



Carmichael Coal Mine

Report No1: Data review and conceptualisation report

Prepared for Bravus Resources

February 2023



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Executive Summary

The Carmichael Coal Mine Project involves the design and construction of a thermal coal mine and supporting infrastructure in the north Galilee Basin, approximately 280 km south of Townsville, 300 km west of Mackay and 160 km northwest of Clermont in Central Queensland.

As a condition of approval, Bravus is required to review the Groundwater Management and Monitoring Program, version 11a (GMMP) and update the numerical groundwater flow model under Environmental Authority (EA) Conditions E5 and E6 and Associated Water Licence (AWL) Condition 55. This report represents the first in a series of groundwater reports, which aims to capture insights from recent research, investigations, and data gathering to formalise an up-to-date version of the hydrogeological conceptual model (HCM). This revised HCM will inform the design, build and calibration of a revised numerical groundwater flow model for the project. Model predictions associated with the latest planned mining activities will be used to support an update to the GMMP.

The updated HCM affirms that the Clematis Sandstone is the source aquifer for the Doongmabulla Springs Complex (DSC). Springs exist via two main mechanisms. The first occurs where structural weakness within the Moolayember Formation allows groundwater to migrate upwards to the ground surface as per the typical mound spring typology. In other areas where the Moolayember Formation aquitard pinches out, Clematis Sandstone outcrop allows for springs to occur preferentially at “break of slope” areas, whereby the watertable intersects topography. Remapping of the Clematis Sandstone outcrops areas defines a zone of potential diffuse rainfall recharge. However, a deep weathering profile that has formed due to scarp retreat is likely to limit recharge where it is present.

Both locally and regionally, groundwater flow directions converge towards the Project site from the south, north and west. The point of convergence varies for different aquifers indicating that different discharge mechanisms are responsible for this flow convergence. For the Clematis Sandstone, the convergence is at the DSC and Carmichael River. For the deeper Permian Bandanna and Colinlea HSUs, the convergence occurs within the mining lease area. For these Permian units, groundwater is conceptualised to continue to flow eastward, where it is either evaporated or continues to flow out of the Galilee Basin. The convergence of flow for these Permian units was previously attributed to the presence of a synform. The updated HCM poses two alternative mechanisms: 1) a local fault or lineament that cuts across the Bandanna, Colinlea and Joe Joe Group formations mainly within the lease area; or 2) a locally permeable Joe Joe Group that acts as an underdrain and lowers pressures in this area.

Between the DSC and the mine area, vertical hydraulic gradients are directed upwards between the upper Rewan Formation and the Clematis Sandstone and are directed downwards from the lower Rewan Formation to the underlying Bandanna Formation in the area of the DSC. Vertical groundwater flow directions between the Rewan Formation and the Bandanna Formation vary depending on the location, however, are predominately downward.

Mine dewatering commenced in August 2019 to facilitate open cut mining. Drawdown will mainly be associated with the targeted Permian coal measures and the host materials, including the Bandanna Formation and the Colinlea Sandstone. Drawdown will propagate radially away from the open cut pits. To date, drawdown effects have only been observed within the Permian units, suggesting that the Rewan Formation is behaving as an effective aquitard, hydraulically isolating the shallower Tertiary and Triassic units from the deeper Permian units.

West of the open cut pits, longwall mine panels will be developed targeting deeper parts of the coal seams. Longwall mining will cause fracturing to occur above the longwall panels, potentially to surface causing up to 4.9 m of land subsidence. A free draining zone may exist for up to 230 m above the longwall panels, where groundwater can seep via gravity directly into the longwall panels, through the goaf zone and originating from the overlying Rewan Formation. This updated estimate represents a larger free draining zone compared to the previous Supplemental EIS model, which assumed 160 m.

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1 Introduction

1.1 Background

The management of groundwater resources at the Carmichael Coal Project (CCP) is underpinned by a scientific adaptive management framework that is implemented through the Groundwater Management and Monitoring Plan (GMMP). This structured, iterative process of adaptive management is focussed on reducing hydrogeologic uncertainty over time via systems monitoring and continuous improvement. The evolution of the hydrogeology conceptual model (HCM) is a fundamental part of this framework.

A HCM is a descriptive representation of a specific groundwater system that incorporates knowledge and interpretation of the geological, hydrological, and hydrogeological conditions in the study area. The HCM summarises the hydrogeological understanding of key processes such as recharge and discharge, and the influence of any boundaries or stresses that may have impact on the flow system. The inherently complex groundwater system is simplified in a way that describes the main features and processes controlling groundwater flow. The degree of simplification is usually guided by the objectives and timescale of the study, and the amount and quality of data available.

The approvals process for the CCP generated geologic and hydrogeologic datasets that were used to develop the initial HCMs for the project. This included separate conceptualisations to support the Environmental Impact Statement (EIS) (GHD 2012c), refinement in the Supplemental EIS (SEIS) Mine Hydrogeology Report (GHD 2013a), and Addendum to the SEIS (AEIS) (GHD 2013b). Since the approvals process, continued monitoring and research programs have generated new data that has allowed more contemporary updates to the HCM within the GMMP itself, with the latest version being Version 11, released on 29 December 2020 (Adani Mining 2020). It was noted in the GMMP that refinement of the HCM over time has provided insight into the complexity and variability of the groundwater regime along the eastern margin of the Galilee Basin, where the CCP is located.

The purpose of this conceptualisation report (hereafter referred to as 'the report') is to capture insights from recent research, investigations, and data gathering to formalise an up-to-date version of the HCM. This revised HCM will inform the design and build of a revised groundwater model for the project; the mining impact predictions from that model will support an update to the GMMP. Therefore, the GMMP embraces the intent of its adaptive management principles by linking the groundwater model to the latest science and research on how the groundwater system functions.

The HCM described in the existing GMMP is thorough and articulates the key hydrogeological elements of the system. There is little value in reproducing all of the details of the existing HCM that have not changed. As such, this report will focus on those elements of the HCM that have changed as a result of gathering new data and investigations. For this reason, this report should be read in conjunction with Section 2.3 of the existing GMMP to gain an appreciation of the entire HCM for the project.

This report is the first deliverable as part of a larger project that evaluates and updates the groundwater model and GMMP to achieve compliance with Environment Authority (EA) conditions E5 and E6 and condition 55 of the Associated Water License (AWL).

1.2 Scope of work

The scope of work for this HCM report is described in EA Condition E6 and AWL Condition 55, as summarised below:

- EA Condition E6, Part A: Review the hydrogeological conceptualisation used in the previous model.
- AWL Condition 55, Part B: Revise the hydrogeological conceptualisation and assumptions of the groundwater model, including:

- any revised geological interpretation;
- any revised hydrogeological parameters or assumptions on recharge;
- any outcomes from the Rewan Connectivity Research Plan or GAB Springs Research Plan; and
- any assumptions of outflow from springs and other water users.

1.3 Structure of report

The structure of the report has been developed to logically step through:

- Summary of previous studies: a high-level summary of the previous HCM (Section 2).
- Research Programs and New Datasets: A description of the new datasets and research (Section 3).
- Revised and updated hydrogeological conceptualisation including:
 - climate (Section 4);
 - revised geological setting (Section 5);
 - revised hydraulic properties (Section 6);
 - revised groundwater levels, trends and flow (Section 7);
 - hydrogeochemistry with a focus on the Doongmabulla Springs source water (Section 9);
 - a detailed assessment of the surface water and groundwater connectivity and the interaction with the spring complexes (Section 10);
 - recharge and discharge processes (Section 11);
 - an overall summary of the key features of the revised HCM (Section 12); and
 - a synthesis of how the new HCM addresses some of the key uncertainties raised during the approval process (Section 13).

2 Summary of previous hydrogeology conceptual model

As described in Section 1, there is little value in reproducing all of the details of the existing HCM that have not changed. As such, this report will focus on those elements of the HCM that have changed as a result of gathering new data and investigations. This section of the report provides a high-level summary of the previous HCM to provide some basic context for the proceeding report sections. Section 2.3 of the existing GMMP should be read in conjunction with this report section.

2.1 Geological units and structures

The CCP is situated along the eastern edge of the northern Galilee Basin. The main stratigraphic units of relevance to the CCP outcrop and subcrop within and adjacent to the mining leases (MLs) and include from top to bottom:

- Quaternary alluvium and Tertiary sediments: confined and unconfined aquifers, notably adjacent to the Carmichael River.
- Triassic Moolayember Formation: an unconfined aquitard.
- Triassic Clematis Sandstone: an aquifer, unconfined in the east and confined in the west.
- Triassic Dunda Beds: a confined aquitard.
- Triassic Rewan Formation: a confined aquitard.
- Permian Bandanna Formation: alternating confined aquitards (interburden) and aquifers (coal seams).
- Permian Colinlea Sandstone: alternating confined aquifers (interburden and coal seams).

The Dunda Beds and Clematis Sandstone outcrop along the western boundary of the CCP area. The Rewan Formation, Bandanna Formation, Colinlea Sandstone and Joe Joe Group subcrop within the CCP area. Tertiary sediments thicken towards the east to reach a maximum thickness of approximately 60 metres (m). Alluvial sediments are present adjacent to the Carmichael River and tributaries. The geometry of the Triassic and Permian subcrops and outcrops reflect a previously described synform, as presented in Figure 2.1.

Structurally, there is an absence of significant regional faults in the area (Biggs, 2014). There are only four minor faults interpreted within the coal strata, with vertical throws of between 20 m and 40 m. Those faults tend to be oriented in a general east-west direction. There is a major synform identified by previous studies, with a northeast to southwest fold axis, that passes broadly through the centre of the site. This synform affects the Betts Creek Beds and Rewan Formation, but not the younger Clematis Sandstone. The axis of the fold tends to align with a regional 'low' observed in potentiometrics.

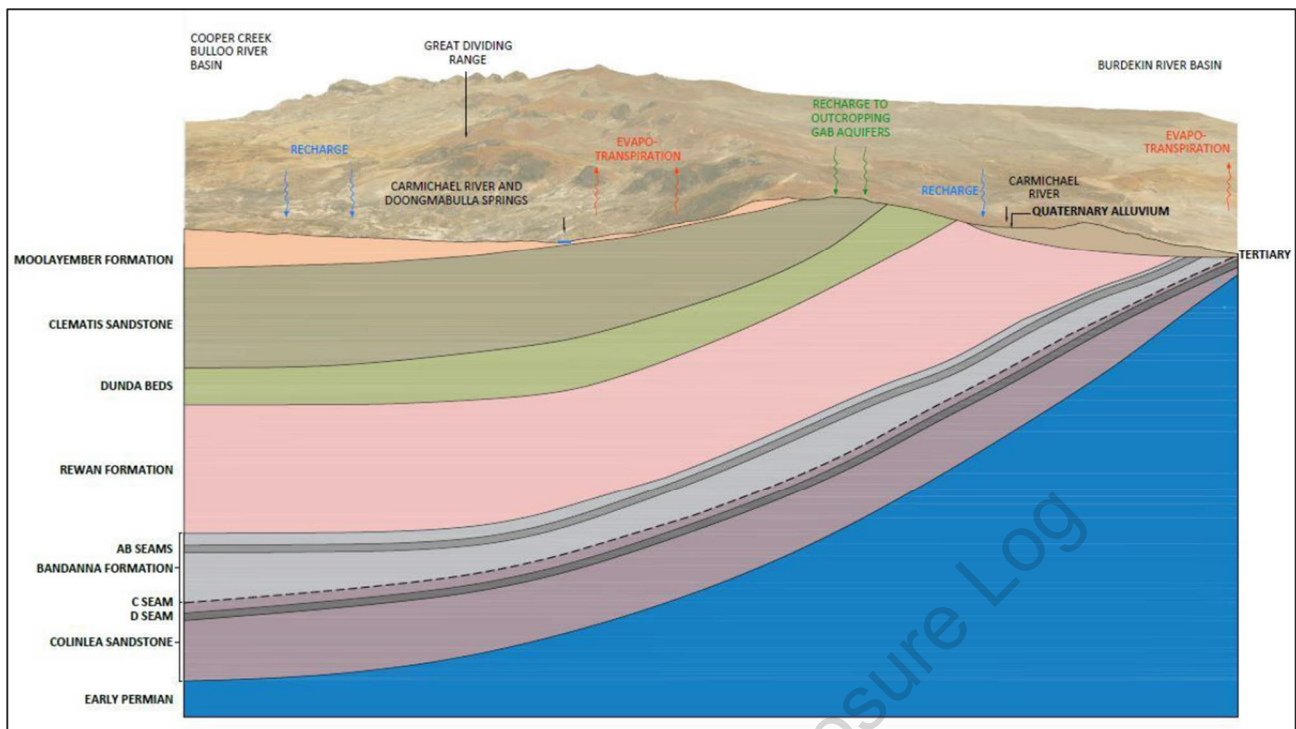


Figure 2.1 Schematic cross-section of the CCP area, after Adani Mining (2020)

2.2 Groundwater recharge and discharge

The main recharge and discharge mechanisms per hydrostratigraphic unit (HSU) are summarised in Table 2.1.

Table 2.1 Summary of recharge and discharge mechanisms per HSU, based on Adani Mining (2020)

HSU	Recharge: Surface water infiltration	Recharge: Diffuse rainfall infiltration	Recharge: Rainfall infiltration in outcrop only	Recharge: Vertical leakage from other units	Recharge: Spring discharge infiltrating to alluvium	Discharge: Baseflow to surface water	Discharge: Vertical leakage to other units or throughflow	Discharge: Evapotranspiration	Discharge: Discharge to springs	Discharge: Rejected recharge	Discharge: uncontrolled discharge to poorly constructed bores
Alluvium	✓	✓		✓	✓	✓	✓	✓			
Tertiary sediments	✓		✓	✓			✓	✓			✓
Moolayember Formation			✓	✓			✓	✓		✓	
Clematis Sandstone			✓				✓	✓	✓		✓
Dunda Beds			✓	✓			✓	✓			
Rewan Formation			✓				✓				

Table 2.1 Summary of recharge and discharge mechanisms per HSU, based on Adani Mining (2020)

HSU	Recharge: Surface water infiltration	Recharge: Diffuse rainfall infiltration	Recharge: Rainfall infiltration in outcrop only	Recharge: Vertical leakage from other units	Recharge: Spring discharge infiltrating to alluvium	Discharge: Baseflow to surface water	Discharge: Vertical leakage to other units or throughflow	Discharge: Evapotranspiration	Discharge: Discharge to springs	Discharge: Rejected recharge	Discharge: uncontrolled discharge to poorly constructed bores
Bandanna Formation				✓			✓				
Colinlea Sandstone				✓			✓		✓		
Joe Joe Group				✓			✓				

2.3 Groundwater flow system

2.3.1 Regional groundwater flow

The regional groundwater flow system along the eastern edges of the Galilee Basin is not uniform in nature. A regional groundwater contour and flow diagram for the Colinlea Sandstone (Figure 2.2) was presented as part of Rewan Formation Connectivity Research Plan (HydroAlgorithmics Pty Ltd 2021). There is a general south to north flow system that originates south of 7,350,000 mN (MGA Zone 55) and diverges or splits along a groundwater divide to the north along the intermontane valley of the Great Dividing Range (GDR). As the flow system diverges along the divide, the western portion flows towards the southwest and is consistent with the dip of the basin. In contrast, the east of the divide, groundwater tends to flow “up-dip” and converges either along a zone of preferential flow for formations beneath the Rewan Formation (previously described as a synform, AECOM 2020), or at the Carmichael River and the Doongmabulla Springs (for formations above the Rewan Formation). This up-dip flow mechanism is similar in nature to the Precipice Sandstone groundwater flow system in the Surat Basin, whereby groundwater flows up-dip to the north of the GDR and converges on the Dawson River.

More locally, flow beneath the Clematis Sandstone convergences towards a groundwater ‘low’, with groundwater flow direction across the site under pre-mining conditions, observed to flow south/southeast north of the Carmichael River and flow towards the northwest from areas south of the Carmichael River (AECOM 2020).

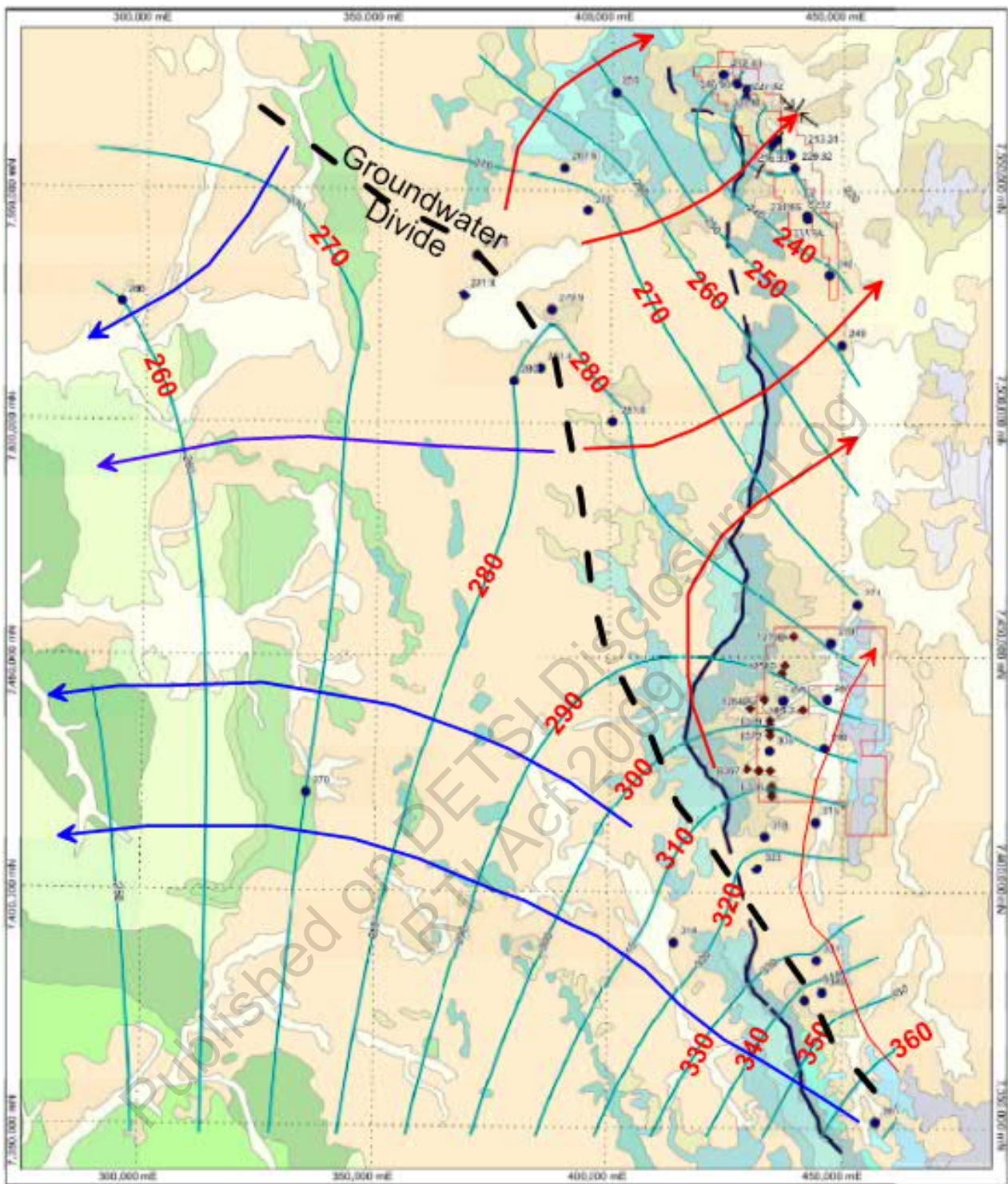


Figure 2.2 Regional groundwater directions in the Colinea Sandstone on the eastern limb of the Galilee Basin (HydroAlgorithmics, 2021)

2.3.2 Local groundwater flow

Based on the standpipe monitoring bores, the local groundwater flow systems for each HSU were interpreted. The key features of the local flow systems are summarised in Table 2.2.

Table 2.2 Summary of local flow system characteristics per HSU, based on Adani Mining (2020)

HSU	Influenced by axis of synform to produce local low in heads	Convergence on Carmichael River and/or DSC	Influenced by regional flow system	Flow along the Carmichael River	Comments
Alluvium	✗	✗	✗	✓	Flow mimics topography and flows west to east along Carmichael River floodplain.
Tertiary sediments	✗	✓	✓	✗	Flow from south to north.
Moolayember Formation	✗	?	?	✗	
Clematis Sandstone	✗	✓	✓	✗	Groundwater flow converges on HD02, indicating discharge to DSC and as baseflow to Carmichael River.
Dunda Beds	✓	✓	✓	✗	Groundwater flow converges on C027P2 and is influenced by synform.
Rewan Formation	✓	✗	✓	✗	Groundwater flow converges towards C008P1 and is influenced by synform
Bandanna Formation	?	✗	✓	✗	Represented by AB Seam. Groundwater flow converges towards C014P2. Low point not aligned with synform, although no data at synform axis to confirm.
Colinlea Sandstone	✓	✗	✓	✗	Represented by D Seam. Groundwater flow converges towards C006P3R and is influenced by synform.
Joe Joe Group	✓	✗	✓	✗	Groundwater flow converges towards C14003P and C14004SP and is influenced by synform. Local change in flow pattern to account for discharge to Mellaluka Spring Complex (MSC) and pumping from Mellaluka homestead.

2.4 Hydraulic properties

The GMMP presents a table of existing field testing (Table 8 of GMMP) and calibrated model values for horizontal hydraulic conductivity (Kh). EMM have taken the reported estimates of field-derived Kh used in the GMMP and presented these as a statistical summary (Table 2.3) and boxplot (Figure 2.3) which summarises the ranges of Kh for each HSU, segregated by the testing type (slug test, packer test or pumping test). The reason for segregating the test type is the issue of scale. Small scale tests like slug tests tend to under-estimate Kh, compared with the HSU-scale estimates used in models and macro-scale tests like packer tests and pumping tests.

Table 2.3 Summary statistics of hydraulic properties, based on GMMP (Adani Mining, 2020), Table 8

HSU	Test type/model	n	Horizontal hydraulic conductivity statistics (m/d)						
			mean	std	min	25%	50%	75%	max
Alluvium	Calibrated model	1	0.2		0.20	0.20	0.20	0.20	0.20
	Slug test	3	3.72	6.30	0.03	0.08	0.14	5.57	11.00
Bandanna	Calibrated model	1	0.002		0.002	0.002	0.002	0.002	0.002
	Packer test	9	0.01	0.02	0.0001	0.001	0.003	0.01	0.05
	Slug test	3	11.69	20.19	0.004	0.03	0.06	17.53	35.00
	Western model region	1	0.0001		0.0001	0.0001	0.0001	0.0001	0.0001
Clematis Sandstone	Calibrated model	1	1.6		1.60	1.60	1.60	1.60	1.60
	Packer test	2	0.01	0	0.01	0.01	0.01	0.01	0.01
	Slug test	1	15		15	15	15	15	15
	Western model region	1	1.55		1.55	1.55	1.55	1.55	1.55
Colinlea Sandstone	Calibrated model	1	0.003		0.003	0.003	0.003	0.003	0.003
	Packer test	7	0.006	0.006	0.0001	0.002	0.01	0.01	0.02
	Pumping test	2	0.15	0.07	0.10	0.13	0.15	0.18	0.20
	Slug test	1	0.07		0.07	0.07	0.07	0.07	0.07
	Western model region	1	0.0001		0.0001	0.0001	0.0001	0.0001	0.0001
Dunda Beds	Calibrated model	1	0.08		0.08	0.08	0.08	0.08	0.08
	Slug test	3	1.08	1.66	0.002	0.13	0.25	1.63	3.00
	Western model region	1	0.08		0.08	0.08	0.08	0.08	0.08
Joe Joe Group	Calibrated model	1	0.0004		0.0004	0.0004	0.0004	0.0004	0.0004
	Packer test	4	0.001	0.0015	0.0002	0.0004	0.001	0.002	0.004
	Slug test	2	0.21	0.29	0.003	0.10	0.21	0.31	0.41
Moolayembe r Fm	Calibrated model	1	0.05		0.05	0.05	0.05	0.05	0.05
	Western model region	1	0.05		0.05	0.05	0.05	0.05	0.05
Rewan Fm	Calibrated model	1	7.40E-05		0.0001	0.0001	0.0001	0.0001	0.0001
	Packer test	24	0.0003	0.0003	0.0001	0.0002	0.0002	0.0004	0.001
	Slug test	4	0.10	0.13	0.002	0.02	0.06	0.15	0.29
	Western model region	1	7.40E-05		0.0001	0.0001	0.0001	0.0001	0.0001
Tertiary	Calibrated model	1	0.01		0.01	0.01	0.01	0.01	0.01
	Slug test	3	0.07	0.087	0.0002	0.03	0.05	0.11	0.17
	Western model region	1	0.01		0.01	0.01	0.01	0.01	0.01

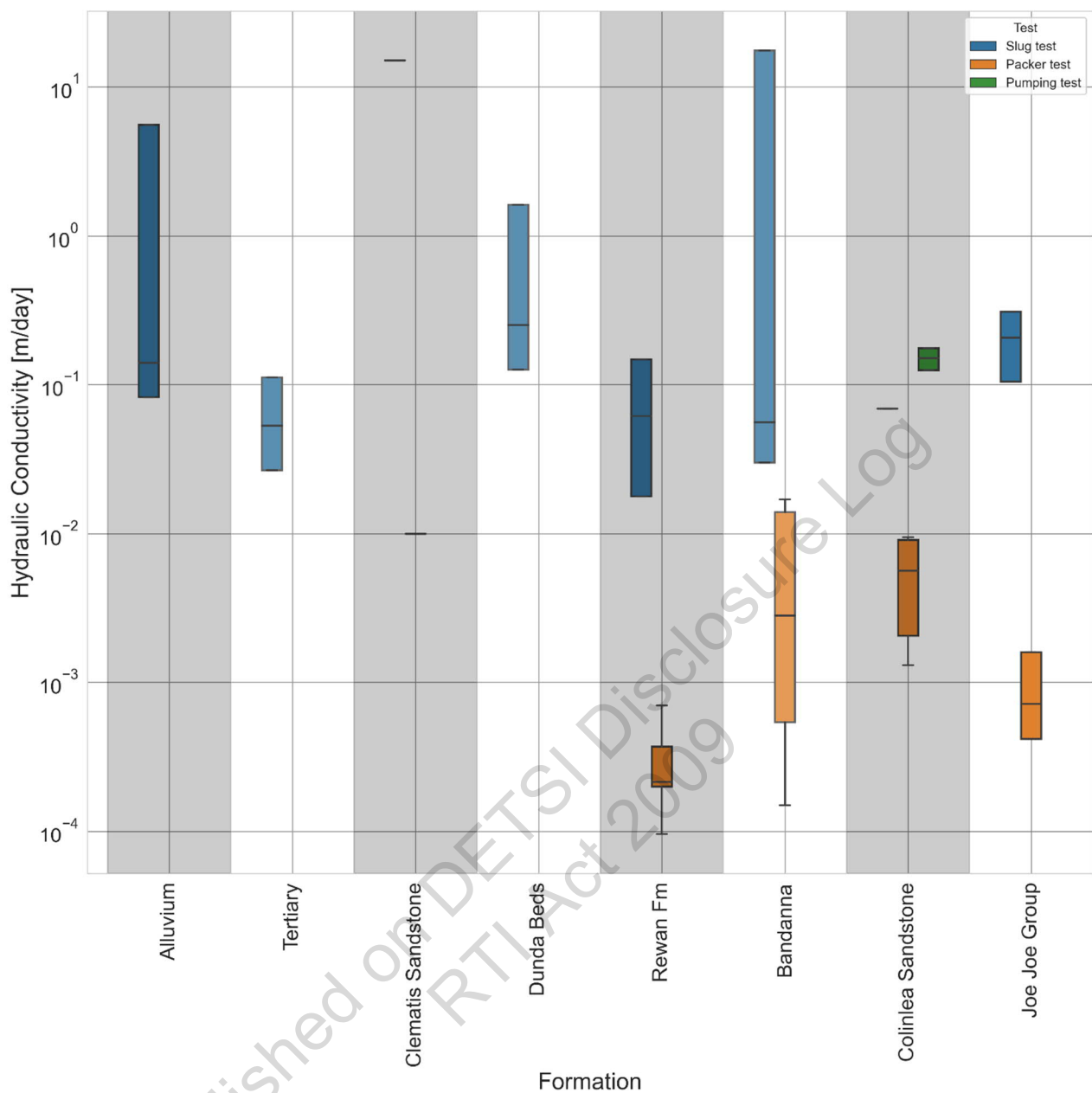


Figure 2.3 Boxplot of K ranges for each HSU by test type – based on data presented in GMMP (Table 8)

2.5 Mining induced conditions

Predicted hydraulic conductivity changes to the Rewan Group, Permian overburden and interburden associated with induced sub-surface fracturing caused by the underground mining were simulated previously in the numerical model. A separate study of subsidence suggested that a free draining fracture zone (conceptualised as Zone A in Figure 2.4) with a maximum height of approximately 150 m above each of the mined seams is likely to develop above the underground longwall mine workings. This free draining fractured zone is likely to be characterized by intense vertical fracturing thus creating potential for direct groundwater inflows from the overlying layers to the workings. Vertical hydraulic conductivity in the free draining fracture zone may be increased by a factor of up to 50. Furthermore, the relative change in vertical hydraulic conductivity is likely to be higher towards the base of the fracture zone than at the top. The most amount of change is thus assumed to be related to the Rewan Formation directly above the longwall panels, whereby a relatively tight aquitard (Section 2.1) will change to reflect a permeable aquifer with the potential for unconfined conditions, at least locally.

For SEIS modelling purposes, the free draining fractured zone had been simulated by increasing the natural (pre-mining) vertical hydraulic conductivity by a factor of 50 for the lower 50 percent of the zone and by a factor of 10 in the upper 50 percent. The development of the free draining fractured zones in the Permian overburden (model layer 8), Rewan Group (model layers 6 and 7) and in the Permian interburden (model layer 10) followed the underground mining schedule.

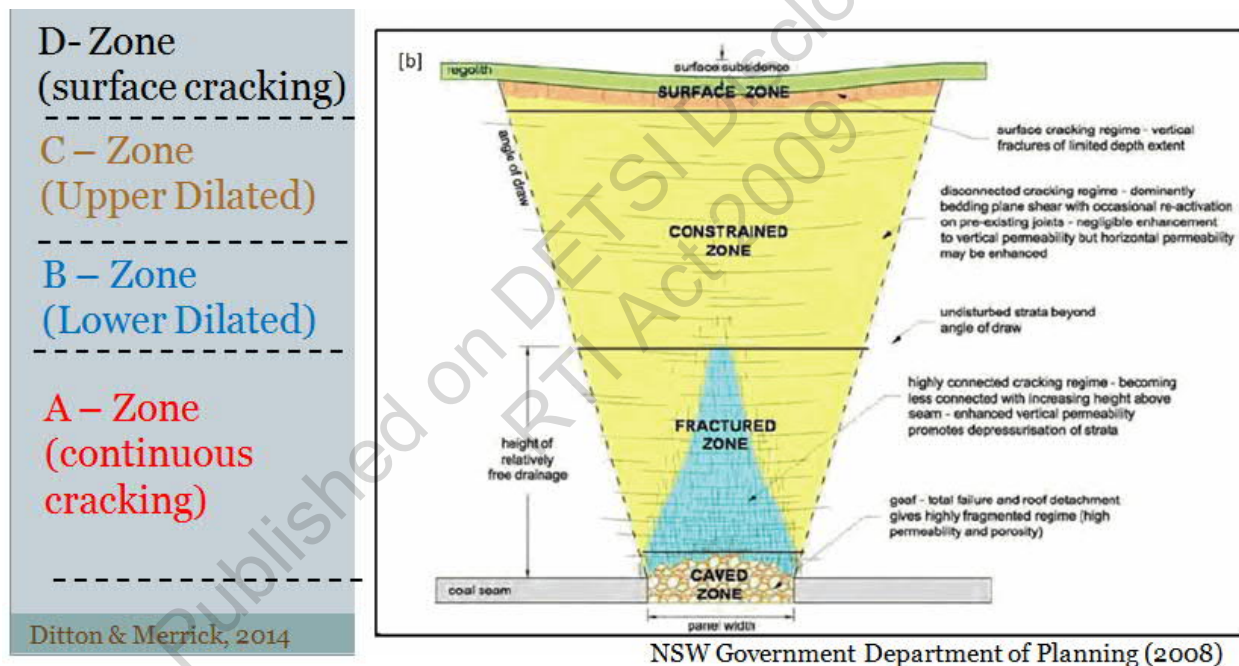


Figure 2.4 The Ditton conceptual model of deformation above a mined coal seam [from Ditton and Merrick, 2014]

2.6 Water balance

The SEIS groundwater model water balance is presented in Table 2.4 and Figure 2.5. These data illustrate that groundwater in the model domain was thought to be sourced partly from rainfall recharge, and partly from locations outside the model domain (as throughflow), and to be discharged primarily as evapotranspiration and discharge to water courses. Discharges at springs were not evaluated in the model water balance.

Table 2.4 SEIS groundwater model steady state water balance (GHD 2013c)

Component	Flow in (kL/d)	Flow out (kL/d)	Net (kL/d)
Recharge	2,533	-	2,533
Evapotranspiration	-	4,001	-4,001
Model boundary (throughflow)	44,680	41,466	3,214
Pumping	-	152	-152
Carmichael River	6,662	7,084	-421
Other water courses	-	1,200	-1,200
Total	53,876	53,904	-28 (-0.05%)

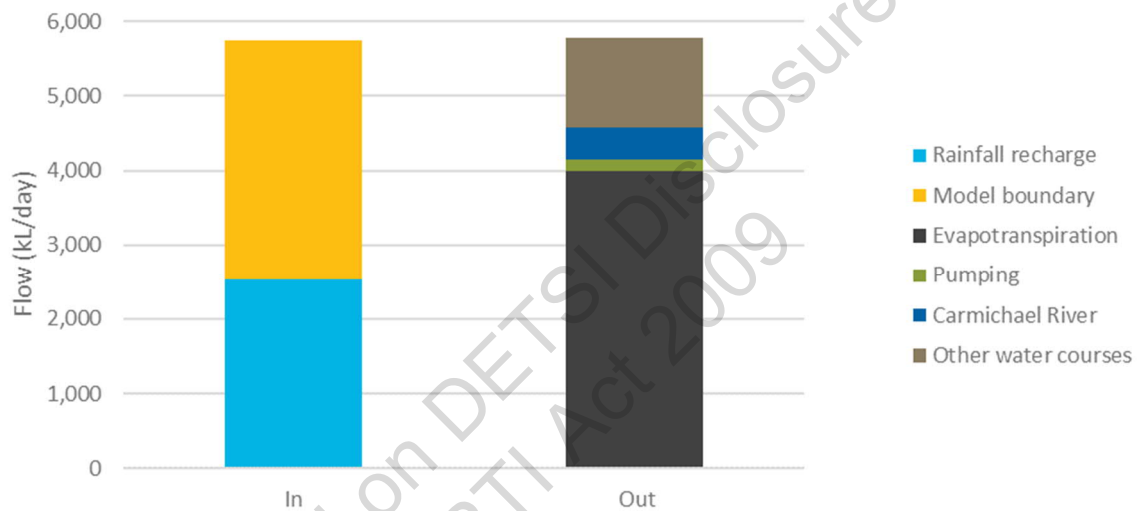


Figure 2.5 SEIS groundwater model steady state water balance net fluxes

2.7 Groundwater-surface water connectivity

2.7.1 Waterways

Within the SEIS groundwater model, all waterways were conceptualised as ephemeral streams, flowing only after rainfall. Other than the Carmichael River, all waterways were modelled as drains (using the RIV model package), allowing groundwater to discharge to dry stream beds where groundwater heads exceeded the ground surface.

The Carmichael River was modelled using the stream (STR) model package, which allows routing of flows and infiltration downstream. The use of the stream package in the model prevented infiltration estimates within the Carmichael River exceeding the volume of water available.

Yearly streamflow and baseflow volumes were not understood at the time of the SEIS. GHD (2013c) described that with the information at hand, there was no certainty whether groundwater discharges to the Carmichael River should be '70, 700 or 7,000 kL/d', with the presented model predicting net discharges of approximately 421 kilolitres per day (kL/d).

2.7.2 Springs

The Doongmabulla springs are described in the EIS (GHD 2012d) as a spring complex containing a number of spring groups (Figure 2.6) with distinct characteristics:

i Joshua

The Joshua spring group comprises one very active spring vent, located near the Doongmabulla homestead and just north of Carmichael Creek. This spring has been heavily modified to provide drinking water for the station homestead and livestock, and now comprises a large 'turkey nest' dam and associated overflow dams (GHD 2012d).

Joshua was described as having a 'modified, high flow spring' morphology.

ii Moses

The Moses spring group is located approximately two kilometres to the south of Joshua and comprises at least 30 vents spread over a radius of 2.5 km, all of which are within 400 m (either north or south) of Cattle Creek. Among these are well-formed mound springs supporting central pools to 1.5 m tall, and small isolated 'seepage mounds' of 20 centimetres (cm) or more. In four locations these mound springs have contributed water to broad shallow pools (often only a few centimetres deep), which has formed wetlands of approximately 3.5 hectares (ha) in total. Elsewhere, mounds have sometimes formed localised shallow pools up to 20 m in diameter. Other springs do not appear to have caused pooling of any kind (GHD 2012d).

The group of springs described as the 'Moses' group by GHD (2012d) is described by the Queensland Department of Regional Development, Manufacturing and Water as containing the following groups:

- Moses;
- Camp;
- Keelback;
- Mouldy Crumpet;
- Bush Pig Trap;
- Wobbly;
- Geschlichen;
- Stepping Stone;
- Bonanza; and
- Camaldulensis.

These spring groups contain the following spring morphologies:

- small artesian seeps, with no or very small mounds (less than 20 cm high) with no wetlands;
- non-mounding artesian spring (Camaldulensis spring) venting from exposed sandstone to a small creek supporting a wetland; and

- mound springs with a raised mound from 0.4 to 1.5 m above ground level, typically with a central pool containing dense vegetation.

iii Little Moses

The Little Moses spring group comprises a small number (two were located during the field inspection) of spring outlets draining into a closed depression that appears to be part of a relict channel of the Carmichael River. The spring outlets are located at approximately the same elevation (ie in a line that is parallel to the elevation contour) within 100 m of each other on a gentle run-off slope near the foot of a plain, at the point at which the plain approaches the Carmichael River. They have not formed mounds and the water is emanating from shallow gullies. The flow is sufficient that, as it approaches the relict channel in which it is collecting, it is eroding a substantial gully (almost 2 m deep and at least 30 m long) back into the plain (GHD 2012d).

Little Moses was described an 'incipient mound spring', as it has a number of characteristics indicate it may be a very young (incipient) spring:

- it does not contain any of the GAB spring wetland endemics, or other spring associated species such as *Hydrocotyle dipleura*;
- it has a dark, clay loam soil (instead of pale, sandy soil); and
- it is located within a woodland of river red gum rather than grassland or bare ground.

iv Other spring groups

A number of Doongmabulla spring groups were not discussed in the EIS:

- 'House', located on the northern side of Dyllingo Creek in the vicinity of Joshua and the Doongmabulla homestead;
- 'Yukkuna Kumoo', located on the northern side of the Carmichael River, 2 km east from Little Moses;
- 'Dusk', located on the northern side of the Carmichael River, 4 km east from Little Moses;
- 'Surprise', located on Surprise Creek, a tributary to Carmichael River 5 km east from Little Moses; and
- The Mellaluka springs were named in the EIS but not described.

The EIS presented a concept of the Doongmabulla springs formed by artesian discharges from the Clematis Sandstone aquifer through local weak points in the overlying Moolayember Formation (Figure 2.7), and the Mellaluka springs formed by discharges originating from the Colinlea Sandstone and travelling through the Tertiary sediments (Figure 2.8). In each case, GHD (2013b) assumed that the ultimate source of water was recharge from the Great Dividing Range and local outcrop areas.

GHD (2012d) reported that the total discharge from all Doongmabulla springs was approximately 1.35 megalitres per day (ML/d) based on an estimate provided by Rod Fensham (Associate Professor, University of Queensland) on 16 January 2012, with much of this volume entering local waterways and contributing to flow in the Carmichael River.

Within the numerical groundwater model, springs were modelled as:

- evapotranspiration (EVT) boundaries, removing groundwater from the model which approached the surface; and
- recharge seepage face (RSF) boundaries, which remove groundwater from the model which reaches the surface.

The volume of water removed from the model in these ways at spring locations was not reported.

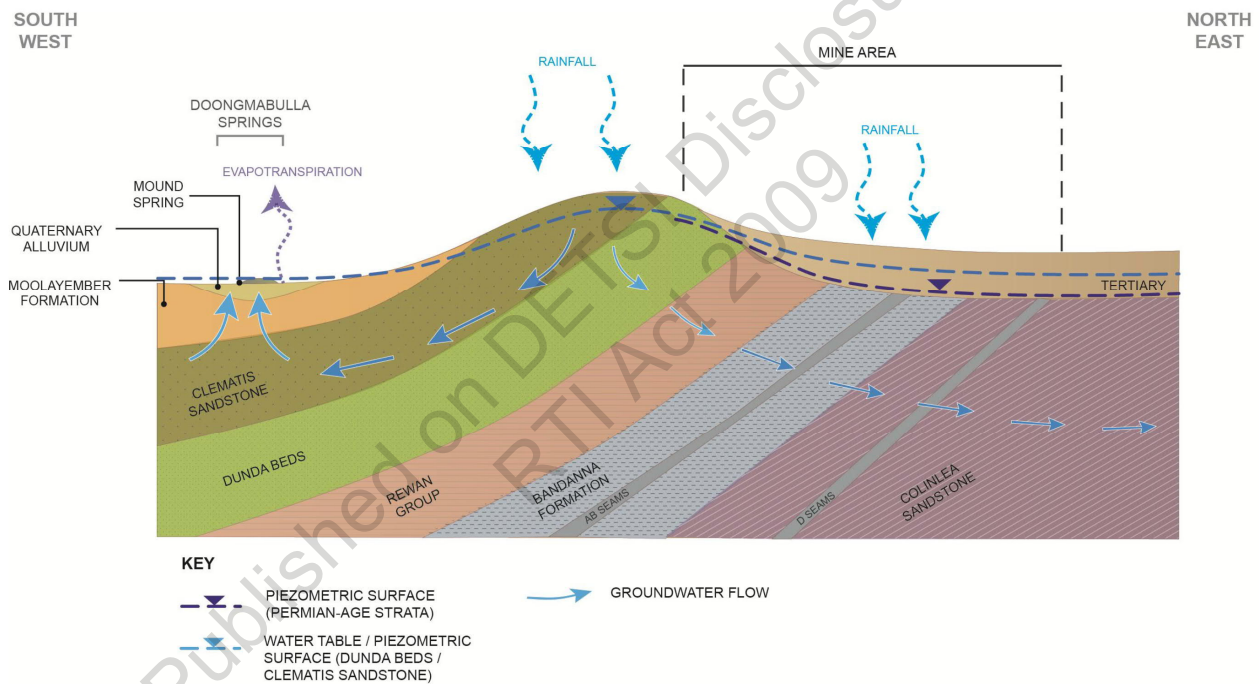


Figure 2.7 SEIS concept of Doongmabulla springs recharge and discharge (GHD 2013b)

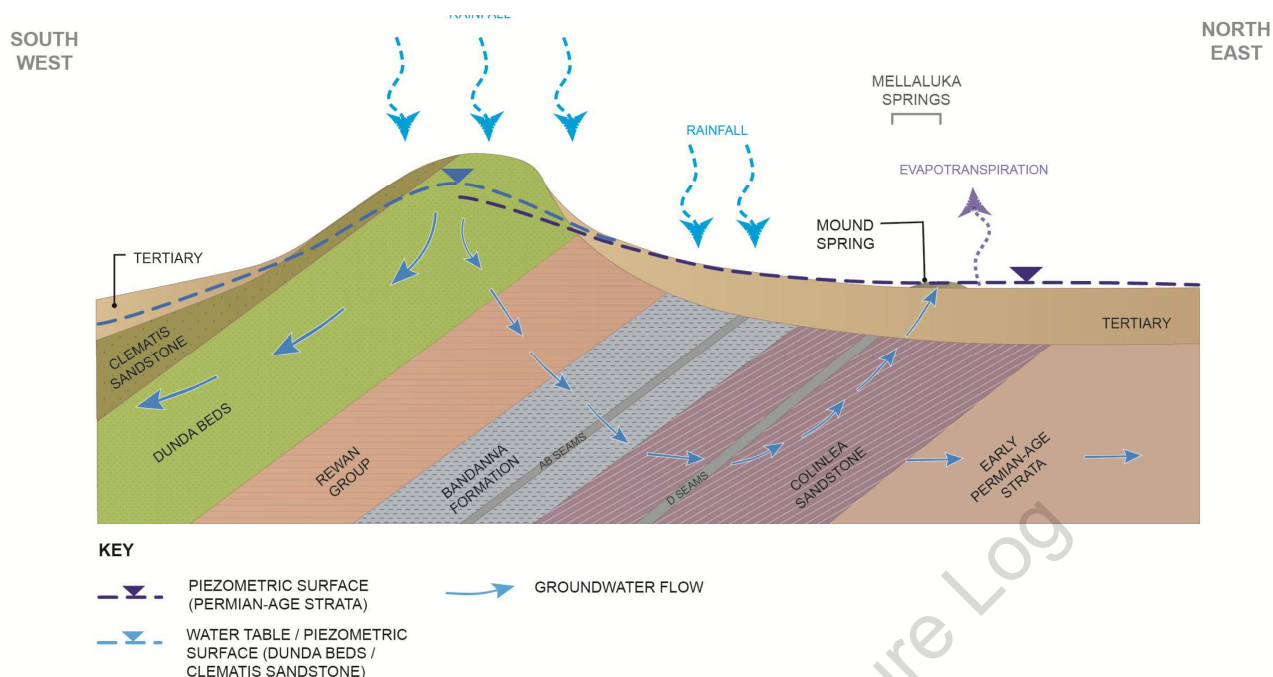


Figure 2.8 SEIS concept of Mellaluka springs recharge and discharge (GHD 2013b)

2.8 Hydrochemistry

The GMMP presents various plots comparing the compositional makeup of surface water within the DSC and Carmichael River and groundwater within the different hydrostratigraphic units. Plots of boron versus sulphate indicate that variations in water chemistry in the surface water and groundwater samples are likely to result from two broad compositional scenarios, as shown in Figure 2.9, and summarised below:

- Rainfall ingress. In this scenario, units are exposed to varying degrees of rainfall recharge that results in compositions moving from relatively high sulphate and boron (ie reflecting the lithological composition) to lower concentrations as groundwater mixes with 'clean' rainwater. This is the likely scenario for Triassic, Tertiary and alluvial sediments.
- Limited rainfall ingress. In this scenario, variation in groundwater quality reflects the compositional nature of the aquifer lithologies with limited rainfall ingress. This is the likely scenario for the Permian units including the Bandanna Formation, Colinlea Sandstone and Joe Joe Group.

The compositional variation shown in the Rewan Formation may have characteristics of both scenarios and represent the compositional change between the younger (higher rates of recharge) lithologies of the Triassic, Tertiary and alluvial sediments versus the older (limited recharge) Permian units.

Overall, water quality results indicate that samples from the DSC and Carmichael River are more compositionally similar to the Clematis Sandstone which is likely to be the source aquifer of the DSC.

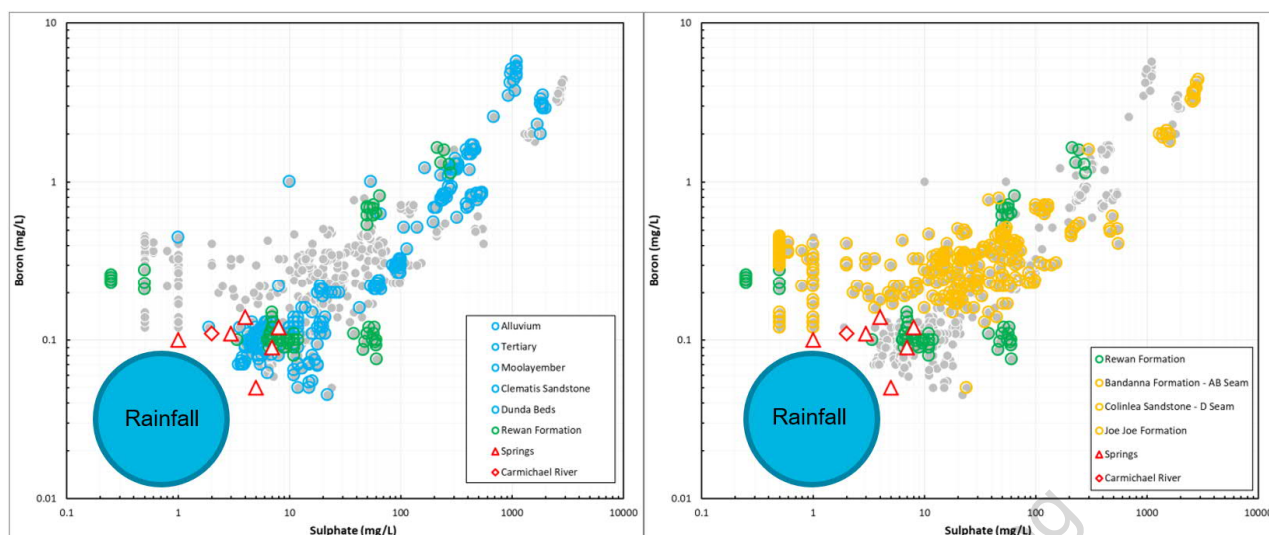


Figure 2.9 Variation in sulphate and boron concentrations from potentially rainfall impacted groundwater (left) and groundwater less impacted by rainfall (right)

2.9 Summary of Previous HCM

The main features of the existing HCM documented as part of the SEIS and summarised in the latest version of the GMMP (AECOM, 2020) and documented by GHD (Appendix K1, 2013) include:

- the Permian coal-bearing units of the Colinslea Sandstone and Bandanna Formation are overlain by (in ascending stratigraphic order) the Triassic Rewan Formation, the Dunda Beds, the Clematis Sandstone (which is also equivalent to the Warang Sandstone) and the Moolayember Formation, which occurs at surface to the west of the mine lease area;
- the Dunda Beds have been logged in boreholes along the western edge of the Adani Lease;
- the nearest recognised Great Artesian Basin (GAB) aquifer unit to the Adani Lease is the Clematis Sandstone;
- the Rewan Formation within the Galilee Basin is characterised by generally fine-grained siltstone and mudstone with intercalated sandstones that contain labile minerals and abundant clay matrix (Vine 1976, Grigorescu 2012). The Rewan Formation subcrops beneath Tertiary/Quaternary alluvium within the mine lease area, and is generally regarded as a regional aquitard;
- although the Dunda beds also lie between the coal seams and the overlying aquifers, the Rewan is the principal resistance layer that imparts control on vertical hydraulic connectivity due to its generally low vertical hydraulic conductivity;
- in general terms the Rewan Formation it is a very distinctive unit that is easily recognisable in drill core and chips;
- groundwater levels, typically flow from the south-west to the north-east and from the west, converging at the site;
- hydraulic gradients are typically upward in the southern area of the mine, and downward in the northern section;
- the strongest upward gradient is observed around the Carmichael River;

- groundwater recharge was estimated between 0 and 44 millimetres per year (mm/yr) based on recharge-runoff modelling and chloride mass balance estimates. During the numerical model calibration stage, recharge rates between 0.1 and 0.5 mm/yr were implemented (GHD, 2013);
- open cut mining was planned for 59 years, with the underground mine starting at Mine Year 6 and being completed at Mine Year 46;
- six open cut pits, with depths in excess of 300 m, are planned to mine the AB seam and the deeper D seam;
- longwall mining was planned to occur to the west of the open cut pits, and extend to depths in excess of 500 m over the life of mine;
- the previous SEIS model predicted peak mine inflow of 26 ML/d at Mine Year 17, with 60% attributed to the underground mine and the remaining 40% from the open-cut mine operation; and
- longwall mining was assumed to create fracturing above the longwall panels, with increase hydraulic conductivity simulated to a height of 150 m. Vertical hydraulic conductivity was increased by a factor of 50 for the lower 50% of the fractured “free draining” zone, and by a factor of 10 in the upper 50%.

2.10 Summary of past review and criticisms

A detailed summary of past review comments of the existing hydrogeological conceptual and numerical models are presented in Section 13. Objections have been raised by a range of reviewers, with specific criticisms relating to the following:

- the range of measured hydraulic parameter data not defined in the HCM;
- uncertainty in geometry of regional hydrostratigraphy;
- low spatial coverage of regional hydrogeological field data;
- estimates of recharge rates not given per outcropping HSU;
- lack of clarity regarding potential presence/influence of faults;
- insufficient detail on lateral and vertical groundwater gradients;
- potential for hydraulic connection between target coal and GAB (ie hydraulic properties of Rewan Formation) not fully understood;
- conceptualisation of springs incomplete, with uncertainty particularly regarding source aquifer for Doongmabulla Springs; and
- magnitude and extent (lateral and vertical) of induced hydraulic property changes from longwall mining activities.

Updates to the conceptual model have been made in conjunction with newly available data (given in Section 3) and with particular focus on responding to uncertainties raised with the previous conceptual model.

3 Research programs and new datasets

3.1 GAB Springs Research Plan

The GAB Springs Research Plan (GABSRP) is required as part of the EPBC Act Approval 2010/5736, Condition 25. The Plan aims to systematically investigate the GAB springs and their connection to Project activities in order to establish facts and reach robust conclusions about whether the project will likely cause a material impact to GAB springs and how these impacts can be managed, if identified.

One of the key objectives of the research plan is to estimate the timing and magnitude of any hydrological changes at the Doongmabulla Springs Complex caused by project activities and contextualising these changes in relation to background trends and influences. While these changes have been modelled as part of the previous approval studies, the objective of the work undertaken in the GABSRP is to further reduce uncertainty in the updated groundwater drawdown predictions and to provide a clearer understanding of how these changes are likely to manifest in the hydrology of the spring wetlands.

The GABSRP is aimed to be delivered over a five-year period with a high-level timeline summarised in Table 3.1. Note that the Rewan Research Package (RP5) has already been delivered and the outcomes are summarised in the Section 3.2. Year 2 packages (RP1.4 to RP3.1) are due for delivery in quarter three of 2022.

Table 3.1 GABSRP research packages, status and timeline

Research package (RP)	Status	Timeline (year)				
		1	2	3	4	5
RP 1.1: Hydrogeology review and monitoring	Completed	■				
RP 1.2: Geochemical survey	Completed	■				
RP 1.3: Geological mapping	Completed	■				
RP1.4: Spring wetland hydro(geo)logical conceptualisations and water balance	In progress	■	■			
RP1.6: Hydrogeological conceptualisation review and updated groundwater modelling	In progress	■	■			
RP2.1: Ecological surveys and monitoring	In progress	■	■			
RP2.2: Hydro-ecological conceptualisation and assessment of key species	In progress	■	■			
RP3.1: Desktop prevention and mitigation scoping study	Yet to start		■			
RP3.2: Pilot testing of prevention and mitigation methods	Yet to start			■	■	
RP3.3: Prevention and mitigation strategy	Yet to start					■
RP4.1: Desktop offset scoping study	Yet to start		■			
RP4.2: Targeted ecological surveys	Yet to start		■			
RP4.3: Targeted hydro-ecological studies	Yet to start		■			
RP4.4: Remediation assessment and trial	Yet to start			■	■	
RP4.5: Remediation and offset strategy	Yet to start					■

Notes: RP1.6 is the current study, with this report representing the first of several deliverables.

3.1.1 RP1.1 – Hydrogeological review and monitoring report

ELA engaged EMM to deliver RP1.1 (EMM, 2021a) which aimed to understand recent groundwater conditions and trends surrounding the CCP through analysis of baseline groundwater level and chemistry data collected between September 2011 and February 2021.

This report found that many bores on site were experiencing a reduction in groundwater levels over time. The decline in groundwater levels was likely due to a combination of climatic factors and mine dewatering activities. A long-term below average rainfall trend occurring from 2013 onwards may have contributed to the decline in groundwater levels, while mine dewatering activities caused more recent groundwater levels to decrease in bores screened within the Bandanna Formation and Colinlea Sandstone.

Statistical analysis of groundwater quality data found that multiple bores in each stratigraphic unit, except for the Moolayember Formation, were found to have decreasing pH, TDS and manganese trends. These trends were determined to likely be due to natural phenomena and not mine-related activities. The data collected suggests that little if any acidification has occurred due to mine dewatering activities.

3.1.2 RP1.2 – Geochemical survey and source water analysis

EMM was engaged by Bravus in 2021 to undertake a geochemical study (EMM, 2021b) into the source aquifer of the DSC which is an update of the 2018 research program (Adani, 2019a). The 2021 geochemical study examined the major and trace element compositions and the isotope characteristics of the surface water sampled from the DSC and both the groundwater sourced from the primary lithological/hydrostratigraphic units of interest and the source rock compositions of these units, to provide a greater level of understanding into the nature of the potential DSC source aquifer. The main findings are summarised in Section 9 and strongly indicate geochemically that the DSC is more likely to be sourced from groundwater originating in the underlying Triassic Clematis Sandstone (with potential input from the Triassic Moolayember Formation), than from groundwater originating from either of the deeper potential groundwater sources in the Permian Bandanna Formation, Colinlea Sandstone, or the Joe Joe Group.

3.1.3 RP1.3 – Geological mapping

Tetra Tech was commissioned to prepare surface geology maps at a scale of 1:25,000 or smaller focusing on the Doongmabulla Springs Complex. The objective of the geological mapping was to improve understanding of the source aquifers to the springs, their pathways and relative contributions. This was achieved by developing more detailed maps of the surface geology and by preparing refined geological cross-sections in proximity to the springs to the depth of the available and augmented boreholes. The scope of work undertaken has included a desktop review of background information including LiDAR data and mapping of approximately 48km² of terrain surrounding the Doongmabulla Springs complex. The updated 1:25,000 geological map is shown in Figure 3.1 and has been considered as part of the Rewan Formation Connectivity Research Plan (RP5) when developing the updated geological model for the CCP.

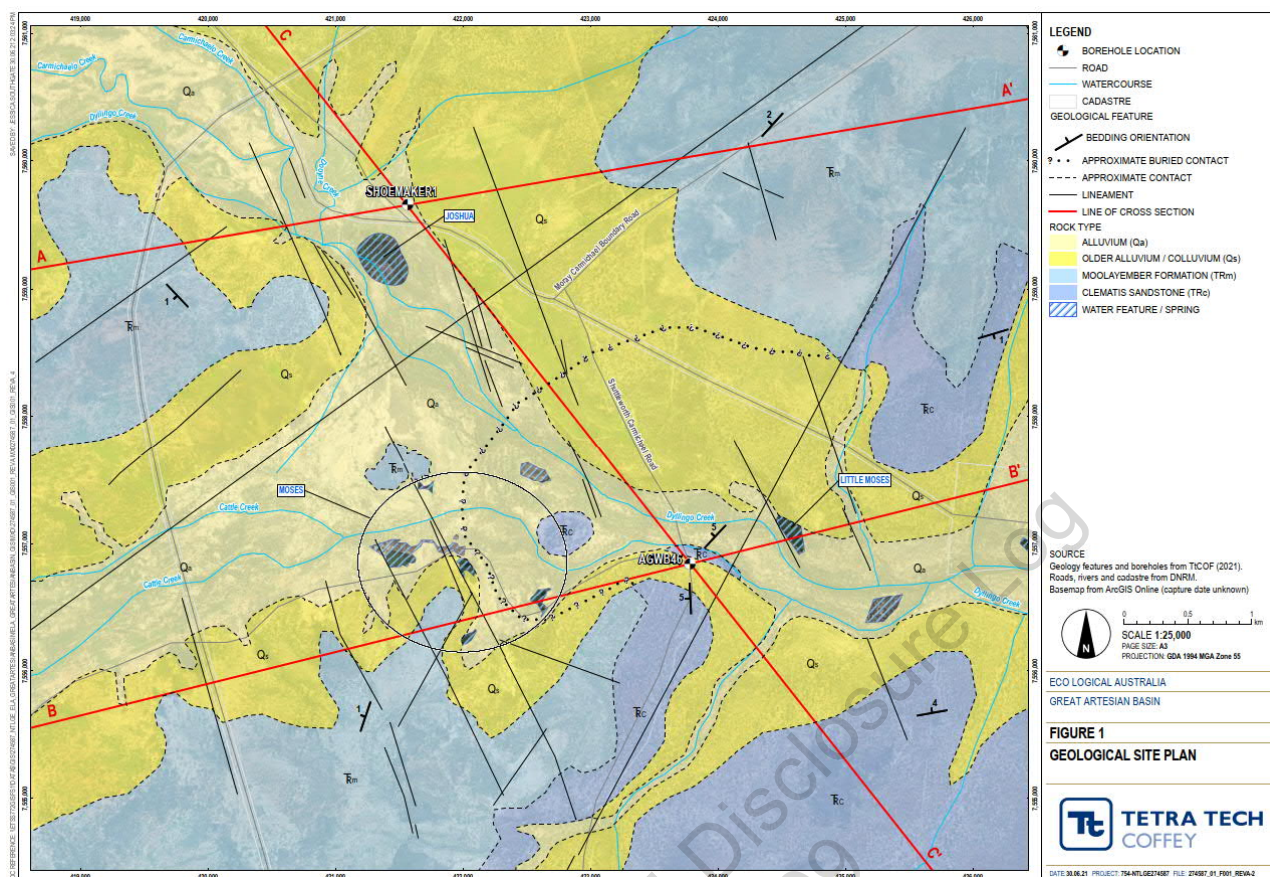


Figure 3.1 Updated 1:25,000 geological map (Tetra Tech Coffey, 2021)

3.1.4 RP1.4 – Spring wetland conceptualisation and water balance

The scope for RP1.4 includes developing a spring wetland hydrogeological conceptualisation and water balance, to be completed over GABSRP years 1 and 2. During year 1, survey data required for the water balance was collected, including detailed LiDAR survey of the Doongmabulla complex area, and survey of spring wetland areas and depths. Spring water balance development is scheduled to be delivered in year 2 of the research program, due in August 2022.

The wetted area and perimeter of Doongmabulla spring wetlands was measured quarterly from May 2019 to August 2020 by FRC Environmental (ELA 2021). Wetland areas and depths varied seasonally, potentially as a result of rainfall runoff and seasonal evaporation rates (Figure 3.2).

An early conceptualisation of the spring water balance is detailed in Section 10.1 and is a precursor of the works to be completed as part of RP1.4.

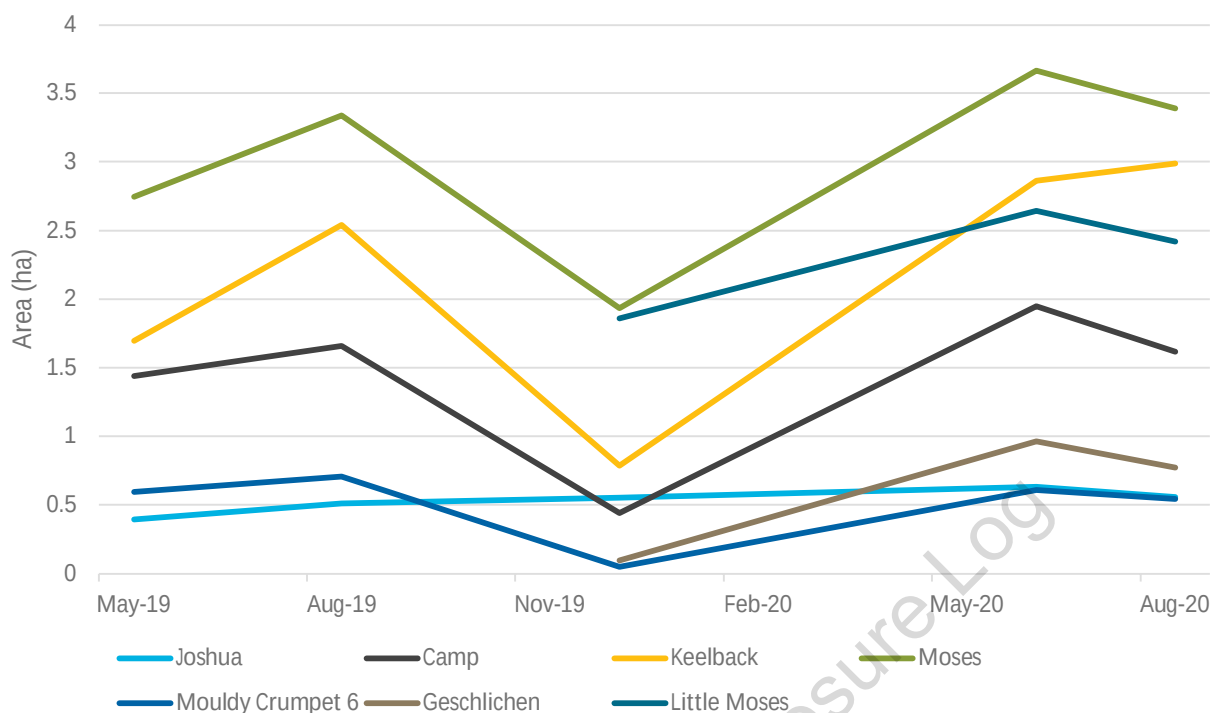


Figure 3.2 Surveyed Doongmabulla wetland areas (ELA 2021)

3.2 Rewan Formation Connectivity Research Plan (RP 5)

During the EIS/SEIS/AEIS phases, various studies related to the geological conceptualisation, hydrogeological setting and development of a numerical groundwater model and related project impacts were scrutinised by the Coordinator General. The approval document “Carmichael Coal Mine and rail project- Coordinator- General Evaluation report” had identified certain areas where further information needed to be collected and additional studies required to reduce uncertainties. The effect of faulting and potential subsidence induced fracturing in the Rewan Formation strata was a large uncertainty highlighted.

With respect to the Rewan formation, the Coordinator-General’s report states that “DNRM agreed with the IESC’s advice that the integrity of the Rewan Formation as an aquitard is critical to the impacts of mining and dewatering activities in this area. DNRM advised that it would therefore support the requirement for the development of a Rewan Formation Connectivity Research Plan for the Carmichael project as was required of Kevin’s Corner in the approval by the Commonwealth Minister for the Environment.” The Rewan Formation Connectivity Research Plan (RFCRP) has been developed to meet the requirements of EPBC Approval Condition 27 of the EPBC approval. The Plan combines existing monitoring and modelling programs with an initial period of intensive desktop research primarily focussed on characterising the Rewan Formation and the contribution of fracturing, faulting and preferential pathways to connectivity within the area impacted by the mine. This will be followed by ongoing monitoring and further validation as operations commence.

The RFCRP commenced in late 2020 with the relevant findings and outcomes presented at a Workshop in Brisbane on the 24 November 2021. The RFCRP consisted of 12 (twelve) individual Research Packages conducted by independent researchers with the appropriate qualifications and experience to meet deliverables as defined under The Plan. All lead researchers, appointed as approved researchers by the Minister, are recognised experts in their fields. The lead researchers had been tasked with specific work scopes and deliverables within their own area of expertise and capability. This has provided for a focussed approach for the individuals to meet the objectives and deliverables required for each specific condition, without requiring individuals to pass judgement on areas which may be beyond their scope or area of defined responsibility and capability.

Table 3.2 Rewan research plan and main findings

Research project	Lead scientist	Main findings and implications to numerical model update
		<p>Rewan Formation -argillaceous characteristics</p> <p>Statistical analysis of downhole gamma and resistivity profiles has demonstrated that the Rewan Formation is more argillaceous than the formations above (Clematis Sandstone) and below (Bandanna Formation), based on persistently higher gamma counts and lower resistivity values throughout most of the Rewan interval.</p> <p>The median resistivity within the Rewan Formation is 12-13 ohm-metres which is indicative of dominant clay/claystone.</p> <p>Further evidence of the Rewan's primarily argillaceous nature is provided by swelling pressures being significantly lower in the Clematis Sandstone than in the Rewan Formation, indicating higher clay content in the latter.</p> <p>Based on the gamma response alone and a nominal demarcation value of 100 API units, the Rewan Formation would be classified as ranging from 24% to 47% sandstone at three examined sites.</p> <p>Net sand intervals (allowing for clay content in the sandstones) form only about 3% of the Rewan's total thickness at three examined sites (Pentagram, 2021).</p> <p>Stratigraphic connectivity</p> <p>When individual hydraulic conductivities in the more permeable intervals of the Rewan are examined spatially, there is no evidence of spatially extensive higher permeability zones.</p> <p>Strata of higher permeability, or vertical zones of higher connectivity, are not supported by the available data. Accordingly:</p> <p>There is very low potential for groundwater flow through the identified thin sand units.</p> <p>There is extremely low potential for vertical groundwater flow through the Rewan Formation.</p> <p>The opportunity for vertical flow between the Bandanna and Rewan formations is also limited.</p> <p>Fractured Zones / Strata alteration</p> <p>Two analytical models for fracture zone height (A) was assessed for the Carmichael underground long wall panels including:</p> <p>Ditton and Merrick, 2014; and</p> <p>Tammetta, 2013.</p> <p>The A-zone height varies from 105 to 297 m for the Ditton method and from 191 to 267 m for the Tammetta method. Respective averages are 232 m (Ditton) and 226 m (Tammetta), while the medians are 252 m (Ditton) and 225 m (Tammetta).</p> <p>The Ditton method indicates that fracturing to ground surface would occur or possibly occur over 28 panels, while the corresponding prediction using the Tammetta algorithm is 24 panels.</p> <p>The expected locations of fracturing to surface (according to the Ditton geology model) has been illustrated within the study. The algorithm prediction is more extensive than anticipated in the SEIS (MSEC, 2013) where a uniform height of 160 m was adopted, without any variation for multi-seam effects. Under this assumption, fracturing to surface would occur over only eight panels.</p> <p>The volume of argillaceous material in the fracture zone and its swelling potential within the Rewan Formation, would serve to limit the degree of vertically connected fractures.</p> <p>Complete fracturing to land surface, if it were to occur, is unlikely to pose prolonged issues due to the ready availability of clay in the Tertiary cover that would facilitate self-sealing of cracks.</p> <p>Fractured heights will need to be assessed appropriately as part of the modelling predictive uncertainty analysis.</p>

3.3 Updated hydrogeological datasets

Data used to update the conceptual groundwater model are summarised in Table 3.3.

Table 3.3 Updated hydrogeological data sets

Data type	Description
Digital Elevation Model	<p>LiDAR data was captured for the Doongmabulla Springs (extent illustrated below) in 2021 by Aerometrex.</p> <p>Horizontal resolution: 1 m</p> <p>Supplied: Imagery (10 cm pixels), canopy height model, ground surface model</p> 
Exploration bore hole data	<p>Additional information received:</p> <ul style="list-style-type: none"> • Coffey, D., Grigorescu, M., Mckellar, J.L. & Isles, A., 2017: A review of the geology and exploration history of the Lopingian (late Permian) coals in the northern Galilee Basin. Queensland Minerals and Energy Review Series, Department of Natural Resources and Mines, Queensland. • Earth Signal Processing (2015) COI 2015 Seismic Reprocessing Project Carmichael Prospect ATP744, Galilee Basin Queensland. • Fallon (2019) Carmichael 2018 Seismic Reprocessing Report, Report prepared for Adani Mining. • COI (2010) 2010 Drilling Programme Montani 1 Well Completion Report ATP 744P Galilee Basin Central Queensland, Report prepared for Comet Ridge. • COI (2010) 2010 Drilling Programme Shoemaker 1 Well Completion Report ATP 744P Galilee Basin Central Queensland, Report prepared for Comet Ridge. • RPS (2012) Galilee Basin Report on the Hydrogeological Investigations, Report prepared for RLMS. • PSM (2011) Carmichael Coal Project – Open Cut Geotechnical Position Statement, Report prepared for Adani Mining. • Carmichael Coal Mine Project lab porosity, rock swell index, triaxial permeability and UCS data (2021).

Table 3.3 Updated hydrogeological data sets

Data type	Description
Groundwater levels	<p>Manual and automatic level logger data for groundwater wells to September 2021:</p> <ul style="list-style-type: none"> Alluvium: 11 sites Bandanna formation: 18 sites Clematis Sandstone: 12 sites Colinlea Sandstone: 17 sites Doongmabulla springs spears: 5 sites Dunda beds: 7 sites Jo-Jo group: 18 sites Moolayember: 2 sites Rewan formation: 13 sites Homestead bores: 4 sites Tertiary sediments: 5 sites Weathered tertiary sediments: 8 sites
Groundwater chemistry	<p>Groundwater chemistry analysis:</p> <ul style="list-style-type: none"> EMM (2021) Carmichael Coal Mine Great Artesian Basin Springs Research hydrogeological review and monitoring report to support Research Package 1.1, Report prepared for Eco Logical Australia, in Appendix A of ELA (2021) Great Artesian Basin Springs Research Plan Year 1 Annual Report, Report prepared for Bravus Mining. EMM (2021) Great Artesian Basin Springs Research Plan geochemical investigation into the source aquifer of the Doongmabulla Springs complex, Report prepared for Bravus Mining.
Rainfall	<p>Bravus weather station data:</p> <ul style="list-style-type: none"> Glenavon (Jan 2020 – May 2020). Labona (Aug 2019 – Feb 2021). GDR (August 2019 – Jan 2022).
Surface water	<p>Stream level data:</p> <ul style="list-style-type: none"> Carmichael River 5 sites Belyando River 2 sites
Pumping data	<p>Aquifer test data:</p> <ul style="list-style-type: none"> URS (2013a) Carmichael Coal Project Groundwater Data Compilation, Report prepared for Adani Mining. GHD (2014) Construction Water Supply Groundwater Impact Assessment Modelling, Memorandum prepared for Bravus Mining. Bravus pumping test data at site C18102PT, undertaken in 2019. Bravus pumping data for mine dewatering commencing in August 2019.
Mine plan	<p>Bankable Feasibility Study (2014) site layout, prepared by Adan Mining Pty Ltd.</p> <p>Supporting documents:</p> <ul style="list-style-type: none"> Geowork Engineering (2015) Carmichael Underground Project Geotechnical design for the northern underground area, Report prepared for Adani Mining. SCT (2014) Assessment of Caving, Overburden Conductivity and Longwall Support Requirements for Carmichael Project Galilee Basin, Report prepared for Adani Mining.

4 Climate

4.1 Long-term rainfall and EVT

Rainfall records are available from several nearby Bureau of Meteorology (BoM) stations as well as on-site stations. Due to limited rainfall data being available from the site stations, which began recording in July 2019, the BoM Ulcanbah station (036050) was used to assess long-term rainfall trends for the area. This station is approximately 30 km west of the CCP and has been operational since 1937.

Long-term average monthly rainfall from Ulcanbah is provided in Table 4.1, as well as the monthly rainfall in 2020 for both the Ulcanbah and Labona Camp (on-site) station. Comparison of the 2020 rainfall data for both stations shows that the Ulcanbah and Labona Camp data are very similar in terms of rainfall trends and magnitude. This suggests that Ulcanbah is an appropriate proxy for the site, and any conclusions derived from the analysis of the long-term Ulcanbah rainfall data should also be applicable to the site.

Long-term average rainfall values from the Ulcanbah station show that the majority of rainfall occurs from December to March. December and January are the wettest months with rainfall exceeding 100 millimetres (mm) on average. June through to September are the driest months, with rainfall below 20 mm on average.

Figure 4.1 compares the potential evapotranspiration occurring at the site to the average rainfall. The average monthly evapotranspiration and rainfall values were obtained from the BoM climate maps (BoM 2022a), which are based on 30-year climatology. This figure shows that the potential evapotranspiration is approximately 50 mm greater than the average rainfall Jan–Aug, and 100 mm greater than average rainfall Sep–Dec.

Table 4.1 Long term average monthly rainfall

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Long-term average rainfall (mm) Ulcanbah (1937–December 2021)	110.0	111.1	67.3	33.5	22.4	17.5	16.6	13.9	10.2	25.7	44.9	64.8	537.6
Ulcanbah rainfall (mm; 2020)	142.2	104.4	15.0	0.0	29.2	0.0	1.5	0.6	18.2	38.7	7.6	252.8	610.2
Site rainfall (mm) Labona Camp (2020)	169	104	82	0	40	0	0	0	17	28	3	247	690

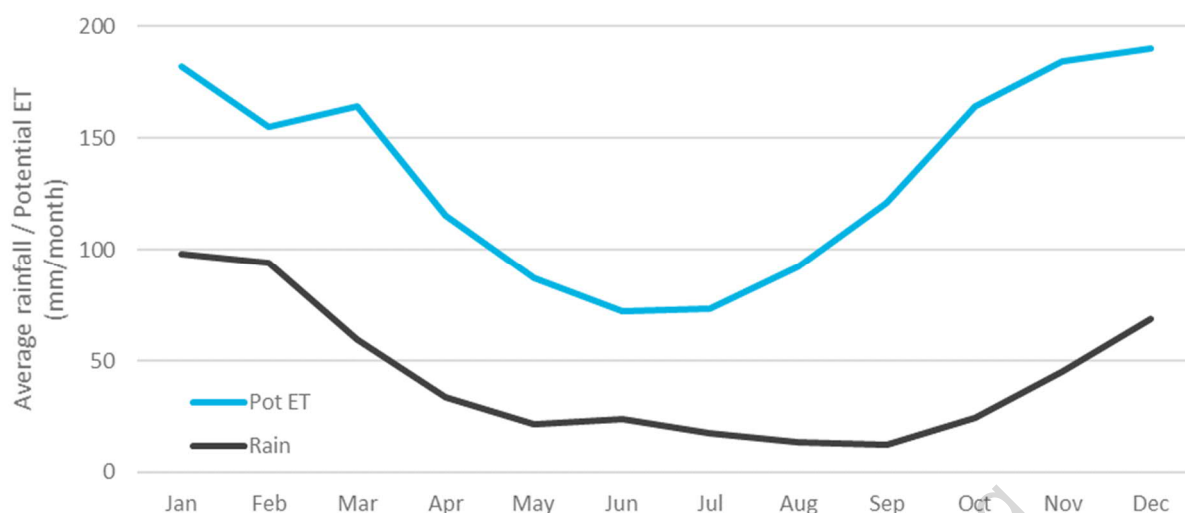


Figure 4.1 Average monthly rain and potential ET (BoM 2022a)

4.2 Cumulative rainfall departure

The cumulative rainfall departure (CRD) method (Weber and Stewart 2004) shows graphically the monthly rainfall trends compared against long-term average monthly rainfall. A rising trend in the CRD indicates periods of above average rainfall (and possibly increased groundwater recharge to unconfined aquifers), whilst a falling slope indicates periods of below average rainfall and hence decreased recharge to unconfined aquifers.

The CRD for the period 1937 to December 2021, calculated from Ulcanbah rainfall data, is shown in Figure 4.2 and can be summarised as follows:

- the area has experienced distinct cycles of above average and below average rainfall since 1937;
- from approximately 2007 until 2013, an above average rainfall trend occurred in the area;
- more recently, the area has generally experienced below average rainfall conditions since 2013;
- it could therefore be expected that groundwater levels in monitoring bores screened across aquifers which are recharged by rainfall may also show a decline in groundwater levels since 2013; and
- the below average rainfall trend appears to be in the process of reversing, as the CRD plot has slowed its descending trend over the past few years. The CRD has remained approximately constant since the start of 2019, indicating roughly average rainfall conditions from January 2019 until December 2021.

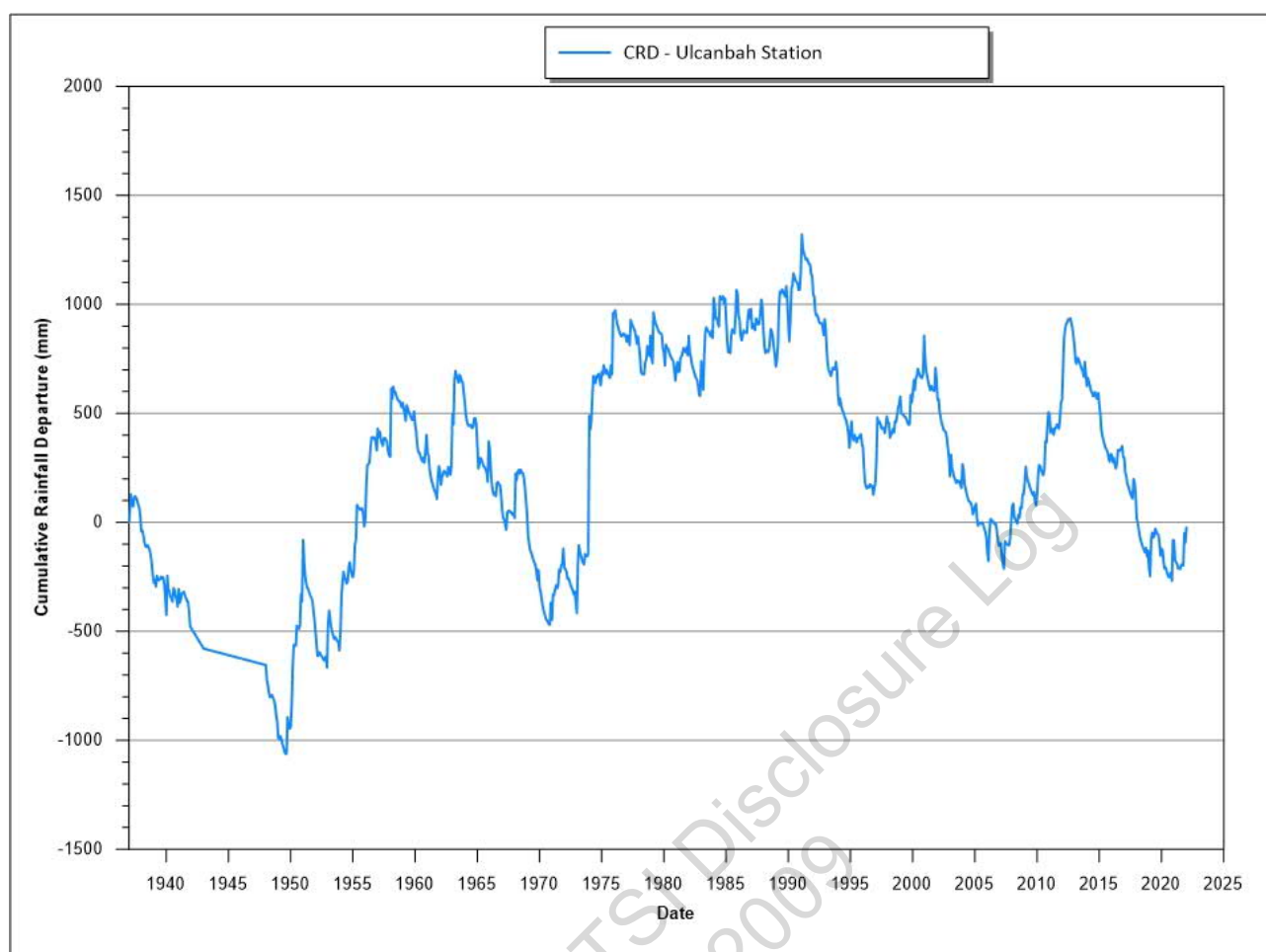


Figure 4.2 Cumulative rainfall departure – Ulcanbah (BoM station 036050)

4.3 Post-EIS climate patterns

Recent rainfall trends occurring in the years following the publication of the EIS (GHD 2013a) in 2013 are shown in Table 4.2. In contrast to the increasing rainfall trend observed from approximately 2007 to 2013, annual rainfall totals were below the long-term average of 537.6 mm from 2014 to 2019. Due to this, groundwater level and quality data collected after 2013 may not be reflective of the baseline data presented in the EIS. Post-2019, the rainfall conditions are more aligned with average rainfall.

Table 4.2 Recent rainfall trends (mm) (2014-2021; Ulcanbah Station 036050)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
2014	59.2	148.2	50.8	13.4	0	9.8	0	23.7	20.2	0	37.8	92	455.1
2015	N/A	9.0	1.4	6.0	0.8	0	0	4.6	0	0	26.8	99.6	>148.2
2016	106.6	78.4	85.4	0	8	43.7	76.2	8.4	13.8	30.8	58.4	13.6	523.3
2017	108.6	42.6	50.6	0	9.4	0	0.8	0.8	0	115.2	29.8	5.2	363
2018	3.8	92.6	39.2	1.4	1.2	2	1.4	0	0	46.2	5.8	90.8	284.4
2019	26.4	77.4	233.8	66.8	0	25.8	48.8	0	0	24.2	6.4	5.8	515.4
2020	142.2	104.4	15	0	29.2	0	1.5	0.6	18.2	38.7	7.6	252.8	610.2

Table 4.2 Recent rainfall trends (mm) (2014-2021; Ulcanbah Station 036050)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
2021	106.0	20.4	60.2	26.4	0	18	13.6	35.1	6.2	25.4	192.6	21.8	525.7

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5 Revised geological setting

Results of the research programs and analysis of the new datasets summarised in Section 3 have allowed for an improved understanding of the geological setting of the CCP.

Overall, work undertaken as part of the various Rewan Research Packages has confirmed the general stratigraphy of the area as was presented in the GMMP. Outcomes from Rewan Research Package 5.5 have confirmed the stratigraphic location of the Rewan Formation separating the deeper Permian sediments from the Clematis Sandstone at the location of the DSC, based on interpretation of 2D seismic lines. Thickness estimations and strata dips of the Triassic and Permian units have also been confirmed with thickness of the Rewan Formation ranging from 240 m to 364 m and the thickness of the Clematis Sandstone ranging from 93 m to 124 m between the CCP and the DSC.

This section presents a summary of the key revisions to the understanding of the geological setting from that which was presented in the latest version of the GMMP and EIS approval documentation. Key revisions were largely informed from a new structural geological model as detailed below.

5.1 New structural geological model

A new representative 3-dimensional structural geological model was built using available surface topography, drill hole data, outcrop geology and geophysics (seismic and AEM) as part of Rewan Research Package 5.6 (Murray 2021). The outcrop data used in construction of this model included both publicly available Queensland Geological Survey Data (ie 1:100,000 and 1:500,000 scale surface geology maps) and the 1:25,000 scale surface geology map compiled as part of the GAB Springs Research Package 1.3 (see Figure 3.1). Drilling data used in the model was based on the output of the lithofacies interpretation undertaken during Rewan Research Package 5.2. This lithofacies interpretation involved an expansion of the original lithofacies interpretation by UQ (2015) to include six additional bores located in the western extent of the area nearer the DSC.

Outputs from the 3-dimensional structural geological model include a series of cross-sections (included in Appendix A) and layer surfaces. The 3-dimensional structural geological model will be used to construct and update layers within the existing groundwater model. Key revisions to the geological setting informed from the 3-dimensional structural geological model are presented below.

5.2 Scarp retreat and weathering profile

A distinct weathering profile, which crosscuts Permian and Triassic sediments, is discernible from borelog observations. The boundary between the base of weathering profile and underlying 'fresh' Triassic sediments forms a distinct topographic scarp which dips towards the east of the mining leases, as illustrated in Figure 5.1. The base of weathering shows a distinct thickening towards the scarp. Murray (2021) states that this morphology is consistent with the process of scarp retreat whereby significant rainfall events have eroded outcrops over time. Murray (2021) further states:

"The Rewan unit is likely to erode preferentially, causing the stiff and more resistive (to weathering) Dunda and Clematis to collapse to the east. As the Clematis collapses, the Moolayember fine-grained rocks will be eroded and mixed to form a scarp weathering profile. The weathering profile will be a very poorly sorted set of sediments dominated by the weathering products of the fine-grained Moolayember and Rewan. The geometry of these scarp materials and the lower permeability more plastic weathering profile may well act as a lateral aquitard for the semi-confined Clematis aquifer".

The weathering zone was not represented as a layer within the existing groundwater model. The weathering zone will be included as a low permeability layer within the updated groundwater model.

6 Hydraulic properties

This section of the report focusses on new hydraulic testing completed during 2020/21 to support research programs on the Rewan Formation integrity and the functioning of the Doongmabulla Springs. These recent targeted tests bolster the hydraulic properties database and provide a more complete understanding of the hydraulic characteristics of key aquifers and aquitards at the site.

6.1 Hydraulic conductivity

Table 6.1 presents a summary of the new hydraulic testing that has been completed in the project study area as part of the 2020/21 hydrogeology research investigations. The locations of the newly drilled bores are shown spatially on Figure 6.1.

These new tests provide additional insights into the permeability of the Rewan Formation aquitard, as well as the Clematis Sandstone, Dunda Beds and Moolayember Formation. Hydro Algorithmics (2021) presents a detailed account of test logistics (locations, depths, formations etc) and the interpreted individual estimates of Kx (packer, shut-in and core tests) or Kz (core tests) as part of RP5.4. Table 6.1 shows that most of this testing was focussed on the Rewan Formation aquitard (37 new tests), to address criticisms of aquitard properties and hydraulic functioning raised during the EIS and SEIS (see Section 13).

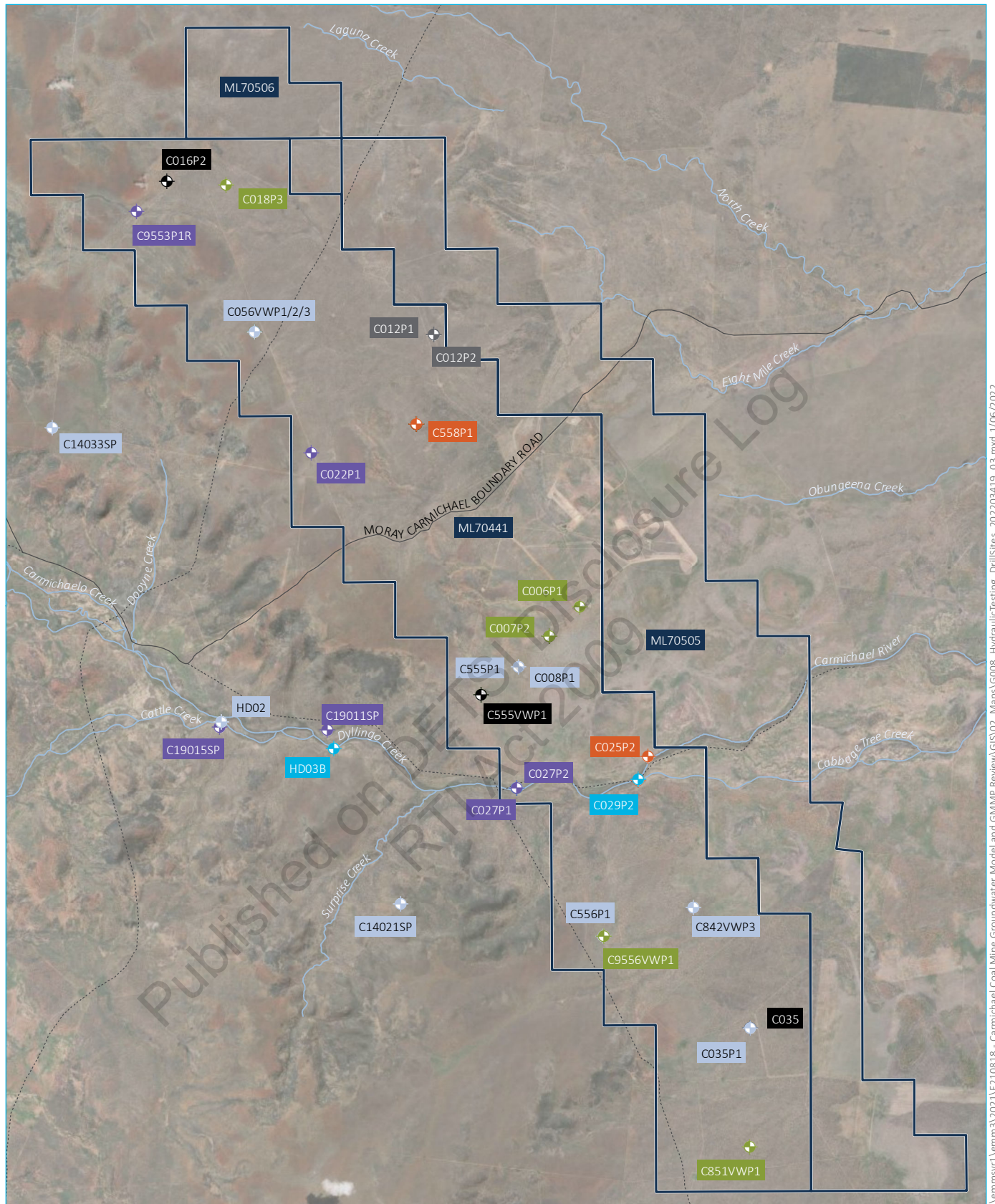
Table 6.1 Summary of new hydraulic testing completed in 2020/21

Test type	Clematis Sandstone	Dunda Beds	Rewan Formation	Moolayember Formation
Packer testing			2 testing locations	
Aquifer testing		2 shut-in tests	1 shut-in test	
Laboratory core testing	2 test intervals (2 Kx; 2 Kz)	4 test intervals (1 Kx; 4 Kz)	17 test intervals (17 Kx; 17 Kz)	1 test interval (1Kx; 1Kz)

Table 6.2 below presents a statistical summary of the 2020/21 laboratory-derived hydraulic conductivity estimates for the Rewan Formation. Overall, this table summarises 21 individual estimates of Kx and 30 individual estimates of Kz for the Rewan aquitard. The average and median Kx values across all tests at all three sites are 9.2×10^{-4} and 2×10^{-5} m/d, respectively. Conversely, the average and median Kz values for the same cohort of sites is 2.7×10^{-6} and 2.2×10^{-5} m/d. The anisotropy ratio for mean estimates of Kx and Kz are in excess of 300.

Table 6.2 Statistical summary of 2020/2021 laboratory-derived hydraulic conductivity estimates for the Rewan Formation (after Hydro Algorithmics, 2021)

Site	Arithmetic Mean Kx (m/d)	Harmonic Mean Kz (m/d)	Median Kx (m/d)	Median Kz (m/d)	Kx / Kz (for means)	Kx / Kz (for medians)
17	1.2×10^{-5}	6.8×10^{-6}	9.0×10^{-6}	4.1×10^{-5}	1.7	0.2
18	1.4×10^{-3}	1.6×10^{-6}	1.0×10^{-5}	4.2×10^{-6}	888	2.4
46	1.0×10^{-3}	3.1×10^{-6}	9.5×10^{-5}	7.5×10^{-5}	331	1.3
ALL	9.2×10^{-4}	2.7×10^{-6}	2.0×10^{-5}	2.2×10^{-5}	335	0.9



Source: EMM (2022); DNRME (2021); DES (2020); GA (2011); ESRI (2022)

KEY

- Mining lease
- Minor road
- Vehicular track
- Named watercourse
- + Screened HSU
- + Alluvium
- + Bandanna Formation
- + Clematis Sandstone
- + Colinlea Sandstone
- + Dunda Beds
- + Joe Joe Group
- + Rewan Formation
- + Tertiary Sediments

Location plan showing drill sites
used for hydraulic testing

Carmichael Coal Mine
Data Review and Conceptualisation Report
Figure 6.1

Table 6.3 presents a statistical summary of packer testing completed for the Rewan Formation (16 tests at seven sites), inclusive of the new 2020/21 datasets. The average Kx value is around 4×10^{-4} m/d and the median of about 2×10^{-4} m/d. These values in Table 6.3 are similar to those reported by JBT Consulting (2015) before the new 2020/21 testing programs (Hydro Algorithmics, 2021). Those previous values ranged between 7×10^{-5} to 1.4×10^{-3} m/d.

Table 6.3 Statistical summary of packer-test derived horizontal hydraulic conductivity estimates for the Rewan Formation (after Hydro Algorithmics, 2021)

Site	Minimum Kx (m/d)	Arithmetic Mean Kx (m/d)	Median Kx (m/d)	Maximum Kx (m/d)
ALL	6.6×10^{-5}	4.3×10^{-4}	2.4×10^{-4}	1.8×10^{-3}

The high density of Kx and Kz estimates generated from dedicated testing at cored holes C14202VWP (Site 17), C14201VWP (Site 18) and C19842C (Site 46), and shut-in testing at C19016SPR allow for interrogation of depth relationships in hydraulic conductivity. Figure 6.2 presents a semi-log scatter plot of Kx and Kz (log) versus depth (linear) for Rewan Formation core testing, packer testing and shut-in testing from the recent 2020/21 program. This plot shows a clear reduction in Rewan Kx and Kz values with depth. This depth relationship is further defined in Table 6.4, which separates the data into incremental 100 m bins. This table shows a sudden drop in Kz below 400 m depth.

Petrophysical analysis of the Rewan Formation indicates that only 7% of the formation is likely to contain more permeable sandstone capable of fluid flow (Pentagram Geophysics, 2021). Further, of the sandstone beds within the Rewan, 84% have a thickness of less than 1 m; hence, the low net to gross for the interval and thin nature of the sandstone lenses themselves, establishes a very low potential for lateral or vertical connectivity for fluid flow. This petrophysical interpretation is consistent with the Kx measurements shown in Figure 6.2. There are zones of slightly higher Kx, that are likely associated with thin and compartmentalised sandstone lenses dominantly surrounded by tighter and fine-grained siltstones and mudstones.

Figure 6.3 presents updated hydraulic conductivity statistics (using all historical and recent data) for each of the HSUs, separated by hydraulic testing type. For comparison, Figure 6.4 presents the same data, segregated chronologically by historical investigations. A comparison of these two figures shows that the 2020/21 testing program has yielded lower ranges of K estimates for the Dunda Beds and Rewan Formation, compared to previous investigations. Of significance to regional and local groundwater flow systems, the Rewan Formation Kx estimates presented on the two figures tend to be several orders of magnitude lower than previous estimates obtained during the AEIS, SEIS and network expansion programs. Conversely, the new testing for the Clematis HSU has yielded similar ranges of K compared to previous investigations. Core testing of the Moolayember Formation has indicated very low K estimates, that classify this unit as a major aquitard across numerous Queensland geological basins.

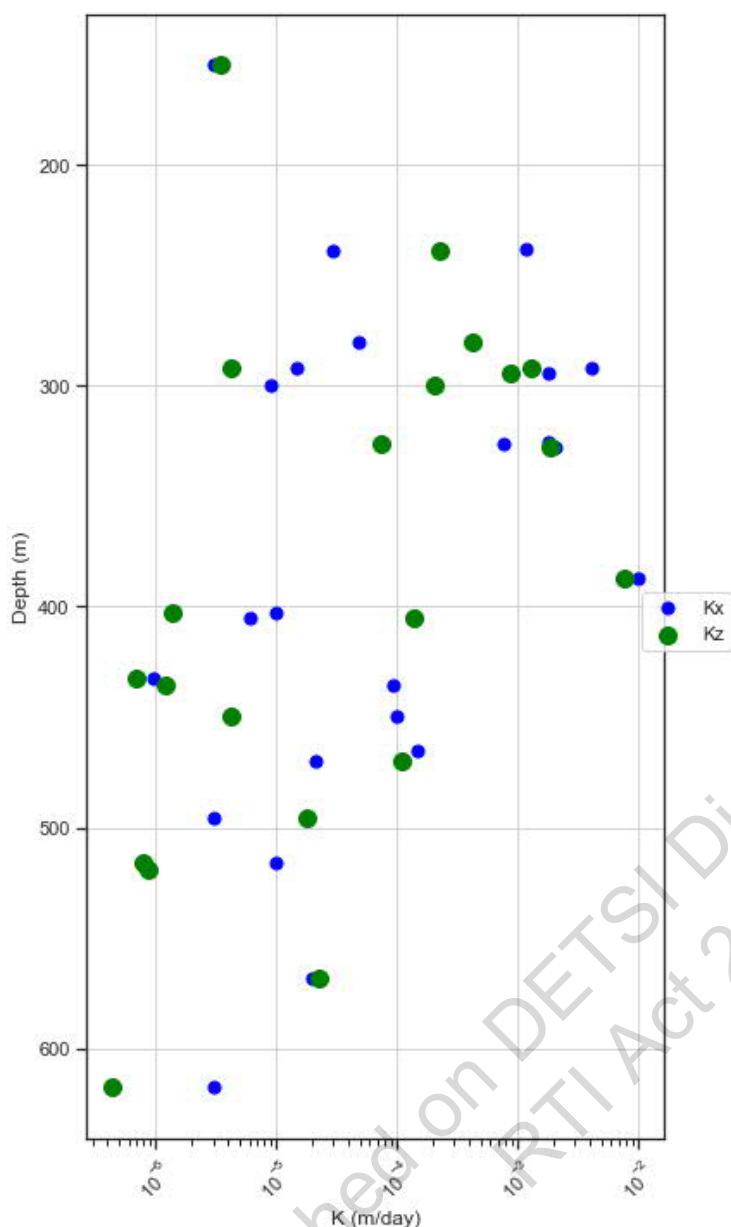


Figure 6.2 Scatter plot of Kx and Kz versus depth for Rewan core, packer and shut-in tests from the 2020/21 program

Table 6.4 Statistical breakdown of Rewan Kz (m/d) in incremental depth bins of 100 m for the new 2020/21 investigation data

	100 to 200 m	200 to 300 m	300 to 400 m	400 to 500 m	500 to 600 m	600 to 700 m
Minimum	3×10^{-6}	4×10^{-6}	7.5×10^{-5}	6.9×10^{-7}	7.8×10^{-7}	4.4×10^{-7}
Median	3×10^{-6}	4.3×10^{-4}	1×10^{-3}	4.2×10^{-6}	8.6×10^{-7}	4.4×10^{-7}
Maximum	3×10^{-6}	1.3×10^{-3}	7.7×10^{-3}	1.3×10^{-4}	2.3×10^{-5}	4.4×10^{-7}
Count	1	5	4	7	3	1

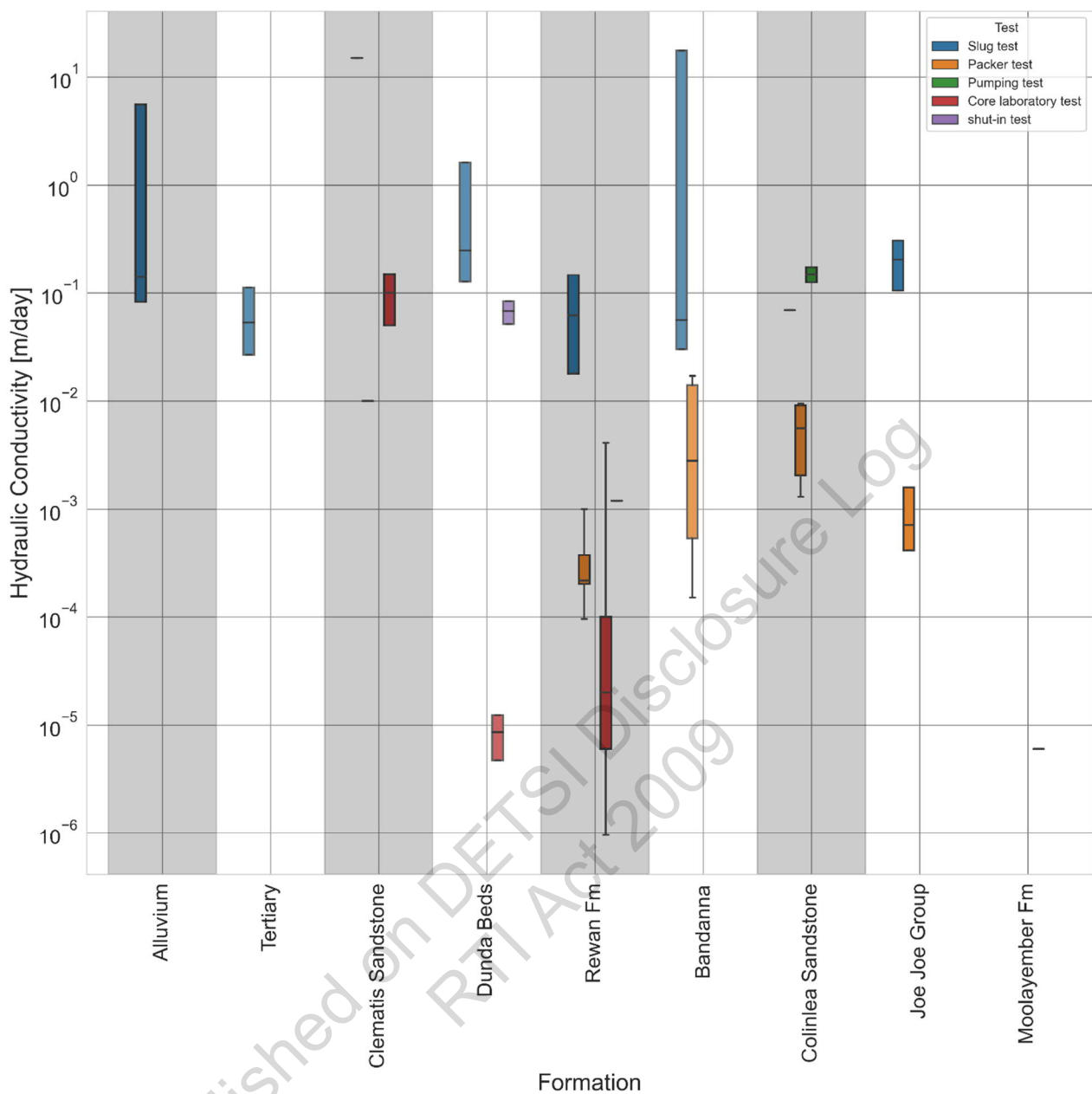


Figure 6.3 Box plot of horizontal hydraulic conductivity estimates by formation grouped by aquifer test type for all historical testing at site

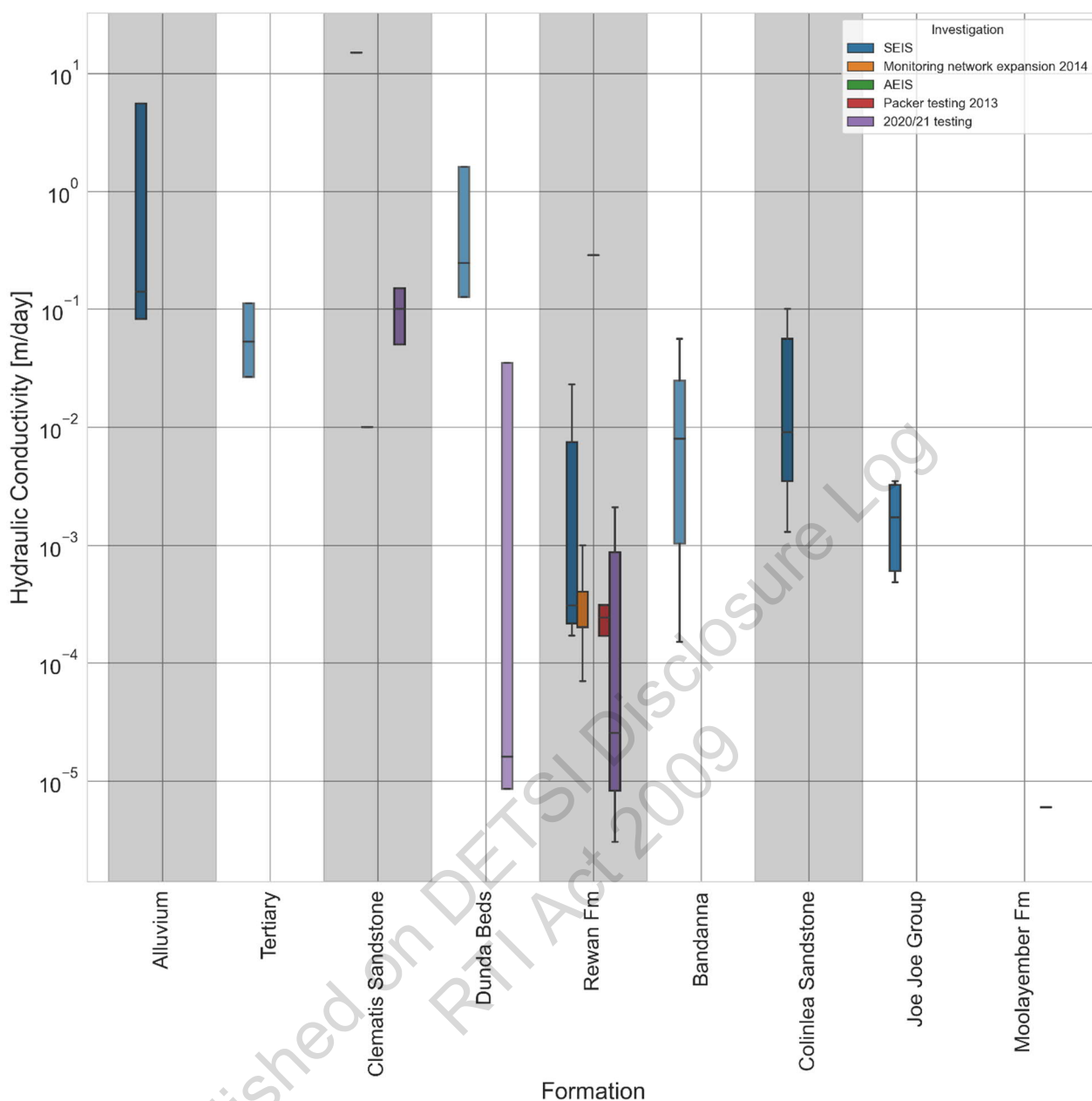


Figure 6.4 Box plot of horizontal hydraulic conductivity estimates by formation grouped by investigation program for all historical testing at site

6.2 Geophysical insights on material properties

Hydro Algorithmics (2021) present a detailed summary of geophysical testing and interpretation at the newly drilled boreholes. The following paragraphs present a high-level summary of Hydro Algorithmics findings.

A full suite of downhole geophysical logs was recorded at sites 3, 45 and 46 (refer to Figure 6.1) within boreholes C19841C, C919013SPR and C19842C, respectively. Pentagram (2021) has developed a detailed geological interpretation of Rewan lithofacies based on the downhole geophysical data. Each 10 cm stratum was classified into one of 19 facies and grouped into one of three lithologies (coal, siltstone, sandstone). The lithologies were then grouped into the major formations in the stratigraphic column. The boundaries between the major formations were also identified and updated. The output of the analyses is a three-dimensional (3D) lithofacies model of the mining lease and its near environs, illustrated by correlation panels across strike and along strike. The main findings from the 3D lithofacies modelling include:

- the Clematis Sandstone has the lowest gamma response due to its arenaceous nature, apart from occasional clayey strata with high gamma counts;
- the Rewan Formation is almost uniformly argillaceous with high gamma counts, with rare sandy intervals (low gamma) which are not correlated laterally; and
- the Bandanna Formation has a wide gamma range, with low gamma opposite coal seams.

By assessing the “shale volume” through the Rewan profiles to account for clay content within sandstone intervals, using the gamma and density logs, Pentagram (2021) calculated net sand intervals¹ of only about 3% at sites 3, 18 and 46, compared to 71-80% in the Clematis profiles. The XRD analysis found a quartz content of 88% for the Clematis Sandstone at site 46, in good agreement with the inference from gamma analysis.

For all bores in the Carmichael area, the corresponding net sand fractions are 7% in the Rewan Formation and 56% in the Clematis Sandstone. This suggests very low potential for lateral groundwater flow and extremely low potential for vertical groundwater flow through the Rewan Formation. Pentagram (2021) also found a lack of continuity between boreholes for identified net sand units, most of which (ie 84%) have a thickness of less than 1 m. In the underlying Bandanna Formation, the proportion of net sand is 15% and most intervals (ie 86%) have a thickness of less than 1 m (Pentagram, 2021). It follows that the opportunity for vertical flow between the Bandanna and Rewan formations is limited.

6.3 Storage Properties

Geotechnical measurements were made on four Rewan Formation core samples by Trilab, with depths ranging from 273 to 470 m, in accordance with Australian Standard AS 4133.4.3.1 (HydroAlgorithmics, 2021). The measurements included Uniaxial Compressive Strength (UCS), Young’s Modulus E and Poisson’s Ratio (η). The latter two properties were derived from a plot of axial stress vs strain for both tangent and secant methods (HydroAlgorithmics, 2021).

Young’s Modulus (E) and Poisson’s Ratio (η) are used to calculate specific storage (S_s) required for groundwater modelling:

Equation 6-1: Specific storage formulation

$$S_s = \rho g (\alpha + n \beta) \quad [L^{-1}]$$

where:

ρ is the density of water	$[ML^{-3}]$
g is gravitational acceleration	$[LT^{-2}]$
α is rock compressibility	$[M^{-1}LT^2]$
n is porosity	$[-]$
β is water compressibility	$[M^{-1}LT^2]$

Equation 6-2: Rock compressibility formulation

$$\alpha = \frac{(1 + \eta)(1 - 2\eta)}{E(1 - \eta)}$$

¹ Defined as having shale volume < 30% and porosity > 10%

In addition, six core samples with notional “clayey” properties were selected for measurement of their swelling potential, with depths ranging from 275 to 473 m. Tests were conducted by Trilab in accordance with Australian Standards AS 4133.3.3 and AS 4133.1.1.1. Test durations varied from 3.6 to 7.1 months. The ratio of final to initial moisture content ranged from 1.3 to 3.8 (median 2.0). Dependent on clay mineralogy, argillaceous rocks are prone to swelling as a result of adsorption of water which can cause an increase in volume or an increase in external pressure.

No previous measurements had been made of E and η , but together they allow determination of the specific storage (S_s) property that is required for groundwater modelling of confined strata (HydroAlgorithmics, 2021). Table 6.5 provides a summary of S_s statistics for the Rewan Formation from laboratory testing.

Table 6.5 Specific storage statistics for the Rewan Formation (after HydroAlgorithmics, 2021)

Method	Minimum S_s (m^{-1})	Arithmetic mean S_s (m^{-1})	Median S_s (m^{-1})	Maximum S_s (m^{-1})
Short Secant	3.7×10^{-7}	2.8×10^{-6}	2.1×10^{-6}	6.6×10^{-6}
Long Secant	3.5×10^{-7}	2.3×10^{-6}	1.7×10^{-6}	5.3×10^{-6}
Ratio	1.05	1.21	1.18	1.23

The key findings from the analysis of relevant geotechnical properties are:

- the average specific storage is about $2.8 \times 10^{-6} m^{-1}$;
- there is no consistent difference between notional “clayey” (argillaceous) and “sandy” (arenaceous) values;
- values range from 3.7×10^{-7} to $6.6 \times 10^{-6} m^{-1}$;
- there is a very wide range of swelling pressures from 5 to 549 kPa, with mean 92 kPa and median 62 kPa;
- Clematis Sandstone swelling pressure values are low as expected (5 and 11 kPa); and
- through the Rewan Formation, 60% of swelling pressure values exceed 50 kPa. This supports the observations by drilling crews that boreholes frequently tend to block from swelling clays.

6.4 Vertical flow paths and effects of longwall mining

As part of the RFCRP, all potential preferential vertical flowpaths were considered as shown in Figure 6.5. The preferential groundwater flow following longwall mining (Flowpath E) was considered the most significant contribution to vertical flow. Evidence was gathered using the following materials and methods:

- geomechanics principles;
- geomechanical modelling;
- groundwater modelling principles;
- core and packer permeability measurements;
- measurement of Young's Modulus, Poisson's Ratio and Uniaxial Compressive Strength (UCS);
- XRD mineralogy;
- measurements of swelling pressure;

- lithofacies model; and
- piezometry.

The findings were:

- preferential groundwater flow will occur through deformed strata above longwall panels;
- groundwater pressures will be reduced either due to actual drainage of water into the goaf or by a flattening of the hydraulic gradient (at higher elevations) without drainage of water;
- a greater disruption of the rock overburden will occur from multi-seam mining where multiple mining footprints overlap;
- numerical geomechanical modelling is capable of predicting complex fracture patterns and aperture distributions. SCT (2021) as part of RP5.10 simulated fractures to ground surface for 100% of longwall panels (Figure 6.6);
- in contrast, the highly fractured zone (Zone A, Figure 2.4), is expected to vary between 105 to 297 m for the Ditton method with a multi-seam correction, with a mean of 252 m. This indicates the analytical solution predicts fracturing to ground surface only over 28 panels, covering 48% of the underground mine footprint (Figure 6.6);
- permeability increases are expected to increase by up to a few orders of magnitude above the longwall panels, with vertical conductivities in the range from 1×10^{-4} to 1×10^{-7} m/s or 8.6 to 8×10^{-3} m/d. This is based on the virgin (pre mining) vertical conductivities of the Rewan ranging from 1×10^{-7} to 1×10^{-11} m/s;
- numerical groundwater modelling relies on a simplification of the fracture network as an equivalent porous medium, with a fracturing height estimated by analytical formulas;
- surficial cracks in the weathered zone or Tertiary cover are likely to self-heal or be readily amenable to mechanical rehabilitation;
- there are predicted to be side-zones of enhanced permeability due to horizontal stress relief within about 200 m of edge longwall panels (Figure 6.7); and
- depressurisation of groundwater in a cone of depression around the mining footprint will enhance groundwater flow through undeformed Triassic and Permian rocks due to increased hydraulic gradient. The numerical model will be used to assess these flows.

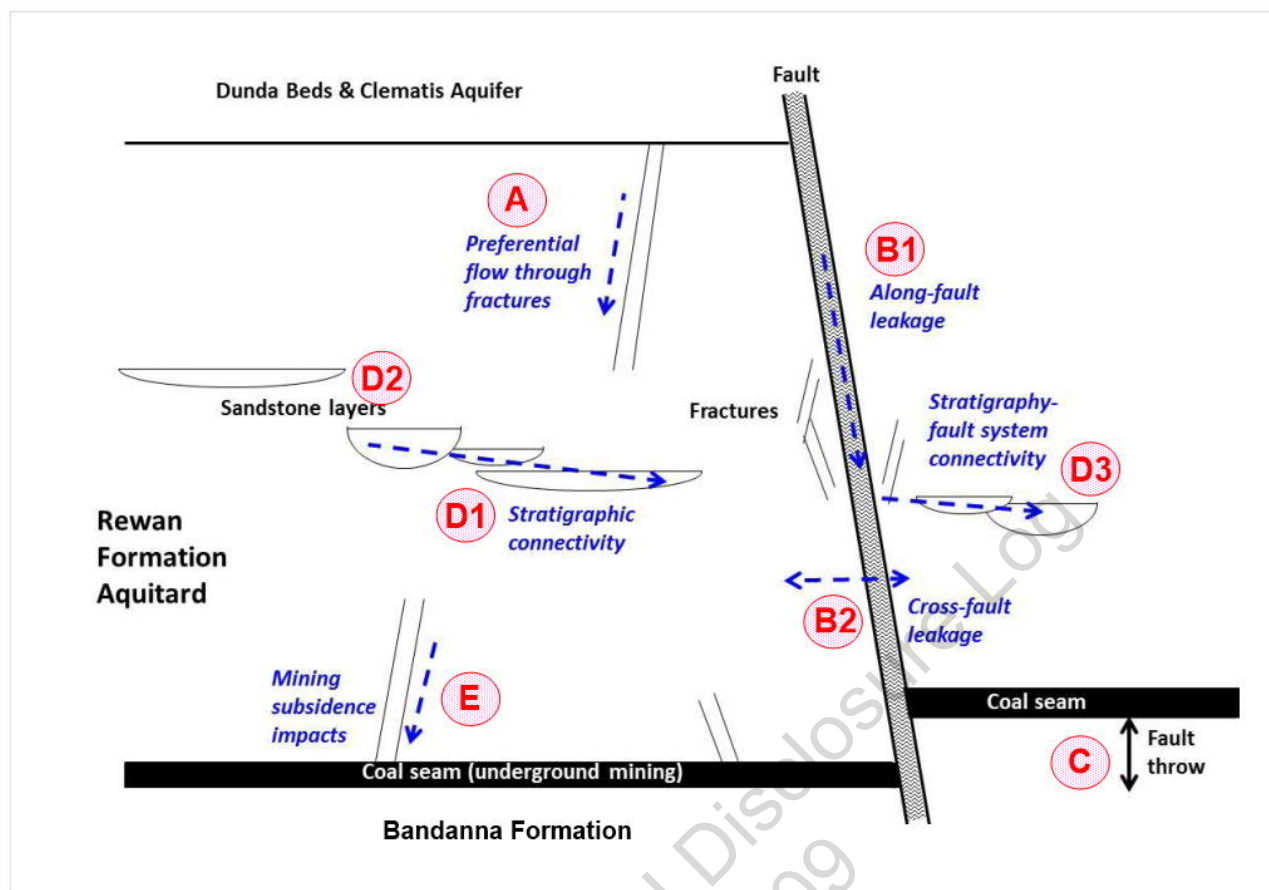


Figure 6.5 Possible connectivity mechanisms within the Rewan Formation (Adani, 2019)

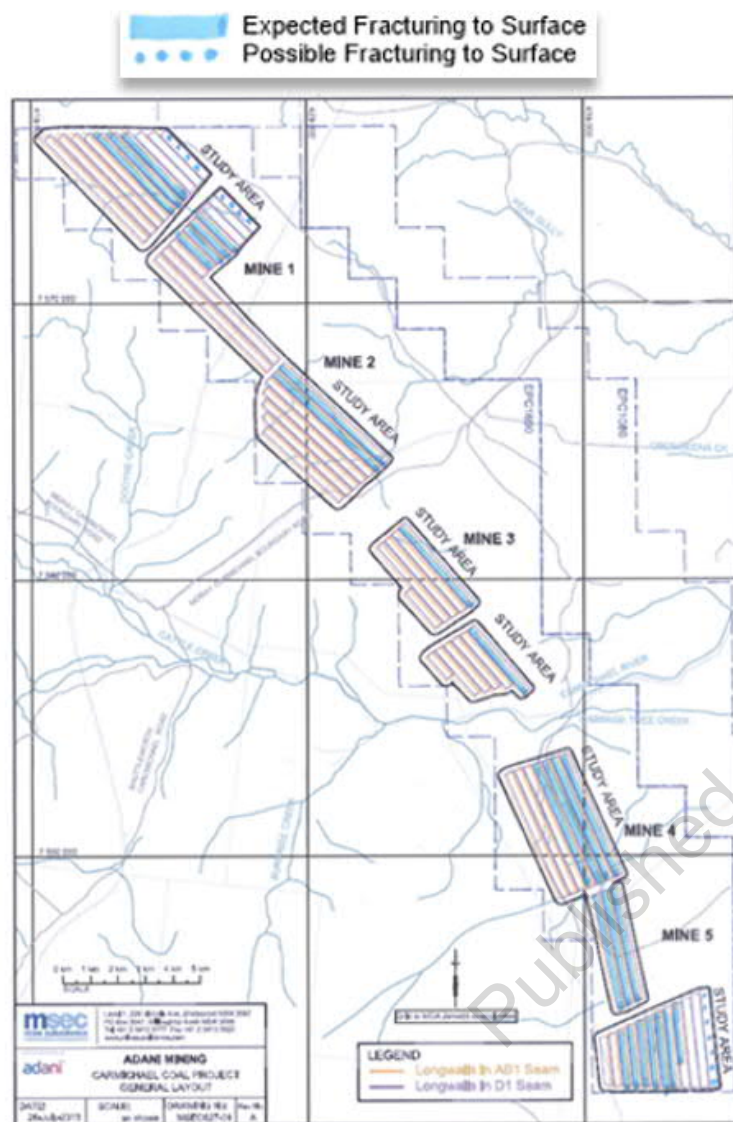
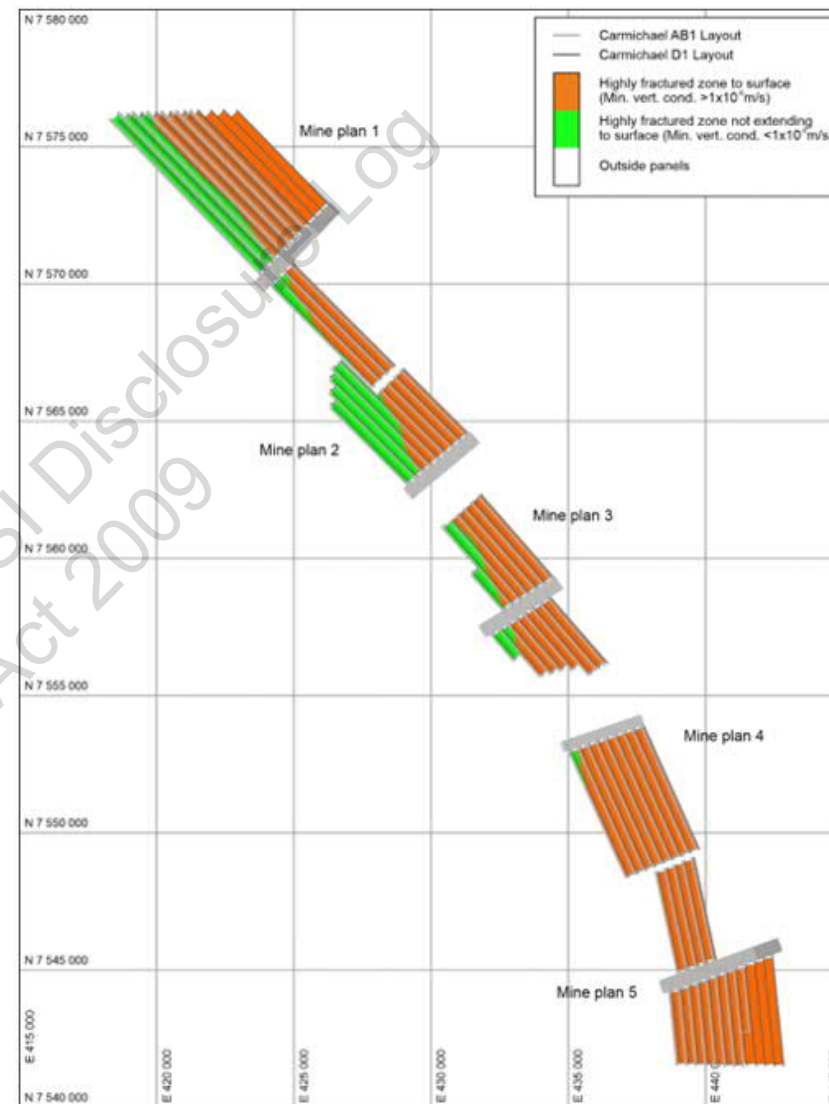


Figure 6.6 Expected fracturing to land surface using analytical (left) and numerical (right) models (Merrick 2021)

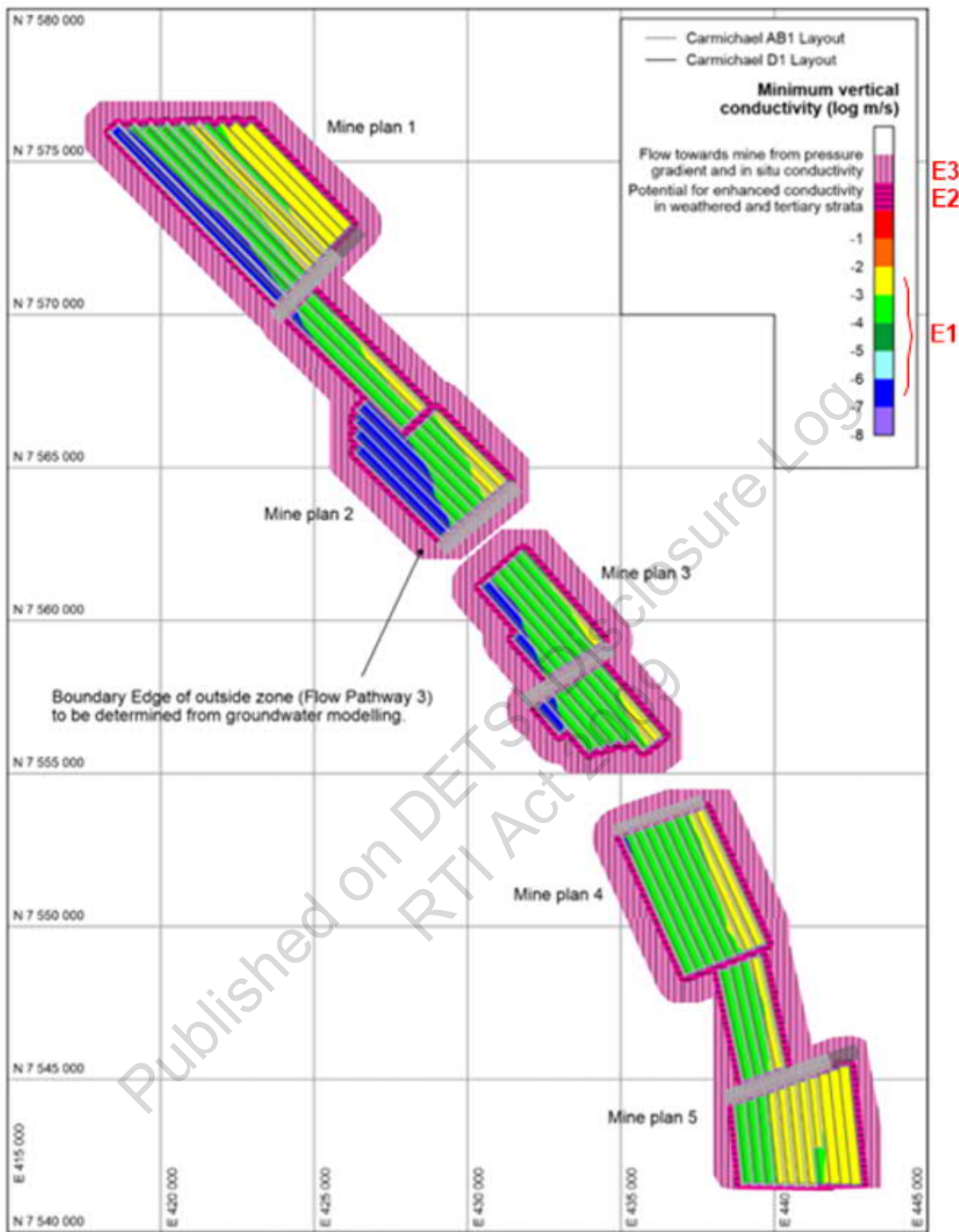


Figure 6.7 Enhanced permeability zones for flow pathways E1, E2 and E3 (SCT, 2021)

7 Pumping regime

Commencing in August 2019, a suite of 27 bores have been pumped intermittently for the purposes of pumping tests and mine dewatering. Up to 23 of these bores have been active within a single month, with peak dewatering rate averaged over a month of 69 L/s. Measured monthly mine dewatering is presented per bore in Figure 7.1 to February 2022. This figure shows the total monthly dewatering rate, with increased abstraction in 2021 and progressive commissioning of bores (eg 19107 PT, 19108 PT, and 19117 PT).

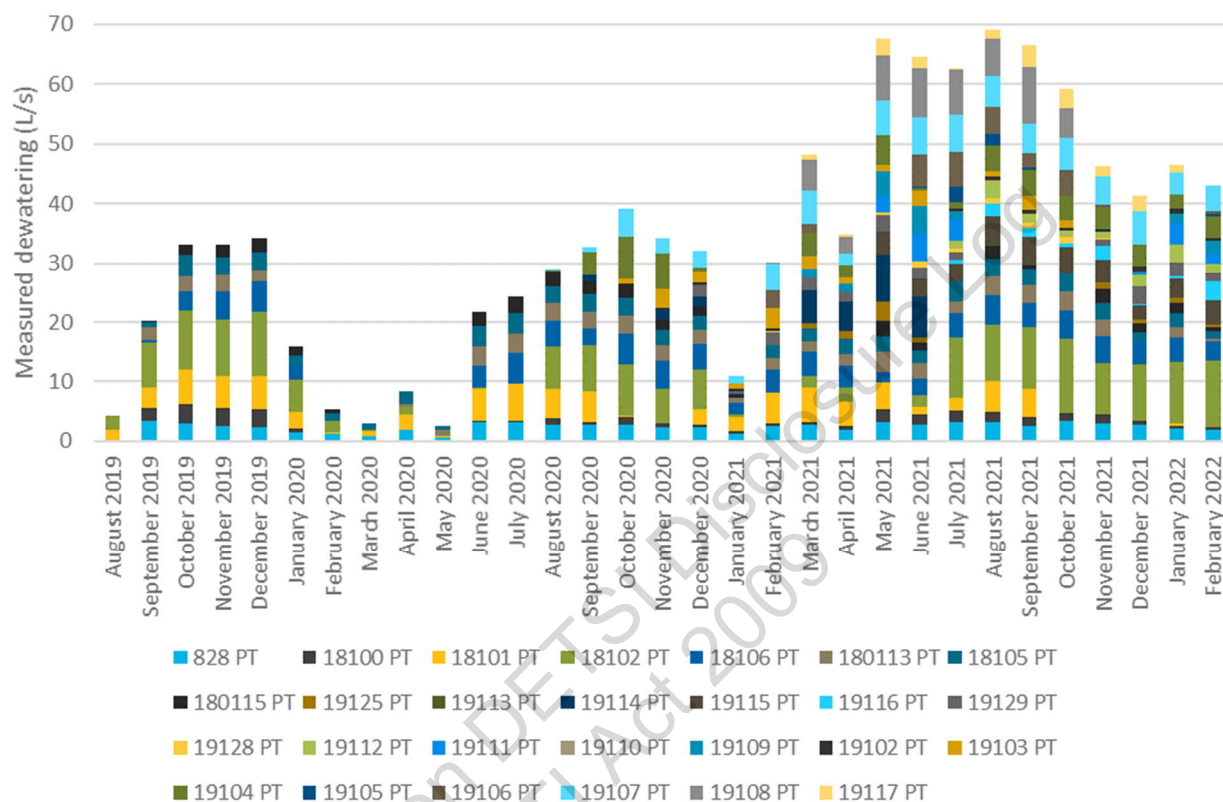


Figure 7.1 Measured mine dewatering

The dewatering bores are screened across multiple hydrostratigraphic units. The majority of bores are screened across the Bandanna Formation and Colinlea Sandstone (including coal seams), and a small number are screened only in D Seam coal or below. Measured mine dewatering grouped by screened unit is presented in Figure 7.2.

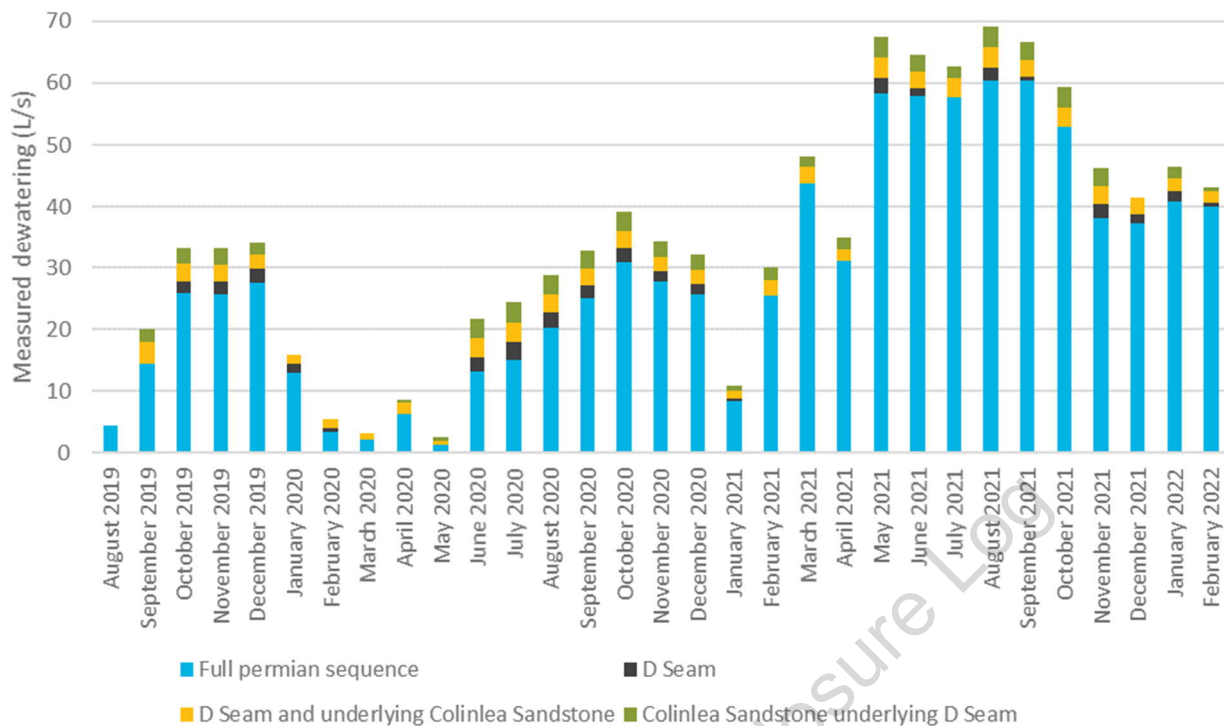
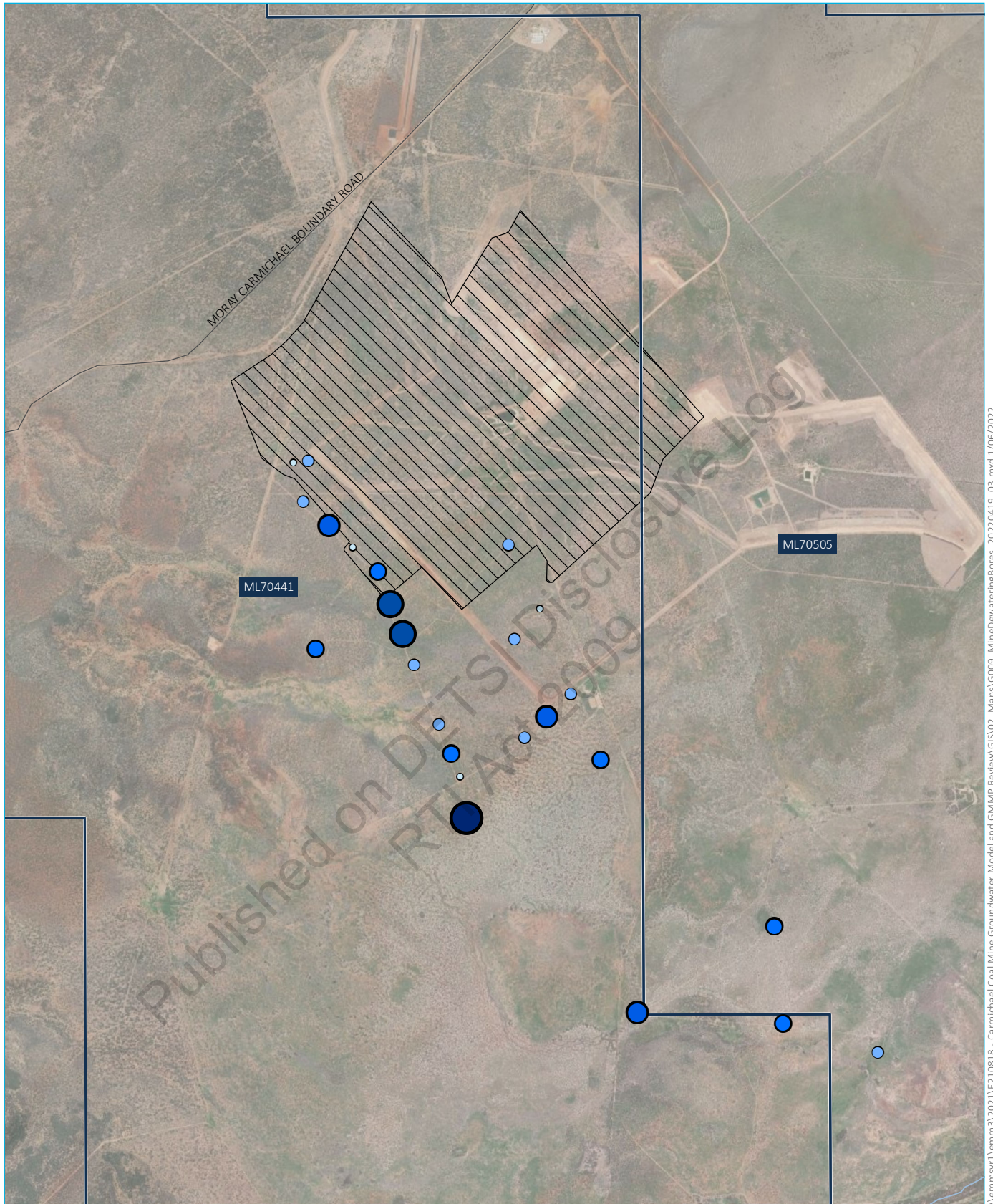
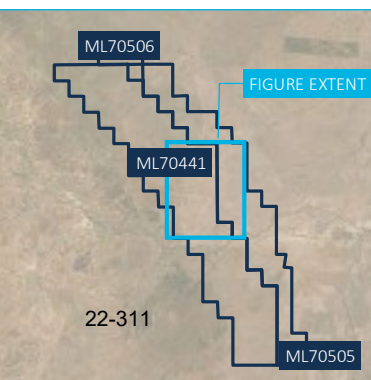


Figure 7.2 Measured mine dewatering grouped by hydrostratigraphic unit

The locality plan of mine dewatering bores is presented in Figure 7.3. Bores are coloured by average dewatering rate from commissioning date to the end of February 2022. The bores cover a transect of approximately 8 km NW to SE, with the highest spatial concentration in the NW. The lowest average pumping rate is 0.37 L/s, and the highest is 5.83 L/s.



KEY

Average dewatering rate (L/s)

- 0.37 - 1.00
- 1.00 - 2.00
- 2.00 - 3.00
- 3.00 - 4.00
- 4.00 - 5.00
- 5.00 - 6.00

□ Mining lease

▨ Open cut 2021

— Minor road

— Named watercourse

File A

Mine dewatering bores and average rates (L/s) since commencement

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Figure 7.3

8 Groundwater Levels

8.1 Hydrograph analysis

There are 108 monitoring bores and VWP sensors with sufficient temporal data before and after dewatering commenced (July 2019) to undertake cause and effect analysis of groundwater level trends. The main causal stresses within the study area include temporal variability in rainfall recharge (below average, average or above average), active mine dewatering from the Bandanna Formation, and landholder pumping from various HSUs including the Joe Joe Group south of the mining lease area. For the analysis, rainfall was represented as Cumulative Departure from Mean Monthly Rainfall (CDMMR), and the date of dewatering was used to split the rainfall and groundwater level data into pre- and during-dewatering periods. There is no available metered landholder groundwater use, and this remains an unknown mechanism with potential to further emphasise declining groundwater level trends.

To discern the potential for a dewatering impact in each of the 108 representative hydrographs the following logic was applied:

- the during-dewatering groundwater level needs to be declining at a rate greater than -10 centimetre per year (cm/yr), being the smallest detectable trend outside of background noise;
- the during-dewatering declining rate needs to be greater than the pre-dewatering rate, with the logic being the climate and landholder bore use are consistently present variables for both time periods, while dewatering is an added stress after mine pumping commenced. This added stress should result in a change in slope in the groundwater level, if the impact were eventuating; and
- for the unconsolidated aquifers (alluvium and Tertiary) and the source aquifer for the DSC (the Clematis Sandstone) the rate of decline in the during-dewatering period is -10 cm/yr greater than the rate of decline pre-dewatering. This is because below average rainfall and landholder pumping can cause declining groundwater levels also. The dewatering period needs to incrementally steepen the rate of declining groundwater levels.
- for the other confined formations (Dunda Beds, Rewan, Bandanna, Colinlea, JoeJoe) the rate of decline in the during-dewatering period is increased to -40cm/yr greater than the rate of decline pre-dewatering. This higher threshold was employed to minimise the amount of false positive dewatering effects that are more likely associated with landholder pumping. In the previous version of the report, a tighter threshold of 10cm/yr was employed and incorrect far-field dewatering effects resulted. These potential non-dewatering effects (as observed at C032P2, C035P2, C844SP, C847SP) tended to be 20-30cm/yr, so a threshold of 40cm/yr was adopted. In a confined aquifer with elastic storage this threshold is deemed to be appropriately set to detect early detection of drawdown without triggering too many false positives from other stresses.

It should be noted that the trend analysis algorithm (coded in Python) was amended for this iteration of the report to address review feedback. Mainly this was associated with the early dewatering trends being missed in some bores. The decomposition and smoothing algorithms were tightened so that less data was lost in the early and late time periods. This led to a better outcome of detecting early drawdown than before, at the cost of slightly more noisy outputs. Very slight changes to trend rates (up to several cm/yr) are the by-product of this change to the trend algorithm.

Trend analysis was undertaken using specific workflows within Python. EMM used the "tsa.seasonal.seasonal_decompose" function within Python's "statsmodels" library. This function takes a time series dataset and uses a LOESS function and additive model to separate out the seasonality and noise within a dataset, and in doing so define an underlying trend. The results are obtained by first estimating the trend by

applying a convolution filter to the data. The trend is then removed from the series and the average of this de-trended series for each period is the returned seasonal component. This tool was applied to the water levels at each of the bores. Further to this a smoothing filter (rolling mean) was applied to both the CDMMR and decomposed water level trend to identify longer-term rising and declining trends. This is important for analysing longer-term climate and drawdown responses outside of seasonal fluctuations.

The monthly water level trend and CDMMR trends were then plotted with the water level logger and CDMMR time series in hydrographs. Pre-dewatering monthly water level trends are presented as orange circles and post dewatering monthly trends are displayed as green circles. Similarly, pre-dewatering monthly CDMMR trends are presented as grey circles and post dewatering monthly trends are displayed as grey hollow circles.

As the monitoring network was progressively established over time, there is an inconsistent pre-dewatering length of record for groundwater levels measured at each bore or VWP. To overcome this issue we did trend analysis on CDMMR as well, to test whether the rainfall stress in the pre-dewatering period was consistent or not. Because it was (generally declining trend from 2012 to 2019), we applied a pre-dewatering groundwater level trend rate, rather than a magnitude, so that each bore could be compared.

The CDMMR rate for the two time periods shows that the pre-dewatering period is represented by dominant below average rainfall conditions from 2013 to 2019. Since 2019, there has been slightly below average to average rainfall conditions.

A trend analysis reliability confidence was prescribed to each representative monitoring site. The logic for this reliability rating was as follows:

- High: The hydrograph had a continuous time series record for pre-dewatering and during-dewatering periods. The trends made hydrogeological sense.
- Medium: The hydrograph had a semi-continuous time series record for pre-dewatering and during-dewatering periods. Any gaps in data did not compromise overall integrity of the trend. The trends made hydrogeological sense.
- Low: The hydrograph had large gaps in the data record. The gaps created shifts in trends that were hard to reconcile. The overall trends do not make hydrogeological sense, or the VWP appears to still be a period of equilibration.

All individual hydrographs are presented in Appendix B. The sub-sections below summarise the outcomes of the hydrograph analysis for each HSU and present a representative hydrograph for discussion purposes.

8.1.1 Alluvium

Table 8.1 presents a summary of the hydrograph analysis for the five representative alluvial bores. All five bores show a positive linear correlation to climate (ie rising groundwater levels during above average rainfall and declining trends during below average rainfall periods). None of the bores show any signs of a dewatering impact (using the logic described in Section 8.1). Figure 8.1 presents a representative hydrograph for C029P1. The rate of decline in groundwater levels is consistent for the pre- and during-dewatering periods, indicating that climate and landholder pumping are dominating the declining antecedent trend. Despite an overall declining groundwater level, there is also seasonal variability in groundwater levels related to effective rainfall recharge.

Figure 8.2 presents a plan view of the representative alluvial bores across the project site with reference to the mine lease, the hydrological systems, and the DSC and MSC. This map shows no dewatering impacts are observed throughout the alluvium associated with the Carmichael River from upstream and downstream of the mine lease area.

Table 8.1 Cause and effect analysis of representative alluvium bores

Bore	HSU	Bore depth (m)	Hydrograph trend reliability ¹	Pre dewatering trend (m/yr)	During dewatering trend rate (m/yr)	Climate influence	Dewatering Impact
C027P1	Alluvium	13	High	-0.373	-0.031	Yes	No
C029P1	Alluvium	13.4	High	-0.060	-0.097	Yes	No
C14027SP	Alluvium	21	High	-0.077	-0.036	Yes	No
C14028SP	Alluvium	20	High	0.022	-0.023	Yes	No
HD03B	Alluvium	11.37	High	0.029	0.066	Yes	No

Notes: Hydrograph trend reliability is a ranking from high to low to reflect whether a given hydrograph trend is interpretable from a hydrogeological perspective. A “high” rating means the hydrograph displays characteristic groundwater responses and is highly suited to trend analysis; a “medium” rating means there are some unusual elements to the hydrograph response, but overall the trend can be analysed; a “low” rating means the hydrograph response is not suitable for further trend analysis due to uncertainty in the groundwater levels. These reliability notes apply to all tables in this report section.

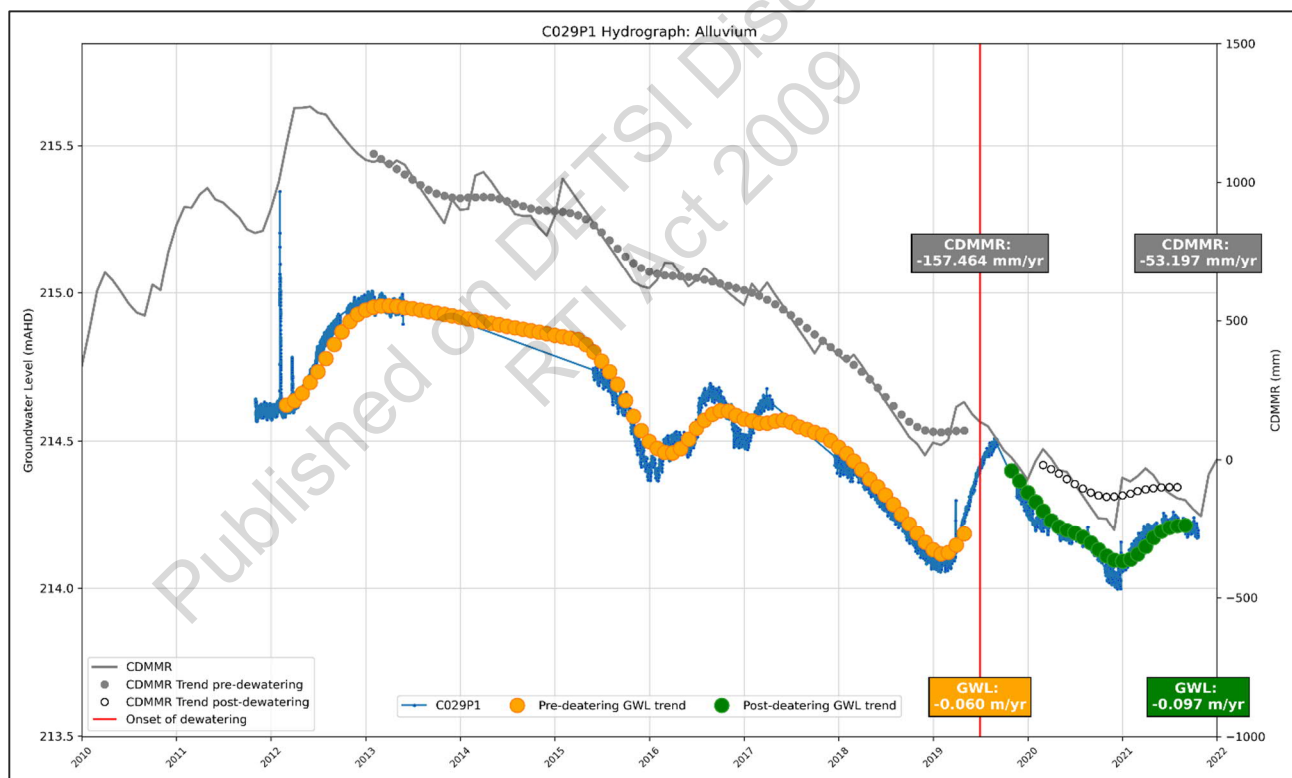
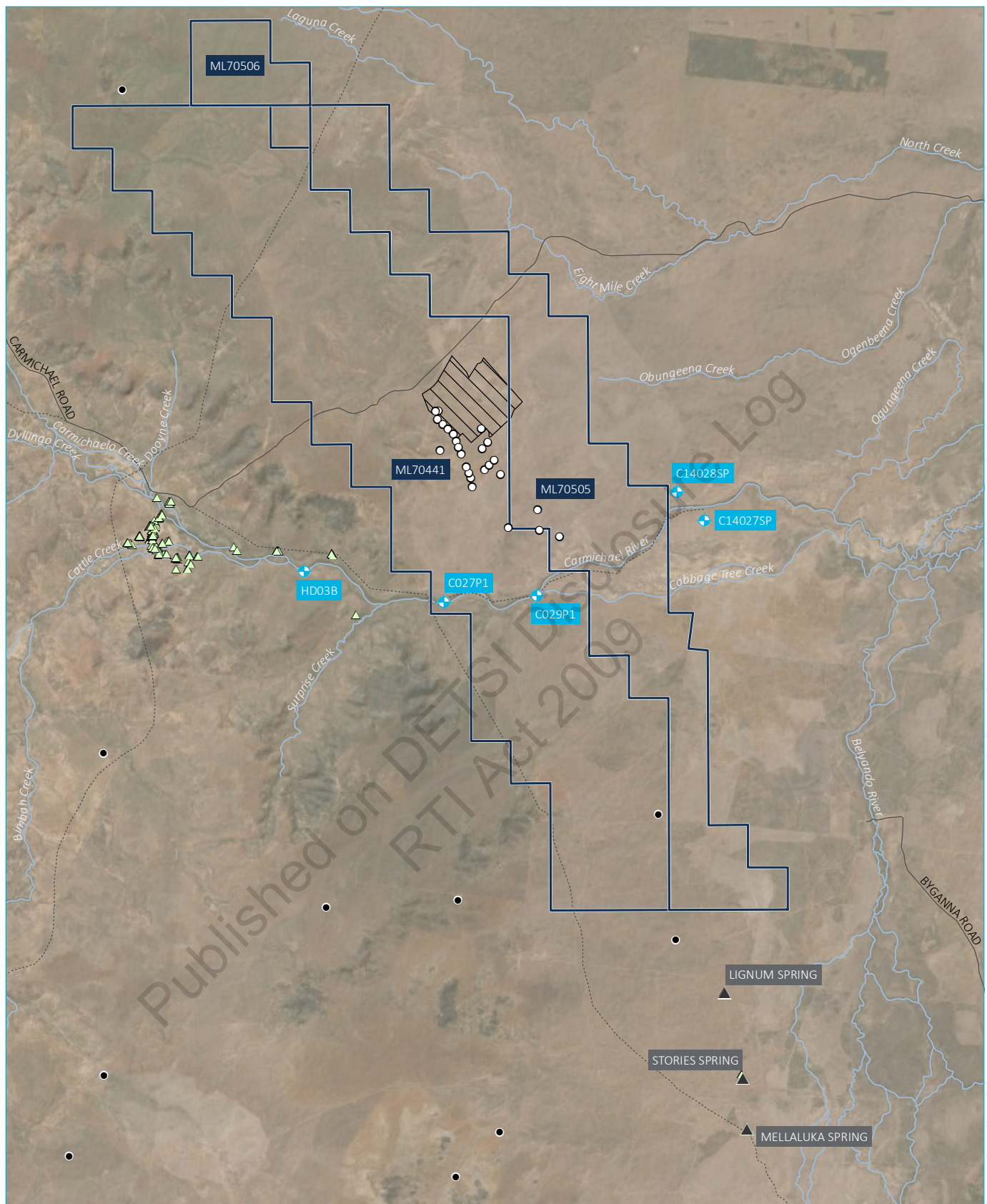


Figure 8.1 Cause and effect hydrograph analysis for alluvium bore C029P1



Source: EMM (2022); DNRME (2021); DES (2020); GA (2011); ASGC (2006)

KEY

- Mining lease
- Open cut 2021
- Minor road
- Vehicular track
- Named watercourse
- ▲ DSC spring
- ▲ Mellaluka spring
- Landholder bore
- Dewatering bore
- + Alluvium bore - no dewatering

Spatial analysis of Alluvium dewatering trends from representative bores with sufficient pre- and during - dewatering data

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Figure 8.2

8.1.2 Tertiary

Table 8.2 presents a summary of the hydrograph analysis for the five representative Tertiary bores. All five bores show a positive linear correlation to climate. None of the bores show any signs of a dewatering impact. Figure 8.3 presents a representative hydrograph for C025P2. The rate of decline in groundwater levels is consistent for the pre- and during-dewatering periods, indicating that climate and landholder pumping are dominating the declining antecedent trend. Despite an overall declining groundwater level, there is also seasonal variability in groundwater levels related to effective rainfall recharge.

Figure 8.4 presents a plan view of the representative Tertiary bores across the project site. This map shows no dewatering impacts are observed throughout the Tertiary cover.

Table 8.2 Cause and effect analysis of representative Tertiary bores

Bore	HSU	Bore depth (m)	Hydrograph trend reliability	Pre dewatering rate (m/yr)	During dewatering rate (m/yr)	Climate influence	Dewatering impact
C025P2	Tertiary	41	High	-0.098	-0.112	Yes	No
C029P2	Tertiary	46	High	-0.016	-0.067	Yes	No
C558P1	Tertiary	41.4	Medium	0.025	-0.015	Yes	No
C9180121SPR	Tertiary	45	High	-0.139	-0.122	Yes	No
C9845SPR	Tertiary	45	High	-0.015	-0.076	Yes	No

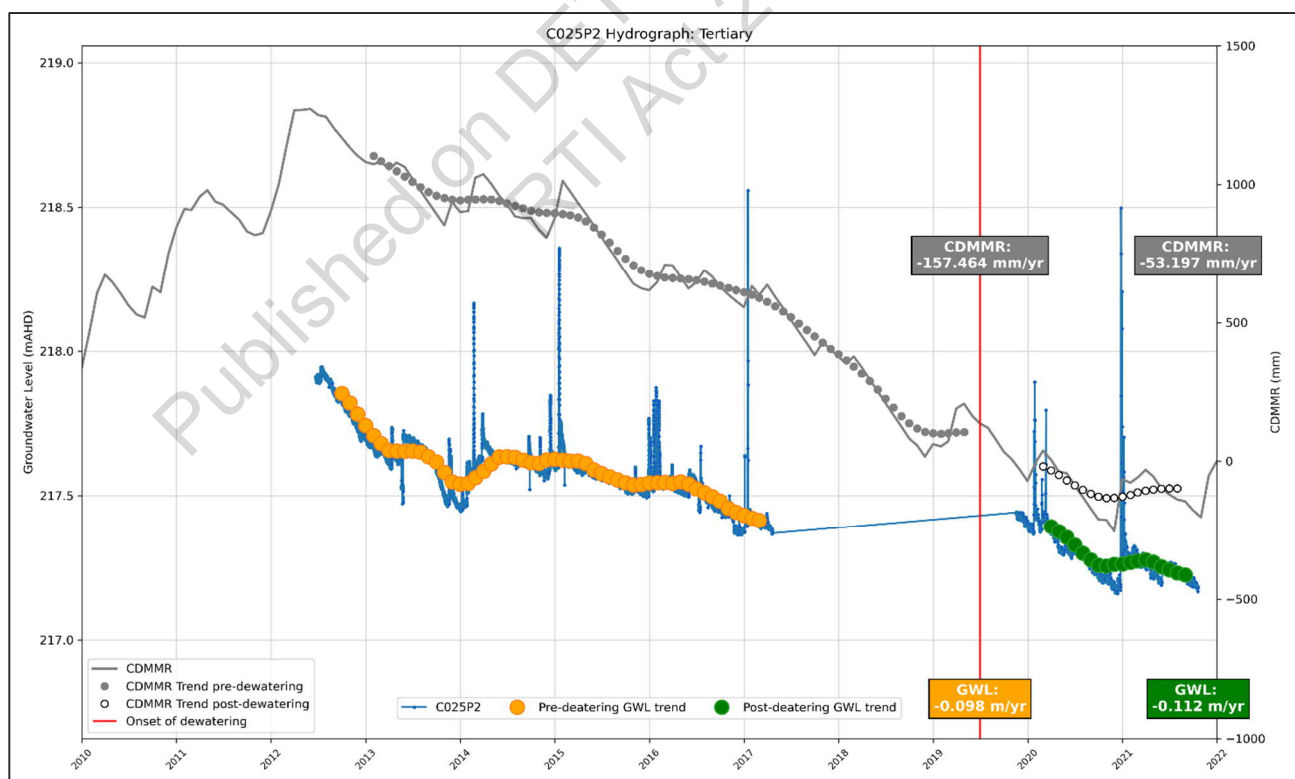
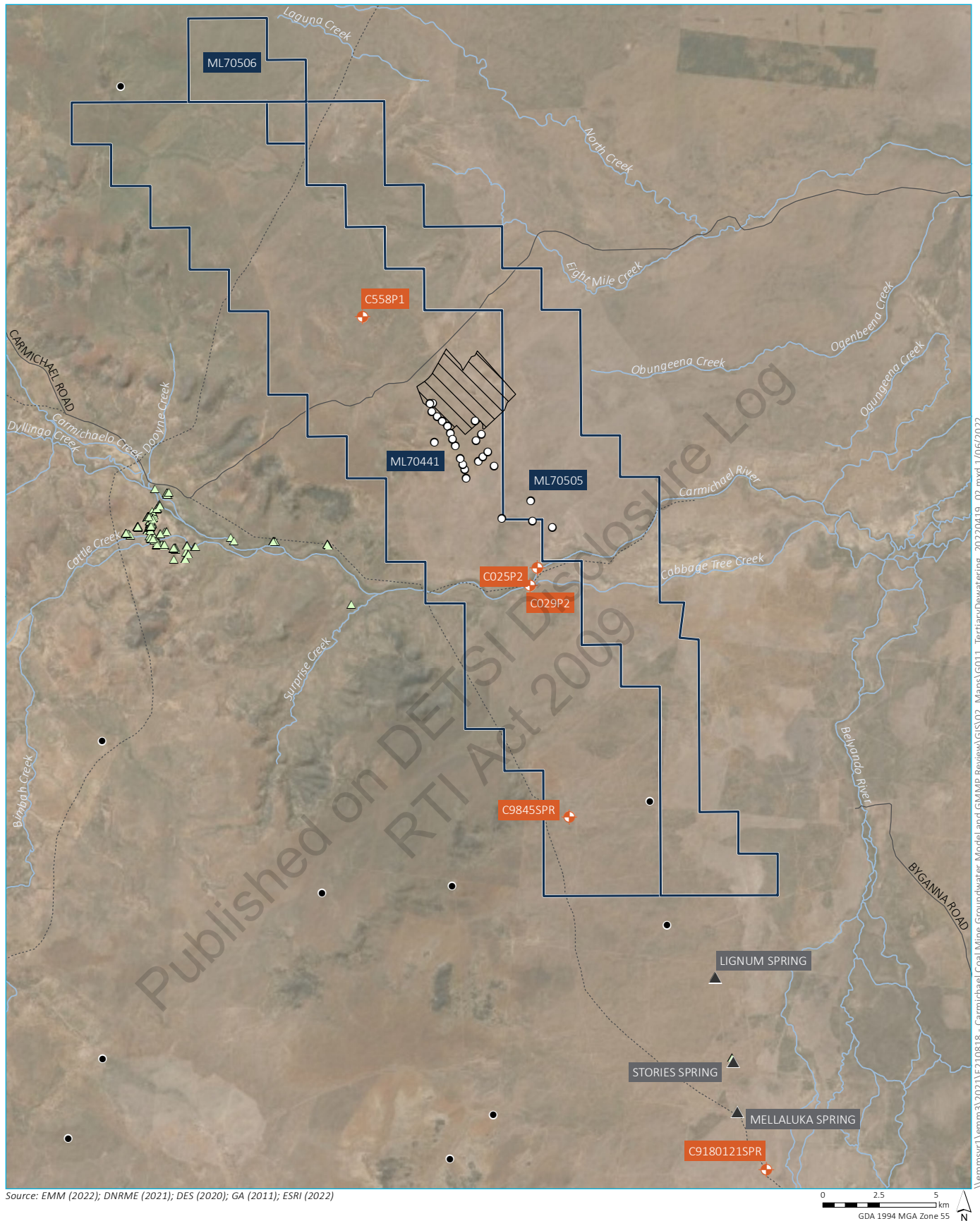


Figure 8.3 Cause and effect hydrograph analysis for Tertiary bore C025P2



KEY

- Mining lease
- Open cut 2021
- Minor road
- Vehicular track
- Named watercourse
- ▲ DSC spring
- ▲ Mellaluka spring
- Landholder bore
- Dewatering bore
- ◆ Tertiary Sediment bore - no dewatering

Spatial analysis of Tertiary Sediment dewatering trends from representative bores with sufficient pre- and during - dewatering data

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Figure 8.4

8.1.3 Clematis Sandstone

Table 8.3 presents a summary of the hydrograph analysis for the seven representative Clematis Sandstone bores. All seven bores show a positive linear correlation to climate, and some bores such as HD02 show strong seasonality with effective rainfall recharge occurring. None of the bores show any signs of a dewatering impact. Figure 8.5 presents a representative hydrograph for HD02. The rate of decline in groundwater levels is – 0.021 m/yr for the pre-dewatering period when below average rainfall occurs. The corresponding period of near average rainfall in the during-dewatering period causes a slight rise in groundwater level trend of + 0.008 m/yr. Overall, across the hydrographs, climate and landholder pumping are dominating the declining and rising antecedent trends. The bores nearest to Carmichael River (HD03A and HD02) show a clear seasonal groundwater rise and decay that may indicate direct hydraulic connection with the river.

Figure 8.6 presents a plan view of the representative Clematis Sandstone bores across the project site. This map shows no dewatering impacts are observed throughout the aquifer and particularly around the DSC, where the Clematis Sandstone is the source aquifer.

Table 8.3 Cause and effect analysis of representative Clematis Sandstone bores

Bore	HSU	Bore depth (m)	Hydrograph trend reliability	Pre dewatering rate (m/yr)	During dewatering rate (m/yr)	Climate influence	Dewatering impact
C14011SP	Clematis	144	Medium	-0.002	0.006	Yes	No
C14012SP	Clematis	168	Medium	-0.009	-0.013	Yes	No
C14013SP	Clematis	72	Medium	-0.042	-0.006	Yes	No
C14021SP	Clematis	46	Medium	-0.105	-0.099	Yes	No
C14033SP	Clematis	200	Medium	-0.018	-0.008	Yes	No
HD02	Clematis	32	High	-0.021	0.008	Yes	No
HD03A	Clematis	37	Medium	-0.053	0.037	Yes	No

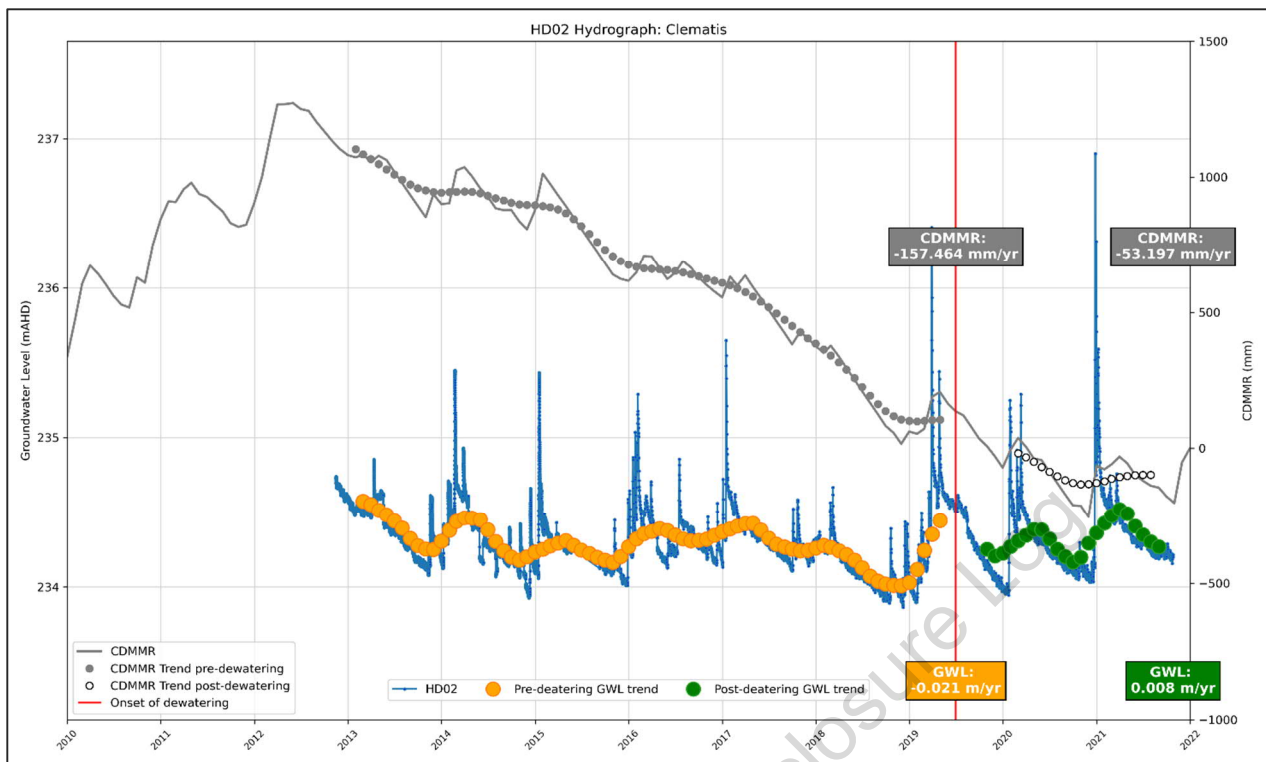
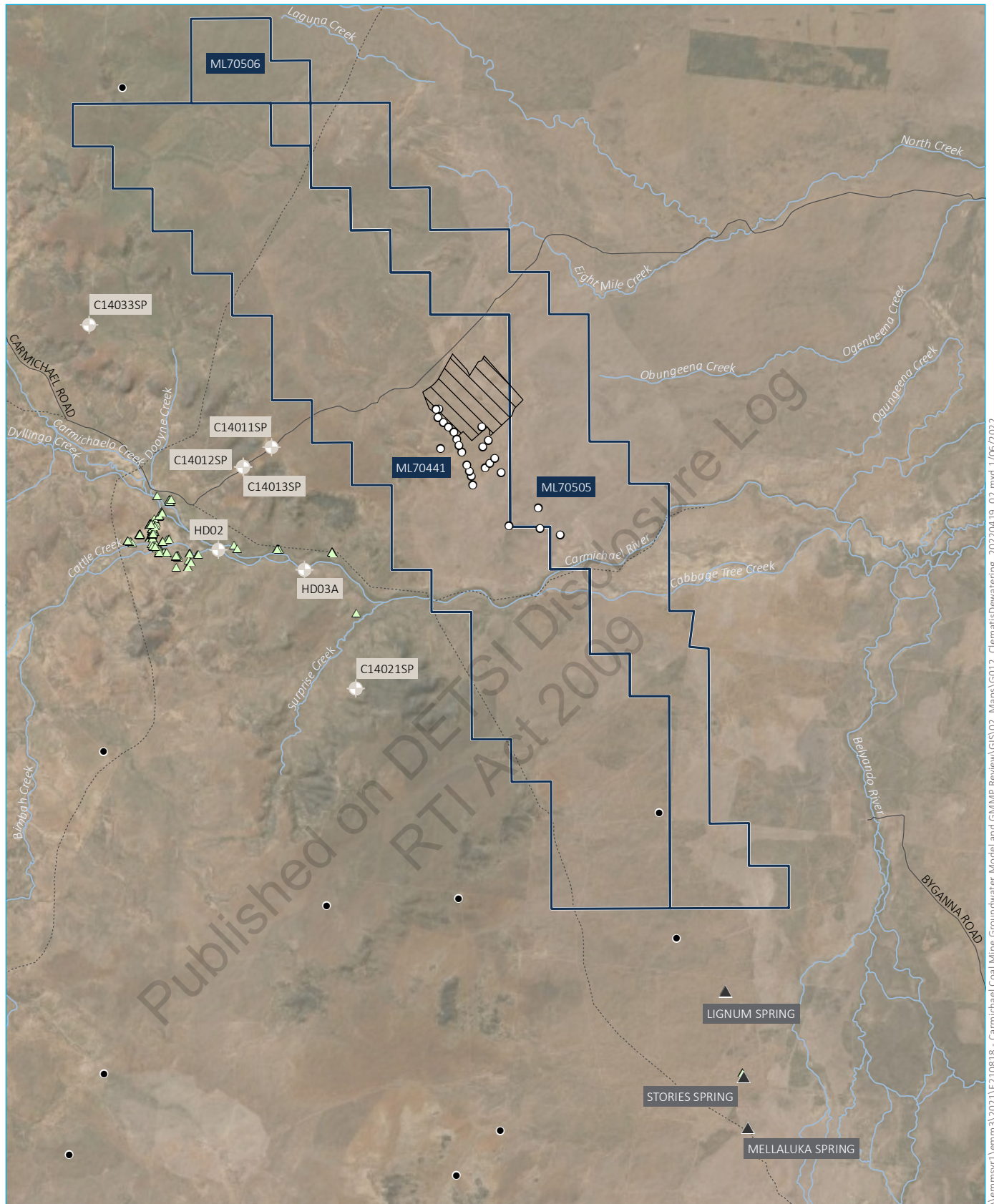


Figure 8.5 Cause and effect hydrograph analysis for Clematis Sandstone bore HD02



Source: EMM (2022); DNRME (2021); DES (2020); GA (2011); ESRI (2022)

KEY

- Mining lease
- Open cut 2021
- Minor road
- Vehicular track
- Named watercourse
- ▲ DSC spring
- ▲ Mellaluka spring
- Landholder bore
- Dewatering bore
- Clematis Sandstone - no dewatering

Spatial analysis of Clematis Sandstone dewatering trends from representative bores with sufficient pre- and during - dewatering data

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Figure 8.6

8.1.4 Dunda Beds

Table 8.4 presents a summary of the hydrograph analysis for the four representative Dunda Beds bores. All four bores show a positive linear correlation to climate. None of the bores show any signs of a dewatering impact. Figure 8.7 presents a representative hydrograph for C180117SP. The rate of decline in groundwater levels is consistent between the pre-dewatering period (-7 cm/yr) and during-dewatering period (-8 cm/yr). Overall, across the hydrographs, climate and landholder pumping are dominating the declining antecedent trends.

Figure 8.8 presents a plan view of the representative Dunda bores across the project site. This map shows no dewatering impacts are observed throughout the HSU.

Table 8.4 Cause and effect analysis of representative Dunda Beds bores

Bore	HSU	Bore depth (m)	Hydrograph trend reliability	Pre dewatering rate (m/yr)	During dewatering rate (m/yr)	Climate influence	Dewatering impact
C022P1	Dunda Beds	67	Medium	-0.024	-0.026	Yes	No
C027P2	Dunda Beds	32.8	High	-0.016	-0.114	Yes	No
C14023SP	Dunda Beds	165.6	Medium	-0.049	-0.068	Yes	No
C180117SP	Dunda Beds	81	High	-0.069	-0.081	Yes	No

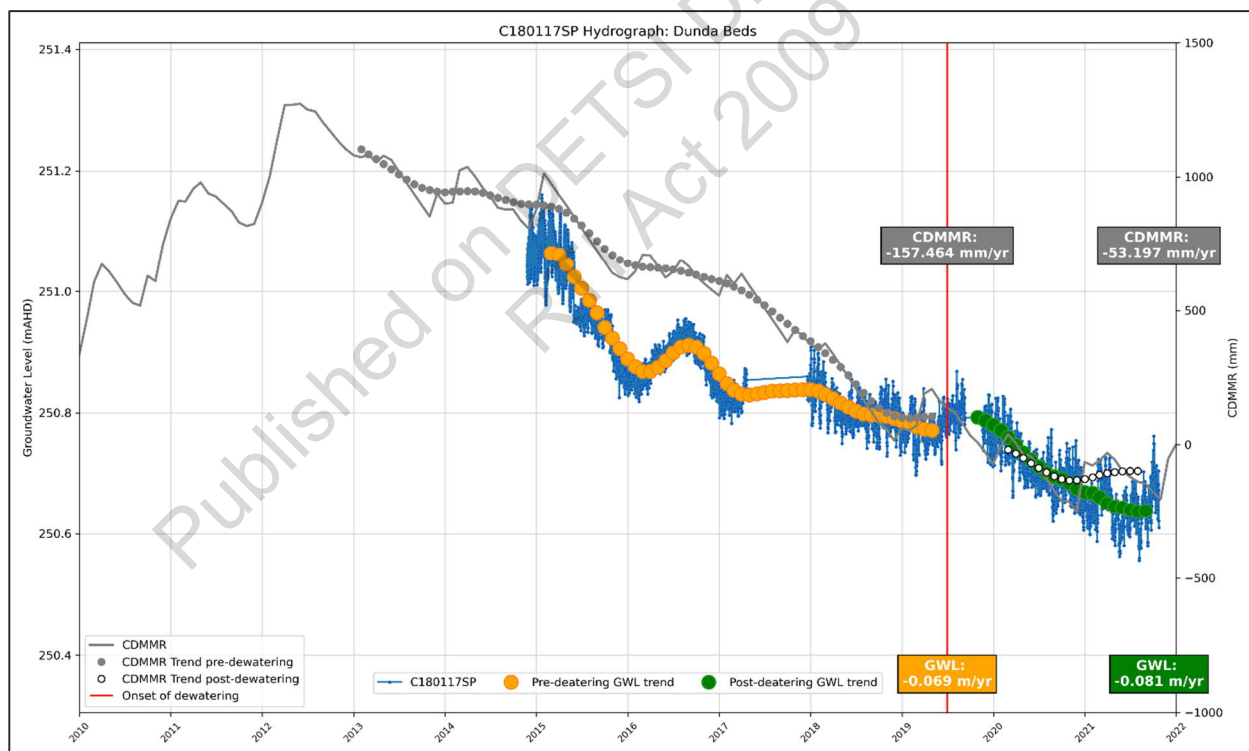
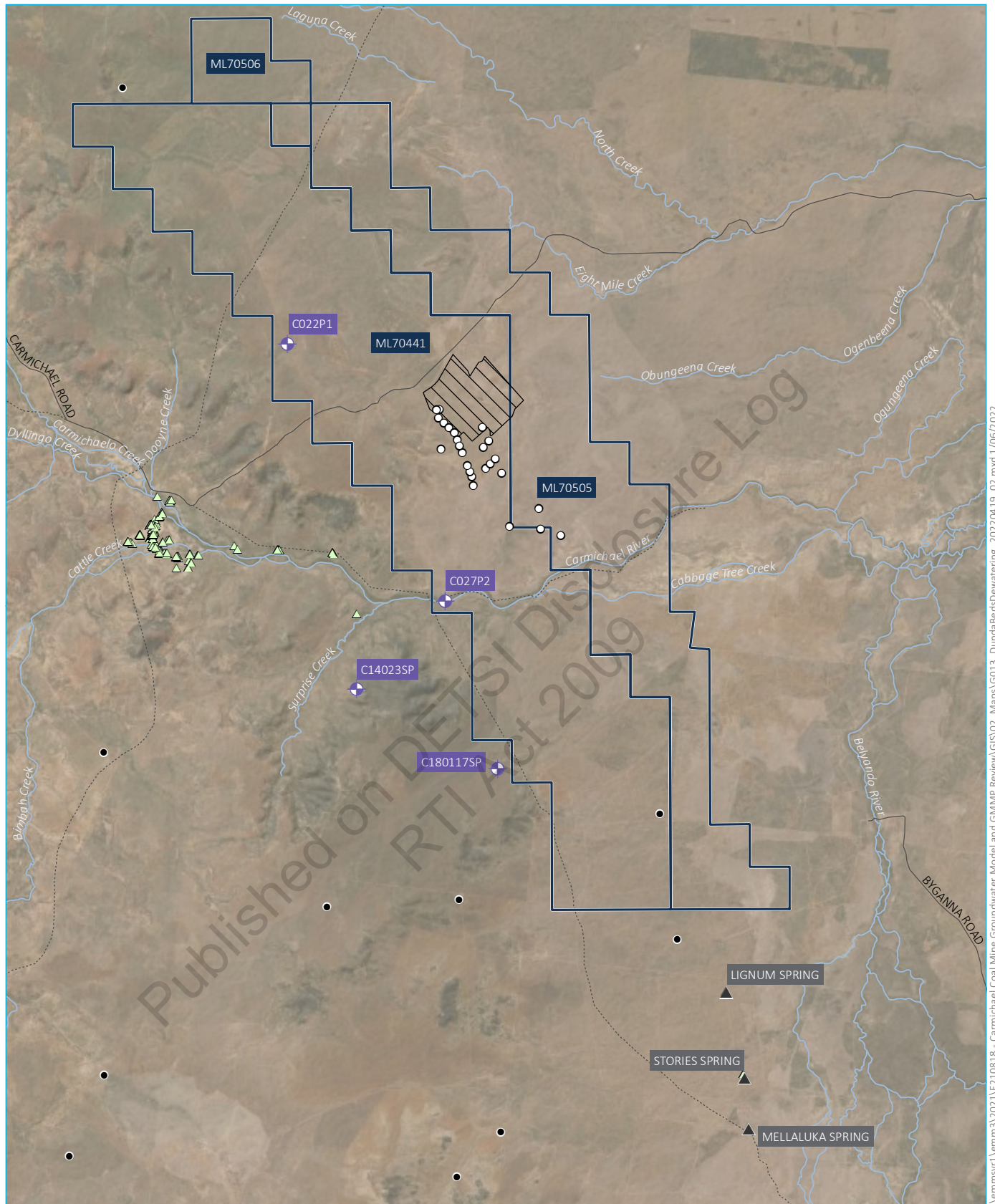
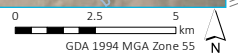


Figure 8.7 Cause and effect hydrograph analysis for Dunda Beds bore C180117SP



Source: EMM (2022); DNRME (2021); DES (2020); GA (2011); ESRI (2022)



KEY

- Mining lease
- Open cut 2021
- Minor road
- Vehicular track
- Named watercourse
- ▲ DSC spring
- ▲ Mellaluka spring
- Landholder bore
- Dewatering bore
- ✕ Dunda Beds - no dewatering

Spatial analysis of Dunda Beds dewatering trends from representative bores with sufficient pre- and during - dewatering

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Figure 8.8

8.1.5 Rewan Formation

Table 8.5 presents a summary of the hydrograph analysis for the 19 representative Rewan Formation bores. Most of the VWPs and bores show subtle positive linear correlation to climate. Three of the VWPs/bores show signs of dewatering impacts, although the magnitudes of drawdown are typically <2 m/yr. Figure 8.9 presents a representative hydrograph for C9838SPR. In this bore, the rate of decline during dewatering is over double the rate of natural decline in the period prior to dewatering, however, it does not have an incremental increase in the rate of drawdown of over 0.4 m/yr and is more likely influenced by climate and landholder pumping. Overall, across the hydrographs, climate and landholder pumping are dominating the declining antecedent trends, with localised impacts from dewatering at 15% of sites.

Figure 8.10 presents a plan view of the representative Rewan sites across the project site. This map shows dewatering impacts are concentrated south of Carmichael River within the lease area. There are no Rewan dewatering impacts as yet directly east of the DSC.

Table 8.5 Cause and effect analysis of representative Rewan Formation bores

Bore	HSU	Bore depth (m)	Hydrograph trend reliability ¹	Pre dewatering rate (m/yr)	During dewatering rate (m/yr)	Climate influence	Dewatering impact
C056VWP3	Rewan	240	Medium	-0.261	-0.096	Yes	No
C14200VWP3	Rewan	101	Low	-0.233	-0.363	Uncertain	No
C14200VWP2	Rewan	199	Low	-0.786	-0.291	Yes	No
C14203VWP2	Rewan	77	Low	21.890	-1.848	No	Yes
C14207VWP2	Rewan	400	Low	-2.717	-0.232	No	No
C555VWP2	Rewan	260.5	Low	-1.268	-1.616	Uncertain	No
C842VWP3	Rewan	130	Medium	-0.312	-1.275	Yes	Yes
C851VWP3	Rewan	103.7	Medium	-0.331	-0.092	Yes	No
C9553VWP3	Rewan	265.4	Low	-0.797	-1.797	Uncertain	Yes
C9556VWP3	Rewan	216	Low	-2.228	-0.235	Yes	No
C966VWP4	Rewan	258	Medium	-2.235	0.355	Yes	No
C966VWP3	Rewan	302.5	Low	-0.764	-0.017	Yes	No
C9836VWP3	Rewan	130	Low	-0.746	-0.353	Uncertain	No
C008P1	Rewan	57.5	Medium	-0.057	-0.136	Uncertain	No
C035P1	Rewan	62	Medium	-0.113	-0.270	Yes	No
C555P1	Rewan	75	Medium	-0.042	-0.151	Yes	No
C556P1	Rewan	83.3	Medium	-0.111	-0.204	Yes	No
C9553P1R	Rewan	66	Medium	0.001	0.005	Uncertain	No
C9838SPR	Rewan	98	High	-0.209	-0.536	Yes	No

Notes: ¹ Low reliability factors: C14200VWP3 has a gap in monitoring between 2017 and 2020 and the more contemporary data has a sudden unexplainable 2m increase in heads post-dewatering. C14200VWP2 has a declining trend throughout the record, and it is not clear if this is climate-related or the VWP equilibrating to formation pressures. C14203VWP2 has an increasing trend throughout the pre-dewatering period that is likely to be the VWP equilibrating to formation pressures. C14207VWP2 has an erratic trend in the pre-dewatering period that may be associated with the VWP equilibrating to formation pressures. C555VWP2 has a declining trend throughout the record, and it is not clear if this is climate-related or the VWP equilibrating to formation pressures. C9553VWP3 has a

declining trend throughout the record, and it is not clear if this is climate-related or the VWP equilibrating to formation pressures. C9556VWP3 has a declining trend throughout the record, and it is not clear if this is climate-related or the VWP equilibrating to formation pressures. C966VWP3 has a declining trend throughout the pre-dewatering record, and it is not clear if this is climate-related or the VWP equilibrating to formation pressures. C9836VWP3 has a declining trend throughout the pre-dewatering record, and it is not clear if this is climate-related or the VWP equilibrating to formation pressures.

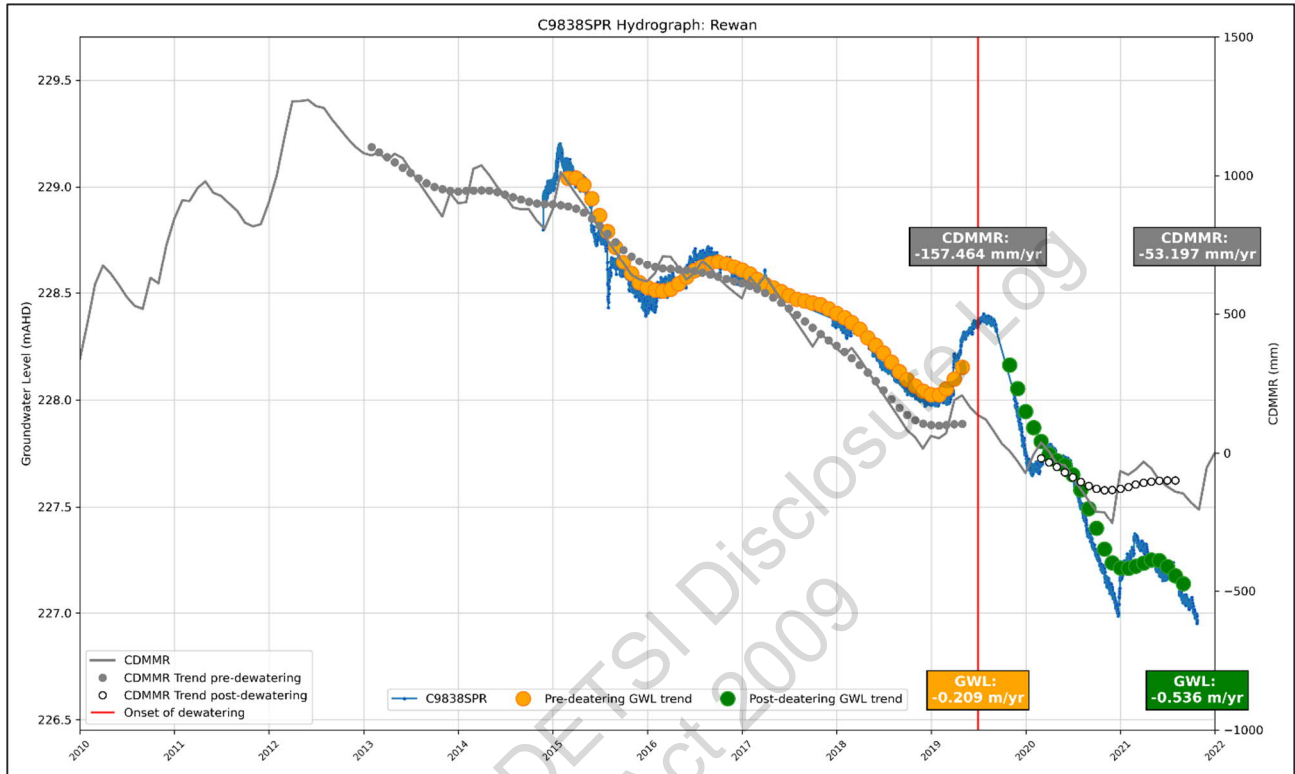
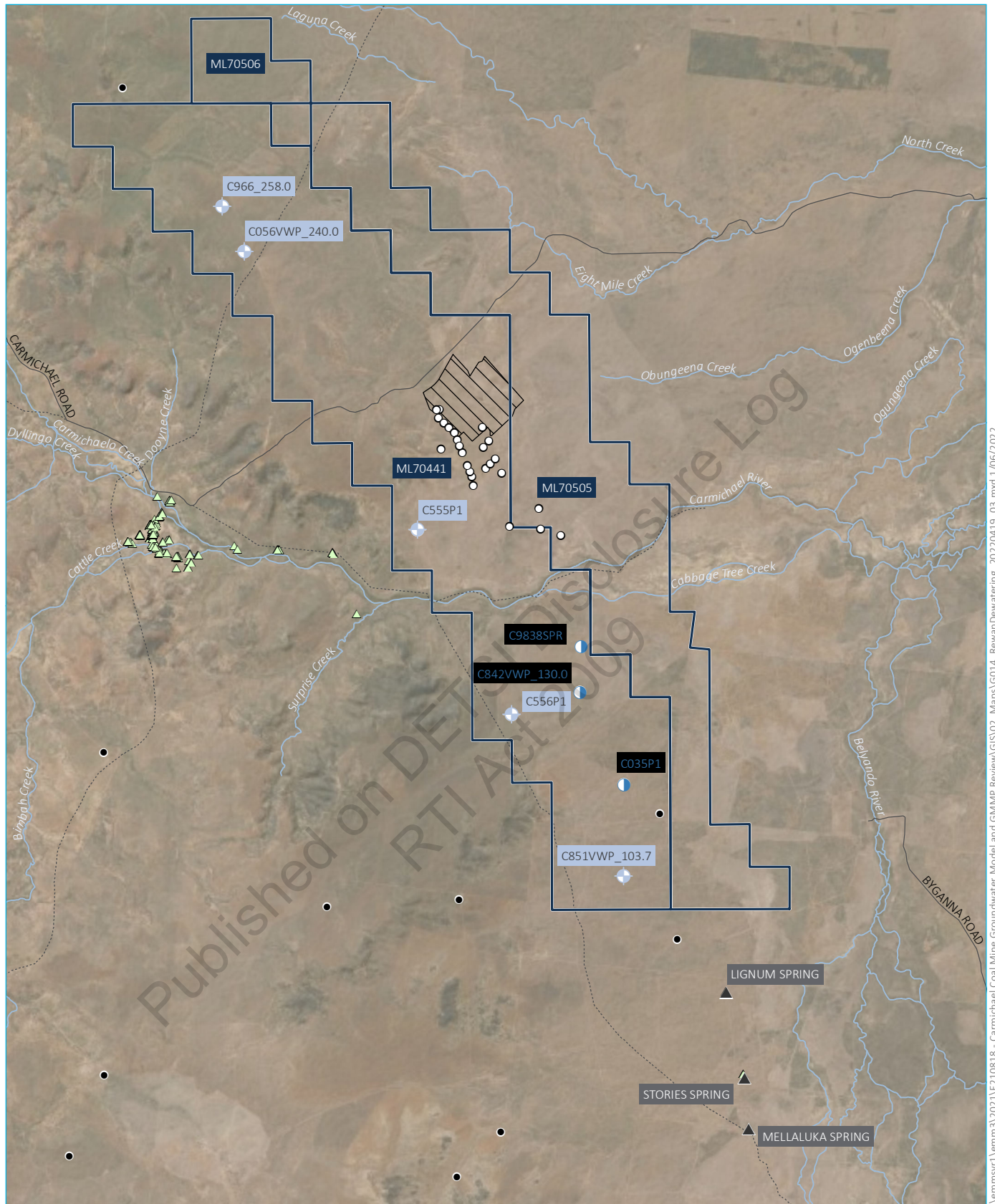


Figure 8.9 Cause and effect hydrograph analysis for Rewan Formation bore C9838SPR



Source: EMM (2022); DNRME (2021); DES (2020); GA (2011); ESRI(2022)

KEY

- Mining lease
- Open cut 2021
- Minor road
- Vehicular track
- Named watercourse
- ▲ DSC spring
- ▲ Mellaluka spring
- Landholder bore
- Dewatering bore
- Rewan Formation - dewatering
- Rewan Formation - no dewatering

Spatial analysis of Rewan dewatering trends from representative bores with sufficient pre- and during - dewatering data

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Figure 8.10

8.1.6 Bandanna Formation

Appendix B presents a summary of the hydrograph analysis for the 29 representative Bandanna Formation bores/VWPs. Most of the VWPs and bores show subtle positive linear correlation to climate. Five of the 29 VWPs/bores show signs of dewatering impacts (medium and high confidence reliability only), with rates of drawdown typically <10 m/yr. Figure 8.11 presents a representative hydrograph for C006P1. In this bore, the rate of decline during dewatering is two orders of magnitude greater than the rate of natural flat-lying to slightly increasing levels in the period prior to dewatering. Overall, across the hydrographs, dewatering is dominating the declining antecedent trends in the central extents of the lease. There are also fewer instances of climate influence on the hydrographs, and some unusual responses that look like the VWP or bore may be equilibrating post-drilling (which have been prescribed as low confidence). Four of the potentially impacted medium and high reliability bores (C032P2, C035P2, C844SP, C847SP) have declining rates of <0.5m/year after dewatering that may be inconclusive at this stage to absolutely confirm this is related to dewatering. Instigating a dewatering threshold of 0.4 m/yr for the Bandanna has resulted in these four sites being classified as no dewatering impact at this stage. Further monitoring is needed to confirm these subtler trends are in fact related to dewatering, and not landholder pumping.

Figure 8.12 presents a plan view of the representative Bandanna Formation sites across the project site. This map shows potential dewatering impacts are concentrated in the immediate vicinity of the dewatering bores and slightly south of Carmichael River within the lease area. Landholder bores are plotted as black symbols and may contribute to some of the drawdown observed in the southern lease extents in the Bandanna. Of note on this figure, the drawdown does not tend to spread laterally beyond the current extents of the dewatering bores, suggesting steep vertical gradients and limited coal permeability.

Table 8.6 Cause and effect analysis of representative Bandanna Formation bores

Bore	HSU	Bore depth (m)	Hydrograph trend reliability ¹	Pre dewatering rate (m/yr)	During dewatering rate (m/yr)	Climate influence	Dewatering impact
C056VWP2	Bandanna	312	Medium	-1.577	-0.396	Yes	No
C14200VWP1	Bandanna	224	Low	0.539	-0.563	No	Yes
C14207VWP1	Bandanna	504	Low	-5.220	-1.515	Uncertain	No
C555VWP1	Bandanna	346	Low	2.610	0.562		No
C558VWP3	Bandanna	73	Low	0.065	0.108	No	No
C842VWP2	Bandanna	177.5	Low	-0.372	-0.189	Uncertain	No
C851VWP2	Bandanna	145.7	Low	-0.245	-0.215	Uncertain	No
C9553VWP2	Bandanna	348.4	Low	3.411	1.774	No	No
C9556VWP2	Bandanna	316	Low	-0.001	-0.002	No	No
C966VWP2	Bandanna	348.5	Low	-0.659	-0.085	Uncertain	No
C966VWP1	Bandanna	355	Low	-0.182	-0.189	Uncertain	No
C968VWP5	Bandanna	244	Low	-0.056	-0.434	Uncertain	No
C968VWP4	Bandanna	258	Low	-0.699	-0.009	Uncertain	No
C006P1	Bandanna	47.3	High	0.029	-2.121	No	Yes
C007P2	Bandanna	179.5	Medium	-0.022	-7.054	No	Yes
C008P2	Bandanna	271.38	High	0.027	-7.526	No	Yes

Table 8.6 Cause and effect analysis of representative Bandanna Formation bores

Bore	HSU	Bore depth (m)	Hydrograph trend reliability ¹	Pre dewatering rate (m/yr)	During dewatering rate (m/yr)	Climate influence	Dewatering impact
C011P1	Bandanna	55	High	0.128	-0.046	Yes	No
C014P2	Bandanna	205	High	0.017	-0.023	Yes	No
C016P2	Bandanna	233	Medium	-0.041	0.022	Yes	No
C018P1	Bandanna	53	High	-0.019	-0.034	Yes	No
C018P2	Bandanna	90	High	-0.005	-0.108	Yes	No
C032P2	Bandanna	263	High	-0.147	-0.341	Yes	No
C034P1	Bandanna	67	Medium	-0.187	-0.348	Uncertain	No
C035P2	Bandanna	110	Medium	-0.089	-0.322	Yes	No
C823SP	Bandanna	111	High	0.918	-8.158	No	Yes
C832SP	Bandanna	102	High	-0.182	-0.916	Yes	Yes
C844SP	Bandanna	179	Medium	-0.125	-0.465	Yes	No
C847SP	Bandanna	87	High	-0.159	-0.354	Yes	No
C9839SPR	Bandanna	173	Medium	-0.167	-0.510	Yes	No

Notes: ¹ Low reliability factors: C14200VWP1 groundwater levels do not stabilise during pre-dewatering period. Not clear if this VWP is still equilibrating to formation pressures. C14207VWP1 groundwater levels do not stabilise during pre-dewatering period. Not clear if this VWP is still equilibrating to formation pressures. C555VWP1 groundwater levels do not stabilise during pre-dewatering period. Not clear if this VWP is still equilibrating to formation pressures. C558VWP3 has an increasing trend throughout entire record, not clear if this is related to equilibration to formation pressures. C842VWP2 groundwater levels do not stabilise during pre-dewatering period. Not clear if this VWP is still equilibrating to formation pressures. C851VWP2 has a 2m offset between pre-dewatering and during-dewatering periods with no interim data to understand why this occurs. C9553VWP2 groundwater levels do not stabilise during pre-dewatering period. Not clear if this VWP is still equilibrating to formation pressures. C9556VWP2 is stable, however, the heads are at -55 mAHd, and make no physical sense. C966VWP2 groundwater levels do not stabilise during pre-dewatering period. Not clear if this VWP is still equilibrating to formation pressures. C966VWP1 has a 1m offset between pre-dewatering and during-dewatering periods with no interim data to understand why this occurs. Not clear yet if VWP has stabilised. C968VWP5 and C968VWP4 have heads that are tens of metres below what is expected based on regional potentiometrics.

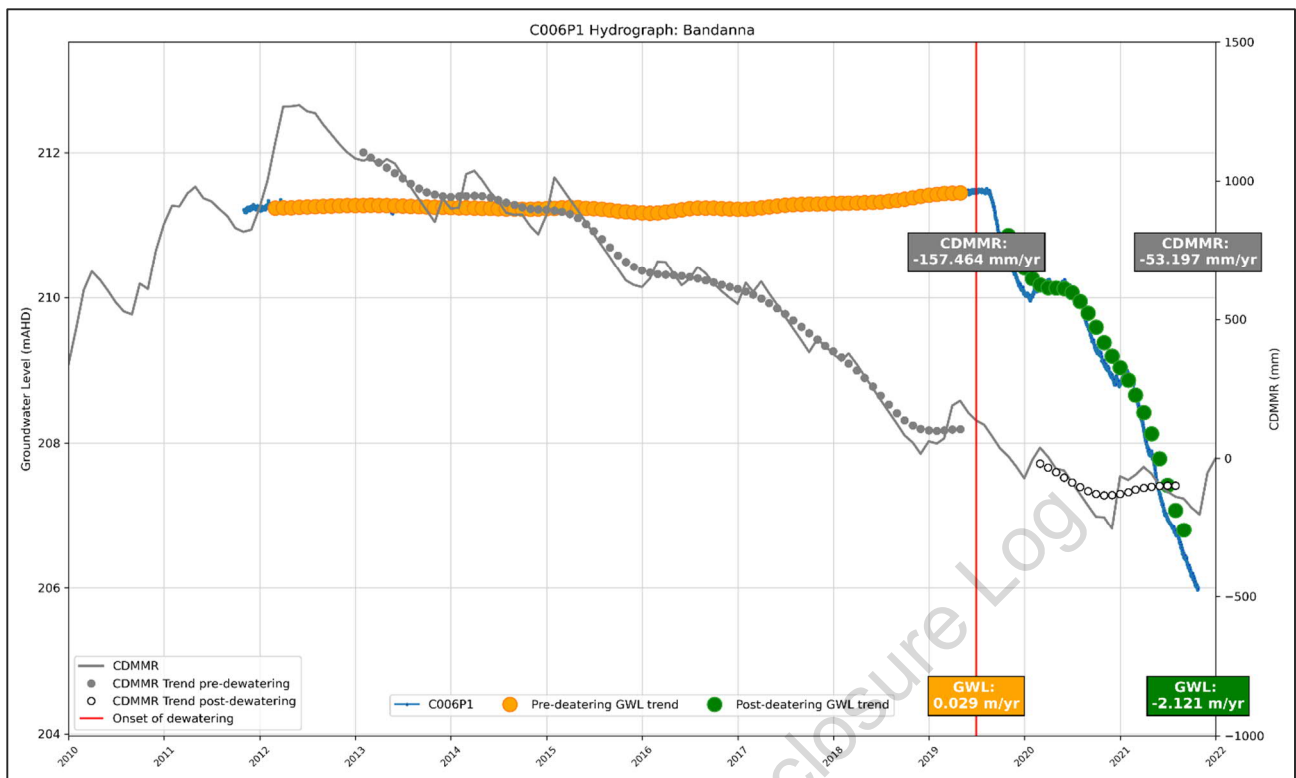
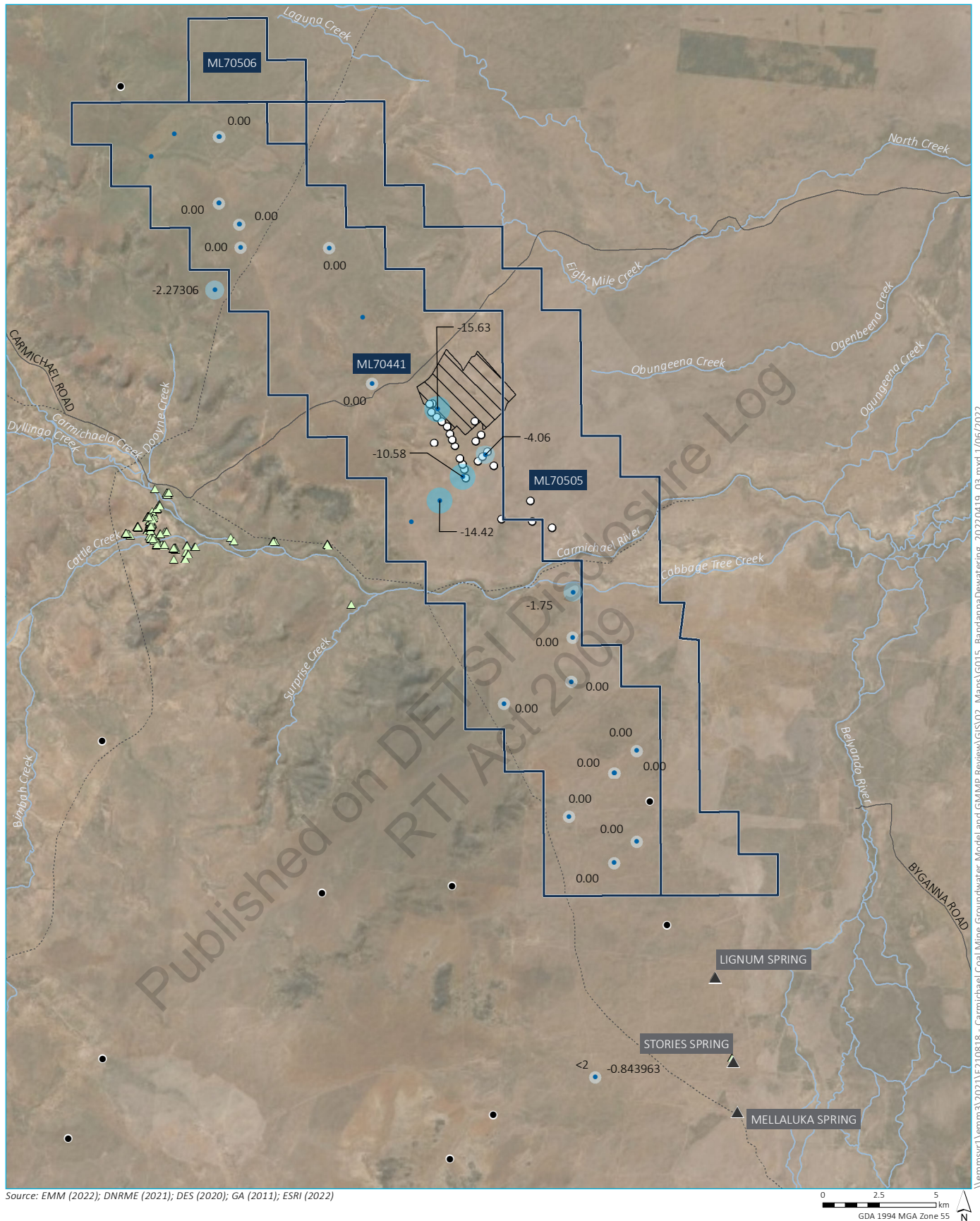


Figure 8.11 Cause and effect hydrograph analysis for Bandanna Formation bore C006P1



KEY

- Mining lease
- Open cut 2021
- Minor road
- Vehicular track
- Named watercourse
- ▲ DSC spring
- ▲ Mellaluka spring
- Landholder bore
- Dewatering bore
- Bandana bore
- Observed dewatering drawdown (m)
- 25 - -10
- 10 - -1
- 1 - 0

Spatial analysis of Bandanna Formation dewatering trends from representative bores with sufficient pre- and during - dewatering data

Carmichael Coal Mine
Data Review and Conceptualisation Report
Figure 8.12

8.1.7 Colinlea Sandstone

Appendix B presents a summary of the hydrograph analysis for the 27 representative Colinlea Sandstone bores/VWPs. Of these 27 sites, 23 have been classified as medium or high reliability. Most of the VWPs and bores show subtle positive linear correlation to climate. Nine of the 23 VWPs/bores show potential signs of dewatering impacts (medium and high confidence reliability only), with rates of drawdown typically <10 m/yr. Figure 8.13 presents a representative hydrograph for C006P3R. In this bore, there is a sudden declining trend that is coincident with the commencement of dewatering preceded by natural flat-lying levels in the period prior to dewatering. Overall, across the hydrographs, dewatering is dominating the declining antecedent trends in the central and southern extents of the lease. There are also fewer instances of climate influence on the hydrographs, and some unusual responses that look like the VWP or bore may be equilibrating post-drilling (which have been prescribed as low confidence).

Figure 8.14 presents a plan view of the representative Colinlea Sandstone sites across the project site. This map shows dewatering impacts spread considerably further than what is observed for the Bandanna Formation (compare with Figure 8.12). This suggests that the Colinlea Sandstone is more transmissive than the Bandanna Formation, and therefore dewatering is likely to be preferentially pumping from this deeper unit. Another key observation on Figure 8.14 is that the dewatering spreads further to the south than the north and that the magnitudes in the south are greater. This anisotropy in the dewatering pattern may indicate either more transmissive sandstones to the south or a partial flow barrier to the north. Landholder bores are plotted as black symbols and may contribute to some of the drawdown observed in the southern lease extents in the Colinlea Sandstone.

Table 8.7 Cause and effect analysis of representative Colinlea Sandstone bores

Bore	HSU	Bore depth (m)	Hydrograph trend reliability ¹	Pre dewatering rate (m/yr)	During dewatering rate (m/yr)	Climate influence	Dewatering impact
C056VWP1	Colinlea	408	Low	4.759	1.315	Uncertain	No
C14203VWP1	Colinlea	247	Low	0.738	-0.756	Uncertain	Yes
C558VWP2	Colinlea	120	Medium	-0.101	-3.032	No	Yes
C558VWP1	Colinlea	178	Medium	-0.449	-0.257	No	No
C842VWP1	Colinlea	235	Medium	-1.766	-0.470	Yes	No
C851VWP1	Colinlea	209.7	Medium	-0.369	-0.139	Yes	No
C9553VWP1	Colinlea	467.43	Low	3.227	0.691	Uncertain	No
C9556VWP1	Colinlea	410	Low	-18.211	0.484	Uncertain	No
C968VWP3	Colinlea	302.5	Medium	-0.066	-0.360	Yes	No
C968VWP2	Colinlea	348.5	Medium	-0.871	-0.154	Yes	No
C968VWP1	Colinlea	355	Medium	-0.811	-0.073	Yes	No
C9836VWP1	Colinlea	296	Medium	-6.986	-0.356	Uncertain	No
C006P3R	Colinlea	118	Medium	0.004	-10.433	Uncertain	Yes
C011P3	Colinlea	105	Medium	-0.011	-0.013	Yes	No
C018P3	Colinlea	161	Medium	0.022	-0.091	Yes	No
C024P3	Colinlea	49	Medium	0.003	-0.031	Yes	No
C034P3	Colinlea	113	Medium	-0.105	-0.665	Yes	Yes

Table 8.7 Cause and effect analysis of representative Colinlea Sandstone bores

Bore	HSU	Bore depth (m)	Hydrograph trend reliability ¹	Pre dewatering rate (m/yr)	During dewatering rate (m/yr)	Climate influence	Dewatering impact
C180112SP	Colinlea	120	Medium	-0.125	-20.747	Uncertain	Yes
C19026SP	Colinlea	260	Medium	0.040	-10.550	Uncertain	Yes
C19029SP	Colinlea	120	Medium	-0.043	-12.955	Uncertain	Yes
C827SP	Colinlea	138	Medium	0.006	-11.316	Uncertain	Yes
C833SP	Colinlea	134	Medium	-0.199	-1.393	Uncertain	Yes
C834SP	Colinlea	151	Medium	-0.213	-1.051	Yes	Yes
C840SP	Colinlea	212	Medium	-0.178	-0.848	Yes	Yes
C848SP	Colinlea	140	Medium	-0.170	-0.364	Yes	No
C975SP	Colinlea	86.73	Medium	0.019	-0.045	Uncertain	No
C9849SPR	Colinlea	170	Medium	-0.170	-0.384	Yes	No

Notes: ¹ Low reliability factors: C056VWP1 groundwater levels do not stabilise during pre-dewatering period. Not clear if this VWP is still equilibrating to formation pressures. C14203VWP1 groundwater levels do not stabilise during pre-dewatering period. Not clear if this VWP is still equilibrating to formation pressures. C9553VWP1 groundwater levels do not stabilise during pre-dewatering period. Not clear if this VWP is still equilibrating to formation pressures. C9556VWP1 groundwater levels are highly erratic and do not stabilise during pre-dewatering period. Not clear if this VWP is still equilibrating to formation pressures.

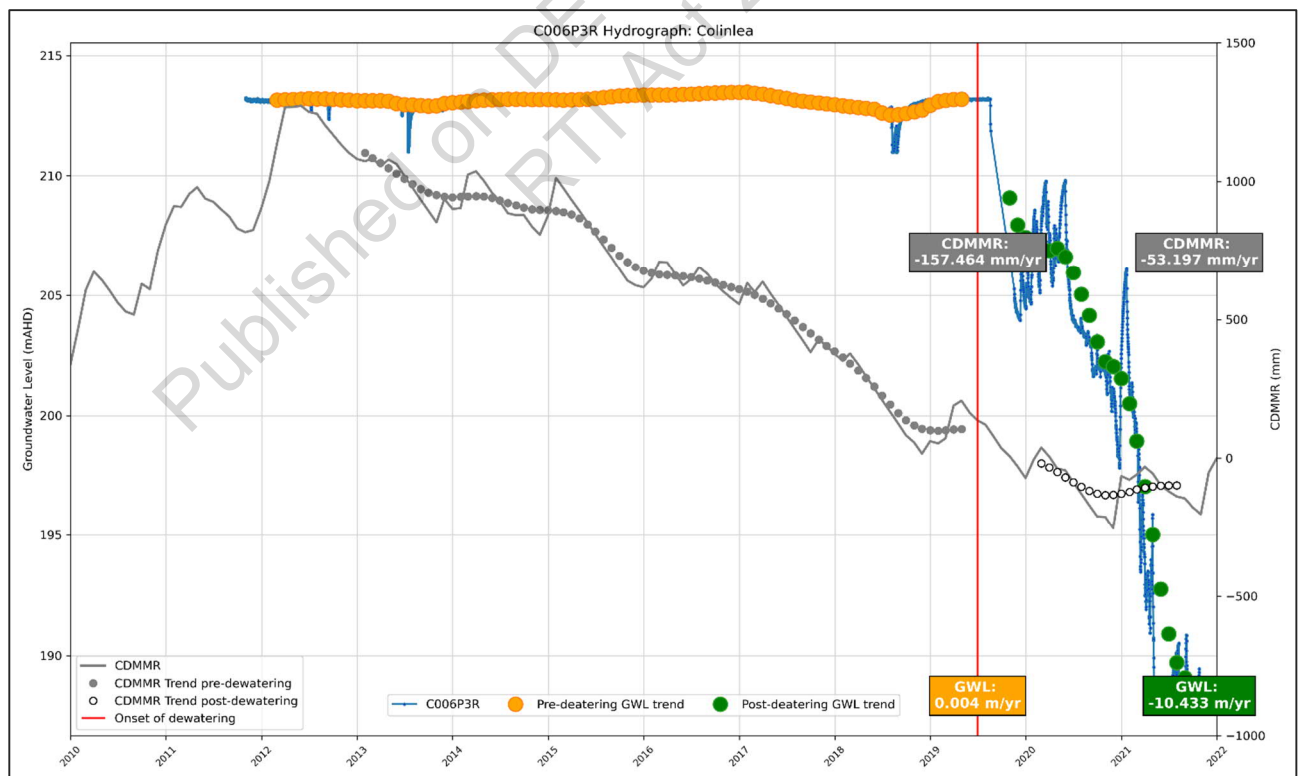
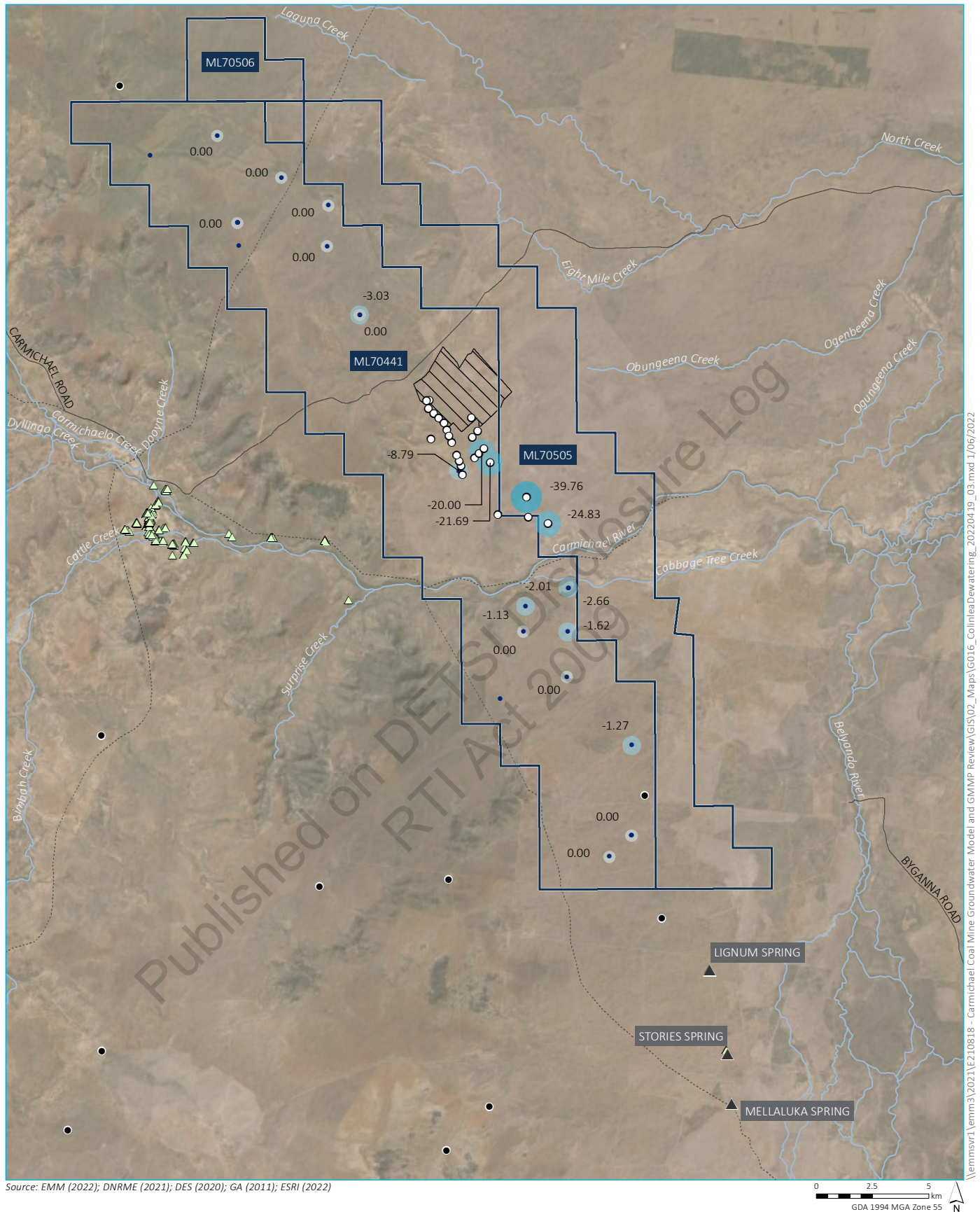
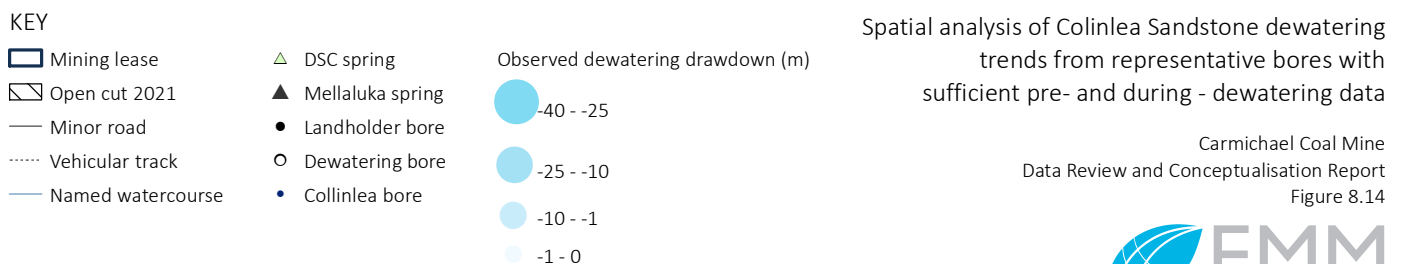


Figure 8.13 Cause and effect hydrograph analysis for Colinlea Sandstone bore C006P3R



8.1.8 Joe Joe Group

Table 8.8 presents a summary of the hydrograph analysis for the 17 representative Joe Joe bores. Of these 17 sites, 16 have been classified as medium or high reliability. Most of the bores show subtle positive linear correlation to climate. Two of the 16 bores show potential signs of dewatering impacts (medium and high confidence reliability only), with rates of drawdown typically <1 m/yr. Figure 8.15 presents a representative hydrograph for C14032SP. In this bore, there is a sudden declining trend that is coincident with the commencement of dewatering preceded by fluctuating natural levels in the period prior to dewatering, however, the rate of decline is not exceeding the 0.4 m/year threshold to be confidently designated as a dewatering impact. Overall, across the hydrographs, declining trends are prevalent in the southern extents of the lease and beyond the southern extents towards MSC. Landholder pumping may be a major contributor to those subtle declining trends. It is difficult to pinpoint the declines to just dewatering efforts in overlying strata.

Figure 8.16 presents a plan view of the representative Joe Joe sites across the project site. This map shows dewatering impacts are concentrated in the south. Landholder bores are plotted as black symbols and are likely to contribute to the drawdown observed in the southern lease extents in the Joe Joe Formation.

Table 8.8 Cause and effect analysis of representative Joe Joe bores

Bore	HSU	Bore depth (m)	Hydrograph trend reliability ¹	Pre dewatering rate (m/yr)	During dewatering rate (m/yr)	Climate influence	Dewatering impact
C012P1	JoeJoe	40	Medium	-0.006	-0.043	Yes	No
C012P2	JoeJoe	59	Medium	-0.017	-0.033	Yes	No
C14002SP	JoeJoe	113.8	Medium	-0.025	-0.034	Yes	No
C14003SP	JoeJoe	70	Medium	-0.012	0.047	Yes	No
C14004SP	JoeJoe	103	Low	0.095	0.678	Uncertain	No
C14006SP	JoeJoe	115.4	Medium	-0.037	-0.223	No	No
C14008SP	JoeJoe	120	Medium	-0.154	-0.400	Yes	No
C14015SP	JoeJoe	144	Medium	-0.097	-0.221	Yes	No
C14016SP	JoeJoe	129	Medium	-0.519	-0.551	Yes	No
C14017SP	JoeJoe	111	Medium	0.302	-0.935	Yes	Yes
C14032SP	JoeJoe	90	High	-0.014	-0.255	Yes	No
C180119SP	JoeJoe	85	Medium	-0.083	-0.255	No	No
C180123SP	JoeJoe	130	Medium	-0.112	-0.152	Yes	No
C914001SPR	JoeJoe	57	Medium	-0.014	-0.084	Yes	No
C914030SPR	JoeJoe	114	Medium	0.056	-0.478	Yes	Yes
C9180124SPR	JoeJoe	86	Medium	0.027	-0.327	Uncertain	No
C9180125SPR	JoeJoe	121	Medium	-0.196	-0.165	Uncertain	No

Notes: ¹ Low reliability factors: C14004SP groundwater levels do not stabilise during pre-dewatering period, and then there is a 2m offset between the pre-dewatering and during-dewatering periods with no interim data to understand why this offset occurs.

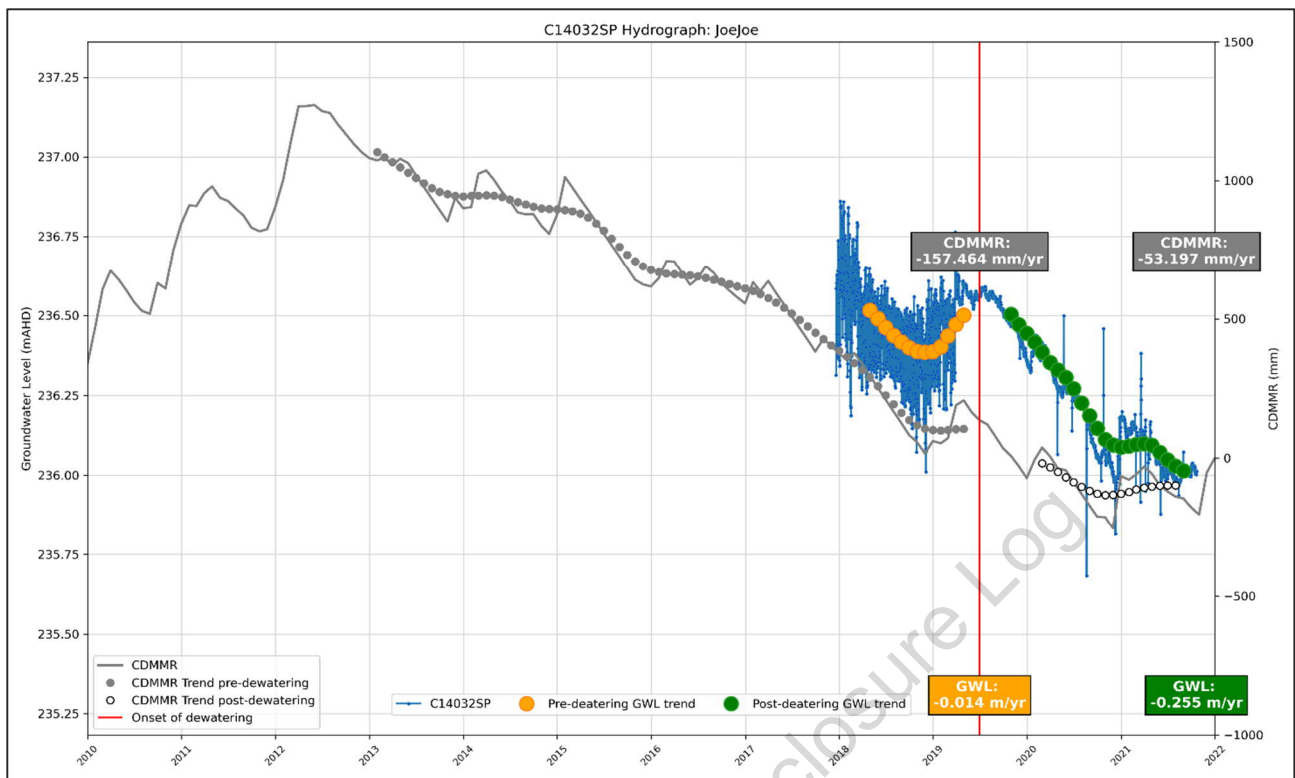
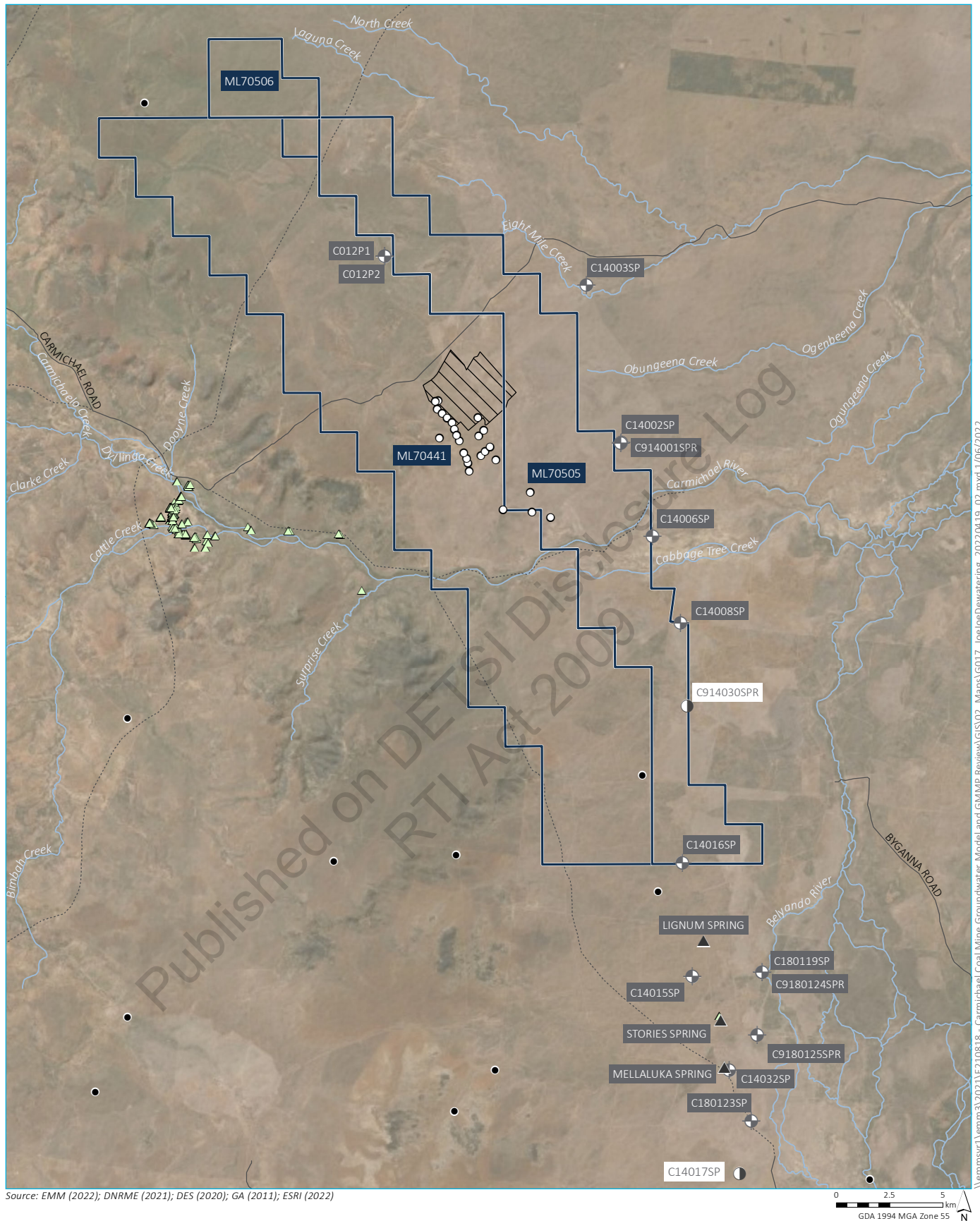


Figure 8.15 Cause and effect hydrograph analysis for Joe Joe bore C14032SP



KEY

- Mining lease
- Open cut 2021
- Minor road
- Vehicular track
- Named watercourse
- ▲ DSC spring
- Dewatering bore
- ▲ Mellaluka spring
- Landholder bore
- Joe Joe - dewatering
- Joe Joe - no dewatering

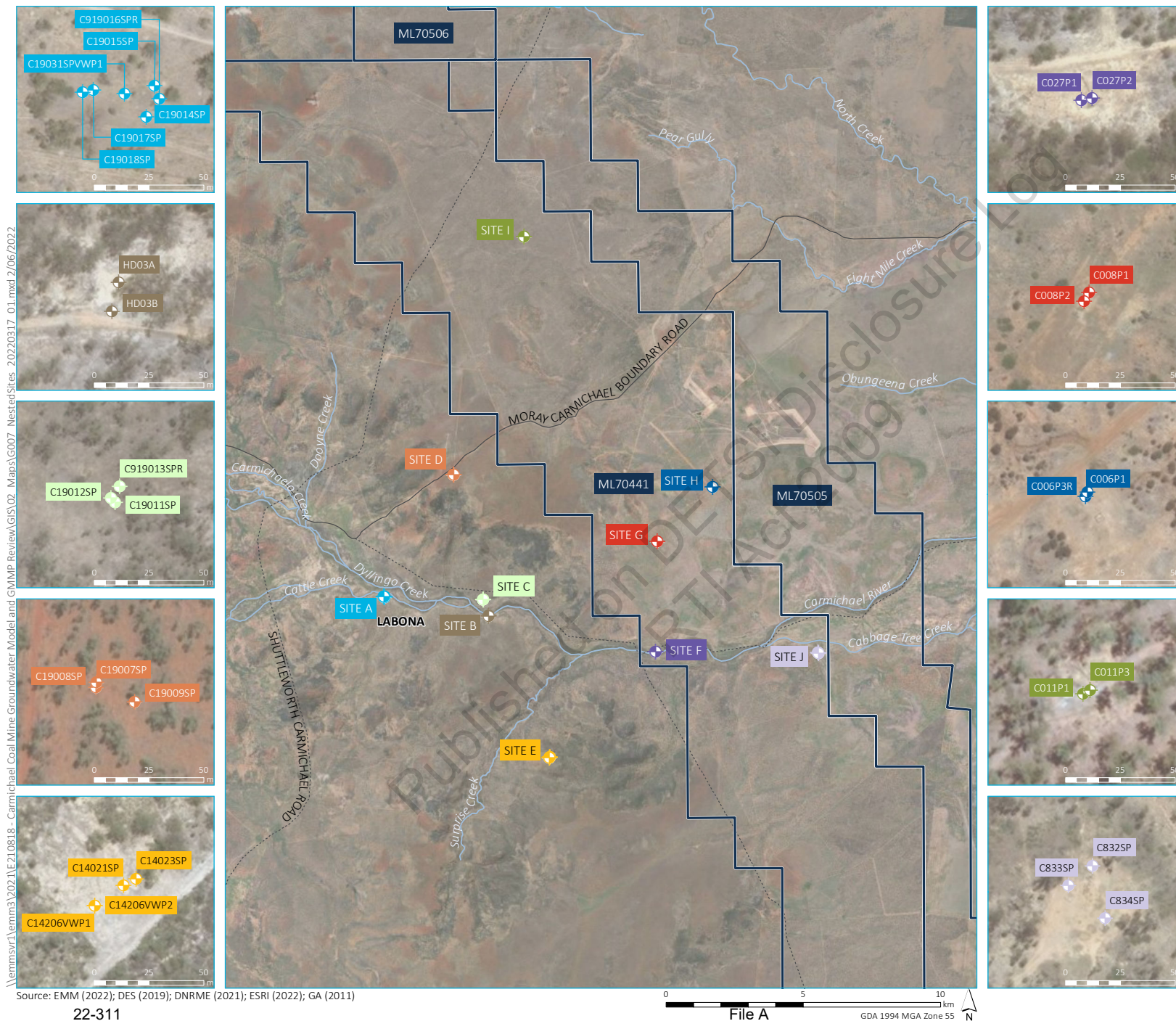
Spatial analysis of Joe Joe dewatering trends from representative bores with sufficient pre- and during - dewatering data

Carmichael Coal Mine
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Figure 8.16

8.2 Representative nested hydrographs

Ten representative nested hydrograph sites were selected for a more detailed review of potential vertical hydraulic gradients between HSUs across the project study area. These sites were selected based on DES feedback on 10 March 2022, as well as detailed analysis by Hydro Algorithmics (2021). The ten sites are shown on Figure 8.17 and described in detail in the sub-sections below.

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RTI Act 2009



- KEY**
- Mining lease
 - Minor road
 - Vehicular track
 - Named watercourse
- Nested bores**
- Site A
 - Site B
 - Site C
 - Site D
 - Site E
 - Site F
 - Site G
 - Site H
 - Site I
 - Site J

Nested bore sites

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Figure 8.17

8.2.1 Site A

There is a nested site (herein referred to as Site A, equivalent to Site 46) with six depth intervals midway between Moses Spring and Little Moses Spring. The bores at this location are summarised in Table 8.9 below. One of the monitoring bores at this location (C19017SP in the Rewan Formation) has four manual readings that are <100 mAHD that are considered unreliable for vertical flow analysis. These manual readings have recovered 60 m over a six-month period and indicate that the monitoring bore is still equilibrating to formation conditions post-drilling and construction. The remaining five sites with reliable readings provide a depth profile that includes Clematis Sandstone, Dunda Beds, Rewan Formation, Bandanna Formation and Colinlea Sandstone. The groundwater pressures at these five sites are shown as a stacked group plot in Figure 8.18. The ground surface elevation as surveyed at C19031SPVWP1, is shown as a horizontal black line at elevation 238.919 mAHD. This figure shows artesian conditions for the upper Rewan, Dunda Beds and Clematis Sandstone with an upward flow potential across these three formations. Conversely, the Bandanna Formation and Colinlea Sandstone groundwater pressures at this site are sub-artesian and ~20 m lower than the Clematis Sandstone pressures. This implies a downward flow gradient in these two Betts Creek Bed units. The data for C19031SP before July 2021 can be ignored and is likely attributable to equilibration of the VWP sensor. There are stable pressures after this point in time, that make sense with respect to the overlying Bandanna Formation observation bore.

Table 8.9 Bore/VWP details at nested site A

Bore	HSU	Completion	Readings	Screen interval (mbgl)	Reliable trend
C19014SP	Clematis Sandstone	Monitoring Bore	Manual + Logger	102 to 114	Yes
C19015SP	Dunda Beds	Monitoring Bore	Manual + Logger	168 to 180	Yes
C919016SPR	Rewan Formation	Monitoring Bore	Manual + Logger	238 to 250	Yes
C19017SP	Rewan Formation	Monitoring Bore	Manual	448 to 460	No
C19018SP	Bandanna Formation	Monitoring Bore	Manual	480 to 492	Yes
C19031SPVWP1	Colinlea Sandstone	VWP	Logger	601.4	Yes

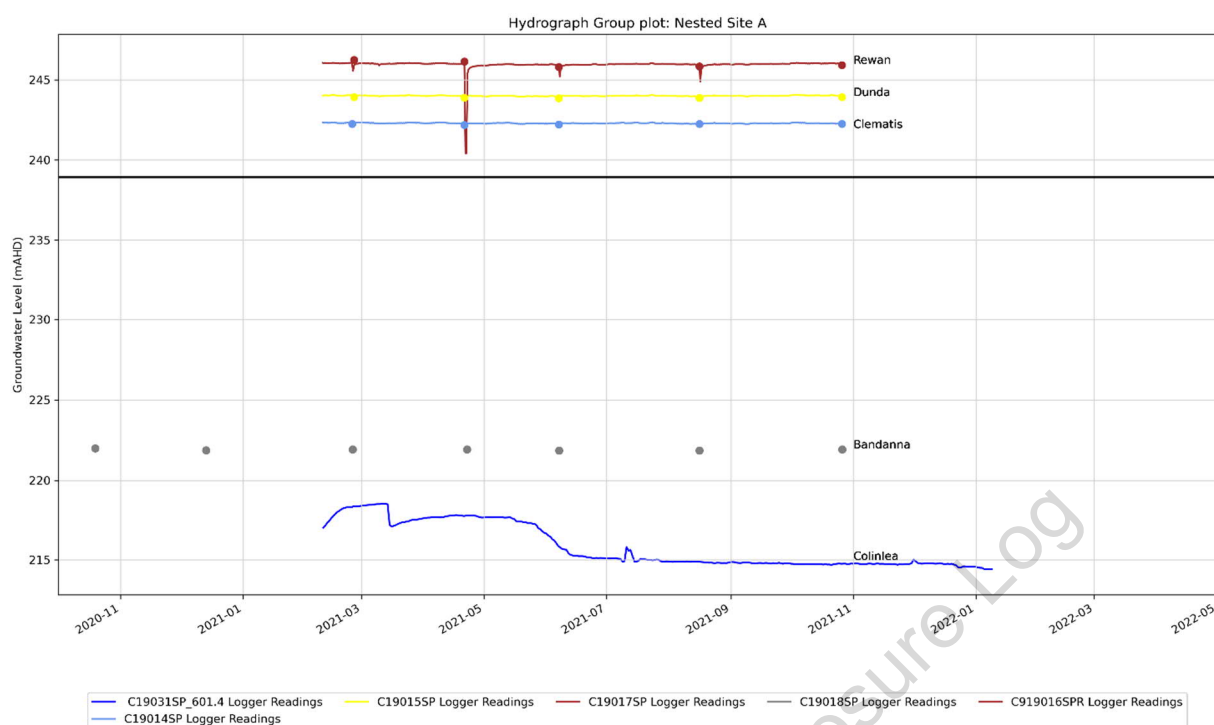


Figure 8.18 Stacked hydrograph group plot that shows nested site A groundwater pressures

8.2.2 Site B

There is a nested site (herein referred to as Site B) with two depth intervals downstream of Little Moses Spring and immediately south of the Carmichael River. The bores at this location are summarised in Table 8.10 below. The two bores are screened across the Clematis Sandstone and the shallow alluvium. The groundwater pressures/elevations at these two sites are shown as a stacked group plot in Figure 8.19. The ground surface elevation as surveyed at HD03A is shown as a horizontal black line at elevation 229.41 mAHD. This figure shows confined, artesian conditions for the Clematis Sandstone with an upward flow potential towards the alluvium, with the alluvium acting as a sub-artesian, unconfined aquifer. Of note, at this site is the synchronous nature of groundwater levels/pressures increasing by up to 1 m in January 2021 in both bores. This sudden increase suggests that both units are being recharged locally from either diffuse rainfall and/or river leakage. This recharge response corresponds to over 200 mm of rainfall in the same month (January 2021). The recharge response for both HSUs indicates effective and rapid recharge processes. Given the proximity to the river, and the rapid response to rainfall, it is plausible that the Carmichael River is recharging both units.

Table 8.10 Bore details at nested site B

Bore	HSU	Completion	Readings	Screen interval (mbgl)	Reliable trend
HD03A	Clematis Sandstone	Monitoring Bore	Manual + Logger	29 to 37	Yes
HD03B	Alluvium	Monitoring Bore	Manual + Logger	6 to 11	Yes

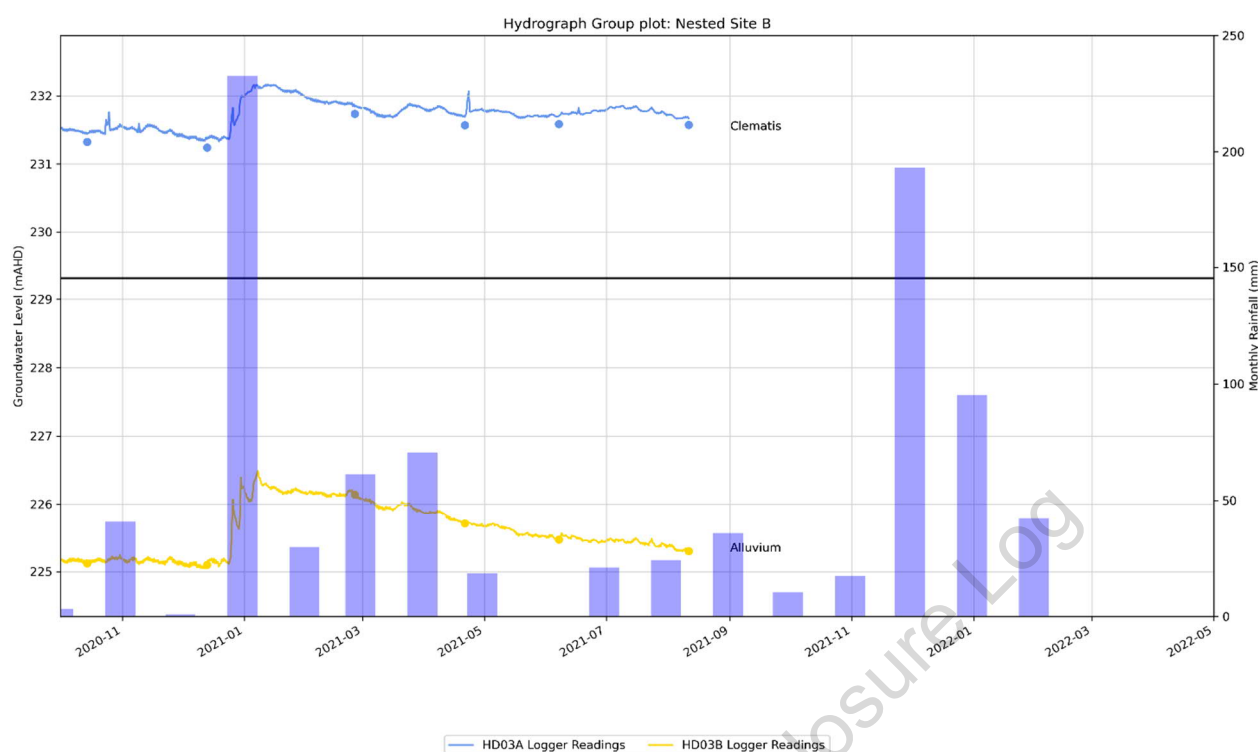


Figure 8.19 Stacked hydrograph group plot that shows nested site B groundwater pressures/levels versus monthly rainfall

8.2.3 Site C

There is a nested site (herein referred to as Site C, equivalent to Site 45) with three depth intervals at a location on the northern side of Carmichael River and ~640 m north of HD03A and HD03B. The bores at this location are summarised in Table 8.11 below. The three bores are screened across the Dunda Beds and the Rewan Formation. One of the bores, C919013SPR, has anomalously low pressures below 30 mAHd, and has recovered over 38 m in a 6-month period of monitoring. This suggests that this deeper bore is still equilibrating post-drilling and is unsuitable for vertical flow analysis.

The groundwater pressures/elevations at the two remaining sites are shown as a stacked group plot in Figure 8.20. The ground surface elevation, as surveyed at C19012SP, is shown as a horizontal black line at elevation 238.4 mAHd. This figure shows confined, artesian conditions for the Dunda Beds and slightly artesian conditions for the Rewan Formation, with a downward flow potential towards the Rewan. There are obvious sampling effects observed in C19012SP, although these quickly equilibrate back to quasi-steady state conditions shortly after each event.

Table 8.11 Bore/VWP details at nested site C

Bore	HSU	Completion	Readings	Screen interval (mbgl)	Reliable trend
C19011SP	Dunda Beds	Monitoring Bore	Manual + Logger	162 to 174	Yes
C19012SP	Rewan Formation	Monitoring Bore	Manual + Logger	212 to 224	Yes
C919013SPR	Rewan Formation	Monitoring Bore	Manual	448 to 460	No

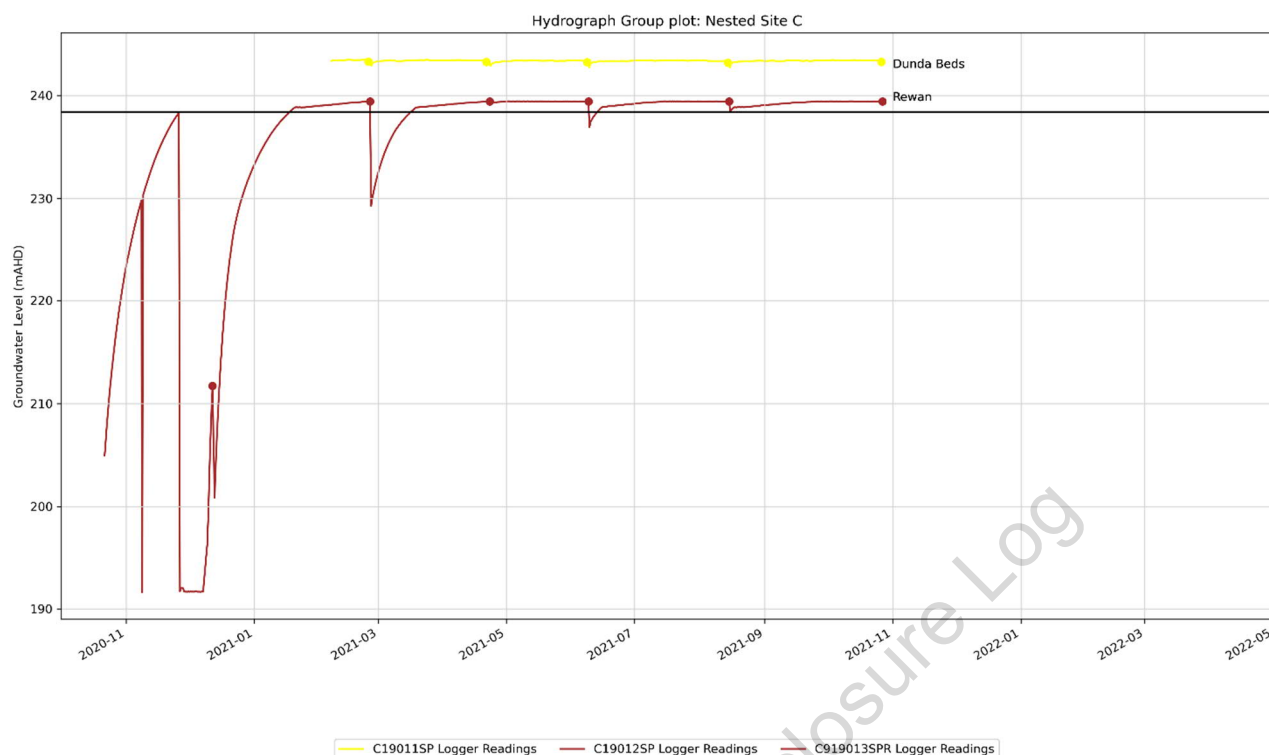


Figure 8.20 Stacked hydrograph group plot that shows nested site C groundwater pressures

8.2.4 Site D

There is a nested site (herein referred to as Site D, equivalent to Site 3) with three depth intervals at a location ~4.5 km north of Carmichael River and ~1.5 km west of the mining lease. The bores at this location are summarised in Table 8.12 below. The three bores are screened across the Dunda Beds and the Rewan Formation. One of the bores, C19009SP, has anomalously low pressures below 30 mAHD, and has recovered over 20 m in a 12-month period of monitoring. This suggests that this deeper bore is still equilibrating post-drilling and is unsuitable for vertical flow analysis. The groundwater pressures at the two remaining sites are shown as a stacked group plot in Figure 8.21. The ground surface elevation, as surveyed at C19007SP, is at elevation 310.28 mAHD (approximately 65 m above pressure in the Rewan). This figure shows confined, sub-artesian conditions for the Rewan Formation and Dunda Beds, with a slight upward flow potential towards the Dunda Beds.

Table 8.12 Bore/VWP details at nested site D

Bore	HSU	Completion	Readings	Screen interval (mbgl)	Reliable trend
C19007SP	Dunda Beds	Monitoring Bore	Manual + Logger	225 to 237	Yes
C19008SP	Rewan Formation	Monitoring Bore	Manual + Logger	271 to 283	Yes
C19009SP	Rewan Formation	Monitoring Bore	Manual	505 to 517	No

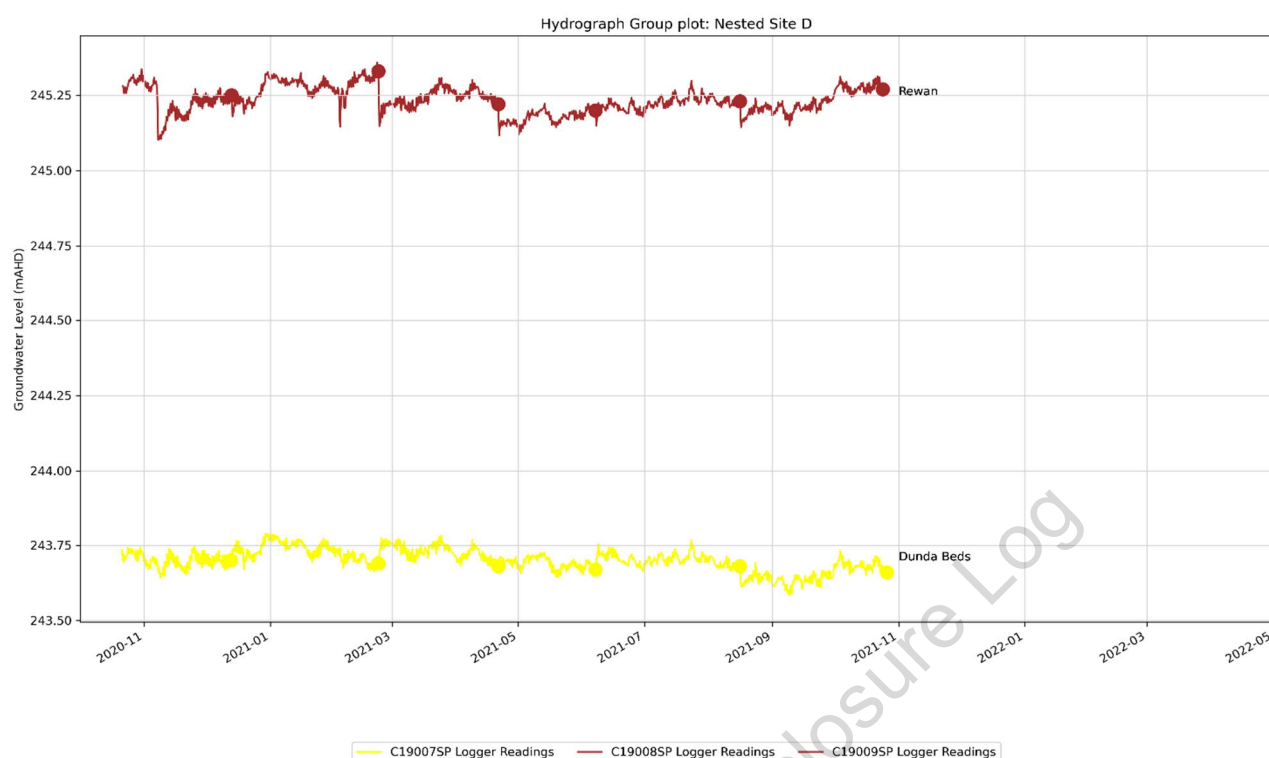


Figure 8.21 Stacked hydrograph group plot that shows nested site D groundwater pressures

8.2.5 Site E

There is a nested site (herein referred to as Site E) with four depth intervals at a location ~3.9 km south of Carmichael River and ~5 km west of the mining lease. The bores at this location are summarised in Table 8.13 below. The two bores are screened across the Clematis Sandstone and Dunda Beds and the two VWP's are monitoring the Rewan Formation and Bandanna Formation. The readings from the two VWP's are spurious and don't make hydrogeological sense. It is likely these are still equilibrating to formation pressures. Both of the VWP's are unsuitable for vertical flow analysis. The groundwater pressures at the two remaining sites are shown as a stacked group plot in Figure 8.22. The ground surface elevation, as surveyed at C14023SP, is at elevation 277.675 mAHD (approximately 30 m above pressure in the Dunda Beds). This figure shows confined, sub-artesian conditions for the Clematis Sandstone and Dunda Beds, with a slight upward flow potential towards the Clematis Sandstone.

Table 8.13 Bore/VWP details at nested site E

Bore	HSU	Completion	Readings	Screen interval (mbgl)	Reliable trend
C14021SP	Clematis Sandstone	Monitoring Bore	Manual + Logger	33 to 39	Yes
C14023SP	Dunda Beds	Monitoring Bore	Manual + Logger	124 to 130	Yes
C14206VWP2	Rewan Formation	VWP	Logger	355	No
C14206VWP1	Bandanna Formation	VWP	Logger	464	No



Figure 8.22 Stacked hydrograph group plot that shows nested site E groundwater pressures

8.2.6 Site F

There is a nested site (herein referred to as Site F) with two depth intervals at a location immediately north of Carmichael River and ~600 m inside the mining lease. The bores at this location are summarised in Table 8.14 below. The two bores are screened across the alluvium Dunda Beds. The groundwater levels/pressures at the two sites are shown as a stacked group plot in Figure 8.23. The ground surface elevation, as surveyed at C027P2, is at elevation 227.58 mAHD (approximately 0.5 m above pressure in the Dunda Beds). This figure shows confined, sub-artesian conditions for the Dunda Beds and unconfined conditions in the alluvium. There is strong upward flow potential towards the alluvium.

Table 8.14 Bore/VWP details at nested site F

Bore	HSU	Completion	Readings	Screen interval (mbgl)	Reliable trend
C027P1	Alluvium	Monitoring Bore	Manual + Logger	6 to 12	Yes
C027P2	Dunda Beds	Monitoring Bore	Manual + Logger	28 to 32	Yes

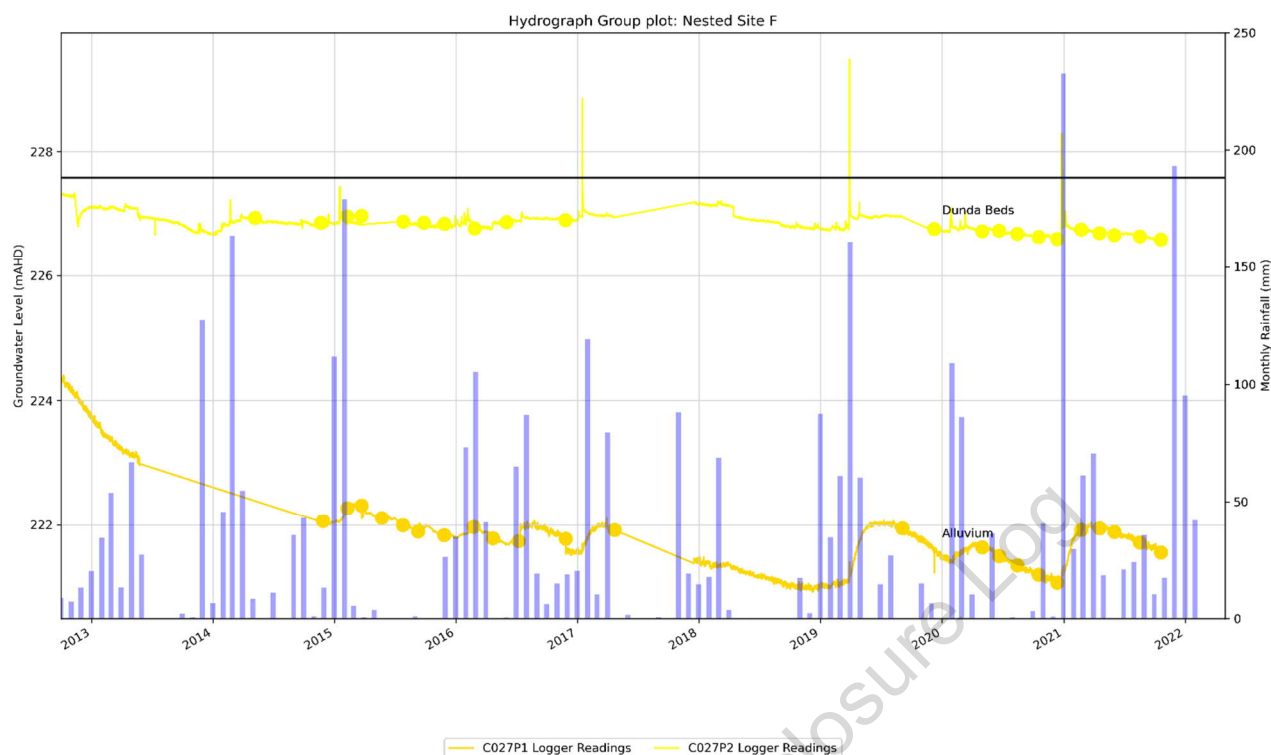


Figure 8.23 Stacked hydrograph group plot that shows nested site F groundwater levels/pressures

8.2.7 Site G

There is a nested site (herein referred to as Site G) with two depth intervals at a location ~3.9 km north of Carmichael River, ~2.4 km inside the mining lease, and ~1.5 km to the southwest of active dewatering bores. The bores at this location are summarised in Table 8.15 below. The two bores are screened across the Rewan Formation and Bandanna Formation. The groundwater pressures at the two sites are shown as a stacked group plot in Figure 8.24. The ground surface elevation, as surveyed at C008P1, is at elevation 238.14 mAHD (approximately 15 m above pressure in the Rewan). This figure shows confined, sub-artesian conditions for both the Rewan Formation and the Bandanna Formation. Pre-dewatering (onset of dewatering marked as vertical red line) there is an upward flow potential towards the Rewan Formation, but after dewatering the flow potential reverses as the drawdown impacts the Bandanna.

Table 8.15 Bore details at nested site G

Bore	HSU	Completion	Readings	Screen interval (mbgl)	Reliable trend
C008P1	Rewan Formation	Monitoring Bore	Manual + Logger	47 to 57.5	Yes
C008P2	Bandanna Formation	Monitoring Bore	Manual + Logger	260 to 271.50	Yes

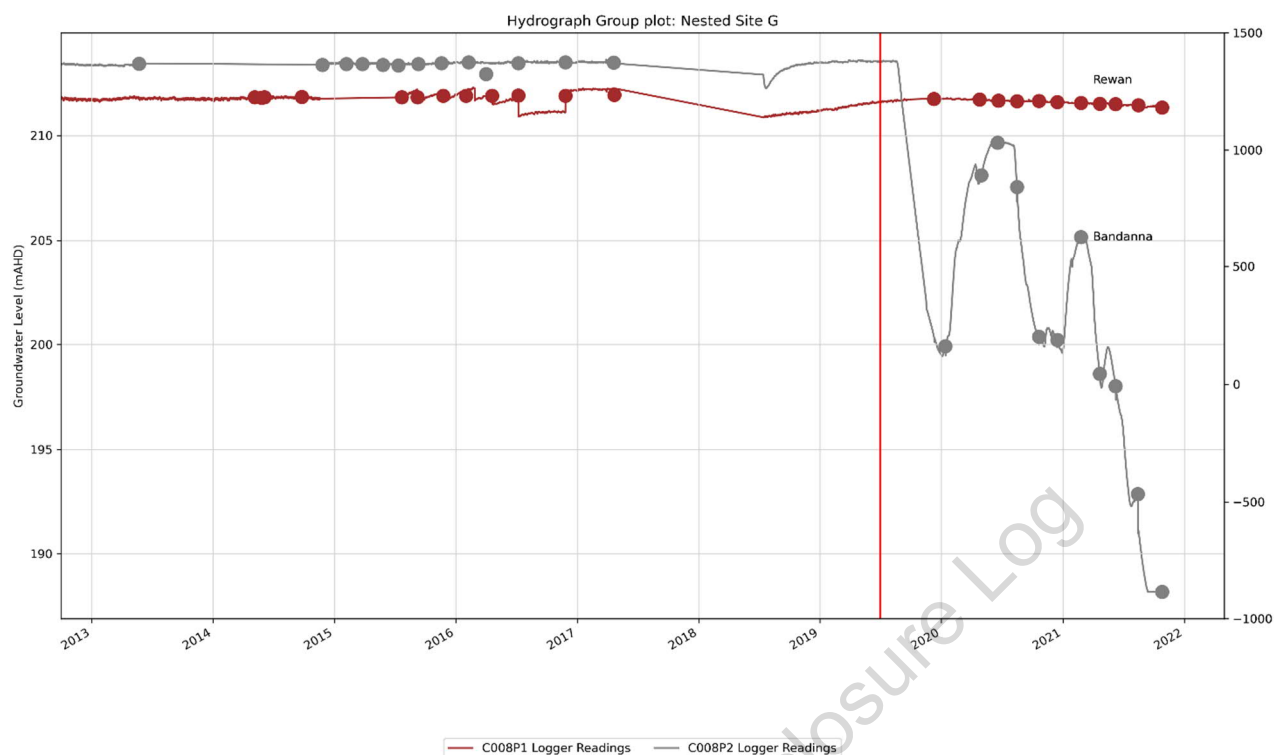


Figure 8.24 Stacked hydrograph group plot that shows nested site G groundwater pressures

8.2.8 Site H

There is a nested site (herein referred to as Site H) with two depths in the middle of a cluster of active dewatering bores. The bores at this location are summarised in Table 8.16 below. The two bores are screened across the Bandanna Formation and Colinlea Sandstone. The groundwater pressures at the two sites are shown as a stacked group plot in Figure 8.25. The ground surface elevation, as surveyed at C006P3R, is at elevation 233.86 mAHD (approximately 20 m above pressure in the Colinlea Sandstone). This figure shows confined, sub-artesian conditions for both the Bandanna Formation and the Colinlea Sandstone. Pre-dewatering (onset of dewatering marked as vertical red line) there is an upward flow potential towards the Bandanna Formation, but after dewatering the flow potential reverses as the drawdown impacts the Colinlea Sandstone in a more pronounced way than the Bandanna Formation. This perhaps infers that more abstraction occurs from the Colinlea Sandstone than from the coal seams of the Bandanna Formation in the area adjacent these bores. The three nearest dewatering bores (C19114PT, C19115PT, and C19116PT) tap the full Permian sequence to the E Seam.

Table 8.16 Bore/VWP details at nested site H

Bore	HSU	Completion	Readings	Screen interval (mbgl)	Reliable trend
C006P1	Bandanna Formation	Monitoring Bore	Manual + Logger	36 to 42	Yes
C006P3R	Colinlea Sandstone	Monitoring Bore	Manual + Logger	108 to 118	Yes

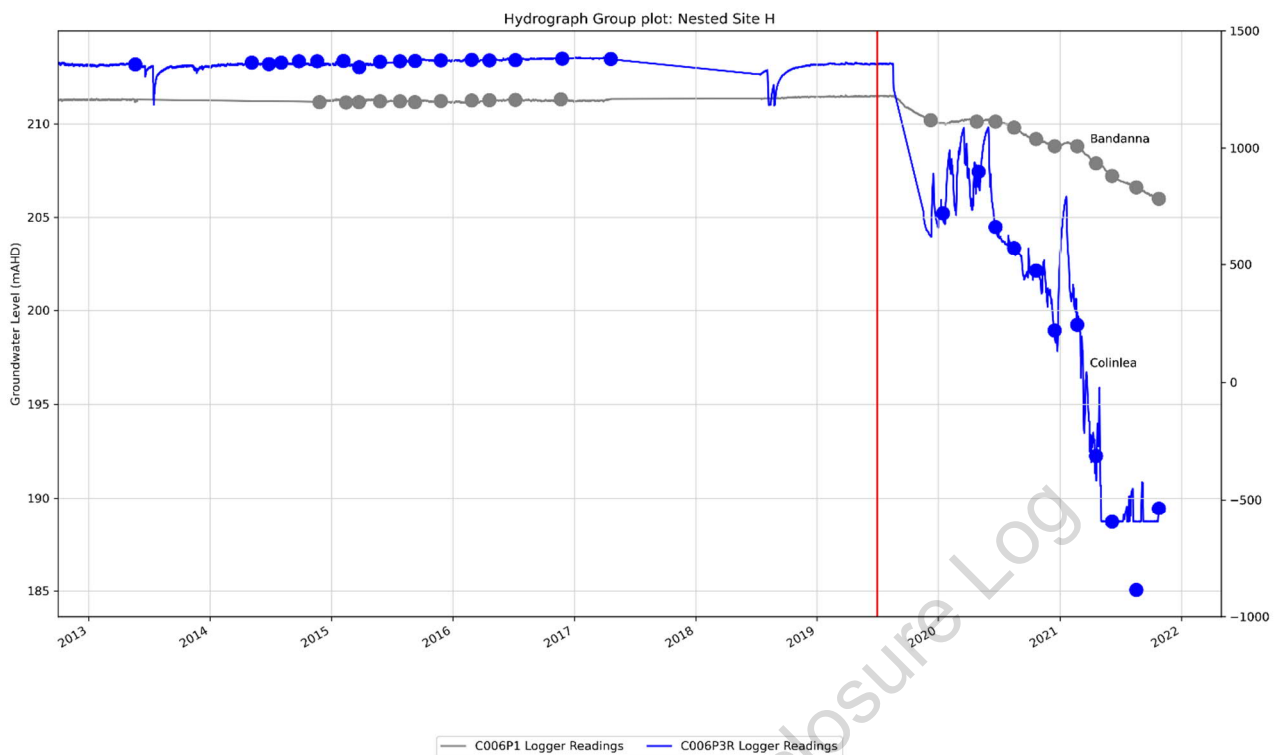


Figure 8.25 Stacked hydrograph group plot that shows nested site H groundwater pressures

8.2.9 Site I

There is a nested site (herein referred to as Site I) with two depths ~8 km to the north of the active dewatering bore network. The bores at this location are summarised in Table 8.17 below. The two bores are screened across the Bandanna Formation and Colinlea Sandstone. The groundwater pressures at the two sites are shown as a stacked group plot in Figure 8.26. The ground surface elevation, as surveyed at C011P1, is at elevation 254.63 mAHD (approximately 24 m above pressure in the Bandanna Formation). This figure shows confined, sub-artesian conditions for both the Bandanna Formation and the Colinlea Sandstone. There is no change in trend for either site when comparing pre-dewatering with during-dewatering (demarcated by vertical red line). Therefore, drawdown has not propagated this far north as yet. Over the nine years of monitoring there is a downward flow potential towards the Colinlea Sandstone.

Table 8.17 Bore/VWP details at nested site I

Bore	HSU	Completion	Readings	Screen interval (mbgl)	Reliable trend
C011P1	Bandanna Formation	Monitoring Bore	Manual + Logger	48 to 54	Yes
C011P3	Colinlea Sandstone	Monitoring Bore	Manual + Logger	94 to 104	Yes

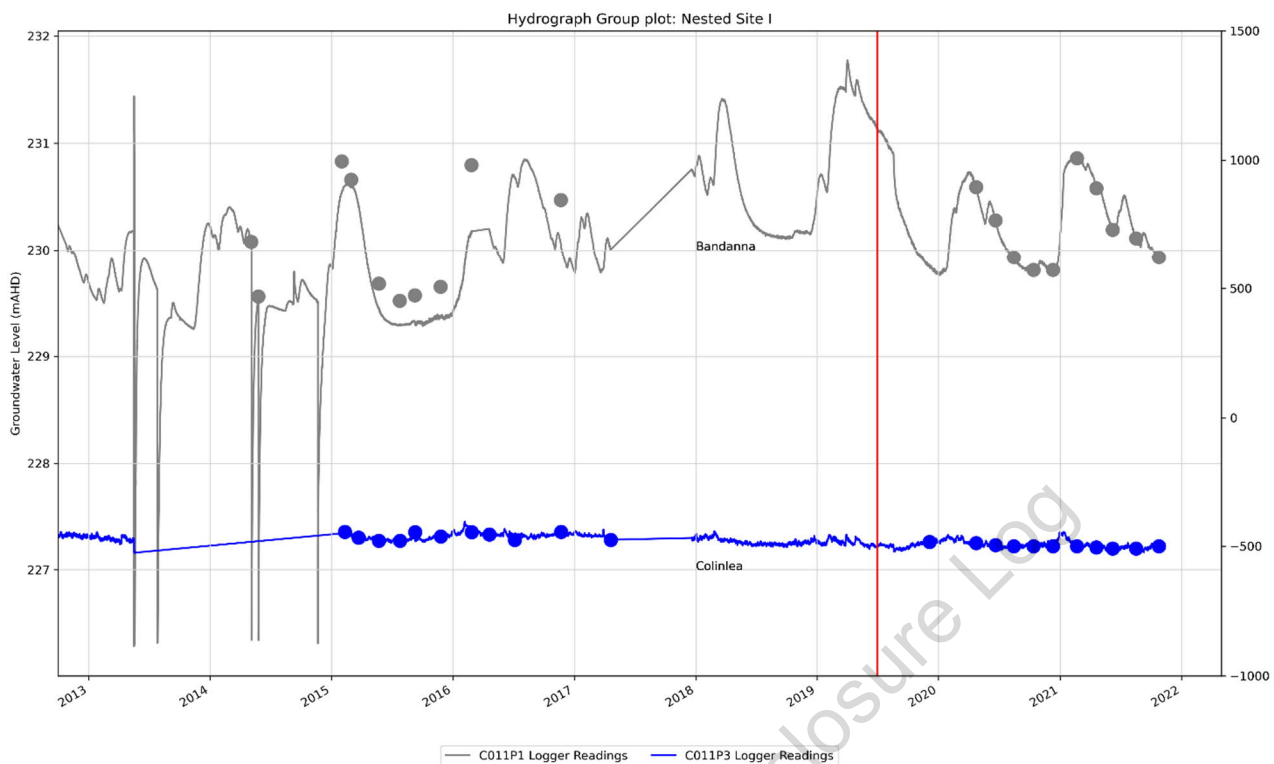


Figure 8.26 Stacked hydrograph group plot that shows nested site I groundwater pressures

8.2.10 Site J

There is a nested site (herein referred to as Site J) with three bores located ~3.7 km to the southeast of the southernmost bore in the active dewatering bore network. The bores at this location are summarised in Table 8.18 below. One of the bores is screened across the Bandanna Formation and two bores tap the Colinlea Sandstone. The groundwater pressures at the three sites are shown as a stacked group plot in Figure 8.27. The ground surface elevation, as surveyed at C832SP, is at elevation 223.41 mAHD (approximately 3 m below the pre-dewatering pressure in the Bandanna Formation). This figure shows confined, artesian conditions for both the Bandanna Formation and the Colinlea Sandstone prior to dewatering activities. At the end of 2021, there is up to ~3.5 m of drawdown observed in the Colinlea Sandstone and ~2 m of drawdown in the Bandanna at this distance of ~3.7 km from the dewatering bores. A downward flow gradient towards the Colinlea Sandstone exists both before dewatering and is enhanced during dewatering activities.

Table 8.18 Bore/VWP details at nested site J

Bore	HSU	Completion	Readings	Screen interval (mbgl)	Reliable trend
C832SP	Bandanna Formation	Monitoring Bore	Manual + Logger	89 to 100	Yes ¹
C833SP	Colinlea Sandstone	Monitoring Bore	Manual + Logger	120 to 132	Yes ¹
C834SP	Colinlea Sandstone	Monitoring Bore	Manual + Logger	140 to 150	Yes ¹

Notes: ¹ This site does record differences between manual and logger data with discrepancies generally between 0.5-1.5m. This may be related to the artesian pressures affecting manual readings before dewatering, because when the Colinlea goes sub-artesian (post-2020), there is clearer alignment between manual and logger data for C833SP and C834SP. With that as the case, the logger data should be used preferentially over manual readings for the pre-dewatering period.

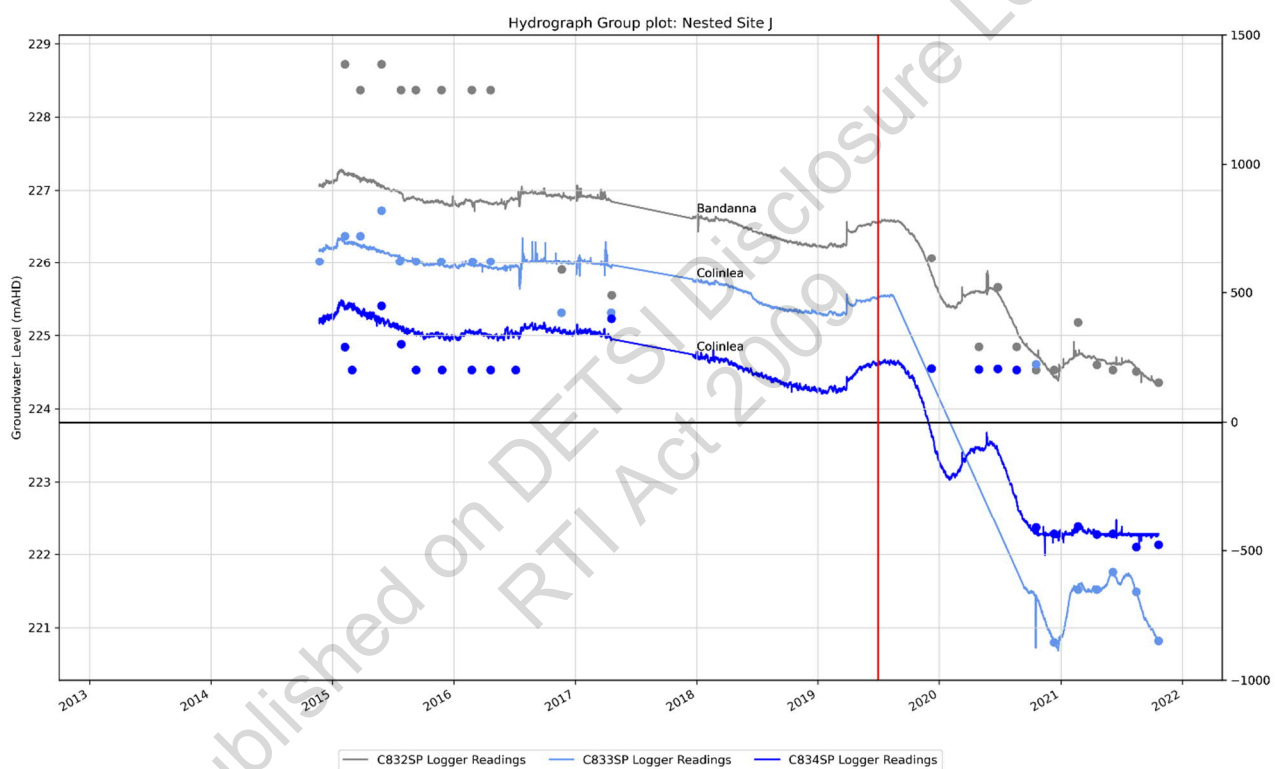


Figure 8.27 Stacked hydrograph group plot that shows nested site J groundwater pressures

8.3 Lateral groundwater flow processes

8.3.1 Regional system

The project site is located along the eastern margins of the Galilee Basin. Unified groundwater level analysis across six coal mine EIS projects and the Bioregional Assessment program have shown that regional groundwater flow systems along this eastern margin are complex (Turvey et al 2014). Data from the 2015 Bioregional assessment and recent groundwater data obtained from the QLD Globe portal (accessed in April 2022) for the Clematis Sandstone are presented below with the following observed:

- Figure 8.28 shows a regional groundwater contour map and flow directions for the Clematis Sandstone. At this scale, groundwater originates from the northwest and southwest, where it flows towards Lake Galilee and then is directed north eastward towards the discharge zone towards the CCP;

- Figure 8.29 shows a regional groundwater contour map and flow directions for the shallower portions of the Bandanna Formation, located above the AB coal seam. Similarly to the Clematis Sandstone, groundwater pressures are observed at their highest to the northwest and southwest. Groundwater flow then converges in the area of Lake Galilee and then follows a northeast direction towards the outcrop area of the coal seams towards the CCP;
- Figure 8.30 shows a regional groundwater contour map and flow directions for the Permian coal interburden of the Bandanna Formation and Colinlea Sandstone. A similar flow pattern to the shallow Permian coal measures is apparent, with an increase in convergence of the regional groundwater flow directions towards the centre of the mining lease;
- as shown previously in Figure 2.2, within the Colinlea Sandstone, there is a regional groundwater divide about 60 km to the west of the Carmichael Project that appears to trend south-north along the intermontane valley. On the western side of the divide which roughly bisects Lake Galilee, flow is generally down-dip from east to west away from the recharge beds. However, on the eastern side of the divide, flow appears to converge at the Carmichael Project, with a south to north flow system from the southern area, near the Galilee South Project, and a north to south flow system from the northern area, near the China Stone Project. Locally, there is also a west to east flow component towards the Doongmabulla Springs Complex. HydroAlgorithmics (2021) noted that the groundwater divide is largely coincident with a belt of Clematis Sandstone outcrop where significant rainfall recharge is suggested to occur; and
- Figure 8.31 shows a regional groundwater contour map and flow directions for the coal underburden, which is likely to reflect the nature of the deeper Colinlea Sandstone and basement material (eg the Joe Joe Group). As reflected in the shallower units, groundwater converges on a regional scale towards the CCP. Groundwater is unlikely to be recharged in the immediate north and south areas as indicated by the Clematis Sandstone and shallow Bandanna Formation plots shown in Figure 8.28 and Figure 8.29 respectively. To the southeast, the groundwater contours suggest that some convergence towards the Belyando River system is occurring, and thus some hydraulic connection between the groundwater system and river system may be possible.

The regional flow systems discussed above converge towards the Carmichael Coal Project, and have been observed at different scales for the following HSUs:

- Clematis Sandstone;
- Dunda Beds;
- Rewan Formation;
- Bandanna Formation;
- Colinlea Sandstone; and
- Joe Joe Group.

HydroAlgorithmics (2021) and EMM (2021) produced updated potentiometric maps for the main HSUs within the CCP area using groundwater levels/pressures from December 2020 and February 2021, respectively. Both sets of potentiometric maps are reproduced in Appendix C. Both sets of maps show consistency in interpreted flow systems.

8.3.2 Local system

The regional groundwater flow systems for the package of HSUs, including the Clematis Sandstone at the top to the Joe Joe Formation at the base, all converge in different parts of the Carmichael Project area. This convergence of flow implies that the project area is a natural discharge zone for these HSUs, and that local flow systems and regional flow systems are consistent.

A review of the local potentiometric maps suggests two groupings of HSUs:

- Group 1: the Clematis Sandstone and Dunda Beds appear to have convergence of groundwater flow from the north, west and south that aligns with the Carmichael River, and for the Clematis, the Doongmabulla Spring Complex also. The artesian heads in the Clematis, Dunda and shallow Rewan, the thinning of the Moolayember aquitard at this location, along with the shallowing of the Clematis and Dunda Beds towards subcrop are obvious contributors towards local discharge to the Doongmabulla Springs, and potentially the Carmichael River alluvium. The artesian pressures in the Clematis, Dunda Beds and upper Rewan to the east of the DSC suggest that pressure may be backed up behind a local barrier to flow. It is not clear if this is the weathered cover above the Clematis outcrop or some sort of lineament that is obstructing flow in these units. Further work is required to determine if this conceptual flow barrier is present.
- Group 2: the Bandanna Formation, Colinlea Sandstone and Joe Joe Group appear to have convergence of groundwater flow within a broad linear SW-NE alignment between Surprise Creek and Eight Mile Creek.

Although there is some debate around the sufficiency of the monitoring network for the Bandanna and Colinlea Sandstone to pinpoint the exact location of this feature, this low point in the potentiometrics is not consistent with any surface water features, springs, or known landholder bores. The previous GMMP describes the presence of a synform being responsible for this potentiometric low. It is not clear how such a feature would lead to continuous drainage of the various HSUs to allow for continued lowering of the groundwater pressures and stimulate regional flow dynamics towards these areas over geological time. The sub-sections below present two alternative conceptualisations that have potential to drive the regional and local convergence of flow across the mining lease area in these Permian units.

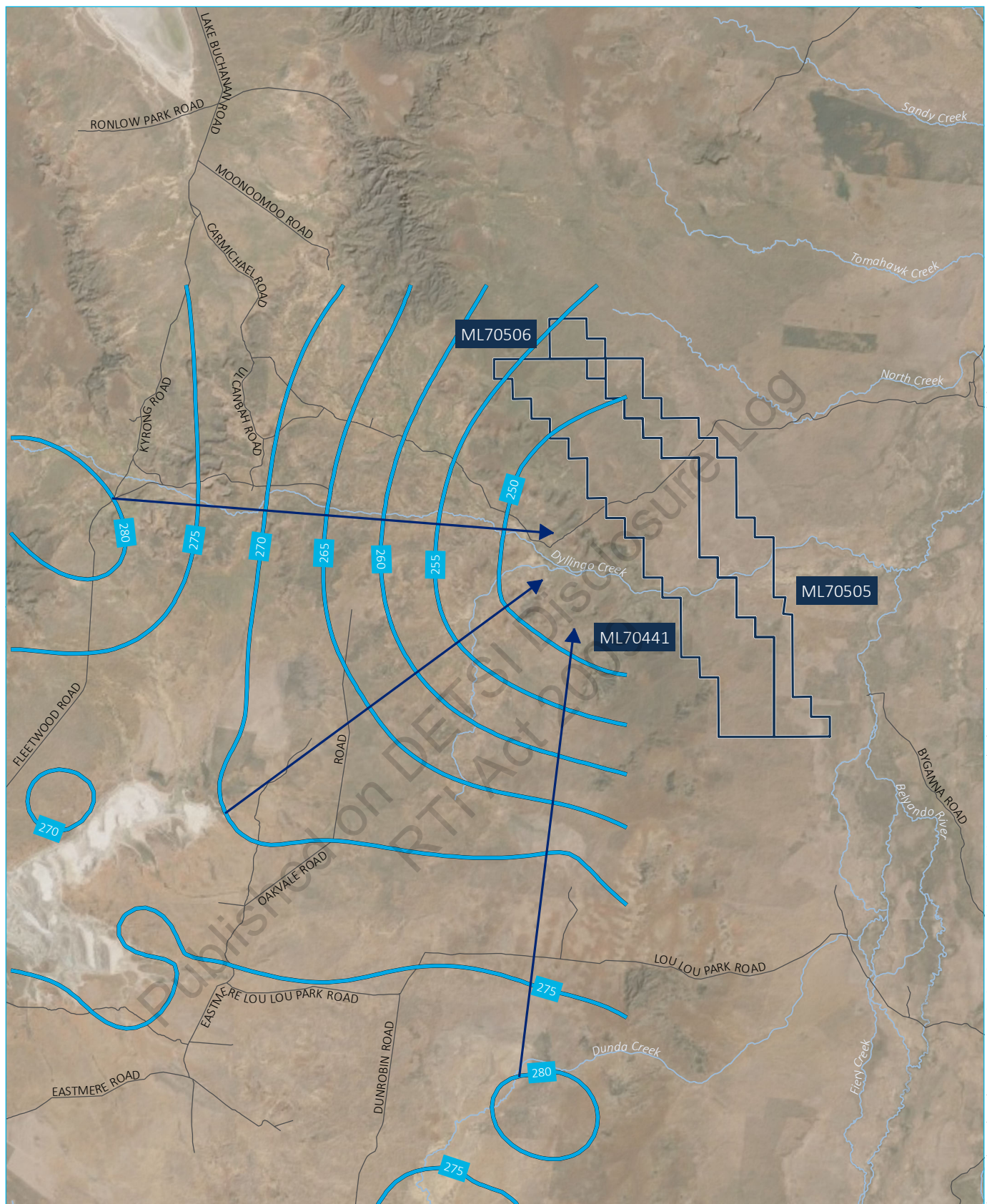
i Local faulting

An alternative conceptualisation is the presence of a local scale lineament or fault between Surprise Creek in the south and Eight Mile Creek in the north. A fault network in this area would be aligned SW to NE and would follow the same orientation as the creeks themselves (particularly on Eight Mile Creek where it suddenly changes direction 90 degrees at the same location where the regional Joe Joe flow convergence occurs at C140035P). A fault through this area might have the potential to hydraulically connect the Bandanna and Colinlea HSUs to the Joe Joe Group further northeast and may lead to discharge of that groundwater as baseflow to Eight Mile Creek or losses to EVT in shallow Joe Joe and/or Tertiary cover. It may also help to explain why there is less drawdown observed in the Colinlea and Bandanna formations 8 km north of dewatering at C011P1 and C011P3 (see Section 8.2.9), yet we see over 2-3.5 m of drawdown in Bandanna and Colinlea, 3.7km to the south of dewatering (C832P, C833P, C834P – see Section 7.2.10), and up to 1 m of drawdown in the Bandanna and Colinlea ~15 km to the south of dewatering (at C847SP, C848SP, C9849SPR). The key observations can therefore be summarised as:

1. The need for a linear feature that cuts across HSUs that is capable of draining water to produce regional and local low points in the pressure (ie the feature needs to vertically or laterally drain water between HSUs).
2. The feature may laterally compartmentalise the Bandanna and Colinlea by leading to differential pressure responses to dewatering activities, as observed in the north compared to the south. If the fault continued beneath Surprise Creek, it may also explain the high artesian heads that back up west of this feature in the Clematis Sandstone, Dunda Beds and upper Rewan Formation in the area of the Doongmabulla Springs.

There is currently insufficient information (bore density on the lease, or Eight Mile Creek surface water gauging, surface water quality of Eight Mile and Surprise creeks) to determine if this alternative fault conceptualisation is valid. Further investigations would be required to test this hypothesis, including a detailed review of the geophysics in this area. Particularly, as the Rewan Research package identified no potential for regional faults and only minor local faults. The SEIS identified a local fault (Fault B) near Moray Carmichael Road (see Figure 8.32) which is near to this axis of lower pressures and is in the correct SW-NE alignment. In the meantime, while the actual mechanism is being resolved, the groundwater modelling for the GMMP update should consider whether this alternative hypothesis can lead to a viable calibration solution. If it can, then this scenario may be carried forward as a sensitivity case for impact prediction and assess how pressure may propagate through the Colinlea, Bandanna, and Joe Joe formations.

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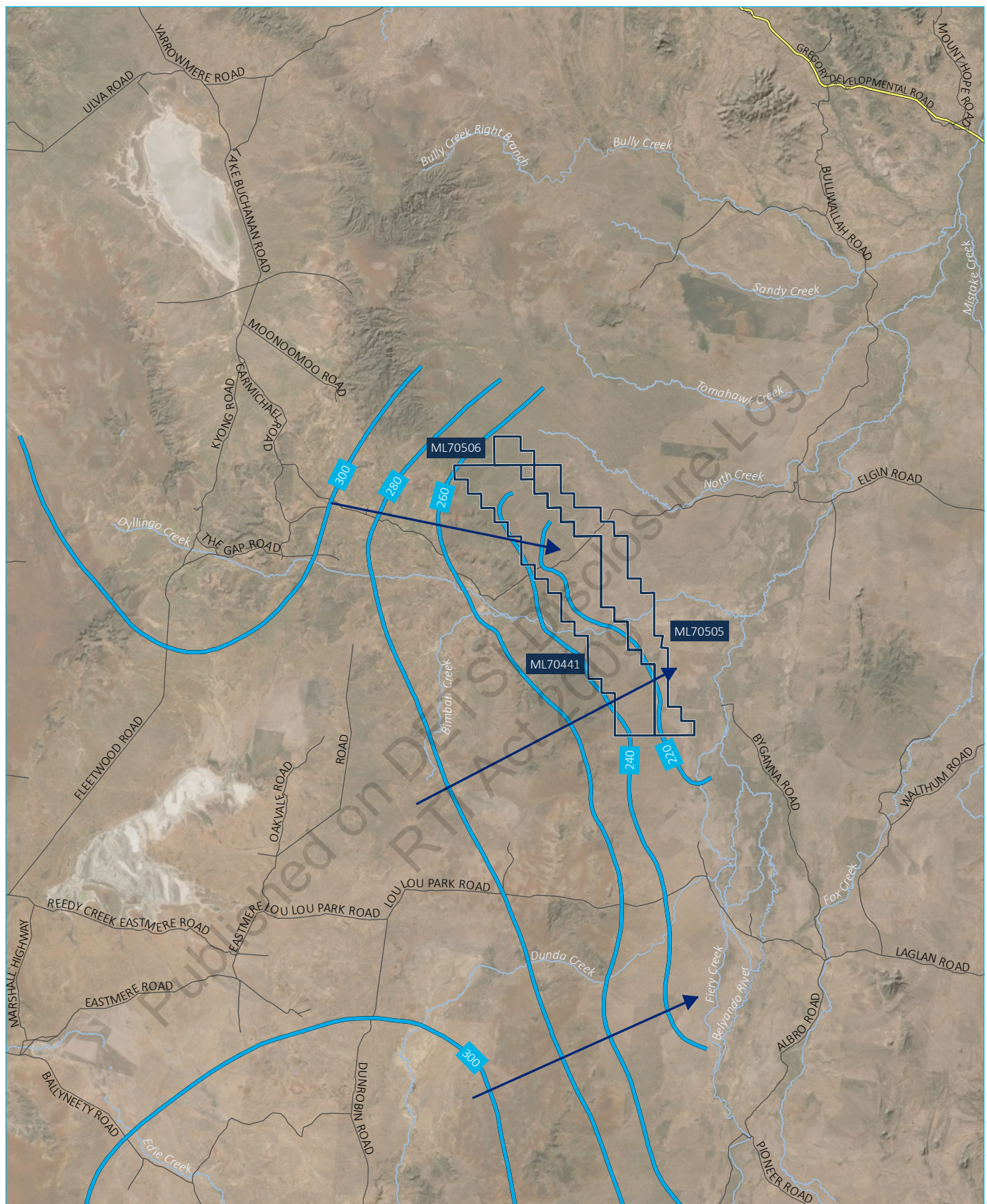
Source: EMM (2022); DNRME (2021); DES (2020); GA (2011); ESRI (2022)

KEY

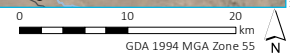
- Mining lease
- ➔ Interpreted groundwater flow line
- Groundwater elevation (mAHd)
- Minor road
- Named watercourse

Conceptual regional groundwater contours in Clematis Sandstone

Carmichael Coal Mine
Data Review and Conceptualisation Report
Figure 8.28



Source: EMM (2022); DNRME (2021); DES (2020); GA (2011); ESRI (2022)

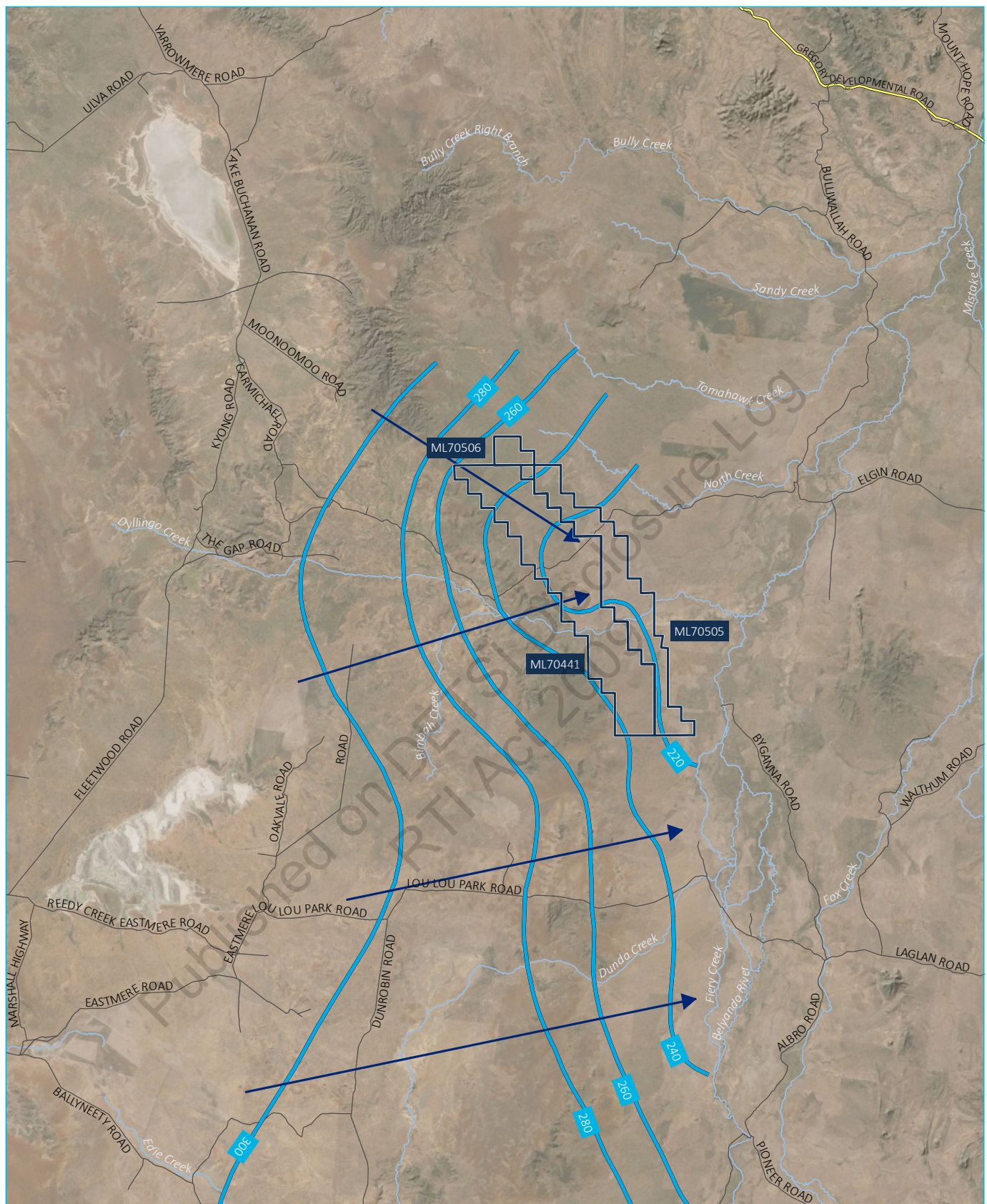


KEY

- Mining lease
- ➔ Interpreted groundwater flow line
- Groundwater elevation (mAHd)
- Major road
- Minor road
- Named watercourse

Conceptual regional groundwater contours within the shallower section of the Bandanna Formation (coal seam overburden)

Carmichael Coal Mine
Data Review and Conceptualisation Report
Figure 8.29



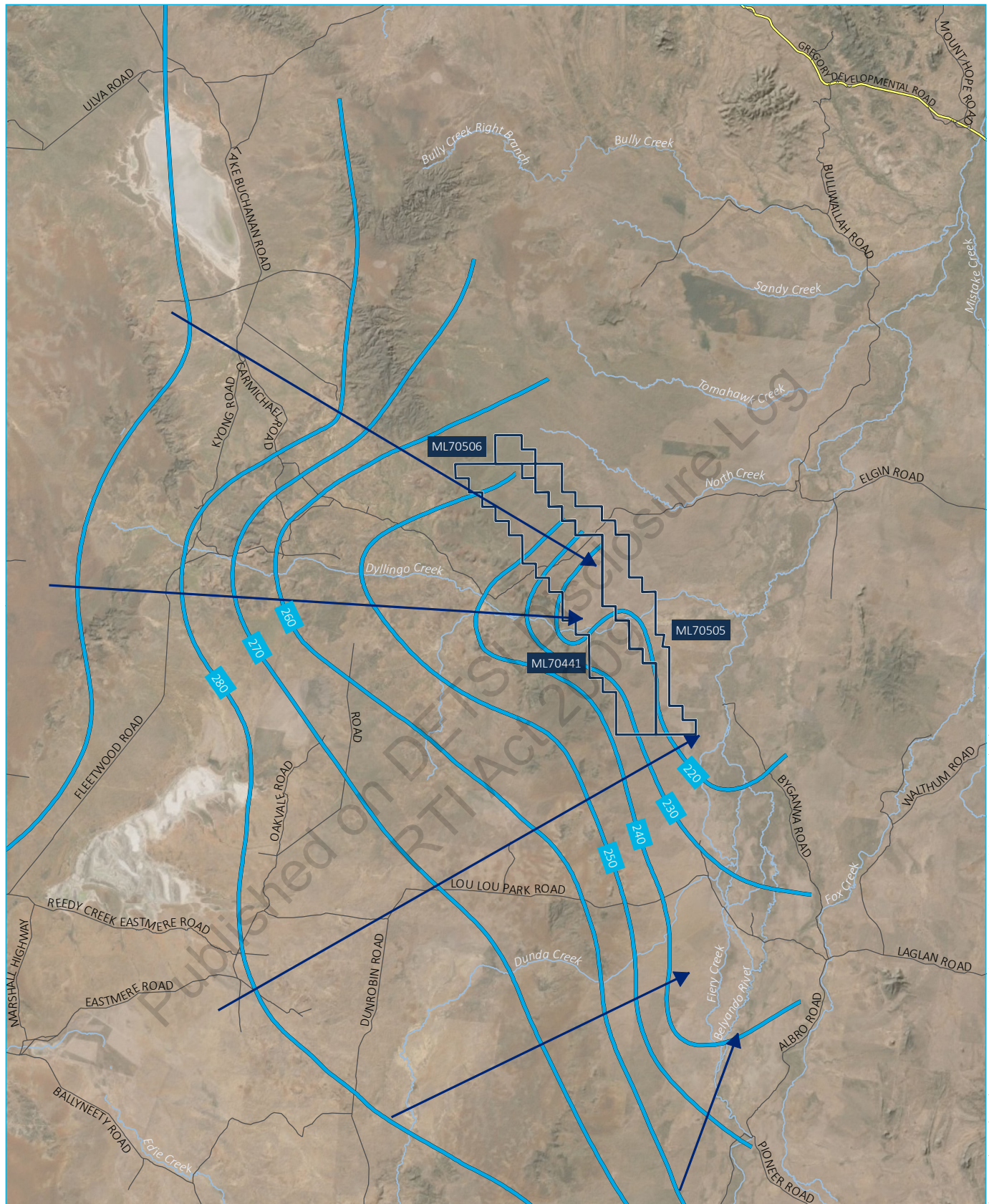
Source: EMM (2022); DNRME (2021); DES (2020); GA (2011); ESRI (2022)

KEY

- Mining lease
- ➔ Interpreted groundwater flow line
- Groundwater elevation (mAHD)
- Major road
- Minor road
- Named watercourse

Conceptual regional groundwater contours within the Permian coal interburden of the Bandanna Formation and Colinlea Sandstone

Carmichael Coal Mine
Data Review and Conceptualisation Report
Figure 8.30



Source: EMM (2022); DNRME (2021); DES (2020); GA (2011); ESRI (2022)

KEY

- Mining lease
- ➔ Interpreted groundwater flow line
- Groundwater elevation (mAHd)
- Major road
- Minor road
- Named watercourse

Conceptual regional groundwater contours within the Permian coal underburden (deeper Colinlea Sandstone / Joe Joe Group)

Carmichael Coal Mine
Data Review and Conceptualisation Report
Figure 8.31

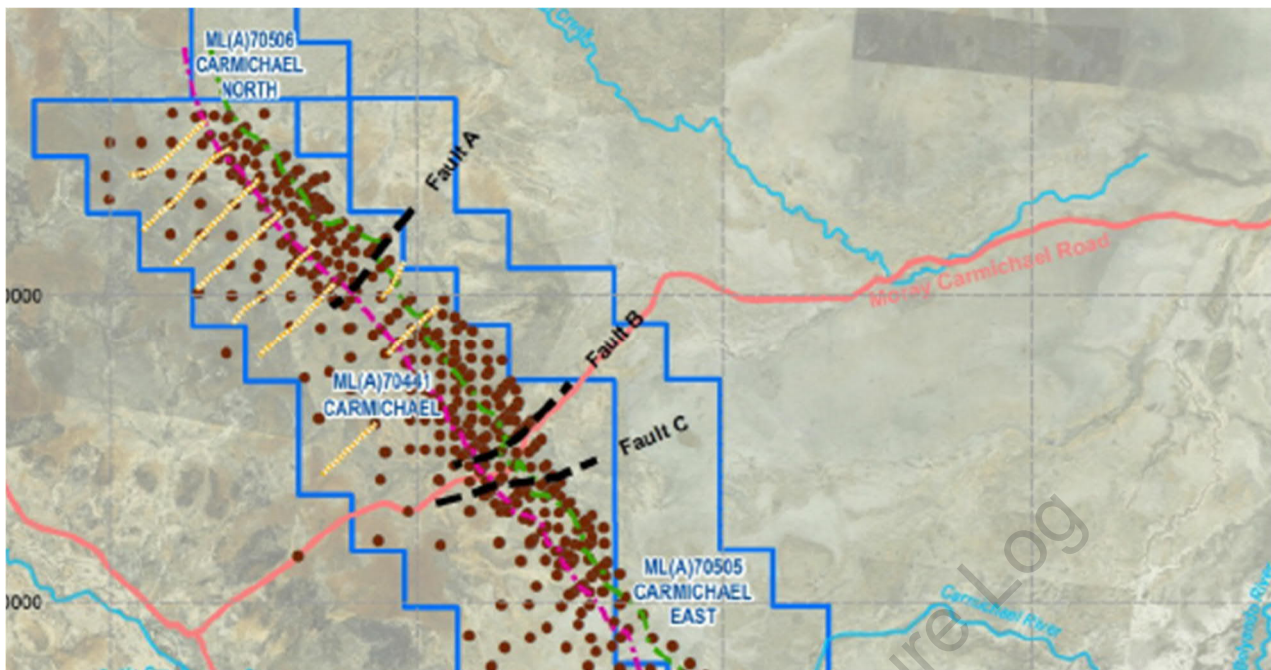


Figure 8.32 Local fault systems identified by Adani in response to IESC during the SEIS

ii Permeable Joe Joe acts as underdrain

An alternative conceptualisation would be a localised permeable zone within the Joe Joe Formation in the vicinity of the proposed synform. This higher permeability zone may be a result of primary porosity (eg facies change to clean sandstones), or secondary porosity (eg intense fracture network or deep faulting) in the shallow parts of the Joe Joe HSU. Either way, the shallow Joe Joe in this area would act as an underdrain for the Colinlea Sandstone and Bandanna Formation and result in drawn down pressures in this area. Those drawn down pressures would then explain the regional convergence of flow over geological time scales. This zone of more permeable Joe Joe Group would need to be aligned in a narrow zone that is similar in orientation to the SW-NE fault hypothesised in the previous sub-section. Of note, nested hydrograph sites G and H do locally deviate from this hypothesis, as they indicate upwards Permian flow potential in these localised areas. If correct, this may suggest the axis of the under-draining mechanism is not occurring at these nested sites.

There is currently insufficient information to rule out this alternative underdrain hypothesis. In the meantime, the groundwater modelling for the GMMP update should test whether this alternative hypothesis can lead to a viable calibration. If it can, then this scenario may be carried forward a sensitivity case for impact prediction and assess how pressure may propagate through the Colinlea, Bandanna, and Joe Joe formations.

8.4 Summary of groundwater level analysis and implications for conceptual model updates

The cause-and-effect analysis of groundwater hydrographs (Section 8.1) has shown that:

- The alluvium, Tertiary, Clematis Sandstone and Dunda Beds have a strong correlation with climate, suggesting rainfall recharge is an important contributor to the dynamics of the groundwater system.
- There are no apparent dewatering impacts in the alluvium, Tertiary, Clematis Sandstone and Dunda Beds, indicating that the Rewan Formation aquitard is hydraulically isolating these upper units from extraction in the Bandanna Formation and Colinlea Sandstone.

- There are drawdown impacts observed during the dewatering period in 3 Rewan sites, 5 Bandanna sites, 9 Colinlea sites and 2 Joe Joe sites. The three Rewan sites all occur in the shallow subcrop zone in the southern extents of the mine lease, with small magnitudes of drawdown observed. The Permian units have much more pronounced dewatering impacts, and these tend to be concentrated in the central and southern extents of the mining lease areas (see Figure 8.12 and Figure 8.14). Landholder pumping to the south of the lease may be a contributor to drawdowns observed in the southern extents of the study area.

The vertical hydrograph analysis (Section 8.2) has indicated:

- Close to the Doongmabulla Springs Complex, artesian conditions occur in the Clematis Sandstone, the Dunda Beds and in the upper part of the Rewan Formation, with lower sub-artesian pressures in the Colinlea and Bandanna formations. From a purely pressure perspective, the source aquifer for the springs complex is most likely the Clematis Sandstone, as it is the shallowest major aquifer that has artesian pressures in an area where the overlying aquitard thins or pinches out.
- There is a very slight reduction in pressure in the Colinlea Sandstone (C19031SPVWP1) after December 2021 which may be the start of depressurisation in this deeper part of the Permian system, although the use of a VWP for trend analysis carries a lower weight of confidence. There are no drawdowns in the Bandanna, Rewan, Dunda, or Clematis at this same site. There is a gap in monitoring between this site and on lease monitoring. Continued monitoring at this site is required to assess if this trend is related to depressurisation from mine dewatering activities.
- Artesian pressures persist in the Clematis Sandstone (Section 8.2.2) and Dunda Beds (Section 8.2.3) down-gradient of the DSC and may indicate further discharge from the Clematis and Dunda Beds into the overlying alluvium.
- There are pronounced dewatering impacts in the Bandanna Formation and Colinlea Sandstone in the near vicinity of the dewatering activities (Section 8.2.7 and Section 8.2.8). This dewatering impact is not observed ~8km to the north (Section 8.2.9) at the nearest nested site. Monitoring bore C014P2, is located ~2.7 km north of the most northern dewatering bore and shows no signs of dewatering drawdown using the trend analysis methodology described in Section 8.1. Apart from that site, there is a potential gap in the dewatering monitoring network. There are dewatering impacts ~ ~3.7 km to the southeast of the southernmost bore in the active dewatering bore network (8.2.10).

The RP5.3 report (Merrick, 2021) also noted the groundwater head in the Permian strata is lower than the head in the Rewan Formation almost everywhere, apart from a small zone south of the Carmichael River and at Site G. It follows that groundwater is not rising through the Rewan Formation and the Permian cannot be the source of the springs in the DSC. Dewatering and subsequent mining will cause localised drawdown and redirection of groundwater flows towards the extraction activity in the Permian sequence (Merrick, 2021).

Regional and project-scale potentiometrics (EMM, 2021a and Merrick, RP5.3 2021) show that groundwater flow systems for The Clematis Sandstone, Dunda Beds, Bandanna Formation, Colinlea Sandstone and Joe Joe Group locally converge at various locations across the project study area. The Clematis Sandstone and Dunda Beds appear to have convergence of groundwater flow from the north, west and south that aligns with the Carmichael River, and for the Clematis, the Doongmabulla Spring Complex also. Conversely, the Bandanna Formation, Colinlea Sandstone and Joe Joe Group appear to have convergence of flow within a broad linear SW-NE alignment between Carmichael River, Surprise Creek, and Eight Mile Creek. This regional low in groundwater levels was previously attributed to the presence of a synform in the GMMP. This updated conceptualisation, however, poses two alternative mechanisms that may account for the convergence of flow in the Permian strata: 1) a local fault or lineament that cuts across the Bandanna, Colinlea and Joe Joe group formations mainly within the lease area; or 2) a locally permeable Joe Joe Group that acts as an underdrain and lowers pressures in this area.

9 Hydrochemistry

EMM was engaged by Bravus in 2021 to undertake a geochemical study (EMM, 2021b) to investigate the probable source aquifer of the DSC as an update to the 2018 DSC research program which was commissioned by Bravus (Adani 2019).

The 2021 geochemical study assessed both rock and water samples. Rock core samples of the alluvium, Clematis Sandstone, Dunda Beds, Rewan Formation and Bandanna Formation were analysed for a variety of parameters including major and trace elements as well as ^{87}Sr and ^{34}S isotopes to characterise the source rock compositions of the geological units. Surface water and groundwater samples were analysed for major and trace elements and various isotopes/tracers including hydrogen, tritium, carbon, oxygen, sulphur and strontium.

Key findings are summarised in the sub-sections below.

9.1 Major and trace elements

Major and trace elements of the DSC surface spring water and groundwater indicate the following:

- DSC surface spring water is relatively fresh, with low major anion and cation concentrations (ie electrical conductivity <700 microsiemens per centimetre ($\mu\text{S}/\text{cm}$)) and low trace element concentrations (eg boron ≤ 0.15 milligrams per litre (mg/L)). Groundwater sampled from the Clematis Sandstone is similarly 'fresh' in terms of major ion and trace element concentrations. This is consistent with the major and trace element concentrations of the Clematis Sandstone rock samples, which are SiO_2 -rich, quartz-dominated sandstones with few accessory minerals.
- Hydrostratigraphic units underlying the Clematis Sandstone, which include the Triassic Rewan Formation and Permian Bandanna Formation, are mineralogically more diverse and contain clay minerals, mica, feldspars and a number of additional accessory minerals. This is consistent with site geological observations which describe these units as having variable compositions of sandstone, siltstone and mudstone.
- Concentrations of major and trace elements in Permian rock units are generally higher than those reported in the Clematis Sandstone.
- Although there is some overlap between major and trace element concentrations between Permian units and Clematis Sandstone, the composition of the DSC is more similar to the Clematis Sandstone (eg see Figure 9.1).
- 'Fresher' water in Permian units only occurs in monitoring bores located on the eastern margins of the CCP mining leases where the units subcrop and is likely to be reflect more direct rainfall recharge into the units.

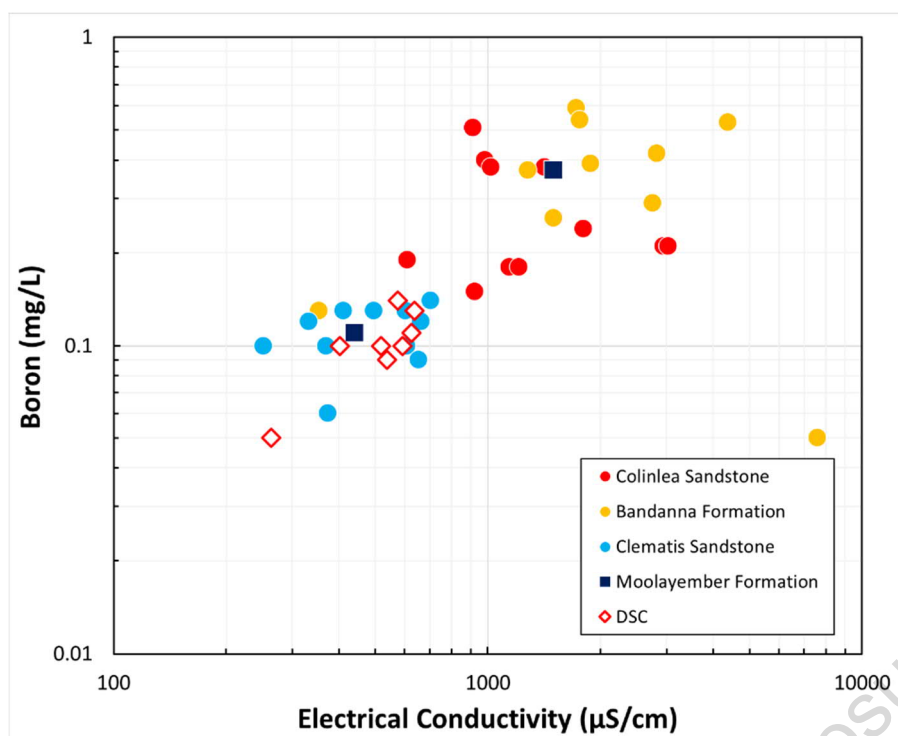


Figure 9.1 Variation in EC and boron

9.2 Isotopes

Stable isotopes of δD and ^{18}O are shown in Figure 9.2 and indicate the following:

- The DSC and the Triassic Clematis Sandstone and Moolayember Formation are isotopically distinct from those of the older Permian units, such as the Colinlea Sandstone and the Bandanna Formation. Variations in ^{18}O and δD show that the surface water samples from the DSC fall on an isotopic trend that is similar to the local meteoric water line (LMWL) defined by the Queensland rainwater samples (which itself is sub-parallel to the global meteoric water line, or GMWL).
- Importantly, groundwater samples from the Triassic Clematis Sandstone (and Moolayember Formation) record isotopic trends that are very similar to the LMWL, defined by rainfall composition, indicating that at least some hydraulic interactions between the Triassic units and rainfall recharge is occurring. In contrast, the Permian-screened groundwater stable isotopes describe a trend that is different to the LMWL – and the GMWL – indicating overall limited rainfall recharge for most samples of these deeper, older units, although some recharge is evident in their trace element compositions.
- Additional samples from the Triassic Rewan Formation show characteristics of both the LMWL and the 'Permian' trend, which is consistent with their major and trace element concentrations and reflects the transitional nature of this unit.

Radiogenic isotope characteristics generally confirm the overall geochemistry of the DSC and the CCP aquifer groundwater, with tritium and ^{14}C highest in samples exposed to the surface with the potential to experience a greater ingress of rainfall.

$^{87}Sr/^{86}Sr$ ratios show that both the groundwater samples and the rock samples vary systematically, with the Permian-screened groundwater recording low $^{87}Sr/^{86}Sr$ ratios compared to the younger Triassic-screened groundwater. Figure 9.3 shows that the surface DSC spring water is isotopically distinct from the Permian groundwater in terms of $^{87}Sr/^{86}Sr$ but is similar to the groundwater sampled from the Triassic Clematis Sandstone

and Moolayember Formation (note the Alluvium sample is highlighted and is similar to the surficial water samples, which may be expected in outcropping units).

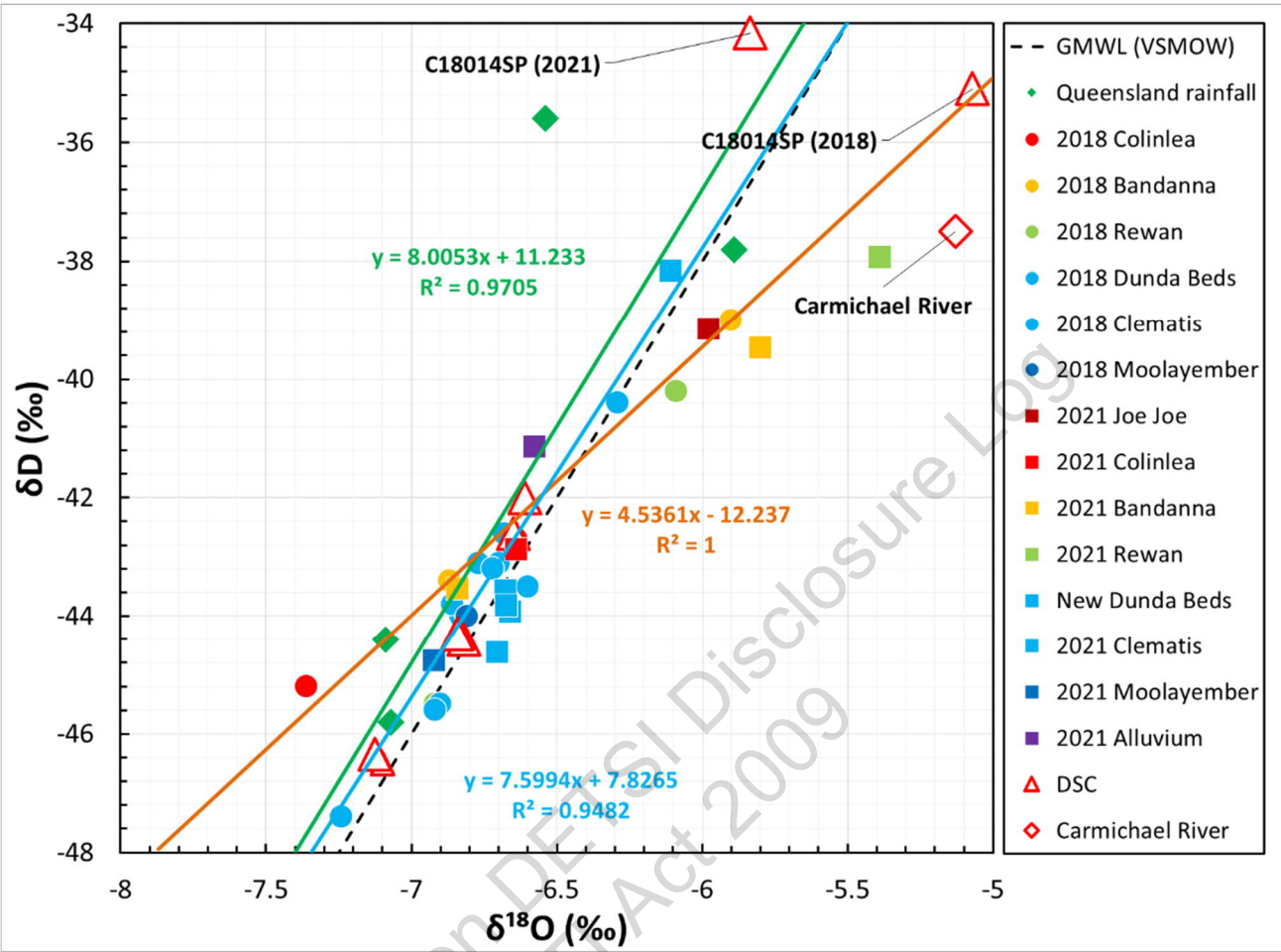


Figure 9.2 Variations in δD and $\delta^{18}O$ referenced to Vienna Standard Mean Oceanic Water (VSMOW)

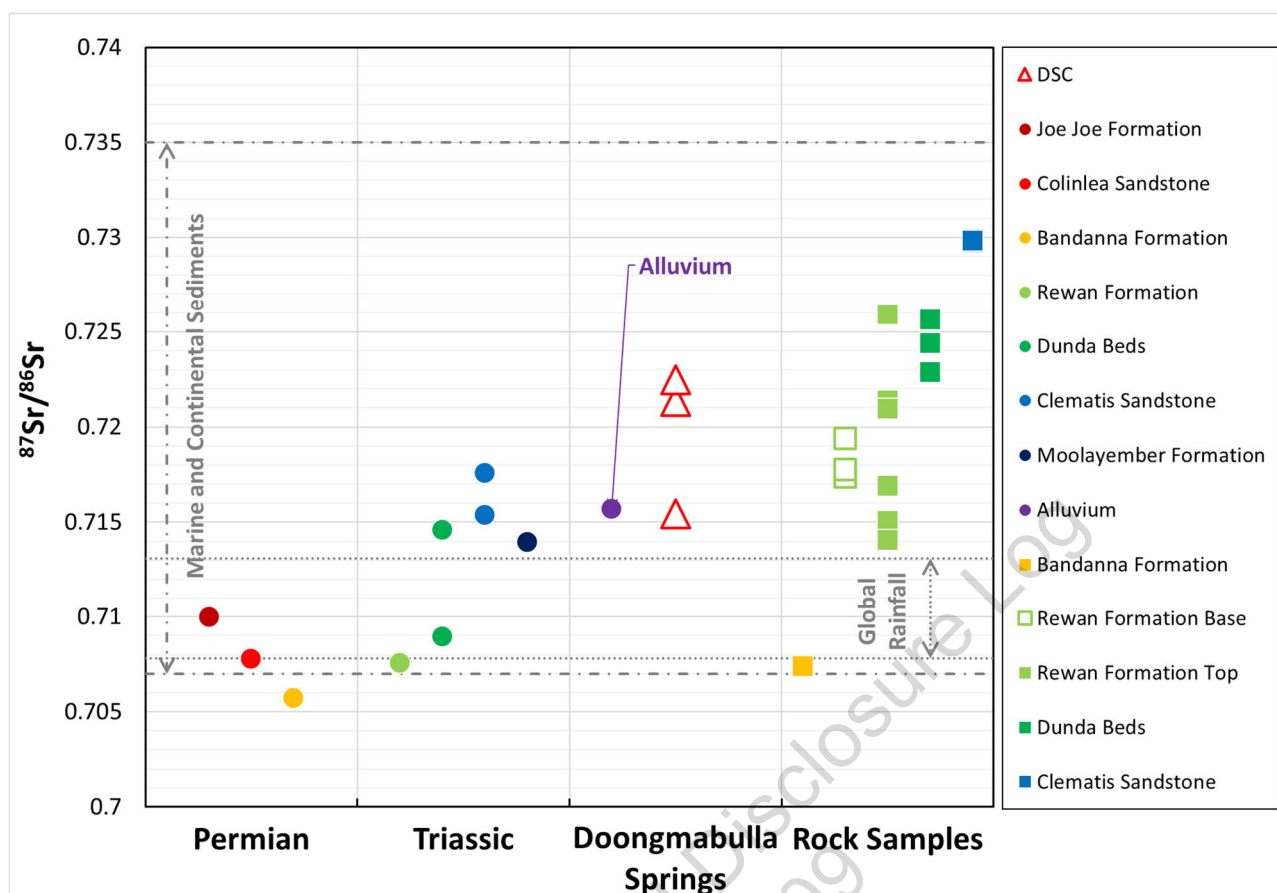


Figure 9.3 Strontium isotope signatures

9.3 Summary

Overall, findings from the hydrochemistry study indicate that the DSC is more likely to be sourced from groundwater originating in the immediately underlying artesian Clematis Sandstone aquifer (with potential input from the Triassic Moolayember Formation), than from groundwater originating from either of the older potential groundwater sources in the Permian Bandanna Formation, Colinlea Sandstone, or the Joe Joe Group.

The low major ion concentrations, the isotope systematics and trace element trends indicate that the Clematis Sandstone ($\pm$ the Moolayember Formation) experiences rainfall recharge and that the DSC is affected by rainfall events, which effectively 'reset' the respective isotope ratios to those following the LMWL defined by Queensland rainfall stable isotopes. Overall, the deeper 'Permian' trends experience limited recharge; however, groundwater sampled in Permian-screened bores on the eastern margin of the Project mine boundaries may experience recharge through rainfall. Groundwater in these Permian subcrop areas is superficially geochemically and isotopically similar to the shallow groundwater units in the west (Clematis Sandstone, Moolayember Formation), which are also recharge influenced.

10 Groundwater connectivity with surface water

10.1 Overview

Within the study area, groundwater discharges at the Doongmabulla Springs Complex and Mellaluka Springs.

Rainfall runoff causes ephemeral creeks and rivers to flow periodically, with greatest flows during the wet season. A portion of the surface flow recharges the alluvial aquifer adjacent to and beneath the waterway, which then contributes to sustaining floodplain vegetation through the dry season.

A conceptual relationship between springs, waterways, and aquifers is illustrated in Figure 10.1. The following sections of this document describe the components of this landscape water balance utilising a variety of data sources.

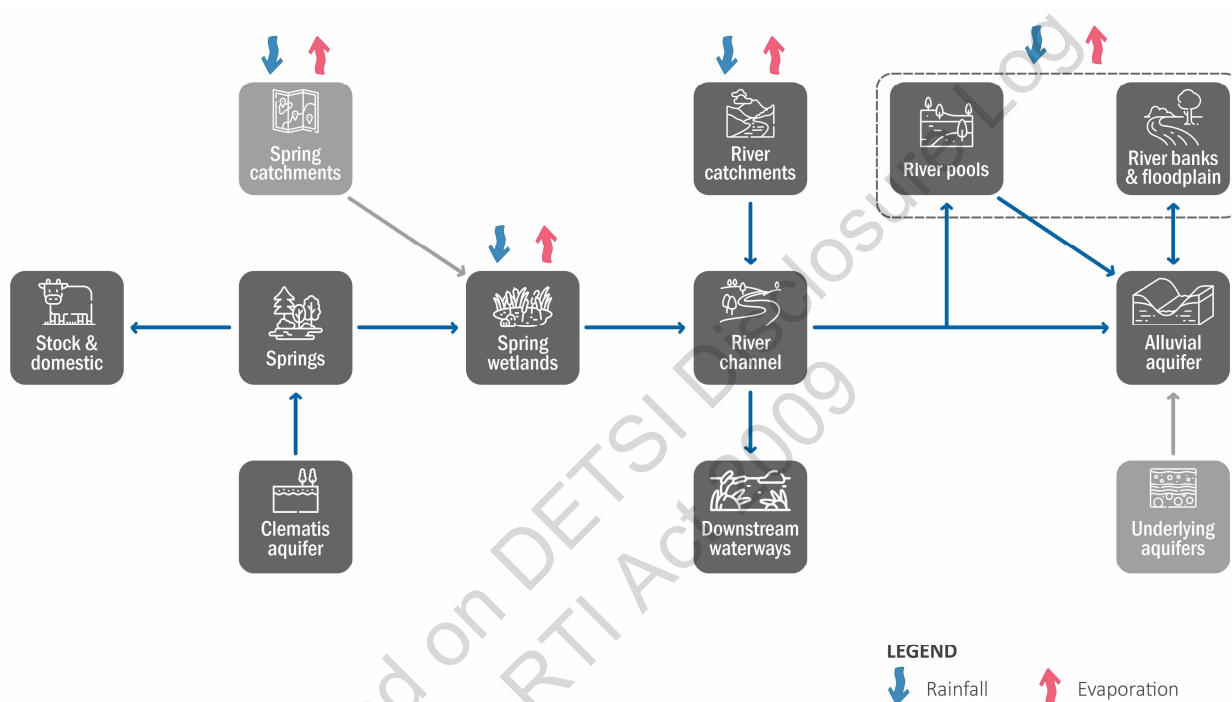


Figure 10.1 Doongmabulla Springs Complex, Dyllingo Creek and Carmichael River water balance concept

10.2 Doongmabulla Springs Complex

10.2.1 Springs description

The Doongmabulla Spring Complex is located approximately 8 km to the west of Carmichael Coal Mine, at the confluence of Bimbah / Cattle Creek, Dyllingo Creek, Carmichael Creek and Carmichael River (GHD 2012a). The spring complex includes a number of named springs and spring groups (Figure 10.2, Table 10.1).

Spring types include small mounds (eg Photograph 10.1), wetlands supported by spring discharges (Photograph 10.2, Photograph 10.3), and patches of wet ground (Photograph 10.4). Discharge locations are typically located at elevations of around 235-240 m AHD, and approximately 5 m above the bed level of nearby creek and river features. No springs have been located within surface water features (ie within the Carmichael River or Dyllingo Creek bed), even though these are the lowest locations within the landscape.

Little Moses, Yukunna Kumoo, Dusk, Camp and Surprise springs have vents on the edge of wetlands with characteristics of outcrop springs (Photograph 10.5), while House, Mouldy Crumpet and Stepping Stone springs have mounded vents characteristic of vertical discharges through confining beds (Fensham et al. 2016).

Table 10.1 Doongmabulla spring groups

Name	Vents	Wetland area (ha) ¹	Comments
Joshua	1	-	Supplies Doongmabulla Homestead via dam and pipe.
House	8	12	
Bonanza	4	<0.1	
Mouldy Crumpet	110	1	Typically represented by small mound springs, with MC06 producing a wetland
Stepping Stone	7	<0.1	
Moses	28	3.3	
Keelback / Little Keelback	8	3.6	
Camp	2	2.2	
Bush Pig Trap	2	<0.1	
Wobbly / Junior Wobbly	2	<0.1	Discharges to a large pool in Cattle Creek
Geschlichen	1	1	
Camaldulensis	1	0.1	
Little Moses	2	3	
Yukunna Kumoo	5	<0.1	
Dusk Spring	5	<0.1	
Surprise	1	1	
TOTAL	176	27	

1. Wetland area measured from aerial photography captured in January 2021. Areas measured via ground survey presented in Figure 3.2 vary.



Photograph 10.1 Example of a Mouldy Crumpet group mound spring (Fensham et al. 2016)



Photograph 10.2 Little Moses wetland (Fensham et al. 2016)



Photograph 10.3 Yukunna Kumoo wetland (Fensham et al. 2016)



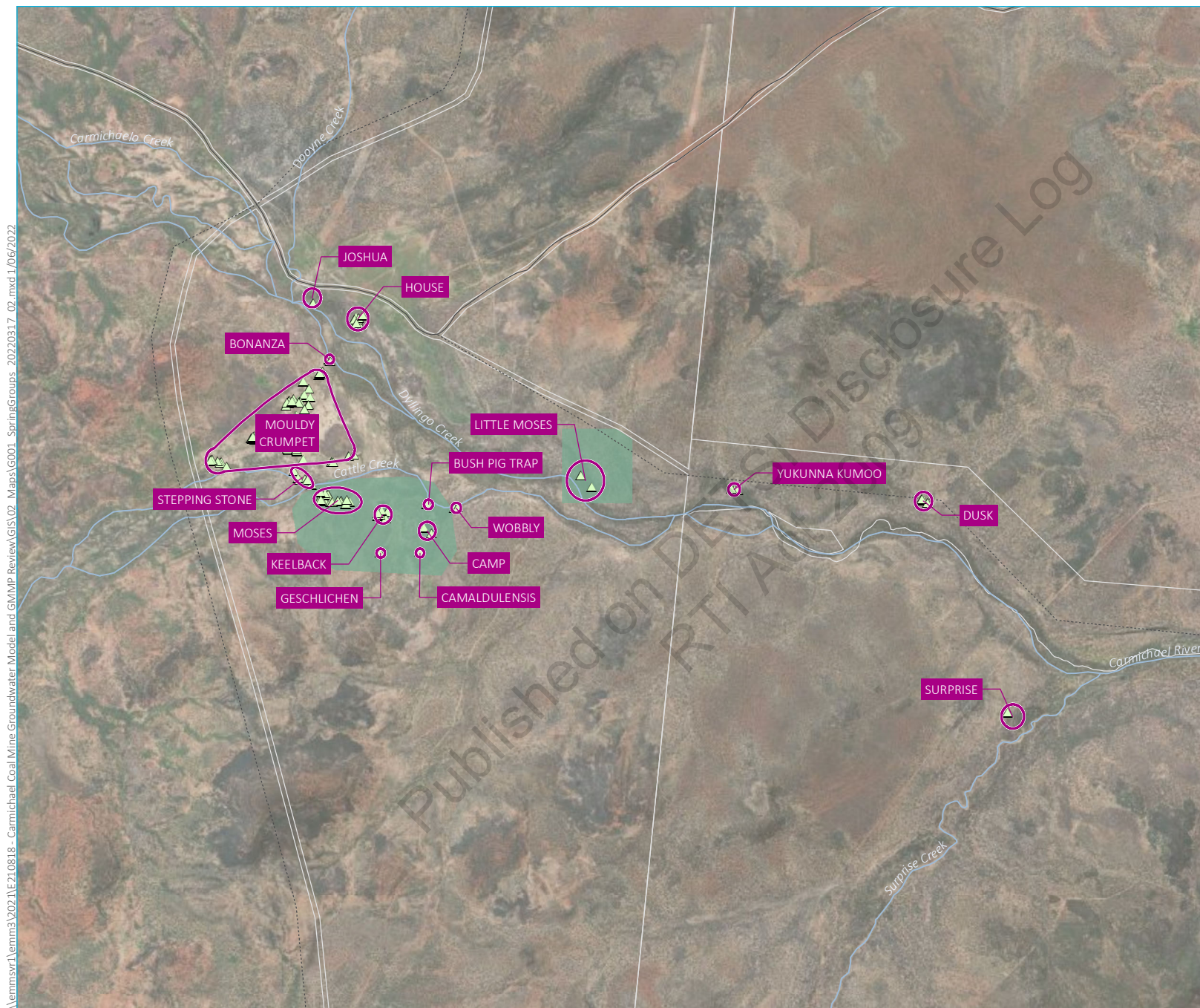
Photograph 10.4 A Dusk spring vent (Fensham et al. 2016)



Photograph 10.5 Camp spring outcrop spring discharge (Fensham et al. 2016)

Joshua spring discharges to a turkey's nest dam and supplies the Doongmabulla homestead. Flow rates from the spring are reported as 5 litres per second (L/s) by some authors (eg Currell et al, 2017). While the flow rate discharged from the aquifer is likely to be constant, utilisation of spring water by the homestead means that the flow rate discharged to the environment varies.

Water discharged from springs typically supports vegetation at the spring location. At some locations the entirety of the discharge volume is lost to evapotranspiration (eg Mouldy Crumpet mound springs), while at other locations where discharges are greater, wetlands are formed. In some cases, these wetlands are terminal features, in other cases water is spilled to nearby creeks, where it supports river pools and bank/floodplain vegetation.



- KEY**
- Doongmabulla spring groups
 - ▲ Spring
 - Minor road
 - Vehicular track
 - Named watercourse
 - Cadastral boundary
 - Doongmabulla Mound Springs Nature Refuge

Doongmabulla spring groups

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Figure 10.2

10.2.2 Spring discharges

i Joshua spring

Joshua spring discharges into a turkey's nest dam which supplies the Doongmabulla homestead. The majority of the spring water is utilised by the homestead, livestock, and occasionally for local road maintenance, with the remainder discharged to Dyllingo Creek via a metered overflow pipe. Homestead, livestock and Council use of spring water is not metered, and so the total spring discharge rate is uncertain.

An adjacent dam is used for staging water harvested from the spring prior to its delivery via reticulation to various homestead paddocks, with flow to this dam manually controlled by a valve (Photograph 10.6). The arrangement of dams and outlets at Joshua spring is illustrated in Figure 10.3.



Photograph 10.6 Homestead offtake from Joshua spring turkey's nest to intermediate storage dam (unmetered)

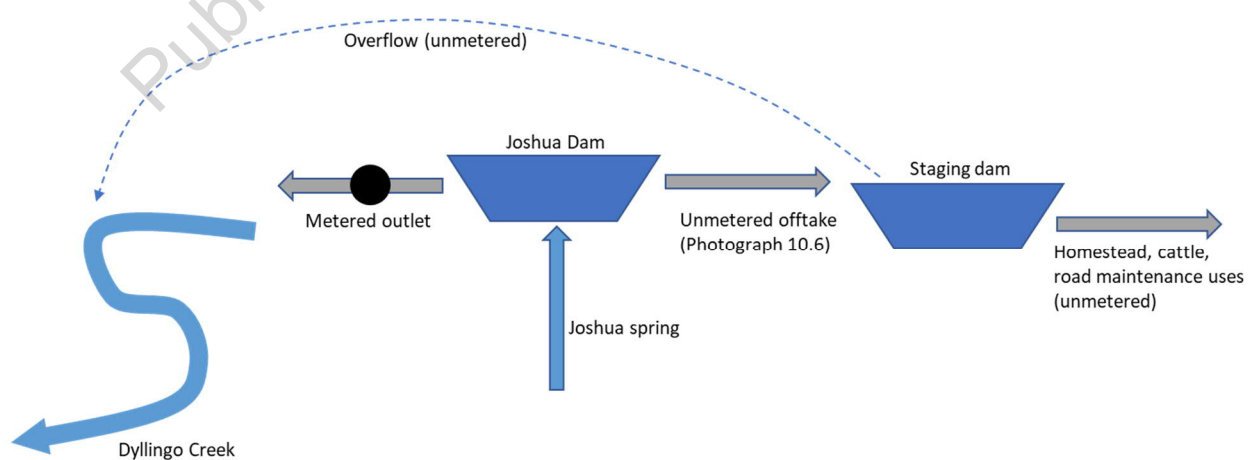


Figure 10.3 Joshua spring outlet arrangements

Recorded overflows to Dyllingo Creek are presented in Figure 10.4. Gaps exist in the data record due to malfunctioning of the flow meter, and the flow meter was replaced in 2019. The current overflow arrangement utilises a 150 mm PVC pipe with bends such that the pipe flows full to allow accurate flow metering.

Flow data recorded since the meter replacement shows that discharges typically are around 1–2 L/s, with a peak of 22 L/s in May 2021 (Figure 10.5).

Data recorded in 2016 and 2017 (Figure 10.6 and Figure 10.7) contain a cyclic pattern with minimum discharges to Dyllingo Creek of around 2 L/s, and peak discharges of around 12 L/s.

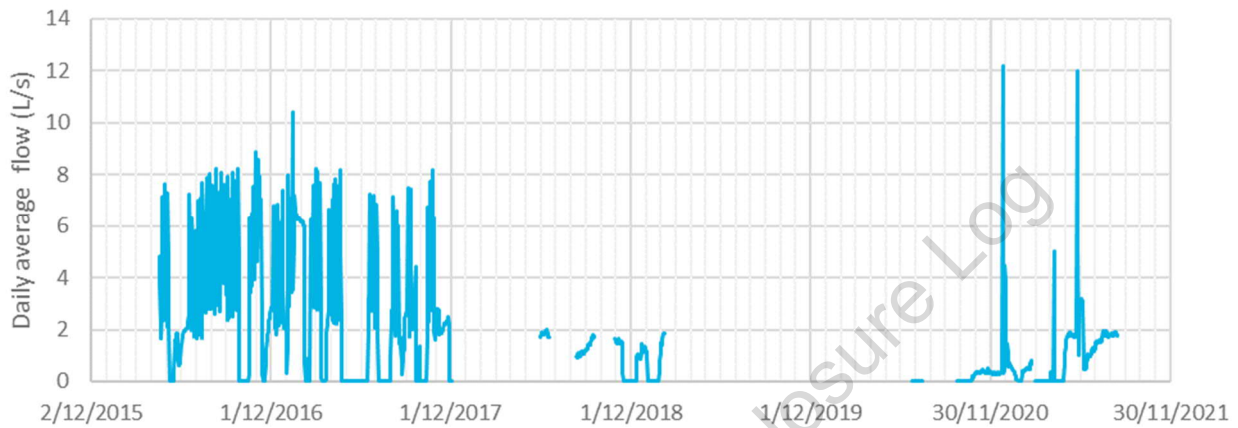


Figure 10.4 Joshua spring overflow to Dyllingo Creek

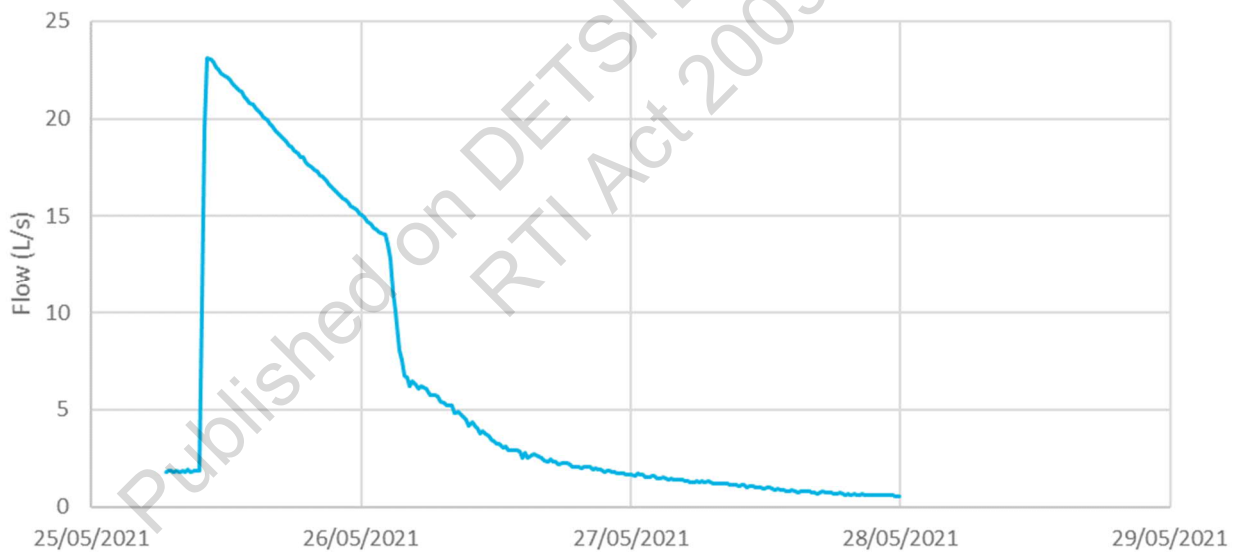


Figure 10.5 Joshua spring overflow to Dyllingo Creek – Peak discharge 2021

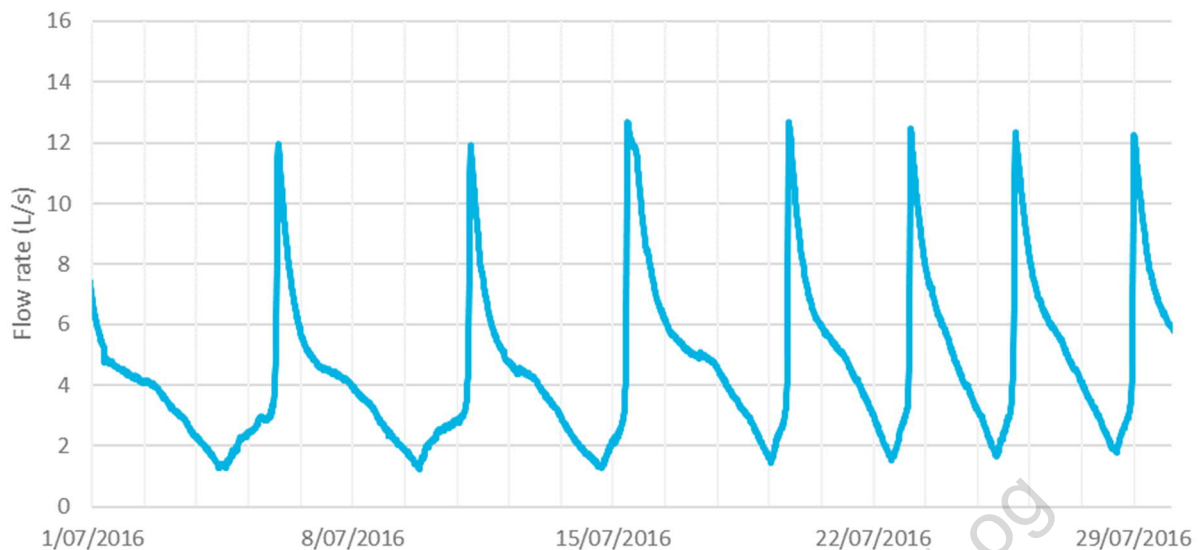


Figure 10.6 Joshua spring overflow to Dyllingo Creek - 2016

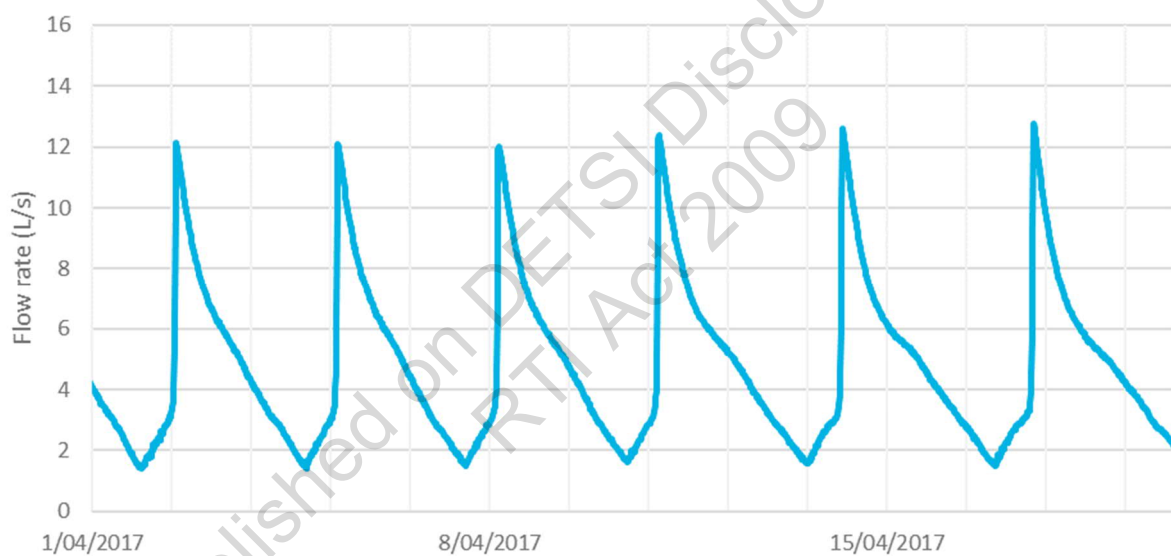


Figure 10.7 Joshua spring overflow to Dyllingo Creek - 2017

The spring dam contains floating water lilies (*Nymphaeaceae gigantea*) (GHD 2012d) which may block the outlet pipes temporarily, resulting in a period of low flow through the overflow to Dyllingo Creek followed by a period of high flow when the blockage clears. This mechanism for flow variance however appears unlikely to explain the regular pattern in the 2016 and 2017 flow data.

It is posited that the 2016 and 2017 flow patterns were caused by:

- a permanently open outlet to Dyllingo Creek, as evidenced by flows remaining above 0 L/s through the presented periods;
- a cyclic open-shut sequence of the homestead offtake valve;
- spring dam water levels increasing when the homestead offtake was closed;

- spring dam water levels decreasing when the homestead offtake was open; and
- flows through the metered outlet to Dyllingo Creek varying in response to the dam water levels.

The rising limb of the 2016 and 2017 flow hydrographs is steep, even when approaching the upper recorded outlet flows of 12 L/s. This implies a groundwater inflow rate to the dam that exceeds 12 L/s.

The high flow rates of 12 L/s are not caused by closing all outlets and letting the dam slowly fill before opening the outlet and allowing a large flow to be released, as flows do not fall to zero in Figure 10.6 and Figure 10.7.

A discharge pattern similar to that recorded in 2016 and 2017 can be obtained by the following hypothetical flows (Figure 10.8):

- groundwater discharge to the spring dam of around 20 L/s;
- harvest at a rate of around 20 L/s for 18 hours/day, potentially decreasing over time as water levels in the dam fall;
- discharge rates to Dyllingo Creek of 2 – 12 L/s varying with the water level in the dam; and
- flows to Dyllingo Creek increase when the homestead offtake valve is closed and decrease when the homestead offtake causes dam water levels to fall.

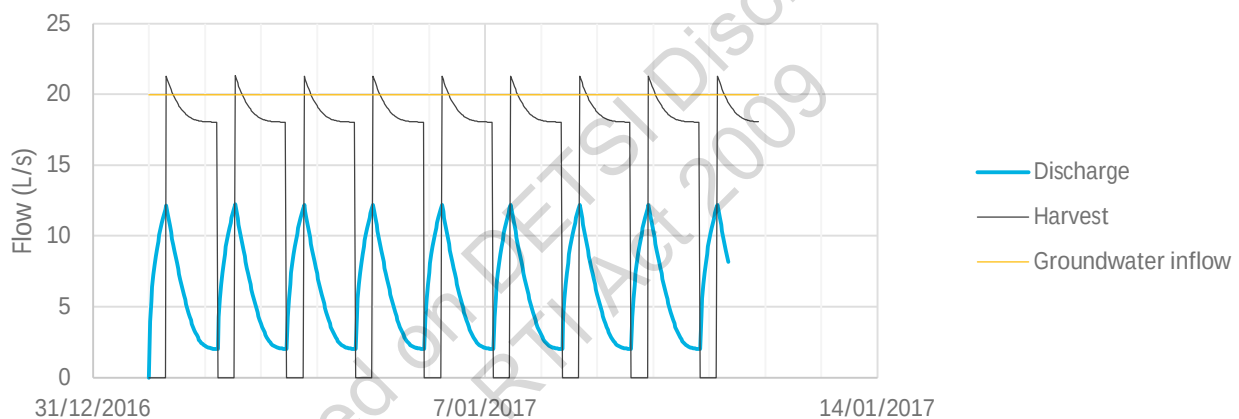


Figure 10.8 Hypothetical Joshua flow sequence

In the hypothetical case presented in Figure 10.8, an average of 6 L/s would be discharged to the environment, and 14 L/s would be harvested.

An average harvest rate of around 15 L/s (1.3 ML/d) is feasible if used to supply water to several thousand head of cattle. The property supports over 5000 head of cattle, though it is not known whether all are watered from this source. As the staging dam occasionally overflows to Dyllingo Creek via an unmetered spillway, the volume used is lower than the volume transferred from Joshua Dam to the staging dam, eg perhaps 15 L/s is taken from Joshua Dam but only 7 L/s from the staging dam, leaving 8 L/s to overflow to Dyllingo Creek. The water balance for Joshua Spring is uncertain, and at best the available data help to constrain the possible ranges of actual flows.

Recorded average discharges to Dyllingo Creek via the metered outlet pipe were around 5 L/s in 2016 but are 2.7 L/s over the full record (ignoring periods of zero recorded flow).

Reasonable flow estimates to inform updating of the numerical groundwater flow model are:

- 15–20 L/s (1.3–1.7 ML/d) discharged from the aquifer; and
- 3 L/s (0.26 ML/d) discharged to Dyllingo Creek.

ii Unaltered springs

The spring water balance for unaltered springs can be described according to Equation 9-1, also illustrated in Figure 10.1. The water balance has six elements and illustrates that when spring discharges are unknown it is necessary to understand ET, rainfall, runoff, and downstream effects to calculate an estimate of spring discharges.

Equation 10-1: Spring water balance

$$\text{Rain} + \text{Runoff} + \text{Spring discharge} = \text{ET} + \text{Overflow} + \text{Infiltration}$$

or

$$\text{Spring discharge} = \text{ET} + \text{Overflow} + \text{Infiltration} - \text{Rain} - \text{Runoff}$$

Water overflowed or infiltrated from wetlands ultimately evaporates or is transpired by vegetation, with the overflow and infiltration processes simply changing the location of the evaporation effect to a location downstream.

Several methods for calculating GAB spring discharge from wetland area have been published, including Williams and Holmes (1978), who proposed a linear relationship based on an average evaporation rate of 6.5 mm/d (Equation 9-2), and Fatchen (2001), who proposed a log relationship (Equation 9-3).

The Williams and Holmes (1978) method is based on the premise that overflow and infiltration are negligible, and that wetland area can be measured at a time of year when rain has not occurred for an extended period, simplifying Equation 9-1 to containing only spring discharge and ET elements. The method assumes a constant ET rate of 6.5 mm/d, equivalent to a yearly rate of 2.4 m. While applying a constant evaporation rate regardless of location was likely appropriate at the time of publishing, detailed site specific estimates of monthly and daily evaporation are now available, allowing improved estimation of the spring water balance.

Equation 10-2: Spring flow rate (Williams & Holmes 1978)

$$Q \left(\frac{L}{s} \right) = A(m^2) \cdot ET \left(6.5 \pm 0.7 \frac{mm}{day} \right) = \frac{A(ha)}{1.25}$$

The Fatchen (2001) method was based on measuring discharges at 33 springs over a period of 15 years, and reportedly has an $R^2=0.561$ (Fensham et al. 2021), indicating the equation is a relatively poor estimator of flow at individual springs, likely due to factors such as differing rates of infiltration depending on soils, overflow from some wetlands but not others, vegetation type, and size of surface catchment. The inclusion of a log term indicates that the equation has been influenced by factors related to the wetland perimeter such as radial infiltration and collection of surface runoff, though these factors are not explicitly expressed as equation parameters.

Equation 10-3: Spring flow rate (Fatchen 2001)

$$\log Q \left(\frac{L}{s} \right) = \frac{\log(A(m^2)) - 3.692}{0.707}$$

Note the correction to the constant 3.692, referred to incorrectly in Fensham et al (2021) as 3.3692

Many wetlands vary in dimensions throughout the year in response to rainfall and evaporation rates, and so Equation 9-2 and Equation 9-3 should be used with minimum seasonal wetland areas, presumed to be the area supported by groundwater alone.

Applying these relationships to the minimum wetland areas shown in Figure 3.2 results in total flow estimates from unaltered Doongmabulla springs of:

- 0.3–0.37 ML/d (Equation 9-2); and
- 1.4 ML/d (Equation 9-3).

White and Lewis (2011), and Petus, Lewis and White (2012) took early steps in improving estimates of GAB spring wetland water balance using MODIS NDVI data, successfully illustrating the effects of groundwater discharge, rainfall, human activity and seasonality and interannual climate trends on spring wetland size. This method can provide time-varying estimates of ET at spring wetlands, but also the region downstream of the wetlands. By measuring all ET associated with a spring, the spring water balance terms 'ET', 'infiltration' and 'overflow' may be accounted for, on the basis that all water discharged is used by vegetation whether at the wetland or nearby.

Refined estimates of actual monthly ET were developed by CSIRO (Guerschman et al. 2021) using various satellite products. Five remotely sensed data products were used with spatial resolutions ranging from 500 m (MODIS, VIIRS), 30 m (Landsat) to 20 m (Sentinel-2), and temporal frequencies ranging from daily (MODIS, VIIRS) to multi-days (Landsat and Sentinel-2). The datasets were calibrated using daily latent heat observations from 30 eddy covariance flux towers located across Australia, and open water sites. At flux towers the method has an exceptional R^2 of 0.93–0.96, while at validation catchment sites the method has a moderately good R^2 of 0.7. Monthly actual ET data estimated via this algorithm are now available via the AET Explorer web interface (CSIRO 2022) (eg Figure 10.9), and have been applied by the current study to estimate both the ET that occurs at spring discharge sites, and the ET anomaly that occurs downstream of spring sites from Cattle Creek, Dyllingo Creek and Carmichael River floodplain vegetation.

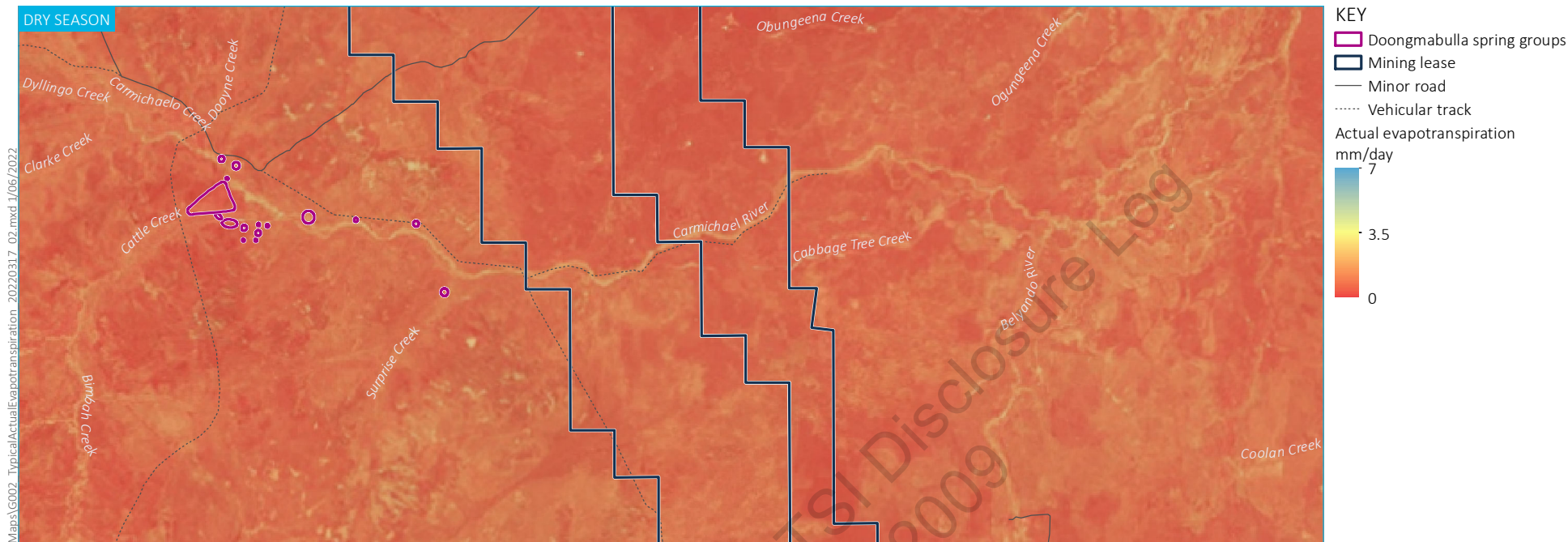
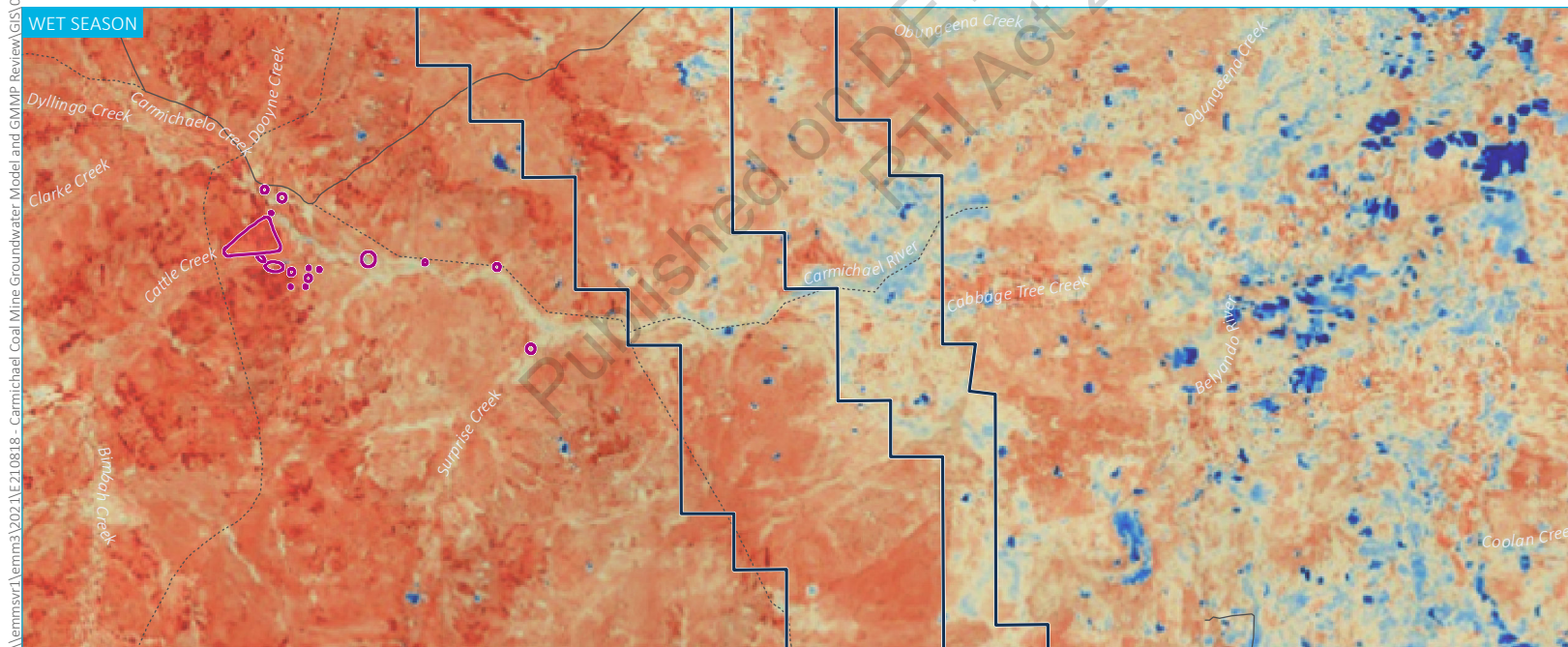
iii Effects of springs on downstream waterways

Regional evapotranspiration (ET) was assessed utilising CSIRO CMRSET monthly remote sensed actual evapotranspiration data (CSIRO 2022). These data show that evapotranspiration within river floodplains is greater than other locations within the landscape, particularly within Dyllingo Creek and the Carmichael River between Joshua spring and the Belyando River during the months of July – December (Figure 10.10).

The ET data indicate that floodplains and river channels in the region tend to support higher ET rates than locations above the floodplain, reflective of higher water availability near waterways (Figure 10.11). ET rates on floodplains upstream of Doongmabulla were around 700 mm/yr, while within the Belyando River ET rates ranged from 730–840 mm/yr, reflective of higher water availability from a larger catchment.

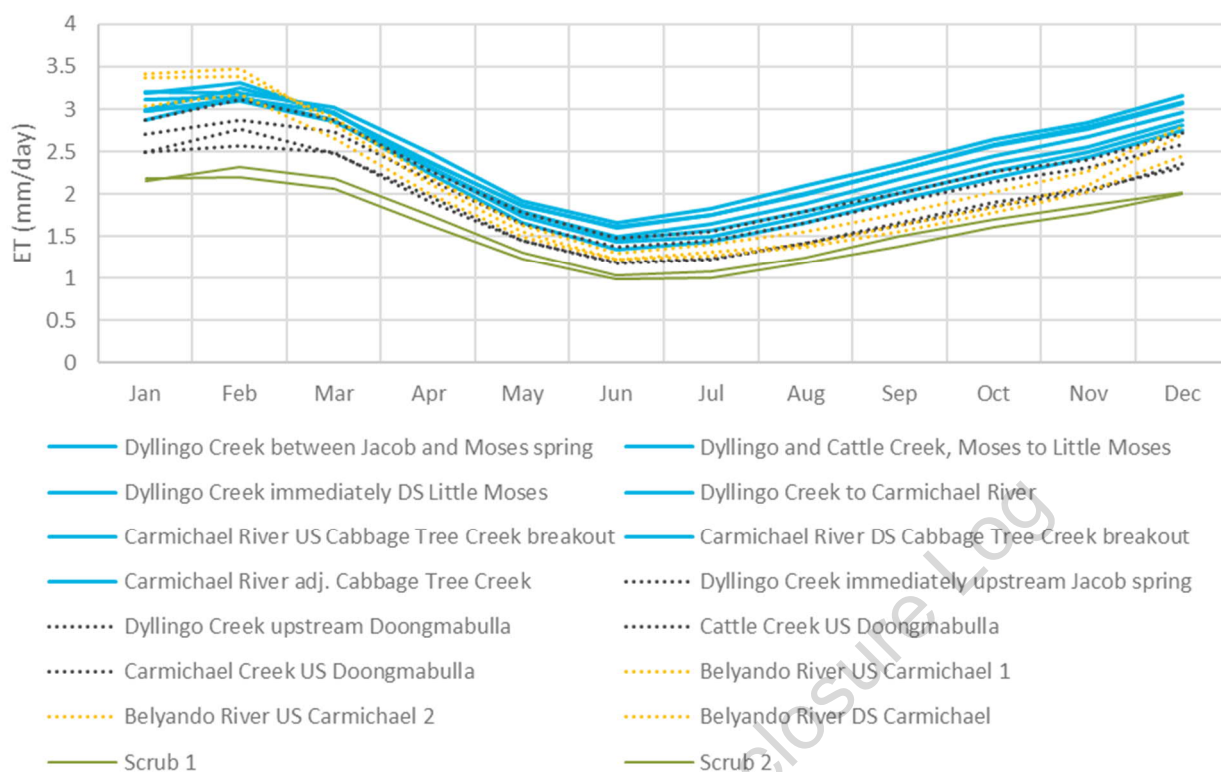
ET rates are approximately 100 mm/yr greater on the floodplain downstream of the Doongmabulla springs than other floodplains in the region (Figure 10.12), which could be an indication of spring discharges. When integrated over the area of the floodplain, the total volume of water evapotranspired from the Dyllingo Creek and Carmichael River floodplain downstream of Doongmabulla (approx. 610 ha) amounts to 5,000 ML/yr, and the volume over and above regional floodplain ET amounts to 260 ML/yr (average of 0.7 ML/d, 8.2 L/s). This result is consistent with the observed discharge from Joshua spring (5 L/s, section 10.2.1) with allowance for discharges from other springs in the complex.

The effects of springs on pools in the Carmichael River is discussed further in section 10.4.2.



Typical actual evapotranspiration
(Top: dry season; Bottom: wet
season) (CSIRO, 2022)

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Figure 10.9



Scrub 1 and Scrub 2 represent regional background ET assumed to be utilising soil moisture
Dashed lines represent floodplain locations assumed to be unaffected by springs, and are the control data for assessing spring effects
Blue lines represent potentially spring affected floodplain locations

Figure 10.10 Monthly CSIRO CMRSET actual evapotranspiration in waterways (CSIRO 2022)

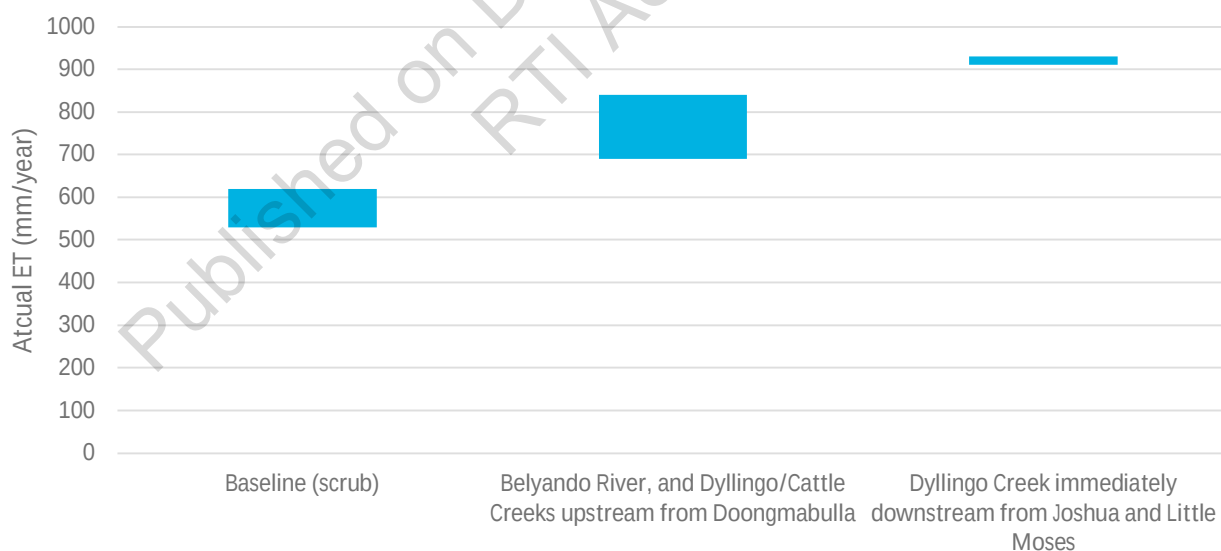
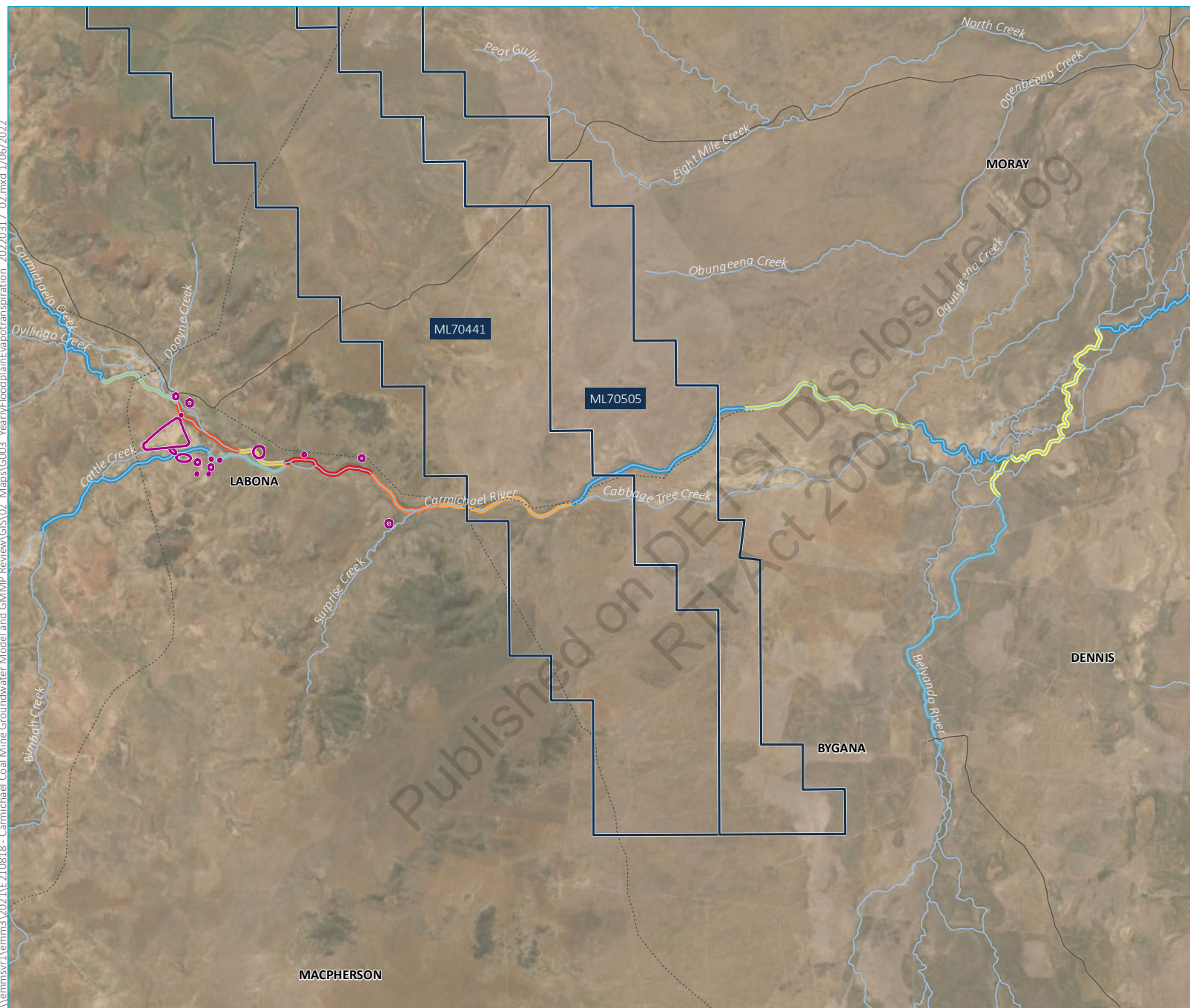


Figure 10.11 Total annual actual ET (CSIRO 2022)

\\lemmsvr1\emms3\2021\2021E210818 - Carmichael Coal Mine Groundwater Model and GMMP Review\GIS\02 Maps\G003 YearlyFloodplainEvapotranspiration 20220317 02.mxd 1/06/2022



- KEY**
- Doongmabulla spring groups
 - Mining lease
 - Minor road
 - Vehicular track
 - Named watercourse
- ET anomaly (mm/year)**
- 0
 - 2
 - 12
 - 17
 - 29
 - 34
 - 37
 - 54
 - 89
 - 98
 - 117

NOTE: ET anomaly calculated as
yearly floodplain ET minus 810 mm/y

Yearly floodplain evapotranspiration
rates anomaly

Carmichael Coal Mine
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Figure 10.12

iv Evapotranspiration from spring wetlands

Actual ET rates measured by the CSIRO CMRSET algorithm were consistently higher at spring fed wetlands than across the landscape generally (Figure 10.13), ranging from 900 mm/yr at Moses to 1,100 mm/yr at Keelback. At two reference 'scrub' sites near Doongmabulla, CSIRO CMRSET reports yearly ET of around 600 mm/yr. Assuming spring catchment runoff is minimal and/or is spilled to downstream waterways, the additional ET at wetland sites over and above the regional ET may be attributed to the spring discharges. Across the Doongmabulla wetlands, approximately 240 ML/yr evaporates from the wetlands and wetland vegetation (Table 10.2), 78 ML/yr more than occurs in the region (Table 10.3).

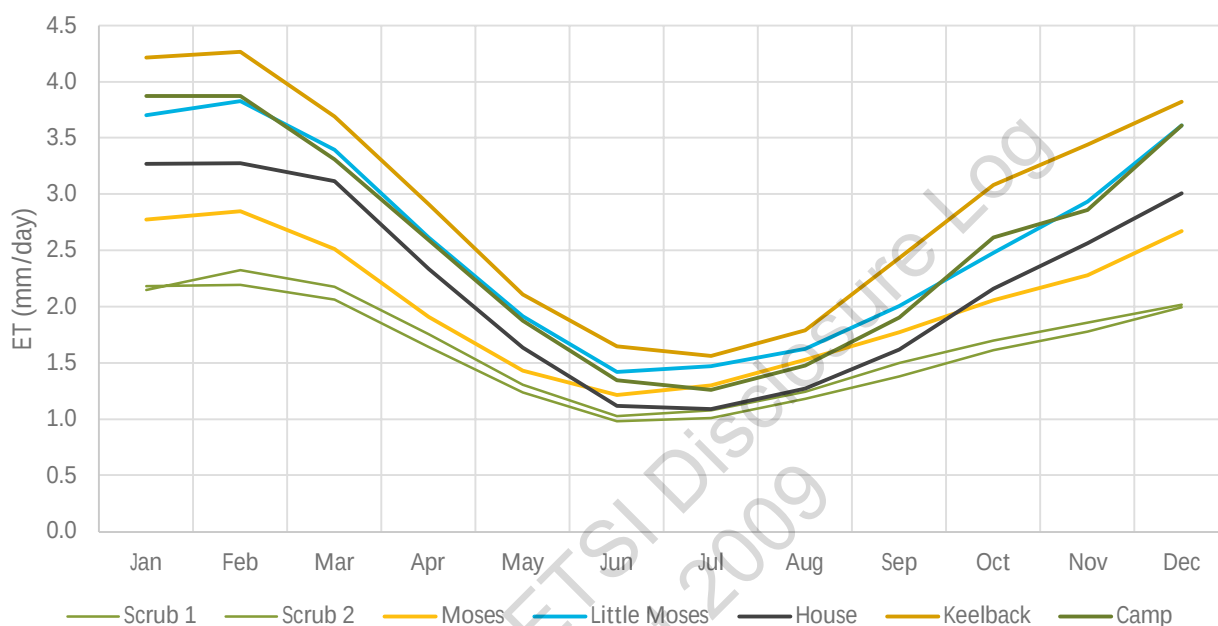


Figure 10.13 Monthly CSIRO CMRSET actual evapotranspiration at wetlands (CSIRO 2022)

Table 10.2 Doongmabulla spring complex ET rates (CSIRO CMRSET ET estimates)

Spring group	Wetland area (ha)	ET rate (mm/yr)	Evapotranspiration		
			ML/yr	ML/d	L/s
House	12	810	97	0.27	3.1
Mouldy Crummet	1	900	9	0.02	0.3
Moses	3.3	890	29	0.08	0.9
Keelback	3.6	1070	39	0.11	1.2
Camp	2.2	930	20	0.06	0.6
Geschlichen	1	900	9	0.02	0.3
Little Moses	3	950	29	0.08	0.9
Surprise	1	900	9	0.02	0.3
TOTAL	27		241	0.66	7.6

Note: ET was not measured for wetlands with area under 2 ha due to data resolution. A rate of 900 mm/yr was applied based on the rates measured at the larger wetlands.

Table 10.3 Doongmabulla spring complex ET anomaly (CSIRO CMRSET ET estimates)

Spring group	Wetland area (ha)	Excess ET (mm/yr)	Evapotranspiration		
			ML/yr	ML/d	L/s
House	12	210	25	0.07	0.8
Mouldy Crumpet	1	300	3	0.01	0.1
Moses	3.3	290	10	0.03	0.3
Keelback	3.6	470	17	0.05	0.5
Camp	2.2	330	7	0.02	0.2
Geschlichen	1	300	3	0.01	0.1
Little Moses	3	350	11	0.03	0.3
Surprise	1	300	3	0.01	0.1
TOTAL	27		78	0.21	2.5

ET anomaly calculated on the basis that regional ET is 600 mm/yr

Wetland areas used for estimating ET anomaly were based on an upper estimate of area from aerial photography, such that ET from the full extent of the wetland would be measured during periods of peak extent.

The Williams and Holmes (1978) method for estimating spring discharges from area and ET presented above aligns with the CSIRO CMRSET data describing ET at the spring wetlands.

v Total spring discharge

The CMRSET data indicates that 0.2 ML/d evaporates at Doongmabulla wetlands (section 10.2.2iv), and that the downstream environment receives an additional 0.7 ML/d (section 10.2.2iii), for a total discharge from the springs to the environment of around 1 ML/d (rounded).

A further 1 to 1.5 ML/d may be harvested from Joshua spring for stock and domestic purposes (section 10.2.2i), leading to an estimate of 2 to 2.5 ML/d total discharge from the groundwater system.

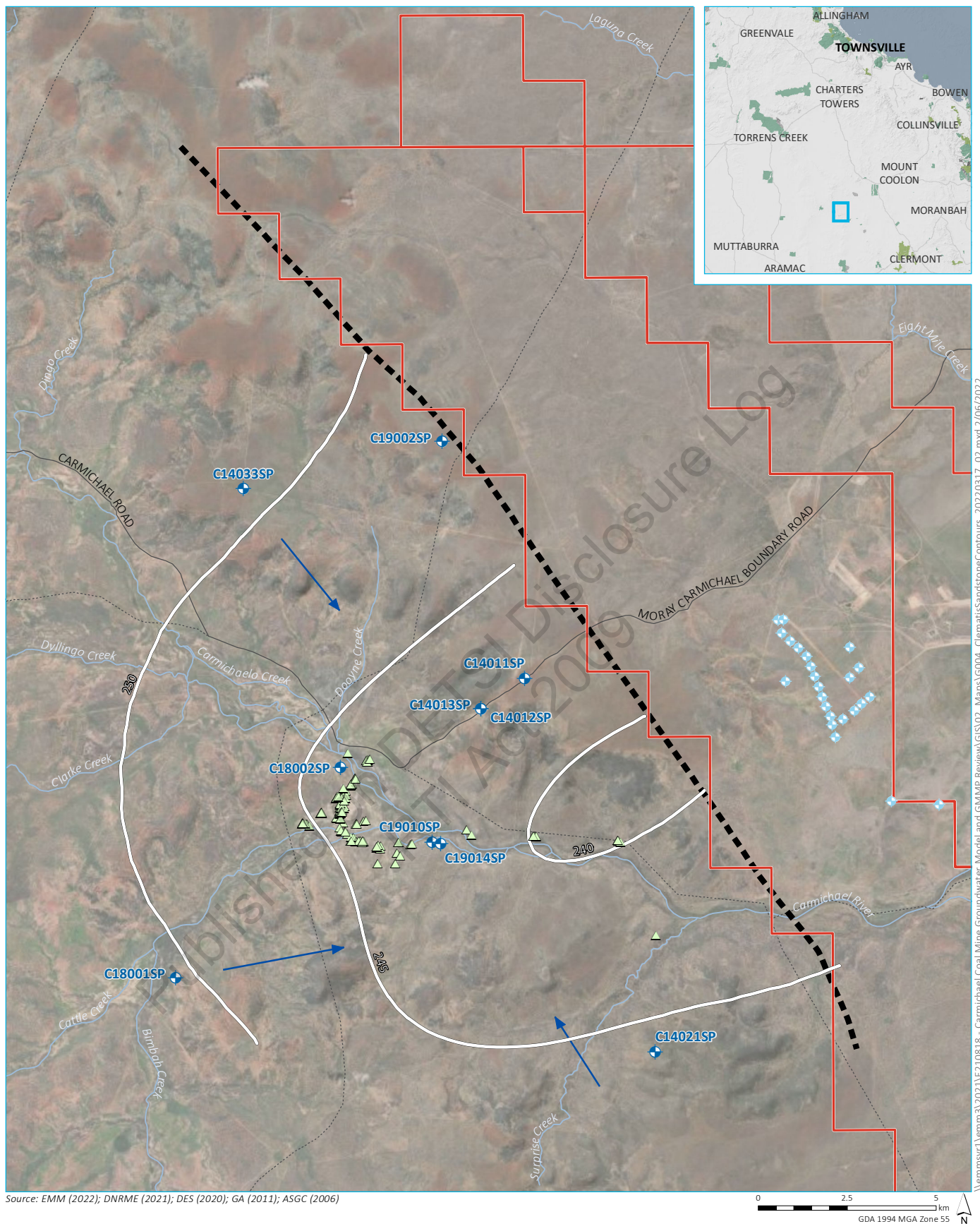
As described in Section 3.1.4, GABSRP task RP1.4 includes development of a springs water balance. It is likely that spring discharge estimates will be refined through that task, at which point discharge estimates provided here would be refined.

10.2.3 Spring water source

The source of water for the Doongmabulla springs has been discussed at length in the literature, with possible sources including both the Triassic Clematis Sandstone, and the Permian Colinlea Sandstone aquifers. Groundwater pressures near the springs (see Section 7.2.1) and hydrochemistry analysis (see Section 9) indicate that the Clematis Sandstone is the source aquifer. There is insufficient groundwater pressure in the Colinlea Sandstone and incompatible water quality to allow for a Permian source aquifer.

The current best estimate of spring water source is from regional throughflow originating from the west and perhaps minor rainfall recharge directly to the Clematis Sandstone, where it outcrops between the Doongmabulla springs and the Carmichael Mine, in the southern area. Sufficient pressure exists within the Clematis to drive water via deeper pathways to the north-western spring groups which exhibit artesian characteristics. As discussed in Section 8.3.2, EMM hypothesis that either the weathered cover (see Figure 5.1) is restricting outflow of Clematis and backing up pressures behind it, or there is a local lineament/fault cutting across Surprise Creek that is backing up flow in Clematis, Dunda and upper Rewan behind it.

Figure 10.14 illustrates the Clematis potentiometric contours based on field data collected during February 2021, which shows pressures around the 240 – 245 mAHD at DSC, exceeding the surface at these spring locations.



KEY

- + Groundwater monitoring well
- Inferred groundwater flow direction
- Mining lease
- Minor road
- Vehicular track
- Named watercourse
- Inferred subcrop
- + Dewatering bore
- ▲ Spring

INSET KEY

- Main road
- National park
- State forest

Clematis Sandstone groundwater contours (February 2021)

Carmichael Coal Mine
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Figure 10.14

10.2.4 Spring stratigraphy

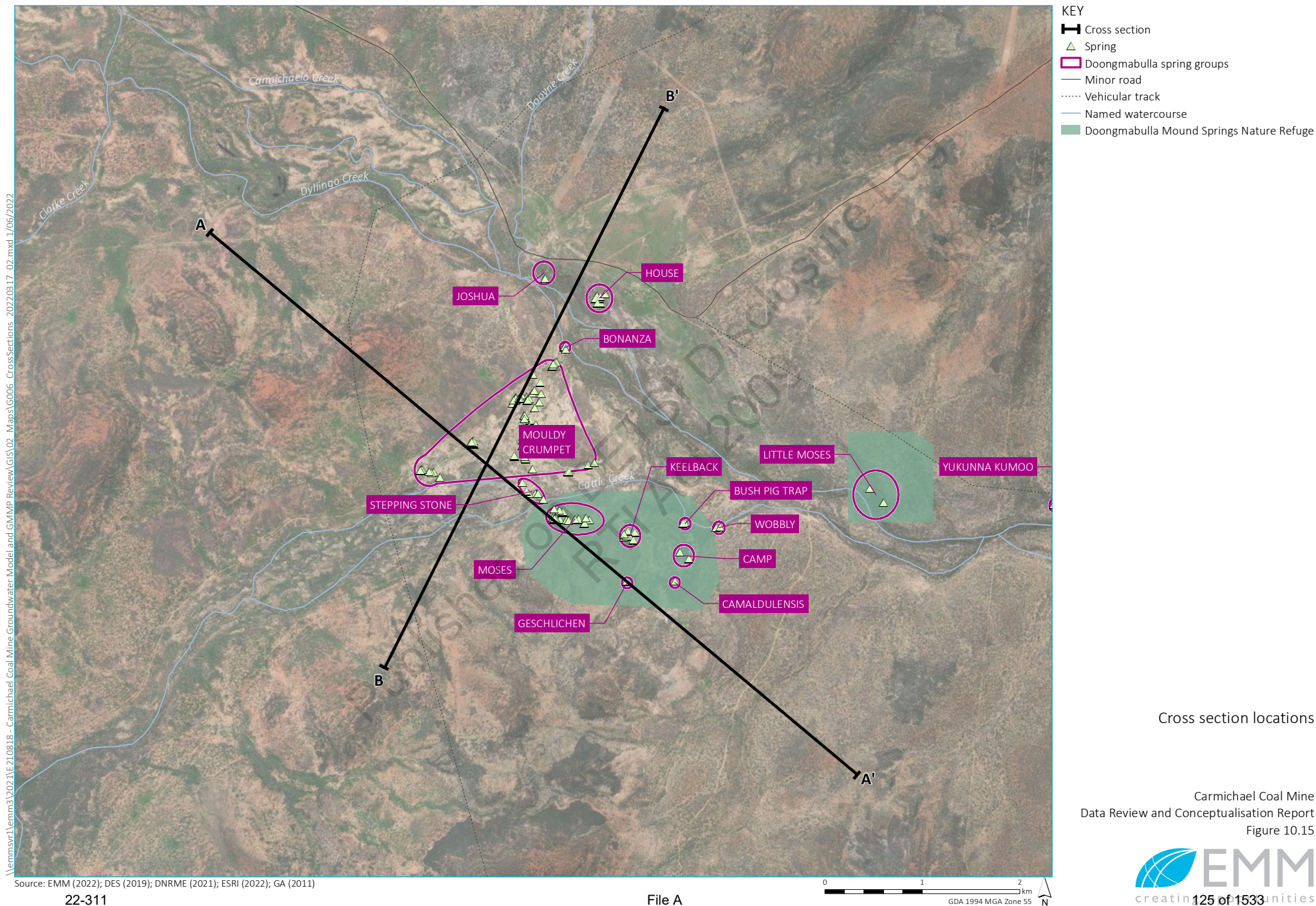
Stratigraphic cross sections through the Doongmabulla springs are presented along A-A' and B-B' as shown in Figure 10.15 utilising the revised stratigraphy described in section 5.

The sections illustrate that at the western springs, including those that lie along B-B', the Moolayember Formation lies above the Clematis Sandstone. As an aquitard, the Moolayember Formation allows artesian conditions to develop in the Clematis below. Local weaknesses in the Moolayember Formation allow spring discharges to occur where the groundwater head in the Clematis Sandstone exceeds the ground surface. Western springs located above Moolayember formation exhibit mound spring characteristics (Fensham et al. 2016), and include:

- Mouldy Crumpet;
- Bonanza;
- House;
- Joshua;
- Stepping Stone; and
- Moses.

Eastern springs located where the Clematis Sandstone outcrops (or subcrops) do not have mounds, and include:

- Keelback;
- Camp;
- Wobbly;
- Bush Pig Trap;
- Little Moses; and
- Surprise.



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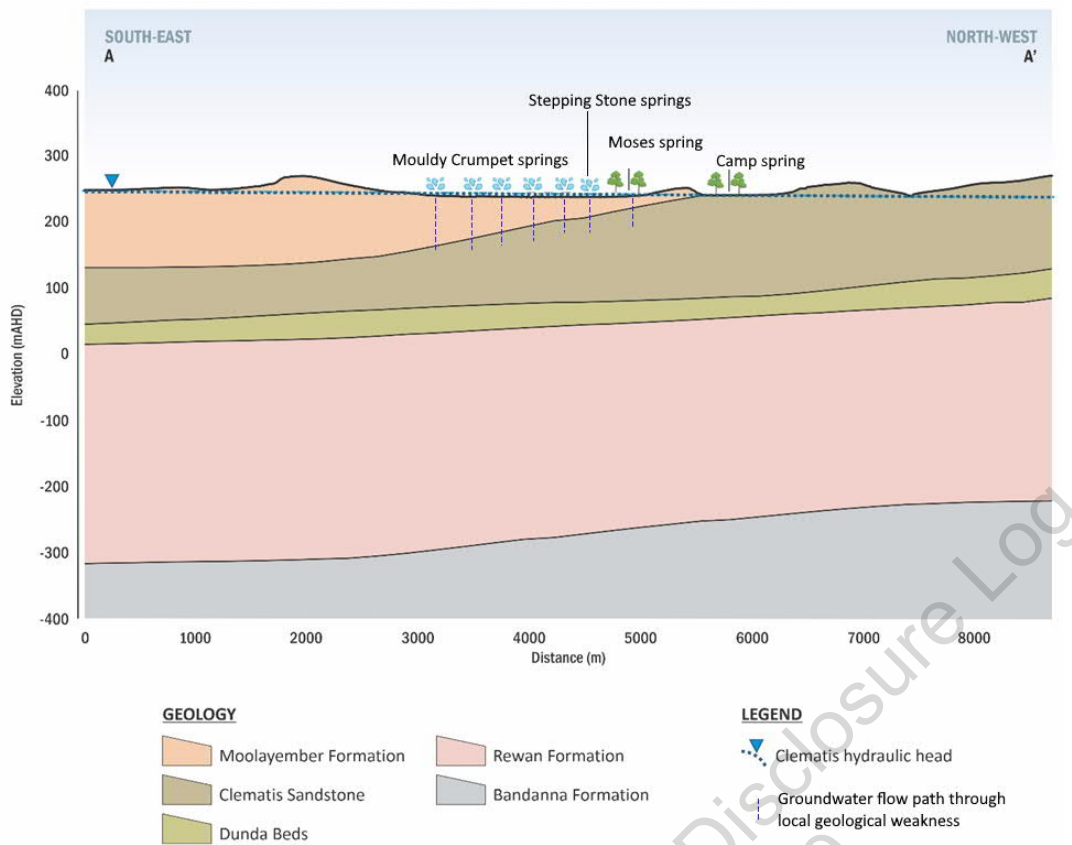


Figure 10.16 Cross section A – A'

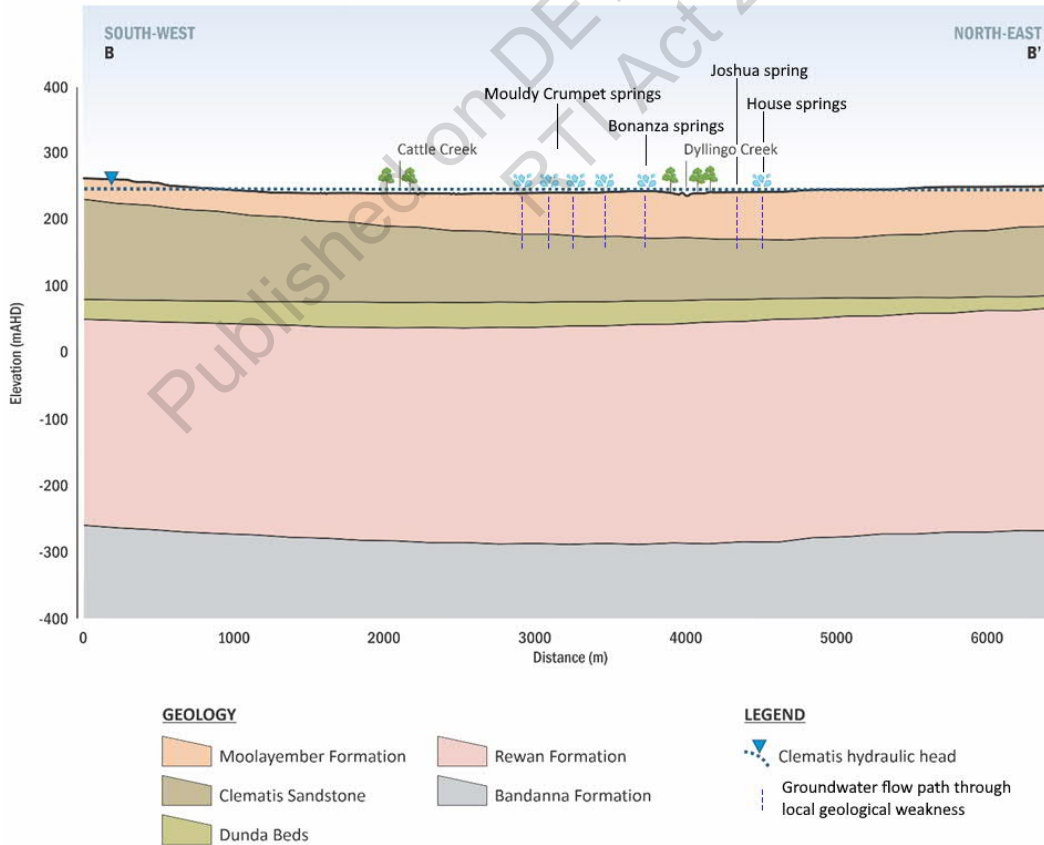


Figure 10.17 Cross section B – B'

10.2.5 Structural linkage

With reference to the spring typology presented in Commonwealth of Australia (2014), it is possible that the western Doongmabulla springs (eg Mouldy Crumpet, and Joshua) are examples of 'Type E' springs, whereby spring waters emanate from the uppermost artesian aquifer through the overlying aquitard. Commonwealth of Australia (2014) provides an example using the concept of a fault breaching the aquitard, though structural weakness caused by other means would have a similar effect.

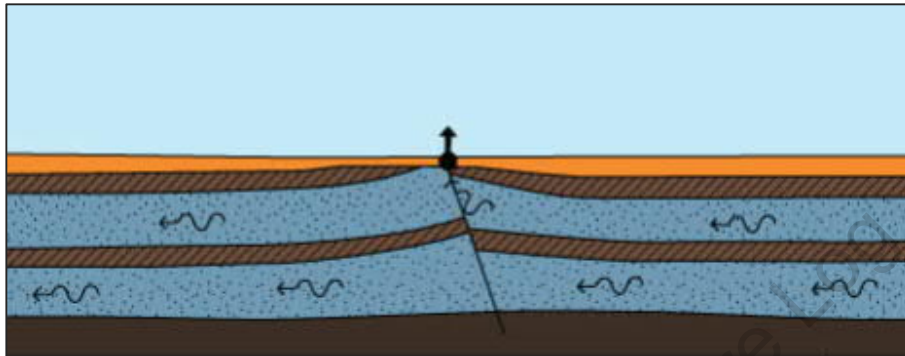


Figure 10.18 'Type E' spring (Commonwealth of Australia 2014)

Little Moses appears to be a 'Type B' spring (Figure 10.19), with spring water emanating from outcropping sediments where the aquifer intersects the surface within a gully, in this case within a relict river channel.

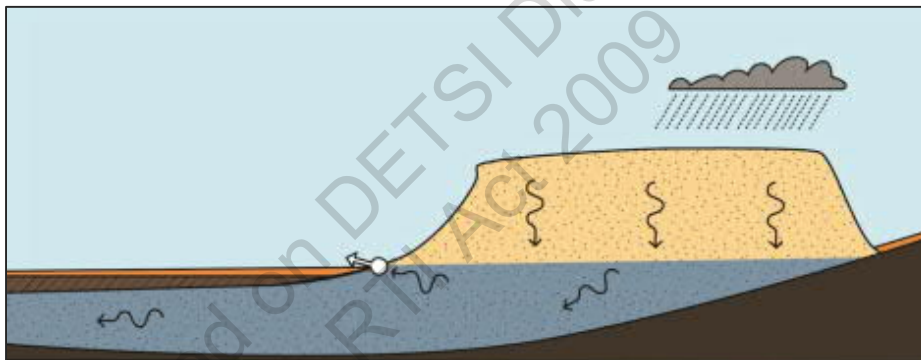


Figure 10.19 'Type B' spring (Commonwealth of Australia 2014)

The remaining eastern springs (eg Camp, and Surprise) are likely 'Type C' springs (Figure 10.20), with discharge at locations where the confining aquitard has thinned or been thinned by erosion (Figure 10.42).

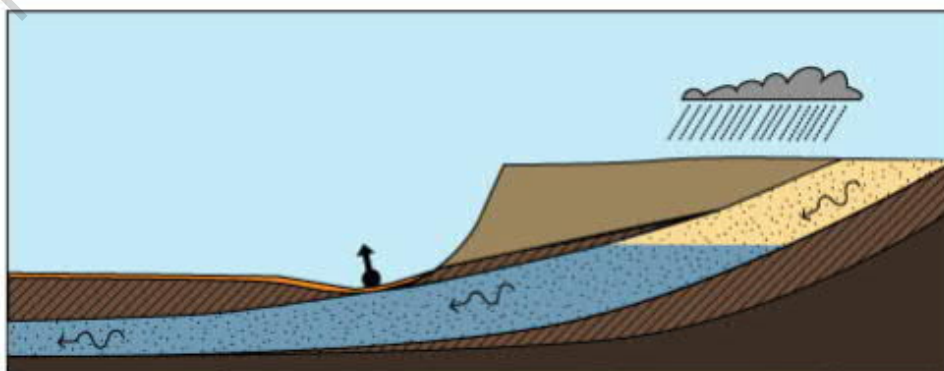


Figure 10.20 'Type C' spring (Commonwealth of Australia 2014)

Spring typologies will be further assessed as part of the Year 2 studies related to the GAB Research Plan.

10.3 Cattle Creek pools

Cattle Creek is an ephemeral braided tributary to Dyllingo Creek which flows through the Doongmabulla spring complex. Salt scarring along Cattle Creek indicates that there may be diffuse discharge of groundwater along the creek floodplain.

The creek contains a large number of ungauged pools visible in satellite photography, which support a higher density of vegetation than the salt scarred floodplain.

At the time the LiDAR elevation data for the springs was captured, pool levels in Cattle Creek near the Moses spring group were 236 m AHD. At the western extent of the LiDAR data, 3 km upstream from the Moses spring group, pool levels were 239 m AHD, indicating a 1 m per km hydraulic gradient.

The Cattle Creek pool levels at the confluence with Dyllingo Creek are lower than the Doongmabulla spring complex discharge water levels, and it is likely that the pools in Cattle Creek are not directly supported by artesian springs. Cattle Creek pools are visible in aerial photography more than 10 km upstream from the Doongmabulla springs indicating that the water source is independent from the spring complex, with pools likely supported by intermittent surface water flows during the wet season, with bank/alluvial storage assisting with pool maintenance. Potential evapotranspiration exceeds rainfall by approximately 50 mm/month through January to July (Figure 4.1), indicating that a pool filled to a nominal depth of 0.5 m could maintain a water volume for close to 10 months, likely being refilled during this time by creek flows.

As Cattle Creek pools are ungauged and have not been surveyed, changes in pool size and depth over time in response to climate sequences cannot be confirmed.

10.4 Carmichael River

10.4.1 Setting

Carmichael River is an ephemeral waterway which begins downstream of the confluence of Cattle Creek and Dyllingo Creek, flowing east past the Carmichael Coal Mine, meeting the Belyando River approximately 10 km downstream from the mine boundary. The main channel of the Carmichael River is less than 10 m wide (Figure 10.22, and the top of banks are approximately 140 m apart, with eucalyptus and grasses populating the banks and floodplain.



Photograph 10.7 Carmichael River (Aug 2010, dry season) (GHD 2012b)





Photograph 10.8 Carmichael River at CAR04 (Top: Oct 2020, dry season; Bottom: Feb 2021, wet season) (C&R Consulting 2021)

10.4.2 River pools

The Carmichael Coal Mine and Rail Project Environmental Impact Statement mine hydrology report (GHD 2012b) (the EIS) describes that there are no streamflow gauging stations along the Carmichael River. Since the EIS was published Adani/Bravus has installed gauges upstream, within, and downstream of the mine site as described by C&R Consulting (2021) (Figure 10.23). Streamflow gauges CAR01, CAR02 and CAR04 on the Carmichael River, and BEL01 and BEL02 on the Belyando River are telemetered with data available via Bravus' weather station online portal. Albinia and Moray West gauges are currently operational but require manual data download. The gauges were installed in 2019–2020 (Figure 10.21) as pressure sensors within river pools providing depth readings at sub-daily intervals.

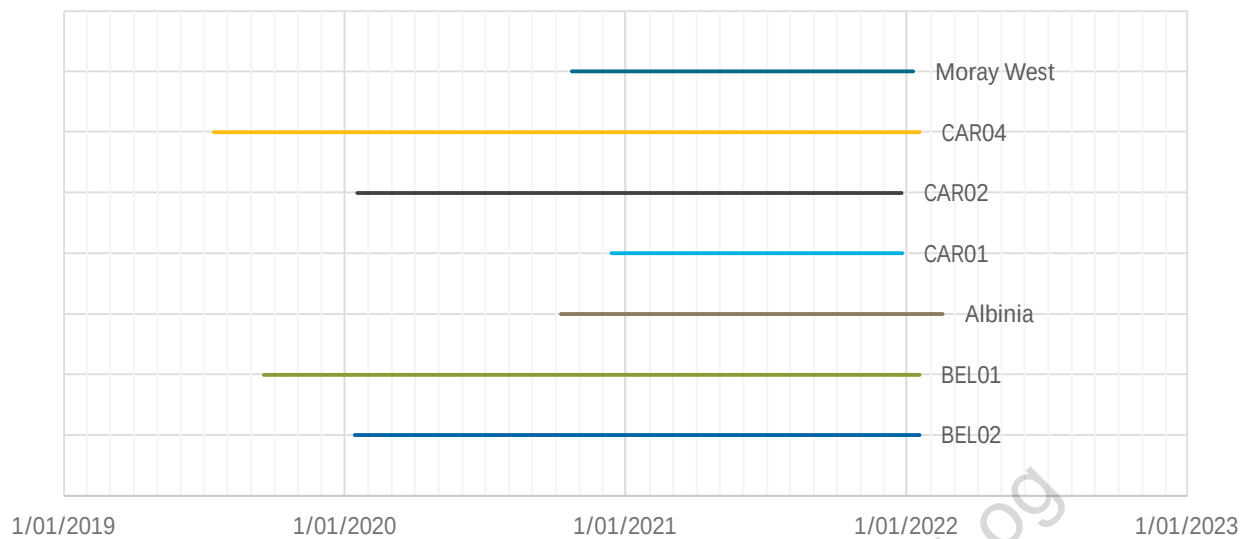
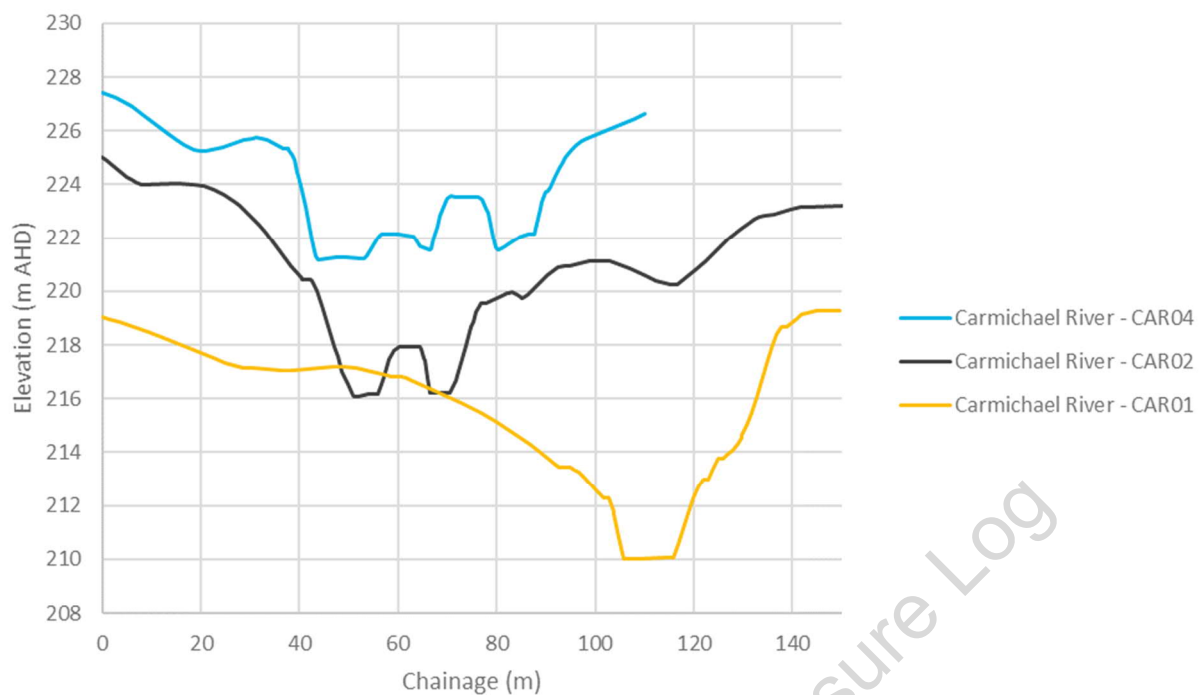
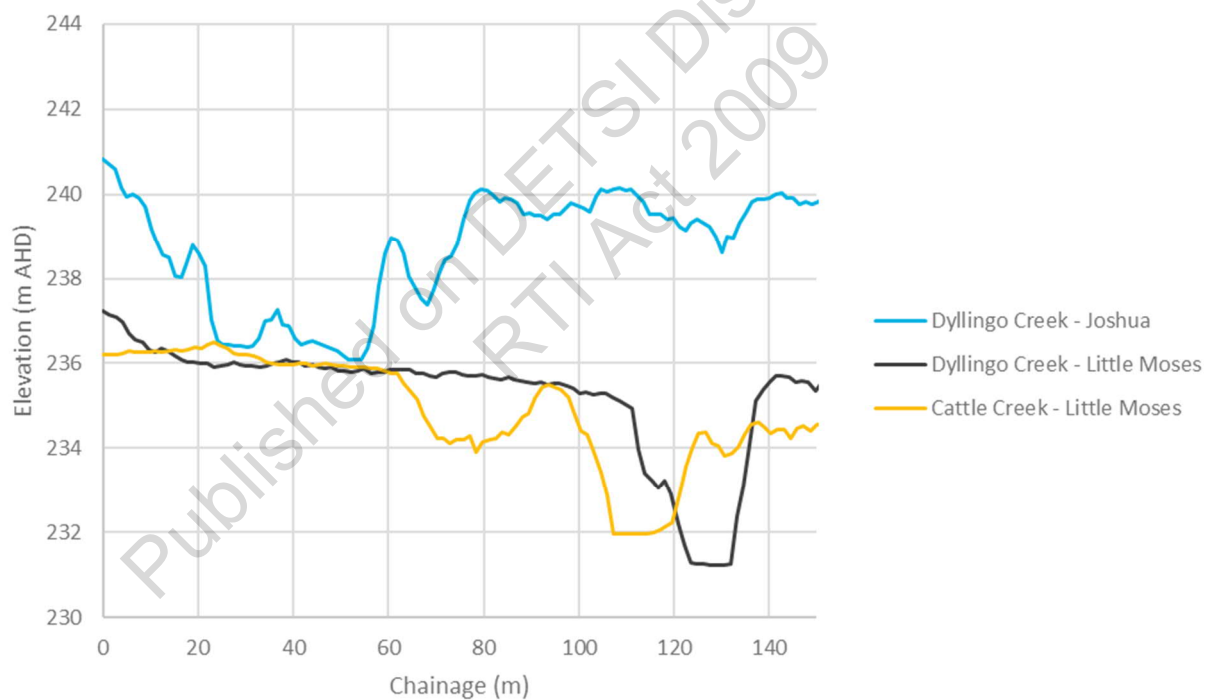


Figure 10.21 Stream gauge data availability

At gauge locations the Carmichael River has a channel width of around 10 m, and a floodplain width of around 100 m (Figure 10.22).

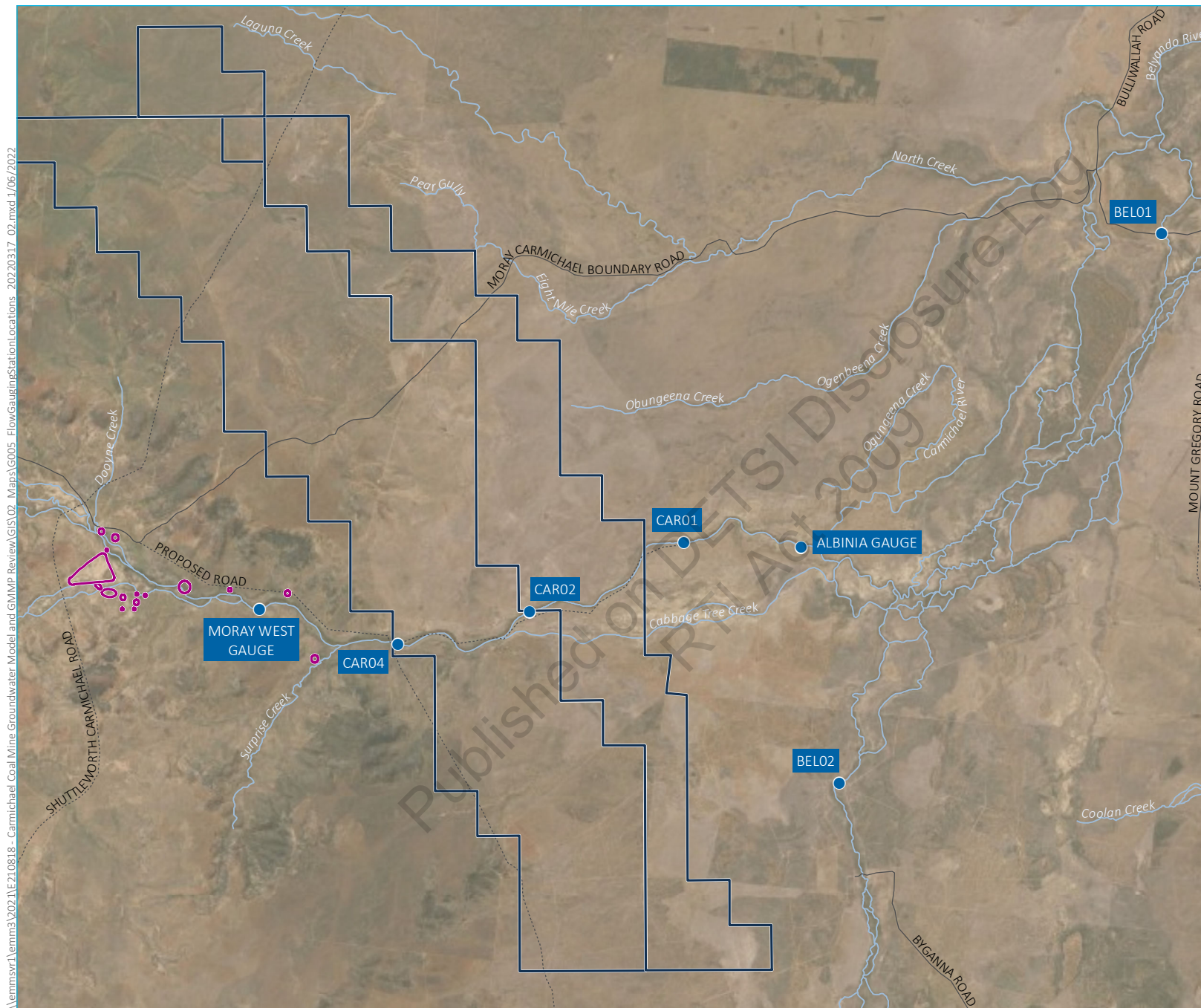


Cross sections above extracted from survey data



Cross sections above extracted from lidar data

Figure 10.22 Waterway cross sections



- KEY**
- Flow gauging station
 - ◻ Doongmabulla spring groups
 - ▭ Mining lease
 - Minor road
 - ⋯ Vehicular track
 - Named watercourse

Flow gauging station locations
at CCMP

Carmichael Coal Mine
Data Review and Conceptualisation Report
Figure 10.23

i Comparison sites – Belyando River

Within the Belyando River, stream gauges recorded significant flow each wet season (Figure 10.24 and Figure 10.25). Between flow events, gauge BEL02 recorded the presence of water for several months. Water levels at BEL02 below 0.7 m depth fell at a constant rate of around 7 mm/d (eg 100 days for the pool to dry by 0.7 m following July 2020), comparable to the daily evaporation rate. With no known springs upstream, the pools in the Belyando River have been interpreted as being filled by seasonal surface water flows, followed by periods of evaporative decline.

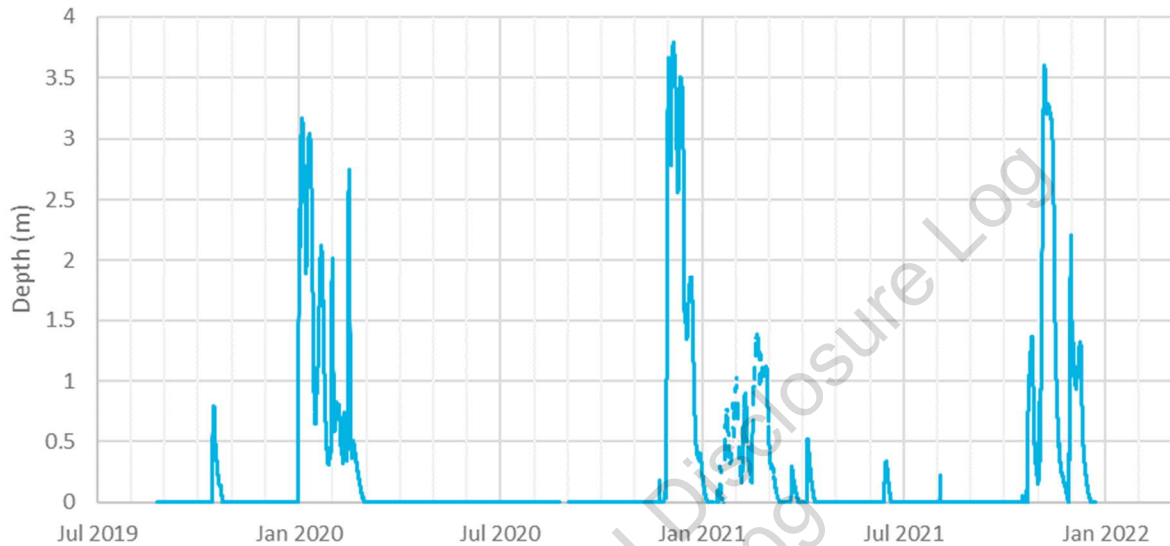


Figure 10.24 Belyando River depth at BEL01

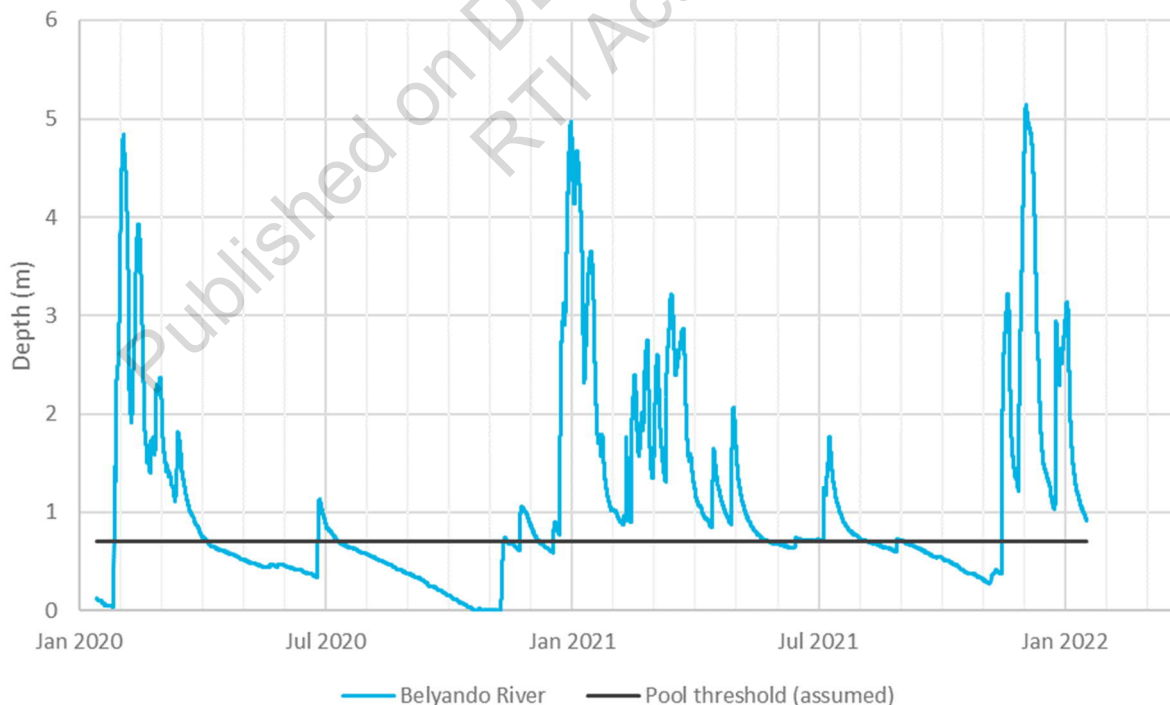


Figure 10.25 Belyando River depth at BEL02

ii Moray West

Moray West is located upstream from the mine site, approximately 3.5 km downstream from Little Moses spring, between Yukunna Kumoo and Dusk springs.

Throughout the gauge record, a permanent pool was recorded at Moray West with depth varying between 0.3 m and 0.48 m (Figure 10.26). The variance in depth may be due to shifting sand bars or obstructions altering the cease-to-flow depth.

The adjacent alluvial groundwater bore HD03B recorded recovery during the December 2020 flow event (Figure 10.27), indicating that surface water infiltrated into the shallow underlying aquifer. During periods of no flow groundwater levels dropped (eg 1 m fall between Dec 2021 and July 2022, average of 4.7 mm fall per day), indicating that the river pool was hydraulically separated from the alluvial groundwater.

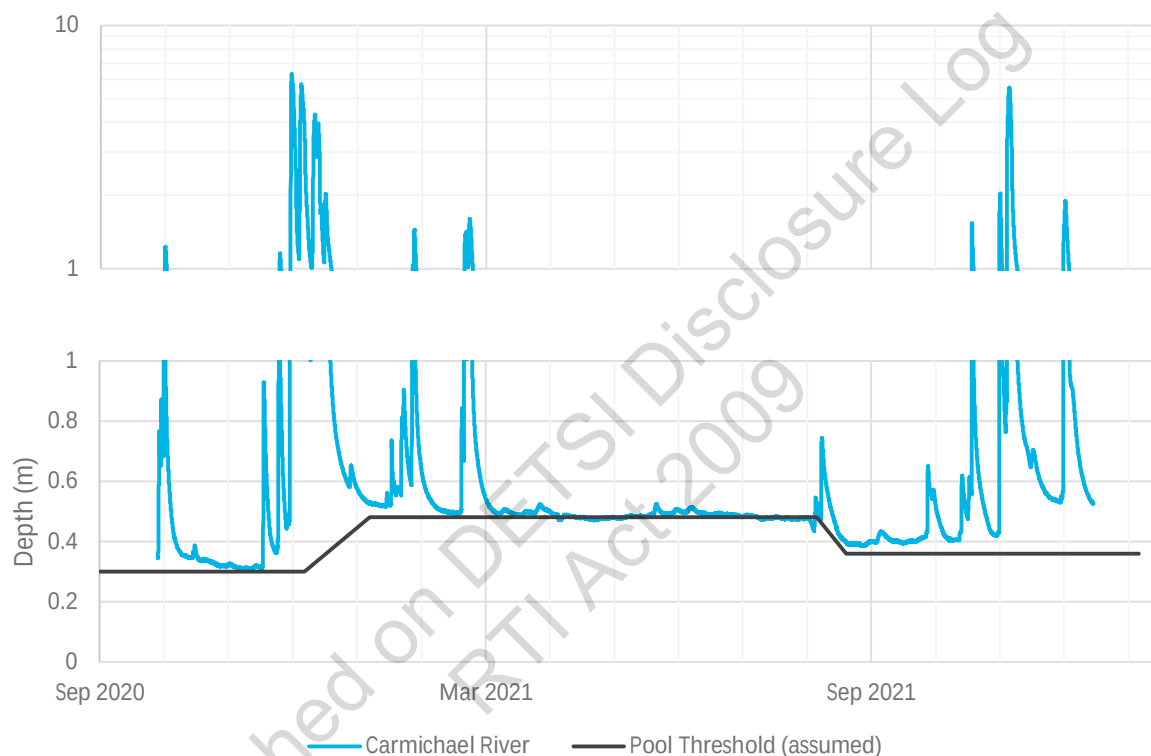


Figure 10.26 Carmichael River depth at Moray West



Figure 10.27 Alluvial groundwater level at HD03B

iii CAR04

At CAR04, located upstream from the mine site, significant flow events were recorded each wet season (Figure 10.28). Between flow events the recorded river level dropped to around 0.15 m depth at each gauge, interpreted as evidence of river pools (eg Figure 10.28).

The gauge record shows that following periods of six months with little or no flow pools may dry until rain induced streamflow occurs, with the record illustrating dry periods of 1–3 months occurring each calendar year. The drying of pools does not appear to be associated with a particular alluvial groundwater level threshold, but rather with the time of year. Drying may be associated with elevated evapotranspiration rates from September to January (Section 4), leading to increased water take by bank vegetation.

The groundwater bore CO27P1 located 470 m from CAR04, is the closest alluvial bore to the gauge. Water levels recorded at CO27P1 were converted to depth below gauge zero using surveyed levels (both the gauge and bore elevations are known in m AHD) for presentation in Figure 10.28, in which it can be seen that alluvial aquifer groundwater levels were responsive to stream flow events, indicating aquifer recharge following overbank flow events. Between aquifer recharge events the aquifer water level drops at a rate of around 80 mm/month, presumed to be due to evapotranspiration by floodplain vegetation accessing the groundwater via their root systems. This also illustrates that the Carmichael River at CAR04 is a losing system.

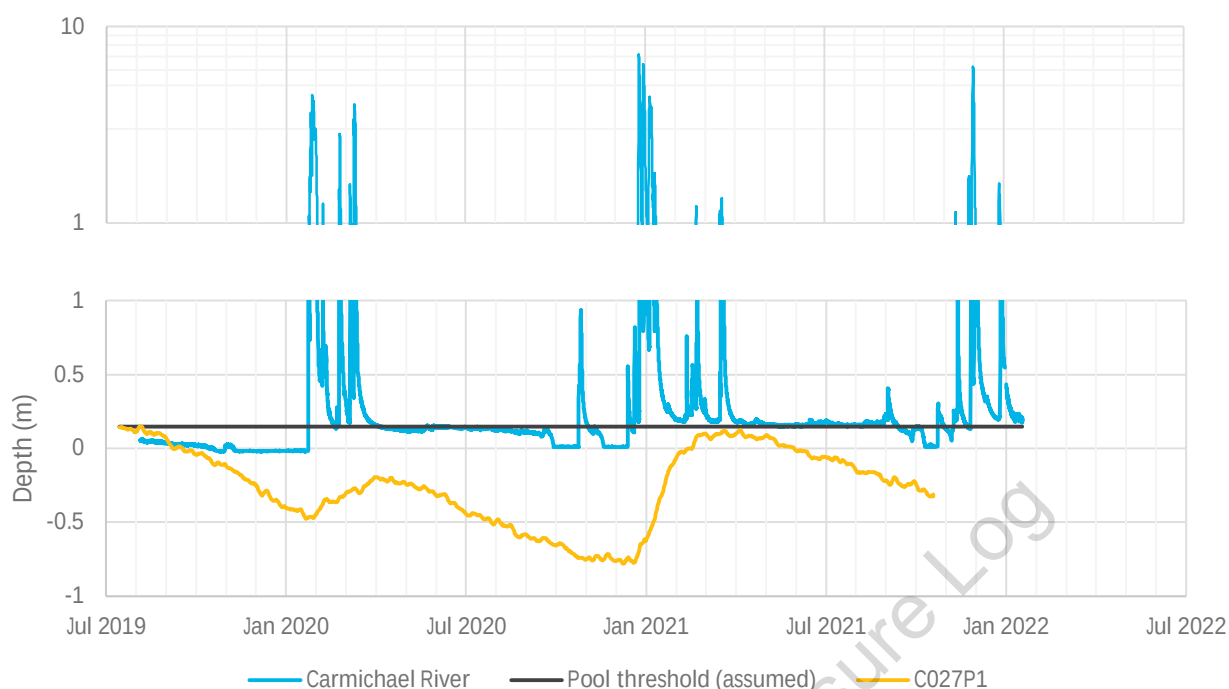


Figure 10.28 Carmichael River depth at CAR04 and nearby alluvial aquifer levels

Between May 2020 and October 2020 there was approximately 5 mm of rainfall near CAR04, with a maximum of 2 mm on a single day. This rainfall would not be sufficient to maintain a river pool, with the total evaporation through this period around 600–800 mm. The local alluvial aquifer did not contribute to maintaining the pool, as alluvial aquifer levels were approximately 0.5 m below the pool level. CAR04 is located on a Carmichael River section identified as having ET elevated above regional floodplain rates (+50 mm/yr) (cf Figure 10.12), and so it is likely that the river pools at this location are maintained by spring discharges flowing within the river channel.

iv CAR02

The closest alluvial groundwater bore to CAR02 is C19001SP, located 560 m upstream of CAR02. Groundwater levels at this location were less responsive than at CAR04, with almost no response to rainfall events evident in the groundwater level hydrograph (Figure 10.29). Alluvial bore C029P1 located 1,300 m upstream from CAR02, approximately at the mid-point between CAR04 and CAR02, presents a minor response to streamflow. Comparison of these data to the C027P1 hydrograph illustrate that the connection between surface water and the alluvial aquifer is not spatially homogeneous, but also that the groundwater level remains below the river bed throughout this river reach, continuing to be a losing system (Table 10.4).

Table 10.4 Water surface elevations

Location	Elevation
CAR04	Gauge zero: 221.8 m AHD
C027P1 (located mid-way between CAR04 and CAR02)	Groundwater elevation: 214.4 m AHD. By interpolation, river bed is approx. 218 m AHD
CAR02	Gauge zero: 216 m AHD

A river pool with an approximate depth of 0.15 m is apparent in the recorded stream depth data at CAR02 between flow events. As with CAR04, this pool is likely maintained through spring discharges.

Drying of the CAR02 river pool was evident in the gauge record, with complete drying occurring from August. This is approximately 1 month earlier than at the CAR04 gauge, likely due to the increased distance of CAR02 from the spring water source. These data indicate that the length of river pools fluctuates throughout the year in response to evapotranspiration rates, with pools shrinking towards Doongmabulla during the late dry season.

CAR02 is located in a river section with ET equivalent to the regional average, ie less floodplain ET than at CAR04. This is consistent with a weaker connection between the river and the aquifer as indicated by the C19001SP hydrograph.

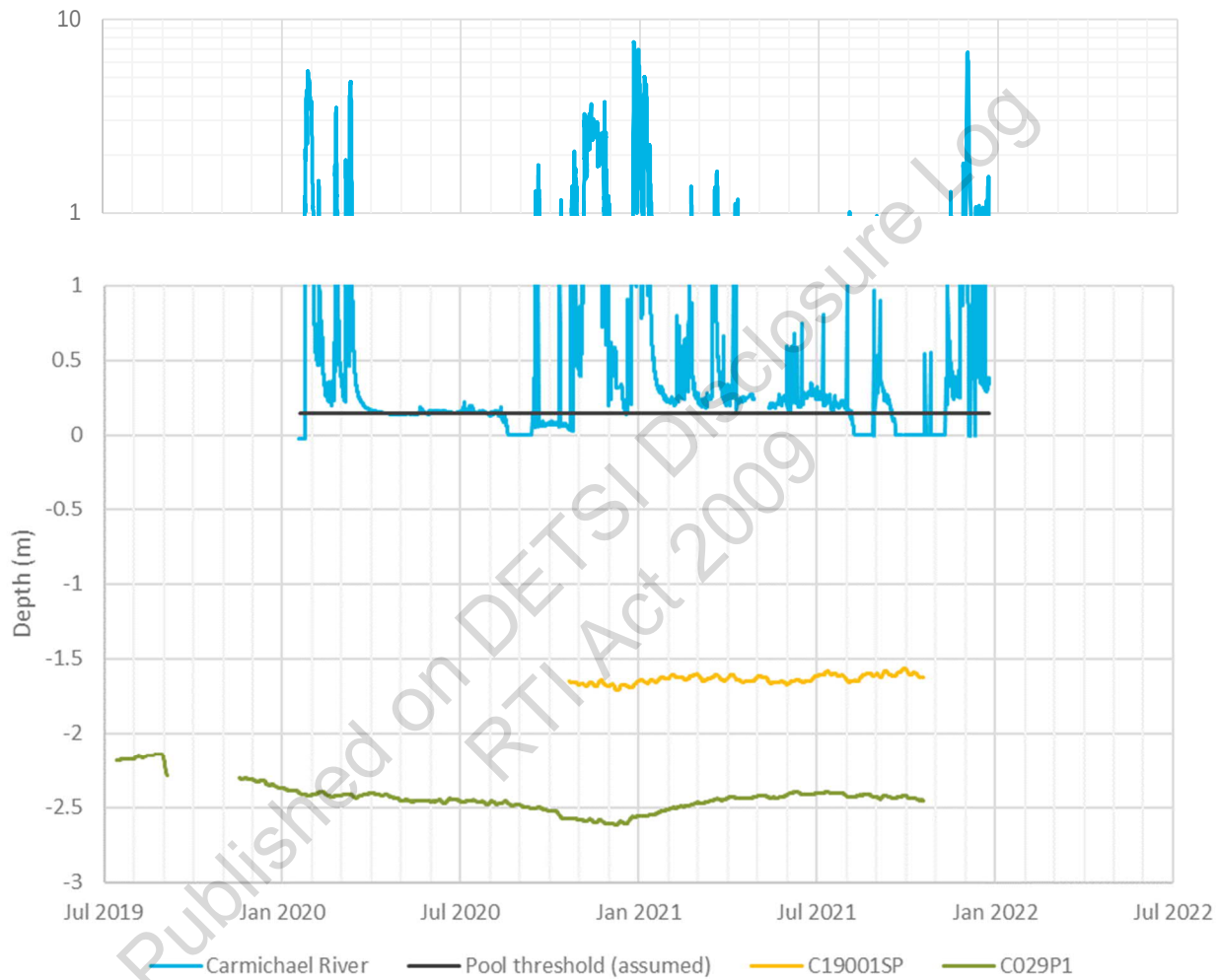


Figure 10.29 Carmichael River depth at CAR02 and nearby alluvial aquifer levels

v CAR01

There are no alluvial groundwater bores located near CAR01. At this gauge, a 0.15 m deep pool formed after flow events as at CAR04 and CAR02 but was shorter lived, drying up at approximately the rate of evaporation (Figure 10.30). This pool behaviour is similar to that observed in BEL02 and indicates that the gauge is beyond the downstream extent of spring discharge effects.

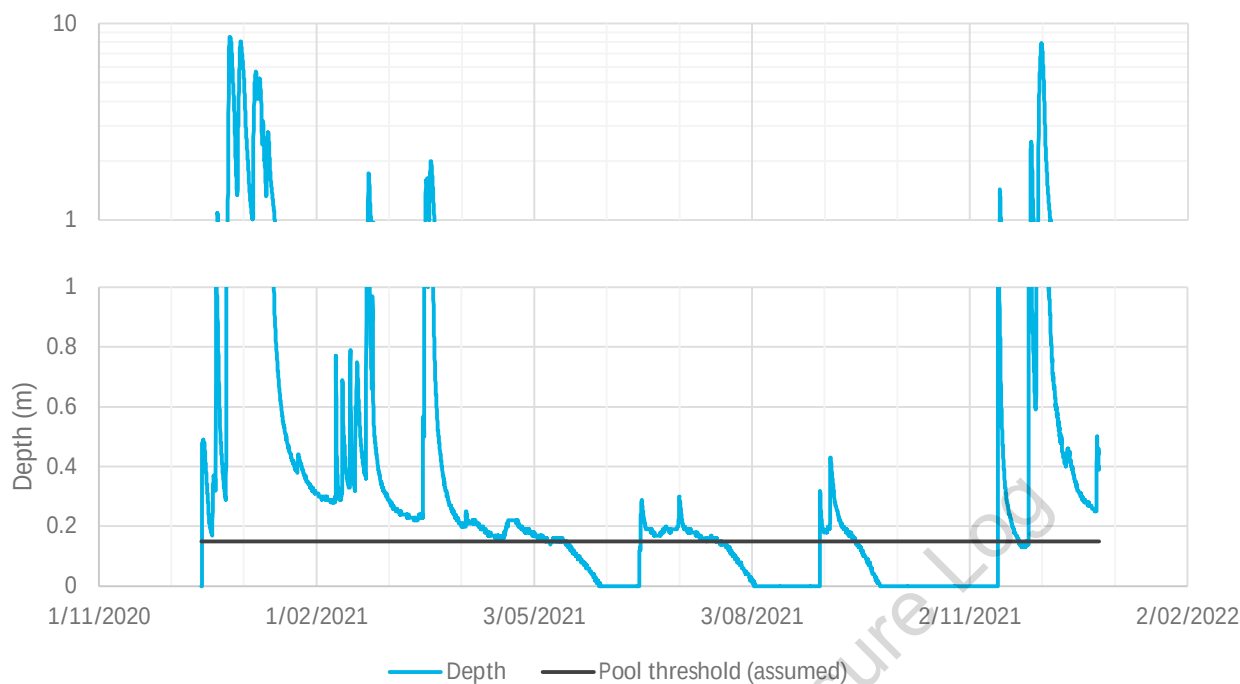


Figure 10.30 Recorded Carmichael River depths at CAR01

vi Albinia

At the Albinia gauge site, an ephemeral pool was recorded. As with the pools at BEL02 and CAR01, the pool water level reduced between flow events at a rate approximately equal to the daily evaporation rate (Figure 10.31). This pool behaviour indicates that the gauge is beyond the downstream extent of spring discharge effects; the pool is filled during flow events and experiences evaporative decline between flow events.

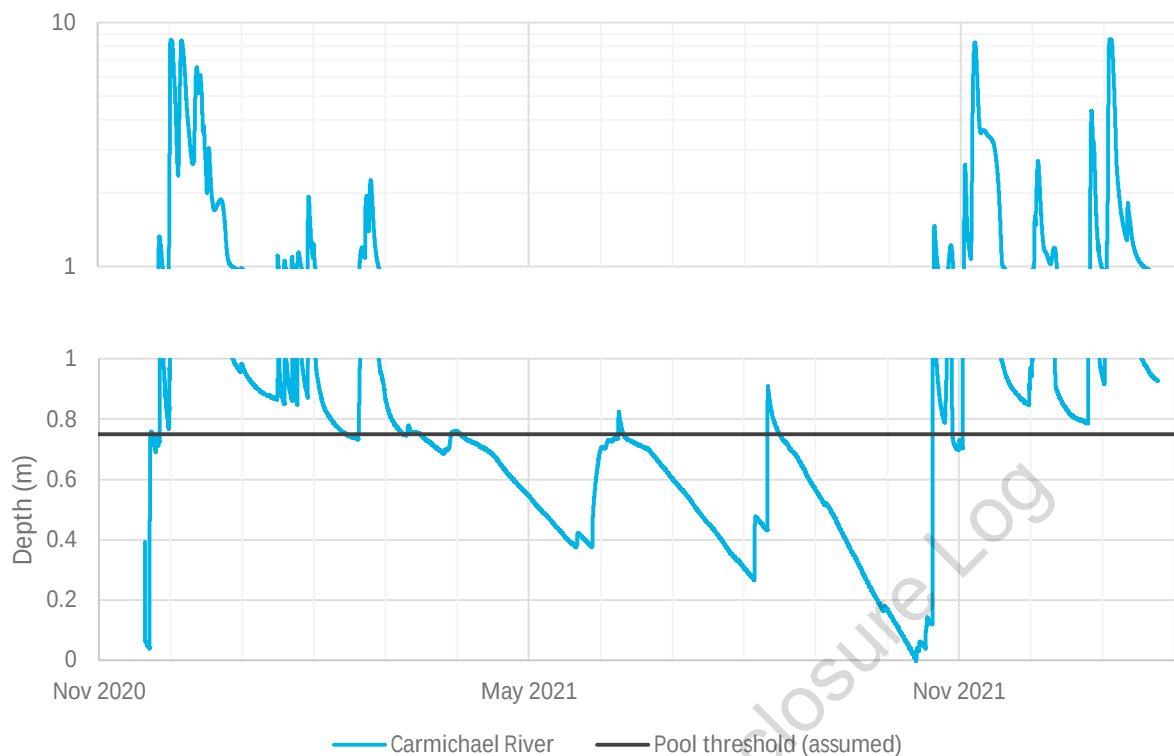


Figure 10.31 Recorded Carmichael River depths at Albinia

vii River pool concept

AECOM (2020) present a concept of spring discharges at Doongmabulla leading to recharge of the Dyllingo Creek / Carmichael River alluvial aquifer, with pools in the Carmichael River existing where the river bed is lower than the surface of the alluvial aquifer. This concept of pool maintenance is likely valid for permanent pools located adjacent in the vicinity of Joshua and Little Moses springs (eg at Moray West), however the analysis presented above illustrates that the river pools become hydraulically disconnected from the alluvial aquifer to the east of the springs, with ephemeral pools in the vicinity of the mine lease likely fed via seasonal flows along the river channel rather than through the aquifer (Figure 10.32). This also suggests the Carmichael River does not receive baseflow from the alluvium and other surrounding aquifers.

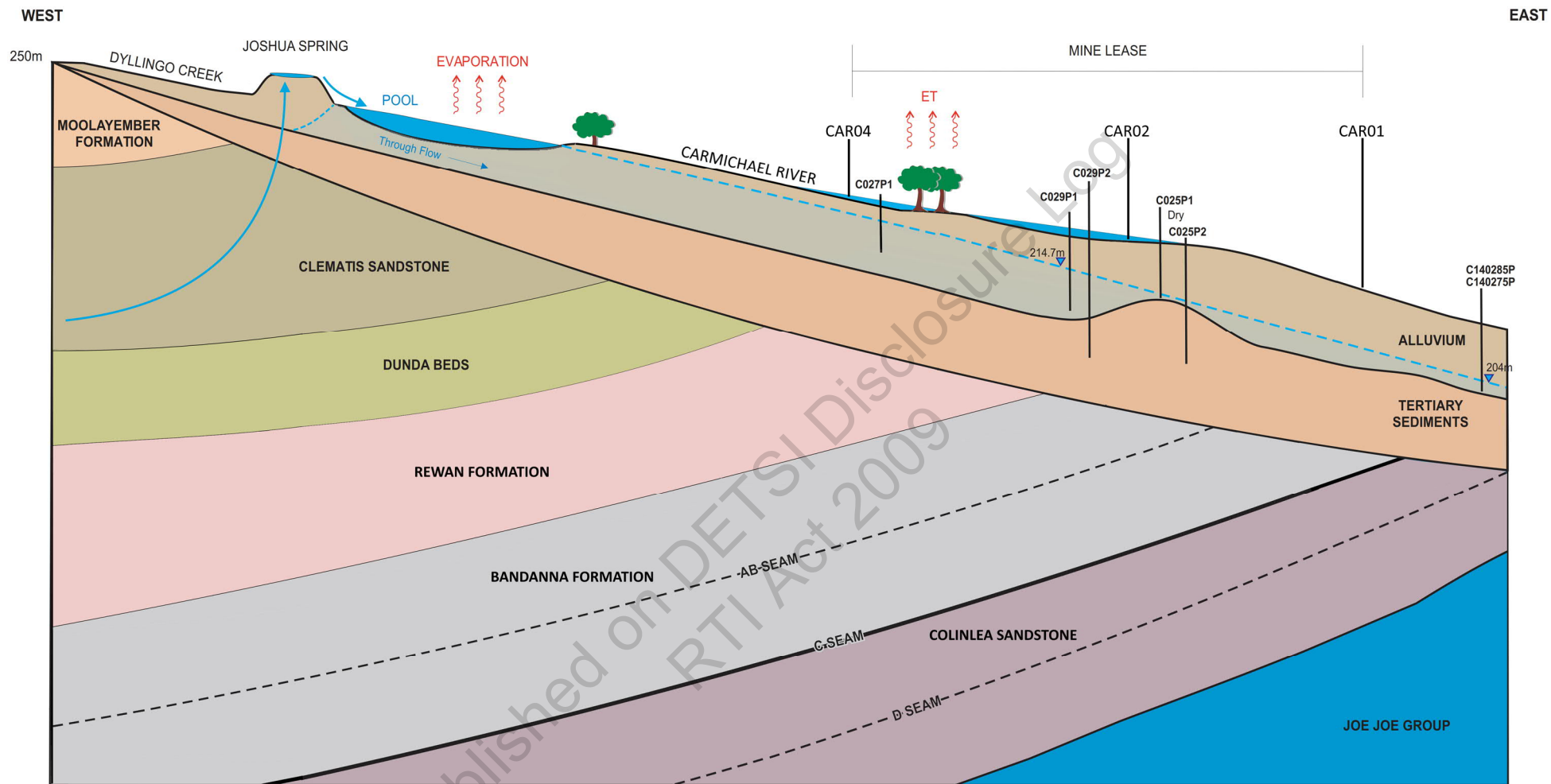


Figure 10.32 Dyllingo Creek and Carmichael River pools concept (modified from AECOM (2020))

10.4.3 Streamflow

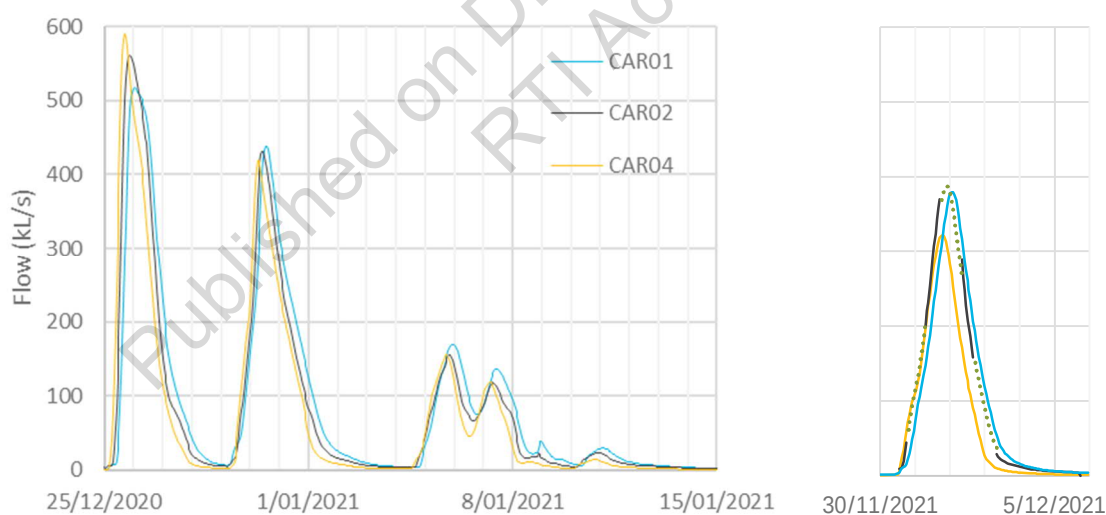
The rating curves that were used to convert depth measurements to flow estimates (published in previous project reports) contain errors and are in the process of being updated via a separate scope of works utilising additional survey of the river channel at and downstream from gauge locations. Preliminary rating revisions were obtained for this conceptual model report, utilising available survey data at CAR04, CAR02 and CAR01, and were used to present the revised flow data in this section. This data may be revised following the completion of the rating update scope of work. In particular, the rating update scope will extend the survey at CAR04 to include the full recorded depth (currently the flow relationship over 500 kL/s is extrapolated), and to extend survey downstream to a greater distance from the gauge location and so incorporate greater detail of channel dimensions which may affect water level at the gauge locations.

During the period of gauge record, the Carmichael River experienced significant flow in December 2020 and December 2021, coinciding with wet season rainfall events. Event flow estimates are presented in Figure 10.33. Each flow event occurred for around 2-3 days, with cease-to-flow conditions occurring before and after each event.

Estimated total flow volumes through each of the flow events are provided in Table 10.5, with Belyando River flows for comparison. In each event flow tended to increase with distance downstream. Differences in peaks are within the range of accuracy of the ratings and these peaks can be treated as being equivalent.

The CAR04 and CAR01 flow peaks are separated by 6 hours, indicating an average flow velocity of 0.7 m/s between these gauges.

The total Belyando River catchment above gauge 120301B is 35,200 km², with the Carmichael River contributing 2,600 km². During the 2020-2021 wet season flow events, rainfall affected the entire Carmichael River catchment, but only a part of the Belyando River catchment, leading to the Carmichael River contributing a significant portion of the flow past gauge 120301B (BoM 2022b).



Note: Dashed 2021 data represents interpolation for periods of missing data.

Figure 10.33 Preliminary revised Carmichael River flow estimates

Table 10.5 Preliminary revised Carmichael River event volumes (GL)

Event start	Event End	Carmichael River			Belyando River
		CAR04	CAR02	CAR01	120301B
25 Dec 2020	28 Dec 2020	58	62	62	
29 Dec 2020	3 Jan 2021	50	54	59	
4 Jan 2021	15 Jan 2021	28	33	39	
Total Dec - Jan		136	150	161	580
30 Nov 2021	5 Dec 2021	49	31	44	No Data

The 2020–2021 wet season runoff at Belyando River gauge 120301B was 95% of the long-term average yearly flow rate. If similar hydrological conditions occurred within the neighbouring Carmichael River catchment, then it may be assumed that average Carmichael River flows are around 150–160 GL/yr, noting however that the data record is relatively short and the Carmichael River flows likely vary significantly year to year.

10.4.4 Baseflow analysis

The waterways in the model domain are ephemeral and lose water to groundwater. Following rainfall events, streamflow recession occurs over a period of hours (Figure 10.33), indicating surface runoff and near surface interflow processes. Depth recession from 1 m to 0.2 m occurs over a period of days (Figure 10.30), likely controlled by river hydraulics, including the geometry of main channel, obstructions such as vegetation, and geomorphological features such as bars and riffles.

Traditional baseflow analysis using numerical filters such as described by Lyne and Hollick (1979) to process streamflow data and separate quickflow and slow flow signals is not valid for losing streams, and so has not been applied.

The magnitude of the loss of water from the river to groundwater cannot be ascertained by comparing the volume of water flowing past each gauge as the magnitude of the volume of water lost to the groundwater is similar to the magnitude of gauge uncertainty. This is because there are catchment inflows and creek breakouts between the gauges which would have a greater effect on flow than infiltration.

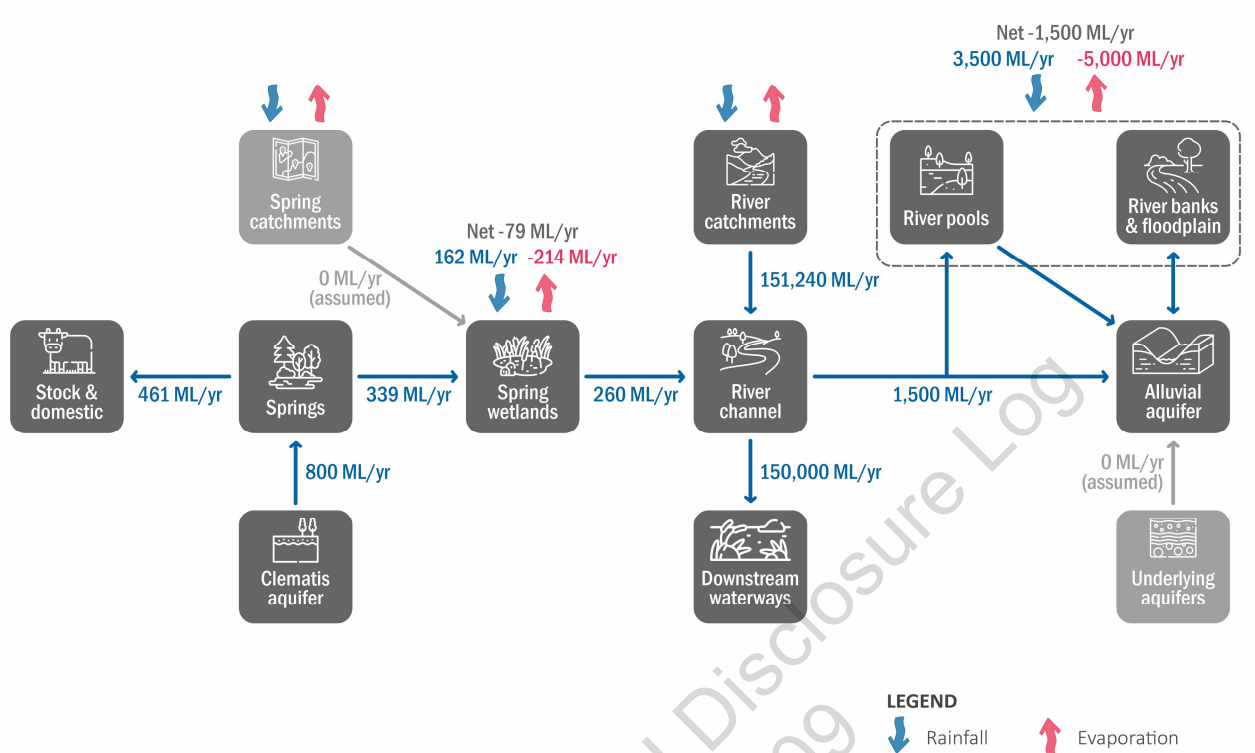
10.5 Doongmabulla Springs Complex, Dyllingo Creek and Carmichael River water balance summary

The conceptual water balance provided as Figure 10.1 is reproduced in Figure 10.34 with the addition of the flow rates presented in preceding report sections.

From Figure 10.34 it can be seen that the total Doongmabulla springs discharges to the environment are expected to be around 339 ML/yr, approximately 1 ML/d. For comparison, GHD (2012) reported a total discharge of 1.35 ML/d, without access to stream gauge or CSIRO CMRSET data. Given the uncertainty in estimating flow rates on the basis of evaporation fluxes, these independent estimates of spring flow rate are remarkably similar.

Yearly runoff from the Dyllingo Creek and Carmichael River catchments is approximately three orders of magnitude greater than spring discharges, and there is evidence that these flows recharge the alluvial aquifer which supports floodplain vegetation. ET on the floodplain is greater than rainfall, indicating that approximately 1% of the surface water flows recharge the alluvial aquifer and are used by floodplain vegetation through the dry season. From the water balance, it appears that the springs may additionally supply around 15–20% of the water

used by floodplain vegetation downstream of the springs. The use of spring water to sustain bank and floodplain vegetation is greatest in the river reaches immediately downstream of Joshua and Little Moses springs (Figure 10.12).



Notes:
 Dyllingo Creek and Carmichael River catchment runoff is based on two years of flow records only. The estimate of yearly flow will likely be revised in future reports as additional data becomes available.
 Spring catchment runoff volumes (if any) are incorporated in this water balance as part of the river catchment runoff.
 Stock and domestic volumes are uncertain and likely vary year to year.
 This figure presents single numbers to illustrate the relative magnitude of flows, but rates are not known with certainty.

Figure 10.34 Approximate Doongmabulla Springs Complex, Dyllingo Creek and Carmichael River water balance

10.6 Mellaluka Springs

10.6.1 Spring discharges

The Mellaluka spring complex (Figure 10.35) contains the Mellaluka spring group, Storys spring, and Lignum spring, each supporting a wetland (Table 10.6). Each spring is located approximately 3 km west of the Belyando River, and none spill water to downstream creeks or waterways.

Table 10.6 Mellaluka spring groups

Name	Vents	Wetland area (ha)
Mellaluka	3	3
Storys	1	<0.1
Lignum	1	0.1

Total yearly actual ET estimated using CSIRO CMRSET is 1,200 mm/yr at Mellaluka, and 530 mm/yr in nearby uncleared scrub. The 670 mm/yr ET anomaly at Mellaluka indicates a groundwater discharge rate of 20 ML/yr (0.05 ML/d, 0.6 L/s).

These data contrast with the estimates of 20 L/s (presented as 1,200 L/min) (1.7 ML/d, 630 ML/yr) reported by Fensham et al (2016). With no wetland overflow to a downstream waterway, a flow of 20 L/s does not align with the observed Mellaluka wetland size. GHD (2013d) reported that the three springs are harvested for stock and domestic purposes, but no data were provided describing harvested volumes.



Figure 10.35 Mellaluka spring group wetland (Fensham et al. 2016)

10.6.2 Spring stratigraphy

The Mellaluka spring complex is located at the interface between Colinlea Sandstone and Jo Joe group subcrops (Figure 10.36, Figure 10.39, Figure 10.40). This interface extends almost due south from the mine site for over 200 km (Figure 10.37).

200 km south of the Carmichael River, the Colinlea potentiometric surface is approximately 350 m AHD, reducing to 210 m AHD at the Carmichael River within the mine lease, ie a groundwater gradient of around 0.7 m/km. At the spring locations, the potentiometric surface reaches the ground surface, and groundwater is discharged to form springs (Figure 10.38) via local weak points through the Tertiary sediments.

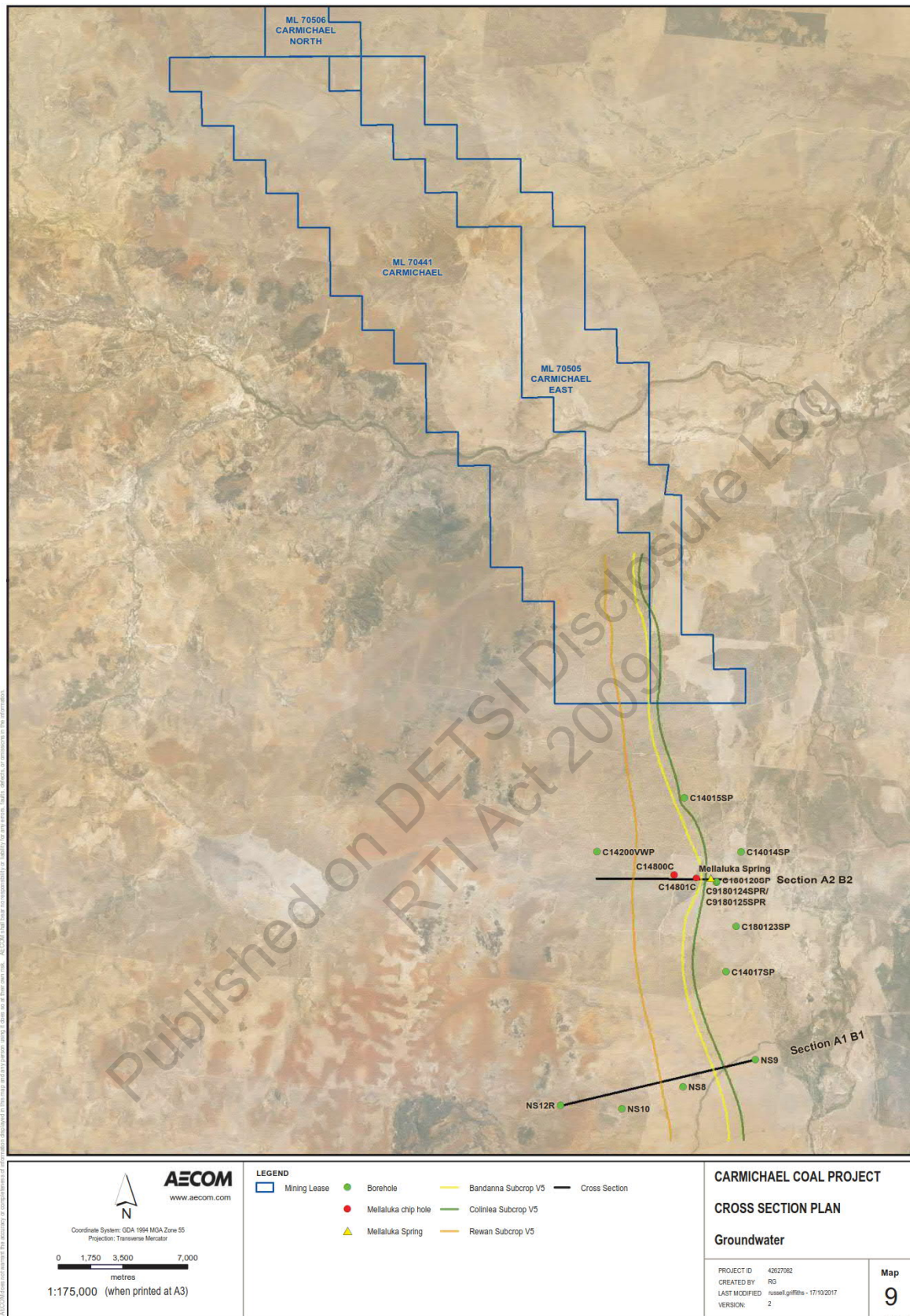


Figure 10.36 Subcrops near Mellaluka springs (AECOM 2020)

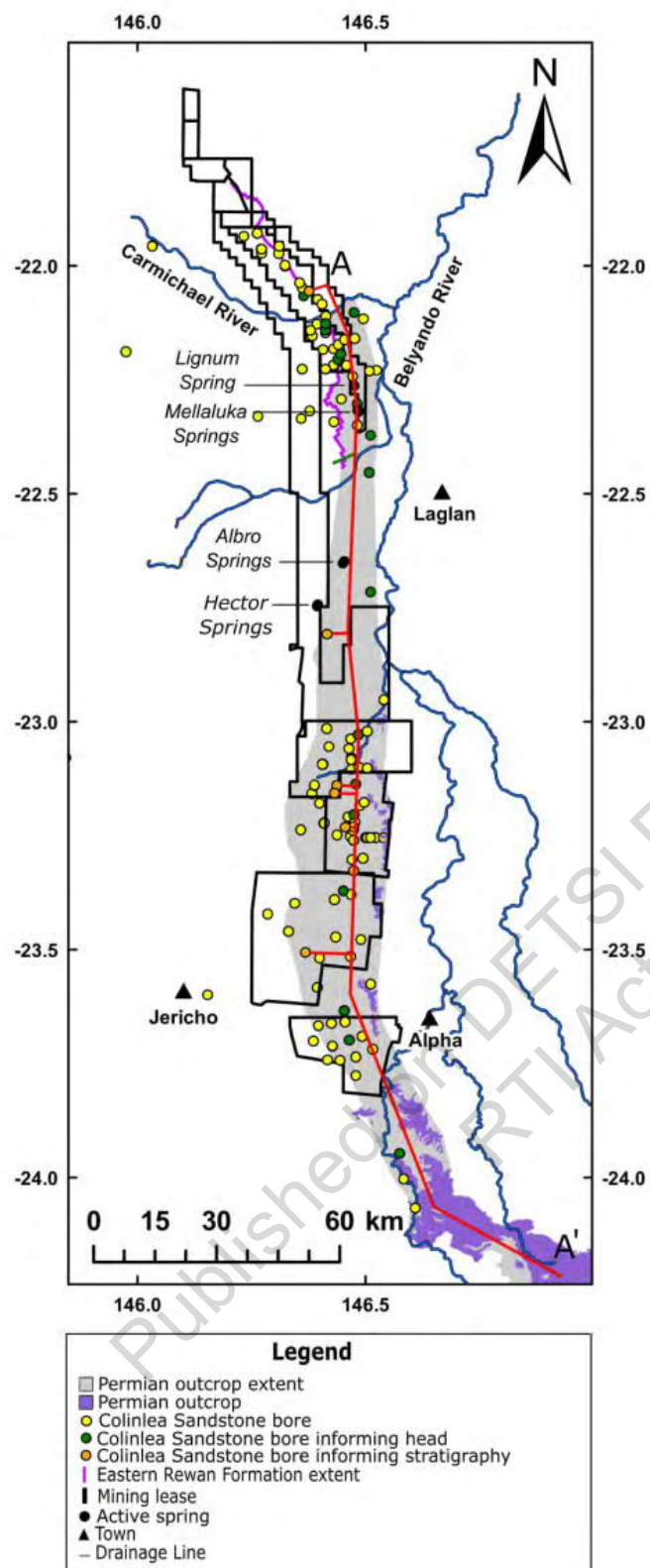
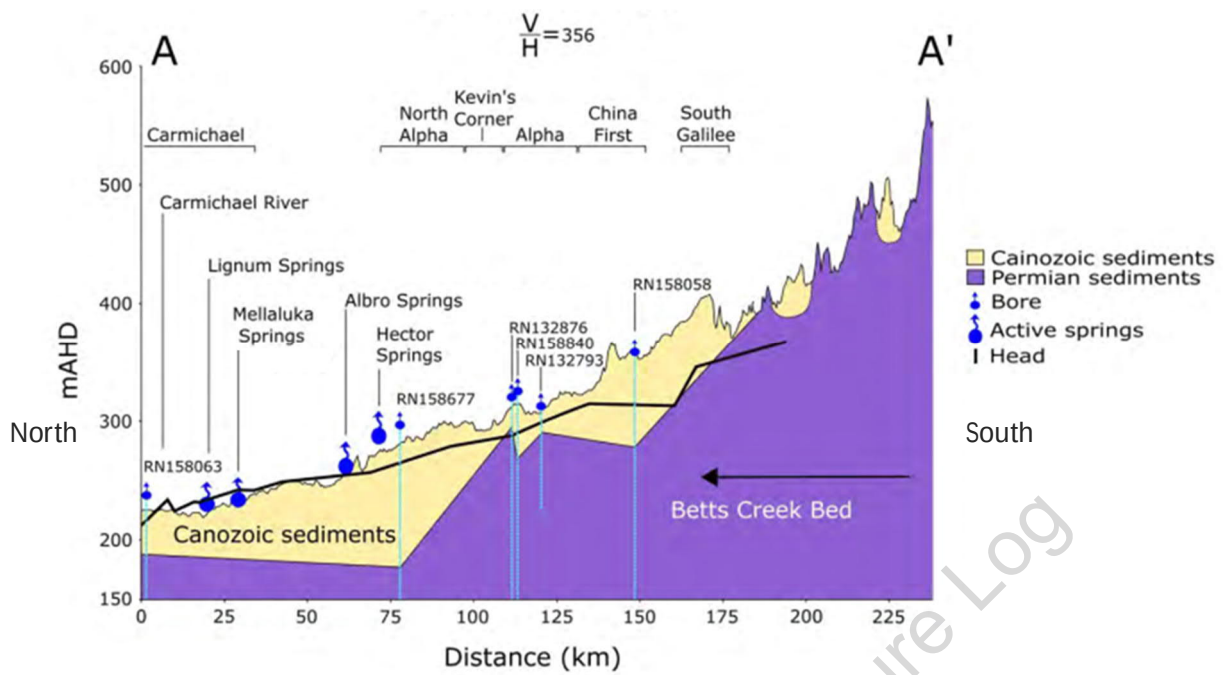
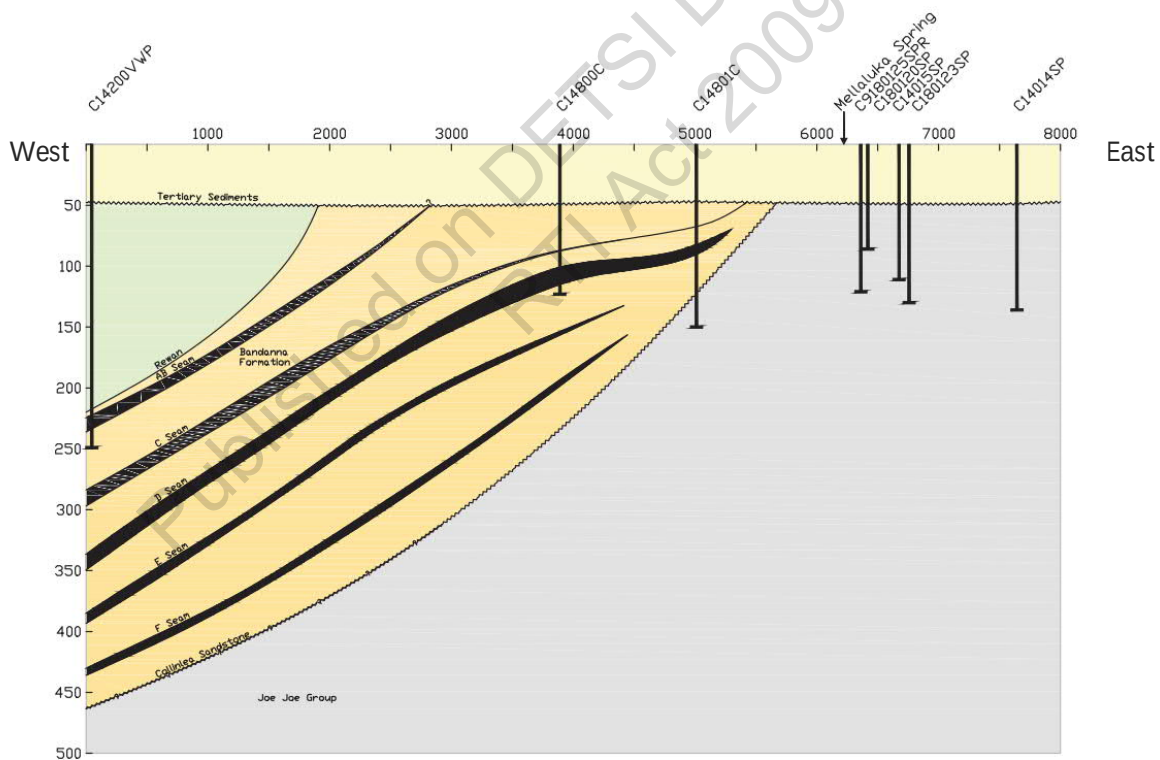


Figure 10.37 Permian outcrop / subcrop extent and associated springs (Fensham et al. 2016)



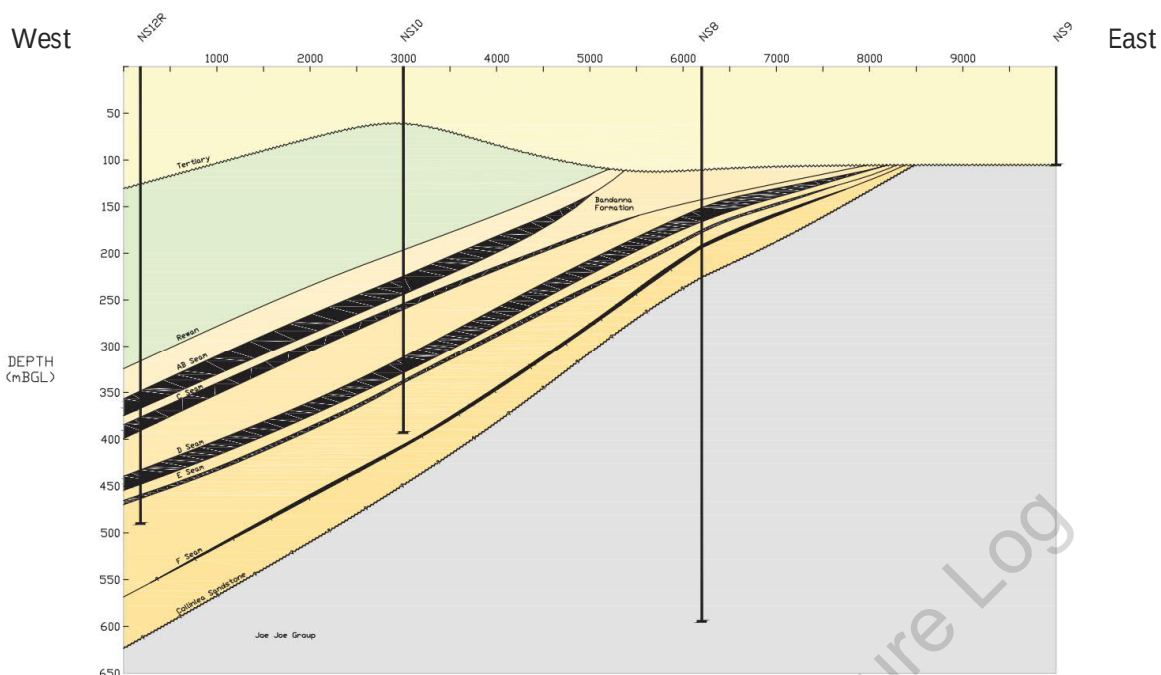
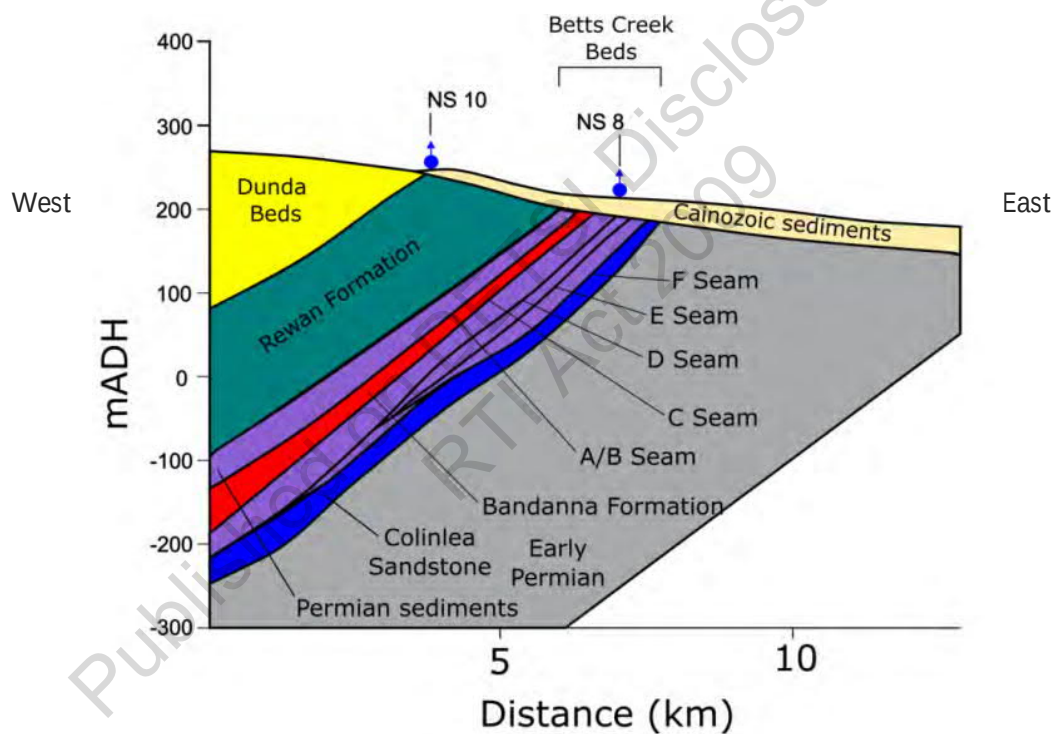
Groundwater flow direction is right to left

Figure 10.38 North-South cross section A-A' with Permian stratigraphy and potentiometric head (Fensham et al. 2016)



Groundwater flow direction is into the page

Figure 10.39 West-East cross section through Mellaluka spring (AECOM 2020)



Groundwater flow direction is into the page

Figure 10.40 West-East cross section NS12R – NS9; Top: AECOM (2020), Bottom: Fensham et al (2016)

10.6.3 Spring water source

The SEIS presented the concept that the water source for the Mellaluka spring complex was the Colinlea Sandstone, while the GMMP (AECOM 2020) presents the concept that the source is Joe Joe Group.

The Mellaluka springs are located above the Joe Joe group formation, immediately to the east of the interface between Colinlea Sandstone and Joe Joe Group.

Similar head and chemistry between bores C19004SP, C19003SP and C14016SP at the southern end of the mining lease indicate that there may be movement of water between Colinlea Sandstone and the upper Joe Joe Group formation.

The extent of linkage between the Colinlea and Joe Joe, and range of possible effects that may occur at the Mellaluka springs will be investigated through groundwater model sensitivity analysis.

10.6.4 Structural linkage

If the predominant flow direction at the springs had been from west to east, the springs could be an example of a 'Type J' spring (Figure 10.41), with spring waters 'emanating from contact between onlapping sediments and outcropping basement with mixing of the groundwater from multiple aquifer sequences' (Commonwealth of Australia 2014), with the multiple aquifer sequences being the discrete coal seams within the Colinlea Sandstone.

However, with the source of water located south of the springs and being transferred north, it appears that the springs are an example of a 'Type C' spring, with discharge at locations where the confining aquitard has been thinned by erosion (Figure 10.42).

Spring typologies will be further assessed and defined as part of the Year 2 studies related to the GAB Research Plan.

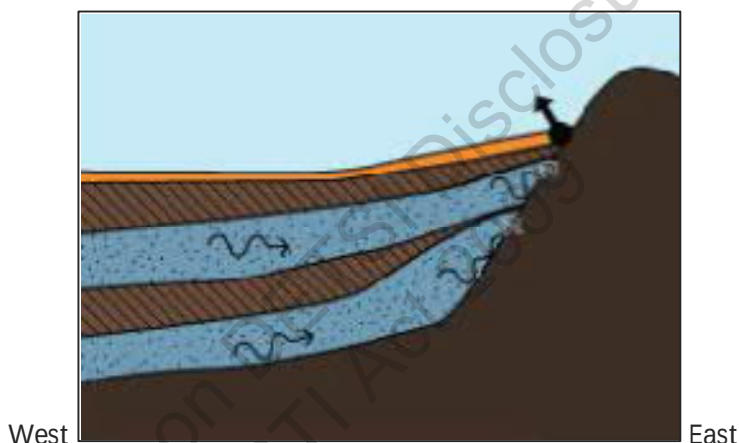


Figure 10.41 'Type J' spring (Commonwealth of Australia 2014)

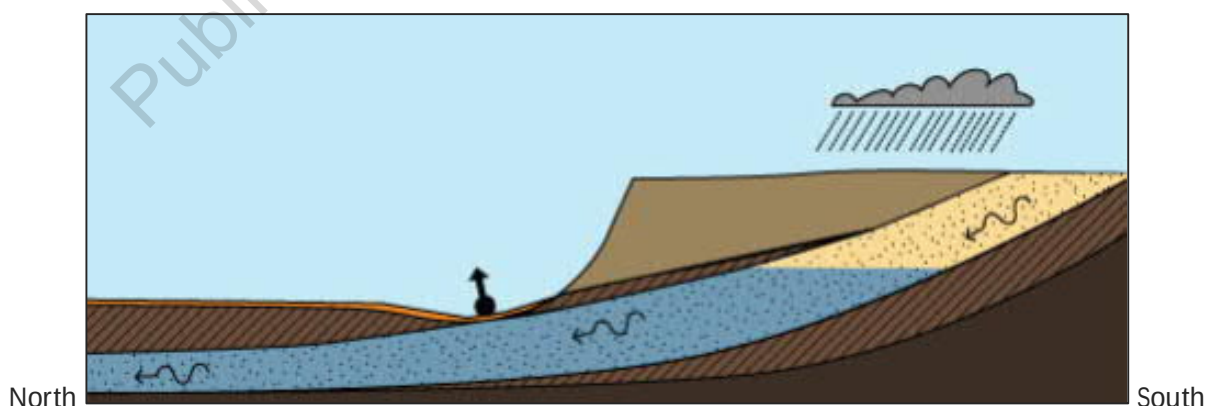


Figure 10.42 'Type C' spring (Commonwealth of Australia 2014)

10.7 Application to the groundwater flow model update

The Doongmabulla spring complex includes a number of spring groups.

The eastern springs occur as sandstone outcrop springs, occurring where Clematis Sandstone is present at the surface. Those located on the northern side of Dyllingo Creek (ie Little Moses, Dusk and Yukunna Kamoo) may utilise recharge from the ranges which lie between the spring group and the mine, with water travelling along a relatively shallow path through the Clematis before discharging.

The western mound springs appear to be sourced from artesian flows from within the Clematis Sandstone which is held under pressure by the Moolayember Formation. The current hydrogeological conceptualisation is that this water is recharged some distance to the west, potentially in the region of Lake Galilee. Groundwater travelling to these springs may follow a deeper path through the Clematis before exiting at multiple discrete vents which likely occur at Doongmabulla due to local weakness or preferential flowpaths.

Within the updated model, it is suggested that the following is considered:

1. groundwater head at all springs should be slightly above the ground surface in the model, as far as the accuracy of the representation of the lidar data within the model allows;
2. it is likely unnecessary to represent spring wetland features within the model, particularly as spills from the wetlands to the surface water system are expected to be larger than evaporation from the wetland areas;
3. discharges from the larger springs with associated wetlands could be represented in the model using a dry river boundary condition or drain boundary condition simulated at surface, consistent with the previous SEIS model, with total outflow (flow rate) calibrated using hydraulic parameters associated with confining units between the spring and the source aquifer; and
4. discharges from the smaller springs, including in particular the Mouldy Crumpet mounds, would be adequately represented using an evapotranspiration boundary condition with an appropriate extinction depth set within the Clematis Sandstone model layer (eg 0.1 m near Mouldy Crumpet representing the rooting depth of grasses).

The Doongmabulla spring groups are each located approximately 5 m above nearby surface water features. Springs have not been identified within the creek and river beds, even though these are lower in the landscape. The western springs (including Joshua spring) discharge above the local ground level via mounds at discrete locations. This means that it will be insufficient to rely only on the intersection of groundwater with the surface to remove water from the model at spring locations. Between the springs, the water table is below the ground surface within the Moolayember Formation, while at the springs the groundwater potentiometric surface is above the ground surface. The current hydrogeological conceptualisation is that pressurised water from the Clematis Sandstone finds preferential pathways to the surface at spring locations. To represent this in the model higher vertical hydraulic conductivity at discrete spring locations may be appropriate to represent local weaknesses or preferential flow paths through the thinning Moolayember aquitard.

The waterways in the model domain are ephemeral, with flow reducing to zero between rain generated flow events. Pools are present within Cattle Creek and Carmichael River between flow events. Little information is available to describe the pools along Cattle Creek, but it appears that they are sustained by surface water flows. Pools within Carmichael River are likely to be partly supplied by river flows and partly by Doongmabulla spring discharges. Alluvial groundwater bores located adjacent to the Carmichael River in the vicinity of the mine lease show that the alluvial groundwater does not support pools within that reach of the Carmichael River, and the presence of pools does not result in the groundwater level being sustained. Recharge of the alluvial groundwater system occurs following streamflow events. This river system could be represented in the groundwater model as:

- a river boundary condition which switches off for between 9 and 11 months of the year;

- when switched on, the river boundary should cover the floodplain to a width of 50–100 m at stage elevation representing the average river height for that particular wet season;
- alluvial groundwater levels may equalise with the river during flow events, but should remain below the river bed between flow events due to evapotranspiration alone, which could be represented using the evapotranspiration package with an extinction depth appropriate to the vegetation type;
- the rate of recharge may be adjusted through river bed conductance parameters to achieve calibration to alluvial bore hydrographs;
- river bed conductance may vary along the river, in part reflecting floodplain characteristics which are difficult to include in the numerical model such as the effect of infiltration from depression storage in over-bank locations in the days following significant flow; and
- near Doongmabulla, where permanent pools are thought to be maintained by spring discharges, the topography as represented in the model should have sufficient resolution that the river bed intersects the alluvial aquifer. Evapotranspiration should then remove a sufficient volume of water from the pool location.

The alluvial aquifer receives overflows from the Doongmabulla springs. To allow calibration of heads and flows within the alluvial aquifer, 0.7 ML/d should be added to the alluvial aquifer at Doongmabulla. Some modelling packages allow the use of scripting to link outflows from one point to inflows at another. If such scripting is not possible in this model, then consideration should be made for whether the volume added to the alluvial aquifer should be adjusted to match spring discharges in any scenarios in which spring discharges vary. For model stability, spring discharge volumes could be spread over a length of Dyllingo Creek, perhaps with 0.3 ML/d added downstream of Joshua spring, and 0.4 ML/d added at the intersection of Dyllingo Creek and Cattle Creek.

The Mellaluka springs occur where the Joe Joe's groundwater potentiometric surface meets the ground surface. With no overland discharges to waterways, the total discharge may be estimated from evaporation fluxes. These spring locations may be represented in the groundwater model using an evapotranspiration boundary condition if accurate topography data are used. Groundwater extracted via evapotranspiration at the Mellaluka spring group should be calibrated to be around 20 ML/yr, while at Storys and Lignum springs discharges should be calibrated to be less than 1 ML/yr. The recharge location is outside the model domain and would need to be represented at the southern boundary of the model.

11 Groundwater recharge and discharge processes

11.1 Recharge process

The following recharge processes have been refined since the previous SEIS modelling and the authorship of the current GMMP (AECOM, 2020), and is summarised below from previous sections of this report:

- The alluvium, Tertiary, Clematis Sandstone and Dunda Beds hydrograph responses have a strong correlation with climate, suggesting rainfall recharge (and recharge from flowing surface water features) is an important contributor to the dynamics of the groundwater system (Section 8).
- The alluvial aquifer receives overflows from the Doongmabulla springs. The alluvium aquifer could receive up to 0.7 ML/d sourced from the DSC.
- Findings from the hydrochemistry study indicate that the DSC is more likely to be sourced from groundwater originating in the immediately underlying artesian Triassic Clematis Sandstone aquifer (with potential input from the Triassic Moolayember Formation), than from groundwater originating from either of the older potential groundwater sources in the Permian Bandanna Formation, Colinlea Sandstone, or the Joe Joe Group.
- The artesian pressures in the Clematis, Dunda Beds and upper Rewan to the east of the DSC suggest that pressure may be backed up behind a local barrier to flow. It is not clear if this is the weathered cover above the Clematis outcrop or some sort of lineament that is obstructing flow in these units.
- Local rainfall recharge may still occur to the outcrop regions of the Clematis Sandstone, particularly areas to the south where the overlying Moolayember is absent and in areas where the thick weathered profile is absent. However recharge, on average, may be limited due to the actual evapotranspiration rates estimated in this area (Section 10), limiting excess drainage. High intensity rainfall events are likely required to effectively recharge the Clematis Sandstone along the local outcrop areas.
- Although not a refinement, the conceptual model still acknowledges that regional flow originates from the south, west and north, due to regional throughflow processes and would provide the majority of groundwater inflow to the system in around the CCP area.

11.2 Discharge process

The following discharge processes have been refined since the previous SEIS modelling and the authorship of the current GMMP (AECOM, 2020), and is summarised below from previous sections of this report:

- The region is recognised as a major discharge zone for the GAB and convergence of flow across all main HSUs implies that regional groundwater systems all discharge at the site.
- Doongmabulla Spring Complex discharge has been estimated as 2 to 2.5 ML/d, with:
 - 0.2 ML/d (78 ML/yr) evaporating in spring wetlands;
 - 0.7 ML/d (260 ML/yr) discharged to Dyllingo Creek and the Carmichael River; and
 - 1 to 1.5 ML/d (360 to 620 ML/yr) utilised for stock and domestic purposes.

- Evapotranspiration will remove groundwater from the alluvial aquifer. Between Doongmabulla and the Belyando River, approximately 1,500 ML/yr is expected to be transpired from the Dyllingo Creek and Carmichael River floodplain alluvial aquifer.
- Triassic HSUs discharge to DSC and potentially to the alluvium and the river due to thinning of Moolayember and emergence of Clematis subcrop to near surface. Artesian heads upstream of Surprise Creek at nested sites B and C and sub-artesian heads downstream of Surprise Creek at nested Sites E and F, in addition to the cessation of springs at Surprise Creek, indicate that this feature seems to have important influence on why groundwater “backs up” (is artesian) and discharges behind this part of the landscape, and then suddenly transitions to sub-artesian on the other side. Discharge from the Permian units coincides with a regional low in groundwater heads along a southwest-northeast alignment. This alignment cuts across the mine lease and does not coincide with any surface water features or vegetation changes. The synform previously described has not been linked to why groundwater is drawn down along this feature.
- As an alternative to the synform, two alternative Permian drainage mechanisms as per Section 8.3.2 have been proposed including:
 - Local faulting which may exist in the Permian units, which is capable of hydraulically connect the Bandanna and Colinlea HSUs to the Joe Joe Group further northeast. Coincidentally, this mechanism aligns spatially with the alignment of Surprise Creek.
 - An alternative conceptualisation would be a localised permeable zone within the Joe Joe Formation in the vicinity of the proposed synform

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12 Summary of HCM

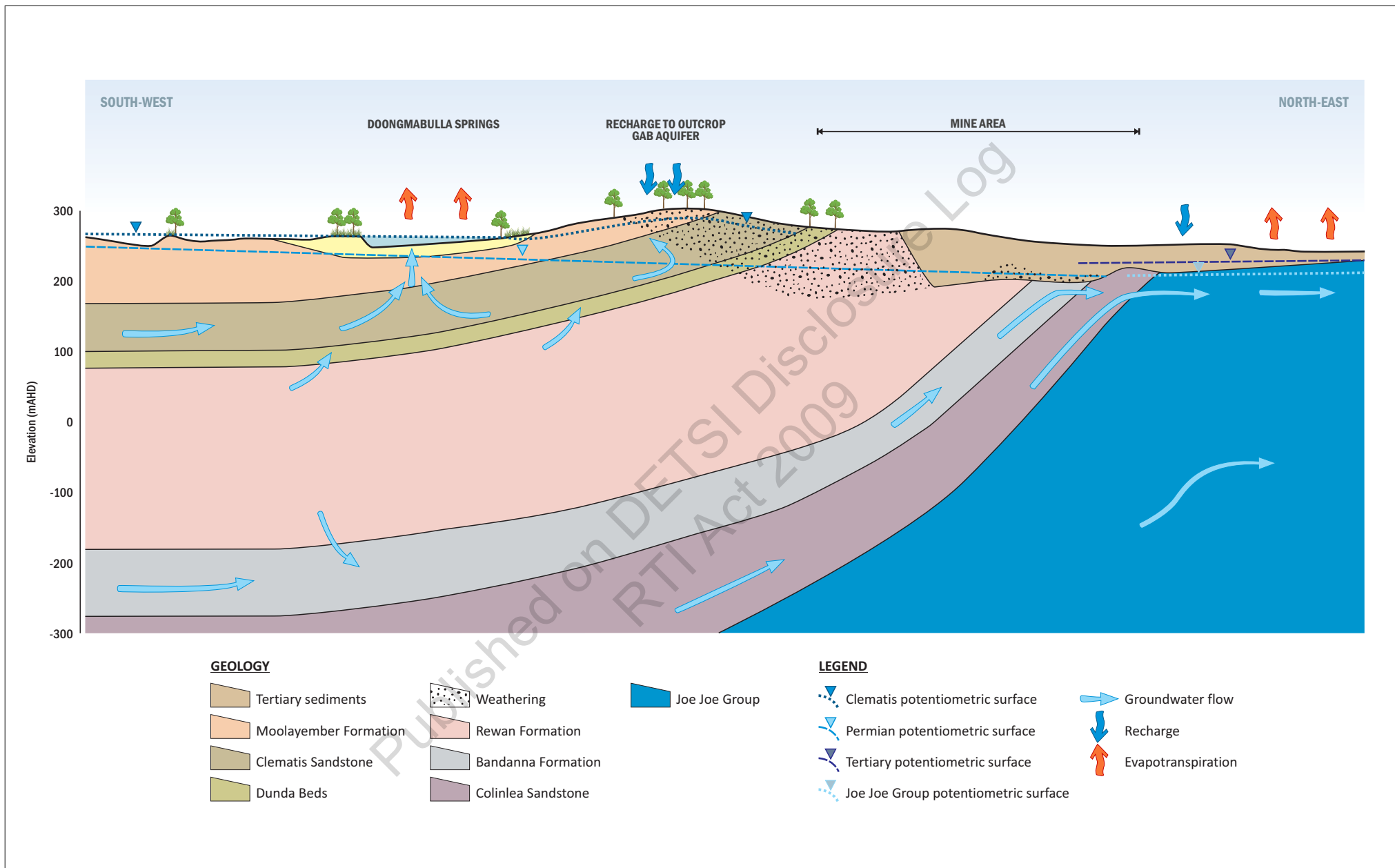
12.1 HCM – pre mining

An updated hydrogeological conceptual model (HCM) has been developed for the CCP under pre-mining conditions and is shown in Figure 12.1. The HCM summarises the following processes which have been analysed and refined during the recent studies and research packages:

- The hydrostratigraphic units along the section, which is aligned roughly through the DSC, shows steeply dipping strata towards the south-west, consist with the previous conceptualisation. The units crop / sub-crop along the scarp.
- The Clematis Sandstone is the source of water for the DSC. Springs exist via two main mechanisms whereby structural weakness within the Moolayember Formation allows groundwater to travel by diffusion upwards to the surface creating the typical mound spring typology. In other areas where the Moolayember Formation pinches out, either at the outcropped area or to the south, springs (if they exist) are created at “break of slope” areas whereby the topography intersects the water table. There is artesian pressures in the Clematis Sandstone, Dunda Beds and upper Rewan Formation up-gradient of Surprise Creek. There may be a flow barrier (weathering or lineament) present in that area that restricts outflow from the Clematis Sandstone and allows for pressure build-up. This increase in pressure drives the discharge to the DSC and also increases pressures in the underlying Dunda Beds and upper Rewan Formation.
- Evapotranspiration occurs where the depth to water table is shallow. This occurs in the area of springs and the alluvial systems associated with the Carmichael River, Dyllingo Creek and Cattle Creek. Evapotranspiration losses would also occur from the alluvial and Tertiary systems associated with the downstream river and creek systems, such as the Belyando River.
- The Moolayember Formation overlays the Clematis Sandstone over a large portion of the region, making the Clematis Sandstone a confined artesian aquifer in some areas.
- The water table would approximate the Clematis Sandstone potentiometric pressure in areas where the Moolayember Formation is absent. In other areas, localised water tables exist in the alluvials.
- On the eastern side of the groundwater divide, regional groundwater flow direction is largely from south to north towards Carmichael River, north to south (again towards river) and west to east (towards the mining lease), generally converging at different points across the project site.
- Localised recharge may be limited along the scarp, with limited potential for recharging the Clematis Sandstone. Rather, analysis of EV rates in this area indicates a rainfall deficit is more likely, and the elevated pressures in the Clematis to the west are more likely associated with a flow constriction in that unit around Surprise Creek. In areas to the south where weathering has not been mapped, the Clematis Sandstone outcrops at surface and thus direct recharge via rainfall is more likely to occur here, especially during the events where rainfall rates exceed EVT.
- A distinct weathering profile, which crosscuts Permian and Triassic sediments, exists above the “fresh” Triassic sediments. The base of weathering shows a distinct thickening towards the scarp and is likely to impede vertical recharge from rainfall, where it exists.
- Between the DSC and the mine area, vertical hydraulic gradients are directed upwards between the Rewan Formation and the Clematis Sandstone and are directed downwards from the Rewan Formation to the underlying Bandanna Formation in the area in the of the DSC.

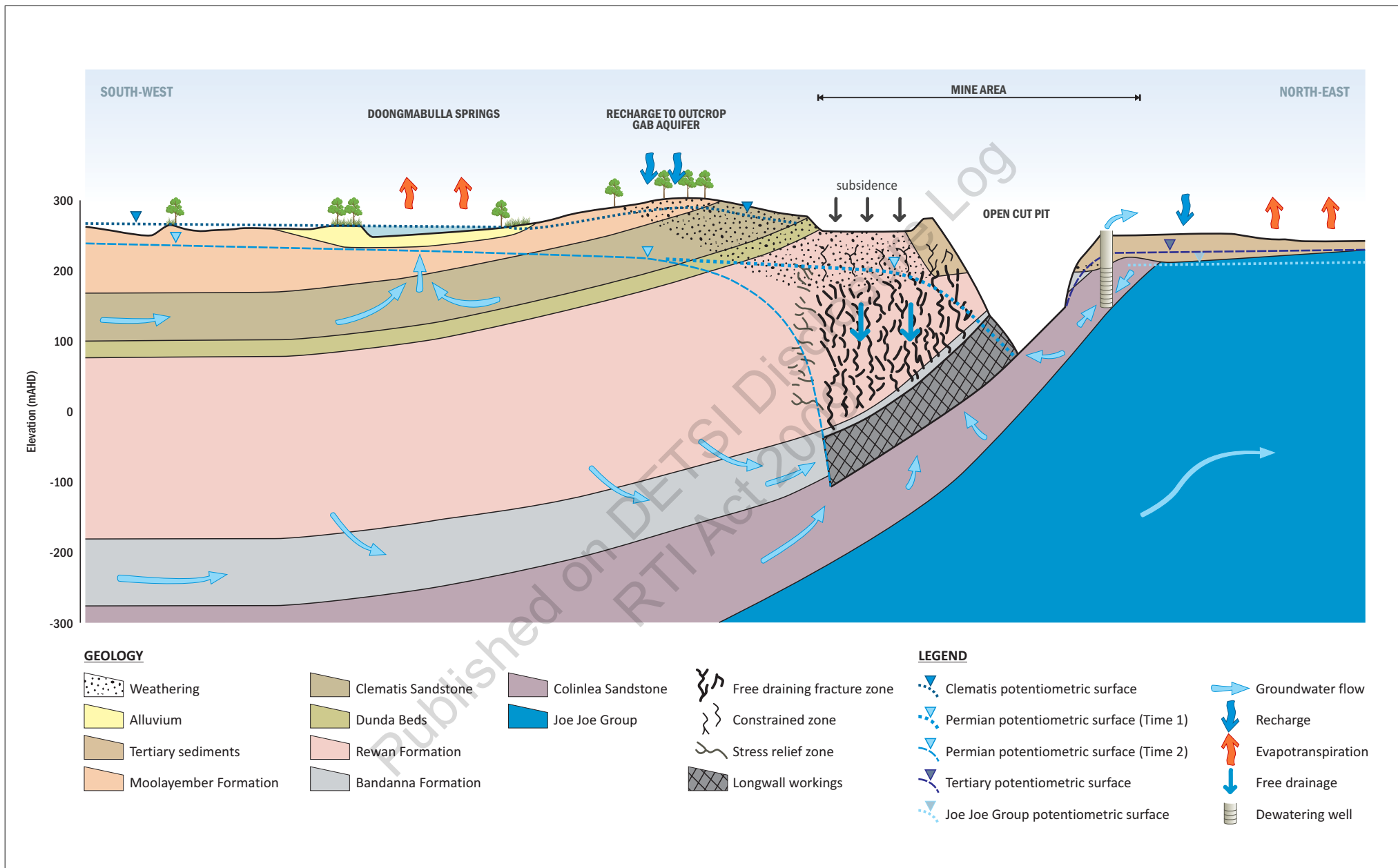
- Vertical groundwater flow directions between the Rewan Formation and the Bandanna Formation vary depending on the location, however, are predominately downward. What is important is that there is clear differentiation between a shallow, artesian, Triassic flow system and a deeper, sub-artesian, Permian flow system. Both systems are compartmentalised by the Rewan aquitard, which reinforces its aquitard integrity over geological time scales. The artesian pressures in the Triassic are conceptualised to occur due to a flow restriction near Surprise Creek and are unrelated to sub-artesian pressures in the deeper Permian HSUs.
- Groundwater flow continues to flow to the east, where it is either evaporated or continues to flow out of the Galilee Basin. Two alternative conceptualisations are presented in Section 8.3.2 to explain the convergence of flow in the Bandanna Formation, Colinlea Sandstone and Joe Joe Group within a broad linear SW-NE alignment between Carmichael River, Surprise Creek, and Eight Mile Creek. This regional low in groundwater levels was previously attributed to the presence of a synform in the GMMP. This updated conceptualisation, however, poses two alternative mechanisms that may account for the convergence of flow in the Permian strata: 1) a local fault or lineament that cuts across the Bandanna, Colinlea and Joe Joe group formations mainly within the lease area; or 2) a locally permeable Joe Joe Group that acts as an underdrain and lowers pressures in this area.

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12.2 HCM - mining

- An updated HCM has been developed for the CCP under mining operation conditions and is shown in Figure 12.2. The HCM summarises the following processes which have been analysed and refined during the recent studies and research packages:
- Open cut mining occurs initially, which includes installation of perimeter dewatering bores, and subsequent removal of overburden and the target coal measures.
- Perimeter production bores will aim to intercept groundwater, and lower the potentiometric pressures, to facilitate dry mining. Residual groundwater which seeps into the open cut pits will either be intercepted by in-pit sumps or will be evaporated.
- Drawdown will mainly be associated with the targeted Permian coal measures and the host materials, including the Bandanna Formation and the Colinslea Sandstone. Drawdown will propagate radially away from the open cut pits as depicted by the “Time 1” potentiometric surface in Figure 12.2.
- Longwall mine panels will develop to the west of the open cut pits, which will target the deeper coal seams. Longwall mining will cause fracturing to occur above the longwall panels, potentially to surface causing up to 4.9 m of land subsidence. A free draining zone may exist for up to 230 m above the longwall panels, where groundwater can seep directly into the longwall panels, through the goaf zone and originating from the overlying Rewan Formation.
- A stress relief zone is likely to occur adjacent to the longwall panels, whereby increased hydraulic conductivities are expected in the Triassic sequence at a distance of up to 200m from the longwall panel edge.
- Additional mine water ingress into the longwall workings will cause drawdown to increase within the Permian units, as depicted by the “Time 2” potentiometric surface in Figure 12.2.
- Increased flow through the Permian units from the west is expected, with some small amount of flow to occur from the lower parts of Rewan Formation, in close proximity to the underground workings.
- No large scale depressurization is expected within the Rewan Formation and the shallower Triassic and Tertiary sediments, limiting the risk of potential impact on the DSC.
- The mine is likely to reach equilibrium over several decades post mining, with the system acting as a long term sink, meaning flow directions will be directed towards the final voids and underground workings, limiting the possibility of any groundwater contaminants migrating off site post-closure.



Mining hydrogeological conceptual model

Carmichael Coal Mine: RP1.6 Hydrogeological conceptualisation review and updated groundwater modelling

Bravus Mining & Resources

12.3 Doongmabulla surface water, groundwater and spring conceptual model

An updated conceptual model has been developed for surface water/groundwater/spring interactions west of the CCP (Figure 12.3).

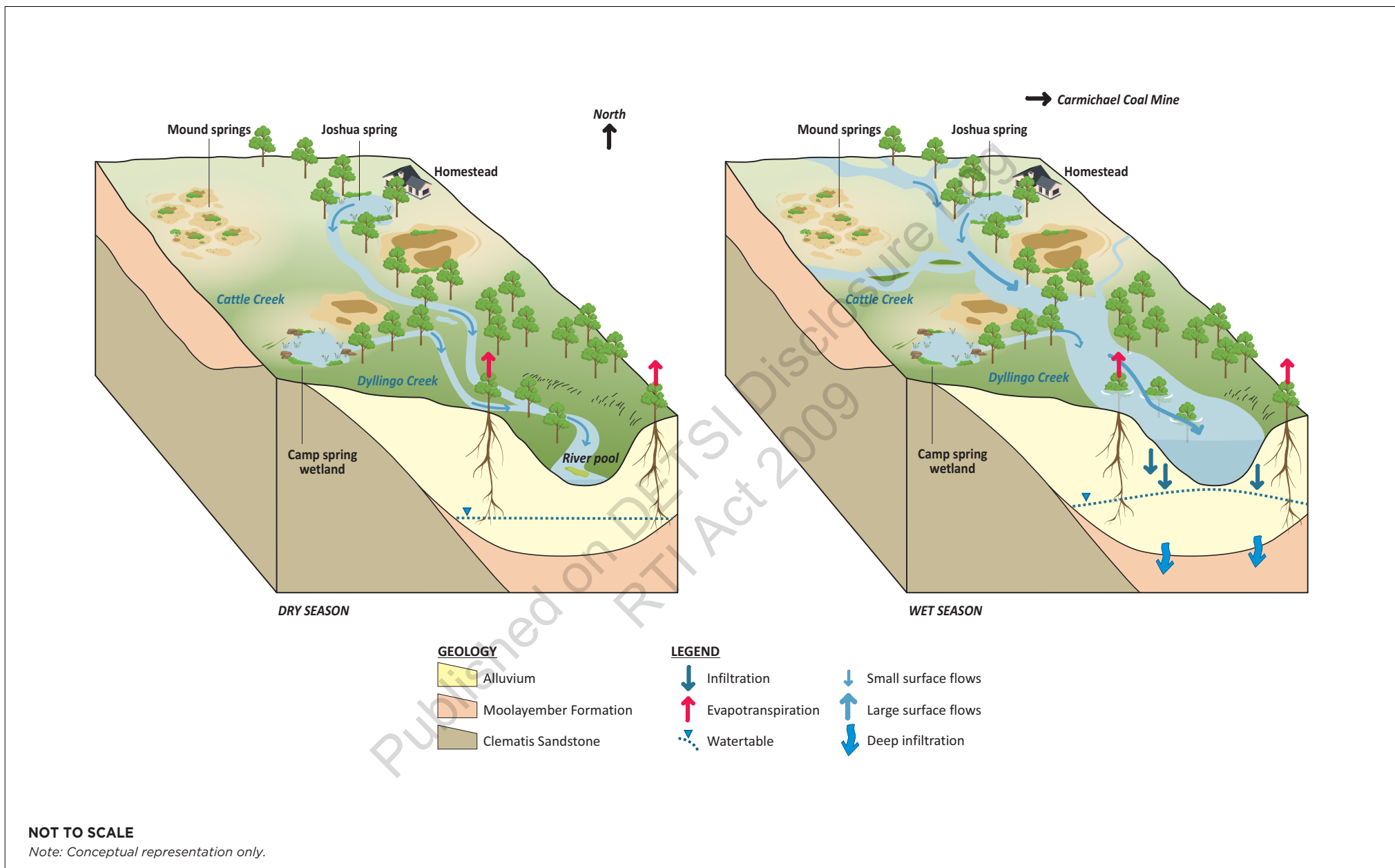
The springs discharge water from the Clematis aquifer at a relatively constant rate year round, dependent on groundwater pressures. A portion of the Joshua spring water is utilised at the Doongmabulla homestead, a portion evaporates at spring wetlands, and a portion flows to Dyllingo Creek and Carmichael River where it sustains river pools. Near the springs, the pools are permanent, but downstream in the Carmichael River near the mine site the pools become ephemeral, with the downstream extent growing and shrinking due to seasonal effects.

The alluvial aquifer tends to have groundwater heads that are lower than the river stage, indicating that the vertical permeability between the river bed and the aquifer is low.

During the dry season, Dyllingo Creek and Carmichael River rarely flow due to rainfall. Other than locations with pools sustained by spring discharges, the waterways become dry. Bank and floodplain vegetation utilises water from the river pools, and from the alluvial aquifer. The alluvial aquifer water levels fall during this time.

During the wet season, rainfall can result in streamflow events with water depths of up to 10 m, spreading over the river floodplain. During these events, water infiltrates through the floodplain and recharges the alluvial aquifer, causing alluvial groundwater levels to rise.

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Surface water/groundwater interaction conceptual model

Carmichael Coal Mine: RP1.6 Hydrogeological conceptualisation review and updated groundwater modelling

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Figure 12.3

13 Approach to addressing past reviews

Following submission of the initial and supplementary EIS, the conceptual hydrogeological model and numerical groundwater flow model have been reviewed by a range of scientists. A summary of review elements from various agencies and the independent reviewer (Hydrogeologic) has been compiled, with the intent of adopting and/or addressing recommended changes where appropriate. The reports addressed in this section are summarised in Table 13.1, with detail of individual comments and recommendations presented in Table 13.2.

A number of reports included recommendations to carry out further studies to support the hydrogeological conceptualisation, in order to better understand flow processes and potential environmental risks posed by the project. Additional studies have been undertaken following submission of the SEIS, as shown in Table 3.1. The updated hydrogeological conceptual model presented in this report is informed by these further studies, with existing and new data summarised in Sections 2 and 3. Further analysis contributing to the conceptual model is presented in later sections. The additional studies and updated conceptual hydrogeological model are considered sufficient to largely resolve most uncertainties that were raised in the reviews, reports and commentaries, with specific points and responses presented in Table 13.2.

Following development of the updated hydrogeological conceptual model, an updated numerical groundwater flow model will be built. An objective of the modelling is to incorporate updates to the conceptual model, alongside incorporating model design elements to overcome identified limitations of the model presented in the SEIS. Recommendations for future groundwater flow modelling are presented in Table 13.2, along with responses regarding proposed model design elements to address these. Table 13.2 will inform the design, calibration and predictive modelling of the updated numerical groundwater flow model.

Table 13.1 Reports providing comments and recommendations

Author(s)	Year	Title	Description
URS	2013	Adani Carmichael coal project numerical groundwater model peer review	Review of numerical groundwater flow model submitted as part of SEIS
GHD	2013	Carmichael coal project groundwater model peer review final comments	Response to recommendations from URS (2013)
IESC	2014	Advice to decision maker on coal mining project	Expert review of SEIS
Hydrogeologic	2014	Carmichael coal project groundwater flow model independent review	Review of numerical groundwater flow model submitted as part of SEIS
GHD	2015	Carmichael coal project response to federal approval conditions – groundwater flow model	Details conceptual and numerical flow model updates and conditional approval model re-runs
CSIRO	2019	Carmichael coal mine – Advice on groundwater management and monitoring and groundwater dependent ecosystem management plans to the Department of the Environment and Energy	Expert review of draft research and management plans submitted to the Department of the Environment and Energy by Adani (now Bravus)

Table 13.2 Approach to address past project criticism

Author/reference	Summary of comments	Data/research/approach
URS 2013b	<p>Field data could have been better integrated into conceptual model, to determine a set of preferred values and ranges for hydraulic conductivity and storage.</p> <p>No storage calibration from steady state model – literature values used.</p> <p>Water balance with high recharge loss.</p> <p>Heterogeneous hydraulic conductivity across layers.</p> <p>Issues raised include: Cumulative percentage discrepancy, stream leakage and baseflow, model parameter variation due to longwall mining, and post closure water balance.</p> <p>Geology – the cross section indicates uniformly dipping units to the west and noted that groundwater flow patterns across the site are contrary to the dip of the units.</p> <p>Are higher potentiometric pressures to the north and south considered for the flow in the report, are enhanced recharge, or structures considered?</p> <p>Suggested that hydraulic connection between the Permian target coal and the GAB be added, querying the potential for faults that could connect the Clematis Sandstone to the Permian unit thus impacting on the GAB.</p> <p>The recharge rates to the Galilee Basin confined Permian units are not well detailed and are incomplete, additional details are required for the confined aquifers and what rates were included across the model domain. Surficial geology has recharge rates of 0 to 44 mm/yr, while modelling used rates of 0.1 to 5mm/yr.</p> <p>It is considered that additional discussion regarding flow patterns, on and adjacent to the mine lease, is required as these flows are contrary to the dip of the geology. Consideration of different flow directions in the Galilee Basin units and GAB units, groundwater divide and groundwater low points north of the Carmichael River.</p> <p>Groundwater flow in the Clematis Sandstone needs to be included in the conceptual model, to indicate flow pattern differences in the GAB units and Galilee Basin units.</p> <p>The Rewan Group as a unit is important for model predictions on the GAB, additional discussion on the sensitivity results should be provided.</p> <p>No source of data or assumptions on the geology outside of the mine lease.</p> <p>Model convergence criteria might be too high at 1×10^{-2} m, typically 1×10^{-3} m is used.</p> <p>Elevated water balance errors in some stress periods of the predictive model represents a genuine shortcoming of the current model.</p> <p>Does hydraulic conductivity vary with depth?</p>	<p>Hydrogeological conceptualisation has been updated to address the key issues raised by this document, including:</p> <ul style="list-style-type: none"> • Drilling and installing monitoring sites to the west of the lease area to provide geological control and to assess Triassic and Permian pressures in the vicinity of the DSC to establish source aquifer. • New geological mapping in the area to the west of the mine lease near the DSC. • New field and laboratory measurements of K and S for the Rewan, Dunda and Clematis HSUs. Detailed analysis of Kx and Kz with depth across the Rewan aquitard. Integrated K datasets have established field-based statistical ranges for each HSU. • The GAB Springs research program and Rewan connectivity research program have produced updated potentiometrics and vertical flow gradients using contemporary data. • A comprehensive hydrogeochemistry and isotopes analysis program has confirmed a Triassic source aquifer for the DSC. • A comprehensive surface water-groundwater investigation has been undertaken to inform the updated HCM and groundwater model. • This revised HCM has undertaken statistical trend analysis on over 100 monitoring locations to identify any potential dewatering impacts in each main HSU. This trend analysis provides direct feedback on how each HSU is responding to over two years of dewatering in the Permian Betts Creek Beds. • Updated nested hydrograph analysis has provided insights on the vertical hydraulic gradients across the site and helped to better understand the mechanisms for DSC discharge, the extent of artesian heads in the Clematis, Dunda Beds and upper Rewan formations, and the impacts of landholder pumping and dewatering on the Permian HSUs. • The Rewan connectivity research program has included review of field data, lithofacies interpretation, interpretation of

Table 13.2 Approach to address past project criticism

Author/reference	Summary of comments	Data/research/approach
	<p>The calibration does not show if the vertical hydraulic gradients were preserved at locations that had multi nested monitoring points.</p> <p>No transient calibration was performed, storage parameters were selected from literature values, effects from river stage changes show a change of several meters, can the steady state model be representative?</p> <p>How were SW/GW interactions assessed in the steady state model for the dry season outside of the mine lease?</p> <p>Please explain how the recharge rate was determined and provide discussion on the effective recharge.</p> <p>Please explain how a robust predictive model can be generated from the current steady state model calibrated to average head data only.</p> <p>Hydraulic conductivity distribution was used for Layers 9 to 12, rather than a uniform value used, resulting in a bull's eye value in one area. Show the distribution and comment on values.</p> <p>A low value of residual saturation was used for the unsaturated zones at 5×10^{-3}.</p> <p>Large mass balance errors were identified at some stress periods, as such the predictive model outcomes are questioned.</p> <p>Horizontal and vertical hydraulic conductivities and storage parameters were not increased for the mined coal seam (the goaf) after mining. Only the vertical hydraulic conductivity was increased for the layers above goaf. The impact of dewatering could be underestimated. Changes to the coal seam parameters is recommended.</p> <p>Water balance needs further discussion, for the post-closure modelling and for the discharge to other water courses, in addition to the error difference. Predicted baseflow impacts require further discussion as rates are different in tables and figures.</p> <p>A mine plan with schedule was not provided. For a 5 year mine plan, how was it applied, equally in yearly increments?</p> <p>No uncertainty analysis was detailed or discussed in the report, an uncertainty analysis could provide additional confidence in model predictions with regards to: storage, hydraulic conductivity and storage after longwall mining, groundwater ingress, and climate change.</p> <p>Recommendations:</p> <ul style="list-style-type: none"> • Clear description of the conceptual model. • Provide a summary of model approaches, objectives and model level. • Validate the location and type of boundaries. • Calibrate the model with transient head targets, flow data, that preserve the vertical head gradients. 	<p>groundwater resources, detailed analysis of hydraulic properties, reprocessing of seismic data, mapping and modelling of fault styles, fault juxtaposition analysis, shale gouge & fault membrane seal analysis, assessment of fault leakage potential, assessment of longwall subsidence on hydraulic properties. These studies have indicated that the Rewan aquitard is a competent aquitard at the site with no potential for natural flow pathways to hydraulically connect the Triassic and Permian formations. The study did identify the key risk for hydraulic connection is related to mine-induced longwall subsidence.</p> <p>Planned updates to groundwater flow model (GWFM):</p> <ul style="list-style-type: none"> • Sensible modelled fluxes and low water balance errors cumulatively and for discrete time intervals • Transient calibration, including flux targets for SW-GW interactions as per Section 10 • Highly parameterised approach to calibration, with parameter bounds guided by (but not restricted to) field data • Hydraulic conductivity reduction with depth in accordance with Section 6.1, nominally for Rewan Formation but also for other HSUs if supported by observed data • Presentation of modelled vertical hydraulic gradients • Detailed calibration sensitivity analysis • Time-varying material properties to include mined coal seam, not just layers above goaf • Type 3 predictive uncertainty analysis

Table 13.2 Approach to address past project criticism

Author/reference	Summary of comments	Data/research/approach
	<ul style="list-style-type: none"> • A review of the model mass balance as it includes negative recharge. • Improve the cumulative percentage error to be under 1%. • Discuss the flow component of the model. • Conduct a sensitivity analysis for the transient predictive model. 	
GHD 2013	This report does not contain any model criticisms or recommendations.	N/A
IESC 2013	<p>Important data gaps exist in the groundwater flow conceptualisation, especially in the deeper groundwater systems, most notably hydraulic head information. The interpretation is not considered to be consistent with expected groundwater flow for deeper formations, given regional geology and accepted regional groundwater flow directions within the GAB. insufficient data provided in the draft SEIS to substantiate the proponent's groundwater flow conceptualisation.</p> <p>The current groundwater model assumes the Rewan Formation will respond uniformly as an aquitard. More data are needed to predict the effect of potential subsidence induced fracturing in the Rewan Formation on leakage rates from the GAB to the coal seam. Information on the degree of groundwater connectivity between the coal seams and the GAB is essential to understand the potential impacts of this project.</p> <p>The source aquifer for the Mellaluka Springs Complex has not been determined, and as such it is not possible to accurately predict impacts from mining on these Springs. For both the Mellaluka and Doongmabulla Springs Complexes there is insufficient information on ecology and water chemistry. The Committee has little confidence in the capacity of the groundwater flow conceptualisation and groundwater flow model to predict the impact on these Spring Complexes.</p> <p>The proponent undertook a limited cumulative impact assessment including four other proposed projects in the region. There are, however, additional relevant proposed projects which should be included.</p> <p>The conceptual model would benefit from an assessment of regional faults.</p> <p>The Committee is not confident that the proponent's groundwater model will be able to accurately predict responses to perturbation of the groundwater system arising from the proposed mine.</p> <p>The Committee has significant concerns in relation to the use of no flow boundaries at most of the edges of the model domain and the truncation of the Clematis Sandstone (and other geological formations) on the western side in the numerical model. The Committee challenges the model boundaries, and the use of no flow boundaries without justification, as it might have profound effects on the model's predictions.</p> <p>The assessment of the height of the subsidence fracture zone above longwall mining was not based on local site data nor with due consideration of multi-seam mining. The connectivity of the fracture network and</p>	<p>Hydrogeological conceptualisation has been updated to address the key issues raised by IESC, including:</p> <ul style="list-style-type: none"> • Drilling and installing monitoring sites to the west of the lease area to provide geological control and to assess Triassic and Permian pressures in the vicinity of the DSC to understand the deeper flow systems, the pressure gradients across the Rewan and to establish the source aquifer for the DSC. It is commonly accepted that flow moves up-dip in the Surat Basin on the northern side of the range due to discharge at the Dawson River and springs. Similarly, at the project site east of the groundwater divide, there is up-dip flow towards discharge locations at the project area. This is discussed in detail in Section 7. • Subsidence-induced fracturing was a major component of the Rewan connectivity research program. Findings from that research have informed the revised HCM in this report. • The GAB Springs Research program is leading to more defined understanding of how the DSC functions. New monitoring bores and VWP's and hydrochemical and isotopes surveys have identified that the Clematis Sandstone is the source aquifer for the springs. Nested sites at the springs and downstream of the springs have shown that the Clematis Sandstone is strongly artesian in this area and is likely restricted to the east, which is driving artesian pressure build up behind that restricted flow outlet. This is leading to pressures building up over geological time and driving discharge to those springs. • The conceptual model has drawn on the Rewan research into fault behaviour at site and how this may influence Rewan

Table 13.2 Approach to address past project criticism

Author/reference	Summary of comments	Data/research/approach
	<p>the relative increase in hydraulic conductivity of strata within this zone needs verification. Subsidence fracture zone height and hydraulic connectivity could have implications for the predictive results.</p> <p>The proponent's field data needs to be further integrated into the groundwater model to establish an appropriate set of values and ranges for model layers' hydraulic parameters for the Rewan Formation. The implications of an increase in the permeability of the Rewan Formation and variations to the local geology and the effects on regional groundwater processes need to be further explored.</p> <p>There remain important data gaps and modelling inaccuracies which bring into question the hydraulic conductivity values employed by the model.</p> <p>However due to uncertainty around model parameters for hydraulic conductivity and the characterisation of the Rewan Formation, conclusions on impacts to the GAB and springs need to be reconsidered.</p> <p>Revision of the groundwater model and more in-depth spring surveys to enable a more rigorous assessment of potential impacts on the Doongmabulla and Mellaluka Springs Complexes.</p> <p>The development of an appropriately scaled regional groundwater model and water balance, commensurate to the size of the development, to reduce uncertainty in regard to cumulative impacts.</p> <p>The conceptual groundwater model is not adequate nor underpinned by sufficient representative data. There is insufficient hydraulic head information, particularly in the deeper geological units.</p> <p>Due to inappropriate boundary conditions the Committee has no confidence in the results of the groundwater model. The Committee considers that the revised groundwater model is not adequate to assess the potential impacts.</p> <p>Groundwater flow in deeper aquifers would be anticipated to conform to the generally recognised regional westerly flow within the GAB from the eastern recharge zone towards the centre of the basin. The independent peer review of the groundwater model undertaken by URS also notes that the model flow direction is at odds, and is not consistent, with the regional flow direction and geology.</p> <p>The URS review of a draft version of the groundwater model recommends that the proponents validate the location and type of boundaries in the model.</p> <p>The model truncates geology on the western side of the numerical model, the no flow boundary condition employed forces the numerical model to indicate groundwater flow towards the Carmichael River based on limited available bore data.</p> <p>No-flow boundaries (particularly for the Triassic and Permian hydrogeological units) in the model need to be justified and appear to be based on the surface water catchments. As a consequence, the Committee has no confidence in the predicted groundwater flows in the Permian and Triassic Formations.</p>	<p>connectivity. This includes dedicated research on reprocessing of seismic data, mapping and modelling of fault styles, fault juxtaposition analysis, shale gouge & fault membrane seal analysis, and assessment of fault leakage potential.</p> <ul style="list-style-type: none"> • New field and laboratory measurements of K and S for the Rewan, Dunda and Clematis HSUs. Detailed analysis of Kx and Kz with depth across the Rewan aquitard. Integrated K datasets have established field-based statistical ranges for each HSU. <p>Planned updates to GWFM:</p> <ul style="list-style-type: none"> • Calibrated parameters to be more closely tied to field data (ie Section 6) • Additional justification on regional boundary conditions, potential sensitivity analysis on no flow boundaries • Detailed uncertainty analysis incorporating potential connectivity between the GAB and the coal seams based on RP5

Table 13.2 Approach to address past project criticism

Author/reference	Summary of comments	Data/research/approach
	<p>There is uncertainty around the capacity of the Rewan Formation to act as an aquitard to limit vertical leakage between adjacent formations. Mean values of hydraulic conductivity are recommended to be used. The formation does not take into consideration any potential of faulting.</p> <p>The Committee is not confident that the proponent's groundwater model, based on the current conceptualisation will be able to accurately predict responses to perturbation of the groundwater system arising from the proposed mine.</p>	
Hydrogeologic 2014	<p>Transient calibration has not been undertaken, which is a model shortcoming that has been addressed via comprehensive sensitivity and uncertainty analysis.</p> <p>To improve the match of three bores in the southern Clematis outcrop would require increased recharge in this key area, and/or aquifer parameter changes, plus contemporaneous groundwater monitoring data for model validation, which is recommended for future investigation.</p> <p>The model stress period arrangement indicates annual increments for the first five years, which is acceptable; however, subsequent stress periods are 5-yearly to 2049, then 10-yearly to 2059, which is possibly a little coarse but not unreasonable; future modelling programs should review and/or refine this arrangement by testing model sensitivity to refined stress periods (no more than 1-2 years).</p> <p>Future model work programs are recommended to investigate refinements of the recharge to improve the match to southern Clematis water levels and to investigate the flow system in the Lake Galilee area. To improve the model matches at these three key Clematis bores would require increased boundary inflows from the south and/or increased rates of modelled Clematis recharge, and/or aquifer parameter changes.</p> <p>Ongoing investigations and monitoring in the area of groundwater flow from the south to north, and a significant flow to the west (and GAB) area are required to provide data for future validation of the model in terms of layer elevations and properties for aquifers/aquitards (including geochemistry and isotopes), groundwater levels and quality and surface-groundwater interactions (notably river and spring flows/levels and geochemistry).</p> <p>It is recommended that model sensitivity be explored for inactive cells immediately east of the Clematis outcrop, and that this boundary condition be tested in the next model update by applying the "dummy layer/parameter" treatment to the currently inactive cells in layers 4 and above in this central area.</p> <p>It is suggested that layer 12 of the model be split into 2 separate layers, this model refinement would be required in the future to help investigate aquifer connectivity with Mellaluka Springs, where significant drawdowns have been predicted, in conjunction with the data that will be acquired from the three monitoring boreholes recently drilled in this area.</p> <p>An involuntary model error was discovered where hydraulic parameters were different on Layer 4 in the eastern half of the model domain. Model design should aim for the implementation of parameters that</p>	<p>Hydrogeological conceptualisation has been updated to address the key issues raised by Hydrogeologic, including:</p> <ul style="list-style-type: none"> Increased monitoring sites in the Clematis Sandstone west of the lease area to better understand flow dynamics in this GAB aquifer. A thorough review of long-term groundwater levels and vertical gradients has provided insights that suggest the Clematis Sandstone is artesian to the west of Surprise Creek and that a flow restriction occurs near Surprise Creek that reduced the eastern flow component of the aquifer sufficiently to raise pressures in this formation to the west. These artesian pressures then drive discharge to the springs. Drilling and installing monitoring sites to the west of the lease area to provide geological control and to assess Triassic and Permian pressures in the vicinity of the DSC to understand the deeper flow systems, the pressure gradients across the Rewan and to establish the source aquifer for the DSC. The conceptual model has drawn on the Rewan research into fault behaviour at site and how this may influence Rewan connectivity. This includes dedicated research on reprocessing of seismic data, mapping and modelling of fault styles, fault juxtaposition analysis, shale gouge & fault membrane seal analysis, and assessment of fault leakage potential. New field and laboratory measurements of K and S for the Rewan, Dunda and Clematis HSUs. Detailed analysis of Kx and Kz with depth across the Rewan aquitard. Integrated K datasets have established field-based statistical ranges for each HSU. Updated nested hydrograph analysis has provided insights on the vertical hydraulic gradients across the site and helped to better

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	<p>warrants refinement in the future to either ensure consistent parameter values across all layers that represent specific units (or to objectively justify the parameter values applied).</p> <p>Further to the drilling on the Rewan Group, further tests be undertaken (chemical and isotope testing of pore water samples from the preserved core) to provide formation-scale aquitard parameters for input to the model.</p> <p>Future investigations should consider applying appropriate episodic recharge volumes to short periods, perhaps using data from the very wet periods of 2010-11 and 2011-12 (rather than annual averages) to validate the model.</p> <p>Further investigation of vertical head gradients is recommended during future work programs, especially once additional data is obtained in relation to the influence of the Rewan aquitard.</p> <p>Future refinements should consider; Lake Galilee recharge/discharge features, eastern outflow boundary conductance parameter consistency across all aquifers, and evaporation rate assumptions and sensitivities for post-closure pit void.</p>	<p>understand the mechanisms for DSC discharge, the extent of artesian heads in the Clematis, Dunda Beds and upper Rewan formations, and the impacts of landholder pumping and dewatering on the Permian HSUs.</p> <ul style="list-style-type: none"> A comprehensive surface water-groundwater investigation has been undertaken to inform the updated HCM and groundwater model. <p>Planned updates to GWFM:</p> <ul style="list-style-type: none"> Active modelled area to be reviewed and updated if necessary Additional vertical refinement of model layers in the area of mining Transient calibration to groundwater heads, including trends from environmental stresses and pumping as assessed in Section 8.1 Calibration to be undertaken as a combination of highly parameterised and zone-based, indicated by conceptualisation and data availability Updated recharge information as per Section 11, incorporating episodic recharge rates Updated stress period durations to more appropriately represent mine plan Explicit simulation of post-closure pit void, including time-varying material properties, direct incident rainfall and evapotranspiration surface based on pit base elevation
GHD 2015	<p>The model covers an active model domain of approximately 8,600 square kilometres. Consequently, there are limited data across a large geographical area, and as mentioned in the bioregional assessment for the area published by CSIRO (Evans et al, 2014), very limited hydrogeological information is available for the model region.</p> <p>It is acknowledged limited calibration and stratigraphic data is available for the area outside of the mine lease, and techniques have been adopted to interpolate discrete observations across a broad area.</p> <p>Of the 168 realisations in the sensitivity analysis, only four were characterised as having a potentially significant change in impact and an insignificant change in model calibration (ie indicative of uncertainty</p>	<p>Hydrogeological conceptualisation has been updated to address the key issues raised by GHD (2015), including:</p> <p>Drilling and installing monitoring sites to the west of the lease area to provide geological control and to assess Triassic and Permian pressures in the vicinity of the DSC to establish source aquifer, and to better constrain regional groundwater flow systems.</p> <p>Planned updates to GWFM:</p>

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	<p>that will require further investigations and data to resolve. These results apply to the hydraulic conductivity of the Tertiary clay in the vicinity of the Mellaluka springs complex, where three additional bores have since been drilled).</p> <p>As the project continues to evolve, the groundwater model will continue to be updated to reflect advances in understanding of the regional hydrogeological conditions.</p> <p>Limited data are available within the western region of the model to develop comprehensive conceptualisations regarding groundwater flow conditions, a point that is documented in the bioregional assessment for the area published by CSIRO (Evans et al, 2014).</p> <p>The following recommendations are provided to guide future investigations and modelling studies, which should also consider the recommendations provided by the independent reviews completed to date:</p> <p>Update calibration targets based upon subsequent groundwater level data collected over the model domain, particularly within the GAB units to the west of the mine.</p> <ul style="list-style-type: none"> • Re-calibrate the model, including transient calibration, using operational and regional monitoring data. • Review modelled discharge to the Carmichael River against the updated stream gauging data accrued over the period since the model development. • Incorporation of the weathered zone into the model. • Review of recharge parameters, particularly in the GAB units. • Update of the model to represent any revisions in the proposed mine plan, including pit sequencing, pit geometry, proposed dewatering methods and closure methods and timing. • Split the existing model layer 12 into two layers to provide separation between the early Permian basement and the D-seams underburden. <p>Thus the accuracy of the predicted river flows and impacts could be enhanced in future modelling work by calibrating river conductance values against reliable baseflow targets for the Carmichael River.</p>	<ul style="list-style-type: none"> • Update to GWFM based on updates to HCM, including explicit representation of weathered zone as per Section 5.2 • Enhanced vertical discretisation in the vicinity of the mine • Transient calibration with updated targets, including surface water discharge fluxes where available • Transient recharge fluxes representing climate during history-matching period • More detail in sensitivity and uncertainty analyses
CSIRO 2019	<p>The review found that the modelling used is not suitable to ensure the outcomes sought by the EPBC Act conditions are met.</p> <p>Comparison of the SEIS model and the two alternate re-run models shows that the location of the western model boundary has little impact on drawdown predictions. However, these re-runs were not calibrated, thus reducing confidence in the predictions that they make. A re-calibration is warranted to improve confidence in model predictions.</p>	<ul style="list-style-type: none"> • A comprehensive groundwater-surface water investigation has been undertaken to inform the updated HCM and groundwater model. This study has assessed both creek flows, creek interactions with groundwater, as well as spring typology and water balances. • New field and laboratory measurements of K and S for the Rewan, Dunda and Clematis HSUs. Detailed analysis of Kx and Kz with depth across the Rewan aquitard. Integrated K datasets have established field-based statistical ranges for each HSU.

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	<p>The SEIS model includes the most recent calibrated parameter set developed for the Carmichael Coal Mine in 2013. Although, it must be noted that model errors increased from 4.5% RMS error reported for the SEIS model to 7.2% when compared to updated data following resurveying bore locations.</p> <p>Representation in the model of surface water flows for the Carmichael River over-predicts flows from the river into the groundwater. As a result the groundwater drawdown in the alluvium (Carmichael River GDEs) will be greater than the predicted model.</p> <p>Parameterisation of the Rewan Formation and Clematis Sandstone by the SEIS model. Calibrated hydraulic conductivity values for the Rewan Formation are very low compared with measured values, which minimises vertical water movement, and hydraulic conductivity values for the Clematis Sandstone are high, which increases the lateral transfer of water.</p> <p>The approach used to model potential impacts to the groundwater system due to mining indicates that the model will under-estimate the amount of drawdown predicted at the DSC and the Carmichael River GDE as a result of model representation of:</p> <ul style="list-style-type: none"> • The unrealistically high modelled flow in the Carmichael River. • Error in the bore heights used to calibrate the model. • Hydraulic conductivity in the Clematis Sandstone and Rewan Formation model layers. <p>Recommendations:</p> <p>Future updates of the model should also use stream flow as one of the calibration parameters;</p> <p>Guidance for uncertainty analysis should be considered in future model updates.</p> <p>Model updates should include recalibration, and clearly define bore reference levels, how they have changed over time and how these changes affect model prediction and performance.</p> <p>Recalibration should include revised bore heights to provide confidence that captured evapotranspiration is not limiting drawdown to the DSC and the Carmichael River GDE.</p> <p>Future model updates should use locally appropriate parameterisations.</p> <p>Sensitivity analysis undertaken for future model updates should seek to assess cumulative sensitivity.</p> <p>Future model updates should include analysis of the sensitivity of the model to parameter changes due to underground mining.</p> <p>To constrain the source aquifer(s) of the DSC, a more sophisticated statistical analysis of hydrochemistry data is required. This includes assessing a wider variety of groundwater and surface water analytes, as well as appropriate use of isotope hydrochemistry analysis.</p> <p>Installation of bores to monitor the groundwater system in the Dunda Beds and Rewan Formation (upper Rewan and lower Rewan) at existing monitoring points in the west of the central zone would allow an</p>	<ul style="list-style-type: none"> • Drilling and installing monitoring sites to the west of the lease area to provide geological control and to assess Triassic and Permian pressures in the vicinity of the DSC to establish source aquifer. A comprehensive hydrogeochemistry and isotopes analysis program has also independently confirmed a Triassic source aquifer for the DSC. <p>Planned updates to GWFM:</p> <ul style="list-style-type: none"> • Recalibration to all available data, including fluxes to surface water • Any changes in model bore heights to be documented • Calibration to assign parameters consistent with HCM • Sensitivity analysis to include relative composite sensitivity • Type 3 (Monte Carlo) predictive uncertainty analysis, including assessment of mining-induced hydraulic parameter changes

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	<p>assessment of any dewatering impact propagating through the Rewan Formation (in effect, nested monitoring bores). Ideally all units from outcrop to sub-Joe Joe coal (Jericho Formation) would be monitored.</p> <p>It is strongly recommended that the monitoring program includes stream flow gauging upstream and downstream of the mine area. Additionally, an improved and re-calibrated flow-discharge relationship for each gauge would improve the accuracy of the data.</p> <p>It is not plausible and reasonable to state unequivocally that the Clematis Sandstone is the sole source aquifer for the DSC, as sufficient uncertainty surrounding hydrogeochemistry, inter-aquifer connectivity and groundwater flow (Currell et al., 2017; Lewis et al., 2018; Webb et al., 2015) exists to necessitate a precautionary approach to the conceptualisation, as ruled by Land Court of Queensland (2015).</p>	

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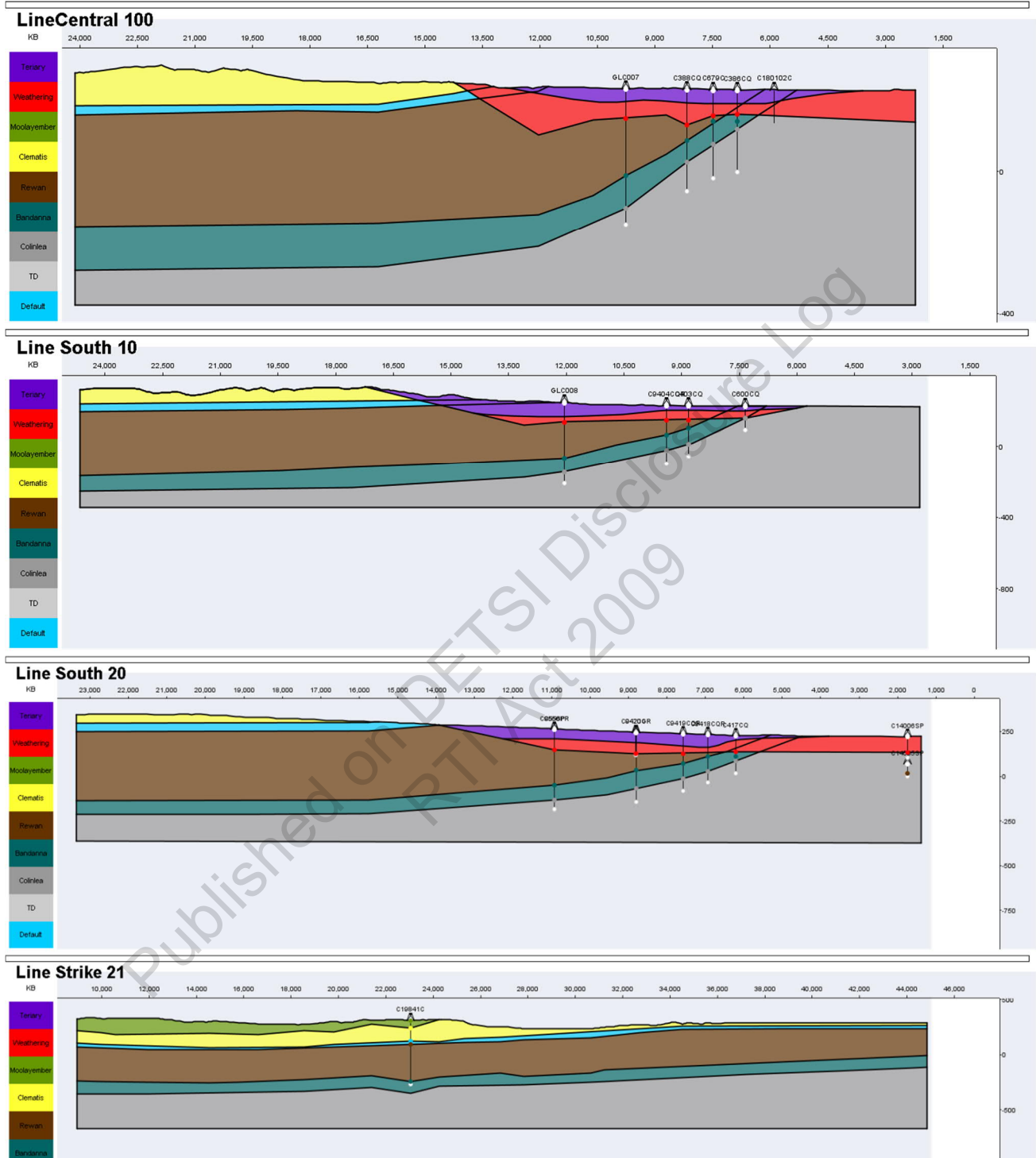
Appendix A

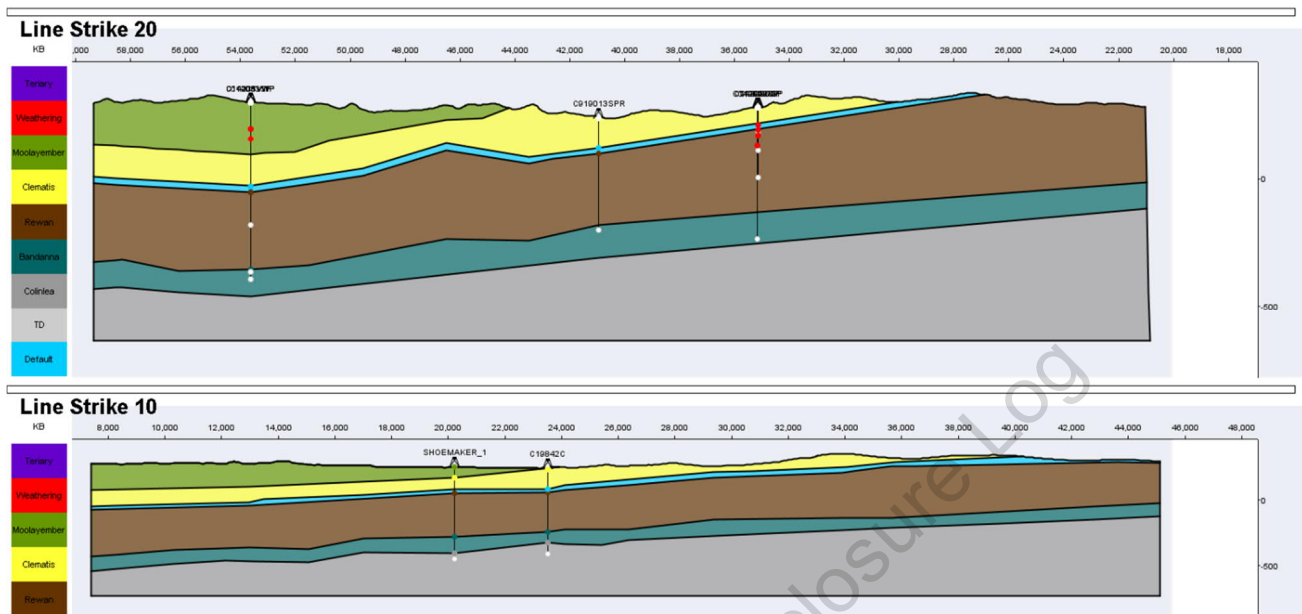
Structural cross-sections

[illegible]

The geological cross-section illustrates the stratigraphic sequence from the Tertiary to the Taranaki Diabase (TD). The units, from top to bottom, are: Tertiary (purple), Weathering (red), Moolayember (brown), Clematis (yellow), Dunda (cyan), Revan (dark brown), Bandanna (teal), Colinlea (grey), and TD (dark grey). The cross-section shows a general dip to the right. Well locations are marked with vertical lines and labels: C127, C128, C129, C130, C131, C132, C133, C134, C135, C136, C137, C138, C139, C140, C141, C142, C143, C144, C145, C146, C147, C148, C149, C150, C151, C152, C153, C154, C155, C156, C157, C158, C159, C160, C161, C162, C163, C164, C165, C166, C167, C168, C169, C170, C171, C172, C173, C174, C175, C176, C177, C178, C179, C180, C181, C182, C183, C184, C185, C186, C187, C188, C189, C190, C191, C192, C193, C194, C195, C196, C197, C198, C199, C200, C201, C202, C203, C204, C205, C206, C207, C208, C209, C210, C211, C212, C213, C214, C215, C216, C217, C218, C219, C220, C221, C222, C223, C224, C225, C226, C227, C228, C229, C230, C231, C232, C233, C234, C235, C236, C237, C238, C239, C240, C241, C242, C243, C244, C245, C246, C247, C248, C249, C250, C251, C252, C253, C254, C255, C256, C257, C258, C259, C260, C261, C262, C263, C264, C265, C266, C267, C268, C269, C270, C271, C272, C273, C274, C275, C276, C277, C278, C279, C280, C281, C282, C283, C284, C285, C286, C287, C288, C289, C290, C291, C292, C293, C294, C295, C296, C297, C298, C299, C300, C301, C302, C303, C304, C305, C306, C307, C308, C309, C310, C311, C312, C313, C314, C315, C316, C317, C318, C319, C320, C321, C322, C323, C324, C325, C326, C327, C328, C329, C330, C331, C332, C333, C334, C335, C336, C337, C338, C339, C340, C341, C342, C343, C344, C345, C346, C347, C348, C349, C350, C351, C352, C353, C354, C355, C356, C357, C358, C359, C360, C361, C362, C363, C364, C365, C366, C367, C368, C369, C370, C371, C372, C373, C374, C375, C376, C377, C378, C379, C380, C381, C382, C383, C384, C385, C386, C387, C388, C389, C390, C391, C392, C393, C394, C395, C396, C397, C398, C399, C400, C401, C402, C403, C404, C405, C406, C407, C408, C409, C410, C411, C412, C413, C414, C415, C416, C417, C418, C419, C420, C421, C422, C423, C424, C425, C426, C427, C428, C429, C430, C431, C432, C433, C434, C435, C436, C437, C438, C439, C440, C441, C442, C443, C444, C445, C446, C447, C448, C449, C450, C451, C452, C453, C454, C455, C456, C457, C458, C459, C460, C461, C462, C463, C464, C465, C466, C467, C468, C469, C470, C471, C472, C473, C474, C475, C476, C477, C478, C479, C480, C481, C482, C483, C484, C485, C486, C487, C488, C489, C490, C491, C492, C493, C494, C495, C496, C497, C498, C499, C500, C501, C502, C503, C504, C505, C506, C507, C508, C509, C510, C511, C512, C513, C514, C515, C516, C517, C518, C519, C520, C521, C522, C523, C524, C525, C526, C527, C528, C529, C530, C531, C532, C533, C534, C535, C536, C537, C538, C539, C540, C541, C542, C543, C544, C545, C546, C547, C548, C549, C550, C551, C552, C553, C554, C555, C556, C557, C558, C559, C560, C561, C562, C563, C564, C565, C566, C567, C568, C569, C570, C571, C572, C573, C574, C575, C576, C577, C578, C579, C580, C581, C582, C583, C584, C585, C586, C587, C588, C589, C590, C591, C592, C593, C594, C595, C596, C597, C598, C599, C600, C601, C602, C603, C604, C605, C606, C607, C608, C609, C610, C611, C612, C613, C614, C615, C616, C617, C618, C619, C620, C621, C622, C623, C624, C625, C626, C627, C628, C629, C630, C631, C632, C633, C634, C635, C636, C637, C638, C639, C640, C641, C642, C643, C644, C645, C646, C647, C648, C649, C650, C651, C652, C653, C654, C655, C656, C657, C658, C659, C660, C661, C662, C663, C664, C665, C666, C667, C668, C669, C670, C671, C672, C673, C674, C675, C676, C677, C678, C679, C680, C681, C682, C683, C684, C685, C686, C687, C688, C689, C690, C691, C692, C693, C694, C695, C696, C697, C698, C699, C700, C701, C702, C703, C704, C705, C706, C707, C708, C709, C710, C711, C712, C713, C714, C715, C716, C717, C718, C719, C720, C721, C722, C723, C724, C725, C726, C727, C728, C729, C730, C731, C732, C733, C734, C735, C736, C737, C738, C739, C740, C741, C742, C743, C744, C745, C746, C747, C748, C749, C750, C751, C752, C753, C754, C755, C756, C757, C758, C759, C760, C761, C762, C763, C764, C765, C766, C767, C768, C769, C770, C771, C772, C773, C774, C775, C776, C777, C778, C779, C780, C781, C782, C783, C784, C785, C786, C787, C788, C789, C790, C791, C792, C793, C794, C795, C796, C797, C798, C799, C800, C801, C802, C803, C804, C805, C806, C807, C808, C809, C810, C811, C812, C813, C814, C815, C816, C817, C818, C819, C820, C821, C822, C823, C824, C825, C826, C827, C828, C829, C830, C831, C832, C833, C834, C835, C836, C837, C838, C839, C840, C841, C842, C843, C844, C845, C846, C847, C848, C849, C850, C851, C852, C853, C854, C855, C856, C857, C858, C859, C860, C861, C862, C863, C864, C865, C866, C867, C868, C869, C870, C871, C872, C873, C874, C875, C876, C877, C878, C879, C880, C881, C882, C883, C884, C885, C886, C887, C888, C889, C890, C891, C892, C893, C894, C895, C896, C897, C898, C899, C900, C901, C902, C903, C904, C905, C906, C907, C908, C909, C910, C911, C912, C913, C914, C915, C916, C917, C918

The geological cross-section shows the following units from top to bottom: Tertiary (purple), Weathering (red), Moolayember (green), Clematis (yellow), Tunda (blue), and Recent (grey). The cross-section is oriented with KB (Kilobars) on the vertical axis, ranging from 22,000 to 0. The horizontal axis represents distance in kilometers, ranging from 22,000 to 0. The cross-section shows the Tunda area, with the Tunda unit (blue) and the Moolayember unit (green) being prominent. The Tunda unit is shown as a thick, relatively uniform layer. The Moolayember unit is shown as a thinner, more irregular layer. The Weathering unit (red) is shown as a thin layer at the top. The Tertiary unit (purple) is shown as a thin layer at the top. The Recent unit (grey) is shown as a thin layer at the bottom. The cross-section also shows several wells, including CO-15, CO-11, and CO-10, which are located in the Tunda area. The cross-section is a detailed representation of the geological structure of the Tunda area, showing the various units and their relationships.

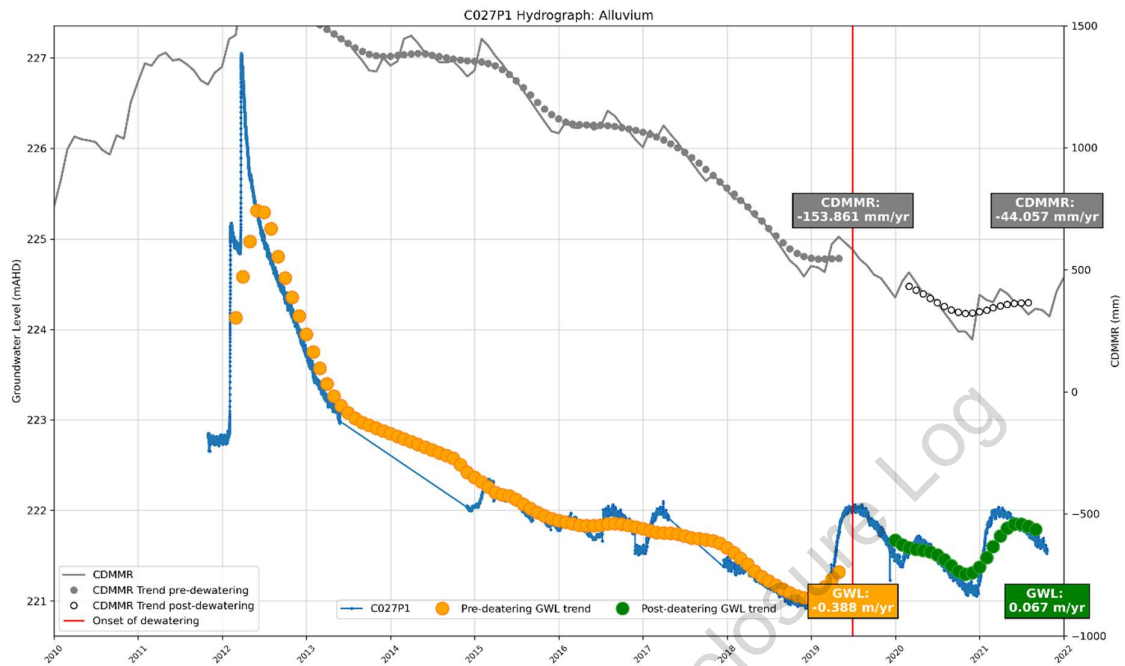
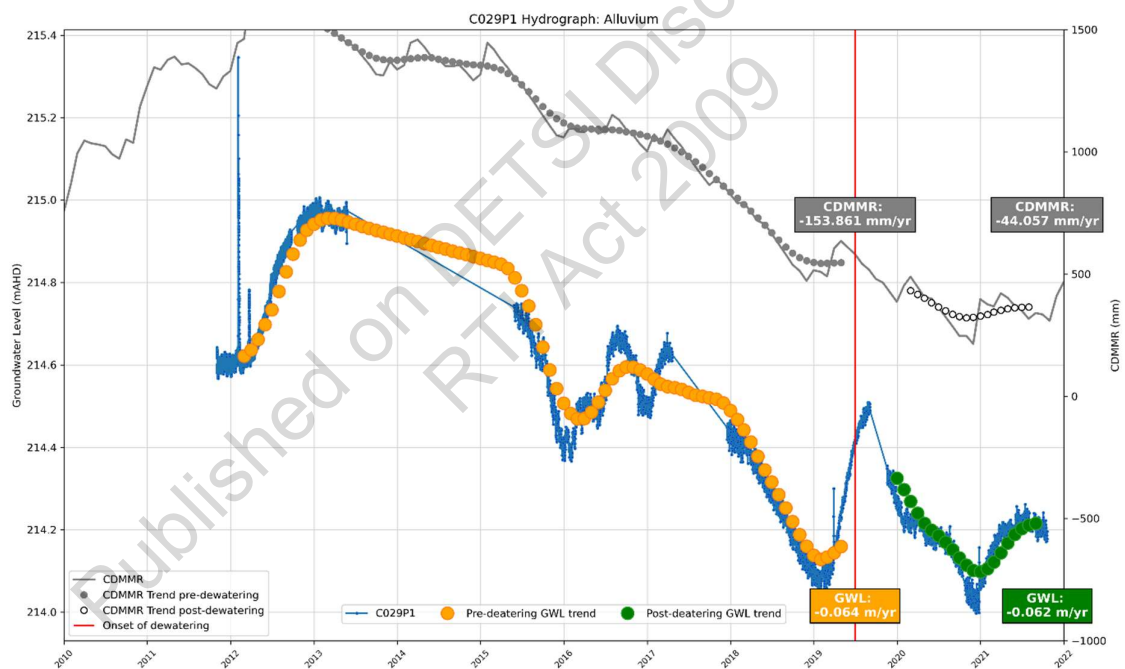


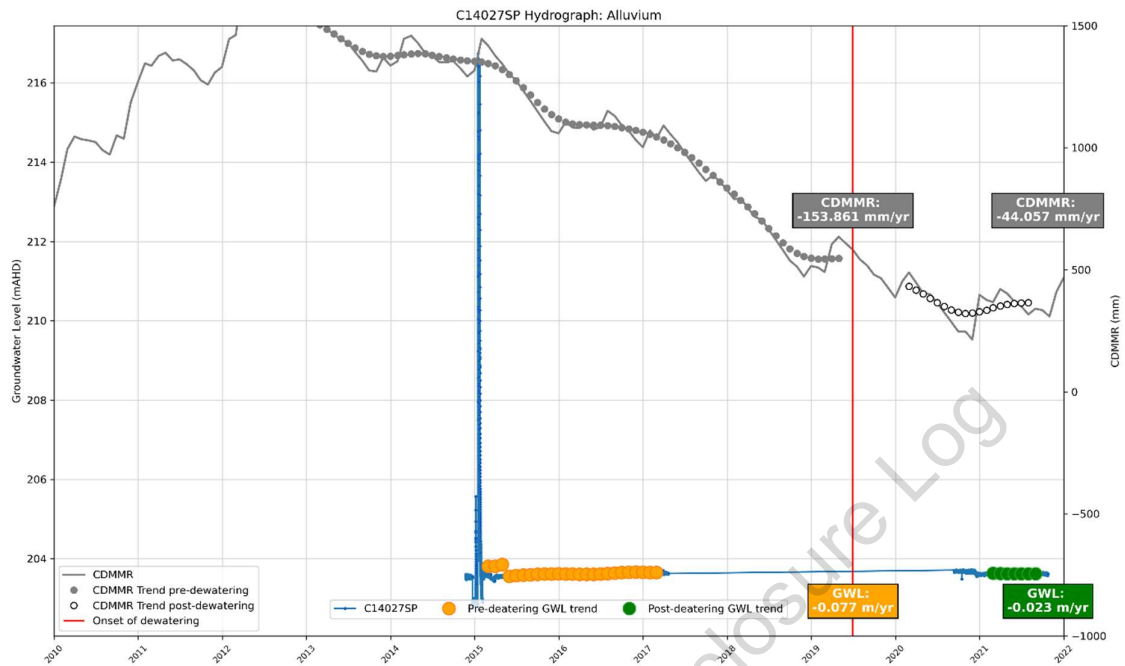
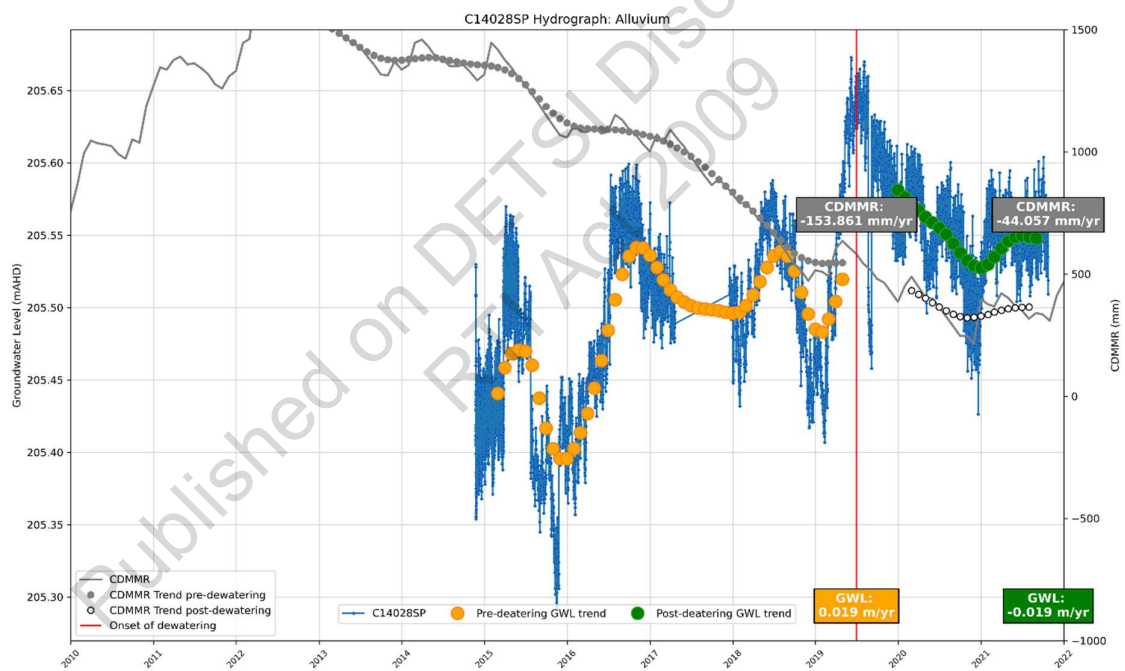


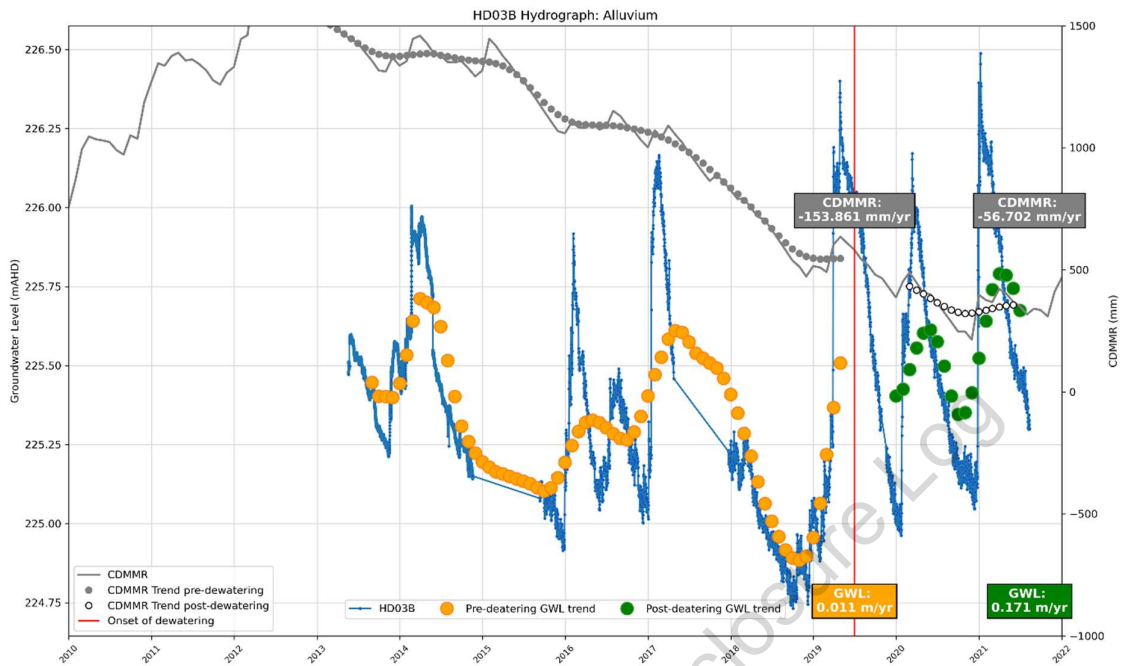
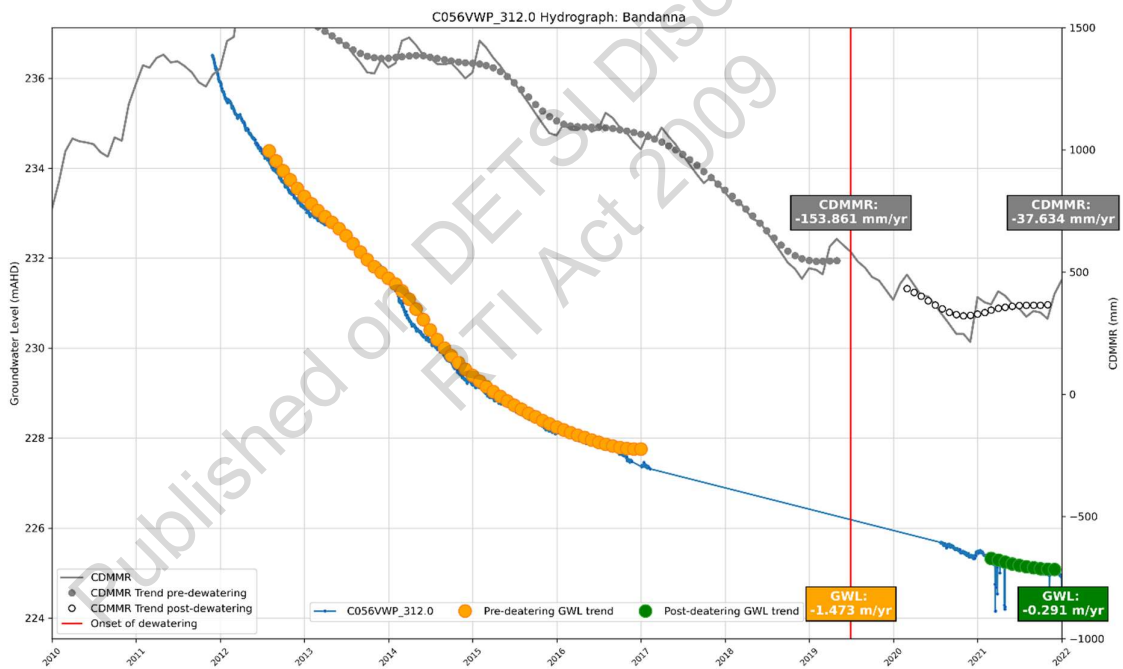
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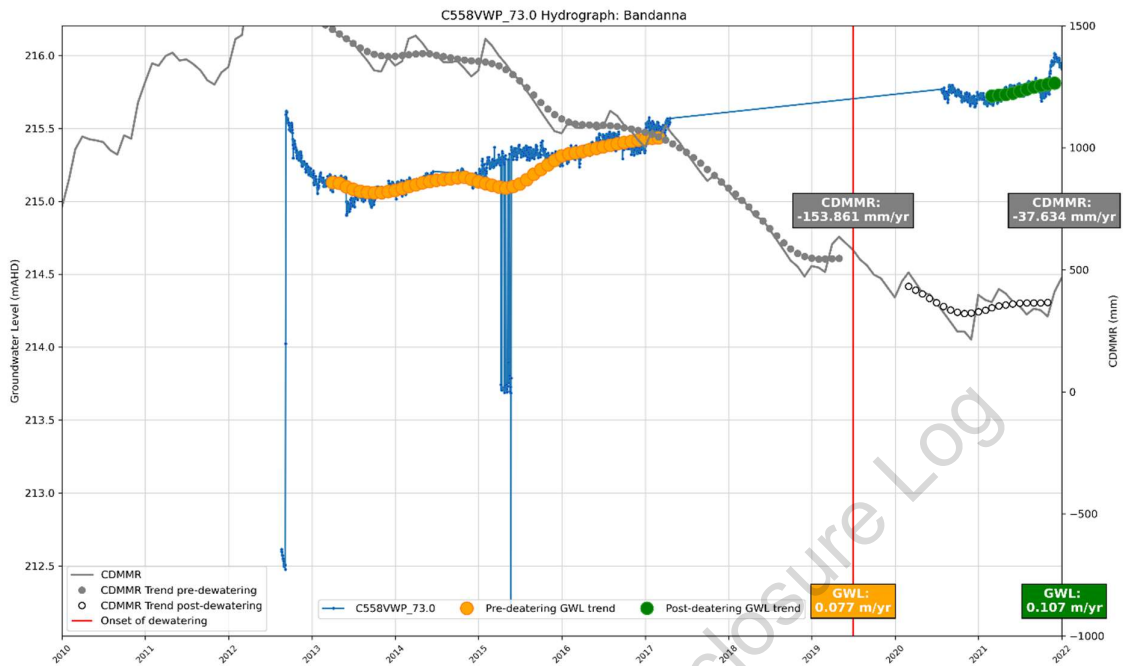
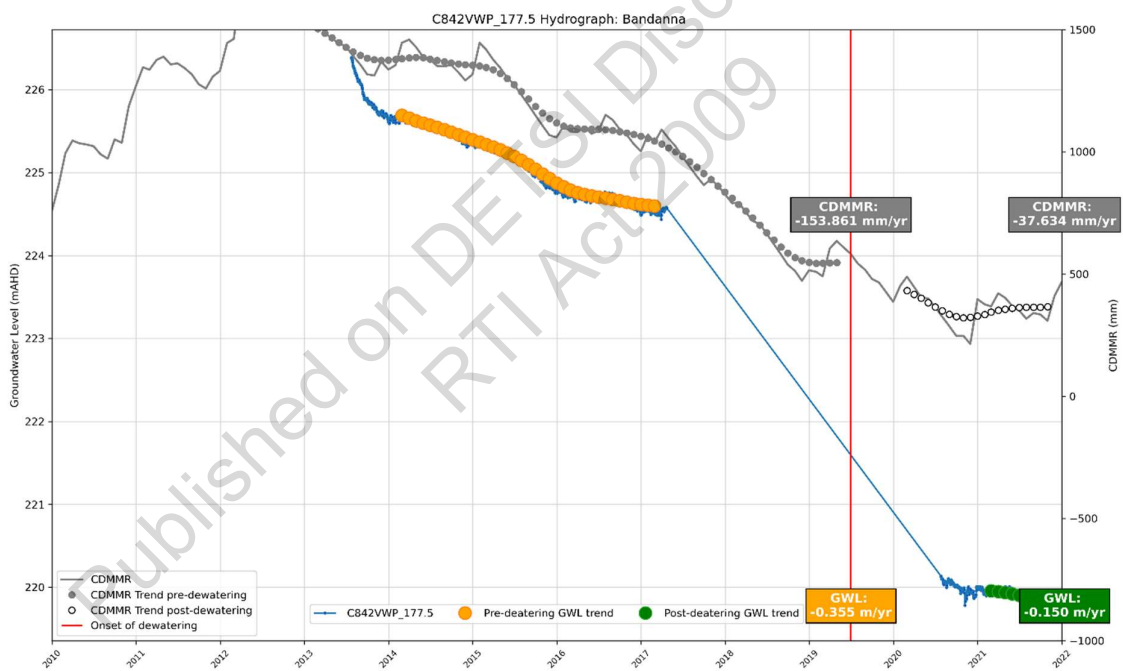
Appendix B

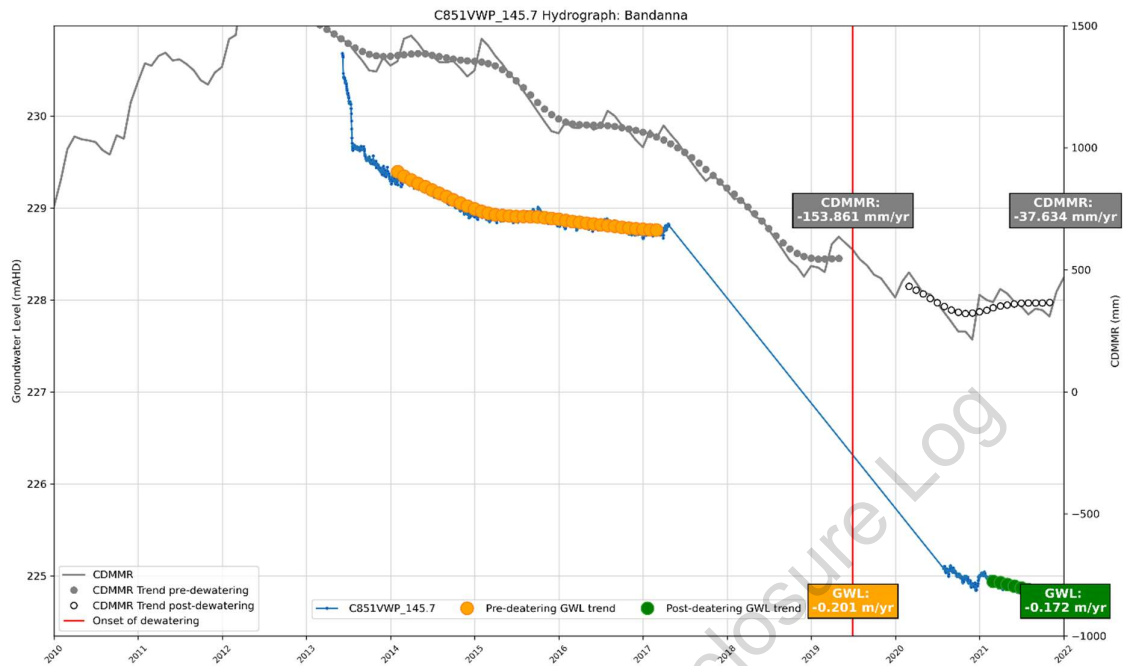
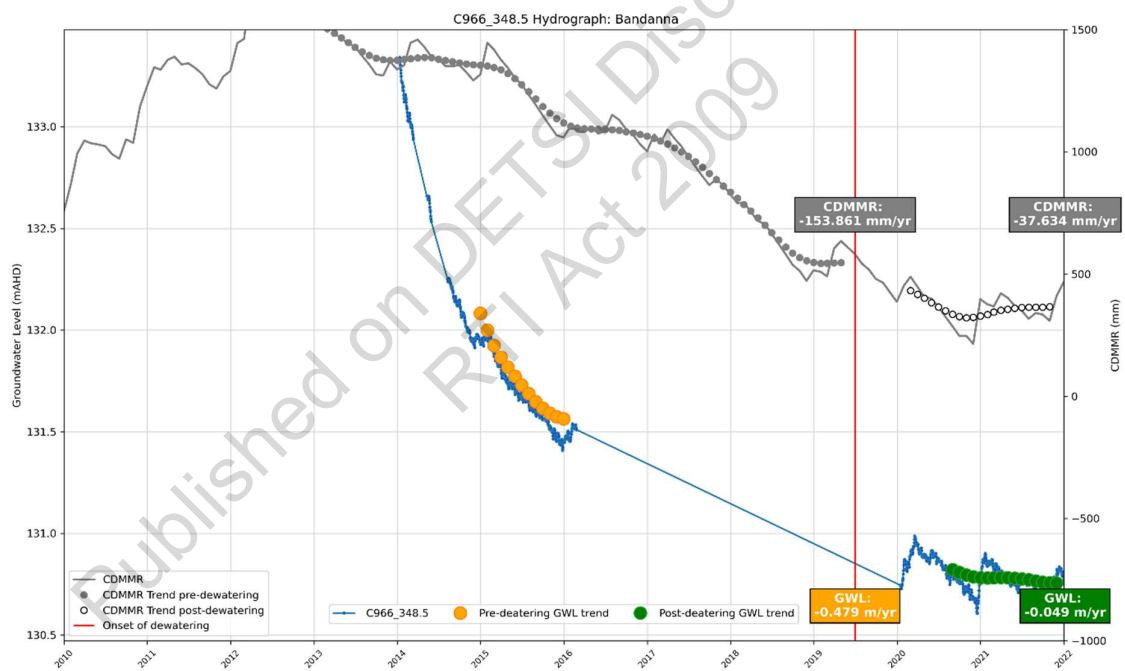
CCM hydrographs

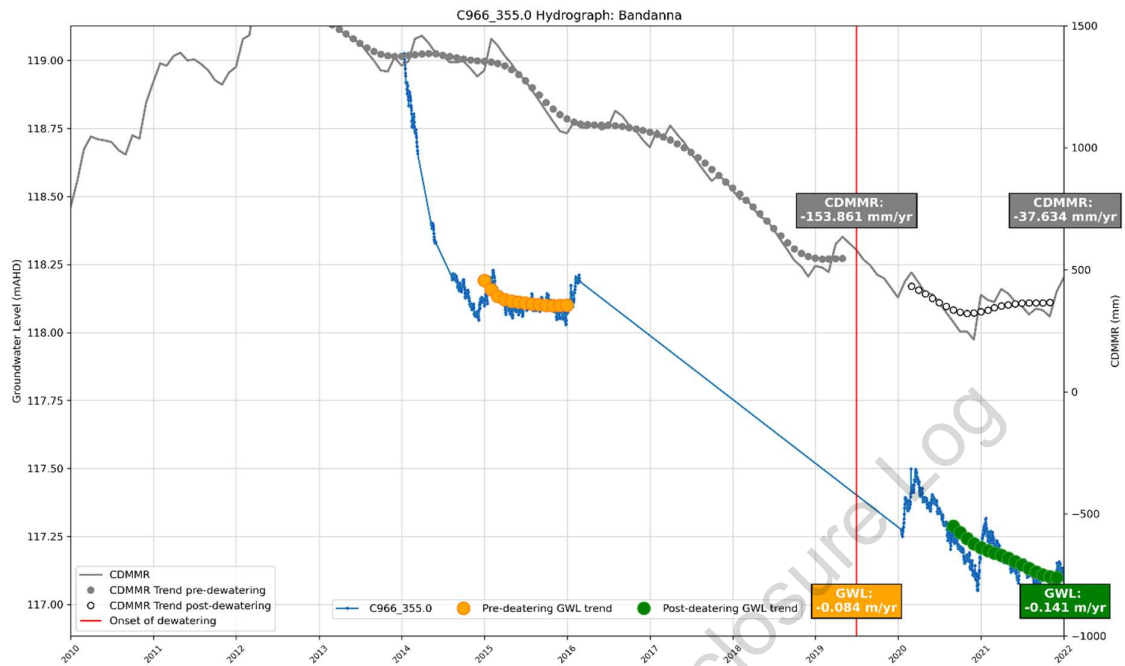
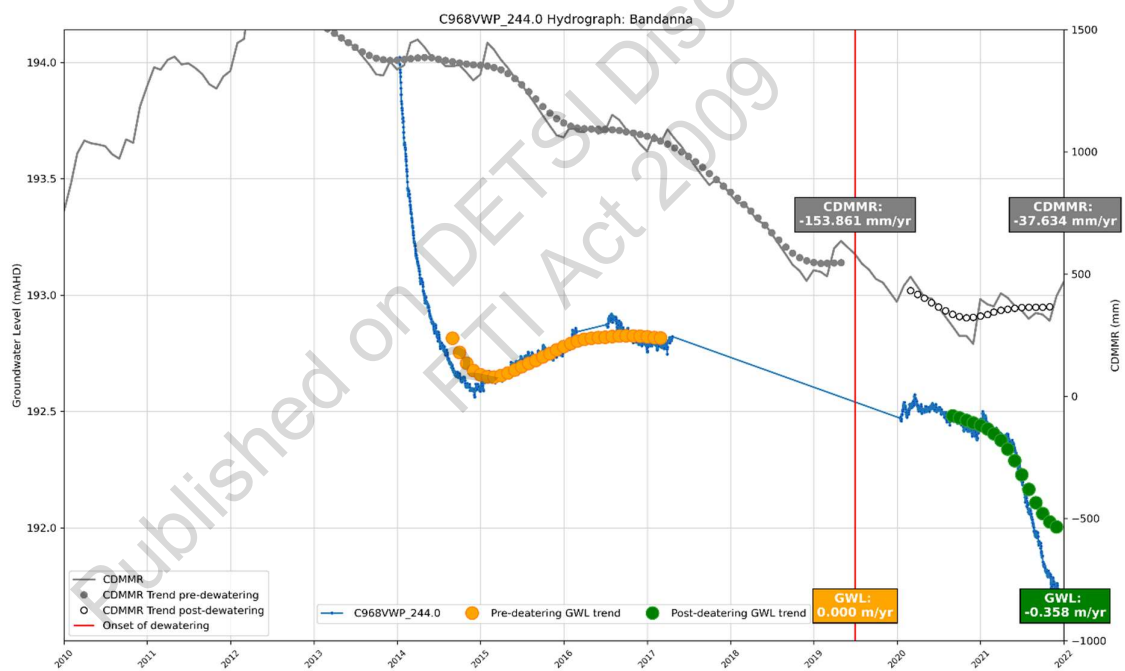


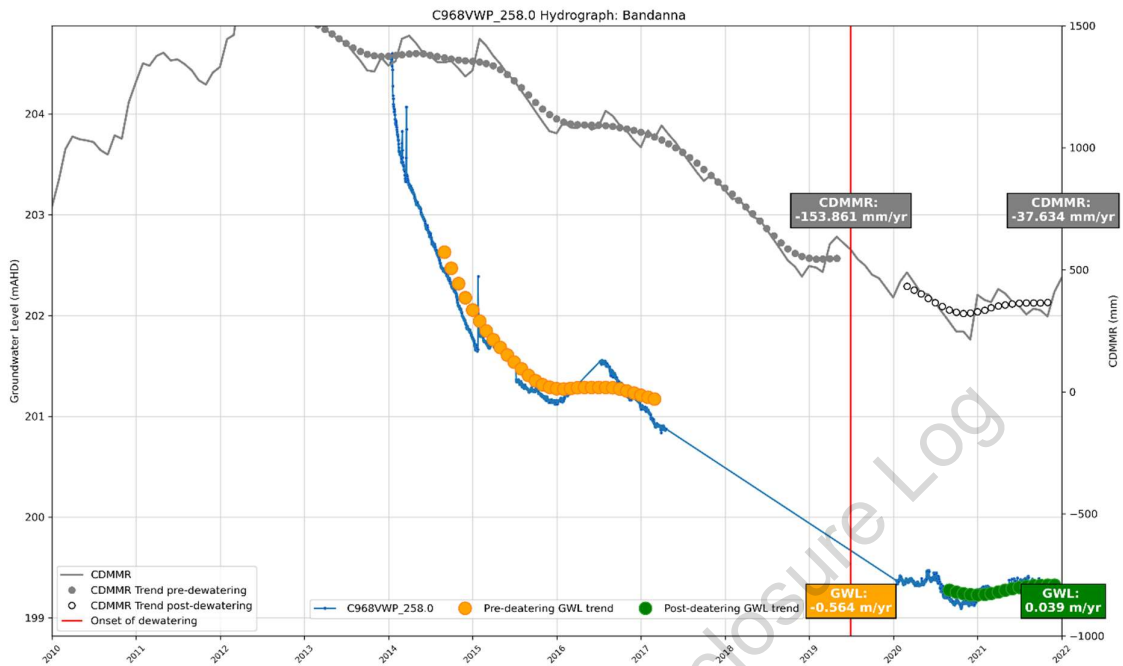
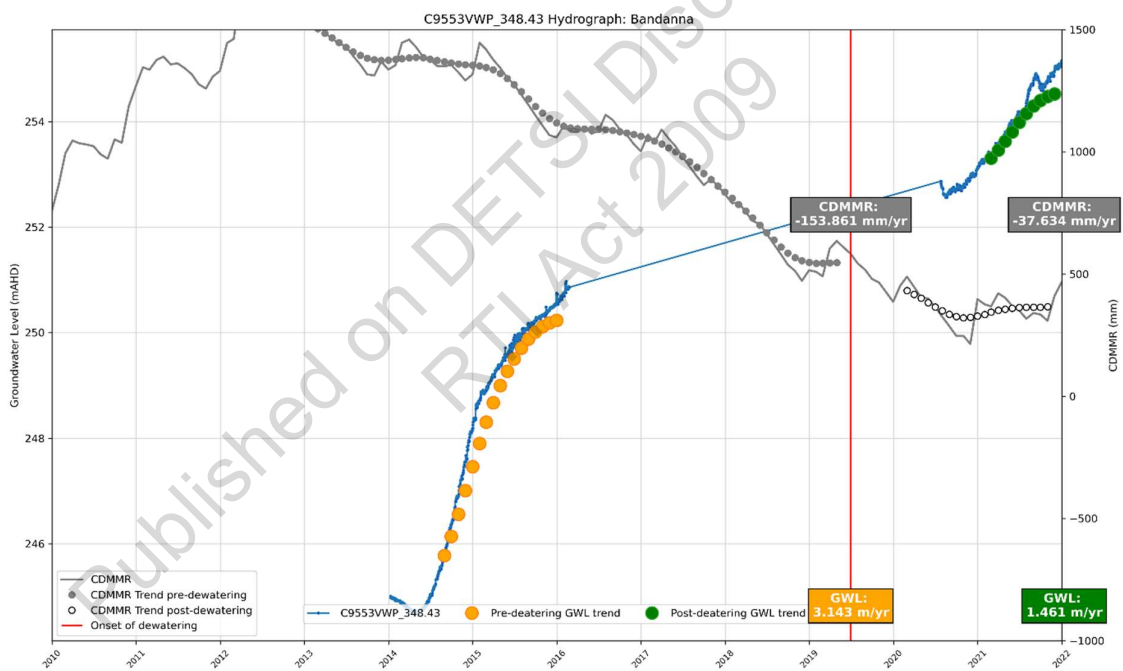


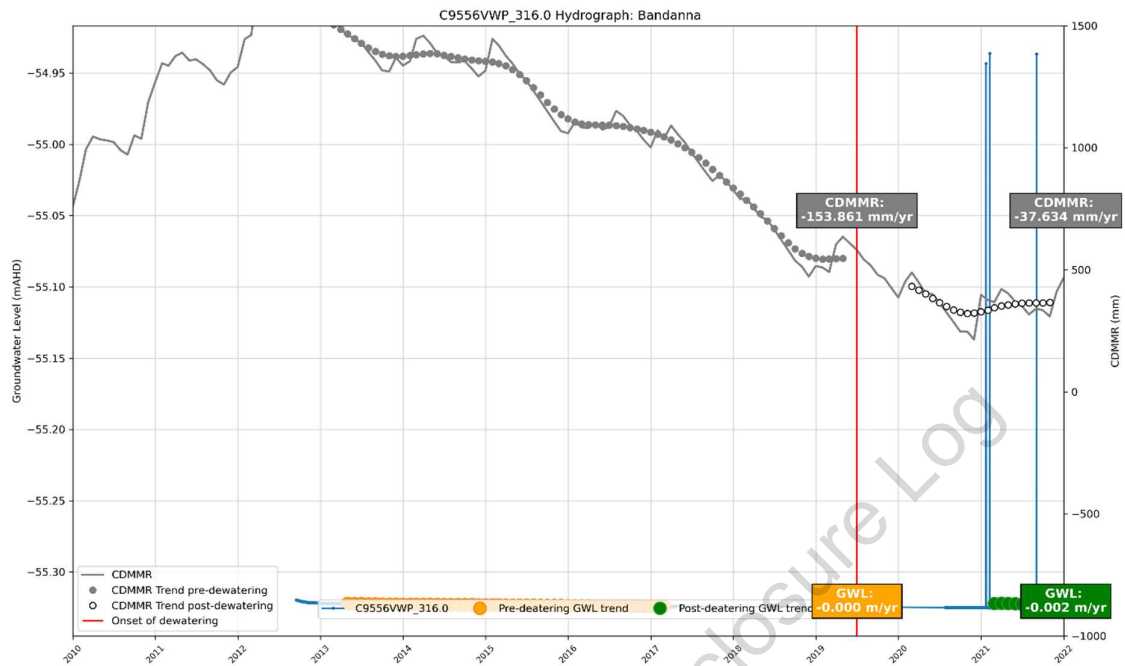
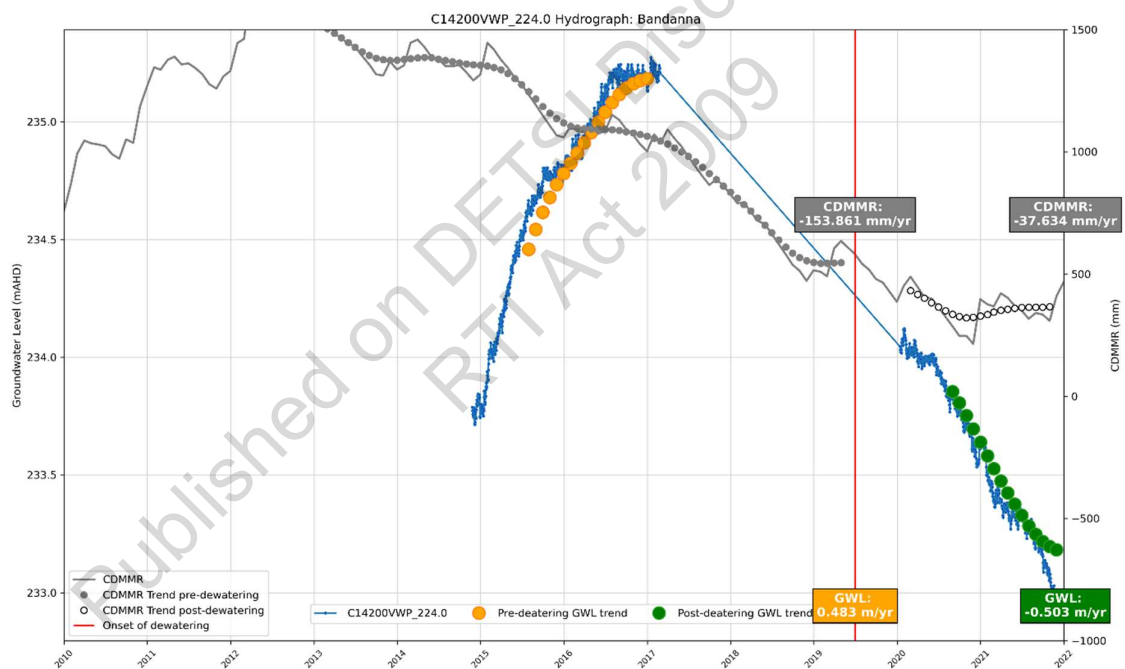


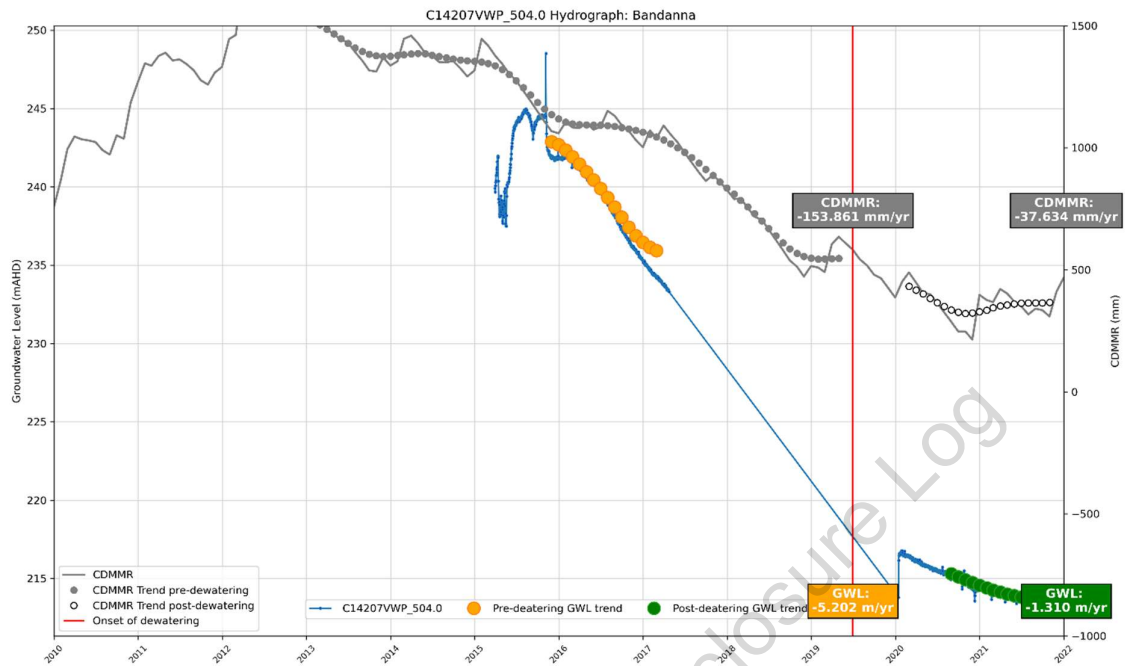
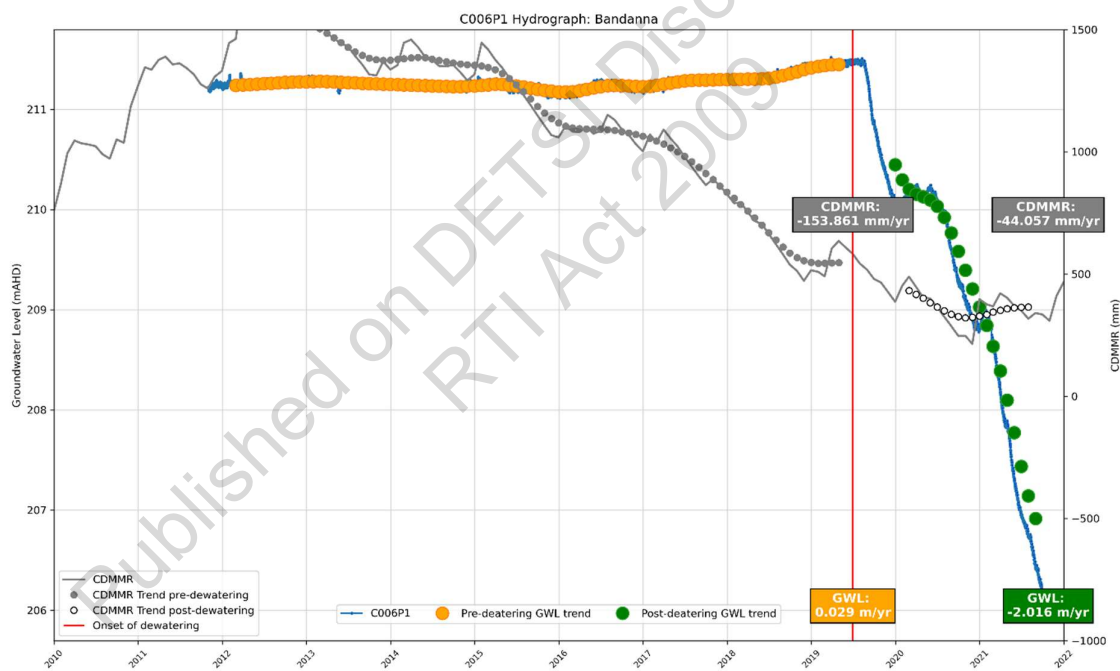


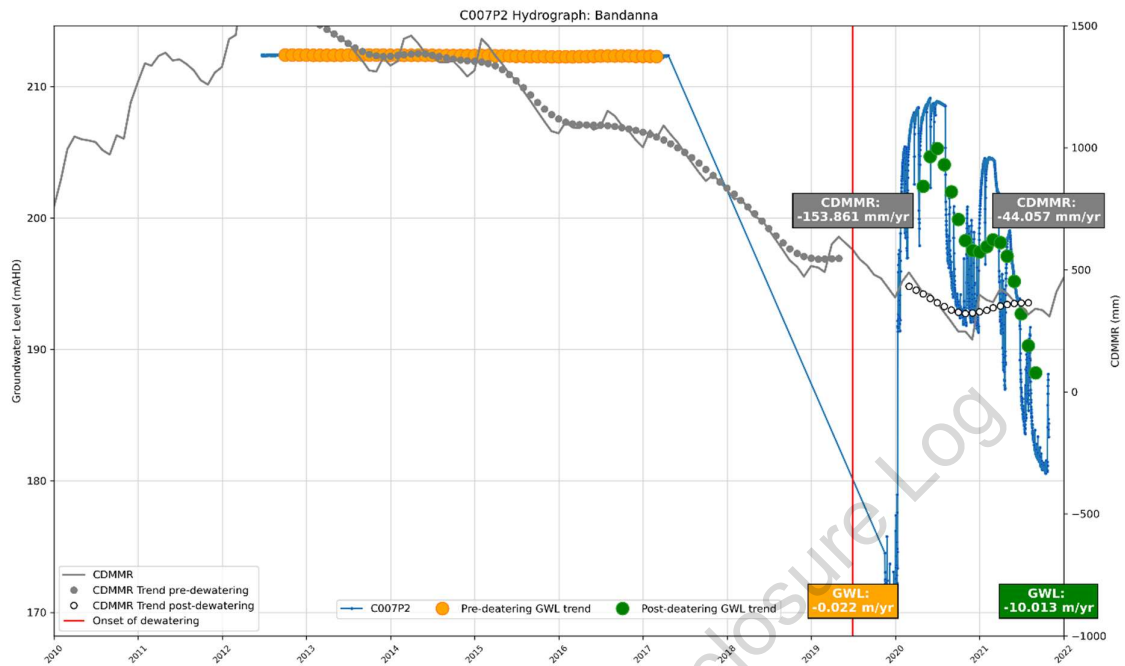
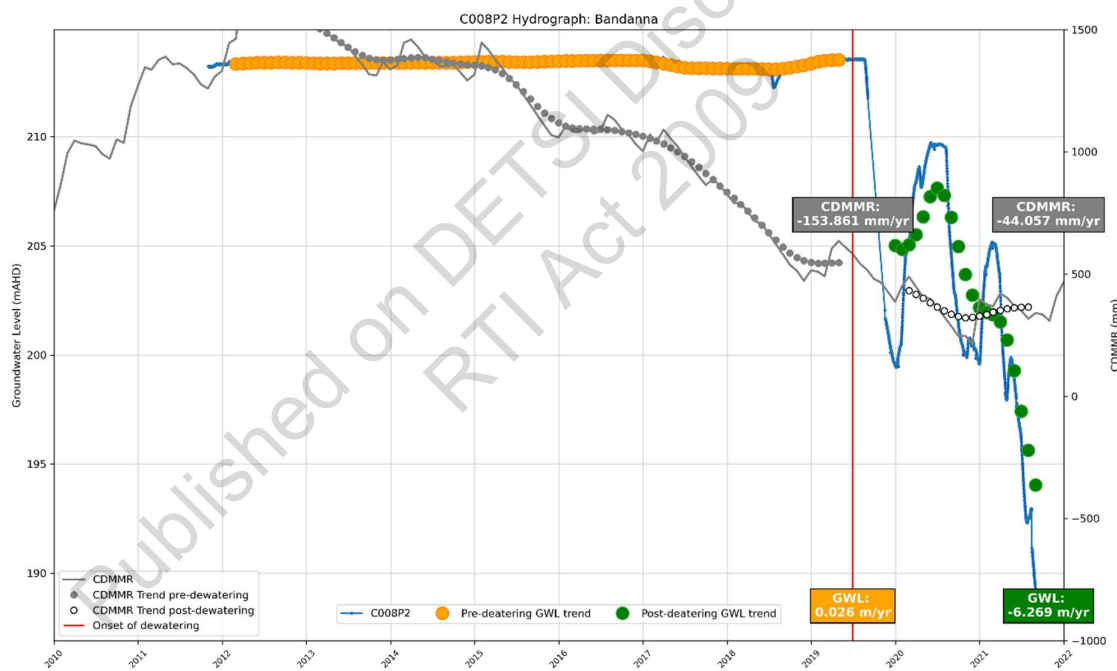


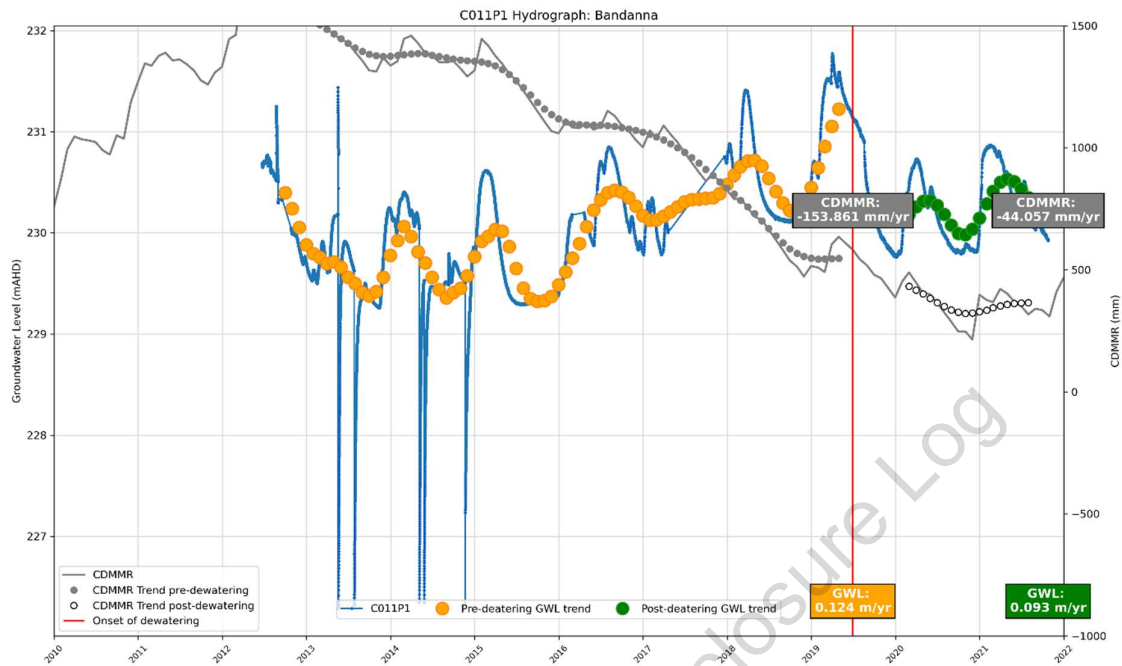
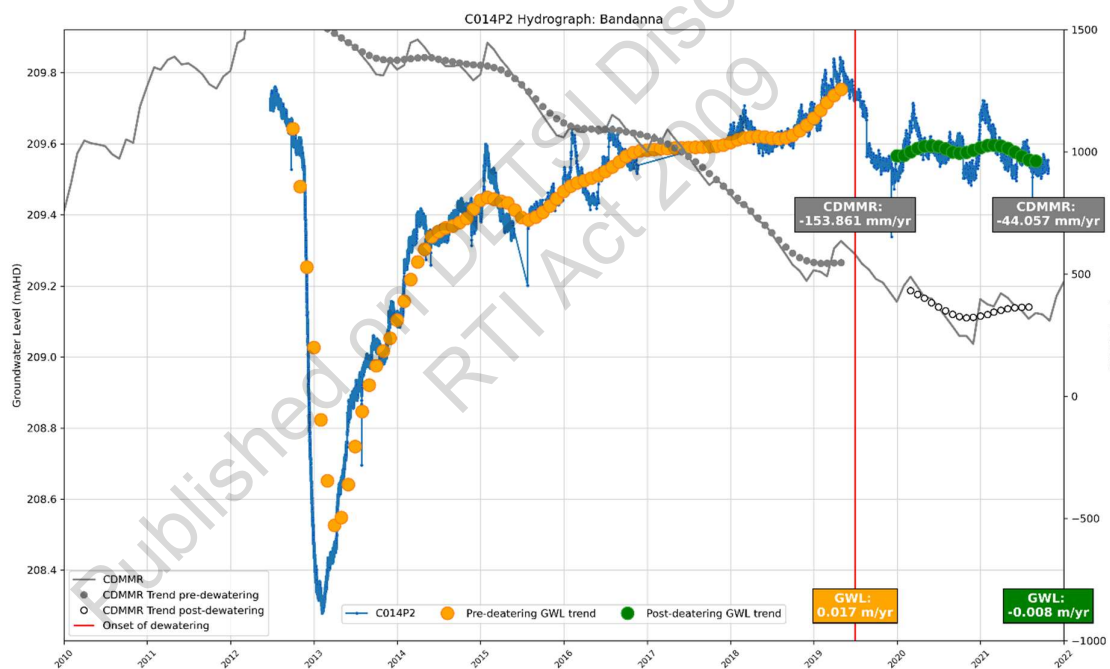


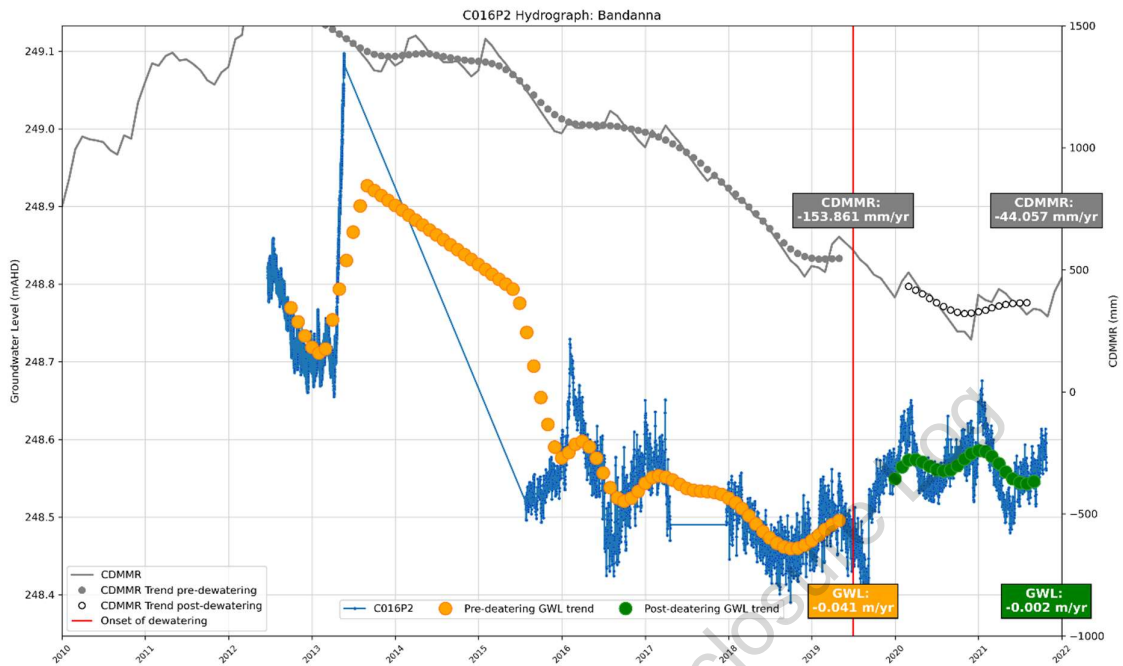
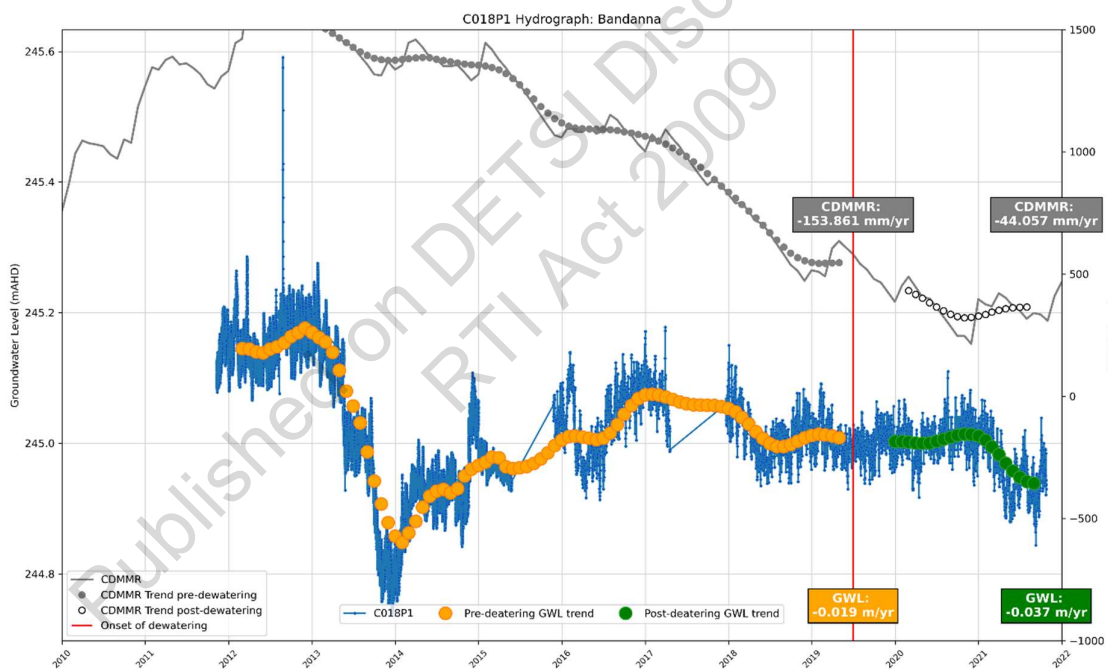


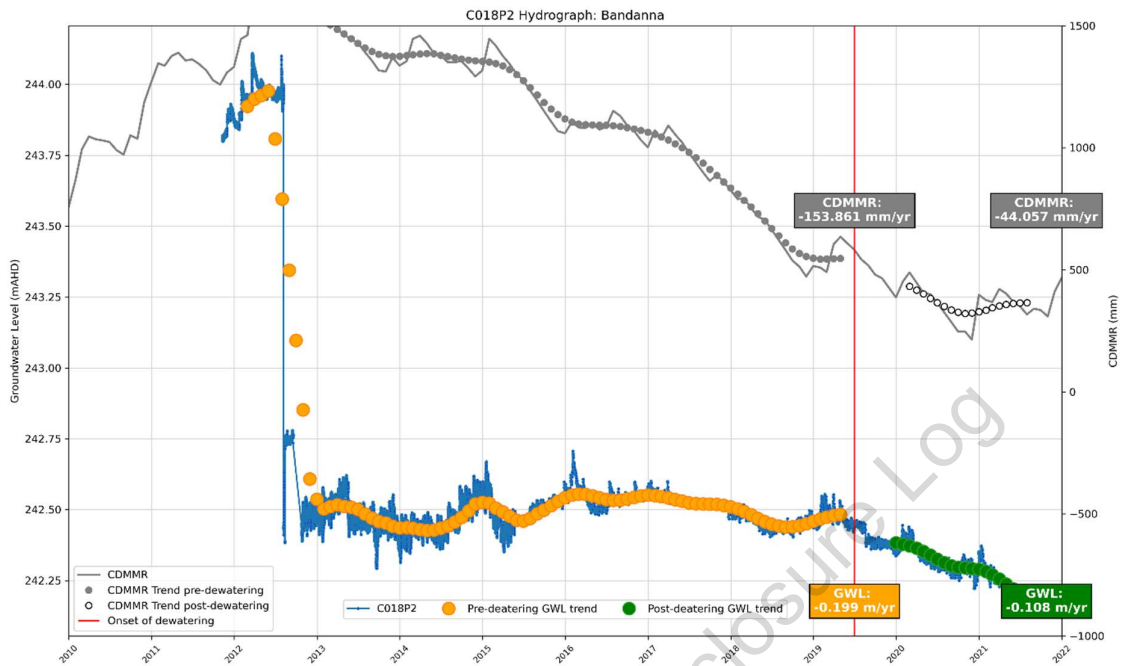
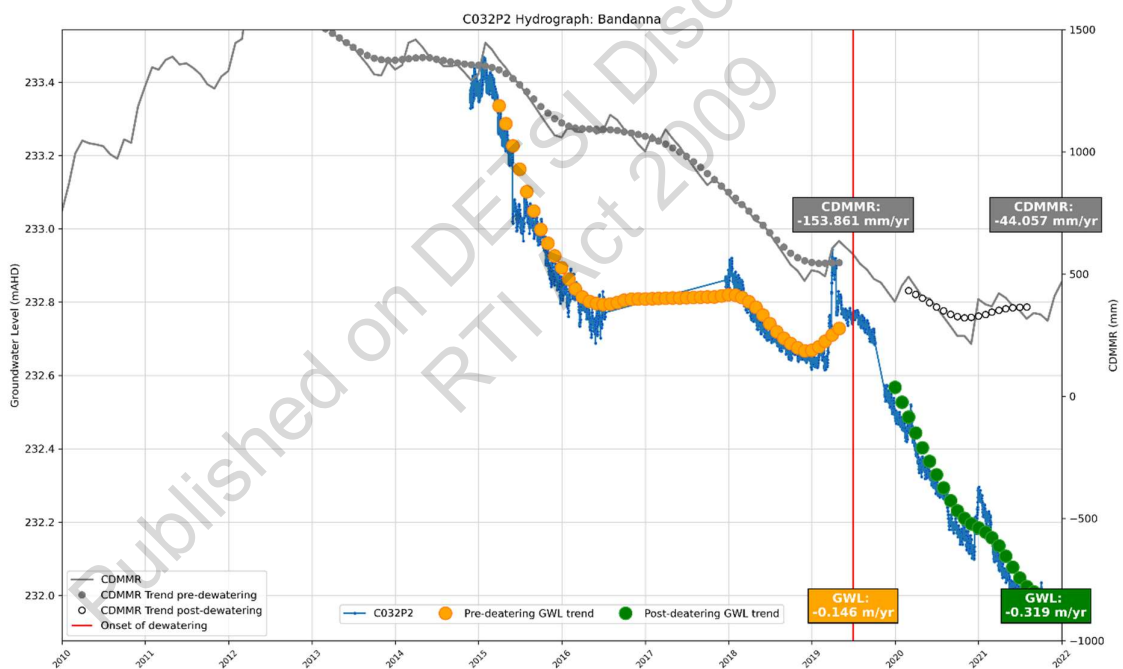


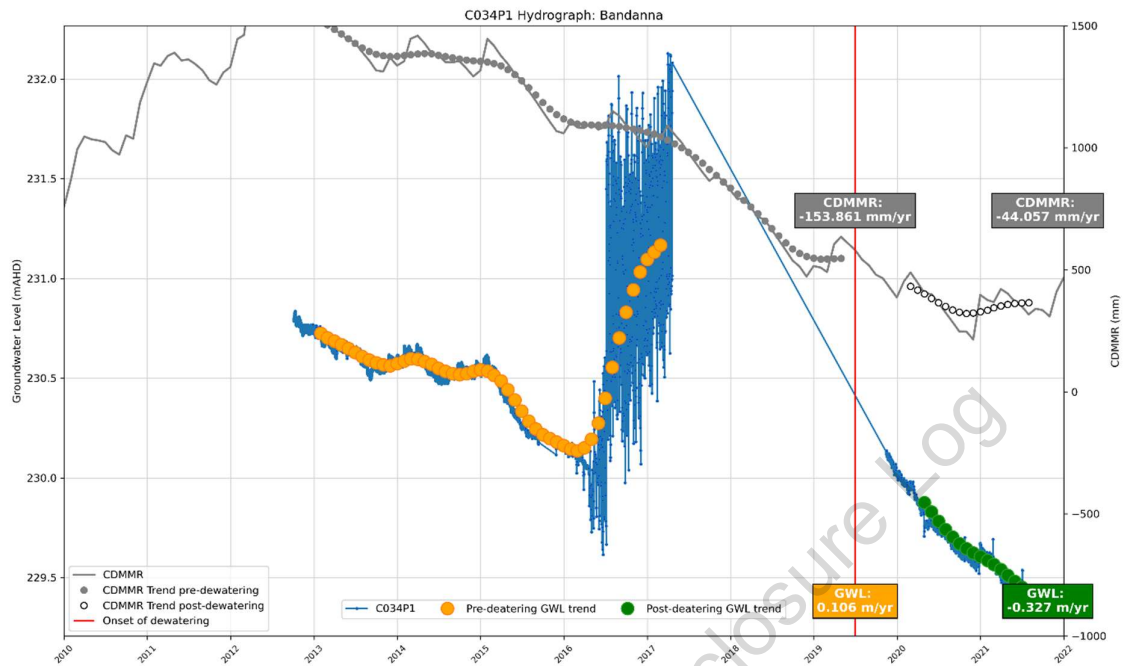
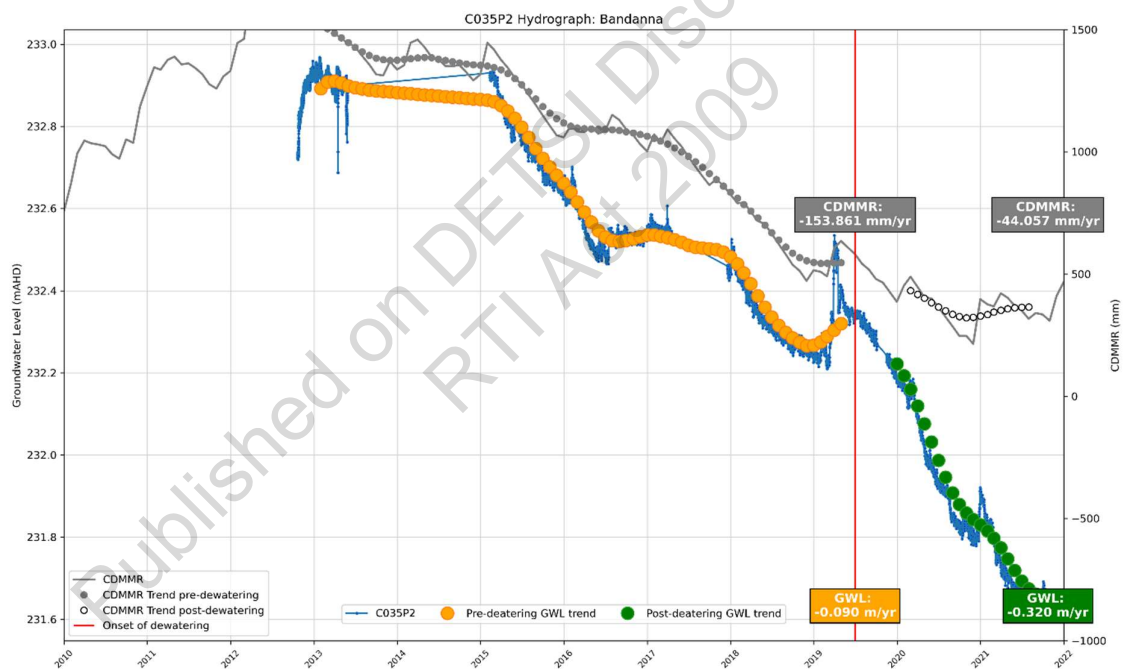


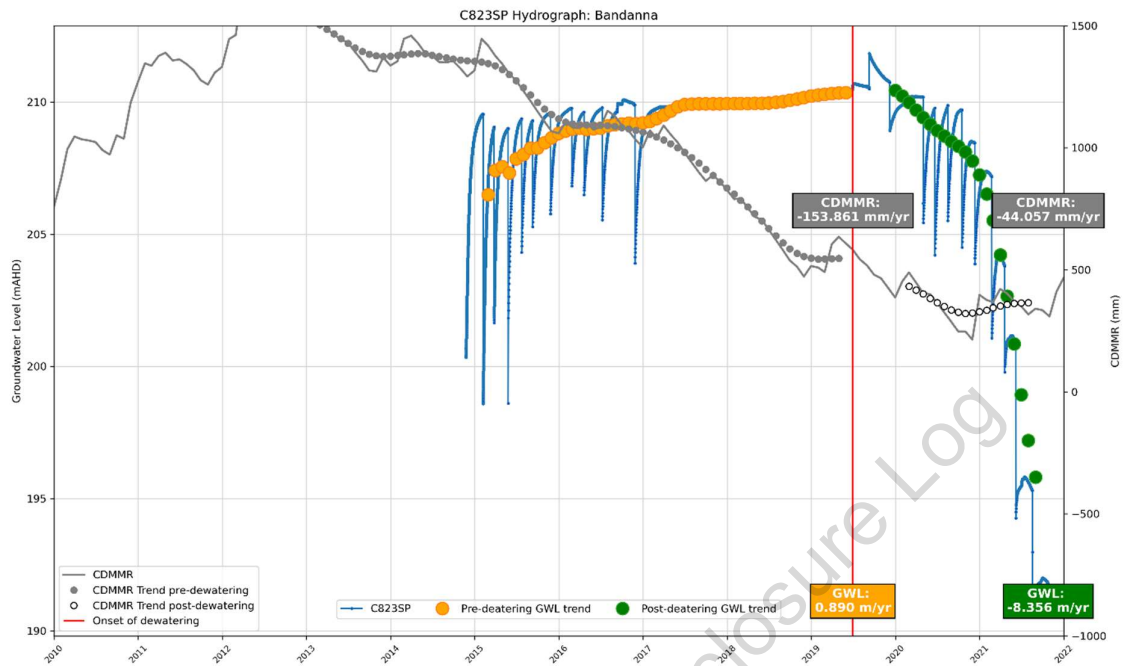
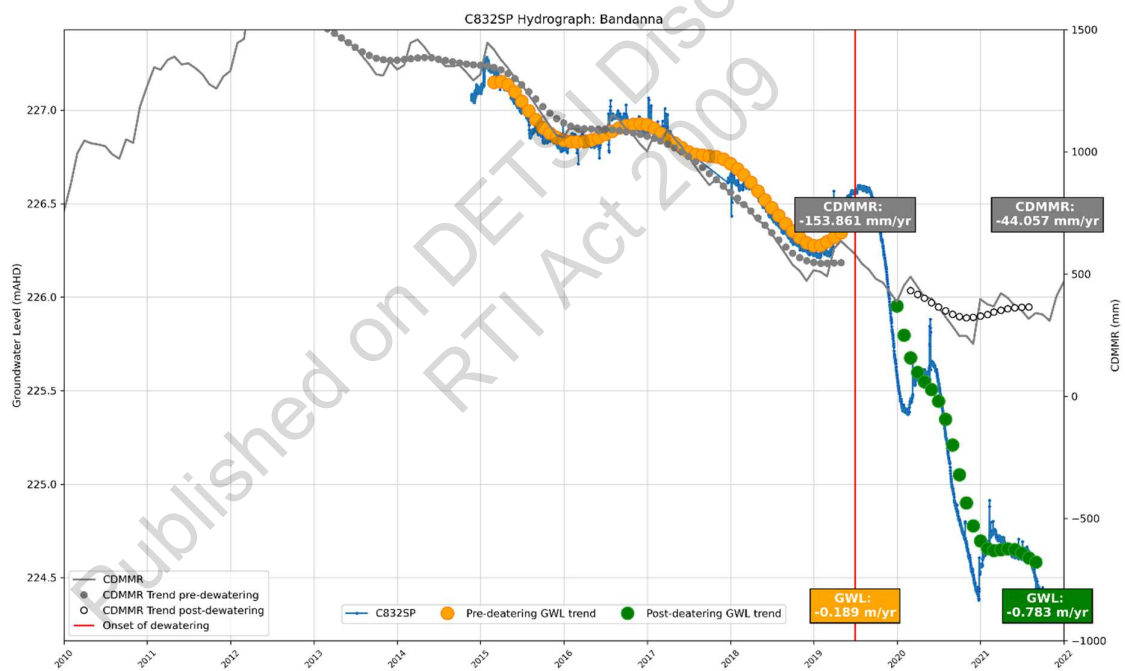


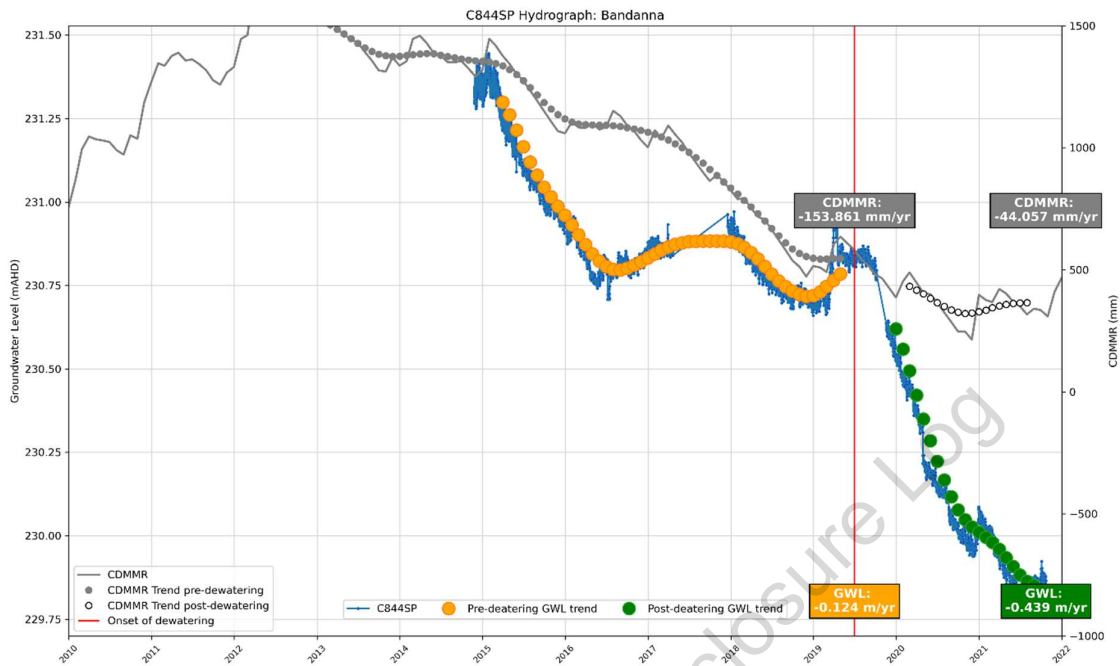
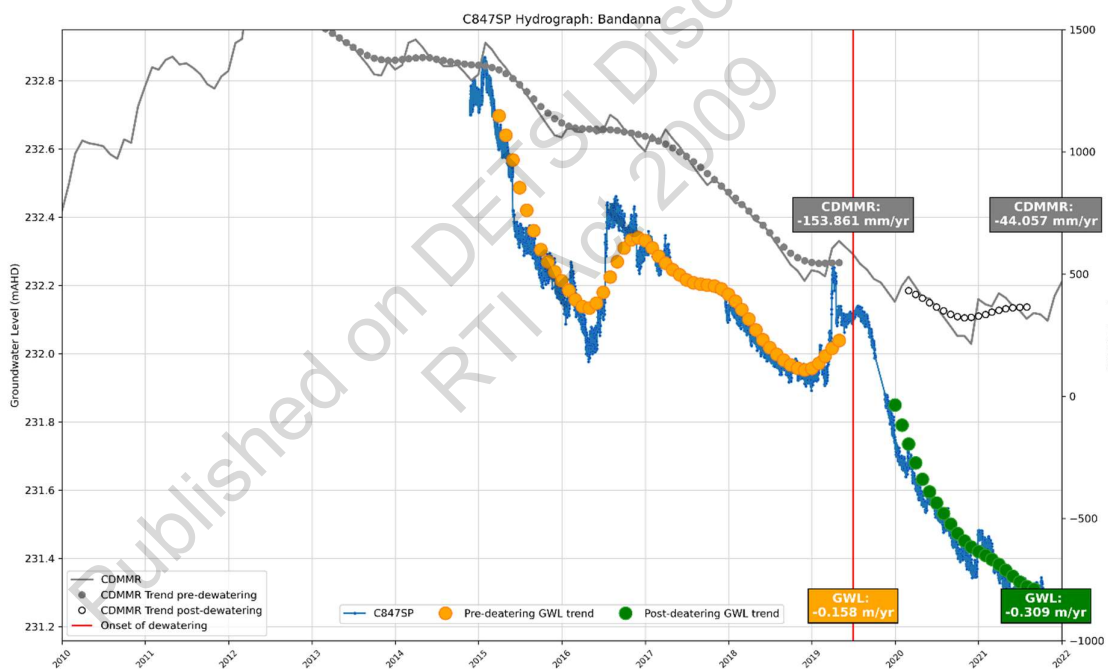


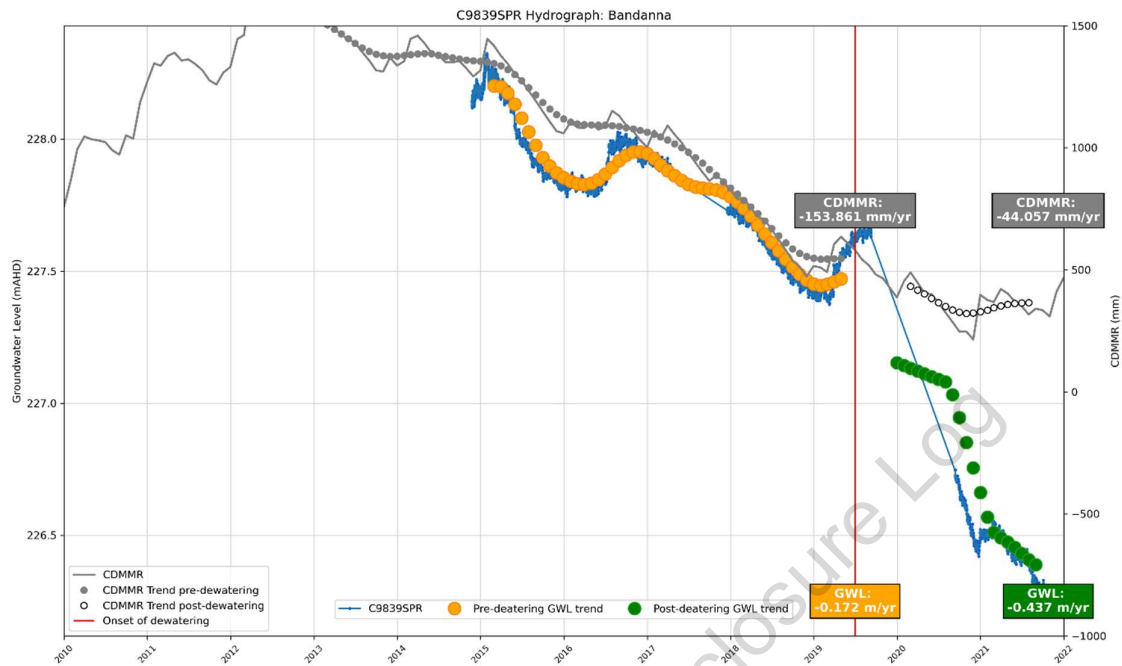
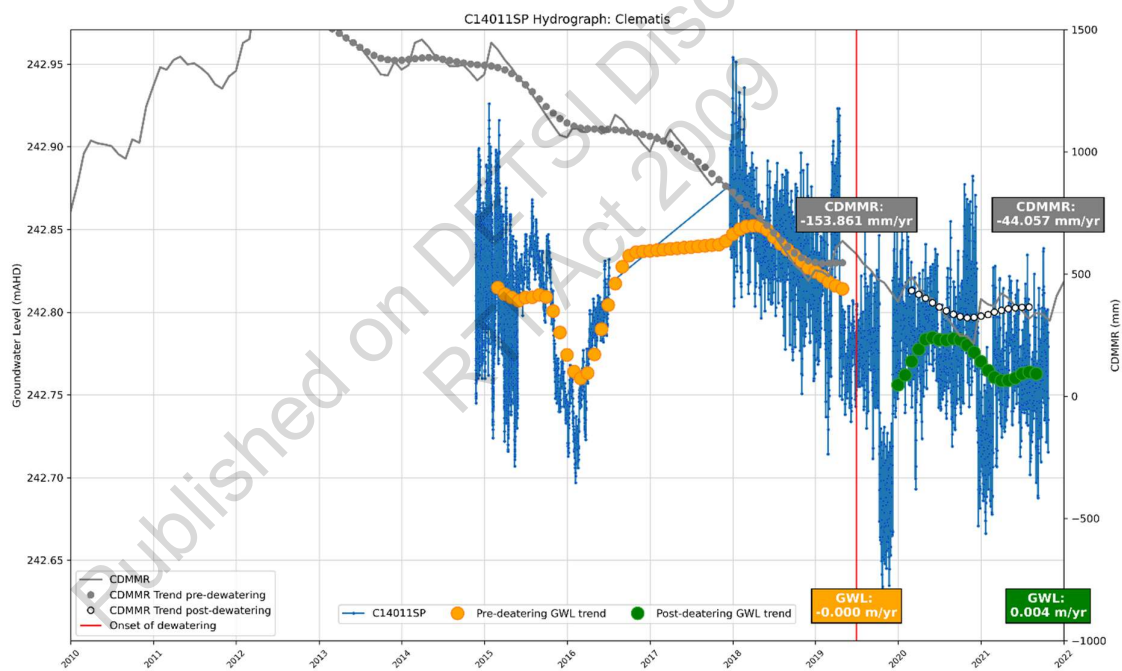


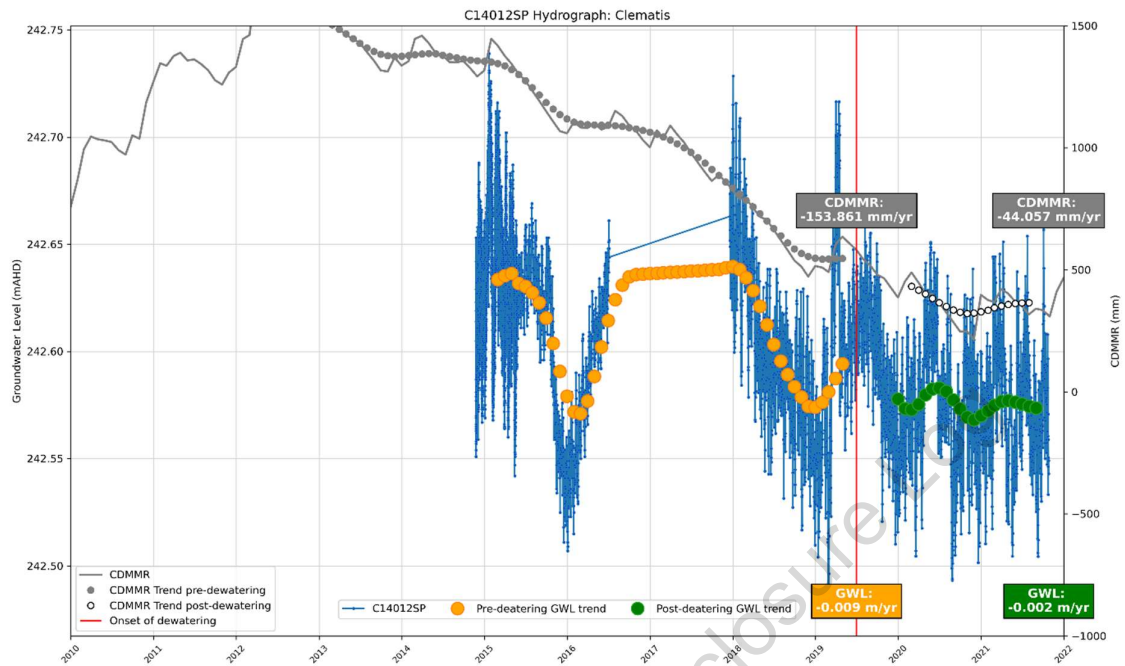
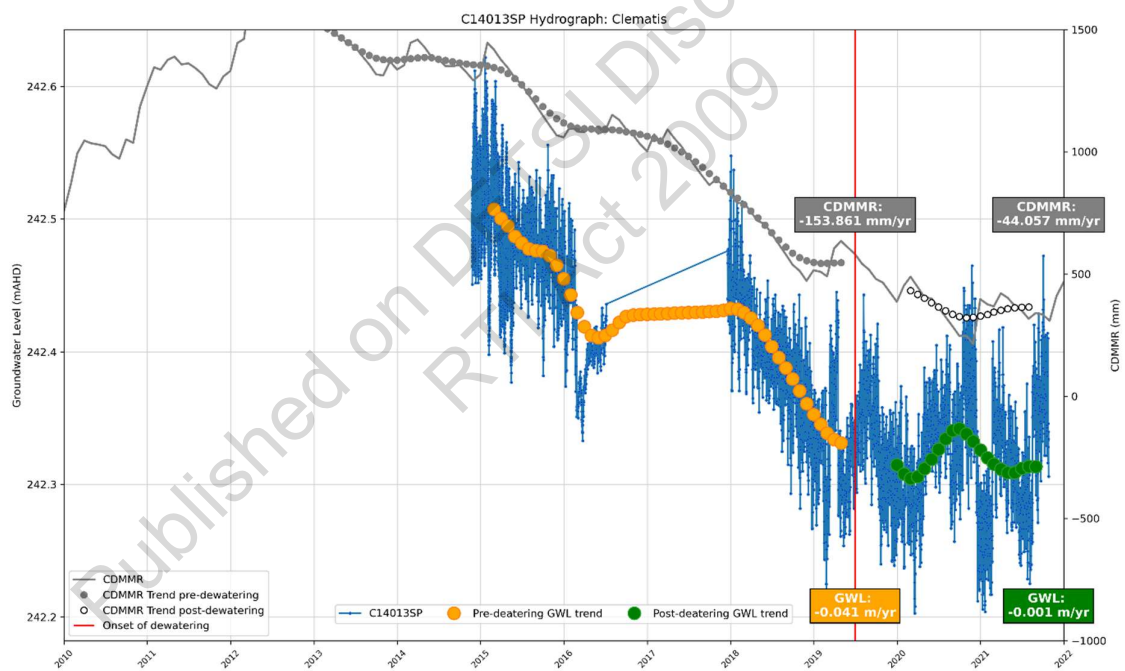


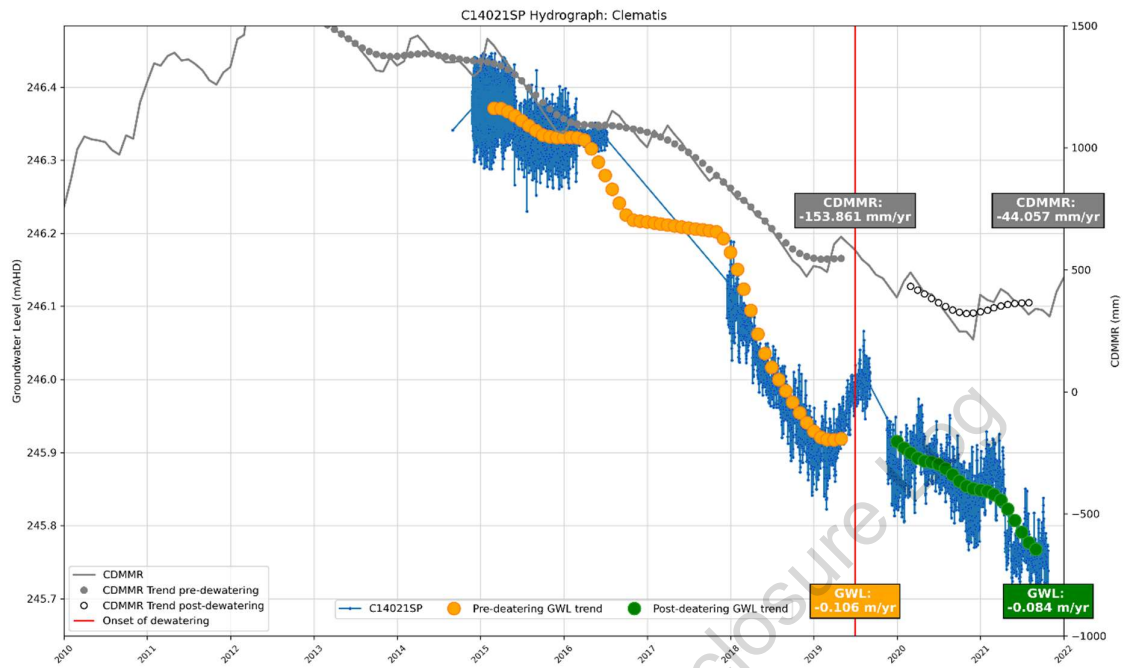
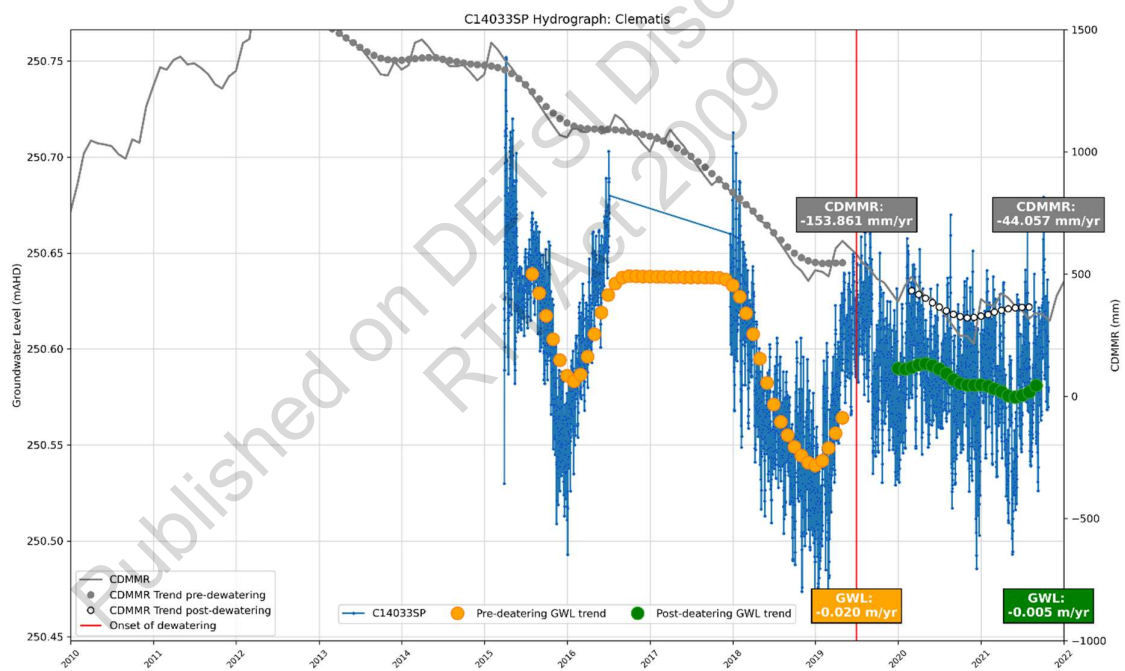


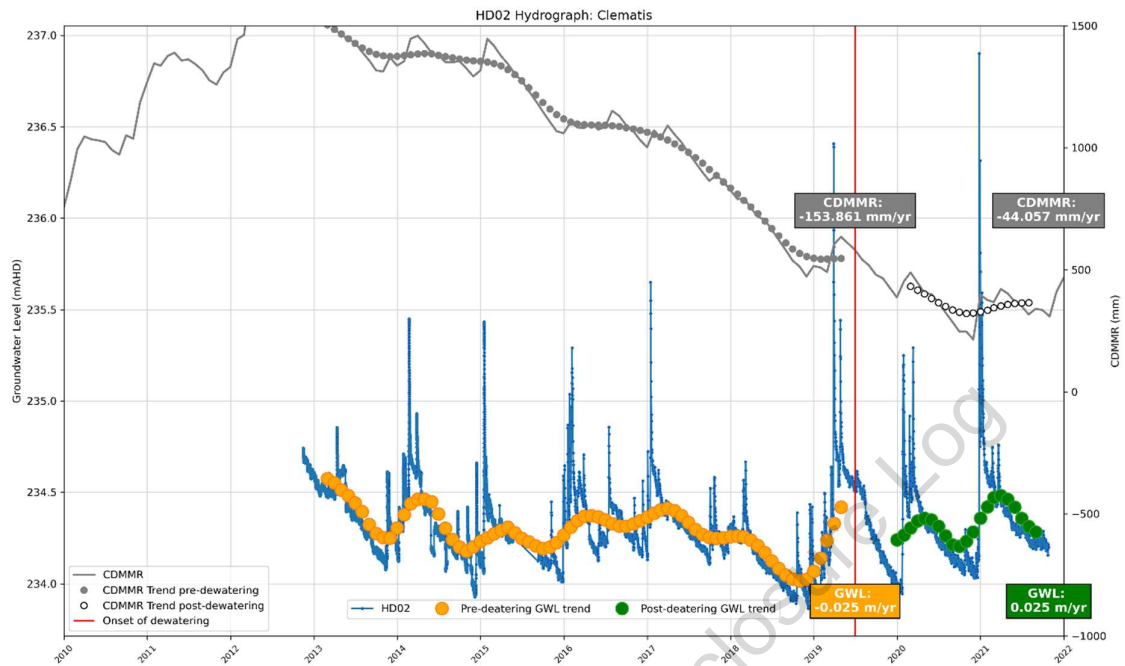
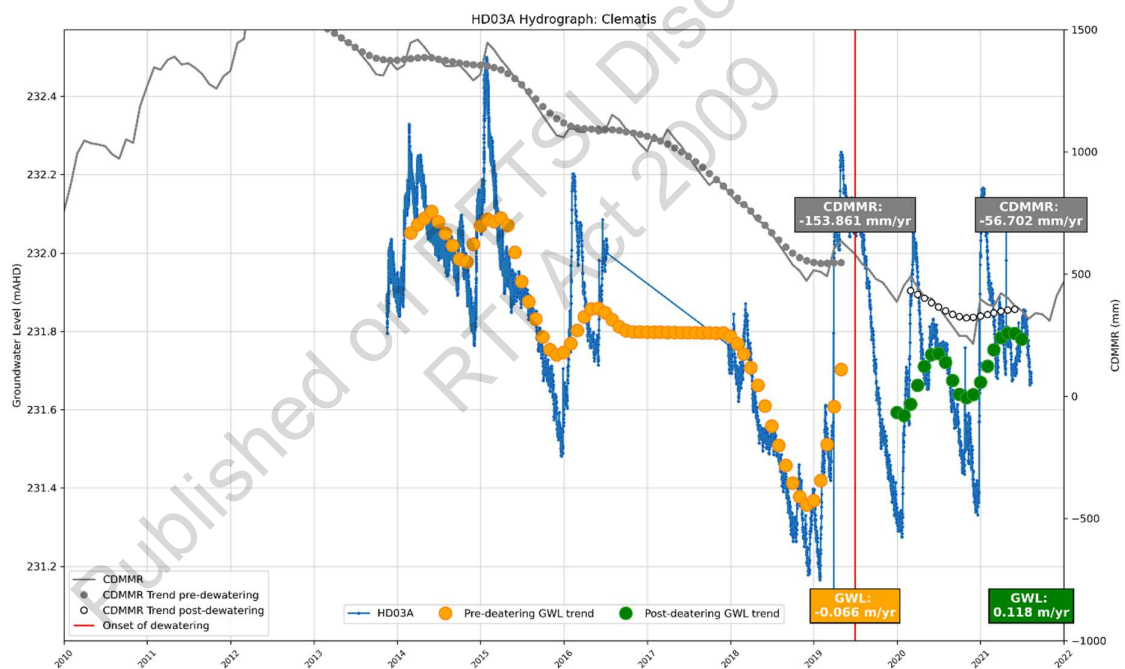


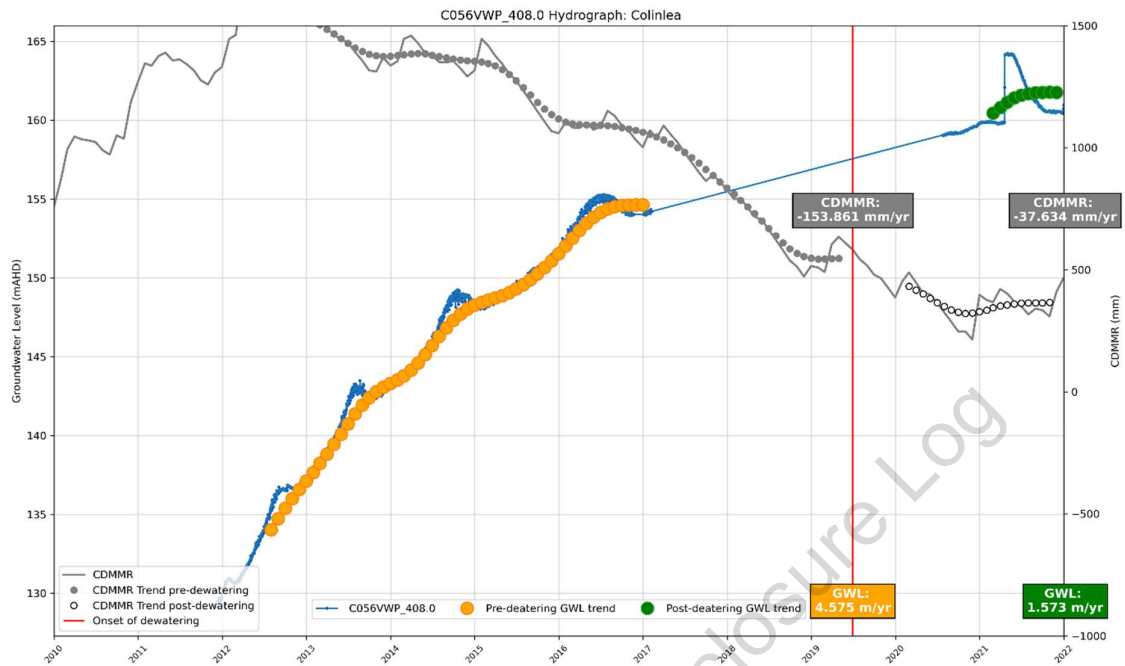
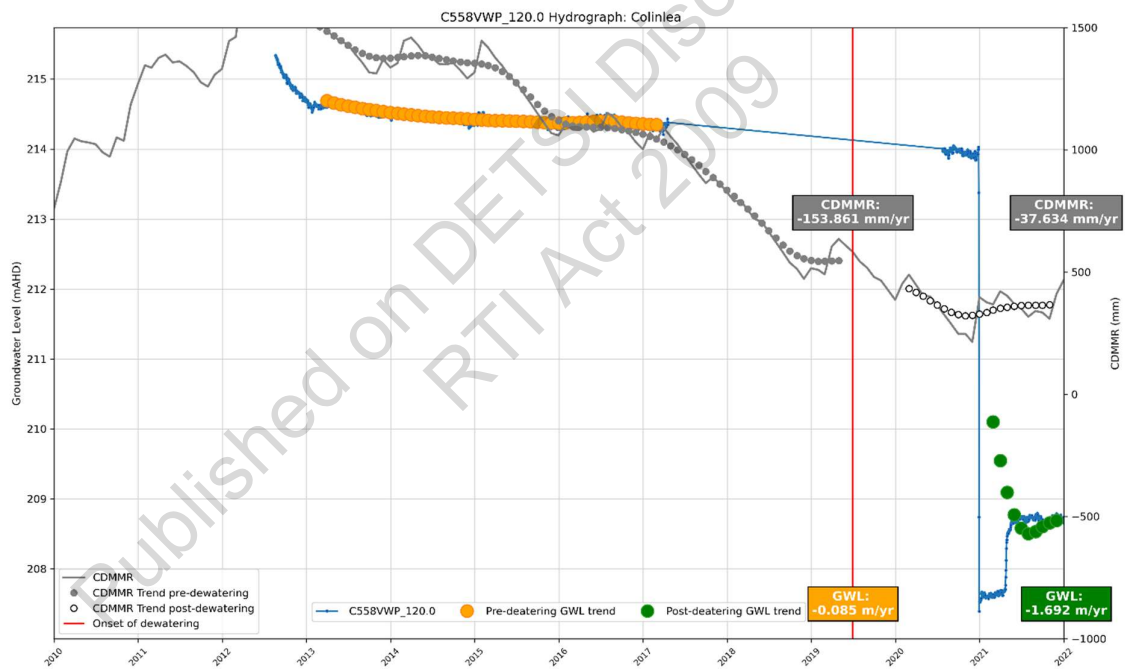


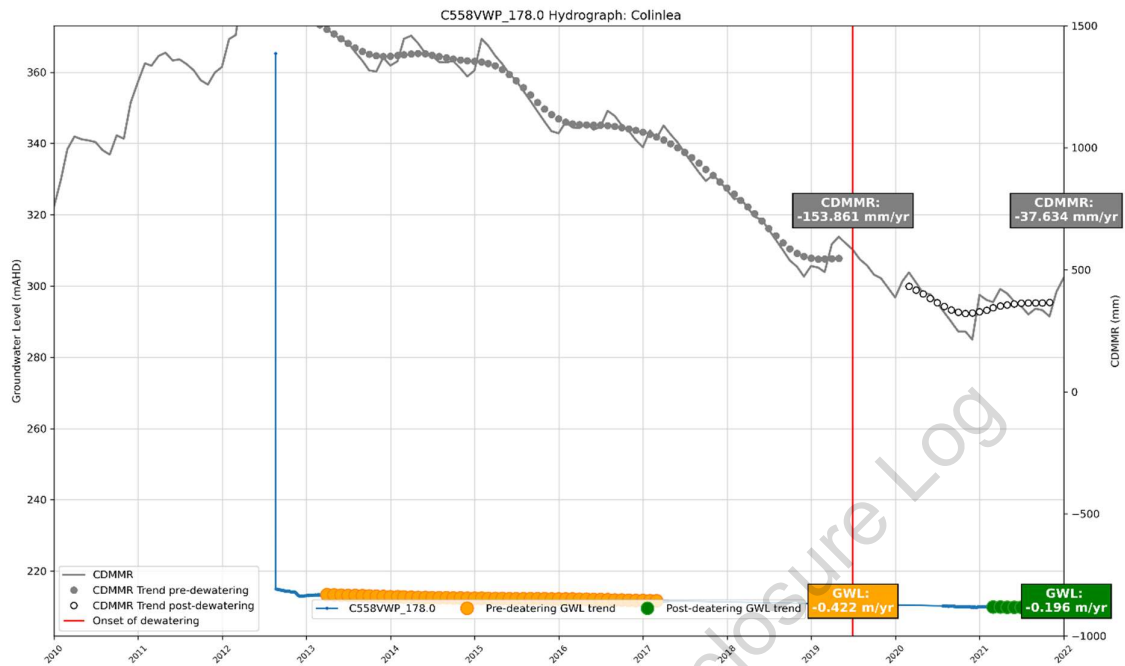
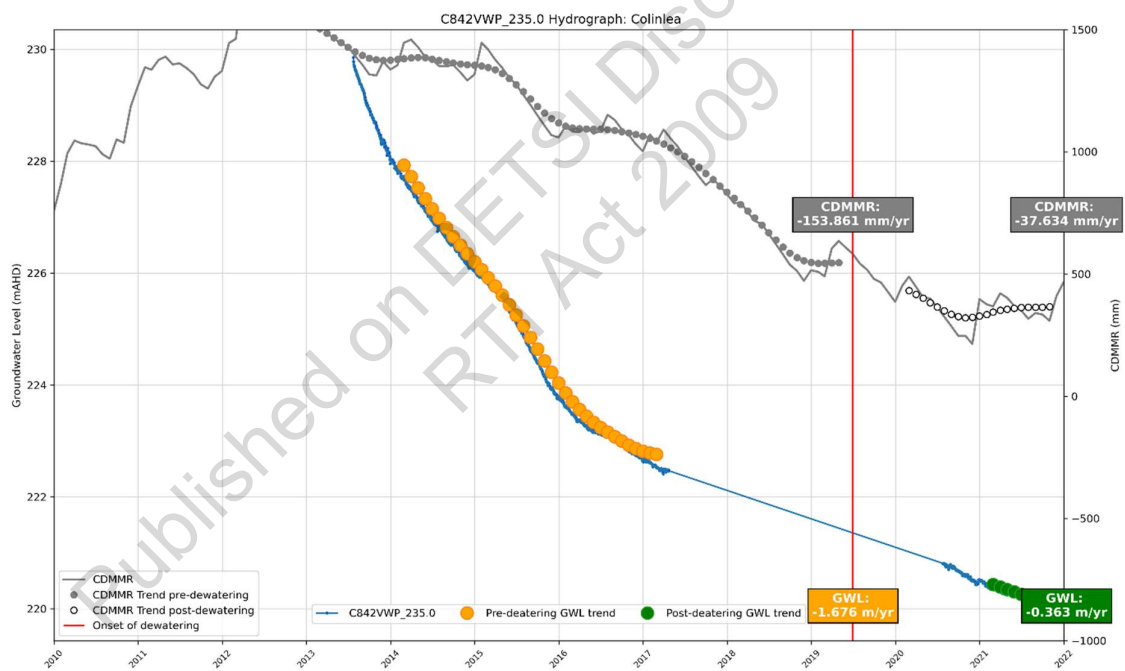


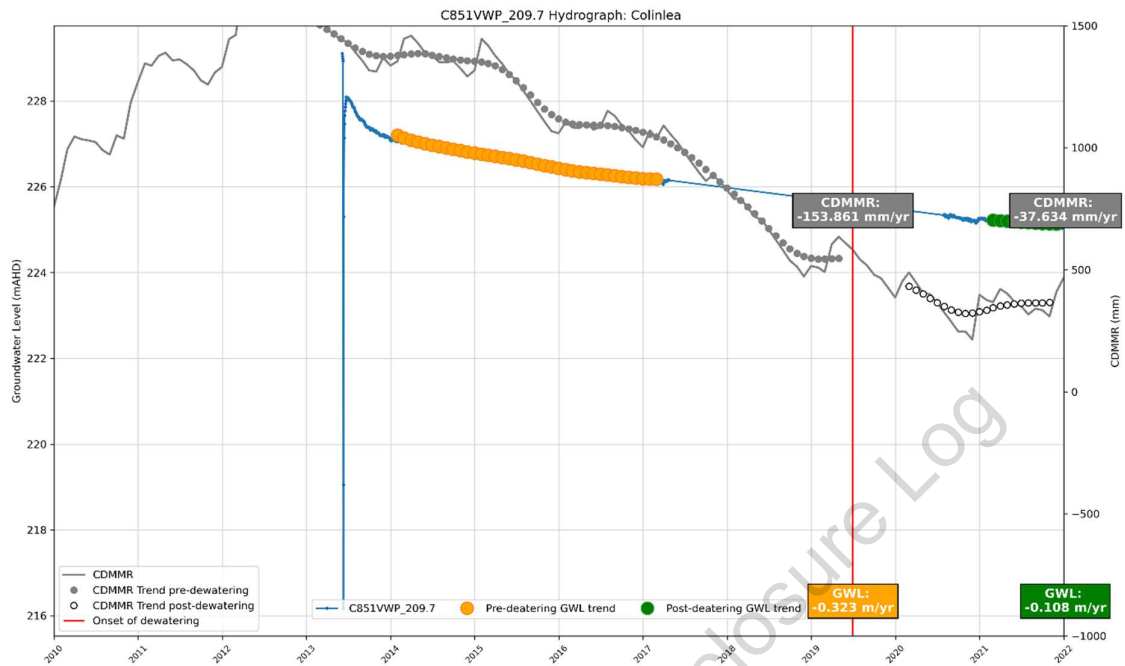
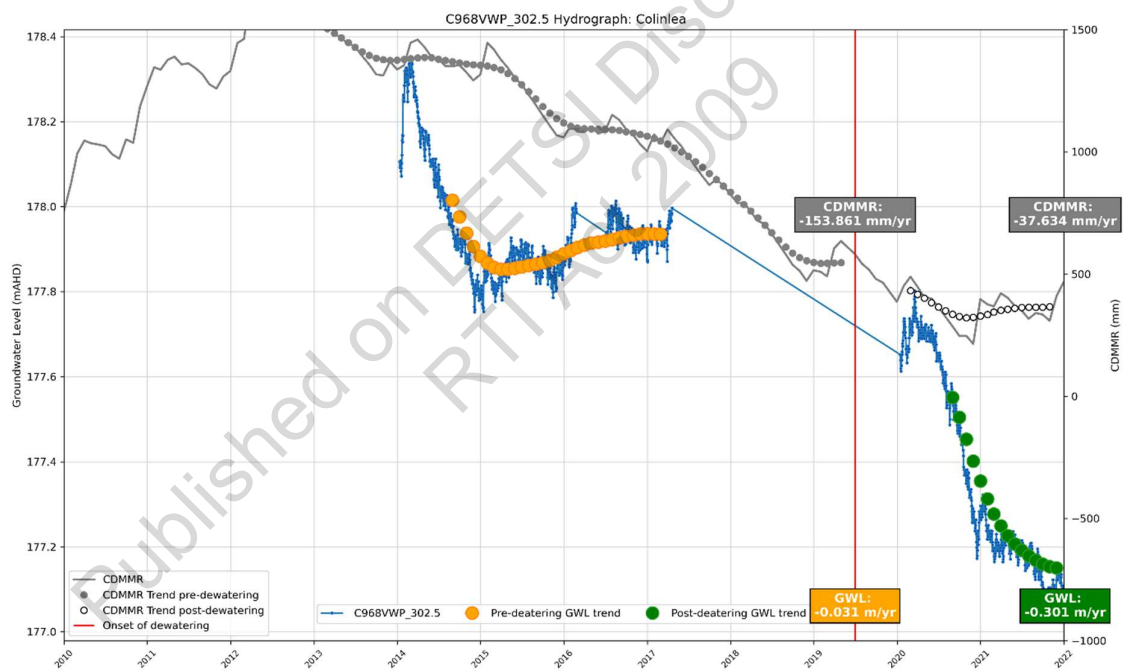


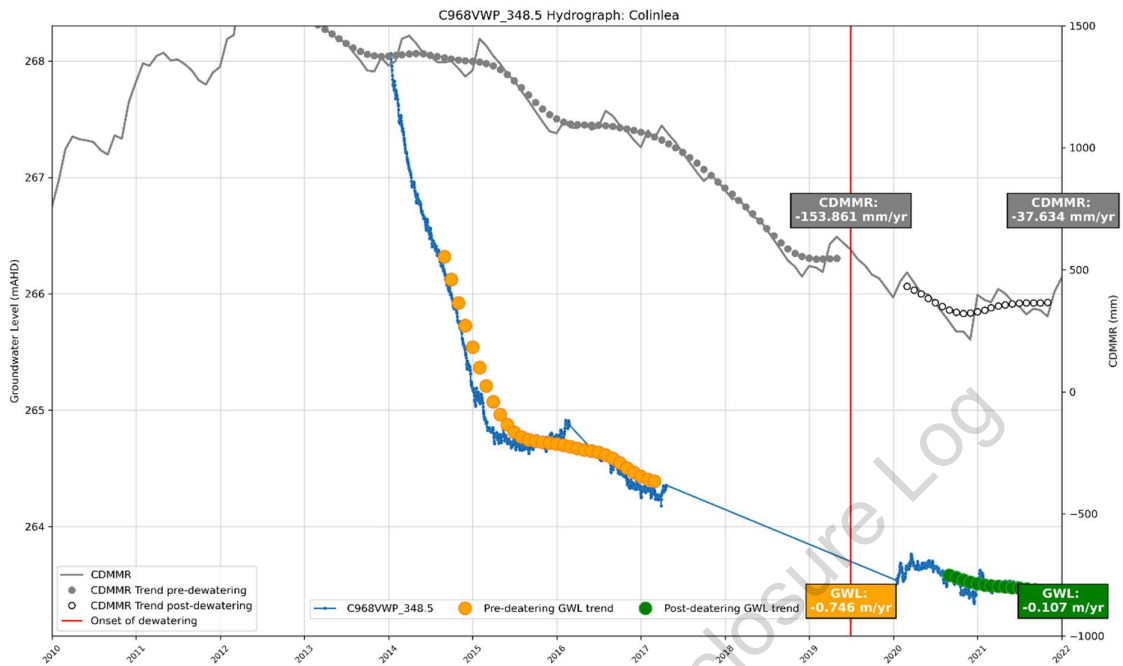
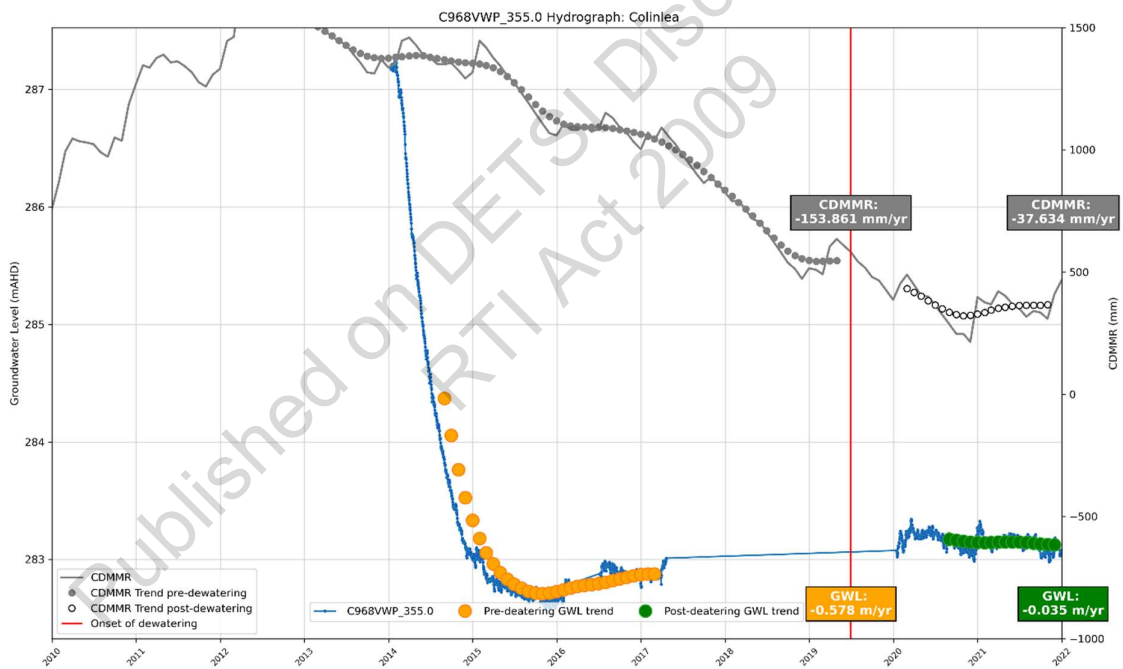


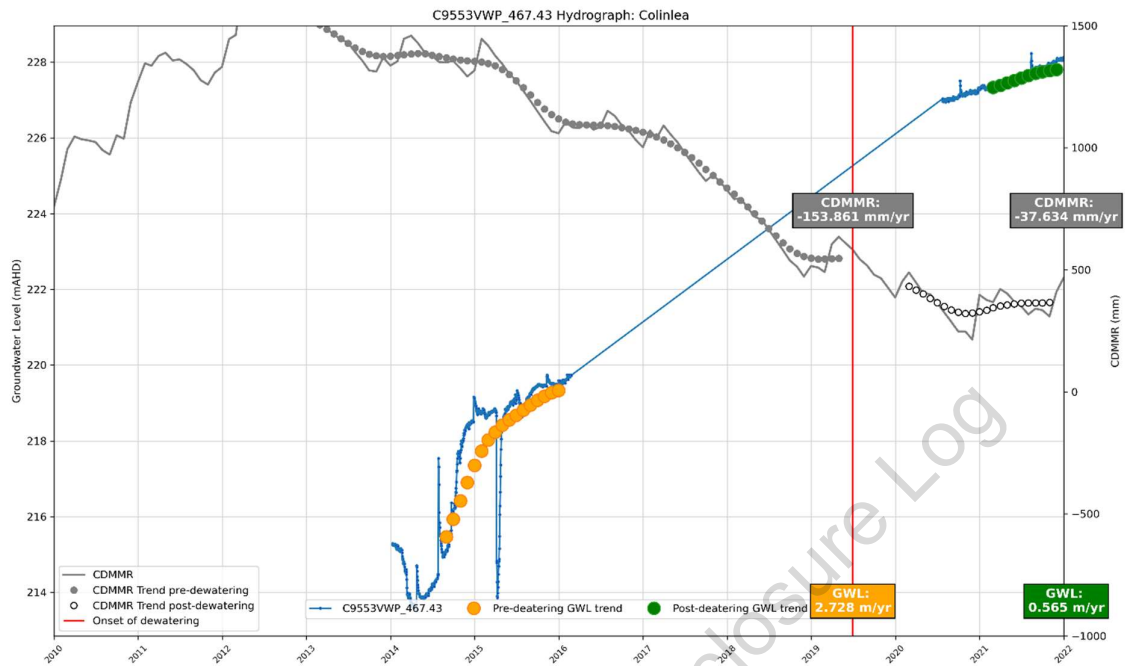
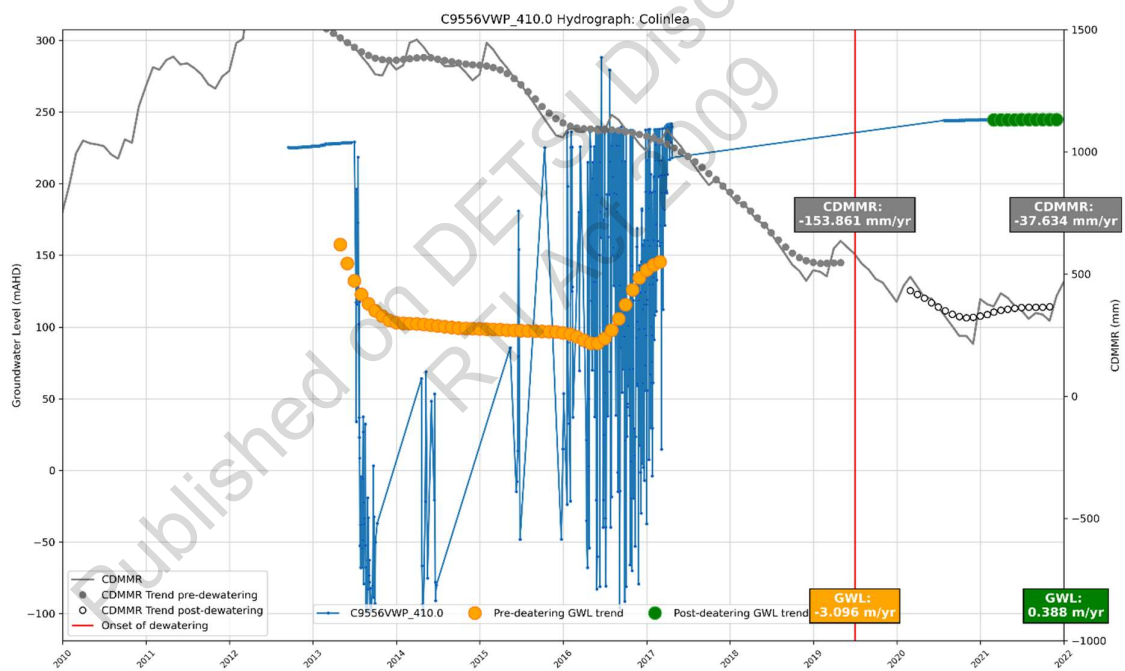


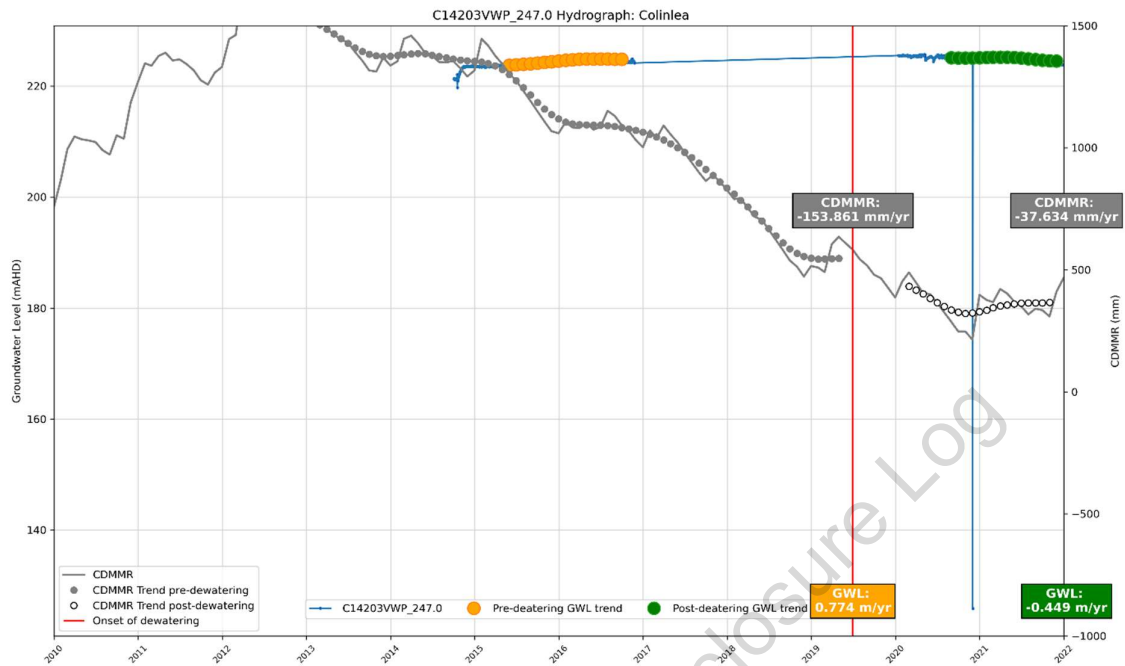
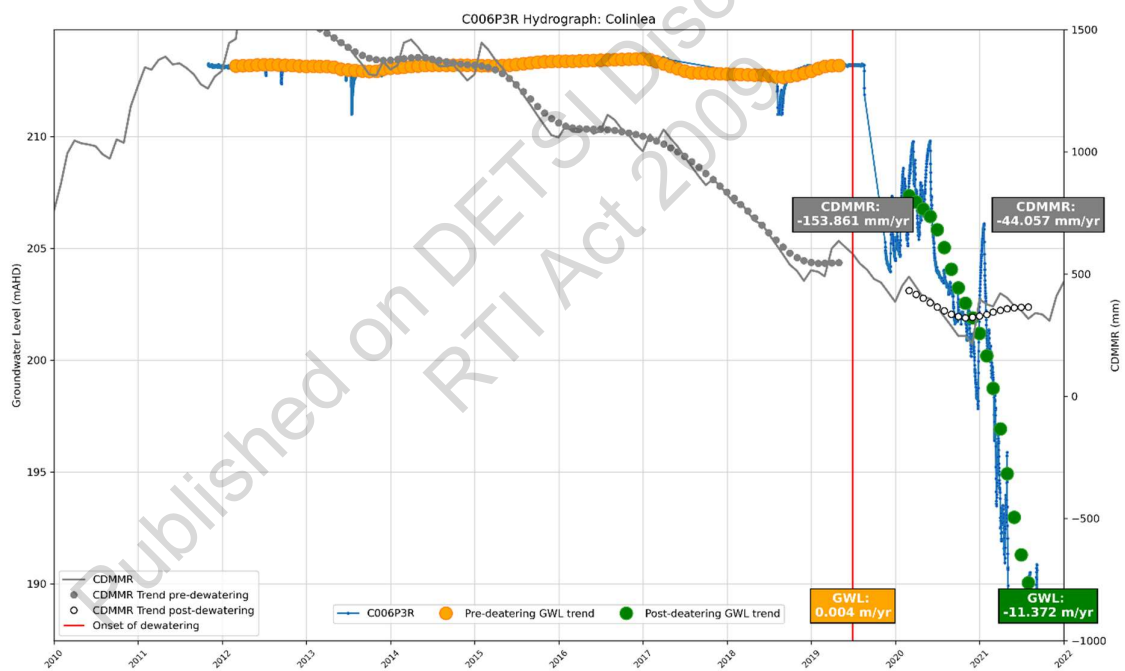


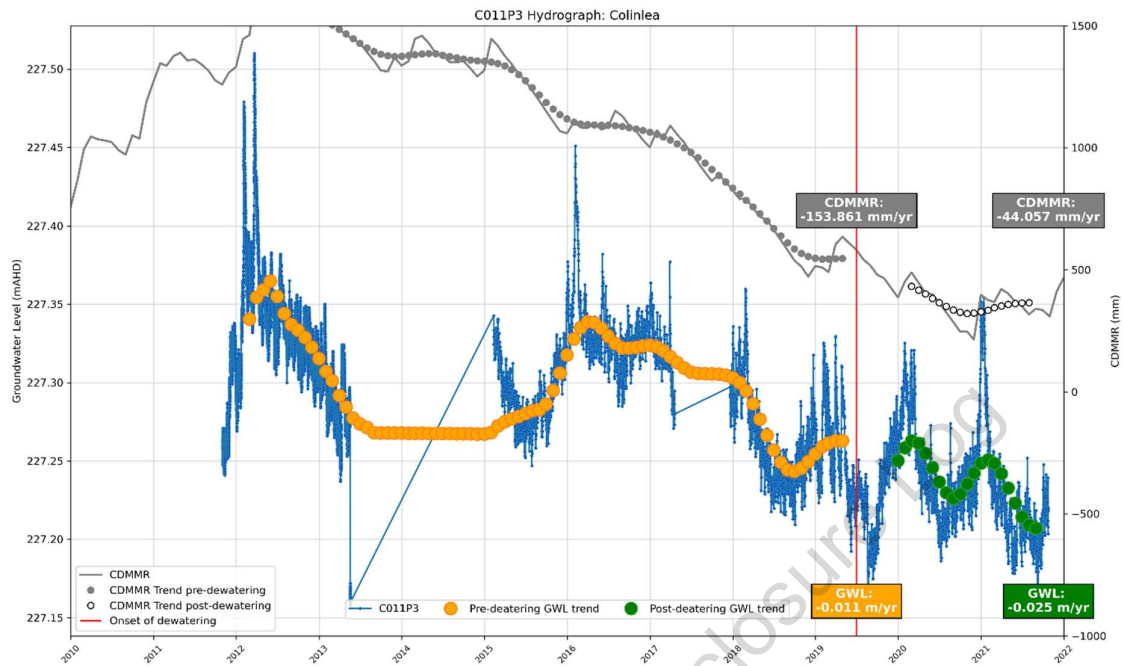
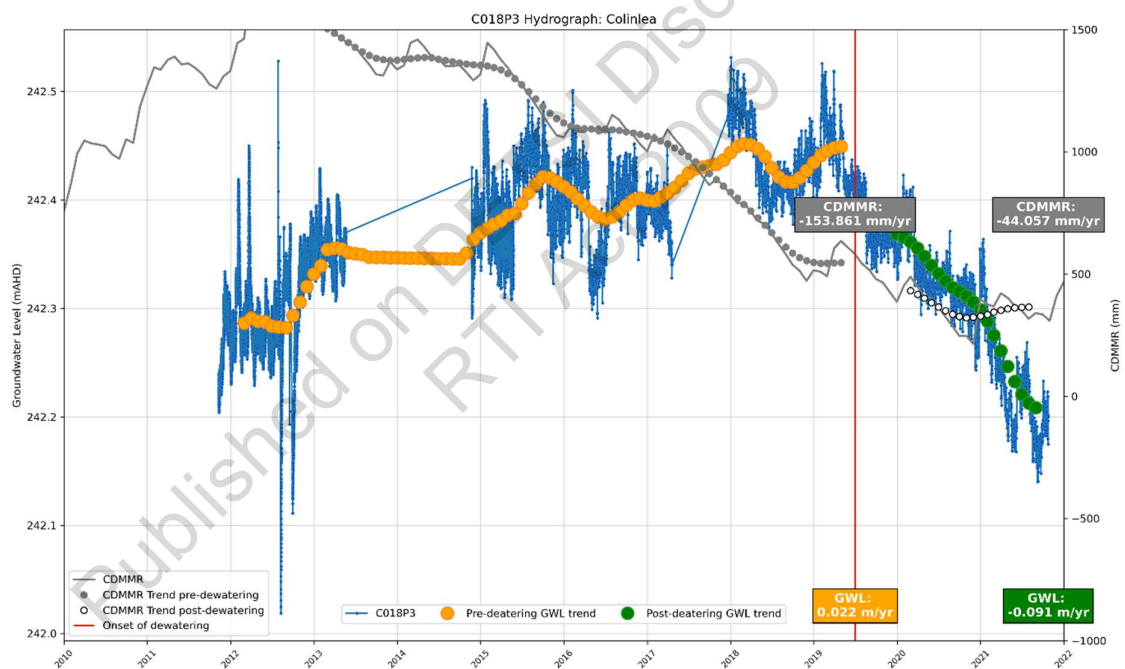


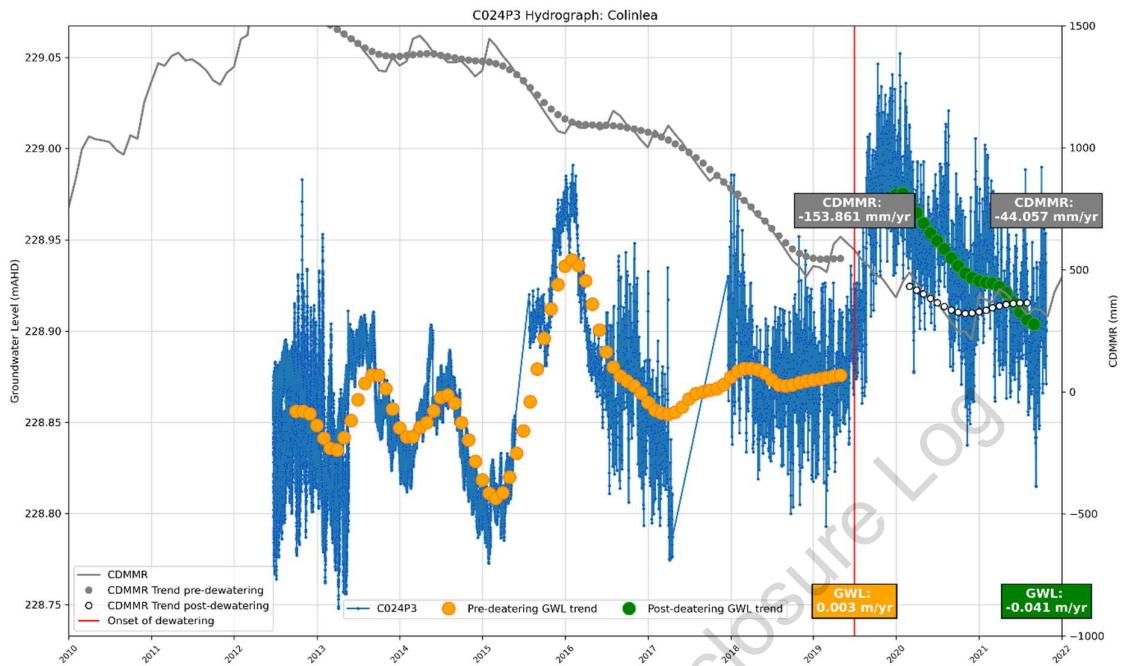
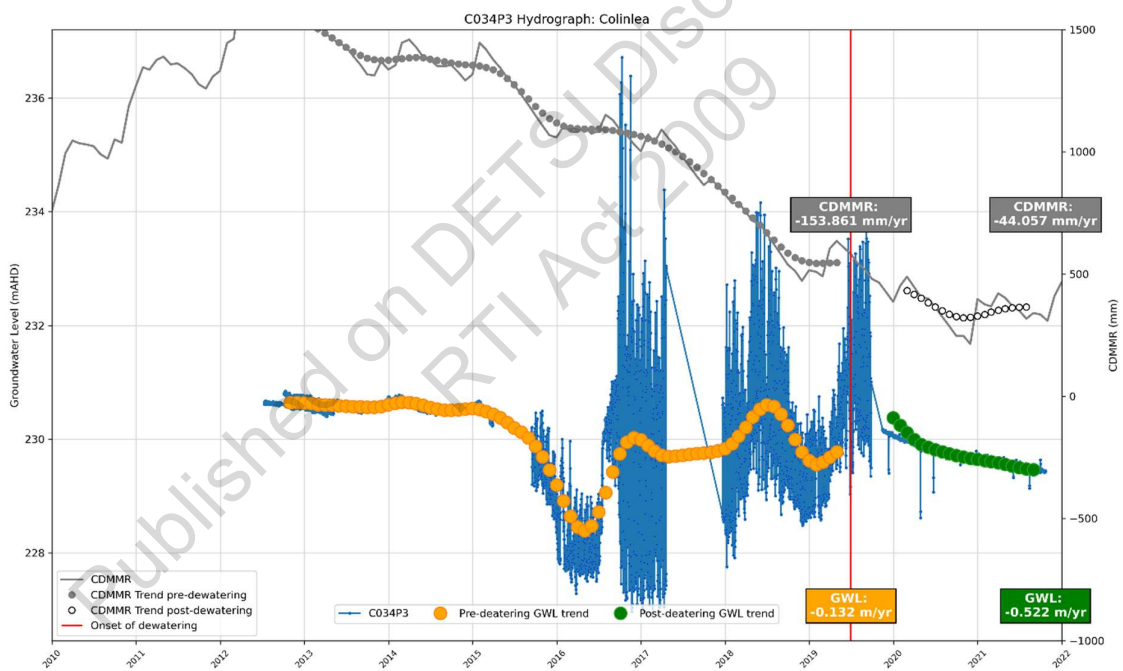


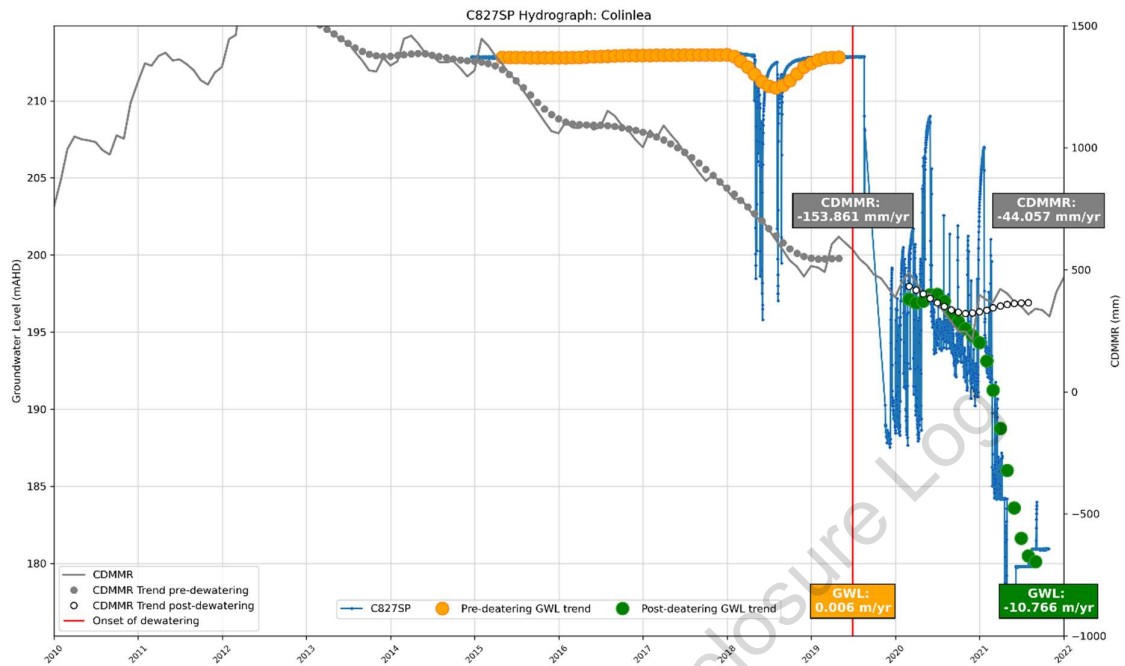
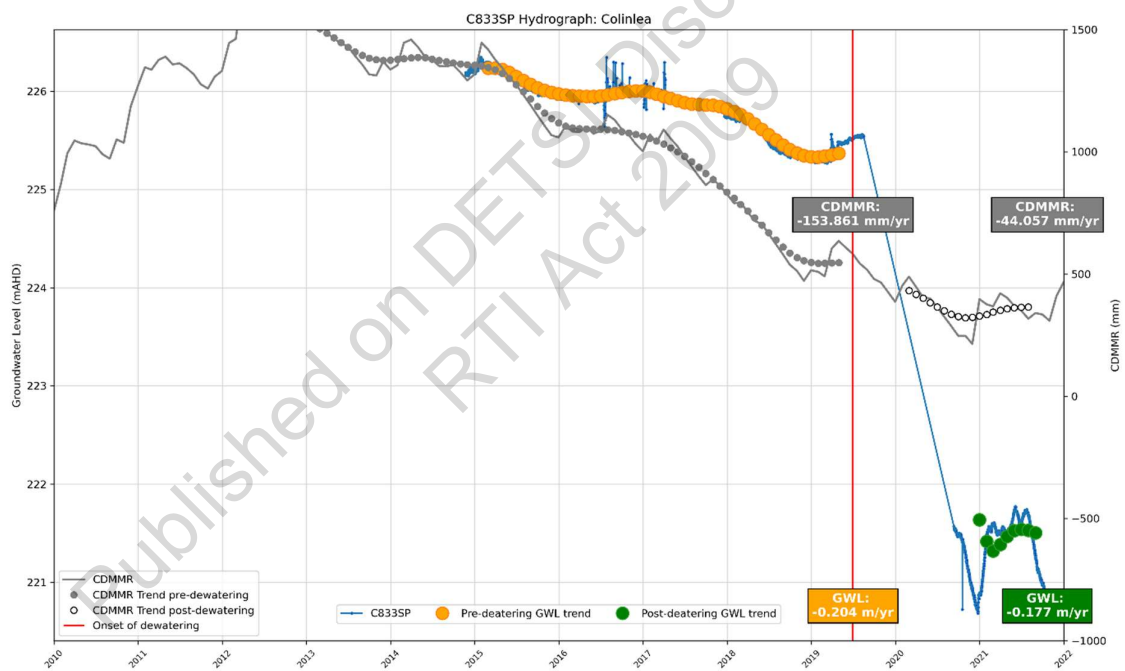


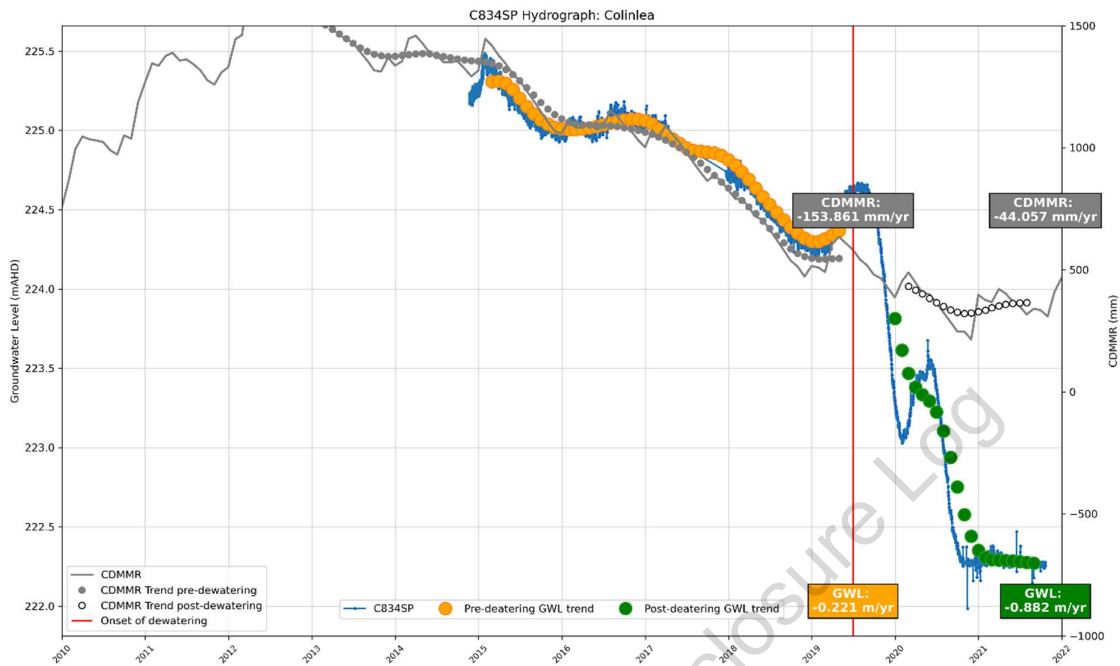
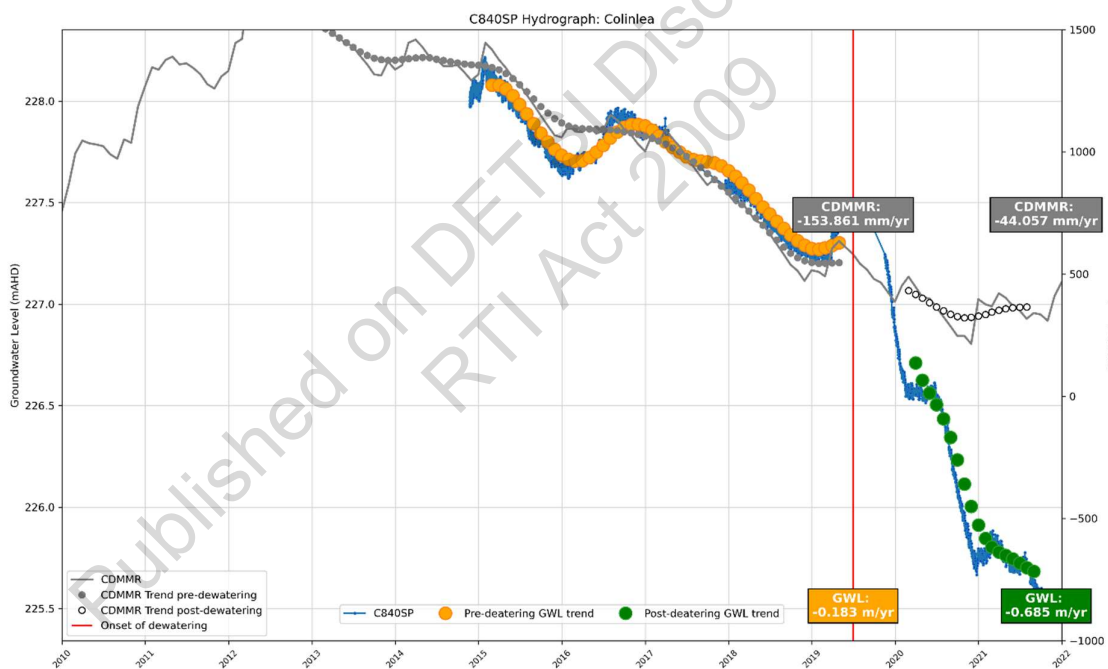


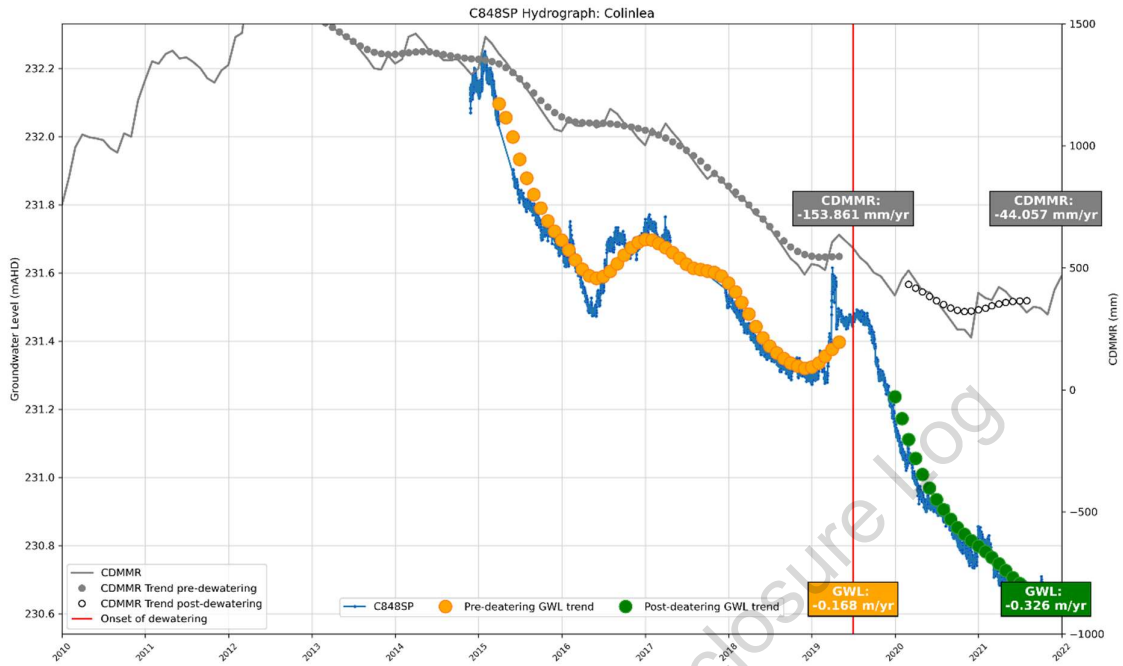
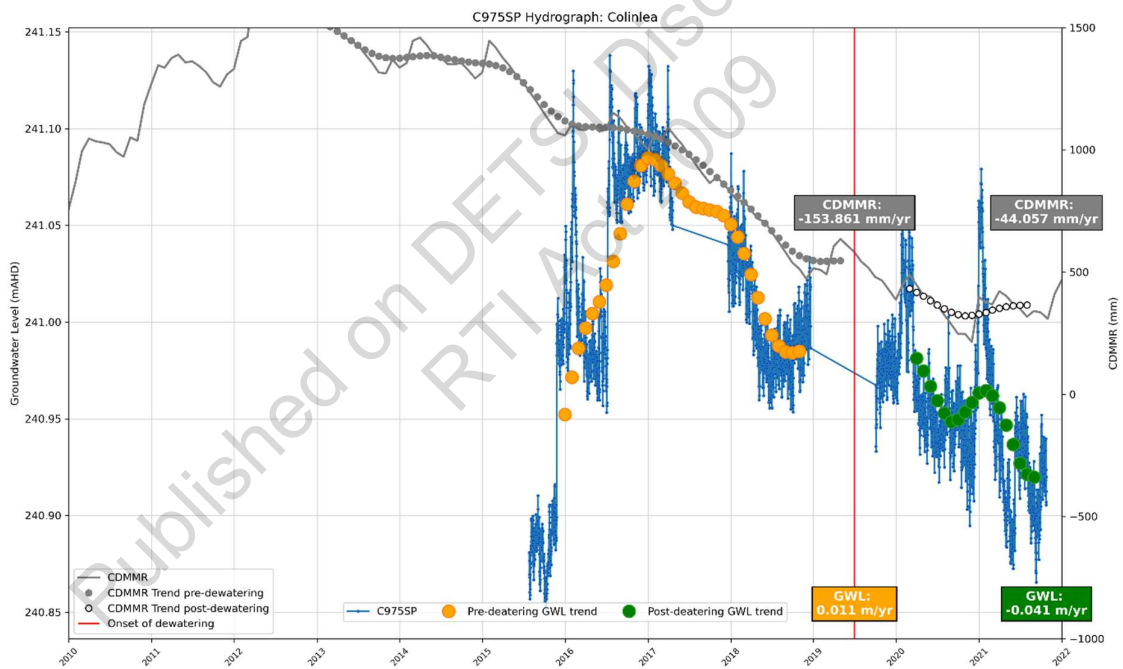


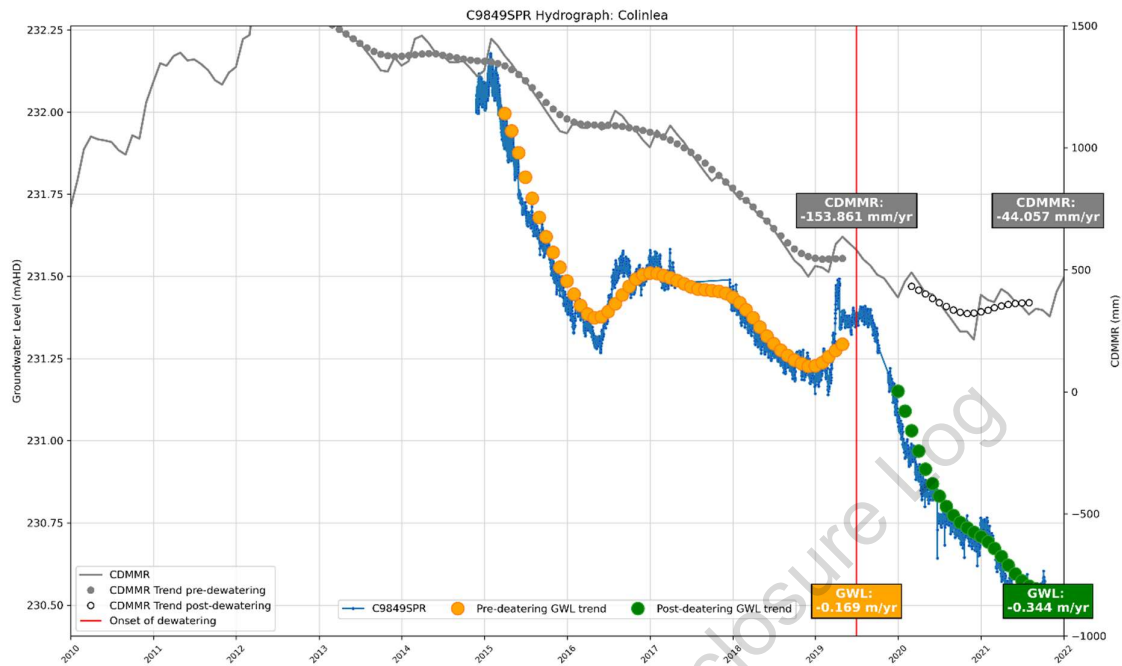
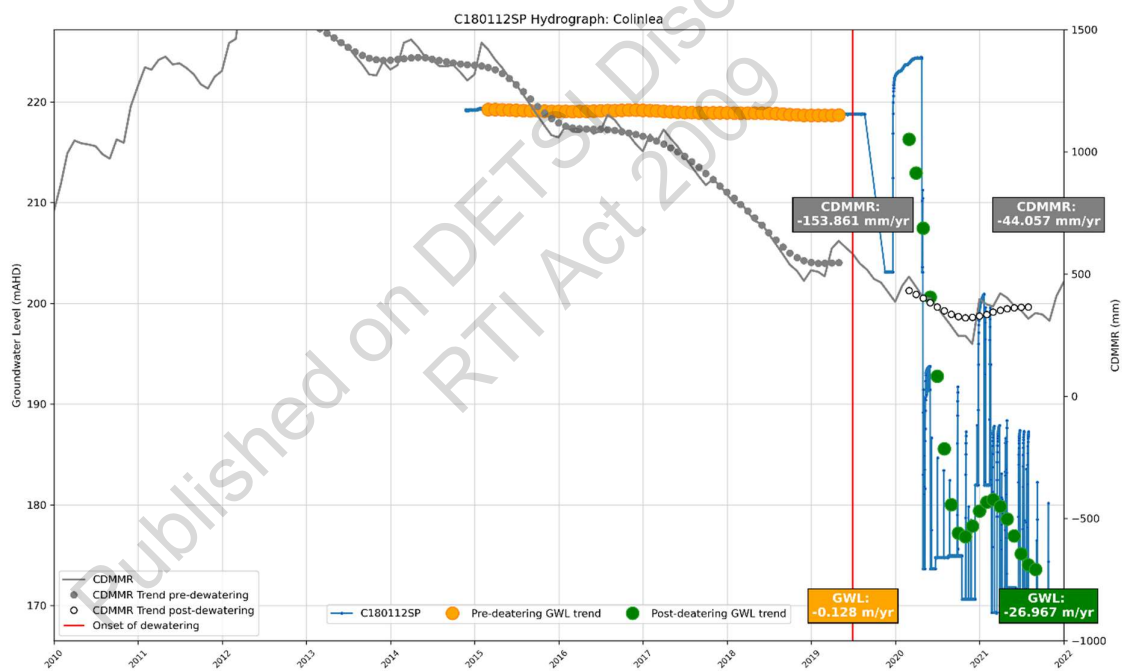


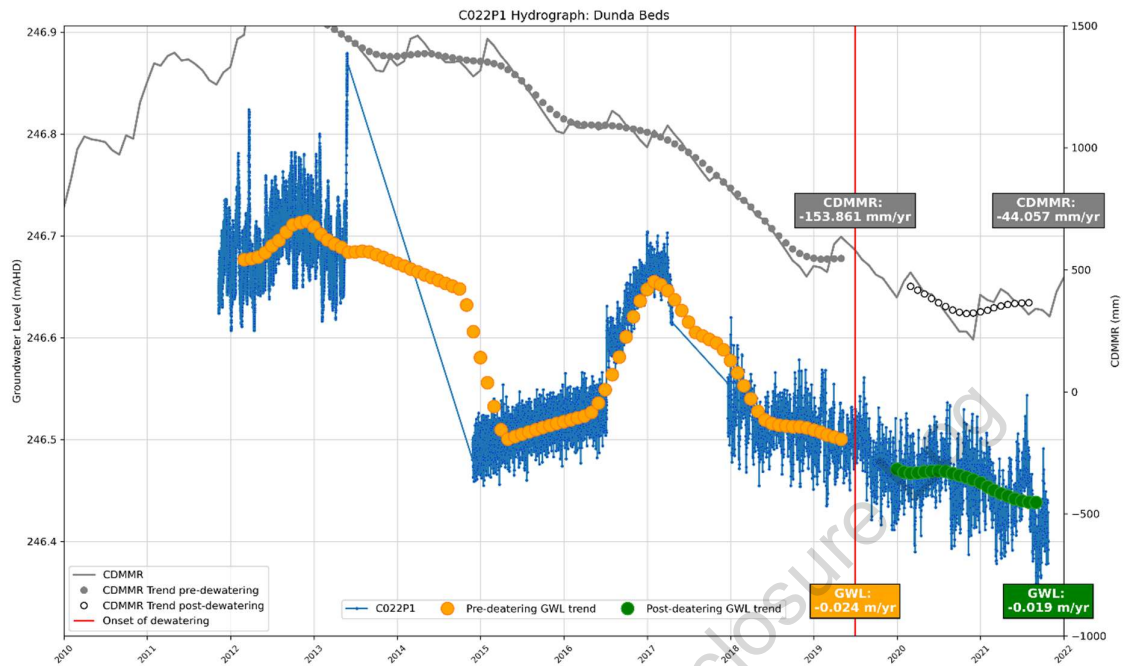
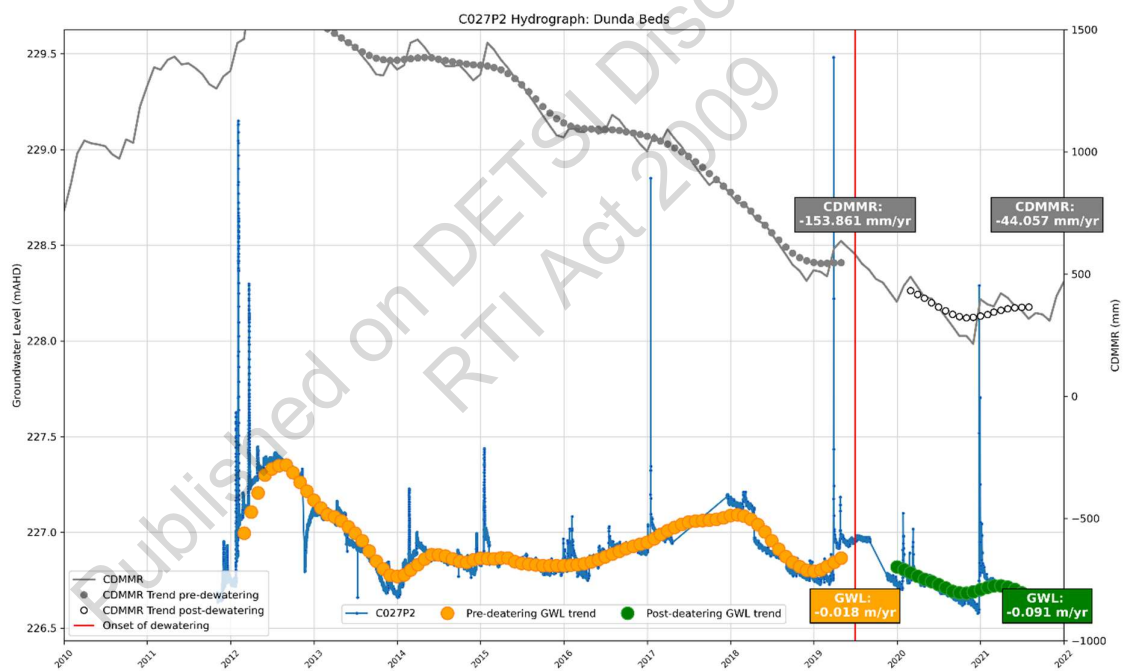


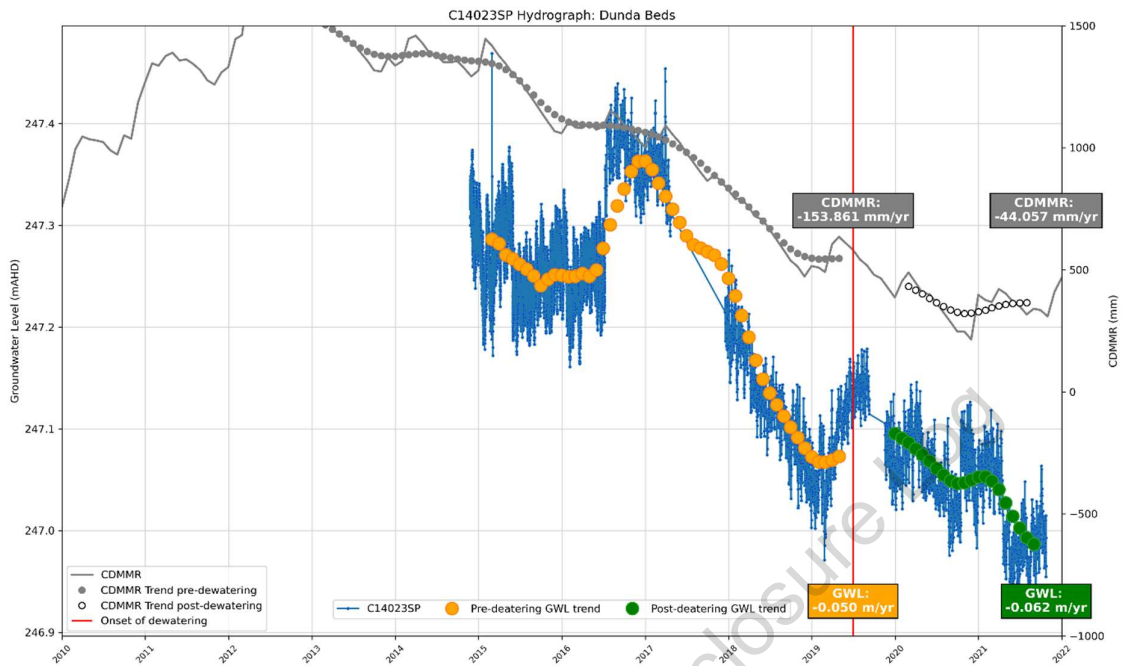
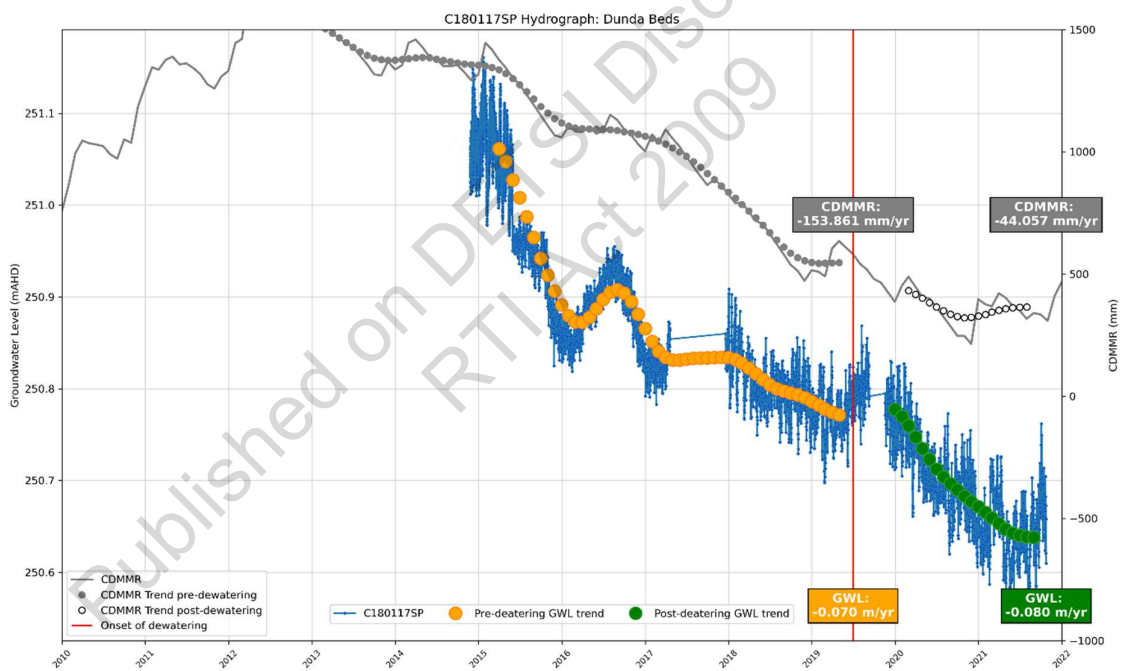


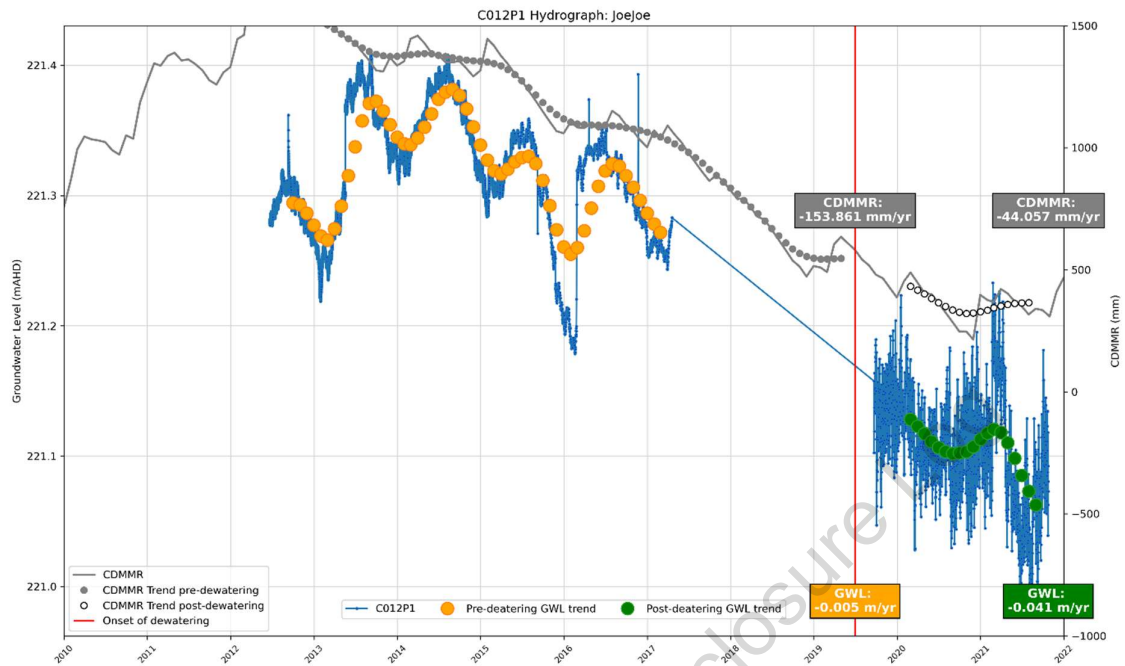
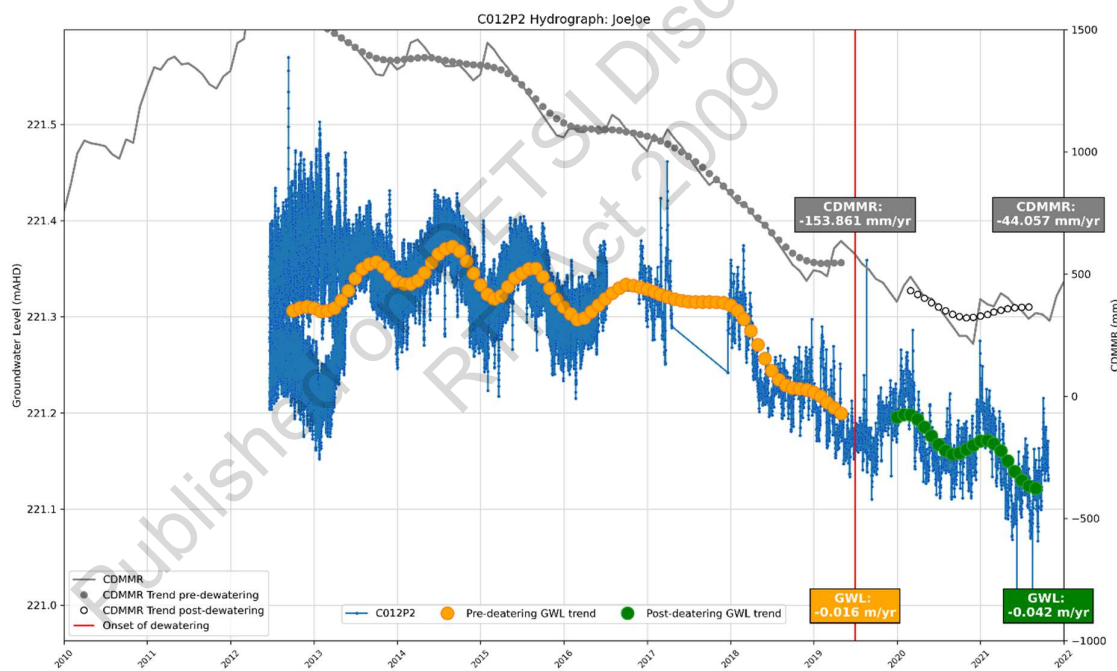


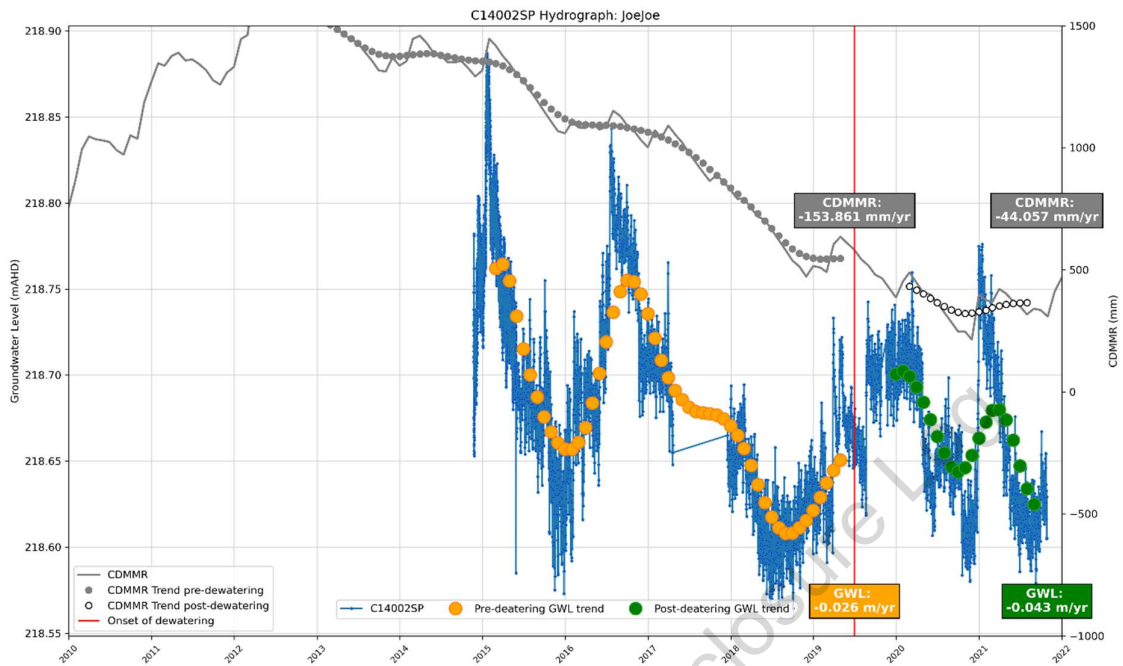
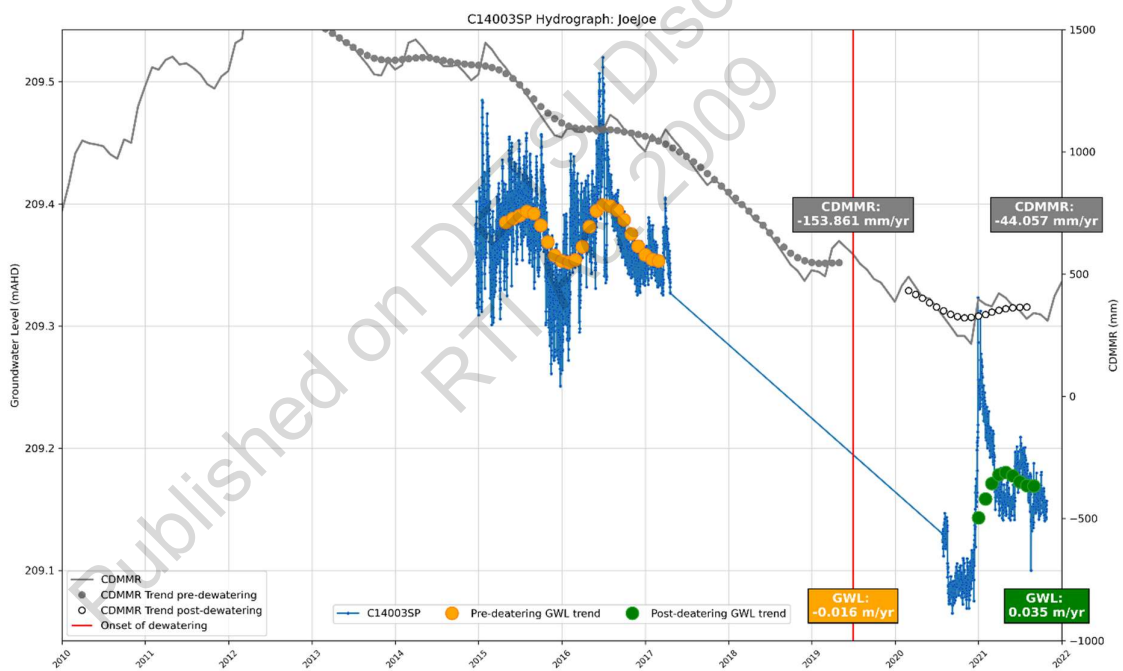


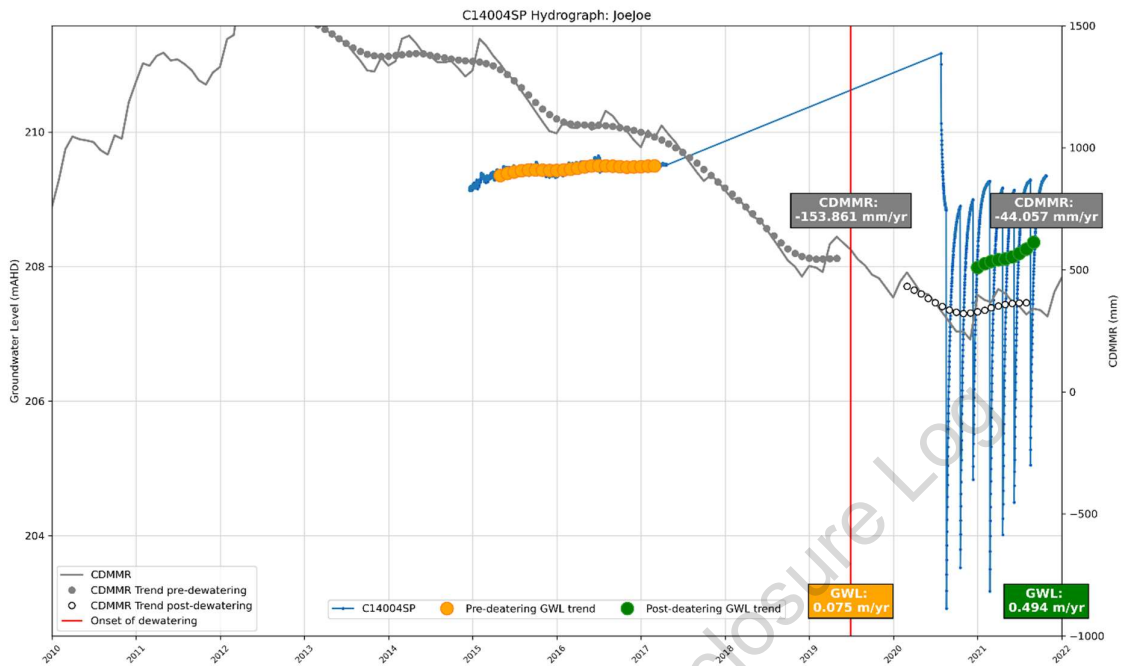
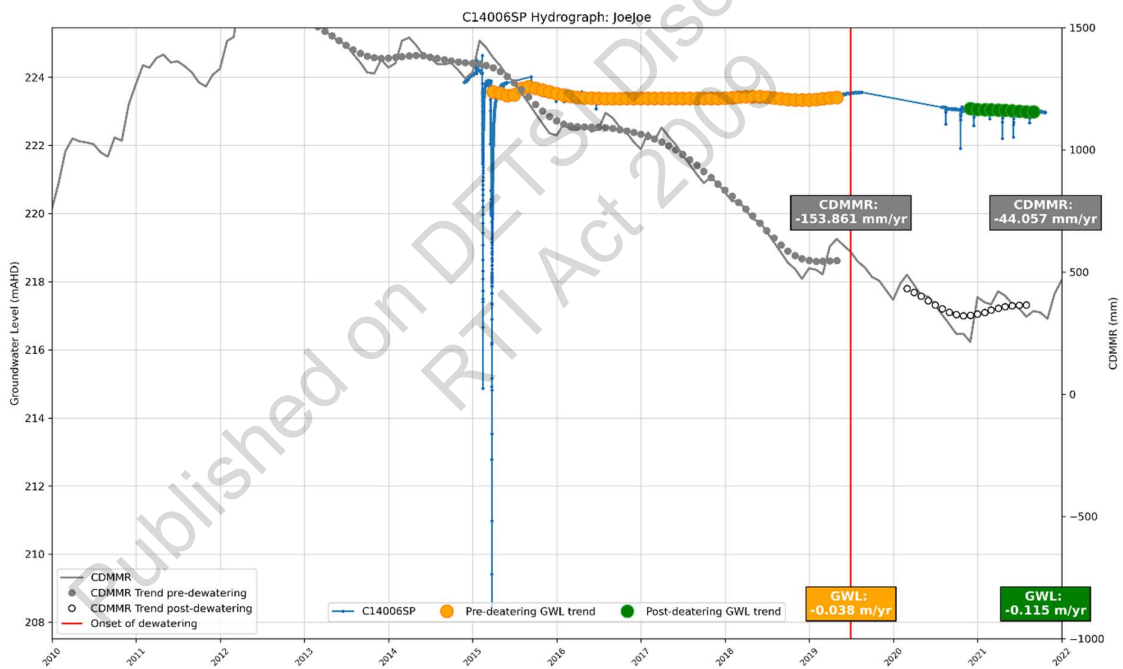


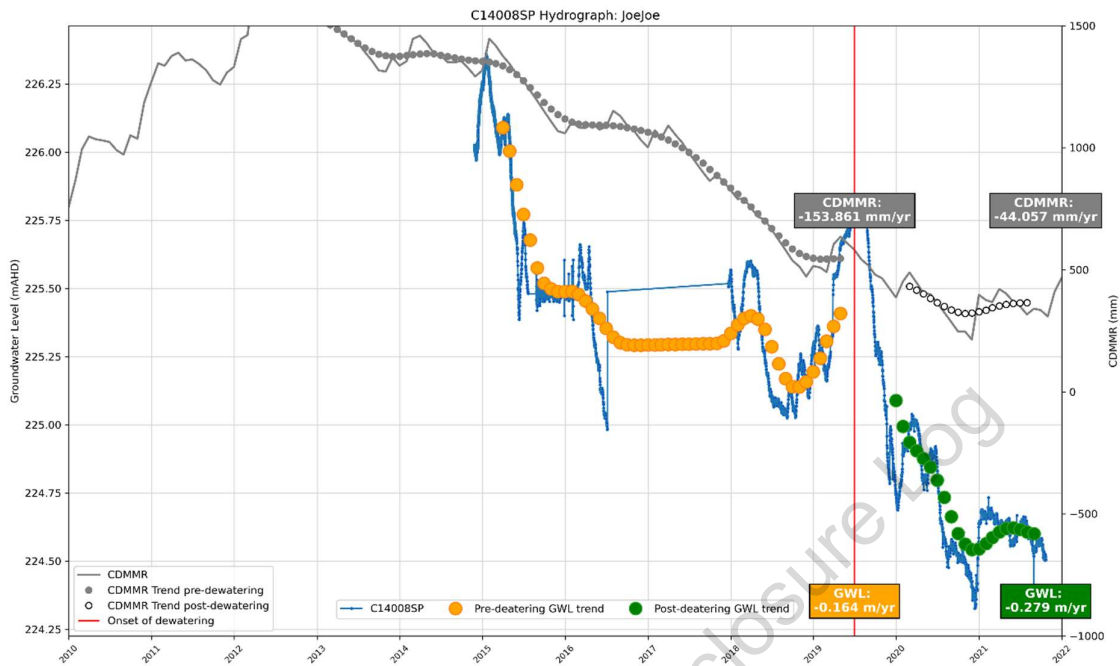
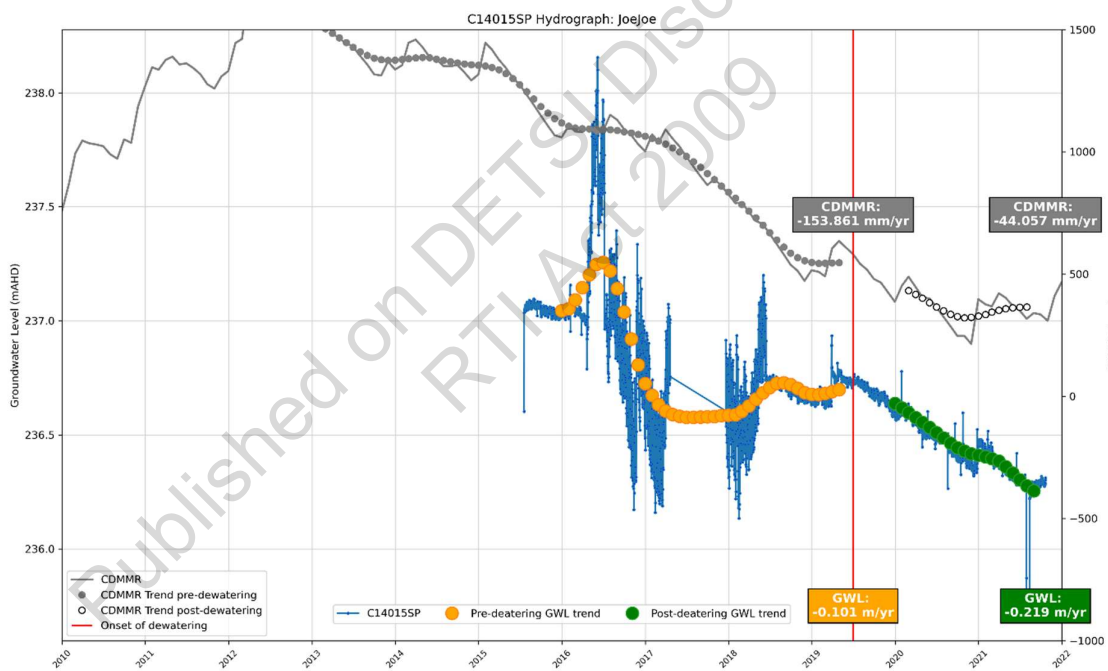


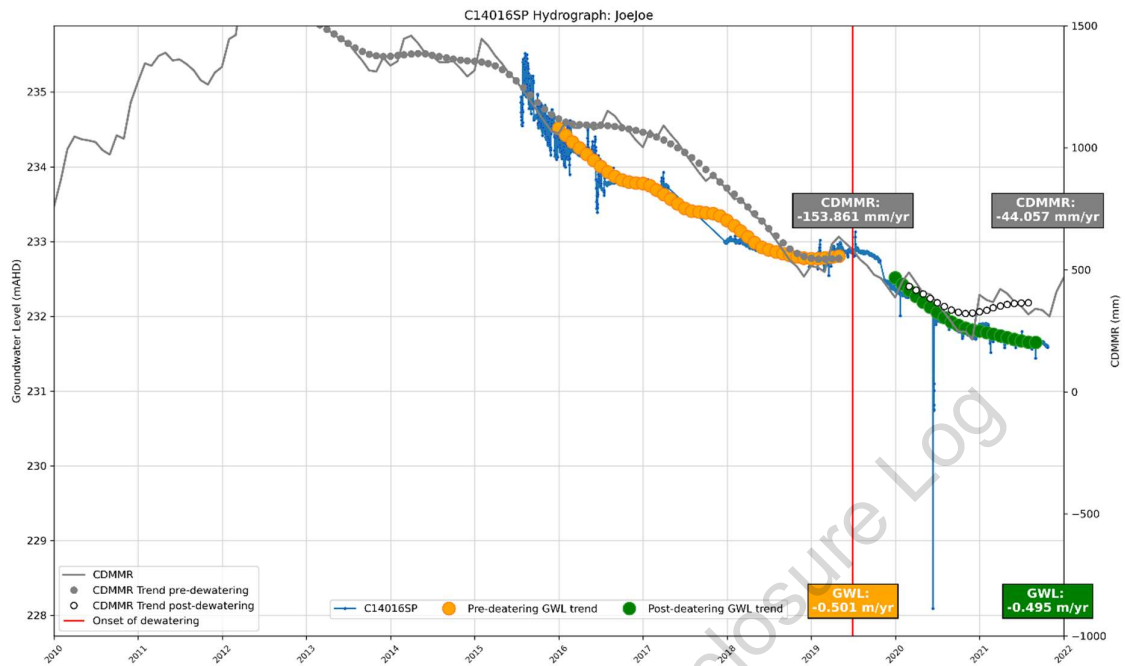
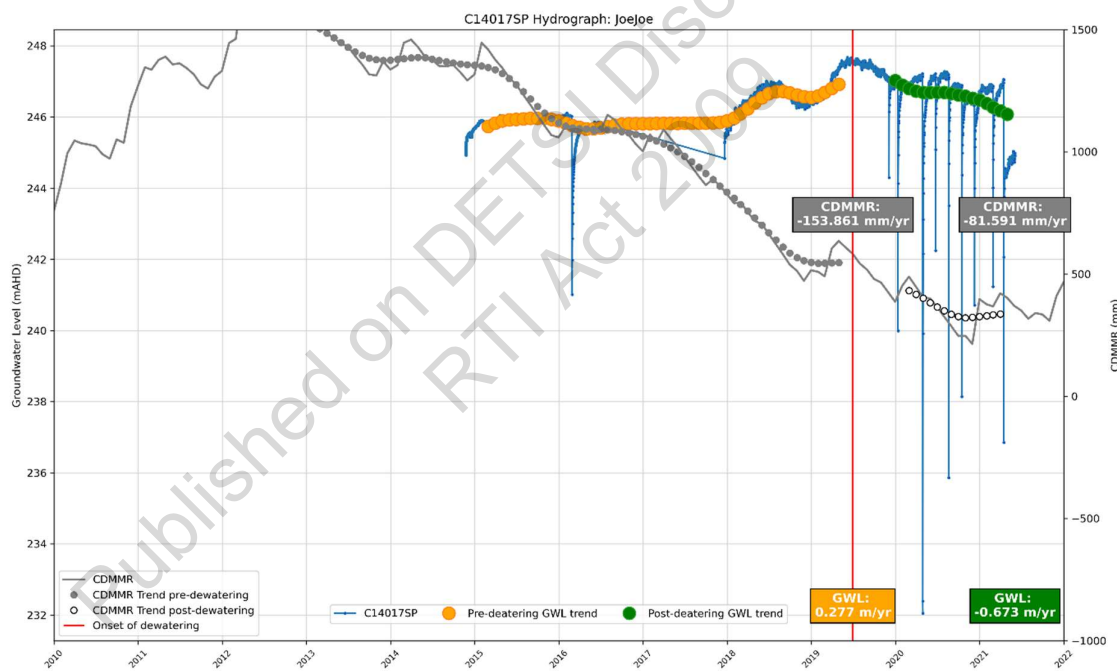


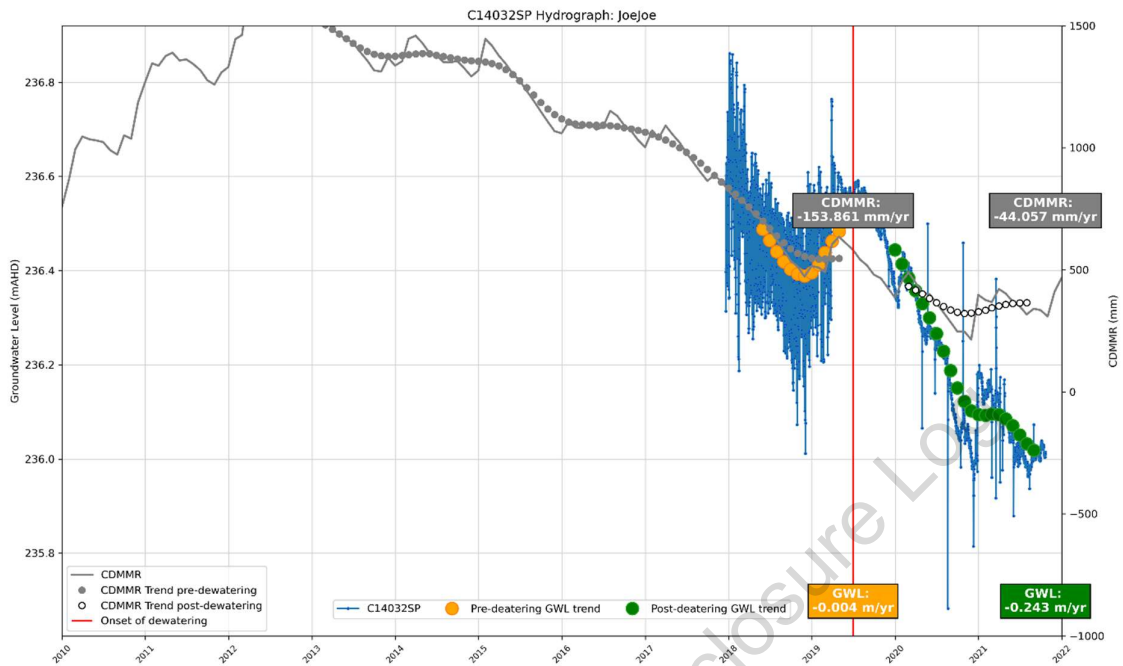
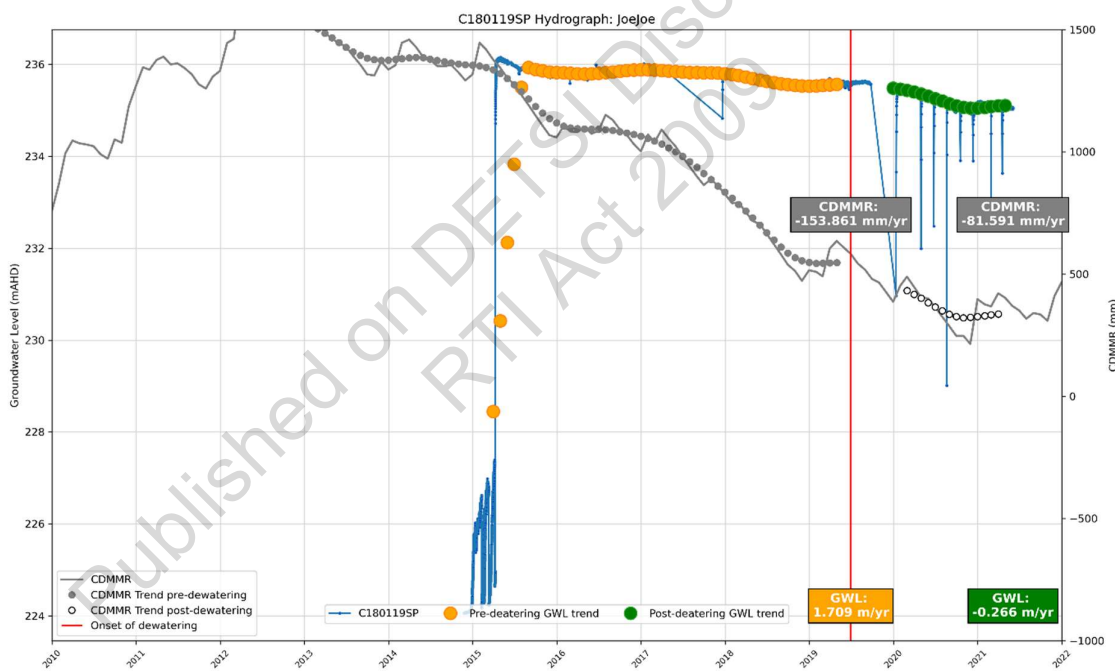


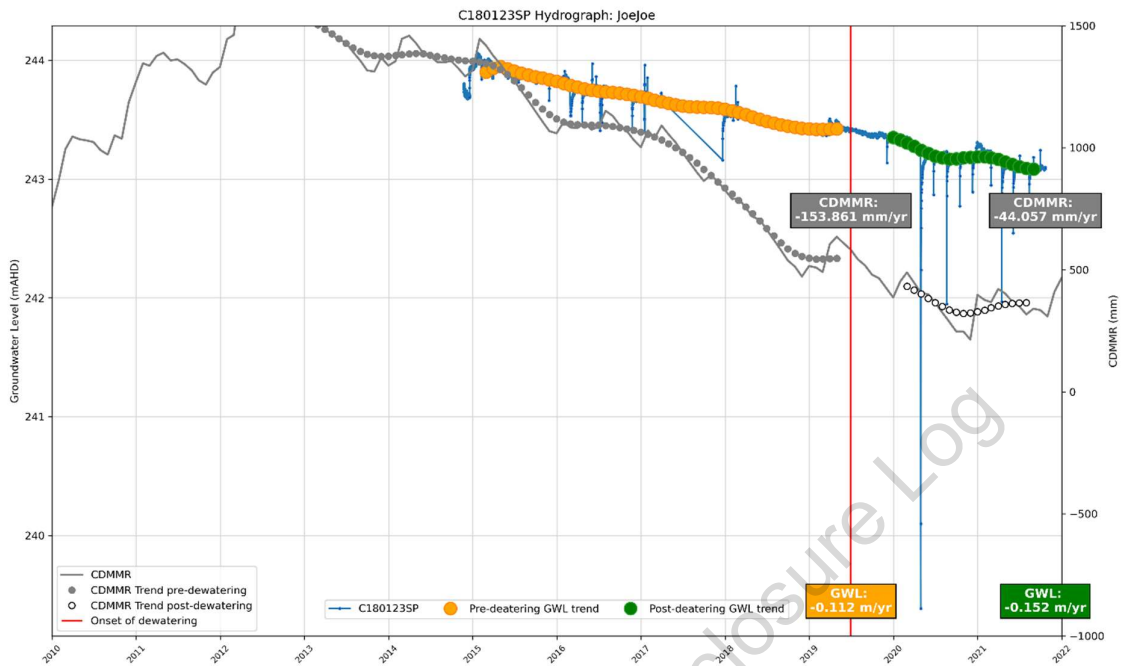
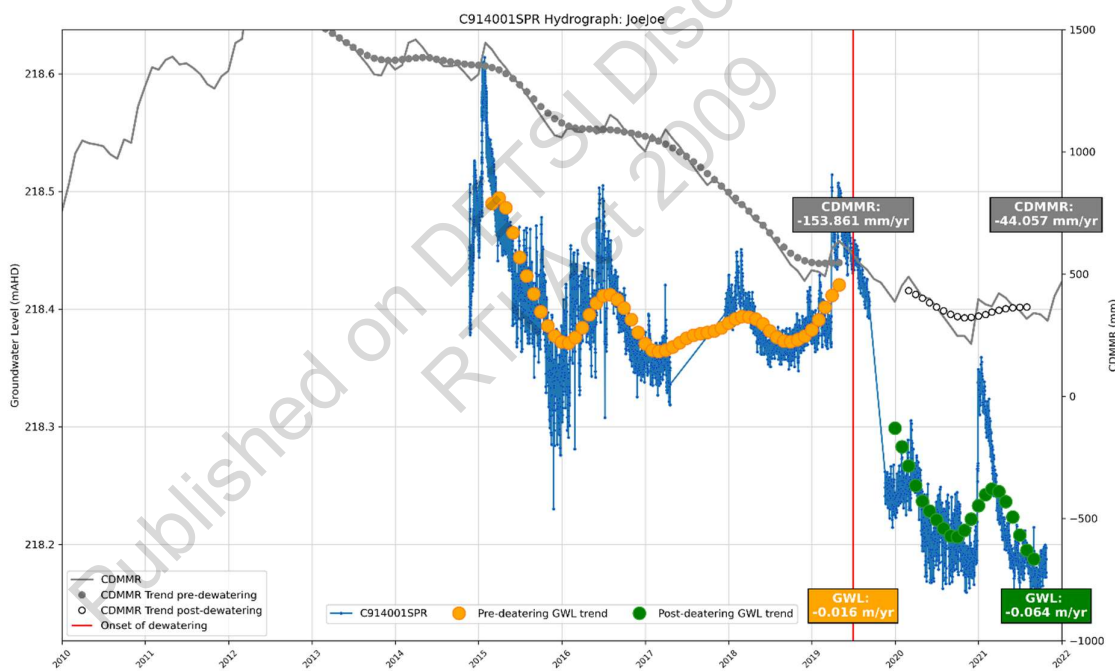


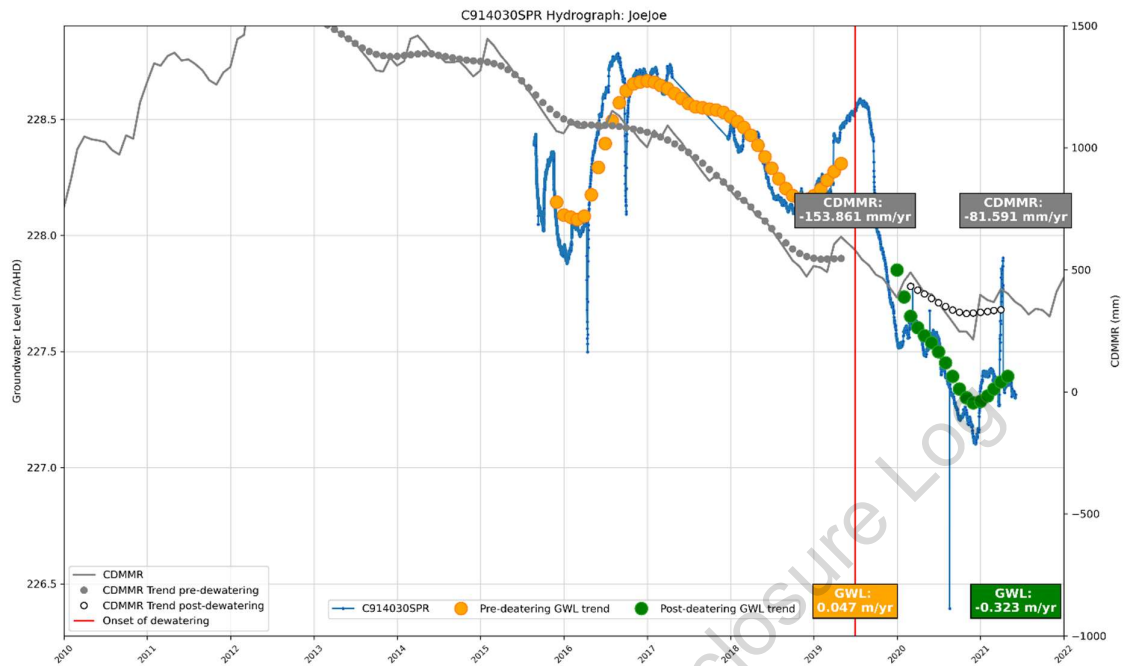
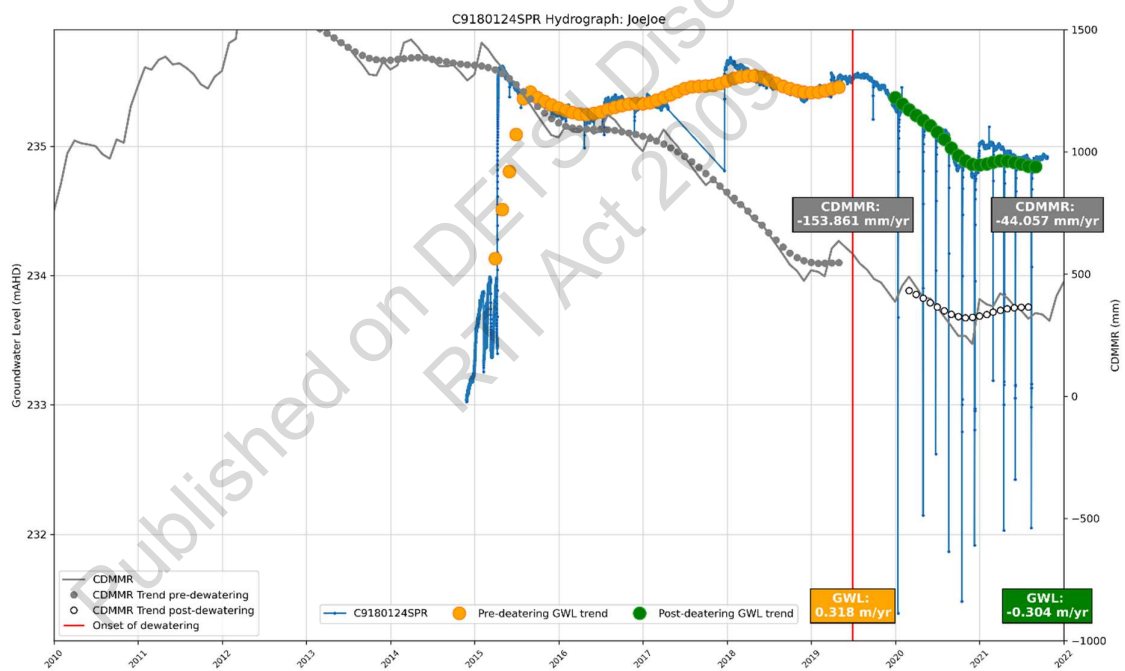


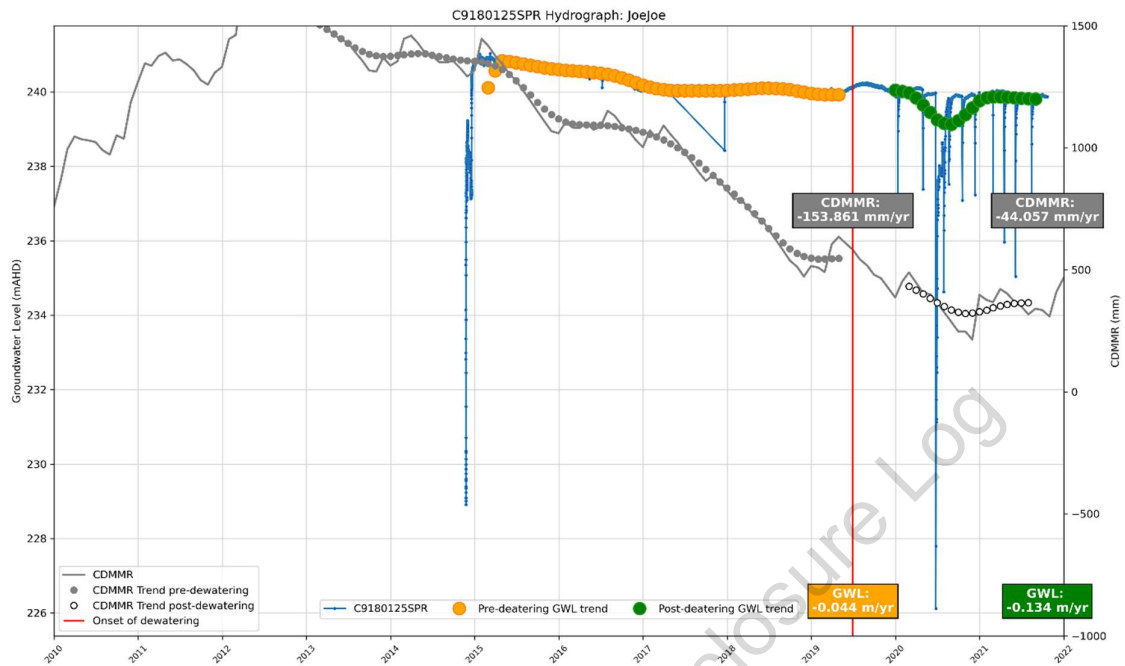
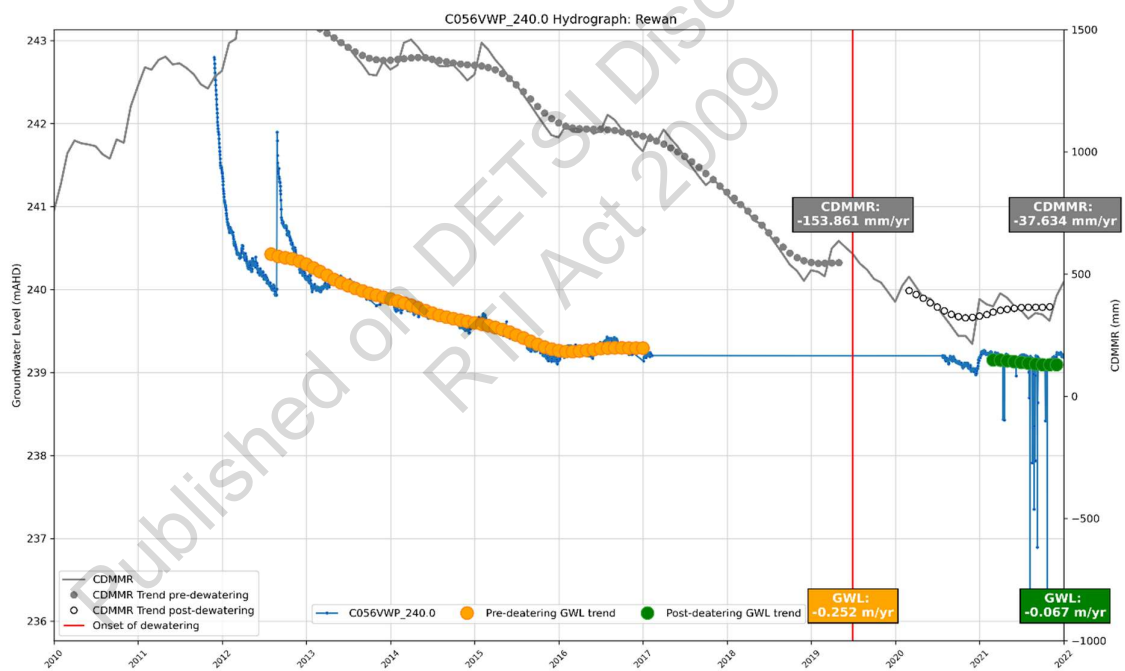


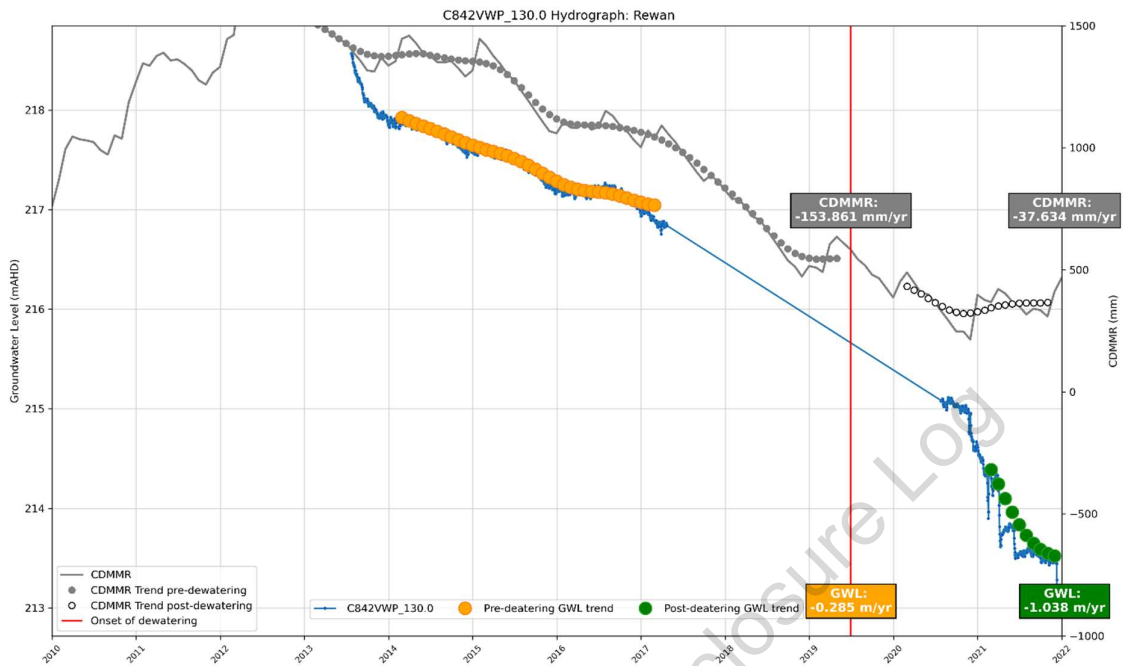
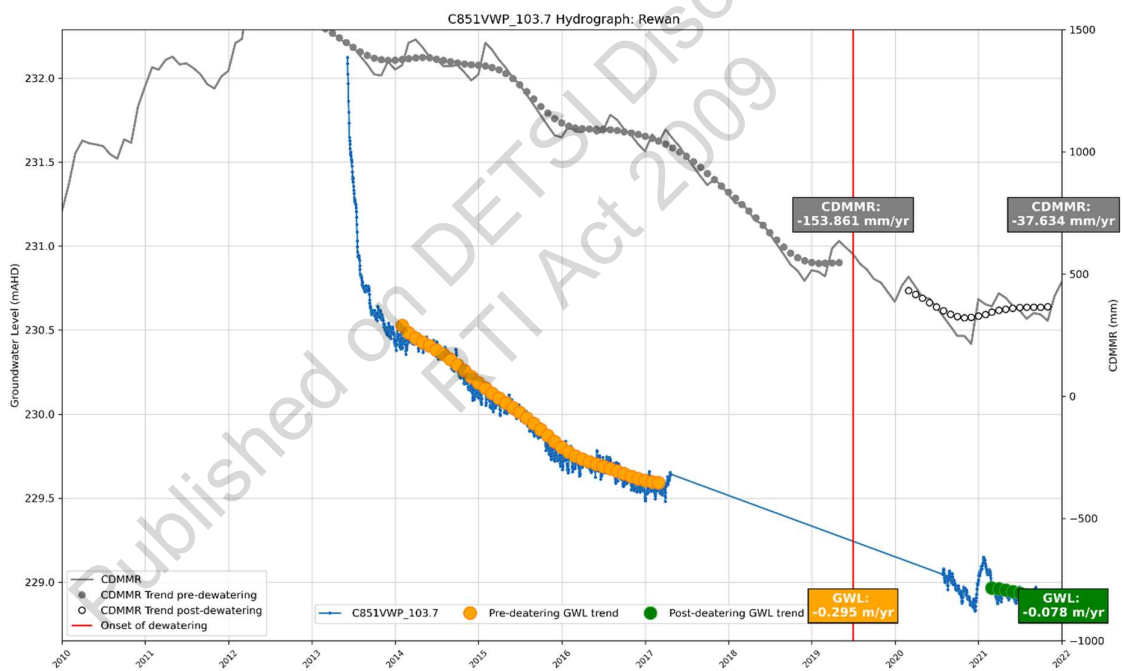


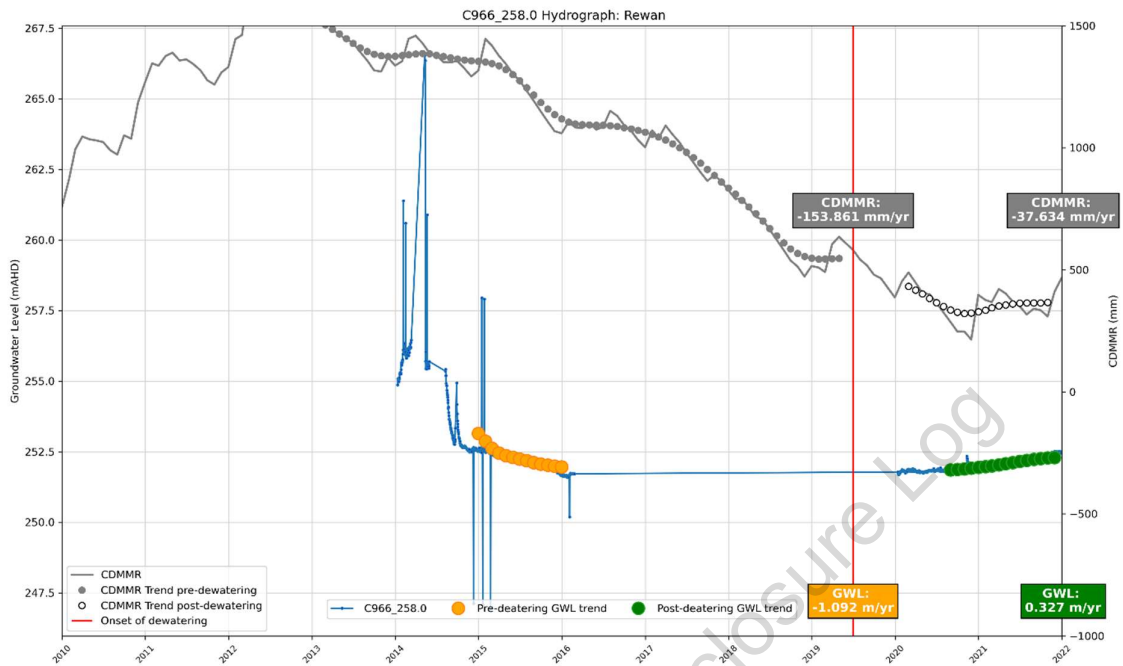
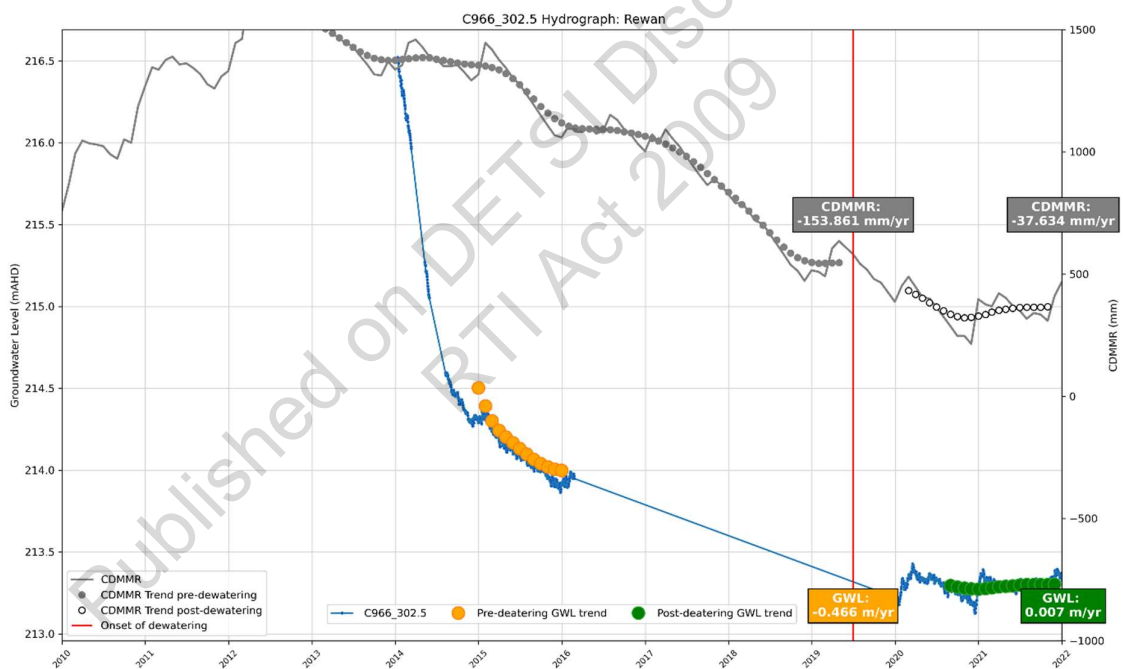


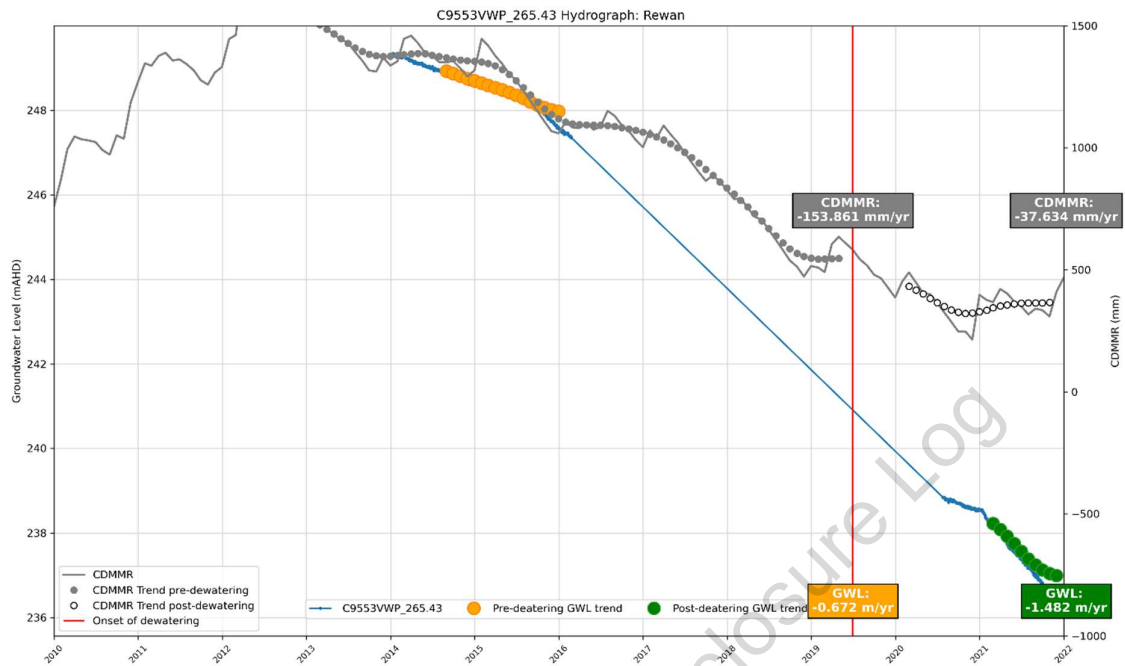
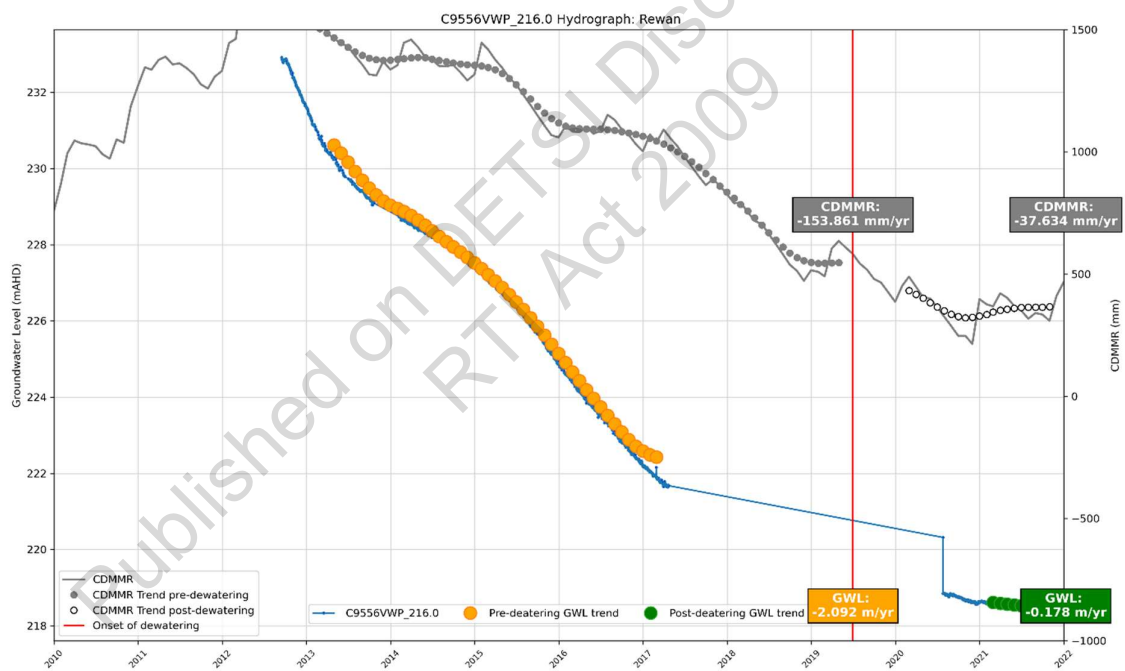


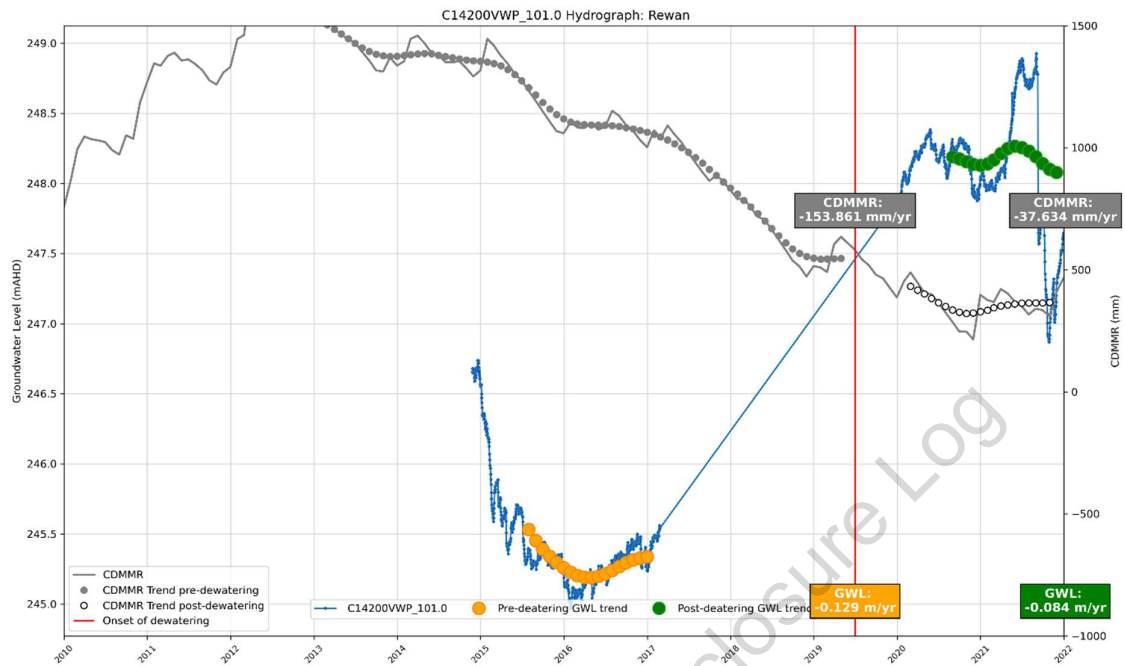
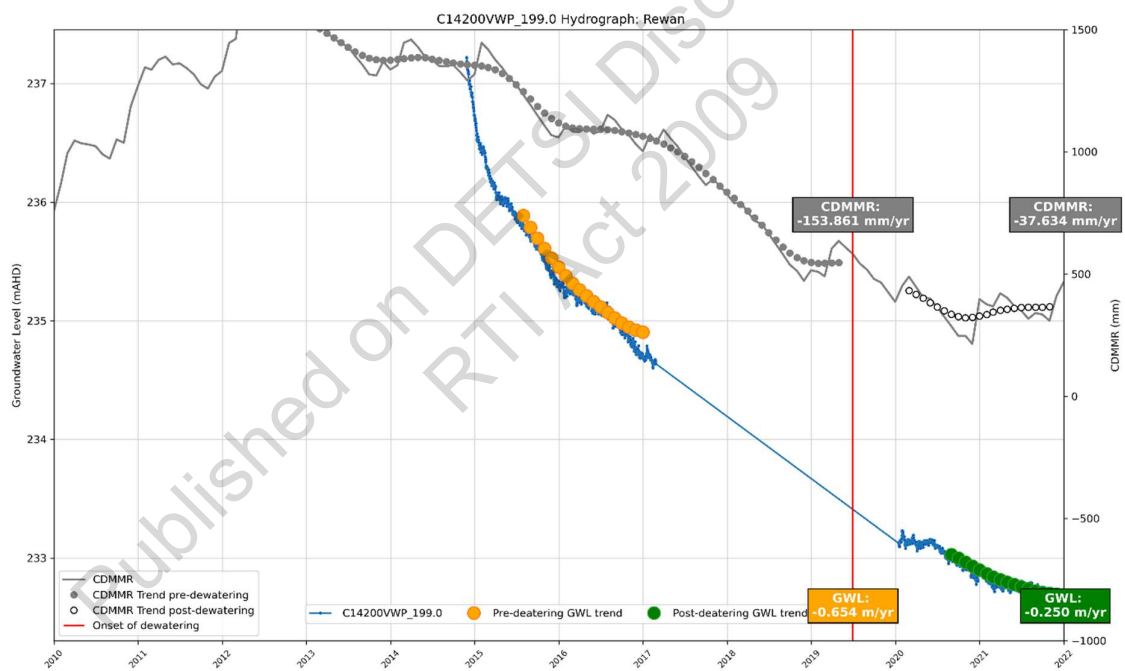


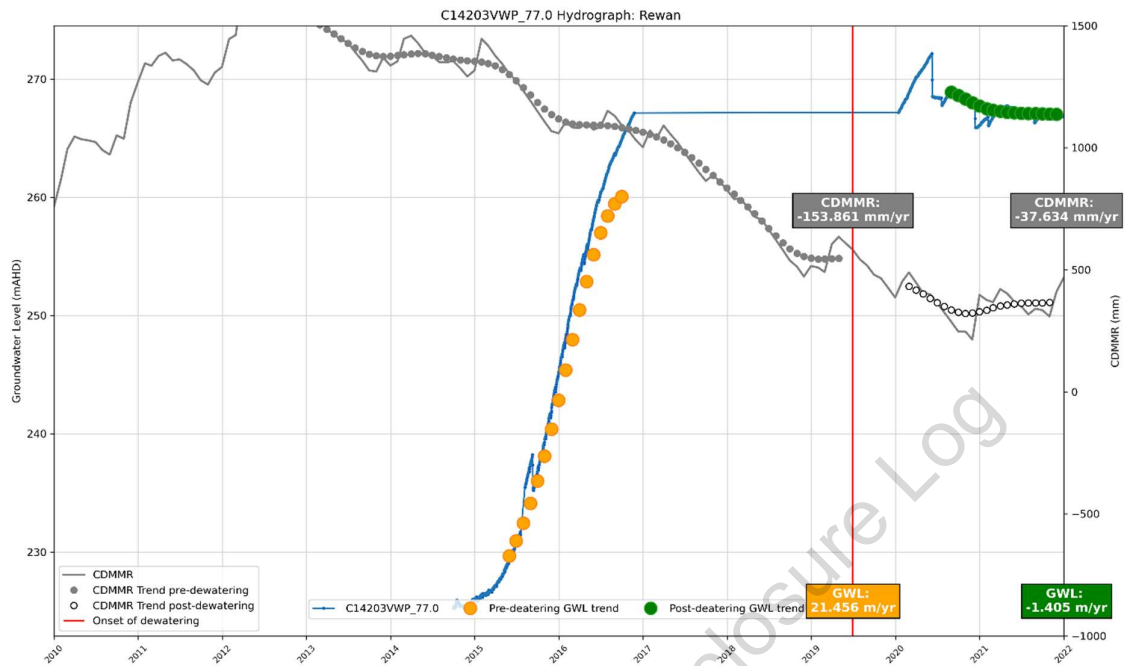
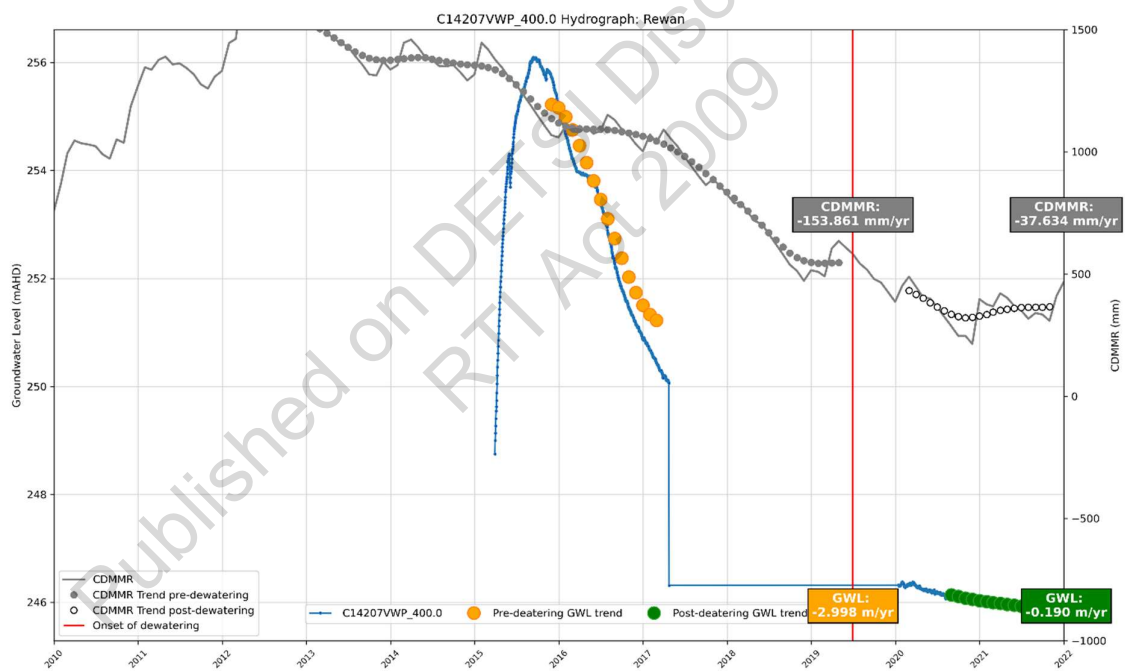


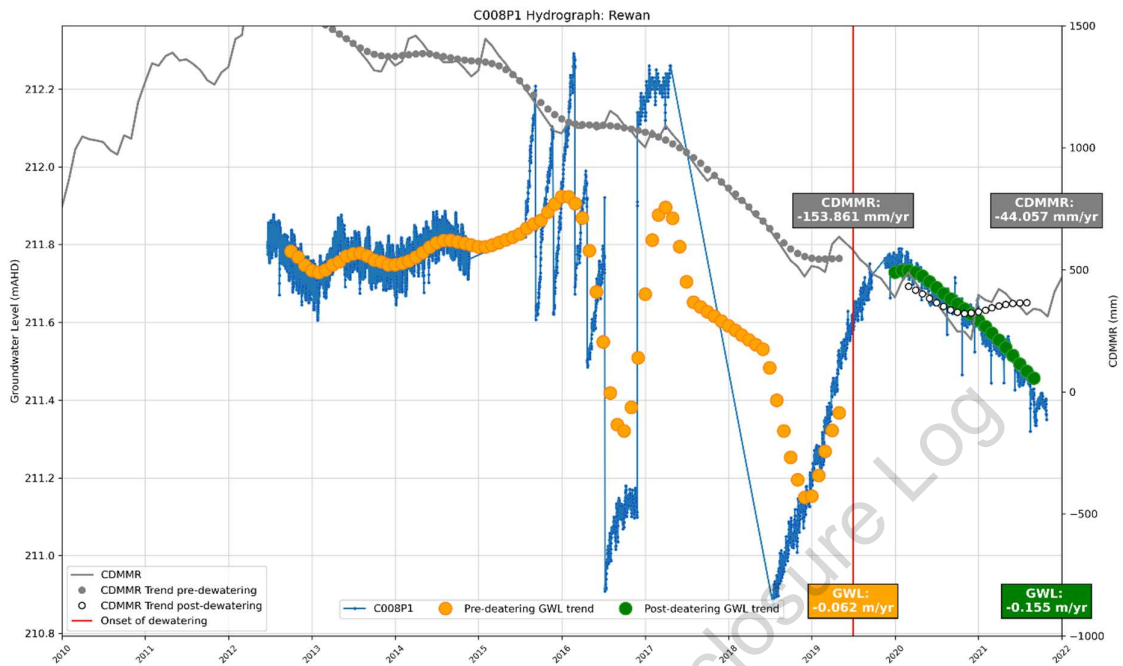
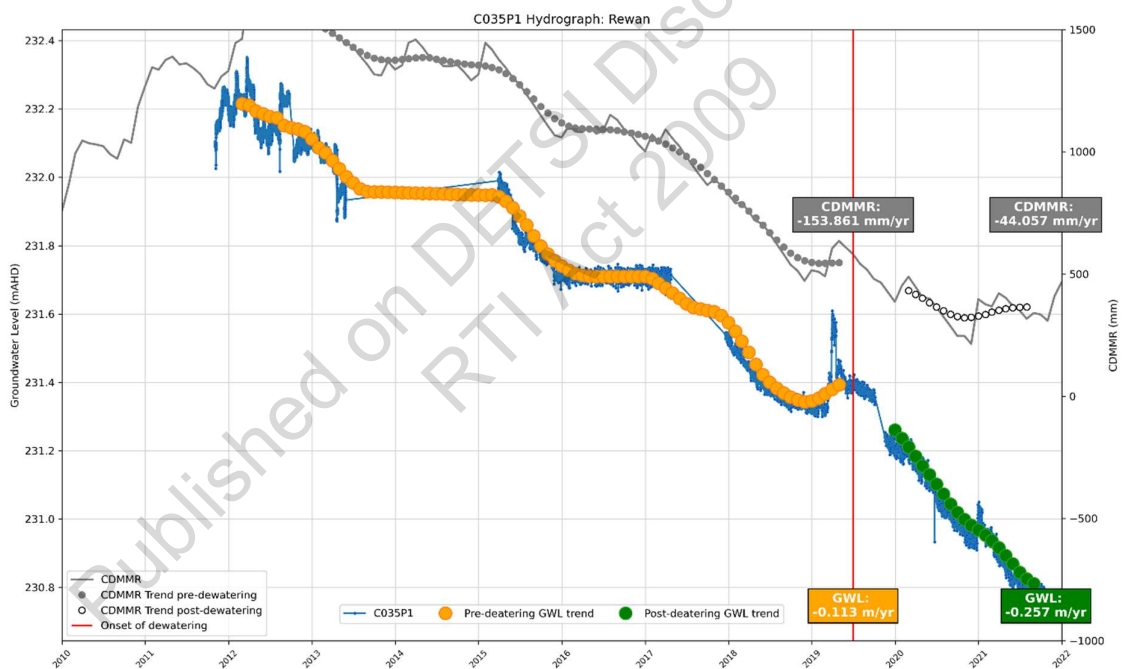


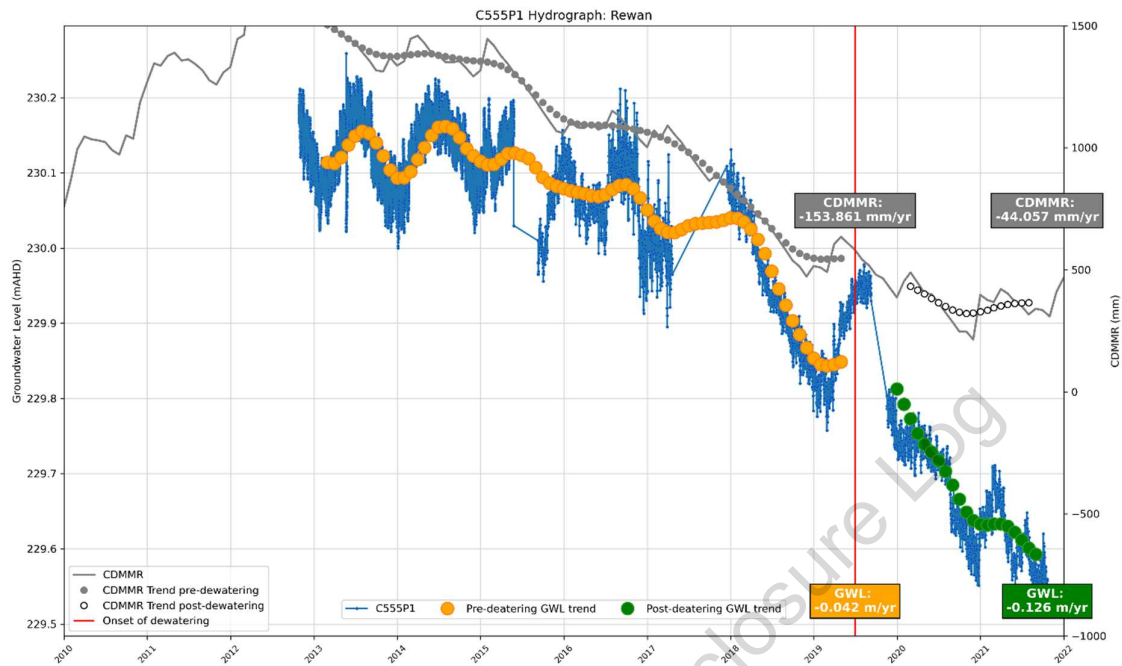
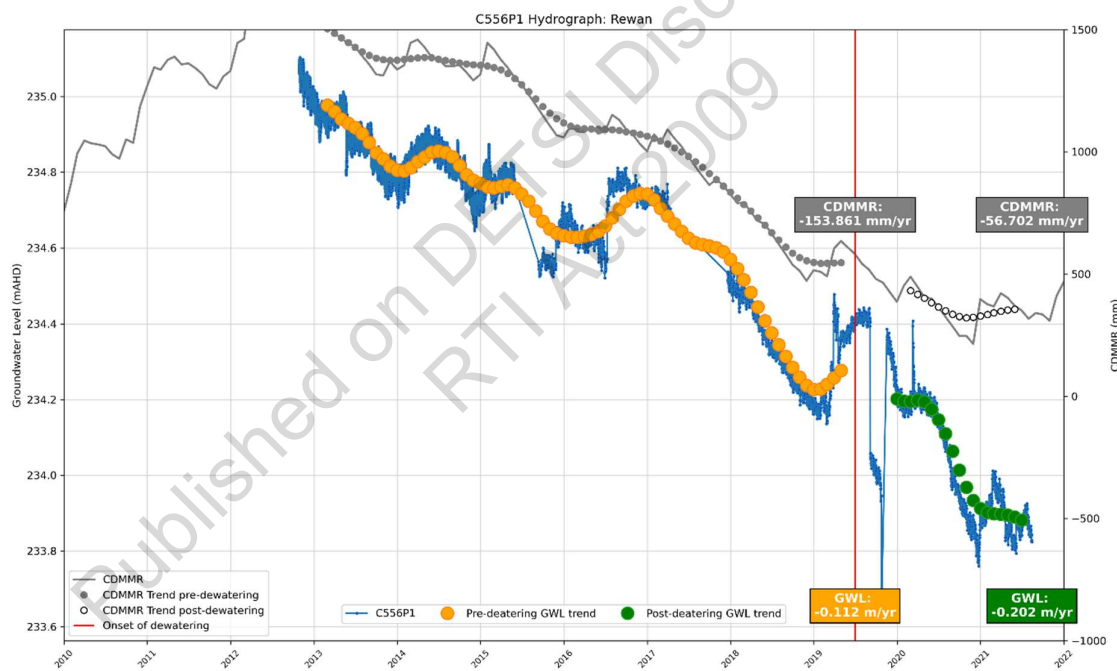


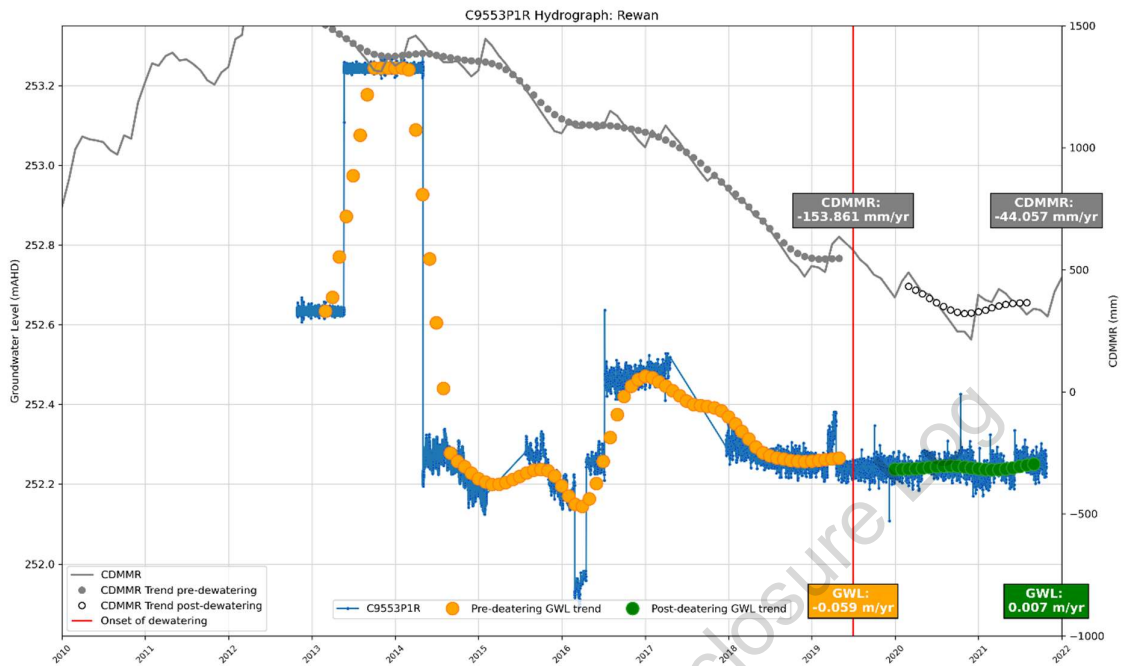
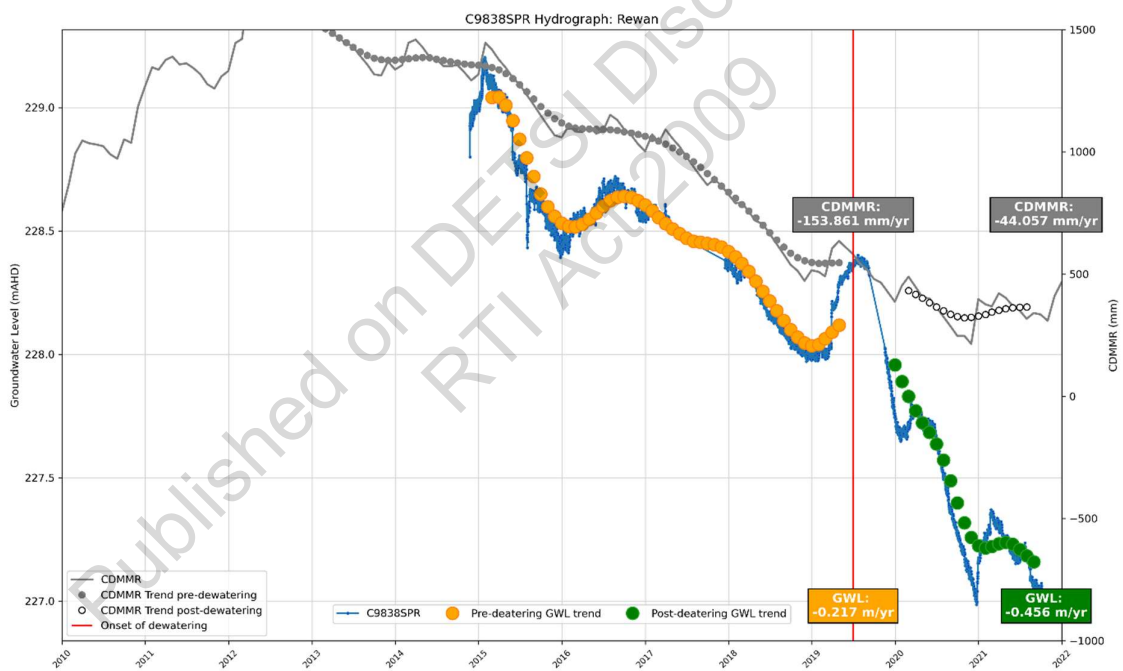


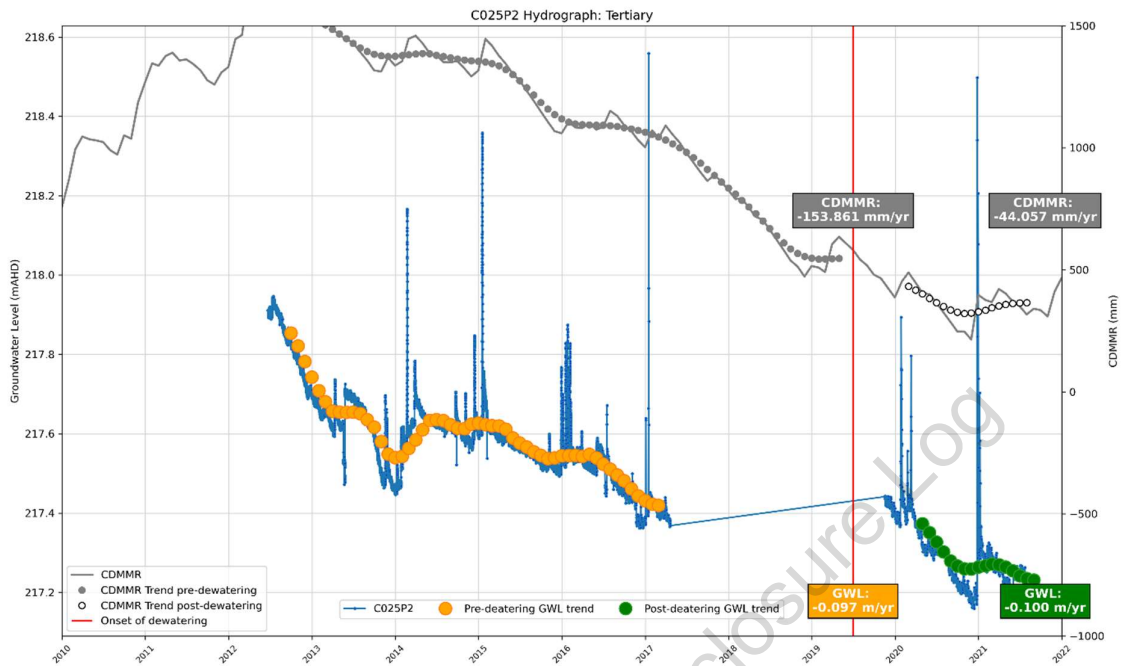
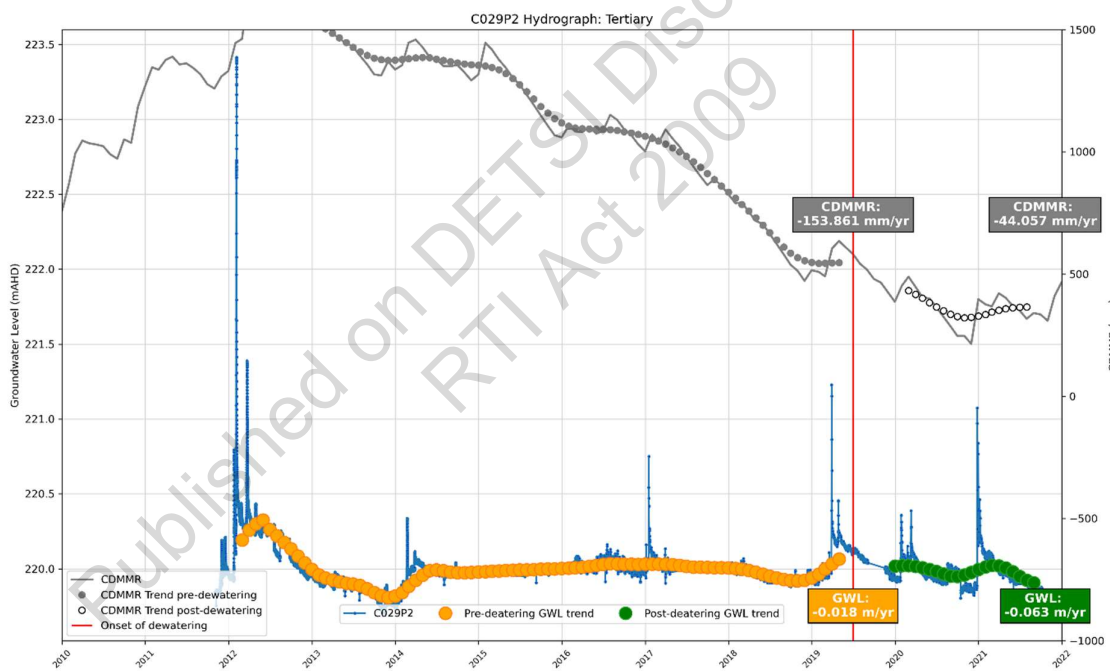


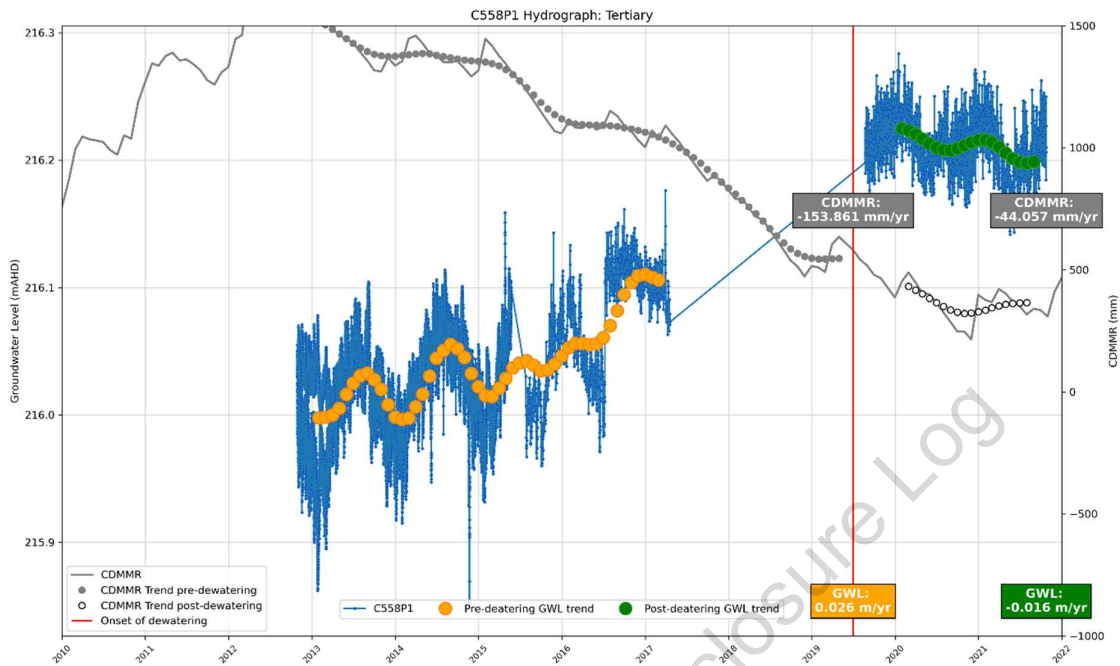
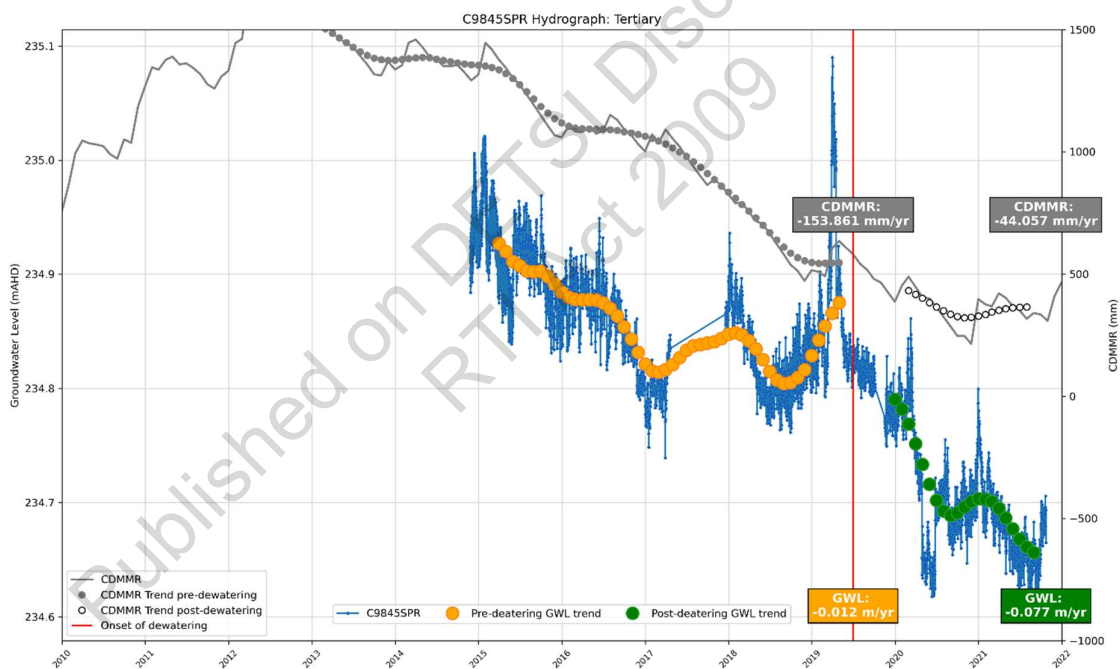


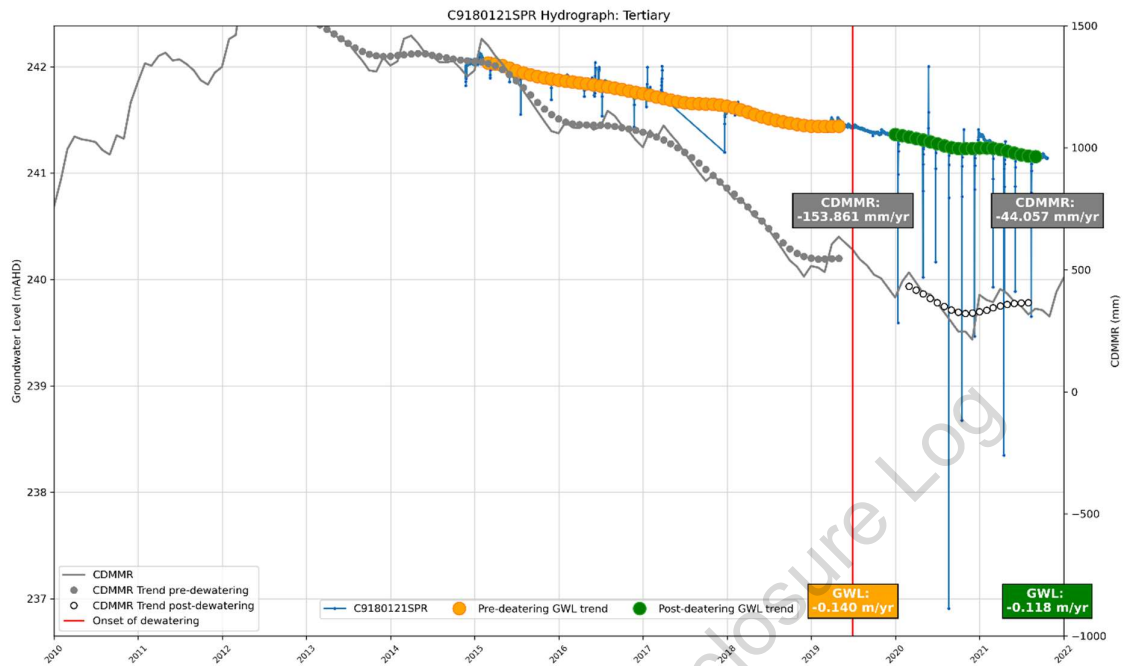






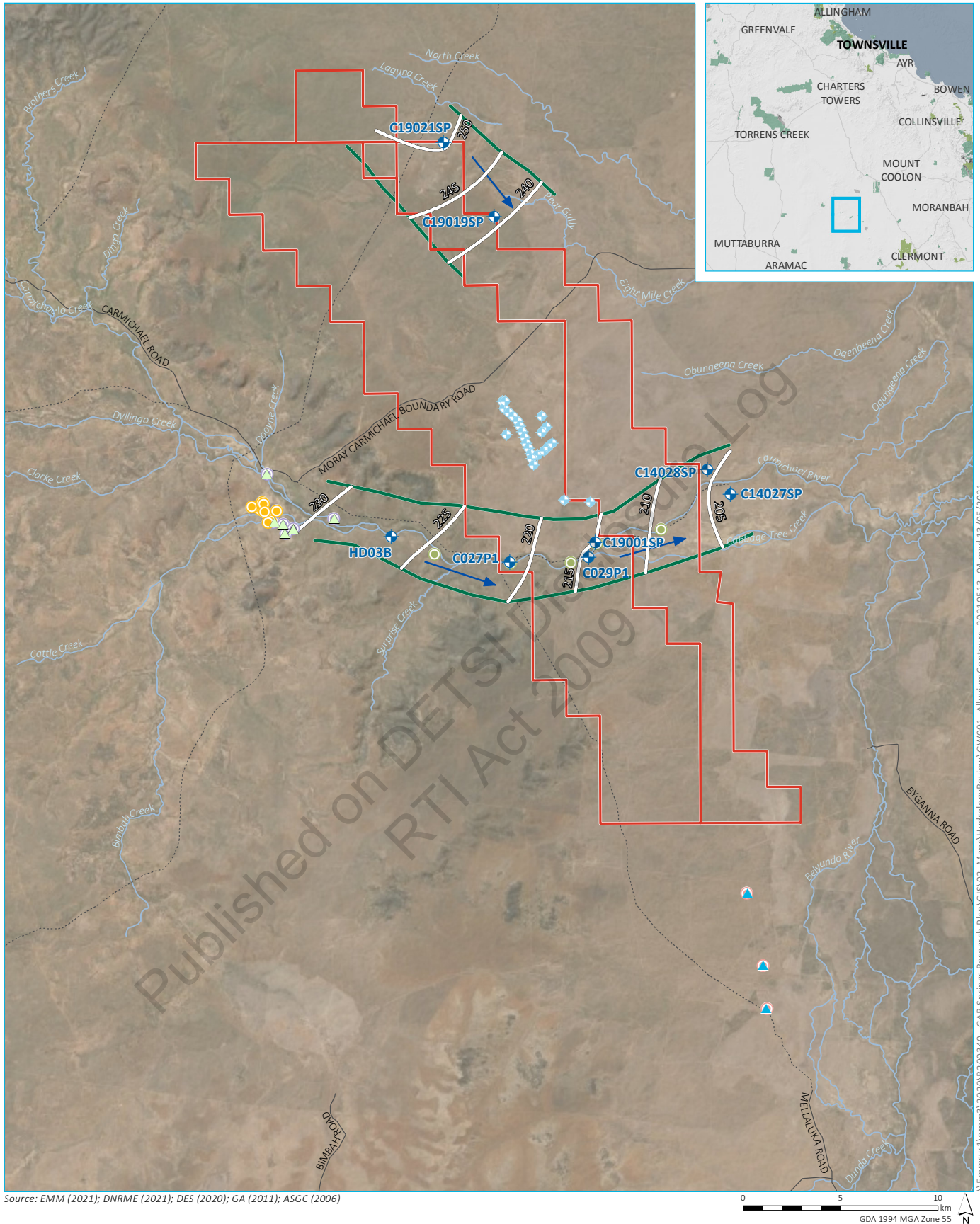






Appendix C

Recent potentiometric maps



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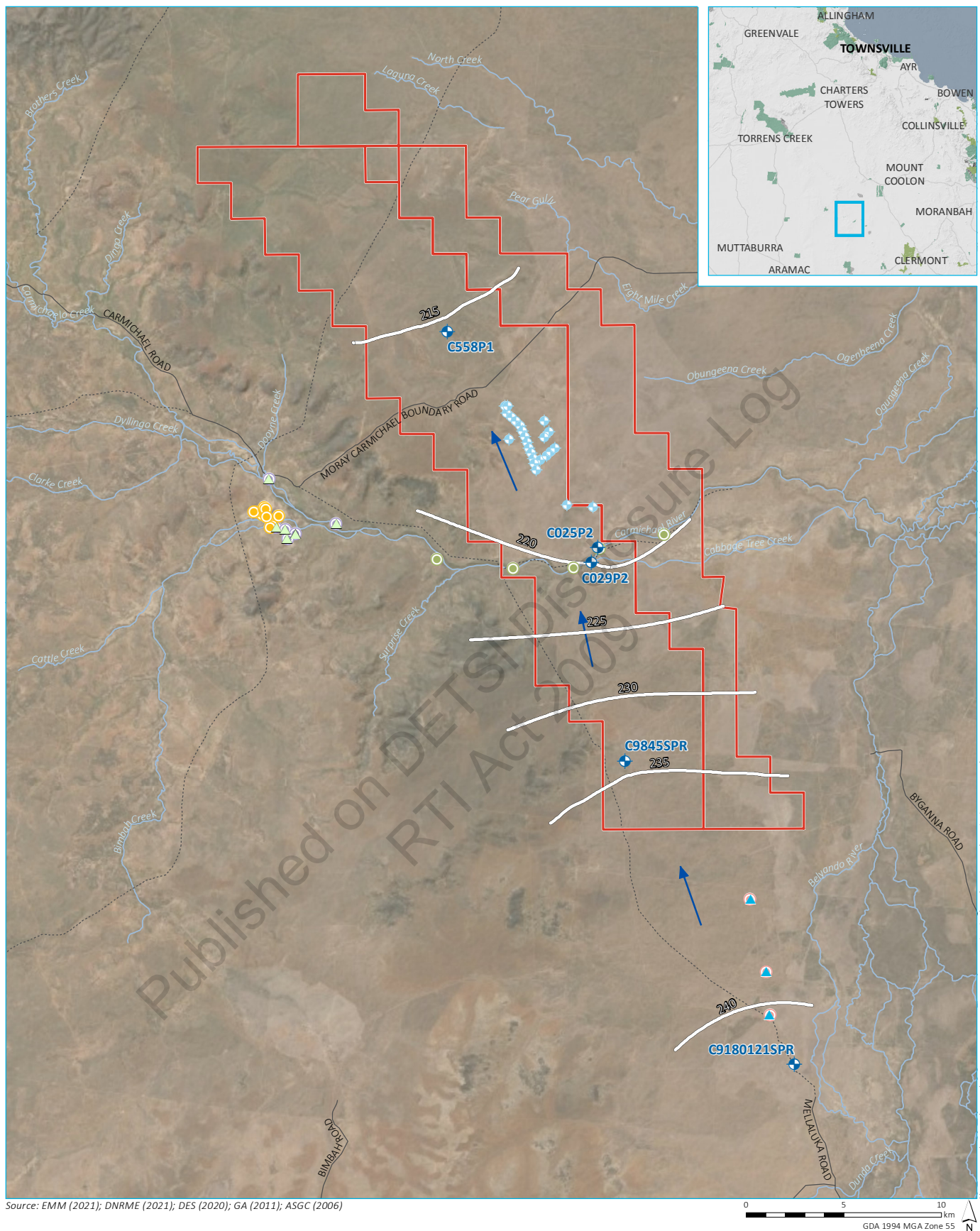
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- Groundwater contours
- Inferred groundwater flow direction
- Mining lease
- Minor road
- Vehicular track
- Named watercourse
- Assumed alluvium extent
- Dewatering bore
- Mellaluka spring
- Doongamabulla spring
- Groundwater dependant ecosystem
- Doongmabulla
- Doongmabulla (Mound Springs)
- Mellaluka
- Waxy Cabbage Palm

INSET KEY

- Main road
- National park
- State forest

Carmichael River alluvium groundwater contours (February 2021)

Carmichael Coal Mine Great Artesian Basin Springs Hydrogeological review and monitoring report
Figure C.1



KEY

- Groundwater monitoring well
- Groundwater contours
- Inferred groundwater flow direction
- Mining lease
- Minor road
- Vehicular track
- Named watercourse
- Dewatering bore
- Mellaluka spring
- Doongamabulla spring
- Groundwater dependent ecosystem
- Doongamabulla
- Doongamabulla (Mound Springs)
- Mellaluka
- Waxy Cabbage Palm

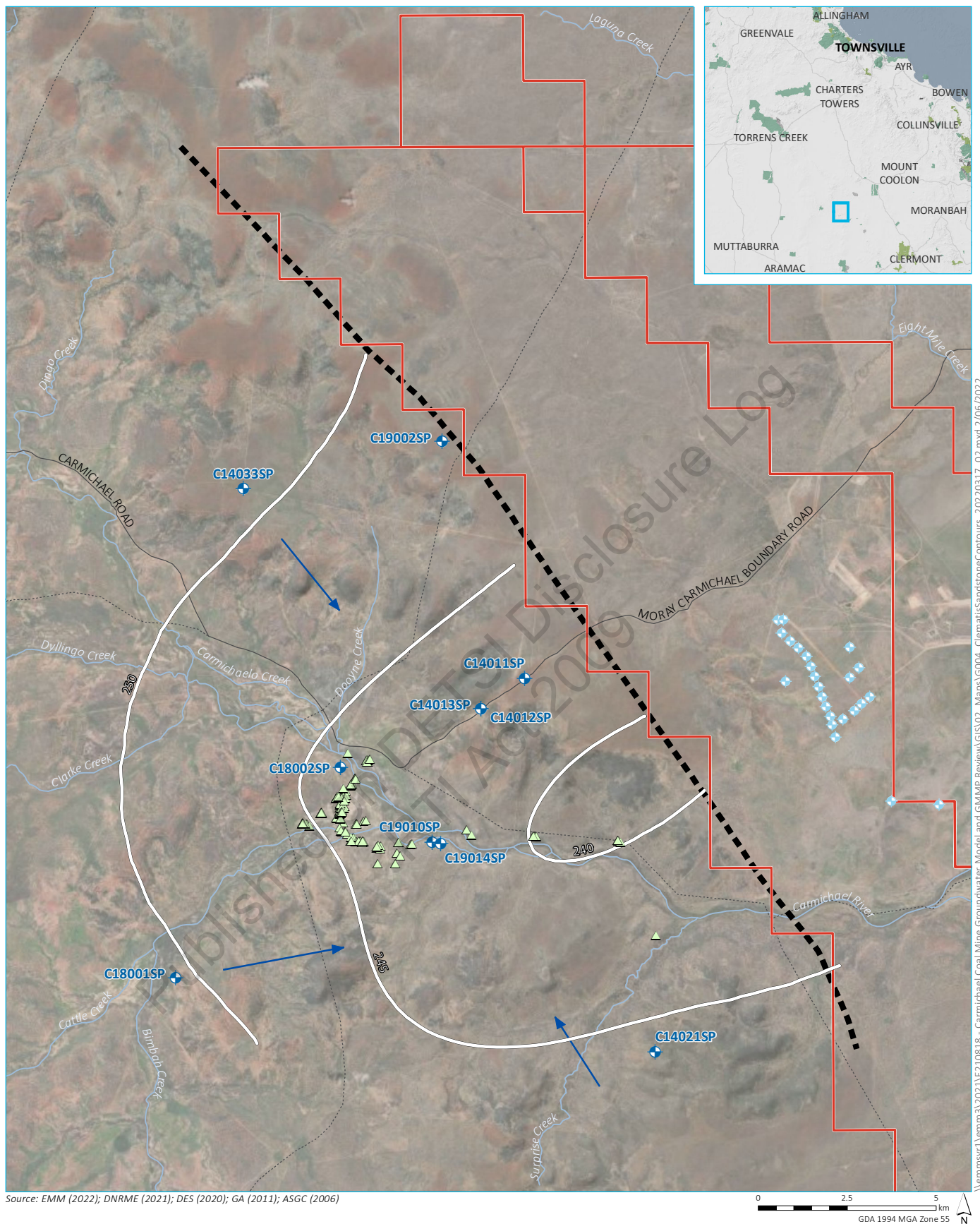
INSET KEY

- Main road
- National park
- State forest

Tertiary sediments
groundwater contours (February 2021)

Carmichael Coal Mine Great Artesian Basin Springs
Hydrogeological review and monitoring report

Figure C.2



KEY

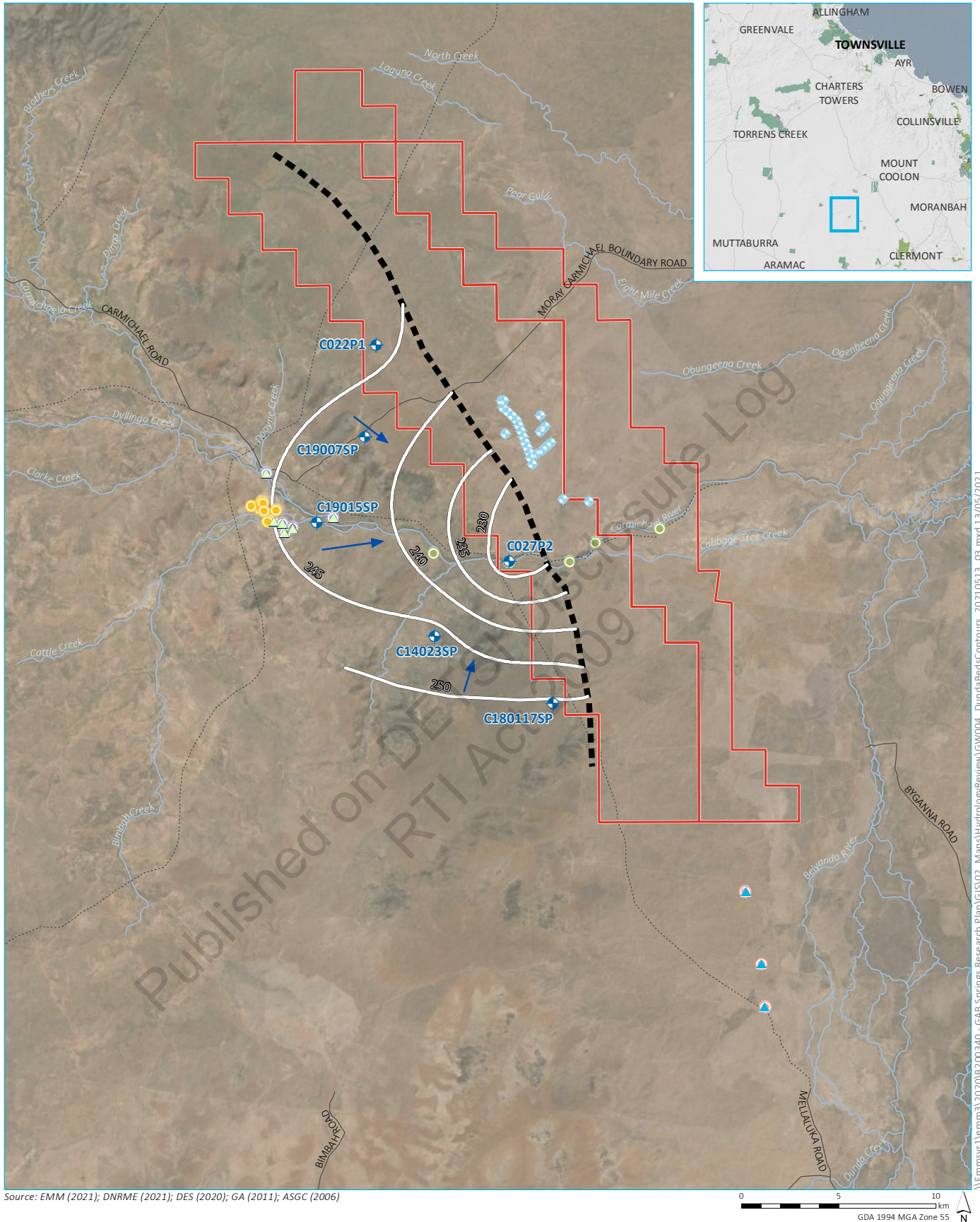
- + Groundwater monitoring well
- Inferred groundwater flow direction
- Mining lease
- Minor road
- Vehicular track
- Named watercourse
- Inferred subcrop
- + Dewatering bore
- ▲ Spring

INSET KEY

- Main road
- National park
- State forest

Clematis Sandstone groundwater contours (February 2021)

Carmichael Coal Mine
Data Review and Conceptualisation Report
Figure C.3



Source: EMM (2021); DNRME (2021); DES (2020); GA (2011); ASGC (2006)

KEY

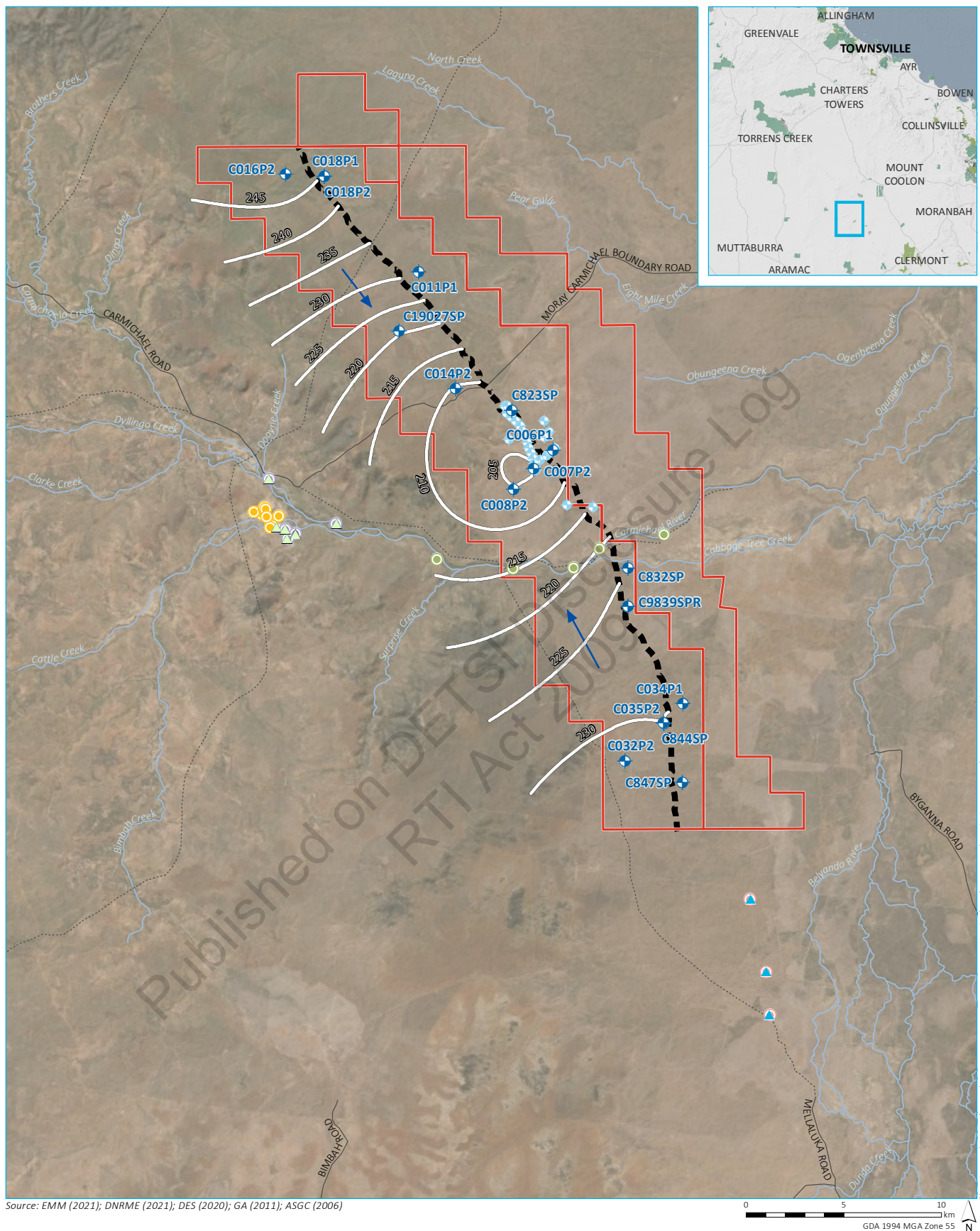
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- Groundwater contours
- Inferred groundwater flow direction
- Mining lease
- Minor road
- Vehicular track
- Named watercourse
- Inferred subcrop
- Dewatering bore
- Mellaluka spring
- Doongamabulla spring
- Groundwater dependant ecosystem
- Doongmabulla
- Doongmabulla (Mound Springs)
- Mellaluka
- Waxy Cabbage Palm

INSET KEY

- Main road
- National park
- State forest

Dunda Beds groundwater contours (February 2021)

Carmichael Coal Mine Great Artesian Basin Springs
Hydrogeological review and monitoring report
Figure C.4



KEY

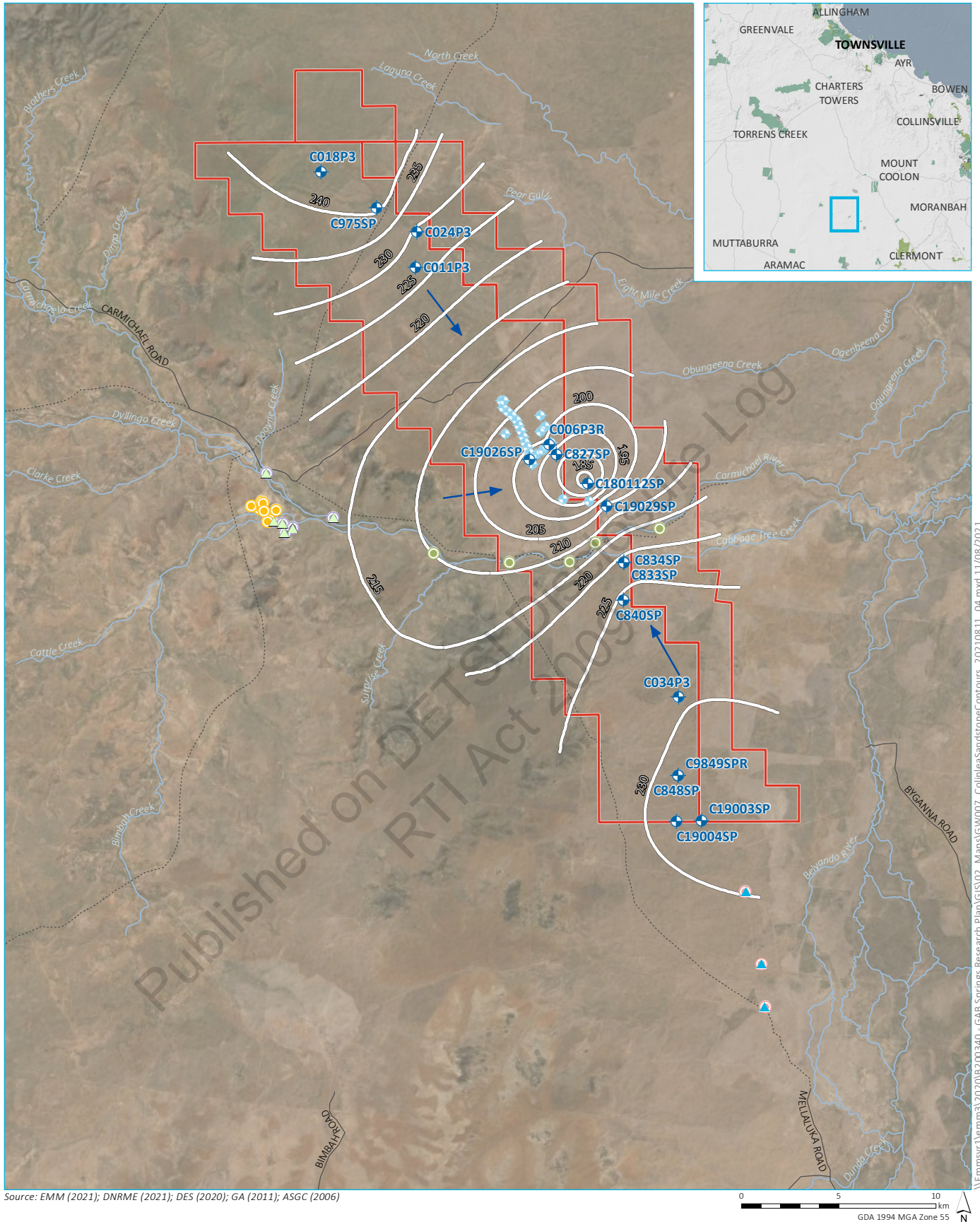
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- Inferred groundwater flow direction
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- Vehicular track
- Named watercourse
- Inferred subcrop
- Dewatering bore
- Mellaluka spring
- Doongamabulla spring
- Groundwater dependant ecosystem
- Doongmabulla
- Doongmabulla (Mound Springs)
- Mellaluka
- Waxy Cabbage Palm

INSET KEY

- Main road
- National park
- State forest

Bandanna Formation (AB seam) groundwater contours (February 2021)

Carmichael Coal Mine Great Artesian Basin Springs
Hydrogeological review and monitoring report
Figure C.5



Source: EMM (2021); DNRME (2021); DES (2020); GA (2011); ASGC (2006)

KEY

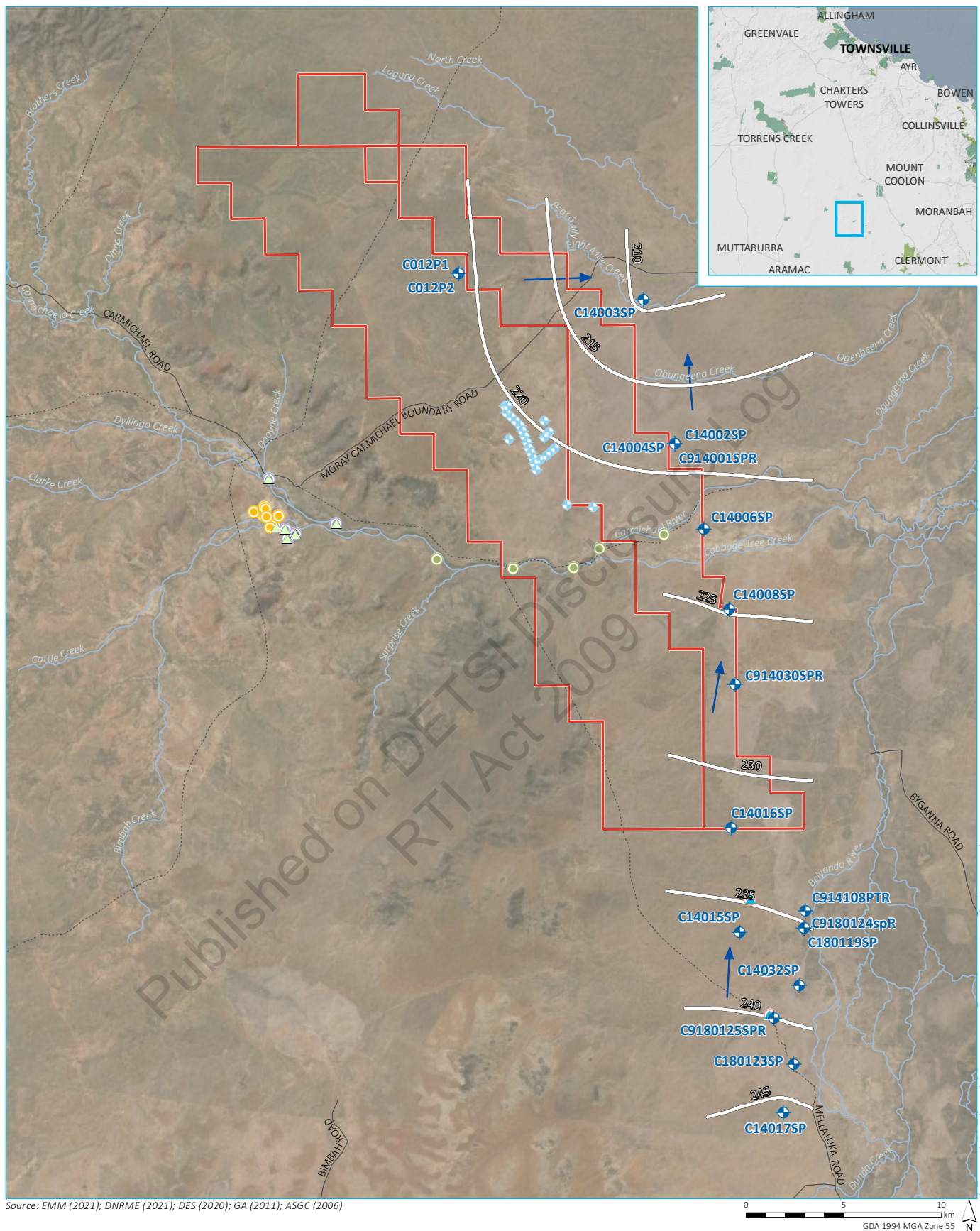
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- Groundwater contours
- Inferred groundwater flow direction
- Mining lease
- Minor road
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- Named watercourse
- Dewatering bore
- Mellaluka spring
- Doongamabulla spring
- Groundwater dependant ecosystem
- Doongmabulla
- Doongmabulla (Mound Springs)
- Mellaluka
- Waxy Cabbage Palm

INSET KEY

- Main road
- National park
- State forest

Colinlea Sandstone (D seam)
groundwater contours (February 2021)

Carmichael Coal Mine Great Artesian Basin Springs
Hydrogeological review and monitoring report
Figure C.6



KEY

- Groundwater monitoring well
- Groundwater contours
- Inferred groundwater flow direction
- Mining lease
- Minor road
- Vehicular track
- Named watercourse
- Dewatering bore
- Mellaluka spring
- Doongamabulla spring
- Groundwater dependant ecosystem
- Doongmabulla
- Doongmabulla (Mound Springs)
- Mellaluka
- Waxy Cabbage Palm

INSET KEY

- Main road
- National park
- State forest

Joe Joe group
groundwater contours (February 2021)

Carmichael Coal Mine Great Artesian Basin Springs
Hydrogeological review and monitoring report
Figure C.7

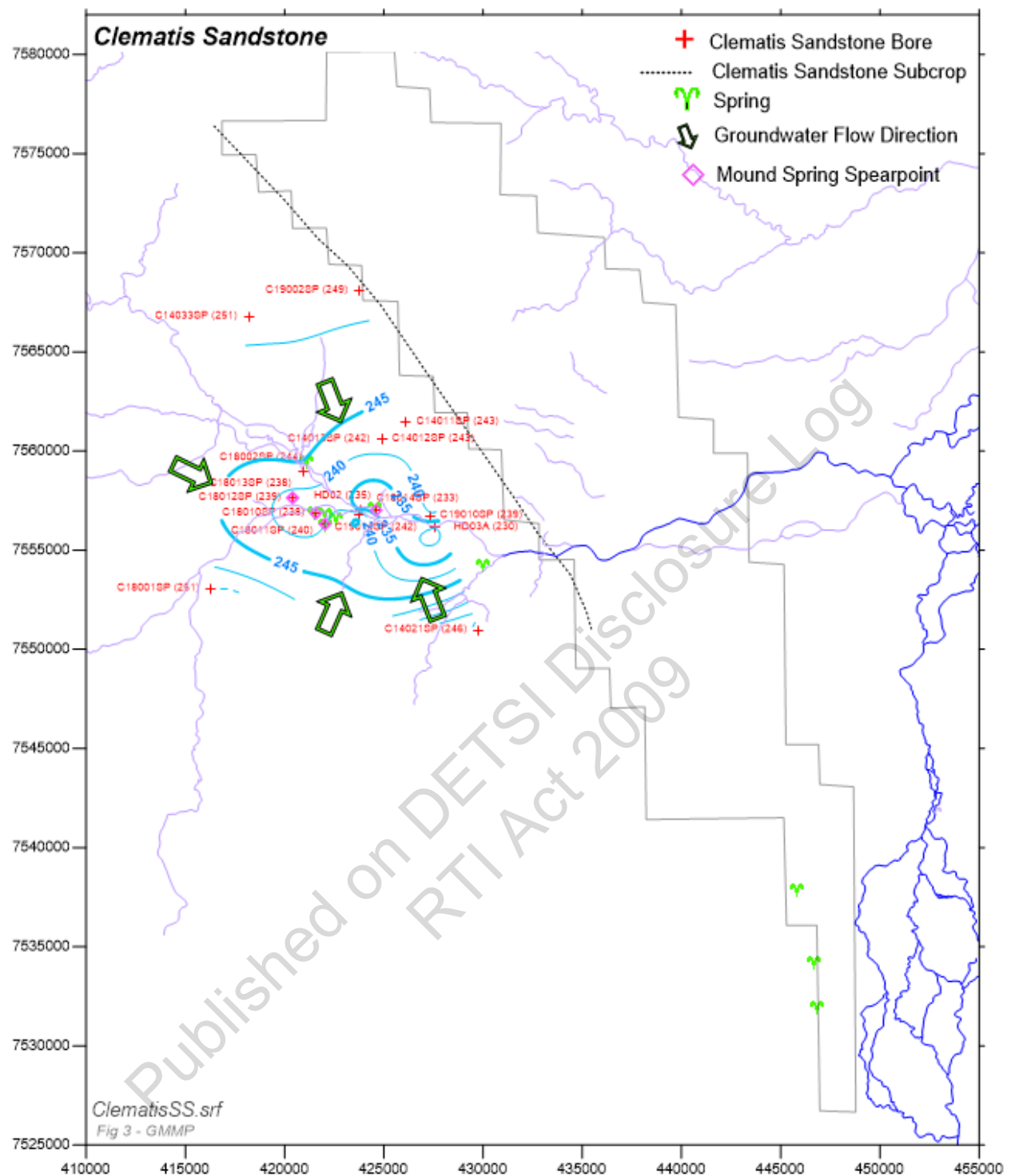


Figure C.8 Groundwater heads in the Clematis Sandstone at December 2020

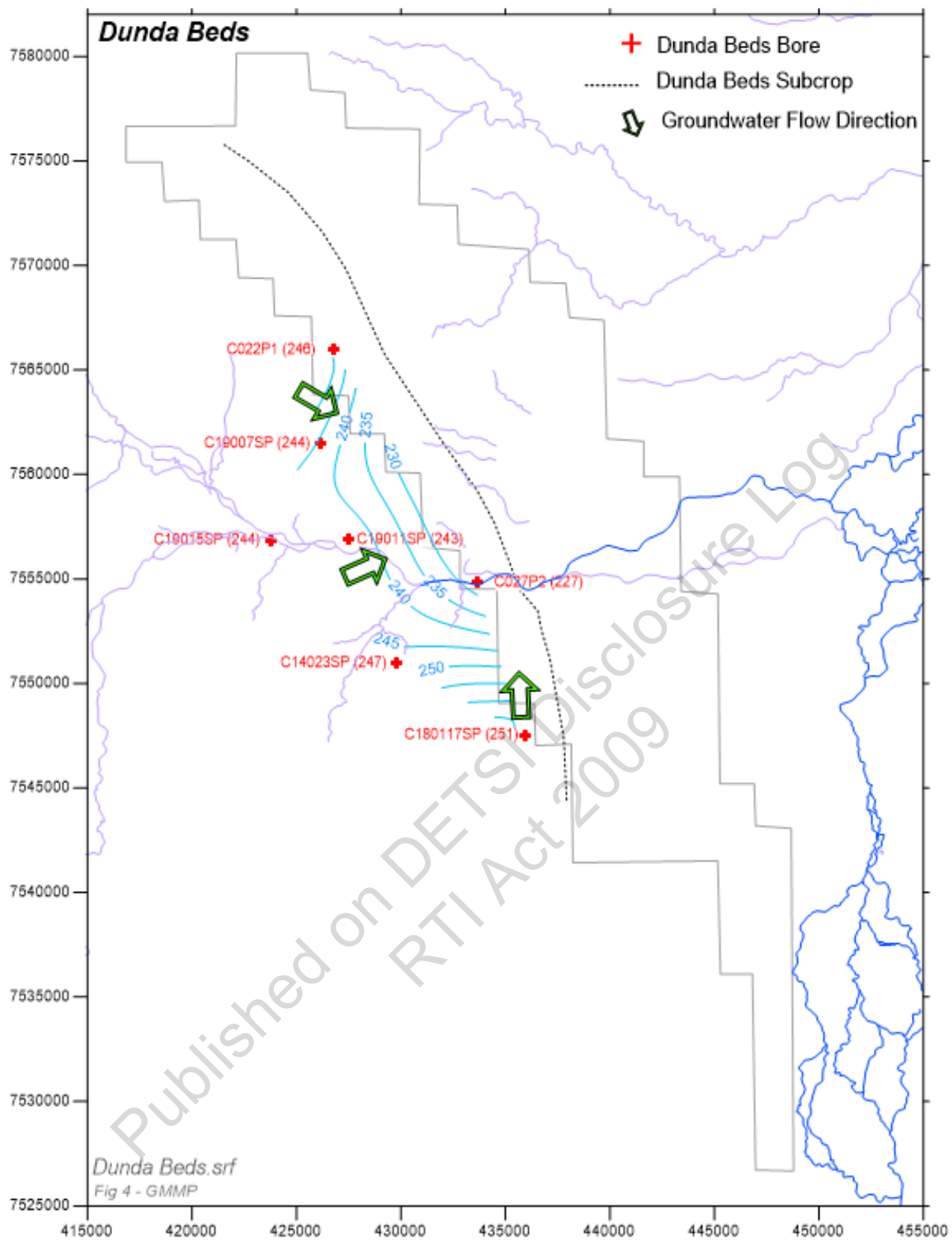


Figure C.9 Groundwater heads in the Dundas Beds at December 2020

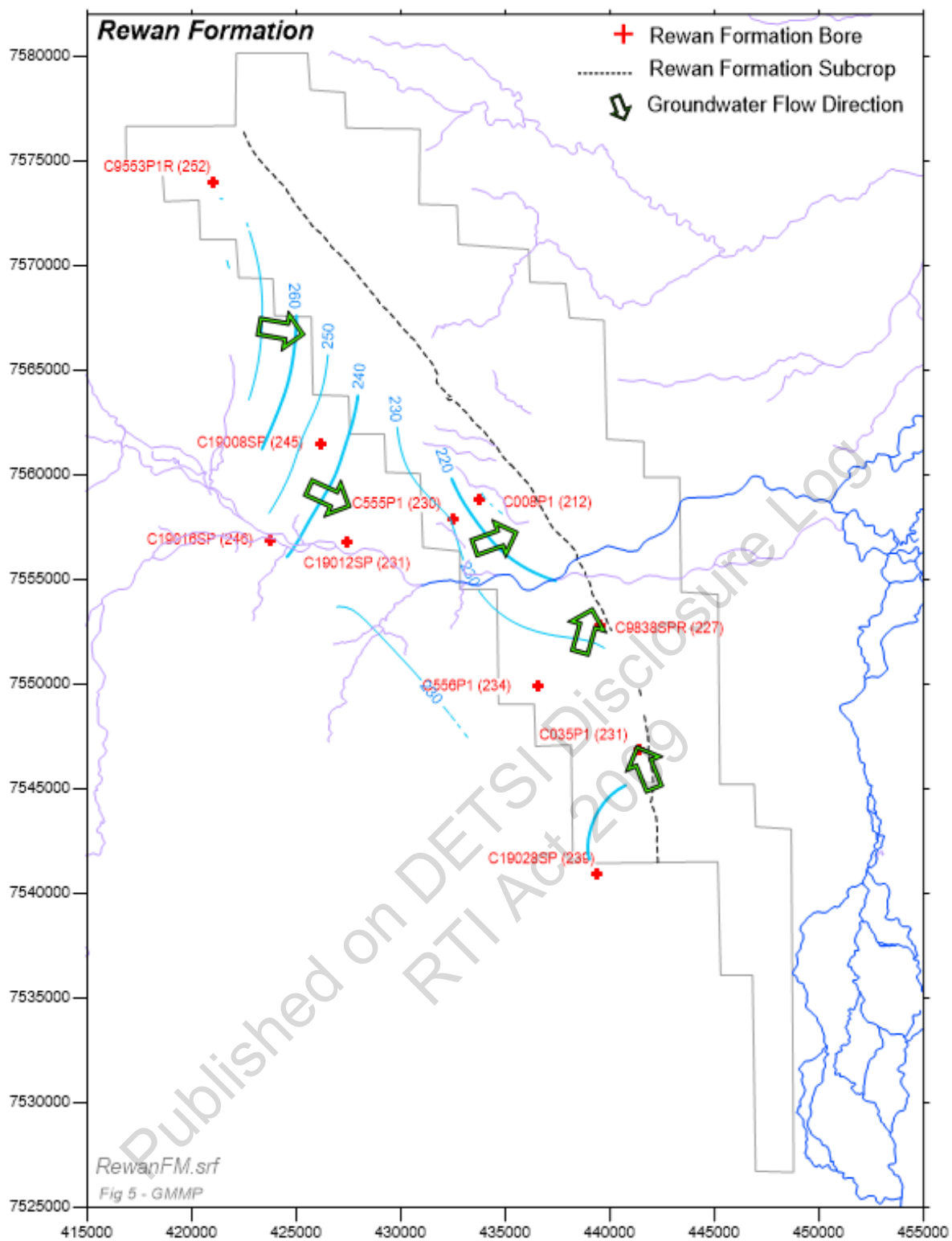


Figure C.10 Groundwater heads in the Rewan Formation at December 2020, excluding VWP data

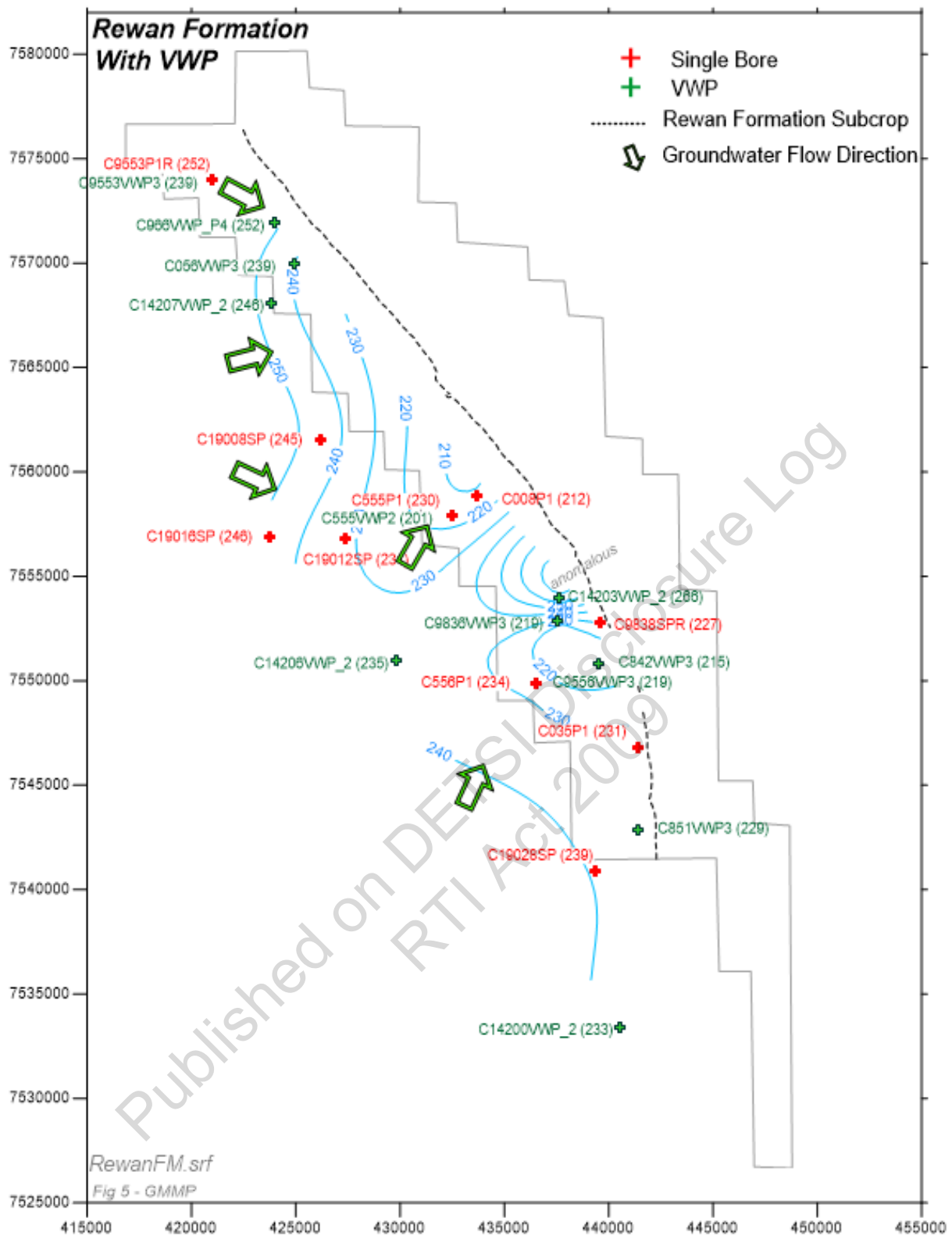


Figure C.11 Groundwater heads in the Rewan Formation at December 2020, including VWP data

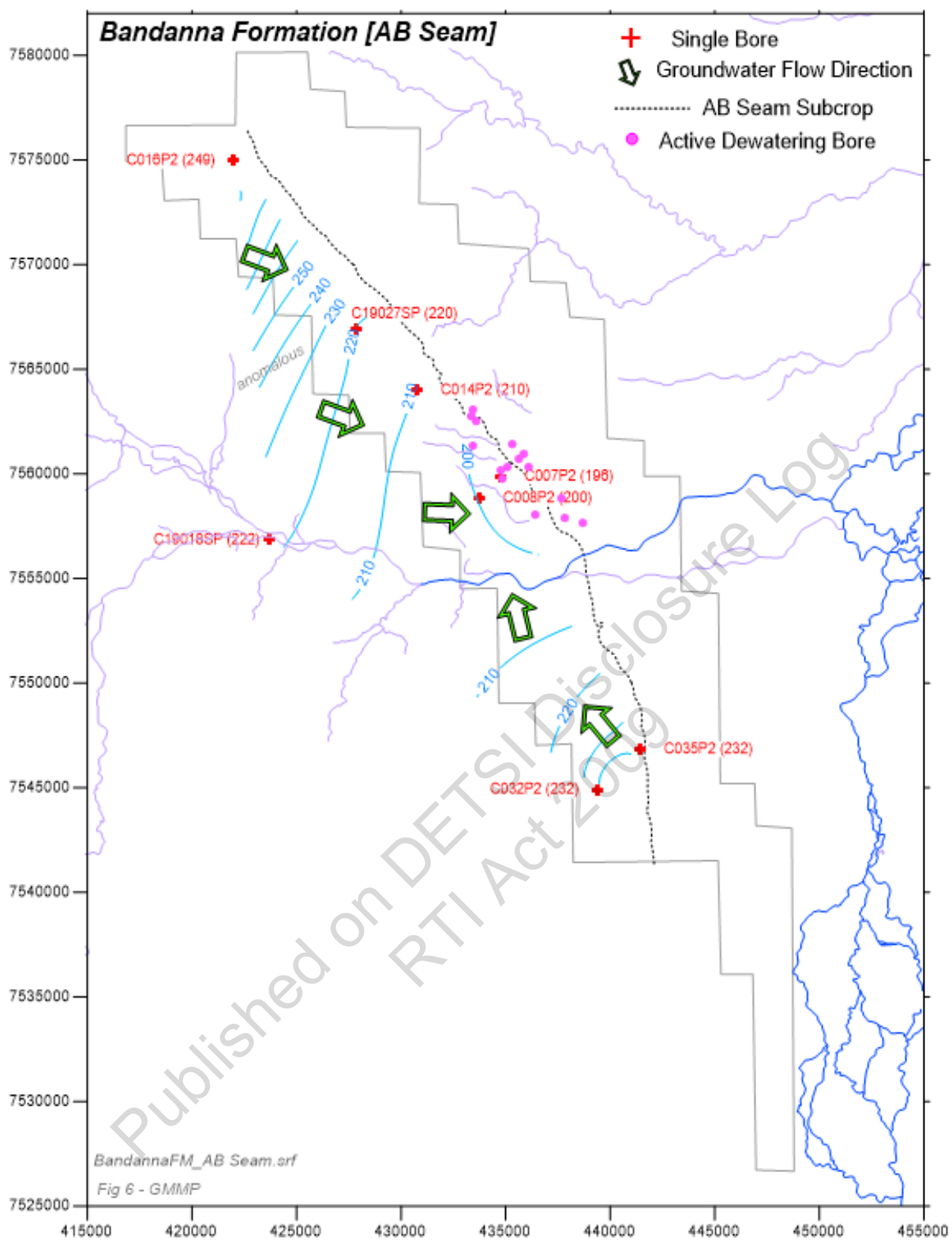


Figure C.12 Groundwater heads in the Bandanna Formation (AB Seams) at December 2020, excluding VWP data

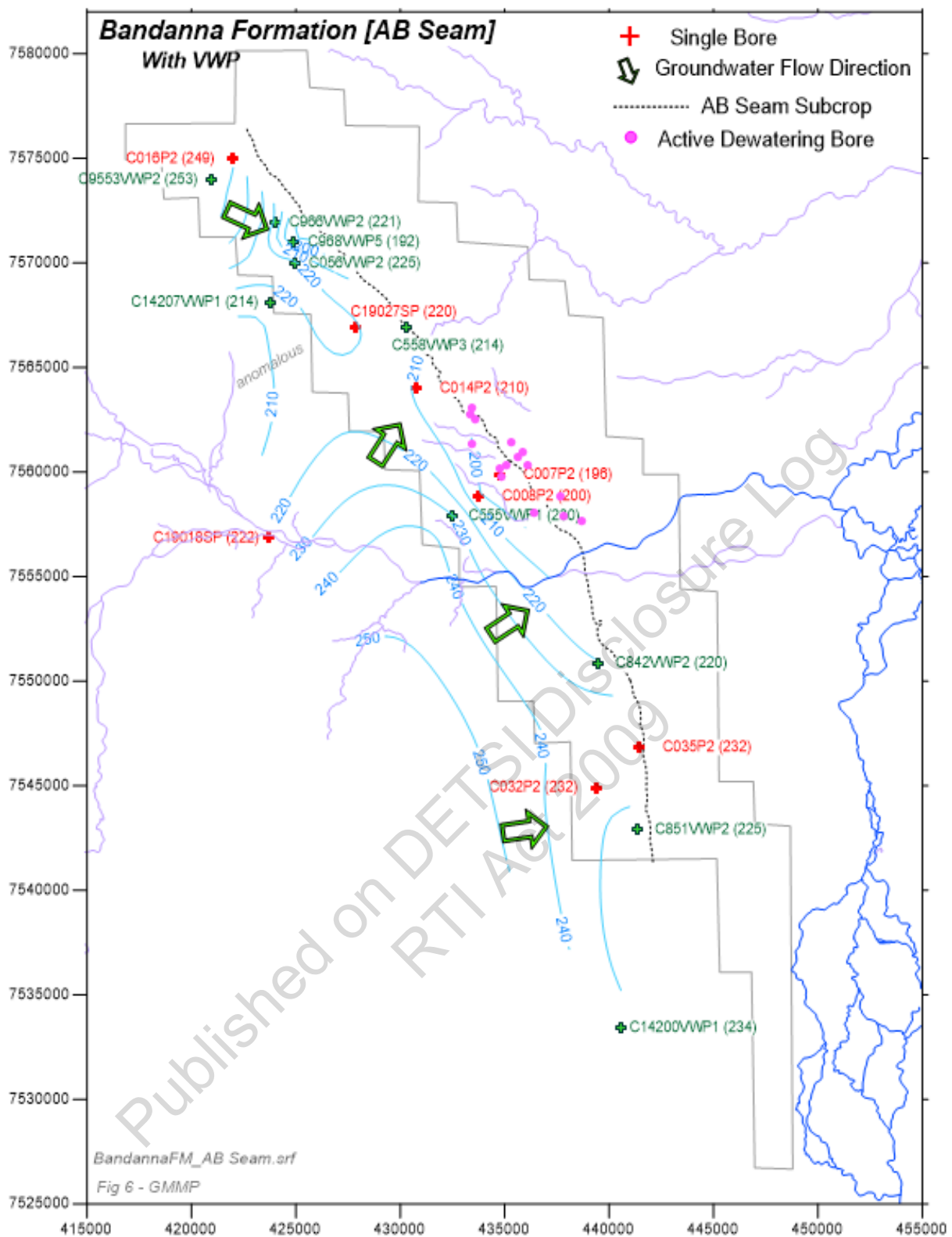


Figure C.13 Groundwater heads in the Bandanna Formation (AB Seams) at December 2020, including VWP data

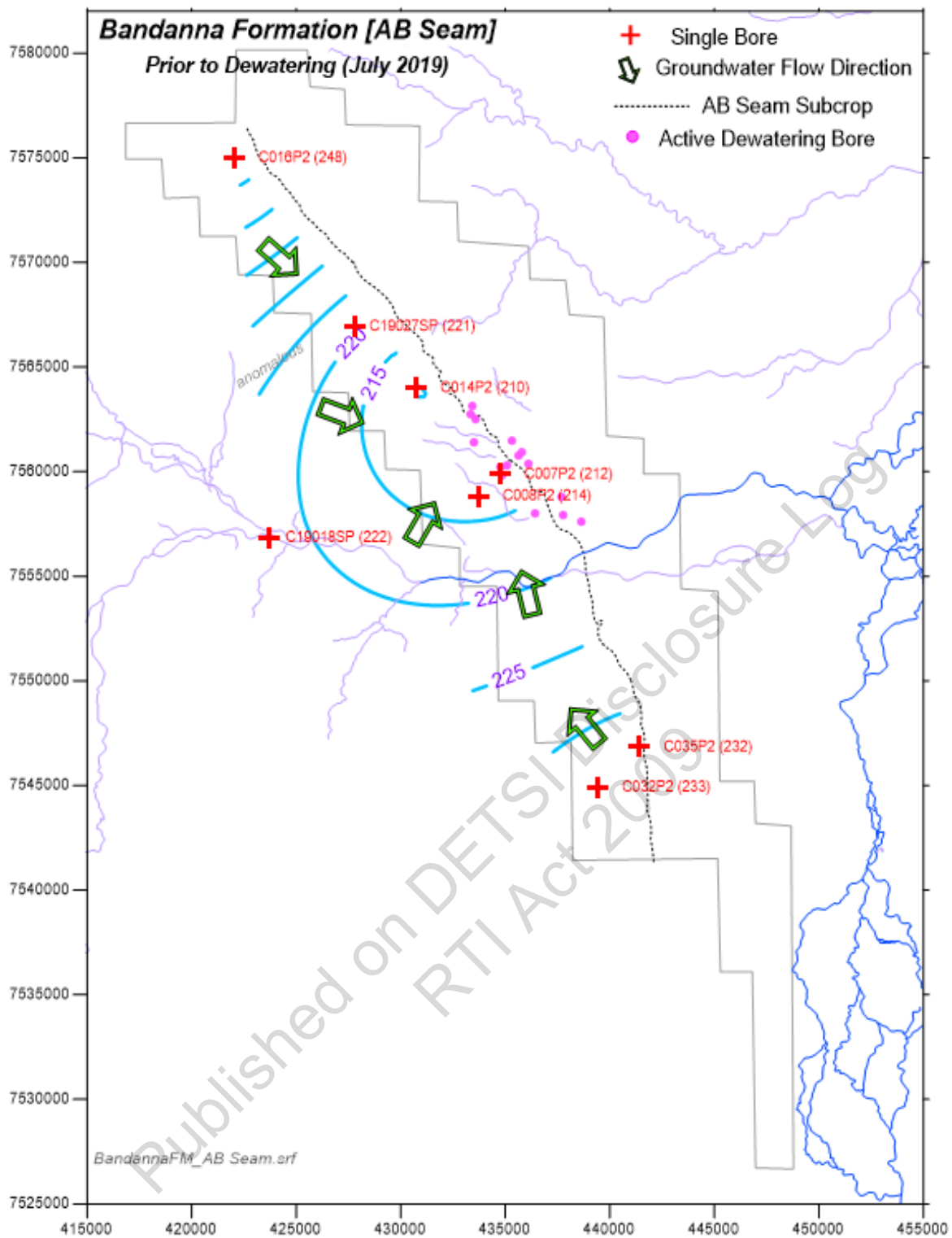


Figure C.14 Groundwater heads in the Bandanna Formation (AB Seams) at July 2019, prior to dewatering

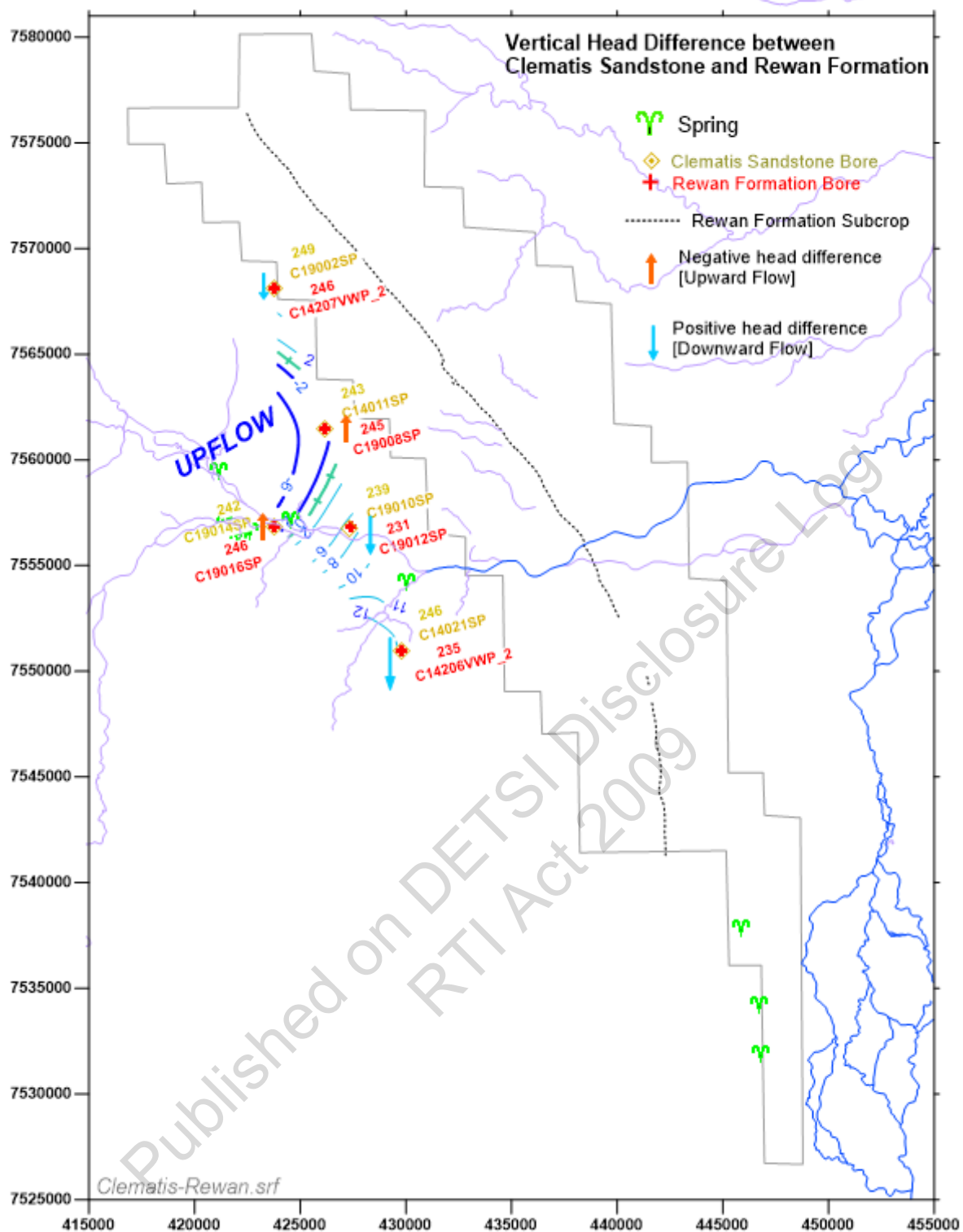


Figure C.15 Vertical head differences between the Clematis Sandstone and the Rewan Formation at December 2020

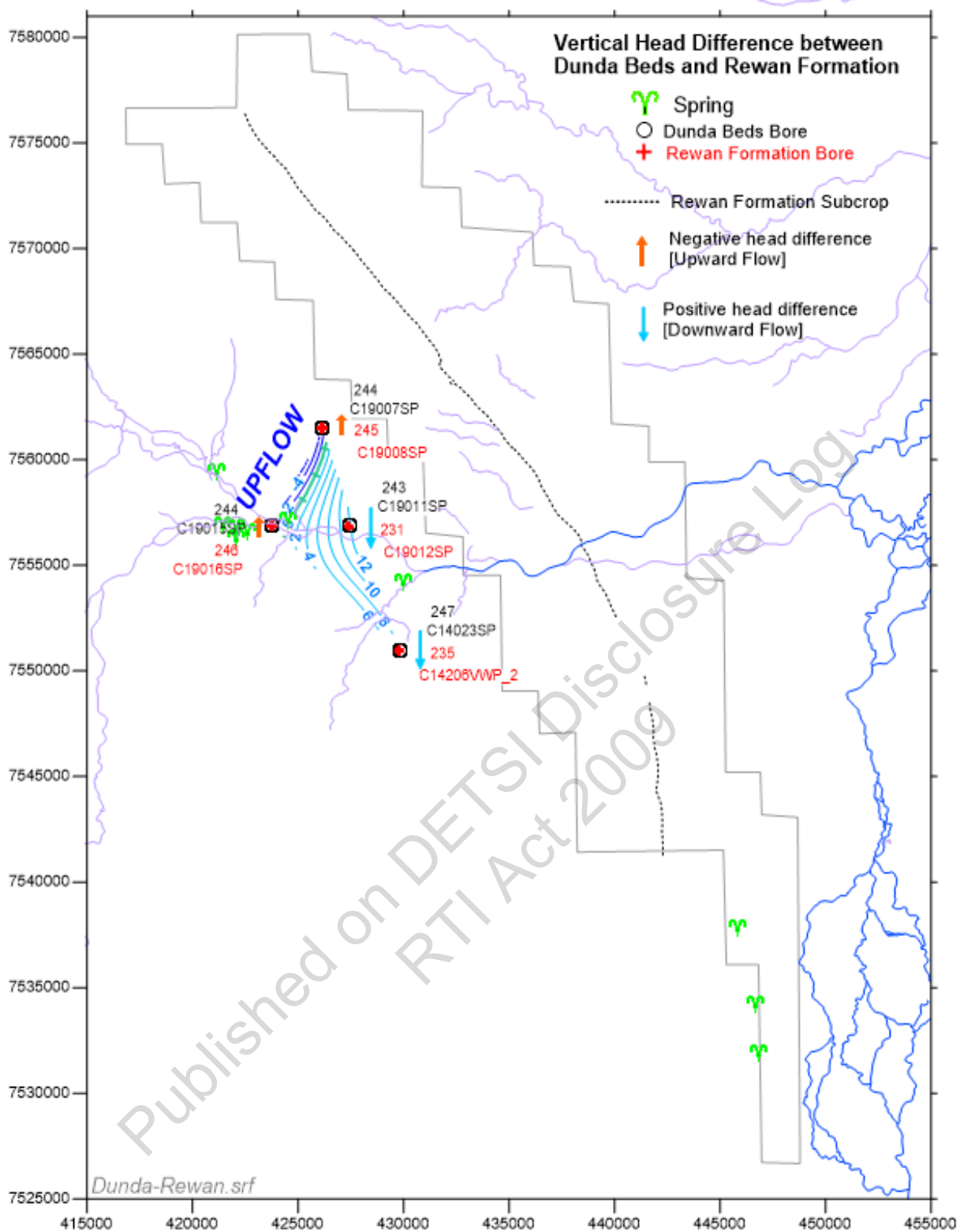


Figure C.16 Vertical head differences between the Dunda Beds and the Rewan Formation at December 2020

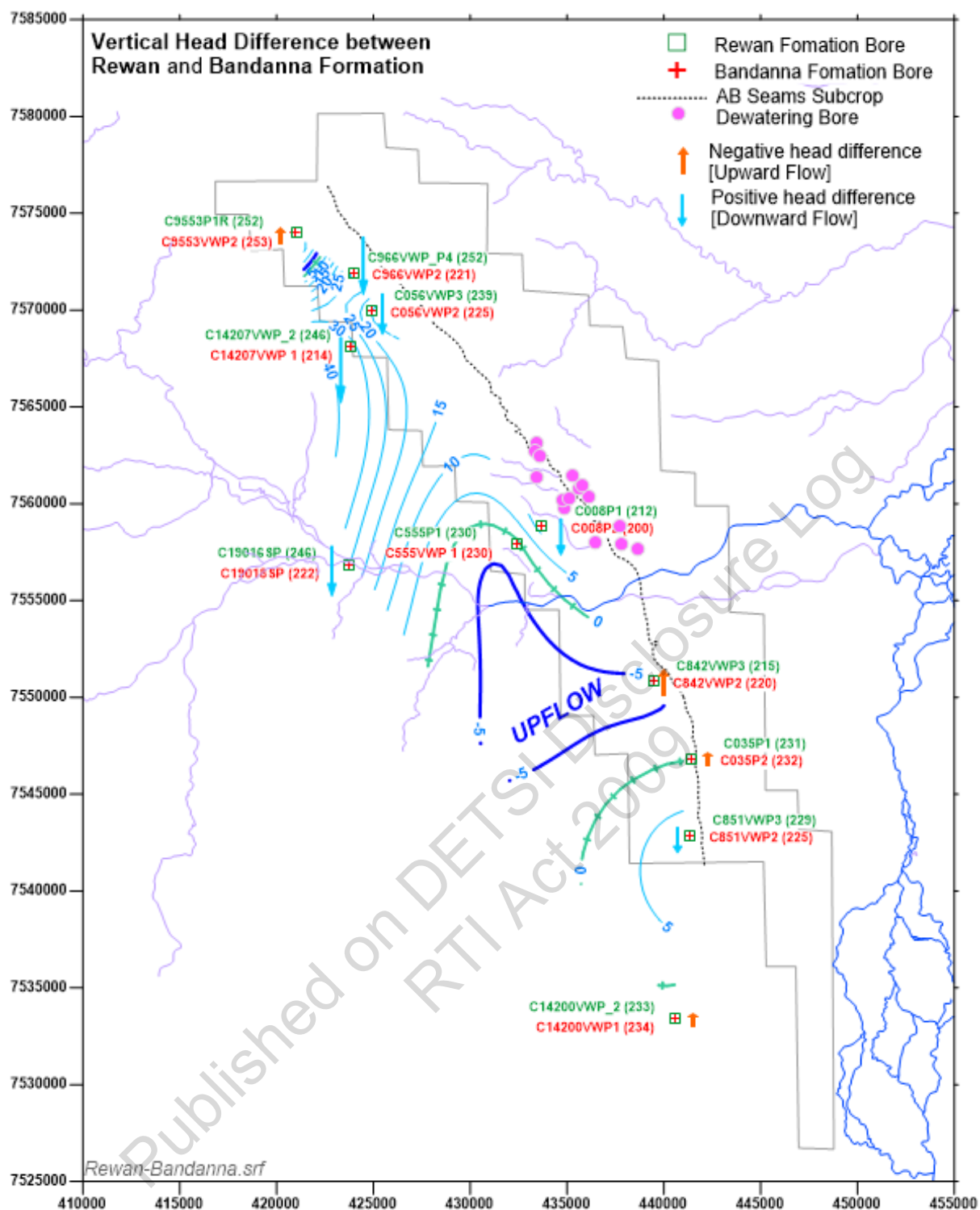


Figure C.17 Vertical head differences between the Rewan Formation and the upper Bandanna Formation at December 2020

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Carmichael Coal Mine and Rail Project

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1 Introduction

Bravus Mining and Resources (Bravus) has commenced development of the Carmichael Coal Mine located in the Galilee Basin, approximately 160 km northwest of Clermont in Central Queensland. The Carmichael Coal Mine and Rail Project was assessed by the Commonwealth and Queensland governments through an Environmental Impact Statement (EIS) process. Conditional approval of the Carmichael Coal Mine and Rail Project was granted by the Queensland Coordinator-General on 8 May 2014 and the Commonwealth Minister for the Environment on 14 October 2015 (EPBC 2010/5736). The Environmental Authority (EA) EPML01470513 for the Mining Leases (ML) 70441, 70505 and 70506 was initially granted on 2 February 2016 and further amended in September 2019 and most recently July 2020.

A Groundwater Management and Monitoring Program (GMMP) has been prepared in accordance with EA Condition E5. Several iterations of the GMMP have been submitted for approval since 2017. The latest version of the GMMP (Version 11) was submitted and approved by the Department of Environment and Science, Qld (DES) in February 2021. The GMMP is also submitted to the Commonwealth department of Agriculture Water and Environment (DAWE) for approval (the version submitted to DAWE is referred to as GMMP Ver 11a).

As per EA Condition E5, the GMMP must be reviewed by a suitably qualified person with a report provided on the outcome of the review to the administering authority by 1 July 2021.

The purpose of this report is to meet the requirement of EA Condition E5 to provide a review of the GMMP before 1 July 2021. This report is the second GMMP review report prepared to comply with EA Condition E5. The first GMMP review report was submitted on 24 June 2020 (Adani 2020) to comply with the EA requirements at that time. It is noted that the wording of EA Condition E5 has been amended since submission of the previous GMMP review. The current wording of EA Condition E5 refers to the review required before 1 July 2021 (ie this report) as the initial review.

1.1 Suitably qualified reviewer

This review of the GMMP was undertaken by Craig Vincent and James Tuff of EMM Consulting Pty Ltd. Craig holds the degree of Master of Science (with distinction) in Geology. Craig has 18 years of industry experience as a hydrogeologist and is a current member of the Australasian Institute of Geoscientists (AIG) and International Association of Hydrogeologists (IAH). James holds a PhD in geology and has over 15 years of experience as a geochemist. He is a member of the AIG, a Fellow of the Geological Society of London and a lifetime Fellow of the Japan Society for the Promotion of Science (JSPS).

2 GMMP review requirements

2.1 EA requirements

Condition E5 of the EA states the following:

*“The GMMP must be reviewed by a suitably qualified person with a report provided on the outcome of the review to the administering authority by **1 July 2021**. After the initial review, the review must be completed within three months of the second anniversary date of commencing box cut excavation and every 5 years following, and the report provided to the administering authority no later than three months of the finalisation of the review.*

The GMMP review and report must include:

- a) an assessment of the groundwater management and monitoring program against the objectives in **Condition E4**.*
- b) an assessment of the GMMP against commitments in section 7 of the administering authority approved GMMP.*
- c) a review of the adequacy of the monitoring locations, frequencies and groundwater quality triggers specified in **Tables E1 – Groundwater quality monitoring locations and frequency for the mine site, Table E2 – Groundwater quality trigger levels and Table E3 – Groundwater level thresholds**.*
- d) a review of the validity of the groundwater monitoring program against the revised model predictions required under **Condition E6**¹.*

Recommendations and certifications made within the review, must be adopted by the EA holder, and be updated within the GMMP for approval by the Administering Authority within three (3) months from the date of the GMMP Review Report.”

It is noted that the review required under Condition E6 (ie bullet point d above) is not required to be submitted until three months following the second anniversary date of commencement of the box cut. As excavation of the box cut did not commence until 10 July 2020, this condition does not need to be addressed until the next GMMP review which is required to be submitted before 10 October 2022.

2.2 GMMP commitments

Section 7 of the GMMP outlines commitments which are required to be undertaken by Bravus. Four commitments (# 17, 23, 28 and 29) relate specifically to review of the GMMP and are detailed as follows:

“17. Conduct a review of the monitoring data, using suitably qualified expert during the review of GMMP to be carried out before 1 July 2021 (or any other time frame as agreed with DES so as to align GMMP review and model re-run to happen concurrently) to update conceptualisations and conduct groundwater numerical model review based on these data.

- To allow for the correct scientific development of the GMMP it is considered (subject to agreement with DES) that the refinement and re-run of the model will occur prior to the update of the GMMP, as the model outputs and modifications can be captured in the GMMP.*

¹ It is noted that the requirement to ‘review validity of the groundwater monitoring program against model predictions’ is wrongly referred in the EA as Condition E9, this requirement actually refers to Condition E6.

- The model re-run is to occur 2 years after the commencement of the box cut and then every 5 years, the same review periods as the GMMP.

23. Include in the review of the GMMP an assessment of groundwater level and water quality data, and the suitability of the monitoring network, as per Condition E5. The GMMP will be reviewed by a suitably qualified person with a report provided on the outcome of the review to the administering authority by 1st July 2021. After the initial review, the review must be completed within three months of the second anniversary date of commencing box cut excavation and every 5 years following.

28. Initial review of the approved GMMP by an appropriately qualified person with a report provided on the outcome of the review to the administering authority by 1 July 2021 (or any other time frame as agreed with DES so as to align the GMMP review and model re-run to happen concurrently). After the initial review, the review will be conducted every five years following, the report provided to the administering authority.

29. The GMMP review will be conducted by 1 July 2021 (or any other time frame as agreed with DES so as to align the GMMP review and model re-run to happen concurrently). The revised GMMP will include statistical analysis of hydrochemistry and groundwater quality data.

- The next iteration of the GMMP (after 2 years of commencement of box cut excavation) will provide piper plots of the major ions for all hydrostratigraphic units included in the EA Conditions (Condition E3a), representative DSC springs, and the Carmichael River surface water.
- Contamination triggers and limits will be updated when the additional statistically sufficient pre-operational hydrochemistry data are collected. It is noted that several monitoring bores do not currently have the required number of analyses to calculate baseline trigger values and are using generic triggers derived from the ANZECC guidelines or average of bore specific data. Additional hydrochemistry results, allowing for the revision of trigger values, will be conducted according to the approach detailed in Section 5.4 of the GMMP.
- During GMMP review and groundwater model re-run consideration of potential impacts to relevant GDE's will be included when considering revision of trigger values."

2.3 DES recommendations

Following review of the previous GMMP review report, which was submitted to the Department of Environment and Science (DES) on 24 June 2020, DES provided a list of recommendations to be addressed in future GMMP review reports. The DES recommendations are provided as follows:

1. A review of monitoring data (water quality and water level) collected under the GMMP. The monitoring data should be compared to triggers, limits and thresholds after each monitoring event. The annual review should determine potential impacts and emerging trends in the data with any downward groundwater level trends compared to modelled drawdown rates. If the actual monitored rates are faster than predicted, the review report should recommend a suitable update of the triggers in the GMMP.
2. Increasing trends in groundwater quality may provide early warning of triggers being approached and should be discussed in the GMMP review report.
3. The GMMP review report must provide the baseline and pre-impact water quality in a format that can be compared to future monitoring data eg time series plots.
4. The GMMP review report should include a review of the adequacy of groundwater monitoring locations, frequencies, groundwater quality trigger and water level thresholds.

5. *The GMMP review report should provide piper plots of major ions for all hydrostratigraphic units and recommendations about revisions to the conceptual model (including isotope tracer results).*
6. *Detail isotope tracer studies used to characterise the groundwater dependent ecosystems.*
7. *The 2020 review report provides details of a number of new and replacement bores – 14 in total. The latitude and longitude of these bores should be provided in the review report to facilitate any necessary EA amendment to include these additional bores.*
8. *The location and target aquifer for all new bores should be detailed in the review report with a recommendation about any necessary EA amendments.*
9. *All exceedances in water quality triggers and limits should be discussed in the review report and recommendations of triggers that need to be revised should be detailed.*
10. *All five surface water gauging stations must be referred to in the review report for the GMMP with the data presented and interpreted.*
11. *The GMMP review report identifies inconsistencies in bore identification details. The review report should make recommendations about any necessary amendments to the GMMP and/or the EA.*

2.4 Summary of GMMP review requirements

A summary of the various GMMP review requirements, and reference to where they have been addressed in the report are presented in Table 2.1

Table 2.1 Summary of GMMP review requirements and where addressed

Review requirement	Description	Relevant section of this report
EA requirement		
EA Condition E5(a)	Assessment of the groundwater management and monitoring plan against the objectives in Condition E4	Section 3.1, Table 3.1
EA Condition E5(b)	Assessment of the GMMP against commitments in section 7 of the administering authority approved GMMP	Section 3.4
EA Condition E5(c)	A review of the adequacy of the monitoring locations, frequencies and groundwater quality triggers specified in Tables E1, E2 and E3	Section 3.2
EA Condition E5(d)	A review of the validity of the groundwater monitoring program against the revised model predictions required under Condition E6	Section 3.3
GMMP commitments specific to GMMP review		
#17	Conduct a review of the monitoring data, using suitably qualified expert during the review of GMMP to be carried out before 1 July 2021.	Section 3.4.17 Section 3.5.1 (assessment of water quality and water level data)
#23	Include in the review of the GMMP an assessment of groundwater level and water quality data, and the suitability of the monitoring network, as per Condition E5.	Section 3.2 (suitability of monitoring network) Section 3.5.1 (assessment of water quality and water level data)
#28	Initial review of the approved GMMP by an appropriately qualified person with a report provided on the outcome of the review to the administering authority by 1 July 2021.	Section 1.1 (qualifications of reviewers)
#29	The GMMP review will be conducted by 1 July 2021. The revised GMMP will include statistical analysis of hydrochemistry and groundwater quality data.	Section 3.4.29 Appendix E (box and whisker plots)
All other GMMP commitments		
#1 to #41	Commitments #1 to #41 as outlined in the GMMP	Section 3.4.1 to Section 3.4.41
GMMP Section 7.1.1	Springs, GDES and baseflow commitments	Section 3.4.42
GMMP Section 7.1.2	Monitoring program updates	Section 3.4.43

Table 2.1 Summary of GMMP review requirements and where addressed

Review requirement	Description	Relevant section of this report
DES recommendations		
#1	Review of monitoring data (water quality and water level) collected under the GMMP. The monitoring data should be compared to triggers, limits and thresholds after each monitoring event. The annual review should determine potential impacts and emerging trends in the data with any downwards groundwater level trends compared to modelled drawdown rates. If the actual monitored rates are faster than predicted, the review report should recommend a suitable update of the triggers in the GMMP.	Section 3.5.1
#2	Increasing trends in groundwater quality may provide early warning of triggers being approached and should be discussed in the GMMP review report.	Section 3.5.2
#3	The GMMP review report must provide the baseline and pre-impact water quality in a format that can be compared to future monitoring data eg time series plots.	Section 3.5.3 Appendix D (comparison to baseline water quality)
#4	The GMMP review report should include a review of the adequacy of groundwater monitoring locations, frequencies, groundwater quality trigger and water level thresholds	Section 3.5.4
#5	The GMMP review report should include piper plots of major ions for all hydrostratigraphic units and recommendations about revisions to the conceptual model (including isotope tracer results).	Section 3.5.5
#6	Detail isotope tracer studies used to characterise the groundwater dependent ecosystems.	Section 3.5.6
#7	The 2020 review report provides details of a number of new and replacement bores – 14 in total. The latitude and longitude of these bores should be provided in the review report to facilitate any necessary EA amendment to include these additional bores.	Section 3.5.7

Table 2.1 Summary of GMMP review requirements and where addressed

Review requirement	Description	Relevant section of this report
#8	The location and target aquifer for all new bores should be detailed in the review report with a recommendation about any necessary EA amendments.	Section 3.5.8
#9	All exceedances in water quality triggers and limits should be discussed in the review report and recommendations of triggers that need to be revised should be detailed	Section 3.5.9
#10	All five surface water gauging stations must be referred to in the review report for the GMMP with the data presented and interpreted.	Section 3.5.10
#11	The GMMP review report identifies inconsistencies in bore identification details. The review report should make recommendations about any necessary amendments to the GMMP and/or EA.	Section 3.5.11

3 GMMP review results

3.1 Assessment against objectives in EA condition E4

An assessment of the GMMP against the objectives in EA Condition E4 is summarised in Table 3.1.

Table 3.1 Assessment against objectives in EA condition E4

EA condition	Review outcome
The GMMP must be developed and implemented to meet the following objectives:	
a) Validation of the groundwater numerical model (including review of boundary and recharge conditions) to refine and confirm accuracy of groundwater impacts predicted;	<p>The GMMP has been prepared to facilitate validation of the groundwater numerical model (including review of boundary and recharge conditions) to refine and confirm accuracy of predicted groundwater impacts. The following have been included in the GMMP to meet the above requirement:</p> <ul style="list-style-type: none"> • An appropriate groundwater monitoring network has been designed and implemented for conducting regular groundwater monitoring to collect continuous data on water levels and water quality parameters for both construction and operational phases of the Project. Groundwater data collection from monitoring bores commenced January 2020. Periodic bi-monthly groundwater monitoring, commenced April 2020 and will be continuing through all phases of mining (Section 6.1 to 6.3 of GMMP) • The monitoring data will be used for validation and comparison of the predicted drawdowns and to check the accuracy of the predicted groundwater impacts. As per the GMMP, this comparison will be made when sufficient groundwater level data has been collected within two years of the commencement of the initial box cut excavation (Section 1.10.1 of GMMP). The excavation of first box cut commenced 10 July 2020.
b) Groundwater level monitoring in all identified geological units present across and adjacent to the mine site to confirm existing groundwater flow patterns and monitor drawdown impacts;	An appropriate groundwater monitoring network has been designed for conducting regular groundwater monitoring of water levels and water quality in all identified geological units present across and adjacent to the mine site and included in the GMMP. This monitoring will help to confirm existing groundwater flow patterns and to monitor drawdown impacts. Baseline monitoring was undertaken between 2011 and 2017. Further monitoring commenced in January 2020 and will be continued through all phases of mining.
c) Identification of groundwater drawdown level thresholds for monitoring the impacts to Groundwater Dependant Ecosystems (including spring complexes and Carmichael River alluvium);	Groundwater drawdown level thresholds have been developed for 48 bores and included in the GMMP for monitoring of potential impacts to Groundwater Dependant Ecosystems (including spring complexes and Carmichael River alluvium). All future monitoring data will be compared against the thresholds to check for exceedances (Section 5.0 of GMMP).
d) Monitoring of aquifers in the area to the south of the mining lease that may affect the Mellaluka springs;	Several groundwater monitoring bores screened across the Joe Joe Group are present in the south of the mining lease to monitor for potential impacts to the Mellaluka Springs Complex. Monitoring bores details are presented in Section 5.3.4 of GMMP.
e) Identify and refine potential impacts on groundwater levels in the Great Artesian Basin Clematis Sandstone and Dunda Beds geological units;	A bore network is established to monitor the groundwater levels in the Great Artesian Basin Clematis Sandstone and Dunda Beds geological units. Further additional networks of bores have been installed during 2020. Monitoring at these new bores commenced in January 2020, and data collected will be used for identifying and refining potential impacts (see Section 5.3 and 6.2 of GMMP)

Table 3.1 Assessment against objectives in EA condition E4

EA condition	Review outcome
f) Estimation of groundwater inflow to mine workings and surface water ingress to groundwater from flooding events using the groundwater model;	Bravus has commenced monitoring of groundwater and surface water flows. Bravus has completed the servicing of existing flow gauging stations on the Carmichael River (Stations BEL01, BEL02, CAR04, CAR01 and CAR02). These flow gauging stations have been operational since September 2019 and January 2020. Bravus has also commissioned a further two flow gauging stations on Carmichael River (Stations – Moray West and Albinia stations) which have been operational since January 2021. The numerical groundwater model will be reviewed, using the monitoring data plus measured mine dewatering volumes, within two (2) years of the box cut excavation ie July 2022, and then at least every 5 years afterwards. Assessment of surface water-groundwater interaction has been included in the groundwater numerical model and will be refined overtime, based on groundwater and surface water monitoring data.
g) Monitoring in any identified source aquifers for alternative water supplies, relevant to any approval issued under the Water Act 2000 for the project;	Two additional bores have been installed for collection of groundwater data to facilitate the model refinement and to better assess the sub-E sediments below the coal seams. Additional investigations will be carried out in future at these bores to provide information regarding the groundwater potential within the sub-E coal seam sediments, which could be used as Make-Good groundwater supplies (Section 3.5.3 and Section 6.2 of GMMP). Monitoring has commenced at these two bores.
h) Monitoring of geological units throughout all phases of mining operations including for the period post-closure in accordance with Appendix 1;	Monitoring recommendations and commitments have been compiled for all phases of mine life, including baseline, construction, operations, and post-closure (Section 6.0 of GMMP)
i) Identifying monitoring bores that will be replaced due to mining activities; and	The GMMP includes the commitment to augment and modify the groundwater monitoring bore network in line with the mine plan and activities. Bravus has installed an additional 15 bores for monitoring groundwater level and quality near the proposed infrastructure facilities since 2018. Bores identified in the GMMP for Operational Phase are based on the first five years of mining, and the Operational Monitoring network will be revised due to decommissioning of some bores (see GMMP Section 6.2).
j) To ensure all potential groundwater impacts from mine dewatering and mine water and waste storage facilities (artificial recharge) are identified, mitigated and monitored.	Bravus has commenced monitoring for the compilation of sufficient, spatially and geological unit-wise, groundwater monitoring data to adequately assess potential impacts from mine-dewatering and mine affected water and waste storage facilities and in turn are identifying, mitigating, and monitoring Impacts. (see Section 6.2 of GMMP). This includes six bores installed in 2018: C18007SP and C18008SP (which have been dry), C18004SP (Alluvium), C18005SP (Alluvium), C18006SP (Alluvium) and C18009SP (Weathered Tertiary), which are monitored under the GMMP. Interim trigger values and contaminant limits have been derived from the four bores with water quality measurements (ten rounds of monitoring) following the methods outlined in the GMMP ver.11 (Section 5.4). The interim proposed values are included in Appendix F.

3.2 Review of the adequacy of the groundwater monitoring locations, frequencies, and groundwater quality triggers specified in Table E1, E3 and E3 of the EA

The groundwater monitoring network provides an adequate number of monitoring locations screened within the major hydrostratigraphic units of concern to the Project and allows for both spatial and temporal variations in water level and water quality to be assessed. The bore monitoring network has been established in consultation with DES. Since publication of the GMMP, Bravus have serviced all bores and renovated some of the bores in the network and have commissioned additional monitoring bores.

Monitoring frequency is every two months, in accordance with the EA conditions, which require the monitoring frequency to be at least every two to three months, and provides six sets of water quality data for the groundwater bores and spring samples in one year. This is adequate to provide 12 datasets over the two years following commencement of the monitoring program (as per the GMMP) and given the logistics of laboratory analysis (including QA/QC procedures, such as holding times) is a reasonable frequency of sampling. This monitoring frequency is expected to continue until July 2022, when sampling every three months is likely to be implemented.

The water quality analysis of each sampling round is compared to the bore-specific and hydrostratigraphic unit-specific trigger values (as outlined in the GMMP). Trigger exceedances are reported if two or more trigger exceedances occur for a given water quality parameter at a given bore over a period of 12 months. These trigger exceedances are reported within 14 days of receipt of the analytical results. Two or more trigger exceedances within 12 months instigates a Stage 1 investigation into the potential cause of the exceedances. Appendix C shows the latest round of water quality trigger exceedances following the April 2021 field sampling.

This review finds that the currently assigned trigger values need to be re-assessed for adequacy for the following reasons:

- The monitored water quality has been consistently reported as exceeding the relevant trigger values since the monitoring program began. This includes the period of monitoring prior to work commencing on site, which effectively recorded baseline water quality. Investigations into trigger exceedances have repeatedly concluded that the exceedances are the result of either recently installed bores/bore renovations affecting water quality equilibrium, the natural variation in the water quality at each bore (including variations resulting from wet/dry conditions), or the set trigger values not adequately accounting for the (natural/pre-works) variations in water quality at each bore.
- Bores installed since the publication of the GMMP have not been assessed for baseline/trigger values. This is particularly relevant to the Alluvium bores installed from 2018, since the alluvium water quality was found to be highly variable and trigger values and individual bore-specific trigger values were developed in the GMMP. Interim bore-specific trigger values and contaminant limits have been derived from these bores (where sufficient data are available) following the methods outlined in the GMMP ver.11 (Section 5.4); the proposed values are presented in Appendix F of this review report.
- In letters to Bravus from the Department of Environment and Science (DES) on 27 October 2020 and 23 March 2021, it was noted that:
 - Numerous exceedances of groundwater quality triggers have occurred over two rounds of groundwater monitoring since December 2019, prior to substantial mining activities commencing such as box cut excavation. This suggests that insufficient baseline data has been collected to date to establish the natural variation within the various groundwater aquifers that are monitored for groundwater quality. It is recommended that where groundwater quality has not been affected by mining activities, it is used to better establish the background groundwater quality at the time of the GMMP review due on 1 July 2021 in accordance with condition E5 of EA EPML01470513.
 - It is recommended that triggers and limits are removed for major ions (calcium, magnesium, potassium, sodium and chloride), alkalinity, total dissolved solids, sulphide and nitrite but are still monitored for interpretation purposes.
 - Exceedances of groundwater triggers are to be identified from samples that have not been compromised. For instance, where samples have breached the holding times for pH, the result must be determined from the in-situ result, not the results from the laboratory.

3.3 Review of the validity of the groundwater monitoring program against the revised model predictions required under Condition E6

Condition E6 of the EA states the following:

*“The numerical groundwater model in the reports titled “Carmichael Coal Mine and Rail Project SEIS: Report for Mine Hydrogeology Report (13 November 2013)” and “Carmichael Coal Mine and Rail Project SEIS: Mine Hydrogeology Report Addendum (24 October 2013)” must be reviewed to incorporate groundwater monitoring data and measured mine dewatering volumes from the GMMP in EA **Conditions E4 and E5**.*

The review must be completed within three months of the second anniversary date of commencing box cut excavation and at least every 5 years thereafter, or at other intervals specified by the administering authority in writing, if the observed groundwater levels and groundwater flow rates to surface water are not consistent with those predicted by the groundwater mode.

.....”

In accordance with EA Condition E6, Bravus will undertake a review of the numerical groundwater model within three months of the second anniversary date of commencement of the boxcut ie 10 July 2022.

3.4 Assessment of GMMP commitments

Section 7.0 of the approved GMMP lists a total of 41 commitments with respect to groundwater monitoring, installation of additional bores, provision of supply of periodic reports, publishing of monitoring data, undertaking of investigations should water level or water quality trigger levels be exceeded, review of the groundwater monitoring program and groundwater numerical model.

An update on the status of each of the commitments in Section 7.0 of the approved GMMP are discussed below.

3.4.1 GMMP commitment #1

1. *Implement this GMMP, which details the location and frequency of groundwater monitoring activities, as well as trigger levels and response actions*

Status: Compliant. Bi-monthly monitoring of groundwater levels and water quality commenced in April 2020 for monitoring locations specified in the GMMP. Following each bi-monthly monitoring event, groundwater levels are compared to water level thresholds and water quality results compared to water quality triggers. Exceedances of water level thresholds and water quality triggers are submitted to DES following each monitoring event.

3.4.2 GMMP commitment #2

2. *Augment the existing groundwater monitoring network over time to enable ongoing groundwater impact evaluations*

Status: Compliant. Augmentation of the groundwater monitoring network for impact evaluations has been undertaken. Bravus has installed 14 additional monitoring bores between the western ML boundary and the Doongmabulla Springs and an additional 15 monitoring bores within the mining lease consisting of 9 new bores and 6 replacement bores (see Table 3.2). All bores have been installed by appropriately licenced drilling contractors in accordance with *Minimum Construction Requirements for Water Bores in Australia, 4th Edition (NUDLC, 2020)* and the *Minimum Standards for the Construction and Reconditioning of Water Bores that Intersect the Sediments of Artesian Basins in Queensland (DNRME, 2017)*.

3.4.3 GMMP commitment #3

3. *Maintain and decommission of bores, according to industry standards, to ensure the management of groundwater resources and the collection of representative groundwater monitoring data.*

Status: Compliant. Servicing of all monitoring bores was undertaken during September-January 2020. Bore servicing included redevelopment (where necessary), upgrading of headworks and servicing of installed groundwater monitoring equipment. Decommissioning of monitoring bores is done in accordance with *Construction and Reconditioning of Water Bores that Intersect the Sediments of Artesian Basins in Queensland* (DNRME, 2017).

3.4.4 GMMP commitment #4

4. *Utilise digital pressure gauges to obtain more accurate pressure readings at all of the artesian monitoring bores during every groundwater monitoring event.*

Status: Compliant. All artesian monitoring bores have now been equipped with ports for measurement with digital pressure gauge to enable more accurate pressure readings to be undertaken.

3.4.5 GMMP commitment #5

5. *Detail all automatic water level loggers (model, setting, and setting information), including the depth of installation within the artesian bore headworks.*

Status: Compliant. Cable lengths were recently measured in all artesian bores to determine the position of the logger within each monitoring bore. The logger position in most artesian bores was found to be different to the position assumed during assessment of historical water levels. As a result, the historical water level elevation in most artesian bores has been updated and this has implications on the water level thresholds which were developed in Table 45 of the GMMP. Historical average water levels were reassessed, and water level thresholds updated to reflect the correct position of the logger in each monitoring bore with the results shown in Table A.1 and Appendix A. It is recommended that water level thresholds in artesian bores be assessed against the updated water level thresholds shown in Table A.1 and the EA condition E5 and table E3-Groundwater level Thresholds of Appendix 5 of the EA to be updated. The next iteration of the GMMP should consider further updating of average baseline water levels to include all monitoring data collected prior to commencement of the box cut excavation (ie 10 July 2020), currently average baseline water levels are only calculated from water levels collected prior to 2017.

Additionally, three sub-artesian monitoring bores with threshold values (C025P1, C180116P and C180118SP) have been replaced with newly drilled bores C19001SP, C19028SP and C19002SP, respectively. There is significant difference in water levels between the old bores and the newly drilled replacement bores meaning that water levels in one of the new bores (C19001SP) always exceed the threshold value which was developed from the old bore. Average groundwater levels and threshold values have been updated to only include water levels measured in the replacement bores with the results shown in Table B.1 and Appendix B. It is recommended that water levels in C19001SP, C19002SP and C19028SP be assessed against the updated water level threshold values shown in Table B.1 and the EA condition E5 and table E3-Groundwater level Thresholds of Appendix 5 of the EA to be updated. Average water levels and water level threshold values for those bores should be reassessed during the next iteration of the GMMP as more data is collected from those bores.

All water level logger settings (model, setting, setting information) are updated in the spreadsheet used for downloading data.

3.4.6 GMMP commitment #6

6. *Compile all automated water level logger data in a standard format for all monitoring bores, such that the data provided is easier to assess and interpret. The format is, in accordance to approval conditions, to be supplied in a format specified by the administering authority. The information will include, as a minimum:*

- *Manual and logger download data*
- *Correction for barometric pressure (non-vented loggers)*
- *Logger set-up details, depth of installation and measurements as depth-to-water*

- *Logger reset or replacement details*
- *Logger type and accuracy*
- *Agreed column naming convention*

Status: Compliant. All automatic logger settings have been updated to be in a standard format used for downloading data with details such as logger model, setting information for barometer pressure correction, other measurement details like temperature and depth of installation and measurements as depth-to-water.

3.4.7 GMMP commitment #7

7. *Groundwater level data from bores in Bandanna Formation (C018P2, C032P2, C034P1 and C823SP), Colinlea Sandstone (C833SP and C834SP) and Joe Joe group (C14006SP, C14008SP, C14014SP (C914108PT), C14015SP, C14016SP, C14017SP, C914030SPR, C180119SP, C180123SP, C9180124SPR, and C9180125SPR) will be reviewed and updated in 2 years based on a review of data (logger data validation with future manual readings and datum measurements).*

Status: Compliant. Bravus has commenced groundwater monitoring as per the monitoring network detailed in Table 62 of the GMMP. Groundwater bores have been monitored since January 2020. The groundwater level data from the above bores will be reviewed and updated after two years.

3.4.8 GMMP commitment #8

Seepage /Infrastructure Bores

8. *Monitor the recently installed (2018) shallow seepage groundwater monitoring bores, prior to construction of mine affected water and waste storage facilities.*

Status: Compliant. Water quality data for six seepage monitoring bores (C18004SP, C18005SP, C18006SP, C18007SP, C18008SP, C18009SP) has been collected since 2018 and will be continued to be collected into the future during routine bi-monthly water quality monitoring². It is noted that two of these monitoring bores (C18007SP and C18008SP) have been dry since installation.

3.4.9 GMMP commitment #9

9. *Install additional monitoring bores located up and down gradient of surface infrastructure considered potential sources of contamination (e.g. mine infrastructure, waste dumps, and tailings areas) before construction of such facilities within 3 months of finalisation of the location of the facilities*

Status: Compliant. Two additional shallow monitoring bores (C19024SP and C19025SP) (see Table 3.2) have been drilled up and down gradient of the explosive storage area which will be used to store Ammonium Nitrate Fuel Oil (ANFO). Monitoring of water levels and water quality has commenced at these locations. Furthermore, Bravus will install additional monitoring bores located up and down gradient of surface infrastructure considered potential sources of contamination (eg mine infrastructure, waste dumps, and tailings areas) within 3 months of finalisation of the location of the facilities.

3.4.10 GMMP commitment #10

Boundary Bores

² Interim bore-specific trigger values and contaminant limits have been included in Appendix F of this review report.

10. *Install five additional bores on the eastern boundary of mining lease, as recommended by DES, to develop additional baseline data for the alluvium and Tertiary sediments in this area so as to allow for the assessment of any possible migration of contaminants to the east of the mine lease*

Status: This commitment has been met. Bravus installed five boundary bores (C19019SP, C19020SP, C19021SP, C19022SP and C19023SP) (see Table 3.2) to develop additional baseline data for the alluvium and Tertiary sediments in this area. Monitoring of these bores will allow for the assessment of any possible migration of contaminants to the east of the mine lease.

3.4.11 GMMP commitment #11

Replacement Bores

11. *Alluvium bore C025P1, regularly recognised to be dry, will be replaced with a new alluvium bore located within deeper alluvium adjacent to the Carmichael River. A bore specific groundwater level threshold will be derived for this bore over time, the groundwater level threshold for existing bore C025P1 will be used in the interim.*

Status: This commitment has been met. A replacement bore (C19001SP) (see Table 3.2) for C025P1 has been installed within deeper alluvium sediments at the same location. Water level and quality data is being collected from C19001SP and will continue to be collected bi-monthly to update groundwater level threshold. As per commitment #5 above, water levels in C19001SP always exceed the threshold value which was calculated from the average water level and natural fluctuations in C025P1. It is recommended that C19001SP be assessed against the updated threshold value presented in Table B.1 which is based on data collected from C19001SP. This threshold value should be re-evaluated during the next update of the GMMP which is scheduled for July 2022.

3.4.12 GMMP commitment #12

12. *A new monitoring bore will be installed into Clematis Sandstone at current location of C180118SP as this bore is currently blocked*

Status: This commitment has been met. C180118SP which is blocked has been replaced with a new bore (C19002SP) (see Table 3.2). Water level and quality data is being collected from the new bore and will continue to be collected bi-monthly. As per commitment #5 above, water levels in C19002SP are naturally lower in elevation than C180118SP. It is recommended that C19002SP be assessed against the updated threshold value presented in Table B.1 which is based on data collected from C19002SP. This threshold value should be re-evaluated during the next update of the GMMP which is scheduled for July 2022.

3.4.13 GMMP commitment #13

13. *Drilling of the replacement bores at C025P1 and C180118SP plus the five additional bores (Figure 30) within the first year of commencement of mining operations*

Status: This commitment has been met. Bores C025P1 and C180118SP have been replaced with C19001SP and C19002SP, respectively. Five additional bores have also been installed (Table 3.2).

3.4.14 GMMP commitment #14

Nested Bores

14. *Additional bores monitoring the Dunda Beds, Rewan Formation, and Permian Betts Creek Beds (which includes the Bandanna Formation and Colinlea Sandstone) will be installed within one year of commencement of mining operations at three locations co-located as far as practicable within 500 m of existing Clematis Sandstone monitoring points as follows: HD02, HD03A, and C14011SP including one bore within the vicinity of the Doongmabulla Springs Complex.*

Status: This commitment has been met. Installation of these additional bores was completed in 2020. Bore details are provided in Table 3.2.

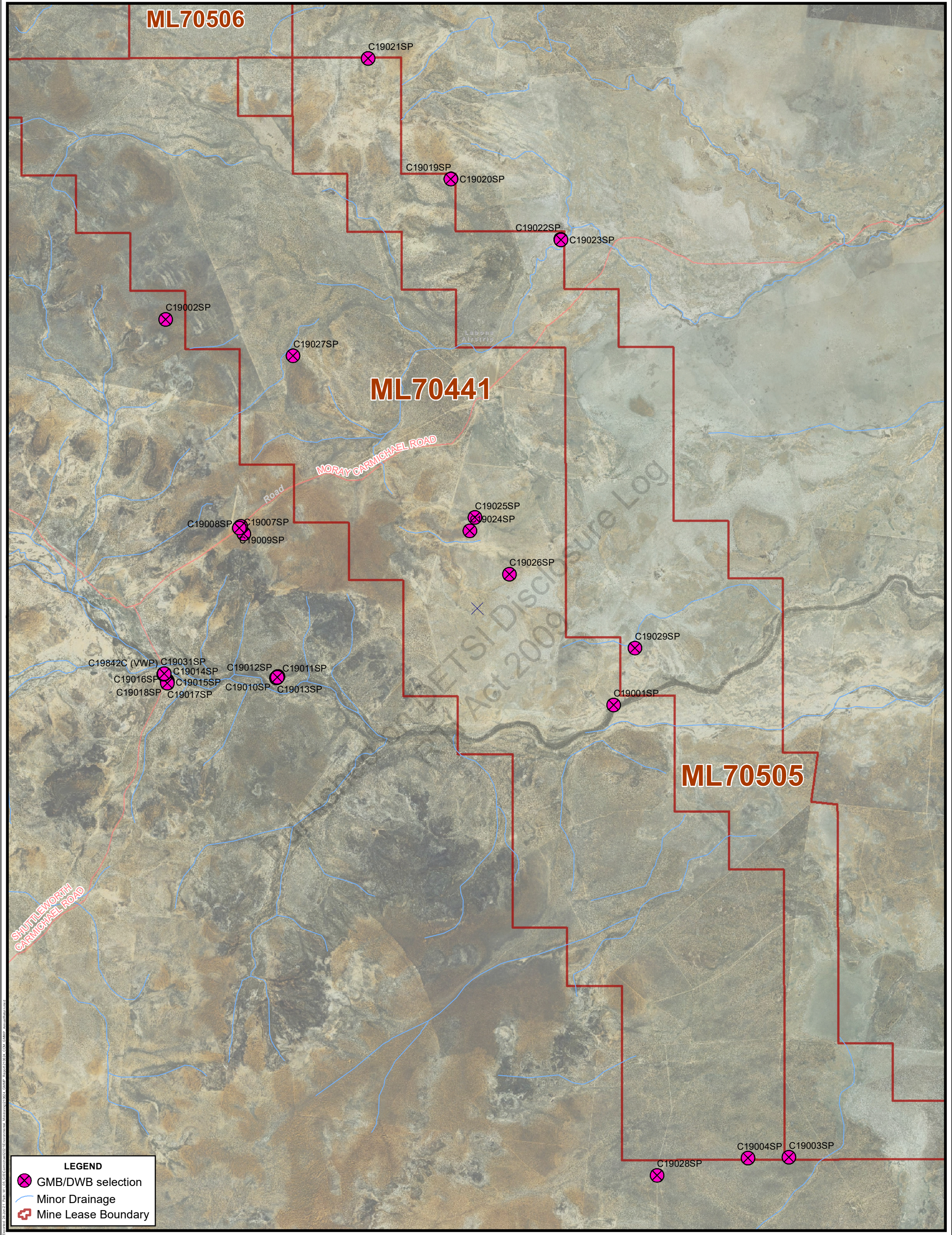
Table 3.2 New groundwater monitoring bores 2019-2020

	Bore ID	Easting ¹	Northing ¹	Surface RL (mAHD) ²	Depth (mBGL) ³	Screen Interval (mBGL) ³	Formation	Remarks
1	C19007SP	426268	7561274	310.28	240	222.7 - 234.7	Dunda beds	Outside & west of ML
2	C19008SP	426268	7561277	310.18	288	271-283	Rewan formation	Outside & west of ML
3	C19009SP	426286	7561268	310.15	517	504-516	Rewan formation	Outside & west of ML
4	C19010SP	427323	7556734	238.41	100	82-94	Clematis SSt	Outside & west of ML
5	C19011SP	427337	7556725	238.07	177	162-174	Dunda beds	Outside & west of ML
6	C19012SP	427331	7556730	238.4	228	212-224	Rewan formation	Outside & west of ML
7	C919013SPR	427346	7556721	238.1	440	428-440	Rewan formation	Outside & west of ML
8	C19014SP	423766	7556814	239.58	120	95.9-107.9	Clematis SSt	Outside & west of ML
9	C19015SP	423768	7556827	239.39	183	168-180	Dunda beds	Outside & west of ML
10	C19017SP	423736	7556825	239.62	463	450.8-462	Rewan formation	Outside & west of ML
11	C19018SP	423737	7556834	239.28	493	481-493	Bandanna formation	Outside & west of ML
12	C19842C (VWP)	423736	7556821	239.77	648	330	Rewan formation	Outside & west of ML
13	C919016SPR	423767	7556821	239.4	256	238-250	Rewan formation	Outside & west of ML
14	C19031SP(VWP)	423753	7556845	238.92	620	605	Colinlea SSt	Outside & west of ML
15	C19019SP	432845	7572555	255.35	15	Aug-14	Alluvium	Boundary bores East of ML
16	C19020SP	432847	7572550	255.15	50	43-49	Weathered Tertiary	Boundary bores East of ML
17	C19021SP	430226	7576369	264.61	15	Aug-14	Alluvium	Boundary bores East of ML
18	C19022SP	436340	7570625	225.23	50	43-49	Weathered Tertiary	Boundary bores East of ML
19	C19023SP	436338	7570630	225.15	15	Aug-14	Alluvium	Boundary bores East of ML
20	C19024SP	433447	7561376	253.59	15	Aug-14	Alluvium	Infrastructure bore
21	C19025SP	433612	7561775	247.49	15	Aug-14	Alluvium	Infrastructure bore
22	C19003SP	443571	7541484	229.8	226	148-160	Colinlea SSt	Sub-E Colinlea Bores
23	C19004SP	442278	7541451	238.43	264	228-240	Colinlea SSt	Sub-E Colinlea Bores

Table 3.2 New groundwater monitoring bores 2019-2020

	Bore ID	Easting ¹	Northing ¹	Surface RL (mAHD) ²	Depth (mBGL) ³	Screen Interval (mBGL) ³	Formation	Remarks
24	C19026SP	434698	7559985	238.44	260	252-259	Colinlea SSt	Replacement bore (C007P3)
25	C19027SP	427832	7566929	262.37	263	252-262	Colinlea SSt	Replacement bore(C020P2)
26	C19028SP	439400	7540894	260.68	53	40-50	Rewan formation	Replacement bore(C180116SP)
28	C19029SP	438684	7557636	224.74	71	63-69	Colinlea SSt	Replacement bore(C180114SP)
27	C19001SP	438025	7555853	227.06	18	Nov-17	Alluvium	Replacement bore(C027P1)
29	C19002SP	423799	7568106	305.33	125	117-123	Clematis SSt	Replacement bore(C180118SP)

Notes: ¹ GDA94 Zone 55, ² mAHD = metres Australian Height Datum, ³ mbGL = metres below Ground Level



CARMICHAEL COAL MINE PROJECT		DISCLAIMER: Every effort has been made to ensure the accuracy of the information contained on this map. As permitted by law, Adani is excluded from all liability to any person or entity with respect to any loss or damage caused directly or indirectly by their use of the information contained on this product. Changes and additions to the information contained on this map are made frequently. Adani does not warrant the accuracy of the information contained on this map.		<div>Scale Bar: 0 1 2 Kilometres</div>		LOCATION MAP		BRAVUS MINING & RESOURCES	
TITLE New Groundwater Monitoring Bores 2019-2020	REV	DESCRIPTION	DATE	SCALE	CURRENT ISSUE	File A	STATUS	PROJECT NO	REV 0 277 of 1533
	0	Original map output	21/09/2020	1:105,000	SIGNATURES				
				SIZE	DRAWN	SW			
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				PROJECTION	APPROVED	DJ		CCM	210624_CCM_GMMP_Report

3.4.15 GMMP commitment #15

15. *Undertake groundwater monitoring and sampling via a suitably qualified and experienced professional in accordance with recognised procedures and guidelines*

Status: Compliant. Bi-monthly water quality sampling is undertaken by suitably qualified personnel from C&R Consultants. Personnel from C&R meet 'suitably qualified personnel' as defined in the EA. Bravus has also engaged suitably qualified contractors to service monitoring bores. All groundwater quality samples are sent to NATA accredited laboratories for analysis.

3.4.16 GMMP commitment #16

16. *For all new bores, to be drilled after the compilation of the initial GMMP, a minimum of 12 datasets over 24 months, will be collected prior to developing groundwater level thresholds and water quality triggers for discussion with DES for inclusion in future iterations of the GMMP*

- *All new bores will be assessed against the water quality triggers developed for each hydrostratigraphic unit until (and if required) bore specific triggers are developed*
- *All new bores will be installed as soon as possible so as to compile additional groundwater data to inform the conceptual model and the refinement of the model as required in Condition E4a and E6*
- *Any consideration of revising the groundwater level thresholds, based on new data acquired, must assess the potential impacts of the revised groundwater level thresholds on GDEs.*

Status: Compliant. Bravus has commenced monitoring of all new bores installed after compilation of the initial GMMP. The groundwater data collected from these additional bores will be used to inform groundwater conceptual model and the refinement of the numerical model as required in EA condition E4a and E6. During the review of the GMMP to be conducted within two years of commencement of box cut excavation, consideration will be given for revising groundwater level thresholds and assess the potential impacts of revised thresholds on GDEs. The GMMP will also be updated to include revised groundwater level thresholds.

3.4.17 GMMP commitment #17

17. *Conduct a review of the monitoring data, using suitably qualified expert during the review of GMMP to be carried out before 1 July 2021 (or any other time frame as agreed with DES so as to align GMMP review and model re-run to happen concurrently) to update conceptualisations and conduct groundwater numerical model review based on these data)*

- *To allow for the correct scientific development of the GMMP it is considered (subject to agreement with DES) that the refinement and re-run of the model will occur prior to the update of the GMMP, as the model outputs and modifications can be captured in the GMMP*
- *The model re-run is to occur 2 years after the commencement of the box cut and then every 5 years, the same review periods as the GMMP*

Status: Compliant. A review of the groundwater quality and water level data has been undertaken as part of this review and is included in Section 3.5.1. Update of the conceptualisations will be undertaken prior to the model re-run and update of the GMMP.

3.4.18 GMMP commitment #18

18. *Hydrochemistry results will be reviewed after each groundwater monitoring event to assess for exceedances (water quality triggers and groundwater level thresholds) and track any emerging trends through the compilation of (water quality and groundwater level) time series plots*

- *For bores where bore specific water quality triggers have not been developed, average values have been used in the interim until a minimum of 8 measurements have been recorded. These interim triggers will be revised and presented in future iterations of the GMMP*

Status: Compliant. The hydrochemistry and water level results are reviewed after each bi-monthly monitoring event and exceedances of trigger levels and thresholds were assessed as per EA conditions and are reported to the administering authority. To date, hydrochemistry and water level data has been reviewed and exceedances reporting during seven bi-monthly monitoring events (ie April/May 2020, June 2020, August 2020, October 2020, December 2020, February 2021 and April 2021). A summary of water quality exceedances during the seven monitoring events is presented in Appendix C and is summarised in Section 3.5.1. The water quality triggers will be revised and presented in future GMMP iterations. A summary of water level exceedances is presented in Section 3.5.1 and Table 3.3.

3.4.19 GMMP commitment #19

19. *Assess groundwater, surface water, and springs using isotope tracers to aid in the assessment of water quality results and groundwater conceptualisation*

Status: Compliant. Bravus commenced assessment of groundwater, surface water, and springs using major elements, trace elements and isotope tracers to aid in the assessment of water quality results and groundwater conceptualisation in 2018/2019 and again in February 2021. Results are pending but summaries of the main isotope investigations are included in Section 3.5.6.

3.4.20 GMMP commitment #20

20. *Non-mining influence on water quality (if exceedances occur which cannot be correlated to mining activities) will be assessed through the consideration of:*

- *Groundwater levels, depth-to-water, and groundwater gradient changes*
- *Identification of land-use changes upgradient of monitoring bores*
- *Regular meetings / discussions with neighbouring landholders to identify activities that may influence groundwater quality*
- *Increasing the water quality analytical suite (assess possible sources)*
- *Water quality “fingerprinting” using major ion chemistry (Scholler Plots, etc.)*

Status: Compliant. Review of bi-monthly water level and water quality data has concluded that exceedances of water levels and water quality are currently not related to mining activities. Exceedances can be attributed to a combination of below average rainfall conditions, nearby landholder abstraction and natural fluctuations. If exceedances during future monitoring are assessed to be due to mining activities, Bravus will undertake an investigation in consideration of the above requirements. Exceedance reporting is outlined in Section 3.5.1.

3.4.21 GMMP commitment #21

21. *Potential groundwater impacts from mine water and waste storage need to be assessed and potential mitigation measures adopted if potential for environmental harm is identified. These mitigation measures include:*

- *Identification and removal of source*
- *Seepage capture schemes, suitable to prevent possible plume migration offsite*
- *Pump and treat schemes to manage possible contaminant plumes*

- *Augmentation of the groundwater monitoring network to validate remediation*

Status: Compliant. For future compliance. If the investigation completed under Section 4.0 of the GMMP and EA condition E10 confirms that groundwater quality impacts exceeded the trigger values, and impacts are as a result of seepage of mine water and waste storage, further detailed investigation will be completed as per EA condition E11, and appropriate mitigating measures will be selected and implemented as per EA condition E12.

3.4.22 GMMP commitment #22

22. *If groundwater level impacts are predicted to be beyond those allowed in the project approvals, mitigation activities with regards to water availability at the GDEs may include:*

- *Limiting thickness of extraction of coal seams and reviewing extraction of multiple coal seams for the underground longwall mining*
- *Freezing mine development at current levels until the completion of investigations and assessments which conclude that further development will not exceed approved impacts*
- *In case the investigation(s) carried out under EA conditions E10 to E14 determines that further mine development would exceed approved impacts to MSES, then the bio-diversity offset strategy will be updated and offsets will be provided*

Status: Compliant. For future compliance. If the investigation completed under Section 4.0 of the GMMP and EA condition E13 confirms that groundwater level impacts exceeded the threshold values for GDEs, and impacts are a result of mining operations, further detailed investigation will be completed as per EA condition E14, and appropriate mitigating measures will be selected and implemented.

3.4.23 GMMP commitment #23

23. *Include in the review of the GMMP an assessment of groundwater level and water quality data, and the suitability of the monitoring network, as per Condition E5. The GMMP will be reviewed by a suitably qualified person with a report on the outcome of the review to the administering authority by 1st July 2021. After the initial review, the review must be completed within three months of the second anniversary date of commencing box cut excavation and every 5 years following.*

Status: Compliant. An assessment of groundwater level and water quality data has been undertaken by (C&R Consulting, 2021) and (EMM, 2021) and is also included in Section 3.5.1 of this report.

3.4.24 GMMP commitment #24

24. *The results of research plans, inclusive of the GAB Springs Research Plan and Rewan Formation Connectivity Research Plan, will be incorporated in to the next iterations of the numerical model review and GMMP (within two years of box cut and every five years after that)*

Status: For future compliance

3.4.25 GMMP commitment #25

25. *Two existing surface water flow monitoring stations CAR04 and CAR01 will be serviced to make them operational. An additional two stream flow gauging stations, one between the Doongmabulla Springs and the western edge of the mining lease, the other downstream of the eastern edge of the mining lease and upstream of the Belyando River confluence, will be installed. These surface water monitoring locations will allow for identification of impacts on the Carmichael River and associated GDEs*

Status: Compliant. Two existing surface flow gauging stations CAR01 and CAR04 have been serviced and are now operational. A third streamflow gauging station CAR02 is also serviced and brought into operation. Bravus has

completed installation of two additional stream flow gauging stations, one between the Doongmabulla Springs and the western edge of the mining lease (Doongmabulla), the other downstream of the eastern edge of the mining lease and upstream of the Belyando River confluence (Albinia). Two additional stream flow gauging stations were also installed on Belyando River (BEL01 and BEL02) downstream and upstream side respectively of confluence with the Carmichael River. The data obtained from these stations will be used in next review of GMMP to identify impacts on GDEs.

Hourly flow rates and daily rainfall are shown in Figure 3.2 for CAR01, CAR02, CAR04, Doongmabulla and Albinia flow gauging stations. The response of these gauging stations to rainfall events during December 2020 and January 2021 are shown in Figure 3.3

Hourly flow rates and daily rainfall are shown in Figure 3.4 for BEL01 and BEL02 flow gauging stations. The response of these gauging stations to rainfall events during December 2020 and January 2021 are shown in Figure 3.5.

Overall, all flow gauging stations show a good response to rainfall events.

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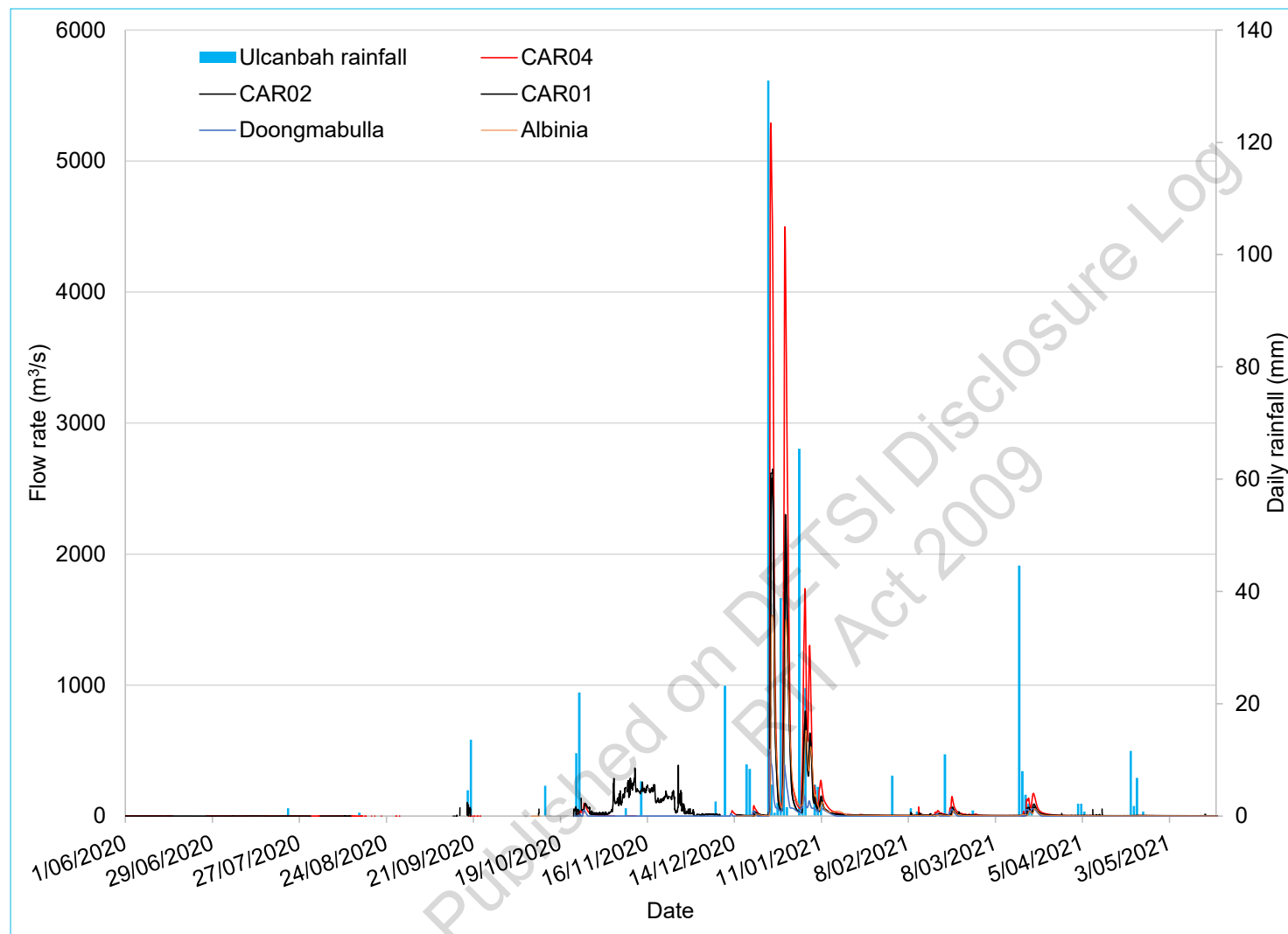


Figure 3.2 Rainfall and flow rates for gauging stations CAR01, CAR02, CAR04, Doongmabulla and Albinia – All data

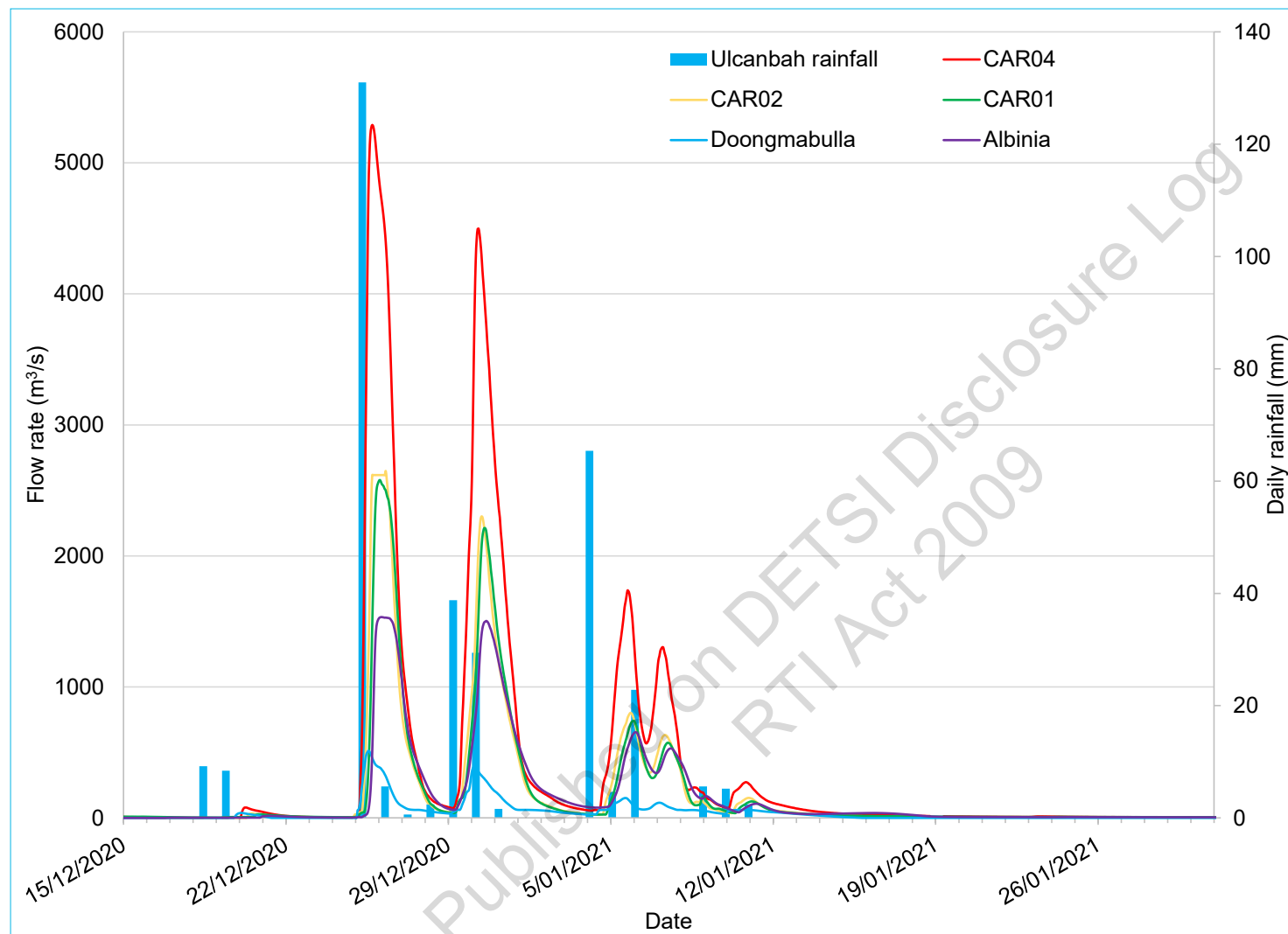


Figure 3.3 Flow rate response to rainfall during December 2020 and January 2021 – CAR01, CAR02, CAR04, Doongmabulla and Albinia flow gauging stations

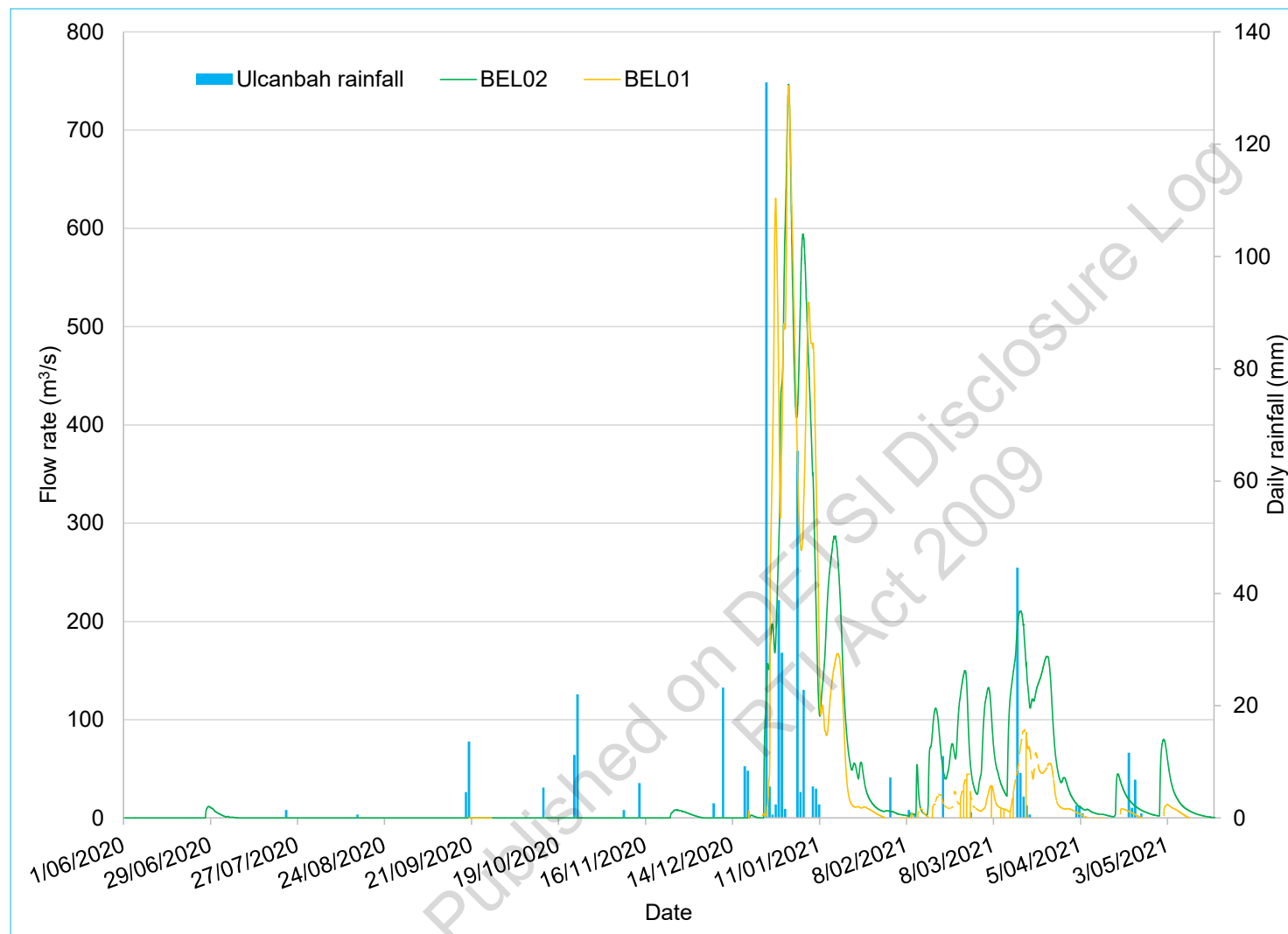


Figure 3.4 Rainfall and flow rates for gauging stations BEL01 and BEL02 – All data

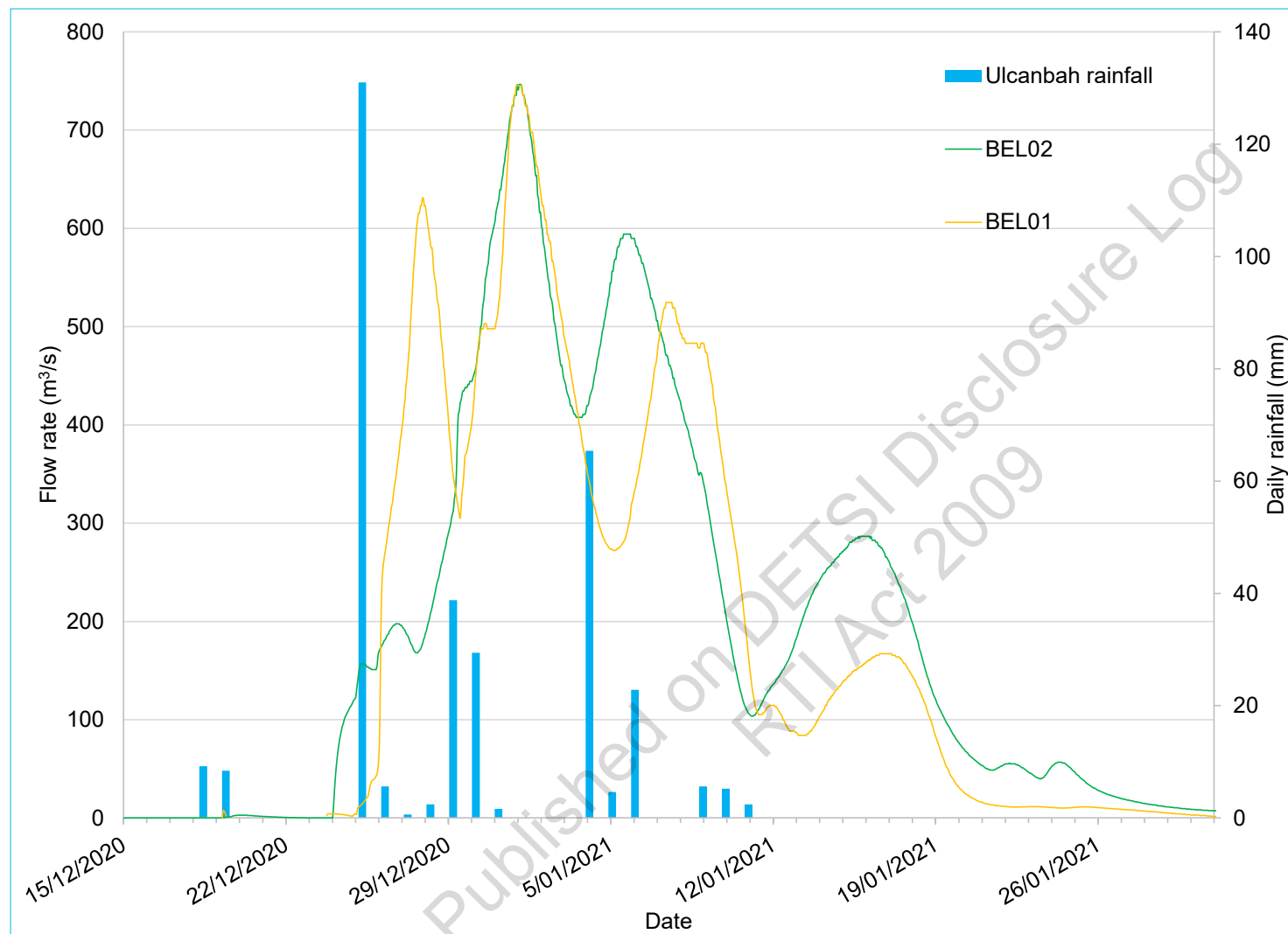


Figure 3.5 Flow rate response to rainfall during December 2020 and January 2021 – BEL01 and BEL02 flow gauging stations

3.4.26 GMMP commitment #26

26. Adani commits to incorporate the following in the groundwater model re-run:

- Review of the previous model conceptualisation (as per Condition E6a and commitment 16) including consideration of hydrochemistry (commitment 18)
- Incorporate available groundwater level and chemistry data from existing and new bores
- Hydrochemistry analysis from groundwater and spring samples
- Inputs from the RFCRP and GABSRP
- Review of groundwater modelling network and locations for ongoing optimisation
- Revision of groundwater drawdown rates for continuing appropriateness
- Revision of early warning triggers for continuing appropriateness
- Inclusion of updated and clearly defined bore reference levels. The review will also include how changes (if any) affect historical model calibration performance
- Transient calibration of the groundwater model, incorporating available bore water level data and surface water flows for the Carmichael River
- Review of evapotranspiration (ET) to assess its influence on model predictions relating to the DSC and the Carmichael River GDEs
- Update of the groundwater model to incorporate additional information obtained since the SEIS, including update of the geological and hydrogeological conceptualisation based on drilling works since the SEIS and groundwater level data from additional nested bores that will be installed near the DSC
- Analysis of rock properties and hydrostratigraphy from the cores of new nested bores to assess and quantify hydraulic properties within and between hydrogeological units
- Incorporate GA airborne electromagnetic survey data (if available during the next iteration of the GMMP)
- Updated sensitivity analysis
- Uncertainty analysis based on recent literature, (e.g. Middlemis and Peeters, 2018, Uncertainty Analysis – Guidance for groundwater modelling within a risk management framework)"
- Systematic consideration of the sources of uncertainty as they pertain to each source aquifer and modelling limitations and document this consideration
- Inclusion of all relevant parameters in a range of modelled scenarios that encompass the identified uncertainties
- Adani will undertake ongoing stream flow gauging, as per Section 2.3.8, and the data will be used as one of the calibration parameters
- Future model updates will be compliant with the recognised modelling guidelines, "Australia Groundwater Modelling Guidelines (Barnett et al. 2012)"
- Model update will use locally appropriate parameterisations including the selection of the appropriate model scale dependent parameters such as hydraulic conductivity

- Sensitivity analysis undertaken for model updates, including an analysis of the sensitivity of the model to parameter changes due to underground mining.

The modelling review will include:

- An independent review and update of the groundwater conceptual model
- An independent review of the numerical groundwater model
- An independent review of the water balance calculations.

The recommendations of the reviews as required in Condition E7, will be, incorporated in the revised / updated GMMP document including a table of changes made in response to the independent reviews.

Status: Compliant. For future compliance during GMMP and Groundwater numerical model review in July 2022.

3.4.27 GMMP commitment #27

27. At the second model re-run (7 years after commencement of box cut), Adani will specifically review both the following:

- Hydrogeological conceptualisation arising from model review and hydrochemistry analysis, consistent with and refined from the first model re-run (2 years after commencement of box cut); and
- Seismic information pertaining to the impacts of underground mining. This mining activity is not scheduled to commence until year 10, and a number of precursors are required before it commences.

If this review determines that additional seismic studies are required to determine the source aquifers of the Doongmabulla Springs Complex, these activities will be completed and that information included into revised modelling. Underground mining will not commence until these actions are completed and only if predicted impacts are consistent with approved impacts. Likewise, if the hydrogeological conceptualisation differs from that of the approved project, approval must be sought prior to relevant impact causing activities, if predicted impacts also differ from those approved.

Further, if any groundwater model re-run, or bore monitoring results, determine:

- Unauthorised impacts may or have occurred to the Doongmabulla Springs Complex from commencement of dewatering operations into the long term post closure; or
- The unlikely scenario that the Permian age hydrostratigraphic units are additional sources to the Doongmabulla Springs Complex

The following mitigation measures and corrective actions will be put in place:

- Limiting thickness of extraction of coal seams and reviewing extraction of multiple coal seams for the underground longwall mining in order to minimise drawdown impacts to Doongmabulla Springs Complex
- Freezing mine development at current levels until the completion of investigations and assessments which demonstrate and conclude that further development will not exceed approved impacts
- Assess the water balance / budgets and evaluate losses at the Doongmabulla Springs Complex, in the context of the Permian age hydrostratigraphic units being a possible additional source of groundwater.

Status: For future compliance.

3.4.28 GMMP commitment #28

28. *Initial review of the approved GMMP by an appropriately qualified person with a report provided on the outcome of the review to the administering authority by 1 July 2021 (or any other time frame as agreed with DES so as to align the GMMP review and model re-run to happen concurrently). After the initial review, the review will be conducted every five years following, the report provided to the administering authority.*

Status: Compliant. This report is prepared to meet this commitment to review the GMMP by 1 July 2021. As per EA condition E5, a further review of GMMP will be undertaken within two years of commencement of the first box cut excavation.

3.4.29 GMMP commitment #29

29. *The GMMP review will be conducted by 1 July 2021 (or any other time frame as agreed with DES so as to align the GMMP review and model re-run to happen concurrently). The revised GMMP will include statistical analysis of hydrochemistry and groundwater quality data*

- *The next iteration of the GMMP (after 2 years of commencement of box cut excavation) will provide piper plots of the major ions for all hydrostratigraphic units included in the EA Conditions (Condition E3a), representative DSC springs, and the Carmichael River surface water*
- *Contaminant triggers and limits will be updated when additional statistically sufficient pre-operational hydrochemistry data are collected. It is noted that several monitoring bores do not currently have the required number of analyses to calculate baseline trigger values and are using generic triggers derived from the ANZECC guidelines or average of bore specific data. Additional hydrochemistry results, allowing for the revision of trigger values, will be conducted according to the approach detailed in Section 5.4.*
- *During GMMP review and groundwater model re-run consideration of potential impacts to relevant GDE's will be included when considering revision of trigger values*

Status: Compliant. This report is prepared to meet this commitment of review of GMMP by 1 July 2021. As per EA condition E5, a further review of GMMP will be undertaken within two years of commencement of the first box cut excavation. Statistical analysis of hydrochemistry and groundwater quality data has been undertaken by (C&R Consulting, 2021) and (EMM, 2021). A statistical analysis showing box and whisker plots of key water quality parameters for each geological unit is also presented in Appendix E.

3.4.30 GMMP commitment #30

30. *Investigate all groundwater-based complaints and maintain a complaint register. The register will be made available to the regulating authority upon request.*

Status: Compliant. Bravus will maintain a compliant register for the life of the project and will be made available to the regulating authority upon request

3.4.31 GMMP commitment #31

31. *Implement make-good agreements with land holders affected by groundwater drawdown*

Status: For future compliance, if impacts as documented in make-good agreements are realised all make good measures as per signed agreement with land holders will be implemented

3.4.32 GMMP commitment #32

32. *Monitoring results will be publicly available on the Adani website (www.bravus.com.au) for the life of the CCP; the groundwater monitoring dashboard on the website will be operational within three months of approval of the GMMP. The data will be uploaded as per Section 4.8.*

Status: Compliant. All monitoring results are made publicly available on the Bravus website. Currently groundwater data collected up to April 2021 is available on the website. All future monitoring data will be made available on the website in accordance with this commitment.

General commitments regarding the groundwater monitoring include the following:

3.4.33 GMMP commitment #33

33. *Sampling will be undertaken in accordance with the current edition of DES's Water Quality Sampling Manual, or subsequent updated versions*

Status: Compliant. All monitoring is being undertaken in accordance with the current edition of DES's Water Quality Sampling Manual. Monitoring is undertaken by suitably qualified personnel from C&R Consulting.

3.4.34 GMMP commitment #34

34. *Groundwater level and groundwater quality results will be maintained for the life of the project and annual data will be compiled in an annual monitoring report. The monitoring data collected annually will be submitted, by 1 July, to the administering authority via WaTERS*

Status: Compliant. Bravus will maintain the groundwater level and groundwater quality results for the life of the project. An annual monitoring report for the period July 2020 to June 2021 will be submitted to administering authority via WaTERS by 01 July 2021 (C&R Consulting, 2021).

3.4.35 GMMP commitment #35

35. *Notification to the regulating authority within one month of receiving water quality analysis results, should any parameters tested exceed agreed trigger levels. This commitment is included in #36 below.*

Status: Compliant. See #36 below.

3.4.36 GMMP commitment #36

36. *Should groundwater monitoring indicate exceedance of any or all of the groundwater level thresholds and / or water quality trigger levels then DES will be notified via WaTERS and an investigation will be instigated and the investigation report will be made available to the administering authority within the time specified in EA conditions E10 and E12 for groundwater quality trigger exceedances and E13 and E14 for groundwater threshold level exceedances respectively.*

Status: Compliant. Reporting of water level and water quality exceedances have been notified via WaTERS and submitted to the administering authority within the specified time for the seven bi-monthly monitoring events which have been undertaken to date. The investigations to assess the cause of exceedances are completed within the specified time for all bi-monthly monitoring events and reports have been submitted to the administering authorities and via WaTERS. Bravus commits to meet the time frames specified for notifying the exceedances and submission of investigation reports in during future monitoring.

3.4.37 GMMP commitment #37

37. *Adani, in the event of a confirmed exceedance of a groundwater drawdown threshold level or water quality trigger, attributable to mining activities will:*

- *Review the mine plan, including the sequencing of mining*
- *Update the model predictions and revise the threshold levels. As per Section 4.7.1.2, any consideration of revising the groundwater threshold levels must assess the potential impacts of the revised groundwater threshold levels on GDEs*

- *Identify potential impacts to GDE's associated with drawdown levels and implement appropriate corrective action processes as outlined in the GDEMP*

Status: Compliant. To date, exceedances of water level thresholds and water quality triggers have not been attributed to mining activities (see Section 3.5.1). In future, Bravus will meet the requirement of this commitment should any groundwater level threshold or groundwater quality trigger are exceeded so as to determine the cause of exceedance including that as a result of mining operations.

3.4.38 GMMP commitment #38

38. *Should any or all the groundwater level Impact thresholds be realised, through the assessment of groundwater monitoring data and comparison to model predictions, then an appropriately qualified person will complete an investigation into the potential for environmental harm (MSES and MNES) and will provide a written report to the regulator as per the conditions. In the event of exceedances of threshold levels on MNES Adani will take the following actions:*

- *Update/revise the numerical groundwater model with the monitoring results*
- *Review of the mine plan including the sequencing of mining*
- *Update the predictions using the revised model to check if the revised predicted drawdown within the DSC are within the approved limits of drawdown impacts (i.e. the interim thresholds)*

Status: For future compliance.

3.4.39 GMMP commitment #39

39. *For completeness, the groundwater monitoring data, factual and interpretative reports (including any possible investigations as a result of triggers / thresholds) will be provided to the Commonwealth regulators as well as the State regulators*

- *All corrective actions and mitigation measures, derived based on possible investigations as a result of triggers / thresholds, will be consistent with the GDEMP*

Status: Compliant. All groundwater monitoring collected during bi-monthly sampling, factual interpretative reports and investigation reports are provided to the Commonwealth regulators as well as the State regulators. Any recommendations resulting from the investigations completed due to triggers / thresholds exceedances including corrective actions and mitigation measures, will also be assessed to be consistent with the GDEMP requirements.

3.4.40 GMMP commitment #40

40. *Conduct regular groundwater monitoring bore assessments and maintenance (where required) as well as ensuring dry or damaged bores (as a result of mining activities) are decommissioned according to the latest editions of the Minimum Construction Requirements for Water Bores in Australia, 4th Edition (NUDLC, 2020) and the Minimum Standards for the Construction and Reconditioning of Water Bores that Intersect the Sediments of Artesian Basins in Queensland (DNRME, 2017)*

Status: Compliant. Regular groundwater monitoring bore assessments and maintenance will be carried out by the qualified personnel deployed by the monitoring contractor. Bravus has followed the bore construction standards as mentioned above while constructing additional bores.

3.4.41 GMMP commitment #41

41. *As the proposed threshold values are reliant on predictions from the numerical groundwater model, to be updated within two years of the box cut excavation then every five years subsequently, Adani will compare the actual measured groundwater level data to predicted drawdown to assess the rate of change. In the instance*

the drawdown rate of the actual data is steeper/ faster than the predicted rate, an investigation will be commenced into the cause of the drawdown rate change.

Status: For future compliance

3.4.42 GMMP commitment –Springs, GDE and Baseflow Commitments

The status of summary of Springs, GDE and Baseflow commitments relevant for this review period is provide below.

- *Adani are committed to utilising bore C027P2 as an early warning trigger for the Carmichael River. Monitoring of the Dunda Beds and Rewan Formation as potential contributors to the Doongmabulla Spring Complex (DSC) will be undertaken to enable spatially comparable data to be collected.*

Status: Compliant. Bore C027P2 is being continuously monitored to assess for potential induced flow from Dunda Beds into coal seams. Bravus is carrying out regular groundwater monitoring in a network of bores installed between the mining lease area and Doongmabulla Springs covering Dunda beds and Rewan formations to enable collection of spatially comparable data.

- *The reporting will include any revised predictive modelling and comments regarding potential impacts on the sensitive ecosystems.*

Status: For future compliance

- *The GMMP will closely interlink to the GDEMP developed by Adani specifically the Doongmabulla Spring Complex, Mellaluka Spring Complex, Carmichael River baseflow and GDEs, and Waxy Cabbage Palm tree communities sub-plans. Data collected from the GMMP will assist in the monitoring of the ecological health at these GDEs and will allow for the identification of potential stress and consequently requirements for mitigation and management measures as outlined in the sub-plans.*

Status: Compliant. Groundwater monitoring data collected under the GMMP is being made available for GDEMP for monitoring of the ecological health at these GDEs.

- *Adani will investigate drilling into deeper Permian age units for the purpose of acquiring data for monitoring purposes and to capture information if required under relevant research programs.*

Status: Compliant. Bravus installed additional monitoring bore (C19031SP-VWP) into deeper Permian age units for the purpose of acquiring data for monitoring purposes and to capture information required under relevant research programs.

- *Adani will also install two additional stream flow gauging stations, one between the Doongmabulla Springs and the western edge of the mining lease, the other downstream of the eastern edge of the mining lease and upstream of the Belyando River confluence.*

Status: Compliant. Bravus completed installation of two additional flow gauging stations Moray west and Albinia station flow gauges. For additional information refer to section 3.4.25.

3.4.43 GMMP commitment –Monitoring program updates

- *To develop the optimum groundwater monitoring plan Adani proposes a phased approach, which will allow for the correct scientific development of the program and allow for variation over time to suit the site/mining phases.*

Status: Compliant. An optimum groundwater monitoring program is developed under GMMP and implemented to suit to the current stage of construction and operational phases of the project.

- *Any revised GMMP will be submitted for approval with the administering authority, prior to the implementation of the next phase of mining/*

Status: Compliant. Bravus submitted updated GMMP to DES and DAWE and both departments approved the same.

3.5 Assessment of DES recommendations

A letter was received from DES dated 12 October 2020 requesting that future GMMP review reports address a number of items as per sections 3.5.1 to 3.5.11 below. Assessment of the DES recommendations for the GMMP review report are provided below.

3.5.1 DES recommendation #1

- 1) *A review of monitoring data (water quality and water level) collected under the GMMP. The monitoring data should be compared to triggers, limits and thresholds after each monitoring event. The annual review should determine potential impacts and emerging trends in the data with any downward groundwater level trends compared to modelled drawdown rates. If the actual monitored rates are faster than predicted, the review report should recommend a suitable update of the triggers in the GMMP.*

Water quality sampled at each bi-monthly monitoring event is reported in accordance with the EA Conditions and the GMMP. Each round of water quality sampling results is compared to the relevant bore-specific and hydrostratigraphic unit-specific triggers values (see Appendix C). If two or more trigger exceedances are reported in a 12-month period for a given water quality parameter at a given bore, the exceedance is reported and triggers a Step 1 investigation (see Section 3.5.9 below).

All monitoring bores are currently equipped with data loggers to measure the water level at regular intervals (minimum 12 hourly intervals). During each monitoring round, loggers are downloaded and average water levels compared to threshold values. The monitored groundwater levels are compared with the water level thresholds and exceedances of water levels during the bi-monthly monitoring rounds are summarised in Table 3.3. No exceedances of water level thresholds to date can be attributed to mining activated associated with the CCP.

The monitoring data are essentially assessed every two months, which includes investigations into the potential impacts of site activities on water quality. Additional assessments are included in bi-annual groundwater reviews (C&R Consulting, 2021) and as part of the ongoing GAB Springs research projects commissioned by Bravus (EMM, 2021). Both the larger groundwater reviews and the ongoing bi-monthly exceedance reports use statistical analysis to assess emerging trends and investigate the potential impact of groundwater drawdown on bore water quality. The primary findings of these studies are summarised below:

The GAB Springs groundwater review (EMM, 2021) considered the groundwater quality and level data collected within and surrounding the CCM and included water quality sampled from 2011 (pre-site activities), the 2017-2018 baseline monitoring water quality and water quality monitored under the current GMMP (up to December 2021). The main conclusions included:

- *Lower groundwater levels were observed due to mine dewatering activities in the lower units. Large reductions in groundwater level of up to 40 m were observed between April 2020 and February 2021 in bores C007P2, C823SP and C008P2 in the Bandanna Formation, as well as bores C833SP, C834SP, C006P3R, C19026SP, C827SP and C180112SP in the Colinlea Sandstone. Various other bores in these formations showed small reductions in groundwater level of 0.05 to 2 m. The bores where the largest changes were observed are located near the mine dewatering bores.*
- *Various bores screened in the Clematis Sandstone, Dunda Beds, Bandanna Formation and Colinlea Sandstone have shown an increase in groundwater level between the December 2020 and February 2021 monitoring events. This increase may be due to the large amount of rainfall in December 2020, where 252.8 mm of rain occurred compared to the long-term average of 65.4 mm.*

- *Multiple bores in each stratigraphic unit, except for the Moolayember Formation, were found to have decreasing pH, total alkalinity, TDS and manganese trends when all available data was statistically analysed with Mann-Kendall trend analyses. This is likely caused by natural phenomena and not mine induced.*
- *Data trends suggest that little if any acidification has occurred due to mine dewatering activities, although some decreasing trends in alkalinity have been noted within the Colinlea Sandstone and Joe Joe bores.*

The bi-annual review of groundwater (C&R Consulting, 2021) assessed the same groundwater dataset (with data from 2011) and made similar conclusions:

- *Following the commencement of dewatering activities at CCMP, numerous bores within the Bandanna Formation and Colinlea Sandstone aquifers – and located within the vicinity of extraction points – have displayed significant variations in standing water level. Multiple bores are co-located with dewatering wells and therefore display strong correlations of pumping schedules, with sharp drawdowns and steady periods of recovery noted. While bores screened within the Bandanna Formation display a steady decline, Colinlea Sandstone bores (C006P3R, C827SP and C180112SP) have recorded standing water level drawdowns between 10 m and 45 m.*
- *All water quality analyses completed during the current reporting period remained relatively consistent over the four monitoring rounds. Interestingly, the initial round completed in December 2019 reported concentrations of pH and EC consistently below concentrations recorded within the subsequent three rounds. It is likely that the change in pH and EC levels are a reflection of all aquifers returning to equilibrium following the massive recharge event associated with tropical cyclone Debbie.*

Dewatering of coal seam aquifers within the Bandanna Formation and Colinlea Sandstone commenced in August/September 2019 from eight bores. Additional dewatering bores have since been progressively commissioned with 21 bores currently used for dewatering purposes. Several monitoring bores within the Bandanna Formation and Colinlea Sandstone were identified as having downwards trends in water levels related to dewatering (EMM, 2021).

Predicted drawdowns within these bores were compared to observed drawdowns. Results for monitoring bores screened across the Bandanna Formation are shown in Appendix G and can be summarised as follows:

- Monitoring bores C823SP, C008P2 and C007P2 show obvious drawdown which is related to dewatering. Overall, the observed groundwater drawdown in these bores show a reasonable correlation to the predicted drawdown.
- Drawdown in monitoring bore C006P1 is less than the predicted drawdown.

Results for monitoring bores screened across the Colinlea Sandstone are shown in Appendix H and can be summarised as follows:

- Monitoring bores C840SP, C006P3R, C827SP and C180112SP show obvious drawdown which is related to dewatering. Overall, the observed groundwater drawdown in these bores show a reasonable correlation to the predicted drawdown.

It is recommended that update of the numerical groundwater model take into account observations seen in monitoring bores affected by dewatering activities.

Table 3.3 Discussion of water level trigger events

Bore ID	Geological unit	Artesian/sub-artesian	Monitoring event where water threshold was exceeded	Reason for exceedance
C14029SP	Tertiary/Joe Joe Group	Artesian	April/May 2020, June 2020, August 2020, October 2020, December 2020, February 2021	Exceedance and decline in water levels was interpreted to be related to prolonged below average rainfall and nearby landholder use. Water levels in C14029SP show a good correlation to the cumulative rainfall departure. Recent adjustment of logger cable lengths indicates that water levels in C14029SP have never actually exceeded the threshold values for this bore (see #5 Section 3.4 and Figure A.5).
C180119SP	Joe Joe Group	Artesian	April/May 2020, June 2020, August 2020, October 2020, December 2020, February 2021	Exceedance and decline in water levels interpreted to prolonged below average rainfall, nearby landholder use, and slow recovery of water levels in the bore following servicing/sampling. Water levels in C1180119SP show a good correlation to the cumulative rainfall departure.
C180122SP	Tertiary/Joe Joe Group	Artesian	April/May 2020, June 2020, August 2020, October 2020, December 2020, February 2021	Exceedance and decline in water levels interpreted to be related to prolonged below average rainfall and nearby landholder use. Water levels in C180122SP show a good correlation to the cumulative rainfall departure.
C180123SP	Joe Joe Group	Artesian	April/May 2020, June 2020, August 2020, October 2020, December 2020, February 2021	Exceedance and decline in water levels interpreted to be related to prolonged below average rainfall, nearby landholder use, and slow recovery of water levels in the bore following servicing/sampling. Water levels in C1180123SP show a good correlation to the cumulative rainfall departure.
C9180125SPR	Joe Joe Group	Artesian	April/May 2020, June 2020, August 2020, October 2020, December 2020, February 2021	Exceedance and decline in water levels interpreted to be related to prolonged below average rainfall, nearby landholder use, and slow recovery of water levels in the bore following servicing/sampling. Water levels in C9180125SPR show a good correlation to the cumulative rainfall departure.
HD03A	Clematis Sandstone	Artesian	April/May 2020	Exceedance of HD03A during April/May 2020 was incorrectly reported. Average water levels in HD03A have not exceeded the water level threshold during bi-monthly monitoring (see Figure A.13)

Table 3.3 **Discussion of water level trigger events**

Bore ID	Geological unit	Artesian/sub-artesian	Monitoring event where water threshold was exceeded	Reason for exceedance
C14006SP	Joe Joe Group	Artesian	June 2020,	The exceedance was reported as the logger data was unable to be downloaded and the manual measurement exceeded the threshold. Recent adjustment of logger cable lengths indicates that water levels in C14006SP have never actually exceeded the threshold values for this bore (see #5 Section 3.4 and Figure A.1).
C19001SP	Alluvium	Sub-artesian	June 2020, August 2020, October 2020, December 2020, February 2021	C19001SP is a replacement bore for C025P1. Exceedances in C19001SP are due to the differences in water level between C19001SP and C025P1. As discussed in #5 Section 3.4, it is recommended that water levels in C19001SP be compared to threshold values calculated from data from C19001SP until sufficient data has been collected from C19001SP (see Figure B.1).
C14003SP	Joe Joe Group	Sub-artesian	August 2020, October 2020, December 2020	Exceedance and decline in water levels interpreted to be related to prolonged below average rainfall. Water levels in C14003SP show a good correlation to cumulative rainfall departure.
C029P1	Alluvium	Sub-artesian	October 2020, December 2020, February 2021	Exceedance and decline in water levels interpreted to be related to prolonged below average rainfall. Water levels in C029P1 show a good correlation to cumulative rainfall departure.

3.5.2 DES recommendation #2

- 2) *Increasing trends in groundwater quality may provide early warning of triggers being approached and should be discussed in the GMMP review report.*

As outlined under Section 3.5.1 above, bi-monthly reporting and investigations of water quality trigger exceedances with comparison to changing groundwater levels has been conducted under the guidance of the GMMP. The trigger exceedances investigations have indicated that variations in water quality are likely to be natural, rather than as a result of site activities.

3.5.3 DES recommendation #3

- 3) *The GMMP review report must provide the baseline and pre-impact water quality in a format that can be compared to future monitoring data eg time series plots.*

As outlined under Section 3.5.1 above, bi-monthly trigger exceedance reporting, bi-annual groundwater quality reviews and additional investigations into impacts on GDEs all make use of the historic dataset to compare to each round of newly-acquired data (see Appendix D for comparison of monitored data with historical water quality ranges).

3.5.4 DES recommendation #4

- 4) *The GMMP review report should include a review of the adequacy of groundwater monitoring locations, frequencies, groundwater quality trigger and water level thresholds.*

The adequacy of water quality trigger values is discussed in Section 3.2.

As discussed in Section 3.5.1 and Table 3.3, water levels for several bores have exceeded threshold values but this can be attributed to below average rainfall and landholder pumping. Exceedances under these circumstances indicates that insufficient baseline water level data has been collected for some bores. It is recommended that baseline average groundwater levels be recalculated during next iteration of the GMMP to include all monitoring data up to the commencement of box cut excavation (ie 10 July 2020). Currently baseline data only includes water level data collected up to 2017.

3.5.5 DES recommendation #5

- 5) *The GMMP review report should provide piper plots of major ions for all hydrostratigraphic units and recommendations about revisions to the conceptual model (including isotope tracer results).*

i Major element geochemistry

Although not part of the EA conditions until the 2022 review, the GMMP has included piper plots showing the major element characteristics of the groundwater from the bores screened in the main hydrostratigraphic units of interest and these plots have been continually updated as part of the trigger exceedances reporting, bi-annual review and additional investigations. A summary of the latest major element geochemistry is provided below. A summary of the isotope characteristics of the spring water and groundwater is provided under Section 3.5.6 below.

An assessment of major element geochemistry was included in the GMMP and has been updated in subsequent water quality monitoring reporting; this is summarised below. Figure 3.6 to Figure 3.17 show the major ion contents, expressed as meq/L, for groundwater sampled from the lithological units of interest; each diagram also includes the major ion concentrations from Doongmabulla Spring Complex (DSC) water and the Carmichael River.

Concentrations of sodium and chloride are relatively high in the Alluvium but are lower in the Tertiary age units and remain low throughout the Triassic lithologies (Moolayember Formation, Clematis Sandstone, Dunda Beds, and Rewan Formation). Permian age Joe Joe Group groundwater records a wide range in major ion concentrations

reflected in the variation in electrical conductivity (EC) values from $\sim 400 \mu\text{S}/\text{cm}$ to $> 50,000 \mu\text{S}/\text{cm}$ (Figure 3.15); samples from the Joe Joe Group may record at least two different water quality types:

1. high salinity;
2. relatively low-salinity-high-alkalinity.

High values of pH ($> \sim 8$), have been recorded in groundwater sampled from Permian age lithologies (Figure 3.15, Figure 3.16, and Figure 3.17), but are not observed in groundwater sampled from the Triassic age, Tertiary sediments, and Alluvium lithologies. DSC major ions record a range of concentrations, although all remain relatively low in sulphate and EC and report neutral to slightly-alkaline pH (e.g., Figure 3.15).

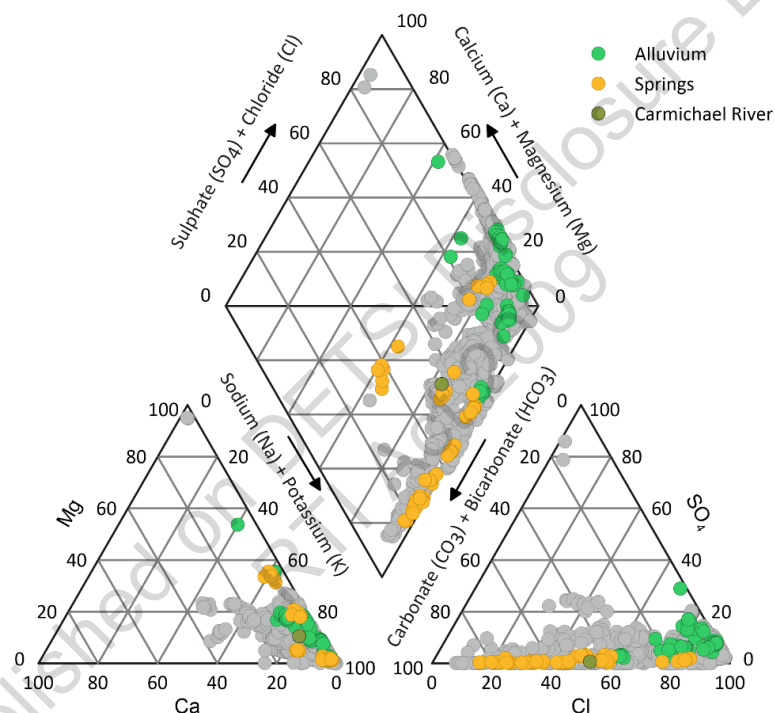


Figure 3.6 Major ion concentrations (as meq/L) in groundwater sampled from the Alluvium bores.

Note: Also shown are the DSC and Carmichael River samples. Grey symbols denote all groundwater samples and are shown for context

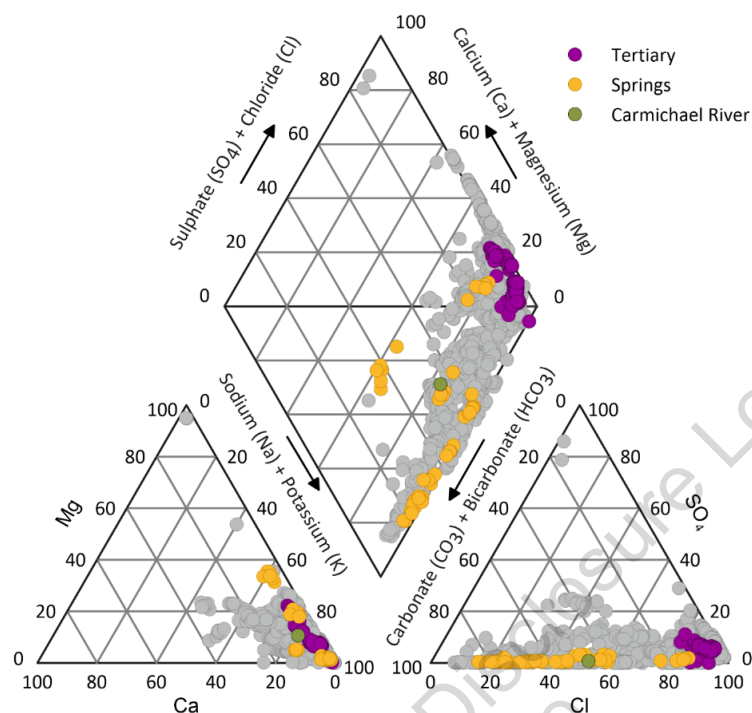


Figure 3.7 Major ion concentrations (as meq/L) in groundwater sampled from the Tertiary bores.

Note: Also shown are the DSC and Carmichael River samples. Grey symbols denote all groundwater samples and are shown for context.

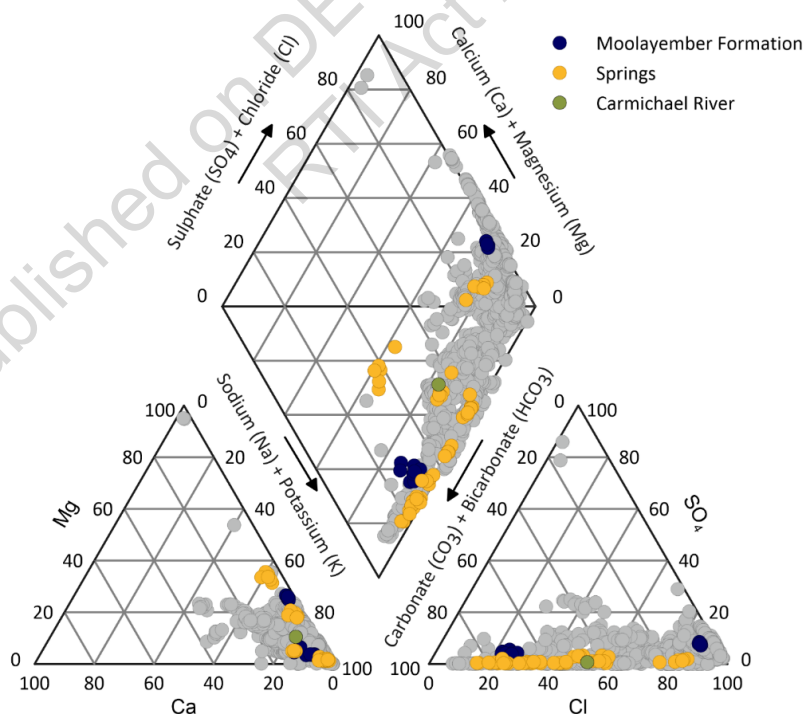


Figure 3.8 Major ion concentrations (as meq/L) in groundwater sampled from the Moolayember Formation bore.

Note: Also shown are the DSC and Carmichael River samples. Grey symbols denote all groundwater samples and are shown for context.

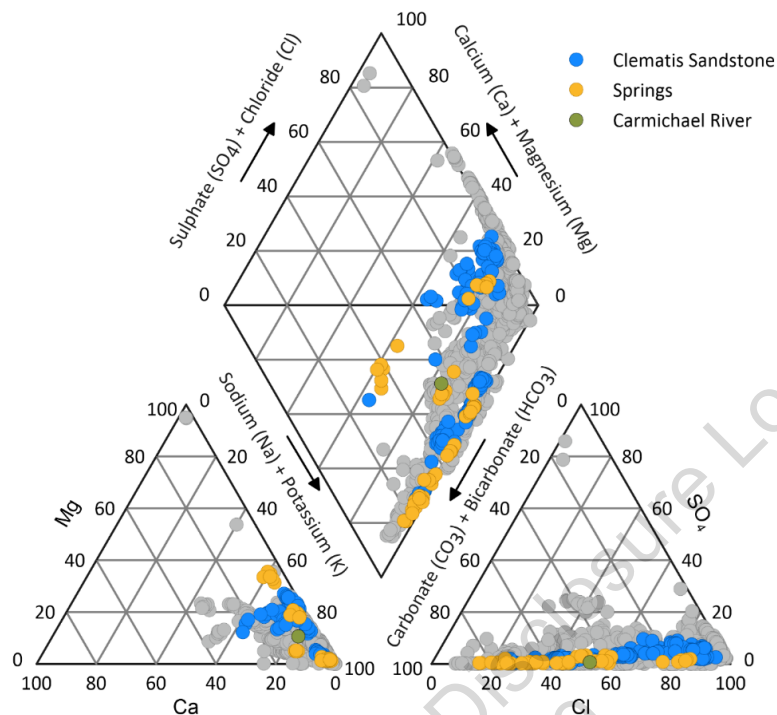


Figure 3.9 Major ion concentrations (as meq/L) in groundwater sampled from the Clematis Sandstone bores.

Note: Also shown are the DSC and Carmichael River samples. Grey symbols denote all groundwater samples and are shown for context.

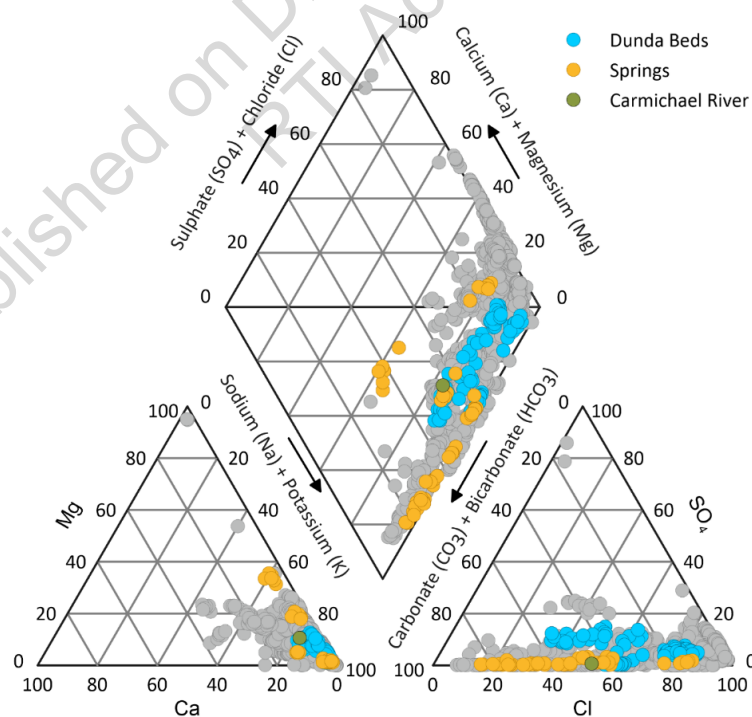


Figure 3.10 Major ion concentrations (as meq/L) in groundwater sampled from the Dunda Beds bores.

Note: Also shown are the DSC and Carmichael River samples. Grey symbols denote all groundwater samples and are shown for context.

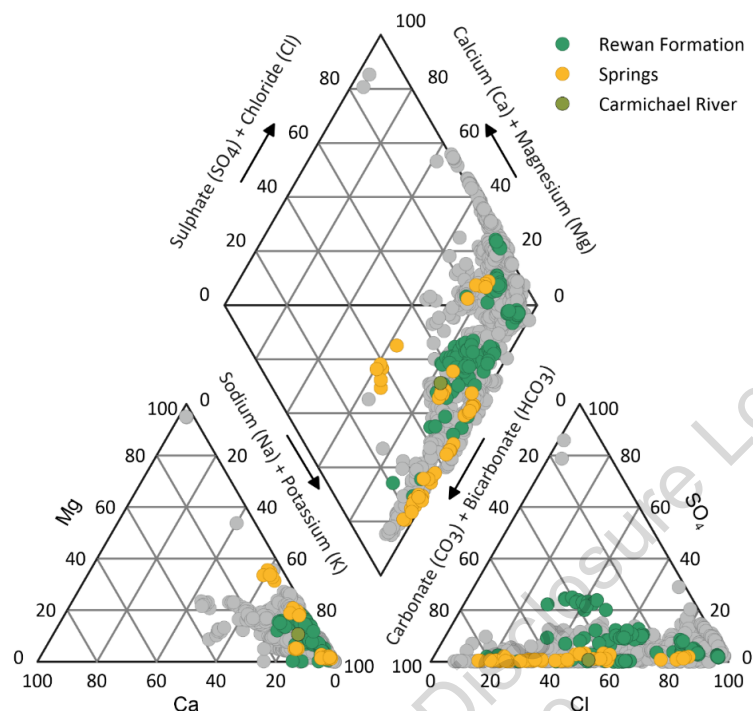


Figure 3.11 Major ion concentrations (as meq/L) in groundwater sampled from the Rewan Formation bores.

Note: Also shown are the DSC and Carmichael River samples. Grey symbols denote all groundwater samples and are shown for context.

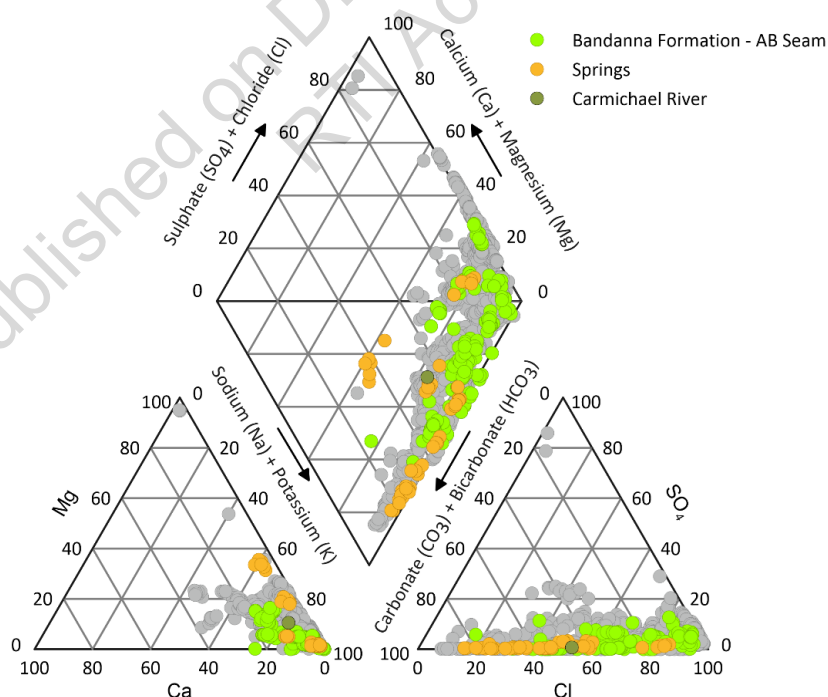


Figure 3.12 Major ion concentrations (as meq/L) in groundwater sampled from the Bandanna Formation bores.

Note: Also shown are the DSC and Carmichael River samples. Grey symbols denote all groundwater samples and are shown for context.

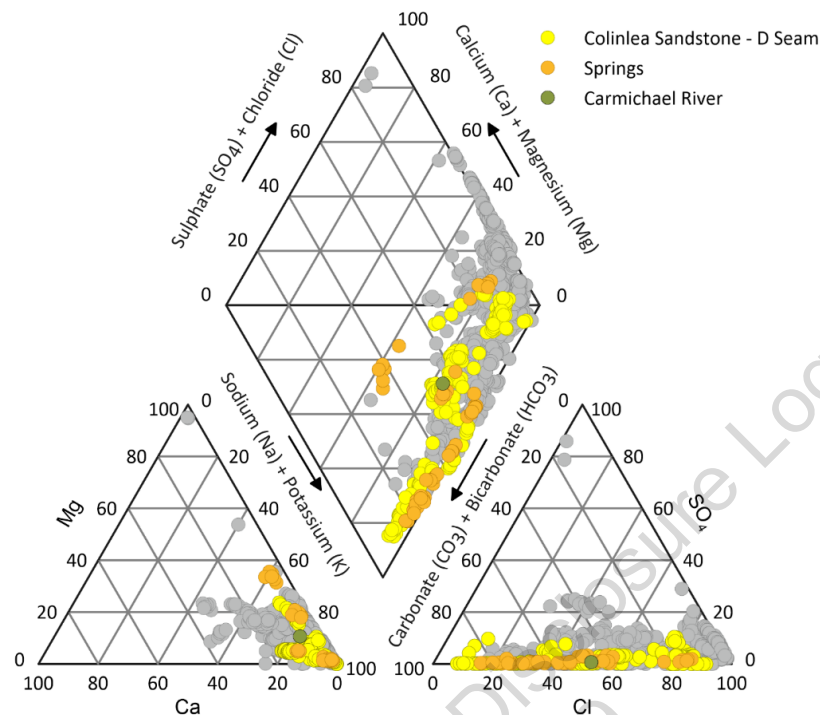


Figure 3.13 Major ion concentrations (as meq/L) in groundwater sampled from the Colinlea Sandstone bores.

Note: Also shown are the DSC and Carmichael River samples. Grey symbols denote all groundwater samples and are shown for context.

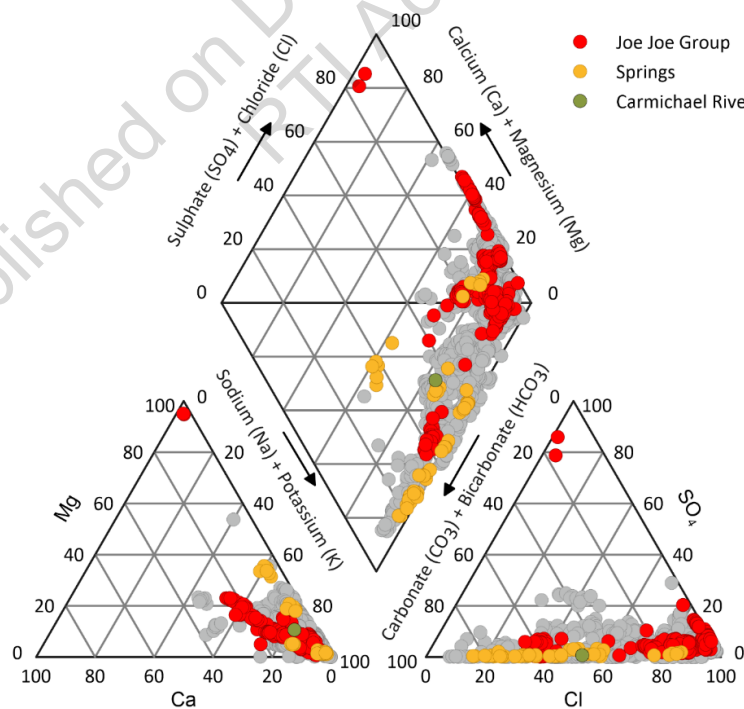


Figure 3.14 Major ion concentrations (as meq/L) in groundwater sampled from the Joe Joe Group bores. A

Note: Also shown are the DSC and Carmichael River samples. Grey symbols denote all groundwater samples and are shown for context

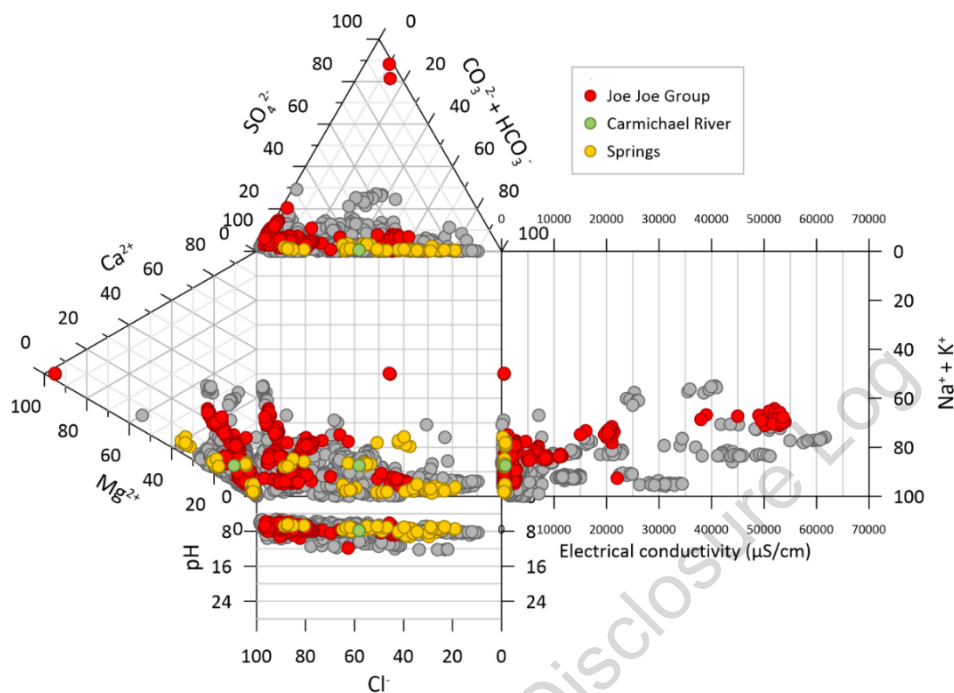


Figure 3.15 Major ion concentrations (as meq/L), pH and EC (in $\mu\text{S/cm}$) in groundwater sampled from the Joe Joe Group bores.

Note: Also shown are the DSC and Carmichael River samples. Grey symbols denote all groundwater samples and are shown for context.

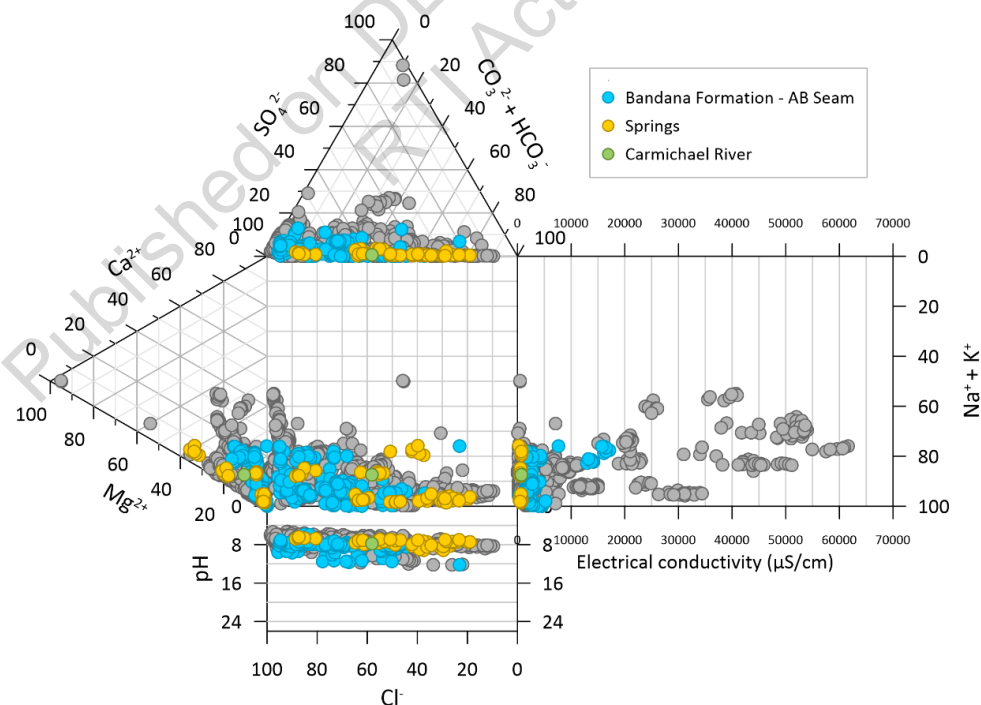


Figure 3.16 Major ion concentrations (as meq/L), pH and EC (in $\mu\text{S/cm}$) in groundwater sampled from the Bandanna Formation bores.

Note: Also shown are the DSC and Carmichael River samples. Grey symbols denote all groundwater samples and are shown for context.

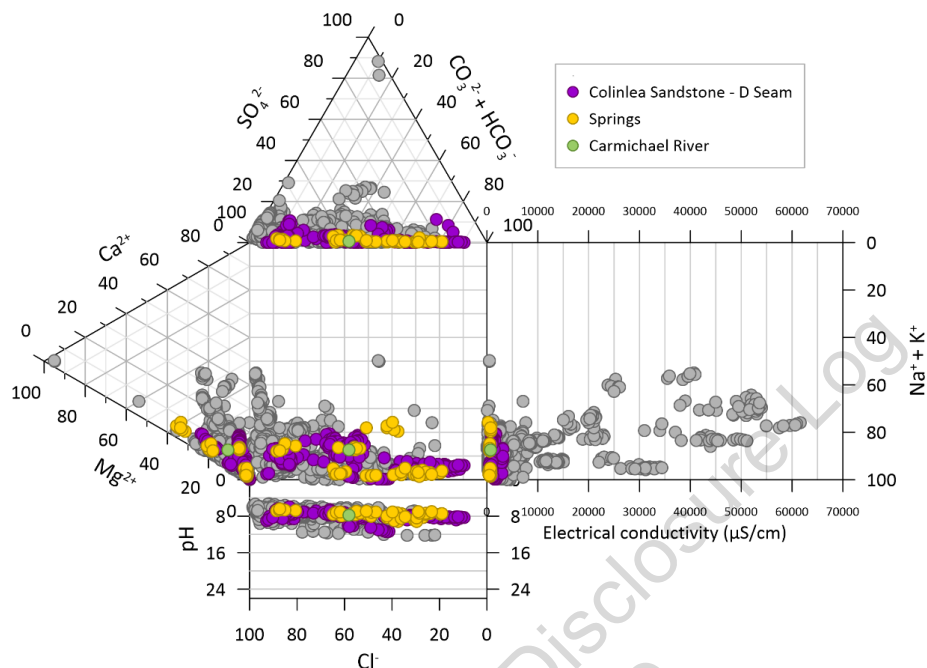


Figure 3.17 Major ion concentrations (as meq/L), pH and EC (in $\mu\text{S/cm}$) in groundwater sampled from the Colinlea Sandstone bores.

Note: Also shown are the DSC and Carmichael River samples. Grey symbols denote all groundwater samples and are shown for context.

3.5.6 DES recommendation #6

6) Detail isotope tracer studies used to characterise the groundwater dependent ecosystems.

i Summary of isotope studies

Isotopes are variants of elements that differ in the number of neutrons in their nucleus (ie they have a different relative atomic mass at the same atomic number). Chemically, the isotopes of a given element (or ion) behave the same at a given set of ambient conditions. Small differences in the ratios of the isotopes of a given element may arise, however, due to the influence of chemical (eg crystal composition and structure), physical (eg temperature) and biological (eg uptake of nutrients) processes. These *fractionations* may be measured and used to provide additional information on the genesis of particular water types.

A number of investigations have been conducted to assess the isotope characteristics of the Doongmabulla Springs Complex (DSC) surface water and groundwater from the main Triassic and Permian hydrostratigraphic units at the CCM to constrain the potential source(s) of the springs. These are summarised in the following sections.

ii 2016 DSITI study

In 2015/16, the Department of Science, Information Technology and Innovation (DSITI) undertook a study based on strontium isotope ratios ($^{87}\text{Sr}/^{86}\text{Sr}$) to attempt to determine the water source of the DSC (Fensham, Silcock, Laffineur, & MacDermott, 2016). Strontium is geochemically similar to calcium and substitutes into most rock-forming minerals. There are four naturally occurring stable isotopes of strontium: ^{81}Sr , ^{84}Sr , ^{86}Sr and ^{88}Sr ; ^{87}Sr is radiogenic and is produced by decay of ^{87}Rb . Different minerals in rocks can have different $^{87}\text{Sr}/^{86}\text{Sr}$ ratios due to different ages of formation, different original Rb/Sr values and different original $^{87}\text{Sr}/^{86}\text{Sr}$ values. For groundwater, the $^{87}\text{Sr}/^{86}\text{Sr}$ derived from any mineral through weathering reactions will be the same ratio as in the original mineral (Kendall, Sklash, & Bullen, 1995). Differences in $^{87}\text{Sr}/^{86}\text{Sr}$ among groundwater samples will result from (i) differences in mineralogy or (ii) differences in the relative amounts of Sr weathered from the source.

Figure 3.18 shows the $^{87}\text{Sr}/^{86}\text{Sr}$ results from the DSITI investigation into the DSC (Fensham, Silcock, Laffineur, & MacDermott, 2016). The results show a wide range of $^{87}\text{Sr}/^{86}\text{Sr}$ values, were noted to be inconclusive and may reflect the wide variation in calcium-bearing minerals in the Eromanga and Galilee basin lithologies. World-wide $^{87}\text{Sr}/^{86}\text{Sr}$ ratios in rainwater suggest that the values measured in the Permian and Triassic units may have experienced some rainfall ingress (Table 3.4).

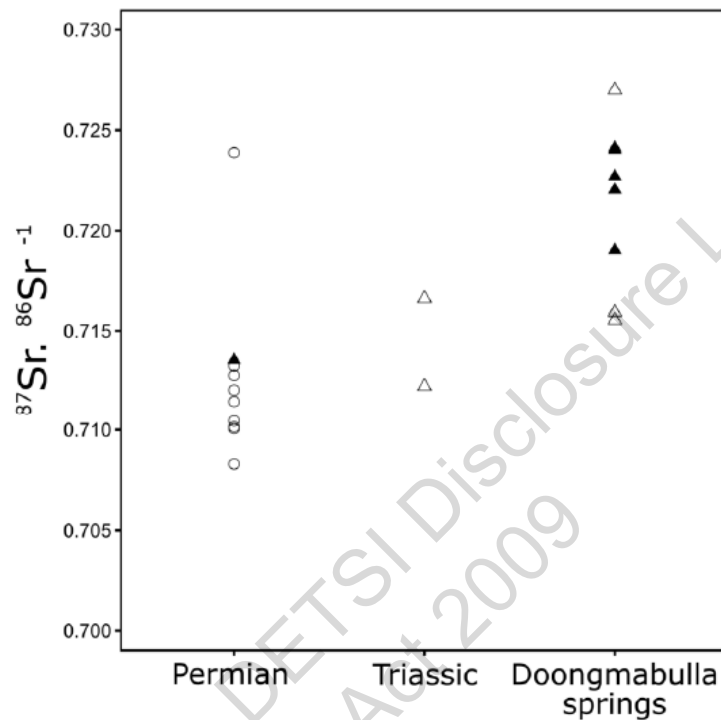


Figure 3.18 Strontium isotope signatures from bores and springs in the vicinity of Mellaluka and Doongmabulla. Circles are bores, triangles are springs with filled symbols representing springs with a discharge character. Open symbols represent springs with a recharge character (after Fensham, Silcock, Laffineur, & MacDermott, 2016)

Table 3.4 $^{87}\text{Sr}/^{86}\text{Sr}$ in global rainfall samples

Location	$^{87}\text{Sr}/^{86}\text{Sr}$	Source
Israel	0.7070 – 0.7092	Herut, Starinsky, & Katz (1993)
China	0.7111 (dessert) – 0.90917 (sea salt)	Xu & Han (2009)
France	0.7092 – 0.7131	Negrel & Roy (1998)
Southeast Australia	0.7100 – 0.7110	Raiber, Webb, & Bennetts (2009)

iii 2019 Bravus/AECOM study

As part of the 2018 field sampling and 2019 investigation, Bravus and AECOM undertook isotope studies on carbon-14 (^{14}C), tritium (^3H) and stable isotopes of hydrogen (δD), carbon ($\delta^{13}\text{C}$) and oxygen ($\delta^{18}\text{O}$), which represent major constituents of water, to provide additional insight into the DSC surface water and Triassic and Permian hydrostratigraphic unit groundwater compositions (Adani & AECOM, 2019).

Variations in δD ($^2\text{H}/^1\text{H}$) and $\delta^{18}\text{O}$ ($^{18}\text{O}/^{16}\text{O}$), referenced to Vienna Standard Mean Oceanic Water (VSMOW), in spring and borehole water samples collected in the September 2018 sampling campaign are summarised in Figure 3.19.

The dashed line represents the Global Meteoric Water Line (GMWL), which is the global trend of fresh water and is used as the standard for $\delta^{18}\text{O}$ and δD ; most global data plot on or close to this line. The line is generally defined as $\delta\text{D} = 8 \times \delta^{18}\text{O} + 10$ (in per mil).

Queensland rainwater samples from Charleville Station show variations from the Global Meteoric Water Line (GMWL), which may be due to temperature, 'raining out' and relative humidity differences. These rainfall samples describe a 'Local Meteoric Water Line', which is sub-parallel to the GMWL. Groundwater samples from the Clematis Sandstone follow a similar trend. A sample from the Carmichael River that deviates from the GMWL shows the effects of riverine evaporation. The spring water samples plot along the 'local' trends, which are similar to the Local Meteoric Line. In contrast, a line describing the Bandanna Formation (and Colinlea Sandstone) groundwater has a marked difference in gradient (~ 4.5 versus ~ 8); Brauv's and AECOM noted that the Colinlea Sandstone samples were not used to generate the trend line, but plot on or very close this 'Permian' line.

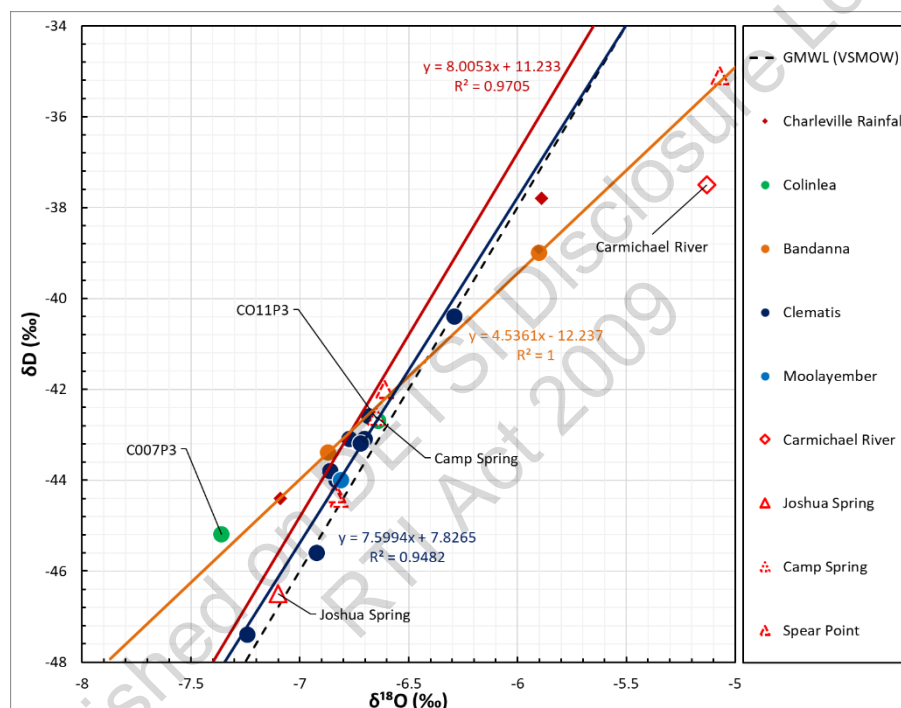


Figure 3.19 Variations in $\delta^{18}\text{O}$ and δD referenced to VSMOW in surface water and groundwater collected in the September 2018 field campaign. GMWL is the Global Meteoric Water Line ($\delta\text{D} = 8\delta^{18}\text{O} + 10$ ‰). A local meteoric line is also calculated based on Charleville isotopic ratios, which is comparable to a line calculated from Clematis groundwater. A line has also been calculated for the Bandanna Formation, which the Colinlea Sandstone groundwater closely follows (after Adani & AECOM, 2019)

Bravus/AECOM also noted in the 2019 study that the isotopic range of ^{13}C and ^{14}C in the Clematis Sandstone groundwater adequately explained the variation in ratios observed in the spring water. In addition, it was noted that tritium results indicated at least three water populations:

- An 'old' water type, with low tritium and groundwater that has experienced limited recharge (associated with the Colinlea samples).
- A 'lower, younger' water type potentially associated with Camp Spring, with tritium close to Clematis groundwater and some of the springs having experienced some surface water recharge.
- An upper 'youngest' water type, associated with Joshua Spring and the Carmichael River, which represent surface water, with the springs fed via the Clematis Sandstone.

To further constrain the potential DSC source(s), in February 2021 Bravus commissioned EMM to undertake a detailed study into the major element, trace element and isotope characteristics of the DSC surface water and groundwater in the CCM hydrostratigraphic units, and to develop a geochemical and mineralogical characterisation of the aquifer units of interest. Geochemical test work included:

- Major and trace element characteristics of groundwater and DSC surface water samples collected by C&R Consulting (C&R) during the bi-monthly water quality monitoring program (February 2021).
- Isotope studies of tritium, ^{14}C , δD , $\delta^{13}\text{C}$, $\delta^{18}\text{O}$ and $^{87}\text{Sr}/^{86}\text{Sr}$ on the February 2021 water quality samples.
- Major element compositions of hydrostratigraphic (rock) samples targeted as potential source aquifers for the DSC using X-ray fluorescence spectroscopy (XRF). This included both in-field (handheld) and laboratory XRF analysis.
- Minor and trace element compositions using inductively coupled plasma atomic emission spectroscopy (ICP-AES) on the hydrostratigraphic units.
- Hydrostratigraphic unit mineralogy by X-ray diffraction (XRD).
- Hydrostratigraphic unit isotope studies of $^{87}\text{Sr}/^{86}\text{Sr}$ and $\delta^{34}\text{S}$.

Results are pending for many of the above geochemical tests; however, some of the recently obtained isotope data are summarised below.

Figure 3.20 revisits the DSITI study and shows the $^{87}\text{Sr}/^{86}\text{Sr}$ ratios of the surface water samples (triangles) and groundwater samples (circles) collected in the February 2021 monitoring round, together with rock samples collected from a range of hydrostratigraphic units at the CCM (squares). Groundwater is divided into Permian units (Bandanna, Colinlea and Joe Joe), Triassic units (Rewan, Dunda, Clematis and Moolayember) and the DSC water; also shown is the $^{87}\text{Sr}/^{86}\text{Sr}$ ratio measured from Alluvium groundwater. Figure 3.20 shows that the aquifer rock and groundwater isotope compositions are likely to be close to equilibrium and that the DSC surface water samples have elevated $^{87}\text{Sr}/^{86}\text{Sr}$ ratios compared to those from the Permian groundwater. The lower estimate of global rainfall $^{87}\text{Sr}/^{86}\text{Sr}$ also suggests that most Permian groundwater sampled in the February 2021 campaign is likely to have experienced only limited recharge.

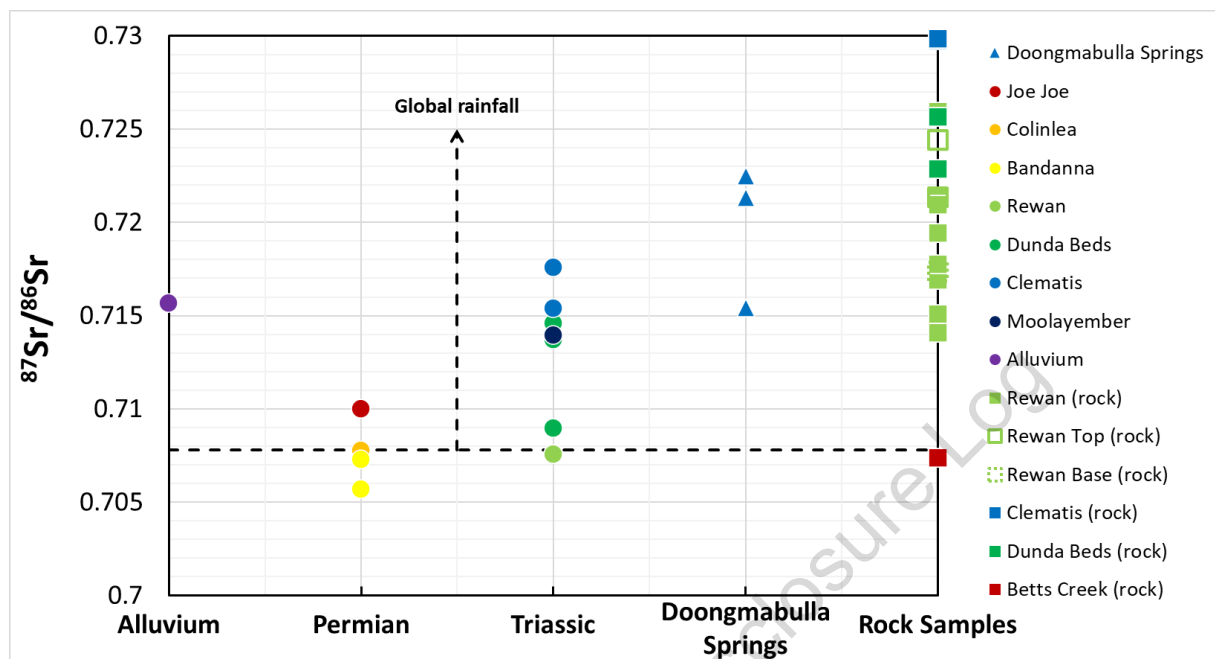


Figure 3.20 Strontium isotope signatures from bores and springs in the vicinity of Doongmabulla. Circles are groundwater, triangles are springs and squares are isotope signatures from hydrostratigraphic units (rock) at the CCM. Also shown is the lower estimate of global $^{87}\text{Sr}/^{86}\text{Sr}$ in rainfall, with the arrow indicating the possible range of ratios (Table 3.4)

Figure 3.21 shows the $\delta^{18}\text{O}$ and δD plot from Figure 3.19 updated following the February 2021 field program. The water samples are again referenced to VSMOW, which typically describes a line with a slope of ~ 8 . Local meteoric lines for rainfall and Clematis groundwater are updated with the 2021 data and are similar to VSMOW. In contrast, the line generated using the Bandanna Formation groundwater (and updated with 2021 data) has a slope of ~ 4.5 . Colinlea samples (updated with 2021 data) fit on this line, whereas most of the spring samples are more closely related to the GMWL. Figure 3.21 shows that the Carmichael River may experience evaporation; this is consistent with the difference in stable isotope ratios observed from sample C18014SP in 2018 and 2021 (dry season sampling in 2018 compared to a high rainfall wet season in 2021).

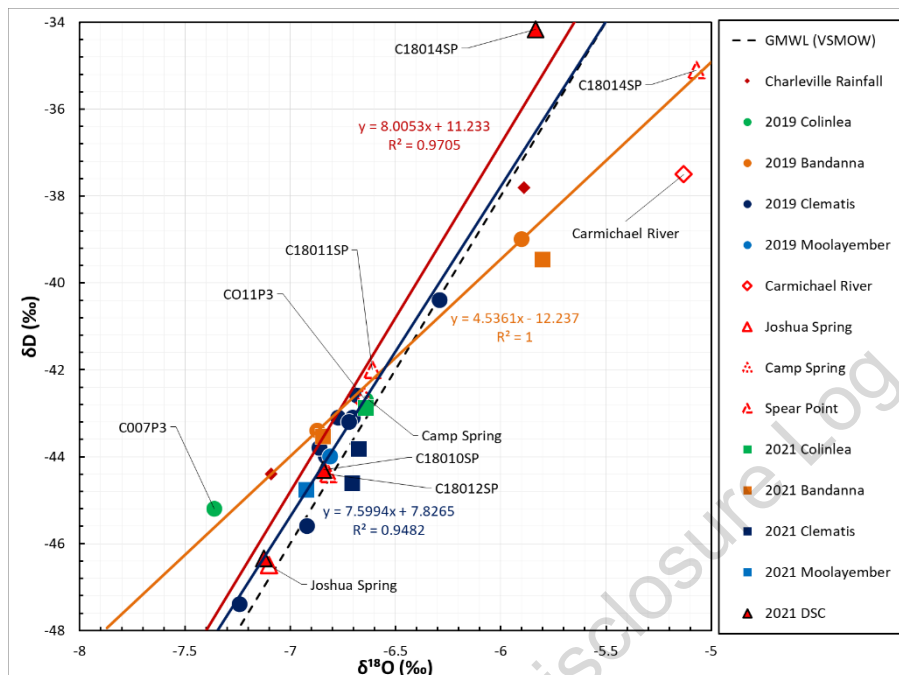


Figure 3.21 Variations in $\delta^{18}\text{O}$ and δD referenced to VSMOW in surface water and groundwater collected in the September 2018 (assessed in 2019) and February 2021 field campaigns. GMWL is the Global Meteoric Water Line ($\delta\text{D} = 8\delta^{18}\text{O} + 10$ ‰). A local meteoric line is also calculated based on Charleville isotopic ratios, which is comparable to the based on the line calculated from Clematis groundwater ratios. A line has also been calculated for the Bandanna Formation, which the Colinlea Sandstone groundwater closely follows

3.5.7 DES recommendation #7

- 7) The 2020 review report provides details of a number of new and replacement bores – 14 in total. The latitude and longitude of these bores should be provided in the review report to facilitate any necessary EA amendment to include these additional bores.

Coordinates for the 14 replacement bores are provided in Table 3.2 above.

3.5.8 DES recommendation #8

- 8) The location and target aquifer for all new bores should be detailed in the review report with a recommendation about any necessary EA amendments.

The location of all new bores are shown in Figure 3.1 New Groundwater Monitoring Bores (2019-2020)

and target aquifer and bore details provided in Table 3.2. The monitoring bores listed in the EA (Table E1 in Appendix 5) will be updated with all new monitoring bores.

3.5.9 DES recommendation #9

- 9) All exceedances in water quality triggers and limits should be discussed in the review report and recommendations of triggers that need to be revised should be detailed.

i Water quality exceedance reporting

Recommendations for revision of trigger values are included in Section 3.2 and are detailed below. Exceedances in water quality triggers and limits have been reported since the groundwater quality monitoring program commenced in late 2019.

Following sample collection and laboratory analysis (and QA/QC verification), water quality parameters obtained in each monitoring round are compared to the hydrostratigraphic unit-specific and bore-specific trigger values relevant to each bore (as outlined in the GMMP) to determine whether trigger exceedances have occurred. On identification of parameters exceeding the hydrostratigraphic unit-specific and bore-specific trigger values twice within 12 months, a Step 1 trigger investigation is initiated, in order to:

‘...determine if the exceedance is a result of:

- 1. Mining activities authorised under this environmental authority, or*
- 2. Natural variation (including climatic influences), or*
- 3. Neighbouring land use resulting in groundwater impacts.’ (GMMP).*

The Step 1 trigger investigation involves assessing the variations in the parameters exceeding trigger values by comparing the parameter values of each of the sampling rounds to the historical baseline groundwater quality at each bore. The majority of the baseline groundwater quality data were collected between 2014 and 2017.

Bores where specific analytes have shown two or more exceedances in the monitoring events performed to date are compared to the relevant groundwater trigger values (Tables 52 to 59 in the GMMP ver 11), as shown in Appendix C. Only the instances where two or more trigger exceedances for a given parameter at a given bore are reported from the sampling rounds.

ii Investigation of groundwater exceedances

The Step 1 trigger investigation is initiated to determine whether the groundwater quality exceedances of triggers could be due to:

- a. Authorised mining activities (eg land disturbance during construction and/or dewatering).
- b. Disturbances such as bore installation / bore renovation with the groundwater yet to re-establish ambient conditions.
- c. The naturally variable geochemistry of the hydrostratigraphic units and its influence on each groundwater aquifer.
- d. Seasonal fluctuations (eg ‘flush’ events following rainfall vs. ‘dry’ conditions).
- e. Contamination from other activities (eg farming, private water use).

iii Site activity-related causes

Site activities (box-cut excavation) commenced on 10 July 2020 and therefore there is a potential for impact on the surrounding groundwater system. Dewatering of coal seam aquifers with eight dewatering bores commenced in August/September 2019 with an additional seven dewatering bores commissioned between August 2020 and December 2020. All dewatering bores are located near to the current location of the box-cut.

Groundwater quality from the water quality monitoring rounds is compared to historical (pre-site activities) water quality in the chosen bores to determine whether the commencement of site activities has had a detrimental impact on parameter values. Key parameters included:

- a. Variations in pH. Although laboratory pH values recorded in samples from most monitoring bores have not exceeded trigger values over the six sampling rounds³, changes in pH often provide an early indication of alterations in groundwater chemistry and an examination of variations in pH is included in the Step 1 investigation. Field pH readings are also examined pending in-situ trigger values.
- b. Variations in EC. Many of the trigger exceedances reported over the monitoring rounds are in major ions (ie calcium, magnesium, sodium, sulphate and chloride). EC is included in the Step 1 assessment to represent the major ion chemistry (as shown by a number of exceedances of bore-specific and hydrostratigraphic-specific EC trigger values in Appendix C).
- c. Variations in iron concentration. Iron is included in the Step 1 assessment because it has historically recorded trigger exceedances across most of the hydrostratigraphic units.
- d. Variations in hydrocarbons. Most hydrocarbon analysis has been reported at or below limits of reporting (LOR). An increase in hydrocarbon concentrations may indicate site activity; hydrocarbon variations are represented by TRH (C10-C40).

Step 1 trigger exceedances investigations (eg bi-monthly exceedances reporting) show that site activities have had little impact on the water quality recorded in the monitoring bores. Parameter values are within the ranges predicted from the historical (pre-site activities) water quality (Appendix D; **Note:** pH values recorded in the field are consistently lower than those reported from laboratory analysis on the same samples). Variations in monitoring bore water quality reported from the sampling rounds reflect the natural bore-specific and hydrostratigraphic unit-specific water quality; slight perturbations may have resulted from the bore renovations carried out prior to sampling as the groundwater quality returned to ambient conditions. However, these remain within the historical variations in water quality recorded since 2014 (pre-site activities) for all bores except bore C14003SP for iron. In addition, values of pH recorded in the sampling rounds are within the upper and lower trigger values, for all bores except C833SP.

Water quality trigger exceedances are relatively evenly spread across the main hydrostratigraphic units over a range of water quality parameters in the sampling rounds (Appendix C). This distribution further suggests that the exceedance values are the result of natural processes and is consistent with the historical (pre-site activities) water quality variations observed during the baseline groundwater studies outlined in the GMMP ver. 11.

Hydrocarbon exceedances are not specific to a particular hydrostratigraphic unit and range from the surficial Alluvium units to the deep Joe Joe Group; these are unlikely to be from construction activities and the activities of other land users and are more likely to reflect natural variations in coal-associated regions, with bore renovations potentially perturbing concentrations (these are expected to reduce in later sampling rounds as the groundwater returns to its ambient state).

It should also be noted that at the concentrations most metals/metalloids and hydrocarbons are reported (ie low mg/L or µg/L levels), slight variations in sampling and laboratory conditions (including recent bore renovations) may result in wide variations in reported values.

iv Natural variations

Groundwater quality may naturally vary over time due to precipitation, evaporation, nearby river flows, biological processes occurring in the aquifer and many other factors. Due to this, exceedances of the trigger levels may be observed without external influences acting on the groundwater. Trigger exceedance investigations have made use

³ Note: The initial pH trigger values were derived from laboratory pH results (GMMP) and the pH exceedances assessments have used laboratory pH results to compare like for like. Breaches in laboratory-mandated holding times for pH have been recorded and DES have recommended that in-situ (field) pH readings are to be assessed where such QA/QC breaches are reported.

of Piper diagrams and hydrographs for each hydrostratigraphic unit to determine whether and how the groundwater exceedances could have been caused by natural processes.

Piper diagrams reported in the groundwater monitoring trigger exceedance reports (updated plots are shown under Section 3.5.5) show that the historical, pre-works, post-works and latest round samples are essentially the same in terms of groundwater type, suggesting that the groundwater has not been influenced by external factors such as site construction since the baseline samples were collected. Some exceptions noted are:

- a. Alluvium bore C18009SP records some pre- and post-works samples with higher proportions of calcium than the historical samples. This bore was installed as part of the seepage monitoring network as per the GMMP and is awaiting assessment of its baseline data prior to assigning trigger values. It is included in this discussion only as a record of completeness until appropriate trigger values are assigned. The alluvium bores are historically noted for their variable groundwater geochemistry (GMMP; AECOM, 2019).
- b. Clematis Sandstone. Some pre- and post-works samples have slightly lower proportions of chloride and fluoride than the historical samples. These samples were from bore C18002SP, which was installed in 2018 (Which is the farthest monitoring bore for Clematis SSt and ~ 4km from another Clematis SSt bore installed in similar depth horizon) and was therefore not included in the baseline study. As the pre- and post-works samples have the same groundwater type, it is likely that this bore has always had a differing groundwater type to the other Clematis Sandstone bores. Since monitoring of this bore commenced in January 2020, additional sampling rounds will confirm the nature of the groundwater at this location.
- c. Joe Joe Group. Two pre-works samples have very high proportions of sulphate and magnesium compared to the other Joe Joe Group samples. These samples were from bores C9180124SPR and C914108PTR and have low EC values (approximately 500 $\mu\text{S}/\text{cm}$) and are therefore prone to large changes in groundwater type following a small increase in concentration of one major ion relative to the others. These points could indicate contamination or sampling error. Subsequent samples, both pre- and post-works, have been within the expected range outlined by the historical data.

v Field parameter exceedances

Following advice from DES⁴, samples that report parameter holding time non-conformances are to be assessed against trigger values based on in-situ (field meter) values. The QA/QC reporting of the groundwater quality monitoring rounds noted holding time exceedances for pH, TDS, ammonia, nitrate and nitrite, of which field pH measurements were measured in-situ and may be assessed against pH trigger values. Exceedances in holding times for pH also represent among the strictest criteria (ie laboratory receipt on the same day as sampling).

Field and laboratory pH values reported in the bi-monthly trigger exceedances reports show a difference from a 1:1 correlation of ~ 20%, with field pH recorded at consistently lower values compared to laboratory pH. Discrepancies between field and pH readings may be due to a number of reasons, such as differences in sample temperatures when analysed in the laboratory compared to analysis in the field. In addition, holding times may affect laboratory pH readings due to the opportunity for sample 'spoils', which may include CO₂ ingress into samples, bacterial action, or precipitation of metals such as iron.

Given the differences in laboratory and field pH, no obvious explanation for the variations in pH and given that the pH triggers were derived from laboratory values, the following action is recommended:

- Both laboratory and field pH are reported in each future monitoring round to continue to assess any variations in the readings.

⁴ DES Notification – Adani Mining Pty Ltd, EPML01470513, 12 November 2020.

vi Other sources of contamination

Other sources of groundwater contamination could come from nearby land users, particularly farms. Nutrients such as ammonia, nitrate and phosphorus from fertilizers are common groundwater contaminants associated with agricultural land use. The low number of trigger value exceedances being associated with nutrients suggests that it is unlikely that nearby agricultural land use has had a significant effect on the groundwater quality. Bravus has confirmed that in the area of the mining lease no significant change in land use has occurred, other than regular pastoral activities, and the mining and construction activities.

The Step 1 trigger investigations have indicated that, although site activities including construction and additional dewatering have commenced, the groundwater does not appear to have been influenced by external factors. The reported trigger exceedances are likely to be due to natural variations in the groundwater within each hydrostratigraphic unit and longer-term environmental trends.

vii Recommendations for trigger values and future monitoring rounds

Recommendations from the Stage 1 trigger exceedances investigations are outlined in Section 3.2 and are summarised as follows:

- Trigger values for major ions should be removed due to the high variability seen in these values and the low potential for adverse effects.
- Updating trigger values based on new data that are shown to not be affected by mining-related activities should be considered. The groundwater environment has changed over time from the baseline monitoring period, as reflected in the declining groundwater levels in many of the bores where trigger value exceedances were noted. The originally derived trigger values may therefore no longer describe the current 'normal' groundwater quality.
- Trigger values should be revised and/or developed for the following:
 - All bore-specific and hydrostratigraphic unit-specific values included in the GMMP to reflect the additional 12 months of water quality monitoring data and to account for the natural variation in water quality. This is especially pertinent following the high rainfall in the 2020/2021 wet season and will take into account high recharge.
 - Bores installed following publication of the GMMP. This is especially relevant to the recently installed Alluvium bores, which may require bore-specific trigger values.
 - Field parameters such as pH and EC. The current trigger values are based on laboratory results which have been shown to differ from field results (see bi-monthly trigger exceedance reporting).
- Due to the high probability that many parameters will end up triggering a Stage 1 investigation only through natural variations, it should be considered that only two consecutive exceedances of the trigger values cause a Stage 1 investigation to be initiated.

3.5.10 DES recommendation #10

- 10) *All five surface water gauging stations must be referred to in the review report for the GMMP with the data presented and interpreted.*

Data for surface water gauging stations are discussed in Section 3.4.25.

3.5.11 DES recommendation #11

- 11) *The GMMP review report identifies inconsistencies in bore identification details. The review report should make recommendations about any necessary amendments to the GMMP and/or the EA.*

The groundwater monitoring network presented in Table 62 of GMMP is revisited and updated to remove inconsistencies in bore identification details. These changes will be incorporated into table E1 Appendix 5 of EA in the next EA amendment.

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4 References

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Appendix A

Updated artesian average baseline water level elevation and thresholds

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Table A.1 Updated artesian average baseline water level elevation and thresholds

Bore ID		Geology	Deepest predicted drawdown (m)	Average groundwater level (mAHD)	Natural Fluctuation (NF) (m)	Groundwater level threshold (criteria)	Groundwater level threshold (mAHD)	Figure
C14006SP	GMMP	Joe Joe Group	0.42	226.03	0.94 (10 months)	0.79 (1/2 NF + 75% of prediction)	225.24	Figure A.1
	Updated			223.44			222.65	
C14008SP	GMMP	Joe Joe Group	1.18	228.34	1.38 (19 months)	1.58 (1/5 NF + 75% of prediction)	226.76	Figure A.2
	Updated			225.97			224.39	
C14015SP	GMMP	Joe Joe Group	6.65	239.15	0.55 (9 months)	5.26 (1/2 NF + 75% of prediction)	233.89	Figure A.3
	Updated			237.05			231.79	
C14016SP ¹	GMMP	Joe Joe Group	27.23	234.13	2.13 (21 months)	25.57 (1/2 NF + 90% of prediction)	208.56	Figure A.4
	Updated							
C14029SP	GMMP	Tertiary/Joe Joe Group	1.90	230.06	0.47 (20 months)	1.66 (1/2 NF + 75% of prediction)	228.40	Figure A.5
	Updated			227.92			226.26	
C914030SPR	GMMP	Joe Joe Group	1.90	230.25	1.29 (20 months)	2.07 (1/2 NF + 75% of prediction)	228.18	Figure A.6
	Updated			228.17			226.10	
C180119SP	GMMP	Joe Joe Group	0.045	238.21	0.49 (22 months)	0.29 (Prediction + ½ NF)	237.92	Figure A.7
	Updated			235.86			235.57	
C180120SP	GMMP	Tertiary/Joe Joe Group	0.02	242.19	2.53 (29 months)	1.29 (Prediction + ½ NF)	240.85	Figure A.8
	Updated			239.85			238.56	
C180122SP	GMMP	Tertiary/Joe Joe Group	0.045	236.04	0.75 (29 months)	0.42 (Prediction + ½ NF)	235.26	Figure A.9
	Updated			233.30			232.88	
C180123SP	GMMP	Joe Joe Group	0.007	246.35	0.67 (28 months)	0.34 (Prediction + ½ NF)	246.01	Figure A.10
	Updated			243.89			243.55	
C9180124SPR ¹	GMMP	Joe Joe Group	0.045	235.31	0.55 (24 months)	0.32 (Prediction + ½ NF)	234.99	Figure A.11
	Updated							
C9180125SPR	GMMP	Joe Joe Group	0.02	243.10	1.07 (25 months)	0.56 (Prediction + ½ NF)	242.54	Figure A.12

Table A.1 Updated artesian average baseline water level elevation and thresholds

Bore ID		Geology	Deepest predicted drawdown (m)	Average groundwater level (mAHD)	Natural Fluctuation (NF) (m)	Groundwater level threshold (criteria)	Groundwater level threshold (mAHD)	Figure
	Updated			240.72			240.16	
HD03A ¹	GMMP	Clematis Sandstone	0.18	232.03	1.02 (44 months)	0.69 (Prediction + ½ NF)	231.34	Figure A.13
	Updated							

Notes: ¹ No change to logger elevation and therefore no change to historical average water levels and threshold value

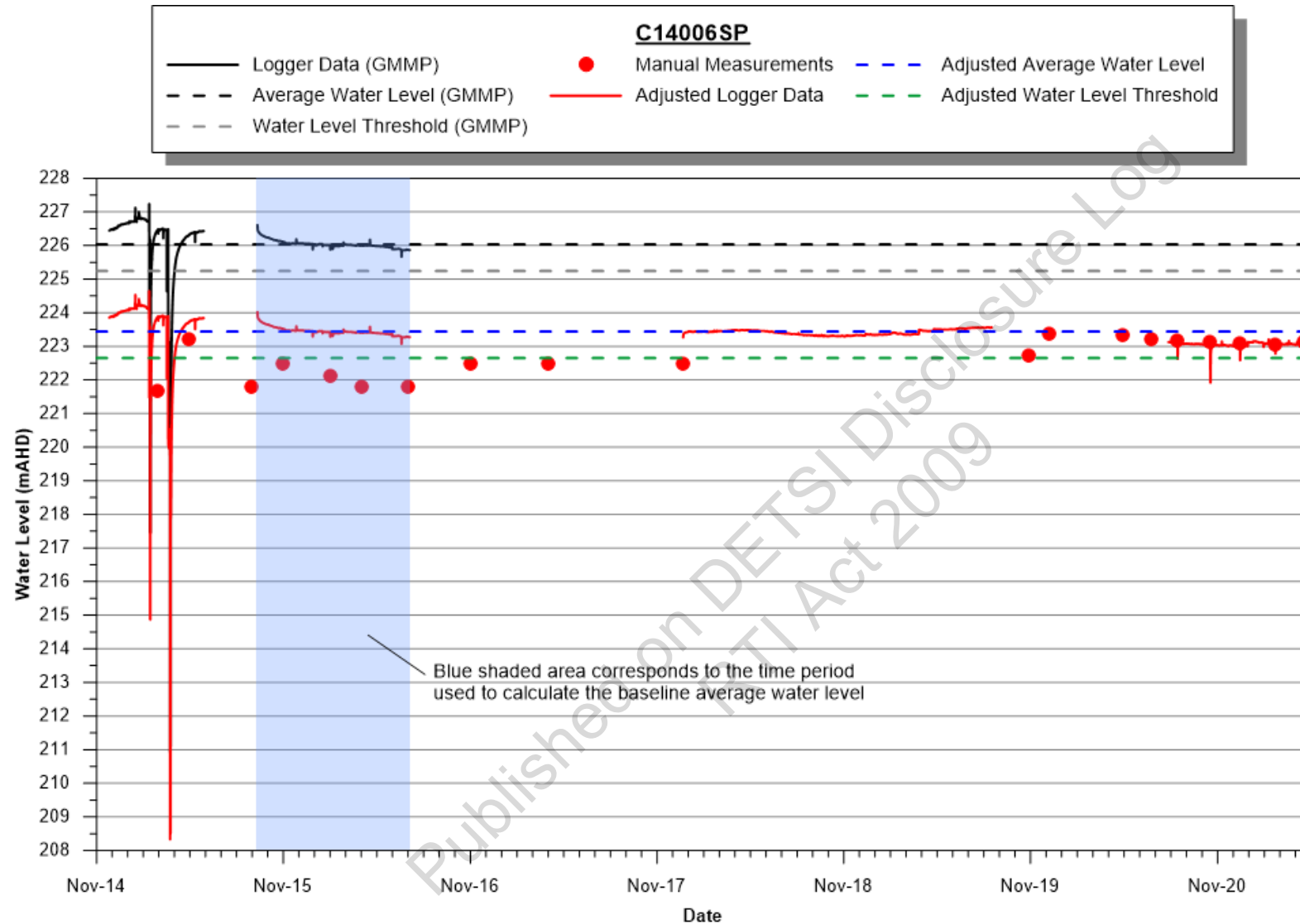


Figure A.1 C14006SP updated water levels and threshold

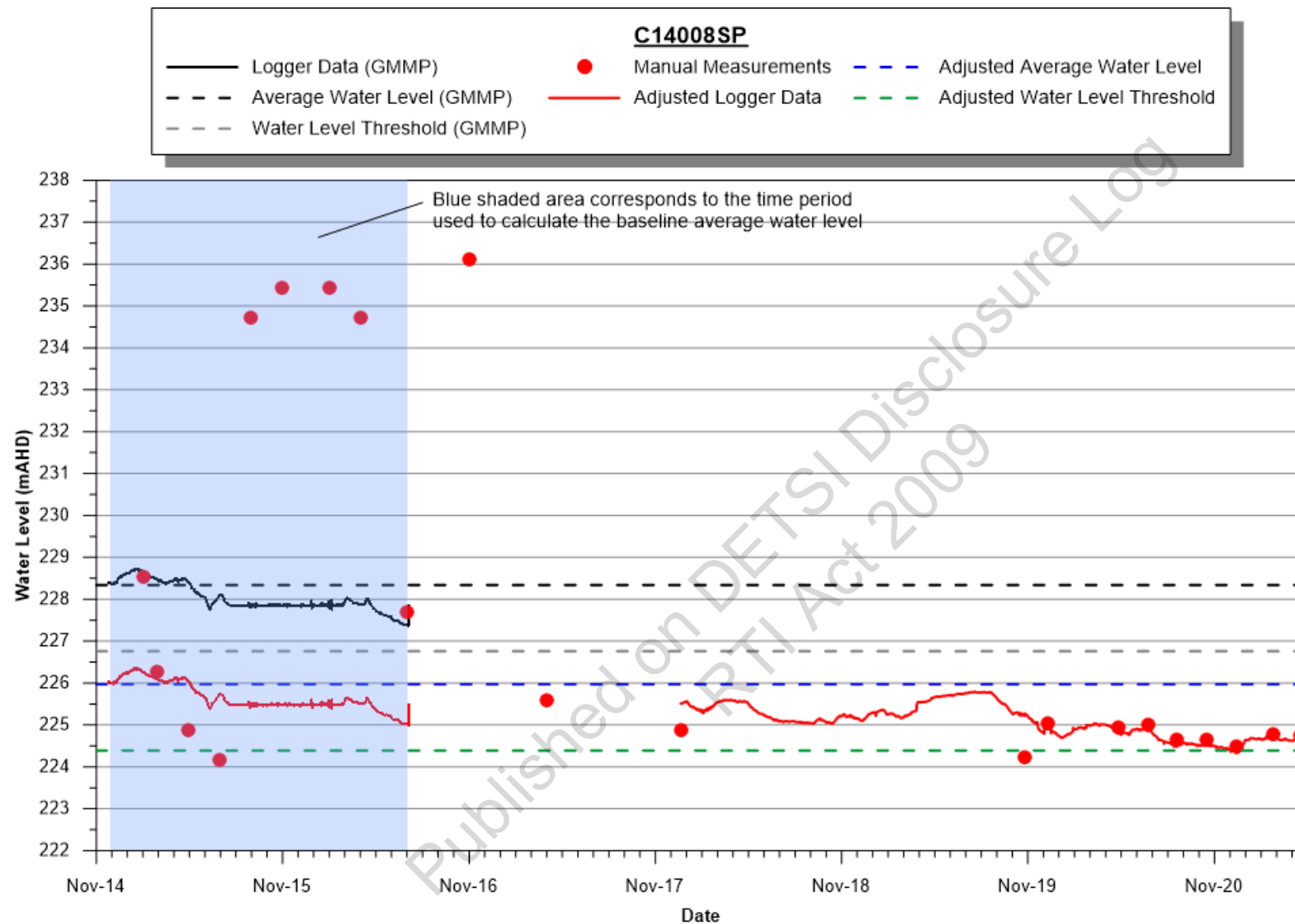


Figure A.2 C14008SP updated water levels and threshold

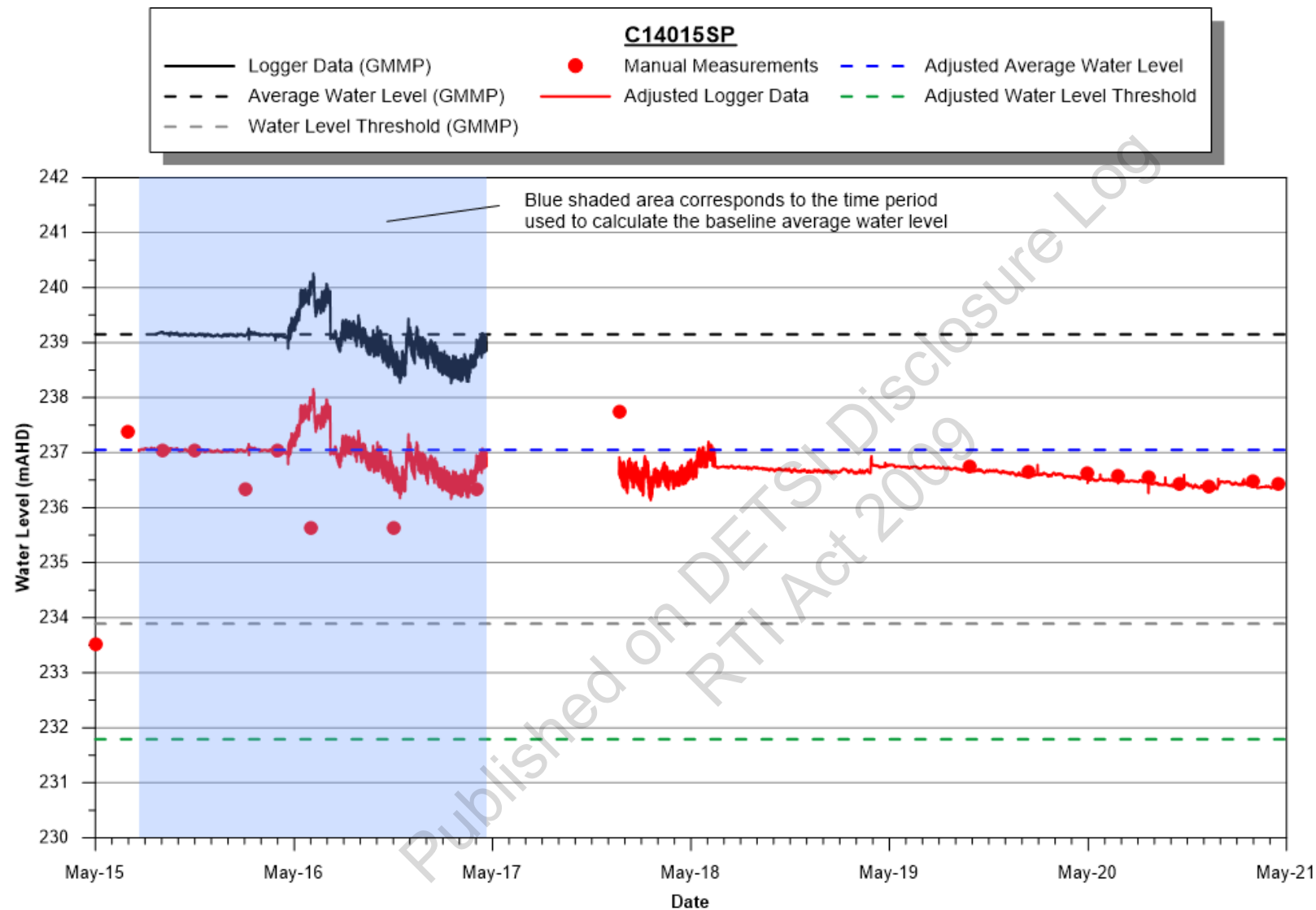


Figure A.3 C14015SP updated water levels and threshold

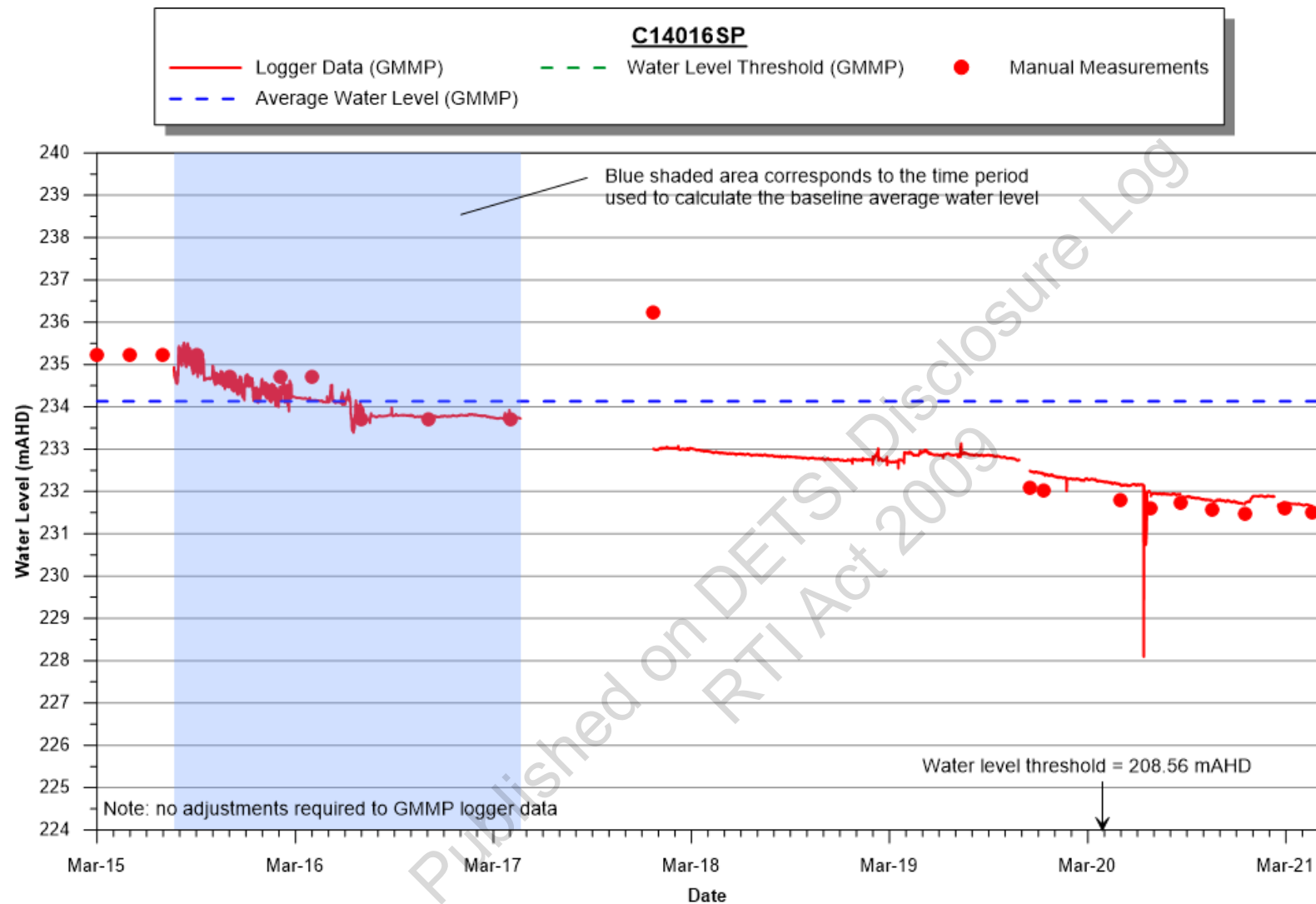


Figure A.4 C14016SP updated water levels and threshold

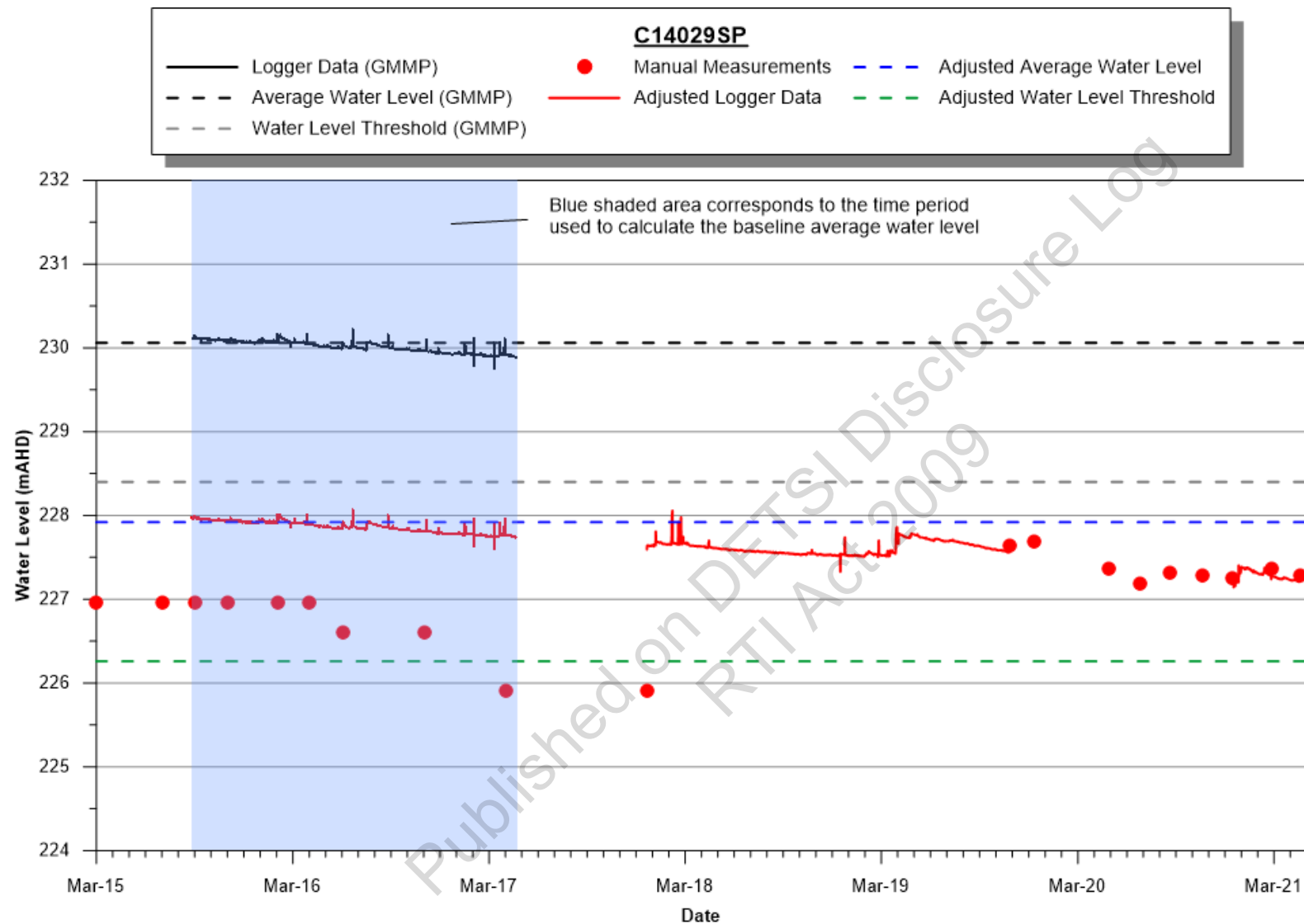


Figure A.5 C14029SP updated water levels and threshold

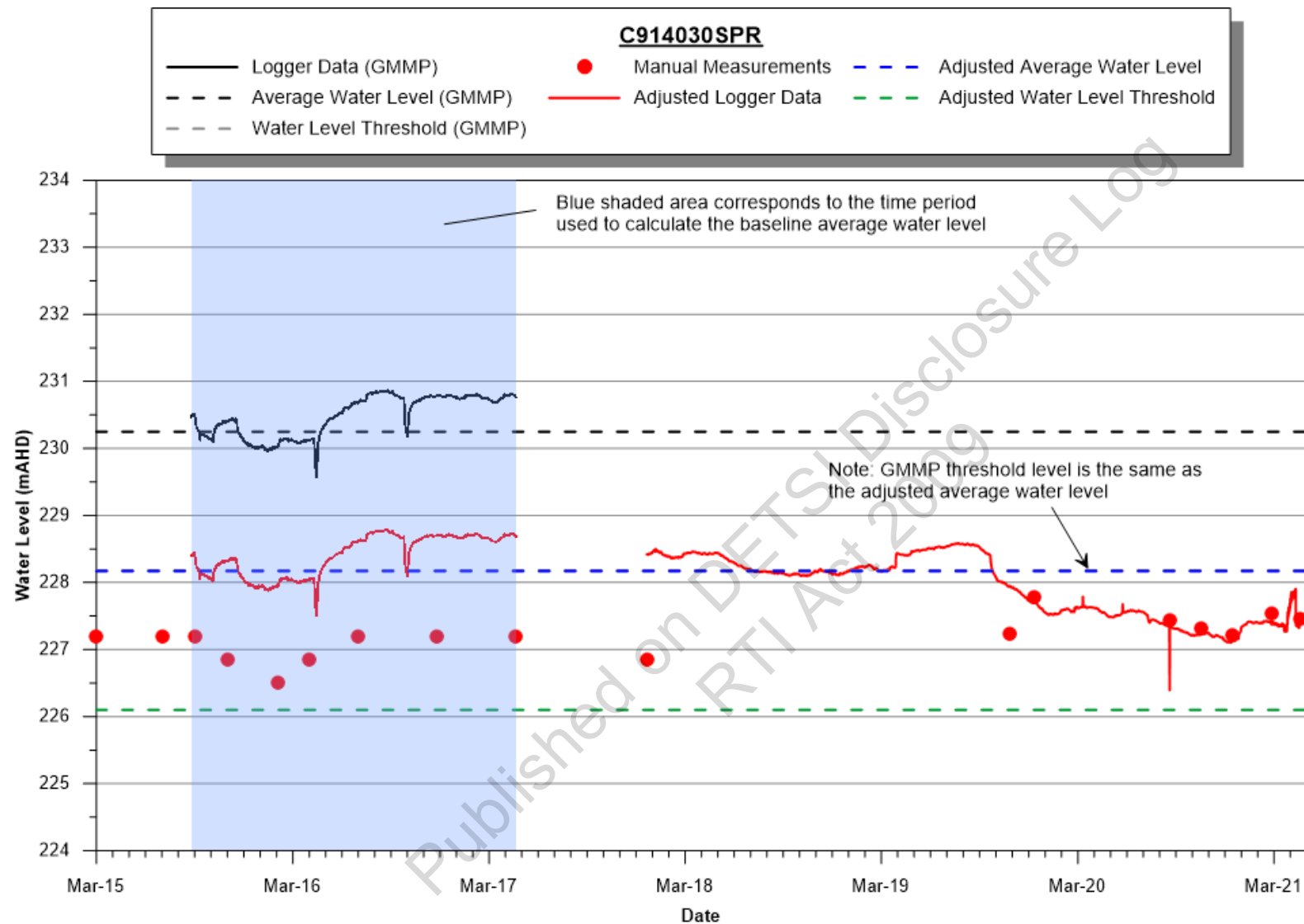


Figure A.6 C914030SPR updated water levels and threshold

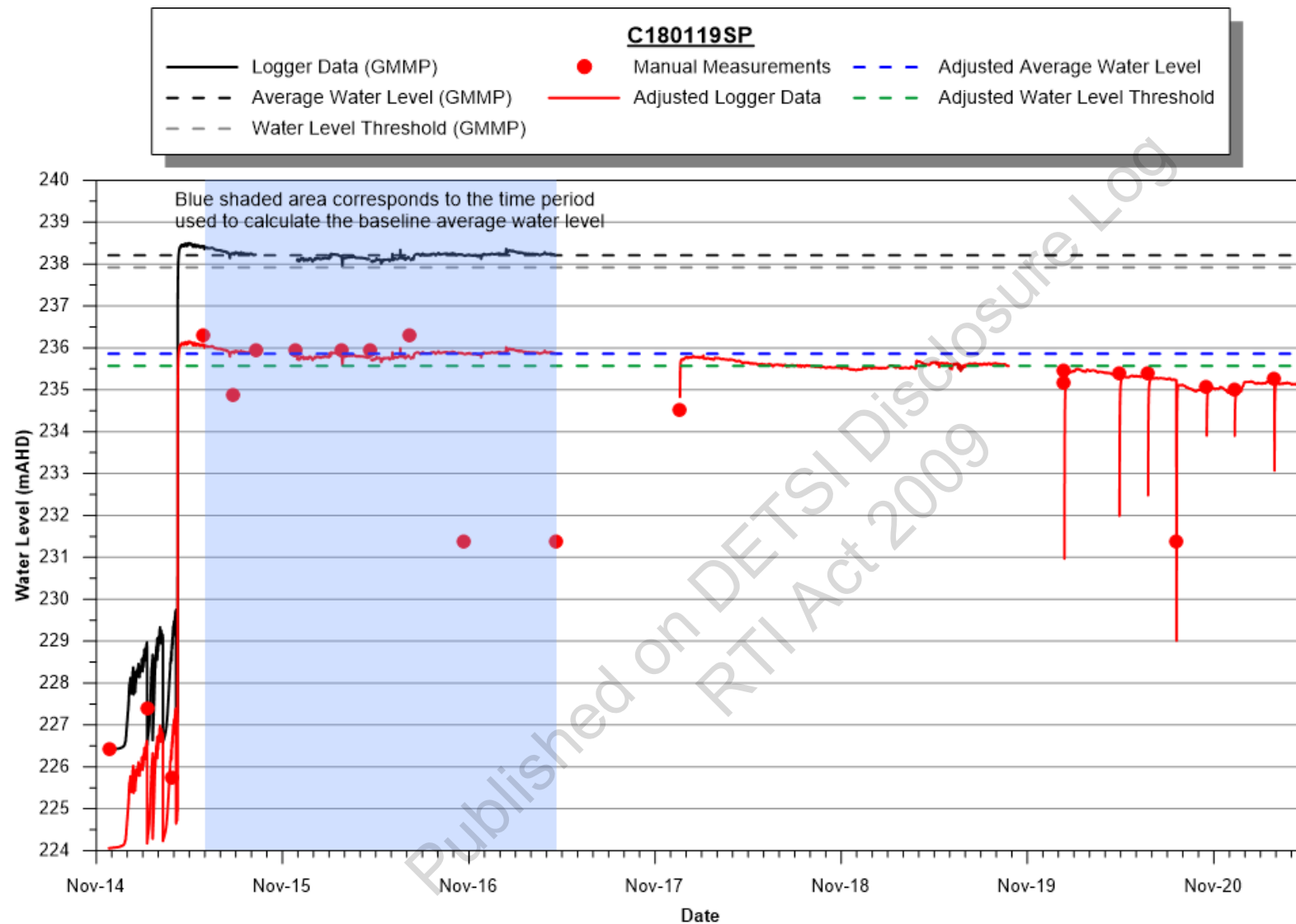


Figure A.7 C180119SP updated water levels and threshold

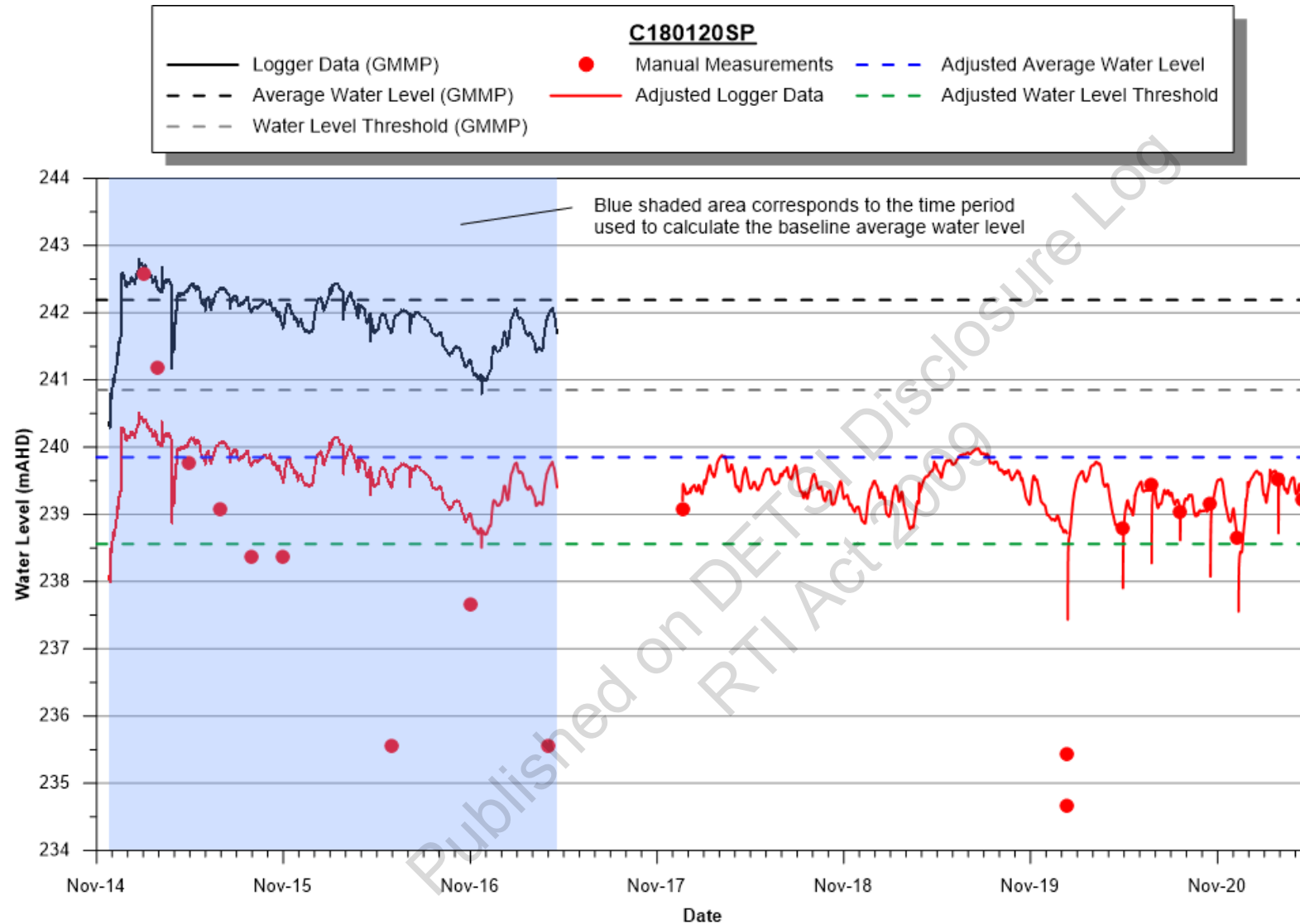


Figure A.8 C180120SP updated water levels and threshold

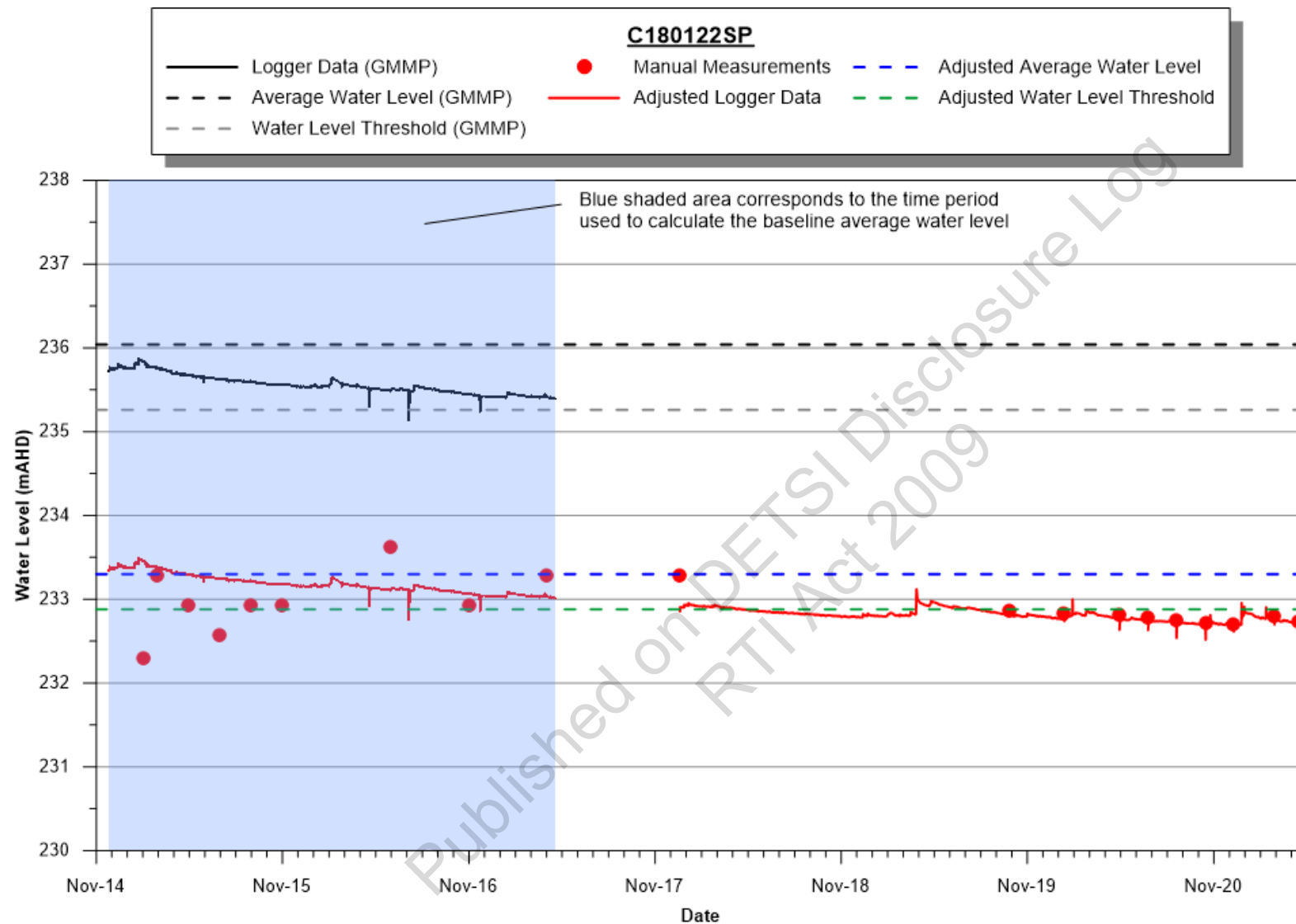


Figure A.9 C180122SP updated water levels and threshold

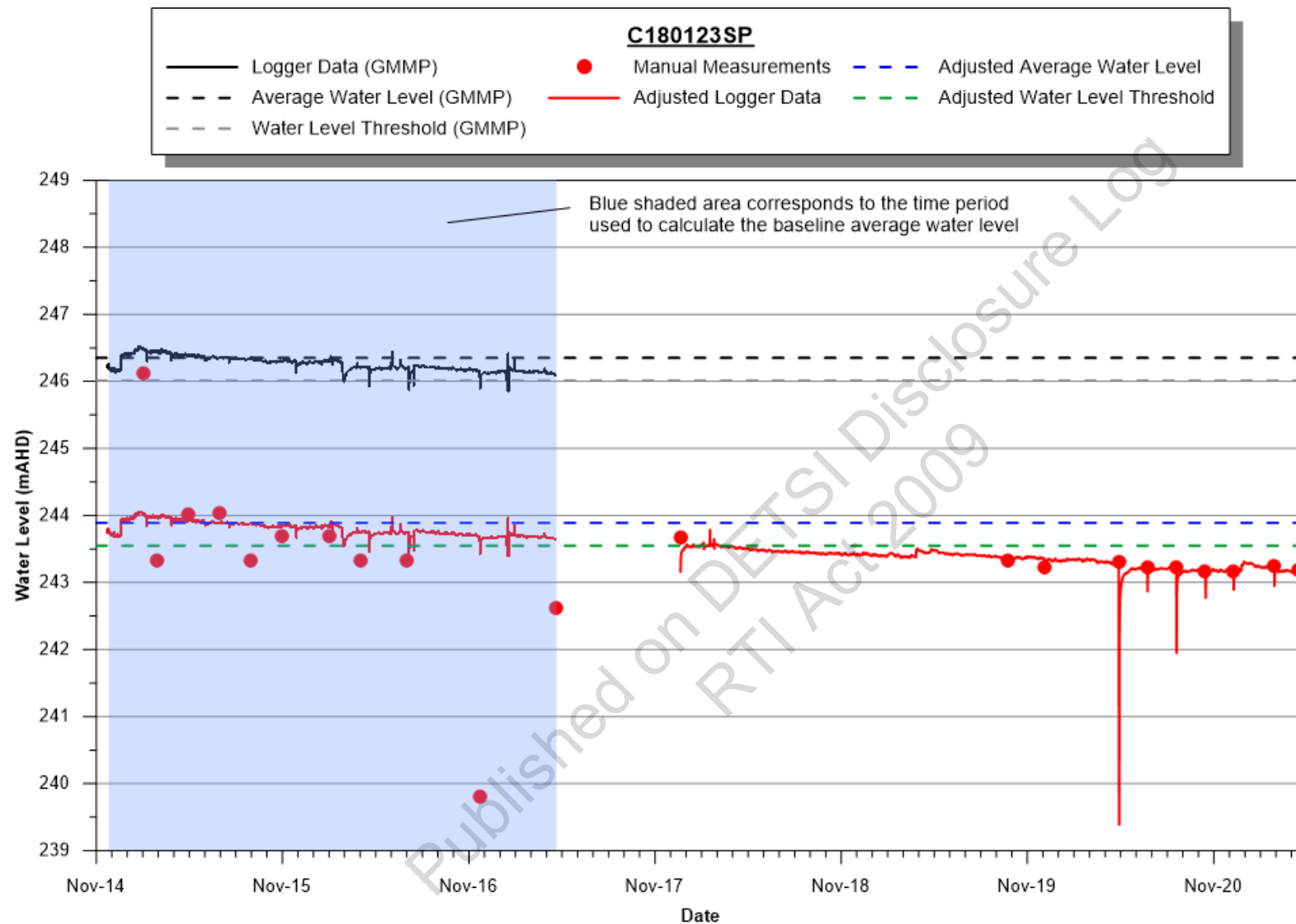


Figure A.10 C180123SP updated water levels and threshold

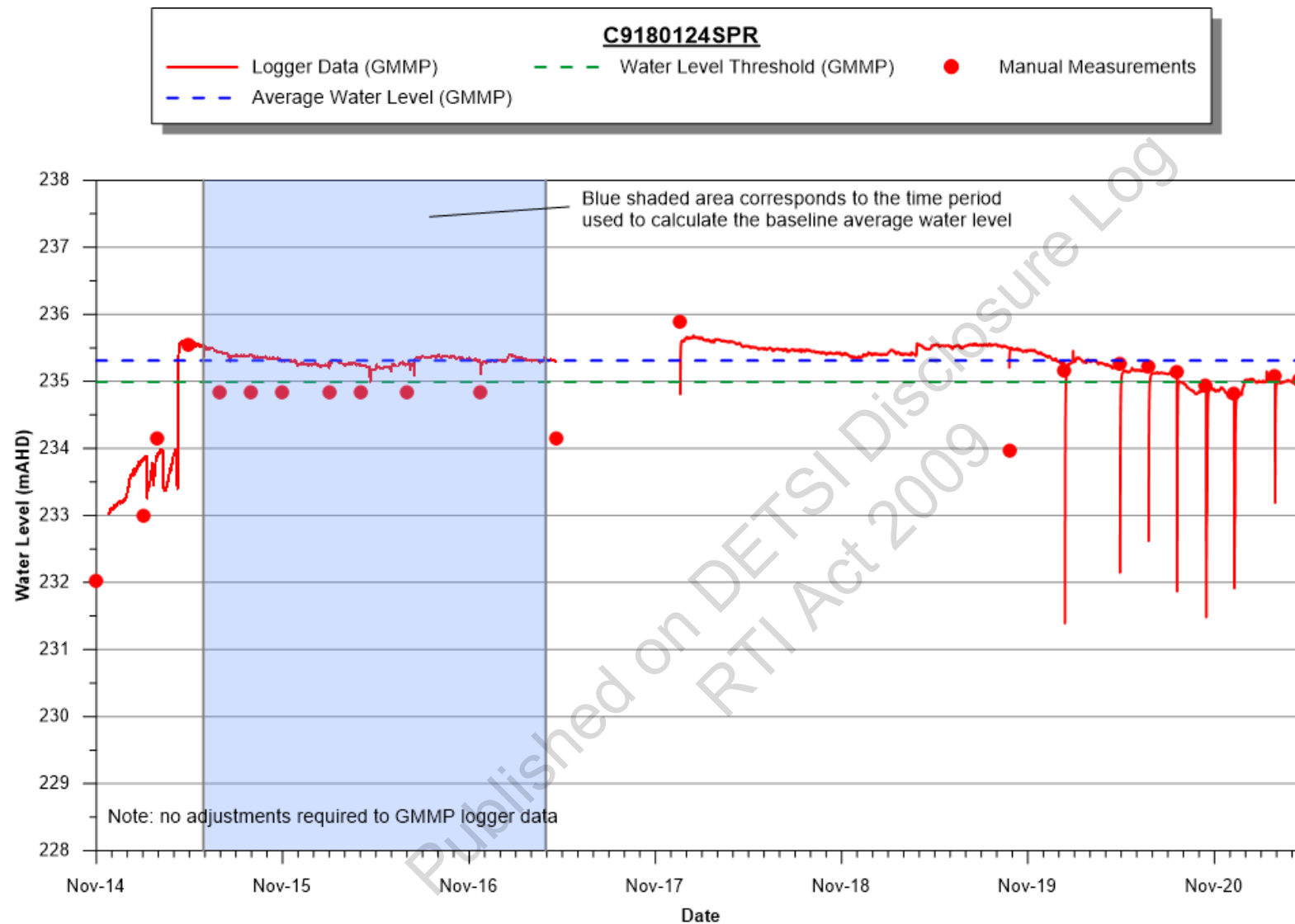


Figure A.11 C9180124SPR updated water levels and threshold

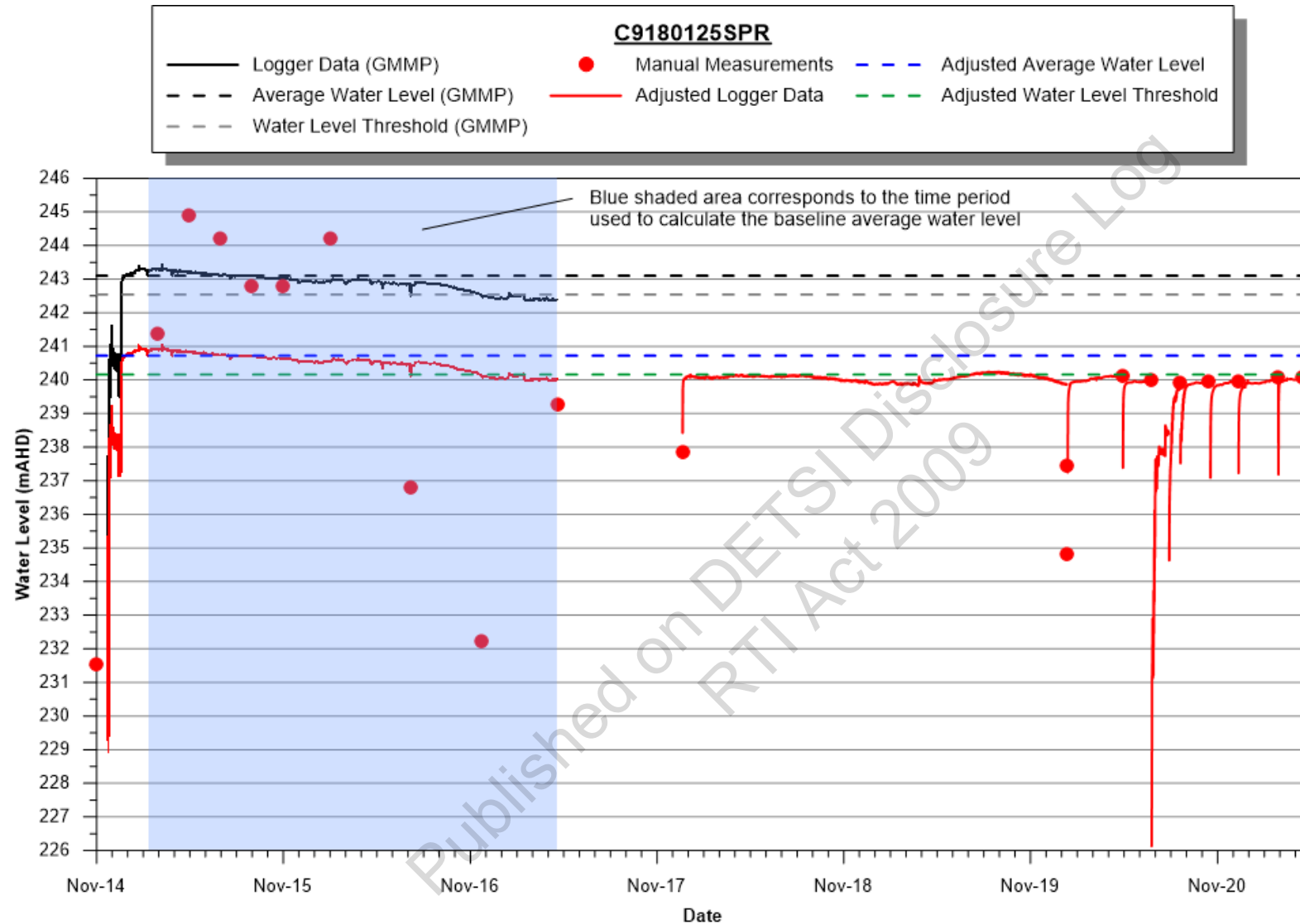


Figure A.12 C9180125SP updated water levels and threshold

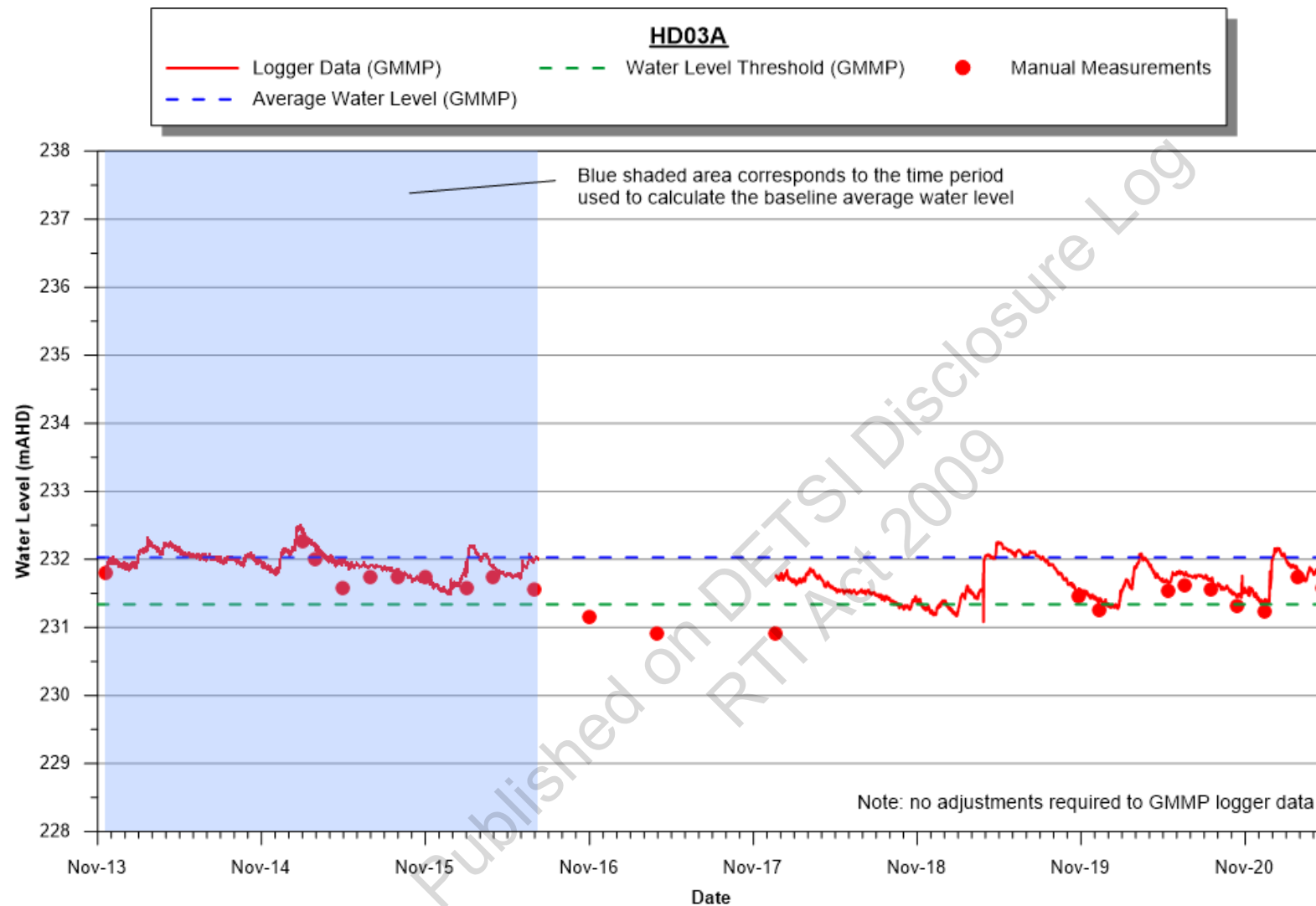


Figure A.13 HD03A updated water levels and threshold

Appendix B

Updated sub-artesian average baseline water level elevation and thresholds for replacement bores

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Table B.1 Updated sub-artesian average baseline water level elevation and thresholds for replacement bores

Original Bore ID	Replacement Bore ID		Geology	Deepest predicted drawdown (m)	Average groundwater level (mAHD)	Natural Fluctuation (NF) (m)	Groundwater level threshold (criteria)	Groundwater level threshold (mAHD)	Figure
C025P1	C19001SP	GMMP	Alluvium	1.87	216.72	0.51 (58 months)	1.19 (1/2 NF + 50% of prediction)	215.53	Figure B.1
		Updated			214.99	0.18 (6 months)	1.03 (1/2 NF + 50% of prediction)	213.97	
C180118SP	C19002SP	GMMP	Clematis Sandstone	2.61	250.17	0.23 (24 months)	2.07 (1/2 NF + 75% of prediction)	248.10	Figure B.2
		Updated			248.92	0.15 (6 months)	2.03 (1/2 NF + 75% of prediction)	246.89	
C180116SP	C19028SP	GMMP	Rewan Formation	16.69	239.12	0.23 (29 months)	15.14 (1/2 NF + 90% of prediction)	223.98	Figure B.3
		Updated			238.97	0.15 (9 months)	15.10 (1/2 NF + 90% of prediction)	223.87	

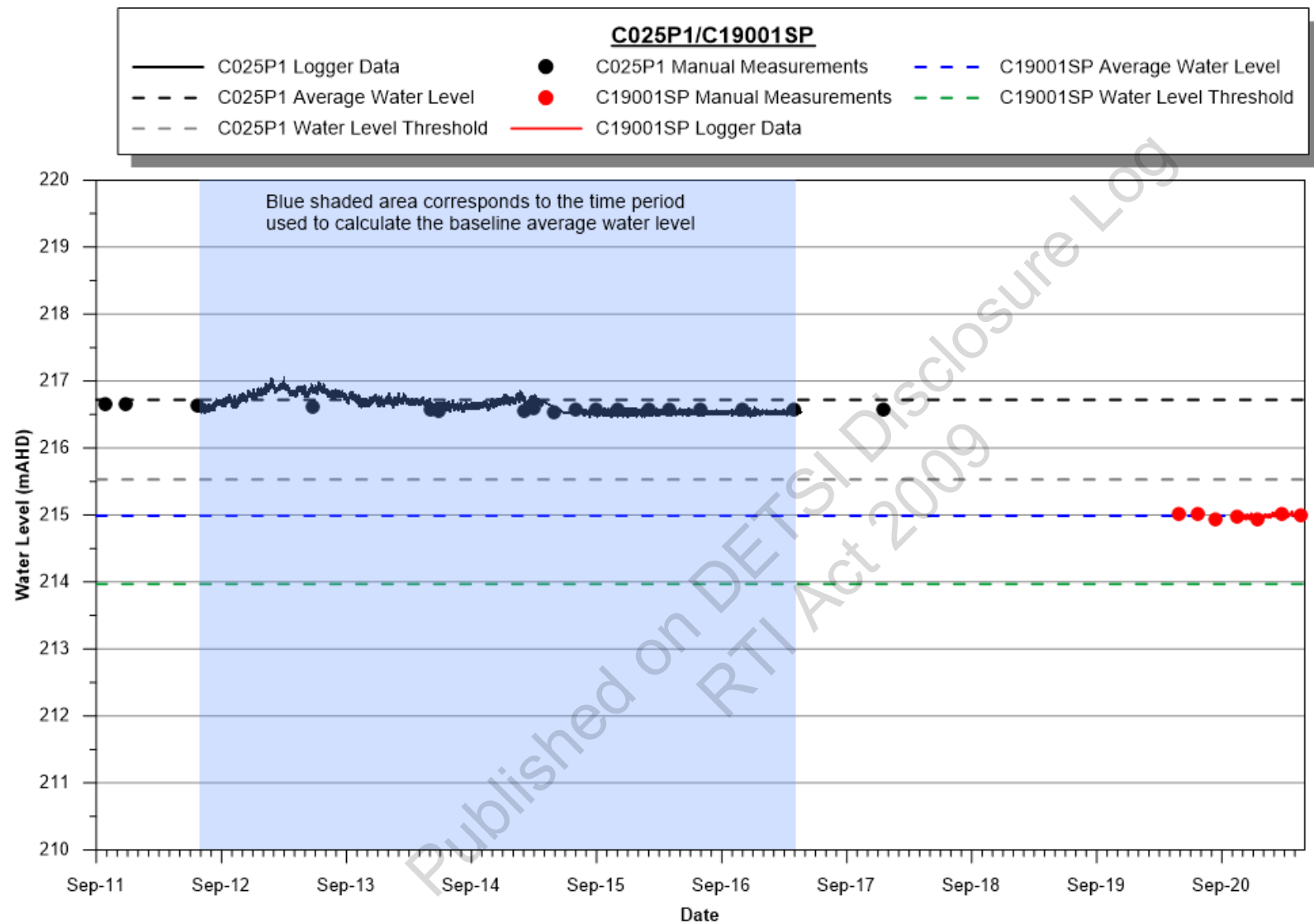


Figure B.1 C025P1/C19001SP water levels and thresholds

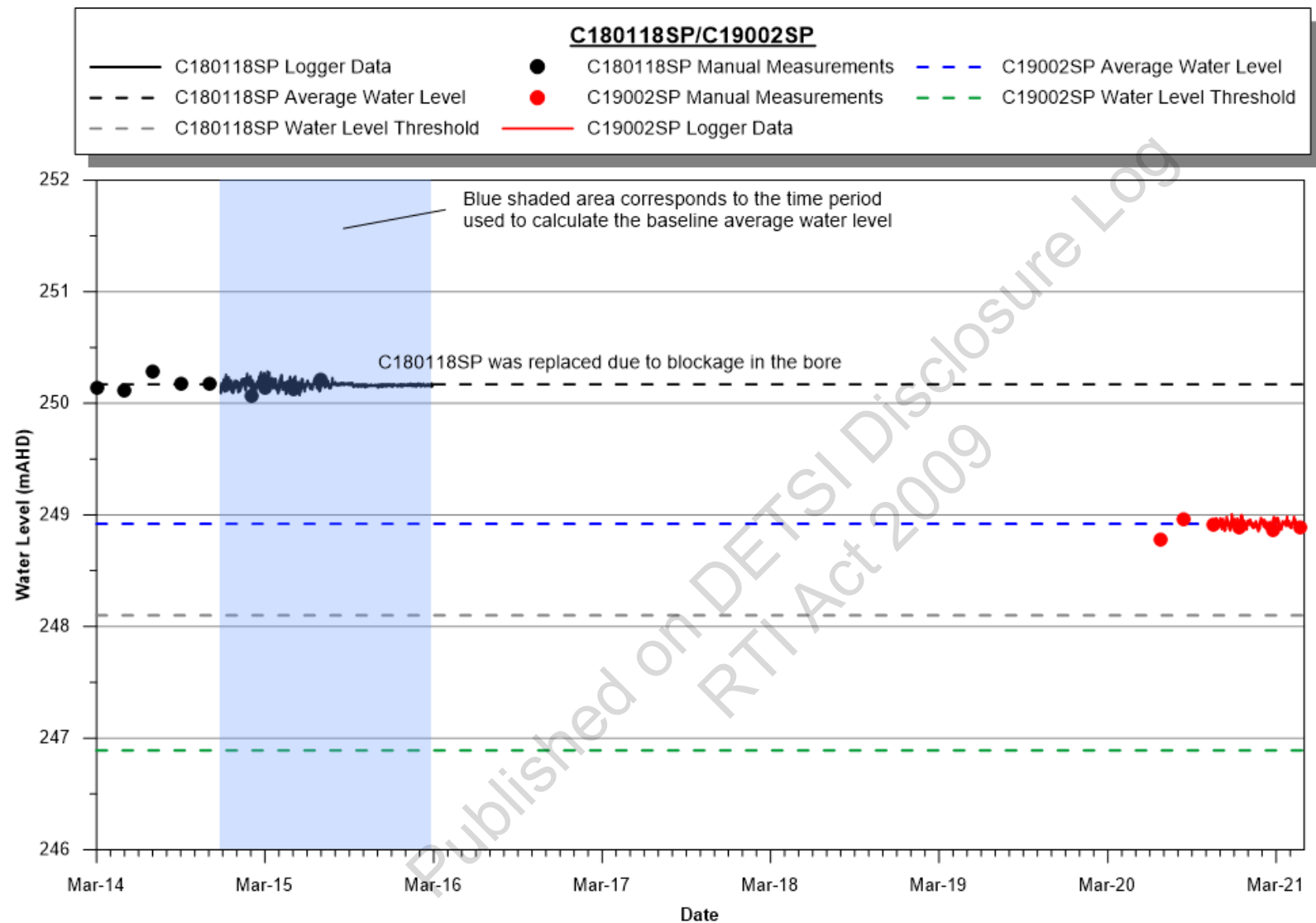


Figure B.2 C180118SP/C19002SP water levels and thresholds

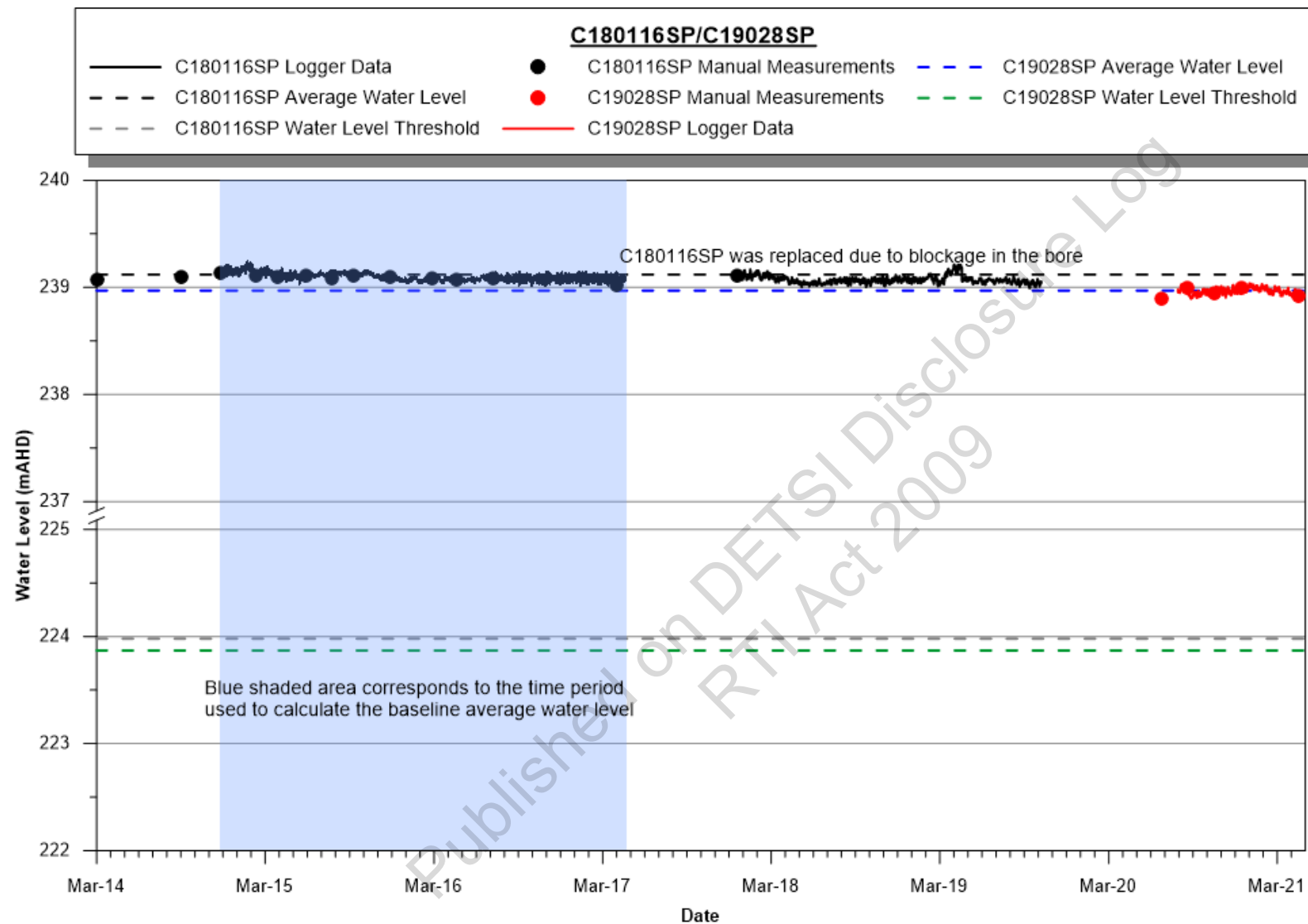


Figure B.3 C180116SP/C19028SP water levels and thresholds

Appendix C

Water quality trigger level exceedances

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Table C.1 Trigger exceedances in the April/May 2020 to April 2021 monitoring rounds

Monitoring Well	Parameter	Units	Trigger Levels (85th Percentiles)	April/May 2020 Sampling	June 2020 Sampling	August 2020 Sampling	October 2020 Sampling	December 2020 Sampling	February 2021 Sampling	April 2021 Sampling
Alluvium Eastern Area										
C14028SP	Calcium	mg/L Ca	800	875	854	928	838	849	906	808
	Chloride	mg/L Cl	16,000	16,400	15,900	16,200	16,000	15,800	16,500	16,100
	Electrical Conductivity	µS/cm	44,000	45,900	41,200	38,200	43,700	44,300	45,000	45,400
	Iron	µg/L Fe	652	1,290	1,140	1,360	1,060	1,000	1,140	970
	Magnesium	mg/L Mg	1000	1,170	1,030	1,260	1,160	1,180	1,120	1,100
	Nickel	µg/L Ni	11	8	8	9	22	14	19	6
	Sodium	mg/L Na	8,305	9,400	8,810	10,100	9,340	8,950	9,230	8,930
	Total Dissolved Solids	mg/L	26,000	32,300	30,100	30,600	32,800	32,800	29,900	30,600
	Zinc	µg/L Zn	26	<LOR	<LOR	<LOR	206	<LOR	<LOR	52
C029P1	Electrical Conductivity	µS/cm	32,000	31,500	26,300	32,900	31,100	34400	28,500	29,100
	Iron	µg/L Fe	954	990	320	<LOR	150	250	1,420	460
	Magnesium	mg/L Mg	360	354	332	391	365	367	287	291
	Sodium	mg/L Na	6,583	7,280	6,980	8,470	7,530	7,370	6,380	6,550
	Total Dissolved Solids	mg/L	20,000	19,700	19,600	21,300	20,400	20,900	18,700	17,500
C027P1	Calcium	mg/L Ca	27	29	28	26	27	25	9	20
	Chromium	µg/L Cr	1	<LOR	<LOR	<LOR	<LOR	<LOR	3	5
	Nickel	µg/L Ni	17	<LOR	<LOR	159	94	58	35	22
	Sodium	mg/L Na	1,209	1,270	1,220	1,220	1,250	1170	408	924
	Sulphate	mg/L SO ₄	450	519	549	490	520	528	139	435
	Total Recoverable Hydrocarbons	ppb (C10 – C40)	Detect above LOR	120	130	<LOR	<LOR	140	<LOR	<LOR
Alluvium Western Area										
HD03B	Copper	µg/L Cu	1.4	<LOR	4	<LOR	<LOR	9	<LOR	<LOR
	Iron	µg/L Fe	530	660	490	490	490	690	1,620	1,260
	T. Phosphorous	mg/L P	0.1	0.14	0.12	0.2	0.13	0.08	0.12	0.38
	Zinc	µg/L Zn	8	<LOR	<LOR	<LOR	23	<LOR	<LOR	11
Tertiary										
C558P1	Calcium	mg/L Ca	80	77	83	81	80	91	87	75
	Chloride	mg/L Cl	2,900	3,050	3,280	2,960	2,960	3,190	3,370	2,890
	Electrical Conductivity	µS/cm	9,360	9,710	9,560	9,630	9,650	9,760	9,650	9,620
	Magnesium	mg/L Mg	215	216	232	230	230	258	230	234
	Nickel	µg/L Ni	34	55	51	43	48	62	69	34
	Sodium	mg/L Na	1,540	1,610	1,630	1,730	1,650	1,740	1,720	1,680
	Sulphate	mg/L SO ₄	240	253	241	259	255	260	257	251
	Total Dissolved Solids	mg/L	5,600	5,630	6,450	6,430	6,210	6,030	6,020	6,760
	Uranium	µg/L U	2	3	2	3	3	2	2	2
	Zinc	µg/L Zn	46	5	18	15	58	13	12	88
C025P2	Boron	µg/L B	1,600	1,270	1,350	1,420	1,630	1,750	1,390	1,300
	Chloride	mg/L Cl	4,500	4,340	4,680	4,270	4,830	4,520	4,710	4,560
	Iron	µg/L Fe	2,750	7,600	6,840	8,340	6,780	6,390	7,190	7,330
	Magnesium	mg/L Mg	120	104	115	125	115	128	112	110
	Nickel	µg/L Ni	11	1	<LOR	<LOR	25	8	20	<LOR

Table C.1 Trigger exceedances in the April/May 2020 to April 2021 monitoring rounds

Monitoring Well	Parameter	Units	Trigger Levels (85th Percentiles)	April/May 2020 Sampling	June 2020 Sampling	August 2020 Sampling	October 2020 Sampling	December 2020 Sampling	February 2021 Sampling	April 2021 Sampling
C029P2 C9180121SPR	Sodium	mg/L Na	2,900	2,620	2,810	2,940	2,940	2,930	2,900	2,720
	Total Recoverable Hydrocarbons	ppb (C10 – C40)	Detect above LOR	<LOR	150	<LOR	140	<LOR	<LOR	120
	Zinc	µg/L Zn	15	12	7	12	121	<LOR	<LOR	30
	Calcium	mg/L Ca	35	36	32	37	33	36	36	31
	Magnesium	mg/L Mg	50	51	49	48	48	52	52	47
	Sodium	mg/L Na	575	660	605	631	632	670	660	608
Clematis Sandstone	Zinc	µg/L Zn	950	411	1,350	998	1,220	1,250	1,170	868
	Chloride	mg/L Cl	150	149	146	158	154	145	149	141
	Iron	µg/L Fe	505	610	640	700	680	610	640	520
	Sodium	mg/L Na	130	136	129	130	128	124	131	121
	Zinc	µg/L Zn	33	43	33	46	70	43	25	20
	Chloride	mg/L Cl	150	159	166	152	174	144	152	146
C14021SP	Sulphate	mg/L SO ₄	19	25	20	18	19	20	21	20
	Zinc	µg/L Zn	33	25	6	8	97	32	27	59
	Copper	µg/L Cu	16	<LOR	2	3	6	18	3	21
C14011SP	pH Low	pH units	6	6.03	5.95	6.15	6.07	6.09	5.6	5.41
	Zinc	µg/L Zn	54	<LOR	16	7	81	94	124	83
	Alkalinity	mg/L CaCO ₃	130	130	133	137	123	124	136	128
C14012SP C14013SP	Chloride	mg/L Cl	110	113	108	112	112	105	108	104
	Cobalt	µg/L Co	4	4	4	5	5	4	4	4
	Magnesium	mg/L Mg	9	8	9	11	9	9	10	9
	pH Low	pH units	6	5.92	5.76	6.09	5.94	6.18	5.56	5.39
	Sulphate	mg/L SO ₄	9	12	10	11	10	10	10	10
	Zinc	µg/L Zn	54	21	38	27	141	126	134	93
C14033SP	Copper	µg/L Cu	16	1	2	3	14	41	13	18
	Lead	µg/L Pb	3.4	a	a	A	7	1	8	2
	Magnesium	mg/L Mg	9	10	10	9	10	10	10	10
	pH Low	pH units	6	6.08	6.13	5.9	6.1	6.15	5.97	5.49
C18001SP	Calcium	mg/L Ca	3	3	3	3	4	4	4	NS
	Chloride	mg/L Cl	110	145	138	152	144	134	143	NS
	Electrical Conductivity	µS/cm	607	647	646	668	640	664	662	NS
	Iron	µg/L Fe	55	1,570	1330	1,740	1,650	1,400	1,640	NS
	Potassium	mg/L K	15	16	16	16	17	18	16	NS
	Sodium	mg/L Na	100	118	121	122	123	117	123	NS
	Zinc	µg/L Zn	54	177	59	57	53	48	61	NS
C18002SP	Alkalinity	mg/L CaCO ₃	130	140	137	137	138	136	132	129
HD02	Aluminium	µg/L Al	55	<LOR	<LOR	<LOR	<LOR	90	70	10
	Chloride	mg/L Cl	110	128	115	126	125	108	9	35
	Electrical Conductivity	µS/cm	607	612	606	628	625	559	99	240
	Iron	µg/L Fe	55	290	290	230	220	220	1,800	1,310
	Sodium	mg/L Na	100	117	122	124	120	116	12	40

Table C.1 Trigger exceedances in the April/May 2020 to April 2021 monitoring rounds

Monitoring Well	Parameter	Units	Trigger Levels (85th Percentiles)	April/May 2020 Sampling	June 2020 Sampling	August 2020 Sampling	October 2020 Sampling	December 2020 Sampling	February 2021 Sampling	April 2021 Sampling
C19002SP	Calcium	mg/L Ca	3	a	49	20	8	6	7	5
Dunda Beds										
C027P2	Calcium	mg/L Ca	1.1	2	1	1	1	1	2	2
	Chloride	mg/L Cl	212	181	195	220	213	205	164	186
	Iron	µg/L Fe	1,325	3,240	2,450	1,200	1,220	710	2,540	2,080
	T. Phosphorous	mg/L P	0.03	0.1	0.08	0.05	0.08	<LOR	0.08	0.07
	Zinc	µg/L Zn	28	<LOR	6	13	110	5	26	39
C022P1	Zinc	µg/L Zn	42	10	11	16	83	49	16	47
C14023SP	Alkalinity	mg/L CaCO ₃	80	136	138	143	135	124	131	131
	Calcium	mg/L Ca	3.5	4	4	4	4	4	4	4
	Chloride	mg/L Cl	69	173	155	179	164	150	158	158
	Electrical Conductivity	µS/cm	350	728	734	710	720	739	740	740
	Potassium	mg/L K	3.8	8	8	8	8	9	8	8
	Sodium	mg/L Na	57	142	153	157	150	138	149	149
	Total Dissolved Solids	mg/L	220	445	401	395	407	352	378	378
C180117SP	Copper	µg/L Cu	100	76	107	121	88	62	3	3
	Iron	µg/L Fe	790	930	1,090	1,630	1,390	1,250	1,460	1,610
	Total Recoverable Hydrocarbons	ppb (C10 – C40)	Detect above LOR	180	210	200	200	120	130	140
	Zinc	µg/L Zn	42	31	10	14	40	93	92	54
Rewan Formation										
C008P1	Ammonia	mg/L N	0.9	0.95	0.37	0.38	0.88	0.39	1.2	0.4
	Boron	µg/L B	370	1,240	1,280	1,290	1,240	1,490	1,450	1,760
	Calcium	mg/L Ca	480	433	480	489	426	503	463	479
	Chloride	mg/L Cl	7,600	8,000	7,600	7,440	7,780	7,870	7,830	7,850
	Cobalt	µg/L Co	1.4	5	9	8	7	7	5	7
	Copper	µg/L Cu	1.4	2	2	<LOR	<LOR	<LOR	<LOR	1
	Electrical Conductivity	µS/cm	21,140	22,700	21,400	21,400	20,300	21,600	21,300	21,000
	Iron	µg/L Fe	800	1,000	1,640	2,010	1,040	2,110	1,530	1,560
	Magnesium	mg/L Mg	410	349	396	390	398	426	380	1,830
	Manganese	µg/L Mn	1,900	2,120	1,860	1,860	1,890	2,050	2,100	6
	Nickel	µg/L Ni	11	13	11	8	10	26	14	1
	Sodium	mg/L Na	3,700	3,570	3,920	3,940	3,770	3,850	3,990	3,640
	T. Phosphorous	mg/L P	0.14	0.18	<LOR	<LOR	0.11	0.08	0.14	0.18
	Total Dissolved Solids	mg/L	14,600	15,700	14,100	12,600	15,500	16,200	14,600	15,500
	Total Recoverable Hydrocarbons	ppb (C10 – C40)	Detect above LOR	210	<LOR	<LOR	200	<LOR	170	<LOR
	Uranium	µg/L U	0.5	11	14	14	14	13	14	13
	Zinc	µg/L Zn	8	<LOR	13	<LOR	52	28	7	47
C035P1	Chloride	mg/L Cl	1,100	1,110	1,060	1,120	1,080	1,040	1,070	1,050
	Sodium	mg/L Na	755	852	743	763	733	670	770	699
C555P1	Calcium	mg/L Ca	6	6	7	7	6	6	7	6
	Chloride	mg/L Cl	170	185	176	190	183	174	179	172

Table C.1 Trigger exceedances in the April/May 2020 to April 2021 monitoring rounds

Monitoring Well	Parameter	Units	Trigger Levels (85th Percentiles)	April/May 2020 Sampling	June 2020 Sampling	August 2020 Sampling	October 2020 Sampling	December 2020 Sampling	February 2021 Sampling	April 2021 Sampling
C556P1	Iron	µg/L Fe	1,635	1,710	1,380	1,830	1,630	820	1,990	1,760
	Sodium	mg/L Na	130	135	143	149	140	132	149	147
	Cobalt	µg/L Co	4	4	4	5	5	4	5	4
C9553P1R	Iron	µg/L Fe	1,635	1,720	1,740	1,800	1,740	1,920	1,580	1,460
	Total Recoverable Hydrocarbons	ppb (C10 – C40)	Detect above LOR	180	190	130	160	140	130	<LOR
	Zinc	µg/L Zn	38	<LOR	<LOR	<LOR	40	79	17	29
C9838SPR	Zinc	µg/L Zn	38	<LOR	30	11	22	52	51	50
C19028SP	Alkalinity	mg/L CaCO ₃	140	a	a	277	273	282	298	284
	Boron	µg/L B	370	a	a	870	830	840	1,030	900
	Calcium	mg/L Ca	6	a	a	23	20	21	24	20
	Chloride	mg/L Cl	170	a	a	1,270	1,320	1,330	1,420	1,430
	Electrical Conductivity	µS/cm	800	a	a	4,620	4,730	4,980	5,290	5,320
	Fluoride	mg/L F	0.7	a	a	1.1	1	1	1	1
	Magnesium	mg/L Mg	8	a	a	38	38	41	45	42
	Potassium	mg/L K	8	a	a	11	11	14	11	12
	Sodium	mg/L Na	130	a	a	946	984	946	1,100	996
	Sulphate	mg/L SO ₄	50	a	a	147	163	191	185	190
	Total Dissolved Solids	mg/L	490	a	a	2,660	2,730	3,010	3,260	2,940
Bandanna Formation										
C007P2	Boron	µg/L B	370	600	570	580	650	630	690	710
	Calcium	mg/L Ca	32	277	312	306	253	294	294	286
	Chloride	mg/L Cl	723	4,540	4,860	4,440	4,870	4,830	5,020	4,760
	Copper	µg/L Cu	1.4	<LOR	1	<LOR	2	<LOR	6	6
	Iron	µg/L Fe	138	860	1,180	1,180	1,300	1,230	1,620	1,240
	Magnesium	mg/L Mg	16	236	265	266	261	276	272	265
	Silver	µg/L Ag	0.05	<LOR	<LOR	2	<LOR	<LOR	<LOR	2
	Sodium	mg/L Na	570	2,220	2,410	2,490	2,320	2,340	2,450	2,200
	Sulphate	mg/L SO ₄	74	330	344	327	356	346	335	339
	Zinc	µg/L Zn	8	<LOR	<LOR	<LOR	24	8	22	36
C008P2	Calcium	mg/L Ca	32	29	40	39	28	28	29	31
	Magnesium	mg/L Mg	16	16	17	17	17	14	16	15
	Sodium	mg/L Na	570	564	558	564	575	488	572	492
	Sulphate	mg/L SO ₄	74	82	96	92	90	88	89	88
	Zinc	µg/L Zn	15	<LOR	<LOR	26	22	<LOR	<LOR	<LOR
C014P2	Boron	µg/L B	370	240	360	320	310	340	390	410
	Fluoride	mg/L F	1	1	1	1.1	1.3	1.1	1.2	1.1
C016P2	Boron	µg/L B	370	330	320	370	400	300	420	420
	Calcium	mg/L Ca	32	84	99	97	99	96	83	88
	Chloride	mg/L Cl	723	840	816	878	824	811	827	814
	Iron	µg/L Fe	138	70	80	100	120	140	60	200
	Magnesium	mg/L Mg	16	17	19	18	19	19	18	19

Table C.1 Trigger exceedances in the April/May 2020 to April 2021 monitoring rounds

Monitoring Well	Parameter	Units	Trigger Levels (85th Percentiles)	April/May 2020 Sampling	June 2020 Sampling	August 2020 Sampling	October 2020 Sampling	December 2020 Sampling	February 2021 Sampling	April 2021 Sampling
C018P2	T. Phosphorous	mg/L P	0.13	0.64	0.21	0.46	0.06	<LOR	0.02	0.06
	Boron	µg/L B	370	460	480	540	580	510	590	580
	Calcium	mg/L Ca	32	43	50	50	50	41	55	44
	Iron	µg/L Fe	138	500	520	560	510	470	460	490
C032P2	Magnesium	mg/L Mg	16	23	26	26	26	25	26	26
	Fluoride	mg/L F	1	0.1	1	1.1	1	1	0.9	1.1
C035P2	Iron	µg/L Fe	138	260	210	210	170	210	180	130
C847SP	Iron	µg/L Fe	138	460	380	430	380	440	430	390
C847SP	Copper	µg/L Cu	2	<LOR	<LOR	2	13	7	6	10
	Zinc	µg/L Zn	15	<LOR	9	10	72	79	53	56
C823SP	Boron	µg/L B	370	a	a	460	480	500	530	540
	Calcium	mg/L Ca	32	a	a	119	120	129	125	133
	Chloride	mg/L Cl	723	a	a	1,250	1,210	1,190	1,220	1,200
	Electrical Conductivity	µS/cm	3,000	a	a	4,360	4,180	4,450	4,380	4,260
	Iron	µg/L Fe	138	a	a	940	800	820	1,100	960
	Magnesium	mg/L Mg	16	a	a	57	53	59	57	63
	Sodium	mg/L Na	570	a	a	720	770	781	740	765
	Total Dissolved Solids	mg/L	1,800	a	a	2,410	3,240	2,460	2,450	2,350
	Total Recoverable Hydrocarbons	ppb (C10 – C40)	Detect above LOR	a	a	210	220	160	<LOR	140
	Zinc	µg/L Zn	15	a	a	<LOR	20	<LOR	<LOR	40
C19027SP	Boron	µg/L B	370	a	a	450	480	460	540	540
Colinlea Sandstone										
C833SP	Mercury	µg/L Hg	0.06	a	a	<LOR	0.5	0.2	<LOR	<LOR
	pH High	pH units	9	a	a	9.59	10.1	10	9.66	10.3
C848SP	Calcium	mg/L Ca	28	29	27	26	28	25	29	28
	Chloride	mg/L Cl	790	848	836	874	823	807	828	814
	Iron	µg/L Fe	1,345	1,980	1,670	1,870	1,510	950	1,230	1,500
	Magnesium	mg/L Mg	23	28	23	26	23	23	24	24
	Sodium	mg/L Na	540	626	529	556	542	491	554	535
C024P3	Chloride	mg/L Cl	200	402	377	403	407	385	391	381
	Cobalt	µg/L Co	1.4	<LOR	<LOR	1	2	5	5	4
	Electrical Conductivity	µS/cm	1,030	1,360	1,410	1,400	1,420	1,420	1,420	1,390
	Iron	µg/L Fe	410	14,900	18,600	18,200	14,700	12,600	13,800	13,700
	Magnesium	mg/L Mg	6	24	25	24	26	28	25	26
	Nickel	µg/L Ni	11	8	7	20	30	51	78	35
	Sodium	mg/L Na	220	216	220	226	229	248	240	230
	Sulphate	mg/L SO ₄	15	21	19	21	19	20	23	21
	T. Phosphorous	mg/L P	0.08	0.21	0.14	0.11	0.11	<LOR	0.16	0.14
	Total Dissolved Solids	mg/L	639	834	874	774	790	786	820	792
	Total Recoverable Hydrocarbons	ppb (C10 – C40)	Detect above LOR	<LOR	<LOR	<LOR	120	<LOR	120	<LOR
	Zinc	µg/L Zn	8	<LOR	16	29	54	23	10	124
C006P3R	Electrical Conductivity	µS/cm	1,030	1,010	938	1,010	1,130	1,330	1,140	1,030

Table C.1 Trigger exceedances in the April/May 2020 to April 2021 monitoring rounds

Monitoring Well	Parameter	Units	Trigger Levels (85th Percentiles)	April/May 2020 Sampling	June 2020 Sampling	August 2020 Sampling	October 2020 Sampling	December 2020 Sampling	February 2021 Sampling	April 2021 Sampling
C011P3	Sodium	mg/L Na	220	250	215	232	247	258	264	230
	Total Dissolved Solids	mg/L	639	582	520	572	720	780	630	680
	Boron	µg/L B	410	410	390	400	450	350	510	510
	Calcium	mg/L Ca	25	21	23	22	23	26	26	22
C018P3	Iron	µg/L Fe	410	410	490	520	460	460	450	480
	Chloride	mg/L Cl	200	160	204	215	214	204	205	202
C034P3	Iron	µg/L Fe	410	800	780	860	820	820	680	800
	Chloride	mg/L Cl	200	486	447	497	489	476	525	510
	Electrical Conductivity	µS/cm	1,030	1,510	1,620	1,710	1,610	1,660	1,800	1,780
	Iron	µg/L Fe	410	3,410	3,060	3,170	2,780	2,800	2,700	2,620
	Magnesium	mg/L Mg	6	11	10	11	10	10	11	10
	Potassium	mg/L K	11	13	11	12	12	13	11	12
	Sodium	mg/L Na	220	327	275	316	306	270	332	301
	Sulphate	mg/L SO ₄	15	18	18	23	21	21	24	24
	Total Dissolved Solids	mg/L	639	910	864	954	918	918	990	1,010
	Zinc	µg/L Zn	25	128	185	196	253	175	165	337
	Copper	µg/L Cu	1.4	<LOR	<LOR	<LOR	5	9	14	6
	Magnesium	mg/L Mg	6	6	5	7	6	7	6	6
	Sulphate	mg/L SO ₄	15	28	22	25	22	23	28	22
	Zinc	µg/L Zn	25	5	16	40	134	22	44	246
C975SP	Calcium	mg/L Ca	25	39	35	33	36	38	39	41
	Chloride	mg/L Cl	200	798	813	852	809	795	835	829
	Copper	µg/L Cu	1.4	2	4	<LOR	<LOR	<LOR	<LOR	<LOR
	Electrical Conductivity	µS/cm	1,030	2,760	3,020	2,960	2,810	2,930	3,030	3,100
	Iron	µg/L Fe	410	1,350	5,810	6,240	5,240	1,460	3,400	5,080
	Magnesium	mg/L Mg	6	22	20	20	19	18	19	19
	Potassium	mg/L K	11	23	20	20	20	23	20	20
	Sodium	mg/L Na	220	659	563	566	558	508	574	564
	Total Dissolved Solids	mg/L	639	1,550	1,740	1,630	1,830	1,630	1,670	1,740
C9849SPR	Calcium	mg/L Ca	25	39	35	33	36	38	39	41
	Chloride	mg/L Cl	200	798	813	852	809	795	835	829
	Copper	µg/L Cu	1.4	2	4	<LOR	<LOR	<LOR	<LOR	<LOR
C19026SP	Electrical Conductivity	µS/cm	1,030	1,760	1,320	958	835	862	921	855
	Sodium	mg/L Na	220	390	282	231	205	188	217	182
	Total Dissolved Solids	mg/L	639	992	730	532	588	638	546	484
Joe Joe Formation										
C14003SP	Alkalinity	mg/L CaCO ₃	48	a	a	57	44	67	72	64
	Cobalt	µg/L Co	29	a	a	35	39	34	36	34
	Electrical Conductivity	µS/cm	53,000	a	a	52,900	50,200	53,200	51,700	53,400
	Iron	µg/L Fe	1,300	a	a	8,810	1,4400	14,200	18,600	17,500
	Magnesium	mg/L Mg	1,600	a	a	1,690	1,530	1,610	1,490	1480
	Sodium	mg/L Na	8,000	a	a	9,950	9,260	8,840	8,800	8,650
	T. Phosphorous	mg/L P	0.05	a	a	0.38	<LOR	0.22	<LOR	<LOR
	Total Dissolved Solids	mg/L	32,000	a	a	42,900	42,000	46,200	50,600	45,200
	Zinc	µg/L Zn	69	a	a	<LOR	220	22	45	156

Table C.1 Trigger exceedances in the April/May 2020 to April 2021 monitoring rounds

Monitoring Well	Parameter	Units	Trigger Levels (85th Percentiles)	April/May 2020 Sampling	June 2020 Sampling	August 2020 Sampling	October 2020 Sampling	December 2020 Sampling	February 2021 Sampling	April 2021 Sampling
C914001SPR	Calcium	mg/L Ca	880	827	889	826	862	897	1,010	790
	Chloride	mg/L Cl	7,070	7,410	7,220	6,930	6,670	7,080	7,240	7,150
	Copper	µg/L Cu	1.4	<LOR	<LOR	4	178	<LOR	<LOR	149
	Electrical Conductivity	µS/cm	21,000	21,300	20,800	20,500	19,600	20,500	20,400	20,200
	Lead	µg/L Pb	3.4	<LOR	<LOR	<LOR	9	<LOR	<LOR	9
	Magnesium	mg/L Mg	435	401	417	440	432	474	474	411
	T. Phosphorous	mg/L P	0.05	<LOR	<LOR	<LOR	0.06	0.08	<LOR	<LOR
	Total Dissolved Solids	mg/L	13,000	14,900	15,000	13,800	15,300	13,600	14,100	14,000
	Zinc	µg/L Zn	60	<LOR	6	19	314	6	<LOR	166
C14017SP	Alkalinity	mg/L CaCO ₃	240	250	257	269	258	253	262	249
	Boron	µg/L B	720	720	720	740	620	740	840	700
	Fluoride	mg/L F	1	1	1	1.1	1.1	1	1.1	1.1
C14006SP	Calcium	mg/L Ca	180	194	172	193	183	190	186	174
	Chloride	mg/L Cl	2,545	2,660	2,760	2,550	2,370	2,540	2,840	2,660
	Iron	µg/L Fe	1,870	8,200	8,200	7,390	7,520	7,310	7,270	7,630
	Magnesium	mg/L Mg	84	87	85	85	83	90	84	82
	Sodium	mg/L Na	1,500	1,520	1,450	1,490	1,520	1,440	1,520	1,430
	Total Dissolved Solids	mg/L	5,100	5,210	4,840	4,990	5,280	5,160	5,230	5,090
C012P1	Boron	µg/L B	425	320	360	380	460	340	480	410
	Magnesium	mg/L Mg	28	30	32	34	34	35	33	32
	Nickel	µg/L Ni	11	2	3	1	2	12	30	<LOR
	Sulphate	mg/L SO ₄	54	56	55	58	49	54	53	50
C012P2	Boron	µg/L B	425	360	420	430	500	400	540	540
	Calcium	mg/L Ca	76	76	82	83	82	89	86	80
	Chloride	mg/L Cl	630	703	675	699	689	667	685	669
	Magnesium	mg/L Mg	28	27	30	30	30	32	30	30
	Sodium	mg/L Na	426	398	409	412	416	454	436	424
	Sulphide	mg/L S ₂	1.4	<LOR	0.3	2	0.3	1.2	0.8	2.5
	Total Recoverable Hydrocarbons	ppb (C10 – C40)	Detect above LOR	<LOR	210	140	<LOR	280	180	240
C14002SP	Boron	µg/L B	425	730	820	860	890	980	930	860
	Calcium	mg/L Ca	76	267	277	285	289	299	292	264
	Chloride	mg/L Cl	630	3,600	3,940	3,410	3,440	3,660	3,900	3,770
	Electrical Conductivity	µS/cm	2,600	11,400	11,300	11,200	10,900	11,200	11,200	11,000
	Iron	µg/L Fe	765	2,710	2,910	3,260	2,920	2,660	2,840	2,850
	Magnesium	mg/L Mg	28	100	102	120	112	120	110	106
	Potassium	mg/L K	15	28	29	30	30	37	30	29
	Sodium	mg/L Na	426	1,890	1,880	2,100	2,160	2,050	2,140	1,930
	Sulphate	mg/L SO ₄	54	371	379	387	375	370	374	363
	T. Phosphorous	mg/L P	0.05	0.06	<LOR	0.01	0.01	0.05	<LOR	0.1
	Total Dissolved Solids	mg/L	1,600	7,320	6,820	6,550	6,980	6,780	6,220	7,300
C14008SP	Cobalt	µg/L Co	6	5	10	11	11	9	10	10
	Iron	µg/L Fe	765	4,870	1,730	2,170	1,900	1,940	1,920	1,920

Table C.1 Trigger exceedances in the April/May 2020 to April 2021 monitoring rounds

Monitoring Well	Parameter	Units	Trigger Levels (85th Percentiles)	April/May 2020 Sampling	June 2020 Sampling	August 2020 Sampling	October 2020 Sampling	December 2020 Sampling	February 2021 Sampling	April 2021 Sampling
C14015SP	Nickel	µg/L Ni	11	5	13	14	13	12	14	13
	Chloride	mg/L Cl	630	647	646	696	686	683	693	684
	Sodium	mg/L Na	426	464	426	445	453	509	488	441
C14016SP	Sulphate	mg/L SO4	54	60	55	63	52	60	58	63
	Chloride	mg/L Cl	630	686	710	766	700	729	732	731
	Electrical Conductivity	µS/cm	2,600	2,390	2,540	2,620	2,570	2,650	2,610	2,670
	Sodium	mg/L Na	426	490	478	489	512	455	528	487
C14032SP	Sulphate	mg/L SO4	54	65	61	65	58	59	56	58
	T. Phosphorous	mg/L P	0.05	0.03	0.04	0.25	0.05	0.11	0.05	0.05
	Chloride	mg/L Cl	630	671	633	700	669	646	661	649
	Iron	µg/L Fe	765	2,230	1,970	1,810	1,880	1,630	1,800	1,750
C180119SP	Magnesium	mg/L Mg	28	37	32	31	30	32	32	30
	Zinc	µg/L Zn	260	69	108	136	1,880	223	272	216
	Iron	µg/L Fe	765	1,450	1,070	1,350	810	770	2,070	780
	T. Phosphorous	mg/L P	0.05	<LOR	<LOR	0.08	0.01	0.02	<LOR	0.18
C914030SPR	Zinc	µg/L Zn	260	2260	1970	2570	769	578	13,000	787
	Cobalt	µg/L Co	6	a	a	9	9	8	8	8
C9180124SPR	Nickel	µg/L Ni	11	a	a	14	11	11	12	12
	Zinc	µg/L Zn	260	432	410	586	648	709	807	526
C9180125SPR	Alkalinity	mg/L CaCO3	290	289	283	314	293	263	280	272
C14004SP	Ammonia	mg/L N	0.9	a	a	1.88	1	1.81	0.91	1.87
	Boron	µg/L B	425	a	a	590	320	450	600	430
	Calcium	mg/L Ca	76	a	a	3,200	3,000	3,020	2,900	3,010
	Chloride	mg/L Cl	630	a	a	21,000	20,100	19,300	20,100	20,200
	Copper	µg/L Cu	19	a	a	10	122	<LOR	<LOR	80
	Electrical Conductivity	µS/cm	2600	a	a	52,600	49,500	52,700	53,800	53,600
	Iron	µg/L Fe	765	a	a	<LOR	290	630	1,730	1,680
	Magnesium	mg/L Mg	28	a	a	1,460	1,310	1,390	1,270	1,240
	Manganese	µg/L Mn	1900	a	a	8,240	6,790	7,080	7,910	7,210
	Potassium	mg/L K	15	a	a	46	44	55	44	45
	Sodium	mg/L Na	426	a	a	10,200	9,180	8,930	8,760	8,460
	Sulphate	mg/L SO4	54	a	a	2,170	2,070	2,080	2,100	1,790
	T. Phosphorous	mg/L P	0.05	a	a	0.2	<LOR	0.12	0.33	<LOR
	Total Dissolved Solids	mg/L	1600	a	a	41,600	48,800	53,200	40,300	47,200
Bores awaiting baseline and trigger value assessment										
Tertiary										
C19022SP*	Alkalinity	mg/L CaCO ₃	60	a	241	a	244	234	a	258
	Ammonia	mg/L N	0.09	a	0.16	a	0.11	0.14	a	0.29
	Boron	µg/L B	307	a	2,950	a	2,870	3,730	a	3,370
	Calcium	mg/L Ca	35	a	2,120	a	2,280	2,190	a	2,370
	Chloride	mg/L Cl	1,100	a	16,300	a	16,100	16,100	a	17,100
	Cobalt	µg/L Co	1.4	a	13	a	11	6	a	<LOR

Table C.1 Trigger exceedances in the April/May 2020 to April 2021 monitoring rounds

Monitoring Well	Parameter	Units	Trigger Levels (85th Percentiles)	April/May 2020 Sampling	June 2020 Sampling	August 2020 Sampling	October 2020 Sampling	December 2020 Sampling	February 2021 Sampling	April 2021 Sampling
	Electrical Conductivity	µS/cm	3,700	a	34,700	a	41,800	43,600	a	46,800
	Iron	µg/L Fe	350	a	5,070	a	7,870	7,160	a	17,900
	Magnesium	mg/L Mg	50	a	1,090	a	1,220	1,210	a	1,180
	Manganese	µg/L Mn	1,900	a	2,340	a	2,360	2,340	a	2,580
	Nickel	µg/L Ni	11	a	50	a	12	36	a	<LOR
	Potassium	mg/L K	15	a	24	a	27	34	a	27
	Sodium	mg/L Na	575	a	7,270	a	7,920	7,630	a	7,910
	Sulphate	mg/L SO ₄	98	a	2,380	a	2,330	2,320	a	1,960
	T. Phosphorous	mg/L P	0.09	a	<LOR	a	<LOR	0.1	a	0.26
	Total Dissolved Solids	mg/L	2,300	a	33,900	a	34,800	38,000	a	35,700
	Uranium	µg/L U	0.5	a	14	a	12	12	a	10
Clematis Sandstone										
C19010SP*	Alkalinity	mg/L CaCO ₃	130	a	a	a	164	159	161	154
	Electrical Conductivity	µS/cm	607	a	a	a	594	618	608	615
	Sodium	mg/L Na	100	a	a	a	131	124	136	120
	T. Phosphorous	mg/L P	0.18	a	a	a	0.21	0.07	0.19	0.16
C19014SP*	Alkalinity	mg/L CaCO ₃	130	a	a	a	140	132	144	144
	Chloride	mg/L Cl	110	a	a	a	119	121	116	110
	Electrical Conductivity	µS/cm	607	a	a	a	653	623	654	644
	Sodium	mg/L Na	100	a	a	a	129	127	135	122
	T. Phosphorous	mg/L P	0.18	a	a	a	0.21	0.15	0.2	0.18
Dunda Beds										
C19007SP*	Alkalinity	mg/L CaCO ₃	130	a	a	a	158	156	142	139
	Calcium	mg/L Ca	3	a	a	a	12	13	10	9
	Chloride	mg/L Cl	110	a	a	a	343	327	363	282
	Electrical Conductivity	µS/cm	607	a	a	a	1,280	1,250	1,380	1,160
	Molybdenum	µg/L Mo	34	a	a	a	40	45	41	23
	Potassium	mg/L K	3.8	a	a	a	7	10	8	7
	Sodium	mg/L Na	100	a	a	a	253	248	284	209
	Sulphate	mg/L SO ₄	16	a	a	a	18	21	24	20
	Total Dissolved Solids	mg/L	16	a	a	a	750	758	824	666
C19015SP*	Alkalinity	mg/L CaCO ₃	130	a	a	a	144	146	147	139
	Calcium	mg/L Ca	3	a	a	a	4	4	4	3
	Chloride	mg/L Cl	110	a	a	a	142	134	141	133
	Electrical Conductivity	µS/cm	607	a	a	a	706	659	711	701
	Potassium	mg/L K	3.8	a	a	a	5	6	5	6
	Sodium	mg/L Na	100	a	a	a	140	139	147	132
	Total Dissolved Solids	mg/L	16	a	a	a	389	383	351	387
C19011SP*	Alkalinity	mg/L CaCO ₃	130	a	a	a	145	144	144	145
	Calcium	mg/L Ca	3	a	a	a	4	4	3	3
	Chloride	mg/L Cl	110	a	a	a	167	161	165	158
	Electrical Conductivity	µS/cm	607	a	a	a	755	774	762	772

Table C.1 Trigger exceedances in the April/May 2020 to April 2021 monitoring rounds

Monitoring Well	Parameter	Units	Trigger Levels (85th Percentiles)	April/May 2020 Sampling	June 2020 Sampling	August 2020 Sampling	October 2020 Sampling	December 2020 Sampling	February 2021 Sampling	April 2021 Sampling
	Potassium	mg/L K	3.8	a	a	a	4	5	4	5
	Sodium	mg/L Na	100	a	a	a	161	148	165	142
	Total Dissolved Solids	mg/L	16	a	a	a	436	425	394	425
Rewan Formation										
C19012SP*	Alkalinity	mg/L CaCO ₃	140	a	a	a	4,640	1,890	1,400	2,950
	Aluminium	µg/L Al	54	a	a	a	1.74	1,940	400	13,900
	Ammonia	mg/L N	0.9	a	a	a	1.01	1.35	4.67	2.83
	Calcium	mg/L Ca	6	a	a	a	69	32	118	62
	Chloride	mg/L Cl	170	a	a	a	869	891	606	802
	Chromium	µg/L Cr	1	a	a	a	0.594	244	7	176
	Copper	µg/L Cu	23	a	a	a	0.217	144	2	93
	Electrical Conductivity	µS/cm	800	a	a	a	20,900	18,400	7,960	15,000
	Fluoride	mg/L F	0.7	a	a	a	2.1	1.5	1.2	1.5
	Molybdenum	µg/L Mo	34	a	a	a	0.758	397	121	251
	pH High	pH units	9	a	a	a	12.4	12.3	12	12.4
	Potassium	mg/L K	8	a	a	a	836	592	133	427
	Sodium	mg/L Na	130	a	a	a	2,240	1,850	985	1,500
	Sulphate	mg/L SO ₄	50	a	a	a	98	198	223	236
	Total Dissolved Solids	mg/L	490	a	a	a	9,540	6,990	2,740	5,370
	Vanadium	µg/L V	6	a	a	a	0.02	30	<LOR	20
C919016SPR*	Alkalinity	mg/L CaCO ₃	140	a	a	a	204	205	194	199
	Aluminium	µg/L Al	54	a	a	a	0.05	170	60	30
	Sodium	mg/L Na	130	a	a	a	177	165	168	145
C19008SP*	Alkalinity	mg/L CaCO ₃	140	a	a	a	a	a	376	293
	Aluminium	µg/L Al	54	a	a	a	a	a	470	280
	Chloride	mg/L Cl	170	a	a	a	a	a	280	258
	Electrical Conductivity	µS/cm	800	a	a	a	a	a	1,620	1,440
	pH High	pH units	9	a	a	a	a	a	10.9	10.4
	Potassium	mg/L K	8	a	a	a	a	a	45	40
	Sodium	mg/L Na	130	a	a	a	a	a	280	235
	Total Dissolved Solids	mg/L	490	a	a	a	a	a	932	802
C19017SP*	Alkalinity	mg/L CaCO ₃	140	a	a	a	a	a	1,470	1,310
	Aluminium	µg/L Al	54	a	a	a	a	a	5,040	3,140
	Ammonia	mg/L N	0.9	a	a	a	a	a	6.93	7.46
	Calcium	mg/L Ca	6	a	a	a	a	a	43	85
	Chloride	mg/L Cl	170	a	a	a	a	a	291	207
	Electrical Conductivity	µS/cm	800	a	a	a	a	a	6,660	6,330
	Fluoride	mg/L F	0.7	a	a	a	a	a	1.2	1.2
	Molybdenum	µg/L Mo	34	a	a	a	a	a	153	80
	pH High	pH units	9	a	a	a	a	a	12.2	12.1
	Potassium	mg/L K	8	a	a	a	a	a	79	51
	Sodium	mg/L Na	130	a	a	a	a	a	805	554

Table C.1 Trigger exceedances in the April/May 2020 to April 2021 monitoring rounds

Monitoring Well	Parameter	Units	Trigger Levels (85th Percentiles)	April/May 2020 Sampling	June 2020 Sampling	August 2020 Sampling	October 2020 Sampling	December 2020 Sampling	February 2021 Sampling	April 2021 Sampling
C919013SPR*	Total Dissolved Solids	mg/L	490	a	a	a	a	a	2,600	1,790
	Alkalinity	mg/L CaCO ₃	140	a	a	a	a	a	946	900
	Aluminium	µg/L Al	54	a	a	a	a	a	700	5,120
	Ammonia	mg/L N	0.9	a	a	a	a	a	2.31	3.76
	Chloride	mg/L Cl	170	a	a	a	a	a	797	459
	Electrical Conductivity	µS/cm	800	a	a	a	a	a	5,390	5,250
	Fluoride	mg/L F	0.7	a	a	a	a	a	2.2	1.3
	Molybdenum	µg/L Mo	34	a	a	a	a	a	235	148
	pH High	pH units	9	a	a	a	a	a	11.7	12
	Potassium	mg/L K	8	a	a	a	a	a	107	80
	Sodium	mg/L Na	130	a	a	a	a	a	976	679
	Sulphate	mg/L SO ₄	50	a	a	a	a	a	104	60
Bandanna Formation										
C19018SP*	Alkalinity	mg/L CaCO ₃	480	a	a	a	1,940	1,480	1,460	1,730
	Calcium	mg/L Ca	32	a	a	a	360	313	198	242
	Chromium	µg/L Cr	1	a	a	a	0.191	8	2	<LOR
	Copper	µg/L Cu	2	a	a	a	0.014	11	6	4
	Electrical Conductivity	µS/cm	3,000	a	a	a	9,500	9,310	7,600	8,530
	Fluoride	mg/L F	1	a	a	a	1.5	1.5	1.5	1.6
	Molybdenum	µg/L Mo	38	a	a	a	0.4	378	369	293
	pH High	pH units	9	a	a	a	12.2	12.2	12.2	12.3
	Potassium	mg/L K	49	a	a	a	421	374	322	342
	Sulphate	mg/L SO ₄	74	a	a	a	140	134	106	112
	Total Dissolved Solids	mg/L	1,800	a	a	a	3,380	3,170	2,160	2,520
	Total Recoverable Hydrocarbons	ppb (C10 – C40)	Detect above LOR	a	a	a	250	320	1190	490
	Zinc	µg/L Zn	15	a	a	a	6	3,030	1,760	760
Colinlea Sandstone										
C19029SP*	Fluoride	mg/L F	6.2	a	a	a	a	a	7.1	6.4
	Sodium	mg/L Na	220	a	a	a	a	a	237	229

- Notes:
- Values highlighted in red are in exceedance of the trigger values.
 - <LOR = value reported at less than the laboratory limit of reporting (LOR).
 - a = not sampled due to bore renovation.
 - NS = not sampled due to wet weather restricting access to the bore.
 - *Bores awaiting baseline and trigger value assessment and exceedances have been compared to trigger values of the overall hydrostratigraphic units. These bores are included in the table for completeness but are not included in the exceedances assessment.

Appendix D

Water quality trigger exceedances compared to contaminant limits and historical variations in baseline water quality

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Table D.1 February 2021 samples with two trigger exceedances compared to GMMP triggers, contaminant limits, historical maxima and minima

Bore	Parameter	Units	Contaminant Trigger Levels (85th Percentiles)	Reported Value	Trigger Exceedance Level (%)	Contaminant Limit		Historical Maximum		Historical Minimum
Alluvium Eastern Area										
C14028SP	Calcium	mg/L Ca	800	906	113	889	EXCEED	900	EXCEED	720
	Chloride	mg/L Cl	16,000	16,500	103	16,890		17,000		8,700
	Electrical Conductivity	µS/cm	44,000	45,000	102	44,890	EXCEED	45,000		390
	Iron	µg/L Fe	652	1,140	175	728	EXCEED	730	EXCEED	20
	Magnesium	mg/L Mg	1,000	1,120	112	1,089	EXCEED	1,100	EXCEED	800
	Nickel	µg/L Ni	11	19	173	11	EXCEED	7	EXCEED	2
	Sodium	mg/L Na	8,305	9,230	111	9,746		9,900		6,200
	Total Dissolved Solids	mg/L	26,000	29,900	115	26,890	EXCEED	27,000	EXCEED	240
C029P1	Electrical Conductivity*	µS/cm	32,000	28,500	89	34,000		34,000		10,900
	Iron	µg/L Fe	954	1,420	149	5,000		5,620		5
	Magnesium*	mg/L Mg	360	287	80	378.3		380		122
	Sodium*	mg/L Na	6,583	6,380	97	7,485		7,540		800
	Total Dissolved Solids*	mg/L	20,000	18,700	94	20,272		20,300		6,810
	Calcium*	mg/L Ca	27	9	33	27		27		1.7
	Nickel	µg/L Ni	17	35	206	34	EXCEED	36		1
	Sodium*	mg/L Na	1,209	408	34	1,300		1,300		92
	Sulphate*	mg/L SO ₄	450	139	31	515		540		13
	Total Recoverable Hydrocarbons*	ppb (C10 – C40)	Detect above LOR	<LOR		Detect above LOR		650		100
Alluvium Western Area										
HD03B	Copper*	µg/L Cu	1.4	<LOR		1.4		4		1
	Iron	µg/L Fe	530	1,620	306	637.2	EXCEED	640	EXCEED	200
	T. Phosphorous	mg/L P	0.1	0.12	120	0.21		0.21		0.09
Tertiary										
C558P1	Calcium	mg/L Ca	80	87	109	81.5	EXCEED	82	EXCEED	14
	Chloride	mg/L Cl	2,900	3,370	116	3,420		3,500		1,370
	Electrical Conductivity	µS/cm	9,360	9,650	103	9,584	EXCEED	9,600	EXCEED	4,820
	Magnesium	mg/L Mg	215	230	107	228.4	EXCEED	230		1
	Nickel	µg/L Ni	34	69	203	50	EXCEED	78		4
	Sodium	mg/L Na	1,540	1,720	112	1,600	EXCEED	1,600	EXCEED	783
	Sulphate	mg/L SO ₄	240	257	107	250	EXCEED	280		1
	Total Dissolved Solids	mg/L	5,600	6,020	108	5,784	EXCEED	5,800	EXCEED	2,940
	Uranium*	µg/L U	2	2	100	2		2		1
C025P2	Boron*	µg/L B	1,600	1,390	87	1,700		1,700		840
	Chloride	mg/L Cl	4,500	4,710	105	4,837		4,900		1,500
	Iron	µg/L Fe	2,750	7,190	261	6,143	EXCEED	24,500		5
	Magnesium*	mg/L Mg	120	112	93	132.7		134		110
	Nickel	µg/L Ni	11	20	182	11	EXCEED	10	EXCEED	1
	Sodium*	mg/L Na	2,900	2,900	100	3,067		3,100		2,100
	Total Recoverable Hydrocarbons*	ppb (C10 – C40)	Detect above LOR	<LOR		Detect above LOR		650		100
C9180121SPR	Calcium	mg/L Ca	35	36	103	37		37		4.1
	Magnesium	mg/L Mg	50	52	104	51.7	EXCEED	52		11

Table D.1 February 2021 samples with two trigger exceedances compared to GMMP triggers, contaminant limits, historical maxima and minima

Bore	Parameter	Units	Contaminant	Reported	Trigger	Contaminant Limit		Historical Maximum	Historical Minimum
			Trigger Levels (85th Percentiles)		Exceedance Level (%)				
	Sodium	mg/L Na	575	660	115	638	EXCEED	644	230
	Zinc	µg/L Zn	950	1,170	123	3,070		12,000	5
Clematis Sandstone									
HD03A	Chloride*	mg/L Cl	150	149	99	158		158	91
	Iron	µg/L Fe	505	640	127	632	EXCEED	640	5
	Sodium	mg/L Na	130	131	101	143		143	66
	Zinc*	µg/L Zn	33	25	76	88		92	5
C14021SP	Chloride	mg/L Cl	150	152	101	158		158	91
	Sulphate	mg/L SO ₄	19	21	111	21		21	11
C14011SP	pH Low*	pH units	6	5.6	93	6		8	5.7
	Zinc	µg/L Zn	54	124	230	695		3,300	5
C14012SP	Alkalinity	mg/L CaCO ₃	130	136	105	150		170	5
C14013SP	Chloride*	mg/L Cl	110	108	98	130		130	56
	Cobalt*	µg/L Co	4	4	100	4		4	1
	Magnesium	mg/L Mg	9	10	111	9.7	EXCEED	9.8	1
	pH Low*	pH units	6	5.56	93	6		8	5.7
	Sulphate	mg/L SO ₄	9	10	111	11		12	1.9
	Zinc	µg/L Zn	54	134	248	695		3,300	5
C14033SP	Lead	µg/L Pb	3.4	8	235	3.4	EXCEED	5	1
	Magnesium	mg/L Mg	9	10	111	9.7	EXCEED	9.8	1
	pH Low*	pH units	6	5.97	100	6		8	5.7
C18001SP	Calcium	mg/L Ca	3	4	133	6.6		13	0.8
	Chloride	mg/L Cl	110	143	130	130	EXCEED	130	56
	Electrical Conductivity	µS/cm	607	662	109	640	EXCEED	640	16
	Iron	µg/L Fe	55	1,640	2,982	80	EXCEED	260	5
	Potassium	mg/L K	15	16	107	17		17	2.4
	Sodium	mg/L Na	100	123	123	126		134	32
	Zinc	µg/L Zn	54	61	113	695		3,300	5
C18002SP	Alkalinity	mg/L CaCO ₃	130	132	102	150		170	5
HD02	Aluminium	µg/L Al	55	70	127	55	EXCEED	24	5
	Chloride*	mg/L Cl	110	9	8	130		130	56
	Electrical Conductivity*	µS/cm	607	99	16	640		640	16
	Iron	µg/L Fe	55	1,800	3,273	80	EXCEED	260	5
	Sodium*	mg/L Na	100	12	12	126		134	32
C19002SP	Calcium	mg/L Ca	3	7	233	6.6	EXCEED	13	0.8
Dunda Beds									
C027P2	Calcium	mg/L Ca	1.1	2	182	3.9		4	0.8
	Chloride*	mg/L Cl	212	164	77	246		250	186
	Iron	µg/L Fe	1,325	2,540	192	2,005	EXCEED	24,900	7
	T. Phosphorous	mg/L P	0.03	0.08	267	0.18		0.19	0.01
C022P1	Zinc*	µg/L Zn	42	16	38	116		2400	5
C14023SP	Alkalinity	mg/L CaCO ₃	80	131	164	95	EXCEED	97	16

Table D.1 February 2021 samples with two trigger exceedances compared to GMMP triggers, contaminant limits, historical maxima and minima

Bore	Parameter	Units	Contaminant Trigger Levels (85th Percentiles)	Reported Value	Trigger Exceedance Level (%)	Contaminant Limit	Historical Maximum	Historical Minimum
C180117SP	Calcium	mg/L Ca	3.5	4	114	5.3	5.4	1
	Chloride	mg/L Cl	69	158	229	76	EXCEED	30
	Electrical Conductivity	µS/cm	350	740	211	398	EXCEED	250
	Potassium	mg/L K	3.8	8	211	4	EXCEED	2
	Sodium	mg/L Na	57	149	261	61	EXCEED	40
	Total Dissolved Solids	mg/L	220	378	172	279	EXCEED	150
	Copper*	µg/L Cu	100	3	3	181.2	210	1
	Iron	µg/L Fe	790	1460	185	2,416	2,670	5
	Total Recoverable Hydrocarbons	ppb (C10 – C40)	Detect above LOR	130	130	Detect above LOR	EXCEED	100
	Zinc	µg/L Zn	42	92	219	116	2,400	5
Rewan Formation								
C008P1	Ammonia	mg/L N	0.9	1.2	133	0.9	EXCEED	0.3
	Boron	µg/L B	370	1450	392	370	EXCEED	1,640
	Calcium*	mg/L Ca	480	463	96	480	505	466
	Chloride	mg/L Cl	7,600	7830	103	7,600	EXCEED	7,950
	Cobalt	µg/L Co	1.4	5	357	1.4	EXCEED	16
	Copper*	µg/L Cu	1.4	<LOR		1.4	62	1
	Electrical Conductivity	µS/cm	21,140	21300	101	21,140	EXCEED	23,000
	Iron	µg/L Fe	800	1530	191	800	EXCEED	3,780
	Magnesium*	mg/L Mg	410	380	93	410	442	386
	Manganese	µg/L Mn	1,900	2100	111	1,900	EXCEED	2,560
	Nickel	µg/L Ni	11	14	127	11	EXCEED	32
	Sodium	mg/L Na	3,700	3990	108	3,700	EXCEED	3,810
	T. Phosphorous*	mg/L P	0.14	0.14	100	0.14	0.37	0.01
	Total Dissolved Solids*	mg/L	14,600	14600	100	14,600	17,200	13,300
	Total Recoverable Hydrocarbons	ppb (C10 – C40)	Detect above LOR	170	170	Detect above LOR	EXCEED	180
	Uranium	µg/L U	0.5	14	2,800	0.5	EXCEED	19
	Zinc*	µg/L Zn	8	7	88	8	118	5
C035P1	Chloride*	mg/L Cl	1,100	1070	97	1,190	1,200	760
	Sodium	mg/L Na	755	770	102	817	822	590
C555P1	Calcium	mg/L Ca	6	7	117	8.2	11	0.6
	Chloride	mg/L Cl	170	179	105	190	191	29
	Iron	µg/L Fe	1,635	1,990	122	3,560	4,350	5
	Sodium	mg/L Na	130	149	115	169	170	38
C556P1	Cobalt	µg/L Co	4	5	125	5.7	6	1
C9553P1R	Iron*	µg/L Fe	1,635	1,580	97	3,560	4,350	5
	Total Recoverable Hydrocarbons	ppb (C10 – C40)	Detect above LOR	130	130	Detect above LOR	EXCEED	650
	Zinc*	µg/L Zn	38	17	45	283	2,700	5
C9838SPR	Zinc	µg/L Zn	38	51	134	283	2,700	5
C19028SP	Alkalinity	mg/L CaCO ₃	140	298	213	157	EXCEED	161
	Boron	µg/L B	370	1,030	278	370	EXCEED	280
	Calcium	mg/L Ca	6	24	400	8.2	EXCEED	11

Table D.1 February 2021 samples with two trigger exceedances compared to GMMP triggers, contaminant limits, historical maxima and minima

Bore	Parameter	Units	Contaminant Trigger Levels (85th Percentiles)	Reported Value	Trigger Exceedance Level (%)	Contaminant Limit		Historical Maximum		Historical Minimum	
	Chloride	mg/L Cl	170	1,420	835	190	EXCEED	191	EXCEED	29	
	Electrical Conductivity	µS/cm	800	5,290	661	845	EXCEED	861	EXCEED	156	
	Fluoride	mg/L F	0.7	1	143	0.9	EXCEED	0.9	EXCEED	0.05	
	Magnesium	mg/L Mg	8	45	563	9.8	EXCEED	10	EXCEED	1.3	
	Potassium	mg/L K	8	11	138	9	EXCEED	9.2	EXCEED	2	
	Sodium	mg/L Na	130	1,100	846	169	EXCEED	170	EXCEED	38	
	Sulphate	mg/L SO ₄	50	185	370	61	EXCEED	61	EXCEED	0.25	
	Total Dissolved Solids	mg/L	490	3,260	665	548	EXCEED	560	EXCEED	101	
	Uranium	µg/L U	0.5	1	200	0.5	EXCEED	1		0.5	
Bandana Formation											
C007P2	Boron	µg/L B	370	690	186	370	EXCEED	610	EXCEED	410	
	Calcium	mg/L Ca	32	294	919	64.5	EXCEED	565		453	EXCEED
	Chloride	mg/L Cl	723	5,020	694	907	EXCEED	5,880		4,350	
	Copper	µg/L Cu	1.4	6	429	1.4	EXCEED	2	EXCEED	1	
	Iron	µg/L Fe	138	1,620	1,174	1,209	EXCEED	760	EXCEED	50	
	Magnesium	mg/L Mg	16	272	1,700	19.6	EXCEED	315		234	
	Sodium	mg/L Na	570	2,450	430	660	EXCEED	2,740		2,550	EXCEED
	Sulphate	mg/L SO ₄	74	335	453	144	EXCEED	554		465	EXCEED
	Zinc	µg/L Zn	8	22	275	8	EXCEED	5	EXCEED	5	
C008P2	Calcium*	mg/L Ca	32	29	91	64.5		90		0.6	
	Magnesium*	mg/L Mg	16	16	100	19.6		21		0.1	
	Sodium	mg/L Na	570	572	100	660		732		210	
	Sulphate	mg/L SO ₄	74	89	120	144		153		0.5	
	Zinc*	µg/L Zn	15	<LOR		27		350		5	
C014P2	Fluoride	mg/L F	1	1.2	120	1.1	EXCEED	1.1	EXCEED	0.2	
C016P2	Boron	µg/L B	370	420	114	502		390	EXCEED	170	
	Calcium	mg/L Ca	32	83	259	64.5	EXCEED	90		0.6	
	Chloride	mg/L Cl	723	827	114	907		934		120	
	Magnesium	mg/L Mg	16	18	113	19.6		21		0.1	
	T. Phosphorous*	mg/L P	0.13	0.02	15	0.6		2.5		0.01	
C018P2	Boron	µg/L B	370	590	159	502	EXCEED	390	EXCEED	170	
	Calcium	mg/L Ca	32	55	172	64.5		90		0.6	
	Iron	µg/L Fe	138	460	333	1,209		2,240		5	
	Magnesium	mg/L Mg	16	26	163	19.6	EXCEED	21	EXCEED	0.1	
C032P2	Iron	µg/L Fe	138	180	130	1,209		2,240		5	
C035P2	Iron	µg/L Fe	138	430	312	1209		2,240		5	
C847SP	Copper	µg/L Cu	2	6	300	2	EXCEED	47		1	
	Zinc	µg/L Zn	15	53	353	27	EXCEED	350		5	
C823SP	Boron	µg/L B	370	530	143	502	EXCEED	390	EXCEED	170	
	Calcium	mg/L Ca	32	125	391	64.5	EXCEED	90	EXCEED	0.6	
	Chloride	mg/L Cl	723	1,220	169	907	EXCEED	934	EXCEED	120	
	Electrical Conductivity	µS/cm	3,000	4,380	146	4,522		4,600		1,200	

Table D.1 February 2021 samples with two trigger exceedances compared to GMMP triggers, contaminant limits, historical maxima and minima

Bore	Parameter	Units	Contaminant Trigger Levels (85th Percentiles)	Reported Value	Trigger Exceedance Level (%)	Contaminant Limit	Historical Maximum	Historical Minimum
C19027SP	Iron	µg/L Fe	138	1100	797	1209	2240	5
	Magnesium	mg/L Mg	16	57	356	19.6	EXCEED 21	0.1
	Sodium	mg/L Na	570	740	130	660	EXCEED 732	210
	Total Dissolved Solids	mg/L	1,800	2,450	136	2,722	2,800	730
	Total Recoverable Hydrocarbons*	ppb (C10 – C40)	Detect above LOR	100	100	Detect above LOR	EXCEED 1,300	100
	Boron	µg/L B	370	540	146	502	EXCEED 390	170
Colinlea Sandstone								
C833SP	Mercury*	µg/L Hg	0.06	<LOR		0.06	0.1	0.05
	pH High	pH units	9	9.66	107	9	EXCEED 11.4	7.2
C848SP	Calcium	mg/L Ca	28	29	104	28	EXCEED 28	24
	Chloride	mg/L Cl	790	828	105	809	EXCEED 810	290
	Iron*	µg/L Fe	1,345	1,230	91	1,891	1,900	5
	Magnesium	mg/L Mg	23	24	104	24	24	19
	Sodium	mg/L Na	540	554	103	569	570	440
C024P3	Chloride	mg/L Cl	200	391	196	224	EXCEED 407	351
	Cobalt	µg/L Co	1.4	5	357	1.4	EXCEED 4	1
	Electrical Conductivity	µS/cm	1,030	1,420	138	1,120	EXCEED 1,720	1,520
	Iron	µg/L Fe	410	13,800	3,366	904	EXCEED 20,800	7,940
	Magnesium	mg/L Mg	6	25	417	6	EXCEED 51	36
	Nickel	µg/L Ni	11	78	709	11	EXCEED 16	1
	Sodium	mg/L Na	220	240	109	271	270	232
	Sulphate	mg/L SO ₄	15	23	153	55	EXCEED 13	1
	T. Phosphorous	mg/L P	0.08	0.16	200	0.17	0.18	0.01
	Total Dissolved Solids	mg/L	639	820	128	720	EXCEED 1,150	1,040
	Total Recoverable Hydrocarbons	ppb (C10 – C40)	Detect above LOR	120	120	Detect above LOR	EXCEED 100	100
	Zinc	µg/L Zn	8	10	125	8	EXCEED 44	5
C006P3R	Electrical Conductivity	µS/cm	1,030	1,140	111	1,120	EXCEED 2,410	890
	Sodium	mg/L Na	220	264	120	271	424	140
	Total Dissolved Solids*	mg/L	639	630	99	720	1,260	523
C011P3	Boron	µg/L B	410	510	124	452	EXCEED 460	50
	Calcium	mg/L Ca	25	26	104	26.2	32	6
	Iron	µg/L Fe	410	450	110	904	2,590	5
C018P3	Chloride	mg/L Cl	200	205	103	224	601	27
	Iron	µg/L Fe	410	680	166	904	2,590	5
C034P3	Chloride	mg/L Cl	200	525	263	224	EXCEED 601	27
	Electrical Conductivity	µS/cm	1,030	1,800	175	1,120	EXCEED 2,410	890
	Iron	µg/L Fe	410	2,700	659	904	EXCEED 2,590	5
	Magnesium	mg/L Mg	6	11	183	6	EXCEED 14	2.6
	Potassium*	mg/L K	11	11	100	15	18	4
	Sodium	mg/L Na	220	332	151	271	EXCEED 424	140
	Sulphate	mg/L SO ₄	15	24	160	55	59	0.5

Table D.1 February 2021 samples with two trigger exceedances compared to GMMP triggers, contaminant limits, historical maxima and minima

Bore	Parameter	Units	Contaminant	Trigger	Exceedance	Contaminant Limit	Historical Maximum	Historical Minimum			
			Trigger Levels (85th Percentiles)	Reported Value					Level (%)		
C975SP	Total Dissolved Solids	mg/L	639	990	155	720	EXCEED	1,260	523		
	Zinc	µg/L Zn	25	165	660	122	EXCEED	310	5		
	Copper	µg/L Cu	1.4	14	1,000	1.4	EXCEED	13	EXCEED	1	
	Magnesium*	mg/L Mg	6	6	100	6		14		2.6	
	Sulphate	mg/L SO ₄	15	28	187	55		59		0.5	
C9849SPR	Zinc	µg/L Zn	25	44	176	122		310		5	
	Calcium	mg/L Ca	25	39	156	26.2	EXCEED	32	EXCEED	6	
	Chloride	mg/L Cl	200	835	418	224	EXCEED	601	EXCEED	27	
	Copper*	µg/L Cu	1.4	<LOR		1.4		13		1	
	Electrical Conductivity	µS/cm	1,030	3,030	294	1,120	EXCEED	2,410	EXCEED	890	
	Iron	µg/L Fe	410	3,400	829	904	EXCEED	2590	EXCEED	5	
	Magnesium	mg/L Mg	6	19	317	6	EXCEED	14	EXCEED	2.6	
	Potassium	mg/L K	11	20	182	15	EXCEED	18	EXCEED	4	
	Sodium	mg/L Na	220	574	261	271	EXCEED	424	EXCEED	140	
	Total Dissolved Solids	mg/L	639	1,670	261	720	EXCEED	1,260	EXCEED	523	
C19026SP	Electrical Conductivity*	µS/cm	1,030	921	89	1,120		2,410		890	
	Sodium*	mg/L Na	220	217	99	271		424		140	
	Total Dissolved Solids*	mg/L	639	546	85	720		1,260		523	
Joe Joe Group											
C14003SP	Alkalinity	mg/L CaCO ₃	48	72	150	50	EXCEED	65	EXCEED	42	
	Cobalt	µg/L Co	29	36	124	32.6	EXCEED	33	EXCEED	22	
	Iron	µg/L Fe	1,300	18,600	1,431	1,788	EXCEED	1,800	EXCEED	8	
	Magnesium*	mg/L Mg	1,600	1,490	93	1,600		1,600		1,400	
	Sodium	mg/L Na	8,000	8,800	110	8,352	EXCEED	8,400	EXCEED	6,200	
	T. Phosphorous*	mg/L P	0.05	<LOR		0.4		0.03		0.01	
	Total Dissolved Solids	mg/L	32,000	50,600	158	32,000	EXCEED	32,000	EXCEED	23,000	
C914001SPR	Calcium	mg/L Ca	880	1,010	115	906.7	EXCEED	910	EXCEED	170	
	Chloride	mg/L Cl	7,070	7,240	102	7,289		7,300		4,200	
	Copper*	µg/L Cu	1.4	<LOR		1.4		6		1	
	Magnesium	mg/L Mg	435	474	109	448.9	EXCEED	450	EXCEED	73	
	T. Phosphorous*	mg/L P	0.05	<LOR		0.4		0.04		0.01	
C14017SP	Total Dissolved Solids	mg/L	13,000	14,100	108	13,000	EXCEED	13,000	EXCEED	8,900	
	Alkalinity	mg/L CaCO ₃	240	262	109	268		430		325	EXCEED
	Boron	µg/L B	720	840	117	786	EXCEED	390	EXCEED	330	
	Fluoride	mg/L F	1	1.1	110	1.1		1.1		1	
	C14006SP	Calcium	mg/L Ca	180	186	103	190		10	EXCEED	5
		Chloride	mg/L Cl	2,545	2,840	112	2,600	EXCEED	228	EXCEED	200
Iron		µg/L Fe	1,870	7,270	389	3,580	EXCEED	50	EXCEED	5	
Magnesium*		mg/L Mg	84	84	100	86		4.1	EXCEED	3	
Sodium		mg/L Na	1,500	1,520	101	1,500	EXCEED	290	EXCEED	240	
	Total Dissolved Solids	mg/L	5,100	5,230	103	5,200	EXCEED	840	EXCEED	750	
	C012P1	Boron	µg/L B	425	480	113	500		4,400		59

Table D.1 February 2021 samples with two trigger exceedances compared to GMMP triggers, contaminant limits, historical maxima and minima

Bore	Parameter	Units	Contaminant	Trigger	Exceedance	Contaminant Limit	Historical Maximum	Historical Minimum		
			Trigger Levels (85th Percentiles)	Reported Value					Level (%)	
C012P2	Magnesium	mg/L Mg	28	33	118	32.9	EXCEED	1,600	2.9	
	Nickel	µg/L Ni	11	30	273	17	EXCEED	66	1	
	Sulphate*	mg/L SO ₄	54	53	98	70		2,900	0.8	
	Boron	µg/L B	425	540	127	500	EXCEED	4,400	59	
	Calcium	mg/L Ca	76	86	113	84	EXCEED	2,700	1.9	
	Chloride	mg/L Cl	630	685	109	724		22,000	100	
	Magnesium	mg/L Mg	28	30	107	32.9		1,600	2.9	
C14002SP	Sodium	mg/L Na	426	436	102	500		8,400	60	
	Total Recoverable Hydrocarbons	ppb (C10 – C40)	Detect above LOR	180	180	Detect above LOR	EXCEED	660	100	
	Boron	µg/L B	425	930	219	500	EXCEED	4,400	59	
	Calcium	mg/L Ca	76	292	384	84	EXCEED	2,700	1.9	
	Chloride	mg/L Cl	630	3,900	619	724	EXCEED	22,000	100	
	Electrical Conductivity	µS/cm	2,600	11,200	431	2,790	EXCEED	54,000	420	
	Iron	µg/L Fe	765	2,840	371	2,659	EXCEED	2,600	EXCEED	5
C14008SP	Magnesium	mg/L Mg	28	110	393	32.9	EXCEED	1,600	2.9	
	Potassium	mg/L K	15	30	200	21	EXCEED	56	3	
	Sodium	mg/L Na	426	2,140	502	500	EXCEED	8,400	60	
	Sulphate	mg/L SO ₄	54	374	693	70	EXCEED	2,900	0.8	
	Total Dissolved Solids	mg/L	1,600	6,220	389	1,801	EXCEED	32,000	250	
	Cobalt	µg/L Co	6	10	167	8	EXCEED	33	1	
	Iron	µg/L Fe	765	1,920	251	2,659		2,600	5	
C14015SP	Nickel	µg/L Ni	11	14	127	17		66	1	
	Chloride	mg/L Cl	630	693	110	724		22,000	100	
	Sodium	mg/L Na	426	488	115	500		8,400	60	
C14016SP	Sulphate	mg/L SO ₄	54	58	107	70		2,900	0.8	
	Chloride	mg/L Cl	630	732	116	724	EXCEED	22,000	100	
	Electrical Conductivity	µS/cm	2,600	2,610	100	2,790		54,000	420	
C14032SP	Sodium	mg/L Na	426	528	124	500	EXCEED	8,400	60	
	Sulphate	mg/L SO ₄	54	56	104	70		2,900	0.8	
	T. Phosphorous*	mg/L P	0.05	0.05	100	0.4		0.7	0.01	
	Chloride	mg/L Cl	630	661	105	724		22,000	100	
	Iron	µg/L Fe	765	1,800	235	2,659		2,600	5	
	Magnesium	mg/L Mg	28	32	114	32.9		1,600	2.9	
	Zinc	µg/L Zn	260	272	105	4,414		9,000	5	
C180119SP	Iron	µg/L Fe	765	2,070	271	2,659		2,600	5	
	Zinc	µg/L Zn	260	13,000	5,000	4,414	EXCEED	9,000	EXCEED	5
C914030SPR	Cobalt	µg/L Co	6	8	133	8		8	1	
	Nickel	µg/L Ni	11	12	109	17		17	1	
C9180124SPR	Zinc	µg/L Zn	260	807	310	4,414		9,000	5	
C9180125SPR	Alkalinity*	mg/L CaCO ₃	290	280	97	365		620	9	
C14004SP	Ammonia	mg/L N	0.9	0.91	101	0.9	EXCEED	0.81	EXCEED	0.005
	Boron	µg/L B	425	600	141	500	EXCEED	4,400	59	

Table D.1 February 2021 samples with two trigger exceedances compared to GMMP triggers, contaminant limits, historical maxima and minima

Bore	Parameter	Units	Contaminant	Trigger						
			Trigger Levels (85th Percentiles)	Reported Value	Exceedance Level (%)	Contaminant Limit		Historical Maximum		Historical Minimum
	Calcium	mg/L Ca	76	2,900	3,816	84	EXCEED	2,700	EXCEED	1.9
	Chloride	mg/L Cl	630	20,100	3,190	724	EXCEED	22,000		100
	Electrical Conductivity	µS/cm	2,600	53,800	2,069	2,790	EXCEED	54,000		420
	Magnesium	mg/L Mg	28	1,270	4,536	32.9	EXCEED	1,600		2.9
	Manganese	µg/L Mn	1,900	7,910	416	1,900	EXCEED	2,700	EXCEED	1
	Potassium	mg/L K	15	44	293	21	EXCEED	56		3
	Sodium	mg/L Na	426	8,760	2,056	500	EXCEED	8,400	EXCEED	60
	Sulphate	mg/L SO ₄	54	2,100	3,889	70	EXCEED	2,900		0.8
	T. Phosphorous	mg/L P	0.05	0.33	660	0.4		0.7		0.01
	Total Dissolved Solids	mg/L	1,600	40,300	2,519	1,801	EXCEED	32,000	EXCEED	250

Note: February 2021 results are included pending the April 2021 trigger exceedances investigation reporting.
Measurements marked with * are not in exceedance of the trigger values but have been included in the table due to exceedances in two or more of the previous monitoring events.

Appendix E

Statistical analysis of water quality results

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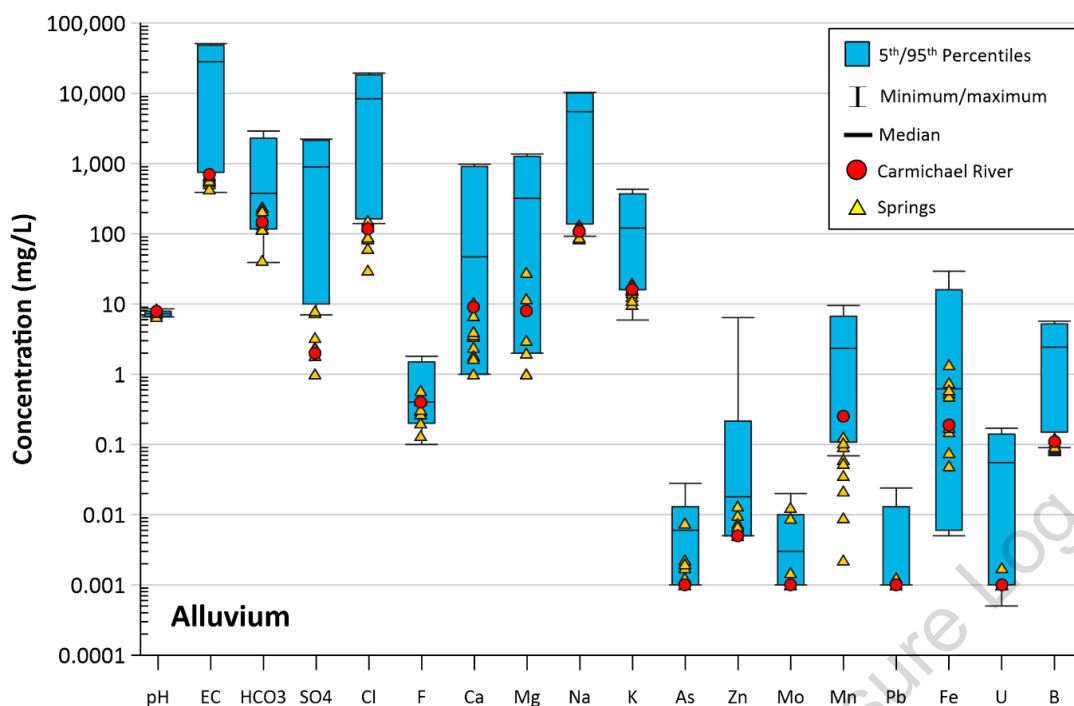


Figure E.1 Median, 5th and 95th percentiles and minimum/maximum values for a range of water quality parameters from Alluvium groundwater. Also shown are compositions from DSC and Carmichael River samples for comparison

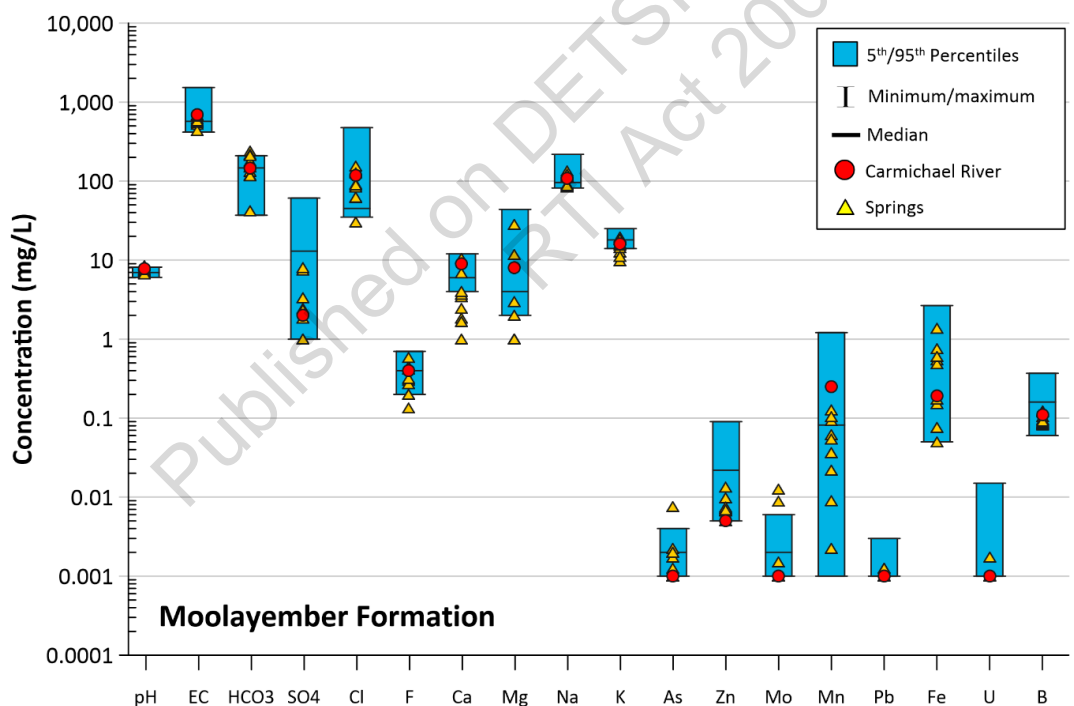


Figure E.2 Median, 5th and 95th percentiles and minimum/maximum values for a range of water quality parameters from Moolayember Formation groundwater. Also shown are compositions from DSC and Carmichael River samples for comparison

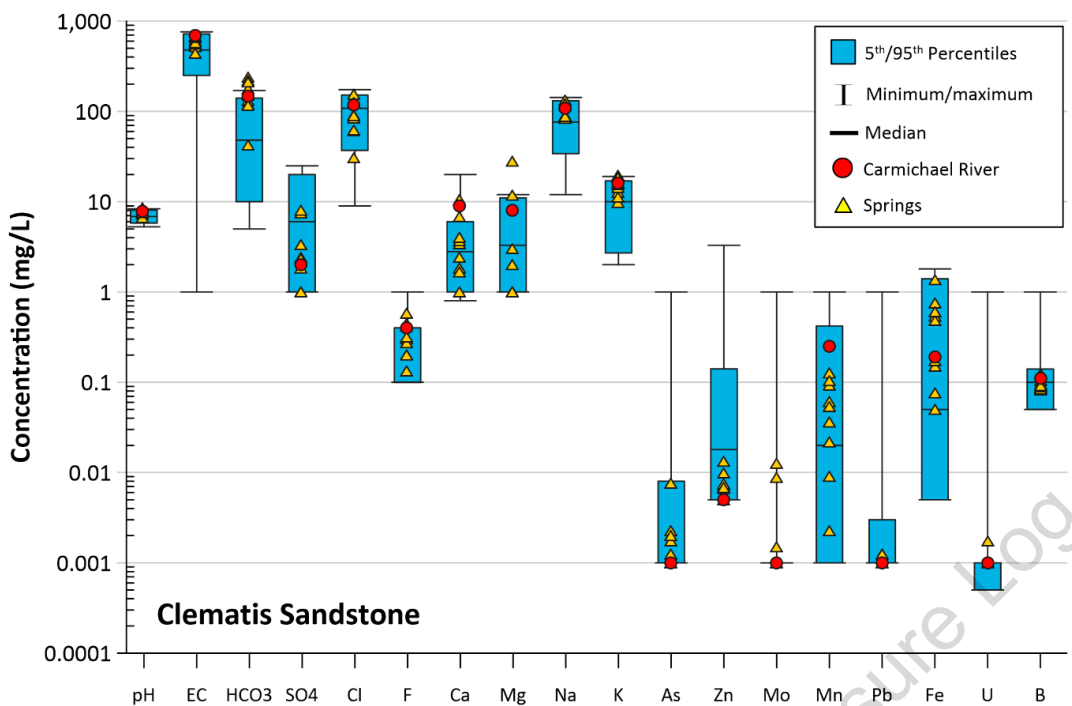


Figure E.3 Median, 5th and 95th percentiles and minimum/maximum values for a range of water quality parameters from Clematis Sandstone groundwater. Also shown are compositions from DSC and Carmichael River samples for comparison

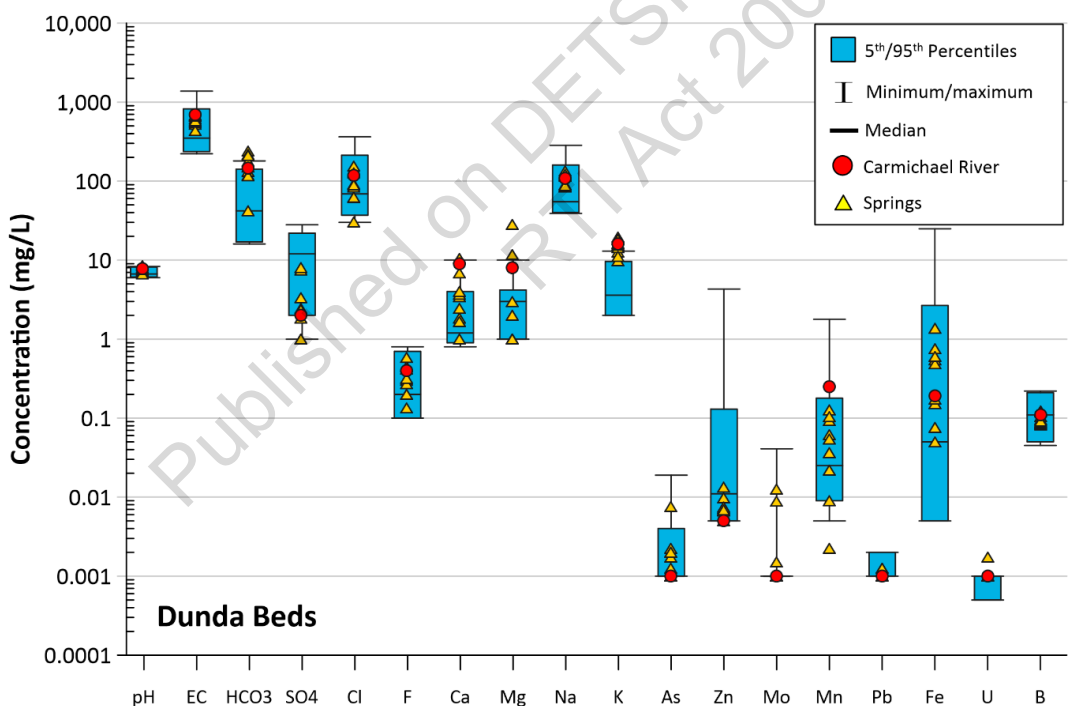


Figure E.4 Median, 5th and 95th percentiles and minimum/maximum values for a range of water quality parameters from Dunda Beds groundwater. Also shown are compositions from DSC and Carmichael River samples for comparison

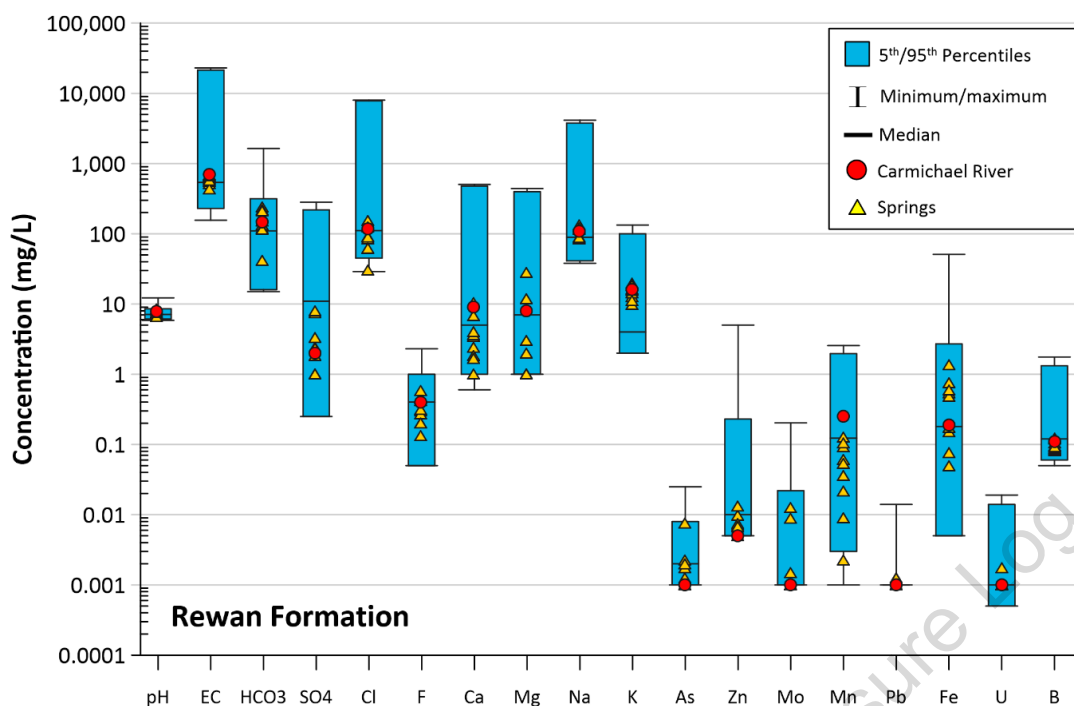


Figure E.5 Median, 5th and 95th percentiles and minimum/maximum values for a range of water quality parameters from Rewan Formation groundwater. Also shown are compositions from DSC and Carmichael River samples for comparison

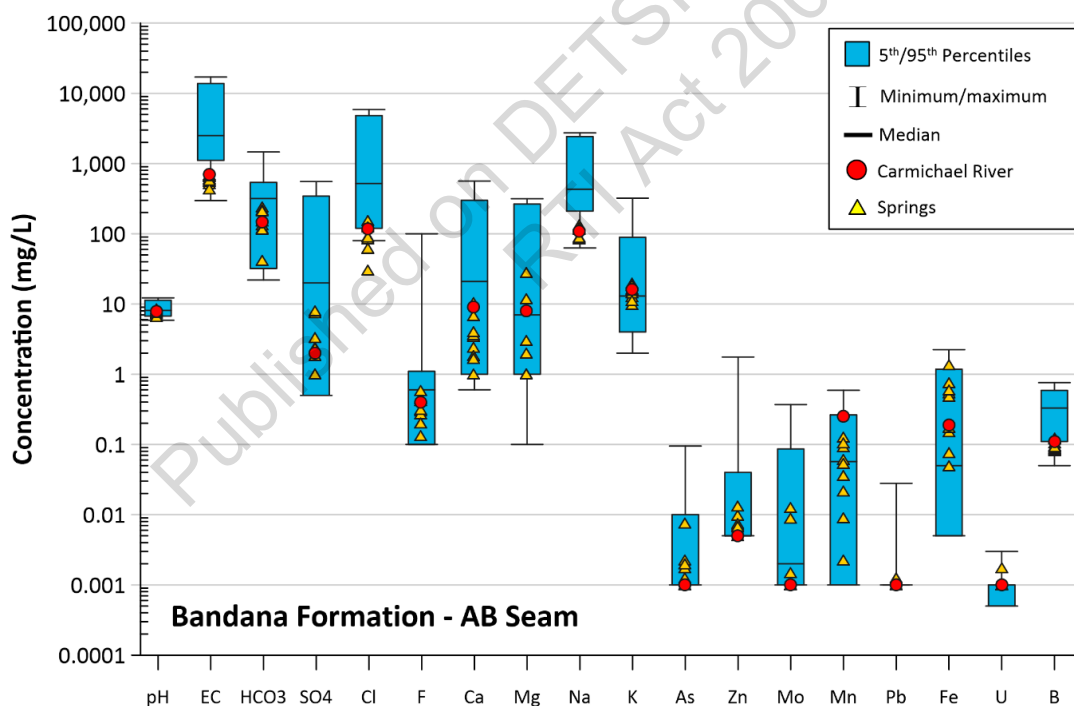


Figure E.6 Median, 5th and 95th percentiles and minimum/maximum values for a range of water quality parameters from Bandana Formation groundwater. Also shown are compositions from DSC and Carmichael River samples for comparison

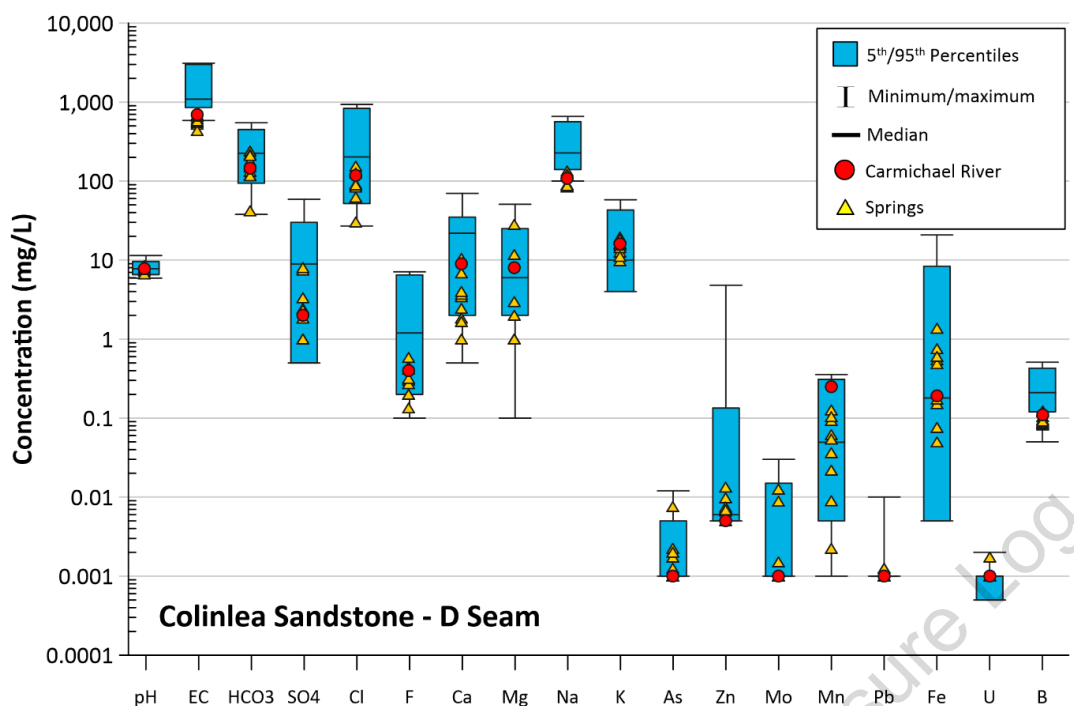


Figure E.7 Median, 5th and 95th percentiles and minimum/maximum values for a range of water quality parameters from Colinlea Sandstone groundwater. Also shown are compositions from DSC and Carmichael River samples for comparison

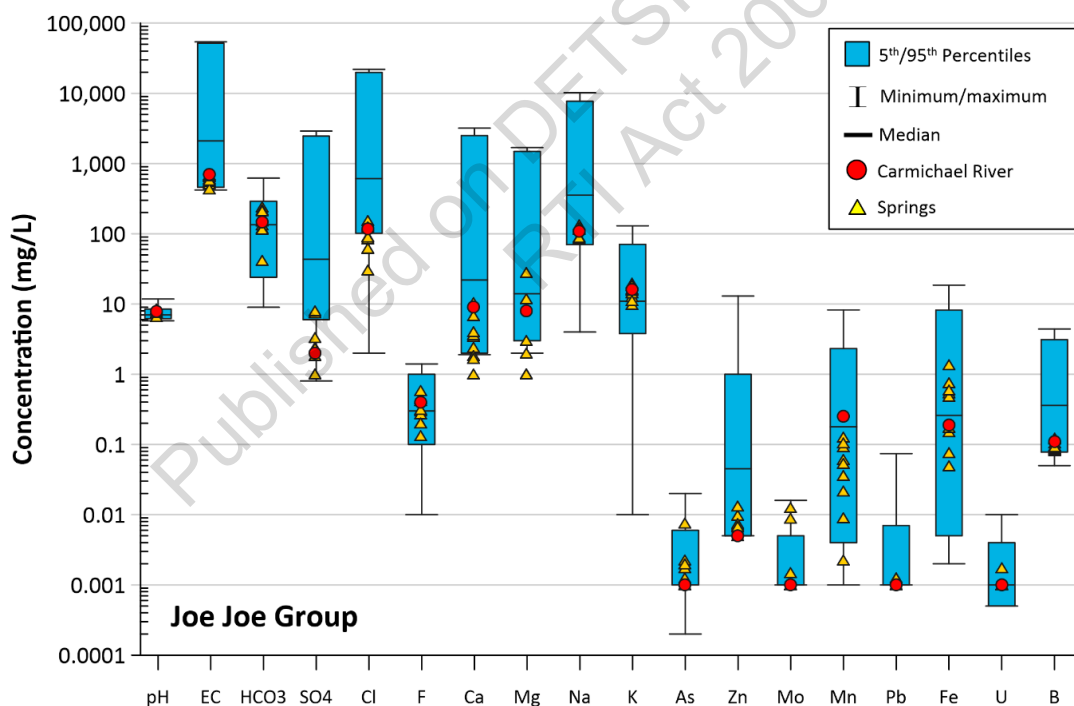


Figure E.8 Median, 5th and 95th percentiles and minimum/maximum values for a range of water quality parameters from Joe Joe Group groundwater. Also shown are compositions from DSC and Carmichael River samples for comparison

Appendix F

Proposed trigger values and contaminant limits for six bores installed in 2018

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F.1 Proposed trigger values and contaminant limits for six bores installed in 2018

Table F.1 Trigger values and contaminant limits derived following the methods outlined in the GMMP ver. 11

Parameter	Trigger values				Contaminant limits			
	C18004SP	C18005SP	C18006SP	C18009SP	C18004SP	C18005SP	C18006SP	C18009SP
pH Value	6-9	6-9	6-9	6 - 9	6-9	6-9	6-9	6-9
Electrical Conductivity @ 25°C	40420	53165	60840	25730	40882	53564	61544	26073
Total Dissolved Solids @180°C	36330	47120	49480	21555	37765	48492	54384	24166
Total Alkalinity as CaCO ₃	224.95	202	232.2	83.9	252.39	209.28	238.52	87.82
Sulfate as SO ₄ - Turbidimetric	787.6	2483	3038	931.4	814.83	2526.4	3151.2	946.73
Chloride	14900	19900	23140	8973	15446	20082	23752	8989.1
Calcium	3166.5	2649.5	2200	2062.5	3188.2	2769.2	2255.2	2298.4
Magnesium	1316	1329.5	1578	426.9	1348.2	1403.7	1607.6	437.19
Sodium	4926.5	9631.5	11760	3627.5	5048.3	9852	12076	3789.2
Potassium	21	20.3	29.8	35	23.73	21.91	33.68	35.91
Aluminium	0.055	0.055	0.055	0.055	0.055	0.0591	0.0776	0.055
Arsenic	0.013	0.013	0.013	0.013	0.013	0.0464	0.013	0.013
Cadmium	0.0002	0.0002	0.0002	0.0002	0.0005	0.004685	0.0005	0.0005
Chromium	0.001	0.001	0.001	0.10875	0.01	0.01	0.01	0.12919
Cobalt	0.0014	0.02	0.0136	0.0014	0.01	0.02455	0.014	0.01
Copper	0.0014	0.0014	0.0014	0.0014	0.02196	0.18104	0.01	0.01
Lead	0.0034	0.0034	0.0034	0.0034	0.01	0.01	0.01	0.01
Manganese	0.2736	2.0295	1.9	1.9	1.9	2.2857	1.9	1.9
Molybdenum	0.034	0.034	0.034	0.0442	0.034	0.034	0.03528	0.047
Nickel	0.0248	0.0365	0.0224	0.011	0.04265	0.05456	0.02944	0.01282
Selenium	0.011	0.011	0.011	0.011	0.05	0.05	0.05	0.05
Silver	0.0005	0.0005	0.0005	0.0005	0.01	0.01	0.01	0.01
Uranium	0.0393	0.09565	0.0678	0.0005	0.04	0.09964	0.07	0.01191
Vanadium	0.006	0.006	0.006	0.006	0.05	0.05	0.05	0.05
Zinc	0.05015	0.187	0.008	0.0379	0.07584	0.61085	0.09208	0.0764
Boron	1.2555	4.7345	5.9	1.319	1.4802	5.0985	6.0244	1.3673
Iron	0.3	0.3	0.414	0.3	0.3	0.3	0.5588	0.3
Mercury	0.0006	0.0006	0.0006	0.0006	0.0006	0.003649	0.0006	0.0006
Fluoride	0.2	0.2	0.2	0.465	0.2	0.473	0.2	0.5
Ammonia as N	0.9	0.9	0.9	0.9	0.9	1.7268	0.9	0.9
Nitrite as N	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1756
Nitrate as N	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Total Phosphorus as P	0.1065	0.3455	0.1	0.1	0.201	0.4428	0.2488	0.1637
Sulfide as S ²⁻	1	1	1	1	1	1	1	1

Table F.1 Trigger values and contaminant limits derived following the methods outlined in the GMMP ver. 11

Parameter	Trigger values				Contaminant limits			
	C18004SP	C18005SP	C18006SP	C18009SP	C18004SP	C18005SP	C18006SP	C18009SP
C6 - C9 Fraction	>LOR	>LOR	>LOR	>LOR	>LOR	>LOR	>LOR	>LOR
C6 - C10 Fraction	>LOR	>LOR	>LOR	>LOR	>LOR	>LOR	>LOR	>LOR
>C10 - C40 Fraction (sum)	>LOR	>LOR	>LOR	>LOR	>LOR	>LOR	>LOR	>LOR
Sum of BTEX	>LOR	>LOR	>LOR	>LOR	>LOR	>LOR	>LOR	>LOR

Notes:

1. Trigger values and contaminant limits have not been derived for bores C18007SP and C18008SP because these bores are consistently dry.
2. Values in bold are derived from bore data; all other values are default ANZ 2018 95% species protection for freshwater systems guidelines, or freshwater low reliability triggers (if 95% guidelines are unavailable).

Appendix G

Predicted versus Observed Drawdown – Bandanna Formation

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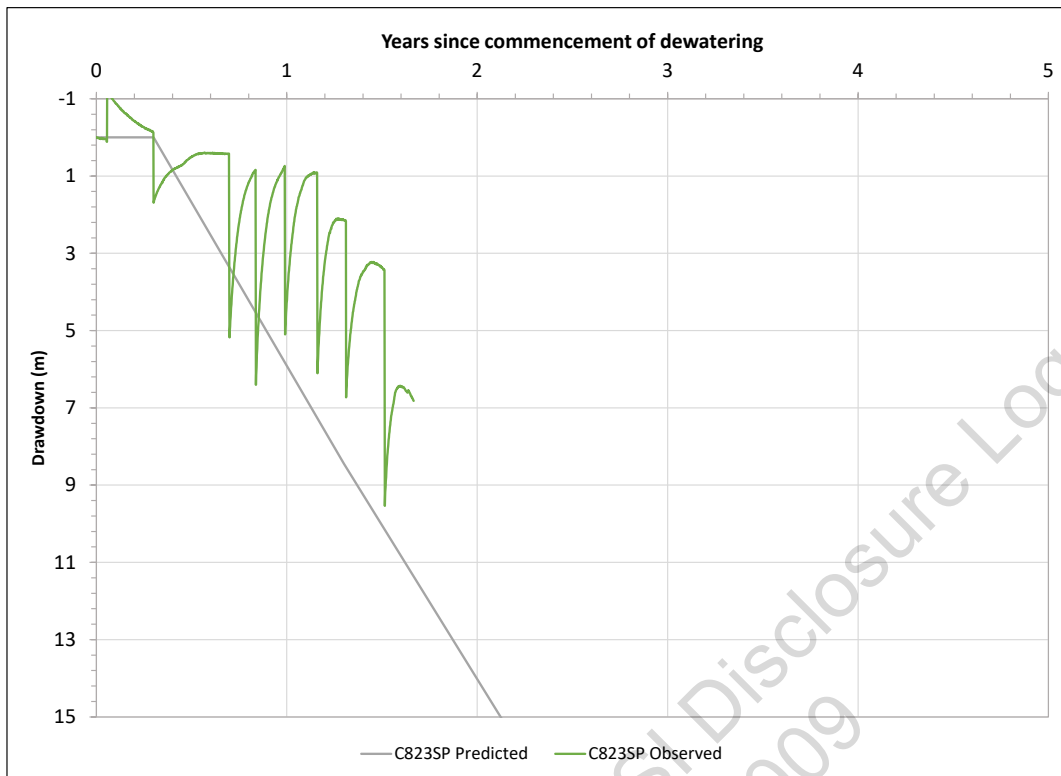


Figure G.1 C823SP predicted vs observed drawdown

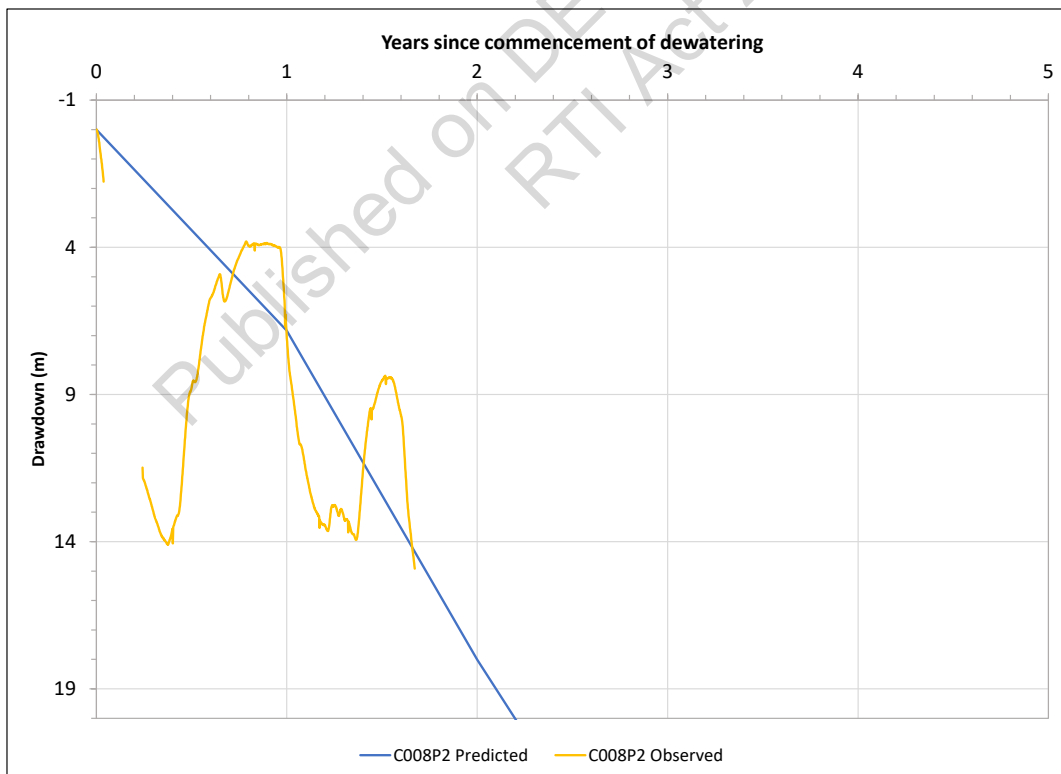


Figure G.2 C008P2 predicted vs observed drawdown

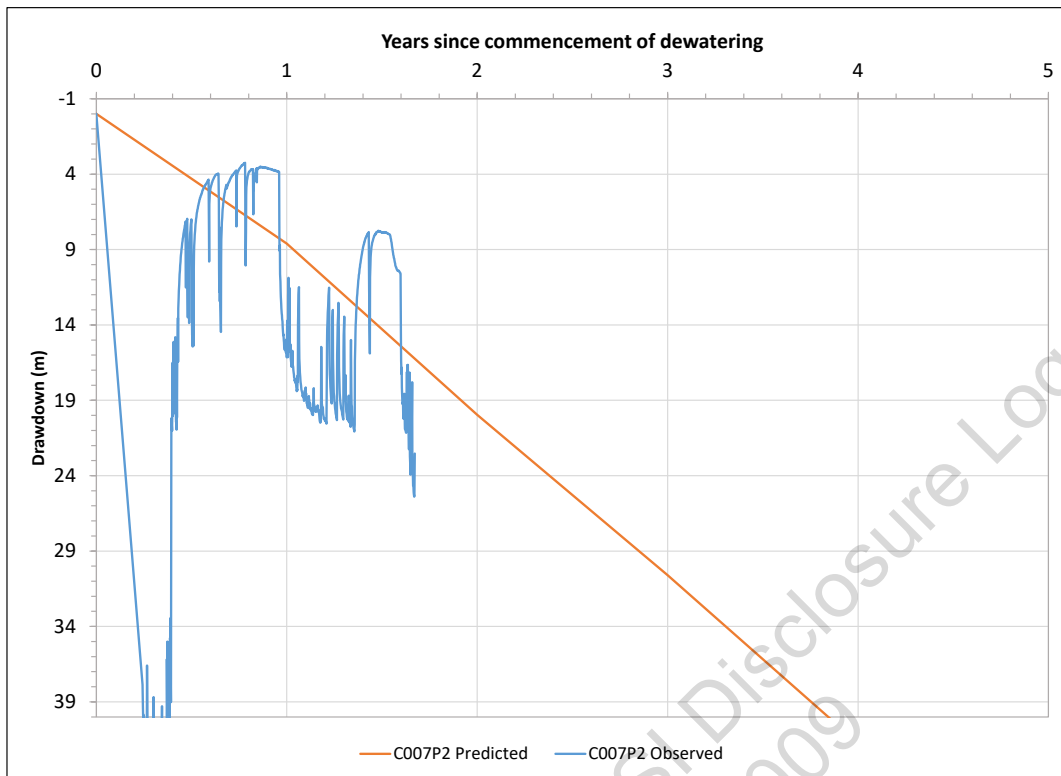


Figure G.3 C007P2 predicted vs observed drawdown

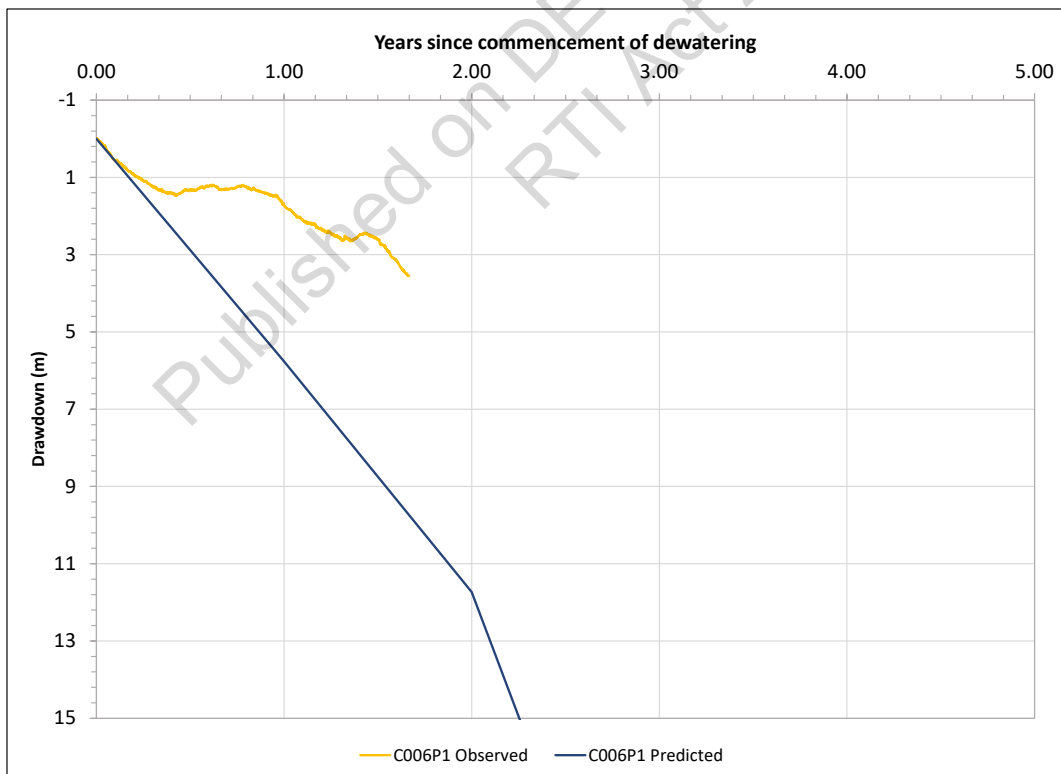


Figure G.4 C006P1 predicted vs observed drawdown

Appendix H

Predicted versus Observed Drawdown – Colinlea Sandstone

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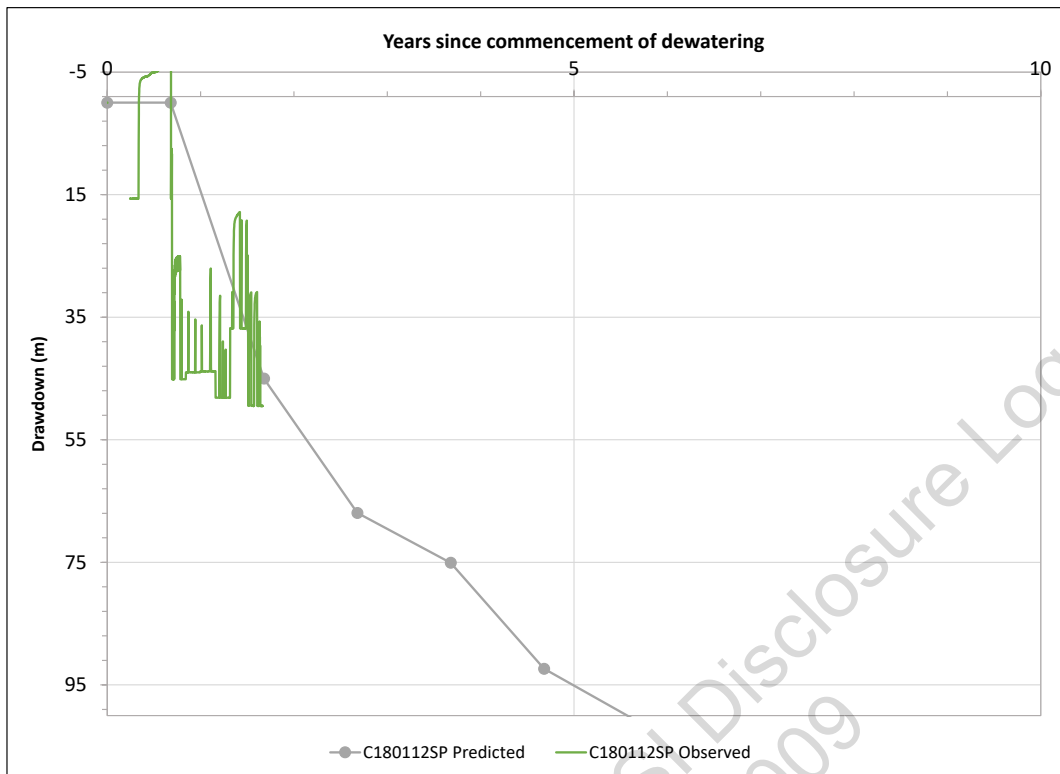


Figure H.1 C180112SP predicted vs observed drawdown

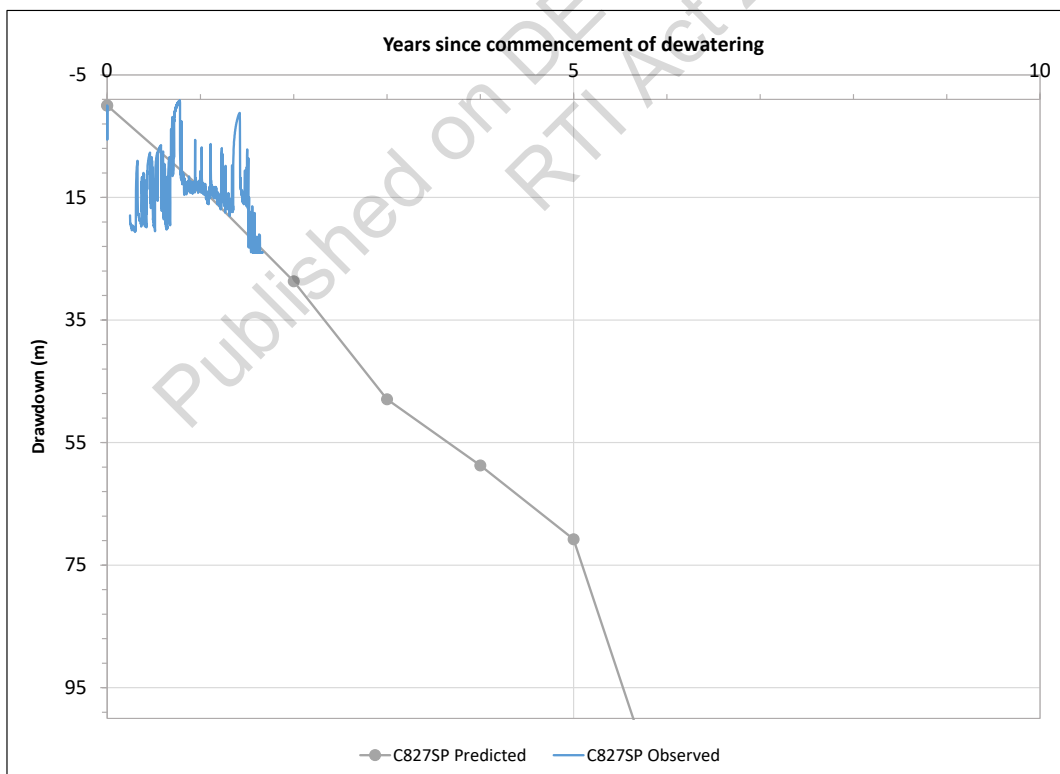


Figure H.2 C827SP predicted vs observed drawdown

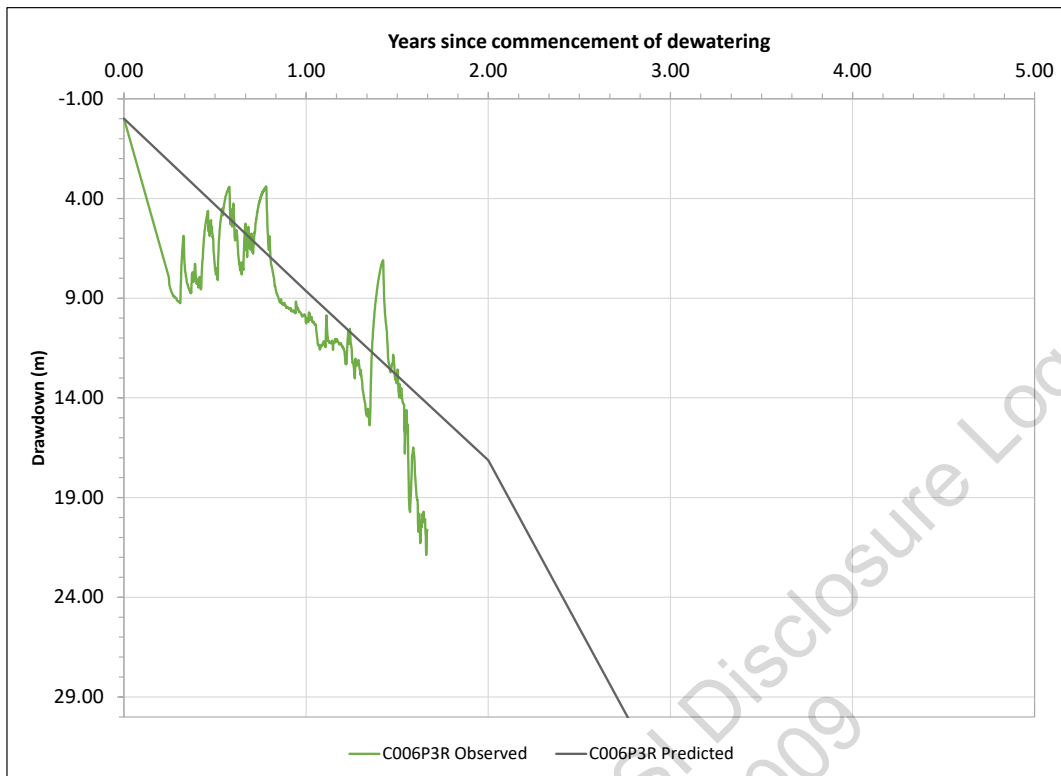


Figure H.3 C006P3R predicted vs observed drawdown

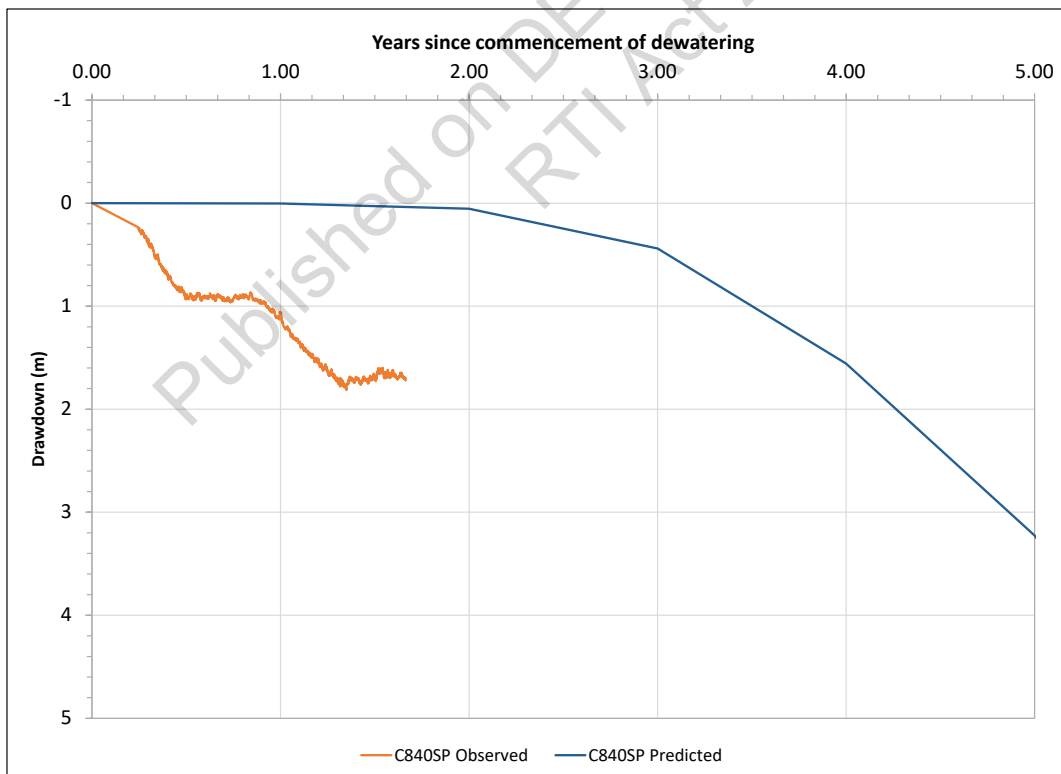


Figure H.4 C840SP predicted vs observed drawdown

email, you acknowledge and accept these risks.

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DES Proposed Additional Monitoring bores

Colinlea Sandstone – D Seam – standpipe monitoring bores required

Site 1

On the western boundary of ML70441 in a location that won't be mined out. This should be located between C007P3 (RN158064) and Doongmabulla Springs. (In the January 2023 version of the GMMP review report Bravus propose new bore number 5 at this location. That is supported by DES).

Currently there are no Colinlea Sandstone monitoring bores (standpipe bores) west of the dewatering bores. In order to better understand the propagation of drawdown from the mine towards the Doongmabulla Springs there should be a Colinlea Sandstone monitoring bore on the western boundary of ML70441.

Site 2

Adjacent C19031VWP (RN190605), between Moses and Little Moses Springs.

There should be a monitoring bore (standpipe bore) in the area of C19031VWP (RN190605) as given the unreliability of the existing VWP bores there can be no guarantee that data from this VWP is representative of the Colinlea Sandstone. This bore is to be located between Moses and Little Moses springs, would provide a reliable head in the Colinlea in this area and also provide information on any propagation of drawdown from the mine to this area in the Colinlea. It would also provide valuable information for developing initial heads information in this western area of the groundwater model.

Site 3

Adjacent C558VWP (RN158596), 4.7 km north-west of the northern most current dewatering bore. (Bravus propose monitoring bore 1 at this location in the GMMP review. That is supported by DES)

There is a lack of Colinlea Sandstone monitoring bores adjacent the northern dewatering bores and immediately north of the dewatering bores. C19026SP (RN190091) and C006P3R (RN158063) are adjacent the southern dewatering bores. The closest monitoring bore north of these two monitoring bores is C011P3 (RN158069) some 11 km to the north-west. No impact from mining is being noted at C011P3 so existing propagation of drawdown north cannot currently be tracked.

Site 4

South of Carmichael River, approximately half-way between C840SP (RN158107) and C034P3 (RN158086) which are approximately 5.8 km apart.

There is a gap between C840SP (most southerly monitoring bore considered impacted, by Bravus in the 2022 annual monitoring report, based on observed water level trends) and C034P3 which is some 5.8 km south of C840SP. Tracking the impact of mining south will therefore also soon become difficult.

Site 5

Directly west of Mellaluka Springs as advised by Bravus in the GMMP review although they suggested not a priority at this time. DES consider that it is.

There are currently no Colinlea Sandstone monitoring bores south of the mining lease.

There is a need in this area to:

- understand the relationship between the Colinlea Sandstone and the Joe Joe and Tertiary
- Understand the impacts of local landholder use on water levels in this area and the challenges in unpacking which stress is causing impact

Therefore, the sooner baseline data is available from the proposed Colinlea Sandstone and Bandanna Formation bores in this area, the better. In the GMMP Review Bravus propose a monitoring bore in this area in the future but not until impacts are noted at the southern boundary of the mining lease. That proposal is not supported by DES as it is considered that there is a need for a monitoring bore at this location now.

Site 6

Adjacent C14012SP (RN158889) (approx. 3.6 km north of Little Moses Spring) as advised by Bravus in the GMMP review, proposed site 2. (This proposal is supported by DES)

This site would provide understanding of groundwater heads in the Colinlea Sandstone north and north-east of the Doongmabulla Springs allowing more accurate development of initial heads for modelling in this area. It would also provide information on any propagation of drawdown from the mine to this area in the Colinlea Sandstone.

Bandanna Formation – AB seam – standpipe monitoring bores required

Site 7

On the western boundary of ML70441 in a location that won't be mined out. This should be located between C008P2 (RN158067) and Doongmabulla Springs. (In the January 2023 version of the GMMP review report Bravus propose new bore number 8 at this location. That is supported by DES).

To the west of the dewatering bores there are only two Bandanna Formation monitoring bores. C008P2 (RN158067) which is located 1.4 km west of the dewatering bores and showing significant impacts from mining and bore C19018SP (RN190229) located 10km west of C008P2, adjacent Moses Springs. In order to better understand the propagation of drawdown from the mine towards the Doongmabulla Springs there should be a Bandanna Formation monitoring bore on the western boundary of ML70441.

Site 8

Adjacent C14012SP (RN158889) (approx. 3.6 km north of Little Moses Spring) as advised by Bravus in the GMMP review, proposed site 6. (This proposal is supported by DES)

This site would provide understanding of groundwater heads in the Bandanna Formation north and north-east of the Doongmabulla Springs allowing more accurate development of initial heads for modelling in this area. It would also provide information on any propagation of drawdown from the mine to this area in the Bandanna.

Site 9

South of Carmichael River, approx half-way between C9839SPR (RN158115) and C034P1 (RN158087) which are approximately 5.8 km apart.

In the Bandanna Formation there is a gap between C9839SPR (almost considered impacted by Bruvus in the 2022 annual groundwater monitoring report) and C034P1 which is some 5.6 km south of C9839SPR. Tracking this impact from dewatering south will therefore soon become difficult.

Site 10

Directly west of Mellaluka Springs as advised by Bravus in the GMMP review although they suggested not a priority at this time. DES consider that it is.

There are currently no Bandanna standpipe monitoring bores south of the mining lease.

There is a need in this area to:

- understand the relationship between the Bandanna Formation, Colinlea Sandstone and the Joe Joe and Tertiary
- Understand the impacts of local landholder use on water levels in this area and the challenges in unpacking which stress is causing impact

Therefore, the sooner baseline data is available from the proposed Bandanna Formation and Colinlea Sandstone bores in this area, the better. In the GMMP Review Bravus propose a monitoring bore in this area in the future but not until impacts are noted at the southern boundary of the mining lease. That proposal is not supported by DES as it is considered that there is a need for a monitoring bore at this location now.

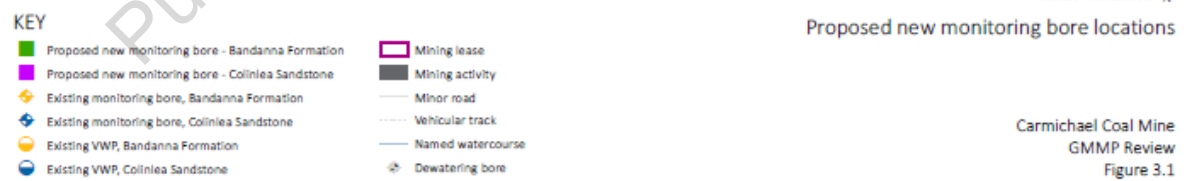
Other Bores Proposed by Bravus in 31 January 2023 GMMP Review report.

Bravus propose 3 other bores (not discussed above) on their western lease boundary.

Two Colinlea Sandstone bores identified in the GMMP Review report as proposed bores 3 and 4 and one Bandanna Formation bore identified as proposed bore 7.

These sites were not requested by DES but are supported by DES as they will improve understanding on existing groundwater gradients from the west to the east and propagation of any drawdown impacts from mining towards the west.

Extract from Figure 3.1 from the January 2023 GMMP review report provided below.



Preliminary review of the Carmichael Coal Mine groundwater model report

Initial Heads

Bandanna Formation, Colinlea Sandstone and Joe Joe Formation

There is an area on the northern side of the Carmichael River encompassing the area of current mining, where in the pre mining period the lowest groundwater levels in the Bandanna Formation and Colinlea Sandstone have been noted as have some in the Joe Joe Formation.

In this current report Table 2.1 – Summary of the Conceptual Hydrogeological model, states:

- *A synform had been proposed during the SEIS phase, with a northeast to southwest fold axis that passes broadly through the centre of the site. The synform affects the Betts Creek Beds and Rewan Formation and the fold axis tends to align with a regional potentiometric 'low'.*
- *Two alternative conceptualisations have been recently proposed by EMM (EMM 2022a) as an alternative to the synform: local faulting or a permeable Joe Joe Group acting as an underdrain. The local fault (or higher permeable zone) is conceptualised to cut across the Bandanna, Colinlea and Joe Joe Group mainly within the lease area.*

The table also states, under the heading of local groundwater flow:

Colinlea Sandstone: Groundwater flow converges towards bore C006P3R and is likely influenced by the local faulting/high permeable zone previously proposed.

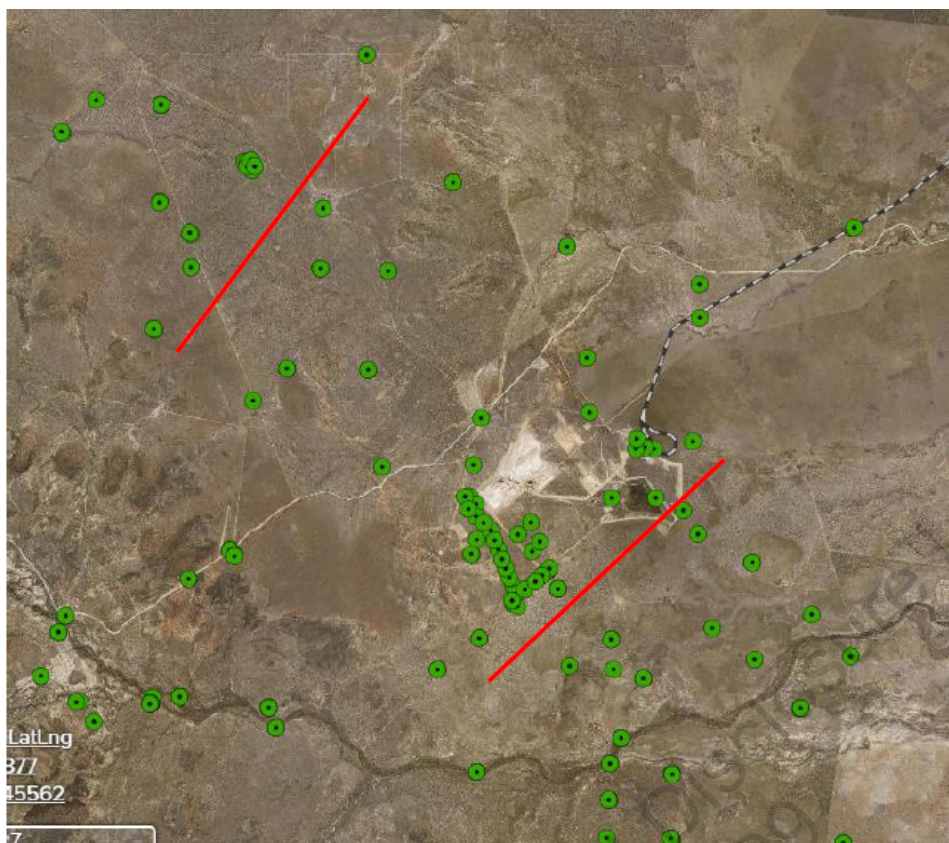
The synform theory is rejected as it does not account for the discharge of groundwater that would be required to cause these groundwater lows.

Whilst EMM have developed alternative conceptualisations they have not incorporated any of these potential discharge processes into the numerical groundwater model.

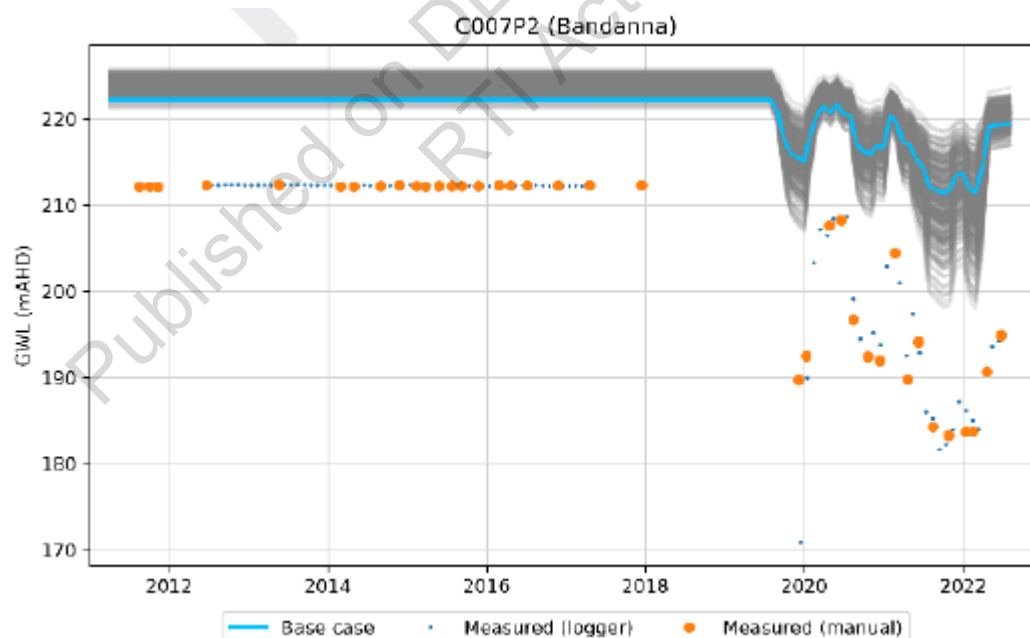
It appears that subsequently the model is unable to replicate these groundwater lows in this area in the pre mining period (pre 2019).

The model simulated initial heads for the calibration hydrographs as provided in Appendix C are therefore generally about 8 to 12 m higher than observed water levels in the Bandanna Formation and Colinlea Sandstone in this area. There are few Joe Joe bores in this area but in two bores located north-east of the current mining the initial heads are 7 m higher than observed water levels.

This is a poor representation of pre mining conditions and not a strong basis for model calibration and prediction in an area where dewatering conditions can provide excellent data for model calibration.

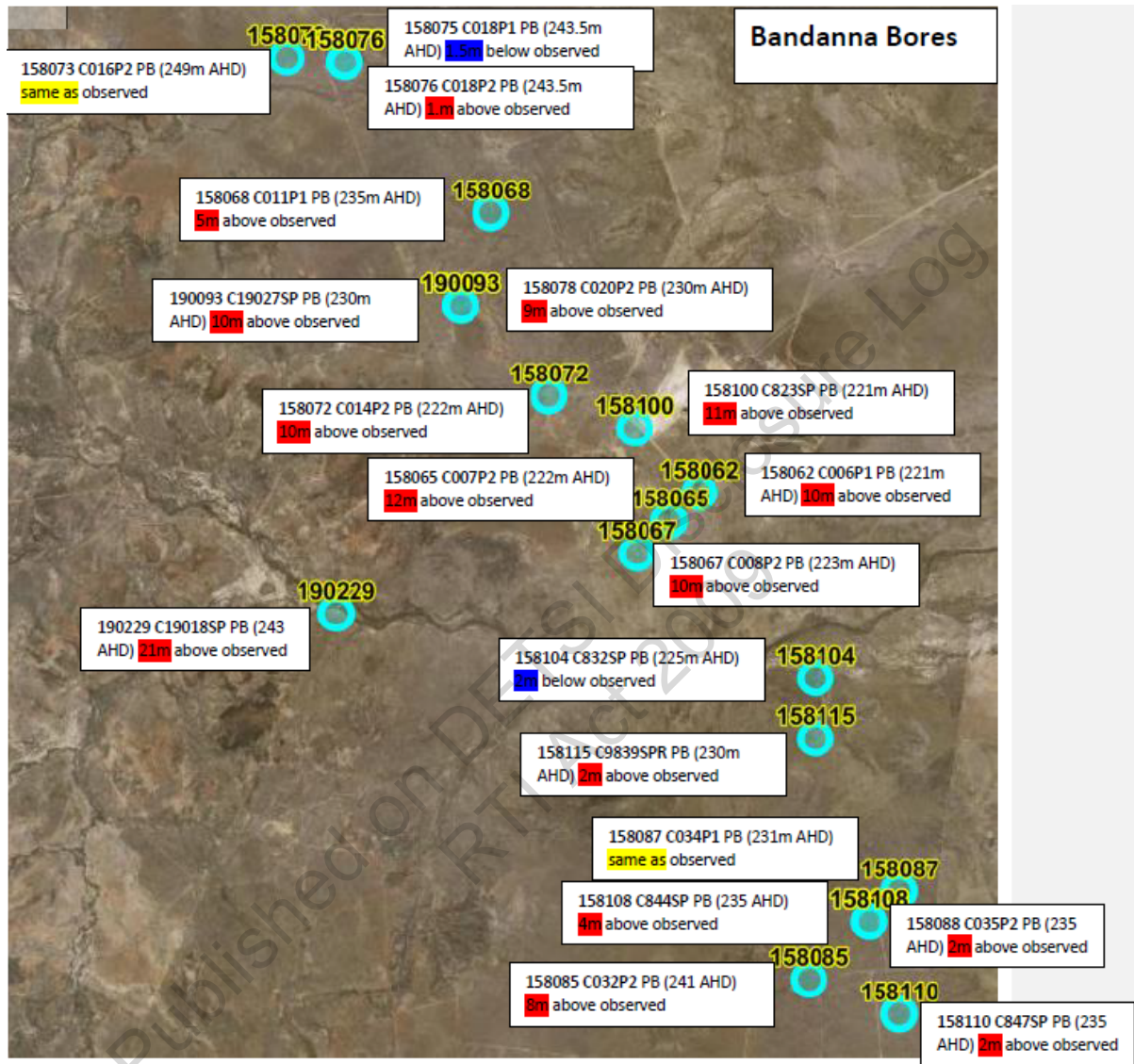


Red lines denote approximate area where model is predicting much higher initial heads than observed water levels in Bandanna, Colinlea and a couple of Joe Joe bores.



C007P2 - Example of an Appendix C calibration hydrograph where modelled initial heads are approx. 12 m higher than observed.

In each geologic unit the calibration hydrographs identified as representing that unit in Appendix C have been examined and an assessment of the variation between modelled base case initial head and observed water level made and then plotted on a map to understand spatial variation of these differences. An example is provided below for the Bandanna Formation. Similar figures are available in Appendix A for all geologic units except the Moolayember.



PB – Predicted Base case initial head

Initial Heads Alluvium

Appendix C contains 5 alluvial bores located in the Carmichael River alluvium. The base case initial heads for these five bores are between 6 and 12 m higher than observed water levels in these bores. This is a poor representation of the alluvial aquifer.

Modelled steady state contours are provided in the report for the Clematis Sandstone, AB Coal Seam and D Coal Seam only. It is not clear how the initial heads for the alluvium was determined.

Given this poor match between simulated and observed heads it is not clear how recharge and discharge processes in the alluvium will be impacted in the model, including its connectivity with Carmichael River surface flows, and how if at all the model can be used to provide commentary on environmental values associated with the river and the alluvium.

There is also concern about 5 other bores in Appendix C which are identified as being in the alluvium and may have been used in the model calibration. These bores appear to be in clayey material to the north of the Carmichael River and if they are in an alluvial aquifer it seems likely to be very poorly connected to the Carmichael River alluvium. Of these 5 bores in question 4 are always dry. It needs to be understood if these 5 bores have been used in the calibration process, if so that seems questionable.

Initial heads in Base Case Tertiary and Weathered Zone

Appendix C contains 5 bores identified as being in the Tertiary sediments only. The 4 northern bores have Base Case initial heads of between 3 and 12 m above observed water levels. The fifth bore, just south of Mellaluka Springs has an initial head 13 m lower than the observed water levels.

It is not clear how the initial heads were determined for the Tertiary sediments and it is not clear how those bores in Appendix C identified as monitoring the Tertiary and Joe Joe (composite) are used in the calibration process, i.e. representing which layer?

In the Weathered Zone, Appendix C contains 8 bores identified as being in the Weathered Zone. Three of these bores are always dry and it is not clear if they have been used for calibration purposes. Of the remaining 5 bores the model simulated initial heads for the Base Case are between 7 and 11 m higher than observed water levels. This would appear a poor match.

Initial Heads other geologic units/ other areas

Clematis- There is a generally fair to good match between initial heads and observed water levels.

Dunda Beds – There is a good match between initial heads and observed water levels.

Rewan Formation – There is generally a fair to good match in the upper Rewan between initial heads and observed water levels, particularly good near the Doongmabulla Springs. It is accepted that in parts of the Rewan, connectivity is poor and modelling of that connectivity can be challenging.

Joe Joe – Outside the area north of the river, previously discussed, the match between simulated initial heads and observed water levels is good.

Bandanna – outside the area north of the river, previously discussed, the match between simulated initial heads and observed water levels is fair to good. The exception is adjacent the Doongmabulla Springs and bore RN190229, C19018SP.

To develop steady state contours the bioregional assessment contours have been used (at DES' suggestion) to obtain regional water levels and in particular those off to the west. This appears to have resulted in an over estimation of initial heads at 190229, near Moses springs of 21 m.

The regional Bioregional Assessment contours in the Bandanna are primarily driven in this area by a drill stem test in coal seam gas exploration hole, Shoemaker No.1 (located 3.5 km north-west of 190229). It had an estimated head in the Bandanna of 245 m AHD. Given that the water level in an open monitoring bore (190229) is likely to be more accurate than that of a drill stem test, in a bore not primarily constructed to obtain water levels, it is considered that more weighting should be given to the water level in 190229 than Shoemaker No.1.

Colinlea- outside the area north of the river, previously discussed, the match between simulated initial heads and observed water levels is fair to good.

Ability to model dewatering impacts

The 2022 Annual Groundwater Monitoring report identified the following bores as being impacted from dewatering based on the observed water level trends in the bores.

Based on the calibration hydrographs provided in Appendix C a comparison of observed vs modelled water levels (Base Case) is provided below.

In summary the model base case may be slightly under predicting drawdown in bores in the AB seam, C Seam and D seam, close to the dewatering bores.

It also appears to have some difficulty predicting impacts in bores which are not directly accessing the seams and may be in less permeable interburden above or below the seams. In these instances (eg C006P1 and C834SP) there is evidence to suggest the model is slightly over estimating impacts.

Further from the dewatering the model appears to be predicting similar of slightly higher impacts then observed.

It is also noted that the base case simulated drawdowns are greater in C008P2 than in C007P2 when C008P2 is well west of C007P2 (adjacent a dewatering bore).

Bandanna

Bore Number	RN	Observed max DD (m)	Base case max DD	Simulated Initial head (Base Case) above observed (m)	Comments
C006P1	158062	8	19	10	Located in interburden above C seam. Has possibly led to underpredicted dd
C007P2	158065	30	10	10	AB Seam
C008P2	158067	25	20	10	AB Seam. Problem here in that more drawdown is predicted in the bore further away from dewatering than C007P2.
C823SP	158100	27	16	11	C seam

C832SP	158104	3	5	-2	C seam
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Colinlea

Bore Number	RN	Observed max DD (m)	Base case max DD	Simulated Initial head above observed (m)	Comments
C006P3R	158063	31	22	8	D Seam
C180112SP	158093	49	21	1	Sand below D seam
C827SP	158102	37	39	9	E Seam
C833SP	158105	5	5	-1	D Seam. Model not picking up differences in 833 and 834, different units different dd but model says the same.
C834SP	158106	2.5	5	0	Clay and siltstone below D seam
C840SP	158107	2	3.5	2	Sand below D seam
C19026SP	190091				Not used in calibration, replaces C007P3
C19029SP	190604				Not used in calibration, replaces C180114SP

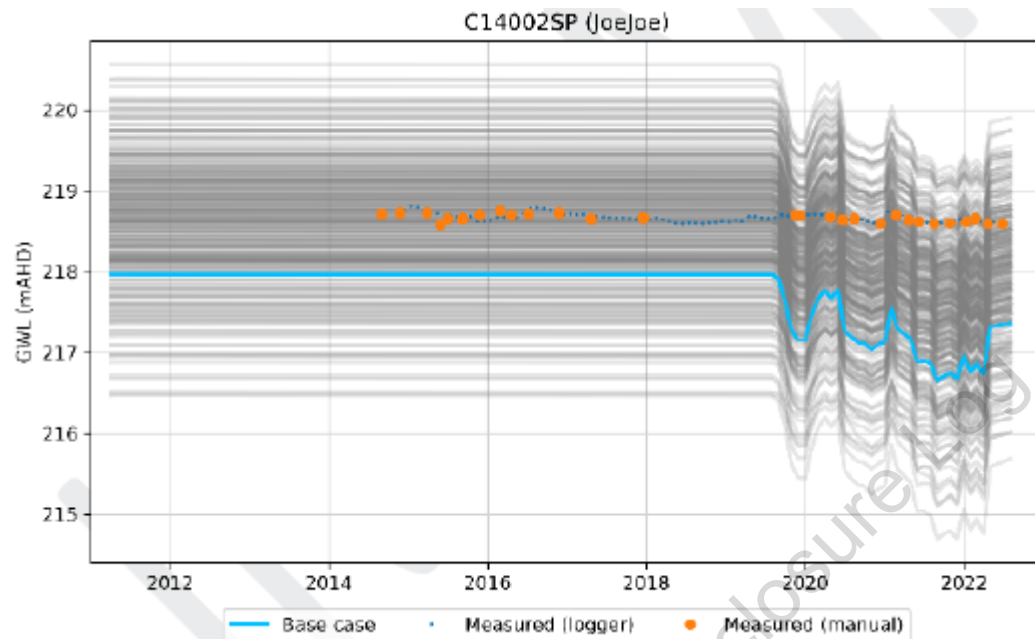
Overpredicting drawdown extent and drawdown

At the southern end of the lease there are predicted drawdowns in the Colinlea from dewatering when there are none observed (C19004SP and C19003SP). There are also predicted drawdowns in the Joe Joe, caused by dewatering, in a number of places in bores (south lease area and down towards Mellaluka Springs) when none had previously been considered to be occurring.

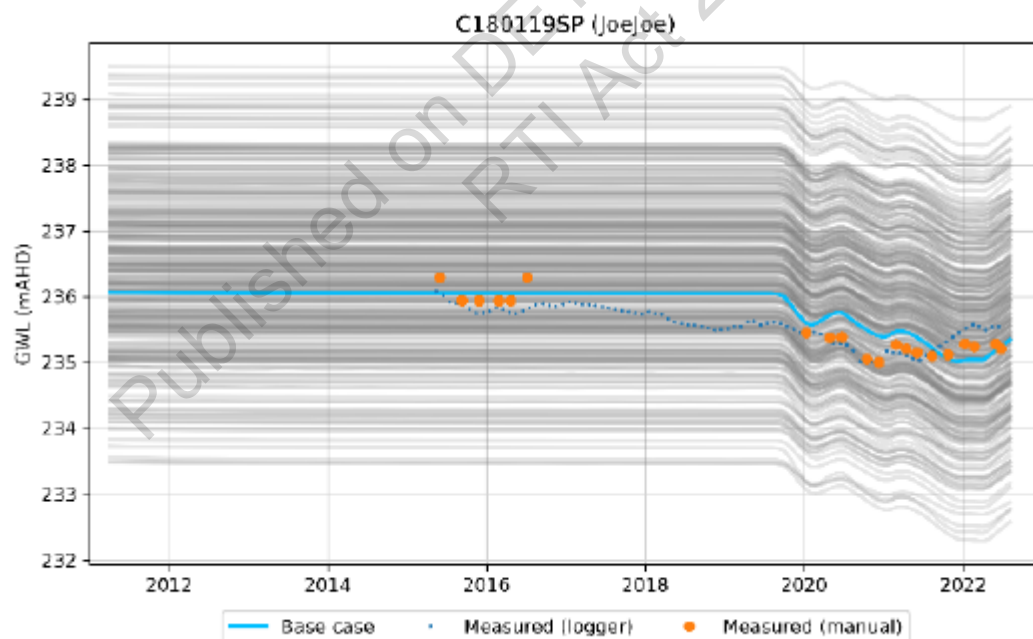
Part of the problem may be that there is some drawdown in some Joe Joe bores to the south caused by local landholder use and the model does not incorporate landholder use so it is trying to replicate the drawdown using dewatering impacts. Perhaps this problem could be addressed by incorporating some landholder use.

The other concern here is the significant increase in predicted impacts in a number of formations including the Joe Joe. In determination of previous groundwater level thresholds in Joe Joe bores adjacent Mellaluka Springs the maximum predicted drawdown had been determined to be less than 1 m. In the new model open cut only scenario, Appendix A in the GMMP Review report, the

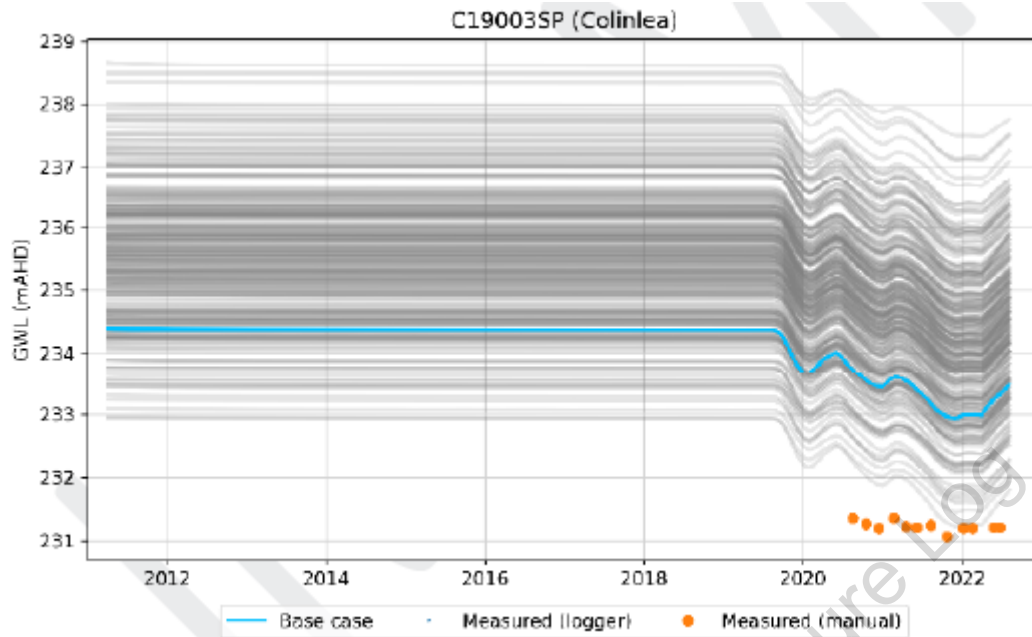
maximum predicted drawdown is now 60 to 80 m in these same Joe Joe bores. Is that realistic or has the model been unduly influence by not including landowner water use in this southern area.



RN165366 Joe Joe bore located south-east of current mining approx. 5 km from nearest dewatering bore. Predicted drawdown from mining when none occurring.



RN158096 Joe Joe bore located 21 km south of the Carmichael River. Some oscillation of observed groundwater levels is occurring and the model is simulating impacts from mining.



RN190228 Colinlea bore located on southern boundary of lease, 15 km south of Carmichael River. No apparent decline in observed groundwater levels and model is simulating impacts from mining.

Calibration Targets

Section 4.1.1 of the draft model report states:

A total of 11,443 history-matching targets were employed. These were subdivided into the following groups:

- 239 hydraulic head targets, grouped by HSU;
- 11,202 head-change targets, grouped by HSU; and
- 2 flux targets.

It is further stated that the weights of the hydraulic head targets were increased to double the relative computational effort towards matching absolute groundwater levels.

However, the number of heads targets vs head change targets is very low and it is not clear if the calibration process may be overly biased towards head change rather than a mixture of head change and absolute heads.

Dewatering Volumes used in modelling

Section 3.5.5 Mining Activities states:

i Production bores

The MODFLOW well (WEL) package is employed to simulate groundwater abstraction from mine dewatering bores. Measured groundwater abstraction for each bore is incorporated in the monthly stress periods in the history-matching period from August 2019 to March 2022 (Table 3.2).

On a number of occasions Bravus and EMM have been asked how they will attribute dewatering volumes to each layer in the model given the dewatering bores typically take water from multiple model layers. DES had been advised that this process would be explained in the model report. It does not appear to have been.

Uncertainty Analysis Presentation of Results

Appendix D provides hydrographs of predicted long term water levels for the Open Cut only scenario.

In the DSC springs the maximum predicted drawdown is about 0.10 m.

The presentation provided by Bravus on 31 January 2023 demonstrated that at an assortment of the DSC springs, in 0% of the predicted model runs the drawdown at these springs exceeded 0.2 m.

However, in section 5.1.1 of the model report, the subject of assessing the likelihood of drawdown, is discussed. Table 5.1, reproduced below provides explanation of the approach.

Table 5.1 Combined numeric, narrative, and visual approach for assessing the likelihood of drawdown

Percentile band (outcomes ranked from small to large)	Colour code	
<P10		It is very unlikely that drawdown exceeds the threshold
P10 to P33		It is unlikely that drawdown exceeds the threshold
P33 to P67		It is as likely as not the drawdown exceeds the threshold
P67 to P90		It is likely that drawdown exceeds the threshold
>P90		It is very likely that drawdown exceeds the threshold

The model report states:

the approach is based on Table 2 of the IESC guidance note on uncertainty analysis (Middlemis and Peeters 2018).

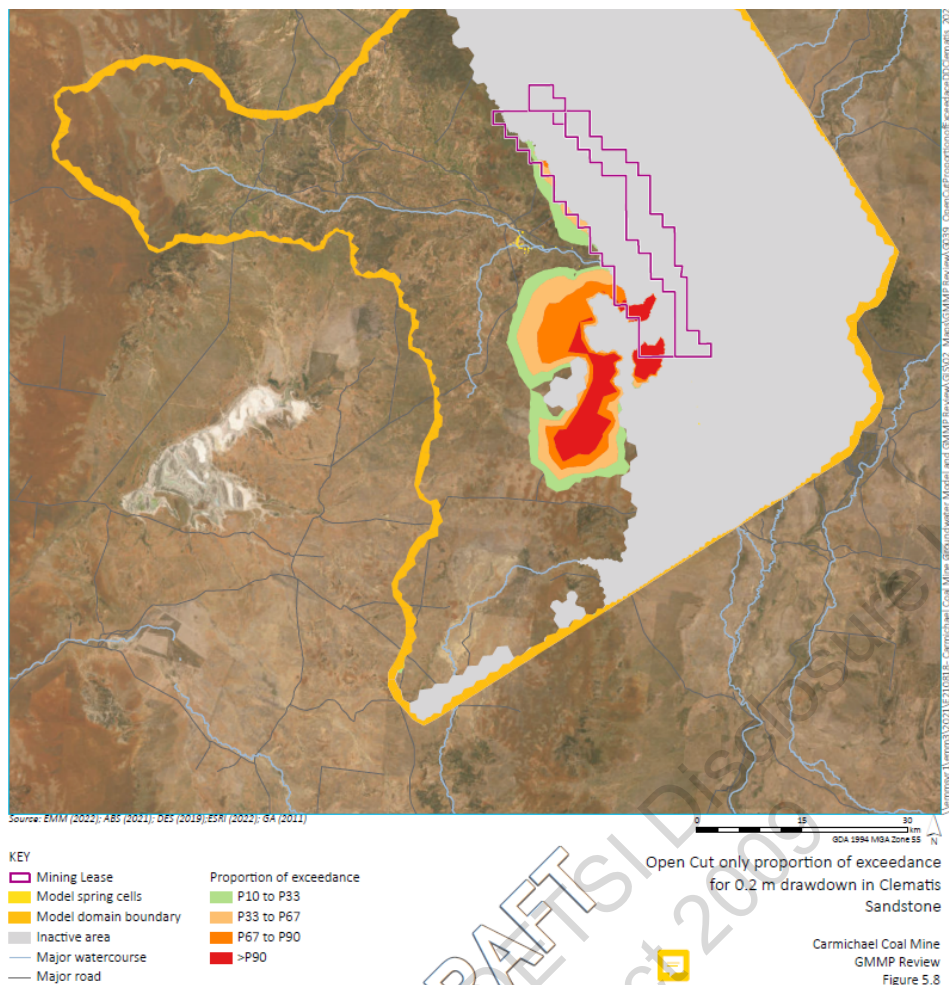
In Figure 5.8, reproduced below, the proportion of exceedance of 0.2 m drawdown (open cut only scenario) is mapped for the P10 to >P90 areas. Less than P10 is not mapped and it is not clear if everywhere else is inferred to be less than P10 or how that is interpreted.

As a result, the model report then states:

*Figure 5.8 shows the contour intervals for the likelihood of exceedance of the 0.2 m drawdown threshold in the Clematis Sandstone for the open cut only scenario. The 'very likely' region is in the south to southwest of the mine lease and away from sensitive receivers. **All DSC springs fall within the 'very unlikely' category, meaning that the springs are predicted to be under little risk of experiencing drawdown in breached of the drawdown threshold.***

This may just be a different way of presenting the same outcomes but it can be somewhat confusing or misleading to firstly see that none of the uncertainty runs are predicted to exceed a drawdown of 0.2m but then in the text of the report it says that it is very unlikely that drawdown will exceed 0.2m at the springs.

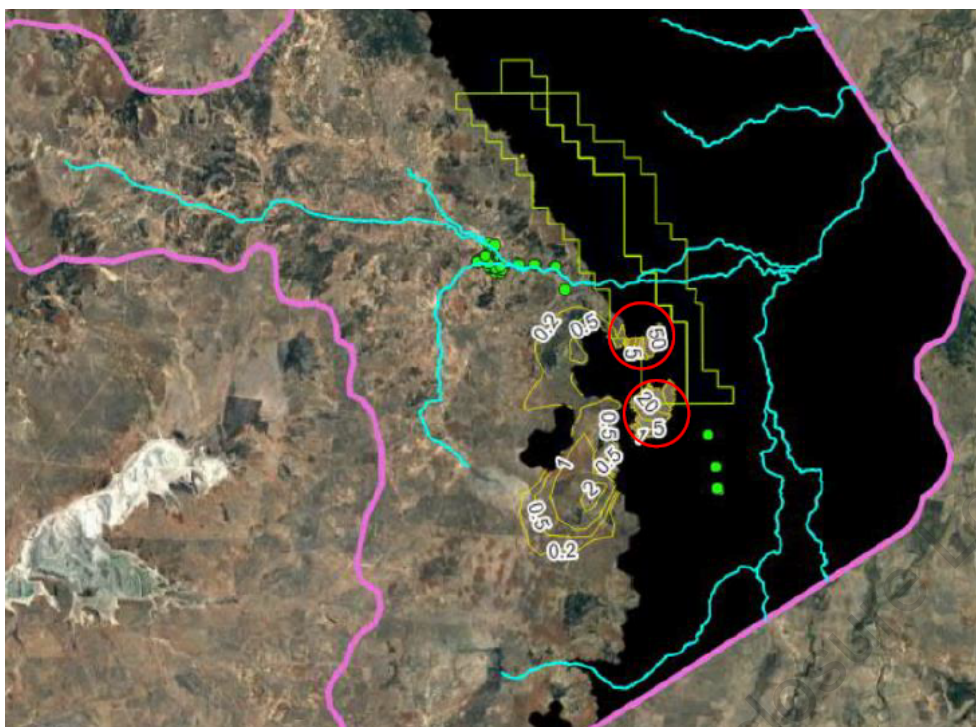
Further advice should be sought on this matter and possibly clarification of how the two pieces of information should be interpreted.



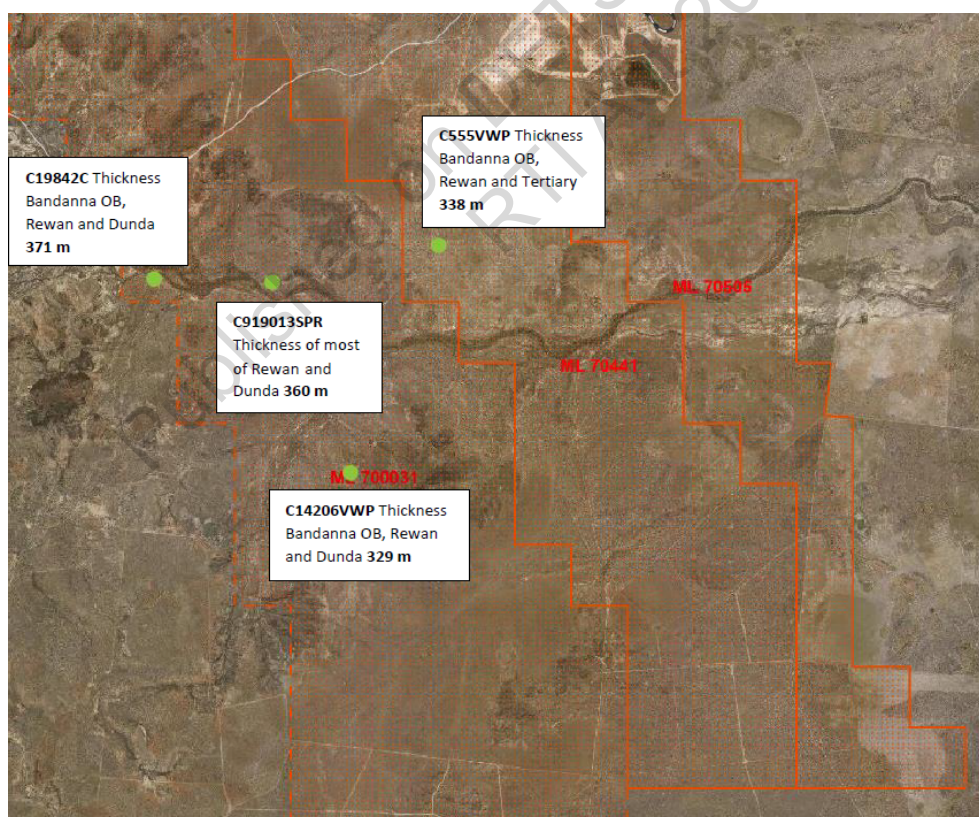
Geology, extent of Clematis and Dunda Beds

There is an area on the south-western edge of the mining lease where the extent of the Clematis Sandstone has been reinterpreted based on the Titus modelled geological layers. Some interpretation has occurred when using the geological layers to update the numerical model layers.

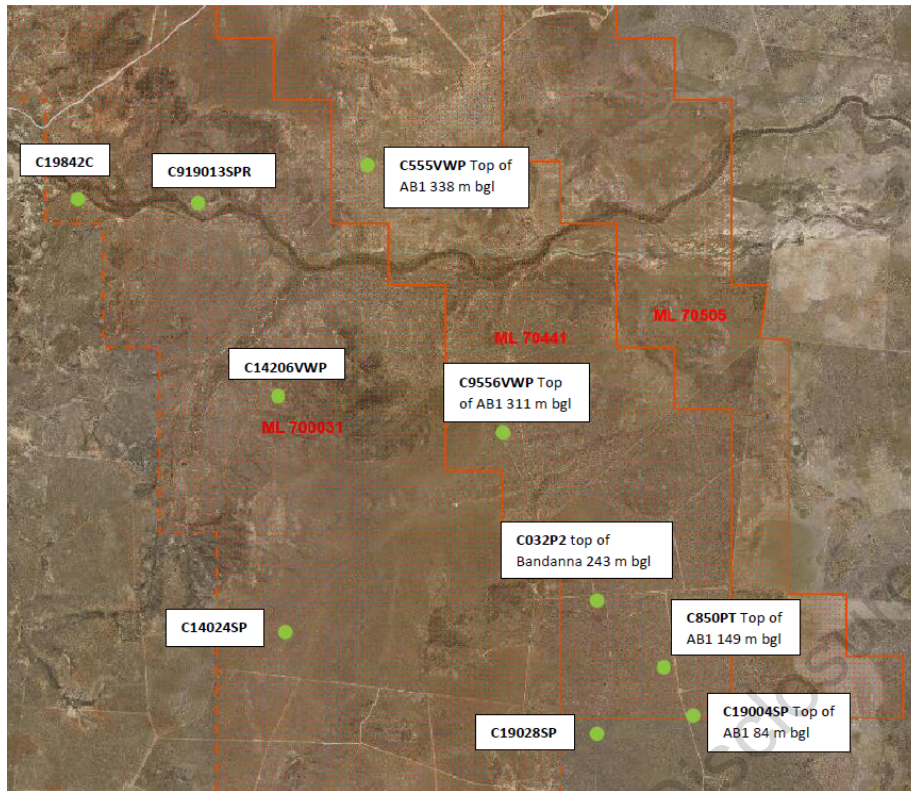
As a result, there are some narrow Clematis extents that are now predicted to intrude into the mining area, where previously they had not. This Clematis mapping was explored further.



The orange circles represent the areas of Clematis Sandstone which are now mapped and modelled as extending into and adjacent the lease area



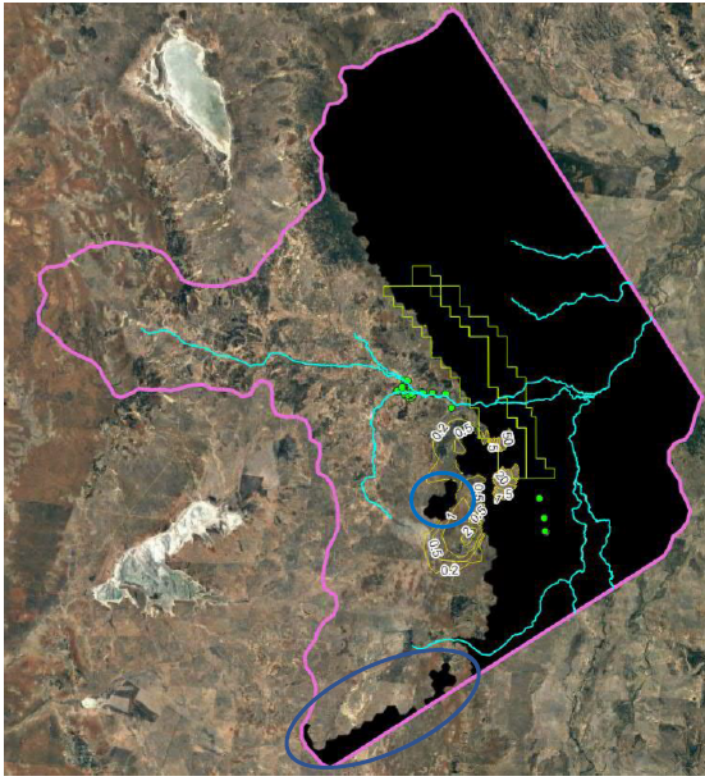
Determining average thickness of the Bandanna overburden (above AB seam) Rewan and Dunda Beds in the area, which is some 330 m in this area.



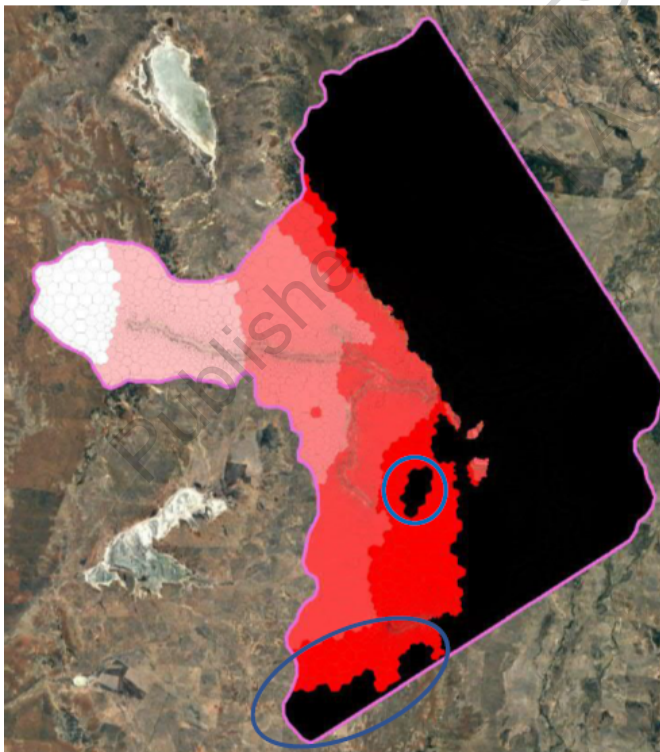
Determining depth to top of AB Seam in the south-western lease area

Based on the average depth of cover above the AB seam and the depth to the AB seam in this area, there appears to be no evidence of Clematis sandstone jutting out into the lease area as has been mapped. That needs review based on actual data.

Other areas of concern with Clematis and Dunda mapping



Clematis



Dunda

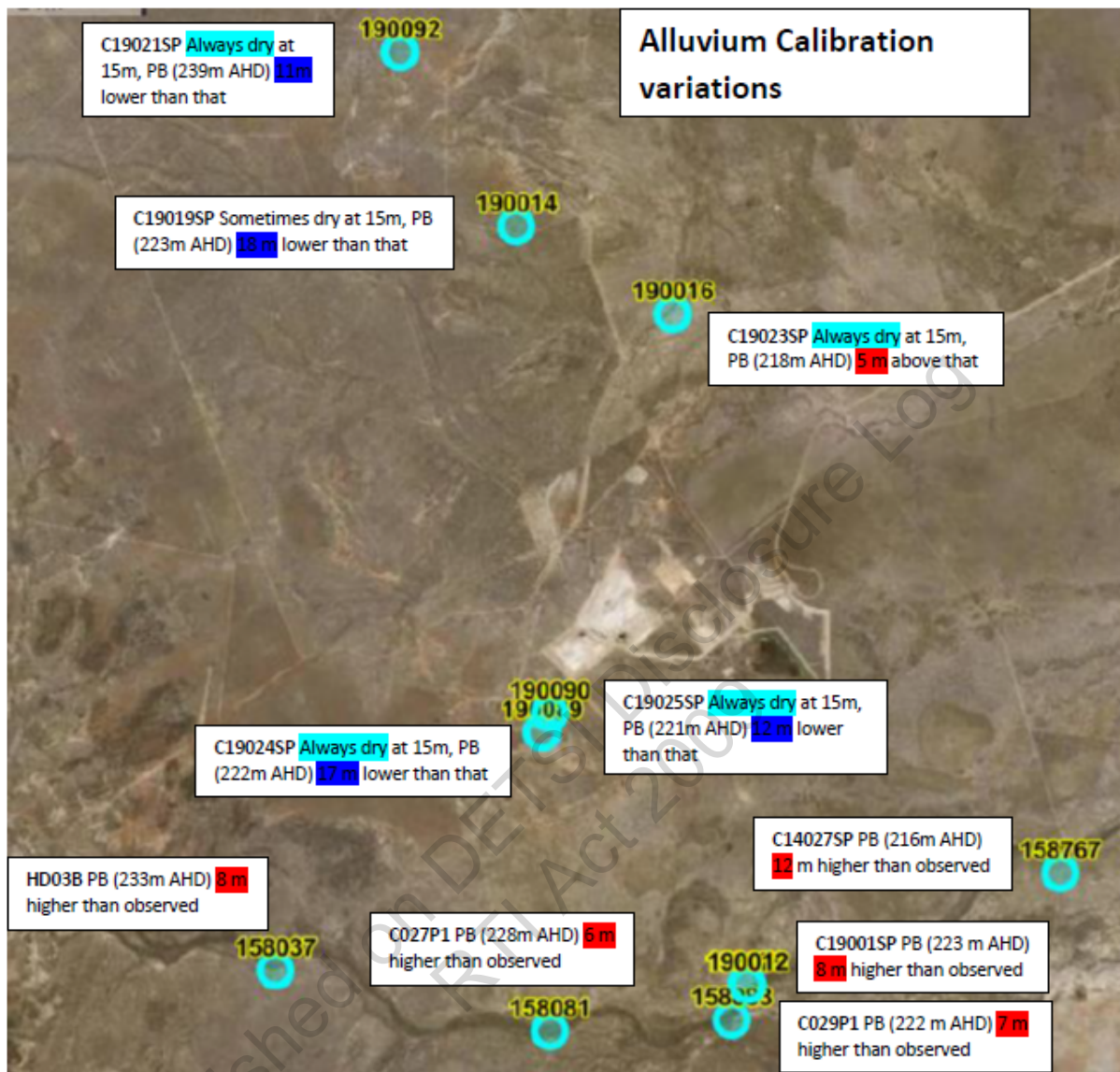
The circled areas show areas of apparent 'holes' in the Clematis and Dunda which are not supported by existing mapping available in the area.

Section 7, Summary and recommendations from the model report states the following:

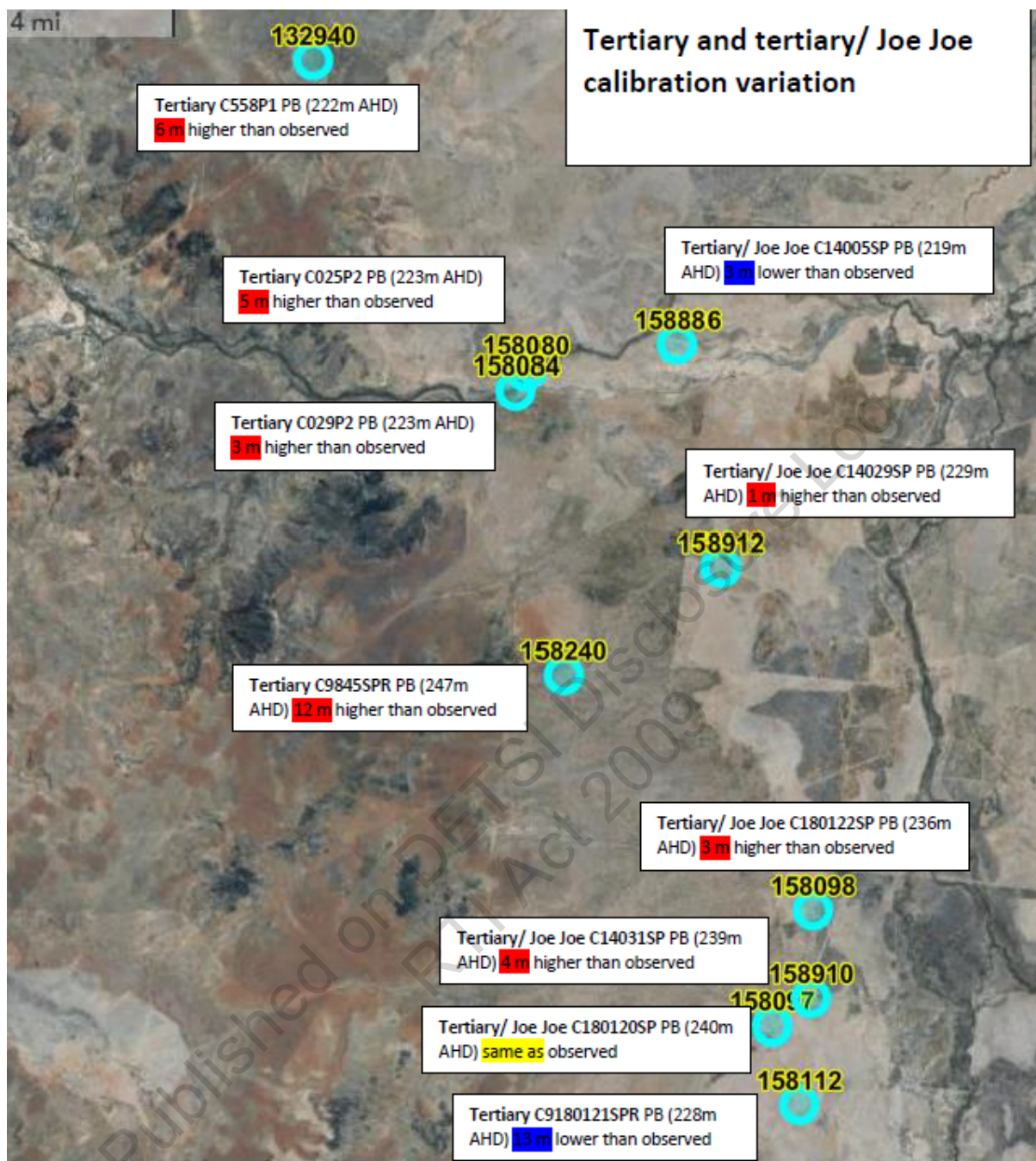
As noted by Murray (2022), tying in the local Rewan Research model to the Bioregional assessment model highlighted some very significant mismatches and worrying errors. Murray recommended that a full review of the broader Bio-regional assessment model is warranted.

This appears to be the problem with the holes identified in the maps above. It is noted that there is now a lot of additional data in this area including from CSG holes and it is considered that a more realistic representation of the Clematis extent could be provided in the model area than has been presented.

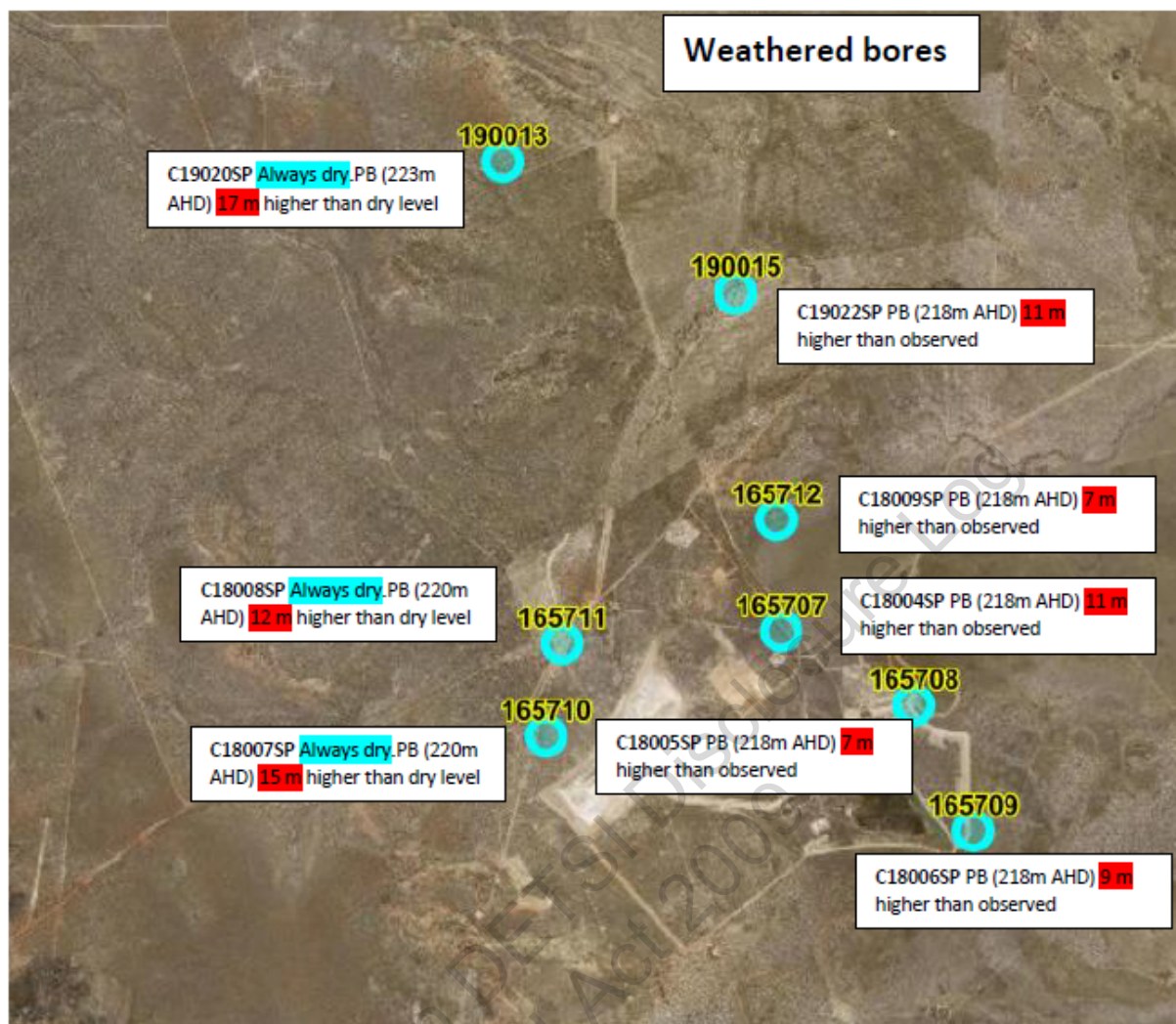
Appendix A

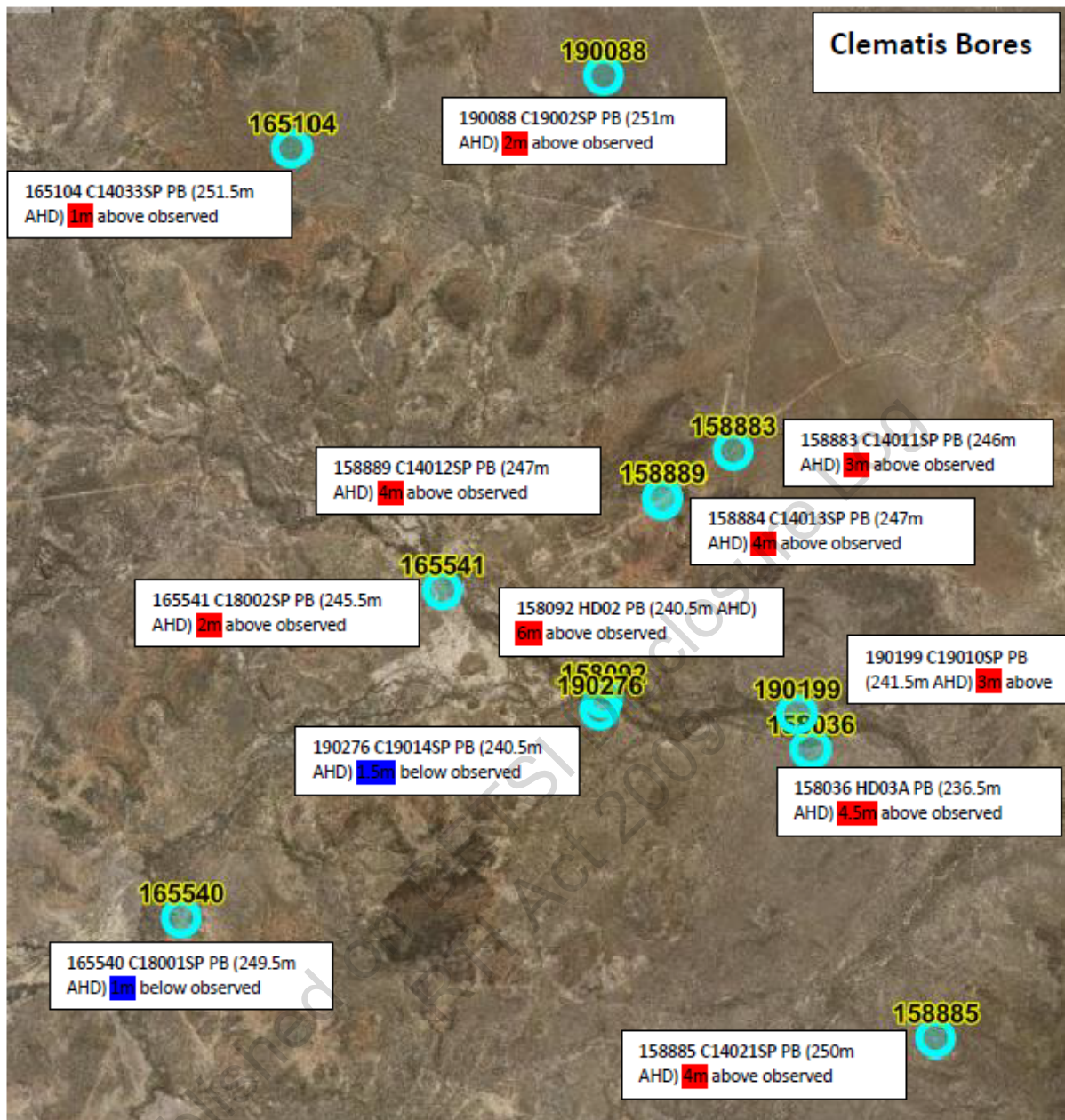


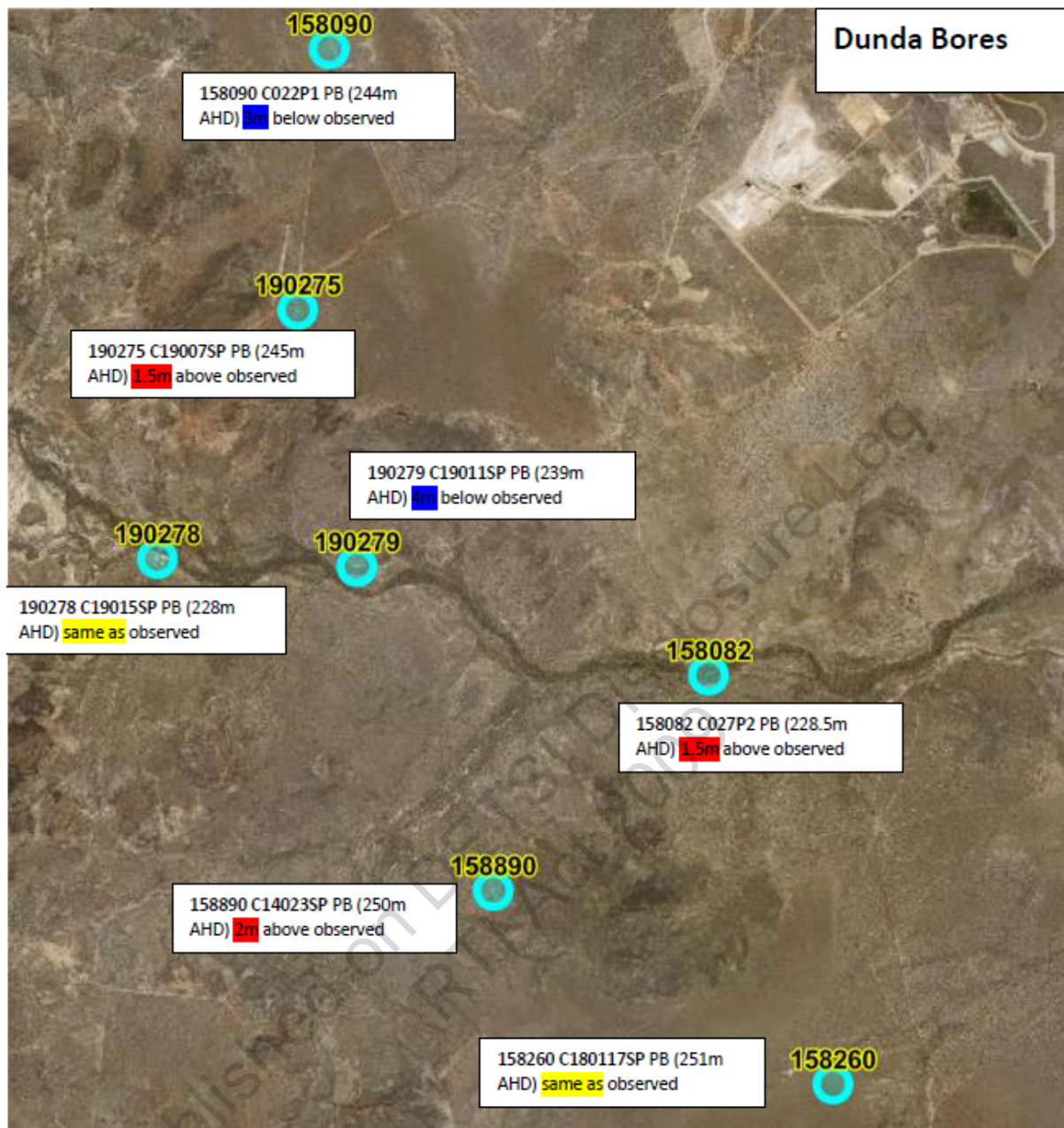
PB – Predicted Base Case initial head

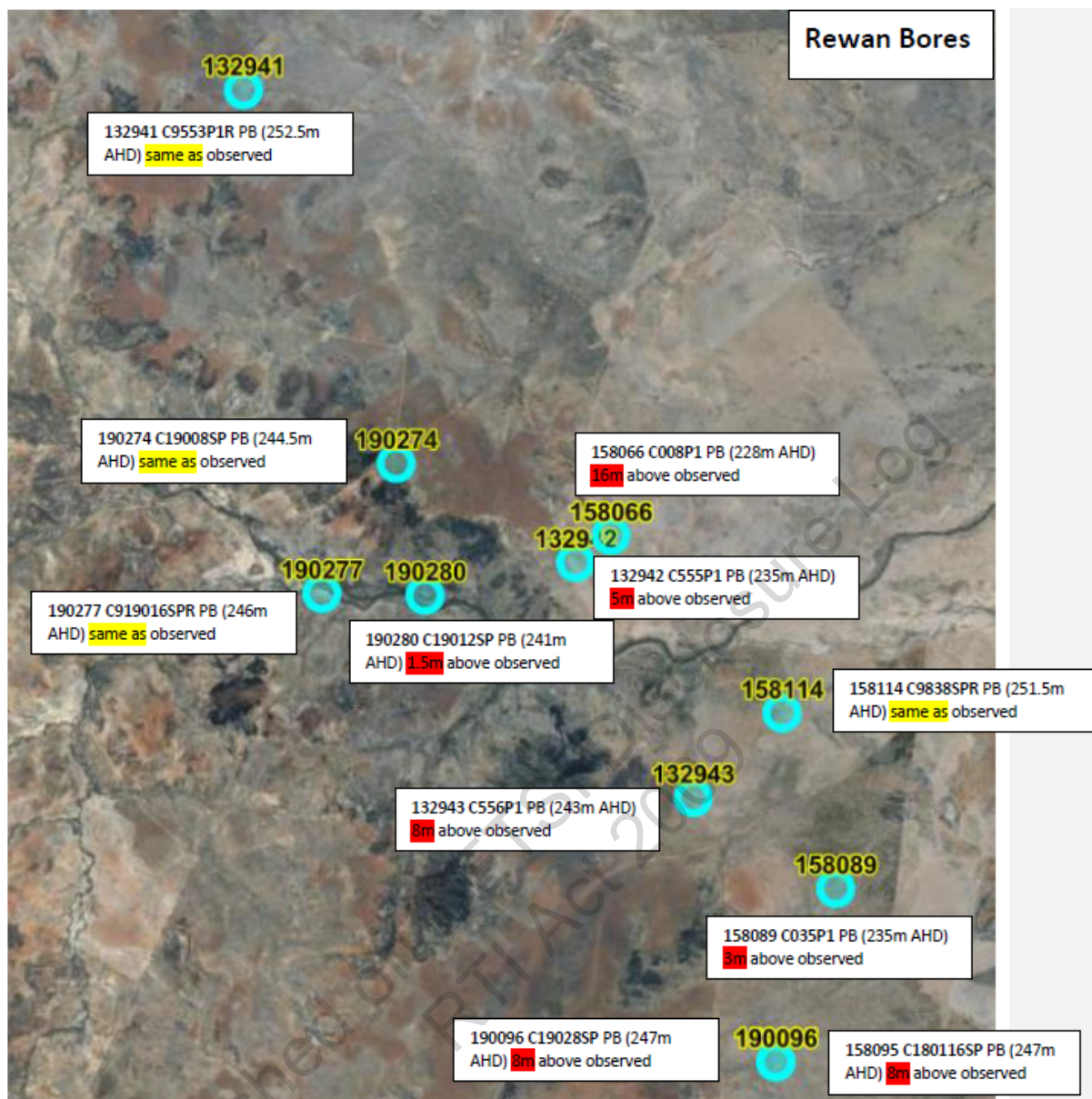


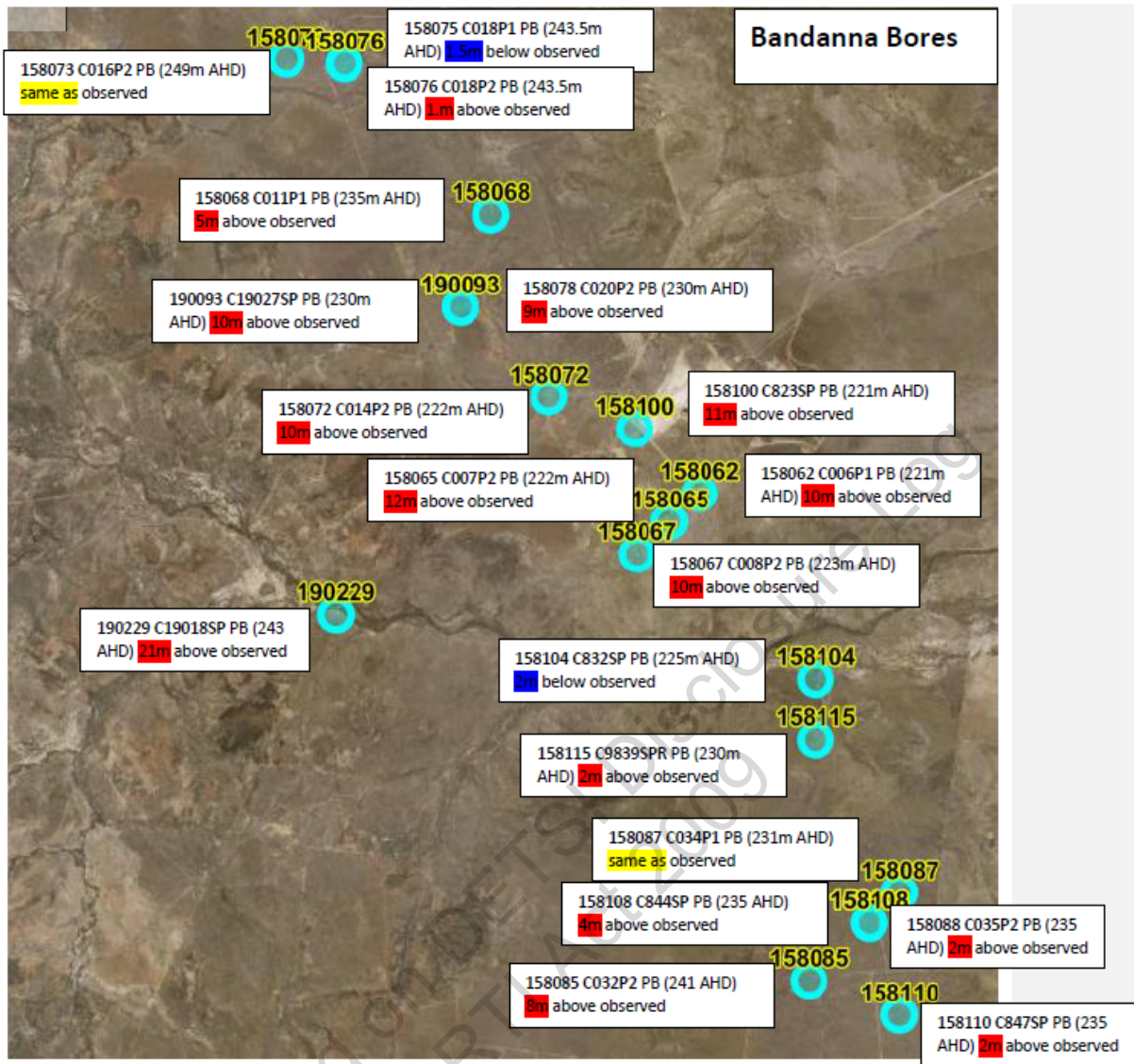
Two sets of bores, those representing the Tertiary Sediments and those accessing both Tertiary and Joe Joe described as composite in Appendix C and not clear what layer they represent in the model

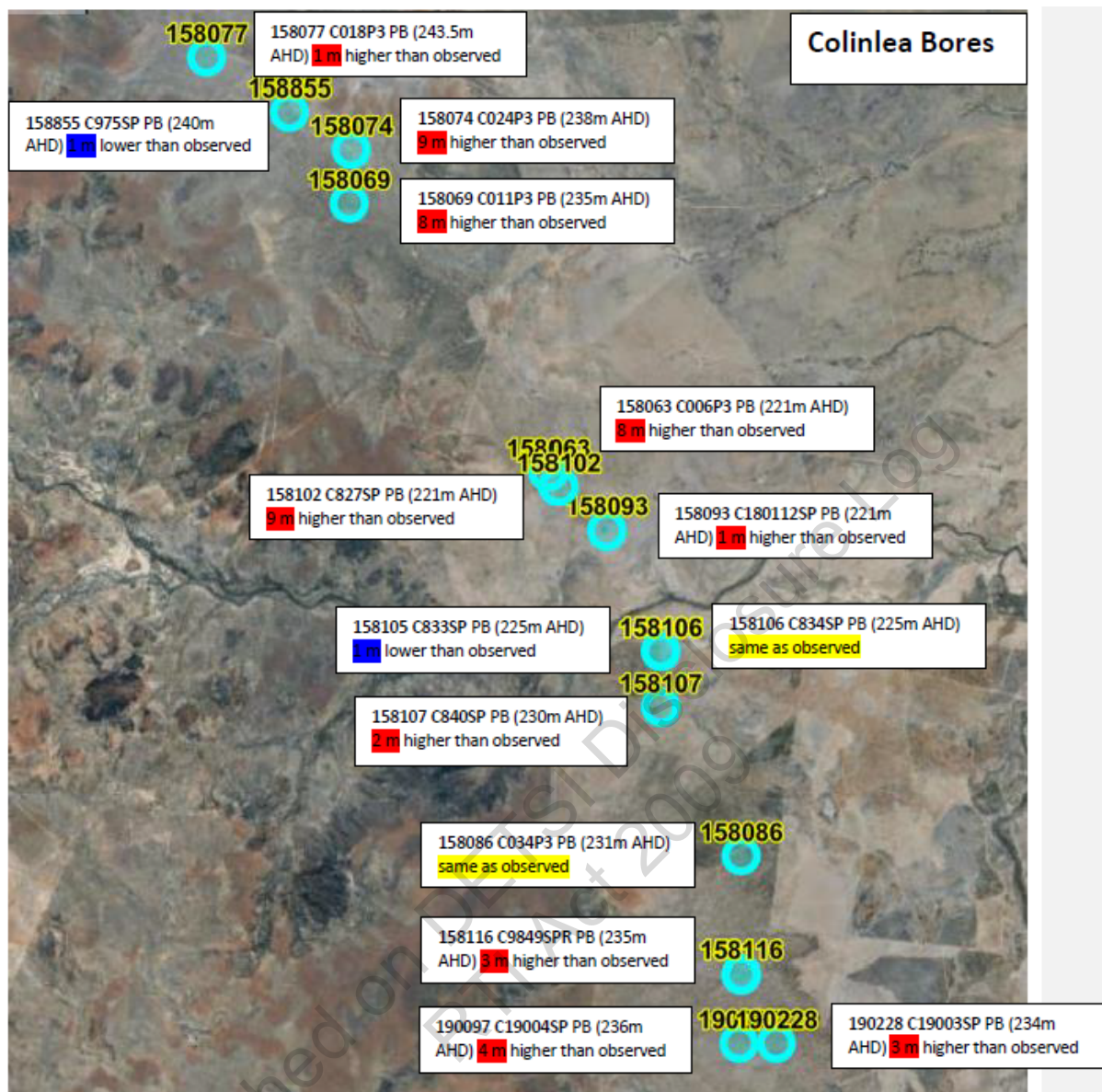




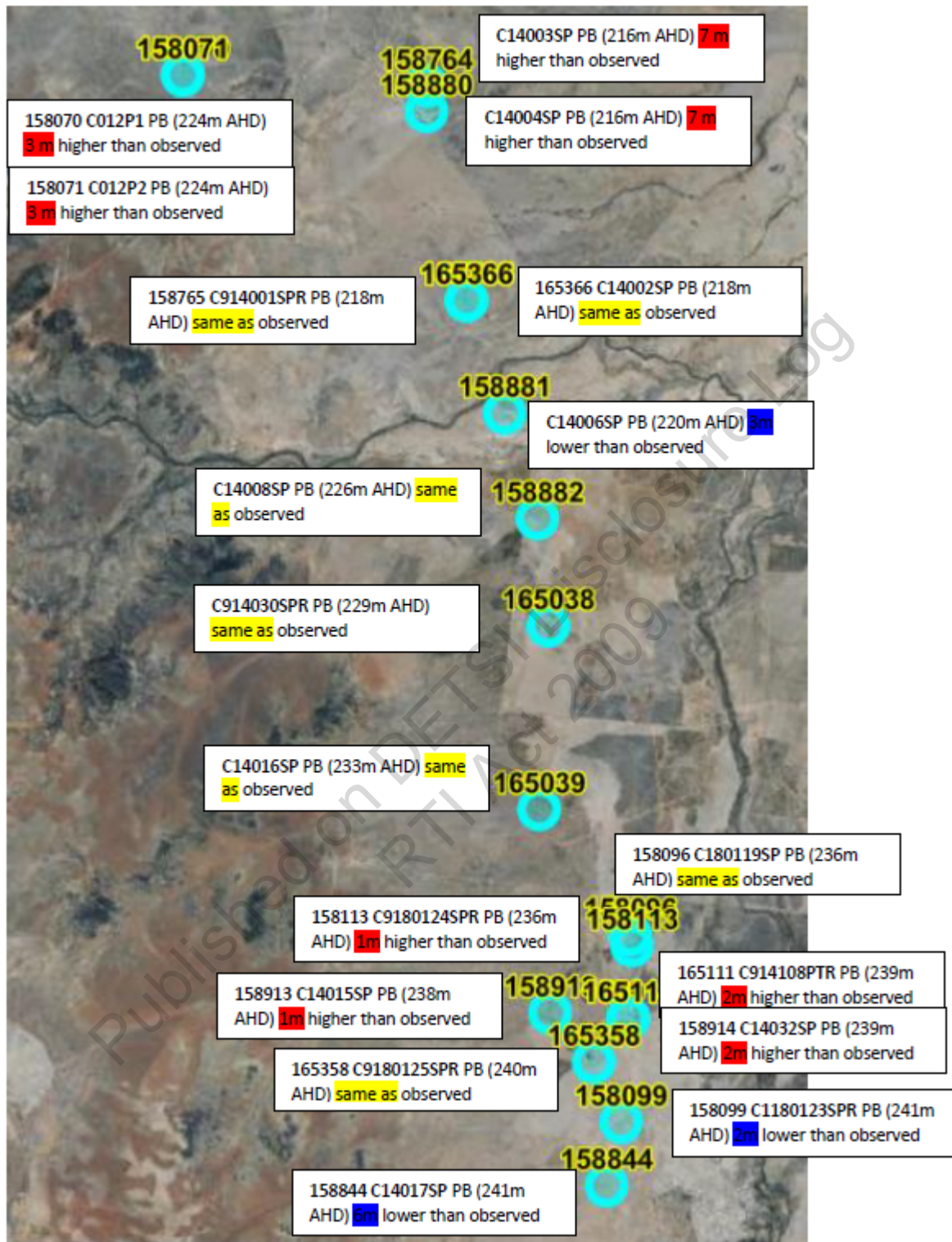








Joe Joe Bores



CSIRO/GA Questions

Model Report

1. Does the uncertainty analysis presented in the GW Review report meet the IESC guidelines and will it provide an acceptable/realistic range of potential impacts?
2. Is the methodology used to model the impacts of long wall mining under the SEIS B scenario adequate and appropriate, particularly with respect to prediction of impacts to the Doongmabulla Springs Complex?
3. Has the use of pilot points resulted in a more accurate representation of parameters instead of using one parameter value per layer?
4. Is the model cell size of 500m in the mining areas appropriate especially with respect to identifying longterm impacts from residual voids post mining?
5. Do the initial heads determined in the history matching process adequately represent the observed groundwater heads and groundwater system. In particular:
 - Does the model represent the pre mining groundwater lows observed north of the Carmichael River in the Bandanna Formation, Colinlea Sandstone and Joe Joe formation? Does the model incorporate findings from the conceptualisation?
 - Do the initial heads and simulated groundwater levels in the Carmichael River alluvium adequately represent that aquifer and if not, how might this affect the understanding of surface water-groundwater interaction? Has the use of dry bores north of the river affected the process?
 - Are the initial heads in the Tertiary sediments and Weathered zone representative of the observed groundwater system in these units? Has the use of dry bores in the Weathered zone affected the process?
 - Has the use of many more head change targets than absolute heads in the history matching process resulted in poorer matches between simulated initial heads and observed heads?
6. Has the modelling approach which does not include landholder water use from bores, in particular the Joe Joe to the south of the lease, resulted in predicted mining impacts in this area that match the head change targets?

The GMMP Review report, Appendix A now includes predicted drawdowns in Joe Joe formation bores in the Mellaluka Springs area of between 60 and 80 m for the open cut only scenario. This is an increase from previous predicted drawdowns (under the 2013 SEIS model) which were less than 1 m for these same bores. Are these increases realistic? Have they been influenced by the lack of landholder water use being included in the model in this area?
7. Does the modelling of the open cut mining only scenario (including parameters used and methodology of the uncertainty analysis) provide an appropriate level of confidence in the predicted impacts to DSC?
8. What additional geological work with respect to the extent of the Clematis Sandstone and Dundas Beds is required to improve the confidence in the modelling outputs for the optimisation model?

9. Have all the additional works as recommended by CSIRO/GA in 2019 been addressed (whether completed or not) to your satisfaction in particular to support the identification of the source(s) aquifer(s)?
10. Has sufficient isotopic work been undertaken to advance our understanding of the source aquifer? GABSprings Research Report 1.
11. What matters must be addressed to the model methodology prior to undertaking an Optimisation model of mining activities to ensure no greater than 0.2m drawdown at DSC?

GMMP report

1. Does CSIRO/GA support the use of GW thresholds based on the open cut only model scenario?
2. Do you support the Bravus proposed additional monitoring bores and locations? Do you support DES recommendations for additional bores? Any additional bores?
3. What action should be taken if the actual monitored rates of groundwater drawdown are faster than predicted?
4. In order to address ongoing and upward trending water quality trigger exceedances – what do you recommend as an appropriate action?
5. Please provide advice on the suitability and reliability of the use of VWP monitors.

Groundwater Management and Monitoring Program - Final Review Report

Carmichael Coal Mine and Rail Project

Prepared for Bravus Mining and Resources

January 2023

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1 Introduction

Bravus Mining and Resources (Bravus) has commenced development of the Carmichael Coal Mine located in the Galilee Basin, approximately 160 kilometres (km) northwest of Clermont in Central Queensland. The Carmichael Coal Mine and Rail Project was assessed by the Commonwealth and Queensland governments through an Environmental Impact Statement (EIS) process. Conditional approval of the Carmichael Coal Mine and Rail Project was granted by the Queensland Coordinator-General on 8 May 2014 and the Commonwealth Minister for the Environment on 14 October 2015 (EPBC 2010/5736). The Environmental Authority (EA) EPML01470513 for the Mining Leases (ML) 70441, 70505 and 70506 was initially granted on 2 February 2016 and further amended in September 2019, July 2020 and most recently April 2022.

A Groundwater Management and Monitoring Program (GMMP) has been prepared in accordance with EA Condition E4. Several iterations of the GMMP have been submitted for approval since 2017. The latest version of the GMMP (Version 11) was submitted and approved by the Department of Environment and Science (DES) in February 2021. The GMMP was also submitted to the Commonwealth department of Agriculture Water and Environment (DAWE) and approved (the version submitted to DAWE is referred to as GMMP Ver 11a).

As per EA Condition E5, the GMMP must be reviewed by a suitably qualified person with a draft GMMP review report provided to the administering authority by 10 October 2022. The draft GMMP review report was provided to DES on 10 October 2022 as required. DES have since reviewed the draft GMMP review report and provided comments via correspondence dated 13 December 2022.

As per EA Condition E6, a final GMMP review report must address any comments made by the administering authority and be submitted to the administering authority within three months of the draft GMMP review report submitted under condition E5. It is noted that the submission date for the final GMMP review report has been extended to 31 January 2023.

The purpose of this report is to meet the requirement of EA Condition E6 to provide a final GMMP review. A summary of responses to DES's comments and where they have been addressed within this report are provided in Appendix F.

The preparation of this report coincides with a review of the numerical groundwater model which is being used to predict groundwater drawdown for the following scenarios:

- Scenario 1: open-cut mining only. This scenario includes the simulation of the open cut pits only, with all underground mine workings excluded.
- Scenario 2: SEIS with previous fracturing assumptions. This scenario uses the updated model but assumes the same fracturing properties (fracturing height and properties multipliers) as the previous GHD 2013 SEIS model.
- Scenario 3: SEIS with updated fracturing assumptions. This scenario simulated the same mine plan as the SEIS, however the representation of fracturing properties above the longwall have been updated.

Additional information about the different modelling scenarios is included in the updated groundwater modelling report (EMM 2023).

It is noted that modelling Scenario 3 is predicting higher impacts at spring locations, especially due to underground mining, and further optimisation of the mine plan is required to limit spring impacts to less than 0.2 m. In the interim, it is recommended that drawdown predictions from model Scenario 1 (open-cut mining only) be used for the development of water level thresholds.

1.1 Suitably qualified reviewer

This review of the GMMP was undertaken by Bill Bull and Craig Vincent of EMM Consulting Pty Ltd (EMM). Craig holds the degree of Master of Science (with distinction) in Geology. Craig has 19 years of industry experience as a hydrogeologist and is a current member of the Australasian Institute of Geoscientists (AIG) and International Association of Hydrogeologists (IAH). Bill has 4 years of experience working as a hydrogeologist/geochemist with EMM.

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2 GMMP review requirements

2.1 EA requirements

Conditions E5 through to E8 of the EA states the following:

Condition E5

The GMMP must be reviewed and a draft GMMP Review Report finalised and provided to the administering authority for comment by **10 October 2022**, and every 5 years thereafter, or after every Groundwater model review undertaken as required by **Condition E9**.

Condition E6

A final GMMP Review Report must address any comments made by the administering authority and submitted to the administering authority within three months of the draft GMMP Review Report submitted under **Condition E5**.

Condition E7

The draft and final GMMP Review Reports required by **Conditions E5 and E6** must include:

- a) an assessment of the groundwater management and monitoring program against the objectives in **Condition E4**.
- b) an assessment of the GMMP against commitments in section 7 GMMP.
- c) a review of the adequacy of the monitoring locations, frequencies and groundwater quality triggers specified in **Tables E1 – Groundwater quality monitoring locations and frequency, Table E3 – Groundwater quality trigger levels and Table E4 – Groundwater level thresholds**; and
- d) a review of the validity of the groundwater monitoring program against the revised model predictions required under **Condition E9**.

Condition E8

Recommendations and certifications made within the final GMMP Review Report required by **Condition E6**, must be adopted by the environmental authority holder, and be updated within the GMMP for approval by the Administering Authority within three (3) months from the date the final GMMP Review Report is provided to the Administering Authority under **Condition E6**.

2.2 GMMP commitments

Section 7 of the GMMP outlines commitments which are required to be undertaken by Bravus. Four commitments (# 17, 23, 28 and 29) relate specifically to review of the GMMP and are detailed as follows:

17. Conduct a review of the monitoring data, using suitably qualified expert during the review of GMMP to be carried out before 1 July 2021 (or any other time frame as agreed with DES so as to align GMMP review and model re-run to happen concurrently) to update conceptualisations and conduct groundwater numerical model review based on these data.

- To allow for the correct scientific development of the GMMP it is considered (subject to agreement with DES) that the refinement and re-run of the model will occur prior to the update of the GMMP, as the model outputs and modifications can be captured in the GMMP.
- The model re-run is to occur 2 years after the commencement of the box cut and then every 5 years, the same review periods as the GMMP.

23. Include in the review of the GMMP an assessment of groundwater level and water quality data, and the suitability of the monitoring network, as per Condition E7¹. The GMMP will be reviewed by a suitably qualified person with a report provided on the outcome of the review to the administering authority by 1st July 2021. After the initial review, the review must be completed within three months of the second anniversary date of commencing box cut excavation and every 5 years following.

28. Initial review of the approved GMMP by an appropriately qualified person with a report provided on the outcome of the review to the administering authority by 1 July 2021 (or any other time frame as agreed with DES so as to align the GMMP review and model re-run to happen concurrently). After the initial review, the review will be conducted every five years following, the report provided to the administering authority.

29. The GMMP review will be conducted by 1 July 2021 (or any other time frame as agreed with DES so as to align the GMMP review and model re-run to happen concurrently). The revised GMMP will include statistical analysis of hydrochemistry and groundwater quality data.

- The next iteration of the GMMP (after 2 years of commencement of box cut excavation) will provide piper plots of the major ions for all hydrostratigraphic units included in the EA Conditions (Condition E3a), representative DSC springs, and the Carmichael River surface water.
- Contamination triggers and limits will be updated when the additional statistically sufficient pre-operational hydrochemistry data are collected. It is noted that several monitoring bores do not currently have the required number of analyses to calculate baseline trigger values and are using generic triggers derived from the ANZECC guidelines or average of bore specific data. Additional hydrochemistry results, allowing for the revision of trigger values, will be conducted according to the approach detailed in Section 5.4 of the GMMP.
- During GMMP review and groundwater model re-run consideration of potential impacts to relevant GDEs will be included when considering revision of trigger values.”

2.3 DES recommendations

Following review of the first GMMP review report (Adani 2020), which was submitted to the Department of Environment and Science (DES) on 24 June 2020, DES provided a list of recommendations to be addressed in future GMMP review reports. The DES recommendations are provided as follows:

1. A review of monitoring data (water quality and water level) collected under the GMMP. The monitoring data should be compared to triggers, limits and thresholds after each monitoring event. The annual review should determine potential impacts and emerging trends in the data with any downward groundwater level trends compared to modelled drawdown rates. If the actual monitored rates are faster than predicted, the review report should recommend a suitable update of the triggers in the GMMP.
2. Increasing trends in groundwater quality may provide early warning of triggers being approached and should be discussed in the GMMP review report.
3. The GMMP review report must provide the baseline and pre-impact water quality in a format that can be compared to future monitoring data eg time series plots.
4. The GMMP review report should include a review of the adequacy of groundwater monitoring locations, frequencies, groundwater quality trigger and water level thresholds.

¹ Commitment #23 from the GMMP originally refers to Condition E5. Due to an amendment to the EA in April 2022, the correct reference is now Condition E7.

5. The GMMP review report should provide piper plots of major ions for all hydrostratigraphic units and recommendations about revisions to the conceptual model (including isotope tracer results).
6. Detail isotope tracer studies used to characterise the groundwater dependent ecosystems.
7. The 2020 review report provides details of a number of new and replacement bores – 14 in total. The latitude and longitude of these bores should be provided in the review report to facilitate any necessary EA amendment to include these additional bores.
8. The location and target aquifer for all new bores should be detailed in the review report with a recommendation about any necessary EA amendments.
9. All exceedances in water quality triggers and limits should be discussed in the review report and recommendations of triggers that need to be revised should be detailed.
10. All five surface water gauging stations must be referred to in the review report for the GMMP with the data presented and interpreted.
11. The GMMP review report identifies inconsistencies in bore identification details. The review report should make recommendations about any necessary amendments to the GMMP and/or the EA.

2.4 Summary of GMMP review requirements

A summary of the various GMMP review requirements, and reference to where they have been addressed in the report are presented in Table 2.1. It is noted that several of the GMMP requirements mention that they are to be carried out before 1 July 2021, in reference to the previous GMMP review report (EMM 2021a). These requirements have been revisited in this review for completeness.

Table 2.1 Summary of GMMP review requirements and where addressed

Review requirement	Description	Relevant section of this report
EA requirement		
EA Condition E7(a)	Assessment of the groundwater management and monitoring plan against the objectives in Condition E4	Section 3.1, Table 3.1
EA Condition E7(b)	Assessment of the GMMP against commitments in section 7 of the administering authority approved GMMP	Section 3.4
EA Condition E7(c)	A review of the adequacy of the monitoring locations, frequencies and groundwater quality triggers specified in Tables E1, E3 and E4	Section 3.2
EA Condition E7(d)	A review of the validity of the groundwater monitoring program against the revised model predictions required under Condition E9	Section 3.3
GMMP commitments specific to GMMP review		
#17	Conduct a review of the monitoring data, using suitably qualified expert during the review of GMMP to be carried out before 1 July 2021.	Section 3.4.17 Section 3.5.1 (assessment of water quality and water level data)
#23	Include in the review of the GMMP an assessment of groundwater level and water quality data, and the suitability of the monitoring network, as per Condition E7.	Section 3.2 (suitability of monitoring network) Section 3.5.1 (assessment of water quality and water level data)
#28	Initial review of the approved GMMP by an appropriately qualified person with a report provided on the outcome of the review to the administering authority by 1 July 2021.	Section 1.1 (qualifications of reviewers)
#29	The GMMP review will be conducted by 1 July 2021. The revised GMMP will include statistical analysis of hydrochemistry and groundwater quality data.	Section 3.4.29
All other GMMP commitments		
#1 to #41	Commitments #1 to #41 as outlined in the GMMP	Section 3.4.1 to Section 3.4.41
GMMP Section 7.1.1	Springs, GDES and baseflow commitments	Section 3.4.42
GMMP Section 7.1.2	Monitoring program updates	Section 3.4.43

Table 2.1 Summary of GMMP review requirements and where addressed

Review requirement	Description	Relevant section of this report
DES recommendations		
#1	Review of monitoring data (water quality and water level) collected under the GMMP. The monitoring data should be compared to triggers, limits and thresholds after each monitoring event. The annual review should determine potential impacts and emerging trends in the data with any downwards groundwater level trends compared to modelled drawdown rates. If the actual monitored rates are faster than predicted, the review report should recommend a suitable update of the triggers in the GMMP.	Section 3.5.1
#2	Increasing trends in groundwater quality may provide early warning of triggers being approached and should be discussed in the GMMP review report.	Section 3.5.2
#3	The GMMP review report must provide the baseline and pre-impact water quality in a format that can be compared to future monitoring data, eg time series plots.	Section 3.5.3
#4	The GMMP review report should include a review of the adequacy of groundwater monitoring locations, frequencies, groundwater quality trigger and water level thresholds	Section 3.5.4
#5	The GMMP review report should include piper plots of major ions for all hydrostratigraphic units and recommendations about revisions to the conceptual model (including isotope tracer results).	Section 3.5.5
#6	Detail isotope tracer studies used to characterise the groundwater dependent ecosystems.	Section 3.5.6
#7	The 2020 review report provides details of a number of new and replacement bores – 14 in total. The latitude and longitude of these bores should be provided in the review report to facilitate any necessary EA amendment to include these additional bores.	Section 3.5.7
#8	The location and target aquifer for all new bores should be detailed in the review report with a recommendation about any necessary EA amendments.	Section 3.5.8
#9	All exceedances in water quality triggers and limits should be discussed in the review report and recommendations of triggers that need to be revised should be detailed	Section 3.5.9
#10	All five surface water gauging stations must be referred to in the review report for the GMMP with the data presented and interpreted.	Section 3.5.10
#11	The GMMP review report identifies inconsistencies in bore identification details. The review report should make recommendations about any necessary amendments to the GMMP and/or EA.	Section 3.5.11

3 GMMP review results

3.1 Assessment against objectives in EA condition E4

An assessment of the GMMP against the objectives in EA Condition E4 is summarised in Table 3.1.

Table 3.1 Assessment against objectives in EA condition E4

EA condition	Review outcome
The GMMP must be developed and implemented to meet the following objectives:	
a) Validation of the groundwater numerical model (including review of boundary and recharge conditions) to refine and confirm accuracy of groundwater impacts predicted;	<p>The GMMP has been prepared to facilitate validation of the groundwater numerical model (including review of boundary and recharge conditions) to refine and confirm accuracy of predicted groundwater impacts. The following have been included in the GMMP to meet the above requirement:</p> <ul style="list-style-type: none"> • A comprehensive groundwater monitoring network has been designed and implemented for conducting regular groundwater monitoring to collect continuous data on water levels and water quality parameters for both construction and operational phases of the Project. Groundwater data collection from monitoring bores commenced January 2020. Periodic bi-monthly groundwater monitoring commenced April 2020 and will be continuing through all phases of mining (Section 6.1 to 6.3 of GMMP). • The monitoring data collected to date is being used for updating and validating the numerical groundwater model. This includes the comparison of predicted and actual drawdowns to confirm the accuracy of the predicted groundwater impacts. • A review of boundary and recharge conditions is also being conducted as part of the groundwater model update.
b) The groundwater monitoring bore locations and purpose for each bore;	<p>Baseline groundwater monitoring bore locations and purposes are outlined in Table 26 of the GMMP (Section 3.1.2). Spearpoint bores C18010SP, C18011SP, C18012SP, C18013SP and C18014SP are detailed in Table 40 of the GMMP while seepage bores C18004SP, C18005SP, C18006SP, C18007SP, C18008SP and C18009SP are described in Table 62 of the GMMP. Bores that have been installed since the last revision of the GMMP are detailed in Table 3.3 and should be included in the next GMMP update.</p> <p>It is noted that bore C14014SP has been renamed to C914108PTR and should be updated in the GMMP.</p>
c) Groundwater level monitoring in all identified geological units present across and adjacent to the mine site to confirm existing groundwater flow patterns and monitor drawdown impacts;	<p>A comprehensive groundwater monitoring network has been designed for conducting regular groundwater monitoring of water levels and water quality in all identified geological units present across and adjacent to the mine site and included in the GMMP. This monitoring will help to confirm existing groundwater flow patterns and to monitor drawdown impacts. Baseline monitoring was undertaken between 2011 and 2017. Further monitoring commenced in January 2020 and will be continued through all phases of mining.</p>
d) Identification of groundwater drawdown level thresholds for monitoring the impacts to Groundwater Dependant Ecosystems (including spring complexes and Carmichael River alluvium);	<p>Groundwater drawdown level thresholds were developed for 48 monitoring locations and included in the GMMP for monitoring of potential impacts to Groundwater Dependant Ecosystems (including spring complexes and Carmichael River alluvium). These thresholds have since been revised based on results from the updated numerical model (updated in 2023). A summary of the revised threshold values to be incorporated into a future revision of the GMMP is presented in Table A.1, Appendix A.</p> <p>All future monitoring data will be compared against the thresholds to check for exceedances (Section 5.0 of GMMP).</p>

Table 3.1 **Assessment against objectives in EA condition E4**

EA condition	Review outcome
e) Monitoring of aquifers in the area to the south of the mining lease that may affect the Mellaluka springs;	<p>Several groundwater monitoring bores screened across the Joe Joe Group and Tertiary sediments are present in the south of the mining lease to monitor for potential impacts to the Mellaluka Springs Complex. Monitoring bores details are presented in Section 5.3.4 of GMMP.</p> <p>Groundwater levels in the Bandanna Formation and Rewan Group are also measured south of the mining lease via vibrating wire piezometer (VWP) C14200VWP.</p>
f) Identifying and refining potential impacts on groundwater levels in the Great Artesian Basin Clematis Sandstone and Dunda Beds geological units;	<p>A bore network is established to monitor the groundwater levels in the Great Artesian Basin Clematis Sandstone and Dunda Beds geological units. Further additional networks of bores have been installed during 2020. Monitoring at these new bores commenced in January 2020, and data collected will be used for identifying and refining potential impacts (see Section 5.3 and 6.2 of GMMP).</p>
g) Estimation of groundwater inflow to mine workings and surface water ingress to groundwater from flooding events using the groundwater model;	<p>Bravus has commenced monitoring of groundwater and surface water flows. Bravus has completed the servicing of existing flow gauging stations on the Carmichael River (Stations BEL01, BEL02, CAR04, CAR01 and CAR02). These flow gauging stations have been operational since September 2019 and January 2020. Bravus has also commissioned a further two flow gauging stations on Carmichael River (Stations –Moray West and Albinia stations) which have been operational since January 2021.</p> <p>The numerical groundwater model is currently undergoing review using the monitoring data plus measured mine dewatering volumes, to meet the commitment of model revision within two (2) years of the box cut excavation. The model will undergo review at least every 5 years going forward.</p> <p>Assessment of surface water-groundwater interaction has been included in the groundwater numerical model and will be refined overtime, based on groundwater and surface water monitoring data.</p>
h) Monitoring in any identified source aquifers for alternative water supplies, relevant to any approval issued under the Water Act 2000 for the project;	<p>Two additional bores have been installed for collection of groundwater data to facilitate the model refinement and to better assess the sub-E sediments below the coal seams. Monitoring has commenced at these two bores and a pumping test has been performed on one of them. Additional investigations will be carried out in future at these bores to provide information regarding the groundwater potential within the sub-E coal seam sediments, which could be used as Make-Good groundwater supplies (Section 3.5.3 and Section 6.2 of GMMP).</p>
i) Identify groundwater quality triggers for monitoring potential impacts to groundwater quality from mining activities;	<p>Bore-specific groundwater quality triggers are described in Section 5.4 of the GMMP. Groundwater quality triggers for most monitoring bores were recently updated in consultation with DES and are included in Table E3 of the amended EA (19 April 2022). These updated trigger levels should be incorporated into the next GMMP revision.</p> <p>A discussion of the adequacy of water quality triggers and suggested changes are presented in Section 3.2 of this review.</p>
j) Monitoring water level and water quality of geological units throughout all phases of mining operations including for the period post-closure and until surrender of this environmental authority;	<p>Monitoring recommendations and commitments have been compiled for all phases of mine life, including baseline, construction, operations, and post-closure (Section 6.0 of GMMP).</p>

Table 3.1 Assessment against objectives in EA condition E4

EA condition	Review outcome
k) Identifying monitoring bores that will be replaced due to mining activities; and	<p>The GMMP includes the commitment to augment and modify the groundwater monitoring bore network in line with the mine plan and activities. Bravus has installed an additional 15 bores for monitoring groundwater level and quality near the proposed infrastructure facilities since 2018.</p> <p>Bores identified in the GMMP for Operational Phase are based on the first five years of mining, and the Operational Monitoring network will be revised due to decommissioning of some bores (see GMMP Section 6.2). Bore C823SP has been decommissioned since the publication of the current GMMP.</p>
l) Identify, monitor and mitigate potential groundwater impacts, including groundwater level and quality, from mine dewatering and mine water and waste storage facilities (artificial recharge).	<p>Bravus has commenced monitoring for the compilation of sufficient, spatially and geological unit-wise, groundwater monitoring data to adequately assess potential impacts from mine-dewatering and mine affected water and waste storage facilities and in turn are identifying, mitigating, and monitoring impacts (see Section 6.2 of GMMP). This includes six bores installed in 2018: C18007SP and C18008SP (which have been dry), C18004SP (Weathered Tertiary), C18005SP (Weathered Tertiary), C18006SP (Weathered Tertiary) and C18009SP (Weathered Tertiary), which are monitored under the GMMP. Trigger values have been derived for the four bores with water quality measurements (ten rounds of monitoring) following the methods outlined in the GMMP ver.11 (Section 5.4). These triggers have been included in Table E3 of the April 2022 EA and should be incorporated into the next GMMP revision.</p>

3.2 Review of the adequacy of the groundwater monitoring locations, frequencies, and groundwater quality triggers specified in Table E1, E3 and E4 of the EA

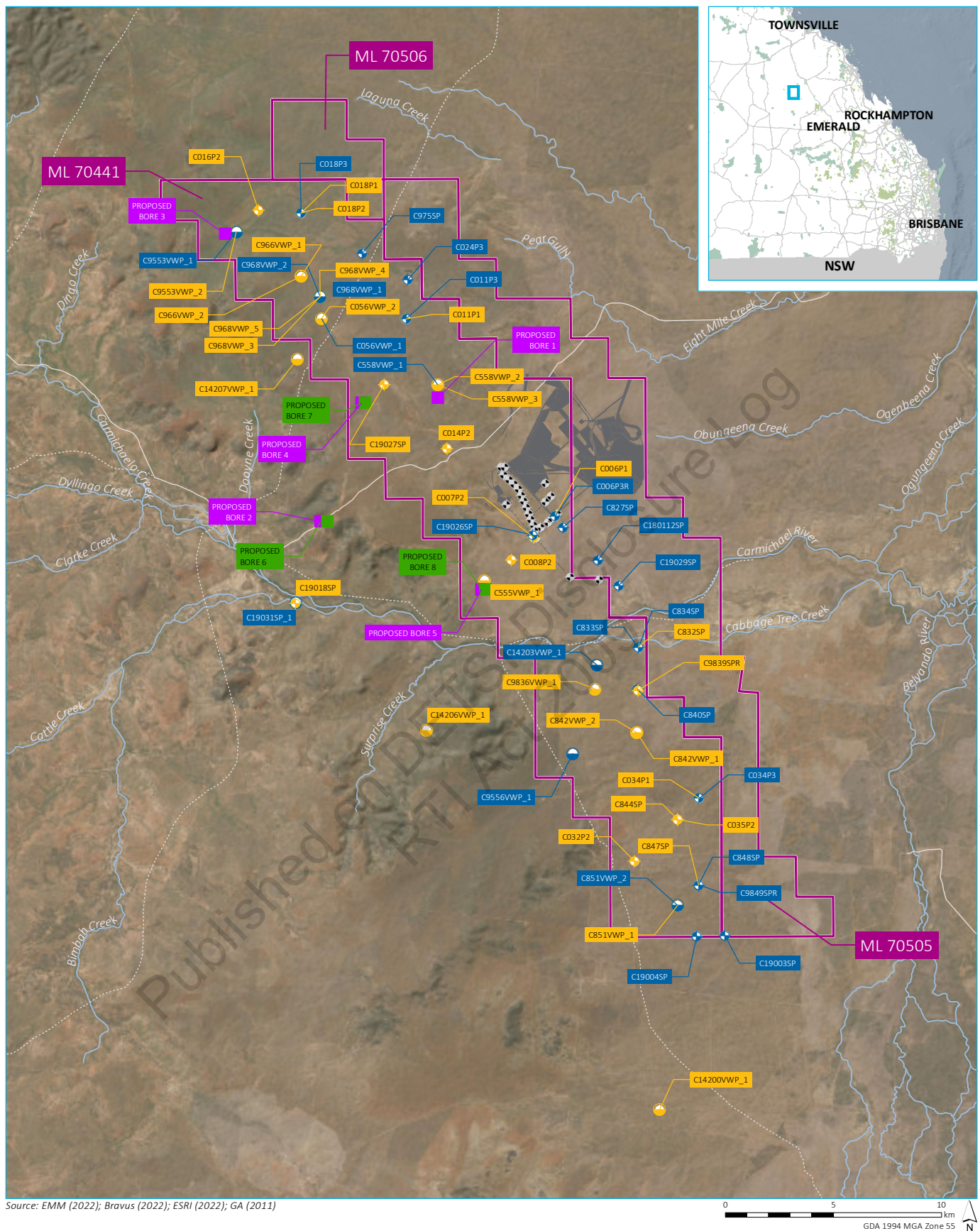
The groundwater monitoring network contains a number of monitoring locations screened within the major hydrostratigraphic units of concern to the Project and allows for both spatial and temporal variations in water level and water quality to be assessed. The bore monitoring network has been established in consultation with DES. Since publication of the GMMP, Bravus have serviced all bores and renovated some of the bores in the network, including the replacement of six blocked groundwater bores, and have commissioned additional monitoring bores.

Monitoring frequency is every two months, in accordance with the EA conditions, which require the monitoring frequency to be at least every two to three months, and provides six sets of water quality data for the groundwater bores and spring samples in one year. This is adequate to provide 12 datasets over the two years following commencement of the monitoring program (as per the GMMP) and given the logistics of laboratory analysis (including QA/QC procedures, such as holding times) is a reasonable frequency of sampling. This monitoring frequency is expected to continue until the approval of the revised GMMP (nominally May 2023) when quarterly sampling is likely to be implemented.

3.2.1 Groundwater monitoring locations

DES's review of the draft GMMP review report identified gaps in the monitoring network which should be addressed to better understand the extent and magnitude of mining/dewatering impacts and support future model updates. Eight locations were identified where additional monitoring bores should be installed to improve the adequacy of the monitoring network. The locations of the proposed additional monitoring bores are shown in Figure 3.1 and discussed below.

It is noted that an assessment of the adequacy of monitoring locations against new drawdown contours has not been undertaken to date. It is recommended that this be undertaken separately following DES's review of the groundwater modelling report.



KEY

- | | |
|--|--|
| ■ Proposed new monitoring bore - Bandanna Formation | □ Mining lease |
| ■ Proposed new monitoring bore - Colinia Sandstone | ■ Mining activity |
| ● Existing monitoring bore, Bandanna Formation | — Minor road |
| ● Existing monitoring bore, Colinia Sandstone | --- Vehicular track |
| ● Existing VWP, Bandanna Formation | — Named watercourse |
| ● Existing VWP, Colinia Sandstone | ⊕ Dewatering bore |

Proposed new monitoring bore locations

Carmichael Coal Mine
GMMP Review
Figure 3.1

i Colinlea Sandstone

C011P3 is the closest Colinlea Sandstone monitoring bore to the north of the dewatering bores, at a distance of 8 km from the nearest dewatering bore. No drawdown due to dewatering has been noted in C011P3 as of the update to the hydrogeological conceptual model (EMM, 2022a). Therefore, installation of an additional monitoring bore between C19026SP and C011P3 in the Colinlea Sandstone is proposed to better delineate the magnitude and extent of drawdown impacts to the north of the dewatering bores. It is recommended that the new monitoring bore (Proposed Bore 1) be installed adjacent to existing site C558VWP (Figure 3.1). C558VWP has one sensor installed across the Colinlea Sandstone and two sensors across the Bandanna Formation. The new monitoring bore will allow comparison of trends between the bore and the existing VWP sensor installed across the Colinlea Sandstone.

Similarly, there is a lack of monitoring bores to the west of the dewatering bores, between C19026SP and C19031VWP (near DSC), to properly delineate drawdown impacts occurring in this area. Therefore, it is also proposed that a monitoring bore be installed in this area to track the propagation of dewatering impacts to the west of the dewatering bores. A bore in this area would also be able to support the west to east groundwater flow conceptualised between the DSC and the site within the Colinlea Sandstone. It is recommended that the new monitoring bore (Proposed Bore 2) be installed adjacent to existing Clematis Sandstone bores C14012SP/C14013SP (Figure 3.1).

Following DES's review of the draft GMMP review report, an additional three Colinlea Sandstone monitoring bores (Proposed Bore 3, 4 and 5) will also be installed on the western boundary of the mining lease to help delineate drawdown impacts (Figure 3.1).

ii Bandanna Formation

As was observed in the Colinlea Sandstone, there is a lack of monitoring bores within the Bandanna Formation to the west of the dewatering bores, between C008P2 and C19018SP (near DSC). Therefore, it is proposed that a monitoring bore is installed in this area to assess dewatering impacts between the mine and the DSC and address knowledge gaps of where drawdown in the Bandanna Formation is currently occurring. It is recommended that the new monitoring bore (Proposed Bore 6) be installed adjacent to existing Clematis Sandstone bores C14012SP/C14013SP (Figure 3.1).

Following DES's review of the draft GMMP review report, an additional two Bandanna Formation monitoring bores (Proposed Bore 7 and 8) will also be installed on the western boundary of the mining lease to help delineate drawdown impacts (Figure 3.1).

iii Bandanna Formation/Colinlea Sandstone – Mellaluka Springs

There are no monitoring bores in the Bandanna Formation or Colinlea Sandstone to the south of the mine, between the mining lease and the Mellaluka Springs. Installation of monitoring bores in this area would allow for a better understanding of any connection between the Bandanna Formation and Colinlea Sandstone with the Tertiary sediments and Joe Joe Formation. These bores would also allow for the propagation of any dewatering/mining impacts to the south towards the Mellaluka Springs to be better monitored.

Bores C19003SP and C19004SP are screened within the Colinlea Sandstone and are located on the southern border of the mining lease, approximately 10 km from the Mellaluka Springs. These bores would act as an early warning of any groundwater impacts propagating towards the Mellaluka Springs and therefore installation of additional bores between the mining lease and Mellaluka Springs could be delayed until mining progresses south and impacts are noted in C19003SP and C19004SP.

3.2.2 Groundwater quality trigger levels

Groundwater quality triggers for most bores and the process for determining which exceedances require investigation were updated in April 2022, with the changes included in the April 2022 update to the EA. These changes should be reflected in the next revision of the GMMP.

The water quality analysis of each sampling round is compared to the bore-specific and hydrostratigraphic unit-specific trigger values (as outlined in Table E1 and Table E3 of the EA). Trigger exceedances are reported if they occur in two consecutive monitoring events for a given water quality parameter and monitoring location. These trigger exceedances must be reported to the administering authority via WaTERS within 10 days of receipt of the assessment of analytical results. An investigation into the potential cause of the exceedances must be commenced within 14 days of becoming aware of the exceedances, and the investigation must be completed within 3 months of commencement. Appendix C shows the latest round of water quality trigger exceedances following the June 2022 field sampling.

Appendix C shows that even after updating the trigger values and investigation methodology in April 2022, exceedance investigations were triggered in 47 of the 69 monitoring bores (78 exceedances across 14 parameters). Exceedances were observed in most hydrogeological units and were unlikely to be related to mining activities due to the spatial distribution of the bores compared to the mine disturbance footprint and/or lack of dewatering impacts within bores. Investigations into trigger exceedances have repeatedly concluded that the exceedances are the result of a combination of the following:

- Natural fluctuations.
- Water level variations.
- Slow stabilisation following bore installation/bore renovations.
- Geochemical processes including oxidation of iron trigger by the introduction of dissolved oxygen during sampling or from increased rainfall recharge.
- Changing climatic conditions from a sustained period of below average rainfall to a more recent period of about average rainfall conditions, but with significant recent rainfall events.

It is recommended that water quality triggers be reassessed within two years and updated for those monitoring bores which have not been impacted by mining activities. This will allow for natural fluctuations in water quality to be better captured in the development of the trigger levels.

Sixteen bores are noted in Table E1 of the EA as not yet having been assigned triggers due to a lack of baseline data. Table 3.2 outlines these bores as well as the number of results available for each bore following the June 2022 groundwater monitoring event. It is noted that bores C19022SP and C19018SP now have more than eight results available, which is the minimum amount specified in Section 5.4.3.2.4 of the GMMP for the development of trigger levels. Trigger levels should be derived for these bores and included in the next revision of the GMMP.

The following is also noted regarding the groundwater quality triggers:

- The contaminant limits in the GMMP should be updated using the same dataset as was used to develop the updated trigger values for consistency.
- Table E2 of the EA should be updated to reflect that electrical conductivity triggers are assessed using laboratory results, not field results as currently indicated.
- Table E2 should include total dissolved solids as a trigger level parameter to be consistent with Table E3 of the EA.

Table 3.2 Bores pending trigger development

Bore	Number of results available (following June 2022 monitoring)
C19022SP	13
C19018SP	10
C19012SP	6
C19010SP	6
C19014SP	6
C19008SP	6
C919013SPR	6
C19017SP	5
C19019SP	2
C19021SP*	0
C19023SP*	0
C19024SP*	0
C19025SP*	0
C18007SP*	0
C18008SP*	0
C19020SP*	0

Note: Bores marked with '*' do not have any results available because they are dry

3.2.3 Groundwater level thresholds

Groundwater level thresholds have been exceeded in several bores since commencement of monitoring, as discussed in the bi-monthly exceedance reports submitted to DES. Investigations have concluded that exceedances of groundwater level thresholds to date are not attributable to mining activities but related to one or more of the following:

- Water levels in replacement bores being compared against water level thresholds developed from older bores which have naturally different water level elevations.
- Amendment of cable lengths (and thus historical water level elevations) in artesian bores.
- Natural water level declines due to prolonged below average rainfall conditions.
- Nearby landholder use.
- Depressurisation and slow recovery following sampling and/or bore renovations.

Groundwater level thresholds have been updated based on the latest modelling predictions and these are shown in Table A.1, Appendix A. Water level thresholds were calculated using the same methodology as presented in Section 5.3.3.1 of the GMMP. The following was also undertaken as part of the water level threshold updating process:

- Baseline average groundwater level elevations and natural fluctuations for each bore were reassessed to incorporate all representative logger data (where available) before commencement of dewatering. Previously, only groundwater level data collected up to 2017 was considered to represent baseline conditions. Hydrographs showing updated baseline datasets are provided in Appendix B.
- For replacement bores installed after commencement of dewatering (ie C19001SP, C19002SP, C19010SP and C19028SP) baseline average groundwater levels and natural fluctuations were calculated from all groundwater level data collected to date. It is noted that none of these bores show any evidence of dewatering impacts to date nor are they predicted to be impacted by mining activities to date.
- Baseline average groundwater levels and natural fluctuations have been corrected for cable length adjustments in artesian bores.
- VWP's have been deemed unsuitable as water level threshold bores and therefore water level thresholds were not reassessed for VWP's.
- The existing five VWP water level threshold locations have been replaced with the following five water level threshold bores:
 - C19010SP and C19014SP installed within Clematis Sandstone.
 - C19008SP and C919016SPR installed within Rewan Formation.
 - C19018SP installed within the AB Seam of the Bandanna Formation.
- It is noted that water level thresholds have only been assigned to C19008SP and C19010SP as these are the only new bores which have greater than two years of monitoring data. Water level thresholds for C19014SP, C919016SPR and C19018SP will be assessed when at least two years of baseline data has been collected from each bore.

The updated groundwater level thresholds for Scenario 1 (open-cut only) and Scenario 3 (SEIS with updated fracturing assumptions) are shown in Table A.1, Appendix A.

It is noted that modelling Scenario 3 is predicting higher impacts at spring locations, especially due to underground mining, and further optimisation of the mine plan is required to limit spring impacts to less than 0.2 m. In the interim, it is recommended that drawdown predictions from model Scenario 1 (open-cut mining only) be used for the development of water level thresholds and incorporated into the next iteration of the GMMP and updated in the EA. Water level thresholds for Scenario 3 will need to be updated after further optimisation of the groundwater model.

3.3 Review of the validity of the groundwater monitoring program against the revised model predictions required under Condition E9

As part of Condition E7(d) of the EA, a review of the validity of the groundwater monitoring program against the revised model predictions is required.

It is recommended that review of the validity of the groundwater monitoring program be undertaken separately following DES's review of the groundwater modelling report.

3.4 Assessment of GMMP commitments

Section 7.0 of the approved GMMP lists a total of 41 commitments with respect to groundwater monitoring, installation of additional bores, provision of supply of periodic reports, publishing of monitoring data, undertaking

of investigations should water level or water quality trigger levels be exceeded, review of the groundwater monitoring program and groundwater numerical model.

An update on the status of each of the commitments in Section 7.0 of the approved GMMP are discussed below.

3.4.1 GMMP commitment #1

1. **Implement this GMMP, which details the location and frequency of groundwater monitoring activities, as well as trigger levels and response actions**

Status: Compliant. Bi-monthly monitoring of groundwater levels and water quality commenced in April 2020 for monitoring locations specified in the GMMP. Following each bi-monthly monitoring event, groundwater levels are compared to water level thresholds and water quality results compared to water quality triggers. Exceedances of water level thresholds and water quality triggers are submitted to DES following each monitoring event.

3.4.2 GMMP commitment #2

2. **Augment the existing groundwater monitoring network over time to enable ongoing groundwater impact evaluations**

Status: Compliant. Augmentation of the groundwater monitoring network for impact evaluations has been undertaken. Bravus has installed 14 additional monitoring bores between the western ML boundary and the Doongmabulla Springs and an additional 15 monitoring bores within the mining lease consisting of 9 new bores and 6 replacement bores (see Table 3.3). All bores have been installed by appropriately licenced drilling contractors in accordance with Minimum Construction Requirements for Water Bores in Australia, 4th Edition (NUDLC, 2020) and the Minimum Standards for the Construction and Reconditioning of Water Bores that Intersect the Sediments of Artesian Basins in Queensland (DNRME, 2017).

3.4.3 GMMP commitment #3

3. **Maintain and decommission of bores, according to industry standards, to ensure the management of groundwater resources and the collection of representative groundwater monitoring data.**

Status: Compliant. Servicing of all monitoring bores was undertaken during September-January 2020. Bore servicing included redevelopment (where necessary), upgrading of headworks and servicing of installed groundwater monitoring equipment. Decommissioning of monitoring bores is done in accordance with Construction and Reconditioning of Water Bores that Intersect the Sediments of Artesian Basins in Queensland (DNRME, 2017).

3.4.4 GMMP commitment #4

4. **Utilise digital pressure gauges to obtain more accurate pressure readings at all of the artesian monitoring bores during every groundwater monitoring event.**

Status: Compliant. All artesian monitoring bores have now been equipped with ports for measurement with digital pressure gauge to enable more accurate pressure readings to be undertaken.

3.4.5 GMMP commitment #5

5. **Detail all automatic water level loggers (model, setting, and setting information), including the depth of installation within the artesian bore headworks.**

Status: Compliant. All water level logger settings (model, setting, setting information) are updated in the spreadsheet used for downloading data.

3.4.6 GMMP commitment #6

6. Compile all automated water level logger data in a standard format for all monitoring bores, such that the data provided is easier to assess and interpret. The format is, in accordance to approval conditions, to be supplied in a format specified by the administering authority. The information will include, as a minimum:

- Manual and logger download data
- Correction for barometric pressure (non-vented loggers)
- Logger set-up details, depth of installation and measurements as depth-to-water
- Logger reset or replacement details
- Logger type and accuracy
- Agreed column naming convention

Status: Compliant. All automatic logger settings have been updated to be in a standard format used for downloading data with details such as logger model, setting information for barometer pressure correction, other measurement details like temperature and depth of installation and measurements as depth-to-water.

3.4.7 GMMP commitment #7

7. Groundwater level data from bores in Bandanna Formation (C018P2, C032P2, C034P1 and C823SP), Colinslea Sandstone (C833SP and C834SP) and Joe Joe group (C14006SP, C14008SP, C14014SP (C914108PT), C14015SP, C14016SP, C14017SP, C914030SPR, C180119SP, C180123SP, C9180124SPR, and C9180125SPR) will be reviewed and updated in 2 years based on a review of data (logger data validation with future manual readings and datum measurements).

Status: Compliant. Bravus has commenced groundwater monitoring as per the monitoring network detailed in Table 62 of the GMMP. These groundwater bores have been monitored since January 2020. Hydrographs containing data up to August 2022 for the bores listed in GMMP commitment #7 are presented in Appendix D. These hydrographs show a good correlation between manual readings and logger data over the past two years.

3.4.8 GMMP commitment #8

Seepage /Infrastructure Bores

8. Monitor the recently installed (2018) shallow seepage groundwater monitoring bores, prior to construction of mine affected water and waste storage facilities.

Status: Compliant. Water quality data for four seepage monitoring bores (C18004SP, C18005SP, C18006SP and C18009SP) has been collected since 2018 and will be continued to be collected into the future during routine bi-

monthly water quality monitoring². It is noted that two seepage monitoring bores (C18007SP and C18008SP) have been dry since installation.

3.4.9 GMMP commitment #9

9. **Install additional monitoring bores located up and down gradient of surface infrastructure considered potential sources of contamination (e.g. mine infrastructure, waste dumps, and tailings areas) before construction of such facilities within 3 months of finalisation of the location of the facilities**

Status: Compliant. Two additional shallow monitoring bores (C19024SP and C19025SP) (see Table 3.3) have been drilled up and down gradient of the explosive storage area which will be used to store Ammonium Nitrate Fuel Oil (ANFO). Monitoring of water levels and water quality has commenced at these locations. Furthermore, Bravus will install additional monitoring bores located up and down gradient of surface infrastructure considered potential sources of contamination (eg mine infrastructure, waste dumps, and tailings areas) within 3 months of finalisation of the location of the facilities.

3.4.10 GMMP commitment #10

Boundary Bores

10. **Install five additional bores on the eastern boundary of mining lease, as recommended by DES, to develop additional baseline data for the alluvium and Tertiary sediments in this area so as to allow for the assessment of any possible migration of contaminants to the east of the mine lease**

Status: This commitment has been met. Bravus installed five boundary bores (C19019SP, C19020SP, C19021SP, C19022SP and C19023SP) (see Table 3.3) to develop additional baseline data for the alluvium and Tertiary sediments in this area. Monitoring of these bores will allow for the assessment of any possible migration of contaminants to the east of the mine lease.

3.4.11 GMMP commitment #11

Replacement Bores

11. **Alluvium bore C025P1, regularly recognised to be dry, will be replaced with a new alluvium bore located within deeper alluvium adjacent to the Carmichael River. A bore specific groundwater level threshold will be derived for this bore over time, the groundwater level threshold for existing bore C025P1 will be used in the interim.**

Status: This commitment has been met. A replacement bore (C19001SP) (see Table 3.3) for C025P1 has been installed within deeper alluvium sediments at the same location. Water level and quality data is being collected from C19001SP and will continue to be collected bi-monthly to update groundwater level threshold. As per commitment #5 above, water levels in C19001SP always exceed the threshold value which was calculated from the average water level and natural fluctuations in C025P1. It is recommended that C19001SP be assessed against the updated threshold value presented in Table A.1, Appendix A which is based on all data collected from C19001SP post-installation. This threshold value should be re-evaluated during the next update of the GMMP.

² Interim contaminant limits have been included in Appendix E of this review report.

3.4.12 GMMP commitment #12

12. A new monitoring bore will be installed into Clematis Sandstone at current location of C180118SP as this bore is currently blocked

Status: This commitment has been met. C180118SP which is blocked has been replaced with a new bore (C19002SP) (see Table 3.3). Water level and quality data is being collected from the new bore and will continue to be collected bi-monthly. As per commitment #5 above, water levels in C19002SP are naturally lower in elevation than C180118SP. It is recommended that C19002SP be assessed against the updated threshold value presented in Table A.1, Appendix A which is based on data collected from C19002SP. This threshold value should be re-evaluated during the next update of the GMMP.

3.4.13 GMMP commitment #13

13. Drilling of the replacement bores at C025P1 and C180118SP plus the five additional bores (Figure 30) within the first year of commencement of mining operations

Status: This commitment has been met. Bores C025P1 and C180118SP have been replaced with C19001SP and C19002SP, respectively. Five additional bores have also been installed (Table 3.3).

3.4.14 GMMP commitment #14

Nested Bores

14. Additional bores monitoring the Dunda Beds, Rewan Formation, and Permian Betts Creek Beds (which includes the Bandanna Formation and Colinlea Sandstone) will be installed within one year of commencement of mining operations at three locations co-located as far as practicable within 500 m of existing Clematis Sandstone monitoring points as follows: HD02, HD03A, and C14011SP including one bore within the vicinity of the Doongmabulla Springs Complex.

Status: This commitment has been met. Installation of these additional bores was completed in 2020. Bore details are provided in Table 3.3.

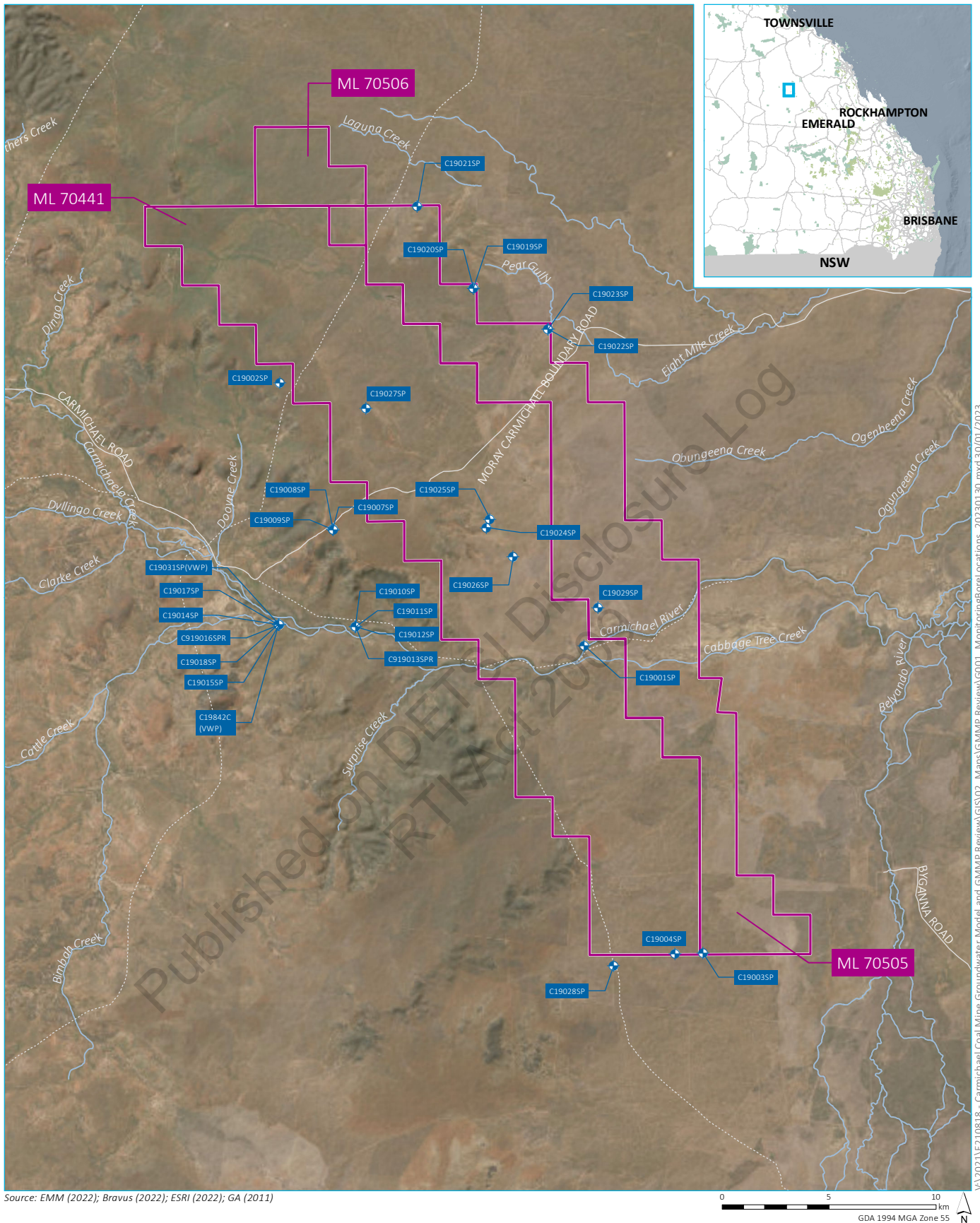
Table 3.3 New groundwater monitoring bores 2019-2020

	Bore ID	Easting ¹	Northing ¹	Surface RL (mAHD) ²	Depth (mBGL) ³	Screen Interval (mBGL) ³	Formation	Remarks
1	C19007SP	426268	7561274	310.28	240	222.7 - 234.7	Dunda beds	Outside & west of ML
2	C19008SP	426268	7561277	310.18	288	271-283	Rewan formation	Outside & west of ML
3	C19009SP	426286	7561268	310.15	517	504-516	Rewan formation	Outside & west of ML
4	C19010SP	427323	7556734	238.41	100	82-94	Clematis SSt	Outside & west of ML
5	C19011SP	427337	7556725	238.07	177	162-174	Dunda beds	Outside & west of ML
6	C19012SP	427331	7556730	238.4	228	212-224	Rewan formation	Outside & west of ML
7	C919013SPR	427346	7556721	238.1	440	428-440	Rewan formation	Outside & west of ML
8	C19014SP	423766	7556814	239.58	120	95.9-107.9	Clematis SSt	Outside & west of ML
9	C19015SP	423768	7556827	239.39	183	168-180	Dunda beds	Outside & west of ML
10	C19017SP	423736	7556825	239.62	463	450.8-462	Rewan formation	Outside & west of ML
11	C19018SP	423737	7556834	239.28	493	481-493	Bandanna formation	Outside & west of ML
12	C19842C (VWP)	423736	7556821	239.77	648	330	Rewan formation	Outside & west of ML
13	C919016SPR	423767	7556821	239.4	256	238-250	Rewan formation	Outside & west of ML
14	C19031SP(VWP)	423753	7556845	238.92	620	605	Colinlea SSt	Outside & west of ML
15	C19019SP	432845	7572555	255.35	15	8-14	Alluvium	Boundary bores East of ML
16	C19020SP	432847	7572550	255.15	50	43-49	Weathered Tertiary	Boundary bores East of ML
17	C19021SP	430226	7576369	264.61	15	8-14	Alluvium	Boundary bores East of ML
18	C19022SP	436340	7570625	225.23	50	43-49	Weathered Tertiary	Boundary bores East of ML
19	C19023SP	436338	7570630	225.15	15	8-14	Alluvium	Boundary bores East of ML

Table 3.3 New groundwater monitoring bores 2019-2020

	Bore ID	Easting ¹	Northing ¹	Surface RL (mAHD) ²	Depth (mBGL) ³	Screen Interval (mBGL) ³	Formation	Remarks
20	C19024SP	433447	7561376	253.59	15	8-14	Alluvium	Infrastructure bore
21	C19025SP	433612	7561775	247.49	15	8-14	Alluvium	Infrastructure bore
22	C19003SP	443571	7541484	229.8	226	148-160	Colinlea SSt	Sub-E Colinlea Bores
23	C19004SP	442278	7541451	238.43	264	228-240	Colinlea SSt	Sub-E Colinlea Bores
24	C19026SP	434698	7559985	238.44	260	252-259	Colinlea SSt	Replacement bore (C007P3)
25	C19027SP	427832	7566929	262.37	263	252-262	Colinlea SSt	Replacement bore(C020P2)
26	C19028SP	439400	7540894	260.68	53	40-50	Rewan formation	Replacement bore(C180116SP)
28	C19029SP	438684	7557636	224.74	71	63-69	Colinlea SSt	Replacement bore(C180114SP)
27	C19001SP	438025	7555853	227.06	18	11-17	Alluvium	Replacement bore(C027P1)
29	C19002SP	423799	7568106	305.33	125	117-123	Clematis SSt	Replacement bore(C180118SP)

Notes: ¹ GDA94 Zone 55, ² mAHD = metres Australian Height Datum, ³ mbGL = metres below Ground Level



KEY

- New monitoring bores
- Mining lease
- Minor road
- Vehicular track
- Named watercourse

New groundwater monitoring bores
(2019-2020)

Carmichael Coal Mine
GMMP Review
Figure 3.2

3.4.15 GMMP commitment #15

15. Undertake groundwater monitoring and sampling via a suitably qualified and experienced professional in accordance with recognised procedures and guidelines

Status: Compliant. Bi-monthly water quality sampling is undertaken by suitably qualified personnel from C&R Consultants. Personnel from C&R meet 'suitably qualified personnel' as defined in the EA. Bravus has also engaged suitably qualified contractors to service monitoring bores. All groundwater quality samples are sent to NATA accredited laboratories for analysis.

3.4.16 GMMP commitment #16

16. For all new bores, to be drilled after the compilation of the initial GMMP, a minimum of 12 datasets over 24 months, will be collected prior to developing groundwater level thresholds and water quality triggers for discussion with DES for inclusion in future iterations of the GMMP

- All new bores will be assessed against the water quality triggers developed for each hydrostratigraphic unit until (and if required) bore specific triggers are developed
- All new bores will be installed as soon as possible so as to compile additional groundwater data to inform the conceptual model and the refinement of the model as required in Condition E4a and E6
- Any consideration of revising the groundwater level thresholds, based on new data acquired, must assess the potential impacts of the revised groundwater level thresholds on GDEs.

Status: Compliant. Bravus has commenced monitoring of all new bores installed after compilation of the initial GMMP. The groundwater data collected from these additional bores will be used to inform the groundwater conceptual model and the refinement of the numerical model as required in EA condition E4a and E9. Water quality triggers for new bores will be developed in consultation with DES when at least eight water quality results have been collected for each bore.

The GMMP will need to be updated to include the revised groundwater level thresholds for Scenario 1 (open-cut mining only) which are presented in Table A.1, Appendix A.

3.4.17 GMMP commitment #17

17. Conduct a review of the monitoring data, using suitably qualified expert during the review of GMMP to be carried out before 1 July 2021 (or any other time frame as agreed with DES so as to align GMMP review and model re-run to happen concurrently) to update conceptualisations and conduct groundwater numerical model review based on these data)
- To allow for the correct scientific development of the GMMP it is considered (subject to agreement with DES) that the refinement and re-run of the model will occur prior to the update of the GMMP, as the model outputs and modifications can be captured in the GMMP
 - The model re-run is to occur 2 years after the commencement of the box cut and then every 5 years, the same review periods as the GMMP

Status: Compliant. Monitoring data has been reviewed and the hydrogeological conceptualisation has been updated by (EMM, 2022a) as part of the numerical model revision which is ongoing and to be completed by 31 January 2023.

3.4.18 GMMP commitment #18

18. Hydrochemistry results will be reviewed after each groundwater monitoring event to assess for exceedances (water quality triggers and groundwater level thresholds) and track any emerging trends through the compilation of (water quality and groundwater level) time series plots

- **For bores where bore specific water quality triggers have not been developed, average values have been used in the interim until a minimum of 8 measurements have been recorded. These interim triggers will be revised and presented in future iterations of the GMMP**

Status: Compliant. The hydrochemistry and water level results are reviewed after each bi-monthly monitoring event and exceedances of trigger levels and thresholds were assessed as per EA conditions and are reported to the administering authority. To date, hydrochemistry and water level data has been reviewed and exceedances reporting during 15 bi-monthly monitoring events between January 2020 and June 2022. A summary of water quality exceedances during the monitoring events is presented in Appendix C and is summarised in Section 3.5.1. Water quality triggers for most monitoring bores were recently updated in consultation with DES. Water quality triggers for newly installed bores will be developed in consultation with DES once sufficient data has been collected and included in future GMMP iterations.

3.4.19 GMMP commitment #19

19. Assess groundwater, surface water, and springs using isotope tracers to aid in the assessment of water quality results and groundwater conceptualisation

Status: Compliant. Bravus commenced assessment of groundwater, surface water, and springs using major elements, trace elements and isotope tracers to aid in the assessment of water quality results and groundwater conceptualisation in 2018/2019 and again in February 2021. Results of the isotope tracers are included in EMM (2021b) and were discussed in the previous GMMP review (EMM 2021a). No additional studies have since been undertaken.

3.4.20 GMMP commitment #20

20. Non-mining influence on water quality (if exceedances occur which cannot be correlated to mining activities) will be assessed through the consideration of:

- **Groundwater levels, depth-to-water, and groundwater gradient changes**
- **Identification of land-use changes upgradient of monitoring bores**
- **Regular meetings / discussions with neighbouring landholders to identify activities that may influence groundwater quality**
- **Increasing the water quality analytical suite (assess possible sources)**
- **Water quality “fingerprinting” using major ion chemistry (Scholler Plots, etc.)**

Status: Compliant. Review of bi-monthly water level and water quality data to date has concluded that exceedances of water levels and water quality are currently not related to mining activities. Exceedances can be attributed to a combination of processes as summarised in Section 3.2.2. If exceedances during future monitoring are assessed to be due to mining activities, Bravus will undertake an investigation in consideration of the above requirements. Exceedance reporting is outlined in Section 3.5.1.

3.4.21 GMMP commitment #21

21. Potential groundwater impacts from mine water and waste storage need to be assessed and potential mitigation measures adopted if potential for environmental harm is identified. These mitigation measures include:

- Identification and removal of source
- Seepage capture schemes, suitable to prevent possible plume migration offsite
- Pump and treat schemes to manage possible contaminant plumes
- Augmentation of the groundwater monitoring network to validate remediation

Status: Compliant. For future compliance. If the investigation completed under Section 4.0 of the GMMP and EA condition E12 confirms that groundwater quality impacts exceeded the trigger values, and impacts are as a result of seepage of mine water and waste storage, further detailed investigation will be completed as per EA condition E13, and appropriate mitigating measures will be selected and implemented as per EA condition E14.

3.4.22 GMMP commitment #22

22. If groundwater level impacts are predicted to be beyond those allowed in the project approvals, mitigation activities with regards to water availability at the GDEs may include:

- Limiting thickness of extraction of coal seams and reviewing extraction of multiple coal seams for the underground longwall mining
- Freezing mine development at current levels until the completion of investigations and assessments which conclude that further development will not exceed approved impacts
- In case the investigation(s) carried out under EA conditions E10 to E14 determines that further mine development would exceed approved impacts to MSES, then the bio-diversity offset strategy will be updated and offsets will be provided

Status: Compliant. For future compliance. If the investigation completed under Section 4.0 of the GMMP and EA condition E15 confirms that groundwater level impacts exceeded the threshold values for GDEs, and impacts are a result of mining operations, further detailed investigation will be completed as per EA condition E16, and appropriate mitigating measures will be selected and implemented.

3.4.23 GMMP commitment #23

23. Include in the review of the GMMP an assessment of groundwater level and water quality data, and the suitability of the monitoring network, as per Condition E5. The GMMP will be reviewed by a suitably qualified person with a report on the outcome of the review to the administering authority by 1st July 2021. After the initial review, the review must be completed within three months of the second anniversary date of commencing box cut excavation and every 5 years following.

Status: Compliant. Since approval of the GMMP, the EA has been amended to include an additional condition for submission of an annual groundwater monitoring report (Condition E18). The annual groundwater monitoring report is required to include an assessment of groundwater level and water quality data. The latest annual groundwater monitoring report was submitted to DES during June 2022. An assessment of the suitability of the monitoring network is included in Section 3.2 above.

3.4.24 GMMP commitment #24

- 24. The results of research plans, inclusive of the GAB Springs Research Plan and Rewan Formation Connectivity Research Plan, will be incorporated into the next iterations of the numerical model review and GMMP (within two years of box cut and every five years after that)**

Status: Results and new datasets completed as part of the GAB Springs Research Plan, Rewan Formation Connectivity Research Plan and ongoing monitoring were used to develop a revised hydrogeological understanding of the Carmichael Coal Mine and surrounding area (EMM 2022a). The revised conceptual understanding has been used to develop the updated groundwater model. The GMMP will be updated to include a summary of the revised conceptualisation.

3.4.25 GMMP commitment #25

- 25. Two existing surface water flow monitoring stations CAR04 and CAR01 will be serviced to make them operational. An additional two stream flow gauging stations, one between the Doongmabulla Springs and the western edge of the mining lease, the other downstream of the eastern edge of the mining lease and upstream of the Belyando River confluence, will be installed. These surface water monitoring locations will allow for identification of impacts on the Carmichael River and associated GDEs**

Status: Compliant. Two existing surface flow gauging stations CAR01 and CAR04 have been serviced and are now operational. A third streamflow gauging station CAR02 is also serviced and brought into operation. Bravus has completed installation of two additional stream flow gauging stations, one between the Doongmabulla Springs and the western edge of the mining lease (Moray West), the other downstream of the eastern edge of the mining lease and upstream of the Belyando River confluence (Albinia). Two additional stream flow gauging stations were also installed on Belyando River (BEL01 and BEL02) downstream and upstream side respectively of confluence with the Carmichael River.

Hourly flow rates and daily rainfall are shown in Figure 3.3 for CAR01, CAR02, CAR04, Moray West and Albinia flow gauging stations. The response of these gauging stations to rainfall events during January, April and May 2022 are shown in Figure 3.4.

Hourly flow rates and daily rainfall are shown in Figure 3.5 for BEL01 and BEL02 flow gauging stations. The response of these gauging stations to rainfall events during January, April and May 2022 are shown in Figure 3.6.

Overall, all flow gauging stations show a good response to rainfall events.

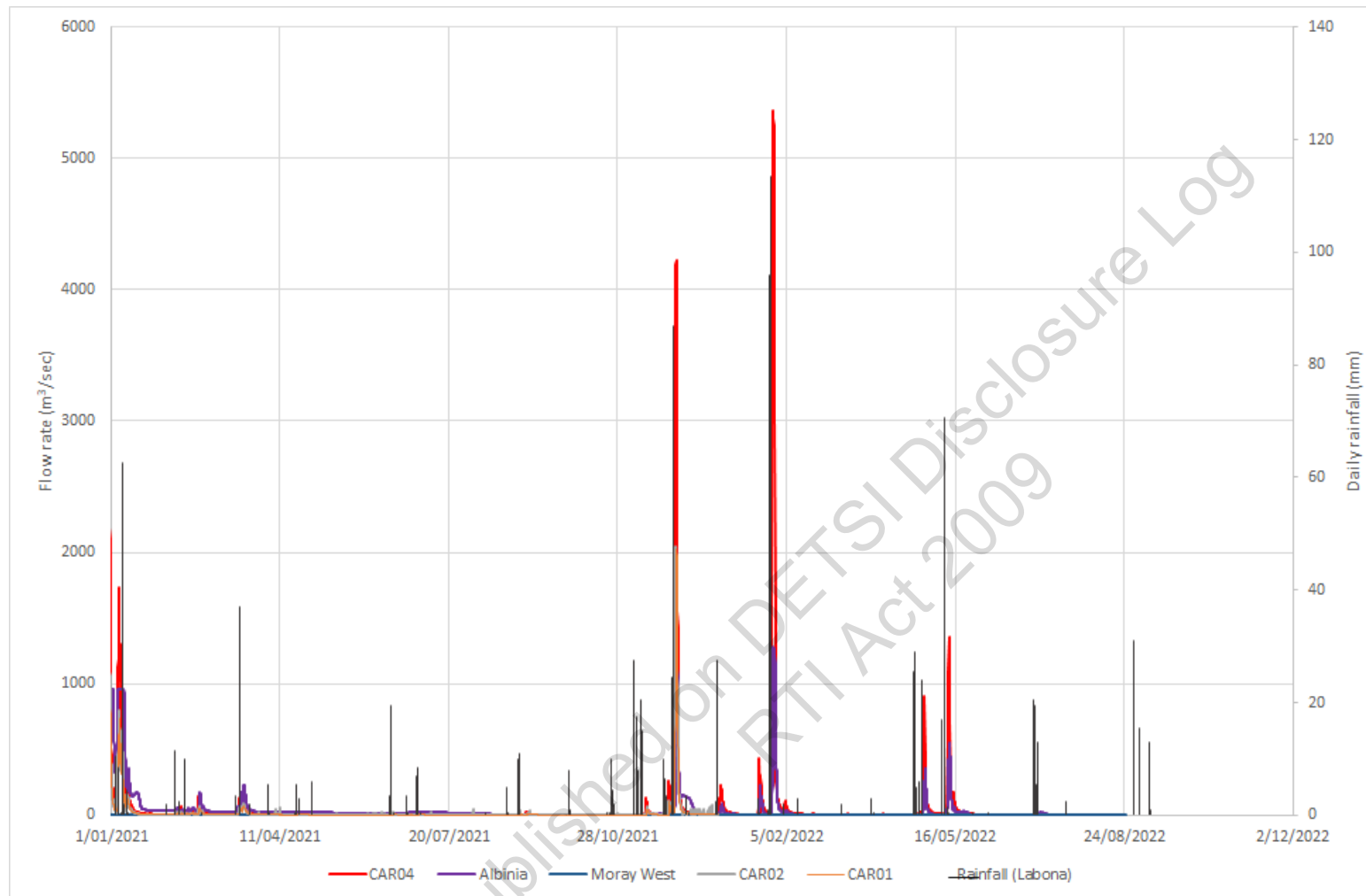


Figure 3.3 Rainfall and flow rates for gauging stations CAR01, CAR02, CAR04, Moray West and Albinia – All data

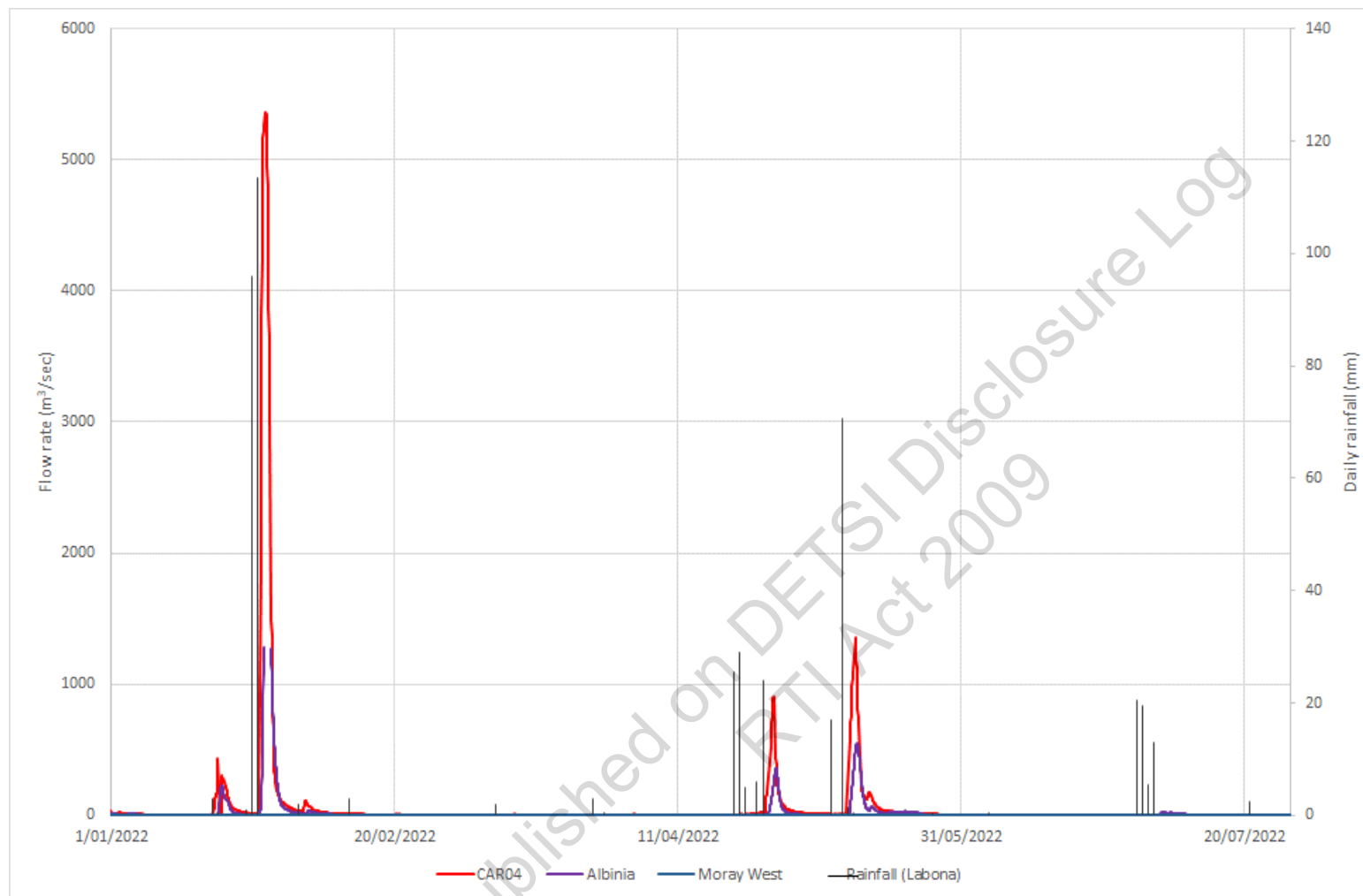


Figure 3.4 Flow rate response to rainfall during January, April and May 2022 – CAR04, Moray West and Albinia flow gauging stations

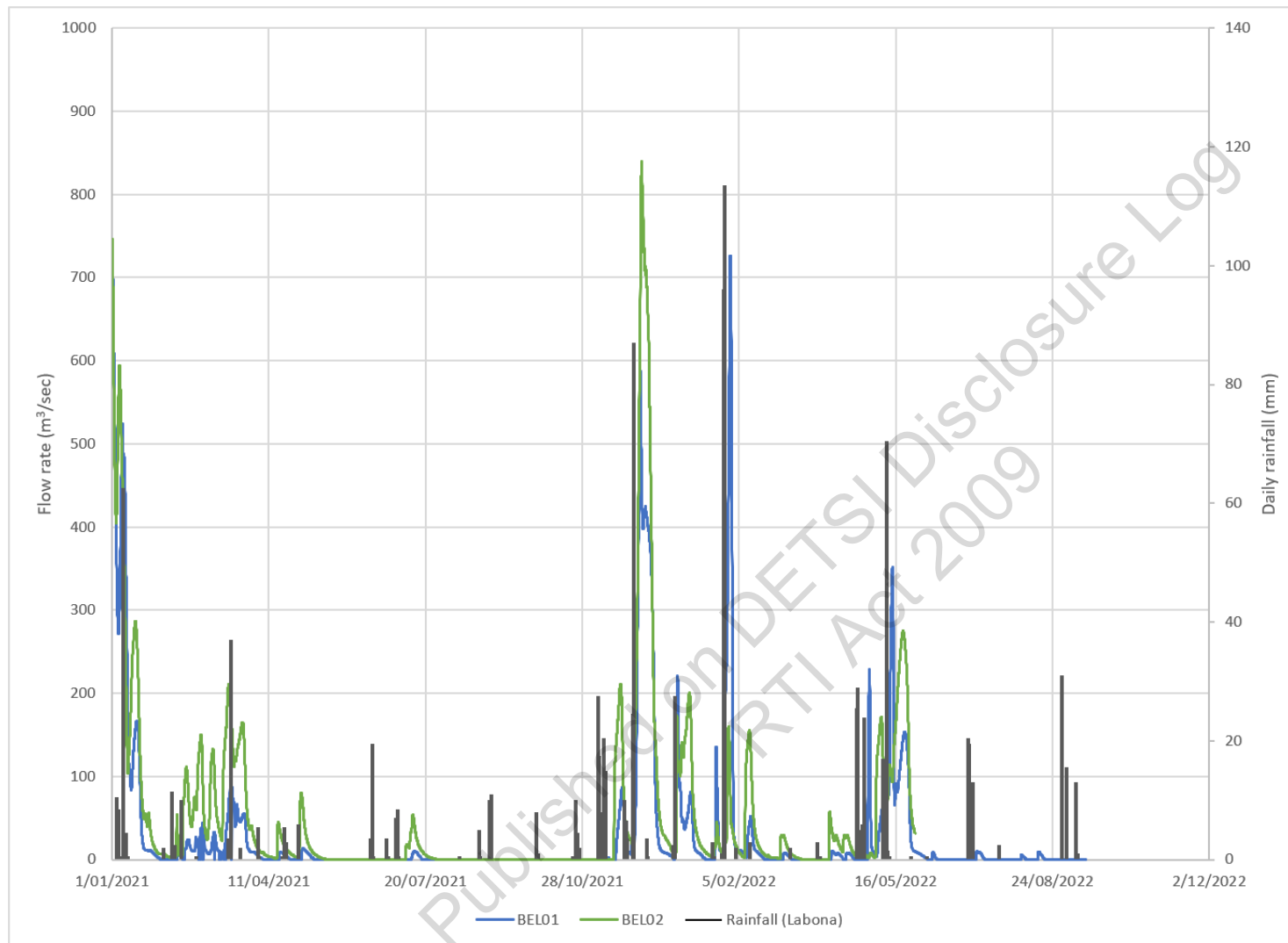


Figure 3.5 Rainfall and flow rates for gauging stations BEL01 and BEL02 – All data

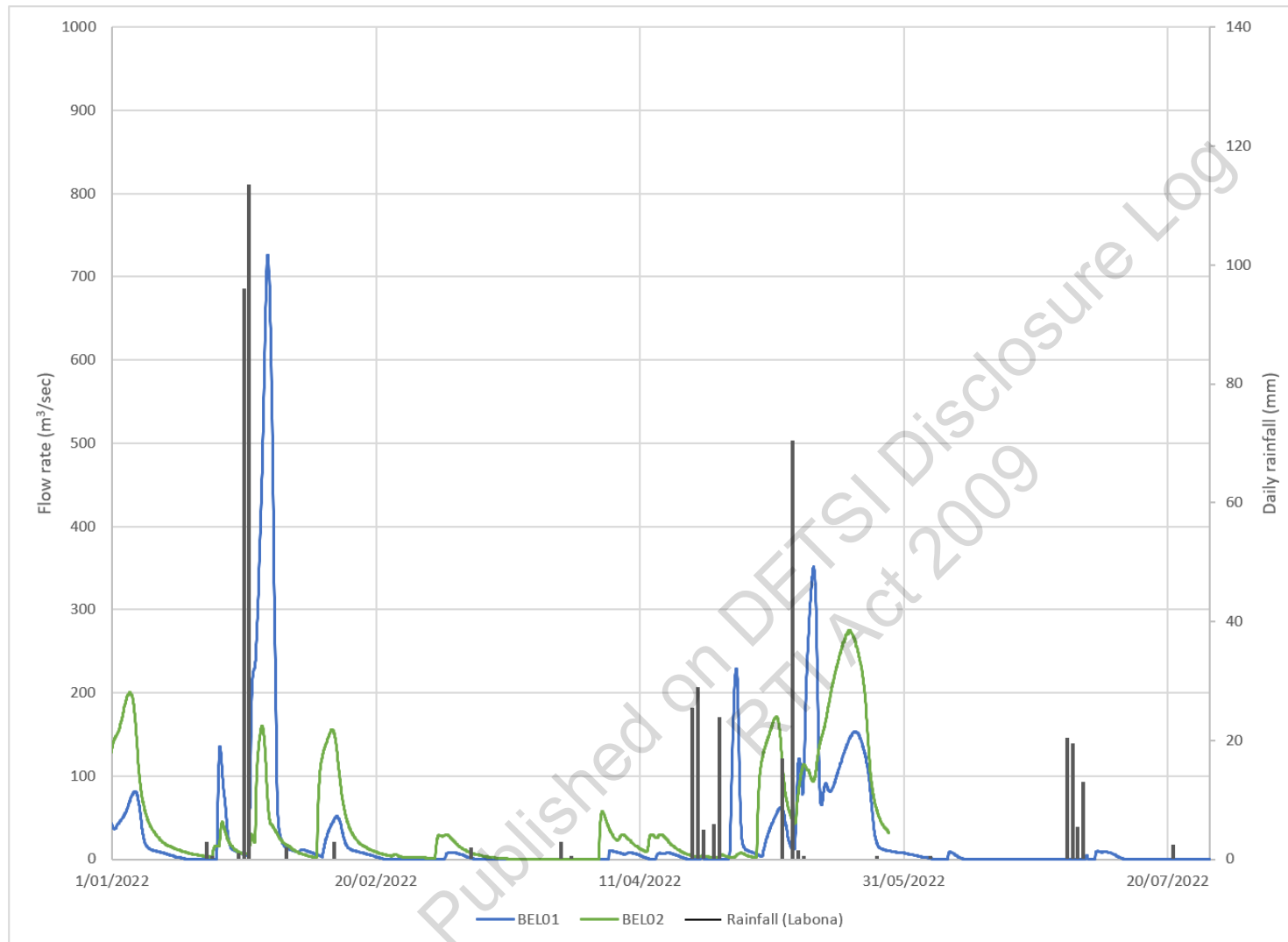


Figure 3.6 Flow rate response to rainfall during January, April and May 2022 – BEL01 and BEL02 flow gauging stations

3.4.26 GMMP commitment #26

26. Adani commits to incorporate the following in the groundwater model re-run:

- Review of the previous model conceptualisation (as per Condition E6a and commitment 16) including consideration of hydrochemistry (commitment 18)
- Incorporate available groundwater level and chemistry data from existing and new bores
- Hydrochemistry analysis from groundwater and spring samples
- Inputs from the RFCRP and GABSRP
- Review of groundwater modelling network and locations for ongoing optimisation
- Revision of groundwater drawdown rates for continuing appropriateness
- Revision of early warning triggers for continuing appropriateness
- Inclusion of updated and clearly defined bore reference levels. The review will also include how changes (if any) affect historical model calibration performance
- Transient calibration of the groundwater model, incorporating available bore water level data and surface water flows for the Carmichael River
- Review of evapotranspiration (ET) to assess its influence on model predictions relating to the DSC and the Carmichael River GDEs
- Update of the groundwater model to incorporate additional information obtained since the SEIS, including update of the geological and hydrogeological conceptualisation based on drilling works since the SEIS and groundwater level data from additional nested bores that will be installed near the DSC
- Analysis of rock properties and hydrostratigraphy from the cores of new nested bores to assess and quantify hydraulic properties within and between hydrogeological units
- Incorporate GA airborne electromagnetic survey data (if available during the next iteration of the GMMP)
- Updated sensitivity analysis
- Uncertainty analysis based on recent literature, (e.g. Middlemis and Peters, 2018, Uncertainty Analysis – Guidance for groundwater modelling within a risk management framework)”
- Systematic consideration of the sources of uncertainty as they pertain to each source aquifer and modelling limitations and document this consideration
- Inclusion of all relevant parameters in a range of modelled scenarios that encompass the identified uncertainties
- Adani will undertake ongoing stream flow gauging, as per Section 2.3.8, and the data will be used as one of the calibration parameters

- Future model updates will be compliant with the recognised modelling guidelines, "Australia Groundwater Modelling Guidelines (Barnett et al. 2012)"
- Model update will use locally appropriate parameterisations including the selection of the appropriate model scale dependent parameters such as hydraulic conductivity
- Sensitivity analysis undertaken for model updates, including an analysis of the sensitivity of the model to parameter changes due to underground mining.

The modelling review will include:

- An independent review and update of the groundwater conceptual model
- An independent review of the numerical groundwater model
- An independent review of the water balance calculations.

The recommendations of the reviews as required in Condition E7, will be, incorporated in the revised / updated GMMP document including a table of changes made in response to the independent reviews.

Status: TBD. Pending DES review of updated groundwater model.

3.4.27 GMMP commitment #27

27. At the second model re-run (7 years after commencement of box cut), Adani will specifically review both the following:

- Hydrogeological conceptualisation arising from model review and hydrochemistry analysis, consistent with and refined from the first model re-run (2 years after commencement of box cut); and
- Seismic information pertaining to the impacts of underground mining. This mining activity is not scheduled to commence until year 10, and a number of precursors are required before it commences.

If this review determines that additional seismic studies are required to determine the source aquifers of the Doongmabulla Springs Complex, these activities will be completed and that information included into revised modelling. Underground mining will not commence until these actions are completed and only if predicted impacts are consistent with approved impacts. Likewise, if the hydrogeological conceptualisation differs from that of the approved project, approval must be sought prior to relevant impact causing activities, if predicted impacts also differ from those approved.

Further, if any groundwater model re-run, or bore monitoring results, determine:

- Unauthorised impacts may or have occurred to the Doongmabulla Springs Complex from commencement of dewatering operations into the long term post closure; or
- The unlikely scenario that the Permian age hydrostratigraphic units are additional sources to the Doongmabulla Springs Complex

The following mitigation measures and corrective actions will be put in place:

- Limiting thickness of extraction of coal seams and reviewing extraction of multiple coal seams for the underground longwall mining in order to minimise drawdown impacts to Doongmabulla Springs Complex

- Freezing mine development at current levels until the completion of investigations and assessments which demonstrate and conclude that further development will not exceed approved impacts
- Assess the water balance / budgets and evaluate losses at the Doongmabulla Springs Complex, in the context of the Permian age hydrostratigraphic units being a possible additional source of groundwater.

Status: For future compliance.

3.4.28 GMMP commitment #28

28. Initial review of the approved GMMP by an appropriately qualified person with a report provided on the outcome of the review to the administering authority by 1 July 2021 (or any other time frame as agreed with DES so as to align the GMMP review and model re-run to happen concurrently). After the initial review, the review will be conducted every five years following, the report provided to the administering authority.

Status: Compliant. The initial GMMP review report is submitted to DES in July 2021. This report is prepared to meet this commitment, and EA condition E5, to review the GMMP within two years of commencement of the first box cut excavation (ie 10 October 2022).

3.4.29 GMMP commitment #29

29. The GMMP review will be conducted by 1 July 2021 (or any other time frame as agreed with DES so as to align the GMMP review and model re-run to happen concurrently). The revised GMMP will include statistical analysis of hydrochemistry and groundwater quality data
- The next iteration of the GMMP (after 2 years of commencement of box cut excavation) will provide piper plots of the major ions for all hydrostratigraphic units included in the EA Conditions (Condition E3a), representative DSC springs, and the Carmichael River surface water
 - Contaminant triggers and limits will be updated when additional statistically sufficient pre-operational hydrochemistry data are collected. It is noted that several monitoring bores do not currently have the required number of analyses to calculate baseline trigger values and are using generic triggers derived from the ANZECC guidelines or average of bore specific data. Additional hydrochemistry results, allowing for the revision of trigger values, will be conducted according to the approach detailed in Section 5.4.
 - During GMMP review and groundwater model re-run consideration of potential impacts to relevant GDE's will be included when considering revision of trigger values.

Status: Compliant. Piper plots were included in the previous GMMP review report submitted in June 2021 and are also included in the bi-monthly exceedance reports. Water quality triggers were recently updated in consultation with DES and included in Table E3 of the amended EA. Water quality triggers for newly installed monitoring bores will be developed in consultation with DES once sufficient samples are collected (minimum eight samples required).

It is recommended that contaminant limits be updated using the same dataset that was used to derive the updated trigger levels. These updated contaminant limits are presented in Appendix E and should be included in the next iteration of the GMMP.

3.4.30 GMMP commitment #30

- 30. Investigate all groundwater-based complaints and maintain a complaint register. The register will be made available to the regulating authority upon request.**

Status: Compliant. No groundwater-based complaints have been received to date. Bravus will continue to maintain a compliant register for the life of the project and will be made available to the regulating authority upon request.

3.4.31 GMMP commitment #31

- 31. Implement make-good agreements with land holders affected by groundwater drawdown**

Status: For future compliance, if impacts as documented in make-good agreements are realised all make good measures as per signed agreement with land holders will be implemented.

3.4.32 GMMP commitment #32

- 32. Monitoring results will be publicly available on the Adani website (www.bravus.com.au) for the life of the CCP; the groundwater monitoring dashboard on the website will be operational within three months of approval of the GMMP. The data will be uploaded as per Section 4.8.**

Status: Compliant. All monitoring results are made publicly available on the Bravus website. Currently groundwater data collected up to August 2022 is available on the website. All future monitoring data will be made available on the website in accordance with this commitment.

General commitments regarding the groundwater monitoring include the following:

3.4.33 GMMP commitment #33

- 33. Sampling will be undertaken in accordance with the current edition of DES's Water Quality Sampling Manual, or subsequent updated versions.**

Status: Compliant. All monitoring is being undertaken in accordance with the current edition of DES's Water Quality Sampling Manual. Monitoring is undertaken by suitably qualified personnel from C&R Consulting.

3.4.34 GMMP commitment #34

- 34. Groundwater level and groundwater quality results will be maintained for the life of the project and annual data will be compiled in an annual monitoring report. The monitoring data collected annually will be submitted, by 1 July, to the administering authority via WaTERS.**

Status: Compliant. Bravus will maintain the groundwater level and groundwater quality results for the life of the project. An annual monitoring report for the period 1 July 2021 to 30 June 2022 was prepared for Bravus in June 2022 (EMM, 2022b), and the data collected was submitted to the administering authority via WaTERS by 1 July 2022.

3.4.35 GMMP commitment #35

- 35. Notification to the regulating authority within one month of receiving water quality analysis results, should any parameters tested exceed agreed trigger levels. This commitment is included in #36 below.**

Status: Compliant. See #36 below.

3.4.36 GMMP commitment #36

36. Should groundwater monitoring indicate exceedance of any or all of the groundwater level thresholds and / or water quality trigger levels then DES will be notified via WaTERS and an investigation will be instigated and the investigation report will be made available to the administering authority within the time specified in EA conditions E10 and E12 for groundwater quality trigger exceedances and E13 and E14 for groundwater threshold level exceedances respectively.

Status: Compliant. Reporting of water level and water quality exceedances have been notified via WaTERS and submitted to the administering authority within the specified time for the bi-monthly monitoring events which have been undertaken to date. The investigations to assess the cause of exceedances are completed within the specified time for all bi-monthly monitoring events and reports have been submitted to the administering authorities and via WaTERS. Bravus commits to meet the time frames specified for notifying the exceedances and submission of investigation reports in during future monitoring.

It is noted that the EA conditions in this commitment are no longer accurate based on changes to condition numbering within the latest EA which was amended 19 April 2022.

3.4.37 GMMP commitment #37

37. Adani, in the event of a confirmed exceedance of a groundwater drawdown threshold level or water quality trigger, attributable to mining activities will:
- Review the mine plan, including the sequencing of mining.
 - Update the model predictions and revise the threshold levels. As per Section 4.7.1.2, any consideration of revising the groundwater threshold levels must assess the potential impacts of the revised groundwater threshold levels on GDEs.
 - Identify potential impacts to GDEs associated with drawdown levels and implement appropriate corrective action processes as outlined in the GDEMP.

Status: Compliant. To date, exceedances of water level thresholds and water quality triggers have not been attributed to mining activities (see Section 3.5.1). In future, Bravus will meet the requirement of this commitment should any groundwater level threshold or groundwater quality trigger are exceeded so as to determine the cause of exceedance including that as a result of mining operations.

3.4.38 GMMP commitment #38

38. Should any or all the groundwater level Impact thresholds be realised, through the assessment of groundwater monitoring data and comparison to model predictions, then an appropriately qualified person will complete an investigation into the potential for environmental harm (MSES and MNES) and will provide a written report to the regulator as per the conditions. In the event of exceedances of threshold levels on MNES Adani will take the following actions:
- Update/revise the numerical groundwater model with the monitoring results.
 - Review of the mine plan including the sequencing of mining.
 - Update the predictions using the revised model to check if the revised predicted drawdown within the DSC are within the approved limits of drawdown impacts (i.e. the interim thresholds).

Status: For future compliance.

3.4.39 GMMP commitment #39

39. For completeness, the groundwater monitoring data, factual and interpretative reports (including any possible investigations as a result of triggers / thresholds) will be provided to the Commonwealth regulators as well as the State regulators.

- **All corrective actions and mitigation measures, derived based on possible investigations as a result of triggers / thresholds, will be consistent with the GDEMP.**

Status: Compliant. All groundwater monitoring collected during bi-monthly sampling, factual interpretative reports and investigation reports are provided to the Commonwealth regulators as well as the State regulators. Any recommendations resulting from the investigations completed due to triggers / thresholds exceedances including corrective actions and mitigation measures, will also be assessed to be consistent with the GDEMP requirements.

3.4.40 GMMP commitment #40

40. Conduct regular groundwater monitoring bore assessments and maintenance (where required) as well as ensuring dry or damaged bores (as a result of mining activities) are decommissioned according to the latest editions of the Minimum Construction Requirements for Water Bores in Australia, 4th Edition (NUDLC, 2020) and the Minimum Standards for the Construction and Reconditioning of Water Bores that Intersect the Sediments of Artesian Basins in Queensland (DNRME, 2017).

Status: Compliant. Regular groundwater monitoring bore assessments and maintenance will be carried out by the qualified personnel deployed by the monitoring contractor. Bravus has followed the bore construction standards as mentioned above while constructing additional bores.

Details of bore maintenance will be included in the annual groundwater monitoring report required under Condition E18 of the EA.

3.4.41 GMMP commitment #41

41. As the proposed threshold values are reliant on predictions from the numerical groundwater model, to be updated within two years of the box cut excavation then every five years subsequently, Adani will compare the actual measured groundwater level data to predicted drawdown to assess the rate of change. In the instance the drawdown rate of the actual data is steeper/ faster than the predicted rate, an investigation will be commenced into the cause of the drawdown rate change.

Status: Observed groundwater level data collected to date has been used to calibrate the updated groundwater model which is currently being developed. Discrepancies between actual and predicted drawdown in monitoring bores to date is a focus for transient recalibration efforts to actual pre-mining dewatering stresses. Groundwater drawdown predictions will be updated as part of the updated groundwater model. These updated predictions will be compared against observed water levels during future reporting to assess the rate of change. Investigations will be undertaken in cases where it is found that the actual drawdown exceeds the drawdown predicted by the groundwater model.

Predicted drawdown (SEIS model) versus observed drawdown are provided in Section 9 of the 2022 Annual Groundwater Monitoring Report.

3.4.42 GMMP commitment –Springs, GDE and Baseflow Commitments

The status of summary of Springs, GDE and Baseflow commitments relevant for this review period is provide below.

- **Adani are committed to utilising bore C027P2 as an early warning trigger for the Carmichael River. Monitoring of the Dundas Beds and Rewan Formation as potential contributors to the Doongmabulla Spring Complex (DSC) will be undertaken to enable spatially comparable data to be collected.**

Status: Compliant. Bore C027P2 is being continuously monitored to assess for potential induced flow from Dundas Beds into coal seams. Bravus is carrying out regular groundwater monitoring in a network of bores installed between the mining lease area and Doongmabulla Springs covering Dundas beds and Rewan formations to enable collection of spatially comparable data.

- **The reporting will include any revised predictive modelling and comments regarding potential impacts on the sensitive ecosystems.**

Status: A report summarising the updated groundwater model is required to be submitted to DES before 31 January 2023. This report will include commentary on potential impacts to GDEs.

- **The GMMP will closely interlink to the GDEMP developed by Adani specifically the Doongmabulla Spring Complex, Mellaluka Spring Complex, Carmichael River baseflow and GDEs, and Waxy Cabbage Palm tree communities sub-plans. Data collected from the GMMP will assist in the monitoring of the ecological health at these GDEs and will allow for the identification of potential stress and consequently requirements for mitigation and management measures as outlined in the sub-plans.**

Status: Compliant. Groundwater monitoring data collected under the GMMP is being made available for GDEMP for monitoring of the ecological health at these GDEs.

- **Adani will investigate drilling into deeper Permian age units for the purpose of acquiring data for monitoring purposes and to capture information if required under relevant research programs.**

Status: Compliant. Bravus installed additional monitoring bores C19031SP-VWP, C19018SP and C19842C into deeper Permian age units for the purpose of acquiring data for monitoring purposes and to capture information required under relevant research programs. An additional eight monitoring bores will be installed within Permian units between the mining lease and Doongmabulla Springs as discussed in Section 3.2.1 and shown in Figure 3.1.

- **Adani will also install two additional stream flow gauging stations, one between the Doongmabulla Springs and the western edge of the mining lease, the other downstream of the eastern edge of the mining lease and upstream of the Belyando River confluence.**

Status: Compliant. Bravus completed installation of two additional flow gauging stations Moray west and Albinia station flow gauges. For additional information refer to Section 3.4.25.

3.4.43 GMMP commitment –Monitoring program updates

- **To develop the optimum groundwater monitoring plan Adani proposes a phased approach, which will allow for the correct scientific development of the program and allow for variation over time to suit the site/mining phases.**

Status: Compliant. An optimum groundwater monitoring program is developed under GMMP and implemented to suit to the current stage of construction and operational phases of the project.

- **Any revised GMMP will be submitted for approval with the administering authority, prior to the implementation of the next phase of mining/**

Status: Compliant. Bravus submitted updated GMMP (ver 11 and ver 11a) to DES and DAWE respectively, and both departments approved the same.

3.5 Assessment of DES recommendations

A letter was received from DES dated 12 October 2020 requesting that future GMMP review reports address a number of items as per sections 3.5.1 to 3.5.11 below. Assessment of the DES recommendations for the GMMP review report are provided below.

3.5.1 DES recommendation #1

1. **A review of monitoring data (water quality and water level) collected under the GMMP. The monitoring data should be compared to triggers, limits and thresholds after each monitoring event. The annual review should determine potential impacts and emerging trends in the data with any downward groundwater level trends compared to modelled drawdown rates. If the actual monitored rates are faster than predicted, the review report should recommend a suitable update of the triggers in the GMMP.**

The amended EA has since been updated to include Condition E18 to submit an annual groundwater monitoring report which must include the following:

- Summary of groundwater monitoring activity undertaken during the year.
- An assessment of water quality data and water level data for long-term trends with time series graphs of all data for all groundwater bores.
- A summary of investigation of exceedances of groundwater quality triggers and groundwater level thresholds carried out under this schedule.
- Month wise dewatering volumes during the year.
- An assessment of any differences between the impacted groundwater level predicted and the actual impacts for the corresponding period.
- A summary of all recommended changes to the GMMP.

The latest annual groundwater monitoring report was submitted to DES during June 2022.

3.5.2 DES recommendation #2

2. **Increasing trends in groundwater quality may provide early warning of triggers being approached and should be discussed in the GMMP review report.**

Bi-monthly reporting and investigations of water quality trigger exceedances with comparison to changing groundwater levels has been conducted according to EA conditions E12, E13 and E14, under the guidance of the GMMP. A thorough annual review (EMM, 2022b) has also been undertaken according to EA conditions E18 and E19 which review these trends. The trigger exceedances investigations have indicated that variations in water quality are likely to be natural, rather than as a result of site activities.

3.5.3 DES recommendation #3

3. **The GMMP review report must provide the baseline and pre-impact water quality in a format that can be compared to future monitoring data eg time series plots.**

Time series plots of all results for all analytes and all monitoring bores have been included in the latest annual groundwater monitoring report (comparing the baseline and pre-impact water quality) which was submitted to DES during June 2022.

3.5.4 DES recommendation #4

4. **The GMMP review report should include a review of the adequacy of groundwater monitoring locations, frequencies, groundwater quality trigger and water level thresholds.**

A review of the adequacy of groundwater monitoring locations, frequencies, groundwater quality triggers and water level thresholds is discussed in Section 3.2.

3.5.5 DES recommendation #5

5. **The GMMP review report should provide piper plots of major ions for all hydrostratigraphic units and recommendations about revisions to the conceptual model (including isotope tracer results).**

Piper plots of major ions for all hydrostratigraphic units were included in the previous GMMP review which was submitted to DES in June 2021 (EMM 2021a). Updated piper plots for each hydrostratigraphic unit are included in the bi-monthly water quality exceedance reports.

A discussion of isotope tracer results collected as part of the GAB Springs Research Plan are included in EMM (2021b). These isotope tracer results have been used to revise the updated conceptualisation report which has previously been submitted to DES (EMM 2022a).

3.5.6 DES recommendation #6

6. **Detail isotope tracer studies used to characterise the groundwater dependent ecosystems.**

Results of isotope tracer studies are discussed in EMM (2021b) and included in the previous GMMP review which was submitted to DES in June 2022 (EMM 2021a). No additional isotope studies or investigations have been undertaken since the previous GMMP review was submitted.

3.5.7 DES recommendation #7

7. **The 2020 review report provides details of a number of new and replacement bores – 14 in total. The latitude and longitude of these bores should be provided in the review report to facilitate any necessary EA amendment to include these additional bores.**

Coordinates for the 14 replacement bores are provided in Table 3.3 above. Any new bores installed since these have been captured in Table E1 (Appendix 5) of the EA, including details such as latitude, longitude and target aquifer.

3.5.8 DES recommendation #8

8. **The location and target aquifer for all new bores should be detailed in the review report with a recommendation about any necessary EA amendments.**

The locations of all new bores are shown in Figure 3.2 and target aquifer and bore details provided in Table 3.3. The monitoring bores listed in the EA (Table E1 in Appendix 5) will be updated with all new monitoring bores.

3.5.9 DES recommendation #9

9. **All exceedances in water quality triggers and limits should be discussed in the review report and recommendations of triggers that need to be revised should be detailed.**

Water quality triggers are discussed in Section 3.2.2 and water level thresholds in Section 3.2.3.

3.5.10 DES recommendation #10

10. **All five surface water gauging stations must be referred to in the review report for the GMMP with the data presented and interpreted.**

Data for surface water gauging stations are discussed in Section 3.4.25.

3.5.11 DES recommendation #11

11. **The GMMP review report identifies inconsistencies in bore identification details. The review report should make recommendations about any necessary amendments to the GMMP and/or the EA.**

The groundwater monitoring network presented in Table 62 of GMMP has been updated. Changes to the monitoring network have been incorporated in Table E1 Appendix 5 of the latest EA amendment.

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4 GMMP review recommendations

Additional Monitoring Bores

Following advice from DES, it is recommended that the following additional monitoring bores be drilled to monitor for water level fluctuations:

- An additional monitoring bore within Colinlea Sandstone to be installed between C19026SP and C011P3 to better delineate the magnitude and extent of drawdown impacts to the northwest of the dewatering bores. It is recommended that this bore be installed adjacent to existing site C558VWP.
- An additional monitoring bore within Colinlea Sandstone between C19026SP and C19031VWP to track future propagation of dewatering impacts in the Colinlea Sandstone between mining and the DSC. It is recommended that this bore be installed adjacent to existing Clematis Sandstone bore C14012SP/C14013SP.
- Three further additional monitoring bores within Colinlea Sandstone on the western boundary of the mining lease to track future propagation of dewatering impacts.
- An additional monitoring bore within Bandanna Formation between C008P2 and C19018SP to track future propagation of dewatering impacts in the Bandanna Formation between mining and the DSC. It is recommended that this bore be installed adjacent to existing Clematis Sandstone bore C14012SP/C14013SP.
- An additional two monitoring bores within Bandanna Formation on the western boundary of the mining lease to track future propagation of dewatering impacts.
- Additional monitoring bores within Bandanna Formation and Colinlea Sandstone in the vicinity of Mellaluka Springs to allow for detection of dewatering impacts near Mellaluka Springs and to improve the understanding of any connection between the Colinlea Sandstone and the Tertiary sediments and Joe Joe Formation. Installation of additional bores between the mining lease and Mellaluka Springs is considered low priority and could be delayed until mining progresses south and impacts are noted in C19003SP and C19004SP.

Groundwater level thresholds

To improve the assessment of groundwater level thresholds, it is recommended that the updated water level thresholds for Scenario 1 (open-cut only mining) shown in Table A.1, Appendix A be used from now on. These groundwater level thresholds have been updated based on the latest modelling predictions and reassessment of baseline datasets as discussed in Section 3.2.3.

Groundwater level thresholds for monitoring bores with less than two years of data should be reassessed for baseline average groundwater level elevations and natural fluctuations when at least two years of baseline data has been collected.

Groundwater quality triggers

The following updates are also noted regarding the groundwater quality triggers:

- The contaminant limits in the GMMP should be updated using the same dataset as was used to develop the updated trigger values for consistency.

- Monitoring bores C19022SP and C19018SP now have more than eight results which is the minimum amount required for development of trigger levels. It is recommended that trigger levels are derived for these bores and included in the next revision of the GMMP.
- Table E2 of the EA should be updated to reflect that electrical conductivity triggers are assessed using laboratory results, not field results as currently indicated.
- Table E2 should include total dissolved solids as a trigger level parameter to be consistent with Table E3 of the EA.
- It is recommended that water quality triggers be reassessed within two years and updated for those monitoring bores which have not been impacted by mining activities. This will allow for natural fluctuations in water quality to be better captured in the development of the trigger levels.

Review of the validity of the groundwater monitoring program against the revised model predictions

It is recommended that review of the validity of the groundwater monitoring program be undertaken separately following DES's review of the groundwater modelling report and results.

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5 References

Adani (2020). Carmichael Coal Mine and Rail Project Groundwater Management and Monitoring Program – Review Report. Prepared 24/06/2020.

EMM (2021a). Groundwater Management and Monitoring Program/Plan – Review Report. Prepared for Bravus Mining and Resources.

EMM (2021b). Carmichael Coal Mine Great Artesian Basin Springs Research Plan.

EMM (2022a). Carmichael Coal Mine Great Artesian Basin Springs Research Plan: RP1.6 Hydrogeological conceptualisation review and updated groundwater model.

EMM (2022b). 2022 Annual Groundwater Monitoring Report – Carmichael Coal Mine. Prepared for Bravus Mining and Resources.

EMM (2023). Carmichael Coal Mine: RP1.6 Hydrogeological conceptualisation and updated groundwater modelling, Report No.2: Numerical groundwater flow model report.

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Appendix A

Updated groundwater level thresholds

Table A.1 **Summary of updated groundwater level thresholds**

Bore ID	Modelling scenario	Geology	Maximum predicted drawdown (m)	Average baseline groundwater level (mAHD)	Natural Fluctuation (NF) over baseline period (m)	Groundwater level threshold criteria	Groundwater level threshold (m)	Groundwater level threshold (mAHD)
Carmichael River Location								
C027P1	Scenario 1	Alluvium	0.02	222.35	6.13	Prediction plus ½ NF	3.09	219.26
	Scenario 3		0.28				3.34	219.01
HD03B	Scenario 1	Alluvium	0.05	225.35	1.67	Prediction plus ½ NF	0.88	224.47
	Scenario 3		0.25				1.08	224.27
C027P2	Scenario 1	Dunda Beds	0.85	226.94	2.85	Prediction plus ½ NF	2.28	224.66
	Scenario 3		19.98			½ NF + 90% of prediction	19.41	207.53
C029P1	Scenario 1	Alluvium	0.09	214.48	1.29	Prediction plus ½ NF	0.74	213.74
	Scenario 3		0.83				1.48	213.00
C029P2	Scenario 1	Tertiary sediments	19.35	220.01	3.71	½ NF + 90% of prediction	19.27	200.74
	Scenario 3		23.88				23.35	196.66
C19001SP	Scenario 1	Alluvium	0.00	215.04	0.35	Prediction plus ½ NF	0.18	214.87
	Scenario 3		0.00				0.18	214.86
C025P2	Scenario 1	Tertiary sediments	29.63	217.59	1.20	½ NF + 90% of prediction	27.26	190.33
	Scenario 3		23.54				21.78	195.81
C14028SP	Scenario 1	Alluvium	30.88	205.49	0.38	½ NF + 90% of prediction	27.98	177.51
	Scenario 3		20.73				18.84	186.65
C14027SP	Scenario 1	Alluvium	0.00	203.62	0.22	Prediction plus ½ NF	0.11	203.51
	Scenario 3		0.05				0.16	203.46

Table A.1 **Summary of updated groundwater level thresholds**

Bore ID	Modelling scenario	Geology	Maximum predicted drawdown (m)	Average baseline groundwater level (mAHD)	Natural Fluctuation (NF) over baseline period (m)	Groundwater level threshold criteria	Groundwater level threshold (m)	Groundwater level threshold (mAHD)
C14006SP	Scenario 1	Joe Joe Group	52.11	223.42	0.94	½ NF + 90% of prediction	47.37	176.05
	Scenario 3		47.08				42.84	180.58
Great Artesian Basin to West of Mine Lease								
C19002SP	Scenario 1	Clematis Sandstone	0.19	248.90	0.31	Prediction plus ½ NF	0.35	248.55
	Scenario 3		1.66			½ NF + 75% of prediction	1.40	247.50
C14033SP	Scenario 1	Clematis Sandstone	0.10	250.59	0.29	Prediction plus ½ NF	0.24	250.35
	Scenario 3		0.93			½ NF + 75% of prediction	0.84	249.75
C14011SP	Scenario 1	Clematis Sandstone	0.18	242.81	0.26	Prediction plus ½ NF	0.31	242.50
	Scenario 3		1.04			½ NF + 75% of prediction	0.91	241.90
C14012SP	Scenario 1	Clematis Sandstone	0.10	242.60	0.26	Prediction plus ½ NF	0.23	242.37
	Scenario 3		0.65			½ NF + 75% of prediction	0.61	241.99
C14013SP	Scenario 1	Clematis Sandstone	0.10	242.42	0.41	Prediction plus ½ NF	0.30	242.12
	Scenario 3		0.65			½ NF + 75% of prediction	0.69	241.73
HD02	Scenario 1	Clematis Sandstone	0.05	234.31	2.54	Prediction plus ½ NF	1.32	232.99
	Scenario 3		0.27			1.54	232.77	
HD03A	Scenario 1	Clematis Sandstone	0.05	231.82	1.42	Prediction plus ½ NF	0.76	231.06
	Scenario 3		0.27			0.98	230.84	
C14021SP	Scenario 1	Clematis Sandstone	0.57	246.16	0.62	Prediction plus ½ NF	0.88	245.28
	Scenario 3		0.74			½ NF + 75% of prediction	0.87	245.29

Table A.1 **Summary of updated groundwater level thresholds**

Bore ID	Modelling scenario	Geology	Maximum predicted drawdown (m)	Average baseline groundwater level (mAHD)	Natural Fluctuation (NF) over baseline period (m)	Groundwater level threshold criteria	Groundwater level threshold (m)	Groundwater level threshold (mAHD)
C022P1	Scenario 1	Dunda Beds	10.57	246.57	0.44	½ NF + 90% of prediction	9.73	236.84
	Scenario 3		172.87				155.80	90.77
C027P2	Scenario 1	Dunda Beds	0.85	226.94	2.85	Prediction plus ½ NF	2.28	224.66
	Scenario 3		19.98			½ NF + 90% of prediction	19.41	207.53
C14023SP	Scenario 1	Dunda Beds	0.71	247.22	0.50	½ NF + 75% of prediction	0.78	246.44
	Scenario 3		0.76				0.82	246.40
C180117SP	Scenario 1	Dunda Beds	2.95	250.87	0.46	½ NF + 75% of prediction	2.44	248.43
	Scenario 3		15.25			½ NF + 90% of prediction	13.95	236.92
C9553P1R	Scenario 1	Rewan Formation	2.90	252.27	0.18	½ NF + 75% of prediction	2.27	250.00
	Scenario 3		118.27			½ NF + 90% of prediction	106.53	145.74
C556P1	Scenario 1	Rewan Formation	3.48	234.66	0.97	½ NF + 75% of prediction	3.10	231.56
	Scenario 3		137.90			½ NF + 90% of prediction	124.60	110.06
C555P1	Scenario 1	Rewan Formation	2.18	230.05	0.50	½ NF + 75% of prediction	1.89	228.16
	Scenario 3		89.23			½ NF + 90% of prediction	80.56	149.49
Doongmabulla to West of Mine Lease								
HD02	Scenario 1	Clematis Sandstone	0.05	234.31	2.54	Prediction plus ½ NF	1.32	232.99
	Scenario 3		0.27				1.54	232.77
HD03A	Scenario 1	Clematis Sandstone	0.05	231.82	1.42	Prediction plus ½ NF	0.76	231.06
	Scenario 3		0.27				0.98	230.84

Table A.1 **Summary of updated groundwater level thresholds**

Bore ID	Modelling scenario	Geology	Maximum predicted drawdown (m)	Average baseline groundwater level (mAHD)	Natural Fluctuation (NF) over baseline period (m)	Groundwater level threshold criteria	Groundwater level threshold (m)	Groundwater level threshold (mAHD)
C14013SP	Scenario 1	Clematis Sandstone	0.10	242.42	0.41	Prediction plus ½ NF	0.30	242.12
	Scenario 3		0.65			½ NF + 75% of prediction	0.69	241.73
C022P1	Scenario 1	Dunda Beds	10.57	246.57	0.44	½ NF + 90% of prediction	9.73	236.84
	Scenario 3		172.87				155.80	90.77
C14012SP	Scenario 1	Clematis Sandstone	0.10	242.60	0.26	Prediction plus ½ NF	0.23	242.37
	Scenario 3		0.65			½ NF + 75% of prediction	0.61	241.99
C14021SP	Scenario 1	Clematis Sandstone	0.57	246.16	0.62	Prediction plus ½ NF	0.88	245.28
	Scenario 3		0.74			½ NF + 75% of prediction	0.87	245.29
C848SP	Scenario 1	D Seam	115.97	231.60	0.98	½ NF + 90% of prediction	104.86	126.74
	Scenario 3		163.60				147.73	83.87
C19010SP	Scenario 1	Clematis Sandstone	0.05	238.59	0.68	Prediction plus ½ NF	0.39	238.20
	Scenario 3		0.30				0.64	237.95
C19014SP	Scenario 1	Clematis Sandstone	0.05	TBD	TBD	Prediction plus ½ NF	TBD	TBD
	Scenario 3		0.27				TBD	TBD
C19008SP	Scenario 1	Rewan Formation	3.35	245.25	0.27	½ NF + 75% of prediction	2.64	242.61
	Scenario 3		20.11			½ NF + 90% of prediction	18.24	227.01
C919016SPR	Scenario 1	Rewan Formation	4.38	TBD	TBD	Prediction plus ½ NF	TBD	TBD
	Scenario 3		8.34				TBD	TBD
C19018SP	Scenario 1	AB Seam	50.92	TBD	TBD	Prediction plus ½ NF	TBD	TBD

Table A.1 **Summary of updated groundwater level thresholds**

Bore ID	Modelling scenario	Geology	Maximum predicted drawdown (m)	Average baseline groundwater level (mAHD)	Natural Fluctuation (NF) over baseline period (m)	Groundwater level threshold criteria	Groundwater level threshold (m)	Groundwater level threshold (mAHD)
Scenario 3			189.43				TBD	TBD
Mellaluka Springs to the southeast of Mine Lease								
C180120SP	Scenario 1	Tertiary/Joe Joe Group	61.91	239.57	2.53	½ NF + 90% of prediction	56.99	182.58
	Scenario 3		85.41				78.13	161.44
C180122SP	Scenario 1	Tertiary/Joe Joe Group	78.87	233.05	0.75	½ NF + 90% of prediction	71.36	161.69
	Scenario 3		92.93				84.01	149.04
C180119SP	Scenario 1	Joe Joe Group	78.87	235.73	1.26	½ NF + 90% of prediction	71.61	164.12
	Scenario 3		92.93				84.27	151.46
C180123SP	Scenario 1	Joe Joe Group	53.02	243.66	0.90	½ NF + 90% of prediction	48.17	195.49
	Scenario 3		74.43				67.44	176.22
C9180124SPR	Scenario 1	Joe Joe Group	78.87	235.40	0.88	½ NF + 90% of prediction	71.42	163.98
	Scenario 3		92.93				84.08	151.32
C9180125SPR	Scenario 1	Joe Joe Group	61.91	240.30	2.61	½ NF + 90% of prediction	57.03	183.27
	Scenario 3		85.41				78.17	162.13
Sentinel Bores								
C14016SP	Scenario 1	Joe Joe Group	105.63	233.52	2.97	½ NF + 90% of prediction	96.55	136.97
	Scenario 3		128.28				116.94	116.58
C9845SPR	Scenario 1	Tertiary sediments	4.68	234.86	0.35	½ NF + 75% of prediction	3.69	231.17
	Scenario 3		30.93			½ NF + 90% of prediction	28.01	206.85

Table A.1 **Summary of updated groundwater level thresholds**

Bore ID	Modelling scenario	Geology	Maximum predicted drawdown (m)	Average baseline groundwater level (mAHD)	Natural Fluctuation (NF) over baseline period (m)	Groundwater level threshold criteria	Groundwater level threshold (m)	Groundwater level threshold (mAHD)
C14029SP	Scenario 1	Tertiary/Joe Joe Group	110.48	227.74	0.74	½ NF + 90% of prediction	99.80	127.94
	Scenario 3		103.59				93.60	134.14
C14003SP	Scenario 1	Joe Joe Group	29.39	209.37	0.27	½ NF + 90% of prediction	26.58	182.79
	Scenario 3		25.78				23.34	186.03
C14030SP/ C914030SPR	Scenario 1	Joe Joe Group	110.48	228.36	1.29	½ NF + 90% of prediction	100.08	128.28
	Scenario 3		103.59				93.87	134.49
C14015SP	Scenario 1	Joe Joe Group	81.36	236.84	0.54	½ NF + 90% of prediction	73.49	163.35
	Scenario 3		106.38				96.01	140.83
C016P2	Scenario 1	AB Seam	34.51	248.52	0.34	½ NF + 90% of prediction	31.23	217.29
	Scenario 3		166.32				149.86	98.66
C14004SP	Scenario 1	Joe Joe Group	29.39	209.44	0.52	½ NF + 90% of prediction	26.71	182.73
	Scenario 3		25.78				23.46	185.98
C14008SP	Scenario 1	Joe Joe Group	89.91	225.50	1.38	½ NF + 90% of prediction	81.61	143.89
	Scenario 3		78.66				71.48	154.02
C19028SP	Scenario 1	Rewan Formation	28.87	238.93	0.22	½ NF + 90% of prediction	26.09	212.84
	Scenario 3		51.96				46.87	192.06
C14024SP	Scenario 1	Clematis Sandstone/Rewan Group	1.43	262.69	0.16	½ NF + 75% of prediction	1.15	261.54
	Scenario 3		1.04				0.86	261.83
C14020SP	Scenario 1	Moolayember	0.06	252.45	0.31	Prediction plus ½ NF	0.22	252.23

Table A.1 **Summary of updated groundwater level thresholds**

Bore ID	Modelling scenario	Geology	Maximum predicted drawdown (m)	Average baseline groundwater level (mAHD)	Natural Fluctuation (NF) over baseline period (m)	Groundwater level threshold criteria	Groundwater level threshold (m)	Groundwater level threshold (mAHD)
	Scenario 3	Formation	0.56			½ NF + 75% of prediction	0.58	251.87

Notes: 1. Updated modelling Scenario 1 = open-cut mining only.

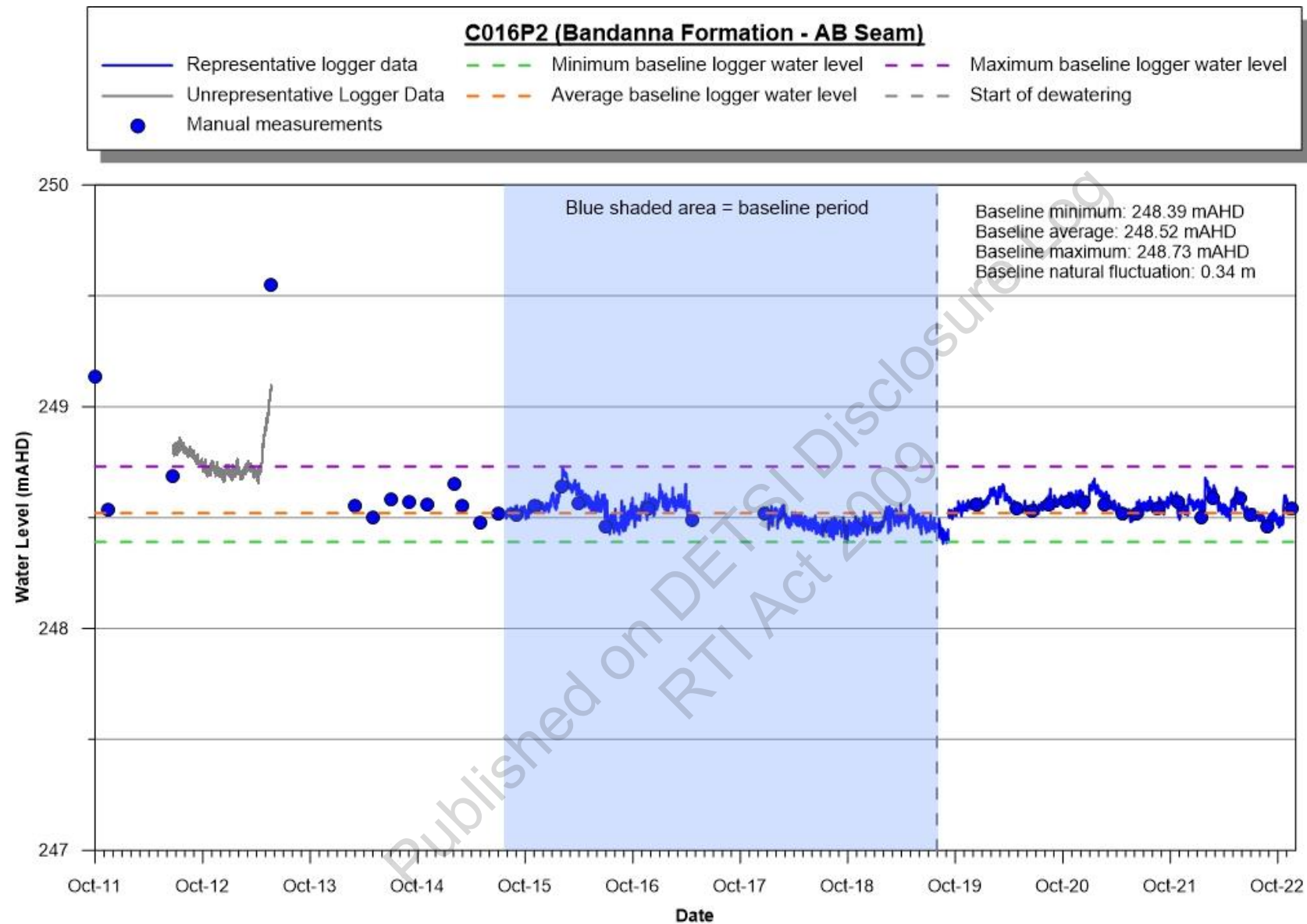
2. Updated modelling Scenario 3 = SEIS with updated fracturing assumptions.

3. TBD = water level threshold to be developed when minimum of two years data is available.

4. Water level thresholds for Scenario 3 to be updated pending results of further groundwater model optimisation.

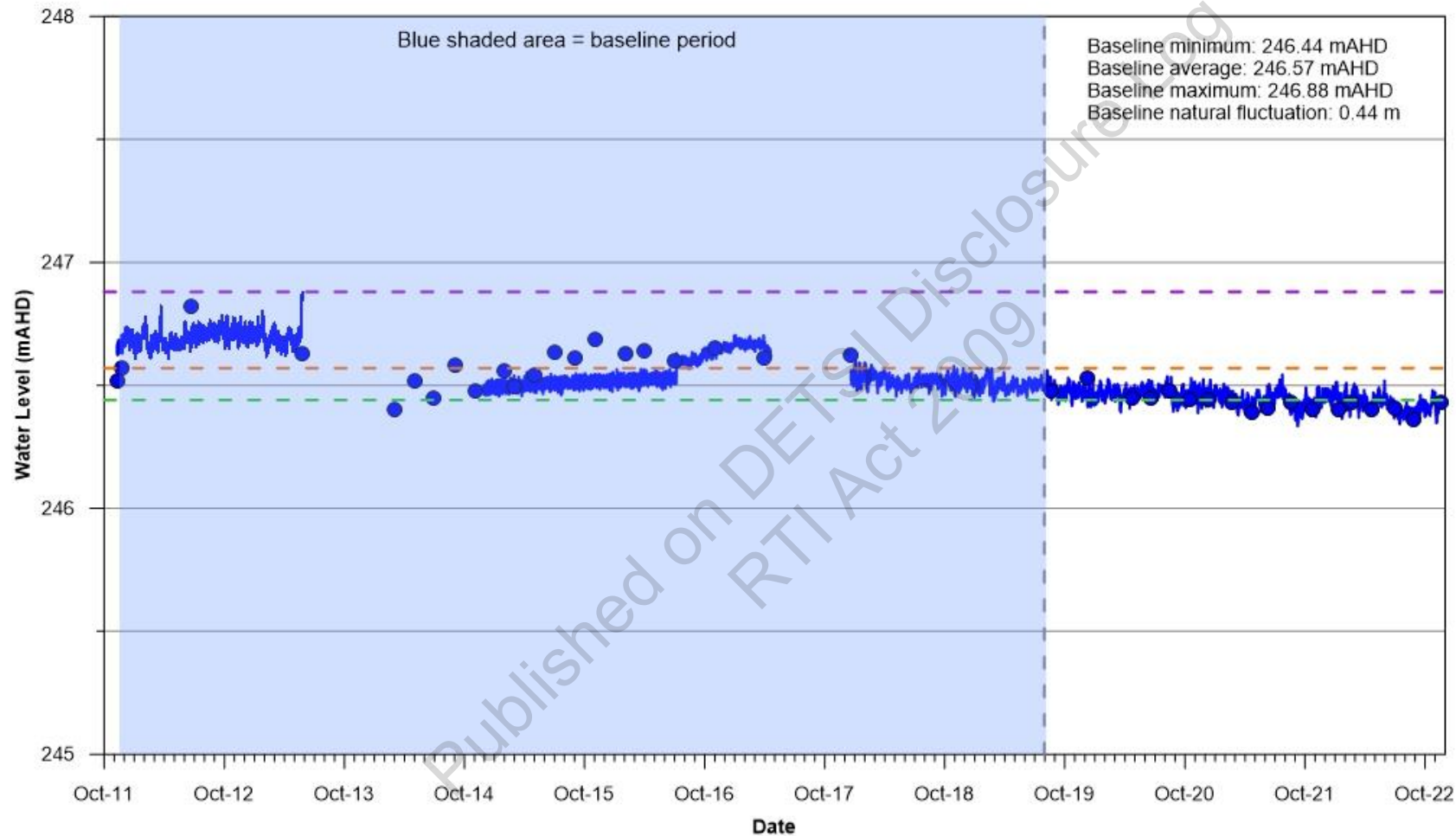
Appendix B

Hydrographs showing updated baseline datasets



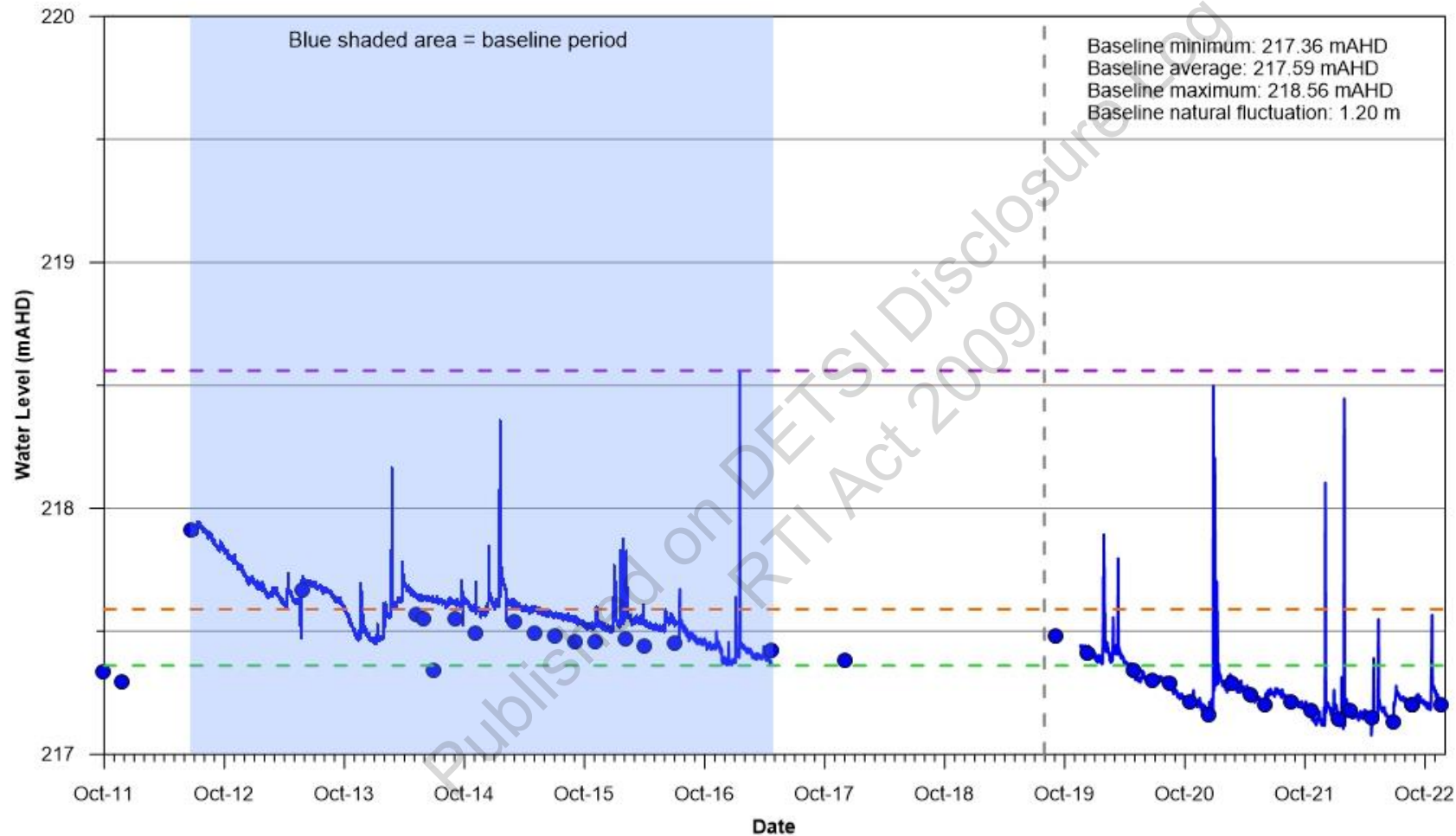
C022P1 (Dunda Beds)

- Representative logger data
- Manual measurements
- - - Minimum baseline logger water level
- - - Average baseline logger water level
- - - Maximum baseline logger water level
- - - Start of dewatering



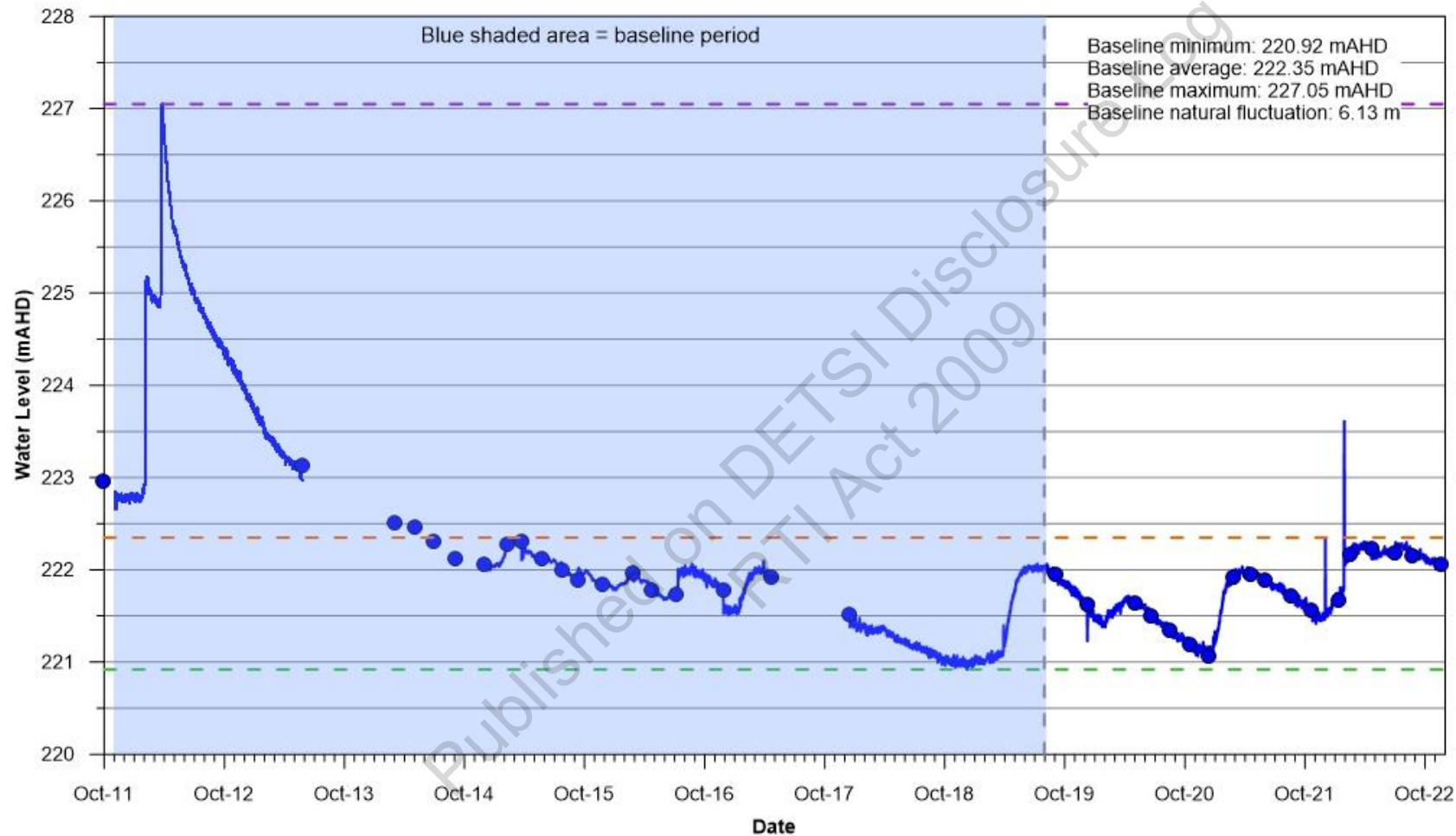
C025P2 (Tertiary sediments)

- Representative logger data - - - Minimum baseline logger water level - - - Maximum baseline logger water level
- Manual measurements - - - Average baseline logger water level - - - Start of dewatering



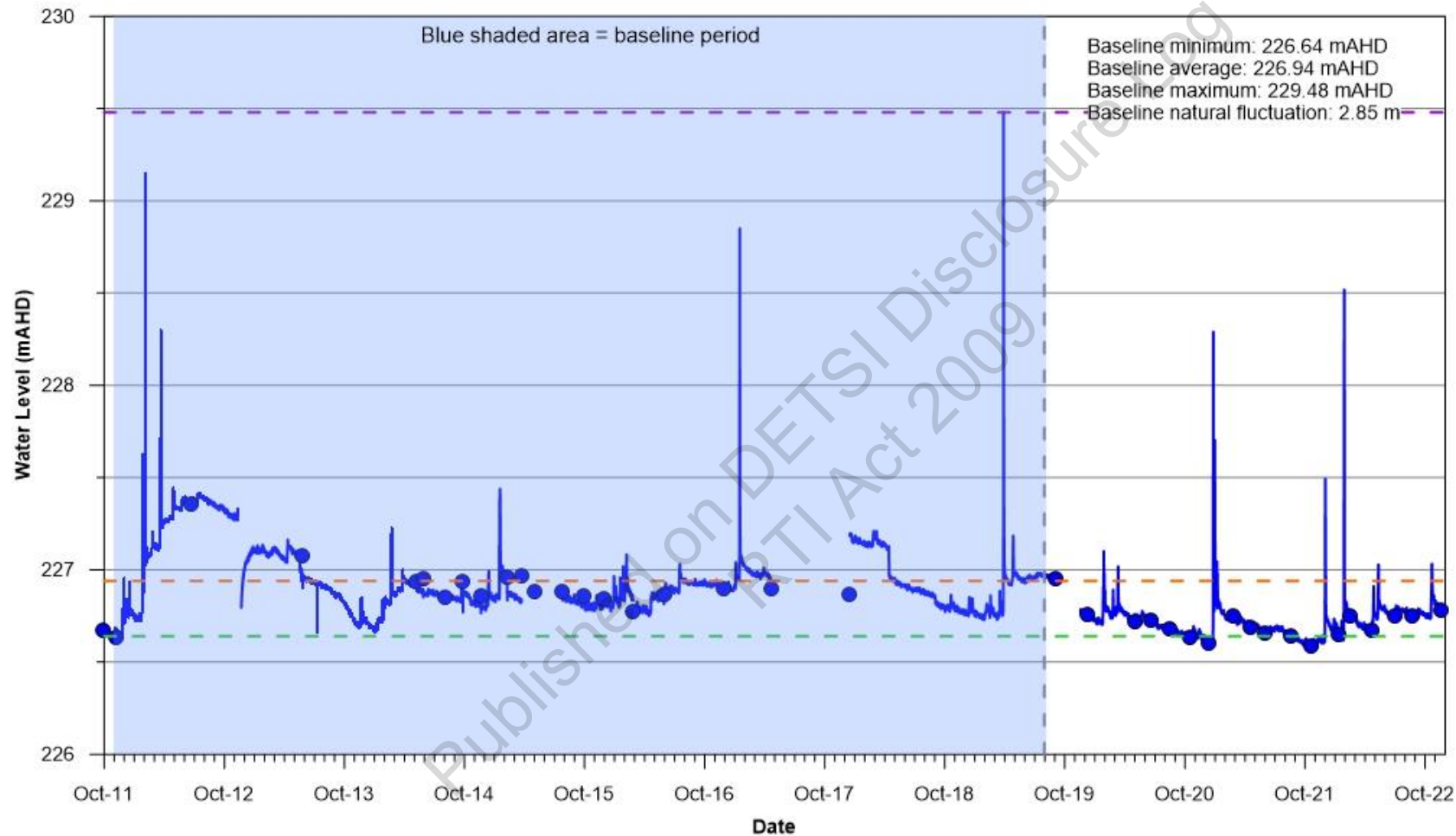
C027P1 (Alluvium)

- Representative logger data
- Manual measurements
- - - Minimum baseline logger water level
- - - Average baseline logger water level
- - - Maximum baseline logger water level
- - - Start of dewatering



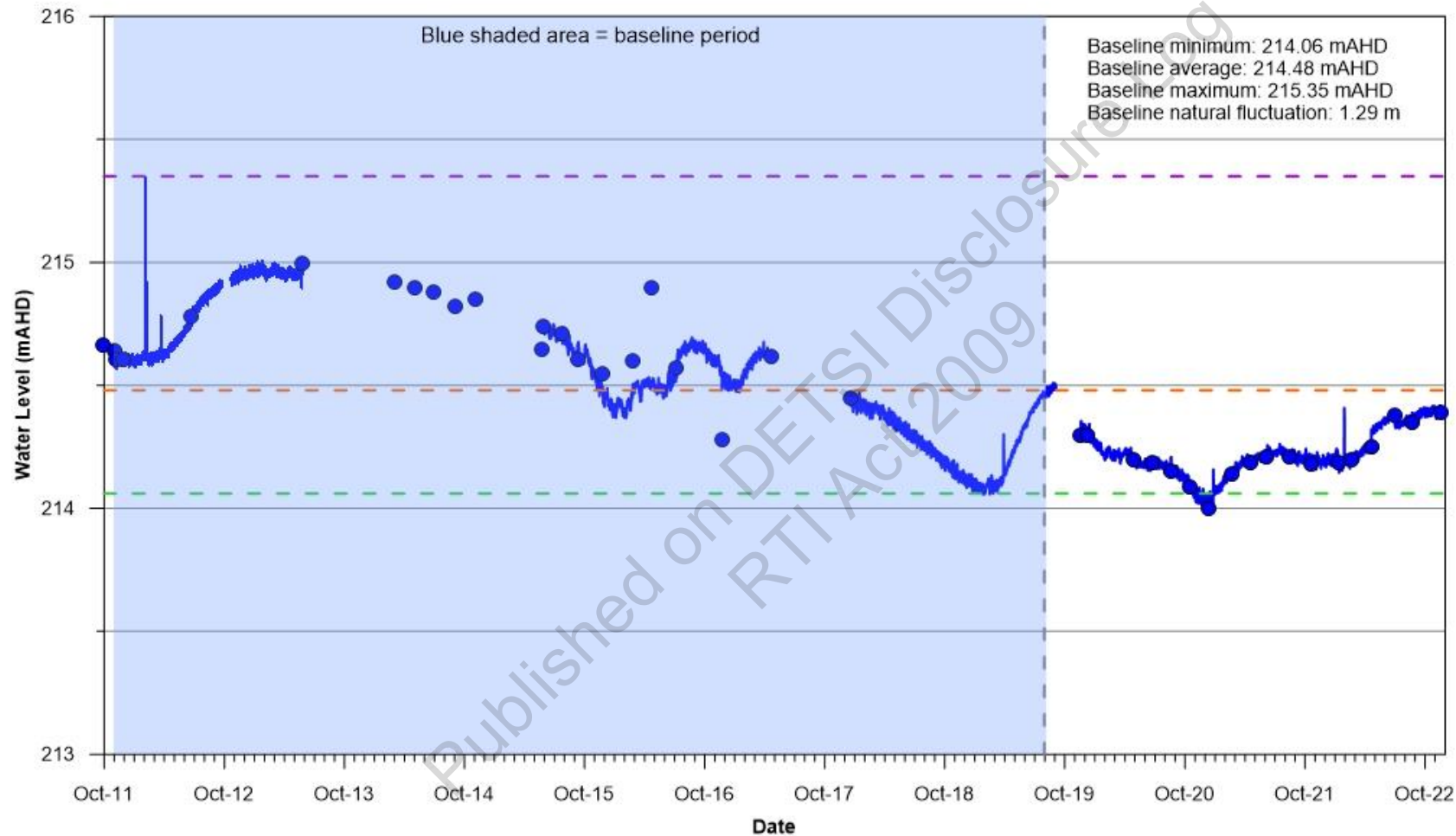
C027P2 (Dunda Beds)

- Representative logger data
- Minimum baseline logger water level
- Maximum baseline logger water level
- Manual measurements
- Average baseline logger water level
- Start of dewatering



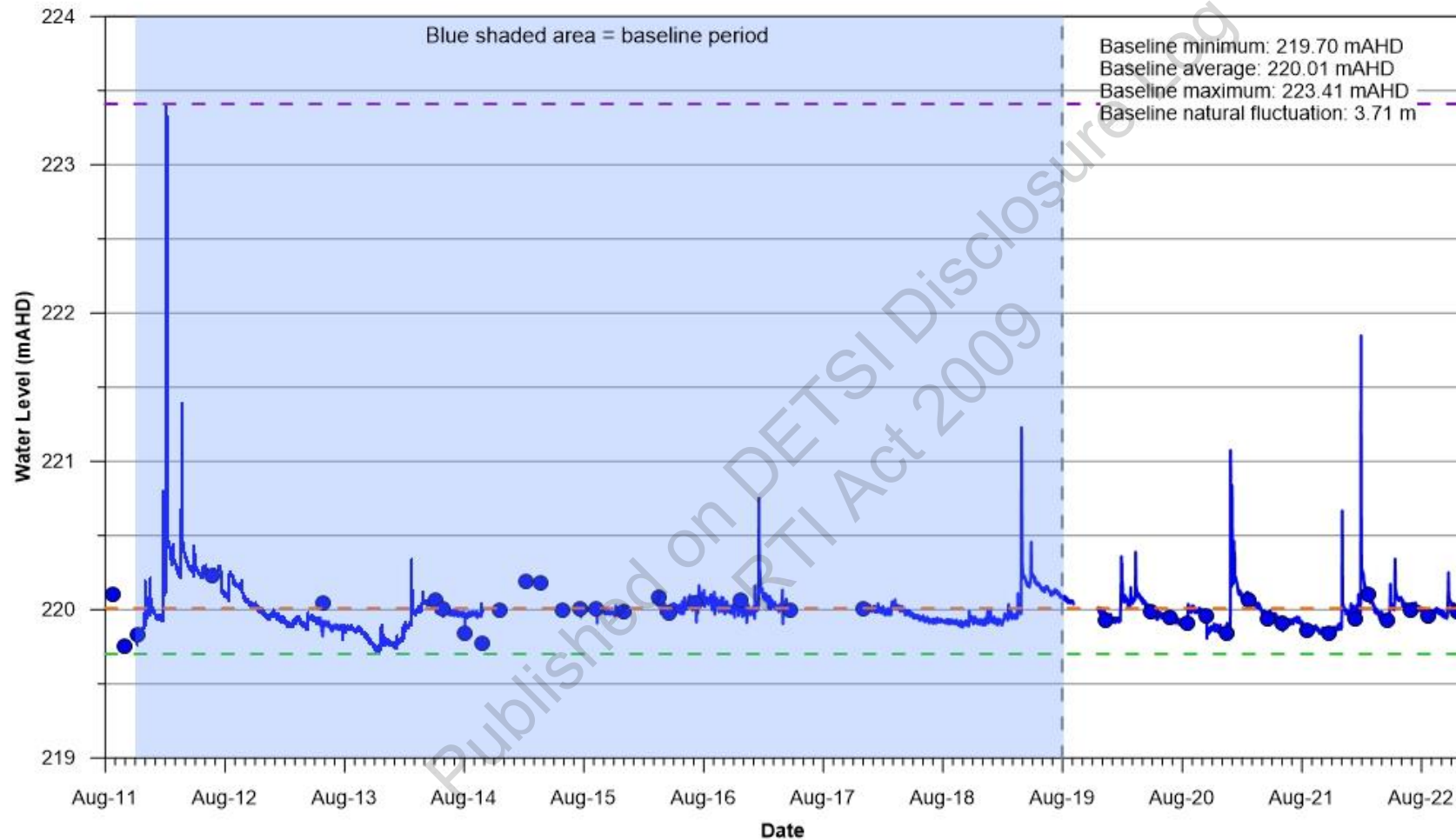
C029P1 (Alluvium)

- Representative logger data
- Manual measurements
- - - Minimum baseline logger water level
- - - Average baseline logger water level
- - - Maximum baseline logger water level
- - - Start of dewatering



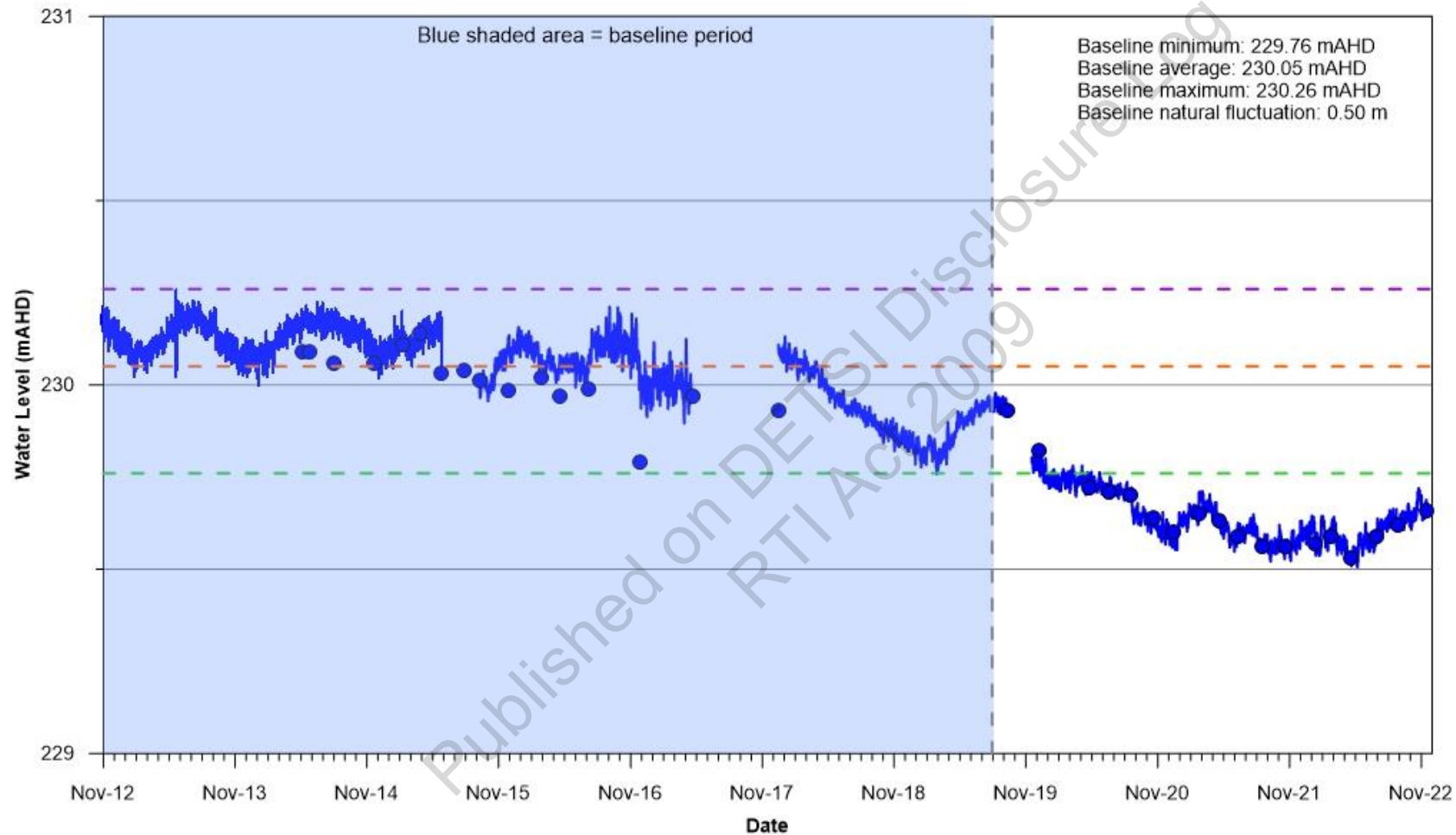
C029P2 (Tertiary sediments)

- Representative logger data
- Manual measurements
- Minimum baseline logger water level
- Average baseline logger water level
- Maximum baseline logger water level
- Start of dewatering



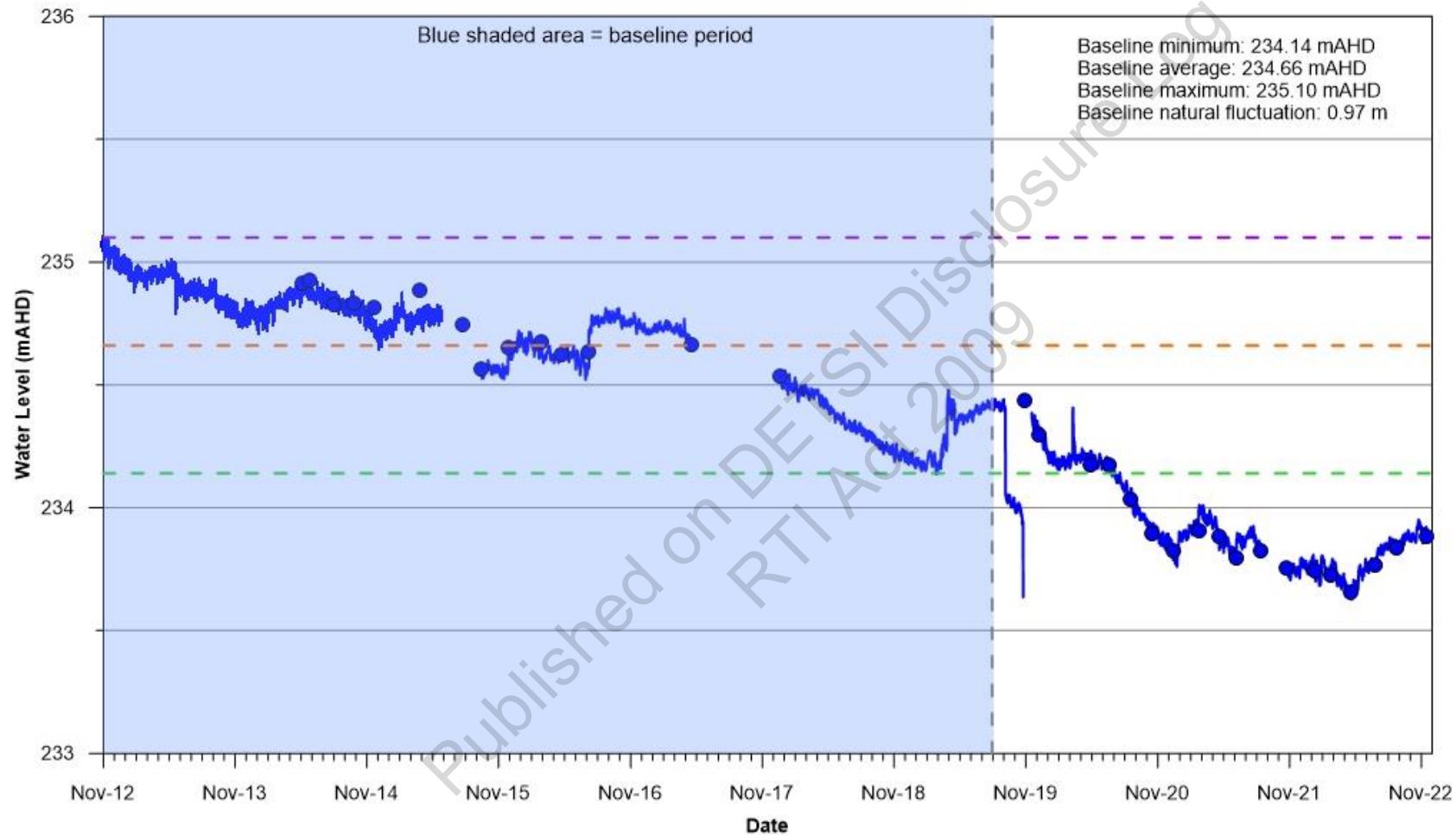
C555P1 (Rewan Formation)

- Representative logger data
- Manual measurements
- - - Minimum baseline logger water level
- - - Average baseline logger water level
- - - Maximum baseline logger water level
- - - Start of dewatering



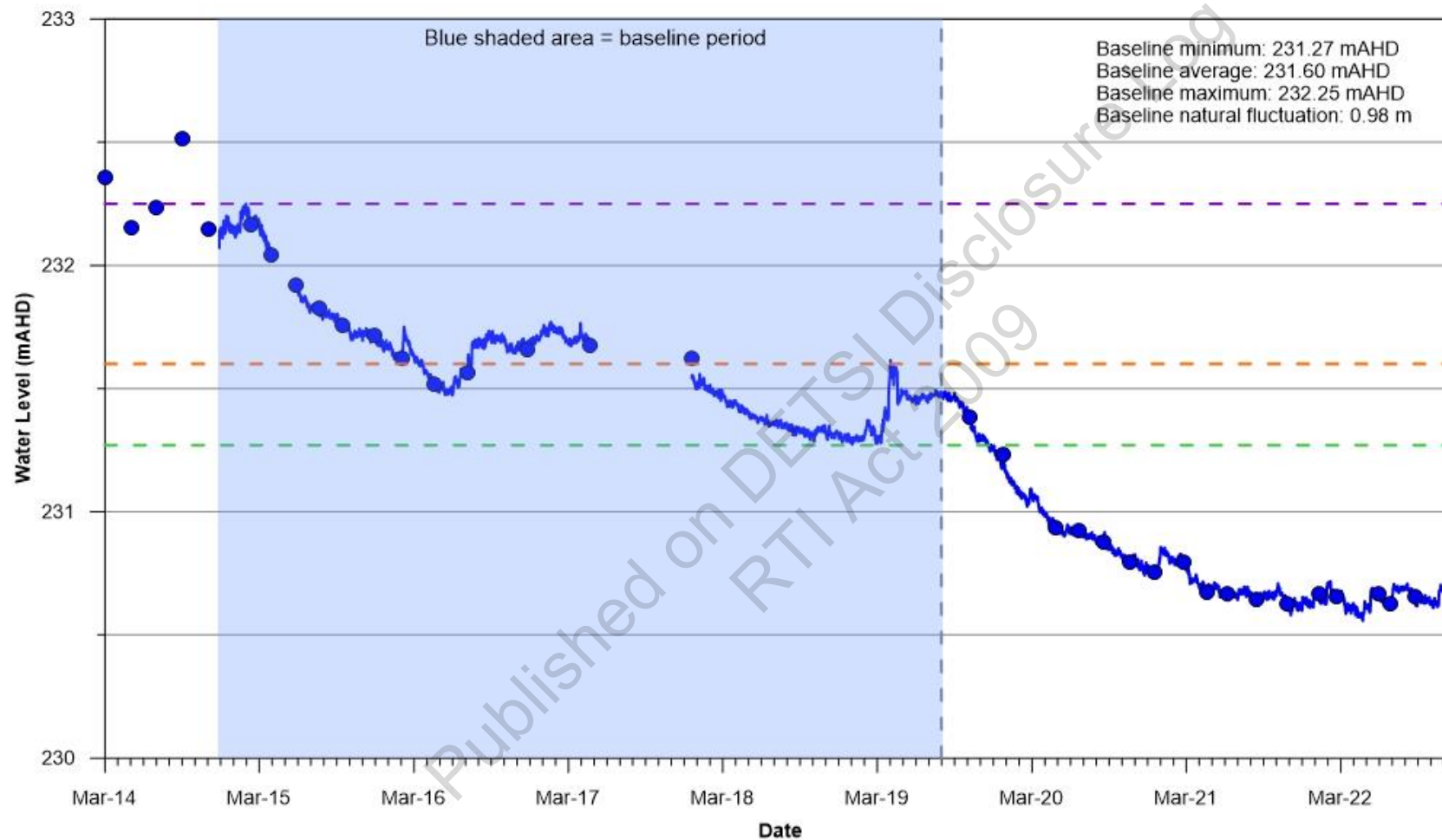
C556P1 (Rewan Formation)

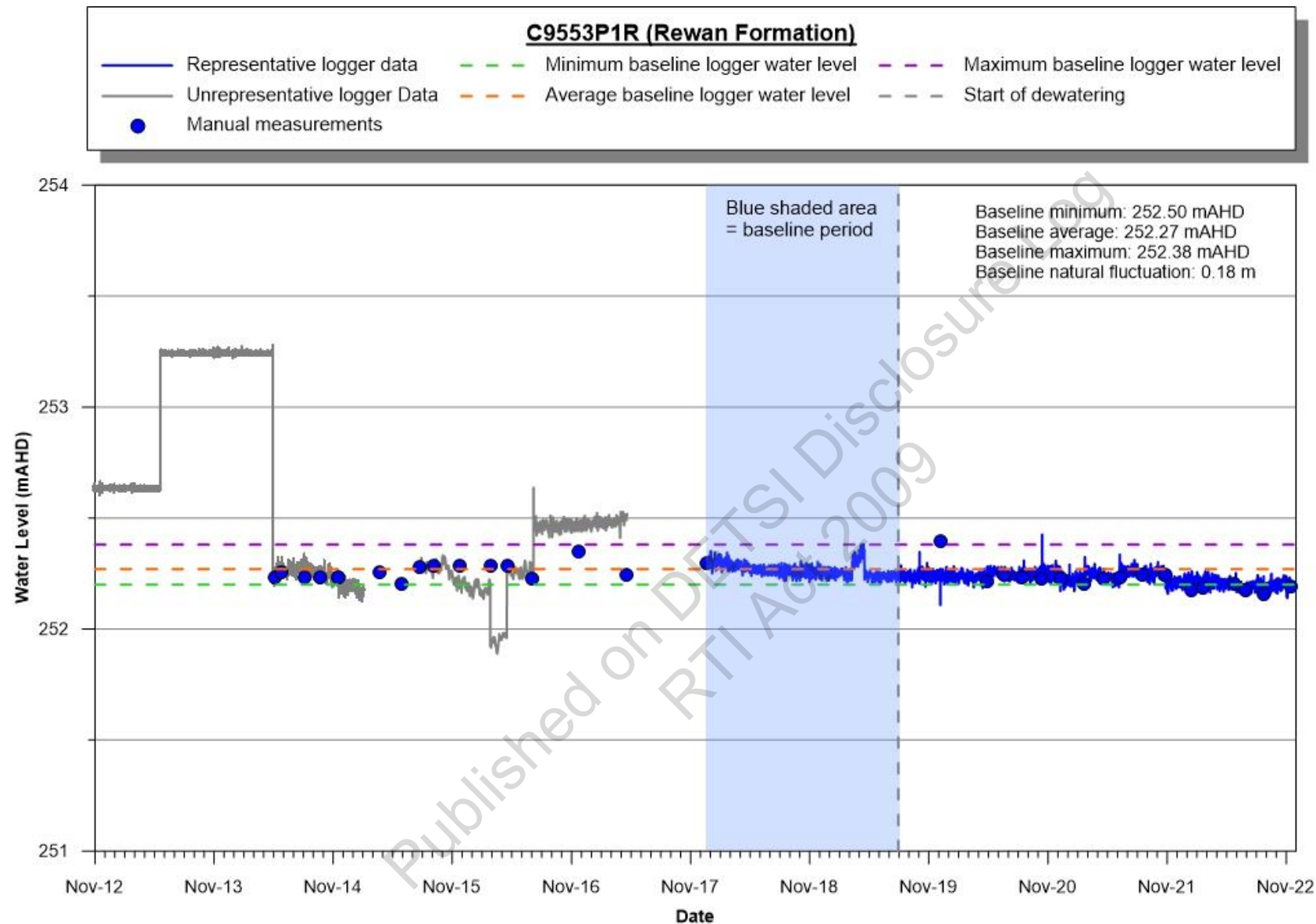
- Representative logger data - - - Minimum baseline logger water level - - - Maximum baseline logger water level
- Manual measurements - - - Average baseline logger water level - - - Start of dewatering



C848SP (Colinlea Formation - D Seam)

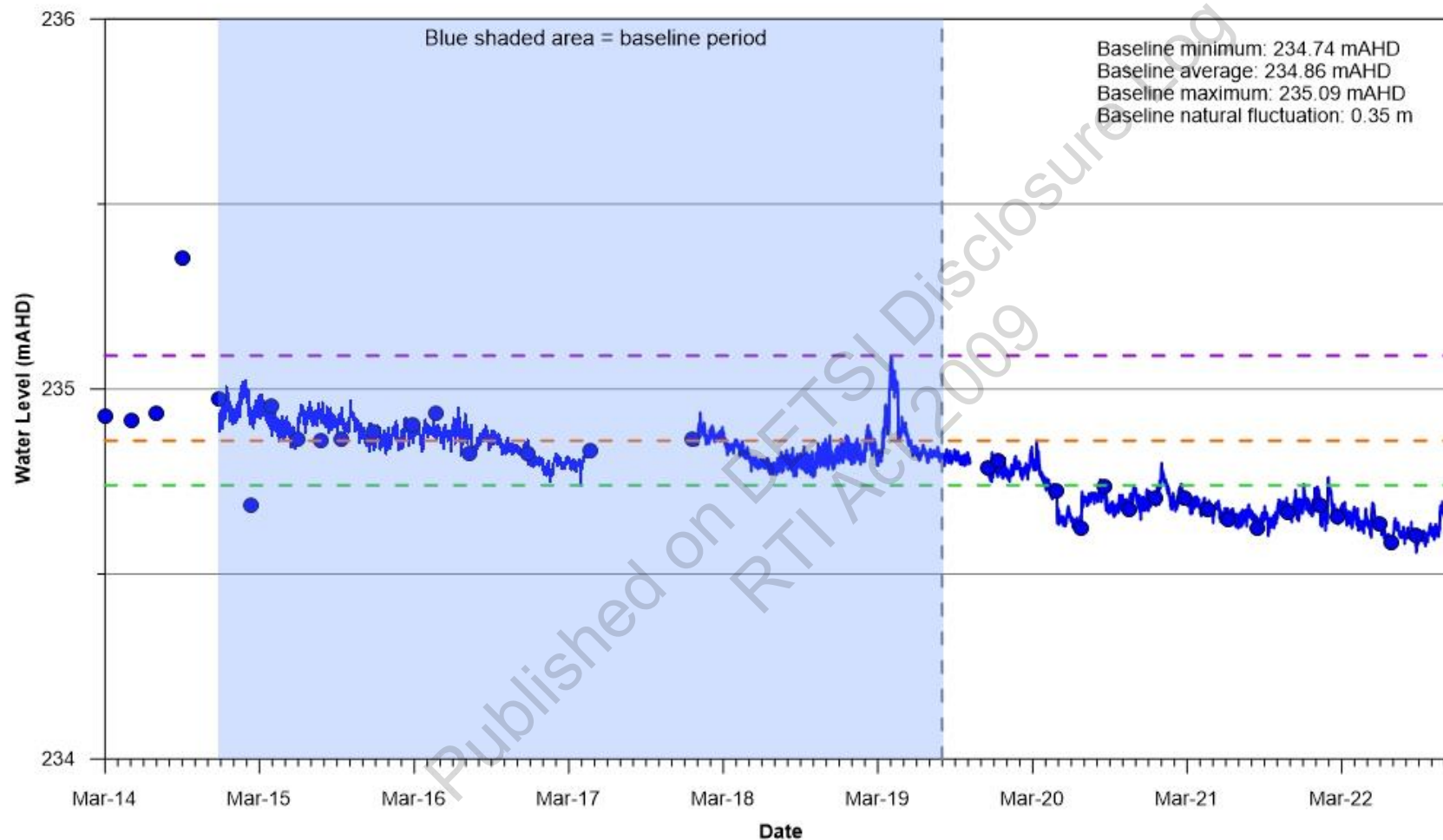
- Representative logger data - - - Minimum baseline logger water level - - - Maximum baseline logger water level
- Manual measurements - - - Average baseline logger water level - - - Start of dewatering





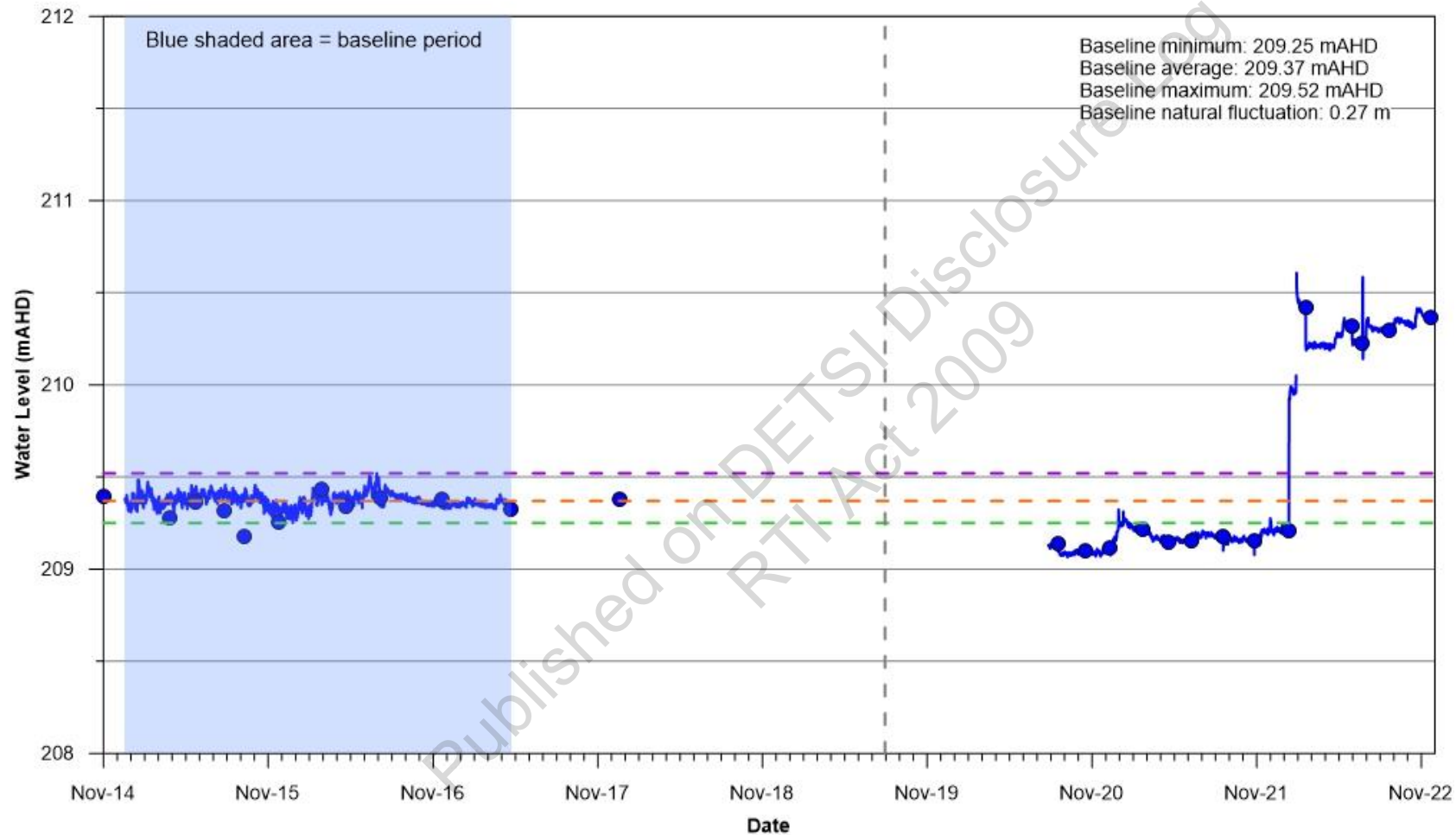
C9845SPR (Tertiary sediments)

- Representative logger data - - - Minimum baseline logger water level - - - Maximum baseline logger water level
- Manual measurements - - - Average baseline logger water level - - - Start of dewatering



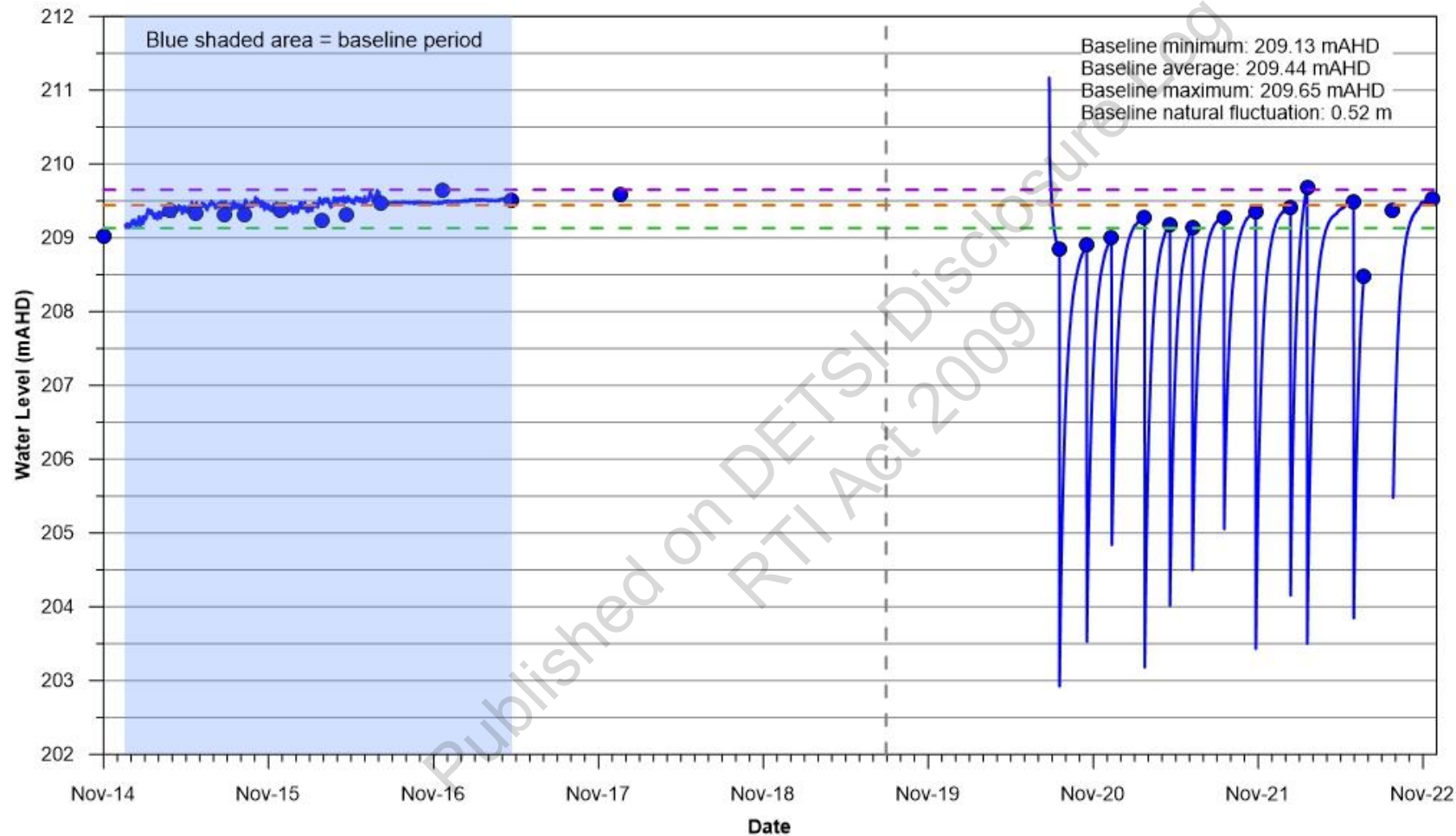
C14003SP (Joe Joe Group)

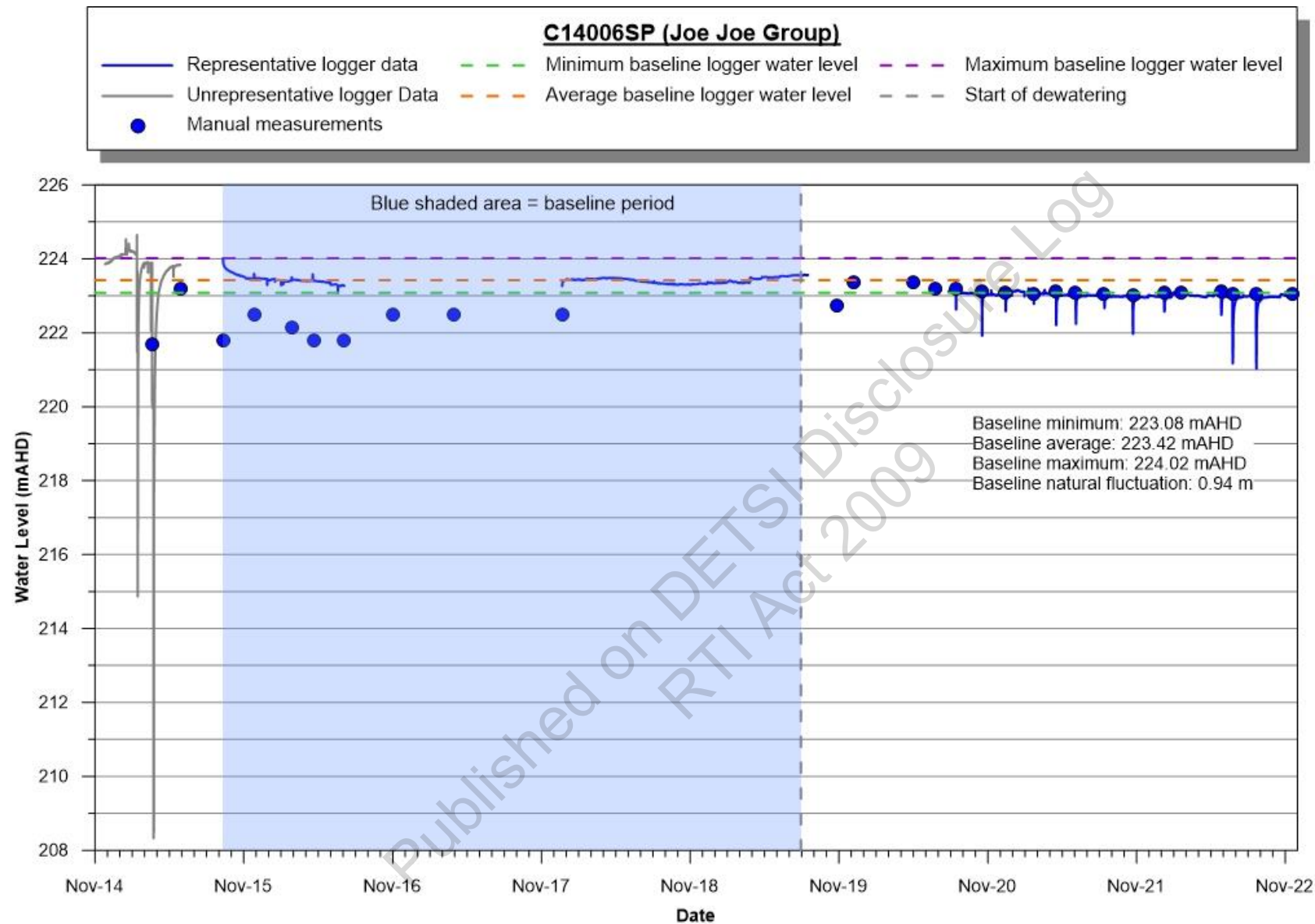
- Representative logger data - - - Minimum baseline logger water level - - - Maximum baseline logger water level
- Manual measurements - - - Average baseline logger water level - - - Start of dewatering



C14004SP (Joe Joe Group)

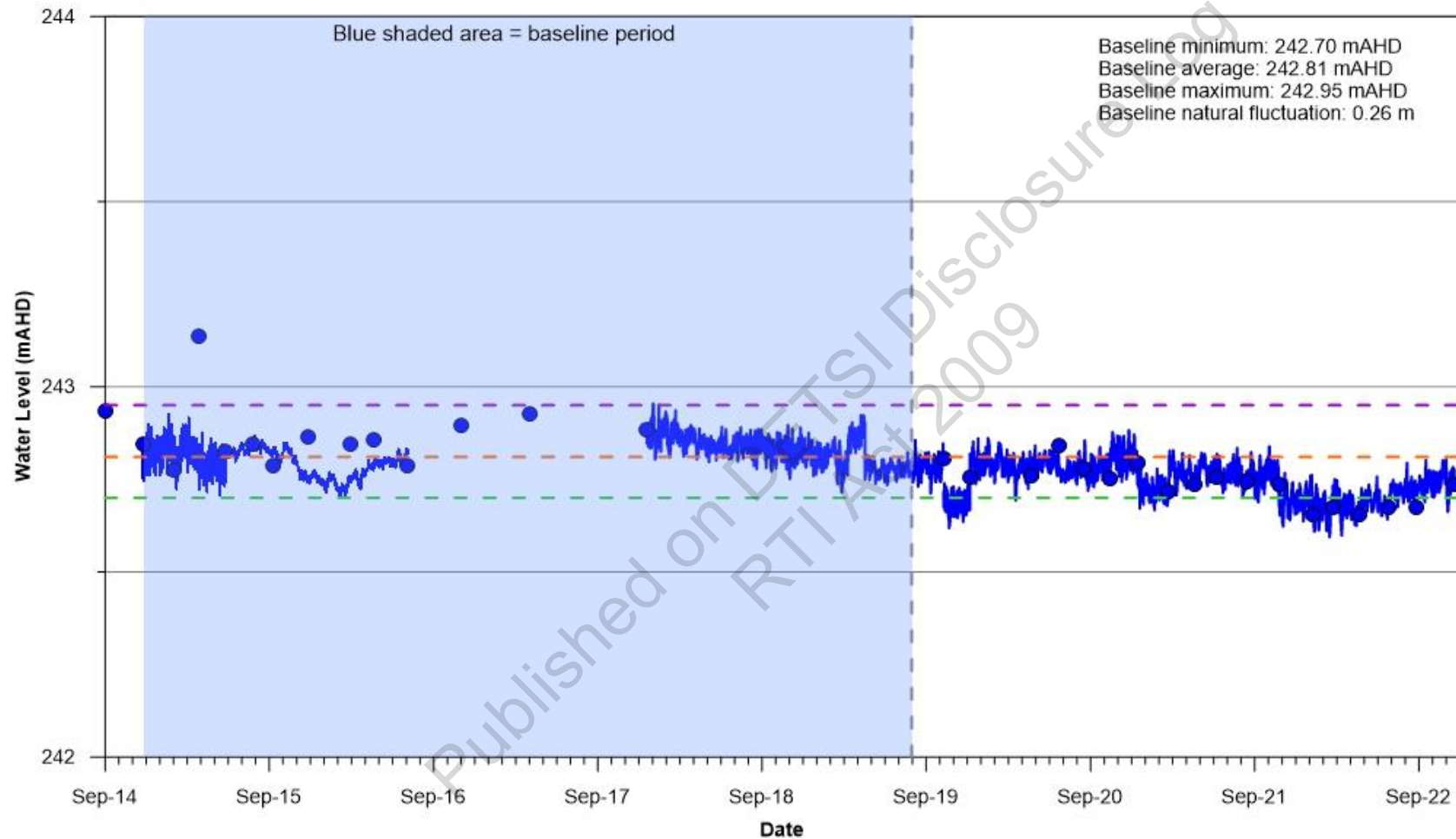
- Representative logger data - - - Minimum baseline logger water level - - - Maximum baseline logger water level
- Manual measurements - - - Average baseline logger water level - - - Start of dewatering





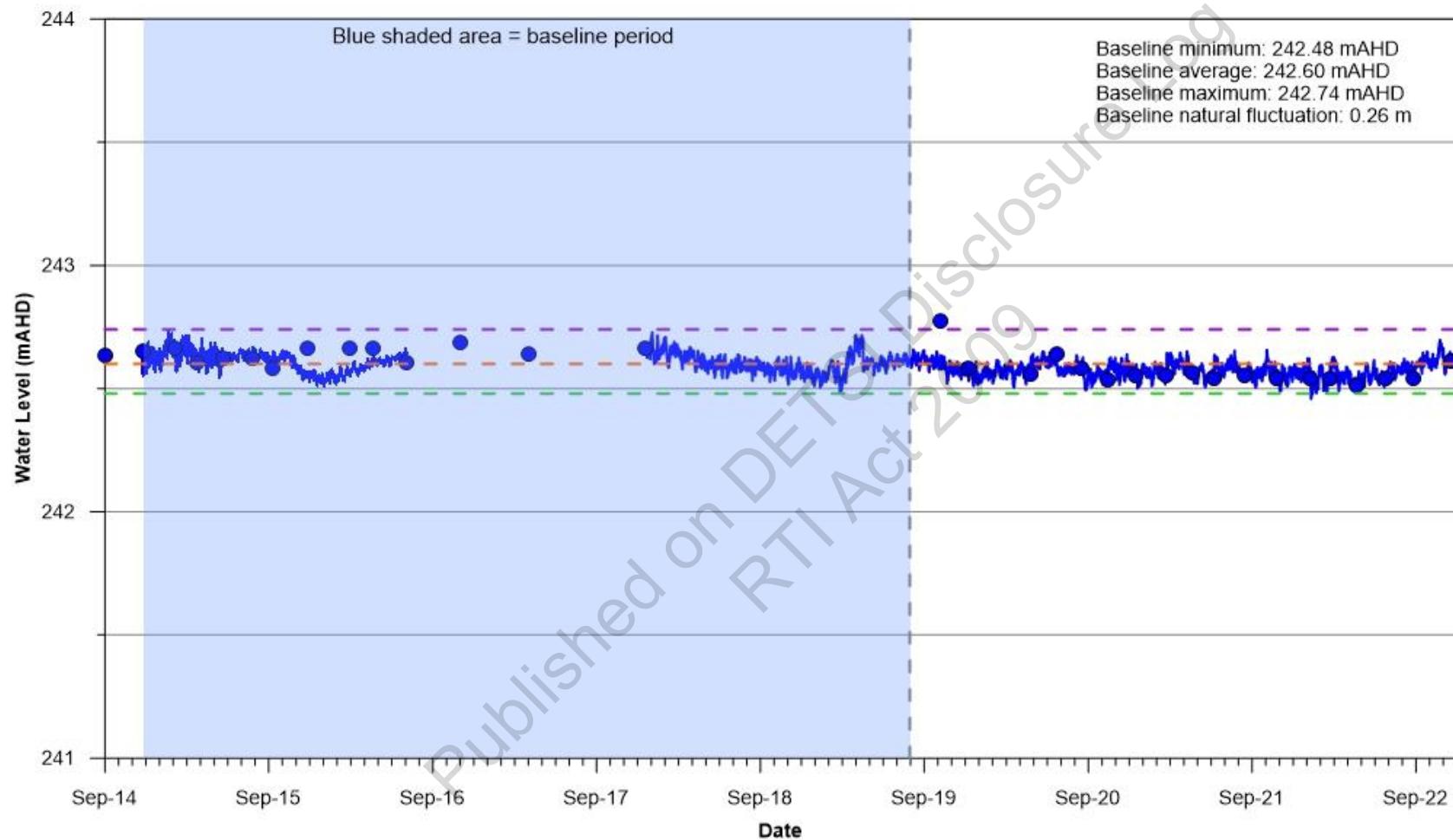
C14011SP (Clematis)

- Representative logger data
- Manual measurements
- Minimum baseline logger water level
- Average baseline logger water level
- Maximum baseline logger water level
- Start of dewatering



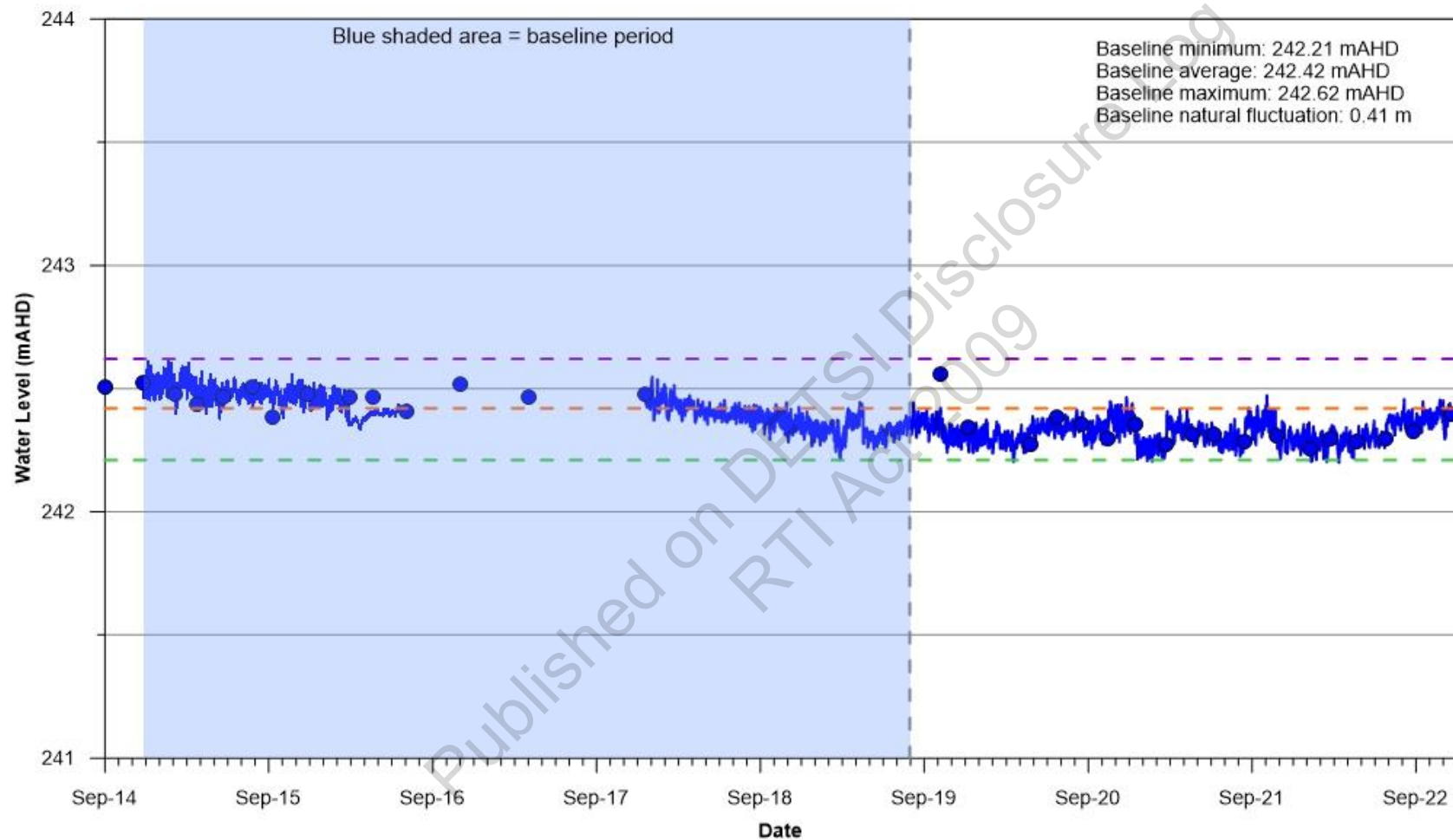
C14012SP (Clematis)

- Representative logger data - - - Minimum baseline logger water level - - - Maximum baseline logger water level
- Manual measurements - - - Average baseline logger water level - - - Start of dewatering



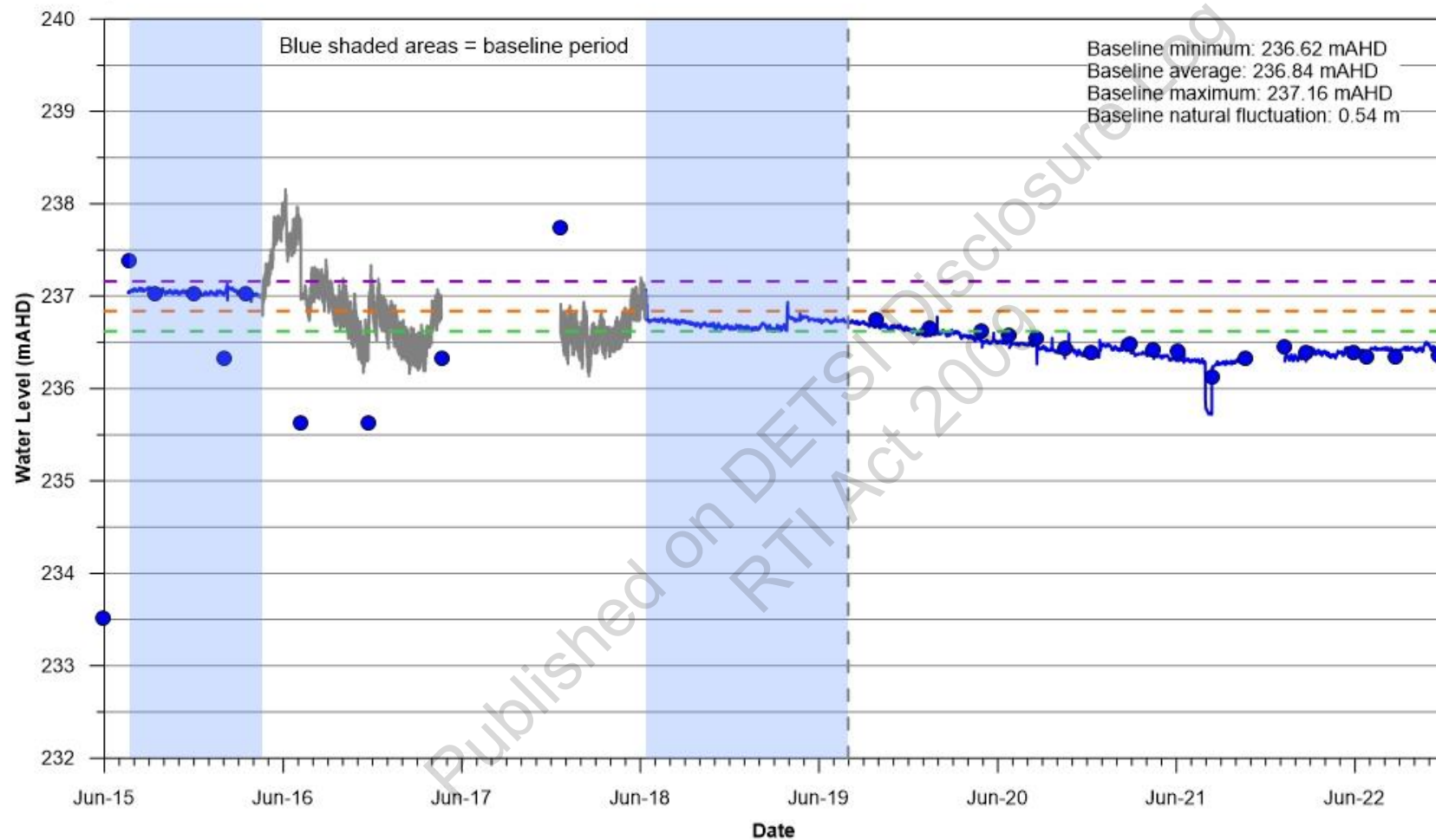
C14013SP (Clematis)

- Representative logger data
- Minimum baseline logger water level
- Maximum baseline logger water level
- Manual measurements
- Average baseline logger water level
- - - Start of dewatering



C14015SP (Joe Joe Group)

- Representative logger Data - - - Minimum baseline logger water level - - - Maximum baseline logger water level
- Unrepresentative logger Data - - - Average baseline logger water level - - - Start of dewatering
- Manual measurements



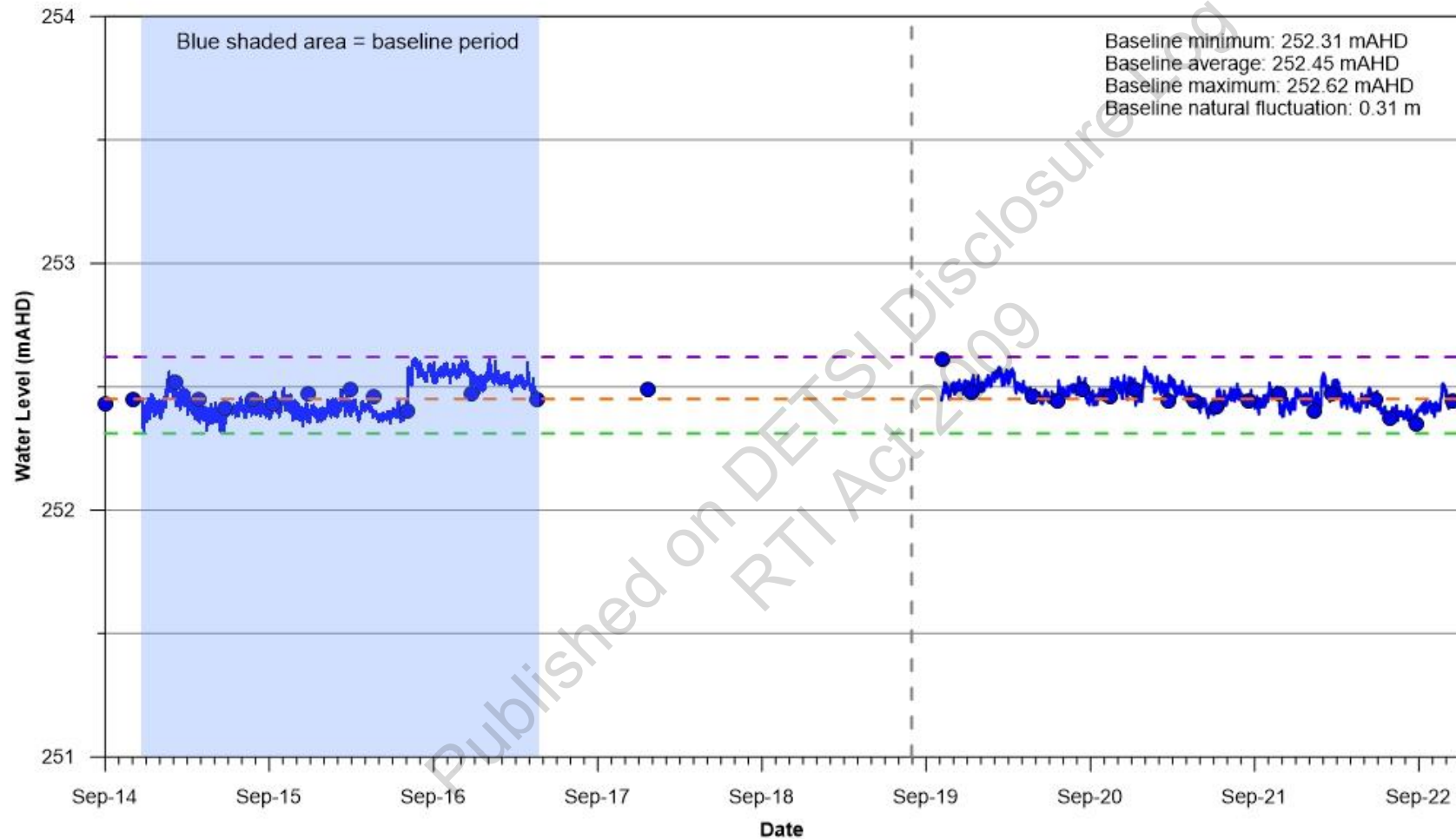
C14016SP (Joe Joe Group)

- Representative logger data - - - Minimum baseline logger water level - - - Maximum baseline logger water level
- Manual measurements - - - Average baseline logger water level - - - Start of dewatering



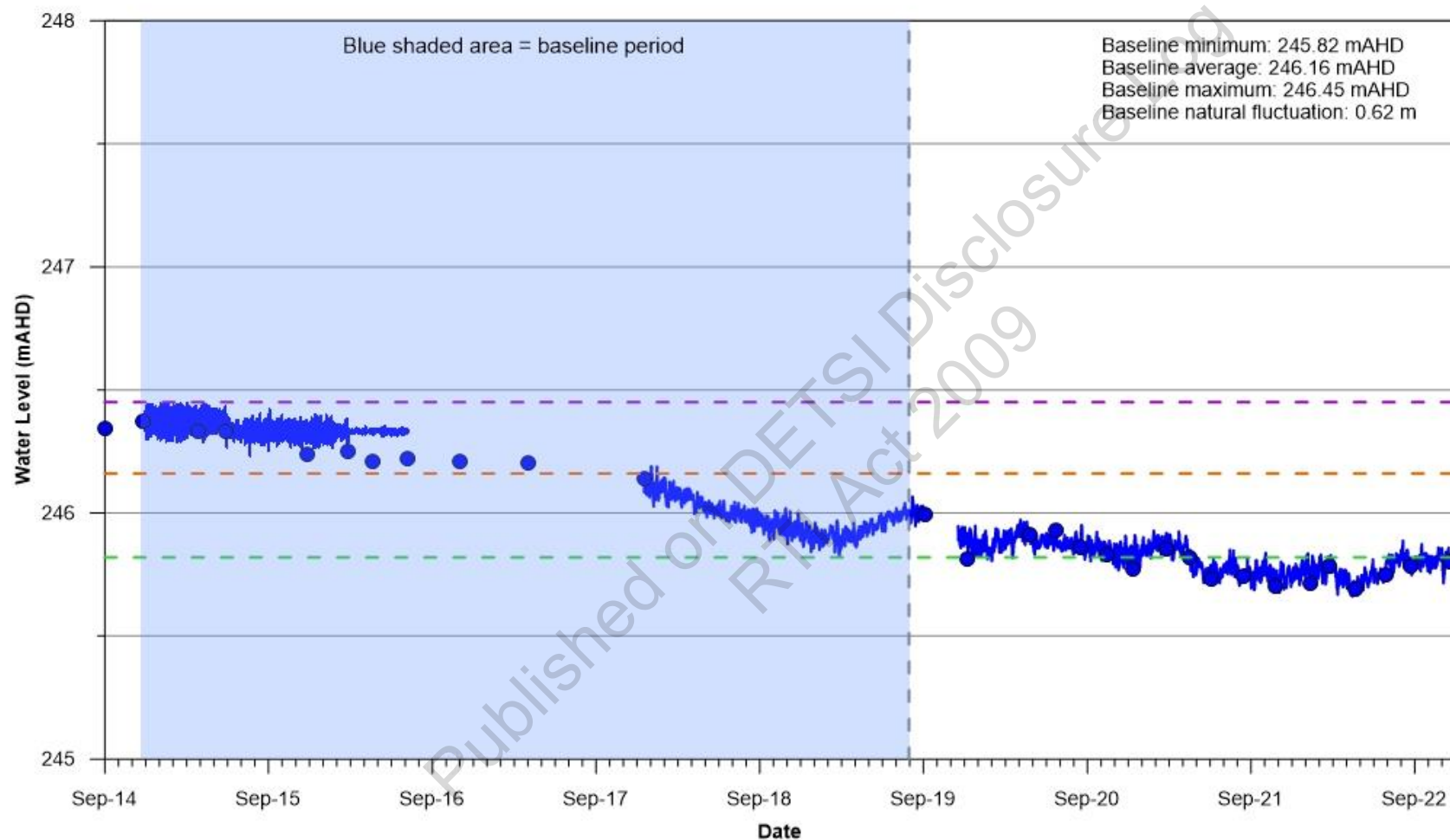
C14020SP (Moolayember)

- Representative logger data
- Manual measurements
- Minimum baseline logger water level
- Average baseline logger water level
- Maximum baseline logger water level
- Start of dewatering



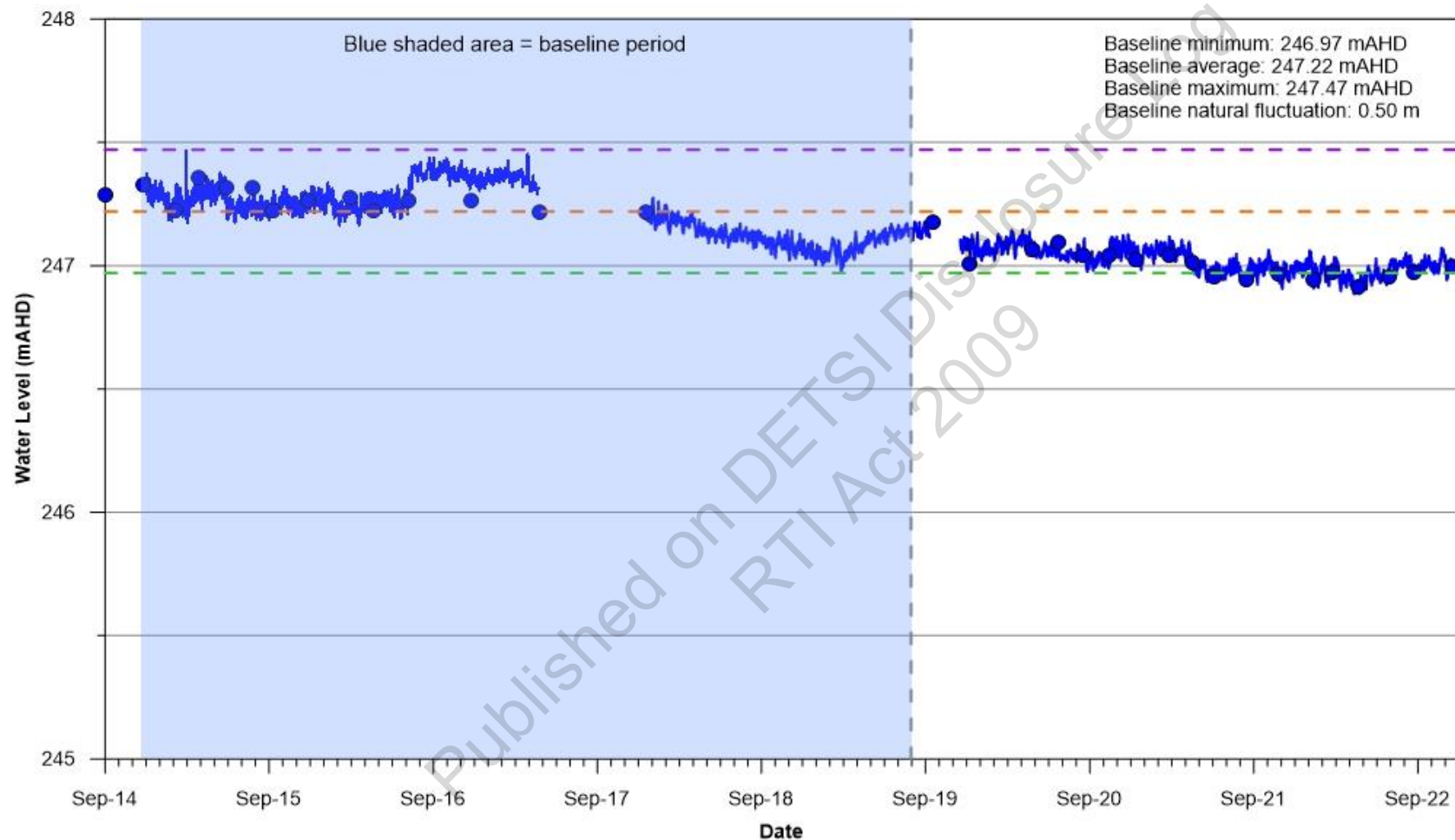
C14021SP (Clematis)

- Representative logger data
- Minimum baseline logger water level
- Maximum baseline logger water level
- Manual measurements
- Average baseline logger water level
- Start of dewatering



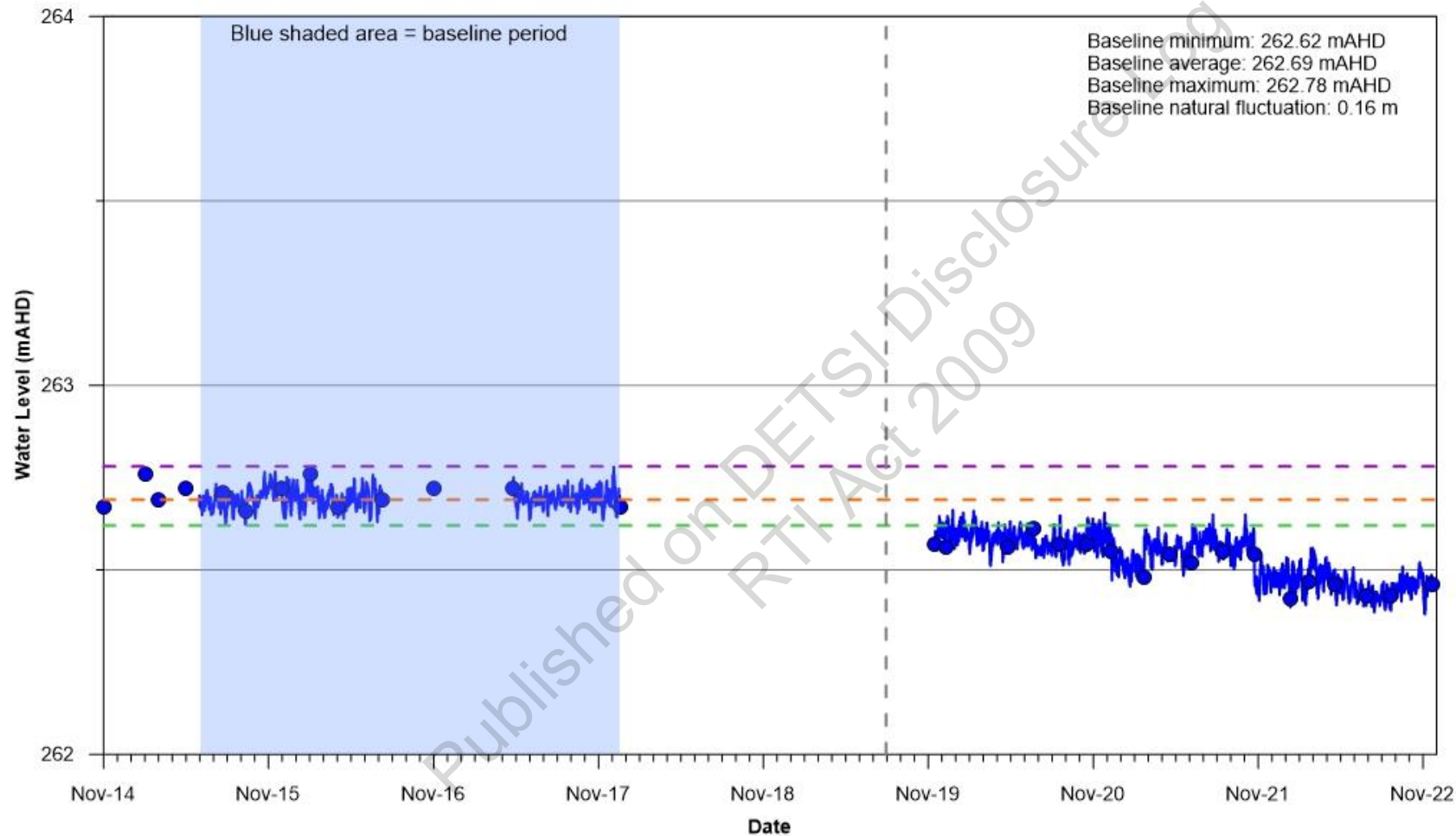
C14023SP (Dunda Beds)

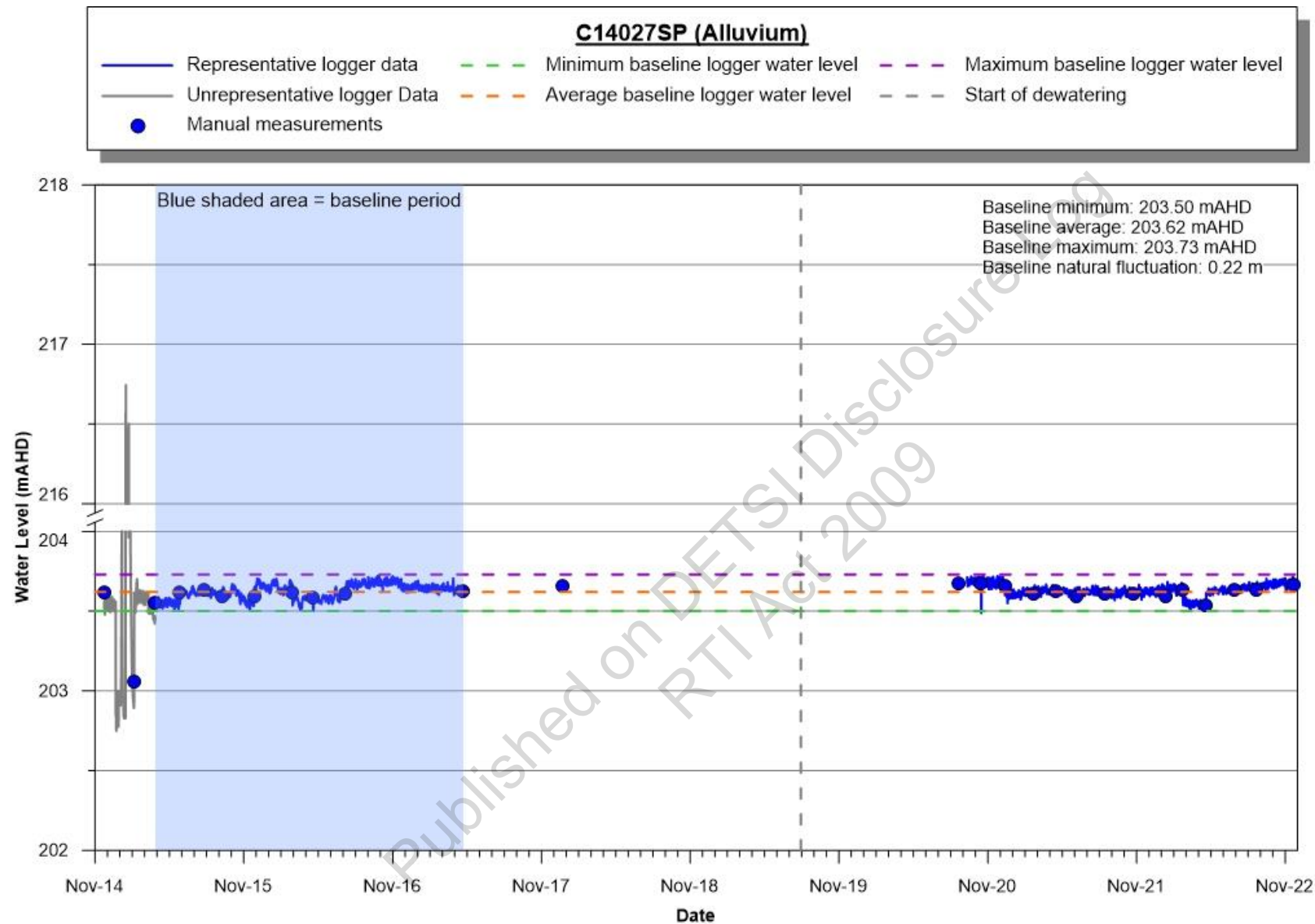
- Representative logger data - - - Minimum baseline logger water level - - - Maximum baseline logger water level
- Manual measurements - - - Average baseline logger water level - - - Start of dewatering



C14024SP (Clematis/Rewan Group)

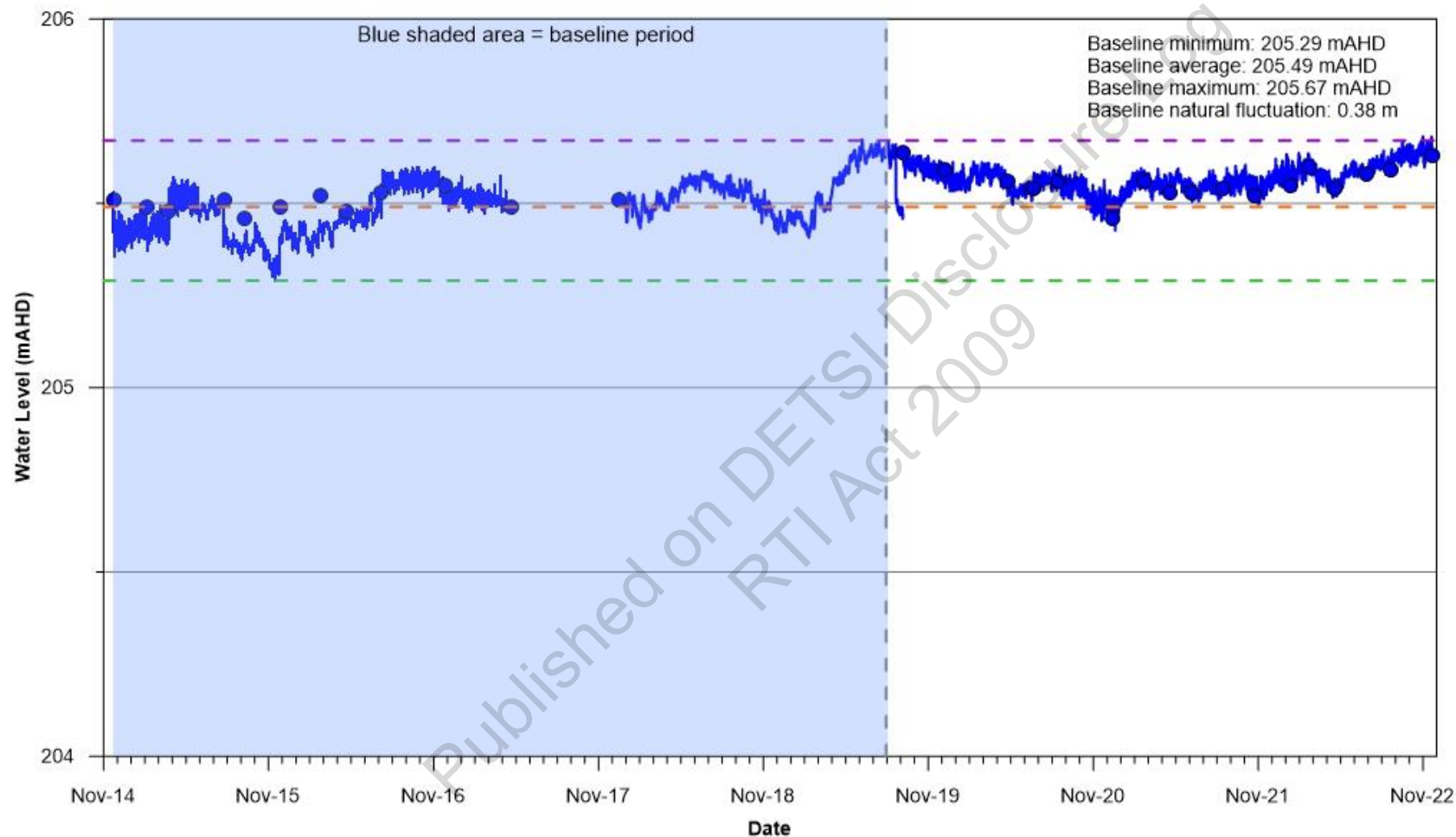
- Representative logger data
- Manual measurements
- Minimum baseline logger water level
- Average baseline logger water level
- Maximum baseline logger water level
- Start of dewatering





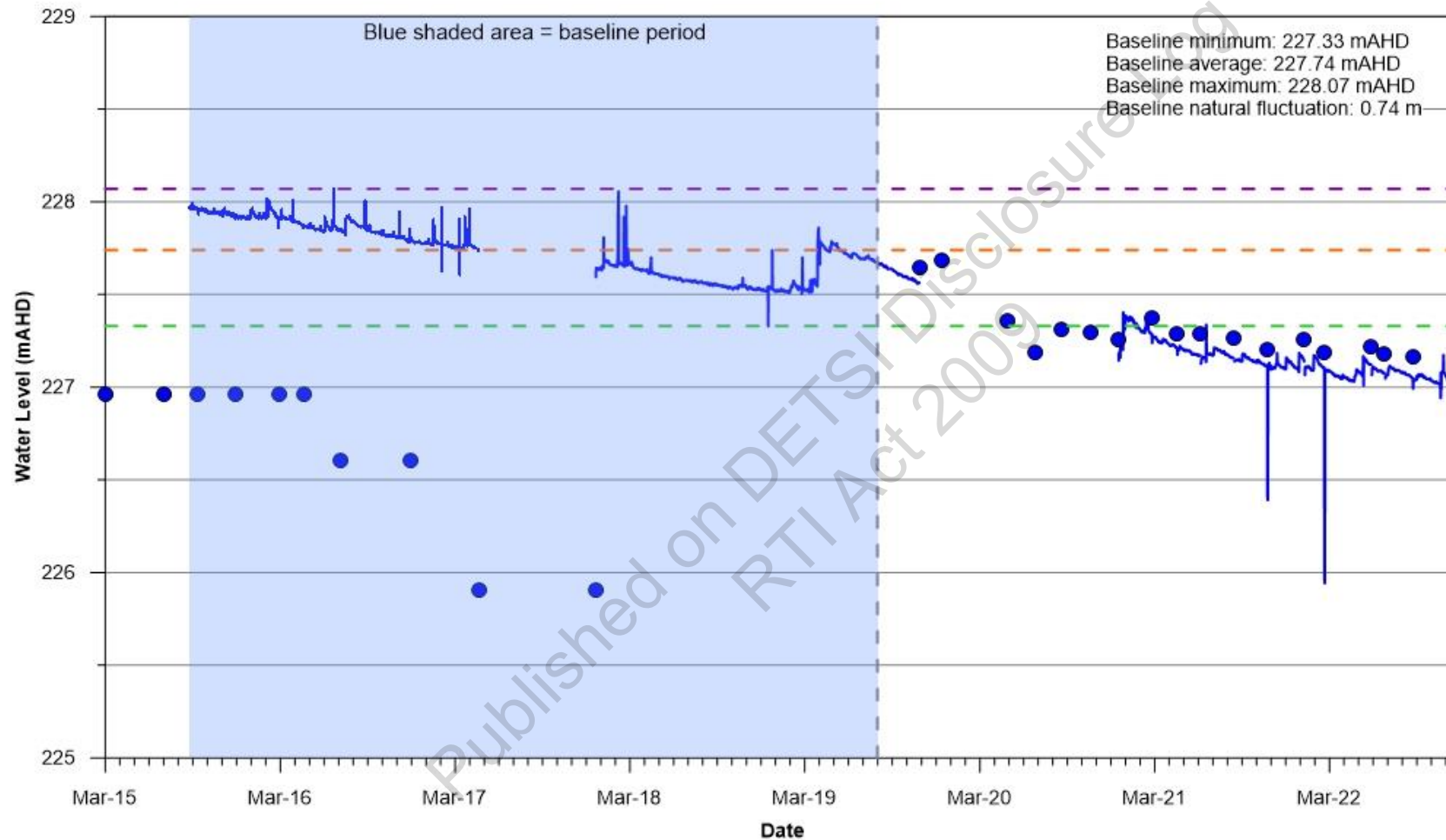
C14028SP (Alluvium)

- Representative logger data - - - Minimum baseline logger water level - - - Maximum baseline logger water level
- Manual measurements - - - Average baseline logger water level - - - Start of dewatering



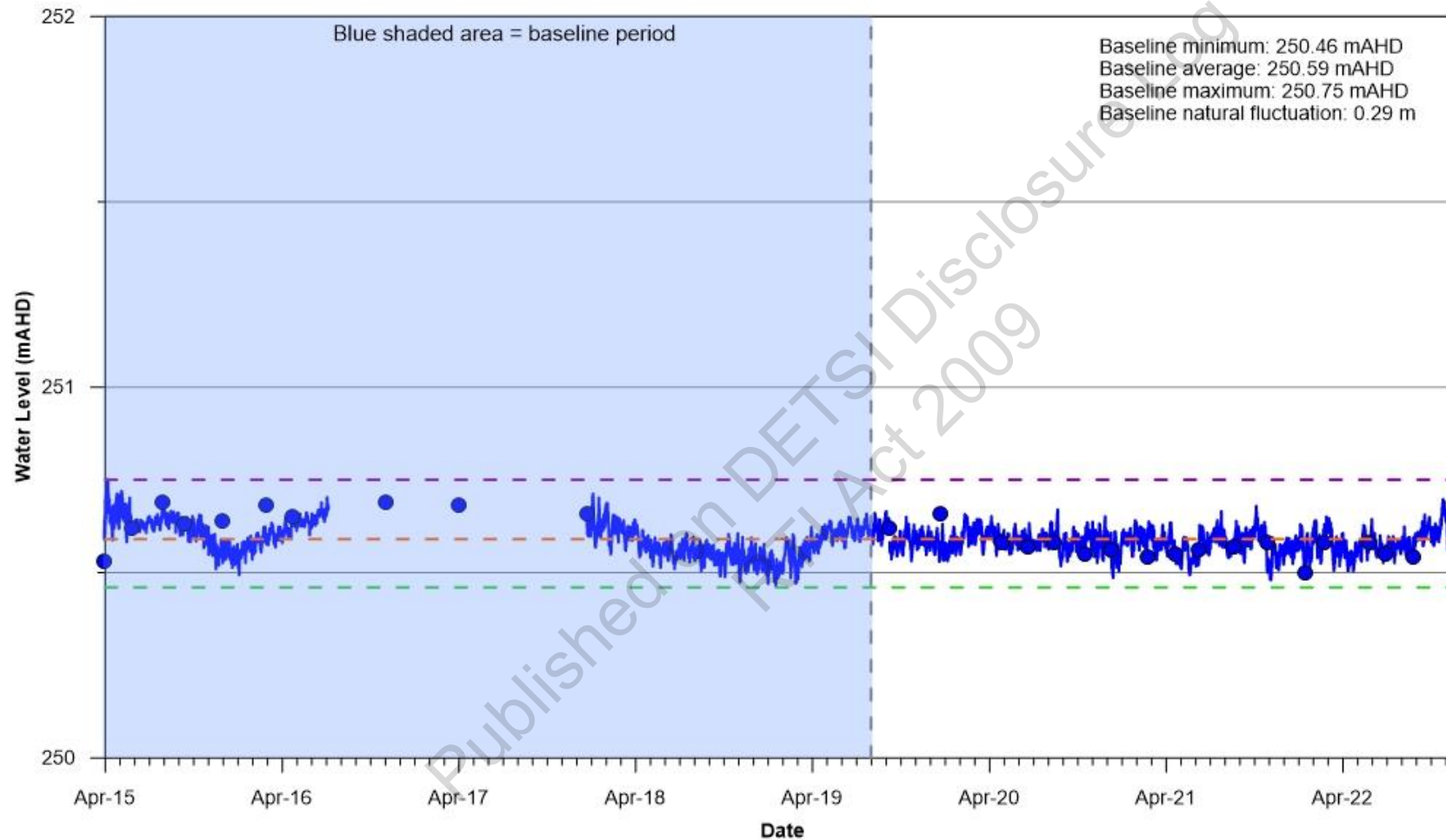
C14029SP (Tertiary sediments/Joe Joe Group)

- Representative logger data - - - Minimum baseline logger water level - - - Maximum baseline logger water level
- Manual measurements - - - Average baseline logger water level - - - Start of dewatering



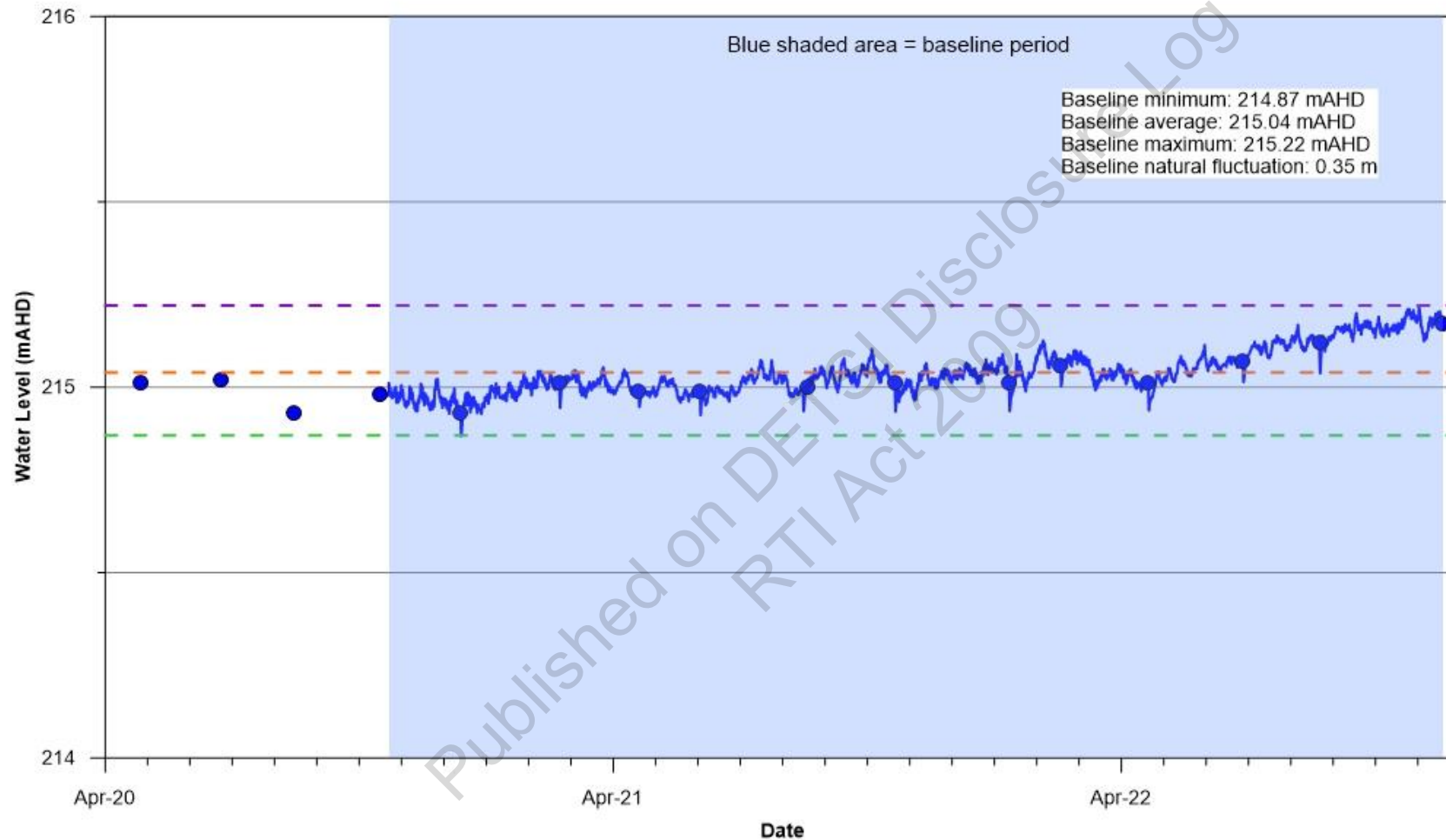
C14033SP (Clematis)

- Representative logger data
- Minimum baseline logger water level
- Maximum baseline logger water level
- Manual measurements
- Average baseline logger water level
- - - Start of dewatering



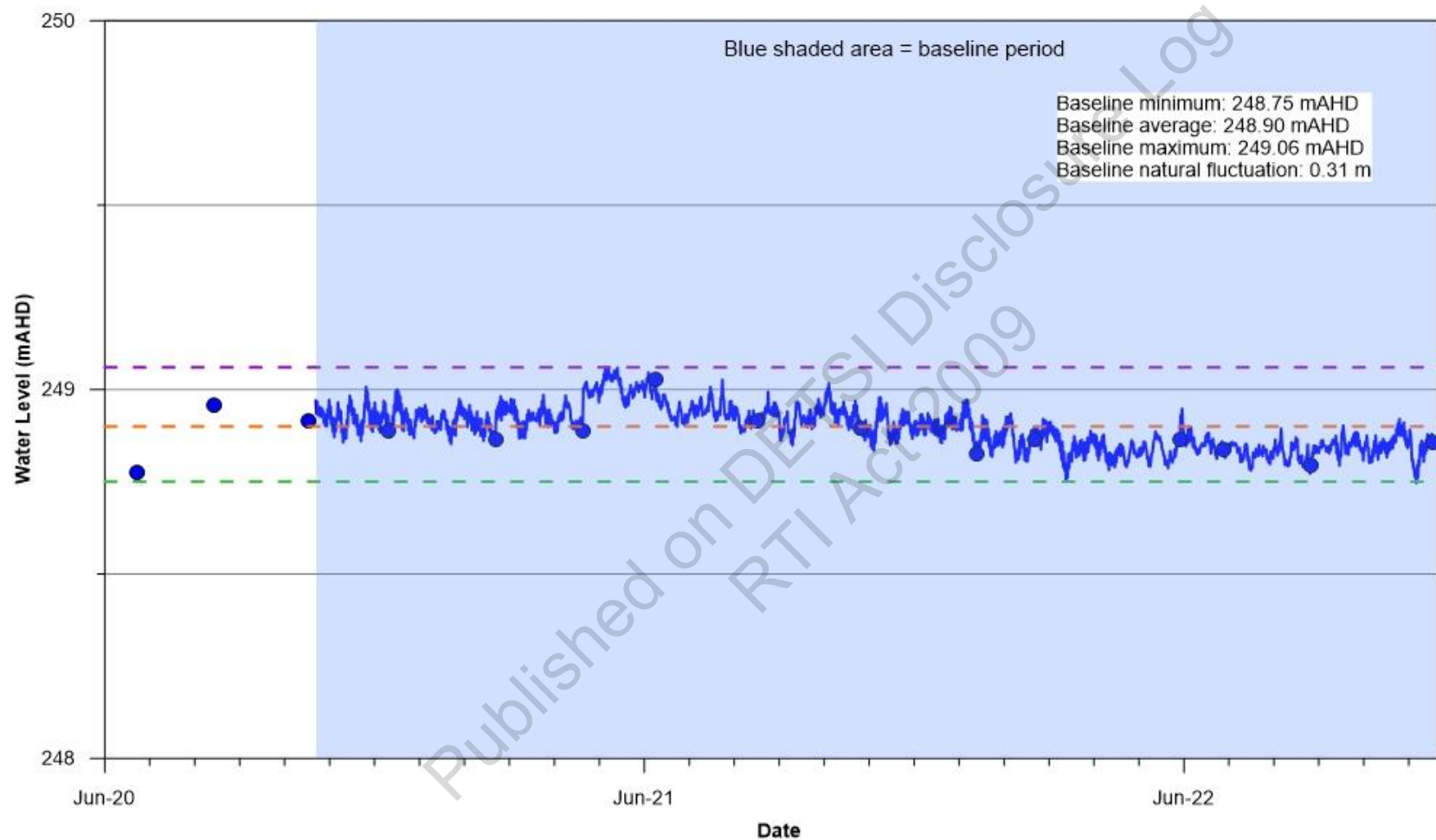
C19001SP (Alluvium)

- Representative logger data
- Manual measurements
- Minimum baseline logger water level
- Average baseline logger water level
- Maximum baseline logger water level



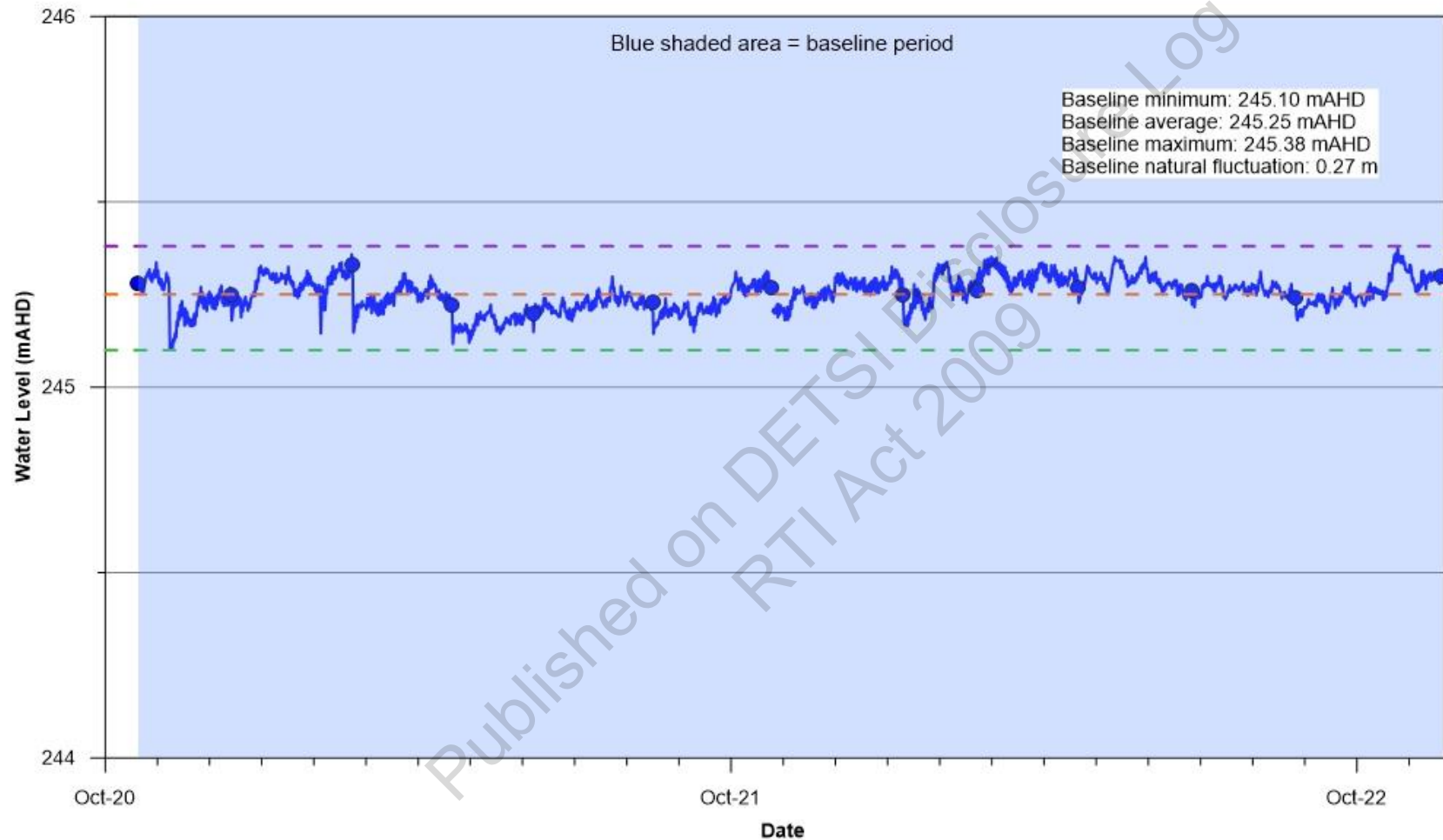
C19002SP (Clematis)

- Representative logger data
- Manual measurements
- Minimum baseline logger water level
- Average baseline logger water level
- Maximum baseline logger water level



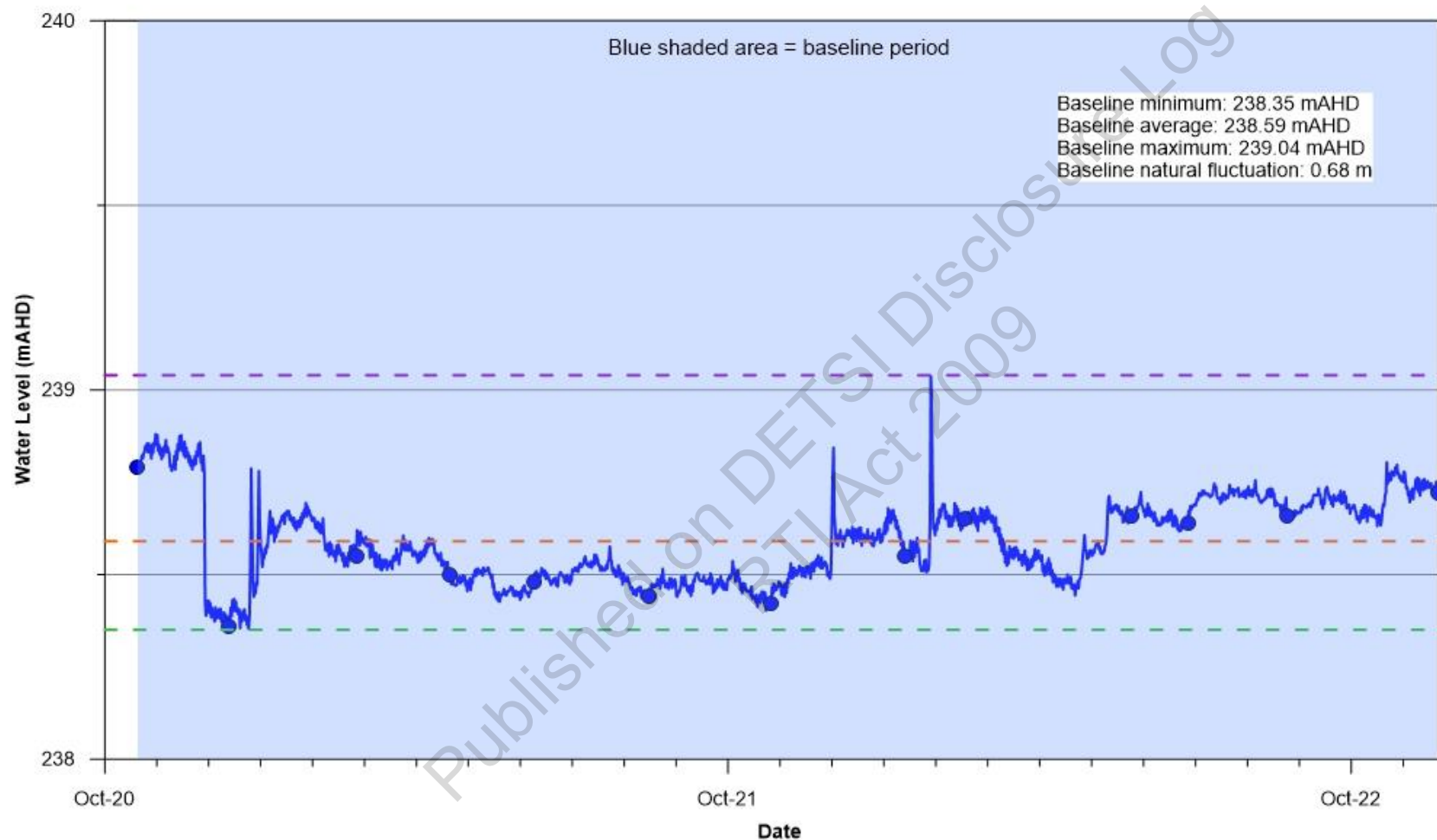
C19008SP (Rewan Formation)

- Representative logger data
- Manual measurements
- Minimum baseline logger water level
- Average baseline logger water level
- Maximum baseline logger water level



C19010SP (Clematis)

- Representative logger data
- Manual measurements
- Minimum baseline logger water level
- Average baseline logger water level
- Maximum baseline logger water level

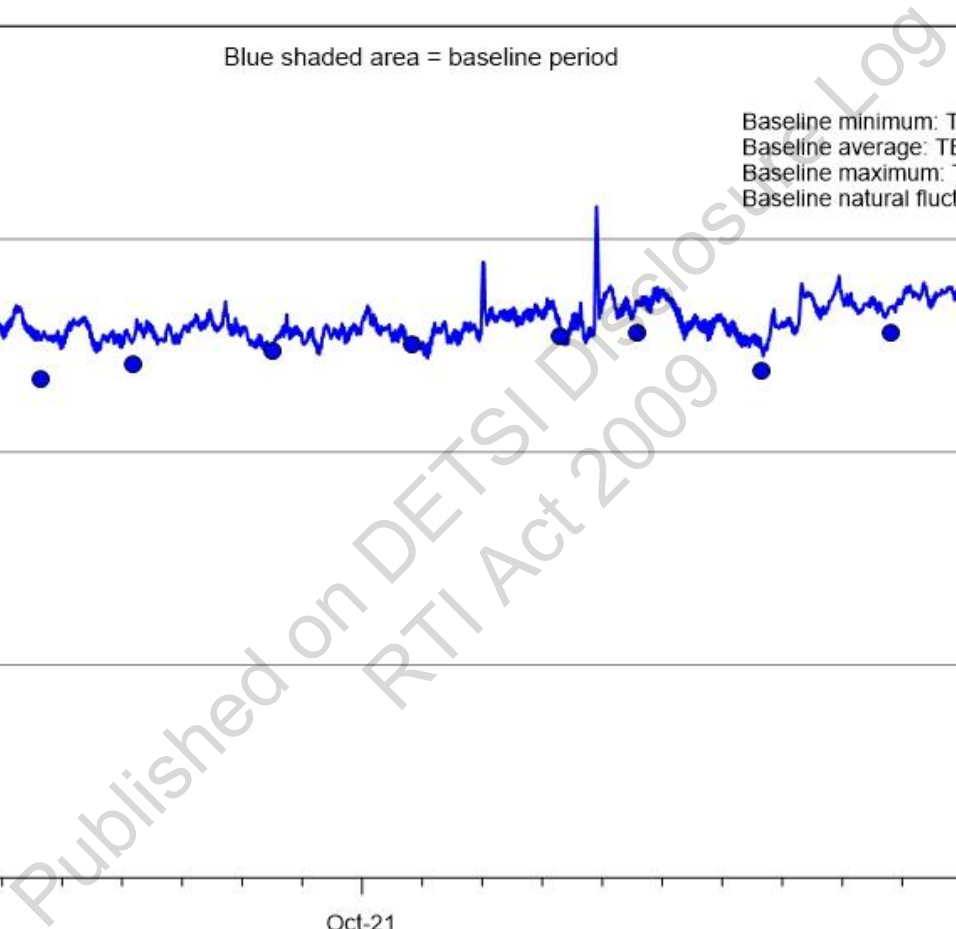


C19014SP (Clematis)

— Representative logger data ● Manual measurements

Representative logger data

Manual measurements



C19018SP (Bandanna Formation)

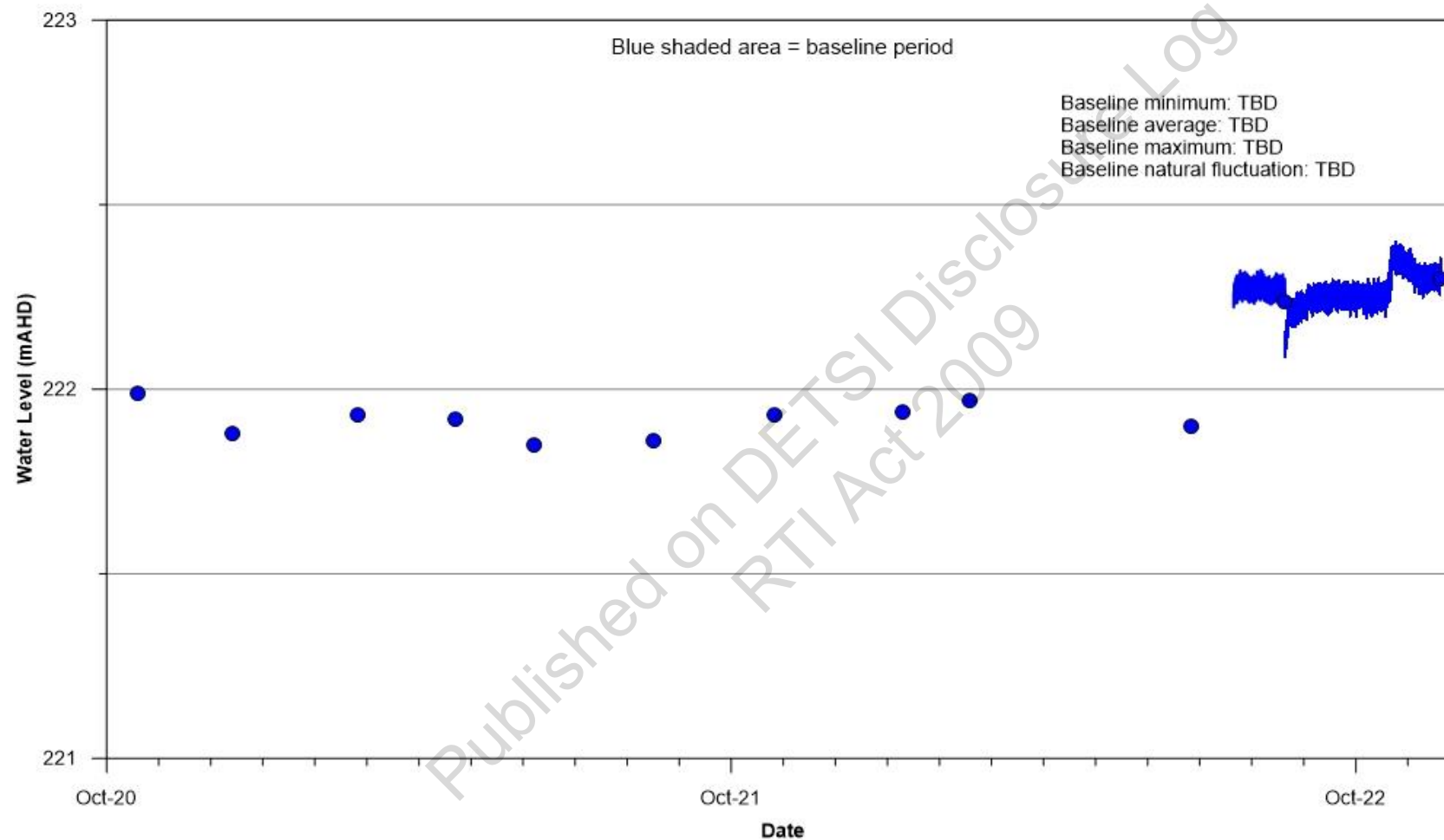
— Representative logger data ● Manual measurements

C19018SP (Bandanna Formation)

— Representative logger data ● Manual measurements

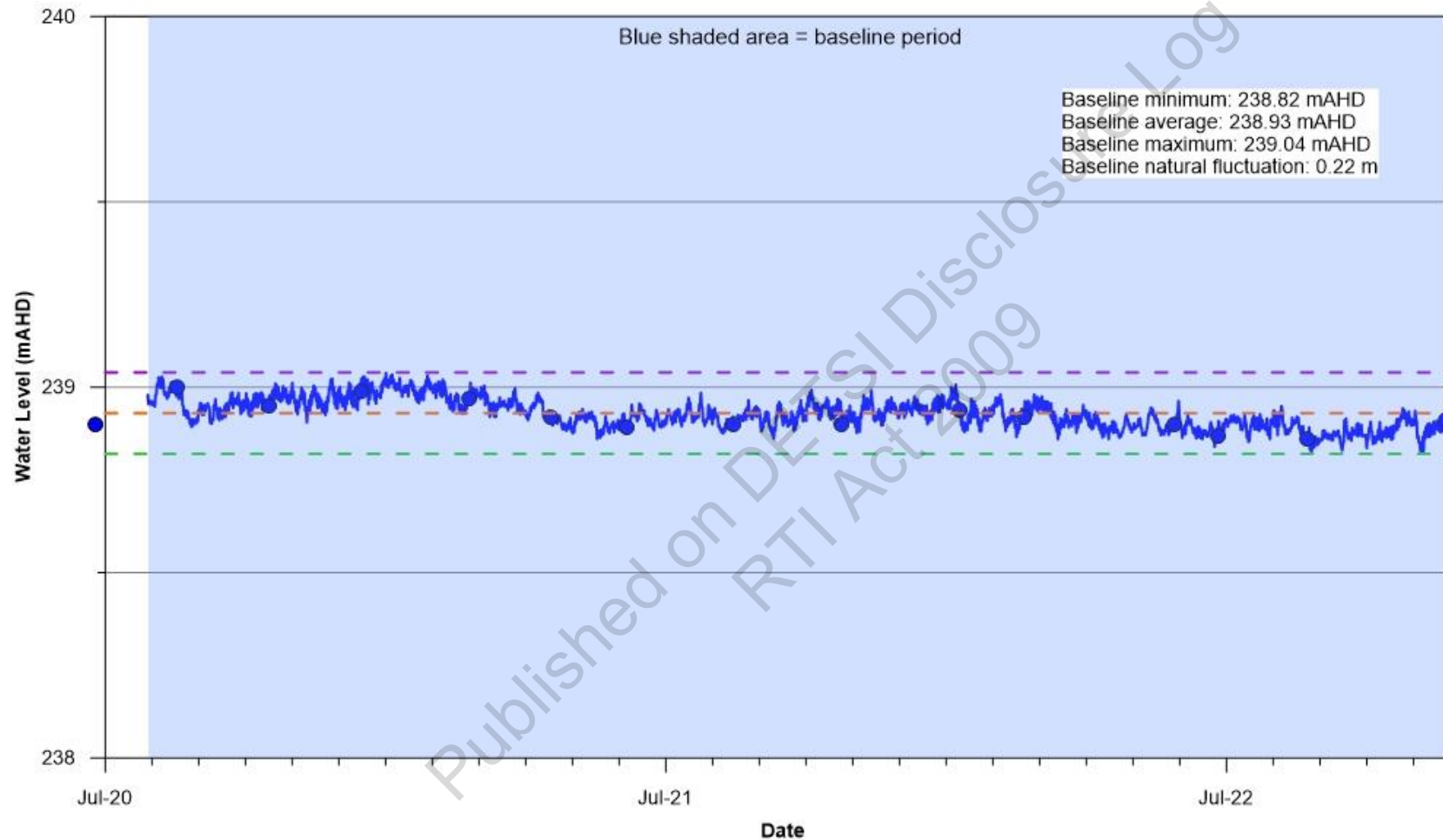
C19018SP (Bandanna Formation)

— Representative logger data ● Manual measurements



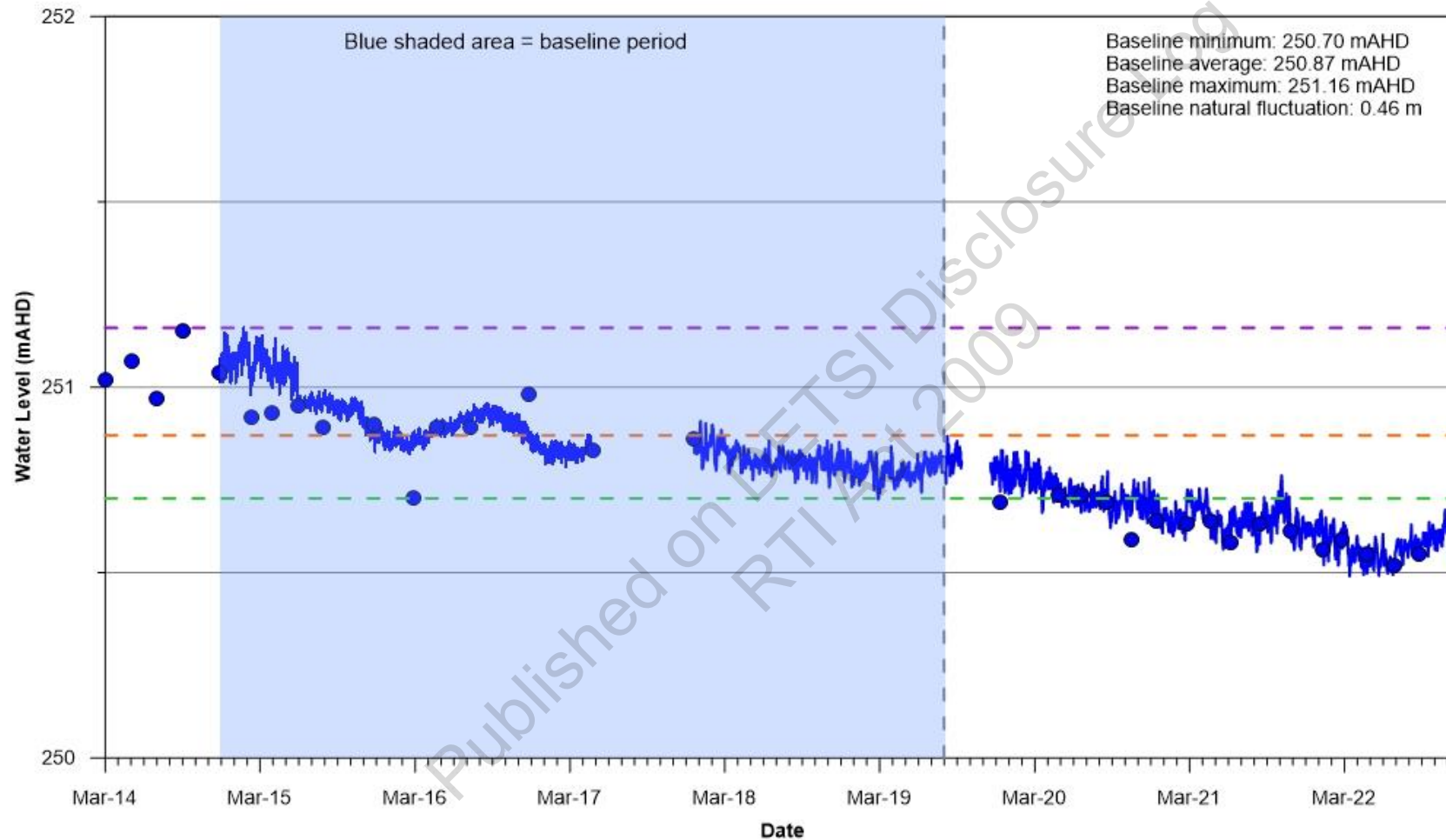
C19028SP (Rewan Formation)

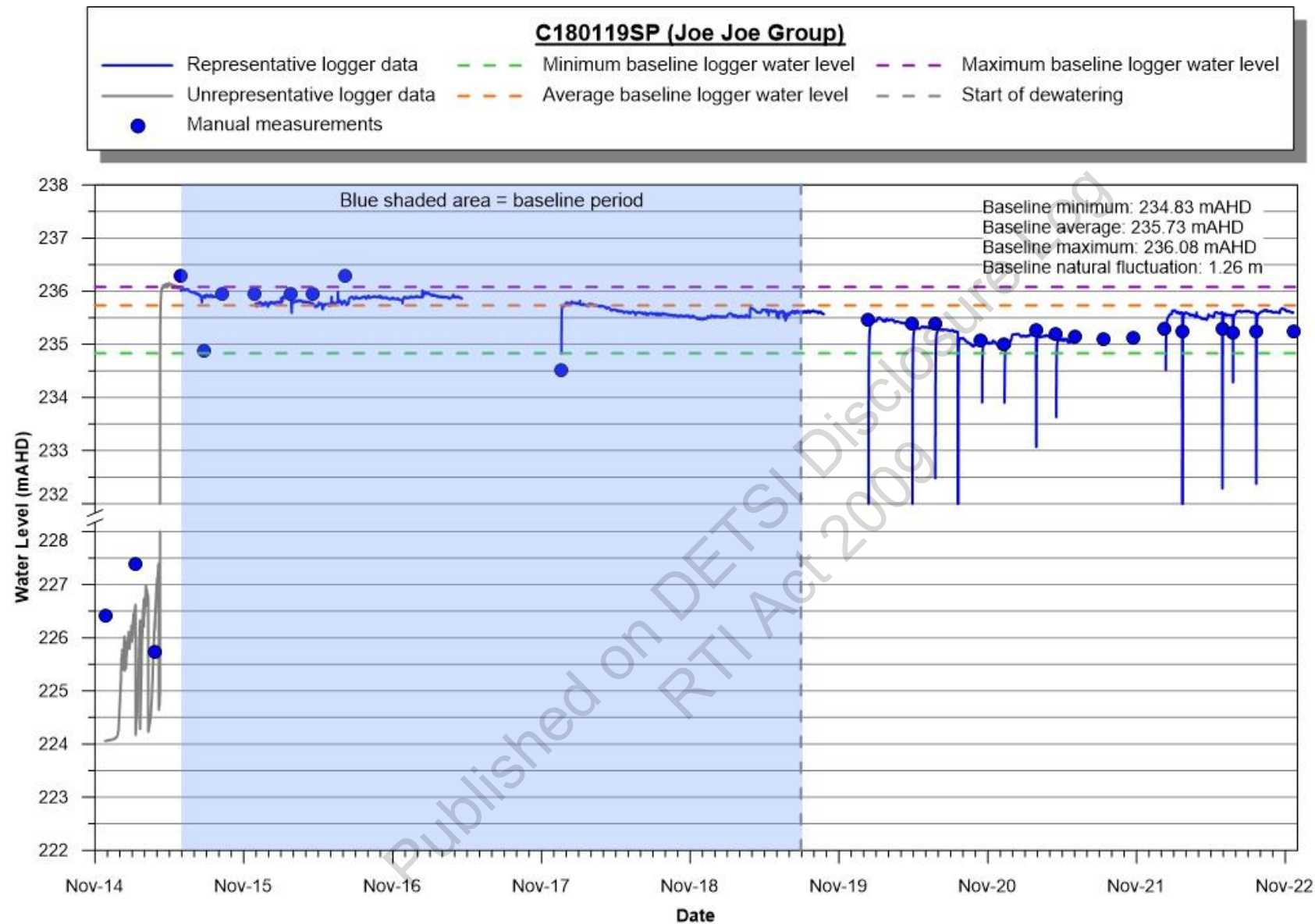
- Representative logger data
- Manual measurements
- Minimum baseline logger water level
- Average baseline logger water level
- Maximum baseline logger water level



C180117SP (Dunda Beds)

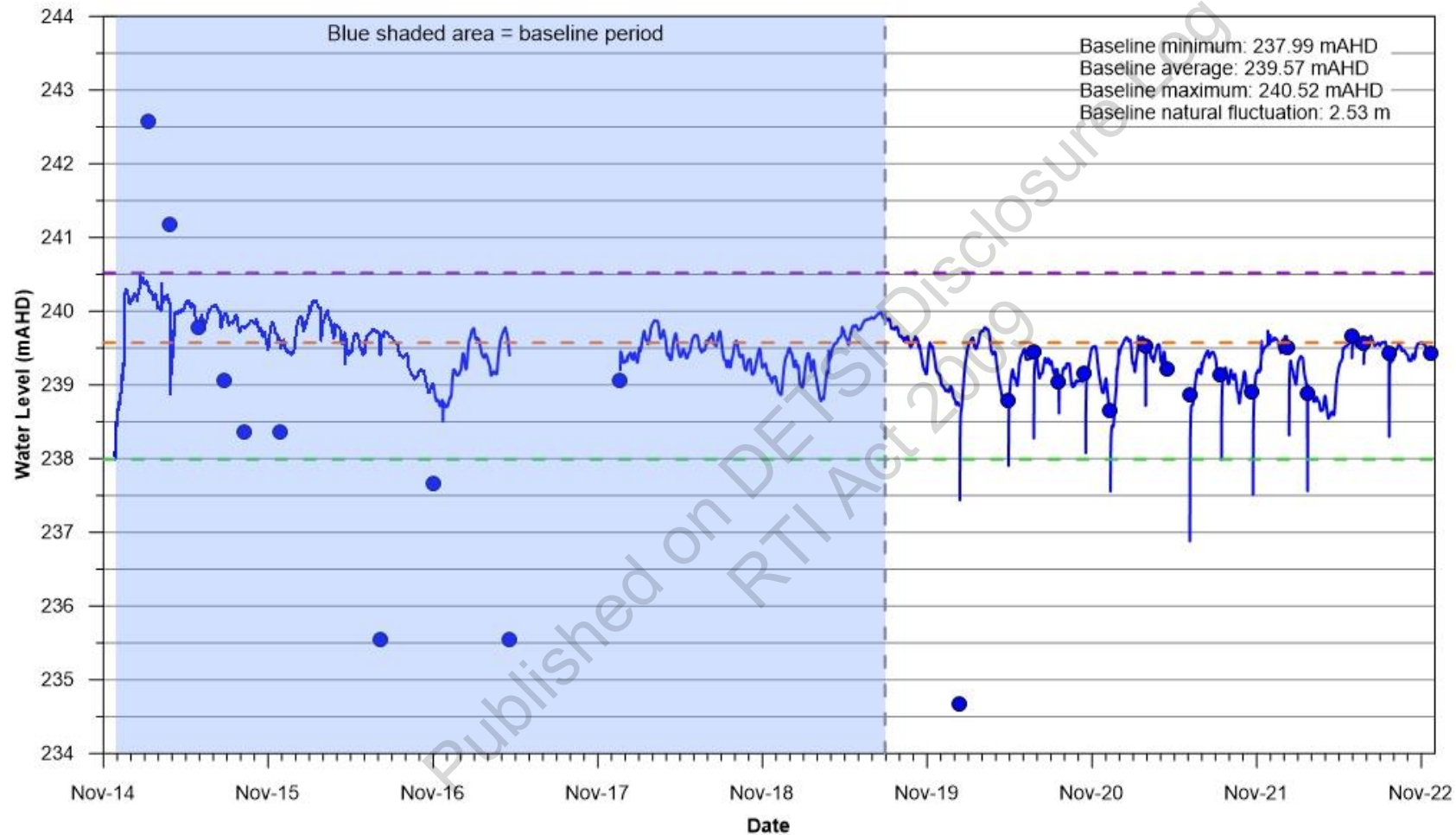
- Representative logger data
- Manual measurements
- Minimum baseline logger water level
- Average baseline logger water level
- Maximum baseline logger water level
- Start of dewatering





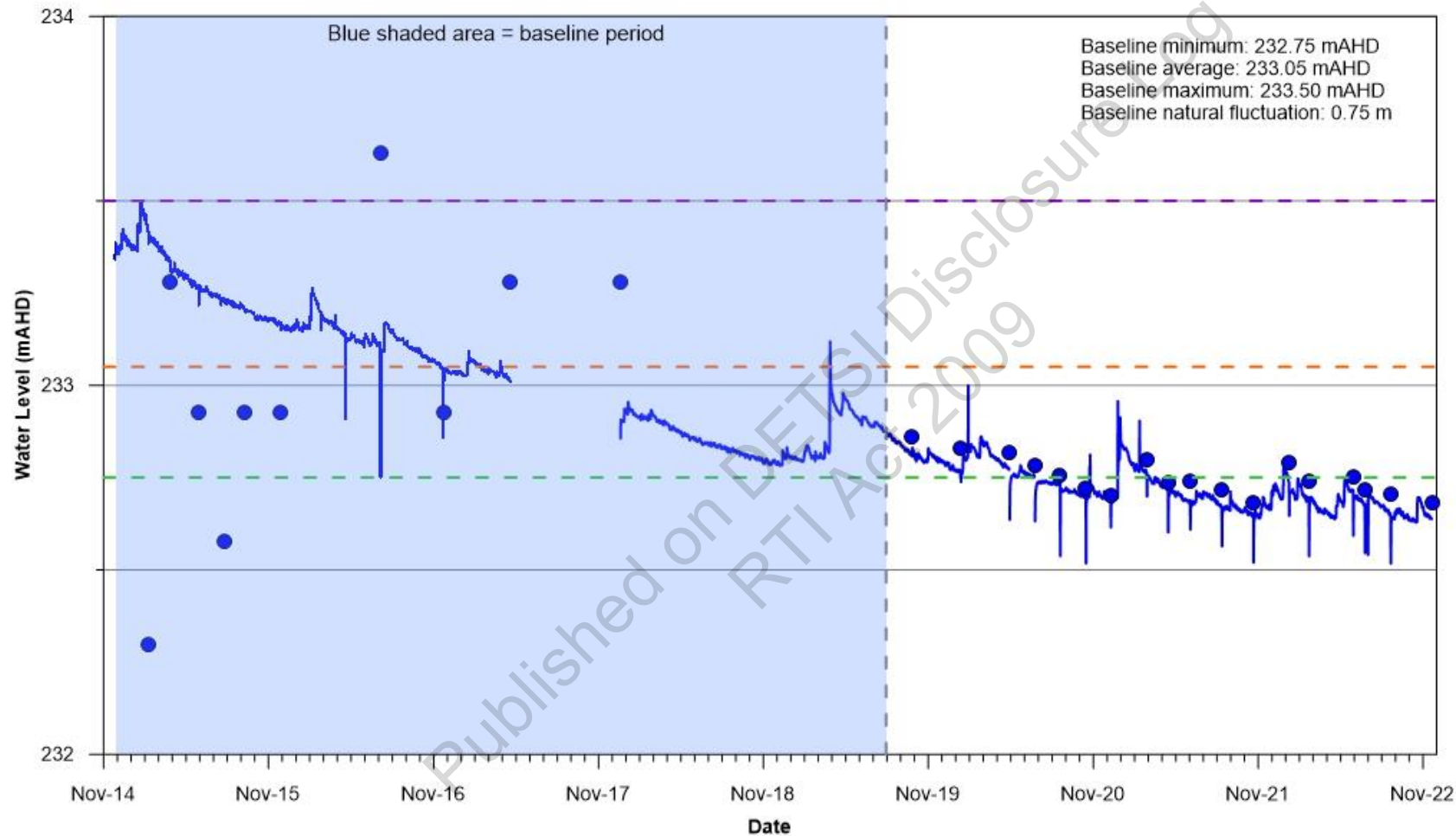
C180120SP (Tertiary sediments/Joe Joe Group)

- Representative logger data - - - Minimum baseline logger water level - - - Maximum baseline logger water level
- Manual measurements - - - Average baseline logger water level - - - Start of dewatering



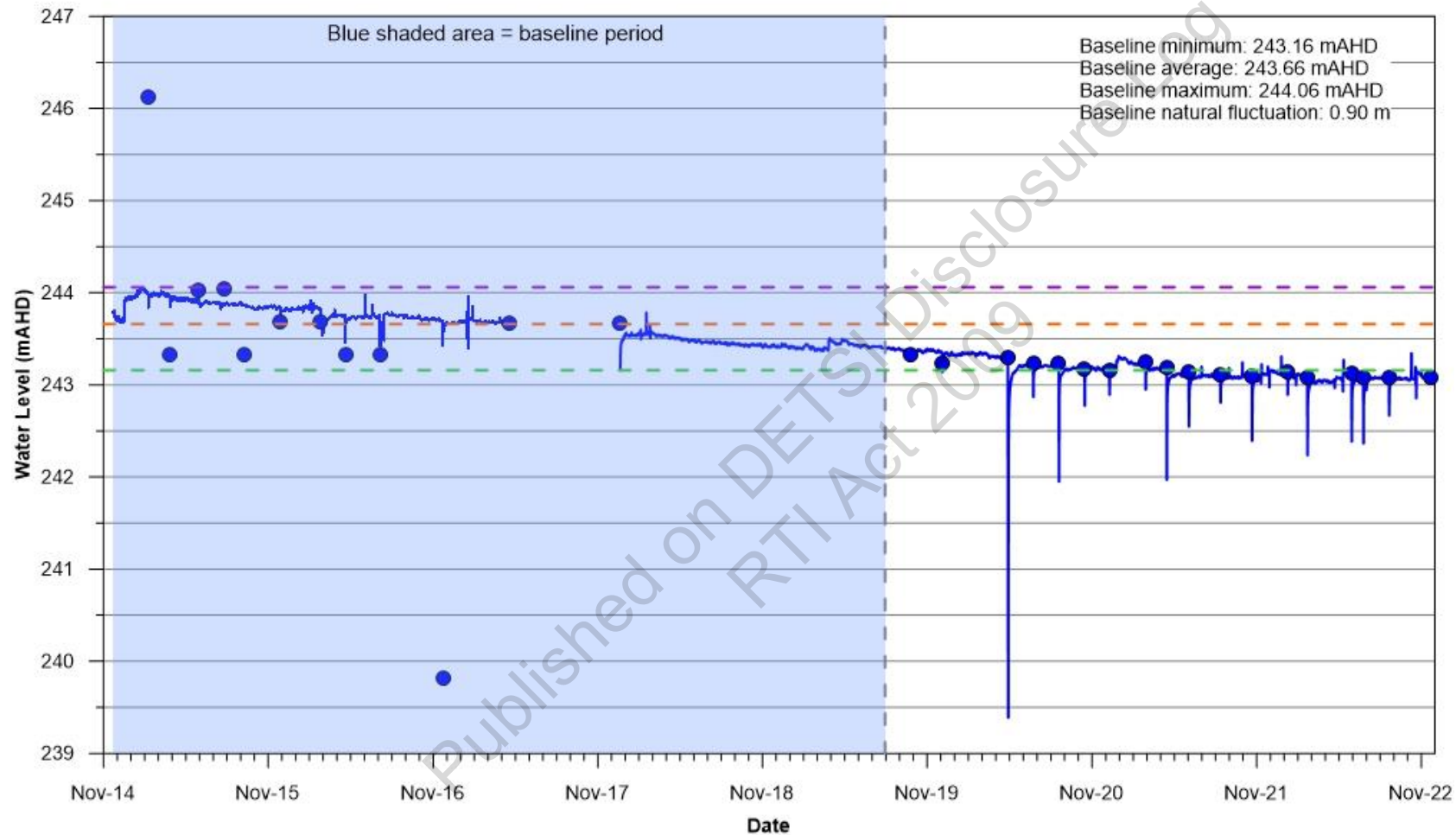
C180122SP (Tertiary sediments/Joe Joe Group)

- Representative logger data - - - Minimum baseline logger water level - - - Maximum baseline logger water level
- Manual measurements - - - Average baseline logger water level - - - Start of dewatering



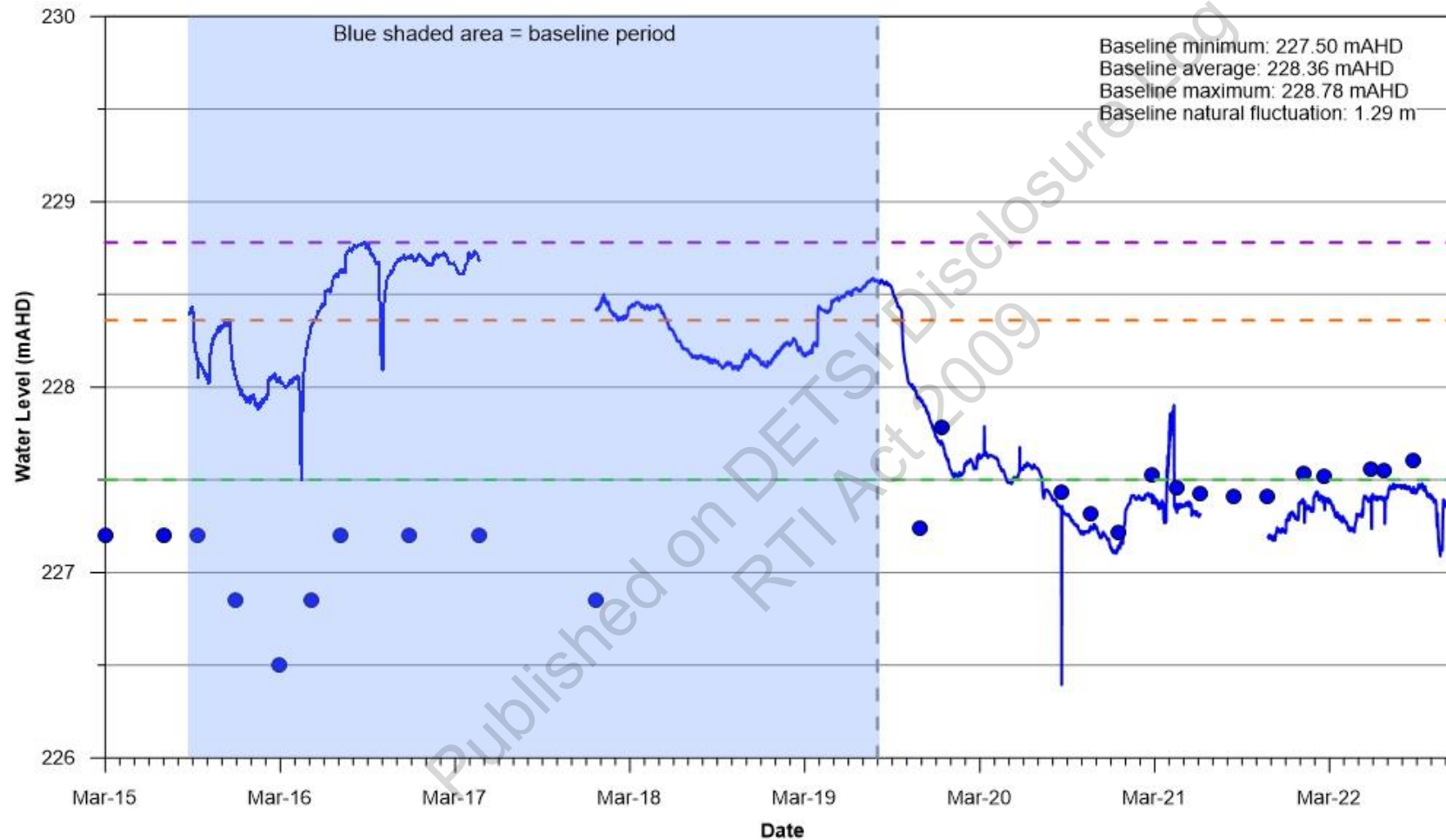
C180123SP (Joe Joe Group)

- Representative logger data - - - Minimum baseline logger water level - - - Maximum baseline logger water level
- Manual measurements - - - Average baseline logger water level - - - Start of dewatering



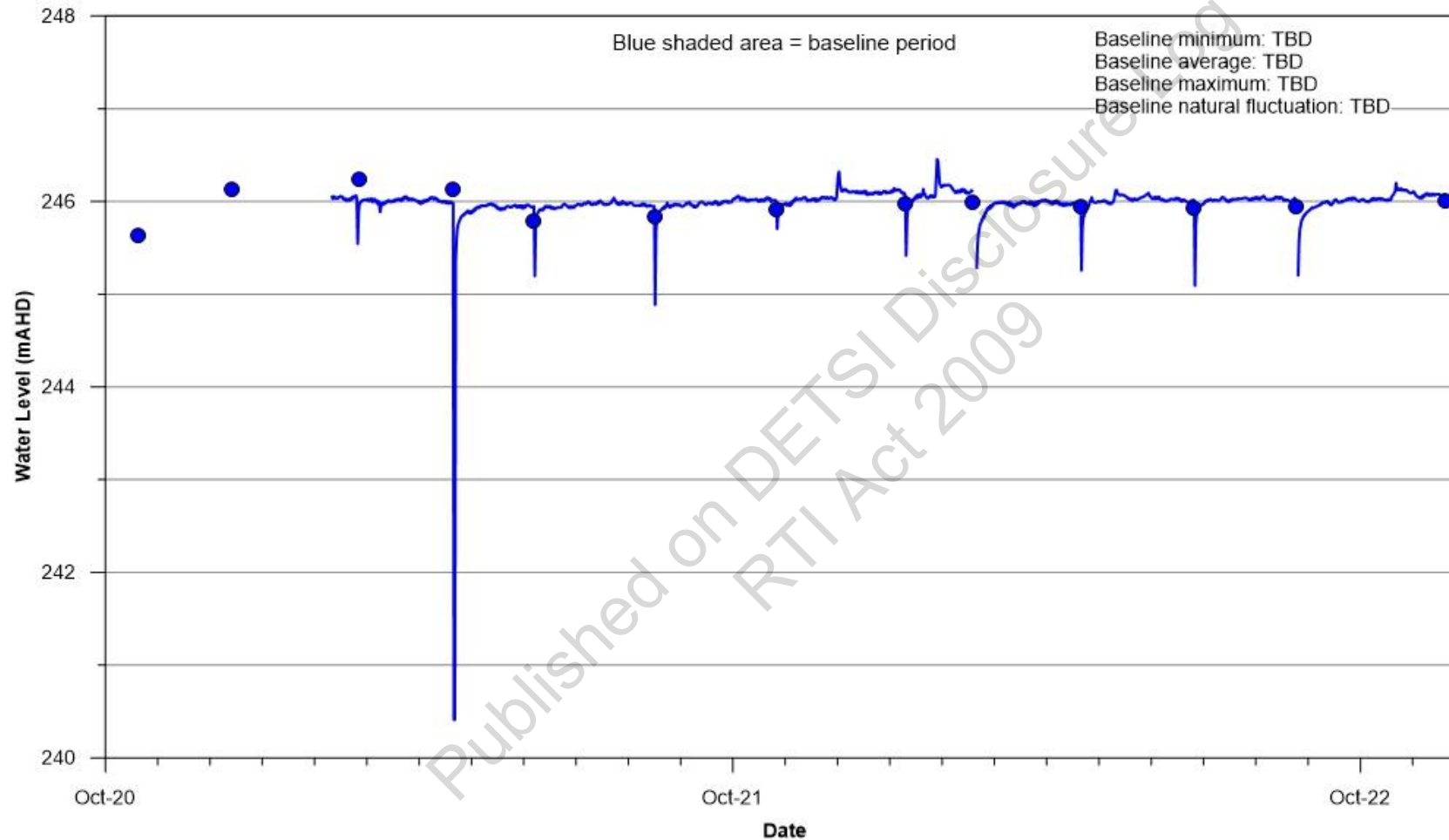
C914030SPR (Joe Joe Group)

- Representative logger data - - - Minimum baseline logger water level - - - Maximum baseline logger water level
- Manual measurements - - - Average baseline logger water level - - - Start of dewatering



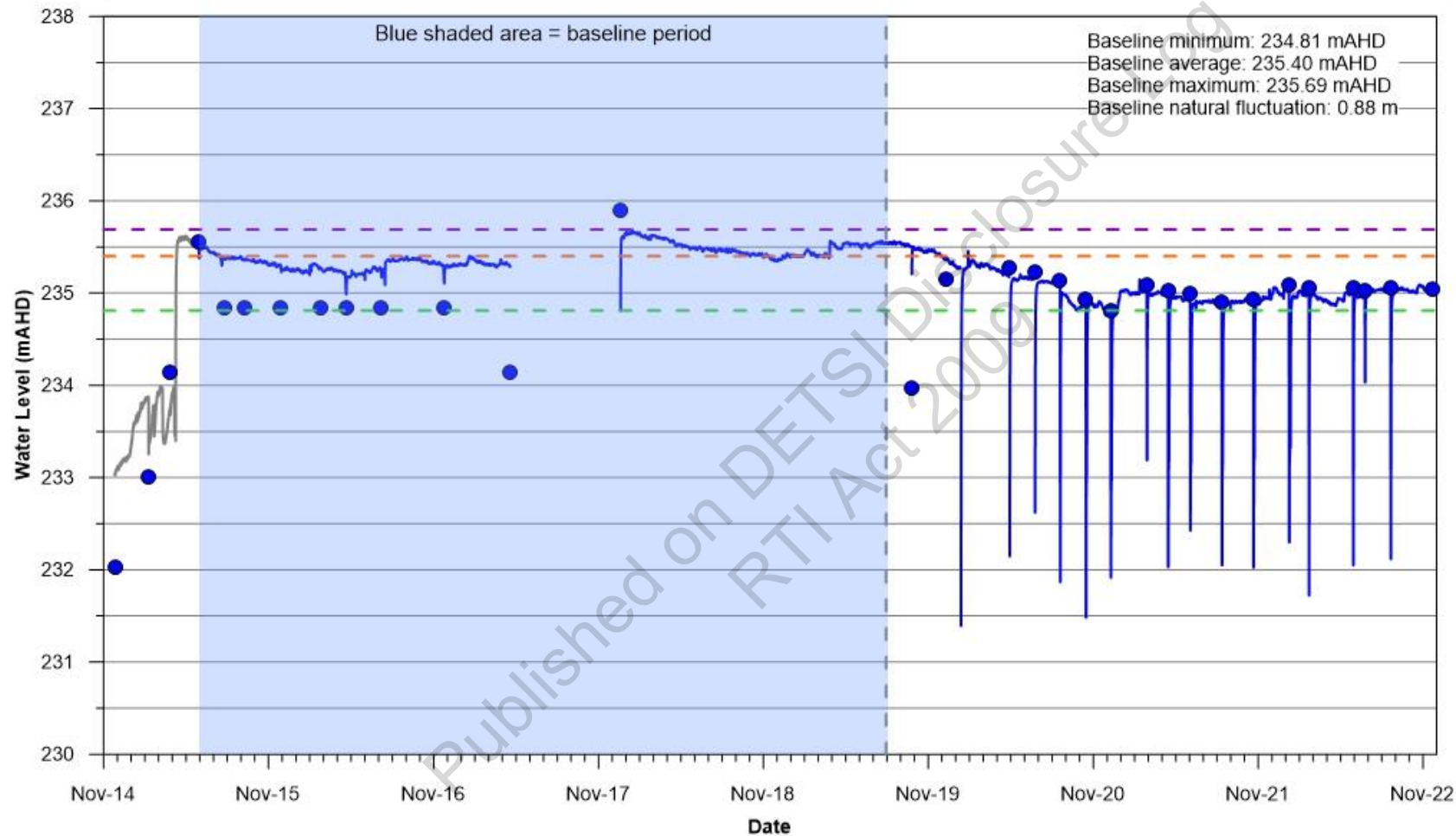
C919016SPR (Rewan Formation)

— Representative logger data ● Manual measurements



C9180124SPR (Joe Joe Group)

- Representative logger data - - - Minimum baseline logger water level - - - Maximum baseline logger water level
- Unrepresentative logger data - - - Average baseline logger water level - - - Start of dewatering
- Manual measurements



C9180125SPR (Joe Joe Group)

- Representative logger data - - - Minimum baseline logger water level - - - Maximum baseline logger water level
- Unrepresentative logger data - - - Average baseline logger water level - - - Start of dewatering
- Manual measurements

