TAHMOOR COAL LW W3-W4

Extraction Plan
Groundwater Technical Report

Prepared for:

Tahmoor Coal Pty Ltd

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BASIS OF REPORT

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

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DOCUMENT CONTROL

Reference	Date	Prepared	Checked	Authorised
665.10010.00006-R01-v3.0	4 May 2021	Maxime Philibert Will Minchin	Graham Hawkes	Graham Hawkes
665.10010.00000-R01-v2.0	28 April 2021	Maxime Philibert Will Minchin	Graham Hawkes	Graham Hawkes
665.10010.00000-R01-v1.0	5 February 2021	Maxime Philibert Will Minchin	Graham Hawkes	Graham Hawkes

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1 Introduction

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.

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 is a wholly owned entity within the SIMEC Mining Division of the GFG Alliance group.

Tahmoor Coal has previously mined 33 longwalls to the north and west of Tahmoor Mine's current pit top location (refer to **Figure 1-2**). The current mining area, the 'Western Domain', is located north-west of the Main Southern Rail between the townships of Thirlmere and Picton. The Western Domain is within the Tahmoor Mine mining area and is within Mining Lease (ML) 1376 and ML 1539 (refer to **Figure 1-2**).

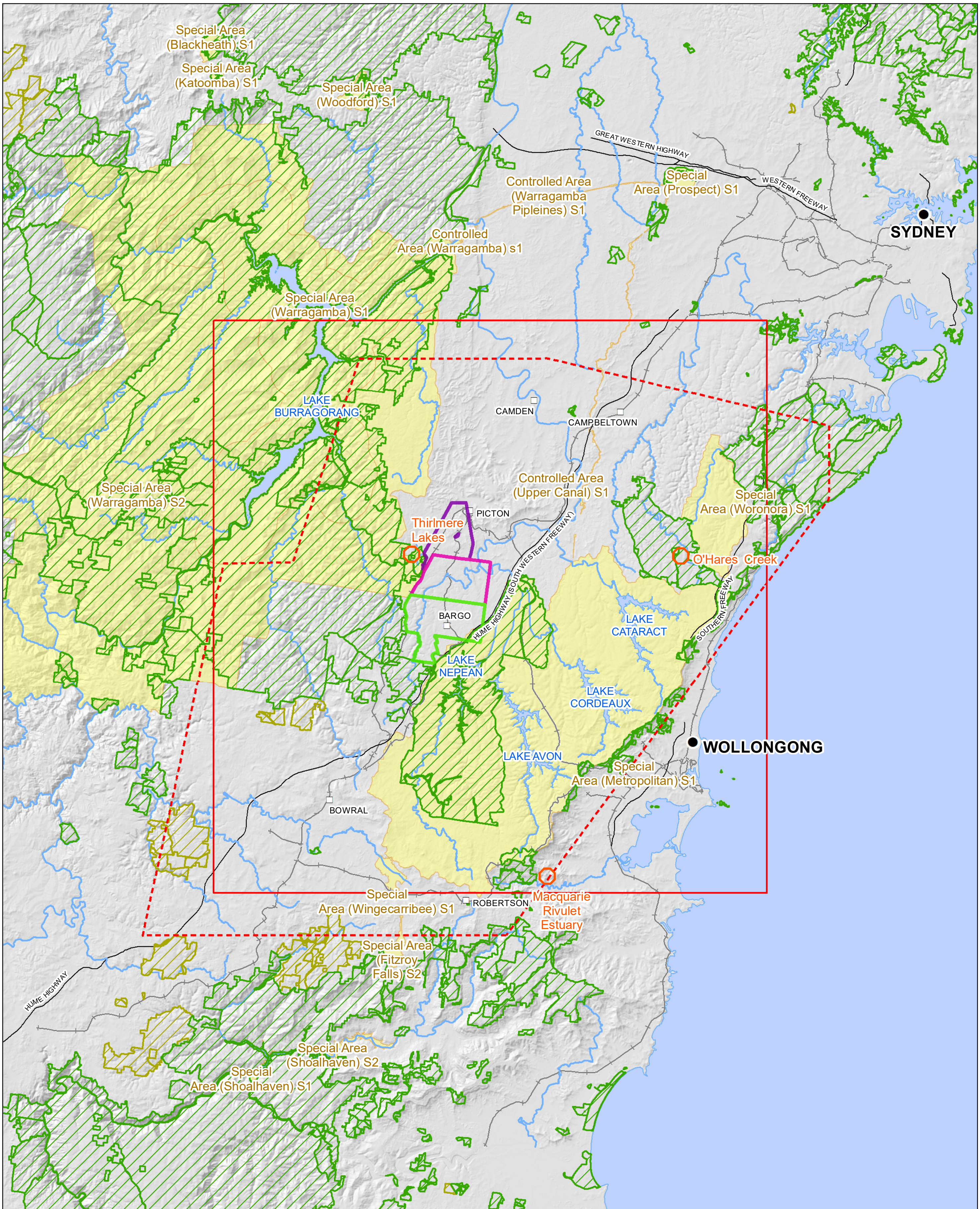
The mine plan for the Western Domain includes four longwalls - Longwalls West 1 to West 4. An Extraction Plan for the first two longwalls in the Western Domain, Longwalls West 1 and West 2 (LW W1-W2), was approved by the NSW Department of Planning, Industry and Environment (DPIE) on 8 November 2019. LW W1 extraction commenced on 15 November 2019 and was completed on 6 November 2020. The extraction of LW W2 commenced on 7 December 2020.

The extraction of the next two longwalls, Longwalls West 3 and West 4 (LW W3-W4), are the focus of this technical report. (**Figure 1-2)**. Extraction of LW W3-W4 are anticipated to begin in August 2021 and April 2022 respectively. Following extraction of the final longwalls in the Western Domain, dewatering of these workings would cease and this part of the Tahmoor Mine (which is the most down-gradient or 'down-dip' area of the mine) would be allowed to fill with water.

This report comprises the groundwater technical report and will inform the Extraction Plan developed for LW W3-W4. It exists to describe the likely environmental effects and ensure that compliance is achieved with relevant internal and external regulatory requirements related to groundwater management at LW W3-W4. This report also presents an analysis of the available baseline data for the proposed monitoring bores, results from numerical groundwater model, and outlines trigger ranges to aid in the identification of adverse mining-related impacts to the groundwater system.

1.1 Extraction Plan Study Area

Proposed LW W3-W4 are oriented north to south, with LW W3 being longer than LW W4 (**Figure 1-2**). Both have a maximum extraction height of approximately 2.15 metres (m) and LW W3 is 283 m wide and LW W4 is 285 m. **Table 1-1** details the extraction parameters for mined and proposed longwalls within the Tahmoor North mining area.



Coordinate System: GDA 1994 MGA Zone 56
Scale: 1:600,000 at A4
Project Number: 665.10010
Date: 30-Apr-2021
Drawn by: JG

Priority GDE
City
Town
Major Roads
Railway
Watercourses
Lakes
National Park Estate
NSW State Forest
Southern Coalfield (approximate)
Study Area for Groundwater Assessment
WaterNSW Special Area

Tahmoor Coal Titles

MLs 1308, 1376, 1539
CCL 716
CCL 747

TAHMOOR COAL LONGWALL W3 AND W4 EXTRACTION MANAGEMENT

Project Location

FIGURE 1-1

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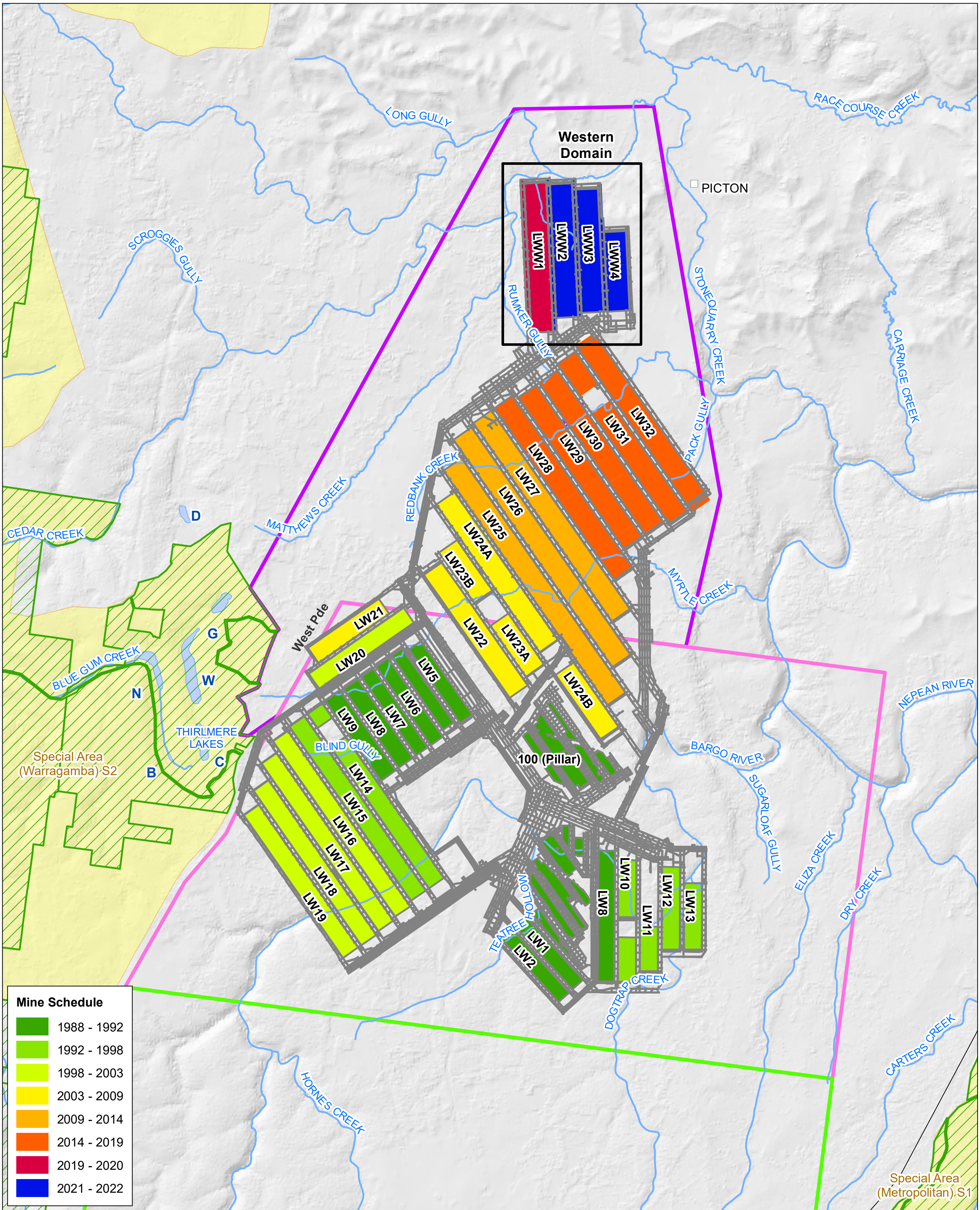


0 1 2 km

Coordinate System: GDA 1994 MGA Zone 56
Scale: 1:63,000 at A4
Project Number: 665.10010
Date: 07-Dec-2020
Drawn by: JG

Minor Town
Major Roads
Watercourses
Lakes
National Park Estate
NSW State Forest
WaterNSW Special

Tahmoor Coal Titles
MLs 1308, 1376, 1539
CCL 716
CCL 747

Lakes:
D = Dry Lake
G = Gandangarra
W = Werri Berri
C = Couridjah
B = Baraba
N = Nerrigorang

SLR

TAHMOOR COAL LONGWALL W3 AND W4 EXTRACTION MANAGEMENT

Mine Plan and Extraction Schedule

FIGURE 1-2

H:\Projects-SLR\620-BNE\665-WOL\665.TAH05 Tahmoor GWMP\GIS\66510010 Fig1_2 Mine plan and extraction schedule.mxd

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 (W/D)			HoF - Tammetta H (mAHD)	Depth to Tammetta H (m)
							Mean	Max	Min	Mean	Max	Min	Mean	Max		
Historical Panels																
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

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 (W/D)			HoF - Tammetta H (mAHD)	Depth to Tammetta H (m)
							Mean	Max	Min	Mean	Max	Min	Mean	Max		
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	285	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	285	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	285	770	-141.8	288.1	2.0	2.1	415	431	451	0.46	0.44	0.42	7.9	282.5
24B	15/10/06	26/08/07	285	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	285	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	285	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	285	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	285	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	26/09/19	283	2376	-252.0	231.1	2.2	2.5	474	487	502	0.40	0.39	0.38	-91.8	299.7
W1	15/11/19	06/11/20	283	1870	-283.0	226.2	2.0	2.1	474	518	547	0.40	0.37	0.35	-18.7	303.3
W2	07/12/20	11/07/21*	283	1675	-283.0	225.8	2.0	2.1	474	518	547	0.40	0.37	0.35	-117.1	306.8
Proposed Panels																
W3	5/08/21*	5/03/22*	283	1540	-266.5	204.3	2.0	2.1	472	503	531	0.40	0.38	0.36	-128.6	225.8
W4	2/04/22*	14/08/22*	285	992	-253.6	204.3	2.15	2.15	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, 2018/2019a). * proposed dates.

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 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 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 W3-W4, 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.

Since the submission of the Tahmoor South Amended Project EIS (SLR/HydroSimulations, 2020), Tahmoor Coal conducted revision to the Western Domain mine plan for LW W3 and LW W4. The panel width for LW W4 has been increased marginally from 283 m to 285 m and the panel lengths for LW W3 and LW W4 have been increased in the south by 120 m and 80 m respectively. The extent of the road development at the northern end of LW W4 has been shifted to the south by approximately 90 m, and more significantly, the northern extent of LW W4 has been moved to the south by 36 m. LW W4 is now at least 680 m south of Stonequarry Creek and 740 m west of Stonequarry Creek where it flows south through Picton. LW W3 is 120 m south of Stonequarry Creek at its closest point. 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, 2020) 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 W3-W4:

- *Stonequarry Creek and tributaries of Redbank Creek have been identified as having the potential to be impacted by extraction at LW W3-W4 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 80 mm and 150mm respectively.*
- *Any water quality impacts that may occur are likely to be localised due to the low flow volumes and ephemeral nature of most of the creeks adjacent to LW W3-W4.*
- *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 32 and W1 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 W3-W4. **Table 1-2** 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 W3-W4 Extraction Plan

Consulted Party	Comments regarding Groundwater	Area where addressed
Department of Regional NSW – Resources Regulator	Advised 23rd May 2019 to commence collecting baseline data for groundwater to inform subsidence monitoring program. No comments pertaining to this Extraction Plan.	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.	-
WaterNSW	No comments pertaining to the Extraction Plan.	-
Wollondilly Shire Council	Provided advice (13th October 2020) regarding additional consultation with landowners of potentially affected dwellings and full compensation of any impacts attributable to subsidence. Indicated key components of the Extraction Plan relating to effects on third-order steams and ecological health of waterways, details of geological and groundwater models, effects on groundwater and surface waters including via re-emergent water from fractures.	- Geology and groundwater models described in **Section 3 and 4**
NSW State Emergency Services	No comments pertaining to the Extraction Plan.	-
NSW Department of Planning, Industry and Environment – Environment, Energy and Science (EES) Group	Provided preliminary comments (29th January 2021) relating to primary concerns relating to subsidence impacts to watercourses. Further discussions will be completed with EES regarding creek remediation success to date, as well as potential subsidence impacts to watercourses prior to Extraction Plan approval.	-

2 Statutory Requirements

This section provides background to the statutory requirements associated with the broader Tahmoor Mine and for LW W3-W4.

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 implementation of Water Sharing Plans (WSPs). WSPs regulate the trade and sharing of surface and groundwaters between competing needs and users throughout NSW.

2.1.1.1 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.

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.

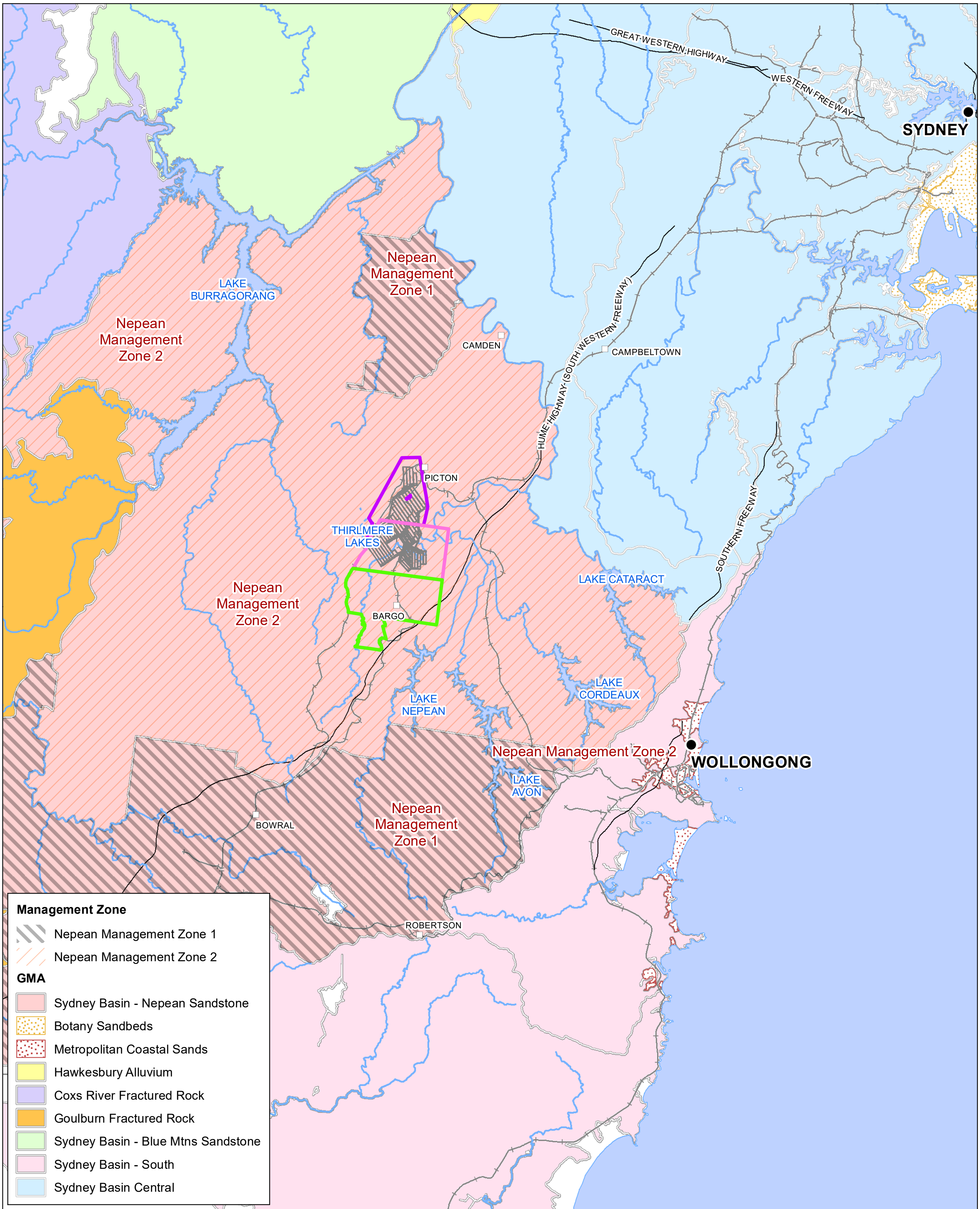
The Sydney Basin – Nepean Sandstone Groundwater Source is further subdivided into Management Zones (MZ), as shown using hatching on **Figure 2-1**. The LW W3-W4 Study Area lies within Nepean Management Zone 2, while Zone 1 covers the southern 'third' of the Groundwater Source as well as a smaller area 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 31,346 ML (based on the WaterNSW *Water Register* 2020-2021 water year)[1].

The Greater Metropolitan Region Unregulated River Water Sources WSP (NOW, 2011c) is the relevant plan for surface waters for the LW W3-W4 Study Area. Within this WSP the Upper Nepean River source is the relevant Water Source, of which the following MZ cover or adjacent to the project site:

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

The Western Domain lies within the Stonequarry Creek MZ.

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



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Coordinate System: GDA 1994 MGA Zone 56
Scale: 1:500,000 at A4
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Date: 04-May-2021
Drawn by: JG

- City
- Town
- Major Roads
- Railway
- Watercourses
- Lakes

Tahmoor Coal Titles

- MLs 1308, 1376, 1539
- CCL 716
- CCL 747

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TAHMOOR COAL LONGWALL W3 AND W4 EXTRACTION MANAGEMENT

Relevant Water Sharing Plan

FIGURE 2-1

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2.1.2 NSW Aquifer Interference Policy

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

The AIP 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 AIP 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 AIP 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 AIP categorises groundwater source productivity (highly productive or less productive) based on characteristics of salinity and aquifer yield. 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 Tahmoor Mine (HydroSimulations, 2018).

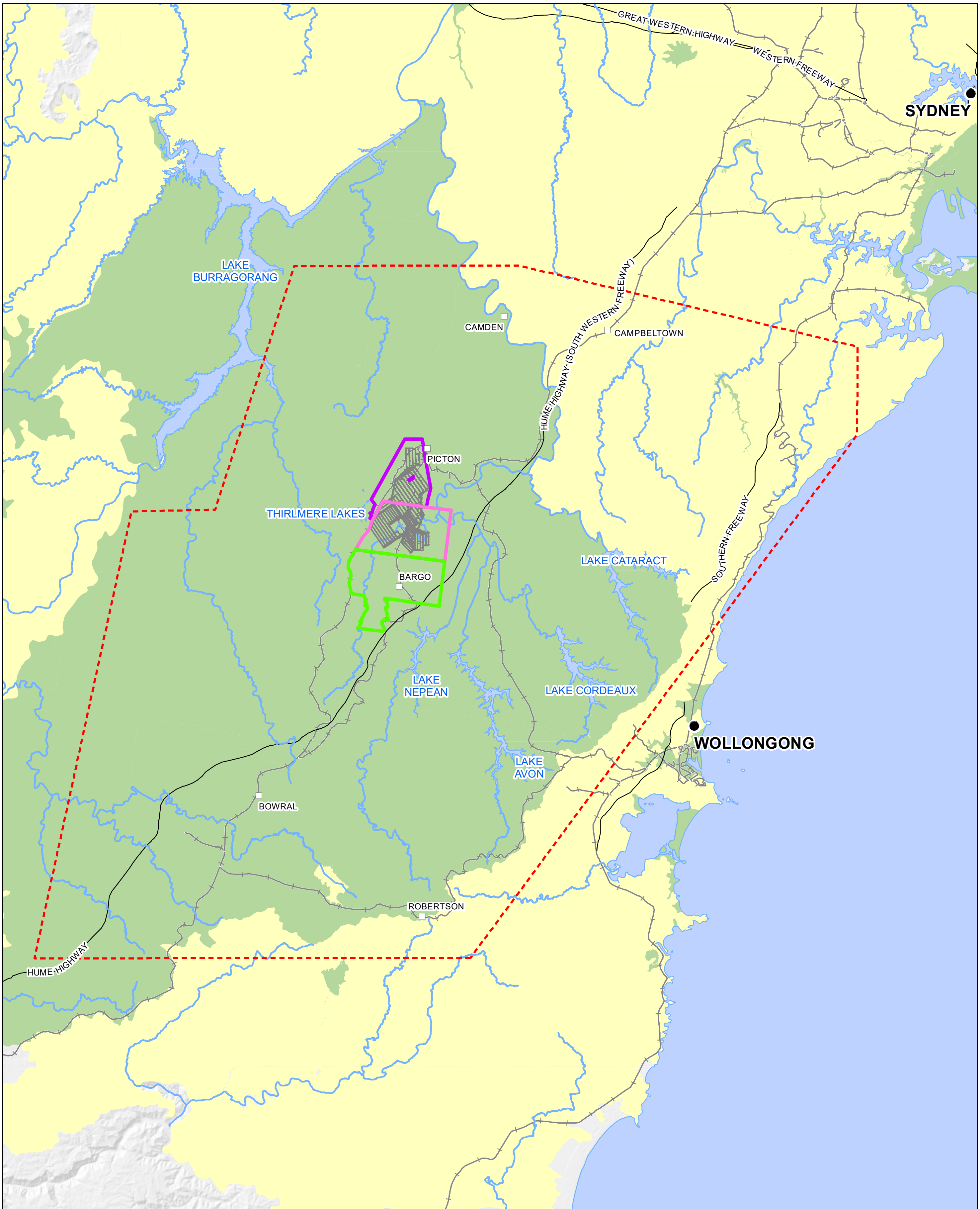
It should be noted that the categorisation of groundwater source productivity does not make any vertical distinction of aquifer productivity. This is relevant as the high yielding Hawkesbury Sandstone aquifer overlies the lower-yielding Narrabeen Group/Permian Coal Measures groundwater systems which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

2.1.3 Water Licensing

Water Access Licences (WAL) held by Tahmoor Coal under the authority of the *Water Management Act 2000* are listed in the **Table 2-1**.

Table 2-1 Tahmoor Coal Water Access Licences

Works approval	WAL title	Issued	Purpose	Share
10WAl18745	WAL 36442	06/12/2013	Mining dewatering (groundwater) (Nepean Sandstone Groundwater MZ2)	1,642 ML
10AL103025	WAL 25777	27/10/2014	Surface Water Take (Maldon Weir MZ)	5 ML
10MW119329	WAL 43572	13/04/2021	Incidental Surface Water Take (Stonequarry Creek MZ)	16 ML



Coordinate System: GDA 1994 MGA Zone 56
Scale: 1:500,000 at A4
Project Number: 665.10010
Date: 04-May-2021
Drawn by: JG

SLR

- City
- Town
- Major Roads
- Railway
- Watercourses
- Lakes

GW Productivity
- Highly Productive
- Less Productive
- Southern Coalfield (approximate)

Tahmoor Coal Titles
- MLs 1308, 1376, 1539
- CCL 716
- CCL 747

TAHMOOR COAL LONGWALL W3 AND W4 EXTRACTION MANAGEMENT

Groundwater Productivity

FIGURE 2-2

H:\Projects-SLR\620-BNE\665-WOL\665.TAH05 Tahmoor GWMP\GIS\66510010 Fig2_2 Groundwater Productivity.mxd

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, 2021b) discusses the EPL in the context of Western Domain operations.

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 five modifications to the DA have been made 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 (Modification 4) 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 (now known as LW W1). Condition section 13H (vii) c) requires 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 2-2.**

Table 2-2 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 or registered 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 of LW W3-W4 on water resources or water quality.	Groundwater impact assessment criteria presented in **Section6**.
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 Section6**
A plan to respond to any exceedances of the groundwater assessment criteria.	**Section6**

2.2.2 Subsidence Performance Measures

Subsidence performance measures for natural and heritage features are listed under Condition 13A of DA 67/98. There are no performance measures specific to groundwater.

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

Tahmoor Mine lies at an elevation of approximately 280 mAHD, and 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 W3-W4 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 W3-W4 and then down to the south-east through the town of Picton as it follows the drop in local topography to its confluence with the Nepean River at approximately 100 mAHD to 150 mAHD.

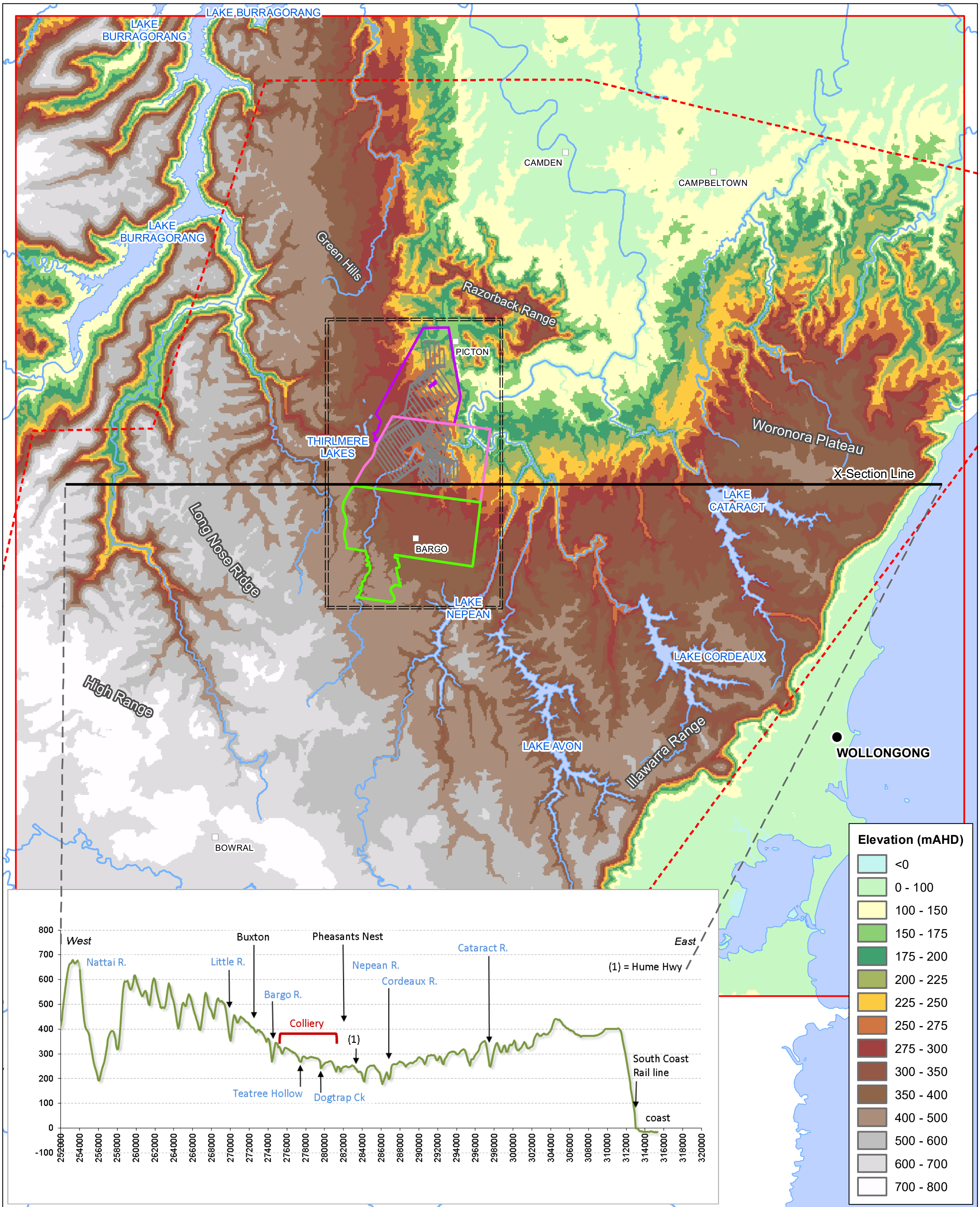
3.2 Rainfall and evaporation

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 rainfall station, and the SILO climate data source provide interpolated and infilled records for 0.05°x0.05° latitude and longitude 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 0.05°x0.05° tile surrounding the location 274250E, 6212950N (**Figure 3-4**) 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.

Average annual rainfall at Tahmoor is approximately 760 mm/yr. Areas with higher rainfall occur to the south and east, while areas to the north and west are typically drier. Monthly average rainfall is presented on **Figure** 3-2, alongside potential evaporation and estimated actual evapotranspiration. Rainfall is generally consistent all year with average monthly totals of 41-87 mm. The highest monthly rainfall is typically in January and February, (82 and 87 mm respectively), while September is typically the driest month (averaging 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 potential evaporation is highest in December (200 mm).

Figure 3-3 shows the historical record of monthly rainfall and potential evaporation, and the calculated trend in rainfall (using "cumulative residual departure" from mean method). This trend (dark green line) shows wet periods as upward gradients, droughts as downward gradients, and average conditions as horizontal. Of note in recent times, there was a significant drought period from mid-2017 until January 2020, with extreme conditions in November 2019 to January 2020, notable for bushfire conditions around Tahmoor and more widely across eastern NSW. Since then, conditions have been wetter than average, including high rainfall totals in February and August 2020, and again in March 2021.



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0 5 10 km

Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:350,000 at A4
Project Number:	665.10010
Date:	04-May-2021
Drawn by:	JG

SLR

- City
- Town
- Watercourses
- Lakes

Tahmoor Coal Titles

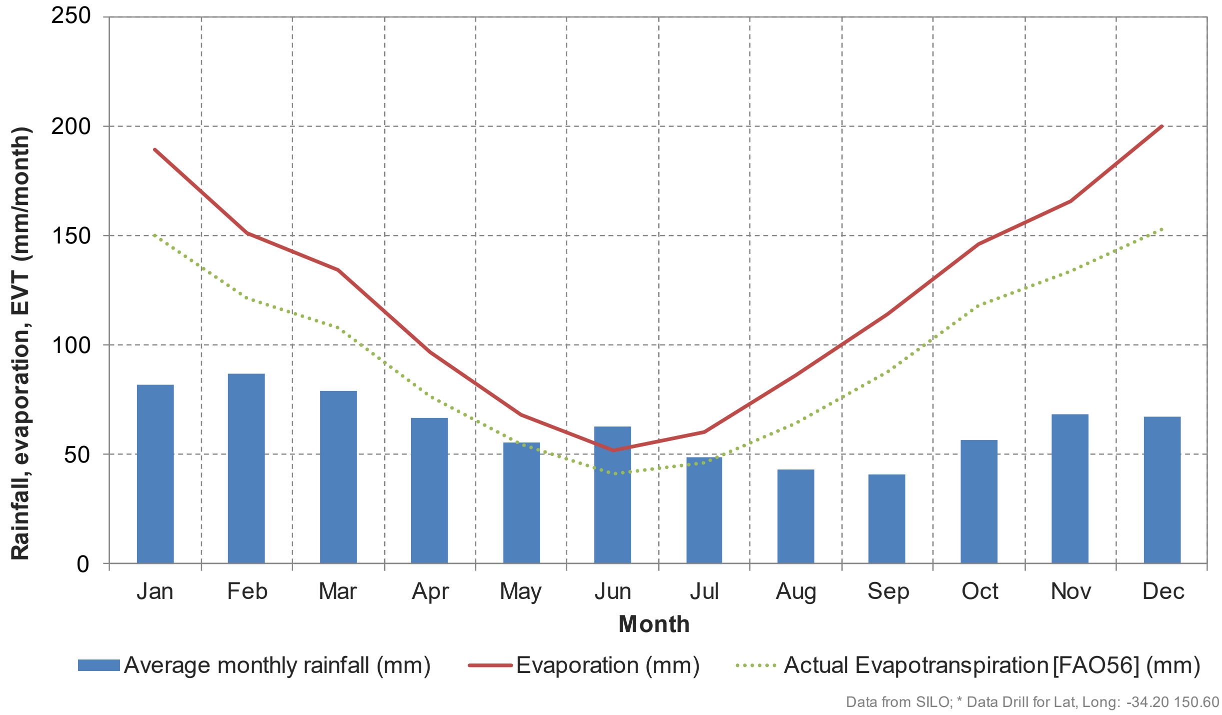
- MLs 1308, 1376, 1539
- CCL 716
- CCL 747

- Lidar Covarage
- Southern Coalfield (approximate)
- Study Area for Groundwater Assessment

TAHMOOR COAL LONGWALL W3 AND W4 EXTRACTION MANAGEMENT

Topographic Setting

FIGURE 3-1



H:\Projects-SLR\660-SrvWOL\660-WOL\665.10010 Tahmoor GW RTS\06 SLR Data\02 Site Notes & Measurements\03 Climate\CRD_Rain_TAH_Apr2021.xlsx

Figure 3-2 Long-term rainfall record and trends

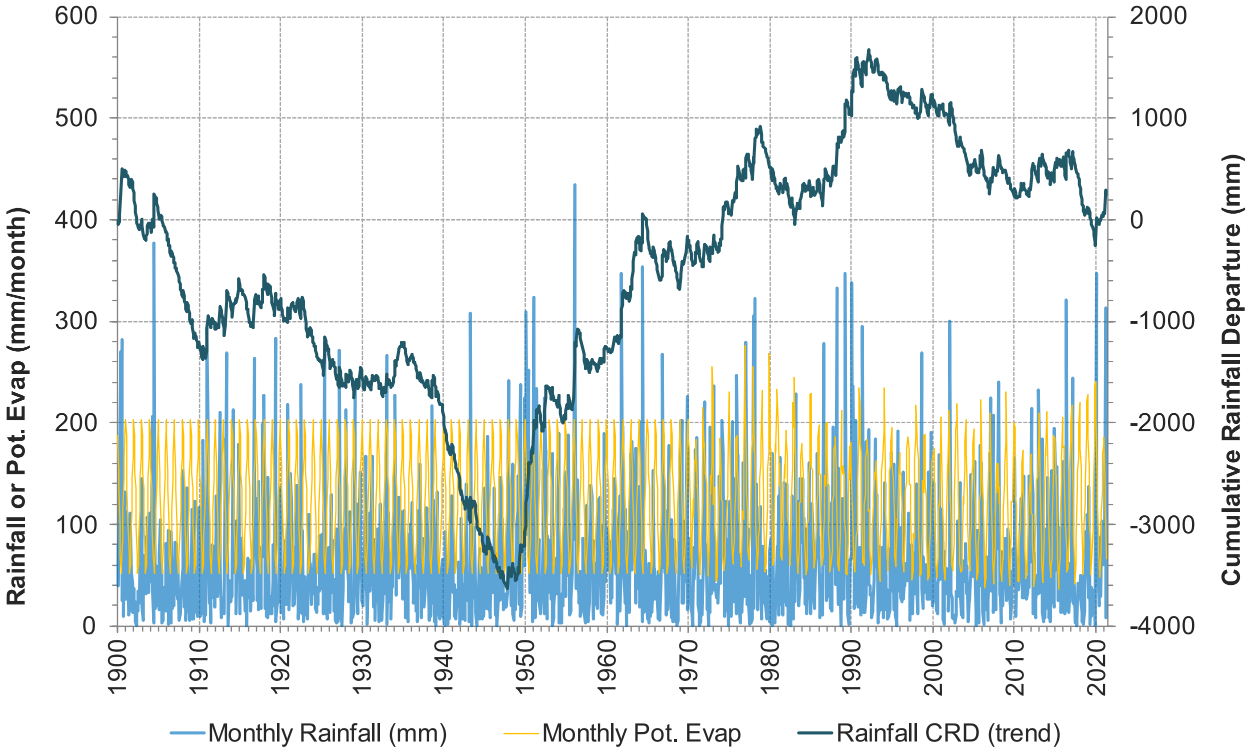
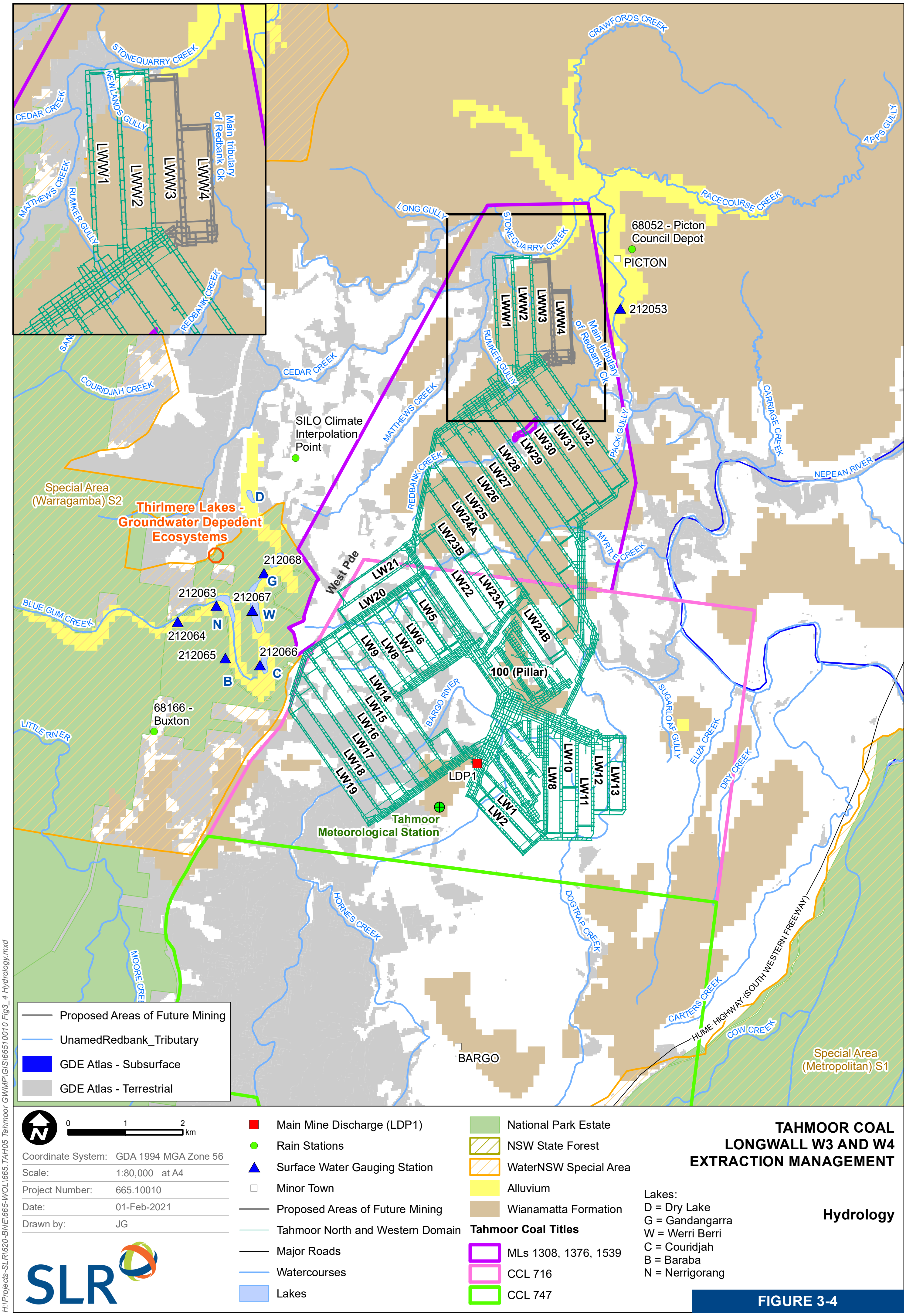


Figure 3-3 Monthly average rainfall and potential evaporation and rainfall trends



TAHMOOR COAL LONGWALL W3 AND W4 EXTRACTION MANAGEMENT

Hydrology

FIGURE 3-4

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 and 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 W3-W4 are (**Figure 3-4**):

- Stonequarry Creek;
- Cedar Creek;
- Matthews Creek;
- Redbank Creek (and Redbank Creek Tributaries); and
- Rumker Gully and Newlands Gully.

The main tributary of Redbank Creek is shown on (**Figure 3-4**). The upper half of the main tributary flows to the east of LW W4 above the longwall pillar and supports several water dams. The downstream part flows to the south east in Redbank Creek through urbanised areas. The flow in the tributaries of Redbank Creek is ephemeral, likely flowing during periods of extended, moderate, high rainfall events (HEC, 2021b) with limited baseflow contributions due its location on the outcropping Wianamatta Group.

HEC (2021a) documents effects on water levels in some pools along Cedar Creek near to LW W1 following the extraction of LW W1. No visible cracking of pools or creek beds has been observed, although gas bubbles have been observed at a site on Matthews Creek, and some monitored pools along Cedar Creek (in particular) are possibly affected by water table drawdown and/or ground movement. Further analysis of the surface water behaviour in the context of groundwater levels is presented in **Section 3.5.8** and **Appendix G**.

Table 3-1 presents the distance of longwalls to main watercourses around Western Domain.

Table 3-1 Distance to main watercourses around Western Domain

Longwall	Distance to Cedar Ck (m)	Distance to Stonequarry Ck (m)	Distance to Redbank Ck (m)	Comment
LW W1	60	140	1100	Pool level effects observed along Cedar Creek (e.g. HEC, 2021a). Site CB is 220 m from LW W1.
LW W2	140	60	920	
LW W3	410	130	730	
LW W4	1010	680	500	Intermittent tributary of Redbank flows over panel footprint

Note: Distances are from the closest point of the panel footprint to the closest point along watercourse

Cedar Creek flows the closest to LW W1, being 60 m from the northern end of the panel (noting the comments above regarding pool level effects). Stonequarry Creek comes within 60 m of the north-eastern corner of LW W2 (the current panel).

LW W3 is proposed to be a similar distance from Stonequarry Creek (140 m) as the recently completed LW W1, and approximately twice the distance as LW W1 was from Cedar Creek (although less than the distance to some affected pools on Cedar Creek), and twice the distance between LW W2 (the current longwall) and Stonequarry Creek.

LW W4 is proposed to be further from these significant watercourses than all of LW W1-W3. The main channel of Redbank Creek flows approximately 500 m west to the LW W4 with intermittent tributary of Redbank Creek flowing above the panel footprint.

Based on the distances, the extraction of LW W3-W4 has the potential to affect the 'middle' reach of Stonequarry Creek to the north of LW W3 (in particular) and upper part of Redbank Creek tributaries with a subsidence effect and the alterations of the surface water flow in a similar fashion to that observed during LW W1 (HEC,2021a and **Section 3.5.8**).

Further details and analysis of the surface water regime and subsidence effect are presented in the Surface Water Technical Report (HEC, 2021b) and the Subsidence Predictions and Impact Assessment Report (MSEC, 2021) which will accompany this Groundwater Technical Report to support the Extraction Plan.

3.4 Geological setting

3.4.1 Stratigraphic setting

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 at Tahmoor. Locally, the underlying geology consists of interbedded Permo-Triassic strata, primarily sandstones, siltstones, claystones and coal seams. **Figure 3-6** and **Table 3-2** describe the regional stratigraphic sequence.

The geological cross-section in **Figure 3-7** shows the strata dips 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 (HBSS) is the dominant outcropping stratigraphic unit in this region. The Wianamatta Group (WNFM), composed of carbonaceous shales, that overlie 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 Group. 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 Group typically appearing as capping material at higher elevations.

Below the Hawkesbury Sandstone are the Narrabeen Group formations, of which the main units are the Bald Hill Claystone (BHCS), which is considered to be a regional aquitard of approximately 10 m thick, and the Bulgo Sandstone (BGSS) which is a thick sandstone/siltstone sequence with minor aquifer potential.

The Bulli (BUCO) and Wongawilli Coal (WWCO) 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.

3.4.2 Structures around the Western Domain

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 major structural feature of interest to Tahmoor Mine is the Nepean Fault. As noted in Tahmoor Coal (2019), "The Nepean Fault encountered at Tahmoor Mine is part of the regional Nepean Fault system. This system is the southern extension of the Lapstone Monocline, and at Tahmoor, it consists of closely spaced sub-vertical en-echelon faults in a zone up to 400 m wide.". Mapping confirms that this fault extends 10 km along the eastern edge of the Tahmoor mine footprint, and extends still further north and south beyond the Tahmoor area (e.g. northward as part of the Lapstone Monocline).

This significant high angle 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. Tahmoor Coal (2019) described this as follows "The Nepean Fault zone is the only hydraulically charged geological structure encountered during mining to date".

Increases in inflow has been observed in mine workings as a result of intersection or proximity of the Nepean Fault zone, noting that previous workings at Tahmoor Mine have intersected or approached to within approximately 100 m of the secondary splays (typically oriented northwest-southeast), such as at Longwalls 31 and 32. However the main north-south trending faults have not been intersected by previous workings, and the closest approach by longwalls was at Longwall 32 (approximately 340 m west) and at Longwall 13 (approximately 480 m west) of such major faults.

SCT (2020d) conducted a detailed investigation of the Nepean Fault Complex [NFC] in 2020 to map the feature(s) (at ground surface) estimate the displacements and the distance of the NFC relative to LW W3-W4 panels. That mapping is presented on **Figure 3-5**. The proximity of the proposed longwalls to the mapped faults (at surface) is summarised as follows:

- LW W3 is 250 m west of the nearest mapped fault trace at the panel's northeastern corner, and 570 m west of the nearest trace at the panel's southeastern corner.
- LW W4 is 20 m west of the nearest mapped surface trace at the panel's northeastern corner, and 245 m west of the nearest trace at the panel's southeastern corner. The average distance from the proposed eastern edge of LW W4 to fault trace is approximately 145 m. Given the assumed proximity of LW W4 to the fault complex and associated disturbed zone, there is potential for subsidence and groundwater behaviour to be influenced by that structural feature.

Based on the estimates above, LW W4 would be significantly closer than previous panels, noting that the displacement or offset of the nearby splay is unknown. Tahmoor Coal has commissioned a further investigation of the displacement of this splay, noting that it is mapped as potentially intersecting the roadways at the north-eastern corner of LW W4 and passing north (**Figure 3-5**) to somewhere near to or beneath Stonequarry Creek, near to surface water monitoring sites SD and SC and their associated pools.

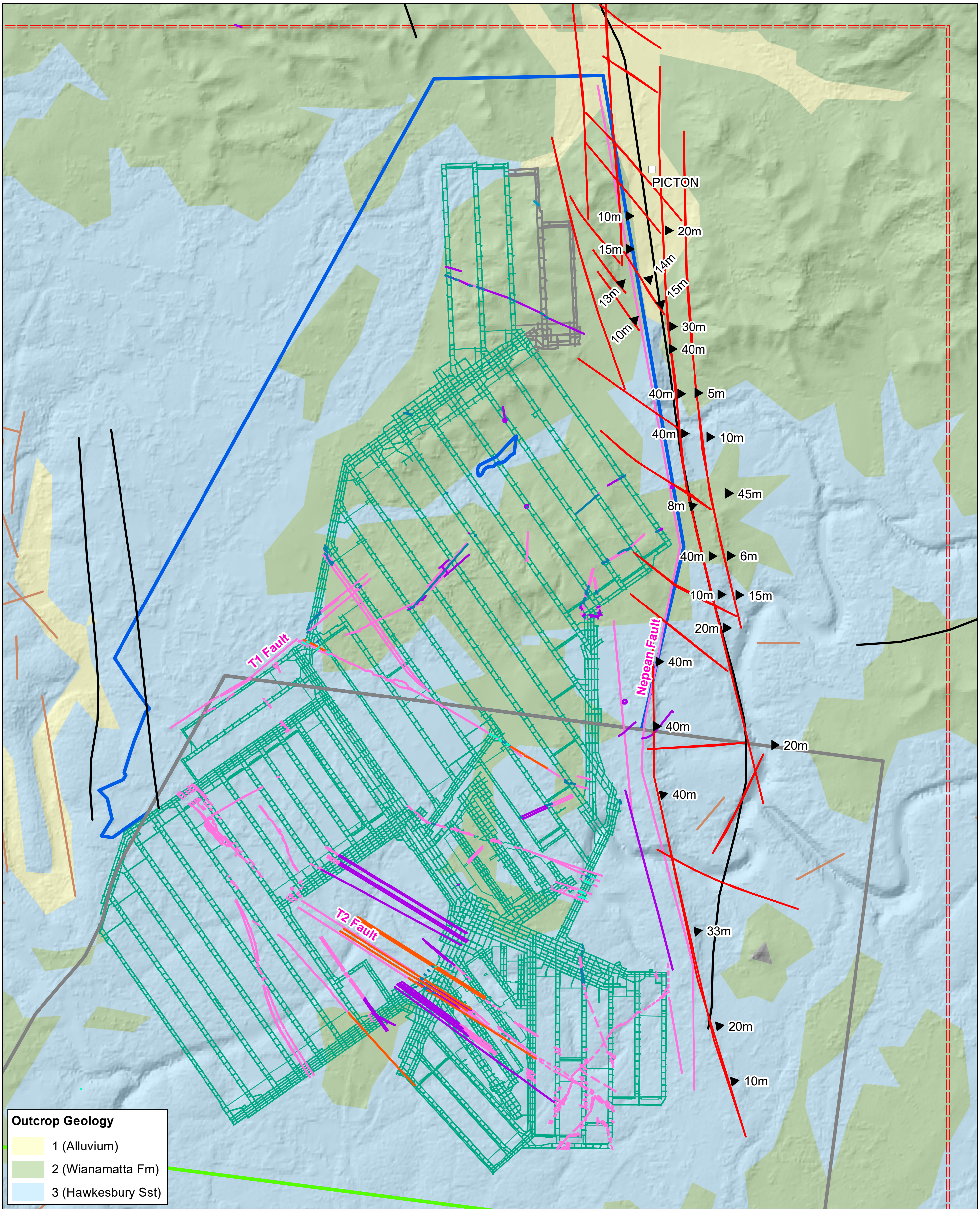
The permeability (Section 3.5.2) of the fault zone and associated damage zone is not known, noting that Fossen (2016) correlates the width of a damage zone to fault displacement (Section 3.5.9). Characterisation of permeability in the HBSS, BHCS and BGSS in the vicinity of LW W4 has been recommended (**Section 7**) and is underway. Further discussion of the potential role of the Nepean Fault in the context of the extraction of LW W4 is presented in **Section 3.5.9**.

The total displacement across the fault complex is approximately 50-60 m down from the west to the east. The individual fault planes vary in the amount of throw as the total offset is distributed between fault ramps and numerous smaller faults (as the offsets interpreted by SCT are labelled on **Figure 3-5**). The maximum incremental displacement of approximately 40 m in the area of Longwall 32 and approximately 800 m to the east of LW W4. The fault splays nearer to LW W4 are observed to have displacements in the range 10-15 m, while the displacement of the splay adjacent to the LW W4 footprint is unknown (see Recommendations in **Section 7**).

A WNW-ESE trending structural feature across the Western Domain has recently been mapped and projected by Tahmoor Coal and is shown on **Figure 3-5**. This structure has been intersected at seam level in Western Domain roadways and as longwall W1 passed through it. It is characterised as a normal fault, with a dip of 85-90°. Displacements are relatively small, with offsets measured in the roadways being 20-50 mm. In some areas the fault is observed with slickensides, in others there is an obvious calcite and/or puggy clay core. Some cavities (100-200 mm wide) were observed to formed in the roof of the seam when the longwall passed through the structure. Site geologists reported that there was no increased incidence or occurrence of groundwater inflow associated with this feature. Site geologists have not reported on the persistence of this feature in the strata above the seam or whether there is evidence of it at the surface.

In April 2021, Tahmoor Coal sent preliminary mapping of a structure on the eastern gateroad of LW W3, to the north of LW W4. The structure was described by Tahmoor Coal in the following text "A small graben structure has recently been mapped on the development. The structure was intersected in a heading and consists of two minor normal faults (displacement of 100 mm) dipping towards each other at 70 degrees and about 6 m apart (essentially a mirror image of each other). It is anticipated that mining in the adjacent heading will allow further verification of the structures orientation and magnitude". These structural features which are oriented approximately southeast northwest (consistent with secondary splays mapped within the Nepean Fault Complex), are shown on **Figure 3-5**.

Section 3.5.2 presents a summary of the hydraulic conductivity of the strata at Tahmoor Mine. Packer testing data at bores P12-14, P16 and P17 has been analysed in the context of hydraulic conductivities measured elsewhere at Tahmoor Mine and also considering data from Dendrobium Mine. These shallow bores intersect the Hawkesbury Sandstone, and the hydraulic conductivities at P13 and P14, both located to the north of LW W1 and LW3 along Stonequarry Creek, are significantly and consistently higher than expected. This is attributed to being caused by an unmapped structural zone; however structure mapping by Tahmoor Coal and others does not show any features correlating to the location of these bores.



0 0.5 1 km

Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:52,000 at A4
Project Number:	665.10010
Date:	04-May-2021
Drawn by:	JG

SLR

- Town
- Geological Structures (2019)
- Southern CF Structure
- Southern CF Fold
- Proposed Areas of Future
- Tahmoor North and Western Domain
- Local Geological model Extent

Nepean Fault Complex (SCT,

- Offset, Estimated
- Surface Trace

Tahmoor Coal Titles

- MLs 1308, 1376, 1539
- CCL 716
- CCL 747

Geological Structures (2020)

- Fault – Projected
- Fault – Mapped
- Dyke - Projected
- Dyke – Mapped

TAHMOOR COAL LONGWALL W3 AND W4 EXTRACTION MANAGEMENT

Geological Outcrop

FIGURE 3-5

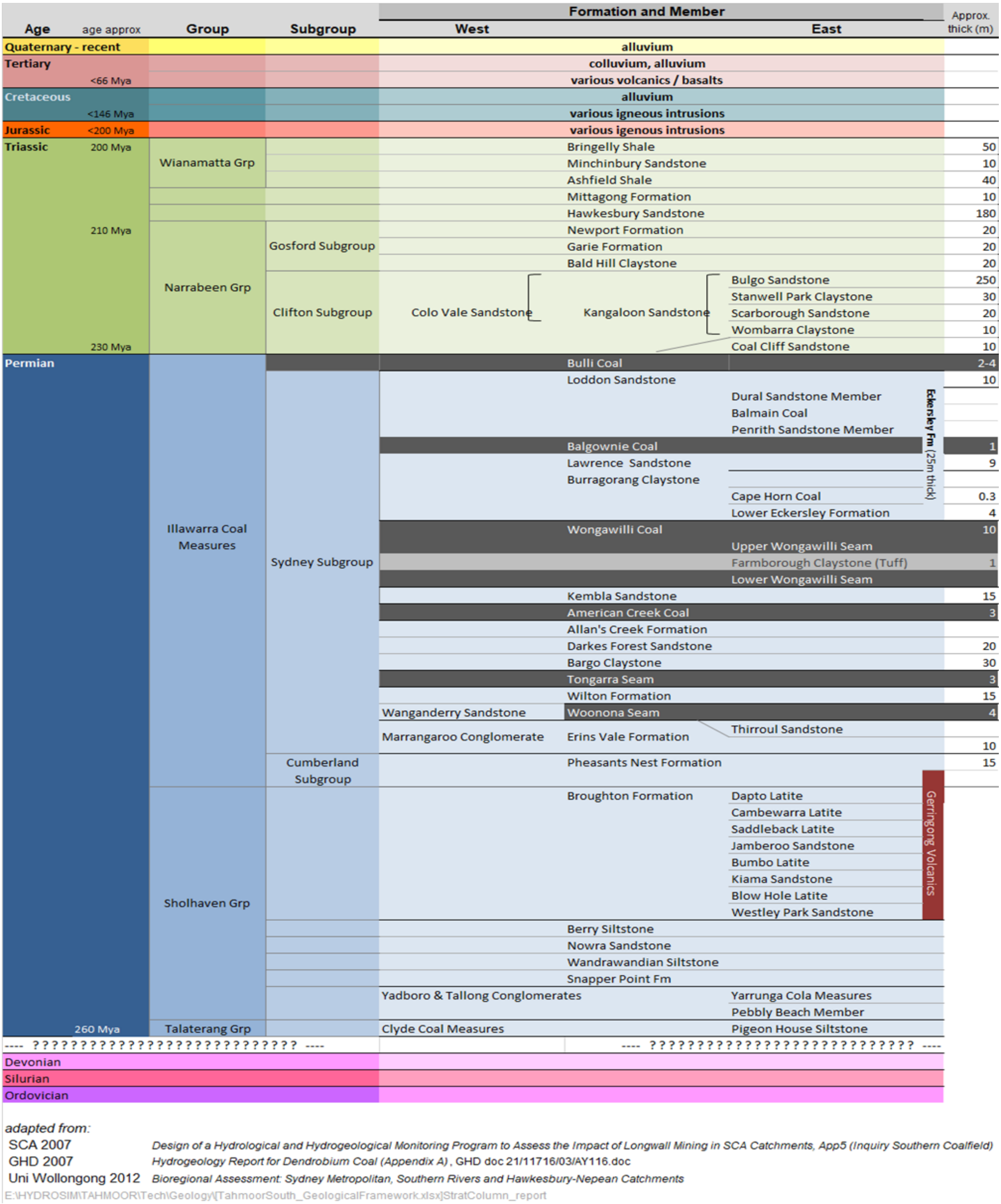


Figure 3-6 Southern Coalfield stratigraphic column

Table 3-2 Stratigraphy and lithology of the Southern Coalfield

<table>
<tr><th>Period</th><th colspan="2">Stratigraphic Unit</th><th>Description</th></tr>
<tr><td>Quaternary</td><td colspan="2">Alluvium and colluvium and other sediments in floodplains, alluvial fans, and high terraces (Qal, Tal, Qs)</td><td>Alluvial and residual deposits comprising quartz and lithic fluvial sand, silt and clay.</td></tr>
<tr><td rowspan="12">Triassic</td><td rowspan="2">Wianamatta Group</td><td>Camden Sub-group</td><td>Shale with sporadic thin lithic sandstone.</td></tr>
<tr><td>Liverpool Sub-group: Bringelly Shale (Rwb), Minchinbury Sandstone and Ashfield Shale (Rwa)</td><td>Dark green and black shales with thin graywacke-type sandstone lenses. Calcareous graywacke-type sandstone and black mudstones and silty shales with sideritic mudstone bands.</td></tr>
<tr><td colspan="2">Hawkesbury Sandstone (Rh)</td><td>Consists of thickly bedded or massive quartzose sandstone (with grey shale lenses up to several metres thick).</td></tr>
<tr><td rowspan="8">Narrabeen Group</td><td>Newport Formation</td><td>Interbedded grey shales and sandstones</td></tr>
<tr><td>Garie Formation</td><td>Cream to brown, massive, characteristically oolitic claystone</td></tr>
<tr><td>Bald Hill Claystone</td><td>Brownish-red coloured “chocolate shale”, a lithologically stable unit</td></tr>
<tr><td>Bulgo Sandstone</td><td>Strong, thickly bedded, medium to coarse-grained lithic sandstone with occasional beds of conglomerate or shale</td></tr>
<tr><td>Stanwell Park Claystone</td><td>Greenish-grey mudstones and sandstones</td></tr>
<tr><td>Scarborough Sandstone</td><td>Mainly of thickly bedded sandstone with shale and sandy shale lenses up to several metres thick</td></tr>
<tr><td>Wombarra Claystone</td><td>Similar properties to the Stanwell Park Claystone</td></tr>
<tr><td>Coal Cliff Sandstone</td><td>Basal shales and mudstones that are contiguous with the underlying Bulli Coal seam.</td></tr>
<tr><td rowspan="5">Permian</td><td colspan="2" rowspan="4">Illawarra Coal Measures</td><td>Interbedded shales, mudstones, lithic sandstones and coals, including the:
• Bulli Coal seam (2-3 m thick);</td></tr>
<tr><td>• Eckersley Formation, including the Balgownie Seam (5-10 m below Bulli Seam), Loddon Sandstone and Lawrence Sandstone.</td></tr>
<tr><td>• Wongawilli Coal seam (7-9 m thick).</td></tr>
<tr><td>• Kembla Sandstone</td></tr>
<tr><td colspan="3">Shoalhaven Group</td></tr>
</table>

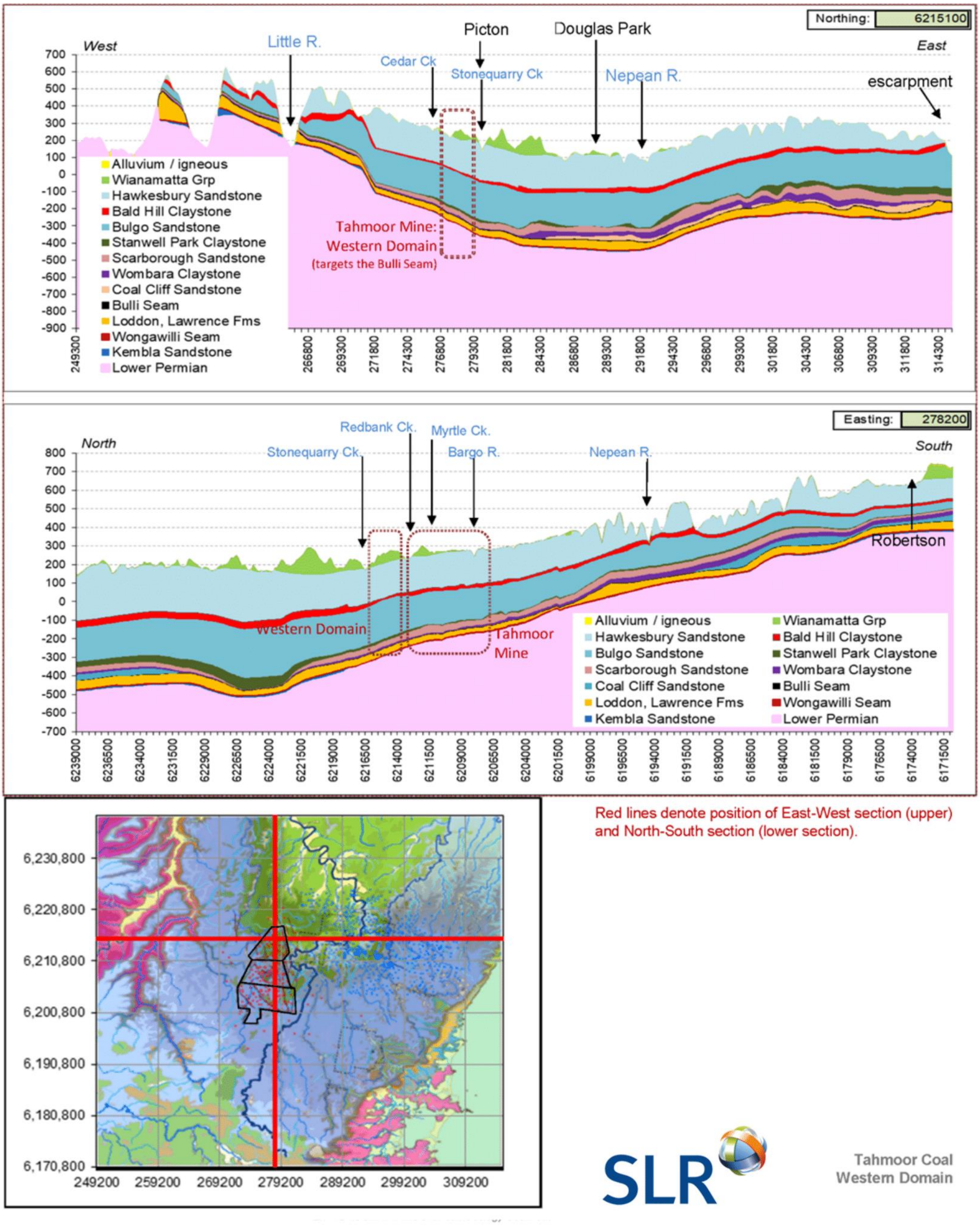


Figure 3-7 Geological cross-sections trough Longwalls W3-W4

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 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 Group 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 outlined below.

3.5.1.1 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 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, rainfall runoff and peak streamflow events.

Alluvial units occur to the north and east of LW W3-W4 along the lower reaches of Stonequarry Creek near Picton (see **Figure 3-5**). The alluvium generally does not intersect the LW W3-W4 mine footprint, except for approximately 75 m^2 of area in the north-eastern corner of LW W3 (based on the Southern Coalfield geology mapping of **Figure 3-5**). The depth of cover in this area of intersection ranges from 460-470 m, so this is not in breach of the AIP requirement to have 100 m vertical distance between alluvium and mine workings.

Publicly available data (BoM, 2020) suggest the presence of surficial clays up to 8 m thick in registered bores intersecting the mapped alluvium to the east of Stonequarry Creek.

3.5.1.2 Wianamatta Group

The Wianamatta Group is composed of the Bringelly Shale Formation, Minchinbury Sandstone and Ashfield Shale Formations that 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 Group is present over all the surface of the area occupied by the LW W4 mine footprint, and across almost all the surface area of LW W3, similar to the area above preceding longwalls W1 and W2.

3.5.1.3 Hawkesbury Sandstone

The Hawkesbury Sandstone is a porous rock aquifer of moderate resource potential. The Hawkesbury Sandstone is greater than 150 m thick in the area of the Western Domain (e.g. is 170 m thick in recently drilled investigation bore WD01; SCT, 2020c). In areas where secondary porosity is apparent, such as in structural zones such as the Nepean Fault zone, higher resource potential can be achieved. Further discussion of resource potential and productivity of the Hawkesbury Sandstone is available in Ross (2014). Hydraulic properties are described in **Section 3.5.2**.Interpreted water table elevations are shown on **Figure 3-8** and the interpreted depth to the water table on **Figure 3-9**.

The interpreted groundwater conditions are based on the most recent available data, which ranges between 2013 and 2020. The contouring on **Figure 3-8** shows that the groundwater gradient is generally flowing in an east to north-easterly direction in the area of Tahmoor Mine.

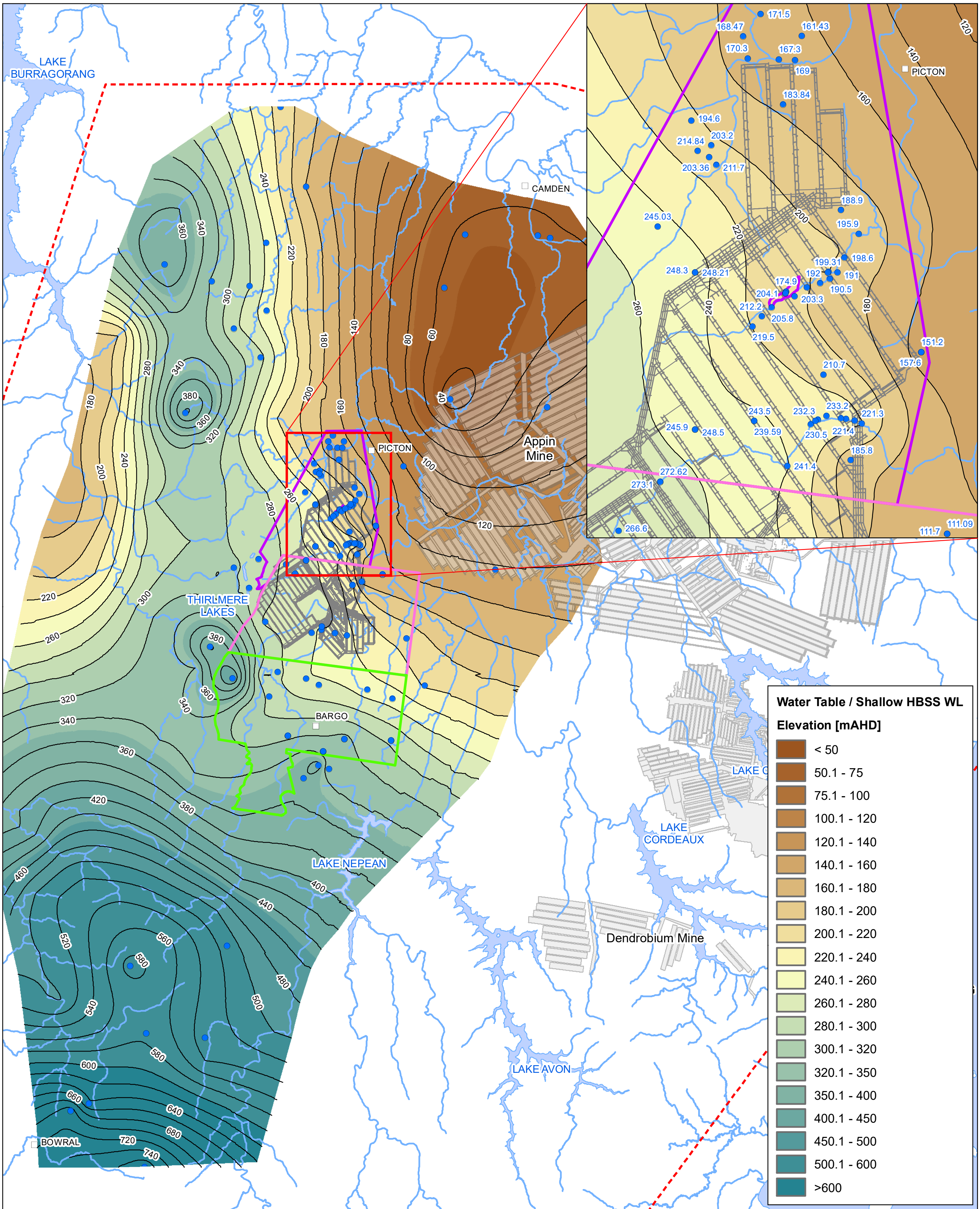
Figure 3-9 shows that groundwater levels are generally closer to the ground surface in areas where surface water drainage exists. This indicates the potential for surface drainage to contribute baseflow to the Hawkesbury Sandstone aquifer. Due to the number of watercourses surrounding Tahmoor Mine and 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 total dissolved solid (TDS) of about 380 mg/L for Hawkesbury Sandstone groundwater (Parsons Brinckerhoff, 2013). These values are supported by the data collected in the previous bore census for the Western Domain (GeoTerra, 2019), where three of the four samples of groundwater electrical conductivity (EC, which is a measure of salinity) were <1,700 µS/cm (approx. 1,000 mg/L).

The latest bore census (GeoTerra,2020) for Western Domain indicates a freshening in the shallow Hawkesbury Sandstones aquifer with a decreasing trend in EC for two out of four samples (GW072402 and GW10546). These registered bores located near Stonequarry Creek and Matthews Creek use groundwater from the shallow Hawkesbury Sandstone aquifer, which has likely been recharged by the extreme rainfall event of February 2020 and could result in a localised reduction of the aquifer salinity. The groundwater extracted at bores GW105546 and GW105228, located further west (close to Cedar Creek) and further north to Western Domain, intersect the Hawkesbury Sandstone and Wianamatta Group, respectively, indicates an increase in groundwater salinity. A lower permeability unit at outcrop, such as the Wianamatta Group, could reduce groundwater recharge to the underlying Hawkesbury Sandstone aquifer. Combined with the below average rainfall conditions, this could favour the accumulation of salts in groundwater.

3.5.1.4 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.



0 2.5 5 km

Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:250,000 at A4
Project Number:	665.10010
Date:	30-Apr-2021
Drawn by:	JG

SLR

- Bores (RWL)
- City
- Town
- Tahmoor North and Western Domain
- Water Table (regional)
- Watercourses
- Lakes
- Southern Coalfield (approximate)

Tahmoor Coal Titles

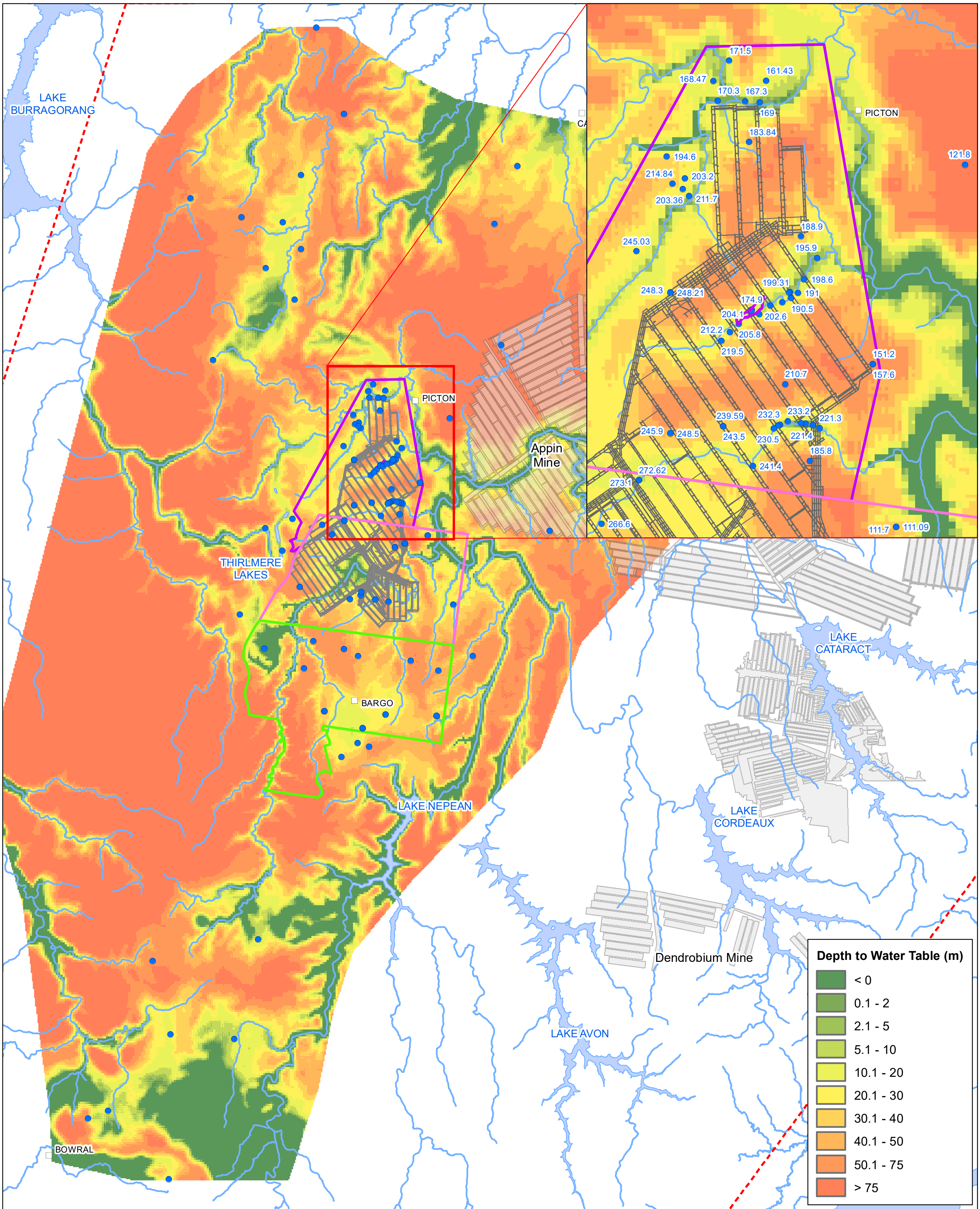
- MLs 1308, 1376, 1539
- CCL 716
- CCL 747

TAHMOOR COAL LONGWALL W3 AND W4 EXTRACTION MANAGEMENT

Interpreted Water Table Elevation

FIGURE 3-8

H:\Projects-SLR\620-BNE\665-WOL\665.TAH05 Tahmoor GWMP\GIS\66510010 Fig3_8 Interpreted water table elevation.mxd



0 2.5 5 km

Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:230,000 at A4
Project Number:	665.10010
Date:	30-Apr-2021
Drawn by:	JG

SLR

- Bore
- City
- Town
- Tahmoor North and Western Domain
- Watercourses
- Lakes
- Southern Coalfield (approximate)

Tahmoor Coal Titles

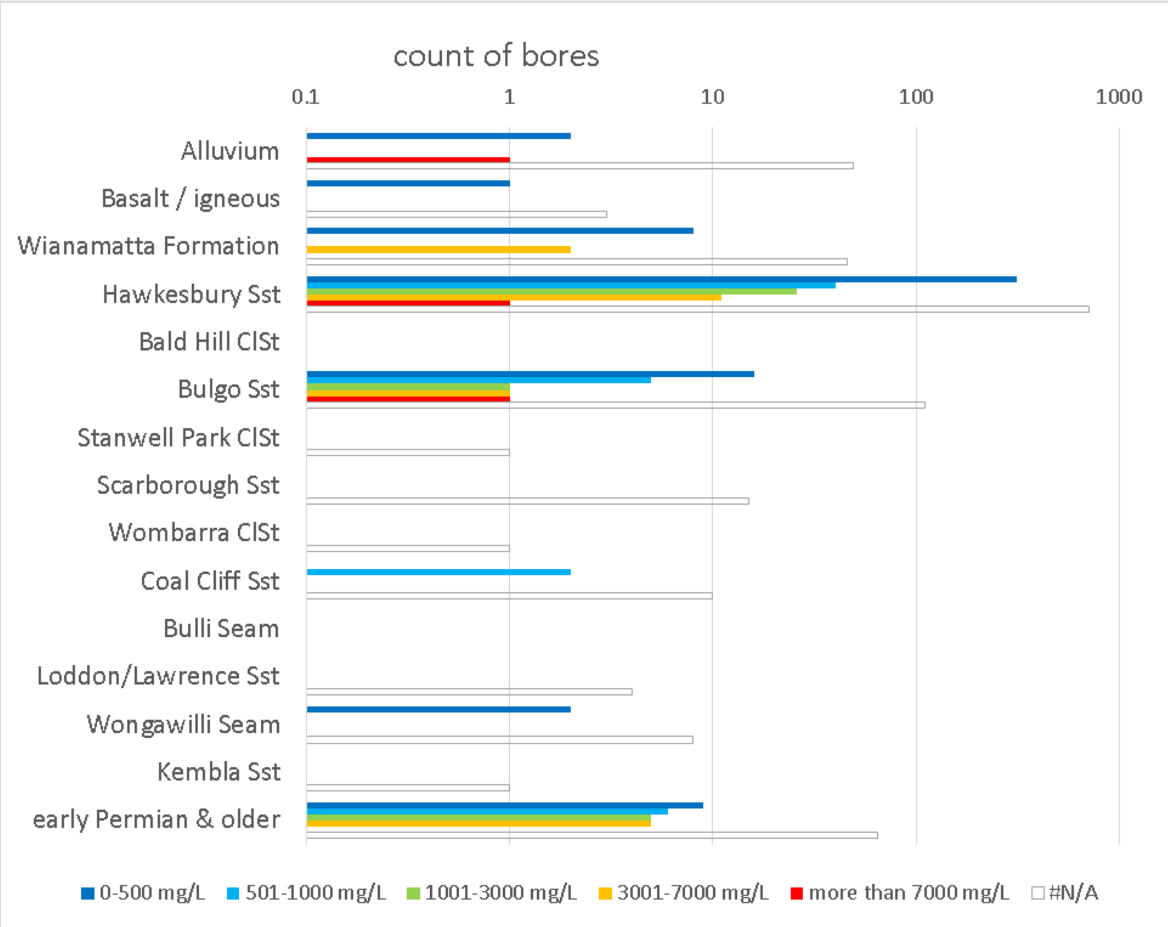
- MLs 1308, 1376, 1539
- CCL 716
- CCL 747

TAHMOOR COAL LONGWALL W3 AND W4 EXTRACTION MANAGEMENT

Interpreted Depth to Water Table Elevation (Aug 2013)

FIGURE 3-9

H:\Projects-SLR\620-BNE\665-WOL\665.TAH05 Tahmoor GWMP\GIS\66510010 Fig3_9 Interpreted depth to water table elevation (Aug 2013).mxd



C:\HydroSim\TAH001\Tech\GroundwaterUse\NSW_GroundwaterWorks_Bores.xlsx

Figure 3-10 Summary of groundwater salinity data

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.

Raw hydraulic conductivity data from pre-mining packer testing and core testing is presented in **Appendix A**. The Kh data from packer testing shows a general trend of declining permeability with depth, which is related to overburden pressure closing secondary porosity.

Figure 3-11A summarises the 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 the appropriate 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, that trend is mainly evident for the non-coal units (**Appendix A**) while the coal seams are exceptions to this general trend:
  - Decreasing from the Hawkesbury Sandstone down to the Wombarra Claystone, then a step up at the Bulli Coal seam due to the higher permeability of the coal material; and
  - A further decreasing trend in the sandstone and siltstone units below the Bulli Coal Seam.
  - Like the Bulli Coal, the Wongawilli Coal seam is more permeable than the surrounding sandstone and siltstone units.
  - 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
- Alluvium hydraulic conductivity has not been measured at or near the site (although in future, data might be available from the Thirlmere Lakes Research Program, TLRP).

Testing of hydraulic conductivity around the Western Domain (**Figure 3-11B**) indicates that at most locations the hydraulic conductivities were 'typical' of those measured elsewhere at Tahmoor Mine, e.g. the results for WD01, located between LW W1 and LW W2, plot lie within the main population of hydraulic conductivities down to 400 m depth.

The same is generally true for the shallower P-series bores around the Western Domain (e.g. P16, P17), but bores at P13 and P14, and to a lesser degree at P12, showed anomalous and significantly higher Kh than elsewhere at Tahmoor Mine, or, based on our experience, higher than any measurements at Dendrobium Mine. These hydraulic conductivities are generally in the range 0.1-5 m/d (median = 0.8, average = 1.9 m/d), and some are at or near the upper limit of the testing equipment (SCT, 2019). These values are 0.5 to 1 order of magnitude higher than the 90th percentile HBSS Kh at Tahmoor. The cause of this is unknown, but the consistency of the high values at neighbouring sites P13 and P14, and slightly lower values at P12, suggests that the data is reliable. A structural feature is a plausible reason for this occurrence, but as described earlier, no structural feature has been identified by Tahmoor Coal geologists that correlates to the location of P13 and P14. It is possible that it is related to the broader Nepean Fault Complex (Section 3.4.2), although the orientation or nature of the feature that might be present at P13 and P14 is unknown.

Permeability testing at P15, north of LW W3 and east of P14, as well as at other sites around the Western Domain, will be conducted in the near future.

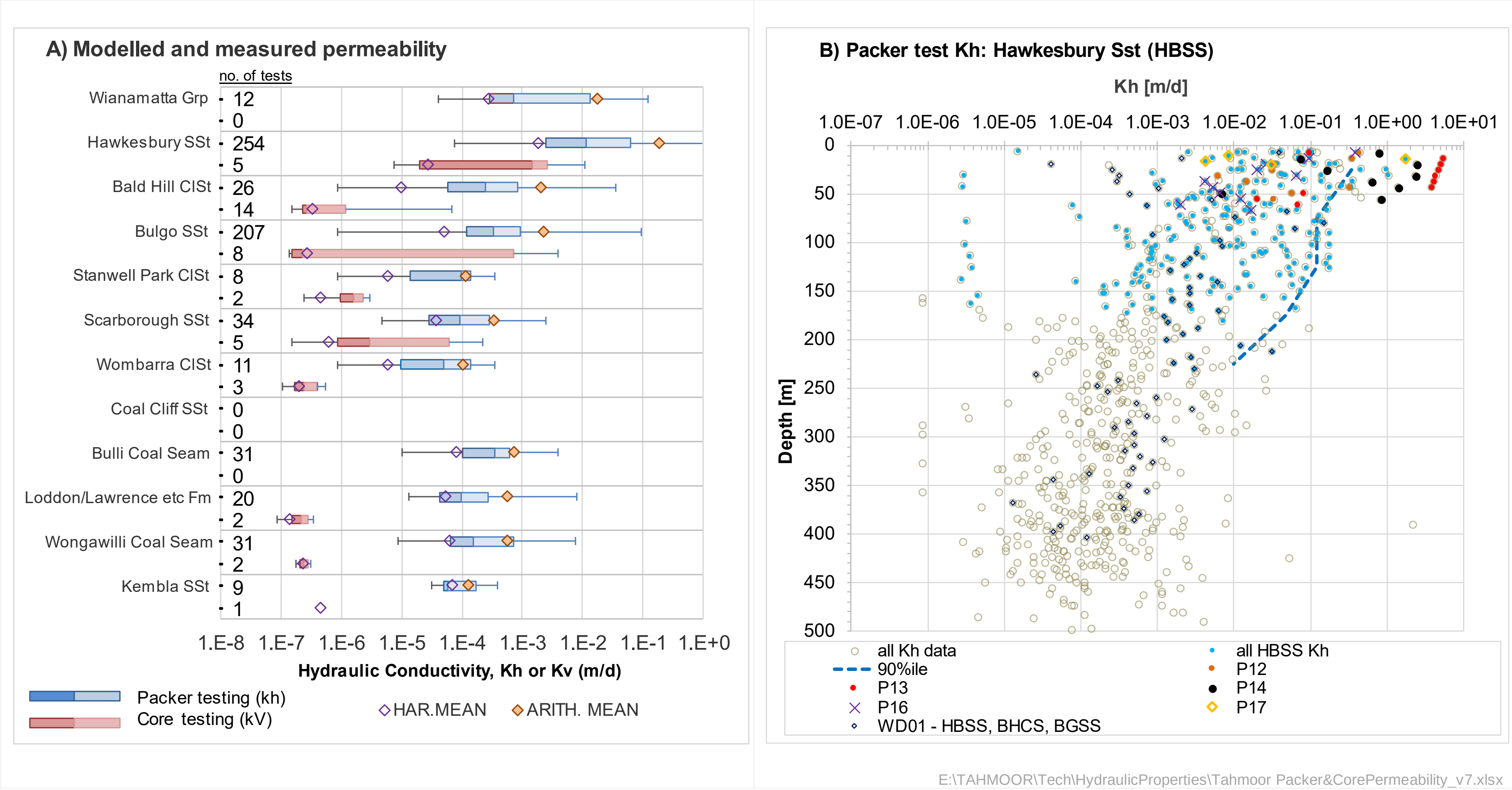


Figure 3-11 Summary of Hydraulic conductivity (Kh and Kv) data

3.5.3 Groundwater use

3.5.3.1 Groundwater Dependent Ecosystems

The Thirlmere Lakes are the closest 'High Priority' Groundwater Dependent Ecosystem within close proximity to Tahmoor Mine (see **Figure 3-4**). Lake Gandangarra is the closest lake to proposed LW W3-W4, however, this is approximately 6 km from LW W3. Due to the distance between the area of proposed longwall extraction and the Thirlmere Lakes it is extremely unlikely that mining-related impacts due to the extraction of LW W3-W4 would have an impact on the groundwater system surrounding these Lakes. The extent of groundwater drawdown associated with LW W3-W4 presented in **Section 4.3.4** is consistent with this assumption.

Other GDEs and EECs (Endangered Ecological Communities) were identified within the region (**Figure 3-4**) and are discussed in the Tahmoor South Amended Project Report (SLR/HS, 2020):

- High Priority GDEs O'Hares Creek located more than 25 km away from Tahmoor.
- Temperate Highland Swamps on Sandstone.
- Cumberland Plain Woodlands (Cumberland Plain Shale Woodlands and Shale Gravel Transition Forest) (Niche, 2018 and DEWHA, 2009)[2].
- Wirrimbirra Sanctuary (regarded as cultural site).

Due to the distance and the fact that other historical and current mining operations are located between Tahmoor and these GDEs/EECs, far field effects from the extraction of LW W3-W4 are not anticipated to reach these areas.

3.5.3.2 Springs

A literature review 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 (GeoTerra), pers. comm.).

3.5.3.3 Anthropogenic Use

Several privately-operated and licensed groundwater bores are present to the north and west of LW W3-W4, as identified in the most recent bore census for the Western Domain and surrounding area (GeoTerra, 2019 and 2020). 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 3-4** (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 from these bores is derived from the Hawkesbury Sandstone aquifer.

Based on a search of the Water Register, Pinneena and BoM Groundwater Explorer information was obtained, 791 bores within the Tahmoor area (i.e. groundwater model domain) returned matches with Water Access Licences (WAL).

[2] Available: http://www.environment.gov.au/biodiversity/threatened/communities/maps/pubs/112-map.pdf

Based on data supplied by WaterNSW, there is a licensed groundwater entitlement of approximately 4,060 ML/year for private or small-scale government use. There is some additional 987,000 ML/year associated with licences held by government agencies (these may be groundwater and surface water licences). Additionally, there is approximately 1,000 ML/year of unlicensed groundwater use for stock and domestic purposes, which is based on the assumption that use for these purposes is 1-2 ML/year. An approximate breakdown of the groundwater use by purpose is presented in **Table 3-3**. These estimates exclude groundwater licences held by mines, including Tahmoor, for groundwater passively entering mine workings.

Table 3-3 Approximately breakdown of Groundwater entitlement (ML/year)

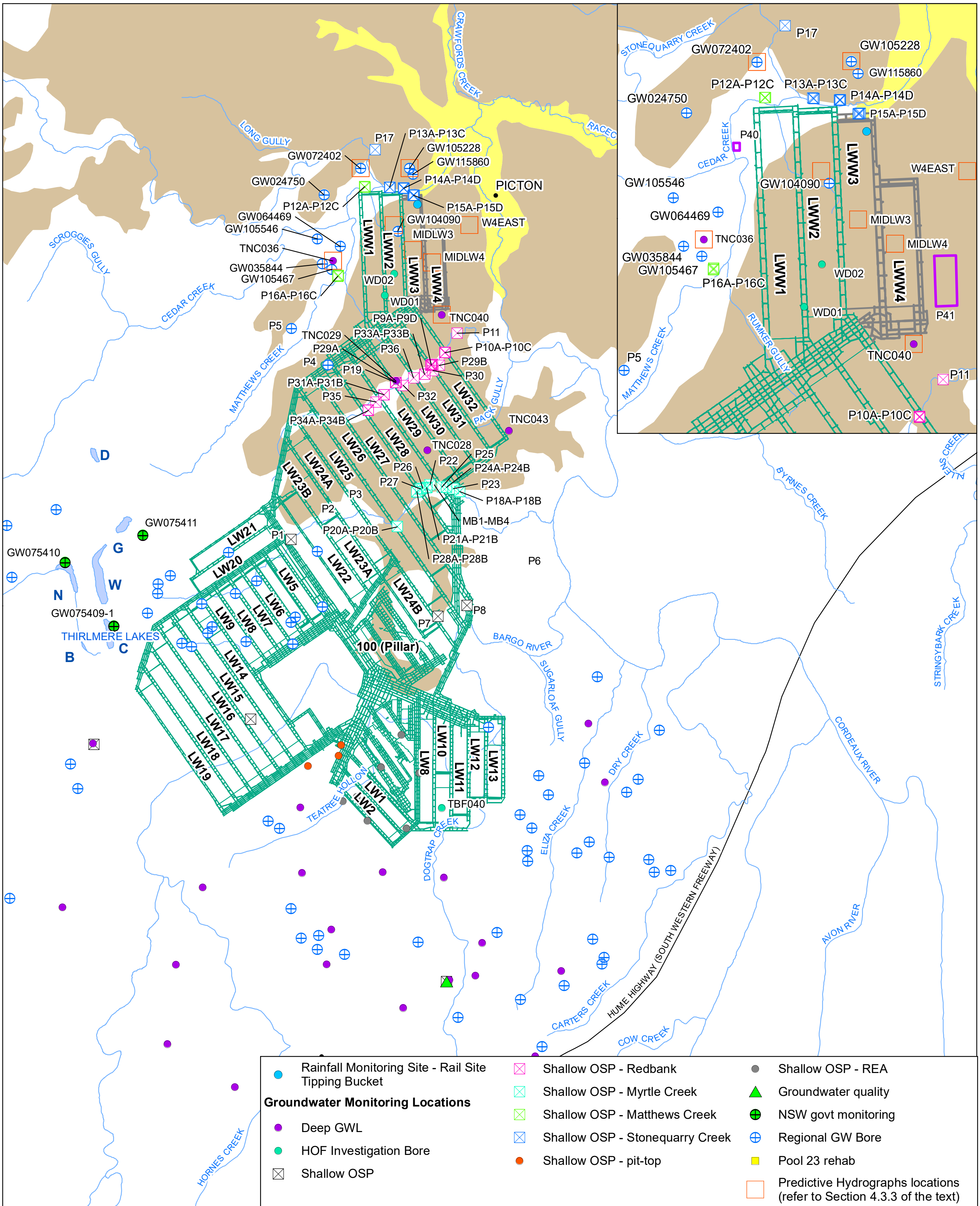
Groundwater Use / Purpose	GW entitlement (ML/year)	Percent (%) of total
Irrigation	2,029	45.4
Stock	993	22.2
Domestic	967	21.7
Industrial	285	6.4
Recreation	146	3.3
Aquaculture	25	0.6
Waste Disposal	2	0.04
Other	18	0.4

Within the registered bore and census datasets, average bore depth is 95 m, median depth is 85 m, ranging from 3 m to 650 m, with a few that are suspected to be exploration bores over 1000 m. Most of the groundwater usage in the area is from the Hawkesbury Sandstone or from surficial alluvium and basalt aquifers (about 89% of the total), with about 10% from the Bulgo Sandstone. This is probably due to generally lower bore yields, poorer water quality, and increased drilling costs for accessing deeper units.

A number of submissions made regarding previous impact assessment and modelling at Tahmoor Mine requested that groundwater usage be simulated in the groundwater model. A review of the NSW Water Register for records of actual usage (compared to licensed entitlement) for the whole Nepean Sandstone Groundwater Source returned:

- ‘0’ ML of actual usage recorded or estimated for the 13 water years from 2004/2005 to 2016/2017;
- 2969.3 ML for 2017/2018 (usage equal to approximately 12% of all entitlement in the Groundwater Source);
- 2853.8 ML for the water year 2018/2019 (11% entitlement);
- 345.7 ML for 2019/2020 (1% entitlement); and
- 21.7 ML for 2020/2021 (year to date).

The records of zero usage are considered by SLR/HydroSimulations (2020) to be ‘false’ zeroes, i.e. simply a lack of metering and estimated use. The lack of records indicates a high degree of uncertainty with estimating historical groundwater usage for this study.



0 1 2 km

Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:80,000 at A4
Project Number:	665.10010
Date:	04-May-2021
Drawn by:	JG

SLR

- Town
- Tahmoor North and Western Domain
- Proposed Areas of Future Mining
- Major Roads
- Watercourses
- Lakes
- Alluvium
- Wianamatta Formation

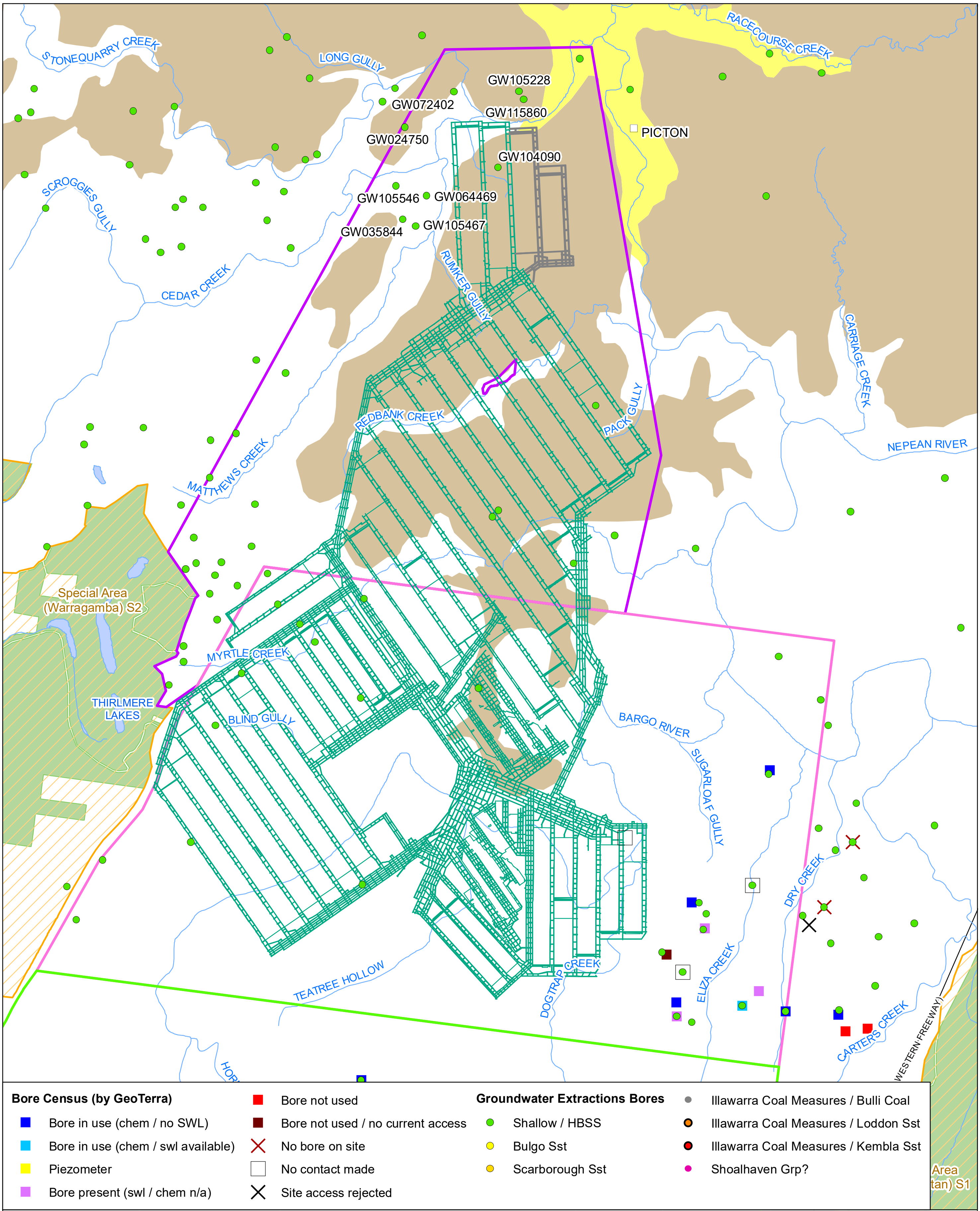
Lakes:
D = Dry Lake
G = Gandangarra
W = Werri Berri
C = Couridjah
B = Baraba
N = Nerrigorang

TAHMOOR COAL LONGWALL W3 AND W4 EXTRACTION MANAGEMENT

Groundwater Monitoring Network

FIGURE 3-12

H:\Projects-SLR\620-BNE\665-WOL\665.TAH05 Tahmoor GWMP\GIS\66510010 Fig3_12 Groundwater monitoring locations.mxd



0 0.5 1 km

Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:60,000 at A4
Project Number:	665.10010
Date:	04-May-2021
Drawn by:	JG

SLR

- Minor Town
- Proposed Areas of Future Mining
- Tahmoor North and Western Domain
- Major Roads
- Watercourses
- Lakes
- National Park Estate
- WaterNSW Special Area

Tahmoor Coal Titles

- MLs 1308, 1376, 1539
- CCL 716
- CCL 747
- Alluvium
- Wianamatta Formation

TAHMOOR COAL LONGWALL W3 AND W4 EXTRACTION MANAGEMENT

Location of Groundwater Users

FIGURE 3-13

H:\Projects-SLR\620-BNE\665-WOL\665.TAH05 Tahmoor GWMP\GIS\66510010 Fig3_13 Location of groundwater users.mxd

Table 3-4 Licensed Groundwater Bores in the vicinity of the Western Domain

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	72.0	11.96*	59 – 59.3	0.50	5.79	4400	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	1.45*	5.68	1263	Stock/Domestic
GW105467	244279	6215251	03/10/03	120.0	32.0	21 – 22 54 – 55 84 – 85 112 – 113	0.63*	4.73	212	Stock/Domestic
GW105546	276997	6215723	05/11/04	163.0	31.9	66 – 67 78 – 79 95 – 96 120 – 121 126 – 127 154 – 155	1.33*	5.25	407	Irrigation
GW115860	278543	6216760	04/06/2018	60	5.0	20, 48 and 55	5.0	5.94	743	Domestic

Note: Coordinates in GDA94 Zone 56. '*' SWL = standing water level (depth to water) as measured by GeoTerra, 2020.

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 stock and domestic use. 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 and 2021b).

The bore yields recorded at GW115860 (5 L/s) and GW105228 (1.4 L/s) are relatively high for bores of this depth (approximately 60 m) in the Hawkesbury Sandstone (A. Dawkins, pers comm.). This may be associated with a structural zone, possibly the nearby Nepean Fault Complex which is mapped 200-300 m to the east, or with the high Kh encountered at P13-P14 (Section 3.5.2).

3.5.4 Groundwater levels - baseline data

For the purpose of monitoring the subsidence related impacts that may result following the extraction of LW W3-W4 a monitoring network consisting of eleven bores has been established. Eleven bores are existing monitoring locations utilised by Tahmoor Coal to monitor groundwater response following the extraction of previous and current longwalls. The shallow open standpipe bores (at sites P12-P14, P16, P17) drilled in 2019 started to collect groundwater level data in May and June 2019, prior to LW W1 commencing. Three additional shallow open standpipe bores were drilled and started to record groundwater levels at site P15 in March 2021 after earlier land access issues. A fourth deeper piezometer is planned at this site.

Further bore installations were conducted at Tahmoor North between June 2019 and February 2020, along Redbank Creek (P10-P11, P19, P29-P36) and Myrtle Creek (P18, P20-P28). Groundwater monitoring is ongoing at these open standpipes to measure groundwater levels, providing additional post-mining data at Tahmoor North. Due to the relative proximity of P10 and P11 from the LW W3-W4, details about these open standpipes are provided in **Table 3-5**. A brief analysis regarding the groundwater trends along Redbank and Myrtle Creek is provided at the end of this section with further discussion about mining-induced impacts discussed in Section **3.5.5**.

Table 3-5 lists the relevant information for each of the existing bores, including P10 and P11 due to their relative proximity of LW W3-W4. **Figure 3-12** presents the monitoring network location at Tahmoor North and the Western Domain.

Near to the Western Domain, three of the existing bores (TNC036, TNC040 and WD01) are equipped with multi-level Vibrating Wire Piezometers [VWPs] which monitor groundwater pressures in multiple stratigraphic units. One further bore (TNC043) was also equipped as such until some sensors failed and the data loggers were stolen in late 2020 – manual readings are still taken periodically. A series of eight VWPs in borehole WD01 were installed prior the extraction of LW W1 (**Section 3.5.7**). The remaining monitoring bores (at sites P9-P17) are a collection of shallow open standpipe bores that screen the Hawkesbury Sandstone at various depths. **Table 3-5** presents a summary of the depths and stratigraphic placement of the instruments at the existing monitoring sites. Additional open standpipe and VWPs monitored shallow groundwater conditions near to recent Tahmoor North longwalls.

The baseline data for the existing monitoring locations are presented on **Figure 3-14** to **Figure 3-18**, with the rainfall residual mass included for comparison to climatic trends. Monitoring at these sites will be ongoing 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.

In accordance with the current Trigger Action Response Plan (TARP) in place, any exceedances in groundwater levels or quality identified across the Western Domain is flagged below. A more detailed summary of performance against the associated response plan for each monitoring location is discussed in **Section 6**.

Table 3-5 Groundwater Monitoring Network relevant to Western Domain – LW W3-W4

ID	Easting	Northing	Type	Status	Sub ID	Depth (mBG)	RL (mAHD)	Geology
Western Domain								
TNC036	277268	6215382	VWP	EX	HBSS-65	65	166.25	HBSS
				EX	HBSS-97	97	134.25	HBSS
				EX	BGSS-169	169	62.25	BGSS
				EX	BGSS-214	214	17.25	BGSS
				F	BGSS-298.5	298.5	-67.25	BGSS
				EX	BGSS-412.5	412.5	-181.25	BGSS
				F	BUSM-463.5	463.5	-232.25	BUSM
WD01	278098	6214828	VWP	EX	S5238	70	-	HBSS
				EX	S4946	90	-	HBSS
				EX	S5302	190	-	HBSS
				EX	S5303	210	-	HBSS
				EX	S5304	230	-	Newport Fm
				F	S4473	300	-	BGSS
				F	S4474	330	-	BGSS
				F	S4475	350	-	BGSS
WD02	278245	6215178	VWP	P	-	not yet drilled	-	(post-mining)
P12	277771	6216561	MB	EX	P12	19.6	181.93	HBSS
	277776.	6216560		EX	P12B	34.6	181.96	HBSS
	277781	6216559		EX	P12C	64.6	181.86	HBSS
P13	278180	6216550	MB	EX	P13A	22.5	178.07	HBSS
	278175	6216554		EX	P13B	37.5	178.22	HBSS
	278170	6216558		EX	P13C	67.5	178.41	HBSS
P14	278398	6216536	MB	EX	P14A	6	173.03	alluvium/colluvium
	278393	6216534		EX	P14B	16.6	173.19	HBSS
	278397	6216542		EX	P14C	31.6	173.81	HBSS
	278391	6216540		EX	P14D	61.6	173.87	HBSS
P15	278550	6216426	MB	EX	P15A	16.1-17.6	177.2*	HBSS
	278545	6216423	MB	EX	P15B	18.6-20.1	177.5*	HBSS
	278556	6216427	MB	EX	P15C	30.5-32.0	177.3*	HBSS
	278561	6216431	MB	-	P15D	not yet drilled	177.0*	HBSS
P16	277370	6215105	MB	EX	P16A	27.5	200.44	HBSS
				EX	P16B	45.5	182.91	HBSS
				EX	P16C	75.5	153.46	HBSS
P17	277935	6217185	MB	EX		22.6	179.03	HBSS

ID	Easting	Northing	Type	Status	Sub ID	Depth (mBG)	RL (mAHD)	Geology
Tahmoor North								
P9	276607	6210937	VWP	F	V1	28	181.06	HBSS
				F	V2	40	169.06	HBSS
				F	V3	60	141.06	HBSS
	278843	6213724	MB	EX	P9A	24	184.96	HBSS
	278835	6213717	MB	EX	P9C	40	169.16	HBSS
	278830	6213713	MB	AD	P9D	68	141.19	HBSS
P10	279054	6213915	MB	EX	P10A	29	202.82	HBSS
	279052	6213917		EX	P10B	44	202.55	HBSS
	279055	6213922		EX	P10C	74	202.41	HBSS
P11	279246	6214229	MB	EX		29	199.57	HBSS
TNC040	279003	6214521	VWP	EX	WNFM-27	27	202.0.	WNFM
				EX	HBSS-65	65	164.03	HBSS
				F	HBSS-111	111	118.03	HBSS
				F	HBSS-225	225	4.03	HBSS
				F	BHCS-252	252	-22.97	BHCS
				F	BGSS-352	352	-122.97	BGSS
				F	SCSS-482	482	-252.97	SCSS
				F	BUCO-501.9	501.9	-272.86	BUSM
TNC043	280076	6212671	VWP	L	HBSS-65	65	150.32	HBSS
				L	HBSS-111.5	111.5	103.82	HBSS
				F	HBSS-213	213	2.32	HBSS
				F	BGSS-240	240	-24.63	BGSS
				F	BGSS-332.6	332.6	-117.28	BGSS
				F	BGSS-405.2	405.2	-189.88	BGSS
				F	BUCO-476.3	476.3	-260.98	BUSM

Coordinates in metres (GDA94 Zone 56). ** ground elevation from LIDAR*

WNFM – Wianamatta Group *BGSS – Bulgo Sandstone* *VWP – vibrating wire piezometer*

HBSS – Hawkesbury Sandstone *SCSS – Scarborough Sandstone* *MBG – metres below ground*

BHCS – Bald Hill Claystone *BUCO – Bulli Coal Seam* *MB – monitoring bore (open standpipe)*

EX – Existing *F- Failed* *AD – Abandoned or Destroyed*

L – Loss of logger (stolen), manual readings still taken.

TNC036 (Figure 3-14) is located almost 500 m to the west of the middle of LW W1 and just west of Matthews Creek. It has a number of sensors placed in the Hawkesbury and Bulgo Sandstones at various depths, as well as one in the Bulli Coal seam (Table 3-5). Groundwater pressures at TNC036 have recently been re-assessed and resulted in the removal of the transducer records at 298 m and 463 m (Groundwater Exploration Services [GES], 2020). 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 from 2016.

There are residual concerns about the reliability of this data, as noted by GES regarding a logger upgrade in 2016: "The rewiring of the loggers in 2016 (for which there was no indication at the time of cable / transducer serial number) and subsequent data processing was based on previously recorded depths which VWP transducers were installed". The implication is that while the pressure trends on Figure 3-14 are likely reliable, they might be assigned to the incorrect piezometer/stratigraphic unit. However, SLR has adopted the updated data 'as-is'.

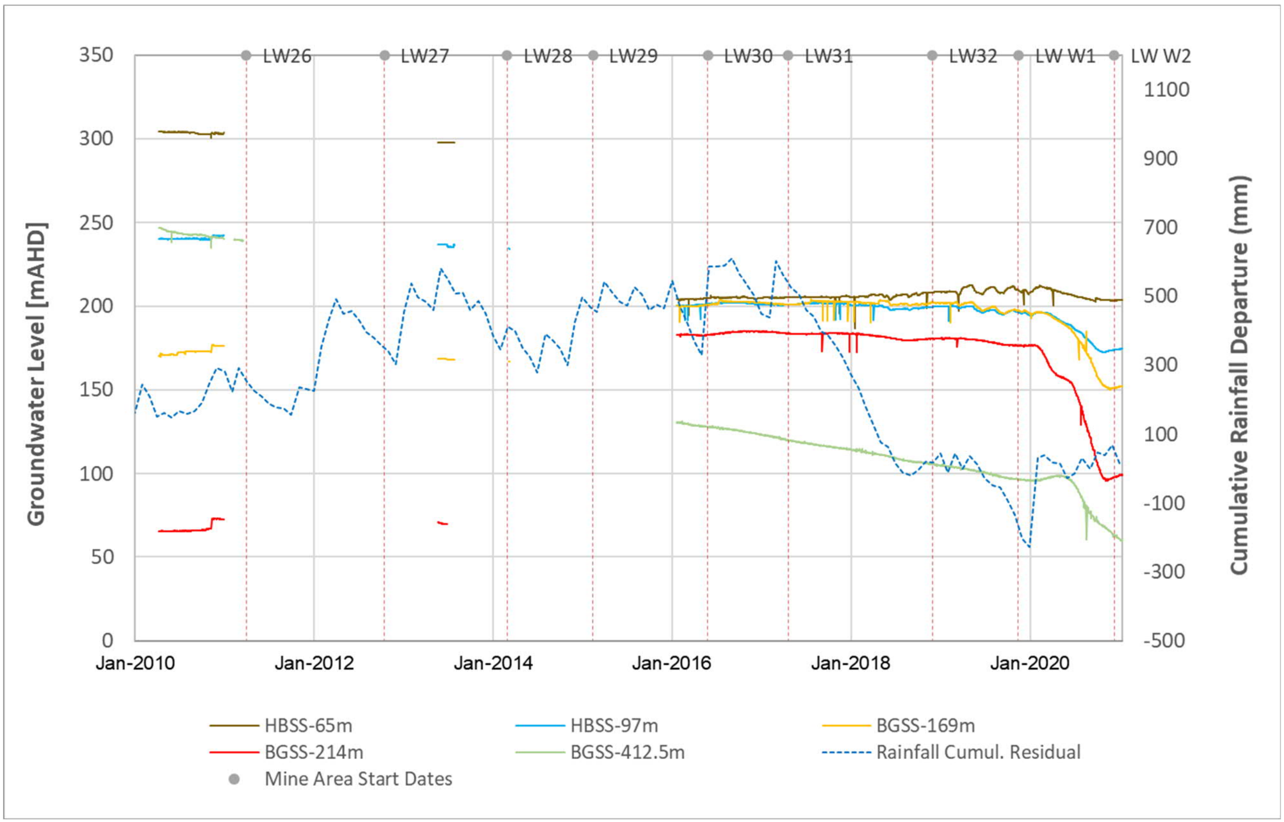


Figure 3-14 Groundwater level trends at TNC036

Approximately 60 m of depressurisation is apparent in the lower Bulgo Sandstone (piezometer BGSS-412.5m) for the period from February 2016 to August 2019, with the rate of drawdown increasing in 2020. The decline in water levels in the lower Bulgo Sandstone is likely related to regional drawdown of deeper aquifers due to the cumulative effect of longwalls 29-32 at Tahmoor. After February 2020, declines are observed in water levels in all monitored horizons and these are considered to be primarily a result of LW W1 extraction, with:

- 80 m or more drawdown in BGSS-214m;
- almost 50 m in BGSS-169m, 24 m in the lower Hawkesbury Sandstone (HBSS-97m); and
- approximately 9 m in the mid-Hawkesbury Sandstone (HBSS-65m).

TNC040 (Figure 3-15) is situated 300 m north of LW32, 650 m south-east of LW W2, and will be 430 m south of LW W4. Eight data sensors installed in TNC040 are positioned within the Wianamatta Group, Hawkesbury Sandstone, Bald Hill Claystone, Bulgo Sandstone, Scarborough Sandstone and Bulli Coal seam (Table 3-5). As of February 2019, the lower four VWP sensors were no longer active due to subsidence effects (GES, 2019). Revisions to the pressure calculations/calibration were also made for two instruments (GES, 2019). The second deepest instrument at 482 m was reclassified to be in Scarborough Sandstone (from Bulgo Sandstone) and the instrument at 252 m was reclassified as monitoring the Bald Hill Claystone.

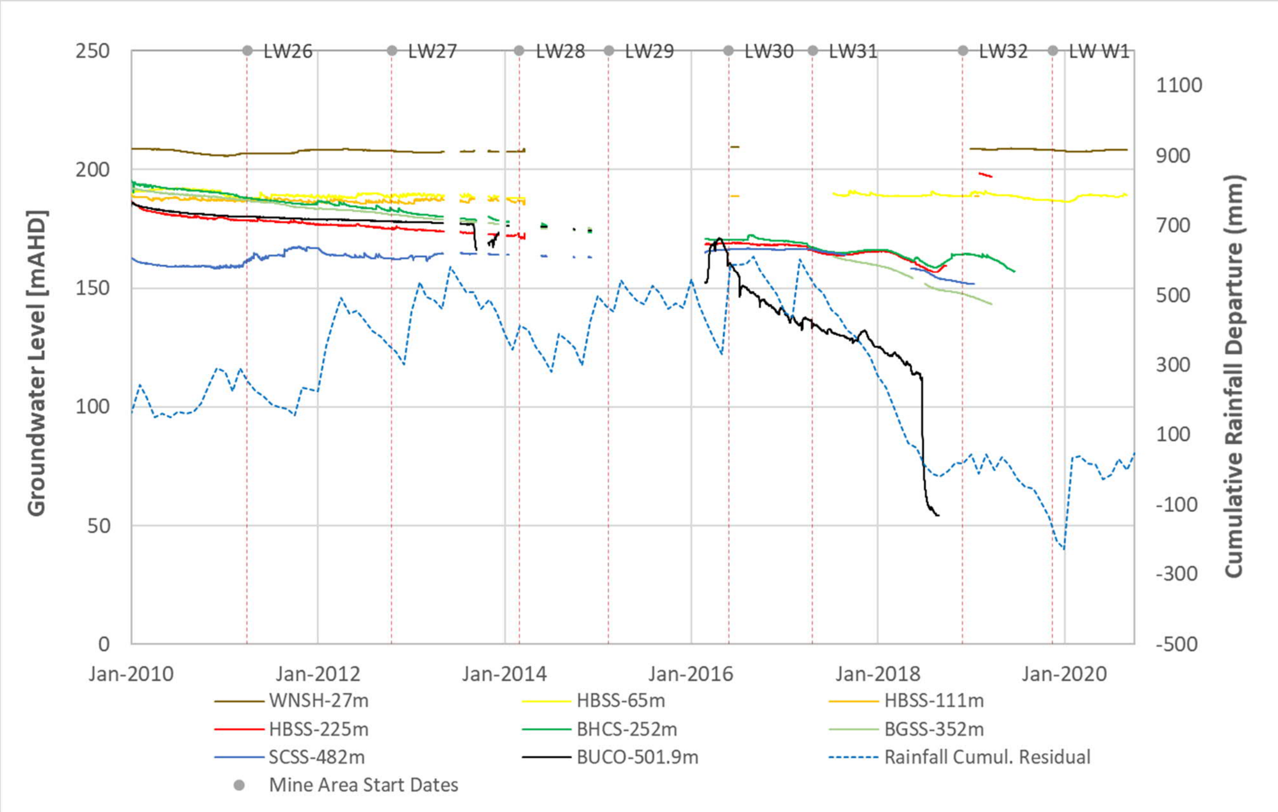


Figure 3-15 Groundwater level trends at TNC040

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 m, BGSS-352 m, SCSS-482 m, and BUCO-501.9 m), and no data collected at any loggers throughout 2015. A gradual decline in water levels at sensors BHCS-252 m, BGSS-352 m, SCSS-482 m and BUCO-501.9 m is apparent over this period as mining approached from the south.

The greatest declines are observed in the Bulli Coal seam, with water levels falling by approx. 110 m from May 2016 until February 2019. More than half of this decline (60 m) occurred from June 2018, in response to nearby mine workings (roadways), until it ceased operating in September 2018. The BHCS-252 piezometer showed a drawdown of approx. 10 m in 2019 as LW32 approached.

As of September 2020, the upper two sensors (WNFM-27m, HBSS-65 m) remain active and do not appear to show an influence from mining. Instead, these loggers, especially HBSS-65 shows some correlation with the rainfall trend.

A vertical profile showing potentiometric head for bore TNC040 has been included in **Figure 3-16** to illustrate groundwater level trends in response to mining in an alternative format to hydrographs. This shows the potentiometric head at various points in time from January 2010 to February 2019.

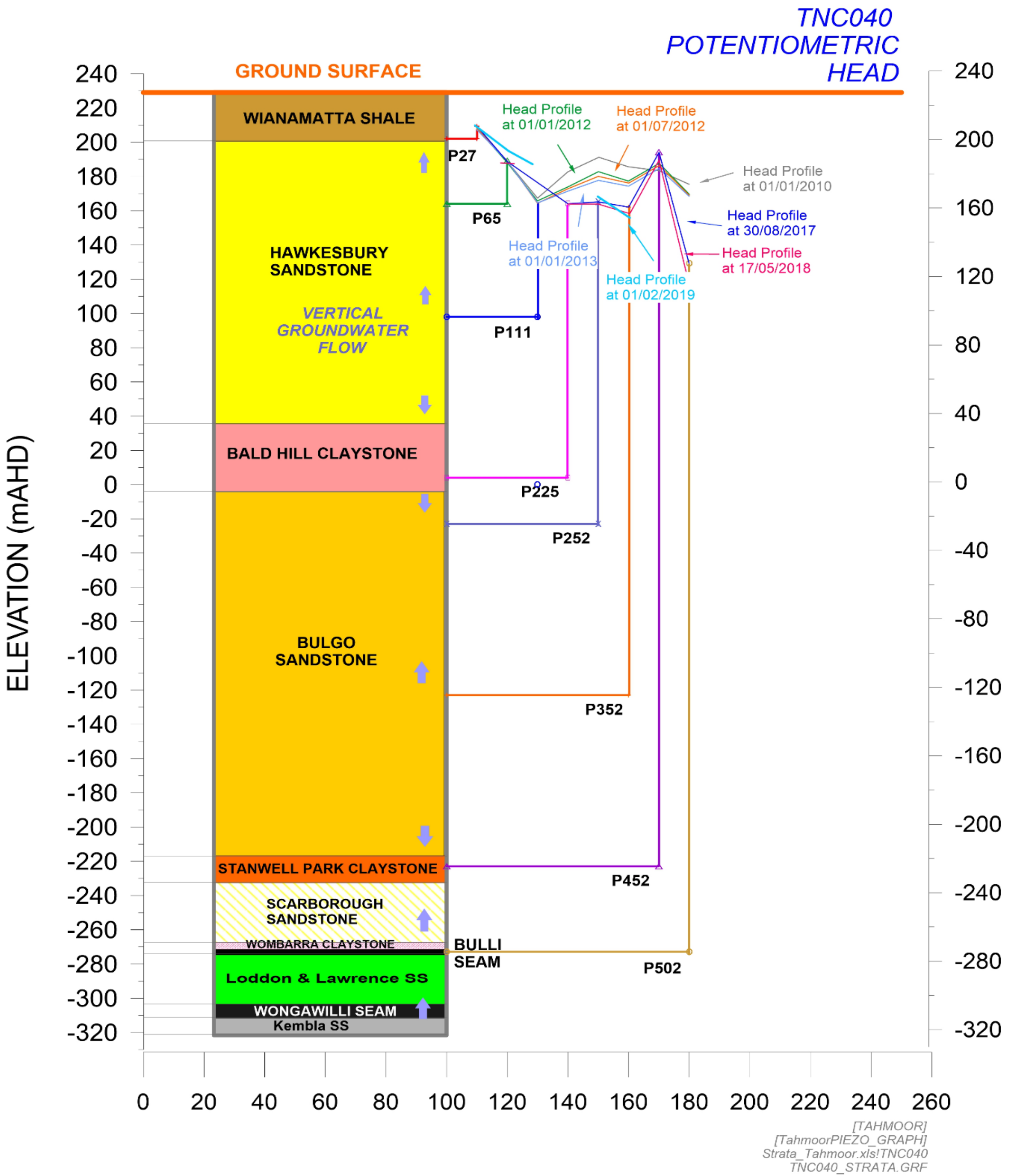


Figure 3-16 Vertical head profile at TNC040

The head profiles for the period 2010 to 2013 show similar behaviour, with heads in the shallow Wianamatta Shale being the highest, lower in the Hawkesbury Sandstone and then higher 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, reflecting depressurisation due to the approach of Tahmoor North longwalls.

TNC043 (Figure 3-17) is also located 140 m east of the southern end of LW32, at the opposite end to TNC040. Monitoring began at this VWP-instrumented bore in July 2010, and as with TNC036 and TNC040, there are some gaps in the record. However, data has been consistently collected since mid-2015. Until October 2019, the HBSS-65 m and HBSS-111.5 m piezometers were the only active instruments at this bore, with the remainder failing in 2018 due to subsidence from nearby LW32. The two upper sensors HBSS-65 m and HBSS-111.5 m at TNC043 remained active until September 2020 before being stolen at the end of 2020 (Table 3-5). Despite the loss of the loggers, manual readings are taken for the upper two sensors approximately monthly.

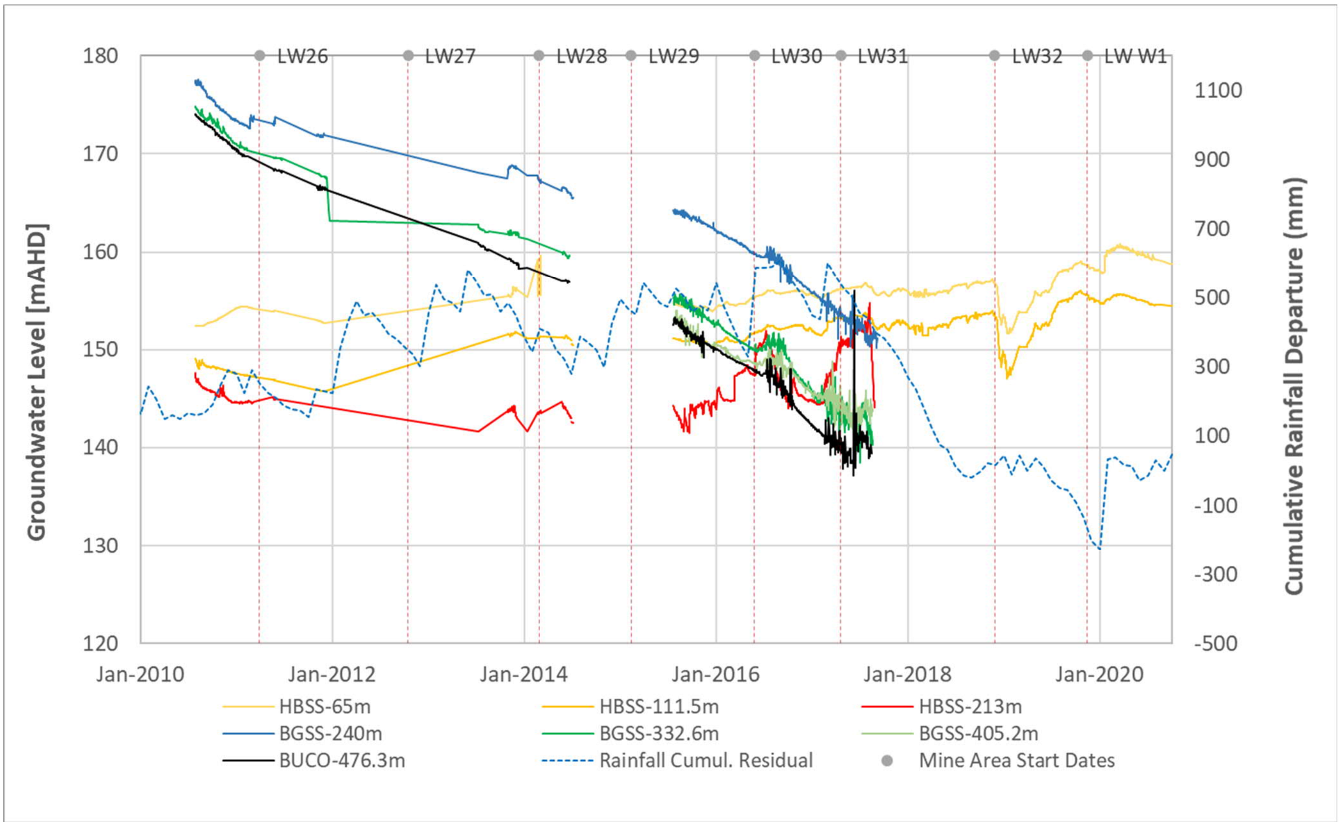


Figure 3-17 Groundwater level trends at TNC043

The lower stratigraphic sequences at this monitoring site (all sensors in the BGSS sensors and the Bulli Coal seam), contain higher groundwater heads than those in the Hawkesbury Sandstone, suggesting higher pressures that may result from aquifer confinement and proximity to the Nepean River, which is the regional drainage feature for the HBSS. 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 of historical mining at Tahmoor and possibly due to the BSO Mine.

The water levels at HBSS-65 m and HBSS-111.5 m present similar trends to one another and both respond clearly to rainfall. In early 2019, water levels at these sensors dropped sharply by about 5 m and recovered over the remainder of 2019 to baseline levels before sensor failure occurs. This decline may have been 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. However, the recovery in groundwater levels do not match with any major rainfall events. The initial decline occurred as mining in LW32 passed these sensors, suggesting that some strata dilation effect occurred (leading to increased aquifer storage), causing a short-term drawdown in shallow groundwater levels prior to recovery and filling of that storage.

Figure 3-18 presents a hydrograph of the pre-mining borehole (WD01) located above a chain pillar between the Western Domain LW W1-W2. The bore is 570 m north of the closest Tahmoor North goaf (LW 32) and was completed while LW W1 was 400 m to the north (Section 3.5.7.1). WD01 is instrumented with VWPs at multiple depths and has been recording groundwater pressures/heads since September 2020.

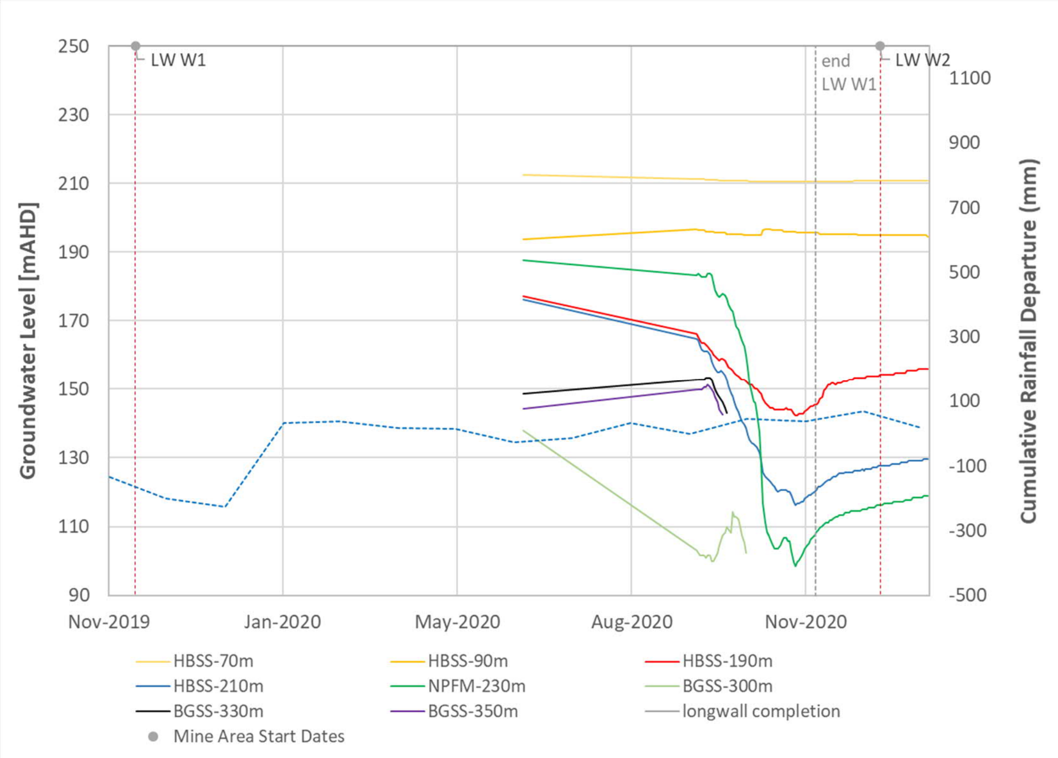


Figure 3-18 Groundwater level trends at WD01

Since monitoring commenced, the two upper instruments HBSS-70 m and HBSS-90 m show stable groundwater levels at about 210 mAHD and 195 mAHD respectively and no mining effect is evident. A sharp decline in groundwater level is observed in HBSS-190 m and HBSS-210 m with a respective drawdown of 23 m and 48 m in October 2020 due to the passing of LW W1, before recovering by approximately 20 m in January 2021. Approximately 80 m of depressurisation is apparent in the Newport Formation (piezometer NPFM-230 m) between September 2020 and October 2020 with the rate of drawdown increasing in October 2020. Groundwater heads in the Newport Formation decline below the Hawkesbury groundwater heads suggesting a change in vertical head gradient from upward to downward. As of late October 2020, groundwater heads in NPFM-230 m start to recover at a similar rate to the lower HBSS following significant rainfall recharge in late October 2020.

Short-term groundwater drawdown of shallow groundwater levels in the lower HBSS and NPFM could be attributed to some strata dilation leading to increased aquifer storage prior to recovery and the filling of storage.

In the Bulgo Sandstone, the two deeper sensors (BGSS-330 m and BGSS-350 m) show higher groundwater pressures than the upper sensor BGSS-300 m (45 m difference), suggestive of some aquifer confinement. During September 2020, water levels at these two lower sensors declined progressively by 10 m and 7 m respectively before sensor failure occurs during mid-September 2020 (significant drawdown after that time is assumed). The BGSS-300 m sensor shows a 3 m decline in early September 2020 with a subsequent increase of 10 m in groundwater level, attributed to strata compression as the longwall approaches, before declining again and then failing due to ground movement in late September 2020. Again, further significant drawdown is assumed after that time, as these Bulgo Sandstone piezometers are likely within the zone of vertically connected fracturing.

P9 monitoring sites are located on the northern bank of Redbank Creek and overlie the pillar between LW31 and LW32, where extraction commenced in November 2018. These bores are not directly relevant to the Western Domain, but show behaviours that would be expected above or near to Western Domain longwalls. Groundwater data has been recorded at P9 since October 2017. The open standpipe bores are screened at 22-24 m (P9A), 37-40 m (P9C) and 65-68 m (P9D), all within the Hawkesbury Sandstone. There were also three VWPs installed in a single P9 bore at 28 m, 40 m and 68 m depths, corresponding to some of the open standpipe intervals (Table 3-5).

One of the standpipe bores P9D (65-68m) and all three VWP sensors at P9 have failed; failures in P9_V1 in May 2018, P9_V2 in May 2019 and P9_V3 in October 2018. This is not surprising given the position between longwall panels and susceptibility to subsidence effects, however measurements of groundwater level are still recorded at P9A (22-24m) and P9C (37-40m) (Figure 3-19).

Figure 3-19 presents a hydrograph of groundwater levels at P9 and P9 open standpipes sites. At the commencement of monitoring the water levels in P9_V1 and P9_V2 were closely related. Greater head separation exists (approximately 5 m) between the water levels in the two shallower VWPs and the deeper instrument (P9_V3), however, groundwater levels at all depths show similar peaks and declines in response to rainfall.

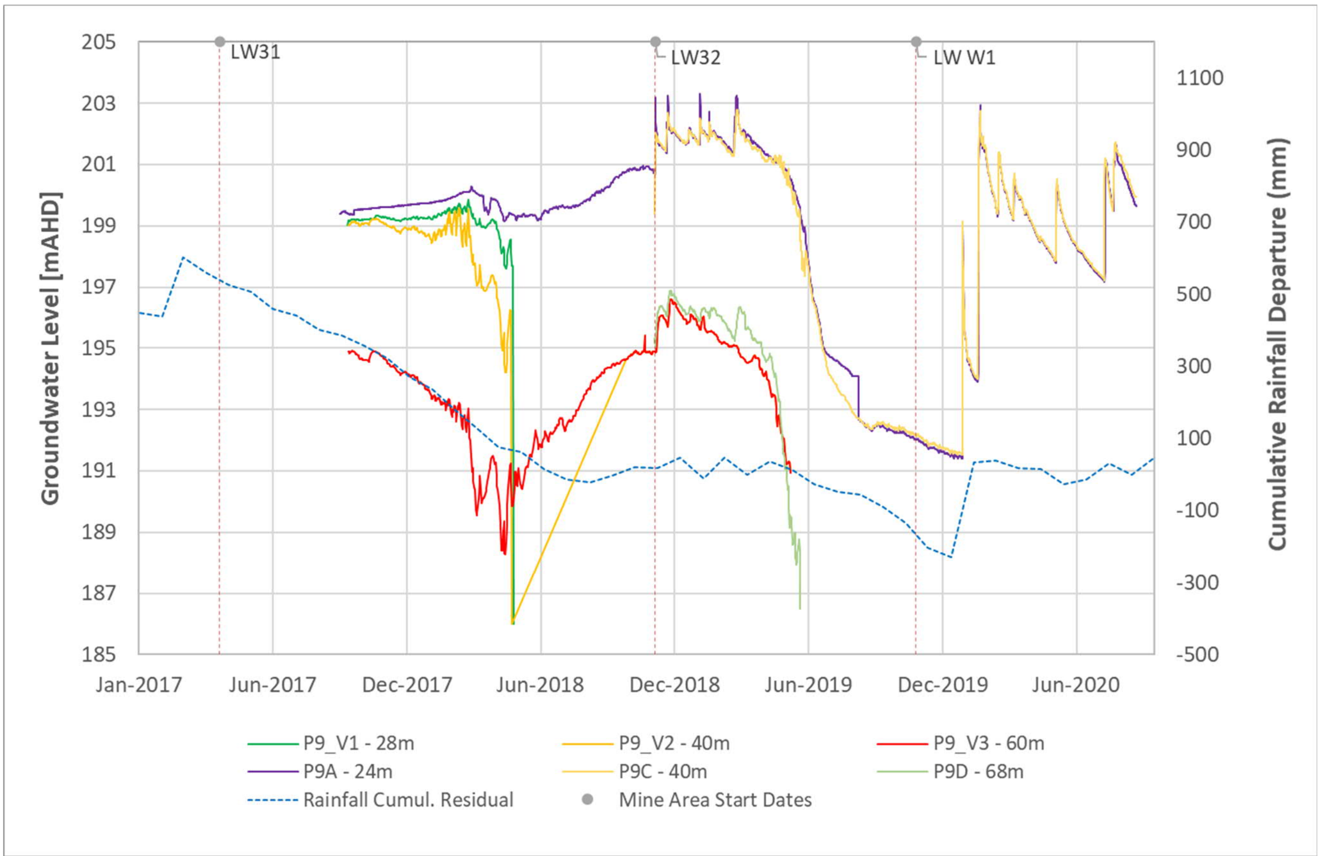


Figure 3-19 Groundwater level trends at P9

Water levels in most of the P9 instruments decline gradually throughout the first half of 2018, following a trend similar to of the rainfall cumulative residual curve. During this period water levels decline by approximately 5 m in each of the VWPs. Following this, groundwater levels drop below the VWP at P9_V1 and P9_V2 and these instruments fail at this point, while pressures at V3 begin to recover. By December 2018, water levels in P9_V3 have fully recovered and are approximately 2 m higher than those first recorded in October 2017. The higher head in P9_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 hydrograph indicates that water drains from shallowest horizons and recharges deeper horizons.

From December 2018 to April 2019, as LW32 advances toward the P9 bores, water levels in P9_V2 and in standpipe bore P9D (65-68m) decline by 2 m, followed by a sharp drawdown of 6 m in May 2019 due to the extraction of LW32, noting that this monitoring site lies above the chain pillar of LW32.

Hydrographs for the shallow standpipe bores (P12-P17) drilled in 2019 around the Western Domain are presented on Figure 3-20 alongside the rainfall trend ("CRD"). P15 sites are not included on this because these were completed in March 2021 after land access issues. Monitoring bores P12-P14 and P17 are located north of the Western Domain longwalls, outside the mine footprint and adjacent to Stonequarry Creek (P13, P14, P17) and Cedar Creek (P12). P16 is situated along Matthew Creek, 300 m west of LW W1 and just upstream to the confluence of Matthews Creek and Rumker Gully. A brief analysis of the groundwater trends in relation to weather and mining activity (Figure 3-20) is presented below.

P12 is the closest bore to LW W1 (50 m north) which was completed in November 2020. The minimum groundwater level elevation recorded at P12C between June and November 2019, prior to LW W1, was 176.3 m AHD, with evidence of groundwater pumping by nearby users, causing drawdown over a short periods (less than 2 months) in the range of 1 m to 3 m.

Groundwater levels at P12C shows a mild response to rainfall in mid-January and February 2020 and started to decline significantly from 180 mAHD in March 2020 to 167 mAHD in November 2020, falling below the baseline level. From mid / late October 2020, groundwater levels at P12C start to stabilise at 167 mAHD following rainfall events and recover to 168.7 mAHD in December 2020. P12C groundwater levels have stabilised to some degree since November 2020, but during that time there have been variations of 1-2 m, possibly in response to rainfall or to the commencement of LW W2. These groundwater level trends at P12C resulted initially in a Level 3 TARP trigger from June 2020 and followed in a Level 4 TARP trigger from December 2020, attributed to mining induced depressurisation of deeper groundwater aquifer but also correlated to a reduction in rainfall recharge events (GeoTerra, 2020). As of March 2021, groundwater levels have slightly recovered to 167.5 mAHD but the Level 4 TARP notified to DPIE, NRAR and Resources Regulator on 30th December 2020 still applies at P12C.

Bores screened within the upper section of the Hawkesbury Sandstone (P12A and P12B) have stable water level that show mild response to rainfall events, as seen for the period between January 2020 and February 2020. The groundwater levels at P12A and P12B have shown a mild decline (less than 0.5 m) in water levels following the commencement of LW W1. Throughout 2020, groundwater levels at P12A have remained relatively stable between 170.3 mAHD and 170.5 mAHD while groundwater levels at P12B exhibited a gradual and consistent decline to December 2020 falling 1.2 m and stabilising at 170 mAHD. After the commencement of LW W2 groundwater levels at P12A and P12B fall less than 1 m to approximately 170 mAHD before stabilising to similar level in March 2021.

Prior to the mining of LW W1, there was an upward hydraulic or pressure gradient from P12C to P12B, and from P12B to P12A consistent with the inferred 'gaining' condition from Matthews Creek. Since the commencement of mining, the gradients have altered so that there is a stronger downward hydraulic gradient from surface water to P12A and then to P12B and P12C.

P13 is located 130 m north-east of LW W1. The minimum groundwater elevation recorded at P13C between June and November 2019, prior to LW W1 mining, was 169.8 m AHD, with a similar minimum of 170.2 m AHD on 6 January 2020, that are reflective of the drought conditions at the time.

The groundwater level at P13C recovered by 2 m following substantial rainfall in mid-January and February 2020, and then began to decline in March 2020, declining consistently through much of 2020. Groundwater levels were recorded at 165.4 m AHD in late October 2020, almost 5 m below the baseline minimum. In accordance with the WMP (Tahmoor Coal, 2020) a Level 4 TARP significance were notified to DPIE, NRAR and Resources Regulator on 30th December 2020 in relation to groundwater level decline at P13C in November 2020. The decline in groundwater level was attributed to mining induced regional depressurisation of deeper aquifers (GeoTerra, 2020h). P13C groundwater levels have stabilised to some degree since November 2020, but during that time there have been variations of 0.5-1 m, possibly in response to rainfall or to the commencement of LW W2. As of 15 March 2021 (end of the available data period), groundwater levels are at 165.8 mAHD, 0.4 m above the post-mining minimum.
Groundwater trends at P13B and P13A have been much more subdued than those in the deeper P13C horizon (mid-Hawkesbury Sandstone). Both piezometers showed relatively stable levels though 2019, declines in late 2019 and early 2020 (severe drought) and recovery due to rainfall in January and February 2020.

Post February 2020 there was a consistent decline to October 2020. At that time, P13B groundwater levels declined by 0.6 m below the baseline minimum to 165.3 m AHD and has stabilised to 165.8 mAHD in March 2021. P13A exhibited drawdown through 2020 to 166.9 m in October 2020, which is similar to the previous minimum. Despite some mild variation, it remains close to this level (167.1 mAHD) on 15 March 2021.

Prior to LW W1, there was an upward hydraulic or pressure gradient from P13C to P13B, and a downward gradient from P13A to P13B, which is consistent with the inferred 'losing' condition from the Stonequarry Creek, based on the shallow groundwater level (P16A) being below creek bed elevation (**Figure 3-20**). Since the commencement of LW W1 mining, the hydraulic gradients have altered so that there is a stronger downward hydraulic gradient from surface water to P13A and then to P13B, and the former upward gradient from P13C to P13B has become effectively neutral.

P14 is located 350 m east of LW W1. Since the start of monitoring in June 2019 each of the open standpipes show a continual and relatively linear decline in water levels which correlate with a reduction in rainfall until February 2020. Water levels respond to the wetter condition from January-February 2020. From March 2020, there is an on-going reduction in the groundwater trends at P14B (approximately 1 m), P14C (approximately 1.5 m) and P14D (approximately 1.2 m) which is likely induced by the extraction of LW W1. Following rainfall events mid-October 2020, water levels at P14B, P14C and P14D start to stabilise and recover by approximately 0.5 m. These groundwater trends are observable until January 2021 and then begin to decline from mid-January 2021 by approximately 0.3-0.5 m, to below the baseline level. The minimum groundwater elevation recorded at P14D between June and November 2019, prior to LW W1, was 164.8 m AHD. In March 2021, groundwater levels at P14D were recorded at 163.2 mAHD and shows the greatest depressurisation at P14 site with an approximate 1.6 m drawdown since the start of mining. As depressurisation is less than two meters in P14 B, C and D, TARP Level 1 Significance still applies.The shallow piezometer P14A (colluvium/alluvium) has shown stable groundwater levels between June and November 2019 with water levels at around 168.6 mAHD, recovery in mid-January and February 2020 and consistent water levels though 2020 with mild responses to rainfall. P14A groundwater levels sit at 170 mAHD in March 2021.

P15 bores are situated 540 m and 220 m northeast of LW W1 and LW W2 respectively, and 60 m north of proposed LW W3. As the time of writing P15A, B and C have been installed at depths 17, 20 and 32 mbgl and equipped with loggers at 12-hourly readings (**Table 3-5**). P15D is planned. A single groundwater level measurement was recorded in each of the completed piezometers in March 2021 and available for this study. The single groundwater level measurement shows groundwater to be around 12.5 to 12.3 mbgl in P15A, P15B and P15C, indicating unconfined conditions in the Hawkesbury Sandstone and suggesting that these three monitored horizons are hydraulically connected, i.e. between 17, 20 and 32 mbgl.

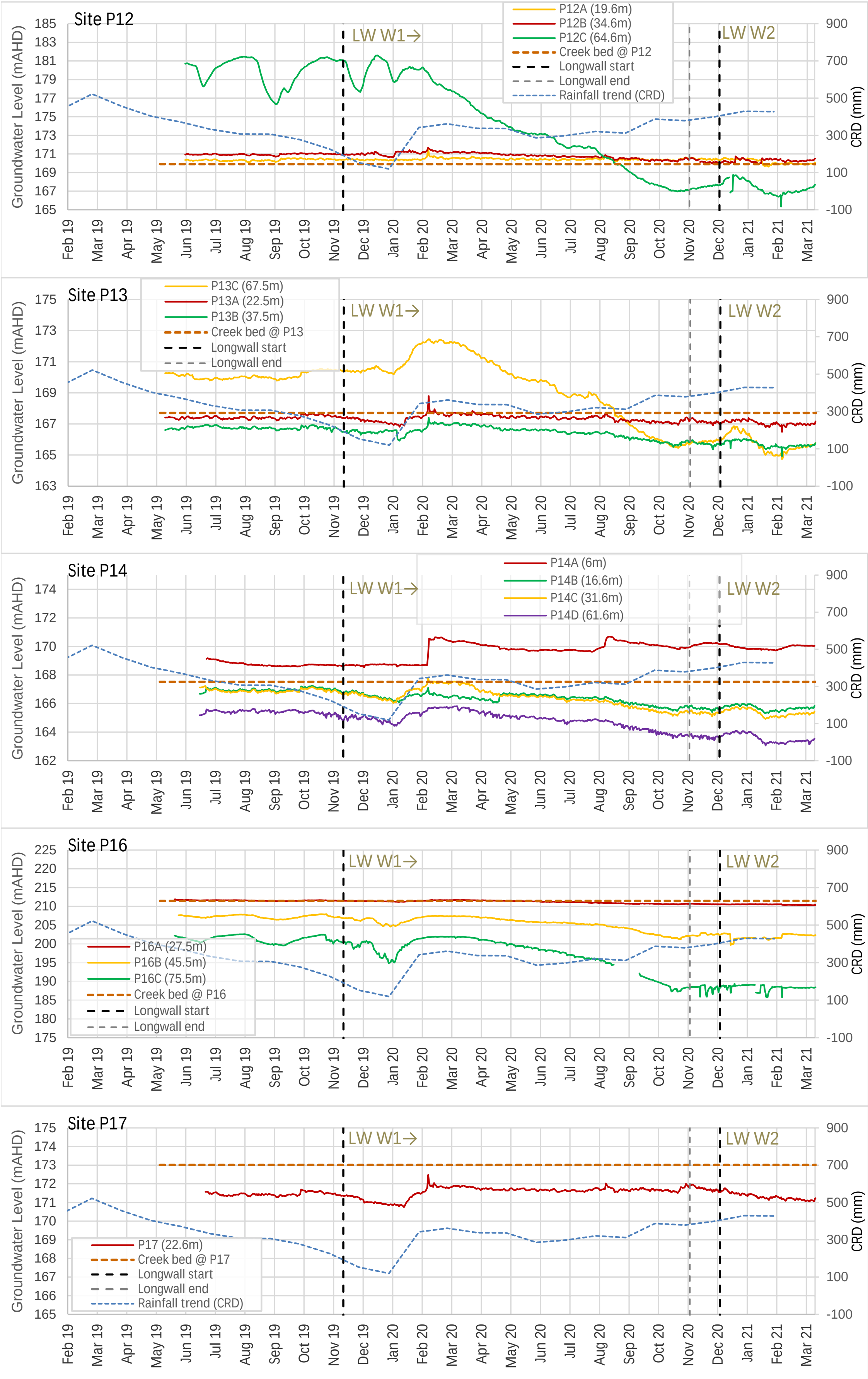


Figure 3-20 Western Domain Bore Hydrographs (bores P12-P17)

P17, situated 600 m north of LW W1, shows clear responses to rainfall. A slight reduction in water levels to 170.8 mAHD (approximately 0.2 m) in December 2019 is attributed to the extraction of LW W1. From March 2020, water levels have recovered to 171.8 mAHD, approximately 0.7 m above the baseline level, and no further response to LW W1 is observed in this hydrograph. Following the completion of LW W1 and commencement of LW W2, groundwater levels at P17 begin to decline by 1 m. In March 2021, groundwater levels at P17 have stabilised at 171 mAHD, a similar level as recorded in December 2020.

P16 situated 430 m east of LW W1 shows minimal responses to rainfall events in the most upper strata (P16A), with stable water levels until December 2019. The minimum groundwater level recorded between June and November 2019, prior to LW W1 at P16B and P16 was 206.4 mAHD and 199.6 mAHD respectively with evidence of groundwater pumping by nearby users, causing drawdown over a short periods (less than 2 months) in the range of 1 m to 2.5 m.

A mild decline less than 1 m is observed from December 2019 to December 2020 with water levels declining just below the creek bed level in August 2020 which could cause mild reductions in baseflow. An apparent downward vertical head gradient is observed at P16, with fluctuations in water levels closely related and a head separation of 4 m between the two lower strata, suggesting the HBSS aquifer is not confined at this location. In the two deeper strata, water levels correlate with rainfall trends until a sharper decline occurs during December 2019, likely due to a severe rainfall deficit followed by the start of LW W1 extraction which exacerbates drawdown. From January 2020, following wetter conditions, water levels at P16 begin to recover and reach baseline levels in March 2020. Post March 2020 there is a gradual reduction in groundwater levels in P16B and P16C with water level declining to 201.3 mAHD and 187.4 mAHD respectively. Following rainfall in mid-October 2020, water levels at P16B and P16C stabilise and recover by approximately 1 m in December 2020. P16B and P16C exhibited some mild drawdown in the range of 2 m over short periods after the commencement of LW W2 and stabilised in March 2021 to similar level as December 2020.

As of March 2021, these groundwater trends at P16B and P16C result in the triggering of Level 4 TARP triggers, likely to be influenced by a reduction in rainfall between March and October 2020 and mining effects from LW W1 and commencement of LW W2. The Level 4 TARP trigger was notified to DPIE, NRAR and Resource Regulator on 30th December 2020.

Figure 3-21 summarises the observed drawdown for each standpipe since the start of LW W1 in relation to the distance to LW W1 and function of the elevation of the bottom of the screen within the Hawkesbury Sandstone.

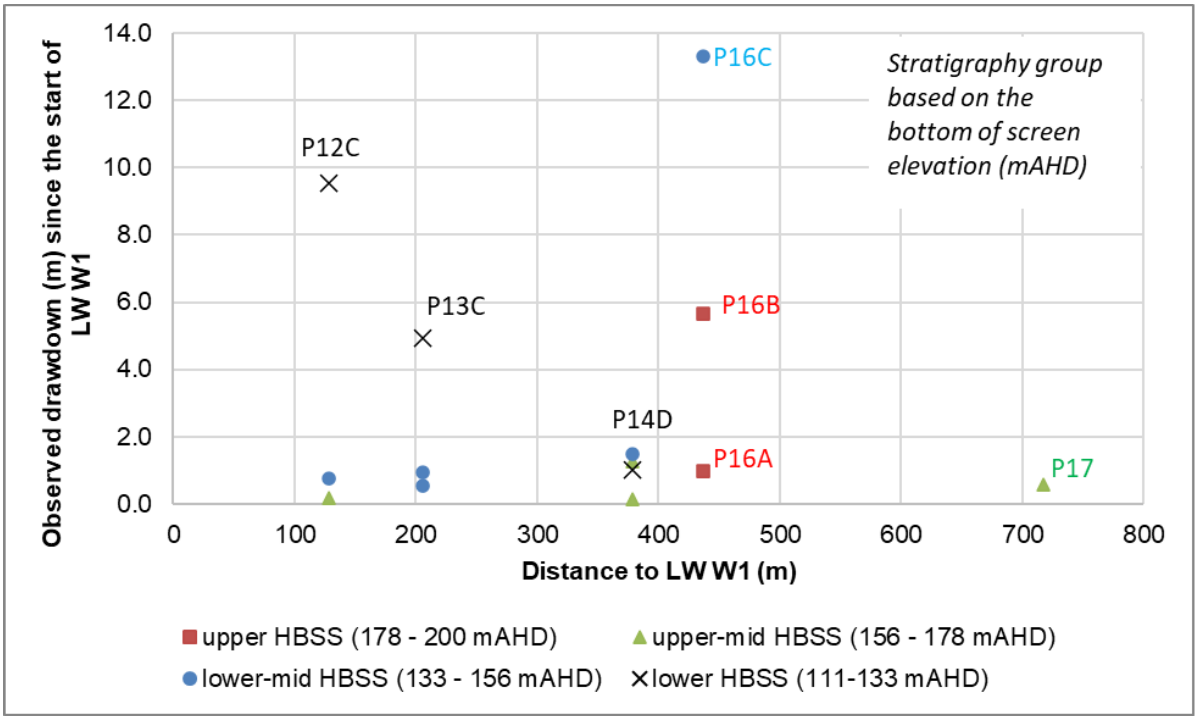


Figure 3-21 Observed drawdown to late 2020 in relation to distance from LW W1

While there is no clear correlation between the distance to LW W1 and observed drawdown in the upper, upper-mid and lower-mid sections of the Hawkesbury Sandstone, the observed drawdown within the lower HBSS appears to be correlated to the distance to LW W1.

The relationship shown in **Figure 3-21** appears to confirm that recent reductions in groundwater levels identified in the inferred lower and mid-HBSS at P12C (TARP Level 4), P13C (TARP Level 4) are likely related to the extraction of LW W1.Drawdown experienced due to previous mining at Tahmoor

The following section presents an analysis of the post-mining groundwater levels measured at the bores recently drilled along the Redbank and Myrtle Creek and above or adjacent to recent Tahmoor North longwalls.

Figure 3-22 shows hydrographs for the bores located on Redbank Creek, ordered from the furthest upstream to the furthest downstream, and plotted alongside the rainfall trend ("CRD"). These standpipes are situated above the Tahmoor longwalls LW28 to LW32 which were extracted between April 2014 and September 2019. P34 to P11 are screened at different depths in the Hawkesbury Sandstone to monitor groundwater levels since early mid-2019 and from January 2020.

The groundwater levels along Redbank Creek are correlated to weather patterns or rainfall events. There is a clear response in groundwater levels to the significant rainfall commencing in January 2020 (P19, P30, P9; P10, P29, P11) with water levels rising between 5 m and 10 m by the end of February 2020.

Figure 3-22 shows that declines in water levels at P10 are observed in the shallowest bores (29 m and 44 m deep) and deeper strata (74 m deep) due to extraction of LW32. The drawdown in the shallower horizons (P10A-P10B) is approximately 7-8 m, while in the deeper bore (P10C), the drawdown is up to 15 m for a period of 1-2 months, before recovering within two months to 5 m above the baseline levels.

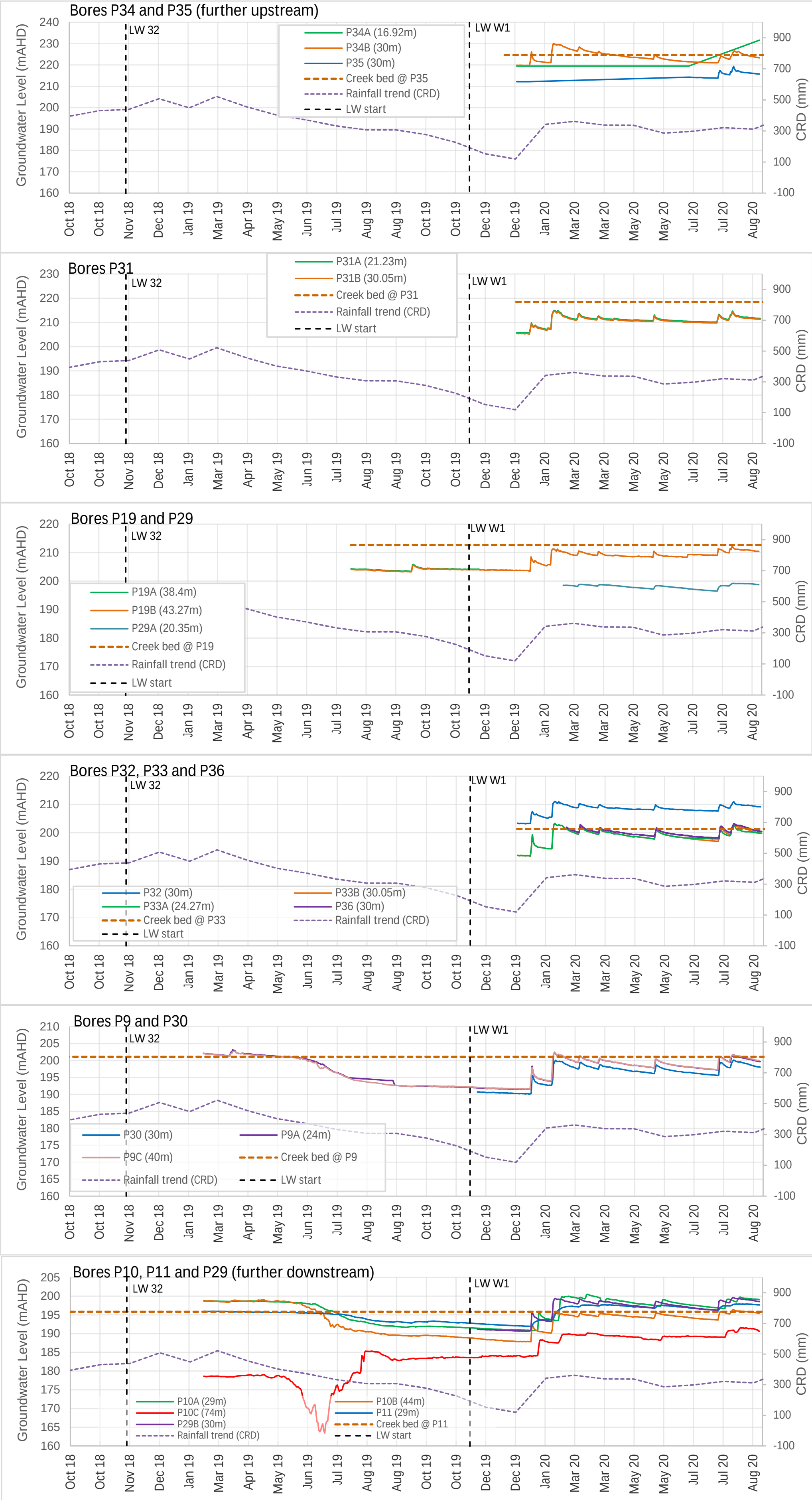


Figure 3-22 Redbank Creek Hydrographs

There is no trend identified with varying hydraulic conductivity and open fractures throughout P10 (SCT, 2019b), suggesting that "surface cracking" is likely limited at this location. However, the recovery behaviour in P10C would suggest that water is draining from shallowest horizons during rainfall events, via open fractures and recharges a slightly deeper horizon. The recovered water level above the baseline level in P10A and P10C could also suggest that surface water upstream to P10 (i.e., P9 area) is intercepted due to limited surface cracking, enhancing groundwater recharge into the upper Hawkesbury Sandstone aquifer.

Bore P11, located along Redbank Creek and 300 m east to LW 32 shows mining induced drawdown of approximately 3 m between July 2019 and January 2020 (**Figure 3-22**). As of September 2020, water levels at P11 have recovered and sit around 2 m above the first recorded level in February 2019.

It is difficult to confidently assess if the shallow groundwater along Redbank Creek was impacted by mining prior to 2019 as monitoring of water levels started between 2019 and 2020, after longwall extraction passed. However, based on experience at other sites, it is likely that some drawdown would have occurred.

The summary information regarding these hydrographs (**Figure 3-22**) is that shallow groundwater is responsive to rainfall since the start of monitoring with water levels sitting just below creek bed level (upstream section) and above creek bed level after rainfall recharge events (i.e. downstream section P10 and P11). Based on the available data, it is likely that shallow groundwater above the longwalls was previously impacted by mining and that for most of these shallow bores water levels have partly recovered to baseline levels, i.e. with some residual drawdown, typically on the order of 1-4 m. Some monitoring sites (e.g. P10C) show recovery to above baseline levels, representing additional recharge from shallower horizons without further downward drainage.

Figure 3-23 presents hydrographs for the bores located on Myrtle Creek from the furthest upstream to the furthest downstream. The open standpipes are situated above the Tahmoor longwalls LW26 to LW28 (bores P28 to P22) and just south to LW29, outside the mine footprint (bores P23-P25 and P18). LW26 was extracted between March 2011 and October 2012. The bores situated along Myrtle Creek have similar construction details as bores located along Redbank Creek. These make up a series of open standpipes screened at different depths in the Hawkesbury Sandstone to monitor groundwater levels since mid-2019.

P20, which is located the furthest upstream, shows stable groundwater levels since September 2019. A linear increase in water levels is observed (approximately3 m) in the deeper strata which correlates with the significant rainfall event of February 2020. The standpipes located on mid-section of Myrtle Creek (P26, P27, P28) between LW27 and LW28 have water levels responding more quickly to the rainfall event of February 2020 than P20. Water levels in the shallow bore P28A (18.25 m) rise quickly by more than 5 m while water levels in bores screened at around 30 mbgl (P26, P27 and P21) have a slower response but with the same magnitude (approximately 5 m) at the end of March 2020.

From January 2020, along the downstream reach (bores P23, P24 and P18), water levels respond progressively to significant rainfall recharge (approximately 3 m recovery).

As of September 2020, it is difficult to assess if the shallow groundwater along Myrtle Creek underwent a mining induced drawdown as monitoring of water levels commenced after mining, although based on the data and discussion of bores P9, P10 and P30 (above) it seems likely that groundwater would have drawdown directly above longwalls. It is inferred from these hydrographs that if mining caused a reduction in Hawkesbury

Sandstone groundwater levels in the past, these have likely recovered to pre-mining conditions, with the possible exception of at P20.

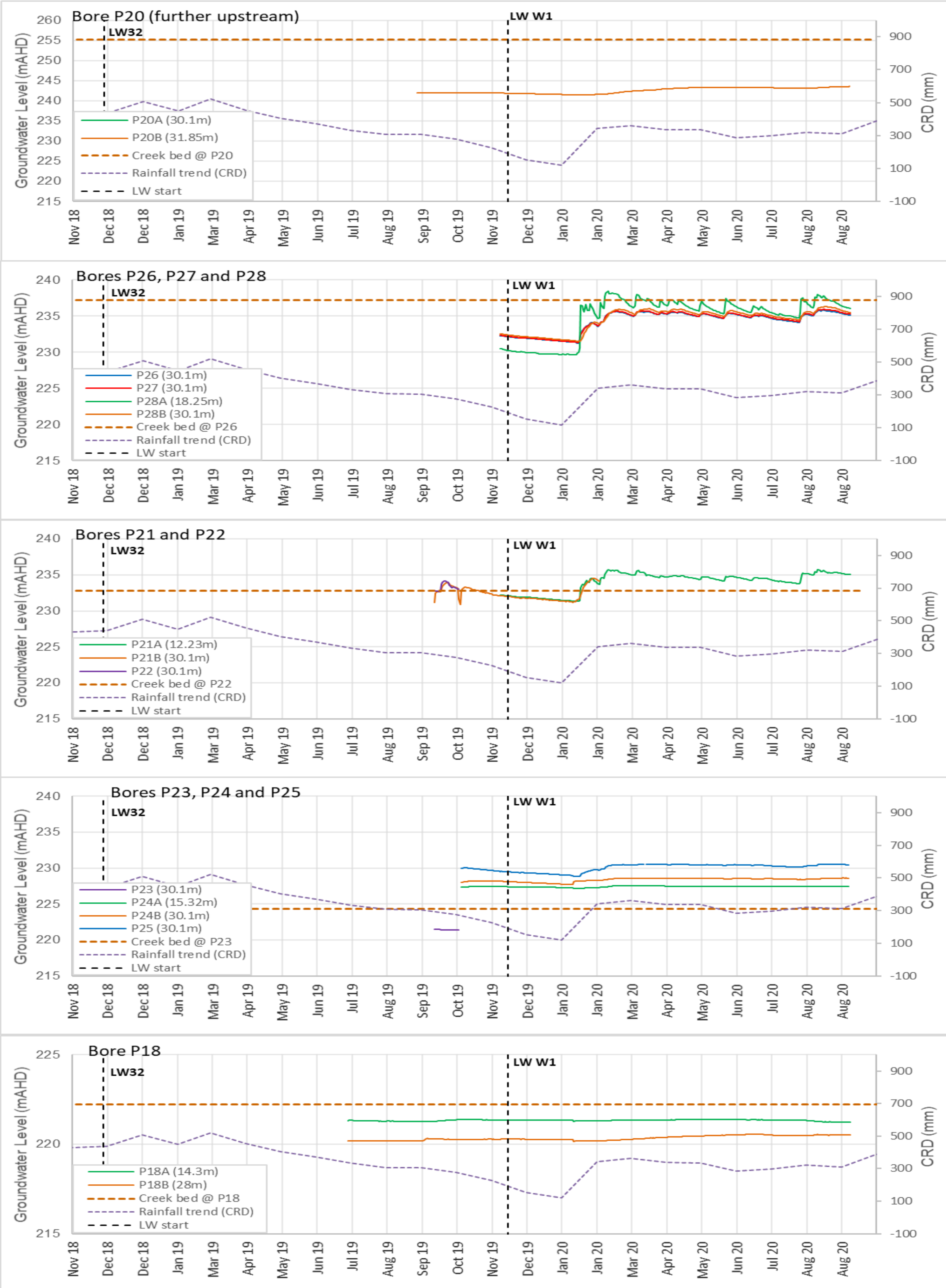


Figure 3-23 Myrtle Creek Bore Hydrographs

SLR

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 (above), are presented on **Figure 3-24** and **Figure 3-25.**

The monitoring bores P1 to P4, 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 3-13**. A summary of the change in groundwater levels prior to the extraction of Longwall 23A (September 2005) and following the extraction of Longwall 32 (September 2019 is provided below:

- Bores overlying 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 due to the land access issues. 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 possible that groundwater levels at this site are influenced by the nearby Nepean Fault.

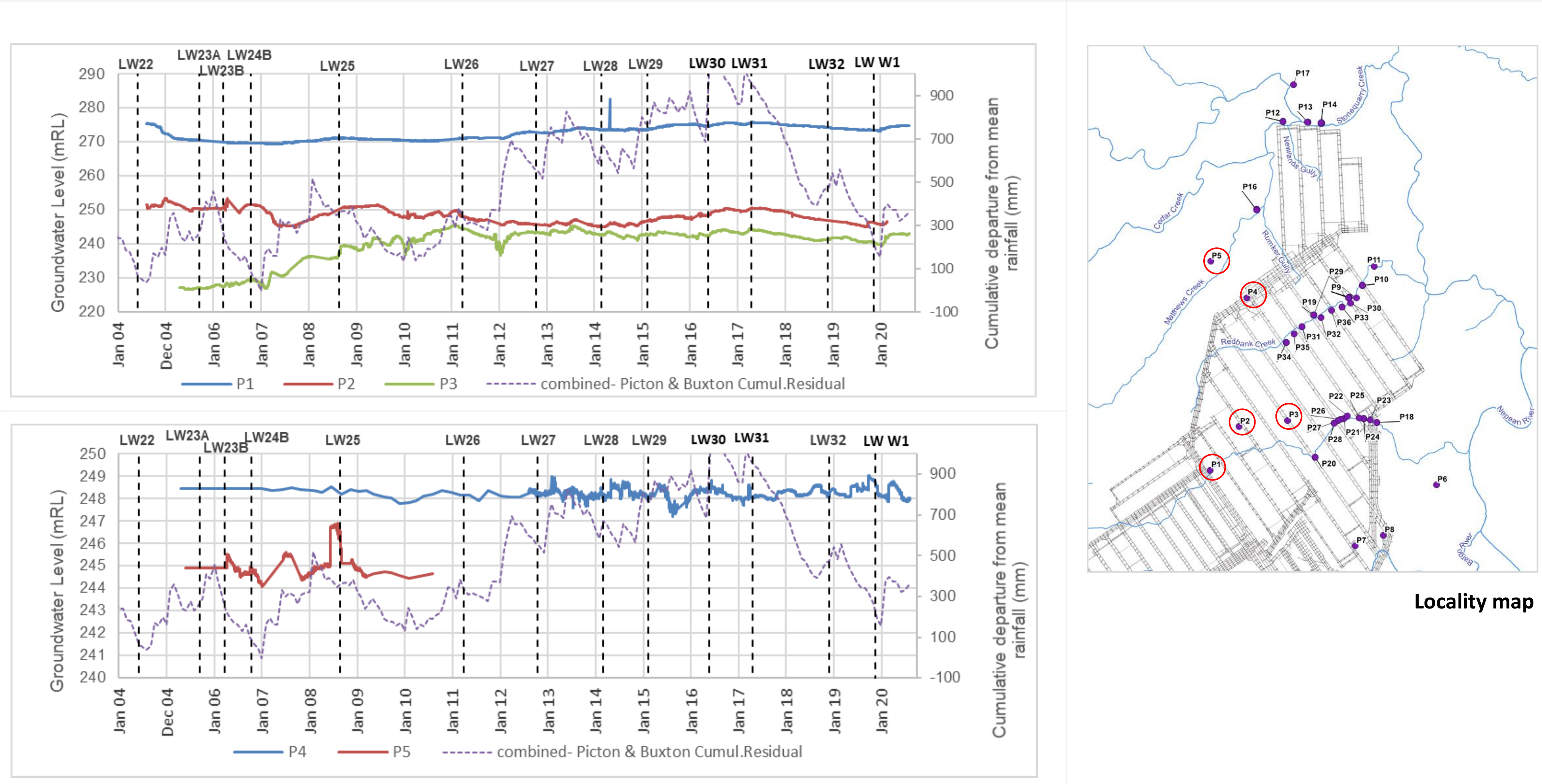


Figure 3-24 Water level trends – shallow aquifer (P1-P5)

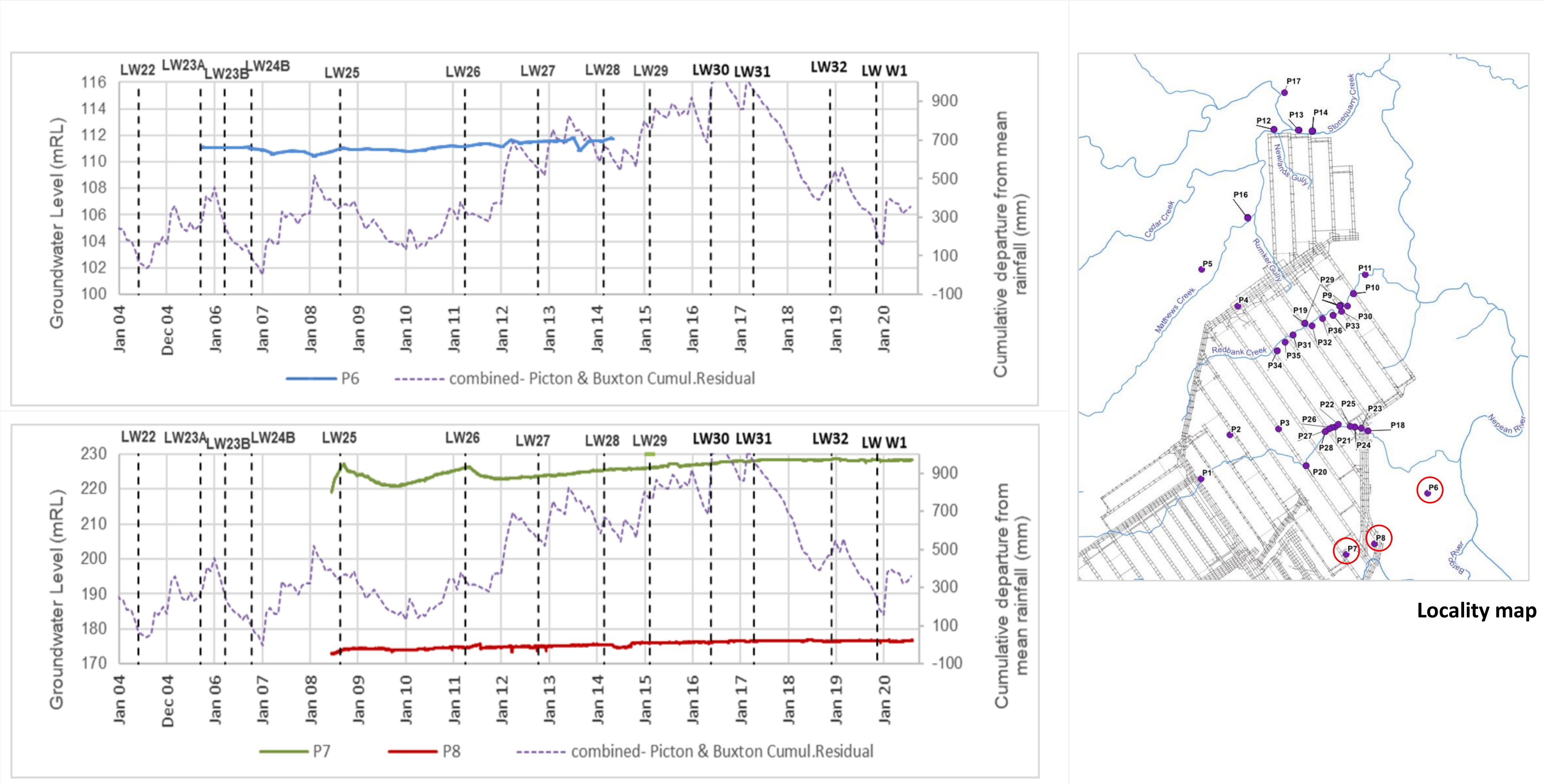


Figure 3-25 Water level trends – shallow aquifer (P6-P8)

3.5.5 Groundwater quality – baseline data

Based on the recommendations made in the previous extraction plan for LW W1-LW2 (HydroSimulations, 2019), Tahmoor Coal has been monitoring the groundwater quality at the Western Domain bores (P12-P14, P16, P17) since May 2019. The analysis of the baseline variability of the groundwater quality presented below for Western Domain bores will help to develop trigger values for EC, pH and specific metals discussed in **Section 6.**

Tahmoor Coal conducts full laboratory water quality analysis on a monthly basis at the groundwater monitoring bores and licensed bores presented in GeoTerra (2020a,i).The results for the following parameters are presented:

- TDS, DOC;
- Nutrients (Total N, Total P);
- Major Ions (Ca, Cl, K, Na, SO_4, HCO_3, F);
- Total Alkalinity, Bicarbonate Alkalinity, Carbonate Alkalinity, Hydroxide Alkalinity; and
- Total and dissolved metals (Fe, Mn, Cu, Pb, Zn, Ni, Al, As, Se, Li, Sr, Co).

A summary of the groundwater quality at the Western Domain bores (P12-P14, P16, P17) prior to mining with a brief comparison to the mining period is presented below.

Field water quality has been undertaken for EC and pH on a monthly basis since May 2019. **Appendix B** presents the baseline data (EC and pH) for the Western Domain bores, with the rainfall residual mass included for comparison to climatic trends.

Water quality measurements show that the Hawkesbury Sandstone across the Western Domain is generally fresh (minimum of 115 µS/cm) to slightly brackish (maximum of 1835 µS/cm) with a median EC estimated at 670 µS/cm. A median pH value of 7.1 indicates near neutral conditions, but pre-mining pH ranges from 201 µS/cm to 1716 µS/cm.

As shown in **Appendix B**, the trend in salinity (EC) is quite stable for most of the bores at the Western Domain with small fluctuations corresponding to variation in groundwater levels and rainfall events during both the baseline and mining periods. The largest fluctuation in groundwater salinity is seen at bore P16 in the two upper strata (P16A-B), with a reduction in EC from about1400 µS/cm to 700 µS/cm at P16A and from about 1000 µS/cm to 600 µS/cm at P16B. These effects are consistent with the 3-year drought preceding high rainfall in January-February 2020 resulting in recharge diluting the concentration of salts in the shallow groundwater.

At P17, a significant drop in EC occurs in August 2020 from 1800 µS/cm to 400 µS/cm with no apparent correlation to rainfalls or groundwater levels, suggesting either some erroneous data, a lag time of couple of months after the early 2020 rainfall to freshen the local shallow aquifer or possibly due to mining related impact with surface water recharging the shallow Hawkesbury Sandstone due to surface cracking. This latter process is very unlikely given the distance (700 m) from LW W1.

Table 3-6 shows the average EC and pH at P12-P14, P16 and P17 for the baseline period and during mining at LW W1. Bores have been grouped following their base screen elevation (mAHD) to compare different sections of the Hawkesbury Sandstone aquifer. Bores screened across the lower Hawkesbury Sandstone (P12C, P13C, P14D) seem to have, on average, a less saline groundwater from 534 (baseline) to 487 µS/cm (post-LW W1) and slightly more alkaline groundwater with a pH of 8.1 (baseline) to 7.5 (post-LW W1) than bores screened in the upper strata for both the baseline and mining periods. Although the bores screened in the upper Hawkesbury Sandstone are more saline (1152 µS/cm to 884 µS/cm), regionally, there is no apparent correlation between depth and EC or pH at the Western Domain bores.

Table 3-6 also indicates an overall reduction in the average salinity and pH between the baseline and mining period for each section of the HBSS aquifer which is likely due to severe drought conditions up to early January 2020 followed by above rainfall average conditions (with especially high rainfall in February 2020) leading to freshening groundwater conditions, rather than being due to some mining-related process.

In terms of water type, the upper Hawkesbury Sandstone aquifer at the Western Domain is strongly dominated by sodium and chloride ions. The dominant sodium type water in the upper Hawkesbury Sandstone is characteristic of shallow groundwater, due to interactions with atmospheric waters. There is an increase in calcium and magnesium in the middle part of the Hawkesbury Sandstone aquifer with slight increase in sulfate. The lower part of the strata is dominated by sulfate and calcium type water, characteristics of deeper aquifer with local increases in carbonate that could suggest some interactions with shallower groundwater.

Table 3-6 EC and pH based on screen bottom elevations at P12-P17 during the baseline and mining periods

Bore depth (mAHD)	Bore	Average EC (baseline)	Average EC (after LW W1 start)	Average pH (baseline)	Average pH (after LW W1 start)
Upper HBSS (178-200 mAHD)	P16A P16B	1153	884	7.2	6.7
Upper mid HBSS (156-178 mAHD)	P12A P14A P14B P17	835	694	6.7	6.3
Lower -mid HBSS (133-156 mAHD)	P12B P13A P13B P14C P16C	1089	774	7.5	7.3
Lower HBSS (111-133 mAHD)	P12C P13C P14D	534	487	8.1	7.5

* P15 not included here due to later completion (2021, rather than 2019)

Table 3-7 shows the average EC and pH in groundwater for different catchments across Tahmoor mine operations. The baseline groundwater quality conditions at the Western Domain indicate a fresher and more neutral groundwater condition than within the HBSS aquifer undermined along Myrtle Creek and Redbank Creek or across the regional aquifer across Tahmoor North (as monitored at P1-P8). The higher salinity and greater alkaline-acidic groundwaters are characteristics of areas located within subsidence fractured zones, which are conditions observed along Redbank Creek and presented in Morrison *et al*. (2019).

Table 3-7 Summary of groundwater quality across Tahmoor Mine Catchments

Area/Catchment	Average EC (µS/cm)	Average pH	Count of observation
Western Domain	739	7.1	191
Myrtle Creek	5432	6.4	105
Redbank Creek	3000	7.9	159
Tahmoor North	3681	5.9	608

Full water quality results for metals are presented in GeoTerra (2020a-h). From May 2019 to the start of mining at LW W1 (baseline period), the following bores have exceeded the ANZECC guidelines triggers for the following metals (GeoTerra, 2020i):

- Cu at P12A-C, P13A-B, P14B.
- Zn at P12A-C, P13A-C, P14A-D, P16A, P17.
- Filtered Mn at P16A and Total Mn at P16A-B, P14D.

Plots of the water quality parameters associated with the exceedances listed above are presented in **Appendix B**.

The ANZECC guidelines (2000) are considered conservative which make even natural groundwater conditions susceptible to apparent trigger exceedances without being impacted by mining, and local baseline data should be used in preference for trigger development if such data is available. Exceedances (compared to published guidelines) identified in the baseline period are likely due to natural fluctuations in groundwater chemistry, possibly associated with other anthropogenic effects such urbanised areas (i.e. surface run-off with high nutrients discharge) and agricultural activities (i.e. fertilizers).

The development of appropriate trigger values undertaken in **Section 6** will take local baseline variability into account and will better target mining related impacts for ongoing conditions and in the future at the Western Domain.

3.5.6 Historical groundwater inflows to Tahmoor North

For the period 2009 to present day, inflows to Tahmoor Mine have been within the range of 2 to 6 ML/d. **Figure 3-26** shows net groundwater inflows against daily water pumped from the mine, alongside the historic rainfall and longwall start dates. Inflows to the mine remained relatively steady throughout the extraction of Longwalls 24B to 32.

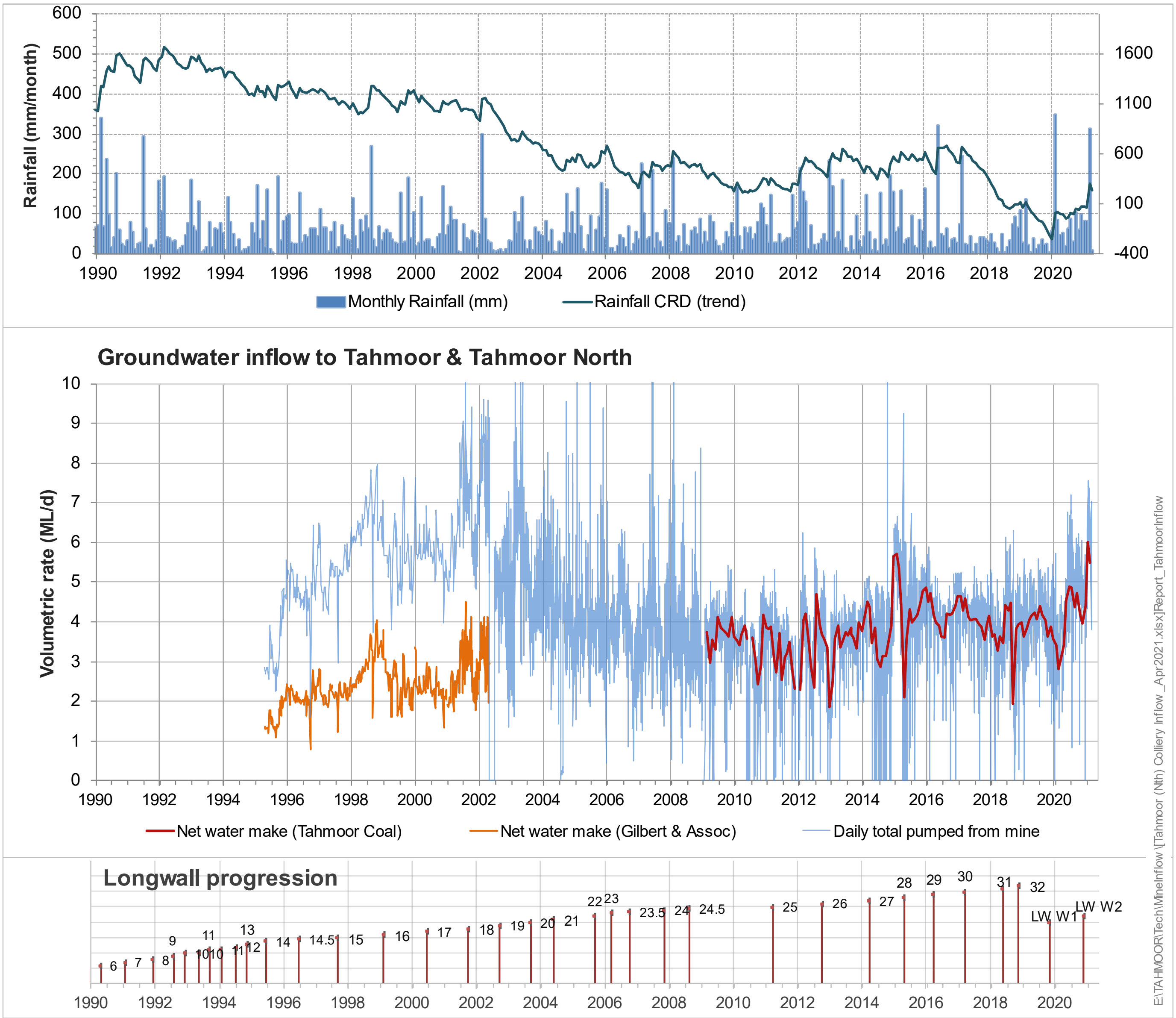


Figure 3-26 Historical record of inflows at Tahmoor North

A spike in inflows occurred following the cutting of Longwall 27, however, between this time and May 2020 inflow rates have declined. The period between mid-2020 shows an increase in inflows to greater than 5 ML/day at the end of July 2020 likely due to the extraction of LW W1. Inflows declined in late 2020, before rising in February 2021 (early in LW W2), with the recent peak at just over 6 ML/d in March and April 2021. Inflows to the Western Domain are not metered in isolation from other parts of Tahmoor North (they are metered along with all other pump-out) but are estimated to be greater than 2.5 ML/d in recent months (based on advice from Tahmoor Coal staff).

The increase in mine inflow in the Western Domain has been discussed with Tahmoor Coal staff and consultants. Other than the minor fault observed in the southern 'half' of LW W1 and LW2, no other obvious geological structures have been noted as intersecting current longwalls, and the faults on the northeastern edge of LW W3 will be mapped and characterised further with respect to potential groundwater inflow. Tahmoor Coal continues to monitor to determine changes in mine inflows and identify where in the workings higher inflows can be observed.

The average inflow to the mine for current water year (July-2020 to date) is 4.9 ML/d, was 4.0 ML/d for the previous water year (July 2019 to June 2020), and was 3.7ML/d for the water year 2018-19.

3.5.7 Investigation into Fracturing above Longwalls

3.5.7.1 Centre-line goaf bores

Following recommendations from HydroSimulations (2019) and guidance by IEPMC (2018, 2019a), Tahmoor Coal commissioned SCT to carry out investigative drilling and analysis of two boreholes across the Western Domain. The objective is to gain an understanding of the caving and fracturing properties above the goaf as well as the potential interactions between mining and the groundwater (SCT, 2020c). The locations of the pre-mining and proposed post-mining borehole are shown on **Figure 3-12**.

The pre-mining borehole (WD01) is located above a chain pillar between the Western Domain LW W1-W2, 570 m from the closest Tahmoor North goaf and was completed while LW W1 was 400 m away (**Figure 3-12**). SCT (2020c) conducted characterisation of the baseline conditions for both in situ ground conditions and groundwater pressure prior to LW W1-W2 extraction (SCT, 2020c). The characterisations concluded to a decreasing permeability with increasing depth, consistent with in situ ground conditions unaffected by mining and a reduction in permeability in the Newport, Garie and Bald Hill Claystone formations.

The post-mining borehole (WD02) is to be located above the centre-line of the Western Domain LW W2, 780 m from the closest Tahmoor North goaf (**Figure 3-12**). The centre line of LW W2 is representative of the height of depressurisation for the panel, and will provide estimates for depressurisation, fracturing and hydraulic conductivity properties (SCT, 2020c). The measured groundwater depressurisation in the subsurface will be assessed and verified in future model predictions.

3.5.7.2 Surface cracking investigations bores

Near-surface fracturing or "surface cracking" can occur due to horizontal tension at the edges of a subsidence trough. The depth of cracking from the surface will typically be less than 20 m; McNally and Evans (2007) stated this is usually but not always transitory. Water loss from surface features (e.g. watercourses, wetlands) into the cracks is unlikely to continue downwards towards the goaf and most will return to surface somewhere down-gradient. This has occurred in earlier mining at Tahmoor, e.g. along the Bargo River and Redbank Creek. The likelihood of future occurrences of surface cracking and upsidence above or adjacent to LW W3-W4 are discussed in the assessment by MSEC (2021), including deformation above and off-set from the longwall footprint.

Leakage of surface water into the surface cracking zone can result in the water quality of any re-emergent water being inferior to that of surface flow in an undisturbed environment (McNally and Evans, 2007). Effects of mining-induced subsidence have occurred at Tahmoor Mine, e.g. along Redbank (GeoTerra, 2019) and Myrtle Creeks.

An assessment conducted by Morrison *et al.* (2019) found that the quality of surface waters in areas directly above extracted longwall panels 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 many cases, metals concentrations decline downstream of the undermined sections, e.g. iron (Fe), nickel (Ni), cobalt (Co), but others remain at elevated levels, e.g. manganese (Mn), barium (Ba), strontium (Sr), noting that the sampling was conducted in dry conditions with minimal runoff present. The decline in some metals is attributed to oxidation and precipitation.

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. HEC (2021) will document expected effects on surface water quality, however it is noted that LW W3 and W4 do not directly undermine watercourses other than minor tributaries of Redbank Creek, so the effects described in Morrison *et al.* (2019) are not expected to be repeated as a result of LW W3 and W4.

Subsidence effects, such as cracking, along watercourses are mapped and documented in the monthly report conducted by GeoTerra and assessed in the monthly surface water report conducted by HEC (e.g. GeoTerra 2020j and HEC 2020b).

Recent investigations along Redbank Creek and Myrtle Creek have been carried out in boreholes to characterise the near surface-strata adjacent to the creeks impacted by the subsidence associated with longwall mining. These investigations involved the observations of borehole conditions and water flows, measurements of borehole diameter to identify voids and open fractures, and lugeon packer tests to measure hydraulic conductivity (SCT, 2020b).

These investigations along Redbank Creek concluded that the presence of open fractures in all boreholes coincided with intervals of increased hydraulic conductivities. Groundwater flow was observed out of these fractures in some bores (e.g. P10 and P19). However, no correlation or patterns were established between fracturing and depth below the creek bed at these targeted areas. Comparable findings were reported by SCT (2020a) along Myrtle Creek, with groundwater flows observed out of open fractures at P18, P21, P23 and P25 but no clear correlation between the zones of increased hydraulic conductivities and the depth below the creek bed was established.

3.5.8 Mining effects on groundwater-surface water interaction

Appendix G presents an analysis of groundwater-surface water interaction at creeks around the Western Domain, specifically Matthews, Cedar and Stonequarry Creeks which flow along the western and northern edges of LW W1, W2 and W3. The detail of that analysis is not repeated here, but the key finding is summarised below.

The analysis suggests that groundwater drawdown and depressurisation as a result of LW W1 extraction as observed at monitoring sites such as P16, P12 and P13 (**Sections 3.5.4** and **0**) has caused a reduction in baseflow or even a change from gaining to losing conditions in sections of these creeks. This, possibly combined with subsurface fracturing (to date, SLR are not aware of any cracking that been observed at surface in these creeks), has led to pool water levels declining to below baseline or below cease-to-flow levels during drier periods in late 2020 and early 2021, and this effect has been clearest at Cedar Creek monitoring site CB (see **Appendix G,** Figure G13).

Given the similarity in proximity between LW W1 and both Matthews and Cedar Creek, and the proximity between LW W3 and Stonequarry Creek (Section 3.3 and Table 3-1), empirically there is a likelihood that groundwater drawdown leading to baseflow reductions could influence pool levels on Stonequarry Creek. With the extraction of LW W3 (and, to a lesser degree, LW W4) it is likely that depressurisation around monitoring sites P14 and P15 will occur, as seen at P12 and P16, and that losing conditions will increasingly prevail at surface water monitoring sites such as monitoring site SB and sites further downstream. This occurrence may disconnect Stonequarry Creek from the groundwater system, thereby increasing the frequency of creek/pool water level decline and low flow conditions along the nearby reach of Stonequarry Creek. Further details are provided in HEC (2021b).

Surface water losses

Appendix G presented an analysis of potential surface water losses that would lead to the recent cease-to-flow occurrences observed at the creek monitoring sites along Matthews, Cedar and Stonequarry Creeks. This was done by comparing the surface water flow at the downstream flow gauge (GS212053, at Picton), and scaling that by the catchment area to the various surface water monitoring sites. There are limitations with the method, but in the absence of other analysis, provides a reasonable method for estimating surface water losses.

A 'best' estimate of the loss of surface water flow being 0.06 ML/d along Matthews Creek, and average of 0.12 ML/d (at monitoring site CB) on Cedar Creek. Over shorter periods, the loss of surface water is inferred to be variable, i.e. higher (up to 0.32 ML/d at monitoring site CB) or lower (0.04 ML/d at monitoring site CB) than these average estimates over short periods (days to weeks), but an average is reported here to inform licensing decisions, and in that regard, the 0.12 ML/d (44 ML/yr) at monitoring CB on Cedar Creek is relevant, even though it is not apparent that losses are 'consumptive', in that these losses are very likely to be localised, and much of this flow is inferred to return to Cedar Creek downstream of monitoring site CB (or other sites were losses are possible, such as CC) or to Stonequarry Creek.

Losses of this magnitude are inferred to cause an increase in the frequency of duration of pool levels declining to below the CTF and even drying out. Pre-mining, such declines were estimated to occur approximately between 3% and 5% of the time (based on the long flow record from Stonequarry Creek at Picton (GS 212053)), and would increase by between 7% and 14% of the time, which means that low-flow or pool recession events are likely to occur about 10-17% of the time, but this could be up to a maximum of 25%[3] of the time at some sites along Cedar Creek.

3.5.9 Potential role of structure

In terms of groundwater or hydrological effects, the key properties of the Nepean Fault Complex (NFC) are listed below, and addressed in the following text:

- Current condition with respect to longitudinal transmissivity;
- Current condition with respect to transverse transmissivity;
- Potential for fault reactivation and possible changes to hydraulic conductivity.

Longitudinal and vertical connection between the goaf of LW W4 and Stonequarry Creek is considered the primary risk pathway in terms of surface water features. Permeability within the fault zone in the vicinity of LW W4 would govern the longitudinal movement of groundwater along the fault and associated damage zone, but this has not been quantified. Given the proximity of the panel to the mapped fault splay (Figure 3-5), this is recommended (Section 7).

[3] multiple low-flow events at monitoring site CB were recorded contemporaneous with Q92-Q88 flows at GS212053, but one short-term low-flow or flow recession event at monitoring site CB was recorded contemporaneous with a Q75 flow at GS212053, from which it might be inferred that such events could occur up to 25% of the time.

In general terms, transmissivity across the fault plane (i.e. transverse connectivity) is governed by stratigraphic units that are adjacent across the fault plane (**Figure 3-27**), including any juxtaposition of these due to fault offsets, as well as the presence and properties of any fault gouge within the core of the fault.

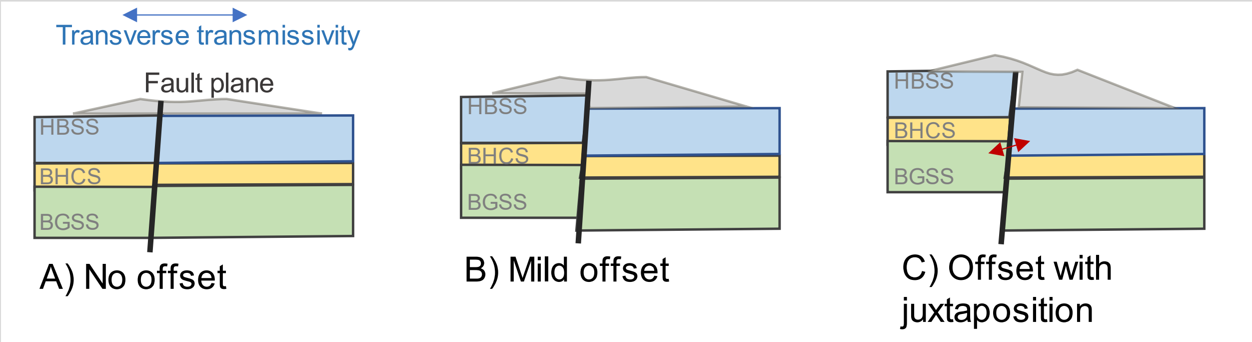


Figure 3-27 Conceptual models of transverse transmissivity and offset strata

For the main splays in the NFC, the throw of 30-40 m is sufficient to cause a 'window' through the Bald Hill Claystone, which is approximately 10 m thick based on the log from bore WD01 (SCT, 2020c). Based on available mapping (SCT, 2020b), the major splays are 1000 m from LW W4. The offset across the fault splay mapped nearest to LW W4 (20-240 m to the east, Section 3.4.2) is unknown but being investigated (**Section 7**), so in the area above or adjacent to LW W4 the potential for juxtaposition between the deeper BGSS and shallower HBSS to the east of the splay, as in Case C on **Figure 3-27**, is uncertain. Tahmoor Coal are in the process of investigating this via drilling, including angled holes, from surface near the northeastern corner of LW W4.

Furthermore, Fossen (2016) correlated fault displacement with the width of the damage zone associated with the fault. Review of Fossen's work suggests that the width of the damage zone is likely to be 1/10th of displacement up to 5-10 times displacement. Based on this, there is potential for the north-eastern part of LW W4 to lie within a damage zone, where jointing and fracturing would be more likely to cause a higher hydraulic conductivity. Tahmoor Coal anticipates work to characterise the inferred fault splay to commence in May 2021. This will begin with the drilling of an angled borehole and with logging results to be assessed regarding the need for further investigation or monitoring (Section 7).

A report by SCT (2021) assessed the potential effects of the fault complex on subsidence above and adjacent to W3 and W4. SCT (2021) concluded that the presence of the Nepean Fault Complex could cause an increase in subsidence above longwalls W3 and W4, especially so for W4 given its proximity. SCT also concluded that "*in the unlikely event that greater than predicted subsidence occurs over Longwalls W3 and W4, there is no expectation of significantly greater than predicted subsidence outside the panel footprint*" and that mobilisation of fault structures due to longwall subsidence is not likely.

4 Predicted Subsidence Impacts and Groundwater Impact Assessment

The potential impacts to groundwater due to longwall mining 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 W3-W4. The following sections briefly summarise the groundwater model and recent model updates, and then document the predicted effects on the groundwater system.

4.1 Groundwater Model Design

An existing numerical groundwater model, as described in HydroSimulations (2019), was utilised to assess impacts due to LW W3-W4. A summary of the model design is included in **Section 4.1.1** below and full details are provided in the HydroSimulations (2019) report.

For the purpose of the LW W3-W4 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 W3-W4 (refer to **Attachment 2**);
- update the model stress period timing with the inclusion of a new stress period during the calibration period covering January 2020 and February 2020, to fully capture high rainfall recharge in the simulation;
- compare modelled hydraulic conductivities against recent packer testing at Western Domain bore WD01 to assess appropriateness;
- update to surface cracking in the MODFLOW-USG Time-Varying Material Properties (TVM) package to reflect the results of the recent surface cracking investigations conducted along Redbank and Myrtle Creek;
- update to height of the fracture zone in TVM package to follow the latest mine plan for the Western Domain longwalls (i.e. timing, cutting height);
- update to RIV package to include recent observations data and update transient stages at fifteen watercourses and at the Thirlmere Lakes; and
- update to the calibration data set with recent groundwater observation data.

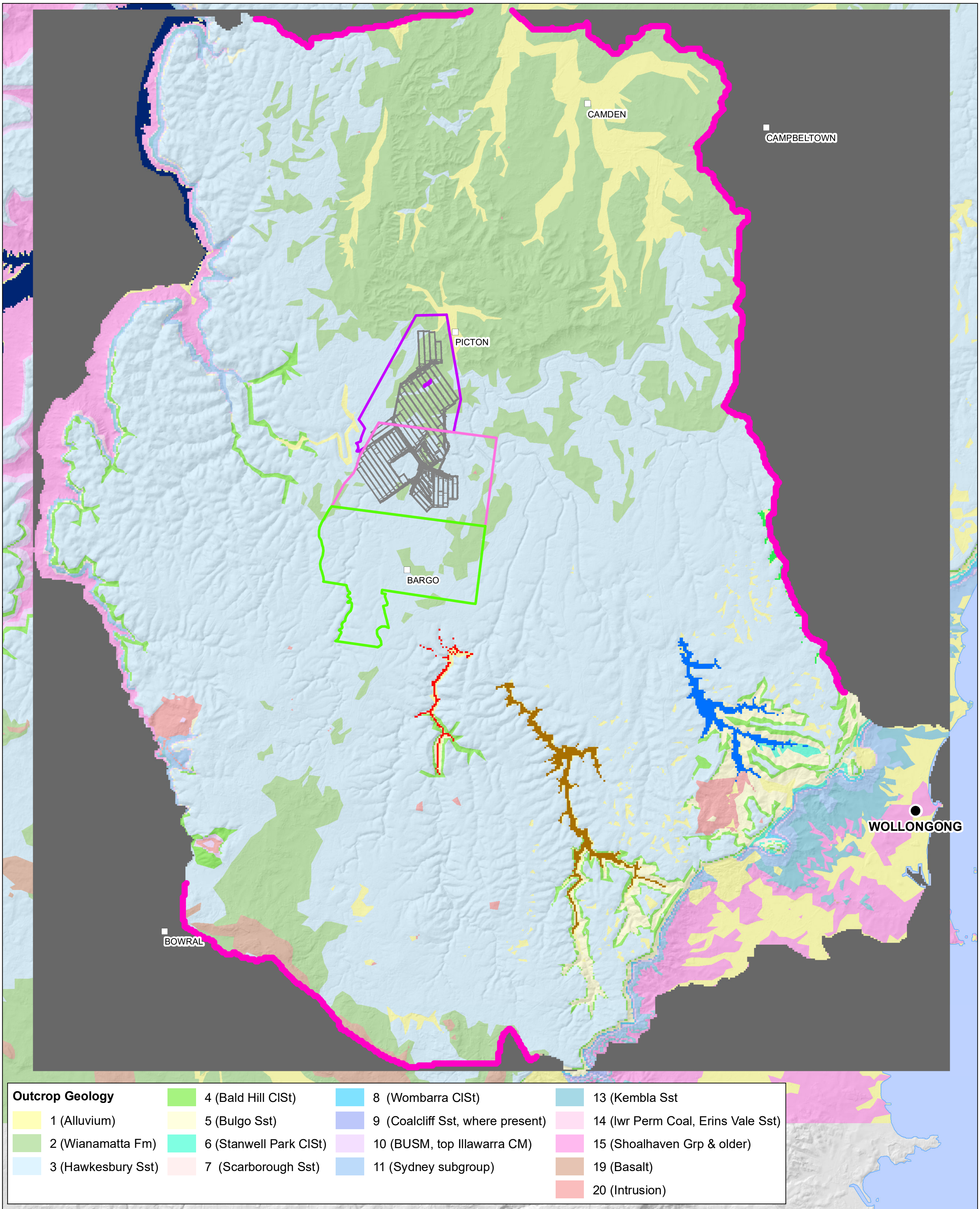
Discussion on each of the updates is included in **Section 4.1.2** to **Section 4.1.5** below.

4.1.1 Previous Groundwater Model (SLR/HydroSimulations, 2020)

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 Amended Project EIS (SLR/HydroSimulations, 2020). The Tahmoor South Project is a planned extension of existing underground coal mining at Tahmoor Mine that was submitted under SSD 17_8445 and was approved in April 2021. A groundwater assessment was conducted by SLR/HydroSimulations (2019) to assess potential groundwater related impacts for the Amended Tahmoor South Project as well as for the subsequent Second Amendment (SLR/HydroSimulations, 2020). As part of those assessments a numerical groundwater model was developed, which captured surrounding operations, including LW W1-W2 and LW W3-W4.

The numerical groundwater model was first developed by HydroSimulations in 2013 using the MODFLOW-SURFACT code, then updated by HydroSimulations (2018) using the MODFLOW-USG code and was further revised by SLR/HydroSimulations (2020) to account for the key amendments presented in SLR/HydroSimulations (2020). 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 Group 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.

As part of the EIS process for the Tahmoor South Project, the groundwater assessment (including data analysis, conceptualisation and modelling) was peer reviewed by Prathapar and Associates (2019) and reviewed for DPIE by HydroGeoLogic (2020).



Coordinate System: GDA 1994 MGA Zone 56
Scale: 1:290,000 at A4
Project Number: 665.10010
Date: 07-Dec-2020
Drawn by: JG

SLR

MODFLOW General Head Boundary
Major Town
Minor Town
Tahmoor North and Western Domain

Tahmoor Coal Titles
MLs 1308, 1376, 1539
CCL 716
CCL 747

MODFLOW IBOUND
0 (inactive area)

MODFLOW River
110mAHD (Burragorang)
284mAHD (Cataract)
298mAHD (Cordeaux)
308mAHD (Nepean)
312mAHD (Avon)

TAHMOOR COAL LONGWALL W3 AND W4 EXTRACTION MANAGEMENT

Groundwater Model Domain and Boundary Conditions

FIGURE 4-1

H:\Projects-SLR\620-BNE\665-WOL\665.TAH05 Tahmoor GWM\PIGIS\66510010 Fig4_1 Groundwater model domain and boundary conditions.mxd

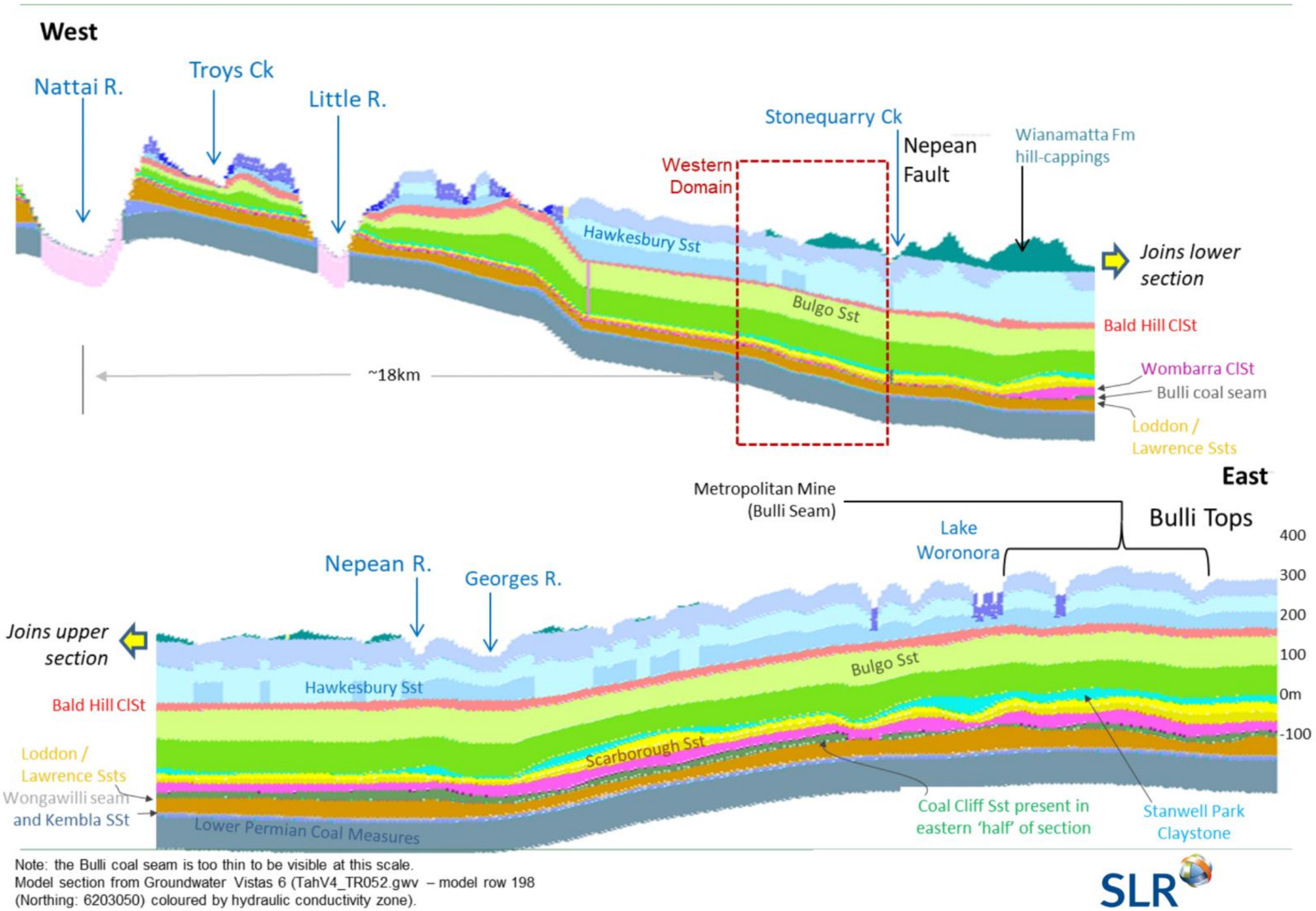


Figure 4-2 Representative Model Cross-section

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 for fifteen watercourses in the vicinity of Tahmoor Mine were assigned a transient stages (**Section 4.1.5**). Thirlmere Lakes were represented in the model using the RIV package with transient lake stages to capture variation of lake level. 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.

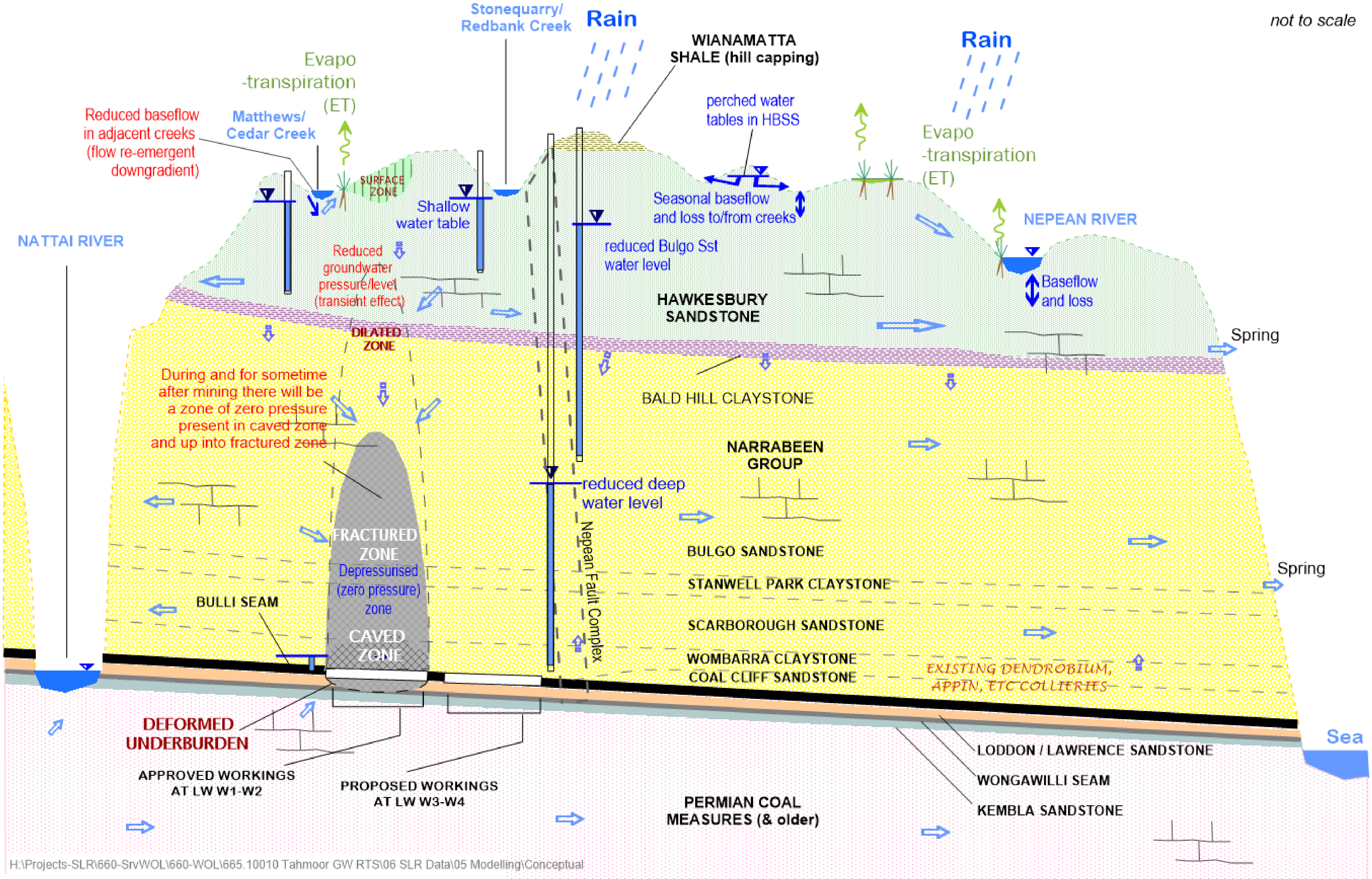


Figure 4-3 Conceptual Model of Pre-Mining (LW W3-W4) Groundwater System

SLR

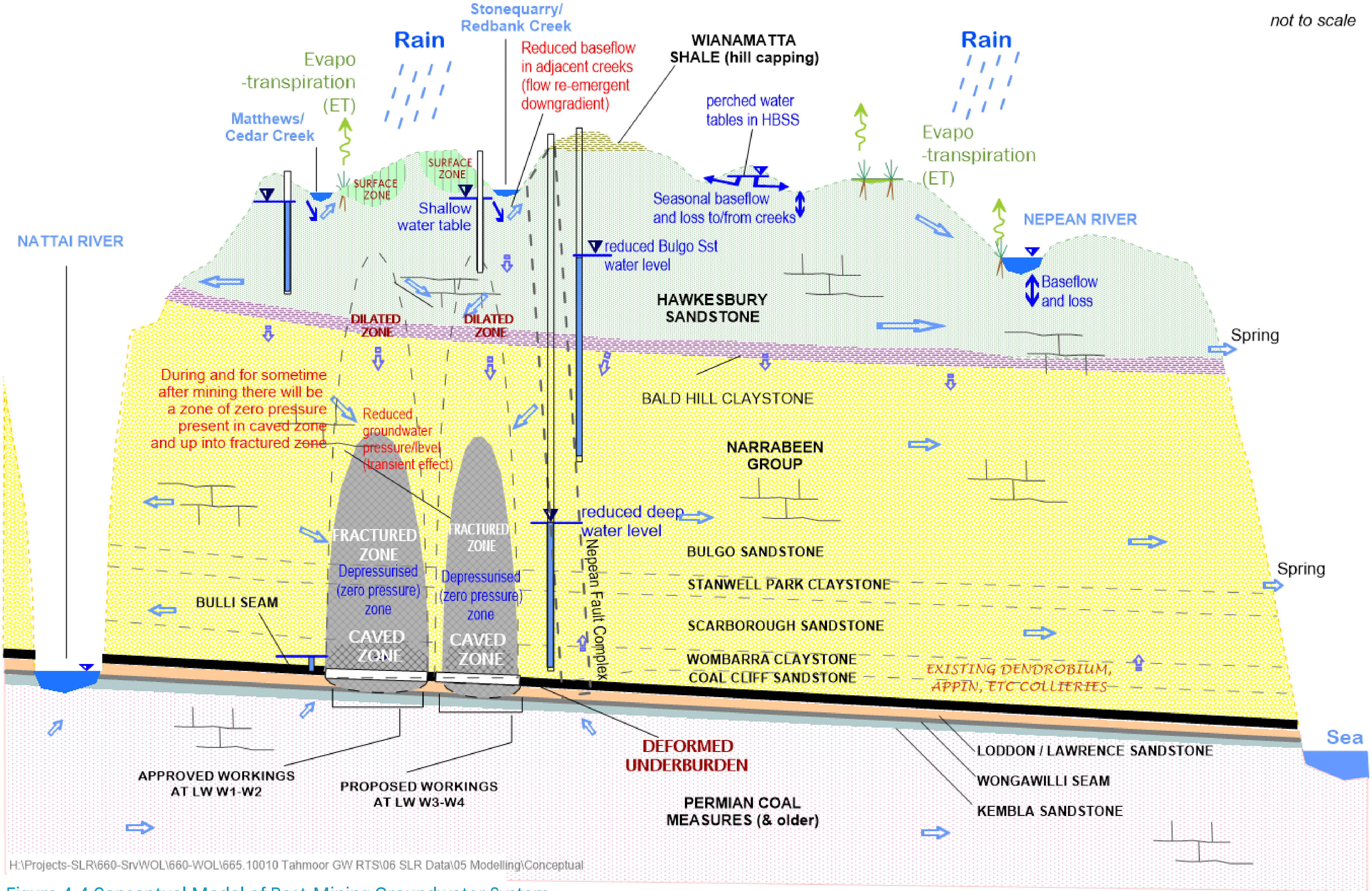


Figure 4-4 Conceptual Model of Post-Mining Groundwater System

Mining is represented in the model using the DRN and TVM packages, and the model simulates mining at, 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 to ensure the model simulates dewatering of these workings. 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 connected fracturing' was calculated on a cell-by-cell basis using the method of Tammetta (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 and 2019a). 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, alongside a schematic of the numerical model representation of that conceptual model in **Figure 4-5 (B)**. 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 SLR/HydroSimulations (2020), 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 connected fracturing was simulated through to the Bulgo Sandstone (model layers 5 and 6) over the Western Domain longwall panels (**Figure 4-7**).

The SLR/HydroSimulations (2020) groundwater model was utilised for the LW W3-W4 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 **Section 4.1.2**and **4.1.5**. Predictions for the Study area are described in **Section 4.3**.

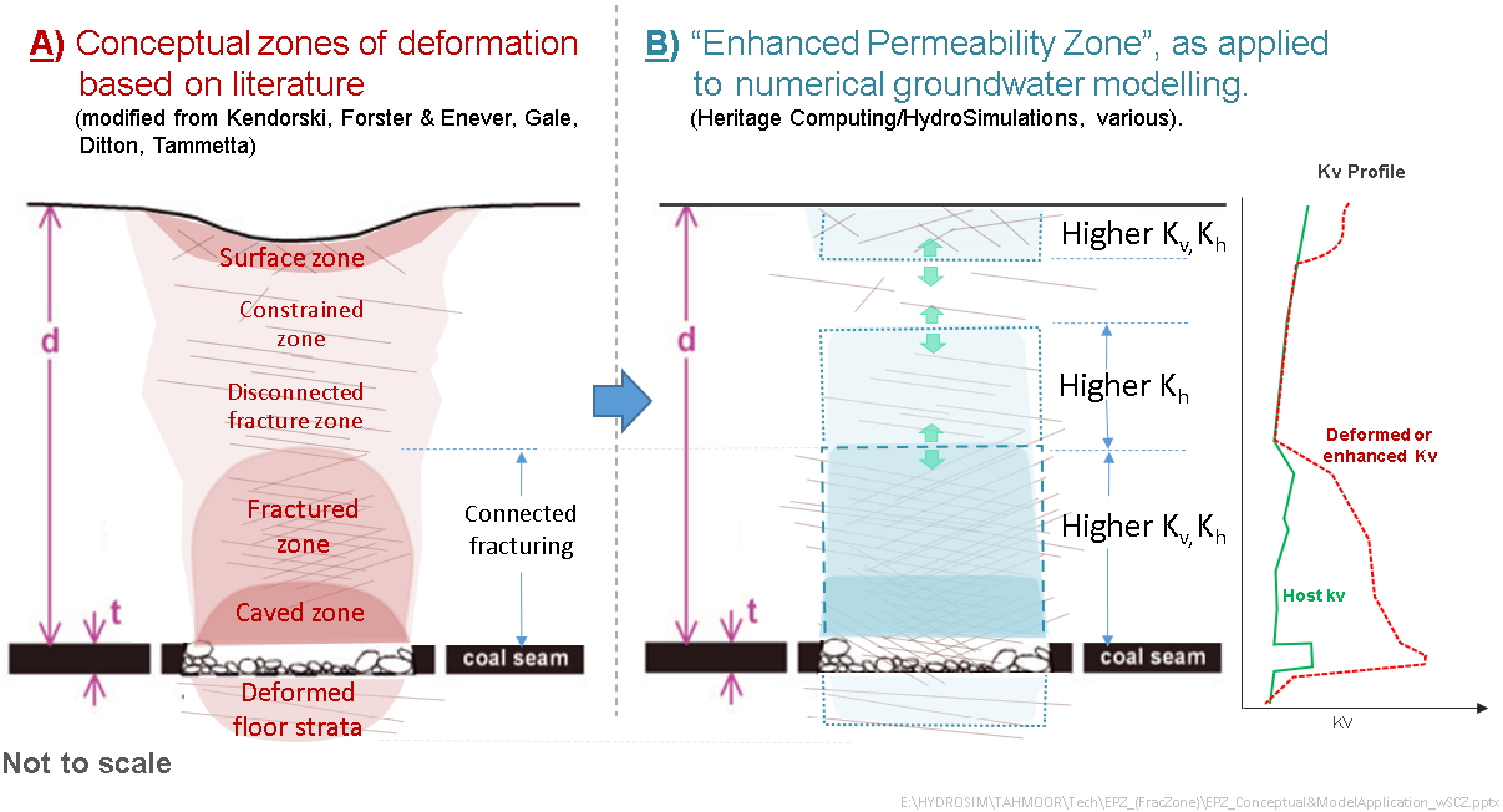


Figure 4-5 Application of enhanced permeability within the groundwater model

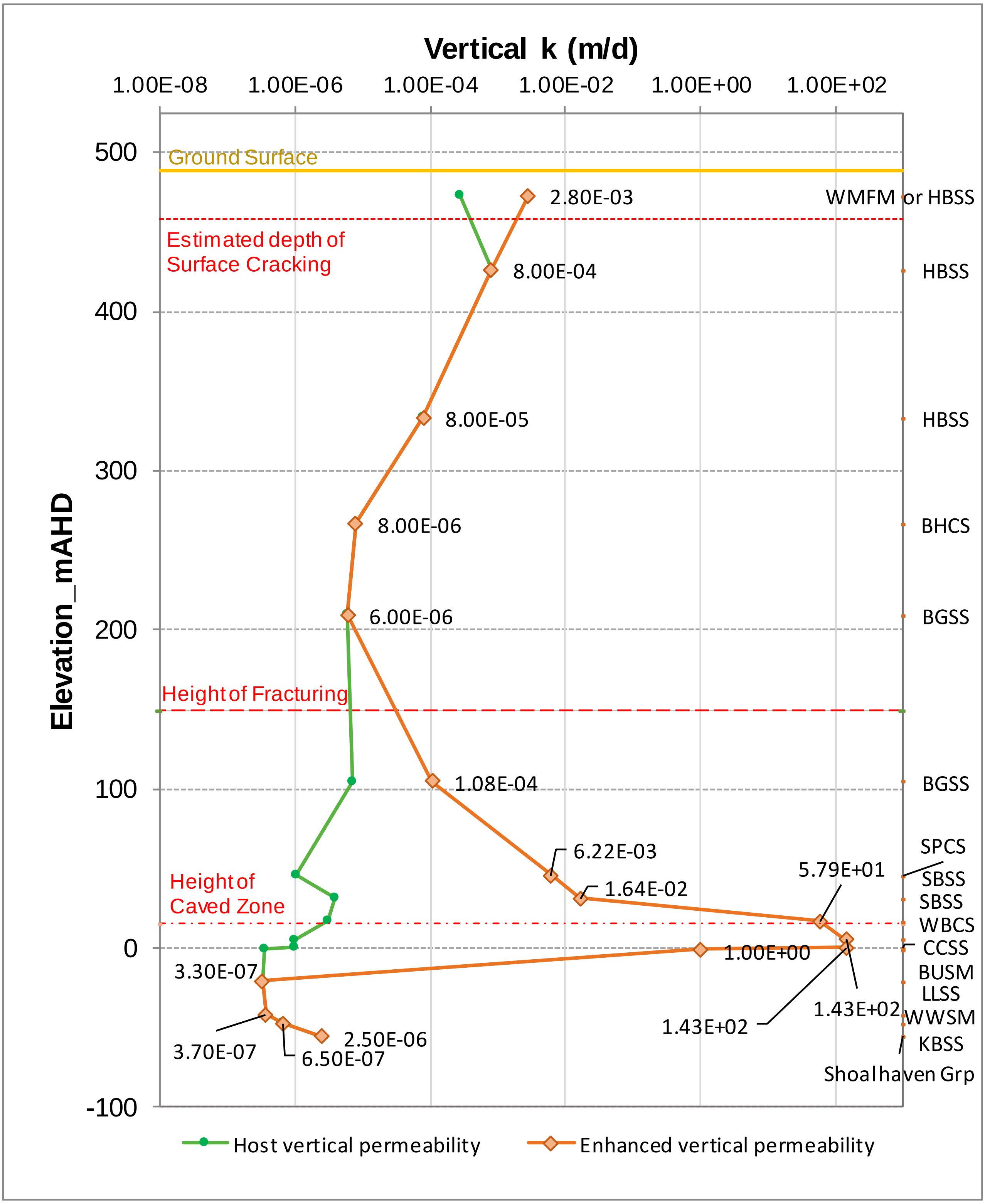
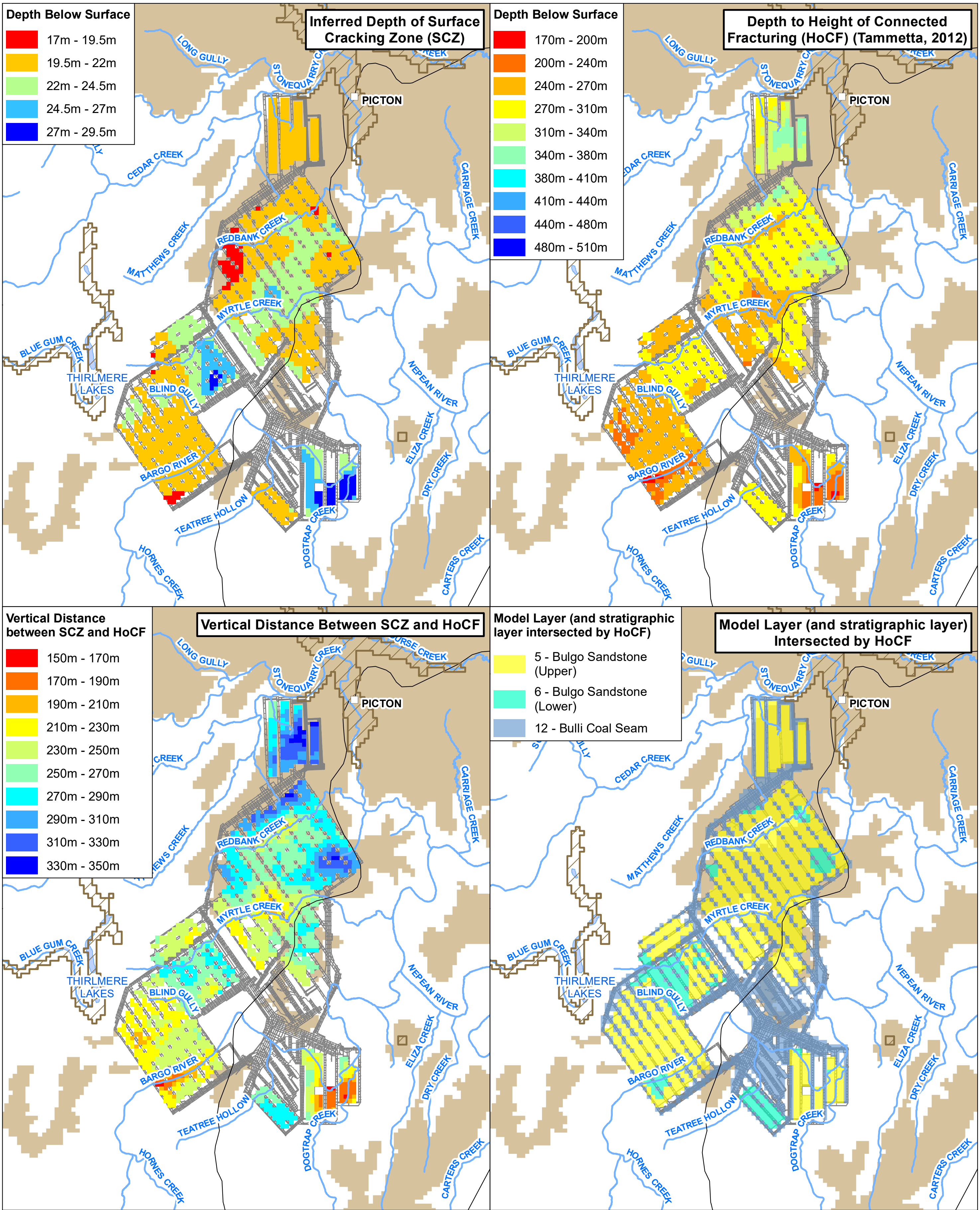


Figure 4-6 Vertical profile illustrating modelled permeability (Kv) above longwalls



N

0 0.5 1 km

Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:120,000 at A4
Project Number:	665.10010
Date:	22-Oct-2020
Drawn by:	JG

- Minor Town
- Mine Layout
- Roads
- Watercourses
- Lakes
- Alluvium
- Wianamatta Formation

SLR

TAHMOOR COAL LONGWALL W3 AND W4 EXTRACTION MANAGEMENT

Spatial Variation in Inferred Surface Cracking Zone and Height of Connected Fracturing

FIGURE 4-7

H:\Projects-SLR\620-BNE\665-WOL\665.TAH05 Tahmoor GWMP\GIS\66510010 Fig4_7 Spatial variation in inferred surface craking zone.mxd

4.1.2 Model Scenarios

Three 'resource development' scenarios were simulated to assess the influence the extraction of LW W3-W4 could have on the regional groundwater system. **Table 4-1** summarises each of these runs. Model scenario A simulates groundwater response to the proposed extraction of LW W3-W4 along with all other historical and approved longwalls at Tahmoor, while scenario B presents the results for groundwater behaviour without the extraction of LW W3-W4 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 W3-W4 on the groundwater system in this region. Model scenario C represents a "null scenario" simulating no mining within the model domain including other mined areas such as Appin and BSO. Comparisons of scenario A to Scenario C allows cumulative impacts to be assessed.

Table 4-1 Groundwater model development scenarios

Development Scenario	Run Name	Model run	Historical Tahmoor Longwalls	LW W3-W4 included?
A	Full	TR104A	Yes (including W1 and W2)	Yes
B	Base case	TR104B	Yes (including W1 and W2)	Not simulated
C	Null	TR104C	Not simulated (and no neighbouring mines)	Not simulated
Model configuration TR104 is considered the 'base case' model for which calibration is reported (Section 4.2).				

4.1.3 Surface Cracking

To provide a more accurate representation of subsidence-induced impacts to the groundwater and surface water systems, changes in hydraulic properties that occur in areas where surface cracking occurs or is likely to occur were simulated. 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 recent data and findings of SCT (2018b, 2020a and 2020b). Evidence from borehole P11 (SCT, 2020b) suggests that surface cracking does not occur at distances outside the panel footprint, so for the numerical model, surface cracking parameters were only calculated in model cells 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 and 2020b).

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 the Western Domain longwalls including LW W3-W4 and the main Tahmoor Mine area is presented on **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 W3-W4 falling between 19.5 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 W3-W4 is approximately 300 m (270 to 350 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 W3-W4.

4.1.4 Basal shears

SCT (2021) stated that there is no evidence for significant unconventional subsidence effects at Tahmoor, and as such these effects, which include movement along basal shears, are not simulated at this site. However, SCT (2021) made the point that low level effects are possible, especially to the east of Longwall W4 near to the Nepean Fault Complex. Additional, based on proximity to the watercourse (**Section 3.3**), such shear planes would likely be more of a risk of acting as a conduit for groundwater flow between LW W3 and the reach of Stonequarry Creek to the north of that panel.

4.1.5 RIV Package

The RIV package from (SLR/HydroSimulations, 2020) groundwater model was used to capture the seasonal flow variations. The transient stages for the fifteen watercourses within Tahmoor and transient stages at the Thirlmere Lakes were updated with recent measurements following the same procedure as in the APR Tahmoor South Project (SLR/HydroSimulations, 2020) study. (**Table 4-2**).

Table 4-2 Watercourses simulated with transient stage

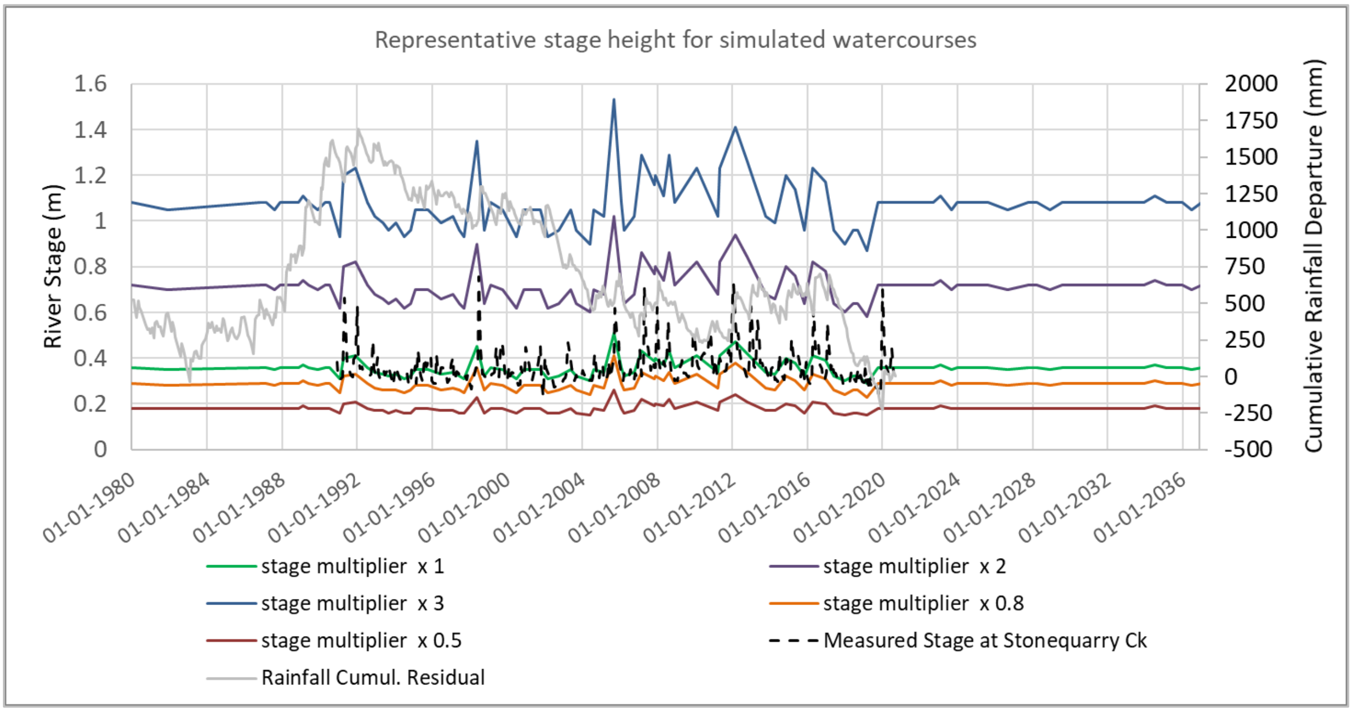
Watercourse Name	Model Reach Number	Multiplier	Median Simulated Stage Height (m)
Stonequarry Creek	29	1*	0.36
Nepean River	25	3	
Bargo River	26	2	
Avon River	27	2	
Cordeaux River	28	2	
Cedar Creek	30	4.5	1.62
Redbank Creek	31	2.1	0.76
Matthews Creek	32	3.9	1.4
Eliza Creek	36	0.8	
Dogtrap Creek	37	0.8	
Cow Creek	38	0.8	
Hornes Creek	39	0.8	
Tea Tree Hollow	40	0.8	
Carters Creek	41	0.8	
Dry Creek	42	0.8	

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 September 2020, whereas the data received from Tahmoor Coal 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 estimate an appropriate multiplier for each watercourse compared to the Stonequarry Creek data. These multipliers have been selected according to the size (catchment area) of watercourses compared to Stonequarry Creek. 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 the Western Domain longwalls. The relevant multiplier and median simulated stage heights for each watercourse is provided in **Table 4-2**. **Figure 4-8A** presents the representative stage heights for these watercourses based on the method outlined above.



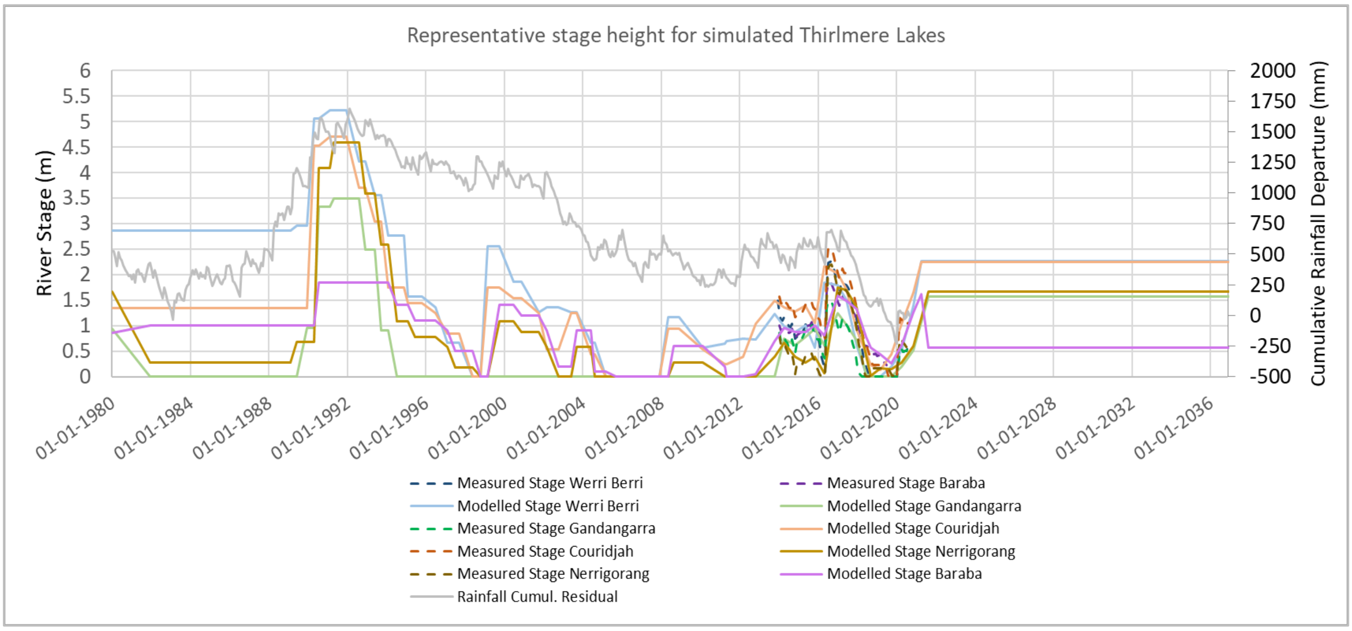


Figure 4-8 Modelled river stages applied to A) watercourses and B) Thirlmere Lakes

Transient lake stages at Thirlmere Lakes were estimated using various data sets as in the previous study (SLR/HydroSimulations, 2020).

The short record of the gauging stations (212063, 212064, 212065, 212066, 212067, 212028) around the Thirlmere Lakes were used to build the transient lake stages at Couridjah and Werri Berri lakes (period 1990 to 2011). Data from Pells and Pells (2016) and Schadler and Kingsford (2016) were also used to complete the gaps lake level records for Couridjah and Werri Berri lakes (**Figure 4-8B**).

Lake stages were set at constant levels for the predictive period. The estimated 'median levels' were set as follows: Gandangarra (303.03 mAHD), Werri Berri (302.0 mAHD), Couridjah (302.5 mAHD), Baraba (304.5 mAHD), and Nerrigorang (301 mAHD) (**Figure 4-8**). The same bed conductance applied in the SLR/Hydrosimulations (2020) model was used for this study.

4.2 Model Performance

The calibration data set for the Tahmoor Model (HydroSimulations/SLR, 2020) was updated with new groundwater level data for the Tahmoor North VWPs as well as the local shallow piezometers (P1-P8; P9 and P10-P11), NSW government monitoring bores (i.e. at Thirlmere Lakes) and Appin Mine bore (i.e. EAW7). The new groundwater level data for the bores drilled along the Redbank Creek and Myrtle Creek at Tahmoor Mine were added to the calibration datasets. Finally, the recent groundwater level observations recorded at Western Domain bores (P12-P17) were included. The updated data set included water levels until September 2020. Model performance was assessed against a range of data and these results are summarised and discussed below.

4.2.1 Hydraulic conductivity

Modelled Kv and Kh were compared against observed data collected via core testing for Kv and packer testing for Kh (Section 3.5.2), and show that permeability is well-constrained by the range of field data (**Figure 4-10**).

Bore WD01 was recently drilled and packer tested (SCT, 2020c) for Tahmoor Coal. Noting that there can be no expectation of a perfect match to field data, which are expected to vary, the packer testing profile has been used to verify model parameters, as shown on **Figure 4-9**. This indicates that the modelled Kh for the WNFM, upper HBSS, BHCS and BGSS are representative of the packer test data. The lower HBSS is simulated with a higher Kh than the bulk of the packer test results between 100-230 m.

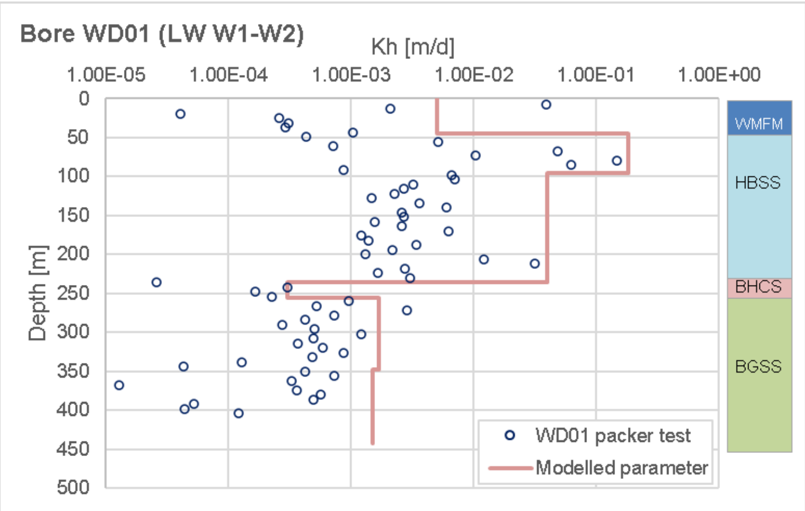


Figure 4-9 Comparison of Western Domain WD01 packer test results and modelled Kh

Given the high Kh encountered in the HBSS at bores P13 and P14 (Section 3.5.2), but not at other sites, a zone of high Kh (Kh = 1 m/d) was included in the model for the area covering and between these two sites.

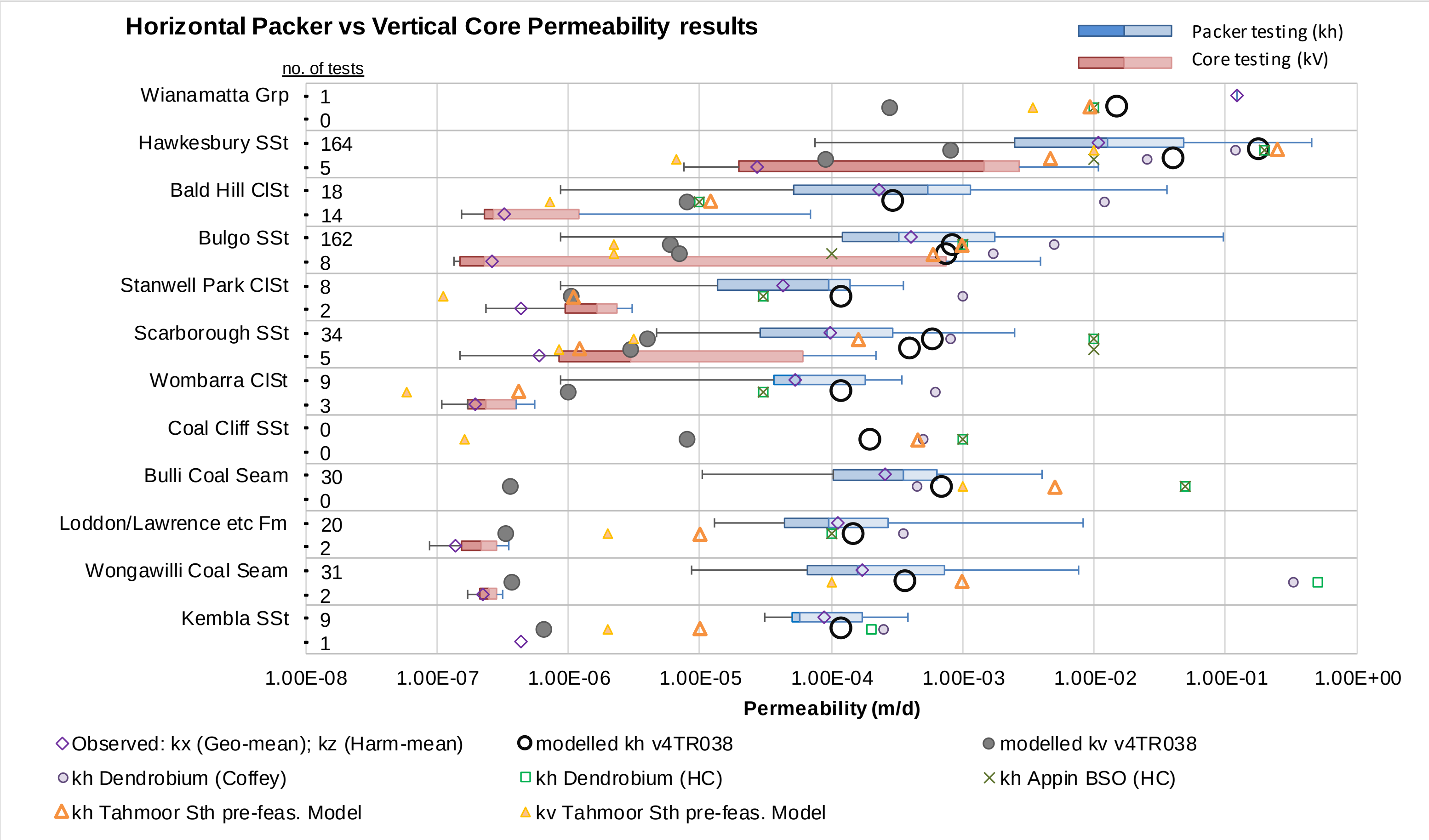


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Figure 4-10 Comparison of modelled hydraulic conductivity and measured data

As in previous versions of the groundwater model, zones to represent the Nepean Fault Complex are included, and these simulate high Kh and Kz than the surrounding strata. This zone has been revised based on the mapping in SCT (2020d) (Section 3.4.2), noting that there is uncertainty about the size, orientation of the disturbed zone around faults (Section 3.5.9).

4.2.2 Transient Calibration Statistics

Model performance was assessed against a range of data and these results are summarised and discussed below. The calibration was validated using the updated calibration data set:

- Based on comparison to transient groundwater level targets the model had a scaled Root-Mean-Square (sRMS) error of 2.9%, with the mean residual equal to 0.2 m. The overall model mass balance error was 0.02%. These statistics indicate that the model is an acceptable match to historical data, based on the content of the Australian Groundwater Modelling Guidelines [AGMG] (Barnett *et al.,* 2012); and
- **Figure 4-11** 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. The performance of the model to replicate the groundwater regime across the Western Domain (LW W1-W4) was acceptable, with a distribution error showing that 197 out of 302 observations were falling between +/-5m error margin, and that the model provided a reasonable estimate of drawdown in the Hawkesbury and Bulgo Sandstones. Groundwater levels simulated in the Bulli Coal Seam were often higher than those observed. The distribution of groundwater residuals for the coal seam shows that the error is largely within the +/-25 m range. The model overestimates the depressurisation at bore S1941 located around the neighbouring mine "Appin Mine" due to the representation of mining in the model that does not capture the latest mine plan at Appin Mine.

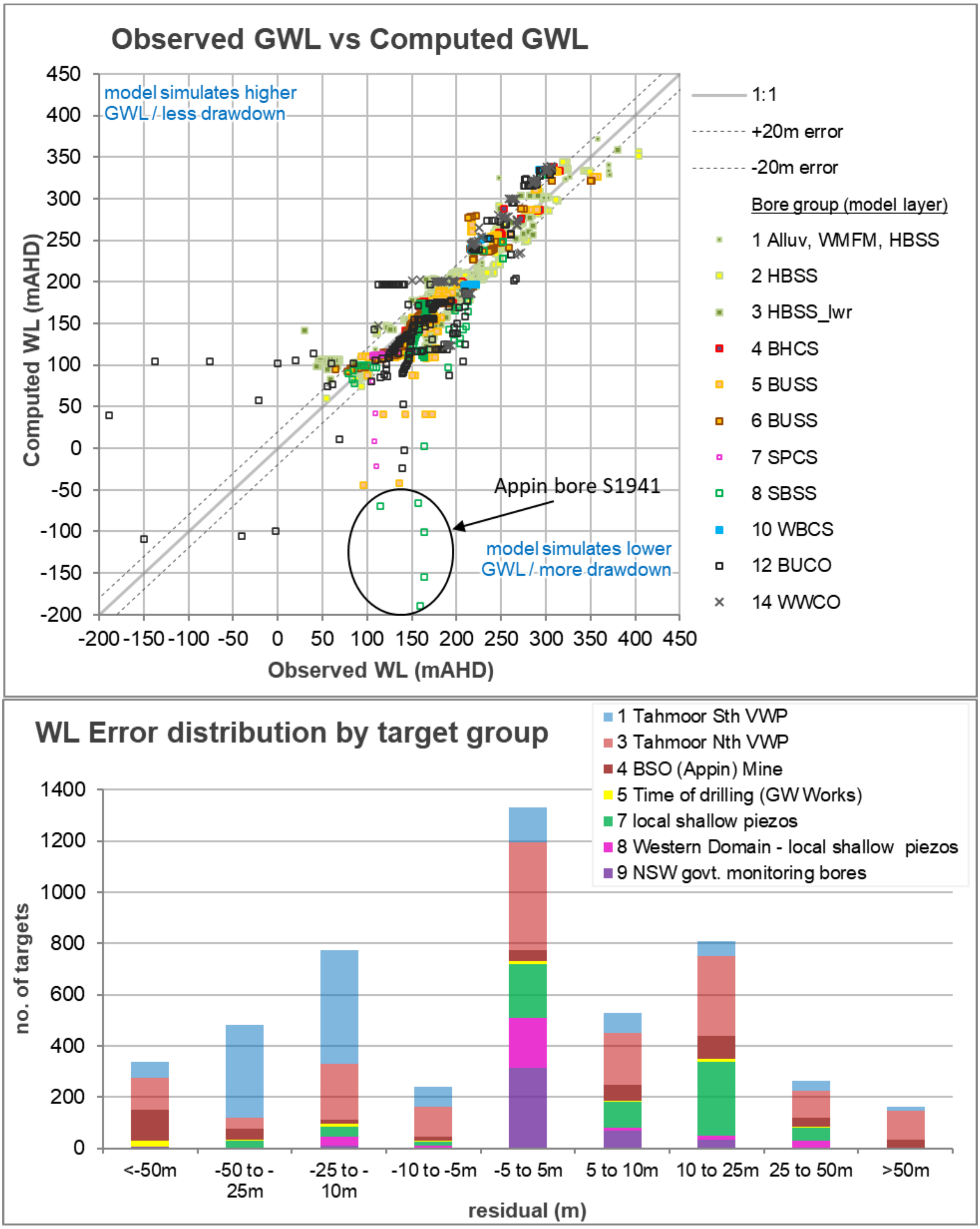

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Figure 4-11 Summary of transient calibration to water levels

4.2.3 Model Performance at the Vibrating Wire Piezometers (VWPs)

The following section presents the model performance at the bores TNC036, TNC040, TNC043 and WD01:

- Modelled pressure head and vertical water level profiles at bore TBF040c show good correlation to observations made in 2014. This bore is the original "HoF borehole" (SCT, 2014). **Figure 4-12** presents these results. The figure shows a good match down the profile, with modelled heads being a good match for those in the Hawkesbury Sandstone (both modelled and observed unaffected by mining) and the Bulgo Sandstone (both modelled and observed influenced by mining). The model tends to overestimate drawdown in the Bald Hill Claystone compared to the observed water levels. Below the upper Bulgo Sandstone, where there are no observed readings, the model simulated negative pressures in response to mining, which matched well with the zero-pressure concept by Tammetta (2013). The model simulates some recovery to positive pressures by 2014, however it is not possible to confirm this is correct. Positive pressure heads are simulated in the layers below the mined Bulli seam. Overall, 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 existing groundwater monitoring locations for LW W3-W4 (TNC036, TNC040, TNC043, WD01) are presented in **Figure 4-13** to **Figure 4-16.** 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; and
- The ability of the model to replicate the timing and magnitude of the observed drawdown in the upper Bulgo Sandstone TNC036 (169 m), TNC040 (252 m) and in the lower Bulgo Sandstone TNC040 (352 m) was improved by adjusting the hydraulic properties in the connected fracture zone. The timing and the degree of depressurisation in the Bulli Seam was also improved at bore TNC040 (**Figure 4-14**). The model replicates within 5 m the observed groundwater levels in the upper Hawkesbury Sandstone (piezometer WD01-70m and WD01-90m). The model does not capture the depressurisation in the lower Hawkesbury Sandstone (piezometer WD01-190m, WD01-210m and WD01-230m) but simulated water level in the lower Hawkesbury Sandstone at the start of monitoring (September 2020) is within 10 m to 15 m of observed. The model seems to replicate within 10 m the observed groundwater level from the upper sensor located in the Bulgo Sandstone (piezometer WD01-300m) while is offset by 50 m at the lower piezometer WD01-330m and WD01-350m due to the three BGSS piezometers being in the same model layer.

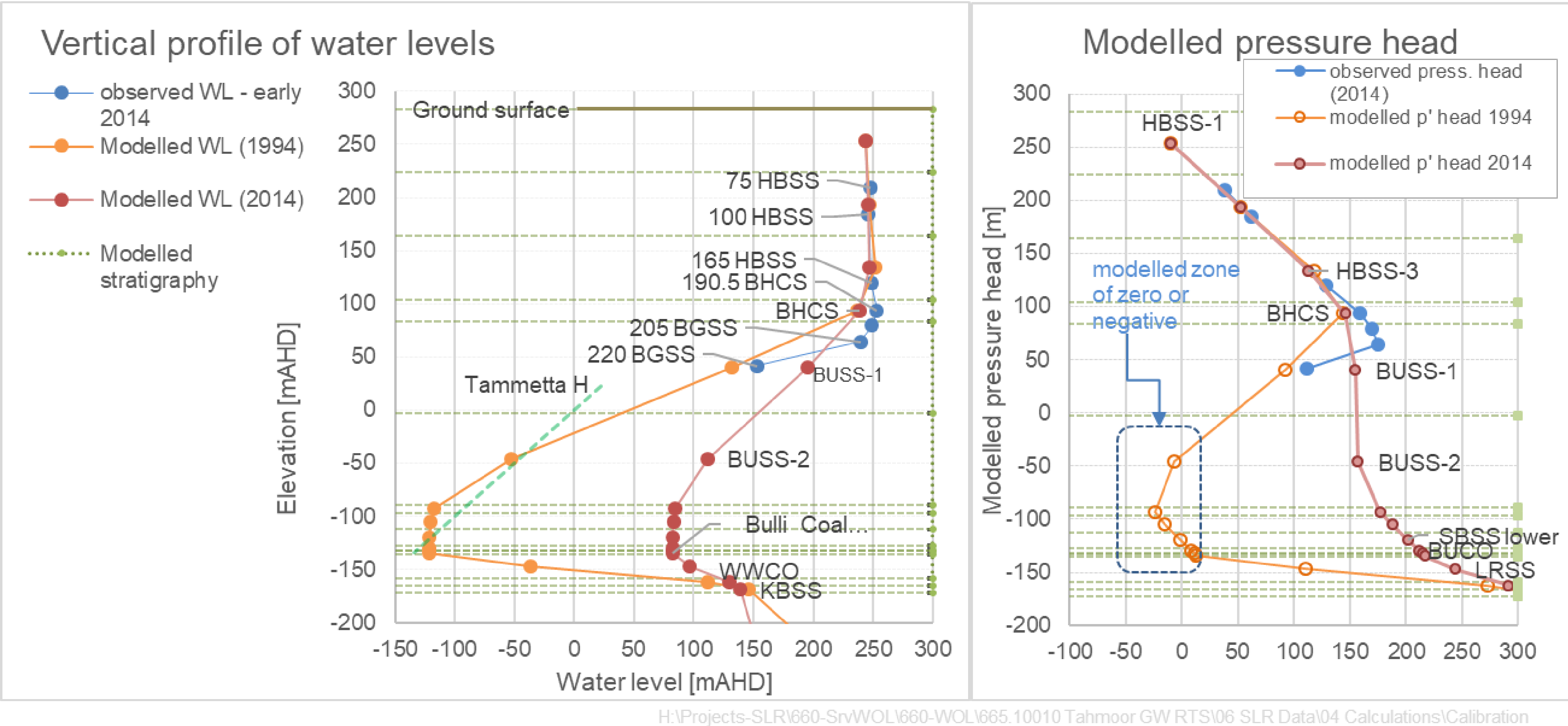


Figure 4-12 Simulation of water levels in TBF040c ('HoF') borehole

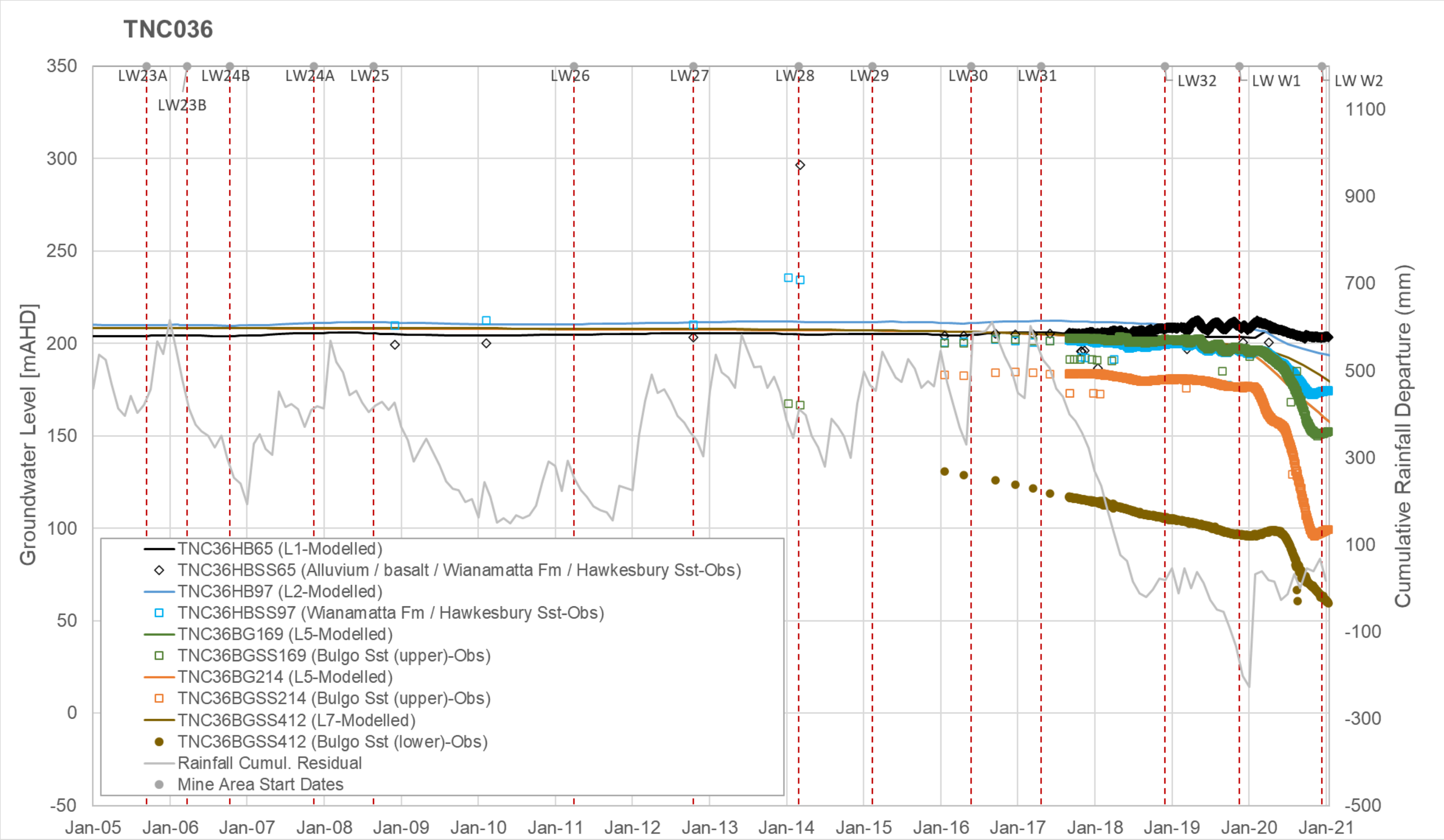


Figure 4-13 Comparison of modelled and observed groundwater levels at TNC036

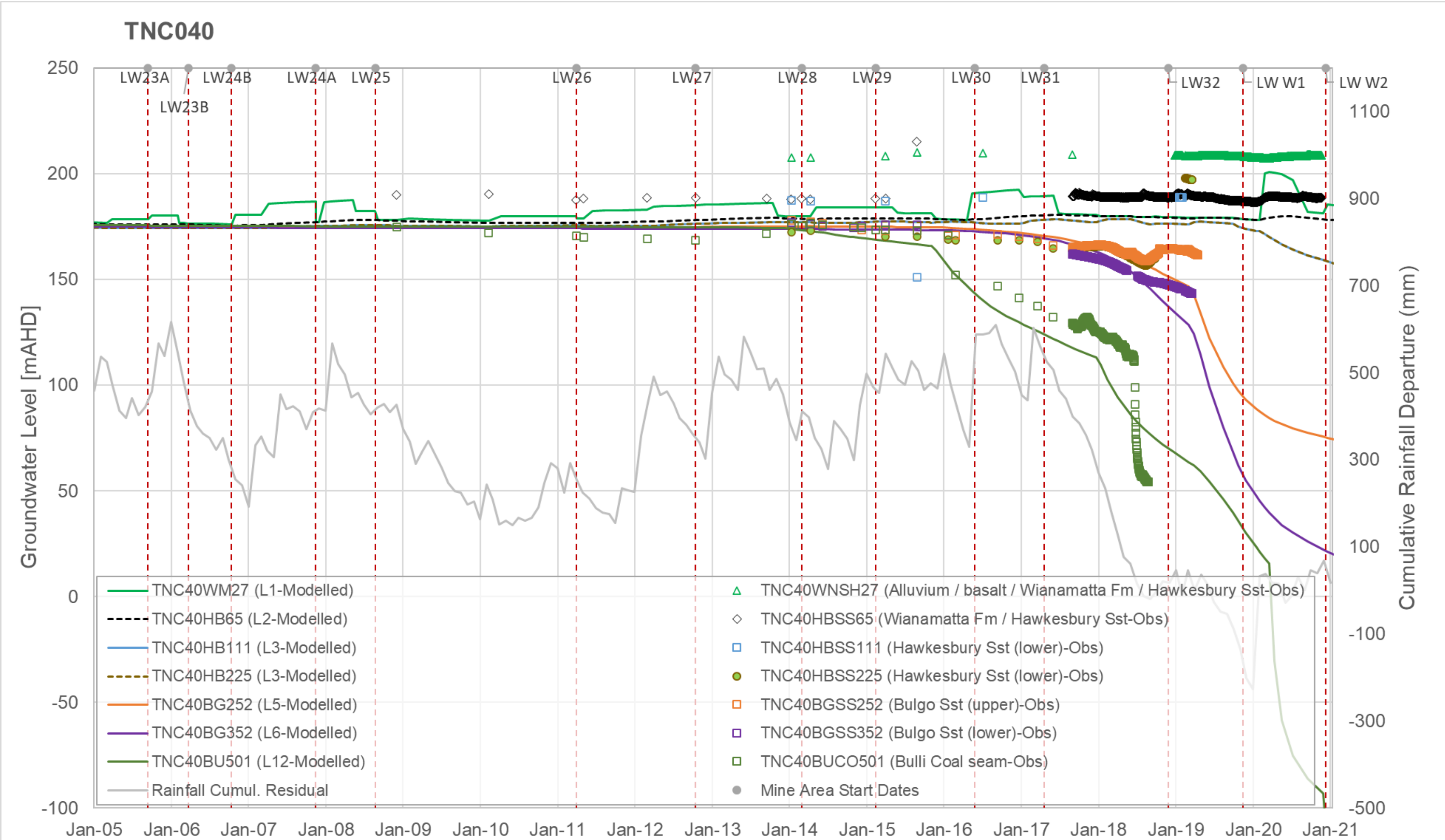


Figure 4-14 Comparison of modelled and observed groundwater levels at TNC040

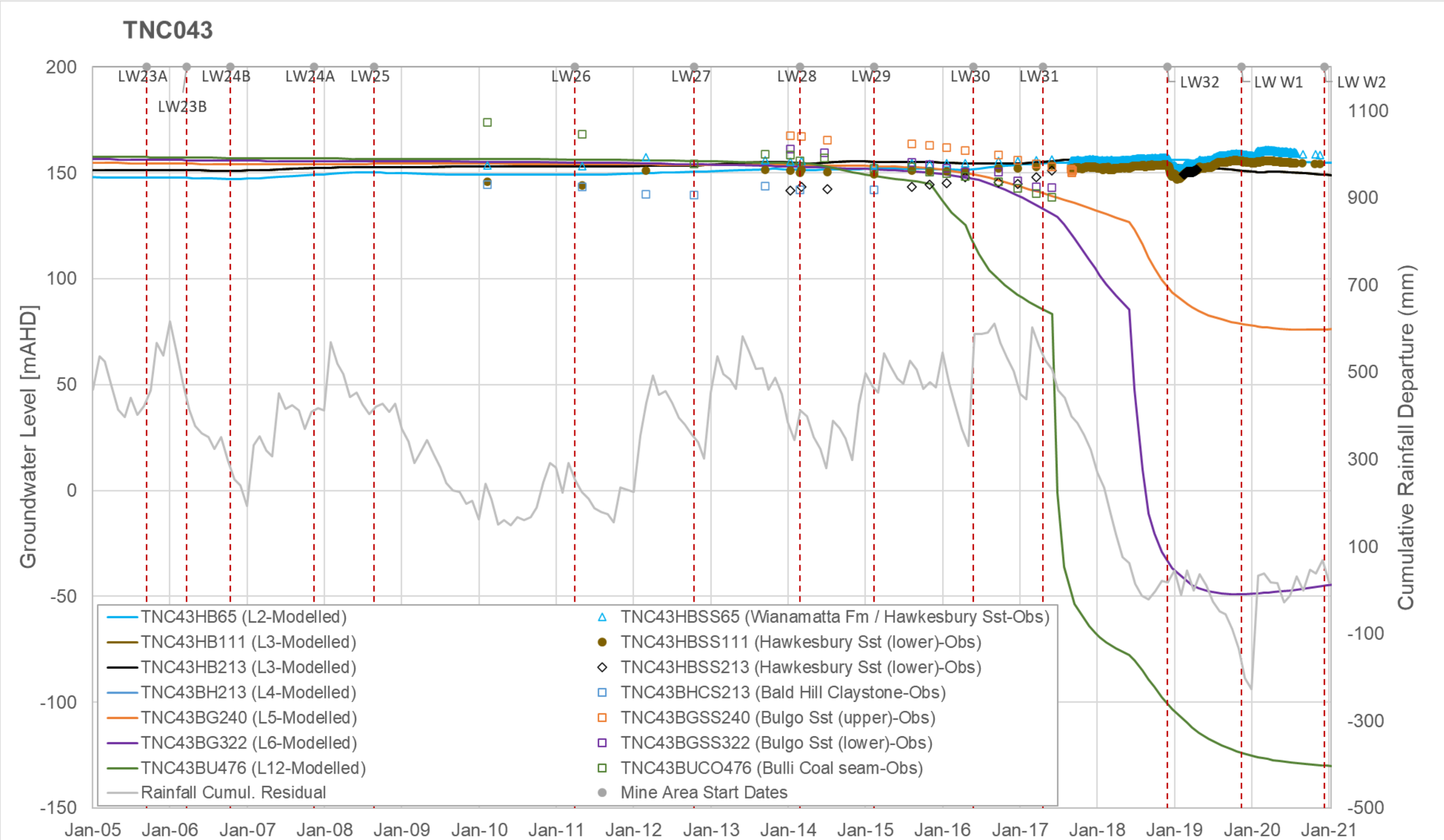


Figure 4-15 Comparison of modelled and observed groundwater levels at TNC043

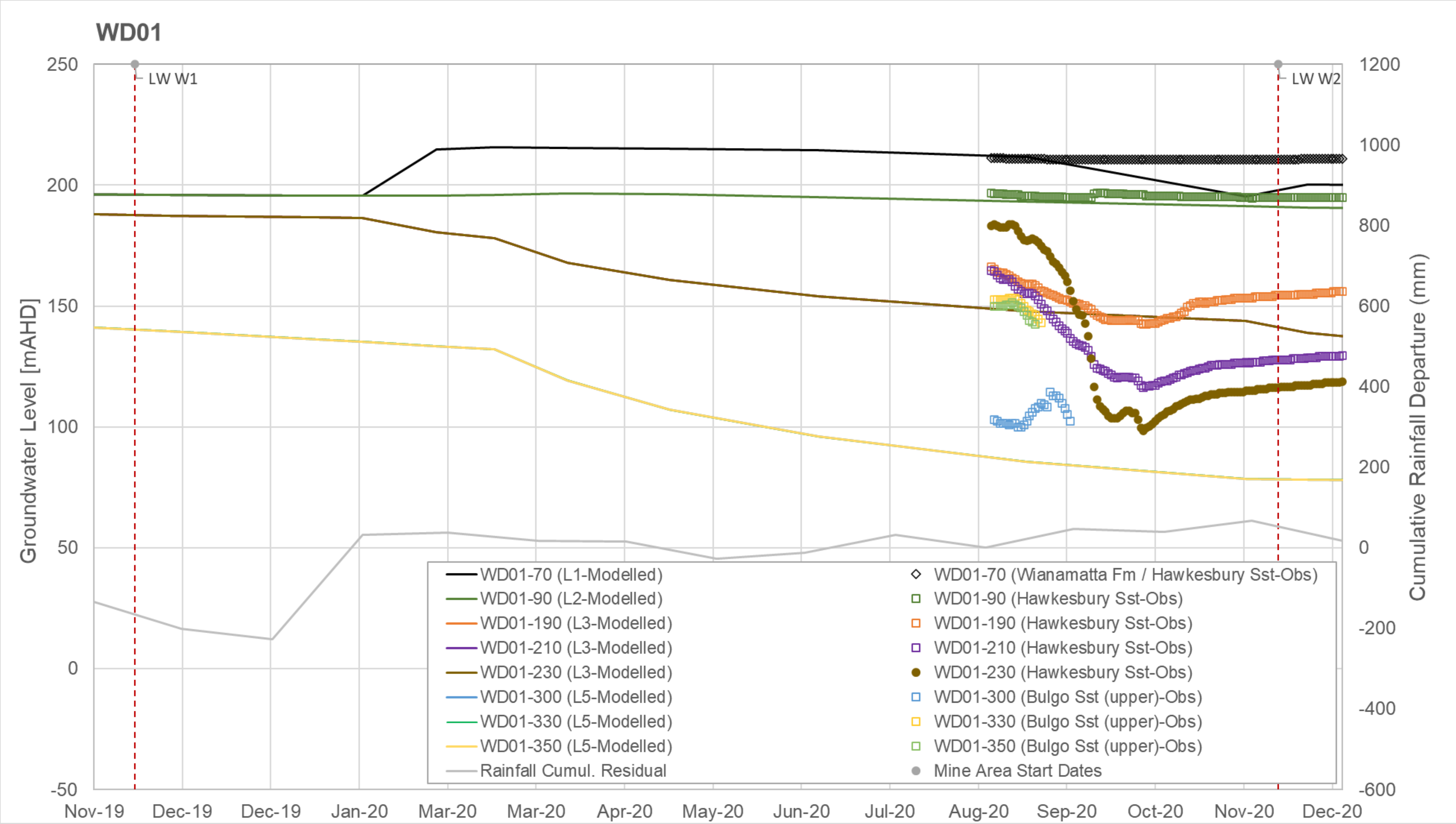


Figure 4-16 Comparison of modelled and observed groundwater levels at WD01

4.2.4 Model Performance at the shallow Open Standpipe Bores (P bores)

4.2.4.1 Tahmoor North

This section presents hydrographs comparing modelled and observed groundwater levels for the existing groundwater monitoring bores located across Tahmoor North (P1-P8, P9) shown on **Figure 4-17** and-**Figure 4-18**, and along Redbank Creek (P10-P36) and Myrtle Creek (P18-P28) presented in **Appendix C**.

- The comparison of modelled and historical observed groundwater levels for P1-P8 (**Figure 4-17**) is consistent with the assessment presented in the Amended Tahmoor South Project EIS (HydroSimulations/SLR, 2020). Modelled water levels at P1 are well captured by the model. P4 and P8 still present an apparent mismatch, with the trends being good but with a consistent offset of 20-30 m.
- At bore P9 (**Figure 4-18**), the model replicates the magnitude (but not the timing) of the LW31-related drawdown observed in the shallow Hawkesbury Sandstones during 2018 (P9A24, P9V1) while in the deeper section of the bore (P9_V3, P9D68) the modelled drawdown is more linear and not as significant as the sharp decline in water levels observed in 2018. The observed drawdown induced by the extraction of LW32 in the shallow and deeper section of the bore is modelled slightly earlier than observed, but the drawdown magnitude is a good match (the timing is due in part to model stress period length, i.e. a structural error). The observed recovery in water levels from February 2020 is also well captured by the model, strengthening the model confidence to replicate the recent change in the groundwater elevation in this area.
- Hydrographs from the Tahmoor Coal's shallow bores along Redbank Creek (**Appendix C**) show, in general, a good match between modelled and observed water levels. There is usually an offset between observed and modelled, typically +/-5 m approx. However, trends and seasonal fluctuation in groundwater level in the Redbank Creek catchment are well represented, especially during the wet period January-February 2020. At bore P10, limited drawdown is simulated in the deep open standpipe bore (P10C) as observed in May 2019, but model captures (couple of months late) the 3 m observed drawdown from August 2019.
- Modelled water levels along the Myrtle Creek catchment (**Appendix C**) are consistently offset below observed water levels. This offset is due to a simplification in model layering. Although the modelled water levels do not align well with the observed levels, the model captures the groundwater trend at P20B, P24A, P25, with a good match in the response to rainfall recharge. The simulated groundwater levels along Myrtle Creek are generally flat whereas some of the observed data exhibit an increase in water levels due to heavy rainfall in February 2020, particularly at P26, P27, P28A-B.

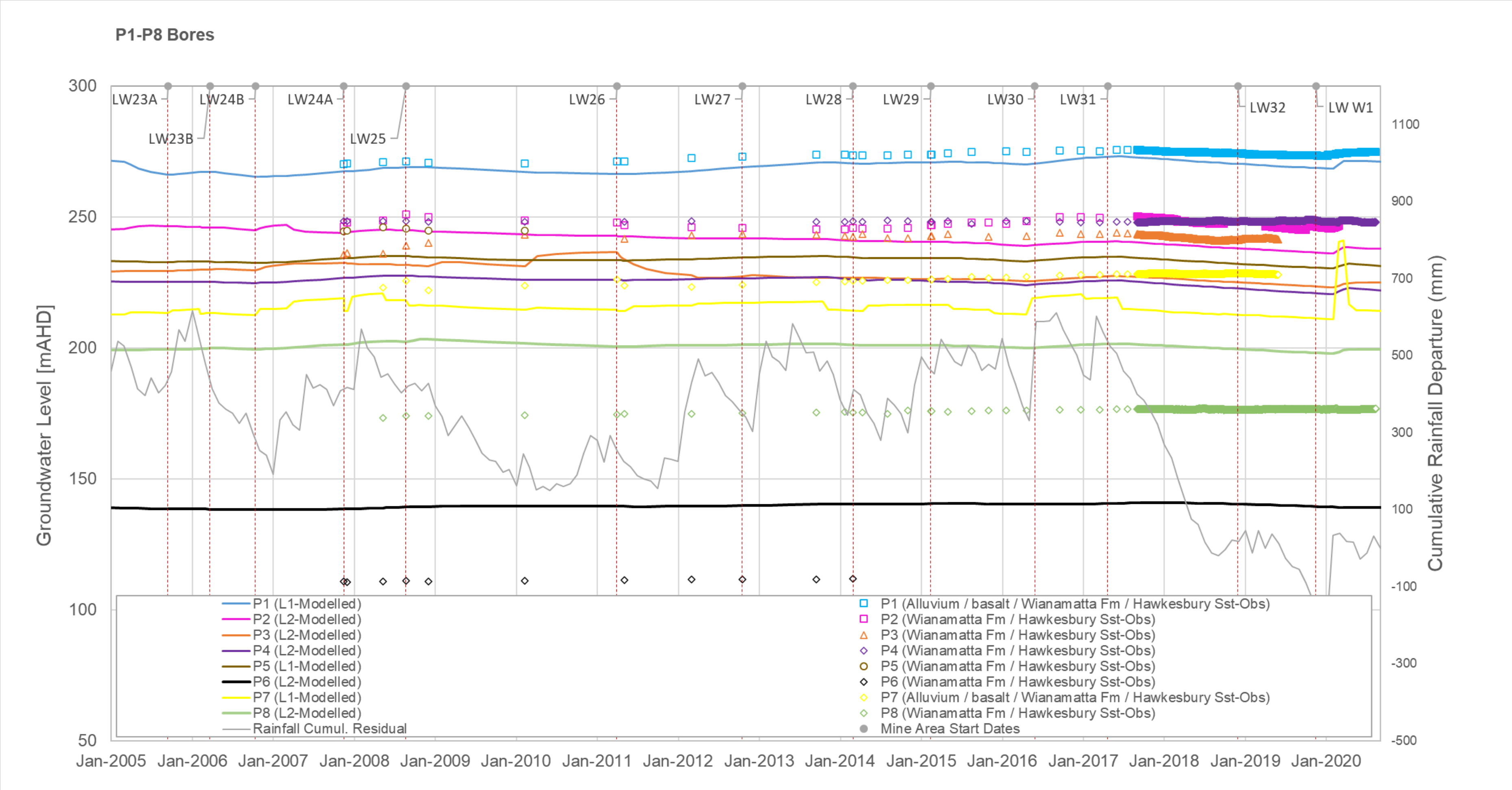


Figure 4-17 Comparisons of modelled and observed groundwater levels at P1-P8

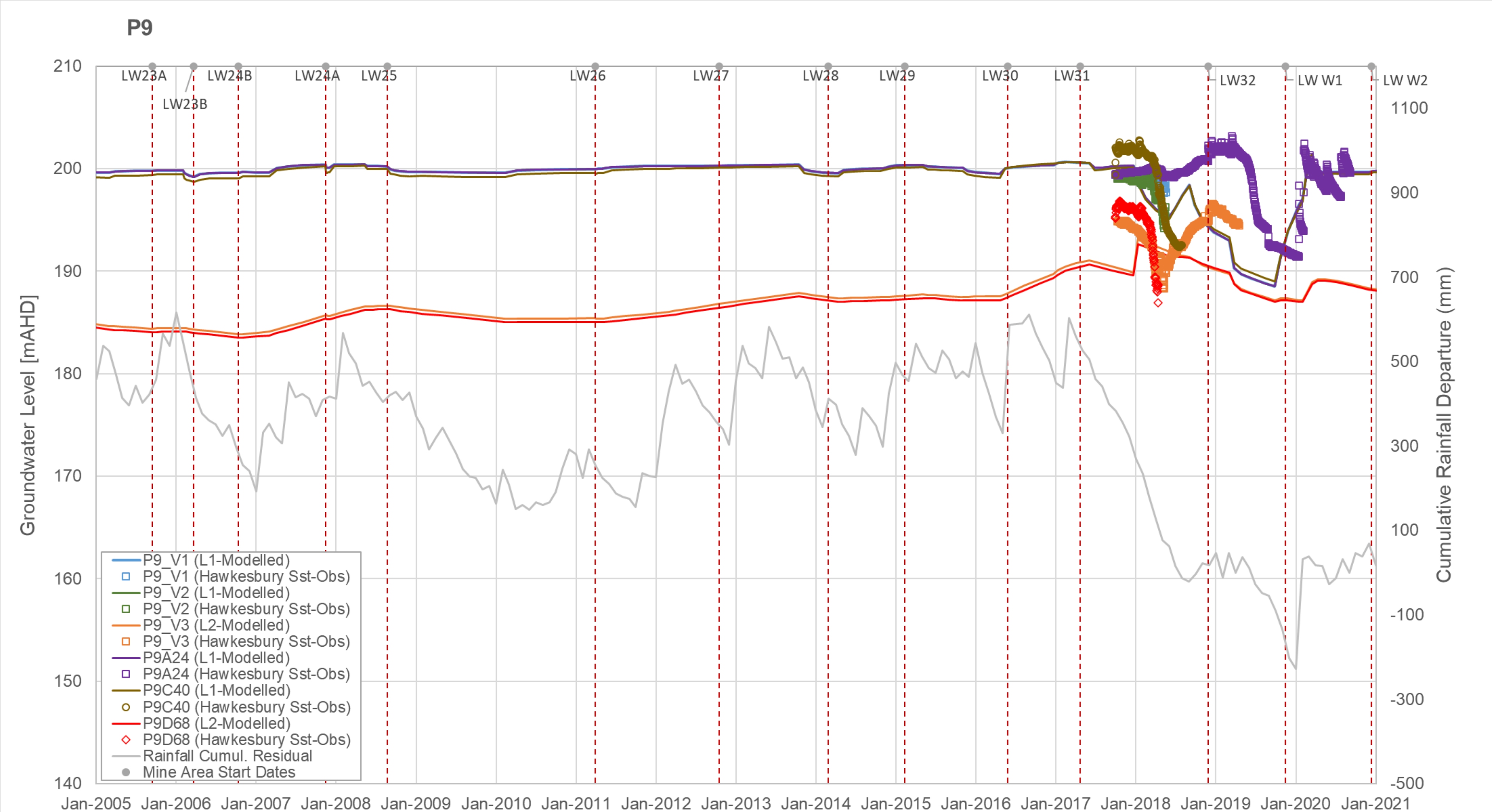


Figure 4-18 Comparisons of modelled and observed groundwater levels at P9

4.2.4.2 Western Domain

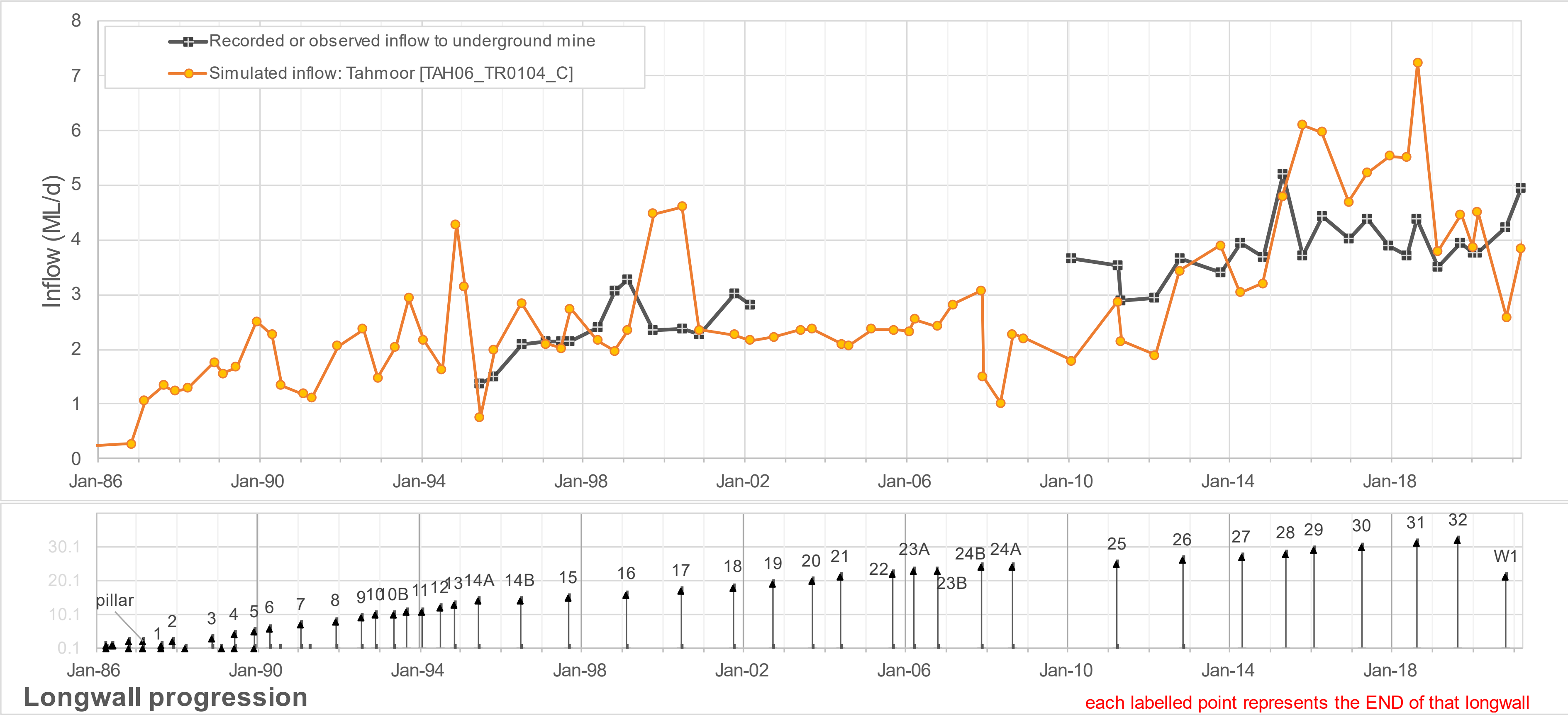
The hydrographs for the Western Bores (P12-P17) are presented in **Appendix C**. Many of these monitoring sites have screens that occupy the same model cell (e.g., P12A to P12C, P14A to P14D), which makes it difficult to represent and replicate observed groundwater levels.

- P12: the modelled water levels from the shallow Hawkesbury Sandstone (Layer 1) is within 0.5 m of observed in the two upper open standpipes (P12A and P12B). The model captures with accuracy the groundwater response to rainfall recharge in February 2020 and subsequent decline in water levels. The model slightly underestimates by 0.5 m the decline in observed water level at P12A. The drawdown at P12C has triggered TARP level 4 as discussed in **Section 6.3.3**, which is captured by the modelled water levels in the upper layer of the model (Layer 2) with a 10 m modelled drawdown. The rate of the observed drawdown at P12C throughout 2020 is well captured by the model with a sharp decline in Feb-May 2020 followed by a reduction in the drawdown in August 2020. While the rate of the modelled drawdown is not as fast as observed between August and November 2020, the model captures the overall magnitude of drawdown since the start of LW W1 and matches the observed stabilisation of the water levels in P12C from early 2021.
- P13: the modelled water levels within the two upper open standpipes (P13A-P13B) are within 2 m and 3 m respectively of observed and present a flat trend with limited responses to the below average rainfall condition before the start of LW W1 but capture the observed above rainfall average condition from early 2020. There is no pumping data to confirm this, but the linear decline in groundwater levels in P13A in Nov-2019 to Feb-2020 has the appearance of a drawdown from a pumping well. Modelled water levels in the deeper strata (P13C) are less than 10 m of observed and present a good match in the reduction of the groundwater trend following the extraction of LW W1. The timing of the modelled drawdown occurs two months earlier than observed with limited responses to rainfall recharge in early 2020. In P13C, the rate of the modelled drawdown and magnitude matches accurately the observed drawdown during 2020. The model captures the subsequent decline in water level due to the extraction of LW W2 in December 2020 with the modelled water level being predicted within 6-7 m of observed water levels. The modelled drawdown between November 2019 (prior LW W1) and early 2021 is approximately 10 m while observed drawdown is 5 m for the same period which makes the model conservative in terms of depressurisation in the Hawkesbury Sandstone.
- P14: The screen interval for P14A is believed to monitor the alluvium (L1) while the three other open standpipes at P14B, P14C and P14D are all within model Layer 2 which makes it difficult to represent each groundwater trend at P14 B-D. At P14A, the model captures very well the groundwater level fluctuations within 1 m of observed but is within 2 m of observed early 2021 (model slightly overestimates decline in water levels while observed water level in P14A respond to rainfall recharge event). At P14B and P14C, modelled groundwater level in Layer 2 (**Appendix C**) overestimates water levels by 10 m but the overall groundwater trend matchs relatively well. The linear reduction in groundwater level in P14B and P14C is slightly overestimated by the model by approximately 5 m after the extraction of longwall W1 and by 3 m following the extraction of longwall W2. P14D modelled water levels are also presented as the Layer 2, within 15 m of observed when LW W1 extraction start and within less than 10 m in early 2021. The linear reduction in observed groundwater level at P14D (approximately 1.6 m) is overestimated but the overall trend is captured in the model, with 5 m and 3m of modelled drawdown after the simulation of mining at LW W1 and LW W2 respectively.

- P16: The simulated water levels at P16A is extracted from Layer 2 (HBSS). At P16A, the model matches the fluctuations in groundwater level with modelled levels very well, with the modelled levels being within 1 m of observed. The timing and magnitude in drawdown in P16A is also well captured with a modelled drawdown within 1 m of observed following the start of mining at LW W1 and LW 2. Modelled groundwater levels at P16B are presented as a water level average from layer 1 (HBSS) and Layer 2 (HBSS), with a good match in groundwater trends during below average rainfall conditions and subsequent rate and magnitude of drawdown after the passage of LW W1. As of March 2021, the model captures the stabilisation in water levels and are within 1 m of observed levels. At P16C, water levels are extracted from Layer 3 (HBSS), are within 5 m of the observed condition before the extraction of LW W1. While the modelled rate of drawdown is slightly faster than observed, the model captures relatively well the depressurisation at P16C with modelled water level within less than 5 m between March and August 2020. The model captures the stabilisation in water levels from October 2020, with modelled water levels sitting approximately 5 m of observed in March 2021.
- P17: The modelled water levels extracted from Layer 1 (HBSS) are overestimated with levels sitting 10 m above the observed condition. While modelled levels are significantly offset, the trends and fluctuations are well matched.

4.2.5 Inflows to Underground Mine Workings

- Modelled groundwater inflows presented on **Figure 4-19** show a good correlation with the observed trend, with some variability in over- and under-predicting the inflow or 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 3.89 ML/d. Modelled inflows for the same period are 4.1 ML/d and 4.6 ML/d respectively. This provides a more conservative estimate of inflows which is appropriate for licensing of groundwater take.



C:\Users\Owner\Dropbox\Tahmoor W3W4\Modelling\Processing\Inflows\[Inflow_ModVsObs_MultipleTimesteps_MineAreas_v6TR0104C_20210419.xlsx]ObservedInflow

Figure 4-19 Comparison of observed and modelled inflow at Tahmoor

4.3 Potential Groundwater Impacts

4.3.1 Deterministic Uncertainty Analysis

A series of alternate predictive models has been run in combination with the development scenarios described in **Section 4.1.2** to assess some of the uncertainty in mine inflows, loss of flows in streams, drawdown at landholder bores. These deterministic scenarios are focused on altering extent and properties of specific geological structure relevant to LW W3-W4. This was achieved by changing and assessing the following:

- modifying the height and hydraulic conductivity in the upper part of the fracture zone and dilated zone to represent uncertainty in the depressurisation effect caused by longwall subsidence.
- modifying the properties of the Nepean Fault Complex near to the Western Domain, as mapped by SCT (2021):
  - by enhancing horizontal hydraulic conductivity (Kh) by a factor ranging from 1.5-2 and enhancing vertical hydraulic conductivity (Kv) by 2 across the Hawkesbury Sandstone (layers 2-3).
  - by reducing horizontal hydraulic conductivity (Kh) by a factor ranging from 2 at depth (layers 4-12) to 10 in the HBSS (layers 2-3) and reducing vertical hydraulic conductivity (Kv) by +1 order of magnitude across the Hawkesbury Sandstone to Bulli Seam (layers 2 to 12).

These scenarios generally focus on the effects (e.g. drawdown, inflow, loss of baseflow) at receptors and assets around the Western Domain. Subsequent sections present results based on these scenarios.

4.3.2 Groundwater Take (mine inflow)

The simulated groundwater inflows to LW W1-W4 are presented on **Figure 4-20**. The values represent inflow at the end of each stress period.

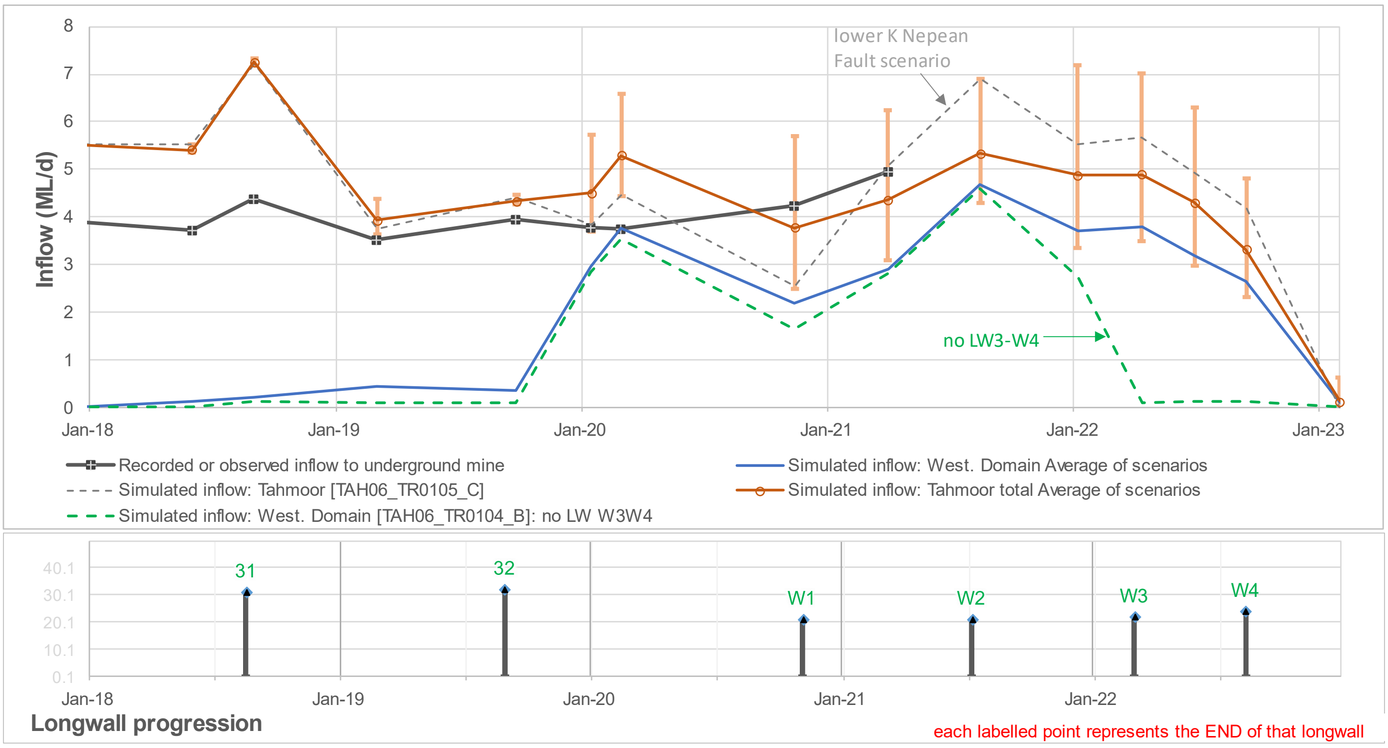


Figure 4-20 Modelled Tahmoor Mine and Western Domain Groundwater Inflows and Uncertainty

The inflow to the Western Domain, including LW W3-W4, is expected to lie in the range of 3-4 ML/d during 2021-2022, with the potential to peak slightly higher for short periods. The extraction of LW W3-W4 would increase the duration of inflow to Tahmoor North, with a total of approximately 4-5 ML/d of inflow during late 2021-2022. The likely uncertainty in predicted inflows is illustrated on **Figure 4-20** with error bars which are calculated based the range from deterministic scenarios.

4.3.3 Loss of Flow in Streams

'Baseflow capture' is the process of weakening an upward gradient from the aquifer into the watercourse ('baseflow') and/or inducing 'leakage' from a creek or river into the aquifer via a downward gradient and thereby reducing surface water flow. This process can result in reduced stream flow at downstream gauging stations (as discussed below) and reductions in pool water levels (recent such effects are documented in **Section 3.5.8** and **Appendix G**, as well as in HEC, 2020a-c and HEC, 2021a,).

HEC (2020a-c) presented an analysis of the stream flow trend at Stonequarry Creek suggesting a declining streamflow rates since 2011, particularly between 2017 and early 2020 due to below average rainfall conditions. There was no mining-related impact (i.e. loss of stream flow) observed along Stonequarry Creek following the start of LW W1, but an increase in stream flow rates was recorded in mid-January to February 2020 following rainfall events (HEC, 2020a). Later in 2020 and into 2021, a period which has been generally wetter than average, short dry periods have resulted in short-term declines in pool level at some sites along Matthews and Cedar Creeks and, to a lesser degree on Stonequarry Creek. HEC (2021a) summarises all such surface water TARP exceedances likely as a result of LW W1. These declines have been correlated, by SLR, against down catchment flows and an estimate of the likely surface water loss at relevant sites has been made (**Section 3.5.8**).

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 (2021).

Table 4-3 presents a summary of the predicted baseflow capture at several creeks directly related to LW W3-W4 and cumulative mining. The impact stated in the table, expressed as ML/year, represent the flow reduction effect impact at any time when comparing predictive scenarios, and are derived from the 'base case' and deterministic scenarios. The maximum and mean loss estimates for Stonequarry Creek are greatly influenced by the hydraulic conductivity (K), which is an uncertain and sensitive parameter, applied to the Nepean Fault Complex (Section 4.3.1) and which is mapped as being in close proximity to LW W4. This is being investigated further at the time of writing, and an update to the licensing strategy for the mine (EMM, 2021) will be provided.

Table 4-3 Flow depletion at nearby watercourses

Watercourse	Cumulative Impact (ML/year)			LW W3-W4 effect (ML/yr)		
	Min	Mean	Max	Min	Mean	Max
Redbank Creek tributary (near LW W4)	0	1	2	0	1	2
Redbank Creek	3	6	9	1	4	6
Matthews Creek	7	13	18	0	2	4
Cedar Creek	15	27	40	1	1	2
Stonequarry Creek to site SD	28	45	99	10	27	44
Stonequarry Creek below site D	0	27	159	0	24	111

E:\TAHMOOR\Model\Processing\ZoneBudget\SWtake\Riv&Lake_BaseflowCapture_6TR098_101_104_105&106_B&C_v2-cumulative_assessment 20210430.xlsx

Losses are likely to occur in localised reaches, and are not ‘consumptive’ or persistent along the full length of watercourses, as per recent effects on Cedar Creek. The watercourses predicted to be most affected by the extraction of LW W3-W4 and the base case estimate of incremental losses are as follows:

- Stonequarry Creek to site SD – predicted flow loss of approximately 0.074 ML/d (27 ML/year), but with associated uncertainty that is being investigated with further field work);
- Stonequarry Creek below SD – losses are likely to be approximately 0.065 ML/d (24 ML/yr); and
- Redbank Creek – maximum flow loss of 0.025 ML/d (9 ML/year).

The greatest losses are predicted to occur in late 2023, i.e. within a year of the cessation of the extraction of LW W4.

The watercourses predicted to be affected the most by the cumulative mining, including LW W1-W4, are:

- Stonequarry Creek to site SD – predicted flow loss of 0.12 ML/d (45 ML/year), again emphasising the ongoing field work to constrain uncertainty in this estimate;
- Stonequarry Creek below SD – losses are likely to be approximately 0.073 ML/d (27 ML/yr); and
- Cedar Creek –flow loss of 0.11 ML/d (40 ML/year).

The impacts for the Redbank Creek tributary located to the eastern side of LW W4 were quantified for this study and represents a near zero baseflow loss due to the extraction of LW W3-W4 and less than 2 ML/year due to cumulative mining.

The effects described above are likely to manifest as reductions in stream flow and pool levels. These effects would occur across the range of flows (i.e. wet and dry conditions), but mainly noticeable in dry periods when baseflow is (or was) the primary source of stream flow.

4.3.4 Groundwater Drawdown

Groundwater drawdown refers the lowering of the groundwater table or potentiometric head 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 or pressure heads can occur.

An assessment of the extent of groundwater drawdown was conducted for this groundwater technical report to understand the extent of incremental lowering of the regional groundwater table that will occur due to the extraction of LW W3-W4. This information will assist in the prediction of potential impacts to 'water supply works', as required by the AIP, as well as providing a basis to develop groundwater triggers.

Figure 4-21 illustrates the depressurisation of the strata surrounding LW W1-W4. It presents a cross-section of 'pressure-head' through model row 196 which passes through LW W3-W4 (and LW W1-W2) from west to east. The upper cross-section shows pre-mining conditions in the region and shows pressure head increasing with depth. The middle cross-section depicts depressurisation following the extraction of LW W3-W4. 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 W3-W4 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 W3-W4. 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 4-22**, showing drawdown predicted to occur at the water table, within the lower HBSS and upper Bulgo Sandstone, and the Bulli Coal Seam due to the extraction of LW W3-W4. Unlike the depressurisation presented in **Figure 4-21** this shows only incremental drawdown due LW W3-W4. Incremental water table drawdown of 2 m is expected to be contained to the area within and adjacent (maximum distance of 600 m from edge of panel) to LW W3-W4 with a greater spread of drawdown in the range 0.2-1 m.

Drawdown within the Bulli Coal Seam (**Figure 4-22**) is predicted to occur radially around LW W3-W4. Maximum drawdown of 300 m is predicted to occur within the longwall footprint, representing dewatering of the seam (workings). The 2 m drawdown contour extends approximately 2 km beyond the edge of LW W3-W4. Drawdown in the other units is similar to that of the Bulli Seam, but with a greater extent due to the transmissivity of these overlying units.

Simulated maximum cumulative drawdown in the same four units is shown on **Figure 4-23**. This shows widespread drawdown due to mining at the Western Domain, Tahmoor North and also from Appin/BSO to the east. Drawdown in the water table is more restricted to around the panel footprint than drawdown in the other layers.

Some of the higher drawdown estimates (e.g. 100 m in the lower Hawkesbury Sandstone) are indicative of areas where the model predicts that some strata may desaturate, even for a short time. In many of these areas, groundwater would recover following completion of mining and cessation of dewatering.

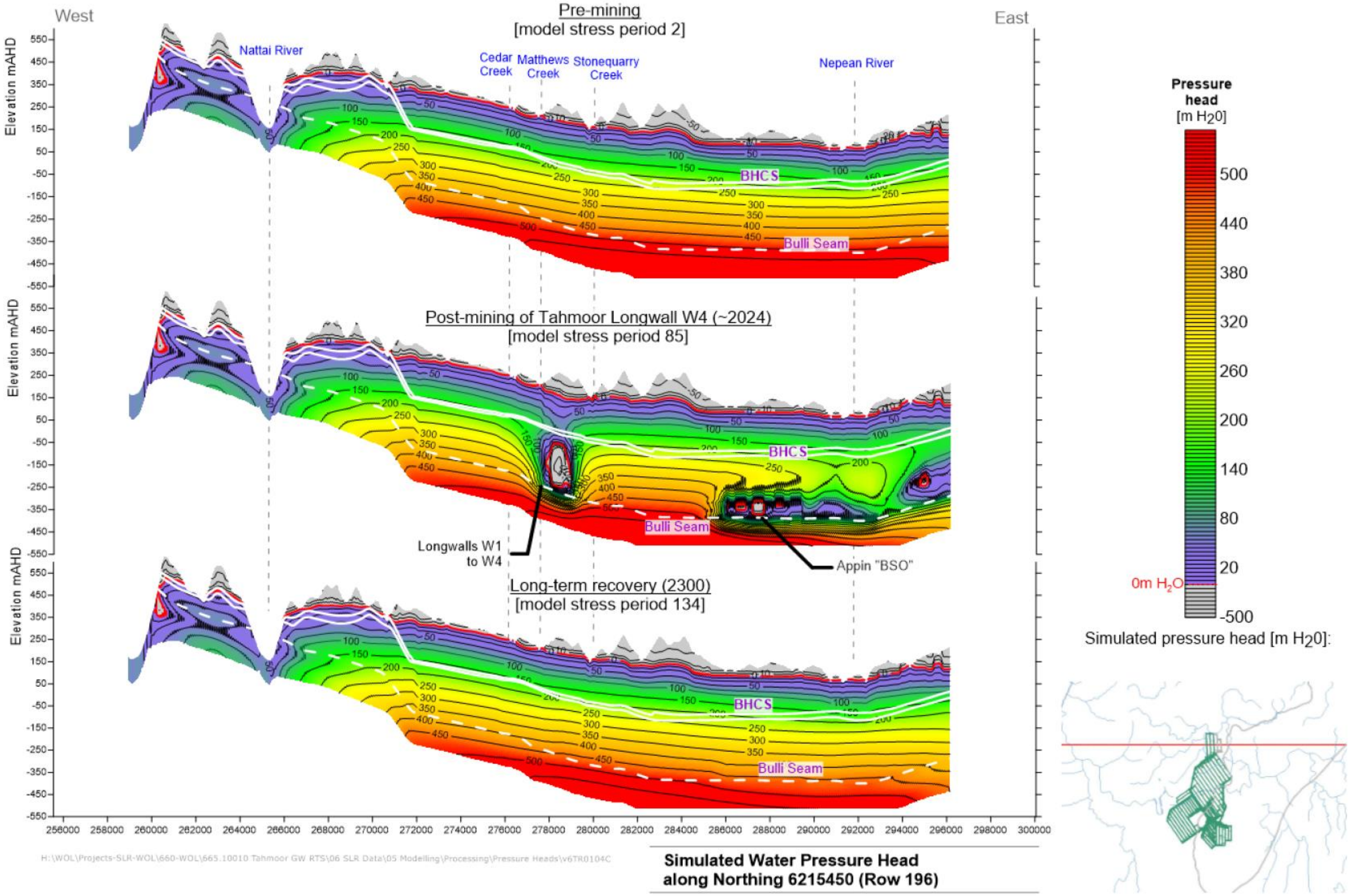
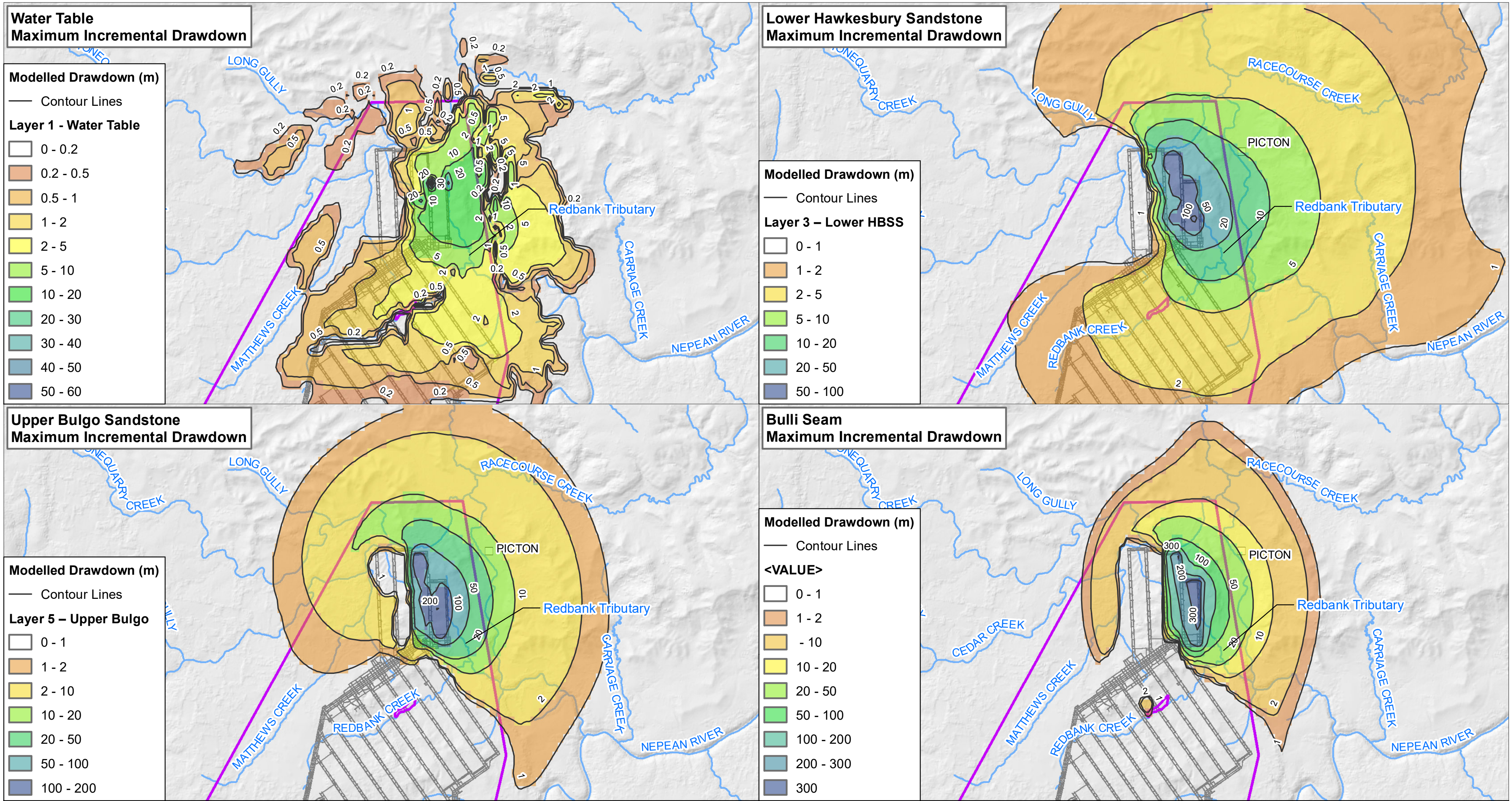


Figure 4-21 Modelled pressure head cross-section



0 1 2 km

Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:100,000 at A4
Project Number:	665.10010
Date:	27-Apr-2021
Drawn by:	JG

Minor Town

Mine Layout

Tahmoor Coal Titles

MLs 1308, 1376, 1539

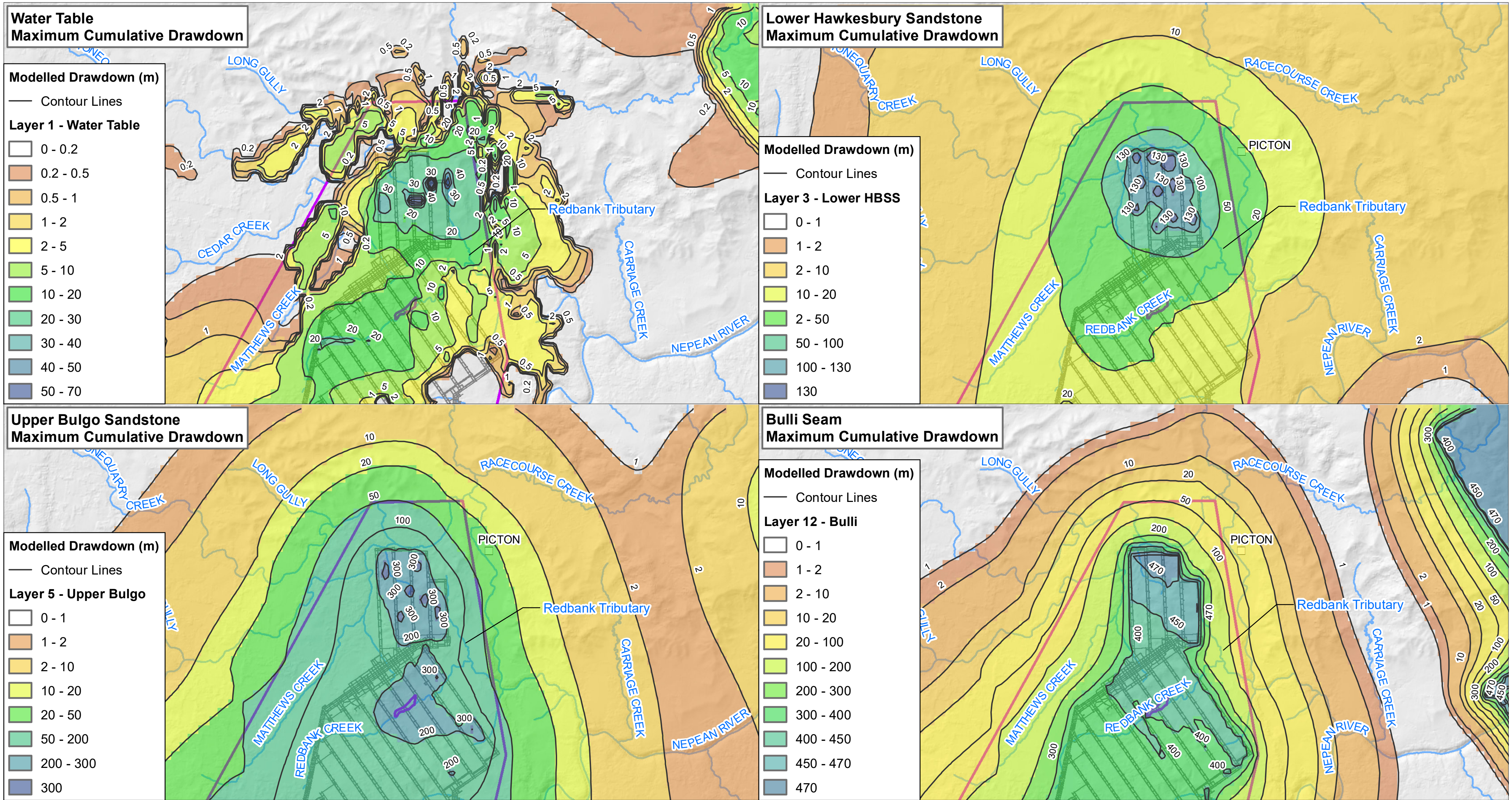
SLR

TAHMOOR COAL
LONGWALL W3 AND W4
EXTRACTION MANAGEMENT

Predicted Maximum Incremental Drawdown in the Water Table (L1), lower Hawkesbury Sandstone (L3), upper Bulgo Sandstone (L5) and Bulli Seam (L12)

FIGURE 4-22

H:\BNE\Projects-SLR\665-WOL\665.TAH05 Tahmoor GWMP\GIS\66510010 Fig4_22 Predicted Maximum Incremental Drawdown in the Water Table (L1), lower Hawkesbury Sandstone (L3), upper Bulgo Sandstone (L5) and Bulli Seam (L12).mxd



0 1 2 km

Coordinate System:	GDA 1994 MGA Zone 56
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Minor Town

Mine Layout

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MLs 1308, 1376, 1539

TAHMOOR COAL
LONGWALL W3 AND W4
EXTRACTION MANAGEMENT

Predicted Maximum Cumulative Drawdown in the Water Table (L1), lower Hawkesbury Sandstone (L3), upper Bulgo Sandstone (L5) and Bulli Seam (L12)

FIGURE 4-23

H:\BNE\Projects-SLR\665-WOL\665.TAH05 Tahmoor GWMP\GIS\66510010 Fig4_23 Predicted Cumulative Drawdown in the Water Table (L1), lower Hawkesbury Sandstone (L3), upper Bulgo Sandstone (L5) and Bulli Seam (L12).mxd

Appendix E presents hydrographs of simulated groundwater levels for the base case model scenario and alternate predictive models (see **Table 4-1**) to show the relative impact of LW W3-W4. The locations of the predictive hydrographs locations are shown on **Figure 3-12**. Appendix E displays hydrographs from the bore located west to east of LW W3-W4. Some hydrographs were produced using real bore locations (TNC036, TNC040, GW105228, GW10490, GW072402 and GW115860), however, the bores used do not necessarily intersect all stratigraphic units presented in the figure. Results for three additional sites that are not real bores have been extracted from the model. These sites are situated in the middle of the panels LW W3-W4 and 500 m to the east of LW W4. These were developed to provide a guide of the expected drawdown in the lower and upper Hawkesbury Sandstone, the Bulgo Sandstone and the Bulli Coal Seam at these locations. The hydrographs for TNC040, GW105228, and locations in the middle of the panels LW W3-W4 and 500 m to the east of LW W4 are discussed below.

Appendix E (*Figure E4*) displays drawdown at each of these model layers as predicted for the centre of LW W3. Unsurprisingly, drawdown is expected to be greatest in this location with the extraction of LW W3-W4 allowing an additional 148 m of drawdown in the Bulli Coal Seam, 188 m in the Bulgo Sandstone. An additional drawdown (40 m) is predicted for the lower Hawkesbury Sandstone (model layer 3) compared to the 8 m predicted to occur in the upper Hawkesbury (model layer 1). The range in additional drawdown is the greatest in the Lower Hawkesbury Sandstone with approximately 30 m difference in drawdown between predictive models.

Appendix E *(Figure E5)* represents predicted drawdown for the area north of LW W3-W4. The bore used for these hydrographs is GW105228 which is located 450 m north of LW W3 (see **Figure 3-12**). As with the previous hydrograph (**TNC040**), mining in other areas of Tahmoor is predicted to generate regional drawdown in this area. The extraction of LW W3-W4 is expected to have an additional or incremental drawdown of 1.3m in layer 1 representing the upper Hawkesbury Sandstone and up to 13.5 m additional drawdown in model layer 3 representing the lower Hawkesbury Sandstone. An additional 30 m m of drawdown is predicted to occur in the Bulgo Sandstone and in the Bulli Coal Seam. The range in additional drawdown is the greatest in the Bulli Seam and Lower Hawkesbury Sandstone with approximately 30 m and 16 m difference, respectively, in drawdown between predictive models.

Appendix E (Figure E7) displays drawdown at each of these model layers as predicted for the centre of LW W4. Unsurprisingly, drawdown is expected to be greatest in this location with the extraction of LW W3-W4 allowing an additional 278 m of drawdown in the Bulli Coal Seam, 279 m in the Bulgo Sandstone. A drawdown (58 m) is predicted for the lower Hawkesbury Sandstone (model layer 3) compared to the 17 m predicted to occur in the upper Hawkesbury (model layer 1). The range in additional drawdown is the greatest in the upper Hawkesbury Sandstone and Lower Hawkesbury Sandstone with approximately 22 m and 31 m difference, respectively, in drawdown between predictive models.

TNC040 (**Appendix E- Figure E8**) represents the drawdown due to the extraction of LW W3-W4 in areas to the south-east of the longwalls. This location is adjacent to longwalls recently extracted by Tahmoor Mine (LW31 and 32) and therefore shows mining related drawdown from these longwalls. As such, the additional drawdown predicted to occur in this area due to mining at LW W3-W4 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 53 m and 127 m respectively. Simulated water level drawdown in both model scenarios for the Hawkesbury Sandstone are predicted to be 20 m in model layer 3 and 8.3 model layer 1 in this area. The range in additional drawdown is the greatest in the Bulgo Sandstone (17 m), followed by the Bulli Seam and upper Lower Hawkesbury Sandstone with approximately 16 m difference, respectively, in drawdown between predictive models.

Appendix E *(Figure E9)* represents predicted drawdown for the area east of LW W3-W4 where no groundwater monitoring is conducted. The predictive hydrograph location used in this area is located 500 m east of LW W4 (see **Figure 3-12**). The extraction of LW W3-W4 is expected to have 13 m of additional or incremental drawdown in layer 1 representing the upper Hawkesbury Sandstone and up to 20 m additional drawdown in model layer 3 representing the lower Hawkesbury Sandstone. An additional 57 m of drawdown is predicted to occur in the Bulgo Sandstone and in the Bulli Coal Seam. The range in additional drawdown is the greatest in the Bulgo Sandstone and the Bulli Seam followed by the upper Lower Hawkesbury Sandstone with approximately 45 m and 22 m difference in drawdown, respectively, between predictive models.

The results from these figures indicate that the immediate vicinity of LW W3-W4 will experience the greatest drawdown impacts from the extraction of these longwalls.

4.3.4.1 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 AIP (NSW Government, 2012) established a 2 m threshold as the maximum allowable drawdown for 'water supply works' to satisfy the considerations for 'minimal harm'. The mean and maximum predicted drawdown for the private bores within the vicinity of LW W3-W4 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 incremental drawdown is also presented and represents the maximum drawdown predicted to occur due to the extraction of LW W3-W4 in addition to the drawdown predicted to occur due to historic and approved mining for Tahmoor Mine.

Table 4-4 Maximum predicted drawdown at private bores due to LW W3-W4 and cumulative mining

Bore	Easting	Northing	Total bore depth (M)	Model Layer	Max Cumulative DDN (m)		Max. Incremental DDN (m)	
					Base Case	Range	Base Case	Range
GW024750*	277098	6216403	11.9	1	12.2	9.3-10.3	2.6	1.9-2.8
GW035844	277150	6215294	45.7	1	3.3	2.6-3.1	1.1	0.2-1.1
GW064469	277346	6215669	91.0	1	4.9	3.8-4.9	1.6	0.3-1.6
GW072402	277685	6216905	42.0	2	8.0	5.4-8.0	2.3	1.6-2.7
GW104090	278208	6215913	150.5	3	114.5	59.4-114.5	56.1	40.6-56.1
GW105228	278451	6216837	63.0	2	10.5	6.2-10.5	3.6	3.6-5.1
GW105467	244279	6215251	120.0	2	17.5	17.5-27.6	4.5	3.6-5.1
GW105546	276997	6215723	163.0	3	36.7	25.6-36.7	10.5	9.1-11.1
GW115860	278543	6216760	60	2	1.3	1.0-1.3	<1	0.3-0.5

Red shading indicates modelled cumulative drawdown > 2 m

H:\WOL\Projects-SLR-WOL\660-WOL\665.10010 Tahmoor GW RTS\06 SLR Data\05 Modelling\Processing\Drawdown\RegisteredBores_OUTPUT_DDNcalculator_v6TR0104A-104C-104B - 105 -106.xlsx

As shown in **Table 4-4**, maximum incremental (due to the extraction LW W3-W4) drawdown in excess of 2 m is predicted to occur at all bores, except for GW035844, GW064469 and GW115860. The maximum incremental drawdown is estimated to be 56.1 m at GW104090. This is expected as this bore as it directly overlies LW W2 and is adjacent to LW W3.

The cumulative impacts of LW W3-W4 and current and historic mining at Tahmoor Mine are predicted to cause drawdown in excess of 2 m at eight of the nine private bores listed in **Table 4-4**. The greatest predicted drawdown is expected to occur at GW104090, GW105546 and GW105546, with estimates of 114.5 m, 36.7 m and 17.5 m respectively. The predicted drawdown of 12.2 m at GW024750 would be inconsequential because the borehole has collapsed or is blocked (this is unrelated to mining – GeoTerra, 2019). The five remaining bores with a drawdown exceeding 2 m are predicted to experience drawdown in the range of approximately 3 to 11 m.

The extent of predicted drawdown at these bores is consistent with the drawdown due to previous mining activity at Tahmoor Mine 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 to **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, actual 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 6.2.1**.

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 2-2**, 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 outlined in **Table 2-2**.

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 in **Section 3.5.3.2**, there are no springs in the vicinity of LW W3-W4 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.

To gain data on the pre-mining conditions in the strata surrounding LW W1-W2, a bore (WD01) with eight VWPs has been installed above the chain pillar between the longwalls (**Section 3.5.7.1** and **Table 3-5**). This hole was packer tested. It is anticipated that a post-mining bore (WD02) will be installed within the centre of panel and in the chain pillar between the longwalls. The installation of this hole is likely to be completed early in 2022.

Given the proximity of LW W4 to the Nepean Fault Complex, characterisation of the permeability of the fault zone and through the stratigraphic sequence in the vicinity of the northeastern corner of this longwall panel is recommended. SLR also recommended that in-seam drilling is recommended to characterise the offset of the fault splay (at seam level) that is inferred to be present adjacent to the eastern edge of LW W4. Tahmoor Coal are progressing with these investigations, and it is anticipated that this characterisation work will be completed by the commencement of LW W3 extraction.

5.1.4 Groundwater levels and quality

As discussed in **Section 3.5.4**, there are four existing bores with VWPs (TNC036, TNC040, TNC043 and WD01) that are routinely monitored by Tahmoor Coal that will be used to monitor groundwater levels in the aquifers surrounding LW W3-W4. In addition, existing standpipe bores (i.e. those at sites P11, P12, P13, P14, P15, P16 and P17) and one proposed shallow open standpipe shown on **Figure 3-12** will provide data on both groundwater level and quality throughout the extraction of LW W1-W2 and then proposed LW W3-W4. Other monitoring locations that may be added to the network in future would be added to the monitoring programs. In addition, bores WD01 (existing) and WD02 (proposed) will monitor groundwater level response directly above Western Domain workings. The construction details of these bores were included in **Table 3-5**, and the locations are presented on **Figure 3-12**.The proposed 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, pH and temperature) 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, $HC0_3$ $SO_{4,}$;
- Total phosphorus and total nitrogen;
- Dissolved metals: (Fe, Mn, Cu, Pb, Zn, Ni, Al, As, Se, Li, Sr, Co) and total Fe, Mn.

Table 5-1 Groundwater Monitoring Program for LW W3-W4

Feature	Monitoring Frequency		
	Prior to Mining	During Mining	Post Mining
Groundwater Quality bores: P12 P13 P14 P15 P16 P17 (and others that may be installed in future)	Field water quality (EC, pH, temperature) monthly.	Field water quality (EC, pH, temperature) monthly.	Field water quality (EC, pH, temperature) monthly for 24 months following completion of LW W4.
	Laboratory analysis (parameters listed above in Section 5.1.4) monthly.	Laboratory analysis (parameters listed above in Section 5.1.4) monthly.	Laboratory analysis (parameters listed above in Section 5.1.4) monthly for 12 months following the completion of LW W4. This period may be extended (potentially with reduced frequency) as per the decision by the Environmental Response Group.

Feature	Monitoring Frequency		
	Prior to Mining	During Mining	Post Mining
Groundwater Quality for Private Groundwater Bores: GW072402, GW105228, GW105467, GW105546, and GW115860. Any other private bores where access is negotiated with landholder.	Field water quality (EC, pH, temperature) and iron staining (visual observations). Pre-mining testing completed during bore census for LW W3-W4 (GeoTerra, 2021b).	Same as above, on a 3-monthly basis.	Same as above on a 3-monthly basis for 12 months following the completion of LW W4. This period may be extended (potentially with reduced frequency) as per the decision by the Environmental Response Group.
Groundwater Level bores: P11 P12 P13 P14 P15 P16 P17 (and others that may be installed in future) (see Section 5.1.4).	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 for 12 months following the completion of LW W4. This period may be extended (potentially with reduced frequency) as per the decision by the Environmental Response Group.
Groundwater Level for Private Groundwater Bores: GW072402, GW105228, GW105467, GW105546, and GW115860. Any other private bores where access is negotiated with landholder.	SWL (where available) and yield data. Pre-mining testing completed in bore census for LW W3-W4 (GeoTerra, 2021b).	Manual monitoring (flow rate and, where available, standing water level) on a 3-monthly basis.	Manual monitoring (flow rate and, where available, standing water level) on a 3-monthly basis for 12 months following the completion of LW W2. This period may be extended (potentially with reduced frequency) as per the decision by the Environmental Response Group.
Groundwater Pressures bores/VWPs: TNC036; TNC040; WD01; WD02 (once installed) (see Section 5.1.3), and TNC043	Minimum continuous 24-hourly readings with monthly logger download. (except TNC043, which is manually read approximately monthly).	Minimum continuous 24-hourly readings with monthly logger download. (except TNC043, which is manually read approximately monthly).	Minimum continuous 24-hourly readings for minimum period of 12 months after LW W2 completed (except TNC043). Monthly logger download for 12 months following the completion of LW W4. This period may be extended (with reduced frequency) as per the decision by the Environmental Response Group.

5.1.5 Height of groundwater depressurisation

As noted in **Section 5.1.3**, one additional bore ('WD02') will be drilled within the longwall footprint of LW W2. This additional bore, together with WD01, 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).

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 depressurisation, as in **Section 5.1.5**) and groundwater inflows to the mine. This comparison will be included in regular groundwater compliance reporting (e.g. annual reviews and/or 6-monthly reporting).

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 for LWW3-W4 – Groundwater

6.1 Previous Study and Proposed Updates

A Trigger Action Response Plan (TARP) was developed by HydroSimulations (2019) to outline the appropriate actions to monitor and manage any potential subsidence and/or depressurisation related impacts that may result due to the extraction of LW W1-W2. The current TARP considers a baseline variability for groundwater levels at the Western Domain monitoring bores (P12-P14, P16 and P17) and private bores.

As recommended by HydroSimulations (2019) a baseline variability for groundwater quality was to be defined after the commencement of the extraction in the Western Domain using representative pre-mining data at each bore. As outlined in **Section 3.5.5**, Tahmoor has been conducting groundwater quality monitoring at each Western Domain bore since May 2019, giving approximately 15-18 months of data at many sites. This makes it achievable to now define a baseline variability for the groundwater quality parameters outlined in the TARP (**Table 6-2**). The following sections discuss the methodology to develop trigger levels for groundwater quality at each monitoring and private bore, summarizes the proposed trigger values for groundwater quality parameters and discusses any exceedances in groundwater level, yield and quality.

The usage of groundwater quality triggers in the following sections refer to the “outside of baseline variability” stated in the TARP (**Table 6-10**).

6.2 Methodology Development

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 6-10** to **Table 6-13** detail the impact assessment trigger criteria and the appropriate action plan to be enacted should a trigger exceedance occur.

6.2.1 Groundwater Level

Trigger levels were developed following an assessment of available baseline data. Water level triggers were developed in HydroSimulations (2019) based on the maximum observed groundwater drawdown or depressurisation for VWPs in bores TNC036, TNC040, and TNC043, as well as those installed at bore P9.

Trigger levels were developed based on data from the four aforementioned bores and the existing suite of ‘P’ bore (P1 to P8; **Figure 3-12** for locations). Historical data indicated that significant mining-related drawdown or depressurisation is typical in strata deeper than 200 mBG, and drawdown or depressurisation 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 bores that monitor depths greater than 200 m groundwater level monitoring results will be compared to groundwater model predictions on an annual basis comparing actual groundwater levels with predictions. In the event that monitoring data suggests divergence from the predicted trends (i.e. from numerical groundwater modelling predictions), the TARP as outlined in **Table 6-13** 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 does not appear to be reliable. This is exemplified by groundwater levels collected at the 299 m-Bulgo Sandstone piezometer, which, according to collected data, is approximately 400 mAHD, or approximately 160 m above the ground surface – this is not consistent with other pressures in this area.

This TARP also excludes loggers located in the Bulli Coal Seam on the basis that as this is the target coal seam, significant drawdown effects are expected due to dewatering of mine workings. 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.

6.2.1.1 Proposed groundwater level TARP

The following section presents the methodology established to estimate trigger values for groundwater levels at each groundwater monitoring bore in and adjacent to the Western Domain. While the analysis in **Section 3.5** reports exceedances using the approved trigger level developed in the extraction plan for LW W1-W2 (SLR, 2019) and presented in the Water Management Plan, the proposed trigger levels presented in **Table 6-1** and **Appendix E** are suggested to be adopted in place of the earlier and currently approved trigger levels to inform if any exceedances in groundwater level drawdown takes place during extraction of LW W3-W4.

Trigger levels for 'P' bores (i.e. P12-P14 and P16-P17) and VWPs (TNC036, TNC040, TNC043) were developed using the predicted (modelled) groundwater level drawdown for higher trigger levels, with a combination of Level 1 and Level 2 criteria from the approved trigger levels (SLR, 2019).

The TARP Significance Levels (2, 3 and 4) were assigned a trigger corresponding to a calculated groundwater elevation for each groundwater monitoring bores. The minimum groundwater level observed during pre-mining of LW W1 for P bores and groundwater levels in shallow VWPs prior LW W1 were used as references level in the TARP level calculations.

The groundwater trigger level for the TARP Level 2 is based on the approved groundwater TARP (**Table 6-11** and **Table 6-12**) using a 2 m drawdown for P bores and 5 m drawdown for shallow VWPs, based on climate variability as described in **Section 6.2.1.** The trigger level for TARP Level 2 for shallow open standpipes or shallow VWPs was calculated by subtracting the 2 m drawdown and 5 m drawdown respectively, to the minimum observed groundwater level at each bore or piezometer prior to extraction of LW W1. Trigger levels for TARP Level 2 at each groundwater monitoring sites are presented in **Table 6-1**.

The groundwater trigger level for TARP Level 3 at each groundwater site was calculated based on the average between trigger level for TARP Level 2 and Level 4 (methodology for Level 4 described below). Trigger levels for TARP Level 3 are presented in **Table 6-1**.

The groundwater trigger level for TARP Level 4 at each groundwater site was calculated based on the maximum modelled drawdown due to a single deterministic scenario (base case model) between the start of LW W1 and the end of the prediction period (year 2500). The maximum modelled drawdown was then subtracted to the minimum observed groundwater level prior mining at LW W1. Trigger levels for TARP Level 4 are presented in **Table 6-1**.

At locations P12A, P13A, P17 and TNC036 (HBSS-65m) the maximum modelled drawdown due to LW W1-W4 is predicted to be less than 2 m (for P' bores) and 5 m (for TNC036 HBSS-65m), due to their relative distance to later longwalls W3-W4. For these sites, using the average of Level 2-4 and the maximum modelled drawdown for TARP Level 3 and Level 4 is not considered appropriate (i.e. trigger levels for TARP Level 3 and 4 would sit at a higher elevation than trigger level for TARP Level 2). Hence, no change in TARPs groundwater level was made for P12A, P13A, P17, and TNC036-HBSS-65m where the approved groundwater TARP presented in **Table 6-11** and **Table 6-12** should continue to be applied during mining of LW W3-W4.

No changes are proposed to be made to the groundwater TARP levels for the deep VWPs, where the approved groundwater TARP presented in **Table 6-13** should continue to be applied during mining of LW W3-W4.

Table 6-1 Summary of Proposed Trigger Levels for Groundwater Level TARPs

Bore	Groundwater Trigger Level (mAHD)		
	TARP Level 2	TARP Level 3	TARP Level 4
Shallow OSP			
P12A	168.1	See table 6.11	See table 6.11
P12B	168.7	See table 6.11	See table 6.11
P12C	174.3	169.8	165.3
P13A	165.2	163.2	161.2
P13B	164.6	162.6	160.7
P13C	167.8	162.4	157.0
P14A	166.6	164.5	162.3
P14B	164.7	159.2	153.8
P14C	164.7	159.4	154.0
P14D	163.2	157.8	152.4
P15A	162.7	155.7	148.7
P15B	163.2	156.2	149.2
P15C	162.9	155.9	148.9
P16A	209.4	208.8	208.3
P16B	204.4	200.8	197.2
P16C	197.6	190.9	184.2
P17	169.3	170.2	171.1
Shallow VWPs (<200m)			
TNC036 - HBSS-65	204.5*	See table 6.12*	See table 6.12*
TNC036 - HBSS-97	191.3*	185.7*	180*
TNC036 - BGSS-169	192.5*	135.7*	79.0*
TNC040 - WNFM-27	203.3	198.2	193.1
TNC040 - HBSS-65	182.1	175.8	169.5
TNC040 - HBSS-111	#	#	#
TNC043 - HBSS-65	153.7	152.5	151.3
TNC043 - HBSS-111.5	150.6	148.5	146.5
WD01- HBSS - 70	206.2	202.4	198.6

Bore	Groundwater Trigger Level (mAHD)		
	TARP Level 2	TARP Level 3	TARP Level 4
WD01- HBSS - 90	191.4	186.7	182.0
WD01- HBSS - 190	F	F	F
Deep VWPs (>200m)			
TNC036 - BGSS-214	See table 6.13	See table 6.13	See table 6.13
TNC036 - BGSS-298.5	*	*	*
TNC036 - BGSS-412.5	See table 6.13	See table 6.13	See table 6.13
TNC036 - BUSM-463.5	*	*	*
TNC040 - HBSS-225	#	#	#
TNC040 - BHCS-252	#	#	#
TNC040 - BGSS-352	#	#	#
TNC040 - SCSS-482	#	#	#
TNC040 - BUCO-501.9	#	#	#
TNC043 - HBSS-213	#	#	#
TNC043 - BGSS-240	#	#	#
TNC043 - BGSS-332.6	#	#	#
TNC043 - BGSS-405.2	#	#	#
TNC043 - BUCO-476.3	#	#	#
WD01- HBSS - 210	See table 6.13	See table 6.13	See table 6.13
WD01- HBSS - 230	F	F	F
WD01- BGSS - 300	F	F	F
WD01- BGSS - 330	F	F	F
WD01- BGSS - 350	F	F	F
Notes: "#" no data after LW W1			
"*" groundwater data not reliable, but will still be reported on			
"F" Sensors failed during mining of LW W1 and LW W2			

6.2.2 Groundwater Quality

The following section presents the methodology established to estimate trigger values for EC, pH and metals at each groundwater monitoring bore and private bores in the Western Domain. **Table 6-2** presents a summary of the proposed trigger levels. The method for deriving TARPs for groundwater quality remains the same as proposed for LW W1-W2.

6.2.2.1 Salinity

Electrical conductivity (EC) is a measure of salinity and is used for monitoring of changes to groundwater salinity. For most of the shallow bores around the Western Domain, there is only a limited pre-mining record of groundwater salinity (i.e., 2-3 observations). As discussed in **Section 3.5.5**, the trend in EC for the monitoring bores and private bores in the Western Domain is relatively stable between the limited pre-mining record and the longer post-mining (post-LW W1) observation data (**Appendix B**). The current extraction of LW W1 has had no discernible effects on the groundwater salinity in the shallow Hawkesbury Sandstone aquifer.

On this basis, the full available EC dataset to September 2020 was used for each monitoring bore and private bores to derive a single EC trigger level for future monitoring. This trigger has been established for each bore as the maximum observed EC during pre-mining and the early mining period, plus ten percent of that value.

The proposed EC trigger levels are shown in **Table 6-2**.

Table 6-2 Summary of Proposed Trigger Levels for Groundwater Quality TARPs

Bore	Trigger Level			Trigger Level Concentrations (mg/L) for metals											
	EC (µS/cm)	pH lower	pH upper	Fe	Mn	Cu	Pb	Zn	Ni	Al	As	Li	Ba	Sr	Se
P12A	942	5.4	8.1	26.4	1.7	0.0110	0.0044	75.90	0.011	0.06	0.011	0.06	0.3	0.1	0.011
P12B	729	5.0	8.2	15.2	1.3	0.0044	0.0076	50.6	0.011	0.04	0.011	0.04	0.4	0.2	0.011
P12C	528	5.9	9.2	23.1	0.8	0.0034	0.0011	0.90	0.011	0.04	0.011	0.1	0.2	0.1	0.011
P13A	1232	5.2	9.4	69.3	1.5	0.0036	0.0014	0.91	0.011	0.04	0.011	0.03	0.4	0.3	0.011
P13B	1269	5.4	9.6	16.6	1.2	0.0020	0.0011	0.22	0.011	0.06	0.011	0.04	0.2	0.3	0.011
P13C	376	6.3	10.2	46.2	1.4	0.0011	0.0011	0.1	0.011	0.1	0.011	0.02	0.1	0.3	0.011
P14A	396	4.1	9.1	15.4	2.0	0.0022	0.0011	0.21	0.011	0.05	0.011	0.01	0.1	0.1	0.011
P14B	915	4.6	8.8	46.2	0.9	0.0022	0.0011	0.22	0.011	0.04	0.011	0.07	0.1	0.2	0.011
P14C	1881	5.3	9.4	19.8	1.5	0.0011	0.0011	0.04	0.011	0.1	0.011	0.11	0.2	0.4	0.011
P14D	1198	5.5	9.6	11.0	1.9	0.0011	0.0011	0.04	0.011	0.04	0.011	0.35	0.1	0.2	0.011
P16A	1539	4.9	7.8	116.0	3.9	0.0011	0.0011	0.1	0.011	0.04	0.011	0.06	0.3	0.5	0.011
P16B	1180	5.9	9.6	41.8	1.8	0.0011	0.0011	0.03	0.011	0.05	0.011	0.04	0.2	0.1	0.011
P16C	1212	6.2	9.5	46.6	1.6	0.0011	0.0011	0.02	0.011	0.05	0.011	0.1	0.1	0.1	0.011
P17	2019	4.8	8.3	10.6	0.6	0.0011	0.0011	0.2	0.011	0.04	0.011	0.11	0.2	0.7	0.011
GW105546	448	3.5	7.2	37.4	1.6	0.0011	0.0011	0.1	0.011	0.03	0.011	0.011	0.05	0.04	0.011
GW105467	1041	3.7	6.8	77.0	3.9	0.094	0.0019	0.2	0.039	0.04	0.011	0.072	0.1	0.04	0.011
GW105228	1793	4.6	7.1	31.4	2.7	0.0011	0.0011	0.2	0.0181	0.04	0.011	0.026	0.23	0.15	0.011
GW072402	8151	4.7	7.5	63.8	0.9	0.0019	0.0011	0.2	0.011	0.03	0.011	0.157	0.3	0.5	0.011
GW115860	948.2	4.9	7.25	14.85	0.85	0.001	0.001	0.02	0.01	0.02	0.01	0.03	0.3	0.18	0.01

6.2.2.2 pH

As seen in **Section 3.5.5**, pH in the Hawkesbury Sandstone aquifer across the Western Domain is generally near neutral conditions during the pre-mining and mining periods to September 2020. Some areas or bores may experience greater pH fluctuations over a short time than others, such as at P12, P13A, P14C, P16 and GW105467 (**Appendix B**).

Each bore was assigned a lower and upper pH trigger level based on the minimum and maximum pH value recorded in the available dataset minus/plus a pH unit. **Table 6-3** presents the range of data used to develop the lower and upper pH trigger levels at the Western Domain bores. To develop the pH baseline variability threshold, the pH samples recorded during the mining period which were +/- one pH unit above or below the baseline trend were excluded from trigger level calculations (**Table 6-3**). Removing outliers observed during the mining period or any trend in the data different from the baseline period was a method to include as many observed points as available and a conservative approach to identify ongoing or/and future water quality trigger level exceedances at the Western Domain.

Table 6-3 Summary of dataset used to develop the pH triggers at the Western Domain bores

Bore	Period	Comment
Open standpipe monitoring bores		
P12A	Baseline[1]	
P12B	Baseline + Mining	Exclude min/max pH value in Feb 2020 (5.2) and Oct 2020 (8.2)
P12C	Baseline	
P13A	Baseline + Mining	Exclude data from July 2020 to Oct 2020
P13B	Baseline + Mining	
P13C	Baseline + Mining	
P14A	Baseline + Mining	
P14B	Baseline + Mining	
P14C	Baseline + Mining	Exclude max pH in April 2020 (9.4)
P14D	Baseline + Mining	
P16A	Baseline + Mining	Exclude max pH in March 2020 (8.0)
P16B	Baseline	
P16C	Baseline + Mining	Exclude min pH in April 2020 (6.25) and October 2020 (5.82)
P17	Baseline + Mining	
Private Bores		
GW105546	Baseline + Mining	
GW105467	Baseline + Mining	Exclude min pH in Oct 2020 (6.25) and October 2020 (3.74)
GW105228	Baseline + Mining	
GW072402	Baseline + Mining	
GW115860	Mining	

[1] Baseline period (from start of monitoring to November 2019 when extraction of LW1 W1 starts

6.2.2.3 Metals

A single trigger level concentration for metals (sampled on monthly basis) was assigned to the Western Domain monitoring and private bore. Only the dissolved metal concentrations were considered in the trigger level calculations and are shown in **Table 6-2**.The following methods to develop the trigger level concentrations are presented below:

a. The 95th percentile of the pre-mining and mining period data was set as a trigger when the maximum metal concentration was recorded during the mining period.

b. When the maximum metal concentration was recorded during the baseline period, the trigger level was defined as the maximum concentration plus ten percent of that value.

The baseline period for the metals concentrations is very short with a maximum of three records, which makes it challenging to reliably identify any influences of mining on metal concentration in groundwater. The two methods described above were used to gain some flexibility with the data available and specificity in metal concentrations trends.

Method (a) was favoured for bores presenting an increase in concentration following the extraction of LW W1. It allowed to set up a trigger level reasonably high to consider natural fluctuations or variability but also to recognise the recent increase in metal concentrations outside the baseline variability that may be due to mining.

Method (b) was favoured for bores presenting a similar trend during the baseline and mining period. This approach aimed to maximize the use of data available (both pre-mining and mining periods) and then increase the confidence in setting up appropriate trigger levels.

Section 6.3 discusses exceedances of metals in groundwater, and the charts in **Appendix F** illustrate those exceedances in the context of the timeseries and trigger levels derived using the methods described above.

6.2.3 Licensed Groundwater Users

Initial monitoring of licensed groundwater user bores was undertaken in the bore census conducted by GeoTerra (2019) prior to the commencement of LW W1 extraction, and by GeoTerra (2021) prior to the commencement LW W3 extraction. Monitoring of water levels and field sampling of water quality parameters is undertaken on a three-monthly basis during the extraction of LW W1-W2 and LW W3-W4, 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 Subsidence Advisory NSW 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 assessed to be a result of mining-related subsidence the mine will enter into negotiations with the landowner in order to formulate a remediation agreement such as stated in the Mine Subsidence Compensation Act (2017). 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.

6.3 Trigger Level Exceedances

6.3.1 Trigger Level Occurrence

Table 6-4 presents the occurrence of trigger level exceedances in groundwater levels and quality (EC and pH) since the start of mining at Western Domain as per the proposed trigger values and the TARP trigger criteria found respectively in Table 6-2 and Table 6-10. Table 6-4 indicates if the trigger level exceedances is active as of March 2021 (the end of available data) or has returned to within baseline variability. Time series plots with the proposed trigger values (EC and pH) are shown in Appendix F (database up to 15-03-2021).

Table 6-4 Trigger Level exceedances since the start of LW W1: Depressurisation, EC and pH

Bore	Trigger Level Exceedance since start of LW W1			
	Max Drawdown (m)	EC	pH min	pH max
Shallow OSP				
P12A				
P12B				
P12C	Level 4		Level 2(I)	
P13A			Level 2(I)	
P13B				
P13C	Level 4			
P14A				
P14B				
P14C				Level 2(I)
P14D				
P16A				Level 2(I)
P16B	Level 4		Level 2(A)	
P16C	Level 4		Level 2 (A)	
P17				
Private Bores				
GW105546				
GW105467				
GW105228				
GW072402				
GW115860				
Shallow VWPs (<200m)				
TNC036 - HBSS-65	Level 4	#	#	#
TNC036 - HBSS-97	Level 4	#	#	#
TNC036 - BGSS-169	Level 4	#	#	#
TNC040 - WNFM-27		#	#	#
TNC040 - HBSS-65		#	#	#
TNC040 - HBSS-111	no data after LW W1	#	#	#

Bore	Trigger Level Exceedance since start of LW W1			
	Max Drawdown (m)	EC	pH min	pH max
TNC043 - HBSS-65		#		
TNC043 - HBSS-111.5		#	#	#
Deep VWPs (>200m)				
TNC036 - BGSS-214	Level 2	#	#	#
TNC036 - BGSS-298.5	Data not reliable	#	#	#
TNC036 - BGSS-412.5	Level 2	#	#	#
TNC036 - BUSM-463.5	Data not reliable	#	#	#
TNC040 - HBSS-225	no data after LW W1	#	#	#
TNC040 - BHCS-252	no data after LW W1	#	#	#
TNC040 - BGSS-352	no data after LW W1	#	#	#
TNC040 - SCSS-482	no data after LW W1	#	#	#
TNC040 - BUCO-501.9	no data after LW W1	#	#	#
TNC043 - HBSS-213	no data after LW W1	#	#	#
TNC043 - BGSS-240	no data after LW W1	#	#	#
TNC043 - BGSS-332.6	no data after LW W1	#	#	#
TNC043 - BGSS-405.2	no data after LW W1	#	#	#
TNC043 - BUCO-476.3	no data after LW W1	#	#	#

Blank cells represent no trigger exceedance or TARP Level 1 Criteria. # Not applicable. Level X (maximum trigger level exceedances recorded)

(A) Exceedance active as of March 2021 (I) Exceedance inactive as of March 2021, levels have returned within the baseline variability

Table 6-5 presents trigger level exceedances in metals concentrations at the shallow and private bores with the number of times metal concentrations exceeded the baseline variability since LW W1 extraction. Table 6-5 indicates if the trigger level exceedances is active as of January-February 2021 for 'P' groundwater monitoring bores and October 2020 for private bores or has returned within baseline variability. Appendix F shows metal concentration plots at bores exceeding the proposed trigger level since extraction of LW W1.

Table 6-5 Trigger Level Exceedances since the start of LW W1: Metal concentrations

Bore	Trigger Level Exceedance since start of LW W1											
	Fe	Mn	Cu	Pb	Zn	Ni	Al	As	Li	Ba	Sr	Se
Shallow OSP												
P12A	3		1	1								
P12B	1			1			2		1			
P12C		1	1				1					
P13A			1	1			1		4 (A)			
P13B	3								3 (A)	1		
P13C									4 (A)			
P14A	3				1							
P14B										1		
P14C					1				1	1	1	
P14D					1					2	1	
P16A	1				1		2		1			
P16B	3(A)	1(A)	1(A)	1(A)	2(A)		1(A)		1	2(A)	1	
P16C	1	1			2				1			
P17	1				2		1(A)			1	1	
Private Bores												
GW105546		1			1		1			1	1(a)	
GW105467			1(a)	1	1	1	1		1	1	1	
GW105228	1	1(a)			1(a)	1	1		1	1(a)	1	
GW072402		1	1		1		1		1	1	1(a)	
GW115860												
Total Exceedances	17	6	6	5	14	2	12	0	19	12	8	0

(A) Exceedance active as of January/February 2021 (a) Exceedance active as of October 2020

6.3.2 Groundwater Quality

6.3.2.1 Electrical Conductivity (EC)

The following section provides analysis and assessment of the EC trigger exceedances recorded in **Table 6-4** based on the time series plot from **Appendix F**.

No trigger exceedances in EC at the open-stand pipes (P12-P14, P16, and P17) and at the private bores around the Western Domain occurred since the start of longwall W1 extraction. All monitoring bores and private bores are within the TARP level 1 Trigger Criteria (**Table 6-10**).

6.3.2.2 pH

The following section provides analysis and assessment of the pH trigger exceedances recorded in based on **Table** 6-10 and time series plot from **Appendix F**.

Short-term increases and decreases (less than 3 months) resulted in the exceedance of the pH trigger at P12B, P12C, P13A, P14C, P16A, P16B (three times) and P16C (twice) reaching the TARP Level 2 threshold since the start of extraction of LW W1.

A reduction in pH below the baseline variability is observed at P12C in February 2020. A single pH exceedance above the pH trigger is recorded at P14C (April 2020) and P16A (March 2020) before stabilising to baseline level. Exceedances in pH from February to April 2020 are likely driven by weather conditions with groundwater chemistry re-equilibrating following significant rainfall early 2020.

At P16B, the trend in pH shows greater fluctuation during the mining period than during the baseline period (although that observation is hampered by there being only two observations in the pre-mining period) with two exceedances in the lower pH trigger level in July 2020 and September 2020. As the reduction occurred for less than three months, a TARP level 2 Trigger Criteria applies. Six months later, in March 2021, pH at P16B declines below the proposed lower pH trigger (pH = 3.54) and is reported as an active exceedance (TARP Level 2) as of March 2021. The previous pH result is recorded in December 2020 at P16B, with no pH measurements undertaken in January and February 2021 that is probably due to on-site operation (addition of oxalic acid in monitoring bore P16B to release the monitoring pump in January 2021). This event may still be the cause of the later exceedance in March 2021, potentially exacerbating acidity in P16B and may not be reflective of natural groundwater or groundwater impacted by mining. The addition of oxalic acid is used to treat iron-bacteria in a bore which suggests that bore is constructed within an oxygenated environment. A break in the bore casing or local fractures could allow groundwater from the shallower strata (higher oxygen concentration) to mix with the monitored groundwater at P16B (45 m bgl – with less oxygen) and form iron-bacteria. Within the deeper strata (P16C), the lower pH trigger level was breached twice in October 2020 and March 2021 reaching TARP Level 2. At P16, the extraction of LW W1 could locally influence the pH, favouring acidic conditions in the shallow Hawkesbury Sandstone aquifer. The requirement to assess groundwater chemistry at P16B should be evaluated in the next review period.

In October 2020, an increase and decline in pH at P12B and P13A, respectively, is observed, exceeding the upper and lower pH trigger levels. These meet the TARP Level 2 criteria but returned to non-exceedance level as of March 2021. From early 2021, a gradual increase in alkalinity is observed at P12B, P13A and P13B, with a single exceedance in the upper pH trigger level in March 2021 at P13B (pH = 9.64 and 0.04 pH unit above the proposed trigger level).

In addition to the bores where changes in pH have reached defined trigger levels, as noted in GeoTerra (2020i), a reduction in pH was observed at P12A in September 2020 (pH = 5.43) and at P13B in July 2020 (pH = 6.39). These values are just above the lower-bound pH trigger of 5.4 (at both P12A and P13B), hence not triggering the TARP Level 2 criteria.

No exceedances in pH based for the proposed trigger value is recorded at the private bores (GW072402, GW105228, GW105467, GW105546, GW115860). It is worth noting that there is an observed reduction in pH at GW105467 from 5.8 in March 2019 to 3.74 in October 2020, sitting just above the lower pH trigger level (3.7). No further decrease in pH is observed at GW105467, with pH slightly increasing to 4.3 in January 2021. The trend is consistent with that seen in P16C. This decrease could be due to natural and in situ ground conditions with the presence of siderite materials that typically cause acidic conditions in the Hawkesbury Sandstone aquifer but could also be mining-related. Future groundwater quality monitoring will help to better define the hydrogeochemistry at this location.

6.3.2.3 Metals

Monitoring bores

As per the TARP **Table 6-10** and proposed metal trigger level presented in **Table 6-2** and **Appendix F**, all the monitoring bores and private bore at the Western Domain triggered the TARP level 2 criteria for specific metals since the extraction of LW W1 (**Table 6-5**).With respect to the monitoring bores:

- A single short-term (less than 3 months) exceedance in dissolved Iron (Fe) triggered TARP Level 2 at P12A, P12B, P13B, P14A, P16A, P16B, P16C and P17. These exceedances were recorded between March and December 2020, and are possibly due to natural fluctuations rather than mining. P13B presents fluctuations in Fe with three exceedances occurring for less than three months in July 2020, October 2020 and December 2020. Dissolved iron concentrations decline back to baseline levels in January/February 2021for all locations except for P16B where two consecutive exceedances are observed throughout December 2020 and January 2021The occurrence of exceedance in dissolved Iron (Fe) concentrations are identified using the proposed trigger level for dissolved Iron (Fe) and return to non-exceedance levels as of February 2021 except for P16B (exceeding in January 2021).
- A single short-term (less than 3 months) exceedance (TARP Level 2) in Manganese (Mn) is recorded at P12C and P16C during mining at LW W1 with 1 mg/L and 2.3 mg/L compared to the trigger of 0.8 mg/L and 1.6 mg/L respectively.(**Table 6-2**) Concentrations revert to below baseline and the trigger levels in February 2021. Early 2021, a single short-term (less than 3 months) exceedance (TARP Level 2) in Manganese is recorded at P16B and is reported as an active exceedance as of January 2021 (**Table 6-5**). The occurrence of exceedance in Manganese (Mn) concentration is identified using the proposed trigger level for dissolved Manganese (Mn) and return to non-exceedance levels as of February 2021 except for P16B.
- A single short-term (less than 3 months) exceedance in Copper (Cu) is recorded at P12A, P12C and P13A (TARP Level 2) during extraction of LW W1. Copper concentrations appear to be slightly higher during mining than pre-mining conditions suggesting an influence of mining on copper concentration in groundwater, but levels drop back to baseline level in February 2021. In February 2021, a single short-term (less than 3 months) exceedance in Copper (Cu) is recorded at P16B (TARP Level 2) with 0.012 mg/L compared to the conservative proposed trigger level of 0.0011 mg/L. The occurrence of exceedance in Copper (Cu) concentrations are identified using the proposed trigger level for Copper (Cu) and return to non- exceedance levels as of February 2021 except for P16B (exceeding in January 2021).

- A single short-term (less than 3 months) exceedance in Lead (Pb) is recorded at each of P12A, P12B, P13A and P16B (TARP Level 2). At P12 and P13, all exceedances occur after the extraction of LW W1, with the exceedances at P12A and P12B being 0.005 mg/L and 0.01 mg/L respectively. Pb concentrations less than detection limits were recorded during the pre-mining period at these locations. In February 2021, Pb levels drop to low levels from 0.001 to 0.002 mg/L, which are near to baseline levels. In February 2021, a single short-term (less than 3 months) exceedance in Lead (Pb) is recorded at P16B (TARP Level 2) with 0.083 mg/L compared to the conservative proposed trigger level of 0.0011 mg/L. The occurrence of exceedance in Lead (Pb) concentrations are identified using the proposed trigger level for Lead (Pb) and return to non- exceedance levels as of February 2021 except for P16B (exceeding in January 2021).
- A single short-term (less than 3 months) exceedance in Zinc (Zn) is recorded at each of P14A, P14C, P14D, P16A, P16A, P16B, P16C and P17 triggering TARP Level 2. Zn concentration at P16A and P16B peak at 0.085mg/L and 0.034mg/L respectively which are three to five times higher than baseline levels measured between April and September 2019. Concentrations at P16A P14 and P17 sites have declined to baseline levels by February 2021. In January 2021, an increase in Zn concentrations were recorded at P16A with 0.052 mgl/L staying just below the proposed trigger level and at P16B with 0.12 mg/L exceeding the proposed trigger level (0.027 mg/L). The occurrence of exceedance in Zinc (Zn) concentrations are identified using the proposed trigger level for Zinc (Zn) and return to non-exceedance levels as of February 2021 except for P16B (exceeding in January 2021).
- Short-term (less than 3 months) exceedance in Aluminium (Al), Lithium (Li), Barium (Ba) and Strontium (Sr) are recorded between December 2019 and February 2021 at the locations highlighted in **Table 6-5**. Some of these exceedances in metal concentration are likely influenced more by natural fluctuations rather than mining, but others might be related to subsidence effects, with a reduction in these concentration throughout the end of 2020 and early 2021. To note that during extraction of LW W2, in January 2021, Al (Aluminium) concentrations at P16B and P17 peak at 0.05 mg/L and 3.2 mg/L triggering the TARP Level 2. At site P13, Li (Lithium) concentrations at the three intakes A, B and C exceeded the proposed trigger level consecutively in January and February 2021 triggering TARP Level 2.
- Although most of metal concentrations in Aluminium (Al), Lithium (Li), Barium (Ba) and Strontium (Sr) are similar to or below baseline levels in February 2021 some exceedance TARP Level 2 remain active as of February 2021. The occurrence of exceedance in Aluminium (Al), Lithium (Li), Barium (Ba) and Strontium (Sr) concentrations are identified using the proposed trigger level for these associated metals and all return to non-exceedance levels as of February 2021 except for P16B and P17 for Al; P13 for Li and P16B for Ba.

Private bores

At the private bores, some metal exceedances triggering TARP level 2 may be influenced by the extraction of LW W1 compared to baseline level which involve:

- Dissolved Mn at GW105228 with a metal concentration almost doubling in October 2020 compared to March 2019 (from 1.5 to 2.8 mg/L). This bore is 650 m northeast of LW W1, so a mining effect seems unlikely.
- Dissolved Cu at GW105467 with near zero concentrations until July 2020 before increasing to 0.11 mg/L in October 2020.
- Dissolved Zn at GW105467, GW105546, GW105228, GW072402 with a peak in Zn concentration being 2 to 19 times higher than the baseline level between July and October 2020. There is a reduction in Zn concentration in October 2020, except for at GW105228 (which is the second-most distant of these bores from LW W1) showing a maximum value of 0.19 mg/L in Oct 2020.

- There is a slight increase in dissolved Al for all these bores during the extraction of LW W1 (doubling concentration), however as of October 2020 concentrations have declined to below exceedance levels.
- No baseline records for Li, Ba and Sr are available, but trends in metal concentrations shows either a reduction in concentration in October 2020 (i.e. Li at GW105467 and GW072402) or a stable concentration level with a single exceedance sitting just above trigger level for less than three months.

Based on visual observations, there are no significant changes in iron-staining at the private bores between the pre and mining periods at the Western Domain. GW072402 presents strong iron-staining from March 2019 (pre-LW W1) to October 2020 (GeoTerra, 2020a). GW105467 and GW105546 have a moderate to low degree of iron staining since monitoring started in March 2019, prior to LW W1 (GeoTerra, 2020i).

There have been no exceedances of arsenic (As) or selenium (Se).

The summary trigger level exceedances for metals presented in **Table 6-5** indicates that exceedances of lithium (Li), iron (Fe), zinc (Zn) barium (Ba) are most prevalent, followed by aluminium (Al) and strontium (Sr). There has been a return to non-exceedance levels in all cases below the proposed trigger levels, except for the following where the exceedance is the last available data point (January/February 2021 for P bores and October 2020 for private bores):

- P13A, P13B, P13C – Lithium (Li)
- P16B – Iron (Fe), Manganese (Mn), Copper (Cu), Lead (Pb), Zinc (Zn), Aluminium (Al), Barium (Ba)
- P17 – Aluminium (Al)
- GW105546 – strontium (Sr).
- GW105467 – copper (Cu), lead (Pb), barium (Ba).
- GW105228 – manganese (Mn), zinc (Zn), lithium (Li), strontium (Sr), barium (Ba).
- GW072402 – strontium (Sr).

6.3.3 Groundwater Levels

The following section examines trigger level exceedances in groundwater level/pressure at shallow bores and VWPs following the extraction of LW W1, to identify whether any impacts can be attributed to a climatic or mining effect. If a mining effect is likely, further actions may be required as per the TARPs presented from **Table 6-11** to **Table 6-13**.

6.3.3.1 Shallow open standpipe bores

As stated in **Section 3.5.4**, groundwater levels at P12C, P13C, P16B and P16C have exceeded the Level 4 TARP criteria due to on-going reduction in groundwater level (more than 2 m) over a period of six months likely caused by mining of LW W1. **Table 6-6** presents the maximum observed drawdown at the shallow P bores since the start of LW W1 extraction. The maximum drawdown was calculated using a reference groundwater water level which is the groundwater level before the extraction of LW W1 for each bore. At P12C, since mid-April 2020 a drawdown greater than 2 m is observed with limited groundwater responses to rainfall. During June 2020, the Level 3 TARP level criteria was reached with an observed drawdown of about 7.5 m and still no responses to rainfall recharge. The linear reduction in groundwater levels progressed and reach a maximum level over October 2020, six months after breaching the 2 m drawdown with a 9 m observed drawdown. As of December 2020, groundwater trends at P12C trigger Level 4 TARP criteria. Actions for the Level 4 TARP level criteria as per the TARP table **Table 6-11** should be on-going at P12C.

At P13C, the groundwater levels started to decrease from March 2020 to fall below the baseline level in early May 2020. A greater than 2 m drawdown was observed from mid-August 2020, triggering the Level 3 TARP level criteria. Although the rate of drawdown seemed to reduce in July 2020 during near above average rainfall conditions, the rate increased from August 2020. The maximum observed drawdown at P13C since the start of the extraction of LW W1 is observed in October 2020 at 5 m. As the drawdown was more than 2 m for more than three months and does not return to within one meter of the baseline level after six months, actions for the Level 4 TARP level criteria as per the TARP **Table 6-11** should be on-going at P13C.

At P16B, the reduction in the groundwater trend is observed since late April 2020, with a greater than 2 m drawdown occurring in August 2020 and no groundwater level responses to rainfall recharge. The Level 3 TARP level criteria was attained three month later in October 2020 at P16B (GeoTerra, 2020i). The maximum observed drawdown is recorded in October 2020 with a 4.5 m reduction in water levels since extraction of LW W1. As of December 2020, actions for the Level 4 TARP level criteria as per the TARP **Table 6-11** should be on-going at P16B.

At P16C, a similar situation as P16B is observed with a reduction in groundwater levels which started late April 2020. In June 2020, a greater than 2 m drawdown was recorded and reached three months later more than 6m in August 2020, triggering the Level 3 TARP level criteria. The maximum observed drawdown at P16C is attained in October 2020 with a 13 m reduction in water levels likely influenced by the depressurisation of LW W1 extraction. Actions for the Level 4 TARP level criteria as per the TARP **Table 6-11** should be on-going at P12C.

The actions required to satisfy TARP level 4 conditions outlined at the above bore locations are to:

- 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.

While the mid and deeper Hawkesbury Sandstones aquifer at P12, P13 and P16 is likely to be depressurised by the extraction of LW W1, the shallow aquifer at those locations does not appear to be impacted by mining induced drawdown. **Table 6-6** presents a maximum drawdown less than meter 1 m in the shallow strata (P12A, P12B, P13A, P13B, P16A) which meets the Level 1 TARP level criteria (**Table 6-11**).

Table 6-6 Maximum Observed Drawdown (m) at open standpipes P12, P13, P14, P16 and P17 during LW W1 and following the commencement of LW W2

Site	P12			P13			P14				P16			P17
OSP^	A	B	C	A	B	C	A	B	C	D	A	B	C	A
Drawdown [m]*	0.2	0.8	9.5	0.6	1.0	4.9	0.1	1.3	1.5	1.3	1.0	5.7	13.3	0.6

Notes: * Drawdown = Observed maximum drawdown; ^OSP = Standpipe

6.3.3.2 Private Bores

There are no trigger exceedances in groundwater levels at the private bore GW072402 following the extraction of LW W1. The standing water level at other private bores is not available due to pumps and headworks restricting bore access.

As no continuous water level is available for the private bores except for GW072402 and GW104090, a method was established to calculate if any potential on-going drawdown at the private bores could be linked to mining of LW W1, using groundwater levels at nearby monitoring bores. For this methodology the closest monitoring bores to each private bore (1st and 2nd closest monitoring bore) were identified and distance recorded. The available aquifer intakes for the private bore were matched to each of the closest open standpipes (P12-P14, P16, P17) screen elevations and VWP intakes elevations (TNC036).

Using the observed drawdown at the monitoring bore locations, a distance-weighted drawdown was calculated between the first and second closest monitoring locations related to each private bore.

The calculated distance-weighted drawdown gives an estimate of a potential observed drawdown at each private bore. **Table 6-7** presents a summary of the estimated drawdown at private bores using groundwater observations at nearby monitoring locations alongside with estimated available drawdown (in metres) recorded during pre-mining inspections by GeoTerra (2019).

Table 6-7 Weighted-distance average for private bores at Western Domain

Private Bore	Aquifer Intakes (mAHD)	Weighted-distance average drawdown (m)	Observed max drawdown (m)	Estimated 'available drawdown at bore (m)
GW072402	121	5.6	No drawdown	60
GW104090	-		-	111
GW105228	155	1.0	-	40
	143.7	1.2	-	
	136	2.9	-	
GW105467	213	1.0	-	88
	180.3	5.6		
	150.3	11.1		
	122	24.0		
GW105546	160	7.3	-	131
	147.5	18.6		
	130.5	*		
	105.5	*		
	99.5	*		
	72	*		
GW024750	-	#	-	-
GW035844	-	#	-	21.4
GW064469	-	#	-	-
GW115860	-	#	#	-

"-" information not available;

"*" not estimated due to no match with monitoring bore screen elevations;

"#" means no calculation undertaken due to lack of private bore information.

Using the above method, potential groundwater level exceedances for private bore, that may be on-going are outlined:

- At GW105228, the lower aquifer intake (136 mAHD) could be experiencing a 2.9 m drawdown and be breaching the TARP Level 2 conditions.
- At GW105467, the two lower aquifer intakes at 150.3 mAHD and 122 mAHD could be experiencing a drawdown in excess of 2 m, with estimates of 11.1 m and 24 m respectively and this be in breach of the TARP Level 2 conditions.
- At GW105546, the two upper aquifer intakes at 160 mAHD and 147.5 mAHD could be experiencing a drawdown in excess of 2 m, with estimates of 7.3 m and 18.6 m respectively and be breaching the TARP Level 2 conditions.
- At GW072402, no drawdown was identified due to the extraction of LW W1 but the calculated drawdown gives an estimate of 5.6 m based on observed level at nearby monitoring bores making drawdown calculations and groundwater exceedances stated above conservative.
- Once bore GW115860 is surveyed and the relevant data is made available, the same method will be applied (as best as possible) at this location.

From **Table 6-7** the calculated weighted-distance average drawdown at each private bore is considerably less the estimated available drawdown suggesting that if any the calculated reduction in groundwater level would occurred at the private bores due to the extraction of LW W1, the privates bore would not be expected to go dry nor would their yields be expected to be significant reduced. Tahmoor Coal have advised that there are no recent claims of reduced bore yield or effects on water quality by neighbouring bore owners.

6.3.3.3 Shallow VWPs

Groundwater level exceedances at the shallow VWP's are recorded in the TNC036 intakes as per the TARP Level 4 criteria (**Table 6-12**).

Table 6-8 presents the observed maximum drawdown at the shallow VWPs since the extraction of LW W1. TNC036 intakes (HBSS-65, HBSS-97 and BGSS-169) shows a maximum depressurisation greater than 5 m in November 2020 without responding to rainfall recharge while the maximum reduction in water level within the TNC040 and TNC043 intakes ranges from 0.8 m to 1.3 m (TARP Level 1).

As per the latest groundwater level dataset available (ending 11th January 2021), the shallow TNC036 intakes present an observed greater than 5 m depressurisation since:

- Mid-August 2020 for HBSS-65m (more than 6 months)
- May 2020 for HBSS-97m (more than 6 months)
- Mid-April 2020 for HBSS-169m (more than 6 months)

For HBSS-65 m water levels are determined not to be controlled by climatic or anthropogenic factors. The water level does not return to within 5 m of the pre 'event' level (or trend occurring prior to the 'event') after 6 months of the 'event' in HBSS-65 m intakes, then a TARP level 4 applies.

For HBSS-97 m and HBSS-169 m water levels are also assessed not to be controlled by climatic or anthropogenic factors. Water levels do not return to within 5 m of the pre 'event' level (or trend occurring prior to the 'event') after 6 months of the 'event' in these intakes, which trigger a TARP level 4 for both HBSS-97 m and HBSS-169 m intakes. Actions required for a TARP 4 level for the shallow VWPs intakes are:

- 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.

Table 6-8 Maximum Observed Drawdown (m) at Shallow VWPs (TNC036, TNC040, TNC043) during LW W1

Bore	TNC036			TNC040			TNC043	
Piezometer	HBSS-65	HBSS-97	BGSS-169	WNFM-27	HBSS-65	HBSS-111	HBSS-65	HBSS-111.5
Obs max drawdown (m)	9	24	48	0.9	0.6	-	0.8	1.3
"-" no observed drawdown								

6.3.3.4 Deep VWPs

Table 6-9 presents observed and predicted depressurisation at TNC036 since the extraction of LW W1.

Figure 6-1 and **Figure 6-2** present the modelled (blueline) and observed (orange marker) drawdown at TNC036 intakes BGSS-214m and BGSS-412.5m since the start of LW LW1 extraction. The blue dashed line represents a threshold established as per the TARP for deep VWP intakes which is the modelled drawdown plus 30 m (**Table** 6-13). The marked threshold allows to visualise periods when the observed drawdown is not within 30 m of predicted (modelled) drawdown.

At TNC036, the observed depressurisation in the two intakes BGSS-214 and BGSS-412.5 respectively exceed the modelled prediction by 36 m and 14 m **Figure 6-1** shows that the observed drawdown at TNC036-BGSS-214m exceeds the modelled drawdown from March 2020 and the 30 m predicted drawdown since September 2020. As water levels are outside the 30 m predicted drawdown for less than 6 months, TARP Level 2 still applies.

Figure 6-2 shows that the observed drawdown at TNC036-BGSS-412.5m exceeds the modelled drawdown from August 2020 but remains within the 30 m predicted drawdown. A TARP Level 2 applies at TNC036-BGSS-412.5m.

Table 6-9 Maximum Observed and Predicted Drawdown (m) at Deep VWPs (TNC036) during LW W1

TNC036 piezometer	BGSS-214	BGSS-412.5
Observed max drawdown (m)	80	37
Predicted max drawdown (m)	44	23

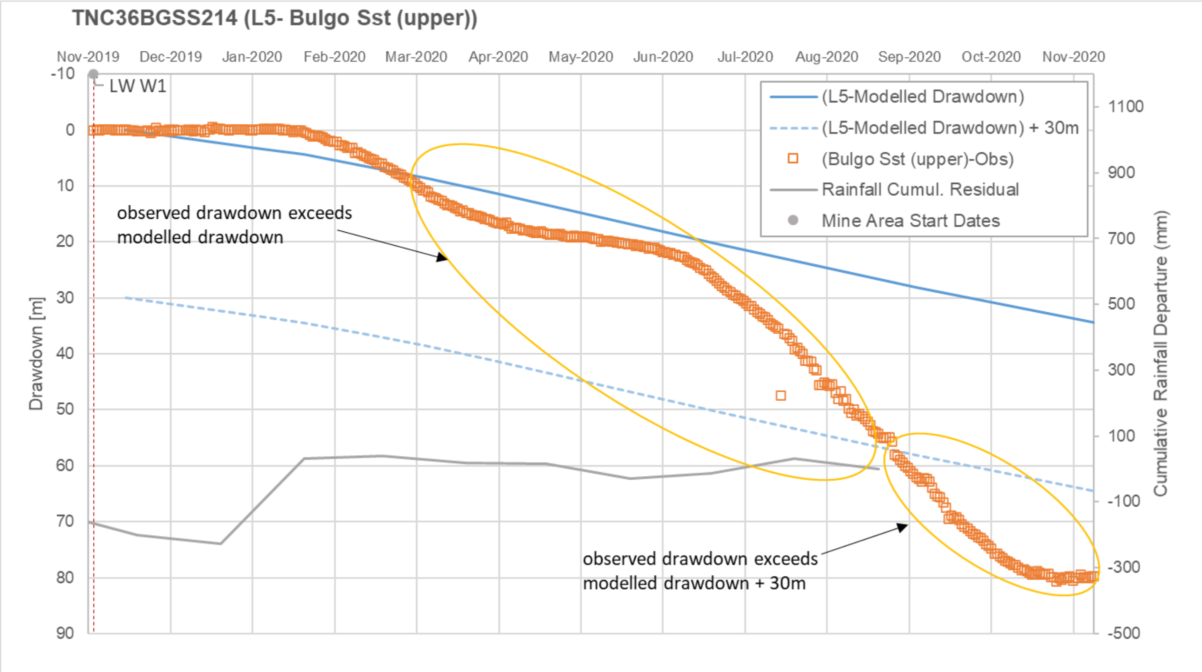

Figure 6-1 Comparison of modelled and observed drawdown at TNC036 (BGSS-214m) with the +30m threshold modelled drawdown

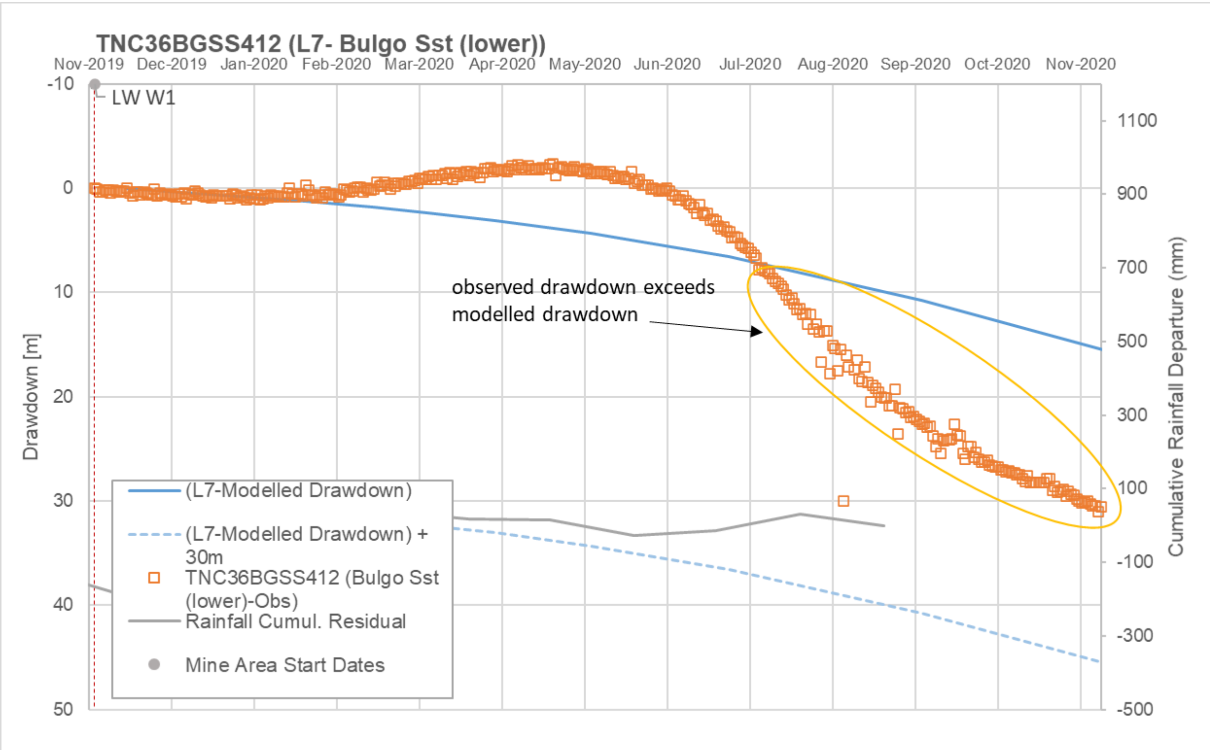

Figure 6-2 Comparison of modelled and observed drawdown at TNC036 (BGSS-412.5m) with the +30m threshold modelled drawdown

6.3.4 Groundwater Yield

GeoTerra (2019) conducted a pre-mining inspection at the private bores in March 2019 followed by quarterly inspections since the start of LW W1 (2020a-i). No significant loss of yield that could impede groundwater use was recorded at the private bores following the extraction of LW W1. The latest available yield information for each private bore is reported in GeoTerra (2021).

6.3.5 Locations of exceedances

This section describes the methodology to establish a baseline variability for groundwater quality and levels for the existing monitoring network in place at the Western Domain and identified any exceedances since the start of LW W1 extraction.

The key conclusions from the trigger exceedances assessment are summarised as follows:

- Ongoing drawdown due to mining along the western side of LW W1 was identified in the mid Hawkesbury Sandstone aquifer at the open standpipes P12C, P13C, P16B and P16C and at TNC036 in the three upper instruments HBSS-65m, HBSS-97m and BGSS-169m. Within the lower Hawkesbury Sandstone, this depressurisation is likely related to strata dilation (leading to an increase in porosity and hence storage) in the above and adjacent to LW W1.
- The decline in groundwater levels at the deeper of the open standpipes is accompanied with short-term reduction in pH at P12C, P16B and P16C and short-term increases (less than 3 months) in metal concentrations, returning to non-exceedance levels as of March 2021, for Cu (P12C), Mn (P12C) and Zn (P16A). Metal concentration exceedances (TARP Level 2) remain active as of January/February 2021 for Li (P13A,B,C), Al (P17) and for several metals (Fe, Mn, Cu, Pb, Zn, Al, Ba) at P16B. Suitability to assess groundwater quality at 16B should be evaluated in the next monitoring period due to the addition of oxalic acid in January 2021 during groundwater sampling.
- The shallower open standpipes at the Western Domain do not show signs of depressurisation due to mining (less than 1 m) but show short-term fluctuation (less than 3 months) in Pb and Cu (P12A, P12B) and in pH (P16A, P13A) returning to non-exceedance levels as of March 2021. To note, the recent increase observed in pH at P13A that may be related to weather conditions and anthropogenic activities conducted on the surface.
- From available information, there is no depressurisation identified at GW072402 then no groundwater level exceedances are recorded at this location. The drawdown at the remaining private bores locations were estimated using the methodology discussed in **Section 6.3.3.2**, with exceedances potentially breaching the TARP Level 2 at GW105467 and GW105546 for various aquifer intakes. These exceedances must be managed with caution as calculations rely on observed groundwater level conditions at nearby monitoring bores and an assumed linear relationship between drawdown and distance to LW W1, and does not take in account local in-situ ground conditions (hydraulic conductivity, transmissivity) at the private/monitoring bores, whose water levels may respond differently to mining. Single exceedances in metal concentrations have been recorded in all private bores after extraction of LW W1. The recent rise in Zn could be linked to mining operations. On-going and future groundwater quality monitoring at the private bores will allow to confidently assess the trend in metal concentration, if correlated to mining or to natural effects. Furthermore, the reduction of pH at GW105467 should be closely monitored.
- Deeper strata at TNC036 (BGSS-214m; BGSS-412.5m) have undergone a clear depressurisation, as expected, but at magnitudes exceeding the predicted modelled drawdown.

6.4 W3-W4 Proposed Groundwater Monitoring Plan and TARPs

Table 6-10 Trigger Action Response Plan – Groundwater Quality Bores P12, P13, P14, P15, P16 and P17 and private bores

Groundwater Quality at monitoring bores and private groundwater bores	<u>**GROUNDWATER QUALITY** – Monitoring bores</u> **LOCATIONS** – (refer to Figure 3-3) <u>Impact sites</u>: P12, P13, P14, P15 P16, and any additional bore(s) (to be drilled). <u>Control sites</u>: P17. **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 12 months following the completion of LW W4. This period may be extended as per the decision by the Environmental Response Group. <u>**GROUNDWATER QUALITY** – Private groundwater bores</u> **LOCATIONS** (refer to Figure 3-3).	**Trigger**	**Action**	**Responses**
		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 trend or response is noted 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 external anthropogenic factors.	Continue monitoring program. Ongoing review of water quality data and consideration of mining and external stresses (in groundwater monthly report).	As defined by the Environmental Response Group.

Feature	Methodology and relevant monitoring	Management		
	<u>Control sites</u>: GW72402, GW105228, GW105467, GW115860 and GW105546 and any other private bores where access is negotiated with landholder **PRE-MINING** - Field water quality (EC, pH) and iron staining. Pre-mining testing completed during bore census (GeoTerra, 2019, 2021b). **DURING MINING** - Field water quality and laboratory analysis on a 3-monthly basis (refer to Section 5.2.1 for parameters). **POST MINING** - Field water quality and laboratory analysis on a 3-monthly basis (refer to Section 5.2.1 for parameters) for 12 months following the completion of LW W4. This period may be extended as per the decision by the Environmental Response Group.		Convene Tahmoor Coal Environmental Response Group to review response.	
		Level 4		
		Medium to long term increase in salinity and/or metals or change in pH outside of baseline 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 external anthropogenic factors.	Continue monitoring and review as per monitoring program. Review of water quality data and consideration of mining and external stresses (in groundwater monthly report).	Report to DPIE (and other relevant agencies) within 7 days of investigation completion (according to Table 6-1 of the Extraction Plan Main Document). <u>For monitoring bores</u>: If it is concluded that there has been a mining-related impact, implement an investigation report. <u>For private groundwater bores</u>: If it is concluded that there has been a mining-related impact, then implement actions in accordance with the make good provisions (Section 6.2.4 of the Water Management Plan) in consultation with the affected landholder.

*the baseline variability was estimated using available data and refers to the proposed trigger levels (refer to section 6.2.2 and Table 6.2)

Table 6-11 Trigger Action Response Plan – Groundwater Levels P12, P13, P14, P15, P16 and P17

Feature	Methodology and relevant monitoring	Management		
		Trigger	**Action**	**Responses**
Groundwater Levels at monitoring bores and private groundwater bores.	**GROUNDWATER LEVEL – Monitoring bores** **LOCATIONS** (refer to Figure 3-3) Impact sites: P12, P13, P14, P15, P16, and any additional bore(s) (to be drilled) Control sites: P17, and possibly P11 **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 12 months following the completion of LW W4. This period may be extended as per the decision by the Environmental Response Group. **GROUNDWATER LEVEL – Private groundwater bores** **LOCATIONS** (refer to Figure 3-3).	**Level 1**		
		Groundwater level remains consistent with baseline variability and/ pre-mining trends with reductions in groundwater level less than two meters and does not trigger Level 2 to Level 4 Significance Level.	Continue monitoring program. Ongoing review of water level data.	No response required
		Level 2		
		Greater than 2 m water level reduction following the commencement of extraction at LW W1 (and LW W2, W3, W4) (refer to Table 6-1 for TARP Significance Level 2). AND 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. Convene Tahmoor Coal Environmental Response Group to review response.	As defined by the Environmental Response Group.
		Level 3		

Feature	Methodology and relevant monitoring	Management		
	Control sites: GW72402, GW105228, GW105467, GW115860 and GW105546 and any other private bores where access is negotiated with landholder **PRE-MINING** – Surface water level (where available) and yield data. Pre-mining testing completed in bore census (GeoTerra, 2019). **DURING MINING** - Manual monitoring (flow rate and, where available, standing water level) on a 3-monthly basis. **POST MINING** - Manual monitoring (flow rate and, where available, standing water level) on a 3-monthly basis for 12 months following the completion of LW W4. This period may be extended as per the decision by the Environmental Response Group.	Water level declines below the water level of TARP Significance Level 3 (refer Table 6-1, calculated as the average of TARP Significance Level 2 and Level 4) following the commencement of extraction at LW W1 (and LW W2, W3 and W4). AND 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 and consideration of mining and external stresses (in groundwater monthly report). Compare against base case and deterministic model scenarios. Convene Tahmoor Coal Environmental Response Group to review response.	As defined by the Environmental Response Group.
		Level 4		
		Water level reduction greater than the maximum modelled drawdown (refer to Table 6-1 for TARP Significance Level 4) following the commencement of extraction at LW W1 (and LW W2, W3 and W4). AND The reduction in water level is determined not to be controlled by climatic or external anthropogenic factors.	Continue monitoring and review as per monitoring program. Review of water level data and consideration of mining and external stresses (in groundwater monthly report) Compare against base case and deterministic model scenarios.	Report to DPIE (and other relevant agencies) 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, implement an investigation report. For private groundwater bores: If it is concluded that there has been a mining-related impact, then implement actions in accordance with the make good provisions (Section 6.2.4 of the Water Management Plan) in consultation with DPIE and the affected landholder.

Table 6-12 Trigger Action Response Plan – Groundwater Pressures TNC036, TNC040, WD01, WD02 - SHALLOW

Feature	Methodology and relevant monitoring	Management		
		Trigger	**Action**	**Responses**
Shallow Groundwater Pressures at VWPs TNC036, TNC040, WD01 and WD02 (once installed).	GROUNDWATER PRESSURE LOCATIONS Impact sites – TNC36, WD01 and WD02 (once installed) (refer to section 5.2.2). Control sites - Groundwater bore/VWP TNC40 (refer to Figure 3-3) 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 12 months following the completion of LW W4. The period may be extended as per the decision by the Environmental Response Group.	**Level 1**		
		No observable mining induced change at VWP intakes located at or above (i.e. shallower than) 200 m depth.	Continue monitoring program. Ongoing review of water level data.	No response required.
		Level 2		
		Greater than 5m water level reduction in VWP intakes located at or above (i.e. shallower than) 200 m depth following the commencement of extraction at LW W1 (and LW W2, W3 and W4) (refer to Table 6-1 for TARP Significance Level 2). AND 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. Convene with Tahmoor Coal Environmental Response Group to review response.	As defined by the Environmental Response Group.
		Level 3		
		Water level declines below the water level of TARP Significance Level 3 (refer Table 6-1, calculated as the average of TARP Significance Level 2 and Level 4) following the commencement of extraction at LW W1 (and LW W2, W3 and W4). AND 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 and consideration of mining and external stresses (in groundwater monthly report). Compare against base case and deterministic model scenarios. Convene Tahmoor Coal Environmental Response Group to review response.	As defined by the Environmental Response Group.

Feature	Methodology and relevant monitoring	Management		
		Level 4		
		Water level reduction greater than the maximum modelled drawdown (refer to Table 6-1 for TARP Significance Level 4) following the commencement of extraction at LW W1 (and LW W2, W3 and W4). AND The reduction in water level is determined not to be controlled by climatic or external anthropogenic factors.	Continue monitoring and review as per monitoring program. Review of water level data and consid-eration of mining and external stresses (in groundwater monthly report). Compare against base case and determ-inistic model scenarios.	Report to DPIE (and other relevant agencies) 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, imple-ment an investigation report.

Table 6-13 Trigger Action Response Plan – Groundwater Pressures TNC036 - DEEP

Feature	Methodology and relevant monitoring	Management		
		Trigger	**Action**	**Responses**
Deep Groundwater Pressures at VWPs TNC036.	<u>**GROUNDWATER PRESSURE**</u> **LOCATIONS** – <u>Impact Sites</u> - TNC36 (refer to Figure 3-3) <u>Control sites</u> - Groundwater bore/VWP TNC040 (refer to Figure 3-3) **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 12 months following the completion of LW W4. This period may be extended as per the decision 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.
		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 to W4 mining effects.	Report to DPIE (and other relevant agencies) within 7 days of investigation completion (according to Table 6-1 of the Extraction Plan Main Document).

Feature	Methodology and relevant monitoring	Management		
				If it is concluded that there has been a mining-related impact, implement an investigation re-port.

7 Recommendations

7.1 Management

Management and monitoring options and the status of these recommendations are described in **Table 7-1**.

Table 7-1 Recommendations and Status

	Recommendation provided by SLR	Status
Management	SCT (2021) discusses the risk of ground movement within the Nepean Fault Complex, noting that the fault splays (based on surface mapping) are less than 50 m from the north-eastern corner of the proposed footprint of LW W4. Further investigation and characterisation of the fault zone in this area, including via drilling from surface and in-seam drilling from existing roadways in the underground mine, is recommended if the current set-back is to remain.	**On-going** Discussion between consultant (SLR, HEC, MSEC, GeoTerra) and Tahmoor Coal on 23 February 2021 to discuss the need for further investigation of the Nepean Fault Complex (NFC). Investigation of NFC started early March; results and assessment will be communicated to DPIE.
	The risks associated with groundwater drawdown and associated with potential basal shears should decline with distance between panels and features. Of the two panels proposed, LW W3 is closest to watercourses (specifically Stonequarry Creek). The current setback is similar in distance to the distance between LW W1 and Matthews Creek (where observed effects on pools have been minimal), but less than the distance between LW W1 and some affected pools (e.g. at site CB) along Cedar Creek.	**On-going** Installation of three shallow piezometers P15 between LW W3 and Stonequarry Creek has occurred, with one more to be installed and packer tested. This will provide further data prior to the proposed extraction of LW W3.
Monitoring	Continue monitoring groundwater levels and quality at P11 and include in TARP as it is relatively close (700-900 m) to LW W3 and W4.	Added to monitoring program (**Section 6.4**)
	Fault characterisation: Boreholes from surface and from underground should be drilled to investigate the displacement of any fault trace in the vicinity of the north-eastern corner of proposed LW W4, noting its proximity to the surface trace (**Figure 3-5**). These bores should be logged, and packer tested to assess for anomalous permeability potentially associated with the Nepean Fault and associated damage zone. This investigation would then allow for adaptive management, i.e. setbacks and changes to longwall geometry, if necessary (above).	**On-going** Characterisation of the inferred nearby fault splay with the drilling of an angled borehole anticipated to commence in May 2021. Logging results will be assessed and based on results; the borehole will be packer tested. Additional boreholes will be drilled if required.
	A second proposed monitoring location in the northern area, north of LW W3 made of a series of open standpipes screened at three depths within the HBSS, adjacent to the closest fault structure mapped by SCT (2021) and south of Stonequarry Creek.	**On-going** Drilling and installation of 3 bores at site P15 has occurred, and the drilling and packer testing of the deepest bore (P15D) is planned for the near future **(Figure 3-12).**

	Recommendation provided by SLR	Status
	Installation of piezometer(s) is planned at a location (P40) adjacent to Cedar Creek monitoring site CB. This site will be installed to monitor the Hawkesbury Sandstone at or just below creek level to inform post-mining groundwater levels and the relationship with surface water levels at monitoring site CB. The piezometer(s) would be installed located on the plateau to the immediate east of the monitoring site. The need for an additional piezometer immediately to the east of monitoring site CD will be reviewed by Tahmoor Coal following a review of surface water and groundwater monitoring data collected and reviewed in August 2021.	Tahmoor Coal has started requesting quotes for the installation of this piezometer and has commenced preparation of the NRAR Groundwater Licence Application. Installation is scheduled for mid-2021. The piezometer is scheduled for installation by 1 August 2021 subject to timely approval of the Groundwater Licence from NRAR.
	Tahmoor Coal are investigating the possibility of installing a monitoring bore (P41) location (**Figure 3-12**) approximately 400 m east of LW W4 and a similar distance to the lower reach of Stonequarry Creek, and within the Nepean Fault Complex mapped by SCT (2021). It is recommended to install a series of open standpipes at three depth intervals within the HBSS at approximately the same elevation as the creek to the east. Access for drilling and bore installations would need further investigations as it is within or adjacent to an urbanised area.	Tahmoor Coal to investigate potential land access for installation of monitoring instruments at P41.

7.2 Data analysis and numerical modelling

We understand that the Tahmoor Mine groundwater model requires further revision within two years of the Tahmoor South Project being determined (approved by the NSW government on 23/04/2021). The current model includes all the relevant detail for simulating Tahmoor Coal mining operations and a representation of neighbouring mines appropriate for cumulative impact assessment. However, many features or aspects require review including:

- Analysis and incorporation of post-mining permeability data from bore WD02 above LW W2.
- Data analysis and conceptualisation require constant review and possible revision. Included in this step are to incorporate relevant findings from the Thirlmere Lakes Research Program (TLRP), and any further refinements to the conceptual model regarding height of connected fracturing, surface cracking and similar subsidence effects relevant to groundwater and surface water.
- The representation of neighbouring mines should be revisited at the next major revision of this model to account for determination of Tahmoor South Project, possible determination of the Dendrobium Extension Project and to account for any changes to the BSO (Appin) mine plan.
- Improvements to model simulation including number of cells, run-time, convergence/stability.
- Updates to representation of model parameters, including hydraulic conductivity and storage properties, including consideration of a pilot point approach to facilitate automated calibration and uncertainty analysis.

These items, and others, are to be addressed in a Groundwater Modelling Plan, required after the approval of the Tahmoor South Project.

8 Definitions and Abbreviations

AIP	Aquifer Interference Policy
BoM	Bureau of Meteorology
BSO	Bulli Seam Operations mine (Appin)
CCL	Consolidated Coal Lease
DPIE	NSW Department of Planning, Industry and Environment
DPIE Water	NSW Department of Planning, Industry and Environment - Water
EC	electrical conductivity (a measure of water salinity)
EES	NSW Department of Planning, Industry and Environment – Environment, Energy and Science
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/yr	millimetres per year
MZ	Management Zone
NFC	Nepean Fault Complex
NRAR	NSW Natural Resources Access Regulator
NSW	New South Wales
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

9 References

ANZECC, 2000; Agriculture and Resource Management Council of Australia and New Zealand and the New Zealand Environment and Conservation Council (ANZECC and ARMCANZ) 2000, Australian and New Zealand guidelines for fresh and marine water quality.

Barnett, B, Townley, L.R., Post, V., Evans, R.E., Hunt, R.J., Peeters, L., Richardson, S., Werner, A.D., Knapton, A. and Boronkay, A., 2012, *Australian Groundwater Modelling Guidelines*. Waterlines report 82, National Water Commission, Canberra.

Department of Primary Industries (DPI) Fisheries, 2015. *Tahmoor Longwalls 31-37 SMP – Fisheries comments.* Email submission made to NSW Trade and Investment, Division of Resources and Energy, 15 April 2015.

EMM, 2021. *Tahmoor Mine Water Licensing Strategy*. Prepared for Tahmoor Coal.

Farrell, J. & M. 2015. *RE: Subsidence Management Plan for Longwalls 31 to 37 Tahmoor Underground Glencore.* Submission made to NSW Trade and Investment, Division of Resources and Energy, March 2015.

Fossen, H. 2016. *Structural Geology* (Second ed.). Cambridge University Press. ISBN: 978-1-107-05764-7

GeoTerra, 2013. *Tahmoor South - Shallow groundwater baseline monitoring*. Report for Tahmoor Coal, document BAR3 - R1A.

GeoTerra, 2014. *Longwall Panels 31 to 37 Streams, Dams and Groundwater Assessment*. Report for Tahmoor Coal, document TA25-R1A, December 2014.

GeoTerra, 2016. *Tahmoor Colliery Longwall 29 Surface Water, Dams and Groundwater End of Panel Monitoring Report.* Report for Tahmoor Coal, document TA28-R1B.

GeoTerra, 2019. *Longwalls West 1 and West 2 Baseline Private Bore Assessment, Tahmoor, NSW.* Report TA36-R1A prepared for Tahmoor Coal Pty. Ltd., May 2019.

GeoTerra, 2020a. *Longwalls West 1 Groundwater Monthly Report, Tahmoor, NSW.* prepared for Tahmoor Coal Pty. Ltd., January 2020.

GeoTerra, 2020b. *Longwalls West 1 Groundwater Monthly Report, Tahmoor, NSW.* prepared for Tahmoor Coal Pty. Ltd., February 2020.

GeoTerra, 2020c. *Longwalls West 1 Groundwater Monthly Report, Tahmoor, NSW.* prepared for Tahmoor Coal Pty. Ltd., March 2020.

GeoTerra, 2020d. *Longwalls West 1 Groundwater Monthly Report, Tahmoor, NSW.* prepared for Tahmoor Coal Pty. Ltd., April 2020.

GeoTerra, 2020e. *Longwalls West 1 Groundwater Monthly Report, Tahmoor, NSW.* prepared for Tahmoor Coal Pty. Ltd., May 2020.

GeoTerra, 2020f. *Longwalls West 1 Groundwater Monthly Report, Tahmoor, NSW.* prepared for Tahmoor Coal Pty. Ltd., June 2020.

GeoTerra, 2020g. *Longwalls West 1 Groundwater Monthly Report, Tahmoor, NSW.* prepared for Tahmoor Coal Pty. Ltd., July 2020.

GeoTerra, 2020h. *Longwalls West 1 Groundwater Monthly Report, Tahmoor, NSW.* prepared for Tahmoor Coal Pty. Ltd., August 2020.

GeoTerra, 2020i. *Longwalls West 1 Groundwater Monthly Report, Tahmoor, NSW.* prepared for Tahmoor Coal Pty. Ltd., November 2020.

GeoTerra, 2020j. *Longwalls West 3 - West 4 Surface Water Technical Report.* prepared for Tahmoor Coal Pty. Ltd., November 2020

GeoTerra, 2021. *Longwalls West 1 Groundwater Monthly Report, Tahmoor, NSW.* prepared for Tahmoor Coal Pty. Ltd., January 2021.

Geoterra, 2021b. Longwalls W3 and W4 Baseline Private Bore Assessment. Report TA41-R1, 13 Jan 2021.

Groundwater Exploration Services [GES], 2019. *TNC40 – Vibrating Wire Piezometer Partial Failure*, 6th February 2019.

Groundwater Exploration Services [GES], 2020. *TNC36 – Vibrating Wire Piezometer Instrumentation Review* 15th October 2020.

Hydro Engineering & Consulting [HEC], 2019. *Tahmoor Mine Extraction Plan LW W1-W2 Surface Water Technical Report.* Report for Tahmoor Coal, doc: J1809-2_R1c.

Hydro Engineering & Consulting [HEC], 2020a. *Tahmoor Mine LW W1 and W2 Surface Water Review – 14 April to 7 May 2020.* Report for Tahmoor Coal, doc: J1809-8_I1b.

Hydro Engineering & Consulting [HEC], 2020b. *Tahmoor Mine LW W1 and W2 Surface Water Review – 8 May to 10 June 2020.* Report for Tahmoor Coal, doc: J1809-8_I2b.

Hydro Engineering & Consulting [HEC], 2020c. *Tahmoor Mine LW W1 and W2 Surface Water Review – 11 June to 17 July 2020.* Report for Tahmoor Coal, doc: J1809-8_I3c.

Hydro Engineering & Consulting [HEC], 2020d. *Tahmoor Mine LW W1 and W2 Surface Water Review – December 2019 to April 2020.* Report for Tahmoor Coal, doc: J1809-8_r1d.

Hydro Engineering & Consulting [HEC], 2021a. *Tahmoor Mine LW W1–W2 Surface Water and Groundwater Investigation*. Report for Tahmoor Coal, doc: J1809-11_r1f_Final.

Hydro Engineering & Consulting [HEC], 2021b. *Tahmoor mine Extraction Plan LW W3–W4 Surface Water Technical Report.* Report for Tahmoor Coal, doc: J1809-10_r1a.

HydroGeologic Inc., MODFLOW SURFACT Software (Version 3.0), Herndon, VA, USA.

HydroGeoLogic, 2020. *Tahmoor South Coal Project Groundwater Assessment Independent Review.* Prepared for NSW Department of Planning and Environment, April 2020.

HydroSimulations, 2018. Tahmoor South Project EIS: Groundwater Assessment. Report HS2018/52 for Tahmoor Coal Pty. Ltd., December 2018.

HydroSimulations/SLR, 2019. Tahmoor LW W1-W2 Extraction Plan: Groundwater Technical Report. Report HS2019/14c for Tahmoor Coal Pty. Ltd., July 2019.

HydroSimulations/SLR, 2020. Tahmoor South Project – Amended Project Report: Groundwater Assessment. Report HS2019/42a_v4.0 for Tahmoor Coal Pty. Ltd., August 2020. IEPMC 2018. *Initial report on specific mining activities at the Metropolitan and Dendrobium coal mines.* 12 November 2018. Available via https://www.chiefscientist.nsw.gov.au/independent-reports/mining-in-the-sydney-drinking-water-catchment.

IEPMC 2018;_Initial report on specific mining activities at the Metropolitan and Dendrobium coal mines, Prepared for the NSW Department of Planning and Environment. Independent Expert Panel for Mining in the Catchment. Available via https://www.chiefscientist.nsw.gov.au/__data/assets/pdf_file/0006/313917/IEPMC-Report_Term-of-Reference-1.pdf

IEPMC 2019a. *Part 1 - Review of specific mining activities at the Metropolitan and Dendrobium coal mines*. October 2019. Available via https://www.chiefscientist.nsw.gov.au/independent-reports/mining-in-the-sydney-drinking-water-catchment. Independent Expert Panel for Mining in the Catchment.

Kembla Coal and Coke Pty. Limited 1993. *Tahmoor North Coal Project An extension of current operations: Environmental Impact Statement Volume 3*. Development application on behalf of Novacoal Australia Pty Limited, 1st February 1993.

Krogh, M. 2015. *Subsidence Management Plan Application for Extraction of Longwalls 31 to 37 at Tahmoor Colliery – Comments*. Submission made to NSW Trade and Investment, Division of Resources and Energy, February 2015.

McNally G. and Evans R. 2007; Impacts of Longwall Mining on surface water and groundwater, Southern Coalfields, NSW. Report prepared for NSW Department of Environment and Climate Change, eWater Cooperative Research Centre, Canberra, Australia.

Mine Subsidence Engineering Consultants [MSEC], 2020. *Subsidence Predictions and Impact Assessment for Natural and Built Features due to the extraction of the proposed Longwalls W3 and W4 in support of the Extraction Plan Application,* Report MSEC1112 | Revision 01 for Tahmoor Coal Pty. Ltd.

Moffitt, R.S., 1999. Southern Coalfield Regional Geology Map, 1:100,000, First Edition. Geological Survey of NSW, Sydney

Morrison K.G, Reynolds J.K. and Wright I.A., 2019; Subsidence Fracturing of Stream Channel from Longwall Coal Mining Causing Upwelling Saline Groundwater and Metal-Enriched Contamination of Surface Waterway. Journal Water Air and Soil Pollution, 230:37. MSEC, 2020. *Tahmoor Coal – Longwalls W3 and W4 - Subsidence Predictions and Impact Assessments for Natural and Built Features due to the extraction of the proposed Longwalls W3 and W4 in support of the Extraction Plan Application*. Report Number MSEC1112 | Revision 01, December 2020.

NSW Government, 2012. *Aquifer Interference Policy*. September 2012.

NSW Government, 2017. *Coal Mine Subsidence Compensation Act 2017 No37 [NSW] Part 2 Compensation for mine subsidence.* August 2017.

NSW Office of Environment and Heritage (OEH), 2015. *RE: Subsidence Management Plan Application for Tahmoor Colliery Longwalls 31 to 37, Glencore.* Submission made to NSW Trade and Investment, Division of Resources and Energy, April 2015.

NSW Office of Water (NOW), 2011a. *Report Card for the Nepean Sandstone Groundwater Source*.

NSW Office of Water (NOW), 2011b. *Water Sharing Plan – Greater Metropolitan Regional Groundwater Sources: Background Document*.
http://www.water.nsw.gov.au/__data/assets/pdf_file/0005/548105/wsp_metro_groundwater_background.pdf

NSW Office of Water (NOW), 2011c. *Water Sharing Plan – Greater Metropolitan Regional Unregulated River Water Sources: Background Document*.
http://www.water.nsw.gov.au/__data/assets/pdf_file/0003/548058/wsp_metro_surface_water_background.pdf

NSW Office of Water (NOW), 2015. *Subsidence Management Plan Application for Extraction of Longwalls 31 to 37 at Tahmoor Colliery*. Submission made to NSW Trade and Investment, Division of Resources and Energy, April 2015.

NSW Trade and Investment, Department of Resources and Energy (DRE), 2015. *Tahmoor Longwalls 31 to 37 SMP – ESU comments & Stop the clock*. Email communication with Tahmoor Coal, 28 April 2015.

Olsen Environmental Consulting (OEC), 1998. *Tahmoor North Underground Extension – Underground Coal Mining to extent the life of Tahmoor Mine, Environmental Impact Statement*. Prepared for Austral Coal, March 1998.

Parsons Brinckerhoff, 2013. *Water Quality Investigation Camden Gas Project*. Report for AGL Upstream Investments, July 2013.

Pells P. and Pells S., 2016; The Water Levels of Thirlmere Lakes – Where did the Water Go, and When Will it Return? IAHR ADP 2016: 20th Congress of the Asia Pacific Division of the International Association of Hydro Environment Engineering & Research, August 28-31 Colombo, Sri Lanka.

Prathapar and Associates, 2019. Peer Review of Tahmoor South Project: Groundwater Assessment. Report for Tahmoor Coal.

PSM, 2017. *Height of cracking - Dendrobium Area 3B, Dendrobium Mine* (No. PSM3021– 002R), Report commissioned by the NSW Department of Planning and Environment.

Rivers SOS, 2015. *RE: Tahmoor Underground SMP Application LWs 31-37.* Submitted by Julie Sheppard on behalf of Rivers SOS to NSW Trade and Investment, Division of Resources and Energy, April 2015.

Rose G., 1966, *Wollongong 1:250 000 Geological Sheet SI/56-09*, 2nd edition, Geological Survey of New South Wales, Sydney.

Ross, J.B. 2014. *Groundwater resource potential of the Triassic Sandstones of the Southern Sydney Basin: an improved understanding*. Aust. Journal of Earth Sciences. https://doi.org/10.1080/08120099.2014.910548.

Russell G.N., Green R.T., Spencer J., Hayes J. (2010) *Thirlmere Lakes groundwater assessment*, NSW Office of Water, Sydney.

Schadler S and Kingsford R.T.,2016; Long term changes to water levels in Thirlmere Lakes – drivers and consequences. Centre for Ecosystem Science, School of Biological, Earth & Environmental Science, University of New South Wales, NSW 2052, Australia.

SCT, 2014. *Longwall 10A Height of Fracture Borehole for Tahmoor South Project – Observations, Measurements, and Interpretation*. Report for Tahmoor Mine, doc TAH4125, March 2014.

SCT, 2018a, *Structure Determinations of the Nepean Fault Adjacent to Tahmoor Mine*. doc TAH4817. May 2018.

SCT, 2018b. *Redbank Creek Shallow Groundwater Investigation*. Report for Tahmoor Coal, doc TAH4909, December 2018.

SCT, 2019a. *Myrtle Creek Characterisation Boreholes* for Tahmoor Coal, doc TAH5004a, December 2019.

SCT, 2020a. *Myrtle Creek CMAP Trial Project: Site 23 Trial Outcomes Report* for Tahmoor Coal, doc TAH5123, January 2020.

SCT, 2020b. *Redbank Creek Characterisation Boreholes* for Tahmoor Coal, doc TAH5004b, March 2020.

SCT, 2020c. *Tahmoor Western Domain, Height of Fracturing Boreholes – Pre and Post Mining Borehole Locations* for Tahmoor Coal, doc TAH5156, March 2020.

SCT, 2020d. *Structure Determinations of the Nepean Fault Adjacent to Picton Rail Tunnel*. Doc TAH5262, December 2020.

SCT, 2021. *Assessment of Rockbar SR17 and Nepean Fault Complex to Support Longwall W3 and W4 Extraction Plan*. Report for Tahmoor Coal, doc TAH5229, February 2021.

Tahmoor Coal, 2019. Coal Resource Recovery Plan: Tahmoor North Western Domain Longwalls W1 and W2. July 2019. http://www.simec.com/media/6911/14-app-e-coal-resource-recovery-plan.pdf

Tammetta, P., 2013. *Estimation of the height of complete groundwater drainage above mined longwall panels*. Groundwater, Volume 51, No. 5, p. 723–734. Paper accepted 2012, published 2013.

University of Wollongong, 2012. *Bioregional Assessment project: Sydney Metropolitan, Southern Rivers and Hawkesbury-Nepean Catchments*. ro.uow.edu.au/cgi/viewcontent.cgi?article=1376&context=smhpapers

Verdon-Kidd, D.C. and Kiem, A.S. 2009. *Nature and causes of protracted droughts in southeast Australia: Comparison between the Federation, WWII, and Big Dry droughts*. Geophysical Research Letters, Volume 36, Issue 22, November 2009.

Vorst, P. 1974. *Geomporphic Environment and Evolution of Thirlmere Lakes, NSW*. Honours Thesis, Macquarie University.

Wollondilly Shire Council, 2015. *Submission on Subsidence Management Plan Application*. Submission made to NSW Trade and Investment, Division of Resources and Energy, March 2015.

Xstrata Coal, 2011. *TNC036 - Borehole Report*; *Tahmoor North Surface Exploration Program*. Report for Tahmoor Colliery, May 2011.

APPENDIX A

Hydraulic conductivity data from field testing

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This information has been retracted
- For more information contact Tahmoor Coal