Australasian Groundwater & Environmental Consultants

Report on

UG4 LW401-408 Extraction Plan Revised Groundwater Technical Report

Prepared for
Moolarben Coal Operations Pty Ltd

Project No. MOO5001.001
August 2023

ageconsultants.com.au

ABN 64 080 238 642

Document details and history

Document details

Project number	MOO5001.001
Document title	UG4 LW401-408 Extraction Plan Revised Groundwater Technical Report
Site address	12 Ulan-Wollar Road, Ulan NSW 2850
File name	MOO5001.001 - UG4 LW401-408 Extraction Plan Revised GW Report V2.02

Document status and review

Edition	Comments	Author	Authorised by	Date
v02.02	Final report	MS/TD	AD	31/08/2023

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Executive Summary

This Report has been prepared in response to conditions of the approval for the Moolarben UG4 Longwalls (LW) 401 to 408 Extraction Plan, in particular Condition 3a to 3g, repeated as follows:

> *Prior to the commencement of longwall mining of LW404 or as otherwise agreed by the Secretary, the Proponent must update the numerical groundwater model and predictions to the satisfaction of the Secretary, including:*
>
> *a) review and update the model conceptualisation for the leakage between the Triassic sandstones and the Permian overburden;*
>
> *b) review and update the model conceptualisation of surface water – groundwater connectivity;*
>
> *c) reassess aquifer drawdown predictions and water balance estimates particularly mine water inflow volumes and groundwater baseflow losses to the Goulburn River;*
>
> *d) reassess the predicted groundwater take;*
>
> *e) complete an independent peer review of the current and updated model by a technical expert endorsed by the Secretary*
>
> *f) consideration of the Final Geological Structural Analysis in Condition 4;*
>
> *g) provide revised predictions based on the updated numerical model including a detailed technical report on:*
>
> > *(i) predicted cumulative impacts from approved mining; and*
> >
> > *(ii) predicted impacts of only the LW401-408 panels.*

LW401-408 Extraction Plan Approval and IAPUM Comments

The LW401-408 Extraction Plan was approved in July 2022 by the Department of Planning and Environment (DPE). In its Statement of Reasons, the DPE provided advice from the Independent Advisory Panel for Underground Mining (IAPUM). The IAPUM notes in its advice:

> *The Panel's assessment is that the current Extraction Plan for LW401 to 408 is extremely unlikely to impact the water supply at "The Drip" ….*

Key comments from the IAPUM that informed Conditions 3a to 3g, which are addressed by this Report, include:

> <u>Extent of saturation in Triassic sandstone</u>
>
> *There is a lack of data in the vicinity of LW401 to 408 to properly define the saturated extent of Triassic sandstone and the current groundwater flow contours. …*
>
> <u>Estimation of baseflow to/from Goulburn River</u>
>
> *The Panel also queries the model's water balance prediction that "mining of LW401 to LW408 is expected to result in negligible change to baseflow in the Goulburn River". The transient model calibration for the period 1984 to 2021 (i.e. the 'baseline period' prior to the commencement of LW401 to 408) quotes the discharge volume to rivers as 21.69 ML/d. This is assumed to capture both licensed discharges and groundwater baseflow contributions. The individual components have not been quantified in any of the reviewed reports. The modelling report (AGE 2021) predicts net baseflow takes of between 0.5 and 0.8 ML/d for the Upper Goulburn water source which could be interpreted to mean that the whole of the upper Goulburn River becomes a losing stream and that all groundwater that would have otherwise discharged as baseflow is retained in groundwater storage or discharges to the underground workings to be disposed of later via licensed discharge.*
>
> <u>Water licensing</u>
>
> *Another associated query is whether the Applicant has sufficient water licence entitlement to cater for the additional groundwater inflows expected over the next 4 years (Table 6.1 of AGE 2021). The predicted 'Moolarben Take' annual volume supposedly includes the additional inflow volumes from LW401 to 408.*

This would mean predicted inflows of only 200 ML/yr for the remainder of the MCC site for each of these 4 years. However, the Applicant reported 2411 ML/yr of groundwater inflows in their 2020 site water balance (Yancoal 2021c) and predicted groundwater inflows of 2396 ML/yr, 3830 ML/yr and 5010 ML/yr for 2019, 2020 and 2021 respectively in an earlier site water balance (Yancoal 2020a). Updated modelling is required to confirm that the Applicant has sufficient licensed volume to account for all mine inflows from 2022/23 onwards.

Background to Groundwater Model Development

In November 2021 Australasian Groundwater and Environmental Consultants Pty Ltd (AGE) completed the Groundwater Technical Report to support the UG4 LW401-408 Extraction Plan. The numerical model used for the Groundwater Technical Report (AGE, 2021) was informed by previous groundwater modelling at the Moolarben Coal Complex undertaken by Peter Dundon and Associates (2006) and SLR (2020), which were the groundwater models that supported the relevant Moolarben Coal Complex approvals at the time.

Following the submission of AGE (2021), the numerical model was further refined by AGE, and underpinned groundwater impact assessments for the assessment processes Moolarben Coal Complex:

- OC3 Extension Project (AGE, 2022a); and
- UG2 Modification (AGE, 2022b).

For both of these groundwater impact assessments, the numerical groundwater model was recalibrated. The modelling reports (AGE, 2022a; AGE, 2022b) were peer reviewed by Brian Barnett, and deemed as fit for purpose for their respective objectives.

DPE-Water provided a submission on the OC3 Extension Project, which stated:

The impact of the project on groundwater and its receptors was estimated using MODFLOW-USG groundwater model that was independently peer reviewed as for the purpose. ***Nevertheless, DPE Water assessed the groundwater model as acceptable with 66% rating.***

Similarly, the Independent Expert Scientific Committee (IESC) in its submission on the OC3 Extension Project stated:

The Drip … is fed by a local shallow aquifer within the Triassic Sandstone on the far side of the Goulburn River. … Environmental Tracers indicate The Drip seepage is distinctive from deeper aquifers, is a localised flow and is probably a perched aquifer.

… The groundwater model selected is appropriate for understanding impacts at the regional scale, and cumulative impacts of multiple mine operations. At this scale, the assumptions adopted are reasonable and commensurate with the likely severity of potential impacts, and the model is capable of assessing the potential impact pathway of depressurisation through the coal seams.

The recalibrated and peer reviewed groundwater model used for the OC3 Extension Project and UG2 Modification was used as the starting point for the additional groundwater modelling undertaken for this report.

Additional Data Available Since the LW401-408 Extraction Plan was Approved

This Report has benefited from data available following the commencement of secondary extraction in UG4. In particular, this includes:

- data available from nested standpipes PZ194 and PZ195, installed following AGE (2021) and prior to the commencement of secondary extraction in UG4 (Figure ES. 1), which provide water level data measured in the Triassic sandstone and Permian Illawarra Coal Measures;
- vibrating Wire Piezometers (VWPs) PZ 102C, PZ 103D, PZ 232 and PZ 235B (Figure ES. 1), installed following AGE (2021);
- calculated mine inflows to UG4; and
- Mine Advice (2023) report providing a review of geological structures.

This data, along with the extensive data collected for the Moolarben Coal Complex, has been used to:

- assess observed impacts of UG4 longwall mining to date;
- recalibrate the numerical model; and
- revise the predictions of potential impacts associated with the remainder of the LW401-408 panels (including cumulative impacts with the remaining approved Moolarben Coal Complex, Ulan Coal Mine and Wilpinjong Coal Mine).

Observations of Impacts of UG4 Longwall Mining to Date

Extent of saturation in Triassic

The saturated thickness of the Triassic sandstone is shown in Figure ES. 2, based on observations up to February 2023. These observations include the additional monitoring sites described above and shown on Figure ES. 1. Detailed groundwater contours for each Hydrostratigraphic are provided within the body of this report in Section 6.5.

Hydrogeological cross-sections are provided in Plate ES. 1 and Plate ES. 2. These illustrate the observed watertable elevation within the Triassic sandstone, and the extent of unsaturated Triassic sandstone in east-west and north-south directions (Plate ES. 1 and Plate ES. 2, respectively).

Observable Drawdown in the Triassic

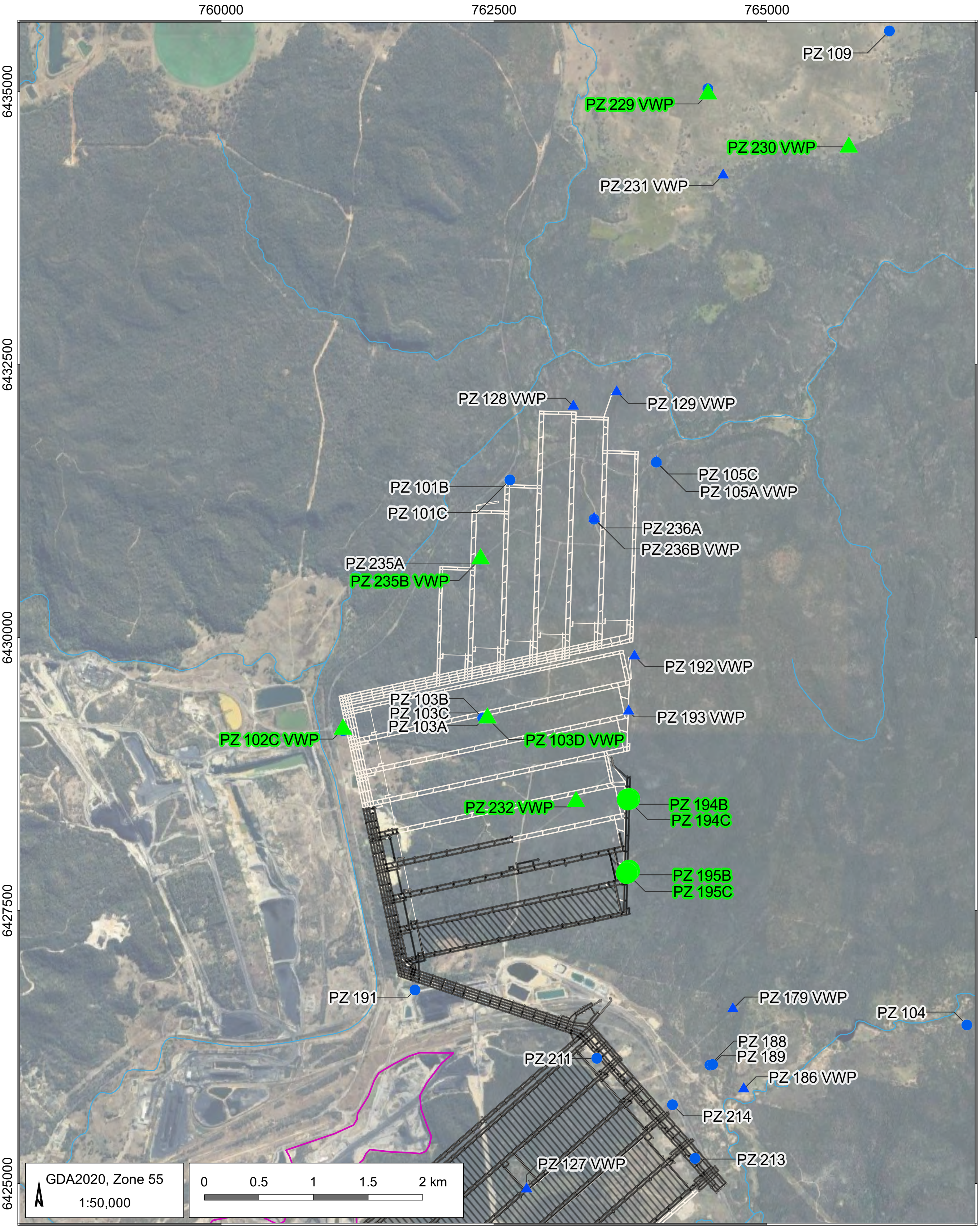
Data from hydrographs available from UG4 monitoring bores indicates no clearly identifiable drawdown (NCID) in the Triassic sandstone up to February 2023, which includes the period of secondary extraction of the full length of LW401 (Figure ES. 3). PZ 195B shows no NCID to February 2023.

It is noted that a preliminary review of more recent data from PZ194B (Figure ES. 3) indicates drawdown has occurred within the Triassic sandstone at this location, likely due to mining in LW402. This is consistent with the model predictions (refer to discussion and figures below).

Observable Drawdown in the Permian

Observations in the Permian up to February 2023 indicates groundwater drawdown of between 0 m and approximately 14 m at UG4 North, with the greater observed drawdowns (13.8 m at PZ 129 and 10 m at PZ105) occurring in the deeper strata (depths of 74m and 80m respectively) (Figure ES. 4). Given these observed drawdowns are greater than those estimated from piezometers located closer to LW401(i.e. PZ 101B, and VWP's installed at 80 m depth at PZ 105A and PZ 193) this indicates there is a significant likelihood that VWP's installed at PZ 129 may have been impacted from adjacent mining operations. This is also consistent with the predicted cumulative impacts extent modelled. PZ 195C shows no NCID to February 2023 at close proximity to mined LW401.

Co-located shallower monitoring bores in the Permian show reduced drawdown at shallower depths (4.3 m drawdown at PZ129 at a depth of 53 m, and NCID at PZ105A at a depth of 28 m) (Figure ES. 4). As above, co-located groundwater monitoring within the Triassic sandstone (e.g. PZ129 and PZ 105C) show NCID (Figure ES. 3). Groundwater data indicates that drawdown in the deeper Permian strata is propagating further than the shallow Triassic sandstone, which is consistent with both the contemporary conceptualisation and the numerical modelling predictions.



LEGEND

Groundwater Monitoring Site (Sites Drilled Since AGE, 2021)
- Standpipe
- VWP

Groundwater Monitoring Network Site (Existing)
- Standpipe
- VWP

- Drainage
- UG Mine plan
- Approximate Extent of OC Mining 2023
- Mine Extent (February 2023)

Groundwater Assessment for Moolarben UG4 Compliance Conditions (MOO5001.001)

Additional Model Calibration Data

AGE

DATE 28/08/2023

FIGURE No: **ES.1**

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
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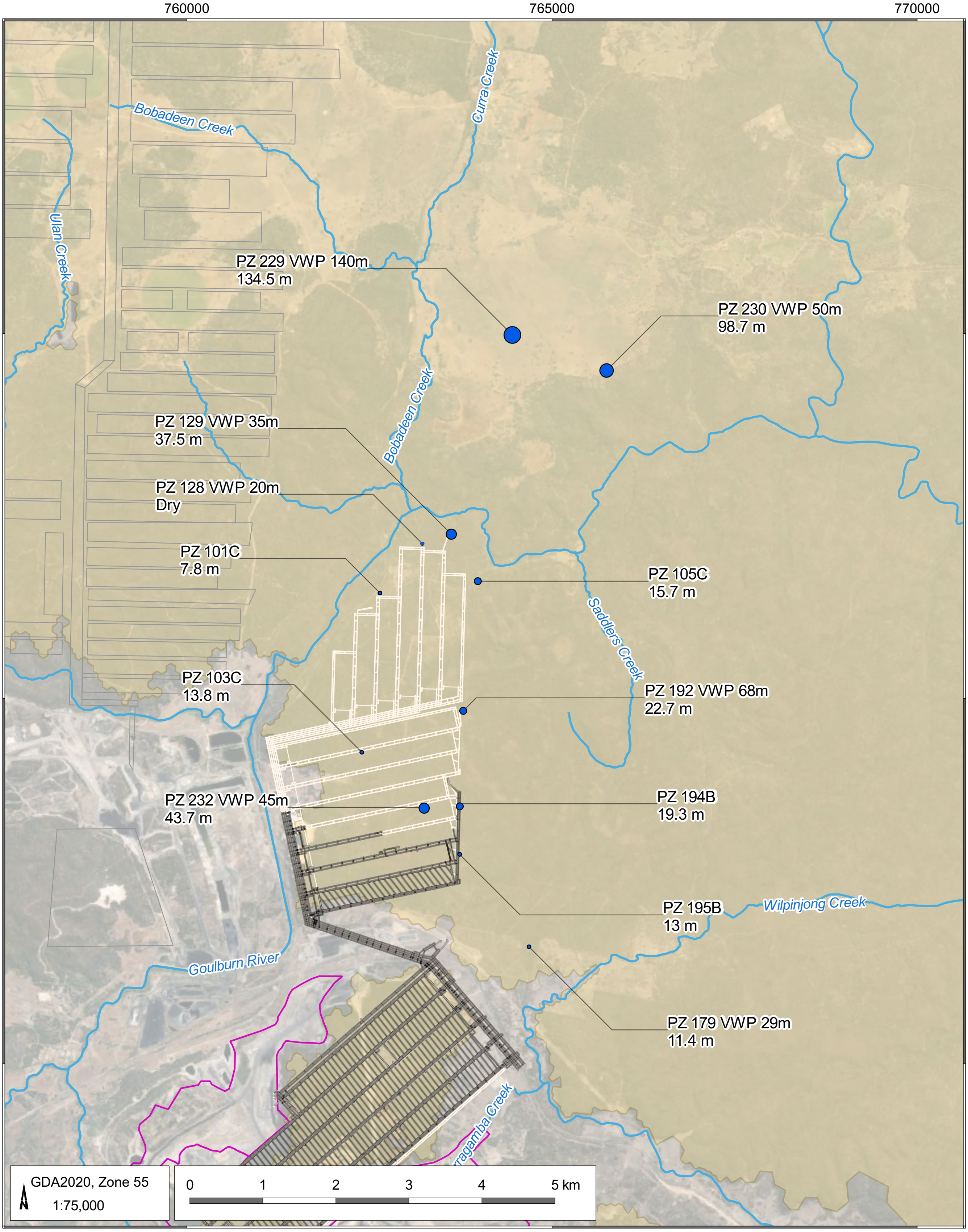


LEGEND

- Drainage
- Approved Ulan Underground Mine Plan
- UG Mine plan
- Approximate Extent of OC Mining 2023
- Modelled Triassic Extent
- Mined Extent (February 2023)

Triassic Saturated Thickness (Bore ID, RSWL,Saturated Thickness)

- 7 to 15 m
- 15 to 20 m
- 25 to 50 m
- 50 to 100 m
- 100 to 140 m

Dry flag: Indicates unsaturated conditions at monitoring point.

Groundwater Assessment for Moolarben UG4 Compliance Conditions (MOO5001.001)

Observed Triassic Saturation Thickness (Dec 2022 to Feb 2023)

AGE

DATE 28/08/2023

FIGURE No: **ES.2**

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:\Projects\MOO5001.001 UG4 Compliance Conditions\3_GIS\Workspaces\001_Deliverable1\ES.02_MOO5001.001_Saturated Triassic Thickness (UG4).qgz

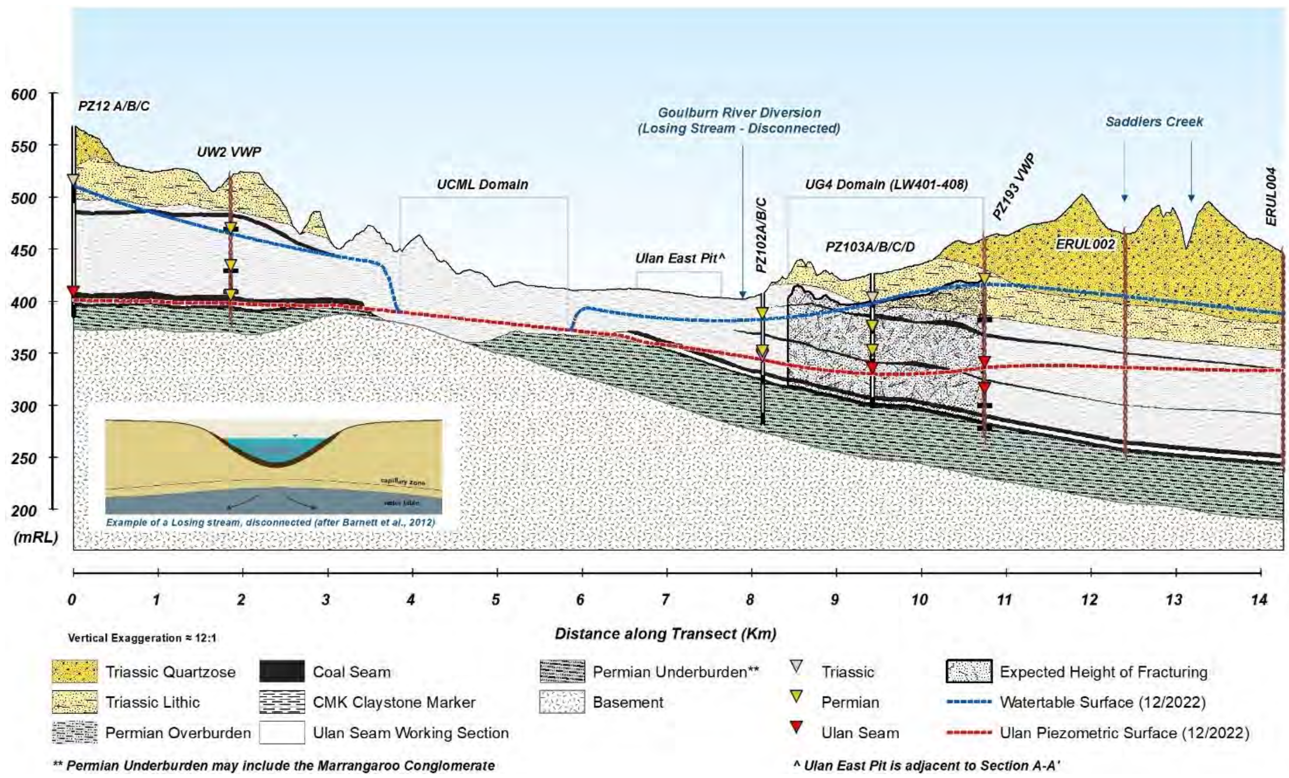


Plate ES. 1 East – West Hydrogeological Cross Section

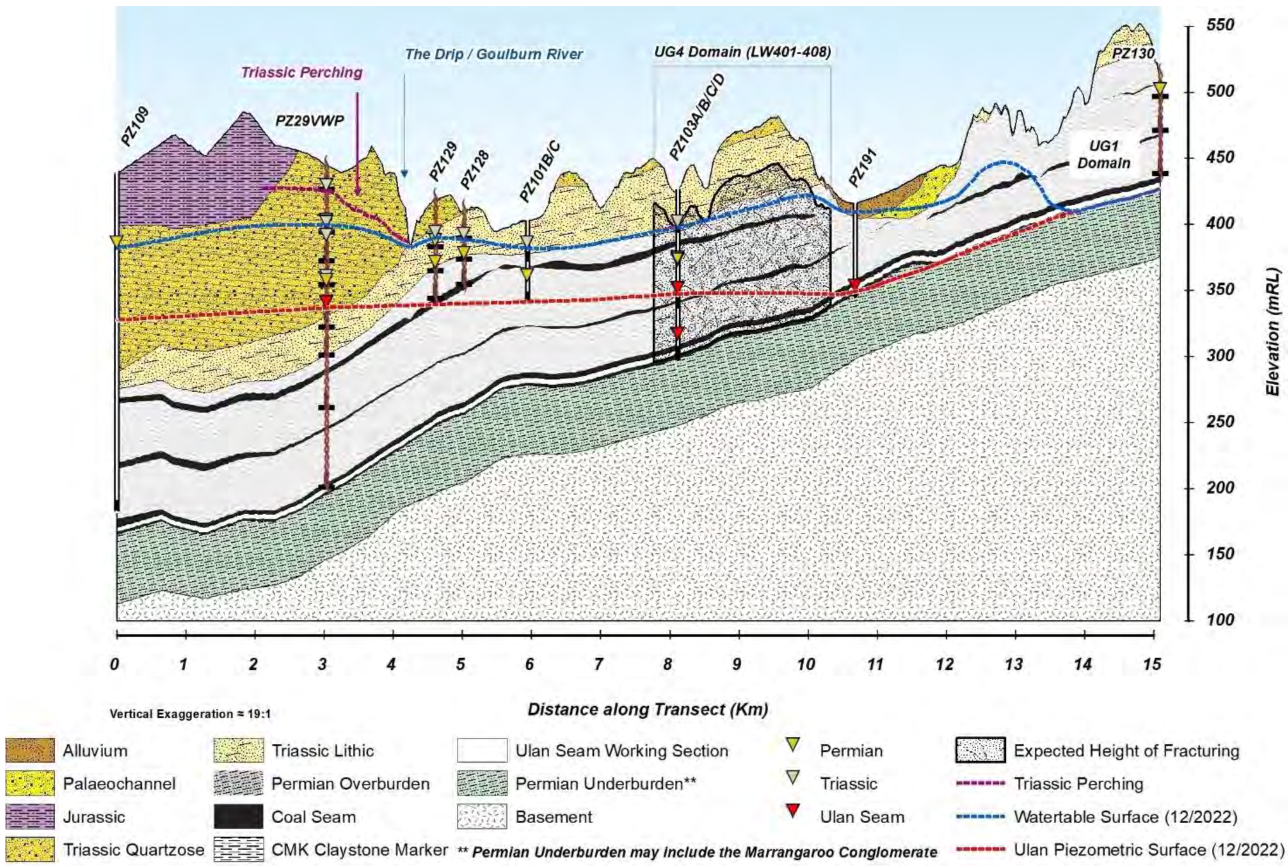


Plate ES. 2 North – South Hydrogeological Cross Section

LEGEND

- Drainage
- UG Mine plan
- Approximate Extent of OC Mining 2023
- Modelled Triassic Extent
- Mined Extent (February 2023)

Triassic (Drawdown in meters)

- 0 to 2 m
- 2 to 5 m
- 5 to 20 m
- 20 to 30 m
- 30 to 52 m

NCID: No Clearly Identifiable Drawdown as at March 2023
** Indicates Lower Confidence Estimate

Groundwater Assessment for Moolarben UG4 Compliance Conditions (MOO5001.001)

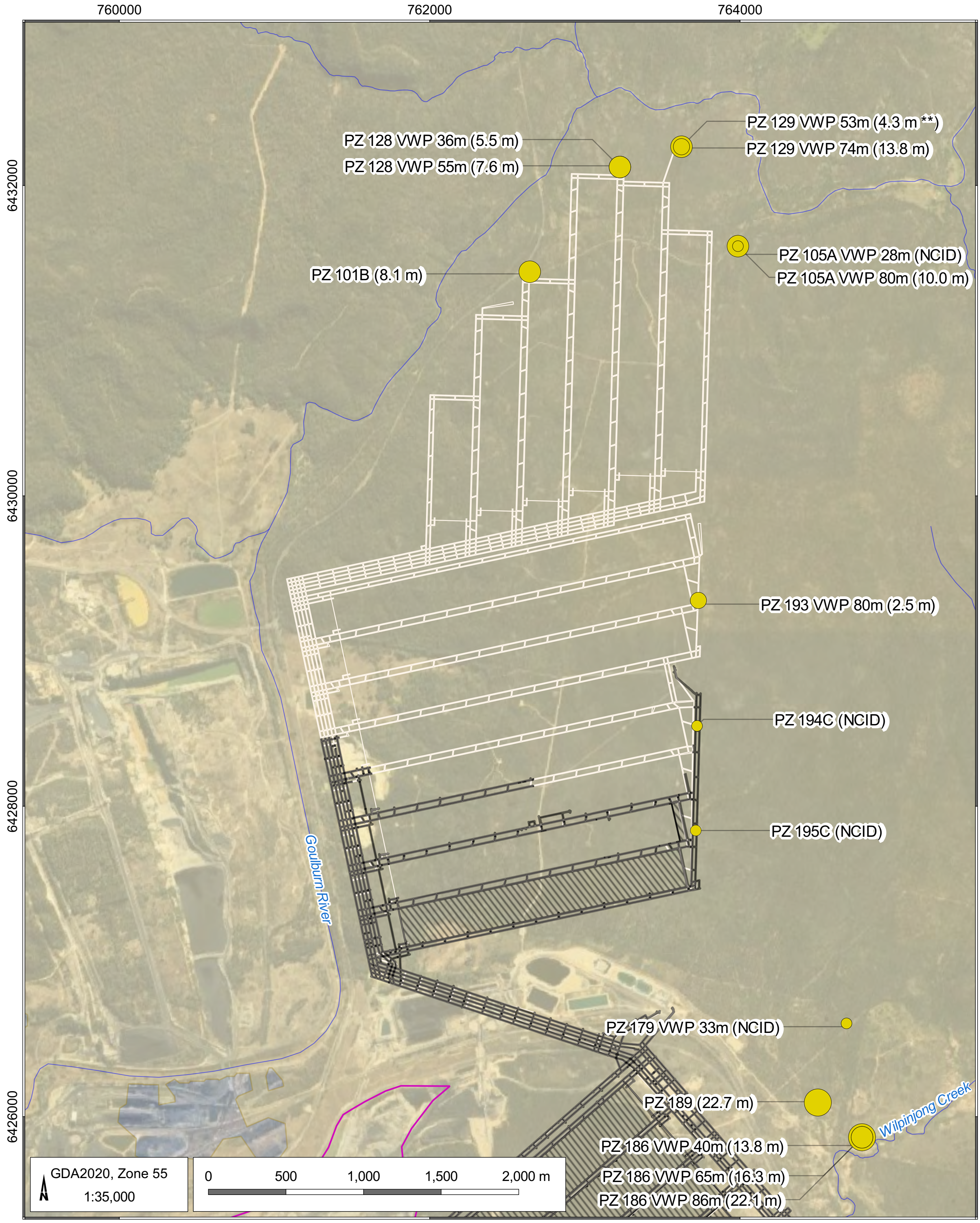
Observable Drawdown in Triassic Sandstone (Up to February 2023)

AGE

DATE 31/08/2023

FIGURE No: **ES.3**

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:\Projects\MOO5001.001 UG4 Compliance Conditions\3_GIS\Workspaces\001_Deliverable1\ES.03_MOO5001.001_Estimated Triassic Drawdown (UG4).qgz



LEGEND

- Drainage
- UG Mine plan
- Approximate Extent of OC Mining 2023
- Modelled Permian Extent
- Mine Extent (February 2023)

Permian (Drawdown in meters)

- 0 to 2 m
- 2 to 5 m
- 5 to 20 m
- 20 to 30 m
- 30 to 52 m

NCID: No Clearly Identifiable Drawdown as at March 2023
** Indicates Lower Confidence Estimate

Groundwater Assessment for Moolarben UG4
Compliance Conditions (MOO5001.001)

Observable Drawdown in Permian (Up to February 2023)

AGE

DATE 31/08/2023

FIGURE No: **ES.4**

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
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Groundwater-Surface Interactions

Estimated groundwater-surface water interaction (between December 2022 and February 2023) along the Goulburn River Diversion and Goulburn River are shown on Figure ES. 5, based on comparison of observed water levels from the closest and shallowest monitoring points relative to river elevations. The data indicates the Goulburn River Diversion is a disconnected losing stream (see also Plate ES. 1), and the Goulburn River is a losing stream along the north-west of UG4 and variably gaining stream to the north and north-east. Data indicates that during extended periods of below average rainfall conditions, the Goulburn River has historically switched between losing and gaining conditions to the northeast of LW414.

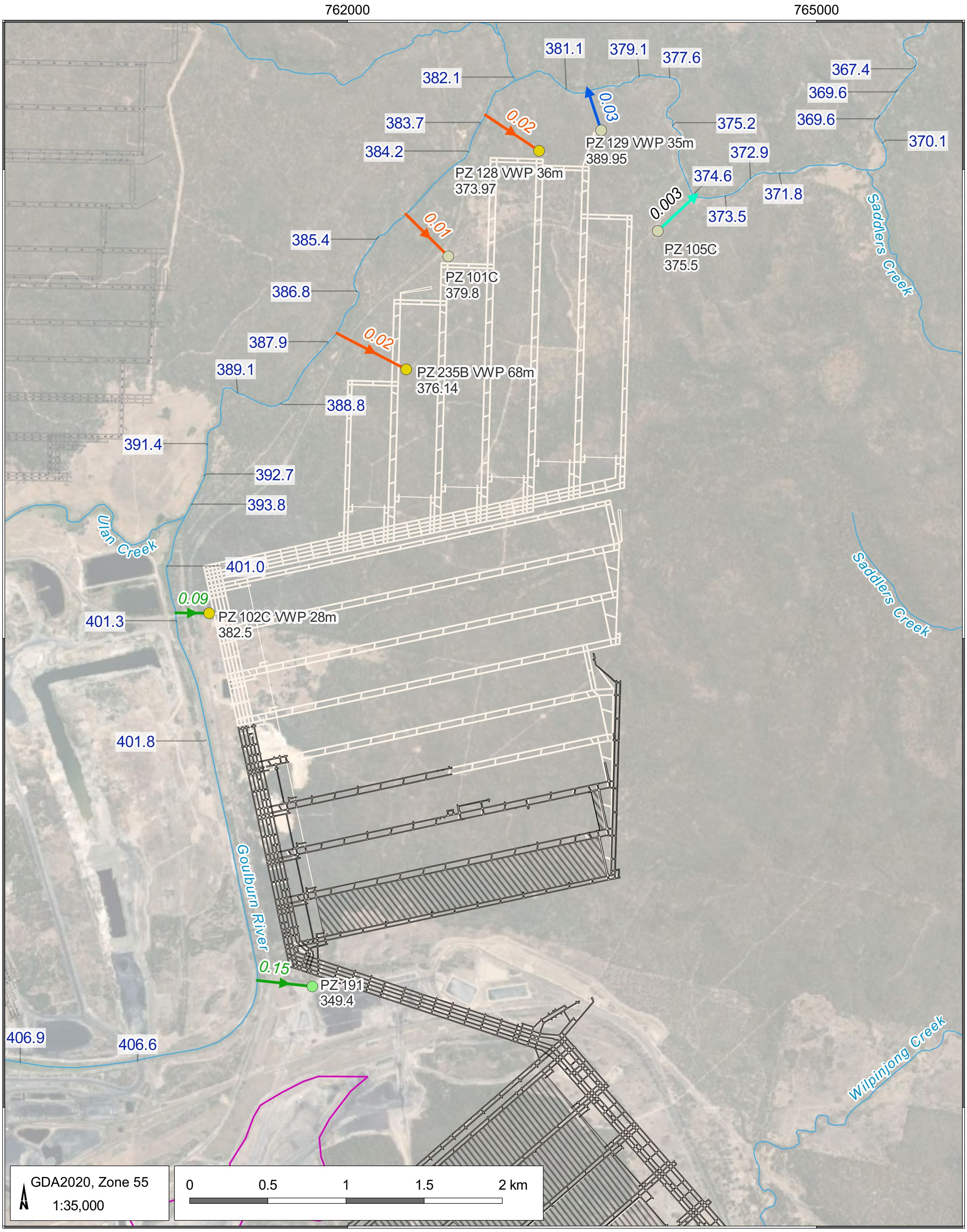
Geological structures

Permian and Triassic strata generally dip to the north north-east at an angle of 1 to 2 degrees. The strata show very little folding, and no major faults have been identified through detailed exploration. Mine Advice (2023) conducted the most recent geological structure analysis for the UG4 Longwall Mining Domain. The stated purpose of the Mine Advice (2023) analysis was to further inform and provide direct input into future groundwater modelling and monitoring assessments that may be undertaken prior to the extraction of Longwall's (LW's) 404 to 414, and to satisfy the following Condition 3f of the LW401-LW408 Extraction Plan.

Mine Advice (2023) made the following conclusions from their analysis:

- It is our assessment that the inferred natural defects in the geology in the UG4 Longwall Mining Domain ***are directly comparable with those in existing areas of UG1 and adjacent areas of the Ulan Mining Complex and are therefore unlikely to significantly enhance groundwater migration and flow*** beyond that predicted by existing height of fracturing models; and
- There is no obvious reason to conduct additional groundwater monitoring or modelling beyond what is currently planned.

Based on the analysis completed by Mine Advice (2023), there is no clear reason to incorporate either the single mapped fault which traverses LW405-408 within the current groundwater model, or the minor faults which traverse the UG4 highway, which connects UG4 to UG1 (Figure ES. 6).



LEGEND

- Approved Ulan Underground Mine Plan
- UG Mine Plan
- Drainage (River Stage mRL)
- Approximate Extent of OC Mining 2023
- Mine Extent (February 2023)
- Triassic Bores
- Permian Bores
- Ulan Bores
- Bore ID
- RSWL

Hydraulic Gradient

- Gaining Stream
- Gaining Stream (Historically Switches Between Losing and Gaining Stream)
- Losing Stream
- Losing Stream (Disconnected)

Groundwater Assessment for Moolarben UG4 Compliance Conditions (MOO5001.001)

Surface Water Groundwater Interaction (Dec 2022 to Feb 2023)

AGE

DATE 30/08/2023

FIGURE No: **ES.5**

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:\Projects\MOO5001.001 UG4 Compliance Conditions\3_GIS\Workspaces\001_Deliverable1\ES.05_MOO5001.001_Goulburn River Hydraulic Gradients.qgz

LEGEND

Drainage
UG Mine plan
Modelled Triassic Extent
Mapped Fault (Vertical Offset m)

Groundwater Assessment for Moolarben UG4 Compliance Conditions (MOO5001.001)

Mapped Geological Structure

AGE

DATE
27/08/2023

FIGURE No:
ES.6

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
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Additional Model Calibration

The numerical model was recalibrated based on data available to February 2023. This, therefore, includes data up to the completion of mining in LW401 (Figure ES. 1).

Thirty new monitoring points have been completed at eleven sites included in the model calibration. VWP represent nested sites with multiple sensors located within the same borehole. New monitoring data include:

- PZ 102C VWP (first data commencing 21 July 2022).
- PZ 103D VWP (first data commencing 21 July 2022).
- PZ 194B (first data commencing 19 July 2022).
- PZ 194C (first data commencing 14 July 2022).
- PZ 195B (first data commencing 14 July 2022).
- PZ 195C (first data commencing 14 July 2022).
- PZ 229 VWP (first data commencing 1 January 2022).
- PZ 230 VWP (first data commencing 1 January 2022).
- PZ 232 VWP (first data commencing 5 September 2022).
- PZ 235B VWP (first data commencing 20 February 2023).
- PZ 238 VWP (first data commencing 20 February 2023).

This also equates to an additional 2 years of calibration data, when compared to calibration periods of:

- January 2005 to April 2021 for AGE (2021); and
- January 2005 to April 2021 for AGE (2022a; 2022b).

The Independent Peer Reviewer found that:

> *I have concluded that the model-predicted heads and fluxes to the underground workings provide an excellent representation of the measured heads and fluxes indicating that the model is well calibrated.*
>
> *By using both head and groundwater flux calibration data, the non-uniqueness in model parameters has been substantially reduced and the resultant model confidence improved. The approach described in the Report represents an appropriate use of available data to constrain model parameters through calibration that uses historical observations at the site and elsewhere in the model domain.*
>
> *The calibration approach is similar to that used in previous versions of this model with the latest work achieving slightly better calibration statistics than those previously reported (5.5% currently reported compared to 6.7% reported by AGE, 2021). The improvement in calibration metrics may be the result of revisions to the conceptualisation and model setup or may simply reflect a better match to the additional data used in the calibration data set.*
>
> *I have concluded that the calibration approach and outcomes meet all reasonable expectations (including guiding principles outlined in Australian Groundwater Modelling Guidelines).*

Key Model Predictions

Drawdown in the Triassic sandstone:

- Predicted drawdown in the Triassic quartzose sandstone is commensurate with AGE (2021). Drawdown of 2 m is predicted to extend to less than 500 m from LW401-408, with between 2 m to 20 m of drawdown predicted to occur across the majority of the eastern side of panels LW401-408. This is generally consistent with the observed saturated thickness of the Triassic sandstone (Figure ES. 2). AGE (2021) reported a marginally larger extent of drawdown across the footprint of LW401-408, however reported a similar lateral extent beyond the longwall panels (Figure ES. 7).
- Predicted drawdown in the Triassic lithic sandstone is commensurate with AGE (2021). Groundwater drawdown of 2 m is predicted to extend to less than 1 km from LW401-408, but with between 20 m to 50 m of drawdown predicted to occur across the entirety of LW401-408. Drawdowns exceeding the observed saturated thickness represent total dewatering of the Triassic sandstone due to mine induced fracturing. AGE (2021) reported a marginally larger extent of drawdown across the footprint of LW401-408, however reported a similar lateral extent of propagation beyond the longwall panels (Figure ES. 8).

Drawdown in the Permian:

- Predicted drawdown in the Permian is commensurate with AGE (2021). Drawdown of 2 m is predicted to extend to less than 7 km from LW401-408, but with greater than 50 m of drawdown predicted to occur across the majority of the northeastern extent of LW401-408. AGE (2021) reported both similar magnitudes and extents of drawdown within the Permian. (Figure ES. 9).

Baseflow loss:

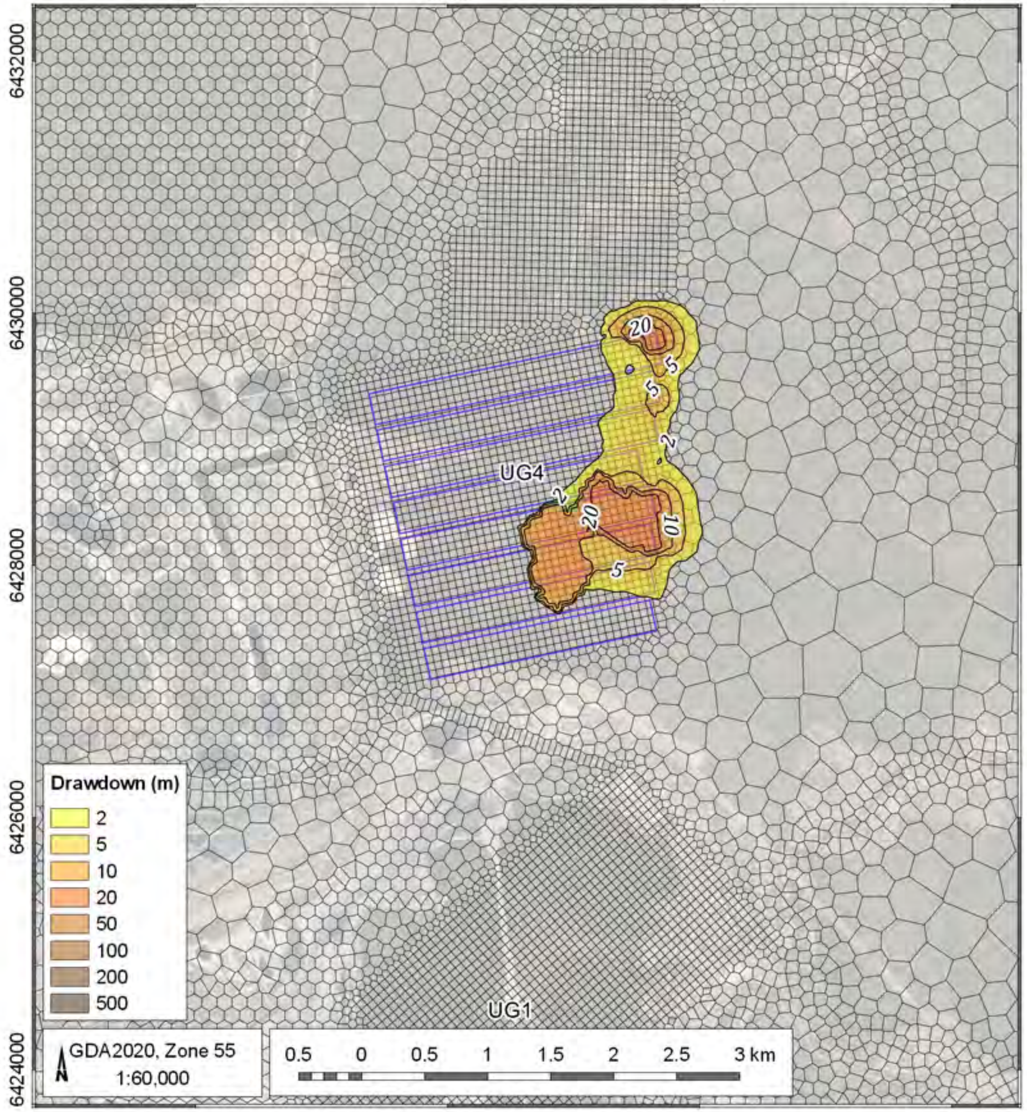
- No reversals of hydraulic gradients to or from the Goulburn River Diversion or Goulburn River have been predicted to occur from the mining of LW401-408 (Figure ES. 10) noting that to the north-east of UG4 the Goulburn River has historically switched between a losing and gaining stream).
- Peak net baseflow loss to the modelled Goulburn River reach has been predicted as 22 ML/yr, while the peak net baseflow loss from the entire Goulburn River Water Source has been predicted as 24 ML/year. The absolute estimates are higher than that predicted by AGE (2021), but occur after the reported period of AGE (2021). The peak net baseflow loss represents a loss of approximately 7% of net modelled baseflow to the Goulburn River or approximately 0.01% of the sustained streamflow estimated during the period February 2020 to February 2022 after licensed mine discharges commenced.

Licensable take:

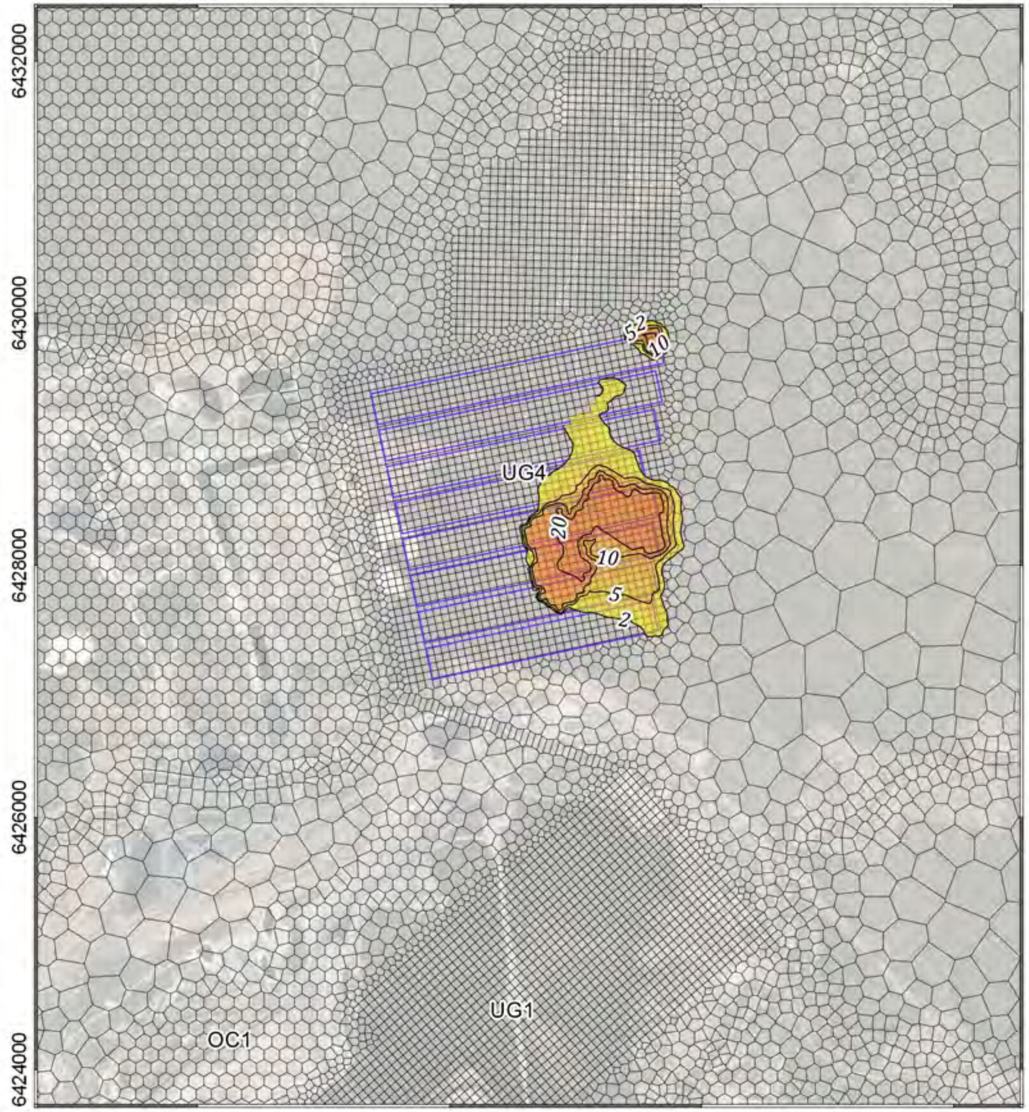
- peak groundwater take from the Sydney Basin-North Coast Groundwater Source has been predicted as 3910 ML/yr;
- peak groundwater take from the Upper Goulburn River Water Source has been predicted as 250 ML/yr; and
- peak groundwater take from the Wollar Creek Water Source has been predicted as 282 ML/yr.

MCO has advised that it has sufficient licence entitlements to account for these predicted licensable takes when considering currently held licences and carryover provisions.

Current



AGE, 2021



LEGEND

- Drawdown contour (m)
- UG4 LW401-408
- Model mesh

Moolarben (MOO5001)

AGE

Modelled drawdown in Triassic quartzose sandstone (current and AGE, 2021)

DATE
31/08/2023

FIGURE No:
ES.7

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
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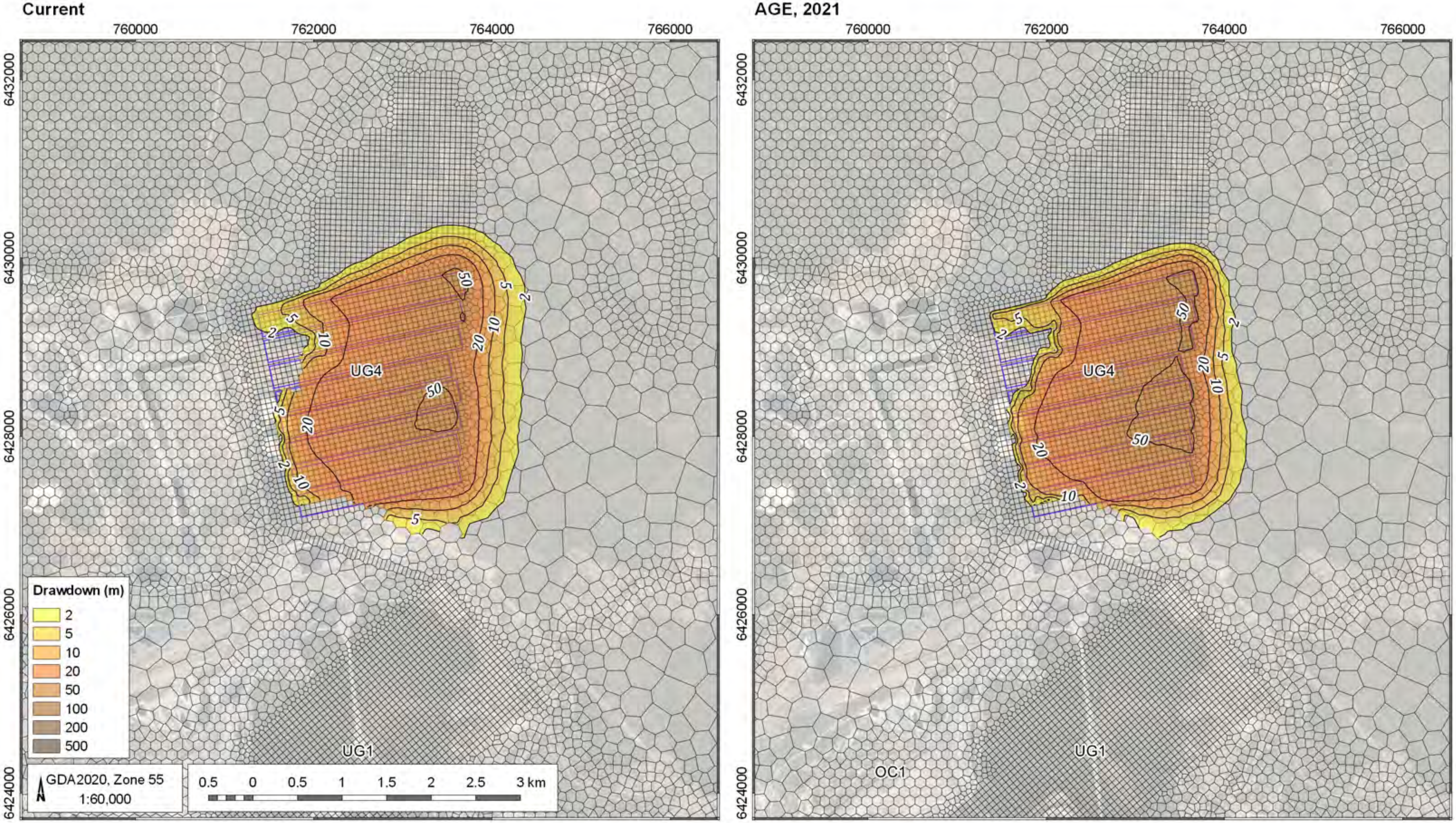

LEGEND
- Drawdown contour (m)
- UG4 LW401-408
- Model mesh

Moolarben (MOO5001)

AGE

Modelled drawdown in Triassic lithic sandstone (current and AGE, 2021)

DATE
31/08/2023

FIGURE No:
ES.8

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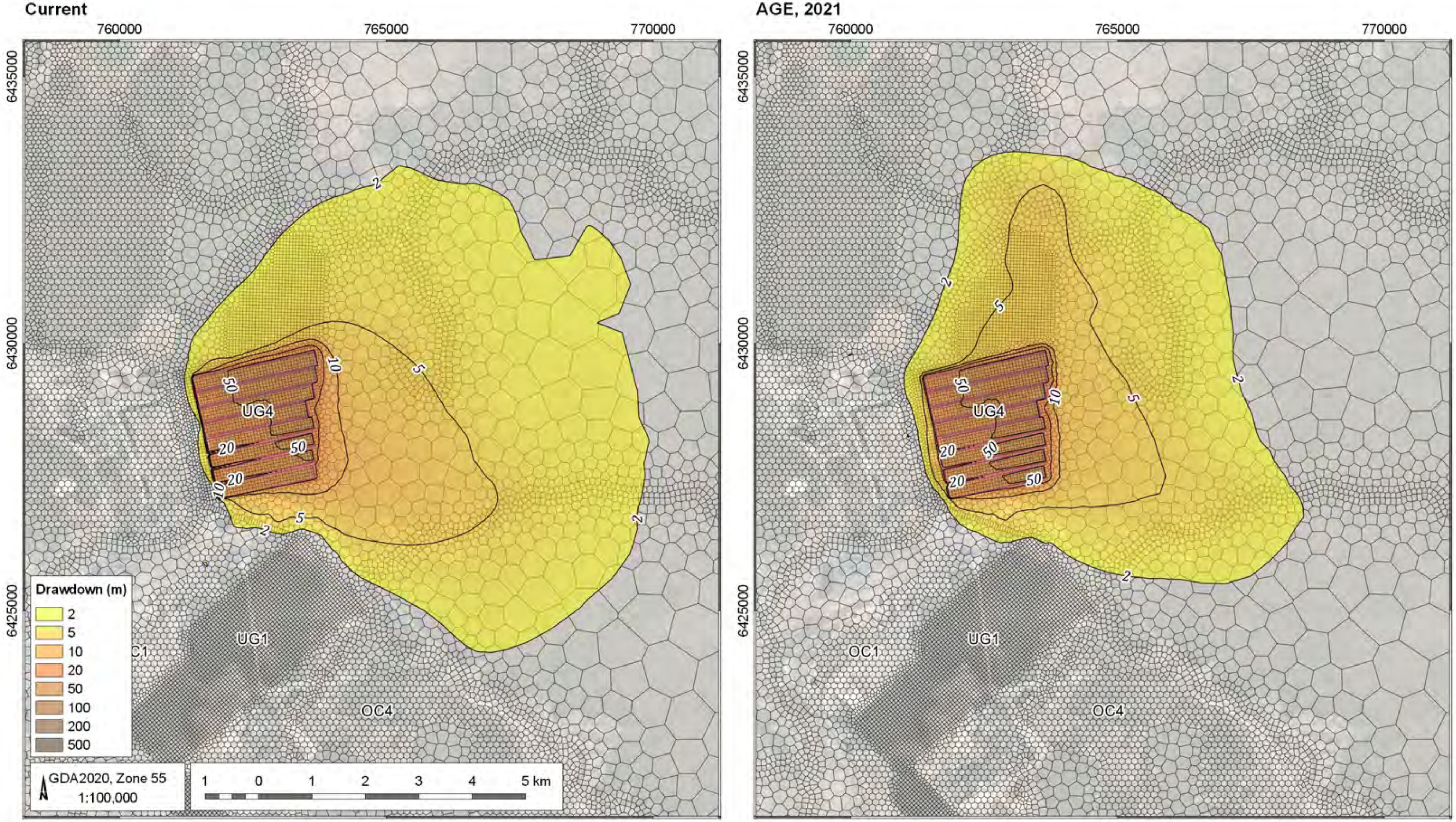

LEGEND
- Drawdown contour (m)
- UG4 LW401-408
- Model mesh

Moolarben (MOO5001)

AGE

Modelled drawdown in Permian (current and AGE, 2021)

DATE
31/08/2023

FIGURE No:
ES.9

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
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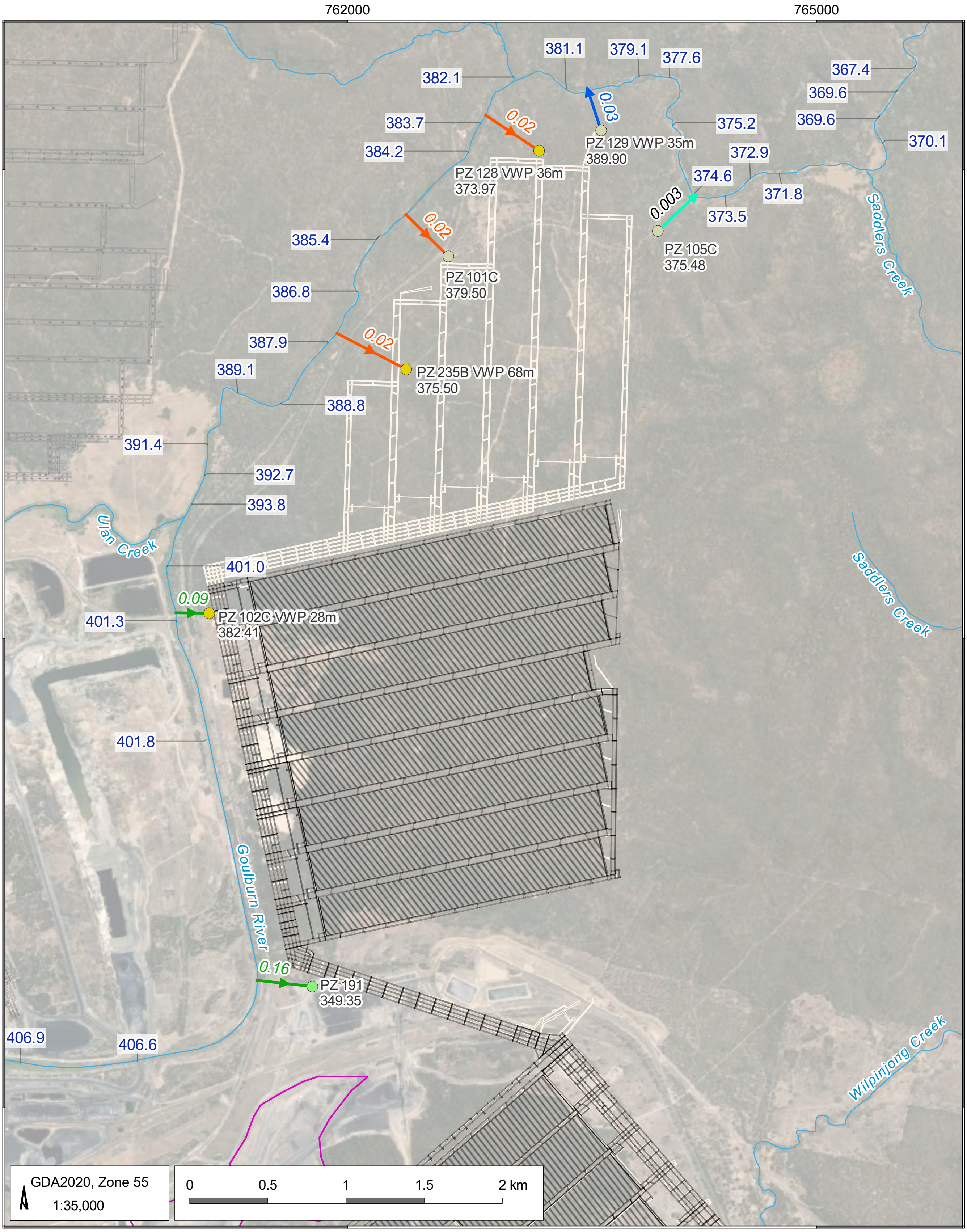

LEGEND

Hydraulic Gradient

- Gaining Stream
- Gaining Stream (Historically Switches Between Losing and Gaining Stream)
- Losing Stream
- Losing Stream (Disconnected)

- Triassic Bores
- Permian Bores
- Ulan Bores

- Approved Ulan Underground Mine Plan
- UG Mine Plan
- Drainage (River Stage mRL)
- Approximate Extent of OC Mining 2023
- Mine Extent (End of LW408)

Note:
RSWL represents Groundwater Levels measured between Dec 2022 to Feb 2023, minus modelled Groundwater drawdown between then and end of Mining LW408.

Groundwater Assessment for Moolarben UG4 Compliance Conditions (MOO5001.001)

Predicted Surface Water / Groundwater Interaction at End of LW401-408

AGE

DATE 30/08/2023

FIGURE No: **ES.10**

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
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Direct Responses to Conditions 3a to 3g

a) review and update the model conceptualisation for the leakage between the Triassic sandstones and the Permian overburden;

Contemporary Conceptual Hydrogeological Model

The main hydrogeological units at the Moolarben Coal Complex include:

- **Quaternary alluvium** associated with the present day drainage system;
- **Tertiary alluvium** associated with the identified palaeochannel that is not related to the present day drainage system;
- **Triassic sandstone** consisting of quartzose Triassic and lithic Triassic sandstone;
- **Permian Illawarra Coal Measures** consists of a sequence of claystone, mudstone, siltstone, and coal measures, which includes the Ulan Seam near the base of the unit;
- **Marrangaroo Conglomerate** – Permian aged conglomerate; and
- **Basement** Includes Carboniferous volcanics and the Gulgong Granite.

Recharge to the groundwater system at the MCC is estimated to be less than two percent of annual rainfall and aligns with the previous estimates by the work others (including MCC and UMC projects).

Groundwater flow directions are dynamic both spatially and temporally. Groundwater flow directions in the surficial units are dominated by topography and discharge features such as the Goulburn River. Deeper units, particularly the Permian ICM, including the Ulan Seam have been impacted by historic mining and will continue to change with time.

Monitoring at UG4 shows that vertical hydraulic head gradients are vertically downwards, indicating recharge from the Triassic sandstone to the Permian ICM occurs. No data suggests any reversal of vertical hydraulic gradients has occurred. Groundwater levels in the shallow Permian can approach similar levels to those in the Triassic sandstone, however there is a much greater vertical separation at depth within the Permian ICM. Groundwater levels in the Triassic sandstone are generally 25 to 50 m above those measured in the Ulan Seam. Some monitoring data show an increase in vertical hydraulic gradients occurring between the Permian ICM and the Ulan Seam due to mining related activities.

At LW401-408, the greatest saturated thickness of the Triassic sandstone has been measured at LW404 (44 metres). Along the eastern margin the Triassic saturated thickness ranges between around 13 m to 23 m. To the south and north, saturated thickness generally decreases to less than 15 m. To the north of future LW413-LW414, saturated thickness is known to increase to around 38 m (Figure ES. 2).

Analysis of hydrographs for all GWMP monitoring points presents compelling evidence to the strong correlation with climate data. This analytical approach achieves an SRMS error of 3.7% based on comparison with the full MCO groundwater dataset.

Groundwater Salinity:

- **Triassic sandstone**: Average TDS of approximately 900 mg/L;
- **Permian**: Average TDS of approximately 1900 mg/L;
- **Ulan Seam**: Average of approximately 1200 mg/L;
- **Marrangaroo Conglomerate**: Average of approximately 1500 mg/L; and
- **Basement**: Average measured TDS of 2200 mg/L.

No clearly identifiable groundwater drawdown up to February 2023 can be inferred within the Triassic sandstone, as a result of MCO operations (see Figure ES. 3 and Figure ES. 4), including at PZ 195B adjacent LW401. At UG4 LW401-408 a maximum groundwater drawdown of approximately 33 m has been inferred at monitoring point PZ 193 within the Ulan Seam. Nested sites show a similar response, with greater drawdowns inferred from the Ulan Seam, and becoming smaller with the increase in depth of cover. This is commensurate with the conceptual model of leakage, whereby the Ulan Seam is depressurised, and overlying units provide vertical leakage towards the Ulan Seam. No drawdown in the Tertiary sediments has been observed beyond 1 km from MCO activities.

While the above conceptualisation is consistent with AGE (2021), the additional data analysed for this technical report and additional modelling provides further justification for this conceptualisation and a greater amount of insight into the vertical 'tightness' of the Permian ICM.

b) review and update the model conceptualisation of surface water – groundwater connectivity;

<u>Surface Water Groundwater Connectivity</u>

Current data suggests that the Goulburn River Diversion is a losing stream and disconnected from the regional watertable (Figure ES. 5). Near UG4 LW401-408, current data suggest that both the Goulburn River Diversion, and the Goulburn River to the west of LW-401-408 are losing streams. Historical groundwater data from monitoring bore PZ 105C suggests that the Goulburn River naturally fluctuates between a losing stream and a gaining stream to the northeast of LW414. Groundwater monitoring data suggest that the west to east stretch of the Goulburn River opposite the Drip is where the river is likely to be a more enduring gaining stream.

The IAPUM in its previous advice stated:

> *The modelling report (AGE 2021) predicts net baseflow takes of between 0.5 and 0.8 ML/d for the Upper Goulburn water source which could be interpreted to mean that the whole of the upper Goulburn River becomes a losing stream and that all groundwater that would have otherwise discharged as baseflow is retained in groundwater storage or discharges to the underground workings to be disposed of later via licensed discharge.*

The IAPUM has misinterpreted the AGE 2021 baseflow predictions. AGE (2021) reported the net change in baseflow, however this does not mean that "the whole of the upper Goulburn River becomes a losing stream. Net change in baseflow can refer a reduction in baselow to the Goulburn River, from reduced hydraulic gradients towards the Goulburn River, as opposed to a reversal in hydraulic gradient.

No reversals of hydraulic gradients to or from the Goulburn River Diversion or Goulburn River have been predicted to occur from the mining of LW401-408 (Figure ES. 10). Peak net baseflow loss to the modelled Goulburn River reach has been predicted as approximately 7% of net modelled baseflow.

c) reassess aquifer drawdown predictions and water balance estimates particularly mine water inflow volumes and groundwater baseflow losses to the Goulburn River;

- Predicted groundwater drawdowns are commensurate with AGE (2021) (Figure ES. 7 to Figure ES. 9).
- Peak groundwater inflows of 3626 ML/yr and 4071 ML/yr have been predicted to occur to LW401-408 and MCC respectively. Predictions reported by AGE (2021) were 4261 ML/yr and 4428 ML/yr respectively.
- Peak net baseflow loss to the modelled Goulburn River reach has been predicted as 22 ML/yr in the 2035/36 water year, while the peak net baseflow loss from the entire Goulburn River Water Source has been predicted as 24 ML/year (during the same period). This represents a peak baseflow loss of approximately 7% of net modelled baseflow to the Goulburn River. AGE (2021) reported a peak net baseflow loss from the Goulburn River Water Source of 0.8 ML/yr in the 2024/25 water year, with predictions reported up until the 2025/26 water year. These changes can be attributed to changes in aquifer parameters (especially storage) in the Triassic sandstone in the current model, with these changes required to address IAPUM comments regarding saturated extent of Triassic sandstone. The uncertainty analysis completed indicates how the effects of modifying aquifer storage (in particular) impacts predicted baseflow.

d) reassess the predicted groundwater take;

Predicted licensable take:

- Peak groundwater take from the Sydney Basin-North Coast Groundwater Source has been predicted as 3910 ML/yr;
- Peak groundwater take from the Upper Goulburn River Water Source has been predicted as 250 ML/yr; and
- Peak groundwater take from the Wollar Creek Water Source has been predicted as 282 ML/yr.

e) complete an independent peer review of the current and updated model by a technical expert endorsed by the Secretary;

- Complete.

f) consideration of the Final Geological Structural Analysis in Condition 4;

There is no clear reason to incorporate either the single mapped fault which traverses LW405-408 within the current groundwater model, or the minor faults which traverse the UG4 highway. The single mapped fault is thought to have very limited vertical extent, with no mapped offset within longwall panels LW405 or LW408. Observations from mining through similar faults had limited significance on total water make and subsided over a relatively short period of time. The mapped fault (Figure ES. 6) does not form an impact pathway beyond the approved mine extent.

The Independent Peer Reviewer found that “Section 5.1.7 addresses this question and I agree with the findings outlined in this section”.

g) provide revised predictions based on the updated numerical model including a detailed technical report on:

(i) predicted cumulative impacts from approved mining; and

(ii) predicted impacts of only the LW401-408 panels.

Predicted drawdown is generally commensurate with AGE (2021). Figure ES. 7 to Figure ES. 9 present a comparison of the predicted impacts from LW401-408. Cumulative impacts for each key Hydrostratigraphic layers have been presented in this report.

UG4 LW401-408 Extraction Plan
Revised Groundwater Technical Report

1 Introduction

The Moolarben Coal Complex is located approximately 40 kilometres (km) north of Mudgee, New South Wales (NSW) (Figure 1.1). The Moolarben Coal Complex is operated by Moolarben Coal Operations Pty Ltd (MCO) on behalf of the Moolarben Joint Venture (Moolarben Coal Mines Pty Ltd [MCM], Yancoal Moolarben Pty Ltd [YM] and a consortium of Korean power companies). MCO, MCM and YM are wholly owned subsidiaries of Yancoal Australia Limited (Yancoal).

MCO has been granted approval to develop Stages 1 and 2 of the Moolarben Coal Project (MCP) under the Environmental Planning and Assessment Act 1979. Approval for Stage 1 of the MCP (05_0117) was granted by the Minister for Planning on 6 September 2007. Approval for Stage 2 of the MCP (08_0135) was granted on 30 January 2015.

The Moolarben Coal Complex (MCC) comprises four approved open cut mining areas (OC1 to OC4), three approved underground mining areas (UG1, UG2 and UG4) and other mining related infrastructure (including coal processing and transport facilities) (Figure 1.2).

Mining operations at the MCC are currently approved until 31 December 2038 with a combined coal production rate of 22 million tonnes per annum (Mtpa), in accordance with Project Approval (05_0117) (Stage 1) and Project Approval (08_0135) (Stage 2).

The Extraction Plan for UG4 Longwalls 401 to 408 was granted conditional approval on 14 July 2022 (Section 1.2). The layout of Longwalls 401 to 408 as approved in the Extraction Plan, incorporates minor shortening of lengths of extraction (Figure 1.3).

This technical report has been prepared to satisfy the requirements of Condition 3 of the UG4 LW401-408 conditional approval (see Section 1.2 for further details).

Brian Barnett has been endorsed by the Department of Planning and Environment (DPE) as a suitable peer reviewer of this technical report and the predictive groundwater model required to meet the requirements of Condition 3.

1.1 Groundwater Assessments at UG4

In November 2021, Australiasian Groundwater and Environmental Consultants Pty Ltd (AGE) completed a Groundwater Technical Report for the MCC's UG4 Longwalls 401 to 408 (AGE, 2021) which informed the LW401 to LW408 Extraction Plan. The technical report provided the following:

- a summary of the groundwater regime in the vicinity of LW401 to 408, including the effects of historical mining activities;
- updated modelling of predicted groundwater impacts from the approved mining of UG4 LWs 401 to 408, including cumulatively with other operations at MCC, Ulan Mine Complex (UMC), and Wilpinjong Coal Mine (WCM);
- identification of suitable monitoring and management measures, including Trigger Action Response Plans; and
- quantification of inflows for LW401 to LW408 and associated water licensing requirements.

The numerical model prepared by AGE (2021) was informed by the previous groundwater modelling of both Peter Dundon and Associates (2006) and SLR (2020) for which subsequent approvals were granted. The AGE (2021) numerical model was improved in several key areas, with extensive additional data, including groundwater monitoring data related to the operation of UG1, and groundwater inflows reported from underground operations.

Following the submission of AGE (2021), the numerical groundwater model was further refined by AGE, and underpinned the following groundwater impact assessments:

- Moolarben Coal Complex OC3 Extension Project Groundwater Impact Assessment (AGE, 2022a); and
- Moolarben Coal Complex UG2 Modification (AGE, 2022b).

Both the OC3 Extension Project and UG2 Modification were independently peer reviewed by Brian Barnett and deemed as fit for purpose for their respective objectives.

The Department of Planning and Environment – Water (DPE Water) provided a submission on the OC3 Extension Project Groundwater Impact Assessment. It stated:

> *The impact of the project on groundwater and its receptors was estimated using MODFLOW-USG groundwater model that was independently peer reviewed as fit for the purpose. Nevertheless, DPE Water assessed the groundwater model as acceptable with 66% rating.*

Further to the independent peer reviews, and feedback from DPE Water, and of particular significance to the mining of LW401-LW408, we note the findings of the Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development (IESC, 2023), who found within their review of the OC3 Extension Project (and the groundwater model which was used as the basis for this report):

- The local and sensitive receptor known as The Drip is '*fed by a local shallow aquifer within the Triassic Sandstone on the far side of the Goulburn River*'. Environmental tracers indicate '*The Drip seepage is distinctive from deeper aquifers, is a localised flow and is probably a perched aquifer*'; and
- '*The groundwater model selected is appropriate for understanding impacts at the regional scale, and cumulative impacts of multiple mine operations. At this scale, the assumptions adopted are reasonable and commensurate with the likely severity of potential impacts, and the model is capable of assessing the potential impact pathway of depressurisation through the coal seams*'.

Numerical modelling completed for this current groundwater technical report has been based on the previously peer reviewed groundwater model, and supplemented with additional groundwater monitoring and inflow data, to support the model recalibration, validation and revised predictions.

1.2 UG4 LW401-408 Extraction Plan Conditional Approval

On 5 January 2022, Moolarben Coal Operations Pty Ltd (Moolarben Coal) lodged their application for approval of a new Extraction Plan for the first eight longwall panels in the UG4 mining area, longwalls LW401 to LW408. Extraction of these panels would occur between 2022 and 2025. The Extraction Plan included a series of detailed management plans, a Subsidence Report and other technical reports. The DPE sought comments on the Extraction Plan from relevant agencies. Advice was received from the Department's Biodiversity, Conservation and Science Directorate (BCS) and Water Group, the NSW Resources Regulator, NSW Environment Protection Authority and Heritage NSW (DPE, 2022b).

The DPE also requested advice from the Independent Advisory Panel for Underground Mining (the Panel) in relation to specific aspects of the draft Extraction Plan. The Panel agreed that '*extraction of longwalls LW401 to LW408 is extremely unlikely to impact water supply at The Drip*'.

The Panel considered that additional monitoring sites and updated numerical modelling is required to better understand baseline groundwater conditions and progressive mining impacts. The Panel also considered that the groundwater model should be updated and be independently peer reviewed prior to the commencement of extraction in Longwall LW404 to provide opportunity for the DPE to consider whether any additional conditions are required.

The DPE considered that the commitments provided in the Extraction Plan are appropriate to assess and manage potential subsidence impacts of longwalls LW401 to LW408 and will '*provide a robust understanding of the existing environment and potential subsidence impacts to inform the assessment of potential future mining in the UG4 area*' (DPE, 2022b). The DPE also noted that '*The Extraction Plan and supporting documents provide a reasonable appreciation of the likely groundwater impacts associated with the underground mining of LW401 to 408 in the southern portion of the UG4 area*'.

The Secretary provided conditional approval of the revised Extraction Plan submitted in June 2022 subject to the groundwater conditions outlined in Table 1.1 (DPE, 2022a).

This report addresses the requirements of condition 3 of the conditional approval (Table 1.1).

Table 1.2 provides details regarding where each of the approval conditions have been addressed in this current groundwater technical report. Table 1.3 provides details of the additional information and analysis that has been provided since the submission of the Extraction Plan in order to fulfil each approval condition.

Table 1.1 Approval conditions relating to groundwater

Condition	Details
3	Prior to the commencement of longwall mining of LW404 or as otherwise agreed by the Secretary, the Proponent must update the numerical groundwater model and predictions to the satisfaction of the Secretary, including: a) review and update the model conceptualisation for the leakage between the Triassic sandstones and the Permian overburden; b) review and update the model conceptualisation of surface water – groundwater connectivity; c) reassess aquifer drawdown predictions and water balance estimates particularly mine water inflow volumes and groundwater baseflow losses to the Goulburn River; d) reassess the predicted groundwater take; e) complete an independent peer review of the current and updated model by a technical expert endorsed by the Secretary f) consideration of the Final Geological Structural Analysis in Condition 4[1] g) provide revised predictions based on the updated numerical model including a detailed technical report on: (i) predicted cumulative impacts from approved mining; and (ii) predicted impacts of only the LW401-408 panels.

Note: [1] AGE assumes this to be an error and should relate to Condition 2.

Table 1.2 Where approval conditions have been addressed

Condition	Report Section
3a	Section 6 (Hydrogeology)
3b	Section 6 (Hydrogeology)
3c	Section 8.2 (Predicted impacts)
3d	Section 8.30 (Water licensing requirements)
3e	Independent peer review
3f	Section 5.1.7 (Geological structure and faulting)
3g(i)	Section 8.2 (Predicted impacts)
3g(ii)	Section 8.2 (Predicted impacts)

Since the groundwater assessment of AGE (2021), additional groundwater studies and a significant amount of additional hydrogeological conceptualisation has been undertaken for the Moolarben Coal Complex. These have been informed by a more temporally and geographically extensive hydrogeological dataset and completed to support specific approval requests including the approval for a modification to the UG2 mining domain, and the OC3 Extension Project. These studies, including further conceptualisation presented in this report, have assisted to address the conditional approval requirements. Table 1.3 provides details of the additional information and analysis that has been provided since the submission of the Extraction Plan, and how these additional analyses answer the salient questions underpinning each approval condition.

Table 1.3 Additional analysis completed to fulfil the conditional approval requirements.

Key Questions	Analysis Completed	Findings / Residual Risk
Condition 3a: Update of the Triassic sandstone and the Permian overburden conceptualisation		
How much water recharges the groundwater system?	Chloride mass balance recharge estimation.	The findings of the chloride mass balance align with both the assumptions of AGE (2021), and those reported by Mackie Environmental Research (2009). Further groundwater sampling is not likely to reduce the uncertainty of these estimates any further and numerical modelling can not be used to estimate these parameters explicitly.
Which direction(s) does groundwater flow?	Production of groundwater contours for all key Hydrostratigraphic units.	This analysis adds significant conceptual understanding of the groundwater system and is a valuable communication tool. The Moolarben Coal Operations groundwater monitoring network is sufficient to enable manual contouring of the key Hydrostratigraphic units with a reasonable amount of accuracy. Additional monitoring points will assist to refine some groundwater contours, however at the mine scale they are not required to understand the general flow directions.
What are the vertical hydraulic gradients between these units?	Production of nested multi-level hydrographs for inferring vertical hydraulic gradients.	This analysis defines the general vertical hydraulic gradients between the key hydrostratigraphic units including the Triassic sandstone and Permian overburden. Additional (new) monitoring points are not required to understand this dynamic of the groundwater system with more resolution.
What is the saturated thickness of the Triassic sandstone?	Triassic saturation thickness plots and revision of hydrogeological cross sections with MCO groundwater level data to December 2022.	Investigation of borehole logs and the MCO geological model have enabled the saturated thickness of the Triassic sandstone to be plotted spatially. This information serves as a comparison for modelled groundwater drawdown. Monitoring coverage is sufficient at this time, to understand the general range in saturated thickness at LW401 to LW408.
How does the groundwater in these units respond to climate?	Detailed analysis and comparison of climate data with groundwater level data.	Appendix A presents the hydrographs for all GWMP monitoring points and presents compelling evidence to the strong correlation with climate data. This analytical approach achieves an SRMS error of 3.7% based on comparison with the full MCO groundwater dataset. Further data or modelling is not required.
What are the hydraulic properties of these units?	Provision of hydraulic testing and measured yield results.	These results were based on a literature review of all available information. Some uncertainty exists in the hydraulic conductivity of the interburden units, as these have not been targeted for extensive hydraulic testing.

Key Questions	Analysis Completed	Findings / Residual Risk
Is there a difference in groundwater quality between these units?	Detailed hydrogeochemical analysis.	A thorough hydrogeochemical analysis was completed for the OC3 Extension study and a summary of those results has been incorporated into this report, which support the current conceptual model of low salinity Triassic sandstone groundwater and higher salinity groundwater within the Permian overburden. Additional (new) groundwater monitoring data is not likely to shift the median or average estimates of these key units due to the volume of data which MCO have already collected. Groundwater modelling cannot constrain these parameters.
How do these hydraulic units react under hydraulic mining stress?	Estimation of observed groundwater drawdown and analysis of spatial groundwater drawdown in proximity to MCC.	This analysis provides significant insight into the behaviour of the groundwater system, and the potential impact pathways which are responsible for the propagation of drawdown. No clearly identifiable groundwater drawdown can be inferred within the Triassic sandstone, after 13 years of MCO operations.
Condition 3b: Update the Conceptualisation of Surface water – Groundwater Connectivity		
Is it possible to define the Goulburn River Diversion stream type as per Barnett et al.?	Analysis of adjacent hydraulic gradients and revision of hydrogeological cross sections with MCO groundwater level data to December 2022.	Current data suggests that the Goulburn River Diversion is likely a Losing stream and disconnected (flow regime class e). Additional shallow and adjacent groundwater monitoring will serve to reduce the uncertainty of this hypothesis. MCO are currently in the process of obtaining the required approvals to expand this type of monitoring.
Is it possible to define the Goulburn River stream type as per Barnett et al.?	Groundwater contouring of the Triassic Sandstone, coupled with analysis of adjacent hydraulic gradients and revision of hydrogeological cross sections with MCO groundwater level data to December 2022.	Current data suggests that the Goulburn River likely switches between a flow-through water body (flow regime b) and is currently a gaining stream (discharge water body or flow regime a) somewhere north of LW414 and just west of The Drip. Additional shallow and adjacent groundwater monitoring will serve to reduce the uncertainty of this conceptualisation.
How much baseflow occurs to the Goulburn River?	Upper range baseflow estimates from recharge calculations and flow net mapping.	This analysis suggests that the groundwater baseflow to the southern side of the Goulburn River will occur at a rate of less than 200 ML/year. Additional surface water gauging downstream of The Drip, together with accurate records of mine approved discharges would support the estimation of groundwater baseflow to the Goulburn River, although even with this infrastructure, would still contain uncertainty.
How much baseflow occurs to Moolarben Creek, which flows into the Goulburn River?	Baseflow analysis coupled with analysis of dam evaporative capacity and literature review of surface water reports.	Baseflow to Moolarben Creek has been estimated to be of the order of 180 – 225 ML/year. During wetter years, groundwater baseflow contributions could increase to 680 ML/year or higher. Being able to calibrate the groundwater model to reliable estimates of baseflow greatly assists to reduce non uniqueness in the groundwater model and adds confidence in the predictions of baseflow losses.

Key Questions	Analysis Completed	Findings / Residual Risk
Condition 3f: Consideration of Geological Structure		
Is there enough information to reliably include known faults in the current groundwater model?	Review of the analysis completed by Mine Advice (2023) and comparison with the modelled mine plan and model layer structure.	Based on the analysis completed by Mine Advice (2023), there is no clear reason to incorporate either the single mapped fault which traverses LW405-408 within the current groundwater model, or the minor faults which traverse the UG4 highway which connect UG4 to UG1. The single mapped fault which spans LW405-408 is thought to have very limited vertical extent, with no mapped offset within longwall panels LW405 or LW408. Observations from mining through the minor faults which traverse the UG4 highway had limited significance on total water make and subsided over a relatively short period of time. The lateral extent of the mapped fault which spans LW405-408 is contained within the footprint of UG4, and therefore does not form an impact pathway beyond the approved mine extent. The expected height of fracturing from mining LW405 to LW408 will induce a change to the vertical hydraulic conductivity above panels LW405-408 which will enable groundwater drainage to a much greater capacity than the drainage which might occur from mining these features discretely with no vertical enhancement. Accordingly, inclusion of these discrete features in the numerical model will not materially affect the total (cumulative) volume of groundwater which is removed from the mining and goafing processes.

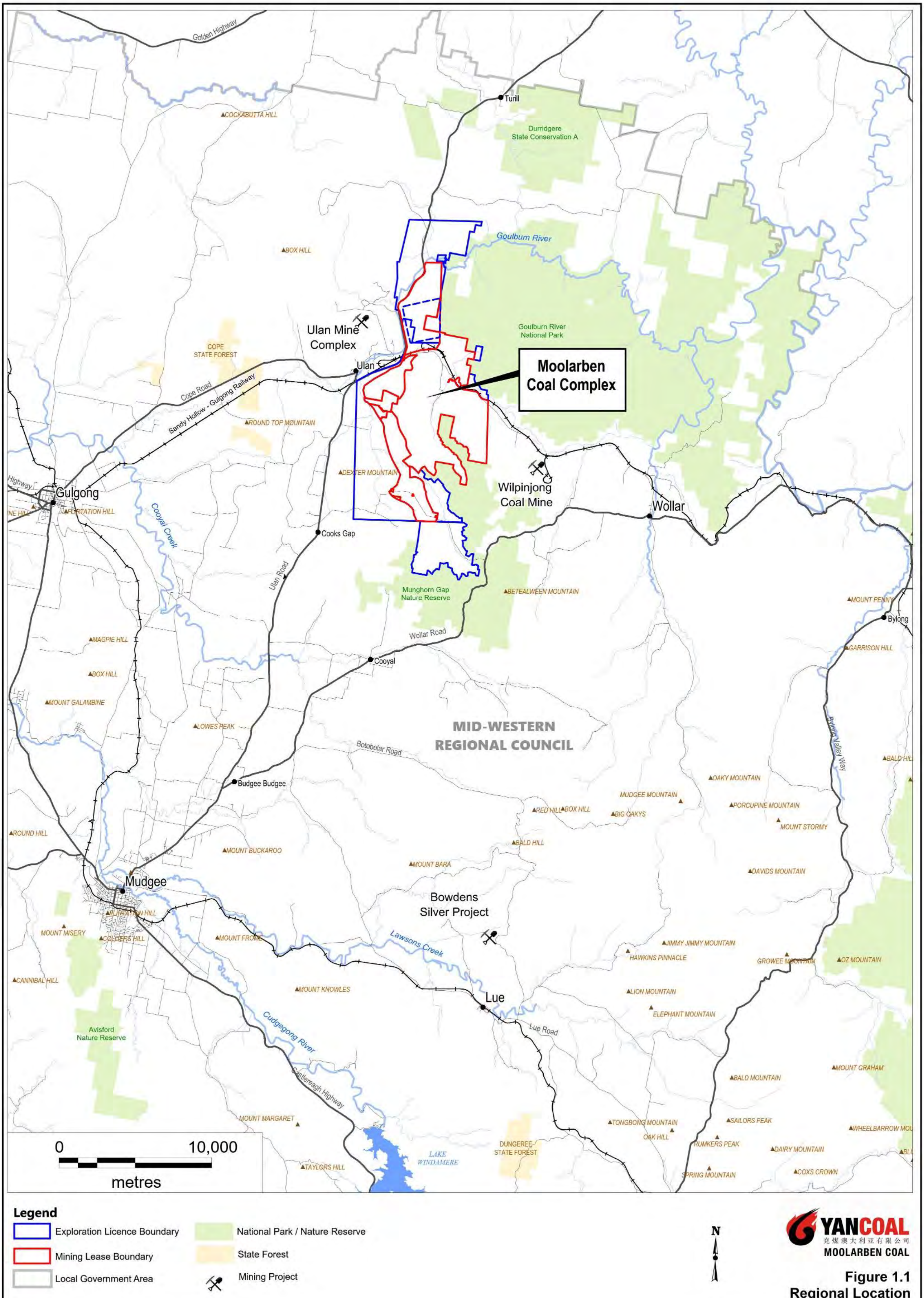


Figure 1.1
Regional Location

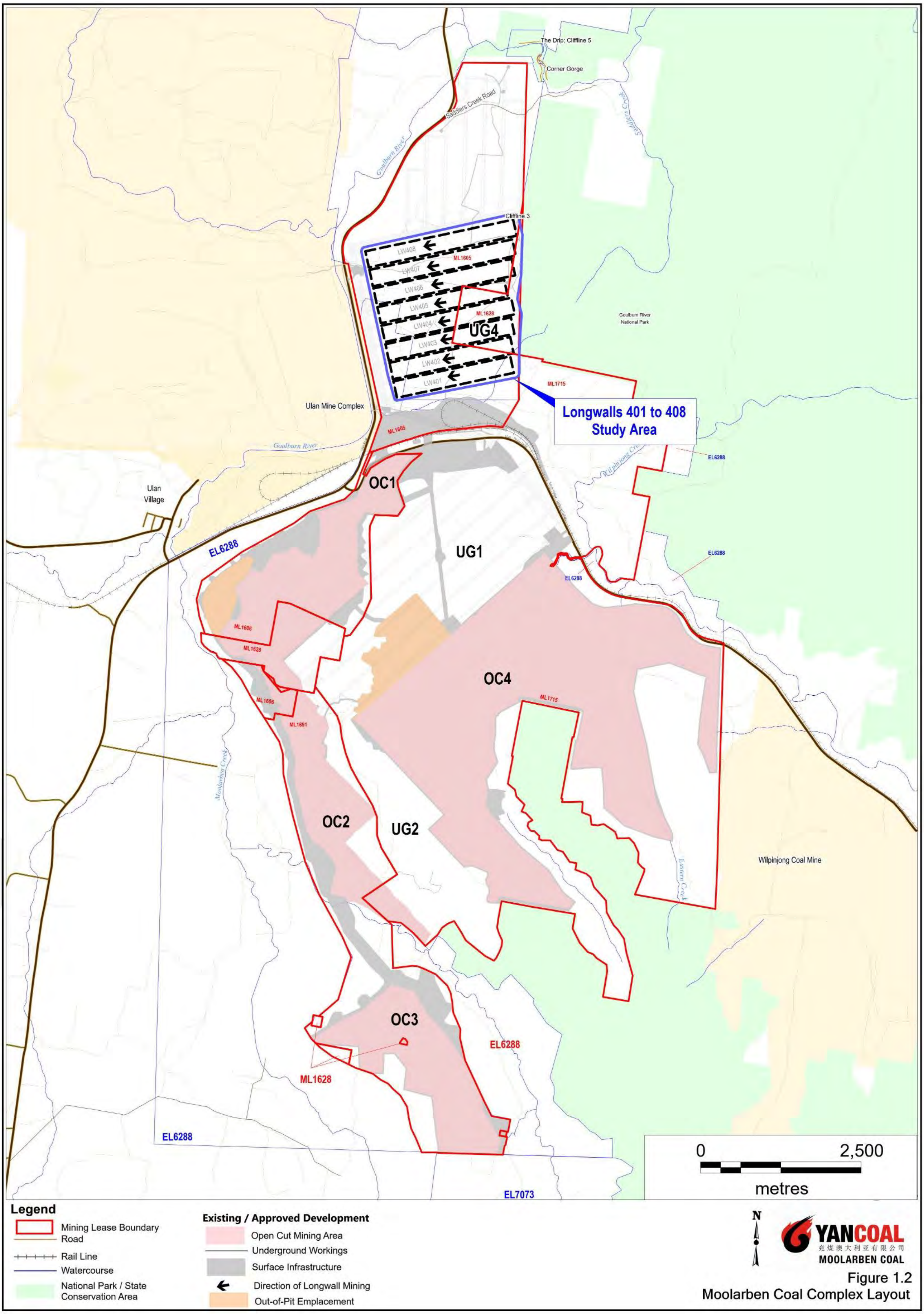


Figure 1.2
Moolarben Coal Complex Layout

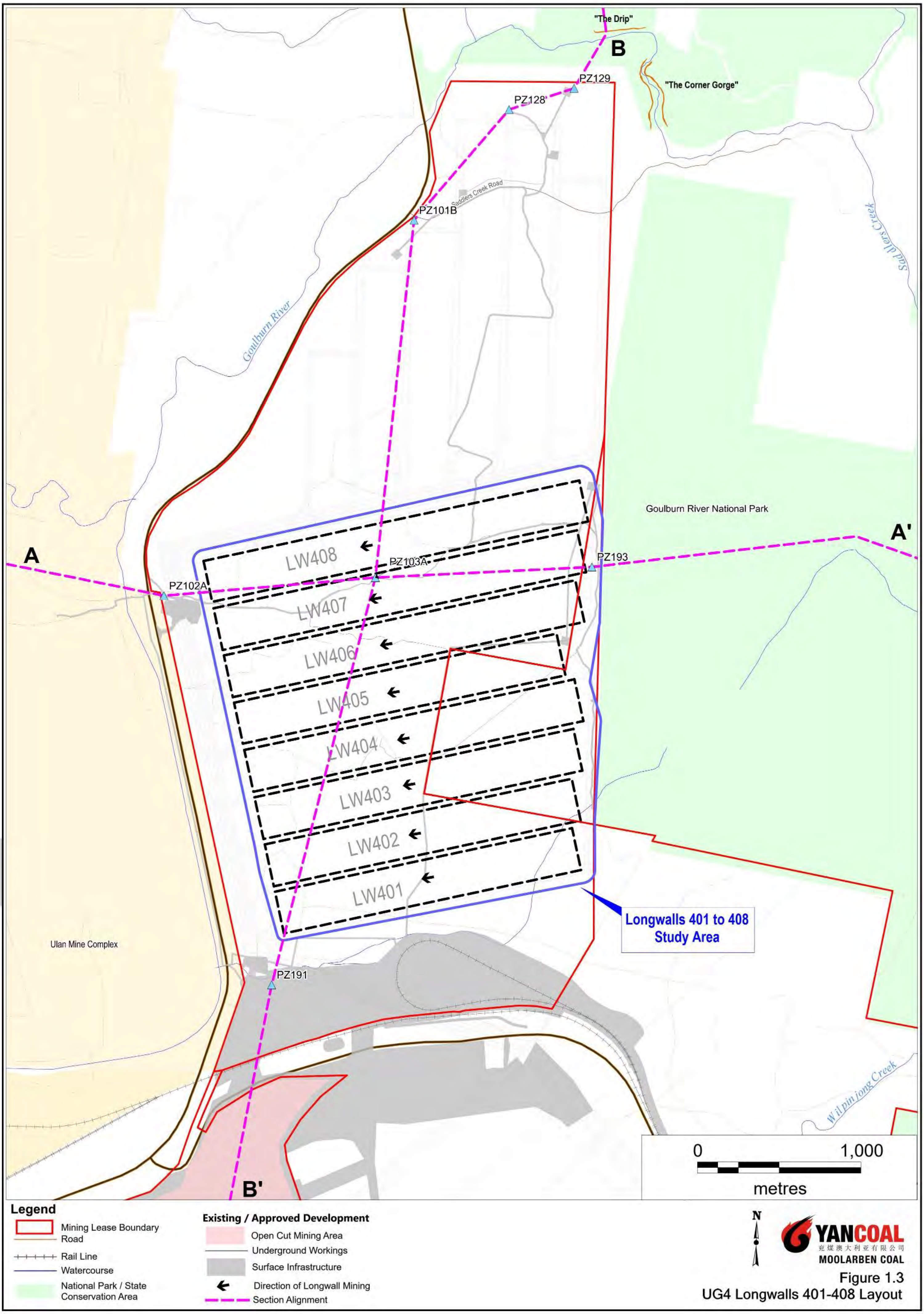


Figure 1.3
UG4 Longwalls 401-408 Layout

2 Mining

2.1 Previous and Current Mining Activities

The MCC is located in a well-established mining precinct, comprising the existing MCC as well as the Ulan Mine Complex (UMC) and Wilpinjong Coal Mine. Mining in the area has been undertaken periodically since the Ulan No. 1 Colliery was established in the 1920's, with substantial expansion occurring in the 1980's with the development of the open cut and adoption of longwall mining at the Ulan Coal Complex (Umwelt, 2009).

Key mining activities in the vicinity of UG4 include (Figure 2.1):

- MCC UG4 (the focus of this report) which mines the Ulan Seam. First workings commenced in UG4 in July 2019 followed by secondary extraction commencing in July 2022;
- MCC UG1, which is located south of UG4 and also mines the Ulan Seam. First workings commenced in UG1 in April 2016 followed by followed by secondary extraction commencing in October 2017 and ceasing in June 2022;
- MCC Open Cut 1 (OC1), which is located south of UG4, commenced in 2010 and has been mined to the base of the Ulan Seam;
- Ulan East Pit, which commenced in the 1980's and operated until 2008 (Figure 2.1). The Ulan East Pit was mined to the base of the Ulan Seam, partially backfilled and is now used as a tailings and mine water storage;
- Highwall mining north of the Ulan East Pit, which was undertaken in the 1990s in the Ulan Seam; and
- Longwall mining at Ulan No. 3, which commenced in 1986 and continues to extract the Ulan Seam.

In addition to these mining activities, the upper reaches of the Goulburn River (upstream of the Goulburn River National Park and adjacent to UG4), have been altered by historic development, including:

- construction of Moolarben Dam in 1957, which has significantly altered flows from Moolarben Creek into the Goulburn River;
- construction of the Goulburn River Diversion upstream of Ulan Creek, which has altered the original flow-path, size and geometry of the Goulburn River channel;
- discharges from the UMC downstream of Ulan Creek; and
- discharge from the MCC upstream of UG4, which commenced in 2020.

2.2 Mining at UG4 LW401-408

Longwall mining at LW401-408 occurs in the Ulan Seam, which has been historically mined at both MCC and UMC (Section 2.1).

The layout of Longwalls 401 to 408 is shown in Figure 2.1. Longwall lengths based on the Extraction Plan Layout are slightly shorter than those based on the Approved Layout. The lengths have been shortened from 10 m (LW401) to 85 m (LW405). With the exception of the shortened lengths, the longwall geometry for the Extraction Plan Layout is the same as that for the Approved Layout. A summary of the longwall dimensions is provided in Table 2.1.

The surface elevations directly above the proposed longwalls in the Extraction Plan Layout vary from a high point of 500 m above the Australian Height Datum (mAHD) above the commencing (eastern) end of LW404, to a low point of 405 mAHD above the finishing end of LW407. The depth of cover to the Ulan Seam above these longwalls varies between a minimum of 83 m at the finishing end of LW401 and LW407, to a maximum of 205 m at the commencing end of LW404.

The seam floor within the mining area generally dips from the southwest towards the northeast. The average dip of the seam within the extents of the proposed longwalls is around 1.6 %. The thickness of the Ulan Seam D-Working Section within the extents of the proposed longwalls varies between 2.8 m and 3.2 m. The proposed mining height for the longwalls is 3.0 m.

The mining of East-West panels LW401 to LW408 will provide valuable site-specific information which will inform future decisions regarding Longwall panels LW409 to LW414. The mining of LW409 to LW414 will be the subject of future extraction plans.

Table 2.1 Geometry of Longwalls 401 to 408 based on the Extraction Plan Layout

Longwall	Overall Void Length Including Installation Heading (m)	Overall Void Width Including First Workings (m)	Overall Tailgate Chain Pillar Width (m)
LW401	1854	260	-
LW402	1912	260	35
LW403*	1982	260	35*
LW404	2046	260	35
LW405	2014	260	35
LW406	2196	260	35
LW407	2271	260	35
LW408	2348	260	35

Note: LW403 Tailgate shortening will occur due to S1MC280 heritage site protection.

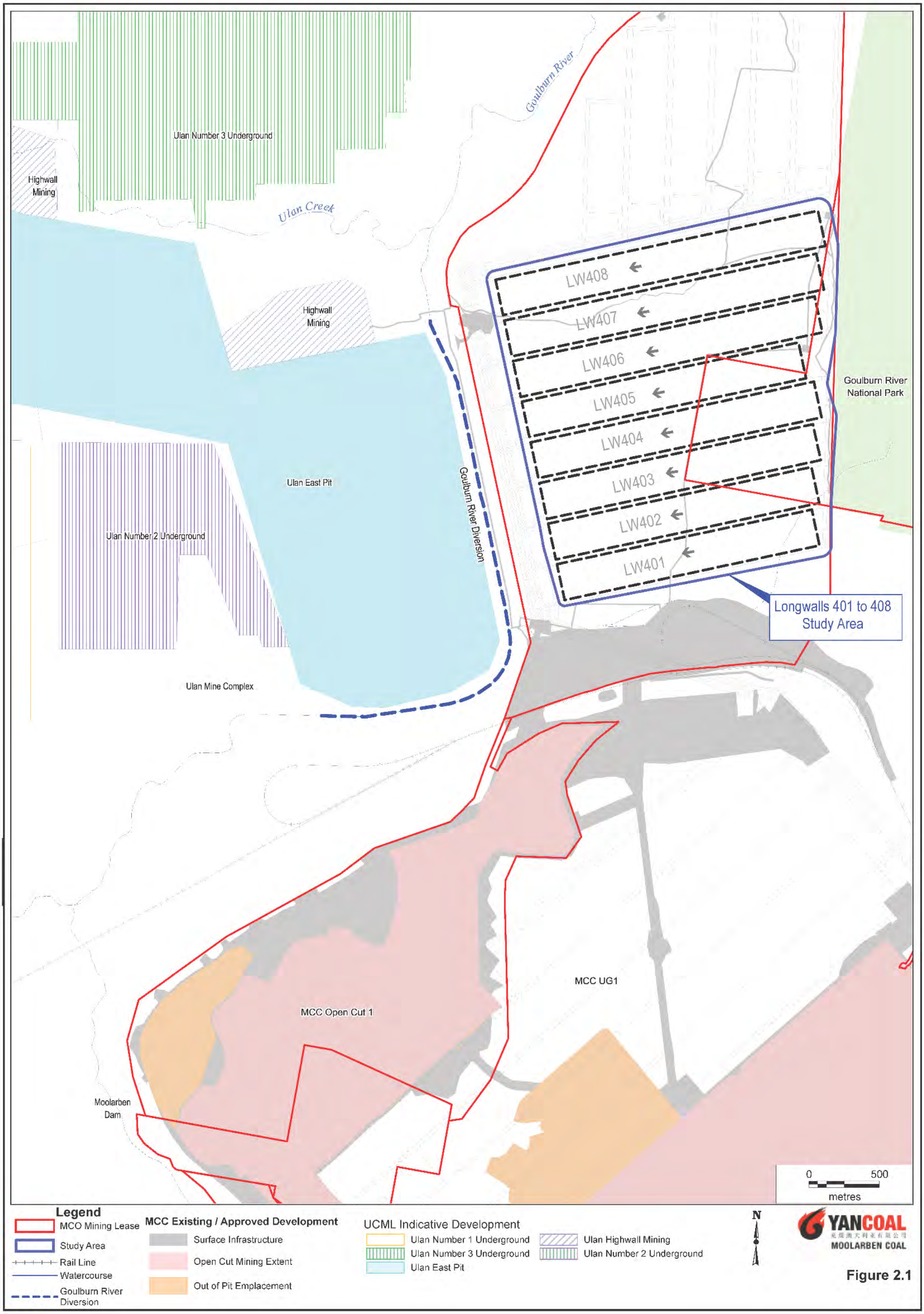

Ulan Number 3 Underground
Highwall Mining
Ulan Creek
Goulburn River
Highwall Mining
LW408
LW407
LW406
LW405
LW404
LW403
LW402
LW401
Goulburn River National Park
Ulan East Pit
Goulburn River Diversion
Ulan Number 2 Underground
Longwalls 401 to 408 Study Area
Ulan Mine Complex
MCC UG1
MCC Open Cut 1
Moolarben Dam
0 500
metres
Legend
MCO Mining Lease
Study Area
Rail Line
Watercourse
Goulburn River Diversion
MCC Existing / Approved Development
Surface Infrastructure
Open Cut Mining Extent
Out of Pit Emplacement
UCML Indicative Development
Ulan Number 1 Underground
Ulan Number 3 Underground
Ulan East Pit
Ulan Highwall Mining
Ulan Number 2 Underground
N
YANCOAL
MOOLARBEN COAL

Figure 2.1

3 Regulatory Framework

3.1 Water Management Act 2000

The *Water Management Act 2000* incorporates the provisions of various prior Acts relating to the management of surface and groundwater in NSW. It provides a single statute for regulation of water access, use and works (e.g. pumps or bores) that affect the licensing of surface water and both alluvial and non-alluvial (i.e. porous rock) groundwater in the vicinity of the Moolarben Coal Complex.

The *Water Management Act 2000* aims to provide sustainable and integrated management of the water sources of NSW for the benefit of both present and future generations. The Moolarben Coal Complex is regulated under the *Water Sharing Plan for the Hunter Unregulated and Alluvial Water Sources 2022* and the *Water Sharing Plan for the North Coast Fractured and Porous Rock Groundwater Sources 2016*.

3.1.1 Water sharing plans

The following water sources are relevant to the Moolarben Coal Complex (Figure 3.1 and Figure 3.2):

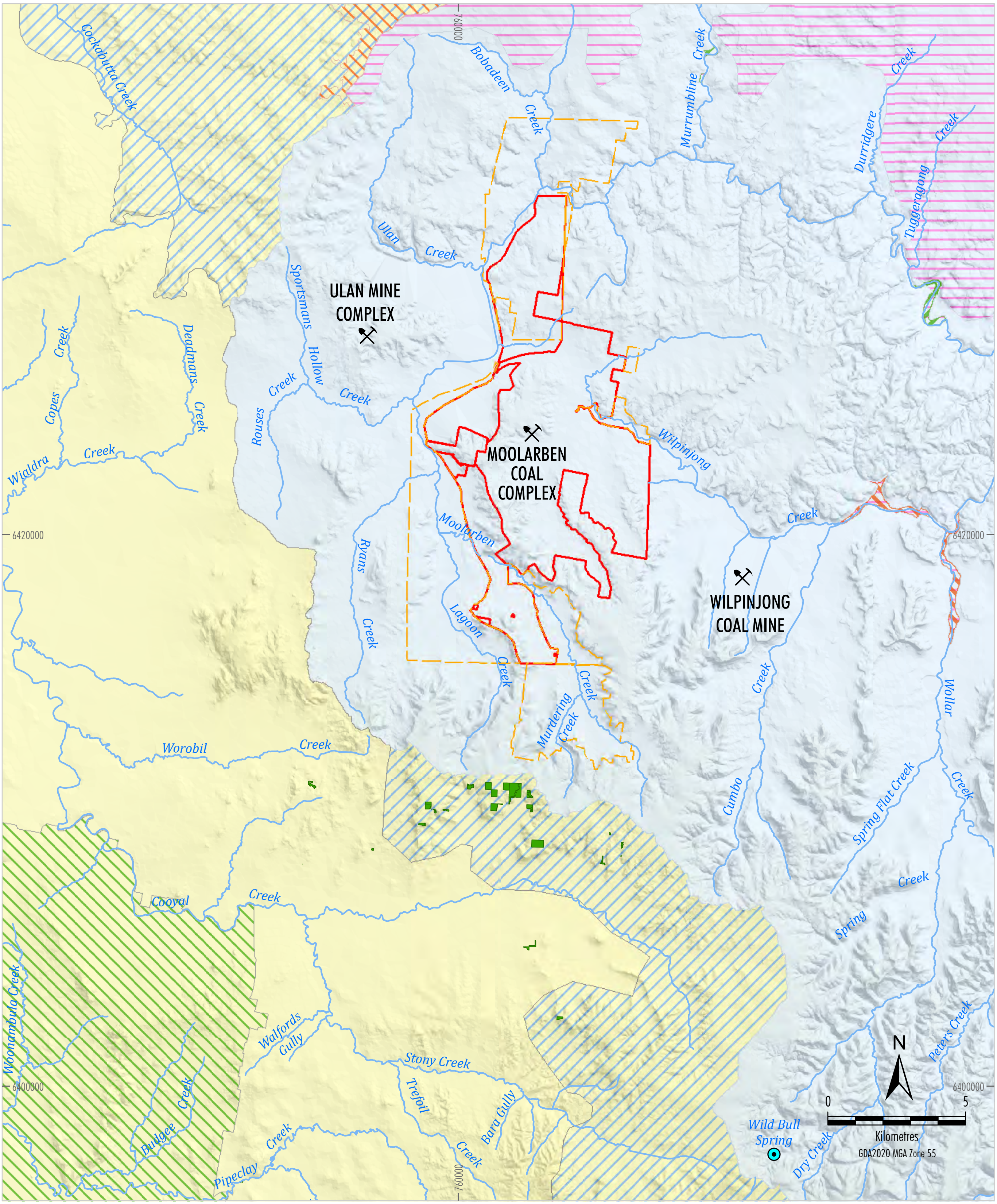
- Water Sharing Plan for the North Coast Fractured and Porous Rock Groundwater Sources 2016:
  - Sydney Basin – North Coast Groundwater Source.
- Water Sharing Plan for the Hunter Unregulated and Alluvial Water Sources 2022:
  - Upper Goulburn River Water Source; and
  - Wollar Creek Water Source.

3.1.2 Water licensing

A summary of water access licences (WALs) held by MCO for the Moolarben Coal Complex is provided in Table 3.1. Yancoal operates a number of mines in the Sydney Basin-North Coast Groundwater Source, which provides opportunities to trade licences between Yancoal-owned assets to meet the specific licensing requirements for each site, which fluctuate from year-to-year. The trading of WAL entitlements is a recognised and legally approved mechanism under the *Water Management Act 2000* to maximise the efficient use of the state's water resources.

Table 3.1 MCO Water Access Licences and Annual Entitlements

Water Source	Total Source Entitlement (units)
Sydney Basin-North Coast Groundwater Source	2,950
Upper Goulburn River Water Source	208
Wollar Creek Water Source	228



LEGEND

Exploration Licence Boundary

Mining Lease Boundary

Water Sharing Plan for the North Coast Fractured and Porous Rock Groundwater Sources 2016

Sydney Basin - North Coast Groundwater Source

Oxley Basin Coast Groundwater Source

High-priority Groundwater Dependent Ecosystem (Wild Bull Spring)

Water Sharing Plan for the NSW Murray Darling Basin Fractured Rock Groundwater Sources 2020

Lachlan Fold Belt MDB Groundwater Source

Lachlan Fold Belt MDB (Mudgee) Management Zone

Water Sharing Plan for the NSW Murray Darling Basin Porous Rock Groundwater Sources 2020

Sydney Basin MDB Groundwater Source

Sydney Basin MDB (Macquarie Oxley) Management Zone

High-priority Groundwater Dependent Ecosystem

Water Sharing Plan for the Hunter Unregulated and Alluvial Water Sources 2022

Unnamed Alluvium in the Upper Goulburn River Water Source

Unnamed Alluvium in the Wollar Creek Water Source

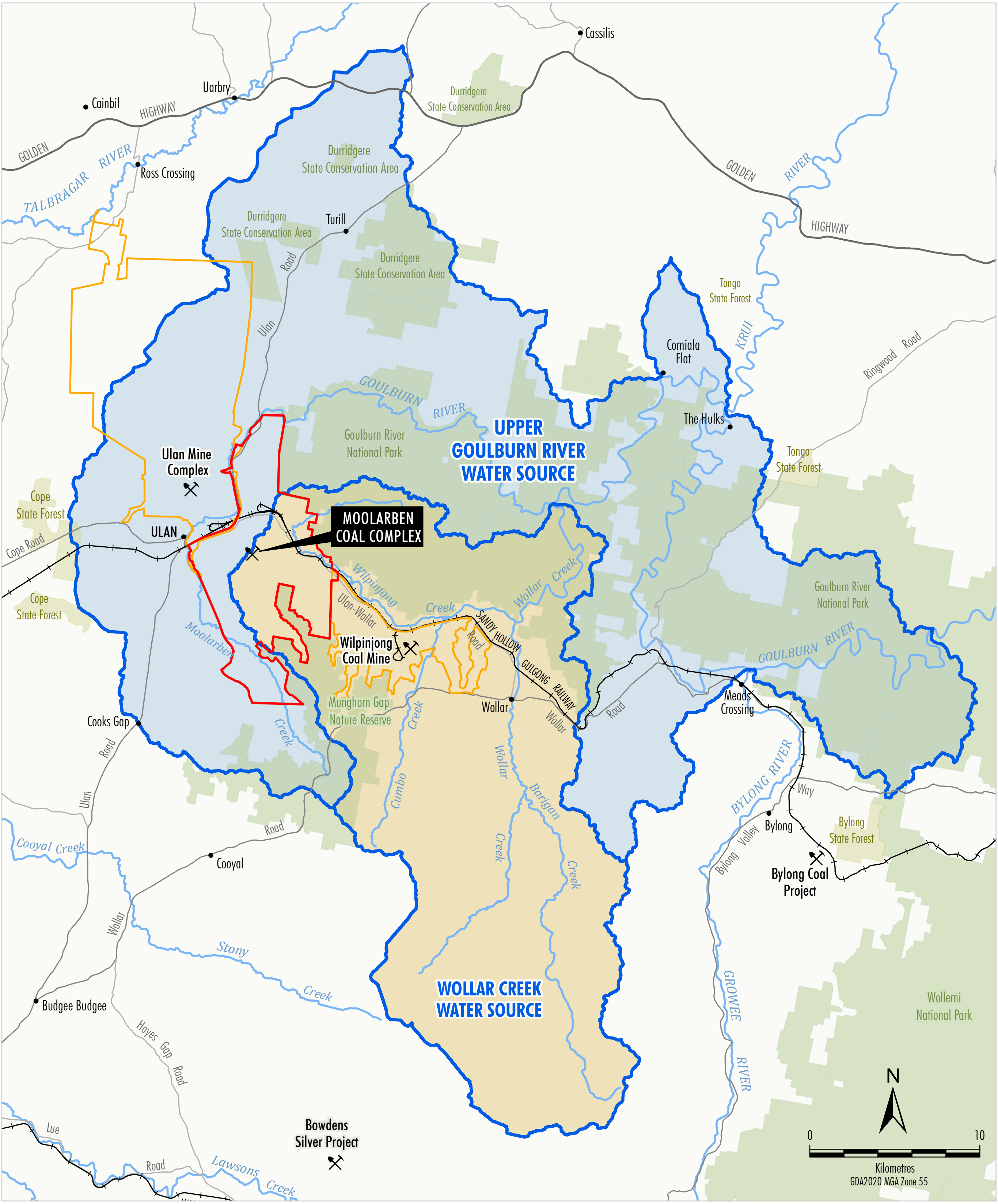
Source: MCO (2022); NSW Spatial Services (2021)

YANCOAL MOOLARBEN COAL

MOOLARBEN COAL COMPLEX

Regional Groundwater Sources

Figure 3.1



LEGEND
National Parks/Nature Reserves
State Forest
MCC Approval Boundary
Other Mining Operation
Mining Operation
Relevant Water Sharing Plan Water Source Boundary

Source: Water NSW (2021); NSW Spatial Services (2021)

YANCOAL MOOLARBEN COAL

MOOLARBEN COAL COMPLEX
Water Sharing Plan for the Unregulated Hunter Catchment - Upper Goulburn River and Wollar Creek Water Sources

Figure 3.2

3.1.3 Aquifer Interference Policy

The Aquifer Interference Policy (AIP) (NSW Government, 2012) was developed by the NSW Government as a component of the NSW Government's Strategic Regional Land Use Policy. The AIP applies state-wide and has been developed to ensure equitable water sharing between various water users and proper licensing of water that is taken by aquifer interference activities, so that the take is accounted for in the water budget and water sharing arrangements.

The AIP also includes minimal impact considerations relating to watertable and groundwater pressure drawdown and changes in groundwater and surface water quality. The AIP establishes minimal impact considerations for groundwater categories of both 'highly productive' and 'less productive' groundwater. 'Highly productive groundwater' is defined by the AIP as a groundwater source that is declared in the Regulations and is based on the following criteria (NSW Government, 2012):

a) has total dissolved solids of less than 1,500 milligrams per litre (mg/L), and
b) contains water supply works that can yield water at a rate greater than 5 litres per second (L/sec).

Groundwater that does not meet the AIP requirements for 'highly productive' is considered 'less productive'.

4 Environmental Setting

The MCC is situated approximately 40 kilometres (km) north of Mudgee and 25 km east of Gulgong, in New South Wales (Figure 1.1). The operation is set in the Western Coalfield, which is located on the northwest margin of the Sydney-Gunnedah-Bowen Basin.

The Western Coalfield contains the Illawarra Coal Measures of mid to late Permian age. Triassic sandstones and conglomerates of the Narrabeen Group overlie the coal measures, which in turn overlie either Late Permian marine sediments (Shoalhaven Group) in the east, or Carboniferous Ulan Granite and Rylstone Volcanics in the west. The Shoalhaven Group contains the Marrangaroo Conglomerate which is present within some parts of the Moolarben Coal Complex.

Small intrusives and remnant basalt flows have been observed in outcrop in the Murragamba and Wilpinjong valleys and have been intersected in some bores (Dundon and Associates, 2006).

4.1 Climate

Climate at the Moolarben Coal Complex can be classed as semi-arid, with excessive evaporative capacity typically occurring throughout most of the year. Variability in rainfall totals can lead to periods where rainfall exceeds that of evaporation, and these generally occur in the cooler winter months of June and July.

4.1.1 Rainfall and Evaporation

The Australian Bureau of Meteorology (BoM) has an extensive monitoring network of rainfall stations located throughout Australia, which have recorded daily rainfall measurements for varying durations, with a large number of stations having continuous records of rainfall data back to the early 1900s (or in some cases, the 1890s or earlier). Records of daily rainfall totals have been recorded at the Ulan Water station (BoM Station No. 062036) since March 1906, which is located at the Ulan Post Office, less than 4 km southwest from UG4. The Ulan Water station does not however collect evaporation rates.

The SILO is a database of Australian climate data from 1889 to the present. It provides daily meteorological datasets for a range of climate variables in ready-to-use formats suitable for modelling, research and climate applications. The data system commenced in 1996 as a project between the Queensland Government and the BoM and was sponsored by the Land and Water Resources Research and Development Corporation. The datasets are constructed from observational data obtained from BoM weather stations, and additional weather recording sites. Climate data obtained from the SILO database shows a very strong correlation with groundwater measurements recorded at the Moolarben Coal Complex, and this is discussed in Section 6.

Table 4.1 provides a detailed summary of the climate data, averaged monthly. Annual rainfall at the site is of the order of 650 mm/yr, with the highest monthly rainfalls typically occurring in the summer months. The greatest likelihood of groundwater recharge will occur in the cooler months of June and July, while evaporation rates are at their lowest, and the ratio of rainfall to evaporation is also at its highest.

Table 4.1 Long Term Climate Data

Month	Ulan Water Mean Rainfall (mm)	Silo Database Mean Rainfall (mm)	Silo Database Mean Minimum Temp (°C)	Silo Database Mean Maximum Temp (°C)	Silo Database Mean Pan Evaporation (mm)	Silo Database Mean Morton's Lake Evaporation (mm)	Silo Rainfall / Pan Evaporation
January	73	69	16	31	228	194	0.30
February	60	63	16	30	179	156	0.35
March	55	57	13	27	156	136	0.36
April	41	41	9	23	104	90	0.40
May	44	43	5	19	66	56	0.65
June	45	47	3	15	44	38	1.06
July	48	50	2	15	50	44	1.01
August	46	46	3	16	72	69	0.64
September	42	46	5	20	104	102	0.44
October	55	55	8	23	150	142	0.37
November	58	65	12	27	184	168	0.35
December	67	68	14	30	227	193	0.30
Annual	642	650	NA	NA	1562	1387	NA

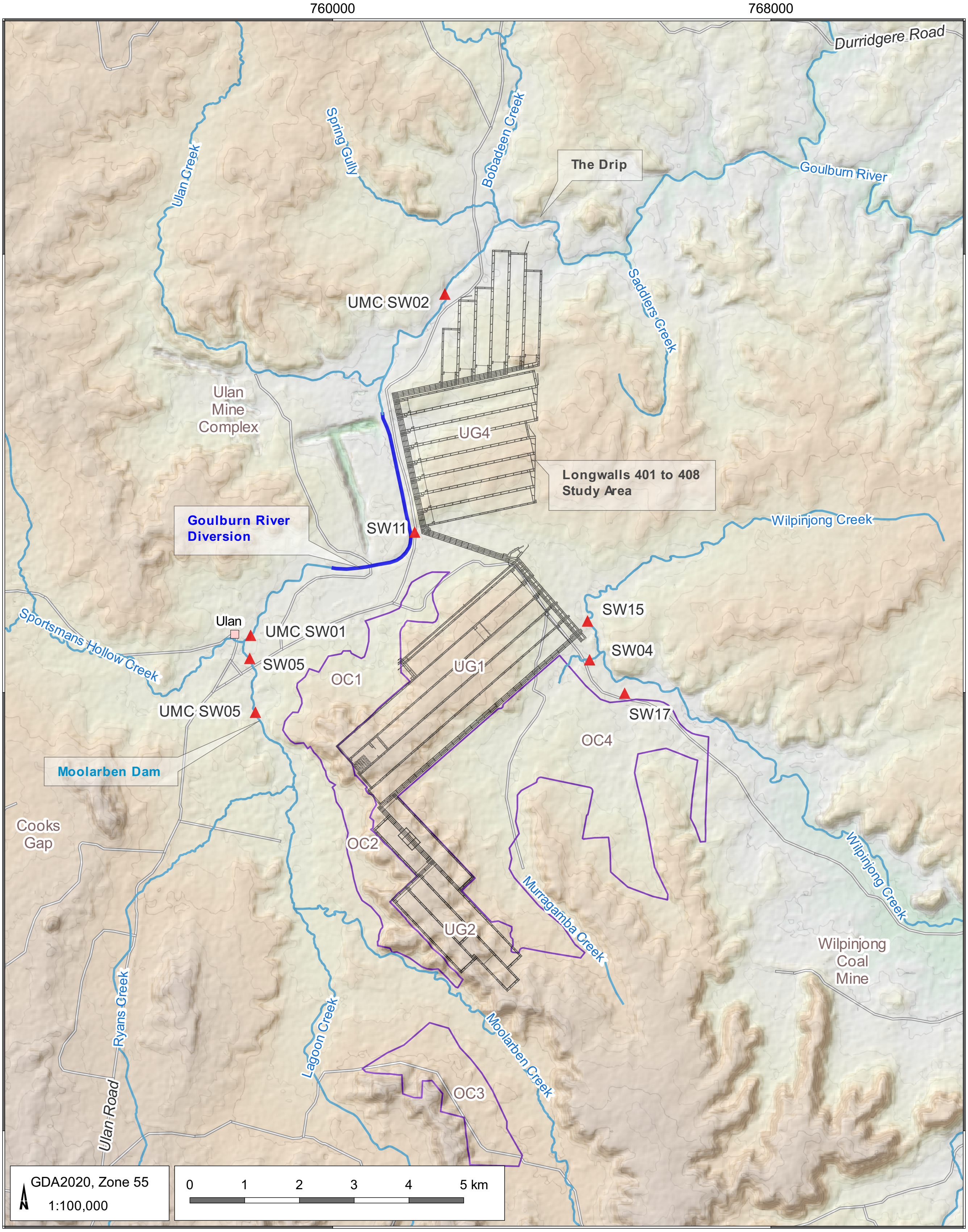
Notes: Data from Ulan Water (Station ID 62036) analysed between March 1906 to July 2022.
Ulan Water (Station 62036) has recorded 46 months of 'null' (or invalid) data during its operation, including 17 null annual totals.
Silo point data obtained for Latitude & Longitude (-32.3, 149.75) and analysed between January 1900 to July 2022.
Months with greatest likelihood of groundwater recharge are shown in blue text.

4.2 Topography and Drainage

Figure 4.1 shows the surface topography and significant drainage features at the MCC and surrounding area. The land surface within the MCC is located within the upper headwaters of the Goulburn River and Wilpinjong Creek catchments, and consists of sandstone plateaus, scree slopes and broad valley floors.

Elevations in the vicinity of the Moolarben Coal Complex range between around 400 metres Australian Height Datum (mAHD) at the Goulburn River in the northeast, to around 750 mAHD to the south of the MCC. Ridges of higher topography are capped by Triassic sandstone, and the broader river valleys of the Goulburn River are eroded into the Permian Coal Measures (Hydrosimulations, 2017).

The surface elevations directly above the proposed longwalls in the Extraction Plan Layout vary from a high point of 500 m above the Australian Height Datum (mAHD) above the commencing (eastern) end of LW404, to a low point of 405 mAHD above the finishing end of LW407.



LEGEND

- Populated place
- Flow gauging stations
- Drainage
- Road
- UG Mine Plan
- Approved OC Extent

Elevation (mAHD)

- 300
- 400
- 500
- 600
- 700

Groundwater Assessment for Moolarben UG4 Compliance Conditions (MOO5001.001)

Topography and Drainage

AGE

DATE 15/08/2023

FIGURE No: **4.1**

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
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4.2.1 Regional drainage

The Moolarben Coal Complex is within the upper Goulburn River catchment. The upper Goulburn River has a catchment area of approximately 2,500 square kilometres (km^2). The catchments for these river systems are separated by the Great Dividing Range, with the Goulburn River system draining east into the Hunter River catchment, and the Talbragar River system draining west to the Macquarie River catchment and eventually into the Murray River. The Goulburn River flows in an easterly direction, eventually joining the Hunter River approximately 150 km downstream of the Moolarben Coal Complex.

4.2.2 Local drainage

The local drainage network in the vicinity of the UG4 is shown in Figure 4.1.

The Goulburn River is the main watercourse in the vicinity of UG4. The Goulburn River has been heavily modified, initially by the construction of Moolarben Dam in 1957 (directly upstream of flow gauging station UMC SW05) by Ulan Power Station, and subsequently by a diversion of the river around the mining surface facilities and historical open cut mining at the UMC (i.e. adjacent the current UMC East Pit and flow gauging station SW11 shown on Figure 4.1). Plate 4.1 shows the Goulburn River Diversion west of LW401.

The Goulburn River Diversion was approved as part of previous Ulan Coal Mine Limited (UCML) operations and was completed in 1982. It diverts a 3.6 km length of the Goulburn River around the UMC East Pit, to a location approximately 700 m east of the river's original flowpath (Ecological Australia, 2018).

The Goulburn River Diversion has been characterised by Advisian (2017) as follows:

- significantly altered flow regime due to the construction of Moolarben Dam and UCM/MCC discharges;
- has a channel bed formed in natural sandstone bedrock with a rocky base covered with a layer of sediment;
- is generally a uniform, well vegetated channel with trapezoidal channel dimensions, river bank heights varying from 4 m to 20 m, and channel bed widths varying from 30 m to 40 m; and
- has aquatic ecology diversity reflective of a disturbed environment that does not provide habitat for threatened aquatic ecology species.

Further downstream of the diversion, the Goulburn River becomes a broad, well vegetated channel formed in natural surface soils and has a coarse sandy base. The channel contains various sand bars, elongated permanent pools and rocky outcrops (Advisian, 2017; Plate 4.2).

Moolarben Dam has a catchment area of approximately 110 km^2 and is located in the upper reaches of the Goulburn River, near the Ulan Mine Complex and Moolarben Coal Complex. It has been postulated that the dam has a considerable volume of seepage through the dam wall (estimated at 129 ML during 2017). Moolarben Creek is a primary tributary of the upper Goulburn River catchment and flows in a northerly direction to join the Goulburn River.

Tributary creeks are generally ephemeral, and flow in response to significant rainfall runoff events and for a limited duration afterwards. The Goulburn River in the vicinity of the MCC is essentially perennial, although some anecdotal evidence suggests it had ceased to flow historically through prolonged periods of drought. Approved UMC and MCC mine discharges ensure that flows in the Goulburn River are now persistent, with MCC discharges occurring to the diversion upstream of UG4 which commenced during 2020.

The western headwaters of the Wilpinjong Creek overlie a significant palaeochannel that may represent an ancient course of the Goulburn River. The palaeochannel is infilled with at least 5 m of alluvium which is generally fine-grained, comprising sands, silts and clays (Dundon and Associates, 2006).

Plate 4.1 Goulburn River Diversion West of LW401 (Advisian, 2017)

Plate 4.2 Goulburn River (Natural) Downstream of UG4 (Advisian, 2017)

4.2.3 Discharge and electrical conductivity

Surface water flow gauging and water quality measurements are conducted at a number of sites near the Moolarben Coal Complex. Details of gauging stations are provided in Table 4.2 and shown on Figure 4.1.

Surface flow measurements are discussed in detail in Section 6, within the baseflow separation analysis.

Table 4.2 Surface Water Gauging Stations (Current and Historic)

Station	Description	Easting	Northing
SW04	Murragamba Creek.	764690	6424595
SW05	Moolarben Creek on Ulan Road. Washed away in flooding in 2010.	758483	6424620
SW11*	Bora Creek on Ulan Road.	761496	6426927
SW15	Wilpinjong Creek at Red Hill.	764653	6425304
SW17	Eastern Creek.	765331	6423985
UMC SW01	Goulburn River, located adjacent Spring Street at Ulan, just downstream of the confluence of Moolarben Creek and Sportsmans Hollow Creek. Ulan operated site, data provided through a data sharing agreement.	758500	6425042
UMC SW02	Goulburn River downstream of the diversion. Located just off Ulan Road. Ulan operated site, data provided through a data sharing agreement.	762047	6431273
UMC SW05	Moolarben Creek at the Moolarben Dam, adjacent Lagoons Road. Ulan operated site, data provided through a data sharing agreement.	758587	6423638

Note: DSW11 is a historic site and is no longer monitored.

With respect to surface water quality, WRM (2022) reported a summary of water sampling results, based on an analysis of data recorded between 2005 to 2021. They reported the following results for the Goulburn River:

- pH readings ranged between 6.6 and 8.1 (20^{th} and 80^{th} percentiles), with median values of between 7.2 and 7.6;
- Electrical Conductivity (EC) readings ranged between 373 and 835 microSiemens per centimetre (µS/cm) (or approximately 205 and 460 mg/L) (20^{th} and 80^{th} percentiles), with median values of between 530 µS/cm and 759 µS/cm (or approximately 290 and 420 mg/L); and
- Turbidity readings ranged between 0.1 and 28.5 Nephelometric Turbidity Units (NTU) (20^{th} and 80^{th} percentiles), with median values of the gauging stations between 0.5 NTU and 15.6 NTU.

5 Geological Setting

The Moolarben Coal Complex is located in the Western Coalfields on the north-western edge of the Sydney-Gunnedah Basin, which contains sedimentary rocks of Triassic and Permian age, including coal measures. The regional stratigraphic sequence comprises Jurassic aged Pilliga sandstone and Purlewaugh siltstone, the Triassic Narrabeen Group and Permian Illawarra Coal Measures (Table 5.1 and Figure 5.1).

Each of the key geological units are discussed further below.

Table 5.1 Summary of Regional Stratigraphy

Age	Unit	Description
Quaternary	Unnamed	Alluvium/colluvium – comprising soil, silt, clay, sand and gravel
Tertiary	Unnamed Liverpool Range Volcanics	Alluvium (palaeochannels) Weathered basalts
Jurassic	Pilliga sandstone Purlewaugh Siltstone	Coarse grained quartzose sandstone, lithic sandstone, conglomerates, claystone and shale
Triassic	Wollar Sandstone (Narrabeen Group equivalent)	Quartzose and lithic sandstone, conglomerates and claystone
Permian	Illawarra Coal Measures	Interbedded claystones, siltstones, sandstones (fine to coarse grained), conglomerate and coal seams. Includes the mined Ulan Seam near the base of the unit
Permian	Marrangaroo Conglomerate	Conglomerate and sandstone
Permian	Shoalhaven Group	Fine-grained silty marine sandstone
Carboniferous	Gulgong Granite / Ulan Granite	Basement. Carboniferous monazite and granites

5.1 Local Geology

Figure 5.1 shows the regional surface geology surrounding the MCC. The main economic coal seams in the Western Coalfields are within the Permian Illawarra Coal Measures (ICM). The ICM include the Ulan Seam which is the target seam at the Moolarben Coal Complex.

5.1.1 Quaternary alluvium and Tertiary sediments

Along the valley floors associated with topographic lows, the coal measures have (in places) been eroded and overlain by Tertiary aged palaeochannel deposits, dominantly comprised of alluvium. Palaeochannel deposits were intersected during the Stage 1 pit development. In places, these palaeochannel deposits have been eroded and superimposed by more recent weathering and Quaternary sedimentation associated with the current drainages of the Goulburn River and Moolarben Creek.

The Quaternary alluvium occurs in association with, and is connected to, the present day streams and rivers, whereas the Tertiary alluvium occurs in a palaeochannel system that is not coincident with the present drainages.

Limited alluvial material is present in the Goulburn River Diversion, which was constructed in Permian bedrock and is now overlain by a layer of sediment. Alluvial sediments are more predominant downstream, where the Goulburn River has a coarse sandy base and developed sand bars are evident (Section 4.2.2). Notwithstanding, the presence of rocky outcrops in the Goulburn River channel indicates an expansive, highly productive alluvial aquifer is not present downstream of UG4.

Drilling data suggests that the maximum thickness of the Tertiary palaeochannel sediments which occurs between UG4 and UG1, is approximately 60 metres.

Johnstone (2007) reported that the palaeochannel sediments comprise poorly-sorted quartzose sands and gravels, semi-consolidated in a clayey matrix. Investigations suggest that the palaeochannel may be part of a larger system that originally emanated from the north or west. Exposures of the channel in the Goulburn River Diversion reveal cross bedding, suggestive of a southerly flow direction (Johnstone, 2007).

Small intrusives and remnant basalt flows of Tertiary, and possibly Jurassic age, have been observed in outcrop in the Murragamba and Wilpinjong valleys and as elevated plateaus mainly to the north of the Moolarben Coal Complex. Basalt flows of up to 30 m have been intersected in some bores. No significant basalt remnants or other igneous intrusives are understood to be present within LW401-408.

Two hydrogeological sections have been generated with the location of the cross sections shown on Figure 5.1. These are presented in Section 6.14 and highlight the total thickness of the key stratigraphic units, monitored saturated thicknesses, vertical hydraulic gradients, and inferred disconnection of the Goulburn River Diversion to the regional watertable.

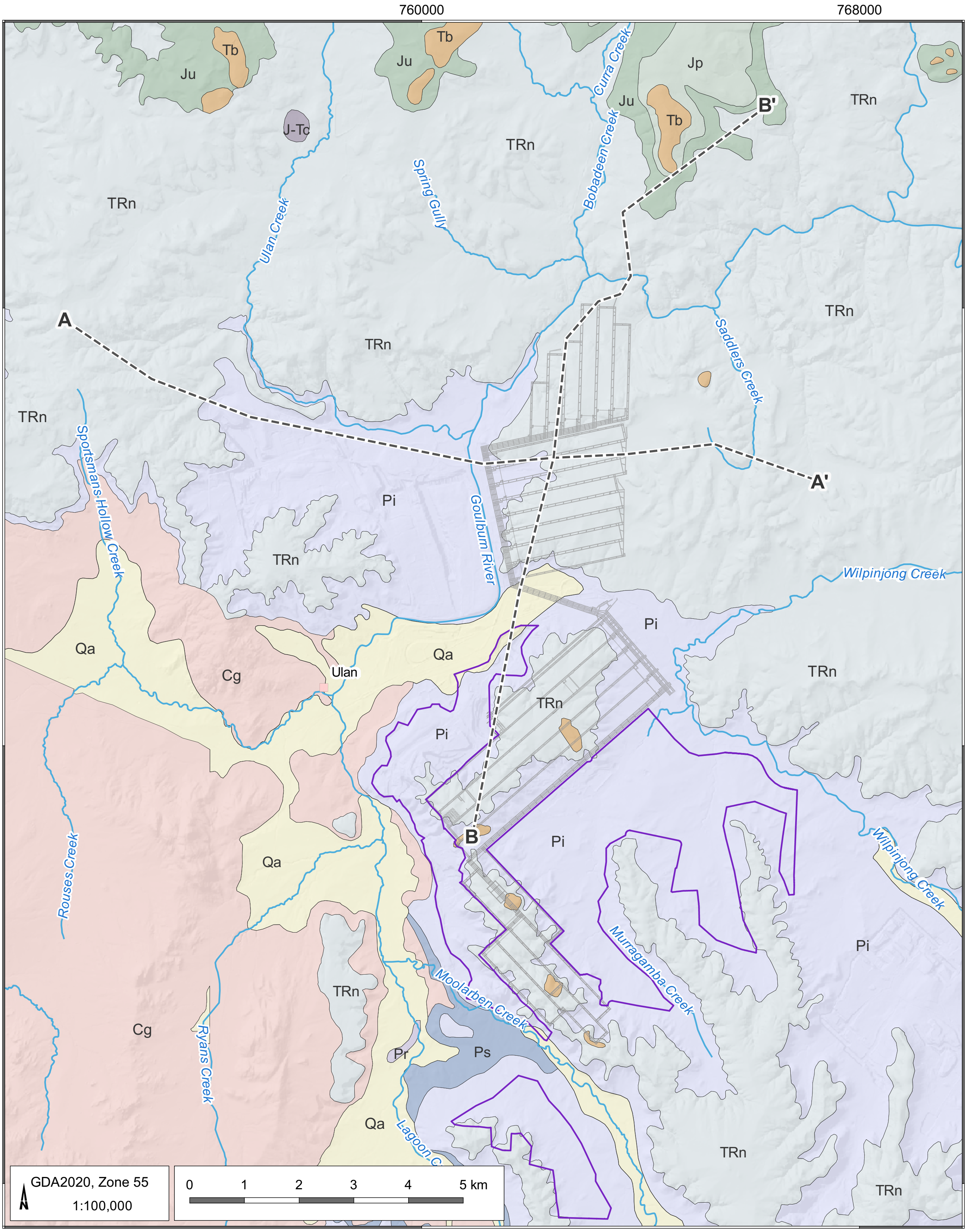
5.1.2 Triassic Wollar Sandstone (Narrabeen Group)

The Wollar Sandstone (which is a Narrabeen Group equivalent) is locally referred to as the 'Triassic Sandstone'. The typical lithology of the Wollar Sandstone includes pebbly to medium grained quartz sandstone, red-brown and green mudstone, and lenses of quartz conglomerate (Wilpinjong Coal, 2005). The contact between the Permian and Triassic is marked by an erosional unconformity.

The Wollar Sandstone comprises two depositional units, a shallower quartzose unit and the deeper lithic unit. The quartzose unit comprises a thick sequence (regionally up to approximately 90 m) of cream to yellow, cross-bedded porous sandstone, conglomerates and claystone. The lithic unit is thinner (regionally up to approximately 35 m) and is generally comprised of a light grey/green, poorly sorted sandstone.

The Wollar Sandstone is largely a stratified/bedded unit with variable hydraulic properties. As documented for the Narrabeen Group, the coarser grained sandstone units can form aquifers, while the claystone units can form aquitards (Australian Government, 2016).

The prominent bedding of the Triassic Sandstone is clearly visible just north of the Moolarben Coal Complex at 'The Drip', a locally significant site of cultural and indigenous value. At the Drip, rainfall propagates down through the sandstone and due to the extreme contrast in horizontal to vertical hydraulic conductivity, flows through and along the more permeable horizons. Some of the Triassic beds include large pebble conglomerates, congruent to beds consisting of much finer grained sandstone / siltstone, and as such, groundwater discharges to the surface at the iconic feature along a dripping cliff face.



LEGEND

- Populated place
- UG Mine Plan
- Drainage
- Hydrogeological Cross Section
- Approved OC Extent

Western Coalfield (north) Regional Geology (1:100k)

- Qa - Quaternary alluvium
- Tb - Tertiary basalts
- J-Tc - Jura-Tertiary volcanics
- Jp - Pilliga Sandstone
- Ju - Purlawaugh Formation
- TRn - Triassic Narrabeen Group
- Pi - Illawarra Coal Measures
- Ps - Shoalhaven Group
- Pr - Rylstone Volcanics
- Cg - Carboniferous granite

Hydrogeological Cross Sections

Section A-A' (refer to Figure 6.31)
Section B-B' (refer to Figure 6.32)

Groundwater Assessment for Moolarben UG4 Compliance Conditions (MOO5001.001)

Regional Mapped Surface Geology

AGE

DATE 08/08/2023

FIGURE No: **5.1**

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
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5.1.3 Illawarra Coal Measures

The Permian Illawarra Coal Measures comprise a well-bedded sequence of claystone, mudstone, siltstone, sandstones (fine to coarse grained) and coal seams. These sedimentary units unconformably on-lap the early Permian Shoalhaven Group or Carboniferous basement. The Permian aged Illawarra Coal Measures are present across the majority of the Moolarben Coal Complex and are generally up to around 90 m thick (from the base of the Triassic, to the base of the Ulan Seam). The total thickness diminishes from the topographic highs towards the low elevations of the valley floor, where the coal measures may have been eroded (and subsequently infilled) completely.

The coal measures conformably underlie the Triassic Wollar Sandstone and the most pervasive coal seams include the Middle River, Goulburn, Turill, Moolarben, Glen Davis, Irondale and Ulan Seams. The Ulan Seam is the main economic seam at MCC and is mined at an extraction height of 3.0 m at UG4.

A stratigraphic column showing increased detail for the coal resources (individual seams and ply nomenclature) is provided as Figure 5.2.

Groundwater storage and movement occurs within the coal seam cleats and fissures. Other sediments in the coal overburden and interburden sequence are relatively impermeable and form aquitards. Some Permian sandstones yield minor groundwater, although in the mined section of the coal measures, these are rare.

5.1.4 Marrangaroo Conglomerate

Underlying the Ulan Seam is the Marrangaroo Conglomerate, which comprises weakly cemented conglomerates and medium to coarse grained sandstones. A limited number of piezometers have been installed into the Marrangaroo Conglomerate. PZ 102A which exists adjacent LW408, has been screened within the conglomerate, and is currently included within the Groundwater Management Plan (GWMP) monitoring network. Other reports have suggested that an intermediate conglomerate exists (Blackmans Flat Conglomerate) between the two units, however a paucity of data (due to the number of piezometers completed to these depths) means that it is difficult to differentiate or substantiate this differentiation.

The Marrangaroo Conglomerate is known to be a relatively permeable, weakly cemented, massive rock.

5.1.5 Shoalhaven Group

Underlying the Marrangaroo Conglomerate lie the Marine sediments of the Shoalhaven Group. The Shoalhaven Group has been reported to consist of fine-grained silty sandstones. No known piezometers have been completed or classified as being completed within the Shoalhaven Group at the MCC although some prior reporting appears to have attributed bores which have been completed within the Marrangaroo Conglomerate, as belonging to the Shoalhaven Group.

5.1.6 Basement

On the western margin of the MCC, the Carboniferous 'Ulan Granite' basement outcrops.

The basement underlying the Shoalhaven Group in EL6288 consists of Carboniferous monzonite and granite. Plutonic intrusions outcrop extensively to the west of the Moolarben Coal Complex. Within EL6288, the contact between the quartz monzonite and the overlying Permian is obscured beneath recent alluvium along the Moolarben Creek. Basement rocks are understood to be clearly visible in outcrop around the Moolarben dam wall located on Moolarben Creek.

Apart from some shallow weathering of the basement rocks, the basement is understood to be relatively impermeable, and constitute a basal aquitard.

5.1.7 Geological structure and faulting

Permian and Triassic strata generally dip to the north north-east at an angle of 1 to 2 degrees. The strata show very little folding, and no major faults have been identified through detailed exploration. Mine Advice (2023) conducted the most recent geological structure analysis for the UG4 Longwall Mining Domain. The stated purpose of the Mine Advice (2023) analysis was to further inform and provide direct input into future groundwater modelling and monitoring assessments that may be undertaken prior to the extraction of Longwall's (LW's) 404 to 414, and to satisfy the following **Condition 3f** of the LW401-LW408 Extraction Plan.

Mine Advice (2023) made the following conclusions from their analysis:

- It is our assessment that the inferred natural defects in the geology in the UG4 Longwall Mining Domain ***are directly comparable with those in existing areas of UG1 and adjacent areas of the Ulan Mining Complex and are therefore unlikely to significantly enhance groundwater migration and flow*** beyond that predicted by existing height of fracturing models.
- There is no obvious reason to conduct additional groundwater monitoring or modelling beyond what is currently planned.

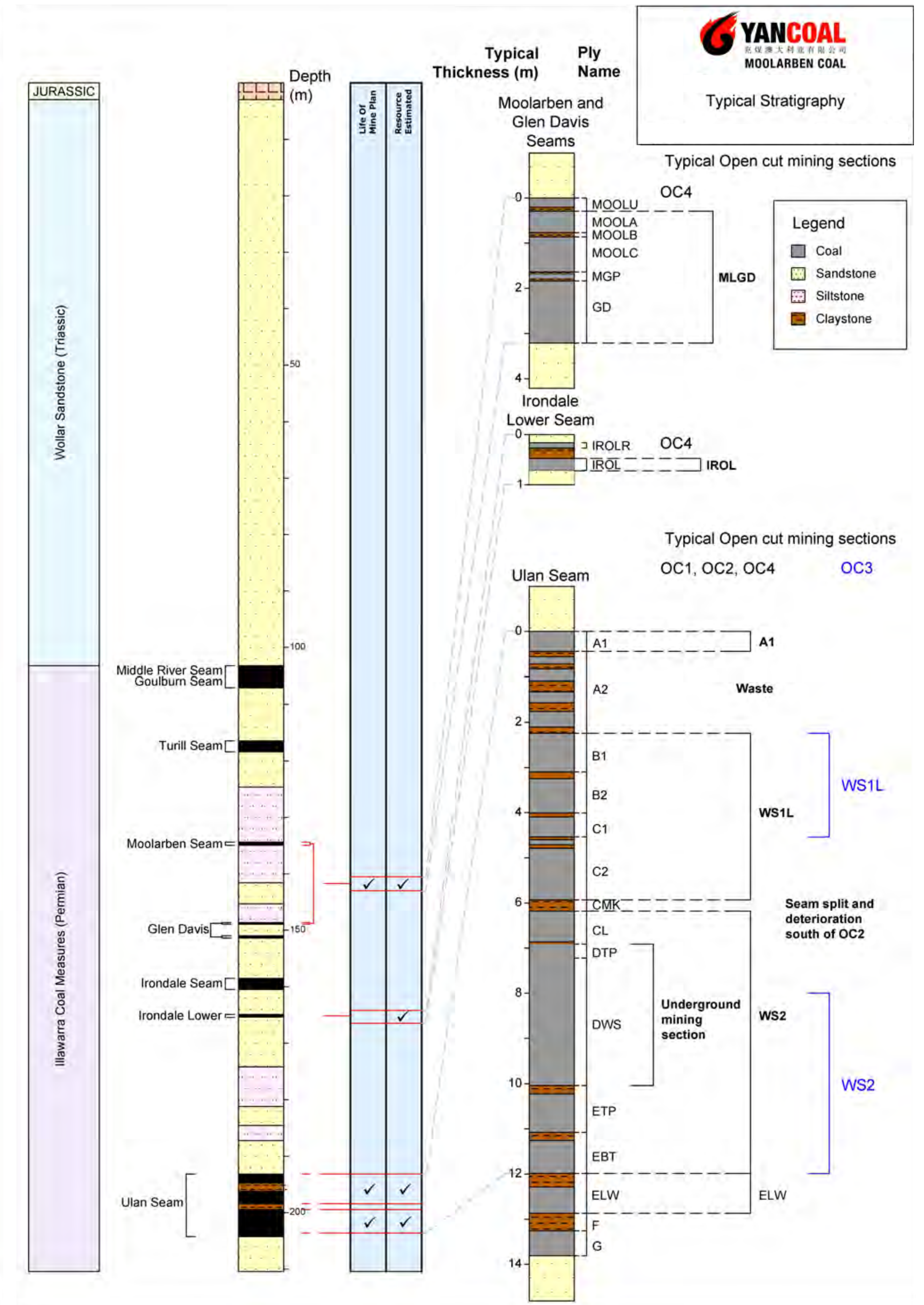
Further to the high-level findings of Mine Advice (2023), other salient findings relating to the decision to incorporate faults within the current AGE numerical groundwater model include:

- Many of the tuff/claystone beds or bands within the immediate roof, including the C-Marker (CMK), appear to act as aquitards or aquicludes, often isolating water bearing/saturated plies or intervals within the upper Ulan Seam from the development working section.
- Cable bolt and strata monitoring holes, which extend through the CMK, would allow groundwater inflows (in some cases up to 5-10 litres per minute from a 10 m-long section of roadway) into what was otherwise a relatively dry working section. The observed groundwater inflows would typically reduce and eventually stop altogether over a period of 1-6 weeks.
- It is noted that faults encountered within the defined Delamination (or Deformation) Zones have typically been laterally discontinuous.
- It is improbable that the Spring Gully Fault will intersect either the UG4 workings, or the predicted subsidence footprint associated with any of the proposed longwall panels.
- While both the Spring Gully and Curra-Greenhills Fault Zones are regionally significant, neither intersect the proposed UG4 mine workings nor the predicted subsidence footprint associated with Longwalls 401 to 414.
- Only one major geological structure is currently inferred to intersect the UG4 workings (Figure 5.3), namely an NE:SW to ENE:WSW orientated (striking) thrust fault dipping to the SE to SSE with a 0-6 m vertical throw bisecting LW's 405-408 and the North Mains between 28 and 30 C/T.
- Given that the contact and adjacent strata conditions associated with the inferred fault are unknown at the current time, a review of other faults intersected within adjacent areas of the UG1 and UG4 workings has been undertaken. Most of the mapped faults are not laterally persistent across the full width of the UG4 Highway panel (Figure 5.3). In the absence of outcrop mapping at surface, nor exposure in surface to seam boreholes within the area, no direct comment can be made regarding their vertical persistence.
- Groundwater inflows from the structures were observed to be variable but were typically in the range of 0-5 litres per minute (from a 10 m-long section of roadway) and abated (and/or stopped completely) within 1-6 weeks of exposure.
- Existing thrust fault exposures within adjacent areas of the UG1 and UG4 workings suggests that faults encountered at Moolarben to-date are not typically dilated (open), are not associated with significant brecciation (strata fracturing) nor infilling (gouge), and do not commonly act as conduits for excessive and ongoing groundwater inflows from higher in the overburden. ***The latter infers that they either have (a) short vertical (upward) persistence, (b) limited dilation under in situ stress conditions, or (c) are self-sealing due to the presence of clay-rich gouge/infill material within the fault contact***.

Based on the analysis completed by Mine Advice (2023), there is no clear reason to incorporate either the single mapped fault which traverses LW405-408 within the current groundwater model, or the minor faults which traverse the UG4 highway, which connects UG4 to UG1. This is due to the following reasons:

- The single mapped fault which spans LW405-408 is thought to have very limited vertical extent, with no mapped offset within longwall panels LW405 or LW408.
- Observations from mining through the minor faults which traverse the UG4 highway had limited significance on total water make, and subsided over a relatively short period of time, as these storages were depleted.
- The lateral extent of the mapped fault which spans LW405-408 is contained within the footprint of UG4, and therefore does not form an impact pathway beyond the approved mine extent.
- The expected height of fracturing from mining LW405-408 will induce a change to the vertical hydraulic conductivity above panels LW405-408 which will enable groundwater drainage to a much greater capacity than the drainage which might occur from mining these features discretely with no vertical enhancement. This is supported by the observations made from the construction of the UG4 Highway.
- The mapped (and modelled) extent of the Triassic sandstone does not fully cover LW406-LW407 where the only mapped offsets occur.
- Inclusion of these discrete features in the numerical model will not affect the total (cumulative) volume of groundwater which is removed from the mining and goafing processes.

Further to the above, the Spring Gully fault to the west of UG4 has already effectively been mined through during the mining of UMC East Pit.



MCC Stratigraphic Column

Figure 5.2

LEGEND

Drainage
UG Mine plan
Modelled Triassic Extent
Mapped Fault (Vertical Offset m)

Groundwater Assessment for Moolarben UG4 Compliance Conditions (MOO5001.001)

Mapped Faults

AGE

DATE 08/08/2023

FIGURE No: **5.3**

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
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6 Hydrogeology

Regional groundwater investigations were carried out for the Moolarben Coal Stage 1 and Stage 2 Projects (and subsequent modifications) and OC3 Extension Project. These investigations included:

- **Moolarben Coal Project – Groundwater Assessment** (Dundon and Associates, 2006);
- **Moolarben Stage 2 – Groundwater Assessment** (Aquaterra, 2008);
- **Moolarben Complex Stage 2 – Preferred Project Report – Groundwater Impact Assessment** (RPS Aquaterra, 2011);
- **Moolarben Coal Project Stage 1 Optimisation Modification – Groundwater Impact Assessment** (AGE, 2013);
- **Moolarben Coal Complex UG1 Optimisation Modification – Groundwater Assessment** (Dundon Consulting, 2015);
- **Moolarben Coal Open Cut Optimisation Modification – Groundwater Impact Assessment** (HydroSimulations, 2017);
- **Moolarben Coal Complex OC3 Extension Project – Groundwater Impact Assessment** (AGE, 2022a); and
- **Technical Memorandum for Moolarben Coal Complex UG2 Modification** (AGE, 2022b).

Various groundwater studies have also been completed for the Ulan Mine Complex and Wilpinjong Coal Mine.

Since 2007, contemporary knowledge of the groundwater system has improved significantly, through further exploration drilling, geophysical surveying to map subsurface features, the construction of new groundwater monitoring infrastructure, ongoing monitoring, additional hydraulic testing, the analysis of groundwater trends in response to mining, and additional numerical groundwater modelling studies. Cumulatively, the completion of these studies has advanced the knowledge base of the groundwater system significantly and has informed various monitoring and management measures.

This section of the report presents a contemporary understanding of the hydrogeological system, and its behaviour in response to hydraulic stresses.

6.1 Hydrostratigraphic Units

The Moolarben Coal Complex is located in the Western Coalfields on the north-western edge of the Sydney-Gunnedah Basin, which contains sedimentary rocks of Triassic and Permian age, including coal measures. The main hydrogeological units within and surrounding the Moolarben Coal Complex include:

- **Quaternary alluvium** associated with the present day drainage system;
- **Tertiary alluvium** associated with the identified palaeochannel that is not related to the present day drainage system;
- **Narrabeen Group** - Triassic sandstone consisting of quartzose Triassic and lithic Triassic sandstone;
- **Illawarra Coal Measures** - Permian coal measures, which includes the Ulan Seam near the base of the unit;
- **Marrangaroo Conglomerate** – Permian aged conglomerate; and
- **Basement** - Units that include Carboniferous volcanics and the Gulgong or Ulan Granite.

Quaternary Alluvium

Quaternary alluvial deposits in the vicinity of the Moolarben Coal Complex are found within the Goulburn River, Moolarben Creek, Lagoon Creek and Wilpinjong Creek. The alluvium comprises fine to coarse grained sands and gravels within a silt/clay matrix.

Limited alluvial material is present in the Goulburn River Diversion, which was constructed in Permian bedrock and is now overlain by a layer of sediment. Alluvial sediments are more predominant upstream, in the natural river channel. The extent and thickness of the Quaternary Alluvium is shown on Figure 5.1 and hydrogeological cross section (B-B’) presented in Section 6.14 respectively.

Tertiary sediments

Tertiary sediments associated with the defined palaeochannel are remnants of inactive river or stream channels that have been filled in, or buried by younger sediment. The infill sediments consist of poorly-sorted semi-consolidated quartzose sands and gravels in a clayey matrix. The sediments are unsaturated across a large proportion of the Moolarben Coal Complex, while between UG4 and UG1, they host the regional watertable in some areas. This is shown on hydrogeological cross section (B-B') presented in Section 6.14.

Triassic Narrabeen Group

The Triassic aged sandstones overly the Permian coal measures. Large extents of the Triassic strata are naturally unsaturated (especially the higher and more permeable upper Triassic quartzose). For example, data from monitoring point PZ 127 VWP 43m located above UG1 suggests that the Triassic sandstone above UG1 was unsaturated prior to underground mining. The same applies to the north of LW412 (UG4 north), where data from PZ 128 VWP 20m show the sensor has been unsaturated for the entire monitoring record. The Triassic aged sandstones provide some water supply potential, however the sandstone is generally low yielding. RPS Aquaterra (2011) reported a median hydraulic conductivity for the Triassic sandstone of 0.3 m/d based on six hydraulic tests results, which suggests the sandstone has a relatively low permeability. The Triassic sandstone supports a small number of stock and domestic bores on private properties to the north of the Moolarben Coal Complex. Groundwater perching within the Triassic sandstones also supports the local and culturally sensitive water feature on the Goulburn River known as The Drip, which is located on the northern side of the Goulburn River. The Goulburn River effectively forms a 'general head' boundary to the north of UG4 LW412-LW414, in the Triassic lithic sandstone and shallow alluvial sediments which host the Goulburn River. Data from piezometers monitoring the deeper Permian ICM suggests these units are not as strongly influenced by the Goulburn River.

Perching of low salinity groundwater above the Permian Illawarra Coal Measures seems to be relatively common in the region, which is not unexpected given the significant contrast in hydraulic conductivity of the units. A number of smaller spring / seeps to the west and south of the OC3 extension project were identified, where low salinity groundwater discharges to the surface at a break in slope at the interface between the Triassic sandstone, and the low permeability Permian Illawarra Coal Measures. These sites are located over 13 km from UG4 but suggest a similar groundwater flow mechanism.

Illawarra Coal Measures

The Permian aged Illawarra Coal Measures are present across the Moolarben Coal Complex. The coal measures conformably underlie the Triassic Narrabeen Group and comprise interbedded claystones, siltstones, sandstones (fine to coarse grained) and coal seams, including the Ulan Seam.

Groundwater storage and movement occurs within the coal seam cleats and fissures, and to a lesser degree within fractures associated with faults intersecting the seams. Other sediments in the coal overburden and interburden sequence are relatively impermeable and tend to behave as aquitards. Some Permian sandstones yield minor groundwater, although in the mined section of the coal measures, these are rare.

The Permian strata can be categorised into the following hydrogeological sub units:

- very low permeability and very low yielding (to essentially dry) sandstone and siltstone, that comprises the majority of the Permian interburden / overburden; and
- low to moderately permeable coal seams, which are the principal water bearing strata within the Illawarra coal measures.

The Permian coal measures are hydraulically confined to semi-confined within the region. At UG1, the coal measures are depressurised locally due to mining activities, although there is some evidence which suggests even above UG1, some positive groundwater pressures are now being recorded in the shallow Permian sediments. Data from PZ 130 VWP 38.5m has recorded positive groundwater pressures since mid 2022, likely in response to the above average rainfall conditions recorded at the MCC.

Marrangaroo Conglomerate and Shoalhaven Group

The Ulan Seam is underlain by the Marrangaroo Conglomerate, which is a conglomerate or sandstone in this area. Regionally the Marrangaroo Conglomerate is known to be moderately permeable and be considered as an aquifer in some local areas due to some bores being able to maintain a reliable source of water. At the Moolarben Coal Complex, the thickness and extent of this unit is largely unknown due to a paucity of data, and limited number of piezometers completed within the unit.

Hydrogeological data from six piezometers at the Moolarben Coal Complex that have been completed in the conglomerate suggest that the unit has a relatively low permeability, with very limited water supply potential.

Beneath the Marangaroo Formation lies the Shoalhaven Group which comprises fine-grained silty marine sandstone. Marine sediments of the Shoalhaven Group (fine-grained silty sandstones), have reportedly been intersected in some drill holes in the southern part of the Moolarben Coal Complex, however limited data is available on this unit.

Basement

The basement underlying the Shoalhaven Group consists of Carboniferous monazite and granite. These basement rocks are clearly visible in outcrop around the weir located on Moolarben Dam. The Carboniferous aged Granite (Cg) shown on Figure 5.1 is the most significant basement unit in the Moolarben area with extensive outcropping occurring at greater than 3 km to the southwest of LW401-408. The Nile Sub-Group was shown to be quite impermeable, and of almost no influence on the flow processes at Wilpinjong Coal Mine (Wilpinjong Coal, 2005).

6.2 Groundwater Monitoring Network

MCO operates in accordance with an approved Water Management Plan (including a Groundwater Management Plan), which has been prepared to address the current statutory obligations contained in the conditions of the NSW Project Approval (05_0117) (as modified) and NSW Project Approval (08_0135) (as modified).

Groundwater Levels

The current groundwater monitoring program for the measurement of groundwater levels is detailed in Table 6.1 and presented geographically as Figure 6.1. The Groundwater Monitoring Program piezometers listed in Table 6.1 are monitored manually on a monthly basis, or continuously by means of automatic dataloggers (MCO, 2020a).

In addition to the groundwater monitoring program, MCO has established additional piezometers (both conventional and vibrating wire piezometers) for other operational and project purposes. While this section of the report focusses on the groundwater monitoring program, all available groundwater data from MCO has been provided and incorporated into the revised conceptual hydrogeological model which underpins both the updated groundwater model and this technical report.

Groundwater Quality

Groundwater quality is also monitored from the Groundwater Monitoring Program standpipe bores listed in Table 6.2. Samples are collected six-monthly and sent for laboratory analysis. Field measurements of EC and pH are also recorded at the time of water quality sampling.

Investigation Trigger Levels

Trigger values are designed as conservative indicators that identify the potential of a performance exceedance. The trigger level values allow for a timely response to the potential of a performance exceedance before an actual performance exceedance occurs.

MCO has established investigation trigger values to determine the need for investigation and possible response actions for potential impacts to groundwater levels and quality in the Alluvial and Triassic strata.

The Permian strata extensively affected by past mining is predicted to undergo further depressurisation from ongoing mining at the Moolarben Coal Complex, the Ulan Mine Complex and the Wilpinjong Coal Mine, and contains groundwater of generally poor quality. Accordingly, trigger levels have not been set for the majority of monitoring piezometers screened in the Permian and Ulan Seams.

The alluvial Water Sharing Plan (WSP) that regulates the alluvial water sources does not designate beneficial uses for the alluvial aquifers in the vicinity of the Moolarben Coal Complex.

Table 6.1 GWMP Monitoring Network (Ordered by Piezometer Number)

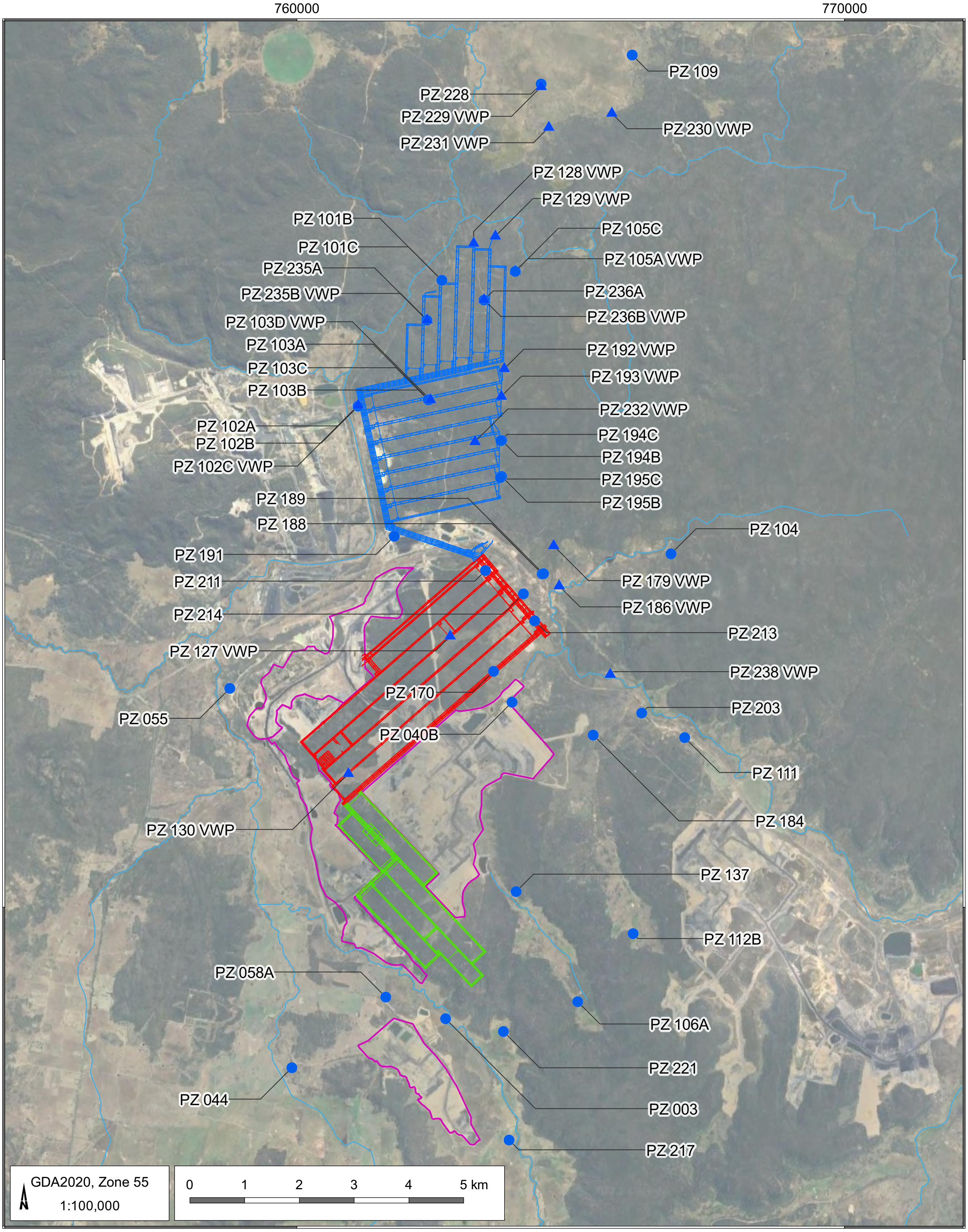
Bore	Type	RL (mAHD)	Depth (m)	Screened interval (m)	Unit screened	Water Level Monitoring Frequency	Water Quality Monitoring Frequency
PZ 003	Stand Pipe Piezometer	474.92	21	9 – 15	Ulan Seam	Manual monthly	6-monthly
PZ 040B	Stand Pipe Piezometer	428.40	45	38 – 44	Permian OB	Manual monthly	6-monthly
PZ 044	Stand Pipe Piezometer	491.30	23	20 – 23	Ulan Granite	Manual monthly	6-monthly
PZ 055	Stand Pipe Piezometer	429.46	15	11 – 14	Marrangaroo Conglomerate	Manual monthly	6-monthly
PZ 058A	Stand Pipe Piezometer	478.39	12	8 – 11	Tertiary Sediment	Manual monthly	6-monthly
PZ 101B	Stand Pipe Piezometer	403.28	60	54 – 60	Permian OB	Manual monthly	6-monthly
PZ 101C	Stand Pipe Piezometer	403.00	30	24 – 30	Lower Triassic	Manual monthly	6-monthly
PZ 102A*	Stand Pipe Piezometer	408.54	125	116 – 125	Marrangaroo Conglomerate	Manual monthly	6-monthly
PZ 102B*	Stand Pipe Piezometer	408.23	86	80 – 86	Ulan Seam	Manual monthly	6-monthly
PZ 102C	Vibrating Wire Piezometer	408.65	69	28 64	Permian Permian	Datalogger Recorded monthly	NA
PZ 103A**	Stand Pipe Piezometer	425.21	128	118 – 127	Ulan Seam	Manual monthly	6-monthly
PZ 103B*	Stand Pipe Piezometer	425.00	87	81 – 87	Permian OB	Manual monthly	6-monthly
PZ 103C	Stand Pipe Piezometer	425.00	30	24 – 30	Lower Triassic	Manual monthly	6-monthly
PZ 103D	Vibrating Wire Piezometer	425.26	90.5	31 55 85	Permian Permian Permian	Datalogger Recorded monthly	NA
PZ 104	Stand Pipe Piezometer	438.93	160	151 – 160	Ulan Seam	Manual monthly	6-monthly
PZ 105A	Vibrating Wire Piezometer	388.93	133	28 80 118 130	Permian OB Permian OB Ulan Seam Ulan Seam	Datalogger Recorded monthly	N/A

Bore	Type	RL (mAHD)	Depth (m)	Screened interval (m)	Unit screened	Water Level Monitoring Frequency	Water Quality Monitoring Frequency
PZ 105C	Stand Pipe Piezometer	389.00	28	20 – 28	Lower Triassic	Manual monthly	6-monthly
PZ 106A	Stand Pipe Piezometer	510.69	131.5	125 – 131	Permian OB	Manual monthly	6-monthly
PZ 109	Stand Pipe Piezometer	437.12	254	246 – 252	Permian OB	Manual monthly	6-monthly
PZ 111	Stand Pipe Piezometer	404.78	83	71 – 77	Ulan Seam	Manual monthly	6-monthly
PZ 112B	Stand Pipe Piezometer	485.67	12	6 – 12	Permian OB	Manual monthly	6-monthly
PZ 127	Vibrating Wire Piezometer	494.55	152	43 68	Triassic Permian OB	Datalogger Recorded monthly	N/A
PZ 128	Vibrating Wire Piezometer	409.52	61	20 36 55	Triassic Permian OB Permian OB	Datalogger Recorded monthly	N/A
PZ 129	Vibrating Wire Piezometer	417.95	74	35 53 74	Triassic Permian OB Permian OB	Datalogger Recorded monthly	N/A
PZ 130	Vibrating Wire Piezometer	535.07	111	38.5 64	Permian OB Permian OB	Datalogger Recorded monthly	N/A
PZ 137	Stand Pipe Piezometer	479.01	23	20 – 23	Permian OB	Manual monthly	6-monthly
PZ 170*	Stand Pipe Piezometer	437.49	31	26 – 29	Permian OB	Manual monthly	6-monthly
PZ 179	Vibrating Wire Piezometer	444.75	145	29 33 145	Triassic Permian OB Ulan Seam	Datalogger Recorded monthly	N/A
PZ 184	Stand Pipe Piezometer	419.4	9	6 – 9	Tertiary palaeochannel	Manual monthly	6-monthly
PZ 186	Vibrating Wire Piezometer	418.76	126	40 65 86 118	Upper Permian Middle Permian Lower Permian Ulan Seam	Datalogger Recorded monthly	N/A
PZ 186a	Vibrating Wire Piezometer	418.76	18	13.5	Tertiary palaeochannel	Datalogger Recorded monthly	N/A
PZ 188	Stand Pipe Piezometer	423.62	18.5	12 – 18	Tertiary palaeochannel	Manual monthly	6-monthly

Bore	Type	RL (mAHD)	Depth (m)	Screened interval (m)	Unit screened	Water Level Monitoring Frequency	Water Quality Monitoring Frequency
PZ 189	Stand Pipe Piezometer	424.17	65	59 – 95	Permian OB	Manual monthly	6-monthly
PZ 191*	Stand Pipe Piezometer	417.69	72	60 – 72	Ulan Seam	Manual monthly	6-monthly
PZ 192	Vibrating Wire Piezometer	453.70	180	68 166 178	Triassic Ulan Seam roof Ulan Seam base	Datalogger Recorded monthly	N/A
PZ 193	Vibrating Wire Piezometer	461.40	186	80 162 184	Permian OB Ulan Seam roof Ulan Seam base	Datalogger Recorded monthly	N/A
PZ 194B	Stand Pipe Piezometer	486.19	88	85 – 88	Triassic	Manual monthly	6-monthly
PZ 194C	Stand Pipe Piezometer	486.70	109.4	100 – 106	Permian	Manual monthly	6-monthly
PZ 195B	Stand Pipe Piezometer	471.43	66	58 – 61	Triassic	Manual monthly	6-monthly
PZ 195C	Stand Pipe Piezometer	470.72	90.8	81 – 87	Permian	Manual monthly	6-monthly
PZ 203	Stand Pipe Piezometer	409.4	21	14 – 20	Tertiary palaeochannel	Manual monthly	6-monthly
PZ 211	Stand Pipe Piezometer	453.05	20	17 – 20	Tertiary palaeochannel	Manual monthly	6-monthly
PZ 213	Stand Pipe Piezometer	427.57	21.6	20.6 – 21.6	Tertiary palaeochannel	Manual monthly	6-monthly
PZ 214	Stand Pipe Piezometer	430.69	25.2	22.2 – 25.2	Tertiary palaeochannel	Manual monthly	6-monthly
PZ 217	Stand Pipe Piezometer	495.30	18	7 – 13	Ulan Seam	Manual monthly	6-monthly
PZ 221	Stand Pipe Piezometer	499.76	66	49 – 58	Ulan Seam	Manual monthly	6-monthly
PZ 228	Stand Pipe Piezometer	494.19	90	76 – 88	Jurassic	Manual monthly	6-monthly
PZ 229	Vibrating Wire Piezometer	492.64	360	84 140 198 253 316	Jurassic Triassic Triassic Permian Permian	Datalogger Recorded monthly	N/A

Bore	Type	RL (mAHD)	Depth (m)	Screened interval (m)	Unit screened	Water Level Monitoring Frequency	Water Quality Monitoring Frequency
PZ 230	Vibrating Wire Piezometer	423.99	246.14	50 100 130 187 238	Triassic Triassic Triassic Permian Ulan Seam	Datalogger Recorded monthly	N/A
PZ 231	Vibrating Wire Piezometer	459.54	282.1	124 170 202 274	Triassic Permian Permian Ulan Seam	Datalogger Recorded monthly	N/A
PZ 232	Vibrating Wire Piezometer	484.62	195.18	45 75 96 132	Triassic Triassic Permian Permian	Datalogger Recorded monthly	N/A
PZ 235A^	Stand Pipe Piezometer	436.17	49	46 – 49	Triassic	Manual monthly	6-monthly
PZ 235B	Vibrating Wire Piezometer	434.86	150	68 96 147	Permian Permian Ulan Seam	Datalogger Recorded monthly	N/A
PZ 236A	Stand Pipe Piezometer	436.71	60	57 – 60	Triassic	Manual monthly	6-monthly
PZ 236B	Vibrating Wire Piezometer	436.72	159	85 110 157	Permian Permian Ulan Seam	Datalogger Recorded monthly	N/A
PZ 238	Vibrating Wire Piezometer	406.43	92	11 25 50 82	Permian Permian Permian Ulan Seam	Datalogger Recorded monthly	N/A

Notes: * Decommissioned for safety of underground operations.
Sites will continue to be monitored until decommissioned.
** Piezometer to be replaced with VWP's to monitor water levels in the Triassic and Upper Permian.
^ May need to be redrilled in the future due to reliability concerns.



LEGEND

Groundwater Monitoring Network Site

- Standpipe
- VWP

- Drainage
- Approximate Extent of OC Mining 2023

- UG1
- UG2
- UG4

Groundwater Assessment for Moolarben UG4 Compliance Conditions (MOO5001.001)

Groundwater Monitoring Program

AGE

DATE 31/07/2023

FIGURE No: **6.1**

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
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Table 6.2 Salinity and pH Trigger Levels

Bore	Depth (m)	Lithology screened	Salinity Triggers			Beneficial Use Category Change Threshold (µS/cm)	pH Trigger Level (5th to 95th percentile)*
			Historical lab EC (5th to 95th percentile) (µS/cm)*	EC Trigger Level (µS/cm)	Beneficial Use Category Based on Lab EC 95th Percentile		
PZ 044	23	Ulan Granite	2728 – 3000 (2910)	3000	Irrigation	7800	5.7 – 7.2 (6.4)
PZ 055	15	Indurated Conglomerate	1321 – 2756 (2380)[a]	2756	Irrigation	7800	5.1 – 6.3 (5.5)[a]
PZ 058a	12	Tertiary Sediment	9405 – 14765 (11100)[d]	14765	Saline	22000	2.8 – 4.7 (3.7)[d]
PZ 101C	30	Lower Triassic	610 – 810 (655)	810	Marginal Potable	2350	6.1 – 7.7 (6.7)
PZ 101B	60	Permian OB	736 – 928 (761)	928	Marginal Potable	2350	6.2 – 7.7 (7.0)
PZ 103C	30	Lower Triassic	310 – 448 (350)[b]	448	Potable	800	5.2 – 6.8 (5.6)[c]
PZ 105C	28	Lower Triassic	198 – 319 (265)	319	Potable	800	5.3 – 7.4 (6.1)
PZ 109	254	Permian OB	660 – 1145 (1040)	1145	Marginal Potable	2350	6.3 – 8.4 (7.3)[e]
PZ 188	18.5	Tertiary palaeochannel	198 – 394 (245)	394	Potable	800	4.7 – 6.9 (5.5)

Notes:
* NB. Historical values in brackets are median values.
a Statistics and revised trigger level at PZ 055 are based on post mining data from 2010 to 2018.
b Revised trigger level at PZ 103C is based on the 90th percentile of historical lab EC data.
c Revised trigger levels at PZ 103C are based on the 10th and 90th percentile of historical field pH data.
d PZ058a triggers to be developed following collection of 12 quality monitoring rounds.

Table 6.3 Investigation Trigger Levels

Piezometer Number	Aquifer Monitored	Minimum Observed Groundwater Level / Pressure		Bottom of Hole / VWP sensor		Saturated Thickness (Lowest to (31 Dec)	Trigger Level	
		mbgl	m AHD	mbgl	mAHD	m	mbgl	mAHD
PZ 101C	Triassic	22.5	380.5	30	373	7.5	25.1	378.0
PZ 105C	Triassic	15.1	373.9	28	361	12.9	17.3	371.7
PZ 129 (35 m)*	Triassic	29.6	388.4	35	383	5.4	32.0	386.0
PZ 055	Marrangaroo Conglomerate	7.6	421.8	15	414.5	7.4	11.3	418.1
PZ 058A	Tertiary sediments	11.4	466.7	12	466.1	0.6	11.7	466.4
PZ 188	Tertiary palaeochannel	10	413.7	18.5	405.1	8.5	14.2	409.4
PZ 203	Tertiary palaeochannel	9	400.4	21	388.4	12	15	394.4
PZ 213	Tertiary palaeochannel	13.7	413.8	22	405.6	8.3	17.9	409.7
PZ 214	Tertiary palaeochannel	16.8	413.9	25	405.7	8.2	20.9	409.8

6.3 Hydraulic properties

The permeability and storativity of the Permian coal measures within the Moolarben Coal Complex is variable. Permeability is generally higher in the coal seams, but is occasionally enhanced in the interburden sediments (generally sandstone, siltstone and mudstone) due to localised fracturing. Elsewhere the interburden has lower permeability than the Ulan Seam and generally behaves as an aquitard (RPS Aquaterra 2011).

The upper Triassic quartzose sandstone has some moderate permeability along horizons, particularly within the conglomerates and coarser grained sandstone lithologies. The lower Triassic lithic sandstone has a generally lower permeability relative to the Triassic quartzose unit.

The basement Carboniferous monzonite and granite rocks are relatively impermeable and are considered to constitute a basal aquitard in the groundwater regime. Nevertheless, groundwater occurs in all these units, and can form local aquifers where relatively higher permeability exists, such as the weathered zone (RPS Aquaterra 2011).

6.3.1 Hydraulic conductivity

During the Stage 1 and Stage 2 investigations, a number of piezometers were hydraulically tested either by a short duration constant pump test or a falling head slug test to estimate hydraulic conductivity aquifer properties. Table 6.4 summarises the hydraulic conductivity data previously reported for the Moolarben Coal Complex.

Table 6.4 Summary of Hydraulic Conductivity Testing – Stage 1 and 2 Groundwater Investigations

Aquifer	Hydraulic Conductivity (m/d)			No. of Tests
	Min.	Max.	Median	
Quaternary alluvium/colluvium/regolith	0.05	3	0.4	10
Tertiary palaeochannel alluvium	0.01	0.2	0.1	5
Triassic sandstone	0.04	7	0.3	6
Upper and Middle Permian Coal Measures	0.0003	14	0.3	30
Lower Permian Coal Measures	0.2	7	3.5	18
Permian Coal Measures - Ulan Seam	0.004	11	0.3	18
Shoalhaven Group	0.06	1	0.2	2
Basement – Monzonite, granite	0.3	0.3	0.3	1

Source: RPS Aquaterra (2011).

Individual test results for all of the hydraulic tests reported by RPS Aquaterra (2011) are not available. A literature review for the individual tests has been completed, and individual hydraulic test results have been plotted as a box and whisker plot (see Figure 6.2). Results shown on Figure 6.2 also include tests which have been completed since 2011. A comparison between Table 6.4 and Figure 6.2 suggests that:

- additional testing in the Tertiary palaeochannel sediments has increased the median estimate of hydraulic conductivity from 0.1 metres per day (m/d) up to 0.75 m/d;
- grouping of all Permian hydraulic tests produces a median estimate of approximately 0.3 m/d which is consistent with the median estimate of the Upper Permian Coal Measures, as reported by RPS Aquaterra (2011);
- a median estimate of 0.3 m/d for the Ulan Seam, is consistent with the previously reported results; and
- the median hydraulic conductivity estimated for the Marrangaroo Conglomerate has been estimated to be approximately 0.1 m/d, based on the hydraulic testing of six piezometers.

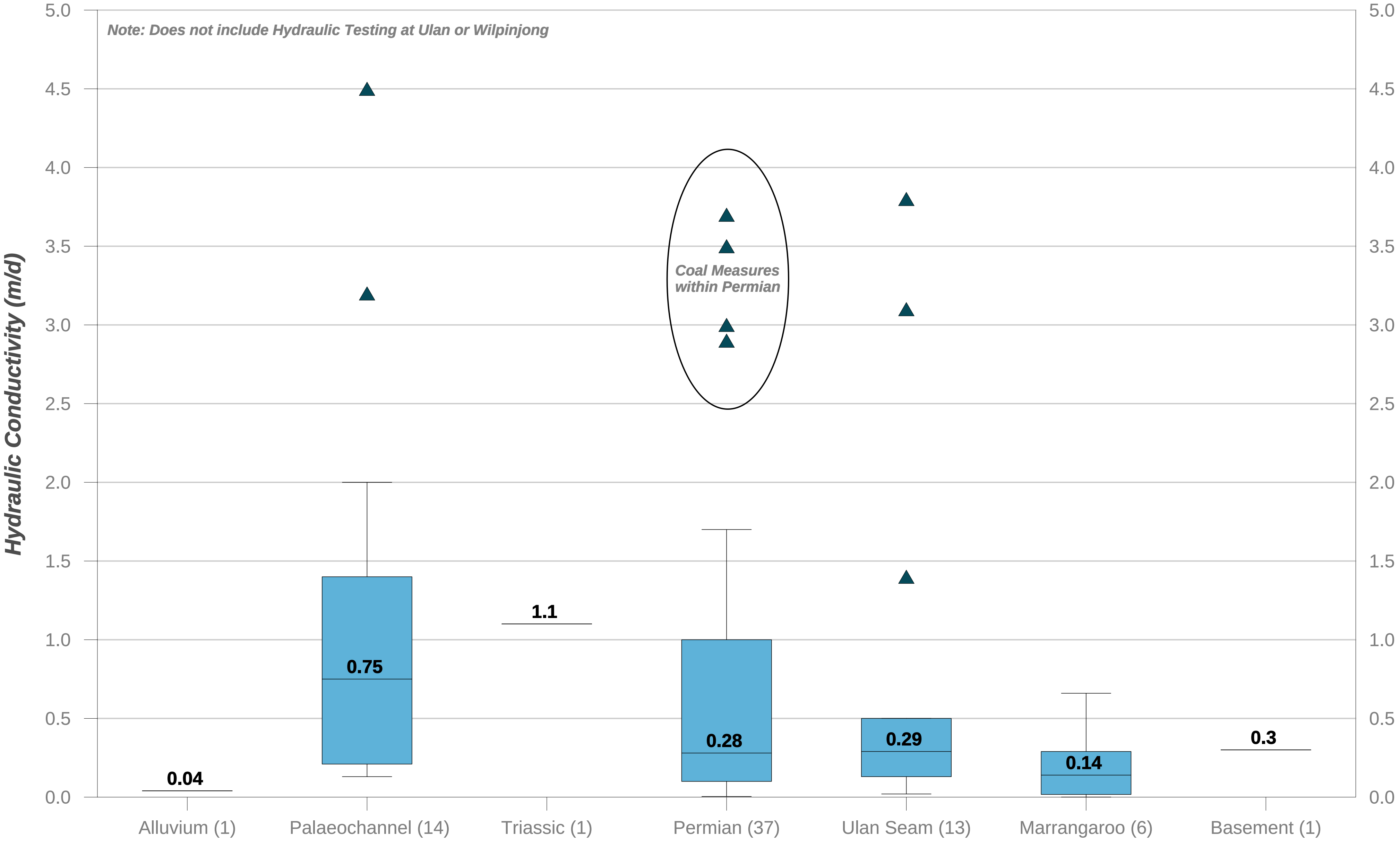
The majority of the hydraulic tests have been obtained from very short term slug tests, or short term pumping tests conducted at extremely low rates. Inspection of individual bore logs reveals that a very large percentage of the Permian bore logs show no intersection of groundwater while drilling, and no corresponding airlift yield. Different hydraulic tests do not appear to have been undertaken, such as packer tests, or core tests (triaxial testing), which are generally considered much more accurate for strata of such low apparent permeability.

For the reasons outlined above, together with an analysis of observation data (particularly groundwater level responses in proximity to mining stresses), some uncertainty exists in the hydraulic parameters previously reported. The hydraulic conductivity of the Permian interburden for example, is expected to be much lower than the results reported, which may have been biased by intervening coal measures.

6.3.2 Storage properties

Specific storage for the Permian strata have been estimated to lie between 1×10^{-6} and 5×10^{-6} m^{-1} with higher specific storage possible for Triassic strata and coal seams. Specific storage for the Ulan Seam has been estimated at 1×10^{-5} m^{-1} to 2×10^{-4} m^{-1} (MER, 2011).

A review of all available MCO reports suggests some uncertainty with respect to both the specific storage and the specific yield of the strata. This is largely a result of the existing testing being limited in duration, and an absence of monitoring bores included for the analysis of 'pumping tests'.



Hydraulic Testing Results - Hydraulic Conductivity (m/d)
Moolarben Groundwater Conceptualisation
Moolarben Coal Operations - UG4 Groundwater Assessment Report

Outlier >> IQR X 5
Box - 1st to 3rd Quartiles
Interquartile Range x 1.5

AGE

DATE
26/08/2022

FIGURE No:
6.2

6.4 Yield and Productivity

The NSW *Aquifer Interference Policy* (AIP) covers water licensing and assessment processes for aquifer interference activities within NSW (NSW Department of Primary Industries – Office of Water, 2012). Groundwater sources within the AIP have been divided into “highly productive” and “less productive” categories.

Highly productive groundwater is defined in the AIP as a groundwater source that is declared in the Regulations, and is to be based on the following criteria:

a) has total dissolved solids of less than 1,500 mg/L, and
b) contains water supply works that can yield water at a rate greater than 5 L/sec.

Given the AIP definition, none of the hydrogeological units surrounding the Moolarben Coal Complex are considered to be highly productive. A combination of low permeability and/or observed groundwater salinity effectively classifies the units as ‘less productive’.

Figure 6.3 presents the reported airlift yields for all groundwater bores at the Moolarben Coal Complex, as obtained from individual bore logs, and reports. Figure 6.3 represents only those bores which recorded an airlift yield. A high proportion of the drilled holes (during piezometer construction) encountered no free groundwater during the drilling process, and as such, the median estimates are biased to the high side, particularly for the lower permeability units (Permian ICM and Basement).

While two airlift yields greater than 5 L/sec have been reported, the process of airlifting generally produces yields which are higher than the yield which can be pumped from bores for sustained periods. This is due to a combination of reasons, including the inflation of airlift yields due to wellbore storage effects, increased depth of testing (airlifting can occur from the base of a bore, while submersible pumps are typically set above the well screen and thus have reduced available drawdown) and aquifer and well losses which occur during production. Both aquifer and well losses which develop during production reduce the amount of available drawdown within a production well over time, thus the planned production rate becomes lower as the planned length of operation increases.

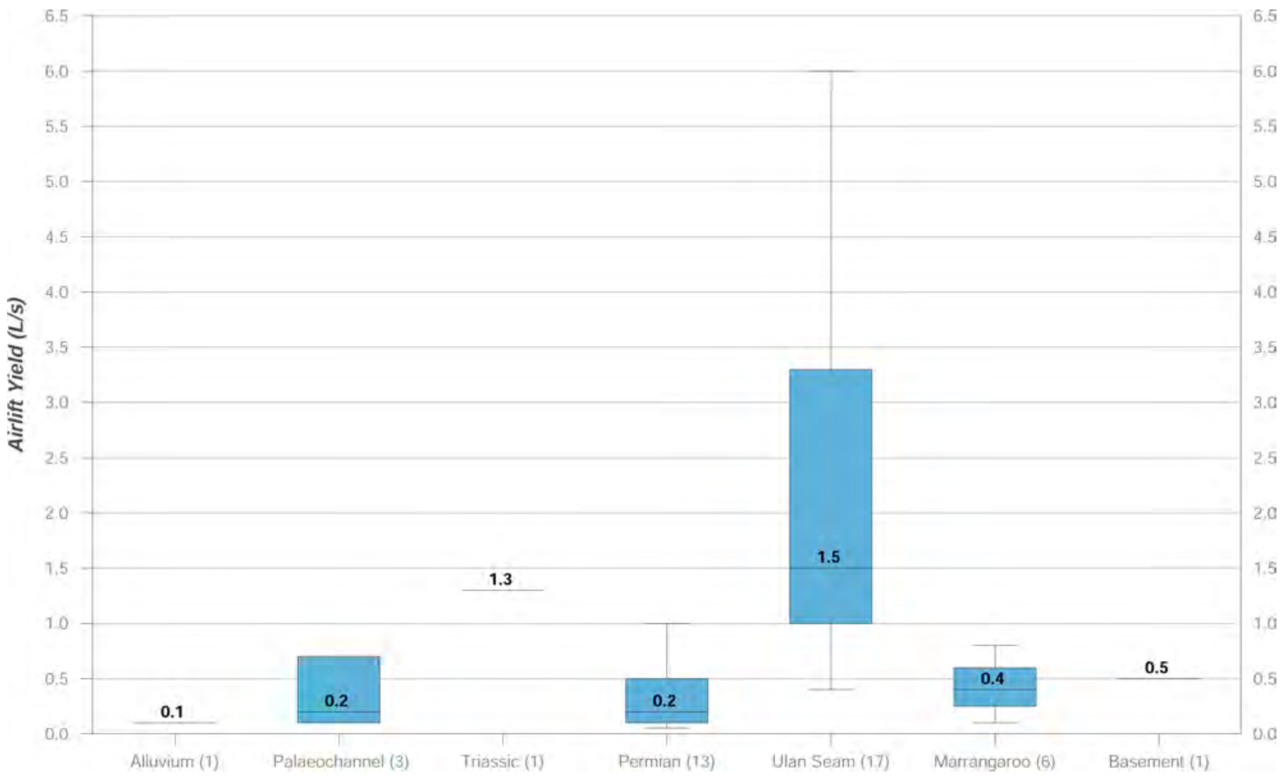


Figure 6.3 Recorded Airlift Yields

6.5 Groundwater Levels and Flow Direction

Given the cumulative nature of impacts which have occurred from adjacent coal operations, a set of observed groundwater contours has been produced for the key Hydrostratigraphic units occurring at UG4; the Triassic sandstone, the Permian interburden, and the Ulan Seam.

Observed contours represent groundwater conditions at the end of 2022 at MCC, but due to the unavoidable temporal nature of groundwater level data collection, observation dates may extend as far back as mid 2022 in order to provide a greater number of control points for the contouring process. Similarly, some more recent data from February 2023 was also added to dataset, from recently installed monitoring infrastructure such as the nested VWP at PZ 235B. Contours surrounding the MCC have been digitised by hand, and include regional control from UMC, WCM and the NSW State groundwater level database. Latest NSW State groundwater level data was downloaded for contouring, however UMC and WCM data span between 2018 to 2022. AGE notes that observed contours are non-unique, in that alternative sets of contours could be constructed that also honour the observation points. Groundwater levels in the deeper Permian ICM have been, and will continue to be impacted by mining and will therefore change with time as mining progresses.

In addition to the groundwater contouring, Appendix A provides the full set of hydrographs for the GWMP monitoring network. Anomalous values on the hydrographs have been flagged (i.e. for example, where vibrating wire head pressures have fallen below the sensor elevation). The SILO based Cumulative Rainfall Deviation (CRD) data has been scaled in order to better understand expected groundwater level responses, and groundwater responses which may have occurred due to the effects of mining.

This section of the report describes general observations of groundwater levels and flow, from completing these works.

6.5.1 Triassic Sandstone

Figure 6.4 presents groundwater contours for the Triassic sandstone. The following observations can be made from Figure 6.4, with comparison to Appendix A:

- groundwater flow at UG4 generally occurs towards the north and northeast, with hydraulic heads ranging from approximately 420 mAHD to the east of UG1, down to approximately 380 m AHD near the Goulburn River;
- at LW401-408 heads in the Triassic generally range between 397 to 416 m AHD;
- further north of the Goulburn River Diversion, before the Goulburn River tends towards the east, the river may be classified as a throughflow stream which gains water from the west, but loses water towards the east, before discharging again at the Goulburn River further to the north, near The Drip;
- a groundwater divide may exist to the west of the Goulburn River, between UMC and the Goulburn River;
- groundwater flow paths have been inferred from the groundwater contours, and in turn, a groundwater flow net has been used to infer the potential Triassic recharge area which may eventually discharge to the Goulburn River. This is discussed in detail in Section 6.11; and
- generally, the Triassic groundwater hydrographs responses show a clear correlation with climate data, while some show a very strong correlation with climate variability (see PZ 105C).

6.5.2 Permian Illawarra Coal Measures

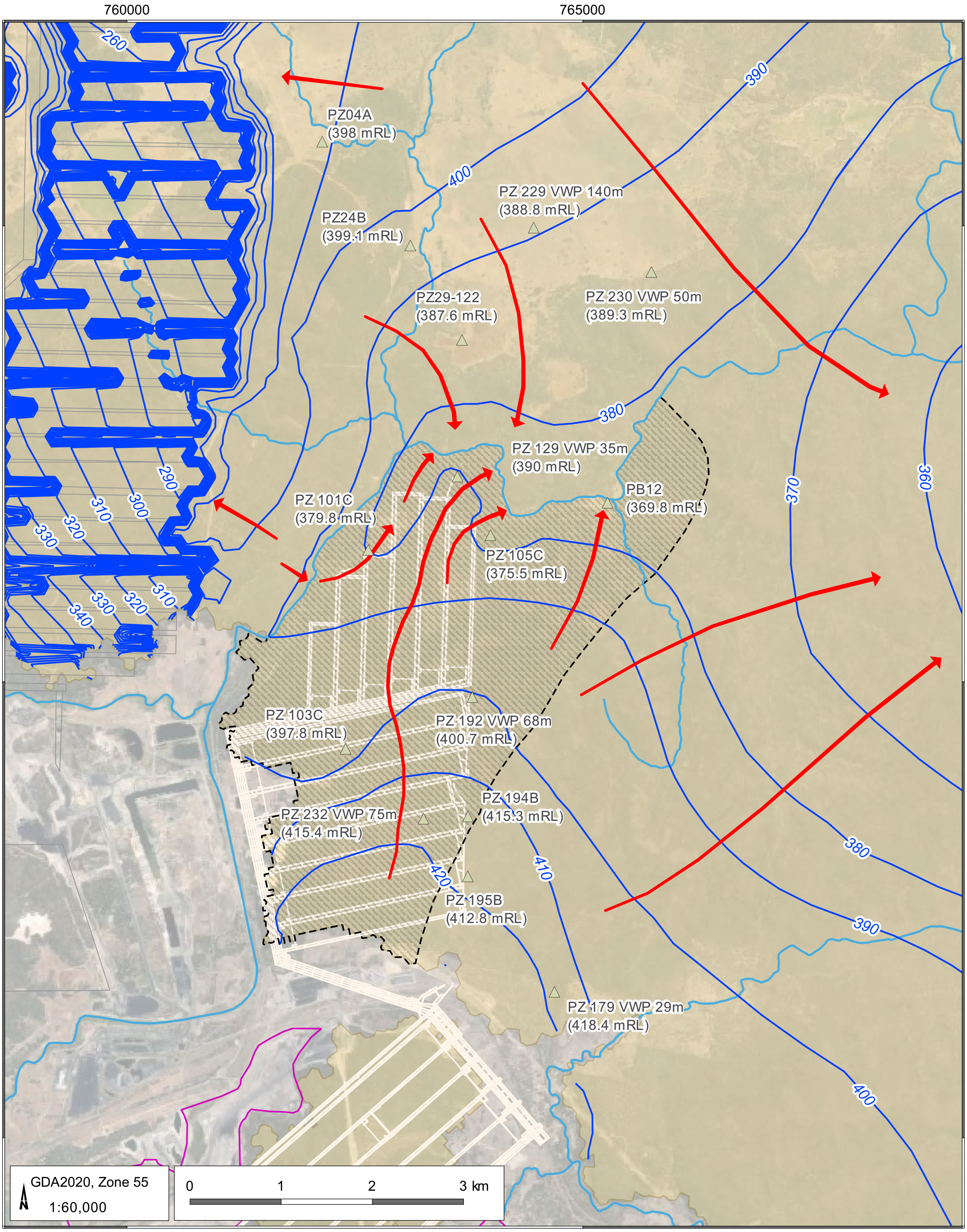
Figure 6.5 presents groundwater contours for the Permian ICM. Some care was required to select the most appropriate monitoring points for contouring, due to the thickness of the ICM and the spread of monitoring across multiple sub-units within the ICM. Notwithstanding, the following observations can be made from these figures, and subsequent comparison to Appendix A:

- groundwater levels are at their highest to the east of the UG4 extent, corresponding with the local topographic high in elevation;
- groundwater flows radially towards the existing UG1 operation in the southwest, towards the topographic lows beyond the range in the east, and towards LW409-414 at the northern extent of the LW401-408 panels;
- at LW401-408 heads in the Permian generally range between 382 to 416 m AHD;
- at UG1, the coal measures are depressurised locally due to mining activities, although there is some evidence which suggests some positive groundwater pressures are now being recorded in the shallow Permian sediments above UG1. Data from PZ 130 VWP 38.5m has recorded positive groundwater pressures since mid 2022, likely in response to the above average rainfall conditions recorded at the MCC;
- to the south of OC4, groundwater generally flows towards the Wilpinjong Coal Mine, or towards Moolarben Coal Complex OC4;
- most of the Permian groundwater hydrograph responses show a reasonable correlation with climate data prior to mining induced departures, while some hydrographs show a strong correlation with climate variability prior to mining induced departures (see PZ 40B); and
- some Permian hydrographs show a strong correlation with climate data with no observed mining effect, where mining impacts may have been expected (see PZ 170).

6.5.3 Ulan Seam

Figure 6.6 presents groundwater contours for the Ulan Seam. The following observations can be made from the contours, with comparison to Appendix A:

- at UG4, groundwater flows in a generally east to north easterly direction from the UMC East Pit, towards the eastern extent of LW401-LW404;
- at LW401-408 heads in the Ulan Seam generally range between 300 to 350 m AHD;
- to the north (towards LW409-LW414), groundwater gradients are somewhat flatter, with a local hydraulic highpoint of approximately 332 m AHD recorded at PZ 105A VWP 130m;
- to the south, groundwater generally flows towards OC4, or towards the Wilpinjong Coal Mine open cuts.
- regionally, the biggest cone of depression is centered around the Ulan underground operations, where groundwater levels decline to around 220 mAHD;
- most of the Ulan Seam groundwater hydrograph responses show a weak to reasonable correlation with climate data (prior to any mining induced departures); and
- some hydrographs show a strong correlation with climate variability prior to mining induced departures (see PZ 191).



LEGEND

- Triassic Piezometer BoreID (RSWL)
- Triassic Groundwater Contour
- Triassic Groundwater Flow Direction
- Drainage
- Approved Ulan Underground Mine Plan
- UG Mine Plan
- Approximate Extent of OC Mining 2023
- Modelled Triassic Extent
- Goulburn River Triassic Recharge Area

Groundwater Assessment for Moolarben UG4 Compliance Conditions (MOO5001.001)

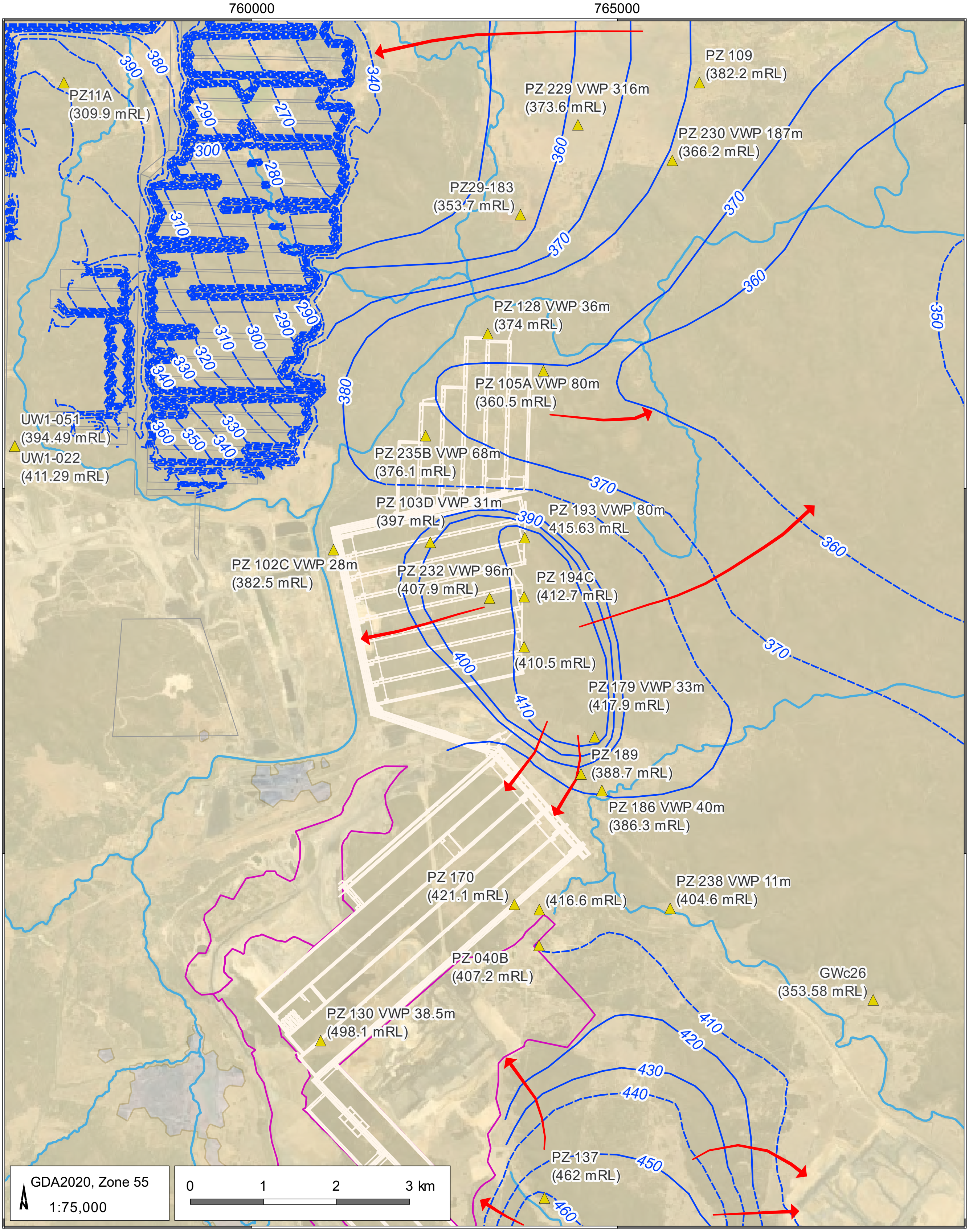
Triassic Groundwater Contours (UG4)

AGE

DATE 31/07/2023

FIGURE No: **6.4**

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:\Projects\MOO5001.001 UG4 Compliance Conditions\3_GIS\Workspaces\001_Deliverable1\06.04_MOO5001.001_Triassic Groundwater Contours (UG4).qgz



LEGEND

- Permian Piezometer BoreID (RSWL)
- Permian Groundwater Contour - Interpolated
- Permian Groundwater Contour - Inferred
- Permian Groundwater Flow Direction
- Approved Ulan Underground Mine Plan
- UG Mine Plan
- Drainage
- Approximate Extent of OC Mining 2023
- Modelled Permian Extent

Groundwater Assessment for Moolarben UG4 Compliance Conditions (MOO5001.001)

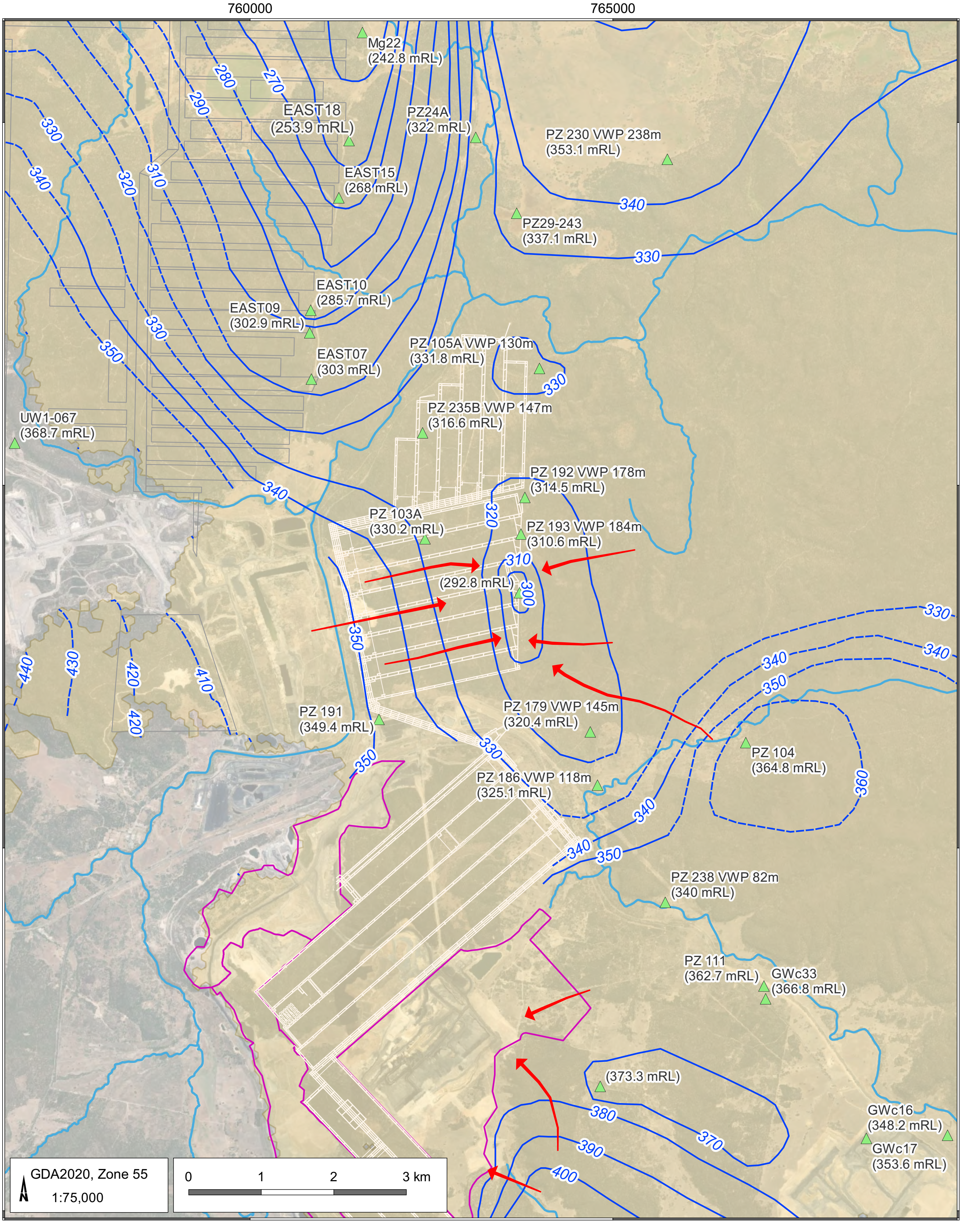
Permian Groundwater Contours (UG4)

AGE

DATE 31/07/2023

FIGURE No: **6.5**

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:\Projects\MOO5001.001 UG4 Compliance Conditions\3_GIS\Workspaces\001_Deliverable1\06.05_MOO5001.001_Permian Groundwater Contours (UG4).qgz



LEGEND

- Ulan Seam Piezometer BoreID (RSWL)
- Ulan Groundwater Contour - Interpolated
- Ulan Groundwater Contour - Inferred
- Ulan Seam Groundwater Flow Direction
- Drainage
- UG Mine Plan
- Approximate Extent of OC Mining 2023
- Modelled Ulan Extent

Groundwater Assessment for Moolarben UG4 Compliance Conditions (MOO5001.001)

Ulan Seam Groundwater Contours (UG4)

AGE

DATE 31/07/2023

FIGURE No: **6.6**

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:\Projects\MOO5001.001 UG4 Compliance Conditions\3_GIS\Workspaces\001_Deliverable1\06.06_MOO5001.001_Ulan Seam Groundwater Contours (UG4).qgz

6.6 Saturated Thickness of Triassic Sandstone

Condition 3a relates to the conceptualisation for the leakage between the Triassic sandstone and the Permian overburden. In order to understand the potential for leakage between these two units, it is important to understand the general distribution of the saturated thickness of the Triassic sandstone.

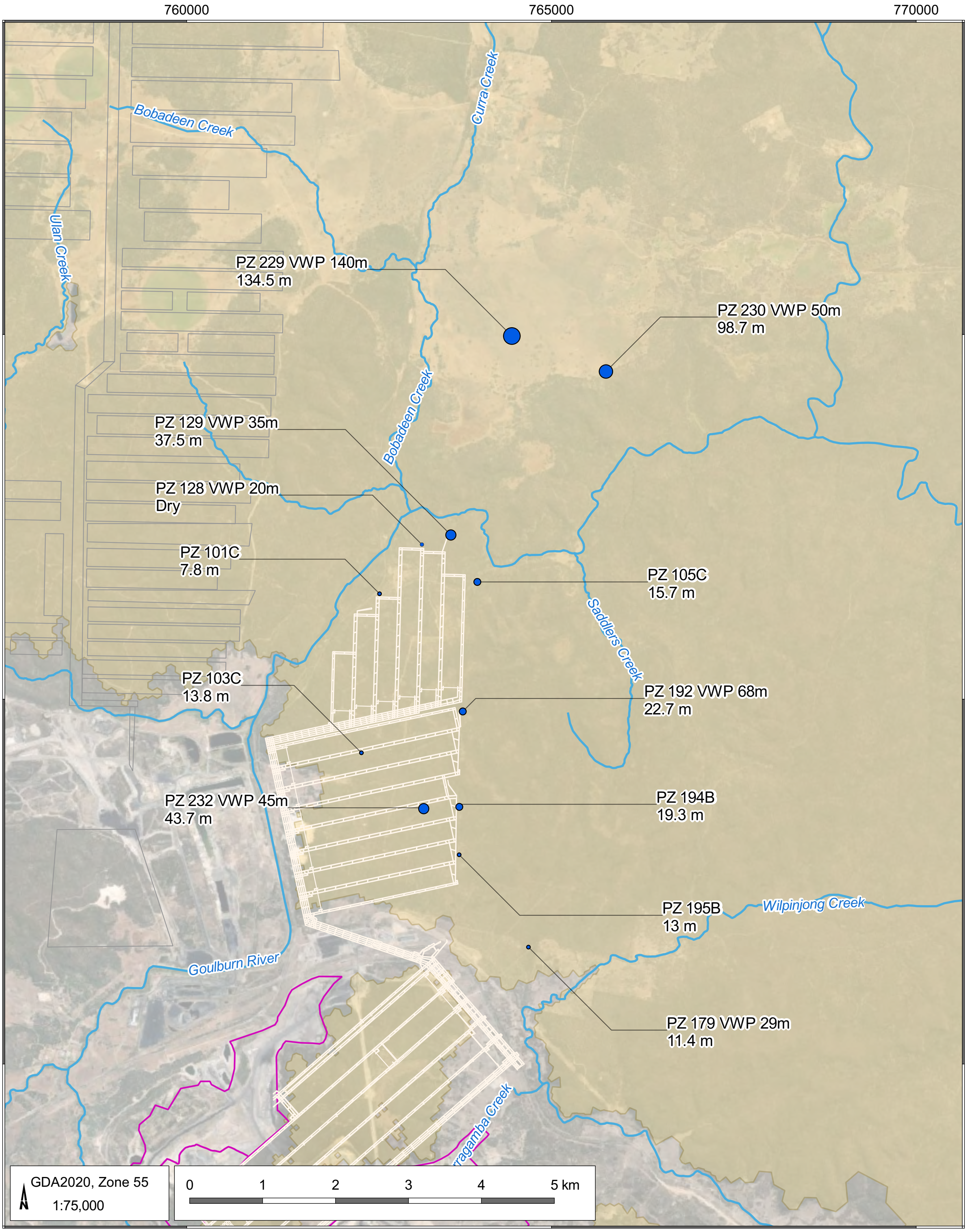
Based on a review of drillhole logs and the MCO geological model, together with the dataset prepared for groundwater contouring, saturated thickness measurements of the Triassic sandstone have been plotted as Figure 6.7. The following can be inferred from this figure:

- At LW401-408, the greatest saturated thickness of the Triassic sandstone occurs at LW404, with an estimated saturated thickness of approximately 44 metres.
- Along the eastern margin of LW401-408, the estimated saturated thickness is much lower than the maximum at UG4, and ranges between 13 m (PZ 195B) to 22.7 m (PZ 192 VWP 68).
- Further to the south of UG4, and to the northeast of UG1, the estimated saturated thickness of Triassic sandstone is approximately 11 m.
- Saturation thicknesses diminish to their thinnest to the north and east of future LW411-412, with total saturated thicknesses expected to be less than 8 m. The vibrating wire piezometer installed at PZ 128 (at 20 m depth) is installed 7 m above the top of Permian mudstone sediments and has recorded unsaturated measurements since its installation in 2007.
- To the northeast of future LW413, the recorded saturated thickness increases to approximately 38 m, as inferred from data collected from monitoring point PZ 129.
- Further north of the Goulburn River, the saturated thickness of the Triassic sandstone is far greater than that measured at UG4 and realises thicknesses of 99 m and 135 m at PZ 230 and PZ 229 respectively.

6.7 Vertical Gradients between Units

Further to understanding the potential for leakage between the Triassic sandstone and the Permian ICM, it is critical to understand the vertical head gradients which exist between these units at UG4 LW401-408. For this reason, all nested sites with measured groundwater level data were plotted as multi-level hydrographs and are presented as Figure 6.8 through to Figure 6.15. The following observations can be made from these figures:

- At all monitoring sites, the vertical hydraulic head gradient is vertically downwards, which implies that the area receives groundwater recharge, and the potential for vertical flow is towards the Ulan Seam. The only very minor exception (to this statement) can be inferred from some of the late time data recorded at PZ 102, which suggests that some potential for upward flow from the Marrangaroo Conglomerate to the Ulan Seam may have occurred in response to mining of the Ulan Seam.
- None of the data suggests any reversal of vertical hydraulic gradients during the monitoring period;
- Monitoring data from PZ 102, PZ 103, PZ 179, and PZ 193 show an increase in vertical hydraulic gradients occurring between the Permian ICM and the Ulan Seam during the monitored period.
- Groundwater levels in the shallow Permian can approach similar levels to those in the Triassic sandstone, however there is a much greater vertical separation at depth within the Permian ICM (see PZ 103).
- Apart from some test pumping which occurred in late 2016 and early 2017 (understood to have occurred from a bore which screened multiple hydrostratigraphic units), there is no evidence that groundwater levels in the Triassic sandstone have been impacted, whereas at the same locations groundwater drawdown is being observed in the deeper Ulan Seam.
- PZ 192 VWP 68m which monitors the Triassic sandstone has deviated from the climate date in 2021 (Appendix A), and also shows a clear response to the test pumping which occurred in 2017. AGE is of the opinion that the grout mix used during this Vibrating Wire Piezometer (VWP) installation may not have been to the correct specification (i.e. the specific gravity was too low and has resulted in a grout mix with a permeability which permits formation pressure to propagate through the seal more readily than it propagates through the Permian ICM). This is evidenced by the fact that the conventional standpipe PZ 103C was not affected by the test pumping, even though the test pumping occurred at much closer proximity to PZ 103C. AGE recommends removing PZ 192 VWP 68m from the GWMP monitoring network now that PZ194B and PZ 195B have been installed.
- Groundwater levels in the Triassic sandstone are generally 25 to 50 m above those measured in the Ulan Seam.



LEGEND

- Drainage
- Approved Ulan
- Underground Mine Plan
- UG Mine plan
- Approximate Extent of OC Mining 2023
- Modelled Triassic Extent

Triassic Saturated Thickness
(Bore ID, RSWL,Saturated Thickness)

- 7 to 15 m
- 15 to 20 m
- 25 to 50 m
- 50 to 100 m
- 100 to 140 m

Dry flag: Indicates unsaturated conditions at monitoring point.

Groundwater Assessment for Moolarben UG4 Compliance Conditions (MOO5001.001)

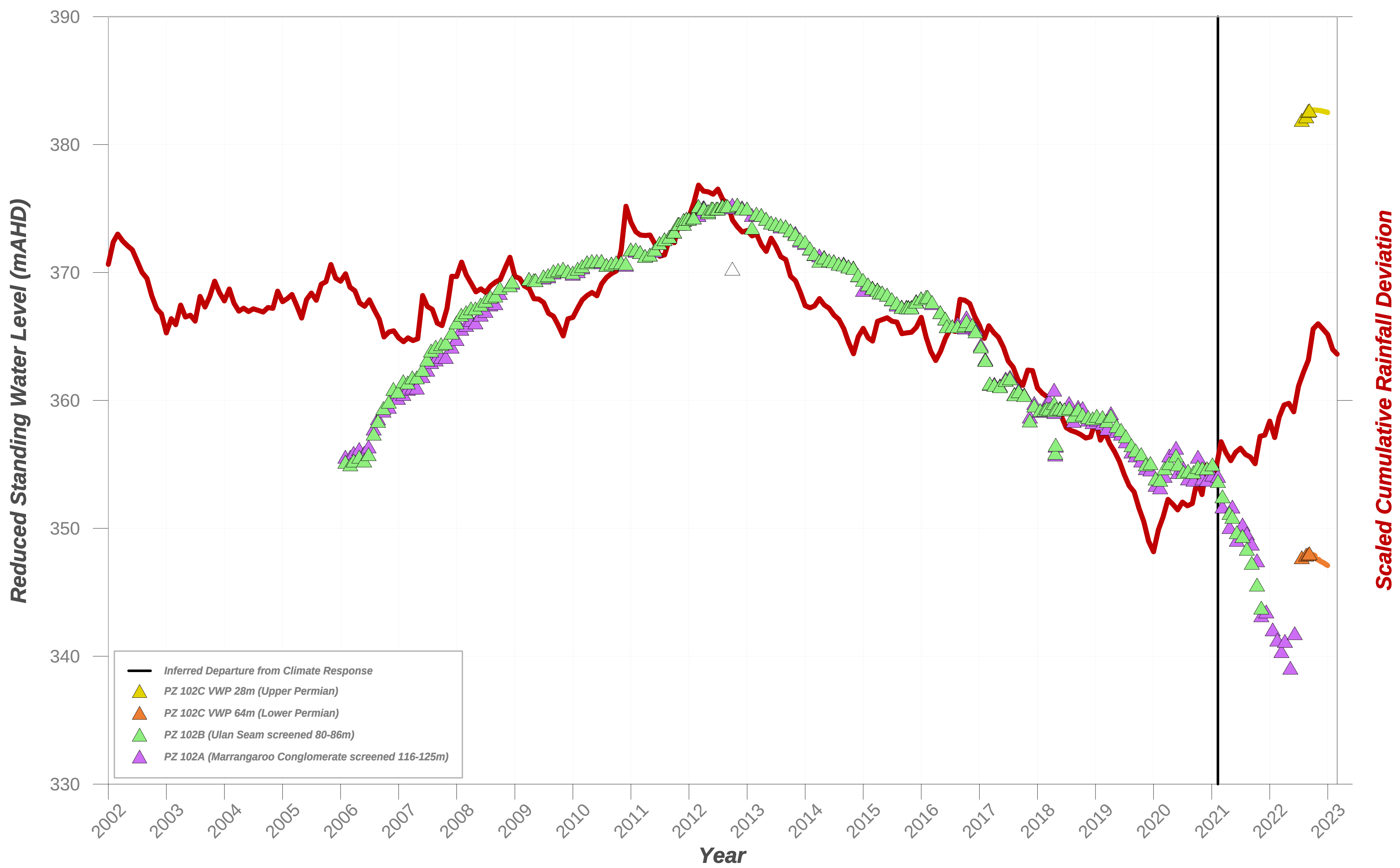
Saturated Triassic Thickness (UG4)

AGE

DATE
31/07/2023

FIGURE No:
6.7

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:\Projects\MOO5001.001 UG4 Compliance Conditions\3_GIS\Workspaces\001_Deliverable1\06.07_MOO5001.001_Saturated Triassic Thickness (UG4).qgz



Hydrograph of Groundwater Level Data for Nested Site ID: PZ 102
Moolarben Groundwater Monitoring
Moolarben Coal Operations - UG4 Groundwater Assessment Report

Manual Dips
Anomalous Reading
Continuous Logger Data
Anomalous Logger Data

AGE

DATE
25/07/2023

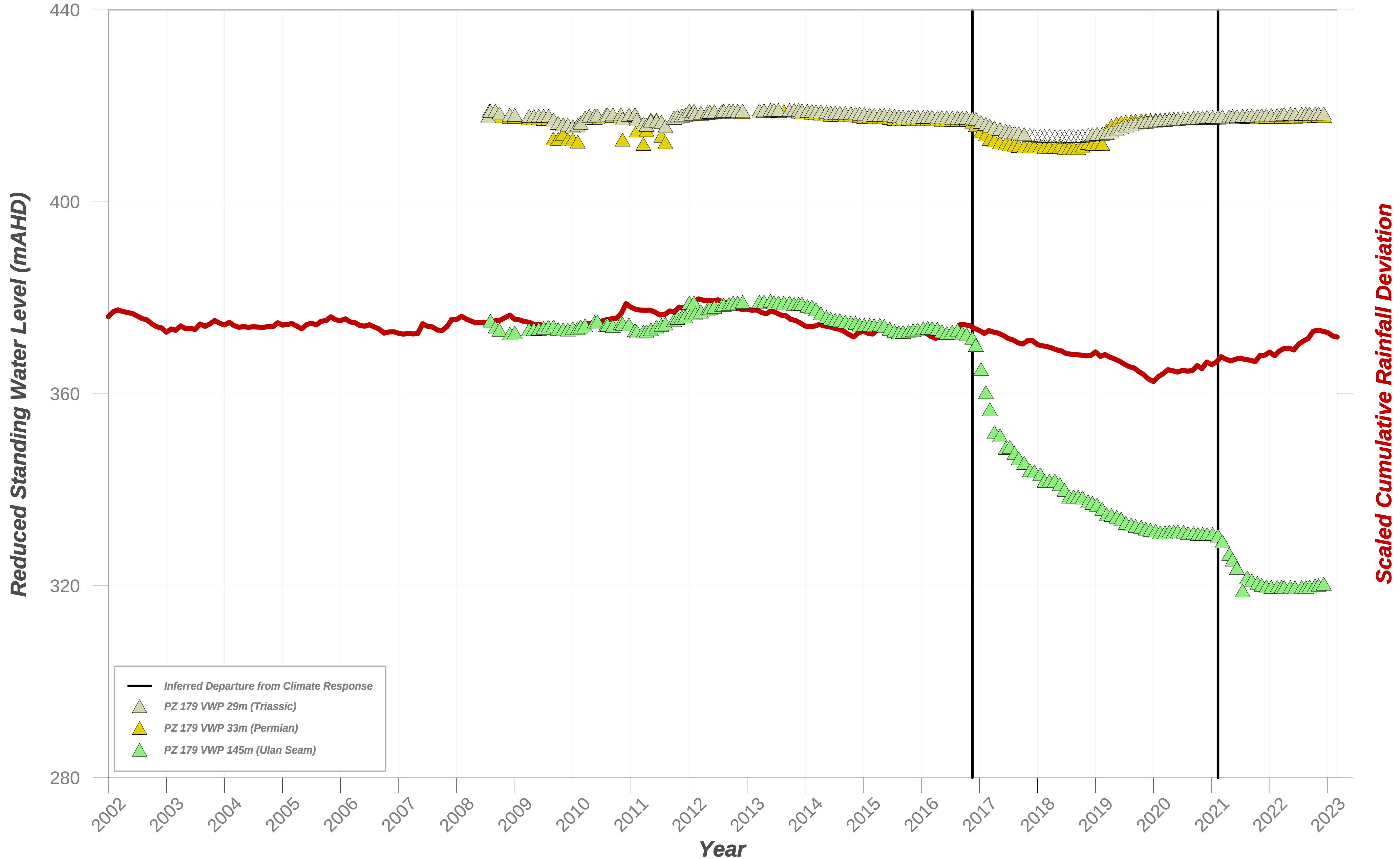
FIGURE No:
6.8

Hydrograph of Groundwater Level Data for Nested Site ID: PZ 103
Moolarben Groundwater Monitoring
Moolarben Coal Operations - UG4 Groundwater Assessment Report

AGE

DATE
25/07/2023

FIGURE No:
6.9



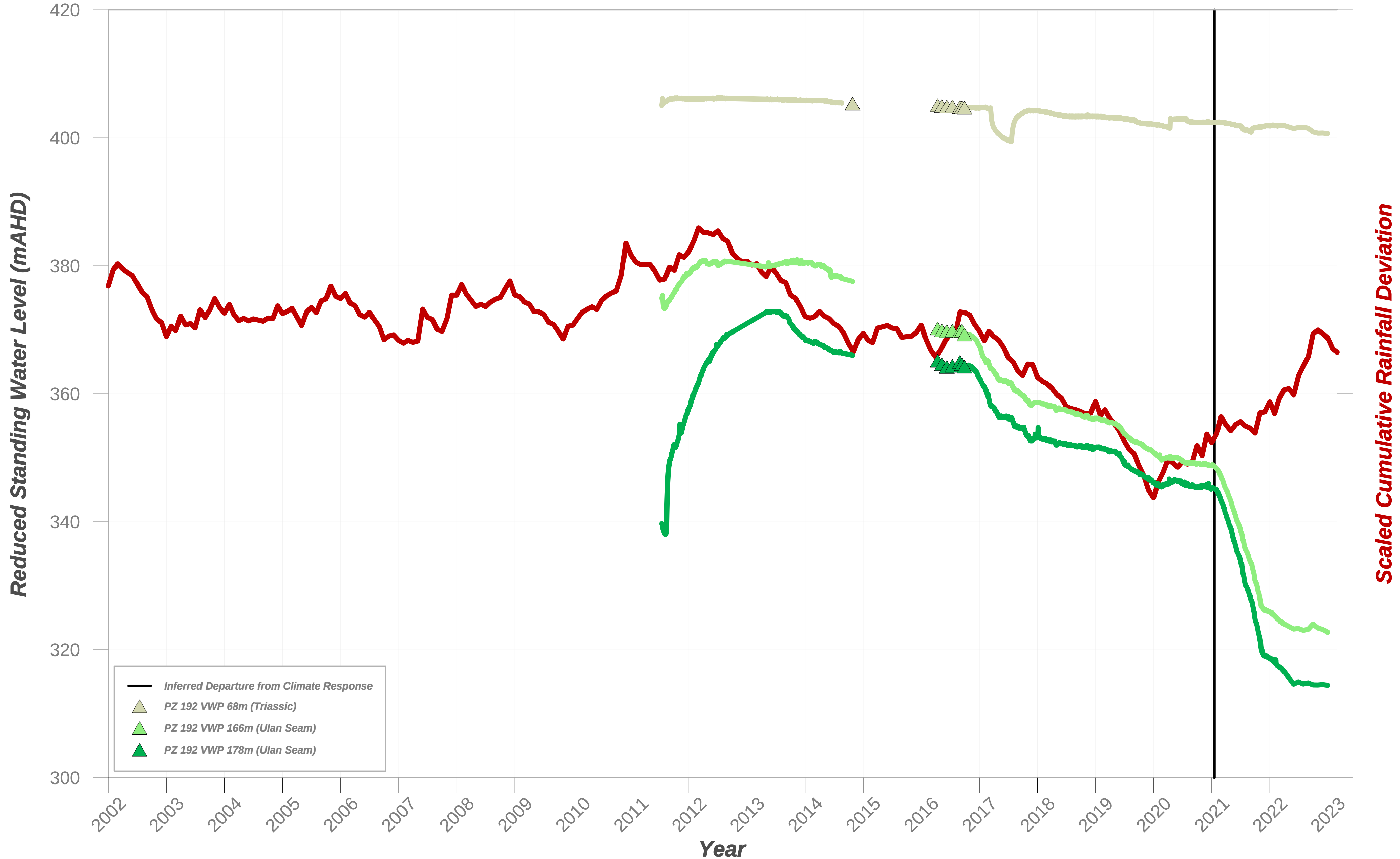
Hydrograph of Groundwater Level Data for Nested Site ID: PZ 179
Moolarben Groundwater Monitoring
Moolarben Coal Operations - UG4 Groundwater Assessment Report

Manual Dips
Anomalous Reading
Continuous Logger Data
Anomalous Logger Data

AGE

DATE 25/07/2023

FIGURE No: **6.10**



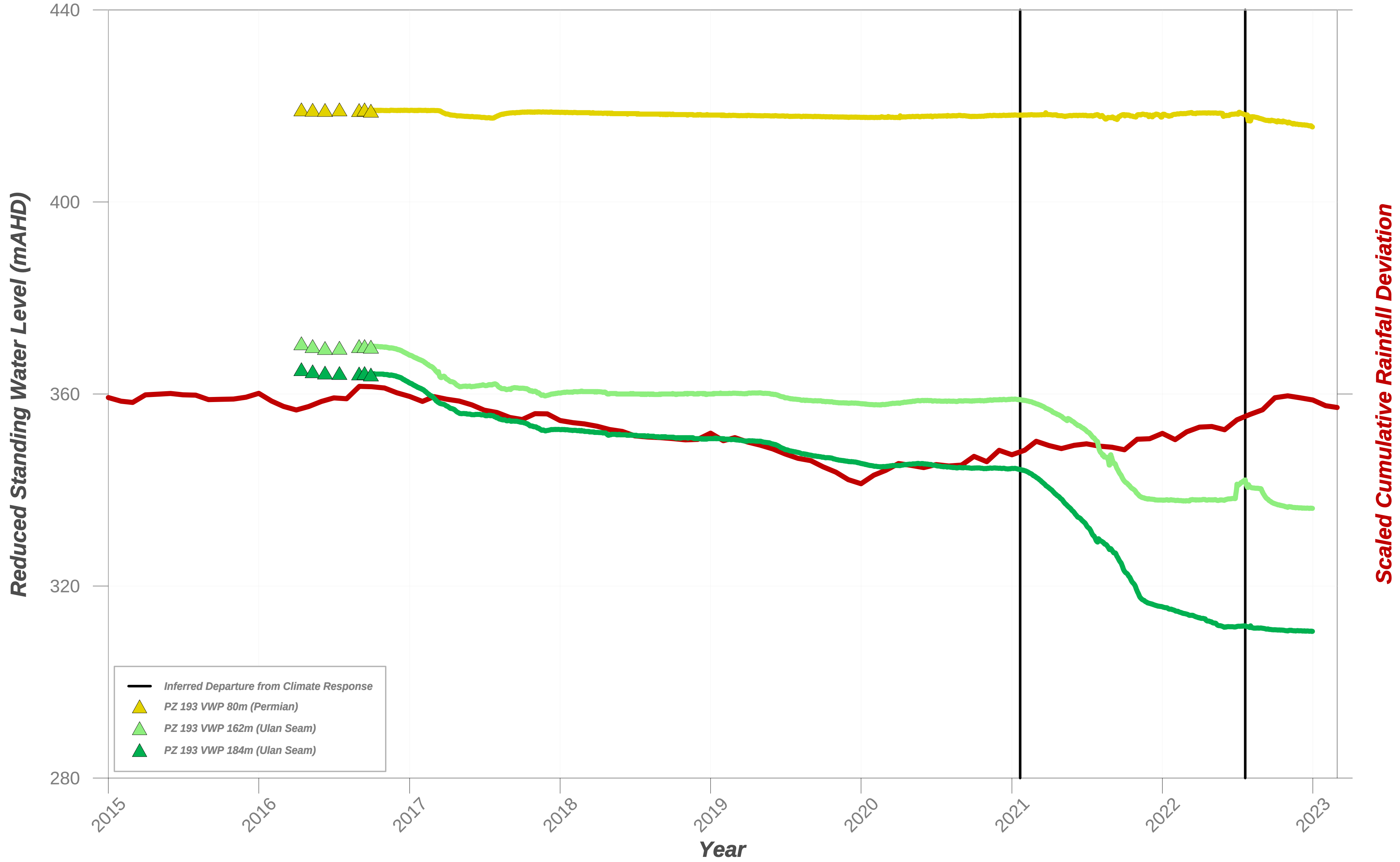
Hydrograph of Groundwater Level Data for Nested Site ID: PZ 192
Moolarben Groundwater Monitoring
Moolarben Coal Operations - UG4 Groundwater Assessment Report

Manual Dips
Anomalous Reading
Continuous Logger Data
Anomalous Logger Data

AGE

DATE
25/07/2023

FIGURE No:
6.11



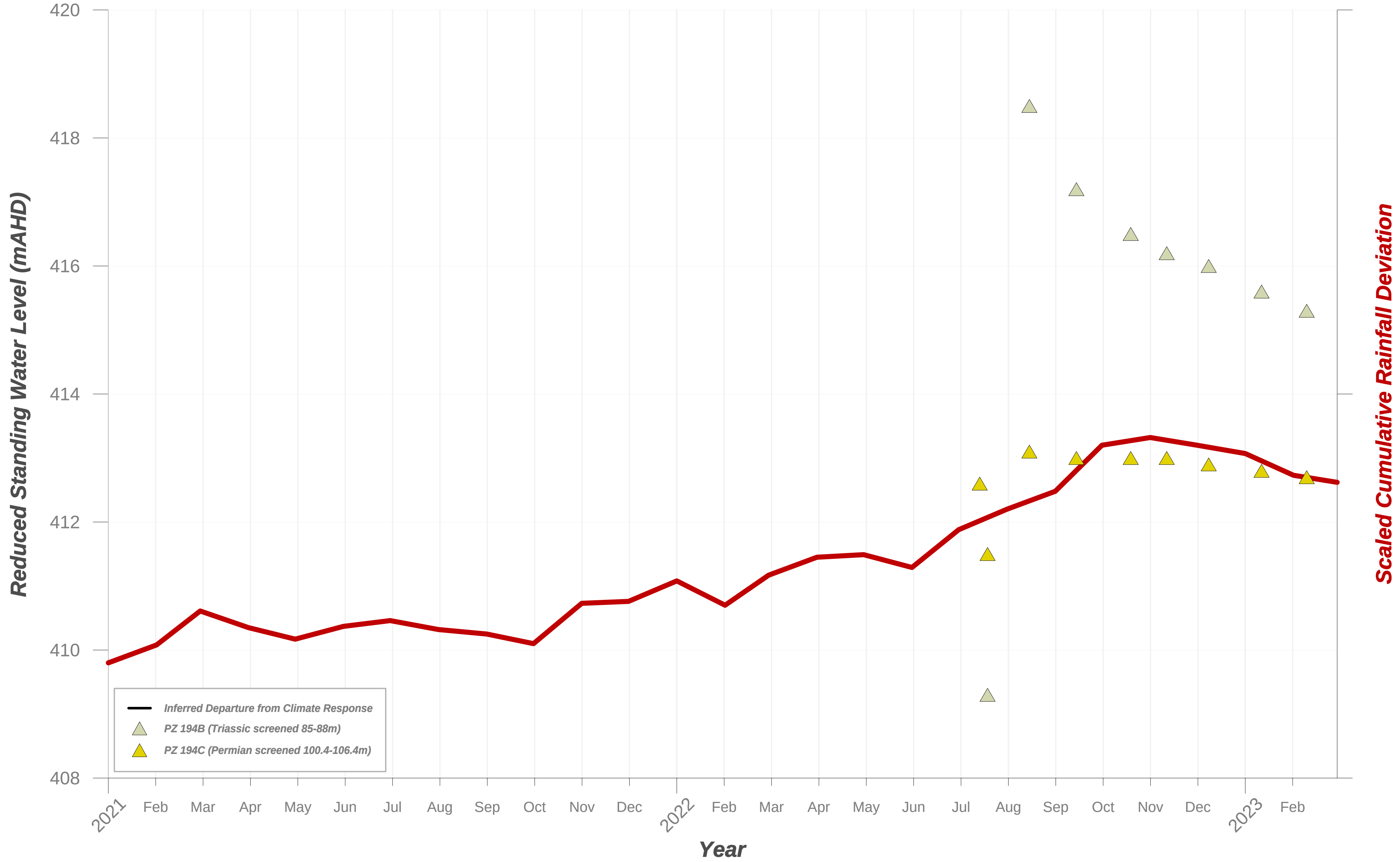
Hydrograph of Groundwater Level Data for Nested Site ID: PZ 193
Moolarben Groundwater Monitoring
Moolarben Coal Operations - UG4 Groundwater Assessment Report

Manual Dips
Anomalous Reading
Continuous Logger Data
Anomalous Logger Data

AGE

DATE
25/07/2023

FIGURE No:
6.12



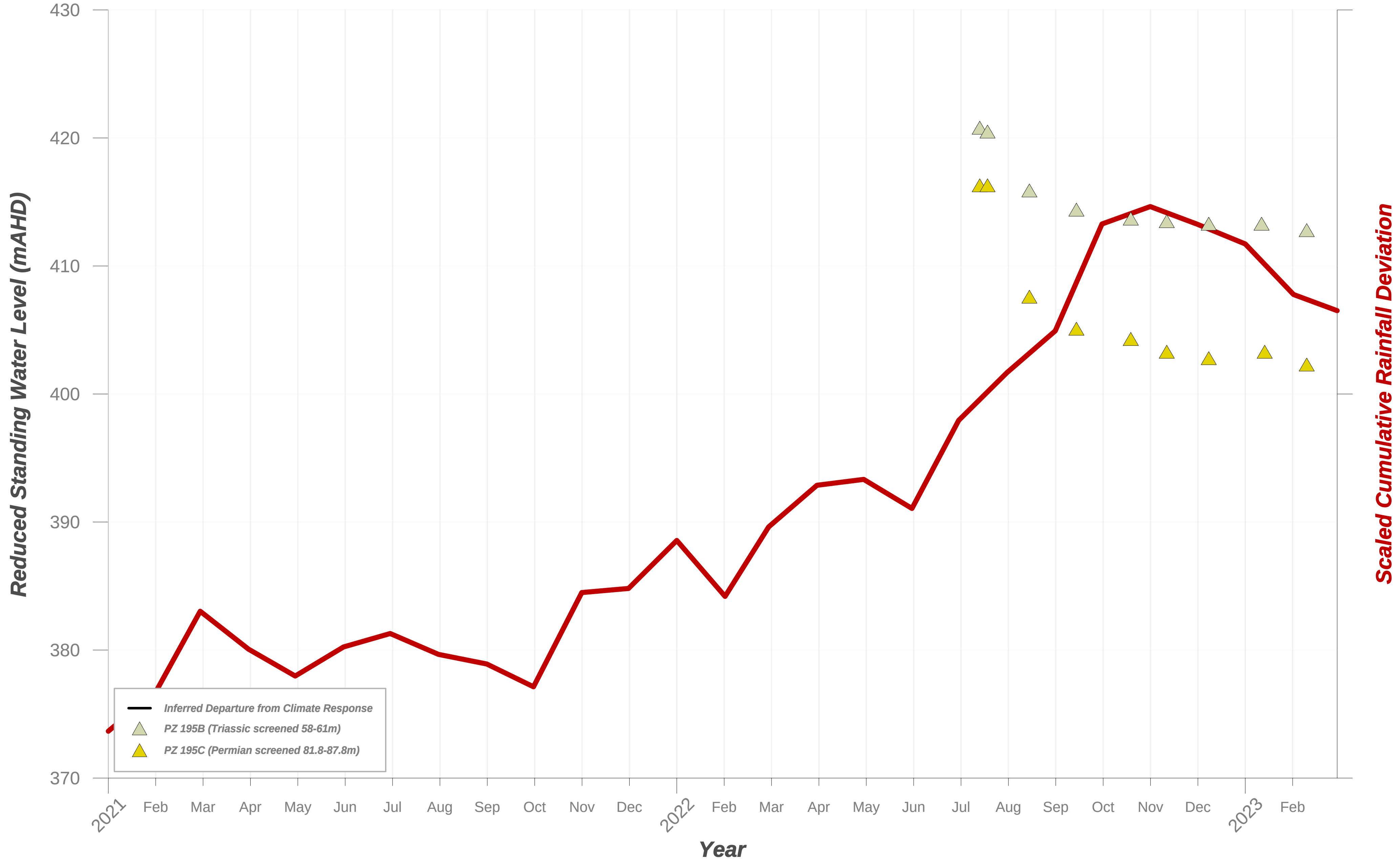
Hydrograph of Groundwater Level Data for Nested Site ID: PZ 194
Moolarben Groundwater Monitoring
Moolarben Coal Operations - UG4 Groundwater Assessment Report

Manual Dips
Anomalous Reading
Continuous Logger Data
Anomalous Logger Data

AGE

DATE
25/07/2023

FIGURE No:
6.13



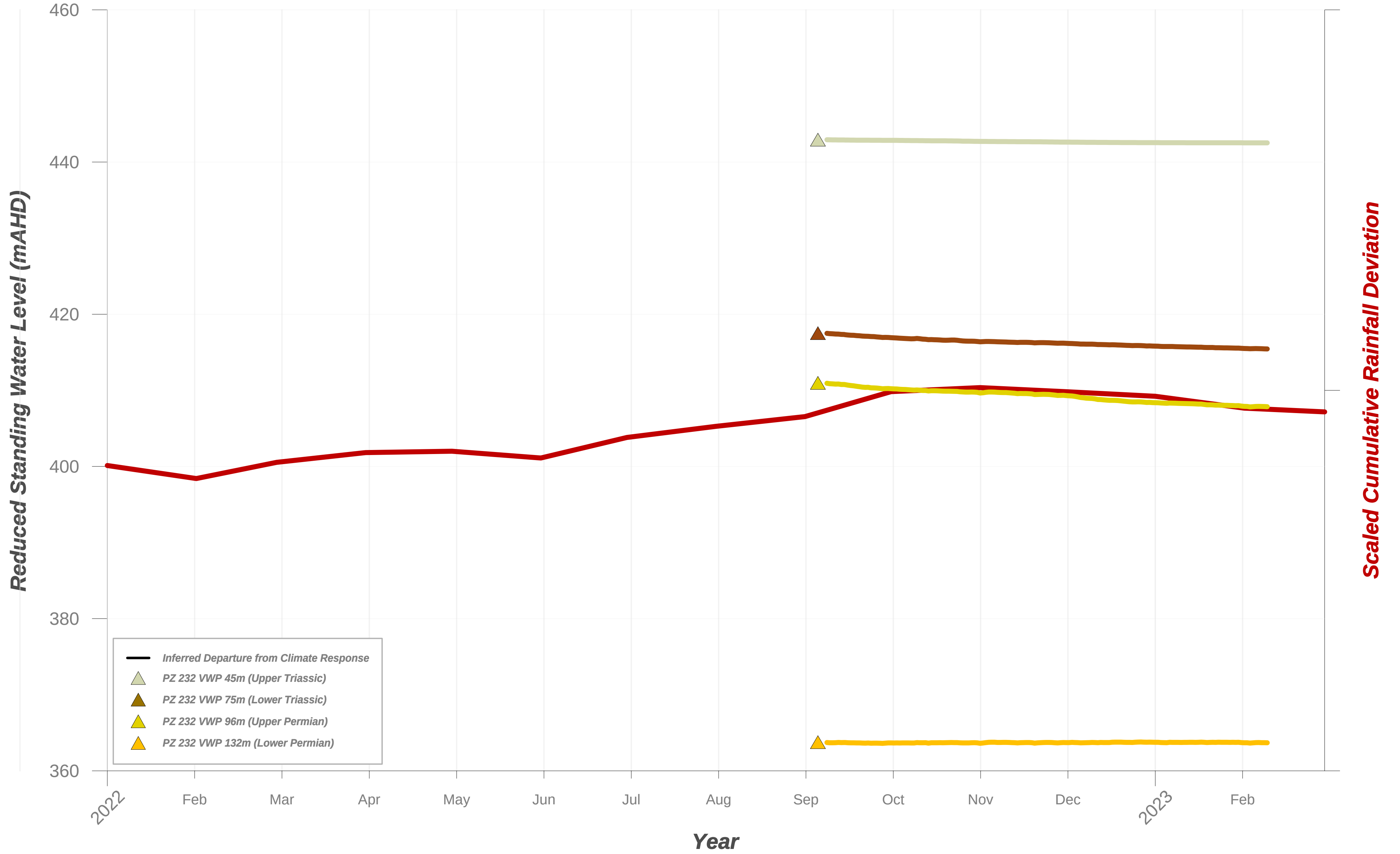
Hydrograph of Groundwater Level Data for Nested Site ID: PZ 195
Moolarben Groundwater Monitoring
Moolarben Coal Operations - UG4 Groundwater Assessment Report

Manual Dips
Anomalous Reading
Continuous Logger Data
Anomalous Logger Data

AGE

DATE 25/07/2023

FIGURE No: **6.14**



Hydrograph of Groundwater Level Data for Nested Site ID: PZ 232
Moolarben Groundwater Monitoring
Moolarben Coal Operations - UG4 Groundwater Assessment Report

Manual Dips
Anomalous Reading
Continuous Logger Data
Anomalous Logger Data

AGE

DATE
25/07/2023

FIGURE No:
6.15

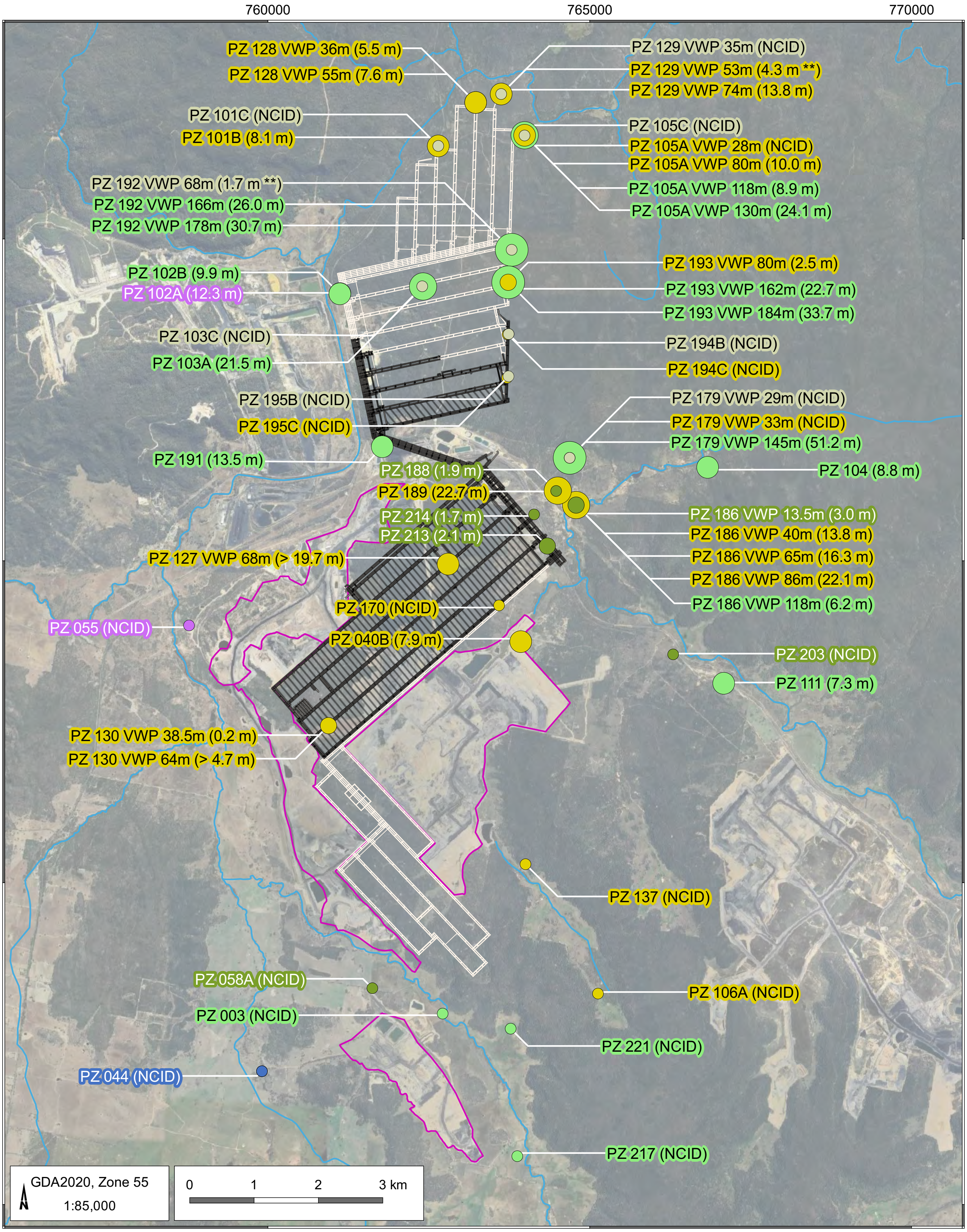
6.8 Estimated Groundwater Drawdown

Appendix A provides a long term (20 year) comparison of groundwater level data against cumulative rainfall deviation, which has been scaled vertically to best fit with the individual hydrograph responses. All available piezometric data from the GWMP monitoring network is represented, with data points considered anomalous identified. Where deviations have occurred from the climate data, these departures have been shown with a vertical line on the hydrograph. After inferring these departure dates, groundwater drawdown has been calculated for each monitoring point, by subtracting the latest reduced standing water level (RSWL) from the RSWL at the time of inferred departure. Where groundwater level data has not been recorded recently, or the analysis could not be completed with a high degree of confidence, these have either been flagged on the figures or omitted from the analysis. This method has been adopted as it is difficult to establish a reliable pre-mining baseline condition, given the long history of mining in the area. The strong correlation between climate data and groundwater level data also means this a reliable method for the estimation of drawdown.

Figure 6.16 to Figure 6.20 present the estimated groundwater drawdown which has been observed at MCC (up to February 2023) which is non climate related. This drawdown may have occurred from any of the adjacent mining activities, or other anthropogenic hydraulic stresses on the groundwater system. Figure 6.21 presents the same data, but displayed on a logarithmic scale, showing the distance of the inferred drawdown, from MCO mined areas (as at the start of 2023). The estimated drawdown is not uniquely identifiable to MCO, and at the greater distances, there is a higher likelihood that the estimated drawdown may have been cumulatively impacted from the adjacent operations. This especially relates to estimates of drawdown from coal measures within the Permian ICM. The distance drawdown plot is commonly used to identify the likely radius of influence of a hydraulic stress on a groundwater system, as resultant groundwater drawdown generally forms the shape of a cone in a heterogenous system whereby greater drawdowns occur closer to the activity and decay logarithmically at distance from the source of drawdown.

The following can be inferred from an analysis of Figure 6.16 through to Figure 6.21:

- At UG4 LW401-408 a maximum groundwater drawdown of approximately 33 m has been inferred at monitoring point PZ 193 within the Ulan Seam.
- At the opposite end of UG4, closer to the UMC East Pit, groundwater drawdown of approximately 10 m has been inferred from PZ 102B within the Ulan Seam.
- Nearer to the middle of UG4, groundwater drawdown of approximately 22 m has been inferred from PZ 103A within the Ulan Seam.
- Close to the UG4 Highway, groundwater drawdown of approximately 14 m has been inferred from PZ 191 within the Ulan Seam.
- Northeast of UG1, groundwater drawdown of approximately 51 m has been inferred from PZ 179 within the Ulan Seam.
- Apart from monitoring site PZ 186, all nested sites show a similar response, with greater drawdowns inferred in the deeper stratigraphic units (mainly monitoring from the Ulan Seam) becoming smaller with the increase in depth of cover (that is, the shallowest units experience the least drawdown at the same location). This is commensurate with the conceptual model of leakage, whereby the Ulan Seam is depressurised, and overlying units provide vertical leakage towards the Ulan Seam.
- Apart from PZ 192 VWP 68 m, no clearly identifiable groundwater drawdown can be inferred within the Triassic sandstone, after 13 years of MCO operations (OC1 commenced in 2010).
- The response at PZ 192 VWP 68m is likely directly related to the construction of that VWP, and it is recommended that this VWP be replaced with a conventional standpipe in the future.
- Very limited (or close to zero) groundwater drawdown can be inferred from some Permian monitoring sites, even at extremely close proximity to mining (see PZ 170 response in Appendix A which is located approximately 30 m adjacent LW105). Furthermore, evidence suggests some positive groundwater pressures are now being recorded in the shallow Permian sediments above UG1 (PZ 130 VWP 38.5 m).
- To date, no groundwater drawdown has been inferred from GWMP monitoring data at more than 5 km from MCO operations, although it is likely that the confined pressure response in the Ulan Seam has propagated further than this distance.
- From Figure 6.21 it can be inferred that no groundwater drawdown in the Tertiary sediments has been observed beyond 1 km from MCO activities.



LEGEND

- Drainage
- UG Mine plan
- Approximate Extent of OC Mining 2023
- Mine Extent (February 2023)

Estimated drawdown (m)

- 0 to 2 m
- 2 to 5 m
- 5 to 20 m
- 20 to 30 m
- 30 to 52 m

Formation

- Tertiary Sediments/Paleochannel
- Triassic
- Permian
- Jurassic
- Ulan Seam
- Marrangaroo Conglomerate
- Basement

NCID: No Clearly Identifiable Drawdown as at March 2023
** Indicates Lower Confidence Estimate

Groundwater Assessment for Moolarben UG4 Compliance Conditions (MOO5001.001)

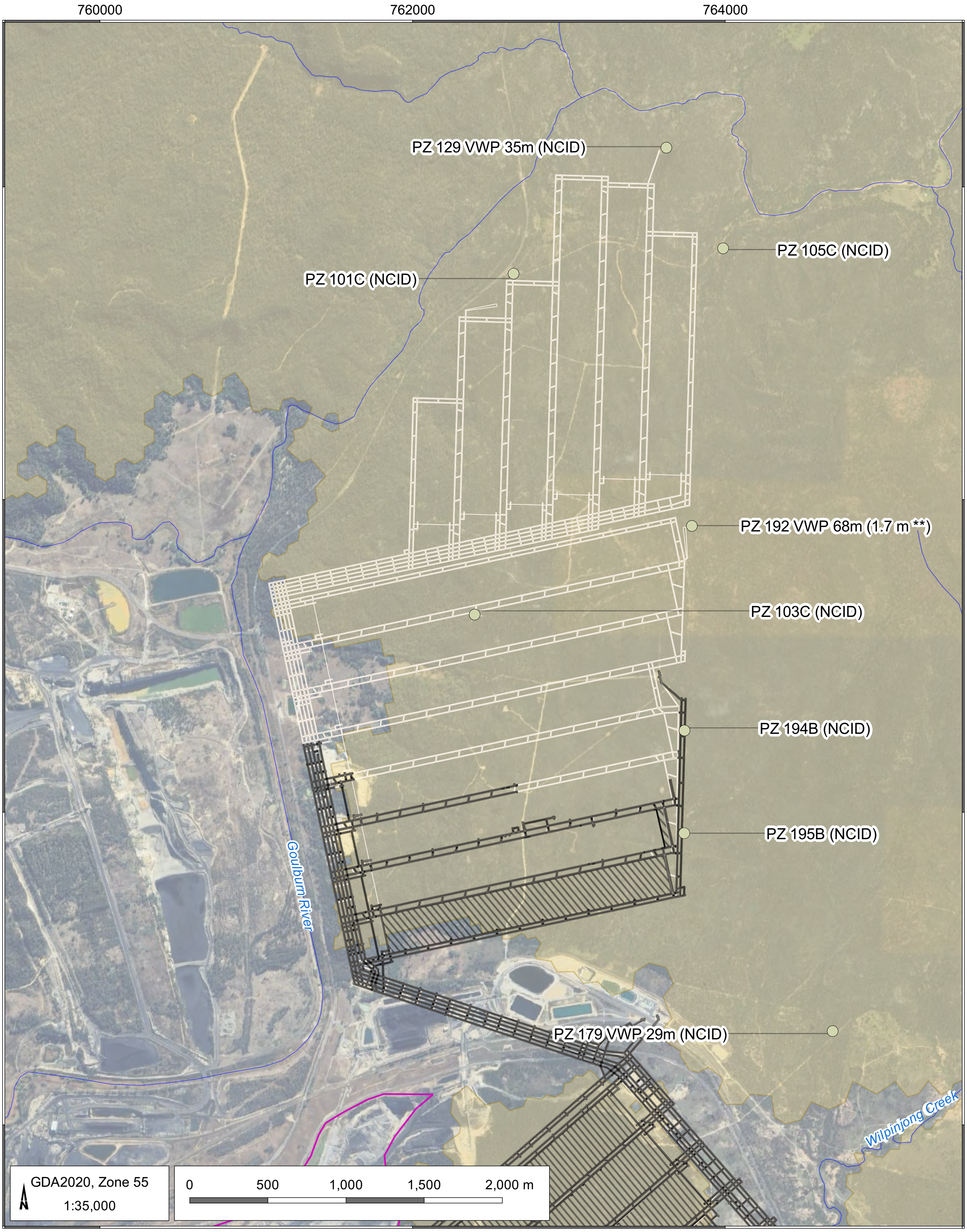
Estimated Drawdown

AGE

DATE 31/08/2023

FIGURE No: **6.16**

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:\Projects\MOO5001.001 UG4 Compliance Conditions\3_GIS\Workspaces\001_Deliverable1\06.16_MOO5001.001_Estimated Drawdown at MCO.qgz



LEGEND

- Drainage
- UG Mine plan
- Approximate Extent of OC Mining 2023
- Modelled Triassic Extent
- Mine Extent (February 2023)

Triassic (Drawdown in meters)

- 0 to 2 m
- 2 to 5 m
- 5 to 20 m
- 20 to 30 m
- 30 to 52 m

NCID: No Clearly Identifiable Drawdown as at March 2023

** Indicates Lower Confidence Estimate

Groundwater Assessment for Moolarben UG4 Compliance Conditions (MOO5001.001)

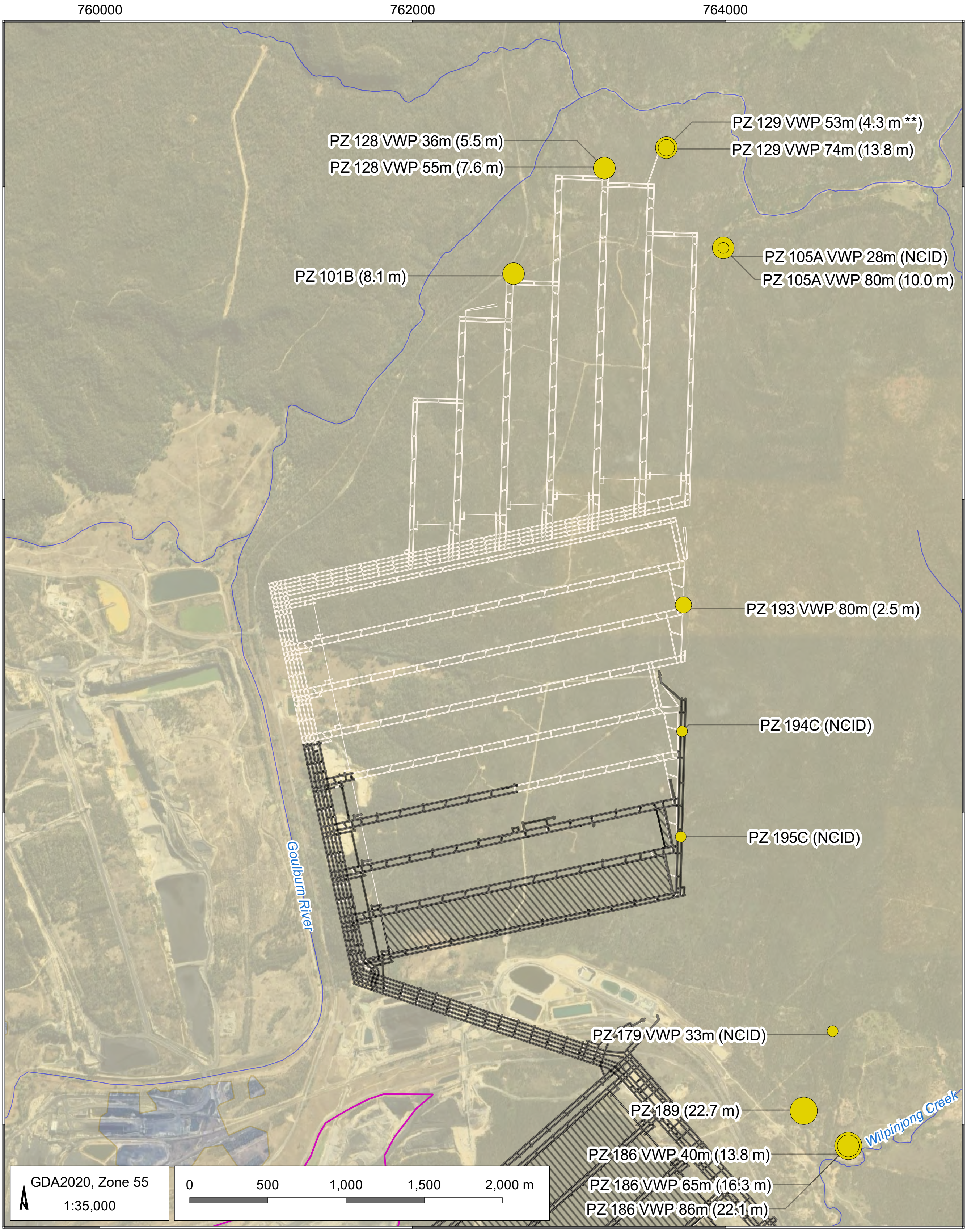
Estimated Triassic Drawdown (UG4)

AGE

DATE 31/08/2023

FIGURE No: **6.17**

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:\Projects\MOO5001.001 UG4 Compliance Conditions\3_GIS\Workspaces\001_Deliverable1\06.17_MOO5001.001_Estimated Triassic Drawdown (UG4).qgz



LEGEND

- Drainage
- UG Mine plan
- Approximate Extent of OC Mining 2023
- Modelled Permian Extent
- Mine Extent (February 2023)

Permian (Drawdown in meters)

- 0 to 2 m
- 2 to 5 m
- 5 to 20 m
- 20 to 30 m
- 30 to 52 m

NCID: No Clearly Identifiable Drawdown as at March 2023
** Indicates Lower Confidence Estimate

Groundwater Assessment for Moolarben UG4 Compliance Conditions (MOO5001.001)

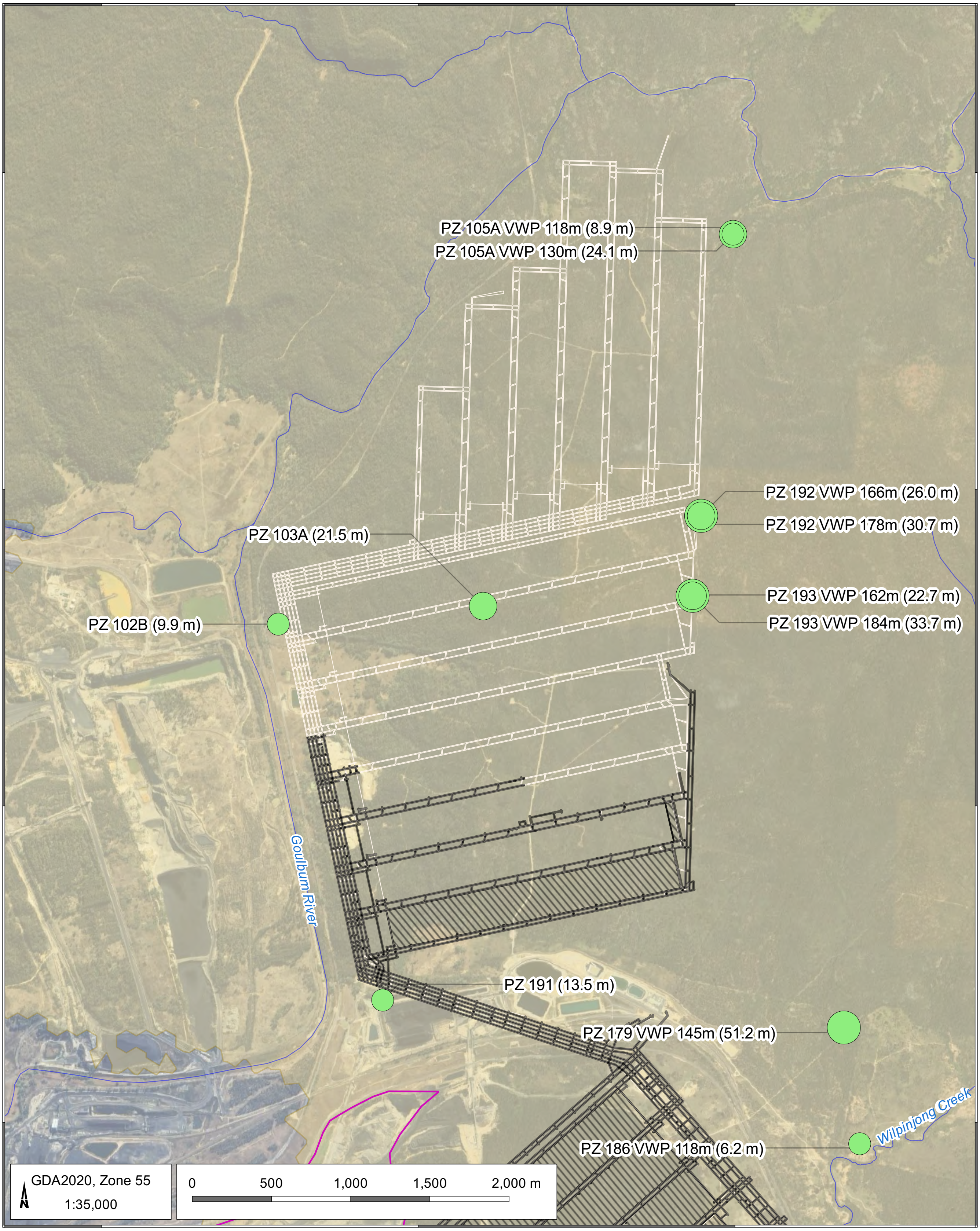
Estimated Permian Drawdown (UG4)

AGE

DATE 31/08/2023

FIGURE No: **6.18**

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:\Projects\MOO5001.001 UG4 Compliance Conditions\3_GIS\Workspaces\001_Deliverable1\06.17_MOO5001.001_Estimated Triassic Drawdown (UG4).qgz



LEGEND

- Drainage
- UG Mine plan
- Approximate Extent of OC Mining 2023
- Modelled Ulan Extent
- Mine Extent (February 2023)

Ulan (Drawdown in meters)

- 0 to 2 m
- 2 to 5 m
- 5 to 20 m
- 20 to 30 m
- 30 to 52 m

NCID: No Clearly Identifiable Drawdown as at March 2023
** Indicates Lower Confidence Estimate

Groundwater Assessment for Moolarben UG4 Compliance Conditions (MOO5001.001)

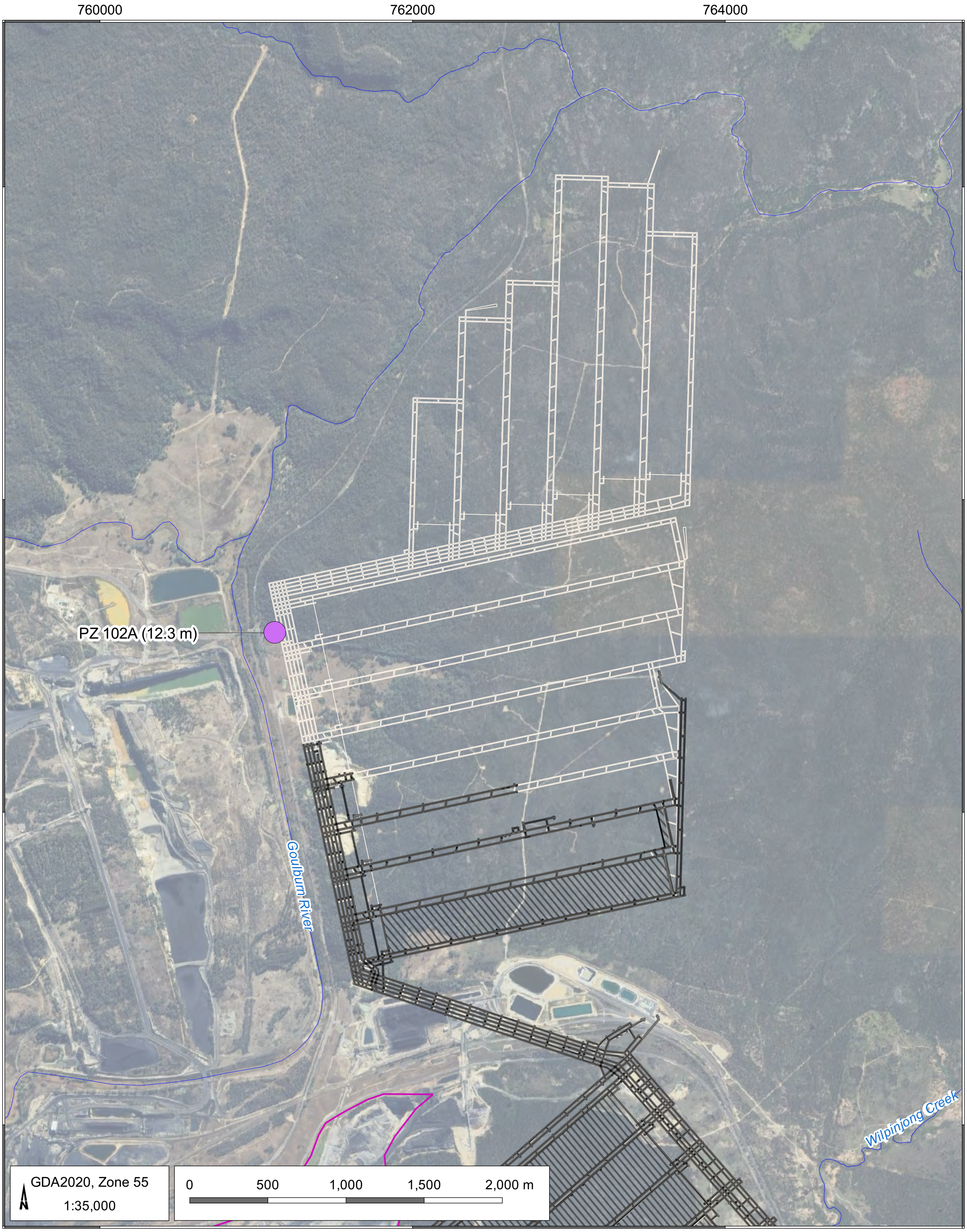
Estimated Ulan Drawdown (UG4)

AGE

DATE 30/08/2023

FIGURE No: **6.19**

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:\Projects\MOO5001.001 UG4 Compliance Conditions\3_GIS\Workspaces\001_Deliverable1\06.17_MOO5001.001_Estimated Triassic Drawdown (UG4).qgz



LEGEND

- Drainage
- UG Mine plan
- Approximate Extent of OC Mining 2023
- Mine Extent (February 2023)

Marrangaroo Conglomerate (Drawdown in meters)

- 0 to 2 m
- 2 to 5 m
- 5 to 20 m
- 20 to 30 m
- 30 to 52 m

NCID: No Clearly Identifiable Drawdown as at March 2023
** Indicates Lower Confidence Estimate

Groundwater Assessment for Moolarben UG4 Compliance Conditions (MOO5001.001)

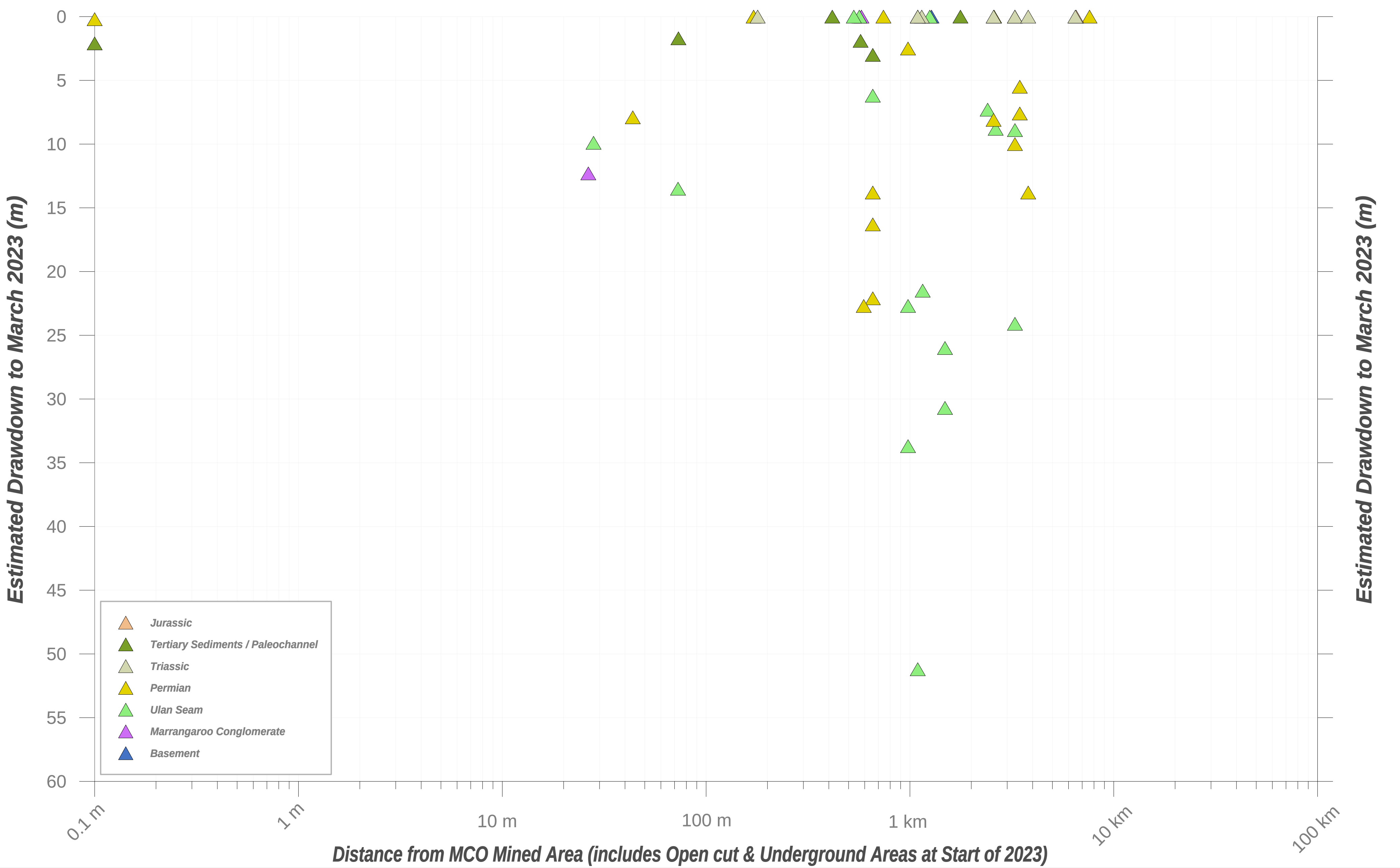
Estimated Marrangaroo Conglomerate Drawdown (UG4)

AGE

DATE 30/08/2023

FIGURE No: **6.20**

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:\Projects\MOO5001.001 UG4 Compliance Conditions\3_GIS\Workspaces\001_Deliverable1\06.17_MOO5001.001_Estimated Triassic Drawdown (UG4).qgz



Estimated Groundwater Drawdown verses Distance from Mine Activities
Moolarben Groundwater Monitoring
Moolarben Coal Operations - UG4 Groundwater Assessment Report

△ △ △ *Estimated Drawdown*

AGE

DATE
29/07/2023

FIGURE No:
6.21

6.9 Groundwater Quality

Groundwater quality is regularly monitored at the Moolarben Coal Complex from several monitoring bores (refer Section 6.2). These bores are screened in different hydrogeological units, and it is a general observation that water quality indicators are highly variable across the site.

This section provides a brief overview of the groundwater quality at MCC and helps to support the hydrogeological conceptual model, especially with respect to the understanding of Triassic and Permian leakage.

6.9.1 Salinity

The following observations can be made:

- Triassic sandstone: Average TDS of approximately 900 mg/L;
- Permian: Average TDS of approximately 1900 mg/L;
- Ulan Seam: Average of approximately 1200 mg/L;
- Marrangaroo Conglomerate: Average of approximately 1500 mg/L; and
- Basement: Average TDS of 2200 mg/L.

6.9.2 Major ions

The following observations relating to major ions can be made (after AGE 2022a):

- The groundwater in the undifferentiated alluvium is generally of sodium chloride type water, with some minor bicarbonate;
- The significant majority of groundwater samples from the Tertiary palaeochannel consists of sodium chloride type waters. A limited number of samples presented sodium chloride waters with minor magnesium and bicarbonate ions;
- The groundwater in the Triassic sandstone is generally composed of sodium chloride type waters, with minor cations generally consisting of magnesium, and minor ions of sulphate and bicarbonate. One sample was bicarbonate dominant;
- Permian groundwaters presented a larger range of constituents. The majority of sampled groundwater from the Permian monitoring bores consists of sodium / magnesium – chloride type water. A significant number of samples were sodium chloride dominant, while the rest of the samples included mixtures of cation ratios, but generally with bicarbonate and chloride anions;
- The most dominant water type from sampled Ulan Seam monitoring bores was of sodium / magnesium - chloride / bicarbonate type water. Mixtures of minor calcium and magnesium, and bicarbonate and sulphate generally made up the minor ion constituents;
- Groundwater sampled from the Marrangaroo Conglomerate yielded a broad mixture of analytes, but typically sodium dominant, with some magnesium and calcium cations. Major ions were generally chloride dominant, but also included sulphate dominant anions, with minor bicarbonates; and
- Not all basement groundwater samples passed the standard ion balance test. Samples that did pass the test consisted of a generally different water type than other waters sampled. Calcium sulphate type groundwater was apparent in one sample, while this was duplicated in other basement bores which did not pass the standard ion test also. A second bore consisted of sodium – chloride / sulphate type water.

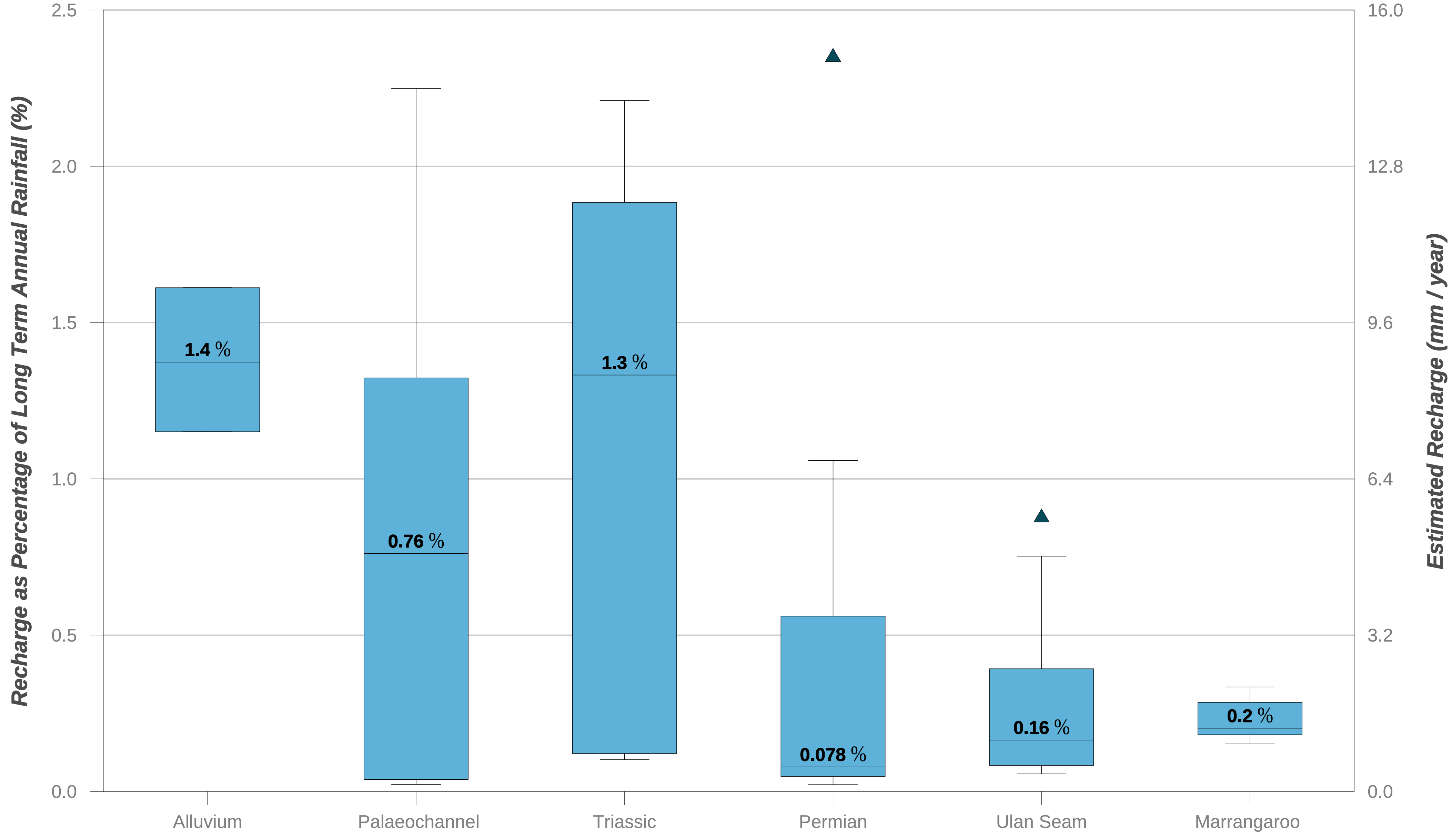
6.10 Groundwater Recharge

Recharge to the groundwater system occurs by the direct infiltration of rainfall and downward percolation through the near surface weathered rock (and alluvium where present). Recharge to the deeper units within the Permian coal measures occurs by downward seepage into the units where they subcrop beneath the alluvium or weathered rock cover.

Figure 6.22 provides estimates of groundwater recharge to each of the main Hydrostratigraphic units at MCC. Estimation was based on the chloride mass balance method, using depositional chloride rates from Davies and Crosbie (2014). Monitoring sites were selected where each of the units monitored were either subcropping or had a screened interval that was only marginally below the water table. As per standard box and whisker plots, the median value (as a percentage of annual rainfall) is reported for each hydrogeological unit.

Recharge to the groundwater system at the MCC is estimated to be less than two percent of annual rainfall. This estimate aligns with the estimates completed by Mackie Environmental Research (2009) when assessing groundwater impacts to the adjacent Ulan Coal Operation.

Mackie (2009) reported that water tables and groundwater pressures in the saturated strata are sustained by rainfall infiltration to the regolith and to underlying hard rock layers with estimates of recharge to deep hard rock strata varying from close to zero, to no more than about 2% of annual rainfall.



Groundwater Recharge Rates estimated by Chloride Mass Balance
Moolarben Groundwater Conceptualisation
Moolarben Coal Operations - UG4 Groundwater Assessment Report

Outlier >> IQR X 5
Box - 1st to 3rd Quartiles
Interquartile Range x 1.5

AGE

DATE
29/07/2023

FIGURE No:
6.22

6.11 Groundwater / Surface Water Interaction

The Goulburn River is likely a losing stream along the full length of the Goulburn River Diversion. This is due in part to groundwater depressurisation and the lowering of the watertable from historical mining activities, as well as changes to the natural flow regime.

Recent groundwater monitoring data from PZ 102C VWP 28 m (which was completed in 2022) support this hypothesis, given the comparison of measured hydraulic heads with Goulburn River Diversion levels ('stage heights'). To gain a better understanding of the groundwater / surface water interaction processes further, Goulburn River stage heights were compared to the closest MCO piezometers groundwater levels. The shallowest monitoring points were selected, as they are deemed to be most representative of the regional watertable and provide the best point of comparison.

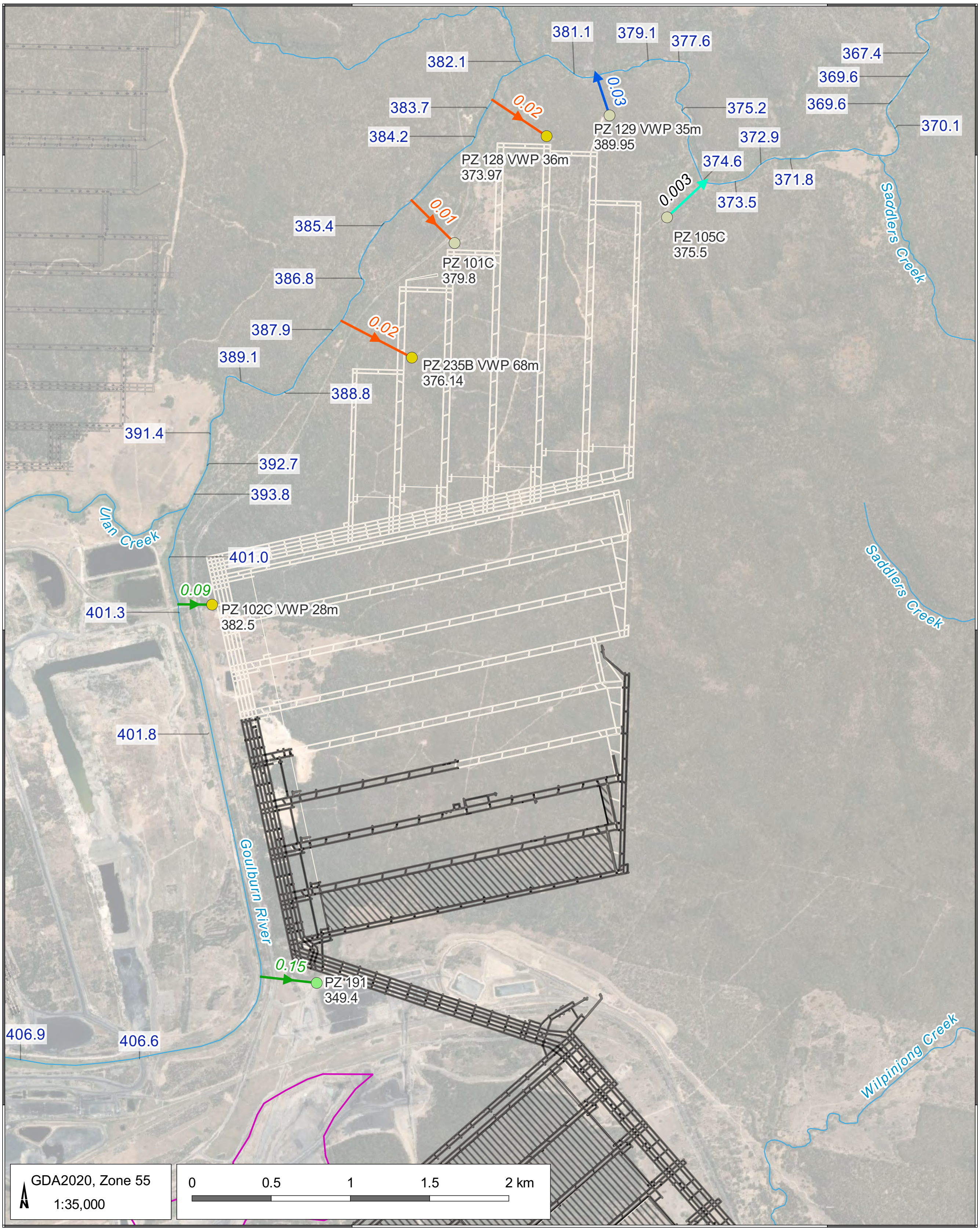
Figure 6.23 presents a comparison of the Goulburn River (including the diversion) stage heights and recent groundwater level monitoring data. For each piezometer, the hydraulic gradient was calculated from the perpendicular distance to the river, and its vector (direction) is displayed as either a gaining or losing stream. Hydrogeological cross section A-A' which is presented in Section 6.14 shows this relationship in cross section.

The following can be inferred from Figure 6.23:

- Adjacent UG4, flow occurs from the Goulburn River Diversion towards UG4, with the calculated hydraulic gradients being 3 to 10 times greater than the other (calculated) regional hydraulic gradients, because these gradients are representative of a disconnected surface water / groundwater system.
- To the west of LW409 and LW412, and to the north of LW412, the Goulburn River has been mapped as a losing stream, with much smaller hydraulic gradients, commensurate with a connected surface water / groundwater system.
- To the north and northeast of LW414, the Goulburn River has been mapped (as at February 2023) as a gaining stream, with hydraulic gradients commensurate with those on the western side where the river is likely losing water to the groundwater system.
- Groundwater data from PZ 105C suggests that to the northeast of LW414, the Goulburn River has switched between a losing and gaining stream, in response to longer term climatic conditions.
- To the north and northeast of LW414, at least some component of this flow towards the Goulburn River may discharge to the rocky cliff faces which occur on the southern side of the Goulburn River (and get evaporated due to the sheer break in slope and likely anisotropy).
- With comparison to Figure 6.4, groundwater flow to the north of LW412 is consistent with the movement of groundwater towards the Goulburn River where it discharges.

As per the discussion in Section 6.5.1, groundwater flow paths in the Triassic sandstone have been inferred from the groundwater contours, and in turn, a groundwater flow net has been used to infer the potential Triassic recharge area which may eventually discharge to the Goulburn River.

This area has been calculated as 15.6 square km. If the average annual rainfall is 650 mm/year (Section 4.1.1) and recharge to the Triassic sandstone is assumed to be 2 % of annual rainfall (i.e. an upper range estimate and higher than the chloride mass balance recharge estimate detailed in Section 6.10), then this would provide an upper bound (maximum) pre-mining long term baseflow estimate to the southern side of the Goulburn River of around 200 ML/year. As per the current hydrogeological conceptualisation, groundwater recharge to the Triassic sandstone will naturally provide downward vertical leakage to the lower Hydrostratigraphic units, and also discharge through evapotranspiration in locations where the depth to water is relatively shallow (including the break of slope at cliff faces on the southern side of the Goulburn River). This upper range estimate should therefore be considered as a guide only for identifying anomalous groundwater baseflow predictions, in the absence of additional streamflow data which could be used to inform baseflow estimates.



LEGEND

- Approved Ulan Underground Mine Plan
- UG Mine Plan
- Drainage (River Stage mRL)
- Approximate Extent of OC Mining 2023
- Mine Extent (February 2023)
- Triassic Bores
- Permian Bores
- Ulan Bores
- Bore ID
- RSWL

Hydraulic Gradient

- Gaining Stream
- Gaining Stream (Historically Switches Between Losing and Gaining Stream)
- Losing Stream
- Losing Stream (Disconnected)

Groundwater Assessment for Moolarben UG4 Compliance Conditions (MOO5001.001)

Surface Water Groundwater Interaction

AGE

DATE 30/08/2023

FIGURE No: **6.23**

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:\Projects\MOO5001.001 UG4 Compliance Conditions\3_GIS\Workspaces\001_Deliverable1\06.23_MOO5001.001_Goulburn River Hydraulic Gradients.qgz

6.11.1 Baseflow estimation

As described in Section 4.2.3, a number of streamflow gauging sites exist near the MCC (Figure 4.1). Flow gauging data from these stations has not been continuous through history, and not all surface flow data is relevant or useful for UG4 assessments.

Table 6.5 provides details of the surface water data made available for this groundwater technical report. Of the data available, three sites are primarily of interest:

- UMC SW01 on the Goulburn River. This site is located downstream of the confluence of Moolarben Creek and Sportsmans Hollow Creek;
- UMC SW02 on the Goulburn River. This site is located downstream of the Goulburn River Diversion; and
- UMC SW05 on Moolarben Creek, noting that this gauging station is directly downstream of the Moolarben Dam, and can be impacted by the surface water storage capacity of the dam.

Table 6.5 Available Surface Water Gauging Station Flow Records

Station	Description	Records Supplied
SW04	Murragamba Creek at Ulan - Wollar Road.	June 2019 - April 2022
SW05	Moolarben Creek on Ulan Road. Washed away in flooding in 2010.	February 2010 - October 2010
SW11	Bora Creek on Ulan Road.	February 2010 - October 2010
SW15	Wilpinjong Creek at Red Hill.	February 2010 - October 2010 June 2019 - April 2022
SW17	Eastern Creek on Ulan - Wollar Road.	January 2019 - October 2020 March 2021 - December 2021
UMC SW01	Goulburn River, located adjacent Spring Street at Ulan, just downstream of the confluence of Moolarben Creek and Sportsmans Hollow Creek. Ulan operated site, data provided through data sharing agreement.	January 2019 - April 2022
UMC SW02	Goulburn River downstream of the diversion. Located just off Ulan Road. Ulan operated site, data provided through data sharing agreement.	January 2016 - December 2016 January 2019 - April 2022
UMC SW05	Moolarben Creek at the Moolarben Dam, adjacent Lagoons Road. Ulan operated site, data provided through data sharing agreement.	November 2011 - December 2012 January 2016 - December 2016 July 2019 - April 2022

Figure 6.24 to Figure 6.30 present the stream flow discharge measurements together with the calculated groundwater baseflows, for sites UMC SW01, UMC SW01 and UMC SW05 respectively. Baseflows have been separated using the Baseflow Index (BFI) tool (University of Oslo, 2015).

A summary of the groundwater baseflow estimates follows:

- Data from the Upper Goulburn River (UMC SW01) gauging station suggests average groundwater baseflows of approximately **150 ML/yr** occurred to the upstream tributaries which feed into the Goulburn River during the relatively drier period between January 2019 to February 2020. Approximately 520 mm of rainfall occurred in these 14 months equating to an average annual rainfall of around 440 mm.
- Data from the Upper Goulburn River (UMC SW01) gauging station suggests average groundwater baseflows of approximately **3,600 ML/yr** occurred to the upstream tributaries which feed into the Goulburn River during the wetter period between July 2021 to March 2022. Approximately 690 mm of rainfall occurred in these 9 months equating to a higher than average annual rainfall of around 920 mm.

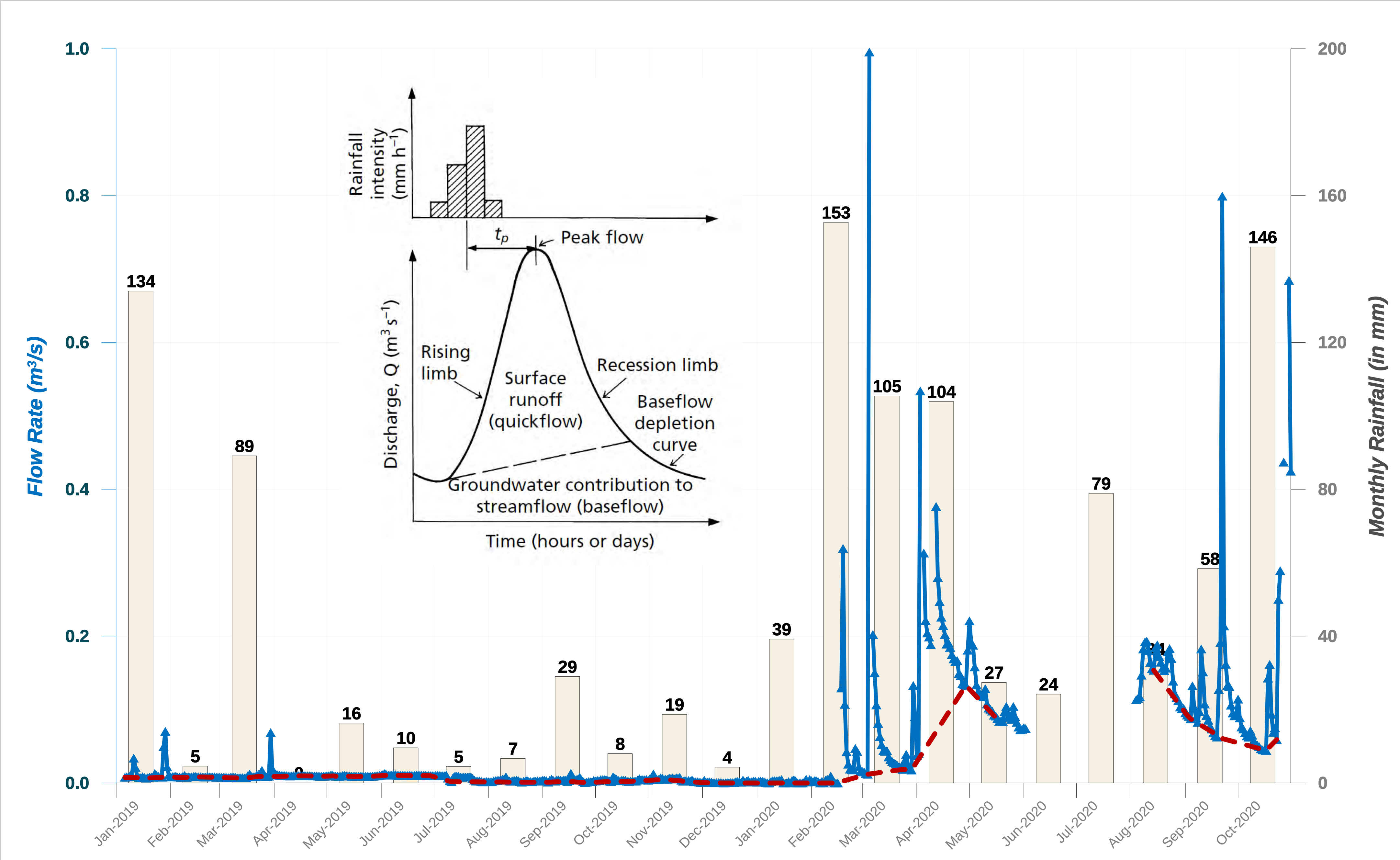
- Data from the Goulburn River Downstream gauging station (UMC SW02) suggests average groundwater baseflows of approximately **1,900 ML/yr** occurred to the Goulburn River during the relatively drier period between January 2019 to January 2020. The analysed period occurs before approved mine discharges from MCC commenced. More recent monitoring data can no longer be used to infer these baseflow incursions due to approved mine discharges. Figure 6.4 suggests the most likely origin of this baseflow is from the western side of the Goulburn River. Approximately 360 mm of rainfall occurred over the 13 months selected for baseflow estimation, which equates to an average annual rainfall of 340 mm (i.e. just over 50% of the long term average).
- Data from the Goulburn River Downstream gauging station (UMC SW02) suggests that groundwater baseflows can not be estimated following the commencement of UMC and MCC approved mine discharges. Approximately **15,800 ML/yr** of flow has been sustained through the wetter period between February 2020 to February 2022, following the commencement of mine approved discharges. Approximately 1870 mm of rainfall occurred in these 25 months equating to an average annual rainfall of 900 mm.
- Data from the Moolarben Creek Dam (UMC SW05) gauging station suggests average groundwater baseflows of approximately **50 ML/yr** occurred to the Moolarben Creek, Lagoon Creek and Ryan's Creek during the relatively average climate conditions between January 2016 to December 2016. Approximately 740 mm of rainfall occurred in these 12 months.
- Data from the Moolarben Creek Dam (UMC SW05) gauging station suggests average groundwater baseflows of approximately **680 ML/yr** occurred to the Moolarben Creek, Lagoon Creek and Ryan's Creek during the wetter climate conditions between June 2020 to March 2022. Around 1620 mm of rainfall occurred over these 22 months, equating to an average annual rainfall of approximately 890 mm.

Streamflow records for historic Moolarben Creek site (SW05) are not reliable enough to provide a reasonable analysis of baseflow estimation.

If groundwater baseflow within Moolarben Creek (and its tributaries) was primarily responsible for meeting the evaporative capacity of the Moolarben Dam during times of drought (plus the additional reported estimated leakage through the dam wall), then baseflow in Moolarben Creek during times of drought would be of the order of **180 – 225 ML/year**. During wetter years, groundwater baseflow contributions could increase significantly, as the Quaternary alluvium storage is replenished, bringing contributions to **680 ML/year or higher.**

As approved UMC and MCC mine discharges ensure that flows in the Goulburn River are now persistent (MCC discharges started occurring to the diversion upstream of UG4 during 2020), effective baseflow estimation to the Goulburn River from streamflow data is now problematic due to the influence of the licensed discharges, which are not related to climatic conditions.

Notwithstanding, MCO is installing two new stream gauges on the Goulburn River upstream and downstream of "The Drip". Data from these gauges, along with coincident records of licensed discharges and climatic data, will provide an opportunity to further refine likely baselow contributions to and from the Goulburn River.

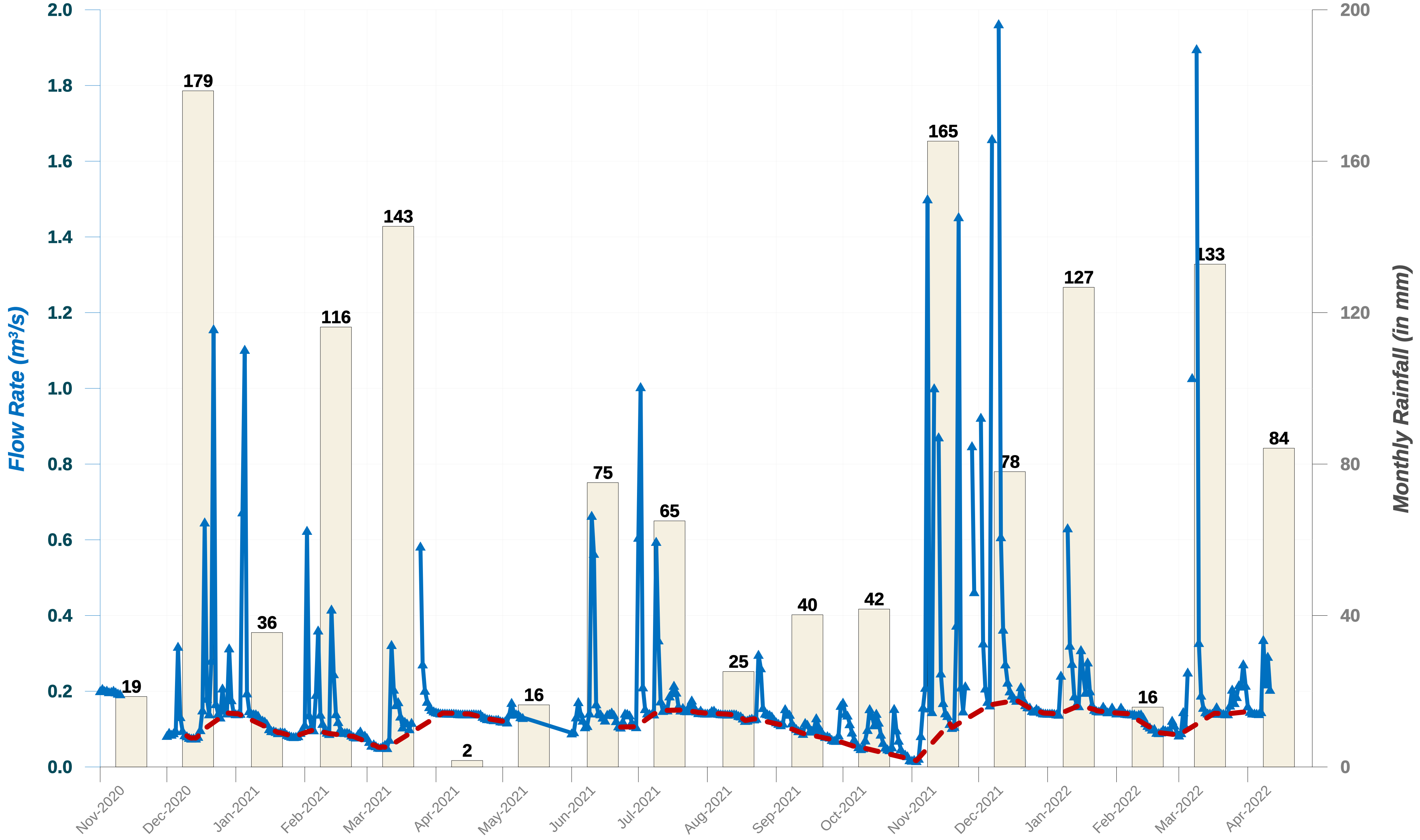


Upper Goulburn River (UMC SW01) - January 2019 to October 2020
Groundwater Baseflow Separation - Groundwater & Surfacewater Conceptualisation
Moolarben Coal Operations - UG4 Groundwater Assessment Report

AGE

DATE 17/08/2023

FIGURE No: **6.24**

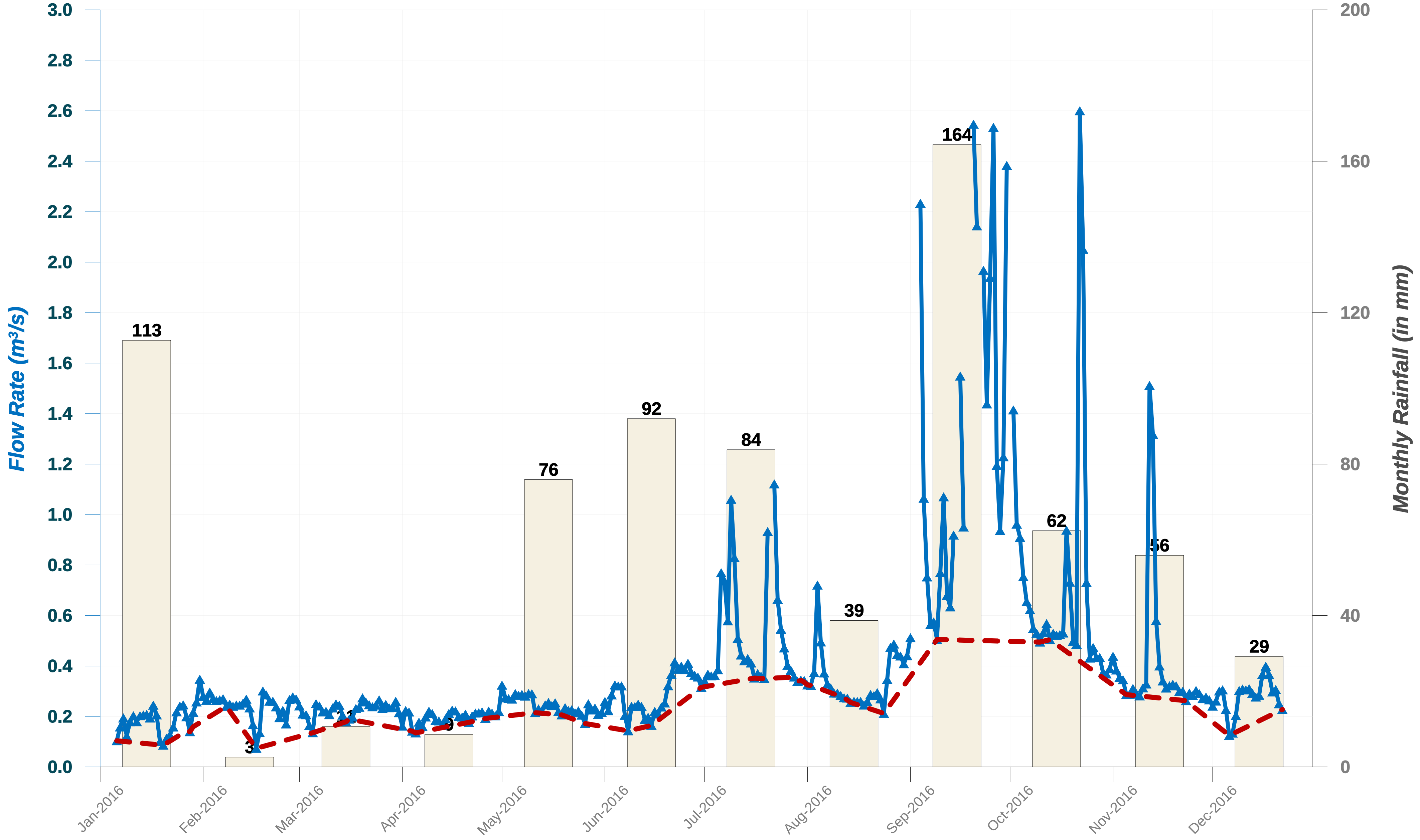


Upper Goulburn River (UMC SW01) - November 2020 to April 2022
Groundwater Baseflow Separation - Groundwater & Surfacewater Conceptualisation
Moolarben Coal Operations - UG4 Groundwater Assessment Report

AGE

DATE
17/08/2023

FIGURE No:
6.25

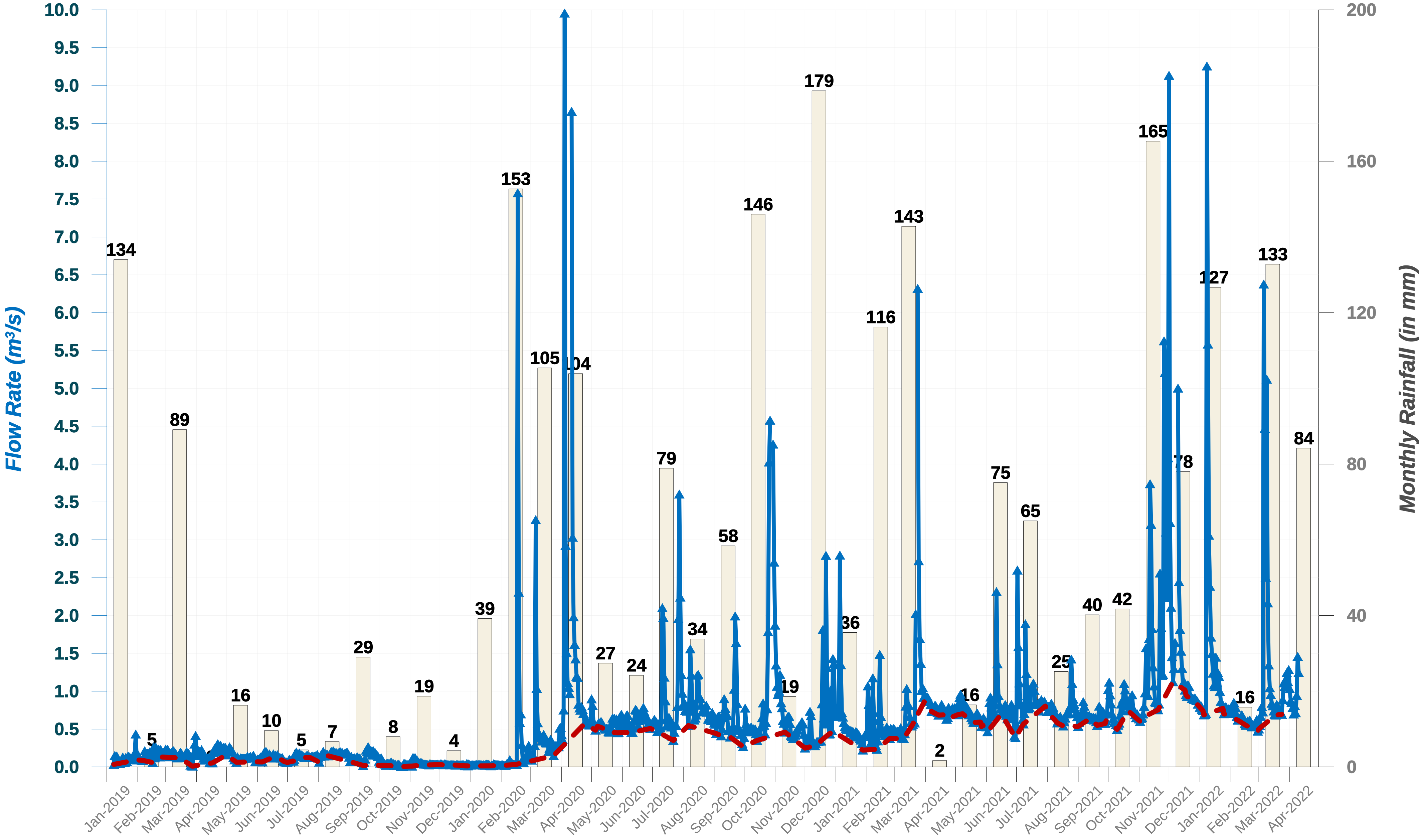


Goulburn River Downstream (UMC SW02) - January 2016 to December 2016
Groundwater Baseflow Separation - Groundwater & Surfacewater Conceptualisation
Moolarben Coal Operations - UG4 Groundwater Assessment Report

AGE

DATE
17/08/2023

FIGURE No:
6.26



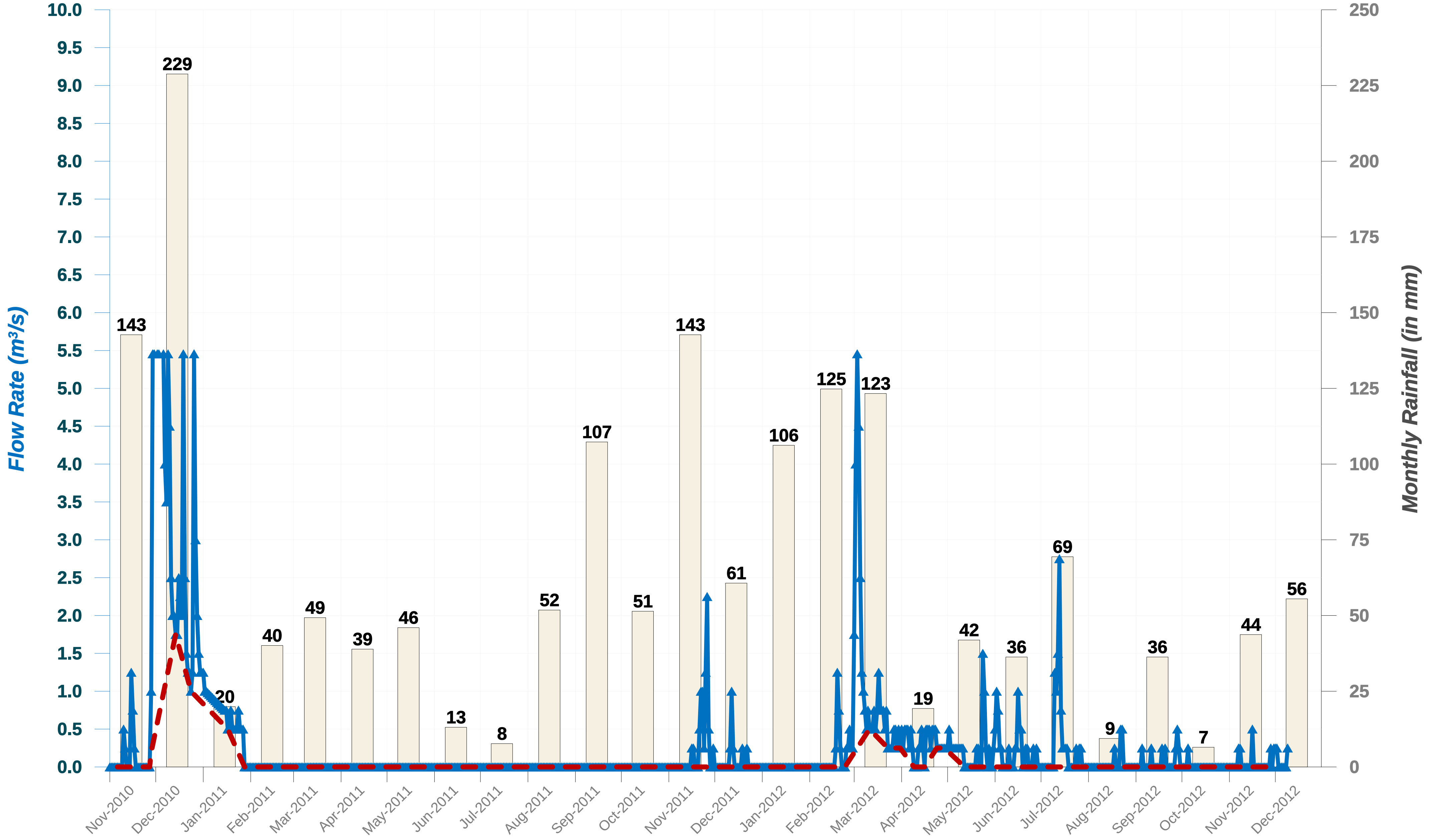
Goulburn River Downstream (UMC SW02) - January 2019 to April 2022
Groundwater Baseflow Separation - Groundwater & Surfacewater Conceptualisation
Moolarben Coal Operations - UG4 Groundwater Assessment Report

Measured Streamflow
Calculated Baseflow
Monthly Rainfall

AGE

DATE
17/08/2023

FIGURE No:
6.27

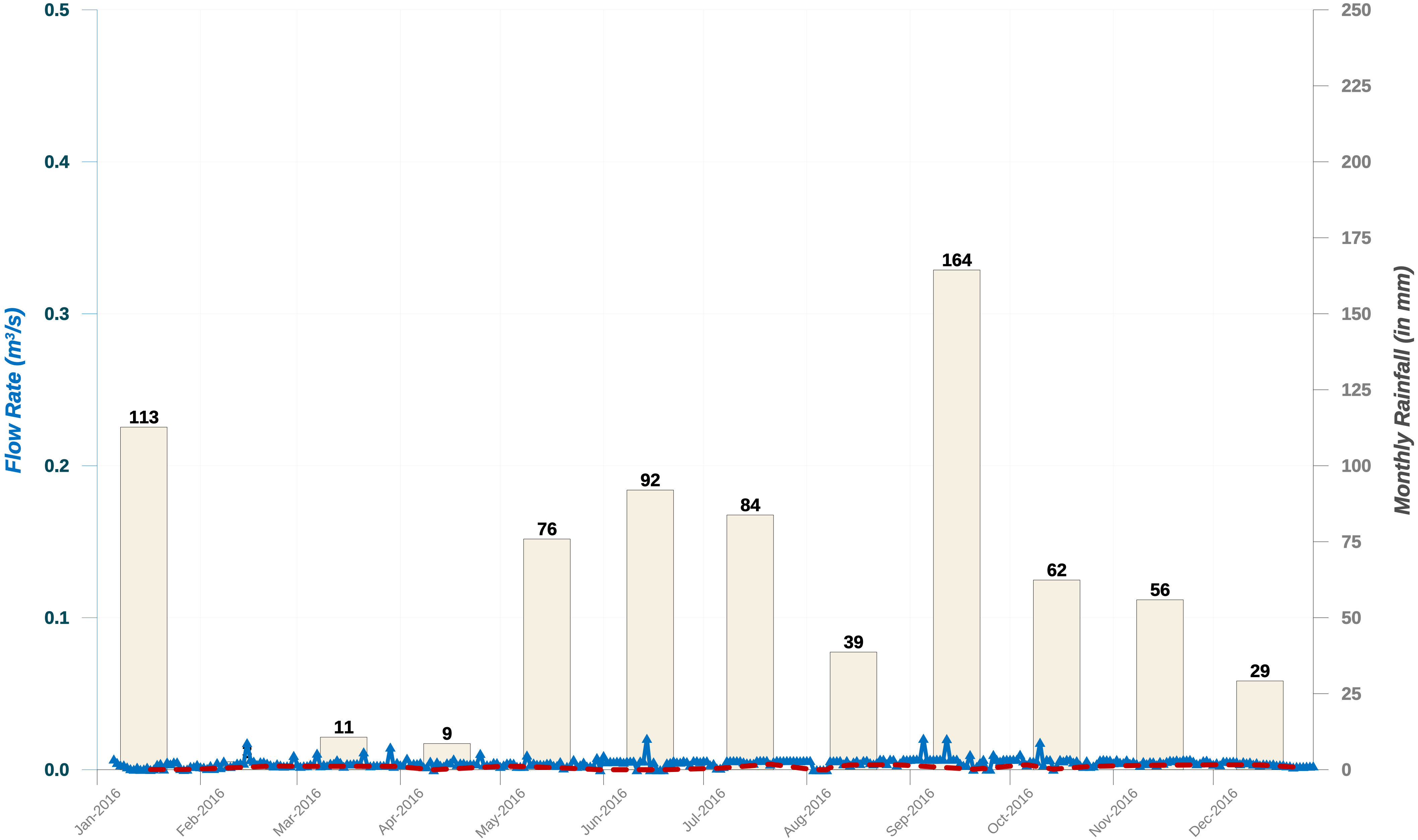


Moolarben Creek at Dam (UMC SW05) - November 2010 to December 2012
Groundwater Baseflow Separation - Groundwater & Surfacewater Conceptualisation
Moolarben Coal Operations - UG4 Groundwater Assessment Report

AGE

DATE
17/08/2023

FIGURE No:
6.28



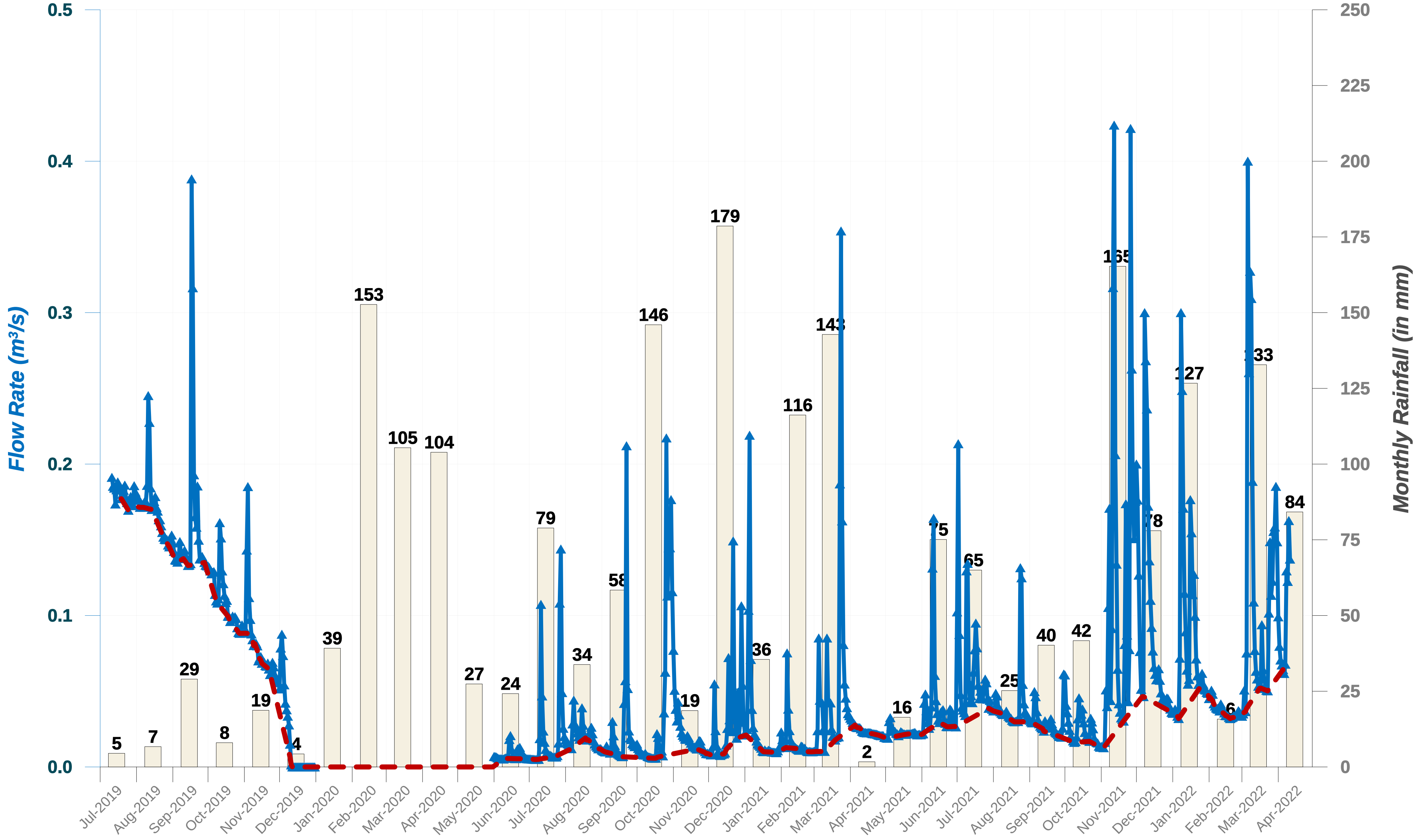
Moolarben Creek at Dam (UMC SW05) - January 2016 to December 2016
Groundwater Baseflow Separation - Groundwater & Surfacewater Conceptualisation
Moolarben Coal Operations - UG4 Groundwater Assessment Report

Measured Streamflow
Calculated Baseflow
Monthly Rainfall

AGE

DATE
17/08/2023

FIGURE No:
6.29



Moolarben Creek at Dam (UMC SW05) - July 2019 to April 2022
Groundwater Baseflow Separation - Groundwater & Surfacewater Conceptualisation
Moolarben Coal Operations - UG4 Groundwater Assessment Report

AGE

DATE
17/08/2023

FIGURE No:
6.30

6.12 Groundwater Ingress to Mining Operations

Measuring mine inflows onsite is quite a complex process. Unlike measuring groundwater levels or pressures, measuring groundwater inflows to opencut pits and underground operations is complicated by many factors. Evaporation, rainfall runoff, pumping for other uses, seepage losses from storages, introduction of other water sources; all of these factors introduce uncertainty into accurately estimating the amount of groundwater inflow to the mining operations.

Groundwater inflows to OC2, OC3 and OC4 are not currently measurable, as evaporation generally far exceeds ingress rates.

Latest (2022) estimates of groundwater inflows (excluding recirculation and process water introduction) to MCC operations are understood to be of the order of:

- OC1 North Void, OC2, OC3, and OC4: too low to be measurable; and
- UG1 & UG4 (first workings) combined: approximately 3,700 ML/yr or 10 ML/d.

6.13 Groundwater Receptors

6.13.1 Groundwater users

Groundwater usage in the area is primarily composed of mine dewatering for the Moolarben Coal Complex and the neighbouring Ulan Mine Complex and Wilpinjong Coal Mine.

There is one private bore in the vicinity of the Moolarben Coal Complex, located to the northeast of UG4. The bore is a relatively shallow bore (24 m) developed in Triassic strata and connected to the river alluvium. The location and baseline condition of this bore is summarised in Table 6.6.

Table 6.6 Baseline Condition of Privately Owned Bores

Work ID	Licence No.	Easting	Northing	Bore Type	Hydrogeological Unit	Water Level (m AHD)	EC (µS/cm)	pH
GW800279	80BL236762	765208	6431971	Domestic	Triassic Narrabeen Group	371 (2020)	730	6.00

Notes: EC = electrical conductivity.
µS/cm = microSiemens per centimetre.
m AHD = metres Australian Height Datum.

6.13.2 The Drip

The Drip is a groundwater dependent ecosystem with local cultural and community significance. The Drip is a cliff face seepage feature located more than 2.5 km north of UG4 Longwall panel 408 and occurs directly adjacent to the northern side of the Goulburn River (Figure 4.1).

Groundwater discharges from The Drip are derived from the perching of groundwater in zones that are exposed in the cliff faces. The perching occurs in the Triassic Narrabeen Group sediments and is formed by accumulations of groundwater above less permeable horizons in the Triassic sequence to the north of the Goulburn River. Groundwater seepage from The Drip occurs at an elevation of approximately 387 to 388 mAHD. The bed of the Goulburn River at that location is approximately 380 mAHD.

Previous groundwater impact assessments have concluded that The Drip will not be affected by the Moolarben Coal Complex. These assertions are reasonable because the Goulburn River effectively forms a 'general head' boundary to the north of UG4 LW412-LW414, in the Triassic lithic sandstone and shallow alluvial sediments which host the Goulburn River. The main mechanisms for potential impacts to affect The Drip, would be through the enhancement of the vertical permeability of the Triassic sandstone (on the northern side of the Goulburn River), or through a reduction in groundwater recharge which supplies flow to The Drip. Neither of these mechanisms are possible from the underground mining of LW401 to LW408.

6.14 Conceptual Groundwater Model Updates

A comprehensive, contemporary analysis has been completed in order to meet conditional approval requirements 3a, 3b and 3f. AGE has assessed all groundwater and surface water data available, including data made available from adjacent mining operations through data sharing agreements. A detailed analysis and comparison of climate data with groundwater head observations has led to a thorough understanding of the hydrogeological behaviour of the system, and its response to previous hydraulic stresses, including natural, climatic stresses, and mining related stresses.

Below is a summary of the work completed to update the hydrogeological conceptualisation for the leakage between the Triassic sandstones and the Permian overburden, update the model conceptualisation of surface water – groundwater connectivity, and consider any geological structural implications:

- hydrogeological database updated with groundwater level and quality data to February 2023;
- detailed analysis and comparison of climate data with groundwater level data;
- provision of hydraulic testing and measured yield results;
- estimation of groundwater drawdown to February 2023;
- production of groundwater contours for all key Hydrostratigraphic units at UG4;
- production of groundwater flow directions for all key Hydrostratigraphic units at UG4;
- assessment of the spatial distribution of Triassic sandstone saturation thickness;
- production of nested multi-level hydrographs for inferring vertical hydraulic gradients;
- analysis of the spatial drawdown distribution in proximity to MCC;
- chloride mass balance recharge estimation;
- surface water – Groundwater hydraulic gradient estimation and connectivity analysis;
- upper bound (guiding estimation) of baseflow to the Goulburn River, based on recharge estimation and flow net mapping;
- baseflow estimations for the Goulburn River prior to mine approved discharges occurring;
- baseflow estimation to upstream Moolarben Creek;
- revision of hydrogeological cross sections with MCO groundwater level data to December 2022;
- addition of PZ 102C VWP and PZ 103D VWP groundwater levels to hydrogeological cross sections;
- update of groundwater contours shown on hydrogeological cross sections;
- detailed hydrogeochemical analysis (for AGE 2022a) which has informed this study; and
- review of the analysis completed by Mine Advice (2023).

AGE has reconstructed the two hydrogeological cross sections originally presented in AGE (2021) for the purpose of illustrating the salient features of the groundwater system in proximity to UG4. The location of the cross section Transect A-A' and Transect B-B' are shown on Figure 5.1 and are presented as Figure 6.31 and Figure 6.32.

The following can be inferred from the two cross sections:

- there has been extensive depressurisation of hard rock aquifers surrounding UG4, as a result of previous and current mining operations;
- groundwater levels in the Permian ICM and Ulan seam have responded to these historic mining activities, however there is no evidence of groundwater drawdown occurring within the Triassic sandstone;
- at all monitoring sites, the vertical hydraulic head gradient is vertically downwards, which implies that the area receives groundwater recharge, and the potential for vertical flow is towards the Ulan Seam;
- groundwater levels in the shallow Permian can approach similar levels to those in the Triassic sandstone, however there is a much greater separation of vertical head differences at depth within the Permian ICM;
- large masses of the Triassic strata are naturally unsaturated;
- the Goulburn River Diversion is effectively a disconnected stream adjacent UG4 LW401 to LW408;

- the Goulburn River is likely a gaining stream near The Drip, however baseflow estimation to this reach of the river is problematic due to the occurrence of approved mine water discharges and no available surface water monitoring station data downstream of The Drip;
- dewatering of the strata directly above LW401 to LW408 is predicted to occur due to the expected height of fracturing and interpolated watertable elevation. As a result, increases to the predicted height of fracturing (from adopting other empirical estimations of fracture height) will have limited effect on the predicted impacts of mining UG4 LW401 to LW408;
- geological structure has not been represented, as only one major geological structure is currently inferred to intersect the UG4 workings and this fault (which spans LW405-408) is thought to have very limited vertical extent, with no mapped offset within longwall panels LW405 or LW408. Observations from mining through the similar minor faults which traverse the UG4 highway had limited significance on total water make, and subsided over a relatively short period of time; and
- the perching of groundwater within the Triassic sandstone associated with The Drip is effectively disconnected from the underling regional watertable. As a result, depressurisation caused by mining at LW401 to 408 will not impact the water supply to The Drip.

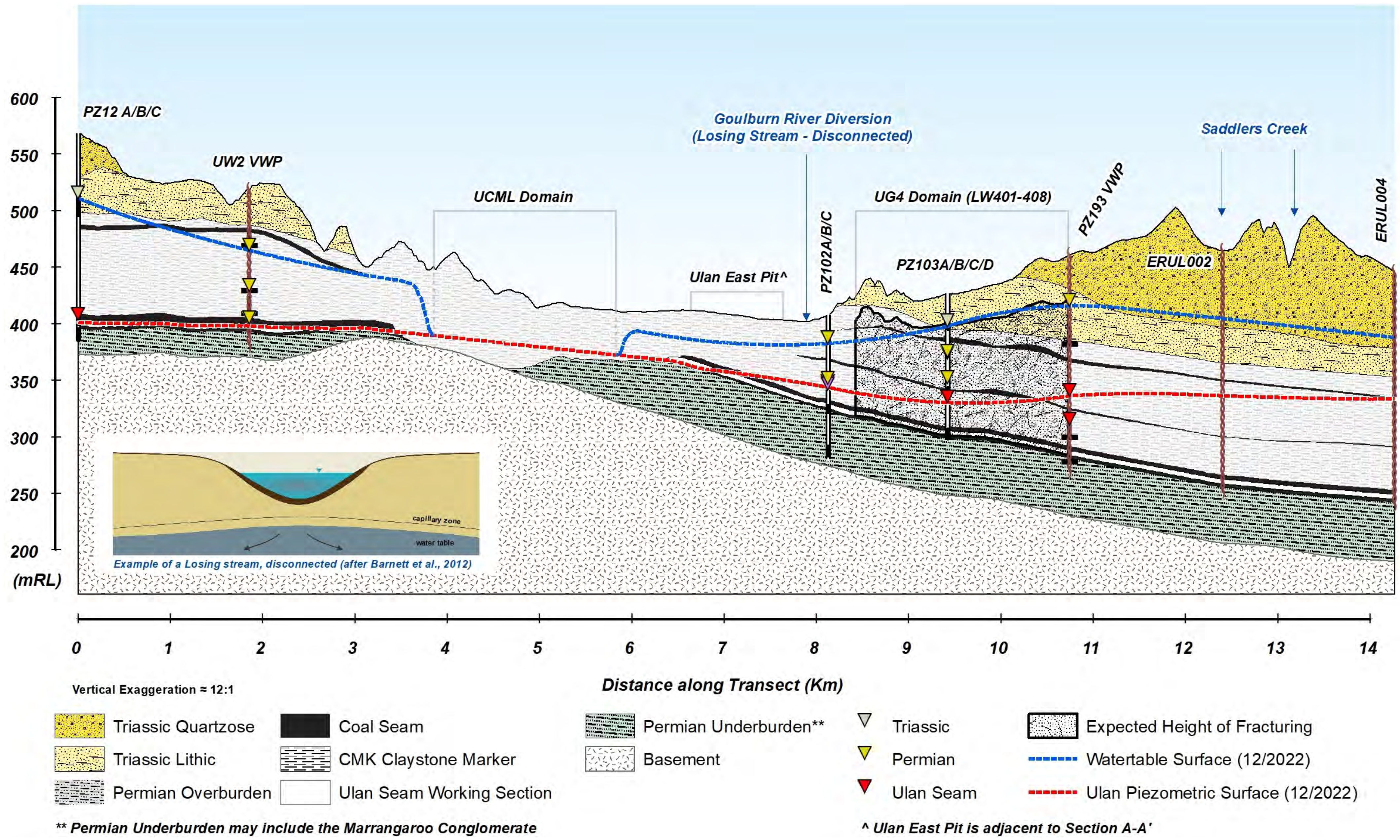
Table 6.7 provides a summary of the conceptual updates and provides recommendations to reduce any residual uncertainty in the contemporary conceptual hydrogeological understanding.

Table 6.7 Conceptual updates and recommendations to address residual areas of uncertainty

Component	Contemporary Understanding	Recommendations
Hydrostratigraphic units	The main hydrogeological units at the Moolarben Coal Complex include: • **Quaternary alluvium** associated with the present day drainage system; • **Tertiary alluvium** associated with the identified palaeochannel that is not related to the present day drainage system; • **Triassic sandstone** consisting of quartzose Triassic and lithic Triassic sandstone; • **Permian Illawarra Coal Measures** consists of a sequence of claystone, mudstone, siltstone, and coal measures, which includes the Ulan Seam near the base of the unit; • **Marrangaroo Conglomerate** – Permian aged conglomerate. • **Basement** Includes Carboniferous volcanics and the Gulgong Granite.	Geological mapping at the MCC and adjoining coal operations provide a detailed and sufficient coverage of the extents and isopachs of these units.
Groundwater recharges	Recharge to the groundwater system at the MCC is estimated to be less than two percent of annual rainfall and aligns with the previous estimates by the work others (including MCC and UMC projects). A median recharge rate of 1.3 % of annual rainfall has been calculated for the Triassic sandstone.	Groundwater monitoring conducted as part of the GWMP is currently sufficient to collect the required data to inform future estimates of recharge.
Groundwater flow mapping	Groundwater flow directions are highly dynamic both spatially and temporally. Groundwater flow directions in the surficial units are dominated by topography and discharge features such as the Goulburn River. Deeper units, particularly the Permian ICM, including the Ulan Seam have been impacted by historic mining and will continue to change with time.	Groundwater monitoring conducted as part of the GWMP is currently sufficient to collect the required data to reconstruct piezometric plans for the key Hydrostratigraphic units in the future.

Component	Contemporary Understanding	Recommendations
Vertical hydraulic gradients	Monitoring at UG4 shows that vertical hydraulic head gradients are vertically downwards, indicating recharge from the Triassic sandstone to the Permian ICM occurs. No data suggests any reversal of vertical hydraulic gradients has occurred. Groundwater levels in the shallow Permian can approach similar levels to those in the Triassic sandstone, however there is a much greater vertical separation at depth within the Permian ICM. Groundwater levels in the Triassic sandstone are generally 25 to 50 m above those measured in the Ulan Seam. Some monitoring data show an increase in vertical hydraulic gradients occurring between the Permian ICM and the Ulan Seam due to mining related activities.	Groundwater monitoring conducted as part of the GWMP is currently sufficient to collect the required data to monitor vertical head gradients in the future.
Saturated thickness of the Triassic sandstone	At LW401-408, the greatest saturated thickness of the Triassic sandstone has been measured at LW404 (44 metres). Along the eastern margin the saturated thickness is expected to range from around 13 m to 23 m. To the south and north, saturated thickness generally decreases to less than 15. To the north of future LW413-LW414, saturated thickness is known to increase to around 38 m.	Groundwater monitoring conducted as part of the GWMP is currently sufficient to collect the required data to monitor the saturated thickness of the Triassic sandstone at UG4 in the future.
Response to climate	Appendix A presents the hydrographs for all GWMP monitoring points and presents compelling evidence to the strong correlation with climate data. This analytical approach achieves an SRMS error of 3.7% based on comparison with the full MCO groundwater dataset.	Groundwater monitoring conducted as part of the GWMP is currently sufficient to perform these kinds of comparisons again in the future. New monitoring data will support this analysis and assist with the identification of any departures from climatic responses.
Hydraulic properties	Hydraulic testing results are generally commensurate with the drillhole logged lithologies. Highest permeabilities have been estimated from testing performed on the Permian coal measures. Some uncertainty exists in the range of likely permeability of the Triassic sandstone and Permian interburden mudstones due to the type of testing required and the current number of tests performed.	If Permian interburden core samples could be collected during the other drilling campaigns, some selected core samples should be retained and sent for laboratory permeability testing. All new Triassic monitoring bores should be completed as standpipes as opposed to VWP installations, and slug tests should be considered on Triassic monitoring bores that have not been tested.
Groundwater quality	• **Triassic sandstone**: Average TDS of approximately 900 mg/L; • **Permian**: Average TDS of approximately 1900 mg/L; • **Ulan Seam**: Average of approximately 1200 mg/L; • **Marrangaroo** Conglomerate: Average of approximately 1500 mg/L; and • **Basement**: Average measured TDS of 2200 mg/L.	Groundwater monitoring conducted as part of the GWMP is currently sufficient to collect the required data to monitor groundwater quality changes in the future.

Component	Contemporary Understanding	Recommendations
Response to stress	No clearly identifiable groundwater drawdown can be inferred within the Triassic sandstone, after 13 years of MCO operations. At UG4 LW401-408 a maximum groundwater drawdown of approximately 33 m has been inferred at monitoring point PZ 193 within the Ulan Seam. Nested sites show a similar response, with greater drawdowns inferred from the Ulan Seam, and becoming smaller with the increase in depth of cover. This is commensurate with the conceptual model of leakage, whereby the Ulan Seam is depressurised, and overlying units provide vertical leakage towards the Ulan Seam. No drawdown in the Tertiary sediments has been observed beyond 1 km from MCO activities.	Groundwater monitoring conducted as part of the GWMP is currently sufficient to perform similar assessments of response in the future.
Goulburn River Diversion Flow regime	Current data suggests that the Goulburn River Diversion is likely a Losing stream and disconnected (flow regime class e).	Additional shallow and adjacent groundwater monitoring will serve to reduce the uncertainty of this hypothesis. MCO are currently in the process of obtaining the required approvals to expand this type of monitoring.
Goulburn River Diversion Water loss	It is currently difficult to empirically measure or estimate the amount of water loss occurring within the Goulburn River Diversion.	The amount of water loss occurring from the diversion is likely to be small in comparison to groundwater discharges and baseflow incursions incurring to the natural flow regime of the Goulburn River. To reliably quantify these losses may not be possible.
Goulburn River Flow regime	Current data suggests that the Goulburn River likely switches between a flow-through water body and a gaining stream somewhere north of LW414 and just west of The Drip. To the northeast of LW414 data suggests that the river naturally switches between losing and gaining conditions, dependent upon longer term climatic conditions.	Additional shallow and adjacent groundwater level monitoring points will serve to reduce the uncertainty of this conceptual understanding (at the locations of new monitoring points).
Goulburn River Baseflow	A preliminary guiding analysis suggests that groundwater baseflow to the southern side of the Goulburn River will occur at a rate of less than 200 ML/year. Baseflow estimates from the Goulburn River downstream gauging station (UMC SW02) indicate that baseflow from the western side of the Goulburn River may have occurred historically at much higher rates (up to the location of the gauging station), however groundwater contouring suggests that the river may also lose water further north of this gauging station. Given the approved mine discharges occurring currently, the estimation of baseflow to the Goulburn River cannot be repeated.	At least one additional surface water gauging station would be required to be installed downstream of the The Drip to allow for the estimation of total baseflow incursions to the Goulburn River, but even with this infrastructure in place, significant uncertainties would likely exist in the estimation of these baseflows.
Geological Structure	There is no clear reason to incorporate either the single mapped fault which traverses LW405-408 within the current groundwater model, or the minor faults which traverse the UG4 highway. The single mapped fault is thought to have very limited vertical extent, with no mapped offset within longwall panels LW405 or LW408. Observations from mining through similar faults had limited significance on total water make and subsided over a relatively short period of time. The mapped fault does not form an impact pathway beyond the approved mine extent.	MCO currently monitor for increases in water make when mining. No further recommendation.

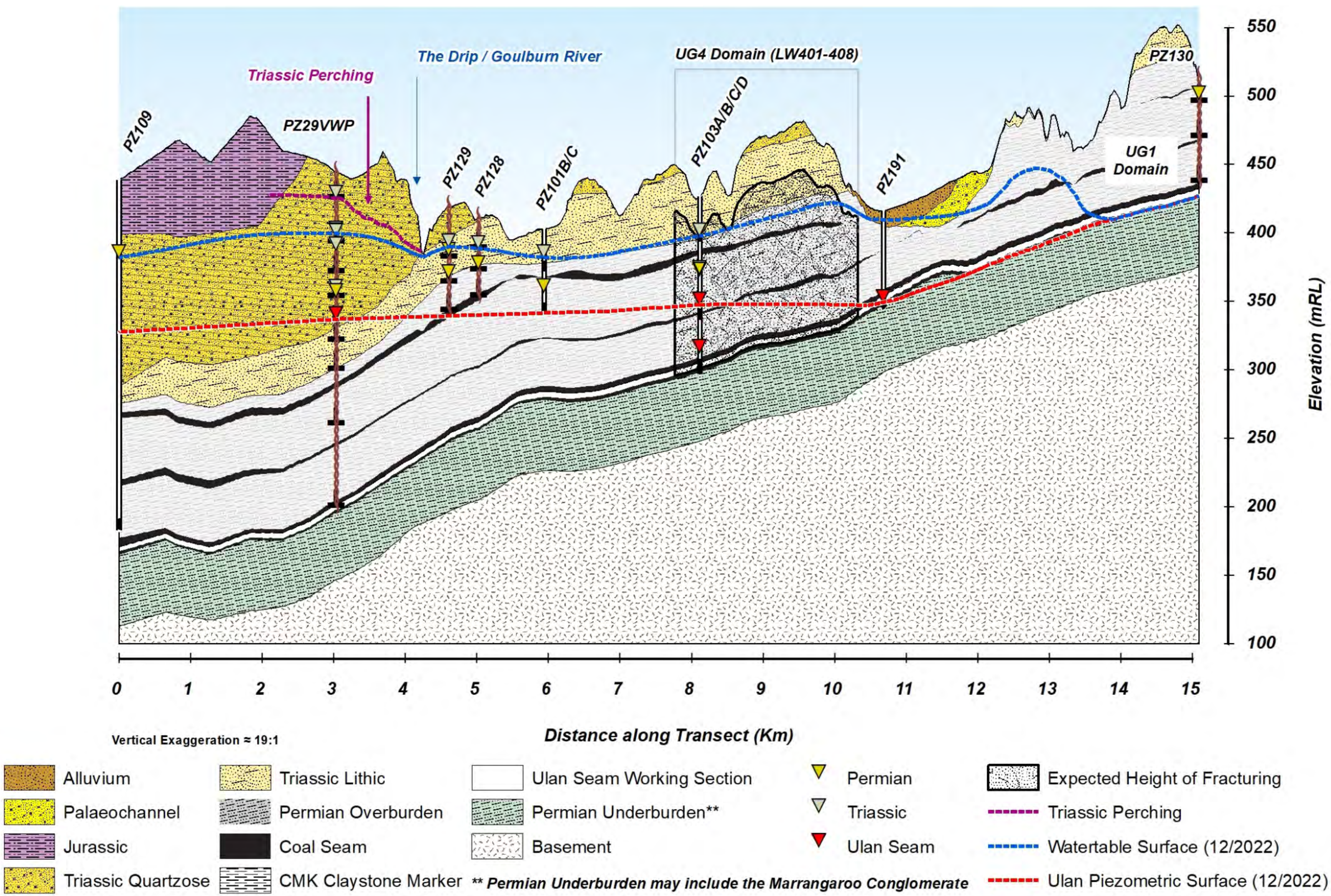


Hydrogeological Conceptual Section A-A' (refer to Figure 5.1 for Transect Location)
Moolarben Groundwater Conceptualisation
Moolarben Coal Operations - UG4 Groundwater Assessment Report

AGE

DATE
17/08/2023

FIGURE No:
6.31



Hydrogeological Conceptual Section B-B' (refer to Figure 5.1 for Transect Location)
Moolarben Groundwater Conceptualisation
Moolarben Coal Operations - UG4 Groundwater Assessment Report

AGE

DATE 09/08/2023

FIGURE No: **6.32**

7 Numerical groundwater model

The previously independently peer reviewed groundwater model (AGE, 2022a) has been further enhanced during 2023, with additional groundwater level data, additional mine inflow observations, and incorporation of hydrogeological conceptual updates presented in this groundwater technical report. The updated numerical model has been used to fulfil Condition 3 of the approval conditions (Table 1.1) as well as assist MCO with future mine water accounting purposes. The model has been updated with the following objectives:

- replicate the historical behaviour of the groundwater regime;
- reassess aquifer drawdown predictions and water balance estimates (particularly mine water inflow volumes and groundwater baseflow losses to the Goulburn River);
- reassess the predicted groundwater take;
- provide revised predictions based on:
  - (i) cumulative impacts from approved mining; and
  - (ii) impacts of only the LW401-408 panels.

7.1 Model setup

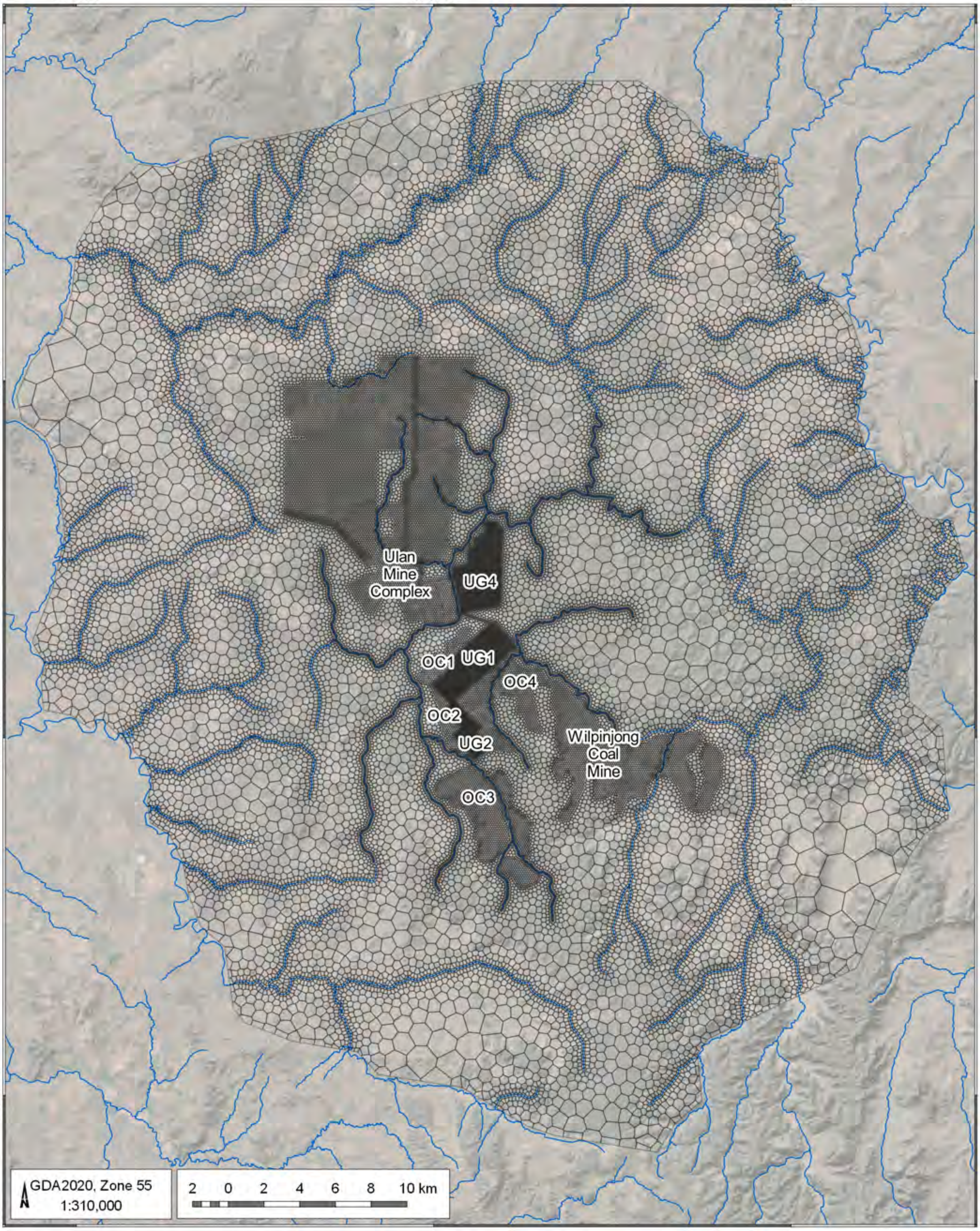
The model utilises the MODFLOW-USG code to simulate groundwater flow in the region. This model code was considered suitable to meet the model objectives because it:

- allows the use of an unstructured mesh where cells can be refined around localised features such as rivers, alluvial aquifers and mining areas, and larger cells used where refinement is not required;
- does not need layers to be continuous over the model domain, allowing layers to stop where geological units pinch out or outcrop, such as coal seams and alluvium;
- effectively reduces the number of cells (with the refinement and pinching options applied) which means faster model run times and a greater number of calibration runs could be completed; and
- better represents flow transfer processes between systems such as bedrock and alluvial groundwater systems, through the pinching out of layers, compared to earlier versions of MODFLOW.

The input files for the MODFLOW-USG model were created using custom Fortran and Python code and run with a MODFLOW-USG edition of the Groundwater Data Utilities by Watermark Numerical Computing (https://pesthomepage.org/programs). The mesh was generated using Algomesh by HydroAlgorithmics.

The extent of the model is approximately 60 km north to south by 50 km west to east. The model comprises of 460,147 cells and the model mesh is presented in Figure 7.1. The model domain was discretised and arranged into 19 layers comprising up to 44,503 cell nodes in each layer with the dimensions of the cells varying according to the features that required representation. The following cells dimensions were adopted:

- Moolarben Coal Complex underground mining areas – 50 x 50 m square cells aligned to the principal axis of the longwall panels ;
- Ulan Mine Complex underground mining areas – 120 m hexagonal cells;
- Open cut mining areas – 120 m hexagonal cells;
- surface drainage lines near to the UG4 – approximately 100 x 100 m Voronoi cells; and
- surface drainage lines far from the UG4 – approximately 200 x 200 m Voronoi cells.



LEGEND

Drainage line

Model mesh

Moolarben (MOO5001)

Model Mesh (Regional View)

AGE

DATE: 18/08/2023

FIGURE No: **7.1**

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:\Projects\MOO5001.001 UG4 Compliance Conditions\3_GIS\Workspaces\001_Deliverable1\07.01_MOO5001_ModelMesh.qgs

The numerical groundwater model includes vertical discretisation, consisting of 19 layers representing the hydrostratigraphic units in the area. The uppermost layers represent the shallow Quaternary alluvium and colluvium sediments, with the lowest layers representing the deep Permian coal measures and Marrangaroo Conglomerate. Table 7.1 lists each model layer and the hydrostratigraphic layer it represents.

Table 7.1 Model layers and hydrogeological units

Model layer	Hydrostratigraphic layer
1	Alluvium and colluvium
2	Palaeochannel
3	Tertiary basalt
4	Jurassic Pilliga/Purlewaugh Fm
5, 6, 7	Triassic sandstone (quartzose)
8, 9	Triassic sandstone (lithic)
10, 12, 14	Permian overburden
11, 13	Permian coal seams
15, 17, 18	Permian Ulan Seam
16	Permian clay interburden
19	Permian underburden

7.2 Model timing

The model timing was chosen to allow detailed representation of seasonal variability and associated groundwater response. The calibration involved an initial steady state calibration to obtain pre-mining conditions, followed by a transient history-matching using water level measurements from the monitoring network. Any regional mining prior to 1984 was not modelled, but any historical effects from this mining would be reflected in the monitoring data used in the groundwater model. Mining prior to 1984 is limited to relatively small-scale mining undertaken at the Ulan Mine Complex that would not have a material effect on water levels in the vicinity of the of the subsequent and current Ulan and Moolarben mining areas.

The transient model was set up as follows:

- 31 Dec 1983 – steady state stress period (1 day);
- 1 Jan 1984 to 31 Dec 1998 – pre-calibration phase of four 5-yearly stress periods;
- 1 Jan 1999 to 31 Dec 2004 – one 6-year stress period;
- 1 Jan 2005 to 30 March 2023 – calibration phase of 219 monthly stress periods;
- 1 May 2021 to 31 Dec 2036 – predictive phase of 55 quarterly stress periods; and
- 1 Jan 2037 to 31 Dec 2712 – 675 years recovery period of 15 stress periods.

The initial transient stress periods (5-yearly and subsequent 6-year stress period) were selected based on a review of available mining information, and the temporal distribution of observation data.

7.3 Boundary conditions

MODFLOW-USG allows the use of boundary conditions, which permit the addition and removal of groundwater from the model domain. These fluxes include natural processes such as baseflow to creeks or groundwater flow across the model extent where aquifers continue outside of the defined model domain. They also include groundwater flow which occurs in response to dewatering activities such as mining.

Boundary conditions applied in the model to represent natural water fluxes are rainfall recharge, evapotranspiration, rivers, and general head boundaries, while mining activities are represented with drains and time-variant materials.

7.3.1 Recharge

The MODFLOW-USG recharge package (RCH) was used to represent diffuse rainfall recharge. Recharge to the groundwater systems occurs via the diffuse infiltration of rainfall through the soil profile, with subsequent deep drainage to underlying groundwater systems.

Groundwater recharge is expected to vary across the model domain due to the distribution of surficial geological units, and was therefore represented using different zones, defined by the outcropping units. Figure 7.2 shows the recharge zones represented in the groundwater model.

Recharge zones were assigned factors which represent the percentage of rainfall (per geological unit) which ends up as groundwater recharge, simulating the capacity of the various lithologies for rainfall infiltration. These factors were calibrated (refer to Section 7.4) and the average recharge rates are provided in Table 7.2.

Through the historical calibration period, observed rainfall totals were used to apply a transient recharge boundary condition, while through the predictive period, average yearly rainfall totals were multiplied by the calibrated recharge factors, and applied at a constant rate through the predictive period.

It should be noted that actual recharge rates are reliant on several other factors beyond rainfall, including evapotranspiration, surface runoff, and interception.

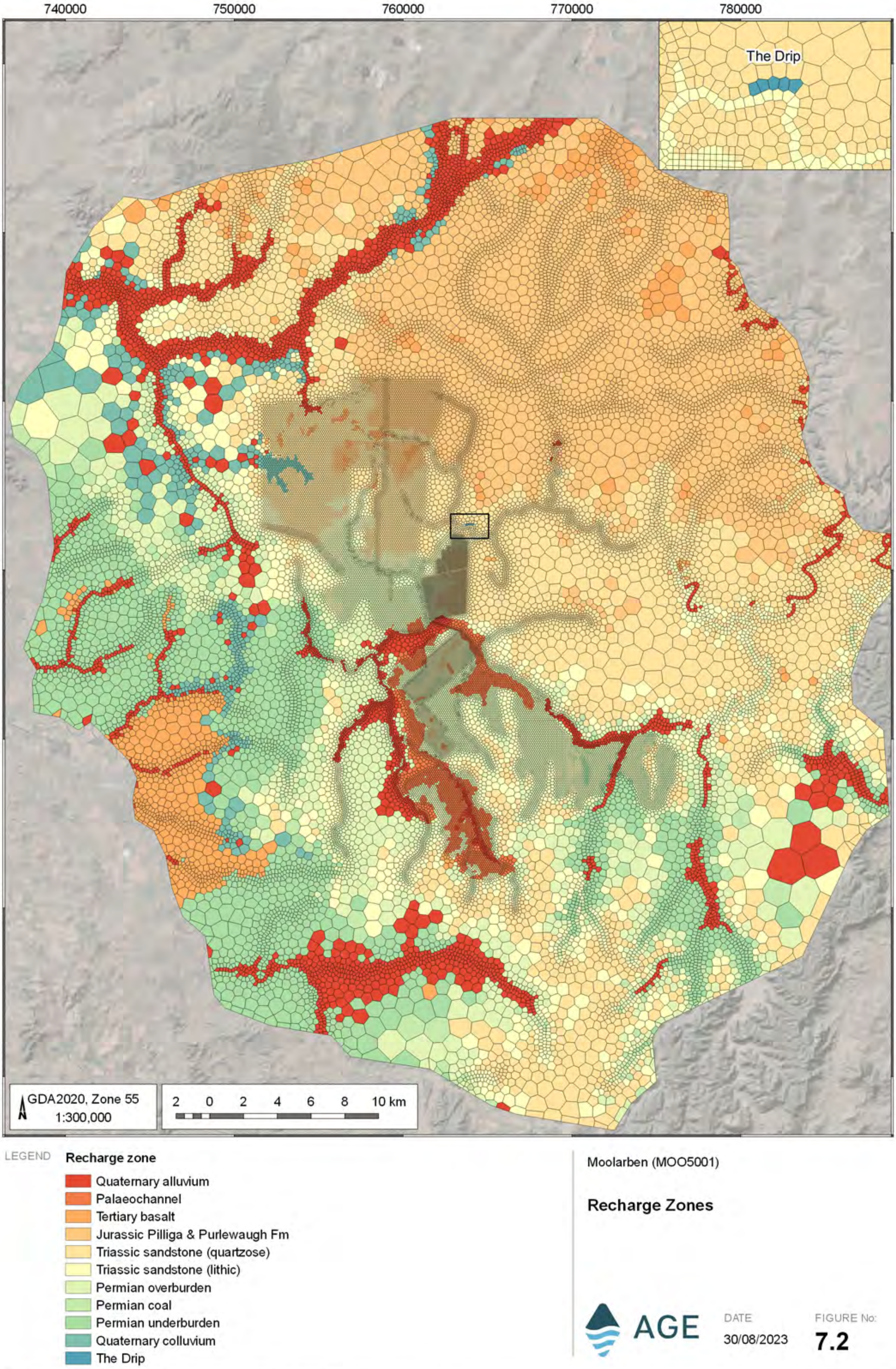
Table 7.2 Rainfall infiltration factors

Hydrostratigraphic layer	Rainfall infiltration factor
Quaternary alluvium	4.87E-02
Quaternary colluvium	4.90E-04
Paleochannel	1.00E-02
Tertiary basalt	2.00E-03
Jurassic Pilliga and Purlewaugh Fm	7.00E-05
Triassic sandstone (quartzose)	7.62E-04
Triassic sandstone (lithic)	1.01E-04
Permian overburden	8.54E-07
Permian coal	9.93E-08
Permian Marrangaroo conglomerate underburden	3.71E-04
The Drip	4.00E-02

7.3.2 Evapotranspiration

Evapotranspiration from the watertable was represented in the numerical model with the evapotranspiration package (EVT). Evapotranspiration occurs from the uppermost active model cells within the model domain at a maximum rate of 0.02 mm/day (1.78 mm/day with a pan factor of 1%), decreasing linearly to an extinction depth of 2 m below topographic surface. Evapotranspiration on backfilled spoil in open-cut pits uses a pan factor of 100% with an applied extinction depth of 2 m below surface.

Due to the general depth of the watertable across the model domain, evapotranspiration is not a significant stress on the groundwater system and observations are accordingly not sensitive to evapotranspiration rates. The bulk of actual water loss due to evapotranspiration will occur from the unsaturated root zone.



Moolarben (MOO5001)

Recharge Zones

AGE

DATE 30/08/2023

FIGURE No: **7.2**

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
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7.3.3 Surface drainage

Surface drainage lines were simulated using the river package (RIV). Surface drainage lines in the model were only able to remove groundwater where the watertable was above the bed of the river, except for the Goulburn River which was assigned a stage height of 0.05 m. This allows the Goulburn River to contribute water into the model where the watertable is below the river stage elevation. To replicate the seepage at the face of the Drip, RIV cells were also assigned along the outcropping cliff cells. These cells act as drains to remove water from the face of the Drip and allow for the prediction of any impacts to The Drip.

Table 7.3 shows the parameters assigned to RIV cells, and all RIV cells are shown Figure 7.3.

Table 7.3 RIV parameters

Segment name	Vertical hydraulic conductivity (m/day)	Width (m)	Incised depth (m)	Bed thickness (m)	Stage height[1] (m)
Goulburn River	0.50	10.0	1.00	1.00	0.05
All other drainage lines	0.50	10.0	1.00	1.00	0.00
The Drip	1.00	1.00	0.50	1.00	0.00

Note: This is the depth of the surface water, above the river bottom elevation.

7.3.4 General head boundary

The general head boundary package (GHB) was used to provide an exchange of water across the model boundary in areas where the aquifers continue beyond the model domain. The GHB boundary condition assigns a specified water level in the cell, and when the predicted head in the model cell rises above the reference elevation, groundwater will flow out of the model. Conversely when the head drops below this elevation, groundwater will flow into the model.

The reference elevation in each boundary cell was set to a nominal 10 m below topography. GHB cells are illustrated with RIV cells in Figure 7.3. GHB cells were assigned to all layers at the periphery of the model, while RIV cells were assigned to the upper most cell (layer independent, due to adoption of MODFLOW USG).

7.3.5 Mining

Historic and proposed mine dewatering is simulated using the drain package (DRN). Cells with the DRN boundary conditioned assigned will remove water from the model when the water level in the model cell (or adjacent cells) is above its designated drain elevation. The DRN cell will not remove water from the model when the water level drops below the drain elevation.

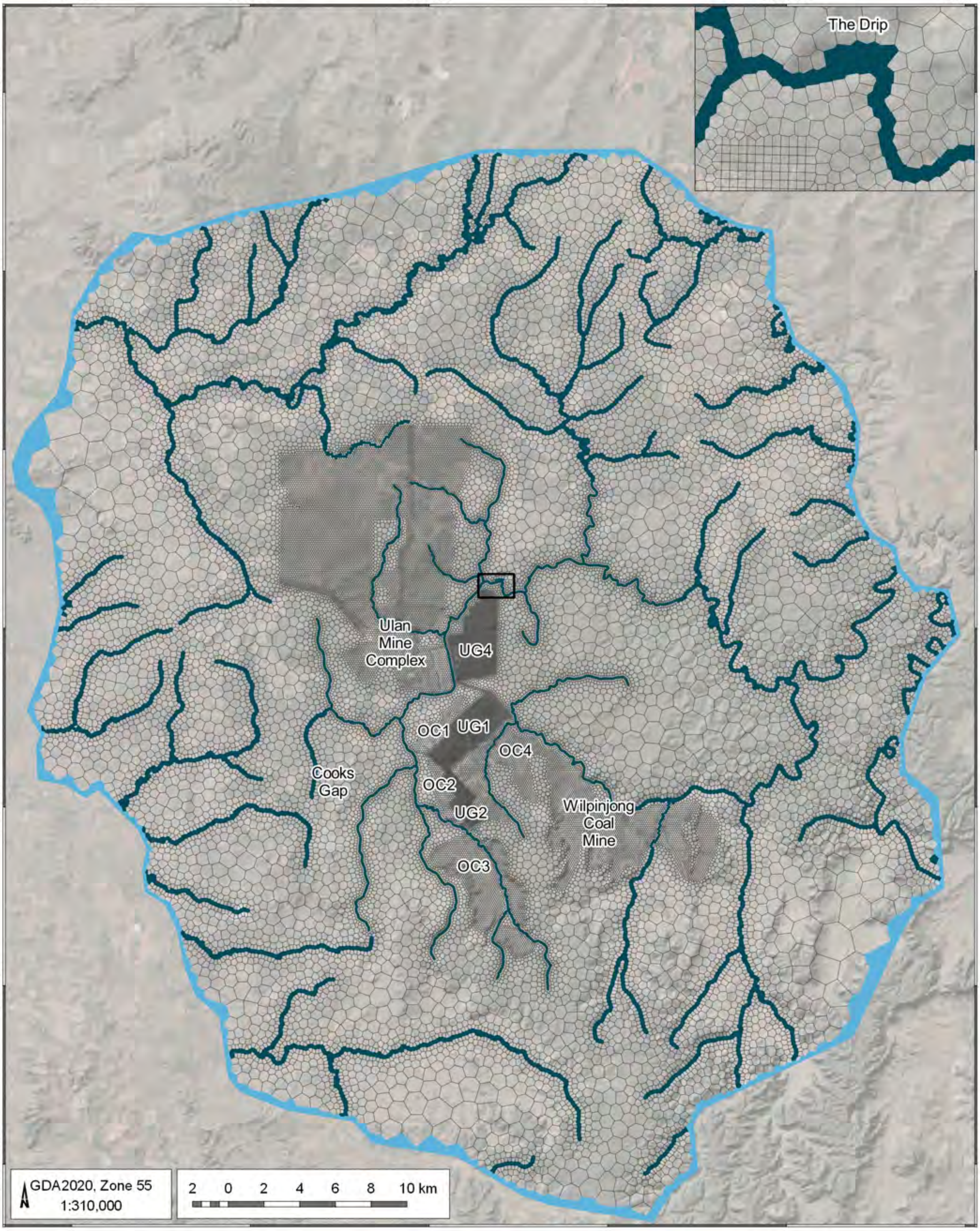
7.3.6 Height of fracturing

Changes were applied to aquifer hydraulic parameters to simulate subsidence of goaf material into the mined void and the formation of a fracture zone above longwall panels. The fracture zone is assumed to form pathways of enhanced vertical and horizontal hydraulic conductivity and allow groundwater to flow through the fractured zone to the underground workings. If a groundwater model cell is between the coal seam roof and the expected height of continuous fracturing, its hydraulic parameters are adjusted accordingly.

Fractures will reduce in size and distribution with height above the coal seam. Two widely used empirical approaches have emerged to determine the height of continuous fracturing; Ditton-Merrick (Ditton and Merrick, 2014) and Tametta (2013). The Ditton-Merrick method was adopted for this assessment because it was formulated in similar geological settings to the Moolarben Coal Complex and allows for consideration of some local geological features that impact on this calculated height.

The height and magnitude of fracturing was calculated above each mined model cell using the Ditton-Merrick empirical method. Fracturing of these cells was then simulated by increasing the storage and hydraulic conductivity using the time-variant materials (TVM) package. Empirical estimates of the height of fracturing using both methods resulted in the mine induced fracturing penetrating the regional water table (as shown on Figure 6.32). As such the selection of either method will result in similar impacts to the groundwater system.

The same approach to height of fracturing was adopted by AGE (2021), AGE (2022a) and AGE (2022b).



LEGEND

Model mesh
RIV cells
GHB cells

Moolarben (MOO5001)

RIV and GHB Cells

AGE

DATE 18/08/2023

FIGURE No: **7.3**

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
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7.4 Model recalibration

The groundwater model was recalibrated with automated parameterisation software (PEST) (Doherty, 2015) using the latest available MCC groundwater level and flow data. Recalibration was performed using a simulation that represents both the pre-mining steady state, and a transient historical period (1984 to 2023). Observations from the recently constructed monitoring bores and vibrating wire piezometers were also included in the model recalibration. The model was recalibrated to confirm that it can replicate both observed water levels and observed groundwater inflows (to the underground operations) to satisfactory quantitative and qualitative standards. Modelled baseflow to the Goulburn River and Moolarben Creek have also been reported to confirm they were commensurate with the revised conceptual model of MCC (Section 7.4.1).

One of the statistical measures recommended by the Australian groundwater modelling guidelines (Barnett et. al., 2012) to determine if a model is sufficiently calibrated is the Scaled Root Mean Squared Error (SRMS). The SRMS of the recalibrated model is 5.5%. The updated hydraulic parameterisation and significant improvements made to the model (since 2021) have led to an improvement in the model's calibration, with the modelled SRMS reducing from 6.7% (AGE, 2021) to 5.5% in the current model, noting that the current model includes a greater number of total observation points. A value of SRMS below 10% generally indicates that a model can be considered calibrated if groundwater flow predictions are also commensurate with observed data. Figure 7.4 presents the comparison of modelled heads to observed heads.

The model's performance was also gauged by history matching the inflows observed from workings at UG1 and first workings associated with UG4. As discussed in Section 6.12, estimates of groundwater inflow to UG1 & UG4 (first workings) combined for 2022 are approximately 3,700 ML/yr or 10 ML/d. Over the same period, modelled inflows peaked at 11.9 ML/d, and had an average of 7.4 ML/d from UG1 and UG4 combined.

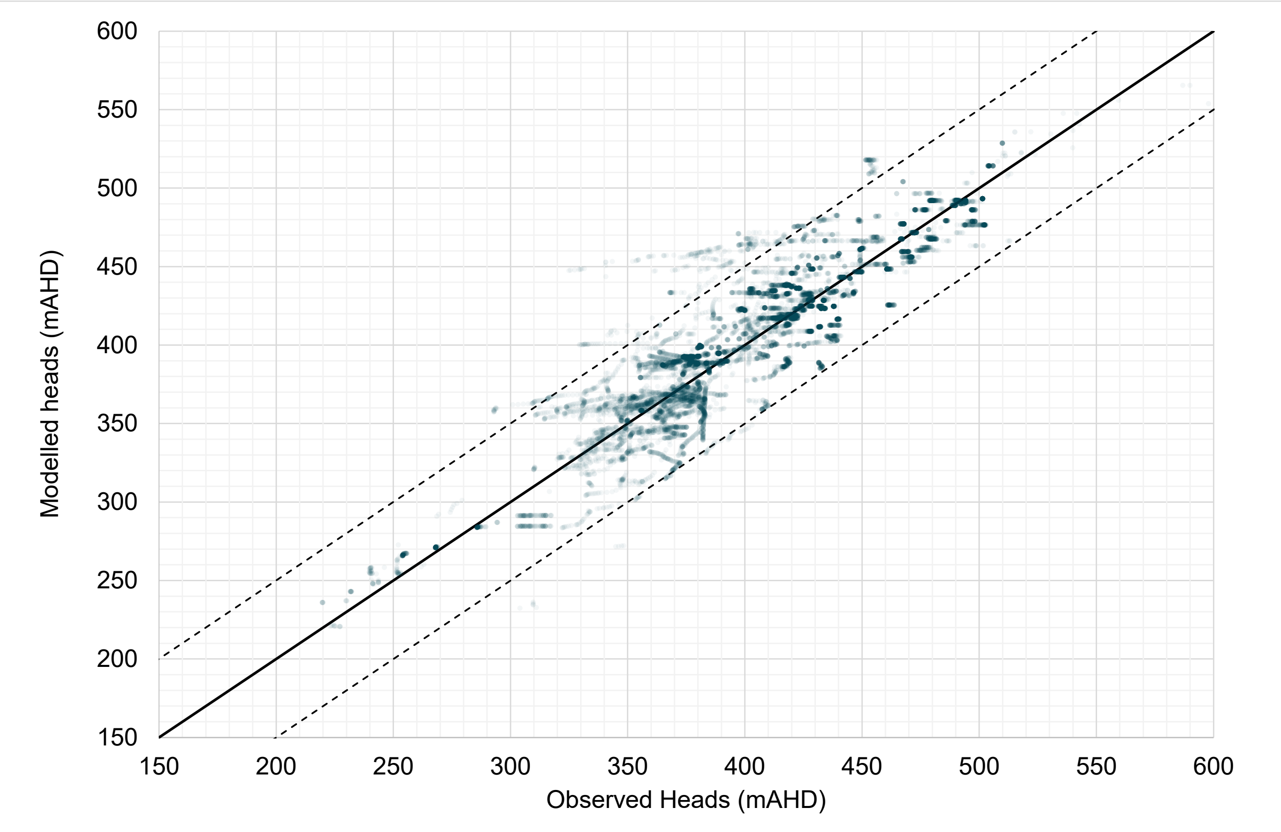


Figure 7.4 Calibration Scatter Plot

Hydraulic properties and groundwater recharge rates were varied during the model recalibration. Note that the values are varied spatially by pilot points to represent heterogeneity in the parameter values.

Permissible parameter ranges per layer during calibration are presented for Kh in Table 7.4, the ratio of Kv/Kh in Table 7.5, specific yield (Sy) in Table 7.6, specific storage (Ss) in Table 7.7, and rainfall infiltration factors in Table 7.8. Table 7.9 presents the average calibrated hydraulic parameters per layer. The maximum K_h value of the coal seams is limited to 0.8 m/day. Figure 7.5 shows the locations of the pilot points.

Table 7.4 Calibration ranges for Kh

Layer	Hydrostratigraphy	Kh (m/day) minimum	Kh (m/day) maximum
1	Alluvium	3.50E-01	3.50E+01
1	Colluvium	5.00-02	5.00E+00
2	Palaeochannel	5.00E-03	5.00E-01
3	Tertiary basalt	1.00E-04	1.00E-02
4	Jurassic Pilliga/Purlewaugh Fm	1.00E-04	1.00E-02
5, 6, 7	Triassic sandstone (quartzose)	1.00E-03	1.00E-01
8, 9	Triassic sandstone (lithic)	5.00E-05	5.00E-03
10, 12, 14	Permian overburden	1.25E-06	1.25E-04
11, 13	Permian coal seams	1.00E-06	1.00E-04
15, 17, 18	Permian Ulan Seam	8.60E-06	8.00E-01
16	Permian clay interburden	1.00E-05	1.00E-03
19	Permian underburden	1.00E-05	1.00E-03

Table 7.5 Calibration ranges for Kv/Kh

Layer	Hydrostratigraphy	Kv/Kh minimum	Kv/Kh maximum
1	Alluvium	1.00E-03	1.00E-01
1	Colluvium	1.00E-03	1.00E-01
2	Palaeochannel	1.00E-03	1.00E-01
3	Tertiary basalt	5.00E-03	5.00E-01
4	Jurassic Pilliga/Purlewaugh Fm	1.00E-05	1.00E-03
5, 6, 7	Triassic sandstone (quartzose)	1.00E-03	1.00E-01
8, 9	Triassic sandstone (lithic)	1.00E-03	1.00E-01
10, 12, 14	Permian overburden	1.00E-03	1.00E-01
11, 13	Permian coal seams	1.00E-03	1.00E-01
15, 17, 18	Permian Ulan Seam	5.00E-02	5.00E+00
16	Permian clay interburden	1.00E-03	1.00E-01
19	Permian underburden	1.00E-03	1.00E-01

Table 7.6 Calibration ranges for Sy

Layer	Hydrostratigraphy	Sy minimum	Sy maximum
1	Alluvium	1.00E-02	5.00E-01
1	Colluvium	8.00E-04	4.00E-02
2	Palaeochannel	1.80E-03	1.80E-01
3	Tertiary basalt	2.00E-03	2.00E-01
4	Jurassic Pilliga/Purlewaugh Fm	1.00E-03	1.00E-01
5, 6, 7	Triassic sandstone (quartzose)	3.00E-03	3.00E-01
8, 9	Triassic sandstone (lithic)	1.00E-03	1.00E-01
10, 12, 14	Permian overburden	1.50E-03	1.50E-01
11, 13	Permian coal seams	2.00E-03	2.00E-01
15, 17, 18	Permian Ulan Seam	2.00E-03	2.00E-01
16	Permian clay interburden	1.50E-03	1.50E-01
19	Permian underburden	5.00E-04	5.00E-02

Table 7.7 Calibration ranges for Ss

Layer	Hydrostratigraphy	Ss minimum	Ss maximum
1	Alluvium	1.30E-06	1.30E-04
1	Colluvium	5.00E-07	5.00E-05
2	Palaeochannel	5.00E-07	5.00E-05
3	Tertiary basalt	5.00E-07	5.00E-05
4	Jurassic Pilliga/Purlewaugh Fm	5.00E-07	5.00E-05
5, 6, 7	Triassic sandstone (quartzose)	1.00E-06	1.30E-05
8, 9	Triassic sandstone (lithic)	8.00E-07	8.00E-05
10, 12, 14	Permian overburden	2.30E-07	1.00E-05
11, 13	Permian coal seams	2.30E-07	2.00E-05
15, 17, 18	Permian Ulan Seam	2.30E-07	2.00E-05
16	Permian clay interburden	2.30E-07	1.00E-05
19	Permian underburden	2.30E-07	1.00E-05

Table 7.8 Calibration ranges for rainfall infiltration factors

Recharge zone	Infiltration factor minimum	Infiltration factor maximum
Quaternary alluvium	9.74E-03	2.44E-01
Quaternary colluvium	9.80E-05	2.45E-03
Paleochannel	2.00E-03	5.00E-02
Tertiary basalt	4.00E-04	1.00E-02
Jurassic Pilliga and Purlewaugh Fm	1.40E-05	3.50E-04
Triassic sandstone (quartzose)	1.52E-04	3.81E-03
Triassic sandstone (lithic)	2.02E-05	5.04E-04
Permian overburden	1.71E-07	4.27E-06
Permian coal	1.99E-08	4.97E-07
Permian Marrangaroo conglomerate	7.42E-09	1.86E-07
The Drip	8.00E-03	2.00E-01

Table 7.9 Calibrated hydraulic parameters

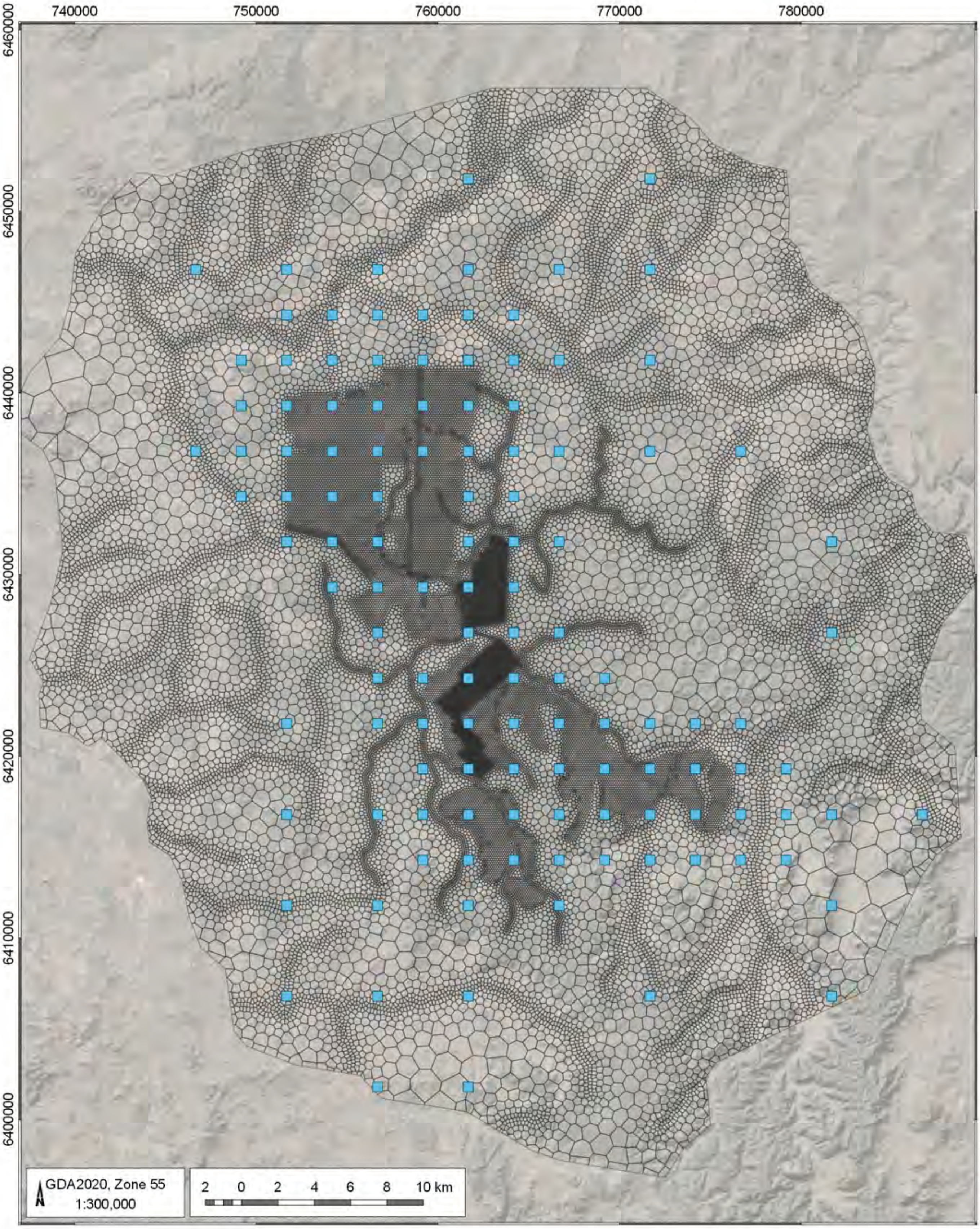
Layer	Hydrostratigraphy	Kh (m/day)	Kv (m/day)	Sy	Ss (m^{-1})
1	Alluvium	4.29E+00	4.37E-02	1.22E-01	1.57E-05
1	Colluvium	5.65E-01	5.46E-03	9.55E-03	6.34E-06
2	Palaeochannel	6.20E-02	5.95E-04	2.06E-02	5.94E-06
3	Tertiary basalt	1.22E-03	5.72E-05	2.42E-02	6.52E-06
4	Jurassic Pilliga/Purlewaugh Fm	1.11E-03	1.10E-07	1.01E-02	5.60E-06
5, 6, 7	Triassic sandstone (quartzose)	1.15E-02	1.21E-04	3.37E-02	1.00E-05
8, 9	Triassic sandstone (lithic)	5.43E-04	5.46E-06	1.07E-02	8.29E-06
10, 12, 14	Permian overburden	1.34E-05	1.35E-07	1.55E-02	1.05E-06
11, 13	Permian coal seams	1.06E-05	1.04E-07	2.14E-02	2.01E-06
15, 17, 18	Permian Ulan Seam	6.14E-01*	1.01E-01	2.01E-02	2.01E-06
16	Permian clay interburden	1.02E-04	1.01E-06	1.52E-02	1.04E-06
19	Permian underburden	1.00E-04	1.01E-06	4.97E-03	9.69E-07

Notes: * A reduction in hydraulic conductivity due to coal cleats closing under increasing overburden pressure generally occurs where, K_h of the coal seam decreases proportionally with depth from the ground surface.

The equation used to calculate K_h in the Ulan Seam can be described by the following equation:

$$K_h = K_0 \cdot e^{sd}$$

where K_0 is a base hydraulic conductivity value of (15 m/d), s is the slope (-0.005), and d is the depth (m) below ground surface.



LEGEND

Pilot point

Model mesh

Moolarben (MOO5001)

Pilot Point Locations

AGE

DATE
18/08/2023

FIGURE No:
7.5

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7.4.1 Modelled baseflows

To address non uniqueness and to confirm the contemporary MCC hydrogeological conceptualisation, baseflow incursions to both the Goulburn River and Moolarben creek were exported from the recalibrated groundwater model. The locations of the Goulburn River and Moolarben Creek model cells are presented in Figure 7.6.

Groundwater baseflow to the Goulburn River has been predicted to be 338 ML/yr at the end of 2022. As per the discussion in Section 6.11, the baseflow to the southern side of the Goulburn River has been estimated to be less than approximately 200 ML/yr, based on an rudimentary analysis of groundwater recharge estimates and groundwater flow net mapping. These estimates represent upper guiding estimates, as they do not account for other groundwater discharge processes such as evapotranspiration or vertical leakage to lower Hydrostratigraphic units. Baseflow estimates from the Goulburn River downstream gauging station (UMC SW02) indicate that baseflow from the western side of the Goulburn River may have occurred historically at much higher rates (up to the location of the gauging station), however groundwater contouring suggests that the river may also lose water further north of this gauging station. Given the approved mine discharges occurring currently, the Goulburn River baseflow estimation can not be repeated. On the basis of all available information, the modelled baseflow rates are plausible within the current hydrogeological conceptualisation. Higher modelled predictions of baseflow are expected, as the modelled 'reach' of the Goulburn River (as per Figure 7.6) is longer than the reach of Goulburn River assumed within the analytical calculations (Figure 6.4).

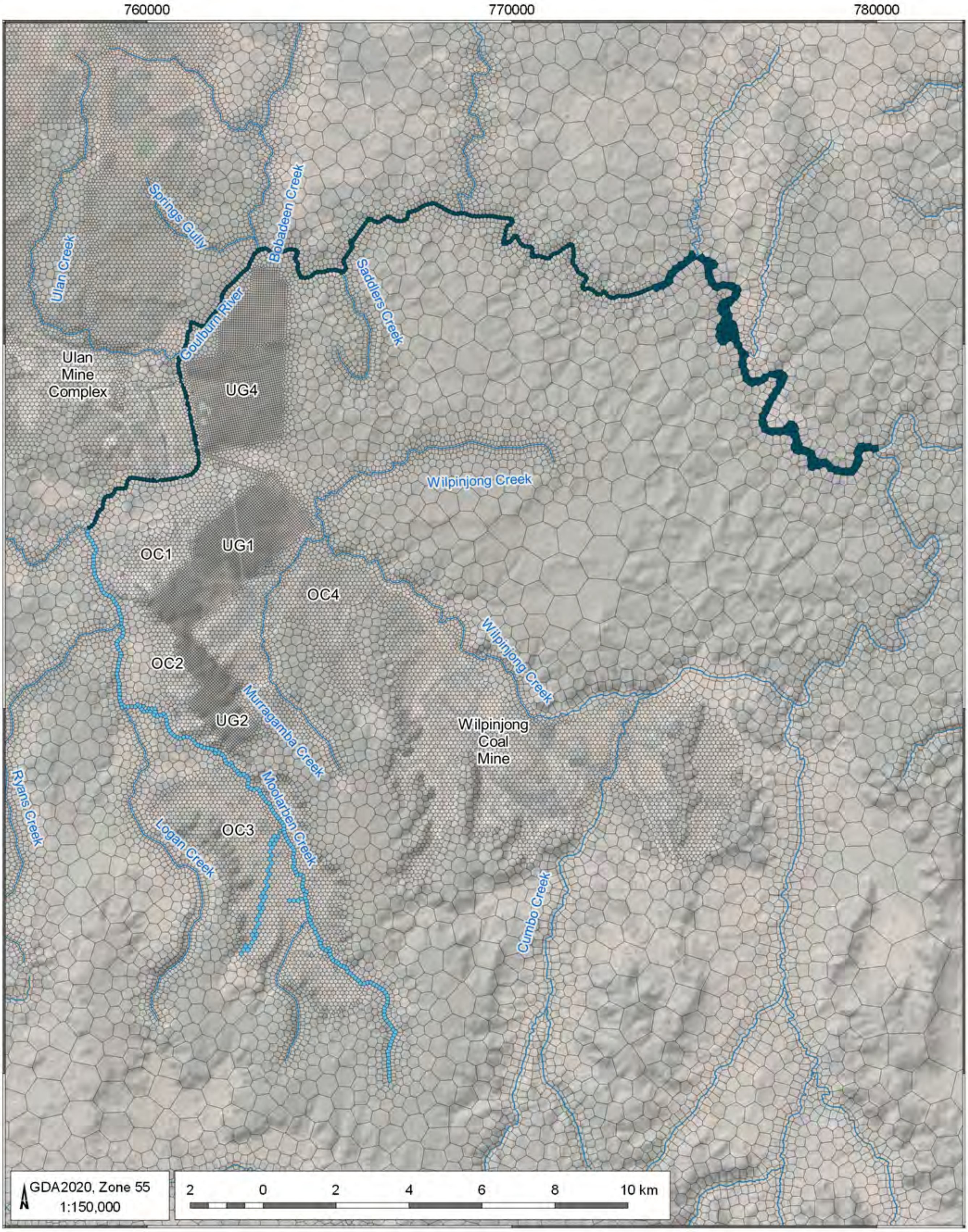
Groundwater baseflow to the Moolarben Creek has been predicted to be 134 ML/yr at the end of 2022, with an average modelled baseflow of 143 ML/yr between 2006 to 2022. We acknowledge that the influence of UG4 LW401-408 on Moolarben Creek is negligible due to creeks' proximity to LW401-408. Baseflow loss to Moolarben Creek is detailed in Section 8 (Table 8.3). However, as Moolarben Creek is upstream of the approved UMC and MCC mine water discharge points, it allows for a more reliable estimation of baseflow. As per the discussion in Section 6.11, groundwater baseflow to Moolarben Creek has been estimated to be of the order of 180 – 225 ML/year.

These results suggest a suitable match between modelled and observed baseflow has been reached, which assists to address issues of model non-uniqueness, and adds confidence in the model's predictions.

The water budget over the transient calibration period (1984 to 2023) is provided in Table 7.10, which shows the average water budget for the transient calibration period.

Table 7.10 Modelled water budget

Parameter	In (ML/day)	Out (ML/day)	In - Out (ML/day)
Storage	21.14	0.66	20.48
Rivers	0.10	25.00	-24.9
Rainfall recharge	23.19	-	23.19
Evapotranspiration	-	1.77	-1.77
General head boundaries (across edge of model domain)	111.05	12.03	99.02
Drains (inflow to mine workings)	-	119.06	-119.06
Total	155.48	158.52	-3.04



LEGEND

- Moolarben Creek cell
- Goulburn River cell
- Model mesh

Moolarben (MOO5001)

Modelled Baseflow Locations

AGE

DATE: 18/08/2023

FIGURE No: **7.6**

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8 Model predictions

Numerical modelling was undertaken to predict the impact that the mining of UG4 LW401-408 will have on the groundwater regime. The objectives of the predictive modelling were to:

- predict groundwater inflows into UG4 LW401-408;
- predict the effect of UG4 LW401-408 on the upper groundwater levels as well as the groundwater pressure responses in the deeper strata;
- predict the loss and/or water take from the water bearing units in the vicinity of UG4 LW401-408; and
- predict any losses to baseflow to inform water licensing requirements.

The model scenarios in Table 8.1 were created and used in various combinations to produce the predictions required.

Table 8.1 Model predictive scenarios

Model Setup	Model Description
1	**No Mining** – simulates no mining in the model domain.
2	**Approved Mining** – simulates all current approved and proposed mining at the Moolarben Coal Complex including UG4 LW401-408. This model also simulates the approved Ulan and Wilpinjong mines.
3	**No UG4** – simulates all current approved and proposed mining at the Moolarben Coal Complex except UG4 LW401-408. This model also simulates the approved Ulan and Wilpinjong mines.
4	**No Moolarben** – simulates only the approved Ulan and Wilpinjong mines.

Predictions have been completed using the recalibrated numerical groundwater model described in Section 7. Model timing is detailed in Section 7.2 and mining of UG4 LW401-408 is modelled from 1 June 2022 until 30 November 2025.

8.1 Groundwater inflows to mining areas

Predicted groundwater inflows for mining activities are presented for the MCC (including UG4 LW401-408), and for UG4 LW401-408 separately in Table 8.5. Predicted groundwater inflows to UG4 LW401-408 are shown in Figure 8.1.

Table 8.2 Predicted groundwater inflows to mining areas

Water Year	MCC (ML)	LW401 to LW408 (ML)
2023/24	3826	3471
2024/25	4071	3626
2025/26	3025	1552

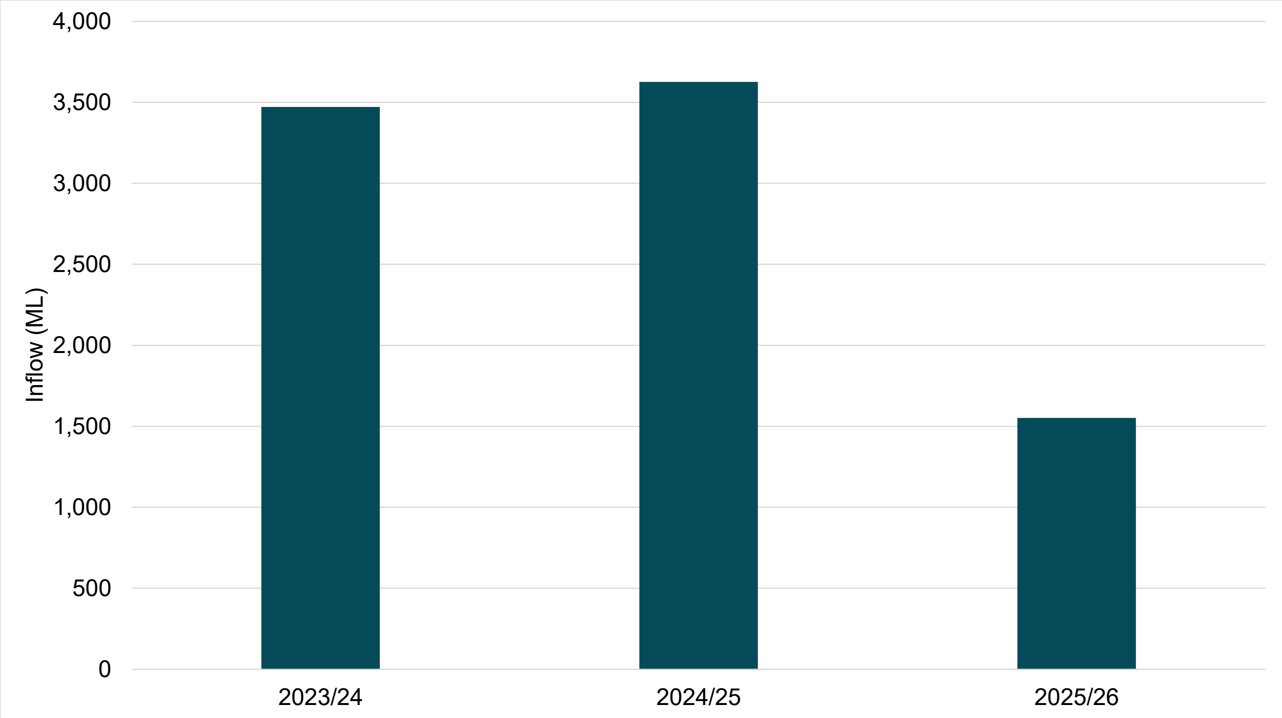


Figure 8.1 Groundwater Inflows UG4 LW401-408

The maximum predicted annual inflow volume to UG4 LW401-408 is 3,626 megalitres and is predicted to occur in the 2024/25 water year. This is commensurate with the timing of the peak modelled inflows of AGE (2021). The model predictions of water take from the Sydney Basin-North Coast Groundwater Source are slightly lower than the modelled predictions of AGE (2021) and have occurred in response to the revised hydraulic parameters adopted across the model domain. The adopted parameters have led to an improved model calibration, with the modelled SRMS reducing from 6.7% (AGE, 2021) to 5.5% in the current model, with the latter including a greater number of total observation points.

8.2 Predicted impacts

This section of the report presents a summary of the predicted impacts to private landholders, groundwater dependent assets, and the water licensing requirements which will need to be met for the duration of the LW401-LW408.

8.2.1 Predicted drawdown

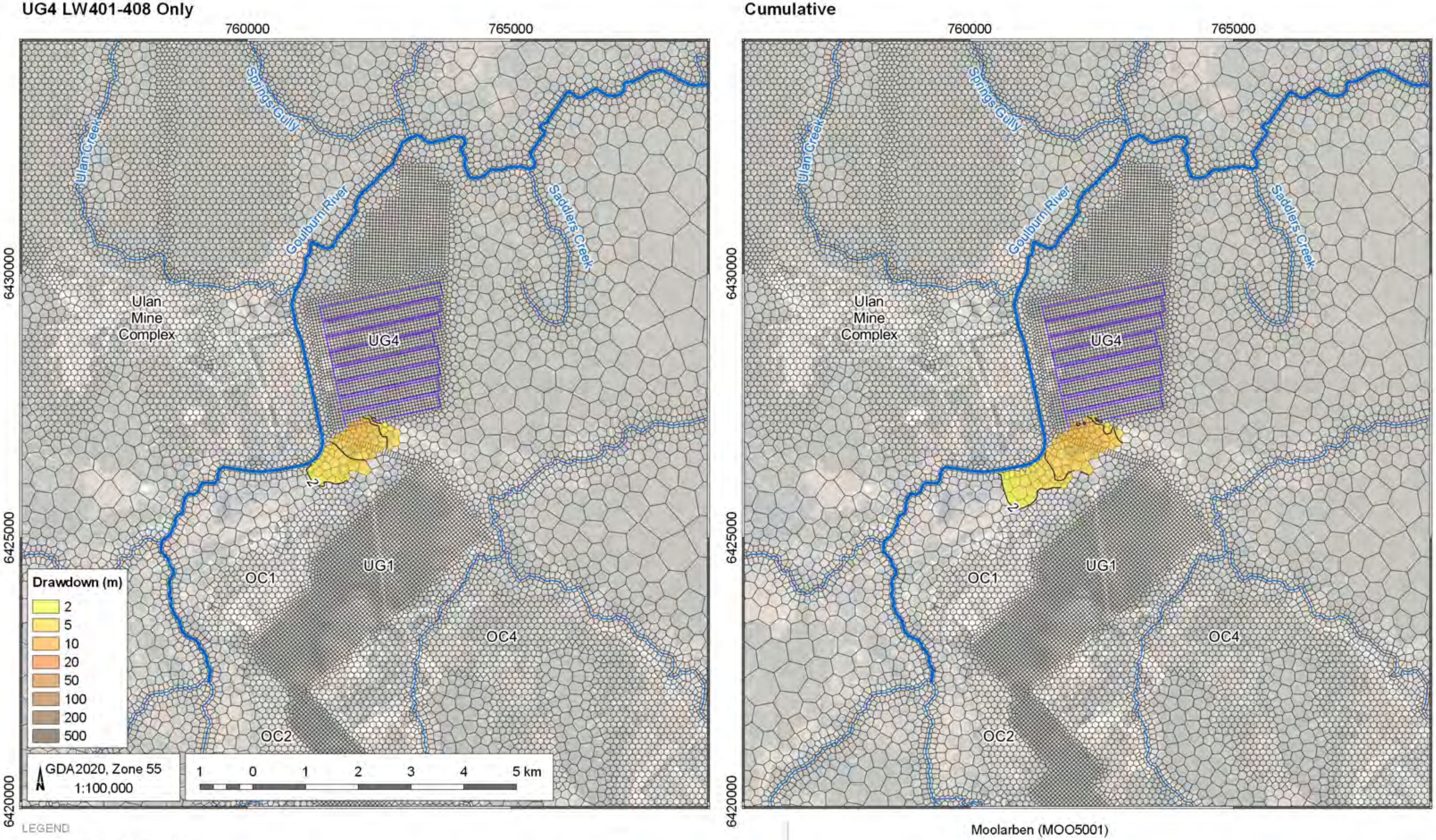
Predicted drawdown contours have been calculated for each of the key Hydrostratigraphic units. Drawdown surfaces are a composite of the maximum drawdown values predicted at each model cell, at any time over the period of mining. The actual duration and timing of the maximum predicted drawdown within each cell varies depending on the proximity of mining over the life of UG4 LW401-408.

Note that the maximum predicted drawdown for reported model layers represents the total reduction in potentiometric head and does not necessarily equate to the total reduction in saturated thickness of that layer. Potentiometric heads may drop below the model layer floor and exceed the layer's potential for dewatering.

Drawdown maps are presented for the Quaternary alluvium (Layer 1), palaeochannel (Layer 2), Jurassic Purlewaugh and Piliga Formations (Layer 4), base of Triassic quartzose (Layer 7), base of Triassic lithic (Layer 9), base of Permian overburden (Layer 14), and Ulan Seam (Layer 17). These maps are shown as Figure 8.2 to Figure 8.8 respectively.

Figure 8.2 to Figure 8.8 present the modelled predictions for the two scenarios as described in Condition 3:

- Maximum predicted drawdown due to UG4 LW401-408; and
- Maximum predicted cumulative drawdown – where drawdown occurs from the approved Moolarben Coal Complex, the UG4 LW401-408 mining area, and neighbouring mines (Ulan Mine Complex and Wilpinjong Coal Mine).



LEGEND

- Drawdown contour (m)
- Minor drainage
- Goulburn River
- UG4 LW401-408
- Model mesh

Moolarben (MOO5001)

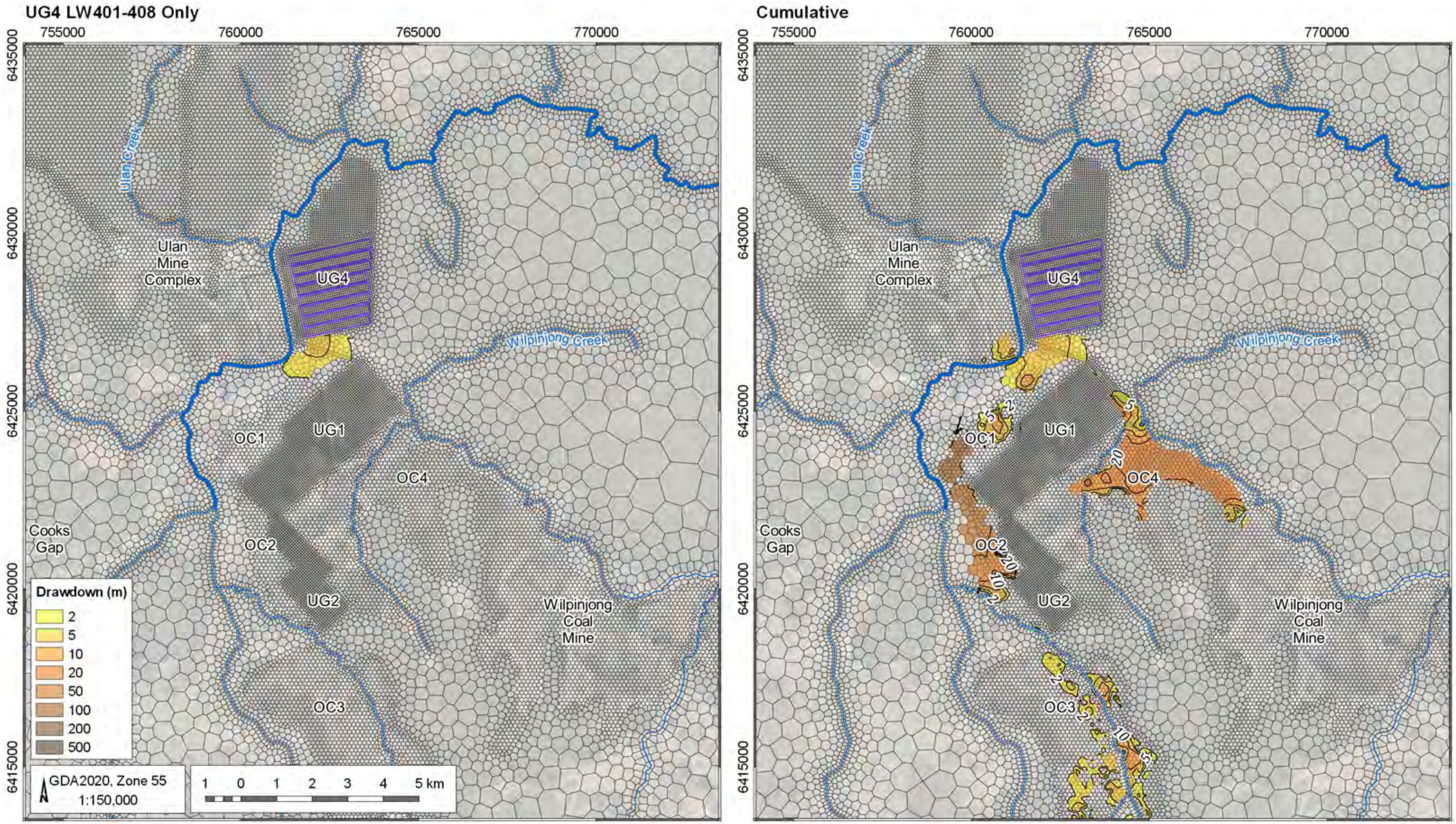
AGE

Maximum Predicted Drawdown in Quaternary Alluvium until End of Mining

DATE
30/08/2023

FIGURE No:
8.2

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:\Projects\MOO5001.001 UG4 Compliance Conditions\3_GIS\Workspaces\001_Deliverable1\08.02_MOO5001_Drawdowns.qgs



LEGEND

- Drawdown contour (m)
- Minor drainage
- Goulburn River
- UG4 LW401-408
- Model mesh

Moolarben (MOO5001)

AGE

Maximum Predicted Drawdown in Palaeochannel until End of Mining

DATE
30/08/2023

FIGURE No
8.3

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
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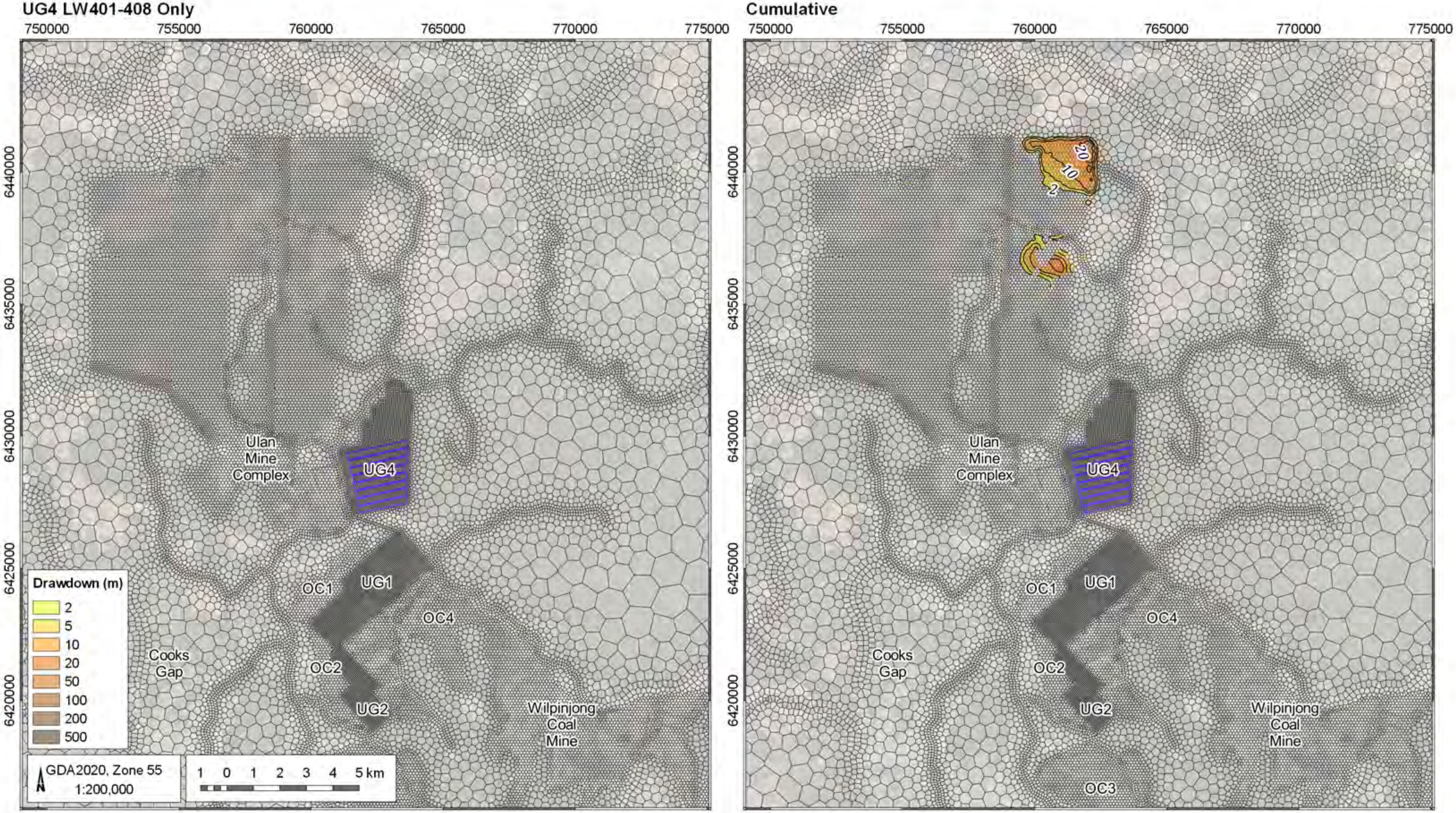

LEGEND
Drawdown contour (m)
UG4 LW401-408
Model mesh

Moolarben (MOO5001)

AGE

Maximum Predicted Drawdown in Jurassic Pilliga & Purlewaugh Formations until End of Mining

DATE
30/08/2023

FIGURE No
8.4

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
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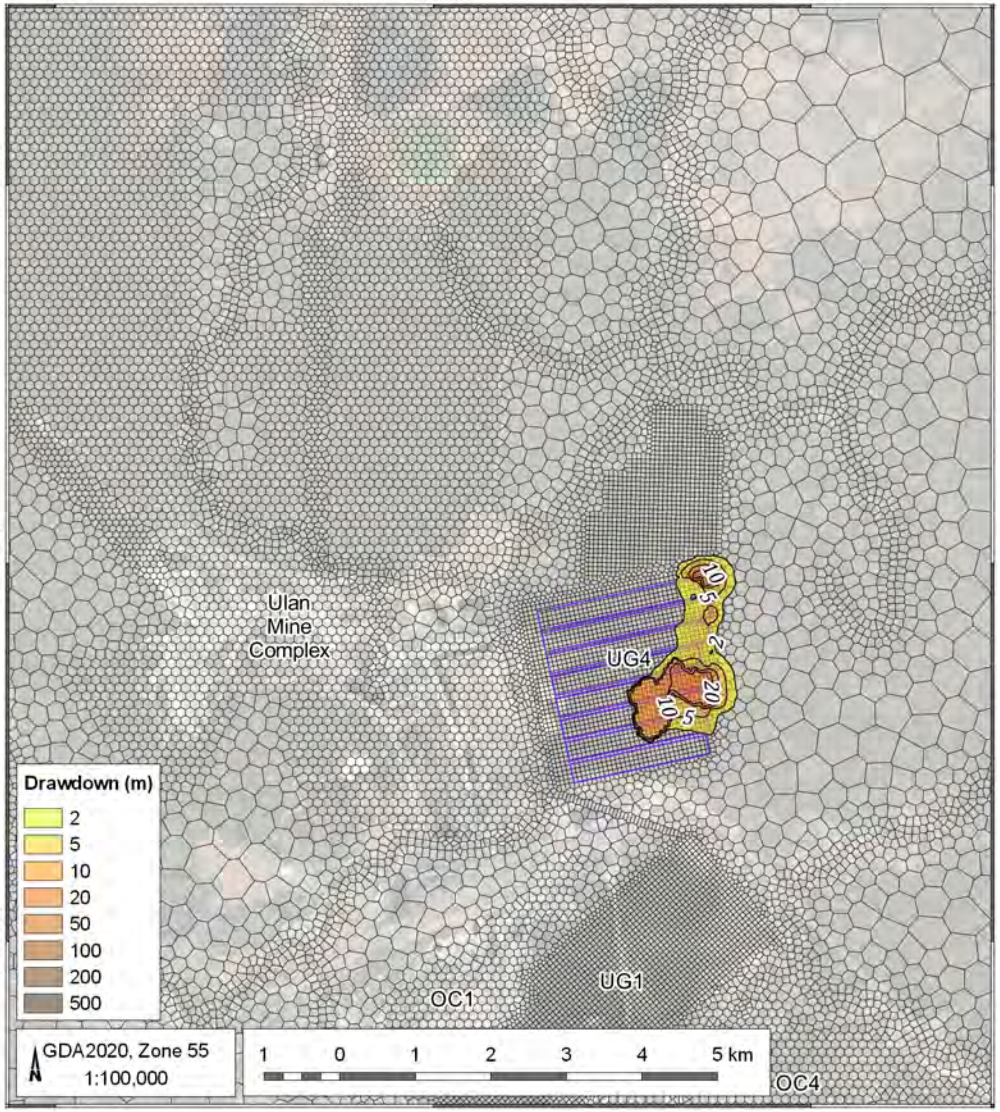
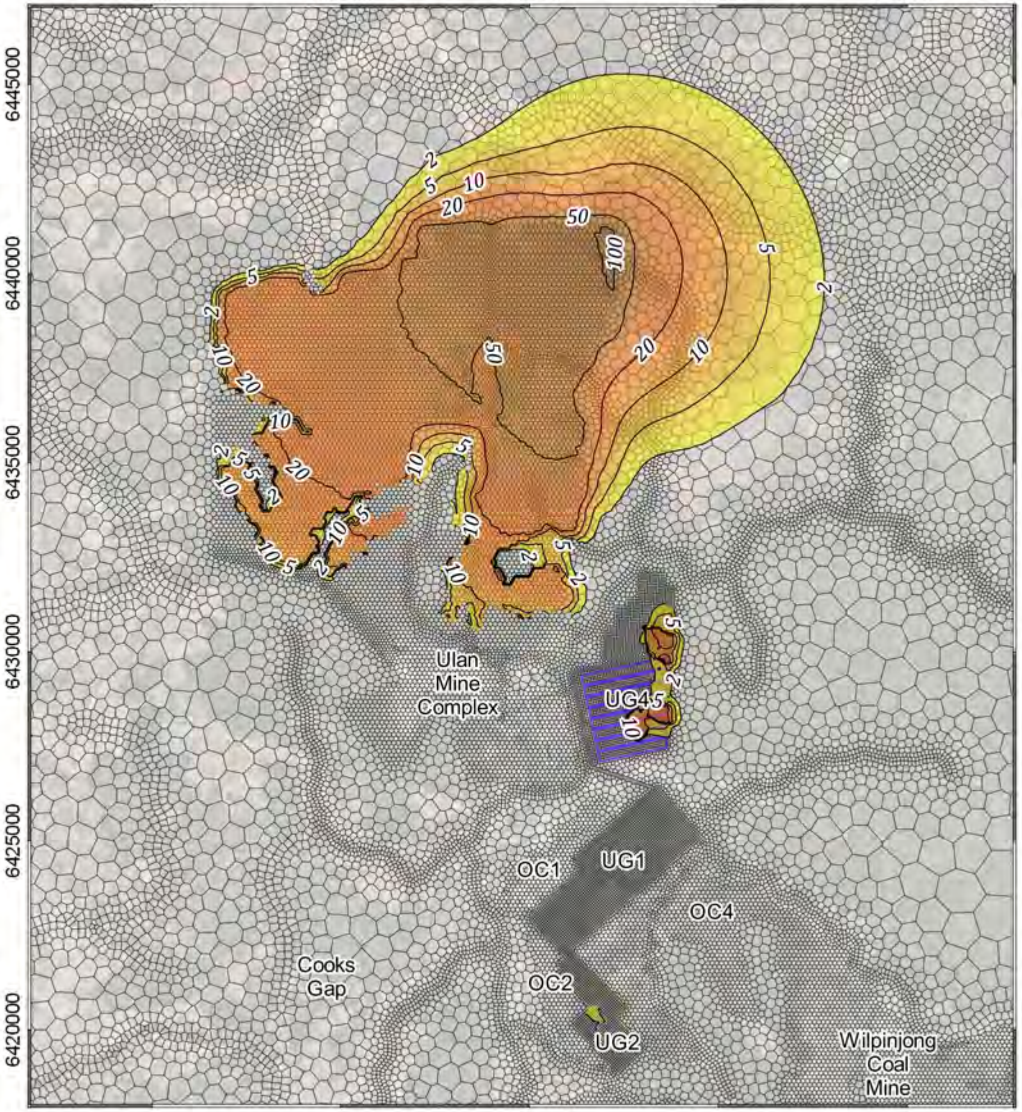
UG4 LW401-408 Only



Cumulative



LEGEND

Drawdown contour (m)

UG4 LW401-408

Model mesh

Moolarben (MOO5001)

AGE

Maximum Predicted Drawdown in Triassic Sandstone (Quartzose) until End of Mining

DATE

30/08/2023

FIGURE No.

8.5

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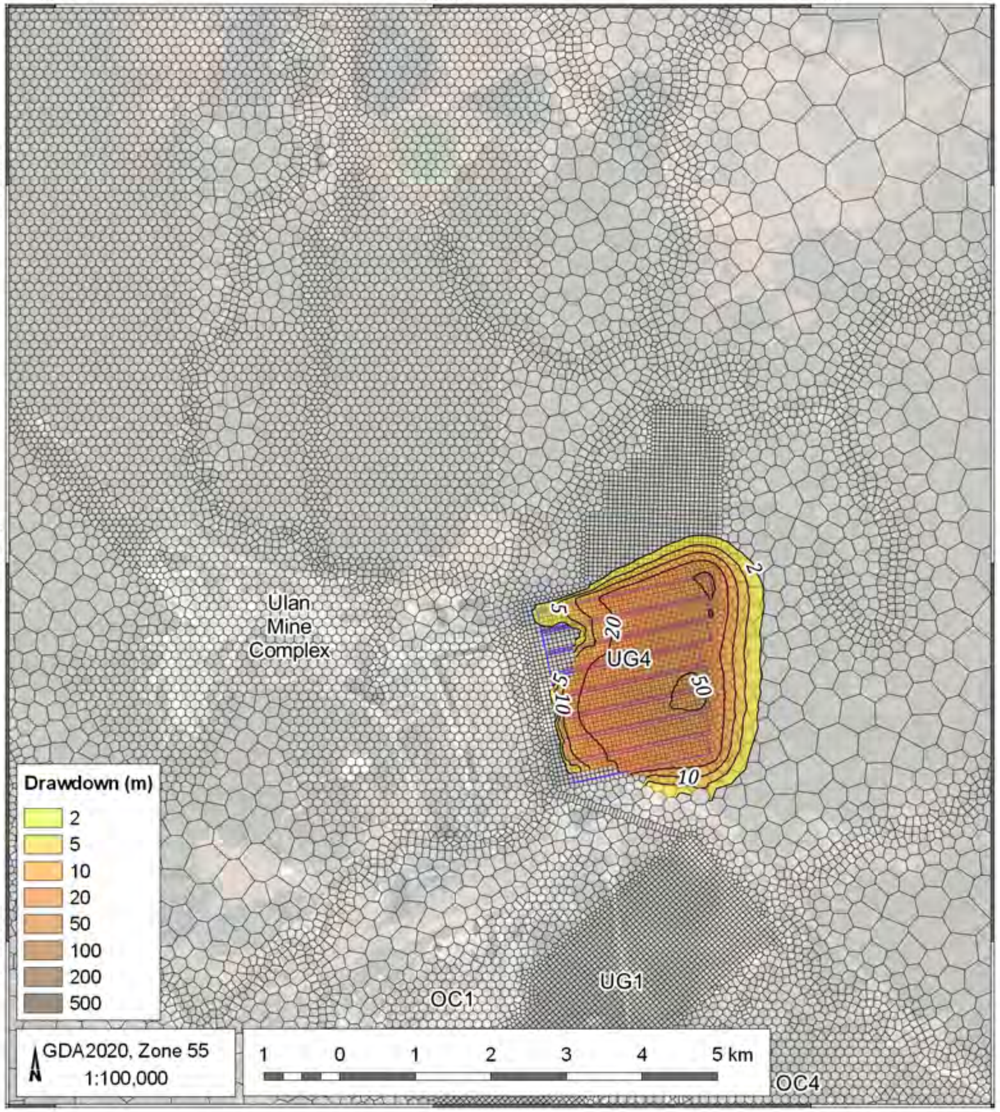
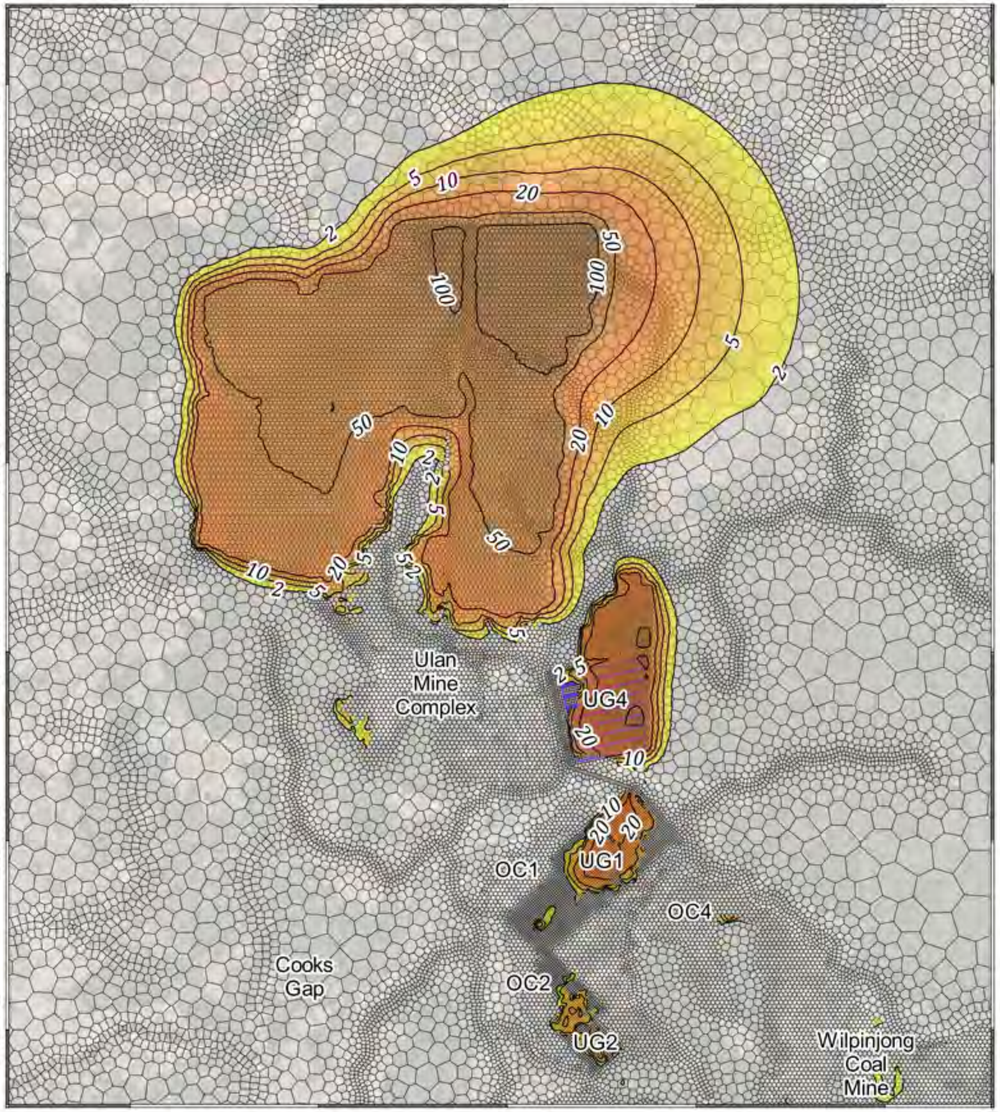
UG4 LW401-408 Only



Cumulative



LEGEND

Drawdown contour (m)

UG4 LW401-408

Model mesh

Moolarben (MOO5001)

AGE

Maximum Predicted Drawdown in Triassic Sandstone (Lithic) until End of Mining

DATE
30/08/2023

FIGURE No.
8.6

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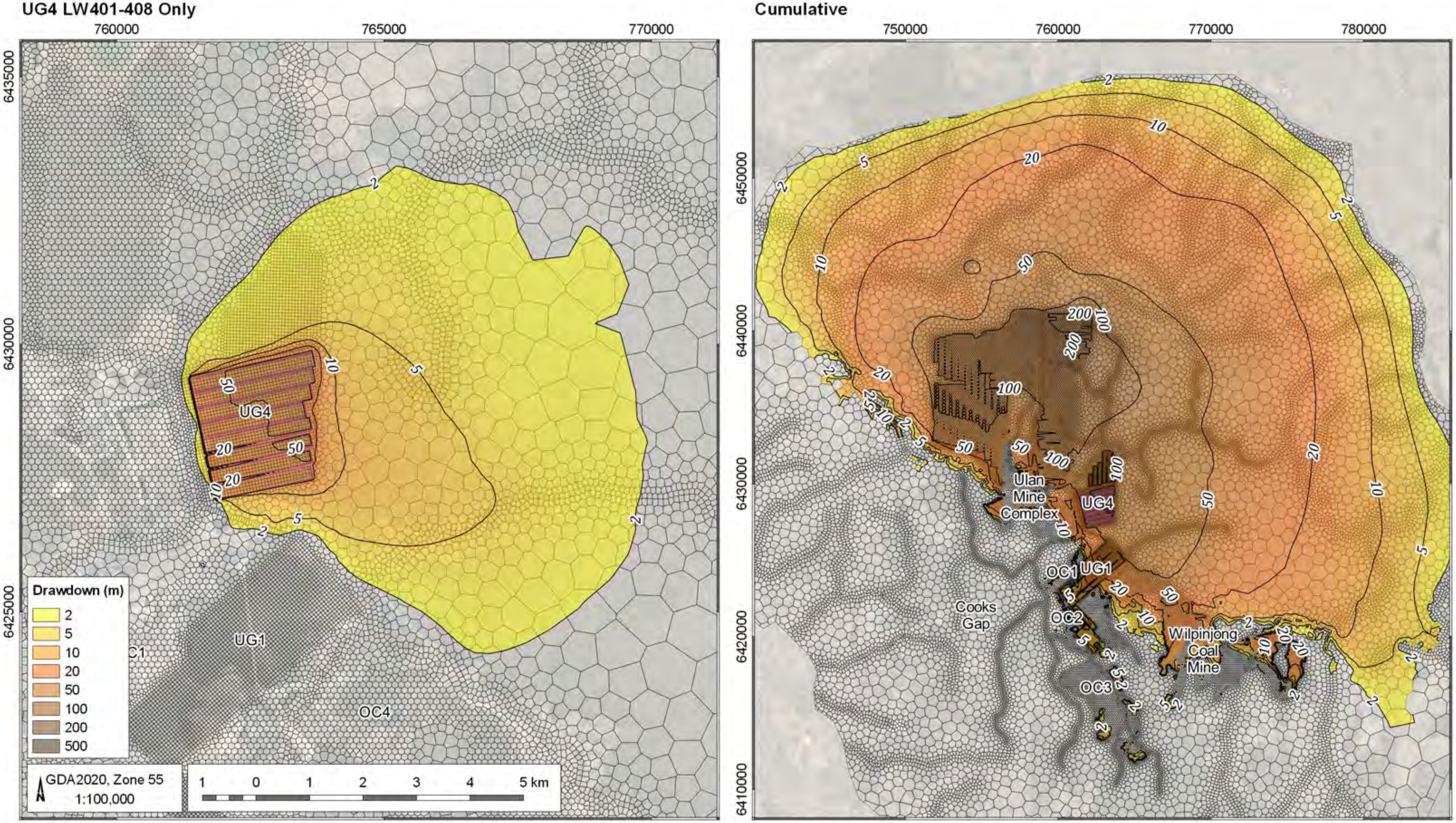


LEGEND

- Drawdown contour (m)
- UG4 LW401-408
- Model mesh

Moolarben (MOO5001)

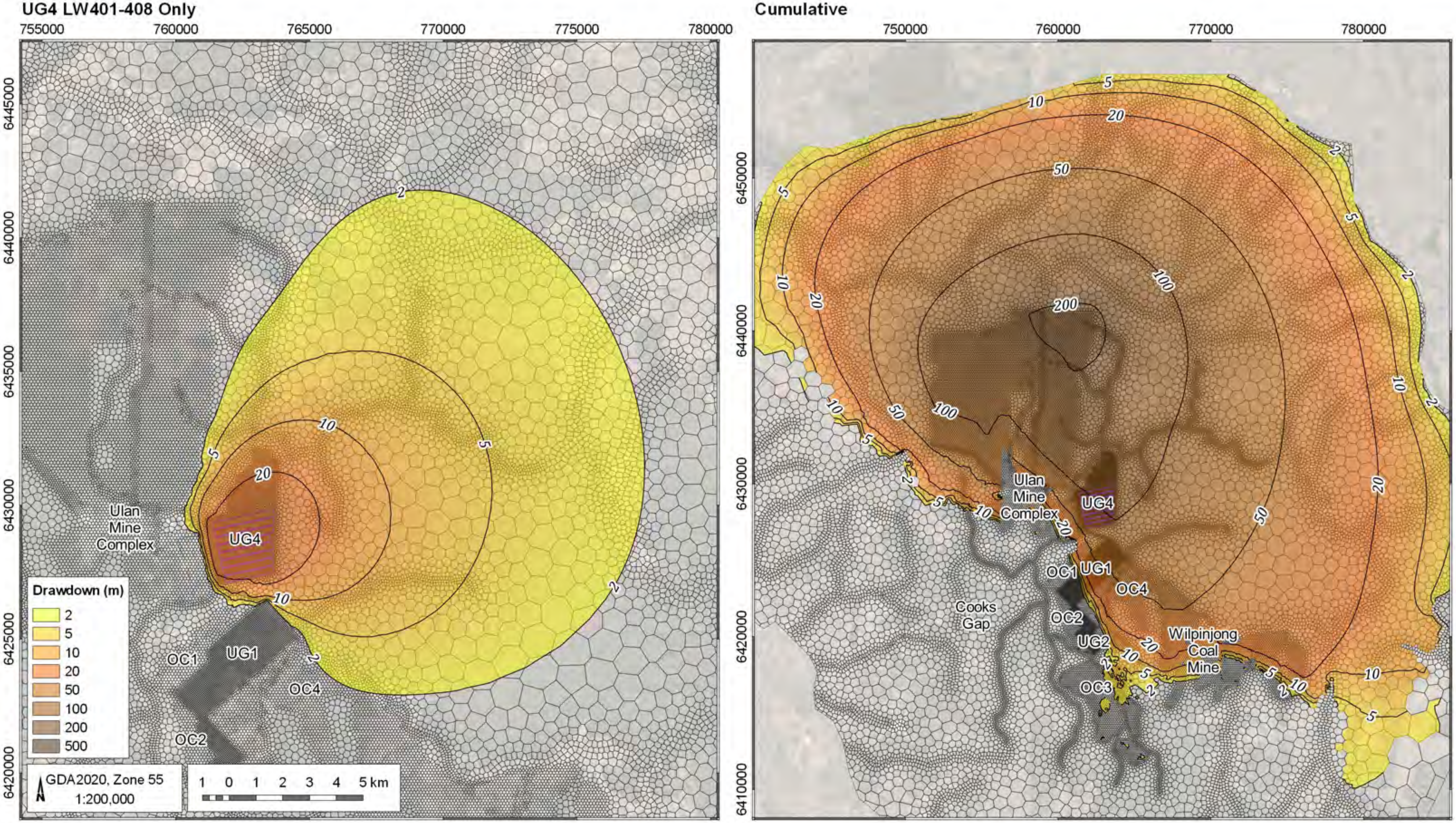
AGE

Maximum Predicted Drawdown in Base of Permian Overburden until End of Mining

DATE
30/08/2023

FIGURE No.
8.7

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:\Projects\MOO5001.001 UG4 Compliance Conditions\3_GIS\Workspaces\001_Deliverable1\08.02_MOO5001_Drawdowns.qgs



LEGEND

Drawdown contour (m)

UG4 LW401-408

Model mesh

Moolarben (MOO5001)

AGE

Maximum Predicted Drawdown in Ulan Seam WS2 until End of Mining

DATE
30/08/2023

FIGURE No.
8.8

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
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The predicted extent of drawdown due to UG4 LW401-408 is generally limited west of UG4 due to the north-eastward dip of Permian and Triassic strata and the subcrop of the Ulan Seam south-west of UG4. As a result, the contribution of groundwater drawdown from UG4 LW401-408 to cumulative drawdowns from the approved Moolarben Coal Complex and surrounding mines is insignificant for most hydrogeological units.

Groundwater drawdown within the Permian ICM is predicted to superimpose (add) a localised but insignificant extra groundwater drawdown component to the total cumulative drawdown, which is constrained by proximity to LW401-408. Predictions show the Permian 2 m drawdown contour extending to less than 7 km from the longwall panels, while regionally cumulative drawdown of greater than 50 m is not uncommon. The confined pressure response in the Ulan Seam, coupled with greater drawdown at the coal face (compared to shallower Hydrostratigraphic units) and a higher aquifer diffusivity (relative to the other Hydrostratigraphic units) allows drawdown to propagate much further in the Ulan Seam, and contributes drawdown to the already regionally impacted groundwater levels of this unit.

The model predicts negligible groundwater drawdown of the unconfined watertable in the vicinity of the Goulburn River resulting from the mining of UG4 LW401-408. Water seeps from the Goulburn River to the watertable as a losing stream (refer to Section 7.3.3). The seepage rate can increase in response to cumulative mining. An increase in the take from Goulburn River is discussed in Section 8.2.4.

8.2.2 Drawdown in private bores

Modelled cumulative groundwater drawdown, which has been calculated as the maximum amount of groundwater drawdown during LW401-408, has been estimated at the only privately owned bore known to be located in the model domain (License 80BL236762) and no groundwater drawdown has been estimated.

8.2.3 Potential impact to The Drip

Based on its elevation in relation to the regional water table, the Drip is conceptualised as a spring fed by shallow groundwater that is perched above the regional groundwater system. It is understood to be perched on a relatively impermeable layer of lithic Triassic sandstone that prevents water from percolating down to the regional water table. It is therefore considered to be hydraulically isolated from the groundwater system that is impacted by mining.

There is no predicted change in the perched water levels associated with The Drip from UG4 LW401-LW408. At their nearest point the longwalls are over 2.5 km south of The Drip.

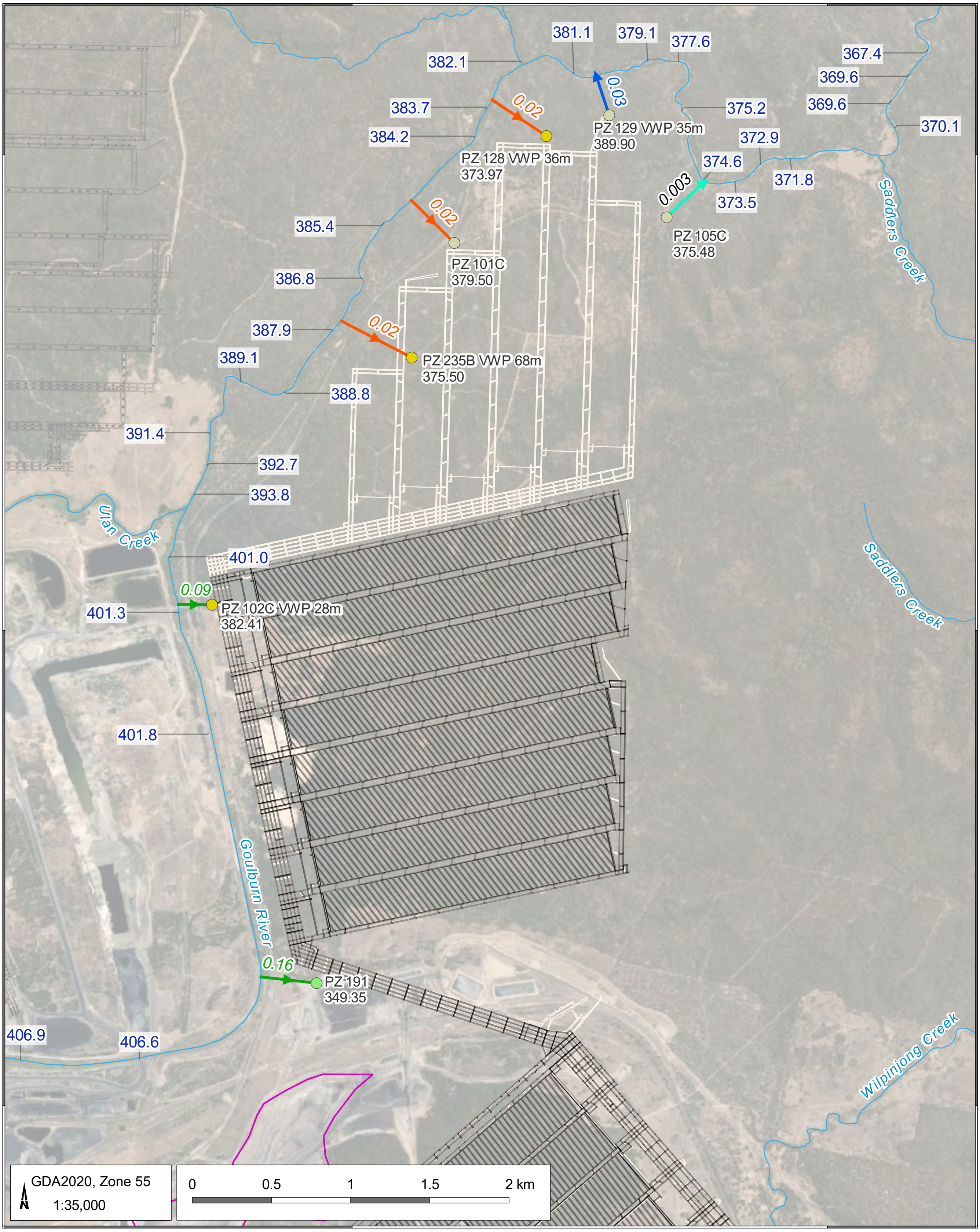
8.2.4 Interception of baseflow

Underground mining and associated mine induced dewatering (and fracturing) will lower the watertable in and around the mine, altering hydraulic gradients in the groundwater regime. This variation could temporarily divert water that might have historically migrated to surface drainages and become baseflow.

The Goulburn River maintains a positive stage height in the model, meaning if the watertable is lower than the river water level, then it will seep water into the aquifer as a losing stream. If the water table is lowered further beneath a losing stream due to mining, then any resultant increase to the seepage rate will also contribute to the total net baseflow take.

Based on recent observations, groundwater baseflow to Bora Creek and two minor drainage lines near UG4 LW401-408 is insignificant as the creek systems are highly ephemeral and generally only flow in response to significant weather events.

Predicted baseflows were extracted from the approved mining and ‘no UG4’ simulations to estimate the predicted change in baseflow due to mining of UG4 LW401-408. The results from this simulation and the baseflow changes are summarised below in Table 8.3. Figure 8.9 displays the resulting hydraulic gradients at the end of mining LW408. With comparison to Figure 6.23, it is clear that no currently observed hydraulic gradients have been reversed. That is, the Goulburn River is not predicted to change from a gaining stream to a losing steam from the mining of LW401-408.



LEGEND

Hydraulic Gradient

- Gaining Stream
- Gaining Stream (Historically Switches Between Losing and Gaining Stream)
- Losing Stream
- Losing Stream (Disconnected)
- Approved Ulan Underground Mine Plan
- UG Mine Plan
- Drainage (River Stage mRL)
- Approximate Extent of OC Mining 2023
- Mine Extent (End of LW408)
- Triassic Bores
- Permian Bores
- Ulan Bores

Note:
RSWL represents Groundwater Levels measured between Dec 2022 to Feb 2023, minus modelled Groundwater drawdown between then and end of Mining LW408.

Groundwater Assessment for Moolarben UG4 Compliance Conditions (MOO5001.001)

Predicted Surface Water / Groundwater Interaction at End of LW401-408

AGE

DATE 30/08/2023

FIGURE No: 8.9

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Table 8.3 Predicted baseflow reduction due to mining of UG4

Water year	Net baseflow take in Upper Goulburn River water source (ML)	Net baseflow take in Moolarben Creek (ML)	Net baseflow take in Wollar Creek Water Source (ML)
2023/24	3.9	0.0	-0.2
2024/25	6.9	0.0	0.2
2025/26	10.5	0.0	0.1
2026/27	12.2	0.0	0.3
2027/28	13.9	0.0	0.3
2028/29	15.1	0.0	-0.4
2029/30	18.1	0.1	0.4
2030/31	19.1	0.0	0.4
2031/32	20.7	0.0	0.4
2032/33	20.	0.0	-0.2
2033/34	22.0	0.0	0.0
2034/35	23.0	0.0	0.1
2035/36	23.9	0.0	-0.1
2036/37	12.2	0.0	0.0

Table 8.4 provides the annual predicted baseflow to the Goulburn River 'reach' as illustrated in Figure 8.11 for both the Approved Mining and No UG4 scenarios. Figure 8.10 displays the predicted baseflow in the Goulburn River reach and indicates the impact that UG4 LW401-408 has on predicted baseflows to the river.

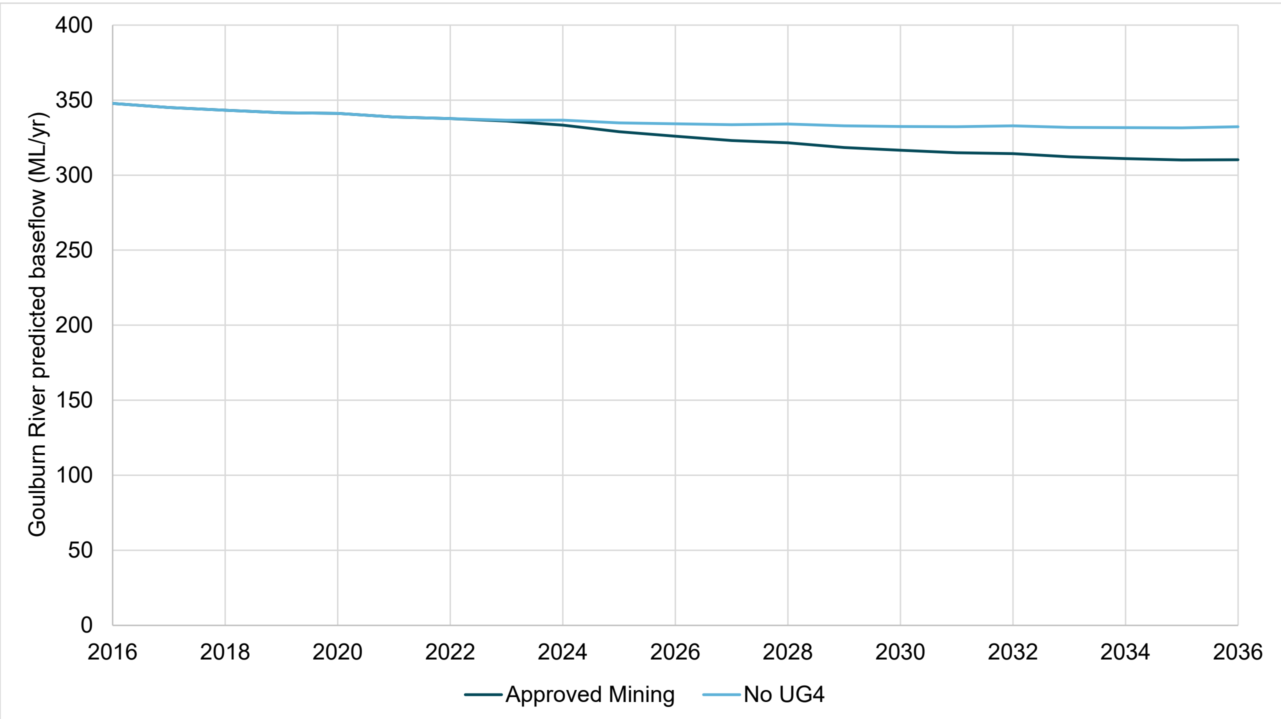
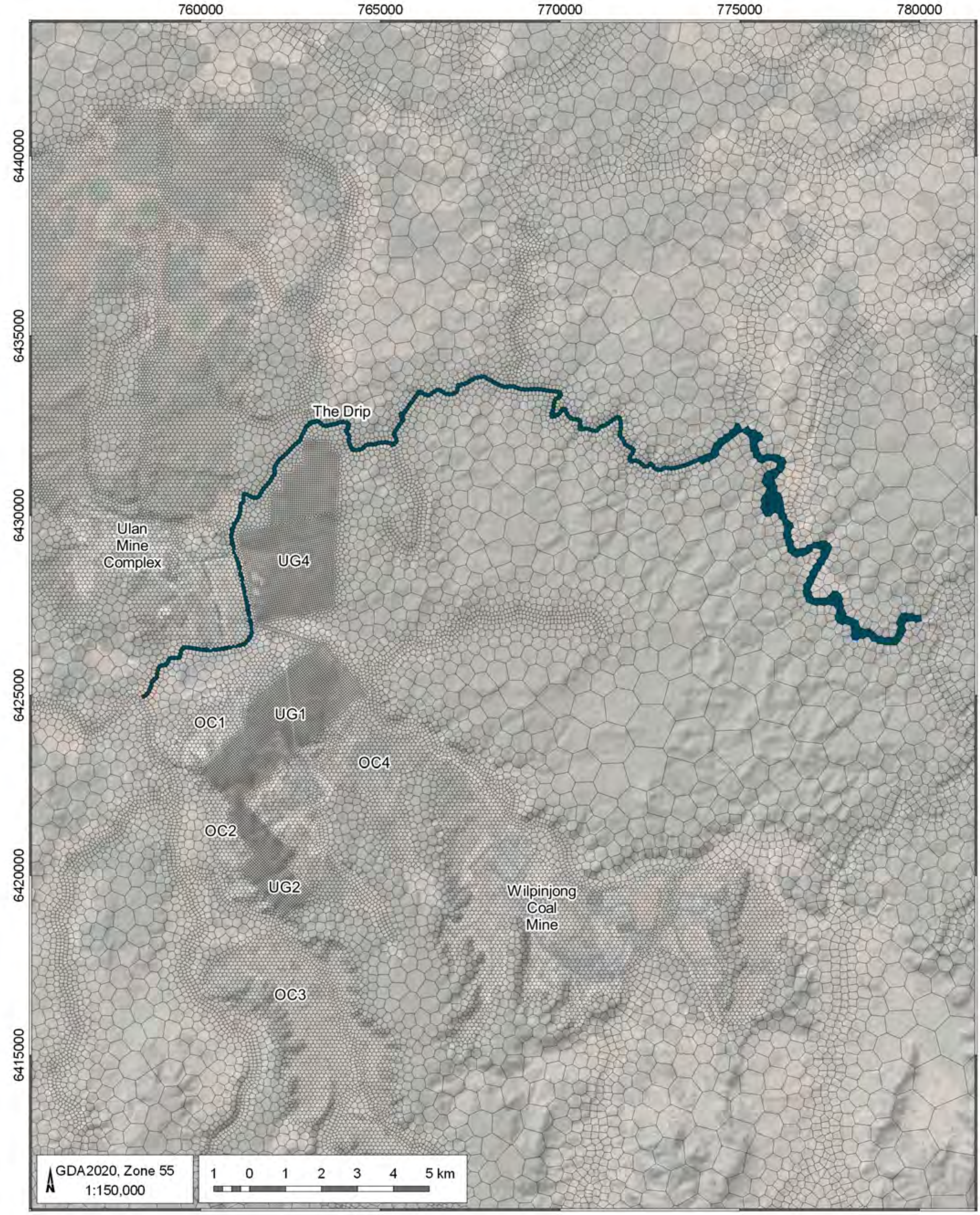


Figure 8.10 Goulburn River annual predicted baseflow

Table 8.4 Goulburn River annual predicted baseflow and predicted baseflow loss

Water year	Goulburn River baseflow (Approved Mining scenario) (ML)	Goulburn River baseflow (No UG4 scenario) (ML)	Baseflow loss attributable to UG4 LW401-408 (ML)
2023/24	333.4	336.6	3.2
2024/25	329.0	334.9	5.9
2025/26	325.9	334.3	8.3
2026/27	323.1	333.7	10.6
2027/28	321.5	334.1	12.6
2028/29	318.5	332.8	14.4
2029/30	316.6	332.5	15.9
2030/31	314.9	332.2	17.3
2031/32	314.3	332.9	18.6
2032/33	312.2	331.8	19.6
2033/34	311.1	331.6	20.5
2034/35	310.2	331.5	21.3
2035/36	310.2	332.3	22.1
2036/37	155.7	167.0	11.3

The difference between the modelled baseflow loss predictions presented in Table 8.3 and Table 8.4 stems from the way in which baseflow loss has been calculated. Table 8.3 presents the baseflow loss to all river cells hosted within the Goulburn River Water Source, whereas Table 8.4 presents the baseflow loss to the specific reach of Goulburn River as shown in Figure 8.11. As such, predictions in Table 8.4 may include sections of the Goulburn River which are hosted by the Sydney Basin-North Coast Groundwater Source.



LEGEND

Goulburn River model cell

Model mesh

Moolarben (MOO5001)

Goulburn River Model Cells

AGE

DATE 30/08/2023

FIGURE No: **8.11**

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
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8.3 Water licensing requirements

Mining of longwall panels LW401 to LW408 will result in a direct take of groundwater from the Sydney Basin-North Coast Groundwater Source, which is regulated under the *Water Sharing Plan for the North Coast Fractured and Porous Rock Groundwater Sources 2016*.

The subsidence and fracturing associated with longwall mining will provide increased connection to overlying and underlying strata, and the hydraulic gradients will result in the flow of groundwater to the mine area. This flow results in indirect take from the surrounding strata.

The amount of incidental water take from surrounding groundwater sources has been determined by comparison of the model scenarios (Table 8.1). Using this process, both the direct and indirect water take has been predicted, by isolating the influence and contribution of those panels.

The estimated water take from the various NSW Water Sources due to LW401 to LW408 are outlined in the following section.

8.3.1 Direct take

The predicted direct take from mining activities is presented for the MCC (including UG4 LW401 to LW408), and for UG4 LW401 to LW408 proportionally in Table 8.5.

Table 8.5 Predicted direct take from the Sydney Basin-North Coast Groundwater Source

Water Year	Licence Entitlement (including carry-over)	Moolarben Take (ML)	LW401 to LW408 Take (ML)
2023/24	5,422	3719	3471
2024/25	4,195	3910	3626
2025/26	2,991	2779	1552

Modelled MCC peak take from the Sydney Basin-North Coast Groundwater Source are generally consistent, but marginally lower than those reported by AGE (2021). The predicted peak take has reduced from 4,428 ML (AGE, 1021) to 3,910 ML based on the latest model updates.

8.3.2 Indirect take

Mine dewatering at MCC has indirect impact on two water sources that are regulated under the *Water Sharing Plan for the Hunter Unregulated and Alluvial Water Sources 2022*. The peak impacts are presented below in Table 8.6.

Table 8.6 Peak water take from the Upper Goulburn River and Wollar Creek Water Sources

Water Source	Licence Entitlement (including carry-over)	Moolarben Peak Take (ML/year)	LW401 to LW408 Peak (ML/year)
Upper Goulburn River Water Source	416	250 (2023/24)	97 (2023/24)
Wollar Creek Water Source	436	282 (2026/27)	0.4 (2025/26)

Modelled MCC peak take from the Upper Goulburn River Water Source has increased from 71 ML (AGE, 2022a) to 250 ML, while the modelled MCC peak take from the Wollar Creek Water Source has increased from 184 ML (AGE, 2021) to 282 ML based on the latest model predictions.

8.4 Predictive Uncertainty

Groundwater models represent complex environmental systems and processes in a simplified manner. This means that predictions from groundwater models, like other environmental models, are inherently uncertain. When considered in a risk management context, a single calibrated model is insufficient to fully predict the range of potential impacts and their likelihood. Uncertainty analysis is therefore important for regulatory decision-making to ensure management options and approaches are appropriate to the level of risk and its likelihood for impact.

Predictions using the base case calibrated model indicate that the impacts from UG4 LW401-408 are constrained to very local impacts, and there are no predicted additional impacts to existing groundwater users or GDEs. These impacts are commensurate with the contemporary hydrogeological conceptualisation, which has been based on all available data, including observations from the mining of the approved MCC, UMC and WMC operations. Local, non-extensive impacts are largely due to the following factors:

- extremely low vertical permeability of the Permian ICM which limits vertical leakance from the overlying Triassic sandstone;
- enhanced fracturing above the underground operation is limited to the footprint of mined longwall panels, and as such the impact pathway for regional impacts to occur is predominantly via vertical leakance through extremely low permeability strata; and
- limited saturation thickness of the upper Triassic sandstone which limits the horizontal propagation of groundwater drawdown.

Predicted local impacts are commensurate with the observed impacts which have occurred in response to the mining of OC1, OC2, OC3, OC4, UG1, and LW 401. The model predictions are therefore commensurate with the current hydrogeological conceptualisation.

With limited and local impacts expected, uncertainty analysis using 'scenario analysis' was considered appropriate. This is one of three recommended methods of undertaking uncertainty analysis as described in the IESC guidelines for uncertainty analysis (Middlemis and Peeters, 2018). Scenario analysis involves assessment of a range of values for a number of targeted parameters (also known as a sensitivity analysis). Parameters which were considered to have the highest degree of uncertainty were identified and assessed as described below.

Table 8.7 provides details of the eight scenarios which were completed and compared to the results of the base case model scenario. All sensitivity scenarios consist of one model run that includes the mining of UG4 LW401-408, and one model run which excludes mining of LW401-408. These two runs are then compared to assess the impacts of each scenario. All scenarios include neighbouring mining operations.

Table 8.7 Suggested Modelled Sensitivity Scenarios

Sensitivity Scenario	Description	Specific Details
1	Increase Hydraulic Conductivity of the Triassic Sandstone and Permian ICM	Increase K_x, K_y & K_z of the Triassic sandstone and Permian ICM by 1 Order of Magnitude.
2	Decrease Hydraulic Conductivity of the Triassic Sandstone and Permian ICM	Decrease K_x, K_y & K_z of the Triassic sandstone and Permian ICM by 1 Order of Magnitude.
3	Increase Storage Properties of the Triassic Sandstone and Permian ICM	Increase S_y & S_s of the Triassic sandstone and Permian ICM by 1 Order of Magnitude.
4	Decrease Storage Properties of the Triassic Sandstone and Permian ICM	Decrease S_y & S_s of the Triassic sandstone and Permian ICM by 1 Order of Magnitude.
5	Increase Recharge	Increase Recharge by 1 Order of Magnitude
6	Decrease Recharge	Decrease Recharge by 1 Order of Magnitude
7	Combined Scenario - High K, High S and High Recharge (S1,S3, S5)	Implement the changes as per S1, S3 and S5. Ie High K, High S and High Recharge
8	Combined Scenario - High K, Low S and High Recharge (S1,S4, S5)	Implement the changes as per S1, S4 and S5. Ie High K, Low S and High Recharge

Notes: No increase to the Ulan Seam Hydraulic Conductivity required, as it is capped with an upper applied rate of 0.8 m/d
Specific yield will be kept below 15%, and Ss will be maintained below the suggested upper physical limit of Rau et al. (2018).

Given the location of LW401-408, the sensitivity analysis targeted the hydraulic properties of the Triassic sandstone and Permian ICM units, and the effect which groundwater recharge has on the propagation of impacts.

8.4.1 Uncertainty in mine inflows

Figure 8.12 shows the variability in modelled mine inflows, due to the change in hydraulic parameters and groundwater stresses (i.e. increased recharge), invoked through the sensitivity analysis.

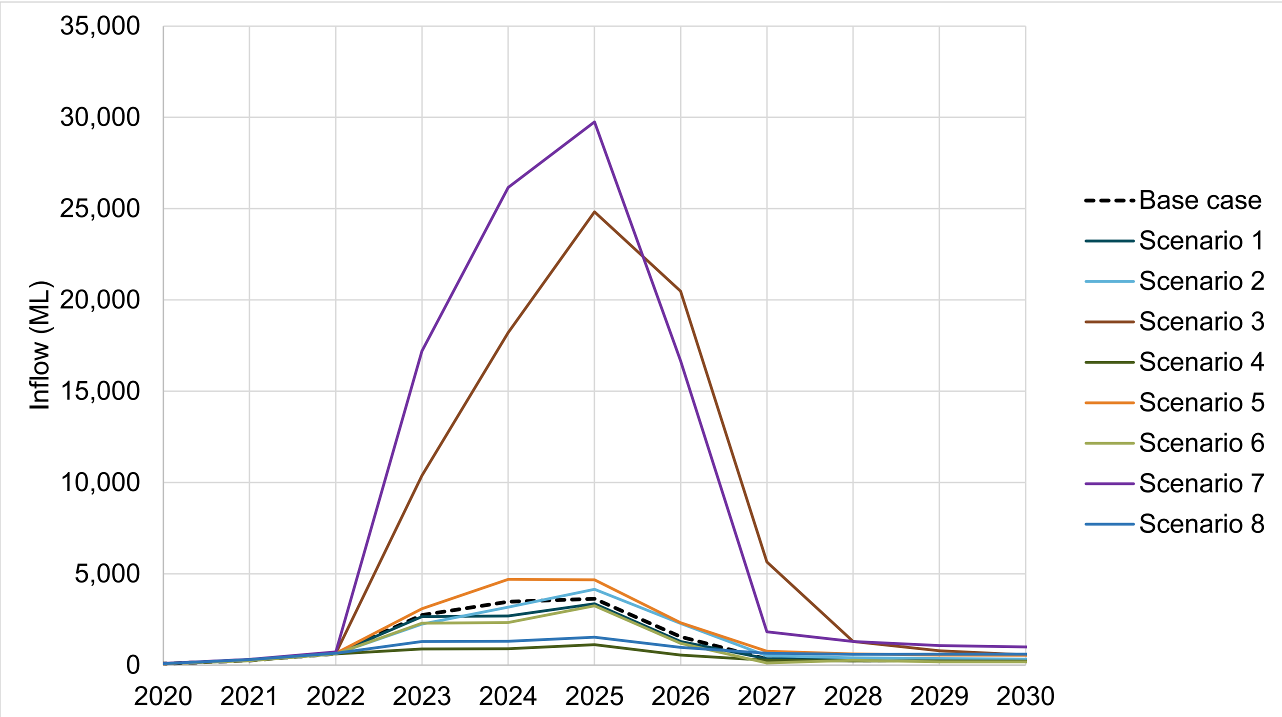


Figure 8.12 Mine Inflows per Sensitivity Scenario

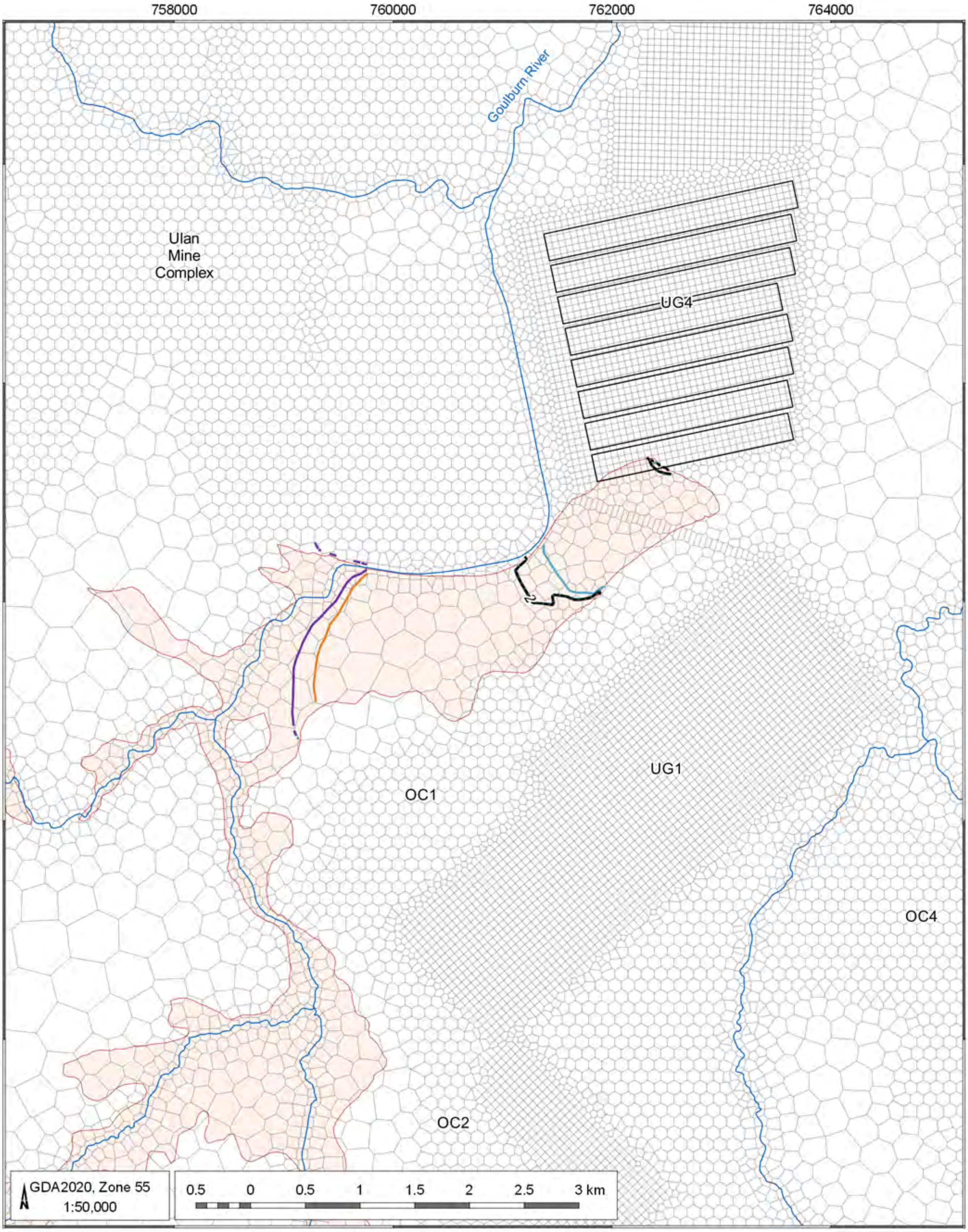
The following can be inferred from Figure 8.12:

- the trend of the modelled inflows is generally consistent with the base case scenario, albeit with significant changes in amplitude observed through the period between 2022 to 2028;
- similar trends in inflows are observed from 2028 onwards; and
- the model is sensitive to changes in aquifer storage, with Scenario 3 & 7 producing unrealistic inflows during 2023, when calculated mine inflows are significantly lower than predicted model inflows.

8.4.2 Uncertainty in modelled drawdown

Figure 8.13 to Figure 8.18 shows the difference in modelled drawdown by comparison of the 2 m modelled drawdown contour for each sensitivity scenario. The 2 m contour represents the maximum modelled drawdown which can occur at any stage during mining, the following can be inferred from these figures:

- the base case geographical impact extent (as defined by the 2 m maximum drawdown contour) is generally consistent in shape with the largest extents predicted, as defined by the sensitivity scenarios;
- the combined parameter scenario (scenario 8), which adopts a combination of both high permeability and low aquifer storage produces the greatest groundwater drawdown extents, which is expected conceptually;
- groundwater drawdown in the Triassic quartzose sandstone owing from the combination of higher permeability and low storage extends the 2 m extent from less than 500 m to approximately 3400 m, which is not consistent with groundwater observations from the mining of UG1; and
- groundwater drawdown in the Triassic quartzose sandstone owing from the other combinations of hydraulic parameters and recharge extend the 2 m extent to less than 1300 m for all other scenarios.



LEGEND

2 Metre Drawdown Contours

- Base case
- Scenario 1
- Scenario 2
- Scenario 3
- Scenario 4
- Scenario 5
- Scenario 6
- Scenario 7
- Scenario 8

- Drainage
- UG4 LW401-408
- Quaternary alluvium mapped extent
- Model mesh

Moolarben (MOO5001)

Predicted Extent of 2 m Drawdown in Quaternary Alluvium for Each Sensitivity Scenario until End of Mining

AGE

DATE 31/08/2023

FIGURE No: **8.13**

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
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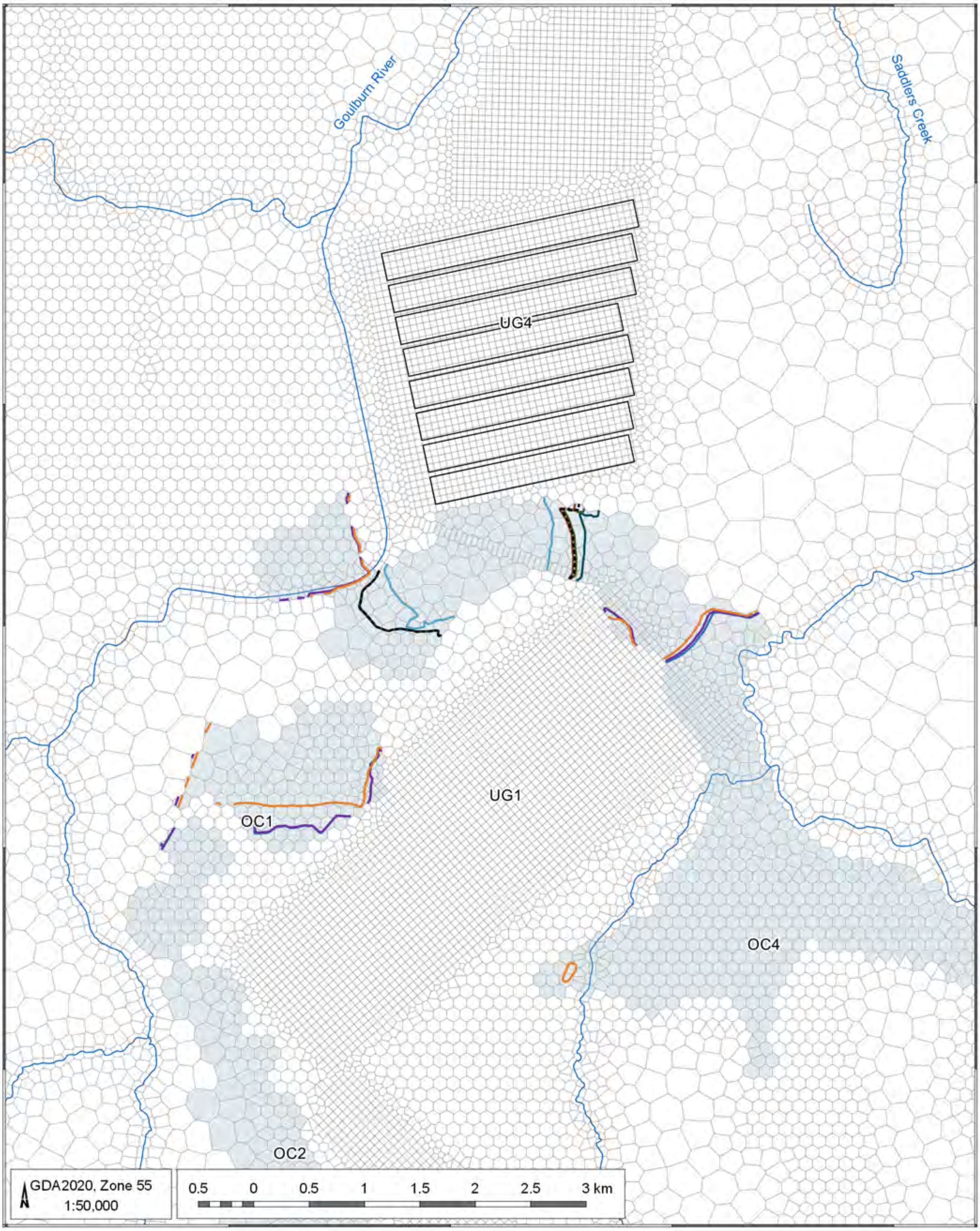

LEGEND

2 Metre Drawdown Contours

- Base case
- Scenario 1
- Scenario 2
- Scenario 3
- Scenario 4
- Scenario 5
- Scenario 6
- Scenario 7
- Scenario 8

- Drainage
- UG4 LW401-408
- Palaeochannel extent
- Model mesh

Moolarben (MOO5001)

Predicted Extent of 2 m Drawdown in Palaeochannel for Each Sensitivity Scenario until End of Mining

AGE

DATE 31/08/2023

FIGURE No: **8.14**

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
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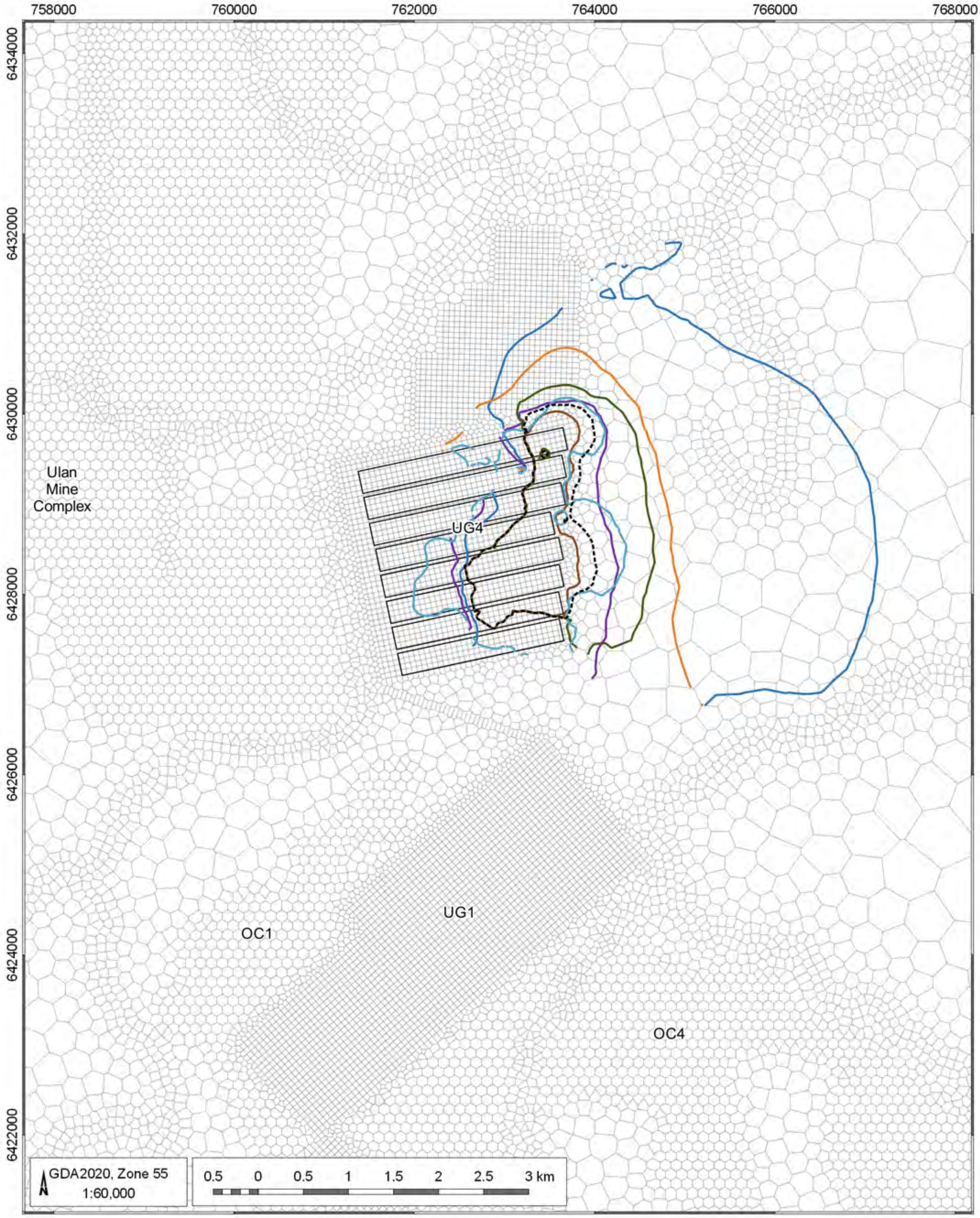

LEGEND

2 Metre Drawdown Contours

- Base case
- Scenario 1
- Scenario 2
- Scenario 3
- Scenario 4
- Scenario 5
- Scenario 6
- Scenario 7
- Scenario 8

UG4 LW401-408

Model mesh

Moolarben (MOO5001)

Predicted Extent of 2 m Drawdown in Triassic Sandstone (Quartzose) for Each Sensitivity Scenario until End of Mining

AGE

DATE 31/08/2023

FIGURE No: **8.15**

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
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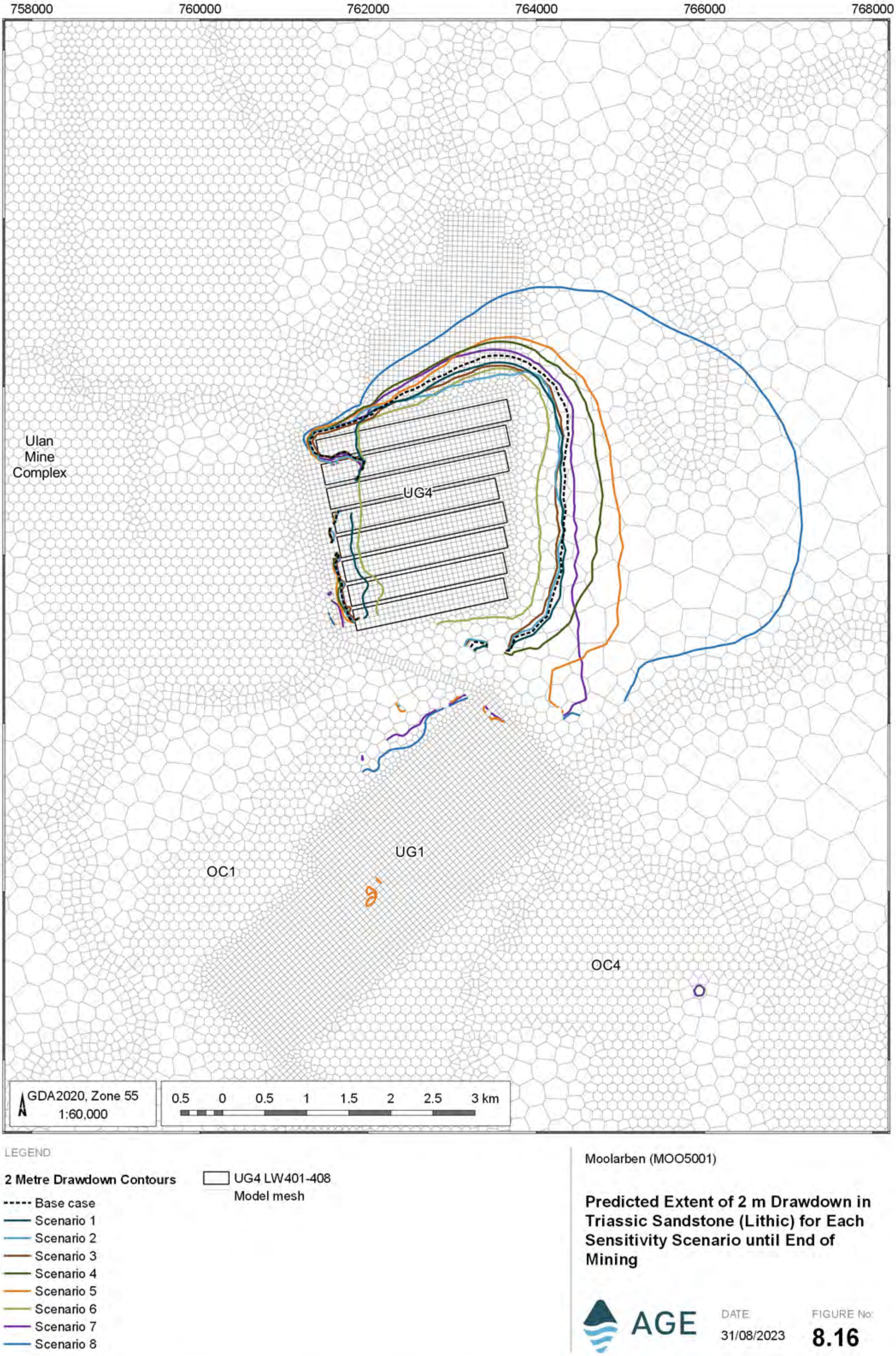

Moolarben (MOO5001)

Predicted Extent of 2 m Drawdown in Triassic Sandstone (Lithic) for Each Sensitivity Scenario until End of Mining

AGE

DATE 31/08/2023

FIGURE No: **8.16**

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
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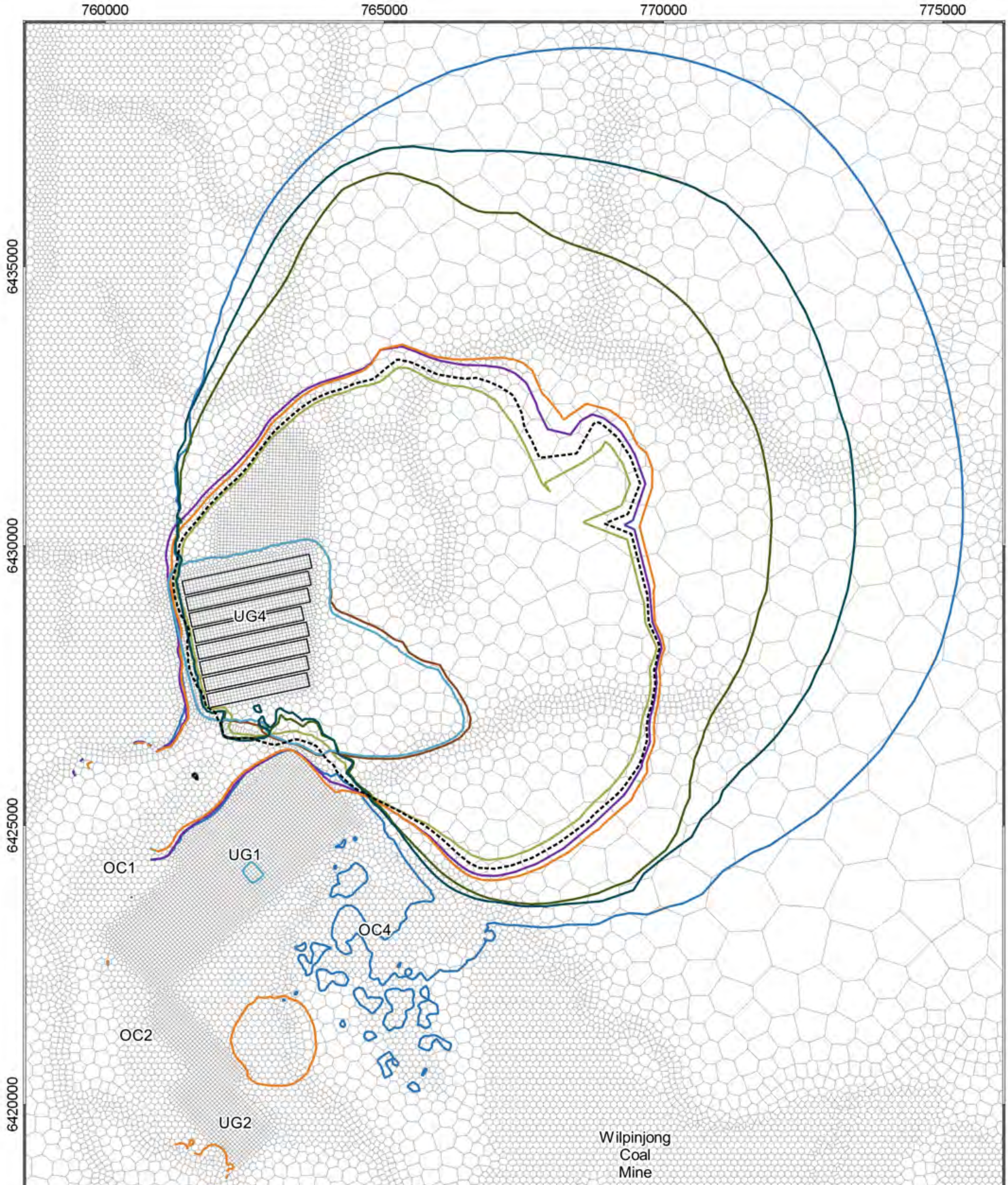


LEGEND

2 Metre Drawdown Contours

- Base case
- Scenario 1
- Scenario 2
- Scenario 3
- Scenario 4
- Scenario 5
- Scenario 6
- Scenario 7
- Scenario 8

UG4 LW401-408

Model mesh

Moolarben (MOO5001)

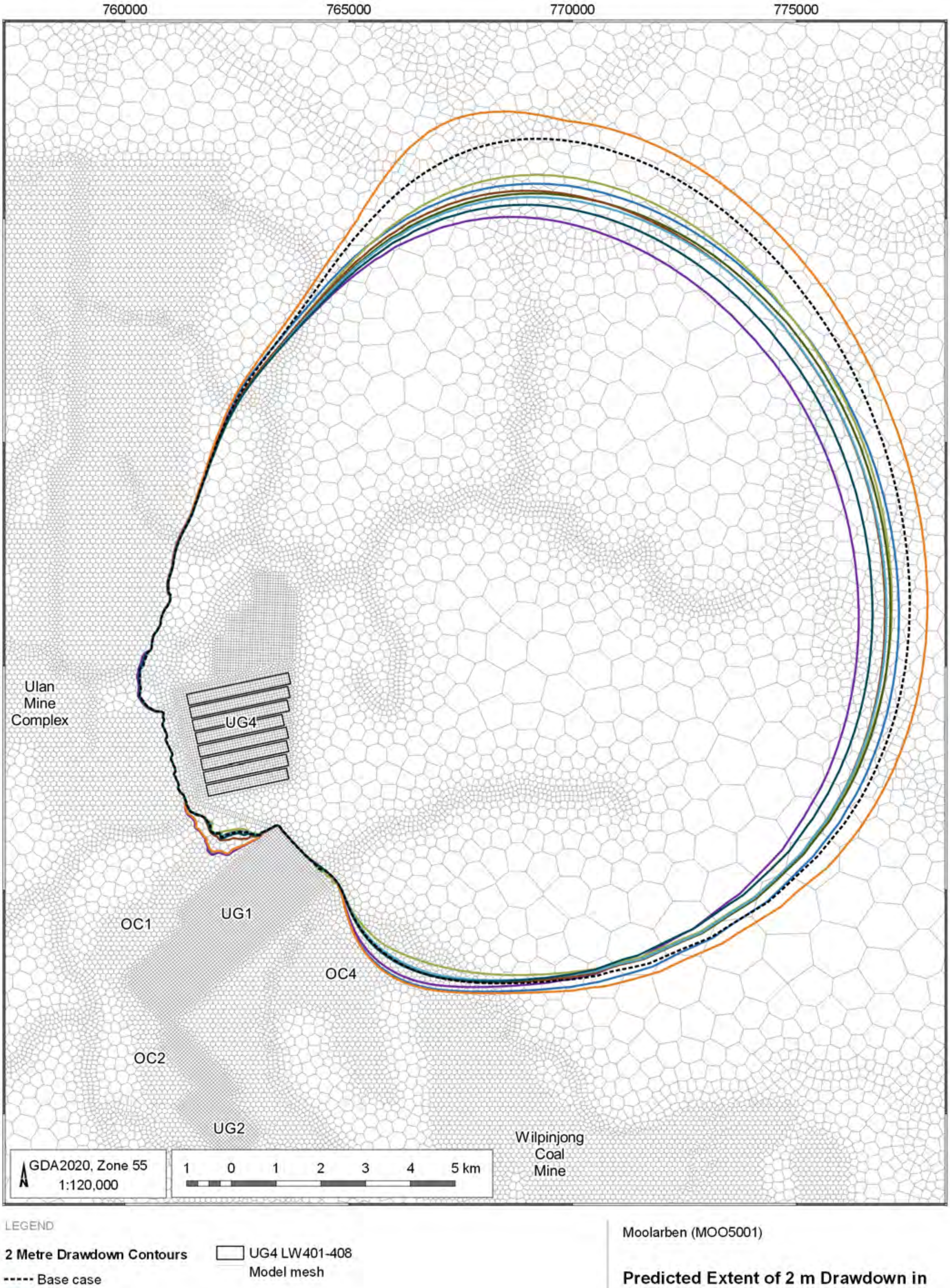
Predicted Extent of 2 m Drawdown in Base of Permian Overburden for Each Sensitivity Scenario until End of Mining

AGE

DATE 31/08/2023

FIGURE No: **8.17**

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:\Projects\MOO5001.001 UG4 Compliance Conditions\3_GIS\Workspaces\001_Deliverable1\08.13_MOO5001_DrawdownsSensitivity.qgs



LEGEND

2 Metre Drawdown Contours

- Base case
- Scenario 1
- Scenario 2
- Scenario 3
- Scenario 4
- Scenario 5
- Scenario 6
- Scenario 7
- Scenario 8

UG4 LW401-408

Model mesh

Moolarben (MOO5001)

Predicted Extent of 2 m Drawdown in Ulan Seam WS2 for Each Sensitivity Scenario until End of Mining

AGE

DATE 31/08/2023

FIGURE No: **8.18**

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
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8.4.3 Uncertainty in baseflow changes

Table 8.8 and Figure 8.19 below present the modelled baseflow reduction for the Goulburn River reach for each of the sensitivity scenarios. Scenario 8 indicates the largest proportion in predicted baseflow loss. Other scenarios predict similar baseflow reductions proportionally (to the base case) with scenarios 1, 2 and 6 predicting a smaller baseflow reduction than the base case, while scenario 5 predicts a slightly higher proportion of baseflow loss.

As per the discussion in Sections 8.4.1 and 8.4.2, sensitivity scenarios 3, 7 and 8 have been identified as not commensurate with observed results from MCC, and as such, modelled baseflow loss is likely to be of the order of less than 10% of baseflow incursions to the Goulburn River, from the mining of LW401-408. This does not represent a significant, or measurable risk to the Goulburn River.

Table 8.8 Modelled Baseflow Reduction due to the LW401-LW408

Sensitivity Scenario	Scenario Description	Peak modelled baseflow reduction at end of mining (%)
Base case	Base case parameters	7.3
1	Increase Hydraulic Conductivity of the Triassic Sandstone and Permian ICM	4.2
2	Decrease Hydraulic Conductivity of the Triassic Sandstone and Permian ICM	5.5
3	Increase Storage Properties of the Triassic Sandstone and Permian ICM	7.2
4	Decrease Storage Properties of the Triassic Sandstone and Permian ICM	7.4
5	Increase Recharge	9.7
6	Decrease Recharge	0.0
7	Combined Scenario - High K, High S and High Recharge (S1,S3, S5)	13.2
8	Combined Scenario - High K, Low S and High Recharge (S1,S4, S5)	14.3

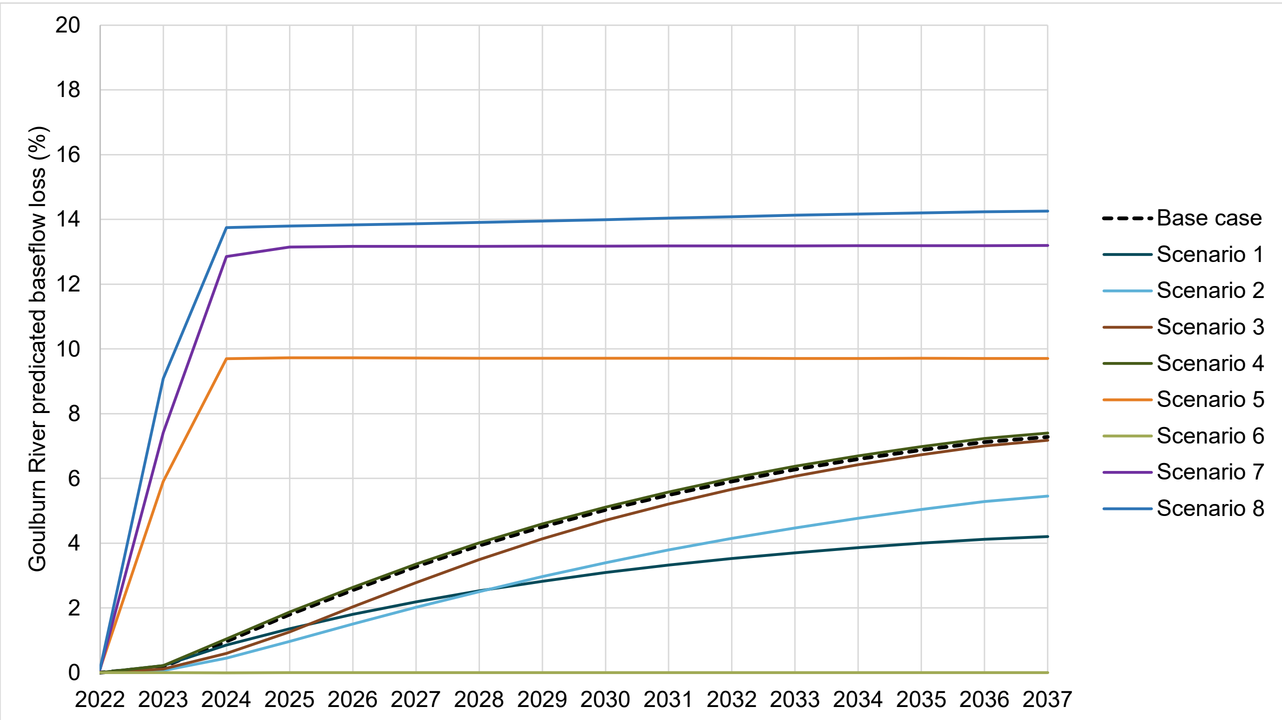

Figure 8.19 Modelled Baseflow Reduction due to LW401-408

9 Summary

A comprehensive, contemporary analysis has been completed in order to update the current hydrogeological conceptual model at the MCC. AGE has assessed all groundwater and surface water data available, including data made available from adjacent mining operations through data sharing agreements. A detailed analysis and comparison of climate data with groundwater head observations has led to a thorough understanding of the hydrogeological behaviour of the system, and its response to previous hydraulic stresses, including natural, climatic stresses, and mining related stresses.

Based on the revised conceptual updates, the independently peer reviewed groundwater model which was reported by AGE (2022a) was updated, in order to predict the impact that the mining of UG4 LW401-408 will have on the groundwater regime. The objectives of the predictive modelling were to:

- predict groundwater inflows into UG4 LW401-408;
- predict the effect of UG4 LW401-408 on the upper groundwater levels as well as the groundwater pressure responses in the deeper strata; and
- predict the loss and/or water take from the water bearing units in the vicinity of UG4 LW401-408, including losses to baseflow to inform water licensing requirements.

Results from the revised model do not show any significant changes to key model predictions associated with LW401-408 mining when compared to AGE (2021).

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Appendix A

Groundwater Monitoring Hydrographs

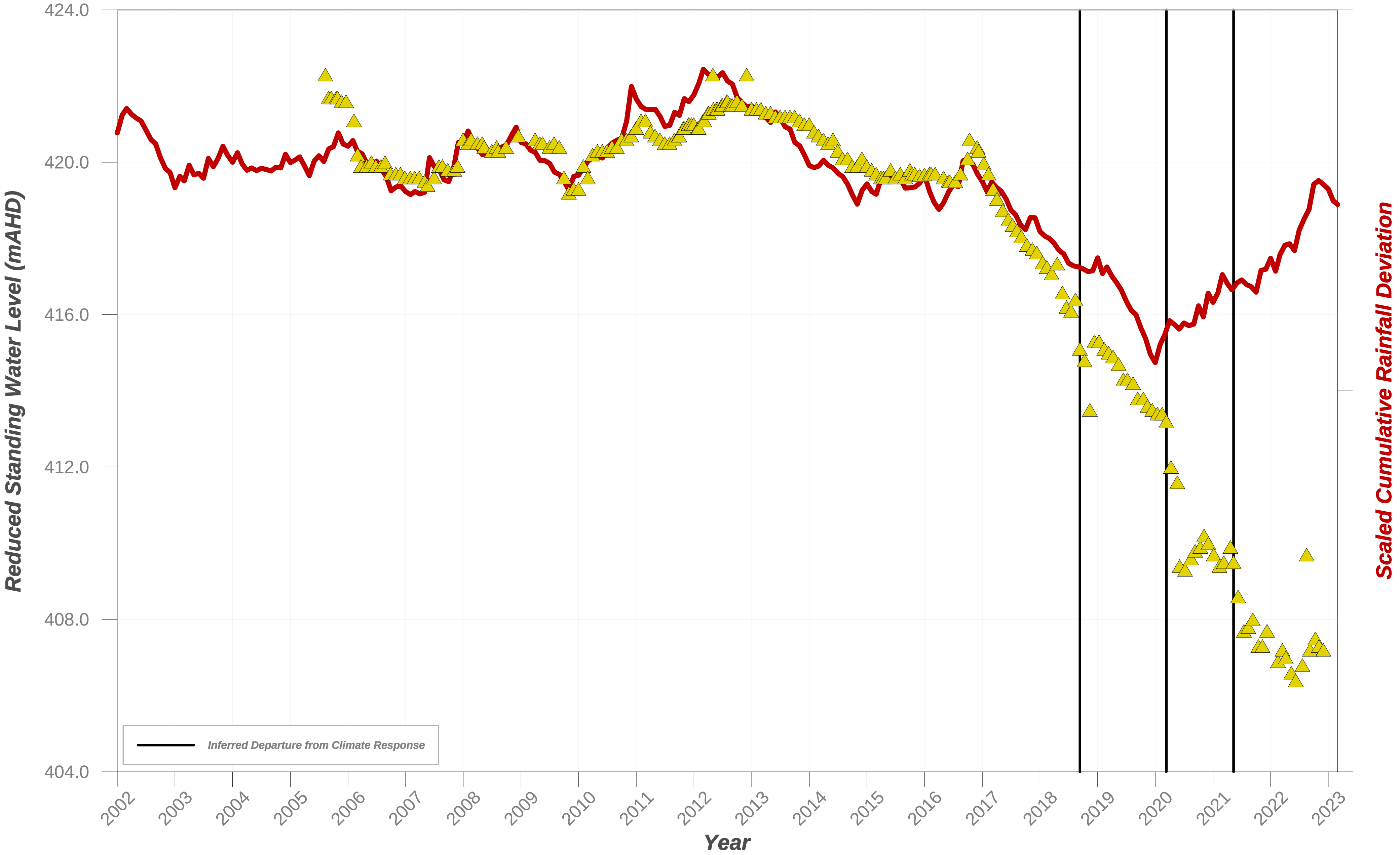
Hydrograph of Groundwater Level Data for Bore ID: PZ 003
Moolarben Groundwater Monitoring - Ulan Seam
Moolarben Coal Operations - UG4 Groundwater Assessment Report

Manual Dips
Anomalous Reading
Continuous Logger Data
Anomalous Logger Data

AGE

DATE
29/07/2023

FIGURE No:
A.001



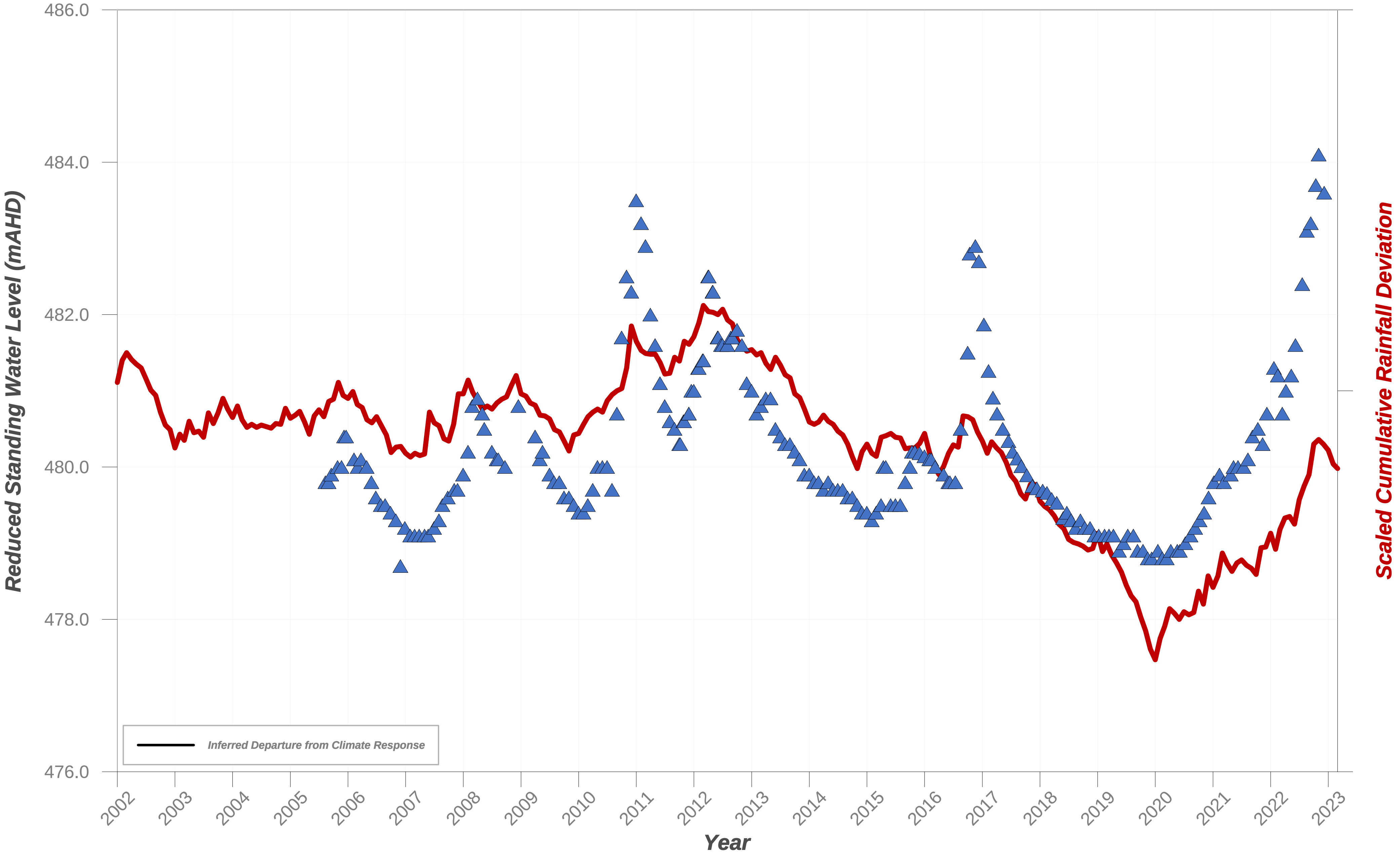
Hydrograph of Groundwater Level Data for Bore ID: PZ 040B
Moolarben Groundwater Monitoring - Permian
Moolarben Coal Operations - UG4 Groundwater Assessment Report

Manual Dips
Anomalous Reading
Continuous Logger Data
Anomalous Logger Data

AGE

DATE
29/07/2023

FIGURE No:
A.002



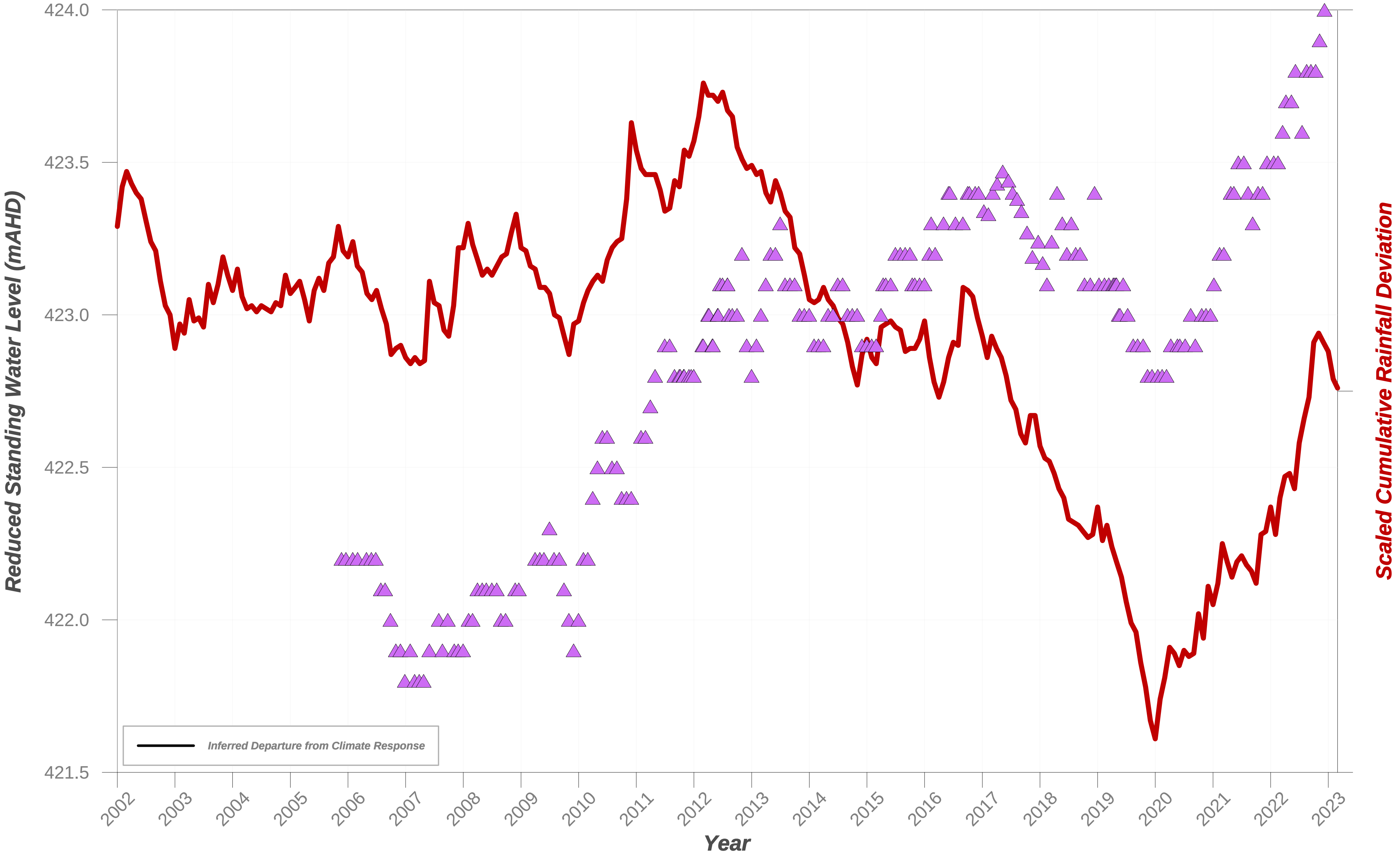
Hydrograph of Groundwater Level Data for Bore ID: PZ 044
Moolarben Groundwater Monitoring - Basement
Moolarben Coal Operations - UG4 Groundwater Assessment Report

Manual Dips
Anomalous Reading
Continuous Logger Data
Anomalous Logger Data

AGE

DATE
29/07/2023

FIGURE No:
A.003



Hydrograph of Groundwater Level Data for Bore ID: PZ 055
Moolarben Groundwater Monitoring - Marrangaroo Conglomerate
Moolarben Coal Operations - UG4 Groundwater Assessment Report

Manual Dips
Anomalous Reading
Continuous Logger Data
Anomalous Logger Data

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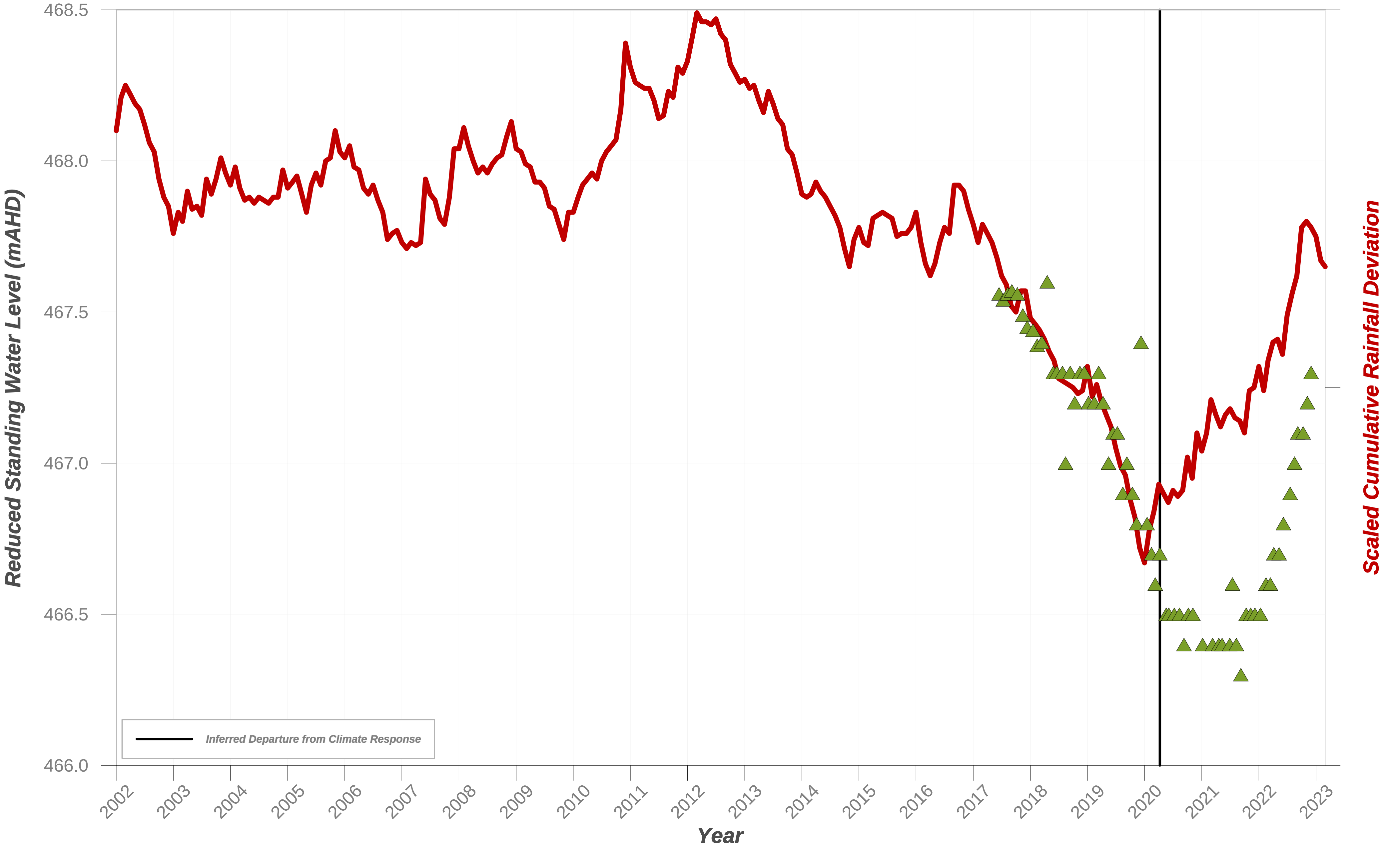
FIGURE No:
A.004



Hydrograph of Groundwater Level Data for Bore ID: PZ 058A
Moolarben Groundwater Monitoring - Tertiary Sediments / Paleochannel
Moolarben Coal Operations - UG4 Groundwater Assessment Report

Manual Dips
Anomalous Reading
Continuous Logger Data
Anomalous Logger Data

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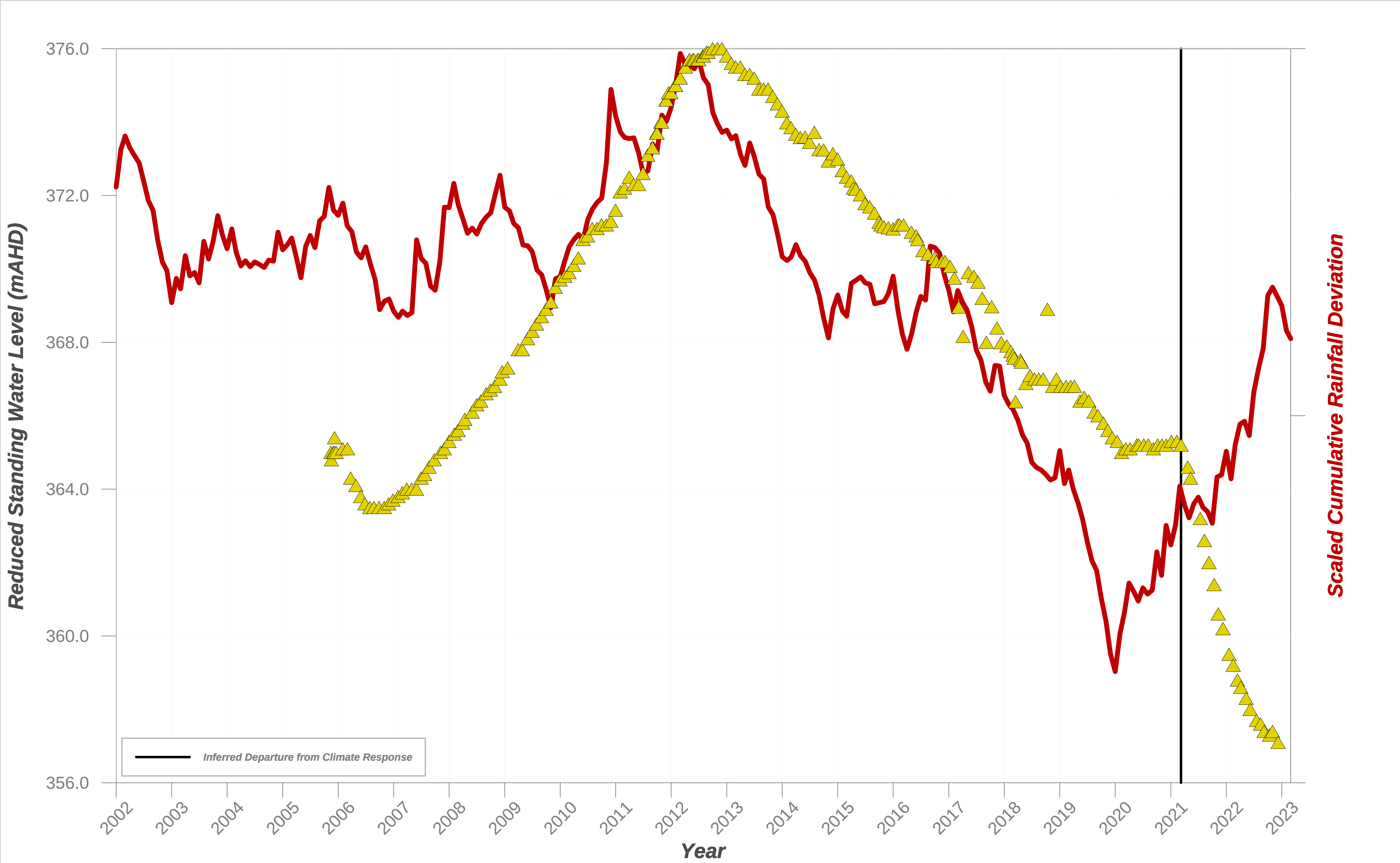
FIGURE No: **A.005**



Hydrograph of Groundwater Level Data for Bore ID: PZ 101B
Moolarben Groundwater Monitoring - Permian
Moolarben Coal Operations - UG4 Groundwater Assessment Report

Manual Dips
Anomalous Reading
Continuous Logger Data
Anomalous Logger Data

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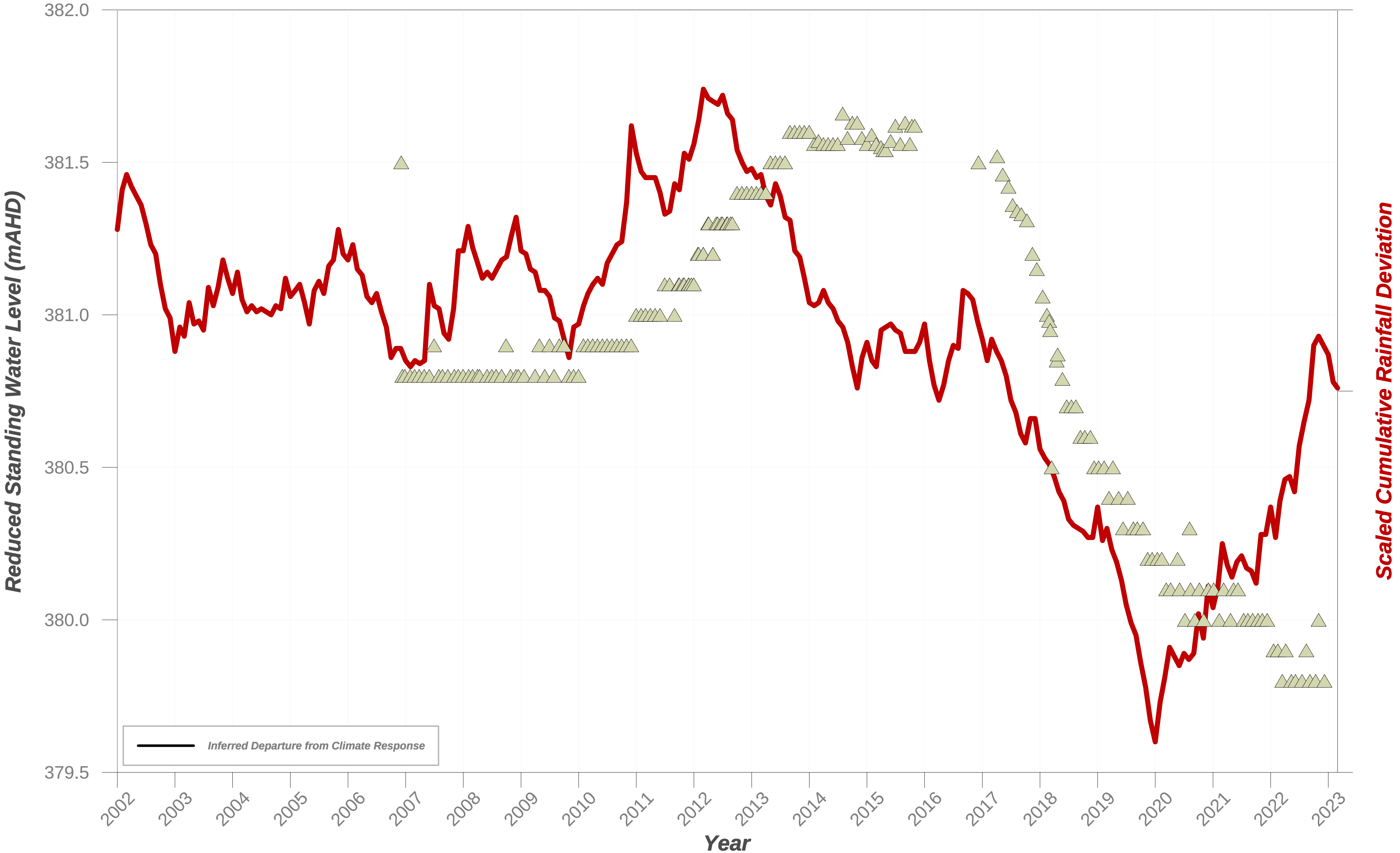
FIGURE No:
A.006



Hydrograph of Groundwater Level Data for Bore ID: PZ 101C
Moolarben Groundwater Monitoring - Triassic
Moolarben Coal Operations - UG4 Groundwater Assessment Report

Manual Dips
Anomalous Reading
Continuous Logger Data
Anomalous Logger Data

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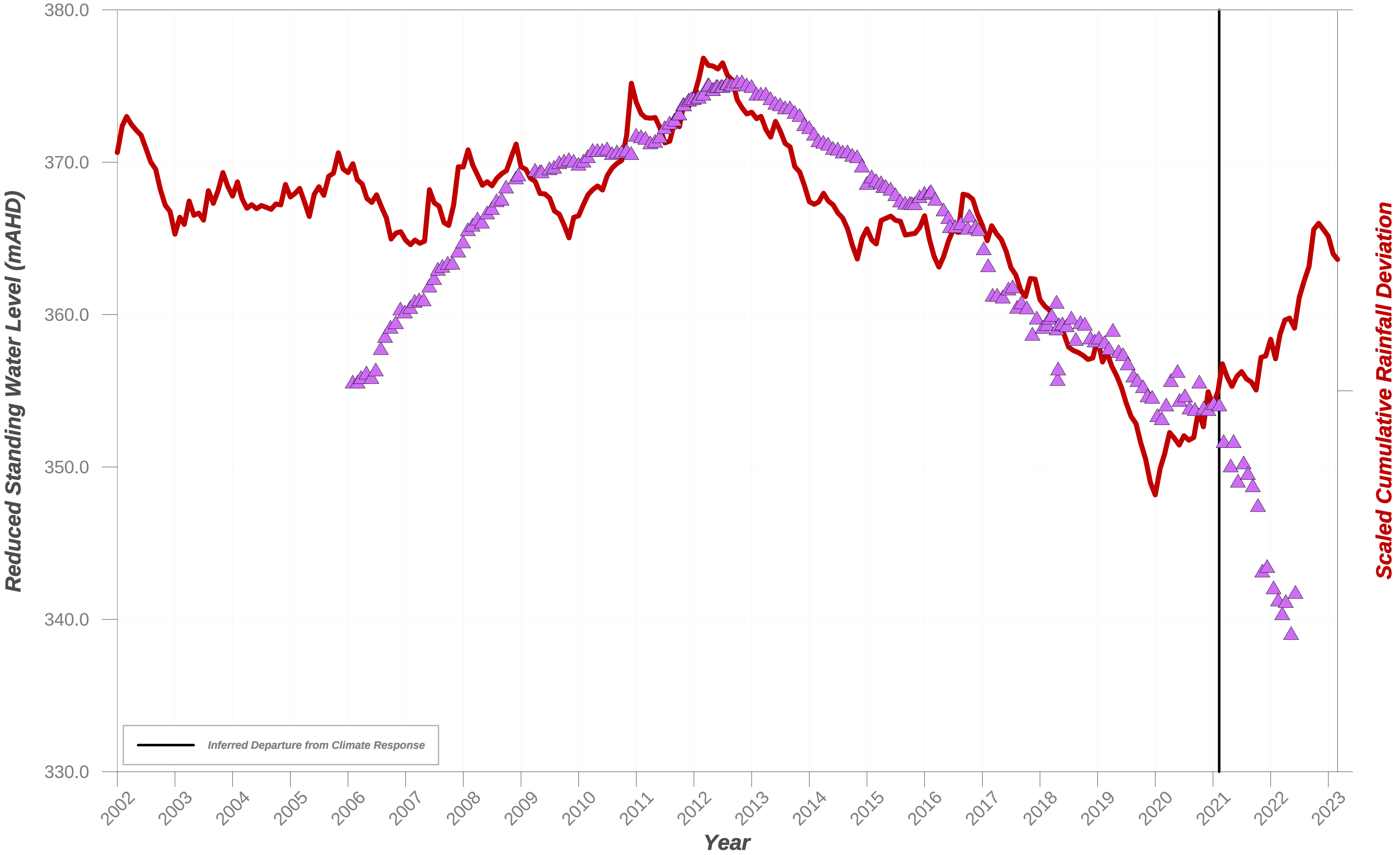
FIGURE No:
A.007



Hydrograph of Groundwater Level Data for Bore ID: PZ 102A
Moolarben Groundwater Monitoring - Marrangaroo Conglomerate
Moolarben Coal Operations - UG4 Groundwater Assessment Report

Manual Dips
Anomalous Reading
Continuous Logger Data
Anomalous Logger Data

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FIGURE No:
A.008

Hydrograph of Groundwater Level Data for Bore ID: PZ 102B
Moolarben Groundwater Monitoring - Ulan Seam
Moolarben Coal Operations - UG4 Groundwater Assessment Report

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FIGURE No: **A.009**

Hydrograph of Groundwater Level Data for Bore ID: PZ 102C VWP 28m
Moolarben Groundwater Monitoring - Permian
Moolarben Coal Operations - UG4 Groundwater Assessment Report

Manual Dips
Anomalous Reading
Continuous Logger Data
Anomalous Logger Data

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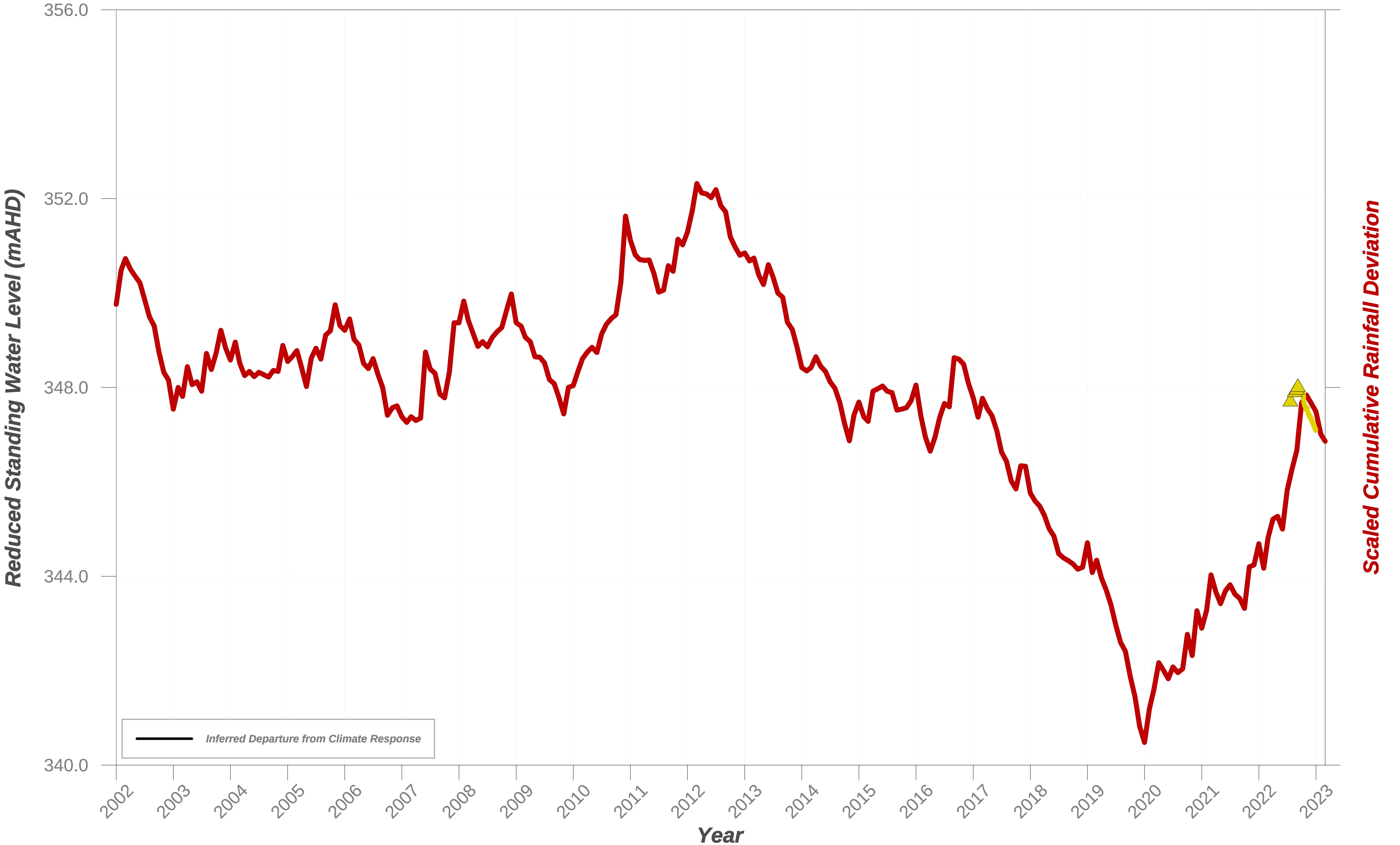
FIGURE No:
A.010



Hydrograph of Groundwater Level Data for Bore ID: PZ 102C VWP 64m
Moolarben Groundwater Monitoring - Permian
Moolarben Coal Operations - UG4 Groundwater Assessment Report

Manual Dips
Anomalous Reading
Continuous Logger Data
Anomalous Logger Data

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FIGURE No:
A.011

Hydrograph of Groundwater Level Data for Bore ID: PZ 103A
Moolarben Groundwater Monitoring - Ulan Seam
Moolarben Coal Operations - UG4 Groundwater Assessment Report

Manual Dips
Anomalous Reading
Continuous Logger Data
Anomalous Logger Data

AGE

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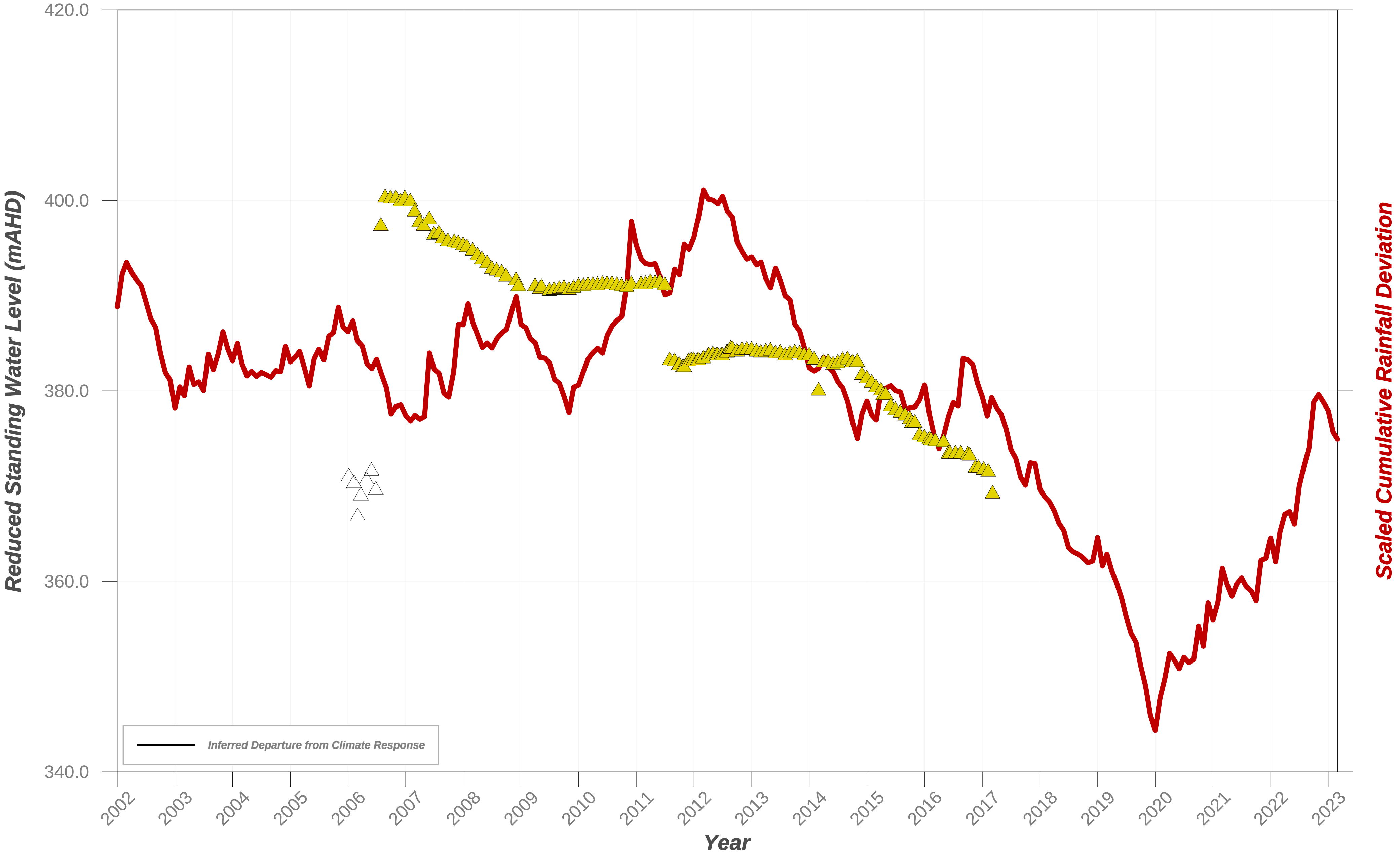
FIGURE No:
A.012



Hydrograph of Groundwater Level Data for Bore ID: PZ 103B
Moolarben Groundwater Monitoring - Permian
Moolarben Coal Operations - UG4 Groundwater Assessment Report

Manual Dips
Anomalous Reading
Continuous Logger Data
Anomalous Logger Data

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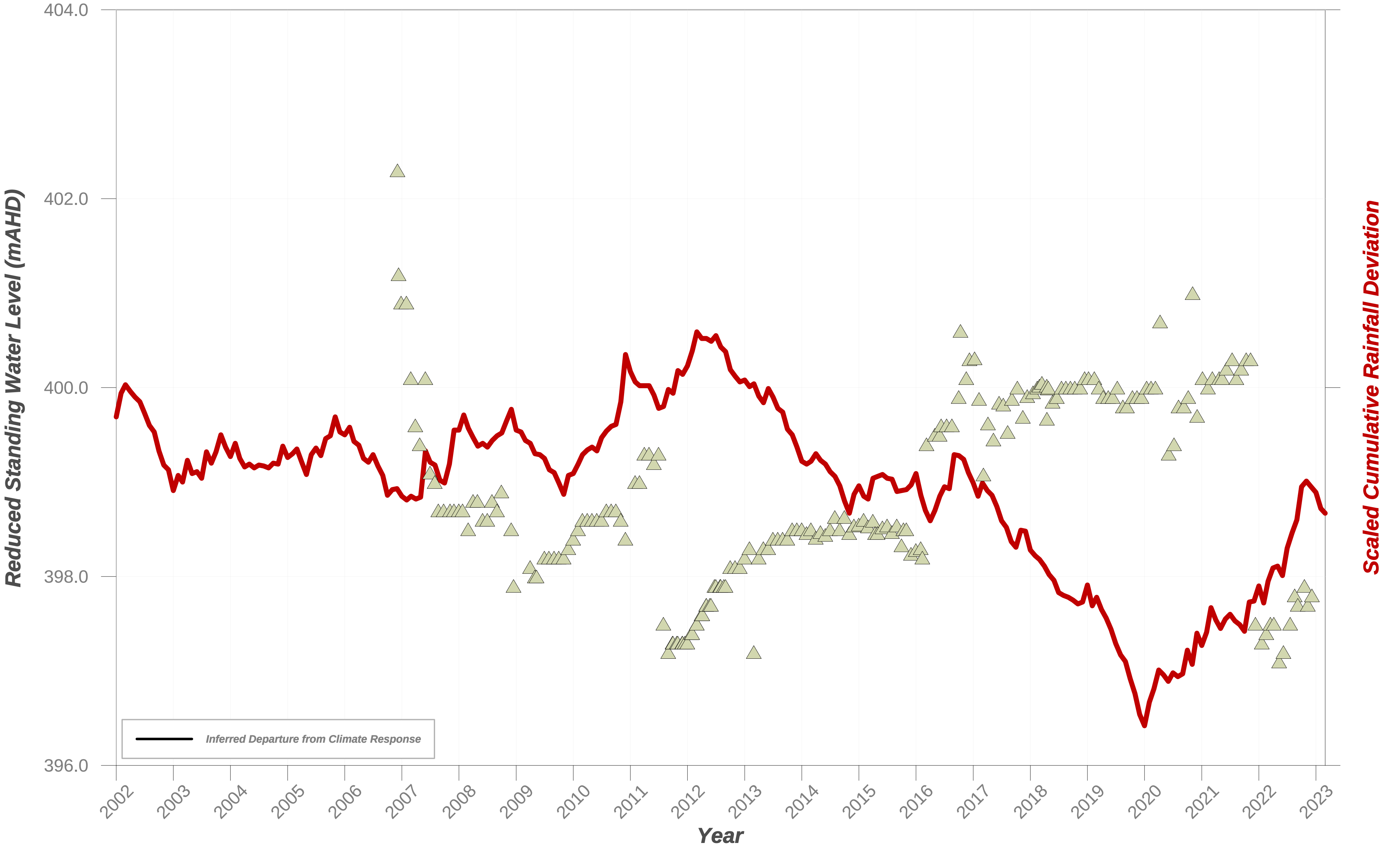
FIGURE No: **A.013**



Hydrograph of Groundwater Level Data for Bore ID: PZ 103C
Moolarben Groundwater Monitoring - Triassic
Moolarben Coal Operations - UG4 Groundwater Assessment Report

Manual Dips
Anomalous Reading
Continuous Logger Data
Anomalous Logger Data

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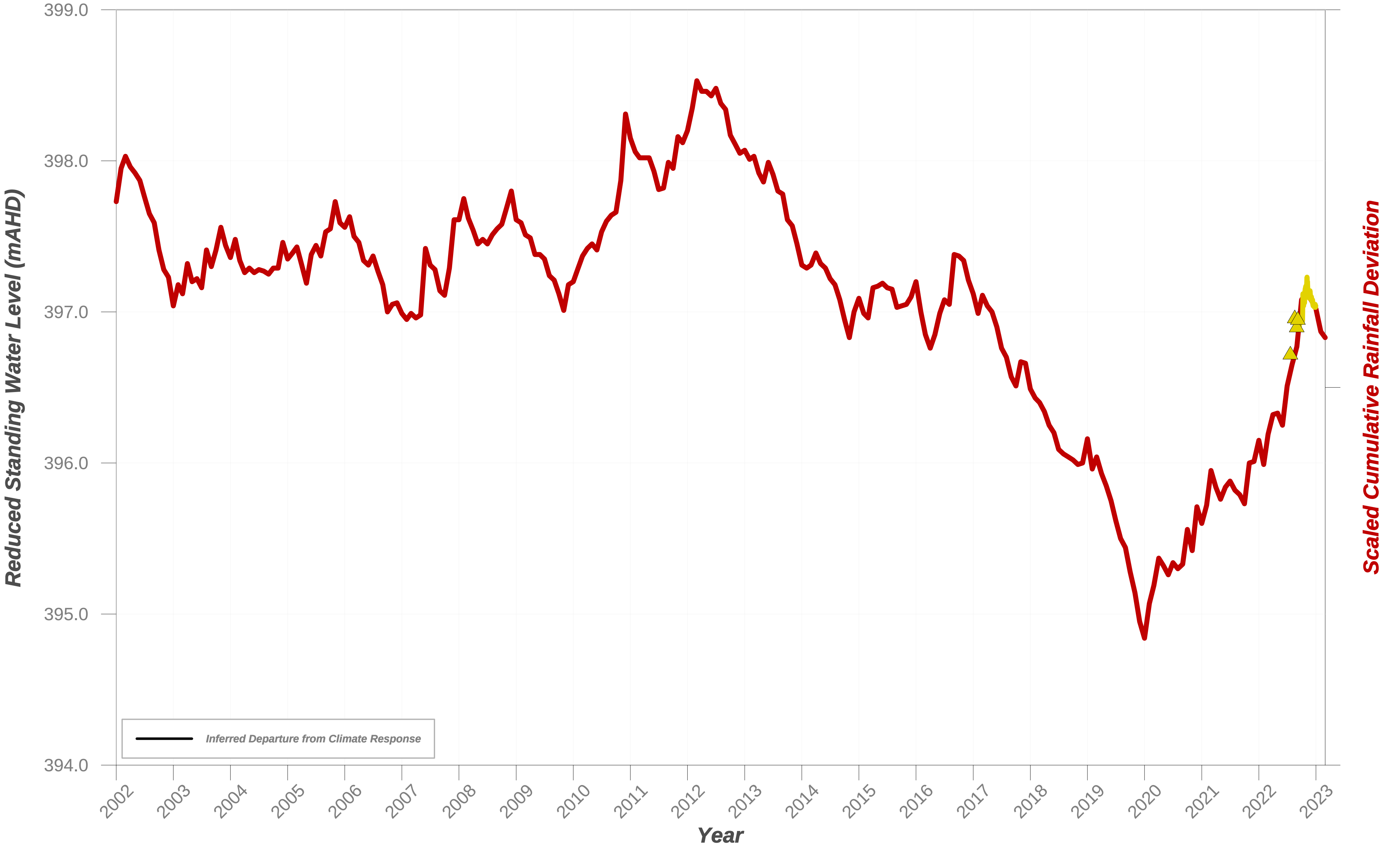
FIGURE No:
A.014



Hydrograph of Groundwater Level Data for Bore ID: PZ 103D VWP 31m
Moolarben Groundwater Monitoring - Permian
Moolarben Coal Operations - UG4 Groundwater Assessment Report

Manual Dips
Anomalous Reading
Continuous Logger Data
Anomalous Logger Data

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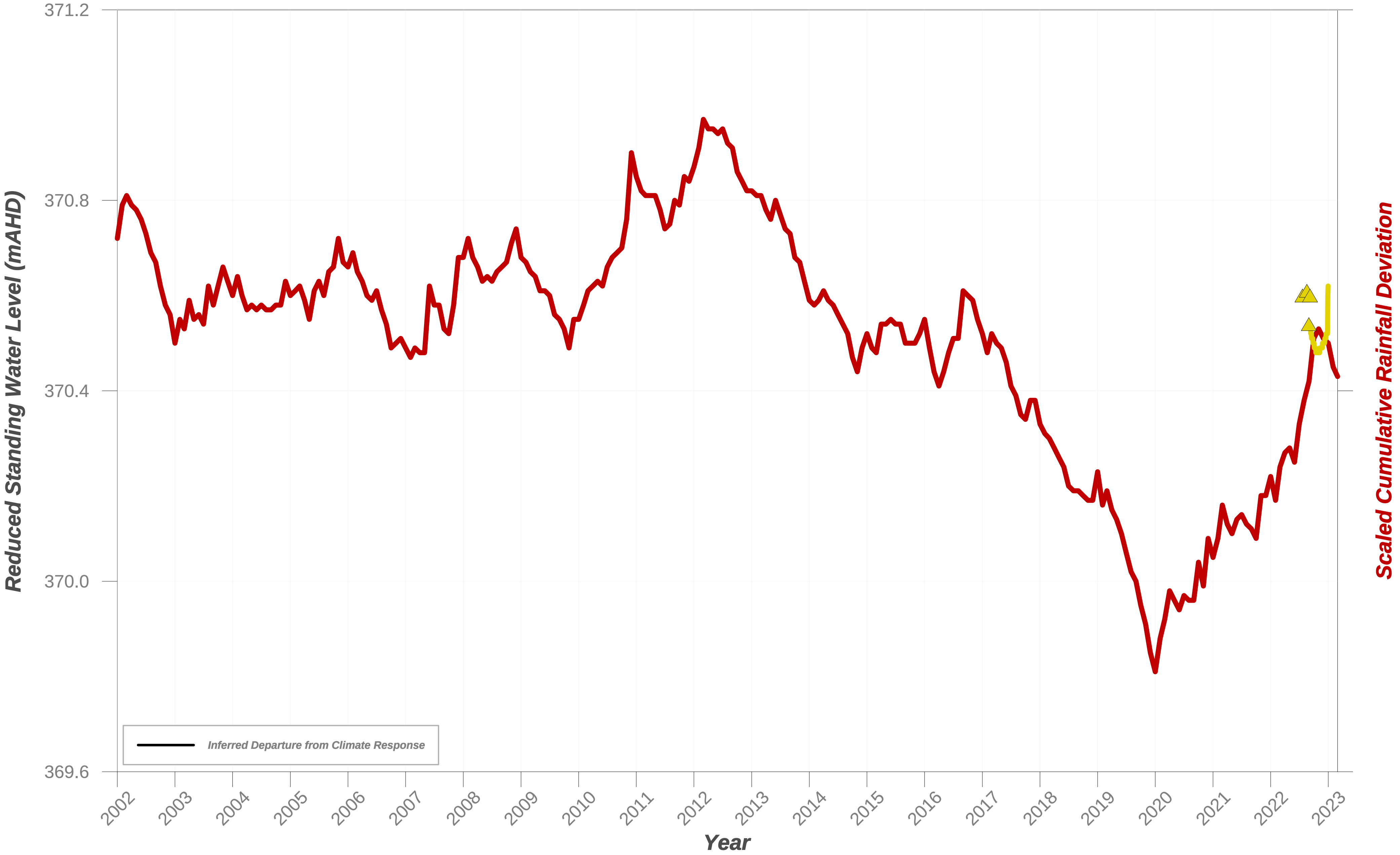
FIGURE No: **A.015**



Hydrograph of Groundwater Level Data for Bore ID: PZ 103D VWP 55m
Moolarben Groundwater Monitoring - Permian
Moolarben Coal Operations - UG4 Groundwater Assessment Report

Manual Dips
Anomalous Reading
Continuous Logger Data
Anomalous Logger Data

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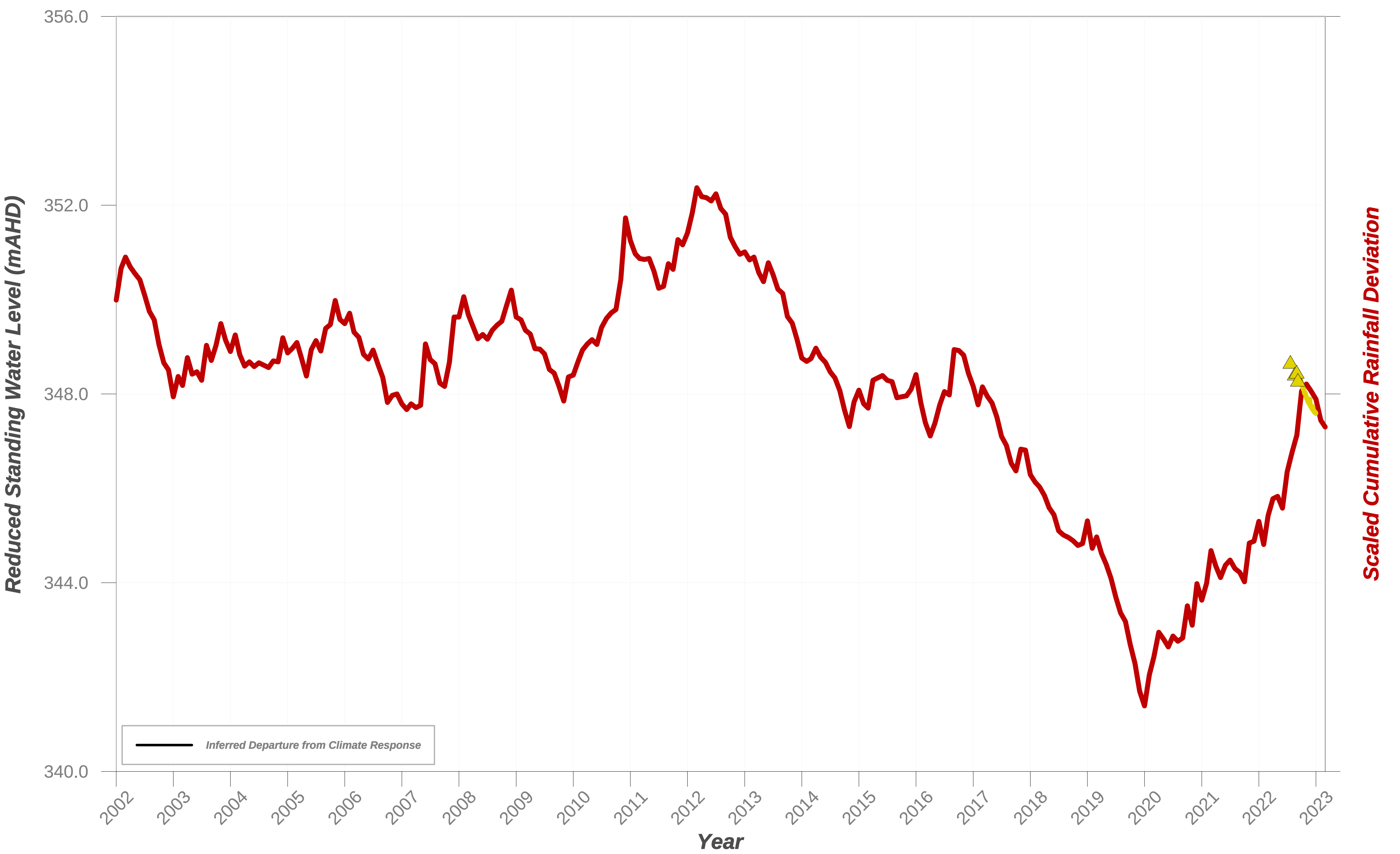
FIGURE No:
A.016



Hydrograph of Groundwater Level Data for Bore ID: PZ 103D VWP 85m
Moolarben Groundwater Monitoring - Permian
Moolarben Coal Operations - UG4 Groundwater Assessment Report

Manual Dips
Anomalous Reading
Continuous Logger Data
Anomalous Logger Data

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FIGURE No:
A.017

Hydrograph of Groundwater Level Data for Bore ID: PZ 104
Moolarben Groundwater Monitoring - Ulan Seam
Moolarben Coal Operations - UG4 Groundwater Assessment Report

Manual Dips
Anomalous Reading
Continuous Logger Data
Anomalous Logger Data

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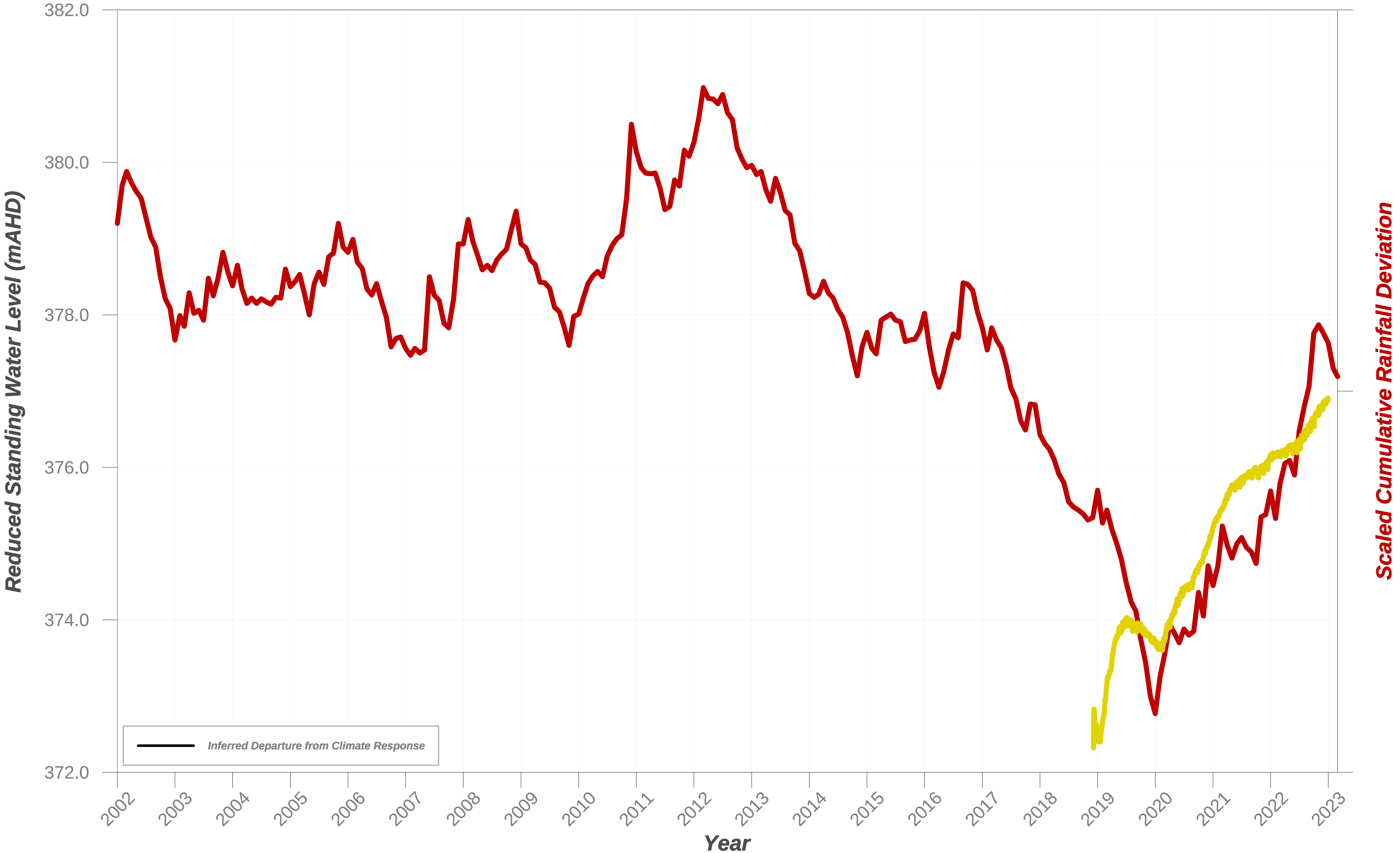
FIGURE No:
A.018



Hydrograph of Groundwater Level Data for Bore ID: PZ 105A VWP 28m
Moolarben Groundwater Monitoring - Permian
Moolarben Coal Operations - UG4 Groundwater Assessment Report

Manual Dips
Anomalous Reading
Continuous Logger Data
Anomalous Logger Data

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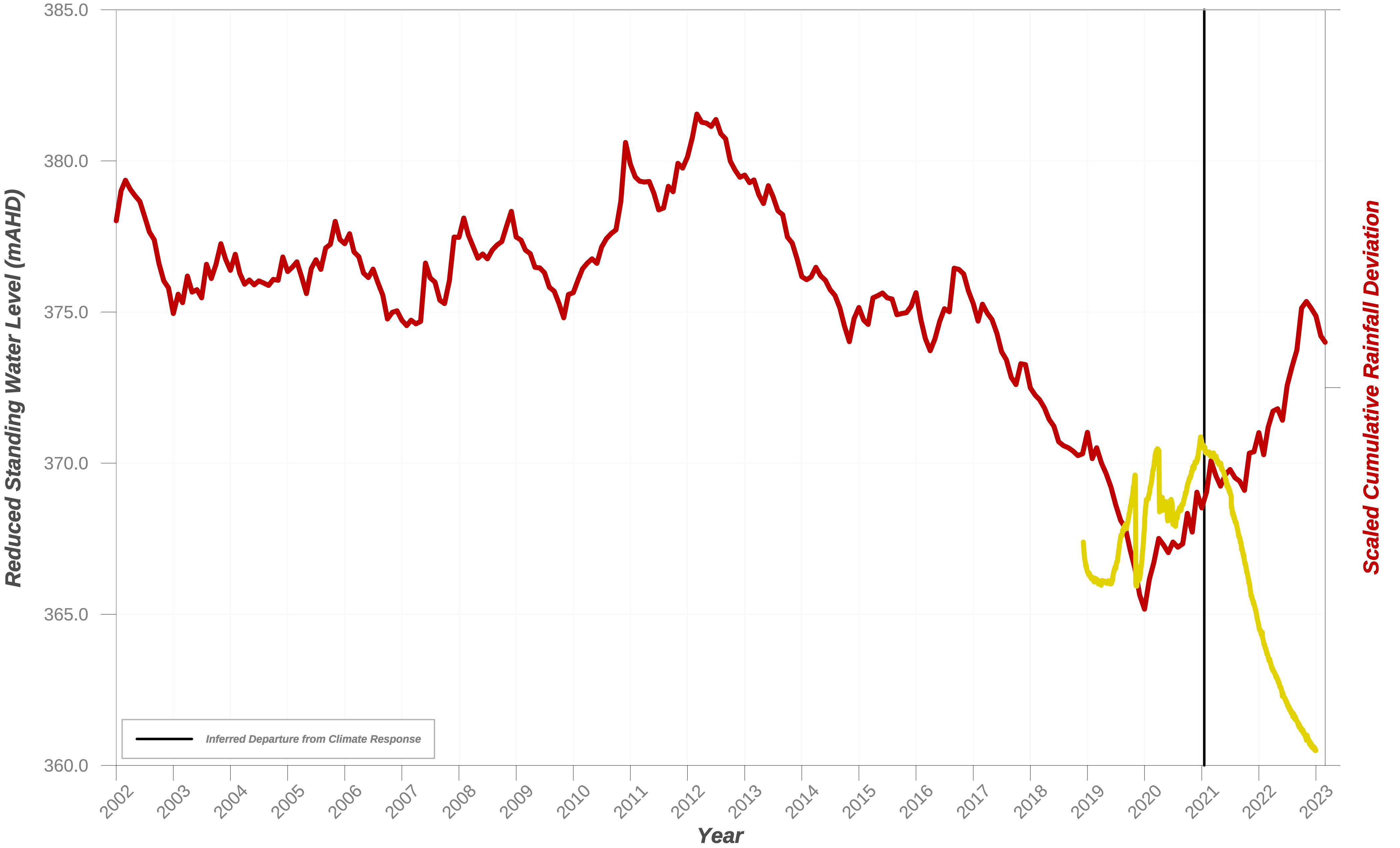
FIGURE No:
A.019



Hydrograph of Groundwater Level Data for Bore ID: PZ 105A VWP 80m
Moolarben Groundwater Monitoring - Permian
Moolarben Coal Operations - UG4 Groundwater Assessment Report

Manual Dips
Anomalous Reading
Continuous Logger Data
Anomalous Logger Data

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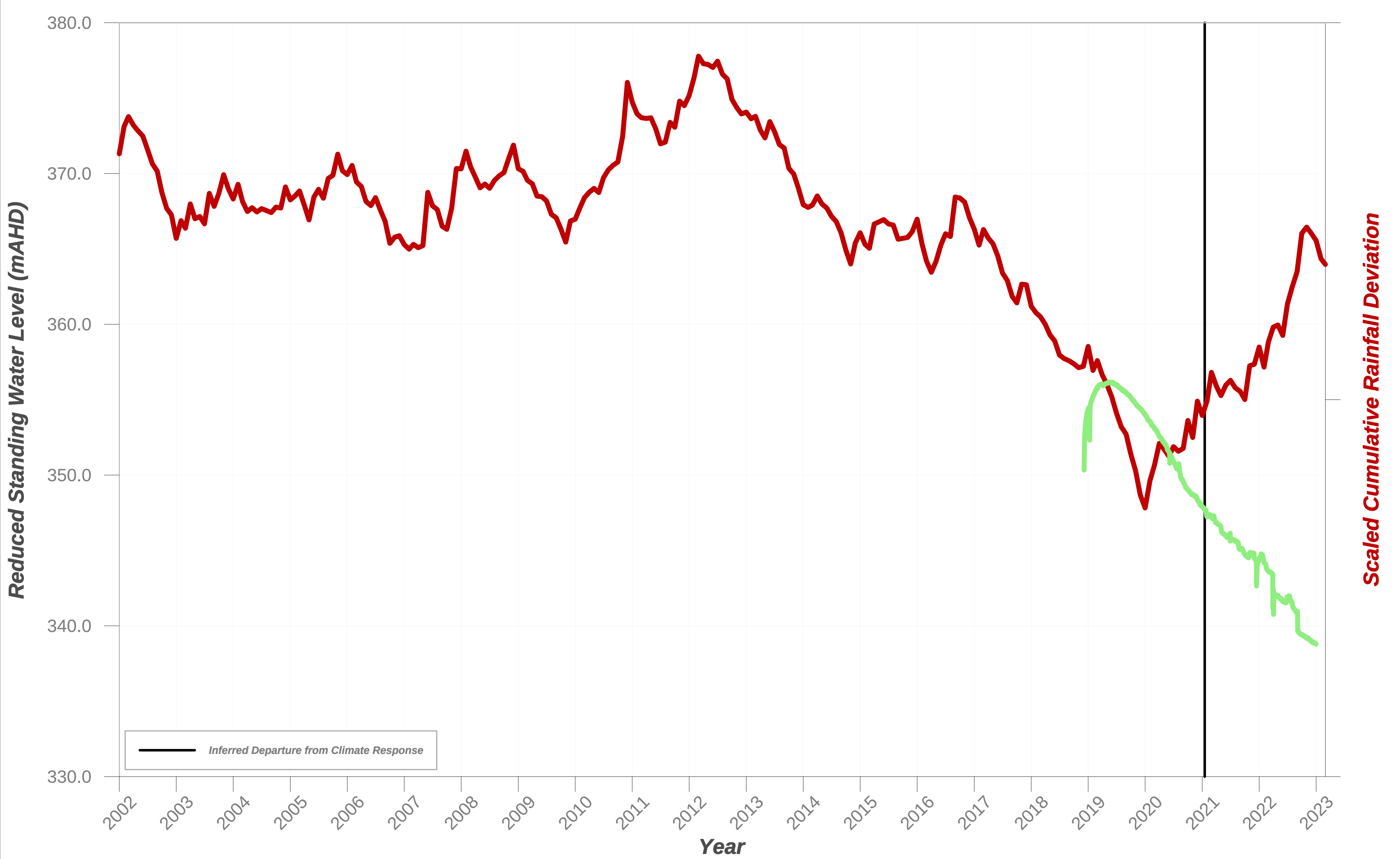
FIGURE No:
A.020



Hydrograph of Groundwater Level Data for Bore ID: PZ 105A VWP 118m
Moolarben Groundwater Monitoring - Ulan Seam
Moolarben Coal Operations - UG4 Groundwater Assessment Report

Manual Dips
Anomalous Reading
Continuous Logger Data
Anomalous Logger Data

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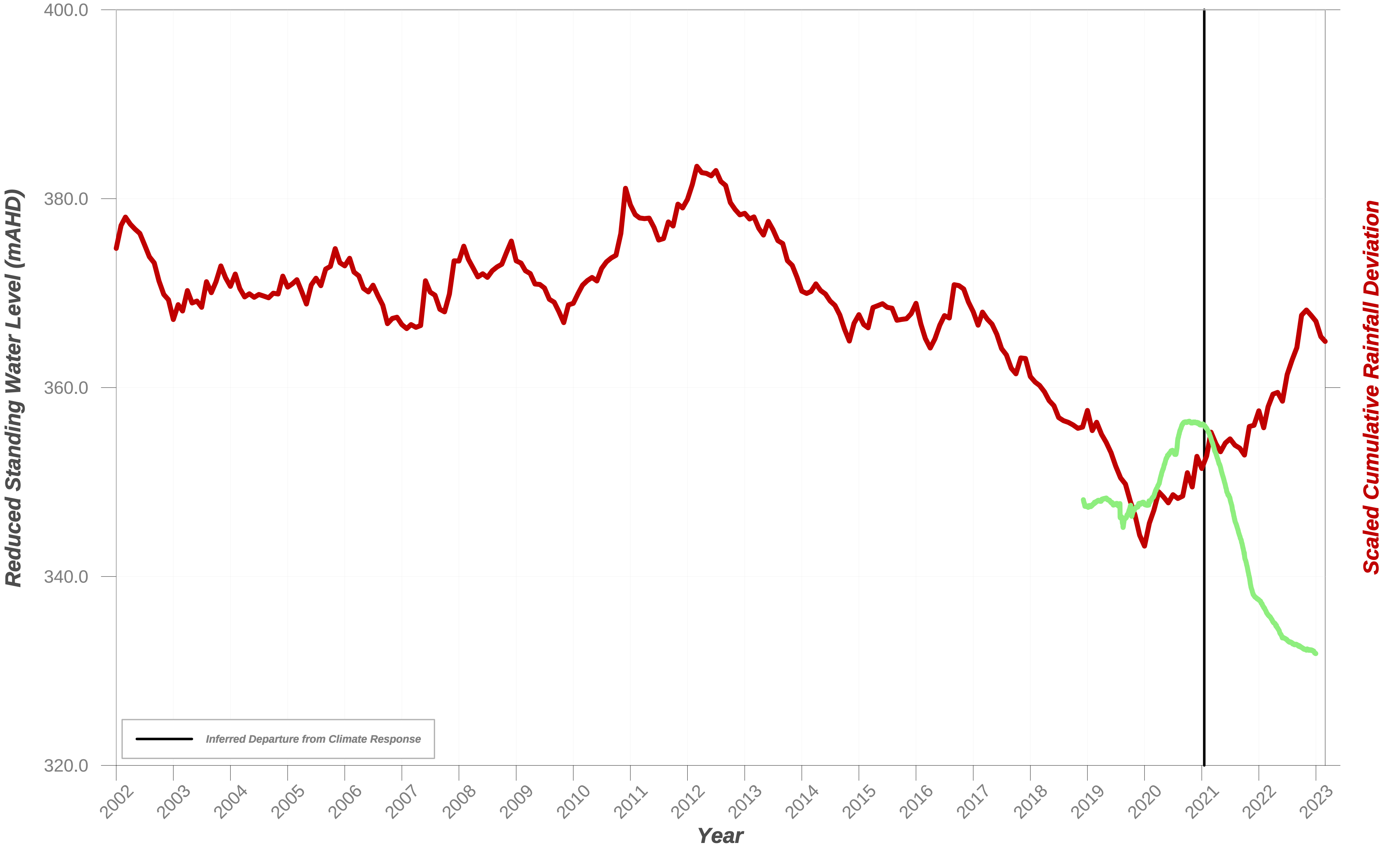
FIGURE No: **A.021**



Hydrograph of Groundwater Level Data for Bore ID: PZ 105A VWP 130m
Moolarben Groundwater Monitoring - Ulan Seam
Moolarben Coal Operations - UG4 Groundwater Assessment Report

Manual Dips
Anomalous Reading
Continuous Logger Data
Anomalous Logger Data

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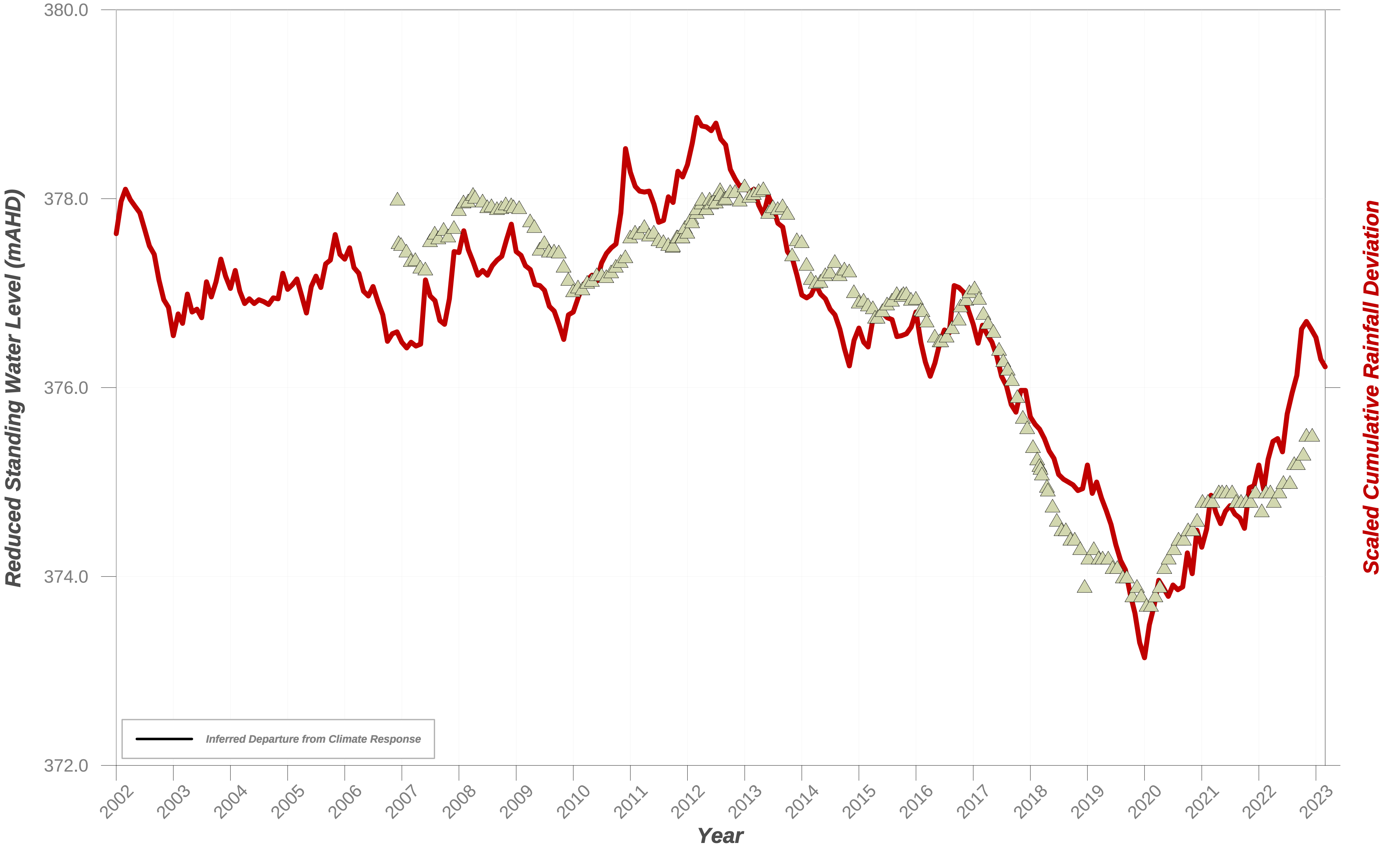
FIGURE No:
A.022



Hydrograph of Groundwater Level Data for Bore ID: PZ 105C
Moolarben Groundwater Monitoring - Triassic
Moolarben Coal Operations - UG4 Groundwater Assessment Report

Manual Dips
Anomalous Reading
Continuous Logger Data
Anomalous Logger Data

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FIGURE No:
A.023

Hydrograph of Groundwater Level Data for Bore ID: PZ 106A
Moolarben Groundwater Monitoring - Permian
Moolarben Coal Operations - UG4 Groundwater Assessment Report

Manual Dips
Anomalous Reading
Continuous Logger Data
Anomalous Logger Data

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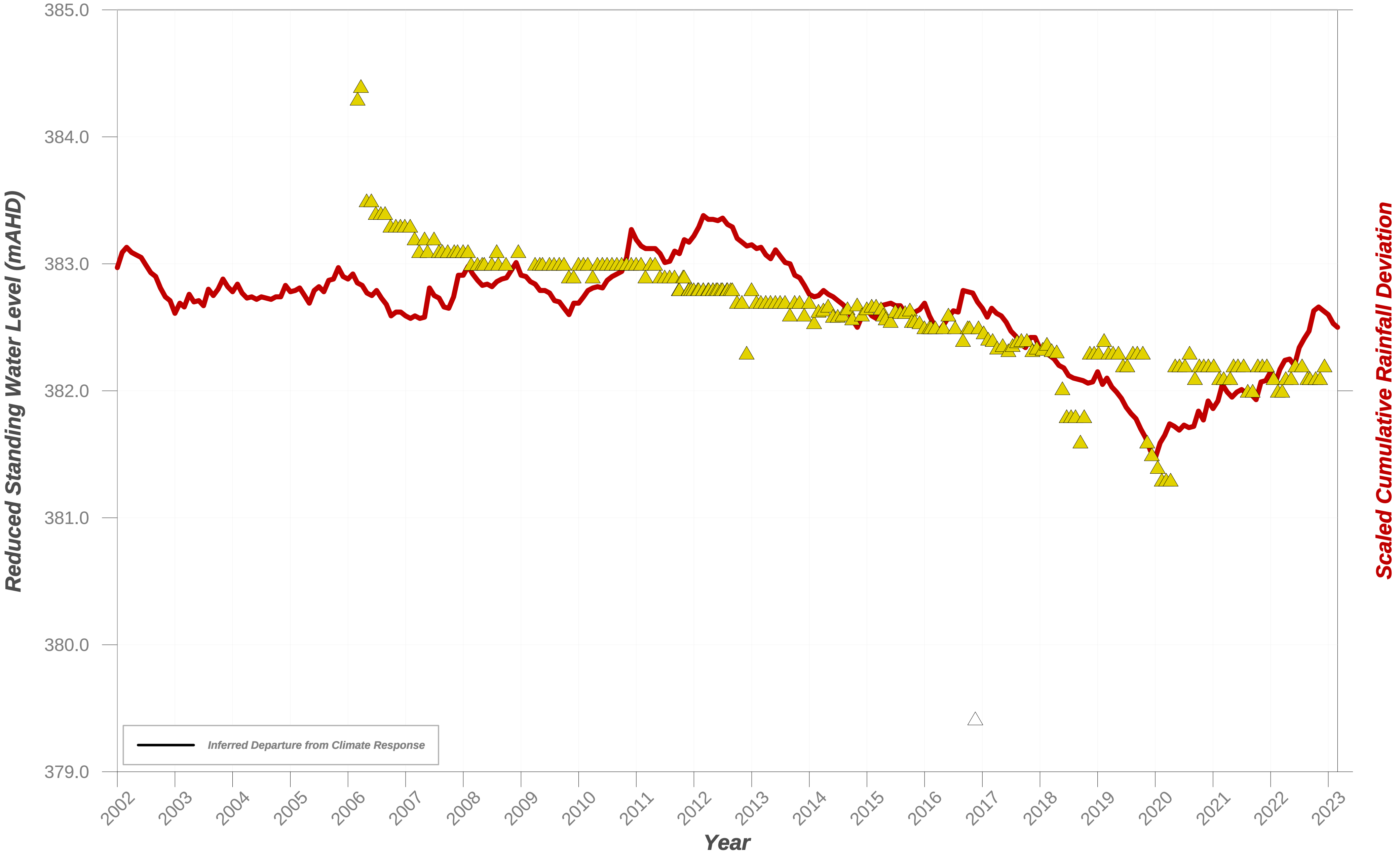
FIGURE No:
A.024



Hydrograph of Groundwater Level Data for Bore ID: PZ 109
Moolarben Groundwater Monitoring - Permian
Moolarben Coal Operations - UG4 Groundwater Assessment Report

Manual Dips
Anomalous Reading
Continuous Logger Data
Anomalous Logger Data

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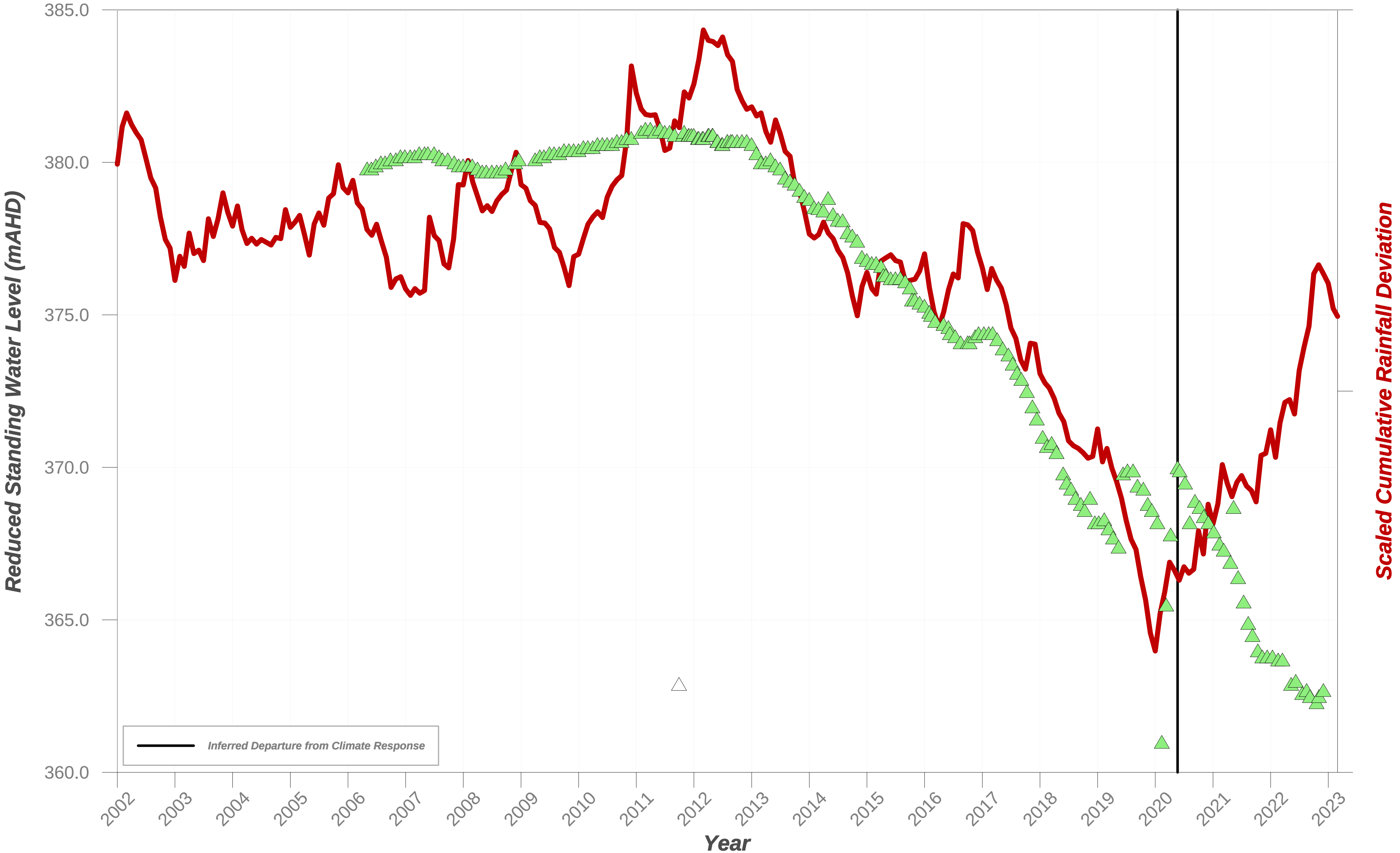
FIGURE No:
A.025



Hydrograph of Groundwater Level Data for Bore ID: PZ 111
Moolarben Groundwater Monitoring - Ulan Seam
Moolarben Coal Operations - UG4 Groundwater Assessment Report

Manual Dips
Anomalous Reading
Continuous Logger Data
Anomalous Logger Data

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FIGURE No:
A.026

Hydrograph of Groundwater Level Data for Bore ID: PZ 112B
Moolarben Groundwater Monitoring - Permian
Moolarben Coal Operations - UG4 Groundwater Assessment Report

Manual Dips
Anomalous Reading
Continuous Logger Data
Anomalous Logger Data

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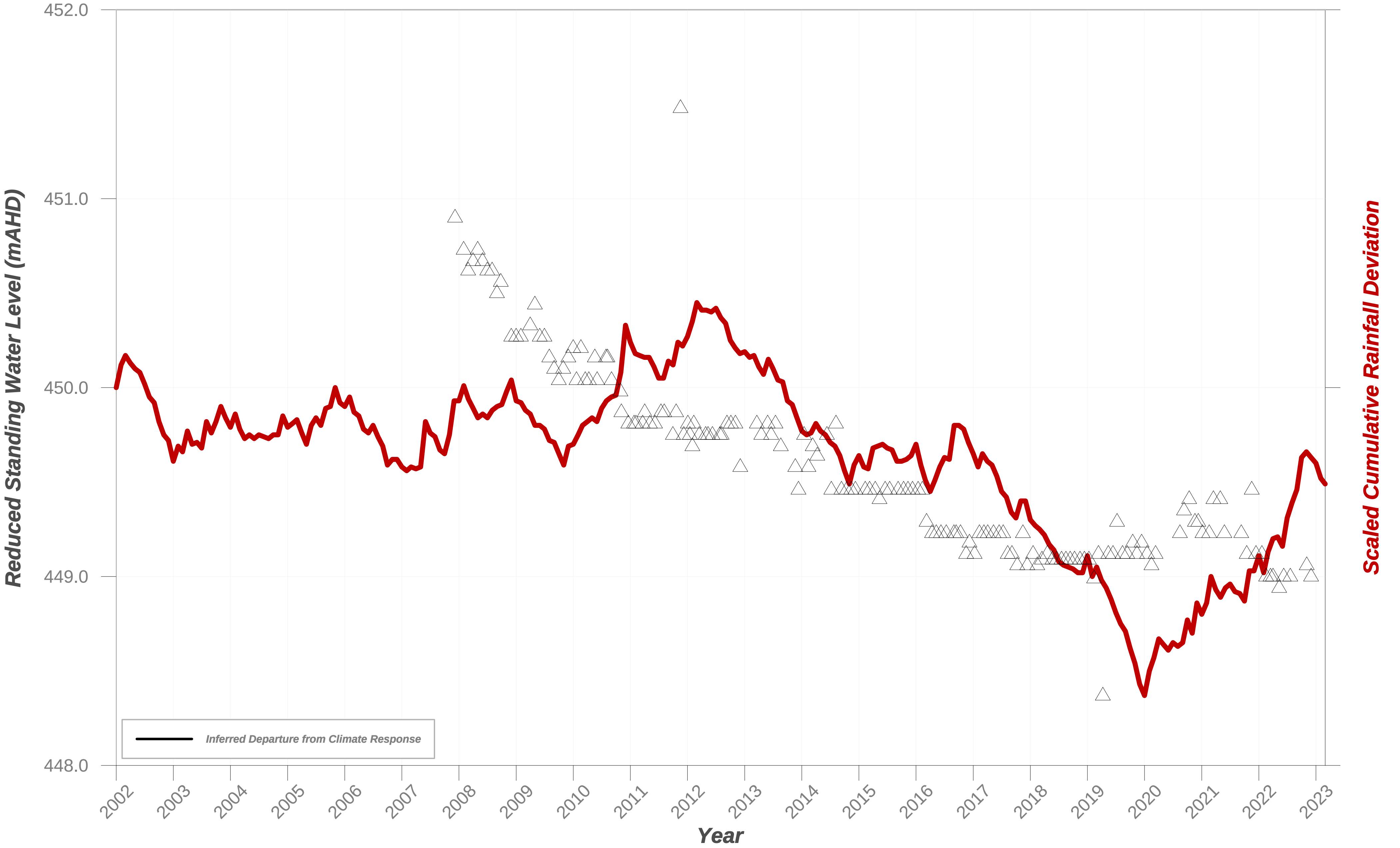
FIGURE No:
A.027



Hydrograph of Groundwater Level Data for Bore ID: PZ 127 VWP 43m
Moolarben Groundwater Monitoring - Triassic
Moolarben Coal Operations - UG4 Groundwater Assessment Report

Manual Dips
Anomalous Reading
Continuous Logger Data
Anomalous Logger Data

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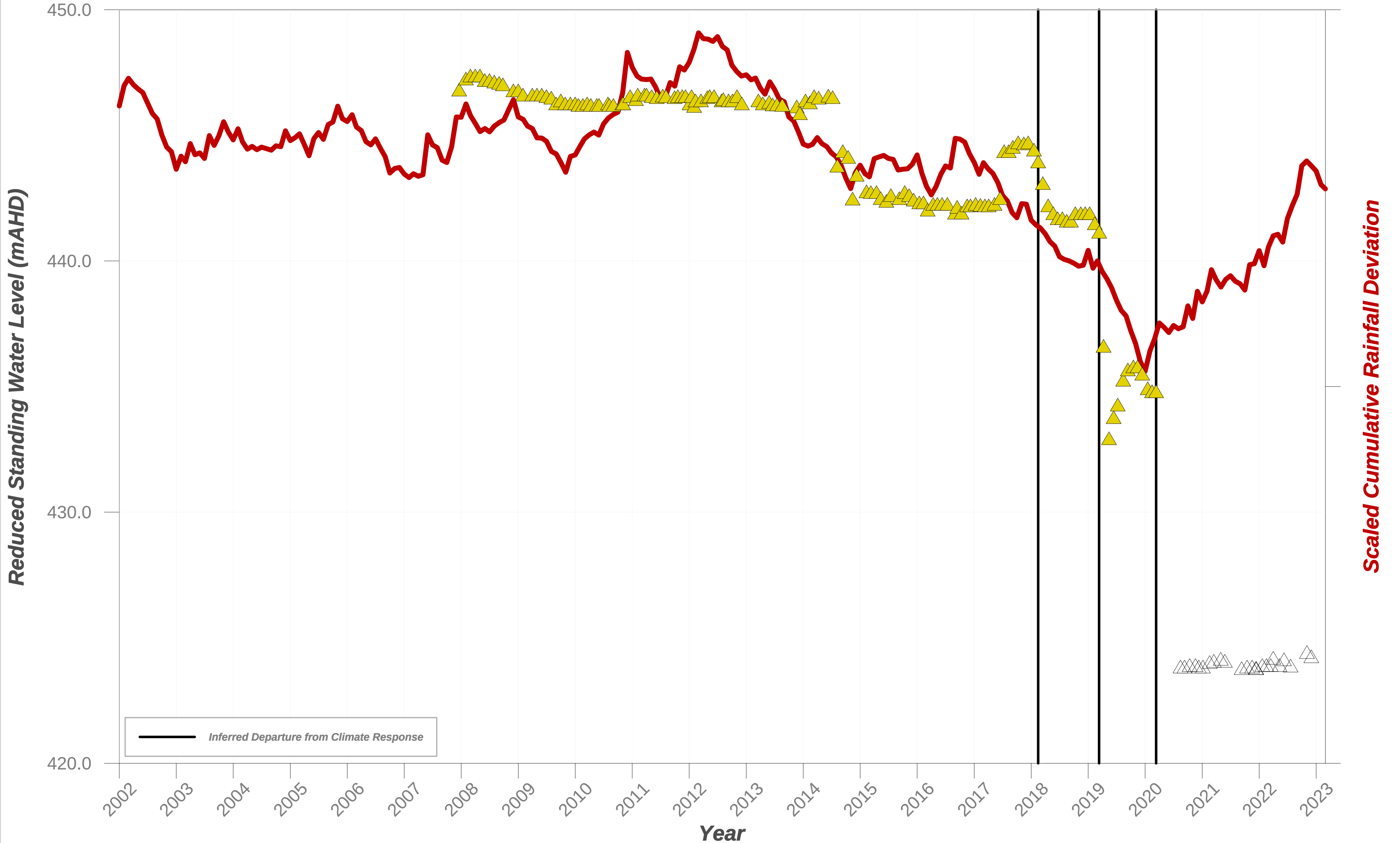
FIGURE No:
A.028



Hydrograph of Groundwater Level Data for Bore ID: PZ 127 VWP 68m
Moolarben Groundwater Monitoring - Permian
Moolarben Coal Operations - UG4 Groundwater Assessment Report

Manual Dips
Anomalous Reading
Continuous Logger Data
Anomalous Logger Data

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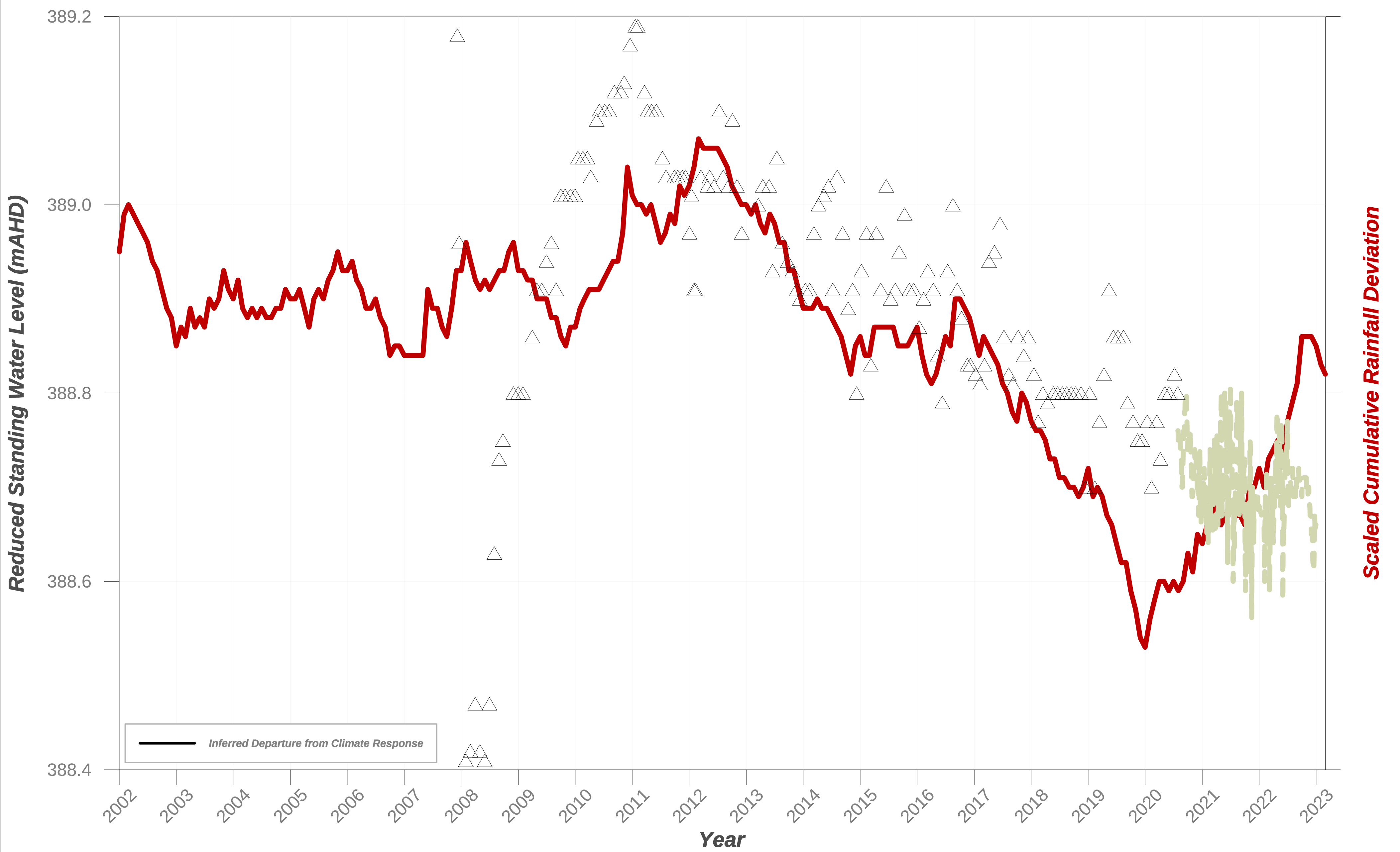
FIGURE No:
A.029



Hydrograph of Groundwater Level Data for Bore ID: PZ 128 VWP 20m
Moolarben Groundwater Monitoring - Triassic
Moolarben Coal Operations - UG4 Groundwater Assessment Report

Manual Dips
Anomalous Reading
Continuous Logger Data
Anomalous Logger Data

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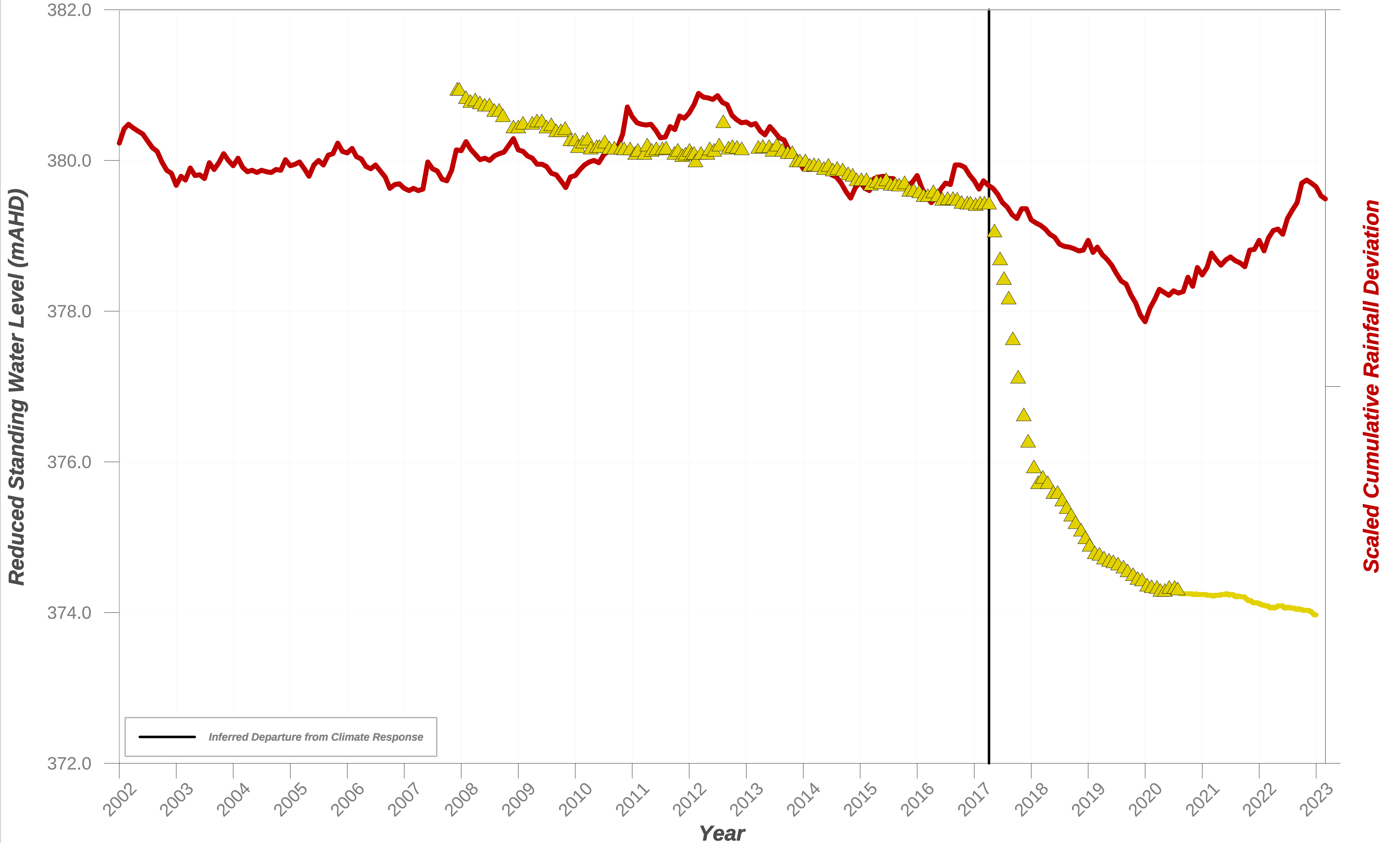
FIGURE No: **A.030**



Hydrograph of Groundwater Level Data for Bore ID: PZ 128 VWP 36m
Moolarben Groundwater Monitoring - Permian
Moolarben Coal Operations - UG4 Groundwater Assessment Report

Manual Dips
Anomalous Reading
Continuous Logger Data
Anomalous Logger Data

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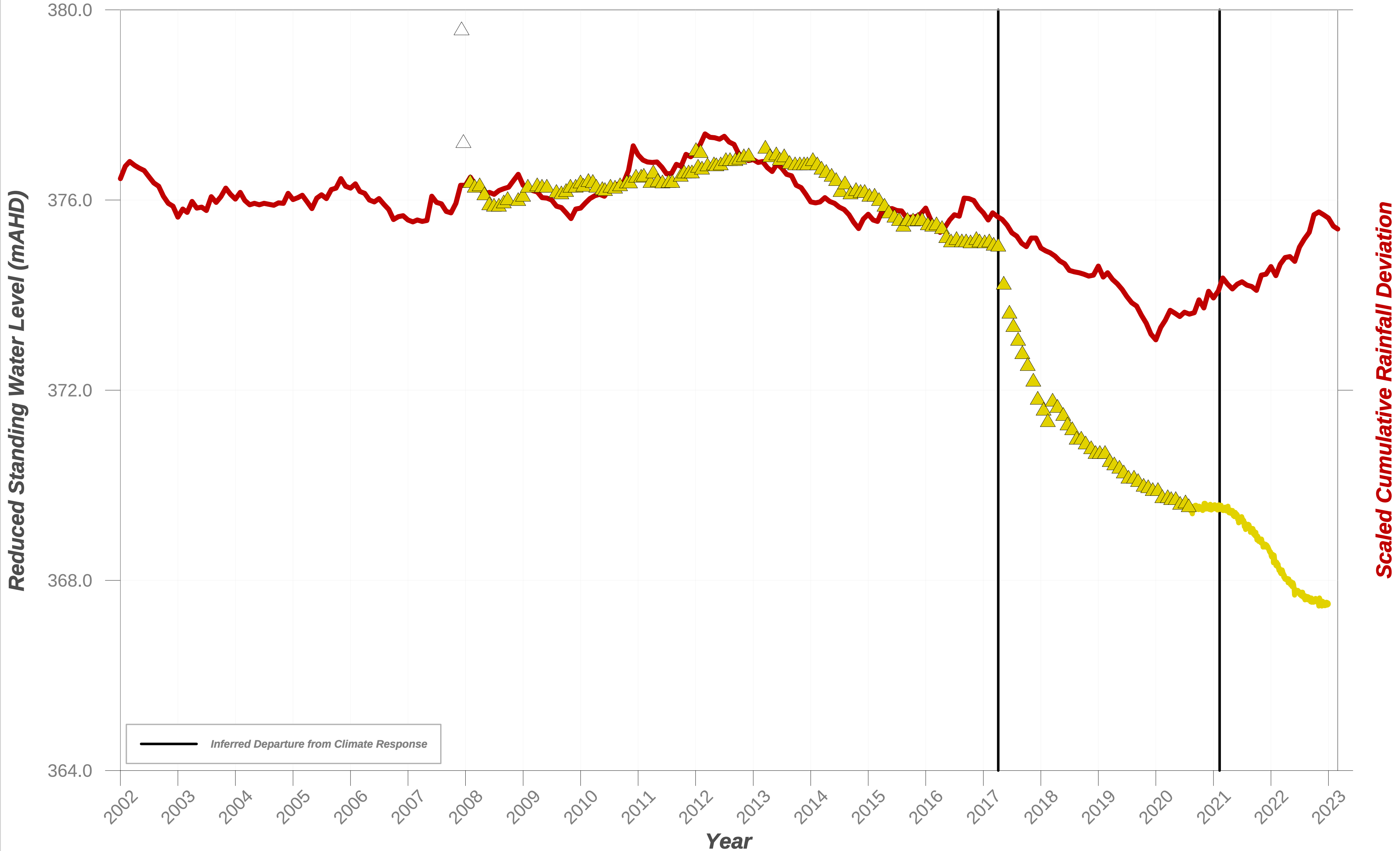
FIGURE No:
A.031



Hydrograph of Groundwater Level Data for Bore ID: PZ 128 VWP 55m
Moolarben Groundwater Monitoring - Permian
Moolarben Coal Operations - UG4 Groundwater Assessment Report

Manual Dips
Anomalous Reading
Continuous Logger Data
Anomalous Logger Data

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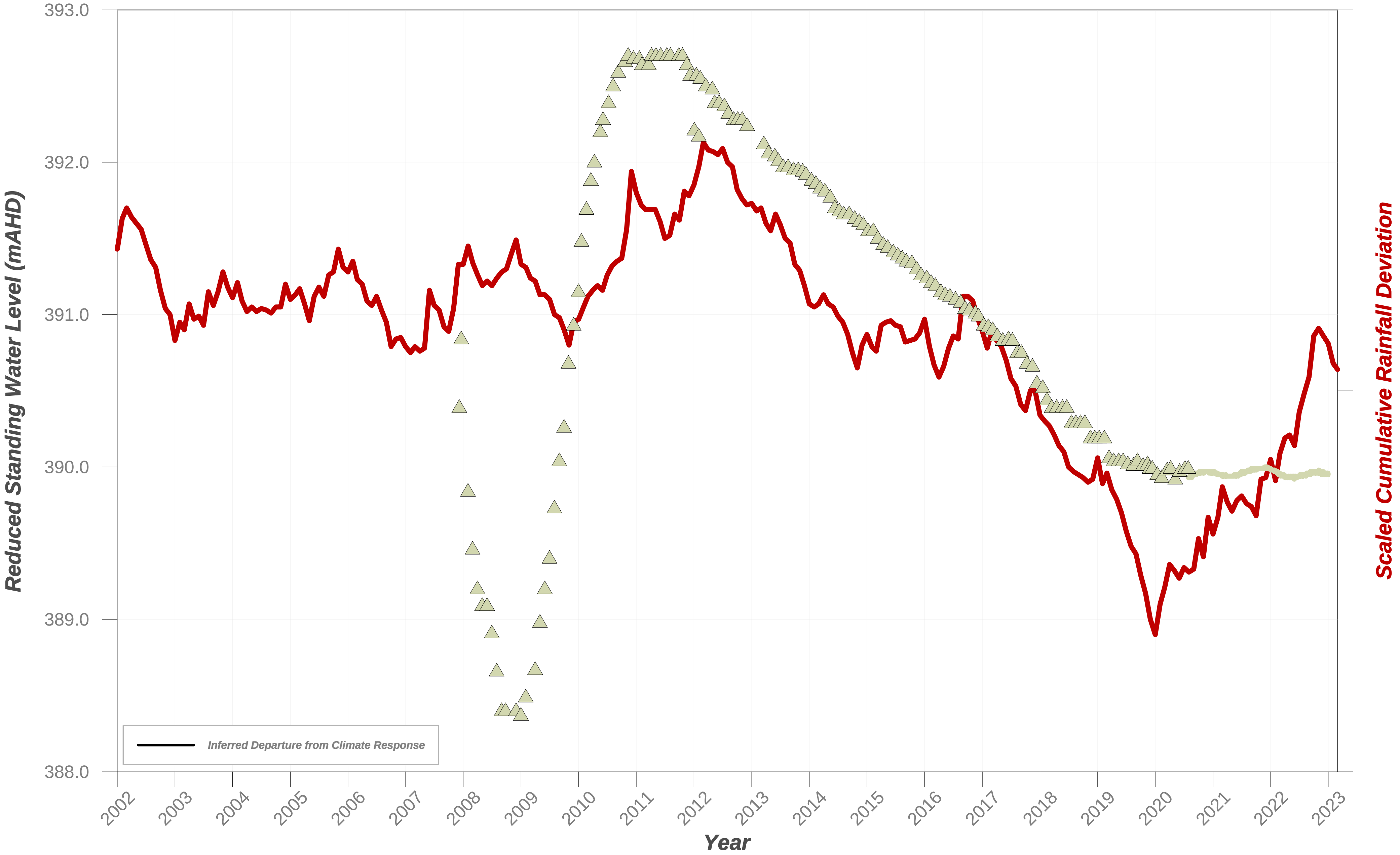
FIGURE No: **A.032**



Hydrograph of Groundwater Level Data for Bore ID: PZ 129 VWP 35m
Moolarben Groundwater Monitoring - Triassic
Moolarben Coal Operations - UG4 Groundwater Assessment Report

Manual Dips
Anomalous Reading
Continuous Logger Data
Anomalous Logger Data

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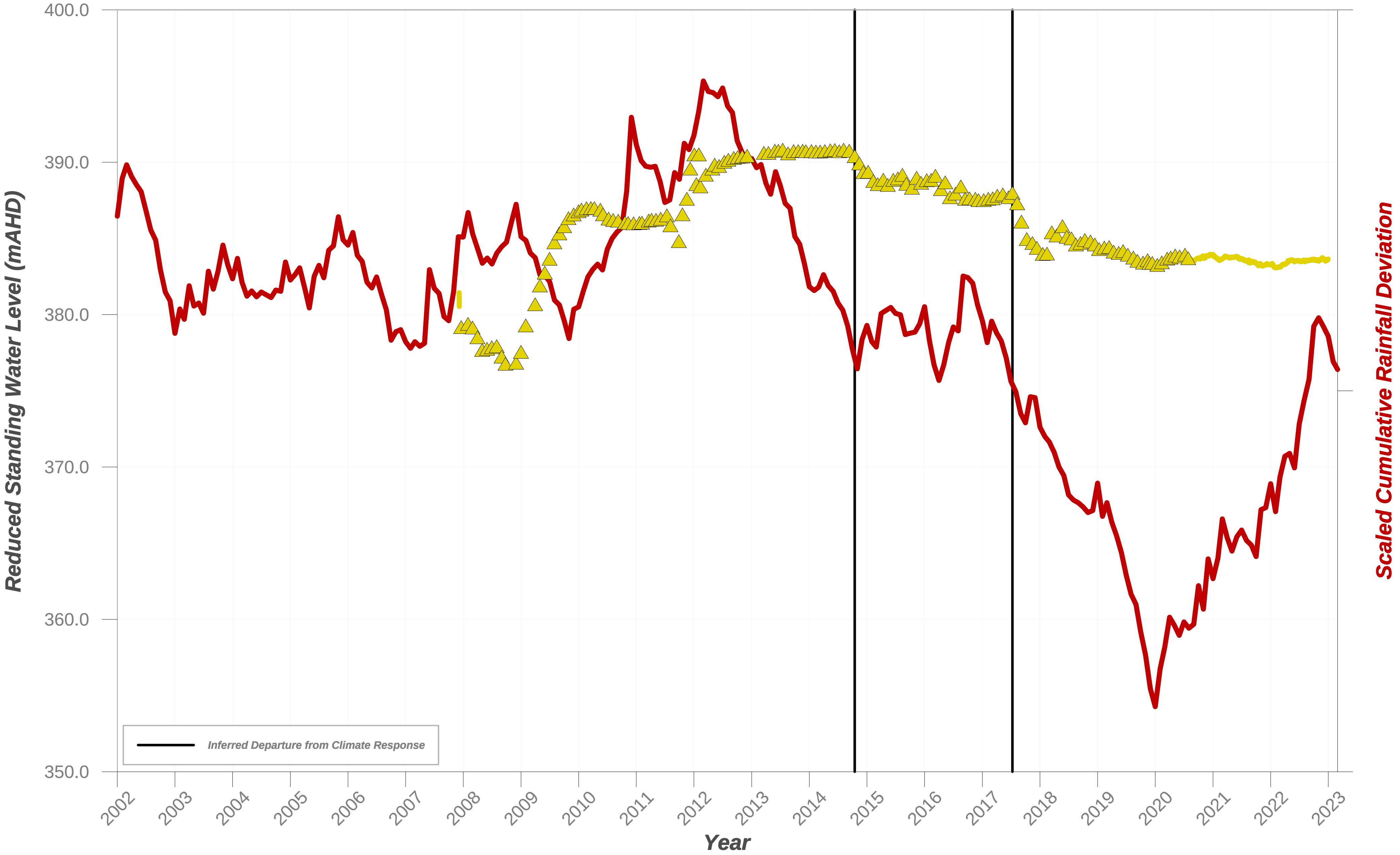
FIGURE No:
A.033



Hydrograph of Groundwater Level Data for Bore ID: PZ 129 VWP 53m
Moolarben Groundwater Monitoring - Permian
Moolarben Coal Operations - UG4 Groundwater Assessment Report

Manual Dips
Anomalous Reading
Continuous Logger Data
Anomalous Logger Data

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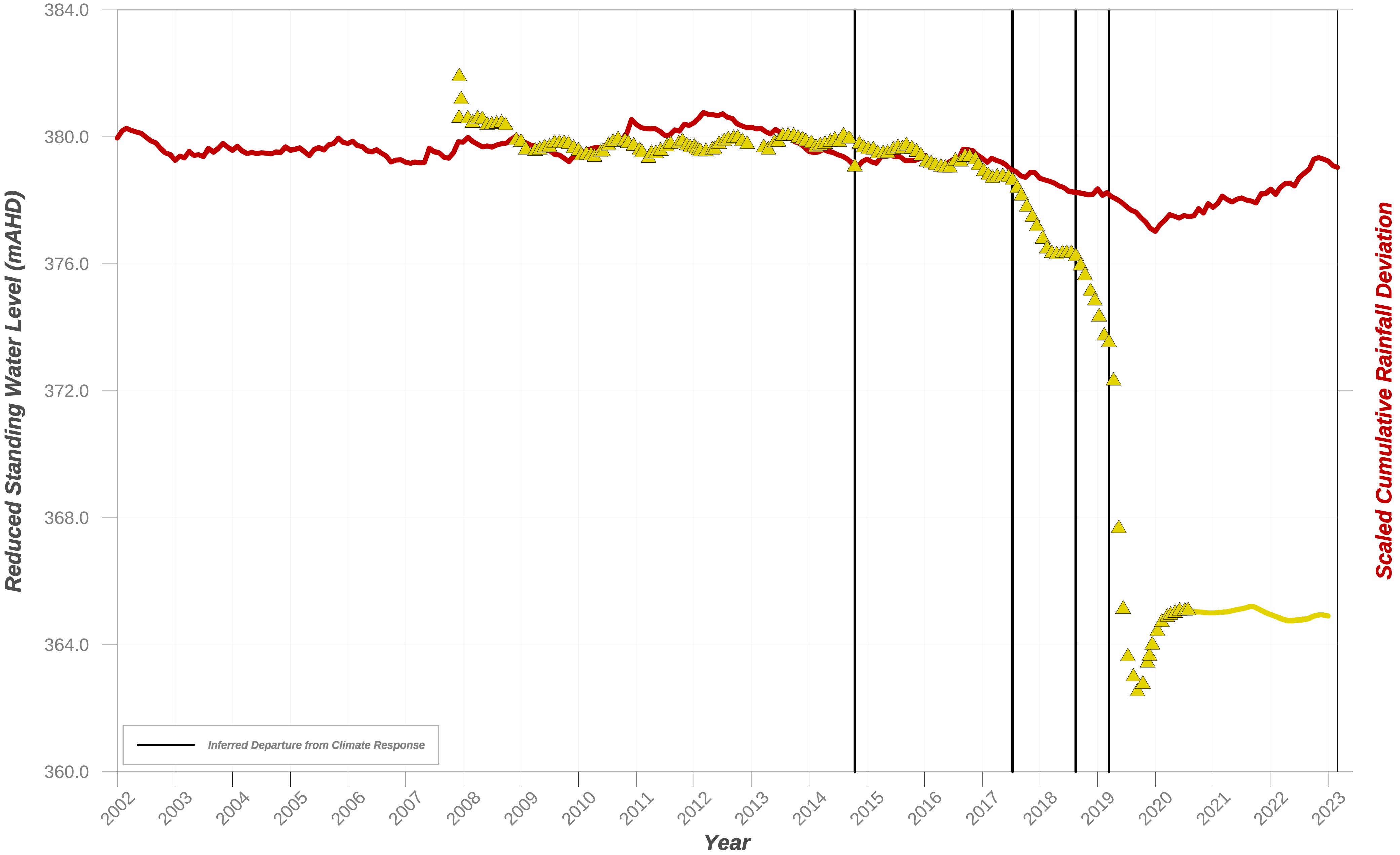
FIGURE No:
A.034



Hydrograph of Groundwater Level Data for Bore ID: PZ 129 VWP 74m
Moolarben Groundwater Monitoring - Permian
Moolarben Coal Operations - UG4 Groundwater Assessment Report

Manual Dips
Anomalous Reading
Continuous Logger Data
Anomalous Logger Data

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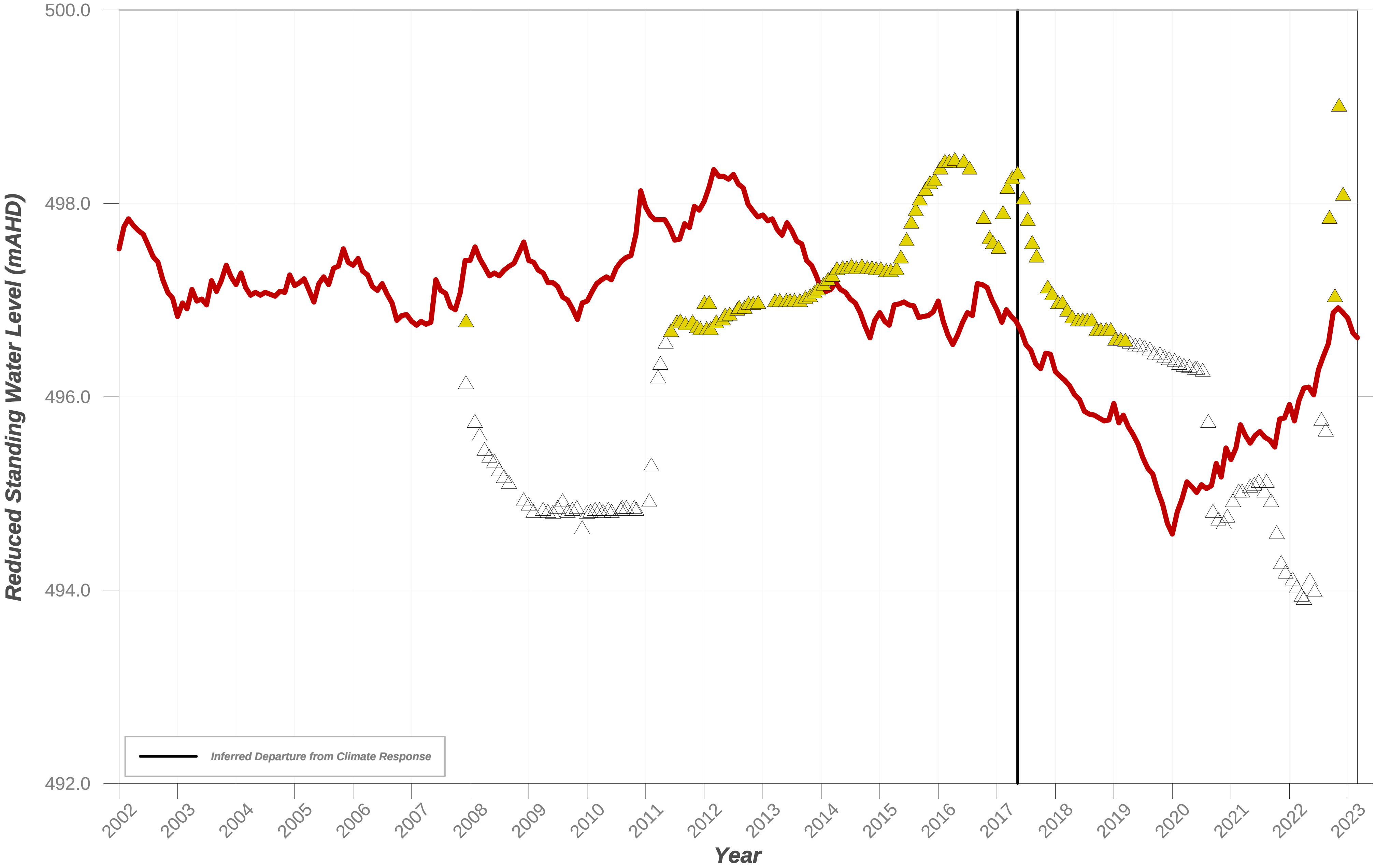
FIGURE No:
A.035



Hydrograph of Groundwater Level Data for Bore ID: PZ 130 VWP 38.5m
Moolarben Groundwater Monitoring - Permian
Moolarben Coal Operations - UG4 Groundwater Assessment Report

Manual Dips
Anomalous Reading
Continuous Logger Data
Anomalous Logger Data

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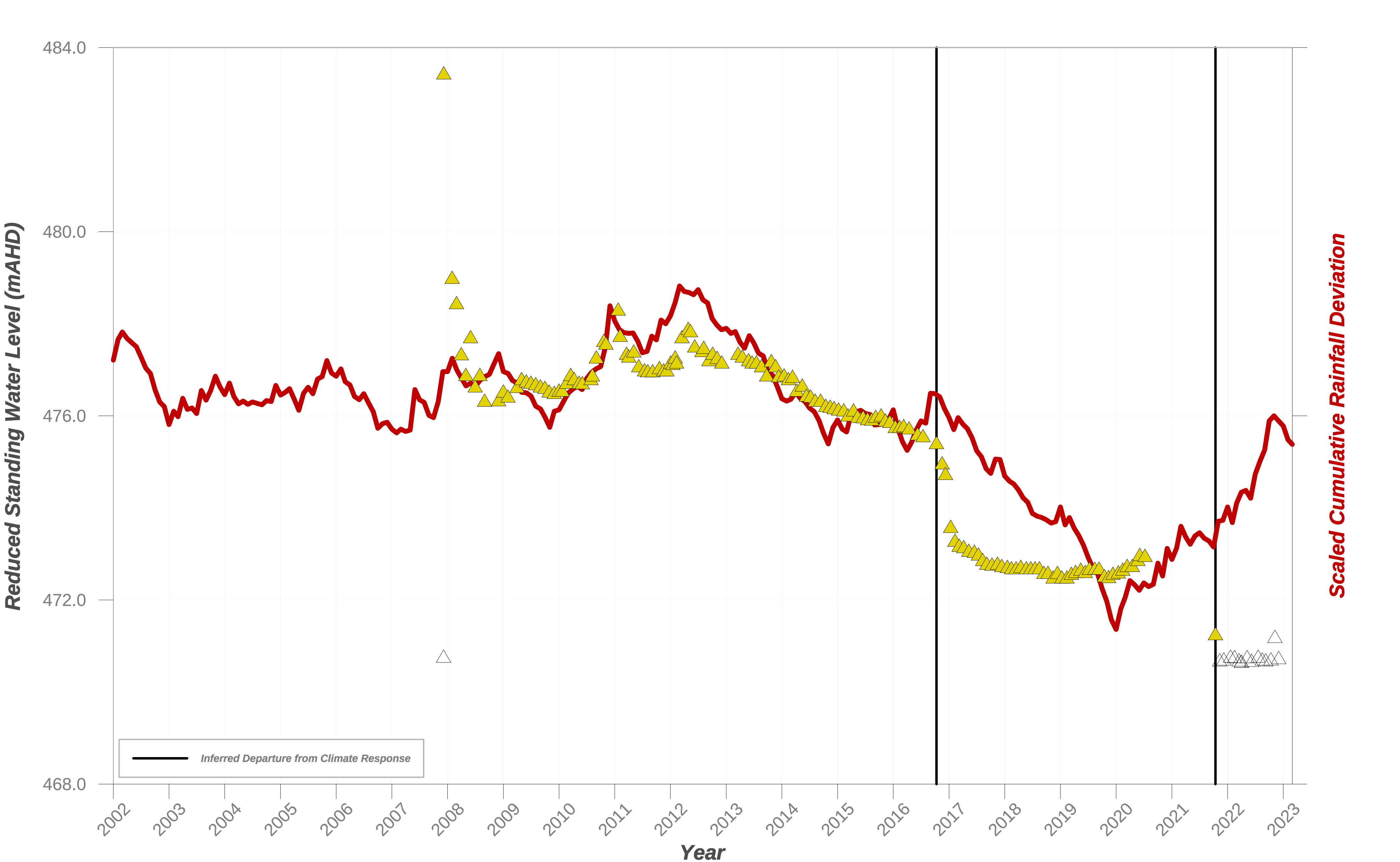
FIGURE No:
A.036



Hydrograph of Groundwater Level Data for Bore ID: PZ 130 VWP 64m
Moolarben Groundwater Monitoring - Permian
Moolarben Coal Operations - UG4 Groundwater Assessment Report

Manual Dips
Anomalous Reading
Continuous Logger Data
Anomalous Logger Data

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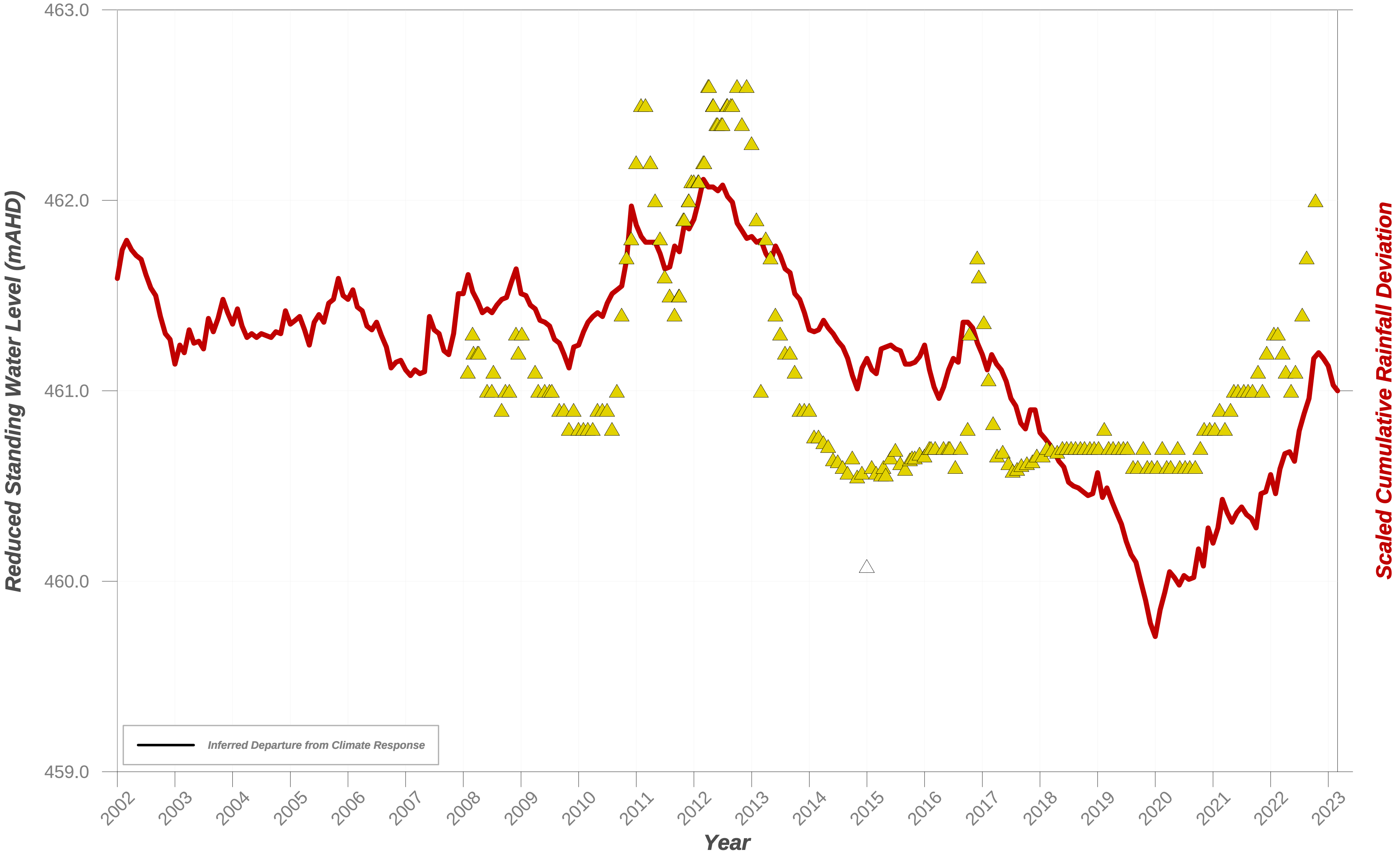
FIGURE No:
A.037



Hydrograph of Groundwater Level Data for Bore ID: PZ 137
Moolarben Groundwater Monitoring - Permian
Moolarben Coal Operations - UG4 Groundwater Assessment Report

Manual Dips
Anomalous Reading
Continuous Logger Data
Anomalous Logger Data

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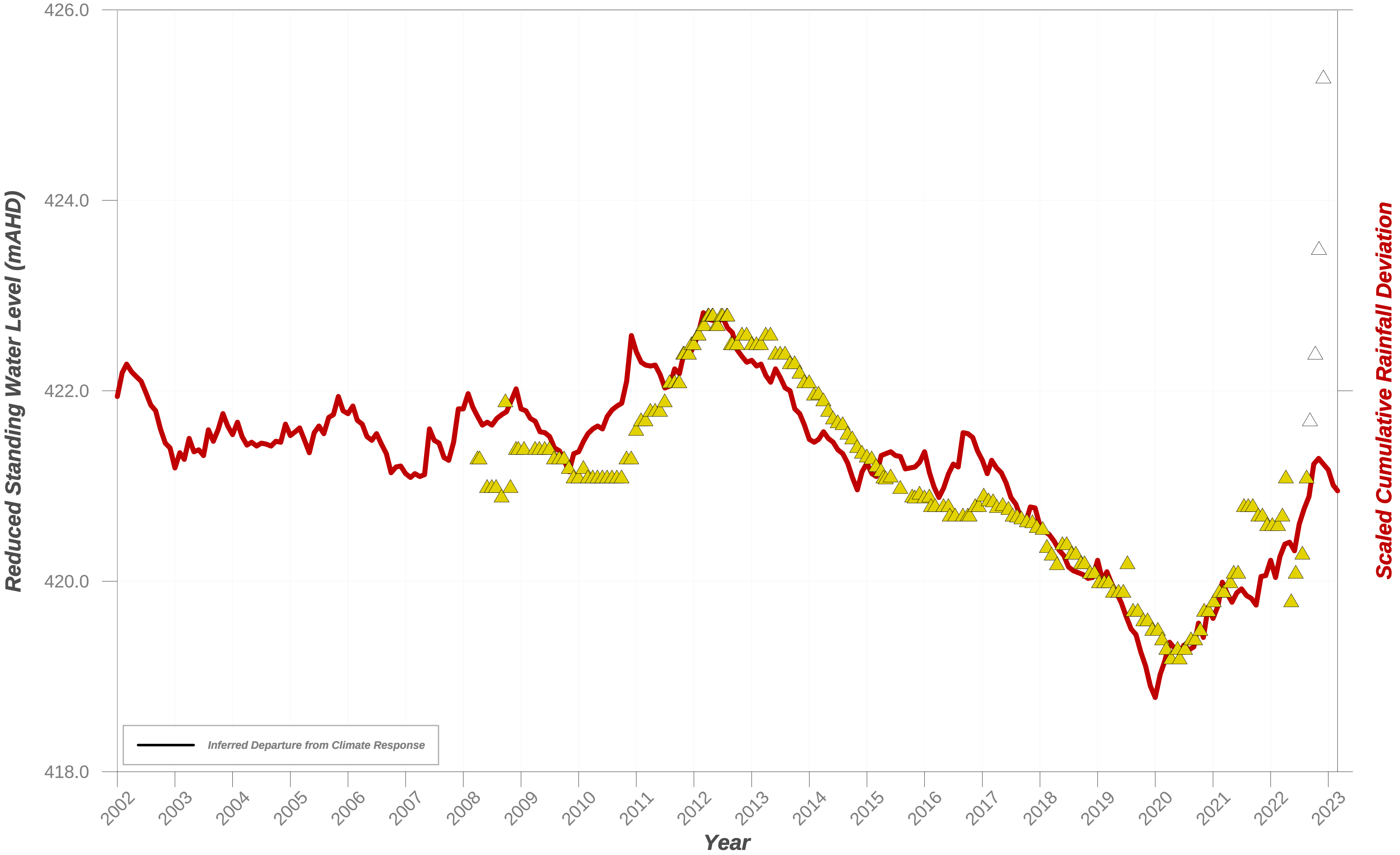
FIGURE No:
A.038



Hydrograph of Groundwater Level Data for Bore ID: PZ 170
Moolarben Groundwater Monitoring - Permian
Moolarben Coal Operations - UG4 Groundwater Assessment Report

Manual Dips
Anomalous Reading
Continuous Logger Data
Anomalous Logger Data

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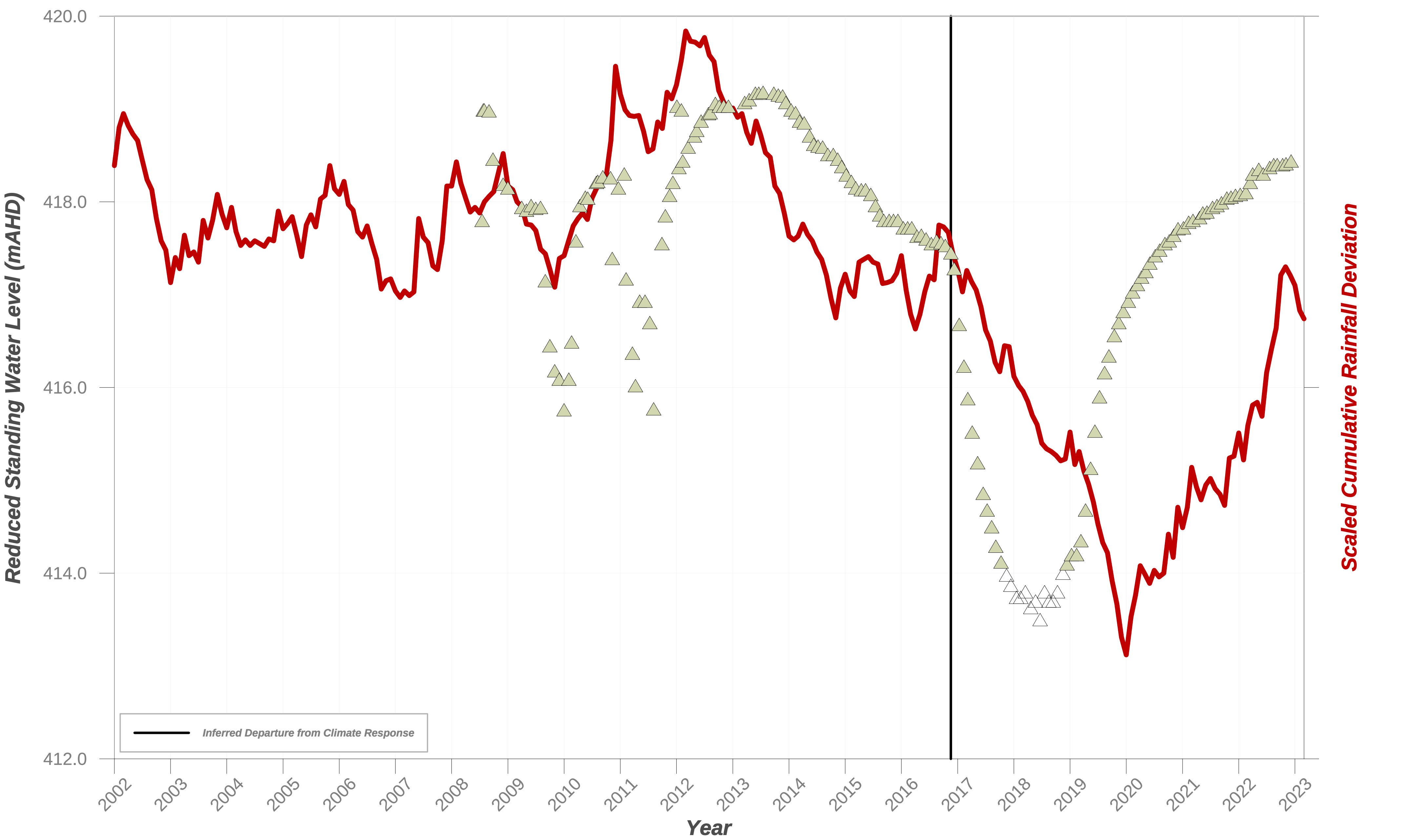
FIGURE No:
A.039



Hydrograph of Groundwater Level Data for Bore ID: PZ 179 VWP 29m
Moolarben Groundwater Monitoring - Triassic
Moolarben Coal Operations - UG4 Groundwater Assessment Report

Manual Dips
Anomalous Reading
Continuous Logger Data
Anomalous Logger Data

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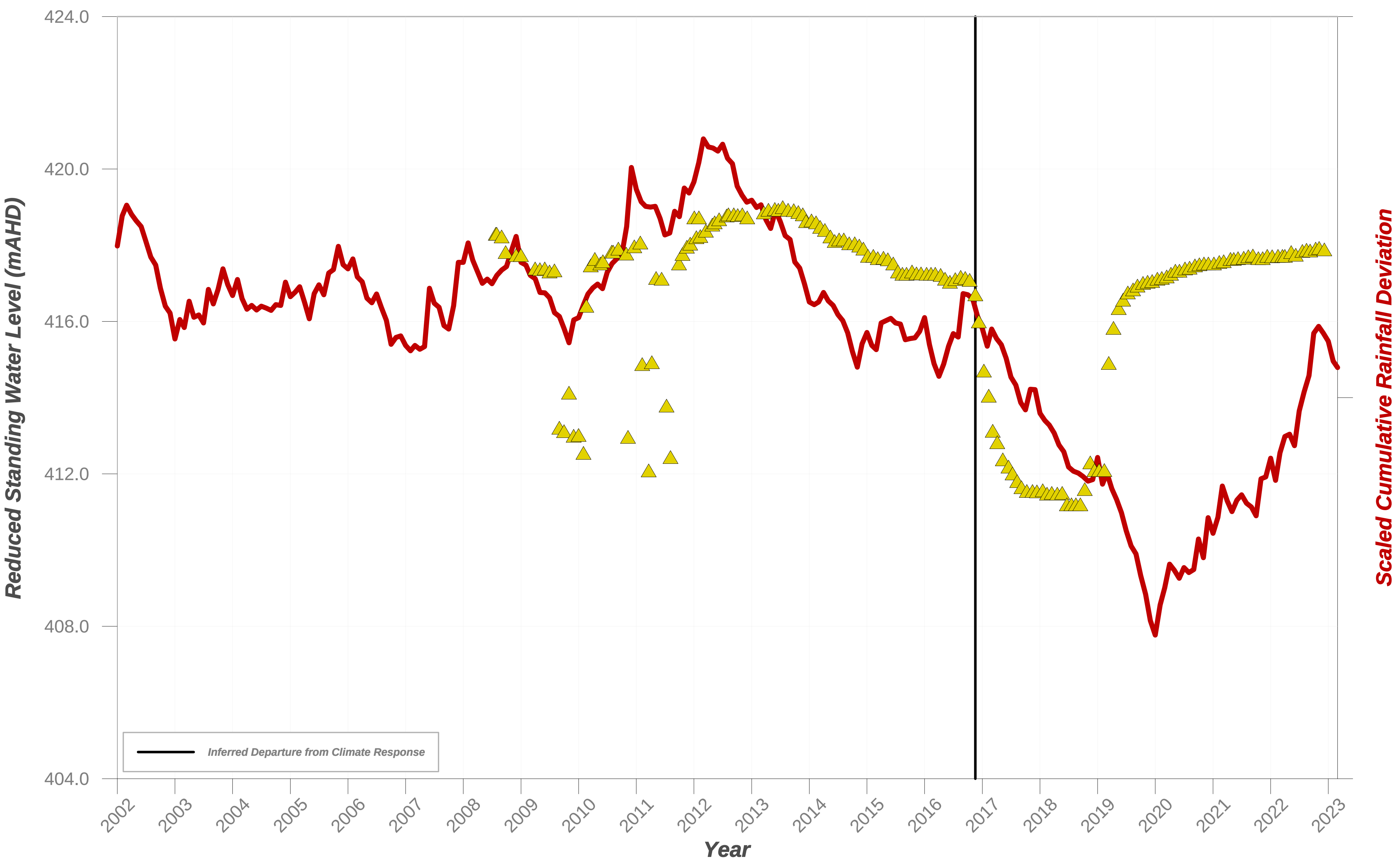
FIGURE No:
A.040



Hydrograph of Groundwater Level Data for Bore ID: PZ 179 VWP 33m
Moolarben Groundwater Monitoring - Permian
Moolarben Coal Operations - UG4 Groundwater Assessment Report

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Anomalous Reading
Continuous Logger Data
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FIGURE No:
A.041

Hydrograph of Groundwater Level Data for Bore ID: PZ 179 VWP 145m
Moolarben Groundwater Monitoring - Ulan Seam
Moolarben Coal Operations - UG4 Groundwater Assessment Report

Manual Dips
Anomalous Reading
Continuous Logger Data
Anomalous Logger Data

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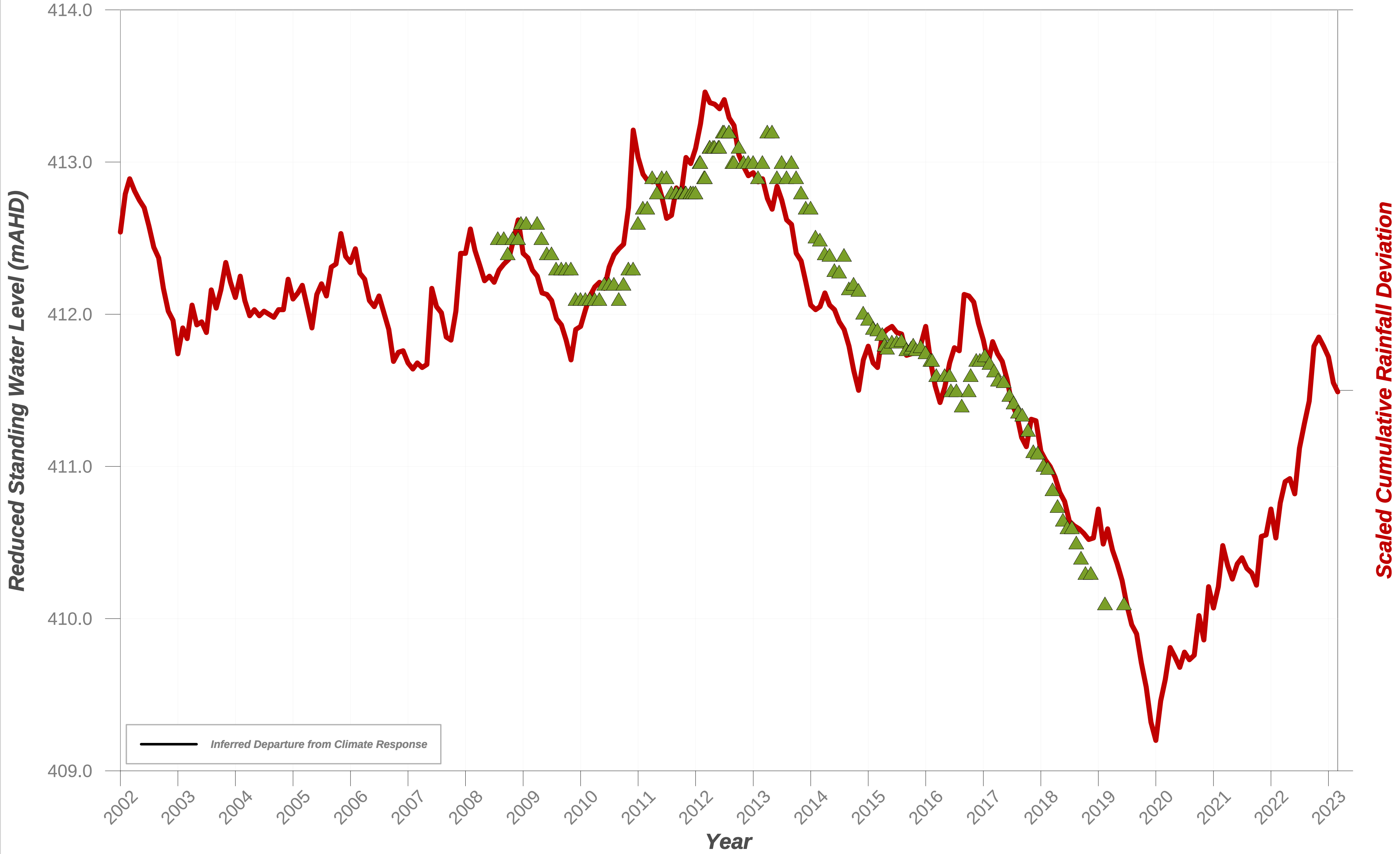
FIGURE No: **A.042**



Hydrograph of Groundwater Level Data for Bore ID: PZ 184
Moolarben Groundwater Monitoring - Tertiary Sediments / Paleochannel
Moolarben Coal Operations - UG4 Groundwater Assessment Report

Manual Dips
Anomalous Reading
Continuous Logger Data
Anomalous Logger Data

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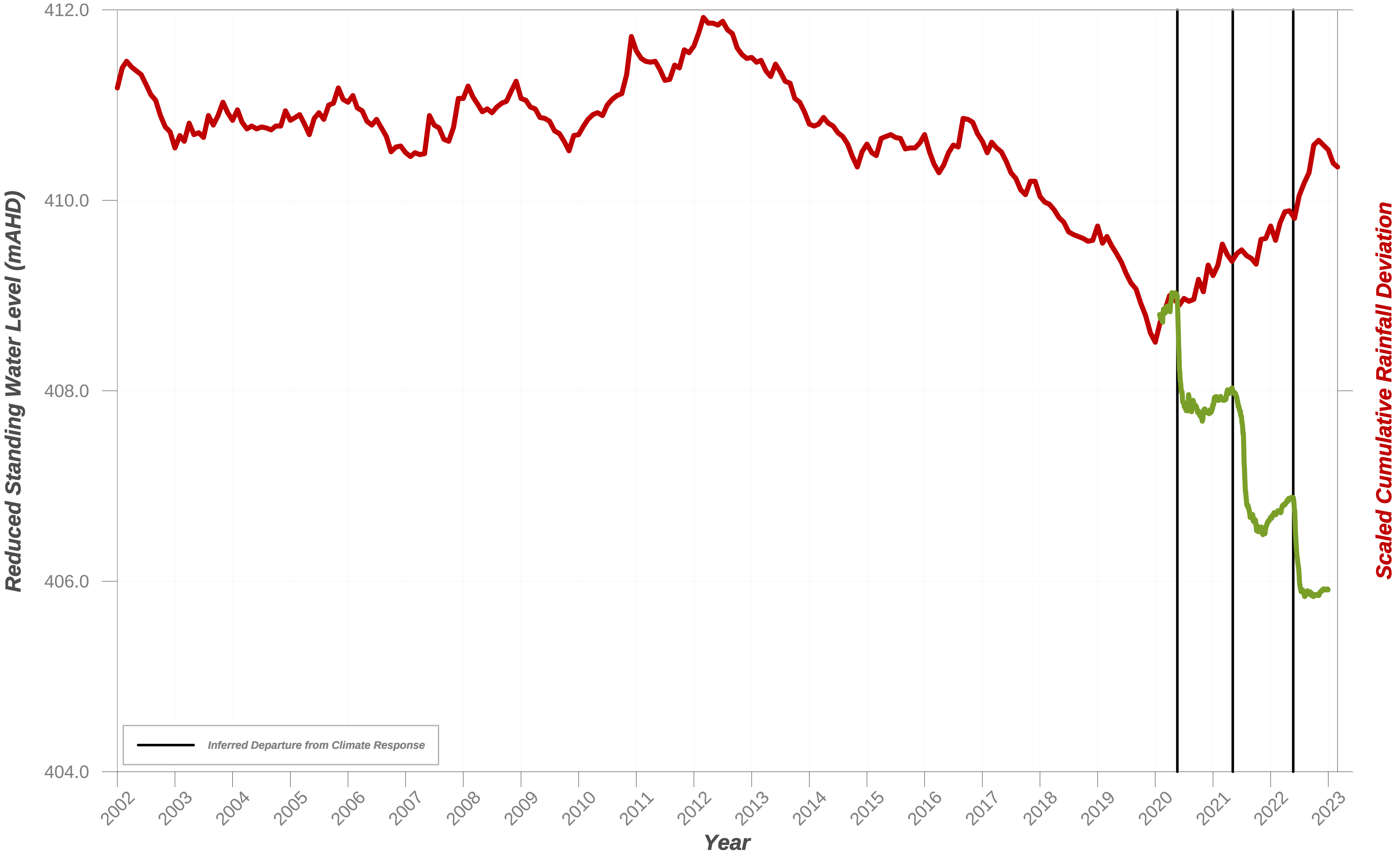
FIGURE No:
A.043



Hydrograph of Groundwater Level Data for Bore ID: PZ 186 VWP 13.5m
Moolarben Groundwater Monitoring - Tertiary Sediments / Paleochannel
Moolarben Coal Operations - UG4 Groundwater Assessment Report

Manual Dips
Anomalous Reading
Continuous Logger Data
Anomalous Logger Data

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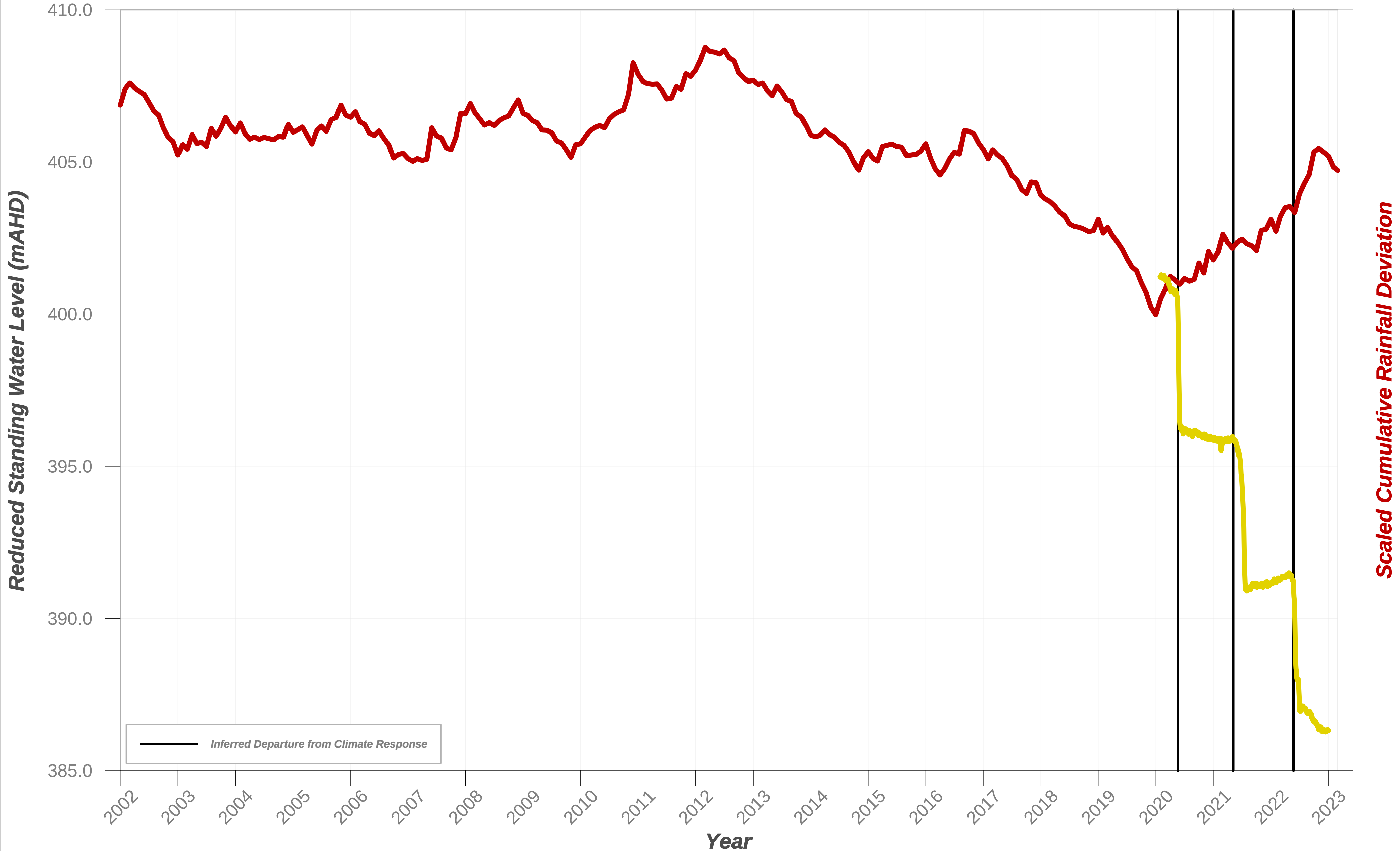
FIGURE No:
A.044



Hydrograph of Groundwater Level Data for Bore ID: PZ 186 VWP 40m
Moolarben Groundwater Monitoring - Permian
Moolarben Coal Operations - UG4 Groundwater Assessment Report

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Anomalous Reading
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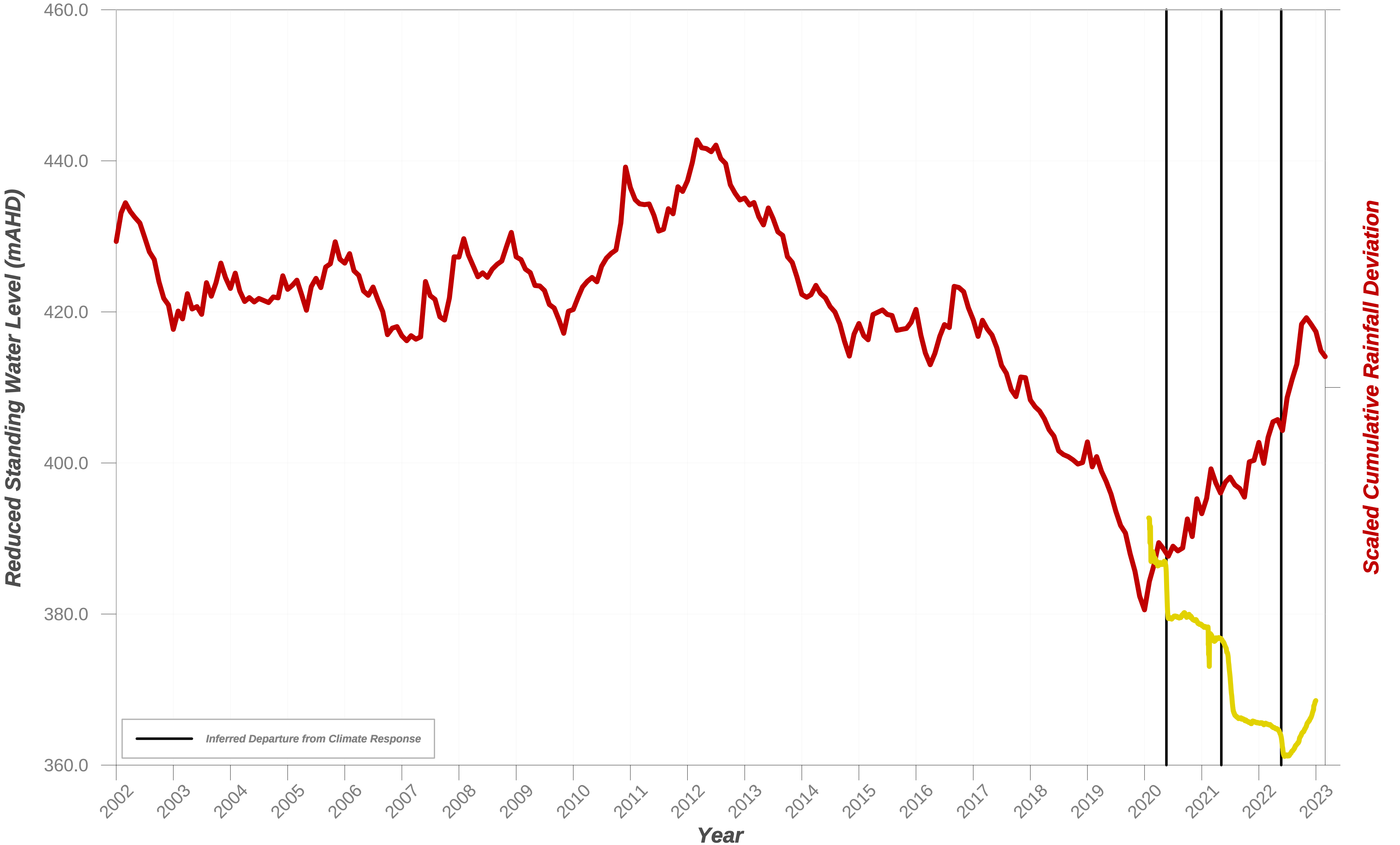
FIGURE No: **A.045**



Hydrograph of Groundwater Level Data for Bore ID: PZ 186 VWP 65m
Moolarben Groundwater Monitoring - Permian
Moolarben Coal Operations - UG4 Groundwater Assessment Report

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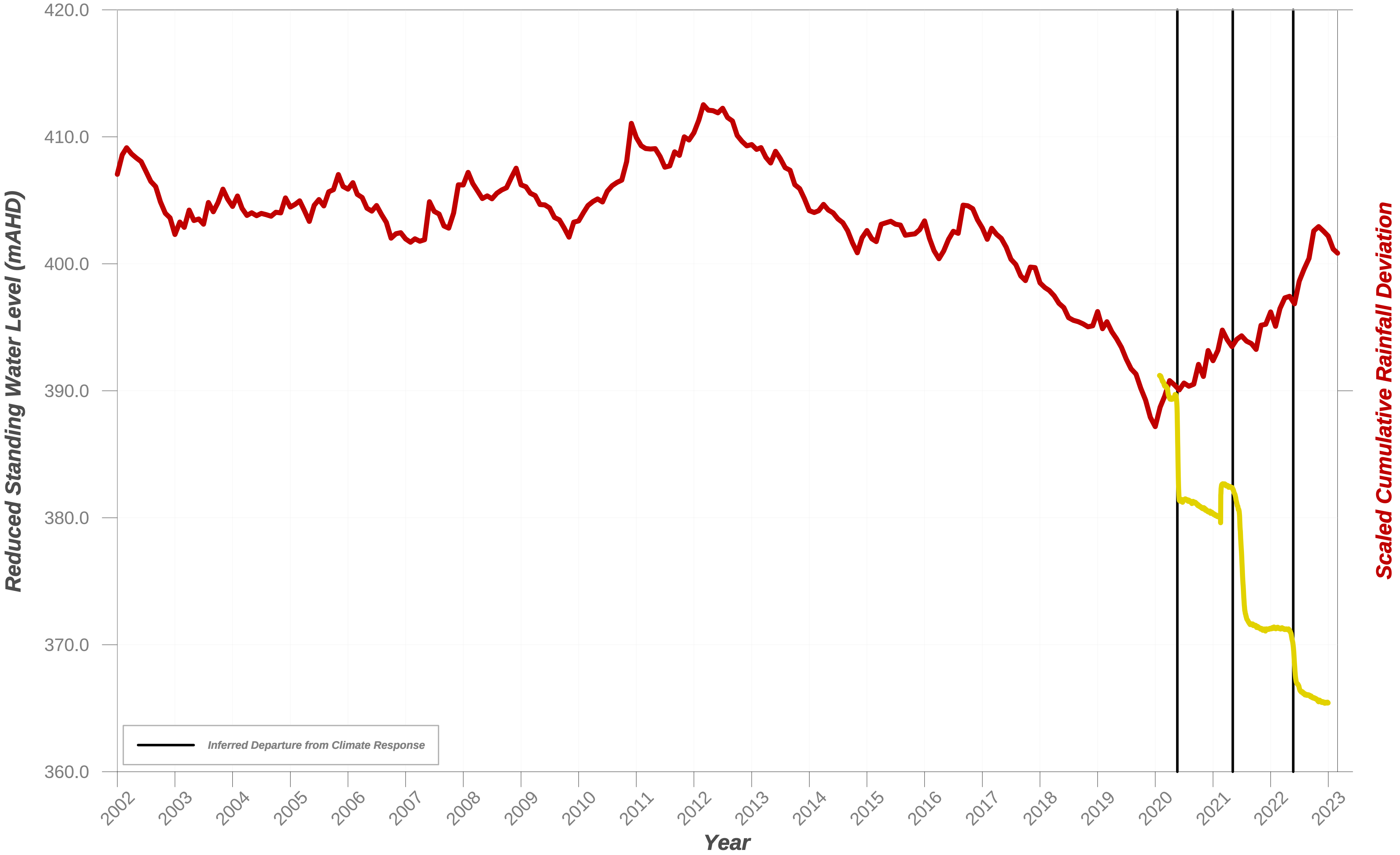
FIGURE No:
A.046



Hydrograph of Groundwater Level Data for Bore ID: PZ 186 VWP 86m
Moolarben Groundwater Monitoring - Permian
Moolarben Coal Operations - UG4 Groundwater Assessment Report

Manual Dips
Anomalous Reading
Continuous Logger Data
Anomalous Logger Data

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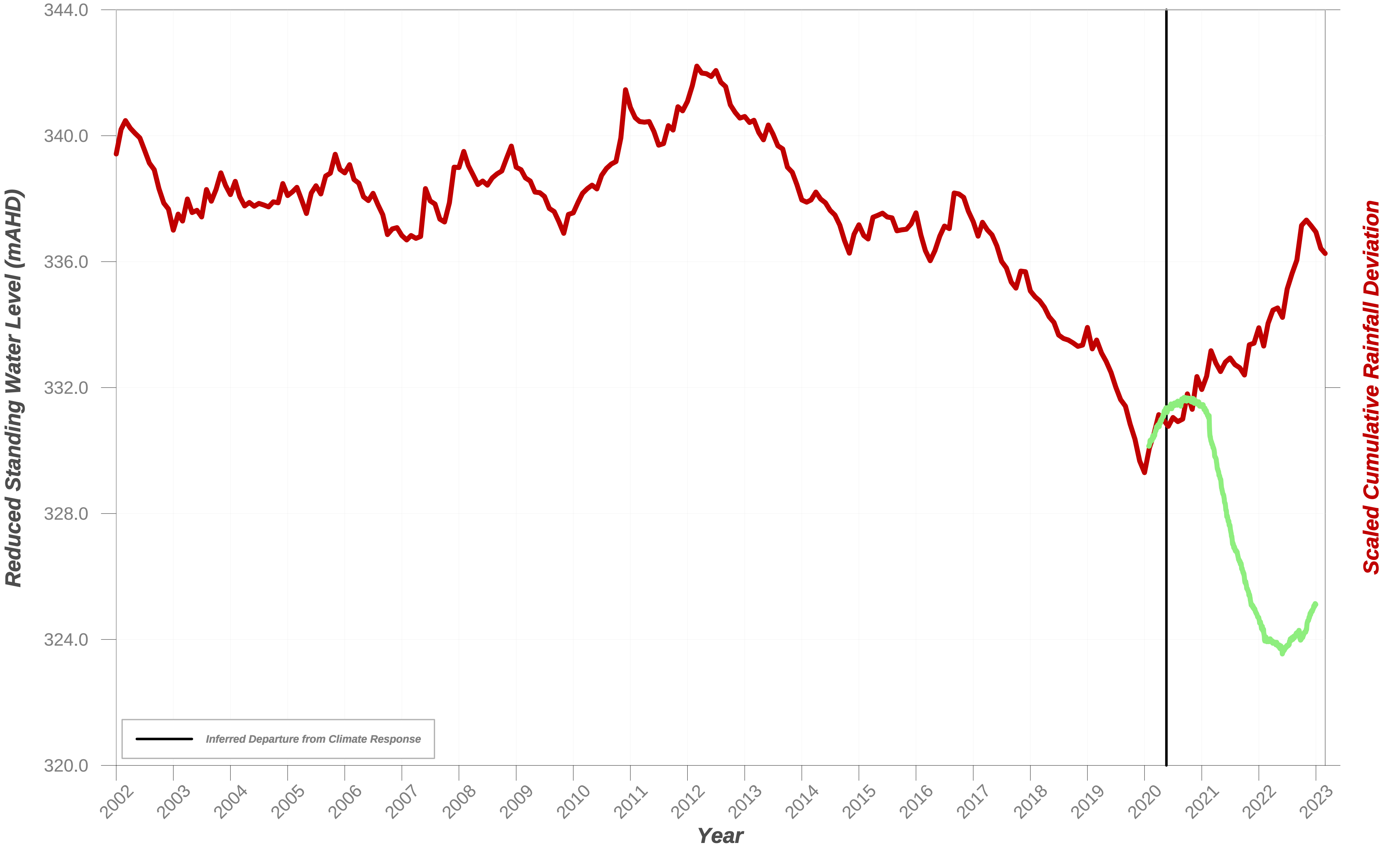
FIGURE No:
A.047



Hydrograph of Groundwater Level Data for Bore ID: PZ 186 VWP 118m
Moolarben Groundwater Monitoring - Ulan Seam
Moolarben Coal Operations - UG4 Groundwater Assessment Report

Manual Dips
Anomalous Reading
Continuous Logger Data
Anomalous Logger Data

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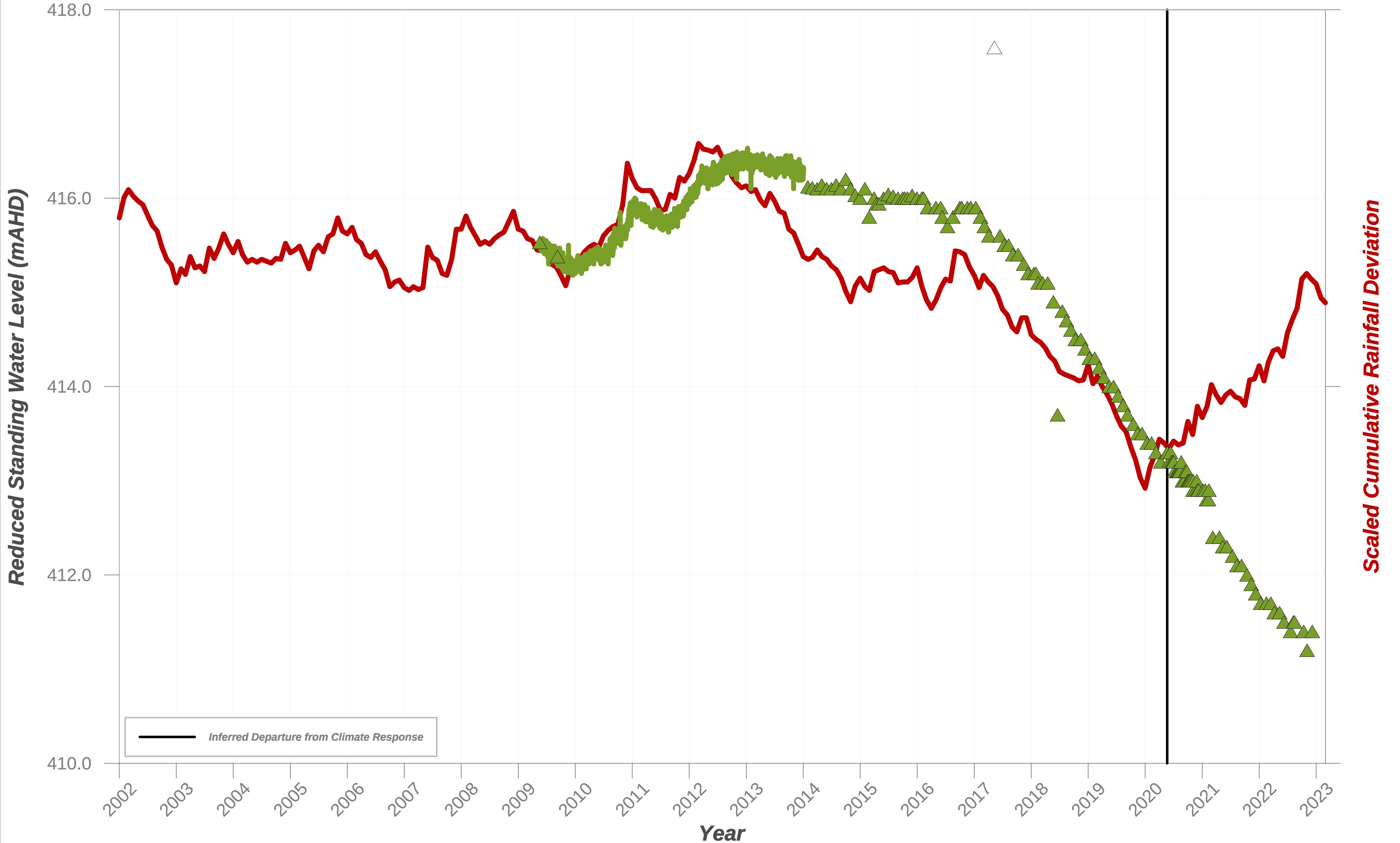
FIGURE No:
A.048



Hydrograph of Groundwater Level Data for Bore ID: PZ 188
Moolarben Groundwater Monitoring - Tertiary Sediments / Paleochannel
Moolarben Coal Operations - UG4 Groundwater Assessment Report

Manual Dips
Anomalous Reading
Continuous Logger Data
Anomalous Logger Data

AGE

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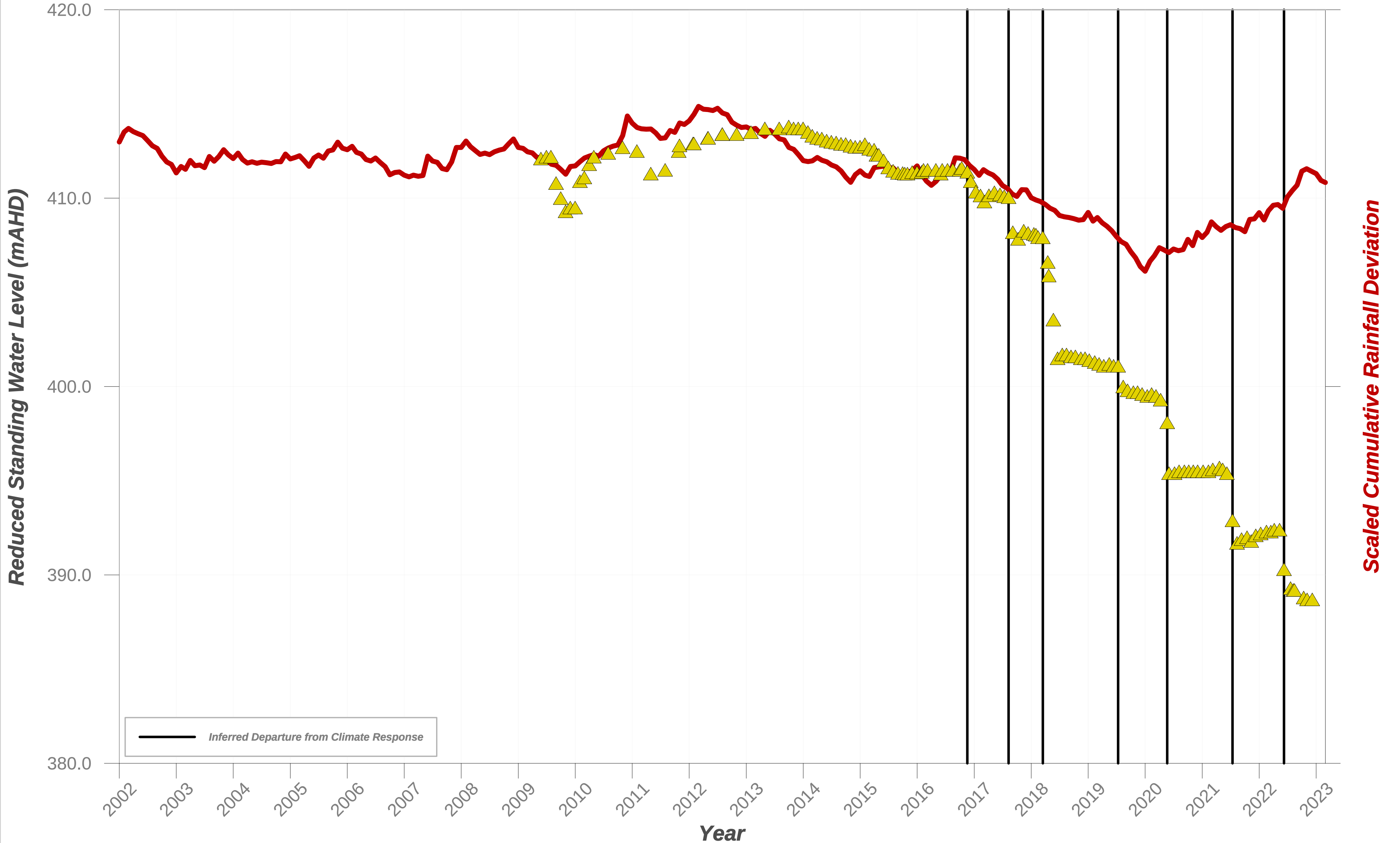
FIGURE No:
A.049



Hydrograph of Groundwater Level Data for Bore ID: PZ 189
Moolarben Groundwater Monitoring - Permian
Moolarben Coal Operations - UG4 Groundwater Assessment Report

Manual Dips
Anomalous Reading
Continuous Logger Data
Anomalous Logger Data

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FIGURE No:
A.050

Hydrograph of Groundwater Level Data for Bore ID: PZ 191
Moolarben Groundwater Monitoring - Ulan Seam
Moolarben Coal Operations - UG4 Groundwater Assessment Report

Manual Dips
Anomalous Reading
Continuous Logger Data
Anomalous Logger Data

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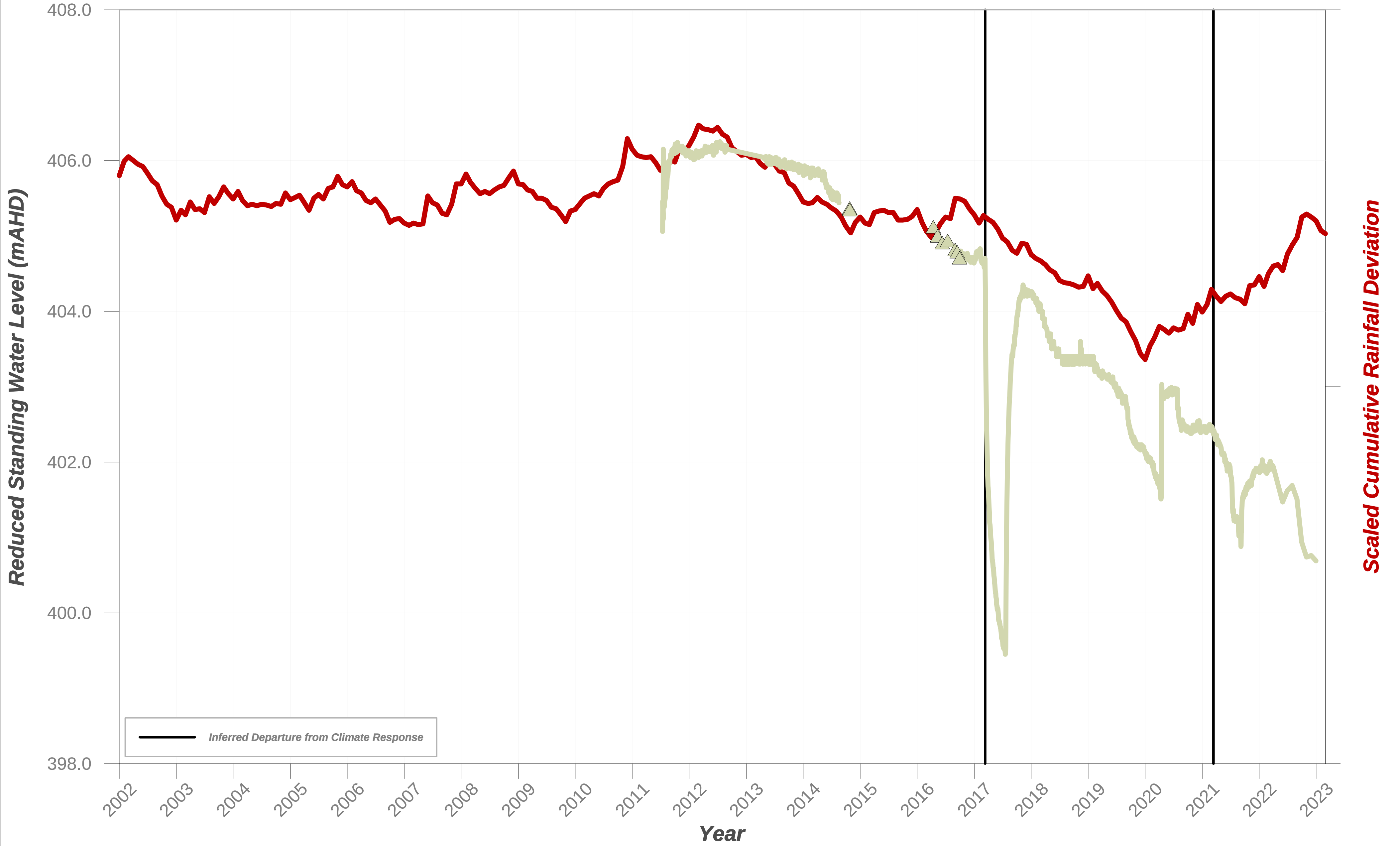
FIGURE No: **A.051**



Hydrograph of Groundwater Level Data for Bore ID: PZ 192 VWP 68m
Moolarben Groundwater Monitoring - Triassic
Moolarben Coal Operations - UG4 Groundwater Assessment Report

Manual Dips
Anomalous Reading
Continuous Logger Data
Anomalous Logger Data

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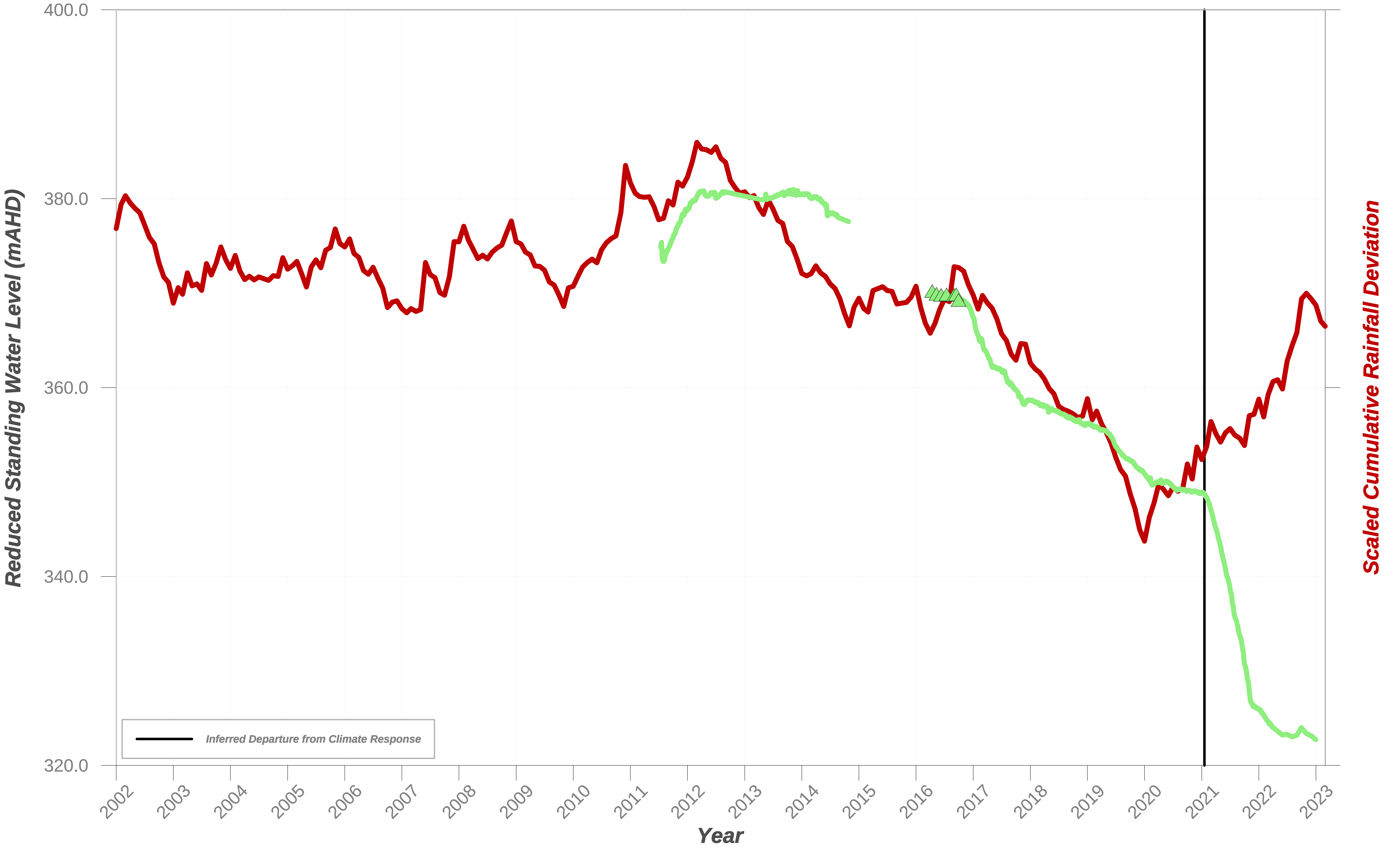
FIGURE No:
A.052



Hydrograph of Groundwater Level Data for Bore ID: PZ 192 VWP 166m
Moolarben Groundwater Monitoring - Ulan Seam
Moolarben Coal Operations - UG4 Groundwater Assessment Report

Manual Dips
Anomalous Reading
Continuous Logger Data
Anomalous Logger Data

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FIGURE No: **A.053**

Hydrograph of Groundwater Level Data for Bore ID: PZ 192 VWP 178m
Moolarben Groundwater Monitoring - Ulan Seam
Moolarben Coal Operations - UG4 Groundwater Assessment Report

Manual Dips
Anomalous Reading
Continuous Logger Data
Anomalous Logger Data

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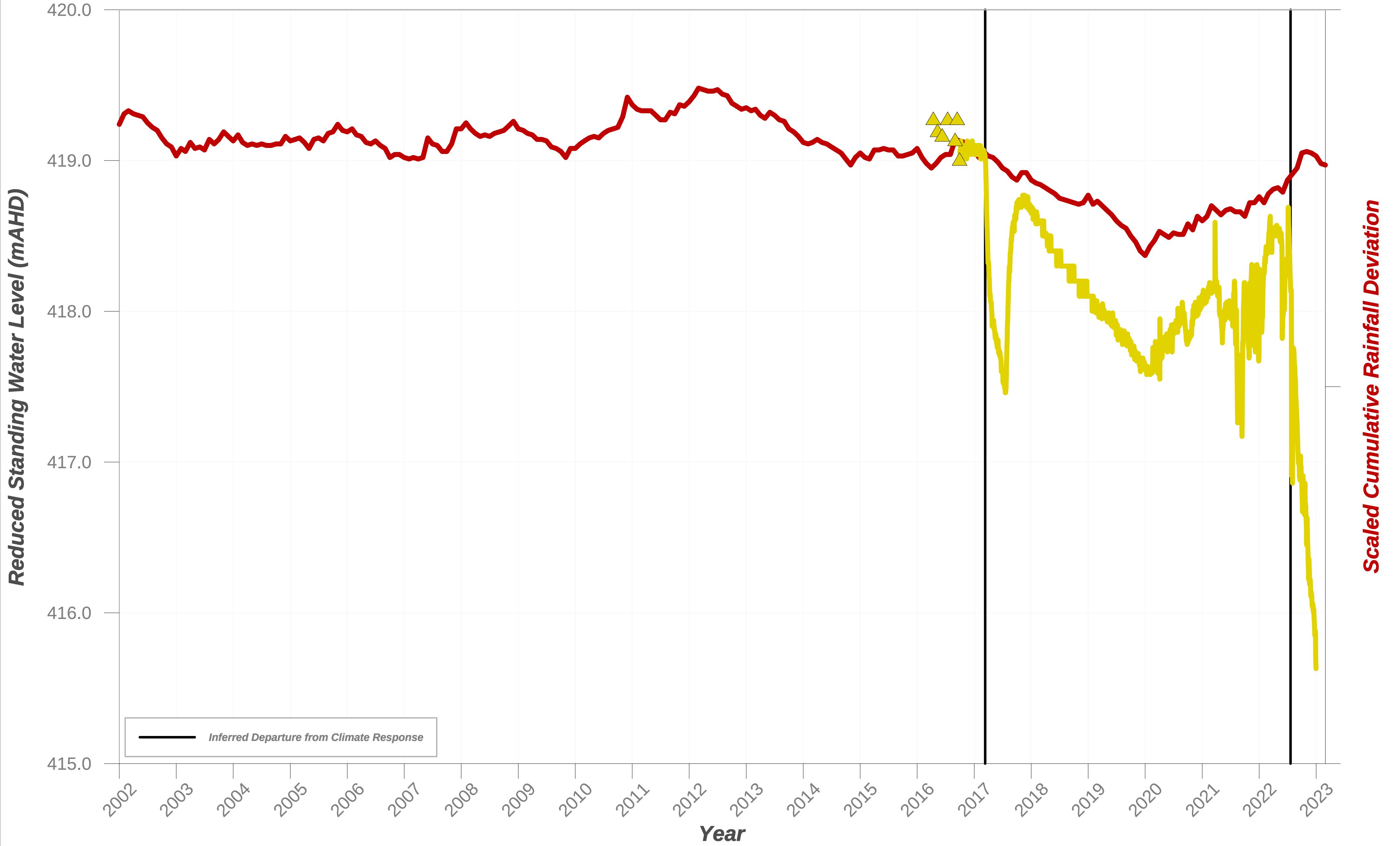
FIGURE No: **A.054**



Hydrograph of Groundwater Level Data for Bore ID: PZ 193 VWP 80m
Moolarben Groundwater Monitoring - Permian
Moolarben Coal Operations - UG4 Groundwater Assessment Report

Manual Dips
Anomalous Reading
Continuous Logger Data
Anomalous Logger Data

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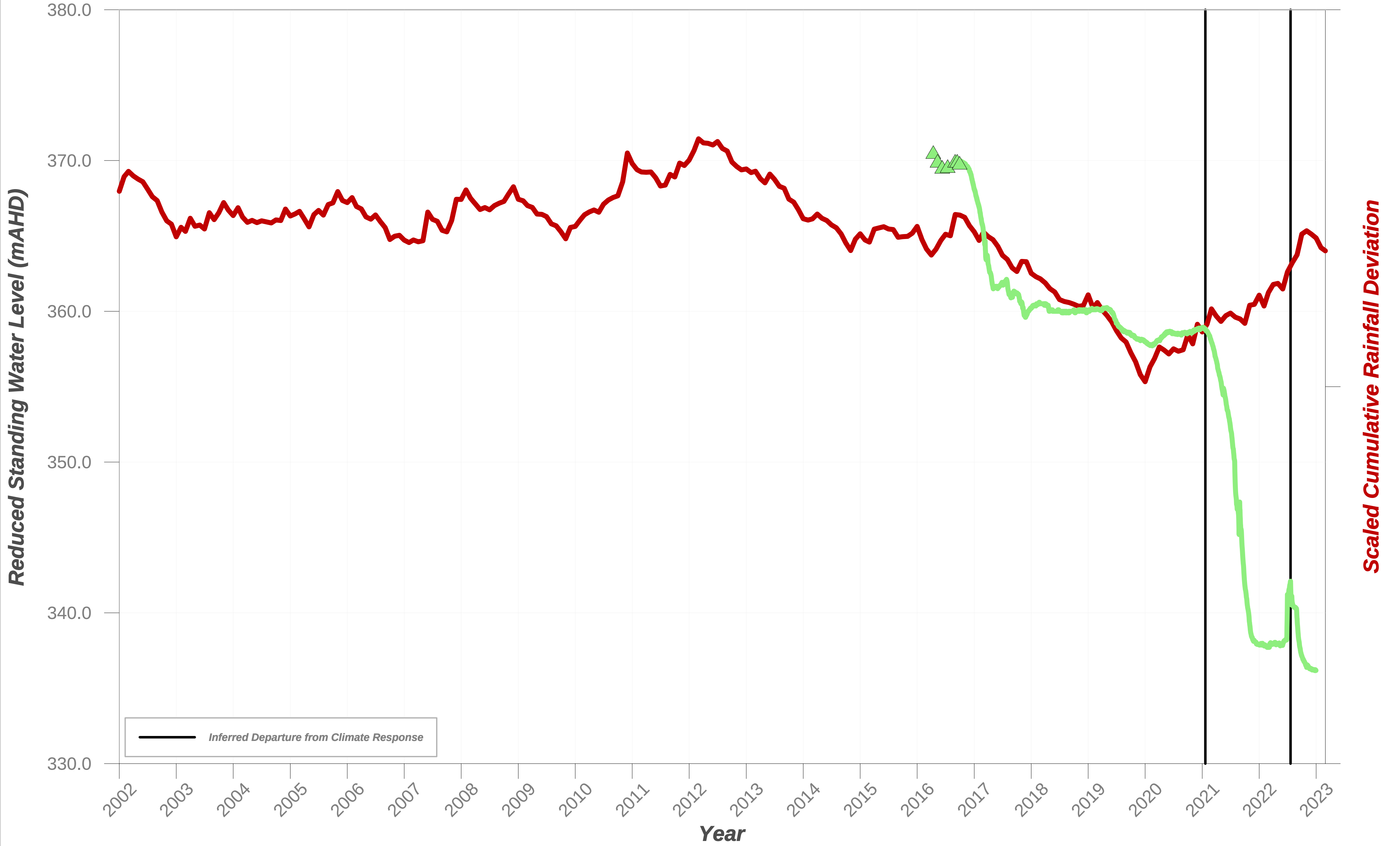
FIGURE No:
A.055



Hydrograph of Groundwater Level Data for Bore ID: PZ 193 VWP 162m
Moolarben Groundwater Monitoring - Ulan Seam
Moolarben Coal Operations - UG4 Groundwater Assessment Report

Manual Dips
Anomalous Reading
Continuous Logger Data
Anomalous Logger Data

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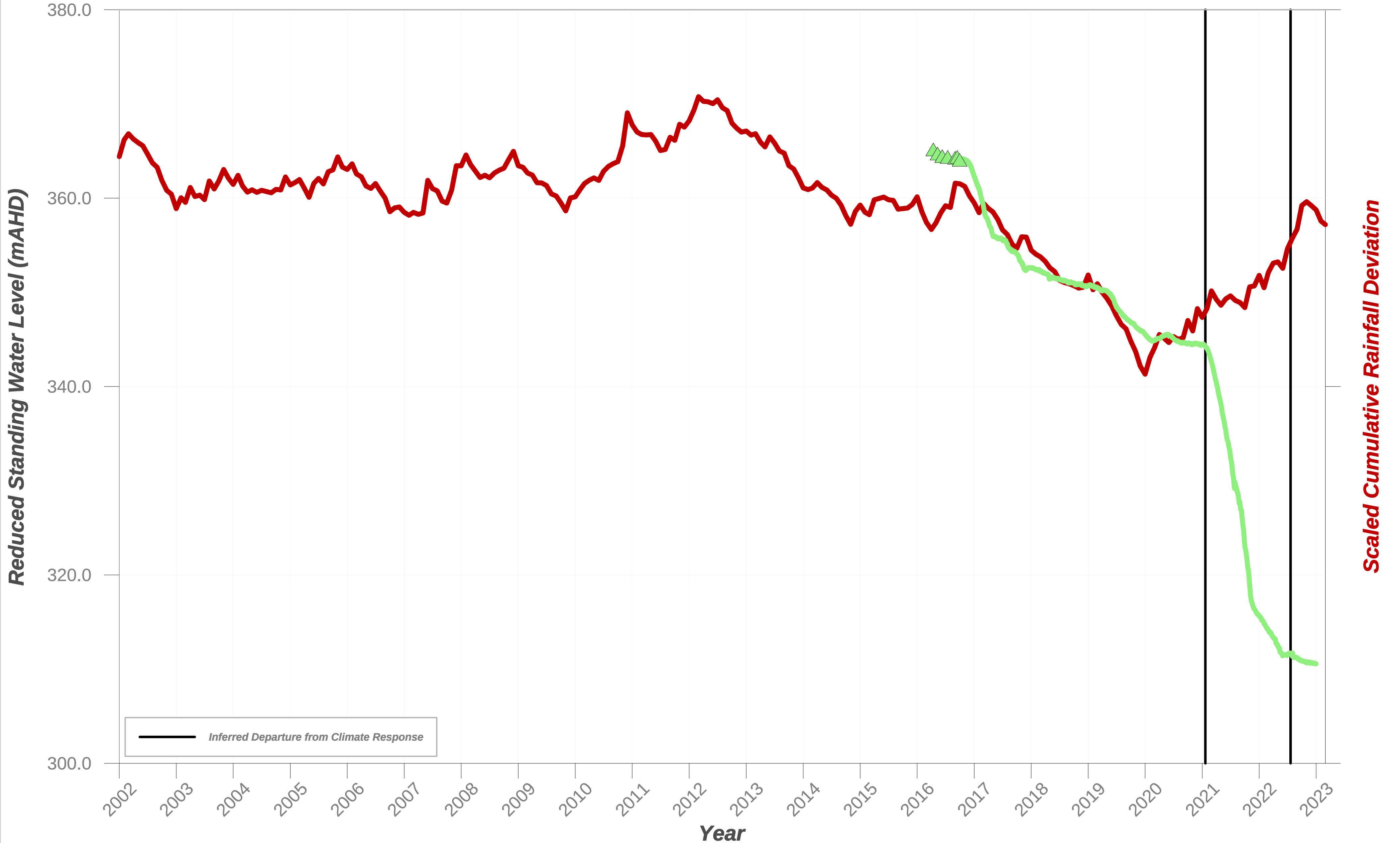
FIGURE No:
A.056



Hydrograph of Groundwater Level Data for Bore ID: PZ 193 VWP 184m
Moolarben Groundwater Monitoring - Ulan Seam
Moolarben Coal Operations - UG4 Groundwater Assessment Report

Manual Dips
Anomalous Reading
Continuous Logger Data
Anomalous Logger Data

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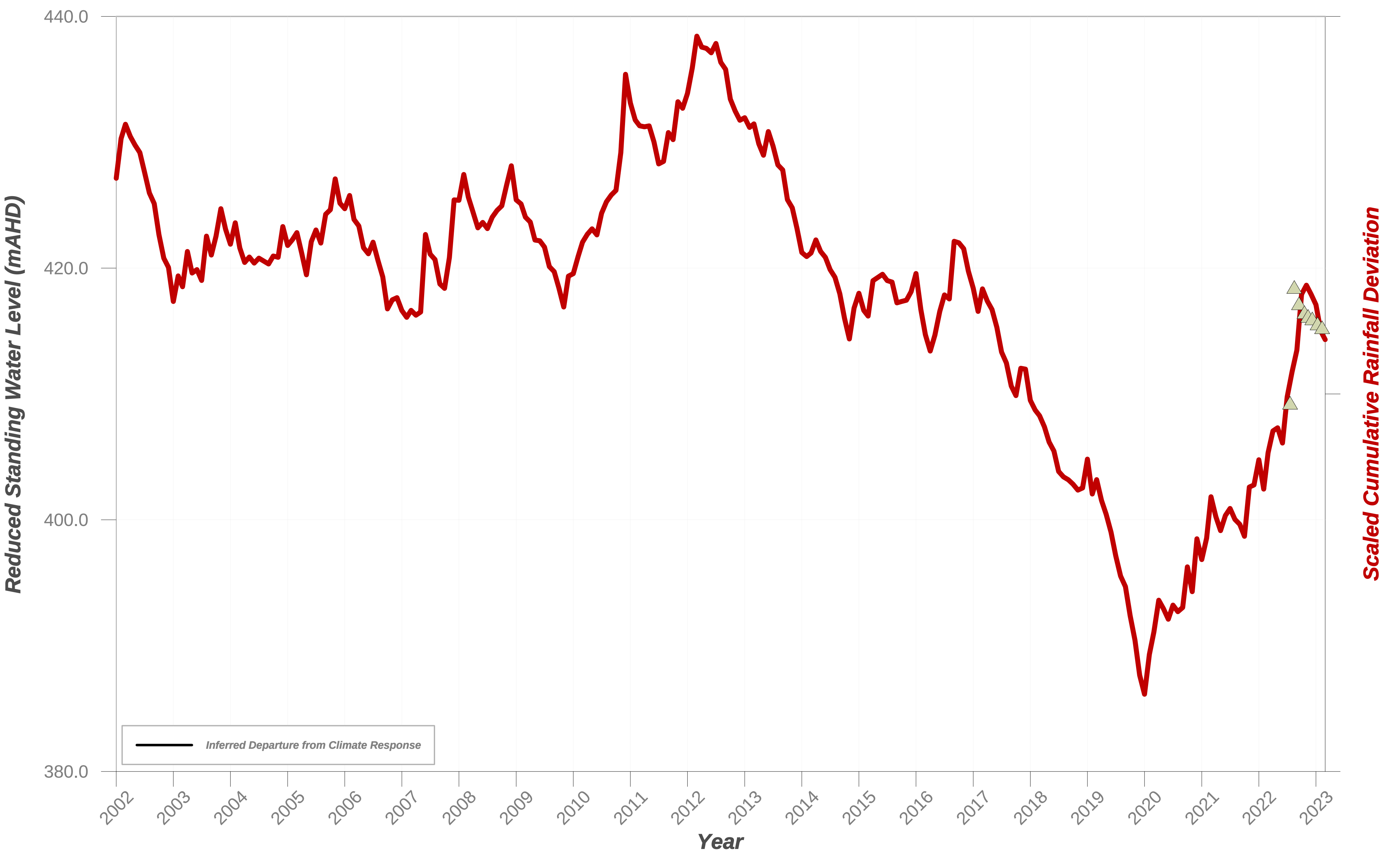
FIGURE No:
A.057



Hydrograph of Groundwater Level Data for Bore ID: PZ 194B
Moolarben Groundwater Monitoring - Triassic
Moolarben Coal Operations - UG4 Groundwater Assessment Report

Manual Dips
Anomalous Reading
Continuous Logger Data
Anomalous Logger Data

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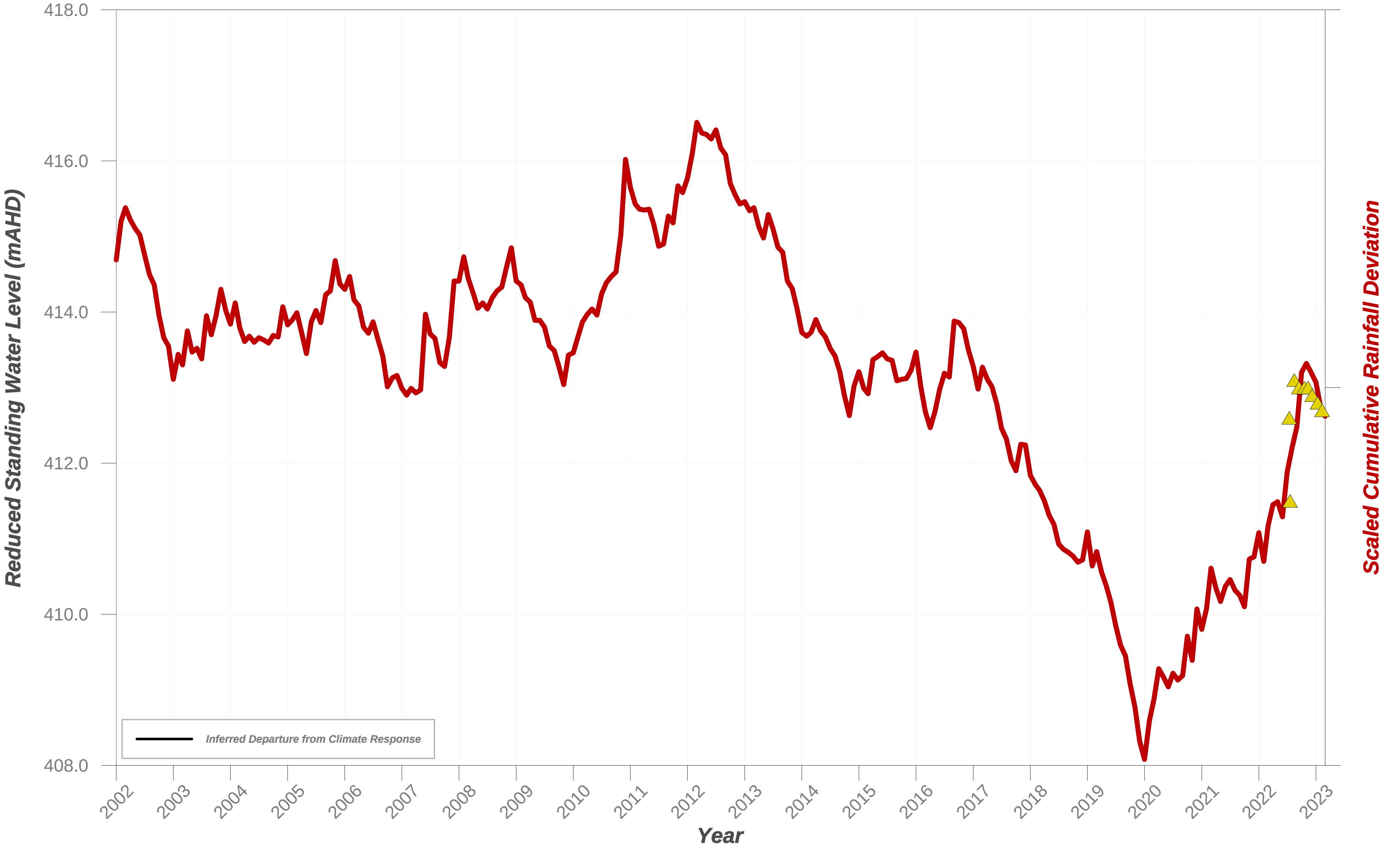
FIGURE No:
A.058



Hydrograph of Groundwater Level Data for Bore ID: PZ 194C
Moolarben Groundwater Monitoring - Permian
Moolarben Coal Operations - UG4 Groundwater Assessment Report

Manual Dips
Anomalous Reading
Continuous Logger Data
Anomalous Logger Data

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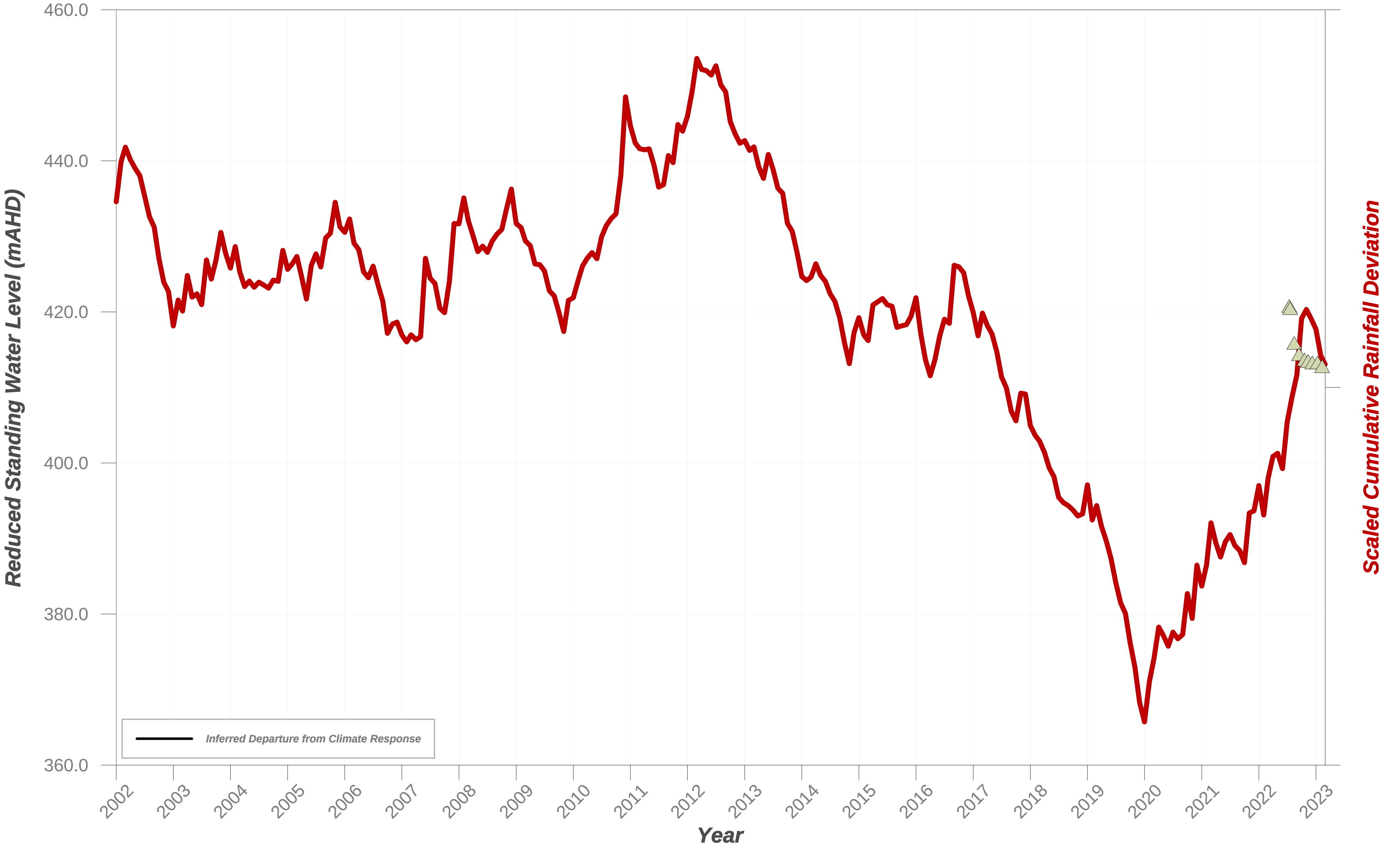
FIGURE No:
A.059



Hydrograph of Groundwater Level Data for Bore ID: PZ 195B
Moolarben Groundwater Monitoring - Triassic
Moolarben Coal Operations - UG4 Groundwater Assessment Report

Manual Dips
Anomalous Reading
Continuous Logger Data
Anomalous Logger Data

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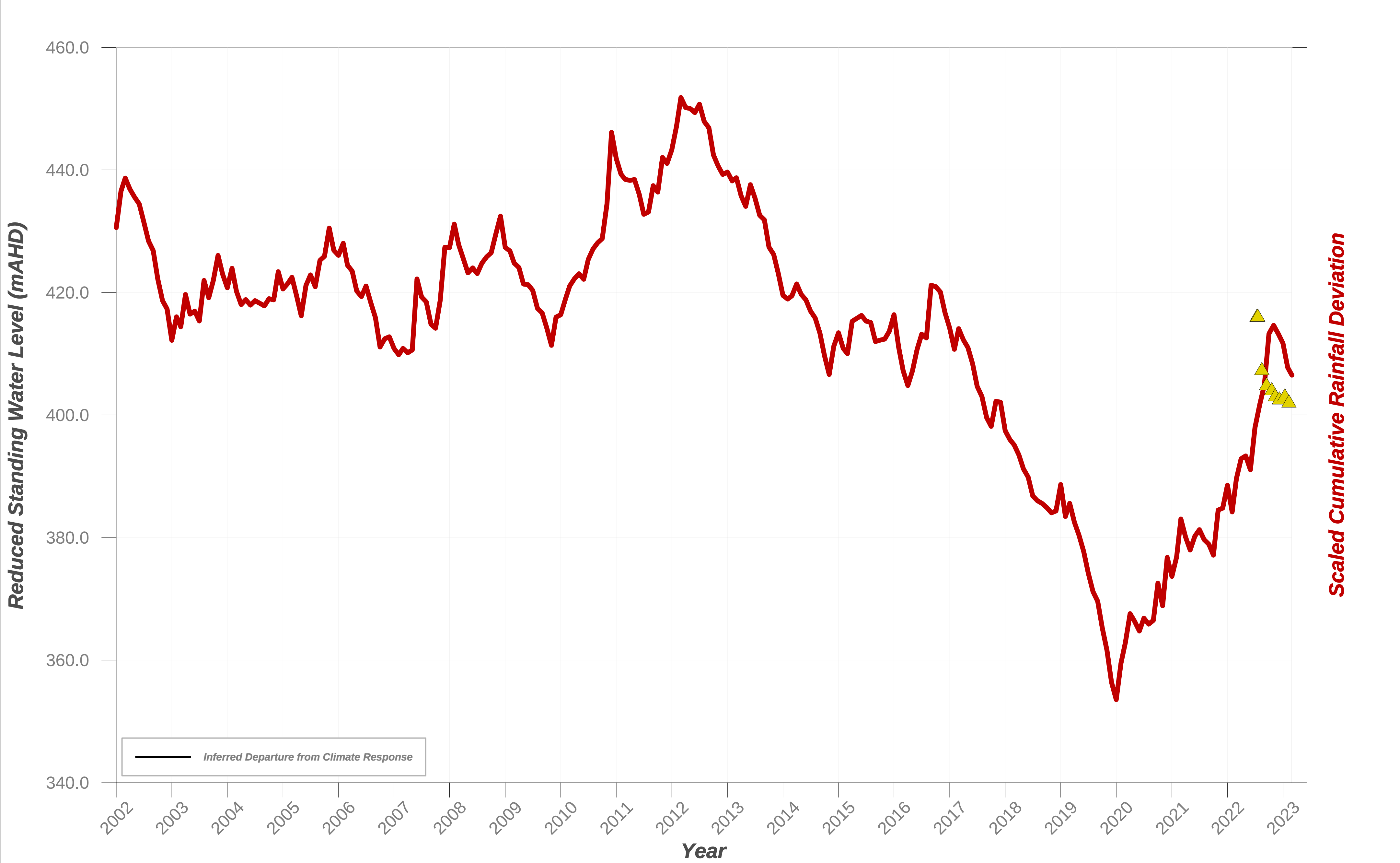
FIGURE No:
A.060



Hydrograph of Groundwater Level Data for Bore ID: PZ 195C
Moolarben Groundwater Monitoring - Permian
Moolarben Coal Operations - UG4 Groundwater Assessment Report

Manual Dips
Anomalous Reading
Continuous Logger Data
Anomalous Logger Data

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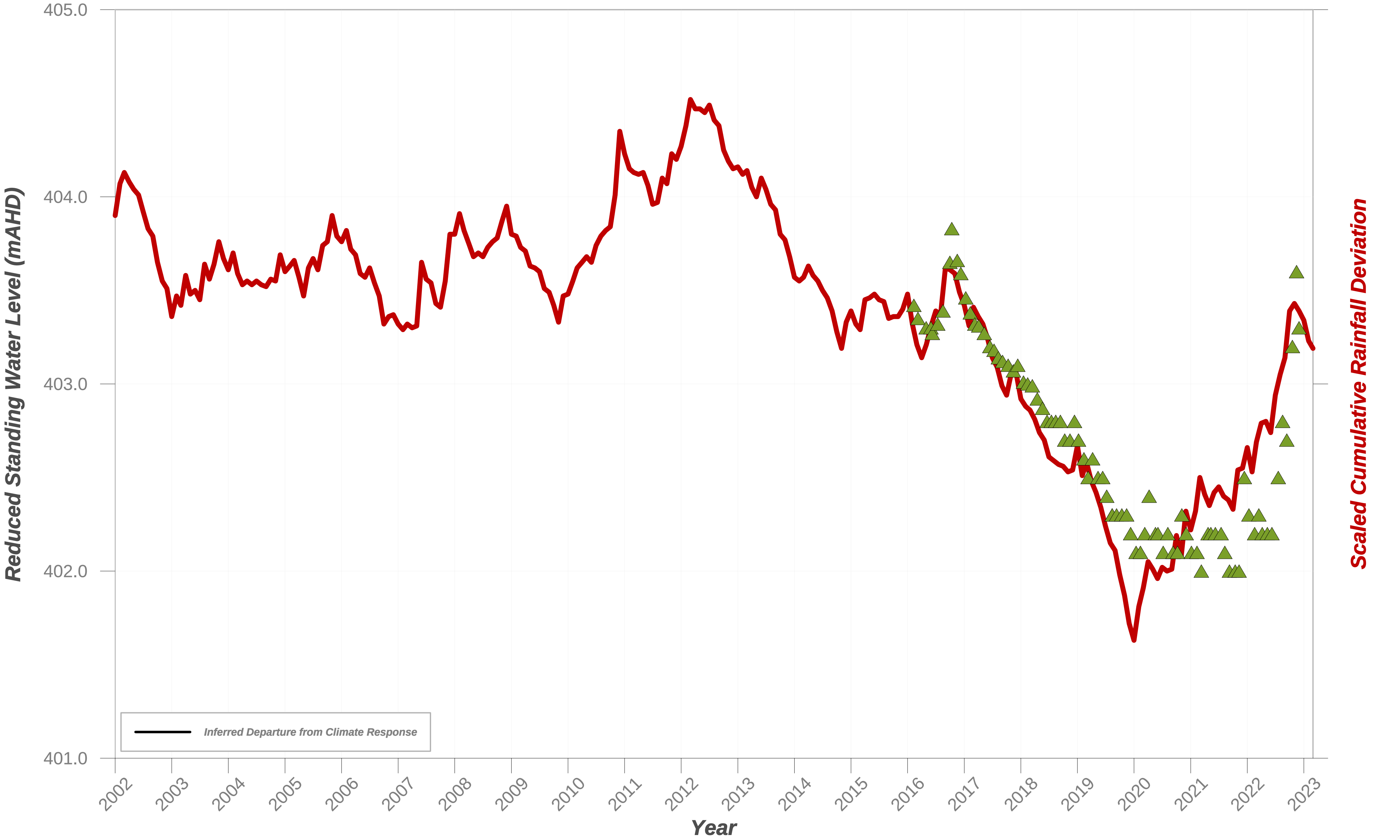
FIGURE No: **A.061**



Hydrograph of Groundwater Level Data for Bore ID: PZ 203
Moolarben Groundwater Monitoring - Tertiary Sediments / Paleochannel
Moolarben Coal Operations - UG4 Groundwater Assessment Report

Manual Dips
Anomalous Reading
Continuous Logger Data
Anomalous Logger Data

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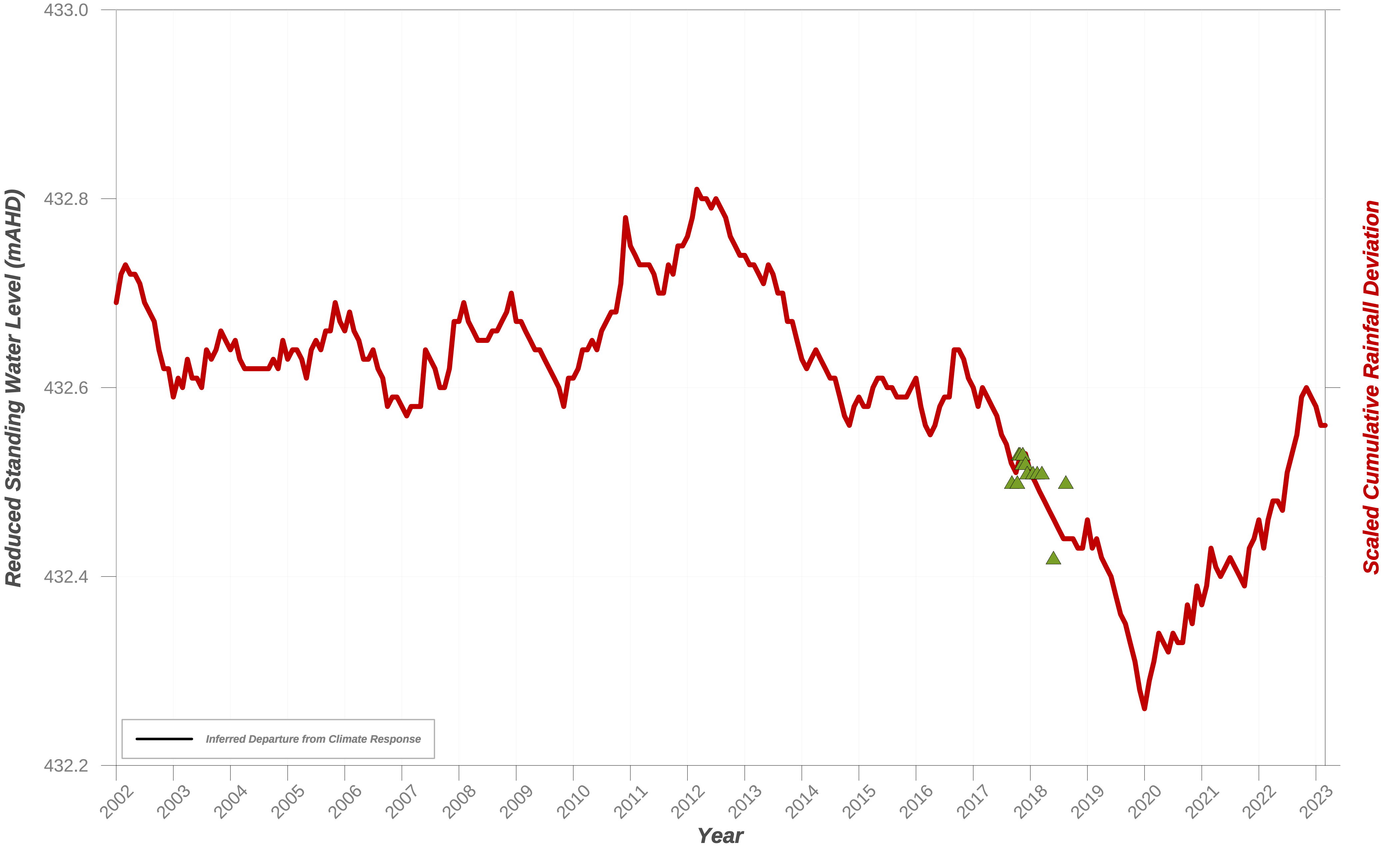
FIGURE No:
A.062



Hydrograph of Groundwater Level Data for Bore ID: PZ 211
Moolarben Groundwater Monitoring - Tertiary Sediments / Paleochannel
Moolarben Coal Operations - UG4 Groundwater Assessment Report

Manual Dips
Anomalous Reading
Continuous Logger Data
Anomalous Logger Data

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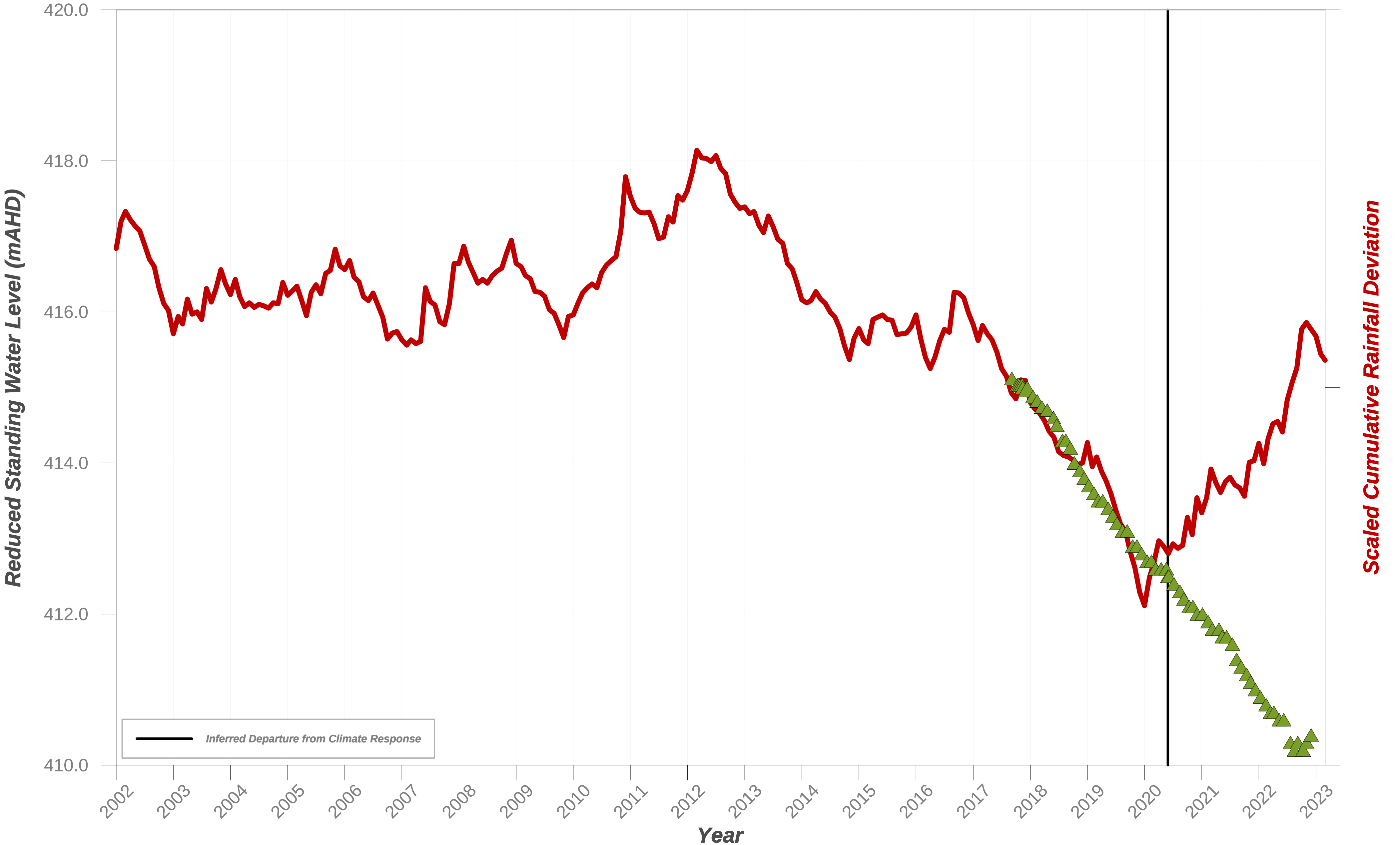
FIGURE No:
A.063



Hydrograph of Groundwater Level Data for Bore ID: PZ 213
Moolarben Groundwater Monitoring - Tertiary Sediments / Paleochannel
Moolarben Coal Operations - UG4 Groundwater Assessment Report

Manual Dips
Anomalous Reading
Continuous Logger Data
Anomalous Logger Data

AGE

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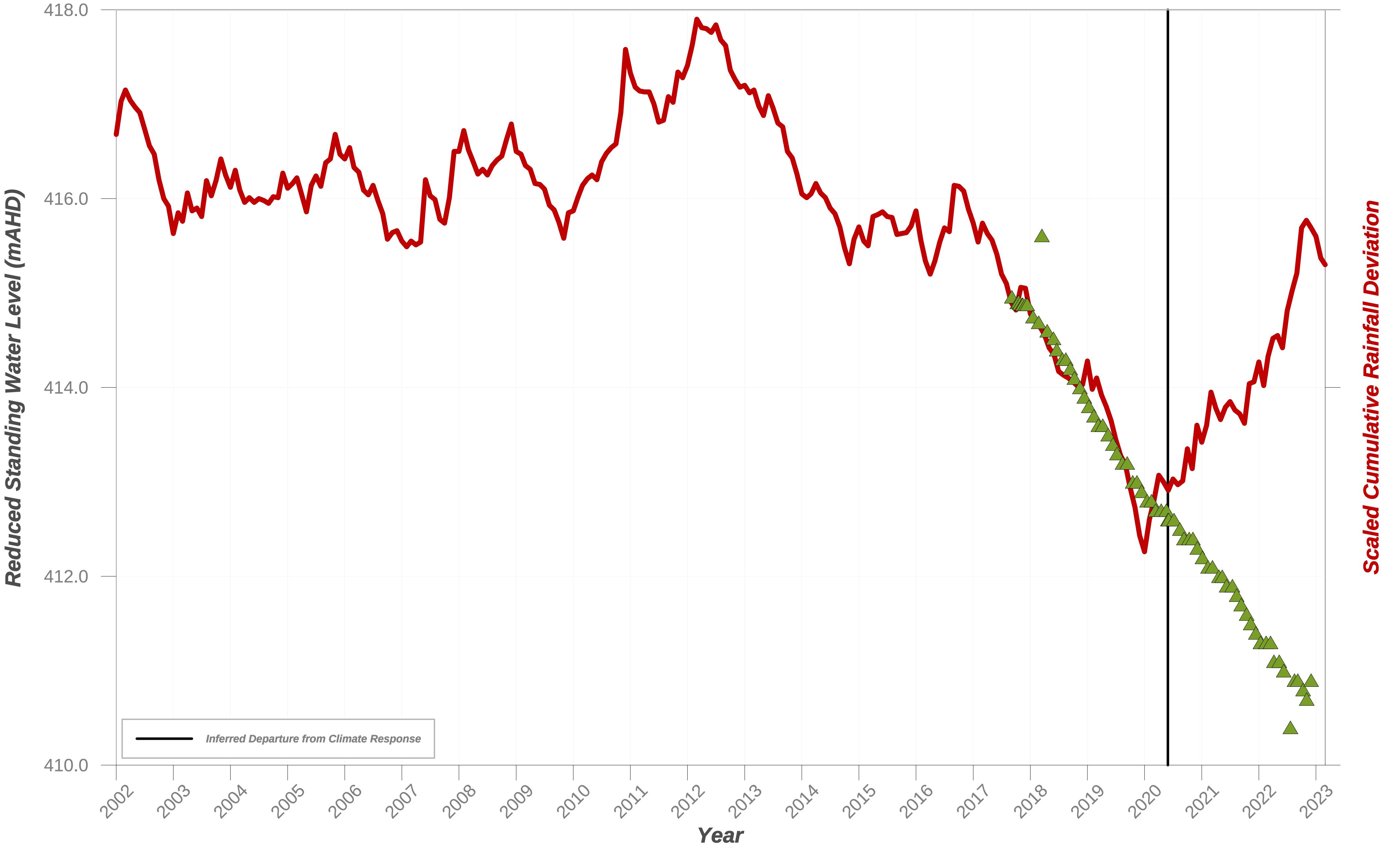
FIGURE No: **A.064**



Hydrograph of Groundwater Level Data for Bore ID: PZ 214
Moolarben Groundwater Monitoring - Tertiary Sediments / Paleochannel
Moolarben Coal Operations - UG4 Groundwater Assessment Report

Manual Dips
Anomalous Reading
Continuous Logger Data
Anomalous Logger Data

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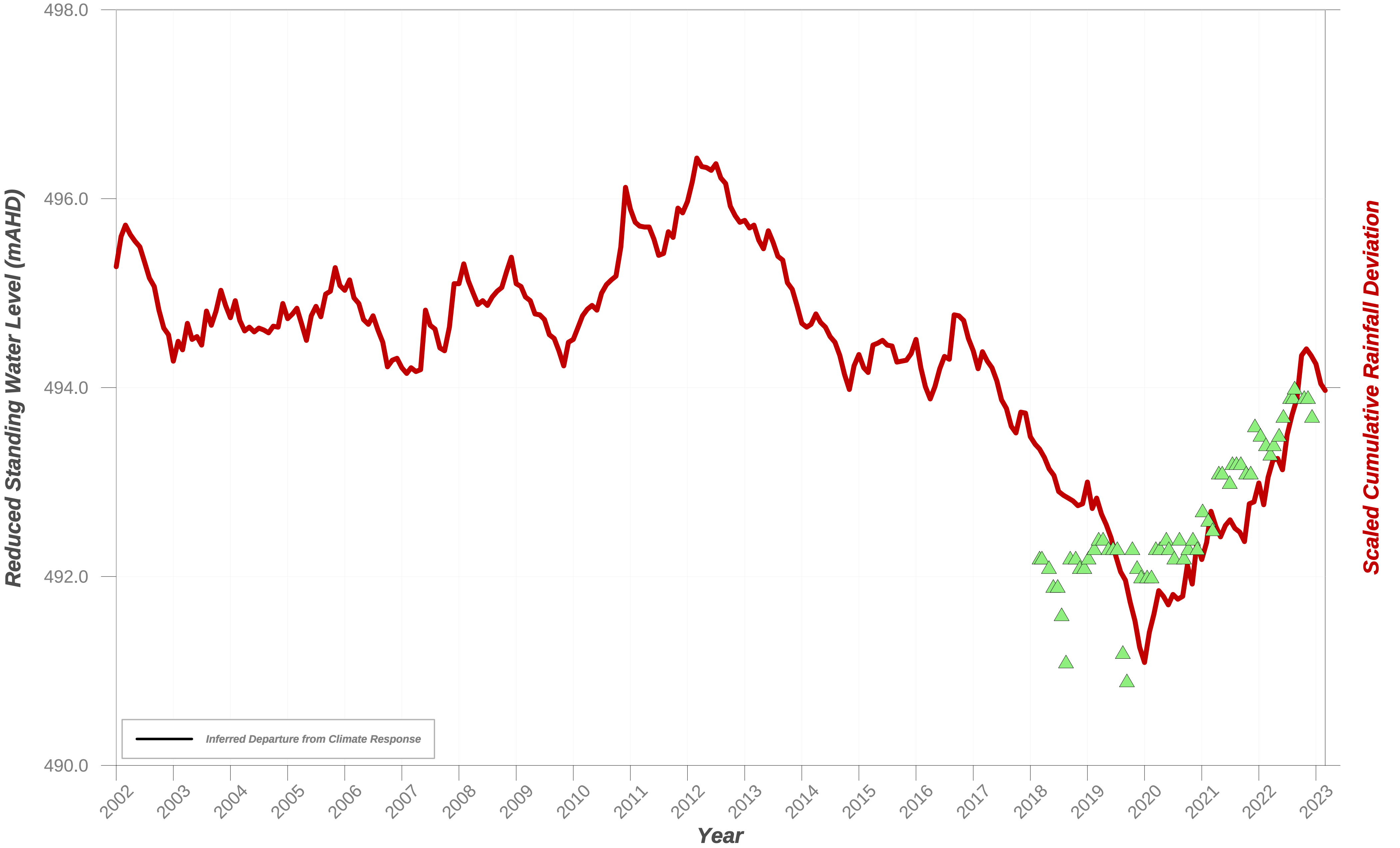
FIGURE No:
A.065



Hydrograph of Groundwater Level Data for Bore ID: PZ 217
Moolarben Groundwater Monitoring - Ulan Seam
Moolarben Coal Operations - UG4 Groundwater Assessment Report

Manual Dips
Anomalous Reading
Continuous Logger Data
Anomalous Logger Data

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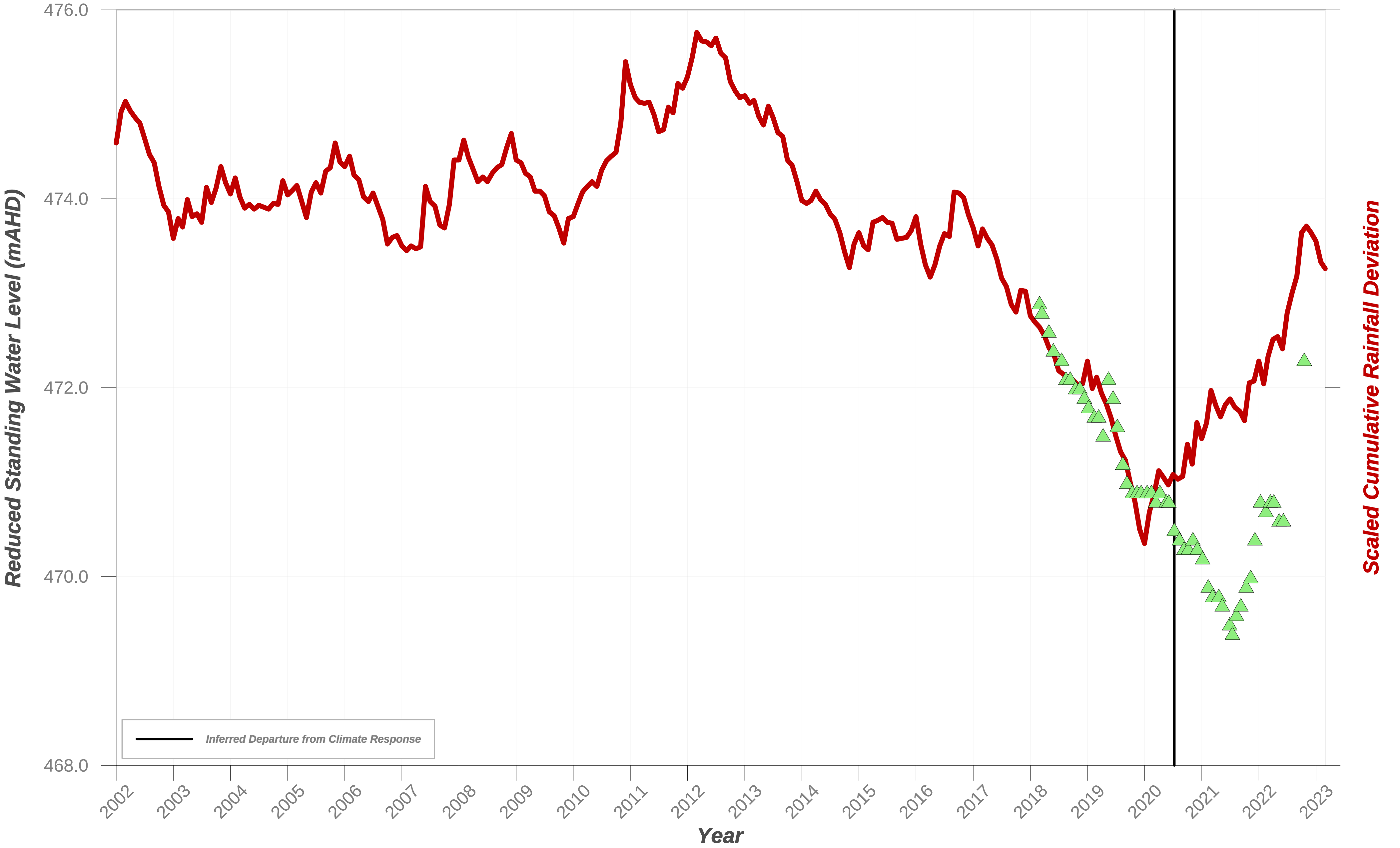
FIGURE No: **A.066**



Hydrograph of Groundwater Level Data for Bore ID: PZ 221
Moolarben Groundwater Monitoring - Ulan Seam
Moolarben Coal Operations - UG4 Groundwater Assessment Report

Manual Dips
Anomalous Reading
Continuous Logger Data
Anomalous Logger Data

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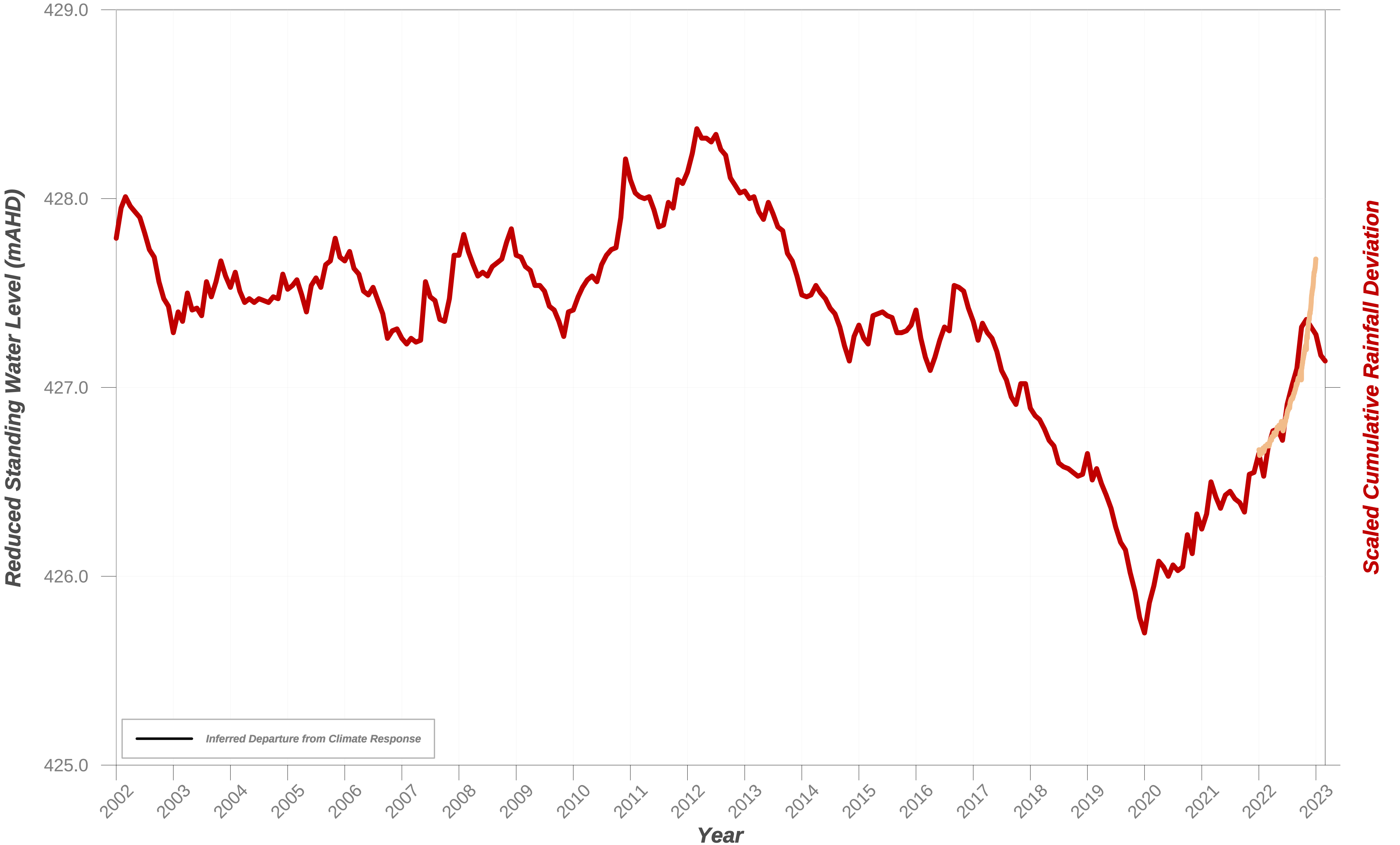
FIGURE No:
A.067



Hydrograph of Groundwater Level Data for Bore ID: PZ 229 VWP 84m
Moolarben Groundwater Monitoring - Jurassic
Moolarben Coal Operations - UG4 Groundwater Assessment Report

Manual Dips
Anomalous Reading
Continuous Logger Data
Anomalous Logger Data

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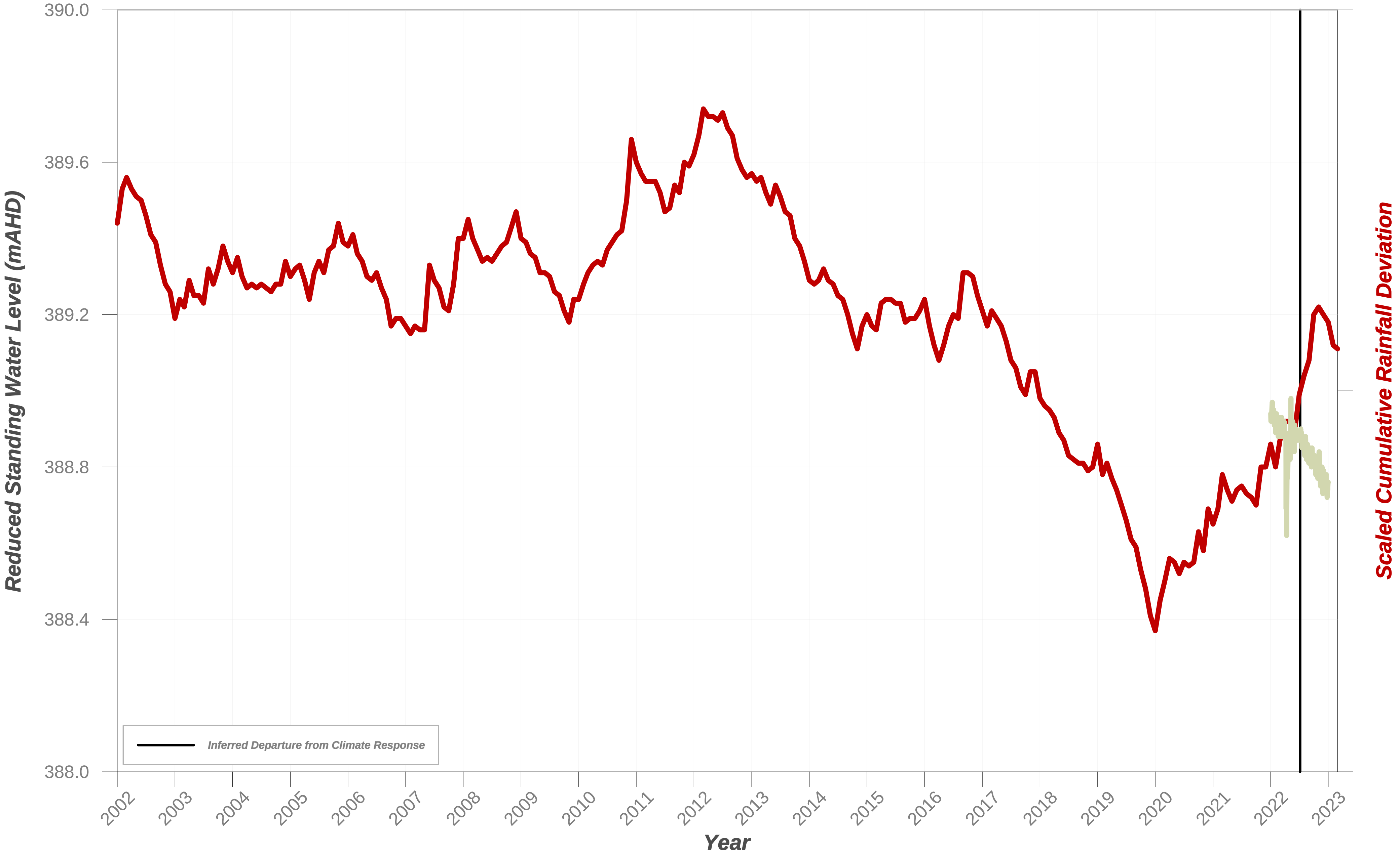
FIGURE No:
A.068



Hydrograph of Groundwater Level Data for Bore ID: PZ 229 VWP 140m
Moolarben Groundwater Monitoring - Triassic
Moolarben Coal Operations - UG4 Groundwater Assessment Report

Manual Dips
Anomalous Reading
Continuous Logger Data
Anomalous Logger Data

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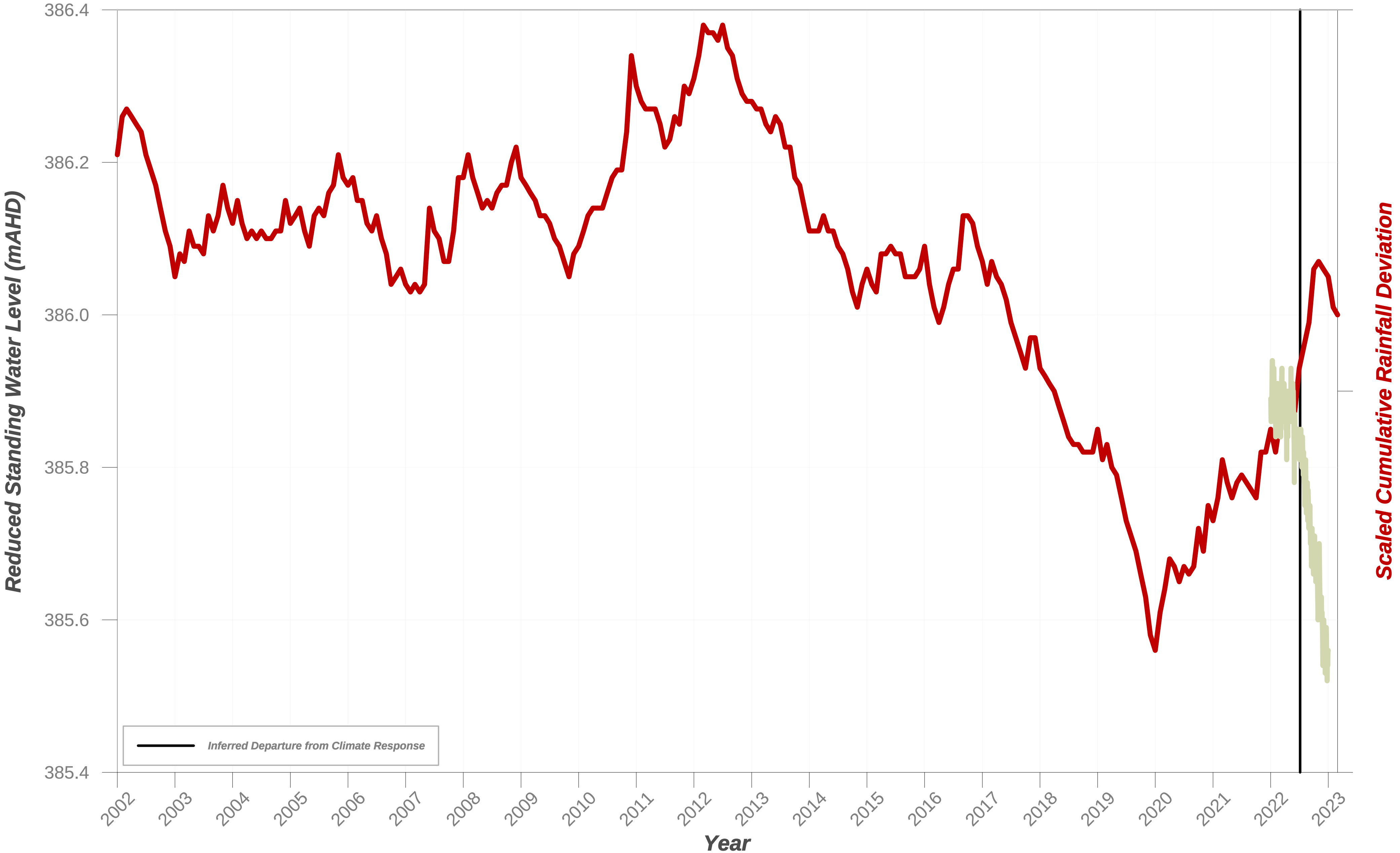
FIGURE No:
A.069



Hydrograph of Groundwater Level Data for Bore ID: PZ 229 VWP 198m
Moolarben Groundwater Monitoring - Triassic
Moolarben Coal Operations - UG4 Groundwater Assessment Report

Manual Dips
Anomalous Reading
Continuous Logger Data
Anomalous Logger Data

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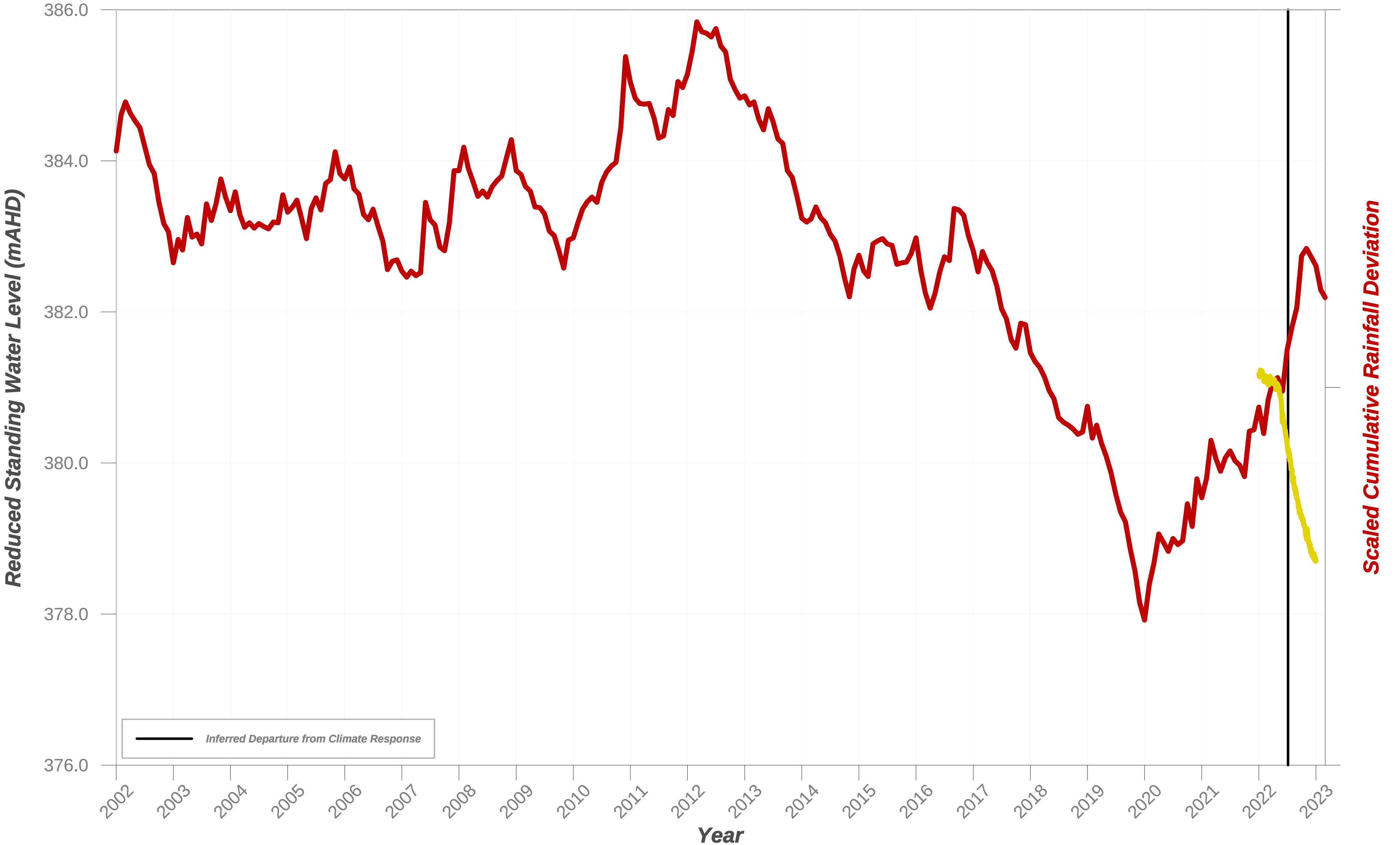
FIGURE No:
A.070



Hydrograph of Groundwater Level Data for Bore ID: PZ 229 VWP 253m
Moolarben Groundwater Monitoring - Permian
Moolarben Coal Operations - UG4 Groundwater Assessment Report

Manual Dips
Anomalous Reading
Continuous Logger Data
Anomalous Logger Data

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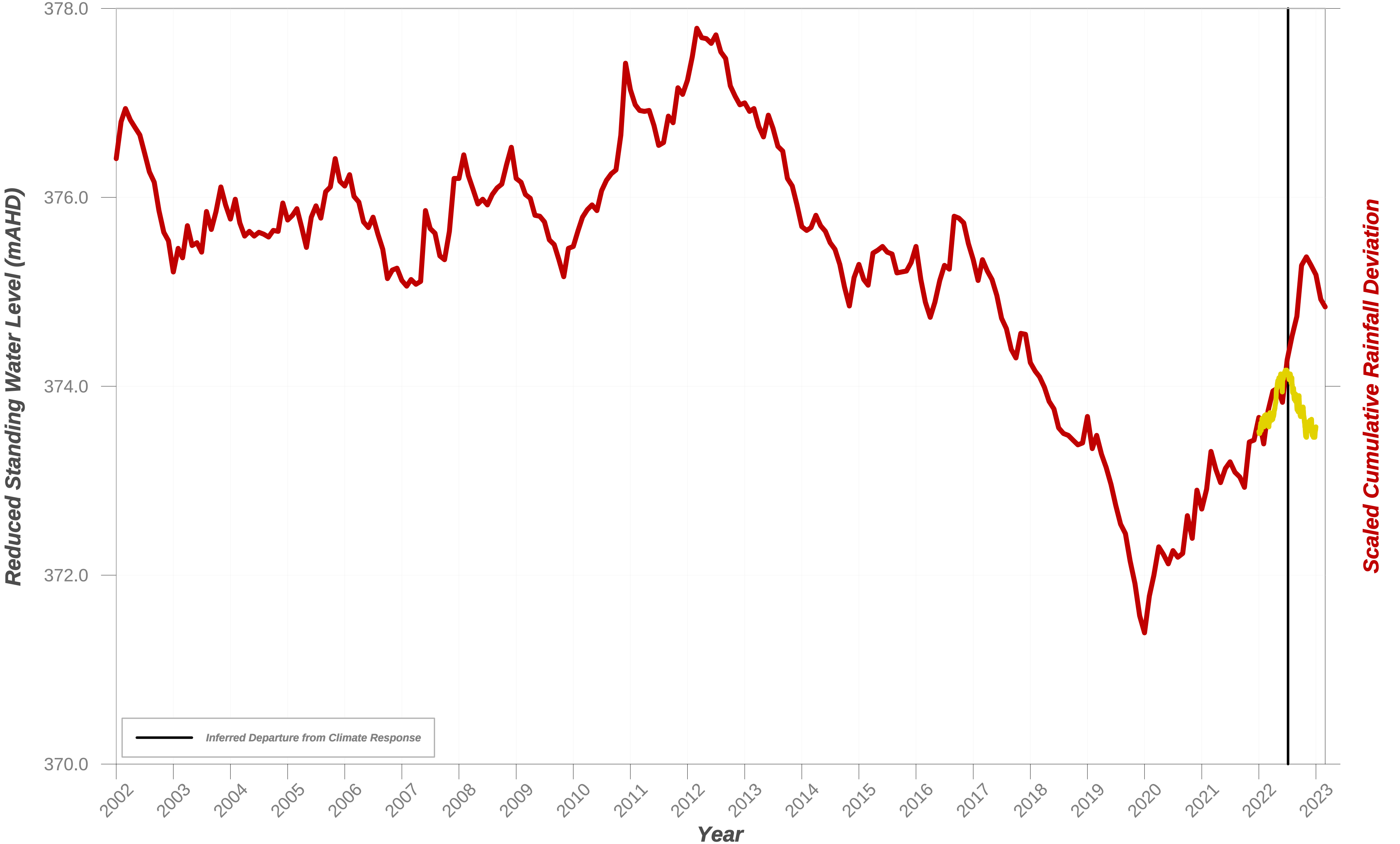
FIGURE No:
A.071



Hydrograph of Groundwater Level Data for Bore ID: PZ 229 VWP 316m
Moolarben Groundwater Monitoring - Permian
Moolarben Coal Operations - UG4 Groundwater Assessment Report

Manual Dips
Anomalous Reading
Continuous Logger Data
Anomalous Logger Data

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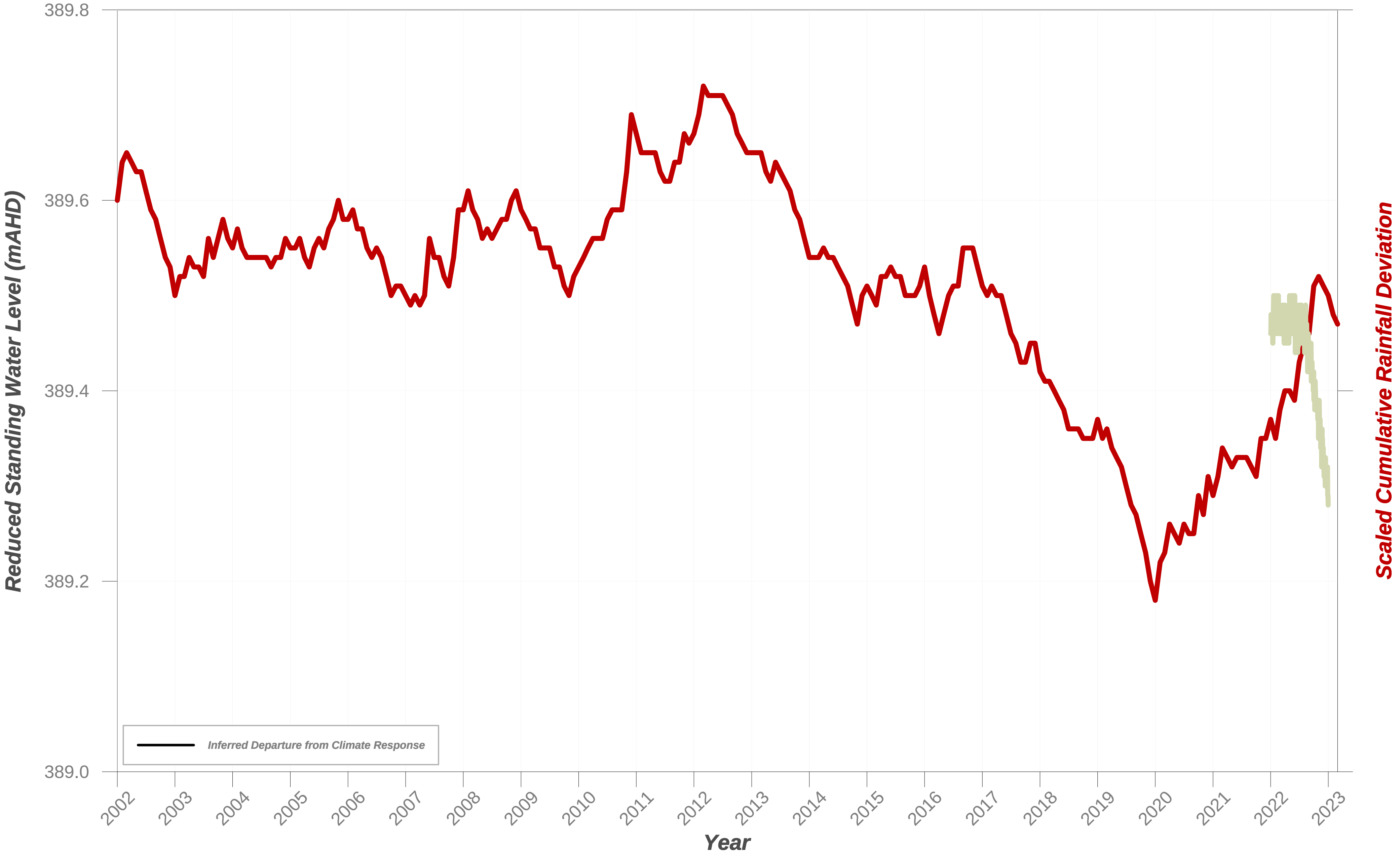
FIGURE No:
A.072



Hydrograph of Groundwater Level Data for Bore ID: PZ 230 VWP 50m
Moolarben Groundwater Monitoring - Triassic
Moolarben Coal Operations - UG4 Groundwater Assessment Report

Manual Dips
Anomalous Reading
Continuous Logger Data
Anomalous Logger Data

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FIGURE No:
A.073

Hydrograph of Groundwater Level Data for Bore ID: PZ 230 VWP 100m
Moolarben Groundwater Monitoring - Triassic
Moolarben Coal Operations - UG4 Groundwater Assessment Report

Manual Dips
Anomalous Reading
Continuous Logger Data
Anomalous Logger Data

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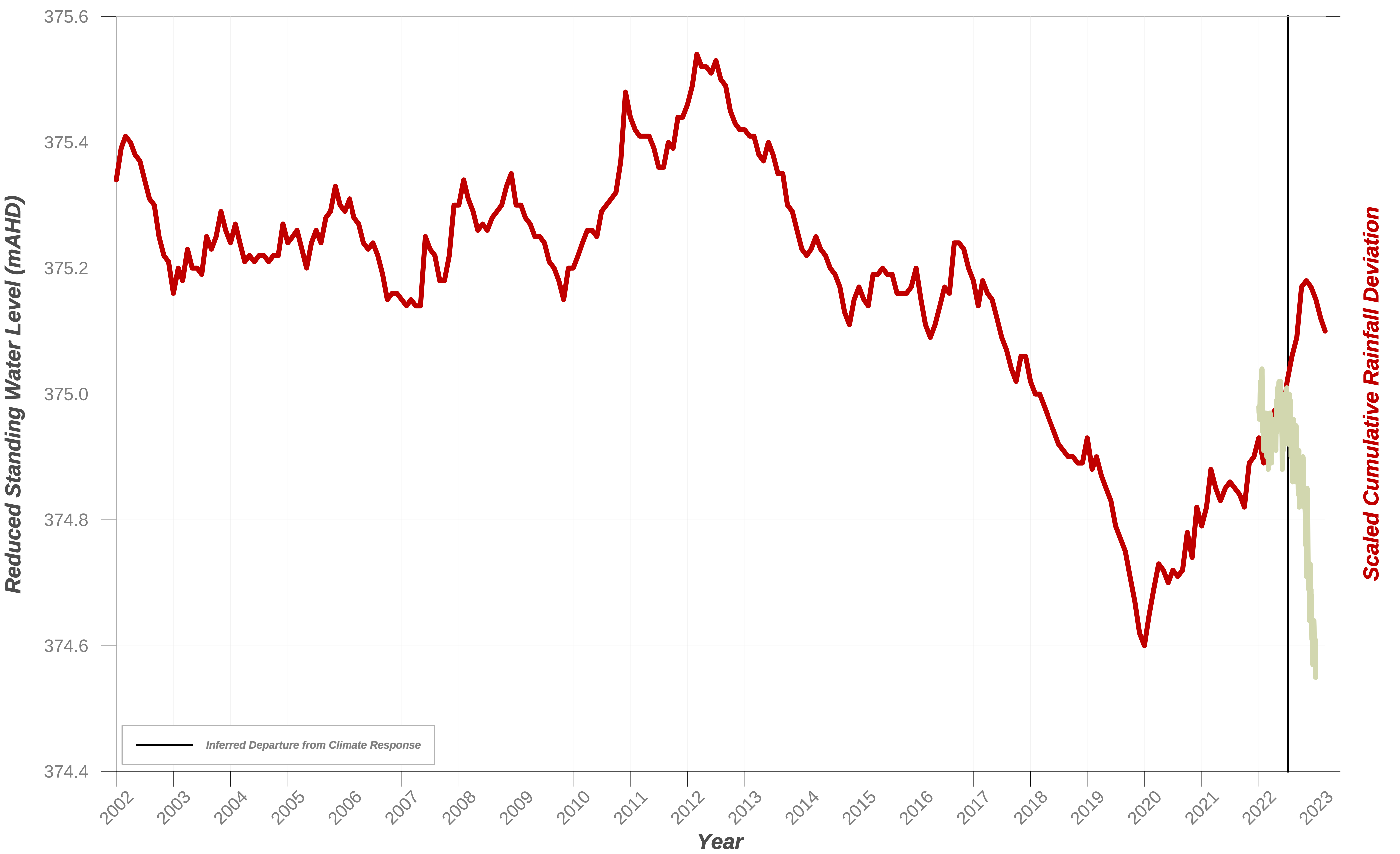
FIGURE No:
A.074



Hydrograph of Groundwater Level Data for Bore ID: PZ 230 VWP 130m
Moolarben Groundwater Monitoring - Triassic
Moolarben Coal Operations - UG4 Groundwater Assessment Report

Manual Dips
Anomalous Reading
Continuous Logger Data
Anomalous Logger Data

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FIGURE No:
A.075

Hydrograph of Groundwater Level Data for Bore ID: PZ 230 VWP 187m
Moolarben Groundwater Monitoring - Permian
Moolarben Coal Operations - UG4 Groundwater Assessment Report

Manual Dips
Anomalous Reading
Continuous Logger Data
Anomalous Logger Data

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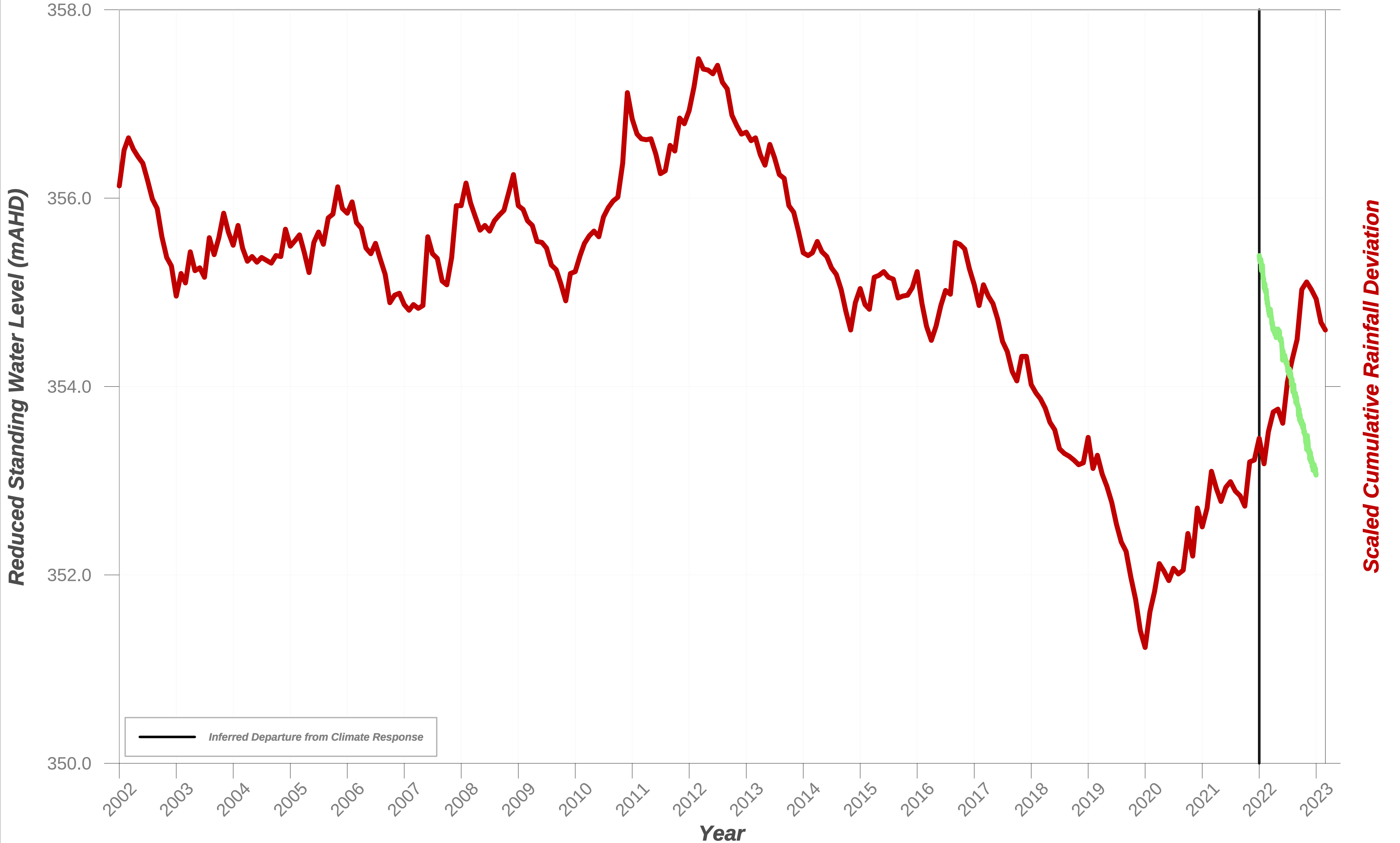
FIGURE No:
A.076



Hydrograph of Groundwater Level Data for Bore ID: PZ 230 VWP 238m
Moolarben Groundwater Monitoring - Ulan Seam
Moolarben Coal Operations - UG4 Groundwater Assessment Report

Manual Dips
Anomalous Reading
Continuous Logger Data
Anomalous Logger Data

AGE

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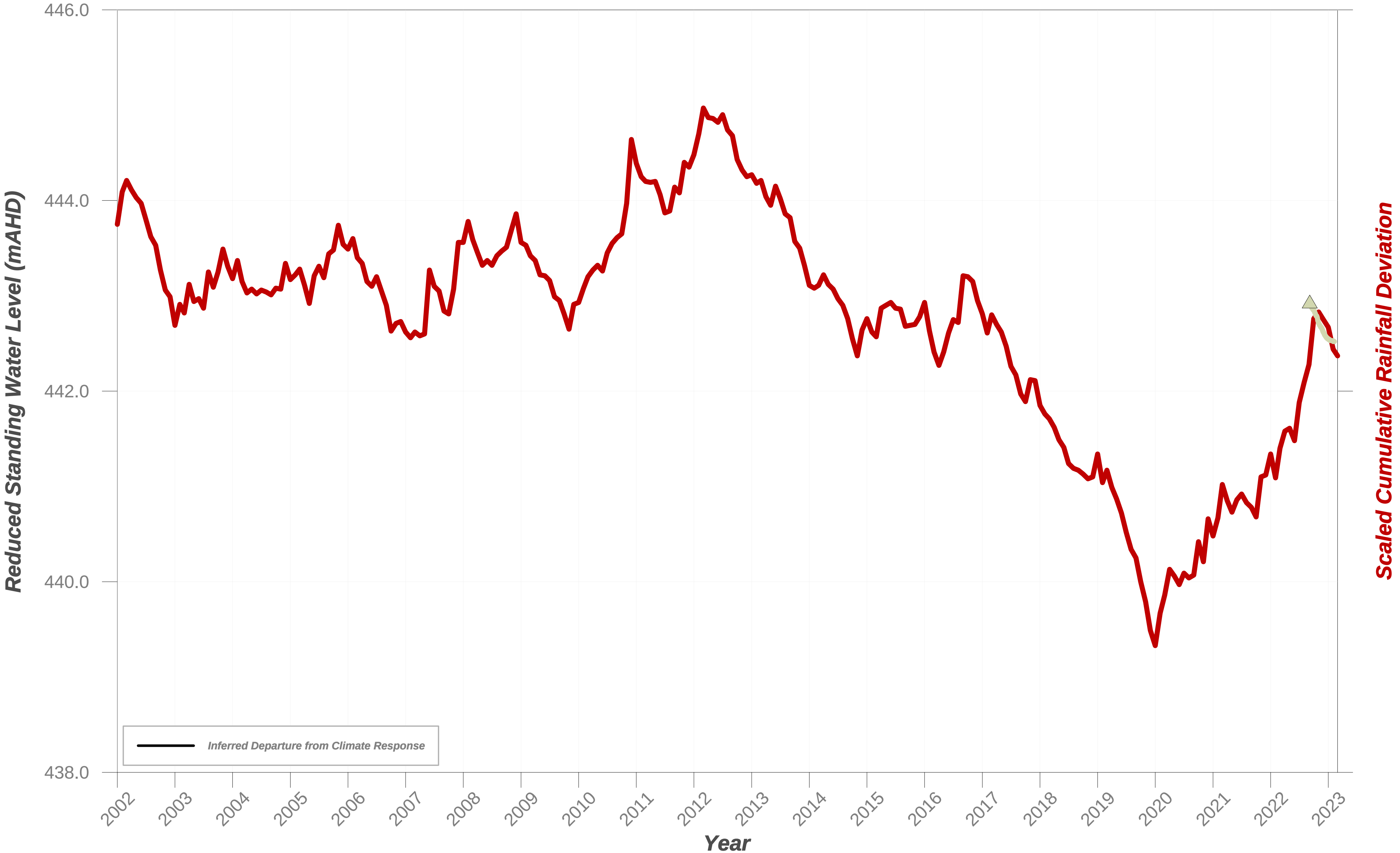
FIGURE No:
A.077



Hydrograph of Groundwater Level Data for Bore ID: PZ 232 VWP 45m
Moolarben Groundwater Monitoring - Triassic
Moolarben Coal Operations - UG4 Groundwater Assessment Report

Manual Dips
Anomalous Reading
Continuous Logger Data
Anomalous Logger Data

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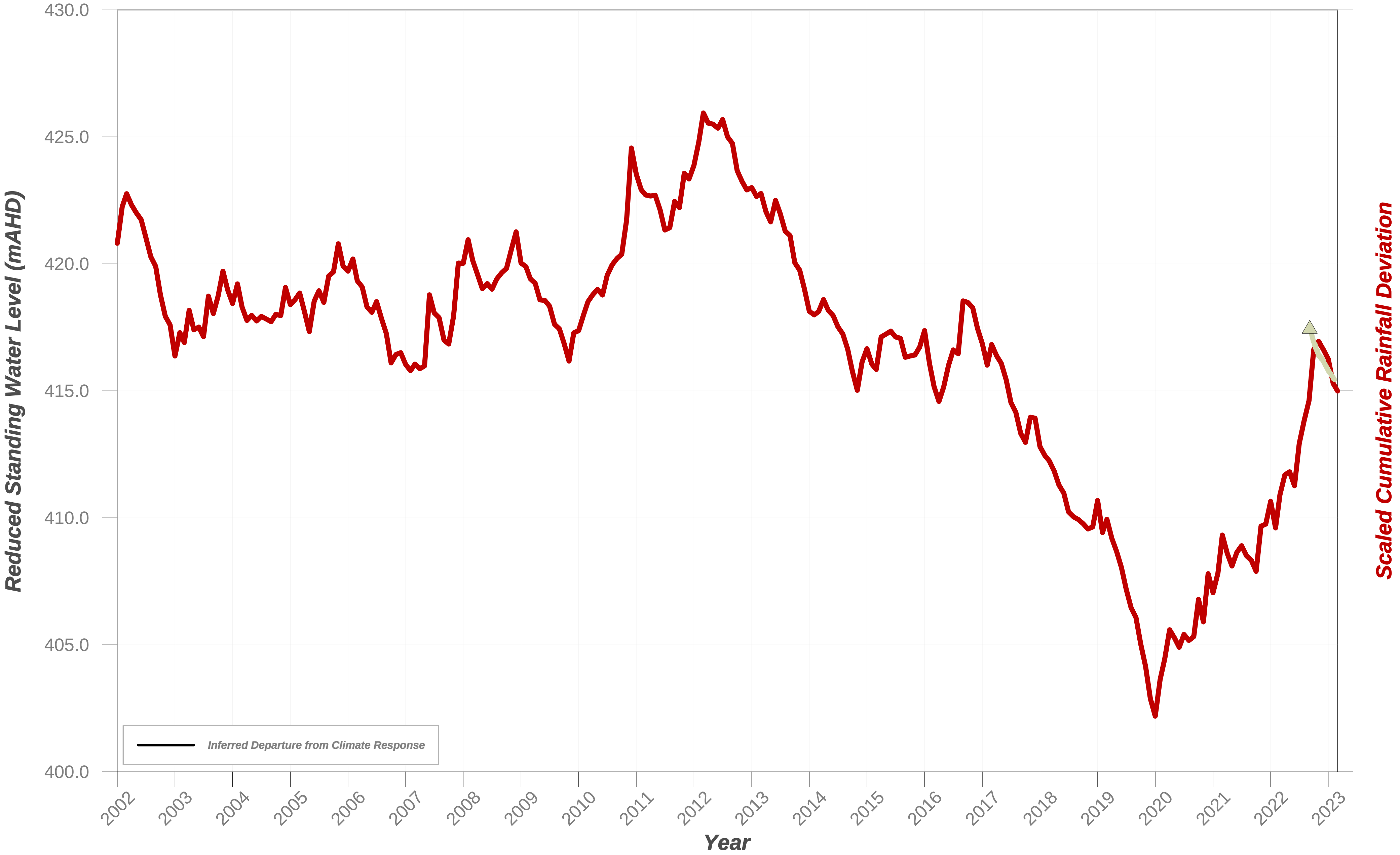
FIGURE No: **A.078**



Hydrograph of Groundwater Level Data for Bore ID: PZ 232 VWP 75m
Moolarben Groundwater Monitoring - Triassic
Moolarben Coal Operations - UG4 Groundwater Assessment Report

Manual Dips
Anomalous Reading
Continuous Logger Data
Anomalous Logger Data

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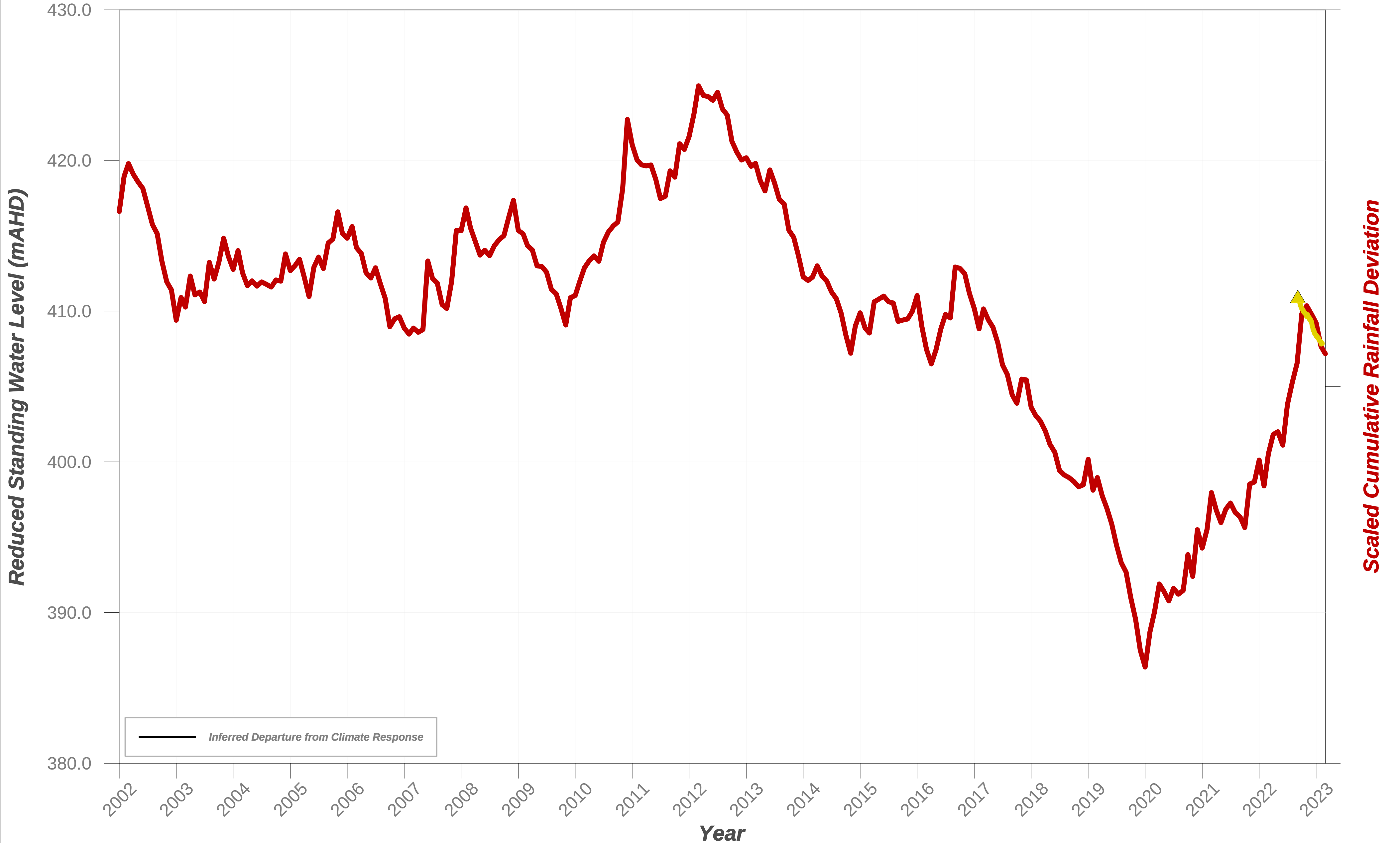
FIGURE No:
A.079



Hydrograph of Groundwater Level Data for Bore ID: PZ 232 VWP 96m
Moolarben Groundwater Monitoring - Permian
Moolarben Coal Operations - UG4 Groundwater Assessment Report

Manual Dips
Anomalous Reading
Continuous Logger Data
Anomalous Logger Data

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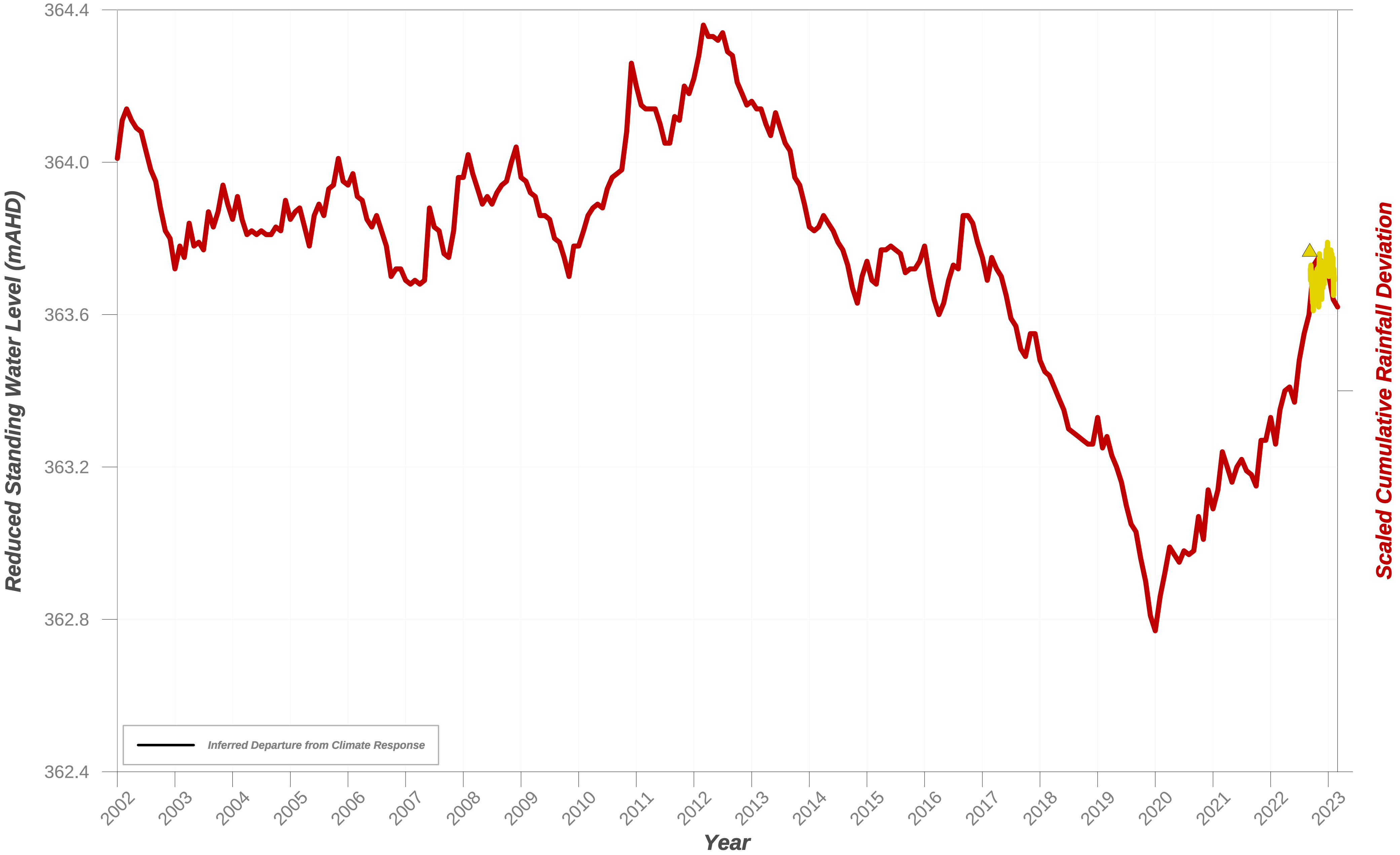
FIGURE No:
A.080



Hydrograph of Groundwater Level Data for Bore ID: PZ 232 VWP 132m
Moolarben Groundwater Monitoring - Permian
Moolarben Coal Operations - UG4 Groundwater Assessment Report

Manual Dips
Anomalous Reading
Continuous Logger Data
Anomalous Logger Data

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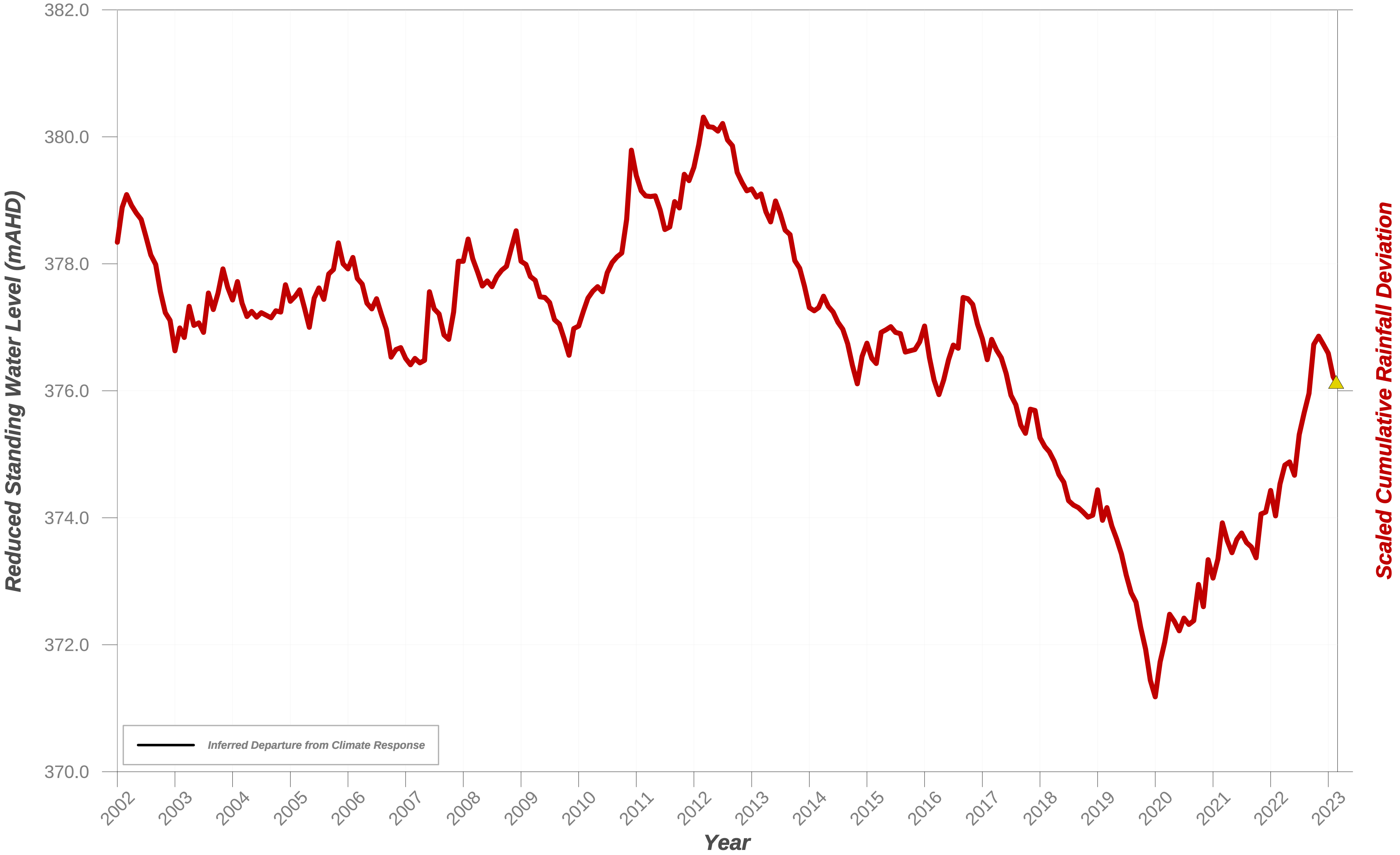
FIGURE No:
A.081



Hydrograph of Groundwater Level Data for Bore ID: PZ 235B VWP 68m
Moolarben Groundwater Monitoring - Permian
Moolarben Coal Operations - UG4 Groundwater Assessment Report

Manual Dips
Anomalous Reading
Continuous Logger Data
Anomalous Logger Data

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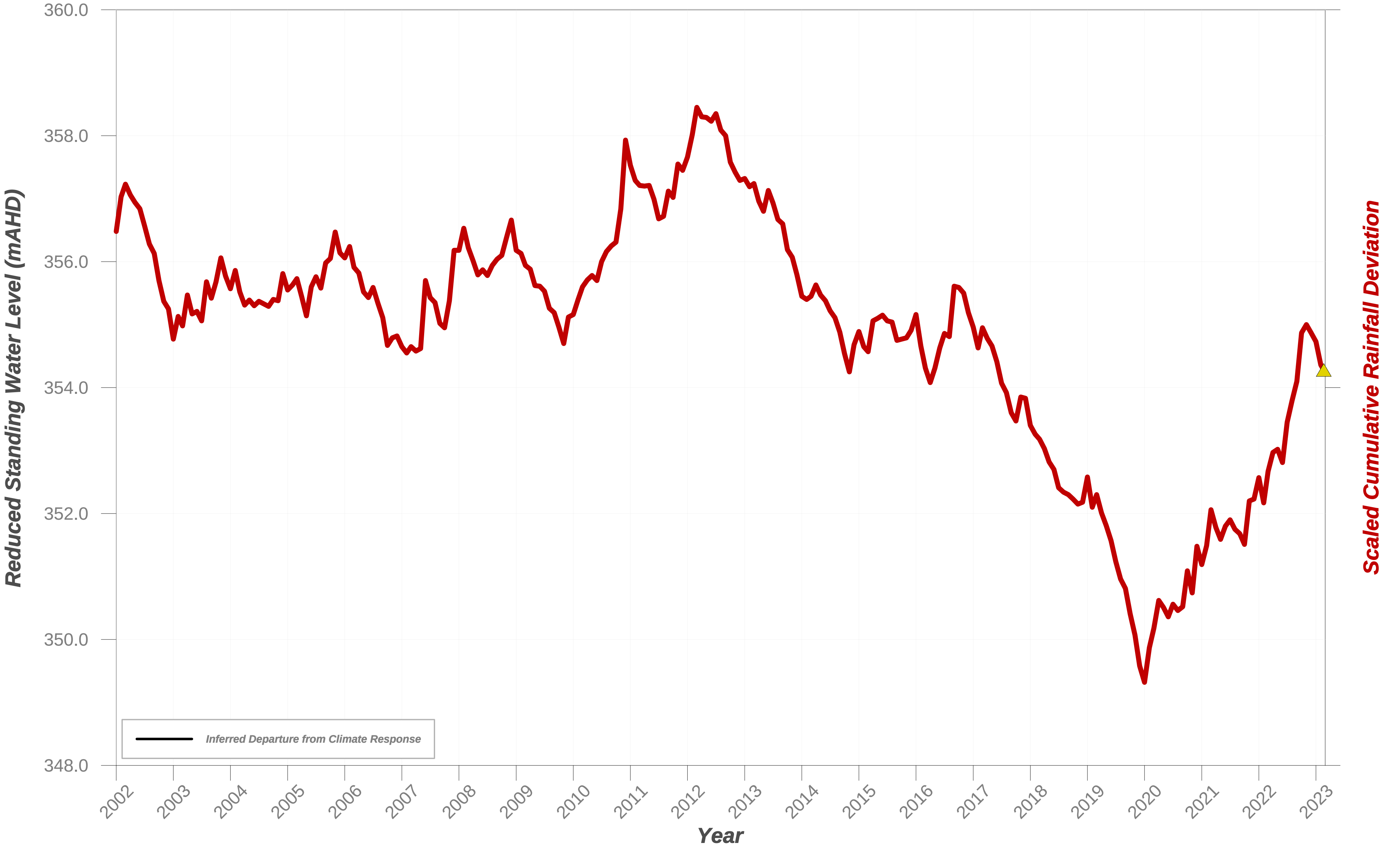
FIGURE No:
A.082



Hydrograph of Groundwater Level Data for Bore ID: PZ 235B VWP 96m
Moolarben Groundwater Monitoring - Permian
Moolarben Coal Operations - UG4 Groundwater Assessment Report

Manual Dips
Anomalous Reading
Continuous Logger Data
Anomalous Logger Data

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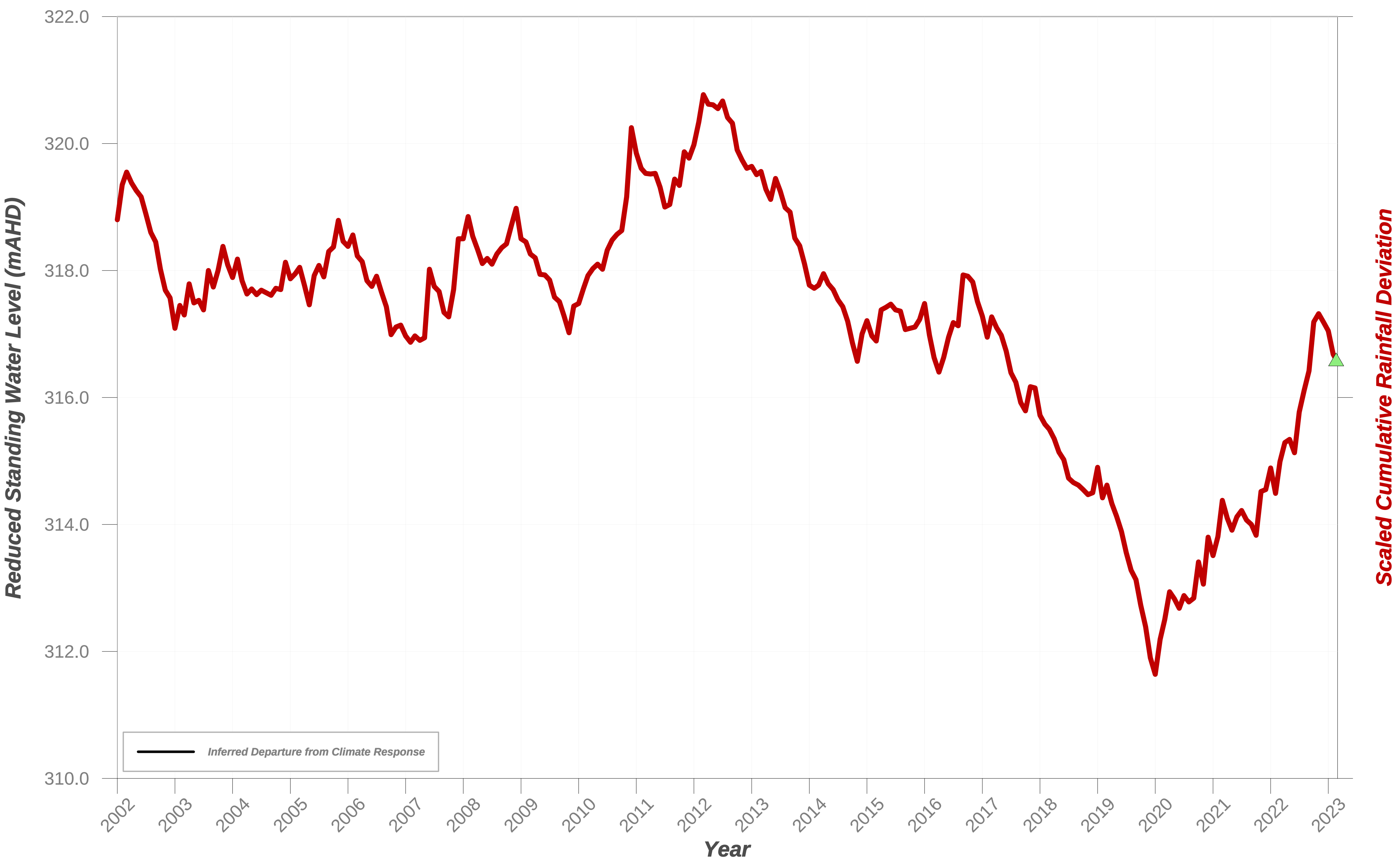
FIGURE No:
A.083



Hydrograph of Groundwater Level Data for Bore ID: PZ 235B VWP 147m
Moolarben Groundwater Monitoring - Ulan Seam
Moolarben Coal Operations - UG4 Groundwater Assessment Report

Manual Dips
Anomalous Reading
Continuous Logger Data
Anomalous Logger Data

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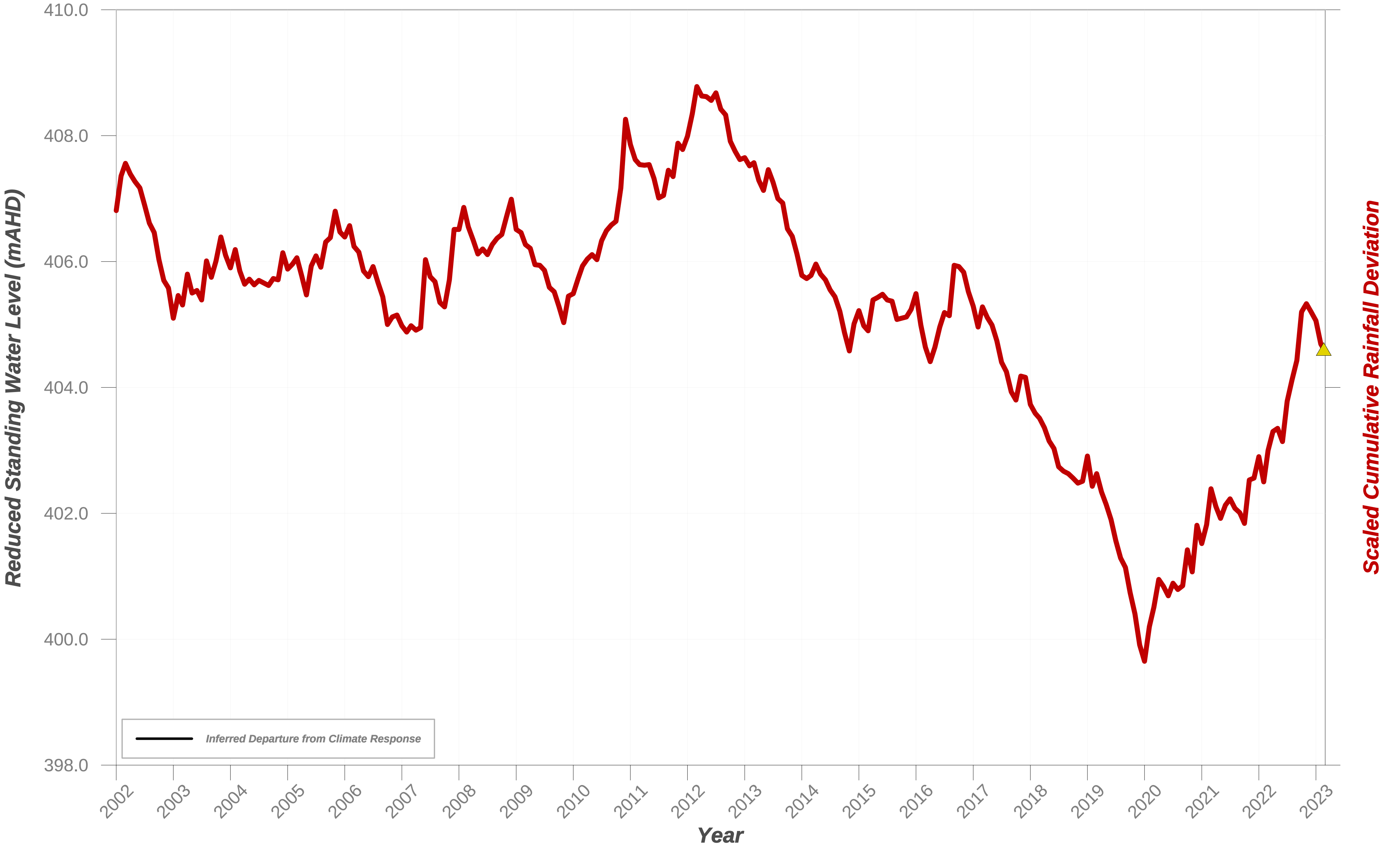
FIGURE No:
A.084



Hydrograph of Groundwater Level Data for Bore ID: PZ 238 VWP 11m
Moolarben Groundwater Monitoring - Permian
Moolarben Coal Operations - UG4 Groundwater Assessment Report

Manual Dips
Anomalous Reading
Continuous Logger Data
Anomalous Logger Data

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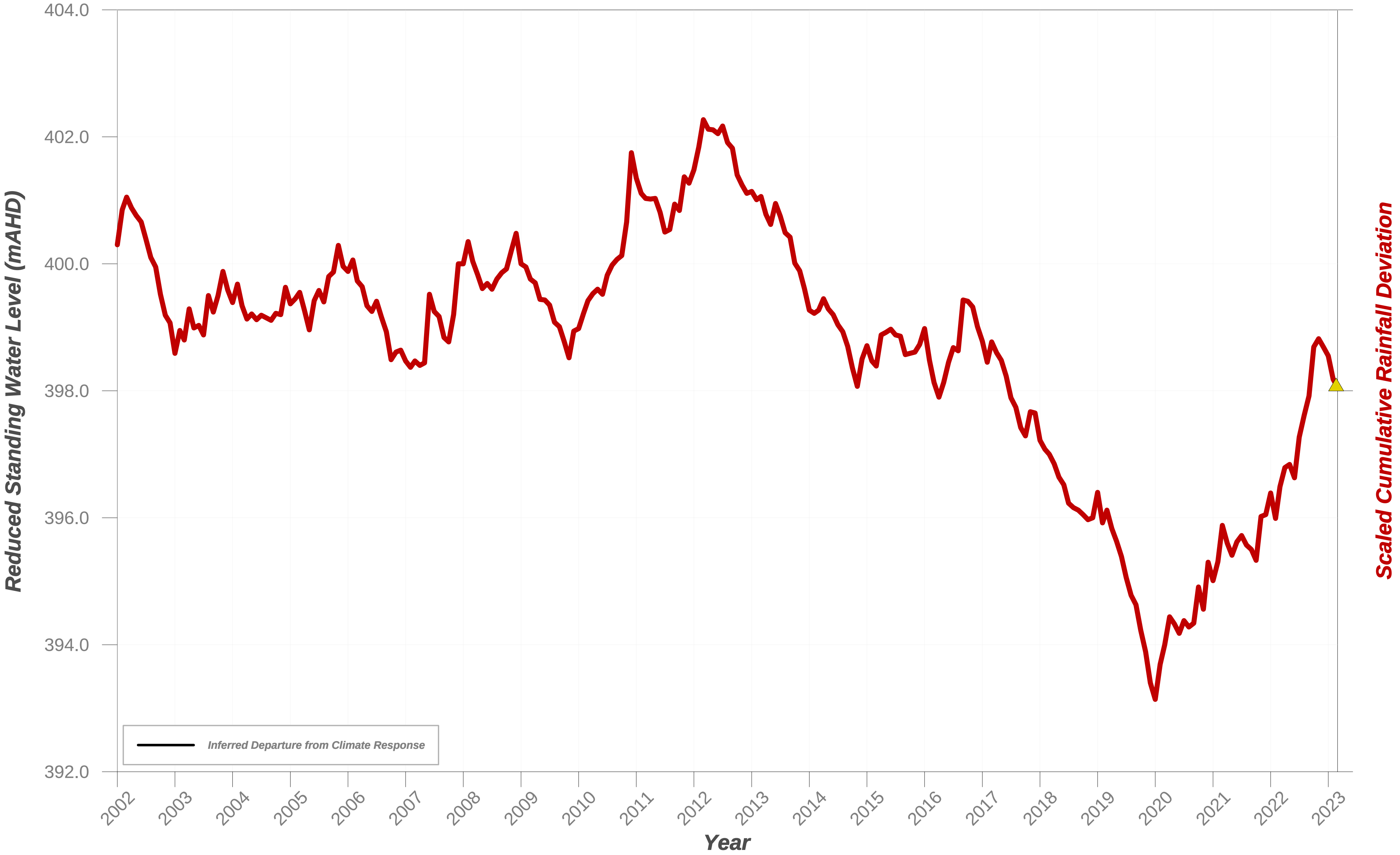
FIGURE No:
A.085



Hydrograph of Groundwater Level Data for Bore ID: PZ 238 VWP 25m
Moolarben Groundwater Monitoring - Permian
Moolarben Coal Operations - UG4 Groundwater Assessment Report

Manual Dips
Anomalous Reading
Continuous Logger Data
Anomalous Logger Data

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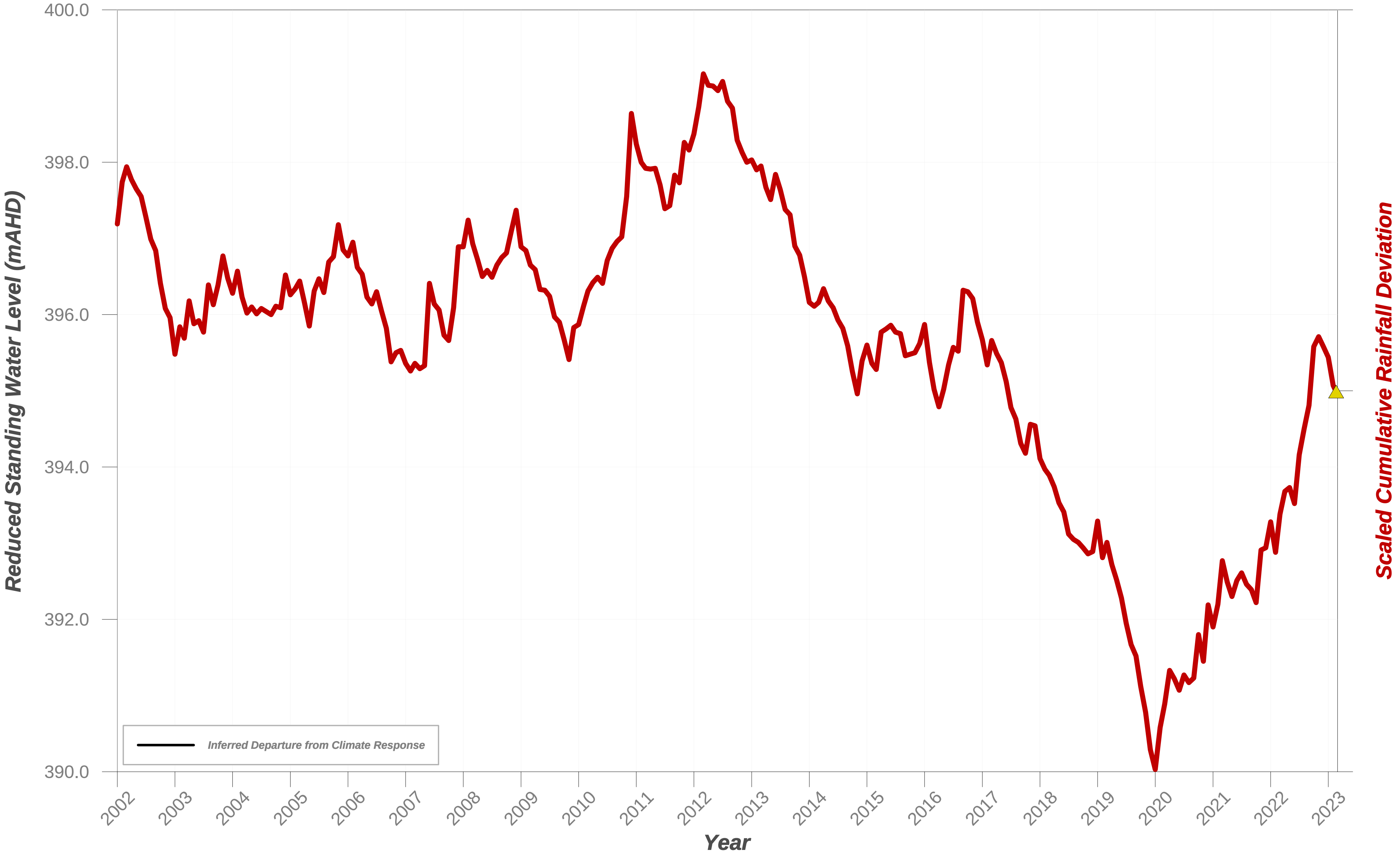
FIGURE No:
A.086



Hydrograph of Groundwater Level Data for Bore ID: PZ 238 VWP 50m
Moolarben Groundwater Monitoring - Permian
Moolarben Coal Operations - UG4 Groundwater Assessment Report

Manual Dips
Anomalous Reading
Continuous Logger Data
Anomalous Logger Data

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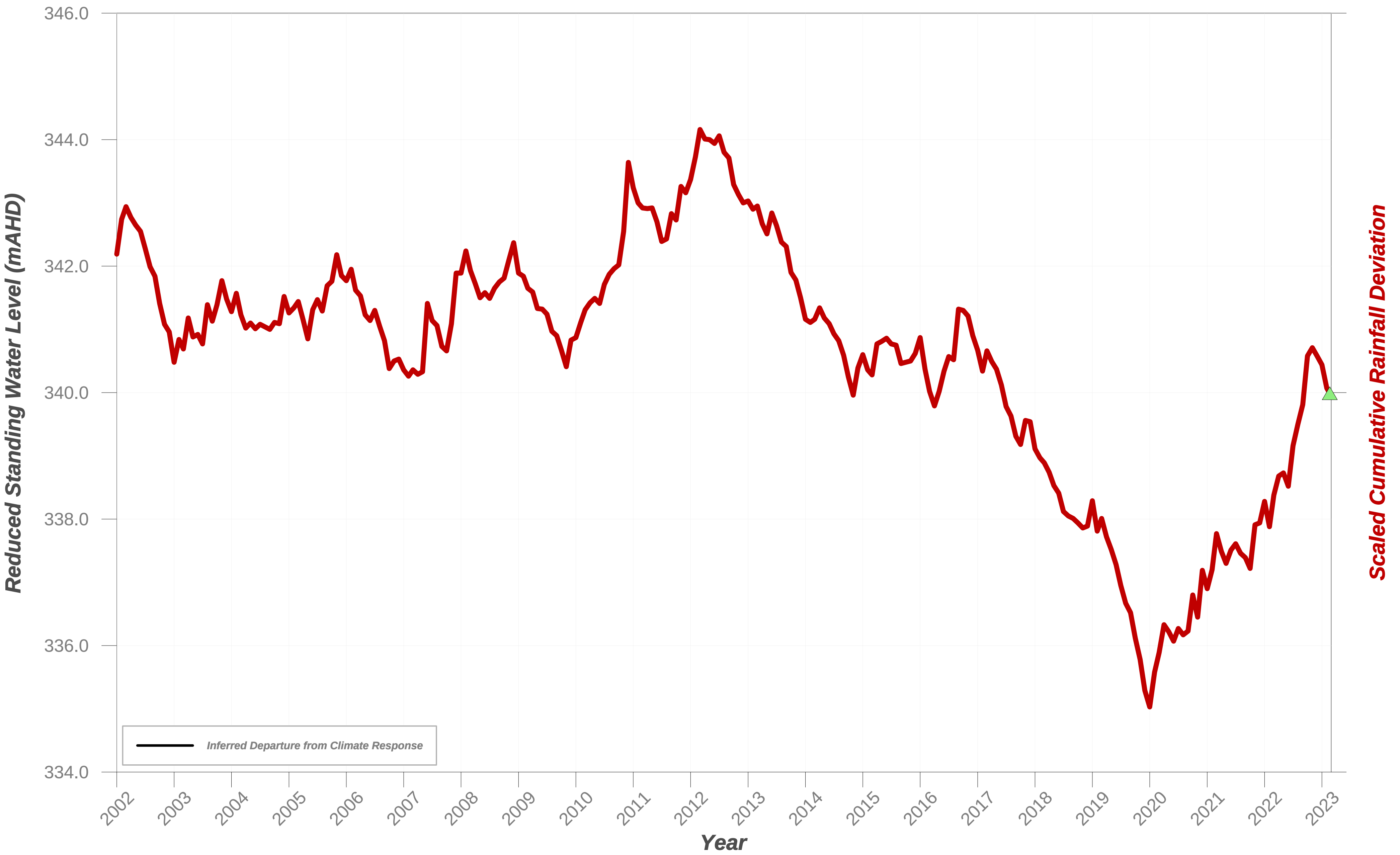
FIGURE No: **A.087**



Hydrograph of Groundwater Level Data for Bore ID: PZ 238 VWP 82m
Moolarben Groundwater Monitoring - Ulan Seam
Moolarben Coal Operations - UG4 Groundwater Assessment Report

Manual Dips
Anomalous Reading
Continuous Logger Data
Anomalous Logger Data

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FIGURE No:
A.088