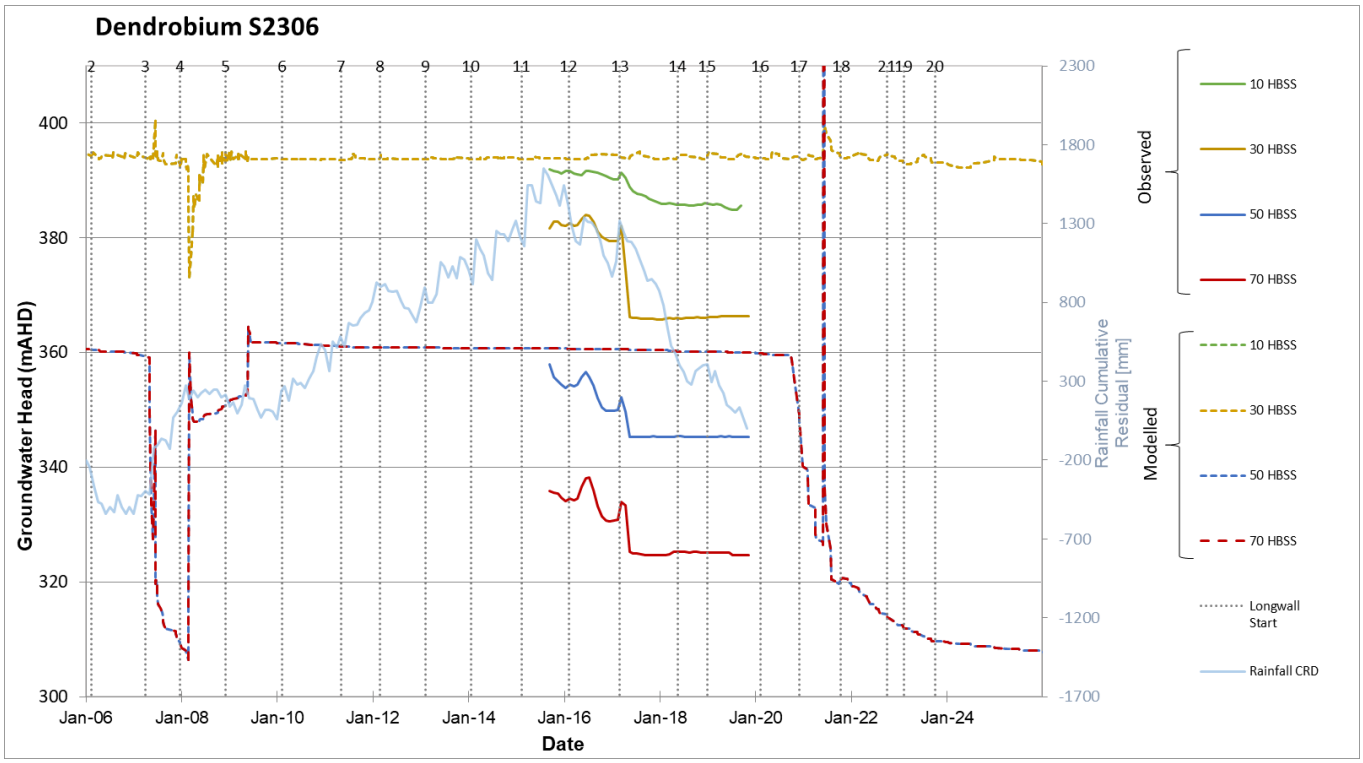


Figure A-9 Modelled and Observed Groundwater levels – S2306

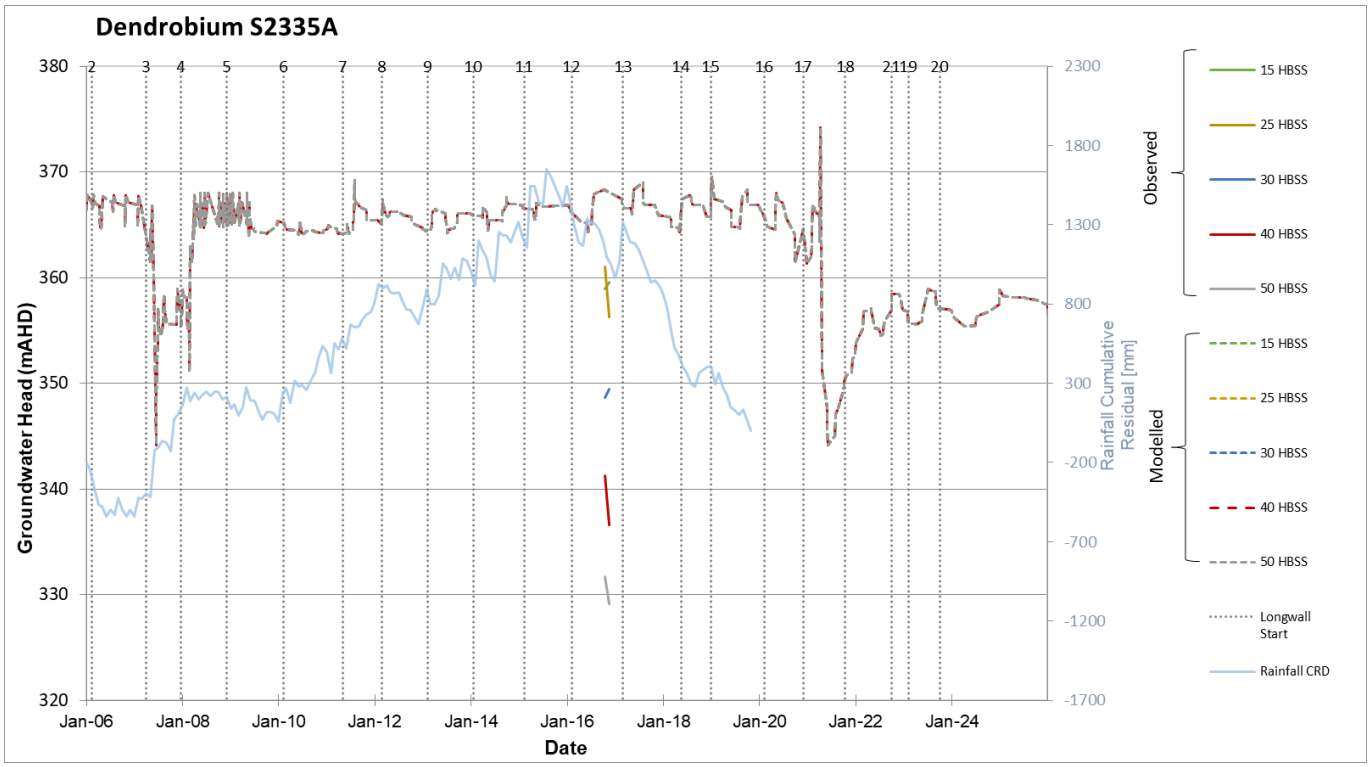


Figure A-10 Modelled and Observed Groundwater levels – S2335A

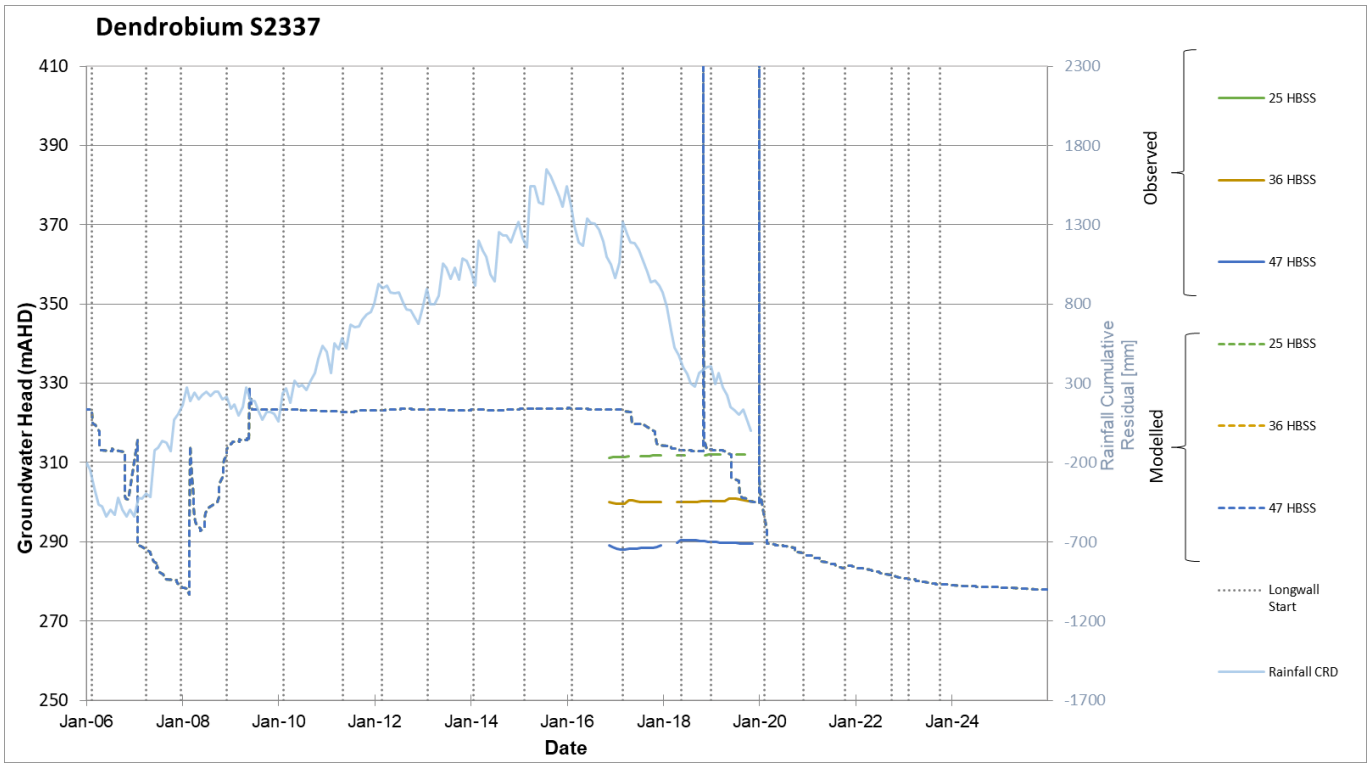


Figure A-11 Modelled and Observed Groundwater levels – S2337

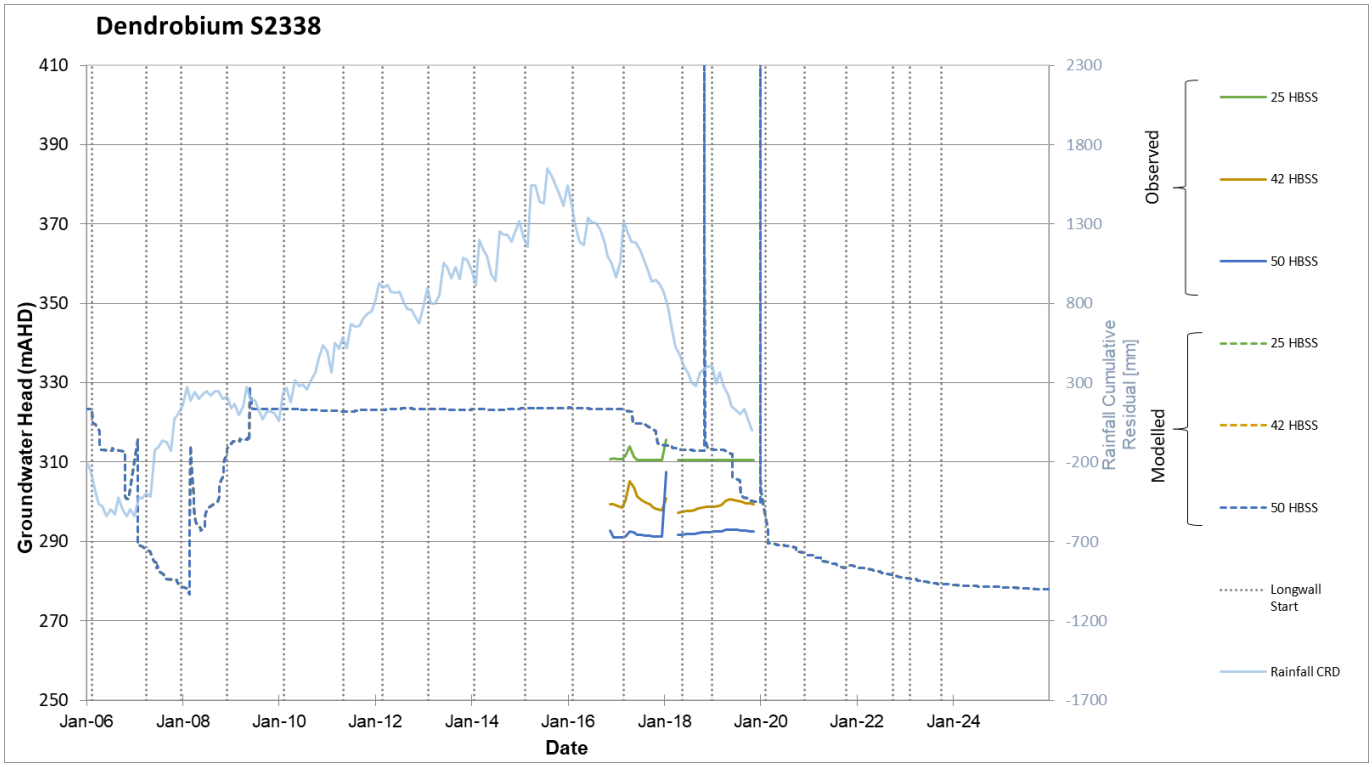


Figure A-12 Modelled and Observed Groundwater levels – S2338

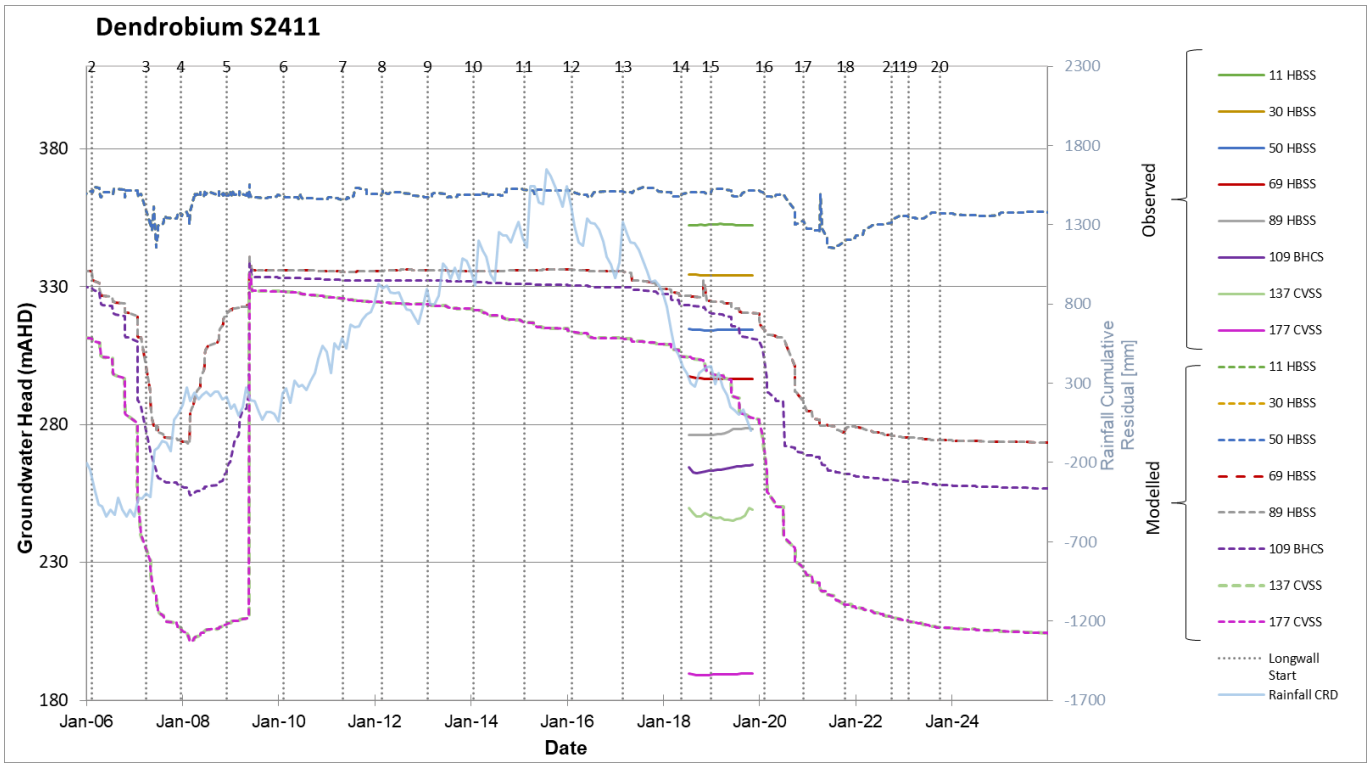


Figure A-13 Modelled and Observed Groundwater levels – S2411

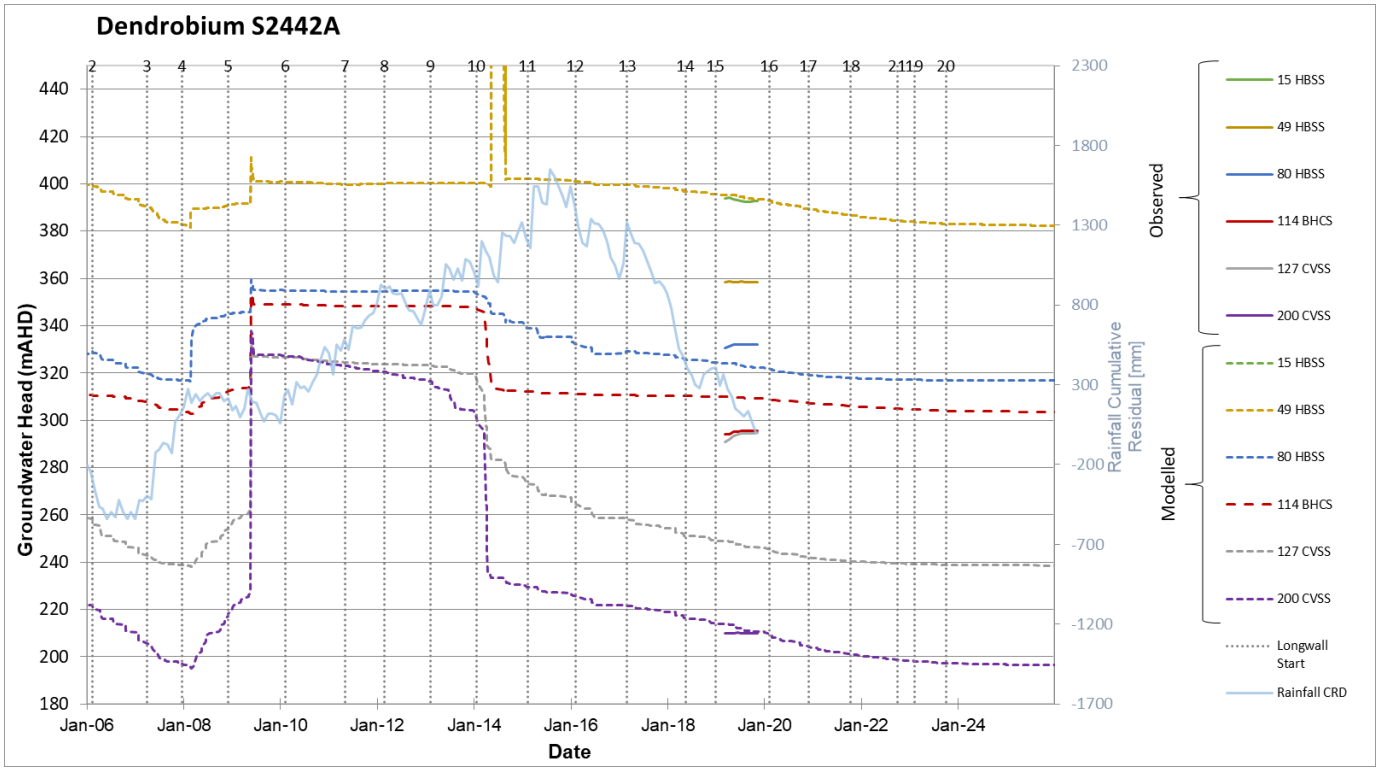


Figure A-14 Modelled and Observed Groundwater levels – S2442A

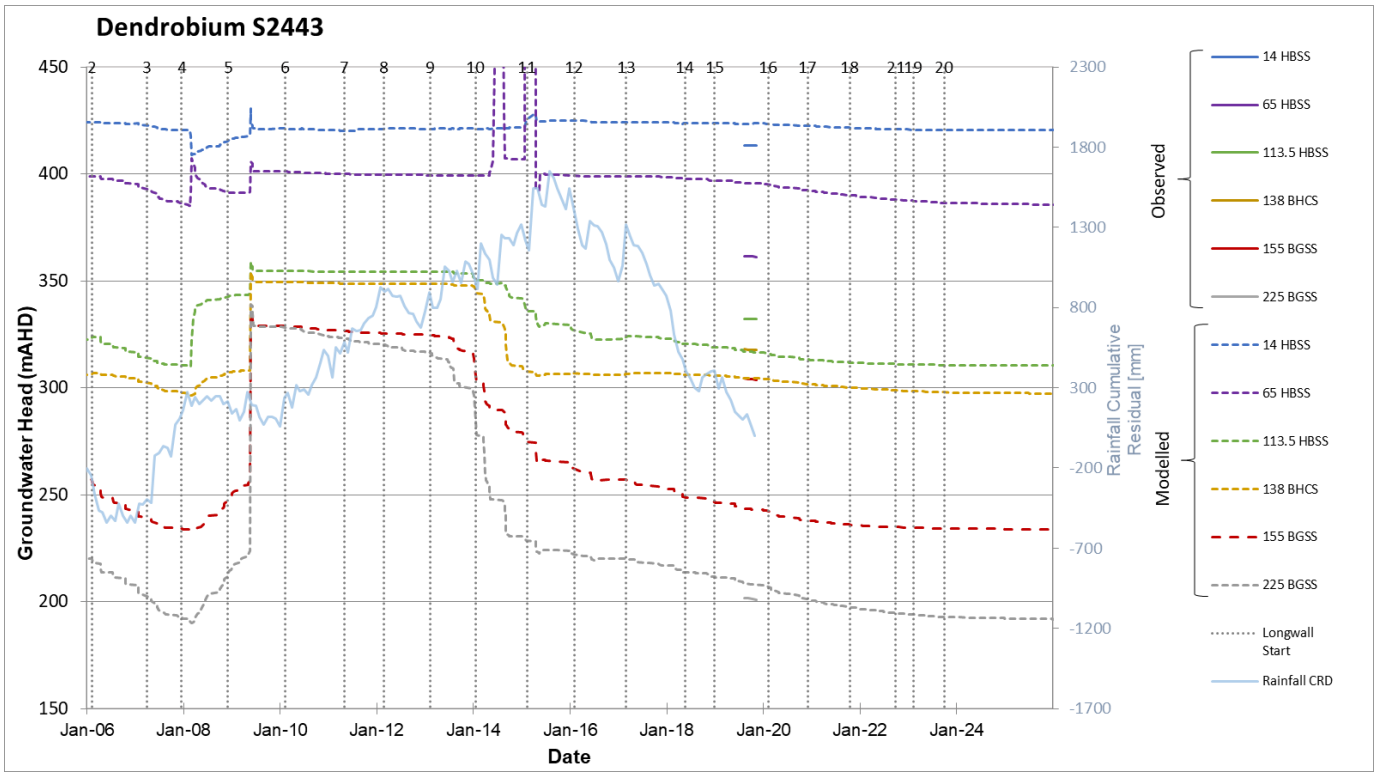


Figure A-15 Modelled and Observed Groundwater levels – S2443

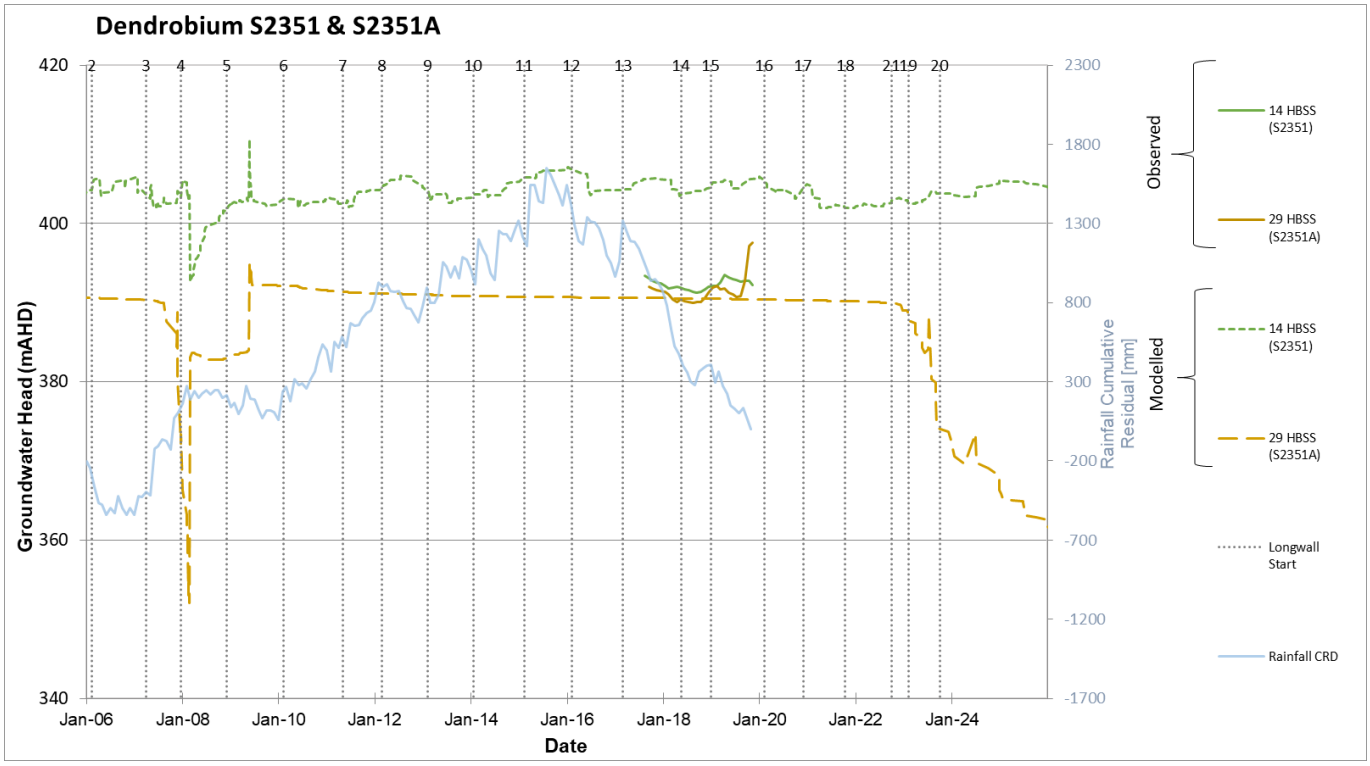


Figure A-16 Modelled and Observed Groundwater levels – S2351 and S2351A

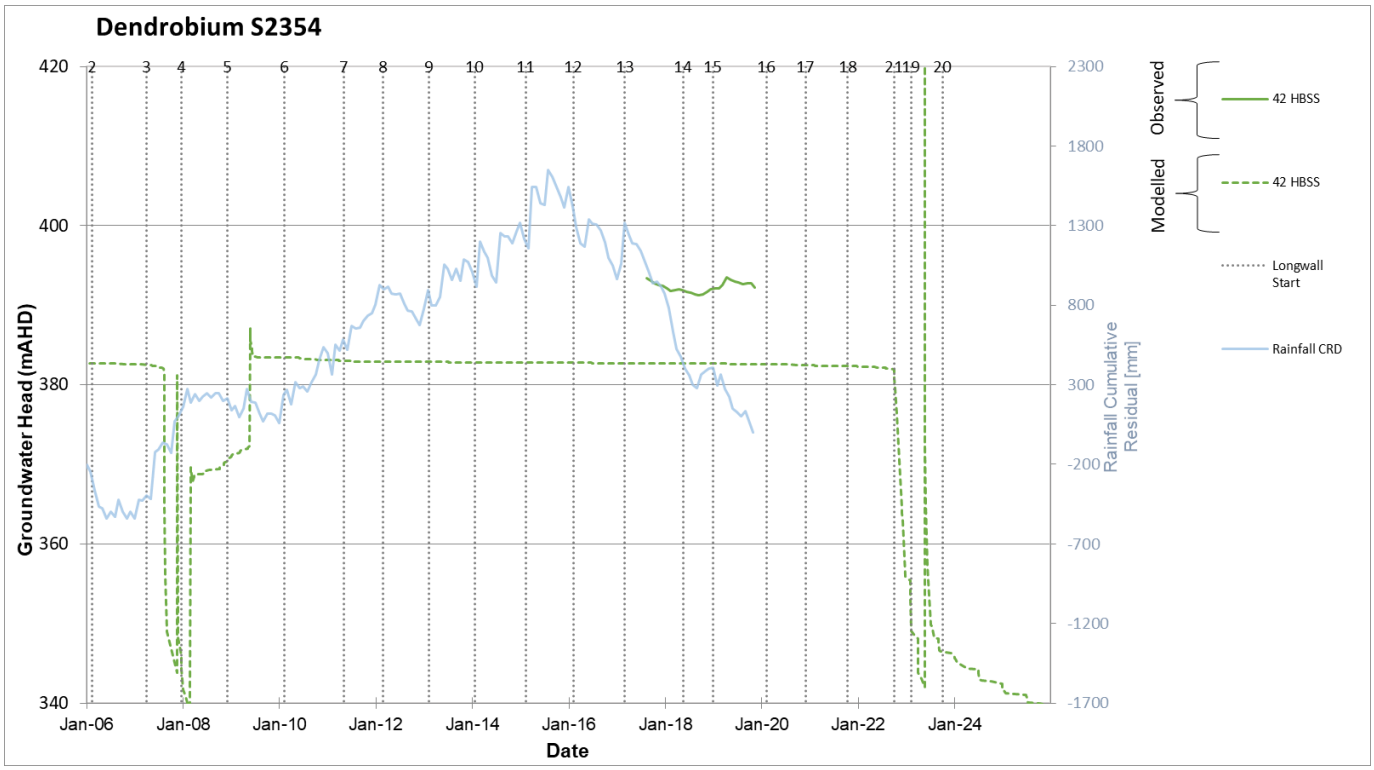


Figure A-17 Modelled and Observed Groundwater levels – S2354

Lake Avon Shoreline Monitoring Locations

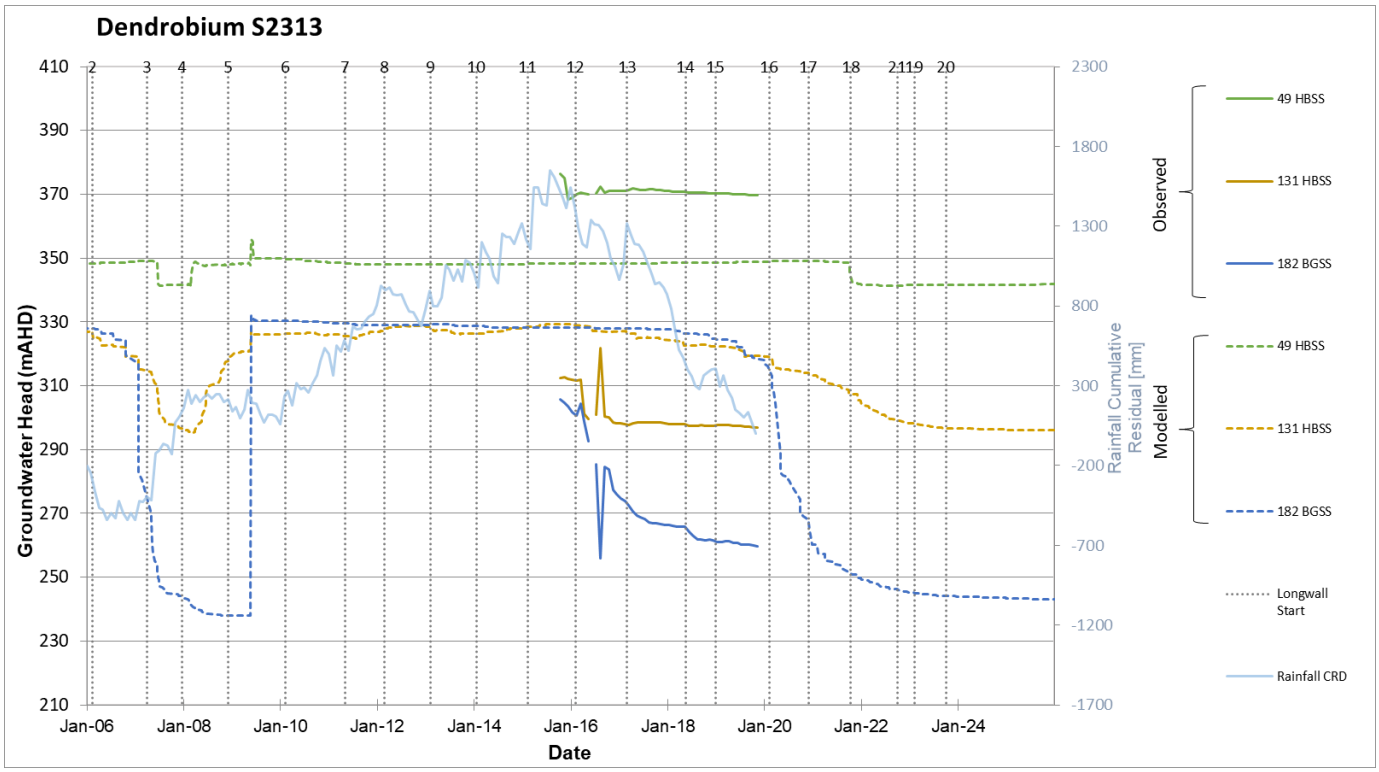


Figure A-18 Modelled and Observed Groundwater levels – S2313

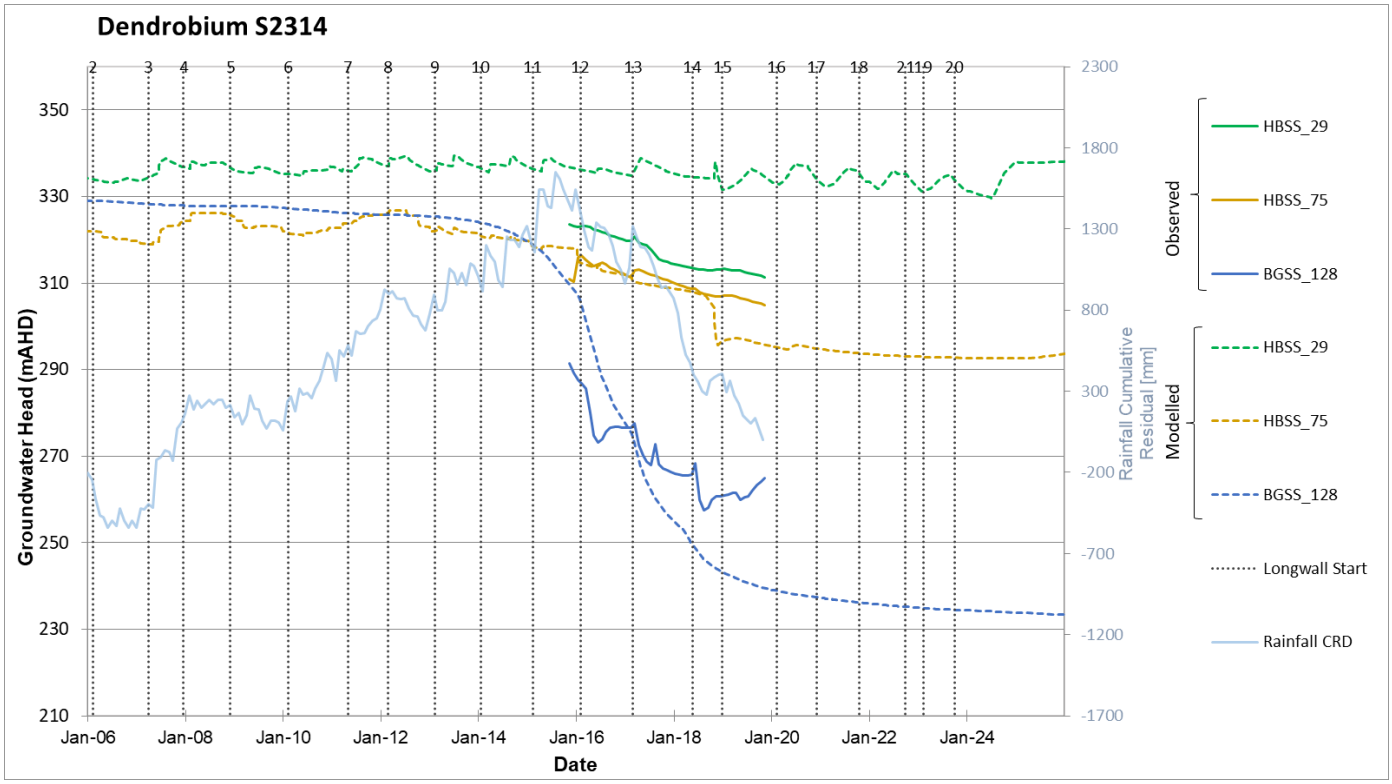


Figure A-19 Modelled and Observed Groundwater levels – S2314

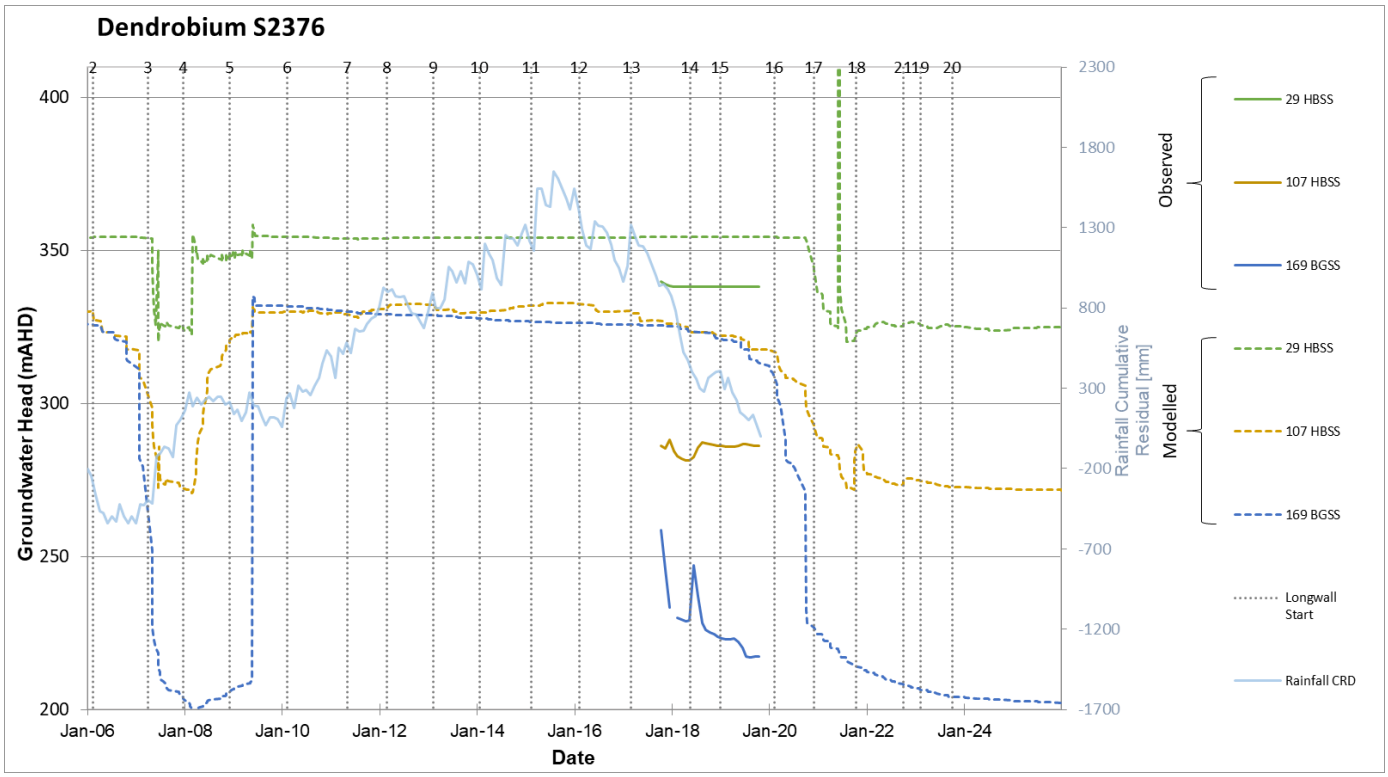


Figure A-20 Modelled and Observed Groundwater levels – S2376

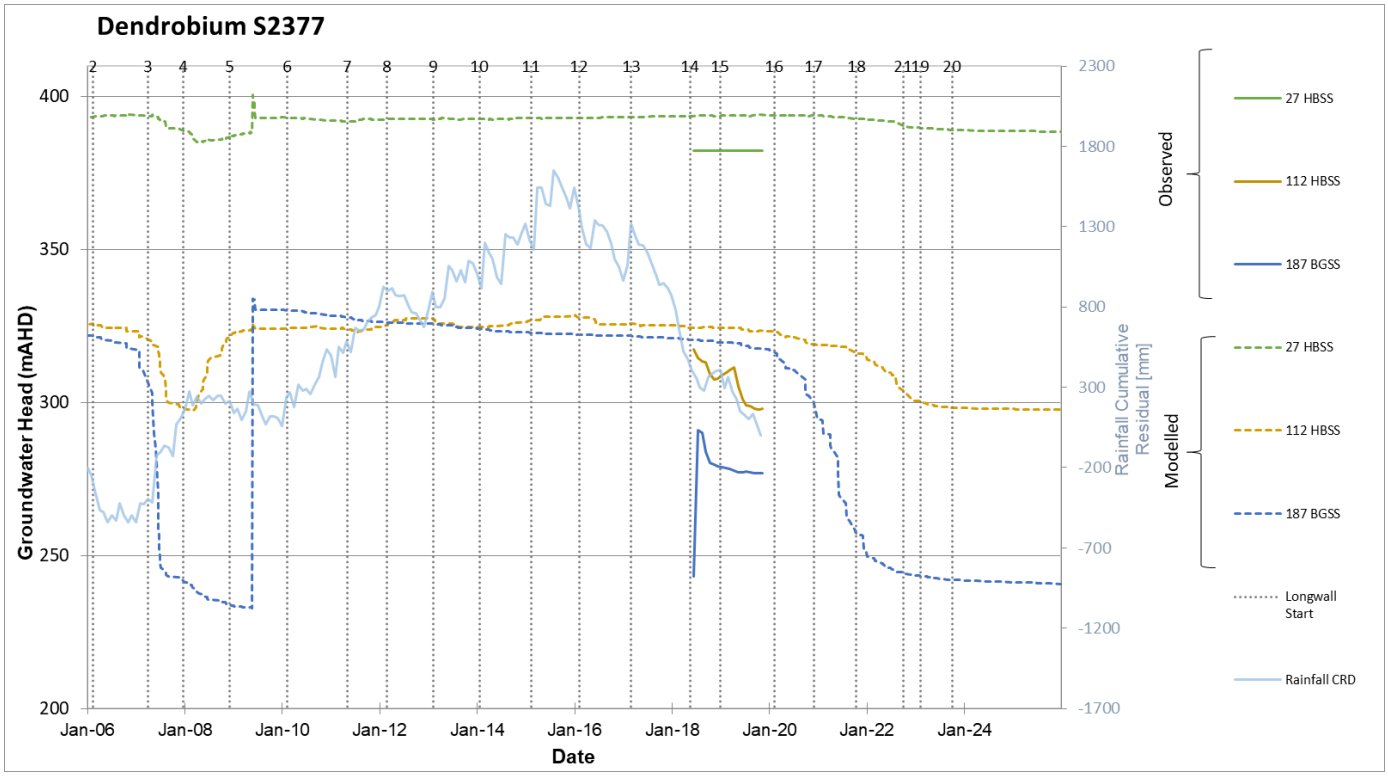


Figure A-21 Modelled and Observed Groundwater levels – S2377

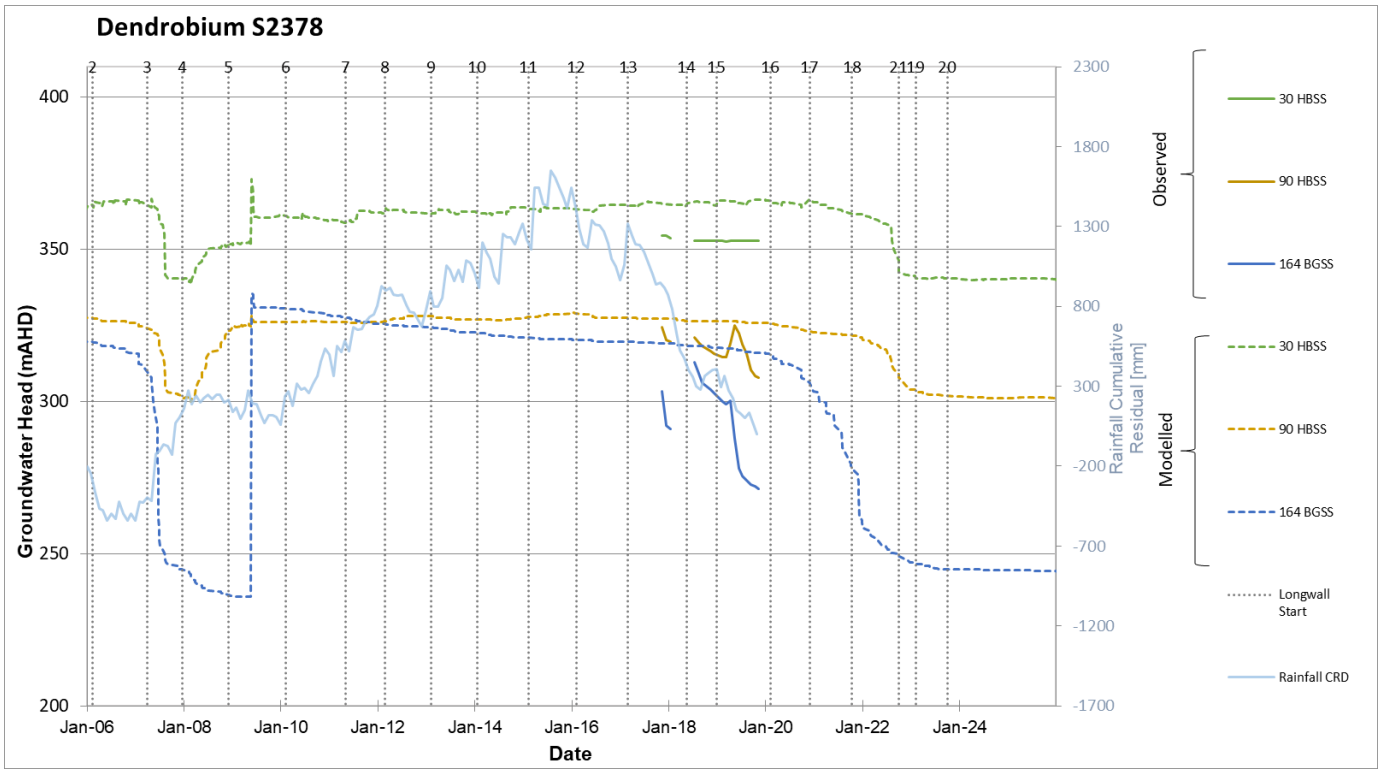


Figure A-22 Modelled and Observed Groundwater levels – S2378

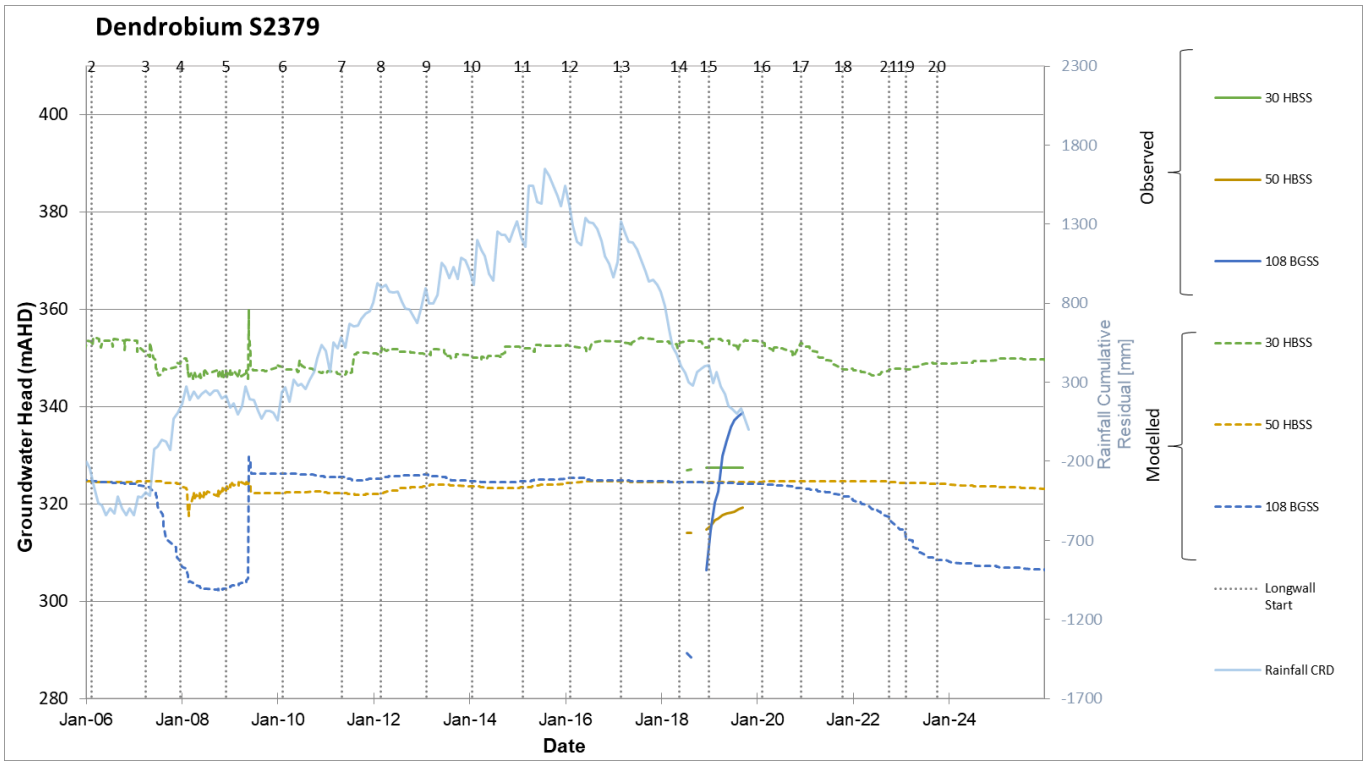


Figure A-23 Modelled and Observed Groundwater levels – S2379

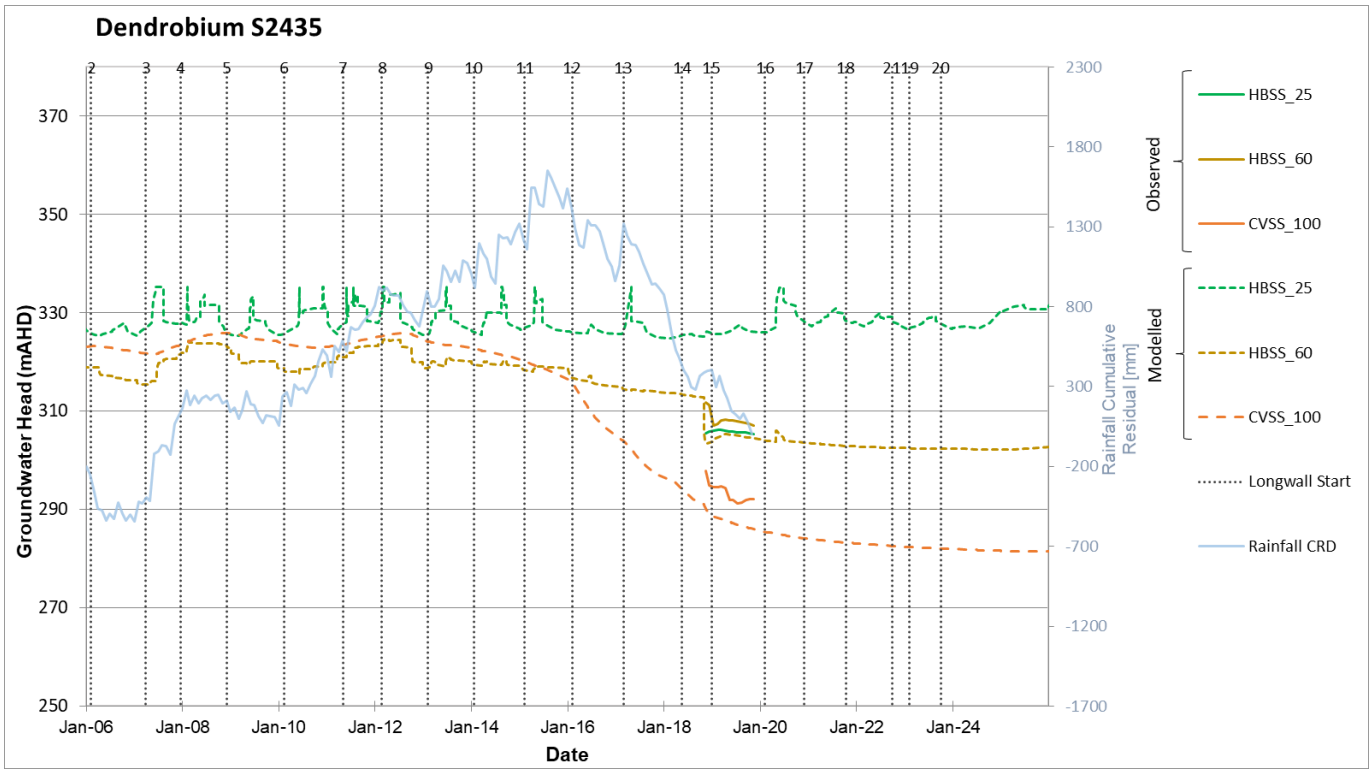


Figure A-24 Modelled and Observed Groundwater levels – S2435

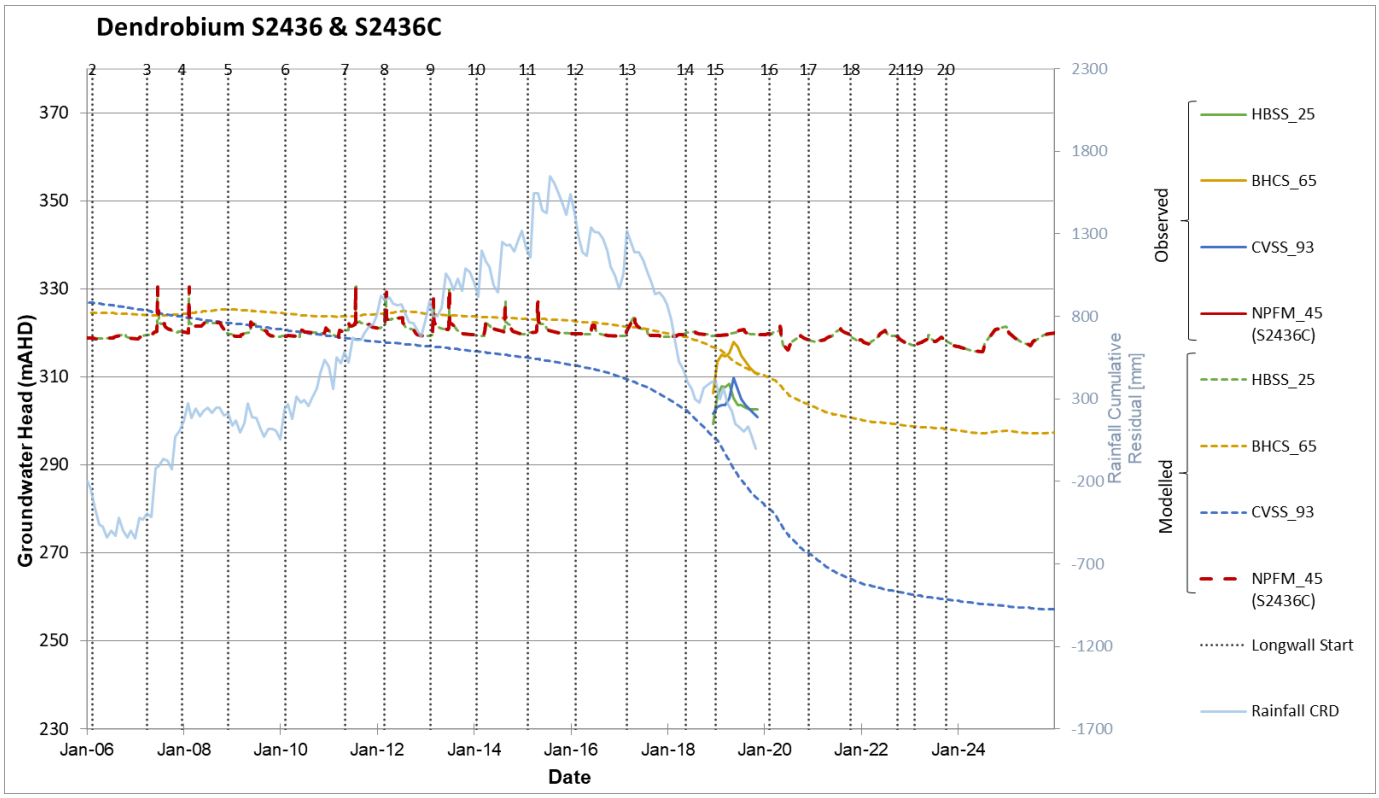


Figure A-25 Modelled and Observed Groundwater levels – S24367 & S2436C

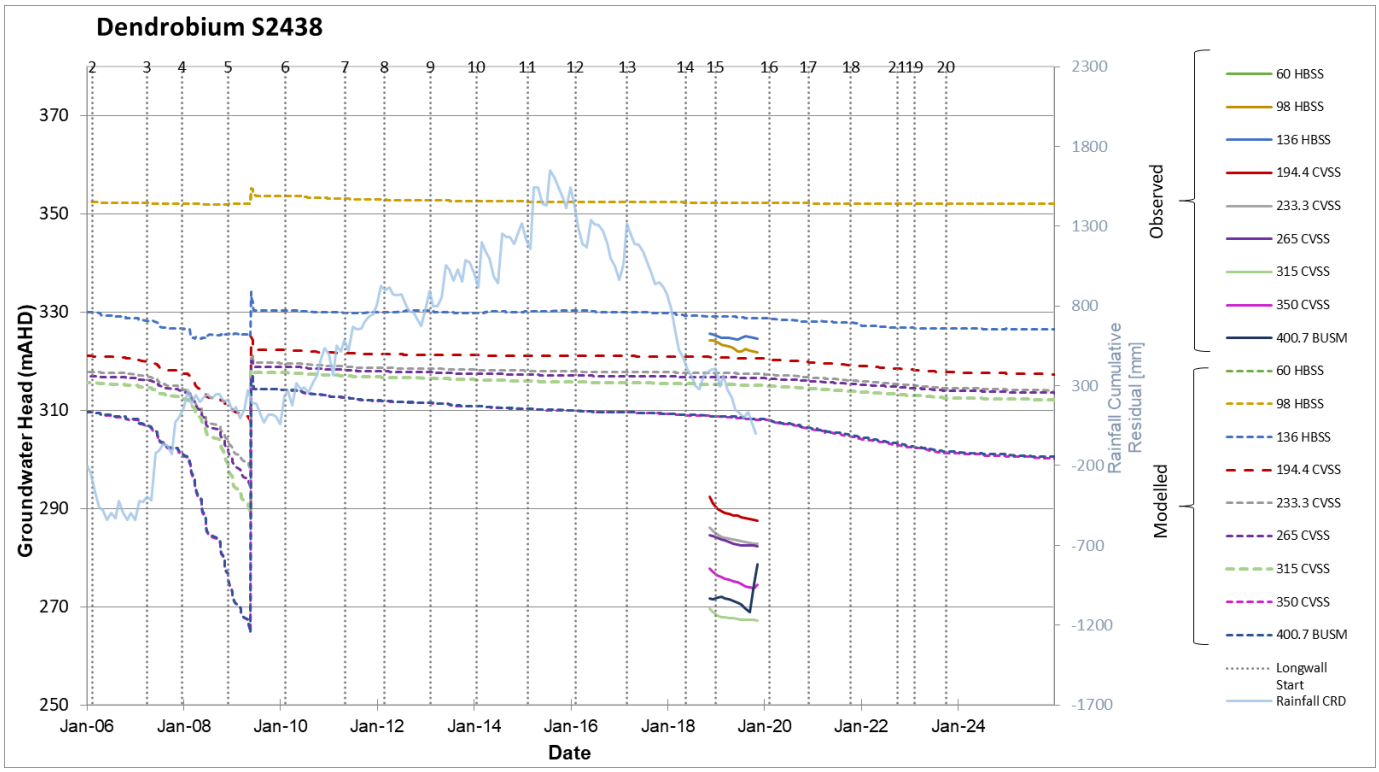


Figure A-26 Modelled and Observed Groundwater levels – S2438

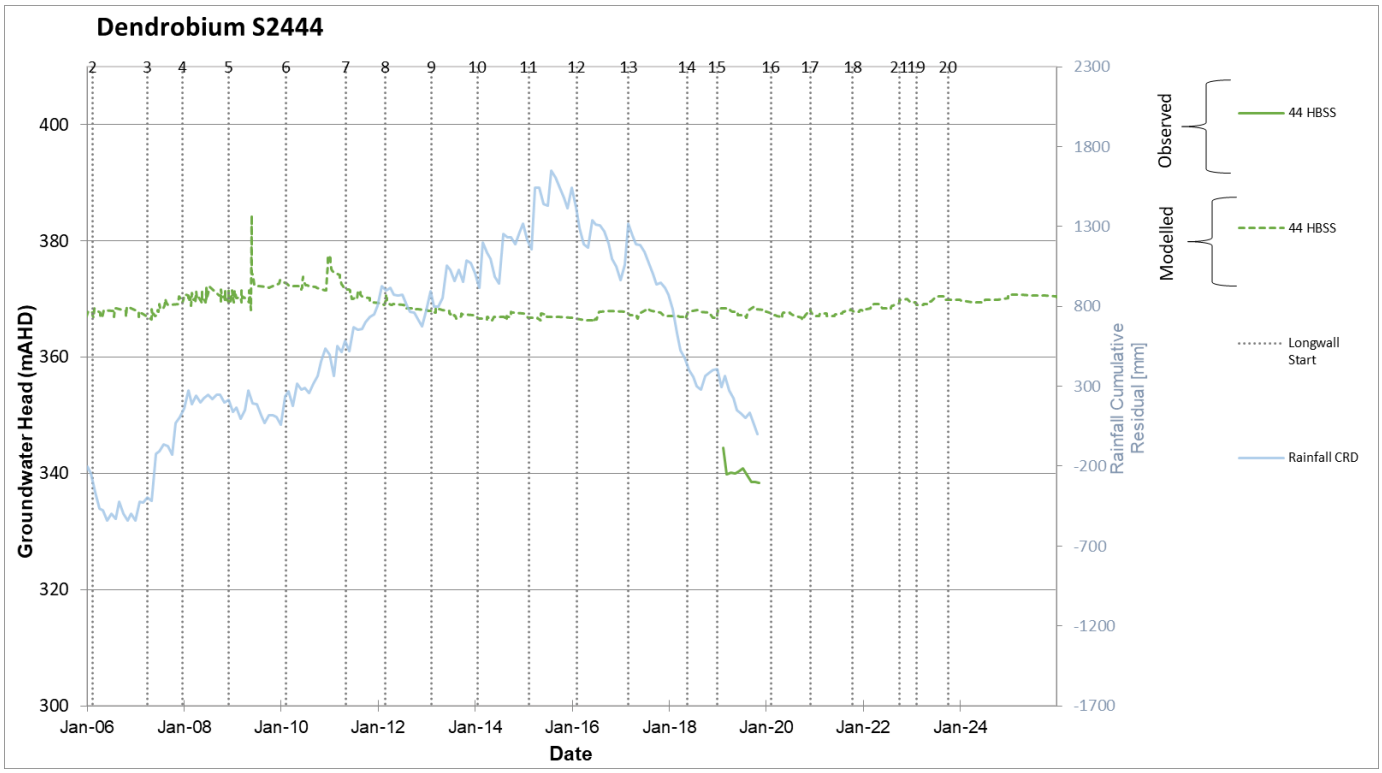


Figure A-27 Modelled and Observed Groundwater levels – S2444

Lake Cordeaux Monitoring Locations

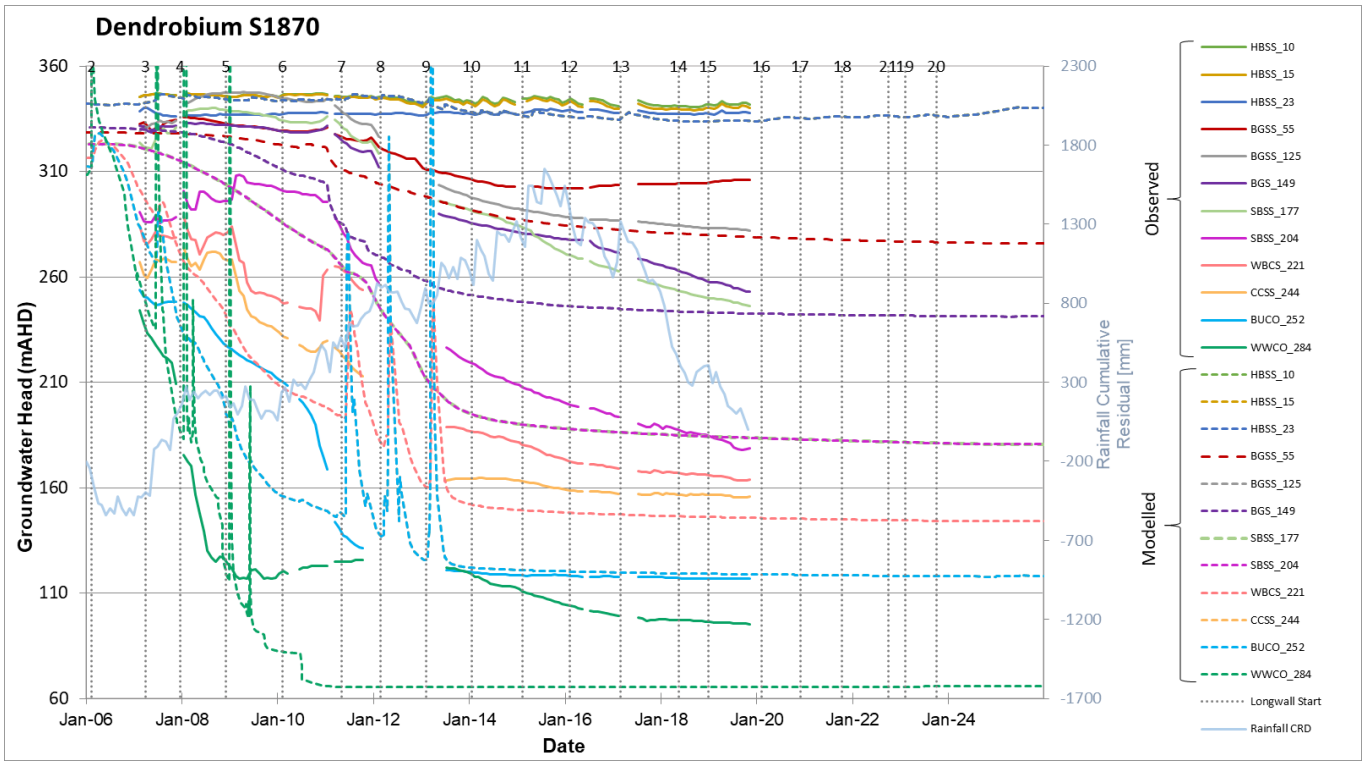


Figure A-28 Modelled and Observed Groundwater levels – S1870

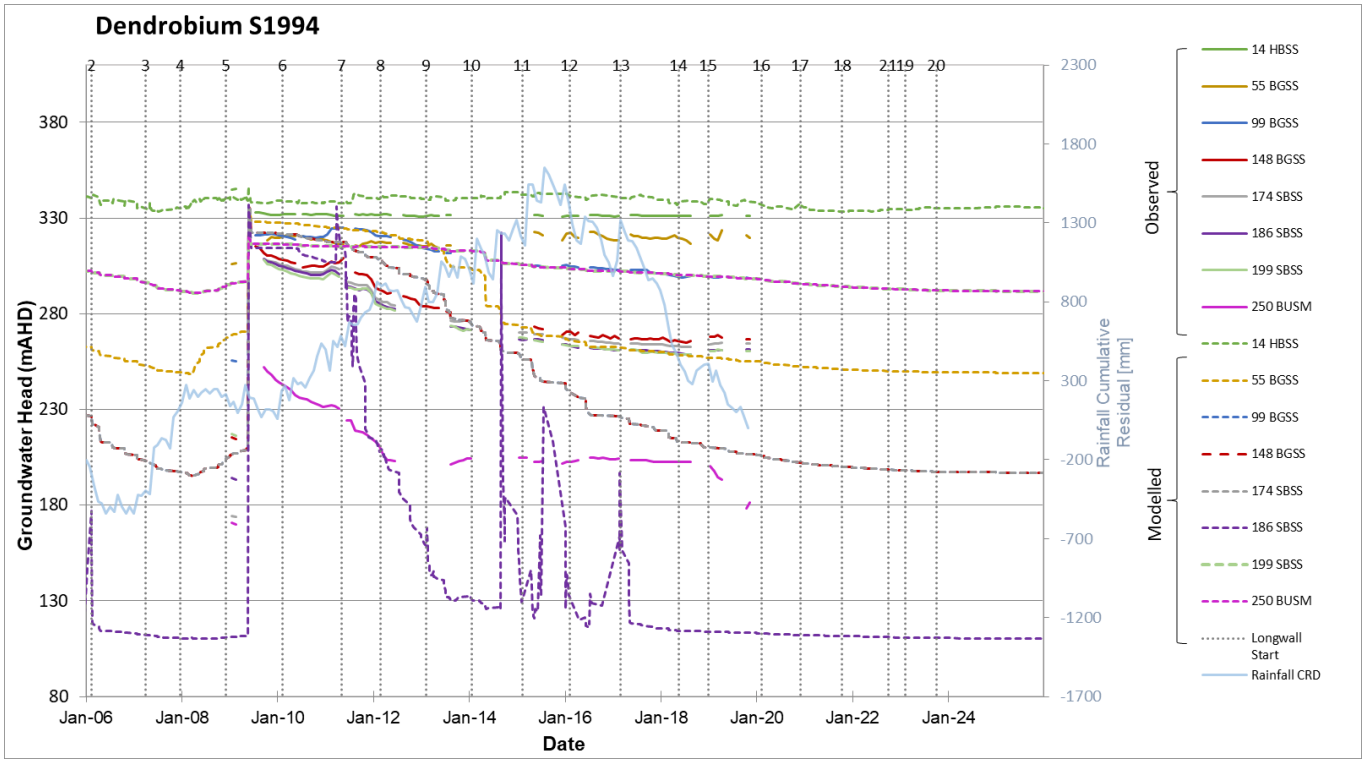


Figure A-29 Modelled and Observed Groundwater levels – S1994

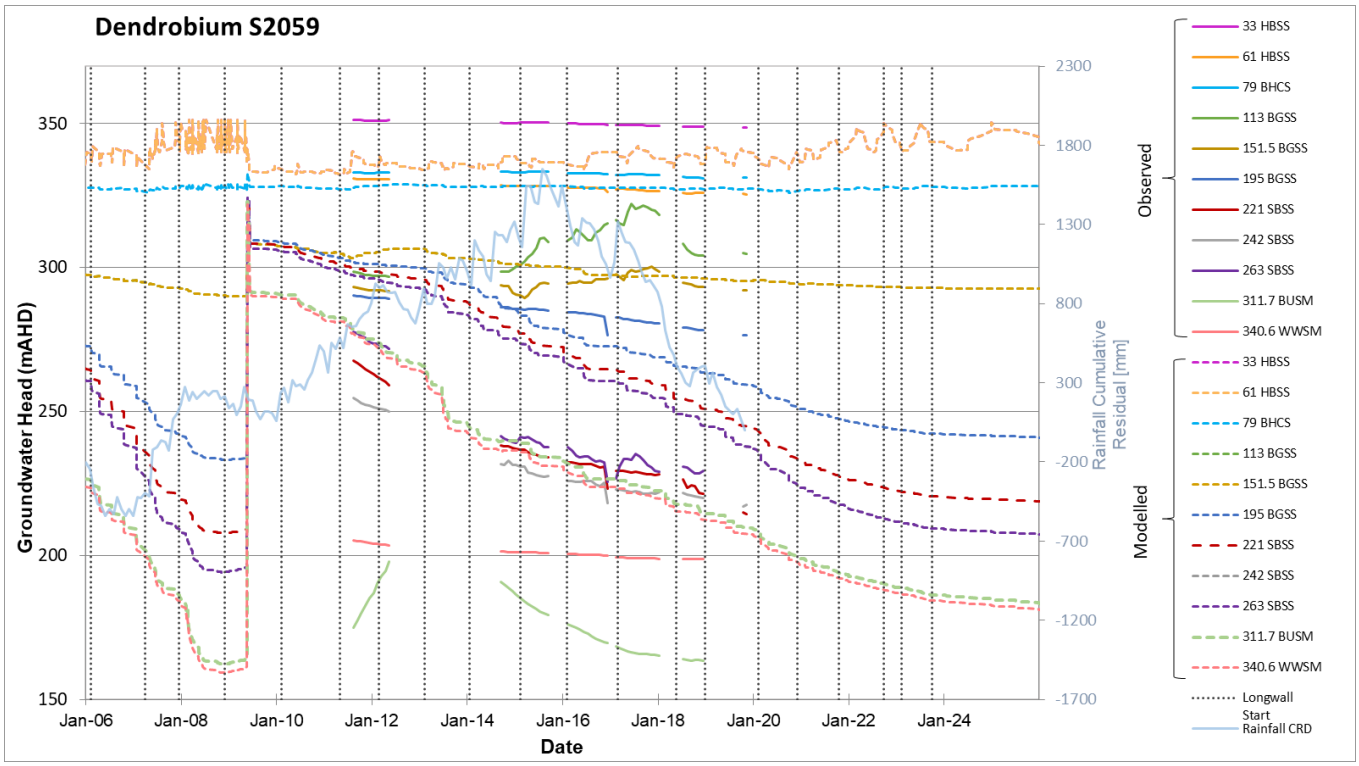


Figure A-30 Modelled and Observed Groundwater levels – S2059

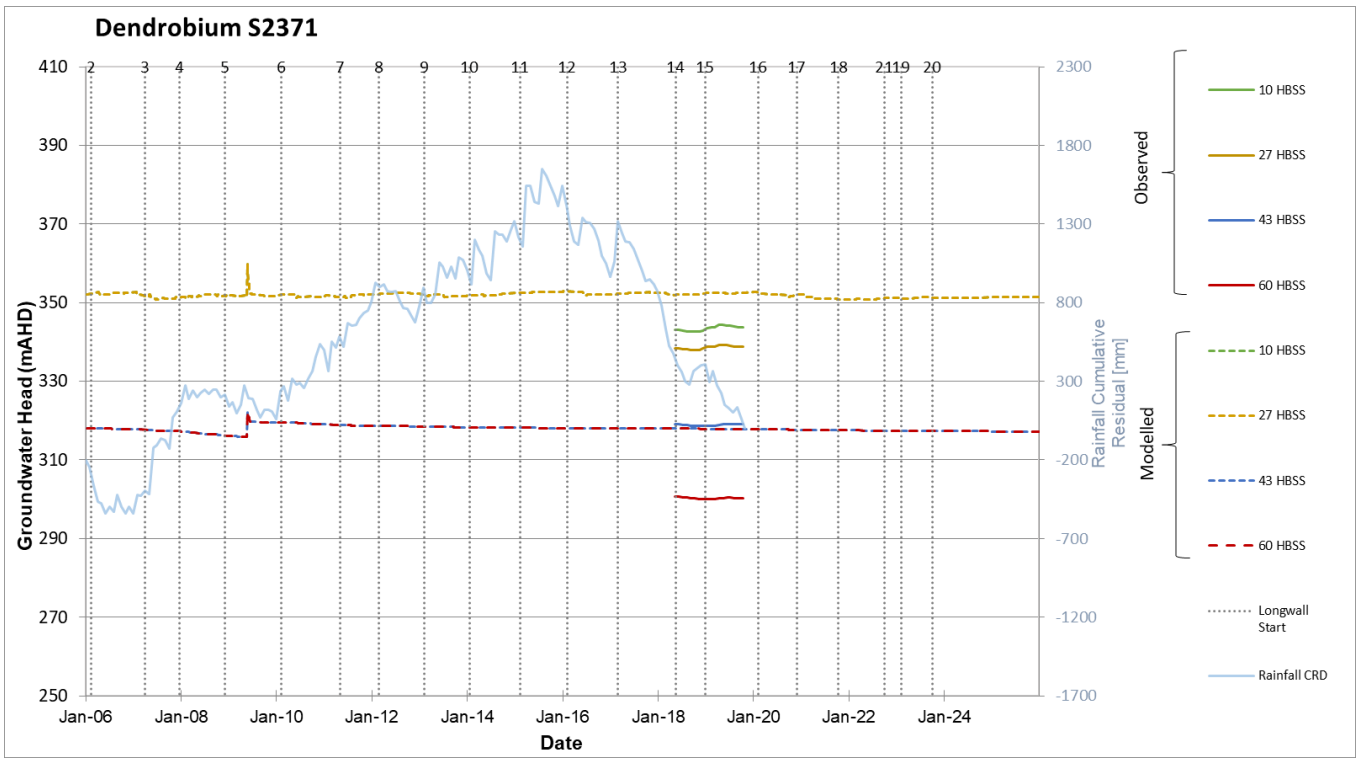


Figure A-31 Modelled and Observed Groundwater levels – S2371

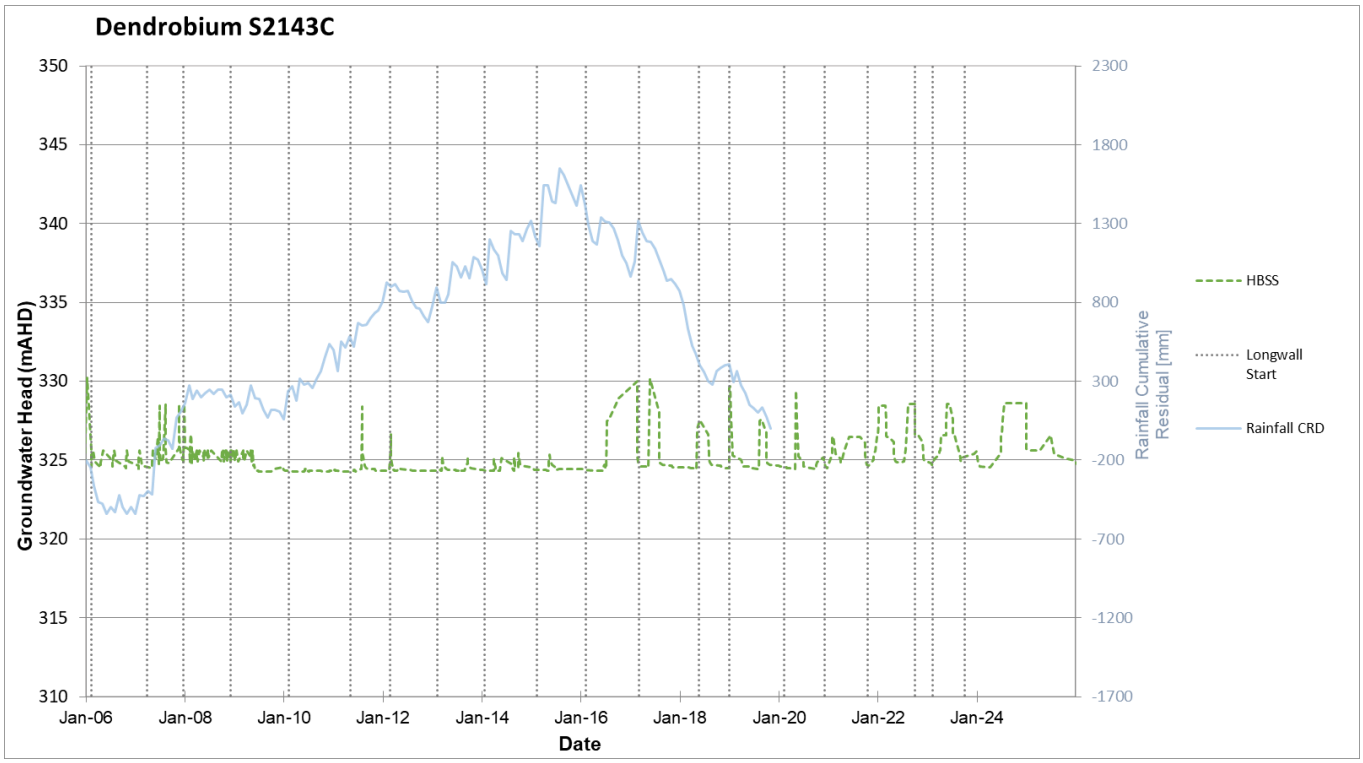


Figure A-32 Modelled Groundwater levels – S2143C

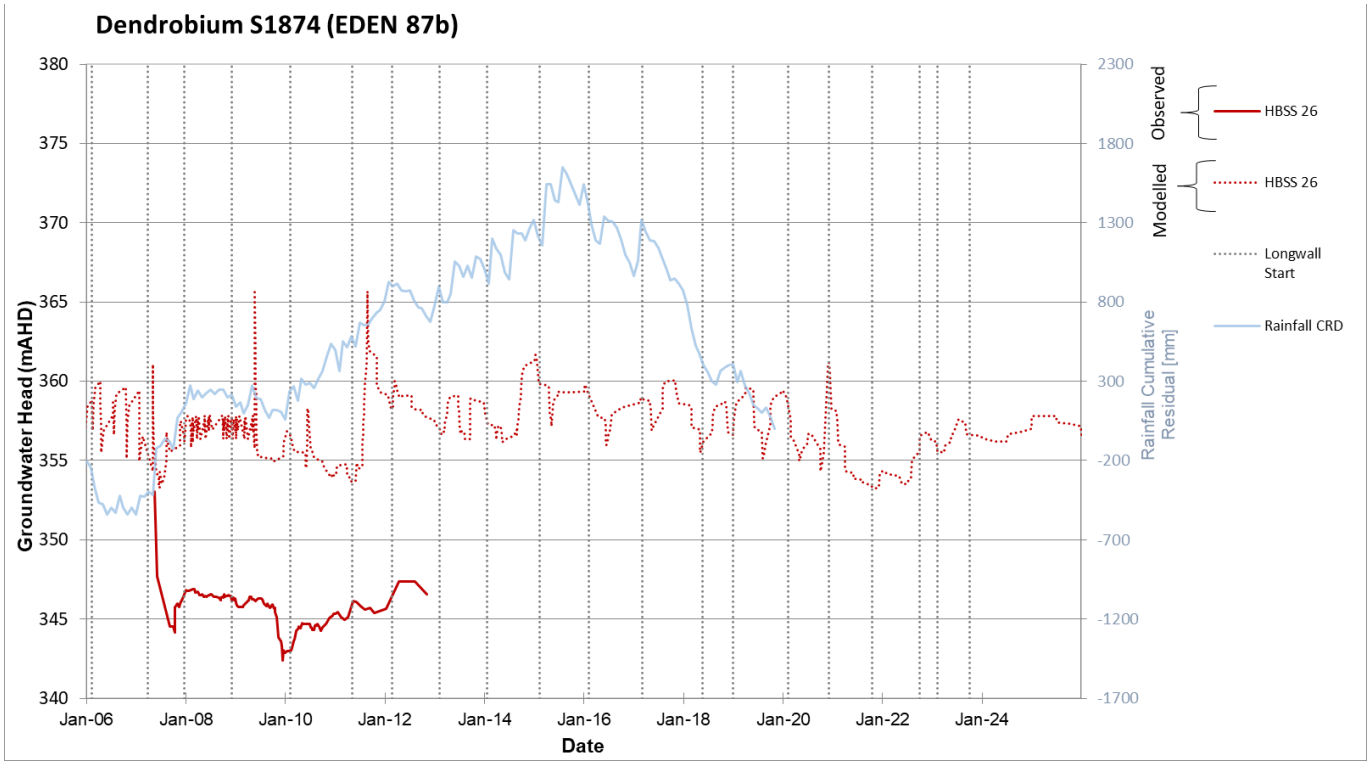


Figure A-33 Modelled and Observed Groundwater levels – S1874

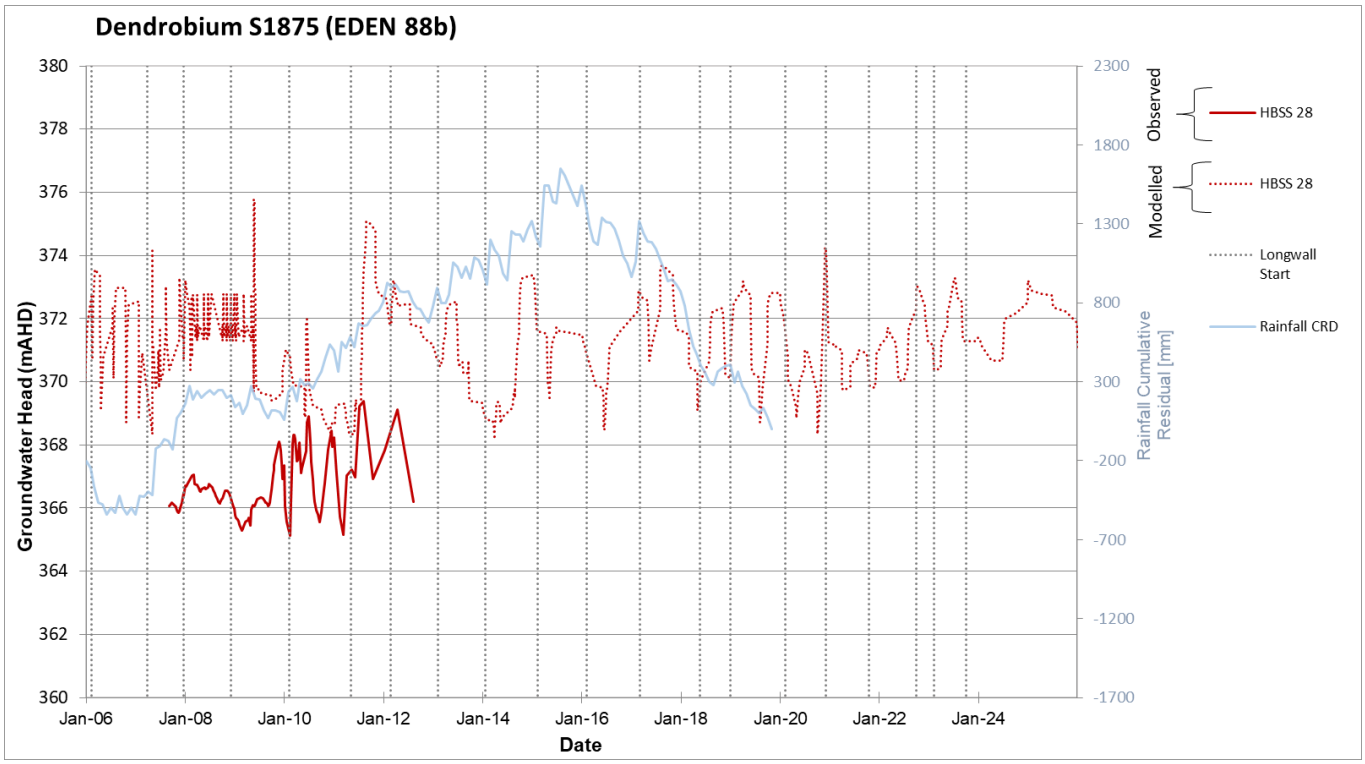


Figure A-34 Modelled and Observed Groundwater levels – S1875

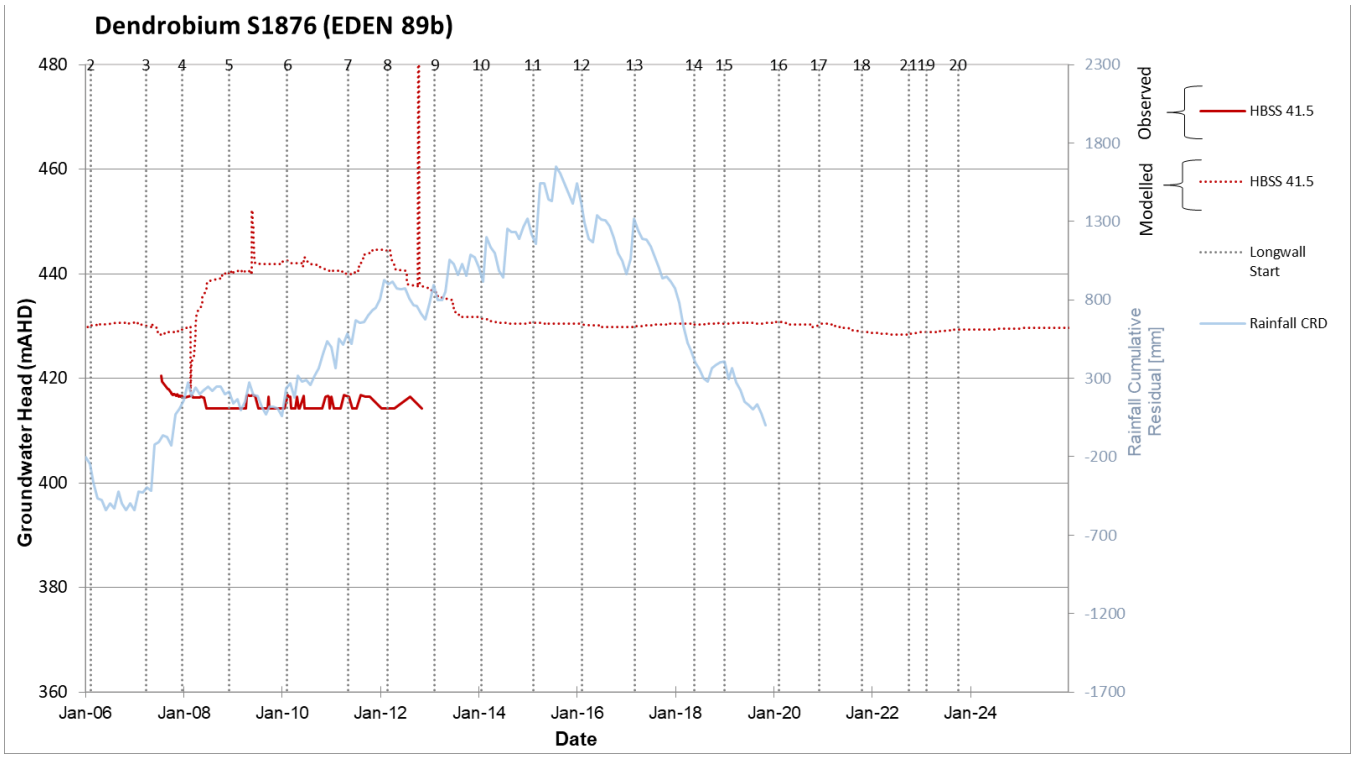


Figure A-34 Modelled and Observed Groundwater levels – S1876

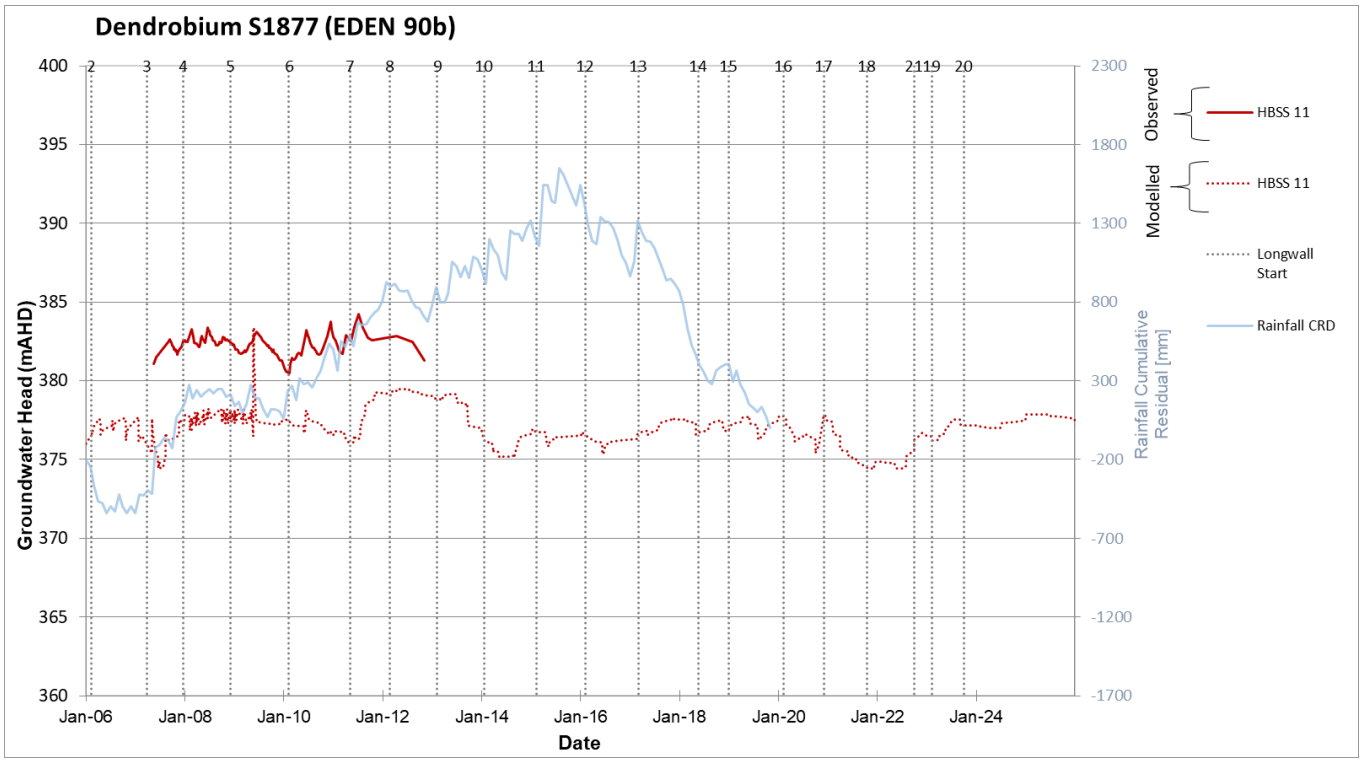


Figure A-35 Modelled and Observed Groundwater levels – S1877

Watercourse Monitoring Locations

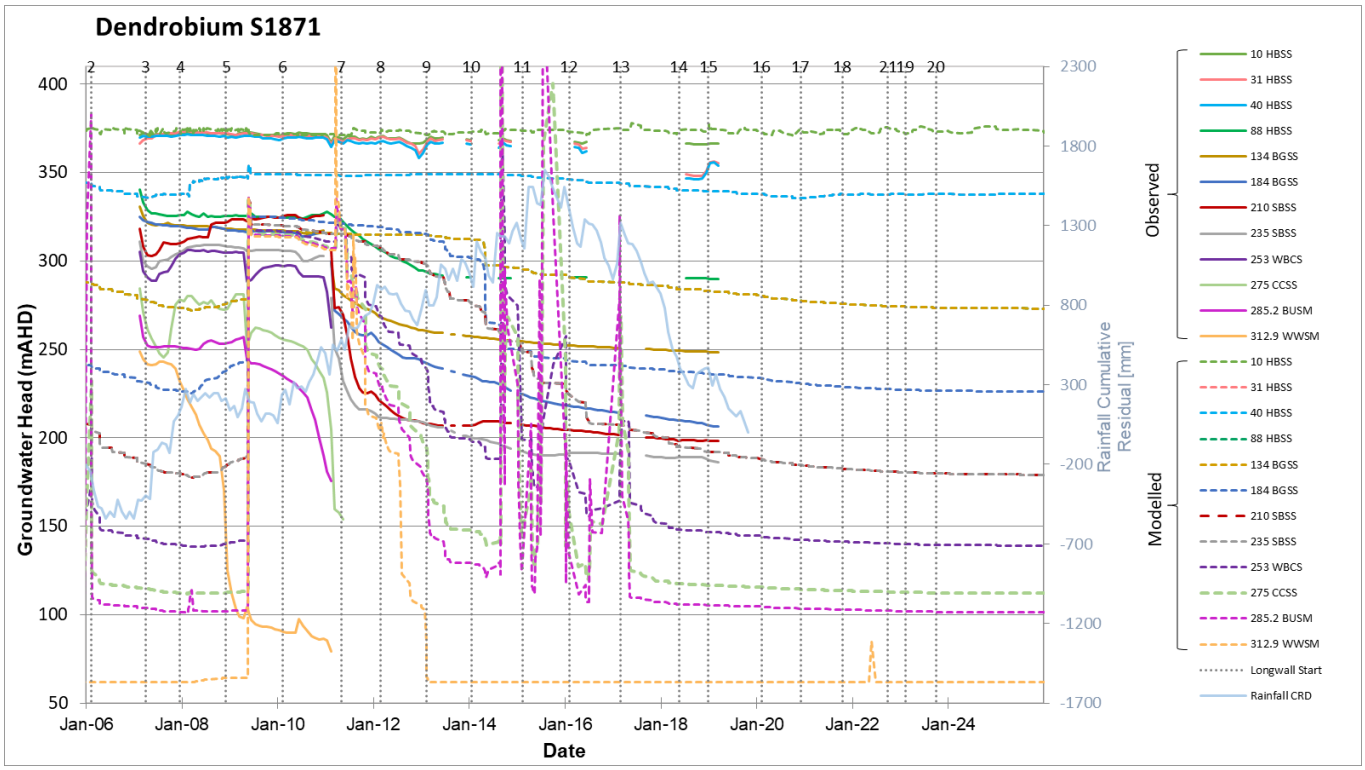


Figure A-36 Modelled and Observed Groundwater levels – S1871

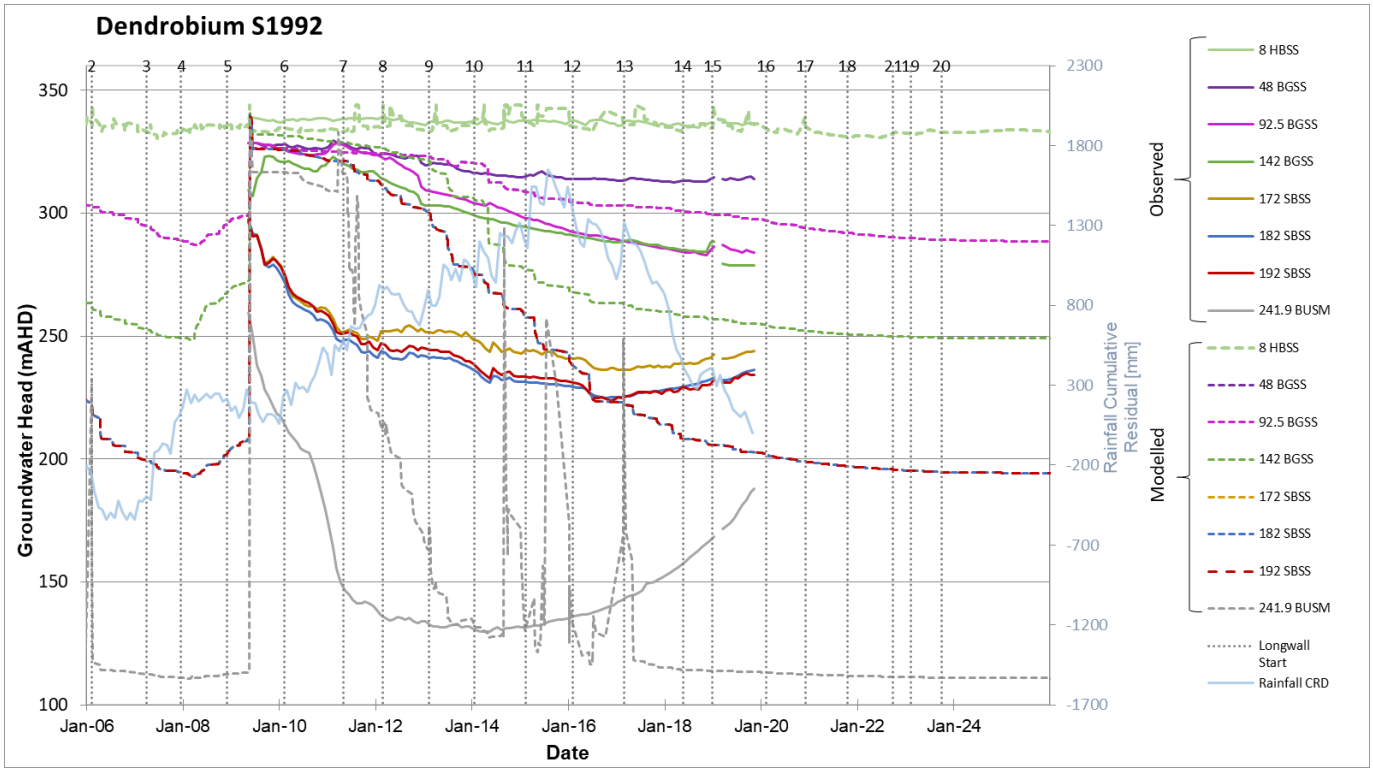


Figure A-37 Modelled and Observed Groundwater levels – S1992

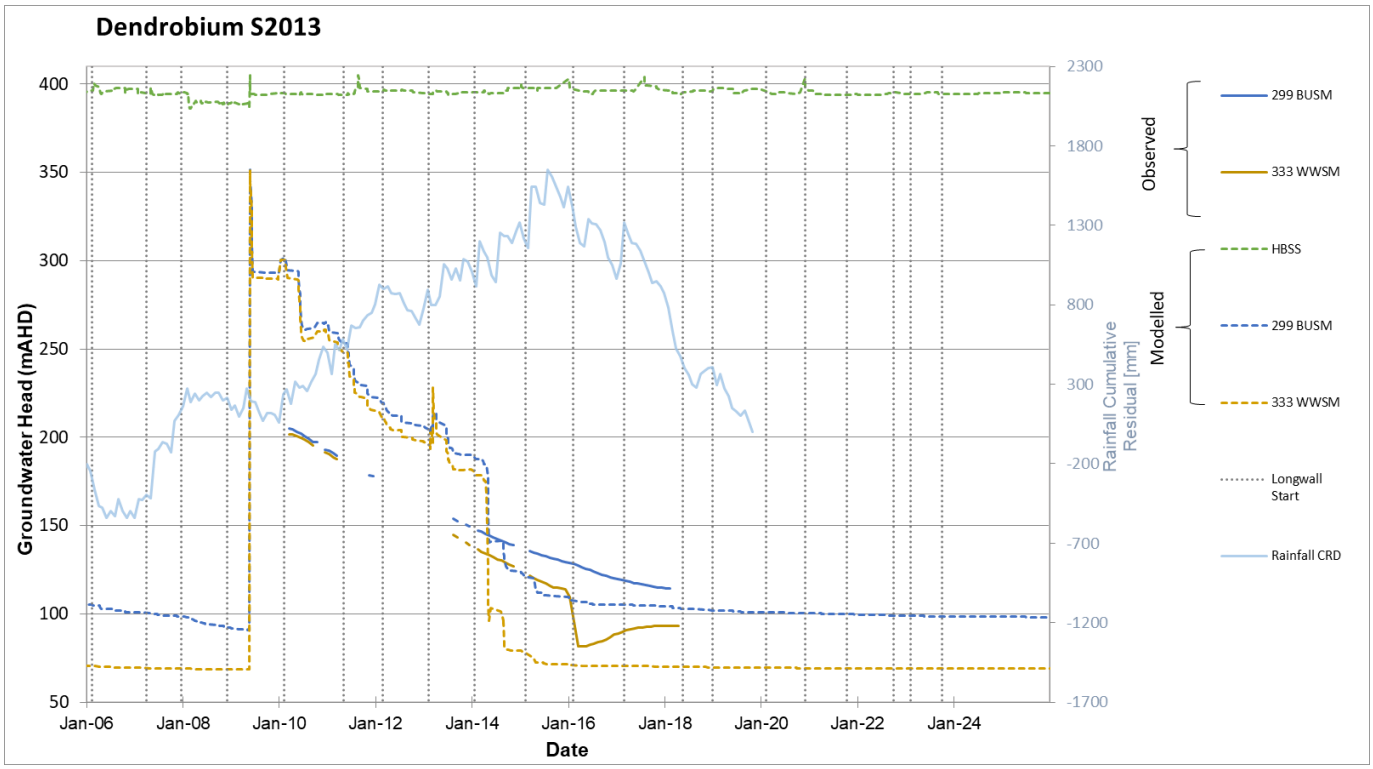


Figure A-38 Modelled and Observed Groundwater levels – S2013

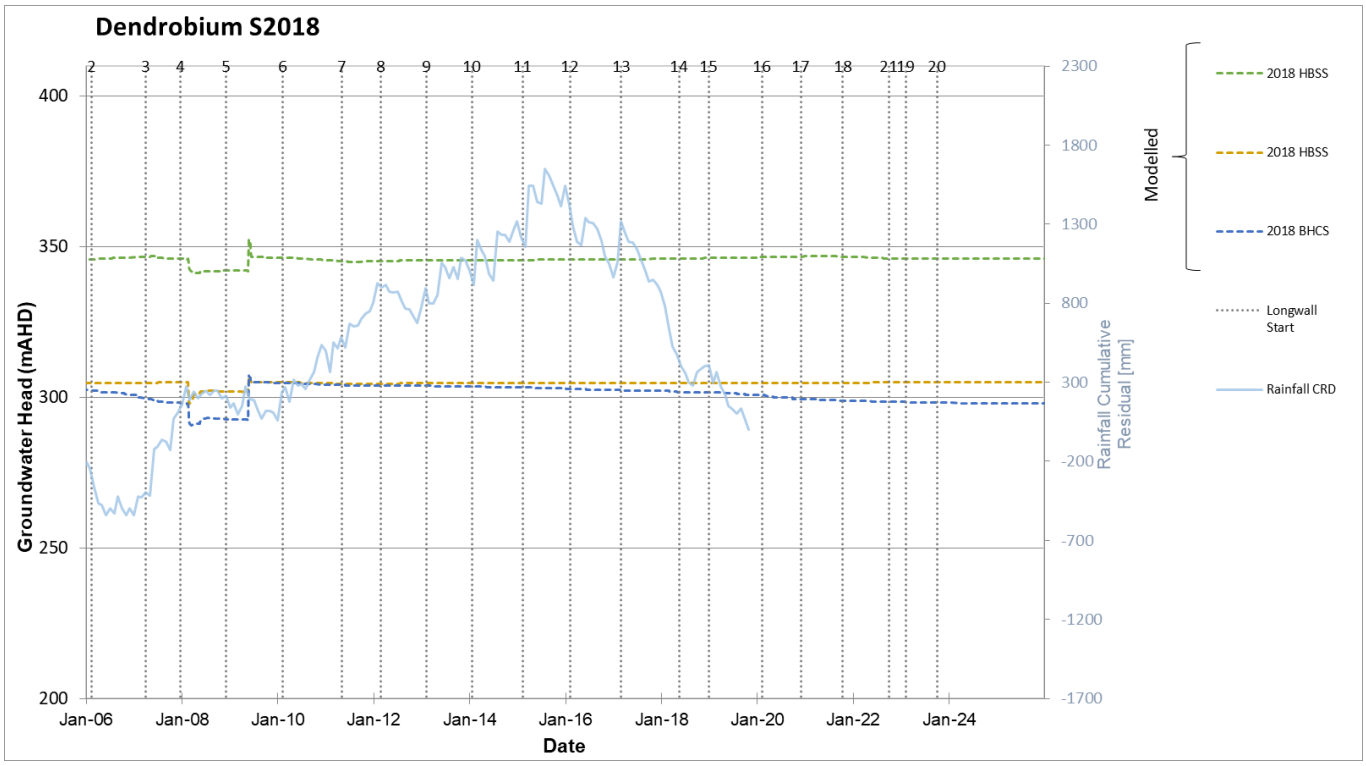


Figure A-39 Modelled Groundwater levels – S2018

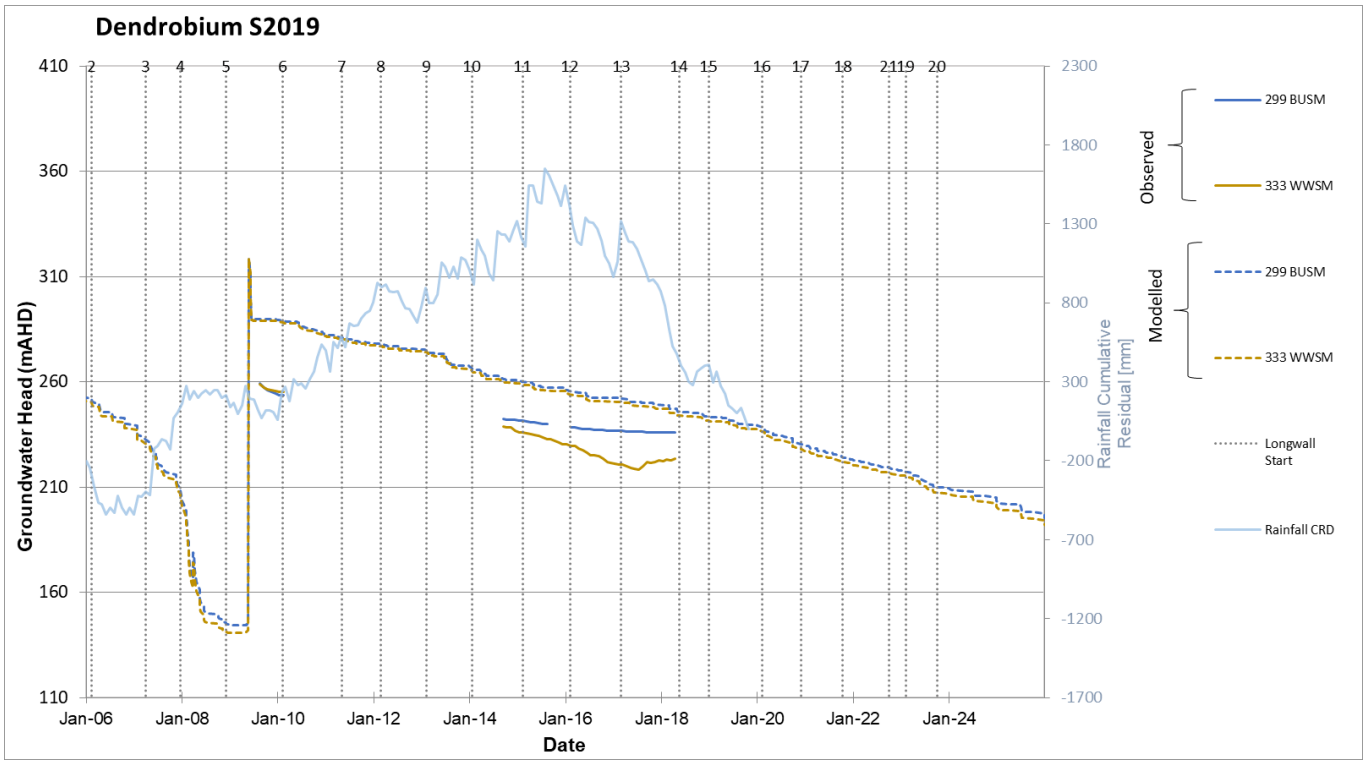


Figure A-40 Modelled and Observed Groundwater levels – S2019

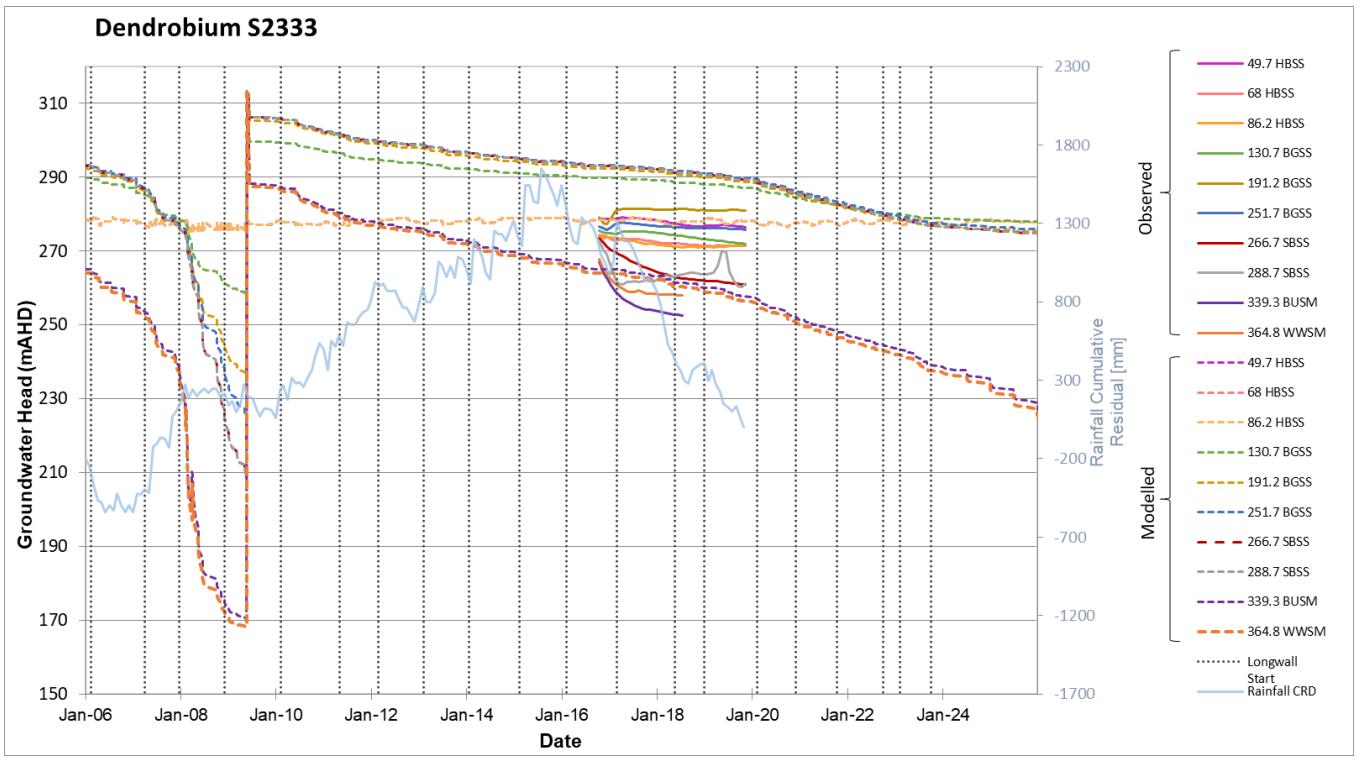


Figure A-41 Modelled and Observed Groundwater levels – S2333

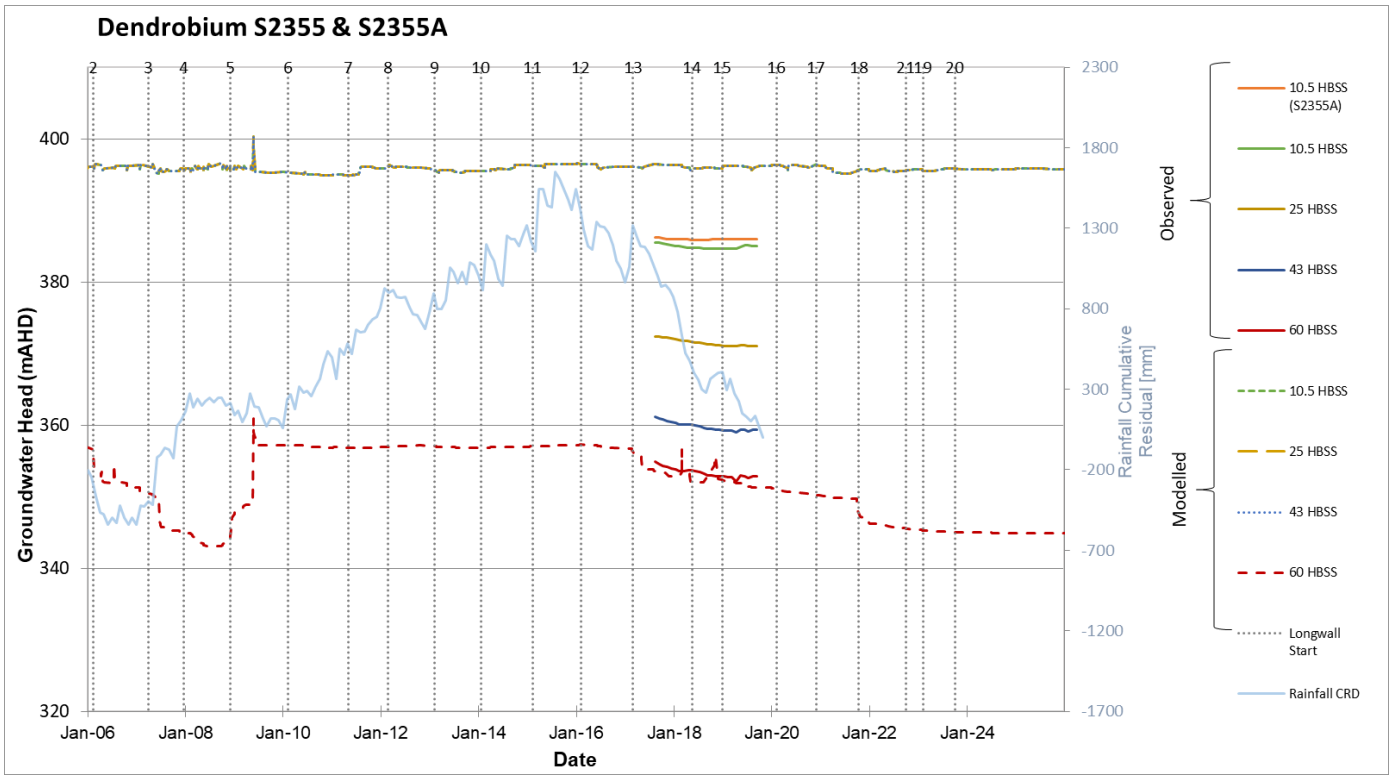


Figure A-42 Modelled and Observed Groundwater levels – S2355 and S2355A

ASIA PACIFIC OFFICES

BRISBANE
Level 2, 15 Astor Terrace
Spring Hill QLD 4000
Australia
T: +61 7 3858 4800
F: +61 7 3858 4801

CANBERRA
GPO 410
Canberra ACT 2600
Australia
T: +61 2 6287 0800
F: +61 2 9427 8200

DARWIN
Unit 5, 21 Parap Road
Parap NT 0820
Australia
T: +61 8 8998 0100
F: +61 8 9370 0101

GOLD COAST
Level 2, 194 Varsity Parade
Varsity Lakes QLD 4227
Australia
M: +61 438 763 516

MACKAY
21 River Street
Mackay QLD 4740
Australia
T: +61 7 3181 3300

MELBOURNE
Suite 2, 2 Domville Avenue
Hawthorn VIC 3122
Australia
T: +61 3 9249 9400
F: +61 3 9249 9499

NEWCASTLE
10 Kings Road
New Lambton NSW 2305
Australia
T: +61 2 4037 3200
F: +61 2 4037 3201

PERTH
Ground Floor, 503 Murray Street
Perth WA 6000
Australia
T: +61 8 9422 5900
F: +61 8 9422 5901

SYDNEY
2 Lincoln Street
Lane Cove NSW 2066
Australia
T: +61 2 9427 8100
F: +61 2 9427 8200

TOWNSVILLE
Level 1, 514 Sturt Street
Townsville QLD 4810
Australia
T: +61 7 4722 8000
F: +61 7 4722 8001

TOWNSVILLE SOUTH
12 Cannan Street
Townsville South QLD 4810
Australia
T: +61 7 4772 6500

WOLLONGONG
Level 1, The Central Building
UoW Innovation Campus
North Wollongong NSW 2500
Australia
T: +61 404 939 922

AUCKLAND
68 Beach Road
Auckland 1010
New Zealand
T: +64 27 441 7849

NELSON
6/A Cambridge Street
Richmond, Nelson 7020
New Zealand
T: +64 274 898 628

Appendix C – Methodology for Developing a Rating Curve and Establishing the Relationship between the Existing WWL and WWL_A

29 May 2020

Watershed HydroGeo
ABN: 95 615 827 499

To: **Josh Carlon**
Illawarra Metallurgical Coal
Dendrobium Mine

50 Jervis St, Nowra N.S.W.
AUSTRALIA 2541
phone: +61 (0)432 812 773

cc: Cody Brady

From: Glenn McDermott (Enviromon)
Will Minchin (WatershedHG)
will.minchin@watershedhg.com

Technical Memo: Methodology and status of developing a rating for WWL_A and for correlating with WWL

Your Ref: Request by Josh Carlon/Cody Brady Our Ref: IMC104–R015

1 Background and Appreciation

This Tech Memo has been prepared in order to fulfil Dendrobium's response obligations to Approval Condition 10e:

Include a methodology for developing a rating curve and establishing the relationship between the existing WWL gauge and the new gauge required to be constructed under condition 13 below

The two gauging sites on lower Wongawilli Creek referred to are:

- WWL, the original gauge; and
- WWL_A, the new gauge.

The two sites are located ~ 300 m from each other, as shown in Figure 1. WWL is the older of the two (established in 2007) just upstream of Wongawilli Creek's junction with Cordeaux River and near Fire Road 6 (FR6). This site has a natural control that has been identified as being 'leaky' and this affects accuracy across a range of flows, especially at low flows. The newer site WWL_A with the half-pipe structure is upstream of WWL and just upstream of the road crossing, and does not leak.

The key dates relating to flow monitoring at the two sites (WWL and WWL_A) were identified as outlined as follows:

Site WWL (data collected by HCS and ALS):

- 26/10/2007 to 14/07/2016-: data collection and processing by HCS (the first hydrographic contractor).
- 14/07/2016 to present (May 2020): data collection and processing by ALS (the current hydrographic contractor).

Site WWL_A (data collected by ALS):

- 21/08/2018 to 12/08/2019: prior to installation of half-pipe structure.
- 12/08/2019 to 16/08/2019: installation of half-pipe structure (disturbed conditions).
- 16/08/2019 to present (May 2020): with half-pipe structure in operation.

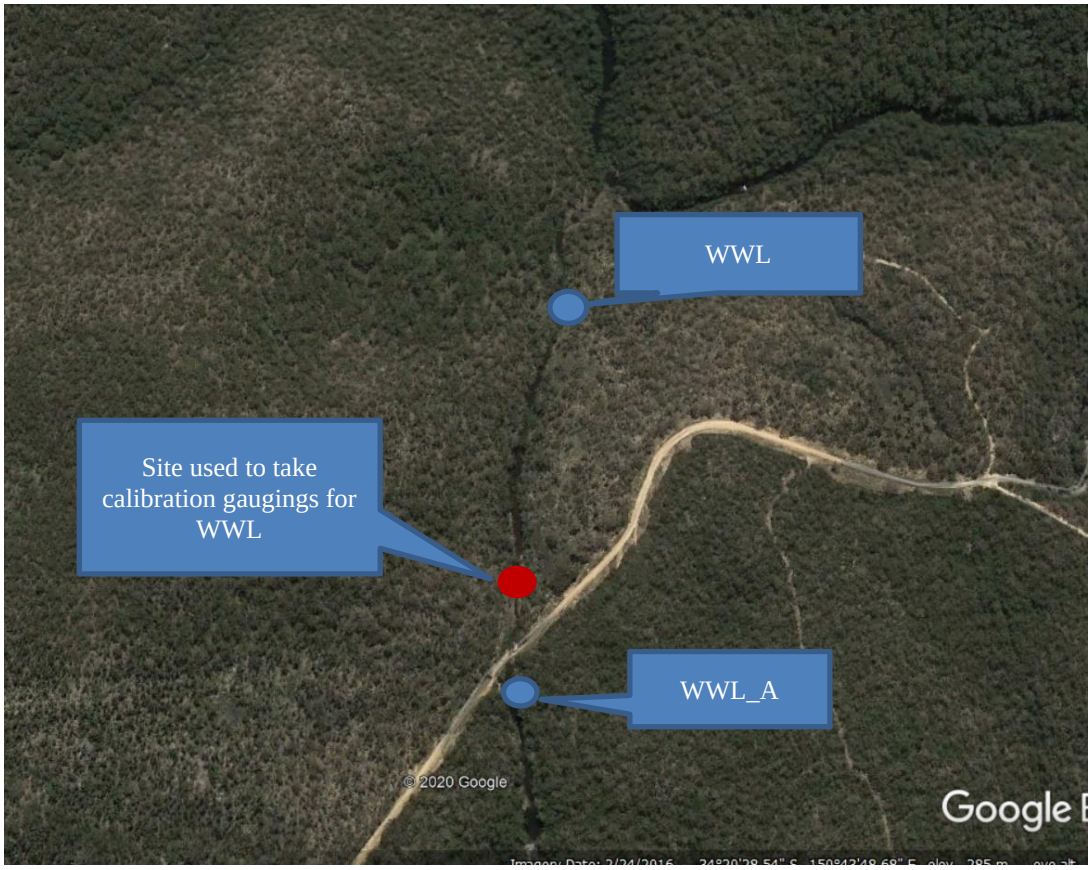


Figure 1 Location of sites WWL and WWL_A

15-minute gauge heights and discharge records for all periods (as well as quality codes) were provided by ALS for this tech memo. It was noted that 5-minute gauge height records could also have been provided for the most recent 6-month period, at both sites- if required. Also provided was the original rating table developed from gaugings (and high flow extrapolation) by HCS, but not the actual gaugings themselves. During the ALS operational period both their rating tables and discharge check gaugings were provided.

It is worth noting that ALS data processing practice for gauge heights is to adjust those periods subject to elevated levels due to debris temporarily stuck in the gauging pool outlet- so that the stored time series of gauge heights is their best estimate of "unaffected" gauge heights- which then relate to the rating table they have developed for the site(s), so that their rating tables are expressed as the relationship between unaffected gauge height and discharge (or flowrate).

It is unknown whether HCS followed a similar practice (i.e. creating unaffected gauge height time series).

2 Methodology

To address the approval condition 10e, the following analysis steps were proposed:

- Review and/or develop rating table for new site WWL_A (with half pipe installed).
- Review and/or develop rating table for old site WWL.
- Adjust gauge height data for WWL to remove diurnal level variation effect.
- Revise WWL's low flow rating by corelating gauge height at WWL with flowrate at WWL_A (i.e. using WWL_A's improved low flow rating).
- Recalculate all low flows at site WWL using the revised WWL low flow rating.

The aim of this memo was to present the full correlation of data from the two sites, the developed rating curve for WWL_A and a full transient timeseries of flows for WWL_A back to November 2007. However, as these analysis steps proceeded it became clear that further consideration was needed as to how best to extract maximum value from site WWL records in low flows, given the significant "fake" diurnal pattern effects evident in the records, as well as definite and variable evidence of leakage and its associated low flow rating changes.

The analysis that has been carried out is present in the following sections, along with a series of actions or considerations required to complete the analysis. These considerations are presented for discussion in Section 6.

3 Review rating table for new site WWL_A

The rating table referred to here is for the period since the half-pipe weir structure was installed. There have been eight (8) check calibration gaugings taken to the end of March 2020, as below in Table 1.

Table 1 Check calibration gaugings taken at WWL_A

MEAS_DATE	START_TIME	END_TIME	GAUGE_NO	START_GH	END_GH	M_GH	FLOW	Comment
20/08/2019	1320	1330	42	0.057	0.057	0.057	0.000074	Volumetric but before debris cleared
3/10/2019	1315	1325	43	0.161	0.161	0.161	0.00544	Pygmy gauged in full flume, two gaugings at 0.47 MLD
1/11/2019	1325	1335	44	0.035	0.035	0.035	0.000289	Flume volumetric 0.025 MLD
14/11/2019	1120	1130	45	0.024	0.024	0.024	0.00007	FLUME 0.00605 MLD
18/02/2020	824	900	46	0.303	0.303	0.303	0.4111	Wet weather gauging
18/02/2020	902	935	47	0.303	0.303	0.303	0.4092	Wet weather gauging
18/02/2020	1245	1310	48	0.3	0.299	0.3	0.3697	Wet weather gauging
18/03/2020	1210	1240	49	0.218	0.218	0.218	0.03945	Flowtracker average = 3.41 MLD

These eight have been used by ALS to formulate their rating table- as listed in Appendix C.

In addition to the above sources, a theoretical rating was available from Enviromon (2020), such that:

- When flow is within the half pipe, the rating was based on scale modelling done by Sydney Water Corporation as part of their clean waterways programme to simulate wet weather overflow pipes in computer models;
- When flow (stage) is above the half-pipe, the rating was based on HECRAS flow routing using an approximate control cross section (but not accounting for the downstream effects of the roadway and its culverts)

These three aspects of the rating are shown plotted in Figures 2 and 3. Note that the depth or level axis has been plotted as depth above cease-to-flow ("CTF") level- to make it comparable with the scale model half-pipe rating.

Points to note about this comparison plot (Figure 2) are:

- At this coarse scale only behaviour above the top of the half pipe can be appreciated.
- The theoretical rating significantly overestimates relative to the ALS gaugings and rating.
- The ALS rating has a "backwards kink" in it just above 0.15 m above CTF level, which is assumed to be due to the downstream circular culvert rating becoming the control, as flow just fills the pipes to their soffits.

Action 1- Find out exactly how ALS extended their rating relationship, and in particular what is their explanation of the backward kink in the rating curve around 0.15m above CTF level?

As the primary reason for installing the new WWL_A site is better accuracy at low flows, a "zoomed in" version of the same plot was done, as shown in Figure 3.

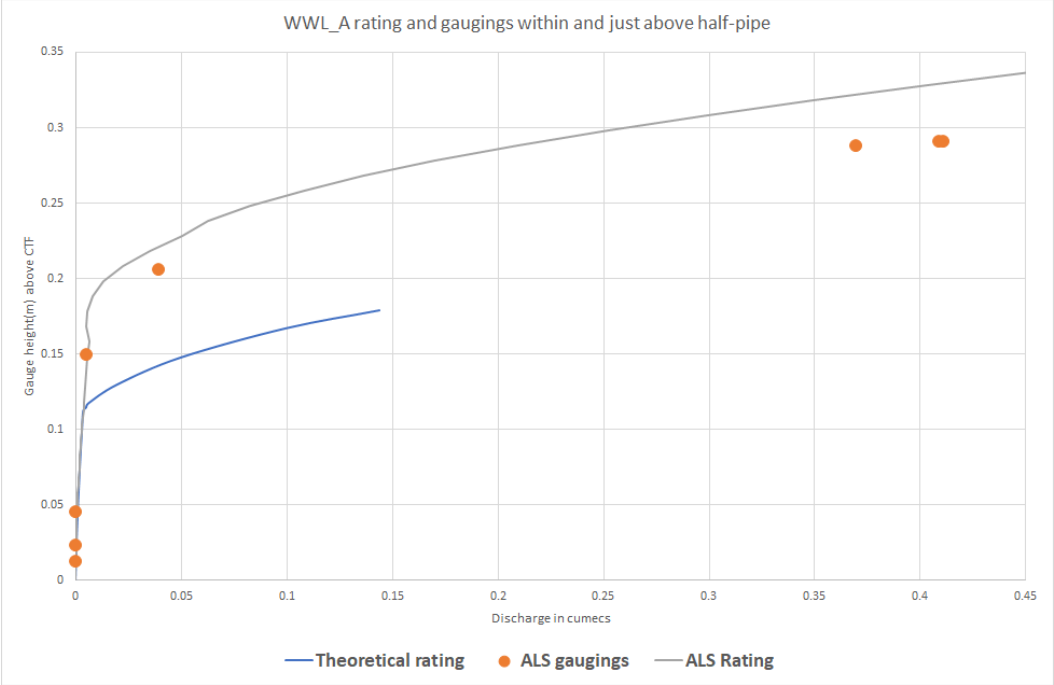


Figure 2 WWL_A ratings and gaugings up to maximum gauging (to date)

Action 2- Also find out why the new ALS rating curve does not plot straight through the three highest gauging points, as these should be the best calibration points for the site's high flow rating

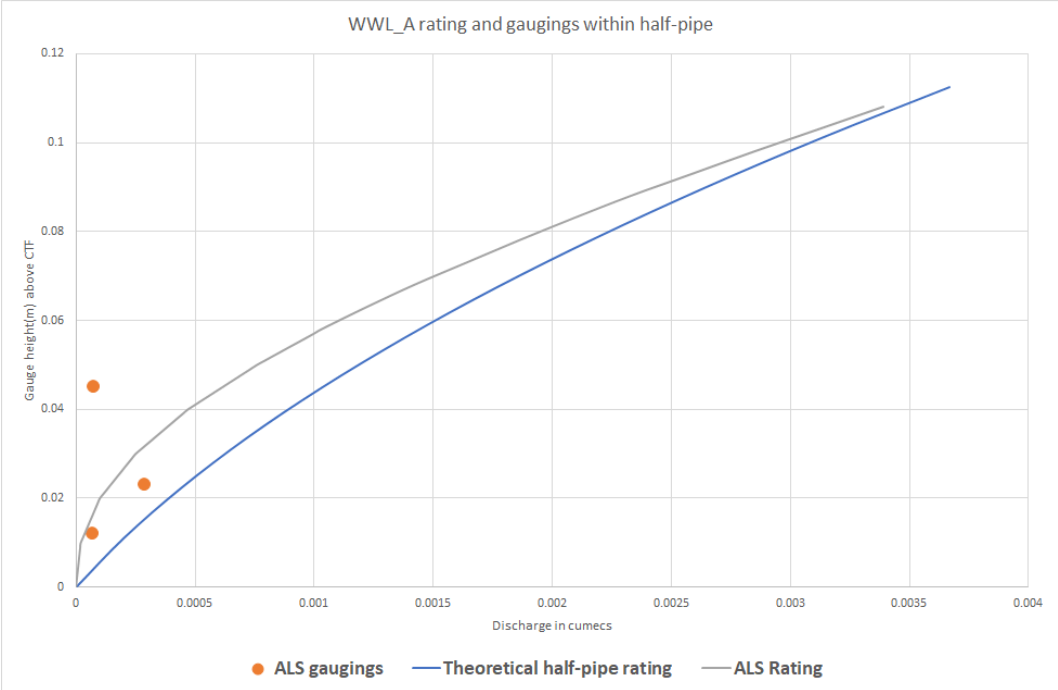


Figure 3 WWL_A ratings and gaugings "focussed in to within the half-pipe

Several further points are notable about this more detailed plot:

- The theoretical rating curve and the ALS rating curve are similar in form, and come close to replicating each other near half-pipe full level.
- The highest gauging (on 20/8/19) was very much less than the theoretical rating. Note that this gauging was affected by debris buildup in the half pipe entrance,

which was cleared after the gauging- but also note that gauge pool level did not come down after the gauging, so this did not explain this difference.

- The two lower gaugings indicate significantly less flowrate than the theoretical rating, being 40% to 60% less for the same levels.

Although it would be possible to revise the low flow rating by reducing the theoretical rating discharges by, say 60% below 0.015m, then by only 40% at depth 0.023m, then gradual transition back to the present ALS rating at pipe half-full (i.e. a level of 0.1125m), there are still some uncertainties to resolve before this can be done confidently, such as:

- A closer review of exactly how each volumetric gauging was taken (what size container, and was the hydrographer confident of their accuracy?);
  - For example if the gaugings were done with a 2 Litre container, then fill time would have been 28 seconds for the smaller gaugings and 7 seconds for the larger gauging;
    - If the timing precision was +/-0.5 seconds then this would translate to an additional 2% discharge uncertainty for the smaller gaugings, but 7% for the larger gauging.
- More gaugings are required before the new half-pipe rating can be finalised, and subsequently used for correlation with WWL records.
- It should be possible to use gaugings taken at other sites with 225mm half pipes, to supplement gauging points taken at site WWL_A- as the Sydney Water scale modelling from which the theoretical rating came, showed that pipe slope had no effect on the rating.

Action 3- Delay decision on using the potentially more accurate low flow rating at WWL_A to calculate correlated flowrates at WWL, until there are more gaugings to base the "in-pipe" rating upon- i.e. wait until there is more confidence in the WWL_A rating curve- and the reasons for any large deviation points are resolved

4 Review rating for WWL

4.1 Inferring what would have been the highest HCS gauging

Dendrobium provided the pre-ALS rating table developed by HCS, as included here in Appendix A. This rating covered a gauge height range from 0.762m to 5.000m, with 0.762m being the CTF (cease to flow) level of the gauging pool outlet. The discharge check gaugings that HCS would have based the lower portion of their rating on **were not available or provided**.

As a means of inferring the highest gauge height that HCS's rating table would have been directly based upon a line of best fit through their gaugings, the quality codes attributed to their time series data records were examined. The most frequently occurring codes for Good, Fair and Poor quality flowrate data were noted as being "5", "69", and "150" respectively.

The detailed definition of these codes reveals how high a flowrate (and gauge height) range the gaugings must have covered:

- "5" was for "good quality continuous data"- this part of the rating would have been fitted to the site calibration gaugings, and covered the range up to 0.13 cumecs and 1.0 m gauge height
- "69" was for "fair quality rating extrapolated data"- which would have extended the rating curve upwards and above the highest gauging. This covered the flow range from 0.13 cumecs up to 1.898 cumecs, and gauge heights from 1.0m up to 1.5m
- "150" was for poor quality "rating table extrapolated due to inadequate gauging information"- which would have extended the rating curve well above the highest gauging, as well as above the fair quality range. This covered the flow range from 1.898 cumecs up to 78.835 cumecs, and gauge heights from 1.5m up to 4.681m

The inferred highest gauging captured by HCS would then have been at or slightly below 1m gauge height and a flowrate of 0.13 cumecs (i.e. 11.2 ML/D).

4.2 Compare ALS to HCS rating differences at site WWL

ALS time series data records of gauge height commence on 14 July 2016 at 00:00, being the same day that HCS finished their data recording. Since that day ALS have captured a total of 29 flow check gaugings, which they have used to define that portion of the rating curve covering the range of the gaugings. The ALS rating table shown in the following figures is provided in Appendix B. The main difference noted in the header of the table (compared with the HCS rating in Appendix A) is that the CTF level has dropped 62mm and is now 0.700m gauge height instead of 0.762m as used in the older HCS table.

Figures 4, 5, 6 and 7 show the plot comparisons between the two ratings, and also ALS gaugings.

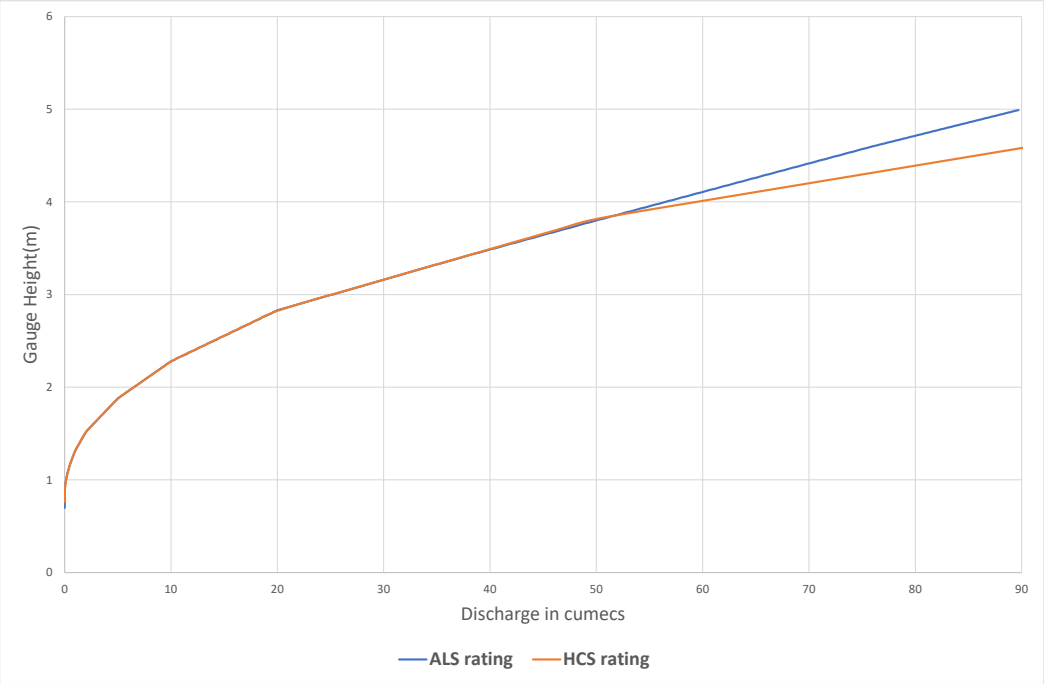


Figure 4 Full range rating plot comparison

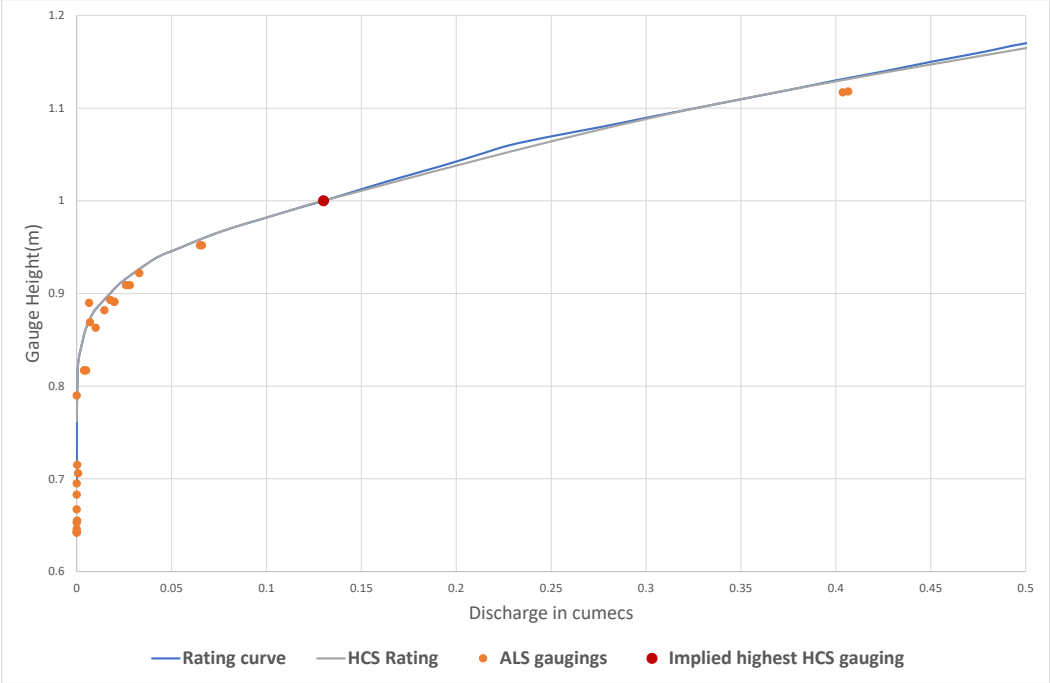


Figure 5 **Gauged flow range rating plot comparison**

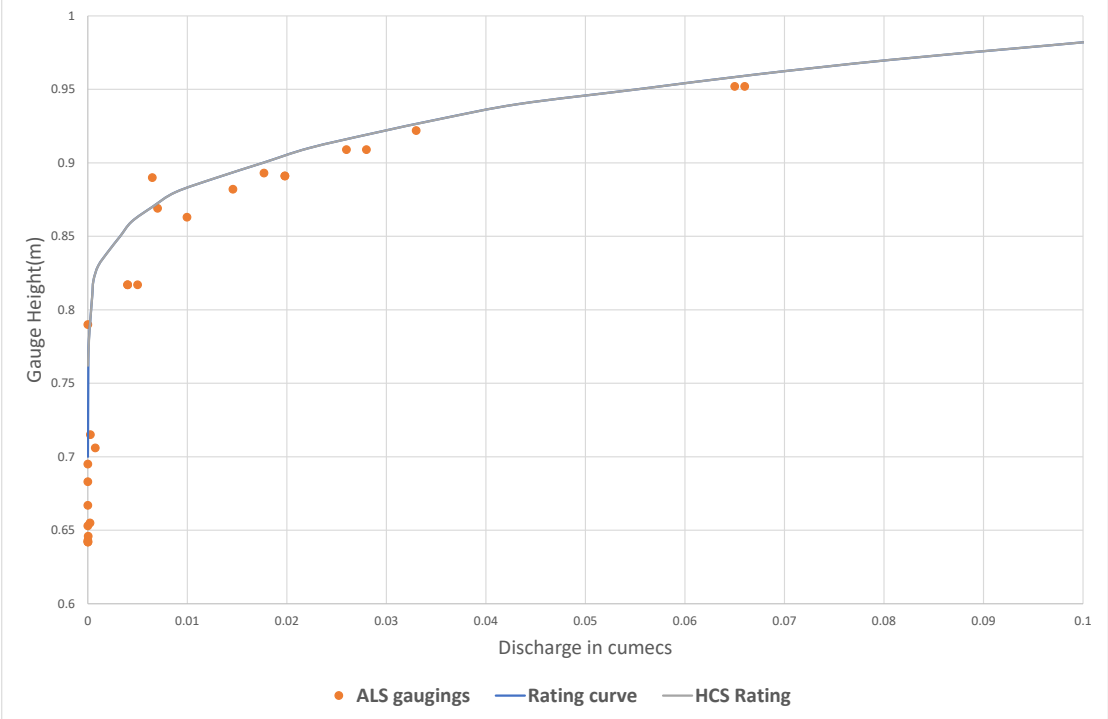


Figure 6 **Low flow range rating plot comparison**

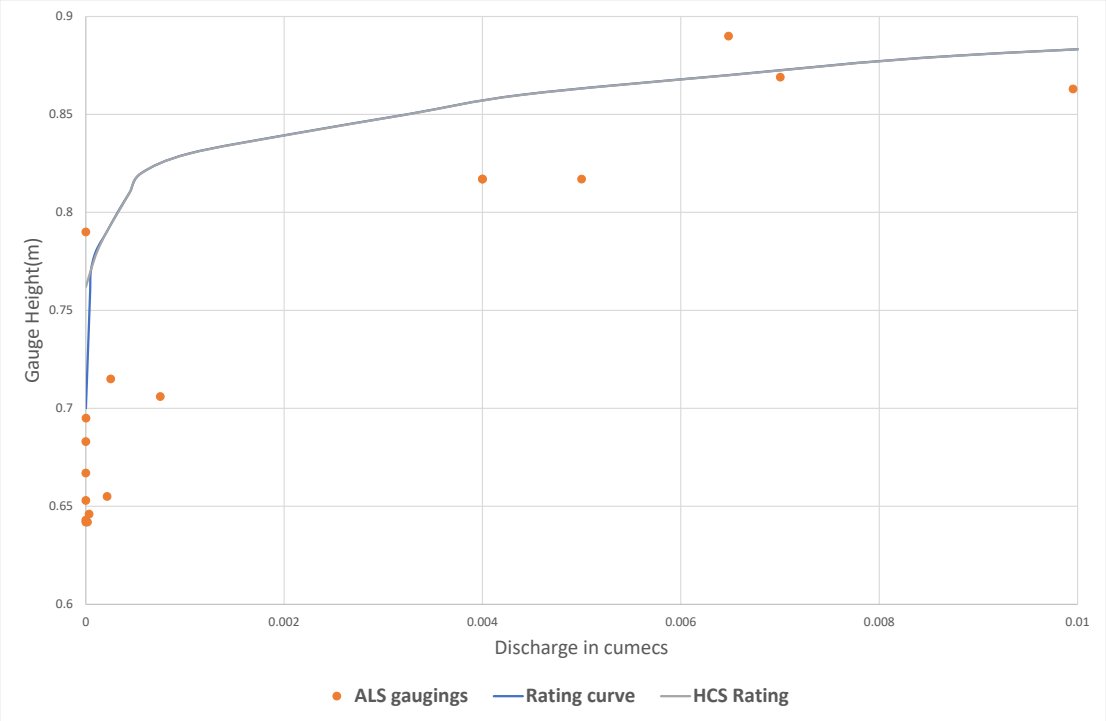


Figure 7 Very low flow range rating plot comparison

Reviewing the four plots shown above reveals the following facts:-

- The rating curves (i.e. HCS and ALS) are largely identical over all flow ranges;
- The only exceptions are:
  - High flows (above 3.9m gauge height) – ALS have less discharge than HCS by up to 20%.

Action 4- Find out what reason ALS had to change the high flow (above 3.9m) rating at this site?

  - Very low flows- although identical for gauge heights above 0.77m, ALS rating indicates greater flow below a 0.77m gauge height;
    - Noting that this is due to the lower CTF level surveyed by ALS (ie 0.7m versus 0.762m)

Action 5- Before preferring to adopt the ALS rating CTF of 0.700m gauge height- review exactly how this was obtained, and why it is different than the 0.762m gauge height used from 2007 to 2016 by HCS?

4.3 Reviewing the check calibration gaugings vs Rating tables

The bulk of the gaugings taken are in the low flow (and low depth) zone. The same group of gaugings shown on the linear plots in Figures 5,6 and 7 were again plotted here in Figures 8 and 9, but without the “less than CTF level” gaugings. This is a Log-Log plot in accord with AS3778 practice for rating curve development, with the vertical axis being depth above CTF level rather than gauge height. The purpose of this kind of plot is to identify where the hydraulic control changes occur, as each straight line segment in the plot represents hydraulic control by an identifiable feature. This allows the change points (levels) from small notch in the rock bar, to broad rock bar (both called section type controls), then to channel control in higher flows, to be identified.

Review of Figure 8 shows that the plotted ALS (and HCS) rating curve is a fair match to these gaugings, including the recent couple of gaugings taken in February 2020 during higher flow conditions at 0.4 cumecs. The exception to this are the three lowest gaugings, which all plot to the right of the rating curve- i.e. indicating greater flowrates than the rating curve. It is

worth noting here that the method of gauging used for site WWL is at a section some 200m upstream of the actual gauging pool outlet, but narrow enough to actually enable the very slow velocities to be measurable with ALSs point velocity hand held gauging equipment. This means that these very low flowrates (and velocities) have greater uncertainty than higher flow gaugings, and so their greater deviations from the rating curve may simply be their greater uncertainty.

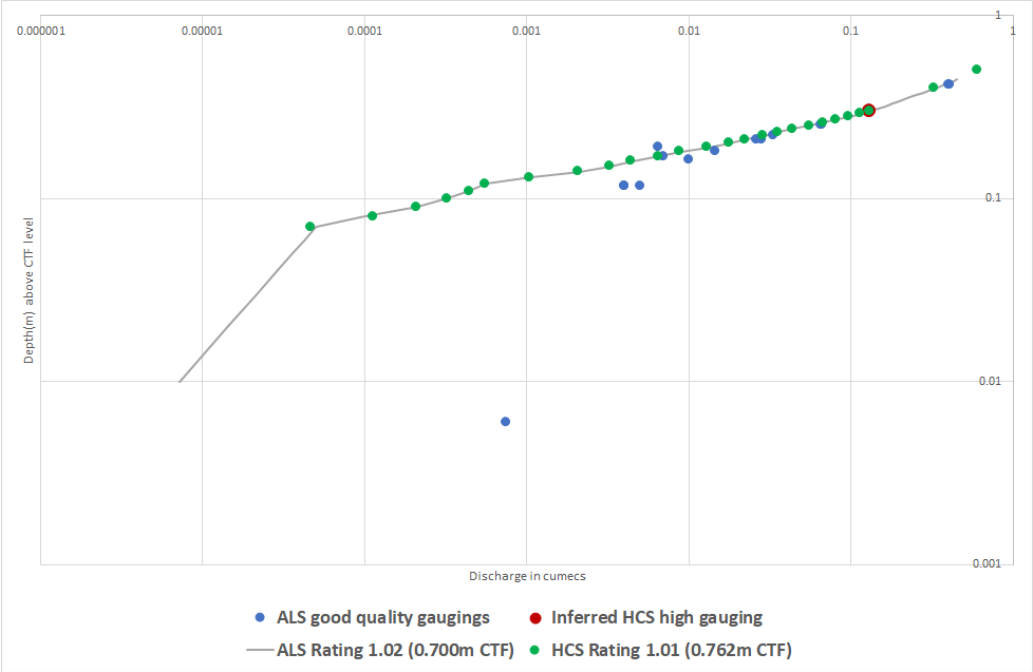


Figure 8 LogLog plot comparing all ALS good quality gaugings with rating curves

Alternatively ALS have noted some by-pass leakage around the site WWL outlet, and these very low flow gaugings (taken upstream) may be supporting evidence of that (i.e. higher flowrate upstream, but flowrate through the control notch is less, due to some bypassing underneath, while pool level is thus a little lower than expected for that flowrate).

As a means of testing for this the four (4) very low flow gaugings taken at site WWL_A were treated as if they were gaugings for site WWL, and the simultaneous gauge height at site WWL extracted for each of the four of them. These additional four gauging points are shown plotted in Figure 9. The higher 3 of these gaugings are a reasonable match to the low flow portion of the rating curve. The very lowest gauging indicates an overestimate relative to the rating curve. This is the same gauging as plots as an underestimation outlier in Figure 3.

Action 6- Closely review the very lowest flow gaugings at sites WWL and WWL_A, with a view to deciding whether or not to treat them as outliers in rating curve formation plots

The reason for making this suggestion is to defer any correlation of WWL_A to WWL until this low flow portion of site WWL's rating can be better confirmed than at present. At present, for flowrates below 0.001 cumecs, there is only one gauging for WWL and three for site WWL_A in this flow range. Of these gaugings, the one for site WWL plots off the rating curve, implying the rating curve is significantly underestimating flow. Of the three "translated from site WWL_A" gaugings, the higher 2 correspond fairly well and appear to confirm the existing rating, while the lowest one implies some underestimation for flow by the rating curve.

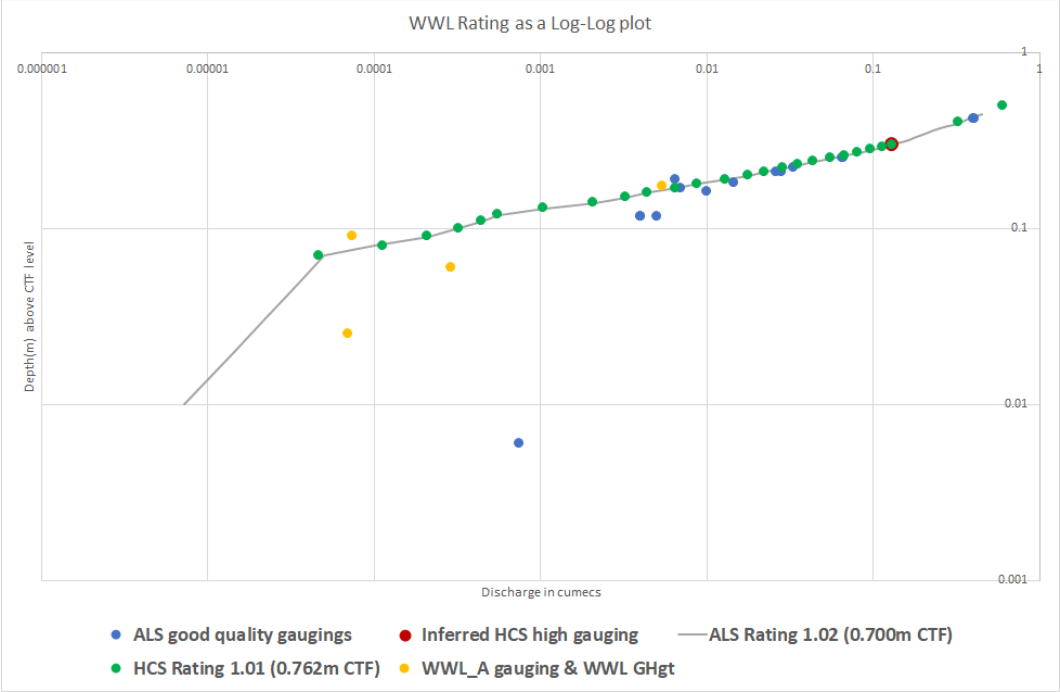


Figure 9 As for Figure 8, but treating the four lowest site WWL_A gaugings as WWL gaugings

4.4 Awareness of further evidence of control leakage

The gaugings not shown on the Figure 8 and 9 LogLog plots were the 9 gaugings taken while gauge heights in the level sensor pool were below the CTF height of 0.700m, as listed here in Table 2.

Table 2 Site WWL gaugings taken below CTF level

Meas Date	Start Time	End Time	Gauge No	Start GH	End GH	Mean GH (m)	Flow m^3/s
15/05/2018	1050	1050	9	0.642	0.642	0.642	0
14/08/2018	1225	1230	12	0.642	0.642	0.642	0.000017
21/02/2018	1130	1130	5	0.643	0.643	0.643	0
25/09/2018	0	0	13	0.646	0.646	0.646	0.000033
19/01/2018	900	900	4	0.653	0.653	0.653	0
23/04/2018	1110	1115	8	0.655	0.655	0.655	0.000215
20/11/2018	915	920	15	0.667	0.667	0.667	0
14/11/2017	1235	1235	3	0.683	0.683	0.683	0
28/06/2018	1315	1315	10	0.695	0.695	0.695	0.000001

Leakage under the control (pool outlet) at site WWL is the inferred reason for these “below CTF” gaugings. It is for this reason that WWL has been identified as unsuitable for accurate measurement of low flows along Wongawilli Creek.

As previously explained, when ALS visit site WWL they take a gauging at an intermediate site, which is a narrow pool some 200m upstream of the actual site, but downstream of the road crossing (Figure 1). This enables them to take a more accurate gauging, within the velocity range of the hand-held point velocity devices they use to take a gauging. If they were to try to take a gauging in the actual WWL pool, which is wider and deeper, velocities in low

flows would be so slow as to not even turn the pygmy current meter, or erroneously register in the doppler point device.

In very low flows at the intermediate gauging site, even a gauging at this better site is nearly impossible to obtain. Hence several of the 9 gaugings listed in Table 9 have zero as their gauged flowrates, but comments by the field team saying that they observed flowrate at the site, but could not gauge it. The 4 gaugings with an actual flowrate listed means that the field team found some way to take a gauging. Two are listed as "visual only", and were presumably based on observing the velocity of small debris in the flow, while the other two are listed as "volumetric" and "flow tracker", using some small plastic container, and a point velocity device, respectively. None of these gaugings would be very accurate.

This "proof of leakage" certainly supports the case to move the site to WWL_A and the "easier to measure low flows" half-pipe structure.

4.5 Site WWL High flow rating compared with gaugings

There have been no high flow gaugings at this site until very recently- after the large storm in February this year. The two gaugings taken could be considered as one, with an average flowrate of 0.4051 cumecs (i.e. 35.0 ML/D), and a gauge height of 1.118 m. This flowrate is high enough to only be equalled or exceeded on 5% of days. As a result, these gaugings are a significant benefit for checking the previous theoretical rating extension used for flowrate calculations.

Reviewing the linear plot on Figure 5, the two high flow gaugings plot some 10% higher than the present rating curve. Without knowing details about the gaugings, it may be that this 10% difference is within the combined measurement uncertainty of the gauging measurement method used.

Action 7- Confirm how the wet weather gaugings were taken and assess if the 10% difference from the rating can be accepted as within discharge measurement uncertainty tolerances.

If this is confirmed, then the high flow rating (at least up to a flowrate of 0.4 cumecs) can be accepted as reliable, and certainly as more reliable than the low flow rating and associated leakage problems.

5 What can be done about filtering the WWL diurnal level pattern?

The diurnal pattern exhibited by the Diver level (pressure) sensor(s) at site WWL is as typified in Figure 10 for the day of record on 18 October 2019. This figure also shows the very slight diurnal pattern in level recorded by the new site WWL_A. Note that this day is after the installation of the half pipe weir and bund at site WWL_A.

This figure has a vertical scale of 50mm for both sites (0.12m to 0.20m for WWL_A, and 0.85m to 0.93m for site WWL)- to make them comparable.

Site WWL varies by 35mm between its minimum and maximum levels for the day, while site WWL_A varies by 9mm between its minimum and maximum for the day.

Note that both sites do exhibit diurnal patterns, with the pattern at WWL_A being much milder due to the Orpheus (gauge pressure type) logger.

Noting that it is possible that the difference in discharge ratings between the two sites may explain the apparent difference in level diurnal patterns (i.e. WWL might only "seem" worse, while actually being much the same), the flowrates for the same day (from their respective ratings), were plotted as per Figure 11.

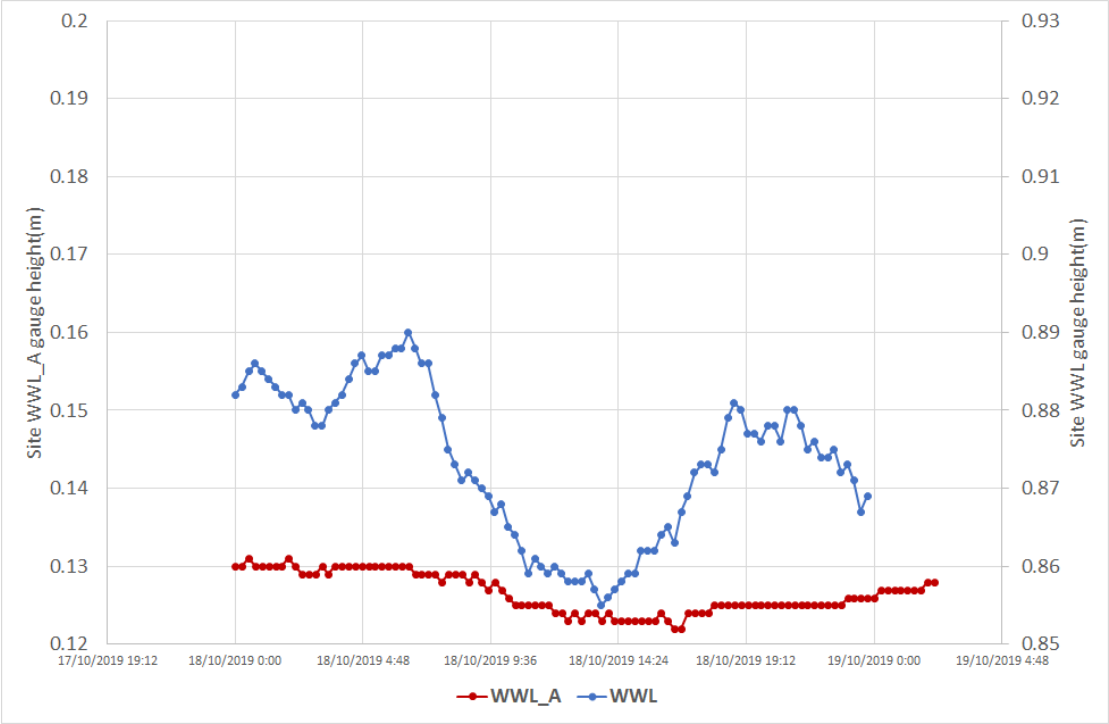


Figure 10 Typical diurnal level pattern on 18 October 2019 (note both scales are 80mm)

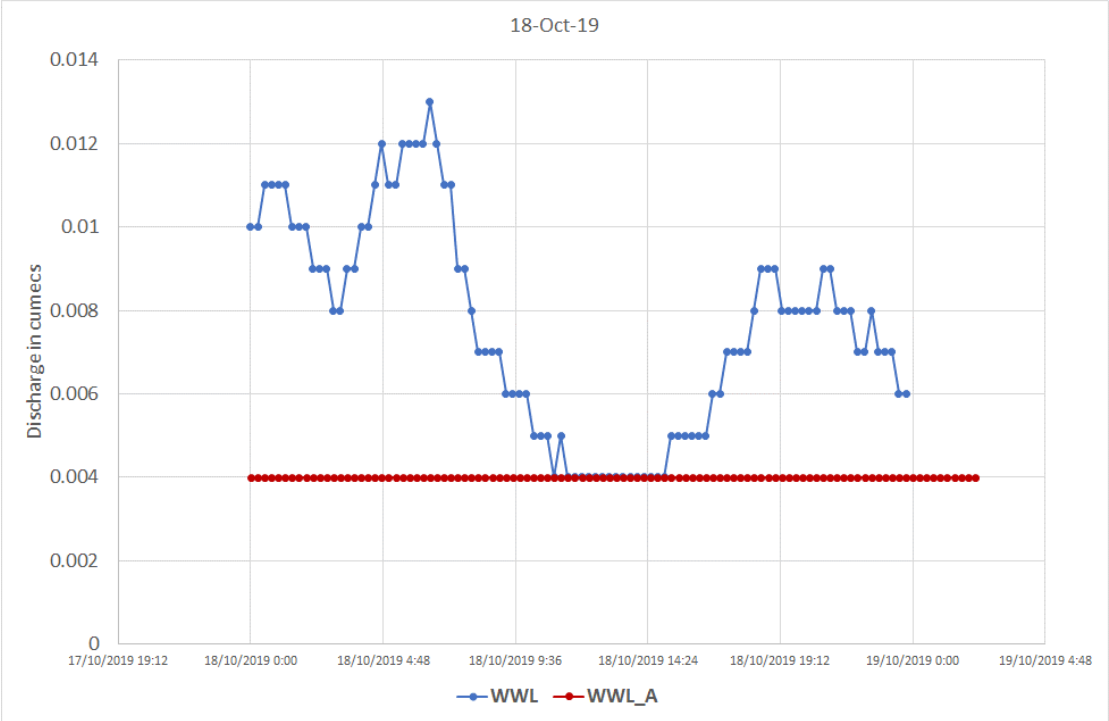


Figure 11 Typical diurnal flowrate pattern on 18 October 2019

As can be observed on Figure 11 the flowrate recorded for WWL does exhibit the same "larger" diurnal pattern than indicated for WWL_A. Note however that the WWL_A rating table for these very low levels is too insensitive to show the effect of the slight (but obvious) diurnal pattern in its level records in Figure 10.

The daily record (diurnal) patterns recorded for 4 other low flow days were extracted and plotted in the same way as Figures 10 and 11. These plots are shown in Appendix D. The summary minimum to maximum diurnal variation differences extracted from these plots are listed here in Tables 3 and 4.

Table 3 Summary of diurnal level differences observed on 5 typical days

Date	Site WWL Ghts(m)			Site WWL_A GHts(m)			Difference of Diffce's (m)
	Lowest	Highest	Diff'ce	Lowest	Highest	Diff'ce	
16-Sep-19	0.772	0.797	0.025	0.054	0.058	0.004	0.021
8-Oct-19	0.879	0.915	0.036	0.162	0.173	0.011	0.025
18-Oct-19	0.855	0.89	0.035	0.122	0.131	0.009	0.026
24-Oct-19	0.812	0.842	0.03	0.077	0.084	0.007	0.023
18-Nov-19	0.686	0.722	0.036	0.008	0.017	0.009	0.027

Table 4 Summary of diurnal flowrate differences observed on 5 typical days

Date	Site WWL Flowrates (m^3/s)			Site WWL_A Flowrates (m^3/s)			Difference of Diffce's (m^3/s)
	Lowest	Highest	Diff'ce	Lowest	Highest	Diff'ce	
16-Sep-19	0	0	0	0.001	0.001	0	0
8-Oct-19	0.009	0.026	0.017	0.006	0.007	0.001	0.016
18-Oct-19	0.004	0.013	0.009	0.004	0.004	0	0.009
24-Oct-19	0	0.002	0.002	0.001	0.002	0.001	0.001
18-Nov-19	0	0	0	0	0	0	0

One conclusion here is that the apparent diurnal flow pattern is definitely larger at site WWL than at site WWL_A.

The question is how much of the pattern is natural (due to evapotranspiration etc) and how much of it is the greater temperature and pressure adjustment hysteresis effects attributable to the Diver "absolute pressure" type logger(s) at WWL, versus the much less affected "gauge pressure" Orpheus type logger at site WWL_A.

If 100% of the greater diurnal pattern at WWL could be attributed to the Diver logger, then a filter could be designed to reduce this pattern. Although other projects in other parts of the world (see the last four items in References) note that diurnal patterns in streams are real and naturally occurring, several of them also note that there is additional "fake" diurnal pattern introduced by absolute type pressure sensors like the Diver sensor used at site WWL

Looking at the Table 4 results it is likely that around 0.001 cumecs (1 L/s) can be inferred and attributed to natural diurnal variation. Also inferable is that the minimum (lowest) flowrates match better than the maximums- suggesting that any filter design should prefer to keep the daily minima but reduce the maxima, as well as the pattern between the two.

Then, if such a natural 0.001 cumec diurnal variation is negligible in terms of subsequent flow loss analysis for the mine, the following approach is suggested for consideration:-

Action 8- Consider how to define a "dry day" and/or a day when flowrates (and gauge heights) are low enough that the falsely high diurnal pattern will inflate daily flow, and for such days, devise a filter that retains the minimum flowrate and time but reduces the rest of the day's pattern downwards so that the maximum flowrate is no more than 0.002 cumecs above the minimum…or something like that…further investigation needed

Note that if this filtering is not done then none of the low flow day records should be used for mine loss analysis, as the flowrates for those days will be overestimated significantly by the Diver sensor's hysteresis behaviour - overestimating gauge heights during the lower temperature portions of the day and night.

6 Recommendations and concluding remarks

Given some of the data issues described above it seemed wise to pause and clarify what options should be reconsidered to consolidate Wongawilli Creek flow records into a single valid time series record for sites WWL and WWL_A, with a view to terminating site WWL.

The options that could be reconsidered are:

6.1 Option 1- The easy option

Accept that there is very little that can be done for the poor accuracy of low flows at site WWL (due to false diurnal patterns and leakage), and accept the flow data "as is" from its commencement in 2007 up until 21 August 2018 when site WWL_A became operational. Then:

- From 21 August 2018 up to 12 August 2019 take flowrate records from site WWL_A with its rating prior to half pipe installation.
- From 12 August 2019 to 16 August 2019, while the half-pipe was being installed, take flow records from site WWL.
- From 16 August 2019 to now rely solely on the new site WWL_A and its half pipe rating to calculate flowrates.
- Note that as rating curve revisions are done for sites WWL, WWL_A prior to half pipe, and WWL_A after half pipe, then ask ALS to recalculate flows and resubmit affected monthly and annual report daily flow summaries.

6.2 Option 2- The harder option

Do not accept that there is nothing that can be done to correct the affected (due to false diurnal patterns and leakage) flow records at WWL, as well as making an effort to bring forward rating curve refinements at both sites, then:-

- Site WWL records from 2007 to 21 August 2018, and from 12 to 16 August 2019;
  - Investigate why ALS rating curve deviates from old HCS rating curve above 3.9m (as per Action 4).
  - Investigate why ALS did not recalibrate the high flow rating to pass through the only wet weather gaugings taken at the site (in February this year)- as per Action 8.
    - Also investigate why the 4 high flow gaugings taken at site WWL_A could not be treated as equating to site WWL gaugings, and used to supplement the high flow gaugings taken further downstream for site WWL (as referred to in Action 8)
  - Investigate why ALS changed the CTF from the previous 0.762m gauge height to 0.700m gauge height- as per Action 5.
  - Obtain older gaugings previously taken by HCS (2007 to 2016), if they are readily available, and check that they are consistent with the ALS gaugings and rating and whether they also indicate evidence of leakage
  - Investigate why ALS did not force the rating curve in very low flows to go through the 3 lowest gaugings.
  - Research and devise a method of identifying "dry days" affected by the false (from the Diver logger limitations) behaviour, and removing it by a filter designed to match observed and recorded daily flow behaviour at site WWL_A (after half pipe installation)- as per Action 8.

- Site WWL_A records from 21 August 2018 up to 12 August 2019 take flowrate records from site WWL_A with its rating prior to half pipe installation;
  - Investigate how ALS established this rating and it's extension to above the gauged range
  - with a check on that rating to include its calibration to the high flow gaugings taken in February 2020, as the half pipe structure should have negligible influence during those high flows.
  - within the 1 year record period use WWL's good quality higher flow rating to postulate peak flowrates at WWL_A, extract WWL_A gauge height, and define "calibration gauging points" on this interim WWL_A rating- to improve it's accuracy in medium to higher flows.
- Site WWL records from 12 August 2019 to 16 August 2019, while the half-pipe was being installed, take flow records from site WWL;
  - Consider applying suggestion 8 to filter the diurnal gauge height pattern for those few days, and recalculating flowrates using WWL's rating.
- Site WWL_A records from 16 August to now, after half pipe installation.
  - How did ALS define the rating above the half pipe, and why is their a backward kink in it around 0.15m?- as per Action 1.
  - Noting the existence of the four wet weather gaugings taken in February and March, investigate why the rating curve was not made to go through these gaugings, instead of (as now) the rating being 50% less discharge at these gauge heights?- as per Action 2.
  - Delay any decision to calculate "within half pipe" flowrates at WWL_A until more gaugings are taken covering a better flow range as per Action 3, (say at least 10), and;
    - Explain why only 1 of the 3 low flow gaugings plot near the present rating curve.
    - Noting that the worst "outlier of these three low flow gaugings had the comment "gauging taken before debris cleared- expedite installation of the low flow rope "leaf catching" barrier at this site.
    - Test if gaugings from other sites with 225mm half pipes can be used to supplement each other's curves (ie as if the pipe slope difference effect was negligible, as was found with Sydney Water scale modelling of overflow pipes from manholes).

6.3 Option 3- something between options 1 and 2

Review the tasks listed under Option 2 and remove any that may be eventually done by ALS following their normal practices, or tasks that are unlikely or impractical to complete.

Whichever option is decided upon, it should be understood that low flow accuracy is very poor at site WWL due to variable subsurface leakage (and associated CTF level and hence rating changes) as well as additional "fake" diurnal pattern effects due to the nature of the pressure logger at the site.

Option 1 (the easy option) requires no further investigatory tasks and hence no delay in proceeding to terminate WWL. Option 2 (the harder option) involves several additional investigatory tasks, but none which require any further measurements or gauge height records from WWL. Option 2 will therefore delay being able to finalise historic daily flow volumes more accurately than at present, but need not delay termination of site WWL. The third option will also allow WWL to be terminated now, but delay being able to finalise revising flowrates, but not as much as for Option 2.

6.4 Conclusion

We have developed a method for fulfilling Condition 10e. While we had envisaged being able to complete this by the current date, some questions and uncertainties arose during the

analysis. We have identified some further steps and data required to complete this task more confidently. Our recommendation is to proceed with Option 2, to finalise the changeover to new site WWL_A and termination of site WWL, to be sooner rather than later.

7 References

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Please contact us if further clarification is required.

Yours sincerely,

Glenn McDermott

0488 436 504

gmcd.enviromon@gmail.com

Will Minchin

0432 812 773

will.minchin@watershedhg.com

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8 Appendix A- HCS rating table for site WWL

Hydrometric Consulting Services HYRATAB V164 Output 16/11/2015

Site 300022 d/s Wongawilli Ck @ Denrobium

Rating Table 1.01 01/11/2007 to Present Interpolation = Lin CTF = 0.7620

Converting 100 Stream Water Level in Metres
Into 141 Stream Discharge in Megalitres/Day

G.H.	0	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.70								0.00400	0.00900	0.0180
0.80	0.0280	0.0380	0.0480	0.0900	0.180	0.280	0.380	0.560	0.760	1.12
0.90	1.52	1.92	2.47	3.07	3.74	4.77	5.79	6.96	8.36	9.78
1.00	11.2	12.6	14.0	15.5	16.9	18.3	19.7	21.7	23.9	26.0
1.10	28.2	30.3	32.5	34.6	36.8	38.9	41.1	43.2	46.1	49.0
1.20	51.8	54.7	57.6	60.5	63.4	66.2	69.1	72.0	74.9	77.8
1.30	80.6	83.5	86.4	90.7	95.0	99.4	104	108	112	117
1.40	121	125	130	134	138	143	147	151	156	160
1.50	164	169	173	180	187	194	202	209	216	223
1.60	230	238	245	252	259	266	274	281	288	295
1.70	302	310	317	324	331	338	346	353	360	367
1.80	374	382	389	396	403	410	418	425	432	443
1.90	454	464	475	486	497	508	518	529	540	551
2.00	562	572	583	594	605	616	626	637	648	659
2.10	670	680	691	702	713	724	734	745	756	767
2.20	778	788	799	810	821	832	842	853	864	880
2.30	895	911	927	943	958	974	990	1005	1021	1037
2.40	1053	1068	1084	1100	1115	1131	1147	1162	1178	1194
2.50	1210	1225	1241	1257	1272	1288	1304	1320	1335	1351
2.60	1367	1382	1398	1414	1430	1445	1461	1477	1492	1508
2.70	1524	1539	1555	1571	1587	1602	1618	1634	1649	1665
2.80	1681	1697	1712	1728	1754	1780	1807	1833	1859	1885
2.90	1911	1937	1964	1990	2016	2042	2068	2095	2121	2147
3.00	2173	2199	2225	2252	2278	2304	2330	2356	2383	2409
3.10	2435	2461	2487	2513	2540	2566	2592	2618	2644	2671
3.20	2697	2723	2749	2775	2801	2828	2854	2880	2906	2932
3.30	2959	2985	3011	3037	3063	3089	3116	3142	3168	3194
3.40	3220	3247	3273	3299	3325	3351	3377	3404	3430	3456
3.50	3482	3508	3535	3561	3587	3613	3639	3665	3692	3718
3.60	3744	3770	3796	3823	3849	3875	3901	3927	3953	3980
3.70	4006	4032	4058	4084	4111	4137	4163	4189	4215	4241
3.80	4268	4294	4320	4365	4411	4456	4502	4547	4593	4638
3.90	4684	4729	4775	4820	4866	4911	4957	5002	5048	5093
4.00	5139	5184	5229	5275	5320	5366	5411	5457	5502	5548
4.10	5593	5639	5684	5730	5775	5821	5866	5912	5957	6003
4.20	6048	6093	6139	6184	6230	6275	6321	6366	6412	6457

G.H.	0	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
4.30	6503	6548	6594	6639	6685	6730	6776	6821	6867	6912
4.40	6957	7003	7048	7094	7139	7185	7230	7276	7321	7367
4.50	7412	7458	7503	7549	7594	7640	7685	7731	7776	7821
4.60	7867	7912	7958	8003	8049	8094	8140	8185	8231	8276
4.70	8322	8367	8413	8458	8504	8549	8595	8640	8699	8758
4.80	8817	8877	8936	8995	9054	9113	9172	9231	9290	9350
4.90	9409	9468	9527	9586	9645	9704	9763	9823	9882	9941
5.00	10000									

---------- Notes ----------
All rated data has been coded as reliable

9 Appendix B- ALS rating table for site WWL

ALS Hydrographics NATIONAL HYRATAB V173 Output 24/04/2020

Site 300022 Wongawilly Creek

Rating Table 1.02 26/10/2007 to Present Interpolation = Lin CTF = 0.7000

Converting 100 Stream Water Level in Metres
Into 140 Stream Discharge Cumecs in Cumecs

G.H.	0	0.001	0.002	0.003	0.004	0.005	0.006	0.007	0.008	0.009
0.700	0.0	.00000071	.00000143	.00000214	.00000286	.00000357	.00000429	.00000500	.00000571	.00000643
0.710	.00000714	.00000786	.00000857	.00000929	0.0000100	0.0000107	0.0000114	0.0000121	0.0000129	0.0000136
0.720	0.0000143	0.0000150	0.0000157	0.0000164	0.0000171	0.0000179	0.0000186	0.0000193	0.0000200	0.0000207
0.730	0.0000214	0.0000221	0.0000229	0.0000236	0.0000243	0.0000250	0.0000257	0.0000264	0.0000271	0.0000279
0.740	0.0000286	0.0000293	0.0000300	0.0000307	0.0000314	0.0000321	0.0000329	0.0000336	0.0000343	0.0000350
0.750	0.0000357	0.0000364	0.0000371	0.0000379	0.0000386	0.0000393	0.0000400	0.0000407	0.0000414	0.0000421
0.760	0.0000429	0.0000436	0.0000443	0.0000450	0.0000457	0.0000464	0.0000471	0.0000479	0.0000486	0.0000493
0.770	0.0000500	0.0000550	0.0000600	0.0000650	0.0000700	0.0000750	0.0000800	0.0000850	0.0000900	0.0000950
0.780	0.000100	0.000111	0.000122	0.000133	0.000144	0.000155	0.000166	0.000177	0.000188	0.000199
0.790	0.000210	0.000221	0.000232	0.000243	0.000254	0.000265	0.000276	0.000287	0.000298	0.000309
0.800	0.000320	0.000332	0.000344	0.000356	0.000368	0.000380	0.000392	0.000404	0.000416	0.000428
0.810	0.000440	0.000452	0.000464	0.000476	0.000488	0.000500	0.000512	0.000524	0.000536	0.000548
0.820	0.000560	0.000608	0.000656	0.000704	0.000752	0.000800	0.000848	0.000896	0.000944	0.000992
0.830	0.00104	0.00114	0.00125	0.00135	0.00146	0.00156	0.00166	0.00177	0.00187	0.00198
0.840	0.00208	0.00220	0.00231	0.00243	0.00254	0.00266	0.00278	0.00289	0.00301	0.00312
0.850	0.00324	0.00336	0.00347	0.00359	0.00370	0.00382	0.00394	0.00405	0.00417	0.00428
0.860	0.00440	0.00461	0.00482	0.00502	0.00523	0.00544	0.00565	0.00586	0.00606	0.00627
0.870	0.00648	0.00671	0.00694	0.00718	0.00741	0.00764	0.00787	0.00810	0.00834	0.00857
0.880	0.00880	0.00922	0.00963	0.0100	0.0105	0.0109	0.0113	0.0117	0.0121	0.0125
0.890	0.0130	0.0134	0.0139	0.0143	0.0148	0.0153	0.0157	0.0162	0.0167	0.0171
0.900	0.0176	0.0181	0.0185	0.0190	0.0194	0.0199	0.0204	0.0208	0.0213	0.0218
0.910	0.0222	0.0229	0.0235	0.0241	0.0248	0.0254	0.0260	0.0267	0.0273	0.0280
0.920	0.0286	0.0293	0.0300	0.0307	0.0314	0.0321	0.0328	0.0334	0.0341	0.0348
0.930	0.0355	0.0363	0.0371	0.0379	0.0386	0.0394	0.0402	0.0410	0.0417	0.0425
0.940	0.0433	0.0445	0.0457	0.0469	0.0481	0.0493	0.0504	0.0516	0.0528	0.0540
0.950	0.0552	0.0564	0.0576	0.0588	0.0599	0.0611	0.0623	0.0635	0.0647	0.0658
0.960	0.0670	0.0684	0.0697	0.0711	0.0724	0.0738	0.0751	0.0765	0.0779	0.0792
0.970	0.0806	0.0822	0.0838	0.0854	0.0870	0.0887	0.0903	0.0919	0.0935	0.0951
0.980	0.0968	0.0984	0.100	0.102	0.103	0.105	0.107	0.108	0.110	0.112
0.990	0.113	0.115	0.116	0.118	0.120	0.121	0.123	0.125	0.126	0.128
1.000	0.130	0.131*	0.133*	0.134*	0.136*	0.138*	0.139*	0.141*	0.143*	0.144*
1.010	0.146*	0.147*	0.149*	0.151*	0.152*	0.154*	0.156*	0.157*	0.159*	0.160*
1.020	0.162*	0.164*	0.166*	0.167*	0.169*	0.171*	0.172*	0.174*	0.176*	0.178*
1.030	0.179*	0.181*	0.183*	0.184*	0.186*	0.188*	0.189*	0.191*	0.192*	0.194*
1.040	0.196*	0.197*	0.199*	0.200*	0.202*	0.204*	0.205*	0.207*	0.209*	0.210*
1.050	0.212*	0.213*	0.215*	0.217*	0.218*	0.220*	0.222*	0.223*	0.225*	0.226*
1.060	0.228*	0.230*	0.233*	0.235*	0.237*	0.240*	0.242*	0.244*	0.247*	0.249*

ALS Hydrographics NATIONAL HYRATAB V173 Output 24/04/2020

Site 300022 Wongawilly Creek

Rating Table 1.02 26/10/2007 to Present Interpolation = Lin CTF = 0.7000

Converting 100 Stream Water Level in Metres
Into 140 Stream Discharge Cumecs in Cumecs

G.H.	0	0.001	0.002	0.003	0.004	0.005	0.006	0.007	0.008	0.009
1.070	0.251*	0.254*	0.256*	0.259*	0.261*	0.264*	0.266*	0.269*	0.272*	0.274*
1.080	0.277*	0.279*	0.281*	0.284*	0.286*	0.289*	0.291*	0.294*	0.296*	0.298*
1.090	0.301*	0.303*	0.306*	0.309*	0.311*	0.314*	0.316*	0.319*	0.321*	0.324*
1.100	0.326*	0.329*	0.331*	0.334*	0.336*	0.339*	0.341*	0.343*	0.346*	0.348*
1.110	0.351*	0.353*	0.356*	0.358*	0.361*	0.363*	0.366*	0.369*	0.371*	0.374*
1.120	0.376*	0.379*	0.381*	0.383*	0.386*	0.388*	0.391*	0.393*	0.396*	0.398*
1.130	0.400*	0.403*	0.406*	0.408*	0.411*	0.413*	0.416*	0.418*	0.421*	0.423*
1.140	0.426*	0.428*	0.431*	0.433*	0.436*	0.438*	0.441*	0.443*	0.445*	0.448*
1.150	0.450*	0.453*	0.455*	0.458*	0.460*	0.463*	0.466*	0.468*	0.471*	0.473*
1.160	0.476*	0.478*	0.481*	0.483*	0.485*	0.488*	0.490*	0.493*	0.495*	0.498*
1.170	0.500*	0.503*	0.507*	0.510*	0.513*	0.517*	0.520*	0.523*	0.527*	0.530*
1.180	0.534*	0.537*	0.540*	0.544*	0.547*	0.550*	0.554*	0.557*	0.560*	0.564*
1.190	0.567*	0.570*	0.574*	0.577*	0.580*	0.583*	0.587*	0.590*	0.593*	0.596*
1.200	0.600*	0.603*	0.606*	0.610*	0.613*	0.616*	0.620*	0.623*	0.626*	0.630*
1.210	0.633*	0.636*	0.640*	0.643*	0.647*	0.650*	0.653*	0.657*	0.660*	0.663*
1.220	0.667*	0.670*	0.673*	0.677*	0.680*	0.683*	0.687*	0.690*	0.694*	0.697*
1.230	0.700*	0.704*	0.707*	0.710*	0.714*	0.717*	0.720*	0.724*	0.727*	0.730*
1.240	0.734*	0.737*	0.740*	0.744*	0.747*	0.750*	0.753*	0.756*	0.760*	0.763*
1.250	0.766*	0.770*	0.773*	0.776*	0.780*	0.783*	0.786*	0.790*	0.793*	0.796*
1.260	0.800*	0.803*	0.806*	0.810*	0.813*	0.817*	0.820*	0.823*	0.827*	0.830*
1.270	0.833*	0.837*	0.840*	0.843*	0.847*	0.850*	0.853*	0.857*	0.860*	0.864*
1.280	0.867*	0.870*	0.874*	0.877*	0.880*	0.884*	0.887*	0.890*	0.894*	0.897*
1.290	0.900*	0.904*	0.907*	0.910*	0.913*	0.917*	0.920*	0.923*	0.926*	0.930*
1.300	0.933*	0.936*	0.940*	0.943*	0.946*	0.950*	0.953*	0.956*	0.960*	0.963*
1.310	0.966*	0.970*	0.973*	0.977*	0.980*	0.983*	0.987*	0.990*	0.993*	0.997*
1.320	1.00*	1.00*	1.01*	1.01*	1.02*	1.02*	1.03*	1.03*	1.04*	1.04*
1.330	1.05*	1.05*	1.06*	1.06*	1.07*	1.07*	1.08*	1.08*	1.09*	1.09*
1.340	1.10*	1.10*	1.11*	1.11*	1.12*	1.13*	1.13*	1.14*	1.14*	1.15*
1.350	1.15*	1.16*	1.16*	1.17*	1.17*	1.18*	1.18*	1.19*	1.19*	1.20*
1.360	1.20*	1.21*	1.21*	1.22*	1.22*	1.23*	1.23*	1.24*	1.24*	1.25*
1.370	1.25*	1.25*	1.26*	1.26*	1.27*	1.27*	1.28*	1.28*	1.29*	1.29*
1.380	1.30*	1.30*	1.31*	1.31*	1.32*	1.33*	1.33*	1.34*	1.34*	1.35*
1.390	1.35*	1.36*	1.36*	1.37*	1.37*	1.38*	1.38*	1.39*	1.39*	1.40*
1.400	1.40*	1.41*	1.41*	1.41*	1.42*	1.42*	1.43*	1.43*	1.44*	1.44*
1.410	1.45*	1.45*	1.46*	1.46*	1.47*	1.48*	1.48*	1.49*	1.49*	1.50*
1.420	1.50*	1.51*	1.51*	1.52*	1.52*	1.53*	1.53*	1.54*	1.54*	1.55*

ALS Hydrographics NATIONAL HYRATAB V173 Output 24/04/2020

Site 300022 Wongawilly Creek

Rating Table 1.02 26/10/2007 to Present Interpolation = Lin CTF = 0.7000

Converting 100 Stream Water Level in Metres
Into 140 Stream Discharge Cumecs in Cumecs

G.H.	0	0.001	0.002	0.003	0.004	0.005	0.006	0.007	0.008	0.009
1.430	1.55*	1.56*	1.56*	1.56*	1.57*	1.57*	1.58*	1.58*	1.59*	1.59*
1.440	1.60*	1.60*	1.61*	1.61*	1.62*	1.63*	1.63*	1.64*	1.64*	1.65*
1.450	1.66*	1.66*	1.66*	1.67*	1.67*	1.68*	1.68*	1.69*	1.69*	1.70*
1.460	1.70*	1.71*	1.71*	1.72*	1.72*	1.72*	1.73*	1.73*	1.74*	1.74*
1.470	1.75*	1.75*	1.76*	1.77*	1.77*	1.78*	1.78*	1.79*	1.79*	1.80*
1.480	1.81*	1.81*	1.81*	1.82*	1.82*	1.83*	1.83*	1.84*	1.84*	1.85*
1.490	1.85*	1.86*	1.86*	1.87*	1.87*	1.88*	1.88*	1.88*	1.89*	1.89*
1.500	1.90*	1.90^	1.91^	1.92^	1.92^	1.93^	1.93^	1.94^	1.94^	1.95^
1.510	1.96^	1.96^	1.97^	1.97^	1.97^	1.98^	1.98^	1.99^	1.99^	2.00^
1.520	2.00^	2.01^	2.02^	2.03^	2.03^	2.04^	2.05^	2.06^	2.07^	2.08^
1.530	2.08^	2.09^	2.10^	2.11^	2.12^	2.12^	2.13^	2.14^	2.15^	2.16^
1.540	2.16^	2.17^	2.18^	2.19^	2.20^	2.20^	2.21^	2.22^	2.23^	2.24^
1.550	2.25^	2.25^	2.26^	2.27^	2.28^	2.29^	2.30^	2.31^	2.32^	2.33^
1.560	2.34^	2.35^	2.35^	2.36^	2.37^	2.38^	2.39^	2.39^	2.40^	2.41^
1.570	2.42^	2.43^	2.44^	2.44^	2.45^	2.46^	2.47^	2.48^	2.48^	2.49^
1.580	2.50^	2.51^	2.52^	2.52^	2.53^	2.54^	2.55^	2.56^	2.56^	2.57^
1.590	2.58^	2.59^	2.60^	2.61^	2.61^	2.62^	2.63^	2.64^	2.65^	2.65^
1.600	2.66^	2.67^	2.68^	2.69^	2.70^	2.71^	2.72^	2.73^	2.74^	2.75^
1.610	2.75^	2.76^	2.77^	2.78^	2.79^	2.80^	2.80^	2.81^	2.82^	2.83^
1.620	2.84^	2.84^	2.85^	2.86^	2.87^	2.88^	2.88^	2.89^	2.90^	2.91^
1.630	2.92^	2.92^	2.93^	2.94^	2.95^	2.96^	2.97^	2.97^	2.98^	2.99^
1.640	3.00^	3.01^	3.01^	3.02^	3.03^	3.04^	3.05^	3.05^	3.06^	3.07^
1.650	3.08^	3.09^	3.10^	3.11^	3.12^	3.13^	3.13^	3.14^	3.15^	3.16^
1.660	3.17^	3.18^	3.19^	3.20^	3.20^	3.21^	3.22^	3.23^	3.24^	3.24^
1.670	3.25^	3.26^	3.27^	3.28^	3.28^	3.29^	3.30^	3.31^	3.32^	3.33^
1.680	3.33^	3.34^	3.35^	3.36^	3.37^	3.37^	3.38^	3.39^	3.40^	3.41^
1.690	3.41^	3.42^	3.43^	3.44^	3.45^	3.45^	3.46^	3.47^	3.48^	3.49^
1.700	3.50^	3.50^	3.51^	3.52^	3.53^	3.54^	3.55^	3.56^	3.57^	3.58^
1.710	3.59^	3.60^	3.60^	3.61^	3.62^	3.63^	3.64^	3.64^	3.65^	3.66^
1.720	3.67^	3.68^	3.69^	3.69^	3.70^	3.71^	3.72^	3.73^	3.73^	3.74^
1.730	3.75^	3.76^	3.77^	3.77^	3.78^	3.79^	3.80^	3.81^	3.81^	3.82^
1.740	3.83^	3.84^	3.85^	3.86^	3.86^	3.87^	3.88^	3.89^	3.90^	3.90^
1.750	3.91^	3.92^	3.93^	3.94^	3.95^	3.96^	3.97^	3.98^	3.99^	4.00^
1.760	4.00^	4.01^	4.02^	4.03^	4.04^	4.05^	4.05^	4.06^	4.07^	4.08^
1.770	4.09^	4.09^	4.10^	4.11^	4.12^	4.13^	4.13^	4.14^	4.15^	4.16^
1.780	4.17^	4.17^	4.18^	4.19^	4.20^	4.21^	4.22^	4.22^	4.23^	4.24^
1.790	4.25^	4.26^	4.26^	4.27^	4.28^	4.29^	4.30^	4.30^	4.31^	4.32^

ALS Hydrographics NATIONAL HYRATAB V173 Output 24/04/2020

Site 300022 Wongawilly Creek

Rating Table 1.02 26/10/2007 to Present Interpolation = Lin CTF = 0.7000

Converting 100 Stream Water Level in Metres
Into 140 Stream Discharge Cumecs in Cumecs

G.H.	0	0.001	0.002	0.003	0.004	0.005	0.006	0.007	0.008	0.009
1.800	4.33^	4.34^	4.35^	4.36^	4.37^	4.38^	4.38^	4.39^	4.40^	4.41^
1.810	4.42^	4.43^	4.44^	4.45^	4.45^	4.46^	4.47^	4.48^	4.49^	4.49^
1.820	4.50^	4.51^	4.52^	4.53^	4.53^	4.54^	4.55^	4.56^	4.57^	4.58^
1.830	4.58^	4.59^	4.60^	4.61^	4.62^	4.62^	4.63^	4.64^	4.65^	4.66^
1.840	4.66^	4.67^	4.68^	4.69^	4.70^	4.70^	4.71^	4.72^	4.73^	4.74^
1.850	4.75^	4.75^	4.76^	4.77^	4.78^	4.79^	4.80^	4.81^	4.82^	4.83^
1.860	4.84^	4.85^	4.85^	4.86^	4.87^	4.88^	4.89^	4.89^	4.90^	4.91^
1.870	4.92^	4.93^	4.94^	4.94^	4.95^	4.96^	4.97^	4.98^	4.98^	4.99^
1.880	5.00^	5.01^	5.03^	5.04^	5.05^	5.06^	5.08^	5.09^	5.10^	5.11^
1.890	5.13^	5.14^	5.15^	5.17^	5.18^	5.19^	5.20^	5.22^	5.23^	5.24^
1.900	5.25^	5.27^	5.28^	5.29^	5.30^	5.31^	5.32^	5.34^	5.35^	5.36^
1.910	5.37^	5.38^	5.40^	5.41^	5.42^	5.43^	5.45^	5.46^	5.47^	5.48^
1.920	5.50^	5.51^	5.52^	5.54^	5.55^	5.56^	5.57^	5.59^	5.60^	5.61^
1.930	5.63^	5.64^	5.65^	5.66^	5.68^	5.69^	5.70^	5.71^	5.73^	5.74^
1.940	5.75^	5.77^	5.78^	5.79^	5.80^	5.82^	5.83^	5.84^	5.85^	5.87^
1.950	5.88^	5.89^	5.90^	5.91^	5.93^	5.94^	5.95^	5.96^	5.97^	5.98^
1.960	6.00^	6.01^	6.02^	6.03^	6.05^	6.06^	6.07^	6.08^	6.10^	6.11^
1.970	6.12^	6.14^	6.15^	6.16^	6.17^	6.19^	6.20^	6.21^	6.22^	6.24^
1.980	6.25^	6.26^	6.28^	6.29^	6.30^	6.31^	6.33^	6.34^	6.35^	6.36^
1.990	6.38^	6.39^	6.40^	6.42^	6.43^	6.44^	6.45^	6.47^	6.48^	6.49^
2.000	6.50^	6.52^	6.53^	6.54^	6.55^	6.56^	6.57^	6.59^	6.60^	6.61^
2.010	6.62^	6.63^	6.65^	6.66^	6.67^	6.68^	6.70^	6.71^	6.72^	6.73^
2.020	6.75^	6.76^	6.77^	6.79^	6.80^	6.81^	6.82^	6.84^	6.85^	6.86^
2.030	6.88^	6.89^	6.90^	6.91^	6.93^	6.94^	6.95^	6.96^	6.98^	6.99^
2.040	7.00^	7.02^	7.03^	7.04^	7.05^	7.07^	7.08^	7.09^	7.10^	7.12^
2.050	7.13^	7.14^	7.15^	7.16^	7.18^	7.19^	7.20^	7.21^	7.22^	7.23^
2.060	7.25^	7.26^	7.27^	7.28^	7.30^	7.31^	7.32^	7.33^	7.35^	7.36^
2.070	7.37^	7.39^	7.40^	7.41^	7.42^	7.44^	7.45^	7.46^	7.47^	7.49^
2.080	7.50^	7.51^	7.53^	7.54^	7.55^	7.56^	7.58^	7.59^	7.60^	7.61^
2.090	7.63^	7.64^	7.65^	7.67^	7.68^	7.69^	7.70^	7.72^	7.73^	7.74^
2.100	7.75^	7.77^	7.78^	7.79^	7.80^	7.81^	7.82^	7.84^	7.85^	7.86^
2.110	7.87^	7.88^	7.90^	7.91^	7.92^	7.93^	7.95^	7.96^	7.97^	7.98^
2.120	8.00^	8.01^	8.02^	8.04^	8.05^	8.06^	8.07^	8.09^	8.10^	8.11^
2.130	8.13^	8.14^	8.15^	8.16^	8.18^	8.19^	8.20^	8.21^	8.23^	8.24^
2.140	8.25^	8.27^	8.28^	8.29^	8.30^	8.32^	8.33^	8.34^	8.35^	8.37^
2.150	8.38^	8.39^	8.40^	8.41^	8.43^	8.44^	8.45^	8.46^	8.47^	8.48^
2.160	8.50^	8.51^	8.52^	8.53^	8.55^	8.56^	8.57^	8.58^	8.60^	8.61^

ALS Hydrographics NATIONAL HYRATAB V173 Output 24/04/2020

Site 300022 Wongawilly Creek

Rating Table 1.02 26/10/2007 to Present Interpolation = Lin CTF = 0.7000

Converting 100 Stream Water Level in Metres
Into 140 Stream Discharge Cumecs in Cumecs

G.H.	0	0.001	0.002	0.003	0.004	0.005	0.006	0.007	0.008	0.009
2.170	8.62^	8.64^	8.65^	8.66^	8.67^	8.69^	8.70^	8.71^	8.72^	8.74^
2.180	8.75^	8.76^	8.78^	8.79^	8.80^	8.81^	8.83^	8.84^	8.85^	8.86^
2.190	8.88^	8.89^	8.90^	8.92^	8.93^	8.94^	8.95^	8.97^	8.98^	8.99^
2.200	9.00^	9.02^	9.03^	9.04^	9.05^	9.06^	9.07^	9.09^	9.10^	9.11^
2.210	9.12^	9.13^	9.15^	9.16^	9.17^	9.18^	9.20^	9.21^	9.22^	9.23^
2.220	9.25^	9.26^	9.27^	9.29^	9.30^	9.31^	9.32^	9.34^	9.35^	9.36^
2.230	9.38^	9.39^	9.40^	9.41^	9.43^	9.44^	9.45^	9.46^	9.48^	9.49^
2.240	9.50^	9.51^	9.52^	9.53^	9.53^	9.54^	9.55^	9.56^	9.57^	9.58^
2.250	9.58^	9.60^	9.62^	9.63^	9.65^	9.66^	9.68^	9.70^	9.71^	9.73^
2.260	9.75^	9.76^	9.77^	9.78^	9.80^	9.81^	9.82^	9.83^	9.85^	9.86^
2.270	9.87^	9.89^	9.90^	9.91^	9.92^	9.94^	9.95^	9.96^	9.97^	9.99^
2.280	10.0^	10.0^	10.0^	10.1^	10.1^	10.1^	10.1^	10.1^	10.1^	10.2^
2.290	10.2^	10.2^	10.2^	10.2^	10.3^	10.3^	10.3^	10.3^	10.3^	10.3^
2.300	10.4^	10.4^	10.4^	10.4^	10.4^	10.5^	10.5^	10.5^	10.5^	10.5^
2.310	10.5^	10.6^	10.6^	10.6^	10.6^	10.6^	10.7^	10.7^	10.7^	10.7^
2.320	10.7^	10.7^	10.8^	10.8^	10.8^	10.8^	10.8^	10.9^	10.9^	10.9^
2.330	10.9^	10.9^	10.9^	11.0^	11.0^	11.0^	11.0^	11.0^	11.1^	11.1^
2.340	11.1^	11.1^	11.1^	11.1^	11.2^	11.2^	11.2^	11.2^	11.2^	11.3^
2.350	11.3^	11.3^	11.3^	11.3^	11.3^	11.4^	11.4^	11.4^	11.4^	11.4^
2.360	11.5^	11.5^	11.5^	11.5^	11.5^	11.5^	11.6^	11.6^	11.6^	11.6^
2.370	11.6^	11.7^	11.7^	11.7^	11.7^	11.7^	11.7^	11.8^	11.8^	11.8^
2.380	11.8^	11.8^	11.9^	11.9^	11.9^	11.9^	11.9^	11.9^	12.0^	12.0^
2.390	12.0^	12.0^	12.0^	12.1^	12.1^	12.1^	12.1^	12.1^	12.2^	12.2^
2.400	12.2^	12.2^	12.2^	12.2^	12.3^	12.3^	12.3^	12.3^	12.3^	12.3^
2.410	12.4^	12.4^	12.4^	12.4^	12.4^	12.5^	12.5^	12.5^	12.5^	12.5^
2.420	12.5^	12.6^	12.6^	12.6^	12.6^	12.6^	12.7^	12.7^	12.7^	12.7^
2.430	12.7^	12.7^	12.8^	12.8^	12.8^	12.8^	12.8^	12.9^	12.9^	12.9^
2.440	12.9^	12.9^	12.9^	13.0^	13.0^	13.0^	13.0^	13.0^	13.1^	13.1^
2.450	13.1^	13.1^	13.1^	13.1^	13.2^	13.2^	13.2^	13.2^	13.2^	13.3^
2.460	13.3^	13.3^	13.3^	13.3^	13.3^	13.4^	13.4^	13.4^	13.4^	13.4^
2.470	13.4^	13.5^	13.5^	13.5^	13.5^	13.5^	13.6^	13.6^	13.6^	13.6^
2.480	13.6^	13.7^	13.7^	13.7^	13.7^	13.7^	13.7^	13.8^	13.8^	13.8^
2.490	13.8^	13.8^	13.9^	13.9^	13.9^	13.9^	13.9^	13.9^	14.0^	14.0^
2.500	14.0^	14.0^	14.0^	14.1^	14.1^	14.1^	14.1^	14.1^	14.1^	14.2^
2.510	14.2^	14.2^	14.2^	14.2^	14.3^	14.3^	14.3^	14.3^	14.3^	14.3^
2.520	14.4^	14.4^	14.4^	14.4^	14.4^	14.5^	14.5^	14.5^	14.5^	14.5^

ALS Hydrographics NATIONAL HYRATAB V173 Output 24/04/2020

Site 300022 Wongawilly Creek

Rating Table 1.02 26/10/2007 to Present Interpolation = Lin CTF = 0.7000

Converting 100 Stream Water Level in Metres
Into 140 Stream Discharge Cumecs in Cumecs

G.H.	0	0.001	0.002	0.003	0.004	0.005	0.006	0.007	0.008	0.009
2.530	14.5^	14.6^	14.6^	14.6^	14.6^	14.6^	14.7^	14.7^	14.7^	14.7^
2.540	14.7^	14.7^	14.8^	14.8^	14.8^	14.8^	14.8^	14.9^	14.9^	14.9^
2.550	14.9^	14.9^	14.9^	15.0^	15.0^	15.0^	15.0^	15.0^	15.1^	15.1^
2.560	15.1^	15.1^	15.1^	15.1^	15.2^	15.2^	15.2^	15.2^	15.2^	15.3^
2.570	15.3^	15.3^	15.3^	15.3^	15.3^	15.4^	15.4^	15.4^	15.4^	15.4^
2.580	15.5^	15.5^	15.5^	15.5^	15.5^	15.5^	15.6^	15.6^	15.6^	15.6^
2.590	15.6^	15.7^	15.7^	15.7^	15.7^	15.7^	15.7^	15.8^	15.8^	15.8^
2.600	15.8^	15.8^	15.9^	15.9^	15.9^	15.9^	15.9^	15.9^	16.0^	16.0^
2.610	16.0^	16.0^	16.0^	16.1^	16.1^	16.1^	16.1^	16.1^	16.1^	16.2^
2.620	16.2^	16.2^	16.2^	16.2^	16.3^	16.3^	16.3^	16.3^	16.3^	16.3^
2.630	16.4^	16.4^	16.4^	16.4^	16.4^	16.5^	16.5^	16.5^	16.5^	16.5^
2.640	16.5^	16.6^	16.6^	16.6^	16.6^	16.6^	16.7^	16.7^	16.7^	16.7^
2.650	16.7^	16.7^	16.8^	16.8^	16.8^	16.8^	16.8^	16.9^	16.9^	16.9^
2.660	16.9^	16.9^	16.9^	17.0^	17.0^	17.0^	17.0^	17.0^	17.1^	17.1^
2.670	17.1^	17.1^	17.1^	17.1^	17.2^	17.2^	17.2^	17.2^	17.2^	17.3^
2.680	17.3^	17.3^	17.3^	17.3^	17.3^	17.4^	17.4^	17.4^	17.4^	17.4^
2.690	17.5^	17.5^	17.5^	17.5^	17.5^	17.5^	17.6^	17.6^	17.6^	17.6^
2.700	17.6^	17.7^	17.7^	17.7^	17.7^	17.7^	17.7^	17.8^	17.8^	17.8^
2.710	17.8^	17.8^	17.8^	17.9^	17.9^	17.9^	17.9^	17.9^	18.0^	18.0^
2.720	18.0^	18.0^	18.0^	18.1^	18.1^	18.1^	18.1^	18.1^	18.1^	18.2^
2.730	18.2^	18.2^	18.2^	18.2^	18.3^	18.3^	18.3^	18.3^	18.3^	18.3^
2.740	18.4^	18.4^	18.4^	18.4^	18.4^	18.5^	18.5^	18.5^	18.5^	18.5^
2.750	18.5^	18.6^	18.6^	18.6^	18.6^	18.6^	18.7^	18.7^	18.7^	18.7^
2.760	18.7^	18.7^	18.8^	18.8^	18.8^	18.8^	18.8^	18.9^	18.9^	18.9^
2.770	18.9^	18.9^	18.9^	19.0^	19.0^	19.0^	19.0^	19.0^	19.1^	19.1^
2.780	19.1^	19.1^	19.1^	19.1^	19.2^	19.2^	19.2^	19.2^	19.2^	19.3^
2.790	19.3^	19.3^	19.3^	19.3^	19.3^	19.4^	19.4^	19.4^	19.4^	19.4^
2.800	19.5^	19.5^	19.5^	19.5^	19.5^	19.5^	19.6^	19.6^	19.6^	19.6^
2.810	19.6^	19.7^	19.7^	19.7^	19.7^	19.7^	19.7^	19.8^	19.8^	19.8^
2.820	19.8^	19.8^	19.9^	19.9^	19.9^	19.9^	19.9^	19.9^	20.0^	20.0^
2.830	20.0^	20.0^	20.1^	20.1^	20.1^	20.2^	20.2^	20.2^	20.2^	20.3^
2.840	20.3^	20.3^	20.4^	20.4^	20.4^	20.5^	20.5^	20.5^	20.5^	20.6^
2.850	20.6^	20.6^	20.7^	20.7^	20.7^	20.8^	20.8^	20.8^	20.9^	20.9^
2.860	20.9^	20.9^	21.0^	21.0^	21.0^	21.1^	21.1^	21.1^	21.2^	21.2^
2.870	21.2^	21.2^	21.3^	21.3^	21.3^	21.4^	21.4^	21.4^	21.5^	21.5^
2.880	21.5^	21.5^	21.6^	21.6^	21.6^	21.7^	21.7^	21.7^	21.8^	21.8^
2.890	21.8^	21.8^	21.9^	21.9^	21.9^	22.0^	22.0^	22.0^	22.1^	22.1^

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Site 300022 Wongawilly Creek

Rating Table 1.02 26/10/2007 to Present Interpolation = Lin CTF = 0.7000

Converting 100 Stream Water Level in Metres
Into 140 Stream Discharge Cumecs in Cumecs

G.H.	0	0.001	0.002	0.003	0.004	0.005	0.006	0.007	0.008	0.009
2.900	22.1^	22.1^	22.2^	22.2^	22.2^	22.3^	22.3^	22.3^	22.4^	22.4^
2.910	22.4^	22.5^	22.5^	22.5^	22.5^	22.6^	22.6^	22.6^	22.7^	22.7^
2.920	22.7^	22.8^	22.8^	22.8^	22.9^	22.9^	22.9^	22.9^	23.0^	23.0^
2.930	23.0^	23.1^	23.1^	23.1^	23.2^	23.2^	23.2^	23.2^	23.3^	23.3^
2.940	23.3^	23.4^	23.4^	23.4^	23.5^	23.5^	23.5^	23.5^	23.6^	23.6^
2.950	23.6^	23.7^	23.7^	23.7^	23.8^	23.8^	23.8^	23.8^	23.9^	23.9^
2.960	23.9^	24.0^	24.0^	24.0^	24.1^	24.1^	24.1^	24.2^	24.2^	24.2^
2.970	24.2^	24.3^	24.3^	24.3^	24.4^	24.4^	24.4^	24.5^	24.5^	24.5^
2.980	24.5^	24.6^	24.6^	24.6^	24.7^	24.7^	24.7^	24.8^	24.8^	24.8^
2.990	24.8^	24.9^	24.9^	24.9^	25.0^	25.0^	25.0^	25.1^	25.1^	25.1^
3.000	25.2^	25.2^	25.2^	25.2^	25.3^	25.3^	25.3^	25.4^	25.4^	25.4^
3.010	25.5^	25.5^	25.5^	25.5^	25.6^	25.6^	25.6^	25.7^	25.7^	25.7^
3.020	25.8^	25.8^	25.8^	25.8^	25.9^	25.9^	25.9^	26.0^	26.0^	26.0^
3.030	26.1^	26.1^	26.1^	26.2^	26.2^	26.2^	26.2^	26.3^	26.3^	26.3^
3.040	26.4^	26.4^	26.4^	26.5^	26.5^	26.5^	26.5^	26.6^	26.6^	26.6^
3.050	26.7^	26.7^	26.7^	26.8^	26.8^	26.8^	26.8^	26.9^	26.9^	26.9^
3.060	27.0^	27.0^	27.0^	27.1^	27.1^	27.1^	27.1^	27.2^	27.2^	27.2^
3.070	27.3^	27.3^	27.3^	27.4^	27.4^	27.4^	27.5^	27.5^	27.5^	27.5^
3.080	27.6^	27.6^	27.6^	27.7^	27.7^	27.7^	27.8^	27.8^	27.8^	27.9^
3.090	27.9^	27.9^	27.9^	28.0^	28.0^	28.0^	28.1^	28.1^	28.1^	28.2^
3.100	28.2^	28.2^	28.2^	28.3^	28.3^	28.3^	28.4^	28.4^	28.4^	28.5^
3.110	28.5^	28.5^	28.5^	28.6^	28.6^	28.6^	28.7^	28.7^	28.7^	28.8^
3.120	28.8^	28.8^	28.8^	28.9^	28.9^	28.9^	29.0^	29.0^	29.0^	29.1^
3.130	29.1^	29.1^	29.1^	29.2^	29.2^	29.2^	29.3^	29.3^	29.3^	29.4^
3.140	29.4^	29.4^	29.5^	29.5^	29.5^	29.5^	29.6^	29.6^	29.6^	29.7^
3.150	29.7^	29.7^	29.8^	29.8^	29.8^	29.8^	29.9^	29.9^	29.9^	30.0^
3.160	30.0^	30.0^	30.1^	30.1^	30.1^	30.2^	30.2^	30.2^	30.2^	30.3^
3.170	30.3^	30.3^	30.4^	30.4^	30.4^	30.5^	30.5^	30.5^	30.5^	30.6^
3.180	30.6^	30.6^	30.7^	30.7^	30.7^	30.8^	30.8^	30.8^	30.9^	30.9^
3.190	30.9^	30.9^	31.0^	31.0^	31.0^	31.1^	31.1^	31.1^	31.2^	31.2^
3.200	31.2^	31.2^	31.3^	31.3^	31.3^	31.4^	31.4^	31.4^	31.5^	31.5^
3.210	31.5^	31.5^	31.6^	31.6^	31.6^	31.7^	31.7^	31.7^	31.8^	31.8^
3.220	31.8^	31.8^	31.9^	31.9^	31.9^	32.0^	32.0^	32.0^	32.1^	32.1^
3.230	32.1^	32.1^	32.2^	32.2^	32.2^	32.3^	32.3^	32.3^	32.4^	32.4^
3.240	32.4^	32.5^	32.5^	32.5^	32.5^	32.6^	32.6^	32.6^	32.7^	32.7^
3.250	32.7^	32.8^	32.8^	32.8^	32.9^	32.9^	32.9^	32.9^	33.0^	33.0^
3.260	33.0^	33.1^	33.1^	33.1^	33.2^	33.2^	33.2^	33.2^	33.3^	33.3^

ALS Hydrographics NATIONAL HYRATAB V173 Output 24/04/2020

Site 300022 Wongawilly Creek

Rating Table 1.02 26/10/2007 to Present Interpolation = Lin CTF = 0.7000

Converting 100 Stream Water Level in Metres
Into 140 Stream Discharge Cumecs in Cumecs

G.H.	0	0.001	0.002	0.003	0.004	0.005	0.006	0.007	0.008	0.009
3.270	33.3^	33.4^	33.4^	33.4^	33.5^	33.5^	33.5^	33.5^	33.6^	33.6^
3.280	33.6^	33.7^	33.7^	33.7^	33.8^	33.8^	33.8^	33.8^	33.9^	33.9^
3.290	33.9^	34.0^	34.0^	34.0^	34.1^	34.1^	34.1^	34.2^	34.2^	34.2^
3.300	34.2^	34.3^	34.3^	34.3^	34.4^	34.4^	34.4^	34.5^	34.5^	34.5^
3.310	34.5^	34.6^	34.6^	34.6^	34.7^	34.7^	34.7^	34.8^	34.8^	34.8^
3.320	34.8^	34.9^	34.9^	34.9^	35.0^	35.0^	35.0^	35.1^	35.1^	35.1^
3.330	35.2^	35.2^	35.2^	35.2^	35.3^	35.3^	35.3^	35.4^	35.4^	35.4^
3.340	35.5^	35.5^	35.5^	35.5^	35.6^	35.6^	35.6^	35.7^	35.7^	35.7^
3.350	35.8^	35.8^	35.8^	35.8^	35.9^	35.9^	35.9^	36.0^	36.0^	36.0^
3.360	36.1^	36.1^	36.1^	36.2^	36.2^	36.2^	36.2^	36.3^	36.3^	36.3^
3.370	36.4^	36.4^	36.4^	36.5^	36.5^	36.5^	36.5^	36.6^	36.6^	36.6^
3.380	36.7^	36.7^	36.7^	36.8^	36.8^	36.8^	36.8^	36.9^	36.9^	36.9^
3.390	37.0^	37.0^	37.0^	37.1^	37.1^	37.1^	37.1^	37.2^	37.2^	37.2^
3.400	37.3^	37.3^	37.3^	37.4^	37.4^	37.4^	37.5^	37.5^	37.5^	37.6^
3.410	37.6^	37.6^	37.7^	37.7^	37.7^	37.7^	37.8^	37.8^	37.8^	37.9^
3.420	37.9^	37.9^	38.0^	38.0^	38.0^	38.1^	38.1^	38.1^	38.2^	38.2^
3.430	38.2^	38.3^	38.3^	38.3^	38.4^	38.4^	38.4^	38.4^	38.5^	38.5^
3.440	38.5^	38.6^	38.6^	38.6^	38.7^	38.7^	38.7^	38.8^	38.8^	38.8^
3.450	38.9^	38.9^	38.9^	39.0^	39.0^	39.0^	39.1^	39.1^	39.1^	39.1^
3.460	39.2^	39.2^	39.2^	39.3^	39.3^	39.3^	39.4^	39.4^	39.4^	39.5^
3.470	39.5^	39.5^	39.6^	39.6^	39.6^	39.7^	39.7^	39.7^	39.8^	39.8^
3.480	39.8^	39.8^	39.9^	39.9^	39.9^	40.0^	40.0^	40.0^	40.1^	40.1^
3.490	40.1^	40.2^	40.2^	40.2^	40.3^	40.3^	40.3^	40.4^	40.4^	40.4^
3.500	40.5^	40.5^	40.5^	40.5^	40.6^	40.6^	40.6^	40.7^	40.7^	40.7^
3.510	40.8^	40.8^	40.8^	40.9^	40.9^	40.9^	41.0^	41.0^	41.0^	41.1^
3.520	41.1^	41.1^	41.2^	41.2^	41.2^	41.2^	41.3^	41.3^	41.3^	41.4^
3.530	41.4^	41.4^	41.5^	41.5^	41.5^	41.6^	41.6^	41.6^	41.7^	41.7^
3.540	41.7^	41.8^	41.8^	41.8^	41.9^	41.9^	41.9^	41.9^	42.0^	42.0^
3.550	42.0^	42.1^	42.1^	42.1^	42.2^	42.2^	42.2^	42.3^	42.3^	42.3^
3.560	42.4^	42.4^	42.4^	42.5^	42.5^	42.5^	42.6^	42.6^	42.6^	42.6^
3.570	42.7^	42.7^	42.7^	42.8^	42.8^	42.8^	42.9^	42.9^	42.9^	43.0^
3.580	43.0^	43.0^	43.1^	43.1^	43.1^	43.2^	43.2^	43.2^	43.3^	43.3^
3.590	43.3^	43.3^	43.4^	43.4^	43.4^	43.5^	43.5^	43.5^	43.6^	43.6^
3.600	43.6^	43.7^	43.7^	43.7^	43.8^	43.8^	43.8^	43.9^	43.9^	43.9^
3.610	44.0^	44.0^	44.0^	44.0^	44.1^	44.1^	44.1^	44.2^	44.2^	44.2^
3.620	44.3^	44.3^	44.3^	44.4^	44.4^	44.4^	44.5^	44.5^	44.5^	44.6^

ALS Hydrographics NATIONAL HYRATAB V173 Output 24/04/2020

Site 300022 Wongawilly Creek

Rating Table 1.02 26/10/2007 to Present Interpolation = Lin CTF = 0.7000

Converting 100 Stream Water Level in Metres
Into 140 Stream Discharge Cumecs in Cumecs

G.H.	0	0.001	0.002	0.003	0.004	0.005	0.006	0.007	0.008	0.009
3.630	44.6^	44.6^	44.7^	44.7^	44.7^	44.7^	44.8^	44.8^	44.8^	44.9^
3.640	44.9^	44.9^	45.0^	45.0^	45.0^	45.1^	45.1^	45.1^	45.2^	45.2^
3.650	45.2^	45.3^	45.3^	45.3^	45.4^	45.4^	45.4^	45.4^	45.5^	45.5^
3.660	45.5^	45.6^	45.6^	45.6^	45.7^	45.7^	45.7^	45.8^	45.8^	45.8^
3.670	45.9^	45.9^	45.9^	46.0^	46.0^	46.0^	46.1^	46.1^	46.1^	46.1^
3.680	46.2^	46.2^	46.2^	46.3^	46.3^	46.3^	46.4^	46.4^	46.4^	46.5^
3.690	46.5^	46.5^	46.6^	46.6^	46.6^	46.7^	46.7^	46.7^	46.8^	46.8^
3.700	46.8^	46.8^	46.9^	46.9^	46.9^	47.0^	47.0^	47.0^	47.1^	47.1^
3.710	47.1^	47.2^	47.2^	47.2^	47.3^	47.3^	47.3^	47.4^	47.4^	47.4^
3.720	47.5^	47.5^	47.5^	47.5^	47.6^	47.6^	47.6^	47.7^	47.7^	47.7^
3.730	47.8^	47.8^	47.8^	47.9^	47.9^	47.9^	48.0^	48.0^	48.0^	48.1^
3.740	48.1^	48.1^	48.2^	48.2^	48.2^	48.2^	48.3^	48.3^	48.3^	48.4^
3.750	48.4^	48.4^	48.5^	48.5^	48.5^	48.6^	48.6^	48.6^	48.7^	48.7^
3.760	48.7^	48.8^	48.8^	48.8^	48.9^	48.9^	48.9^	48.9^	49.0^	49.0^
3.770	49.0^	49.1^	49.1^	49.1^	49.2^	49.2^	49.2^	49.3^	49.3^	49.3^
3.780	49.4^	49.4^	49.4^	49.5^	49.5^	49.5^	49.6^	49.6^	49.6^	49.6^
3.790	49.7^	49.7^	49.7^	49.8^	49.8^	49.8^	49.9^	49.9^	49.9^	50.0^
3.800	50.0^	50.0^	50.1^	50.1^	50.1^	50.2^	50.2^	50.2^	50.3^	50.3^
3.810	50.3^	50.4^	50.4^	50.4^	50.5^	50.5^	50.5^	50.6^	50.6^	50.6^
3.820	50.7^	50.7^	50.7^	50.7^	50.8^	50.8^	50.8^	50.9^	50.9^	50.9^
3.830	51.0^	51.0^	51.0^	51.1^	51.1^	51.1^	51.2^	51.2^	51.2^	51.3^
3.840	51.3^	51.3^	51.4^	51.4^	51.4^	51.5^	51.5^	51.5^	51.6^	51.6^
3.850	51.6^	51.7^	51.7^	51.7^	51.8^	51.8^	51.8^	51.9^	51.9^	51.9^
3.860	52.0^	52.0^	52.0^	52.0^	52.1^	52.1^	52.1^	52.2^	52.2^	52.2^
3.870	52.3^	52.3^	52.3^	52.4^	52.4^	52.4^	52.5^	52.5^	52.5^	52.6^
3.880	52.6^	52.6^	52.7^	52.7^	52.7^	52.8^	52.8^	52.8^	52.9^	52.9^
3.890	52.9^	53.0^	53.0^	53.0^	53.1^	53.1^	53.1^	53.2^	53.2^	53.2^
3.900	53.3^	53.3^	53.3^	53.3^	53.4^	53.4^	53.4^	53.5^	53.5^	53.5^
3.910	53.6^	53.6^	53.6^	53.7^	53.7^	53.7^	53.8^	53.8^	53.8^	53.9^
3.920	53.9^	53.9^	54.0^	54.0^	54.0^	54.1^	54.1^	54.1^	54.2^	54.2^
3.930	54.2^	54.3^	54.3^	54.3^	54.4^	54.4^	54.4^	54.5^	54.5^	54.5^
3.940	54.6^	54.6^	54.6^	54.6^	54.7^	54.7^	54.7^	54.8^	54.8^	54.8^
3.950	54.9^	54.9^	54.9^	55.0^	55.0^	55.0^	55.1^	55.1^	55.1^	55.2^
3.960	55.2^	55.2^	55.3^	55.3^	55.3^	55.4^	55.4^	55.4^	55.5^	55.5^
3.970	55.5^	55.6^	55.6^	55.6^	55.7^	55.7^	55.7^	55.8^	55.8^	55.8^
3.980	55.9^	55.9^	55.9^	55.9^	56.0^	56.0^	56.0^	56.1^	56.1^	56.1^
3.990	56.2^	56.2^	56.2^	56.3^	56.3^	56.3^	56.4^	56.4^	56.4^	56.5^

ALS Hydrographics NATIONAL HYRATAB V173 Output 24/04/2020

Site 300022 Wongawilly Creek

Rating Table 1.02 26/10/2007 to Present Interpolation = Lin CTF = 0.7000

Converting 100 Stream Water Level in Metres
Into 140 Stream Discharge Cumecs in Cumecs

G.H.	0	0.001	0.002	0.003	0.004	0.005	0.006	0.007	0.008	0.009
4.000	56.5^	56.5^	56.6^	56.6^	56.6^	56.7^	56.7^	56.7^	56.8^	56.8^
4.010	56.8^	56.9^	56.9^	56.9^	57.0^	57.0^	57.0^	57.1^	57.1^	57.1^
4.020	57.2^	57.2^	57.2^	57.2^	57.3^	57.3^	57.3^	57.4^	57.4^	57.4^
4.030	57.5^	57.5^	57.5^	57.6^	57.6^	57.6^	57.7^	57.7^	57.7^	57.8^
4.040	57.8^	57.8^	57.9^	57.9^	57.9^	58.0^	58.0^	58.0^	58.1^	58.1^
4.050	58.1^	58.2^	58.2^	58.2^	58.3^	58.3^	58.3^	58.4^	58.4^	58.4^
4.060	58.5^	58.5^	58.5^	58.5^	58.6^	58.6^	58.6^	58.7^	58.7^	58.7^
4.070	58.8^	58.8^	58.8^	58.9^	58.9^	58.9^	59.0^	59.0^	59.0^	59.1^
4.080	59.1^	59.1^	59.2^	59.2^	59.2^	59.3^	59.3^	59.3^	59.4^	59.4^
4.090	59.4^	59.5^	59.5^	59.5^	59.6^	59.6^	59.6^	59.7^	59.7^	59.7^
4.100	59.8^	59.8^	59.8^	59.8^	59.9^	59.9^	59.9^	60.0^	60.0^	60.0^
4.110	60.1^	60.1^	60.1^	60.2^	60.2^	60.2^	60.3^	60.3^	60.3^	60.4^
4.120	60.4^	60.4^	60.5^	60.5^	60.5^	60.6^	60.6^	60.6^	60.7^	60.7^
4.130	60.7^	60.8^	60.8^	60.8^	60.9^	60.9^	60.9^	61.0^	61.0^	61.0^
4.140	61.1^	61.1^	61.1^	61.1^	61.2^	61.2^	61.2^	61.3^	61.3^	61.3^
4.150	61.4^	61.4^	61.4^	61.5^	61.5^	61.5^	61.6^	61.6^	61.6^	61.7^
4.160	61.7^	61.7^	61.8^	61.8^	61.8^	61.9^	61.9^	61.9^	62.0^	62.0^
4.170	62.0^	62.1^	62.1^	62.1^	62.2^	62.2^	62.2^	62.3^	62.3^	62.3^
4.180	62.4^	62.4^	62.4^	62.4^	62.5^	62.5^	62.5^	62.6^	62.6^	62.6^
4.190	62.7^	62.7^	62.7^	62.8^	62.8^	62.8^	62.9^	62.9^	62.9^	63.0^
4.200	63.0^	63.0^	63.1^	63.1^	63.1^	63.2^	63.2^	63.2^	63.3^	63.3^
4.210	63.3^	63.4^	63.4^	63.4^	63.5^	63.5^	63.5^	63.6^	63.6^	63.6^
4.220	63.7^	63.7^	63.7^	63.7^	63.8^	63.8^	63.8^	63.9^	63.9^	63.9^
4.230	64.0^	64.0^	64.0^	64.1^	64.1^	64.1^	64.2^	64.2^	64.2^	64.3^
4.240	64.3^	64.3^	64.4^	64.4^	64.4^	64.5^	64.5^	64.5^	64.6^	64.6^
4.250	64.6^	64.7^	64.7^	64.7^	64.8^	64.8^	64.8^	64.9^	64.9^	64.9^
4.260	65.0^	65.0^	65.0^	65.0^	65.1^	65.1^	65.1^	65.2^	65.2^	65.2^
4.270	65.3^	65.3^	65.3^	65.4^	65.4^	65.4^	65.5^	65.5^	65.5^	65.6^
4.280	65.6^	65.6^	65.7^	65.7^	65.7^	65.8^	65.8^	65.8^	65.9^	65.9^
4.290	65.9^	66.0^	66.0^	66.0^	66.1^	66.1^	66.1^	66.2^	66.2^	66.2^
4.300	66.3^	66.3^	66.3^	66.3^	66.4^	66.4^	66.4^	66.5^	66.5^	66.5^
4.310	66.6^	66.6^	66.6^	66.7^	66.7^	66.7^	66.8^	66.8^	66.8^	66.9^
4.320	66.9^	66.9^	67.0^	67.0^	67.0^	67.1^	67.1^	67.1^	67.2^	67.2^
4.330	67.2^	67.3^	67.3^	67.3^	67.4^	67.4^	67.4^	67.5^	67.5^	67.5^
4.340	67.6^	67.6^	67.6^	67.6^	67.7^	67.7^	67.7^	67.8^	67.8^	67.8^
4.350	67.9^	67.9^	67.9^	68.0^	68.0^	68.0^	68.1^	68.1^	68.1^	68.2^
4.360	68.2^	68.2^	68.3^	68.3^	68.3^	68.4^	68.4^	68.4^	68.5^	68.5^

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Into 140 Stream Discharge Cumecs in Cumecs

G.H.	0	0.001	0.002	0.003	0.004	0.005	0.006	0.007	0.008	0.009
4.370	68.5^	68.6^	68.6^	68.6^	68.7^	68.7^	68.7^	68.8^	68.8^	68.8^
4.380	68.9^	68.9^	68.9^	68.9^	69.0^	69.0^	69.0^	69.1^	69.1^	69.1^
4.390	69.2^	69.2^	69.2^	69.3^	69.3^	69.3^	69.4^	69.4^	69.4^	69.5^
4.400	69.5^	69.5^	69.6^	69.6^	69.6^	69.7^	69.7^	69.7^	69.8^	69.8^
4.410	69.8^	69.9^	69.9^	69.9^	70.0^	70.0^	70.0^	70.1^	70.1^	70.1^
4.420	70.2^	70.2^	70.2^	70.2^	70.3^	70.3^	70.3^	70.4^	70.4^	70.4^
4.430	70.5^	70.5^	70.5^	70.6^	70.6^	70.6^	70.7^	70.7^	70.7^	70.8^
4.440	70.8^	70.8^	70.9^	70.9^	70.9^	71.0^	71.0^	71.0^	71.1^	71.1^
4.450	71.1^	71.2^	71.2^	71.2^	71.3^	71.3^	71.3^	71.4^	71.4^	71.4^
4.460	71.5^	71.5^	71.5^	71.5^	71.6^	71.6^	71.6^	71.7^	71.7^	71.7^
4.470	71.8^	71.8^	71.8^	71.9^	71.9^	71.9^	72.0^	72.0^	72.0^	72.1^
4.480	72.1^	72.1^	72.2^	72.2^	72.2^	72.3^	72.3^	72.3^	72.4^	72.4^
4.490	72.4^	72.5^	72.5^	72.5^	72.6^	72.6^	72.6^	72.7^	72.7^	72.7^
4.500	72.8^	72.8^	72.8^	72.8^	72.9^	72.9^	72.9^	73.0^	73.0^	73.0^
4.510	73.1^	73.1^	73.1^	73.2^	73.2^	73.2^	73.3^	73.3^	73.3^	73.4^
4.520	73.4^	73.4^	73.5^	73.5^	73.5^	73.6^	73.6^	73.6^	73.7^	73.7^
4.530	73.7^	73.8^	73.8^	73.8^	73.9^	73.9^	73.9^	74.0^	74.0^	74.0^
4.540	74.1^	74.1^	74.1^	74.1^	74.2^	74.2^	74.2^	74.3^	74.3^	74.3^
4.550	74.4^	74.4^	74.4^	74.5^	74.5^	74.5^	74.6^	74.6^	74.6^	74.7^
4.560	74.7^	74.7^	74.8^	74.8^	74.8^	74.9^	74.9^	74.9^	75.0^	75.0^
4.570	75.0^	75.1^	75.1^	75.1^	75.2^	75.2^	75.2^	75.3^	75.3^	75.3^
4.580	75.4^	75.4^	75.4^	75.4^	75.5^	75.5^	75.5^	75.6^	75.6^	75.6^
4.590	75.7^	75.7^	75.7^	75.8^	75.8^	75.8^	75.9^	75.9^	75.9^	76.0^
4.600	76.0^	76.0^	76.1^	76.1^	76.1^	76.2^	76.2^	76.2^	76.3^	76.3^
4.610	76.4^	76.4^	76.4^	76.5^	76.5^	76.5^	76.6^	76.6^	76.6^	76.7^
4.620	76.7^	76.7^	76.8^	76.8^	76.8^	76.9^	76.9^	76.9^	77.0^	77.0^
4.630	77.1^	77.1^	77.1^	77.2^	77.2^	77.2^	77.3^	77.3^	77.3^	77.4^
4.640	77.4^	77.4^	77.5^	77.5^	77.5^	77.6^	77.6^	77.6^	77.7^	77.7^
4.650	77.8^	77.8^	77.8^	77.9^	77.9^	77.9^	78.0^	78.0^	78.0^	78.1^
4.660	78.1^	78.1^	78.2^	78.2^	78.2^	78.3^	78.3^	78.3^	78.4^	78.4^
4.670	78.5^	78.5^	78.5^	78.6^	78.6^	78.6^	78.7^	78.7^	78.7^	78.8^
4.680	78.8^	78.8^	78.9^	78.9^	78.9^	79.0^	79.0^	79.0^	79.1^	79.1^
4.690	79.2^	79.2^	79.2^	79.3^	79.3^	79.3^	79.4^	79.4^	79.4^	79.5^
4.700	79.5^	79.5^	79.6^	79.6^	79.6^	79.7^	79.7^	79.7^	79.8^	79.8^
4.710	79.9^	79.9^	79.9^	80.0^	80.0^	80.0^	80.1^	80.1^	80.1^	80.2^
4.720	80.2^	80.2^	80.3^	80.3^	80.3^	80.4^	80.4^	80.4^	80.5^	80.5^

ALS Hydrographics NATIONAL HYRATAB V173 Output 24/04/2020

Site 300022 Wongawilly Creek

Rating Table 1.02 26/10/2007 to Present Interpolation = Lin CTF = 0.7000

Converting 100 Stream Water Level in Metres
Into 140 Stream Discharge Cumecs in Cumecs

G.H.	0	0.001	0.002	0.003	0.004	0.005	0.006	0.007	0.008	0.009
4.730	80.6^	80.6^	80.6^	80.7^	80.7^	80.7^	80.8^	80.8^	80.8^	80.9^
4.740	80.9^	80.9^	81.0^	81.0^	81.0^	81.1^	81.1^	81.1^	81.2^	81.2^
4.750	81.3^	81.3^	81.3^	81.4^	81.4^	81.4^	81.5^	81.5^	81.5^	81.6^
4.760	81.6^	81.6^	81.7^	81.7^	81.7^	81.8^	81.8^	81.8^	81.9^	81.9^
4.770	82.0^	82.0^	82.0^	82.1^	82.1^	82.1^	82.2^	82.2^	82.2^	82.3^
4.780	82.3^	82.3^	82.4^	82.4^	82.4^	82.5^	82.5^	82.5^	82.6^	82.6^
4.790	82.7^	82.7^	82.7^	82.8^	82.8^	82.8^	82.9^	82.9^	82.9^	83.0^
4.800	83.0^	83.0^	83.1^	83.1^	83.1^	83.2^	83.2^	83.2^	83.3^	83.3^
4.810	83.4^	83.4^	83.4^	83.5^	83.5^	83.5^	83.6^	83.6^	83.6^	83.7^
4.820	83.7^	83.7^	83.8^	83.8^	83.8^	83.9^	83.9^	83.9^	84.0^	84.0^
4.830	84.1^	84.1^	84.1^	84.2^	84.2^	84.2^	84.3^	84.3^	84.3^	84.4^
4.840	84.4^	84.4^	84.5^	84.5^	84.5^	84.6^	84.6^	84.6^	84.7^	84.7^
4.850	84.8^	84.8^	84.8^	84.9^	84.9^	84.9^	85.0^	85.0^	85.0^	85.1^
4.860	85.1^	85.1^	85.2^	85.2^	85.2^	85.3^	85.3^	85.3^	85.4^	85.4^
4.870	85.5^	85.5^	85.5^	85.6^	85.6^	85.6^	85.7^	85.7^	85.7^	85.8^
4.880	85.8^	85.8^	85.9^	85.9^	85.9^	86.0^	86.0^	86.0^	86.1^	86.1^
4.890	86.2^	86.2^	86.2^	86.3^	86.3^	86.3^	86.4^	86.4^	86.4^	86.5^
4.900	86.5^	86.5^	86.6^	86.6^	86.6^	86.7^	86.7^	86.7^	86.8^	86.8^
4.910	86.9^	86.9^	86.9^	87.0^	87.0^	87.0^	87.1^	87.1^	87.1^	87.2^
4.920	87.2^	87.2^	87.3^	87.3^	87.3^	87.4^	87.4^	87.4^	87.5^	87.5^
4.930	87.6^	87.6^	87.6^	87.7^	87.7^	87.7^	87.8^	87.8^	87.8^	87.9^
4.940	87.9^	87.9^	88.0^	88.0^	88.0^	88.1^	88.1^	88.1^	88.2^	88.2^
4.950	88.3^	88.3^	88.3^	88.4^	88.4^	88.4^	88.5^	88.5^	88.5^	88.6^
4.960	88.6^	88.6^	88.7^	88.7^	88.7^	88.8^	88.8^	88.8^	88.9^	88.9^
4.970	89.0^	89.0^	89.0^	89.1^	89.1^	89.1^	89.2^	89.2^	89.2^	89.3^
4.980	89.3^	89.3^	89.4^	89.4^	89.4^	89.5^	89.5^	89.5^	89.6^	89.6^
4.990	89.7^	89.7^	89.7^	89.8^	89.8^	89.8^	89.9^	89.9^	89.9^	90.0^
5.000	90.0^									

---------- Notes ----------
All rated data has been coded as reliable
except where the following tags are used...
* ... Reliable Estimate
^ ... Rating Table Extrapolated

10 Appendix C- ALS rating for site WWL_A

ALS Hydrographics NATIONAL HYRATAB V173 Output 24/04/2020

Site 300022A WWL Orpheus

Rating Table 1.01 16/08/2019 to Present Interpolation = Lin CTF = 0.0120

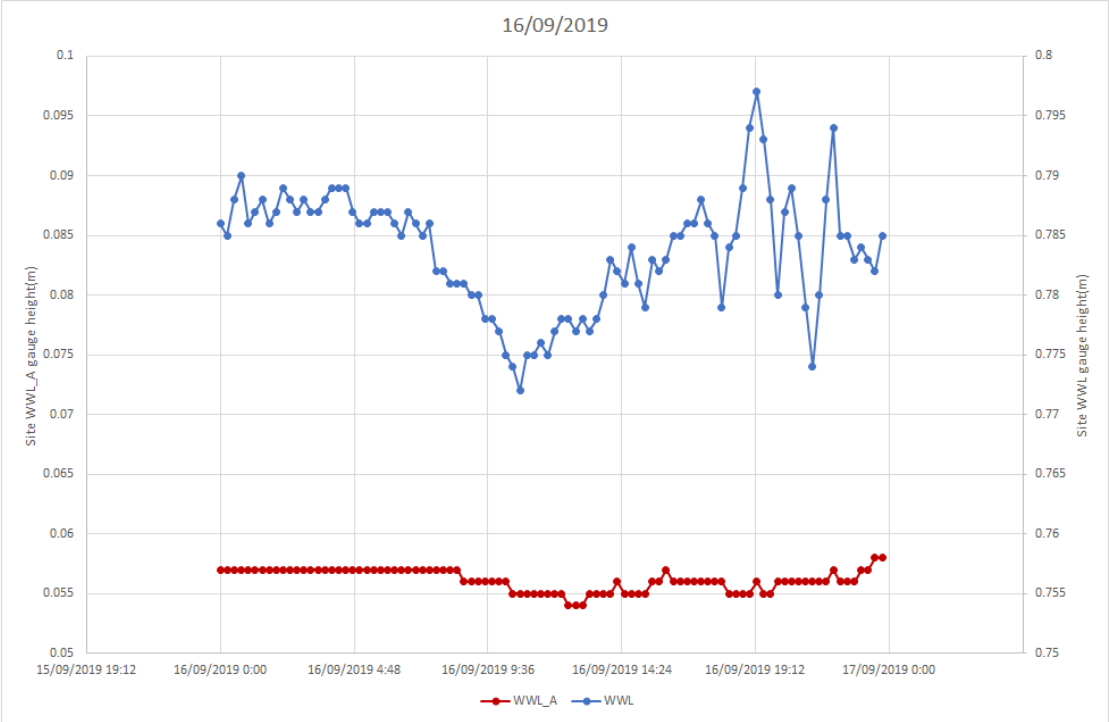
Converting 100 Stream Water Level in Metres
Into 140 Stream Discharge Cumecs in Cumecs

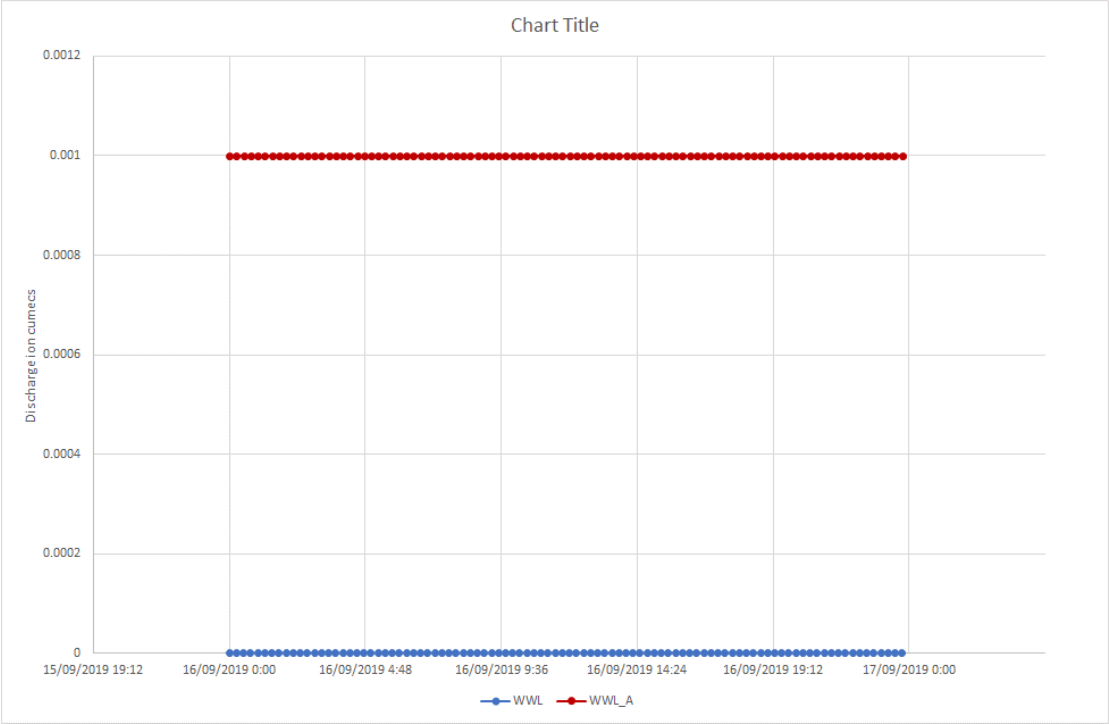
G.H.	0	0.001	0.002	0.003	0.004	0.005	0.006	0.007	0.008	0.009
0.000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.010	0.0	0.0	0.0	.00000200	.00000400	.00000600	.00000800	0.0000100	0.0000120	0.0000140
0.020	0.0000160	0.0000180	0.0000200	0.0000280	0.0000360	0.0000440	0.0000520	0.0000600	0.0000680	0.0000760
0.030	0.0000840	0.0000920	0.000100	0.000115	0.000130	0.000145	0.000160	0.000175	0.000190	0.000205
0.040	0.000220	0.000235	0.000250	0.000272	0.000294	0.000316	0.000338	0.000360	0.000382	0.000404
0.050	0.000426	0.000448	0.000470	0.000499	0.000528	0.000557	0.000586	0.000615	0.000644	0.000673
0.060	0.000702	0.000731	0.000760	0.000794	0.000828	0.000862	0.000896	0.000930	0.000964	0.000998
0.070	0.00103	0.00107	0.00110	0.00114	0.00118	0.00122	0.00126	0.00130	0.00134	0.00138
0.080	0.00142	0.00146	0.00150	0.00155	0.00159	0.00164	0.00168	0.00173	0.00177	0.00182
0.090	0.00186	0.00191	0.00195	0.00200	0.00205	0.00209	0.00214	0.00219	0.00224	0.00229
0.100	0.00233	0.00238	0.00243	0.00248	0.00254	0.00259	0.00264	0.00270	0.00275	0.00280
0.110	0.00285	0.00291	0.00296	0.00301	0.00307	0.00312	0.00318	0.00323	0.00328	0.00334
0.120	0.00339	0.00345	0.00350	0.00356	0.00361	0.00367	0.00373	0.00379	0.00384	0.00390
0.130	0.00396	0.00401	0.00407	0.00412	0.00417	0.00422	0.00427	0.00433	0.00438	0.00443
0.140	0.00448	0.00453	0.00458	0.00464	0.00469	0.00475	0.00480	0.00486	0.00492	0.00497
0.150	0.00503	0.00508	0.00514	0.00521	0.00527	0.00534	0.00541	0.00548	0.00554	0.00561
0.160	0.00568	0.00574	0.00581	0.00589	0.00597	0.00604	0.00612	0.00620	0.00628	0.00636
0.170	0.00643	0.00651	0.00659	0.00640	0.00621	0.00602	0.00583	0.00564	0.00545	0.00526
0.180	0.00507	0.00488	0.00469	0.00481	0.00493	0.00505	0.00517	0.00530	0.00542	0.00554
0.190	0.00566	0.00578	0.00590	0.00617	0.00644	0.00671	0.00698	0.00725	0.00752	0.00779
0.200	0.00806	0.00833	0.00860	0.00914	0.00968	0.0102	0.0108	0.0113	0.0118	0.0124
0.210	0.0129	0.0135	0.0140	0.0150	0.0160	0.0170	0.0181	0.0191	0.0201	0.0211
0.220	0.0221	0.0231	0.0241	0.0255	0.0268	0.0282	0.0295	0.0309	0.0322	0.0336
0.230	0.0349	0.0363	0.0376	0.0392*	0.0408*	0.0424*	0.0440*	0.0456*	0.0472*	0.0488*
0.240	0.0504*	0.0520*	0.0536*	0.0547*	0.0559*	0.0570*	0.0582*	0.0593*	0.0604*	0.0616*
0.250	0.0627*	0.0638*	0.0650*	0.0672*	0.0694*	0.0716*	0.0737*	0.0759*	0.0781*	0.0803*
0.260	0.0825*	0.0847*	0.0869*	0.0895*	0.0921*	0.0947*	0.0973*	0.0999*	0.103*	0.105*
0.270	0.108*	0.110*	0.113*	0.116*	0.119*	0.122*	0.125*	0.127*	0.130*	0.133*
0.280	0.136*	0.139*	0.142*	0.145*	0.149*	0.152*	0.156*	0.159*	0.163*	0.166*
0.290	0.170*	0.173*	0.177*	0.181*	0.185*	0.189*	0.193*	0.197*	0.201*	0.205*
0.300	0.209*	0.213*	0.217*	0.222*	0.226*	0.230*	0.235*	0.239*	0.243*	0.248*
0.310	0.252*	0.257*	0.261*	0.266*	0.270*	0.275*	0.280*	0.285*	0.289*	0.294*
0.320	0.299*	0.304*	0.308*	0.313~	0.319~	0.324~	0.329~	0.334~	0.339~	0.344~
0.330	0.349~	0.354~	0.359~	0.365~	0.370~	0.376~	0.381~	0.386~	0.392~	0.397~
0.340	0.403~	0.408~	0.414~	0.419~	0.425~	0.431~	0.437~	0.443~	0.448~	0.454~
0.350	0.460~	0.466~	0.471~	0.478~	0.484~	0.490~	0.496~	0.502~	0.508~	0.514~
0.360	0.521~	0.527~	0.533~	0.539~	0.546~	0.552~	0.559~	0.565~	0.572~	0.578~
0.370	0.585~	0.591~	0.598~	0.604~	0.611~	0.618~	0.625~	0.632~	0.639~	0.645~
0.380	0.652~	0.659~	0.666~	0.673~	0.680~	0.688~	0.695~	0.702~	0.709~	0.716~
0.390	0.723~	0.731~	0.738~	0.745~	0.753~	0.760~	0.768~	0.776~	0.783~	0.791~
0.400	0.798~	0.806~	0.813~	0.821~	0.829~	0.837~	0.845~	0.853~	0.861~	0.868~
0.410	0.876~	0.884~	0.892~	0.900~	0.909~	0.917~	0.925~	0.933~	0.942~	0.950~
0.420	0.958~	0.966~	0.974~	0.983~	0.992~	1.00~	1.01~	1.02~	1.03~	1.04~
0.430	1.05~	1.05~	1.06~	1.07~	1.08~	1.09~	1.10~	1.11~	1.12~	1.13~
0.440	1.14~	1.15~	1.16~	1.17~	1.18~	1.19~	1.20~	1.20~	1.21~	1.22~
0.450	1.23~	1.24~	1.25~	1.26~	1.27~	1.28~	1.29~	1.30~	1.31~	1.32~
0.460	1.33~	1.34~	1.35~	1.36~	1.37~	1.38~	1.39~	1.40~	1.42~	1.43~
0.470	1.44~	1.45~	1.46~	1.47~	1.48~	1.49~	1.50~	1.51~	1.52~	1.53~
0.480	1.54~	1.55~	1.56~	1.57~	1.59~	1.60~	1.61~	1.62~	1.63~	1.64~
0.490	1.65~	1.66~	1.67~	1.69~	1.70~	1.71~	1.72~	1.73~	1.74~	1.75~
0.500	1.77~	1.78~	1.79~	1.80~	1.81~	1.82~	1.84~	1.85~	1.86~	1.87~
0.510	1.88~	1.89~	1.91~	1.92~	1.93~	1.94~	1.95~	1.97~	1.98~	1.99~
0.520	2.00~	2.01~	2.03~	2.04~	2.05~	2.06~	2.08~	2.09~	2.10~	2.11~
0.530	2.13~	2.14~	2.15~	2.16~	2.18~	2.19~	2.20~	2.22~	2.23~	2.24~
0.540	2.25~	2.27~	2.28~	2.29~	2.31~	2.32~	2.33~	2.35~	2.36~	2.37~
0.550	2.39~	2.40~	2.41~	2.42~	2.44~	2.45~	2.47~	2.48~	2.49~	2.51~

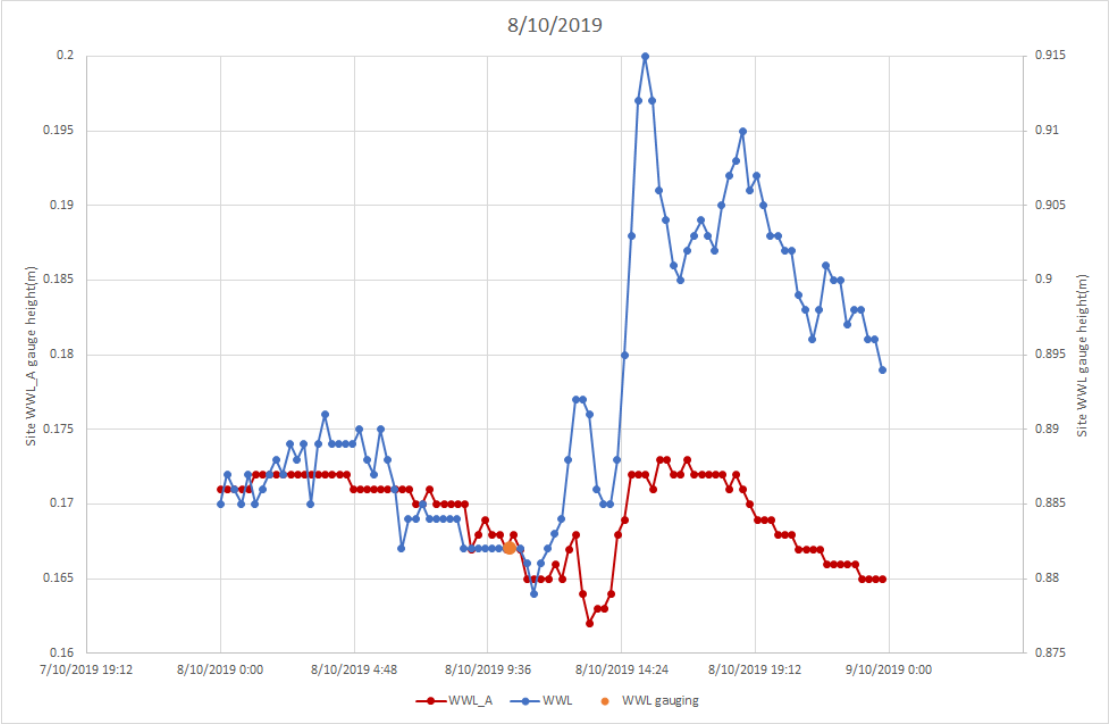
0.560	2.52~	2.53~	2.55~	2.56~	2.57~	2.59~	2.60~	2.62~	2.63~	2.64~
0.570	2.66~	2.67~	2.69~	2.70~	2.71~	2.73~	2.74~	2.76~	2.77~	2.79~
0.580	2.80~	2.81~	2.83~	2.84~	2.86~	2.87~	2.89~	2.90~	2.92~	2.93~
0.590	2.95~	2.96~	2.97~	2.99~	3.00~	3.02~	3.03~	3.05~	3.06~	3.08~
0.600	3.09~	3.11~	3.12~	3.14~	3.15~	3.17~	3.19~	3.20~	3.22~	3.23~
0.610	3.25~	3.26~	3.28~	3.29~	3.30~	3.32~	3.33~	3.35~	3.36~	3.37~
0.620	3.39~	3.40~	3.42~	3.43~	3.44~	3.45~	3.47~	3.48~	3.49~	3.50~
0.630	3.52~	3.53~	3.54~	3.56~	3.57~	3.58~	3.60~	3.61~	3.62~	3.64~
0.640	3.65~	3.66~	3.67~	3.69~	3.70~	3.72~	3.73~	3.74~	3.76~	3.77~
0.650	3.78~	3.80~	3.81~	3.83~	3.84~	3.85~	3.87~	3.88~	3.90~	3.91~
0.660	3.93~	3.94~	3.95~	3.97~	3.98~	4.00~	4.01~	4.03~	4.04~	4.06~
0.670	4.07~	4.09~	4.10~	4.12~	4.13~	4.15~	4.16~	4.18~	4.19~	4.21~
0.680	4.22~	4.24~	4.25~	4.27~	4.29~	4.31~	4.33~	4.35~	4.36~	4.38~
0.690	4.40~	4.42~	4.44~	4.46~	4.48~	4.50~	4.51~	4.53~	4.55~	4.57~
0.700	4.59~	4.61~	4.63~	4.65~	4.67~	4.69~	4.71~	4.72~	4.74~	4.76~
0.710	4.78~	4.80~	4.82~	4.84~	4.86~	4.88~	4.90~	4.92~	4.94~	4.96~
0.720	4.98~	5.00~	5.02~	5.04~	5.06~	5.08~	5.10~	5.12~	5.14~	5.16~
0.730	5.18~	5.20~	5.22~	5.24~	5.26~	5.28~	5.30~	5.32~	5.35~	5.37~
0.740	5.39~	5.41~	5.43~	5.45~	5.47~	5.49~	5.51~	5.53~	5.55~	5.58~
0.750	5.60~	5.62~	5.64~	5.66~	5.68~	5.70~	5.73~	5.75~	5.77~	5.79~
0.760	5.81~	5.83~	5.85~	5.88~	5.90~	5.92~	5.94~	5.96~	5.99~	6.01~
0.770	6.03~	6.05~	6.07~	6.10~	6.12~	6.14~	6.16~	6.19~	6.21~	6.23~
0.780	6.25~	6.28~	6.30~	6.32~	6.35~	6.37~	6.39~	6.41~	6.44~	6.46~
0.790	6.48~	6.51~	6.53~	6.55~	6.58~	6.60~	6.62~	6.65~	6.67~	6.69~
0.800	6.72~	6.74~	6.76~	6.79~	6.81~	6.83~	6.86~	6.88~	6.91~	6.93~
0.810	6.95~	6.98~	7.00~	7.03~	7.05~	7.07~	7.10~	7.12~	7.15~	7.17~
0.820	7.20~	7.22~	7.24~	7.27~	7.29~	7.32~	7.34~	7.37~	7.39~	7.42~
0.830	7.44~	7.47~	7.49~	7.52~	7.54~	7.57~	7.59~	7.62~	7.64~	7.67~
0.840	7.70~	7.72~	7.75~	7.77~	7.79~	7.82~	7.84~	7.87~	7.89~	7.92~
0.850	7.94~	7.97~	7.99~	8.02~	8.04~	8.06~	8.09~	8.11~	8.13~	8.16~
0.860	8.18~	8.20~	8.23~	8.25~	8.27~	8.30~	8.32~	8.35~	8.37~	8.39~
0.870	8.42~	8.44~	8.47~	8.49~	8.51~	8.54~	8.56~	8.59~	8.61~	8.64~
0.880	8.66~	8.69~	8.71~	8.74~	8.76~	8.79~	8.81~	8.84~	8.86~	8.89~
0.890	8.91~	8.94~	8.96~	8.99~	9.01~					

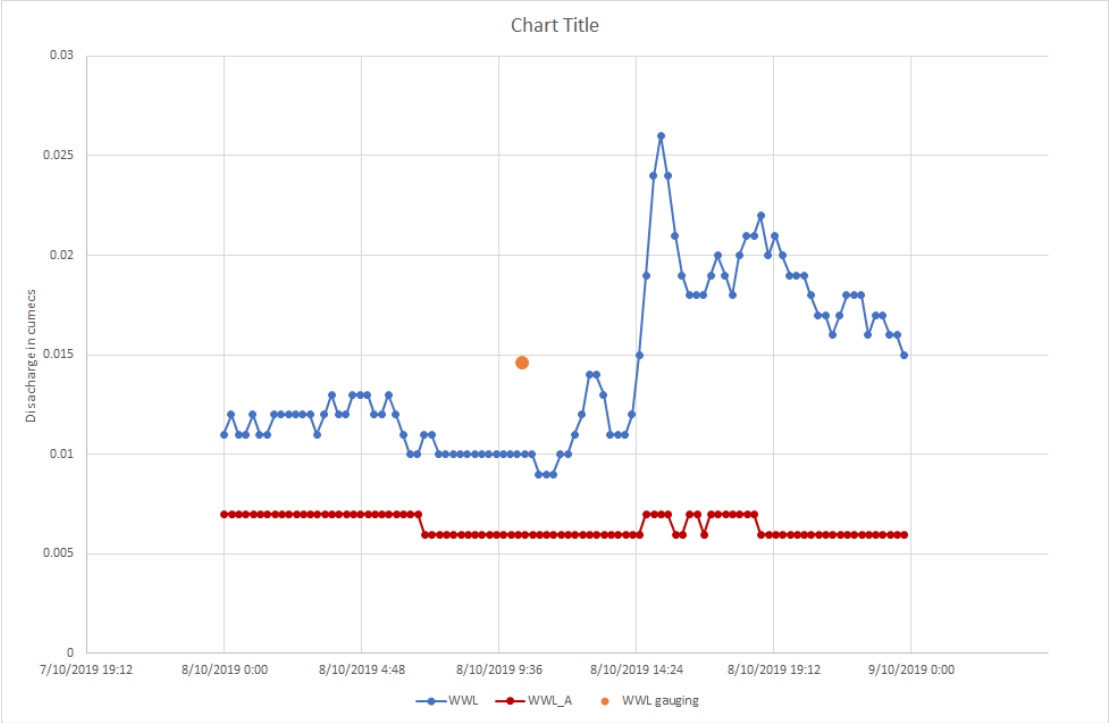
---------- Notes ----------
All rated data has been coded as reliable
except where the following tags are used...
* ... Reliable Estimate
~ ... Discharge Suspect, Rating under review

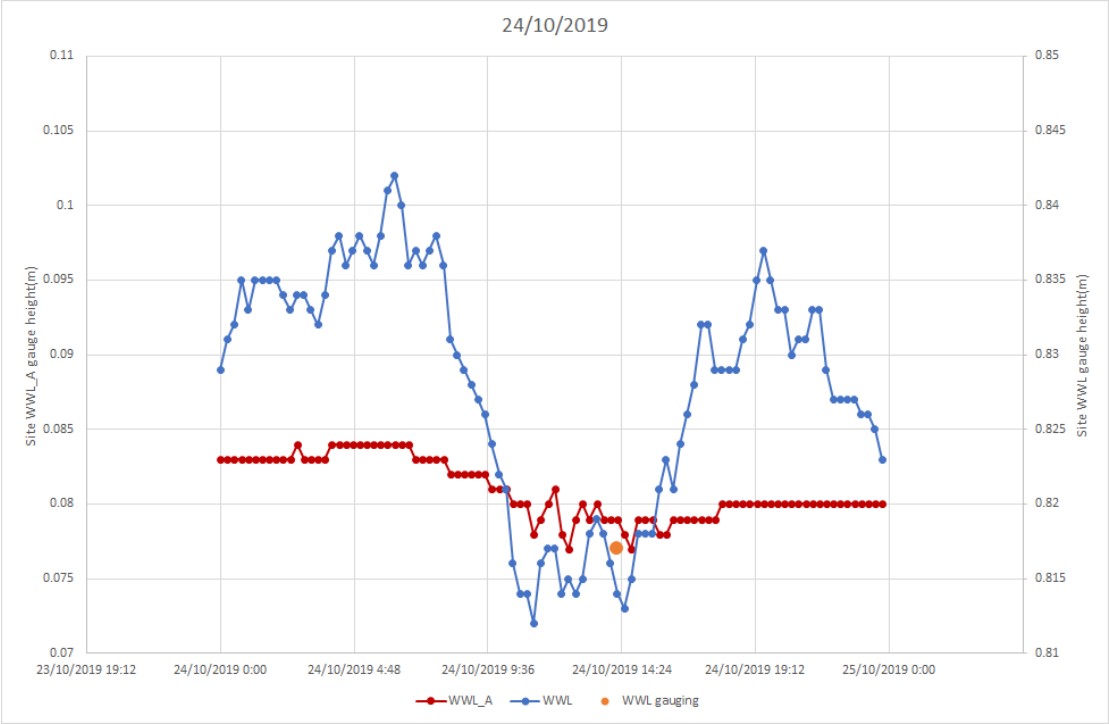
11 Appendix D- Diurnal pattern plots for 4 low flow days

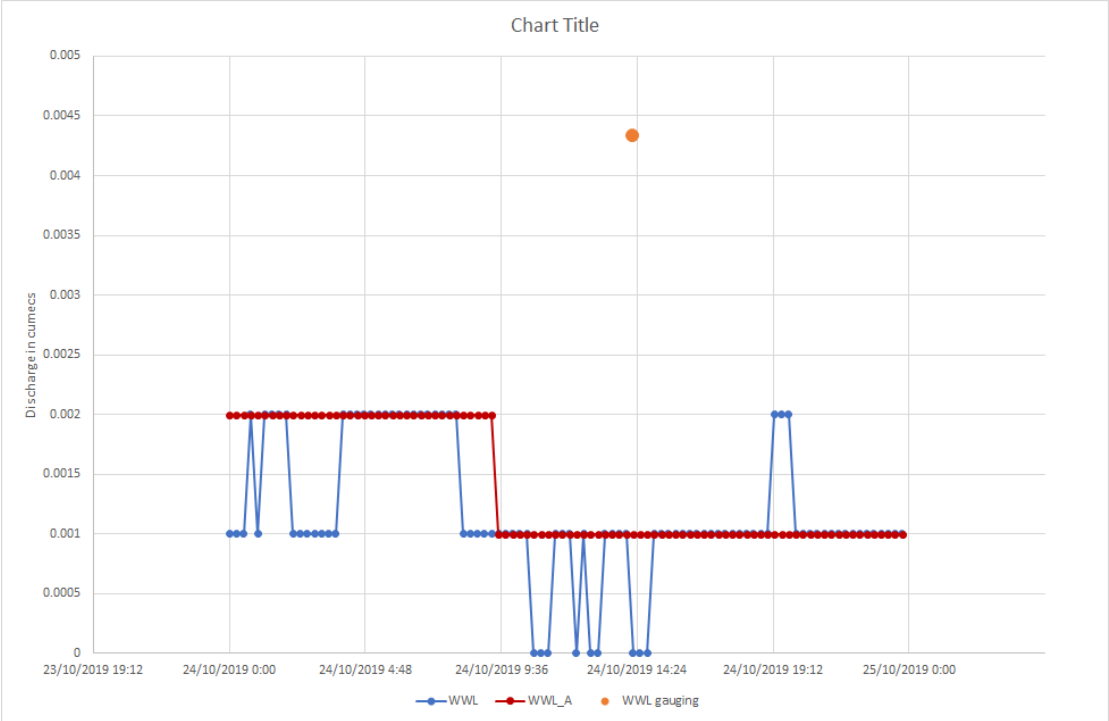


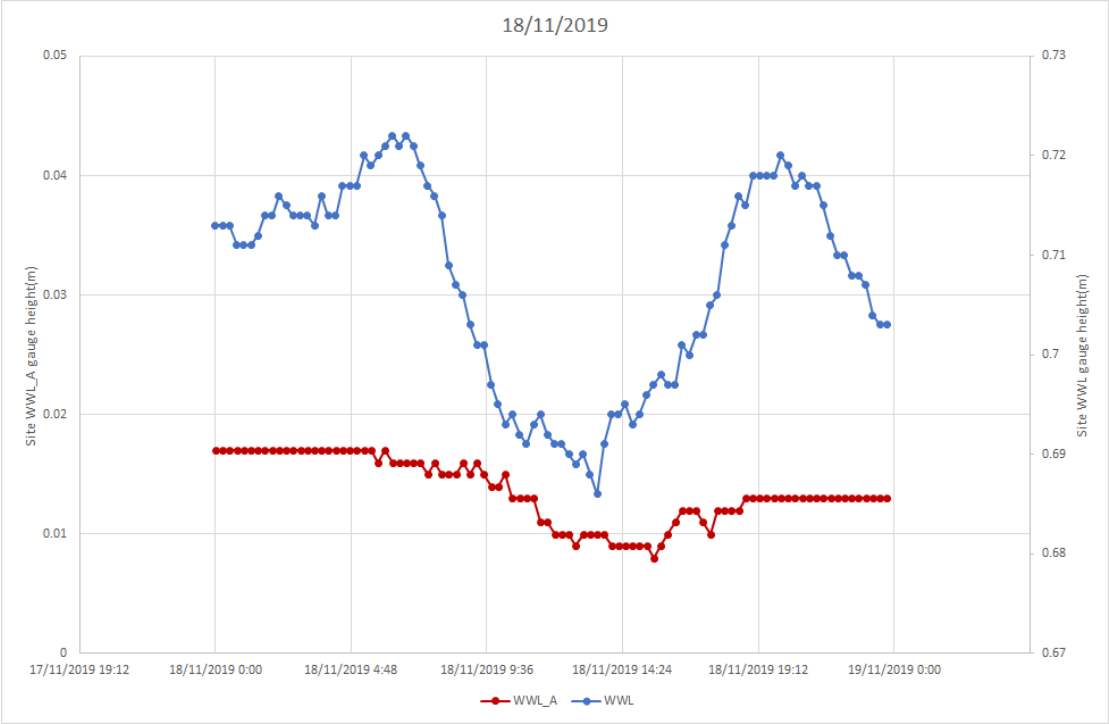


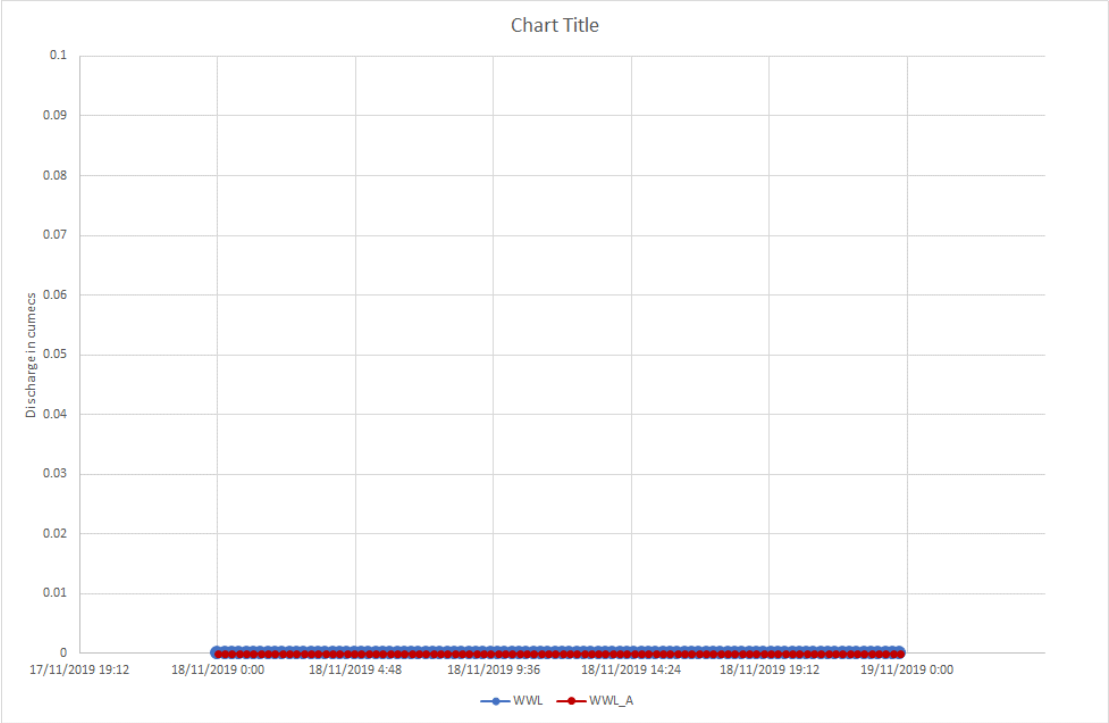

8/10/2019
Site WWL_A gauge height(m)
Site WWL gauge height(m)
0.2
0.195
0.19
0.185
0.18
0.175
0.17
0.165
0.16
0.915
0.91
0.905
0.9
0.895
0.89
0.885
0.88
0.875
7/10/2019 19:12
8/10/2019 0:00
8/10/2019 4:48
8/10/2019 9:36
8/10/2019 14:24
8/10/2019 19:12
9/10/2019 0:00
WWL_A
WWL
WWL gauging


Chart Title
Disacharge in cumecs
0.03
0.025
0.02
0.015
0.01
0.005
0
7/10/2019 19:12
8/10/2019 0:00
8/10/2019 4:48
8/10/2019 9:36
8/10/2019 14:24
8/10/2019 19:12
9/10/2019 0:00
WWL
WWL_A
WWL gauging


24/10/2019
Site WWL_A gauge height(m)
Site WWL gauge height(m)
0.11
0.105
0.1
0.095
0.09
0.085
0.08
0.075
0.07
0.85
0.845
0.84
0.835
0.83
0.825
0.82
0.815
0.81
23/10/2019 19:12
24/10/2019 0:00
24/10/2019 4:48
24/10/2019 9:36
24/10/2019 14:24
24/10/2019 19:12
25/10/2019 0:00
WWL_A
WWL
WWL gauging


Chart Title
Discharge in cumecs
0.005
0.0045
0.004
0.0035
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
23/10/2019 19:12
24/10/2019 0:00
24/10/2019 4:48
24/10/2019 9:36
24/10/2019 14:24
24/10/2019 19:12
25/10/2019 0:00
WWL
WWL_A
WWL gauging


18/11/2019
Site WWL_A gauge height(m)
Site WWL gauge height(m)
0.05
0.04
0.03
0.02
0.01
0
0.73
0.72
0.71
0.7
0.69
0.68
0.67
17/11/2019 19:12
18/11/2019 0:00
18/11/2019 4:48
18/11/2019 9:36
18/11/2019 14:24
18/11/2019 19:12
19/11/2019 0:00
WWL_A
WWL


Chart Title
Discharge in cumecs
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
17/11/2019 19:12
18/11/2019 0:00
18/11/2019 4:48
18/11/2019 9:36
18/11/2019 14:24
18/11/2019 19:12
19/11/2019 0:00
WWL
WWL_A

Appendix D – Agency Feedback and Responses

Table 9-1 Agency feedback and responses – Longwalls 20 and 21

BCD Submission	Response
Performance measures not measurable and specific • We note no change in performance measures. As per previous advice: "We support the development of specific, meaningful and measurable performance measures for streams in the Dendrobium 3C Area. The performance measure and triggers in the associated TARP need to be related to the materiality of flow loss. Terms such as 'negligible' and 'minor' must be defined in quantitative terms".	A review of the Area 3B WIMMCP TARP was undertaken in consultation with WaterNSW and DPE between 2018 and 2020 (Watershed HydroGeo 2019b). The revised 3B TARP levels have been adapted for the Area 3A WIMMCP including the TARPs, this is discussed in detail in **Section 3.6**. Key features of the updated TARPs are: • Inclusion of a comparison of flows recorded at relevant sub-catchment monitoring sites around the Dendrobium mining area against reference sites, supplemented by rainfall-runoff modelling. • Assessment of sub-catchment hydrology against indicators appropriate to identifying and quantifying potential effects on the broad hydrological behaviour within each sub-catchment; including effects on cease-to-flow conditions that may be significant to ecological values, and effects on median flow which is significant for the water resource potential. A further assessment has been implemented to analyse the mining effects on low-flows that are known to occur along the "middle reach" of Wongawilli Creek, between Area 3A and 3B. Surface water flow sites in the mining area will be assessed against the key flow reference sites during assessments for the End of Panel (EoP) Report. The assessment comprises three checks of pre- versus post-mining behaviour for each assessment site. Trigger values are proposed for water flow parameters in the TARP (Appendix A). The TARPs are based on the following parameters and assessments: A. Change in flow exceedance (Q%ile) behaviour compared to key flow reference sites. In essence, this aims at quantifying an otherwise visual or qualitative assessment of flow behaviour (compared to normalised key flow reference site flow); B. Relative change in the frequency of cease-to-flow days compared to key reference sites; C. Relative change in Q50 (median flow) compared to key reference sites flows; and D. Baseflow reduction along Wongawilli Creek, between Areas 3A and 3B. More detail on the calculation procedure for these assessments is presented in **Appendix F** of this document. These methods were developed and refined in consultation with agencies, and originally documented in Watershed HydroGeo (2019b). If any of these indicate an impact is likely to have occurred, then the EoP Report will describe the impact as it relates to one or more of the broad hydrological behaviours, a reduction in the water resource indicator, or impact that could affect the ecological values of the stream. In the event that there is a reduction in Q50 median flow (Assessment C) or base flow reduction (Assessment D), and there is a Performance Measure related to that watercourse, then the reduction would be compared against the predicted losses

BCD Submission	Response
	from contemporary groundwater and surface water assessments to assess whether effects that cannot be explained by natural variability "exceed prediction". The assessment will determine if the impact is 'within Prediction' or 'exceeding Prediction', with further actions triggered by that outcome. In addition to the TARP review, IMC has recently upgraded key flow gauging stations in Dendrobium Area 3. The revised TARPs in conjunction with the improved flow measurements will provide more robust measurement and assessment of surface water flow against Performance Measures.
WaterNSW Submission	**Response**
The plans only apply to the approved LW 21 whose finishing end is 240 m from Wongawilli Creek.	This is correct, Longwall 20 requires SMP Approval.
The reports are sound and adequate information has been provided with regards to monitoring and managing impacts due to LW21. In particular, the recently revised water flow assessment and TARP methodology has been incorporated for assessing water quantity impacts on Wongawilli Creek.	Noted.
Impacts and Monitoring of Wongawilli Creek - A detailed email from Howard Reed to South32 (D2020/15623 - DPIE Planning email - Dendrobium Coal Mine - Request for Further Information re Area 3C Longwall 20) is referred to in this regard. The focus of the email is a request for more information with regards to predicted LW20 impacts on Wongawilli Creek. The key issue raised by DPIE is the non-acceptance and query on the 10% rockbar fracturing model being used for assessment. This should be followed up with DPIE.	SMP approval for Longwall 20 is not being sought by IMC.
There is adequate flow and pool water level measurement locations on Wongawilli Creek as well as groundwater bores to determine groundwater depressurization near LW21 and Wongawilli Creek. However the sensitivity of the proposed monitoring and TARP system is not adaptive i.e. to stop LW21 should impacts and consequences be seen to approach Trigger Level 3 for pool level changes. South32's position is that they have setback LW21 to ensure a 200mm valley closure is not reached at Wongawilli Creek.	IMC will update the subsidence impact and valley closure model prior to completion of extraction of Longwall 21. Future SMP applications in Area 3C will use the revised model as an adaptive management measure directed to avoiding exceedances of the performance measures for Wongawilli Creek.
There is only one swamp near LW 21 in Area 3C - Den144 near the valley base of Stream WC20 and it is not directly undermined by LW21. Some impacts in terms of change in groundwater and	This is addressed in the Area 3C SIMMCP (see Section 5.33).

BCD Submission	Response
moisture levels in this swamp is predicted and proposed to be monitored.	

Table 9-2 Agency feedback and responses – Longwalls 22 and 23

BCD Submission	Response
Changes to Longwall Layout Needed BCS does not support the direct undermining of upland swamp EECs (in particular the 4.8 ha Swamp 7) by longwalls 22 & 23. It is recommended that South 32 redesign longwalls 22 & 23 to avoid catastrophic damage to the Swamp 7 EEC and associated drainage lines. The design of longwalls 20 & 21 clearly demonstrates the feasibility of designing short longwalls which do not interact with swamps or major streams.	The predicted impacts to swamps in the Longwalls 22 and 23 SMP study area are defined in several documents supporting the SMP application (Attachments B, C, E and F). These impacts are in line with those predicted in the Dendrobium Area 3 Environmental Assessment. In April 2015, the Dendrobium Mine Consent was modified by adding Condition 15 to enable the provision of Strategic Biodiversity Offsets, whereby IMC could provide land that has conservation values which exceed the conservation values required to meet relevant offsetting requirements prescribed in a condition of an approval, and that the excess conservation values could be relied upon to meet future offsetting requirements under the Dendrobium Mine Consent and the Bulli Seam Operations Consent (08_0150). The Maddens Plains Offset Area was transferred to the NSW National Parks and Wildlife Service to provide physical offsets for impacts to vegetation communities and species, in addition to swamp research funding. The Department confirmed in writing that the Maddens Plains Offset Area can be used to offset residual biodiversity impacts for Area 3C in a letter to IMC dated 17 September 2019. The design and layout of Longwalls 20 and 21, the first in the Area 3C series were constrained by underground geological features and surface features such as Wongawilli Creek. These features limited the dimensions of Longwalls 20 and 21.
Surface to Seam Fracturing It is also recommended that the width of the longwalls (305m) is reduced to prevent surface to seam fracturing over the majority of the mine layout. SCT (2019) suggest the height of fracture zone, as observed from monitoring and modelling of goafs, is typically between 1-1.75 times the panel width and can be approximated to 1.5 times the panel width. Under such rough rules of thumb, 360m wide longwalls would lead to heights of the fracture zone extending 305m to 534m above the coal seam; or 458m above the coal seam if approximated using 1.5 times the panel width. Since the depth of cover is given as 290-390m, then this would mean that surface to seam fracturing is likely to occur over the entire longwall layout area using the 1.5 times panel width approximation. Use of Tammetta's equation suggests surface to seam connective fracturing will occur to heights between 355-374m for a longwall width of 305m and seam	Experience at Dendrobium Mine and other mining operations in the Southern Coalfield shows that surface impacts related to subsidence can occur at panel widths significantly narrower than 305 m. MSEC (2019) conducted an analysis of variable longwall widths and concluded the following: • although maximum predicted vertical subsidence decreases as longwall void width reduces, the predicted conventional strains are still sufficient to result in the fracturing of bedrock for reduced longwall widths down to approximately 150 m; • valley related effects are seen at narrow longwall widths and, therefore, so are related potential impacts; and • strains due to the valley related effects would still be sufficient to result in fracturing of rockbars, pools and bedrock above and adjacent to the longwalls and, therefore, resultant surface water losses for reduced longwall widths down to approximately 150 m. While narrower longwall panels would reduce total vertical subsidence, and correspondingly reduce predicted tilts and strains in narrower panels, the strains due to the valley-related effects would still be sufficient to result in fracturing of rockbars, pools and bedrock above and adjacent to the longwalls. Accordingly, adverse environmental impacts are still anticipated for reduced longwall widths down to approximately 150 m.

BCD Submission	Response
extraction of 3.9m. This means that surface to seam fracturing is likely to occur wherever surface AHD is less than ~370m. This is the majority (not 'some') of the project area above the proposed longwalls. Throughout many of the reports submitted for the proposal, statements are made such as: *On the basis that there is no connective fracturing to any deeper storage, it is likely that the diverted surface water flows will re-emerge at the limits of fracturing and dilation* Given previous experiences at Dendrobium, the work of SCT (2019) and Tammetta, and the IEPMC, this is clearly an inappropriate 'basis' to consider. The assumption should be that there will be connective fracturing, as has been demonstrated from previous longwall mining in Dendrobium Areas 3B, 3A and 2 (Expert Panel Report).	In addition, the continuation of 305 m wide panels avoids further value loss and coal sterilisation when compared to mining with narrower longwall panels (e.g. due to increased coal recovery). Surface to seam fracturing has been the subject of ongoing investigation throughout Dendrobium operations in Area 3. Condition 19, Schedule 3 of the Area 3B SMP Approval requires undertaking an assessment of the height of connective fracturing and the extent of surface cracking before and after the extraction of Longwalls 14, 15, 16 and 17. Investigation holes were drilled above both existing and planned Longwalls 12, 13, 14, 15 and 16 in Area 3B and Longwalls 6 and 7 in Area 3A, allowing assessment of effects above longwalls of different width. Longwalls in Area 3B are 305 m wide and Longwalls 6 and 7 in Area 3A are 249 m wide, including first workings. Assessment is detailed in HGEO (2020a;b) and is peer review ed by Hebblewhite (2020a;b). The investigation focused on fracturing, strata permeability and groundwater pressures to allow comparison with predictions from the three prevailing methods for estimating the height of fracturing. The findings of those investigations were described in Sections 3.6 and 4.1 of the Groundwater Assessment (Watershed HydroGeo, 2021), with key points summarised below: • horizontal (low angle) fracturing to the surface (consistent with Tammetta H); • high angle fracturing is most significant to approximately 200-250 m above the goaf, declining above that with the exception of intense fracturing in the Bald Hill Claystone; • packer testing show s clear increase in horizontal hydraulic conductivity (kh) through the profile; • groundwater levels show depressurisation/draw down through the profile following longwall extraction. Within approximately 200 m above the goaf (i.e. mid-Bulgo Sandstone or below), no recovery has been observed. Above this, up to the mid-HBSS, groundwater levels have started to recover after a period of about 3 years. These observations have been used to refine the conceptual model of fracturing above longwalls at Dendrobium (as was recommended by the IEP). The subsequent methods to simulate deformation and fracturing in the Dendrobium Regional Groundwater Model (Watershed HydroGeo, 2021) are consistent with that IEP recommendation in that the Tammetta method is used, and recent investigations are used to define where connected and disconnected fracturing and strata dilation occur. This has resulted in an improvement in calibration to groundwater drawdown and inflow compared to previous modelling that assumed seam-to-surface connection.
Deficiencies in Monitoring Monitoring and assessment is deficient in a number of areas. The aquatic flora and fauna assessment (Cardno 2021) identifies that there has been very limited aquatic flora and fauna survey in the area and streams that are	Supplementary aquatic surveys of LC5 and LC6 were undertaken by Cardno in August 2021. The Aquatic Flora and Fauna Assessment has been updated to incorporate these results. The assessment for LC5 and LC6 are detailed in Section 4.2.3.1 of Cardno (2021) and are based on recent survey, mapping and photographs of these watercourses. Previous survey was of physical characteristics of the watercourses and the presence of barriers to fish passage from Lake Cordeaux in

BCD Submission	Response
most likely to be impacted by longwalls 22 & 23; and much of this is based on decade old survey information. The report largely concentrates on impacts to Wongawilli Ck and Cordeaux Reservoir, ignoring impacts to LC5 and LC6. Both streams are likely to be permanent streams due to the swamps located in their headwaters (including the 4.8 ha Swamp 7 EEC). If the current configuration of LW 22 & 23 is adopted, all surface water will be lost and likely move directly into the mine due to connective fracturing. This will likely leave LC5 & LC6 without any aquatic habitat. This has not been appropriately considered in the aquatic flora and fauna assessment. There is also no identified offsetting of stream and aquatic fauna/flora impacts.	to LC5 and LC6. The presence of significant barriers to fish passage at the confluence of these drainage lines and Lake Cordeaux was confirmed following surveys undertaken in August 2021. LC5 and LC6 flow directly over Longwalls 22 and 23 and are located almost entirely within 400 m of each longwall. Subsidence predictions (MSEC 2021) indicate that subsidence and fracturing is expected to occur in sections of watercourse directly above the longwalls, and that fracturing is possible to occur in watercourses up to approximately 400 m from the longwalls. It was predicted that a localised significant impact to aquatic habitat and biota would occur in these watercourses and that a localised reduction in the population size of aquatic biota would occur. At a catchment scale, such impacts would be minor. This assessment is consistent with that provided in Section 4.2.3.1 of Cardno (2021). Given available hydrological data, field observations during drought conditions, and the relatively small catchment sizes of LC5 and LC6, these drainage lines appear likely to stop flowing and several pools would become dry during drought. However, larger pools would provide refuge for aquatic biota for several months following low rainfall. See response above regarding biodiversity offsets provided for Area 3C mining impacts.
Watershed Hydrogeo suggests there are: recently installed gauging stations near to Longwalls 20-23: • LC5S1 on LC5: commenced monitoring 4/04/2019. This watercourse could be affected slightly by Longwall 21, and likely to be affected by Longwalls 22 and 23. • CR36S1 on CR36: commenced monitoring 5/09/2019. This watercourse could be affected slightly by Longwall 23. And that: IMC has received approval for additional surface water monitoring gauges around Area 3C on WC20, WC24, WC26, and are investigating a site on LC6 near Longwalls 22 and 23. None of this data appears to be in the assessment.	Surface water flow gauges installed as at May 2024 are listed in Table 3-5. Data from LC5 and CR36 are included in the Surface Water Assessment (HGEO, 2021), with the presentation of hydrographs, flow duration curves, and water quality analyses. WC24 is not included as this site was only recently established.
HGEO identify 34 pools in WC26, 29 (56%) of which lie directly above Longwall 23. Swamp Den153 EEC also lies directly above LW23. None of these have any baseline water level measurements (or piezometer monitoring) taken or an identified monitoring plan that can assess impact (eg BACI design).	Four water level monitoring sites have been established on WC26 and WC26A; including three water level bench marks and a water level logger near the confluence with Wongawilli Creek. These sites were established: • WC26_Channel 4 - 9/10/2020; • WC26_Pool 14 - 9/10/2020; • WC26_Pool 19 - 13/08/2021; • WC26_Pool 32 - 9/08/2021; and

BCD Submission	Response
	• WC26A_Pool 4 - 6/8/2021. This will provide more than 2 years of pre-mining baseline data. The data from these sites allows for comparison of pre-mining to post mining conditions within the watercourse. This information is provided in the Area 3C SIMMCP. IMC have established a piezometer and paired soil moisture monitoring site within Swamp 153.
HGEO identify 20 pools in LC5 downstream of Swamp Den09 EEC. Seventeen (85%) of which are in the 600m boundary and seven (35%) of these lie directly above Longwalls 22 & 23. HGEO identify 57 pools in LC6, 52 (91%) of which are within the 600m boundary and 23 (40%) directly above Longwalls 22 & 23. None of these pools have any baseline water level measurements taken or an identified monitoring plan that can assess impact (eg BACI design).	Seven water level monitoring sites have been established on LC5 and LC5A; including five water level bench marks and two water level logger sites near the confluence with Lake Cordeaux. The below sites have been established: • LC5_Rockbar 11 • LC5_Pool 13 • LC5_Rockbar 7 • LC5_Rockbar 11 • LC5_Pool 26 • LC5_S1 • LC5A_Pool 6 Most sites have over two yearsof pre-mining baseline data for tributary LC5. Those without were established more recently. The data from these sites allows for comparison of pre-mining to post-mining conditions within the watercourse. Four water level monitoring sites have been established on LC6; including three water level bench marks and a water level logger near the confluence with Lake Cordeaux. These sites were established: • LC6_Pool 51 • LC6_Pool 36 • LC6_Pool 16 • LC6_Rockbar1 All sites have more than two years pre-mining baseline data for tributary LC6. The data from these sites allows for comparison of pre-mining to post mining conditions within the watercourse.
Swamp Den07 EEC lies directly over Longwall 23. Swamps Den154, Den155, Den 156, Den09 are wholly or partially within the 400m boundary. Another unnamed swamp near swamp Den09 is within the 600m boundary. Many of these swamps have no stated monitoring. This identifies the paucity of baseline data for the area and streams that are most likely to be impacted by longwalls 22 & 23.	Dendrobium operations have been longwall mining in the catchment since 2005, beginning with Dendrobium Area 1 when monitoring of upland swamps was established. Mining operations have expanded into Areas 2, 3A and 3B since then with the monitoring program evolving over this period to incorporate results, findings and lessons learnt. In parallel with this, IMC has undertaken extensive biophysical surveys, assessment and research of the Dendrobium mining area which have contributed to the understanding of how upland swamps are impacted by mining. Recommendations on upland swamp monitoring from various agencies, independent panels, consultants and research institutions have been adopted and incorporated into the monitoring program. Condition 11c of the Area 3C SMP requires IMC to update the SIMMCP to fully reflect the recommendations of the IEP on the Longwalls 20 and 21 SMP application dated 13 December 2019;

BCD Submission	Response
	relating to monitoring of swamp impacts which directly relate to impact monitoring, management, remediation and contingency planning in respect of swamps. Condition 11d requires IMC to update the SIMMCP to fully reflect the advice of the IEP on the Longwalls 20 and 21 SMP application dated 13 December 2019 relating to monitoring of swamp impacts. The SIMMCP has been updated to address these conditions which form part of the foundation of the monitoring approach proposed for Area 3C. A key monitoring recommendation from IEP (2019b) is: "*18. Future swamp monitoring and modelling programs should be designed to:* *a. 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."* The majority of impacts to upland swamps are likely to occur above the proposed longwall and within the groundwater impact zone (120 m buffer). 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. Beyond the 35 degree angle of draw study area, impacts to features such as swamps and watercourses are expected to be minor or negligible. All swamps within the 35 degree angle of draw are included in the Area 3C monitoring program.
WaterNSW Submission	**Response**
Mine design The proposed mining dimensions for Longwalls 22 and 23 are consistent with longwalls in Area 3A and 3B, and those proposed in the Dendrobium Area 5 & 6 Expansion Project. It is generally accepted that panel dimensions such as those proposed cause surface-to- seam connectivity in parts, if not all, of the extraction area. A comparison of the panel width/depth of cover (W/D) relationship indicates that the W/D ratio over much of the proposed longwalls is between 1.1 and 1.2. This is greater or at least comparable to most longwalls above Area 3A and 3B w here surface-to- seam connectivity has occurred. It is now widely understood and accepted that narrower longwalls (and/or a low er mining height) can have significant benefits in reducing impacts on water resources, including: • A reduction in catchment losses due to regional depressurisation,	See response to BCD submission above. Additionally, we acknowledge the comments regarding W/D ratios at Longwalls 22 and 23, as presented on Figure 4-3 of the Groundwater Assessment (Watershed HydroGeo, 2021), and that this contributes to potential impacts to near-surface and surface features. However, the comments regarding "generally accepted that panel dimensions such as those proposed cause surface-to- seam connectivity in parts, if not all, of the extraction area" and "This is greater or at least comparable to most longwalls above Area 3A and 3B where surface-to- seam connectivity has occurred" appear to be counter to comments by WaterNSW (07/07/2021): *"it appears that fracturing is not 'connective' such that it leads to rapid migration of water from the surface in Area 3B*". The investigations into the height of fracturing in Area 3A and 3B support a conceptual model where the height of connected fracturing, and free drainage, is not to the surface in Areas 3A and 3B (but is considered to occur in Area 2), and that there is a zone of disconnected fracturing and/or strata dilation above the connected fracture zone. This is not to reject the idea that 'disconnected' fracturing (above the zone of connected fracturing) does not cause environmental impacts, just that the type and duration of effects, especially losses from the surface water catchment, are different.

BCD Submission	Response
• A reduction in the intensity of surface fracturing in less incised areas of the landscape, near or adjacent to watercourses, and • Improved chances of stream remediation. It is also widely accepted that non-conventional subsidence effects and impacts on surface water resources and upland swamps is best managed by not undermining them and ensuring adequate setbacks typically at least 400 m. The Independent Expert Panel for Mining in the Catchment (IEPMC) has recommended "adopting a precautionary approach and basing mine design on preventing the height of free drainage in the Special Areas from extending to the surface or interacting with surface fracture networks".	
Surface water losses Inflow or groundwater take is predicted through groundwater modelling to be up to 12 ML/day, with the extraction of Longwall 22 causing an increase in inflow of up to 2-3 ML/day and Longwall 23 causing an increase in inflow of up to 2-3.5 ML/day. It is acknowledged that Dendrobium Mine is causing surface water losses within the Special Area of up to 5 ML/day (IEPMC, 2019). The IEPMC also estimated that 40 to 50% of previous inflows to mine workings is from surface water. This is water that would have otherwise reported to Sydney's drinking water catchment. The proposed extraction of Longwalls 22 and 23 would result in further depressurisation and surface water loss.	Subsidence is an unavoidable consequence of longwall mining and includes vertical and horizontal movement of the land surface. The predicted impacts detailed in the specialist assessments meet the performance requirements in the Dendrobium Mine Development Consent (DA 60-03-2001). Several layout alternatives for Area 3C were assessed by IMC using a multi-disciplinary team including environment, community, mining and exploration expertise. These included variations in the number of longwalls and orientations, lengths, and setbacks of the longwalls from key surface features. These options were reviewed, analysed and modified until an optimised longwall layout in Area 3C was achieved. In addition, a reduced maximum extraction height of 3.9 m will continue to be in place for Longwalls 22 and 23, as it has been since Longwall 14. IEP (2019a) also found impacts to catchment after 100 years of historical mining to be insignificant compared to other losses to the system "The losses referred to in Section 3.2.3 are low compared to other components of Sydney's supply and demand, for example recent losses from the Dendrobium, Russell Vale and Wongawilli mines of less than 8 ML/day on average compare to estimated leaks from the Sydney Water supply infrastructure of approximately 130 ML/day (Sydney Water, 2018)." Localised flow losses are clearly evident as a result of longwalls passing under or near watercourses (e.g. WC21, DC13, DCS2, LA4, and others). However, as discussed previously, if net losses in the magnitude stated here (5 ML/d) were occurring from Sydney's drinking water catchment, then flow losses of approximately 1 ML/d magnitude should be apparent at Wongawilli Creek gauge WWL and Donalds Castle Creek gauge DCU. However this is not the case, and the presence of groundwater recovery above and adjacent to longwalls supports this (which leads to different environmental effects).

BCD Submission	Response
Impacts on watercourses Several significant watercourses are likely to be impacted by Longwalls 22 and 23, including Wongawilli Creek, and Lake Cordeaux tributaries LC5 (770 m length of which is above the panels and pillars (44% of the total length of LC5)), and LC6. Impacts could include surface cracking, loss of flow, pool level decline and rock bar fracturing. Several tributaries of Lake Cordeaux have already been impacted by mining in Dendrobium Areas 1, 2 and 3A. The proposed longwalls would further contribute to impacts in the Lake Cordeaux catchment within the Metropolitan Special Area.	Mine layouts for Longwalls 22 and 23 have been developed using an Integrated Mine Planning Process. This process considers impacts to the mining operation as well as environmental impacts when designing mine layouts. Where impacts cannot be avoided or successfully remediated as is the situation for connectivity between near surface groundwater and deep groundwater, offsets have been provided to compensate for these potential impacts. Subject to Condition 14 of Schedule 3 of the Development Consent: *The Applicant shall provide suitable offsets for loss of water quality or loss of water flows to WaterNSW storages, clearing and other ground disturbance (including cliff falls) caused by its mining operations and/or surface activities within the mining area, unless otherwise addressed by the conditions of this consent, to the satisfaction of the Secretary. These offsets must:* *a) be submitted to the Secretary for approval by 30 April 2009;* *b) be prepared in consultation with WaterNSW;* *c) provide measures that result in a beneficial effect on water quality, water quantity, aquatic ecosystems and/or ecological integrity of WaterNSW's Special Areas or water catchments.* IMC transferred 33 ha of land adjacent to the Cataract River to WaterNSW to meet the above condition.
Impacts on upland swamps Upland Valley infill Swamp 7 located along Lake Cordeaux tributary LC5 extends over an area of 5.4 ha and is one of the largest and most significant swamps within the Dendrobium Mine footprint. This swamp is one of the designated Control Swamps under an active research program. This swamp would be undermined by Longwalls 22 and 23. WaterNSW is concerned that the hydrology of the swamp may be irreversibly affected. Swamp 7 should be considered in a similar manner to Swamp 15a overlying Dendrobium Area 3A and consideration should be given to application of similar performance measures.	See response regarding swamp offsetting for Area 3C. Swamp 15A in Area 3A received particular consideration in the Department's assessment of Dendrobium Development Consent Modification 6. As a result, the Consent contains a detailed performance measure that specifically relates to Swamp 15A. There is no similar condition imposed on Swamp 7. The Department state in their reasons for approvals of Longwall 19 SMP: "*It must be noted that this performance measure was not imposed in order to prevent any impact on Swamp 15a. Pages 22-24 of the Department's Assessment Report for Mod 6 make this quite clear.*" The Area 3C SIMMCP details the monitoring that is in place for Swamp 7.
Consideration should also be given to increasing the setback from Wongawilli Creek and Cordeaux Reservoir to 400 m to avoid impacts and ensure compliance with the relevant performance measures and modifying the mine layout to avoid directly undermining LC5 and Swamp 7, and LC6.	Wongawilli Creek is located at minimum distances of 345 m and 320 m from the finishing ends of Longwall 22 and 23, respectively. The proposed setbacks were determined using the rockbar impact model, consistent with other longwalls in Areas 3A and 3B to limit predicted valley closure to 200 mm across the rockbars of Wongawilli Creek. The maximum predicted total closure for the rockbars along Wongawilli Creek within the Study Area occurs on Rockbars 21 to 23 which is 190 mm. The predicted rate of impact for the rockbars along this creek after the extraction of the proposed longwalls, therefore, is in the order of 6 % based on the maximum predicted closure (MSEC 2021). Based on the cumulative multidisciplinary assessment provided in the Longwalls 22 and 23 SMP application, IMC considers the setback

BCD Submission	Response
	appropriate to achieve compliance with the Wongawilli Creek performance measure of "minor impacts". The Department state in their reasons for approvals of Longwall 19 SMP which has a setback of 175 m from Wongawilli Creek: "the Department has given careful consideration to the potential reduction in risk of Type 3 impacts within Wongawilli Creek by imposing an increase on IMC's planned 175 m setback. It considers that the risk of such impacts is already low (c.8%, based on MSEC's existing database of similar impacts). It considers that the available reductions in risk (i.e. 1% or 2%) are not significant in themselves. Most significantly, it considers that the existing rate of Type 3 impacts in Wongawilli Creek (which has been affected by the extraction of ten longwalls, two of which were closer to Wongawilli Creek than is proposed for Longwall 19) is very low. On this basis, the Department accepts IMC's proposed setback of Longwall 19 from Wongawilli Creek of 175 m." The setbacks of Longwalls 22 and 23 carry a reduced risk of 6% probability of rockbar fracturing to that of the most recently approved Dendrobium Longwall 19. IMC has undertaken extensive exploration and research campaigns to understand potential seepage from Area 3B longwalls adjacent to Avon Reservoir. IMC installed monitoring bores at 8 locations to assess geotechnical and groundwater conditions in the barrier zone between Lake Avon and Longwalls 12 to 18. Each monitoring site is re-drilled and tested following the extraction of the adjacent longwall to assess changes to strata permeability. Groundwater monitoring in the Lake Avon barrier zone shows widespread depressurisation of all strata in response to mining in Area 3B and a general hydraulic gradient towards Area 3B, consistent with numerical model predictions. Groundwater levels at the base of the Hawkesbury Sandstone were likely near or just above the lake level prior to mining and have since declined below the lake level. There is evidence for recovery in groundwater pressures in the Colo Vale Sandstone at site AD2. The water loss predictions from Avon Reservoir from the numerical groundwater model (Watershed HydroGeo 2020) and the local-scale numerical model (HGEO 2020c) both indicate that the mining of the Area 3B longwall series, including the unextracted Longwall 18, would not exceed the 1 ML/day Dams Safety NSW limit. The experience derived from Area 3B operations, the Avon Dam borehole series and the predictions from the regional groundwater model in Watershed HydroGeo (2021), Section 7.4.3 indicate a maximum leakage from Cordeaux Reservoir due to Dendrobium operations is 0.11-0.36 ML/d. The upper estimate from the modelling presented in Watershed HydroGeo (2021) (0.36 ML/d) is lower than Dams Safety NSW's prescribed tolerable limit of 1 ML/d. Therefore, the need for further setbacks is not considered necessary for Longwalls 22 and 23. Tributaries LC5 and LC6 are not subject to specific performance measures in accordance with the Area 3C SMP Approval. Swamp 7 is addressed in response above.

BCD Submission	Response
WaterNSW also recommends consideration of an adaptive management approach with relevant monitoring and Trigger Action Response Plans aimed at protecting Wongawilli Creek, Lake Cordeaux, Lake Cordeaux tributaries LC5 and LC6 and upland swamp 7.	IMC does not support the increased risk to mining operations which would result from implementing an adaptive management approach to Wongawilli Creek, Lake Cordeaux or the surface features LC5, LC6 and Swamp 7. The risks to each of these features is discussed in the response above and is considered comparable to previous Areas 3A and 3B. IMC has demonstrated compliance with performance measures in End of Panel reports and Dam Safety NSW reporting for the relevant SMP approvals which are in place to limit impacts to sensitive features. Adaptive management options are limited for longwall mining operations. IMC has considered mine layouts for Longwalls 22 and 23 that have been developed using an integrated mine planning process. This process looks to avoid impacts which are greater than those defined in the Development Consent or SMP approvals.
DPE RFI dated 14 April 2023	**Response**
The Subsidence Management Plan (SMP) Approval for Area 3C (condition 10 (f) of Schedule 3) requires the review of the WIMMCP to "fully reflect the advice of the of the Independent Expert Panel dated March 2022 on the Subsidence Management Plan 2021 relating to improving performance measures for watercourses". This advice is included in Section 6 (pages 16-18) of the Panel's submission and discussed issues with the performance measures for 'minor' environmental consequences for Wongawilli Creek relating to flow and water levels, as referenced in Table 6.1 of the WIMMCP.	It is acknowledged the current performance measures and TARPs for pool water levels are focussed on effects related to surface cracking, and not baseflow loss.
The advice notes that the exceeding predictions/performance indicators for this performance measure do not cover baseflow losses, specifically the measure for "fracturing within Wongawilli Creek resulting in diversion of surface flow such that >10% of the pools have water levels lower than baseline period". It is noted that a similar pool level trigger (Level 3) is reflected in the TARP (Appendix A) of the WIMMCP. This measure focuses on pool water level loss associated with fracturing and does not cover pool water level baseflow loss due to groundwater depressurisation (as it is understood has been experienced in Pool 43A).	As above. It is not proposed to modify the assessments and Performance Measures related to subsidence movements and fracturing re: 10% of pools with fracturing. Any new performance indicators should be based on new TARPs related to pool water levels at sites with level loggers (currently 9 sites in A3C – see orange symbols on the figure below), and analyse for changes (see #4a and #4b, below). Further investigation, in the event of effects on pool levels being detected, would include review of groundwater level/ drawdown/ gradients and possible impacts on baseflow, as well as comparison against groundwater modelling. We note that baseflow losses are predicted, and so some effect, especially during periods of low flow (as occurred in 2017-18) are expected. Further, the loss of baseflow is now (partially) offset by the financial compensation to WaterNSW (as required under Schedule 3 Condition 9 of the Longwalls 22 and 23 SMP Approval) and the new water trading rule to account for incidental surface water take implemented by the NSW Government.

BCD Submission	Response
Further, the Panel advised that "for the application of Method D to pool water level reductions or increases in cease-to-flow days, an appropriate threshold for changes in cease-to-flow days has not been specified, nor has the associated trigger for pool water or flow loss" (page 17).	Assessment Method D was developed to allow analysis of flow behaviour in mid-Wongawilli Creek using the ~30 sites where qualitative observations are made in the absence of suitable flow monitoring sites in this reach. Assessment Method D was not originally designed to use or analyse pool water level logger data (6 sites on Wongawilli Creek between A3A and A3B, partly because of a lack of baseline data). That said, there is scope for a TARP applied to pool level logger data (as in #2 above that results in a similar assessment as used in Assessment Method D). See response to #4a (below).
It is noted that a brief response to this advice is provided in Section 2.2.3 (Table 2-5) of the WIMMCP, however a full understanding of the adequacy of this response is difficult without a clear explanation of the Water Flow Assessment Methods A-D and associated triggers (which are only summarised in Section 3.6).	Watershed HydroGeo (2019b) was the result of multiple discussions with agencies (both in meetings and draft versions of documentation) and documents Assessments A-D in a step-by-step manner. Relevant content has been added to (new) Appendix F of the WIMMCP.
It is requested that the WIMMCP be further updated to specifically address the Panel's advice in relation to: • Inclusion of baseflow loss in the pool water level exceeding predictions/performance indicators and associated TARP; and • Appropriate thresholds for cease-to-flow days and pool water level or flow loss (likely to require further explanation of the Water Flow Assessment Methods A-D).	Pool water level TARPS and performance measures have been developed. In the main, this includes assessment of 4 possible modes of impact (re: baseline levels, recession rates and change of behaviour compared to Reference Sites). These are documented in Table 1.2 of Appendix A. Cease-to-flow frequency at flow monitoring sites already have agreed thresholds (Method B). Cease-to-flow (CTF) frequency at pools – (putting pool sites with loggers aside for the moment), pools are not observed on a continual basis (i.e. normally monthly observations, then weekly when mining within 400m). This means that such CTF frequency cannot be determined, and therefore thresholds are not appropriate. Flow loss thresholds have been agreed for flow monitoring sites (Method C). Method D also assess potential flow losses along Wongawilli Creek, but uses only a binary "below prediction"/ "exceeding prediction" outcome. Pool water level TARPs that focus on water level behaviour (whether fracturing is observed or not, i.e. so focus on the potential for baseflow loss to be the main driver of an impact) and performance measures are now documented in the WIMMCP (as noted above). If triggered, Assessment D is carried out to estimate whether the loss of flow is within the prediction from modelling.

Appendix E – Flow Gauging Stations

Location: LC6 (LC6S1) E 293571, N 6194873	**Elevation:** 314.57m	**Status:** Installed	**Type of structure:** Weir
 LC6S1, looking at weir. (Taken 17/03/2023)		 LC6S1, looking at the weir downstream. (Taken 16/01/2023)	

Location: LC5 (LC5S1) E 293043, N 6195327	**Elevation:** 314.72m	**Status:** Installed	**Type of structure:** Weir



LC5S1 Weir. (Taken 20/12/2021).



LC5S1 weir looking downstream (Taken 12/05/2019).

Location: LC5 (LC5S2) E292573, N6195119	**Elevation:** 337m	**Status:** Installed (date unknown, WaterNSW site)	**Type of structure:** V-notch Weir (WaterNSW Site)



LC5S2, looking downstream (Taken 13/02/2024)

Location: WC20 (WC20S1) E 290906, N 6194133	**Elevation:** 303.86m	**Status:** Installed.	**Type of structure:** Weir
 WC20S1, looking downstream of weird. (Taken 23/08/2022)			

Location: WC20 (WC20S2) E 291474, N 6194007	**Elevation:** 354.82m	**Status:** Installed	**Type of structure:** Weir
 WC20S2, looking upstream at weir. (Taken 20/12/2022)		 WC20S2, looking downstream of weir. (Taken 20/12/2022).	

Location: WC21 (WC21S1) Coords – 290529 6194255	**Elevation:** 282.95m	**Status:** Active	**Type of structure:** Natural Rockbar
 WC21S1 Looking upstream (Taken 20/05/2021)		 WC21S1 Looking downstream (Taken 20/05/2021)	

Location: WC24 (WC24S1) E 290861, N 6194659	**Elevation:** 286.91m	**Status:** Installed (16/6/2021)	**Type of structure:** Weir



WC24S1 Looking upstream. (Taken 9/8/2021)



WC24S1 Looking downstream. (Taken 9/8/2021)



WC24S1, looking at the weir on the day of installation. Taken (16/6/2021)



WC24S1, looking at the weir on the day of installation. Taken (16/6/2021)

Location: WC26 (WC26S1) E 290704, N 6195411	**Elevation:** 278.01m	**Status:** Installed	**Type of structure:** Weir
 WC26S1 weir looking downstream. (Taken 20/12/2022)			

Location: WC26 (WC26S2) E291092, N6195217	**Elevation:** To Be Provided	**Status:** Installed	**Type of structure:** Weir
 WC26S2 site prior to weir install. (Taken July 2021)			

Location: (WC11) WC11S1	**Elevation:** 349.5m	**Status:** Installed December 2022	**Type of structure:** Weir



WC11S1, looking upstream. Taken 26/02/2024.

Location: Wongawilli Creek (WWL_A) E 290963, N 6197375	**Elevation:** 263.28m	**Status:** Active (Installed August 2018)	**Type of structure:** Weir



WWL_A Looking upstream (Taken 27/09/2023)

Location: CR36 (CR36S1) Coords: E 291481, N 6197652	**Elevation:** 272.85m	**Status:** Installed (03/09/2019)	**Type of structure:** Weir
 CR36S1 Looking upstream (Taken 08/01/2021)		 CR36S1 Looking downstream (Taken 08/01/2021)	



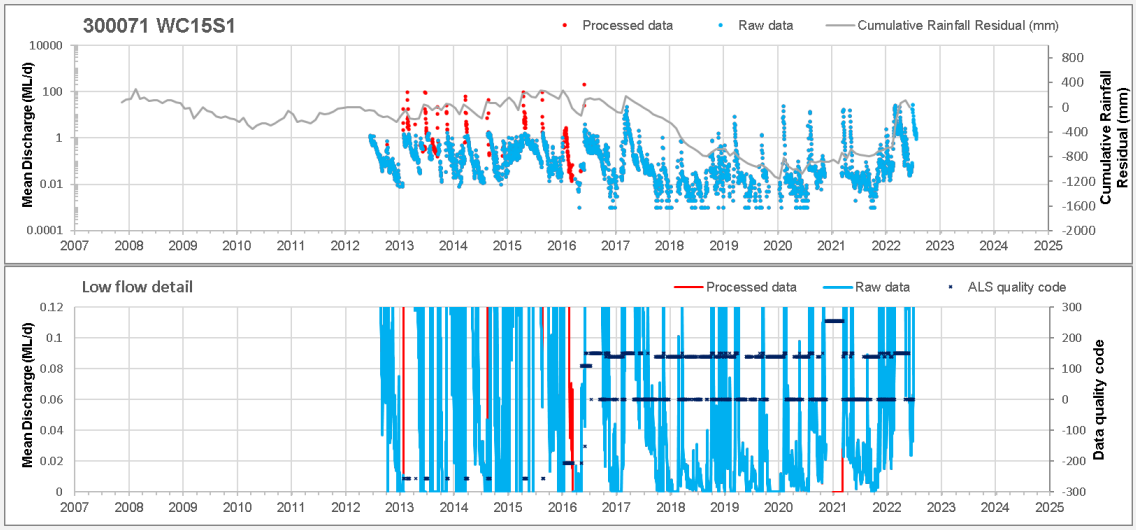
CR36S1 Looking at the weir (Taken 08/01/2021)

Location: LC7 (LC7S1) Yet to be installed	**Elevation:** To Be Confirmed	**Status:** Proposed	**Type of structure:** Weir
Location: LC9 (LC9S1) Yet to be installed	**Elevation:** To Be Confirmed	**Status:** Proposed	**Type of structure:** Weir

Appendix F – Surface Water Flow (Quantity) TARP Procedure

The following details the procedure employed for each of the Surface Water flow TARP Assessments in a step-by-step manner, including how these are reported in the End of Panel reports.

Phase	Procedure
Data Collation and Processing	Mean daily flow is provided by the contracted hydrographers (since 2016, this is ALS Hydrographics (ALS)). ALS take the monitored sub-daily stage data and use that to convert to sub-daily volumetric flow (via the rating curve) and then calculate average daily flow from that. Rating curves are periodically updated, and so historical flow data is re-calculated if the rating curve is updated. One problem is that ALS only re-rate the period for which they have been contracted (i.e. commencing 11/05/2016). Because the TARPs are aimed at detecting change in hydrology, Watershed HydroGeo is forced to carry out re-rating of any available flow record from pre-11/05/2016. This is done using a correlation of flows in the post-11/05/2016 period.
	• Gaps in the available flow record are treated prior to analysis (with the overall aim of maximising the available data, without artificially skewing or affecting the important metrics (Q50, cease-to-flow frequency). Note that longer periods are harder to infill than shorter periods (e.g. 1-2 days). Steps are: • High flows (e.g. "above rating curve") – filled using daily flow estimated from neighbouring catchment, pro-rated by catchment area. The intent is that a NULL entry cannot be used in estimation of median flow for a period, but a high flow provides the appropriate information for estimation of Q50 for a period, and also is not mistaken for zero flow (i.e. calculation of cease-to-flow frequency). • Data loss due to equipment failure or similar issue – similar procedure to the above (using flow data from neighbouring catchment pro-rated by catchment area). • Reporting of 'raw' data (as provided by ALS) and 'processed' data is presented in each EOP report. An example of this is shown below, where red data indicates infilled (processed) flow data.



Data from WaterNSW sites is also collated and reviewed. No gaps in the O'Hares Creek (213200) flow record have been filled (there are few in any case). Some gaps are filled in the Sandy Creek (2122205) record, but not all.

Assessment periods	The relevant period for each assessment site is stated in the EOP reports (example below, with annotations of each numbered step (e.g. #1, #2). **Pre-mining** period for an assessment site is defined by: • 1) The earliest date in the flow monitoring record (assuming that is prior to a nearby longwall being extracted directly under the monitored sub-catchment). • 2) The last date in the flow record prior to the first longwall passing beneath the monitored sub-catchment. **Post-mining** period for an assessment site is defined by: • 3) The date on which first longwall "entered" (i.e. starting passing beneath) the monitored sub-catchment. • 4) The end date of the relevant longwall (for which the End of Panel report is assessing) plus 30 days.

Table 14. Flow assessments A, B and C for the sub-catchment to DC13S1

DC13S1	Pre-mining	Post-mining
	to start LW9	end LW18 + 30days
	1 27/06/2012	3 10/02/2013
	2 9/02/2013	4 16/06/2022

Example from EOP reporting – Relevant Periods

Assessment Methods A-D

Assessment Method A: (change in flow %iles)

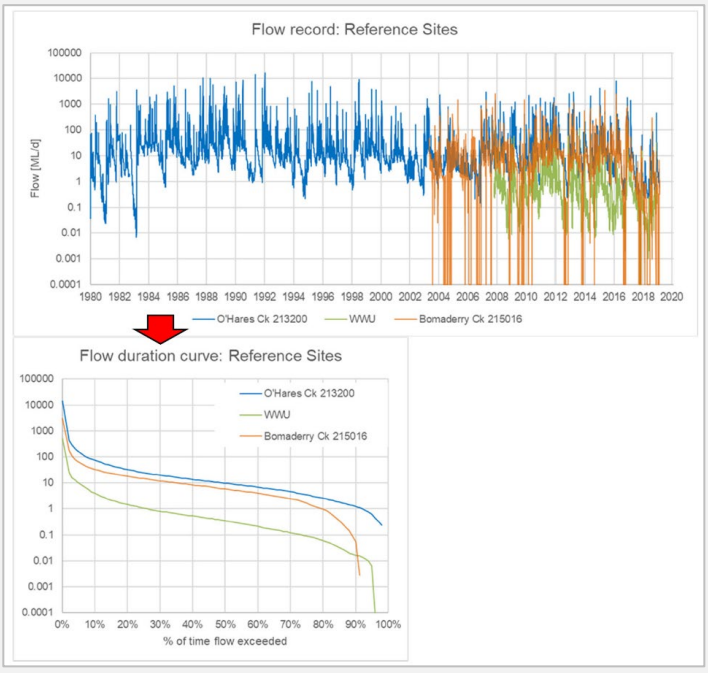
The steps for Asssessment Method A are documented below and an example from the EOP reports is presented below (with annotations of some of the numbered step (e.g. #1, #2).

1) For the pre-mining period (which is calculated based on the available data for each Assessment Site – see above), the Flow Duration Curve is calculated for each Reference Site and for the Assessment Site.

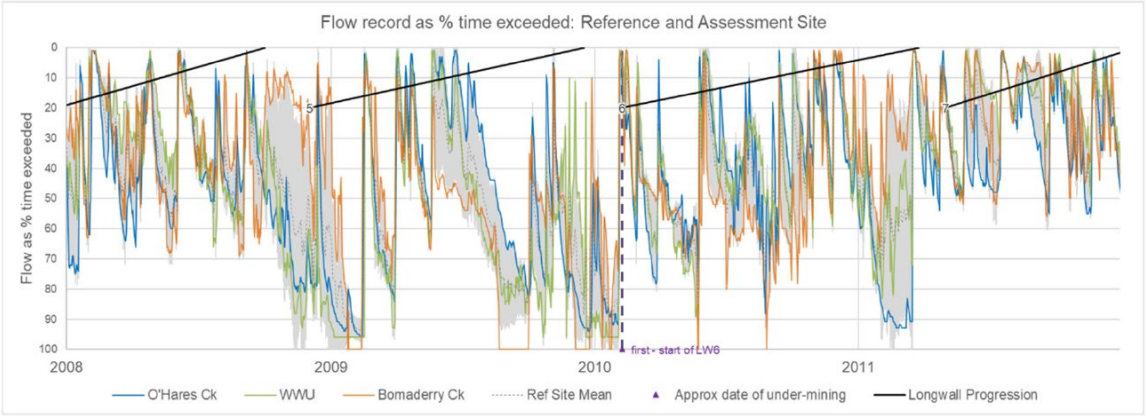
   An example, originally presented as Figure 3-3 of Watershed HydroGeo (2019), Is duplicated here:

   This shows the flow which is exceeded for X% of the time e.g. Q10 is the flow exceeded 10% of the time, i.e. a high flow.

   Q90 is the flow exceeded 90% of the time, i.e. a low flow. Q50 is the flow exceeded 50% of the time, i.e. the median flow.



2) For the pre-mining period, the transient flow record (in ML/d) is then re-calculated as “flow percentiles” for each site. An example of this is shown below (showing sites originally considered as possible Reference Sites). Note that on this figure, the Y-axis is the % of time exceeded (not ML/d).



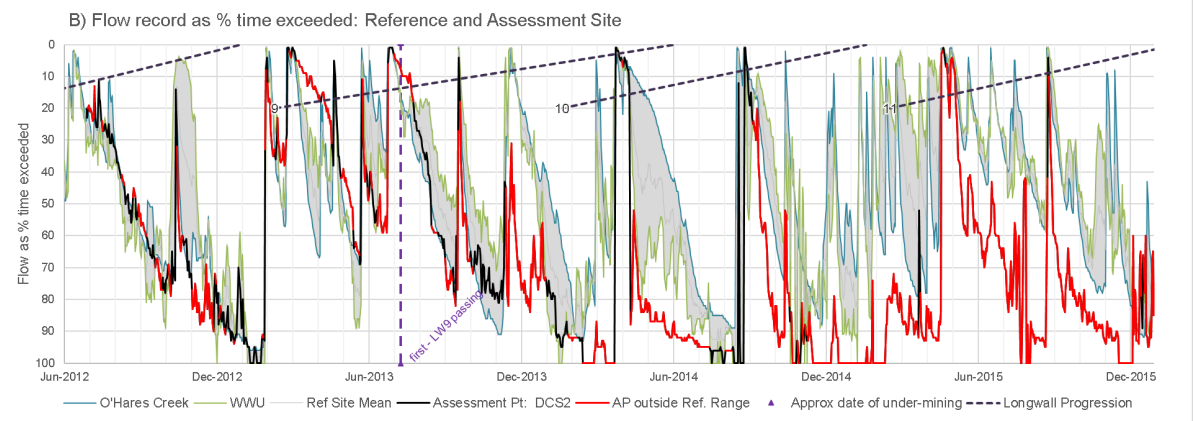
Example from flow percentile calculation for Assessment Method A

3) Then the flow percentiles through time for the Assessment Site are compared to those of the Reference Sites.

The figure below plots the flow percentiles for the Reference Sites (green and blue series), with the area between the two lines shaded in grey.

The flow percentile for the Assessment Site is plotted in black/red, where the black symbology is used for when the Assessment Site %ile is similar to (within the range) that of the Reference Sites. The intent is that when a flow equivalent to Q90 occurs at one site, a similar flow (e.g. Q95-Q85) is likely to occur at other nearby sites.

The red symbology is used when the Assessment Site %ile falls outside the range indicated by the Reference Sites. It is seen that this does occur in the pre-mining period (to the left of the dashed purple line).



Example of flow record converted to % time exceeded: Assessment Site vs two Reference Sites

The amount of time that the Assessment Site %ile falls outside the Reference Site range is calculated for the pre-mining period (expressed as a percentage of the total time in the pre-mining period).

4) For pre-mining period Assessment Site flows being lower than Reference Site flows, see #4 on figure below.

5) For pre-mining period Assessment Site flows being higher than Reference Site flows, see #5.

Then the same re-calculation of the post-mining flow record is carried out using post-mining flows (ML/d) for the Assessment Site and Reference Sites compared to the pre-mining flow duration curve i.e. the flow duration curve for the post-mining period is not used.

The chart above shows this for the Assessment Site (to the right of the dashed purple line).

Then the amount of time that the Assessment Site %ile falls outside the Reference Site range is calculated for the post-mining period (expressed as a percentage of the total time in the post-mining period).

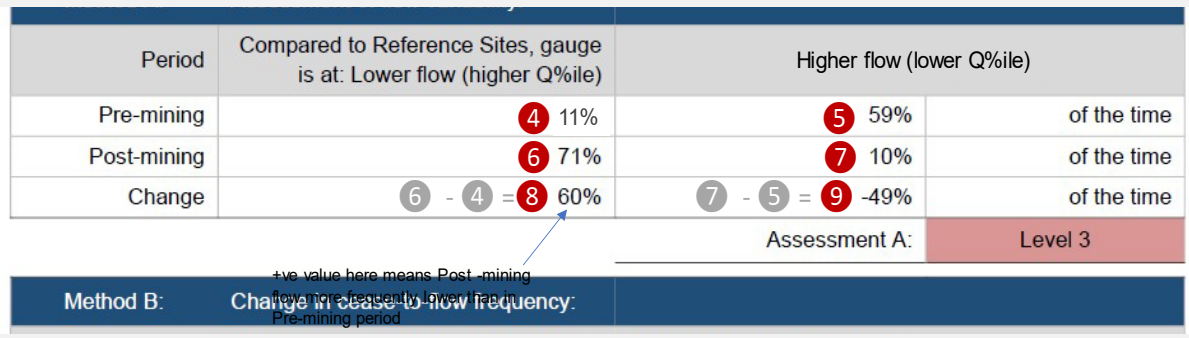
6) For post-mining period Assessment Site flows being lower than Reference Site flows, see #6.

7) For post-mining period Assessment Site flows being higher than Reference Site flows, see #7.

8) Then the change in the proportion of time that the Assessment Site % flow exceeded lies beyond (below) the range of Reference Site Q%ile in the pre- and post-mining periods is calculated.

   #8 is then used to assess the TARP Trigger Level.

9) And then the change in the period that Assessment Site % flow exceeded lies above the range of Reference Site Q%iles is calculated and reported (#9). However the focus is on #8 because the main concern is an increase in the frequency of lower flows from pre- to post-mining periods.



Example from EOP reporting – Assessment Method A

Trigger Levels – Assessment Method A

Greater proportion of time with lower flow than expected based on Reference Q%	Inference
Proportion of time increased by < 10%	No evidence of impact (or any impact below detection considering natural variability)
Proportion of time increased by >= 10%	Possible impact (Level 1)
Proportion of time increased by >= 15%	Level 2
Proportion of time increased by >= 20%	Level 3

Assessment Method B: change in frequency of cease-to-flow days

The steps for Asssessment Method B are documented below and an example from the EOP reports is presented below (with annotations of each numbered step (e.g. #1, #2)).

For this assessment, "cease-to-flow" ("CTF") frequency is defined as [no. of days with a daily average flow of zero] / [total number of days in the period for which there is a valid flow record]. (for a small number of sites, accuracy of flow gauging means that a very small non-zero flow is used as a proxy for zero flow - this is stated in the EOP reports).

1) For the pre-mining period (which is calculated based on the available data for each Assessment Site – see above), the number of cease-to-flow ("CTF") days is calculated for each of the two Reference Sites.
2) For the post-mining period, CTF frequency is calculated in the same manner for the two Reference Sites.
3) The change in CTF frequency % is calculated for each of the two Reference Sites;

   change (#3) = ([CTF post-mining] - [CTF pre-mining]) = (#2 - #1)
4) "Natural Variability" is calculated as the average of the change in CTF frequency from the two Reference Sites (see #3, above).
5) For the pre-mining period (which is calculated based on the available data for each Assessment Site – see above), CTF frequency is calculated for the Assessment Site. The method is as per #1, above.
6) For the post-mining period, CTF frequency is calculated for the Assessment Site.
7) The change in CTF frequency % is calculated for the Assessment Site;

   change (#7) = ([CTF post-mining] - [CTF pre-mining]) = (#6 - #5)
8) The change in CTF frequency estimated to be due to mining, i.e. removing the influence of natural variability (i.e. weather), is calculated as:

   change (#8) = (#7 - #4)

This is then used to assess the TARP Trigger Level.

Method B:	Change in cease-to-flow frequency:		
Cease to flow as % of daily record during		pre- and post- mining periods	
Site	Pre-mining	Post-mining	Change
O'Hares Creek	1 0.0%	2 0.0%	2 - 1 = 3 0.0%
WWU	10.1%	4.6%	-5.5%
Average Ref. Site change (= natural variability):			4 -2.7%
DC13S1	5 0.0%	6 14.5%	6 - 5 = 7 14.5%
	no. of cease-to-flow days increased:		7 - 4 = 8 17.2%
		Assessment B:	Level 2

Example from EOP reporting – Assessment Method B

Trigger Levels – Assessment Method B

Greater proportion of time with cease-to-flow	Inference
Proportion of time increased by < 5% above Reference Site change	No evidence of impact (or impact within natural variability)
Proportion of time increased 5-10%	Possible impact (Level 1)
Proportion of time increased 10-20%	Level 2
Proportion of time increased >=20%	Level 3

Assessment Method C: change in median flow (Q50)

The steps for Asssessment Method C are documented below and an example from the EOP reports is presented below (with annotations of each numbered step (e.g. #1, #2).

1) For the pre-mining period (which is calculated based on the available data for each Assessment Site – see above), the median flow (Q50) is calculated for the two Reference Sites.
2) For the post-mining period, Q50 is calculated for the two Reference Sites.
3) The % change in Q50 is calculated for each of the two Reference Sites;
   change = ([Q50 post-mining] - [Q50 pre-mining]) / [Q50 pre-mining])
   = (#2 - #1) / #1
4) "Natural Variability" is calculated as the average of the % change in Reference Site Q50 (see #3, above). The minimum and maximum % changes are also reported.
5) For the pre-mining period (which is calculated based on the available data for each Assessment Site – see above), Q50 is calculated for the Assessment Site.
6) For the post-mining period, Q50 is calculated for the Assessment Site.
7) The % change in Q50 is calculated for the Assessment Site;
   (change = [Q50 post-mining] / [Q50 pre-mining]).
8) The "expected" post-mining Q50 for the Assessment Site is estimated from the Min/Mean/Max % change in Reference Site Q50 (= #4 x #5). This provides context of the potential change in flow at the Assessment Site.
9) The % change in Assessment Site Q50 (#7) beyond "Natural Variability" (#4) is calculated (= #7 - #4) / 'denominator'. When these TARP methods were originally proposed (based on Watershed HydroGeo, 2019b), it was using the Pre-Mining Q50 (#1) as the 'denominator'. Having now used this method for 4 years, we consider that this should still be reported for consistency with the previous method, but should not be used for the TARP Trigger Level.
10) Following on from #9, it is considered more appropriate to use the 'expected Q50' (#8) as the denominator' to calculate the % impact, as this avoids skewing the result to pronounced wet/dry baseline periods. This also provides a more meaningful estimate of the impact as a % of the flow that should have been expected in the assessment period. <u>We propose that this modified version be used to determine the TARP Trigger Level.</u>
11) The volumetric (ML/d) change in Assessment Site Q50 between pre- and post-mining periods is then estimated from the % change (= #9 x #1).

Method C: Change to median flow (Q50):			
Reference Site Q50 [ML/d]	Q50 (pre-)	Q50 (post-)	% Change
O'Hares Creek	1 5.46	2 7.16	3 31%
WWU	0.40	0.44	10%
Natural variability	Min	Mean	Max
from 2 x Ref. Sites	10%	20%	31% 4
Assessment Site Q50 [ML/d]	Q50 (pre-)	Q50 (post-)	% Change
DC13S1	5 0.126	6 0.055	7 -56%
'Expected post-mining Q50' at	Min	Mean	Max
DC13S1	4 x 5 = 8 0.138	0.151	0.164
Change beyond natural	Min	Mean	Max
% change (of pre-mining Q50)	7 - 4 = 9 -65.7%	-76.5%	-87.3%
% change (of 'expected Q50')	10 / 8 = 10 **-60%**	**-64%**	**-67%**
ML/d change from natural	9 x 1 = 11 -0.083	**-0.096**	-0.109
		Assessment C:	Level 3

Example from EOP reporting – Assessment Method C

Trigger Levels – Assessment Method C

Relative change in Q50	Inference
Q50 reduction <10% (above Reference Site change)	No evidence of impact (or impact within natural variability)
Q50 reduction of 10-15%	Possible impact (Level 1)
Q50 reduction of 15-20%	Level 2
Q50 reduction >=20%	Level 3

Additional Detail

Following a request from DPHI, we have included some additional detail regarding the change to the method at #10 (above). For this item, we recommend to alter the basis of the trigger level so that it is based on change in flow as a % of 'expected Q50' flow rather than as a % of 'pre-mining Q50'. A worked example is provided here to illustrate the why this is justified.

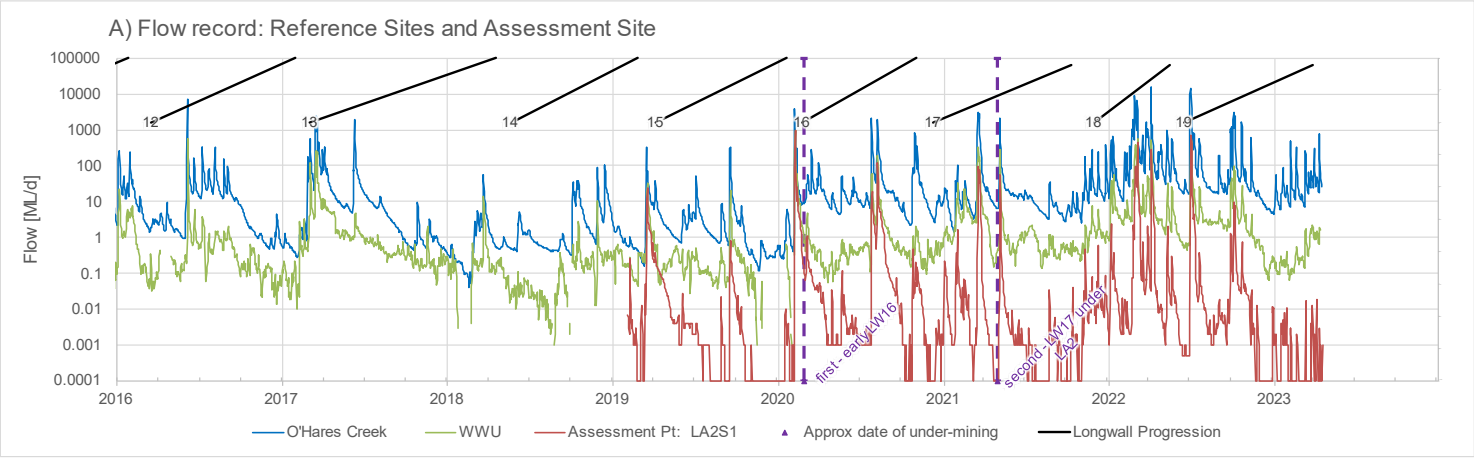
In the Longwall 19 End of Panel report, the following data was presented for site LA2 (see hydrograph below). Monitoring commenced in early 2019, and mining passed approximately 1 year later. Given the short baseline, perhaps an estimate of flow reduction should not have been calculated as it violates the theory of BACI analysis, but we try to maximise the utility of whatever data is available.

Of note however is that the baseline corresponds almost exactly with the last 12 months of the 2017-19 drought, which was then followed by three wet years, including record rainfall in 2022.

Assessment Method C, as tabulated in the End of Panel Report, is included below. In regard to the dry baseline conditions and wetter post-mining conditions, this is reflected in the 1350% and 550% change in flow at the two reference sites on lines 1 and 2 (line numbers denoted in blue).

The change in flow between pre-mining and post-mining periods at the Assessment site is calculated first as a % change compared to the Reference Sites, then converted to a ML/d. We emphasise is that this recommended modification to the WIMMCP does not alter the calculated 'change in median flow' as ML/d.

Then this change in ML/d was expressed for the purpose of the TARP as a % of pre-mining flow. As shown on line 5, for this site, the result is -851% (of pre-mining Q50). This highlighted value is mathematically correct, but not conceptually useful for describing the effect of mining.



Flow Hydrograph for LA2 and Reference Sites

Example from Longwall 19 EOP

Method C: Change to median flow (Q50) at Assessment Site at LA2S1				
	Reference Site - Q50 [ML/d]	**Q50 (pre-)**	**Q50 (post-)**	**Change**
1	O'Hares Creek	1.25	18.21	1352%
2	WWU	0.14	0.90	550%
	Natural variability	**Min**	**Mean**	**Max**
3	From relevant Ref Sites	550%	951%	1352%
	Assessment Site - Q50 [ML/d]	**Q50 (pre-)**	**Q50 (post-)**	**Change**
4	LA2S1	0.002	0.004	100%
	Change beyond natural	**Min**	**Mean**	**Max**
5	compared to Ref Site change	-450.4%	-851.4%	-1252.4%
6		-0.009	-0.017	-0.025
7	**Assessment**			**Level 3**

Now we present the recommended change to the method.

If we use the % change in flow at the Reference Sites between pre- and post-mining periods, we can make an estimate of what the Q50 should have been at LA2 for the post-mining period in the absence of mining. This is the 'expected Q50' shown on line 8. Then comparing that to the measured post-mining Q50, the change in flow as a % of what was expected is highlighted on line 9 (i.e. 81%, range 69-86%). This result is more useful when communicating % reductions in flow because it is related to the same period that the change occurred, rather the pre-mining period, and this % is therefore much less influenced by the dominance of wet/dry conditions in the pre- and post-mining periods.

The existing trigger levels for Levels 1, 2 and 3 remain applicable, i.e. this site would still trigger Level 3.

Expected post-mining Q50 [ML/d]				
		Min	**Mean**	**Max**
8	LA2S1 – expected post-mining Q50	0.013	0.021	0.029
	Change in flow beyond natural	Min	Mean	Max
9	compared to 'expected' Q50	-69%	-81%	-86%

Sites with a longer baseline period will be less affected by this change, but we note that the % change can be larger or smaller. E.g. using the existing method, the % change at SC10C (for the LW19 period) was -22% (range -10 to -34%) of pre-mining Q50, but if expressing this using the 'expected Q50', this would alter the reported change to -30% (range -17 to -40%), which is relatively consistent with the existing method.

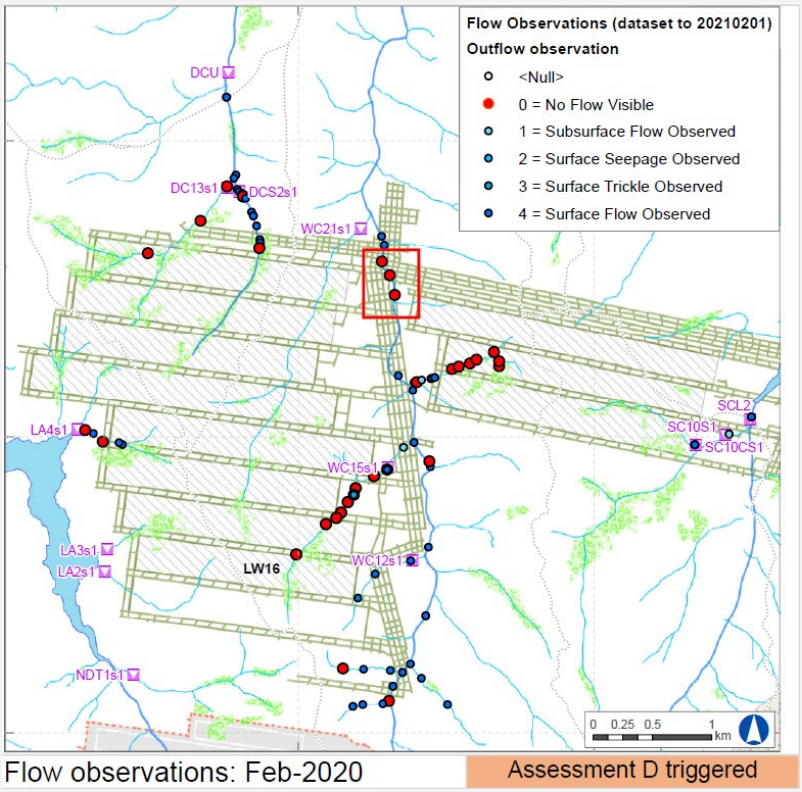
Assessment Method D: cease-to-flow in mid-Wongawilli Creek

SMP approval conditions required that potential baseflow losses along Wongawilli Creek be monitored and assessed. One of the constraints for monitoring this behaviour is the lack of a suitable site for an intermediate gauging station between WWU and WWL. IMCEFT routinely make qualitative observations of flow conditions (e.g. “surface flow”/”subsurface flow”/”not flowing”) along watercourses around Areas 3A, 3B and 3C (see Section 3.3). These are usually at pools, where the inflow to and outflow from pools are described. Of these, the outflow condition is considered more relavent to potential impact to that pool/site.

The initial part of the assessment relies on the qualitative observations from IMCEFT being plotted in GIS, and those on Wongawilli Creek (not the tributaries) are plotted and symbolised to highlight observations of no flow (no outflow) from pools along Wongawilli Creek (the example here is from Feb-2020).

Assessment Method D is then triggered when:

- there are two or more spatially consecutive observations of ‘no flow’ from the outlet of a pool along Wongawilli Creek, OR
- a pool along Wongawilli Creek is observed as being dry.



Flow observations: Feb-2020 — Assessment D triggered

If two (or more) consecutive ‘no flow’ observations along Wongawilli Creek or a pool along Wongawilli Creek is recorded as being dry, then there is assumed to be a reliable no flow condition along Wongawilli Creek.

Because qualiatative observations are made on an approximately monthly basis, this assessment may occur outside of the EOP reporting process, i.e. be triggered by routine monthly observations along Wongawilli Creek.

One potential limitation of this assessment is the ability to reliably record “no flow” compared to “no observable” flow; the latter may be caused by flow through a permeable substrate (e.g. sand bar, matted vegetation). It is for this reason that consecutive observations of “no flow” are used as the trigger for the assessment.

An example for Feb-2020, as tabulated in the EOP report for Longwall 16, is shown below with annotations of the following steps:

1) This shows three pool sites for which “no flow” observations were made.
2) The catchment area upstream of the point where the “no flow” observations occur is measured in GIS.
3) The catchment area for each of the gauged subcatchments upstream of the “no flow” occurrence is summed.
4) The recorded upstream flow at WWU and other gauged tributaries upstream of the point where the “no flow” observations occur (e.g. WC15, WC12 gauged flows) is found from the flow data provided

Assessment Method D: cease-to-flow in mid-Wongawilli Creek

by ALS for the same day that the flow observations were made at the relevant pools. These are summed at #4.

5) The gauged flows (#4) are factored up to account for the ungauged catchment contributing to the "no flow" observations (= [#2 / #3] x #4.

   The factored and unfactored flow losses are then used as the bounds of the likely flow losses along Wongawilli Creek.

6) These are then annualised (#5 x 365), and, for the purpose of reviewing the Performance Measure (see below), are compared against :

   - Downstream flows at WWL;
   - Estimates of Wongawilli Creek losses from groundwater modelling.

Table 21. Assessment D for Wongawilli Creek: February 2020

Assessment D	Feb-20	Level 2
1 Date(s) of relevant no flow observations		
Pool 42a	4/02/2020	
Pool 43a	4/02/2020	
Pool 43b	4/02/2020	
2 Catchment area upstream of relevant "no flow" sites		
12.55	km²	
Monitored flow at upstream and tributary sites		
	Catch. area km²	4/02/2020
WWU	3.211	0 ML/d
WC12	2.434	0.008 ML/d
WC15	1.192	0 ML/d
Total	3 6.837	4 **0.008** ML/d
Factored up by catch. area		**0.015** ML/d
Flow at downstream sites		(context)
	Catch. area km²	4/02/2020
WC21	2.434	0.026 ML/d
WWL_A	19.602	0 ML/d
WWL	20.079	0 ML/d
Inferred flow loss for middle reach, i.e. to "no flow" sites		
	Min	Max
Daily	4 0.008	5 0.015 ML/d
Annualised 6	2.92	5.36 ML/yr

(2 / 3) x 4 = 5

Example from EOP report (Longwall 15)

There are no assessment levels (e.g. level 1, 2, 3).The results are expressed as 'within prediction' or 'exceeding prediction'. If the result is 'exceeding prediction' it would then be analysed further to understand possible reasons.

An example of the reporting is presented below.

Assessment Method D: cease-to-flow in mid-Wongawilli Creek

Example of assessment of Performance Measure (from Longwall 15 EOP report):

Wongawilli Creek – minor environmental consequences	
Agreed measure:	*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".*

Assessment D for flows along the middle of Wongawilli Creek (Table 21) suggests that flow reductions are in the order of 0.008 to 0.015 ML/d (equivalent to 2.9 to 5.4 ML/yr). These estimates are:

- 1-2% of predicted losses for Wongawilli Creek made by recent groundwater modelling (398 ML/yr from the approved Longwall 17 SMP Application); and
- 1-2% of predicted losses for Wongawilli Creek made by recent groundwater modelling (271 ML/yr from the Longwall 19 SMP Application).
- Therefore, the estimated losses are "within prediction", and this Performance Measure is met.

Appendix G – Landscape Monitoring Program and Trigger Action Response Plan

Table G.1 – Dendrobium Area 3C Landscape Monitoring

MONITORING SITE	SITE TYPE	MONITORING FREQUENCY	MONITORING PARAMETERS
LANDSCAPE FEATURES – TARGETED SITES			
Area 3C **Cliffs** All mapped cliff sites within 400m active mining area Targeted monitoring sites include: - LC6_CL1 - LC9_CL1 - WC26_CL1 - WC26_CL2 - WC26_CL3	The categories of site inspection include: Specific targeted monitoring sites based on potential risk Re-visits to identified impact sites	A baseline survey prior to mining Monthly monitoring of targeted sites within the 400m active mining area Post-mining inspection of all sites following completion of the longwall.	Baseline and during mining inspection includes the following: Morphological type Dimensions Drainage Disturbance of site Erosion Aggradations Inundation Rock Fracturing Changes in runoff Vegetation disturbance Rockfalls Soil cracking Slumping
Steep Slopes Steep slopes within 400m active mining area Targeted monitoring sites include: - LW22_SS1 - LW22_SS2 - LW22_SS3 - LW23_SS1 - LW23_SS2 - LW23_SS3 - LW21a_SS1 - LW21a_SS2 - LW21a_SS3 - LW21a_SS4 - LW21a_SS5 - LW21_SS3 - LW21_SS1 - LW21_RO2 - LW21_RO1 - LW21_FR6F - LW21_AT1			
Fire Trails All fire trails/access tracks in 400m active mining area. Targeted monitoring sites include: - LW22_AT1 - LW22_FR6F - LW23_AT1 - LW23_FR6F - LW21a_AT1 - LW21a_AT2 - LW21a_FR6C - LW21_FR6F - LW21_AT1			

MONITORING SITE		SITE TYPE	MONITORING FREQUENCY	MONITORING PARAMETERS
INSPECTION OF ACTIVE MINING AREA - LANDSCAPE FEATURES				
Area 3C	All cliff, steep slopes and fire trail sites in subsidence area *(Refer to Figure 3-1 for location of sites General observation of active mining areas)*	The categories of site inspection include: General inspection of all active subsidence areas Re-visits to identified impact sites	Weekly monitoring when longwall extraction is within 400 m of feature	During mining recording includes impacts to: Drainage Disturbance of site Erosion Aggradations Inundation Rock Fracturing Changes in runoff Changes in vegetation Impacts to fauna/fish Rockfalls Soil cracking Slumping

Table G.2 – Dendrobium Area 3C Landscape Impacts, Triggers and Response

Landscape Feature	Reporting Trigger	Trigger Response
AREA 3C* **Cliffs** All mapped cliff sites in active mining area **Steep Slopes** Steep slopes in active mining area **Fire Trails** All fire trails and access tracks active mining area ** Refer to Figure 3-7*	***Level 1*** • Rock fall from a cliff which is left mostly intact (<10% length), resulting in insignificant ground disturbance • Surface movement or rock displacement with negligible soil surface exposed • Crack at the surface, which should not result in any significant erosion or impede access • Crack or fracture up to 100mm width • Crack or fracture up to 10m length • Erosion in a localised area which could be expected to naturally stabilise without CMA and within the period of monitoring	• Continue monitoring program • Report impacts to key stakeholders • Summarise actions and report in the End of Panel Report and Annual Review
	Level 2 • Rock fall or overhang collapse at a cliff site, where characteristics of the cliff have changed, and there has been significant ground disturbance • Surface movement or rock displacement that has exposed significant areas of soil • A crack at the surface, which could result in significant erosion or movement at the surface • A crack at the surface with potential risk to safety and/or fauna entrapment • A crack in the fire trail, which could result in significant erosion or impede vehicle access • Crack or fracture between 100 and 300mm width • Crack or fracture between 10 and 50m length • Significant erosion at any location, which is not likely to naturally stabilise within the period of monitoring, or is located in a sensitive area e.g. swamps, creek, lake shore, and may result in increased sediment transport to Cordeaux Dam or has been previously identified as Level 1, but is not likely to naturally stabilise within the monitoring period	• *Actions as stated for Level 1* • Review monitoring frequency • Notify technical specialists and seek advice on any CMA required • Provide safety signage and barricades as appropriate • Implement approved repairs to ensure safety and serviceability on fire trails • Implement agreed CMAs as approved (subject to agency feedback) *Note: CMAs are to be proposed based on appropriate management of environmental and other consequence of impacts i.e. cracking at the surface with insignificant consequences may not require specific CMAs other than ongoing monitoring to confirm there are no ongoing impacts*
	Level 3 • Major cliff collapse where the characteristics of the cliff change significantly and there is significant ground disturbance that is unlikely to naturally stabilise within the monitoring period • Crack or fracture over 300 mm width • Crack or fracture over 50 m length • Mass movement of a slope causing large areas of exposed soil with potential for further movement	• *Actions as stated for Level 2* • Immediately notify key stakeholders and relevant technical specialists and seek advice on any CMA required • Site visits with stakeholders if required

Note: "Key Stakeholders" include DPE, WaterNSW, the Biodiversity Conservation Division of BCS (BCD) and Resources Regulator and/or their Successor Agencies.