SOUTH32

DENDROBIUM
AREA 3C

AUGUST 2020




AREA 3C

WATERCOURSE IMPACT, MONITORING, MANAGEMENT AND CONTINGENCY PLAN

Table of Contents

Tables

Figures

Appendices

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

Persons involved in the development of this document

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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 and 3A. Longwalls in Area 3B are 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 s75W 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 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.

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 shall prepare a Watercourse Impact Monitoring, Management and Contingency Plan to the satisfaction of the Secretary. Each such Plan must:

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

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

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

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

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

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

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

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

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

1.3 Study Area

The Study Area is defined as the surface area that could be affected by the mining of the proposed Longwalls 20 and 21 (**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 the proposed Longwalls 20 and 21;

- The predicted limit of vertical subsidence, taken as the 20 mm subsidence contour, resulting from the extraction of the proposed longwalls; 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 410 m directly above the proposed Longwalls 20 and 21. 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 (2019).

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 20 and 21 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, Industry and Environment (DPIE);
- Biodiversity Conservation Division within DPIE; and
- WaterNSW.

In accordance with Condition 10(a), Schedule 3 of the Area 3C SMP Approval, WaterNSW will be consulted on proposed changes to the WIMMCP.

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

1.5.1 Longwall 21 SMP Approval

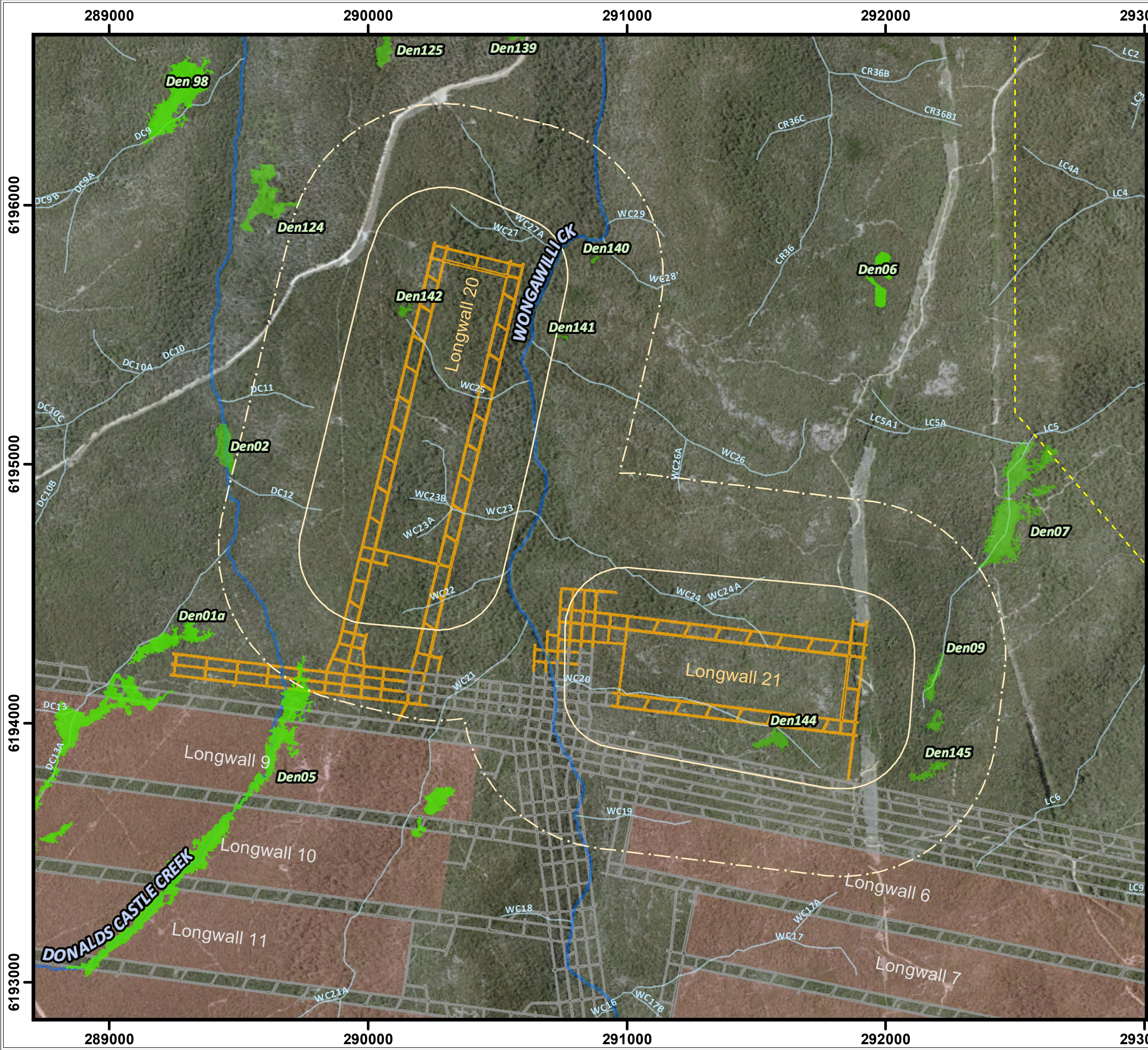
In accordance with the Area 3C SMP Approval Condition 10a, Schedule 3, the WIMMCP was provided to BCD and WaterNSW in June 2020 for consultation. Agency feedback was received with **Table 1-1** providing details of feedback and associated responses.

Table 1-1 Agency Feedback and Responses

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 DPIE 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 EoP Report. The assessment comprises three checks of pre- versus post-mining behaviour for each assessment site. Trigger values are proposed for water flow parameters in the TARP (Appendix A). The TARPs are based on the following parameters and assessments: A. Change in flow exceedance (Q%ile) behaviour compared to key flow reference sites. In essence, this aims at quantifying an otherwise visual or qualitative assessment of flow behaviour (compared to normalised key flow reference site flow); B. Relative change in the frequency of cease-to-flow days compared to key reference sites; C. Relative change in Q50 (median flow) compared to key reference sites flows; and D. Baseflow reduction along Wongawilli Creek, between Areas 3A and 3B. A more detailed discussion of these assessments, developed and refined in consultation with agencies, is provided in Watershed HydroGeo (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 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, South32 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	Noted.

assessing water quantity impacts on Wongawilli Creek.	
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 South32 at this time. Further assessment is required to be undertaken to support the Longwall 20 SMP Application.
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 moisture levels in this swamp is predicted and proposed to be monitored.	This is addressed in the Area 3C SIMMCP (see Section 5.33).



DENDROBIUM AREA 3C SMP

Watercourses above Dendrobium Mine Area 3C

Figure 1-1

- Study Area (35 deg Angle of Draw)
- Study Area (600 m Boundary)
- Upland Swamps
- Creeks
- Tributaries
- Existing Mine Workings
- Proposed Longwall Layout
- Dendrobium Goaf
- DSC Notification Areas

Date: June, 2020
Author: B.Agland

Version 1
Horizontal Datum
MGA - Zone 56

0 250 500 1,000
Meters

2 PLAN REQUIREMENTS

Extraction of coal from Longwalls 20 and 21 will be in accordance with the conditions set out in the Dendrobium Development Consent 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 20 and 21 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 Attachment A of the Surface Water Quality and Hydrology Assessment (HGEO 2019). The monitoring program is incorporated into this plan and the Longwalls 20 and 21 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 and Donalds Castle Creek is classed as a second 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.

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

2.1 Dendrobium Development Consent

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

Dendrobium Development Consent Condition	Relevant WIMMCP Section
Condition 4 – Schedule 3 Prior to carrying out any underground mining operations that could cause subsidence in either Area 3A, Area 3B or Area 3C, the Applicant shall prepare a Watercourse Impact Monitoring, Management and Contingency Plan to the satisfaction of the Secretary. Each such Plan must:	
(a) demonstrate how the subsidence impact limits in conditions 1 - 3 are to be met;	**Sections 3**, **4** and **5**
(b) include a monitoring program and reporting mechanisms to enable close and ongoing review by the Department and DPI of the subsidence effects and impacts (individual and cumulative) on Wongawilli Creek, Sandy Creek and Sandy Creek Waterfall;	**Section 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 DECC, WaterNSW and DPI;	**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 Executive Director of DPIE on 19 December 2019. IMC are required to seek further approval from the Department for Longwall 20 as per Condition 1 of Schedule 4 which states "*This Subsidence Management Plan Approval does not include approval of Longwall 20. The Applicant must obtain the approval of the Secretary (under condition 7 of Schedule 3 of the development consent) for the extraction of Longwall 20 prior to commencing development of the maingate and/or tailgate for that longwall.*"

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

Table 2-2 Dendrobium 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 June 2020 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**
(d) reflect the nine monitoring program recommendations included in *Height of Cracking - Dendrobium Area 3B* (PSM, 2018); and	**Section 2.2.2**
(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.	**Appendix C**

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

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.

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	Distinction between primary and secondary monitoring sites is displayed on **Figures 3-2** and **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. Flow measurement accuracy of the monitoring sites WWL, WWL_A and LA3S1 is being assessed by an independent hydrographer (Enviromon) at the time of writing.
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	Primary flow monitoring sites WWL/WWL_A will have a minimum four years of baseline monitoring data. Capturing a minimum four years of baseline data is not possible at all Area 3C primary flow monitoring sites due to insufficient time to currently scheduled mining. LC5 was established in April

	2019 and Longwall 21 is scheduled to be extracted in January 2023 which is two months short of four years of baseline data. Future proposed mining Areas 5 and 6 will have a minimum of four years baseline flow monitoring data.
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 3 will be installed ahead of mining to achieve 2 years baseline data (subject to timing and approval timeframes of any request to install additional monitoring). Monitoring will be conducted throughout the mining period and for at least 2 years following active subsidence. A review of the continuation of post mining monitoring will be carried out in consultation with DPIE, WaterNSW and other relevant agencies where required.
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	There are no representative large valley infill swamps within 600 m of the current Longwalls 20 and 21 footprint. IMC will install paired piezometers in representative large valley infill swamps within Area 3C where practical. Future proposed mining Areas 5 and 6 have paired piezometers installed in swamps.
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 where required. This assessment methodology and reasoning for the changes is detailed in Watershed Hydrogeo 2019 and was developed in consultation with WaterNSW and DPIE.
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 3 will be installed ahead of mining to achieve 2 years baseline data (subject to timing and approval timeframes of any request to install additional monitoring). Monitoring will be conducted throughout the mining period and for at least 2 years following active subsidence or until the consequences of mining have stabilised. A review of the continuation of post mining monitoring will be carried out in consultation with DPIE, WaterNSW and other relevant agencies where required.
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 discusses 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 South32 web page as required by

	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 compliance is undertaken by a suitable independent expert and published	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 natural rock bar control arrangements and diver level sensors. This work is currently still underway at the time of writing. Recommendations for improvement will be implemented as required.
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, including LA2, LA3 and NDT1 in Area 3B. For Area 3C, the weir at FR6 on Wongawilli Creek is a primary monitoring surface water flow site. This site has been upgraded.

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	Prior to the commencement of secondary extraction of longwalls in Area 3C, IMC will update the Area 3C WIMMCP to include information on each relevant gauging station. Information to be detailed for each gauge may include:
	• location;
	• zero gauge elevation;
	• date of installation;
	• type of structure;
	• photos of gauging station;
	  - upstream;
	  - downstream;
	  - control/flume/weir lip;
	  - base of control e.g. rock/sediment;
	• rating curve; and
	• record of all check gaugings.

iv. additional basal shear monitoring, implemented as a priority between the Avon Dam and LW 14 to 18 before mining commences. The sites should be designed to complement the construction and monitoring strategy (geotechnical and groundwater) used at sites S2313 and S2314.	Monitoring bores of similar construction to S2313 and S2314 were installed adjacent to Longwalls 14 to 17 (S2377, S2378, S2436 and S2379), including installation of Time Domain Reflectometry (TDR) at S2377, S2378 and S2379. Each installation includes vibrating wire piezometers (for groundwater level monitoring) and sampling pumps (for groundwater analysis). TDR cables enable detection of ground movement including basal shear associated with longwall subsidence. Drilling and testing at each site is repeated following longwall extraction to assess changes in strata permeability.

	Due to the topography and accessibility between Lake Reservoir and Longwall 18, a monitoring bore is unable to be installed at this site.
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 DPIE 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 BCD 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 achievable if mining that results in iron staining is approved upstream of that designated area.	At Dendrobium, iron staining generally isn't observable more than 600 m downstream of mining. Local discolouration of streambeds and rock faces by iron hydroxide precipitation can continue for a number of years but is a temporary impact.

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 WIMMCP has been updated to reflect the nine monitoring program recommendations included in *Height of Cracking - Dendrobium Area 3B* (PSM, 2018). **Table 2-4** details how the recommendations have been 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.	South32 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 South32s 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. South32 and consultant experts participate in the IMMP.

	Additionally, the SMP Application for Longwalls 20 and 21 includes an independent consultant facilitated risk assessment (Attachment E of the SMP [Axys 2019]) 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. This 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).
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).
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 DPIE, WaterNSW and other relevant agencies where required. Where impacts are observed, the monitoring period will be extended and this will be reported in Impact Assessment Reports and End of Panel (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 may have experienced influence from other mining areas. This will be taken into consideration and an alternate site may 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 DPIE 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	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

order to ensure all the aspects of the “complex system” are captured.	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**).

2.3 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;
- Dendrobium Mining Operations Plan FY 2016 to FY 2022;
- Relevant occupational health and safety approvals; and
- Any additional leases, licences or approvals resulting from the Dendrobium Approval.

Table 2-5 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 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
Donalds Castle Creek	Donalds Castle Creek	Water Quality, Observations, Photo, Water Level, Flow, Aquatic Ecology
DC13	Donalds Castle Creek	Water Quality, Observations, Photo, Water Level, Flow
Wongawilli Creek	Wongawilli Creek	Water Quality, Observations, Photo, Water Level, Flow, Aquatic Ecology
WC20	Wongawilli Creek	Water Quality, Observations, Photo, Water Level, Flow
WC24	Wongawilli Creek	Water Quality, Observations, Photo, Water Level, Flow
WC26	Wongawilli Creek	Water Quality, Observations, Photo, Water Level, Flow
WC29	Wongawilli Creek	Observations, Photo, Water Level
LC5	Lake Cordeaux	Water Quality, Observations, Photo, Water Level, Flow

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 will be monitored to achieve the two-year baseline monitoring period. Details on the assessment process and triggers for potential baseflow reductions on Wongawilli Creek are detailed in Watershed Hydrogeo (2019) and **Appendix A**.

This monitoring provides key data to assess the Donalds Castle and Wongawilli Creeks 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:
    - Wongawilli and Donalds Castle Creeks, DC13 (commenced 2001);
    - WC20, WC24, WC26, WC29 (proposed sites);
    - LC5 (previously used as a reference site for Area 3B; additional proposed sites);
    - Swamp 5 (commenced March 2005);
    - Swamps 7 (previously used as reference sites for Area 3B);
    - Swamps 9, 144 and 145 (proposed sites).
- Reference sites:
    - Swamps 15a, 22, 24, 25, 33, 84, 85, 86, 87 and 88.
    - Wongawilli Creek, Sandy Creek, WC11 (Swamp 33), SC9A (Swamp 84), SC10A, NDC1, DC10 (Swamp 85), D10 and Gallahers Creek (Swamp 88).

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.

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

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 both Donalds Castle Creek and Wongawilli Creek. For Lake Cordeaux, the performance measure is applicable to monitoring site LC5_S1.

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 (HydroSimulations 2019). 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 3 to investigate and monitor the highly connected fracture network above the goaf and the upwards migration of the phreatic surface.

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

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

To investigate groundwater-surface water dynamics in Wongawilli Creek, two monitoring bores are proposed to be installed between the creek and the proposed longwalls, preferably within the Wongawilli Creek valley (contingent on access and approvals). The boreholes would be installed in the Hawkesbury Sandstone and upper Bulgo Sandstone and the data would be paired with surface water flow data from Wongawilli Creek monitoring sites.

3.6 Surface Water Flow and Pool Water Level

Existing surface water flow gauges and data loggers are installed at key stream flow monitoring sites; additional sites are proposed be installed to effectively monitor streams that may potentially experience influence from mining the proposed longwalls (**Figure 3-3**). 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 (Illawarra Coal 2011), 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.

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

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

This monitoring provides key data to assess the Donalds Castle and Wongawilli Creeks 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 Donalds Castle Creek or 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.

An independent hydrologist is currently working to systematically identify and quantify the accuracy of the above processes. The aim of the assessment is to document accuracy across the range of flows at all sites.

The flow monitoring sites are installed downstream of the mining area to assess any changes in surface flow from a catchment resulting from the mining. Sites have previously been installed using natural flow control features such as rockbars. However, in line with the recommendations of the IEP (2019a) and approval from WaterNSW, the installation of low-flow 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); Donalds Castle Creek and its tributary DC13 (Area 3B); and Lake Avon tributaries LA2, LA3, LA4 and NDT1 (Area 3B). The historical flow record has been plotted alongside the record from a nearby ‘control’ gauge i.e. a gauge that was not mined under, either at all or not during the period of interest.

A review of the Area 3B WIMMCP Trigger Action Response Plan (TARP) was undertaken in consultation with WaterNSW and DPIE between 2018 and 2020 (**Appendix A**). 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.

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

IMC commissioned the development of a regional-scale numerical groundwater flow model in support of mining at Dendrobium Colliery (Coffey Geotechnics 2012). IMC commissioned HydroSimulations (2014) to review and enhance the model 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 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. IMC is committed to this process and will continue these investigations.

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 are proposed to be installed within several swamps in Area 3C (**Figure 3-4**). Within Area 3C long-term piezometer records are available for Swamp 2 (Donalds Castle Creek) and Swamp 7 (LC5 – Lake Cordeaux tributary). Swamps 15a (SC10), 22, 24, 25, 33 (WC11), 84 (SC9A), 85 (DC10), 86, 87 and 88 (Gallahers Creek) are established reference monitoring sites and will continue to be monitored. 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 in Dendrobium Area 3 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; and between Longwalls 20 and 21. 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 (2019). Monitoring of landscape features such as cliffs, slopes and rock outcrop will be undertaken in Area 3C.

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, Fauna and Ecosystem Function

Terrestrial flora and vegetation communities in the Study Area are described in the SMP Terrestrial Ecology Assessment (Niche 2019b). Aquatic flora and fauna in the Study Area are described in Attachment B of the SMP, the Area 3C Aquatic Ecology Assessment (Cardno 2019).

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

A monitoring program designed to detect potential impacts to terrestrial ecology and ecosystem function 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**).

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

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

- The size of the swamps and the groundwater dependent communities contributing to the swamps;
- The composition and distribution of species within the swamps;
- RCE including a photographic record of each stream assessment site;
- Water quality, including pH, DO, ORP, temperature, turbidity and EC;
- Aquatic macrophytes, including presence, species composition and total area of coverage;
- Aquatic macroinvertebrates using the Australian River Assessment System (AUSRIVAS) sampling protocol and artificial aquatic macroinvertebrate collectors;
- Fish presence and numbers using backpack electro fisher and/or baited traps; and
- Presence of threatened species (including Macquarie perch, Littlejohn's tree frog, Giant burrowing frog, Adams emerald dragonfly, Giant dragonfly and Sydney hawk dragonfly).

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

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

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

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

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

Aquatic ecology monitoring sites for Area 3C are shown in Attachment B of the SMP, the Aquatic Ecology Assessment (Cardno 2019). 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 in Attachment B of the SMP (Cardno 2019)**.**

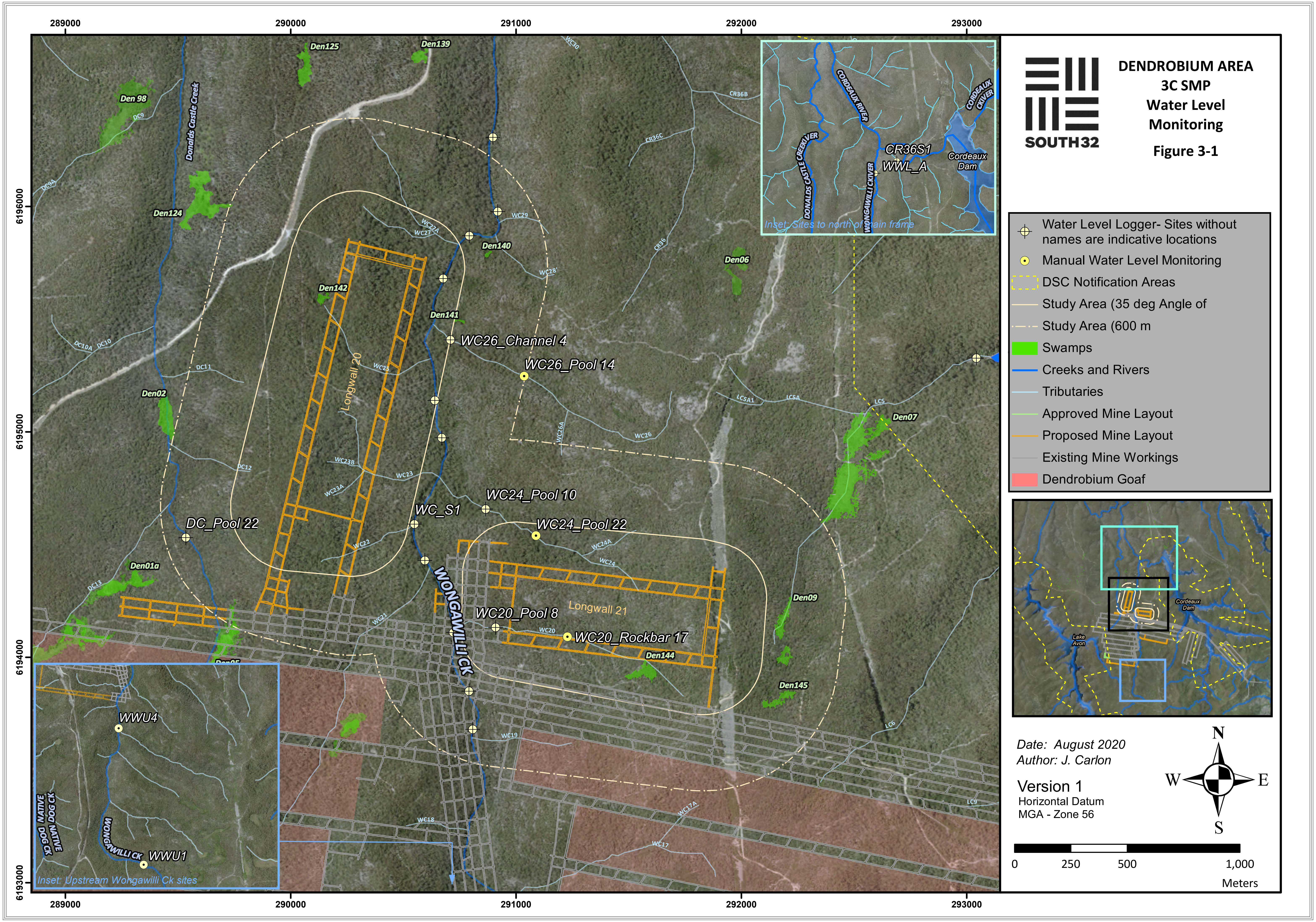
Observation data will also be collected as part of the monitoring program. Locations where significant changes have been observed (e.g. drainage of pools) will be mapped, documented and reported.

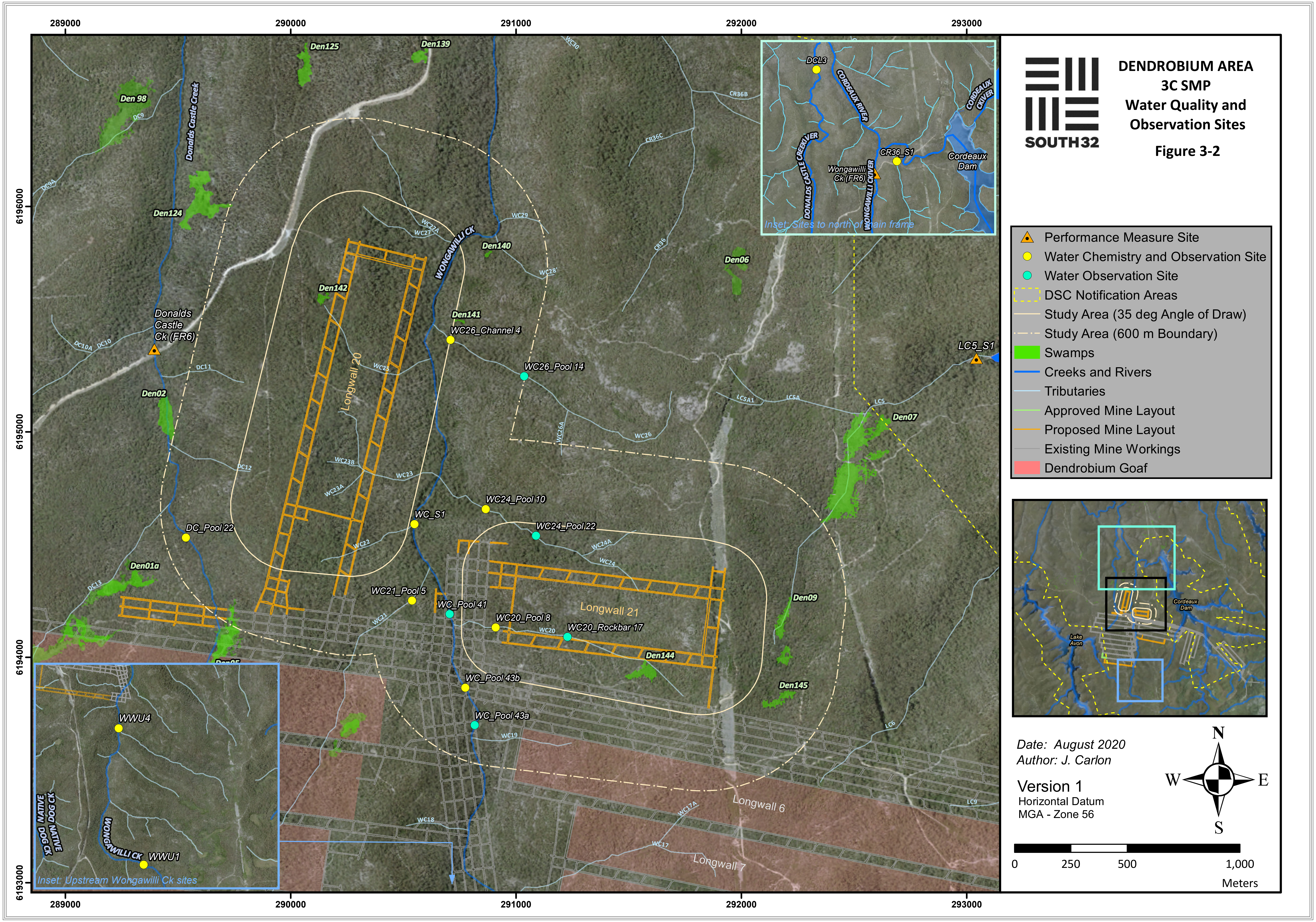
3.12 Reporting

EoP Reports are prepared in accordance with Condition 9, Schedule 3 of the Dendrobium Area 3 Modification Approval. Results from the monitoring program are included in the EoP Report and in the Annual Environmental Management Report (AEMR). These reports detail the outcomes of monitoring undertaken; provide results of visual inspections and determine whether performance indicators have been exceeded.

Monitoring results will be reviewed monthly by the IC Subsidence Management Committee. However, if the findings of monitoring are deemed to warrant an immediate response, the Superintendent 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 Area 3 Modification Approval and are made publicly available in accordance with Condition 11, Schedule 8.


DENDROBIUM AREA
3C SMP
Water Level
Monitoring
Figure 3-1
SOUTH32
Water Level Logger- Sites without names are indicative locations
Manual Water Level Monitoring
DSC Notification Areas
Study Area (35 deg Angle of
Study Area (600 m
Swamps
Creeks and Rivers
Tributaries
Approved Mine Layout
Proposed Mine Layout
Existing Mine Workings
Dendrobium Goaf
Date: August 2020
Author: J. Carlon
Version 1
Horizontal Datum
MGA - Zone 56
N
S
W
E
0
250
500
1,000
Meters
Inset: Sites to north of main frame
CORDEAUX RIVER
DONALDS CASTLE CREEK RIVER
WONGAWILLI CK RIVER
CORDEAUX CK RIVER
CR36S1
WWL_A
Cordeaux Dam
CR36B
CR36C
Inset: Upstream Wongawilli Ck sites
WWU4
WWU1
WONGAWILLI CK
NATIVE DOG CK
Lake Avon
289000
290000
291000
292000
293000
6196000
6195000
6194000
6193000
Den125
Den139
Den 98
Den124
Den140
Den142
Den141
Den06
Den02
Den07
Den01a
Den09
Den144
Den145
Donalds Castle Creek
WONGAWILLI CK
Longwall 20
Longwall 21
WC26_Channel 4
WC26_Pool 14
WC24_Pool 10
WC_S1
WC24_Pool 22
DC_Pool 22
WC20_Pool 8
WC20_Rockbar 17
DC9
DC9A
DC10
DC10A
DC11
DC12
DC13
WC30
WC29
WC28
WC27
WC27A
WC26
WC26A
WC25
WC24
WC24A
WC23
WC23A
WC23B
WC22
WC21
WC20
WC19
WC18
WC17
WC17A
CR36
LC5
LC5A
LC5A1
LC6
LC9



SOUTH32
DENDROBIUM AREA
3C SMP
Water Quality and
Observation Sites
Figure 3-2
Performance Measure Site
Water Chemistry and Observation Site
Water Observation Site
DSC Notification Areas
Study Area (35 deg Angle of Draw)
Study Area (600 m Boundary)
Swamps
Creeks and Rivers
Tributaries
Approved Mine Layout
Proposed Mine Layout
Existing Mine Workings
Dendrobium Goaf
Date: August 2020
Author: J. Carlon
Version 1
Horizontal Datum
MGA - Zone 56
N
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250
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1,000
Meters
Inset: Sites to north of main frame
Inset: Upstream Wongawilli Ck sites
Cordeaux Dam
Lake Avon
Longwall 20
Longwall 21
Longwall 6
Longwall 7
Donalds Castle Ck (FR6)
Wongawilli Ck (FR6)
LC5_S1
DCL3
CR36_S1
WWU4
WWU1
DC_Pool 22
WC26_Channel 4
WC26_Pool 14
WC24_Pool 10
WC24_Pool 22
WC_S1
WC21_Pool 5
WC_Pool 41
WC20_Pool 8
WC20_Rockbar 17
WC_Pool 43b
WC_Pool 43a
Donalds Castle Creek
WONGAWILLI CK
CORDEAUX RIVER
Den 98
Den124
Den125
Den139
Den140
Den141
Den142
Den02
Den01a
Den06
Den07
Den09
Den144
Den145
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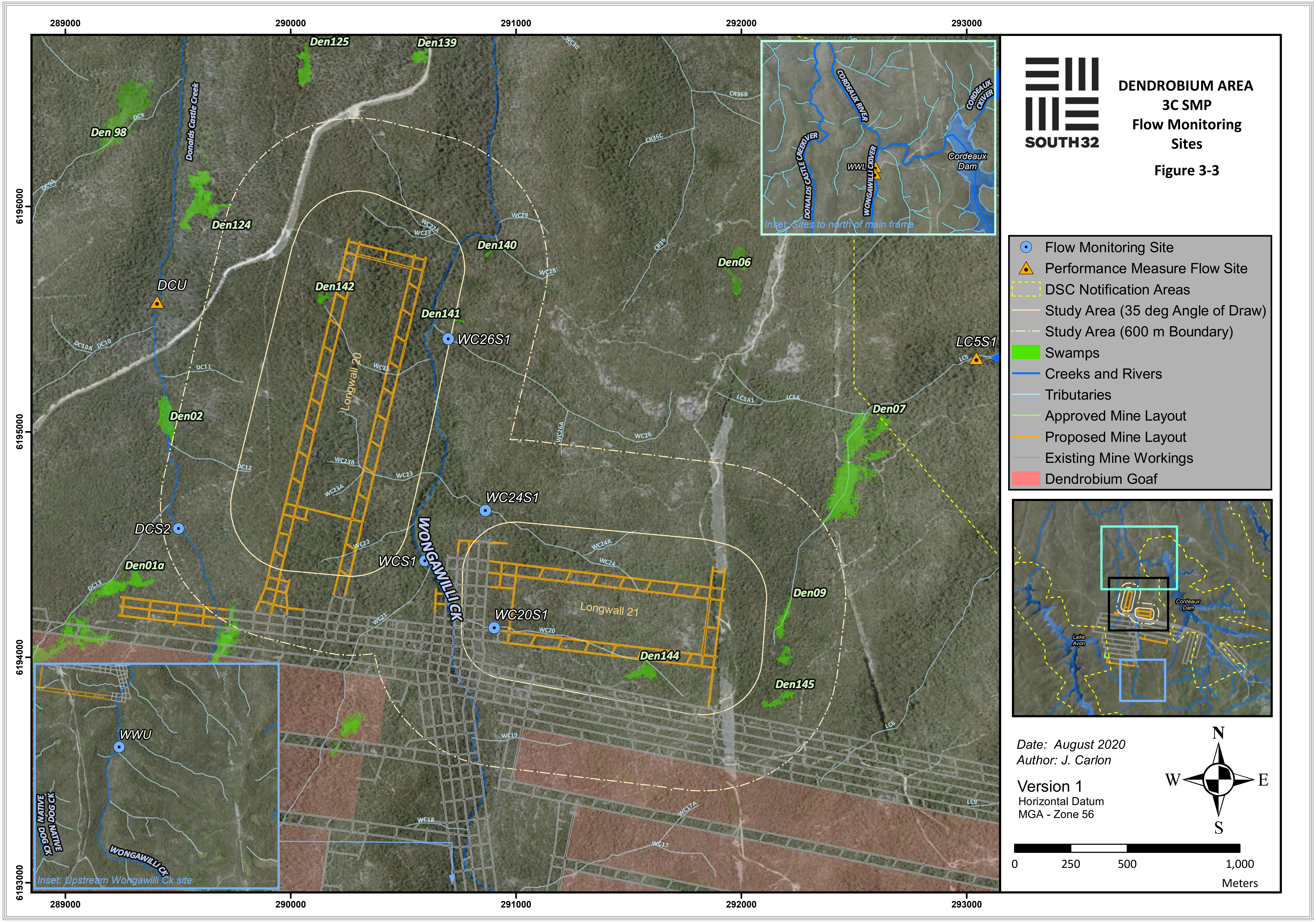

DENDROBIUM AREA
3C SMP
Flow Monitoring
Sites
Figure 3-3
SOUTH32
Flow Monitoring Site
Performance Measure Flow Site
DSC Notification Areas
Study Area (35 deg Angle of Draw)
Study Area (600 m Boundary)
Swamps
Creeks and Rivers
Tributaries
Approved Mine Layout
Proposed Mine Layout
Existing Mine Workings
Dendrobium Goaf
Date: August 2020
Author: J. Carlon
Version 1
Horizontal Datum
MGA - Zone 56
0
250
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Meters
N
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Longwall 20
Longwall 21
WONGAWILLI CK
Donalds Castle Creek
DCU
DCS2
WC26S1
WC24S1
WCS1
WC20S1
LC5S1
WWU
WWL
Den125
Den139
Den 98
Den124
Den140
Den06
Den142
Den141
Den02
Den07
Den01a
Den09
Den144
Den145
Cordeaux Dam
Lake Avon
CORDEAUX RIVER
Inset: Sites to north of main frame
Inset: Upstream Wongawilli Ck site
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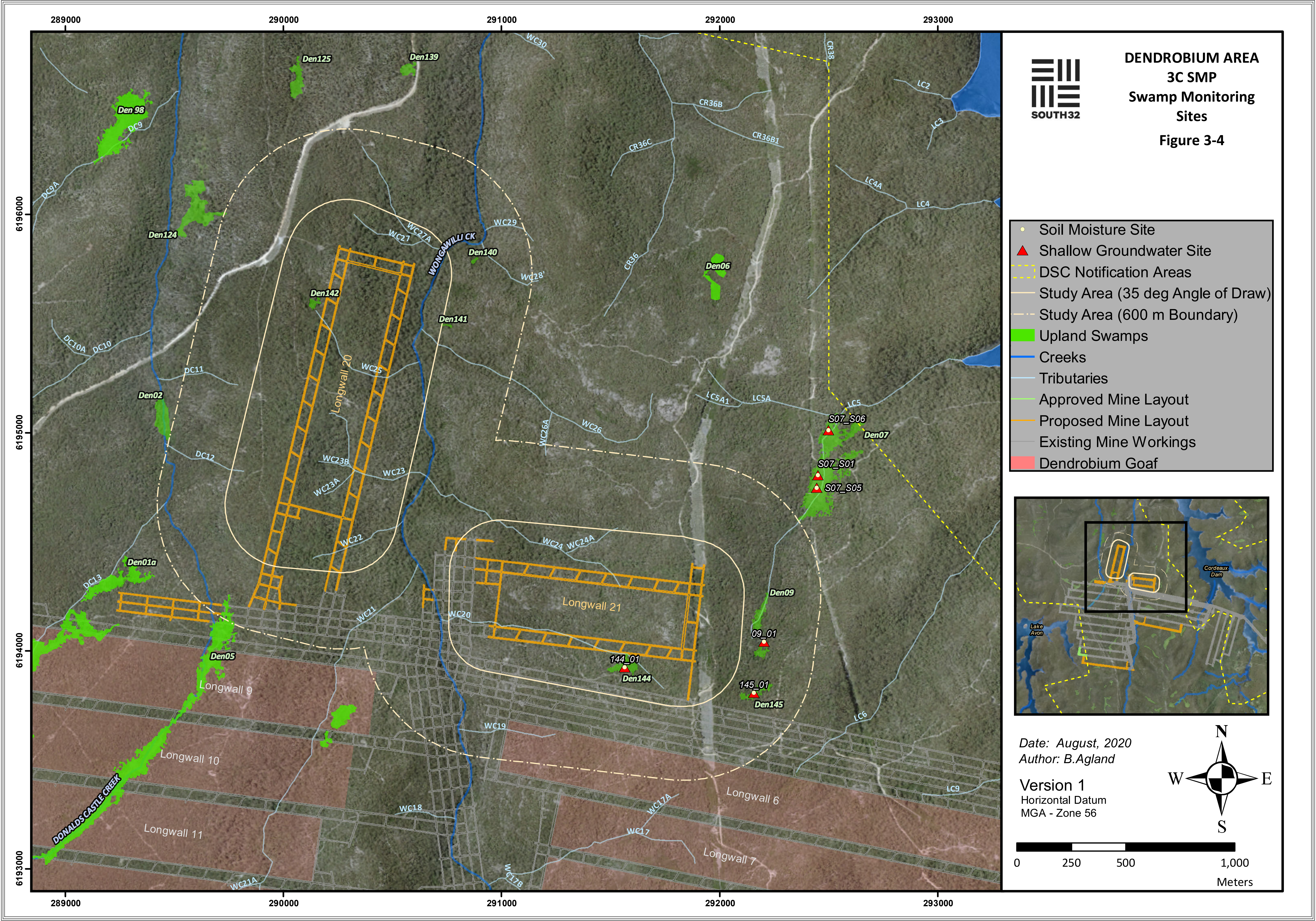
DENDROBIUM AREA
3C SMP
Swamp Monitoring
Sites
Figure 3-4
SOUTH32
Soil Moisture Site
Shallow Groundwater Site
DSC Notification Areas
Study Area (35 deg Angle of Draw)
Study Area (600 m Boundary)
Upland Swamps
Creeks
Tributaries
Approved Mine Layout
Proposed Mine Layout
Existing Mine Workings
Dendrobium Goaf
Date: August, 2020
Author: B.Agland
Version 1
Horizontal Datum
MGA - Zone 56
N
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Meters
Cordeaux Dam
Lake Avon
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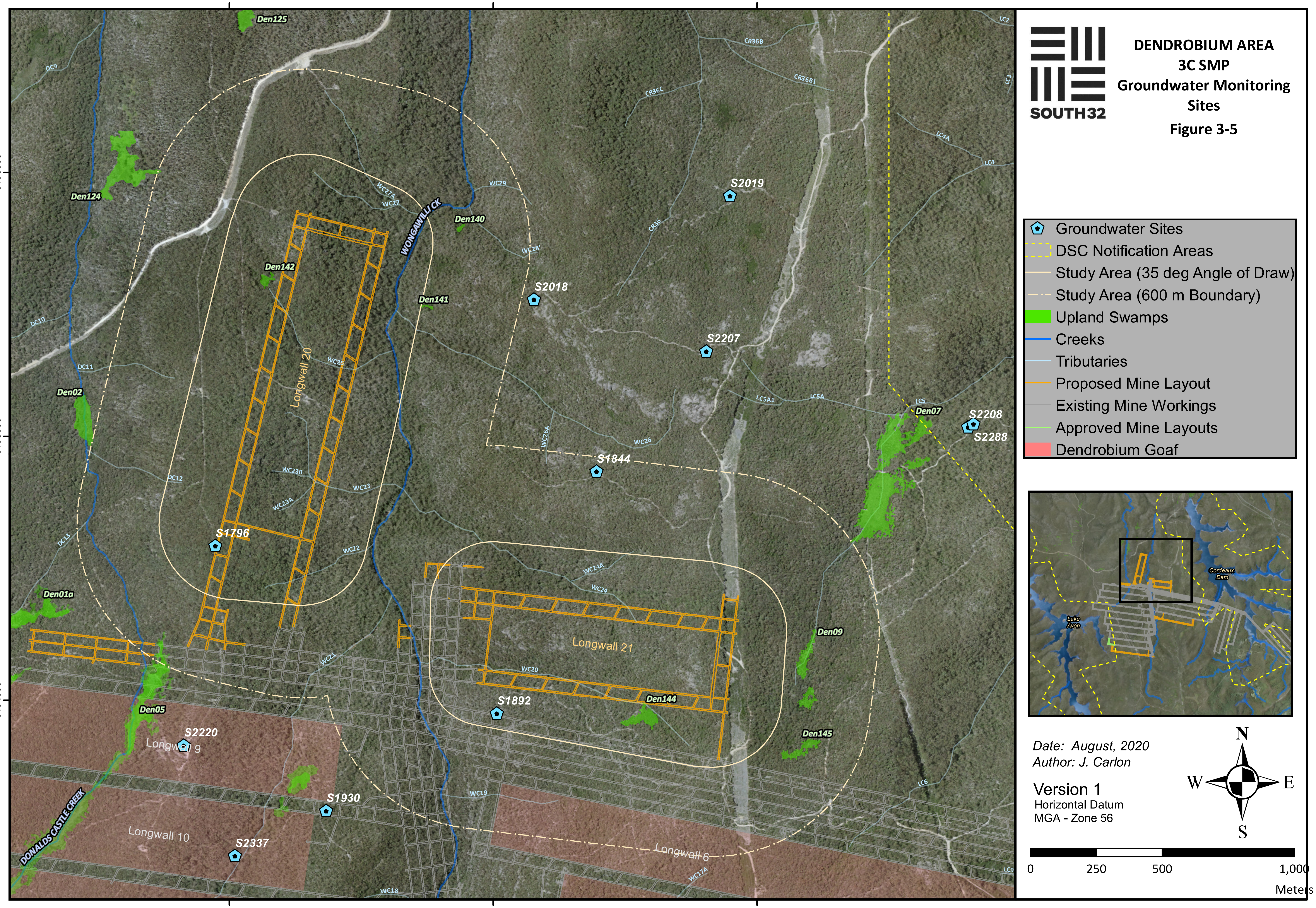
Longwall 20
Longwall 21
Longwall 9
Longwall 10
Longwall 11
Longwall 6
Longwall 7
WONGAWILLI CK
DONALDS CASTLE CREEK
Den125
Den139
Den 98
Den124
Den140
Den142
Den141
Den06
Den02
Den01a
Den05
Den07
Den09
Den144
Den145
S07_S06
S07_S01
S07_S05
09_01
144_01
145_01
DC9
DC9A
DC10A
DC10
DC11
DC12
DC13
WC30
WC29
WC27A
WC27
WC28'
WC25
WC23B
WC23
WC23A
WC22
WC24
WC24A
WC26
WC26A
WC21
WC20
WC19
WC18
WC17A
WC17
WC17B
WC21A
CR38
CR36B
CR36B1
CR36C
CR36
LC2
LC3
LC4A
LC4
LC5A1
LC5A
LC5
LC6
LC9



SOUTH32
DENDROBIUM AREA
3C SMP
Groundwater Monitoring
Sites
Figure 3-5
Groundwater Sites
DSC Notification Areas
Study Area (35 deg Angle of Draw)
Study Area (600 m Boundary)
Upland Swamps
Creeks
Tributaries
Proposed Mine Layout
Existing Mine Workings
Approved Mine Layouts
Dendrobium Goaf
Cordeaux Dam
Lake Avon
Date: August, 2020
Author: J. Carlon
Version 1
Horizontal Datum
MGA - Zone 56
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Longwall 21
Longwall 9
Longwall 10
Longwall 6
WONGAWILLI CK
DONALDS CASTLE CREEK
S2019
S2018
S2207
S2208
S2288
S1844
S1796
S1892
S2220
S1930
S2337
Den125
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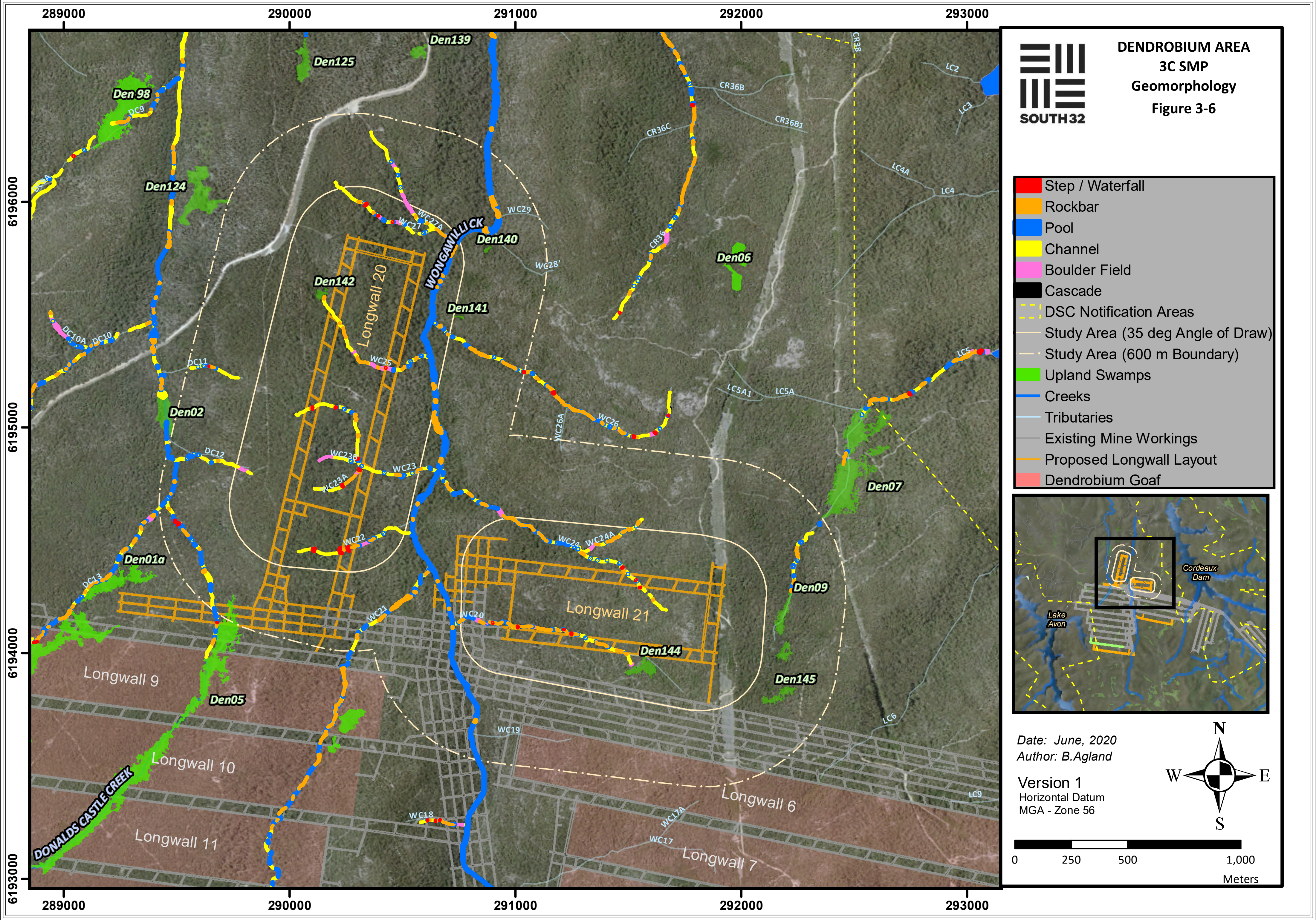

DENDROBIUM AREA
3C SMP
Geomorphology
Figure 3-6
SOUTH32
Step / Waterfall
Rockbar
Pool
Channel
Boulder Field
Cascade
DSC Notification Areas
Study Area (35 deg Angle of Draw)
Study Area (600 m Boundary)
Upland Swamps
Creeks
Tributaries
Existing Mine Workings
Proposed Longwall Layout
Dendrobium Goaf
Cordeaux Dam
Lake Avon
Date: June, 2020
Author: B.Agland
Version 1
Horizontal Datum
MGA - Zone 56
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Den139
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Den 98
DC9
Den124
DC4A
CR36B
CR36C
CR36B1
CR38
LC2
LC3
LC4A
LC4
WC29
WC27A
WC27
WONGAWILLI CK
Den140
WG28'
Den06
CR36
Den142
Longwall 20
Den141
DC10A
DC10
DC11
WC25
LC5
LC5A1
LC5A
Den02
WC26A
WC26
DC12
WC23B
WC23
WC23A
Den07
WC22
WC24
WC24A
Den01a
DC13
Den09
WC21
WC20
Longwall 21
Den144
Den145
Longwall 9
Den05
WC19
LC6
Longwall 10
Longwall 6
LC9
DONALDS CASTLE CREEK
Longwall 11
WC18
WC17A
WC17
Longwall 7

4 PERFORMANCE MEASURES AND INDICATORS

Performance measures and indicators have been derived from the Dendrobium Development Consent. 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 Modified Development Consent
• Operations shall not cause subsidence impacts at Donalds Castle Creek other than "minor impacts" (such as minor fracturing, gas release, iron staining and minor impacts on water flows, water levels and water quality); • Operations shall not cause subsidence impacts at Wongawilli Creek other than "minor impacts" (such as minor fracturing, gas release, iron staining and minor impacts on water flows, water levels and water quality); • Operations will not result in reduction (other than negligible reduction) in the quality or quantity of surface water or groundwater inflows to Lake Cordeaux or Lake Avon or surface water inflow to the Cordeaux River at its confluence with Wongawilli Creek.

A detailed list of performance measures and triggers is included in the TARPs in **Appendix A: Table 1.2**.

4.1 Impact Mechanisms

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

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

- Groundwater depressurisation
  - The creation of an excavation below the water table can affect groundwater in a number of basic ways. In all cases, because the fluid pressure in an excavation is much lower than that of the fluid that originally occupied the space, a flow system is established with the excavation acting as a sink into which surrounding groundwater flows. The rate of flow and observed extent of depressurisation depend on the hydrogeological properties of the rock mass. If the excavated area is sufficiently large, the spatial extent and rate of flow into the sink can be enhanced by the formation of fractures.
- Surface water diversions
  - Diversions into a shallow, localised fracture network, where loss of flow from a surface water is likely to return to the system at some point downstream, which based on observations of the SCI (2008) may vary from 20 m for specific rockbars to more than 200 m.
- Surface water permanent losses
  - Diversions into deeper, dilated shear surfaces on bedding planes, where these form a conduit for lateral water flow, which may or may not report to the same catchment (i.e. it may become a permanent loss).
- Groundwater depressurisation
  - Groundwater within the Hawkesbury Sandstone and Narrabeen Group as well as the Permian coal measures is recharged from rainfall and water bodies where the lithologies occur at outcrop, as well as potential downward leakage from overlying strata (Hydrosimulations 2018).
- Water quality
  - Water quality within watercourses is affected by numerous factors including runoff from swamps and interactions between bedrock and water, with fracturing of bedrock due to mining causing local water quality impacts.

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

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

4.2 Potential for Connectivity to the Mine Workings

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

4.3 Potential for Fracturing Beneath the Watercourses

Based on the predicted systematic and non-systematic subsidence movements (MSEC 2019) the bedrock below the watercourses are likely to fracture as a consequence of subsidence induced strains.

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

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

The effects of mining on surface water flow following the completion of Longwall 15 was measured and assessed in the Longwall 15 EoP Report using the revised surface flow TARPs. The assessments indicate that sub-catchments in the upper part of the Donalds Castle Creek catchment (i.e. DC13S1 and DCS2) have been and continue to be affected by mining, as is the tributary LA4 of Lake Avon (at LA4S1) and probably in the neighbouring tributary LA3 (although analysis is hampered by a short baseline flow record) (HGEO 2020). The findings for DC13, DCS2 (both at Level 3 for all three flow assessments), and LA4 (effects identified by all three assessments) are similar to those for the EoP report for Longwall 14, as presented in Watershed HydroGeo (2019). LA3 has been affected by mining for the first time by Longwall 15.

Similarly, the flow characteristics at WC21S1 and WC15S1 within the Wongawilli Creek catchment have altered as a result of mining, with these sites triggering Levels 2 and 3 for the three assessments. As with the sub-catchments above, the effects at WC21 and WC15 are similar to those for the previous longwall. WC12 is as yet unaffected by mining (HGEO 2020).

Changes to stream flow characteristics are not evident at the downstream gauge on Wongawilli Creek Lower (WWL), despite mining-related effects being clear and significant at upstream tributaries (e.g. WC21, WC15). This suggests that some or all flow lost in headwater catchments is returned downgradient, and/or that upstream diversions or losses are not significant in relation to the larger catchment water balance given the natural variability and the accuracy of flow measurements. Analysis of available surface water flow observation records for Wongawilli Creek triggered a Level 2 TARP in February 2020. TARP Assessment D was carried out, and indicated that flow reductions due to mining were in the order of 0.008 to 0.015 ML/d.

The assessment against the Performance Measures for Donalds Castle Creek, Wongawilli Creek, Lake Avon and Cordeaux River were all met (HGEO 2020).

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 2019). 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 (2019). 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 LC5, WC20, WC21, WC22. WC23, WC24, WC25, WC26, WC27 and WC28, 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 the Lake and would be unlikely to have any detrimental effect on local freshwater ecology and unable to affect bulk water supply quality.

4.7 Water Storages

Dendrobium Mine is located within the Metropolitan Special Area. There are two reservoirs located in the vicinity of the mining area. The Cordeaux and Avon Reservoirs are located at minimum distances of 1.6 km and 2.8 km, respectively, from the proposed Longwalls 20 and 21. The Cordeaux Dam Wall and Avon Dam Wall are located at distances of more than 3 km and 7 km, respectively, from the proposed longwalls.

The predicted vertical and horizontal movements at the Cordeaux and Avon Reservoirs and their associated dam walls are very small and are unlikely to be measurable. Previous experience of mining in Areas 1, 2, 3A and 3B has not resulted in adverse impacts on these structures. It is unlikely, therefore, that the reservoirs and dam walls would experience adverse impacts due to the extraction of the proposed Longwalls 20 and 21.

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 20 and 21 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 15, submitted to the Department in May 2020, found that the Performance Measures for Donalds Castle Creek, Wongawilli Creek, Lake Avon and Cordeaux River were all met (HGEO 2020).

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

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

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

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

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 differential subsidence movements predicted.

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

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

Predicted impacts were assessed for Wongawilli Creek (third order) and all other drainage lines (first and second order) within Area 3C in Attachment D of the SMP (MSEC 2019).

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 20 and 21 are provided in MSEC (2019). 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 predicted conventional strains resulting from the extraction of proposed Longwalls 20 and 21, based on applying a factor of 15 to the maximum predicted curvatures, are 8 mm/m tensile and 11 mm/m compressive. These strains represent typical values when the ground subsides regularly with no localised or elevated strains due to near-surface geological structures or valley closure effects. 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 2.3 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 between the proposed Longwalls 20 and 21. The thalweg (i.e. base or centreline) of the creek is 125 m east of the tailgate of Longwall 20 and 240 m west of the finishing end of Longwall 21, at the closest points to the proposed longwalls. 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 Wongawilli Creek located within the Study Area based on the 35° angle of draw line is approximately 0.8 km. The length of the creek located within the Study Area based on the 600 m boundary is approximately 3.0 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	Areas 3A and 3B	< 20	140	200
	LW20	< 20	140	200
	LW21	< 20	150	210

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 150 mm upsidence and 210 mm closure. The maximum predicted valley related effects within the Study Area occur adjacent to the completed Longwalls 9 and 10 in Area 3B.

The maximum predicted additional valley related effects due to the extraction of the proposed Longwalls 20 and 21 are 60 mm upsidence and 150 mm closure. The maximum additional valley related effects occur where Wongawilli Creek is located closest to the proposed Longwall 20.

Wongawilli Creek could experience compressive strains due to the valley closure movements. The predicted strains have been determined based on the analysis of ground monitoring lines for valleys with similar heights located at similar distances from previously extracted longwalls in the Southern Coalfield, as for Wongawilli Creek. The maximum predicted compressive strain for Wongawilli Creek due to the extraction of the proposed Longwalls 20 and 21 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 3.7 mm/m (i.e. 0.37 %, or 1 in 270). The predicted changes in grade due to the extraction of Longwalls 20 and 21 (less than 0.5 mm/m), 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.

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

It is not anticipated that these changes would result in adverse impacts on the creek, due to the mining-induced tilt, since the predicted changes in grade are less than 0.05 %.

Potential for fracturing of bedrock and surface water flow diversions

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

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 20 and 21, is 210 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 20 and 21, is low, i.e. affecting less than 10 % 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), mining-induced subsidence and depressurisation can result in a reduction in the baseflow component and subsequent reductions in low-flows and increases in the duration of cease-to-flow conditions (HGEO 2019).

Baseflow contribution for Wongawilli Creek has been estimated as 10-16 % (1.22 – 1.95 ML/day) of average daily yield (HydroSimulations 2019 and HGEO 2019).

Incremental baseflow reductions in Wongwawilli Creek have been estimated at 0.2 ML/day (after 2 years of Longwall 21 extraction) and 0.18 ML/day (after 10 years of Longwall 21 extraction) (HGEO 2019).

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

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 Donalds Castle Creek

5.3.1 Description

The section of Donalds Castle Creek located within the Study Area is a second order perennial stream with a small base flow and increased flows for short periods after significant rain events. The creek generally flows in a northerly direction and drains into the Cordeaux River more than 4 km to the north of the proposed longwalls.

The bed of the creek comprises exposed bedrock containing rockbars with standing pools. There are also other controlling features including channels, steps and debris accumulations.

Donalds Castle Creek is located to the west of the proposed longwalls. The thalweg of the creek is 470 m from the maingate and finishing end of Longwall 20, at its closest point. Donalds Castle Creek is located outside the Study Area based on the 35° angle of draw. The total length of the creek located within the Study Area based on the 600 m boundary is approximately 0.8 km.

Donalds Castle Creek crosses directly above the completed Longwalls 9 to 12 in Area 3B upstream of the proposed longwalls. The total length of creek that has been directly mined beneath in Area 3B is approximately 1.5 km.

5.3.2 Subsidence Predictions

A summary of the maximum predicted values of total vertical subsidence, upsidence and closure for Donalds Castle Creek is provided in (**Table 5-2**). The values are the maxima anywhere along the section of the creek located within the Study Area based on the 600 m boundary and include the predicted movements due to the previously extracted longwalls in Area 3B.

Table 5-2: Maximum predicted total vertical subsidence, upsidence and closure for Donalds Castle Creek

Location	Area or Longwall	Maximum predicted total vertical subsidence (mm)	Maximum predicted total upsidence (mm)	Maximum predicted total closure (mm)
Donalds Castle Creek	Area 3B	< 20	90	170
	LW20	< 20	90	180
	LW21	< 20	90	180

The section of Donalds Castle Creek located within the Study Area is predicted to experience less than 20 mm vertical subsidence after the extraction of the proposed Longwalls 20 and 21. 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 upsidence (**Table 5-2**) and closure occur adjacent to the existing longwalls in Area 3B. Only very small additional movements are predicted to occur in this location due to the extraction of the proposed Longwalls 20 and 21.

The section of Donalds Castle Creek located downstream of the previously extracted longwalls in Area 3B could experience additional valley-related effects, where it is located closest to the proposed Longwall 20. The maximum predicted additional valley related movements for the section of creek located within the Study Area are less than 20 mm upsidence and less than 20 mm closure. Only low-levels of additional valley related effects are predicted due to the distance of Donalds Castle Creek from the proposed longwalls.

Donalds Castle Creek could experience compressive strains due to the low-level valley closure movements. The predicted strains have been determined based on the analysis of ground monitoring lines for valleys with similar heights located at similar distances from previously extracted longwalls in the Southern Coalfield, as for Donalds Castle Creek. The maximum predicted compressive strain for Donalds Castle Creek due to the extraction of the proposed Longwalls 20 and 21 is 1 mm/m 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

Donalds Castle Creek is predicted to experience less than 20 mm additional vertical subsidence due to the extraction of the proposed Longwalls 20 and 21. Whilst the creek could experience very low-levels of additional vertical subsidence, it is not expected to experience measurable conventional tilts. That is, the predicted changes in grade along the creek due to the conventional movements are less than 0.5 mm/m (i.e. less than 0.05 %, or 1 in 2000).

The average natural grade of the section of Donalds Castle Creek within the Study Area is approximately 35 mm/m (i.e. 3.5 %, or 1 in 30). The predicted changes in grade due to the extraction of the proposed Longwalls 20 and 21, therefore, are considerably less than the average natural grade. Therefore, it is unlikely that there would be adverse changes in the potential for ponding, flooding or scouring of the banks along the creek due to the mining-induced tilts.

Potential for fracturing of bedrock and surface water flow diversions

Fracturing occurred in Rockbar DC-RB33 along Donalds Castle Creek, due to the extraction of Longwall 9, which resulted in the diversion of surface water flows in that location (i.e. Type 3 impact). This rock bar is located outside the Study Area at a distance of 660 m south-west of the finishing end of the proposed Longwall 20.

At this distance, Rockbar DC-RB33 is not predicted to experience measurable additional upsidence or closure movements due to the extraction of Longwalls 20 and 21. It is unlikely that additional fracturing would occur at this rockbar due to these proposed longwalls.

The remaining rockbars along Donalds Castle Creek downstream of Rockbar DC-RB33 are predicted to experience additional closure movements of less than 20 mm. The maximum predicted compressive strain for the creek due to the valley closure effects is 1 mm/m based on the 95 % confidence level.

Fracturing has been observed up to approximately 400 m outside of previously extracted longwalls in the Southern Coalfield. Donalds Castle Creek is located 470 m from the maingate and finishing end of Longwall 20, at its closest point to the proposed longwalls.

It is considered unlikely, therefore, that fracturing would occur along Donalds Castle Creek due to the extraction of Longwalls 20 and 21 due to the low-levels of predicted movements and its distance from the proposed longwalls.

Baseflow Reduction

Where stream flow is partly sustained by the discharge of groundwater from adjacent aquifers (baseflow), mining-induced subsidence and depressurisation can result in a reduction in the baseflow component and subsequent reductions in low-flows and increases in the duration of cease-to-flow conditions (HGEO 2019).

Baseflow contribution for Donalds Castle Creek has been estimated as 1 - 6 % (0.017 – 0.099 ML/day) of average daily yield (HydroSimulations 2019 and HGEO 2019). The predicted maximum incremental baseflow reductions in Donalds Castle Creek due to Longwalls 20 and 21 extraction is estimated by the Regional Groundwater model at 0.14 ML/day (after 2 years of Longwall 21 extraction) and 0.008 ML/day (after 10 years of Longwall 21 extraction) (HGEO 2019). This could result in cease-to-flow conditions up to 60% of the time at DCU, although an increase to 3-5% is considered more likely based on available pre- and postmining surface water flow data (HGEO 2019).

5.4 Drainage Lines

5.4.1 Description

The unnamed drainage lines are located above and adjacent to Longwalls 20 and 21. These drainage lines are first and second order streams that form tributaries to Wongawilli Creek. 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.

5.4.2 Subsidence Predictions

The drainage lines are located across the Study Area and, therefore, could experience the full range of predicted subsidence movements. A summary of the maximum predicted values of total vertical subsidence, tilt and curvature for the drainage lines is provided in **Table 5-3**. The total parameters represent the accumulated movements within the Study Area due to the extraction of the existing and proposed longwalls.

Table 5-3: Maximum predicted total subsidence, tilt and curvature for the drainage lines

Location	After longwall	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})
Drainage Lines	LW20 and LW21	2050	30	0.50	0.75

The maximum predicted total tilt for the drainage lines is 30 mm/m (i.e. 3.0 %, or 1 in 33). The maximum predicted total conventional curvatures are 0.50 km^{-1} hogging and 0.75 km^{-1} sagging, which represent minimum radii of curvatures of 2 km and 1.3 km, respectively.

The drainage lines have shallow incisions into the natural surface. The predicted valley related movements, therefore, are small and not considered significant when compared with the predicted conventional movements provided in the above table.

The maximum predicted conventional strains for the drainage lines, based on applying a factor of 15 to the maximum predicted conventional curvatures, are 8 mm/m tensile and 11 mm/m compressive. The predicted strains directly above the proposed longwalls are 6 mm/m tensile and compressive based on the 95 % confidence level.

5.4.3 Impact Assessment

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

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

The maximum predicted tilt for the drainage lines within the Study Area is 30 mm/m (i.e. 3.0 % or 1 in 33). The predicted mining-induced tilts are less than the natural gradients of the drainage lines that typically vary between 100 mm/m and 200 mm/m (i.e. 10 % 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.

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 14 in Area 3B, including fracturing in the rockbars and exposed bedrock, dilation and uplift of the bedrock, iron staining, surface water flow diversions and reduction in pool water levels. These impacts predominately occurred directly above the extracted longwalls. However, fracturing was also observed up to 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 20 and 21. 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, 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. The TARPs for Area 3C watercourses are included in **Appendix A: Table 1.2**.

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

Monitoring of environmental aspects provides key data when determining any requirement for 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.

6.3 Avoiding and Minimising

Mine layouts for Dendrobium Area 3C have been developed using IMC's 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, Wongawilli Creek, Donalds Castle Creek; and a number of geological constraints such as dykes, faults, and particularly the Dendrobium Nepheline Syenite Intrusion, which has intruded into the Wongawilli Seam north-west of the proposed Longwall 20. 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.

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

The layouts at Dendrobium Mine have been modified to reduce the potential for impacts to surface features. Changes to a mine layout have significant flow-on impacts to mine planning and scheduling as well as economic viability. These issues need to be taken into account when optimising mine layouts. The process adopted in designing the Dendrobium Area 3C mine layout incorporated the hierarchy of avoid/minimise/mitigate as requested by the DPIE 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.

The layout of the proposed longwalls is designed to avoid Wongawilli and Donalds Castle Creeks. Wongawilli Creek is located between the proposed Longwalls 20 and 21. The thalweg (i.e. base or centreline) of the creek is 125 m east of the tailgate of Longwall 20 and 240 m west of the finishing end of Longwall 21, at the closest points to the proposed longwalls. Donalds Castle Creek is located to the west of the proposed longwalls. The thalweg of the creek is 470 m from the maingate and finishing end of Longwall 20, at its closest point and outside the 35°.angle of draw of Longwall 21.

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.

6.4 Mitigation and Rehabilitation

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

As indicated in *Schedule 2, Conditions 1 and 14* of the Development Consent (Minister for Planning 2008), 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 TSC Act 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 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 or Donalds Castle Creeks are impacted from subsidence and where there is limited ability for these fractures to seal naturally they will be sealed with an appropriate and approved 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.

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, compensatory measures will be considered. Any compensatory measure will consider the level of impact requiring compensation, the compensatory measures available and the practicality and cost of implementing the measure.

Subject to Condition 14, 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; 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 biodiversity offset strategy has been developed in consultation with BCD and WaterNSW for the approval of the Secretary of DPIE. The Secretary DPIE approved the Strategic Biodiversity Offset in accordance with Condition 15 of Schedule 2 of the Development Consent for the Dendrobium Coal Mine 16th December 2016. The Secretary also expressed satisfaction that the Strategy fulfils the requirements of Condition 9 of the SMP for Area 3 (2016).

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 focused on Swamps 1B and 14.

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 AEMR.

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

The site-specific rehabilitation action plan will be circulated to relevant stakeholders for comment prior to finalisation. Approval from WaterNSW is required to access the land to conduct works and implement environmental controls.

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 Contingent Measures for Watercourses

Feature	Performance Measure	Predicted Impacts	How Monitored	How Managed	Exceeding Prediction	Contingent Measures
Wongawilli Creek	**Minor environmental consequences** including: minor fracturing, gas release and iron staining; and minor impacts on water flows, water levels and water quality	Minor environmental consequences including: minor fracturing, gas release and iron staining; and minor impacts on water flows, water levels and water quality	• Observation of Wongawilli Creek for fracturing, gas release and iron staining • Measurement of pool water levels • Measurement of surface water flow • Measurement of surface water quality	The longwalls have been setback 125 m and 240 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[1] • 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

[1] 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	
Donalds Castle 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 Donalds Castle Creek for fracturing, gas release and iron staining • Measurement of pool water levels • Measurement of surface water flow • Measurement of surface water quality	Longwall 20 is 470 m from Donalds Castle Creek. Donalds Castle Creek lies outside the 35° angle of draw of Longwall 21. 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 Donalds Castle 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 Donalds Castle 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[2] • gas release results in vegetation dieback that does not revegetate • gas release results in mortality of threatened species or ongoing loss of aquatic habitat • iron staining and associated increases in dissolved iron resulting from the mining is	Grouting of fractures in rockbar and bedrock base of any significant pool where flow diversion results in pool water level lower than baseline period Provide residual environmental offset for any mining impact as required by Condition 14 Schedule 3 of the Development Consent

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

Feature	Performance Measure	Predicted Impacts	How Monitored	How Managed	Exceeding Prediction	Contingent Measures
					observed in water at the Donalds Castle Creek downstream monitoring site Donalds Castle Ck (FR6) • ±3 standard deviation change (positive for EC, negative for pH and DO) from the baseline mean, for a minimum of two consecutive monitoring events 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 longwall is 1.6 km from Lake Cordeaux	Mining results in more than negligible reduction in the quality or quantity of surface water or groundwater inflows to Lake Cordeaux, including: • measured surface water flow reduction, based on Assessment Methods C, D, to be compared against predictions made in contemporary groundwater modelling conducted (to the satisfaction of the Secretary) to assess whether effects that cannot be explained by natural variability[3] [4] • mining results in two consecutive exceedances or three exceedances of the ±3 standard deviation level (positive for EC, negative for pH and DO) from the baseline mean within six months that cannot be attributed to natural variation	Grouting of fractures in rockbar and bedrock base of any significant pool where flow diversion results in pool water level lower than baseline period Provide residual environmental offset for any mining impact as required by Condition 14 Schedule 3 of the Development Consent
Cordeaux River	Operations do not result in reduction (other than **negligible reduction**) in the quality or quantity of surface water inflow to the Cordeaux River at its	Negligible reduction in the quality and quantity of surface water inflow to the Cordeaux River at its	• Observation of Wongawilli Creek for iron staining • Measurement of surface water flow	The longwalls have been setback 125 m and 240 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:	Grouting of fractures in rockbar and bedrock base of any significant pool where flow diversion results in pool

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

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

Feature	Performance Measure	Predicted Impacts	How Monitored	How Managed	Exceeding Prediction	Contingent Measures
	confluence with Wongawilli Creek	confluence with Wongawilli Creek	• Measurement of surface water quality		• measured surface water flow reduction in Wongawilli Creek at its confluence with Cordeaux River is greater than predicted by modelling (to the satisfaction of the Secretary) that cannot be attributed to natural variation[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	water level lower than baseline period Provide residual environmental offset for any mining impact as required by Condition 14 Schedule 3 of the Development Consent

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

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

7 INCIDENTS, COMPLAINTS, EXCEEDANCES AND NON-CONFORMANCES

7.1 Incidents

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

7.2 Complaints Handling

IMC will:

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

7.3 Non-Conformance Protocol

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

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

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

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

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

8 PLAN ADMINISTRATION

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

8.1 Roles and Responsibilities

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

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

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

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

Manager Approvals

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

Principal Approvals

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

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 South32 website in accordance with Condition 11, Shedule 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 – Watercourse Monitoring and Trigger Action Response Plan

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

Table 1.1 – Dendrobium Area 3 Watercourse Monitoring

Monitoring Site		Site Type	Monitoring Frequency	Parameters
OBSERVATIONAL MONITORING				
AREA 3A	Sandy Creek and tributaries (including SC7 and SC10) Wongawilli Creek and tributaries *Refer to Figure 3-1 of 3A WIMMCP*	Observation and photo point monitoring: • Sites based on an assessment of risk • Streams and swamps • Pools and rockbars • Previously observed impacts that warrant follow-up inspection	• Monthly 2 years pre- and post-mining, weekly when longwall is within 400 m of monitoring site • Reference sites 6 monthly	Visual signs of impacts to creeks and drainage lines (i.e. cracking, vegetation changes, increased erosion, changes in water colour, soil moisture etc.) determined by comparing baseline photos with photos during the mining period Manual Field Testing: Key water quality parameters in pools analysed to identify any changes resulting from mining including pH, Temp, EC, DO and ORP Pool water levels to identify any changes resulting from mining. At suitable sites, pool water levels will be measured with a pressure transducer and continuous logger. A benchmark for manual readings will be installed at sites that are not suitable for a logger
AREA 3B	**Impact Sites** Native Dog, Wongawilli and Donalds Castle Creeks, WC21, WC18, WC16, WC15, WC12, WC9, WC7, LA5, LA4, LA3, LA2, LA1, ND1, ND2 and DC13 Swamps 5, 10, 11, 13, 14, 23, 35a, 35b, 1a, 1b, 8, 3 and 4 *Refer to Figures 2-2 to 2-11 and 2-25 to 2-32 of 3B WIMMCP* **Reference Sites** Wongawilli Creek, Sandy Creek, Gallaghers Creek, LC5(1), WC11, DC10, SC9A, CR36 and D10 Swamps 2(1), 7(1), 15a, 22, 24, 25, 33, 84, 85, 86, 87 and 88 *Refer to Figures 2-12 to 2-25, 2-28 to 2-30 and 2-33 to 2-35*			
AREA 3C	**Impact Sites** (2, 3) Wongawilli Creek, WC20, WC24, WC26, LC5(1) Swamps 7, 9, 144 and 145 **Reference Sites** CR36 (Cordeaux River tributary)			
WATER CHEMISTRY				
AREA 3A	**Wongawilli Creek** WWU1, WWU4, WC_Pool 46, WWM2, WC_Pool 43b and Wongawilli Creek (FR6) WC17_S1 (Wongawilli Creek tributary) WC14_S1 (Wongawilli Creek tributary) WC13_S1 (Wongawilli Creek tributary) **Sandy Creek** SCk_Rockbar 5 (Sandy Creek adjacent to LW7) SC10_Rockbar 3 (Sandy Creek tributary) SC10C_Pool 1 (SC10 tributary) SC7_S1 (Sandy Creek tributary) **Lake Cordeaux**	• Collect sample • Field water quality	• Monthly monitoring pre, during and post mining for two years	Lab. Analytes: • (incl. lab checks of pH, lab. check of EC, DOC, Na, K, Ca, Mg, Filt. SO4, Cl, T. Alk., Total Fe, Mn, Al, Filt. Cu, Ni, Zn, Si)

	Sandy Creek Arm (lake site) *Refer to Figure 3-2 of 3A WIMMCP*			
AREA 3B	**Wongawilli Creek** WWU1 (Wongawilli Creek headwaters) WWU4 (Wongawilli Creek upstream) WC_Rockbar 39 (Wongawilli Creek adjacent to LW17) WC Pool 49 (Wongawilli Creek adjacent to LW15) WC_Pool 46 (Wongawilli Creek adjacent to LW12) WWM2 (Wongawilli Creek adjacent to LW11) WC_Pool 43b (Wongawilli Creek downstream of LW9) Wongawilli Creek (FR6) (Wongawilli Creek downstream) WC21_Pool 5 (Wongawilli Creek tributary downstream of mining) WC21 Pools 30 and 53 (Wongawilli Creek tributaries over mining) WC15_Pool 28 (Wongawilli Creek tributary downstream of mining) WC15_Pool 9 (Wongawilli Creek tributary downstream of mining) WC15_Pool 2 (Wongawilli Creek tributary downstream of mining) WC7_Pool 1(Wongawilli Creek tributary downstream of mining) WC12_Pool 1 (Wongawilli Creek tributary downstream of mining) **Lake Avon** LA4_S1, LA4_S2, LA5_S1, LA5_S2, LA3 Pool 4, LA2 Pool 5, LA1 and LA_1 (Lake Avon tributaries downstream of mining) NDC_Pool 1 (Native Dog Creek downstream of mining) NDC_Pool 3 (Native Dog Creek downstream of mining)NDC1 (Native Dog Creek upstream of Area 3B) ND1_Pool 2 (tributary to Native Dog Creek downstream of mining) **Donalds Castle Creek** Donalds Castle Creek (FR6) (Donalds Castle Creek lower) DCL3 (Donalds Castle Creek Upstream approx. 1km from Cordeaux River) DC_Pool 22 (Donalds Castle Creek downstream of mining) DC13_Pool 2b (Donalds Castle Creek tributary downstream of mining) **Lake Cordeaux** *LC5_S1 (Reference Site)* *Refer to Figure 2-35* **Cordeaux River** CR36_S1 (Cordeaux River tributary Reference Site)			

AREA 3C	**Wongawilli Creek** WWU1 (headwaters; upstream of Area 3C) WWU4 (upstream of Area 3C) Wongawilli Creek (FR6) (Wongawilli Creek downstream) WC_Pool 43b (adjacent to Longwall 20) WC_S1 (downstream of Longwall 21) WC20_S1 (downstream of Longwall 21) [4] WC24_S1 (downstream of Longwall 21) [4] WC26_S1 (downstream of Longwall 21) [4] **Donalds Castle Creek** Donalds Castle Creek (FR6) (Donalds Castle Creek lower) DC_Pool 22 DCL3 (Donalds Castle Creek upstream of Cordeaux River confluence) **Lake Cordeaux** LC5_S1[1] (downstream of Longwall 21) **Cordeaux River** CR36_S1 (Reference site northeast of Area 3C)			
WATER FLOW				
Ref Sites	**O'Hares Creek** [NSW govt site] 213200 (O'Hares Creek @ Wedderburn) **Wongawilli Creek** WWU (Wongawilli Creek upstream)	• Some data (for reference sites) is provided by WaterNSW		Other reference sites may be used depending on data availability and quality (e.g. Woronora River 2132101 and Bomaderry Creek 215016)
AREA 3A	**Wongawilli Creek** WWU (Wongawilli Creek upstream) WWL_A (Wongawilli Creek downstream) WC14S1 (Wongawilli Creek tributary) **Sandy Creek** SCL2(Sandy Creek at downstream) SC10S1 and SC10CS1 (Sandy Creek tributary) *Refer to Figures 3-5 of 3A WIMMCP*	• Pressure transducer with data logger • Flow gauging site (volumetric or flow meter). Low-profile weir or suitable natural rockbar control	• Continuous 1-hour logging intervals	Automatic pool water level measurements which are converted to flows by calculation of rating curves using measured creek cross sections/measured flows at the monitoring point. Hydrological changes are assessed by comparing pre- and post-mining observed flows from impact or assessment sites to flow data from similar reference sites (that are not impacted by mining).
AREA 3B	**Wongawilli Creek** WWU (Wongawilli Creek upstream) WWL_A (Wongawilli Creek downstream) WC21S1 (Wongawilli Creek tributary downstream of mining) WC15S1 (Wongawilli Creek tributary downstream of mining) WC12S1 (Wongawilli Creek tributary downstream of mining) **Donalds Castle Creek** DCU (Donalds Castle Creek @ FR6) DC13S1 (Donalds Castle Creek tributary downstream of mining) DCS2 (Donalds Castle Creek downstream of mining) **Lake Avon** LA4S1 (Lake Avon tributary downstream of mining)			

	LA3S1 (Lake Avon tributary downstream of mining) LA2S1 (Native Dog Creek tributary downstream of mining) NDCS1 (Lake Avon tributary downstream of mining) NDTS1 (Native Dog Tributary downstream of mining) **Lake Cordeaux** LC5S1 (Reference Site) **Cordeaux River** CR36S1 (Cordeaux River tributary Reference Site) *Refer to Figure 2-36 of 3B WIMMCP*			
AREA 3C	**Wongawilli Creek** WWU (Wongawilli Creek upstream) WWL_A (Wongawilli Creek downstream) WWL (Wongawilli Creek downstream) WCS1 (Wongawilli Creek downstream) WC20S1 (Wongawilli Creek tributary downstream of mining) WC24S1 (Wongawilli Creek tributary downstream of mining) WC26S1 (Wongawilli Creek tributary within the study area) **Donalds Castle Creek** DCU (Donalds Castle Creek downstream of mining) DCS2 (Donalds Castle Creek within study area) **Lake Cordeaux** LC5S1[1] (Downstream of LW20) **Cordeaux River** CR36S1 (Cordeaux River tributary Reference Site)			
AQUATIC ECOLOGY				
AREAS 3A, 3B and 3C	**Impact Sites:** Sites 2, 3, 4, X4, X5 and X6 (Wongawilli Creek) Sites X2 and X3 (WC21) Site X1 (Donalds Castle Creek) Sites 8, 9, 11, 12 and 13 (Sandy Creek Catchment) *Refer to Figure 2-57 of 3B WIMMCP* **Reference Sites:** Site 1 (Wongawilli Creek – until LW15) Site 5 (Wongawilli Creek) Site 14 (Donalds Castle Creek) Site 6 (WC21) Site 7 (Sandy Creek) Sites 15 and 16 (Kentish Creek) *Refer to Figure 2-57 of 3B WIMMCP*	• Quantitative and observational monitoring	• Two baseline monitoring campaigns prior to mining during autumn and spring • Biennial monitoring during mining in autumn and spring • Biennial monitoring post mining for two years or as otherwise required • Biennial monitoring targets sites as mining progresses through the domain	Macroinvertebrate sampling and assessment using the AUSRIVAS protocol and quantitative sampling using artificial collectors In consideration of Adams Emerald Dragonfly, Giant Dragonfly and Sydney Hawk Dragonfly, individuals of the genus Austrocorduliidae and Gomphomacromiidae, Petalura are identified to species level if possible Fish are sampled by visual observations and dip netting in Area 3A, and sampled using baited traps in Area 3B
TERRESTRIAL ECOLOGY				

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

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

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

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

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

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

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

	• Gas release results in vegetation dieback, mortality or loss of aquatic habitat • Observable increase in iron staining within the mining area continues more than 600m from the longwall	movements and impacts are complete), including monitoring and reporting on success • Review relevant TARP and Management Plan in consultation with key agencies
	Exceeding Prediction • Structural integrity of the bedrock base of any significant permanent pool or controlling rockbar cannot be restored i.e. pool water level within the pool after CMAs continues to be lower than baseline period • Gas release results in vegetation dieback that does not revegetate • Gas release results in mortality of threatened species or ongoing loss of aquatic habitat • Iron staining and associated increases in dissolved iron resulting from the mining is observed in water at the Donalds Castle Creek downstream monitoring site Donalds Castle Creek (FR6) • Iron staining and associated increases in dissolved iron resulting from the mining is observed in water at Wongawilli Creek downstream monitoring site Wongawilli Creek (FR6)	• *Actions as stated for Level 3* • Investigate reasons for the exceedance • Update future predictions based on the outcomes of the investigation • Provide residual environmental offset for any mining impact where CMAs are unsuccessful as required by Condition 14 Schedule 3 of the Development Consent
DC13, LC5, WC20, WC21, WC22, WC23, WC24, WC25, WC26, WC27 and WC29 General observation of streams in active mining areas when longwall is within 400m	***Level 1*** • Crack or fracture up to 100mm width at its widest point with no observable loss of surface water or erosion • Crack or fracture up to 10m length with no observable loss of surface water or erosion • Erosion in a localised area (not associated with cracking or fracturing) which would be expected to naturally stabilise without CMA and within the period of monitoring • Observable release of strata gas at the surface • Observable increase in iron staining within the mining area	• Continue monitoring program • Submit an Impact Report to BCD, DPIE, MEG, WaterNSW • Report in the End of Panel Report • Summarise actions and monitoring in AEMR
	Level 2 • Crack or fracture between 100 and 300mm width at its widest point or any fracture which results in observable loss of surface water or erosion • Crack or fracture between 10 and 50m length • Soil surface crack that causes erosion that is likely to stabilise within the monitoring period without intervention • Observable increase in iron staining within the mining area continues to outside the mining area i.e. 400m from the longwall	• *Actions as stated for Level 1* • Review monitoring frequency • Submit letter report to DPIE, MEG and WaterNSW and seek advice on any CMA required • Implement agreed CMAs as approved (subject to agency feedback)
	Level 3 • Crack or fracture over 300mm width at its widest point	• *Actions as stated for Level 2* • Offer site visit with BCD, DPIE, MEG, WaterNSW

	• Crack or fracture over 50m length • Fracturing observed in the bedrock base of any significant permanent pool which results in observable loss of surface water • Soil surface crack that causes erosion that is unlikely to stabilise within the monitoring period without intervention • Gas release results in vegetation dieback, mortality or loss of aquatic habitat • Observable increase in iron staining within the mining area continues more than 600m from the longwall	• Implement additional monitoring or increase frequency if required • Develop site CMA (subject to agency feedback). This may include: grouting of rockbar and bedrock base of any significant pool where it is appropriate to do so in consultation with BCD, DPIE, MEG, WaterNSW • Completion of works following approvals and at a time agreed between S32, DPIE, MEG and WaterNSW (i.e. may be after mining induced movements and impacts are complete), including monitoring and reporting on success • Review relevant TARP and Management Plan in consultation with key agencies
WATER QUALITY		
Wongawilli Creek **Relevant Performance Measure(s):** • Wongawilli Creek - minor environmental consequences Wongawilli Creek (FR6) Baseline means: • pH 5.98 • EC 98.8 uS/cm • DO 89.5%	***Level 1*** • One exceedance of the ±3 standard deviation level (positive for EC, negative for pH and DO) from the baseline mean within six months: – pH 4.45 – EC 154.1 uS/cm – DO 50.5%	• Continue monitoring program • Submit an Impact Report to BCD, DPIE, MEG, WaterNSW • Report in the End of Panel Report • Summarise actions and monitoring in AEMR
	Level 2 • Two non-consecutive exceedances of the ±3 standard deviation level (positive for EC, negative for pH and DO) from the baseline mean within six months: – pH 4.45 – EC 154.1 uS/cm – DO 50.5%	• *Actions as stated for Level 1* • Review monitoring frequency • Submit letter report to DPIE, MEG and WaterNSW and seek advice on any CMA required • Implement agreed CMAs as approved (subject to agency feedback)
	Level 3 • Three exceedances of the ±3 standard deviation level (positive for EC, negative for pH and DO) from the baseline mean within six months: – pH 4.45 – EC 154.1 uS/cm – DO 50.5%	• *Actions as stated for Level 2* • Offer site visit with BCD, DPIE, MEG, WaterNSW • Implement additional monitoring or increase frequency if required • Review relevant TARP and Management Plan in consultation with key agencies • Develop site CMA (subject to agency feedback). This may include: • Limestone emplacement to raise pH where it is appropriate to do so • Completion of works following approvals and at a time agreed between S32, DPIE, MEG and WaterNSW (i.e. may be after mining induced movements and impacts are complete), including monitoring and reporting on success
	Exceeding Prediction	• *Actions as stated for Level 3*

	• Mining results in two consecutive exceedances or three exceedances of the ±3 standard deviation level (positive for EC, negative for pH and DO) from the baseline mean within six months: – pH 4.45 – EC 154.1 uS/cm – DO 50.5%	• Investigate reasons for the exceedance • Update future predictions based on the outcomes of the investigation • Provide residual environmental offset for any mining impact where CMAs are unsuccessful as required by Condition 14 Schedule 3 of the Development Consent
Donalds Castle Creek **Relevant Performance Measure(s):** • Donalds Castle Creek - minor environmental consequences Donalds Castle Creek (FR6) Baseline means: • pH 5.41 • EC 116 uS/cm • DO 85.6%	***Level 1*** • One exceedance of the ±3 standard deviation level (positive for EC, negative for pH and DO) from the baseline mean within six months: – pH 3.60 – EC 185.8 uS/cm – DO 40.1%	• Continue monitoring program • Submit an Impact Report to BCD, DPIE, MEG WaterNSW • Report in the End of Panel Report • Summarise actions and monitoring in AEMR
	Level 2 • Two non-consecutive exceedances of the ±3 standard deviation level (positive for EC, negative for pH and DO) from the baseline mean within six months: – pH 3.60 – EC 185.8 uS/cm – DO 40.1%	• *Actions as stated for Level 1* • Review monitoring frequency • Submit letter report to DPIE, MEG and WaterNSW and seek advice on any CMA required • Implement agreed CMAs as approved (subject to agency feedback) •
	Level 3 • Three exceedances of the ±3 standard deviation level (positive for EC, negative for pH and DO) from the baseline mean within six months: – pH 3.60 – EC 185.8 uS/cm – DO 40.1%	• *Actions as stated for Level 2* • Offer site visit with BCD, DPIE, MEG, WaterNSW • Implement additional monitoring or increase frequency if required • Review relevant TARP and Management Plan in consultation with key agencies • Collect laboratory samples and analyse for: • pH, EC, major cations, major anions, Total Fe, Mn & Al • Filterable suite of metals • Develop site CMA (subject to agency feedback). This may include: • Limestone emplacement to raise pH where it is appropriate to do so • Completion of works following approvals and at a time agreed between S32, DPIE, MEG and WaterNSW (i.e. may be after mining induced movements and impacts are complete), including monitoring and reporting on success
	Exceeding Prediction	• *Actions as stated for Level 3* • Investigate reasons for the exceedance

	• Mining results in two consecutive exceedances or three exceedances of the ±3 standard deviation level (positive for EC, negative for pH and DO) from the baseline mean within six months: – pH 3.60 – EC 185.8 uS/cm – DO 40.1%	• Update future predictions based on the outcomes of the investigation • Provide residual environmental offset for any mining impact where CMAs are unsuccessful as required by Condition 14 Schedule 3 of the Development Consent
Lake Cordeaux **Relevant Performance Measure(s):** • Lake Cordeaux - negligible reduction in the quality of surface water inflows to Lake Cordeaux LC5_S1 Site[1] Baseline means: • pH 6.11 • EC 93 uS/cm • DO 87.6%	***Level 1*** • One exceedance of the ±3 standard deviation level (positive for EC, negative for pH and DO) from the baseline mean within six months: – pH 3.96 – EC 137 uS/cm – DO 49.4%	• Continue monitoring program • Submit an Impact Report to BCD, DPIE, MEG, WaterNSW • Report in the End of Panel Report • Summarise actions and monitoring in AEMR
	Level 2 • Two non-consecutive exceedances of the ±3 standard deviation level (positive for EC, negative for pH and DO) from the baseline mean within six months: – pH 3.96 – EC 137 uS/cm – DO 49.4%	• *Actions as stated for Level 1* • Review monitoring frequency • Submit letter report to DPIE, MEG and WaterNSW and seek advice on any CMA required • Implement agreed CMAs as approved (subject to agency feedback)
	Level 3 • Three exceedances of the ±3 standard deviation level (positive for EC, negative for pH and DO) from the baseline mean within six months: – pH 3.96 – EC 137 uS/cm – DO 49.4%	• *Actions as stated for Level 2* • Offer site visit with BCD, DPIE, MEG, WaterNSW • Implement additional monitoring or increase frequency if required • Review relevant TARP and Management Plan in consultation with key agencies • Collect laboratory samples and analyse for: – pH, EC, major cations, major anions, Total Fe, Mn & Al – Filterable suite of metals • Develop site CMA (subject to agency feedback). This may include: – Limestone emplacement to raise pH where it is appropriate to do so – Grouting of fractures in rockbar and bedrock base of any significant pool where flow diversion results in pool water level lower than baseline period

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

<table>
<tr><td rowspan="2"></td><td></td><td>Completion of works following approvals and at a time agreed between S32, DPIE, MEG and WaterNSW (i.e. may be after mining induced movements and impacts are complete), including monitoring and reporting on success</td></tr>
<tr><td>Exceeding Prediction
Mining results in two consecutive exceedances or three exceedances of the ±3 standard deviation level (positive for EC, negative for pH and DO) from the baseline mean within six months:
– pH 3.96
– EC 137 uS/cm
– DO 49.4%</td><td>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</td></tr>
<tr><td colspan="3">POOL WATER LEVEL</td></tr>
<tr><td rowspan="4">Donalds Castle Creek and Wongawilli Creek

Relevant Performance Measure(s):
Donalds Castle Creek - minor environmental consequences
Wongawilli Creek - minor environmental consequences</td><td>Level 1
Single pool on a subject Creek is observed as dry</td><td>Continue monitoring program
Carry out Water Flow Assessment Method D.
Submit letter report to DPIE, MEG and WaterNSW
Report in the End of Panel Report
Summarise actions and monitoring in AEMR</td></tr>
<tr><td>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</td><td>Actions as stated for Level 1
Review monitoring frequency
Submit letter report to DPIE, MEG and WaterNSW and seek advice on any CMA required
Implement agreed CMAs as approved (subject to agency feedback)</td></tr>
<tr><td>Level 3
Fracturing resulting in diversion of flow such that <10% of the pools have water levels lower than baseline period</td><td>Actions as stated for Level 2
Offer site visit with BCD, DPIE, MEG, WaterNSW
Implement additional monitoring or increase frequency if required
Review relevant TARP and Management Plan in consultation with key agencies
Develop site CMA (subject to agency feedback). This may include: grouting of rockbar and bedrock base of any significant pool where it is appropriate to do so in consultation with BD, DPIE, MEG, WaterNSW
Completion of works following approvals and at a time agreed between S32, DPIE, MEG and WaterNSW (i.e. may be after mining induced movements and impacts are complete), including monitoring and reporting on success</td></tr>
<tr><td>Exceeding Prediction</td><td>Actions as stated for Level 3
Investigate reasons for the exceedance</td></tr>
</table>

	• Fracturing resulting in diversion of flow such that >10% of the pools have water levels lower than baseline period	• Update future predictions based on the outcomes of the investigation • Provide residual environmental offset for any mining impact where CMAs are unsuccessful as required by Condition 14 Schedule 3 of the Development Consent
SURFACE WATER FLOW		
Donalds Castle Creek, Wongawilli Creek, Lake Cordeaux and Cordeaux River **Relevant Performance Measure(s):** • Donalds Castle Creek - minor environmental consequences • Wongawilli Creek - minor environmental consequences • Lake Cordeaux - negligible reduction in the quantity of surface water inflows to Lake Cordeaux[2] • Cordeaux River - negligible reduction in the quantity of surface water inflow to the Cordeaux River at its confluence with Wongawilli Creek[3] **Surface Water Flow Reference Sites** (as in Table 1.1)**:** • Wongawilli Creek - WWU (Wongawilli Creek upstream); • O'Hares Creek at Wedderburn (213200); • (other such sites, if necessary, include Woronora River 2132101 and Bomaderry Creek 215016) NB. This section of the TARP contains four Water Flow Assessment Methods, labelled A, B, C and D, which are specified in detail in Watershed HydroGeo (2019) Hydrological changes are assessed by comparing pre- and post-mining observed flows from impact	***Level 1*** • A) Lower flow than expected (additional 10-15% of days where Q% lower than Reference Q%) • B) 5-10% increase in cease-to-flow frequency beyond natural) • C) Reduction in Q50 (10-15% beyond natural)	• Continue monitoring program. • Submit an Impact Report to BCD, DPIE, MEG, WaterNSW. • Report in the End of Panel Report. • Summarise actions and monitoring in AEMR.
	Level 2 • A) Lower flow than expected (additional 15-20% of days where Q% lower than Reference Q%). • B) 10-20% increase in cease-to-flow frequency (beyond natural) • C) 15-20% reduction in Q50 (beyond natural) • D) Observation that the subject Creek has ceased to flow at spatially consecutive monitoring sites.	• *Actions as stated for Level 1* • Review monitoring frequency. • D) → carry out Water Flow Assessment Method D. • Submit letter report to DPIE, MEG and WaterNSW and seek advice on any CMA required. • Implement agreed CMAs as approved (subject to agency feedback).
	Level 3 • A) Lower flow than expected (additional >20% of days where Q% lower than Reference Q%) • B) >20% increase in cease-to-flow frequency (beyond natural) • C) >20% reduction in Q50 (beyond natural)	• *Actions as stated for Level 2* • Offer site visit with BCD, DPIE, MEG, WaterNSW. • Implement additional monitoring or increase frequency if required. • Develop site CMA (subject to agency feedback). This may include: grouting of rockbar and bedrock base of any significant pool where it is appropriate to do so in consultation with BCD, DPIE, MEG, WaterNSW. • Completion of works following approvals and at a time agreed between S32, DPIE, MEG and WaterNSW (i.e. may be after mining induced movements and impacts are complete), including monitoring and reporting on success. • Review relevant TARP and Management Plan in consultation with key agencies.
	Exceeding Prediction • Measured surface water flow reduction, based on Assessment Methods C, D, to be compared against predictions made in contemporary groundwater modelling conducted to the satisfaction of the Secretary to assess whether effects that cannot be explained by natural variability "exceed prediction".	• *Actions as stated for Level 3* • Investigate reasons for the exceedance. • Update future predictions based on the outcomes of the investigation.

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

or assessment sites to flow data from the reference sites. *Natural variability ('NV') will be defined as the 'average' change at the selected reference sites. Triggers may occur when the apparent impact at a site (NV + x% change) could be less than maximum observed variability at one of the reference sites.*		• Provide residual environmental offset for any mining impact where CMAs are unsuccessful as required by Condition 14 Schedule 3 of the Development Consent.
Tributaries of Donalds Castle Creek and Wongawilli Creek and other affected watercourses not subject to performance measures **Surface water flow Reference sites** (as in Table 1.1)**:** • Wongawilli Creek - WWU (Wongawilli Creek upstream); • O'Hares Creek and Wedderburn (213200); • (other such sites, if necessary, include Woronora River 2132101 and Bomaderry Creek 215016) NB. This section of the TARP contains four Water Flow Assessment Methods, labelled A, B, C and D, which are specified in detail in Watershed HydroGeo (2019). Hydrological changes are assessed by comparing pre- and post-mining observed flows from impact or assessment sites to flow data from the reference sites. *Natural variability ('NV') will be defined as the 'average' change at the selected reference sites. Triggers may occur when the apparent impact at a site (NV + x% change) could be less than maximum observed variability at one of the reference sites.*	***Level 1*** • A) Lower flow than expected (additional 10-20% of days where Q% lower than Reference Q%) • B) 5-10% increase in cease-to-flow frequency (beyond natural) • C) 10-20% reduction in Q50 (beyond natural)	• Continue monitoring program. • Submit an Impact Report to BCD, DPIE, MEG, WaterNSW. • Report in the End of Panel Report. • Summarise actions and monitoring in AEMR.
	Level 2 • A) Lower flow than expected (additional 20-30% of days where Q% lower than Reference Q%) • B) 10-20% increase in cease-to-flow frequency (beyond natural) • C) 20-30% reduction in Q50 (beyond natural)	• Actions as stated for Level 1 • Review monitoring frequency. • Submit letter report to DPIE, MEG and WaterNSW and seek advice on any CMA required. • Implement agreed CMAs as approved (subject to agency feedback).
	Level 3 • A) Lower flow than expected (additional >30% of days where Q% lower than Reference Q%) • B) >20% increase in cease-to-flow frequency (beyond natural) • C) >30% reduction in Q50 (beyond natural)	• *Actions as stated for Level 2* • Offer site visit with BCD, DPIE, MEG, WaterNSW. • Implement additional monitoring or increase frequency if required • Develop site CMA (subject to agency feedback). This may include: grouting of rockbar and bedrock base of any significant pool where it is appropriate to do so in consultation with BCD, DPIE, MEG, WaterNSW. • Completion of works following approvals and at a time agreed between S32, DPIE, MEG and WaterNSW (i.e. may be after mining induced movements and impacts are complete), including monitoring and reporting on success. • Review relevant TARP and Management Plan in consultation with key agencies.
AQUATIC ECOLOGY		
	Level 1	• Continue monitoring program

Pool water level, interconnectivity between pools and loss of connectivity, noticeable alteration of habitat • Donalds Castle Creek catchment – 1 site • Wongawilli Creek catchment – 8 sites	• Reduction in aquatic habitat for 1 year	• Submit an Impact Report to BCD, DPIE, MEG, WaterNSW • Report in the End of Panel Report • Summarise actions and monitoring in AEMR
	Level 2 • Reduction in aquatic habitat for 2 years following the active subsidence period	• *Actions as stated for Level 1* • Review monitoring frequency • Submit letter report to DPIE, BCD, MEG and WaterNSW and seek advice on any CMA required • Implement agreed CMAs as approved (subject to agency feedback)
	Level 3 • Reduction in aquatic habitat for >2 years following the active subsidence period	• *Actions as stated for Level 2* • Offer site visit with BCD, DPIE, MEG, WaterNSW • Implement additional monitoring or increase frequency if required • Review relevant TARP and Management Plan in consultation with key agencies • Develop site CMA (subject to agency feedback). This may include: grouting of rockbar and bedrock base of any significant pool where it is appropriate to do so in consultation with BCD, DPIE, MEG, WaterNSW • Completion of works following approvals and at a time agreed between S32, DPIE, MEG and WaterNSW (i.e. may be after mining induced movements and impacts are complete), including monitoring and reporting on success
TERRESTRIAL FAUNA – THREATENED FROG SPECIES		
Pool water level, interconnectivity between pools and loss of connectivity, noticeable alteration of habitat • Donalds Castle Creek catchment – 2 site • Wongawilli Creek catchment – 2 sites	***Level 1*** • Reduction in habitat for 1 year	• Continue monitoring program • Submit an Impact Report to BCD, DPIE, MEG, WaterNSW • Report in the End of Panel Report • Summarise actions and monitoring in AEMR
	Level 2 • Reduction in habitat for 2 years following the active subsidence period	• *Actions as stated for Level 1* • Review monitoring frequency • Submit letter report to DPIE, BCD, MEG and WaterNSW and seek advice on any CMA required • Implement agreed CMAs as approved (subject to agency feedback)
	Level 3 • Reduction in habitat for > 2 years following the active subsidence period	• *Actions as stated for Level 2* • Offer site visit with BCD, DPIE, MEG, WaterNSW • Implement additional monitoring or increase frequency if required • Review relevant TARP and Management Plan in consultation with key agencies

		• Develop site CMA (subject to agency feedback). This may include: grouting of rockbar and bedrock base of any significant pool where it is appropriate to do so in consultation with BCD, DPIE, MEG, WaterNSW • Completion of works following approvals and at a time agreed between S32, DPIE, MEG and WaterNSW (i.e. may be after mining induced movements and impacts are complete), including monitoring and reporting on success

Regulatory Agency Acronyms

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

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
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Australia

SLR Ref: 665.10009-R03
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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
665.10009-R03-v3.0	3 February 2020	Braiya White, Claire Stephenson	Claire Stephenson	Claire Stephenson
665.10009-R03-v2.0	28 January 2020	Braiya White, Claire Stephenson	Claire Stephenson	Noel Merrick

CONTENTS

DOCUMENT REFERENCES

TABLES

FIGURES

APPENDICES

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

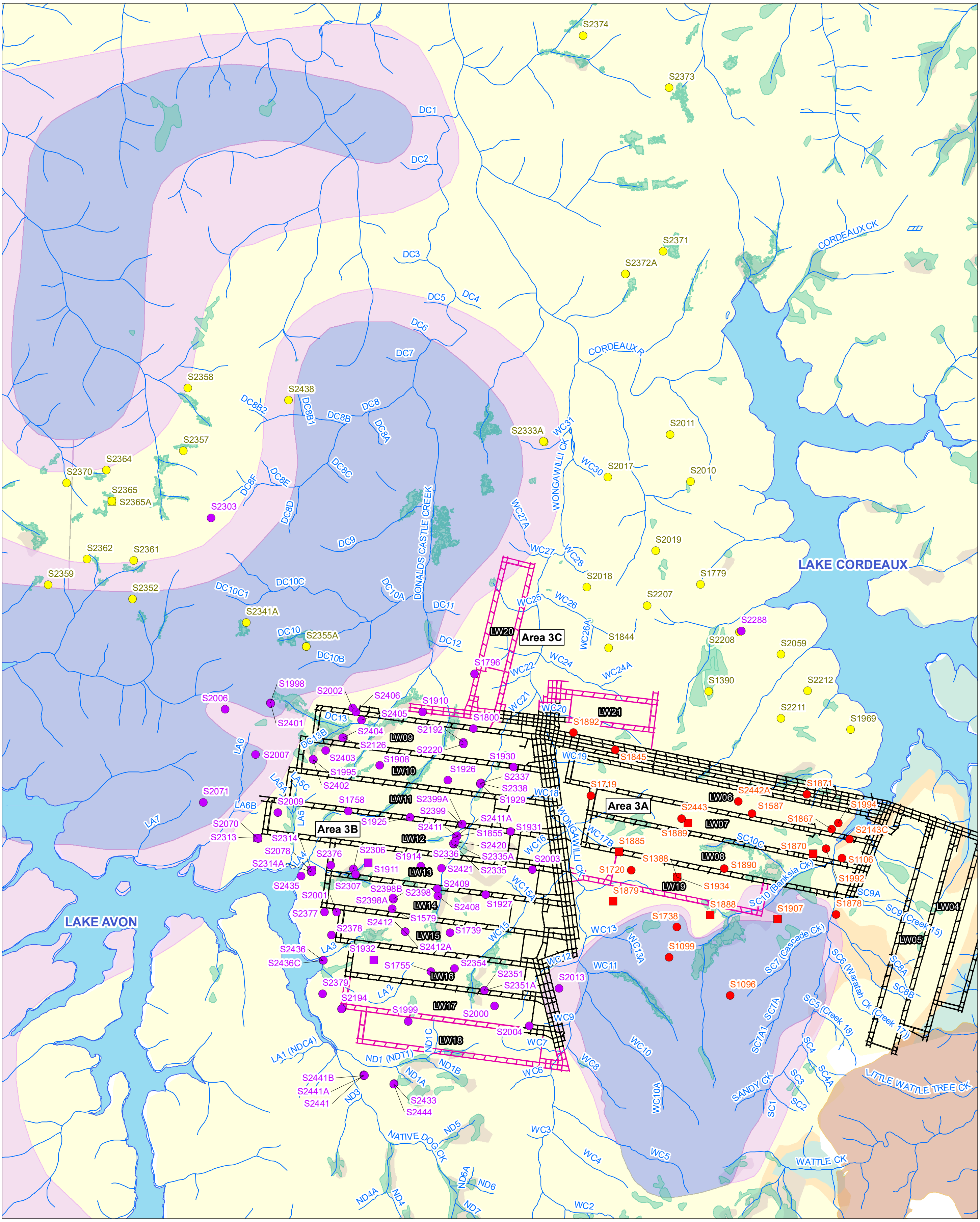
Groundwater quality is sampled at selected VWPs in Areas 3A, 3B and 3C via pumps fixed within the VWP borehole. Currently, 22 of the site VWPs are equipped for water quality sampling at multiple vertical intervals. Each borehole has up to three pumps, with the Hawkesbury Sandstone, Bulgo Sandstone or 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
HBSS – Hawkesbury Sandstone
SBSS – Scarborough Sandstone
Coordinates are for GDA94 MGA56
BGSS – Bulgo Sandstone



H:\Projects-SLR\620-BNE\665-WOL\665.10009\ArcGIS\66510009_00007 Existing Groundwater Monitoring Network.mxd

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

Project No.: 665.10009
Date: 22-Jan-2020
Drawn by: JG
Sheet Size: A4

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

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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

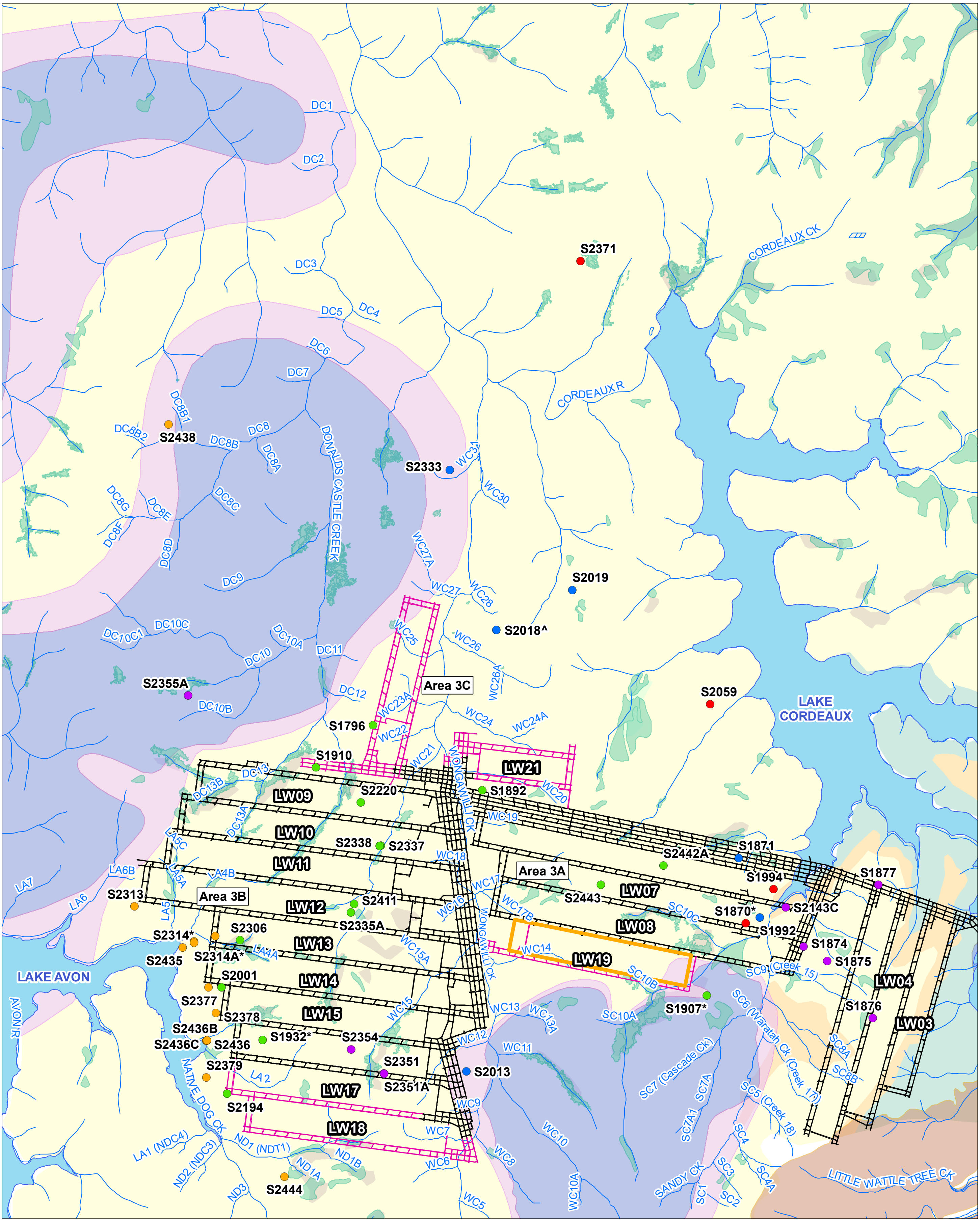
Monitoring Group	Area	S-Index	Bore Name	Easting	Northing	Collar RL (mAHD)	Total depth (mbgl)	No. Sensors	No. Piezometers by Geology								
									HBSS	BHCS/BACS	BGSS	SBSS	WBCS	CCSS	BUSM	WWSM	TGSM
Longwall	3A	S1892	ED Dendrobium DDH 99	291014.1	6193952.0	356.1	389.2	8	2		2	2			1	1	
	3A	S1907	ED Dendrobium 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	
Watercourses	3A	S1992	EDEN119	293732.1	6192706.8	339.1	250.0	8	1		4	2			1		
Watercourses	3C	S2333	D-A3C-14-12	290697.1	6197087.4	310.9	-	10	3		3	2			1	1	
Watercourses	3B	S2013	EDEN134	290857.7	6191198.2	399.7	-	4	P	P					1	1	
Watercourses	3C	S2018^	EDEN137	291154.4	6195520.3	369.0	-	4	P	P					1	1	
Watercourses	3B	S2019	EDEN138	291897.6	6195913.7	361.8	-	4	P	P					1	1	
Watercourses	3B	S2355	A5_S85_DBH	288136.2	6194877.8	396.6	70.6	4	4								
Watercourses	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.



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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

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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.

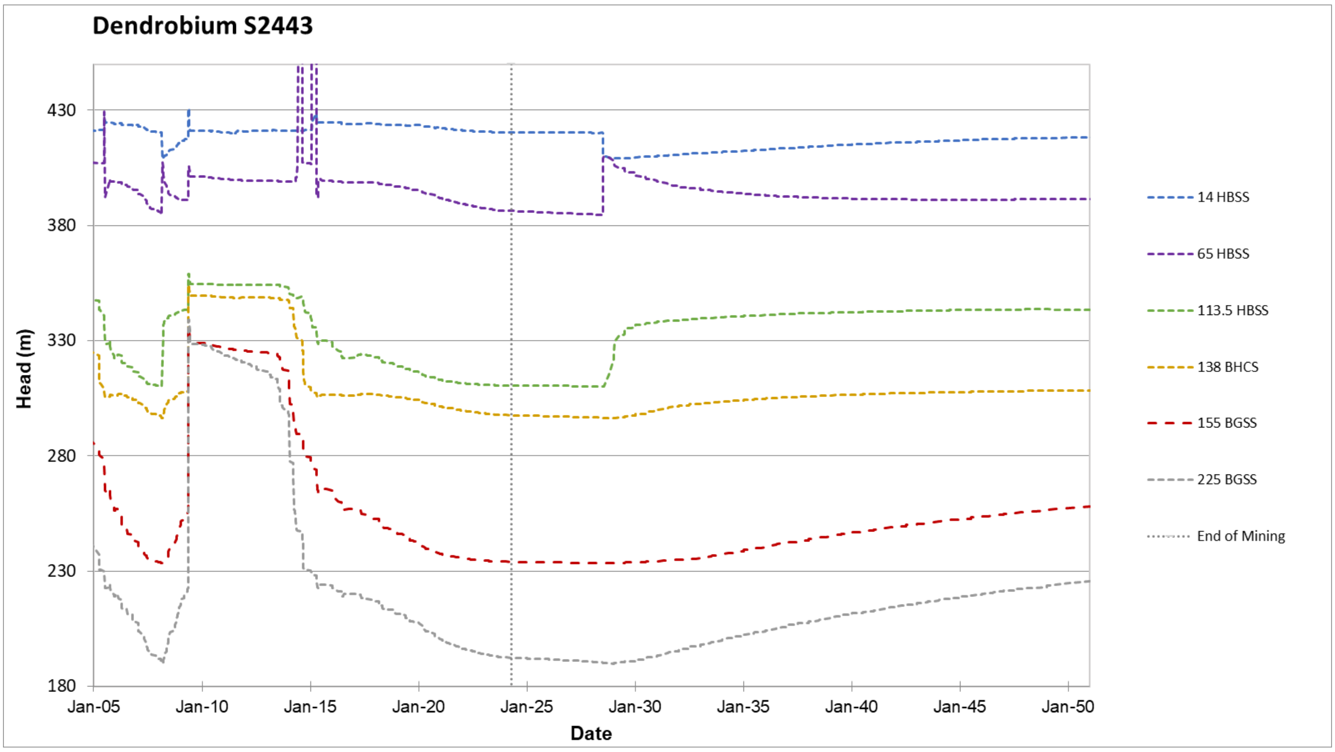

Figure 3 Modelled Groundwater Levels for Bore S2443

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.

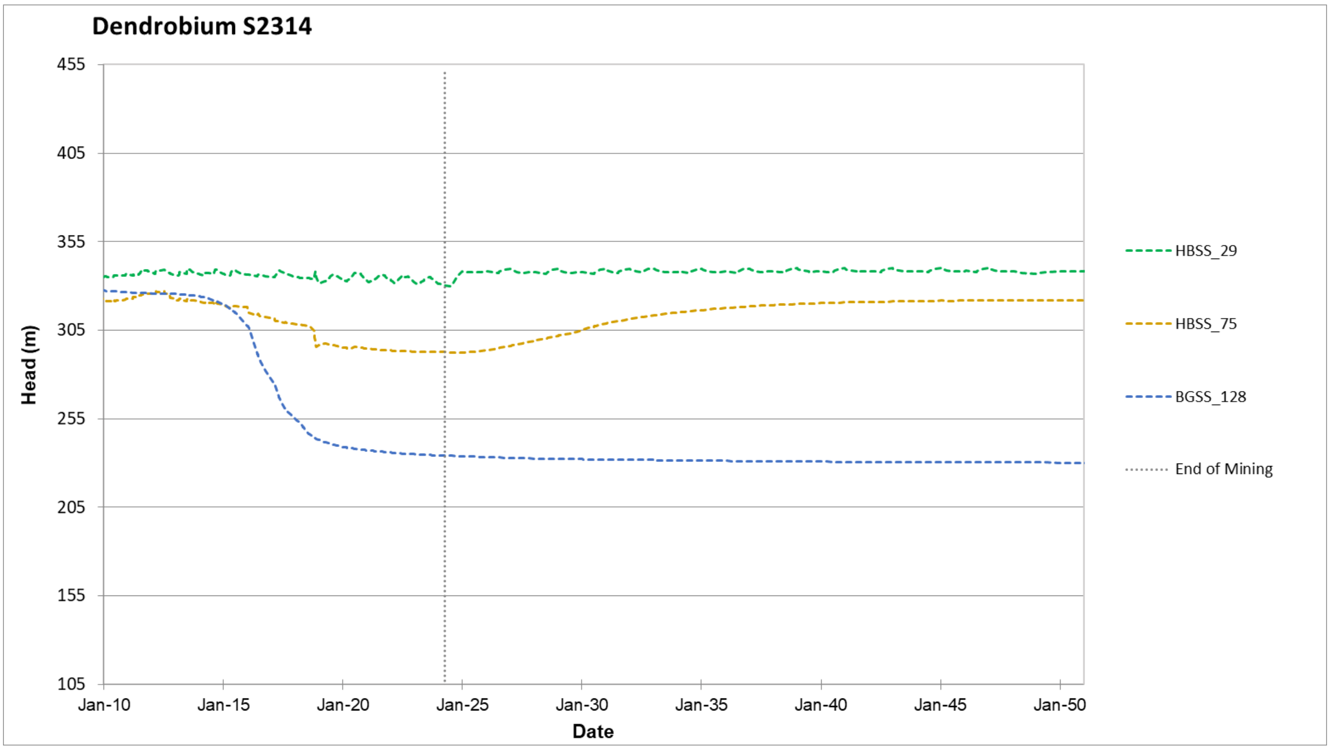

Figure 4 Modelled Groundwater Levels for Bore S2314

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.

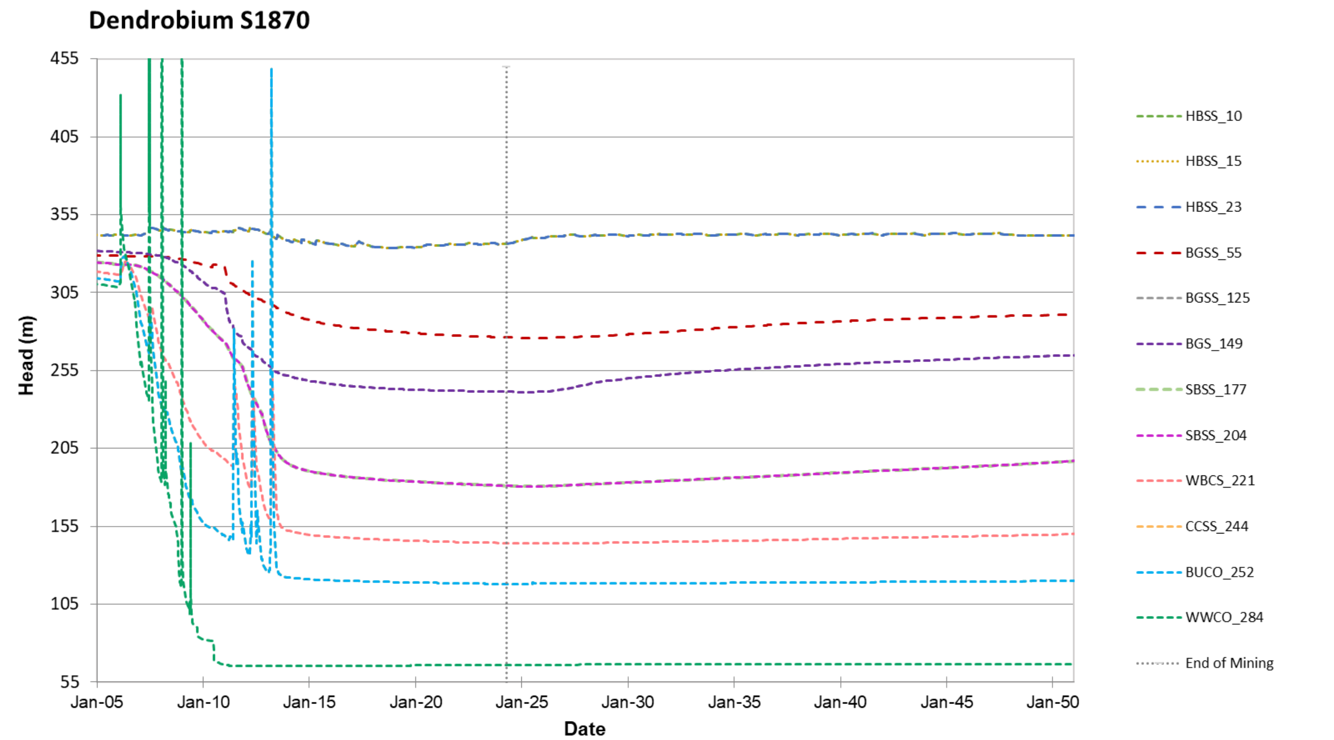

Figure 5 Modelled Groundwater Levels for Bore S1870

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.

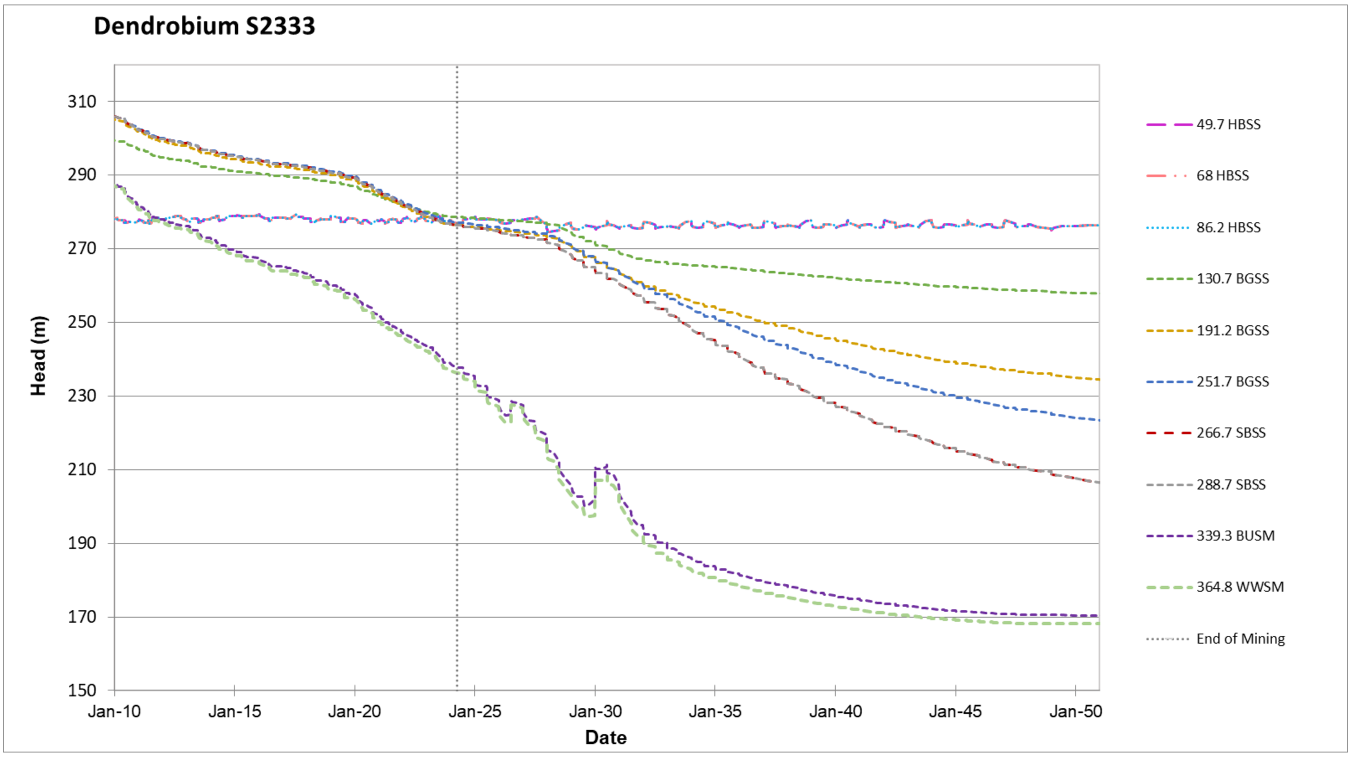

Figure 6 Modelled Groundwater Levels for Bore S2333

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.

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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

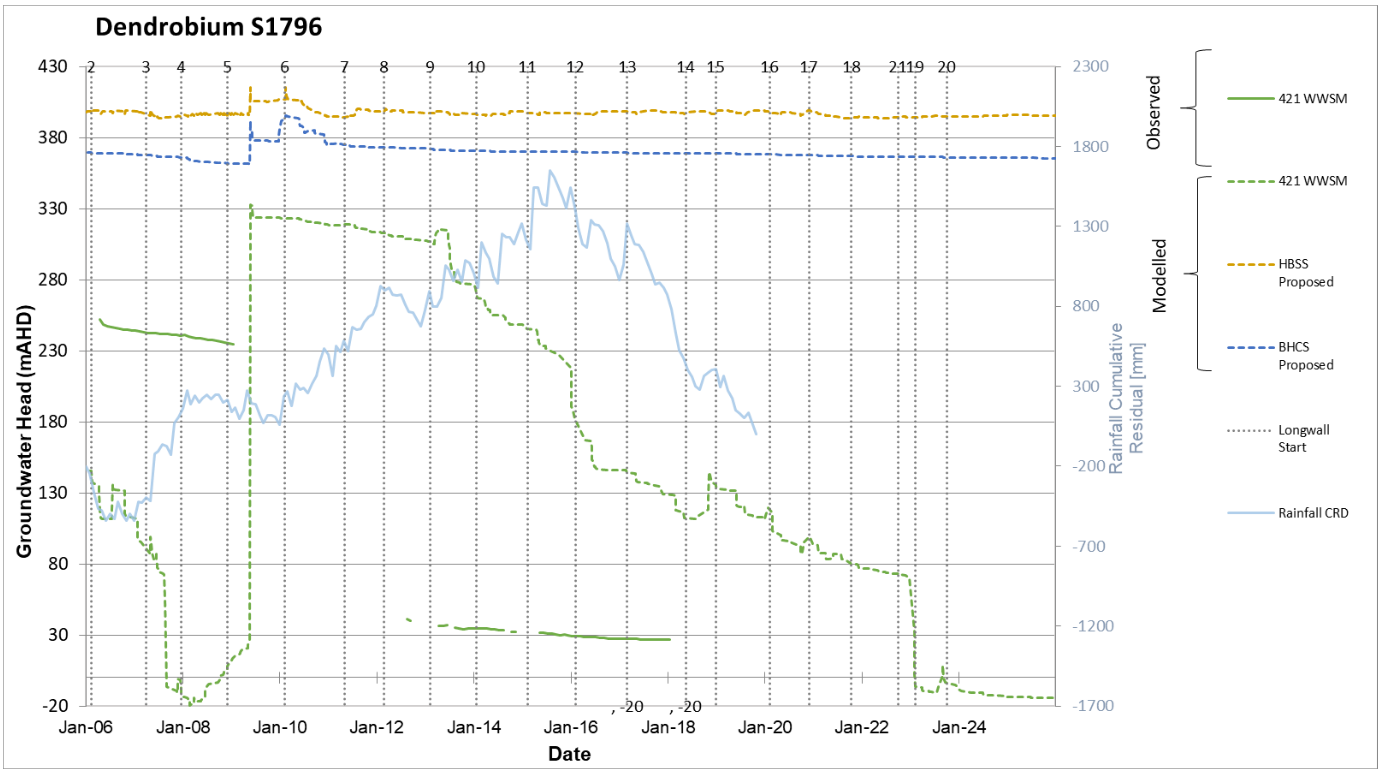

Figure A-1 Modelled and Observed Groundwater levels – S1796

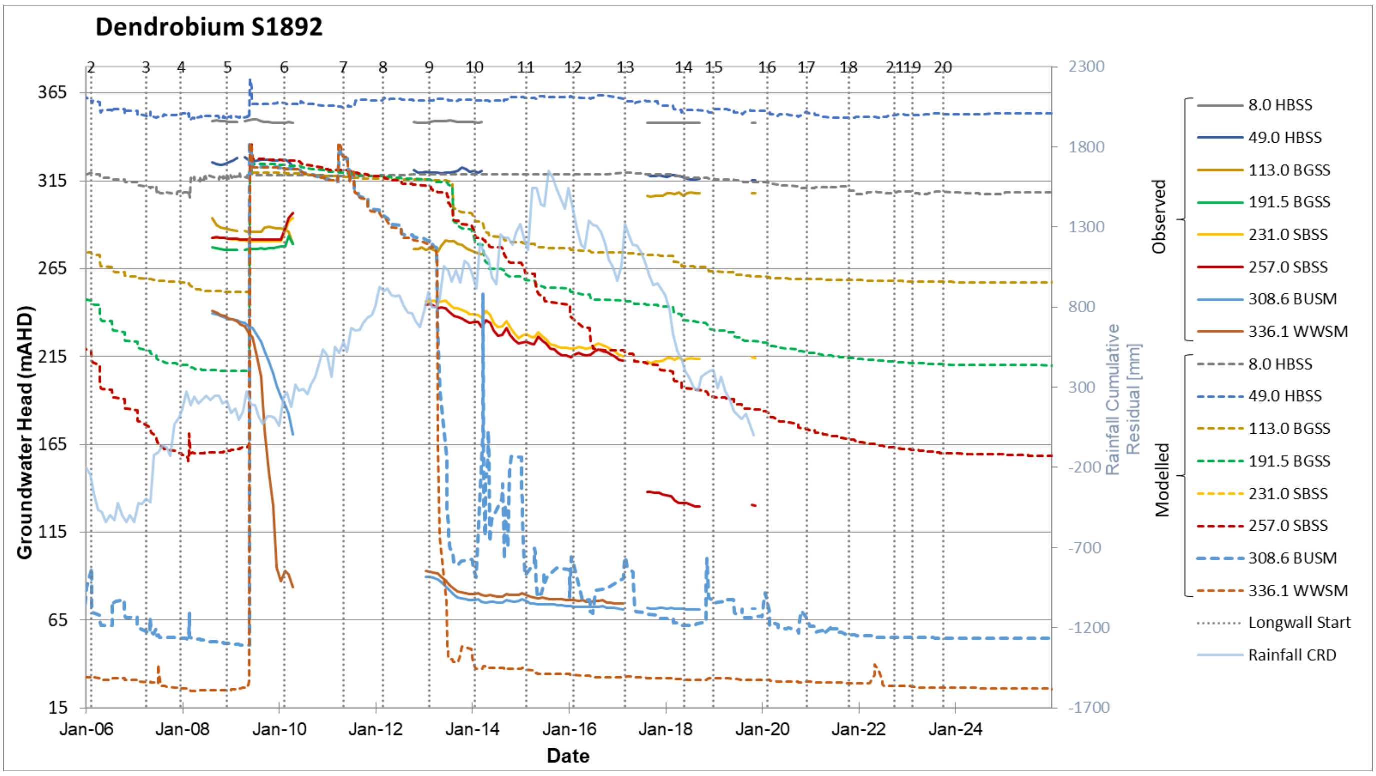

Figure A-2 Modelled and Observed Groundwater levels – S1892

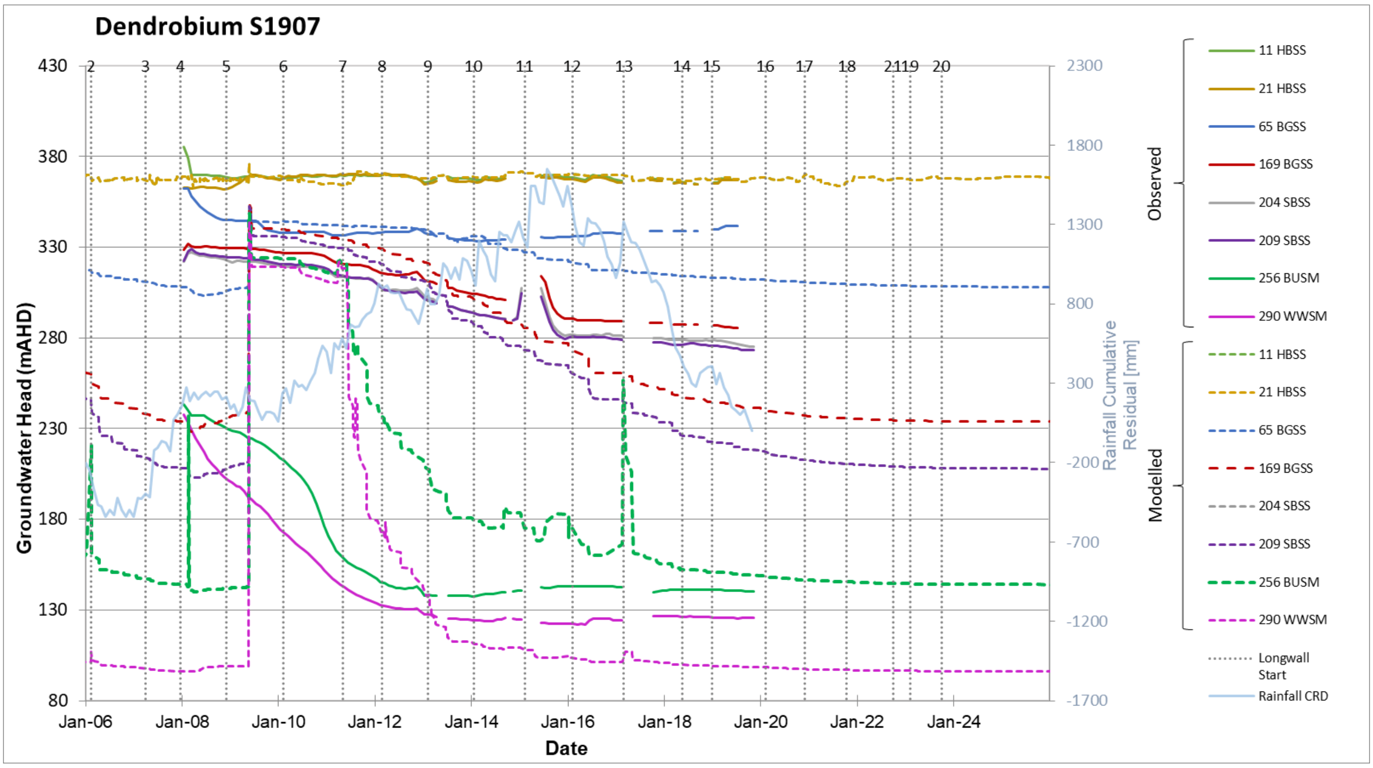

Figure A-3 Modelled and Observed Groundwater levels – S1907

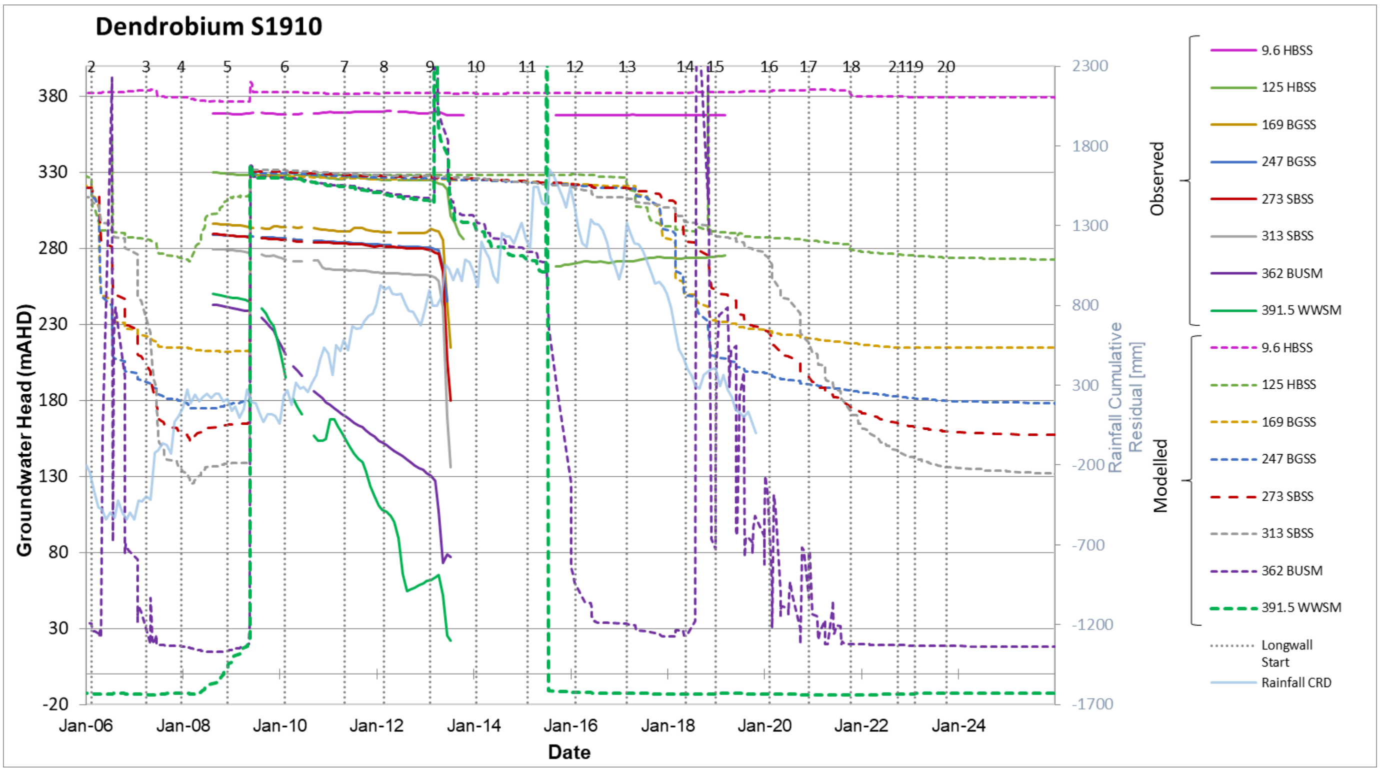

Figure A-4 Modelled and Observed Groundwater levels – S1910

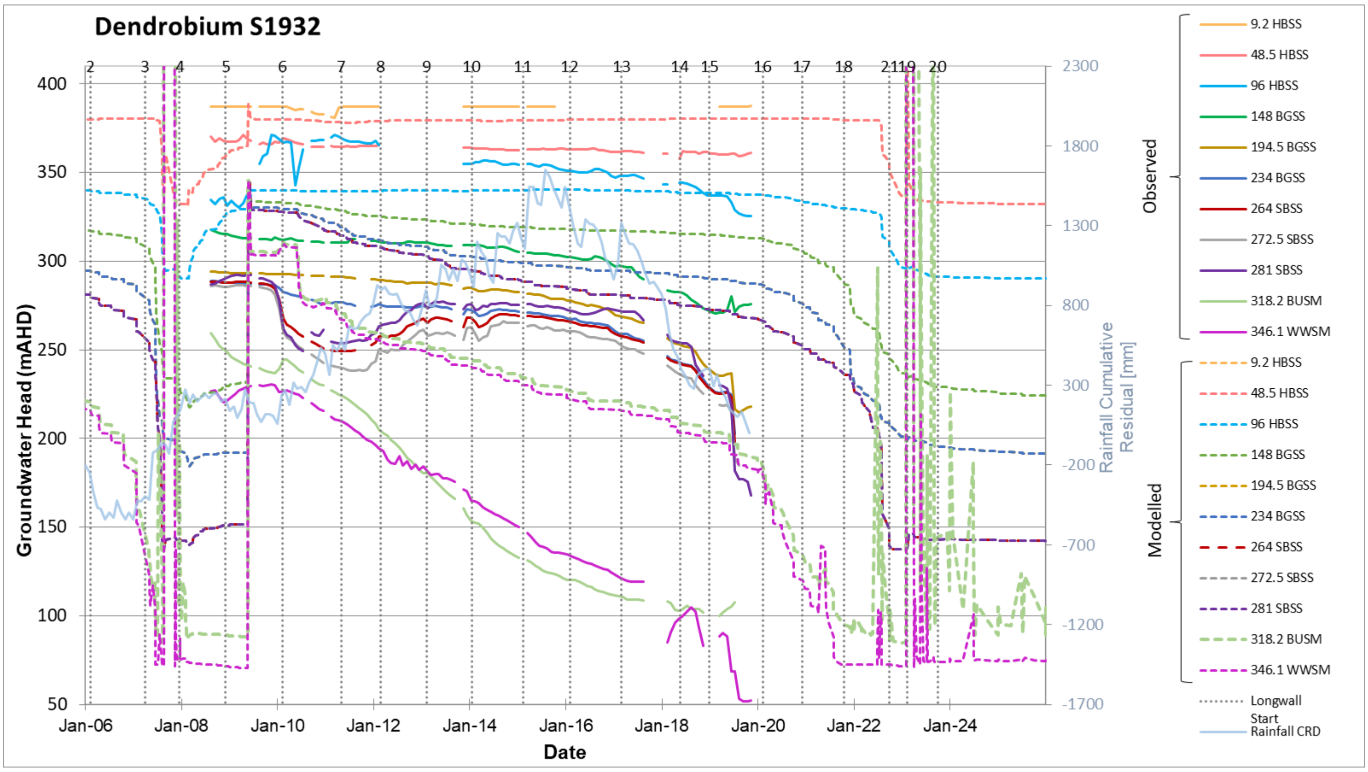

Figure A-5 Modelled and Observed Groundwater levels – S1932

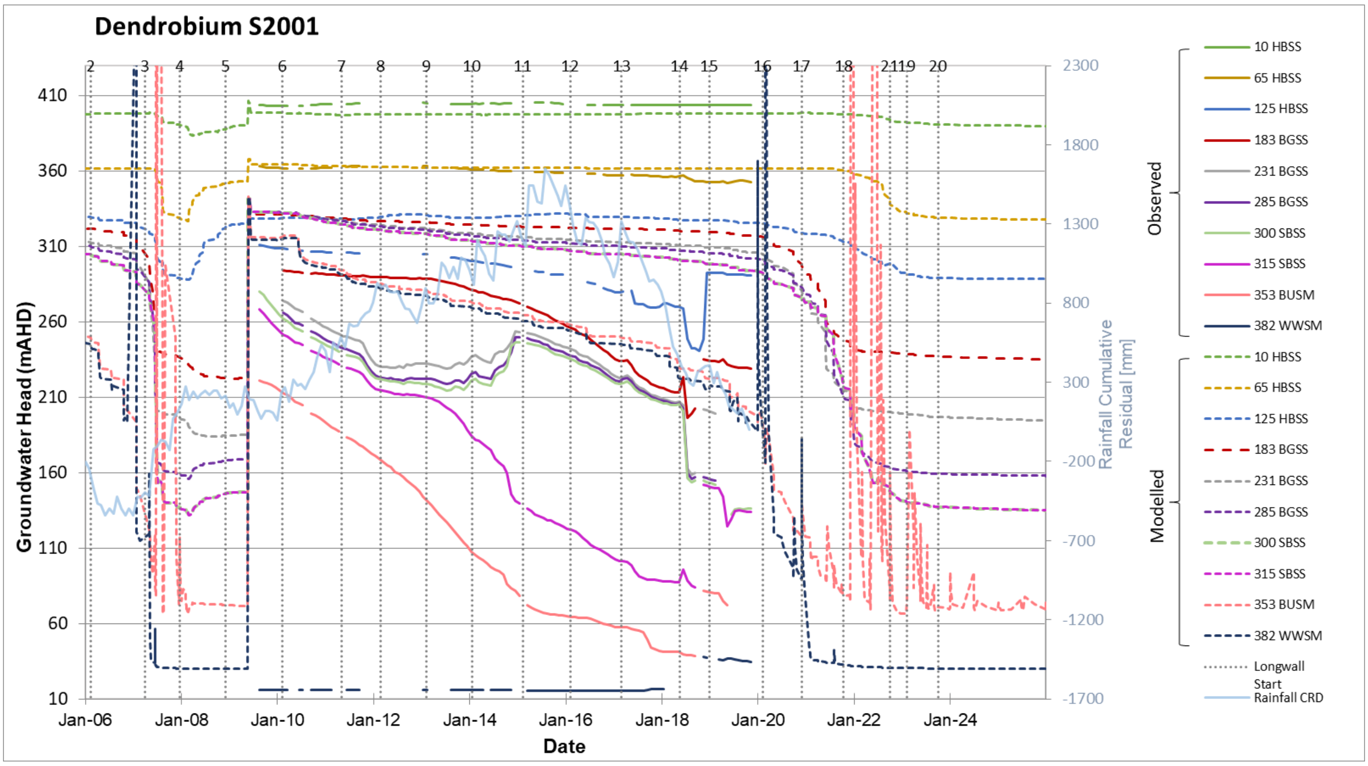

Figure A-6 Modelled and Observed Groundwater levels – S2001

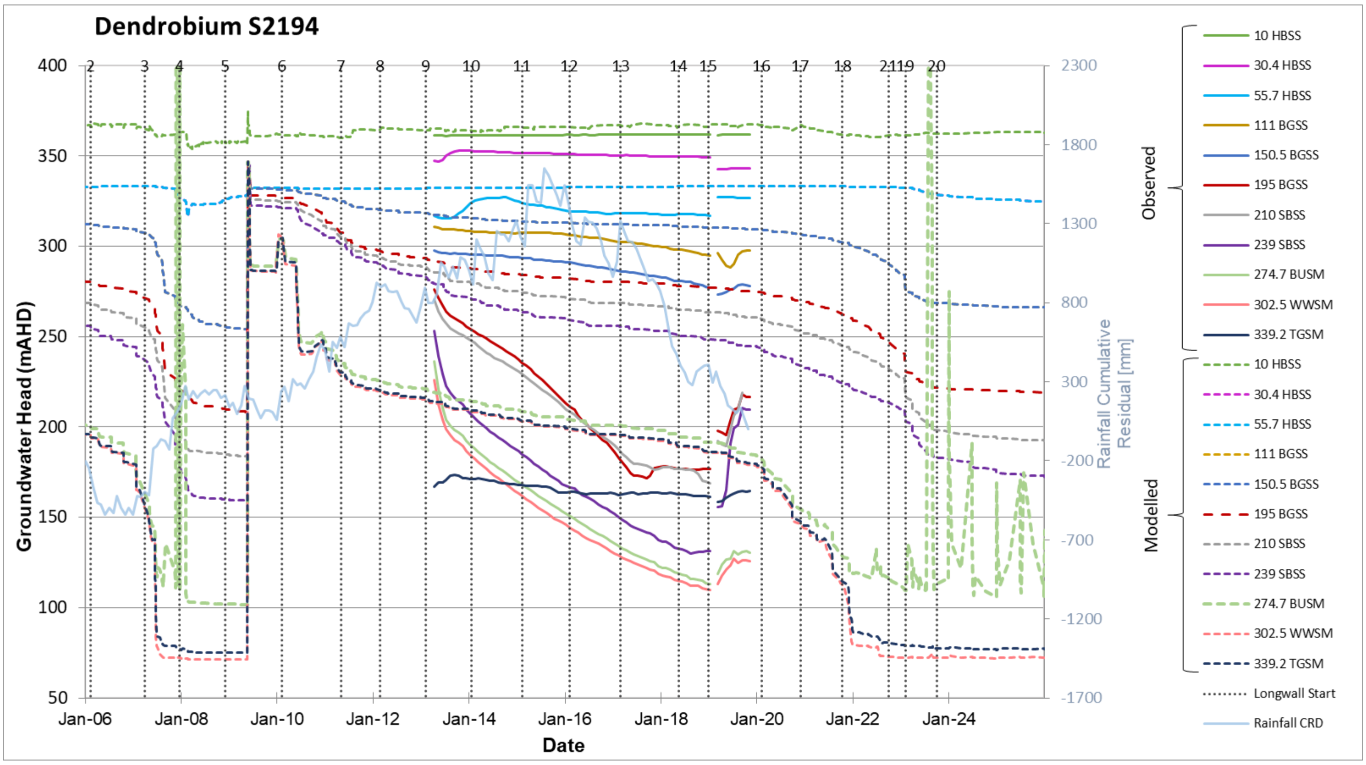

Figure A-7 Modelled and Observed Groundwater levels – S2194

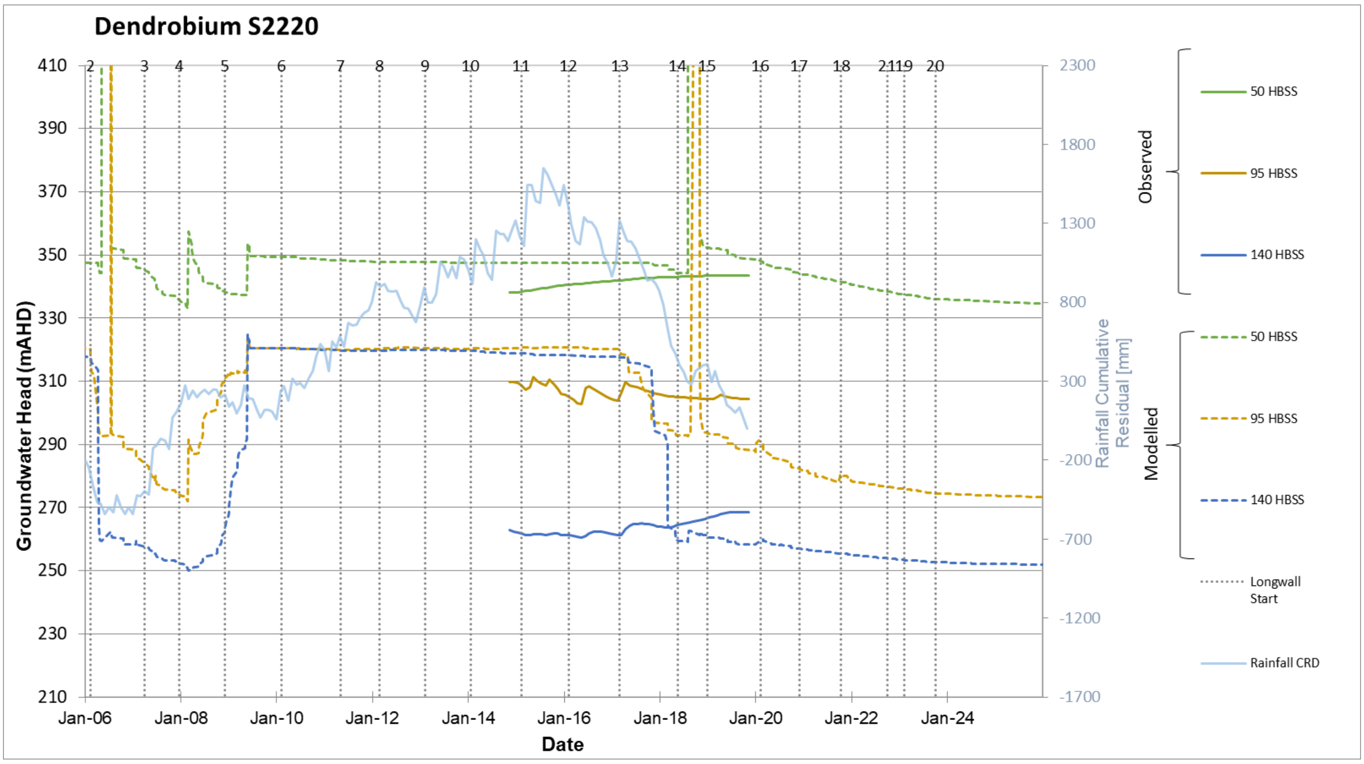

Figure A-8 Modelled and Observed Groundwater levels – S2220

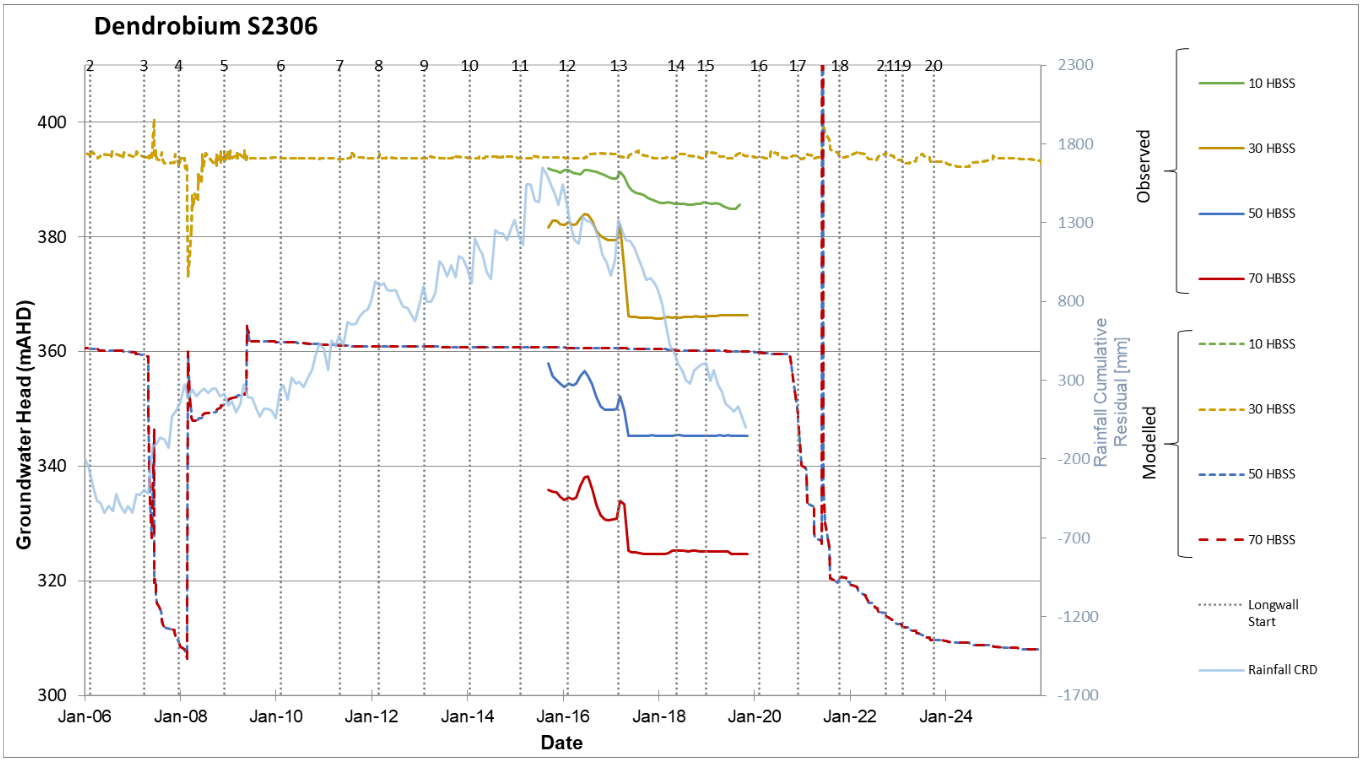

Figure A-9 Modelled and Observed Groundwater levels – S2306

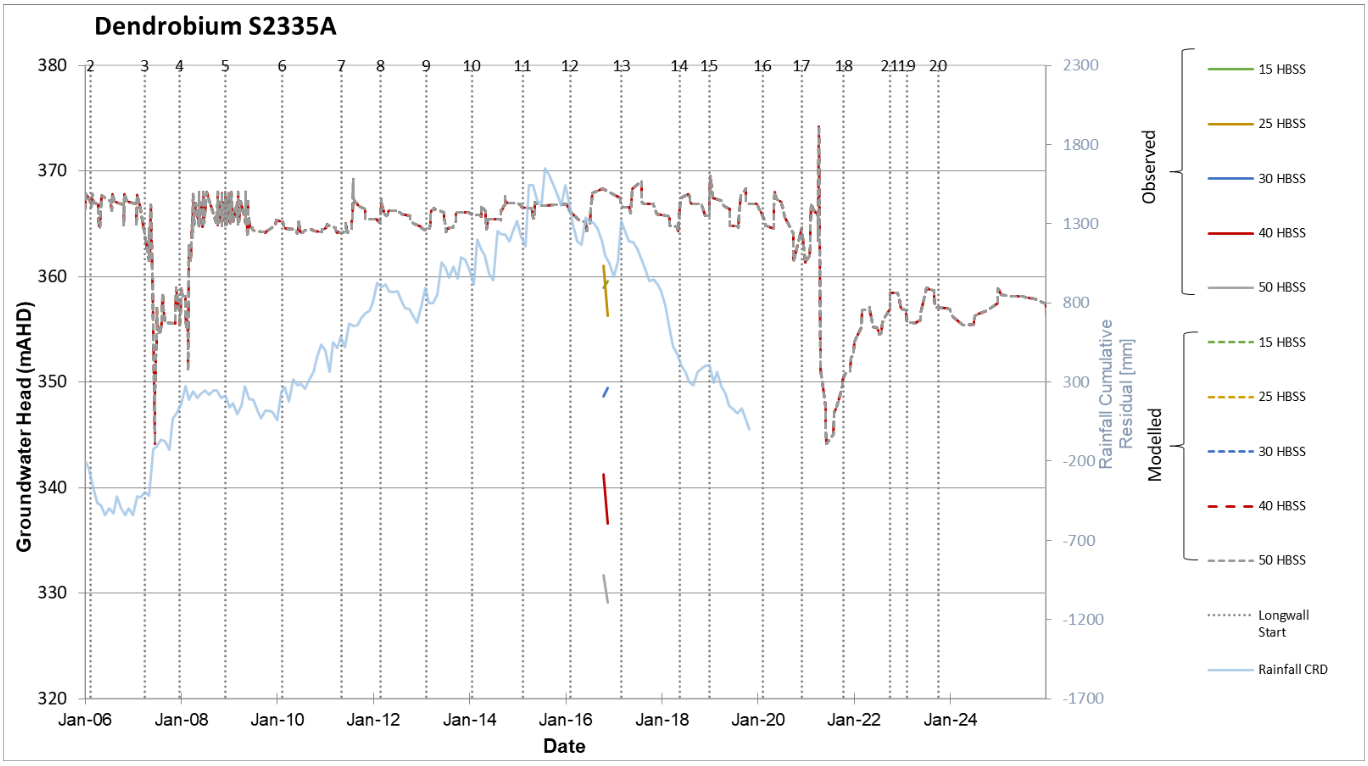

Figure A-10 Modelled and Observed Groundwater levels – S2335A

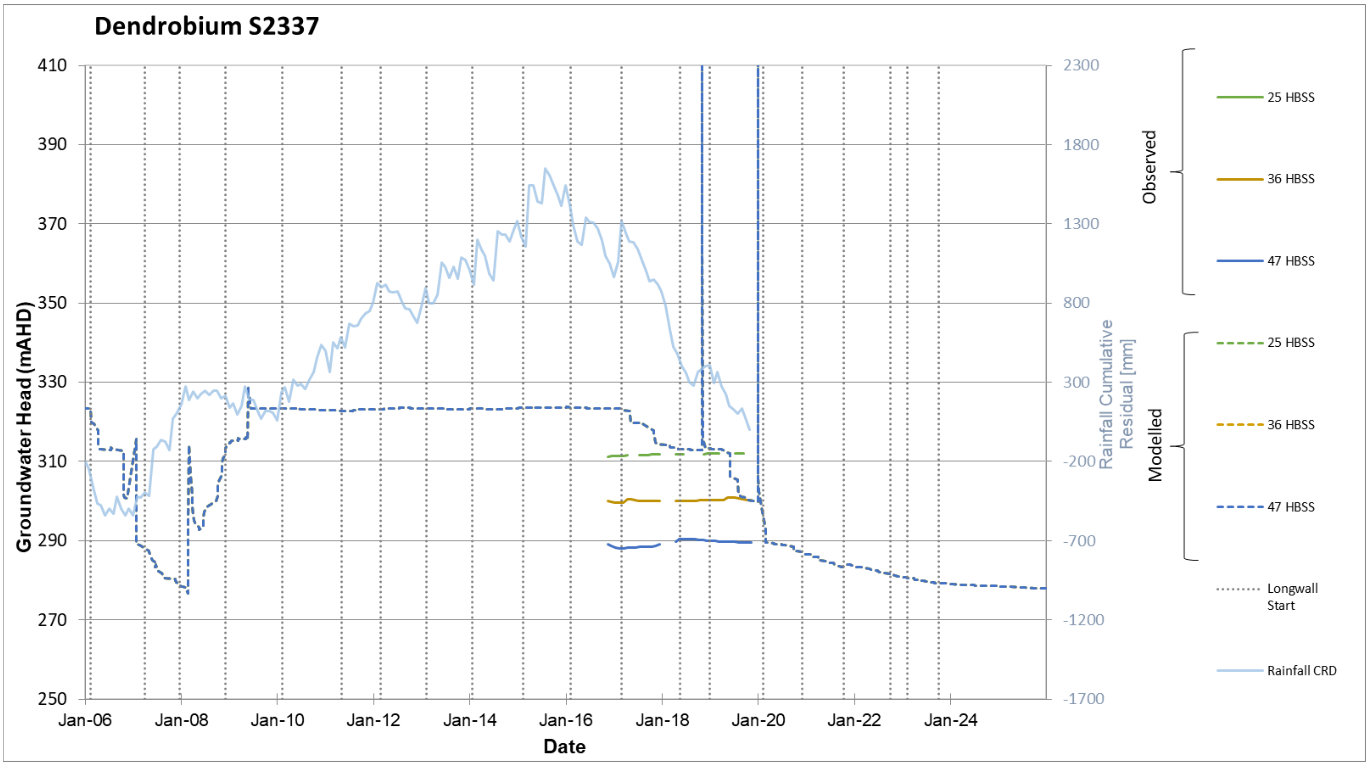

Figure A-11 Modelled and Observed Groundwater levels – S2337

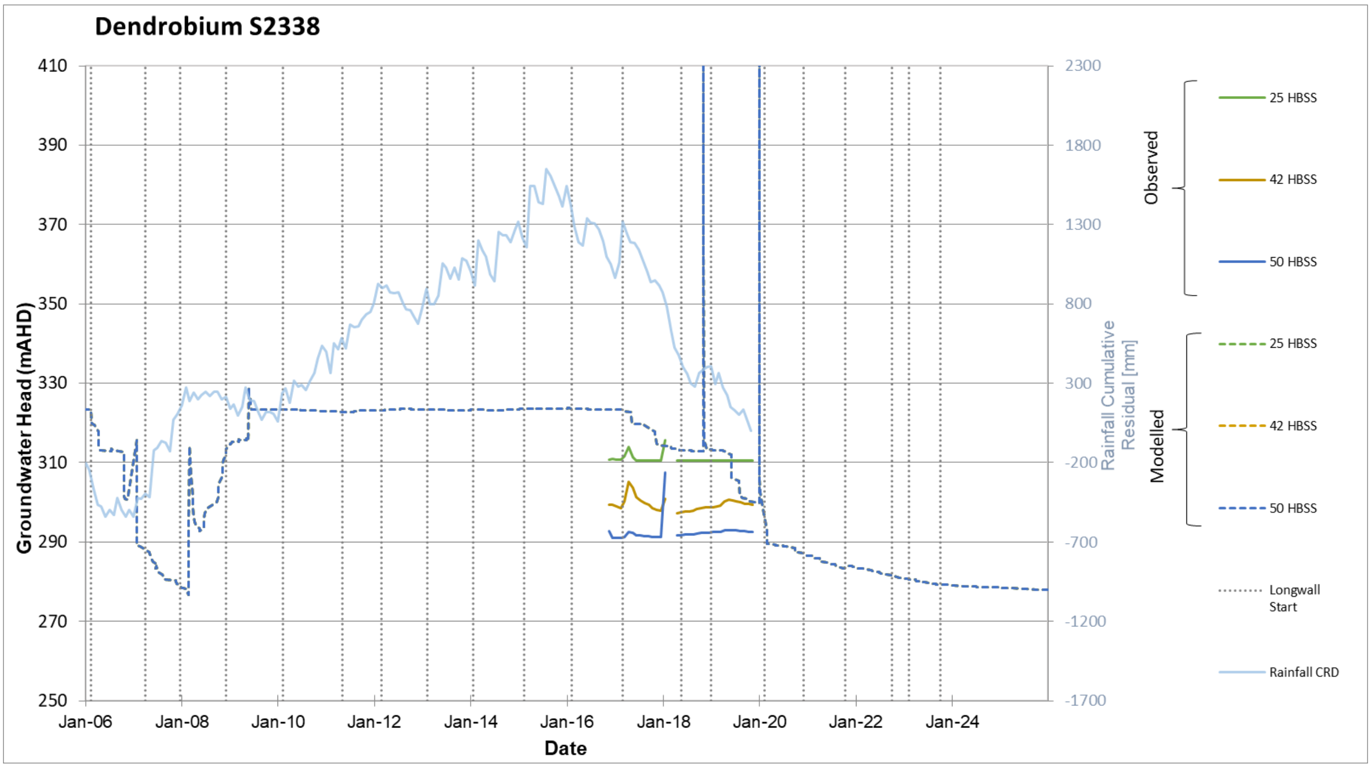

Figure A-12 Modelled and Observed Groundwater levels – S2338

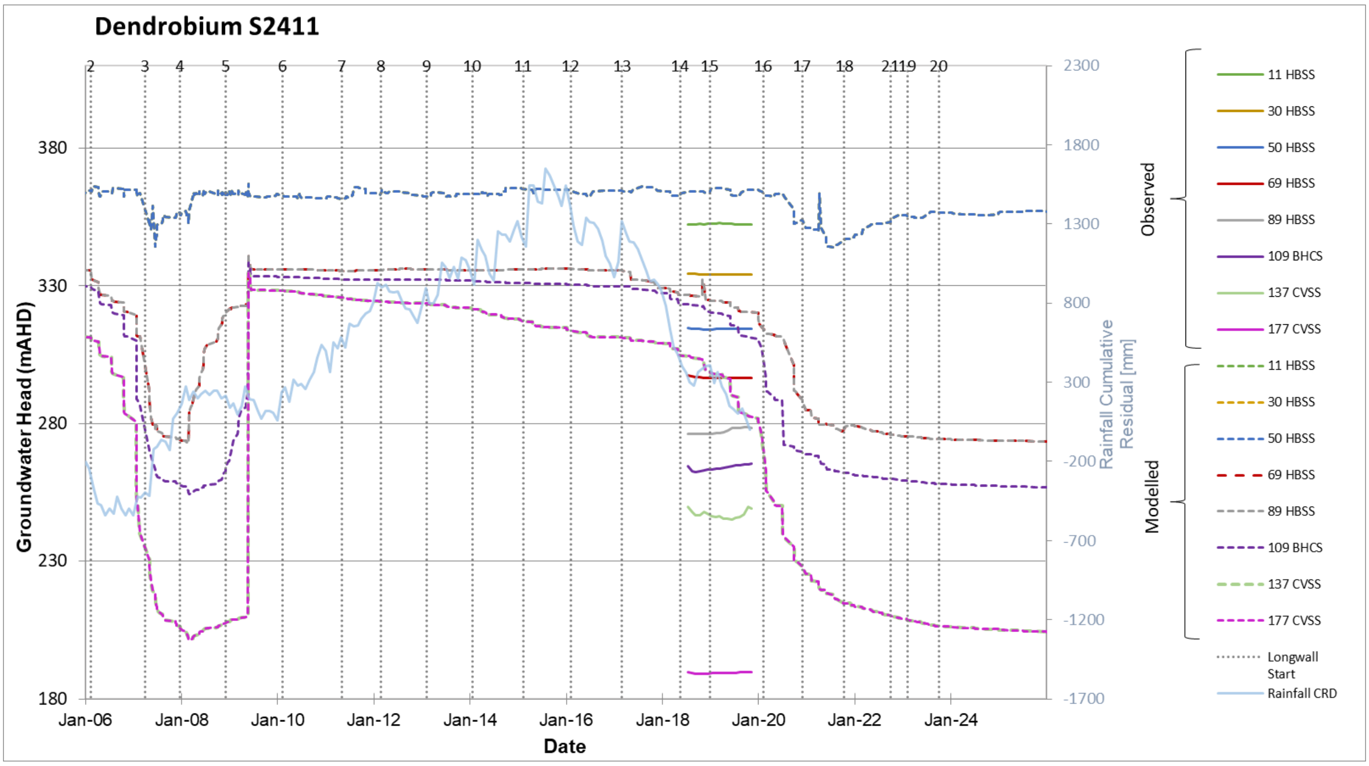

Figure A-13 Modelled and Observed Groundwater levels – S2411

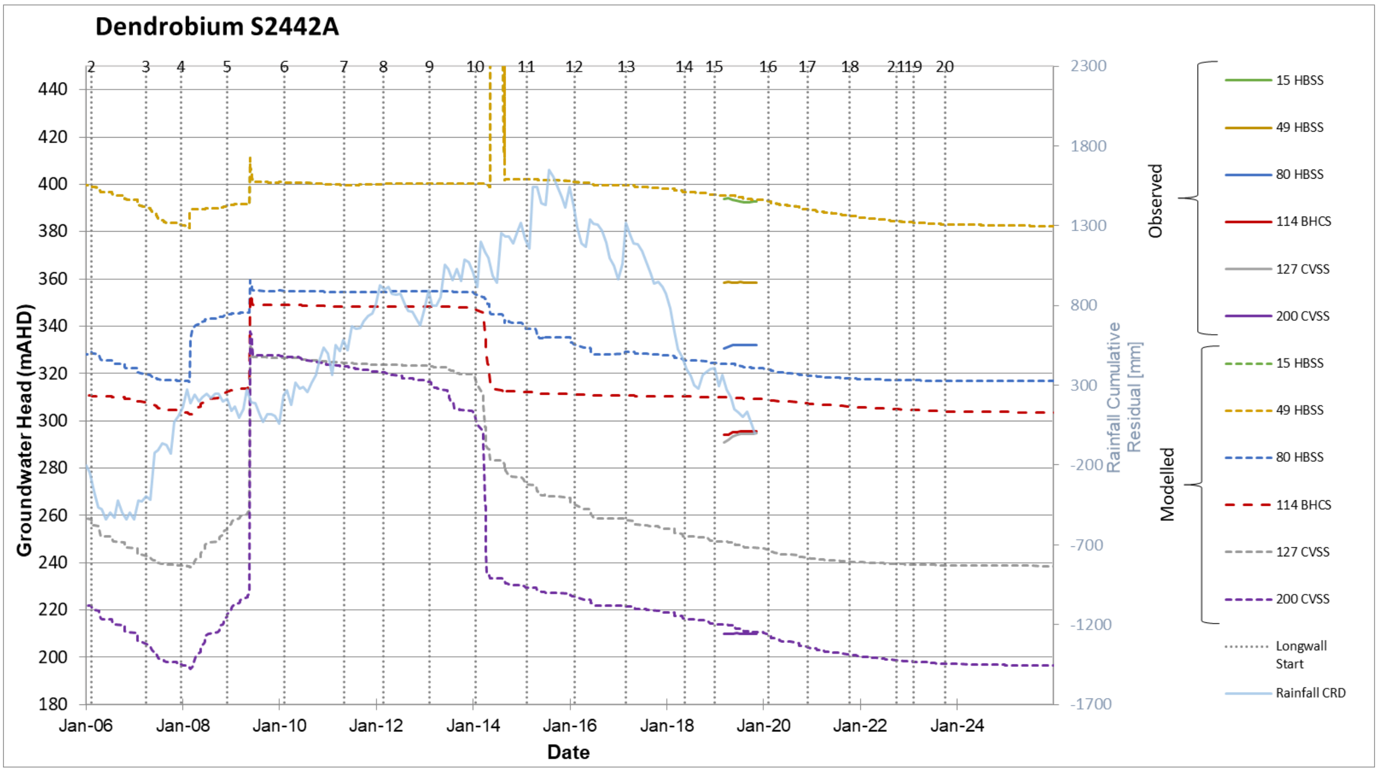

Figure A-14 Modelled and Observed Groundwater levels – S2442A

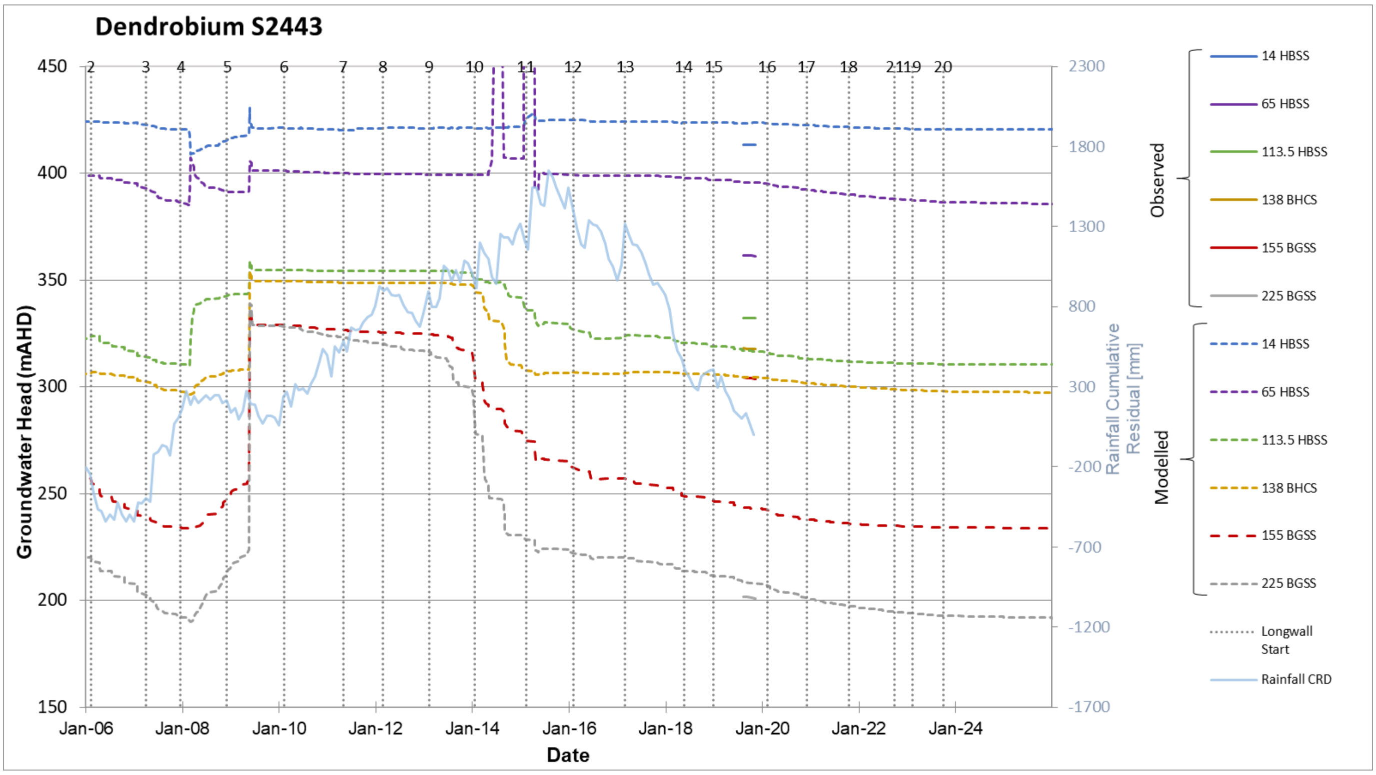

Figure A-15 Modelled and Observed Groundwater levels – S2443

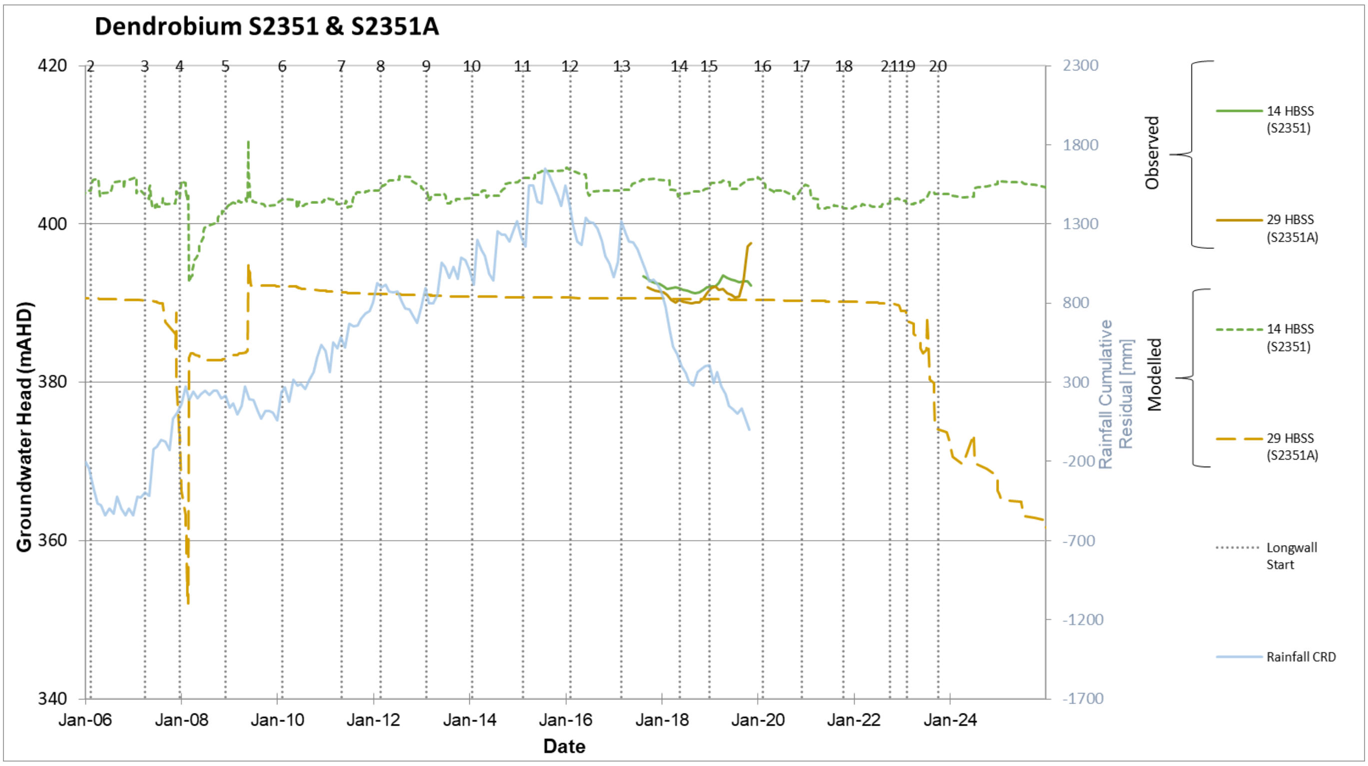

Figure A-16 Modelled and Observed Groundwater levels – S2351 and S2351A

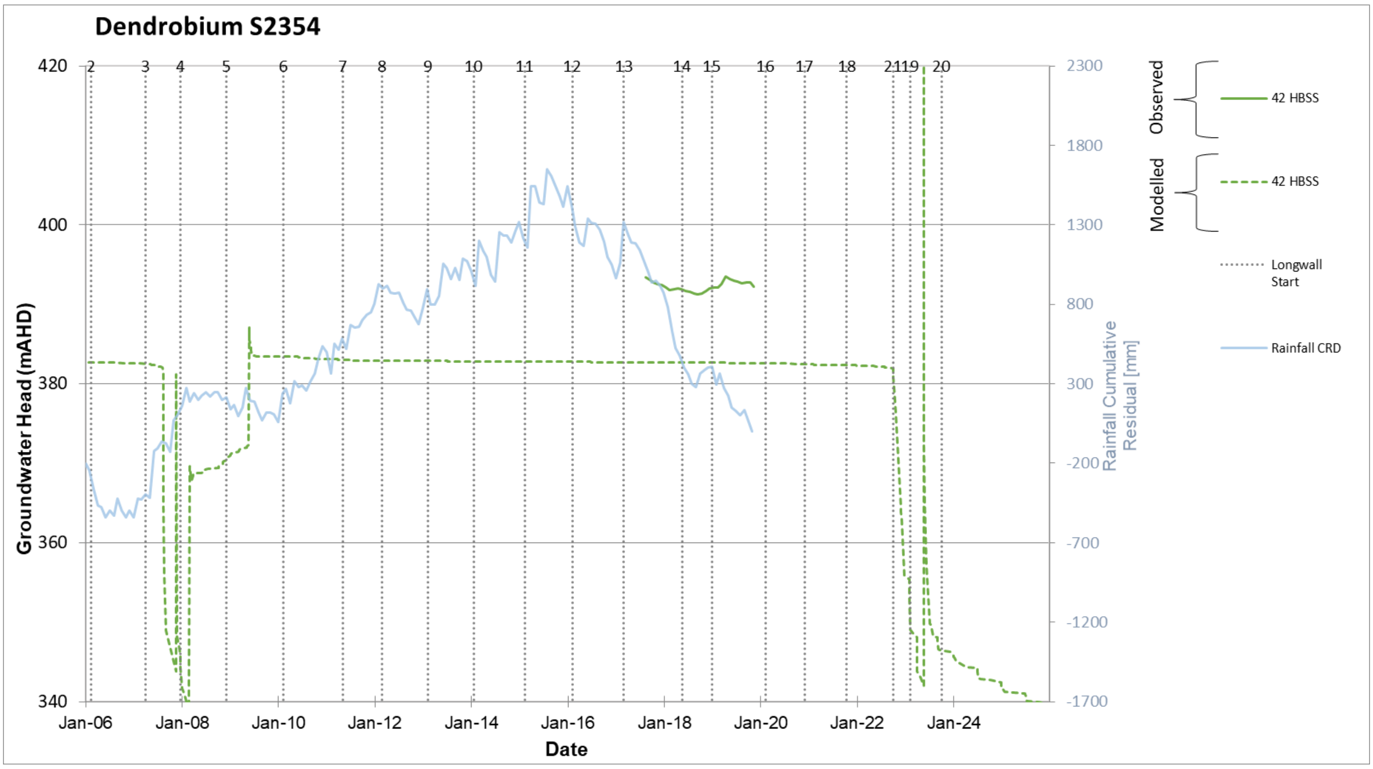

Figure A-17 Modelled and Observed Groundwater levels – S2354

Lake Avon Shoreline Monitoring Locations

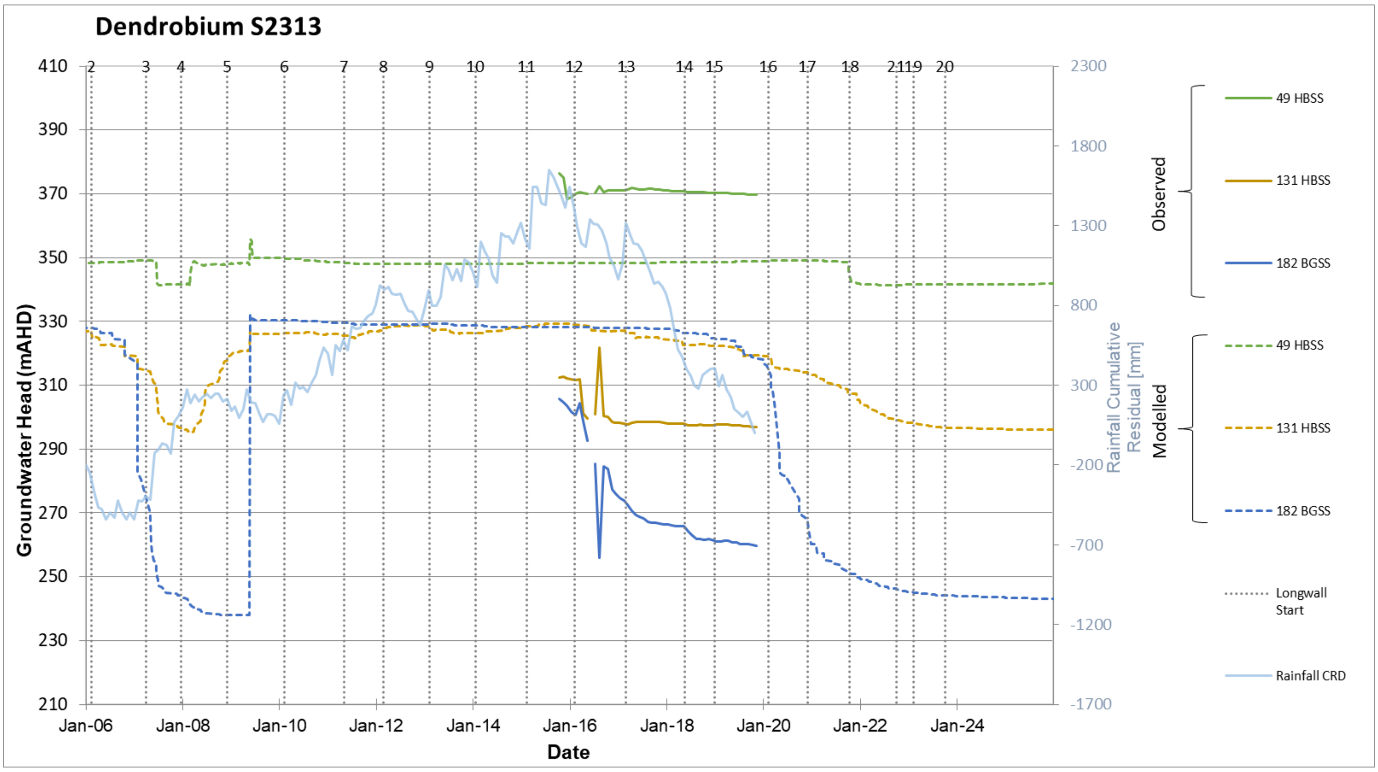

Figure A-18 Modelled and Observed Groundwater levels – S2313

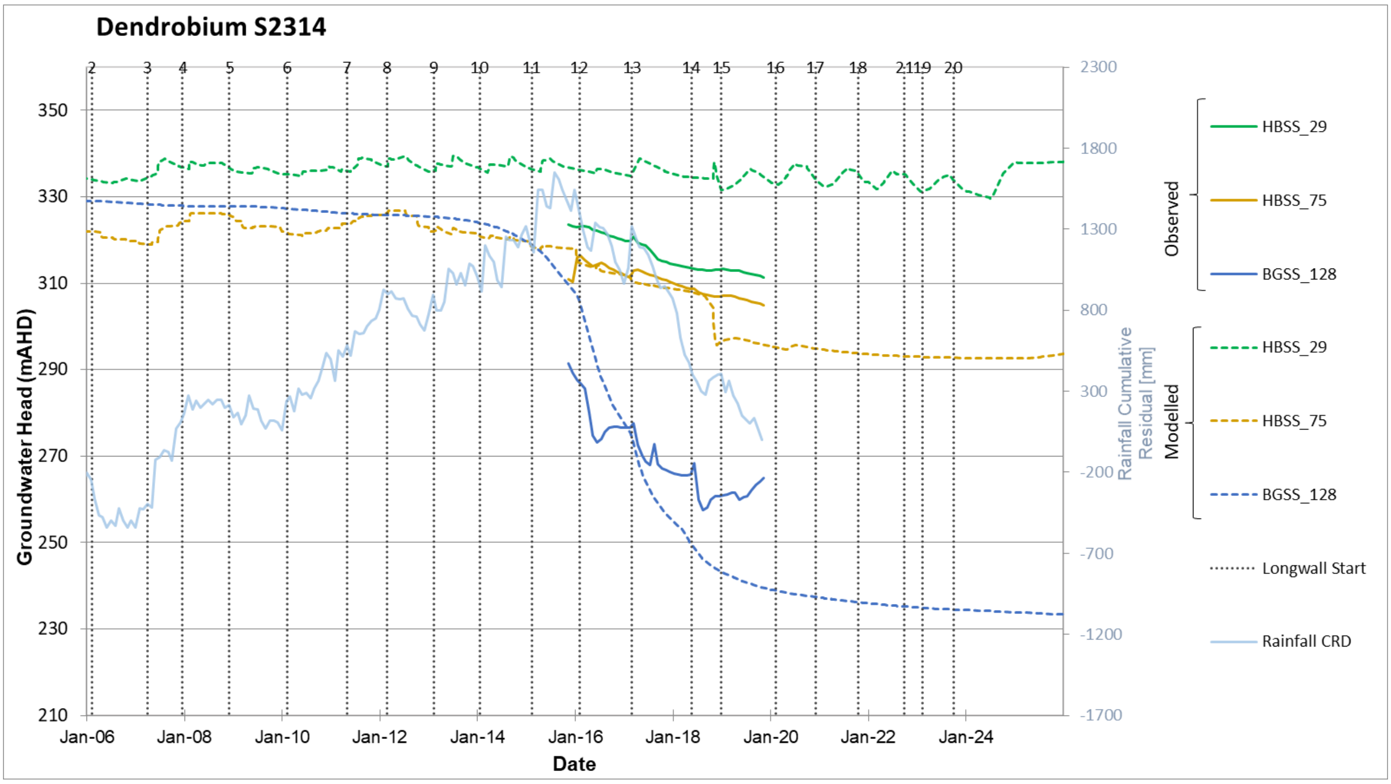

Figure A-19 Modelled and Observed Groundwater levels – S2314

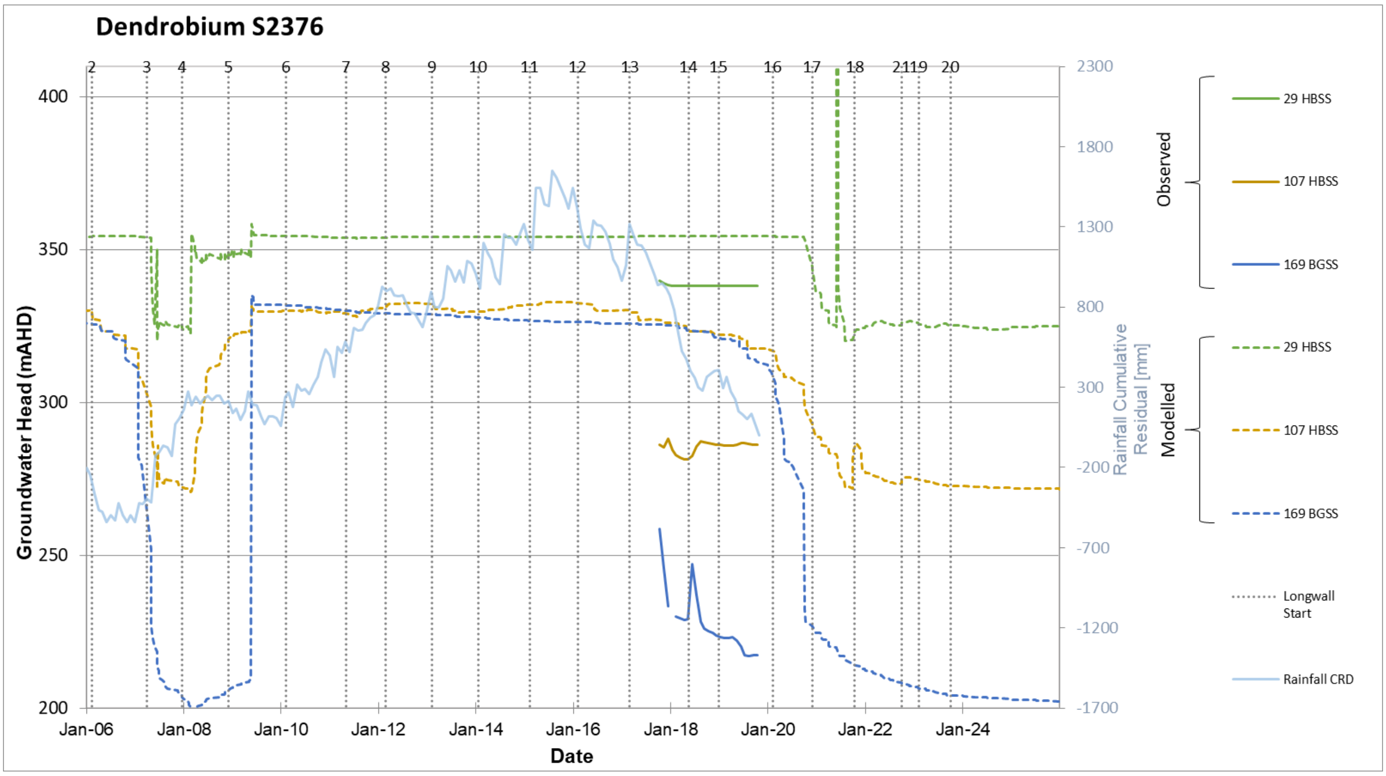

Figure A-20 Modelled and Observed Groundwater levels – S2376

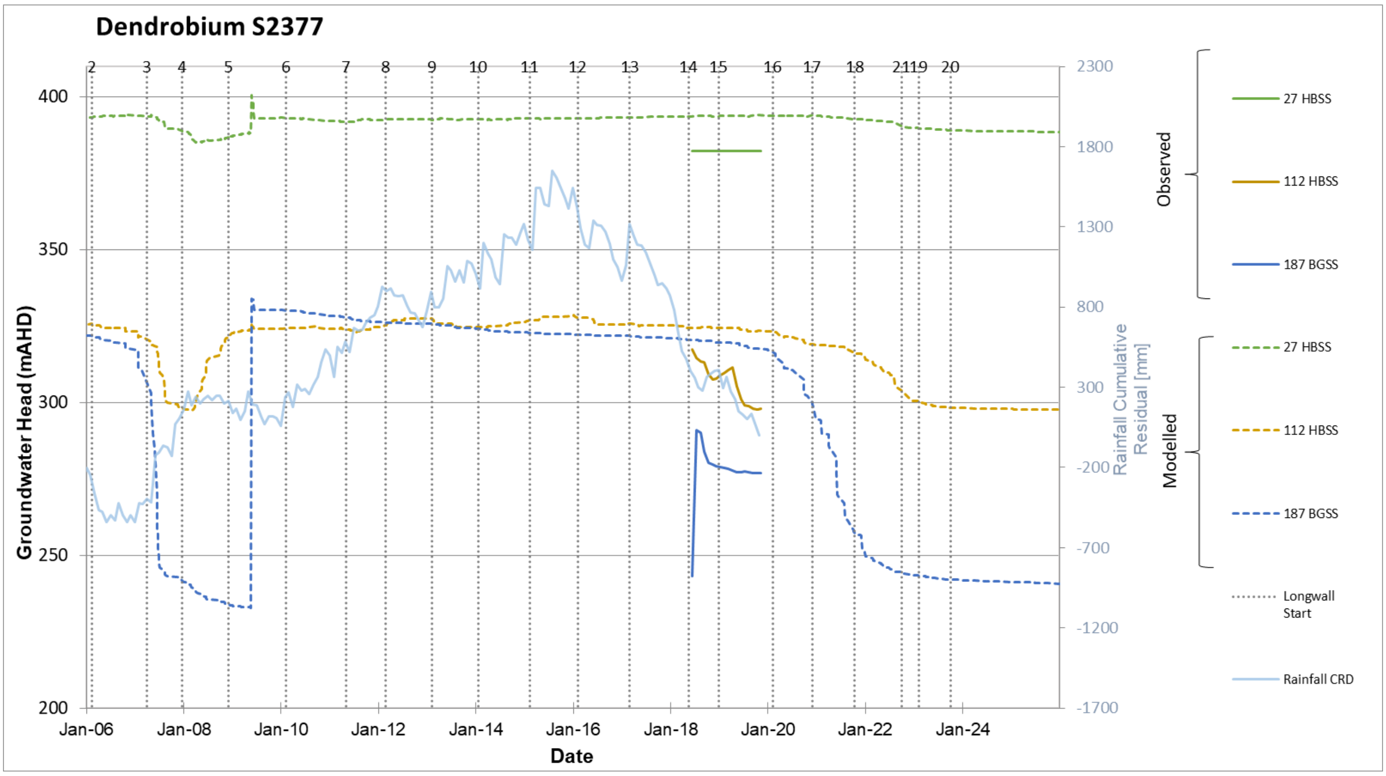

Figure A-21 Modelled and Observed Groundwater levels – S2377

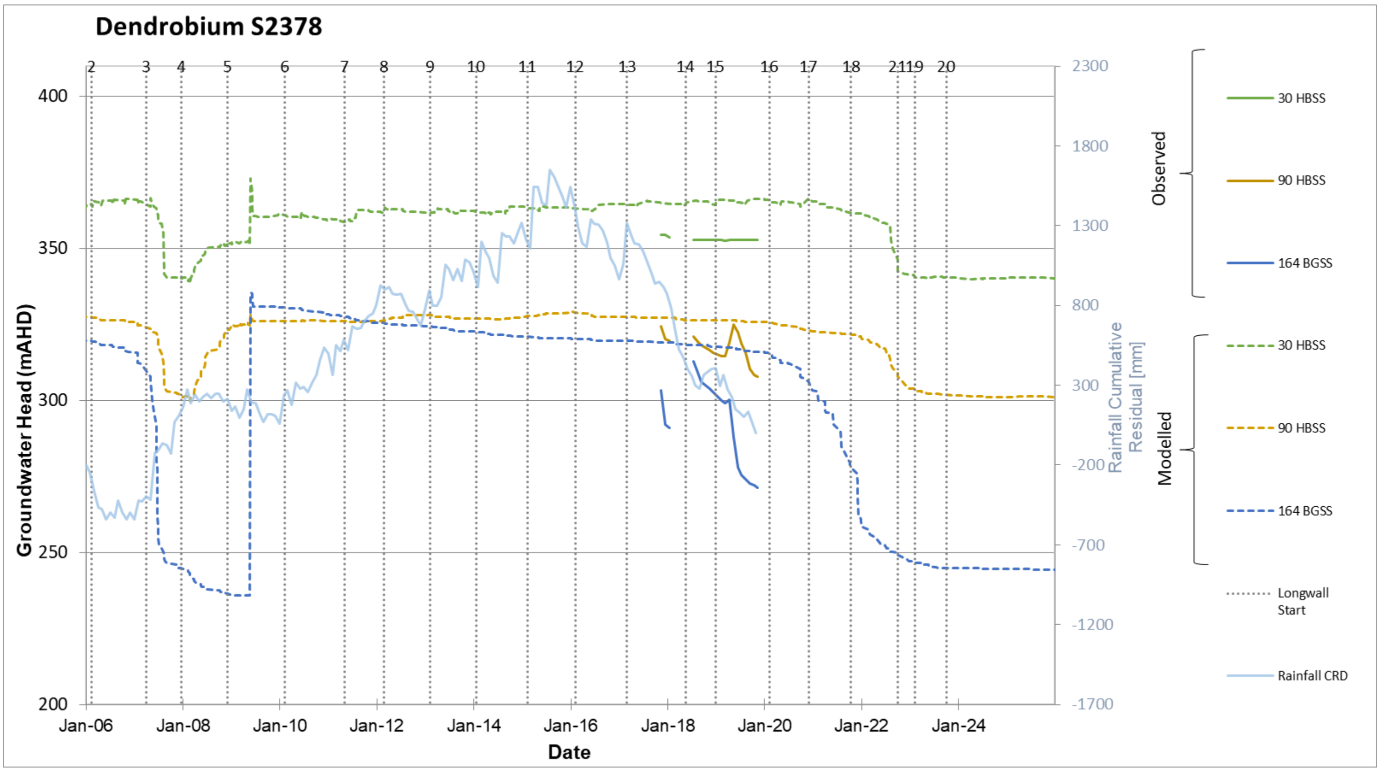

Figure A-22 Modelled and Observed Groundwater levels – S2378

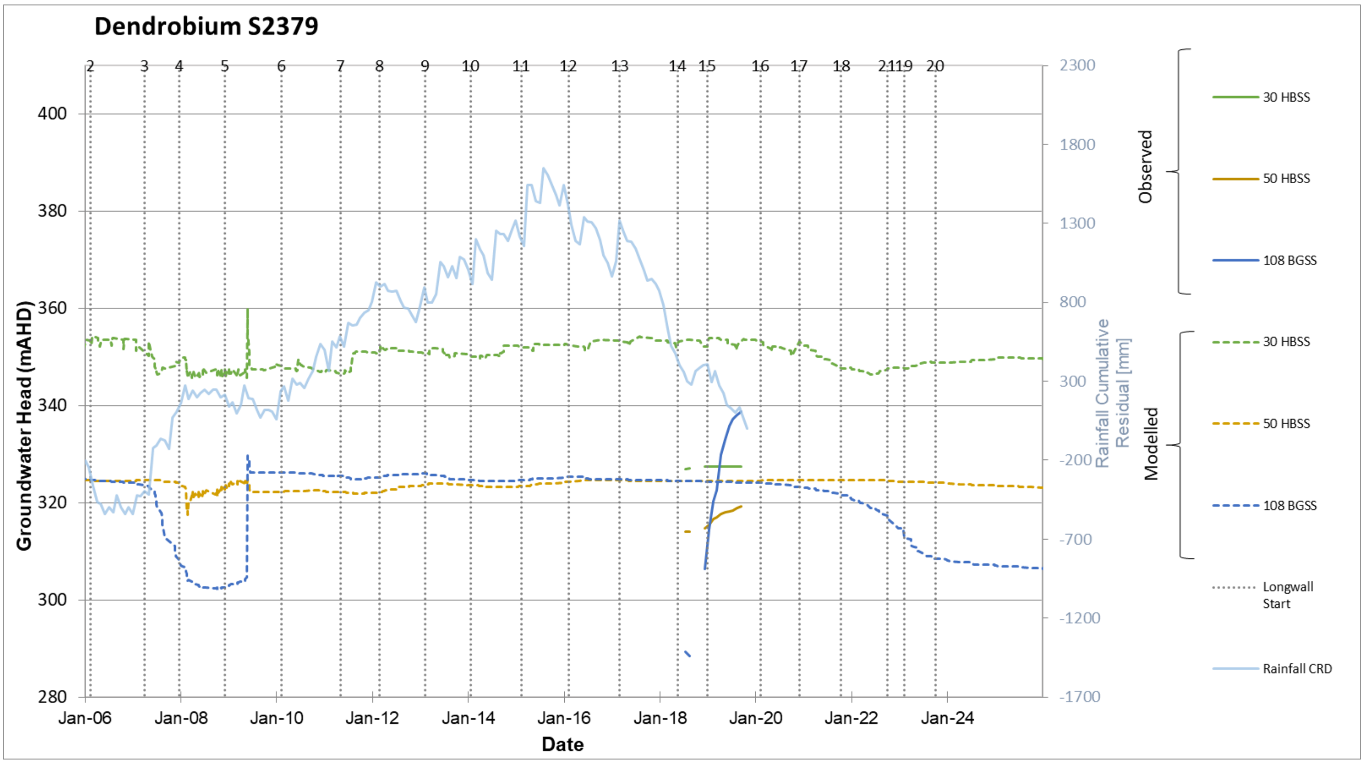

Figure A-23 Modelled and Observed Groundwater levels – S2379

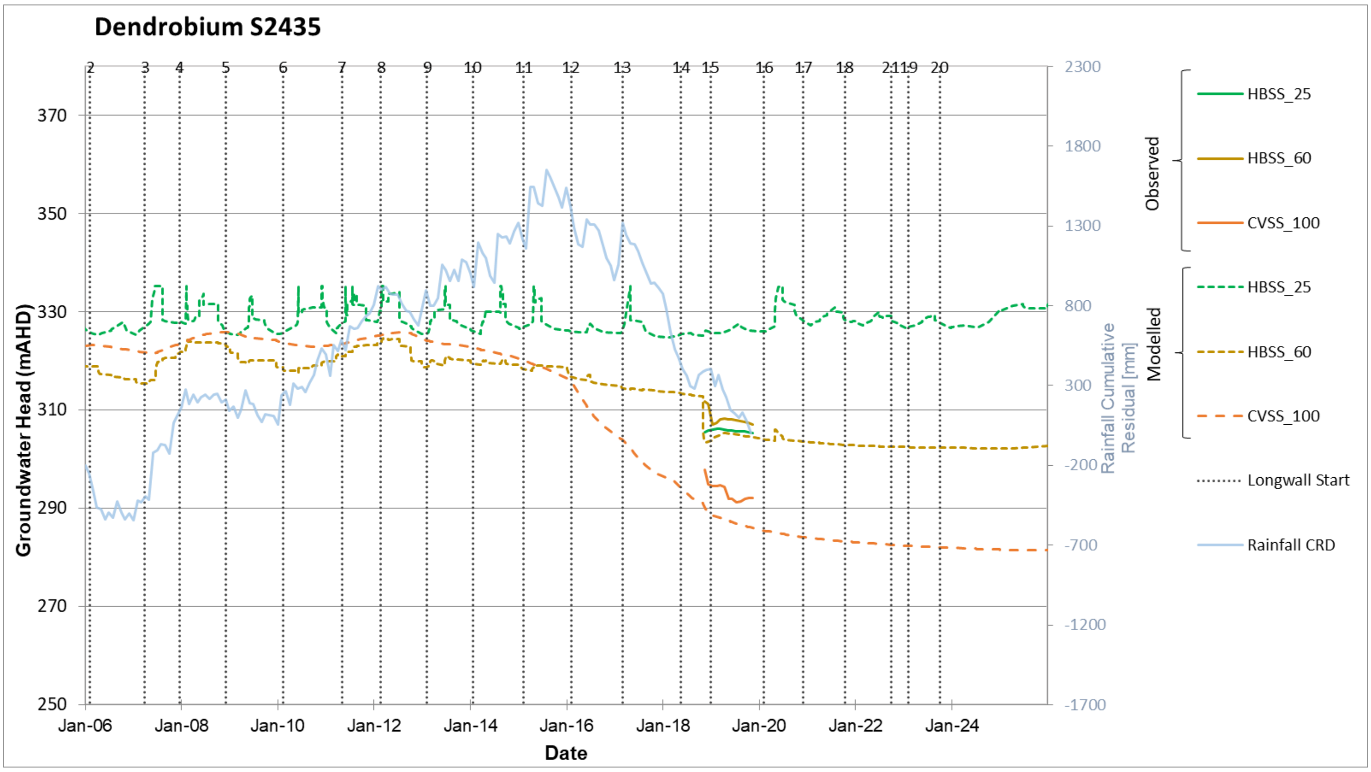

Figure A-24 Modelled and Observed Groundwater levels – S2435

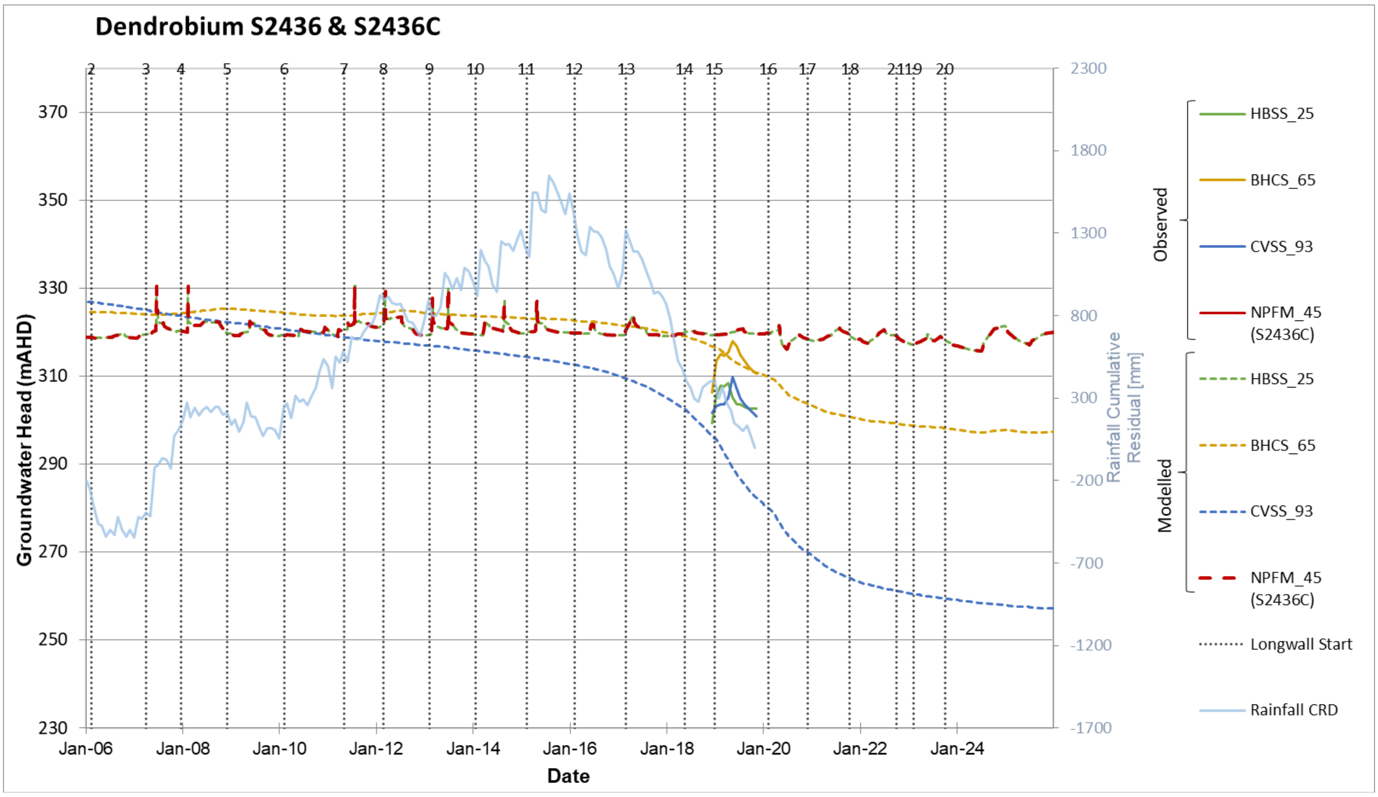

Figure A-25 Modelled and Observed Groundwater levels – S24367 & S2436C

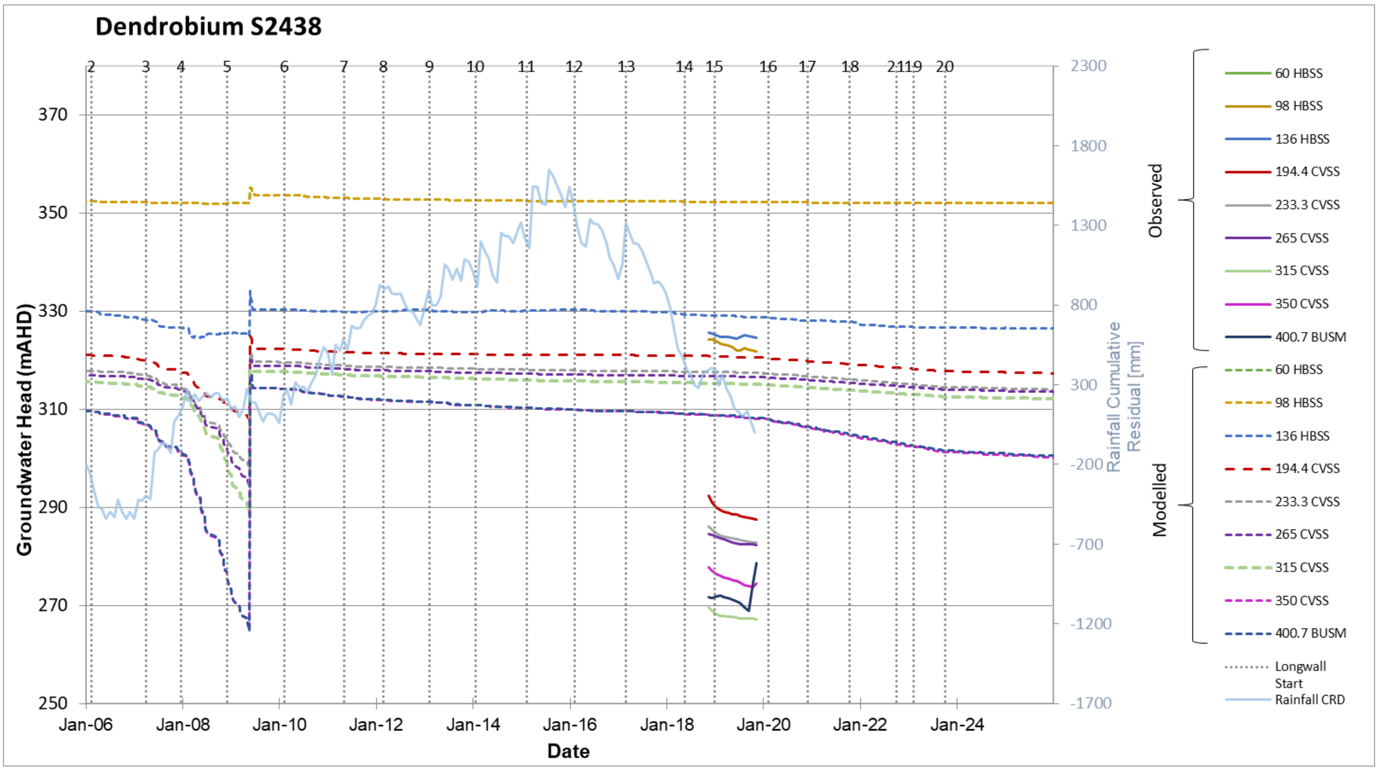

Figure A-26 Modelled and Observed Groundwater levels – S2438

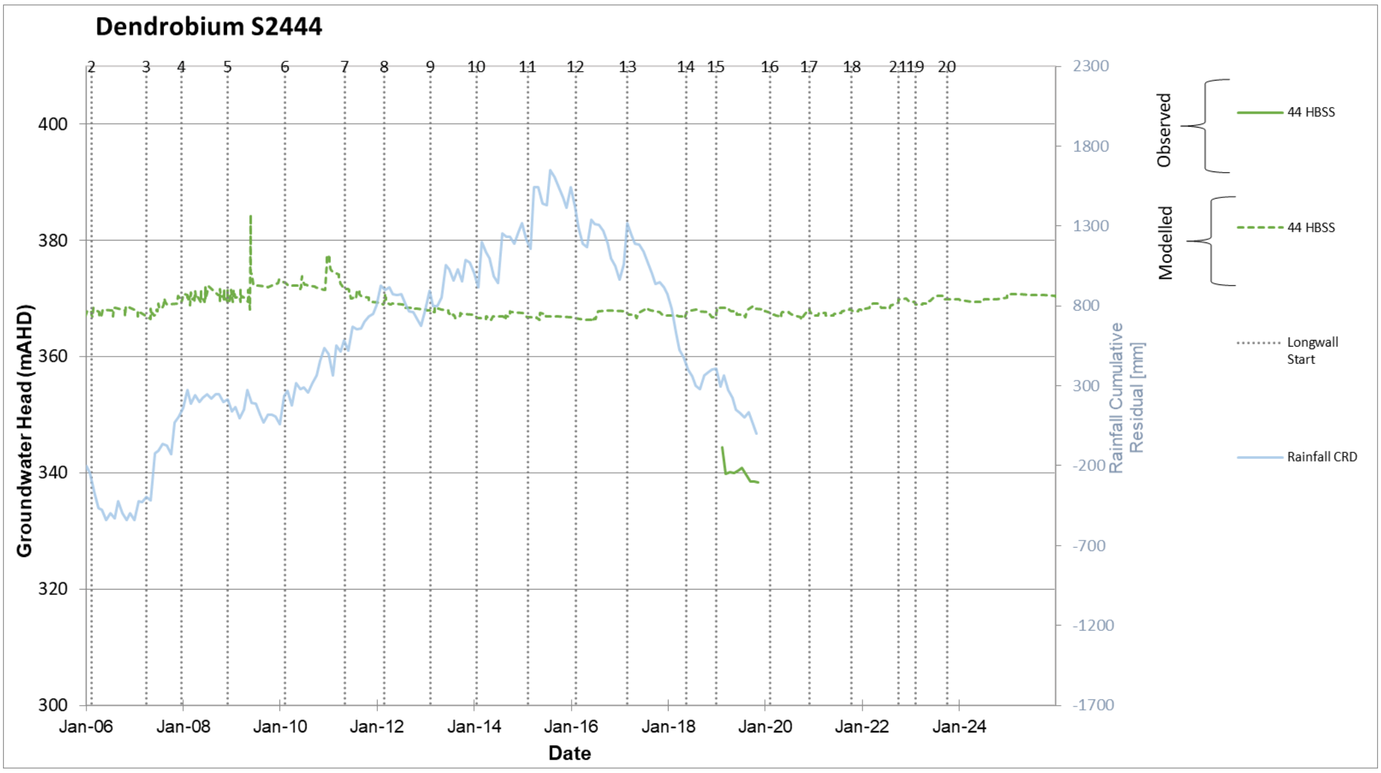

Figure A-27 Modelled and Observed Groundwater levels – S2444

Lake Cordeaux Monitoring Locations

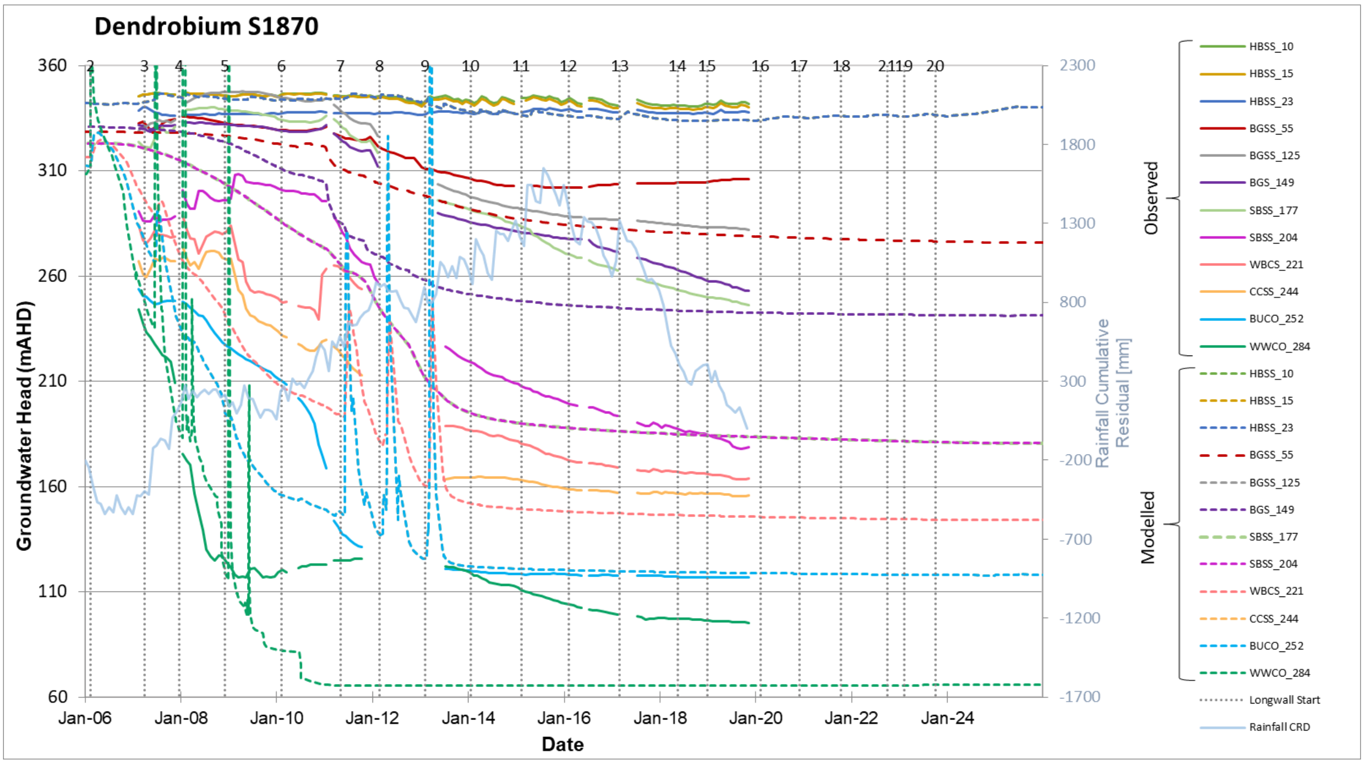

Figure A-28 Modelled and Observed Groundwater levels – S1870

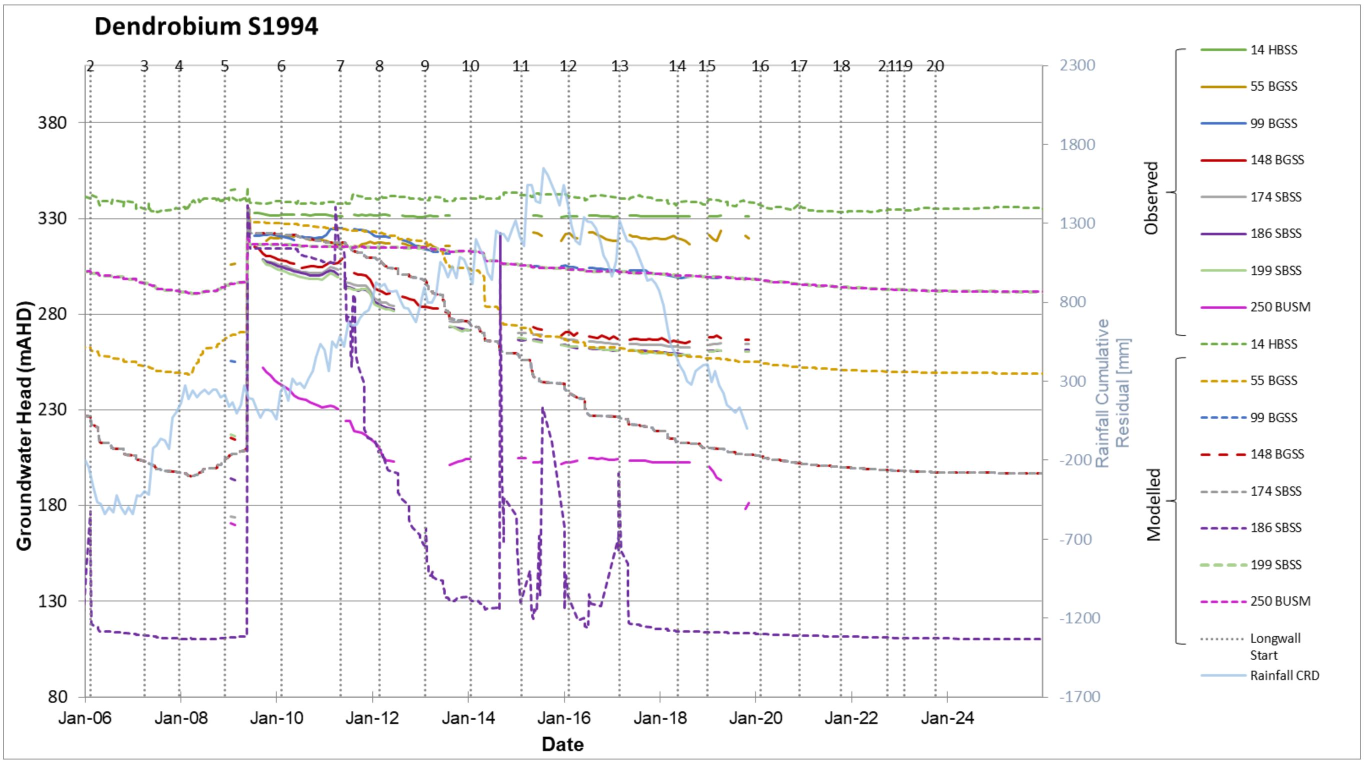

Figure A-29 Modelled and Observed Groundwater levels – S1994

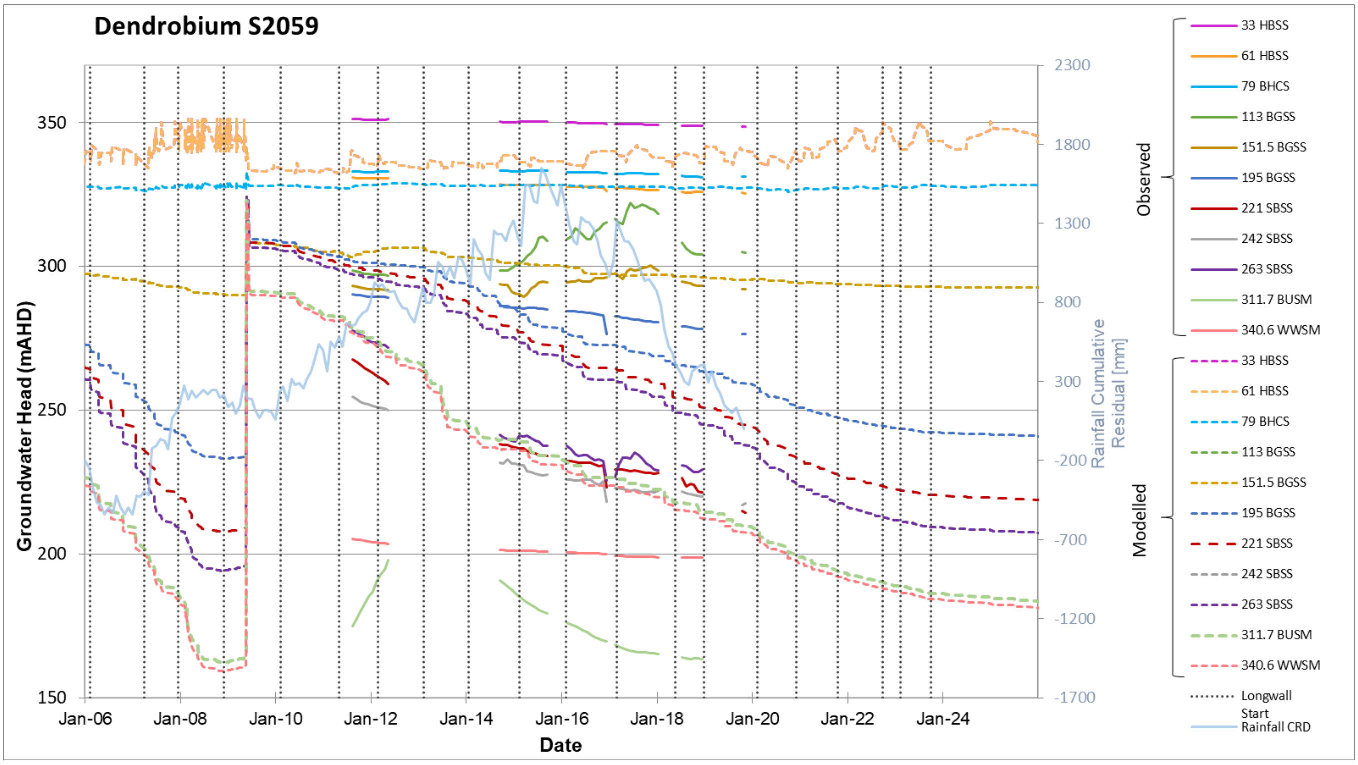

Figure A-30 Modelled and Observed Groundwater levels – S2059

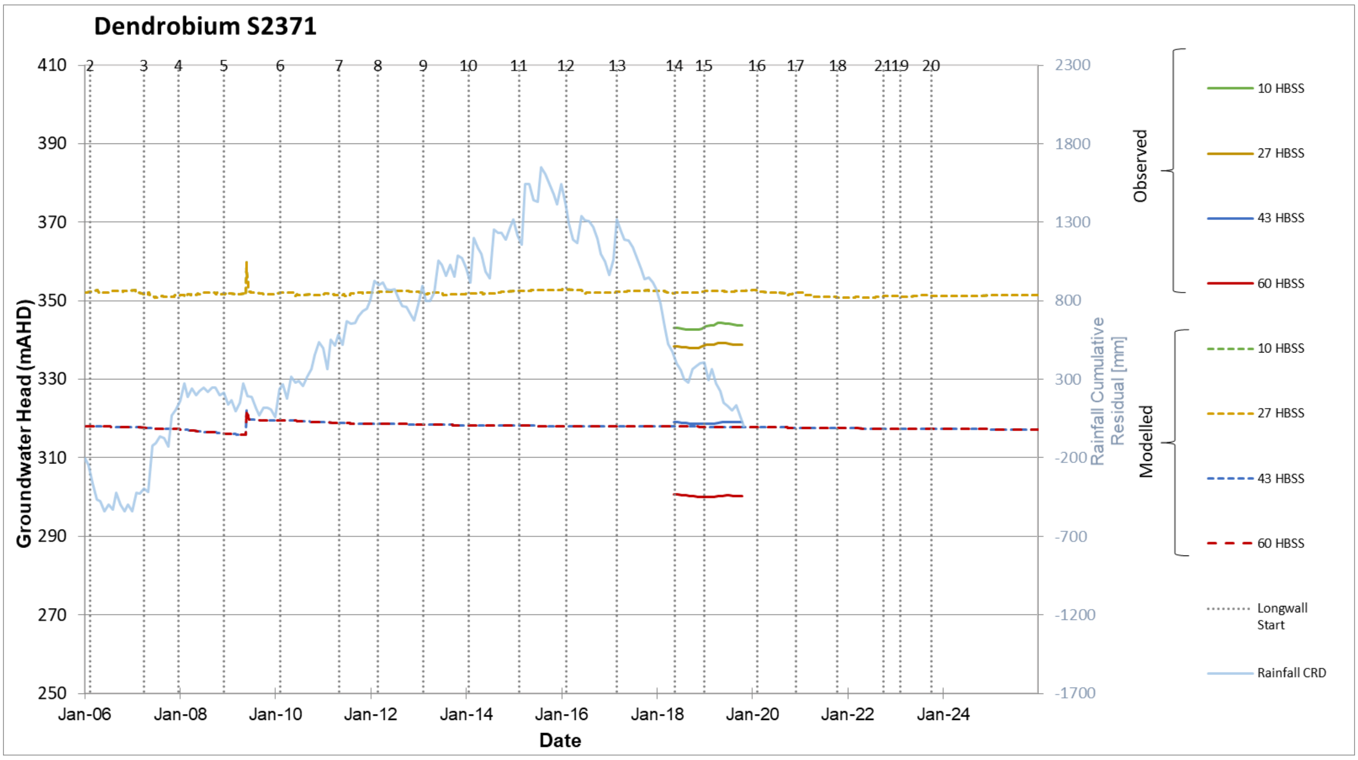

Figure A-31 Modelled and Observed Groundwater levels – S2371

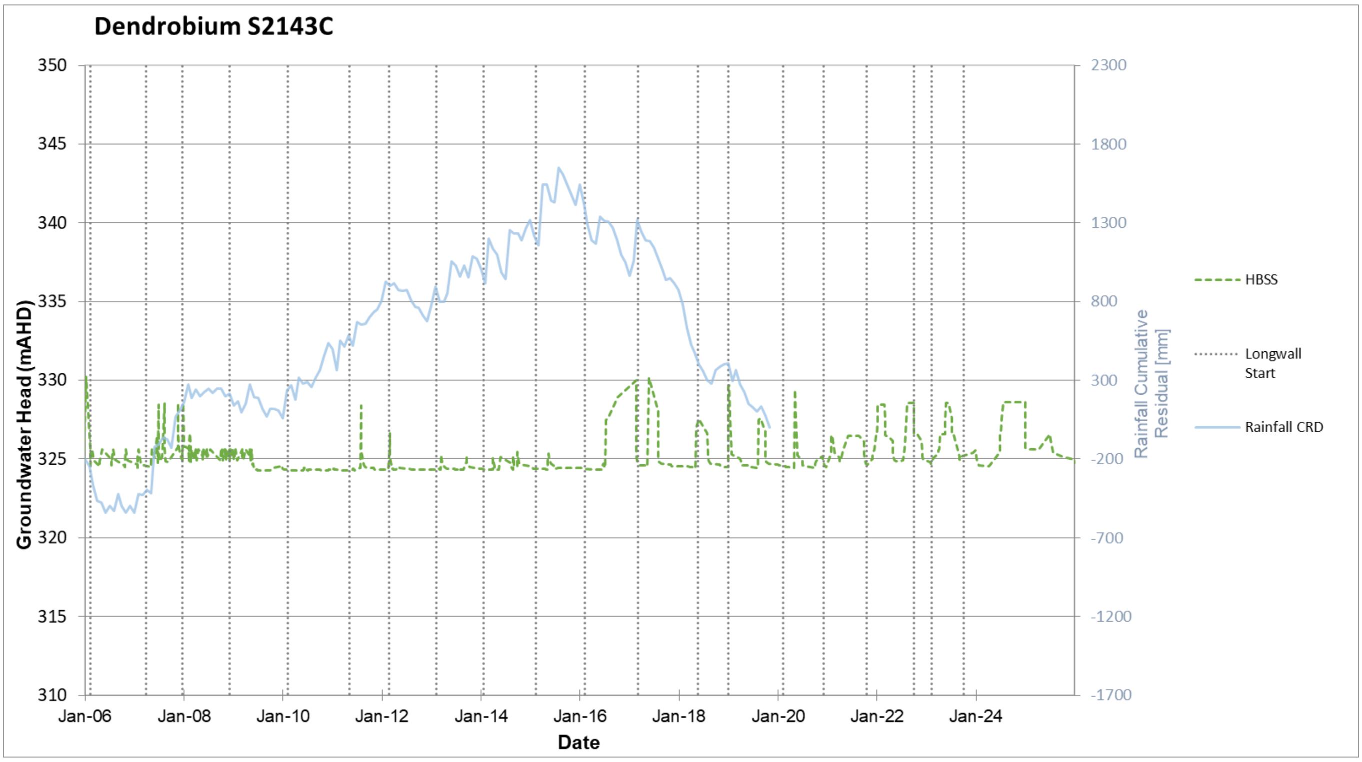

Figure A-32 Modelled Groundwater levels – S2143C

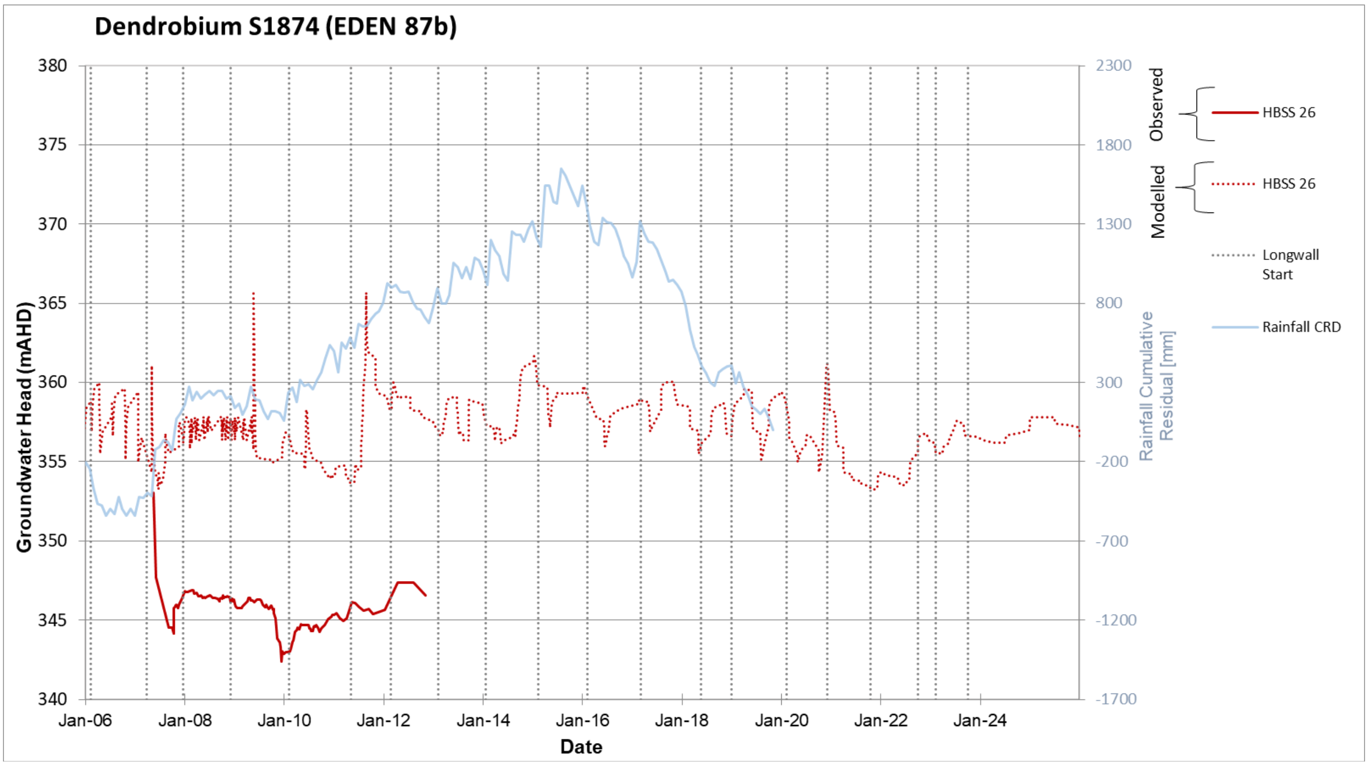

Figure A-33 Modelled and Observed Groundwater levels – S1874

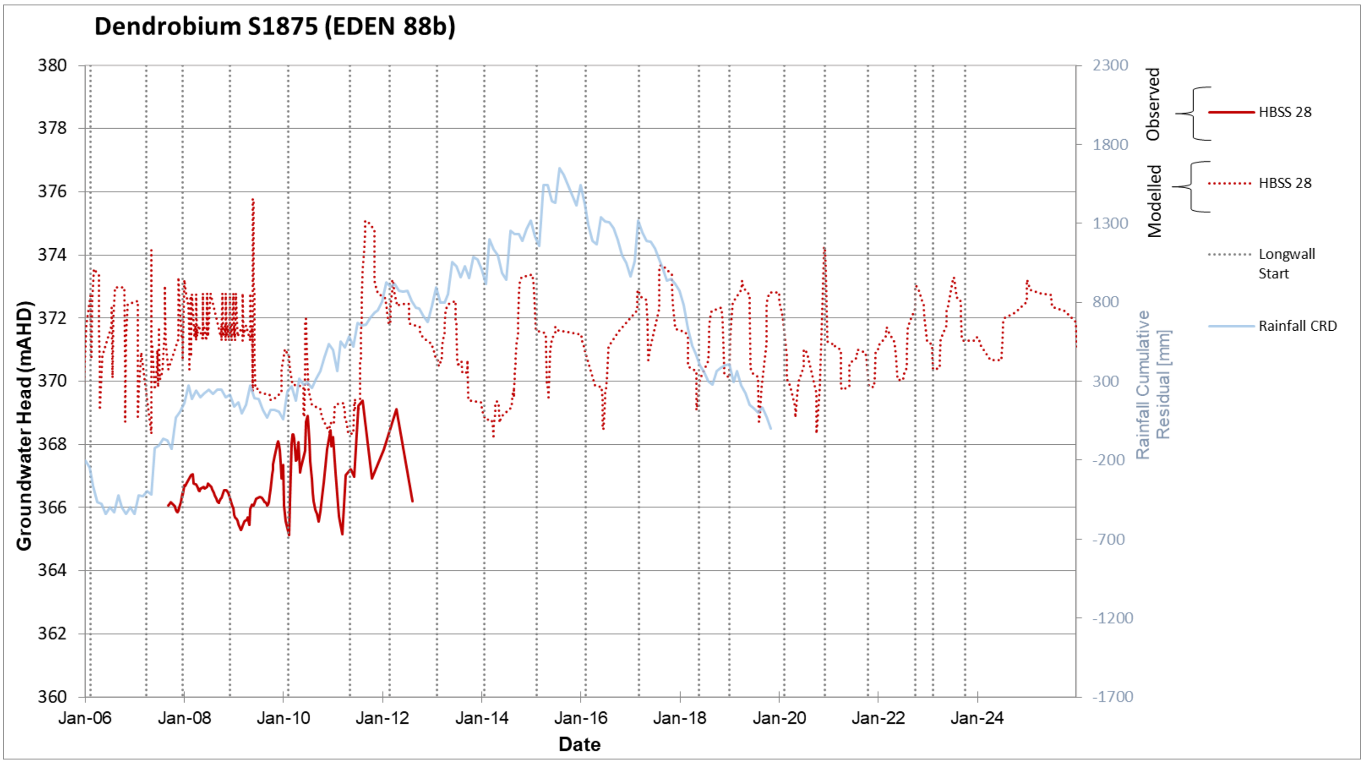

Figure A-34 Modelled and Observed Groundwater levels – S1875

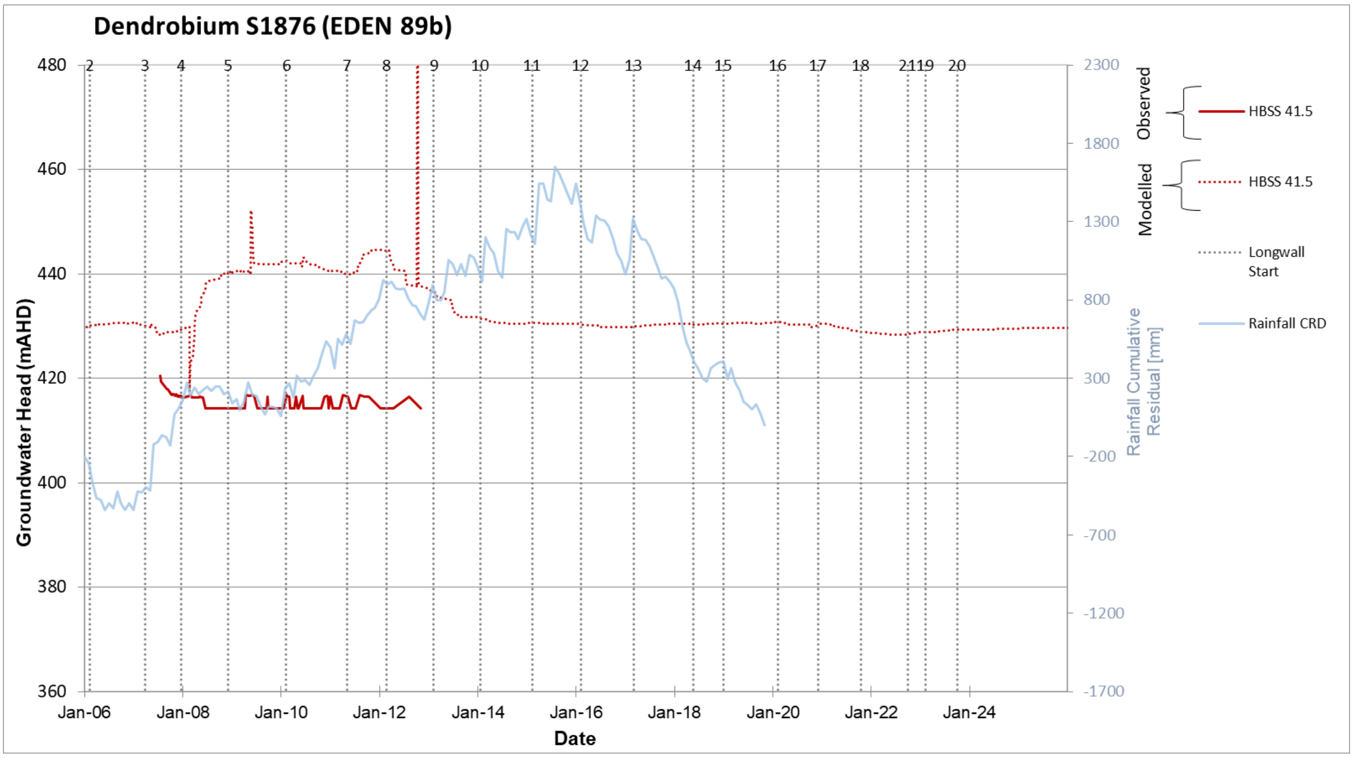

Figure A-34 Modelled and Observed Groundwater levels – S1876

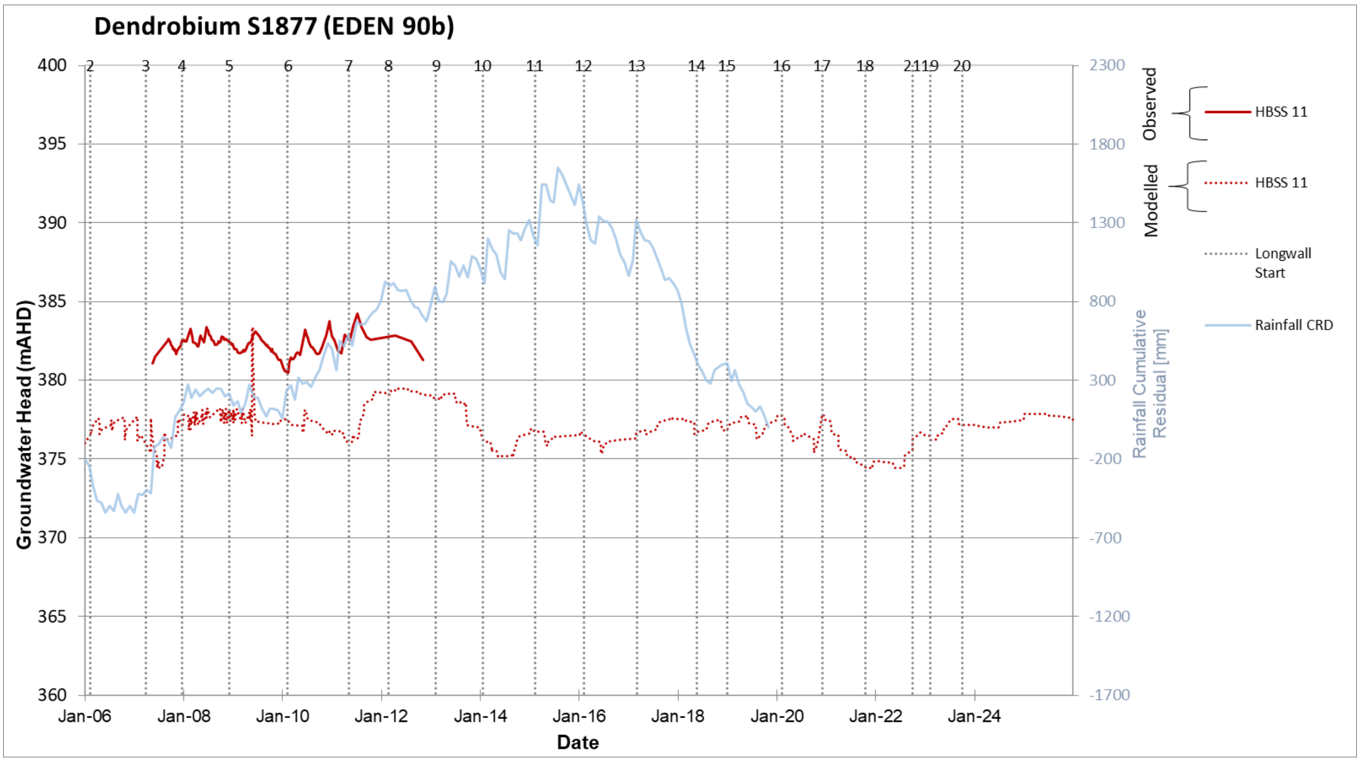

Figure A-35 Modelled and Observed Groundwater levels – S1877

Watercourse Monitoring Locations

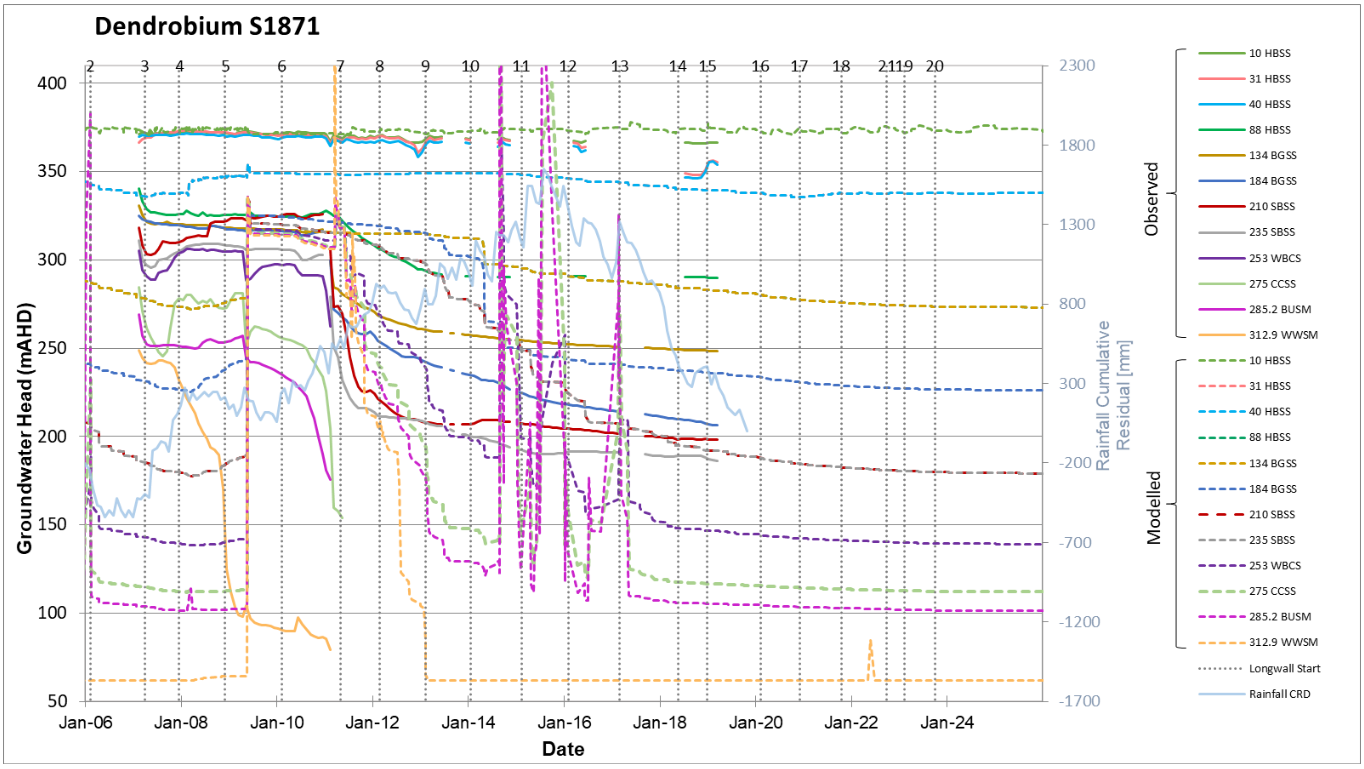

Figure A-36 Modelled and Observed Groundwater levels – S1871

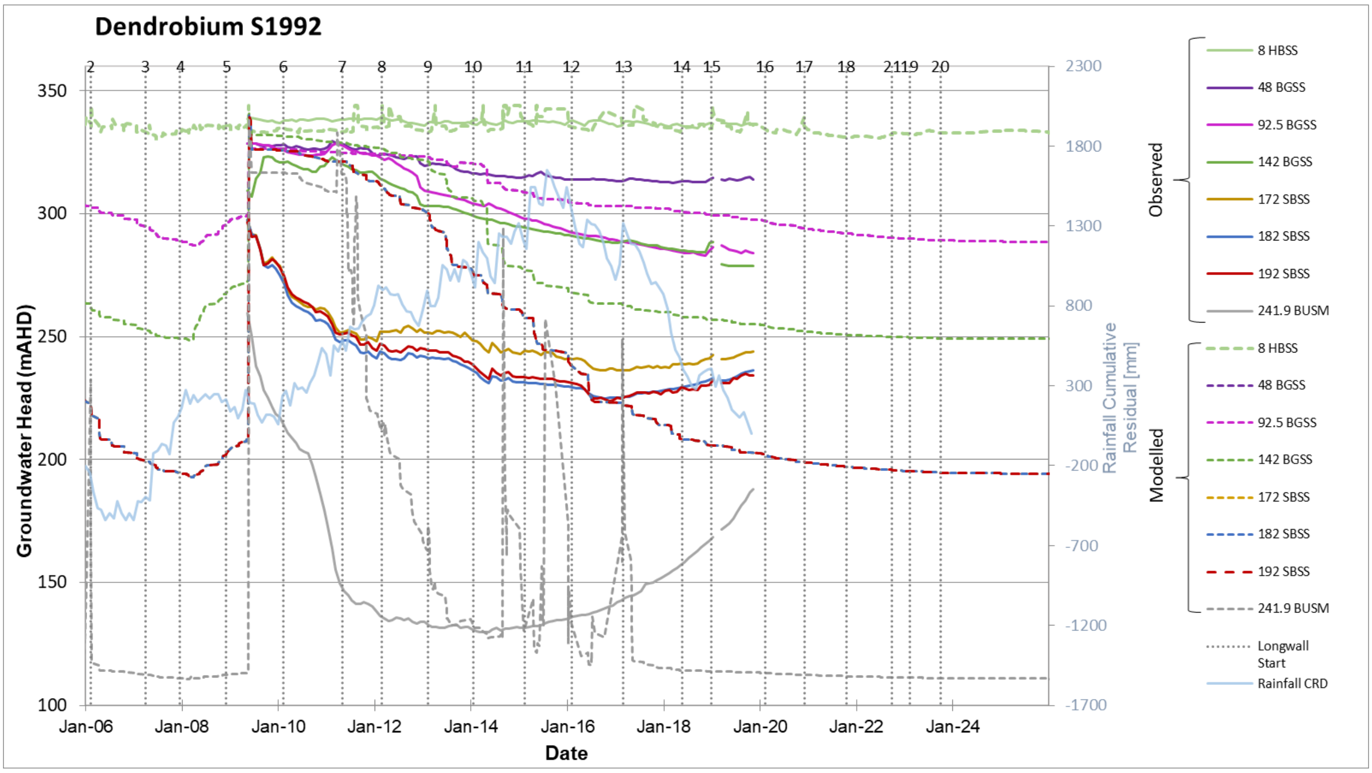

Figure A-37 Modelled and Observed Groundwater levels – S1992

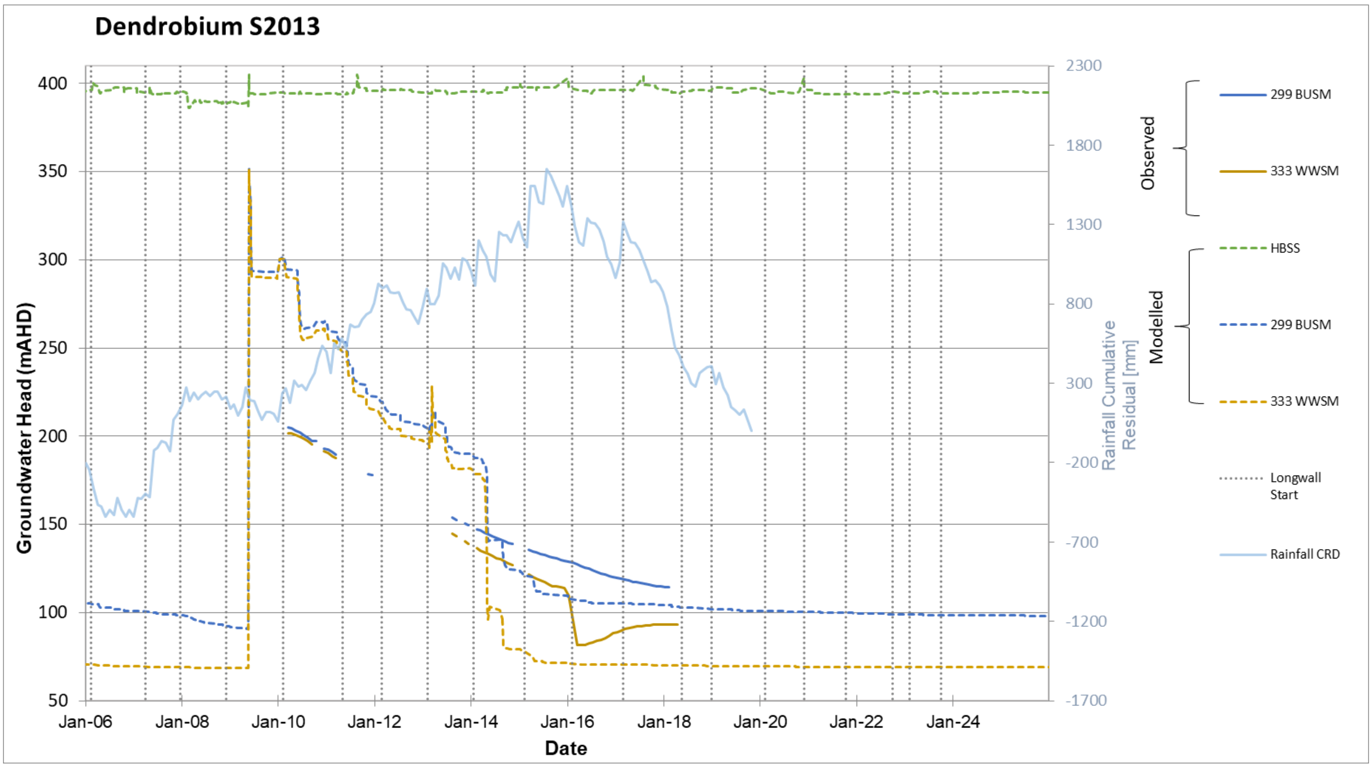

Figure A-38 Modelled and Observed Groundwater levels – S2013

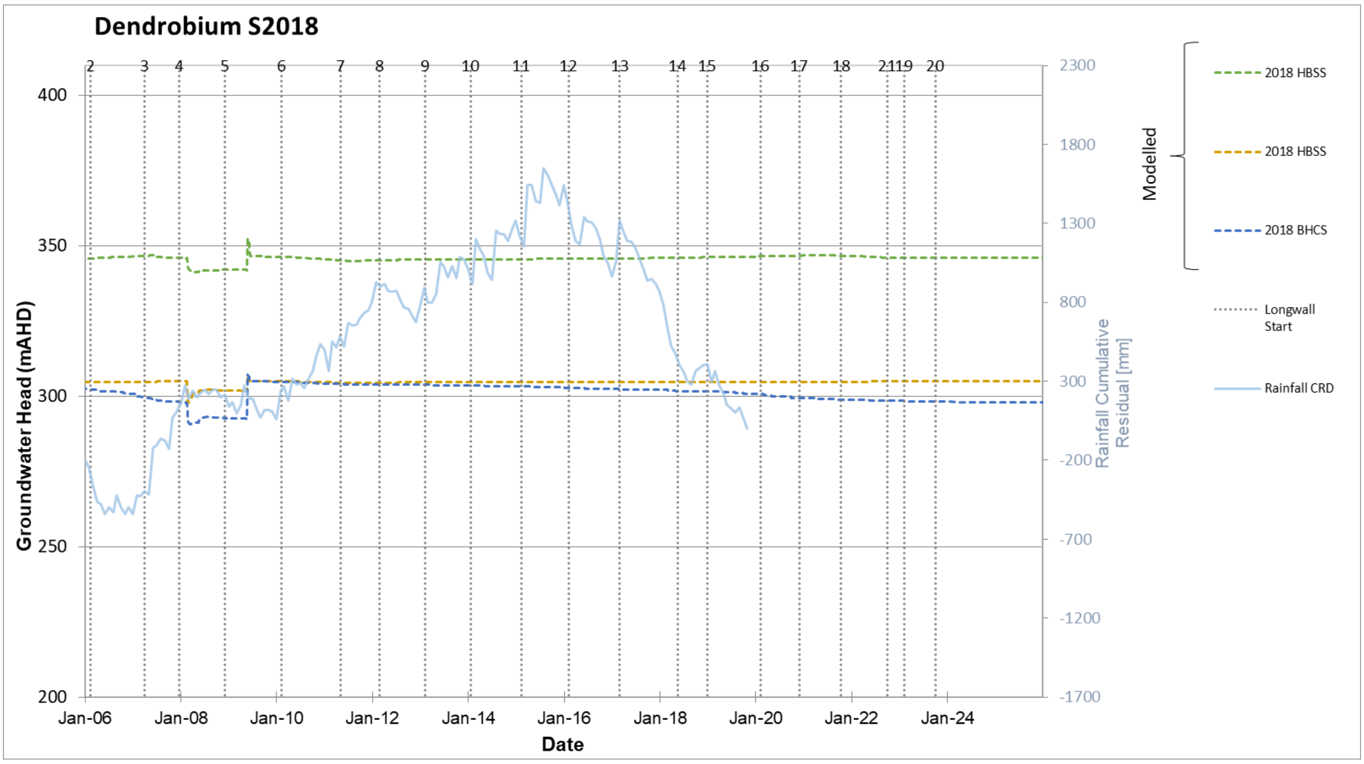

Figure A-39 Modelled Groundwater levels – S2018

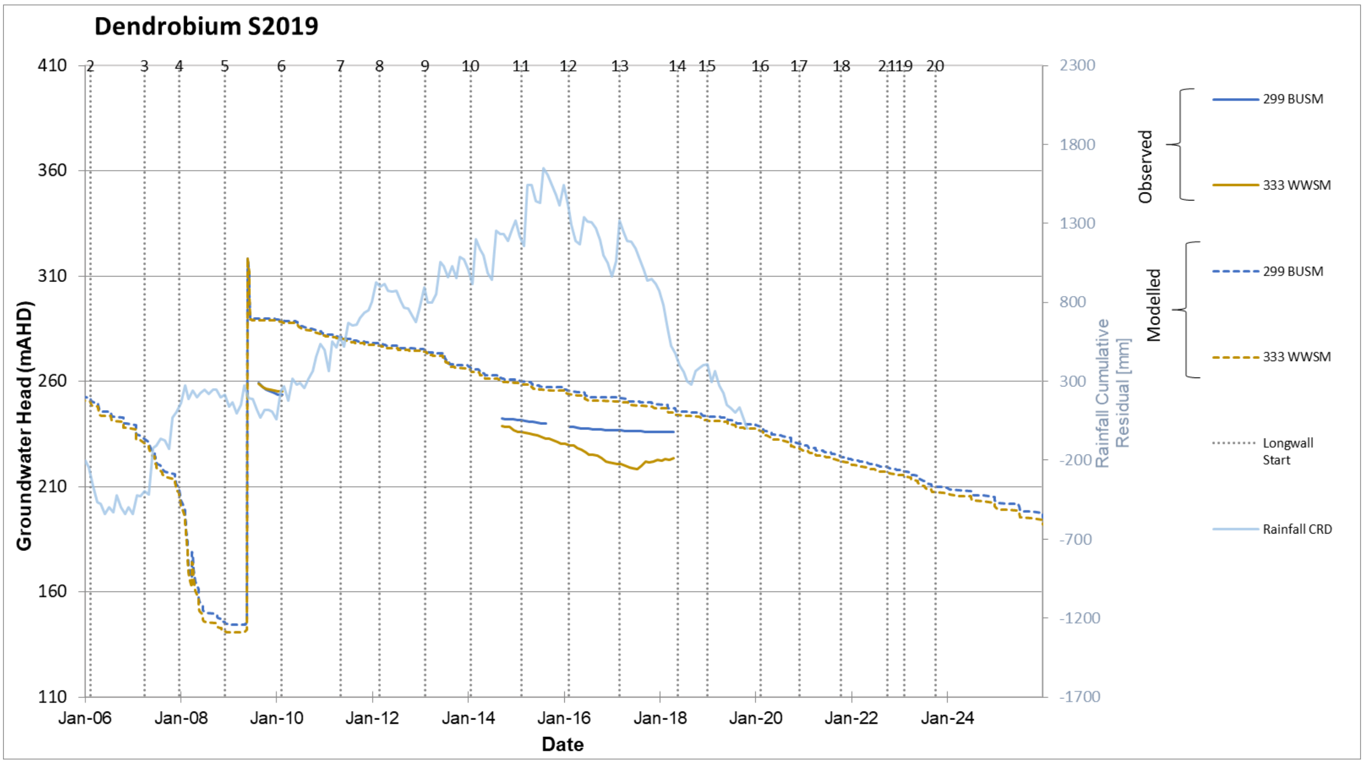

Figure A-40 Modelled and Observed Groundwater levels – S2019

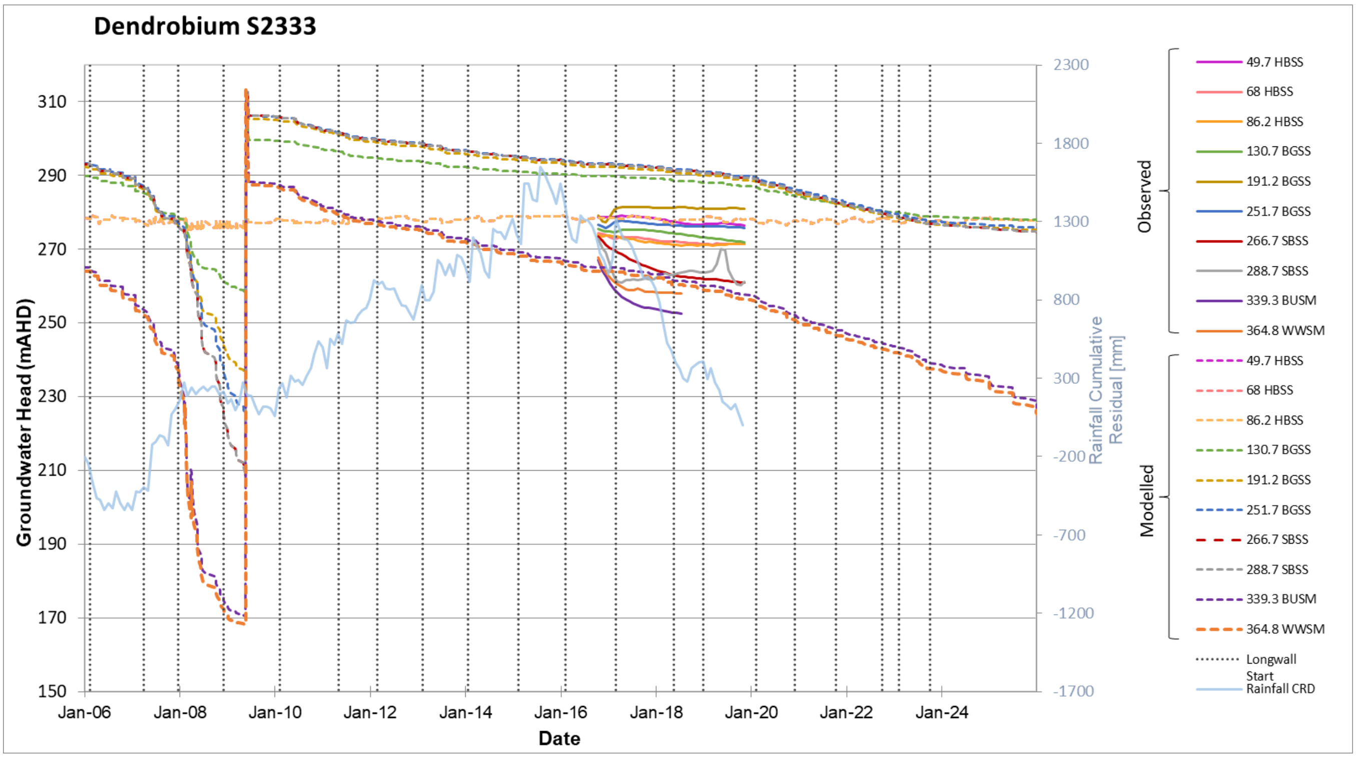

Figure A-41 Modelled and Observed Groundwater levels – S2333

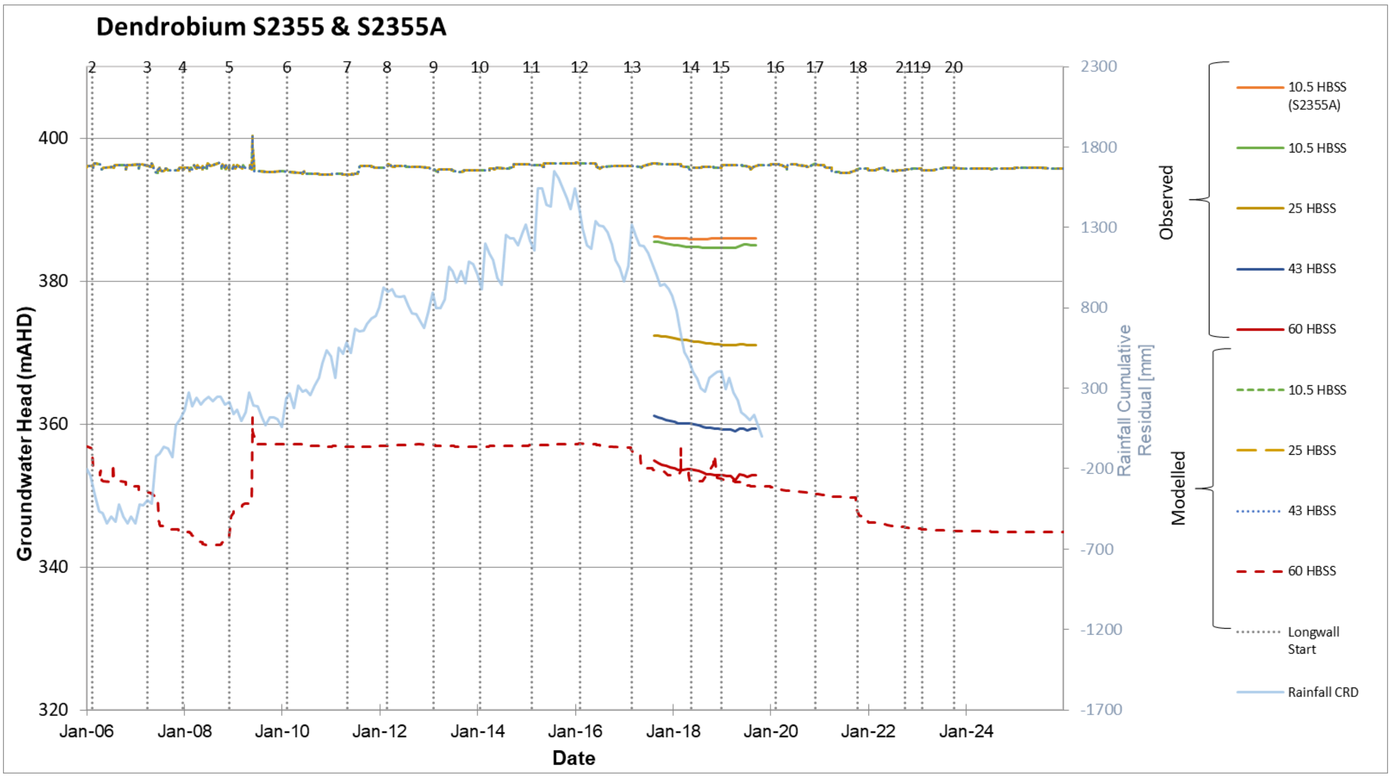

Figure A-42 Modelled and Observed Groundwater levels – S2355 and S2355A

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

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29 May 2020

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

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.

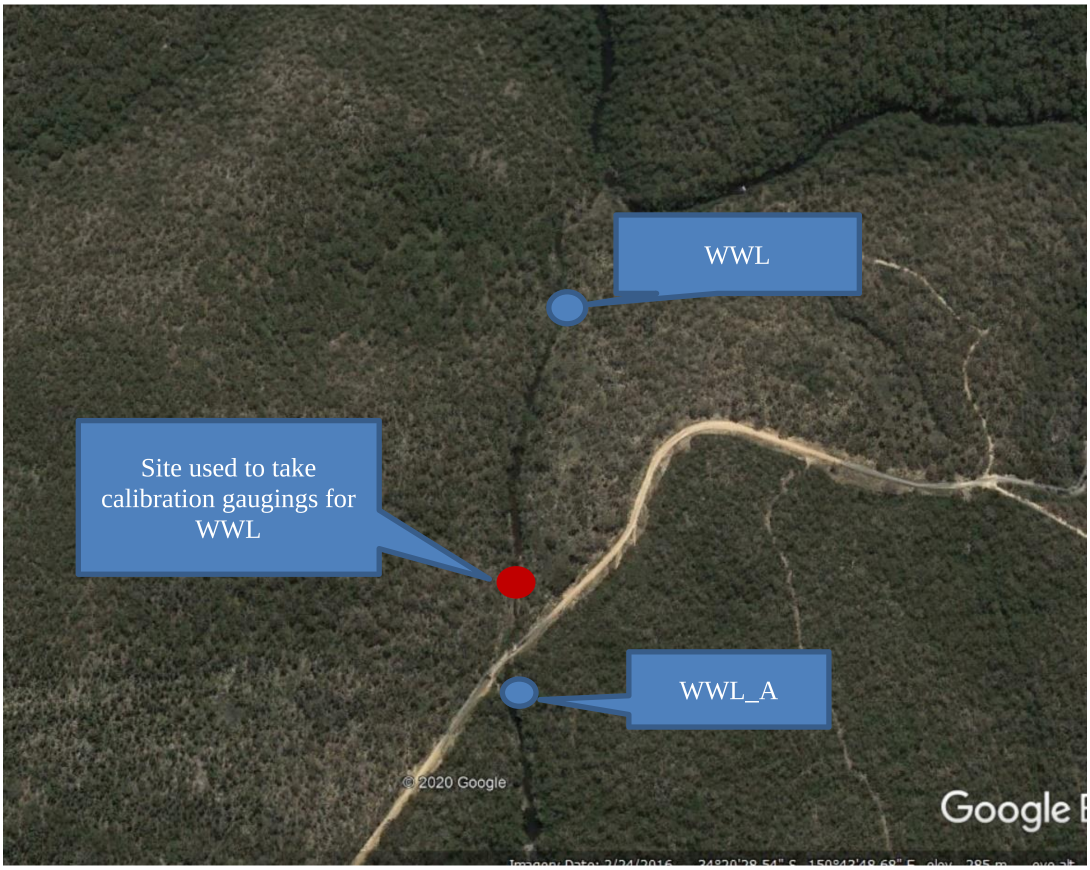

Figure 1 **Location of sites WWL and WWL_A**

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.

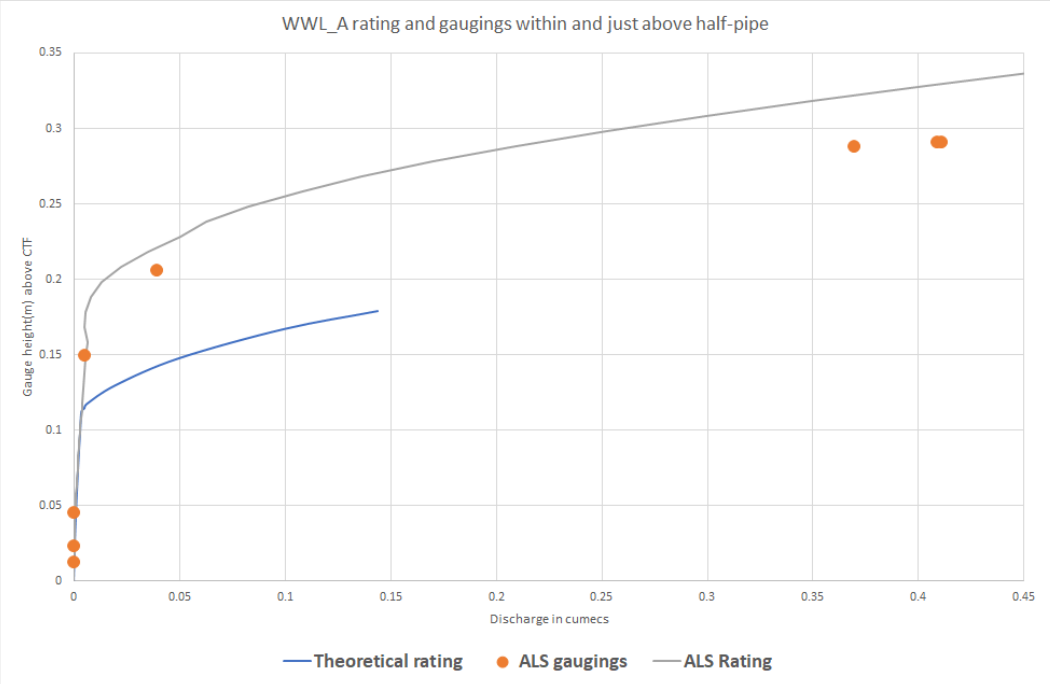

Figure 2 **WWL_A ratings and gaugings up to maximum gauging (to date)**

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

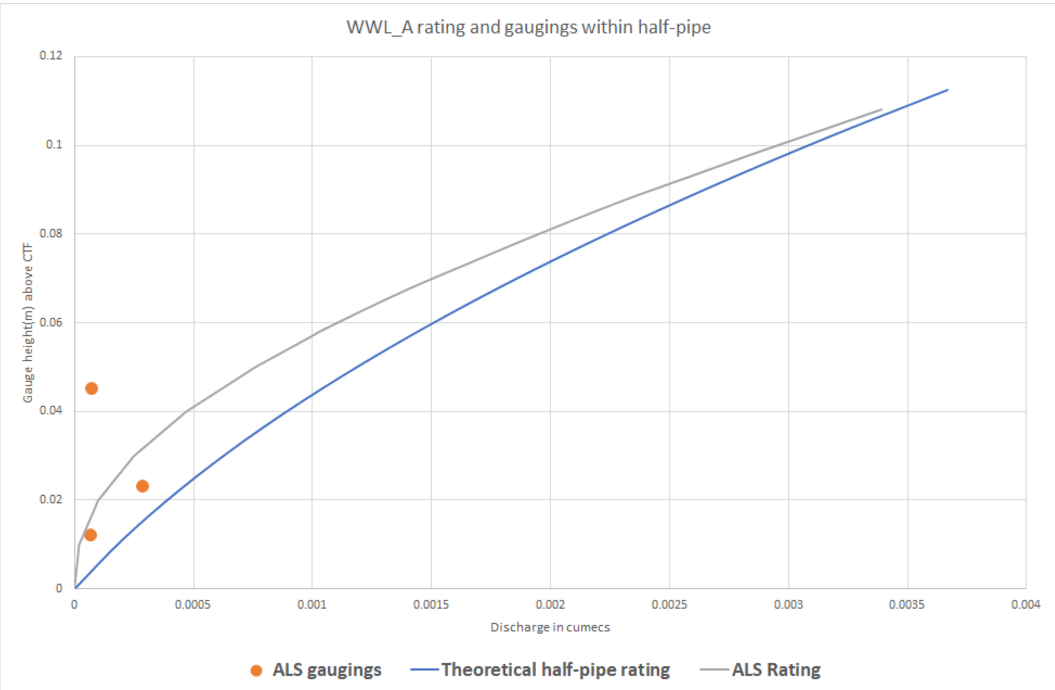

Figure 3 **WWL_A ratings and gaugings "focussed in to within the half-pipe**

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.

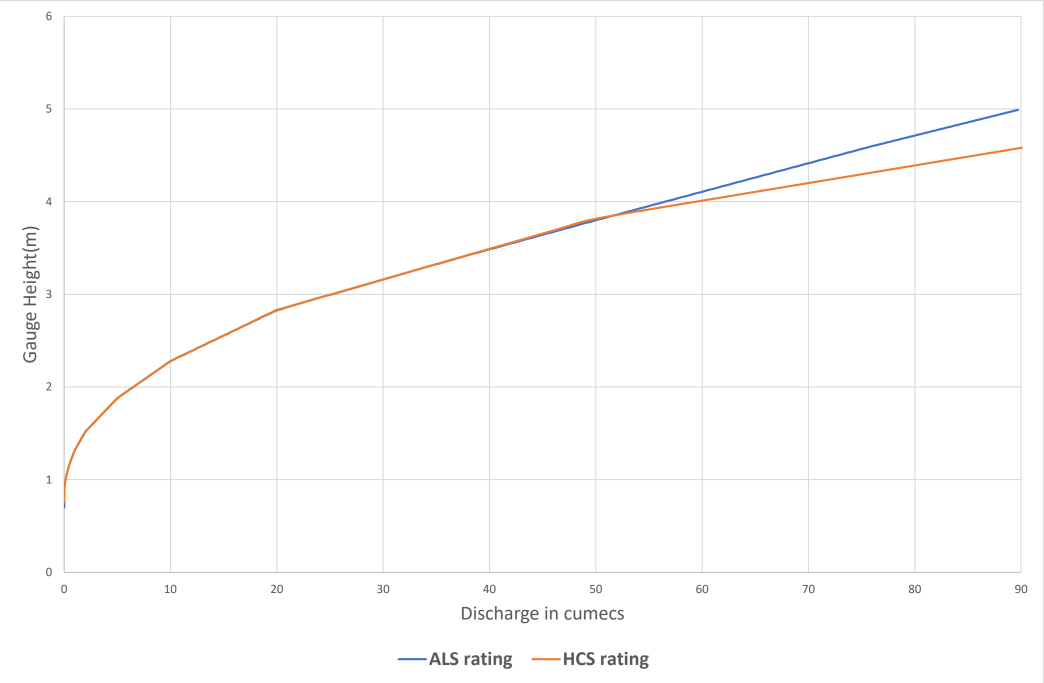

Figure 4 Full range rating plot comparison

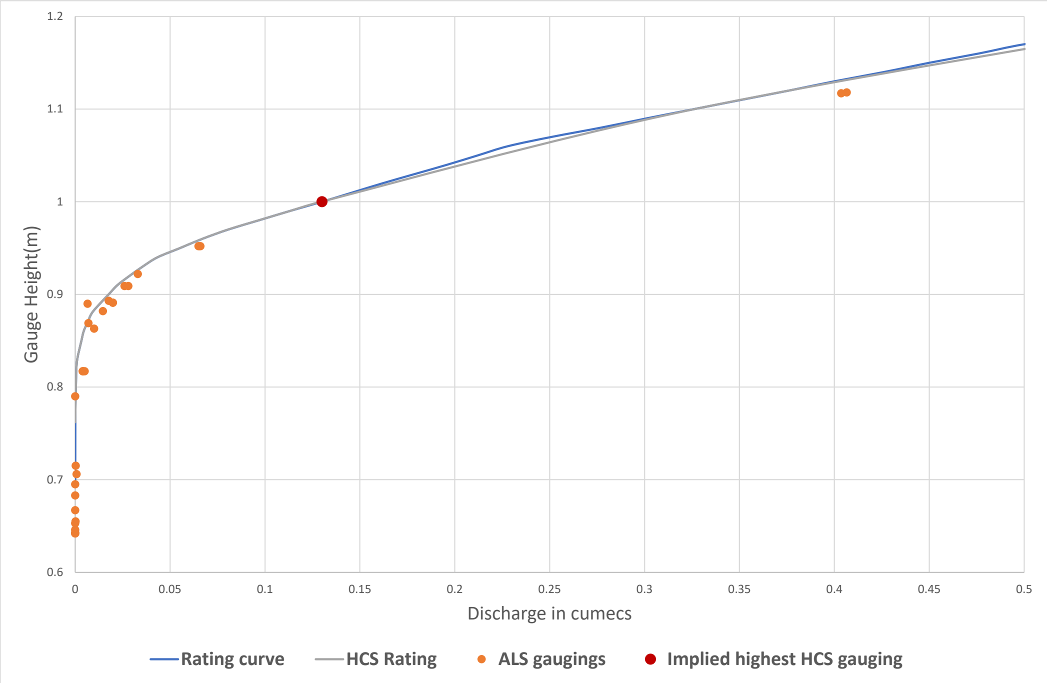

Figure 5 Gauged flow range rating plot comparison

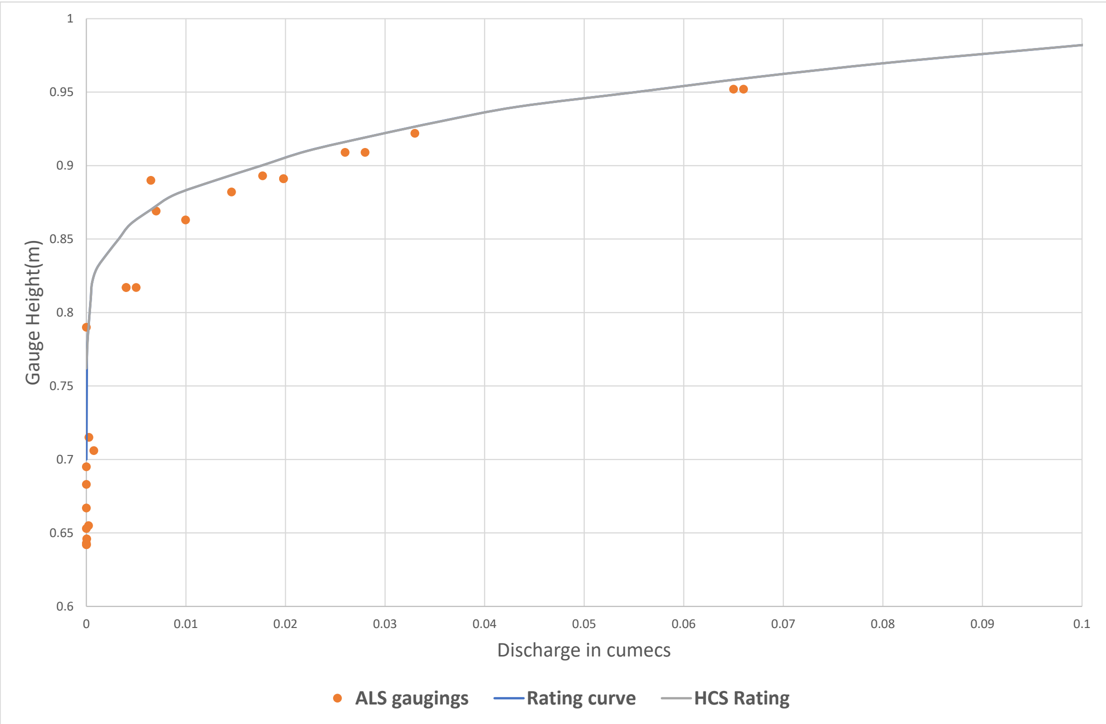

Figure 6 Low flow range rating plot comparison

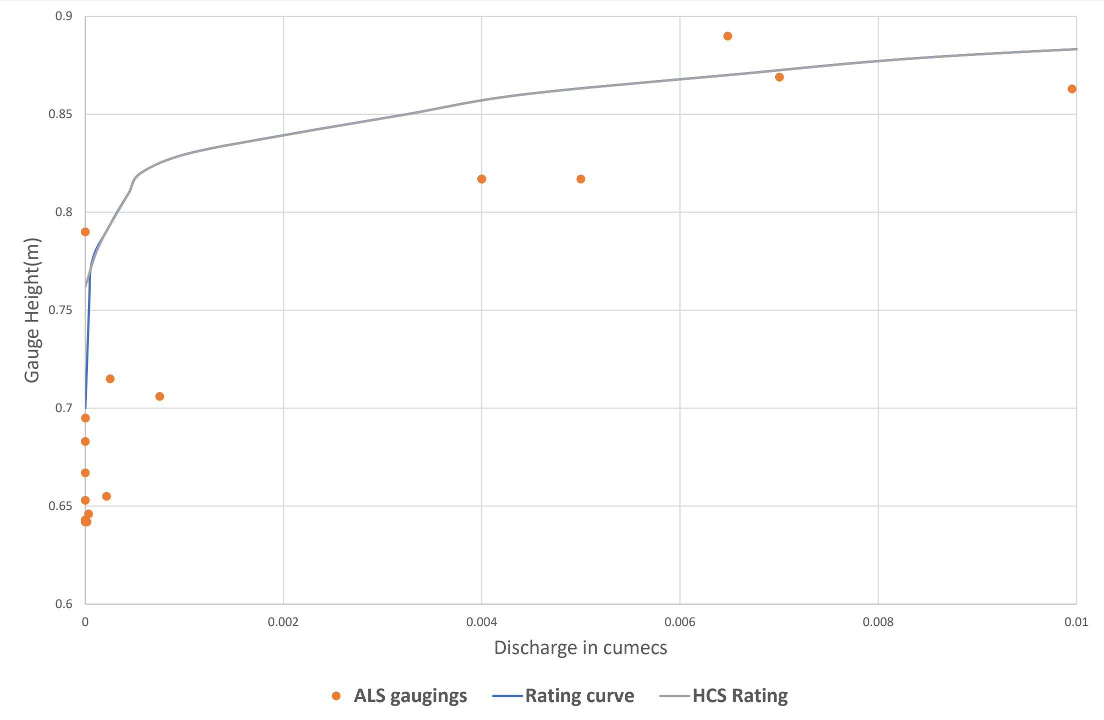

Figure 7 Very low flow range rating plot comparison

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.

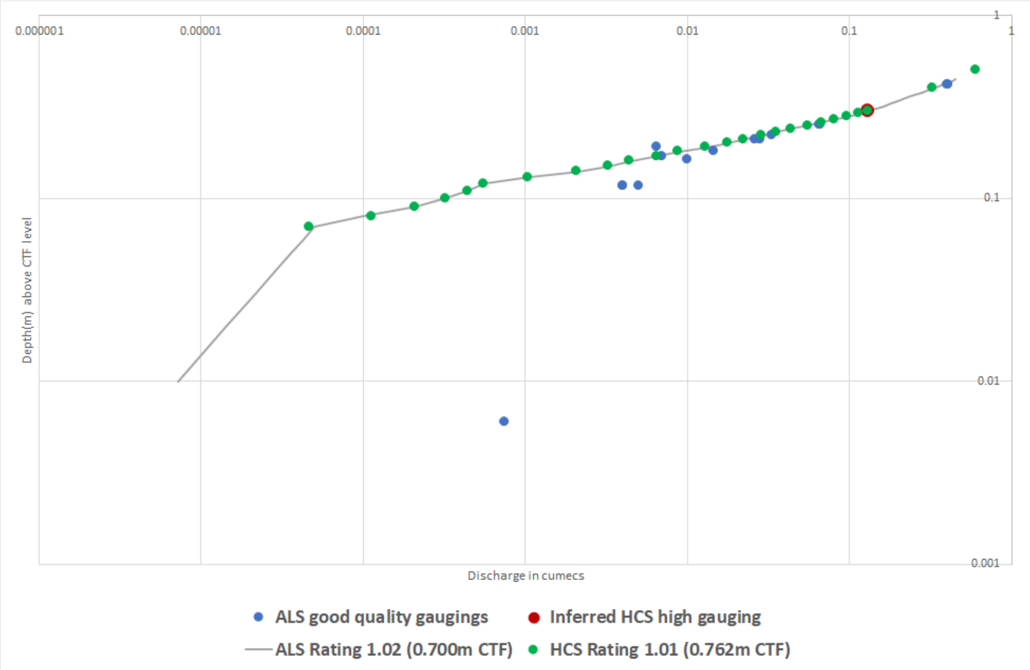

Figure 8 LogLog plot comparing all ALS good quality gaugings with rating curves

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.

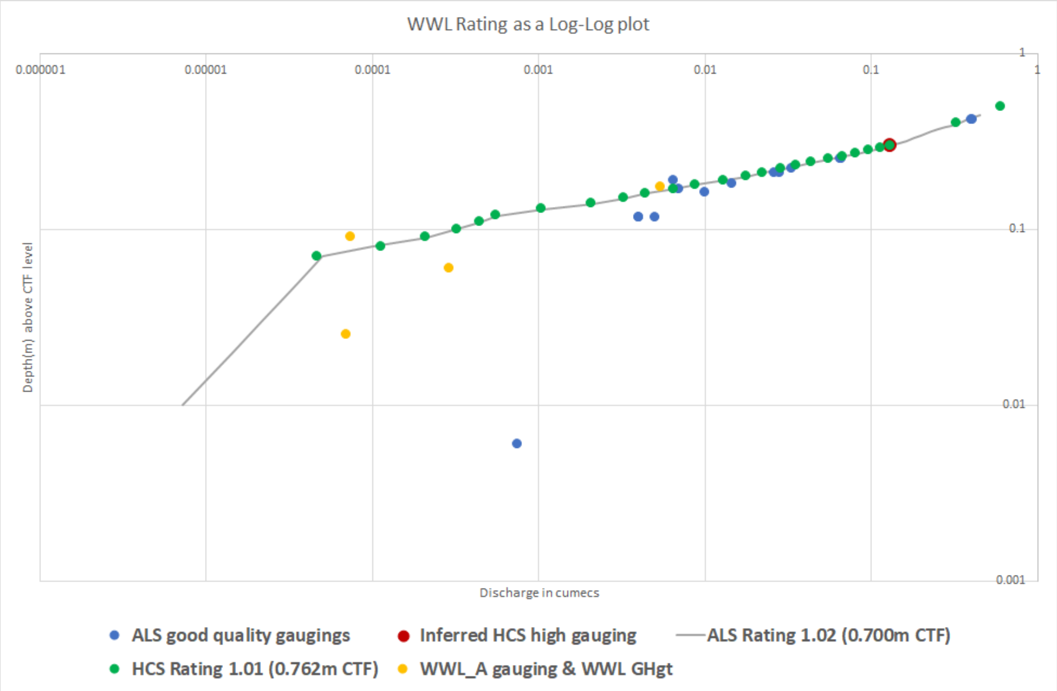

Figure 9 As for Figure 8, but treating the four lowest site WWL_A gaugings as WWL gaugings

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.

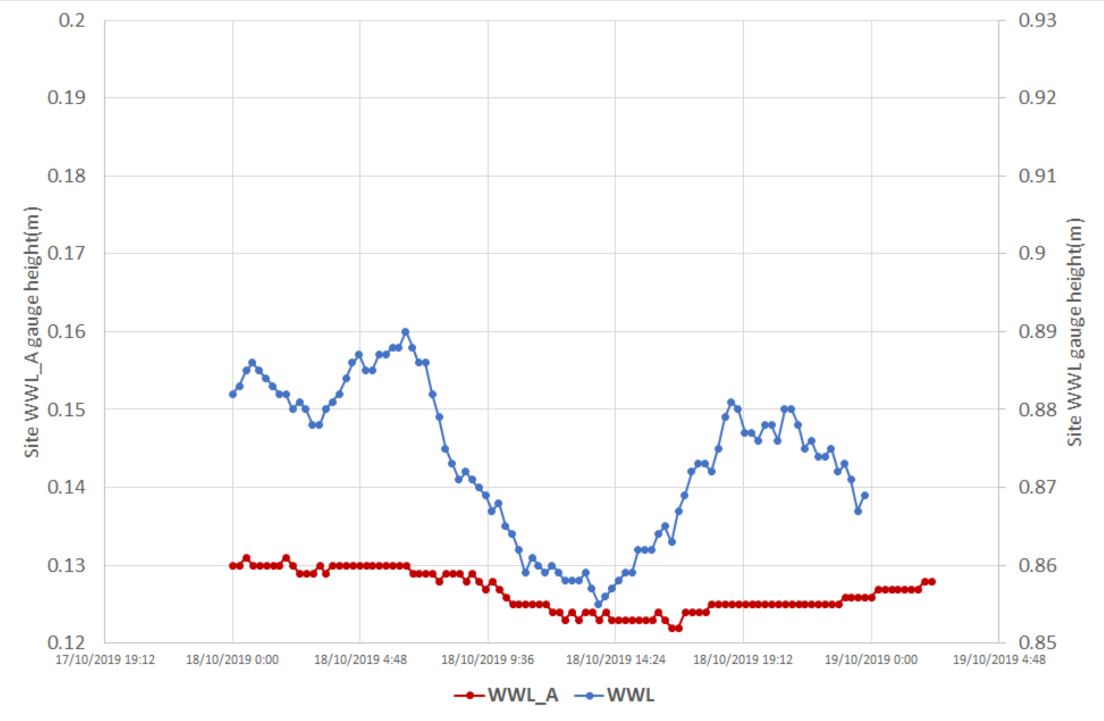

Figure 10 **Typical diurnal level pattern on 18 October 2019 (note both scales are 80mm)**

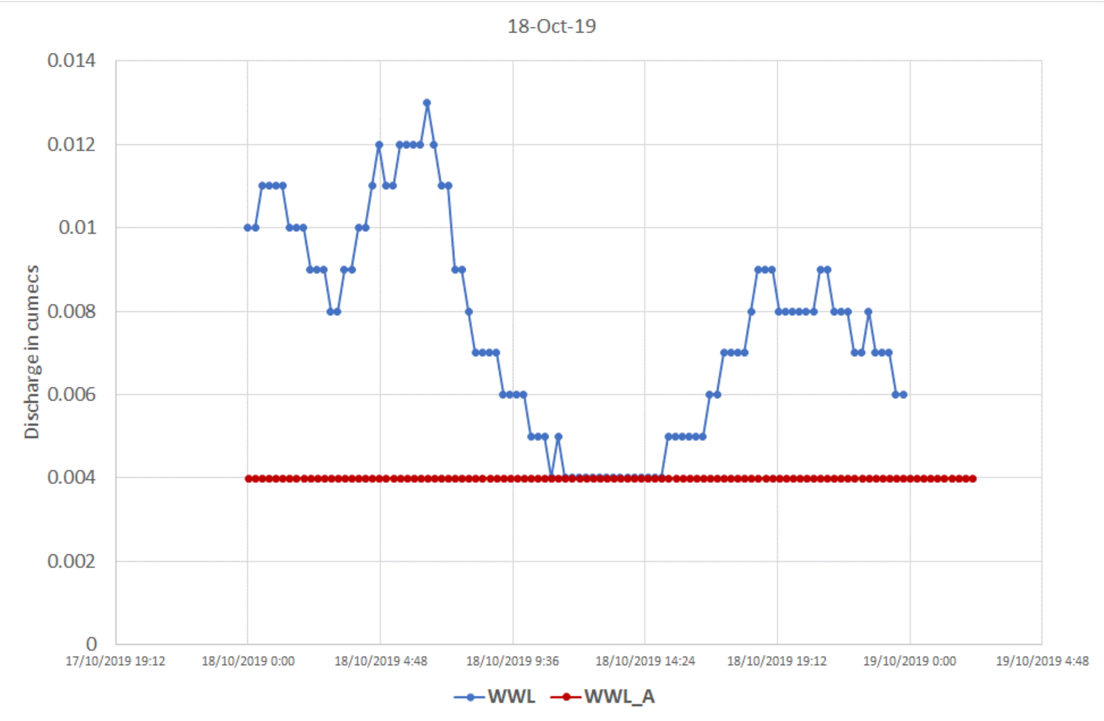

Figure 11 **Typical diurnal flowrate pattern on 18 October 2019**

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,

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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									

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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^

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
2.900	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

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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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Site 300022 Wongawilly Creek

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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
4.370	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

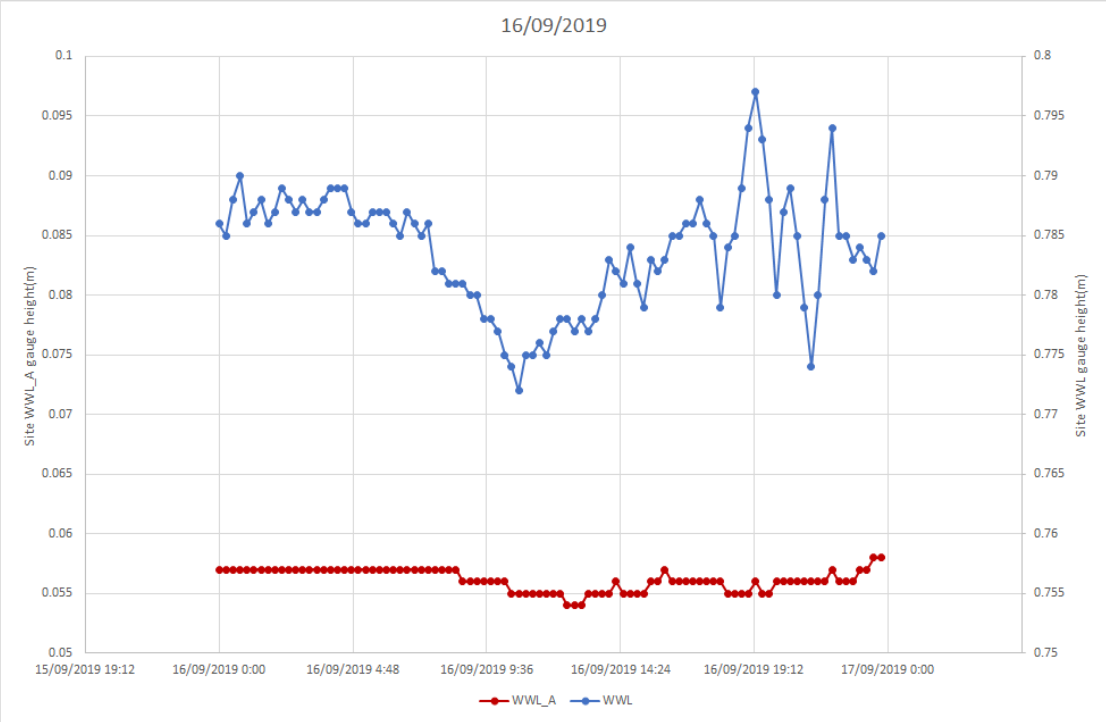
G.H.	0	0.001	0.002	0.003	0.004	0.005	0.006	0.007	0.008	0.009
0.000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.010	0.0	0.0	0.0	.00000200	.00000400	.00000600	.00000800	0.0000100	0.0000120	0.0000140
0.020	0.0000160	0.0000180	0.0000200	0.0000280	0.0000360	0.0000440	0.0000520	0.0000600	0.0000680	0.0000760
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~

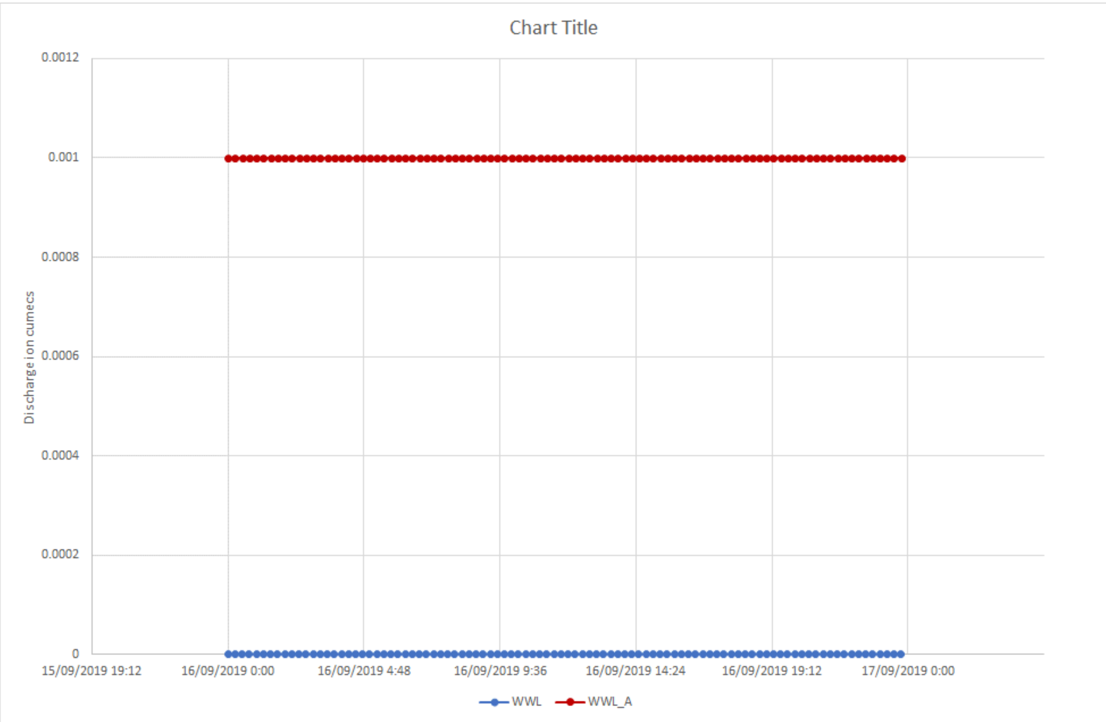
0.560	2.52~	2.53~	2.55~	2.56~	2.57~	2.59~	2.60~	2.62~	2.63~	2.64~
0.570	2.66~	2.67~	2.69~	2.70~	2.71~	2.73~	2.74~	2.76~	2.77~	2.79~
0.580	2.80~	2.81~	2.83~	2.84~	2.86~	2.87~	2.89~	2.90~	2.92~	2.93~
0.590	2.95~	2.96~	2.97~	2.99~	3.00~	3.02~	3.03~	3.05~	3.06~	3.08~
0.600	3.09~	3.11~	3.12~	3.14~	3.15~	3.17~	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~					

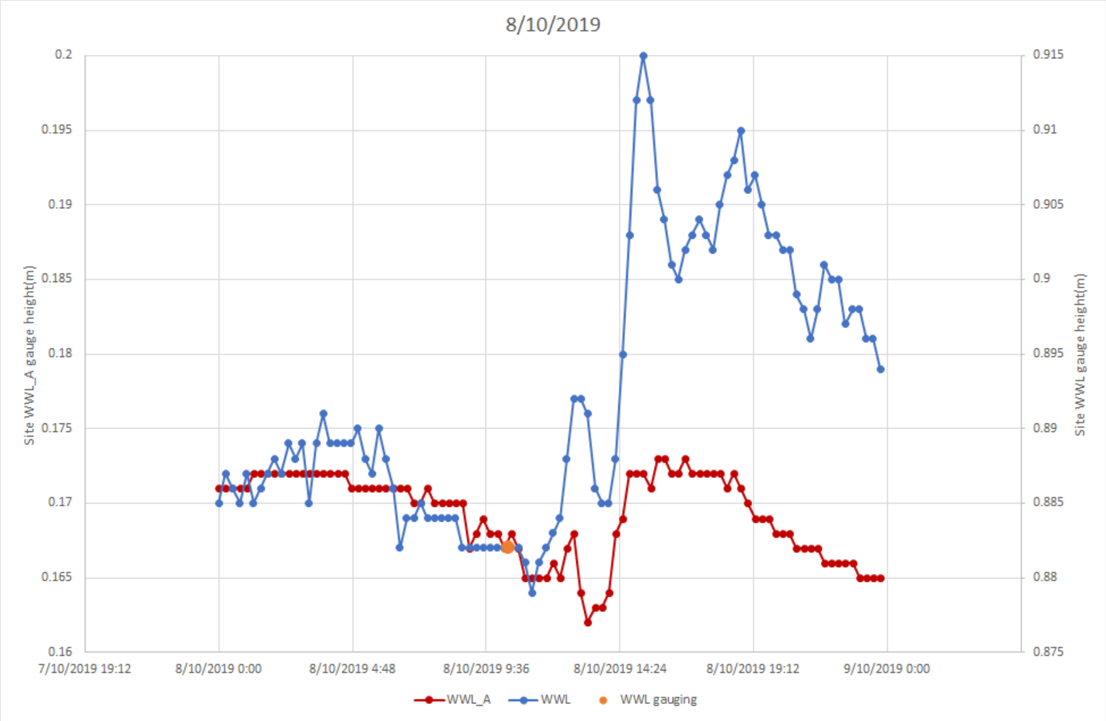
------------------ Notes -------------------

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

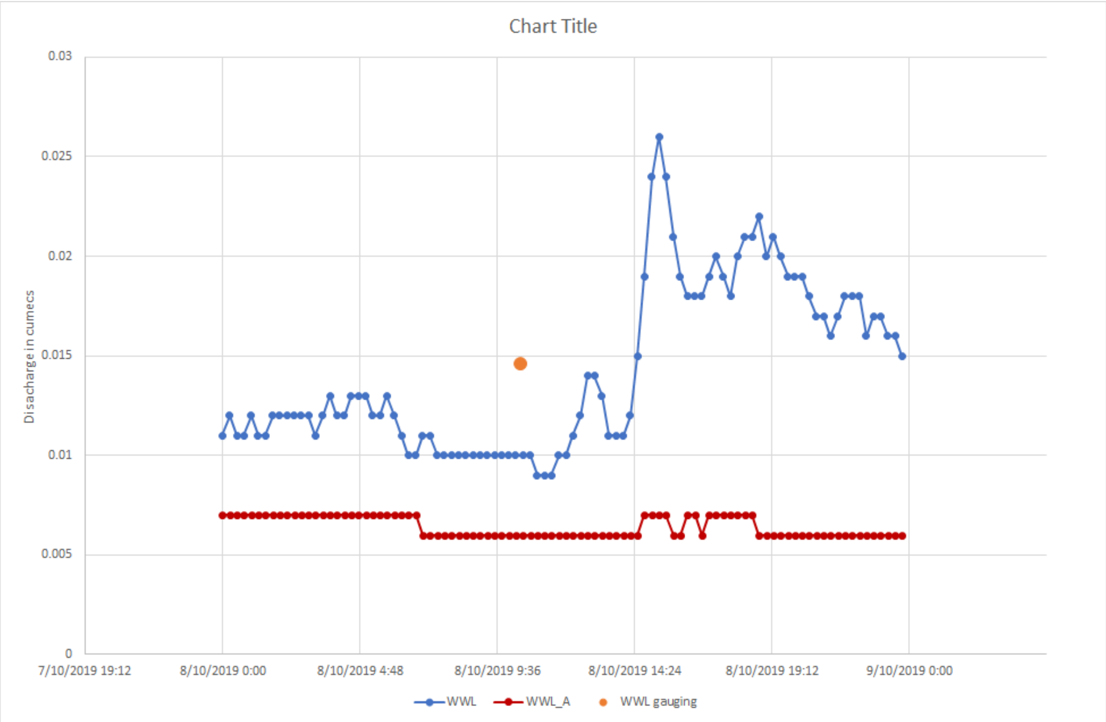
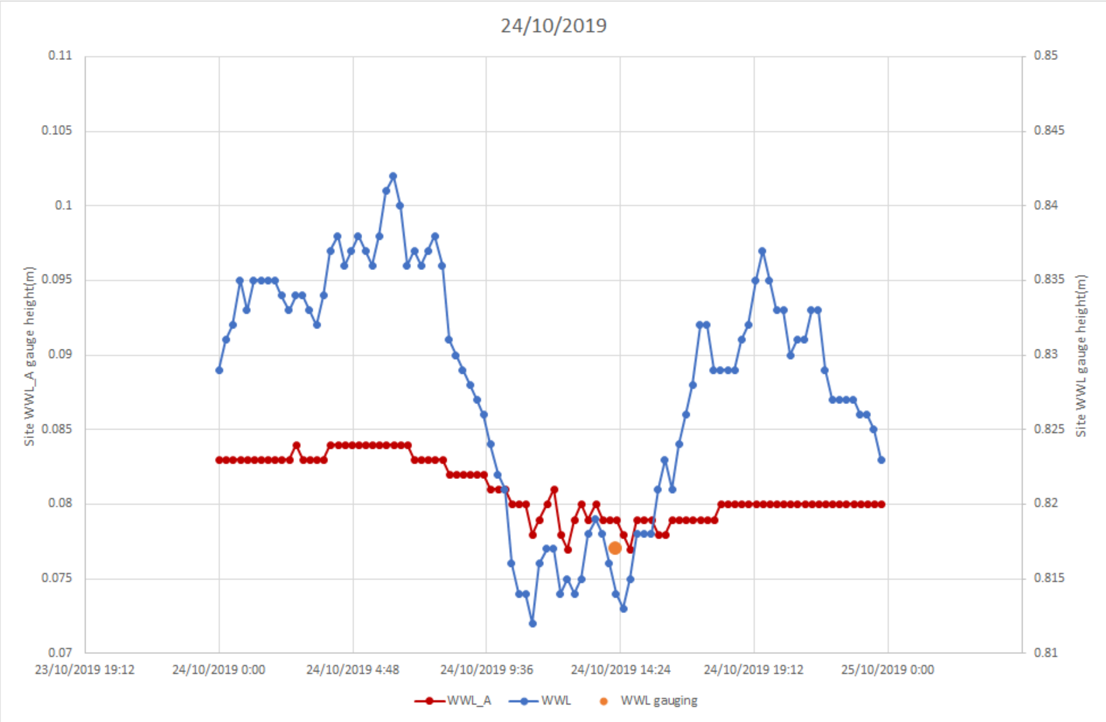


Chart Title
Disacharge in cumecs
0.03
0.025
0.02
0.015
0.01
0.005
0
7/10/2019 19:12
8/10/2019 0:00
8/10/2019 4:48
8/10/2019 9:36
8/10/2019 14:24
8/10/2019 19:12
9/10/2019 0:00
WWL
WWL_A
WWL gauging


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

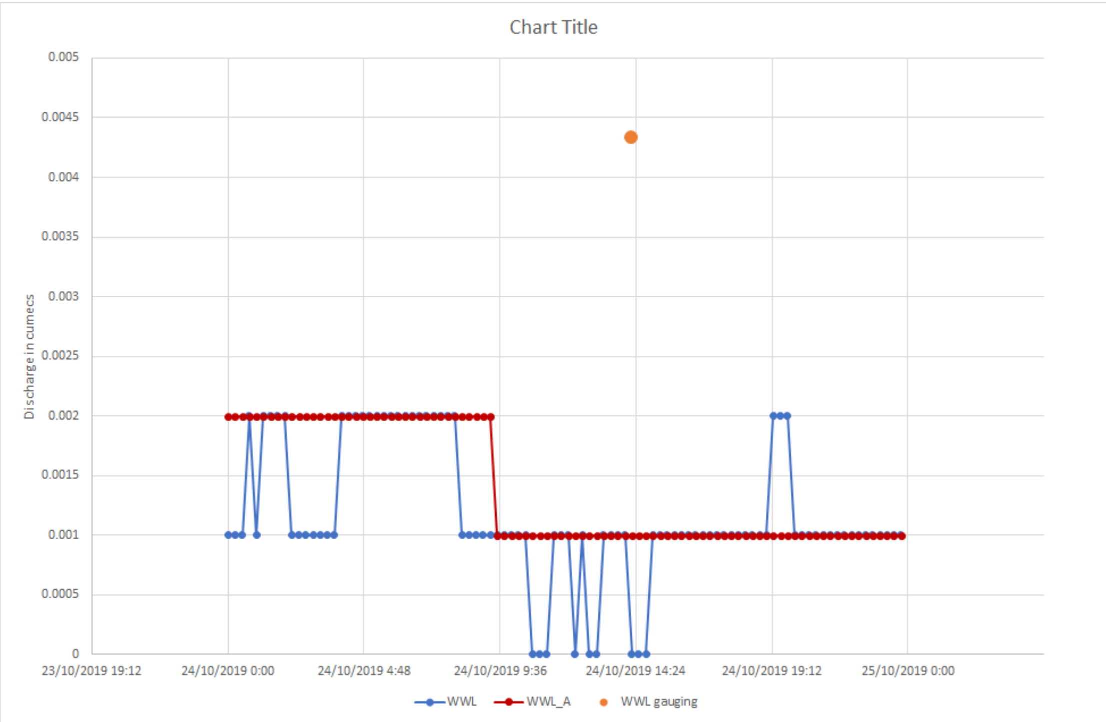
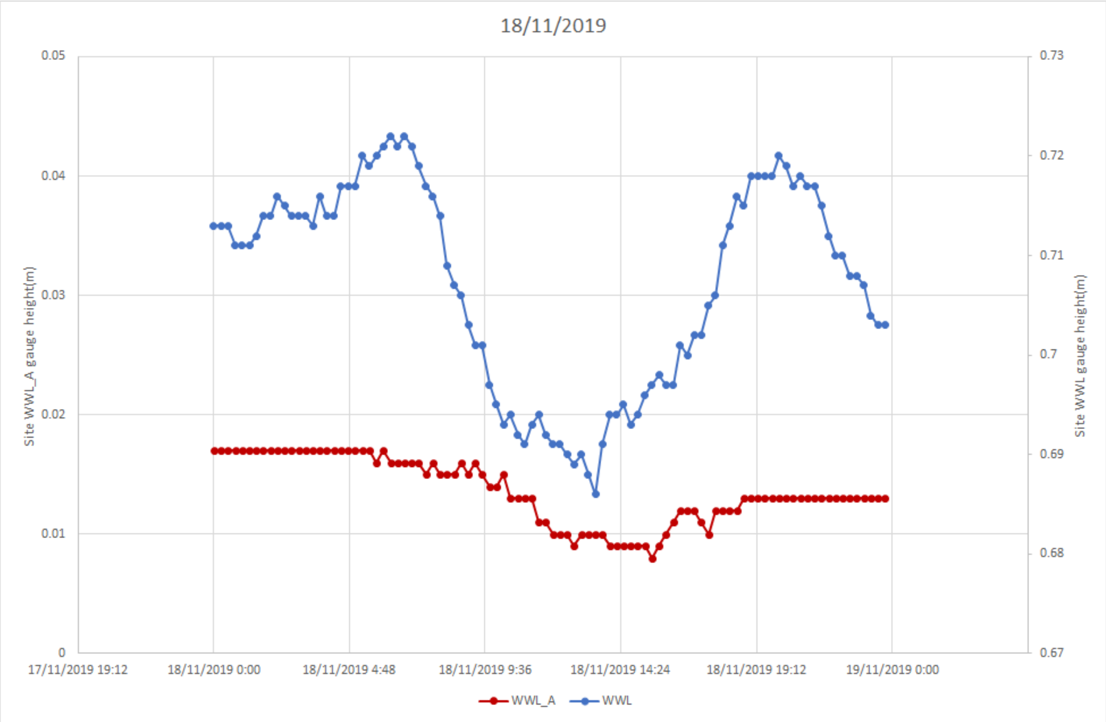


Chart Title
Discharge in cumecs
0.005
0.0045
0.004
0.0035
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
23/10/2019 19:12
24/10/2019 0:00
24/10/2019 4:48
24/10/2019 9:36
24/10/2019 14:24
24/10/2019 19:12
25/10/2019 0:00
WWL
WWL_A
WWL gauging


18/11/2019
Site WWL_A gauge height(m)
Site WWL gauge height(m)
WWL_A
WWL

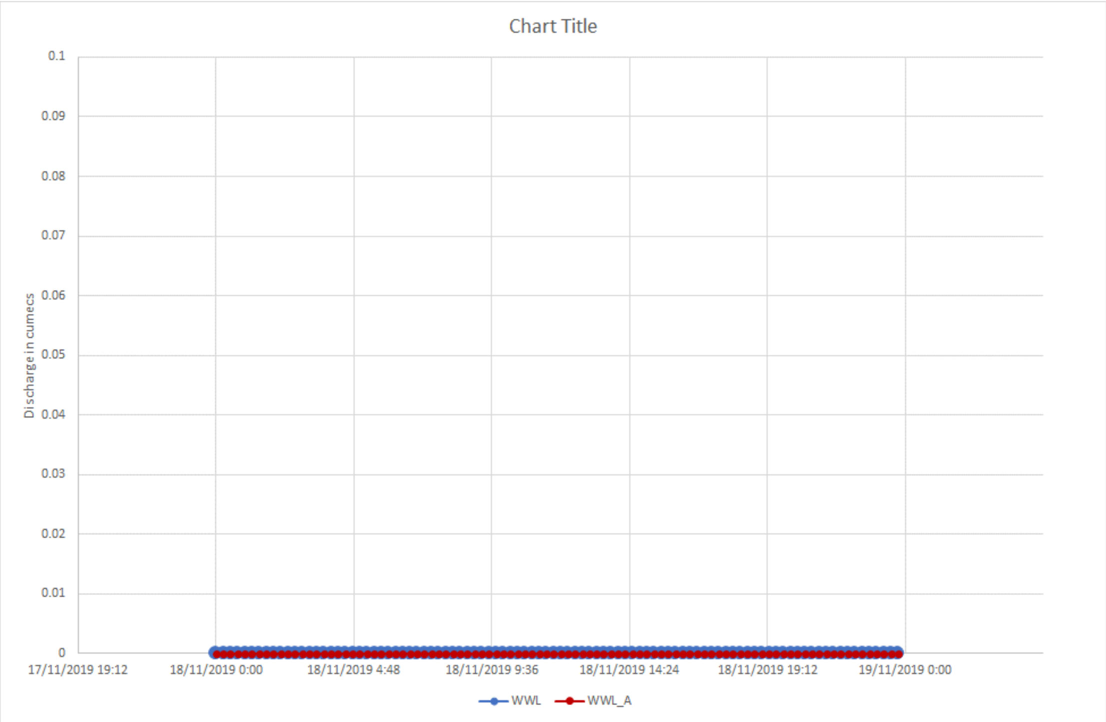


Chart Title
Discharge in cumecs
WWL
WWL_A