Tahmoor Coal LW W1-W2 Extraction Plan:

Groundwater Technical Report

FOR
Tahmoor Coal Pty Ltd

PREPARED BY

NPM Technical Pty Ltd
trading as HydroSimulations, and
SLR Consulting Australia Pty Ltd company.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ATTACHMENTS

1 INTRODUCTION

The Tahmoor Coal Mine (Tahmoor Mine) is an underground coal mine located approximately 80 kilometres (km) south-west of Sydney between the towns of Tahmoor and Bargo, New South Wales (NSW) (refer to **Figure 1-1**). Tahmoor Mine produces up to three million tonnes of Run of Mine (ROM) coal per annum from the Bulli Coal Seam. Tahmoor Mine produces a primary hard coking coal product and a secondary higher ash coking coal product that are used predominantly for coke manufacture for steel production. Product coal is transported via rail to Port Kembla and Newcastle for Australian domestic customers and export customers.

The Tahmoor Mine has been operated by Tahmoor Coal Pty Ltd (Tahmoor Coal) since Tahmoor Mine commenced in 1979 using bord and pillar mining methods, and via longwall mining methods since 1987. Tahmoor Coal, trading as Tahmoor Coking Coal Operations (TCCO), is a subsidiary within the SIMEC Mining Division (SIMEC) of the GFG Alliance (GFG).

Tahmoor Coal has previously mined 32 longwalls to the north and west of the Tahmoor Mine's current pit top location (refer to **Figure 1-2**). Tahmoor Coal has recently completed mining of Longwall 32 in accordance with Development Consents and Subsidence Management Plan Approval.

Tahmoor Coal proposes to extend underground coal mining to the north of the existing mined area. This new area is referred to as the 'Western Domain' refer to **Figure 1-2** which will include Longwalls West 1 (LW W1) to West 4 (LW W4) at Picton and Thirlmere. The first two longwalls to be mined are LW W1 and Longwall West 2 (LW W2) (collectively referred to as LW W1-W2), which will be the focus of this Extraction Plan. Longwalls W3 and W4 are shown on the mine plan but are not considered further in this report. They will be considered in future management plans and assessments.

The proposed LW W1-W2 are located within Mining Lease (ML) 1376 and ML 1539 (refer to **Figure 1-2**).

This report comprises the groundwater technical report and will support the Extraction Plan developed for LW W1-W2. It exists to ensure that compliance is achieved with relevant internal and external regulatory requirements related to groundwater management at LW W1-W2. This report will present an analysis of the available baseline data for the proposed monitoring bores, results from numerical groundwater model, and outline trigger ranges to aid in the identification of adverse mining-related impacts to the groundwater system.

1.1 EXTRACTION PLAN STUDY AREA

Tahmoor Mine has been in operation since 1979, with 32 longwalls extracted to date. Extraction at LW W1 began in November 2019 and W2 is anticipated to begin in August 2020.

Proposed LW W1-W2 are oriented north to south, with W1 being slightly longer than W2 **(Figure 1-2**). Both have a maximum extraction height of approximately 2.1 metres (m) and are 283 m wide. **Table 1-1** details the extraction parameters for mined and proposed longwalls within the Tahmoor North mining area.

Table 1-1 Historical and Proposed Longwall Dates and Dimensions

LONG WALL	DATE START	DATE END	VOID WIDTH (m)	LW LENGTH (m)	ELEVATION OF BUSM (mAHD)	GROUND ELEVATION (mAHD)	CUTTING HEIGHT (m)		DEPTH OF COVER (m)			RATIO WIDTH/DEPTH			HOF - TAMETTA H (mAHD)	DEPTH TO TAMETTA H (m)
Historical Panels							Mean	Max	Min	Mean	Max	Min	Mean	Max		
1	02/03/87	16/08/87	190	1050	-127.0	285.4	2.1	2.6	381	401	419	0.50	0.47	0.45	-18.7	303.3
2	17/08/87	26/11/87	190	1050	-119.0	281.7	2.1	2.1	380	402	408	0.50	0.47	0.47	-14.3	291.7
3	21/03/88	16/11/88	180	1120	-129.2	293.9	2.5	2.6	414	423	431	0.46	0.45	0.44	-14.0	307.9
4	05/02/89	04/06/89	170	1130	-123.0	294.4	2.6	2.7	412	421	427	0.46	0.45	0.44	-19.4	308.3
5	05/06/89	03/12/89	180	1200	-115.8	297.5	2.5	2.8	402	414	423	0.47	0.46	0.45	9.3	290.9
6	04/12/89	21/04/90	180	1200	-110.1	297.4	2.4	2.7	399	408	417	0.48	0.47	0.46	14.7	286.6
7	16/07/90	28/01/91	180	1200	-105.4	296.3	2.3	2.5	386	401	412	0.49	0.47	0.46	8.3	289.8
8	17/04/91	05/12/91	200	1640	-140.8	273.9	2.5	2.7	386	412	426	0.49	0.46	0.45	2.7	271.9
9	06/12/91	26/07/92	180	1220	-94.5	300.1	2.2	2.3	383	395	403	0.50	0.48	0.47	11.3	291.2
10A	27/07/92	03/12/92	230	770	-134.7	262	2.7	2.9	400	412	416	0.47	0.46	0.46	21.9	247.4
10B	04/12/92	16/05/93	230	710	-150.2	262	2.4	2.5	382	398	418	0.50	0.48	0.45	21.9	247.4
11	17/05/93	21/01/94	235	560	-142.5	265.7	2.8	2.9	381	409	417	0.50	0.46	0.46	55.2	238.1
12	22/01/94	07/07/94	230	1030	-166.1	247.3	2.6	2.9	393	410	434	0.48	0.46	0.44	7	242.6
13	08/07/94	11/11/94	230	830	-170.6	242.5	2.7	2.9	398	411	421	0.48	0.46	0.45	13.8	233.2
14A	31/01/95	15/06/95	235	215	-75.3	292.5	2.0	2.1	388	389	390	0.49	0.49	0.49	31.4	270
14B	16/06/95	26/06/96	235	2150	-91.9	292.5	2.2	2.2	373	387	393	0.51	0.49	0.48	31.4	270
15	27/06/96	07/09/97	235	2650	-87.4	299.2	2.1	2.3	357	385	402	0.53	0.49	0.47	45.4	271.2
16	08/09/97	15/02/99	235	2675	-74.1	306.1	2.1	2.2	340	378	392	0.56	0.50	0.48	54.6	272.8
17	16/02/99	21/06/00	235	2555	-63.3	313.3	2.1	2.3	327	375	389	0.58	0.51	0.49	64.5	269.4
18	22/06/00	02/10/01	235	2360	-52.6	316.1	2.1	2.3	319	369	387	0.59	0.52	0.49	75.3	264.2
19	03/10/01	29/09/02	235	2175	-44.3	317.2	2.1	2.3	306	361	410	0.62	0.53	0.46	84.1	258.6
20	30/09/02	11/09/03	235	1445	-103.9	302.7	2.2	2.4	393	407	435	0.48	0.47	0.44	10.6	293.5
21	12/09/03	30/05/04	235	1080	-97.4	308.1	2.2	2.3	400	405	409	0.47	0.47	0.46	17.2	293.4
22	02/06/04	11/07/05	283	1875	-142.8	283	2.2	2.3	414	425	441	0.46	0.45	0.43	-10.5	291.9
23A	07/09/05	20/02/06	283	775	-156.7	279.4	2.2	2.2	428	435	449	0.44	0.44	0.42	13.3	268.8
23B	15/03/06	21/08/06	283	770	-141.8	288.1	2.0	2.1	415	431	451	0.46	0.44	0.42	7.9	282.5

LONG WALL	DATE START	DATE END	VOID WIDTH (m)	LW LENGTH (m)	ELEVATION OF BUSM (mAHD)	GROUND ELEVATION (mAHD)	CUTTING HEIGHT (m)		DEPTH OF COVER (m)			RATIO WIDTH/DEPTH			HOF - TAMETTA H (mAHD)	DEPTH TO TAMETTA H (m)
24B	15/10/06	26/08/07	283	2260	-153.2	286.2	2.1	2.3	420	440	457	0.45	0.43	0.42	-1.4	287.1
24A	15/11/07	19/07/08	283	980	-166.4	270.9	2.2	2.3	428	438	462	0.44	0.43	0.41	-49.4	317.0
25	22/08/08	27/02/11	283	3580	-164.8	278.5	2.2	2.5	422	443	462	0.45	0.43	0.41	-10.5	286.2
26	30/03/11	11/10/12	283	3480	-175.3	275.5	2.2	2.5	422	450	474	0.45	0.42	0.40	-17.2	287.3
27	08/11/12	22/03/14	283	3030	-183.3	273	2.2	2.5	424	456	491	0.45	0.42	0.39	-14.1	282
28	24/04/14	17/05/15	283	2620	-196.7	263.3	2.2	2.3	421	460	513	0.45	0.41	0.37	-34.7	290.5
29	29/05/15	13/04/16	283	2310	-209.5	256.7	2.2	2.3	424	465	498	0.45	0.41	0.38	-44.8	292.4
30	26/05/16	13/04/17	283	2310	-221.9	250	2.2	2.3	430	473	506	0.44	0.40	0.38	-58.7	296.2
31	20/04/17	17/08/18	283	2340	-234.1	241.9	2.1	2.2	434	474	512	0.44	0.40	0.37	-82.7	304.5
32	28/11/18	29/08/19	283	2376	-252.0	231.1	2.2	2.5	474	487	502	0.40	0.39	0.38	-91.8	299.7
Proposed Panels							**Mean**	**Max**	**Min**	**Mean**	**Max**	**Min**	**Mean**	**Max**		
W1	Nov-2019	Aug-2020	283	1870	-283.0	226.2	2.0	2.1	474	518	547	0.40	0.37	0.35	-117.1	306.8
W2	Aug-2020	Apr-2021	283	1675	-283.0	225.8	2.0	2.1	474	518	547	0.40	0.37	0.35	-119.1	311.1
W3*	May-2021	Dec-2021	283	1425	-266.5	204.3	2.0	2.1	472	503	531	0.40	0.38	0.36	-128.6	225.8
W4*	Dec-2021	May-2022	283	915	-253.6	204.3	1.9	2.0	455	484	516	0.42	0.39	0.37	-90.9	256.1

Notes:

LW = Longwall. BUSM = Bulli Coal seam. HOF = Height of (Connected) Fracturing (estimated using H calculated from Tammetta, 2013, as recommended in IEPMC, 2018).

*Mine plan for W3 and W4 is preliminary at this stage.

1.2 STRUCTURE OF THIS DOCUMENT

This Groundwater Technical Report will form an Appendix to Tahmoor Coal's overarching Water Management Plan (WMP), and is structured as follows:

Section 1: Provides background on previous studies conducted at the site that are considered relevant to the Groundwater Technical Report.

Section 2: Outlines the statutory requirements applicable to the Groundwater Technical Report.

Section 3: Describes the existing environment of the Investigative Area with respect to groundwater and associated drainage lines.

Section 4: Details the predicted subsidence impacts and consequences to groundwater resources within the Investigative Area.

Section 5: Describes the monitoring, mitigation and management plan for the Investigative Area.

Section 6: Details the Trigger Action Response Plans (TARPs) and adaptive management measures

1.3 PREVIOUS STUDIES

1.3.1 BACKGROUND

The coal seam targeted by Tahmoor Coal is the Bulli Coal Seam. Within the footprint of the Tahmoor Mine the Bulli Coal Seam lies at a depth of around 375 m to 500 m. Several other underground mines operating within the Southern Coalfield, near to the Tahmoor Mine, also target this seam. These mines include South32's Bulli Seam Operations ["BSO"] (historical Appin and West Cliff mines), Tower Mine, Russell Vale Mine, and Cordeaux Mine. South32's Dendrobium Mine lies further to the southeast and targets the deeper Wongawilli Coal seam.

As with other current mining operations in the Southern Coalfield, Tahmoor Mine employs longwall mining methods. IEPMC (2018) provided the following summary of this method:

> *Longwall mining involves delineating blocks or panels of coal that are typically 150 m to 400 m wide and between 1,500 m and 4,000 m long. A longwall panel is formed by driving tunnels (roadways) down its longitudinal boundaries and connecting them at the inbye extremity of the block. A continuous miner is used to cut roadways. The longwall mining equipment comprising a skin-to-skin bank of enclosed hydraulic supports, a conveyor and a coal cutting machine (shearer) is installed in this roadway. The longwall block is progressively extracted on the retreat; mining slices of coal about 1 m thick (deep) across the full width of the block. As the coal is removed, the hydraulic supports are lowered, advanced and reset in sequence and the roof caves in behind the supports to constitute the goaf. The extent of caving, fracturing and subsidence of the ground above the goaf is determined primarily by the mining dimensions and the nature of the geology.*
>
> *The headings comprising the longitudinal roadways are referred to as gateroads. The driving of longwall gateroads is referred to as longwall development, with a set of gateroads constituting a longwall development panel. Hence, it takes two longwall development panels to delineate a longwall block. The pillars left between each longwall block are referred to as interpanel pillars or chain pillars.*

The subsidence, deformation and fracturing above and adjacent to the longwalls, and the need to dewater mine workings, are the primary modes of impact to adjacent groundwater and surface water systems.

1.3.2 SUBSIDENCE

The Western Domain lies within Mining Leases (ML) 1376 and 1539. The approved and existing EIS for these leases, and subsequently LW W1-W2, were prepared in 1993 (Kembla Coke and Coal Pty. Ltd., 1993) and 1998 (OEC, 1998) respectively. A subsidence monitoring program was established at Tahmoor Mine in 1984, and this data was used alongside calculations using the incremental profile method to predict subsidence related impacts for future Tahmoor North Longwalls (OEC, 1998). Although predictions were made for all proposed longwalls, OEC identified that within the time between the extraction of the first and last longwalls at Tahmoor North, substantial changes in the understanding of subsidence and how it is predicted could occur. Therefore, the nature of the impacts to natural features due to subsidence in each EIS was general, particularly in relation to potential impacts to groundwater. Both EIS's noted that mining-related impacts were likely to be negligible, with no permanent lowering of the water table expected.

A Subsidence Management Plan (SMP) for Longwalls 31 to 37 was initially submitted in 2014 by Tahmoor Coal (GeoTerra, 2014), however, this SMP was not approved completely, with only LW31 and LW32 being individually approved for extraction. This SMP was placed on public exhibition to provide government agencies, community members and other relevant stakeholders the opportunity to submit feedback on the report. A number of submissions were made against the SMP and are summarised in **Attachment 1**.

Based on the feedback from government agencies and the community, Tahmoor Coal revised the mine plan. The revised mine plan has reoriented LW W1-W2 so that they no longer directly undermine creeks within the area. This revised mine plan has been utilised in this groundwater assessment and is illustrated in **Figure 1-2.**

The report prepared by Mine Subsidence Engineering Consultants (MSEC, 2019) in support of this Extraction Plan has identified the following potential subsidence related impacts to the groundwater system as a result of extraction at LW W1-W2:

- *Matthews, Cedar and Stonequarry Creeks have been identified as having the potential to be impacted by extraction at LW W1-W2 due to the close proximity of these watercourses to the longwall panel. The maximum predicted vertical subsidence, total upsidence and total closure for these creeks ranges between 60 to 90 mm, 90 to 160 mm, and 60 to 180 mm respectively.*
- *Any water quality impacts that may occur are likely to be localised due to the low flow volumes and ephemeral nature of the creeks surrounding LW W1-W2.*
- *A temporary lowering of the regional piezometric surface due to an increase in secondary porosity and permeability is likely. Data from subsidence over Longwalls 22 to 28 suggest that up to 15 m of lowering could occur. However, rainfall recharge will infiltrate secondary void space to allow recovery to occur.*

1.3.3 CONSULTATION

Tahmoor Coal consulted with several government bodies in the preparation of the Extraction Plan for LW W1-W2. **Table 1-2** below lists each of the consulted groups and their specific comments (if any) pertaining to considerations to be made regarding groundwater.

Table 1-2 Summary of consultation for LW W1-W2 Extraction Plan

CONSULTED PARTY	COMMENTS REGARDING GROUNDWATER	AREA WHERE ADDRESSED
NSW Department of Planning and Environment – Resources Regulator	Advised 23rd May 2019 to commence collecting baseline data for groundwater to inform subsidence monitoring program.	Baseline data provided in **Section 3.5.4**
NSW Infrastructure – Natural Resources Access Regulator	No comments pertaining to the Extraction Plan.	-
NSW Environment Protection Authority	No comments pertaining to the Extraction Plan.	-
Water NSW	No comments pertaining to the Extraction Plan.	-
Wollondilly Shire Council	No comments pertaining to groundwater.	-
NSW State Emergency Services	The SES contact requested a copy of the Emergency Management Plan to assess the plans for emergency evacuations and vertical rescue. This was provided by Tahmoor Coal. The flood impact assessment conducted by WRM (2019) for LW W1-W2 determined that there would be a negligible increase in flood risk as a result of the proposed mining in the Western Domain. The Public Safety Management Plan and Water Management Plan will therefore not be including emergency management procedures as flood risk is not likely to increase as a result of mining.	-

2 STATUTORY REQUIREMENTS

This section provides background to the statutory requirements associated with the broader Tahmoor Mine and for LW W1-W2.

2.1 RELEVANT LEGISLATION AND POLICY

2.1.1 WATER MANAGEMENT ACT 2000

The *Water Management Act 2000* is the regulatory framework for the management and control of water use within NSW. In conjunction with the *Water Act 1912*, it governs the licensing of water to users. In addition, the *Water Management Act 2000* allows for the development and regulation of Water Sharing Plans (WSPs). WSPs regulate the trade and sharing of surface and groundwaters between competing needs and users throughout NSW.

Relevant Water Sharing Plans and Groundwater Management Areas

Tahmoor Mine currently extracts groundwater that drains into underground mine workings and pumps this water to the surface via three dewatering lines before treating the water and discharging it off site.

The Tahmoor Mine falls within the 'Greater Metropolitan Region Groundwater Sources' WSP (NOW, 2011b), which commenced in 2011. **Figure 2-1** indicates the extent of this WSP, along with the various groundwater sources in this region that are regulated by the WSP. A WSP is used to manage the average long-term annual volume of water extracted from a given groundwater source. The relevant Groundwater Source for the Tahmoor Mine is:

- Sydney Basin Nepean Sandstone.

Other relevant Groundwater Sources include:

- Sydney Basin – Central, located 10 km to the east and north-east;
- Sydney Basin – South, located 15-20 km east and south-east; and
- Goulburn GMA - located over 25 km to the west and south.

The Sydney Basin – Nepean Sandstone Groundwater Source is further subdivided into Management Zones (MZ), as shown using hatching on **Figure 2-1**. The LW W1-W2 Study Area lies within Nepean Management Zone 2, while Zone 1 covers the southern 'third' of the Groundwater Source as well as a smaller area to the west of Camden. The Nepean Sandstone Groundwater Source has and annualised limit on entitlement (LTAAEL) of 99,568 ML (NOW, 2011a), while current entitlement is 25,658 ML (based on the WaterNSW *Water Register* 2018-2019 water year)[1].

The Greater Metropolitan Region Unregulated River Water Sources WSP (NOW, 2011c) is the relevant plan for surface waters for the LW W1-W2 Study Area. Within this WSP the Upper Nepean River source is the relevant management area, of which the following MZ cover the project site:

- Pheasants Nest Weir to Nepean Dam MZ;
- Stonequarry Creek MZ; and
- Maldon Weir MZ.

[1] See: https://waterregister.waternsw.com.au/water-register-frame

2.1.2 NSW AQUIFER INTERFERENCE POLICY

Underground mining generally requires the dewatering of the geological strata. In accordance with the NSW Aquifer Interference (AI) Policy, such activity is classified as an 'Aquifer Interference'. In order to meet the requirements of the 'minimal impact considerations', outlined within the AI Policy, a groundwater assessment is conducted.

The AI Policy requires an estimation of "all quantities of water that are likely to be taken from any water source during and following cessation of the activity and all predicted impacts associated with that activity...". Water take and impact estimation is to be based on a "complex modelling platform" for any mining activity not subject to the Gateway process, where the model makes use of the "available baseline data that has been collected at an appropriate frequency and scale and over a sufficient period of time to incorporate typical temporal variations".

The NSW Aquifer Interference Policy (AI Policy) was developed to provide a framework to guide the assessment of impacts that may result following the 'take' of water from an aquifer. It outlines the requirements for obtaining licences for approved aquifer interference activities, as well as considerations for the assessment of impacts (NSW Government, 2012).

The AI Policy specifies 'minimal harm considerations' for highly and less productive aquifers, while also defining thresholds for water table and groundwater pressure drawdown, and changes in groundwater and surface water quality. There are separate minimal impact considerations for:

- "Highly productive" groundwater;
- "Less productive" groundwater;
- "Water supply" works;
- "High Priority" Groundwater Dependent Ecosystems (GDEs); and
- "High Priority" Culturally significant sites.

The AI Policy categorises groundwater source productivity (highly productive or less productive) based on characteristics of salinity and aquifer yield. The Tahmoor Mine is located within the 'Highly Productive' Hawkesbury Sandstone aquifer (**Figure 2-2**). The Hawkesbury Sandstone aquifer is the most utilised aquifer in this region. Water sourced from the Narrabeen Group and Permian Coal Measures comprises the remaining portion of water sourced around the Tahmoor Mine (HydroSimulations, 2018).

It should be noted that the categorisation of groundwater source productivity does not make any vertical distinction of aquifer productivity. This is pertinent as the high yielding Hawkesbury Sandstone aquifer overlies the lower yielding Narrabeen Group/Permian Coal Measures groundwater systems which are present at greater depths.

2.1.3 WATER LICENSING

A single Water Access Licence (WAL) has been awarded to Tahmoor Coal under the authority of the *Water Management Act 2000*. The following table outlines the details of this licence.

Works approval	WAL title	Issued	Purpose	Share
10WAI18745	WAL36442	Dec 2013	Mining dewatering (groundwater)	1642 units

Tahmoor Coal also holds a discharge licence, issued by the NSW EPA. This licence, Environment Protection Licence (EPL) 1389, permits the discharge of wastewater and 'made water' from the underground mine to surface water. The discharge location, LDP1, is shown on **Figure 3-1**. The Surface Water Technical Report (HEC, 2019) has concluded that the extraction of longwalls within the Western Domain will not affect the licence conditions of this EPL.

2.2 PROJECT APPROVAL CONDITIONS

The activities at the Tahmoor North Coal Mine were initially approved under the conditions of Development Application (DA 67/98) in 1999. Since this approval four modifications to the DA have been made in order to maintain the relevance of the approval conditions to changes in legislation and policy, industry practice, as well as environmental and community values. In September 2018 additional conditions (13A to 13J) were added to the DA to make provision to report on and measure the impacts of subsidence on natural, built and heritage features in the landscape. Under condition 13H of this modified section is the request to prepare an Extraction Plan for all longwalls after and including Longwall 33 (referred to here as LW W1). Condition section 13H (vii) c) requests the inclusion of a WMP to accompany this Extraction Plan.

2.2.1 WATER MANAGEMENT PLAN

This groundwater technical report has been prepared as part of the WMP. A summary of the requirements of the WMP, as in condition 13H (vii) c) of the Development Application, that are relevant to this groundwater assessment and where they are addressed in this document are presented in **Table 2-1** below.

Table 2-1 Requirements of the WMP as per DA 67/68 addressed in this report

Requirement	Section of this report where addressed
Inclusion of detailed baseline data pertaining to: - Groundwater levels, yield and quality in the region, including for privately licensed bores.	Available groundwater data was reviewed and discussed in **Sections 3.5.3 and 3.5.4**.
Groundwater impact assessment criteria, including trigger levels for investigating any potentially adverse impacts on water resources or water quality.	Groundwater impact assessment criteria presented in **Section 6**.
A groundwater monitoring program to monitor and report on: - Springs, their discharge quantity and quality, as well as associated groundwater dependent ecosystems; - Groundwater inflows to the underground mining operations; - The height of groundwater depressurisation; - Background changes in groundwater yield/quality against mine-induced changes, in particular on groundwater bore users in the vicinity of the site; - Permeability, hydraulic gradient, flow direction and connectivity of deep and shallow groundwater aquifers.	Groundwater monitoring program included in **Section 5**
A program to validate the groundwater models for the development, and compare monitoring results with modelled predictions.	**Section 5.1** and **Section 6**
A plan to respond to any exceedances of the groundwater assessment criteria.	**Section 6**

2.2.2 SUBSIDENCE PERFORMANCE MEASURES

Subsidence performance measures for natural and heritage features are listed under Condition 13A of DA 67/98. There were no performance measures specific to groundwater. However, a performance measure for Stonequarry Creek, Cedar Creek and Matthews Creek was provided as part of the Extraction Plan approval (Condition 7, sections 1 to 3) (DPIE, 2019). The conditions are outlined in **Table 2-2** below.

Table 2-2 Subsidence Performance Measures

FEATURE	SUBSIDENCE PERFORMANCE MEASURES	SUBSIDENCE PERFORMANCE INDICATORS
Stonequarry Creek, Cedar Creek and Matthews Creek	No connective cracking between the surface, or base of the alluvium, and the underground workings.	This performance indicator will be considered to be exceeded if analysis of inflow data suggests high correlation to rainfall events and significant departure from recent groundwater model predictions. This would be supported by analysis of pre- and post-mining goaf centreline bore data.

3 EXISTING ENVIRONMENT

This section provides an analysis of the natural characteristics of the Study Area, along with an assessment of available baseline data.

3.1 TOPOGRAPHY

The Tahmoor Mine lies at approximately 280 mAHD, approximately 20 km west of the Illawarra Escarpment (**Figure 3-1**). It is surrounded by several deeply incised river valleys that flow in a predominantly northward direction. Within the mine lease the topography declines to the north-east as the rivers grade into the floodplains associated with the Nepean River around Camden.

The area occupied by LW W1-W2 is lower than the existing Tahmoor North operations, with elevations decreasing from 225 mAHD to 175 mAHD towards Stonequarry Creek. Stonequarry Creek flows from the north of LW W1-W2 and then down to the south-east as it follows the drop in local topography to its confluence with the Nepean River at approximately 100 mAHD to 150 mAHD.

3.2 RAINFALL AND EVAPORATION

Rainfall data in the area is available from a number of sources. BoM operate two rainfall stations, Picton Council Depot (68052) and Buxton (68166) which are both near to Tahmoor Mine. Tahmoor Coal operate their own station, and the SILO climate data source provide interpolated and infilled records for 0.05°x0.05° tiles.

Due to the occasional gaps in the data for the BoM sites, and the relatively short record of data held by Tahmoor (the mine's record has no gaps, but started in July 2006), the SILO record for the location 274253.9E, 6212954.2N has been adopted for this report to understand long-term trends. This record has been compared against the other data sources to verify its appropriateness for this task.

The spatial trends in long-term average rainfall across the region are shown on **Figure 3-2**. Average annual rainfall at Tahmoor is approximately 758 mm/yr. Areas with higher rainfall occur to the south and east, while areas to the north and west are typically drier.

Monthly rainfall is presented on **Figure 3-3**, alongside potential evaporation and evapotranspiration. Rainfall is generally consistent all year with values falling between ~50-80 mm. The highest rainfall occurs in January and February, at 82 and 85 mm respectively, while September is the driest month with an average rainfall of 41 mm for the period of record. Evaporation and evapotranspiration show similar trends with higher rates during the summer months and lower in winter. The average monthly evapotranspiration is highest in December at 153 mm.

3.3 SURFACE WATER

The Tahmoor mining lease is located in the Upper Hawkesbury-Nepean Catchment. The Nepean River is the major watercourse in this catchment, flowing perennially from the south through Lake Nepean. The Bargo, Avon and Cordeaux are major tributaries to the Nepean River in this area. The Bargo River flows eastward through the lower portions of the Tahmoor mine plan. The Avon and Cordeaux Rivers are positioned to the south-east of the Tahmoor mining leases. They flow northward before reaching their confluences with the Nepean River 4 and 6 km, respectively, to the east of the mining leases. These watercourses are shown on **Figure 3-4**.

The primary watercourses of interest overlying and adjacent to LW W1-W2 are:

- Stonequarry Creek;

- Cedar Creek;
- Matthews Creek;
- Redbank Creek; and
- Rumker Gully and Newlands Gully.

Effects of mining induced subsidence have been reported as occurring at Redbank Creek (e.g. Geoterra, 2019). A detailed assessment conducted by Morrison *et. al.* (2019) found that the quality of surface waters was degraded in the direct vicinity of surface cracking features along Redbank Creek, with higher salinity and metal concentrations measured compared to an unaffected reference site. In order to assess future impacts of subsidence, monitoring and analysis of both ground and surface water quality is essential to determine whether subsidence has occurred.

Further detail and analysis of the surface water regime is presented in the Surface Water Technical Report which will accompany this Groundwater Technical Report to support the WMP.

3.4 GEOLOGICAL SETTING

The Tahmoor Mine is situated within the Southern Coalfield in the sedimentary Sydney Basin (University of Wollongong [UOW], 2012). **Figure 3-5** presents the outcropping geology near Tahmoor Mine. Locally, the underlying geology consists of interbedded Permo-Triassic strata, primarily sandstones, siltstones, claystones and coal seams, with the Bulli and Wongawilli Coal Seams being the main economic seams in this area. **Figure 3-6** presents the regional stratigraphic sequence.

The geological cross-section in **Figure 3-7** shows the strata dips down towards the north and the centre of the Sydney Basin, as well as a mild dip in the east towards the Illawarra Escarpment. The fluvially-deposited Triassic Hawkesbury Sandstone is the dominant outcropping stratigraphic unit in this region. The Wianamatta Formation, composed of soft shales, overlies the Hawkesbury Sandstone and is more apparent to the north of the mine. Due to the high silica content of this sequence, the Hawkesbury Sandstone exhibits higher resistance to erosion than the Wianamatta Formation. As such, soil production on the Hawkesbury Sandstone is low and the sandstone is the common bed material for the watercourses in this region (UOW, 2012), with the Wianamatta Formation typically appearing as capping material at higher elevations. The Hawkesbury Sandstone is approximately 200 m thick in the area of the Western Domain.

As stated above, the Bulli and Wongawilli Coal Seams are the main deposits of economic significance in this region, **Figure 3-6** shows that these coal seams belong the Sydney Subgroup of the Permian Illawarra Coal Measures (ICM) (UOW, 2012). The Bulli Coal Seam is the youngest coal seam of the ICM and is approximately 2-4 m thick. This is the seam targeted by Tahmoor Coal and the neighbouring BSO Mine.

As shown in **Figure 3-5** the region is dissected by several faults, folds, and dykes of volcanic origin, varying in age from Jurassic to Tertiary. This figure presents the results of structural mapping carried out by Tahmoor Coal over the mine footprint. The Nepean Fault is the major structural feature of interest to operations conducted by Tahmoor Coal. Recent mapping in SCT (2018a) indicates that this fault extends along the full length of the eastern edge of the Tahmoor North mine footprint and is approximately 10 km in length.

This significant structural feature is known to be transmissive, and mine workings that intersect this zone can produce more water, i.e. be wetter than, areas that are located away from this zone. LW W2, which is the nearer of the two panels, is located at least 600 m, and more typically

1000 m, from the fault and disturbed zone, and are therefore unlikely to be influenced by that structural feature.

3.5 GROUNDWATER

This section presents a summary of hydrogeological units and groundwater use (environmental and anthropogenic) relevant to the Western Domain.

3.5.1 HYDROGEOLOGICAL UNITS

The major hydrostratigraphic units that characterise the area around the Tahmoor Mine are the Sydney Basin Triassic and Permian rock units, with the Hawkesbury Sandstone being the primary aquifer. These aquifers fall within the *Nepean Sandstone Groundwater Source* and have been classified as being 'Highly Productive' by the NSW Government based on considerations of bore yield and groundwater quality. The Bulgo Sandstone and Illawarra Coal Measures of the Narrabeen Group supply additional water to this system; however, contributions are substantially lower.

The extent of surficial units around Tahmoor Mine are presented on **Figure 3-5**. Generally, there is limited extent of surficial alluvium in this region. However, the Western Domain is located near the main body of alluvium in this area, i.e. along Stonequarry Creek downstream (east) of the Western Domain, extending downgradient to Picton. The shales of the Wianamatta Formation are more extensive, especially to the north of Tahmoor Mine, but have limited potential as aquifers.

Further discussion on each of the key hydrogeological units relevant to the Study area is included below.

Alluvium

The alluvium is composed of two main units – the Thirlmere Lakes alluvium and the Quaternary to modern alluvium. The Thirlmere Lakes alluvium is Cretaceous in age and are positioned within a thin valley to the West of the Tahmoor Mine. It has been described as 'laterised alluvium' (Moffit, 1999) and is characterised by clayey sands and sandy clays with maximum thicknesses of 40 m to 60 m. The modern to Quaternary aged alluvium typically exists within watercourses in the northern regions of the mine lease.

Groundwater conditions are likely to be unconfined. Recharge to the alluvium is expected to be predominantly from rainfall and peak streamflow events.

Alluvial units occur to the east of LW W1-W2 along the lower reaches of Stonequarry Creek, near Picton (see **Figure 3-5**). The alluvium does not intersect the LW W1-W2 mine footprint.

Wianamatta Formation

The Wianamatta Formation shales have been largely eroded and are present as hill cappings overlying the Hawkesbury Sandstone in the northern region of the Tahmoor Coal leases. The shales have poor permeability and water quality, however, can lead to the development of springs in areas in contact with the Hawkesbury Sandstone.

The Wianamatta Formation is present over the surface of the area occupied by the LW W1-W2 mine footprint.

Hawkesbury Sandstone

The Hawkesbury Sandstone is a porous rock aquifer of moderate resource potential. In areas where secondary porosity is apparent, such as in structural zones such as the Nepean Fault zone, higher resource potential can be achieved.

Interpreted water table elevations are shown on **Figure 3-8** and the interpreted depth to water table on **Figure 3-9**. The interpreted water conditions are based on the most recent available data, which ranges between 2013 and 2018. The contouring on **Figure 3-8** shows groundwater is generally flowing in an east to north-easterly direction over the mine. **Figure 3-9** shows that groundwater levels are generally closer to the ground surface in areas where surface water drainage exists. This indicates the potential for surface drainage to contribute baseflow to the Hawkesbury Sandstone aquifer. Due to the number of watercourses surrounding Tahmoor Mine and the regional topography (see **Section 3.1**), the depth from the ground surface to the water table is shallower compared to the surrounding region. Over the mine, the water table is approximately 20 m below the ground surface. In areas not associated with surface drainage lines, such as that south-west of the mine, the depth to the water table is between 40 and 50 m.

A breakdown of groundwater salinity into approximately 'beneficial use' categories, for all sampled units, is presented on **Figure 3-10**. Hawkesbury Sandstone exhibits a range of salinities (fresh to saline) with a median value of approximately 500 mg/L (GeoTerra, 2013a). Publicly available data from AGL's Camden Gas Project indicated an average TDS of about 380 mg/L for Hawkesbury Sandstone groundwater (Parsons Brinckerhoff, 2013). These values are supported by the data collected in the recent bore census for the Western Domain (GeoTerra, 2019), where three of the four samples of groundwater EC were <1,700 uS/cm (approx. 1,000 mg/L). Further discussion of resource potential and productivity of the Hawkesbury Sandstone is available in Ross (2014).

Illawarra Coal Measures

An average TDS of 11,000 mg/L and a range 3,200-27,500 mg/L was reported for groundwater from the Illawarra Coal Measures, which includes the Bulli Coal Seam.

3.5.2 HYDRAULIC CONDUCTIVITY

For the purpose of describing or quantifying how water flows through a porous or fractured medium, the term 'permeability' is used interchangeably with 'hydraulic conductivity' in this report. Horizontal permeability is abbreviated as Kh, and vertical permeability is abbreviated to Kv.

Figure 3-11 shows the summaries of pre-mining packer test (Kh) and core testing (Kv) data, summarised as quartiles of the sample population for each stratigraphic unit, with the units listed by age (or depth). Additionally, the arithmetic mean of Kh data and the harmonic mean of Kv is presented – this is consistent with the suggested method for characterising permeability (Domenico and Schwartz, 1997).

Key points from **Figure 3-11** are:

- Variation between measured horizontal core permeabilities compared to the values derived from packer tests. This is not uncommon and is expected because packer tests measure the (local scale) joint and fracture permeability whilst the core data typically measure the host rock mass permeability (i.e. conductivity of the intergranular pore spaces);
- The packer test dataset from Tahmoor suggests a decreasing permeability with depth of the rock mass as a whole; however, the trend seems to be in two parts:
  - decreasing from the Hawkesbury Sandstone down to the Wombarra Claystone, an apparent step up between Wombarra Claystone and the Bulli Coal seam; and
  - a further decreasing trend in the units older than the Bulli Coal Seam. There is a weak trend of decreasing matrix permeability with depth observed in the core data.
- The difference in the strength of the trend in the packer and core data is unsurprising, as depth of cover is unrelated to matrix lithology, although this can cause some

reduction of intergranular pore space. Depth of cover has more influence on the presence or absence, and the magnitude of open joints and fractures, with more open joints expected at shallower depths;

- The core data set provides a useful lower bound on hydraulic conductivity, however packer tests do not necessarily provide the upper bound, due to the scale at which testing is effective. Pumping tests may, or may not, be able to stress connected joint and fracture networks, leading to higher measured permeabilities; and
- Alluvial hydraulic conductivity has not been measured at or near the site.

This dataset provides a sound basis for constraining the parameters used in the groundwater model.

3.5.3 GROUNDWATER USE

Groundwater Dependent Ecosystems

The Thirlmere Lakes are the closest 'High Priority' Groundwater Dependent Ecosystem within close proximity to the Tahmoor Mine (see **Figure 3-4**). Lake Gandangarra is the closest lake to proposed LW W1-W2, however, this is approximately 5 km from LW W1. Due to the distance between the area of proposed longwall extraction and the Thirlmere Lakes it is unlikely that mining-related impacts due to the extraction of LW W1-W2 would have an impact on the groundwater system surrounding these Lakes. The extent of groundwater drawdown associated with LW W1-W2 presented in **Section 4.3.3** confirms this assumption.

Springs

Literature indicates that is likely that the Hawkesbury Sandstone may contain springs that have developed in saturated and perched aquifers within this unit. However, no springs or soaks have been identified in the vicinity of this study area (GeoTerra, 2013). 'Spring-like' behaviour can be observed at Redbank and Myrtle Creek, however, this process is observed in a post-mining environment where surface subsidence has a significant effect on hydrology and is a result of submerged stream flow re-emerging in downstream sections (A. Dawkins, pers. comm.).

Anthropogenic Use

Several privately-operated and licensed groundwater bores are present to the north and west of LW W1-W2, as identified in the most recent bore census for the Western Domain and surrounding area (GeoTerra, 2019). The primary usage of these bores is for farming and irrigation.

The construction details of each bore, as well as the intended use of the water received is presented in **Table 3-1** (locations are available on **Figure 3-12** and **Figure 3-13**). The drilling dates for these bores range from 1968 to 2004. All water extracted at these bores is derived from the Hawkesbury Sandstone aquifer, with yields of up to 2.67 L/s (GeoTerra, 2019).

Table 3-1 Licensed Groundwater Bores

BORE	X	Y	DRILL DATE	BORE DEPTH (m)	SWL (mBG)	AQUIFER INTAKES (m)	YIELD (L/s)	pH*	EC (µS/cm)	TYPE OF BORE
GW024750	277098	6216403	01/01/68	11.9						Stock/Domestic – collapsed
GW035844	277150	6215294	01/11/68	45.7	24.3	28.3 - 28.6 42.9 – 43.5	1.01			Irrigation
GW064469	277346	6215669	01/11/87	91.0		46 - 80	0.50			Domestic

GW072402	277685	6216905	26/09/94	42.0	12.2*	59 – 59.3	0.50	6.52	7410	Stock/Domestic – pump removed
GW104090	278208	6215913	17/12/01	150.5	39.0	78 – 79 93 – 98 121 – 123 136 - 139	1.10			Recreation
GW105228	278451	6216837	27/03/03	63.0	23.0	29 – 29.2 40.5 – 40.7 48.5 – 48.7	1.82*	6.12	1630	Stock/Domestic
GW105467	244279	6215251	03/10/03	120.0	32.0	21 – 22 54 – 55 84 – 85 112 – 113	0.47*	5.80	892	Stock/Domestic
GW105546	276997	6215723	05/11/04	163.0	31.9	66 – 67 78 – 79 95 – 96 120 – 121 126 – 127 154 – 155	1.60*	6.21	286	Irrigation

Note: Coordinates in GDA94 Zone 56
‘*’ SWL = standing water level (depth to water) as measured by GeoTerra, 2019.

A summary of groundwater salinity data in **Figure 3-10** indicates that water quality at bores within the Hawkesbury Sandstone is generally fresh and suitable for such purposes. There has been no continuous collection and monitoring of water level or quality data at these bores throughout the history of their use, and therefore a detailed analysis of bore condition cannot be performed. However, a snapshot of current conditions is presented in the recent bore census (GeoTerra, 2019).

3.5.4 GROUNDWATER LEVELS - BASELINE DATA

For the purpose of monitoring the subsidence related impacts that may result following the extraction of LW W1-W2 a monitoring network consisting of ten bores has been established. Four of these bores are existing monitoring locations utilised by Tahmoor Coal to monitor groundwater response following the extraction of previous and current longwalls. The remaining six are proposed shallow open standpipe bores that were being drilled at the time of writing. **Table 3-2** lists the relevant information for each of these bores, and **Figure 3-12** presents their location.

Three of the existing bores are multi-level Vibrating Wire Piezometers (VWPs) (TNC036, TNC040 and TNC043) monitoring groundwater in multiple stratigraphies. **Table 3-2** presents a summary of the depths and stratigraphic placement of the instruments at these four existing monitoring sites. The baseline data for the four existing monitoring locations are presented on **Figure 3-14** to **Figure 3-17**, with the rainfall residual mass included for comparison to climatic trends. Monitoring at these sites will be ongoing in order to continue to provide additional baseline and post-mining data. An analysis of the groundwater level data collected so far for each monitoring location is presented below.

Table 3-2 Groundwater Monitoring Network – LW W1-W2

ID	EASTING	NORTHING	STATUS	TYPE	SUB ID	RL (mAHD)	GEOLOGY
P9	276607.38	6210936.60	No longer operational	MB	V1 (28m)	181.06	HBSS
					V2 (40m)	169.06	HBSS
					V3 (60m)	141.06	HBSS
TNC036	277268.60	6215382.00	Existing	VWP	HBSS 65	166.25	HBSS
					HBSS 97	134.25	HBSS
					BGSS 169	62.25	BGSS

ID	EASTING	NORTHING	STATUS	TYPE	SUB ID	RL (mAHD)	GEOLOGY
					BGSS 214	17.25	BGSS
					BGSS 298.5	-67.25	BGSS
					BGSS 412.5	-181.25	BGSS
					BUSM 463.5	-232.25	BUSM
TNC040	279003.56	6214520.88	Existing	VWP	WNFM 27	202.0.	WNFM
					HBSS 65	164.03	HBSS
					HBSS 111	118.03	HBSS
					HBSS 225	4.03	HBSS
					BHCS 252	-22.97	BHCS
					BGSS 352	-122.97	BGSS
					SCSS 482	-252.97	SCSS
					BUCO 501.9	-272.86	BUSM
TNC043	280076.55	6212671.35	Existing	VWP	HBSS 65	150.32	HBSS
					HBSS 111.5	103.82	HBSS
					HBSS 213	2.32	HBSS
					BGSS 240	-24.63	BGSS
					BGSS 332.6	-117.28	BGSS
					BGSS 405.2	-189.88	BGSS
					BUCO 476.3	-260.98	BUSM
P12	277766	6216628	Existing	MB	P12A	162.33	HBSS
					P12B	147.37	HBSS
					P12C	117.26	HBSS
P13	278178	6216545	Existing	MB	P13A	155.57	HBSS
					P13B	140.72	HBSS
					P13C	110.91	HBSS
P14	278455	6216515	Existing	MB	P14A	167.03	HBSS
					P14B	156.60	HBSS
					P14C	142.21	HBSS
					P14D	112.28	HBSS
P15	278840	6216515	Proposed if access available	MB	-	-	-
P16	277370	6215105	Existing	MB	P16A	200.44	HBSS
					P16B	182.91	HBSS
					P16C	153.46	HBSS
P17	277935	6217185	Existing	MB	P17	156.43	HBSS

Notes:
Coordinates in GDA94 Zone 56

VWP – vibrating wire piezometer

ID	EASTING	NORTHING	STATUS	TYPE	SUB ID	RL (mAHD)	GEOLOGY
Coordinates for proposed bores are estimates only as these bores were being drilled at time of writing.				MBG – metres below ground MB – monitoring bore			
WNFM – Wianamatta Formation HBSS – Hawkesbury Sandstone BHCS – Bald Hill Claystone				BGSS – Bulgo Sandstone SCSS – Scarborough Sandstone BUCO – Bulli Coal Seam			

TNC036 (**Figure 3-14**) is located to the west of LW W1 and Matthews Creek. It consists of seven sensors placed in the Hawkesbury and Bulgo Sandstones at various depths, as well as one in the Bulli Coal Seam. Data collected from 2010 to 2011 at TNC036 appears erroneous, likely due to influence from construction. Consistent data that appears representative of local groundwater conditions has been collected at the VWP from 2016. Depressurisation is apparent in the Bulli Coal Seam and the lower Bulgo Sandstone (BGSS 412.5) for the period from February 2016 to February 2019. Such declines are not observed in water levels at shallower monitoring locations. The decline in water levels in the lower Bulgo Sandstone and Bulli Coal Seam is likely related to regional drawdown of deeper aquifers due to the cumulative impact of mining at Tahmoor Mine.

TNC040 (**Figure 3-15**) is situated south-east of LW W1-W2, adjacent to LW 32. The eight data sensors that comprise TNC040 are positioned within the Wianamatta Formation, Hawkesbury Sandstone, Bald Hill Claystone, Bulgo Sandstone, Scarborough Sandstone and Bulli Coal Seam. In February 2019, GES reported that this VWP experienced a partial failure with the lower four VWP sensors no longer being active (GES, 2019). Revisions to the host strata were also made for two instruments (GES, 2019). The second deepest instrument was reclassified to be in Scarborough Sandstone (from Bulgo Sandstone) as it was estimated to be at a depth of 482 m. The fourth instrument was reclassified as monitoring the Bald Hill Claystone from its original classification as being in the Hawkesbury Sandstone.

Data has been collected at TNC040 since late 2009 (**Figure 3-15**). The data that was obtained between early 2014 and 2016 was inconsistent with data being collected intermittently by the four lower sensors in 2014 (BHCS 252, BGSS 352, SCSS 482, and BUCO 501.9), and no data collected at any loggers throughout 2015. A gradual decline in water levels at sensors BHCS 252, BGSS 352, SCSS 482 and BUCO 501.9 is apparent over this period. The greatest declines are observed in the Bulli Coal Seam, with water levels falling by ~110 m from May 2016 until February 2019. More than half of this decline (~60 m) occurred from June 2018, in response to recent mine workings, until it ceased operating in September 2018. The three uppermost sensors (WNFM 27, HBSS 65 and HBSS 111) do not appear to show an influence from mining. Instead these loggers, particularly WNFM 27, show good correlation with the rainfall trend.

TNC043 (**Figure 3-16**) is also located along the eastern side LW32, at the opposite end to TNC040. Monitoring began at this VWP in July 2010, and as with TNC036 and TNC040, the record is irregular. However, data has been consistently collected since mid-2015. As of February 2019, HBSS 65 and HBSS 111.5 are the only active loggers at this VWP, with the remainder failing from August to September 2018 due to subsidence from nearby Longwall 32. The water levels at HBSS 65 and 111.5 present similar trends to one another, responding well to rainfall. Since the beginning of 2019, water levels at these sensors have dropped sharply, by about 5 m. This decline may be related to the extended period of reduced rainfall in this region, as illustrated by the rainfall residual mass curve, possibly caused by mining effects or possibly due to nearby groundwater pumping during the extended dry period.

The lower stratigraphies at this monitoring location (all BGSS sensors and the Bulli Coal Seam sensor), show higher groundwater heads than those in the Hawkesbury Sandstone, suggesting higher pressures that may result from aquifer confinement. Each of these sensor shows a continual and relatively linear decline in water pressure since monitoring commenced in 2010.

As with other monitoring locations (above), this is likely to have occurred in response to the cumulative mining impacts from Tahmoor and possibly due to the BSO Mine.

Bore P9 was an open standpipe bore screened at three depths from 28 m, 40 m and 68 m, all within the Hawkesbury Sandstone. This bore was located on the northern bank of Redbank Creek and overlies the roadway between Longwall 31 and Longwall 32, where extraction commenced in November 2018. This bore is no longer operational following subsidence experienced due to the direct undermining of LW 30, 31 and 32. The historical data collected from the bore has been included in this report to provide context for the groundwater levels around the site as no data was available for the newly drilled bores.

Figure 3-17 presents a hydrograph of groundwater levels at screened depth in P9. At the commencement of monitoring the water levels in V1 and V2 were closely related. Greater head separation exists (~5 m) between the two shallower screened water levels and the deeper V3, however, groundwater levels at all depths show similar peaks and declines in response to rainfall recharge. Water levels in all bores decline gradually throughout the first half of 2018, following a trend similar to that shown by the rainfall residual mass curve. During this period water levels decline by approximately 5 m at each screened depth. Following this, groundwater levels drop below the base of the screened interval at V1 and V2, and V3 begins to enter a period of recovery. In December 2018, water levels in V3 have fully recovered and sit ~2 m higher than those first recorded in October 2017.The higher head in V3 at this time may be related to surface fracturing along Redbank Creek. An investigation of shallow groundwater in boreholes (including P9) around Redbank Creek was conducted by SCT in late 2018 (SCT, 2018b). This report identified increases in hydraulic conductivity at bore P9 in the presence of subsidence-induced “surface cracking”. This indicates the water drains from shallowest horizons and recharges a slightly deeper horizon.

A vertical profile showing potentiometric head for bore TNC040 has been included in **Figure 3-18**. This figure shows the potentiometric head at various points in time from January 2010 to February 2019. The head profiles for this bore for the period 2010 to 2013 show similar behaviour, with heads in the shallow Wianamatta Shale being the highest before dropping in the Hawkesbury Sandstone and then rising again in deeper strata. Potentiometric heads for the deeper strata in the more recent profiles (2017 to 2019) do not show the same behaviour as the earlier data these loggers reflecting the regional depressurisation of the water table due to mining in other areas of the Tahmoor Mine.

3.5.5 DRAWDOWN EXPERIENCED DUE TO PREVIOUS MINING AT TAHMOOR

A brief summary of the drawdown experienced at several other shallow standpipe bores monitored by Tahmoor Coal is presented below. This has been included to provide an indication of the extent of drawdown experienced in shallower strata due to previously completed longwall extraction. The hydrographs for eight shallow standpipe bores, of similar construction to P9 (as above), are presented on **Figure 3-19** and **Figure 3-20**. The monitoring bores P1 to P4 and P7 to P8 are positioned between Longwalls 22 to 28. The remainder, bores P5 and P6, are located outside of the longwall footprint and adjacent to watercourses of interest with P5 adjacent to Matthews Creek and P6 alongside the Nepean River. The locations of these bores are presented on **Figure 3-12**. A summary of the change in groundwater levels prior to the extraction of Longwall 23A (September 2005) and following the extraction of Longwall 31 (August 2018) is provided below:

- Bores overlying the longwall panels (P1–P3, and P7) show mining related drawdown in the range of approximately 6 to 10 m. Recovery at the bores positioned within the centre of a longwall panel (P1 and P2) typically took 10 years. For bore P7, positioned at the southern end of LW 25, recovery was moderately faster, occurring in around 6-7 years.

- For bores overlying roadways or development headings (P4 and P8) the drawdown response was minimal. Bore P4 remained responsive to rainfall, however, it experienced several small drawdown events in the range of 1 m. Recovery following these events generally occurred within 6 months.
- Effects of mining on bores located outside of the mine footprint are difficult to assess as monitoring was discontinued at bores P5 and P6. For the available data, water levels at bore P5 appeared to remain responsive to rainfall with no observable mining related drawdown. Data from P6 does not show response to either climate or mining. It is believed that groundwater levels at this last site are influenced by the nearby Nepean Fault.

3.5.6 HISTORIC GROUNDWATER INFLOWS TO TAHMOOR NORTH

For the period 2009 to present day, inflows to the Tahmoor Mine have been within the range of 2 ML/d to 6 ML/d. **Figure 3-21** shows net groundwater inflows against daily water pumped from the mine, alongside the historic rainfall and longwall start dates. Inflows to the mine have remained relatively steady throughout the extraction of Longwalls 24B to 32. A spike in inflows occurred following the cutting of Longwall 27, however, since this time inflow rates have declined.

The average inflow for the previous year of data (May 2018 to May 2019) is 3.7 ML/d. Average inflows for the previous year were slightly higher at 3.9 ML/d.

4 PREDICTED SUBSIDENCE IMPACTS AND GROUNDWATER IMPACT ASSESSMENT

The potential impacts to groundwater can be divided into two principal types:

1. impacts to groundwater level, i.e. drawdown and depressurisation, and associated changes in groundwater quantity due to groundwater discharge into the mine workings and changes to strata permeability and porosity; and
2. impacts to water quality characteristics due to enhanced aquifer connectivity/mixing.

Potential impacts were assessed utilising a numerical groundwater model that has simulated the progressive extraction of LW W1-W2. The following sections briefly summarise the groundwater model and recent updates to that model, and then document the predicted effects on the groundwater system.

4.1 GROUNDWATER MODEL DESIGN

An existing numerical groundwater model, as described in HydroSimulations (2018), was utilised to assess impacts due to LW W1-W2. A summary of the model design is included in **Section 4.1.1** below and full details are provided in the HydroSimulations (2018) report.

For the purpose of the LW W1-W2 Extraction Plan, minor updates to the model were conducted, including:

- update to model scenario timing in order to fully capture the extraction and impacts of LW W1-W2 (refer to **Attachment 2**);
- inclusion of surface cracking in TVM package; and
- update to RIV package to include transient stages at four watercourses.

Discussion on each of the updates is included in **Section 4.1.2** to **Section 4.1.4** below.

4.1.1 PREVIOUS GROUNDWATER MODEL (HYDROSIMULATIONS, 2018)

The numerical model utilised to provide estimates of predicted impacts to the groundwater system for this groundwater assessment has been adapted from the model utilised in the Tahmoor South EIS (HydroSimulations, 2018). The Tahmoor South Project is a proposed extension of existing underground coal mining at Tahmoor Mine that was submitted in January 2019 under SSD 17_8445. A groundwater assessment was conducted by HydroSimulations to assess potential groundwater related impacts for the Tahmoor South Project. As part of this assessment a numerical groundwater model was developed, which captured surrounding operations, including LW W1-W2.

The numerical groundwater model was developed by HydroSimulations (2018) using MODFLOW-USG code. The model covers an area of 3,237 km^2 and comprises 16 layers. **Figure 4-1** illustrates the model area and boundary conditions present in the simulation, underlain by the regional geology. A representative cross-section of the model is included in **Figure 4-2** and depicts the model layering in the area surrounding the Western Domain. Layer 1 is present across the full model domain and represented alluvium, basalt as well as surficial sequences of the Wianamatta Formation and Hawkesbury Sandstone. The Bulli Coal Seam is represented as Layer 12, with a mean thickness of 2.2 m. The model was calibrated in steady state and transient modes, with the transient calibration run from 1980 to 2018. Model timing was varied based on mine progression, with most stress periods around 180 days (6 months) in length but do vary from 20 days to over a year.

Conceptual model cross-sections depicting the key stressors prior to and following mining are included in **Figure 4-3** and **Figure 4-4**. The major influences to groundwater flow in the pre-mining scenario are climatic; rainfall, surface water interactions via watercourses, and evapotranspiration. Following mining subsurface fracturing and deformation of the strata associated with mining provide an additional stress to the functioning of the natural groundwater system.

Watercourses were represented in the model using the RIV package, with the width varied for the different watercourses. The river stage height was maintained at a constant level above the riverbed, with a 1 m bed thickness applied. Thirlmere Lakes were represented in the model using the RIV package with the lake stages set at a constant level of between 301.0 mAHD to 304.6 mAHD. Rainfall recharge was varied spatially based on the surface geology, with the recharge rates established through analysis of literature and field data and via steady state calibration. Evaporation was simulated using the EVT package, with the extinction depth set at 1 m in zones of cleared land, and 3 m in areas with trees. The potential rate of evaporation from groundwater was set at 183-365 mm/yr.

Mining was represented in the model using the DRN and TVM packages, and included mining at Tahmoor South, Tahmoor, Tahmoor North, Appin, West Cliff, Tower, Russell Vale, Cordeaux and Dendrobium. A drain conductance of 100 m^2/day was applied for all longwalls, roadways and development headings. The TVM package was utilised to represent changes in hydraulic parameters (hydraulic conductivity and storage) associated with enhanced permeability in the strata overlying the coal seam following mining. The zone of enhanced permeability or 'height of fracturing' was calculated on a cell-by-cell basis using the Tammetta method (2013). The use of the Tammetta method for this purpose is supported by data collected by SCT (SCT, 2014) utilised during calibration, and in addition is the preferred method to represent the fractured zone by the IEPMC (IEPMC, 2018). The hydraulic properties in areas that fell with this enhanced permeability zone were modified from the 'host' or natural values using a 'log-linear function' which was then calibrated to mine inflow and hydraulic heads around the mine.

Figure 4-5 presents a conceptual illustration of the deformation zones commonly observed above longwall panels. The area of connected fracturing above a longwall general exhibits enhanced vertical hydraulic conductivity (Kv) as the overlying strata collapses. The simulated change in Kv, as modelled in HydroSimulations (2018), is displayed on **Figure 4-6**. This exemplifies the departure between the host Kv and post-mining Kv that extend from the coal seam to the height of fracturing. These changes decrease with vertical distance (height) above the coal seam to the upper limit of the estimated height of fracturing. The height of fracturing was simulated through to the Bulgo Sandstone (model layers 5 and 6) over the longwall panels (see **Figure 4-7**).

The HydroSimulations (2018) groundwater model was utilised for the LW W1-W2 Extraction Plan. The model set up is largely the same as was described above, however, there have been several modifications. These modifications are outlined in **Sections 4.1.3** and **4.1.4**. Predictions for the Study area are described in **Section 4.3**.

4.1.2 MODEL SCENARIOS

Three scenarios of the numerical groundwater models were run to assess the influence the extraction of LW W1-W2 will have on the regional groundwater system. **Table 4-1** summarises each of these runs. Model scenario A predicted groundwater response to the proposed extraction of LW W1-W2, while scenario B presents the results for groundwater behaviour without the extraction of LW W1-W2 but including the remainder of the historical and approved Tahmoor Mine. A comparative assessment of the results from each of these model runs isolates the impact of LW W1-W2 on the groundwater system in this region. Model scenario C represents a 'null' scenario, simulating no mining within the model domain. Comparison of scenario A to scenario C allows cumulative impacts to be assessed.

Table 4-1 Groundwater Model Scenarios

SCENARIO	MODEL RUN	RUN DESCRIPTION	HISTORICAL AND APPROVED TAHMOOR LONGWALLS	LW W1-W2 INCLUDED?
A	V4TR052	Full Impact	Yes	Yes
B	V4TR053	Base case	Yes	Not simulated
C	V4TR054	Null	Not simulated	Not simulated

4.1.3 SURFACE CRACKING

In order to provide more accurate representation of subsidence-induced impacts to the groundwater and surface water systems, efforts were made to simulate the changes in hydraulic properties that occur in areas where surface cracking occurs or is likely to occur. As discussed in **Section 4.1.1**, the model utilises the time varying material (TVM) package to simulate changes in hydraulic conductivity and storage and is guided by the data and findings of SCT (2018b). For the numerical model, surface cracking parameters were only calculated in areas overlying the longwall panel. The depth below the surface to where surface cracking extends was calculated as ten times the extraction height of a given longwall. In areas estimated to be affected by surface cracking, the host horizontal and vertical hydraulic conductivity were both multiplied by 10 to represent the enhanced permeability of the fracture zone. The use of these multipliers is supported by a recent investigation into the changed hydraulic properties of sections of Redbank Creek that have experienced surface subsidence (SCT, 2018b).

The change in Kv for areas affected by surface cracking is depicted in **Figure 4-6**. This figure presents a profile of simulated changes in Kv following mining for a model cell within LW W1. The estimated depth of the surface cracking for LW W1-W2 and the main Tahmoor Mine area is presented in **Figure 4-7**. The estimated depth of the SCZ over the mine does not exceed 30 m, with the estimated depth of cracking over LW W1-W2 falling between 17 m and 22 m. The bottom right panel of this figure presents the distance between the estimated SCZ and the height of connected fracture (HoCF). The vertical distance between the SCZ and HoCF over LW W1-W2 is approximately 300 m (294 to 354 m). As a result, it is unlikely that surface to seam connectivity, which is a risk discussed in PSM (2017) and IEPMC (2018), will occur as a result of the extraction of LW W1-W2.

4.1.4 RIV PACKAGE

In the previous model (HydroSimulations, 2018) watercourses were simulated with the MODFLOW River (RIV) package using a single or constant stage height. In order to better capture seasonal flow variations the RIV package was updated to include transient stages for four watercourses adjacent to LW W1-W2 (see **Table 4-2**).

Table 4-2 Watercourses simulated with transient stage

WATERCOURSE NAME	MODEL REACH NUMBER	MULTIPLIER	MEDIAN SIMULATED STAGE HEIGHT
Stonequarry Creek	29	-	0.36
Cedar Creek	30	4.5	1.62
Redbank Creek	31	2.1	0.76
Matthews Creek	32	3.9	1.40

Multipliers developed in relation to Stonequarry Ck stage (station 212053)

Transient river stages were estimated from observed data from the NSW Government monitoring station on Stonequarry Creek (212053) and data collected by Tahmoor Mine at several monitoring locations along Redbank, Cedar, Matthews and Stonequarry Creeks. The government data comprised monthly readings collected from 1990 to April 2019, whereas the data received from Tahmoor only covered the six months preceding and including April 2019. Additional, historic data for Redbank Creek for the period December 2009 to July 2013 was also obtained to provide an indication of water levels prior to fracturing (as described in SCT, 2018b).

Due to the longer period of available data for station 212053 on Stonequarry Creek, stages for each model stress period were calculated using that record. Average stage levels were calculated for model periods that correlated with dates of available data. For those model periods where no data was available, a long-term average was applied. The monitoring data collected by Tahmoor Coal for the four specific creeks was then used to calibrate and calculate an appropriate multiplier for the Stonequarry Creek data. For Redbank Creek, the historic data was used for this purpose to provide a more conservative estimate of impacts that may occur due to the extraction of LW W1-W2. The relevant multiplier and median simulated stage heights for each watercourse is provided in **Table 4-2**. **Figure 4-8** presents the representative stage heights for these watercourses based on the method outlined above.

4.2 MODEL PERFORMANCE

Model performance was assessed against a range of data and these results are summarised and discussed below:

- Modelled Kv and Kh were compared against observed data collected via core testing for Kv and packer testing for Kh, and show that permeability is well-constrained by the range of field data (see **Figure 4-9**);
- Based on comparison to transient groundwater level targets the model had a scaled Root-Mean-Square (sRMS) error of 1.5%, with the mean residual equal to -4.2 m. The overall model mass balance error was 0.07%. These statistics are all considered acceptable, even very good, based on the content of the Australian Groundwater Modelling Guidelines [AGMG] (Barnett et al., 2012);
- **Figure 4-10** presents a graphical comparison or 'scatterplot' of computed and observed groundwater levels alongside the distribution of error in calculated water levels for several key bore groups. Groundwater levels computed in shallower strata perform best when compared to their observed counterparts, with most of these falling within the +/-25 m error margin. Whereas, groundwater levels computed in the Bulli Coal Seam were often higher than those observed. The distribution of groundwater residuals shows that the error is largely within the +/-25 m range;
- Modelled pressure head and vertical water level profiles at bore TBF040c show good correlation to observations made in 2014. This bore is the "HoF borehole" (SCT, 2014). **Figure 4-11** presents these results. The figure shows a good match to the vertical profile of groundwater pressures, indicating that the model does a good job of simulating depressurisation in deeper strata and minimal drawdown above the zone of connected fracturing;
- Hydrographs comparing modelled and observed groundwater levels for the four existing groundwater monitoring locations for LW W1-W2 (TNC036, TNC040, TNC043, P9 (historic)) are presented in **Figure 4-12** to **Figure 4-15**. Under unstressed conditions (pre-mining) the model does not replicate the small difference in vertical head observed at the VWPs. While the model predicts the onset of drawdown due to mining more slowly than occurs in reality, it does capture the overall magnitude of mining-related drawdown. This is particularly obvious in the drawdown simulated in the Bulli Coal Seam and Bulgo Sandstone at bore TNC040 (**Figure 4-13**); and

- Modelled groundwater inflows presented on **Figure 4-16** show good correlation with the observed trend, however, often over-predict the volume of water entering the mine workings. Observed inflow for the available data is on average approximately 3.8 ML/d, with the average for 2018 to present being 3.6 ML/d. Modelled inflows for the same period are 6.2 ML/d and 5.5 ML/d respectively. This provides a more conservative estimate of inflows which is beneficial for licencing of groundwater take.

4.3 POTENTIAL GROUNDWATER IMPACTS

4.3.1 GROUNDWATER TAKE (DIRECT)

The simulated groundwater inflows to LW W1-W2 are presented on **Figure 4-17**. The values represent inflow at the end of each mined panel, and six months after completion of LW W2 (assuming no new mining). The inflow to LW W1-W2 is expected to lie in the range of 0.1 ML/d to 2.2 ML/d, with the greatest inflow predicted during the extraction of LW W1. This generates on average an additional 0.7 ML/d of inflow to the rates predicted for the mine in the scenario without the extraction of LW W1-W2 being simulated.

4.3.2 LOSS OF FLOW IN STREAMS

'Baseflow capture' is the process of inducing leakage from a creek or river into the aquifer via a downward gradient or weakening an upward gradient from the aquifer into the watercourse and thereby reducing the rate at which baseflow occurs.

As surface cracking parameters were employed using the TVM package (see **Section 4.1.3**) the results and impacts described here consider the impacts of subsidence-induced cracking. Subsidence cracking usually results in some loss of surface flow, either baseflow or runoff, over a short section of a watercourse. This process and effects of the baseflow losses reported here are dealt with in HEC (2019).

Table 4-3 presents a summary of the predicted baseflow capture at several creeks relevant to LW W1-W2. The impact in ML/d represents the maximum baseflow impact due to the extraction of LW W1-W2 and due to the cumulative mining activity at Tahmoor Mine. The accumulated total at the end of the table represents the total flow loss experienced in Stonequarry Creek when taking into account upstream flow gain. Tahmoor Coal commissioned flow monitoring at watercourses surrounding LW W1-W2 in late 2018. Once more data (>1 year) becomes available this impact can be reassessed.

Table 4-3 Flow depletion at nearby watercourses

WATERCOURSE	LW W1-W2 incremental effect		Tahmoor Coal Mine Cumulative Impacts	
	Best estimate Max. (ML/d)	Best estimate Max. (ML/yr)	Best estimate Max. (ML/d)	Best estimate Max. (ML/yr)
Matthews Creek	-	-	0.033	12
Cedar Creek	-	-	0.017	6
Redbank Creek	0.0015	0.5	0.049	18
Stonequarry Creek	-	-	0.042	15
Stonequarry Creek accumulated total	-0.004	-1.4	0.230	52

T:\TAHMOOR\Model\Processing\ZonBud\LW_W1-W2\Riv&Lake_BaseflowCapture_4TR052-53-54_cumulative_assessment.xlsx

4.3.3 GROUNDWATER DRAWDOWN

Groundwater drawdown refers the lowering of the groundwater table in a given aquifer. This mechanism is a typical response to aquifers that are associated with mining, as the groundwater within workings is removed to aid extraction. Following the cessation of mining recovery of groundwater levels can occur.

An assessment of the extent of groundwater drawdown was conducted for this groundwater technical report in order to understand the extent of incremental lowering of the regional groundwater table that will occur as a result of the extraction of LW W1-W2. This information will assist in the prediction of potential impacts to 'water supply works', as required by the AI Policy, as well as providing a basis to develop groundwater triggers.

Figure 4-18 illustrates the incremental depressurisation of the strata surrounding LW W1-W2 throughout the modelled scenario. It presents a cross-section of 'pressure-head' through model row 196 which passes through LW W1-W2 from east to west. The upper cross-section shows pre-mining conditions in the region and shows pressure head increasing with depth. The middle cross-section depicts depressurisation due to the extraction of LW W1-W2. The depressurisation is localised to the longwalls and shows complete depressurisation in and above the Bulli Coal Seam, consistent with the conceptual model. The extraction of LW W1-W2 has little to no effect on the regional pressure head, especially in comparison to the depressurisation simulated to have occurred at the BSO Mine to the east of LW W1-W2. The final cross-section represents conditions under long-term recovery, which are largely the same as those presented for pre-mining conditions.

A plan view of drawdown is presented in **Figure 4-19**, showing drawdown predicted to occur at the water table and within the Bulli Coal Seam due to the extraction of LW W1-W2. Unlike the depressurisation presented in **Figure 4-18** this shows only incremental drawdown due LW W1-W2. The incremental water table drawdown is expected to be contained to the area within and adjacent (maximum distance of 180 m from edge of panel) to LW W1-W2 and is within the range of 2 to 10 m.

Drawdown within the Bulli Coal Seam (**Figure 4-19**) is predicted to occur radially around LW W1-W2. Maximum drawdown of 400-500 m is predicted to occur within the longwall footprint. The 2 m drawdown contour extends approximately 1 km beyond the edge of LW W1-W2.

Figure 4-20 to **Figure 4-22** present hydrographs of simulated groundwater levels for each model scenario (see **Table 4-1**) to show the relative impact of LW W1-W2. The hydrographs were produced using real bore locations, however, the bores used do not necessarily intersect all stratigraphic units presented in the figure. These were developed to provide a guide of the expected drawdown expected in the lower and upper Hawkesbury Sandstone, the Bulgo Sandstone and the Bulli Coal Seam at these locations.

Figure 4-20 displays drawdown at each of these model layers as predicted for the centre of LW W2. Unsurprisingly, drawdown is expected to be greatest in this location with the extraction of LW W1-W2 allowing an additional ~410 m of drawdown in the Bulli Coal Seam, 70 m in the Bulgo Sandstone. Marginal drawdown (<1 m) is predicted for the lower Hawkesbury Sandstone (model layer 3) compared to the ~5 m predicted to occur in the upper Hawkesbury (model layer 1). This difference is likely to be a result of the changes in hydraulic parameters simulated to occur as a result of surface cracking in the upper layer.

TNC040 (see **Figure 3-12**) is used to represent the drawdown due to the extraction of LW W1-W2 in areas to the south-east of the longwalls on **Figure 4-21**. This location is adjacent to longwalls recently extracted by Tahmoor (LW31 and 32) and therefore shows mining related drawdown from these longwalls. As such, the additional drawdown predicted to occur in this area as a result of mining at LW W1-W2 is not as great as was presented in the previous figure. The additional drawdown for the Bulgo Sandstone and Bulli Coal Seam is estimated to be approximately 18 and 35 m respectively. Simulated water levels in both model scenarios for the Hawkesbury Sandstone are predicted to the almost the same, with <0.5 m difference in simulated heads for model layers 1 and 3 in this area.

Figure 4-22 represents predicted drawdown for the area north of LW W1-W2. The bore used for these hydrographs is GW072402 which is located between Stonequarry and Cedar Creeks (see **Figure 3-12**). As with the previous figure (**Figure 4-21**), mining in other areas of Tahmoor is predicted to generate regional drawdown in this area. The extraction of LW W1-W2 is expected to have no additional impact on the upper model layers representing the Hawkesbury Sandstone. An additional ~20 m of drawdown is predicted to occur in the Bulgo Sandstone, and a further ~100 m in the Bulli Coal Seam.

The results from these figures indicate that the immediate vicinity of LW W1-W2 will experience the greatest impacts from the extraction of these longwalls.

Private bores

In order to predict potential impacts to the relevant private bores (see **Section 3.5.3**) an assessment of maximum predicted drawdown was made. The AI Policy (NSW Government, 2012) established a 2 m threshold as the maximum allowable drawdown for 'water supply works' in order to satisfy the considerations for 'minimal harm'. The mean and maximum predicted drawdown for the private bores within the vicinity of LW W1-W2 are presented in **Table 4-4**. It should be noted that the maximum drawdown value represents the greatest drawdown at any period within the model. The cumulative drawdown is also presented and represents the maximum drawdown predicted to occur due to the extraction of LW W1-W2 in addition to the drawdown predicted to occur as a result of historic and approved mining for the Tahmoor Mine.

Table 4-4 Maximum predicted drawdown at private groundwater bores due to LW W1-W2

BORE	EASTING	NORTHING	TOTAL BORE DEPTH (m)	MODEL LAYER	MAX. INCREMENTAL DDN (m)	MEAN INCREMENTAL DDN (m)	MAX. CUMULATIVE DDN (m)
GW024750*	277098	6216403	11.9	1	1.0	<0.1	8.4
GW035844	277150	6215294	45.7	1	0.1	<0.1	1.5
GW064469	277346	6215669	91.0	1	0.1	<0.1	1.2
GW072402	277685	6216905	42.0	2	1.5	0.1	3.6
GW104090	278208	6215913	150.5	3	2.9	0.4	7.6
GW105228	278451	6216837	63.0	2	1.8	0.2	3.7
GW105467	244279	6215251	120.0	2	1.3	0.4	4.4
GW105546	276997	6215723	163.0	3	1.1	<0.1	4.9

DDN = groundwater drawdown. Red highlighted cells are those where predicted maximum drawdown >2 m.
*bore has failed (collapsed) in an event unrelated to mining.

As shown in **Table 4-4**, maximum incremental (due to the extraction LW W1-W2) drawdown in excess of 2 m is only predicted to occur at bore GW104090, with a maximum incremental drawdown of 2.9 m. This is expected as this bore directly overlies LW W2. The remaining bores are all predicted to experience a maximum incremental drawdown within the range of 0.1 to 1.8 m.

The cumulative impacts of LW W1-W2 and current and historic mining at the Tahmoor Mine are predicted to cause drawdown in excess of 2 m at six of the eight private bores listed in **Table 4-4**. The greatest predicted drawdown is expected to occur at GW024750 and GW104090, with estimates of 8.4 and 7.6 m respectively. However, drawdown experienced at

GW024750 will be inconsequential because the borehole has collapsed. The four remaining bores with drawdown in excess of 2 m are predicted to experience drawdown in the range of approximately 3.5 to 5 m.

The extent of predicted drawdown at these bores is consistent with the drawdown due to previous mining activity at Tahmoor at other shallow bores (e.g. P1-P5 bores), with drawdown being the greatest at bores directly overlying mine workings, and typically about 1 m at shallow bores located away from the longwall footprint. Refer back to **Section 3.5.5** for a complete summary of these trends.

Due to the high density of watercourses in this region it is possible that the simulation of watercourses using the RIV package and the applied river stage may affect predicted drawdown in areas near to watercourses. As such, experienced drawdown, particularly in during drier climatic periods, may be greater than the predictions presented here. For this reason, on-going monitoring of shallow groundwater levels is critical, as outlined in **Section 6.1.1**.

Tahmoor Coal have committed to "make good" provisions for any groundwater users shown to be adversely affected by mine operations and associated impacts.

5 MANAGEMENT, MONITORING AND EVALUATION

In accordance with the requirements set out in **Table 2-1**, and to monitor and manage the potential impacts to groundwater as outlined in **Section 4.3** above, the following monitoring program will be undertaken.

5.1 GROUNDWATER MANAGEMENT PROGRAM

The following sub-headings are based on the requirements in **Table 2-1**.

5.1.1 SPRINGS AND GROUNDWATER DEPENDENT ECOSYSTEMS (GDES)

The nearest High Priority GDEs are the Thirlmere Lakes, located 5 km from the Western Domain longwalls. Monitoring via NSW government bores and surface water gauges is on-going. No other High Priority GDEs are relevant (near to) to Tahmoor Mine.

As stated previously, there are no springs in the vicinity of LW W1-W2 or the surrounding watercourses. Therefore, monitoring and management of such features is currently unnecessary.

5.1.2 GROUNDWATER INFLOW

At Tahmoor Mine, groundwater inflow is calculated via a water balance including groundwater pump-out, potable water pumped in, water retained in coal and other components. This process is recommended to continue for the Western Domain.

5.1.3 PERMEABILITY

Hydraulic conductivity or permeability testing via packer and core testing is conducted at many of the bores drilled at Tahmoor Mine. This practice should continue, and results recorded in a database. This should include a record of whether testing occurs in a 'pre-mining' or 'post-mining' environment, to assist in the understanding of how longwall subsidence affects strata permeability.

In order to gain data on the pre-mining conditions in the strata surrounding LW W1-W2, three bores, with up to ten VWPs in each, are proposed to be installed within the centre of panel and in the chain pillar between the longwalls. These holes will be packer tested prior to mining. It is anticipated that these bores will be installed by the end of 2019, however, this is subject to obtaining Land Access Agreements. Following mining it is proposed that additional holes will be drilled and packer tested to assess permeability.

5.1.4 GROUNDWATER LEVELS AND QUALITY

As discussed in **Section 3.5.4**, there are three existing bores with VWPs (TNC036, TNC040 and TNC043) that are routinely monitored by Tahmoor Coal that will be used to monitor groundwater levels in the aquifers surrounding LW W1-W2. The construction details of these bores were included in **Table 3-2**, and the locations are presented on **Figure 3-12**.The additional groundwater monitoring program, including frequency of monitoring and type of monitoring is included in **Table 5-1**.

Full water quality analysis includes measurement of field parameters (EC and pH) and collection of samples in accordance with industry standards, which will be submitted to a NATA accredited laboratory for analysis of:

- Physical parameters: pH, EC and TDS;
- Major ions: Ca, Cl, K, Na, Mg, F, SO_4;
- Total phosphorus and total nitrogen;

- Total alkalinity as $CaCO_3$, HCO_3, CO_3, DOC; and
- Total and dissolved metals: (Fe, Mn, Cu, Pb, Zn, Ni, Al, As, Se, Li, Sr, Co).

Table 5-1 Groundwater Monitoring Program for LW W1-W2

FEATURE	MONITORING FREQUENCY		
	PRIOR TO MINING	**DURING MINING**	**POST MINING**
Groundwater Quality bores: • P12 • P13 • P14 • P16 • P17	Field water quality (EC, pH) monthly.	Field water quality (EC, pH) monthly.	Field water quality (EC, pH) monthly.
	Laboratory analysis monthly for TDS, Na, K, Ca, Mg, F, Cl, SO_4, HCO_3, $CaCO_3$, CO_3, DOC, Total N, Total P, Fe, Mn, Cu, Pb, Zn, Ni, Al, As, Se, Li, Sr, Co.	Laboratory analysis monthly for TDS, Na, K, Ca, Mg, F, Cl, SO_4, HCO_3, $CaCO_3$, CO_3, DOC, Total N, Total P, Fe, Mn, Cu, Pb, Zn, Ni, Al, As, Se, Li, Sr, Co.	Laboratory analysis monthly for TDS, Na, K, Ca, Mg, F, Cl, SO_4, HCO_3, $CaCO_3$, CO_3, DOC, Total N, Total P, Fe, Mn, Cu, Pb, Zn, Ni, Al, As, Se, Li, Sr, Co.
Groundwater Quality for Private Groundwater Bores: • GW72402, • GW105228, • GW105467, and • GW105546 • Any other private bores where access is negotiated with landholder.	Field water quality (EC, pH) and iron staining. Pre-mining testing completed during bore census (GeoTerra, 2019).	Same as above, on a 6-monthly basis.	Same as above on a 12-monthly basis.
Groundwater Level bores: • P12 • P13 • P14 • P16 • P17	Minimum continuous 24-hourly readings with monthly logger download and dip meter.	Minimum continuous 24-hourly readings with monthly logger download and dip meter.	Minimum continuous 24-hourly readings with monthly logger download and dip meter.
Groundwater Level for Private Groundwater Bores: • GW72402, • GW105228, • GW105467, and • GW105546, • Any other private bores where access is negotiated with landholder.	SWL and yield data. Pre-mining testing completed in bore census (GeoTerra, 2019).	Manual dip on a 6-monthly basis.	Manual dip on a 12-monthly basis.
Groundwater Pressures bores/VWPs: • TNC036; • TNC040; • TNC043; • And 3 additional bores to be drilled (see **Section 5.1.3**)	Minimum continuous 24-hourly readings with monthly logger download.	Minimum continuous 24-hourly readings with monthly logger download.	Minimum continuous 24-hourly readings for minimum period of 12 months after LW W2 completed.

5.1.5 HEIGHT OF GROUNDWATER DEPRESSURISATION

As noted in **Section 5.1.3**, one additional bore (two in total) will be drilled within the longwall footprint of both LW W1 and LW W2. These bores will have piezometers installed under both pre- and post-mining conditions to monitor groundwater depressurisation in the subsurface and will be used to assess or verify predictions. This is consistent with guidance by IEPMC (2018).

Additionally, a bore will be drilled above the chain pillar to monitor depressurisation between the panels.

5.2 VERIFY MODEL PREDICTIONS

Groundwater monitoring results will be compared to groundwater model predictions on an annual basis to compare actual and predicted groundwater levels and/or drawdowns (e.g. height of depressuriation, as in **Section 5.1.5**) and groundwater inflows to the mine.

5.3 GROUNDWATER BASELINE MONITORING TO SUPPORT FUTURE EXTRACTION PLANS

As indicated in **Table 5-1** a period of post-mining monitoring is to occur for all monitoring bores of interest. This is to ensure that any changes to conditions at these bores are continually monitored while also providing baseline data to support future groundwater extraction plans, both in terms of the conceptual understanding of the effects of longwall mining (e.g. height of fracturing and depressurisation) and improving confidence in the ability to simulate these in numerical models.

6 TRIGGER ACTION RESPONSE PLAN - GROUNDWATER

A Trigger Action Response Plan (TARP) has been developed to outline the appropriate actions to monitor and manage any potential subsidence and/or drawdown related impacts that may result as a result of extraction of LW W1-W2.

6.1.1 GROUNDWATER LEVEL AND QUALITY EFFECTS

TARPs have been developed based on the groundwater management program outlined in **Section 5.1**, and describe necessary responses for exceedances in groundwater quality and groundwater level triggers at 'P' bores, as well as exceedance of groundwater pressure triggers developed for VWPs. **Table 6-1** to **Table 6-4** below detail the impact assessment trigger criteria and the appropriate action plan to be enacted should a trigger exceedance occur.

Triggers were developed following an assessment of available baseline data. Water level triggers were developed based on the maximum observed drawdown for VWPs TNC036, TNC040, and TNC043, as well as bore P9. Although drilling of the proposed 'P' bores was not complete at the time of writing and thus no baseline data pertaining to water levels and quality is available, triggers were developed based on data from the four aforementioned bores as well as the existing suite of 'P' bore (P1 to P8, refer to **Figure 3-12** for locations). Historical data indicated that significant mining-related drawdown is typical in strata deeper than 200 mBG, and drawdown is less severe and less persistent in strata shallower than 200 mBG. Therefore, it was assumed that any effect to water levels above this depth could lead to greater impacts than predicted. Climatic variations have not caused reductions in groundwater levels at shallow open-standpipe bores in excess of 2 m. Differences at VWPs observed due to climate, however, were observed to cause reductions in water levels of up to 5 m. Therefore, a water level reduction of greater than 2 m for shallow standpipe bores and 5 m for shallow VWP loggers for a period beyond 6 months was considered to be a possible indicator of greater than predicted impacts to groundwater.

For monitoring bores located at depths greater than 200 m groundwater monitoring results will be compared to groundwater model predictions on an annual basis to compare actual groundwater levels with predictions. In the event that monitoring reports suggest divergence from the predicted trends (i.e. from numerical groundwater modelling predictions), the TARP as outlined in **Table 6-4** will be implemented. Currently, this TARP has only been developed for VWPs TNC040 and TNC043. TNC036 has been excluded from this TARP as the data collected from lower stratigraphies is does not appear to be reliable. This is exemplified by groundwater levels collected at the 299 m Bulgo Sandstone logger, which according to collected data sit around 400 mAHD, approximately 160 m above the ground surface at this point. This TARP also excludes loggers located in the Bulli Coal Seam on the basis that as this is the target coal seam, impacts are expected. Additionally, there are no groundwater users of this aquifer (environmental or anthropogenic) that warrant the need to investigate head changes in this unit. However, monitoring should continue and be assessed for all VWP loggers regardless of their inclusion in the TARP.

6.1.2 LICENSED GROUNDWATER USERS

Initial monitoring of licensed groundwater user bores was undertaken in the bore census conducted by GeoTerra (2019). Monitoring of water levels and field sampling of water quality parameters is proposed to be undertaken on a six-monthly basis during the extraction of LW W1-W2, and on an annual basis following mining.

Monitoring of water levels at neighbouring users should ensure, where possible, that 'resting' water levels are tested.

Should private groundwater users be impacted by mining activity the appropriate make good provisions will be enacted. These are currently defined in Sections 7.1 and 7.2 of the Tahmoor Coal Groundwater Management Plan (GeoTerra, 2015), and this document should be referred to for a full definition of the make good provisions that apply to subsidence related impacts to private bore groundwater yield and quality. A summary of these provisions is included below.

Should there be a reduction in the available yield at a private bore due to subsidence related impacts Tahmoor Coal is required to provide an alternative water supply until the bore recovers. If the bore does not recover, remediation measures including but not limited to the establishment of a new bore, will be carried out. If drawdown in the bore exceeds 10 m over a period of 2 months as a result of subsidence it is outlined that negotiations will be undertaken between the mine, landowner and Mine Subsidence Board to identify one or more appropriate actions outlined in the Groundwater Management Plan for the remediation of the bore.

Should the private bore experience an adverse change in water quality (particularly salinity or iron) that is determined to be a result of mining-related subsidence the mine will enter into negotiations with the landowner in order to formulate a remediation agreement. This remediation may consider one or all of the three measures outlined in the Groundwater Management Plan which involve remediation of the bore, providing an alternate water source or compensation.

Table 6-1 Trigger Action Response Plan – Groundwater Quality Bores P12, P13, P14, P16 and P17 and private groundwater bores

Feature	Methodology and relevant monitoring	Management		
		Trigger	**Action**	**Response**
Groundwater Quality at monitoring bores and private groundwater bores.	**GROUNDWATER QUALITY – Monitoring bores** **LOCATIONS** - Groundwater bores P12, P13, P14, P16, P17 (refer to Figure 3-3). **PRE-MINING** - Field water quality and laboratory analysis monthly (refer to Section 5.2.1 for parameters). **DURING MINING** - Field water quality and laboratory analysis monthly (refer to Section 5.2.1 for parameters). **POST MINING** - Field water quality and laboratory analysis monthly (refer to Section 5.2.1 for parameters) for a duration to be determined once the data has been evaluated by the Environmental Response Group. **GROUNDWATER QUALITY** – Private groundwater bores **LOCATIONS** - Private groundwater bores GW72402, GW105228, GW105467, and GW105546 and any other private bores where access is negotiated with landholder (refer to Figure 3-3). **PRE-MINING** - Field water quality (EC, pH) and iron staining. Pre-mining testing completed during bore census (GeoTerra, 2019). **DURING MINING** - Field water quality and laboratory analysis on a 6-monthly basis (refer to Section 5.2.1 for parameters). **POST MINING** - Field water quality and laboratory analysis on a 12-monthly basis (refer to Section 5.2.1 for parameters) for a duration to be determined once the data has been	Level 1		
		• No observable changes in salinity, pH or metals outside of the baseline variability.	• Continue monitoring program. • Ongoing review of water quality data.	• No response required.
		Level 2		
		• Short term increase (< 3 months) in salinity and/or metals, or change in pH outside of baseline variability*. The effect does not persist after a significant rainfall recharge event. AND/OR • A similar response is also identified at other monitored bores or private groundwater bores.	• Continue monitoring program. • Ongoing review of water quality data. • Convene Tahmoor Coal Environmental Response Group to review response.	• As defined by the Environmental Response Group.
		Level 3		
		• Short term increase (< 3 months) in salinity and/or metals or change in pH outside of baseline variability*. The effect persists after a significant rainfall recharge event. AND/OR • The change in water quality is determined not to be controlled by climatic or anthropogenic factors.	• Continue monitoring program. • Ongoing review of water quality data. • Conduct review of data to confirm whether water level reduction is not caused by climatic or anthropogenic impacts. • Convene Tahmoor Coal Environmental Response Group to review response.	• As defined by the Environmental Response Group. • Consider increasing monitoring frequency at monitoring bores where Level 3 has been reached to fortnightly, and private groundwater bores where Level 3 has been reached to a more regular timeframe than ordinarily monitored as per negotiations with the landholder. Consider increasing review of data to fortnightly.
		Level 4		
		• Increase in salinity and/or metals or change in pH outside of baseline	• Continue monitoring and review as per monitoring program or at revised	• Report to DPIE within 7 days of investigation completion

	evaluated by the Environmental Response Group.	variability* with the effect persisting for greater than 3 months or after a significant rainfall recharge event. AND • The change in water quality is determined not to be controlled by climatic or anthropogenic factors.	frequency decided under Level 3 TARP response. • Convene Tahmoor Coal Environmental Response Group to undertake an investigation to assess whether change in behaviour is related to LW W1-W2 mining effects.	(according to Table 6-1 of the Extraction Plan Main Document). • For monitoring bores: If it is concluded that there has been a mining-related impact, then implement a corrective management action plan for the site in accordance with a timeframe as recommended by the Environmental Response Group in consultation with the Resources Regulator. • For private groundwater bores: If it is concluded that there has been a mining-related impact, then implement a corrective management action plan for the bore in accordance with the make good provisions (Section 6.2.4 of the Water Management Plan) in consultation with the affected landholder.
* Baseline variability is to be defined as soon as practicable after the commencement of extraction in the Western Domain using representative pre-mining data collected at each bore.				

Table 6-2 Trigger Action Response Plan – Groundwater Levels P12, P13, P14, P16 and P17 and private groundwater bores

Feature	Methodology and relevant monitoring	Management		
		Trigger	**Action**	**Response**
Groundwater Levels at monitoring bores and private groundwater bores.	**GROUNDWATER LEVEL – Monitoring bores** **LOCATIONS** - Groundwater bores P12, P13, P14, P16, P17 (refer to Figure 3-3). **PRE-MINING** - Minimum continuous 24-hourly readings with monthly logger download and dip meter. **DURING MINING** - Minimum continuous 24-hourly readings with monthly logger download and dip meter. **POST MINING** - Minimum continuous 24-hourly readings With monthly logger downloaded and dip meter for a duration to be determined once the data has been evaluated by the Environmental Response Group.	Level 1		
		• Groundwater level remains consistent with baseline variability and/ pre-mining trends with reductions in groundwater level not persisting after significant rainfall recharge events	• Continue monitoring program. • Ongoing review of water level data.	• No response required
		Level 2		
		• Up to 2 m water level reduction over a period of up to 3 months following the commencement of extraction at LW W1. Groundwater level rise in response to significant rainfall recharge event is observed. AND/OR • The reduction in water level is determined to be controlled by climatic factors or local bore usage for private water supply bores.	• Continue monitoring program. • Ongoing review of water level data. • Convene Tahmoor Coal Environmental Response Group to review response.	• As defined by the Environmental Response Group.
	GROUNDWATER LEVEL – Private groundwater bores **LOCATIONS** - Private groundwater bores GW72402, GW105228, GW105467, and GW105546 and any other private bores where access is negotiated with landholder (refer to Figure 3-3). **PRE-MINING** - SWL and yield data. Pre-mining testing completed in bore census (GeoTerra, 2019) **DURING MINING** - Manual dip on a 6-monthly basis.	Level 3		
		• Up to 2 m water level reduction over a period of up to 3-months following the commencement of extraction at LW W1. Negligible groundwater level rise in response to a significant rainfall recharge event. AND/OR • The reduction in water level is determined not to be controlled by climatic or external anthropogenic factors.	• Continue monitoring program. • Ongoing review of water level data. • Conduct review of data to confirm whether water level reduction is not caused by climatic or anthropogenic impacts. • Convene Tahmoor Coal Environmental Response Group to review response.	• As defined by the Environmental Response Group. • Consider increasing monitoring frequency at monitoring bores where Level 3 has been reached to fortnightly, and private groundwater bores where Level 3 has been reached to a more regular timeframe than ordinarily monitored as per negotiations with the landholder. Consider increasing review frequency to fortnightly.
		Level 4		

	POST MINING - Manual dip on a 12-monthly basis for a duration to be determined once the data has been evaluated by the Environmental Response Group.	• Greater than 2 m water level reduction for a period greater than 3 months. AND • Water level (for a specific depressurisation event) does not return to within 1 m of the pre 'event' level (or trend occurring prior to the 'event') after 6 months of the 'event'. AND • The reduction in water level is determined not to be controlled by climatic or anthropogenic factors.	• Continue monitoring and review as per monitoring program or at revised frequency decided under Level 3 TARP response. • Convene Tahmoor Coal Environmental Response Group to undertake an investigation to assess whether change in behaviour is related to LW W1-W2 mining effects. •	• Report to DPIE within 7 days of investigation completion (according to Table 6-1 of the Extraction Plan Main Document). • For monitoring bores: If it is concluded that there has been a mining-related impact, then implement a corrective management action plan for the site in accordance with a timeframe as recommended by the Environmental Response Group in consultation with the Resources Regulator. • For private groundwater bores: If it is concluded that there has been a mining-related impact, then implement a corrective management action plan for the bore in accordance with the make good provisions (Section 6.2.4 of the Water Management Plan) in consultation with the affected landholder.

Table 6-3 Trigger Action Response Plan – Groundwater Pressures TNC036, TNC040, TNC043 – SHALLOW

Feature	Methodology and relevant monitoring	Management		
		Trigger	**Action**	**Response**
Shallow Groundwater Pressures at VWPs TNC036, TNC040, and TNC043.	<u>**GROUNDWATER PRESSURE**</u> **LOCATIONS** - Groundwater bores/VWPs TNC36, TNC40, TNC43 (refer to Figure 3-3) and proposed additional bore to be drilled (refer to Section 5.2.2). **PRE-MINING** - Minimum continuous 24-hourly readings with monthly logger download. **DURING MINING** - Minimum continuous 24-hourly readings with monthly logger download. **POST MINING** - Minimum continuous 24-hourly readings with monthly logger downloaded for a duration to be determined once the data has been evaluated by the Environmental Response Group.	Level 1		
		• No observable mining induced change at VWP intakes located at or above 200 m depth.	• Continue monitoring program. • Ongoing review of water level data.	• No response required.
		Level 2		
		• Up to 5 m water level reduction in VWP intakes located at or above (i.e. shallower than) 200 m depth over a period of up to 3 months following the commencement of extraction at LW W1. Groundwater level rise in response to significant rainfall recharge event is observed. AND/OR • The reduction in water level is determined to be controlled by climatic factors.	• Continue monitoring program. • Ongoing review of water level data. • Convene Tahmoor Coal Environmental Response Group to review response.	• As defined by the Environmental Response Group.
		Level 3		
		• Up to 5 m water level reduction in VWP intakes located at or above (i.e. shallower than) 200 m depth over a period of up to 3-months following the commencement of extraction at LW W1. Negligible response of groundwater level following a significant rainfall recharge event AND/OR • The reduction in water level is determined not to be controlled by climatic or external anthropogenic factors.	• Continue monitoring program • Ongoing review of water level data. • Conduct review of data to confirm whether water level reduction is not caused by climatic or anthropogenic impacts. • Convene Tahmoor Coal Environmental Response Group to review response.	• As defined by the Environmental Response Group. • Consider increasing download frequency at groundwater bores where Level 3 has been reached to a fortnightly basis. Consider increasing review frequency to fortnightly.
		Level 4		
		• Greater than 5 m water level reduction in VWP intakes located at or above (i.e.	• Continue monitoring and review as per monitoring program or at revised	• Report to DPIE within 7 days of investigation completion (according

		shallower than) 200 m depth for a period greater than 3 months. AND • Water level (for a specific depressurisation event) does not return to within 5m of the pre 'event' level (or trend occurring prior to the 'event') after 6 months of the 'event' in VWP intakes located at or above 200 m depth. AND • The reduction in water level is determined not to be controlled by climatic or anthropogenic factors.	frequency decided under Level 3 TARP response. • Convene Tahmoor Coal Environmental Response Group to undertake an investigation to assess whether change in behaviour is related to LW W1-W2 mining effects. •	to Table 6-1 of the Extraction Plan Main Document). • If it is concluded that there has been a mining-related impact, then implement a corrective management action plan in accordance with a timeframe as recommended by the Environmental Response Group in consultation with the Resources Regulator.

Table 6-4 Trigger Action Response Plan – Groundwater Pressures TNC040, TNC043 – DEEP

Feature	Methodology and relevant monitoring	Management		
		Trigger	**Action**	**Response**
Deep Groundwater Pressures at VWPs TNC036, TNC040, and TNC043.	**GROUNDWATER PRESSURE** **LOCATIONS** - Groundwater bores/VWPs TNC36, TNC40, TNC43 (refer to Figure 3-3) and three additional bores to be drilled (refer to Section 5.2.2). **PRE-MINING** - Minimum continuous 24-hourly readings with monthly logger download. **DURING MINING** - Minimum continuous 24-hourly readings with monthly logger download. **POST MINING** - Minimum continuous 24-hourly readings for 12 months after LW W2 completed. Monthly logger downloaded for a duration to be determined once the data has been evaluated by the Environmental Response Group.	Level 1		
		• Observed data does not exceed predicted (modelled) impacts at VWP intakes located below (i.e. deeper than) 200 m depth (excluding those monitoring the Bulli Coal Seam).	• Continue monitoring program. • Ongoing review of water level data.	• No response required.
		Level 2		
		• Calculated or observed drawdown (based on 2009-2015 baseline data) for VWP intakes below 200 m depth (excluding those within the Bulli Coal Seam) is within 30 m of predicted (modelled) drawdown.	• Continue monitoring program. • Ongoing review of water level data. • Convene Tahmoor Coal Environmental Response Group to review response.	• As defined by the Environmental Response Group.
		Level 3		
		• Calculated or observed drawdown (based on 2009-2015 baseline data) for VWP intakes below 200 m depth (excluding those within the Bulli Coal Seam) exceeds predicted (modelled) drawdown by 30 m for a period of 6 months or more.	• Continue monitoring program. • Ongoing review of water level data. • Convene Tahmoor Coal Environmental Response Group to review response.	• As defined by the Environmental Response Group. • Consider increasing download frequency at groundwater bores where Level 3 has been reached to a fortnightly basis. Consider increasing review frequency to fortnightly.
		Level 4		
		• Calculated or observed drawdown (based on 2009-2015 baseline data) for VWP intakes below 200 m depth (excluding those within the Bulli Coal Seam) exceeds predicted (modelled) drawdown by 30 m for a period of 12 months or more.	• Continue monitoring and review as per monitoring program. • Convene Tahmoor Coal Environmental Response Group to undertake an investigation to assess whether change in behaviour is related to LW W1-W2 mining effects.	• Report to DPIE within 7 days of investigation completion (according to Table 6-1 of the Extraction Plan Main Document). • If it is concluded that there has been a mining-related impact, then implement a corrective management action plan in accordance with a timeframe as recommended by the Environmental Response Group in consultation with the Resources Regulator.

7 ADAPTIVE MANAGEMENT STRATEGY FOR GROUNDWATER

The Extraction Plan Approval provided by the DPIE (2019) required that an adaptive management strategy be included as part of the Water Management Plan that “sets quantifiable assessment criteria and provides parameters for when additional setbacks from relevant watercourses should be implemented”. This has been addressed in the Surface Water Technical Report (HEC, 2020). In addition to this requirement, a letter issued by DPIE-Water on the 30th of September 2019 required that this adaptive management strategy include “provision for additional relevant monitoring bores being installed and included in the monitoring network, based on impacts to local resources.”

In order to meet these requirements and support the adaptive management strategy developed for surface water resources, the following describes the adaptive management strategy for groundwater.

The current groundwater monitoring network includes several recently drilled open-standpipe bores that are positioned within the shallow aquifer adjacent to Stonequarry Creek, specifically bores P12, P13, P14, P16 and P17 (see **Figure 3-12** for locations). These bores are positioned progressively along Stonequarry Creek so as to collect data that would determine the downstream distance any potential subsidence related impacts in the watercourse. However, as part of the adaptive management strategy for groundwater it is necessary to have provisions that allow for additional groundwater monitoring bores be drilled should any of the existing bores cease to function, or it is determined that the data being collected is insufficient or not representative of the local conditions.

Identifying potential subsidence related impacts to local water resources and network sufficiency should be made by a suitably qualified person following the assessment of groundwater level data collected at as a result of mining of LW W1. An assessment of pre- and post-mining permeability data collected from LW W1 as outlined in **Section 5.1.5** will also be used in assessing whether the existing monitoring network is sufficient.

Should additional monitoring bores be required it would be necessary to convene with the ERG and suitably qualified professionals as to the best location to install these bores.

8 DOCUMENT INFORMATION

8.1 DEFINITIONS AND ABBREVIATIONS

AI	Aquifer Interference (Policy)
BoM	Bureau of Meteorology
BSO	Bulli Seam Operations mine (Appin)
CCL	Consolidated Coal Lease
DoI Water	NSW Department of Industry Water (formerly Office of Water, DPI Water, CL&W)
DPE	NSW Department of Planning and Environment
EC	electrical conductivity
EIS	environmental impact statement
EPA	Environment Protection Authority
ET	evapotranspiration
GDE	groundwater dependant ecosystems
GMA	groundwater management area
GWL	groundwater level
HoF	height of fracturing (above mined seam)
k	hydraulic conductivity
Kh or Kx	hydraulic conductivity – horizontal
Kv or Kz	hydraulic conductivity – vertical
LDP	licensed discharge point
LW	longwall
mAHD	metres above Australian Height Datum
mBG	metres below ground
mg/L	milligrams per litre (measure of salinity)
ML/d	megalitres per day (megalitre(s) = 1,000,000 litres)
ML	mining lease
mm/a	millimetres per annum
MZ	Management Zone
NRAR	NSW Natural Resources Access Regulator
NSW	New South Wales
OEH	NSW Office of Environment & Heritage
RIV	MODFLOW's River package
ROM	run of mine
SCZ	surface cracking zone
sRMS	scaled Root-Mean-Square
TARP	Trigger Action Response Plan (for underground coal mines)
TDS	total dissolved solids
ToR	Terms of Reference
VWP	Vibrating Wire Piezometers
WAL	Water Access Licence
WSP	Water Sharing Plan

8.2 ATTACHMENTS

- **ATTACHMENT 1** – MINE DEVELOPMENT AND MODEL STRESS PERIOD SCHEDULE.

8.3 REFERENCES

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9 ATTACHMENTS

ATTACHMENT 1 - MINE DEVELOPMENT AND MODEL STRESS PERIOD SCHEDULE

SP	Purpose	START	END	DAYS	Tahmoor	Appin	West Cliff	Tower	Bellambi	Cordeaux	Dendrobium
1	Initialise (SS)			1							
2	HISTORIC	Jan-80	Dec-81	701	100 (pillar)						
3	HISTORIC	Dec-81	Oct-86	1795	100, 200, 300 (pillar)	LW12	LW6				
4	HISTORIC	Nov-86	Mar-87	121	no longwall mining	LW14	LW7				
5	HISTORIC	Mar-87	Aug-87	168	LW1	LW14, LW15	LW7, LW8				
6	HISTORIC	Aug-87	Nov-87	102	LW2	LW15					
7	HISTORIC	Nov-87	Mar-88	115	no longwall mining		LW9				
8	HISTORIC	Mar-88	Nov-88	241	LW3	LW15, LW16	LW10, LW11	LW1			
9	HISTORIC	Nov-88	Feb-89	80	no longwall mining	LW16	LW11				
10	HISTORIC	Feb-89	Jun-89	120	LW4	LW17	LW11, LW12				
11	HISTORIC	Jun-89	Dec-89	182	LW5		LW12, LW13, LW14	LW2			
12	HISTORIC	Dec-89	Apr-90	139	LW6	LW18	LW14, LW15	LW2, LW3			
13	HISTORIC	Apr-90	Jul-90	85	no longwall mining	LW18, LW20A		LW3			
14	HISTORIC	Jul-90	Jan-91	197	LW7	LW20A, LW21A		LW4A, LW4B			
15	HISTORIC	Jan-91	Apr-91	78	no longwall mining	LW21A, LW21B	LW16	LW4B			
16	HISTORIC	Apr-91	Dec-91	233	LW8	LW21B, LW22A	LW17	LW5A, LW5B			
17	HISTORIC	Dec-91	Jul-92	234	LW9	LW22A, LW22B, LW23	LW17, LW18	LW6			
18	HISTORIC	Jul-92	Dec-92	130	LW10A	LW23	LW18				
19	HISTORIC	Dec-92	May-93	164	LW10B	LW23, LW24	LW18, LW19	LW7			
20	HISTORIC	May-93	Sep-93	116	LW11	LW24	LW19, LW20	LW7, LW8			
21	HISTORIC	Sep-93	Jan-94	134		LW24		LW8, LW9			
22	HISTORIC	Jan-94	Jul-94	167	LW12	LW25		LW9			
23	HISTORIC	Jul-94	Nov-94	127	LW13		LW20	LW10			
24	HISTORIC	Nov-94	Jan-95	80	no longwall mining						
25	HISTORIC	Jan-95	Jun-95	136	LW14A	LW26		LW10, LW11			
26	HISTORIC	Jun-95	Oct-95	127	LW14B		LW21	LW11, LW12			
27	HISTORIC	Oct-95	Jun-96	250		LW27	LW21, LW22	LW12, LW13			
28	HISTORIC	Jun-96	Feb-97	226		LW 28A		LW13, LW14			
29	HISTORIC	Feb-97	Jun-97	134	LW15	LW 28B	LW22	LW14			
30	HISTORIC	Jun-97	Sep-97	78		LW29					
31	HISTORIC	Sep-97	May-98	250			LW23	LW14, LW15			
32	HISTORIC	May-98	Oct-98	155	LW16	LW 401		LW15			
33	HISTORIC	Oct-98	Feb-99	121		LW 402	LW24	LW16			
34	HISTORIC	Feb-99	Oct-99	229	LW17		LW24, LW25	LW16, LW17			
35	HISTORIC	Oct-99	Jun-00	263		LW 403	LW25, LW26	LW17			
36	HISTORIC	Jun-00	Nov-00	149	LW18		LW26	LW18			
37	HISTORIC	Nov-00	Oct-01	319		LW 404	LW27	LW18, LW19			
38	HISTORIC	Oct-01	Feb-02	145	LW19		LW27, LW28	LW19			
39	HISTORIC	Feb-02	Sep-02	217		LW 405	LW28	LW19, LW20			
40	HISTORIC	Sep-02	May-03	239	LW20		LW28, LW29	LW20			
41	HISTORIC	May-03	Sep-03	108		LW405, LW406					
42	HISTORIC	Sep-03	May-04	262	LW21	LW406	LW29				
43	HISTORIC	May-04	Aug-04	65	LW22		LW29, LW30				
44	HISTORIC	Aug-04	Feb-05	209		LW407	LW30				
45	HISTORIC	Mar-05	Sep-05	197			LW30, LW31				LW1
46	HISTORIC	Sep-05	Jan-06	140	LW23A	LW408					
47	HISTORIC	Feb-06	Mar-06	49			LW31				
48	HISTORIC	Mar-06	Oct-06	205	LW23B		LW31, LW31A				LW2
49	HISTORIC	Oct-06	Feb-07	139	LW24B	LW 301	LW31A, LW32				
50	HISTORIC	Mar-07	Nov-07	259		LW 302 and Appin West LW701					
51	HISTORIC	Nov-07	Nov-07	16		Appin West LW701					LW3
52	HISTORIC	Dec-07	May-08	161	LW24A						
53	HISTORIC	May-08	Aug-08	104			LW32				LW4
54	HISTORIC	Aug-08	Nov-08	101							
55	HISTORIC	Dec-08	Feb-10	435	LW25	Appin Area7	West Cliff Area5				LW5
56	HISTORIC	Feb-10	Mar-11	414		Appin Area7	West Cliff Area5 - LW34				LW6
57	HISTORIC	Mar-11	May-11	35		Appin Area7	West Cliff Area5 - LW34				no longwall mining
58	HISTORIC	May-11	Feb-12	301	LW26	Appin Area7 - LW704	West Cliff Area5 - LW34				LW7
59	HISTORIC	Feb-12	Oct-12	229		Appin Area7 - LW704	West Cliff Area5 - LW35				LW8
60	HISTORIC	Oct-12	Oct-13	365	LW27	Appin Area7	West Cliff Area5 - LW36				LW8
61	HISTORIC	Oct-13	Apr-14	178		Appin Area7, Appin Area9					LW9
62	HISTORIC	Apr-14	Nov-14	205	LW28	Appin Area7, Appin Area9					
63	HISTORIC	Nov-14	May-15	181	LW28	Appin Area7, Appin Area9					LW10
64	HISTORIC	May-15	Nov-15	184	LW29	Appin Area7, Appin Area9					
65	HISTORIC	Nov-15	Apr-16	169	LW29	Appin Area7, Appin Area9					LW11
66	HISTORIC	Apr-16	Dec-16	246	LW30	Appin Area7, Appin Area9					
67	HISTORIC	Dec-16	Apr-17	116	LW30	Appin Area7, Appin Area9					LW12
68	HISTORIC	Apr-17	Dec-17	249	LW31	Appin Area7, Appin Area9					
69	HISTORIC	Dec-17	Aug-18	243	LW31	Appin Area7, Appin Area9					LW13
70	HISTORIC	Aug-18	Feb-19	165	LW32	Appin Area7, Appin Area9					
71	PREDICTIVE	Feb-19	May-19	91	LW32	Appin Area7, Appin Area9					LW14
72	PREDICTIVE	May-19	Aug-19	90	LW32	Appin Area7, Appin Area9					
73	PREDICTIVE	Aug-19	Oct-19	61		Appin Area7, Appin Area9					LW15
74	PREDICTIVE	Oct-19	Jan-20	106	Western Dom. W1	Appin Area7, Appin Area9					
75	PREDICTIVE	Jan-20	May-20	121	Western Dom. W1	Appin Area7, Appin Area9					LW16
76	PREDICTIVE	May-20	Aug-20	107	Western Dom. W1	Appin Area7, Appin Area9					
77	PREDICTIVE	Aug-20	Dec-20	101	Western Dom. W2	Appin Area7, Appin Area9					LW17
78	PREDICTIVE	Dec-20	Apr-21	113	Western Dom. W2	Appin Area7, Appin Area9					
79	PREDICTIVE	Apr-21	Aug-21	124		Appin Area7, Appin Area9					LW18
80	PREDICTIVE	Aug-21	Dec-21	120		Appin Area7, Appin Area9					LW19
81	PREDICTIVE	Dec-21	May-22	151		Appin Area7, Appin Area9					LW19
82	PREDICTIVE	May-22	Nov-22	184		Appin Area7, Appin Area9					
83	PREDICTIVE	Nov-22	Jun-23	212		Appin Area7, Area9, Area8					
84	PREDICTIVE	Jun-23	Jan-24	233		Appin Area7, Area9, Area8					
85	PREDICTIVE	Jan-24	Jun-24	133		Appin Area7, Appin Area8					
86	PREDICTIVE	Jun-24	Jun-25	373		Appin Area7, Appin Area8					
87	PREDICTIVE	Jun-25	Jun-26	357		Appin Area7, Appin Area8					
88	PREDICTIVE	Jun-26	Jun-27	384		Appin Area7, Appin Area8					
89	PREDICTIVE	Jun-27	Jun-28	347		Appin Area7, Appin Area8					
90	PREDICTIVE	Jun-28	Jan-29	228		Appin Area7, Appin Area8					
91	PREDICTIVE	Jan-29	Jan-30	351		Appin Area8					
92	PREDICTIVE	Jan-30	Jan-31	365		Appin Area8					
93	PREDICTIVE	Jan-31	Jun-31	180		Appin Area8					
94	PREDICTIVE	Jul-31	Jan-32	194		Appin Area8					
95	PREDICTIVE	Jan-32	Jun-33	537		Appin Area8					
96	PREDICTIVE	Jul-33	Jan-34	194		Appin Area8					
97	PREDICTIVE	Jan-34	Jun-34	171		Appin Area8					
98	RECOVERY	Jul-34	Jan-35	214		Appin Area8					
99	RECOVERY	Jan-35	Jun-35	151		Appin Area8					
100	RECOVERY	Jul-35	Dec-35	184		Appin Area8					
101	RECOVERY	Jan-36	Jun-36	182		Appin Area8					
102	RECOVERY	Jul-36	Dec-36	184		Appin Area8					
103	RECOVERY	Jan-37	Jun-37	181		Appin Area8					
104	RECOVERY	Jul-37	Dec-37	184		Appin Area8					
105	RECOVERY	Jan-38	Jun-38	181		Appin Area8					
106	RECOVERY	Jul-38	Dec-38	184		Appin Area8					
107	RECOVERY	Jan-39	Jun-39	181		Appin Area8					
108	RECOVERY	Jul-39	Dec-39	184		Appin Area8 and Appin Area3 Ext.					
109	RECOVERY	Jan-40	Jun-40	182		Appin Area8 and Appin Area3 Ext.					
110	RECOVERY	Jul-40	Dec-40	184		Appin Area3 Ext.					
111	RECOVERY	Jan-41	Dec-41	365							
112	RECOVERY	Jan-42	Dec-42	365							
		cont	cont	cont							
132	RECOVERY	1/01/2300	1/01/2500	73050							

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(note this has been produced with modelling in mind, so dates/longwall/areas are not always completely accurate. It is produced for impact assessment (including cumulative impact), and considered accurate enough for that purpose)

Comparative mine schedule for modelling and impact assessment

FIGURES

1 INTRODUCTION

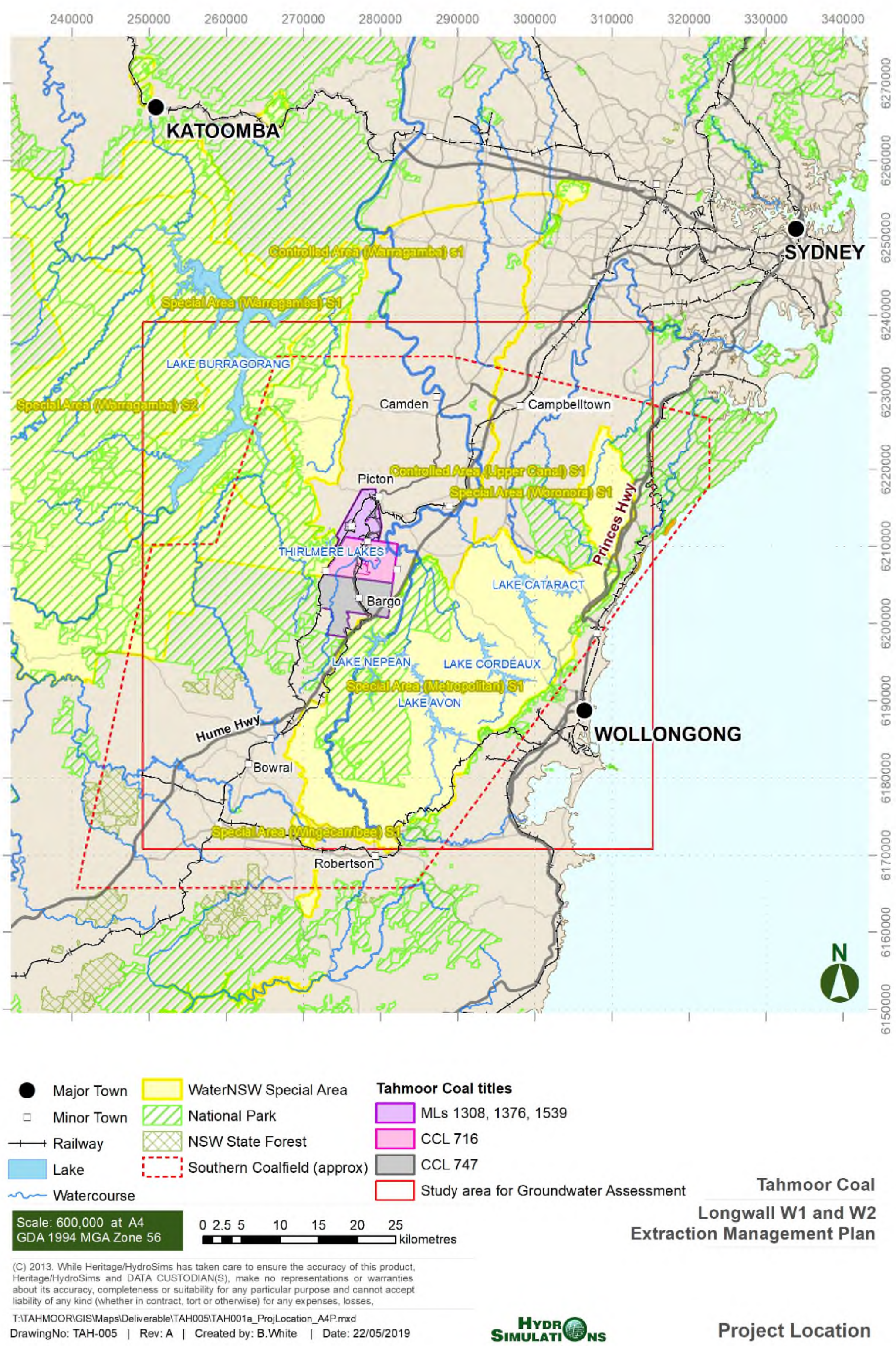

Figure 1-1 Project Location

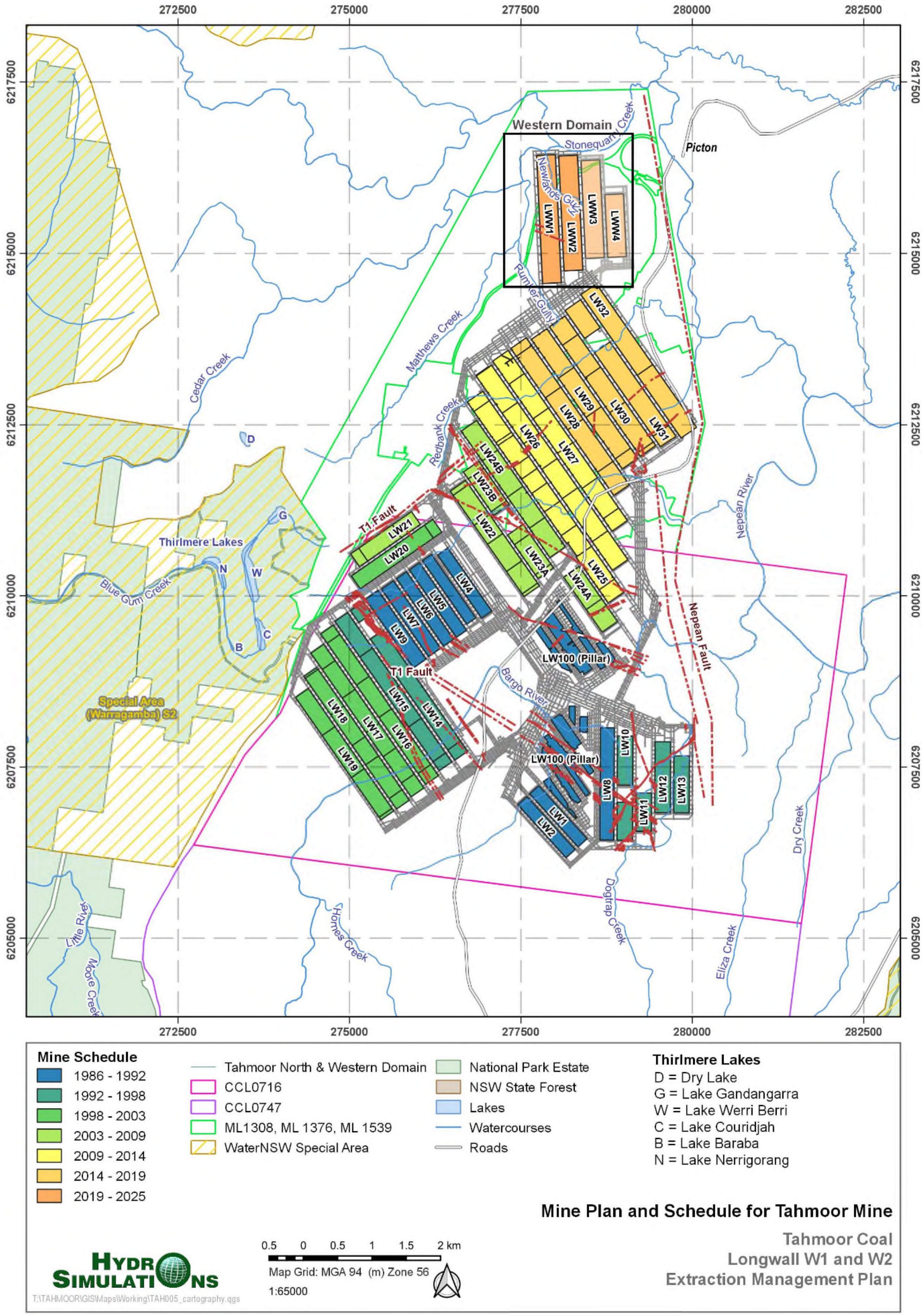

Figure 1-2 Mine plan and extraction schedule

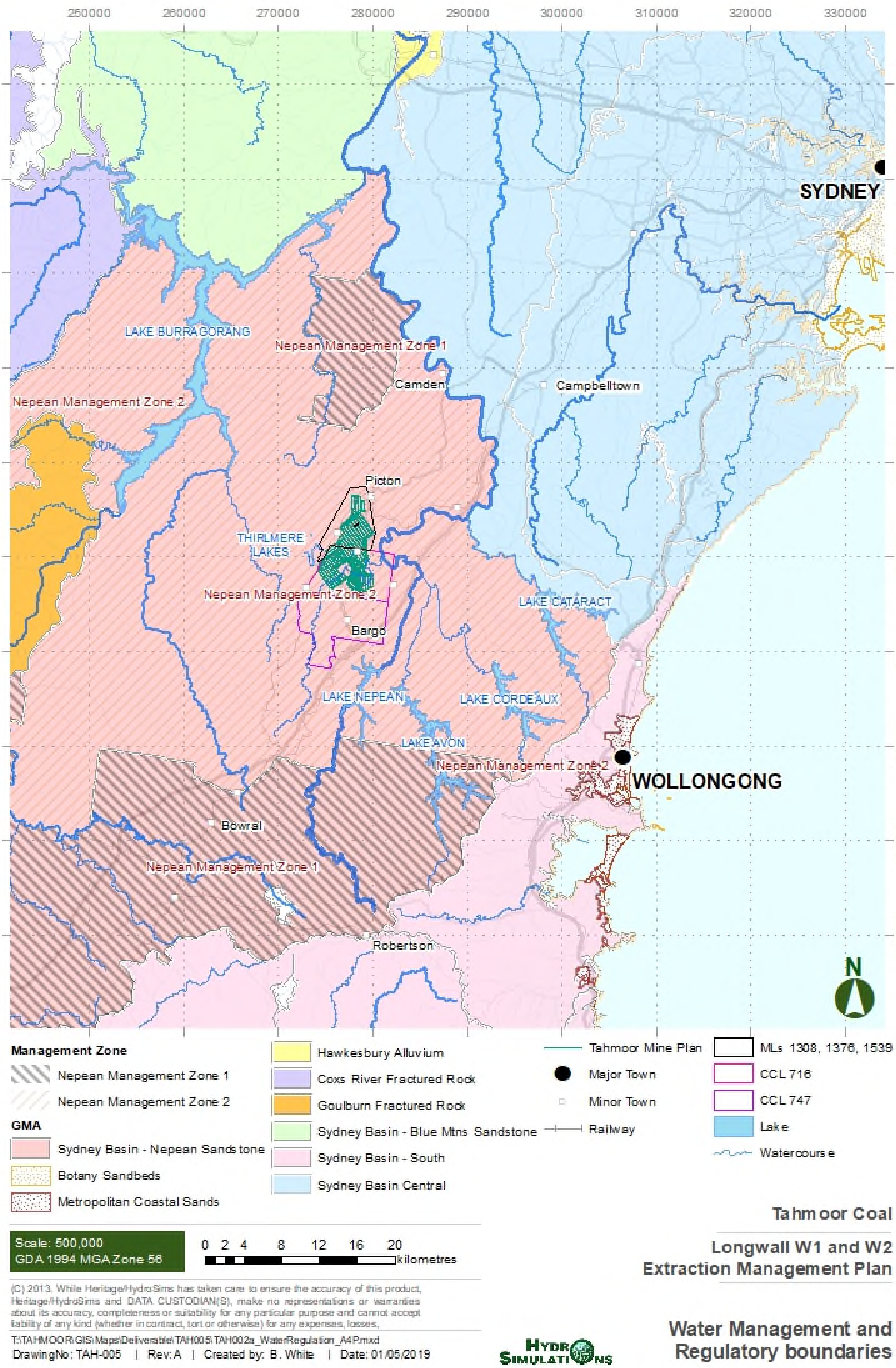

Figure 2-1 Relevant Water Sharing Plan

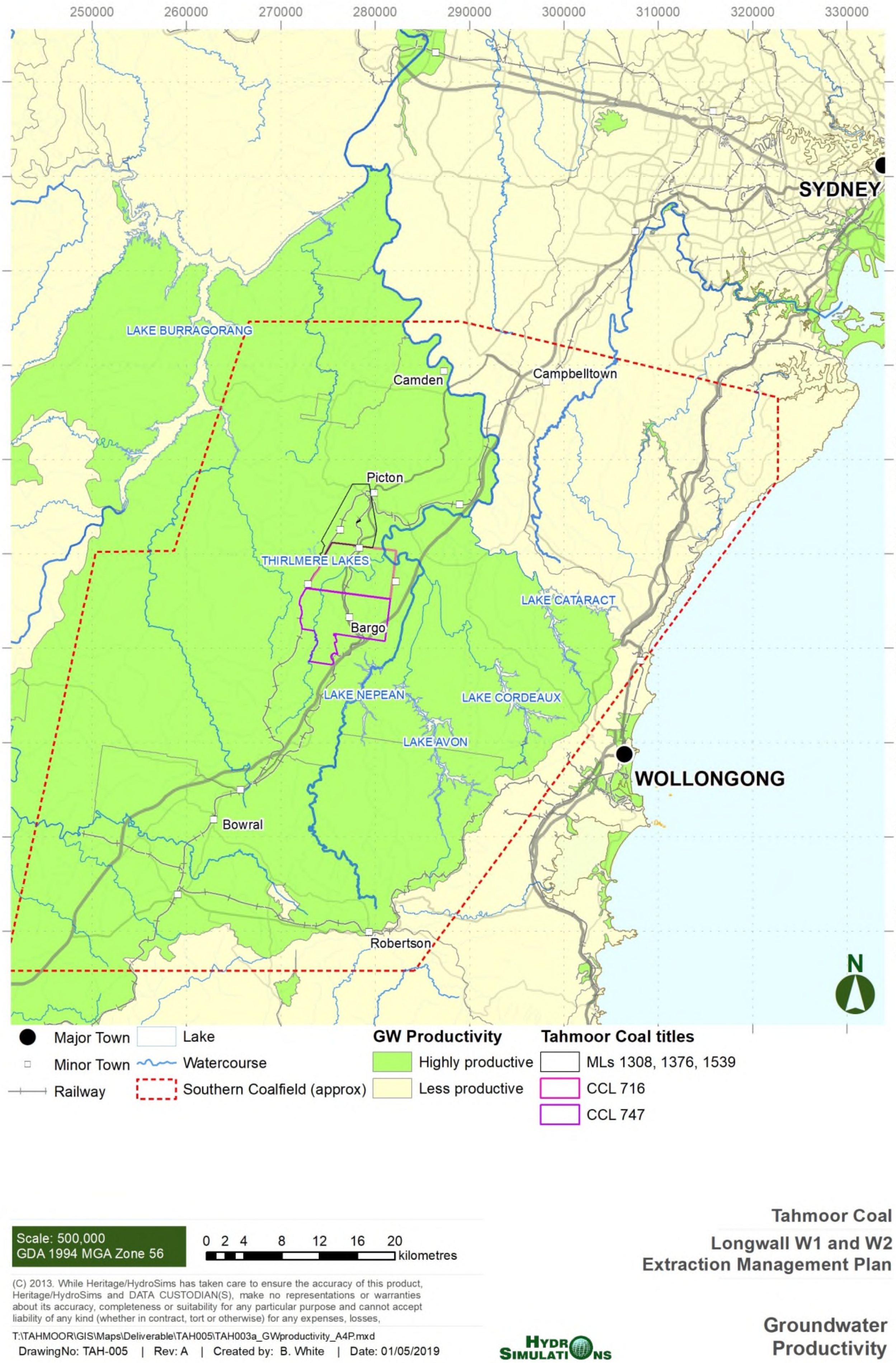

Figure 2-2 Groundwater Productivity

3 EXISITING ENVIRONMENT

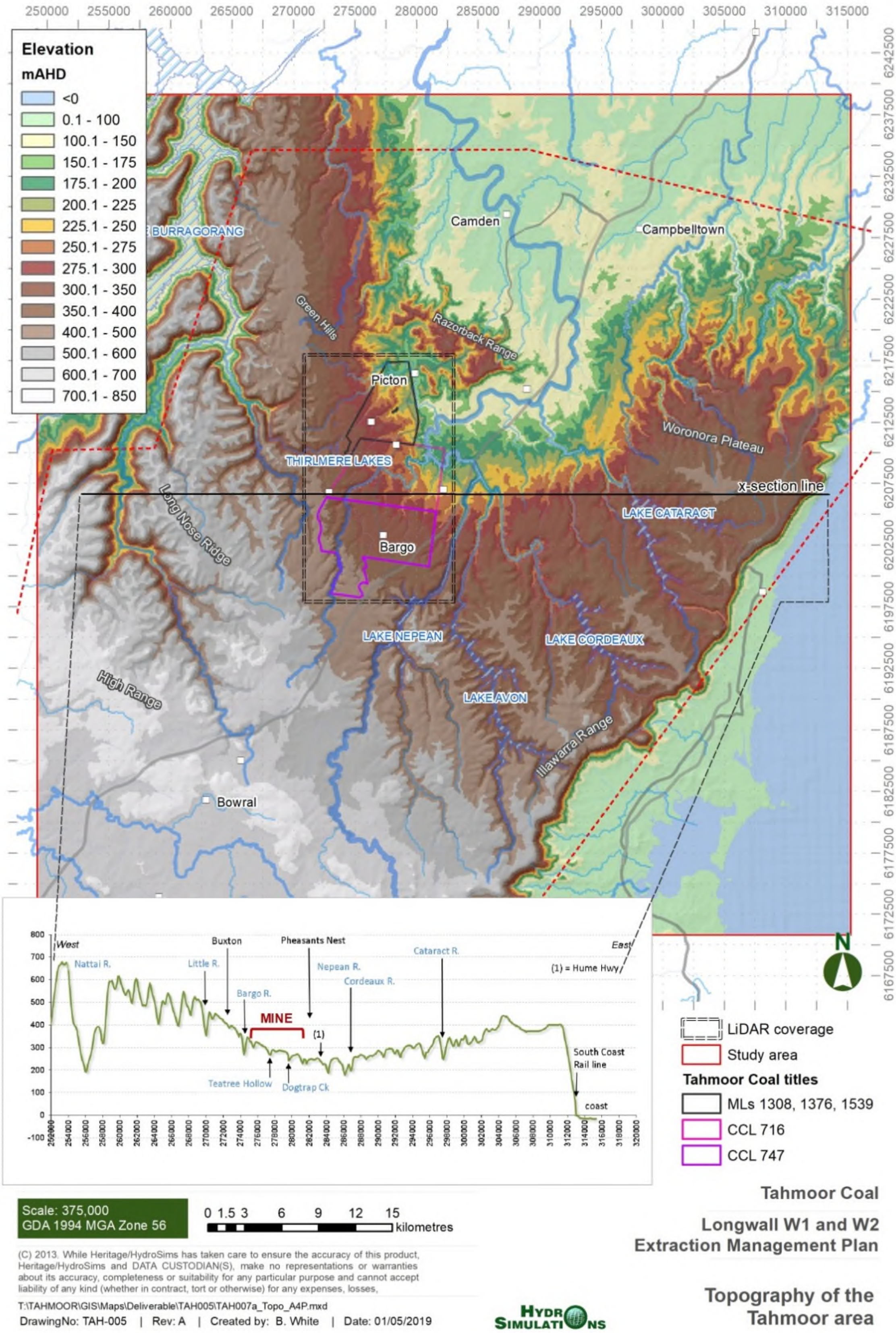

Figure 3-1 Topographic setting

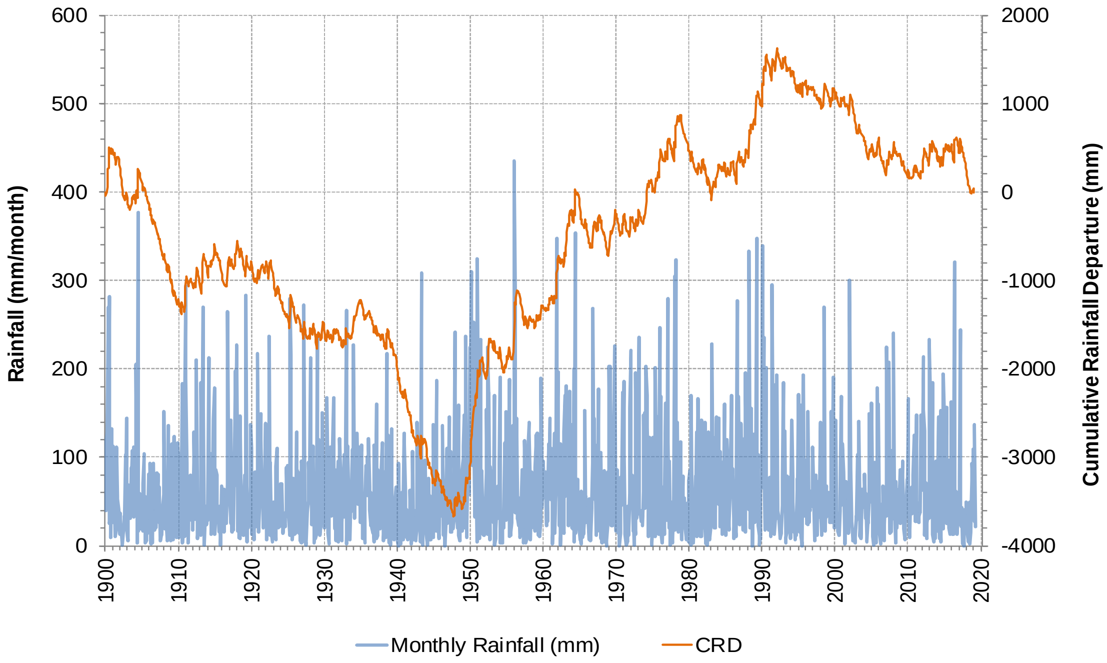

Figure 3-2 Long-term rainfall record and trends

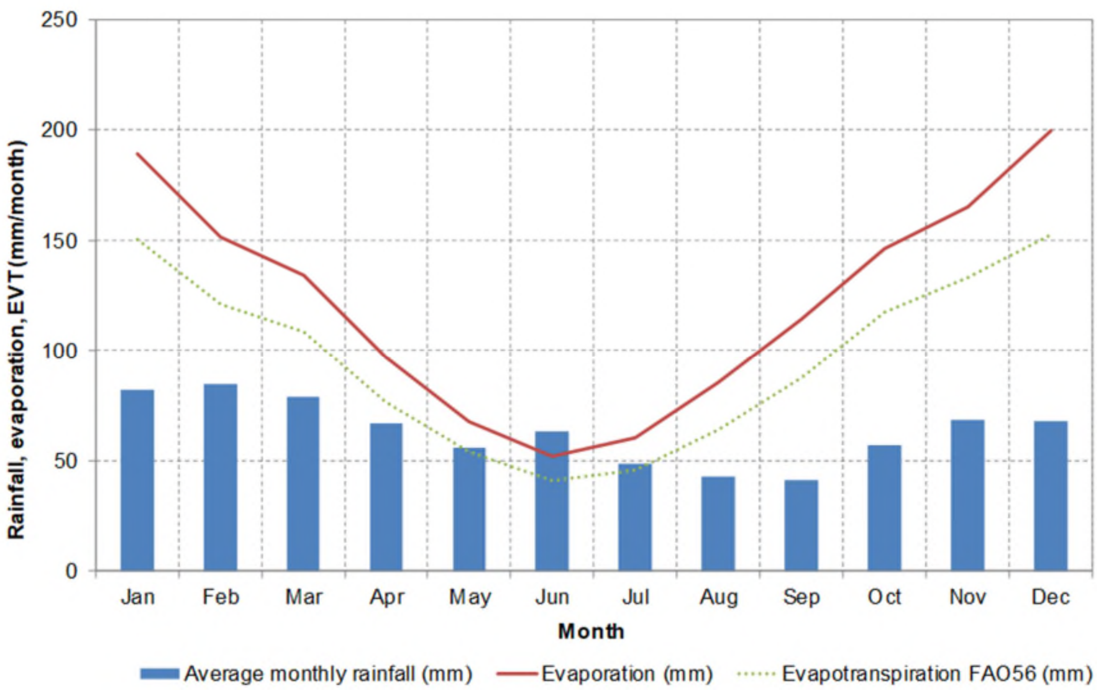

Figure 3-3 Monthly average rainfall and potential evaporation rainfall

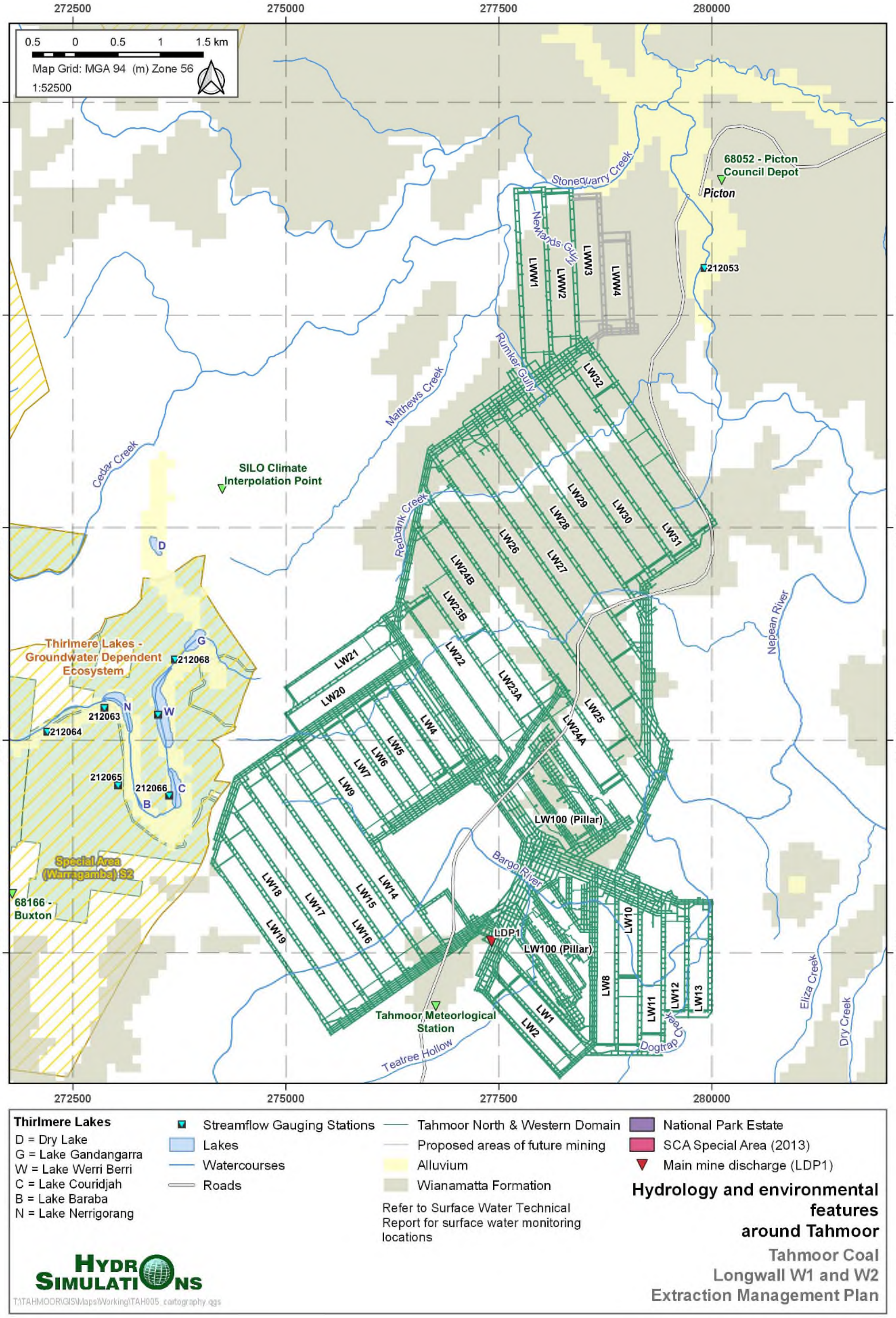

Figure 3-4 Hydrology

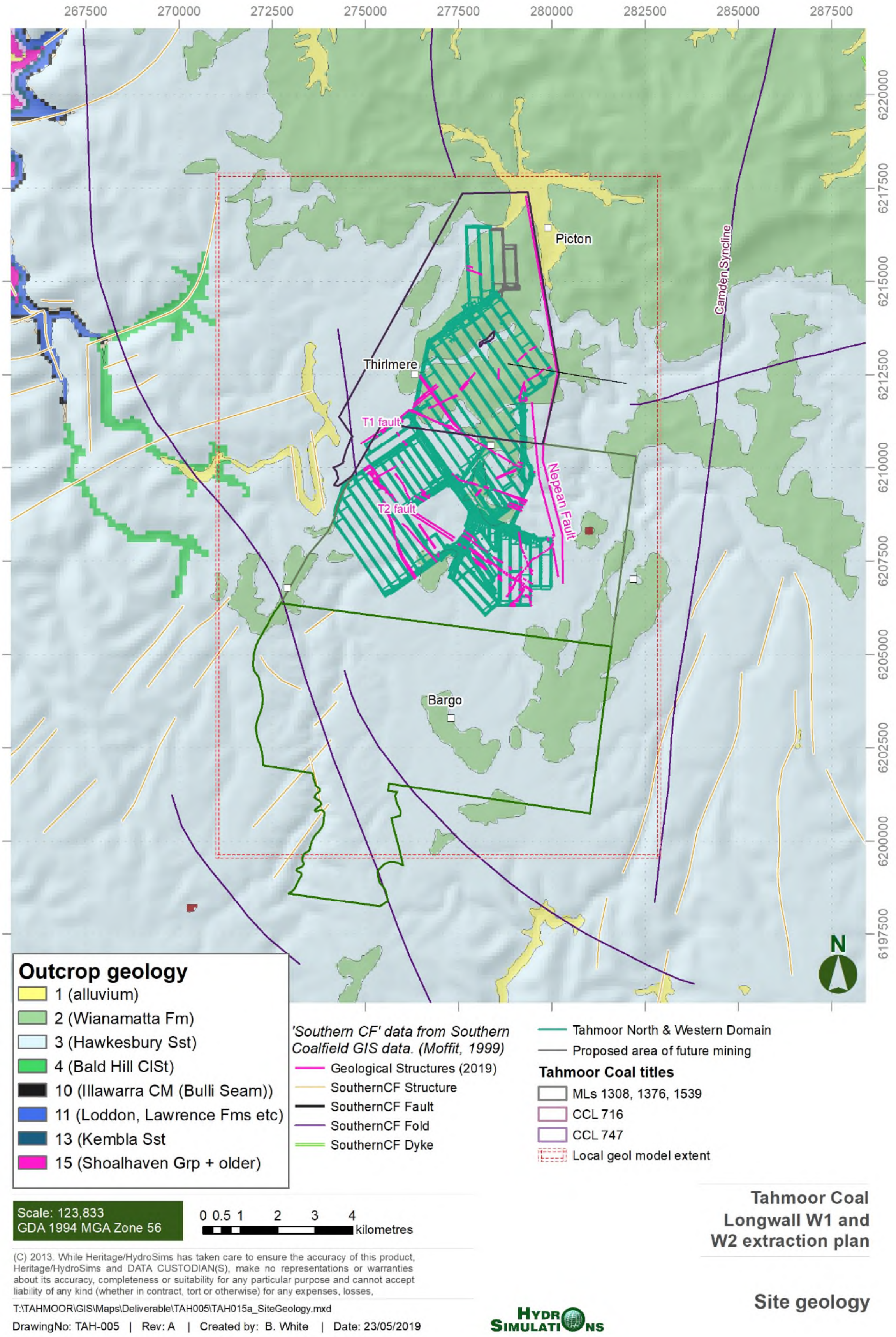

Figure 3-5 Geological Outcrop

Age	age approx	Group	Subgroup	Formation and Member: West	Formation and Member	Formation and Member: East	Approx. thick (m)
Quaternary - recent					alluvium		
Tertiary					colluvium, alluvium		
	<66 Mya				various volcanics / basalts		
Cretaceous					alluvium		
	<146 Mya				various igneous intrusions		
Jurassic	<200 Mya				various igenous intrusions		
Triassic	200 Mya	Wianamatta Grp			Bringelly Shale		50
		Wianamatta Grp			Minchinbury Sandstone		10
		Wianamatta Grp			Ashfield Shale		40
					Mittagong Formation		10
					Hawkesbury Sandstone		180
	210 Mya	Narrabeen Grp	Gosford Subgroup		Newport Formation		20
		Narrabeen Grp	Gosford Subgroup		Garie Formation		20
		Narrabeen Grp	Gosford Subgroup		Bald Hill Claystone		20
		Narrabeen Grp	Clifton Subgroup	Colo Vale Sandstone	Kangaloon Sandstone	Bulgo Sandstone	250
		Narrabeen Grp	Clifton Subgroup	Colo Vale Sandstone	Kangaloon Sandstone	Stanwell Park Claystone	30
		Narrabeen Grp	Clifton Subgroup	Colo Vale Sandstone	Kangaloon Sandstone	Scarborough Sandstone	20
		Narrabeen Grp	Clifton Subgroup	Colo Vale Sandstone	Kangaloon Sandstone	Wombarra Claystone	10
	230 Mya	Narrabeen Grp	Clifton Subgroup			Coal Cliff Sandstone	10
Permian		Illawarra Coal Measures			Bulli Coal		2-4
		Illawarra Coal Measures	Sydney Subgroup		Loddon Sandstone		10
		Illawarra Coal Measures	Sydney Subgroup			Dural Sandstone Member (Eckersley Fm (25m thick))	
		Illawarra Coal Measures	Sydney Subgroup			Balmain Coal (Eckersley Fm (25m thick))	
		Illawarra Coal Measures	Sydney Subgroup			Penrith Sandstone Member (Eckersley Fm (25m thick))	
		Illawarra Coal Measures	Sydney Subgroup		Balgownie Coal		1
		Illawarra Coal Measures	Sydney Subgroup		Lawrence Sandstone		9
		Illawarra Coal Measures	Sydney Subgroup		Burragorang Claystone		
		Illawarra Coal Measures	Sydney Subgroup			Cape Horn Coal	0.3
		Illawarra Coal Measures	Sydney Subgroup			Lower Eckersley Formation	4
		Illawarra Coal Measures	Sydney Subgroup		Wongawilli Coal		10
		Illawarra Coal Measures	Sydney Subgroup			Upper Wongawilli Seam	
		Illawarra Coal Measures	Sydney Subgroup			Farmborough Claystone (Tuff)	1
		Illawarra Coal Measures	Sydney Subgroup			Lower Wongawilli Seam	
		Illawarra Coal Measures	Sydney Subgroup		Kembla Sandstone		15
		Illawarra Coal Measures	Sydney Subgroup		American Creek Coal		3
		Illawarra Coal Measures	Sydney Subgroup		Allan's Creek Formation		
		Illawarra Coal Measures	Sydney Subgroup		Darkes Forest Sandstone		20
		Illawarra Coal Measures	Sydney Subgroup		Bargo Claystone		30
		Illawarra Coal Measures	Sydney Subgroup		Tongarra Seam		3
		Illawarra Coal Measures	Sydney Subgroup		Wilton Formation		15
		Illawarra Coal Measures	Sydney Subgroup	Wanganderry Sandstone	Woonona Seam		4
		Illawarra Coal Measures	Sydney Subgroup	Marrangaroo Conglomerate	Erins Vale Formation	Thirroul Sandstone	10
		Illawarra Coal Measures	Cumberland Subgroup		Pheasants Nest Formation		15
		Sholhaven Grp			Broughton Formation	Dapto Latite (Gerringong Volcanics)	
		Sholhaven Grp			Broughton Formation	Cambewarra Latite (Gerringong Volcanics)	
		Sholhaven Grp			Broughton Formation	Saddleback Latite (Gerringong Volcanics)	
		Sholhaven Grp			Broughton Formation	Jamberoo Sandstone (Gerringong Volcanics)	
		Sholhaven Grp			Broughton Formation	Bumbo Latite (Gerringong Volcanics)	
		Sholhaven Grp			Broughton Formation	Kiama Sandstone (Gerringong Volcanics)	
		Sholhaven Grp			Broughton Formation	Blow Hole Latite (Gerringong Volcanics)	
		Sholhaven Grp			Broughton Formation	Westley Park Sandstone (Gerringong Volcanics)	
		Sholhaven Grp			Berry Siltstone		
		Sholhaven Grp			Nowra Sandstone		
		Sholhaven Grp			Wandrawandian Siltstone		
		Sholhaven Grp			Snapper Point Fm		
		Sholhaven Grp		Yadboro & Tallong Conglomerates		Yarrunga Cola Measures	
		Sholhaven Grp				Pebbly Beach Member	
	260 Mya	Talaterang Grp		Clyde Coal Measures		Pigeon House Siltstone	
---- ???????????????????????????? ----						---- ???????????????????????????? ----	
Devonian							
Silurian							
Ordovician							

adapted from:

SCA 2007 — *Design of a Hydrological and Hydrogeological Monitoring Program to Assess the Impact of Longwall Mining in SCA Catchments, App5 (Inquiry Southern Coalfield)*

GHD 2007 — *Hydrogeology Report for Dendrobium Coal (Appendix A), GHD doc 21/11716/03/AY116.doc*

Uni Wollongong 2012 — *Bioregional Assessment: Sydney Metropolitan, Southern Rivers and Hawkesbury-Nepean Catchments*

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Figure 3-6 Southern Coalfield stratigraphic column

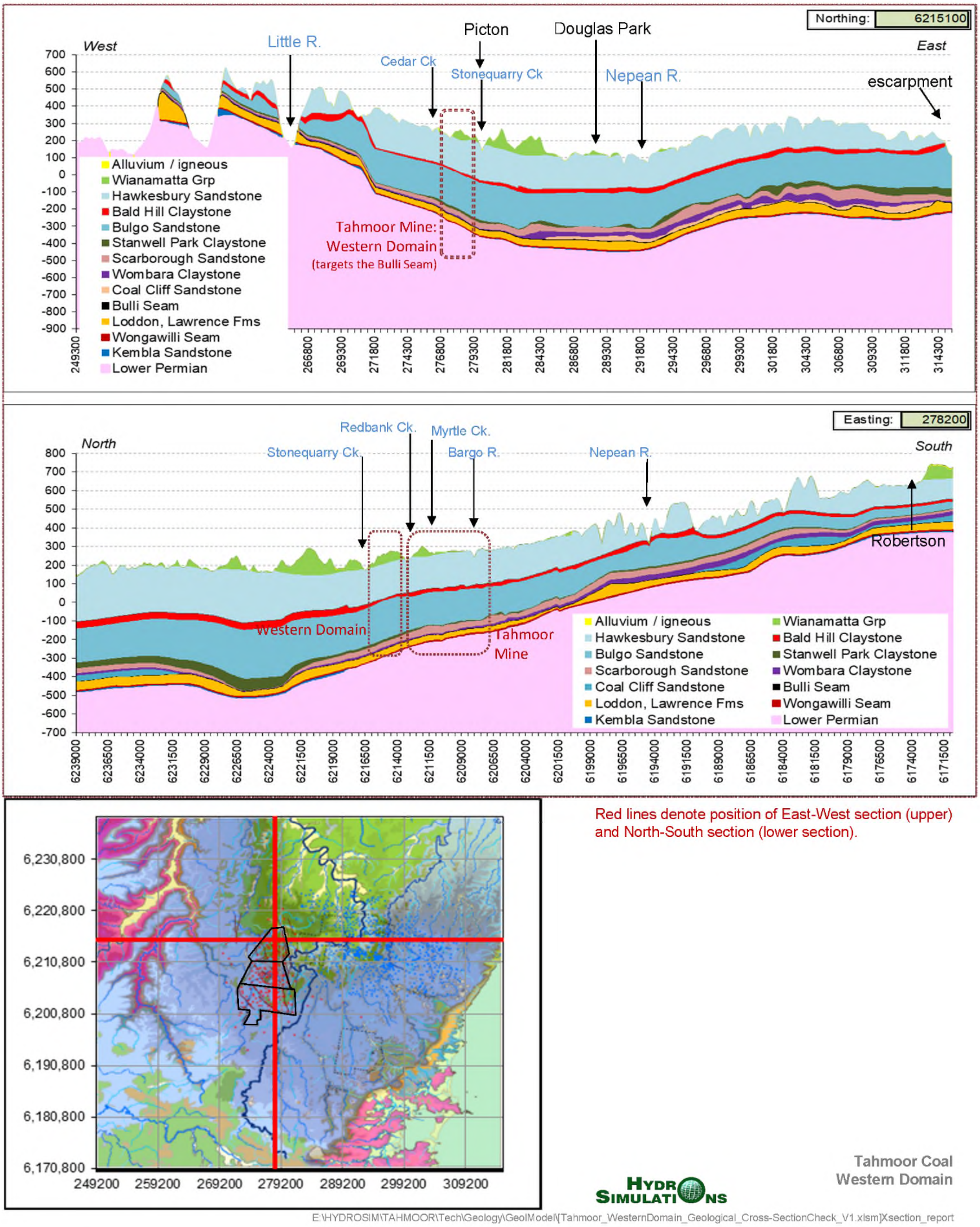

Figure 3-7 Geological cross-sections

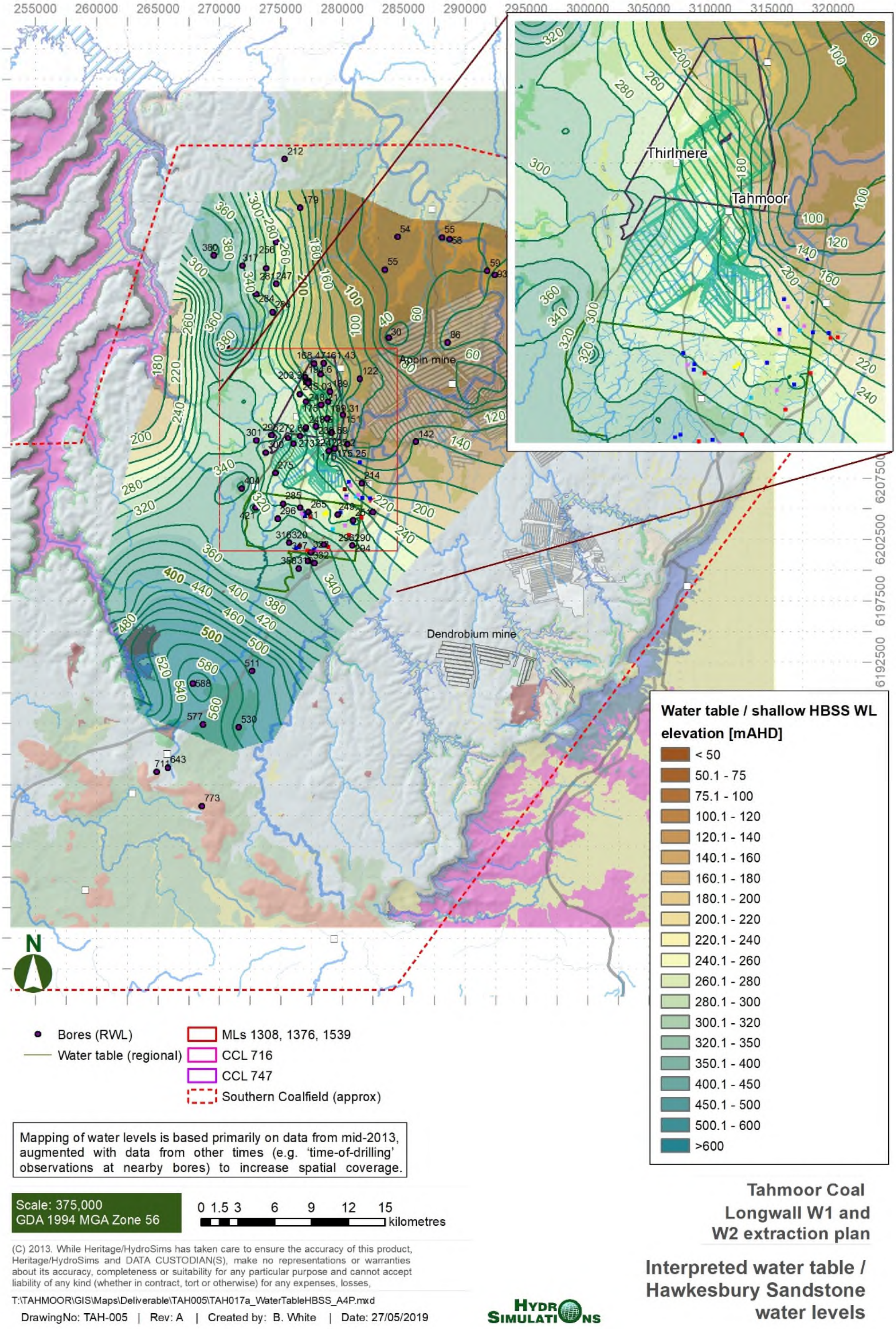

Figure 3-8 Interpreted water table elevation

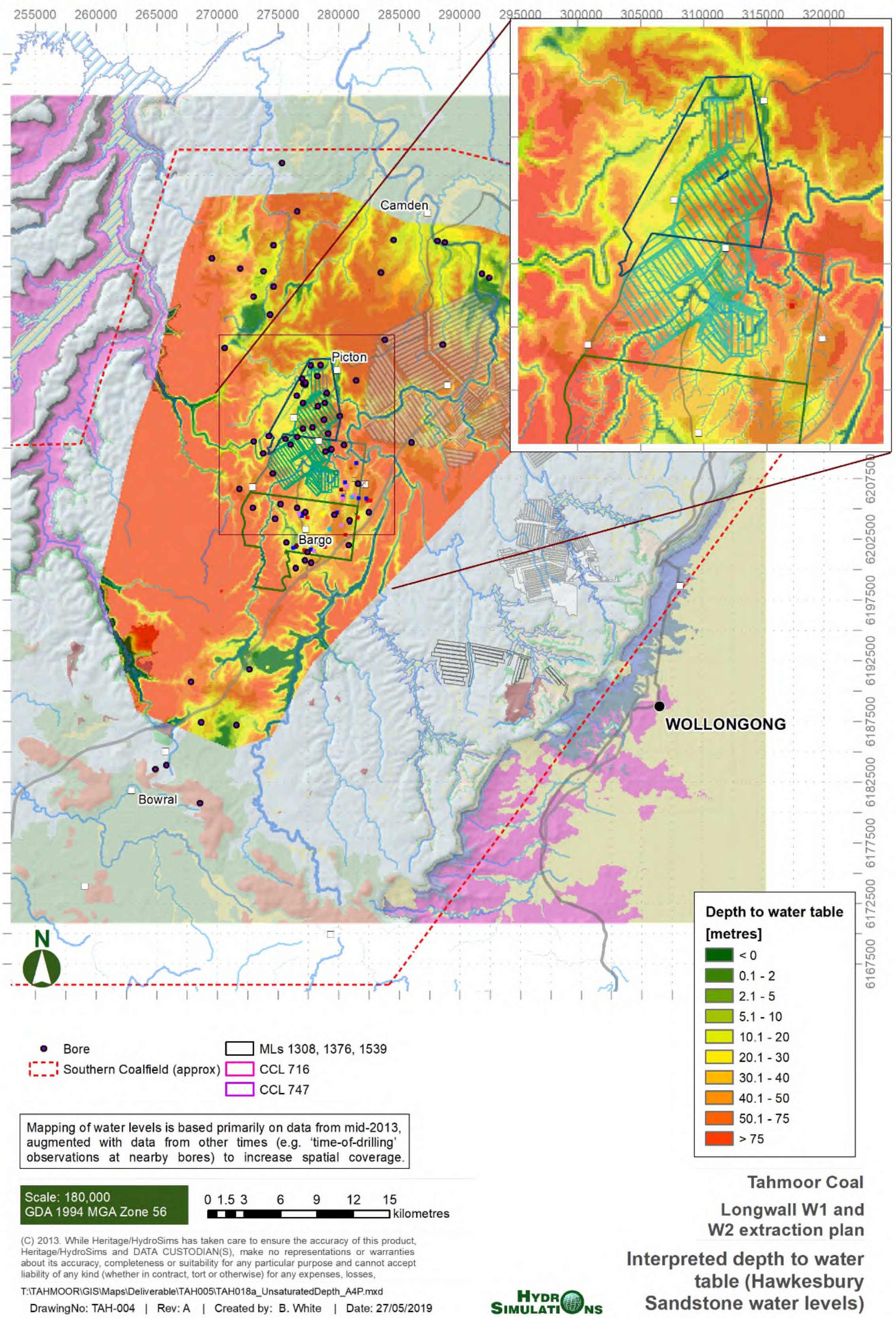

Figure 3-9 Interpreted depth to water table elevation (Aug 2013)

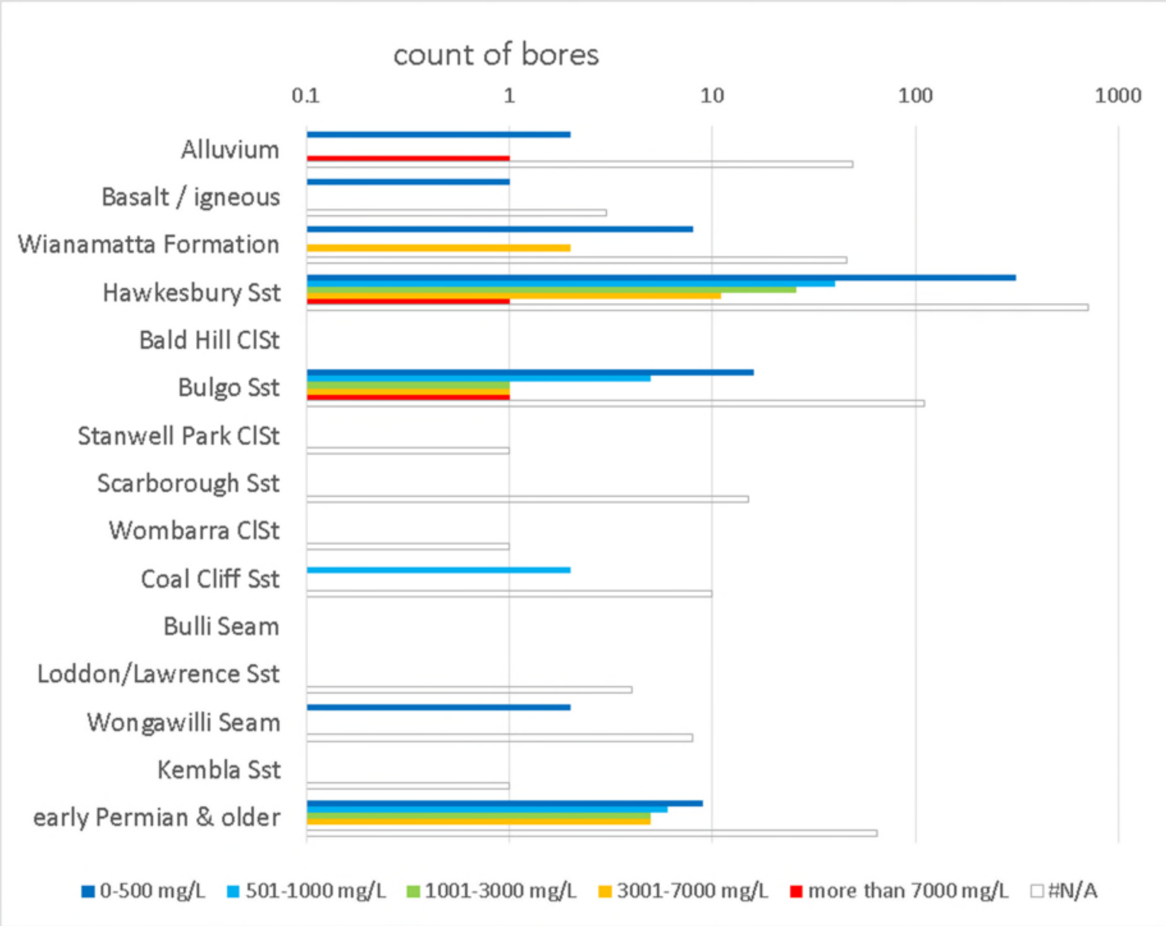

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Figure 3-10 Summary of groundwater salinity data

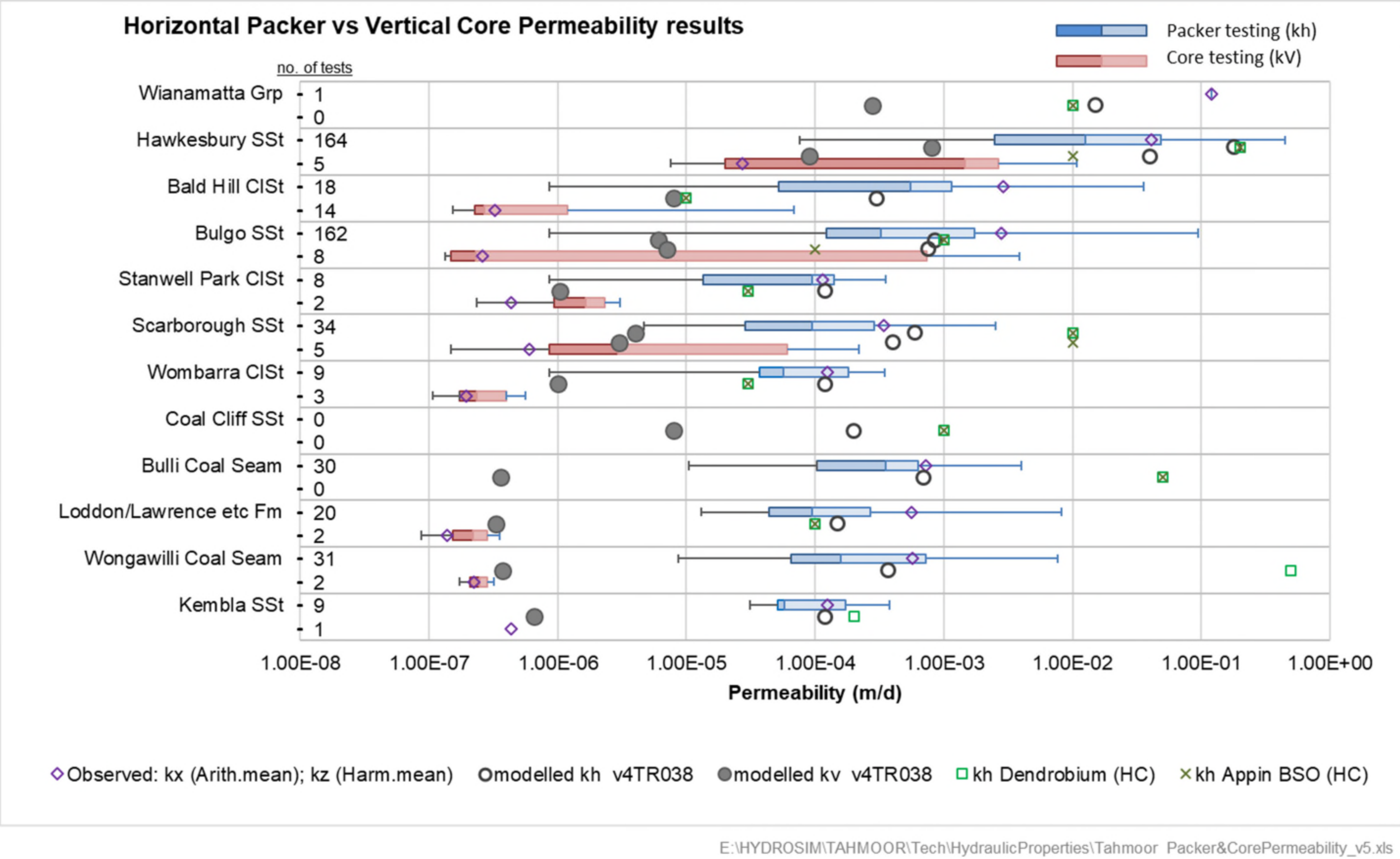

Figure 3-11 Summary of Hydraulic conductivity (Kh and Kv) data

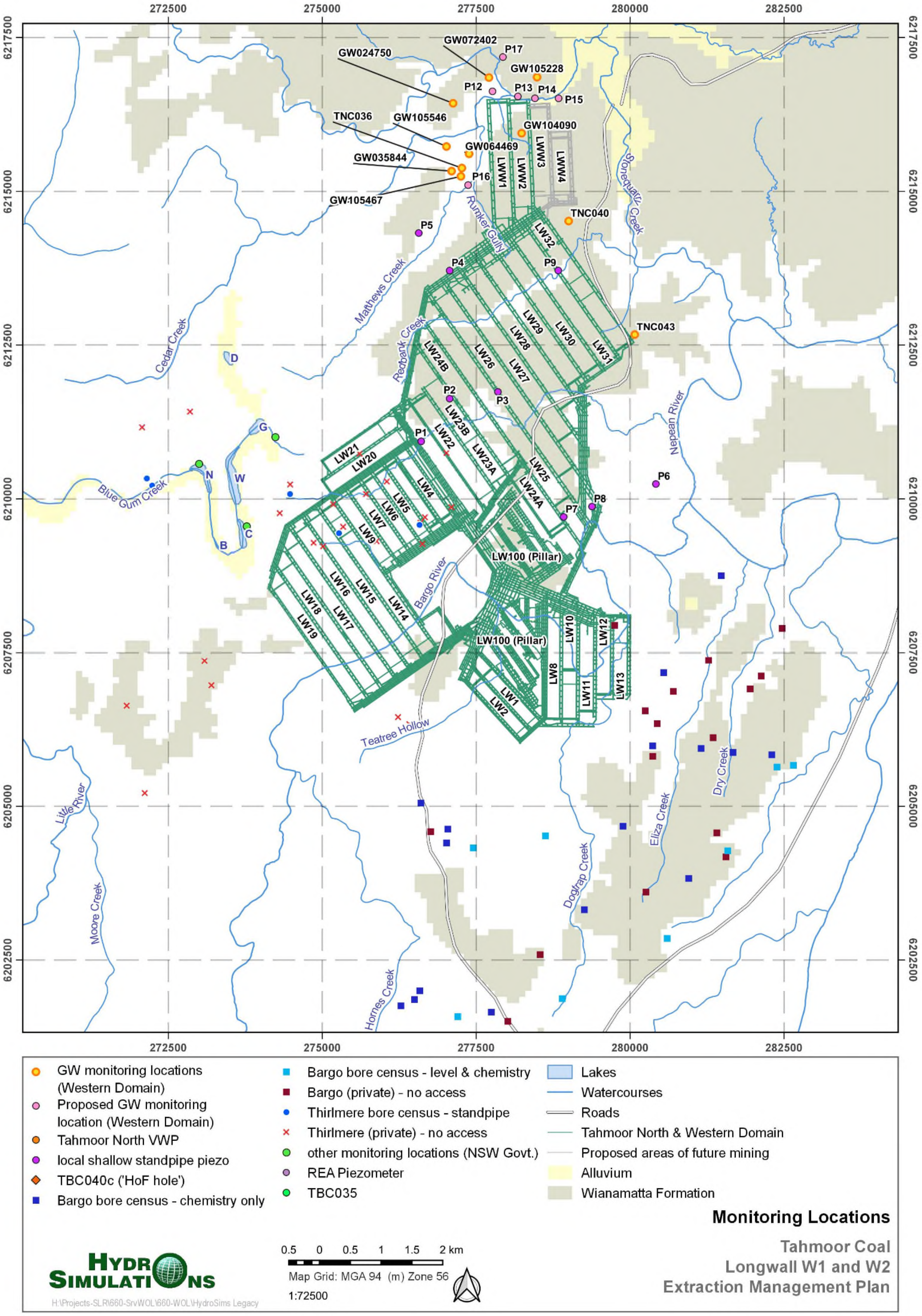

Figure 3-12 Groundwater monitoring locations

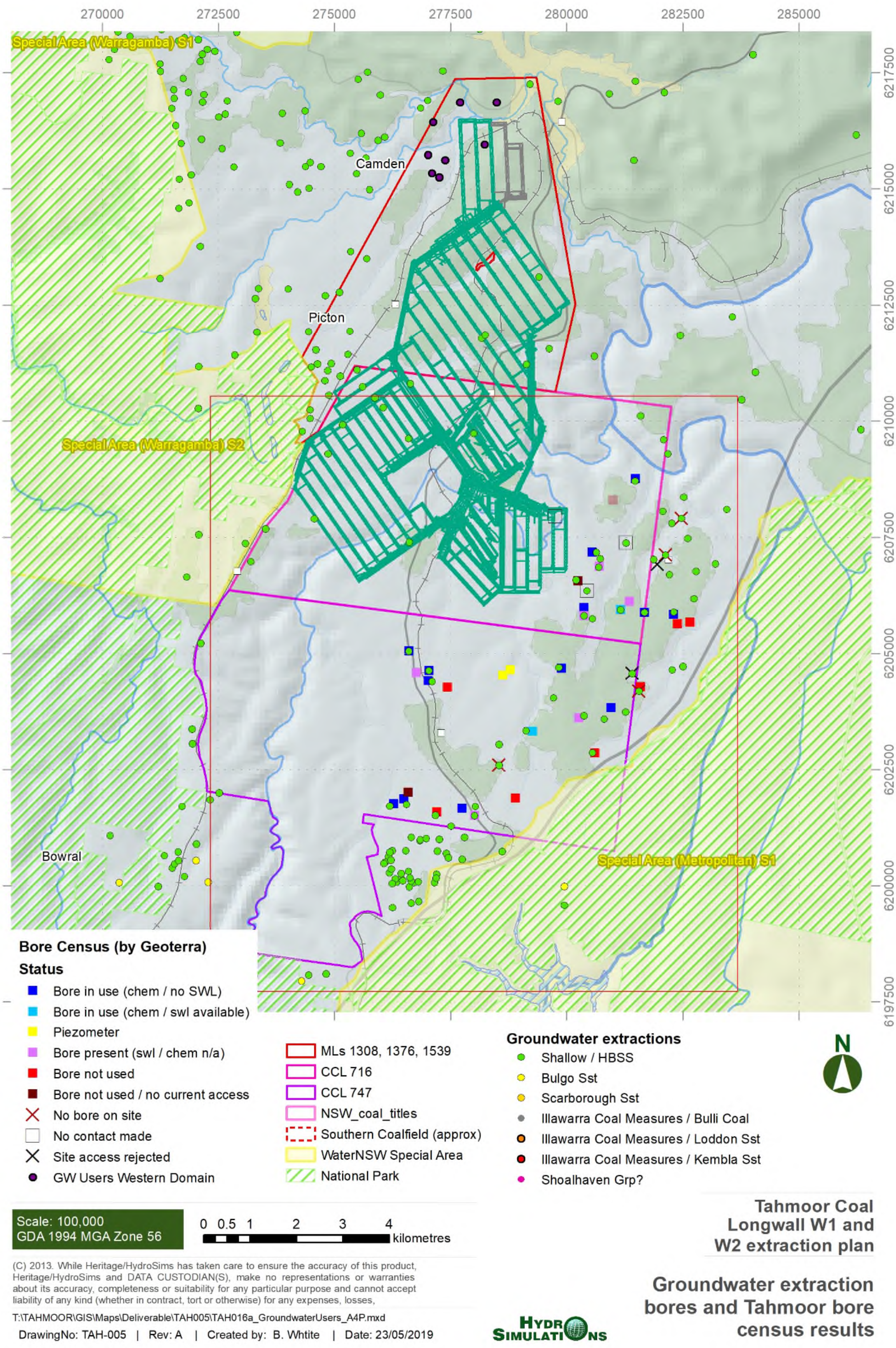

Figure 3-13 Location of groundwater users

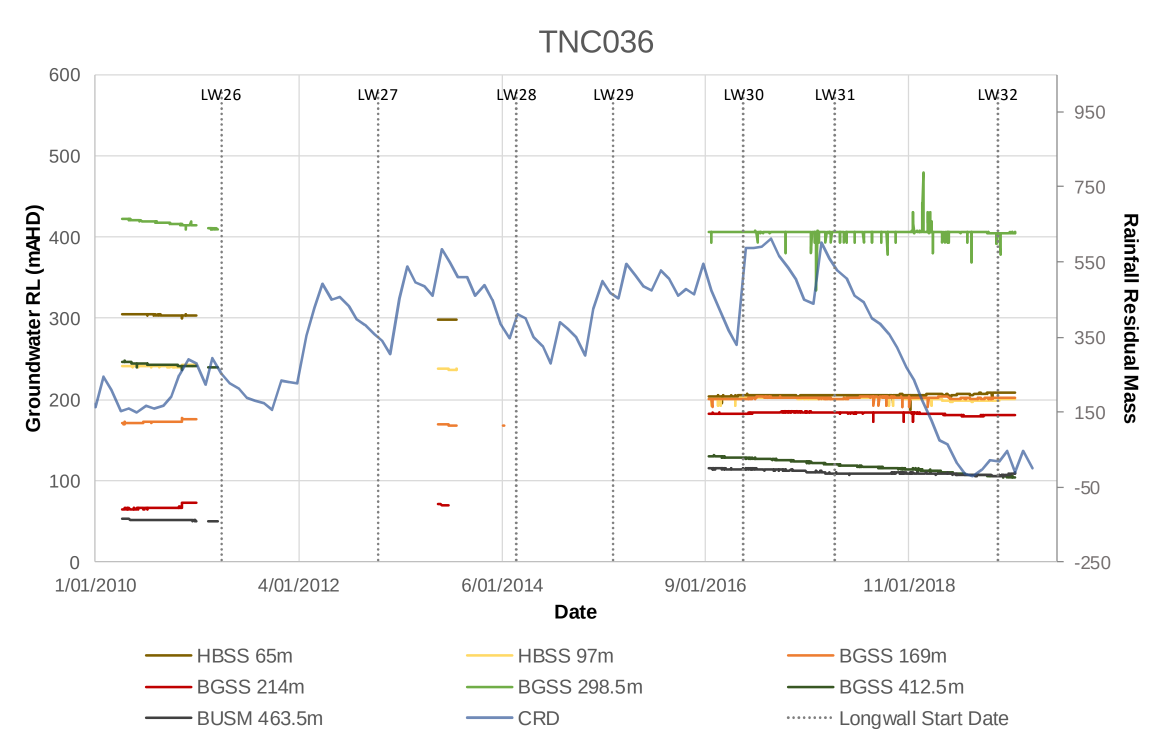

Figure 3-14 TNC036 baseline data

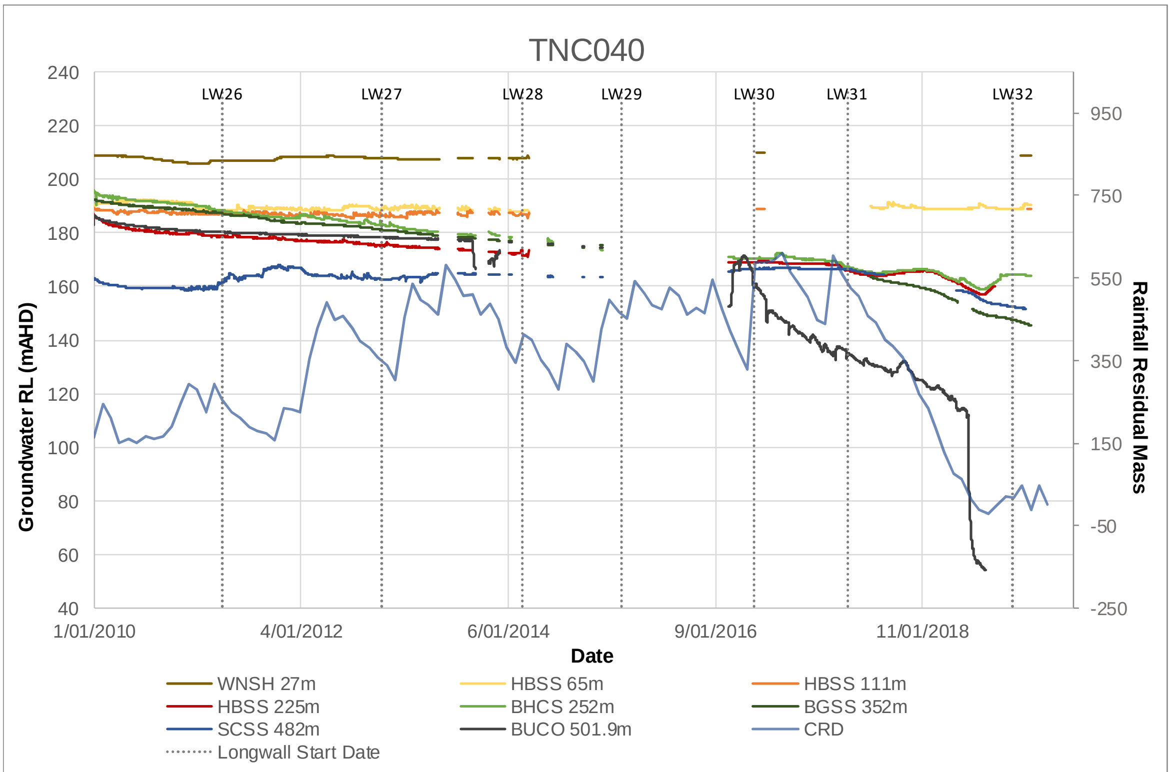

Figure 3-15 TNC040 baseline data

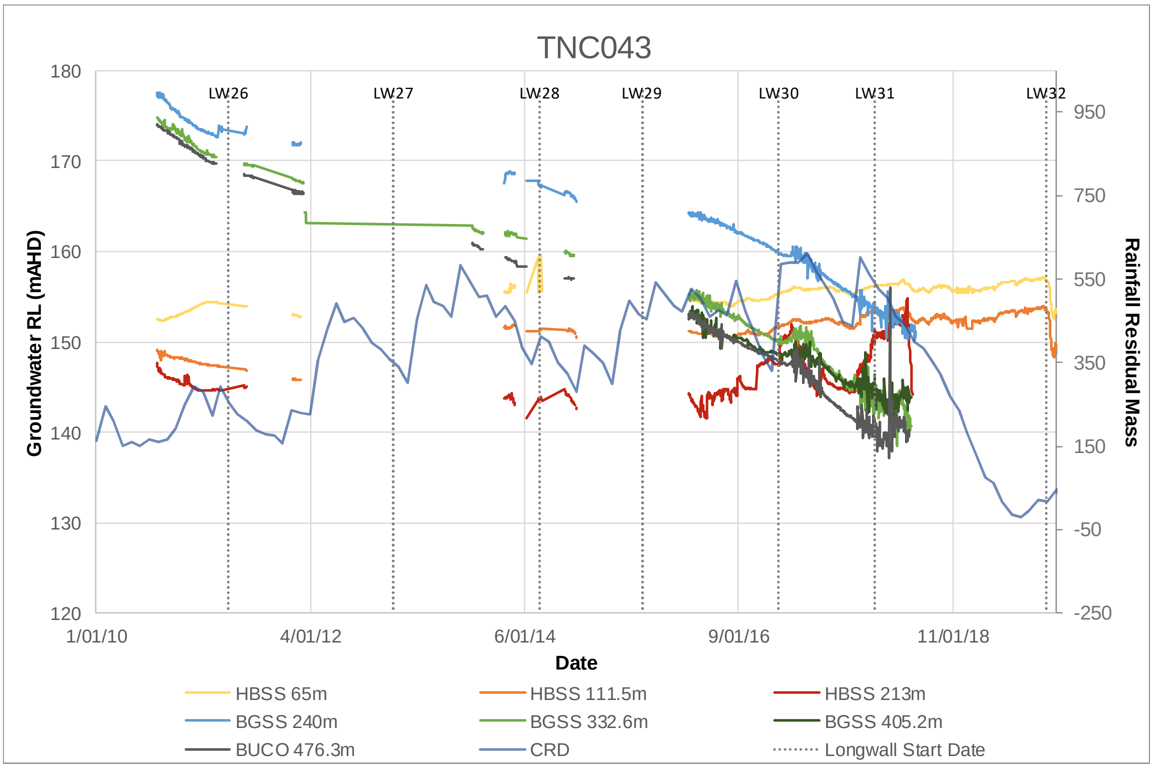

Figure 3-16 TNC043 baseline data

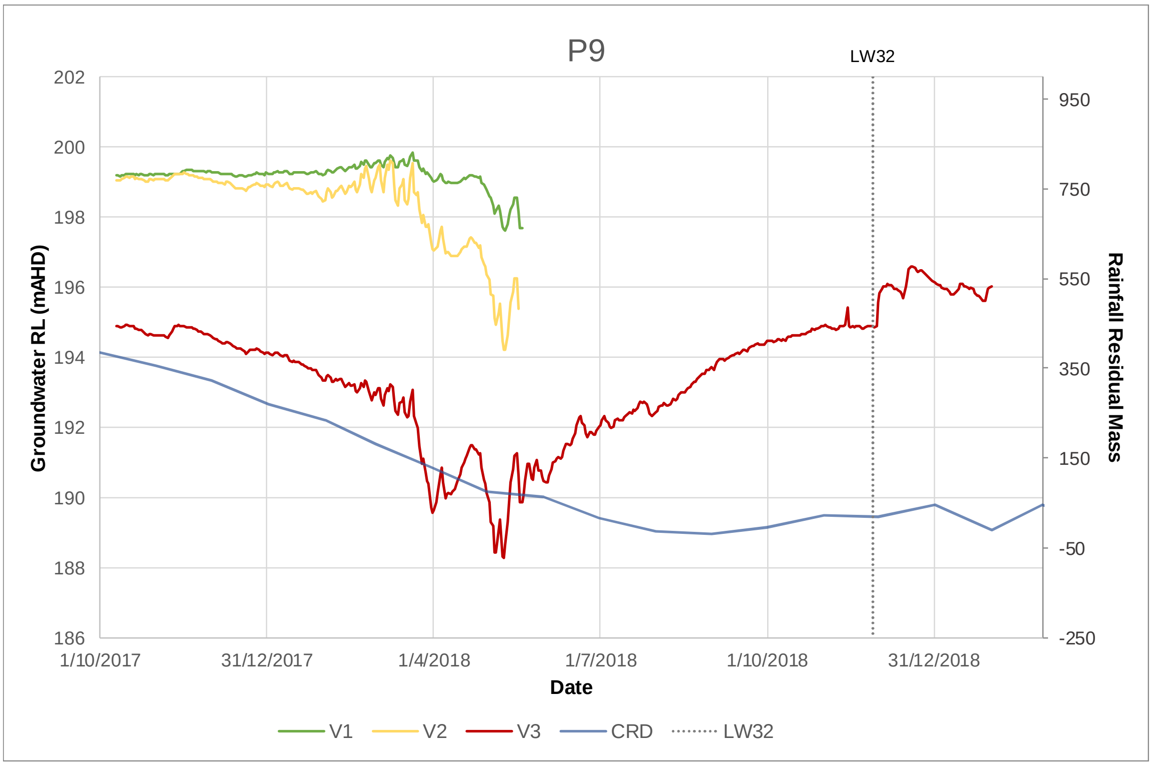

Figure 3-17 P9 baseline data

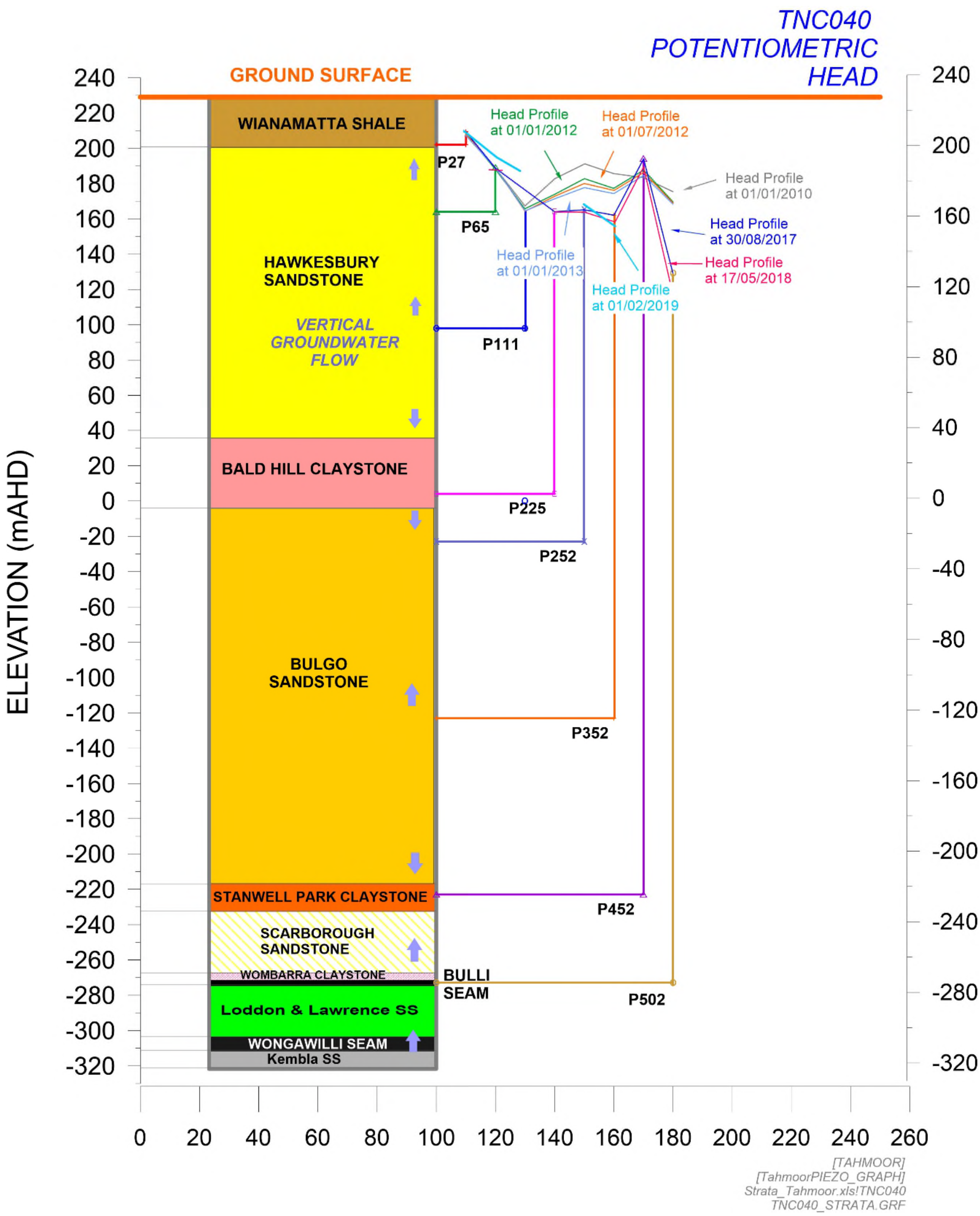

Figure 3-18 Vertical head profile at TNC040

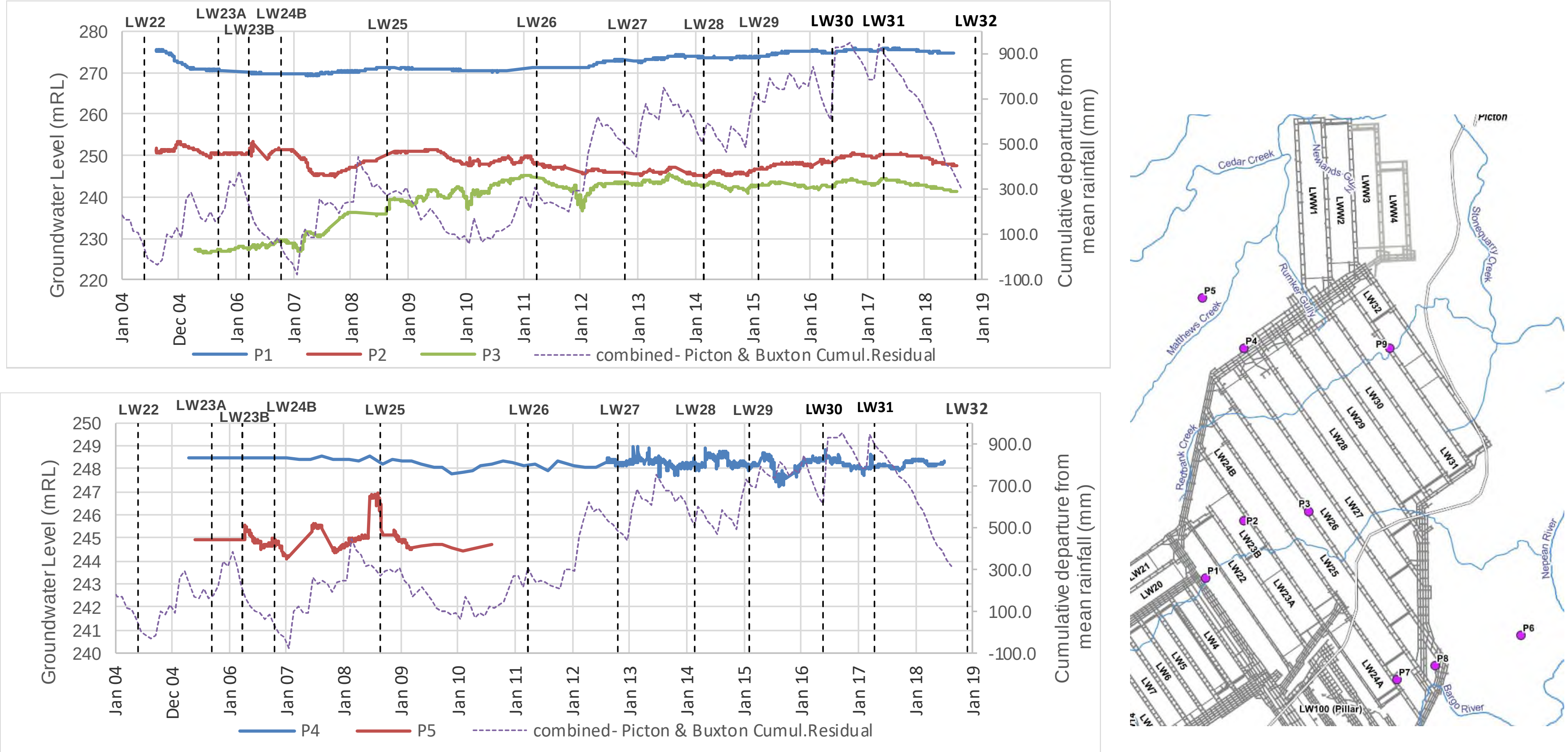

Figure 3-19 Water level trends – shallow aquifer (P1-P5)

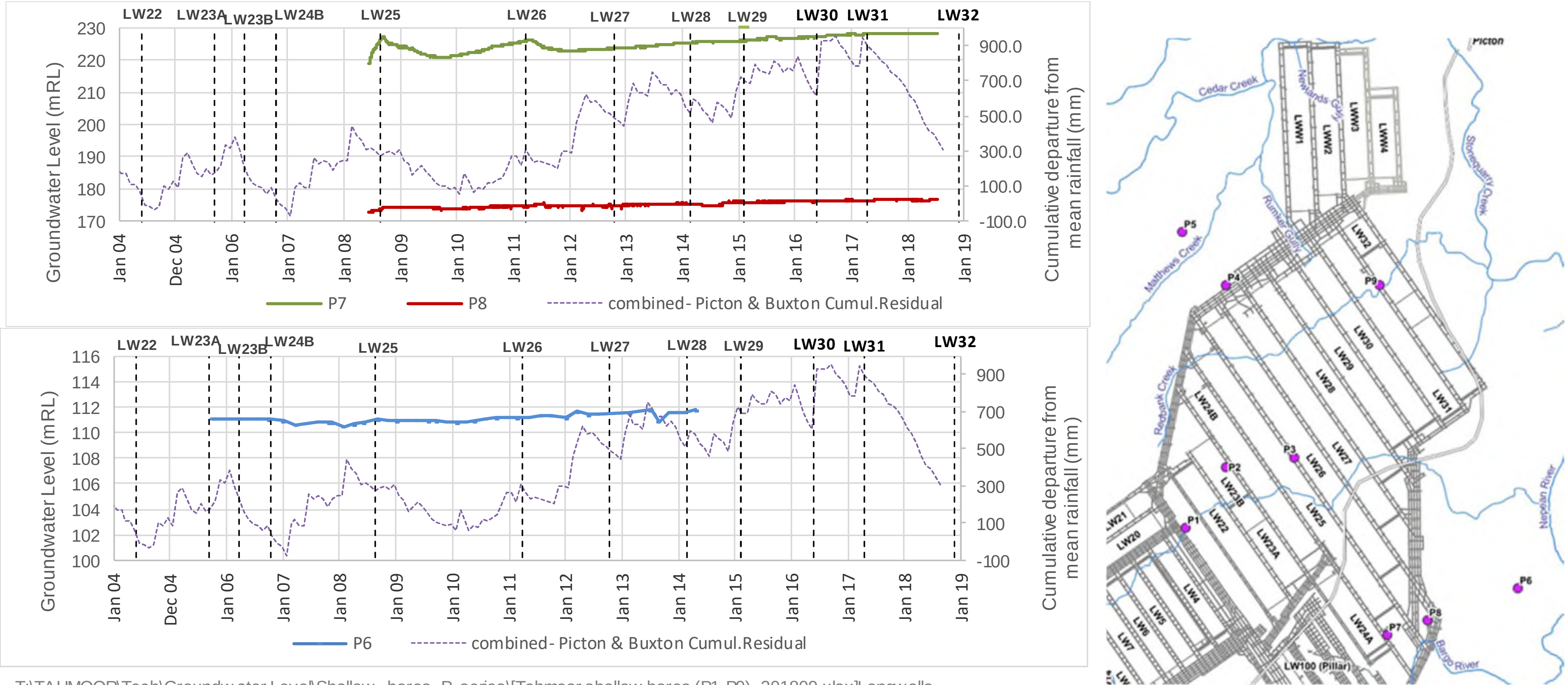

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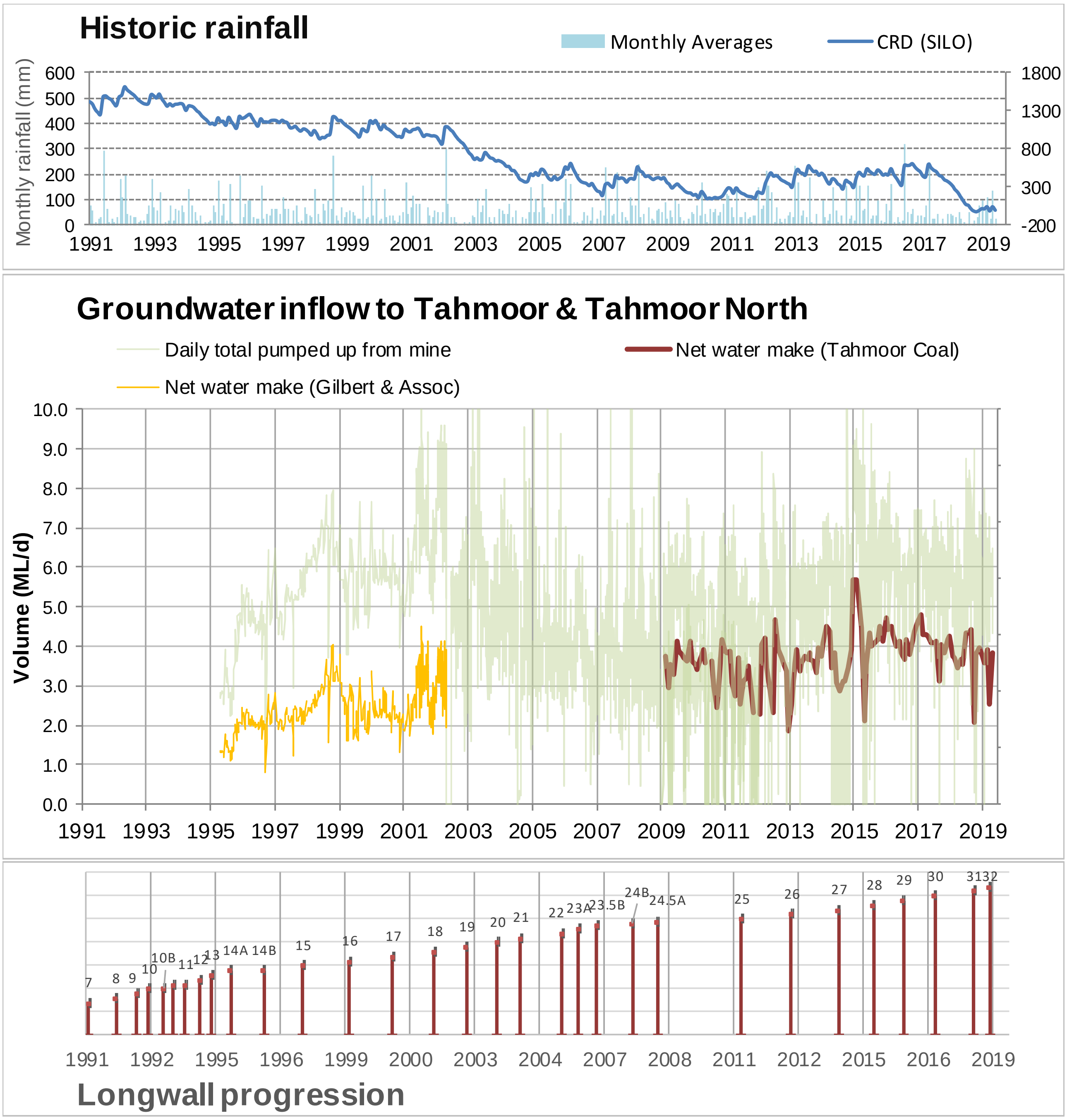
Figure 3-20 Water level trends – shallow aquifer (P6-P8)



T:\TAHMOOR\Tech\Climate\[CRD_Rain_TAH05 v0.2.xlsx]SILO graph data

Figure 3-21 Historical record of inflows at Tahmoor North

4 GROUNDWATER IMPACT ASSESSMENT

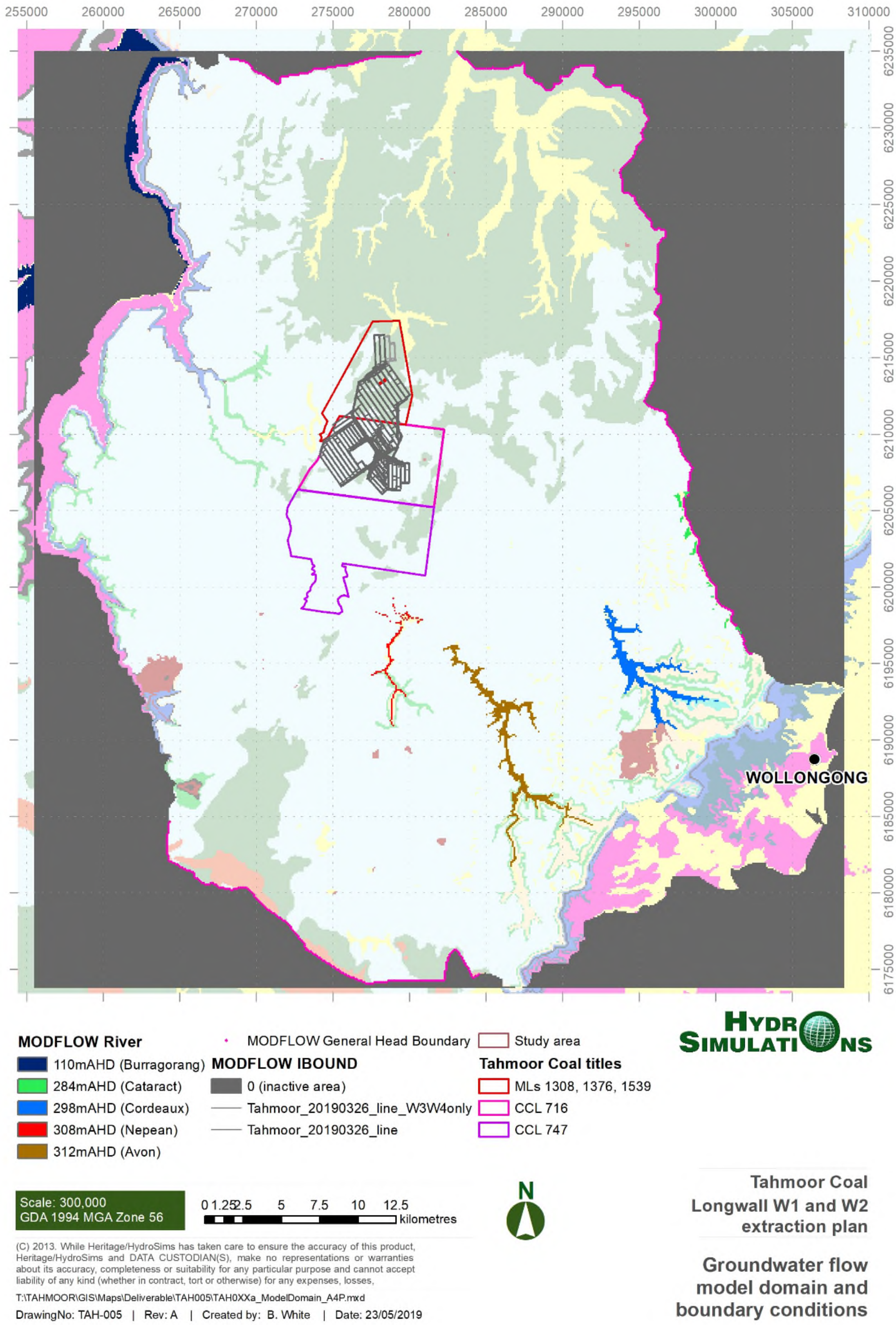
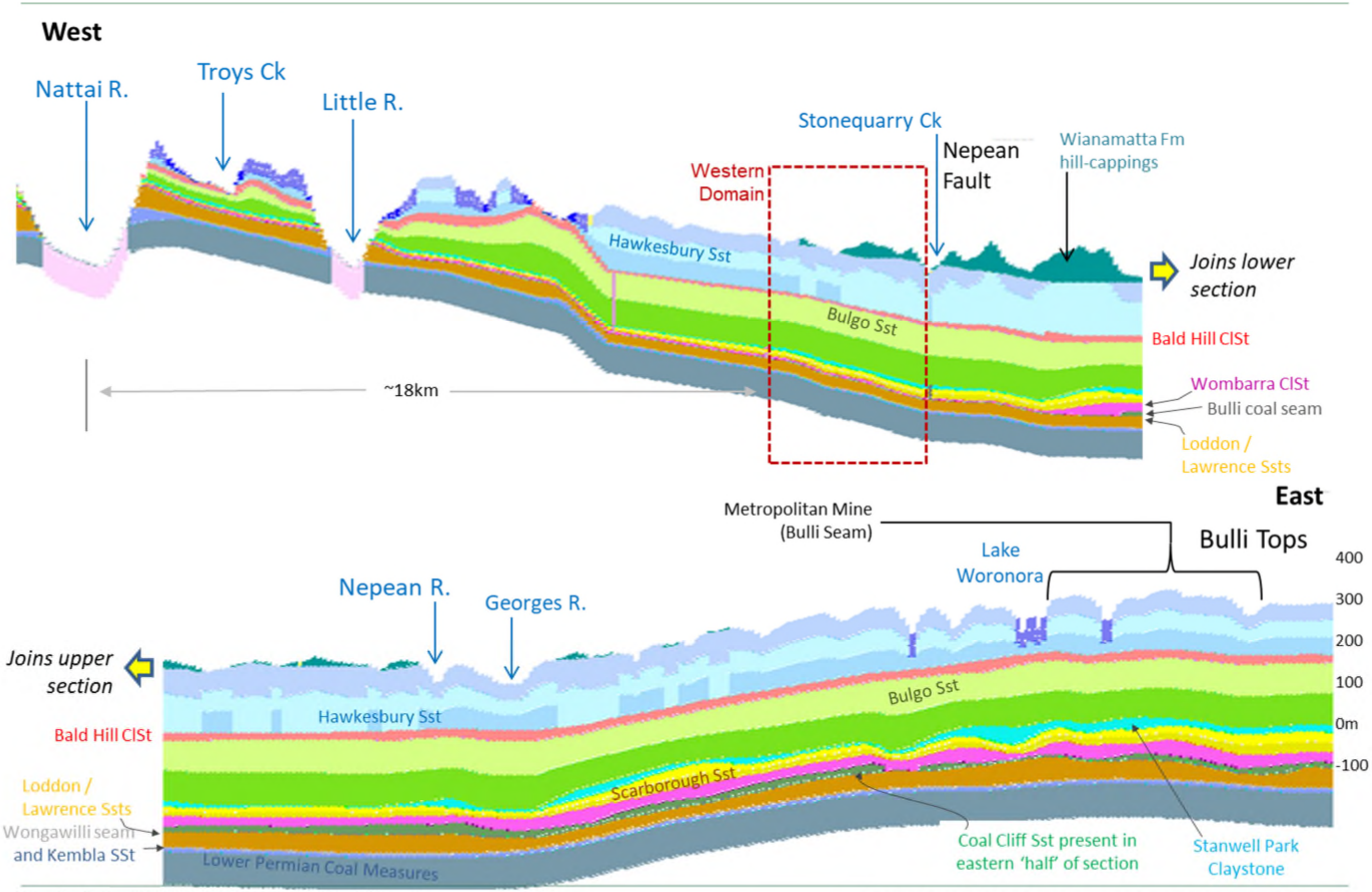


Figure 4-1 Groundwater model domain and boundary conditions



Note: the Bulli coal seam is too thin to be visible at this scale.
Model section from Groundwater Vistas 6 (TahV4_TR052.gwv – model row 198 (Northing: 6203050) coloured by hydraulic conductivity zone).

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HYDROSIMULATIONS

Figure 4-2 Representative Model Cross-section

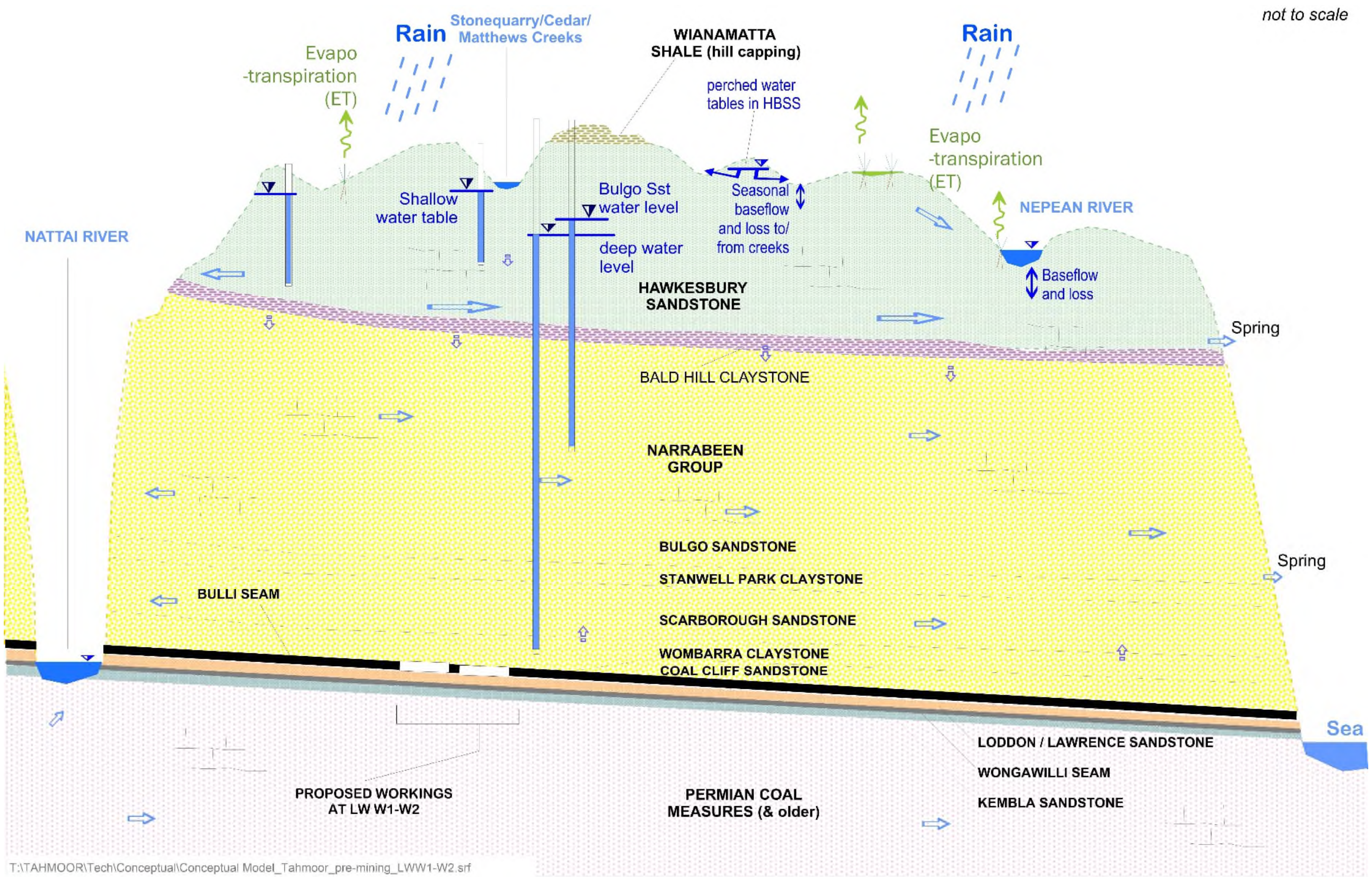

Figure 4-3 Conceptual Model of Pre-Mining Groundwater System

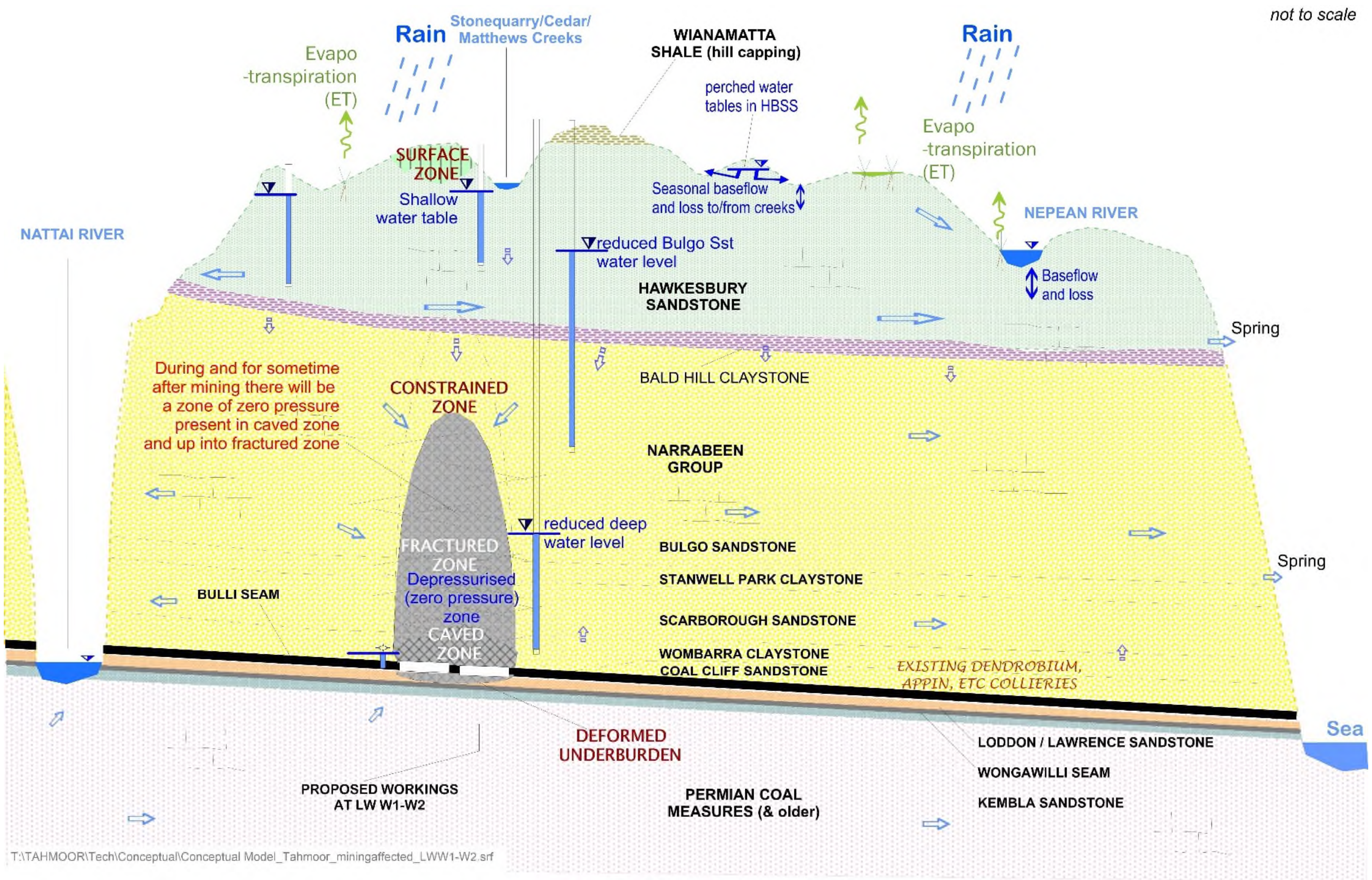

Figure 4-4 Conceptual Model of Post-Mining-Groundwater System

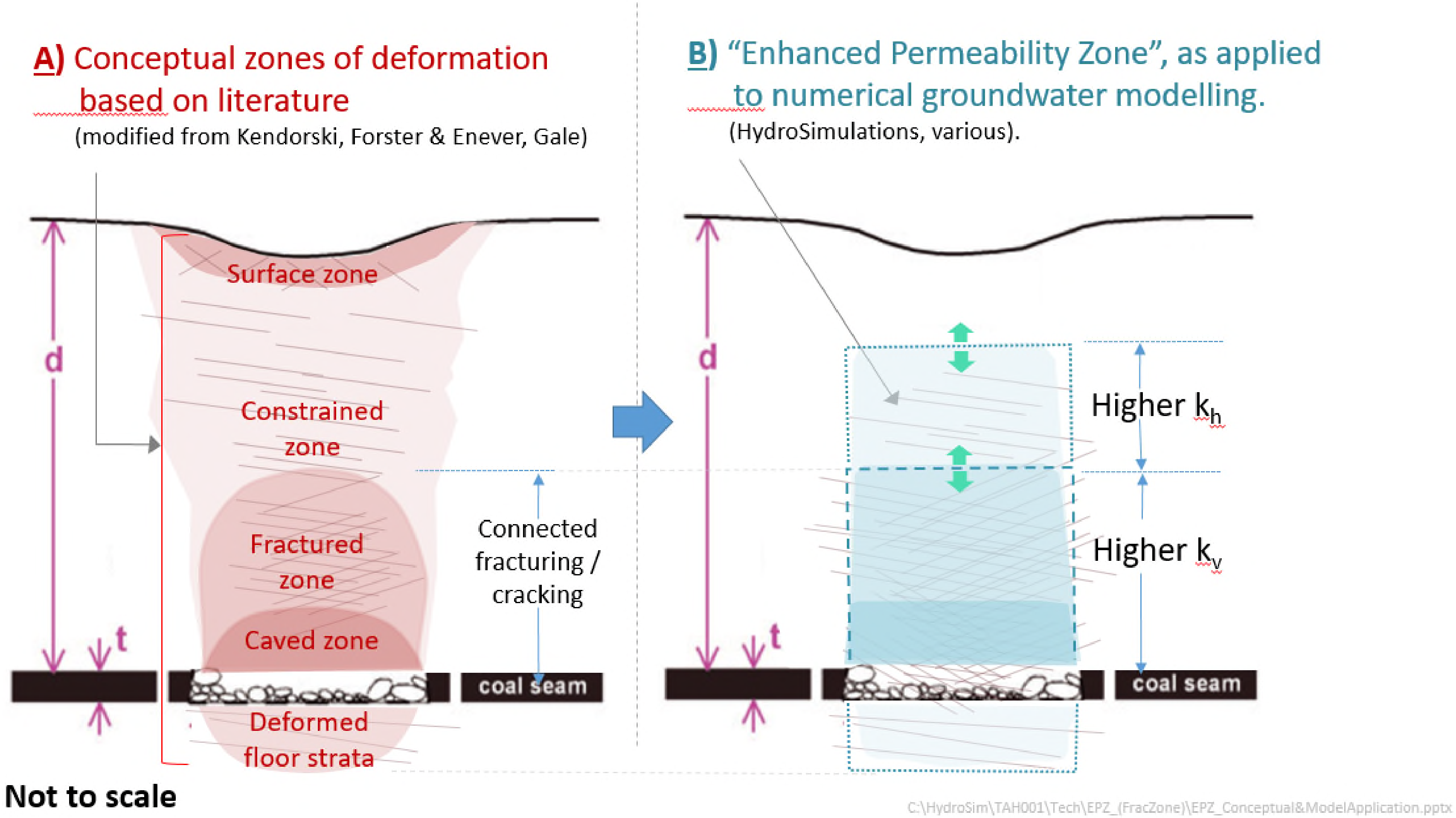

Figure 4-5 Application of enhanced permeability within the groundwater model

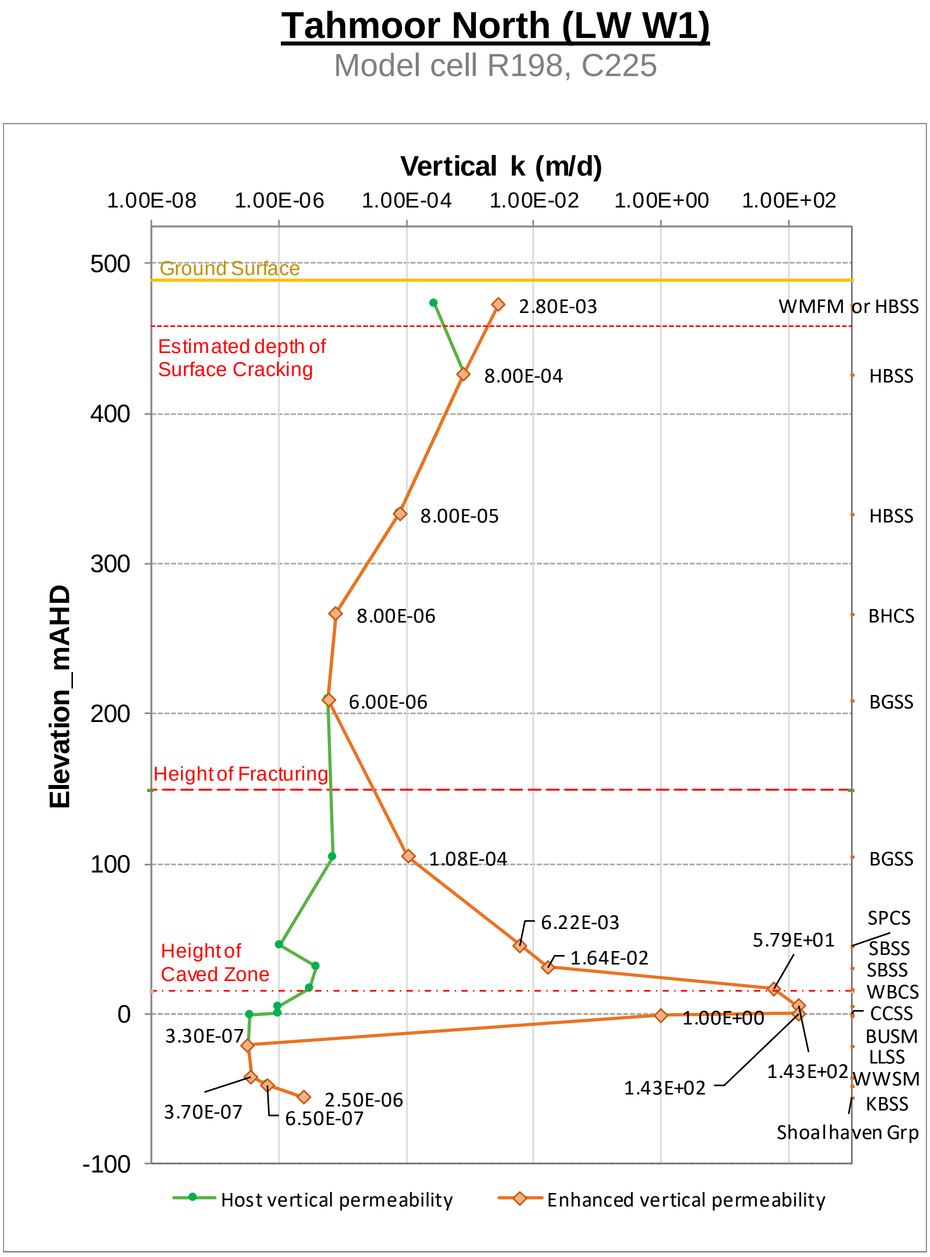

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Figure 4-6 Vertical profiles illustrating modelled permeability in the fractured zone

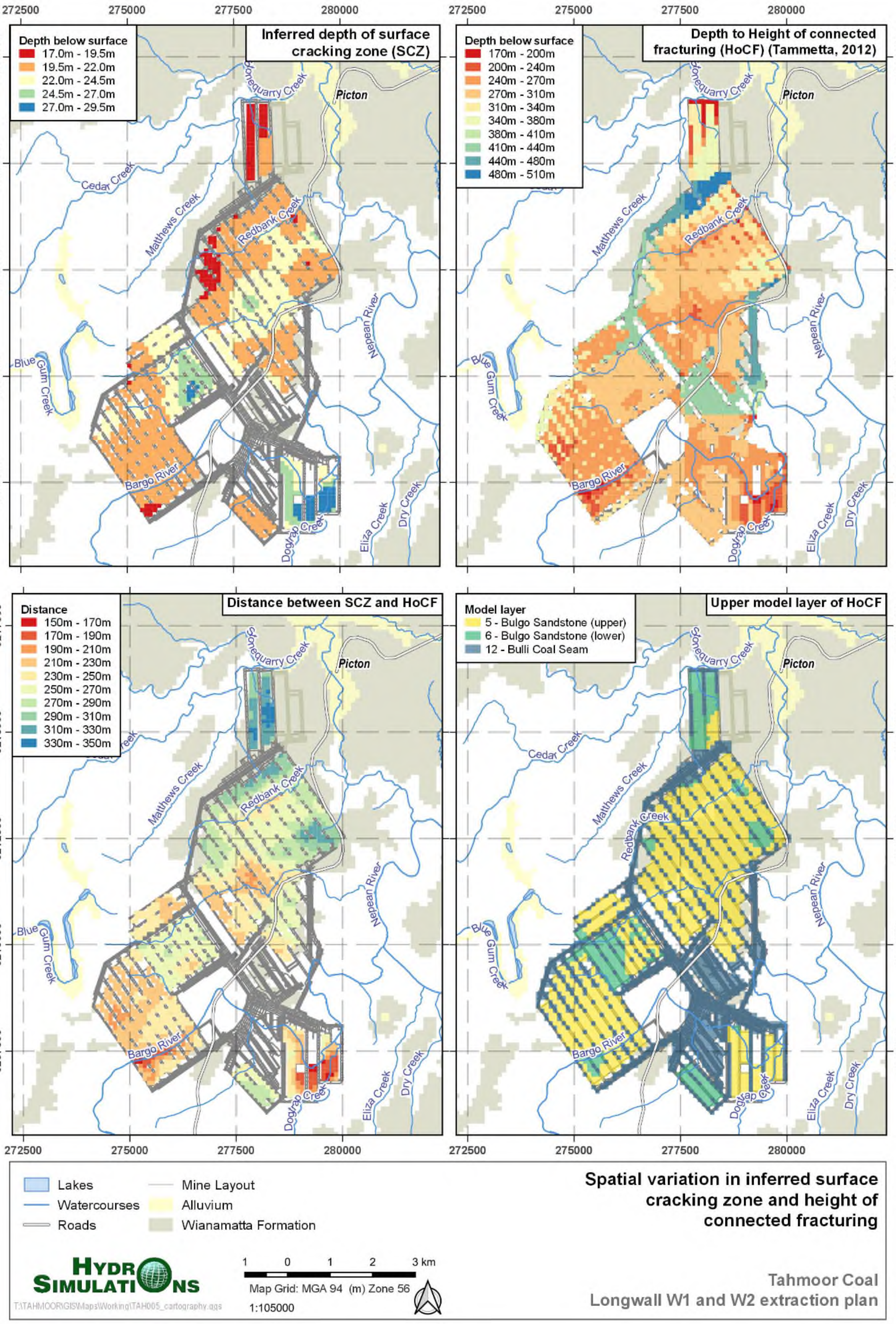

Figure 4-7 Modelled subsidence and deformation

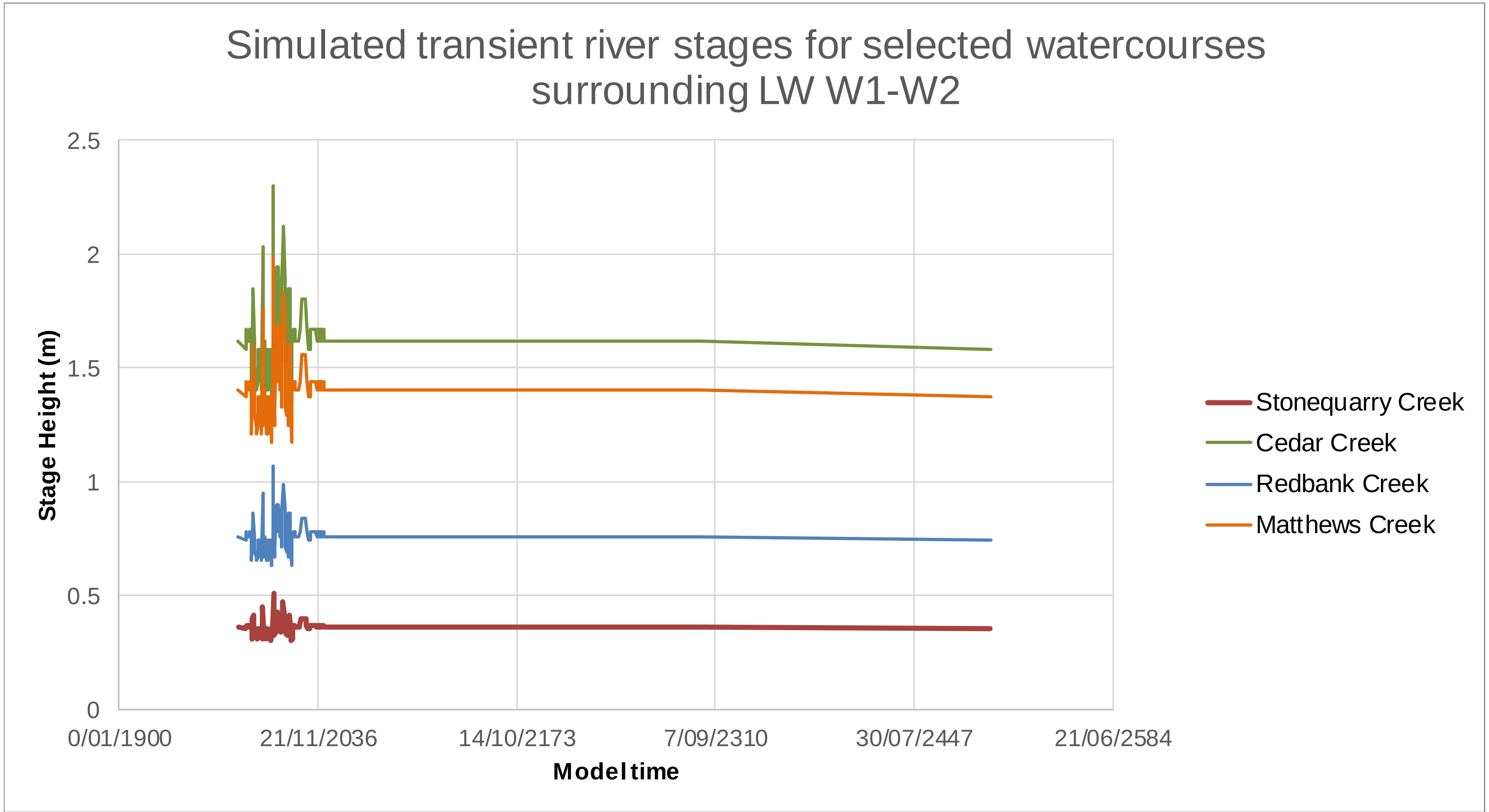

Figure 4-8 Simulated transient river stages for Stonequarry, Cedar, Redbank and Matthews Creeks

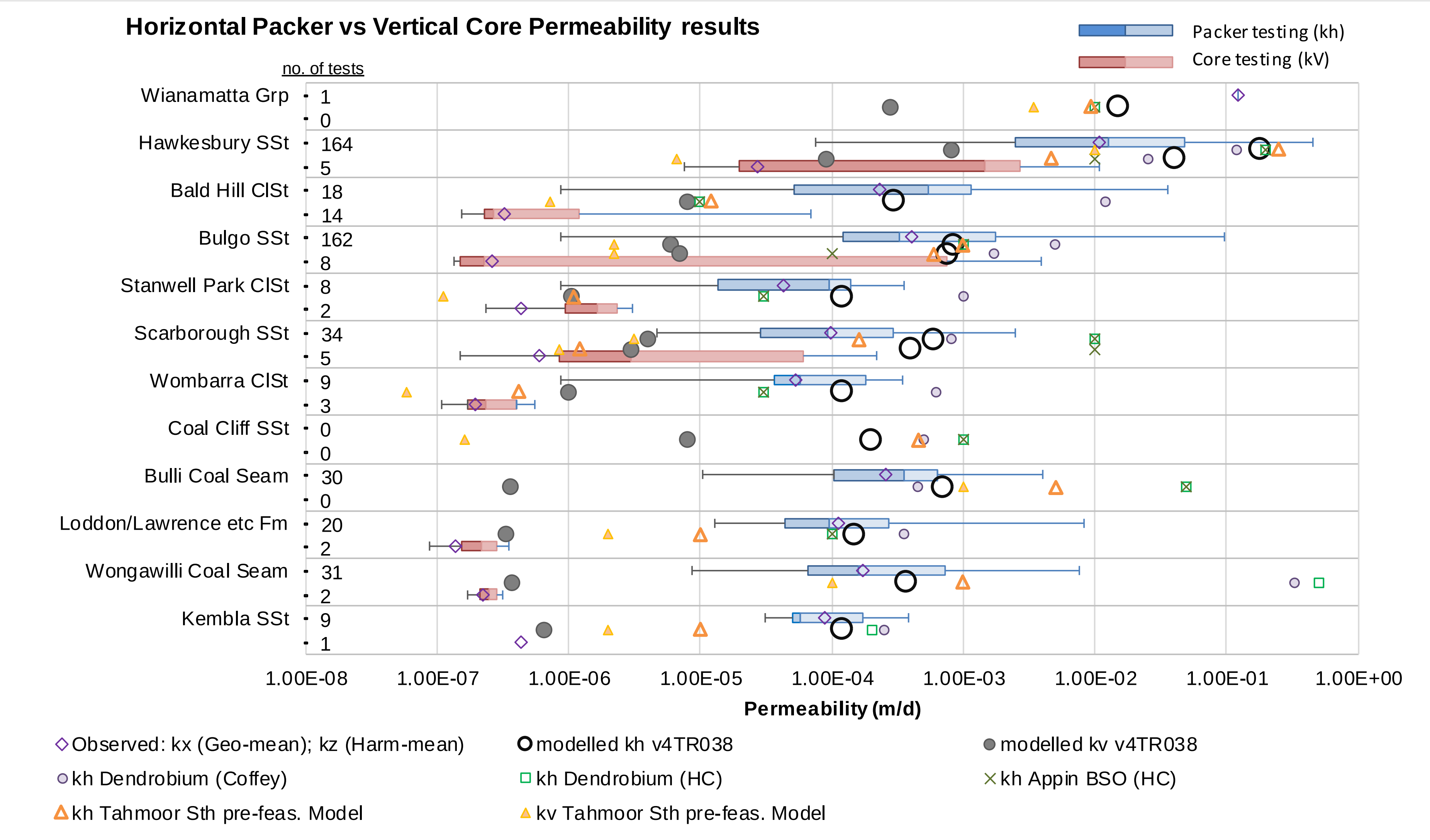

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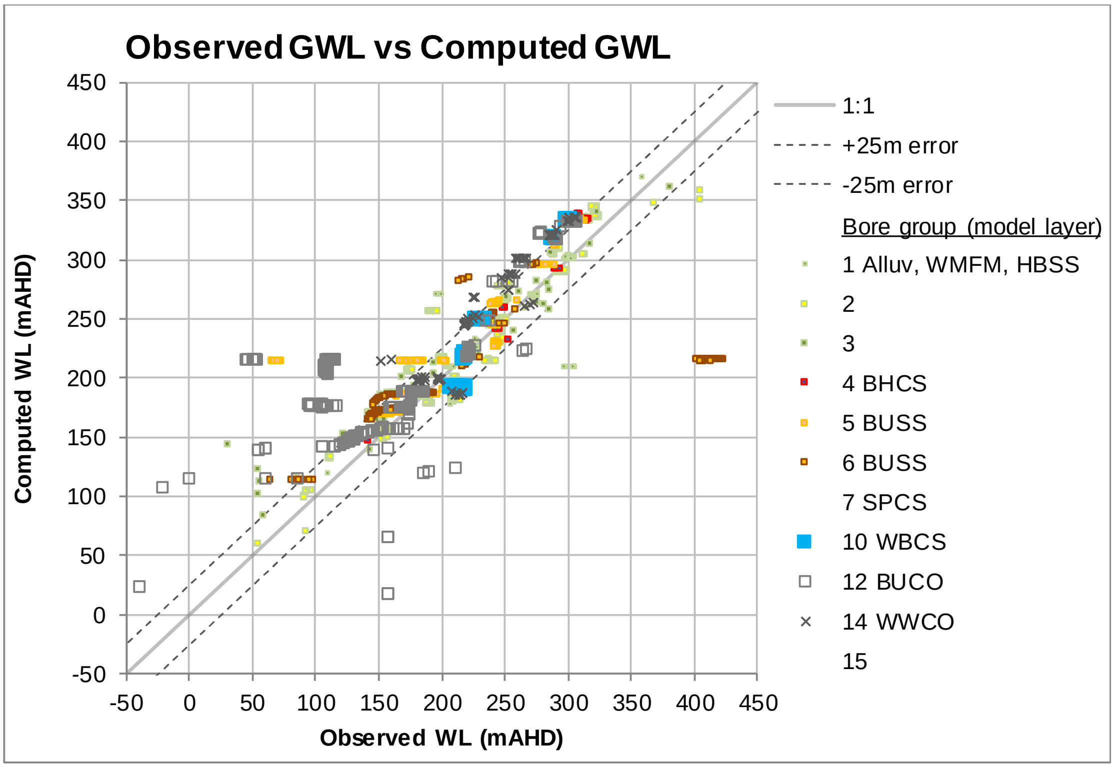
Figure 4-9 Comparison of modelled hydraulic conductivity and measured data



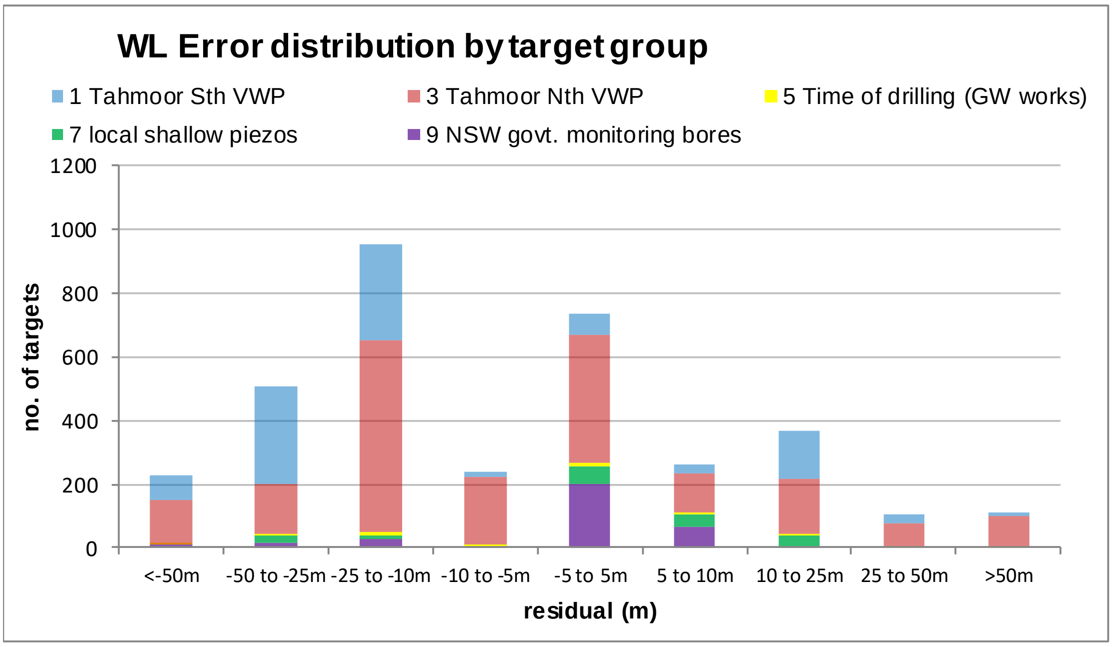


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Figure 4-10 Summary of transient calibration to water levels

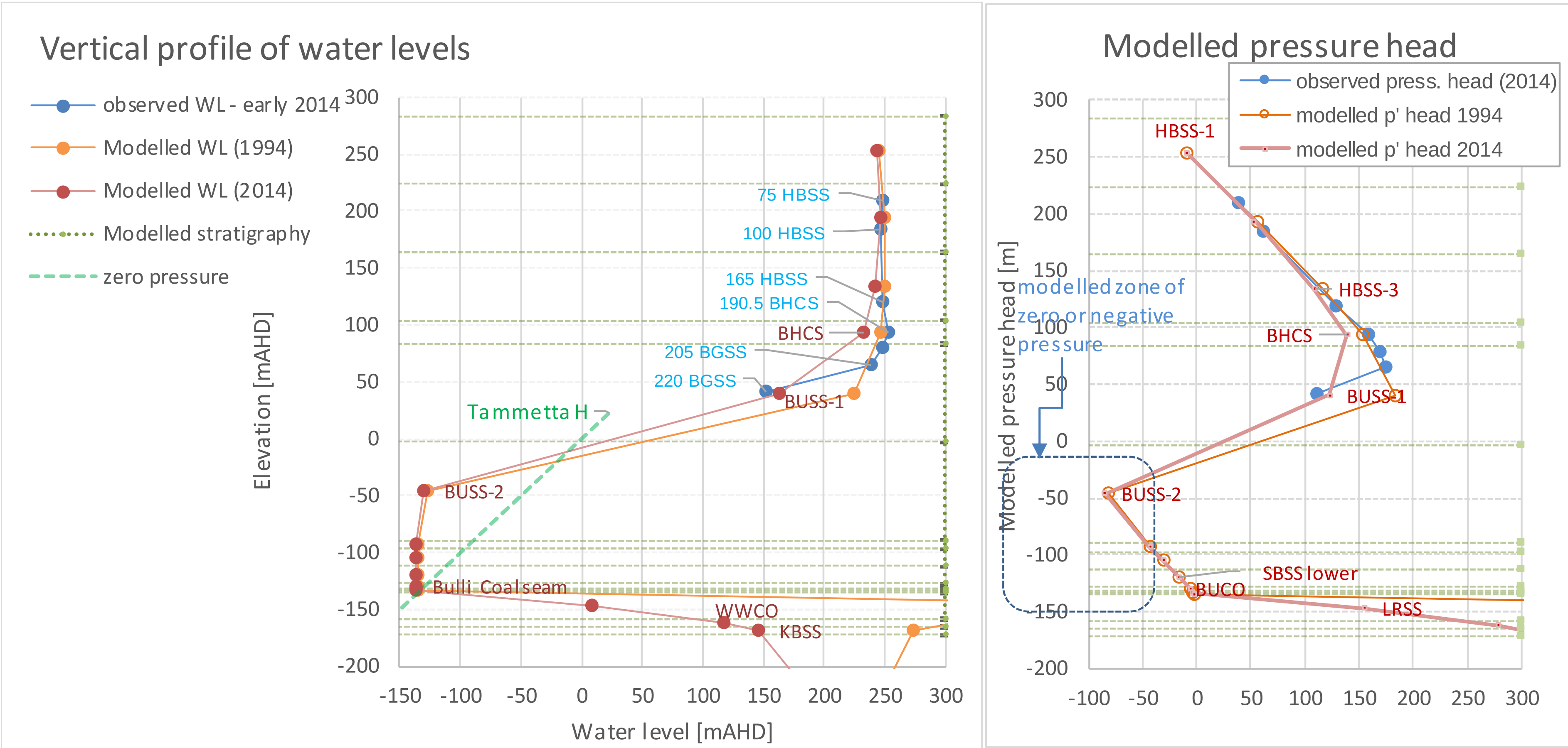

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Figure 4-11 Simulation of water levels in TBF040c ('HoF') borehole

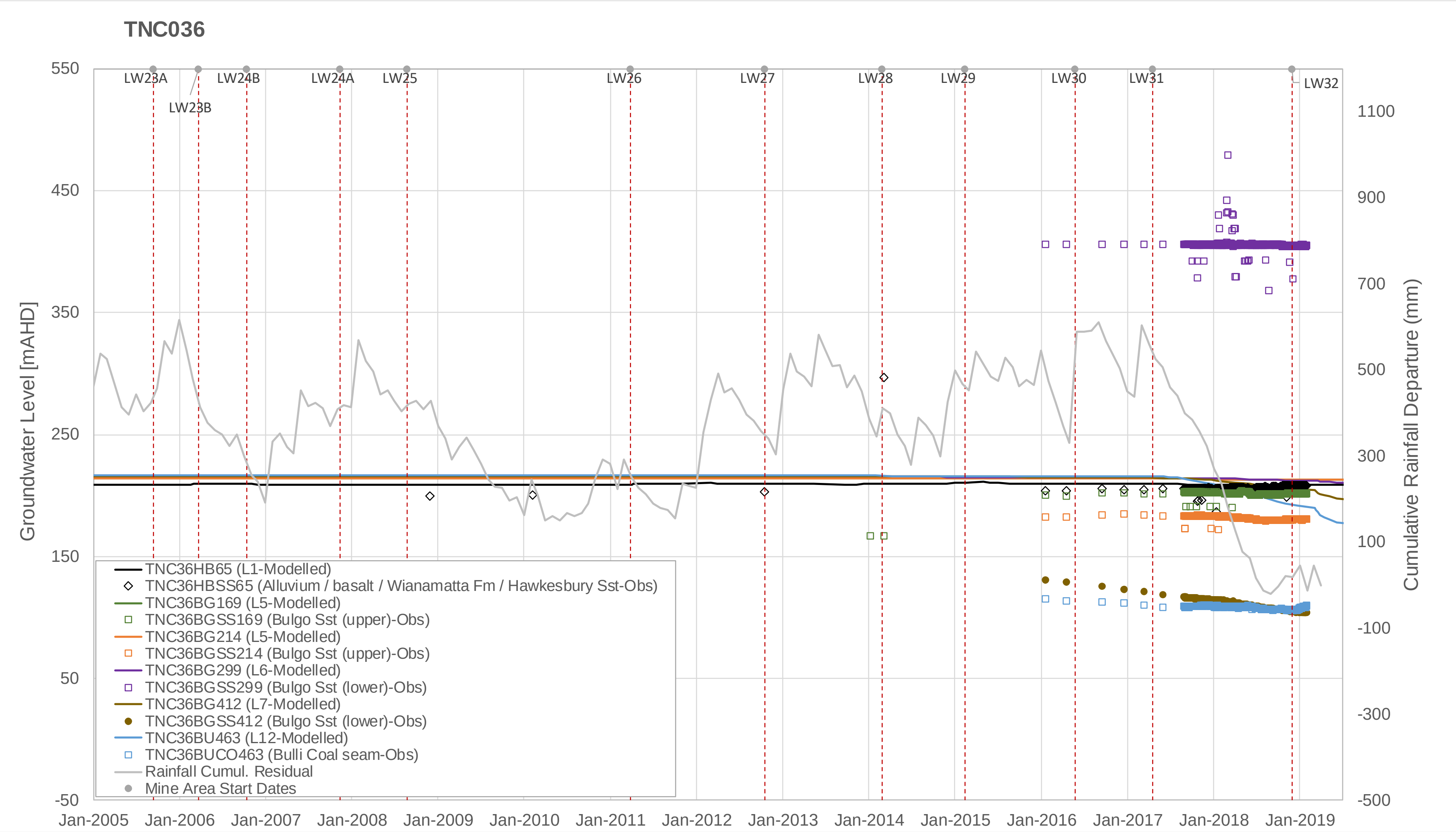

Figure 4-12 Comparison of modelled and observed groundwater levels at TNC036

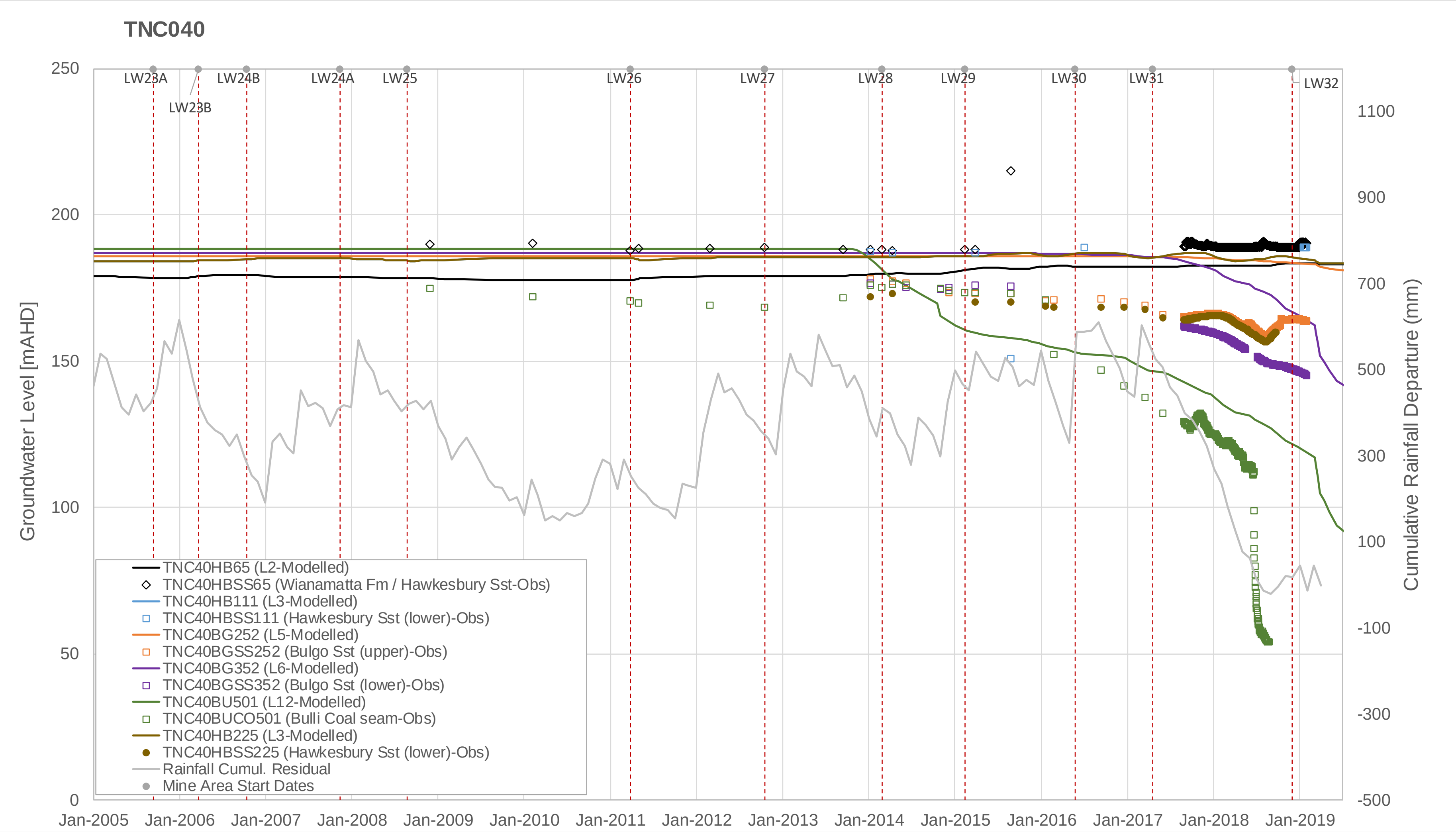

Figure 4-13 Comparison of modelled and observed groundwater levels at TNC040

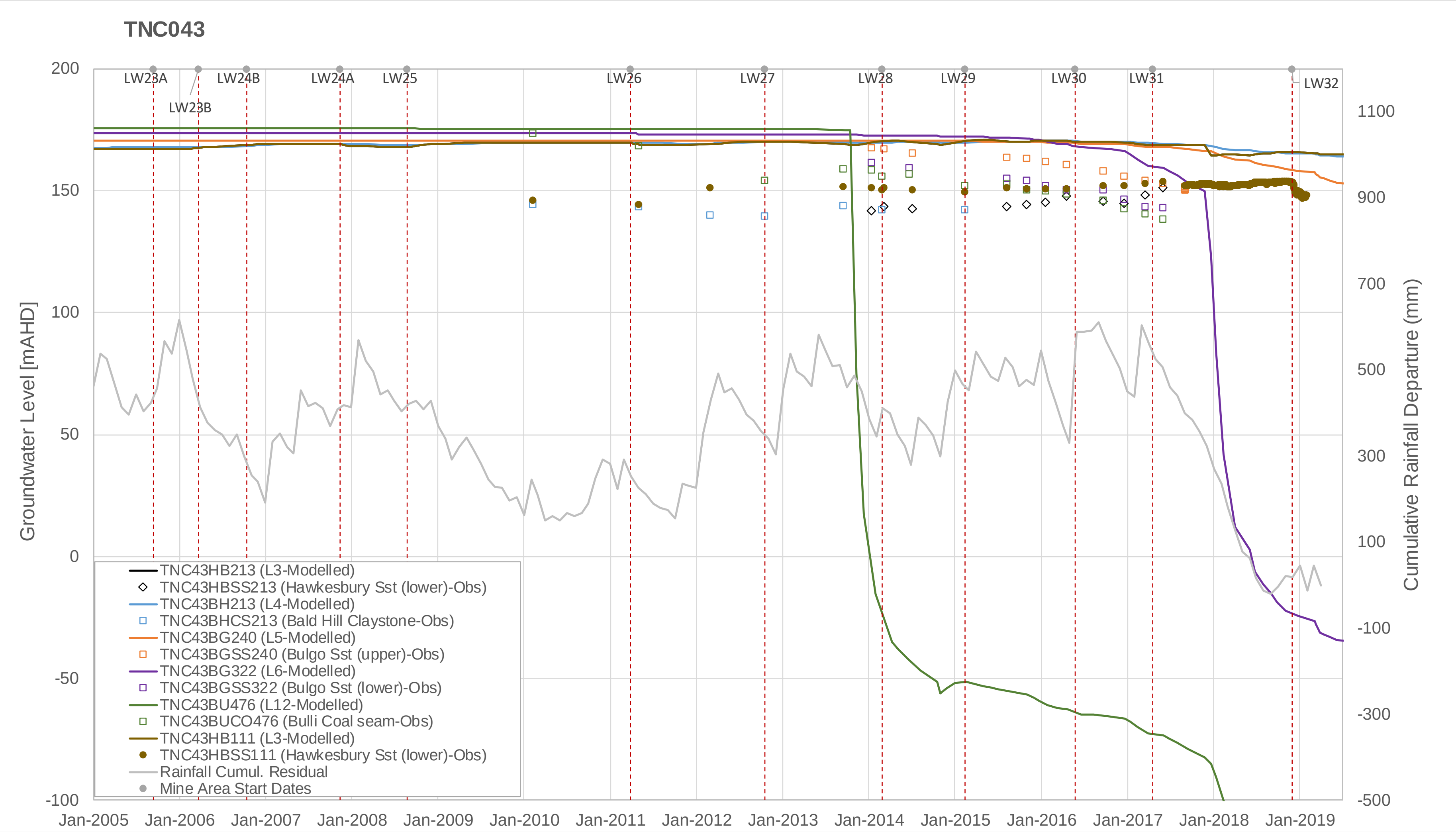

Figure 4-14 Comparison of modelled and observed groundwater levels at TNC043

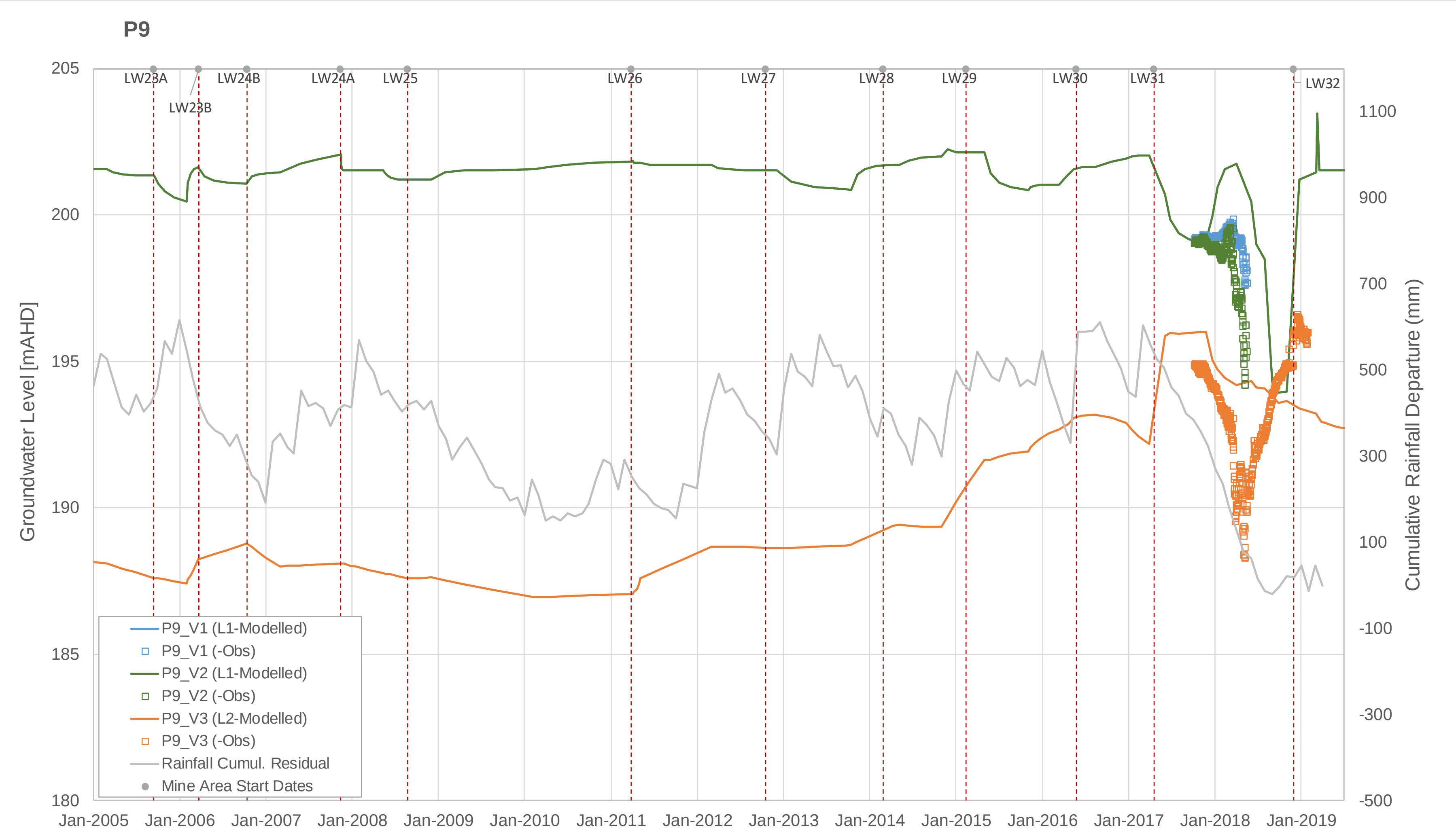

Figure 4-15 Comparison of modelled and observed groundwater levels at bore P9

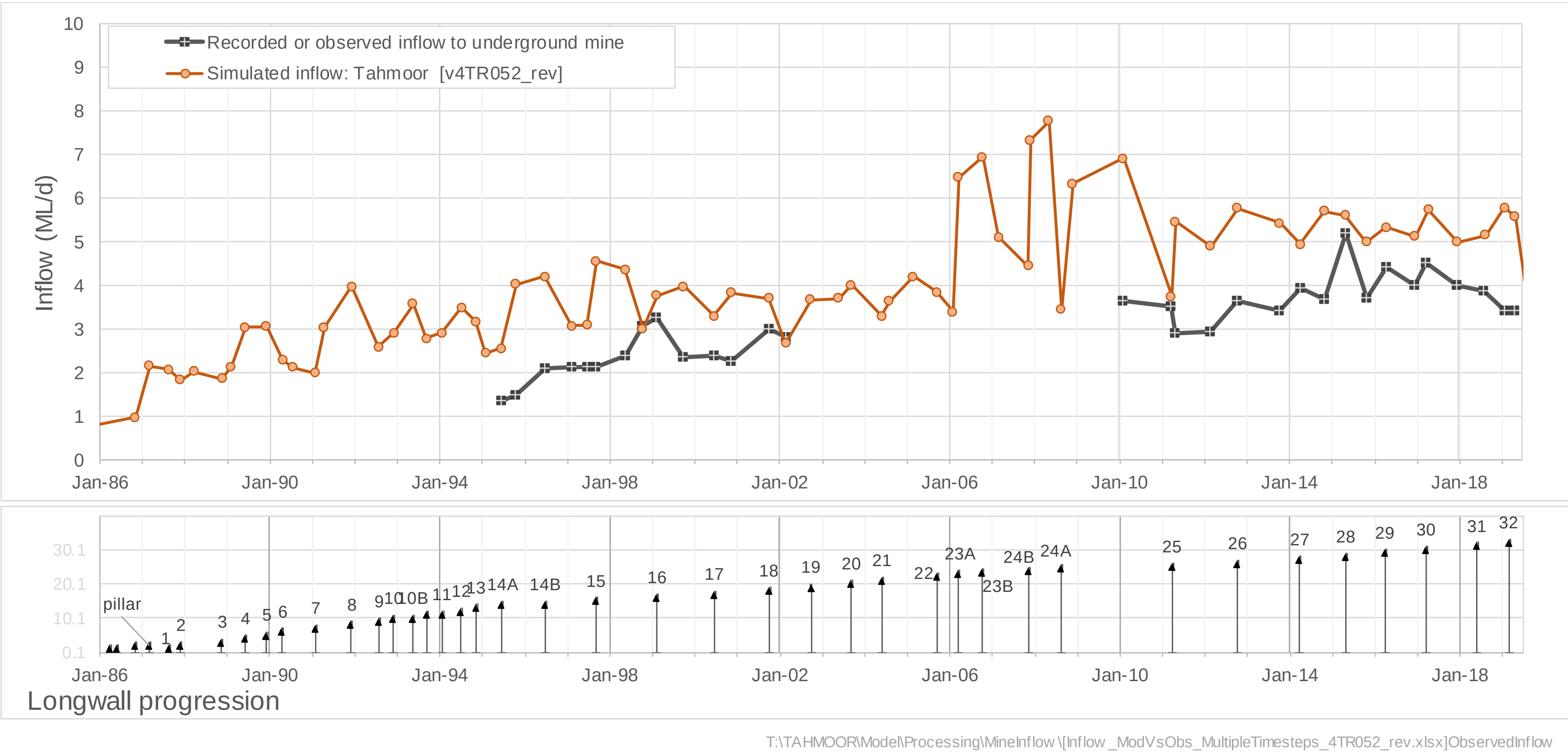

Figure 4-16 Comparison of observed and modelled inflow at Tahmoor

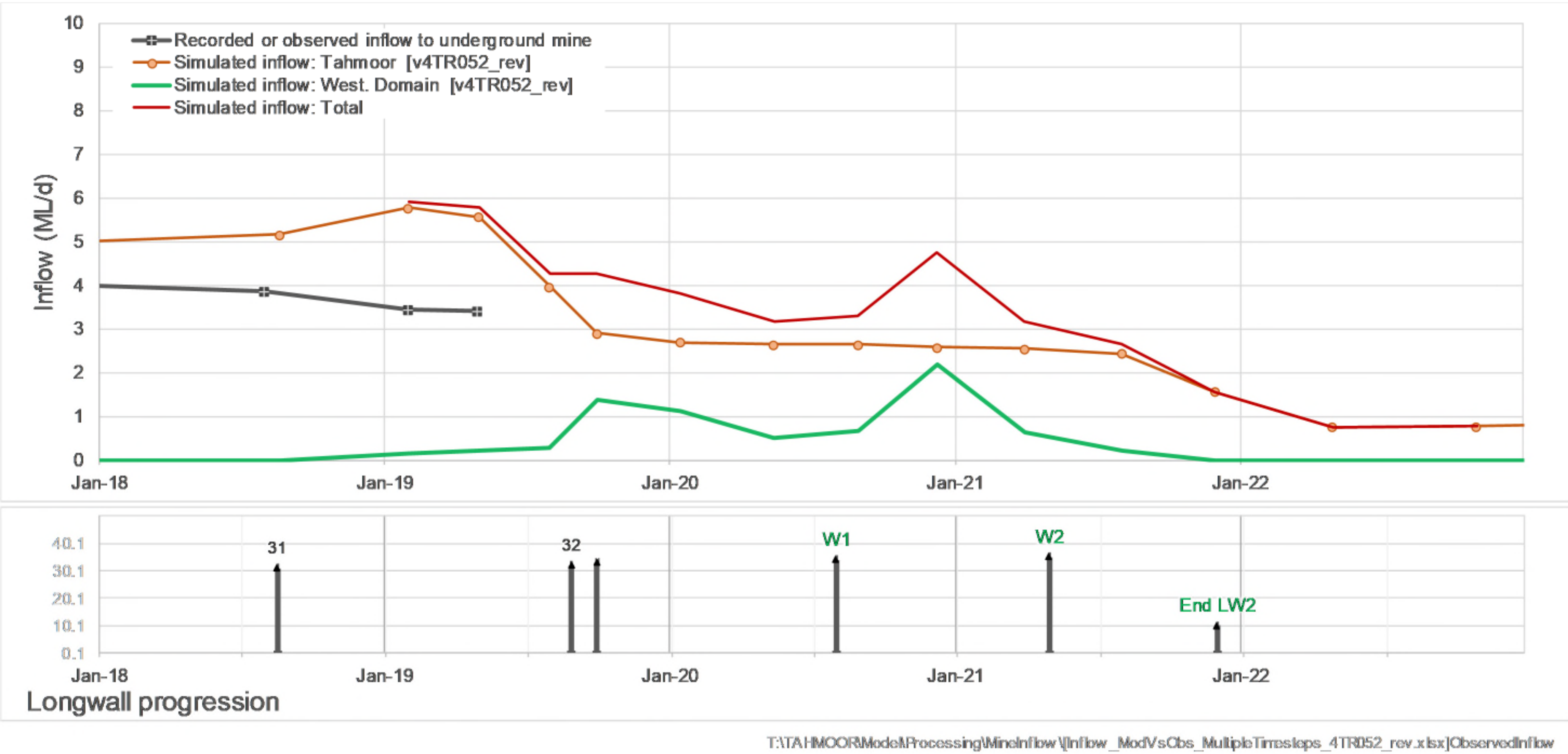

Figure 4-17 Modelled Tahmoor Mine and Western Domain Groundwater Inflows and Uncertainty

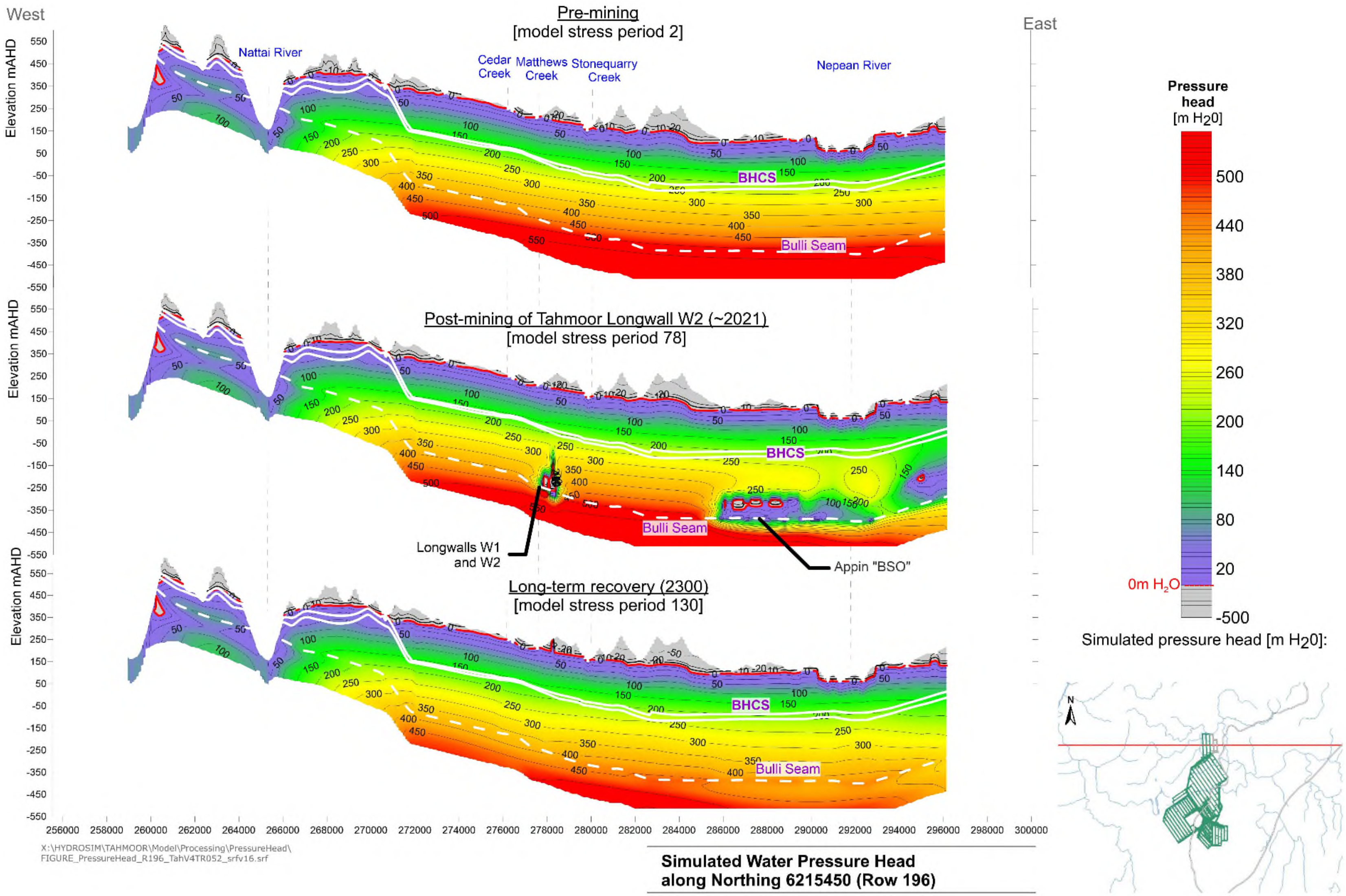

Figure 4-18 Modelled pressure head cross-section

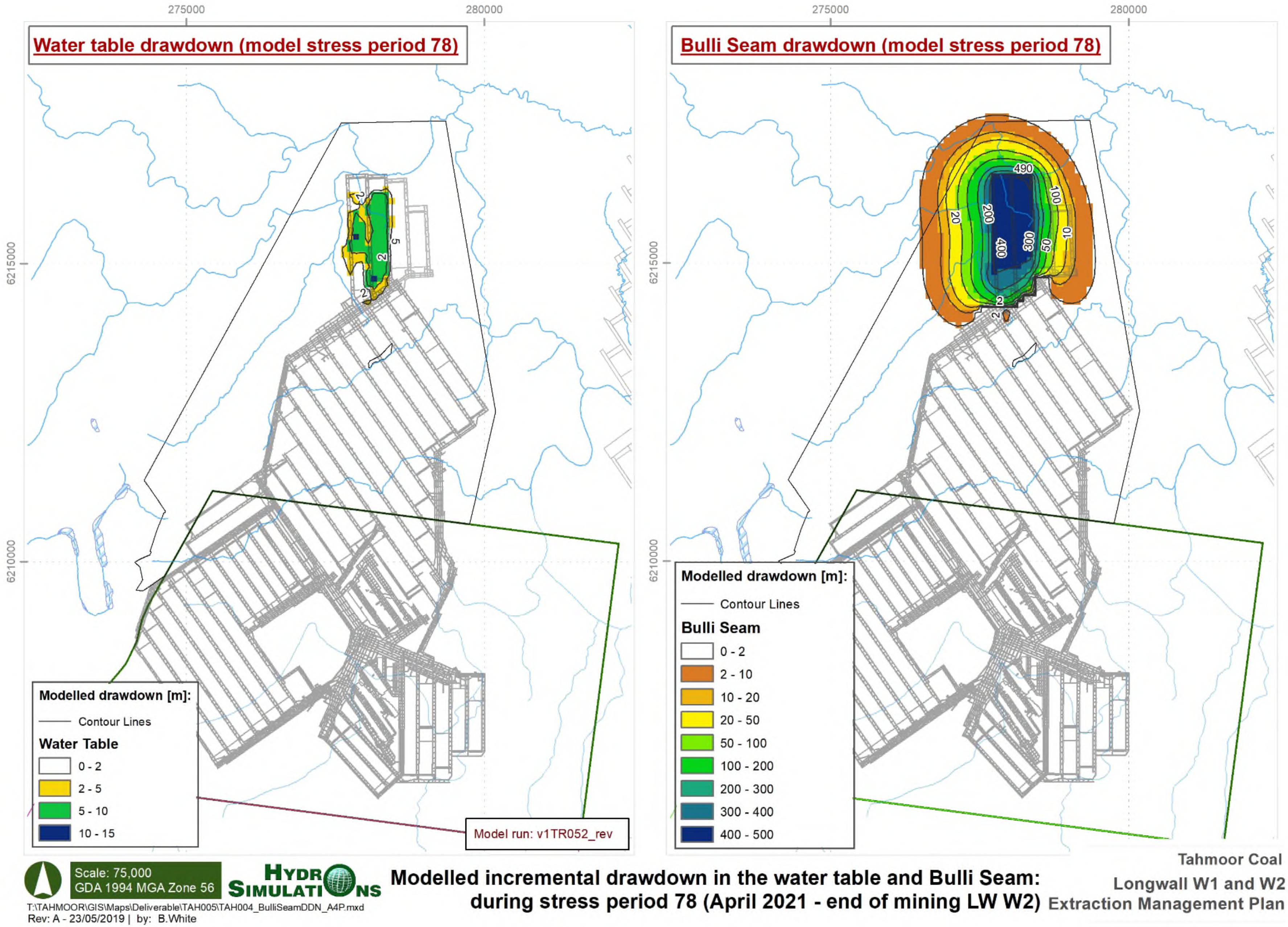

Figure 4-19 Predicted incremental drawdown in the water table and Bulli Coal Seam (2034)

The bore chosen here does not necessarily intersect or even monitor all the stratigraphic units indicated here. The location was chosen to provide a guide to water levels around LW W1-W2. Refer to Figure 3-12 for locations. *This location is at GW104090.*

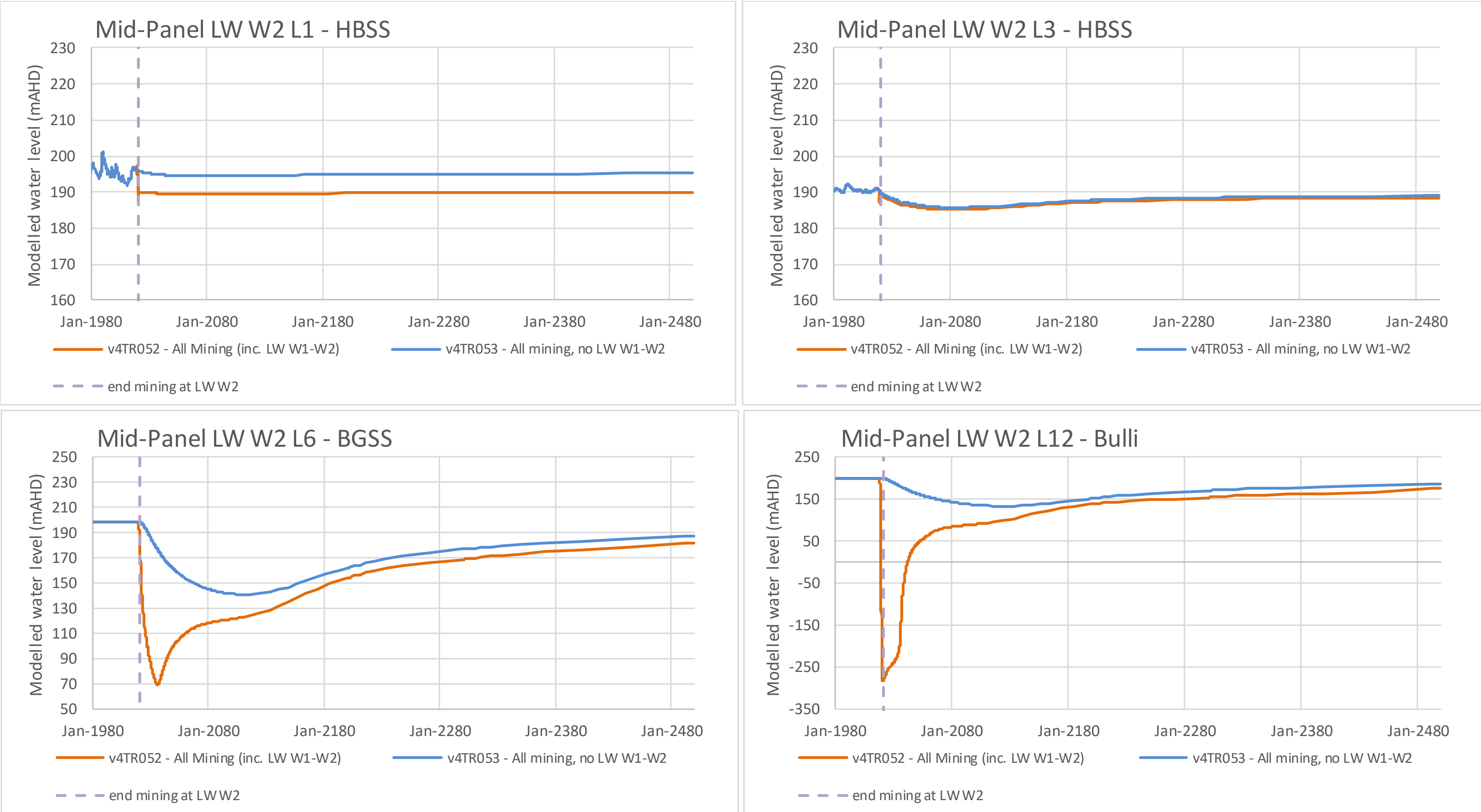

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Figure 4-20 Modelled groundwater levels: Mid-Panel LW W2

The bore chosen here does not necessarily intersect or even monitor all the stratigraphic units indicated here. The location was chosen to provide a guide to water levels around LW W1-W2. Refer to Figure 3-12 for locations. This location is at TNC040.

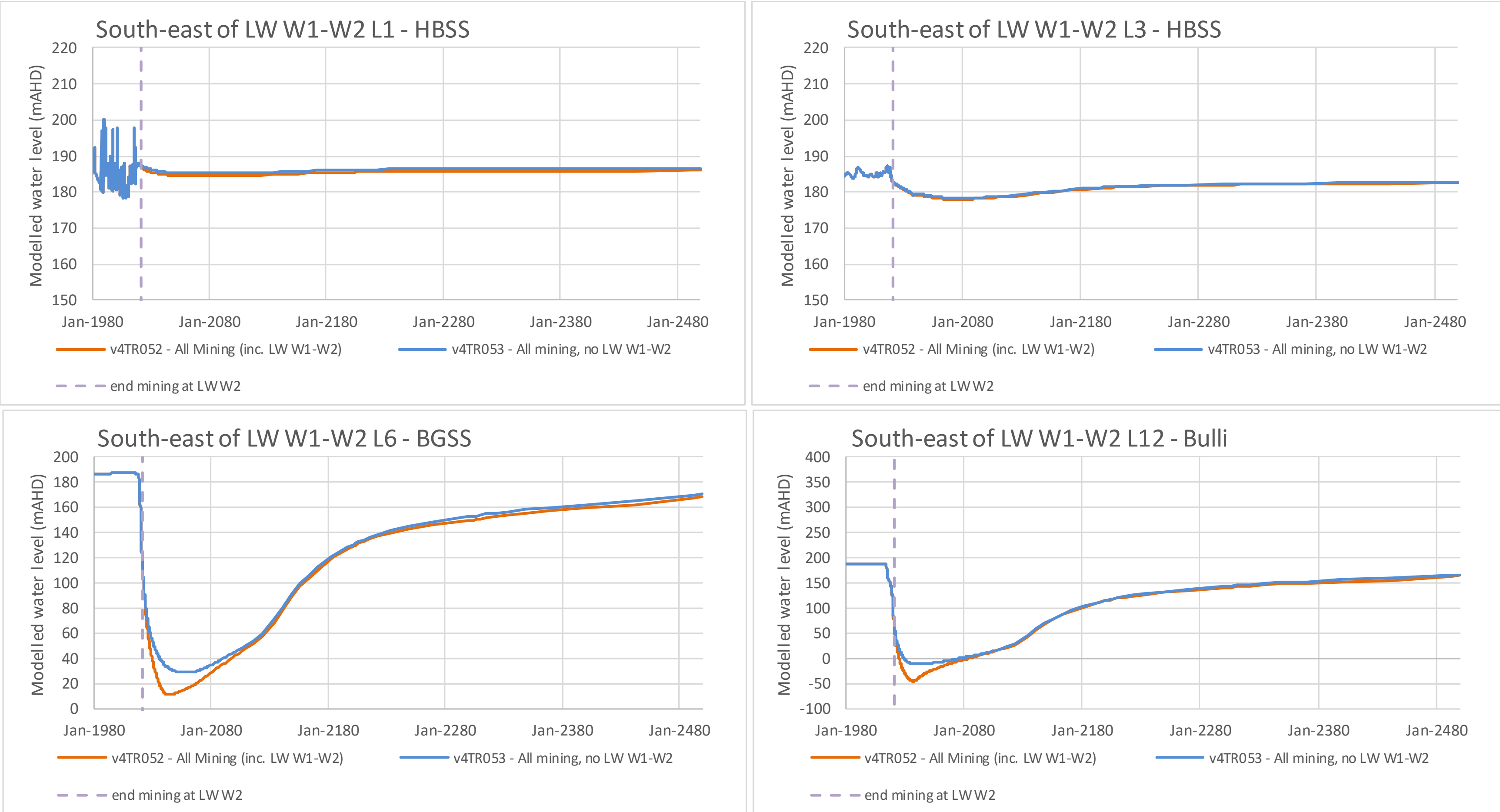

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Figure 4-21 Modelled groundwater levels: South-east of LW W1-W2

The bore chosen here does not necessarily intersect or even monitor all the stratigraphic units indicated here. The location was chosen to provide a guide to water levels around LW W1-W2. Refer to Figure 3-12 for locations. *This location is at GW072402.*

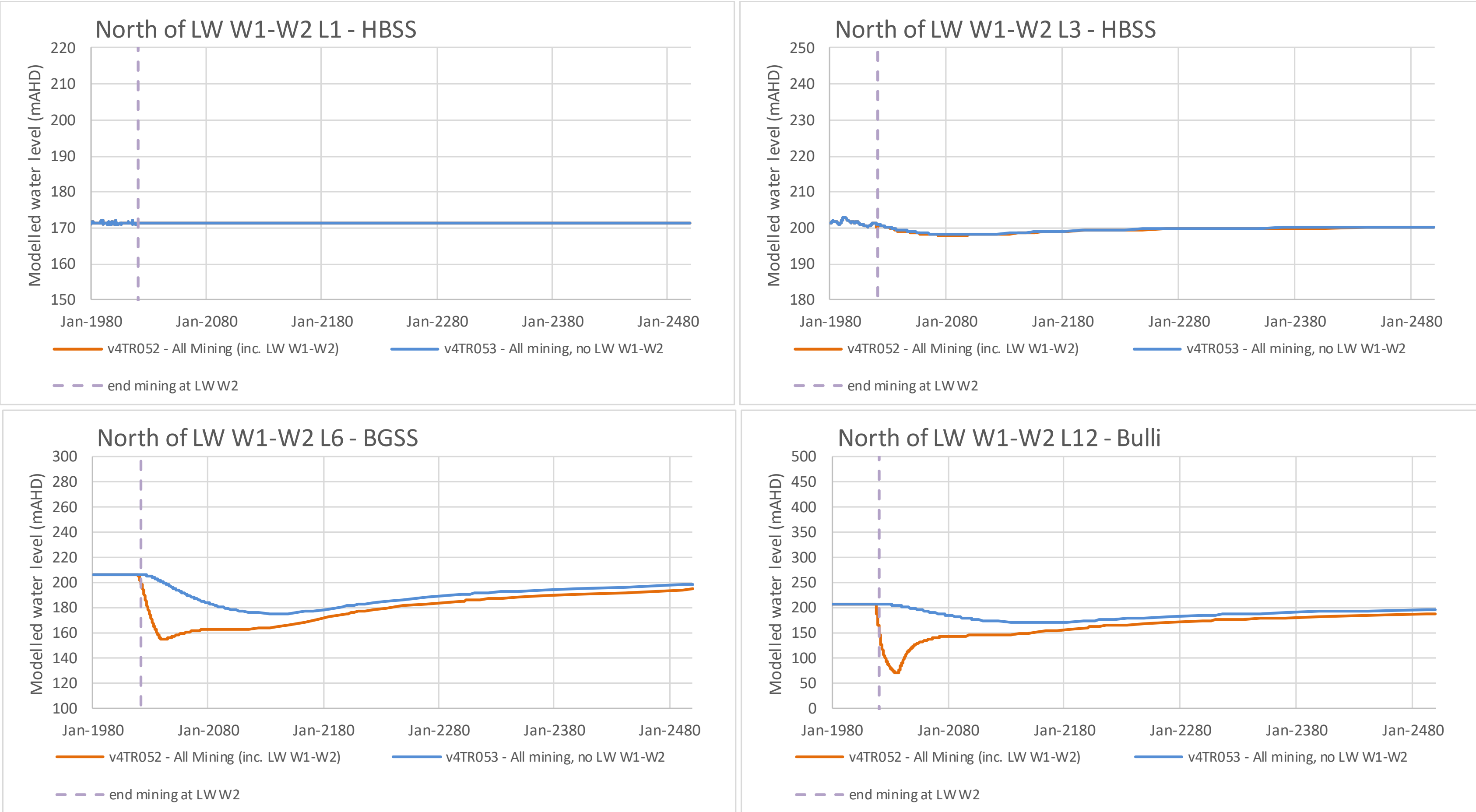

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Figure 4-22 Modelled groundwater levels: North of LW W1-W2