SOUTH32 Illawarra Metallurgical Coal

LONGWALLS 709 TO 711 AND 905 WATER MANAGEMENT PLAN

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DOCUMENT REVISION LOG

Persons authorising this Plan

Name	Title	Date
Gary Brassington	Manager Approvals	October 2021

Document Revisions

Revision	Description of Changes	Date
ICH Document		
1.0	Original Document	July 2021
1.1	Updated to address feedback from Agencies	October 2021

Persons involved in the review of this Plan

Name	Title	Company	Exp (yrs)
Cody Brady	Principal Approvals	South32	5
Gary Brassington	Manager Approvals	South32	25
Josh Carlon	Coordinator Environment	South32	12
Scott Ellerton	Infrastructure Engineer	South32	7

1. INTRODUCTION

1.1 Project Background

South32 Illawarra Metallurgical Coal (IMC) operates the Bulli Seam Operations (BSO) Appin Mine, extracting hard coking coal used for steel production.

On 22 December 2011 the Planning and Assessment Commission (PAC), under delegation of the Minister for Planning, approved BSO (MP 08_0150) under Part 3A of the *Environmental Planning and Assessment Act 1979* (EP&A Act) to continue mining operations until 2041.

This Water Management Plan (WMP) supports the Longwalls 709 to 711 and 905 Extraction Plan for mining of coal in Appin Areas (AA) 7 and 9 mining domains. The relationship between this WMP and the other components of the Extraction Plan is shown in Figure 1 of the Extraction Plan.

1.2 Scope

This WMP has been prepared in accordance with the BSO Approval (MP 08_0150) Condition 5 (h), Schedule 3 as follows:

> 5. The Proponent shall prepare and implement an Extraction Plan for first and second workings within each longwall mining domain to the satisfaction of the Secretary. Each extraction plan must:
>
>   h) include a Water Management Plan, which has been prepared in consultation with OEH , SCA and (NOW), which provides for the management of the potential impacts and/or environmental consequences of the proposed second workings on watercourses and aquifers, including:
>
>   - surface and groundwater impact assessment criteria, including trigger levels for investigating any potentially adverse impacts on water resources or water quality;
>   - a program to monitor and report stream flows and assess any changes resulting from subsidence impacts;
>   - a program to monitor and report ground water inflows to underground workings; and
>   - a program to predict, manage and monitor impacts on groundwater bores on privately owned land.

The Study Area for the Extraction Plan is defined in accordance with MSEC (2021) as the surface area predicted to be affected by the proposed mining of Longwalls 709 to 711 and 905 and encompasses the areas bounded by the following limits:

- A 35^{o} angle of draw line from the maximum depth of cover, which equates to a horizontal distance varying between 530 m and 750 m around the limits of the proposed extraction areas for Longwalls 709 to 711 and 905, and
- The predicted limit of vertical subsidence, taken as the 20 mm subsidence contour, resulting from the extraction of the proposed Longwalls 709 to 711 and 905.

Additionally, features potentially sensitive to far field movements, which includes horizontal, valley closure and upsidence movements that may be outside the 20 mm subsidence zone or 35° angle of draw line have been assessed.

1.3 Objectives

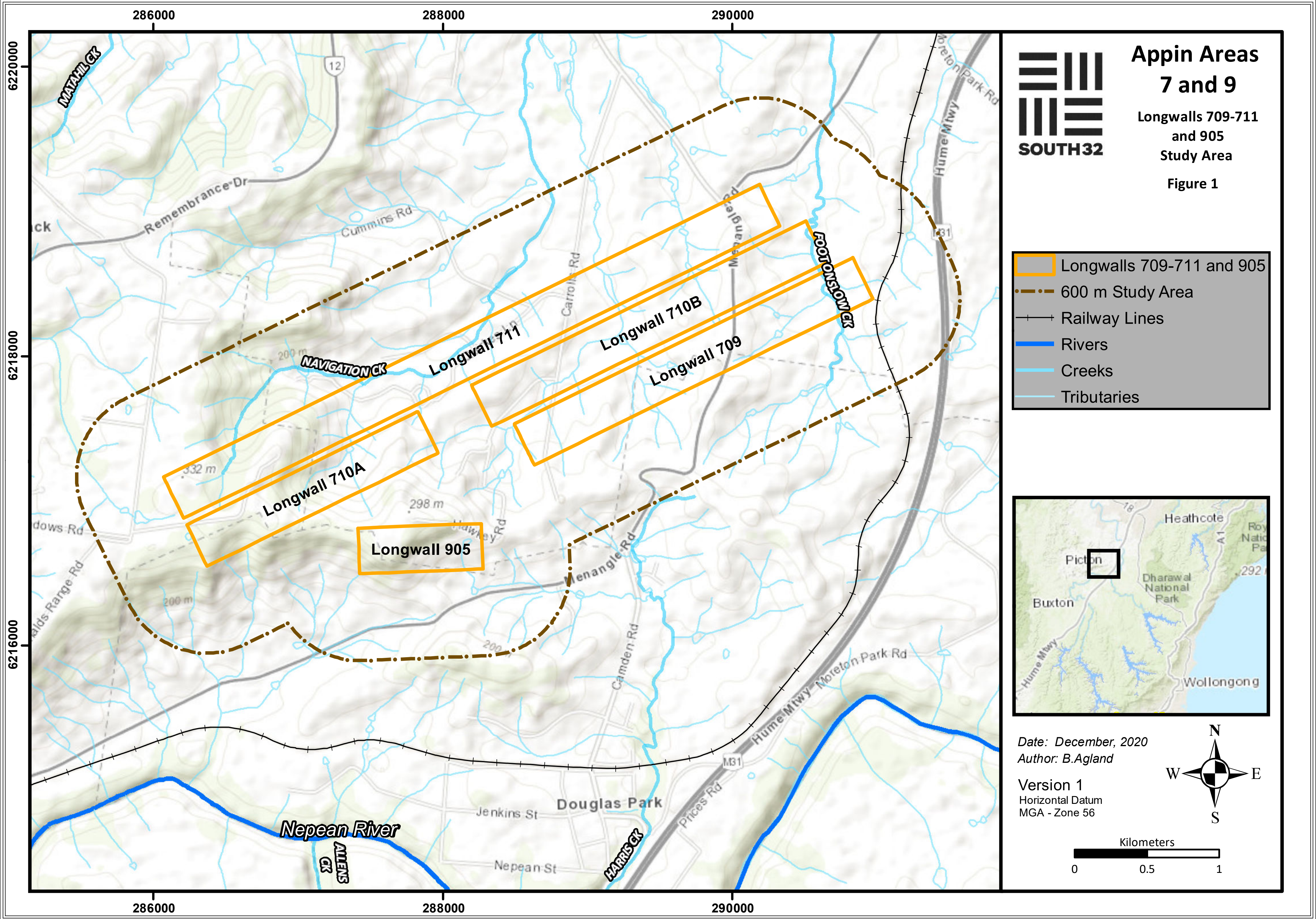
The objectives of this WMP are to identify at risk surface water and groundwater features and characteristics within the Longwalls 709 to 711 and 905 Study Area and to manage the potential impacts and/or environmental consequences of the proposed workings on watercourses and aquifers.

1.4 Consultation

This WMP will be developed in consultation with:

- Biodiversity Conservation and Science Directorate (BSC);
- Natural Resources Access Regulator (NRAR); and
- WaterNSW.

South32 will make the WMP and associated documentation publicly available on the South32 website in accordance with Condition 11, Schedule 6 of the BSO Approval.



Appin Areas 7 and 9
Longwalls 709-711 and 905 Study Area
Figure 1
SOUTH32
Longwalls 709-711 and 905
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Moreton Park Rd
Prices Rd
Douglas Park
Jenkins St
Nepean St
Heathcote
Picton
Buxton
Dharawal National Park
Wollongong
Date: December, 2020
Author: B.Agland
Version 1
Horizontal Datum
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2. STATUTORY REQUIREMENTS

Extraction of coal from Longwalls 709 to 711 and 905 will be in accordance with the conditions set out in the BSO Approval, applicable legislation as detailed in Section 2.2 and the requirements of relevant licences and permits, including conditions attached to mining leases.

2.1 BSO Approval

Condition 5 (h), Schedule 3 of the BSO Approval requires the preparation of a WMP to manage the potential impacts and/or environmental consequences of the proposed second workings on groundwater and surface water features in the Study Area, including the Nepean River.

This WMP also addresses the requirements detailed in Condition 6 Schedule 3 and Condition 2, Schedule 6 of the BSO Approval as shown in Table 1.

Due consideration has been given to all the BSO Approval Conditions in the preparation of this WMP, including those relating to auditing, rehabilitation and environmental management.

Table 1 Management Plan Requirements

Project Approval Conditions	Relevant WMP Section
Condition 6, Schedule 3 The Proponent shall ensure that the management plans required under Condition 5 (g)-(l) above include:	
a) an assessment of the potential environmental consequences of the Extraction Plan, incorporating any relevant information that has been obtained since this approval;	Section 0
b) a detailed description of the measures that would be implemented to remediate predicted impacts.	Section 0
Condition 2, Schedule 6 The Proponent shall ensure that the management plans required under this approval are prepared in accordance with any relevant guidelines, and include:	
(a) detailed baseline data;	Section 3
(b) a description of:	
- the relevant statutory requirements (including any relevant approval, licence or lease conditions);	Section 2
- any relevant limits or performance measures/criteria;	Section 5

- the specific performance indicators that are proposed to be used to judge the performance of, or guide the implementation of, the project or any management measures;	Section 5 to 8
(c) a description of the measures that would be implemented to comply with the relevant statutory, limits, requirements or performance measures/criteria;	Section 5 to 8
(d) a program to monitor and report on the: - impacts and environmental performance of the project; - effectiveness of any management measures (see c above);	Section 6
(e) a contingency plan to manage any predicted impacts and their consequences and to ensure that ongoing impacts reduce to levels below relevant impact assessment criteria as quickly as possible;	Section 8
(f) a program to investigate and implement ways to improve the environmental performance of the project over time;	Section 6
(g) a protocol for managing and reporting any: - incidents; - complaints; - non-compliances with statutory requirements; and - exceedances of the impact assessment criteria and/or performance criteria; and	Section 9
(h) a protocol for periodic review of the plan.	Section 10

2.2 Legislation and Guidelines

Legislation applicable to water, erosion and sediment control management may include but is not limited to:

- *Protection of the Environment Operations Act 1997* (POEO Act);
- Protection and the Environment Operations (Underground Petroleum Storage Systems) Regulation 2014;
- *Environmental Planning and Assessment Act 1979 (EP&A Act)*;
- *Water Act 1912*;
- *Water Management Act 2000*;
- Water Management (General) Regulation 2018;
- *Mining Act 1992*;
- *Water NSW Act 2014*;
- Sydney Water Regulation 2017;
- *Soil Conservation Act 1938*; and
- National Environment Protection (National Pollutant Inventory) Measure 1998.

2.3 Relevant Leases and Licences

The following licences or permits may be applicable to South32's operations in AA7 and 9:

- Mining Leases as per Table 2.
- Environment Protection Licence (EPL) 2504 which applies to BSO, including Appin and West Cliff Mines. A copy of the licence can be accessed at the EPA website via the following link http://www.epa.nsw.gov.au/prpoeo/index.htm
- BSO Mining Operation Plan (MOP) 1/10/2020 to 30/09/2024 (V1.3).
- Water Access Licences (WALs) issued by the NSW DPIE - Water (formerly the Department of Industry - Water) under the *NSW Water Management Act, 2000*, including WAL 36481, 36477 and 37464 under the *Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources 2011* and WAL 30145 and 35519 under the *Water Sharing Plan for the Greater Metropolitan Region Unregulated River Water Sources 2011*.
- All relevant Occupational Health, Safety, Environment and Community approvals.
- Any additional leases, licences and approvals resulting from the BSO Approval.

Table 2 Appin Mine Leases, Licences and Other Reference Documents

Mining Lease - Document Number	Start	Finish
CCL 767	29 Oct 1991	08 Jul 2029
CL 388	22 Jan 1992	22 Jan 2034
ML 1382	20 Dec 1995	20 Dec 2037
ML 1433	24 Jul 1998	23 Jul 2019[1]
ML 1678	27 Sep 2012	26 Sep 2033

[1] Application for the renewal of Mining Lease 1433 which was lodged with the NSW Department of Planning and Environment – Division of Resources and Geoscience (Division) on 18 July 2018.

3. BASELINE ASSESSMENT

Baseline groundwater (Heritage Computing, 2009) and surface water assessments (Gilbert and Associates, 2009) were undertaken in support of the BSO Environmental Assessment (EA). The Study Area for these assessments included the Longwalls 709 to 711 and 905 Study Area.

Supplementary Assessments for groundwater (SLR 2021a) (refer Attachment A) and surface water (SLR 2021b) (refer Attachment B) were undertaken for the purposes of this Extraction Plan.

The rivers within the Appin Mine area generally flow in a northerly direction and have perennial flows influenced by dam releases, catchment runoff and baseflow contributions from the incised Hawkesbury Sandstone. There are no drinking water catchment areas, or declared special areas within the Study Area. The Hawksbury-Nepean Catchment covers approximately 21,400 km^2.

3.1 Nepean River

The closest river is the Nepean River, which is 1.5 km south of the Longwalls 709 to 711 and 905 (MSEC, 2021). The Longwalls 709 to 711 and 905 Study Area includes drainage lines which predominately flow into the Nepean River.

Water flows from the Nepean River are derived from a number of sources and include flows from catchment areas, licensed discharges, including Appin and Tahmoor Mines, and runoff from agricultural and urban areas.

Water flows in the Nepean River:

- Vary greatly and are highly responsive to rain events due to the significant areas of catchment.
- Regulated flows from upstream dams and baseflow contributions where incised into Hawkesbury Sandstone.
- Natural flow within the Nepean River and its associated watercourses have been significantly altered by water storages such as dams and weirs. Some natural catchment flows are retained by large storage dams upstream of Appin Mine for the purpose of the Sydney water supply system. Water is also retained by numerous farm dams within the local part of the Nepean River catchment.
- Flows in a northerly direction, with flow of around 310 ML/day (Maldon Weir) since 2010.

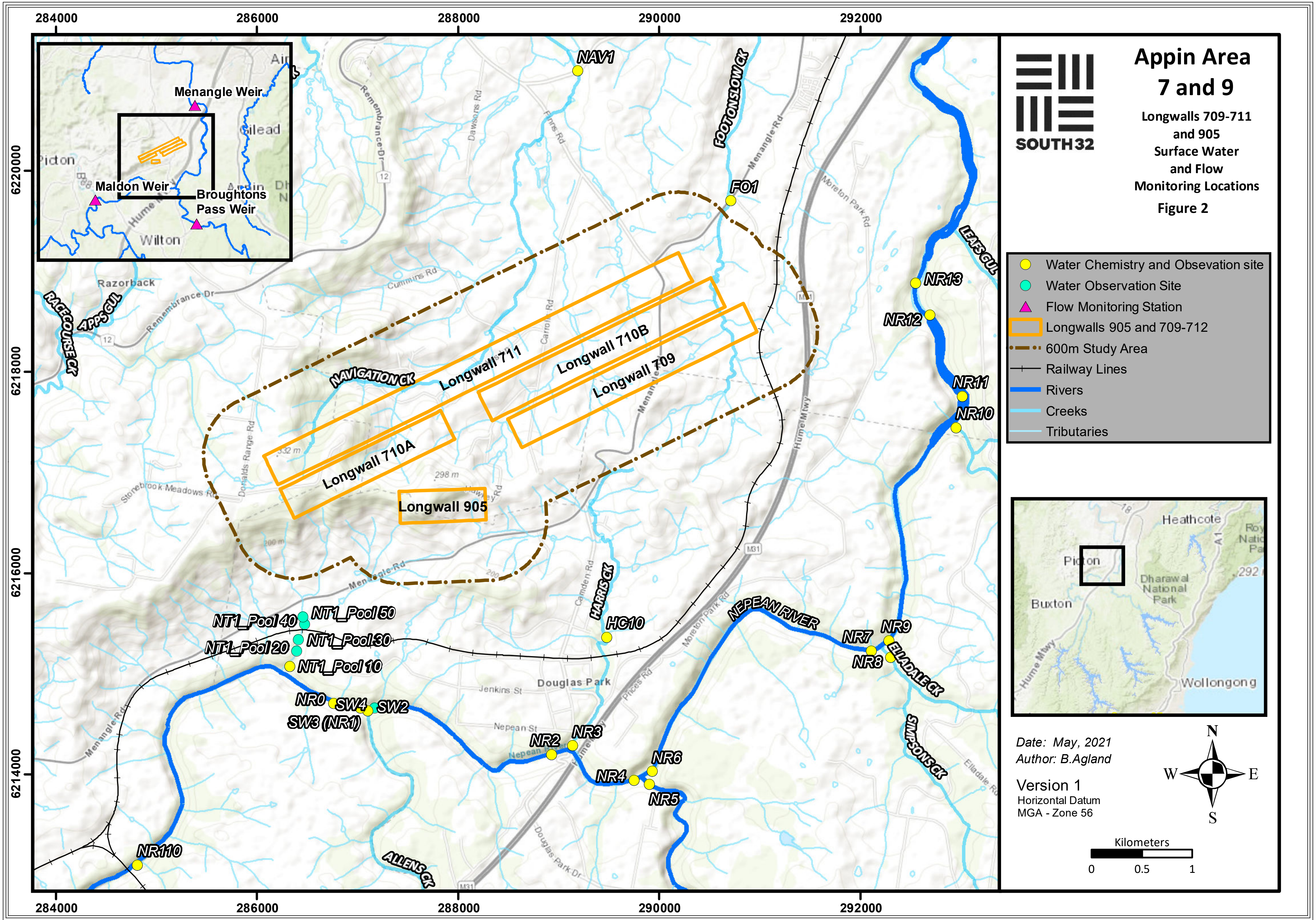
Surface water monitoring is conducted at the main rivers at government stream gauges (Maldon, Menangle and Broughtons Weirs). The locations of the Maldon, Menangle and Broughtons Pass gauging sites are included in Figure 2. These flow monitoring stations are located on the Cataract or Nepean River, being directly upstream and downstream of the approved BSO footprint. Flow monitoring on the Cataract River at Broughtons Pass Weir measures the flow of the major tributary input to Nepean River between the two Nepean River flow stations. The approach to monitoring of flow for the longwalls is proposed to be the same as for mining of the previous AA7 and 9 longwalls. Figure 2 shows the location of the existing water quality monitoring sites.

Daily flow records for Maldon, Menangle and Broughtons Pass weirs from 1990 have been assessed in order to study the dry weather recessions in the Nepean River adjacent to the proposed mining areas. The difference in flows should be equivalent to runoff from all catchments between these two weirs responding to local rainfall minus any abstractions by licensed pumps in the River.

The Nepean River is a 'gaining river' in terms of surface water - groundwater interaction. The potential for infiltration of water into the groundwater system is very low as the Nepean River lies in a well incised gorge which represents the regional low point in the piezometric surface (SLR 2021b). The potential for sub-bed diversion of surface water is very low as the Nepean River is flooded and the gradient is very flat, significantly removing the effects of gravity to force surface flow through any fracture network that develops. Water levels in the Nepean River and its tributaries are monitored using observations and measured benchmarks. The water level is recorded before, during and after mining and is assessed against catchment rainfall and discharges from the WaterNSW controlled weirs. This method of monitoring has been used for the previous AA7 and 9 and will be implemented for the proposed longwalls.

IMC also conducts monitoring of surface water levels and quality at the major rivers as well as creeks and tributaries across the site and to the north. This includes monitoring of ponded water (pools) along the Georges River and Nepean River. Surface water monitoring has been undertaken at the site for a baseline period between 2002 – 2020.

Water quality monitoring of the Nepean River and tributaries within the Study Area are shown in Table 3.


Appin Area 7 and 9
Longwalls 709-711 and 905 Surface Water and Flow Monitoring Locations
Figure 2
SOUTH32
Water Chemistry and Obsevation site
Water Observation Site
Flow Monitoring Station
Longwalls 905 and 709-712
600m Study Area
Railway Lines
Rivers
Creeks
Tributaries
Date: May, 2021
Author: B.Agland
Version 1
Horizontal Datum MGA - Zone 56
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Kilometers
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284000
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Menangle Weir
Maldon Weir
Broughtons Pass Weir
Picton
Wilton
Gilead
Razorback
Heathcote
Dharawal National Park
Buxton
Wollongong
Longwall 711
Longwall 710B
Longwall 709
Longwall 710A
Longwall 905
NAVIGATION CK
FOOTONSLOW CK
HARRIS CK
NEPEAN RIVER
ELLADALE CK
SIMPSONS CK
ALLENS CK
LEAFS GUL
APPS GUL
RACECOURSE CK
NAV1
FO1
NR13
NR12
NR11
NR10
NR9
NR7
NR8
HC10
NT1_Pool 50
NT1_Pool 40
NT1_Pool 30
NT1_Pool 20
NT1_Pool 10
NR0
SW4
SW2
SW3 (NR1)
NR2
NR3
NR4
NR5
NR6
NR110
Douglas Park
Remembrance Dr
Menangle Rd
Cummins Rd
Camden Rd
Moreton Park Rd
Hume Mtwy
Donalds Range Rd
Stonebrook Meadows Rd
Jenkins St
Nepean St
Douglas Park Dr
Prices Rd
Elladale Rd
Dawsons Rd
Finns Rd
Carroll Rd

Table 3 Baseline Water Quality Data (SLR 2020b)

River	EC (uS/cm)		pH		DO (%)		TDS (mg/l)		Fe (mg/L)		Mn (mg/L)	
	Average	St.Dev.	Average	St.Dev.	Average	St.Dev.	Average	St.Dev.	Average	St.Dev.	Average	St.Dev.
Nepean River												
NR110	319	147	7.9	0.3	90.5	14.8	171	76	0.3	0.2	0.03	0.02
NR0	378	173	7.9	0.5	89.5	13.2	208	89	0.3	0.2	0.3	0.02
NR4	223	104	7.6	0.4	85.7	18.4	128	57.8	0.4	0.2	0.3	0.01
NR12	186	67	7.4	0.3	87.2	10.1	107	39	0.4	0.1	0.3	0.01
NR13	182	55	7.4	0.3	85.7	12.6	105	31	0.4	0.1	0.3	0.01
NR50	296	240	7.6	0.4	84.1	19.7	167	135	0.4	0.4	0.5	0.09
Allens Creek - Perturbation												
SW2	704	229	8.1	0.4	95.7	18.4	394	151	0.5	0.4	0.02	0.02
Cataract River - 169Perturbation												
NR5	169	118	7.2	0.5	73.1	29.6	97	61	0.7	0.8	0.08	0.12
Elladale Creek - Perturbation												
NR8	1640	1229	7.6	0.3	72.4	20.5	909	696	0.8	0.5	0.32	0.82

Ousedale Creek - Perturbation												
NR10	1486	1007	7.8	0.5	91.4	13.9	805	548	0.6	1.4	0.05	0.32
Menangle Creek - Perturbation												
NR40	1376	772	7.7	0.4	54.1	31.7	727	411	2.1	2.0	1.1	1.6
Foot Onslow Creek												
F01	1616	901	8.0	0.4	73.5	22.3	909	525	1.5	2.0	0.3	0.4
Navigation Creek												
NAV1	2565	1943	7.6	0.4	27.8	21.4	1470	1124	5.1	6.0	1.8	1.0
Harris Creek												
HC10	1561	688	7.9	0.3	81.5	25.0	935	425	0.7	2.3	0.2	0.4
NR3	1550	956	7.9	0.3	53.1	26.9	864	531	0.7	1.1	0.5	0.9

3.2 Watercourses within the Study Area

Minor creeks and tributaries of the Nepean River are present across the Appin Mine area. This includes the headwaters of Navigation Creek, Navigation Creek Tributary 1, Foot Onslow Creek and Harris Creek that are third order streams within the Study Area.

Watercourses within the Study Area have upper reaches with shallow incisions into the surface soils, which have been derived from the Wianamatta Group, and steep natural gradients ranging from 2-40%. The lower reaches of these creeks have substantial incisions into the surface soils, with exposed sandstone platforms in the bases and rock outcropping in the valley sides. Natural gradients of third order streams range from 0.5-4%.

Watercourses within the Study Area contribute to a small portion of the total Hawkesbury-Nepean Catchment (<0.2%) with runoff from predominately cleared, agricultural land with small pockets of remnant vegetation. The creeks are largely ephemeral, but pools have naturally formed in some areas. Like the receiving Nepean River, flows within ephemeral creeks have been altered by farm dams which intersect the drainage lines at a number of locations. Runoff from within the catchments is influenced by input of nutrients from adjacent farmland and salinity from the marine sediments of the Wianamatta Shale (SLR 2021b).

The creeks that have third order sections located within the Study Area or within 600 m of the proposed longwalls are Foot Onslow Creek, Harris Creek, Navigation Creek and Navigation Creek Tributary 1. There are no creeks with sections greater than third order located within the Study Area or within 600 m of the proposed longwalls.

A summary of the third order creeks that are located within the Study Area are provided in Table 4.

Table 4 Third order creeks located within the Study Area

Name	Location	Total length of third order section above the mining area (km)	Total length of third order section within the Study Area (km)
Foot Onslow Creek	Directly above Longwalls 708B, 709 and 710B	1.3	2.1
Harris Creek	Outside mining area, adjacent to Longwall 706	0.04	0.4
Navigation Creek	Directly above Longwall 711	1.2	2.1
Navigation Creek Tributary 1	Directly above Longwalls 709, 710B and 711	1.7	2.2

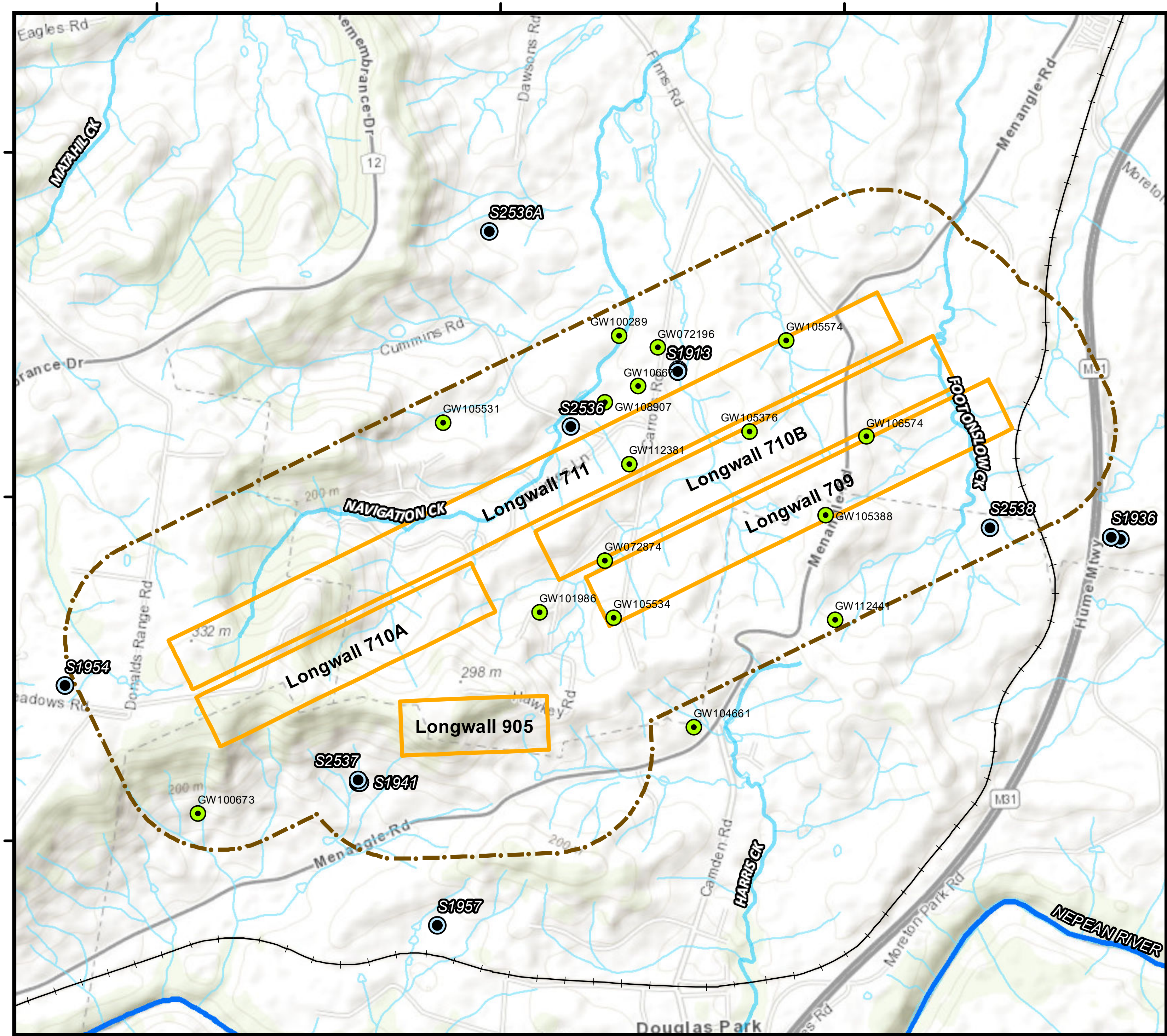
3.3 Groundwater

The primary hydrostratigraphic units within the Appin Mine area are:

- Quaternary alluvium – localised along rivers and creeks, likely unconfined and recharged from rainfall and surface water flow. Discharge to surface water (baseflow contributions) possible where gradients enable this, with potential for downward seepage where unconformity overlies HBSS. Groundwater flow likely follows topography and streamflow direction towards the north;
- Hawkesbury Sandstone – main groundwater source and widely accessed for groundwater supply and provides baseflow contributions where incised along major rivers (i.e. Cataract River, Nepean River and Georges River). Groundwater flow generally in a northerly direction, and locally influenced where intersected by rivers and private abstraction bores;
- Narrabeen Group – sandstones that can be used for groundwater supply, and low permeability claystones that generally act as aquitards; and
- Illawarra Coal Measures – with groundwater occurrence largely associated with the more permeable coal seams, with confined groundwater conditions. Groundwater flow generally in a northerly direction, and locally depressurised due to current and historical mining and coal seam gas.

There are 14 registered bores within the Study Area (Figure 3). The details of the registered bores in the Appin Mine area are shown in Appendix C of SLR (2021a).

Updated hydrographs for Boreholes used in the groundwater modelling for S1913, S1941, S2060, S2281, S2282, S2283, S2080, S2315 and S2308 are included in Appendix C.



Appin Area 7 and 9

Longwalls 709-711 and Longwall 905 Groundwater Monitoring and Private Borehole Locations

Figure 3

SOUTH32

- Groundwater Monitoring
- Private Boreholes
- Longwalls 709-711 and 905
- 600 m Study Area
- Railway Lines
- Rivers
- Creeks
- Tributaries

Date: September, 2021
Author: B.Agland

Version 1
Horizontal Datum
MGA - Zone 56

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4. PREDICTED IMPACTS

In accordance with the findings of the Southern Coalfield Inquiry (2008) and Independent Expert Panel for Mining in the Catchment (2019a), subsidence impacts are defined as:

- **Subsidence effects** are defined as the deformation of ground mass such as horizontal and vertical movement, curvature and strains.
- **Subsidence impacts** are the physical changes to the ground that are caused by subsidence effects, such as tensile and sheer cracking and buckling of strata.
- **Environmental consequences** are then identified, for example, as a loss of surface water flows and standing pools.

4.1 Subsidence Effects

There are no rivers within the 600 m Study Area. The closest river is the Nepean River which is located to the south and to the east of the proposed longwalls. The centreline of the Nepean River is located 1.5 km south of the commencing (i.e. western) end of Longwall 710A and 1.6 km east of the finishing (i.e. eastern) end of Longwall 709, at its closest points to the proposed longwalls.

The predicted impacts on the third order creeks that are located within the Study Area is provided in Table 5.

Table 5 Maximum Predicted Subsidence Effects for Rivers Creeks and Tributaries located within the Study Area (MSEC 2021)

Name	Maximum predicted total subsidence (mm)	Maximum predicted total upsidence (mm)	Maximum predicted total closure (mm)
Nepean River (not within Study Area)	<20	<20	<20
Foot Onslow Creek	1400	300	250
Harris Creek	500	350	300
Navigation Creek	950	350	475
Navigation Creek Tributary 1	1350	550	800

The groundwater bores could experience adverse impacts due to the extraction of the proposed Longwalls 709 to 711 and 905, particularly the bores located directly above the proposed mining area. Impacts could include lowering of the piezometric surface, blockage of the bores due to differential horizontal displacements at different horizons within the strata and changes to groundwater quality.

SLR (2021a) predicted negligible depressurisation of most of the landholder bores, except GW072874 and GW105534 which have a predicted 3 m and 4 m of incremental depressurisation in the lower HBSS due to mining at Longwalls 709 to 711 and 905, respectively.

While no drawdown is predicted within the surficial strata as part of the groundwater assessment, the subsidence assessment did identify potential for surface cracking along the third order creeks. This has the potential for localised impacts on surface water flow, which may influence recharge to the alluvium within proximity to the Study Area and potentially landholder bores accessing alluvial groundwater in this particular area (i.e. GW100289).

Local geological structures such as fracturing and shearing could cause significantly greater depressurisation at individual bores (SLR 2021a). This is consistent with Heritage Computing (2009) findings 'for bores located directly above mined longwalls, there is a risk of damage to bore casing from subsidence related movement'.

4.2 Subsidence Impacts

The predicted subsidence effects for the Nepean River, due to the mining of Longwalls 709 to 711 and 905, are less than 20 mm vertical subsidence, less than 20 mm upsidence and less than 20 mm closure. While the Nepean River could experience very low levels of vertical subsidence or valley-related effects, it is not predicted to experience measurable tilts, curvatures or strains. It is unlikely, therefore, that the Nepean River would experience adverse physical impacts due to the mining-induced movements from Longwalls 709 to 711 and 905. Gas release zones have been observed along the river during the mining of longwalls in Areas 7 and 9. Further gas release zones could develop due to the mining of the proposed longwalls.

MSEC (2021) predict that fracturing of shallow (10 m to 20 m depth) bedrock for the creeks could develop due to the Project, particularly in areas immediately above the longwall panels. Surface tension cracks are also likely to occur, typically with widths in the order of 25 mm to 50 mm.

5. PERFORMANCE MEASURES AND INDICATORS

The BSO Approval provides subsidence impact performance measures (Condition 1, Schedule 3). Table 6 details the conditions relevant to watercourses within the Study Area.

The term 'negligible' is defined within the Project Approval as "s*mall and unimportant, such as not to be worth considering*" or as otherwise defined in Table 6 for the Nepean River and other watercourses.

Table 6 Subsidence Impact Performance Measures (BSO Approval)

Watercourses (Condition 1 Schedule 3)	
Nepean River	Negligible environmental consequences including: • negligible diversion of flows or changes in the natural drainage behaviour of pools; • negligible gas releases and iron staining; and • negligible increase in water cloudiness.
Other Watercourses	No greater subsidence impact or environmental consequences than predicted in the EA and PPR.

In order to mitigate the potential subsidence impacts and environmental consequences from the mining of Longwalls 709 to 711 and 905, monitoring and recording will be undertaken prior to mining, throughout the extraction and at the completion of subsidence (refer Section 6).

In the event that any subsidence impact is recorded, consideration would be given to implementing appropriate management, remediation and/or mitigation measures in consultation with the NRAR, other relevant stakeholders and with the approval of the landholder (refer Section 7).

If the subsidence impact performance measures are exceeded, IMC will notify DPIE, BCD, NRAR and other stakeholders and implement the Contingency Plan (Section 8).

6. MONITORING AND REPORTING

6.1 Surface Water Quality Monitoring

There is adequate baseline data to fully characterise water quality conditions prior to the commencement of mining in the Study Area. This includes monitoring locations within the Study Area, as well as monitoring locations in downstream waterways (SLR 2021b). There are no watercourses which flow into the Study Area, with the headwaters of Harris, Navigation and Foot Onslow Creeks being within the Study Area.

Locations of water quality monitoring sites include:

- Nepean River – NR110, NR0, SW2, NR4, NR5, NR8, NR10, NR12, NR13, NR40, NR50;
- Navigation Creek – NAV1;
- Foot Onslow Creek – FO1; and
- Harris Creek – HC10, NR3.

Riverine water quality TARPs will be implemented for the adjacent AA7 and 9 Nepean River monitoring sites (see section 7.1).

6.2 Water Flow Monitoring

Flow monitoring in the Nepean River is undertaken upstream and downstream of the mining area. Water levels in the Nepean River adjacent to the mining area are also monitored. Observational monitoring of streams will also take place within the mining area.

Nepean River flow monitoring and analysis for AA7 and 9 will be undertaken similar to the current monitoring program. The Longwall 701 to 707 and Longwalls 901 to 902 End of Panel Reports provide details of the proposed data analysis and approach. Daily flow records for Maldon, Menangle and Broughtons Pass weirs from 1990 have been assessed in order to study the dry weather recessions in the Nepean River adjacent to the proposed mining areas. The difference in flows should be equivalent to runoff from all catchments between these two weirs responding to local rainfall minus any abstractions by licensed pumps in the river.

Dry weather recessional phases in the Menangle minus Maldon and Broughtons Pass flow datasets significantly removes the influence of catchment inflows and allows analysis of those recessions for normal behaviour, i.e. relative to the record of baseline recessions prior to the commencement of mining. The recession flow period is more sensitive to any diversions of flow as the diversion would be a higher percentage of the total flow during that period and therefore this is the most appropriate period for detailed analysis. These tests have been conducted for the AA7 and 9 End of Panel Reports and proven to be an acceptable measure for identifying any diversions of flow.

The location of the Maldon, Menangle and Broughtons Pass gauging sites is included in Figure 2. These flow monitoring stations are ideally located on the Nepean River, being directly upstream and downstream of the approved Bulli Seam Operations footprint. Flow monitoring on the Cataract River at Broughtons Pass Weir measures the flow of the major tributary input to Nepean River between the two Nepean River flow stations.

The Nepean River low flow water surface is 61.10 mAHD at Douglas Park weir and 60.84 mAHD at Menangle. Groundwater monitoring bores between AA7 mining and the Nepean River show that the groundwater levels remain higher than the River, ensuring the hydraulic gradient toward the river is maintained. This approach to monitoring water levels in the river and the nearby piezometric gradient is a very useful approach to detect any redirection of surface water flow into nearby strata, which could represent a reduction in surface water flow in the river. Groundwater monitoring has been installed between AA9 mining and the Nepean River which will be able to identify any reversal of groundwater gradient away from the river.

The approach to monitoring the Nepean River flow during Longwalls 709 to 711 and 905 mining is proposed to be the same as for future mining in AA7 and 9. There are currently no plans to implement additional flow monitoring (e.g. Douglas Park Weir) on the following basis:

- The proposed photographic, groundwater level, pool water level, flow and cease to flow monitoring are adequate to compare pre, during and post mining recessional behaviour in the river.
- The Douglas Park Weir has a complex construction (e.g. multiple flow paths and a by-pass flow fish ladder) which does not lend itself to developing good gauging e.g. the relationship between water level and flow.

6.3 Pool Water Level Monitoring

The Nepean River is a 'gaining river' in terms of surface water - groundwater interaction. The potential for infiltration of water into the groundwater system is very low as the Nepean River lies in a well incised gorge which represents the regional low point in the piezometric surface. The potential for sub-bed diversion of surface water is very low as the Nepean River is flooded and the gradient is very flat, significantly removing the effects of gravity to force surface flow through any fracture network that develops.

Water levels in the Nepean River and its tributaries are monitored using observations and measured benchmarks. The water level is recorded before, during and after mining and is assessed against catchment rainfall and discharges from the WaterNSW controlled weirs. This method of monitoring has been used for AA7 and 9 with no impacts to the water levels of the Nepean River observed during the period of extraction. Pool water level monitoring is conducted at monitoring sites NR110, NR0, NR2, NR5, NR6, NR8, NR9, NR10, NRL25, NRL35 and NRL40.

Given the ephemeral natural of the other third order creeks within the Study Area, there is a lack of suitable pool water monitoring sites. No monitoring of pool water levels is proposed on these creeks.

6.4 Groundwater Monitoring

An extension of the current groundwater monitoring program will be used to monitor the subsidence effects from the extraction of Longwalls 709 to 711 and 905 on groundwater within the Study Area (refer Table 7).

If significant excursions from the predicted model outcomes occur, this will trigger the need for model re-calibration and/or further investigation.

Consultation with bore owners and the monitoring of bores will be incorporated into the PSMPs for relevant properties and, with the agreement of the landowner would include:

- Interview with landowner before a bore is mined beneath to determine the normal rate and duration of pumping.
- Details obtained on the type and set up of the pump in each bore, if installed.
- Post mining interview to compare rate and duration of pumping.
- Measurement of the bore yield if used and access is available.
- Observations on the presence and quantum of iron hydroxide precipitating from the pumped water before and after mining.
- Observations of any gas in the bores.

Table 7 Monitoring in IMC Piezometers

Reference	Standing water levels	Vertical profiles of potentiometric head	Groundwater Quality
S1913	-	Y	
S1941		Y	
S1954		Y	
S2157		Y	
S2536		Y	Y
S2536A	Y		Y
S2537		Y	Y
S2538		Y	Y
Private Bores	Y		

Notes: Where a private bore is used and access is granted, monitoring before and after the site is mined beneath. Monitoring sites will be measured and data logged at least twice daily in the pre-mining baseline, impact and post-mining period.

IMC has established four groundwater monitoring boreholes in the Longwalls 709 to 711 and 905 Study Area to monitor groundwater levels:

- S2536 – single piezometer at a depth of 15.6 m in the alluvium, established 27 August 2021.
- S3536A – single piezometer at a depth of 136.6 m in the HBSS, established 27 July 2021.
- S2537 – single piezometer at a depth of 129.5 in the HBSS, established 5 July 2021.

- S2538 – single piezometer at a depth of 129.5 m in the HBSS, established 12 July 2021.

6.5 Mine Water Inflows

Statutory inspections of the mine workings will be undertaken by IMC to ensure mine safety. The statutory inspections will identify the first indication of a water inflow to the mine.

The statutory inspections are well suited to this monitoring due to the frequency of inspections and familiarity with normal conditions. Any unusual inflows detected during inspections will be sampled and tested as part of the Appin water balance monitoring.

A Mine Water Balance will be used to quantify water inflows by calculating the difference between total mine inflows and mine outflows.

Monitoring of the mine water balance will comprise:

- Metered water reticulated into the mine.
- Metered water reticulated out of the mine.
- Measurement of the in-situ moisture content of the coal during routine channel sampling for coal quality.

Given the large fluctuations in daily water usage and the cycle period for water entering the mine, being used by machinery and draining to sumps for return pumping to the surface, an average (e.g. 20 day) will be used to provide a more realistic estimate of water make.

6.6 Reporting

Results from the monitoring program will be reported annually in the Annual Review. The Annual Review will detail the outcomes of monitoring undertaken; provide results of visual inspections; and determine whether performance indicators have been exceeded and whether CMAs are required.

Monitoring results will be reviewed monthly in the IMC Subsidence Review Meeting. However, if the findings of monitoring are deemed to warrant an immediate response the Principal Approvals will initiate the requirements of the TARP (refer Table 8).

Monitoring results will be made publicly available in accordance with BSO Approval Conditions 8 and 11, Schedule 6 and will also be included in the Annual Review in accordance with Condition 4, Schedule 6.

7. MANAGEMENT AND MITIGATION STRATEGIES

The predicted impacts for the watercourses and drainage lines within the Study Area are nil to negligible and no mitigation measures are currently proposed for any of these predicted impacts. Where there are impacts to farm dams these would be repaired utilising standard dam building techniques and/or an alternate water supply would be provided in consultation with and agreement of the landowner.

The main impacts predicted for groundwater are lowering of some groundwater levels due to dilation of the strata above the longwalls. Where this lowering impacts groundwater sources to landholders the following mitigation measures may be proposed:

- Automated and optimised pump system.
- Lowering of the pump intake.
- Establishment of a new bore.

With these mitigation measures in place the impact of lower groundwater levels are predicted to be negligible.

IMC will review the need to implement additional management and mitigation measures during routine monitoring (refer Section 6) and during the finalisation of PSMPs with affected landholders.

7.1 Trigger Action Response Plan

The AA7 and 9 Trigger Action Response Plan (TARP) is provided in Table 8.

Table 8 Trigger Action Response Plan

Monitoring	Trigger	Action
Surface Water Quality[#]		
Nepean River N110 (Upstream perturbations) SW2 (Upstream perturbations from Allens Creek) NR5 (Upstream perturbations from Cataract River) NR8 (Upstream perturbations from Elladale Creek) NR10 (Upstream perturbations from Ouesdale Creek) NR40 (Upstream perturbation from Menangle Creek) Impact Sites: NR0 NR4 (assess influence from Harris Creek) NR12 NR13 NR50 **Creeks and Tributaries** NAV1 FO1 HC10 NR3	***Level 1**** Impact monitoring sites when comparing the baseline period to the mining period for that site: • pH reduction greater than 1 standard deviation but less than 2 standard deviation from pre-mining mean resulting from the mining for two consecutive months • DO reduction greater than 1 standard deviation but less than 2 standard deviation from pre-mining mean resulting from the mining for two consecutive months • Identification of strata gas plume of flow rate <3000 L/min • Trend analysis shows deviation from baseline post mining.	• Continue monitoring program • Submit an Impact Report to BCD, DPI Fisheries and other relevant stakeholders • Report in the End of Panel Report • Summarise actions and monitoring in Annual Review
	Level 2* Impact monitoring sites when comparing the baseline period to the mining period for that site: • pH reduction greater than 2 standard deviation from pre-mining mean resulting from the mining for two consecutive months • DO reduction greater than 2 standard deviation from pre-mining mean resulting from the mining for two consecutive months • EC increases greater than 2 standard deviation from pre-mining mean resulting from the mining for two consecutive months • Identification of strata gas plume of flow rate >3000 L/min • Trend analysis shows significant deviation from baseline post mining.	• *Actions as stated for Level 1* • Review monitoring program • Notify relevant technical specialists and seek advice on any CMA required • Implement agreed CMAs as approved *Note: CMAs are to be proposed based on appropriate management of environmental and other consequences of mining impacts i.e. water quality changes with insignificant consequences may not require specific CMAs other than ongoing monitoring to confirm there are no ongoing impacts* Strata Gas Emission Plume: • Estimate gas emission flow rates. Re-estimate should significant change be observed • Take sample of plume (if possible) for: - chemical composition - dissolved methane from exactly above gas plume and at established downriver monitoring site - dissolved sulfide and total phenols from exactly above gas plume and at nearest downriver monitoring site
	Level 3* Impact monitoring sites when comparing the baseline period to the mining period for that site:	• *Actions stated for Level 2* • Notify BCD, DPIE, DPI - Fisheries, NRAR relevant resource managers and technical specialists and seek advice on any CMA required • Invite stakeholders for site visit

	• Level 2-type reduction in water quality resulting from the mining observed for six consecutive months	• Develop site CMA (subject to stakeholder feedback) • Completion of works following approvals, including monitoring and reporting on success • Review the TARP and Management Plan in consultation with key stakeholders *Note: CMAs are to be proposed based on appropriate management of environmental and other consequences of mining impacts i.e. water quality changes with insignificant consequences may not require specific CMAs other than ongoing monitoring to confirm there are no ongoing impacts*
	Exceeding Performance Measures Mining results in more than negligible gas releases, iron staining or water cloudiness	• *Actions stated for Level 3* • Investigate reasons for the exceedance • Update future predictions based on the outcomes of the investigation • Provide environmental offset if CMAs are unsuccessful
Groundwater		
Groundwater inflows to the mine **Private Bores** GW072196 GW072874 GW100289 GW100673 GW101986 GW104661 GW105376 GW105388 GW105531 GW105534 GW105574 GW106574 (grouted) GW106675 GW108907 GW112381 GW112441 (grouted) IMC Boreholes S1913	***Level 1**** • Increase in water flow from the goaf between 2.7 to 3 ML/day (over 20 day average) • 5.0 – 7.5 m reduction in the Hawkesbury Sandstone greater than predicted standing water level or pressure (outside of pumping influences in private bores) over a minimum 2 month period	• Continue monitoring program • Submit an Impact Report to BCD, DPIE, Resources Regulator and other relevant stakeholders • Report in the End of Panel Report • Summarise actions and monitoring in Annual Review
	Level 2* • Increase in water flow from the goaf between 3 to 3.4ML (over 20 day average) • 7.5 – 10 m reduction in the Hawkesbury Sandstone greater than predicted standing water level or pressure (outside of pumping influences in private bores) over a minimum 2 month period	• *Actions as stated for Level 1* • Review monitoring frequency • Notify relevant technical specialists and seek advice on any CMA required • Implement agreed CMAs as approved *Note: CMAs are to be proposed based on appropriate management of environmental and other consequences of mining impacts i.e. cracking at the surface with insignificant consequences may not require specific CMAs other than ongoing monitoring to confirm there are no ongoing impacts*
	Level 3* • Abnormal increase in water flow from the goaf >3.4ML (20 day average) • >10m reduction in the Hawkesbury Sandstone standing water level or pressure (outside of pumping influences in private bores) over a minimum 2 month period • Mining results in groundwater bores unsafe, unserviceable or damaged	• Actions as stated for Level 2 • Notify BCD, DPIE, Resources Regulator and relevant resource managers and technical specialists and seek advice on any CMA required • Invite stakeholders for site visit • Develop site CMA (subject to stakeholder feedback). This may include: - Make area safe - Any actions agreed to in the Property Subsidence Management Plan

S1941 S1954 S2157 S2536 S2536A S2537 S2538		- Provisions of alternate water supply where this has been impacted by mining • Completion of works following approvals, including monitoring and reporting on success • Review the Groundwater Model, TARP and Management Plan in consultation with key stakeholders *Note: CMAs are to be proposed based on appropriate management of environmental and other consequences of mining impacts i.e. cracking at the surface with insignificant consequences may not require specific CMAs other than ongoing monitoring to confirm there are no ongoing impacts*

* These may be revised in consultation with DPIE and other key stakeholders following analysis of natural variability within the pre-mining baseline data.

the upstream (NR110) monitoring site and a series of sites within tributaries of the Nepean River are utilised to indicate perturbation at the proposed Longwalls 709 to 711 and 905 impact monitoring sites within the Nepean River. This provides a means of distinguishing upstream effects unrelated to the mining of the proposed longwalls. The following premise applies:

- A TARP at River site NR0 should only be considered to have been triggered whenever an equivalent change (from the long term mean) is not exhibited for the same parameter at the upstream site NR110.
- A TARP at River site NR4 should only be considered to have been triggered whenever an equivalent change (from the long term mean) is not exhibited for the same parameter at the upstream sites NR110 or SW2 (monitors for upstream perturbation from Allens Creek).
- A TARP at River site NR12 and NR13 should only be considered to have been triggered when an equivalent change (from the long term mean) is not exhibited for the same water quality analyte at the upriver sites; NR110, SW2, NR5, NR8 or NR10 (monitors upstream perturbation from Allens Creek, Cataract River, Elladale Creek and Ousedale Creek).
- A TARP at River site NR50 should only be considered to have been triggered when an equivalent change (from the long term mean) is not exhibited for the same water quality analyte at the upriver sites; NR110, SW2, NR5, NR8, NR10 or NR40 (monitors upstream perturbation from Allens Creek, Cataract River, Elladale Creek, Ousedale Creek and Menangle Creek).

8. CONTINGENCY RESPONSE PLAN

Contingency and emergency response options are available and will be implemented if it is demonstrated that environmental consequences are greater than those predicted or authorised by the BSO Consent. This would involve:

- Capture photographic record.
- Notify relevant stakeholders soon as practicable.
- Notify relevant agencies and specialists soon as practicable.
- Offer site visits with stakeholders.
- Contract specialists to investigate and report on changes identified.
- Provide incident report to relevant agencies.
- Establish weekly monitoring frequency until stabilised.
- Updates from specialists on investigation process.
- Inform relevant agencies and stakeholders of results of investigation.
- Develop site CMA in consultation with key stakeholders if required, (pending stakeholder availability) and seek approvals.
- Implement CMA as agreed with stakeholders following approvals.
- Conduct initial follow up monitoring and reporting of CMA completion.
- Review Management Plan.
- Report in regular reporting and Annual Review.

IMC will consult with appropriate specialists and relevant agencies in order to devise an appropriate response in respect to any identified exceedance.

The development and implementation of contingency measures will be specifically designed to address the circumstances of the exceedance and assessment of environmental consequences.

The following measures will be considered:

- Where low DO concentration in the Nepean River can be attributable to mining induced gas emissions (i.e. falling below the level of Level 1 TARPs), it is proposed that this would trigger a higher degree and frequency of monitoring as well as consultation with stakeholders.
- Where low DO concentration exceeds Level 2 TARPs - undertake further consultation for development and implementation of remedial action.
- Redrilling or cleaning and lowering of pumps for damaged bores.
- In the event that water flow diversion is identified within the Nepean River, grouting will be undertaken to restore surface flow. Either hand grouting, pattern or curtain grouting or deep angle hole cement grouting can be used with appropriate approvals.

If the contingency measures implemented by IMC fail to remediate the impact or the Secretary determines that it is not reasonable or feasible to remediate the impact, IMC will provide a suitable offset to compensate for the impact to the satisfaction of the Secretary in accordance with the BSO Approval Condition 2, Schedule 3 or Condition 14, Schedule 4.

9. COMPLAINTS AND COMPLIANCE MANAGEMENT

9.1 Incidents

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

9.2 Complaints and Dispute Resolution

IMC has a 24 hour, free call community number (1800 102 210) and email address (illawarracommunity@south32.net) through which all complaints and general enquiries regarding environmental or community issues associated with IMC's operations can be reported.

All complaints received in relation to Appin Mine are managed in accordance with the Handling Community Complaints, Enquiries and Disputes Procedure.

Upon receipt of a community complaint, preliminary investigations will commence as soon as practicable to determine the likely cause of the complaint using information such as activities being undertaken on site at the time or area of the complaint.

An initial response will be provided to the complainant within 24 hours of the complaint being made, with a follow up response being provided as soon as practicable once a more detailed investigation is complete.

A summary of all complaints received during the reporting year will be provided as part of the Annual Review. A log of complaints is also maintained on the South32 website at:

https://www.south32.net/our-business/australia/illawarra-metallurgical-coal/documents.

9.3 Non-Compliance, Corrective Action and Preventative Action

Events, non-compliances, corrective actions and preventative actions are managed in accordance with the Reporting and Investigation Standard and Environmental Compliance/Conformance Assessment and Reporting Procedure. These procedures, which relate to all IMC operations, detail the processes to be utilised with respect to event and hazard reporting, investigation and corrective action identification. The key elements of the process include:

- identification of events, non-conformances and/or non-compliances:
- recording of the event, non-conformance and/or non-compliance in the event management system G360;
- investigation/evaluation of the event, non-conformance and/or non-compliance to determine specific corrective and preventative actions;
- assigning corrective and preventative actions to responsible persons in G360; and

- review of corrective actions to ensure the status and effectiveness of the actions.

Exceedances or non-compliances will be reported to all relevant agencies via the Annual Review or notified in accordance with Section 8.

For any incident, as defined by the BSO Approval, IMC will notify the Secretary and any other relevant agencies as soon as practicable after IMC identifies or is made aware of the incident.

10. PLAN ADMINISTRATION

This WMP will be administered in accordance with the requirements of the Appin Mine Environmental Management Strategy (EMS) and the BSO Approval Conditions. A summary of the administrative requirements is provided below.

10.1 Roles and Responsibilities

Statutory obligations applicable to this Plan are identified and managed via an online compliance management system (TICKIT). The online system can be accessed from the link below:

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

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

Parties responsible for environmental management in AA7 and 9 and the implementation of the Plan include:

Manager Approvals

- Ensure that the requisite personnel and equipment are provided to enable this Plan to be implemented effectively.
- Authorise the Plan and any amendments thereto.

Principal Approvals

- Document any changes to the Plan, recognising the potential for those changes to affect other aspects of the Plan.
- Provide regular updates to IMC on the results of the Plan.
- Arrange information forums for key stakeholders as required.
- Prepare any report in accordance with the Plan.
- Maintain records required by the Plan.
- Organise and participate in assessment meetings called to review mining impacts.
- Within 24 hours, respond to any queries or complaints made by members of the public in relation to aspects of this Plan.
- Organise audits and reviews of the Plan.
- Address any identified non-conformances, assess improvement ideas submitted and implement if considered appropriate.

- Arrange for the implementation of any agreed actions, responses or remedial measures.
- Check surveys required by this Plan are conducted and record details of instances where circumstances prevent these from taking place.

Environmental Field Team Coordinator

- Instruct suitable person(s) in the required standards for inspections, recording and reporting and be satisfied that these standards are maintained.
- Investigate significant subsidence impacts.
- Identify and report any non-conformances with the Plan.
- Participate in any other assessment meetings called to review subsidence impacts in the area affected by mining.

Survey Coordinator

- Collate survey data and present in an acceptable form for review at assessment meetings.
- Bring to the attention of the Principal Approvals any findings indicating an immediate response may be warranted.
- Bring to the attention of the Principal Approvals any non-conformances identified with the Plan provisions or ideas aimed at improving the Plan.

Technical Experts

- Conduct the roles assigned to them in a competent and timely manner to the satisfaction of the Principal Approvals and formally provide expert opinion as requested.

Person(s) Performing Inspections

- Formally bring to the attention of the Environment Field Team Coordinator any nonconformances identified with the Plan, or ideas aimed at improving the Plan.
- Conduct inspections in a safe manner.

10.2 Resources Required

The Manager Approvals provides resources sufficient to support this Plan.

Equipment may be needed for this Plan. Where this equipment is of a specialised nature, it will be provided by the supplier of the relevant service. All equipment is to be appropriately maintained, calibrated and serviced as required in operation manuals.

It shall be the responsibility of the Manager Approvals to ensure that personnel and equipment are provided as required to allow the provisions of this Plan to be implemented.

10.3 Training

All staff and contractors working on IMC sites are required to complete the IMC training program which includes:

- An initial site induction (including all relevant aspects of heritage, environment, safety and community).
- Safe Work Methods Statements and Job Safety Analyses, Toolbox Talks and Preshift communications.
- On-going job specific training and re-training (where required).

All training records are maintained by the IMC Training Department.

It shall be the responsibility of the Manager Approvals to ensure that all persons and organisations having responsibilities under this Plan are trained and understand their responsibilities.

The person(s) performing regular inspections shall be under the supervision of the Environment Field Team Coordinator and be trained in observation and reporting. The Environment Field Team Coordinator shall be satisfied that the person(s) performing the inspections are capable of meeting and maintaining this standard.

10.4 Review and Update

In accordance with Condition 5 of Schedule 6 of the BSO Approval, the WMP will be reviewed, and if necessary revised, within three months, of:

- the submission of an Annual Review;
- the submission of an incident report;
- the submission of an Independent Environmental Audit (IEA) report; or
- any modification to the conditions of the BSO Approval (unless the conditions require otherwise).

If significant deficiencies in this WMP are identified in the interim period, the Plan will be modified as required. This process has been designed to ensure that documentation continues to meet current requirements, including changes in technology and operational practice, and expectations of stakeholders.

11. REFERENCES

Heritage Computing. 2009. *Bulli Seam Operations Groundwater Assessment, A Hydrogeological Assessment in support of the Bulli Seam Operations* Environmental Assessment for Illawarra Coal Holdings Pty Ltd, HC2009/5, July 2009.

Mine Subsidence Engineering Consultants, 2009, *Bulli Seam Operations Subsidence Assessment*. Report for BHP Billiton Illawarra Coal.

MSEC 2021, *Appin Longwalls 709 to 711 and 905: Subsidence Predictions and Impact Assessments for the Natural and Built Features due to the Extraction of the Proposed Longwalls 709 to 711 and 905 at Appin Colliery*. Report for South32 IMC.

NSW Department of Planning (2008). *Impacts of Underground Coal Mining on Natural Features in the Southern Coalfield. Strategic Review*.

SLR, 2021a. *Appin Mine Extraction Plan Groundwater Impact Assessment*. Prepared for: South 32 - Illawarra Metallurgical Coal. SLR Ref No: 665.10015.00003-R01-V5.0.docx, April 2021.

SLR, 2021b. *Appin Mine Extraction Plan Surface Water Assessment Longwalls 709 to 711 And 905*. Prepared For: South 32 - Illawarra Metallurgical Coal. Water Assessment- Final-v2.0.docx, April 2021.

Appendix A – Appin Longwalls 709 to 711 and 905 Groundwater Impact Assessment (SLR 2021a)

APPIN MINE EXTRACTION PLAN

Groundwater Impact Assessment

Prepared for:

South 32 - Illawarra Metallurgical Coal

SLR Ref: 665.10015-R01
Version No: -v5.0
April 2021

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BASIS OF REPORT

DOCUMENT CONTROL

Reference	Date	Prepared	Checked	Authorised
665.10015-R01-v5.0	7 April 2021	Tingting Liu	Graham Hawkes	Graham Hawkes
665.10015-R01-v4.0	31 March 2021	Tingting Liu	Graham Hawkes	Graham Hawkes
665.10015-R01-v3.0	23 March 2021	Tingting Liu	Graham Hawkes	Graham Hawkes
665.10015-R01-v2.0	19 January 2021	Tingting Liu	Graham Hawkes	Graham Hawkes
665.10015-R01-v1.0	22 December 2020	Tingting Liu	Graham Hawkes	

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APPENDICES

1 Introduction

The Appin Mine is located approximately 25 km north-west of Wollongong. Appin Mine is owned and operated by Illawarra Metallurgical Coal (IMC), a subsidiary of South32 Limited (South32). The existing mining operations are undertaken in accordance with Project Approval 08_0150 for the Bulli Seam Operations (BSO), granted in December 2011 and modified in October 2016 to incorporate the Appin Ventilation Shaft No. 6 Approval.

IMC is currently extracting Longwall 708B in Appin Area 7 and Longwall 903 in Area 9. In accordance with the development consent conditions, an Extraction Plan (EP) is required to be prepared prior to commencement of secondary extraction. The EP outlines the proposed management, mitigation, monitoring and reporting of potential impacts from the secondary extraction of approved longwalls at Appin Mine. IMC will seek EP approval for Longwalls 709, 710A, 710B, 711 and 905, henceforth referred to as the Project.

Heritage Computing (2009) conducted the groundwater impact assessment for the approved operations relevant to the Project. SLR Consulting Australia Pty Ltd (SLR) was engaged by South32 to complete a technical review of the groundwater impacts for the Project (Longwalls 709, 710A, 710B, 711 and 905). This report presents the latest groundwater modelling methodology and results, as well as discussion on the impact predictions for the Project compared to the remodelled approved operations and predictions by Heritage Computing (2009).

1.1 Project Description

The Project relates to Longwalls 709, 710A, 710B, 711 and 905, as presented in **Figure 1**. The proposed mining includes:

- Longwall709 – Planned to be mined from January 2022 to July 2023, panel width of 319 m and average extraction height up to 3.02 m;
- Longwall710A – Planned to be mined from July 2023 to April 2025, panel width of 319 m and average extraction height up to 3.10 m;
- Longwall710B – Planned to be mined from July 2023 to April 2025, panel width of 319 m and average extraction height up to 3.00 m;
- Longwall711 – Planned to be mined from April 2025 to October 2026, panel width of 319 m and average extraction height up to 3.15 m; and
- Longwall905 – Planned to be mined from May 2022 to March 2023, panel width of 300 m and average extraction height up to 3.03 m.

The Project is within Areas 7 and 9 of the approved BSO, which has been previously assessed by Heritage Computing (2009). Appin Mine as shown in **Figure 1** is defined as the existing and proposed mining operations at Appin from January 2010 to December 2026 including Longwalls 709, 710A, 710B, 711 and 905 in this study. Details on the approved operations at Appin Mine and the previously predicted groundwater impacts are included in **Section 1.1**.

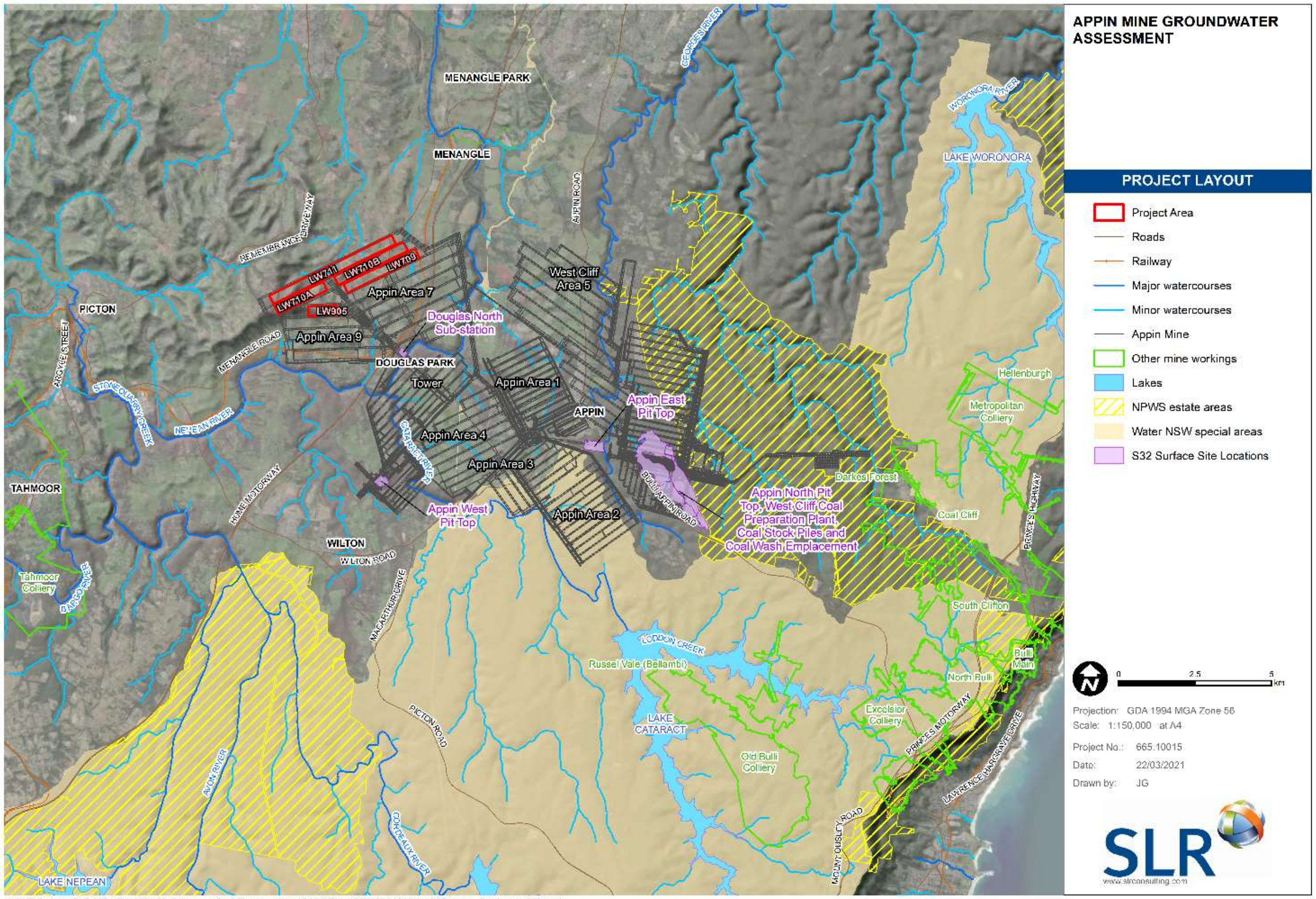

Figure 1 Project Layout

1.2 Approved Operations

Appin Mine extracts coal from the Bulli Coal Seam within the Permian aged Illawarra Coal Measures via the longwall mining method. The Appin Mine refers to the current and previous mine areas, which comprises the former Tower Colliery and West Cliff Mine.

The Appin Mine includes Area 1, Area 2, Area 3, Area 4, Area 5, Area 7, Area 9 and North Cliff (**Figure 1**). The current active mine areas are in Area 7 and Area 9. It should be noted that the approved Area 9 (BSO) is more extensive than the currently mined Area 9, as shown in **Figure 1**. A summary of the mine areas, years mined, and current status is shown in **Table 1**.

Table 1 Appin Mine Areas and Timing

Mine Area	Longwall Panels	Date From	Date To	Date Approved To	Status/ Comment
Tower	1 - 20	1978	2002	-	Historic mining
Appin Area 1	1 - 12	1969	1986	-	Currently used for underground mine water storage (White Panel), transferred from current mining areas.
Appin Area 2	12 - 29	1986	1997	-	Historic mining
Appin Area 3	301 - 302	1998	2007	-	Historic mining
Appin Area 4	401 - 408	1998	2007	-	Currently used for underground mine water storage, transferred from current mining areas.
West Cliff Area 5	1 - 32	1983	2016	2040 (BSO)	Historic mining
Appin Area 7	701 - 714	2007	Present	2040 (BSO)	Active Mining
Appin Area 9	901 - 910	2016	Present	2040 (BSO)	Active Mining

The groundwater impact assessment for the BSO conducted by Heritage Computing (2009) included development of a numerical groundwater model to predict impacts. The BSO groundwater assessment findings included:

- Negligible loss of groundwater yield to the Cataract Reservoir, Broughtons Pass Weir and Woronora Reservoir;
- Negligible reduction in groundwater contribution to total stream flows;
- Drawdown in Hawkesbury Sandstone (HBSS) with predicted 1 m drawdown contour extending up to 5 km from the mine footprint. The extent of drawdown was most significant north to north-east of Area 8 and Area 9;
- Extensive depressurisation predicted for aquifers beneath the Bald Hill Claystone (i.e. Bulgo Sandstone, Scarborough Sandstone and Bulli Seam), with the 10 m drawdown contour extending over 6 km north of the mine footprint;
- Reduction in water level of up to 23 m at some private production bores intersecting the HBSS and up to 85 m for bores within the Bulgo Sandstone, with main impacts around the Razerback Range at Area 9 (Appin West);
- Mine inflows of around 4 ML/day across the entire BSO operations at the end of mining, averaging 2 ML/day each year over 30 years; and

- At the end of the 100 year recovery period, water levels in the main hydrogeological units had recovered to at least, and often higher than, the levels recorded at the start of mining (Year 1). The higher water levels observed after the recovery period are due to the starting heads including some residual impacts of historical dewatering at the Appin Mine and West Cliff Colliery, Metropolitan, Darkes Forest, Bellambi West and Tahmoor Colliery. These mines are completely deactivated during the recovery period.

1.3 Camden Gas Project

The AGL Camden Gas Project is on Petroleum Production Lease (PPL) 1 to 6 and Petroleum Exploration Licence (PEL2), at the northern end of Appin Mine. The Camden Gas Project has been in operation since 2001, with production to cease by 2023. AGL hold two Water Access Licenses (24856 and 24736) and Works and Use Approvals (10WA112288 and 10WA112294) with a current total allocation of 30 ML/year. The Camden Gas Project comprises 137 wells (86 currently active) targeting the Bulli and Balgownie seams north of the Project. Further discussion on the geology and location of the wells is provided in **Section 2.4**.

The Coal Seam Gas (CSG) activities involve abstraction of water to induce gas flow, resulting in a reduction in water pressure in the target seam. This depressurisation around the CSG wells is observed in the site monitoring data discussed in **Section 1.1.1**. Previous studies by AGL (2013) predicted limited potential for impact on the overlying stratigraphy, due to the presence of the low permeability claystones preventing any significant vertical flow. IMC groundwater monitoring indicates potential localised depressurisation within the Scarborough Sandstone of the Narrabeen Group (**Section 1.1.1**). However, there are no impacts predicted or observed within the HBSS due to CSG activities (AGL, 2013).

2 Environmental Setting

2.1 Climate and Topography

Daily rainfall observations have been recorded by IMC since 2014 at Appin East, Appin North, Appin West (part) and at the Ventilation Shaft No.6. However, due to the short period of monitoring, long-term BoM site data associated to the SILO point grid has been used for this Project. There are several Bureau of Meteorology (BoM) stations in the area with long-term data, including Darkes Forest (068024), Cataract Dam (068016), Wedderburn (068159), Douglas Park (068200). The BoM data was obtained from SILO point grid (Latitude -34.20 Longitude 150.75) located between Douglas Park and Appin and used to evaluate the climatic conditions at Appin Mine. The data was obtained through the Scientific Information for Landowners (SILO) database, from January 1890 to September 2020. Based on the SILO data, the long-term (1890 to 2020) average yearly rainfall for the Project area is 986 mm/yr.

Figure 2 shows the long-term rainfall trends based on the SILO data, as defined by the cumulative departure from mean or cumulative rainfall deficit curve. This shows the historical occurrence of dry periods (downward rainfall trend), wetter than average periods (upward rainfall trend). The recent April 2017 to December 2019 rainfall deficit is assessed by BoM as the 'lowest on record'.

Potential evaporation (PE) is also available from BoM. Long-term average PE is approximately 1576 mm/yr at Appin, and slightly lower at Wollongong on the coast (1520 mm/yr). Actual evapotranspiration (ET) at Appin is approximately 922 mm/yr. A comparison of average monthly rainfall and PE is presented in **Figure 3**. This shows that in July there is a rainfall excess, with a rainfall deficit in all other months.

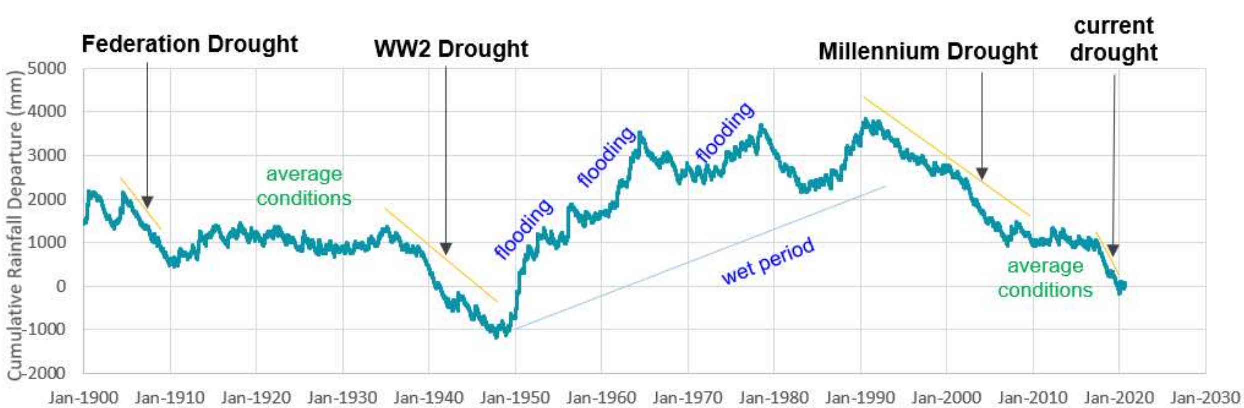

Figure 2 Cumulative Rainfall Departure

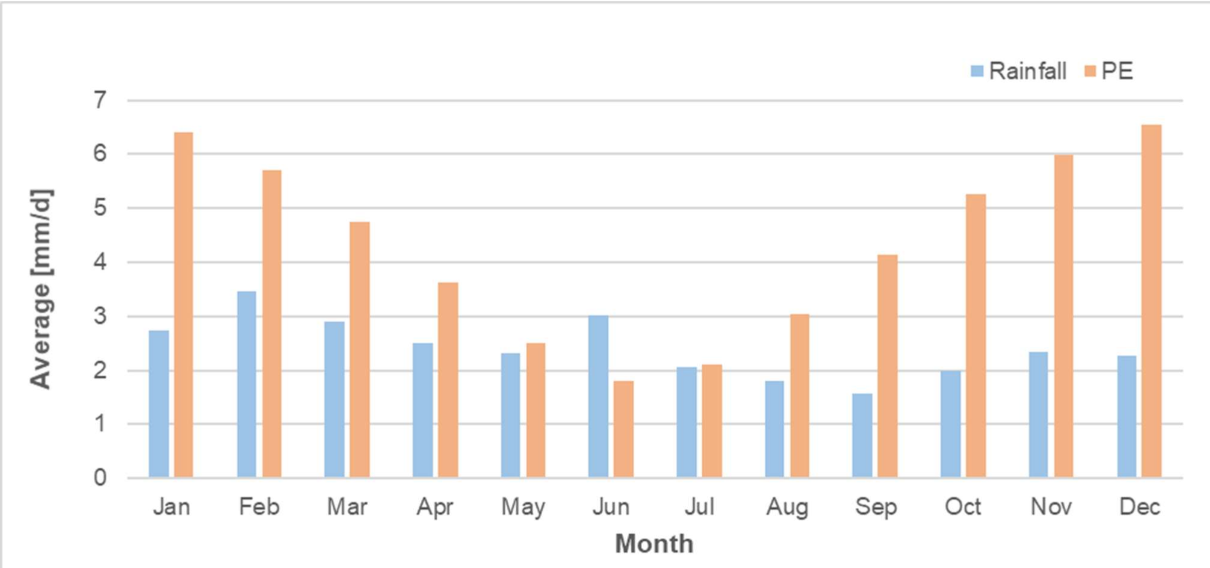

Figure 3 Average Monthly Rainfall and Potential Evaporation

2.2 Topography

Appin Mine is located to the west of the Woronora Plateau and the Cumberland Plain inland of the Illawarra Escarpment approximately 23 km northwest of Wollongong, NSW. Topography within the Project area ranges from 100 mAHD to 320 mAHD, with the topographic high associated with Razorback Range on the western part of the Project area (**Figure 4**).

On the plateau to the north the topography generally slopes to the north or northwest, toward the center of the Sydney Basin. The topography of the eastern part (West Cliff Area 5) falls from 250 mAHD to 130 mAHD while the western area slopes gently from approximately 250 mAHD (south along the Nepean Valley) to 60 mAHD near Menangle Park to the north.

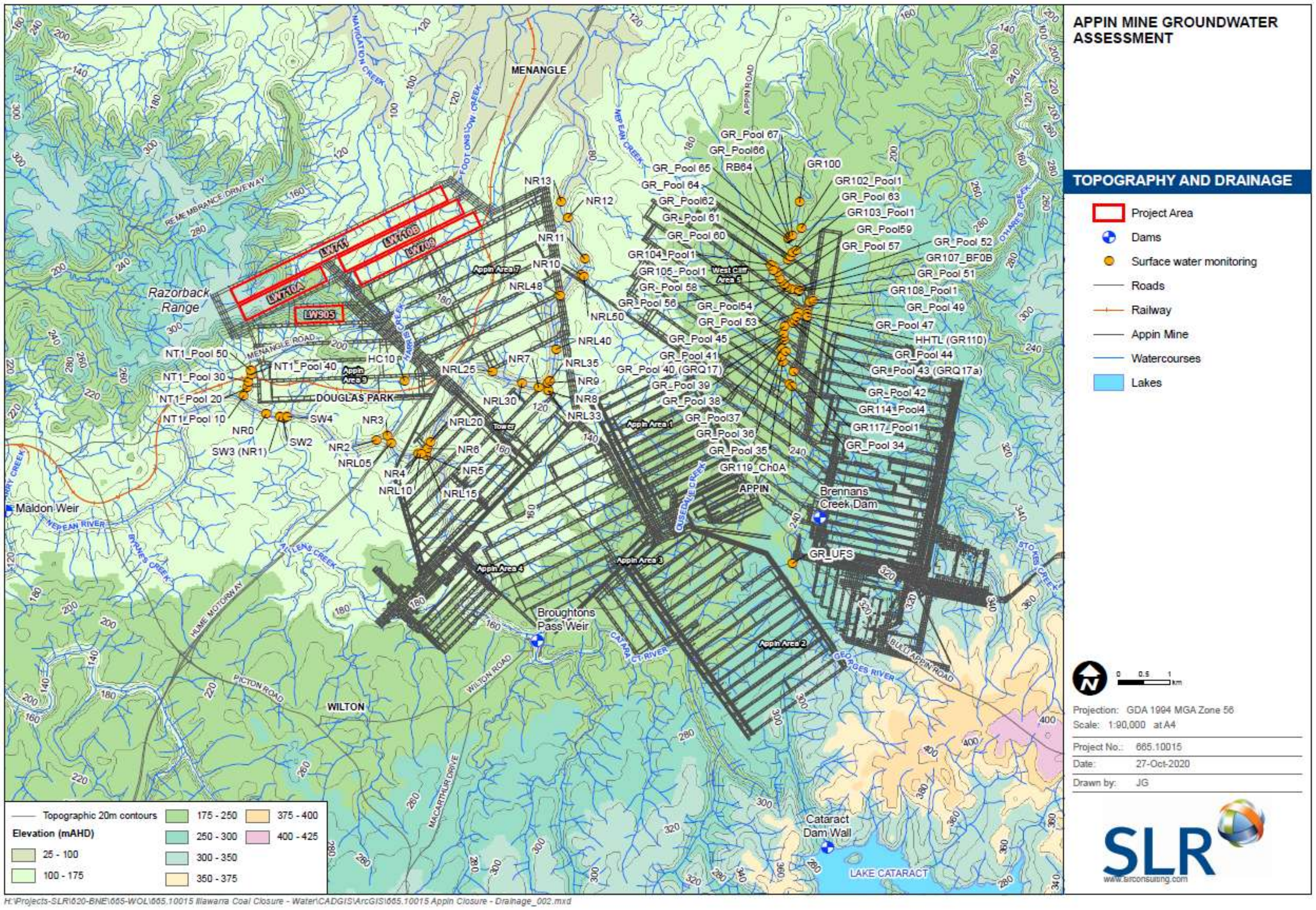

Figure 4 Topography and Drainage of Appin Mine

2.3 Surface Water and Drainage

Appin Mine is located within the Georges River and the Hawkesbury-Nepean catchments. Major rivers in the area include the Nepean River, Cataract River, Stonequarry Creek and Georges River (**Figure 4**). The rivers within the Appin Mine area generally flow in a northerly direction and have perennial flows influenced by dam releases and baseflow contributions from the incised HBSS.

The closest river is the Nepean River, which is 1.5 km south of the Project footprint. Minor creeks and tributaries of the Nepean River are present across the Appin Mine area. This includes Navigation Creek, Navigation Creek Tributary 1, Foot Onslow Creek and Harris Creek that are third order streams within the Project area. The creeks are largely ephemeral, but pools have naturally formed in some areas, and farm dams have also been established in some locations (MSEC, 2021).

Surface water monitoring is conducted at the main rivers at government stream gauges. IMC also conduct monitoring of surface water levels and quality at the major rivers as well as creeks and tributaries across site and to the north. This includes monitoring of ponded water (pools) along Georges River and Nepean River.

Summary details for each of the main rivers near the Project are included in **Table 2**. River stage levels for Nepean River, Cataract River and Stonequarry Creek are shown in **Figure 5**, along with IMC observation data for one of the Georges River pools (GR_POOL63). The river levels generally correlate with rainfall trends (CRD), but also show influence from dam releases/regulation where water levels rise during periods of below average rainfall.

Table 2 Major River System at Appin Mine

River	Characteristics	Surface Water Flow
Nepean River	Regulated flows from upstream dams and baseflow contributions where incised into Hawkesbury Sandstone. Present across surface of Appin Mine area (Area 7).	Main government stream gauge 212216 (Nepean River at Camden Weir), as well as 212238 (Menangle Weir) and 212208 (Maldon Weir). Plus IMC Nepean River (NR) monitoring. Flows in a northerly direction, with flow of around 310 ML/day (Maldon Weir) since 2010.
Cataract River	Regulated flows from Lake Cataract. Present across surface of Appin Mine area (Area 4 and Tower).	Main government stream gauge 212230 (Cataract River at Broughtons Pass), as well as 212231 (Jordans Crossing) and 212232 (Cataract Dam). Flows in a northerly direction towards Nepean River, with flow of around 92 ML/day (Broughton Pass Weir) since 2010, with surface water elevations generally around 130 mAHD to 132 mAHD.
Stonequarry Creek	Stonequarry Creek Management Area at north-west side of Area 9.	Government stream gauge 212053 (Stonequarry Creek at Picton). Flows in a general southerly direction to the Nepean River near Maldon. Flow around 22 ML/day (Picton) since 2010, with surface water elevations generally around 148 mAHD.
Georges River	Regulated flows from upstream dam (Brennans Creek Dam). Present across surface of Appin Mine area (West Cliff area).	IMC monitoring of pool levels along Georges River (GR_POOL). River flows in a northerly direction, with flow of around 4.2 ML/day (Brennans Creek Dam) since 2010.

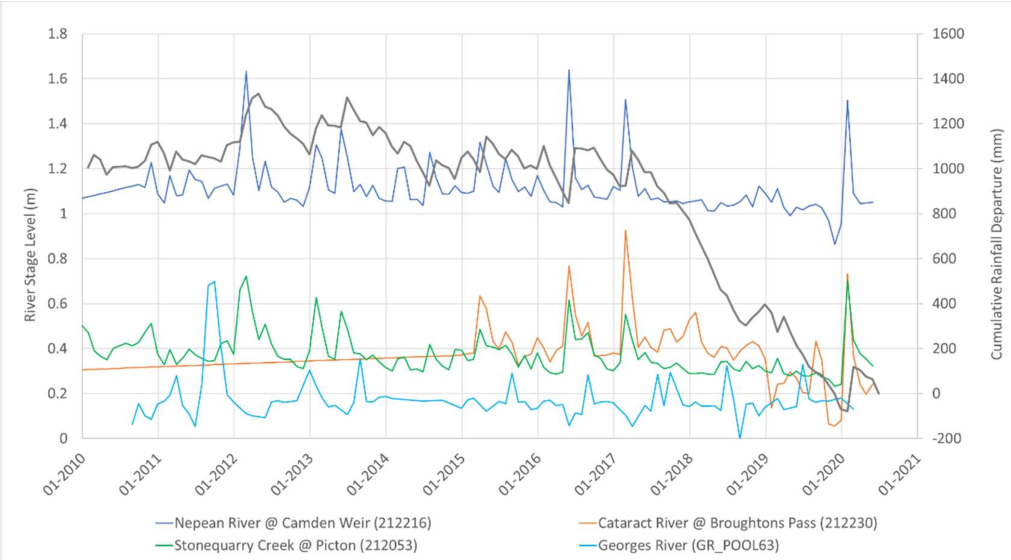

Figure 5 Surface Water Stages

A summary of average water quality monitored at the site surface water monitoring points is included in **Table 3**. The results show that the major rivers have contributions from dam releases, and are incised into the HBSS (i.e. Nepean River, Cataract River and Georges River) and generally contain fresh (low salinity) water. In contrast the minor tributaries, particularly those that occur where the Wianamatta Group is present at surface (i.e. Navigation Creek), have more brackish water quality and higher total dissolved solids (TDS).

Table 3 Summary of Surface Water Monitoring at Appin Mine

River	Average EC (µS/cm)	pH	TDS (mg/L)	Monitoring Period
Nepean River	291	8	164	2002 - 2020
Cataract River	168	7	97	2002 - 2020
Georges River	929	7	538	2008 - 2020
Ousedale Creek	1478	8	801	2002 - 2020
Menangle Creek	1373	8	725	2003 - 2020
Elladale Creek	1632	8	904	2002 - 2020
Allens Creek	743	8	397	2003 - 2020
Navigation Creek	2793	8	1581	2006 - 2020
Harris Creek	1663	8	924	2002 – 2020 / 2010 - 2020
Foot Onslow Creek	1680	8	944	2008 - 2020

Comparison between rainfall trends and the Nepean River surface water quality over time is presented in **Figure 6**. The Nepean River at Appin Mine has a long-term EC average of 291 µS/cm and median of 244 µS/cm, with no significant change between its downstream (NR0) and upstream (NR50) segment. The peaks in volume discharge correlate to above average rainfall conditions over time, which freshen water in the river system.

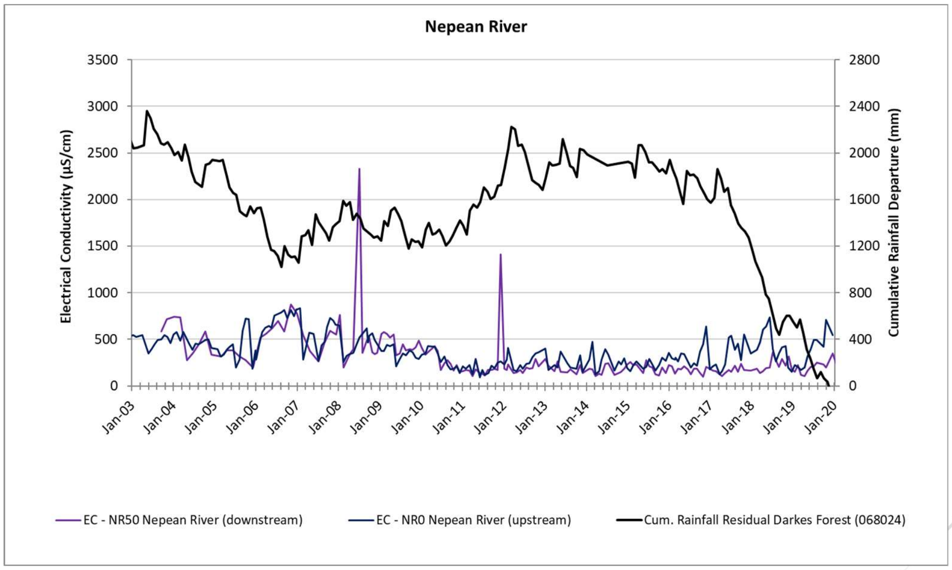

Figure 6 Water Quality along the Nepean River

2.4 Geology

Appin Mine is located within the Southern Coalfield of the Sydney Basin. The stratigraphy of the Southern Sydney Basin is presented in **Table 4** and shown in **Figure 7**, based on the Southern Coalfield 1:100,000 geological map (Moffitt 1999). A cross section through Area 7, Area 8 and Area 9 has also been created based on the site geological model and presented in **Figure 8**.

The Triassic Wianamatta Group is present at surface across the site (**Figure 7**) and ranges in thickness from less than 10 m to 200 m at Razorback Range. Quaternary floodplain alluvium is also mapped as being present on the northern side of the Project area, localised along Nepean River and its tributaries (i.e. Navigation Creek). The Quaternary alluvium along the Nepean River is currently mined at Menangle Quarry, approximately 4.5 km north-east of the Project **Figure 7**.

The HBSS is also present at surface and underlies the Wianamatta Group where it is present. The HBSS comprises bedded sandstone units and is around 170 m thick (MSEC, 2021). The HBSS is incised along the major rivers (i.e. Nepean River) and contributes baseflow. Around the Project there are also several registered bores accessing groundwater from the HBSS (Sydney Basin Nepean Groundwater Source) for stock, domestic, irrigation and industrial uses as discussed further in **Section 2.6.4.2**.

The HBSS is underlain by the Triassic sandstones, siltstones and claystones of the Narrabeen Group. This includes the Bulgo Sandstone, Scarborough Sandstone and Coal Cliff Sandstone, as well as the Bald Hill Claystone, Stanwell Park Claystone and Wombarra Claystone.

As illustrated in **Figure 8**, the Permian aged Illawarra Coal Measures underlie the Narrabeen Group. The Illawarra Coal Measures consist of interbedded sandstone, shale and coal seams, with a thickness of approximately 200 m to 300 m. The Bulli Seam is the primary economic sequence of interest at Appin Mine. Within the Project area the Bulli Seam is around 2.8 m to 3.3 m thick and around 530 m to 750 m below surface (MSEC, 2021). The strata around the Bulli Seam provides good conditions for longwall mining and in particular the floor is hard and competent (Moffitt, 1999). The immediate roof can range from mudstone, interbedded siltstone and sandstone, to sandstone.

The Permian coal measures dip approximately 2 % in a north-westerly direction, towards the Douglas Park syncline (MSEC, 2021). The major geological structures (faults) in the region include the Nepean Fault Zone, O'Hares Fault and J-Line Fault. Within the Project area (Area 7 and 9) there is a series of NNW-SSE orientated dykes and minor faults with displacement of less than 3 m (MSEC, 2021). However, previous mining through these structures at Longwall703 to Longwall706 and Longwall901 to Longwall903 did not cause any change in vertical subsidence (MSEC, 2021). In addition, since the 1970s in-seam drilling has been undertaken in advance of all development underground. No hydraulically charged structures were intersected at Appin Mine during the in-seam drilling process or progression of mining.

Table 4 Southern Sydney Basin Stratigraphy

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

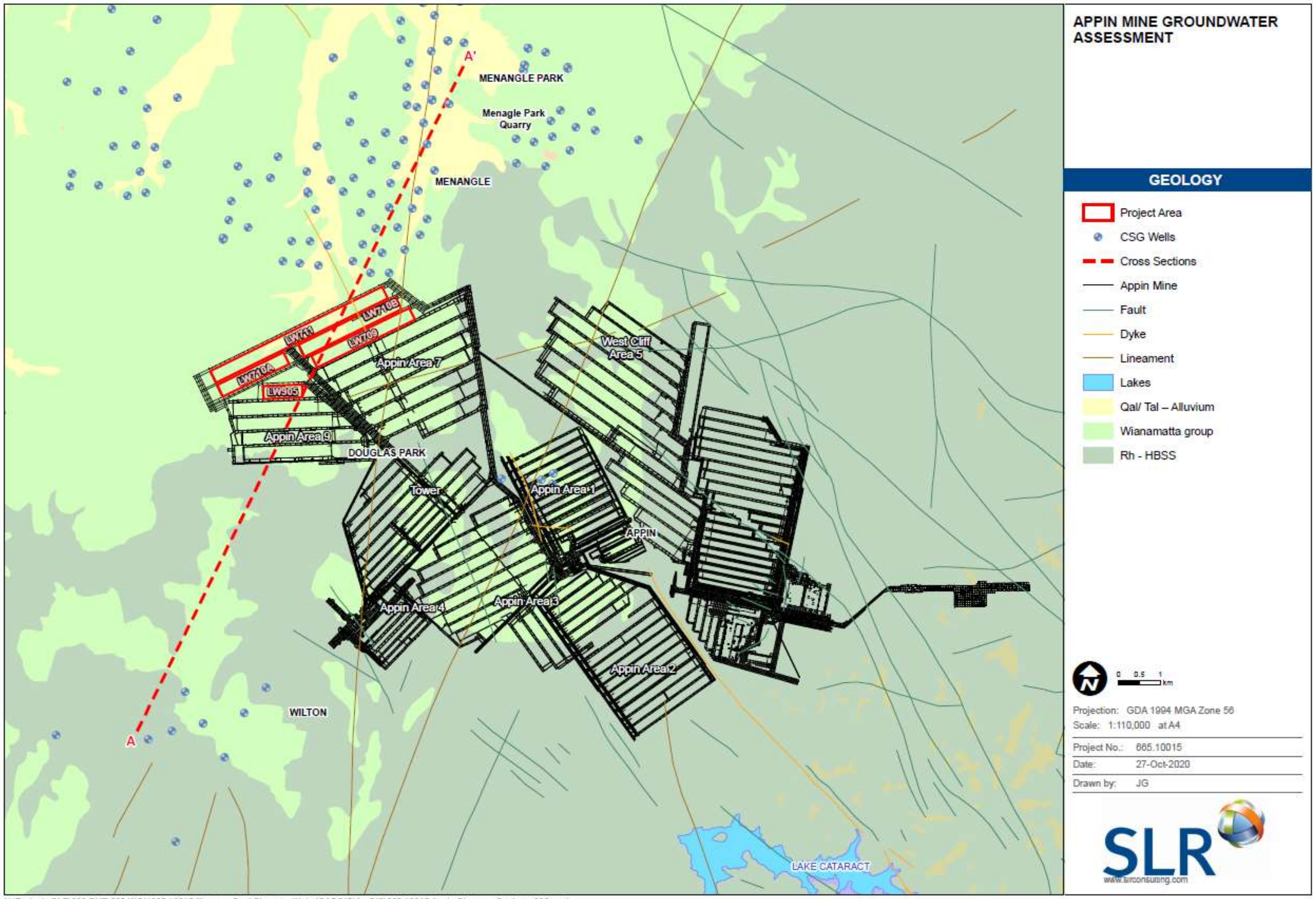

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Figure 7 Geology around Appin Mine

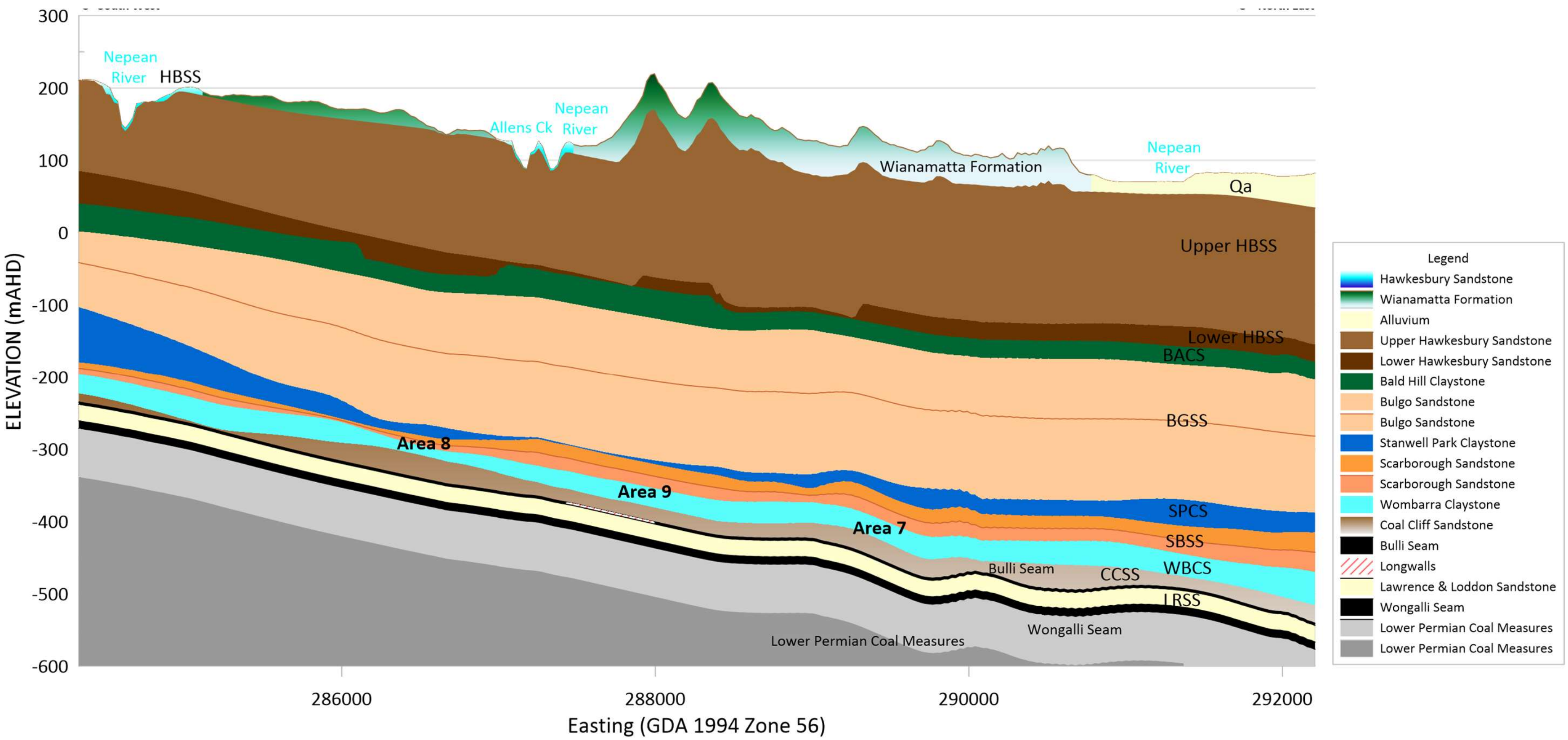

Figure 8 Geological Section A-A' – Appin Area 7, 8 and 9

2.5 Mine Subsidence

Above Longwalls 709 to 711 and 905 in the Bulli Seam, the depth of cover is between 530 m to 750 m. Potential subsidence impacts to the creeks and watercourses directly above and adjacent to longwalls have been assessed by MSEC (2021). MSEC (2021) found localised ponding could develop in some isolated locations. However, there are no predicted reversals of stream grade due to the Project, and no large-scale adverse changes in levels of ponding or scouring of banks along creeks due to subsidence related tilt.

Based on the experience of mining beneath ephemeral creeks and tributaries in the Southern Coalfield, it is likely that some fracturing will occur along the streams within the Study Area, particularly those located directly above or adjacent to the mining area. Some standing pools could experience a reduction or loss of water holding capacity. Fracturing will predominately occur where the creeks and tributaries are located directly above the mining area. Impacts can also occur outside the mining area, with minor and isolated fracturing occurring at distances up to approximately 400 m outside the longwalls, as previously observed at Appin Colliery and elsewhere in the Southern Coalfield. The mining-induced compression due to valley closure effects can also result in dilation and the development of bed separation in the topmost bedrock, as it is less confined. This additional dilation due to valley closure is expected to develop predominately within the top 10 m to 20 m of the bedrock. Compression can also result in buckling of the topmost bedrock resulting in heaving in the overlying surface soils.

The maximum predicted total vertical subsidence for the existing, approved and proposed longwalls is 1,550 mm and maximum predicted total tilt is 8 mm (MSEC 2021). The maximum predicted subsidence effects on the Nepean River due to the Project is less than 20 mm vertical subsidence, upsidence and closure (MSEC, 2021). The maximum predicted subsidence effects on the third order creeks (i.e. Navigation, Foot Onslow and Harris) is 1,400 mm vertical subsidence, 525 mm upsidence and 800 mm total closure.

2.6 Hydrogeology

2.6.1 Groundwater Network

Appin Mine has an extensive network of groundwater monitoring infrastructure that provides the capability to monitor:

- Deep groundwater levels using vibrating wire piezometers (VWPs) in each mining area;
- Shallow groundwater levels using VWPs, shallow screened bores and open standpipes along Nepean River, Georges River and Cataract River; and
- Groundwater quality via in-built borehole pumps and within the mine workings (goaf seep).

Monitoring instruments are positioned throughout the mining lease with instruments installed:

- Above the longwall footprints in all areas;
- Adjacent to the key receptors (alluvium, high economic aquifers, and landholder bores); and
- Adjacent to key watercourses being monitored from mining related subsidence (Nepean River, Georges River, and Cataract River).

The construction details of the VWPs, monitoring bores, and the monitored geology are shown in **Figure 9** and co-ordinates are presented in **Appendix A**. The groundwater monitoring program includes daily readings of pressure head at the VWP's, and manual measurement of water levels at the monitoring bores, as well as quality sampling and analysis for electrical conductivity (EC), pH, major ions, minor ions, metals, and a range of isotopes.

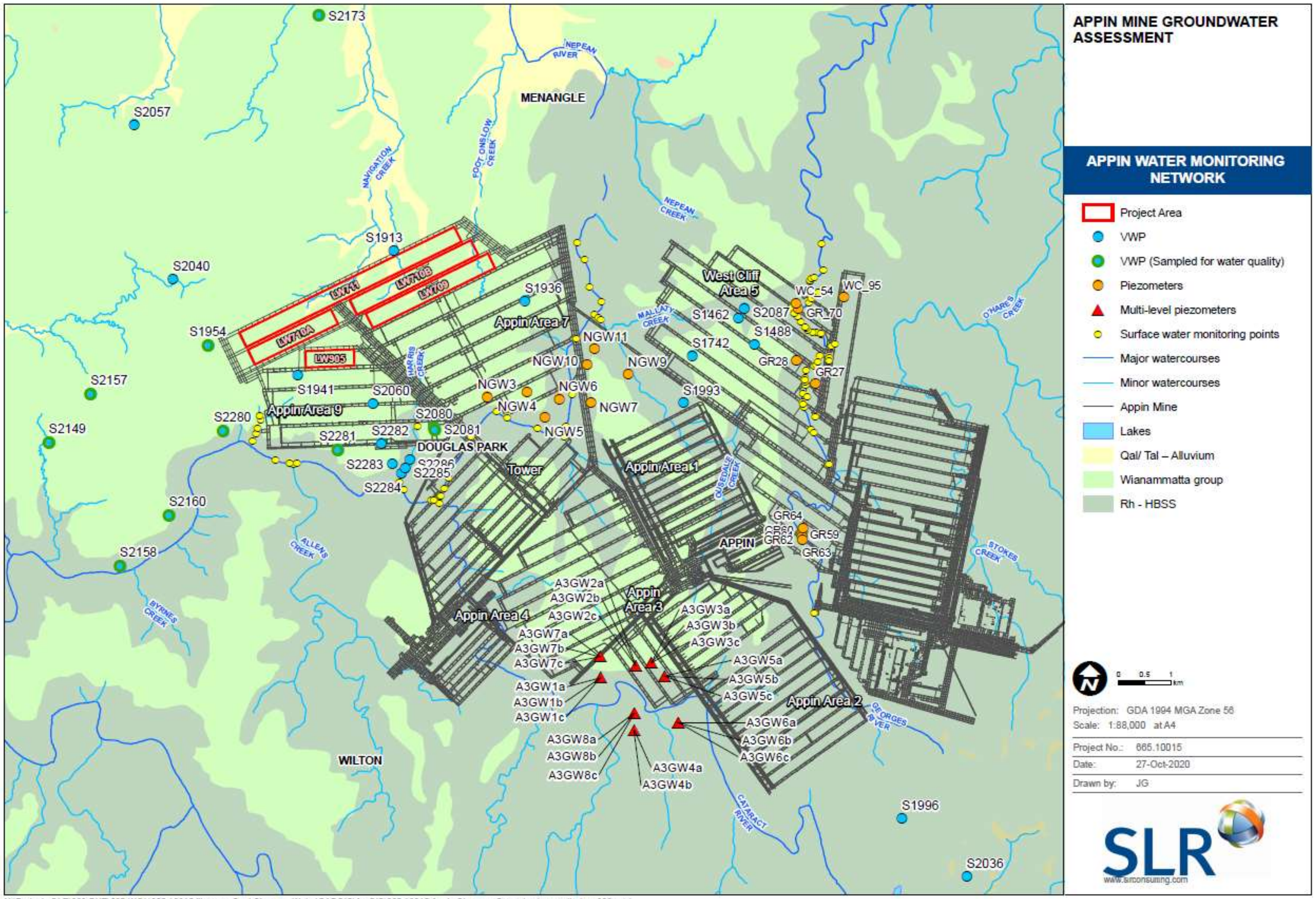

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Figure 9 Appin Groundwater and Surface Water Monitoring Network

2.6.2 Groundwater Trends

2.6.2.1 Alluvium

Based on 1:100,000 Southern Coalfield geology mapping (Moffitt, 1999), Quaternary alluvium has been mapped within the Project area along Navigation Creek and Foot Onslow Creek. Quaternary alluvium is also mapped along the Nepean River over 3 km north of the Project. The alluvium generally comprises heterogenous distribution of clay, silt, sand and gravel. CSIRO (2015) regolith mapping indicates the alluvium within the Project area is likely less than 10 m thick, increasing in thickness to around 20 m with proximity to the Nepean River in the north.

There are no site monitoring bores within alluvium, but there are registered bores within alluvium along Navigation Creek and Nepean River (and its tributaries) to the north. The available registered bore information indicates groundwater is present within the alluvium around 5 m to 8 m below surface. Alluvial groundwater flow likely follows topography and streamflow, flowing in a general northerly direction.

There are several registered bores within alluvium north of Appin Mine, which are noted as potentially being used for irrigation purposes, as discussed further in **Section 2.6.4.2**.

2.6.2.2 Wianamatta Group

The Wianamatta Group is present at outcrops across the Project area. The Wianamatta Group thickens with distance to the north-west and can be up to 100 m thick. The Wianamatta Group is composed of the Bringelly Shale (BrSh), Minchinbury Sandstone and Ashfield Shale (AsSh).

Groundwater in the Wianamatta Group is associated with perched water table zones with limited vertical flow. **Figure 10** shows a groundwater flow at S1954 (Area 7) controlled by a downward vertical head gradient in the Bringelly Shale from 280 mAHD to 220 mAHD. The perched water table at this location is separated by a difference of 100 m groundwater head from the regional water table present in the HBSS.

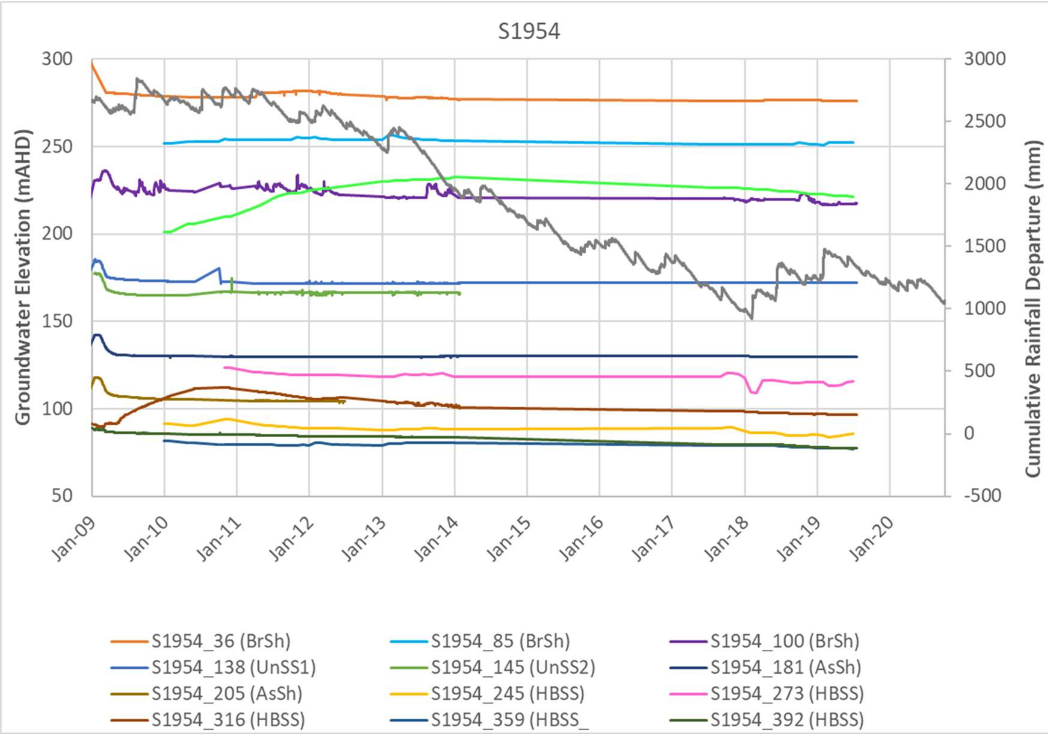

Figure 10 Hydrograph – S1954

2.6.2.3 Hawkesbury Sandstone (HBSS)

The HBSS outcrops in the region as the Woronora Plateau, and is present across most of the historical mining at Appin (West Cliff, Tower, Area 1, 2, 3 and 4). The HBSS forms a major aquifer, due to its regional extent, coverage at surface that enables rainfall recharge and accessible for landholder water usage (bores). It is a thick aquifer (>200 m) with numerous high and low permeability horizons or lenses. Within the Appin Mine area it has been described as having low groundwater yields but good groundwater quality (Heritage Computing 2009).

Due to the stratification of the sandstone sequences, groundwater flow is primarily horizontal, with minor vertical leakage. Groundwater movement is controlled by the topography with flow towards major rivers that are deeply incised into the sandstone (i.e. Nepean River). Surrounding the Project area monitoring within a range of vertical profiles is conducted at VWPs S1954 (**Figure 10**), S1913 (**Figure 11**) and S1941 (**Figure 12**). As shown in the hydrographs there is a general downward gradient within the HBSS. To the east groundwater levels range from 380 mAHD across the Woronora Plateau, down to around 70 mAHD to 90 mAHD along the Nepean River (**Figure 13**).

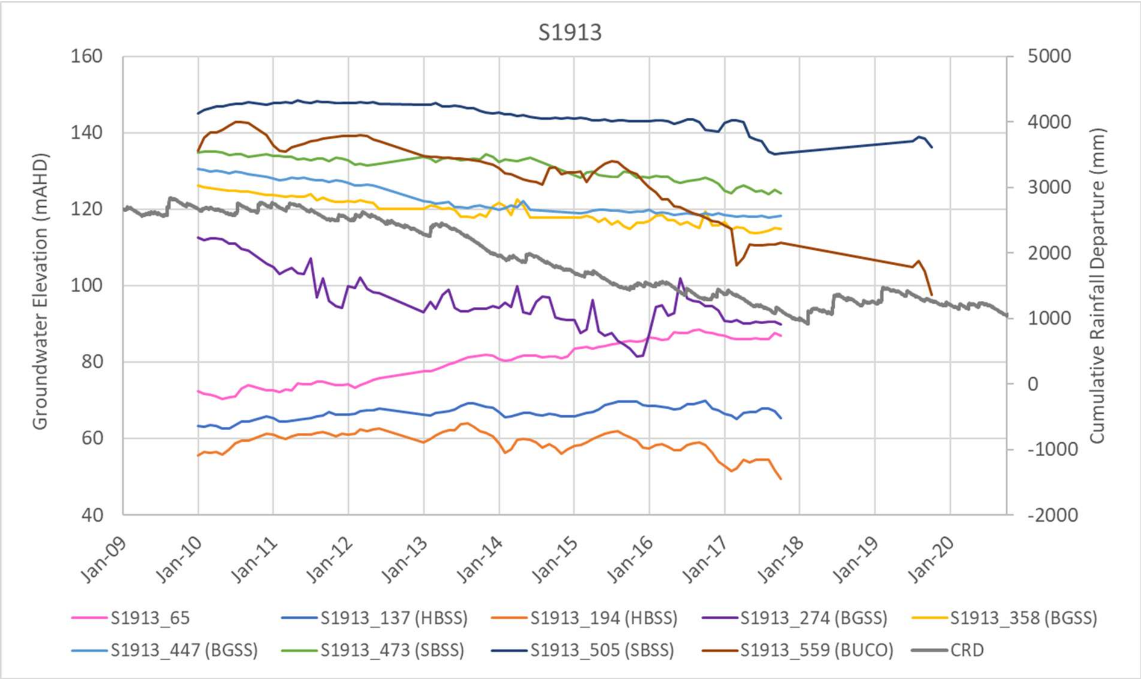

Figure 11 Hydrograph – S1913

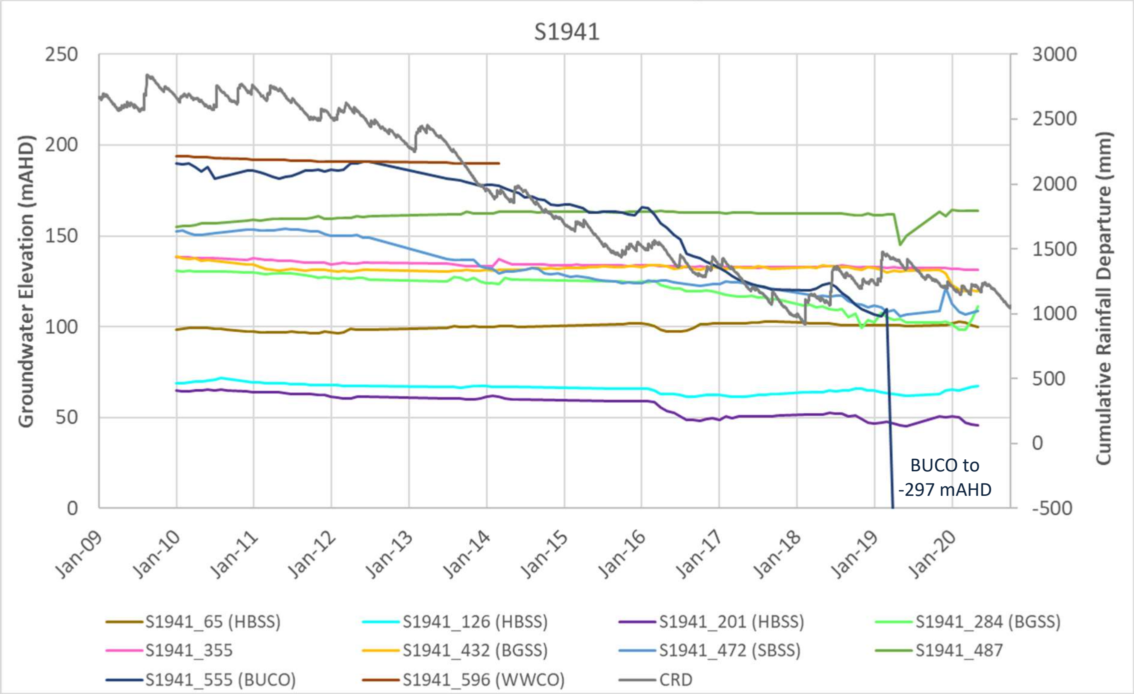

Figure 12 Hydrograph – S1941

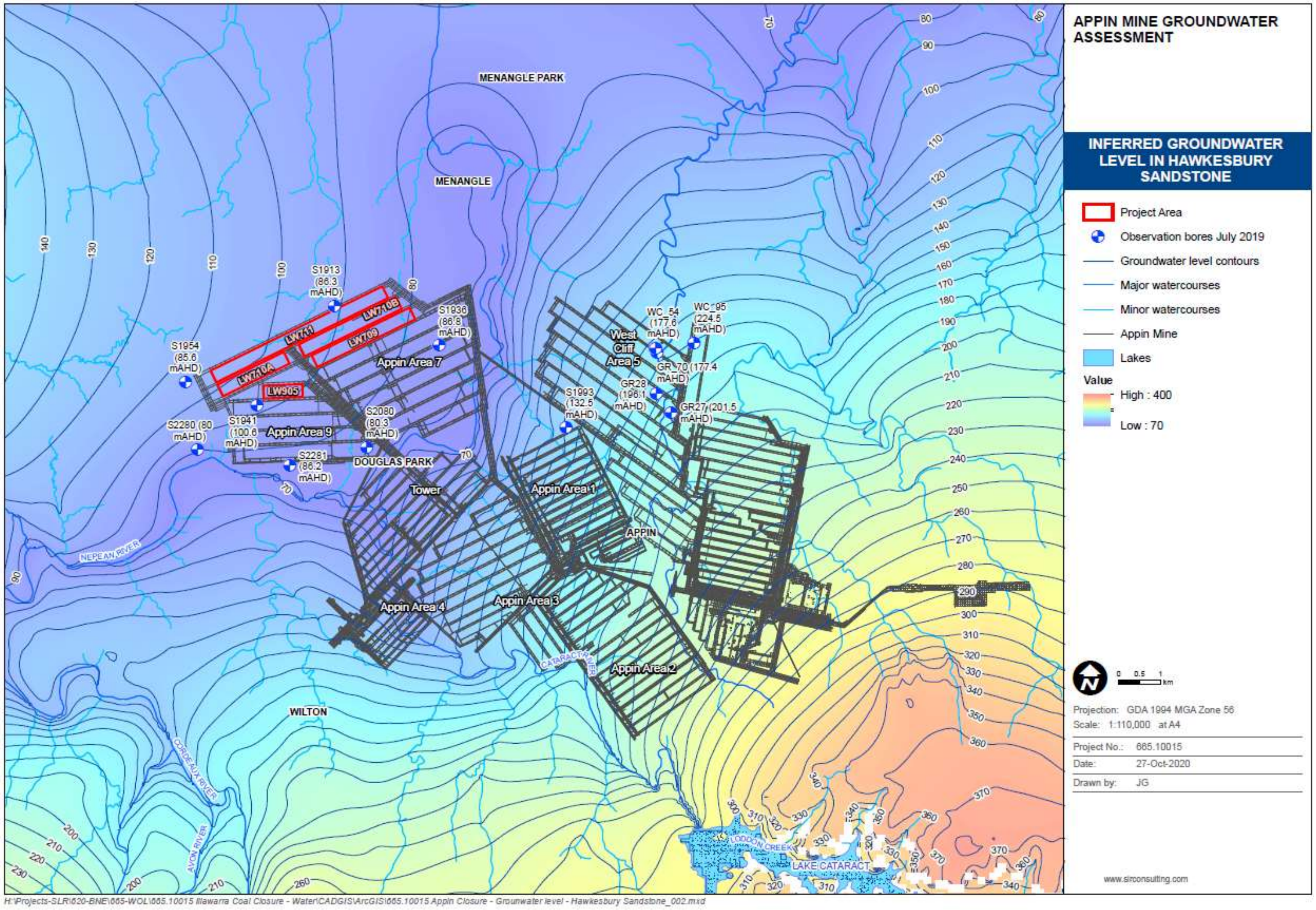

Figure 13 Inferred Potentiometric Level in the HBSS

2.6.2.4 Narrabeen Group

The Narrabeen Group is a sequence of interbedded sandstone, claystone, and siltstone present across the Appin Mine. It thickens north westerly from Appin Area 3 extended to Appin Area 7. The major unit is the Bulgo Sandstone which has a poor groundwater quality due to the higher salinity than the HBSS. Groundwater flows north-westerly at the base of the unit through bedding planes, joints and fractures. The Narrabeen Group comprises three formations of very low permeability called aquitards. These aquitards impede vertical flow within the unit and are described below:

- The Bald Hill Claystone at the top of the Bulgo Sandstones interrupts the vertical groundwater flow from the HBSS. The aquitard is present across the Appin Mine and has a thickness of approximately 25 m.
- The Stanwell Park Claystone limits the interaction of groundwater between the Bulgo Sandstone and the Scarborough Sandstone and is present across the Appin Mine with a higher thickness over Area 7 (20 m) than in Area 3 extended (6 m). The Wombarra Claystone forms the base of the Narrabeen Group and also impedes vertical flow to the Illawarra Coal Measures. It is present across the Appin Mine and thickens south-easterly from 30 m at Appin Area 7 to 41 m in Area 3 extended.

The hydraulic gradient within the Narrabeen Formation spatially varies due to the differences in hydraulic properties over varying depths. In the Project area groundwater heads (at depth) tend to be higher than those observed in the HBSS (bore S1913 - **Figure 11**). The hydrograph for VWP 1941 (**Figure 12**) also shows gradual depressurisation within the Scarborough Sandstone and Bulgo Sandstone with progression of mining and depressurisation of the Bulli Seam. This depressurisation of the Narrabeen Group is also visible in response to the Camden Gas Project that is active at the northern side of the Project and is influencing current groundwater conditions. This is shown by the potentiometric level trends in **Figure 14** for VWP S2177, which is located around 5.7 km north of the Project and 500 m to 1 km from five active CSG wells (EM05, EM07, EM09, MP15 and MP30). **Figure 14** shows a 40 m decline in potentiometric levels in the Scarborough Sandstone from commencement of monitoring, along with a decline in the Bulli Seam.

On a regional scale, groundwater flows horizontally from elevated areas in the southeast and western side of Appin Mine, with a hydraulic gradient towards the north. Potentiometric levels in the upper Bulgo Sandstone range from 300 mAHD in the south east to 90 mAHD to 100 mAHD across Appin Mine (

Figure 15).

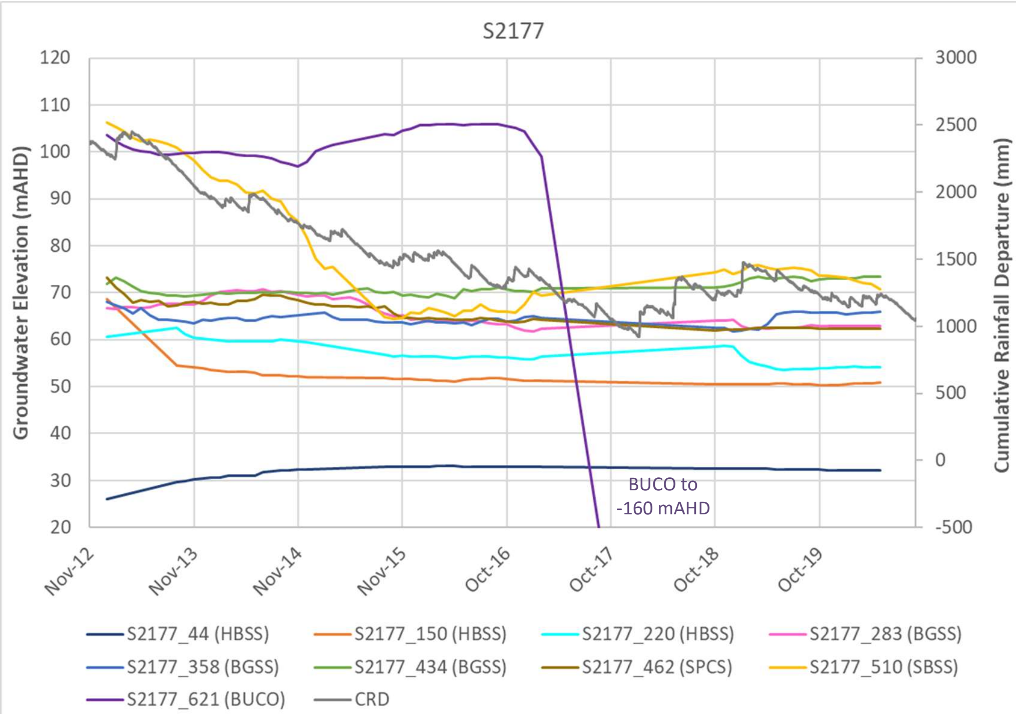

Figure 14 Hydrograph – S2177

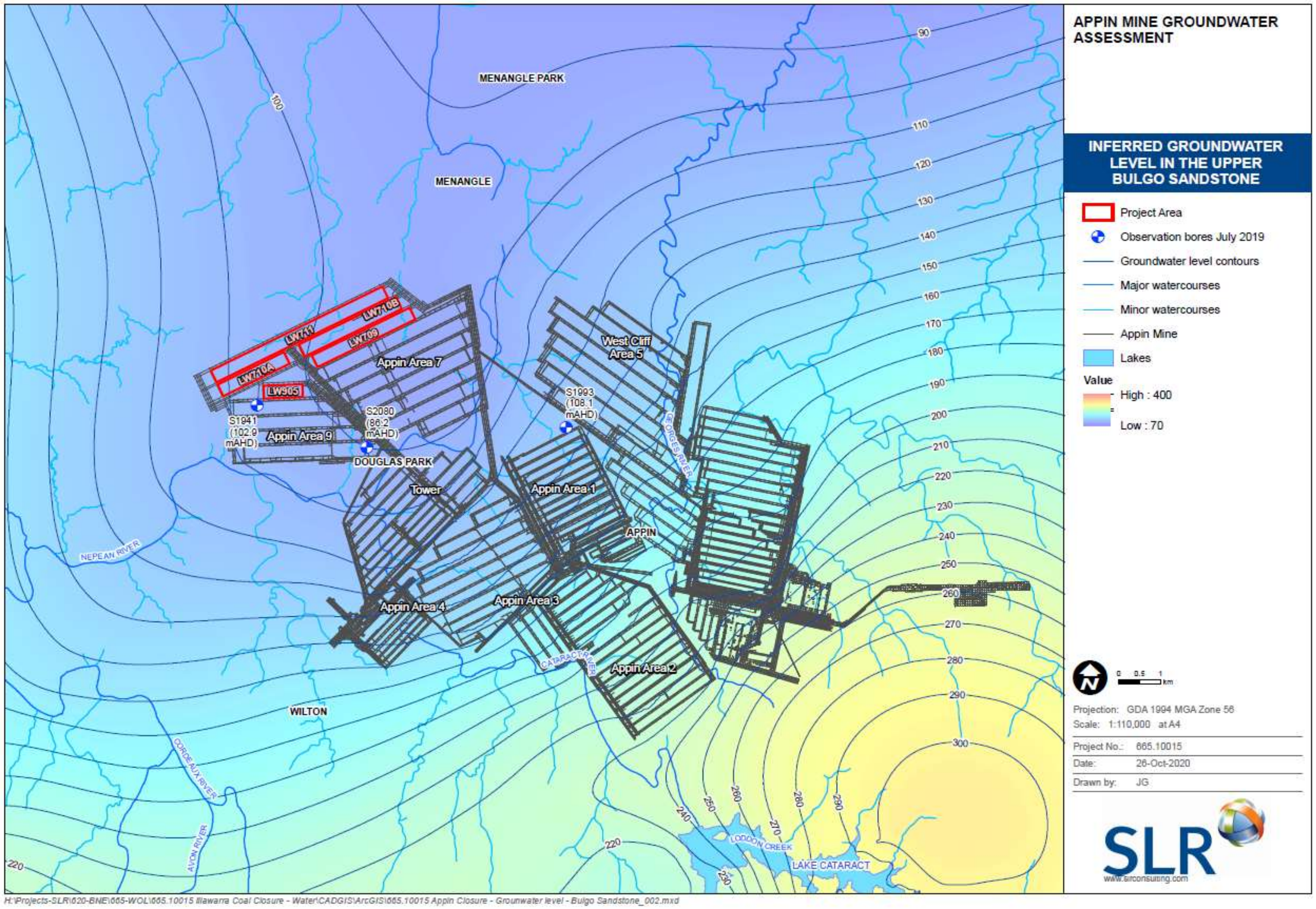

Figure 15 Inferred Potentiometric Level in Upper Bulgo Sandstone

2.6.2.5 Illawarra Coal Measures

The Illawarra Coal Measures are the primary economic sequence of interest in the Sydney Basin, and consist of interbedded sandstones, shale and coal seams with a thickness of approximately 200 m to 300 m. The two main coal seams mined in the Southern Coalfield are the uppermost Bulli Seam and the Wongawilli Seam (Holla and Barclay, 2000). Within the Project extent of the longwall mining area, the Bulli Seam is around 530 m to 750 m below surface. The coal seams outcrop to the east of Appin Mine, where coal seams are truncated (eroded) along the Illawarra Escarpment.

Figure 16 shows the groundwater heads in the Bulli Seam in July 2019. Mining activities have modified the pre-mining heads in the Bulli Seam. Mine workings act as a groundwater sink in the surrounding area of Appin Mine. The depressurisation of the strata is observed across the historical and active mining areas as seen in Area 7 at bore S1936 (**Figure 17**) and higher-pressure head away from mining at bore S1913 (**Figure 11**).

The depressurisation of the strata is observed across the historical and active mining areas as seen in Area 9 at bore S1994 (**Figure 18**). Groundwater heads in Wongawilli Seam are in the range of about 1 to 5 m higher than the heads in Bulli Seam during the pre-mining period.

On a regional scale, the groundwater in the both Bulli Seam and Wongawilli Seam flows towards the north. Groundwater within the Permian coal measures are semi-confined where they occur at subcrop, becoming confined with depth towards the north-west. Groundwater heads range from 220 mAHD in the south-east to 110 mAHD north of Appin Mine (**Figure 16**).

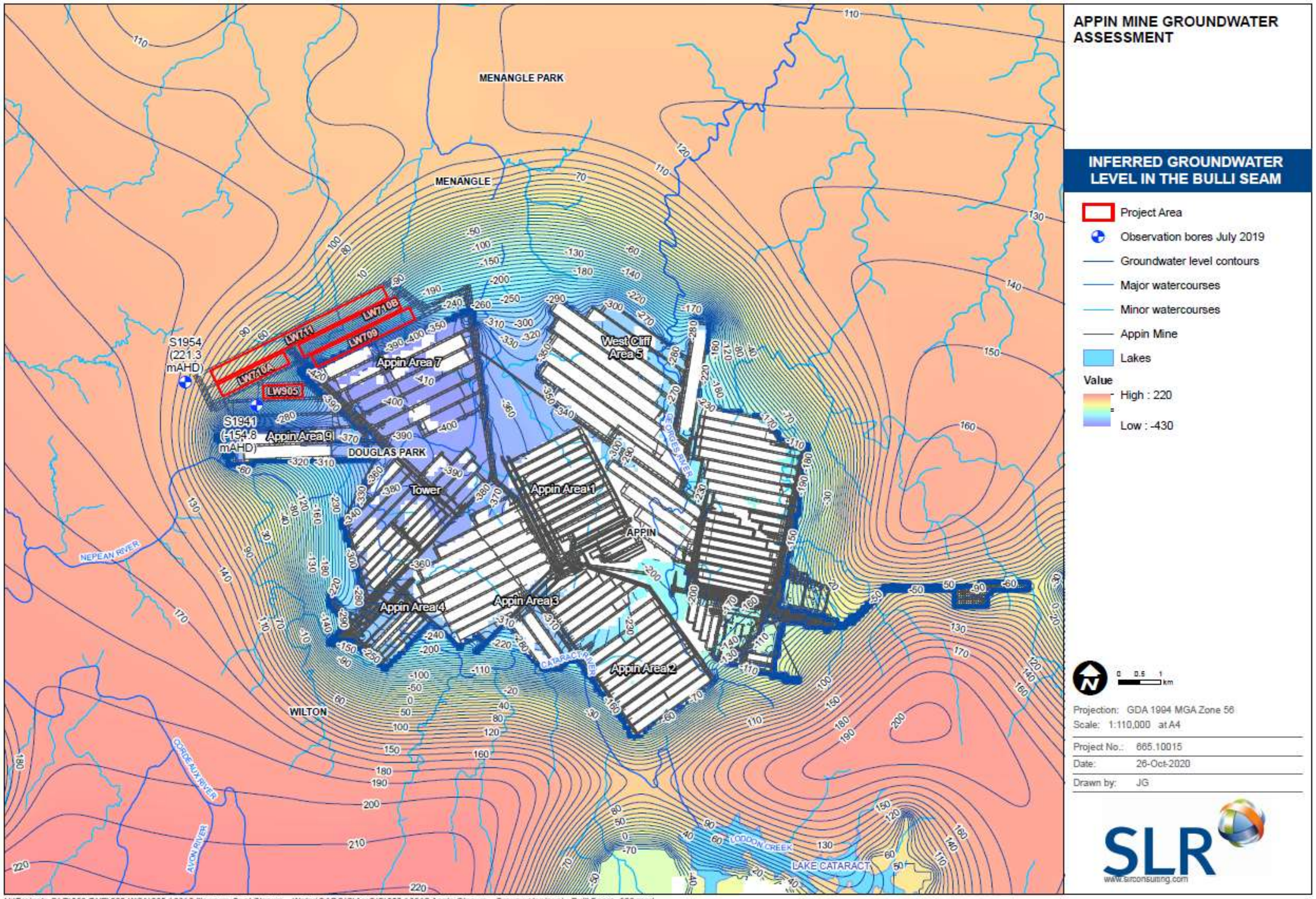

Figure 16 Inferred Potentiometric Level in Bulli Seam

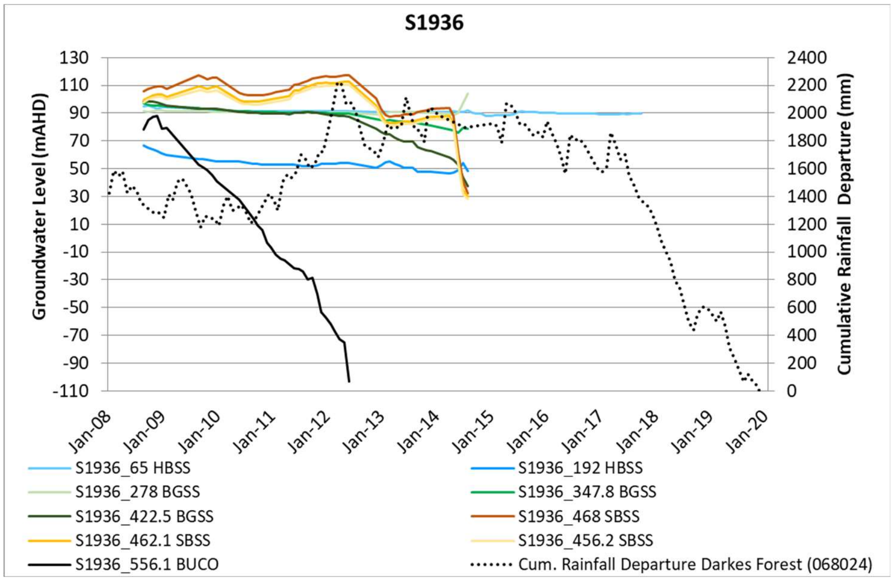

Figure 17 Hydrograph - S1936

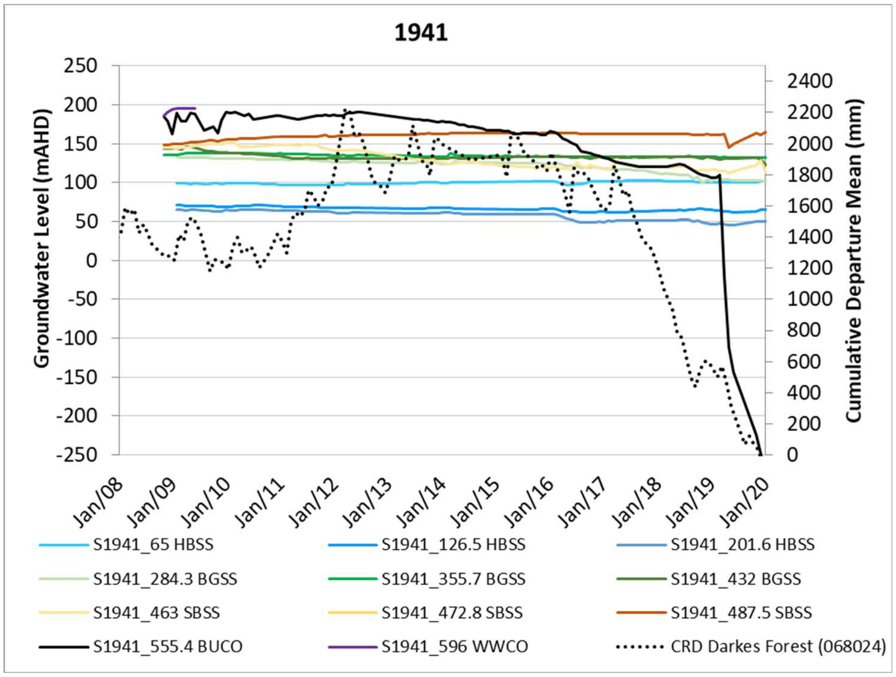

Figure 18 Hydrograph - S1941

2.6.3 Groundwater Quality

A summary table of groundwater quality data collected at site from bores screened within the Wianamatta Group, HBSS and Bulgo Sandstone is presented in **Appendix B**.

In summary, water within:

- Nepean River surface water is generally fresh (median EC 244 µS/cm) and generally has neutral pH (median pH 7.7).
- Wianamatta Group is generally moderately saline (median EC 4,750 µS/cm). The results show that water is not suitable for drinking water, generally suitable for short term irrigation and water for some stock (i.e. sheep and dairy cattle). But generally has iron concentration above the trigger for long term irrigation water use, and low yields so not considered a productive groundwater source (Heritage Computing, 2009).
- HBSS is brackish (median EC 2,060 µS/cm) but can have variable water quality with the 5th and 95th percentile of site data ranging between 460 µS/cm and 6,458 µS/cm. Generally has a neutral pH (median pH of 7.5), but also highly variable with a 5th and 95th percentile of site data ranging between 6.4 and 11.9. Typically has a sodium-calcium type water, and is generally suitable for short term irrigation and stock water. But generally has iron concentration above the trigger for long term irrigation water use.
- Bulgo Sandstone within the Narrabeen Group is generally moderately saline (median EC ~4,950 µS/cm) and generally has neutral pH (median pH 7.2). Typically has a sodium-bicarbonate type water and is generally suitable for short term irrigation and water for some stock (i.e. sheep and dairy cattle). But generally, has iron concentrations above the trigger for long term irrigation water use.

The available data indicates there are no groundwater bores on site where water quality data is collected from the Permian coal measures. It is assumed water within the coal measures would generally be moderately saline to saline. With consideration of mine closure, as groundwater recovers, minerals that were oxidised under the drained conditions (i.e. sulphur) can undergo dissolution, in turn lowering the pH of the infilling waters (Wright *et al.*, 2018). More acidic waters can lead to increased dissolution of precipitated metals such as zinc, iron and nickel (Wright *et al.*, 2018; Price and Wright, 2016). The degree of acidity encountered during the saturation of the mine workings is dependent upon the acid forming potential of the mined material (Harries, 1997).

2.6.4 Groundwater Receptors

2.6.4.1 Swamps

Upland headwater swamps have been mapped in the region; however the closest swamps are approximately 9,000 m from the Project area and are therefore not considered potential receptors for this Project.

2.6.4.2 Landholder Bores

A search of the BoM's National Groundwater Information System (NGIS) was carried out for registered bores within the model extent. The search indicated that there are 1,006 registered bores, of which 512 are functional, 453 are unknown, 26 are proposed, and 14 are abandoned, non-functional, or removed. The function of all bores identified in the database is presented below in **Table 5.** There are 49 registered bores within 5 km of Appin Mine/Project area. The location of these bores is shown in **Figure 19**.

Table 5 Registered Use of Groundwater Bores Within the Model Extent

Use	Count	Percent of Total
Commercial and Industrial	16	1.6
Dewatering	10	1.0
Exploration	9	0.9
Irrigation	139	13.8
Monitoring	379	37.6
Other	9	0.9
Stock and Domestic	33	3.3
Unknown	34	3.4
Water Supply	377	37.5
Total	**1,006**	**100.0**

A majority of groundwater users are located to the north of the Project, within the Wianamatta Group outcrop area, and to the southwest, within the HBSS outcrop area. Most landholders are located within the HBSS (453) and Bulgo Sandstone (322). Of these, 207 bores could be extracting water from the HBSS for water supply, irrigation, household, stock, and domestic purposes. There are 237 bores extracting water from the Bulgo Sandstone. Based on bore depth and the surface geology map, there is potential for approximately 64 registered bores (depth < 30m) targeting alluvium along the Nepean River and the Mount Hunter Rivulet, north to Appin Mine. These bores are used for monitoring (39), irrigation (15), water supply (4), stock (1) and other uses (5). Maximum yield of private bores surrounding Appin Mine does not exceed 1.5 L/s. Details of the registered bores in the Appin Mine Area are shown in **Appendix C**.

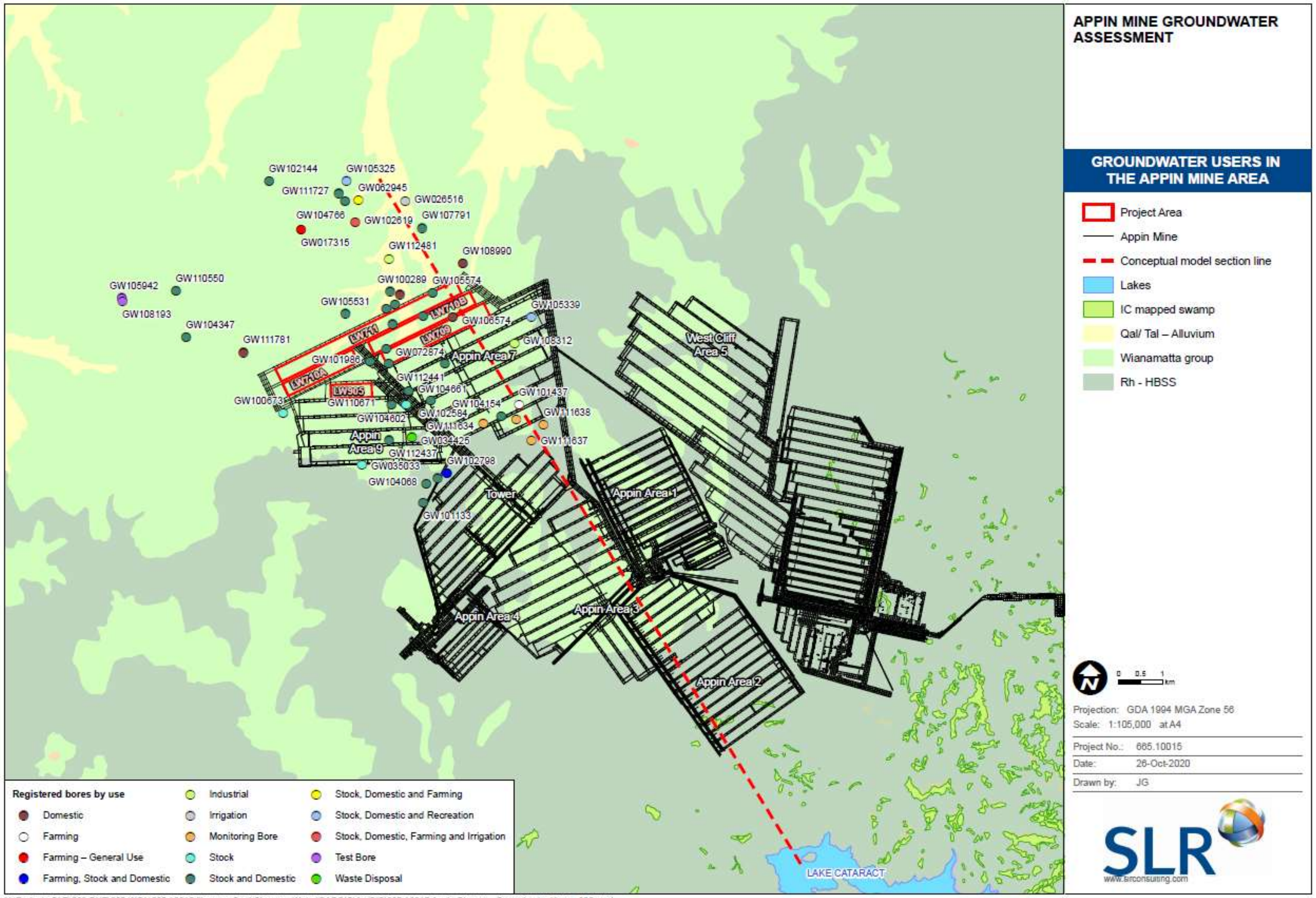

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Figure 19 Groundwater Users in the Appin Mine area

3 Conceptual Groundwater Model

The primary hydrostratigraphic units within the Appin Mine area are:

- Quaternary alluvium – localised along rivers and creeks, likely unconfined and recharged from rainfall and surface water flow. Discharge to surface water (baseflow contributions) possible where gradients enable this, with potential for downward seepage where unconformably overlies HBSS. Groundwater flow likely follows topography and streamflow direction towards the north;
- HBSS – main groundwater source and widely accessed for groundwater supply and provides baseflow contributions where incised along major rivers (i.e. Cataract River, Nepean River and Georges River). Groundwater flow generally in a northerly direction, and locally influenced where intersected by rivers and private abstraction bores;
- Narrabeen Group – sandstones that can be used for groundwater supply, and low permeability claystones that generally act as aquitards; and
- Illawarra Coal Measures – with groundwater occurrence largely associated with the more permeable coal seams, with confined groundwater conditions. Groundwater flow generally in a northerly direction, and locally depressurised due to current and historical mining and CSG.

The Appin Mine intersects the Bulli Seam, which ranges from 530 m to 750 m below surface at the Project, and generally dips in a north-westerly direction. With mine progression at Appin, the hydraulic properties of the stratigraphy overlying the Bulli Seam is changed due to goaf effects from longwall mining. There is no site specific data on the insitu hydraulic properties for Appin, but extensive data for surrounding mines (Dendrobium and Tahmoor) indicates the goaf and fractured zone can result in an enhanced permeability of 2 to 3 orders of magnitude, depending on the strata (HGEO, 2019).

Within overlying stratigraphy, not impacted by goaf effects, the influence from depressurisation of the mined coal seam is limited by the low vertical conductivity and the presence of low permeability claystones that can act as aquitards (i.e. Bald Hill Claystone).

Current groundwater levels indicate depressurisation within the Bulli Seam extends approximately 1 km to 2 km from active mine areas, consistent with previously assessed impacts for the BSO (Heritage Computing 2009). Current monitoring data also shows depressurisation within the Scarborough Sandstone and Bulgo Sandstone due to mining and within the Scarborough Sandstone due to CSG activities (Camden Gas Project). Drawdown within the Scarborough Sandstone, Bulgo Sandstone and lower HBSS was previously predicted for BSO (Heritage Computing, 2009).

There is no visible depressurisation or drawdown within the HBSS in response to mining or CSG. Drawdown in the HBSS is visible outside of the mine area in localised areas around registered landholder water supply bores, which appears to relate to local bore usage and not related to mining. Overall, no adverse impacts beyond those previously predicted have been observed due to existing operations at Appin Mine.

4 Groundwater Modelling

4.1 Groundwater Model Setup

This study utilised the SLR (2020) numerical model, which was based on the groundwater model HydroSimulations (2018) and previously based on the Heritage Computing (2009) which was used for the Appin Mine groundwater assessment (Heritage Computing, 2009). The SLR (2020) groundwater model utilises MODFLOW-USG code and was developed in Groundwater Vistas Version 7 (GWVistas 7).

As part of the study, the following updates were undertaken on the SLR (2020) model:

- Extending the model and create a 3D mesh of Voronoi cells.
- Update model layer to reflect Lidar data (Layer 1).
- Differentiate alluvial materials (Layer 1) from the Wianamatta Group and the weathered HBSS (Layer 2), plus refine thickness of alluvial materials along rivers and across swamps areas.
- Split the thick groundwater units such as the HBSSs and the Bulgo Sandstones into three separate layers to better accommodate groundwater model targets (i.e. VWP sensors) and to improve the alignment of the height of fracture within the numerical model layers.
- Use pinch out function in MODFLOW-USG to remove the dummy layers based on geological layers. These features allow the total cell count to be reduced, and the conceptual correctness of the model to be improved.
- Update model timing to quarterly stress periods (SP) to account for seasonal changes and mining schedule.

4.1.1 Model Extent and Mesh Design

The groundwater model domain is shown in **Figure 20**. The model extends approximately 52 km from west to east and approximately 43 km from north to south, covering an area of approximately 2070 km^2. The groundwater model extent was designed to be large enough to accommodate future mining at Appin Mine and to cover any potential associated impacts.

The HydroAlgorithmics software "AlgoMesh" was used to generate the 3D Voronoi cells grid. The large spatial area of the model extent resulted in the need for an unstructured grid with varying cells sizes, and refinement in the areas of interest, in order to reduce the total cell count to a manageable size. The mesh over the whole model extent is shown in **Figure 20**. The following features have been included in the mesh design:

- A regular (aligned) square grid of cells was enforced in Appin Mine proposed and historical longwall mining after 2009, rotated in line with the longwalls (100 m), and in those of Tahmoor Mine (150 m), Metropolitan Mine (150 m).
- A regular hexagonal grid of cells was used to refine all historical mining before 2009 with cell size of 200 m in Appin, Metropolitan and Russell Vale Mines and 300 m in Tahmoor.
- Polylines along mapped rivers and creeks were used to ensure the mesh conformed to mapped drainage network, and to enforce variable details along streams (e.g. greater detail along streams closest to Appin Mine). Voronoi cells sizes along rivers and creeks varies from 100 m to 300 m.
- A regular hexagonal grid of cells was used to refine the mesh across the different Appin Mine shafts, with maximum cell size of 50 m.

- The mapped alluvial boundaries present across the model extent were used to enforce finer cell resolution in a range of 200 m and 400 m cell size.
- Escarpment areas were refined by 300 m cell size.
- Regular hexagonal grid of cells was used to refine the mesh across the reservoirs (i.e. Cataract and Woronora) with maximum cell size of 200 m.

The cell count for layer one is 56,119. Over the 18 model layers, with pinch-out areas (where a layer is not present) in layers 2 to 17, the total cell count for the model is 995,059.

4.1.2 Model Layers

The groundwater model consists of 18 layers as listed in **Table 6**. Model layer 1 is present across the whole model extent, and includes the Quaternary Alluvium, swamps, Wianamatta Group and HBSS. The Wianamatta Group has been split across layers 1 and 2 where present. The HBSS has been split into 5 layers, and the Bulgo Sandstone has been split into 3 layers to allow vertical gradients through the stratigraphic column to be represented.

The Bulli Seam is represented in layer 15 for the purpose of modelling longwall mining at Appin, Metropolitan, Tahmoor and all other historical mines. The Wongawilli Seam is represented in layer 17 for the purpose of modelling longwall mining at Russell Vale East.

Model layers 2 to 17 are not present across the whole model domain, the layers have been pinched out where the geology has been eroded at outcrop.

Table 6 Groundwater Model Layers

Layer	Geology
1	Alluvium/ Wianamatta Group / Weathered HBSS
2	Wianamatta Group / Weathered HBSS
3	Upper HBSS
4	Upper HBSS
5	Lower HBSS
6	Bald Hill Claystone
7	Bulgo Sandstone
8	Bulgo Sandstone
9	Bulgo Sandstone
10	Stanwell Park Claystone
11	Upper Scarborough
12	Lower Scarborough
13	Wombarra Claystone
14	Coal Cliff Sandstone
15	Bulli Coal Seam
16	Loddon Sandstone
17	Wongawilli Seam
18	Lower Permian Coal Measures

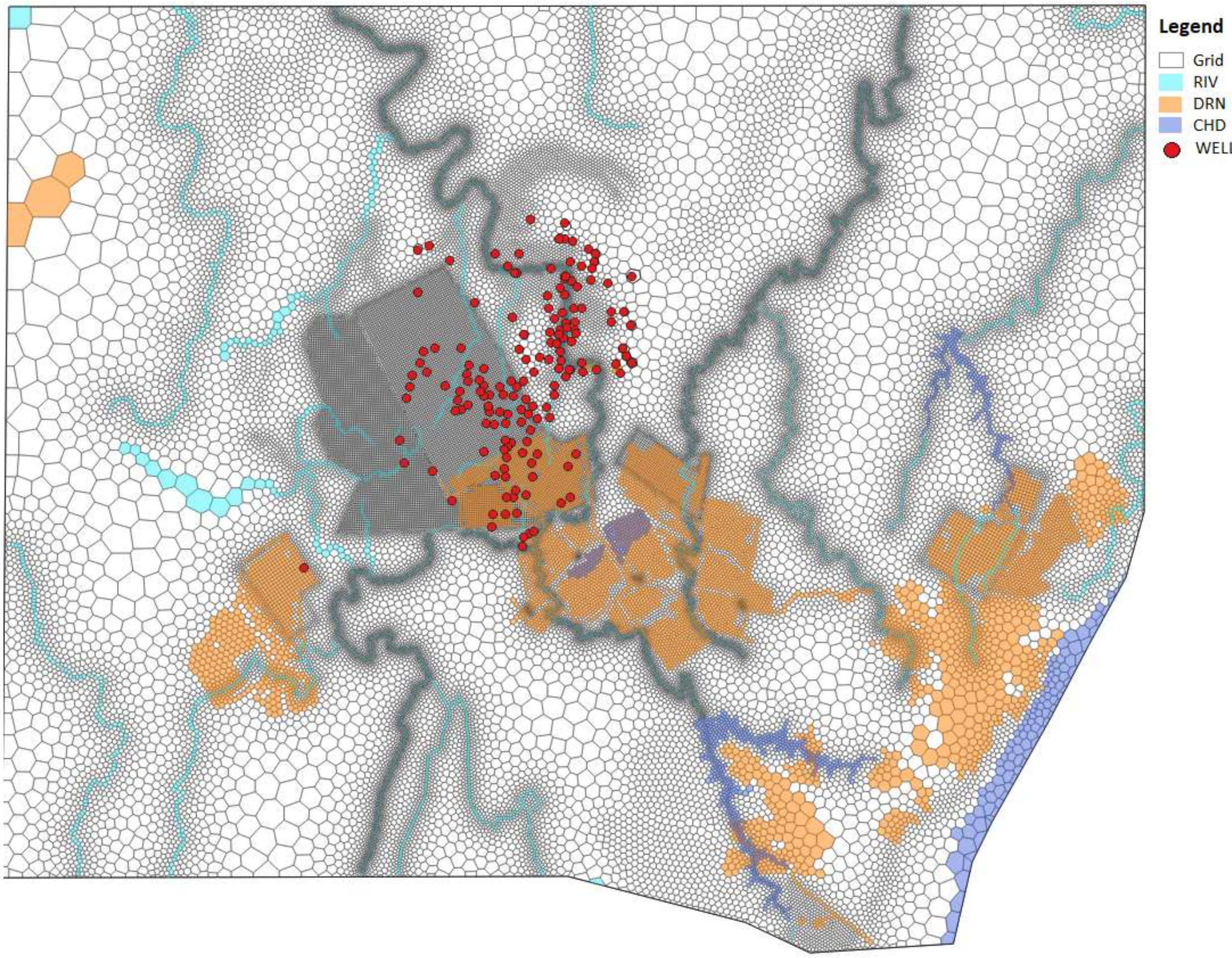


Figure 20 Model Domain and Model Grid

4.1.3 Model Timing

The stress period timing in the model was updated to include more temporal detail to better capture seasonal trends in recharge to alluvium and outcrop formations, as well as a better inclusion of the mine schedule into the model. To achieve this, the historical and predictive stages of the model were updated to:

- Transient historical period from 1 January 2010 to 30 June 2020 with quarterly stress periods; and
- Transient predictive period from 1 July 2020 to 31 December 2027 with quarterly stress periods.

4.1.4 Model Scenarios

To calculate the impacts associated with mining at Longwalls 709, 710A, 710B, 711 and 905 (709 to 711 and 905) the following scenarios were run:

- NULL Run – No mining in region;
- Null Appin Mine Run – All foreseeable neighbours mining, AGL CSG and registered borefields, excluding the Appin Mine;
- Approved + Project Appin Mine Run – All approved mining, including mining of Longwall709 to 711 and 905; and
- NULL Extension Run – All approved mining excluding mining of Longwall709 to 711 and 905.

4.1.5 System Stresses

This section presents a summary of the main model inputs to replicate system stresses that were varied as part of this study, including streamflow, recharge and mining.

4.1.5.1 Wells

AGL held 137 bore licences for the Camden Gas Project gas production wells from two Water Access Licences (24856 and 24736) which have a combined allocation of 30 ML per year, with 15 ML allocated to the Sydney Basin Central Groundwater Source and 15 ML allocated to the Sydney Basin Nepean Groundwater Source, and are licensed for industrial purposes (AGL, 2018).

The MODFLOW Well (WELL) package has been used to present these Camden Gas Project production wells to replicate depressurisation within the Bulli Seam (**Figure 20)**. Within the model the Camden Gas Project wells commenced operation based on the date of installation and were turned off at 2023 (AGL, 2018).

The WELL package was also used to capture the water take from 83 licensed registered water supply bores within the model domain. Five wells are screened in Bulli Seam, four in the Wianamatta Group, one in the Bulgo Sandstone with the remainder screened in the HBSS. The extraction rate has been assumed as 5 ML/year or if unknown the shared component volume. Within the model the wells were started based on information on the drilled date and remain active until the end of model prediction period.

4.1.5.2 Streamflow

All major watercourses, as shown in **Figure 21,** are represented using the MODFLOW River (RIV) package. The main rivers (Nepean River, Cataract River and Stonequarry Creek) were replicated with a time-variant stage based on the observed levels from the stream stations. Remaining third order streams where no observation data was available were modelled with a constant 1 m stage. Forth order streams/ephemeral drainage lines were represented as 'river' boundary cells in the model, with the stage equal to the base of the riverbed.

The modelled stage levels along Nepean River, Cataract River and Stonequarry Creek are presented in **Figure 21**, compared to observed monthly levels at stream stations and Cumulative Rainfall Departure (CRD).

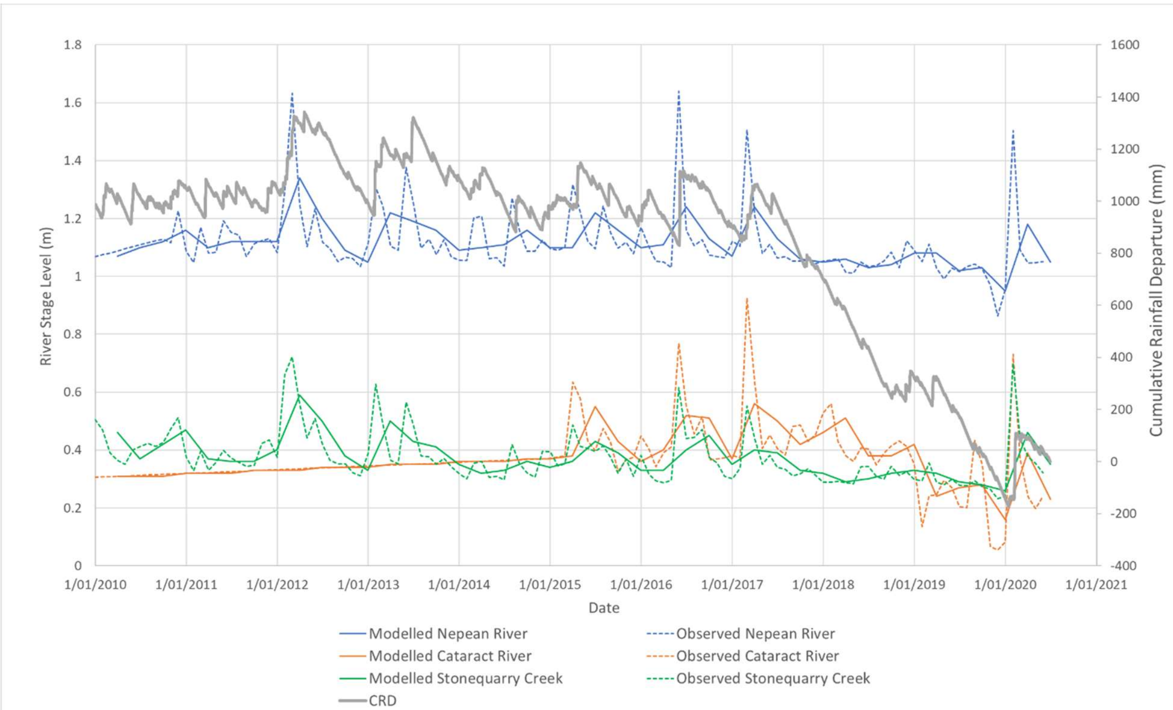


Figure 21 Modelled Stage Levels vs Cumulative Rainfall Departure (CRD)

4.1.5.3 Recharge and Evapotranspiration

Diffuse rainfall recharge is simulated using the recharge package (RCH). Recharge was distributed in laterally distinct zones within the model domain. In this study, the zones are based on outcropping geology (**Figure 7**) and observation rainfall from multiple rainfall stations. A portion of annual rainfall was assigned to each zone and varied to match historical observed quarterly rainfall.

For the predictive model average quarterly rainfall was applied from July 2020 to December 2027. The modelled recharge for alluvium is presented in **Figure 22**.

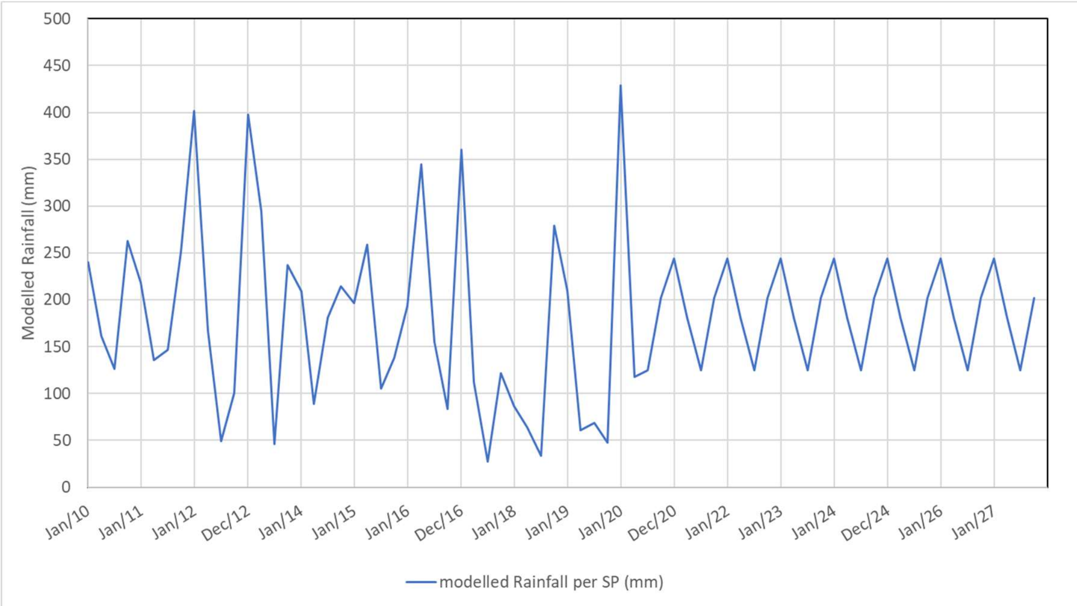


Figure 22 Modelled Rainfall Recharge to Alluvium and Outcrop Formations

Evapotranspiration (ET) from shallow water tables is simulated using the ET package and is represented in the upper most cells of the model domain down to an extinction depth of 1 3 m. A uniform ET rate of 1.4 mm/day was applied to the model.

4.1.5.4 Mining

The MODFLOW Drain (DRN) package is used to simulate mine dewatering in the model for the Project and the surrounding mines. Drain boundary conditions allow a one-way flow of water out of the model. When the computed head drops below the stage of the drain, the drain cells become inactive (Rumbaugh and Rumbaugh, 2011). This is an effective way of theoretically representing removal of water seeping into a mine over time, with the actual removal of water being via pumping and evaporation.

Longwall extraction drain cells are only applied to the layer representing the mined coal seam. A high drain conductance of 100 m^2/day was applied to the drain cells to simulate the effect of mining. The hydraulic properties were varied with time using the Time-Variant Materials (TVM) package of MODFLOW-USG. For the underground mines, the hydraulic properties where changed with time in the goaf and overlying fractured zone directly above each longwall panel. The DRN and TVM packages were updated for the study to align with the updated model timing.

4.1.6 Simulation of Goaf and Fracturing

4.1.6.1 Background

The hydraulic properties of overburden material above a mined coal seam will change in time due to caving and subsidence above longwall panels. It is generally accepted that there will be a sequence of deformational zones consisting of the caved zone, the fracture zone (a lower zone of connective cracking and an upper zone of disconnected cracking), the constrained zone and the surface zone.

High permeability is expected in the caved zone where there is direct connectivity with the mined goaf. In the lower part of the fracture zone, the collapsed rocks will have a substantially higher vertical hydraulic conductivity than the undisturbed host rocks. In the disconnected-cracking fractured zone, the vertical hydraulic conductivity is not predicted to be significantly greater than under natural conditions. Depending on the width of the longwall panels and the depth of mining, and the presence of low permeability lithologies, some increase in horizontal hydraulic conductivity can be expected in the constrained zone. Near-surface fracturing can occur due to horizontal tension at the edges of a subsidence trough in the surface zone.

4.1.6.2 Model Simulation

The model simulated the gradual changes to the hydrostratigraphic units in response to mining (e.g. longwall goafing) using the MODFLOW-USG TVM (time varying materials) package. Goafing and fracturing was simulated within the numerical groundwater model by changing the parameters within the coal seam and overlying strata as the longwall panel was progressed.

The simplified ramp function used in the existing model was applied to vertical hydraulic conductivity (Kv), gradually decaying to the estimated maximum height of connective cracking. Storage properties (specific yield [Sy]) and specific storage (Ss) were also increased in the mined coal seam layer to 10% and 1E-5 m^{-1}, respectively.

The height of fracturing in the model is based on the Ditton and Merrick (2014) subsurface fracture height prediction model for longwall mines in NSW Coalfield. This model includes the key fracture height driving parameters of panel width (W), cover depth (H), mining height (T) and local geology factors to estimate the A and B zone horizons above a given longwall panel. The A Zone corresponds with the connective-cracking part of the fracture zone, while the B Zone corresponds with the disconnected-cracking part of the fracture zone which is equivalent to the lower dilated part of the constrained zone. Formula is offered for the model as:

- Geology Model, which depends on W, H, T and t' (where t' is the effective thickness of the strata where the A Zone height occurs).

The formula for fracture zone height (A) for single-seam mining is:

- Geology Model: A = 1.52 W'0.4 H0.535 T0.464 t'-0.4 +/- (0.10 - 0.15) W'.

where W' is the minimum of the panel width (W) and the critical panel width (1.4H).

Information on the panel width and extraction height was provided for historical mining at Appin to calculate the goaf and fracturing. For the predictive model the panel width and average extraction height was provided for Longwalls709, 710A, 710B, 711 and 905 and the fracture zone height calculated, as presented in **Figure 23**. The predicted fractured height is in the range of 211 m to 270 m above the roof of the Bulli Seam up to the Bulgo Sandstone comparing with the model layer elevations (model layers 7 and 8).

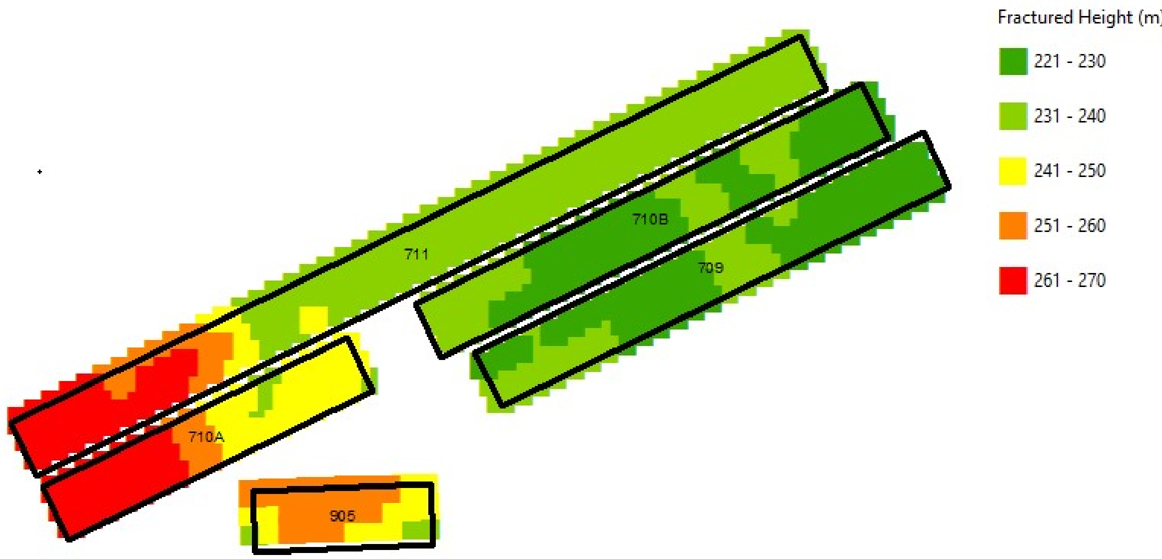


Figure 23 Predicted Fracture Zone Height (m) above workings

4.2 Model Calibration

Transient model calibration was conducted from January 2010 to June 2020. Initial heads were provided from the Model Initial Conditions steady-state, 10 years with historical mining and 40 years recovery period for historical mining. Calibration of hydraulic conductivity and storage was conducted based on historical groundwater levels and mine inflows.

4.2.1 Calibrated Parameters

Table 7 summarises the calibrated values for horizontal and vertical hydraulic conductivity plus specific yield and specific storage. Both manual and automatic (Parameter ESTimation) calibration (PEST) were carried out. PEST was used to identify the most suitable hydraulic conductivity, specific yield, specific storage and percentage rainfall recharge in zones within the Appin, Tahmoor and Metropolitan mining areas.

Table 7 Calibrated Hydraulic Properties

Layer	Zone	Kx [m/d]	Kz [m/d]	Kx/Kz	Sy	Ss [m-1]
1	Alluvium - 1	6.381E+00	1.582E-01	2.479E-02	1.925E-01	2.268E-05
	Wianamatta Group - 19	1.974E-03	3.125E-05	1.583E-02	1.000E-02	1.000E-07
	HBSS - 20	1.933E-02	2.158E-03	1.116E-01	5.190E-02	1.002E-07
	Swamps - 21	1.000E+01	7.673E-01	7.673E-02	1.000E-01	1.000E-07
	Lake and Bay - 22	9.058E+01	1.696E+01	1.872E-01	5.000E-02	1.000E-07
	Escarpment Zone -23	6.178E-01	6.093E-01	9.862E-01	9.686E-03	1.000E-07
2	Wianamatta Group - 2	1.080E-05	1.747E-08	1.617E-03	2.998E-03	1.000E-05
	HBSS - 24	1.819E-03	1.819E-03	1.000E+00	2.470E-02	1.000E-05
	HBSS under Wianamatta Group -25	2.541E-03	2.541E-03	1.000E+00	1.049E-02	1.000E-05
3	Upper HBSS	4.048E-02	4.048E-04	1.000E-02	3.374E-02	7.204E-06
4	Upper HBSS	1.247E-03	1.576E-04	1.264E-01	1.062E-02	1.000E-05
5	Lower HBSS	1.766E-04	3.174E-06	1.797E-02	1.000E-02	1.000E-05
6	Bald Hill Claystone	2.573E-05	2.246E-06	8.730E-02	5.000E-03	1.000E-07
7	Bulgo Sandstone	2.837E-03	2.837E-05	1.000E-02	1.000E-02	1.000E-07
8	Bulgo Sandstone	8.532E-04	2.675E-05	3.136E-02	1.000E-02	1.000E-06
9	Bulgo Sandstone	5.000E-03	5.000E-05	1.000E-02	1.000E-02	1.000E-06
10	Stanwell Park Claystone	8.097E-07	3.660E-07	4.520E-01	5.000E-03	1.000E-07
11	Upper Scarborough	5.163E-05	5.163E-07	1.000E-02	1.000E-02	1.000E-05
12	Lower Scarborough	5.000E-05	5.060E-07	1.012E-02	1.000E-02	1.000E-05
13	Wombarra Claystone	8.615E-07	5.459E-09	6.337E-03	7.500E-03	1.000E-07
14	Coal Cliff Sandstone	5.000E-05	2.695E-06	5.391E-02	7.500E-03	2.381E-06
15	Bulli Coal Seam	1.089E-03	2.682E-04	2.463E-01	1.000E-02	1.000E-07
16	Interburden	1.950E-05	2.361E-07	1.211E-02	7.500E-03	1.000E-07
17	Wongawilli Seam	1.499E-02	1.499E-03	1.000E-01	1.000E-02	1.000E-07
18	Lower Permian Coal Measures	5.000E-05	5.135E-07	1.027E-02	5.000E-03	1.000E-06

Layer	Zone	Kx [m/d]	Kz [m/d]	Kx/Kz	Sy	Ss [m-1]
7 - 18	Faults	8.650E-02	2.272E-02	2.627E-01	9.900E-03	1.221E-07

Table 8 presents the range in recharge values for the model domain, as a percentage of quarterly rainfall. The PEST calibration simulates an optimised rainfall recharge. The calibrated recharge rates are lower than the Heritage Computing (2009) model, which may relate to significantly greater calibration dataset and the increase in model stress periods to quarterly and use of observed streamflow data to better capture seasonality.

Table 8 Rainfall Recharge Ranges

Zone	Calibrated Recharge (% Quarterly Rainfall)	Heritage Computing (2009) Recharge (% Annual Rainfall)
Alluvium/Swamps	5	20
Wianamatta Group	1	7.5
Western HBSSs	1	5
Eastern HBSSs	2	5
Centred HBSSs	4	5

4.2.2 Water Balance

The water balance during the transient calibration period across the entire model area is summarised in **Table 9**. The average inflow (recharge) to the groundwater system is approximately 134.8 ML/d, comprising rainfall recharge (76%), leakage from streams to the groundwater system (3%) and constant head boundary inflow (1%).

The largest proportion of model outflows is ET (59%), followed by baseflow to rivers and streams (14%), ET (17%), constant head boundary outflow (4%), mine inflows (3%) and wells (<1%). There was a net gain in storage of approximately 0.2 megalitres per day (ML/d) over the calibration period.

Table 9 Groundwater Model - Water Budget/Balance (Jan 2010 -June 2020)

Component	Groundwater Inflow (Recharge) (ML/day)	Groundwater Outflow (Discharge) (ML/day)	Inflow – Outflow (ML/day)
Rainfall Recharge	103.0	-	103.0
Evapotranspiration	-	80.0	-80.0
Rivers/Creeks	4.2	19.5	-15.3
Constant Head (CHD)	1.2	5.3	-4.1
Mines	-	3.6	-3.6
Wells	-	0.3	-0.3
Storage	**26.4**	**26.2**	**0.2**
Total	**134.8**	**134.8**	**0.0**

4.2.3 Model Performance

The transient calibration was undertaken using the automated calibration utility PEST to match the available transient water level data. A total of 13,916 targets heads were established for 260 sites. Groundwater targets were utilised in the groundwater model where valid information on bore construction or geology information was available and data was collected from 2010.

Figure 24 presents the observed and simulated groundwater levels graphically as a scattergram. The industry standard method to evaluate the performance of the model is to examine the error between the modelled and observed (measured) water levels in terms of the root mean square (RMS). A root mean square (RMS) expressed as:

$$RMS = \left[1/n \sum (h_o - h_m)_i^2\right]^{0.5}$$

where: n = number of measurements

ho = observed water level

hm = simulated water level

RMS is considered to be the most suitable measure of error, if errors are normally distributed. The RMS error calculated for the calibrated model is 53.5 m. If the ratio of the RMS error to the total head change in the system is small, the errors are only a small part of the overall model response. The total measured head change across the model domain is 29.7 m; therefore, the ratio of RMS to the total head loss (SRMS) is 6.0 % with weighting applied to the values and a mass balance error of less than 0.01%. The SRMS is a useful guide on the measure of fit between observed and modelled data (Barnett *et al.*, 2012). The performance of the model calibration was also assessed by checking history matching between observed and modelled groundwater trends and responses to stresses like mining, CSG and landholder bore abstraction. Visual representation of the fit between observed and modelled levels is shown in **Appendix D**. The average residuals for points around the study area are also presented in **Figure 25**. The residuals were calculated as observed minus modelled, therefore a positive value indicates observed levels are higher than modelled and vice versa.

The calibration statistics for the transient simulation for each groundwater models are shown in **Table 10.**

Table 10 Transient Calibration Statistics

Calibration Statistics	Heritage Computing (2009)	HydroSimulations (2018)	SLR (2021)
Number of Data (n)	220	4275	9770
Root Mean Square (RMS) (m)	98.3	95	53.5
Scaled Root Mean Square (SRMS) (%)	9.6	33	6
Mean residual (m)	39.5	36.1	4.4
Mean absolute residual (m)	117.9	56.1	29.7

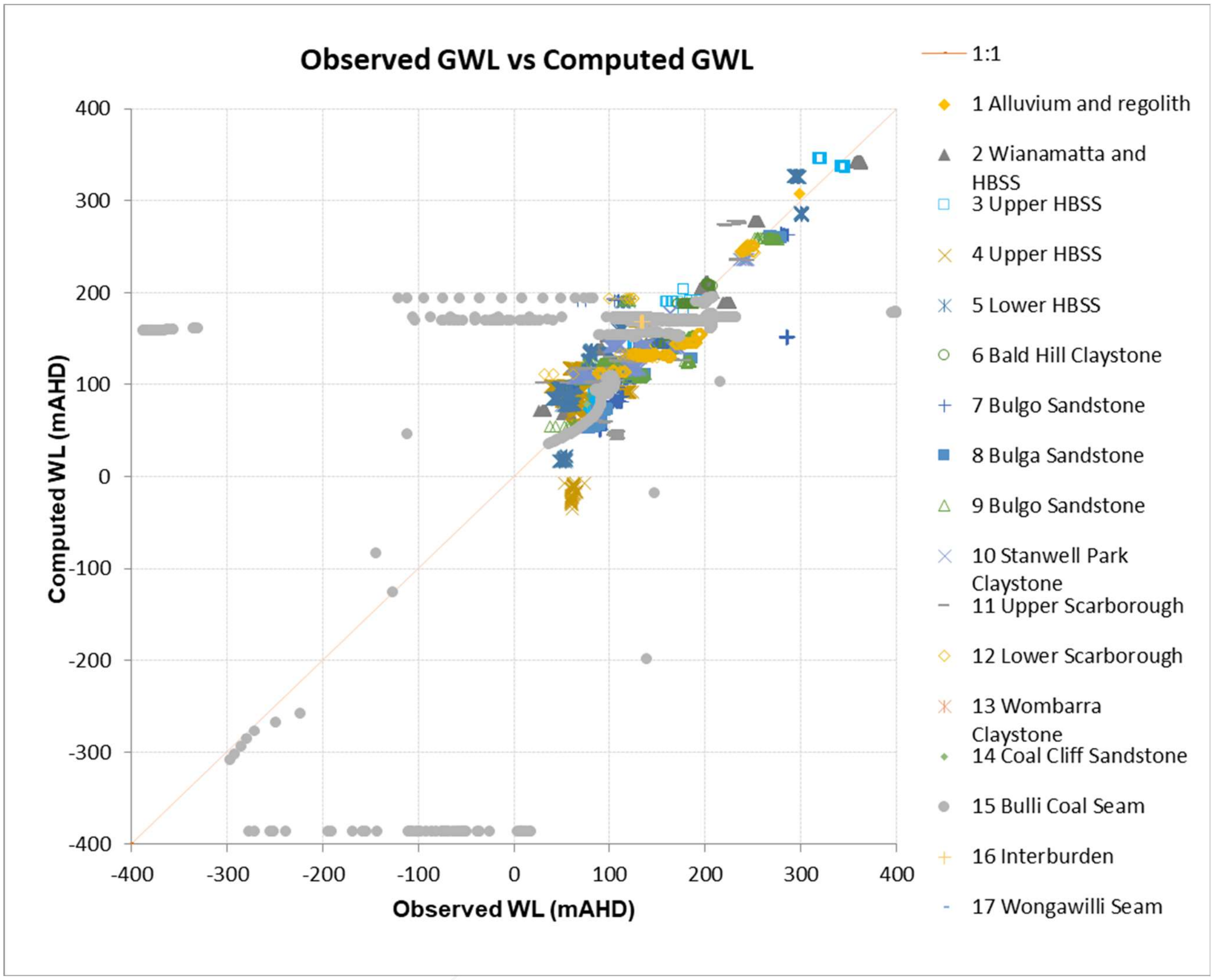


Figure 24 Modelled vs Observed Groundwater Levels

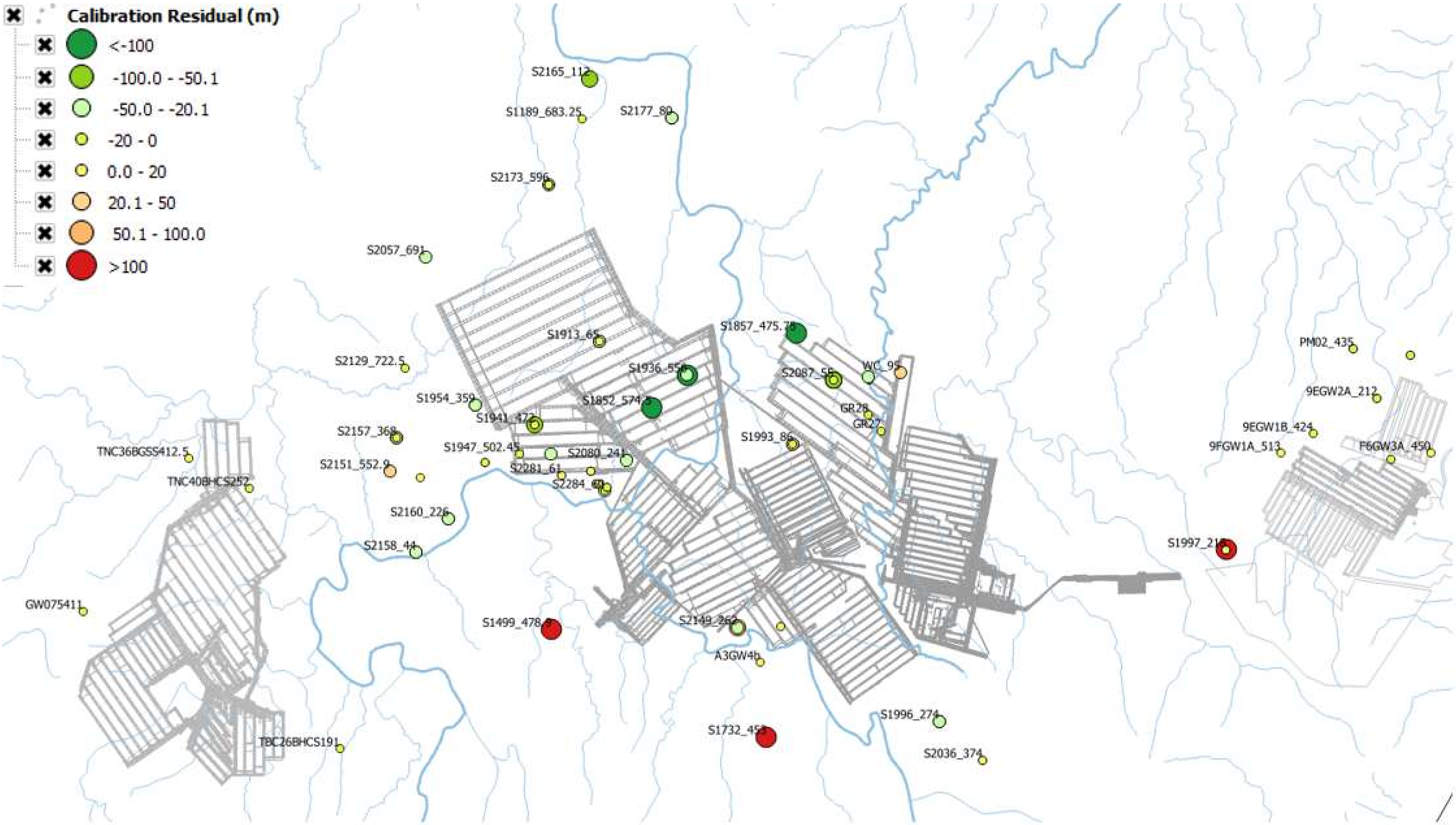


Figure 25 Map of Average Groundwater Level Residuals

4.3 Groundwater Modelling Results

The model results for the Project were calculated by comparing the Approved +Project run with the Null Extension run to show the incremental impact due to the Project compared to current approved operations at Appin Mine. The results in the following sections include the predicted mine inflows, groundwater drawdown and drawdown at landholder bores.

4.3.1 Mine Inflows

Predicted mine inflows for Areas 7 and 9 are presented in **Figure 26**. No change in peak inflows is predicted due to the extraction of the proposal Longwalls 709 to 711 and 905 (when compared to the Approved Run). The graph shows that extraction of Longwalls 709 to 711 and 905 will result in up to 0.63 ML/day (230.88 ML/year) of groundwater inflows.

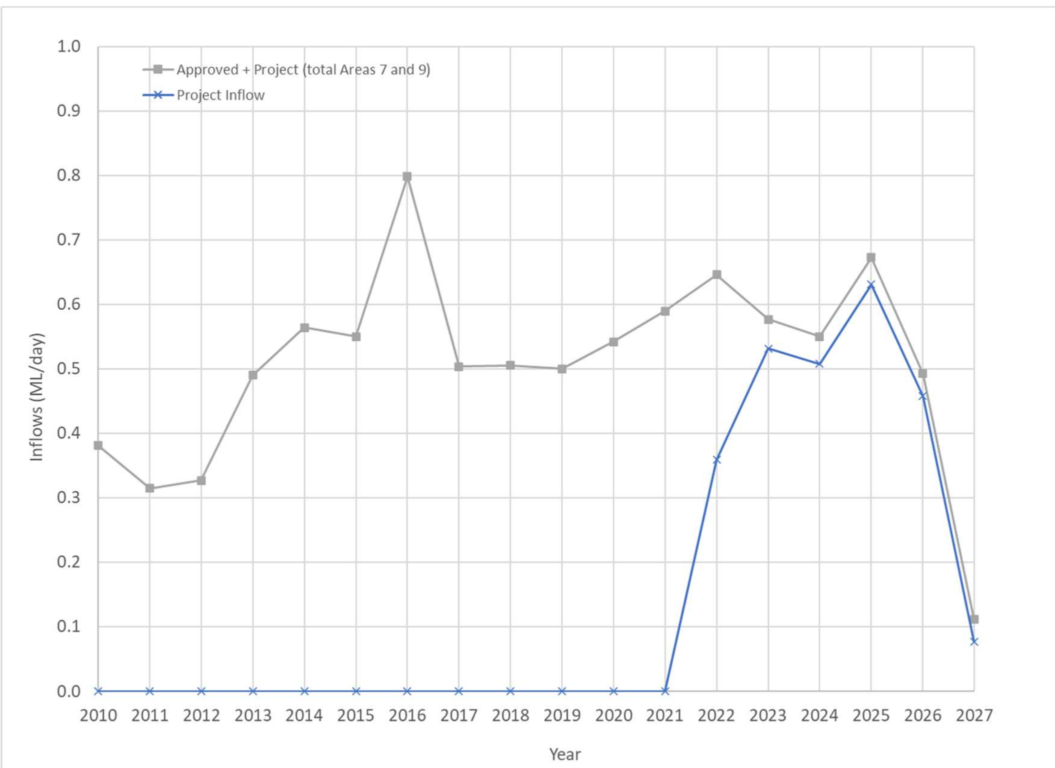


Figure 26 Predicted Mine Inflow for Appin Mine

4.3.2 Groundwater Incremental Depressurisation due to mining at Longwalls 709 to 711 and 905

The potential effects, in particular groundwater drawdown and depressurisation, due to the changes in mining at Longwalls 709 to 711 and 905 have been assessed by subtracting the NULL Extension Run water levels from the Approved + Project Run water levels.

The effects of approved underground mining, neighbouring mines and other influences such as wells and rainfall recharge are the same in both models, so by comparison of the NULL Extension and Approved + Project Runs, the incremental effects of the changes in mining at Longwalls 709 to 711 and 905 can be identified uniquely.

Figures 27 to **33** present the predicted maximum change in depressurisation in the Alluvium (Model Layer 1), Wianamatta Group (Model Layer 2), Upper HBSS (Model Layer 3), Lower HBSS (Model Layer 5), Upper Bulgo Sandstone (Model Layer 7), Lower Scarborough Sandstone (Model Layer 12) and Bulli Seam (Model Layer 15), respectively.

The findings are:

- Negligible change in drawdown is predicted in the Alluvium (Model Layer 1) (**Figure 27**) and Wianamatta Group (Model Layer 2) **(Figure 28)** due to mining at Longwalls 709 to 711 and 905.
- Depressurisation in the upper HBSS (Model Layer 3) are predicted to be minor (i.e. localised areas of +/- 2 m of depressurisation). (**Figure 29**).
- The Lower HBSS (Model Layer 5) is predicted to experience up to 7.5 m of depressurisation (**Figure 30)**.
- In Upper Bulgo Sandstone (Model Layer 7) depressurisation is predicted to be approximately 100 m (**Figure 31**).
- The Lower Scarborough Sandstone (Model Layer 12) is predicted to experience significant (depressurisation of up to 250 m on Longwall905, 200 m on Longwall709 and 150 m on Longwalls 710 to 711) due to mining at Longwalls 709 to 711 and 905 (**Figure 32**).
- For the Bulli Coal Seam (Model Layer 15) there is significant depressurisation predicted due to mining at Longwalls 709 to 711 and 905 (**Figure 33**). As is to be expected, the area of greatest impact closely coincides with the mined area (about 600 m depressurisation at Longwalls 709 to 711 and 905 within the coal seam).

Figure 27 Incremental Maximum Depressurisation (m) in Alluvium and Regolith due to Mining at Longwalls 709 to 711 and 905

Figure 28 Incremental Maximum Depressurisation (m) in the Wianamatta Group due to Mining at Longwalls 709 to 711 and 905

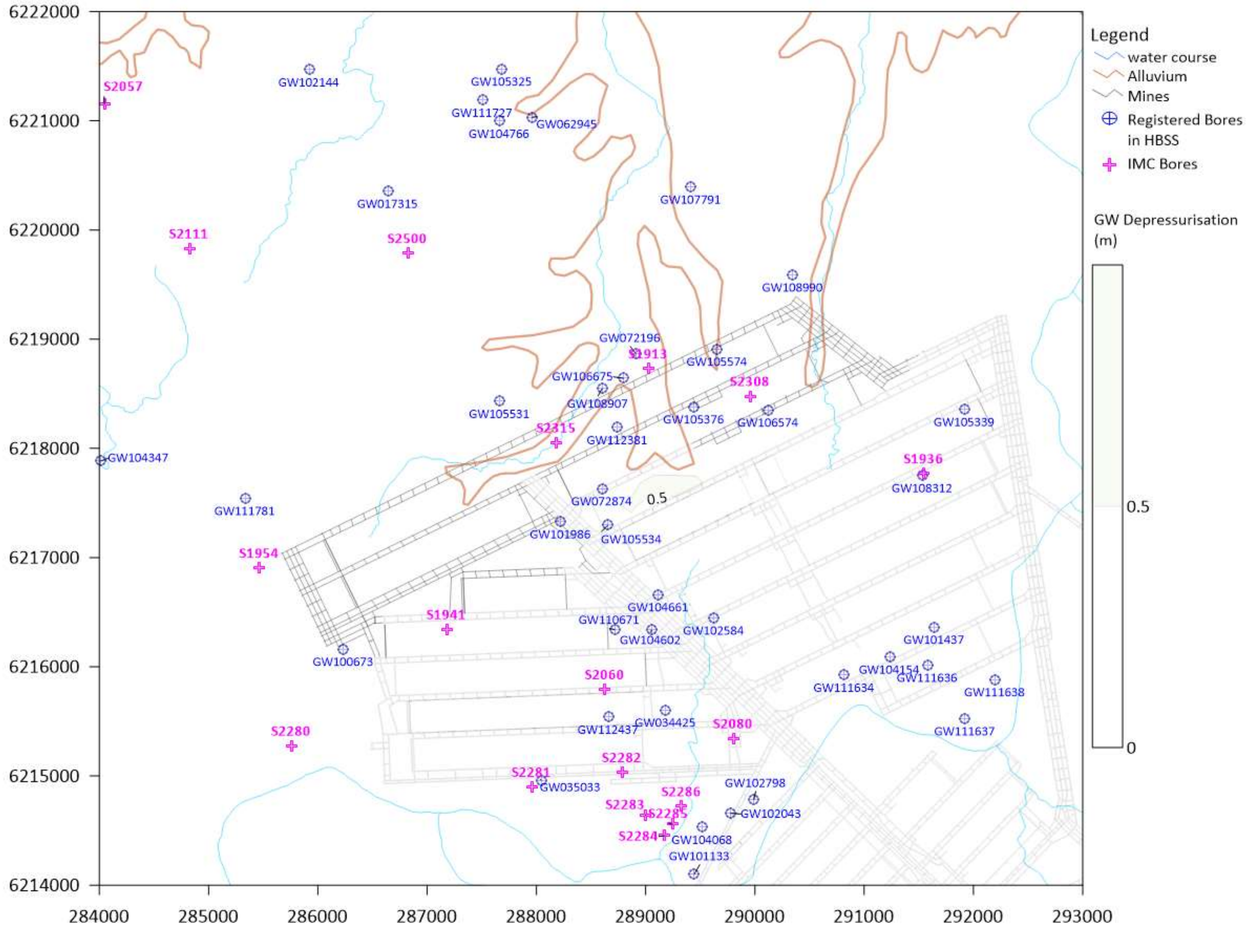


Figure 29 Incremental Maximum Depressurisation (m) in Upper HBSS due to Mining at Longwalls 709 to 711 and 905

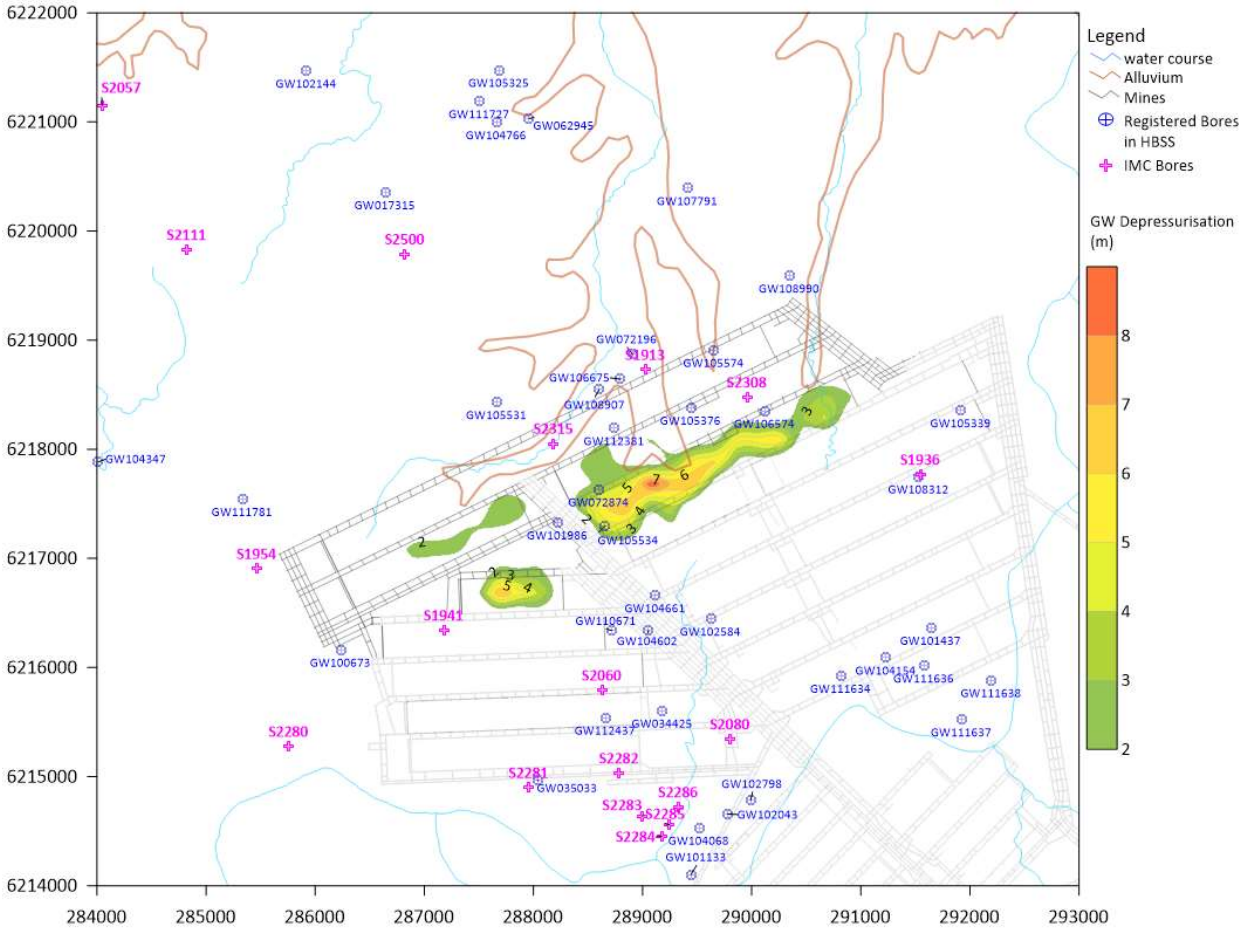


Figure 30 Incremental Maximum Depressurisation (m) in Lower HBSS due to Mining at Longwalls 709 to 711 and 905

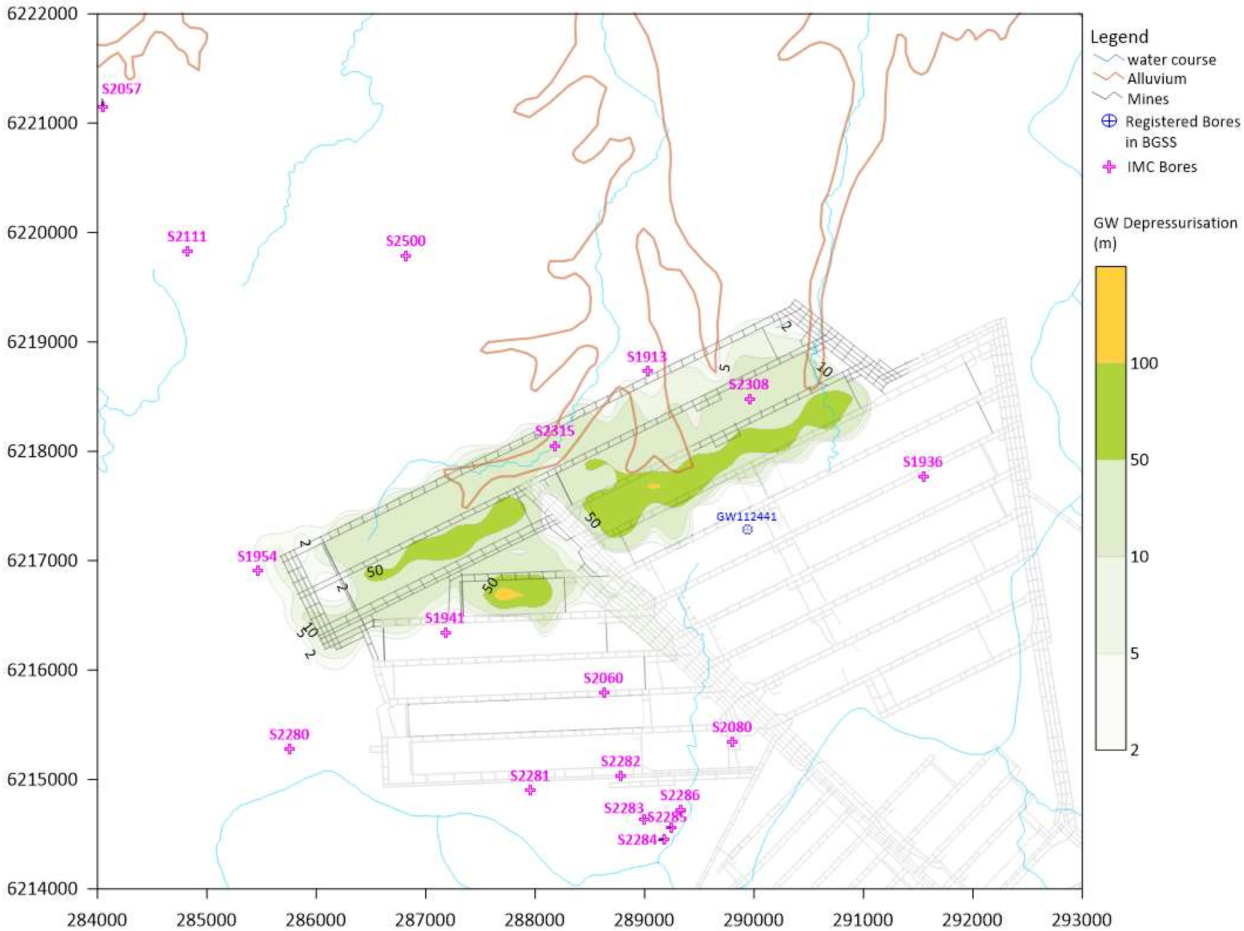


Figure 31 Incremental Maximum Depressurisation (m) in Upper Bulgo Sandstone due to Mining at Longwalls 709 to 711 and 905

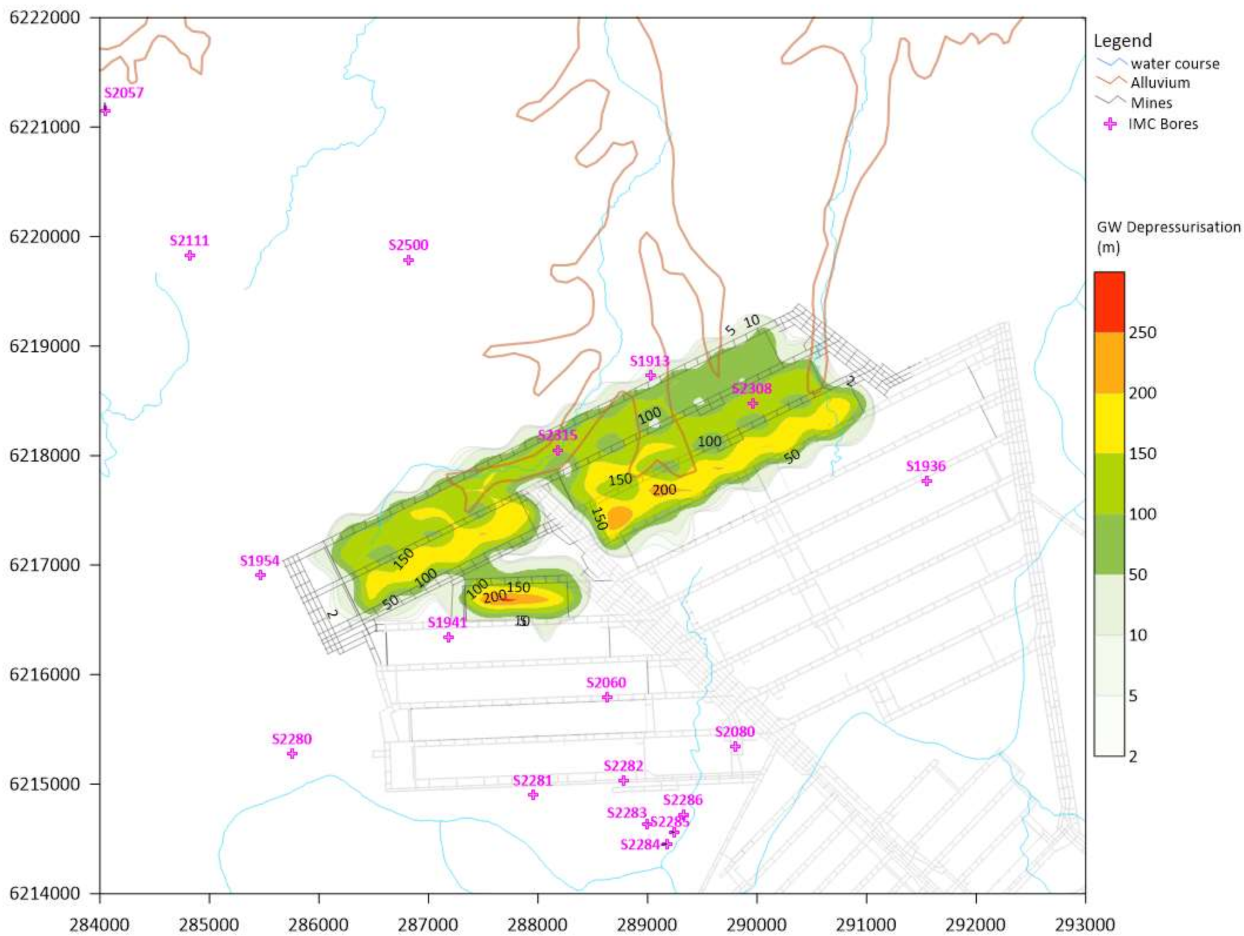


Figure 32 Incremental Maximum Depressurisation (m) in Lower Scarborough Sandstone due to Mining at Longwalls 709 to 711 and 905

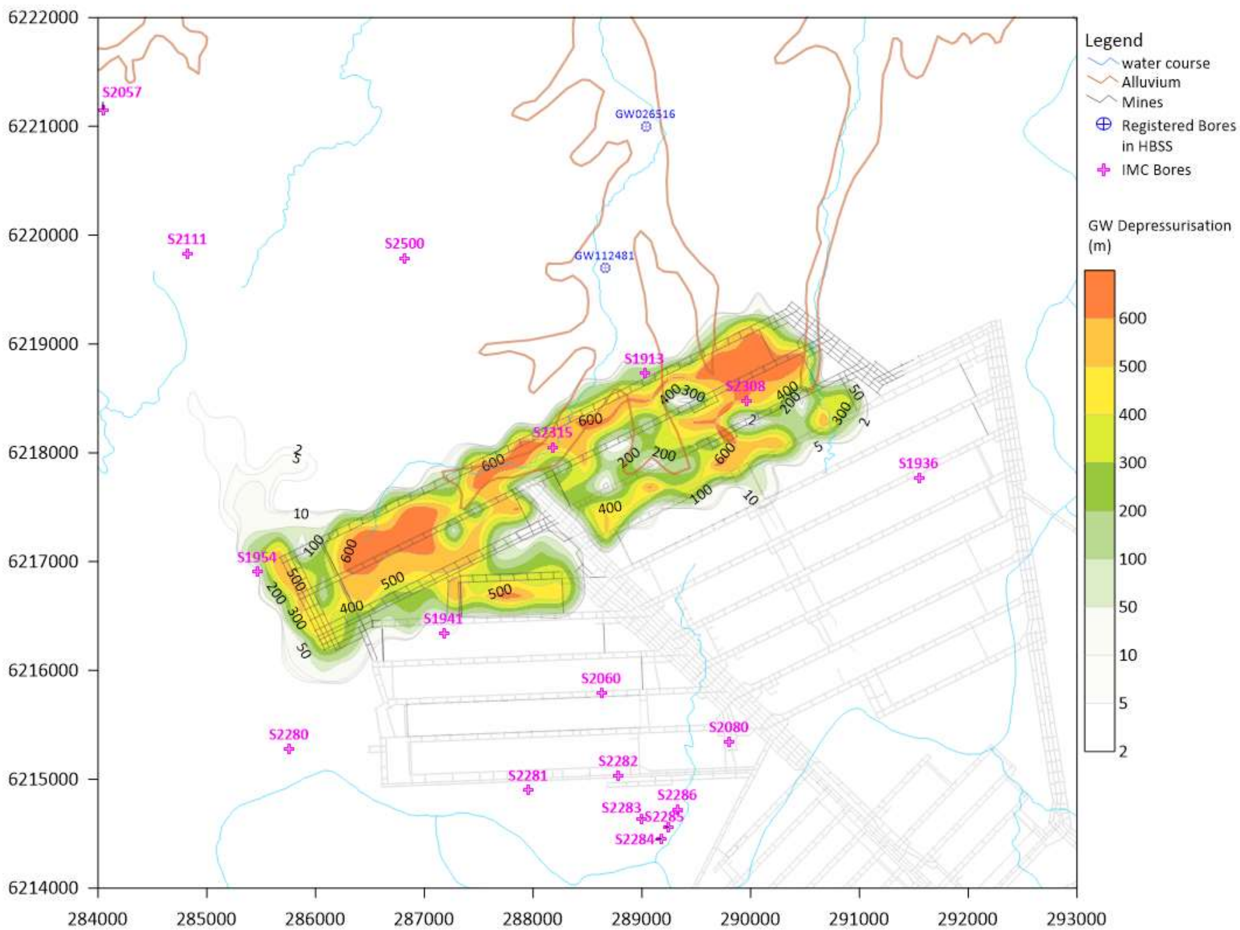


Figure 33 Incremental Maximum Depressurisation (m) in the Bulli Seam due Mining at Longwalls 709 to 711 and 905

4.3.3 Groundwater Cumulative Depressurisation

This section presents the predicted groundwater depressurisation for all operations based on comparison between the NULL Run and the Approved + Project Appin Mine Run. The predicted maximum depressurisation is cumulative as it includes the effects of concurrent surrounding foreseeable underground mines and wells.

Figures 34 to **40** present the predicted maximum change in depressurisation in the Alluvium (Model Layer 1), Wianamatta Group (Model Layer 2), Upper HBSS (Model Layer 3), Lower HBSS (Model Layer 5), Upper Bulgo Sandstone (Model Layer 7), Lower Scarborough Sandstone (Model Layer 12) and Bulli Seam (Model Layer 15), respectively.

Depressurisation due to Appin Mine and groundwater abstraction has been derived by comparison between cumulative and due to Appin Mine is summarised in **Table 11**.

Table 11 Summary of Cumulative Depressurisation

Hydrostratigraphic Unit	Maximum Predicted Depressurisation (m)			
	Appin Mine	Abstraction	Cumulative	Figure
Alluvium	0	2*	2	**Figure 34**
Wianamatta Group	0	5	5	**Figure 35**
HBSS upper	<1	50	50	**Figure 36**
HBSS lower	8	142	150	**Figure 37**
Bulgo Sandstone	100	80	180	**Figure 38**
Lower Scarborough Sandstone	250	100	350	**Figure 39**
Bulli Seam	600	0/500^	600/500^	**Figure 40**

Note: * abstraction due to a sand quarry
^ includes depressurisation from CSG mining

Compared with the incremental depressurisation due to Longwalls 709 to 711 and 905, the predicted cumulative depressurisations (see **Figures 35 to 40**) outside the mine layout are all located around the registered bores and AGL CSG wells caused by the water supply extraction and CSG mining.

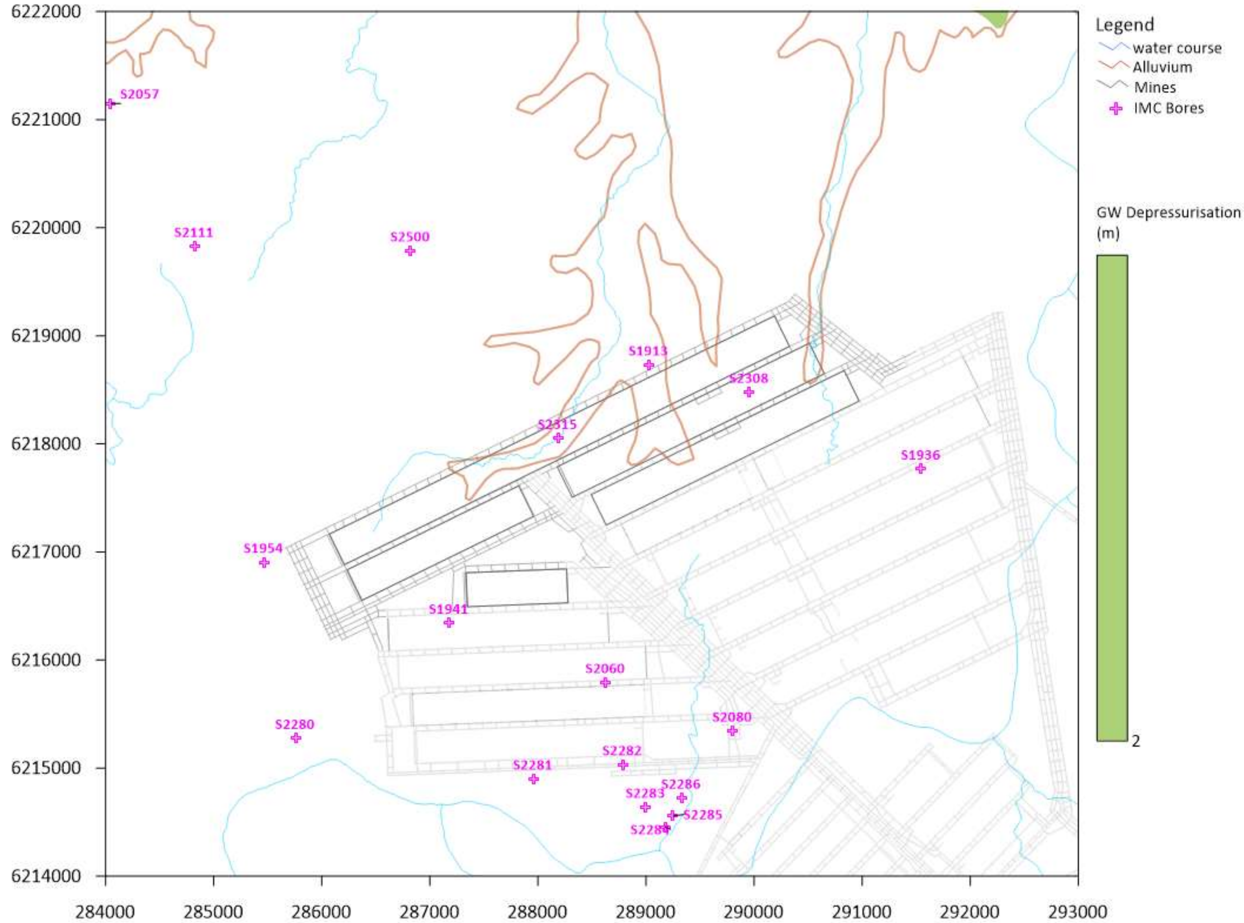


Figure 34 Cumulative Maximum Depressurisation (m) in Alluvium and Regolith

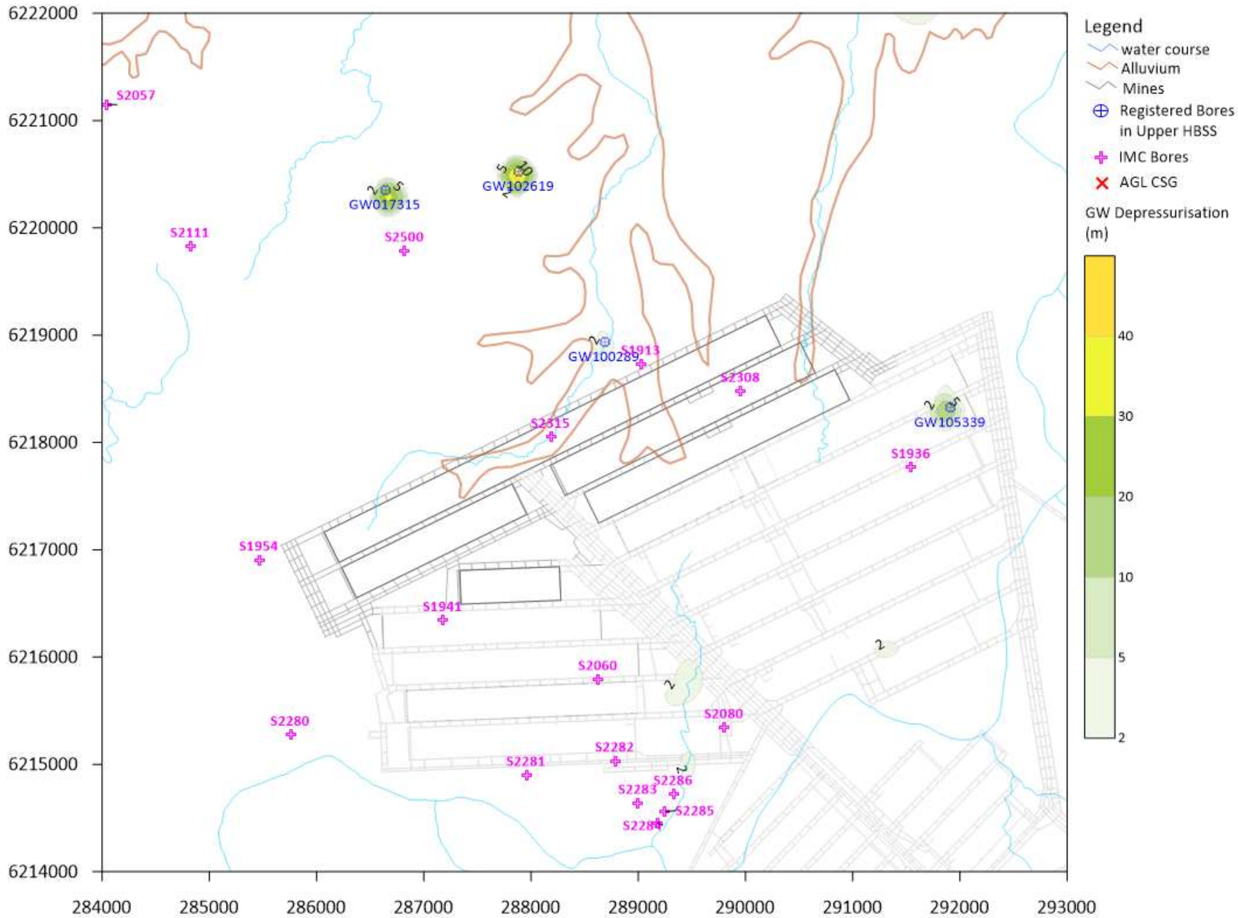


Figure 35 Cumulative Maximum Depressurisation (m) in Wianamatta Group

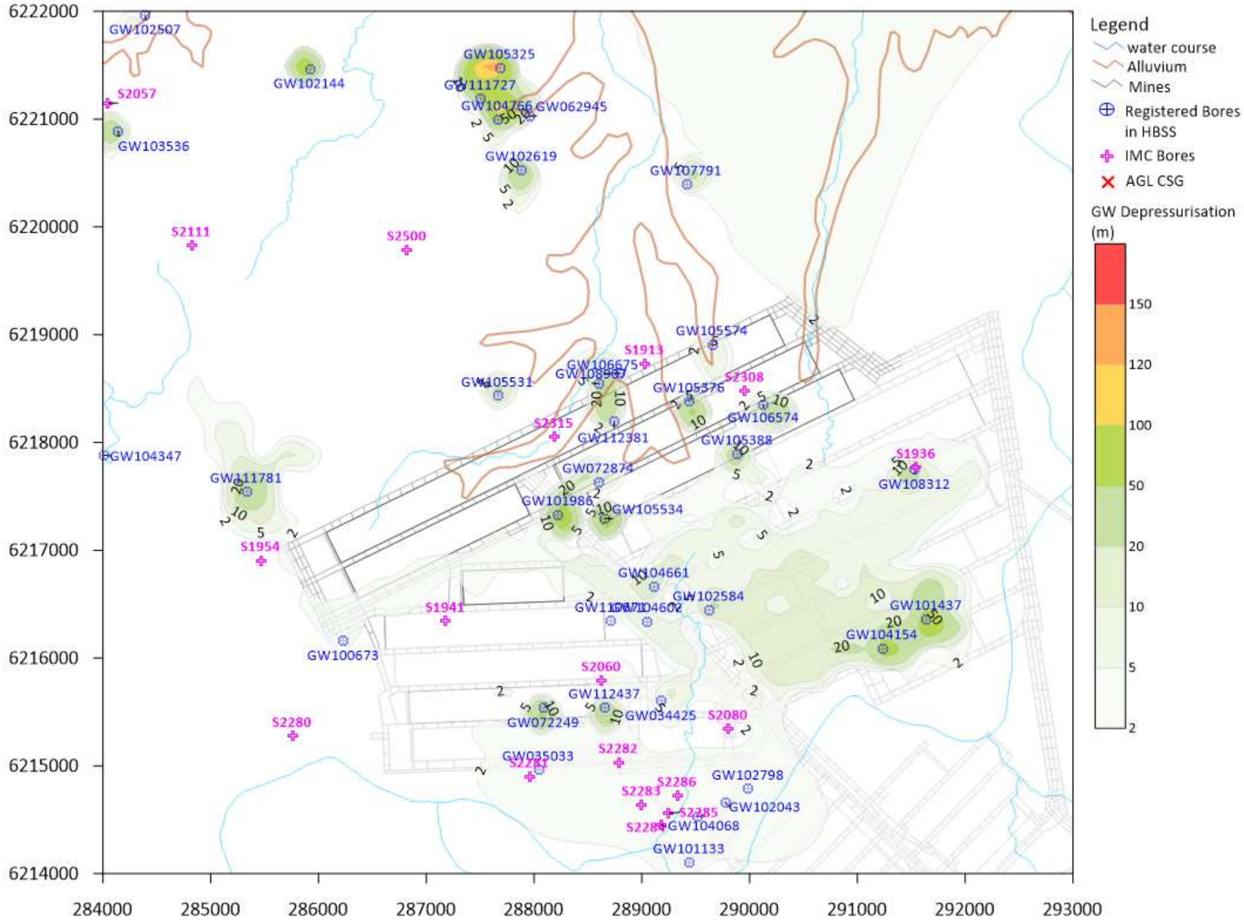


Figure 36 Cumulative Maximum Depressurisation (m) in Upper HBSS

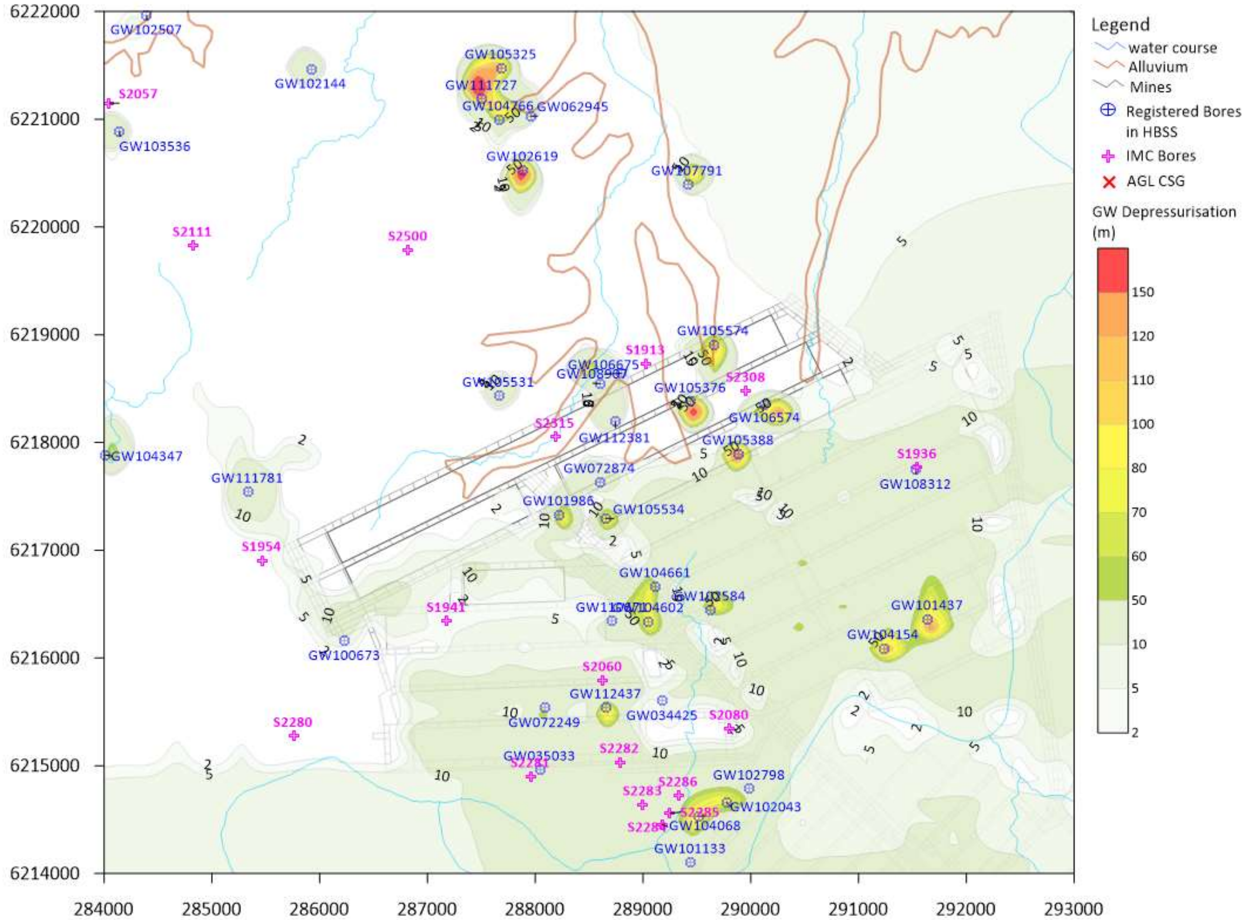


Figure 37 Cumulative Maximum Depressurisation (m) in Lower HBSS

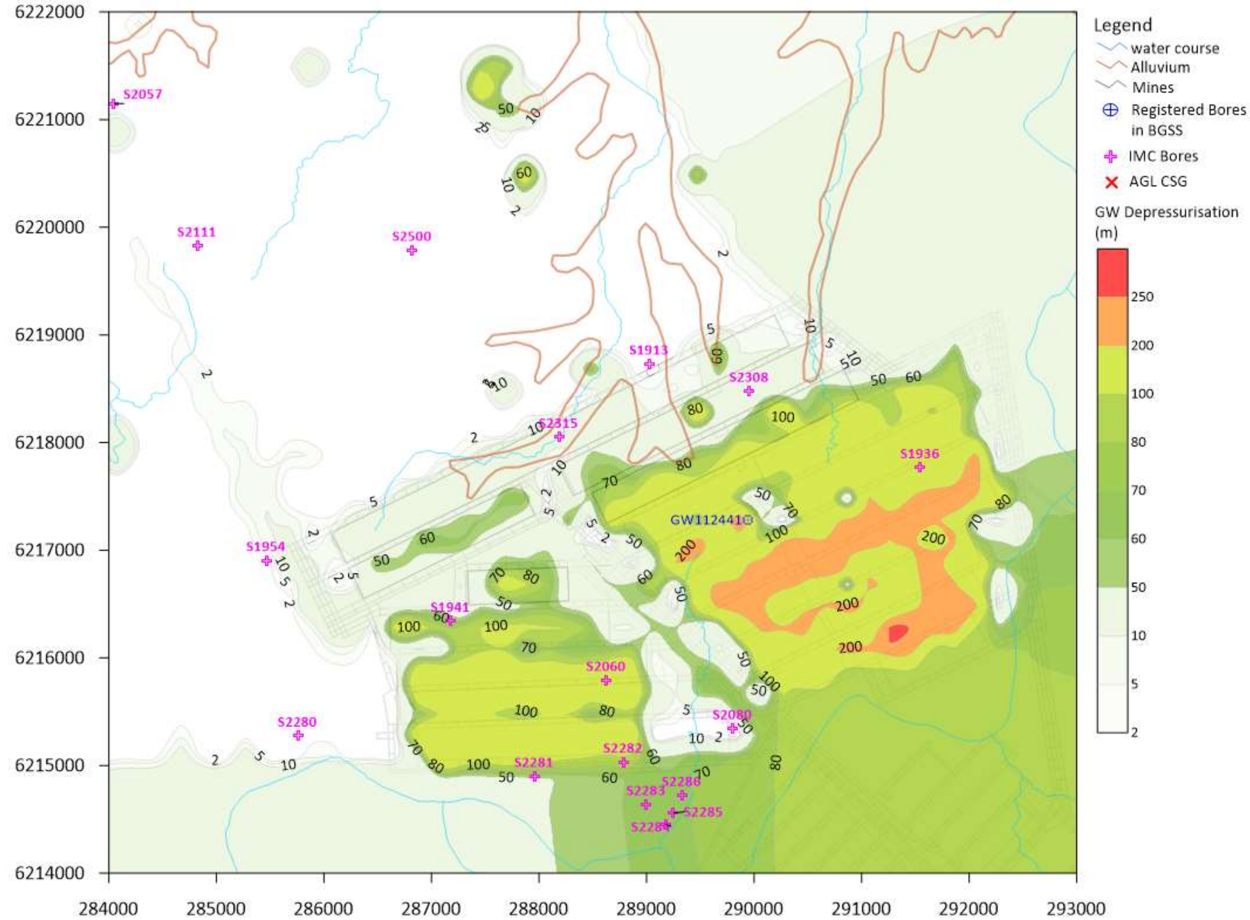


Figure 38 Cumulative Maximum Depressurisation (m) in Upper Bulgo Sandstone

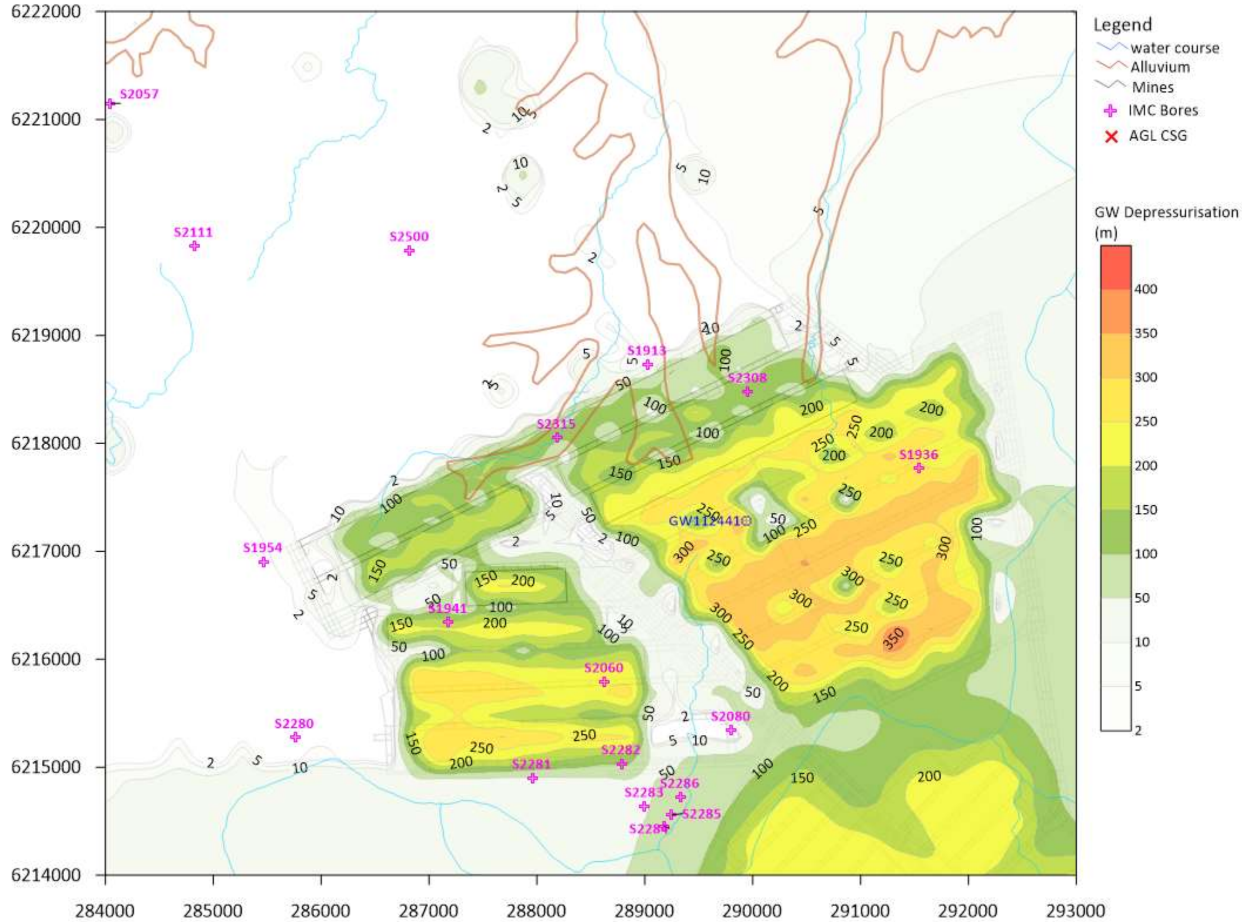


Figure 39 Cumulative Maximum Depressurisation (m) in Lower Scarborough Sandstone

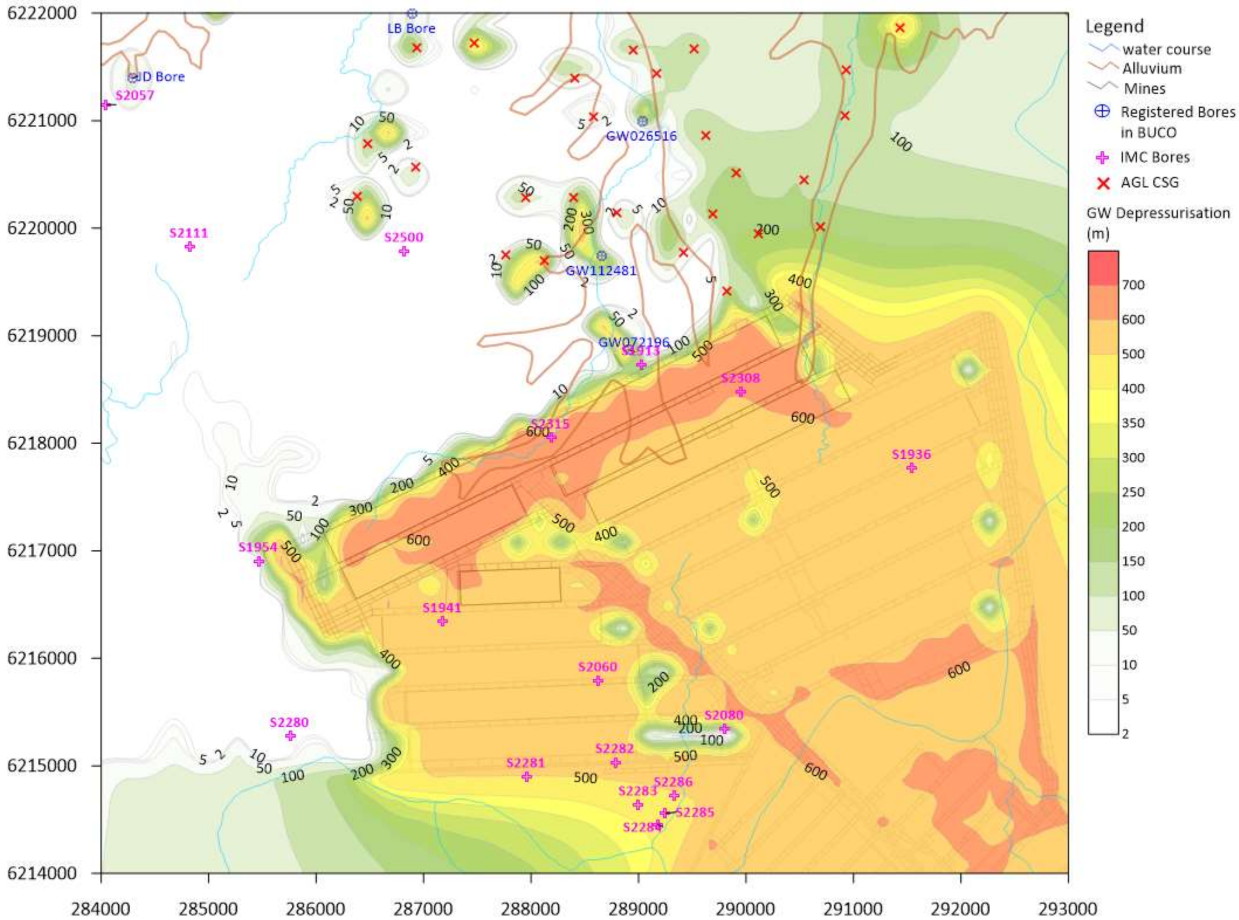


Figure 40 Cumulative Maximum Depressurisation (m) in the Bulli Seam

4.3.4 Drawdown - Landholder Bores

As discussed in **Section 2.6.4.2**, there are 49 registered bores within 5 km of the Appin Mine/Project area. Within the BSO assessment by Heritage Computing (2009) it was concluded that:

- negligible drawdown was predicted for landholder bores within the shallow surficial strata (model layer 1);
- 3 m to 6 m of depressurisationat three bores within the upper HBSS;
- 3 m to 23 m of depressurisation at 35 bores within the lower HBSS; and
- 30 m to 85 m of depressurisation at nine bores within the Bulgo Sandstone.

Table 12 shows the maximum predicted drawdown for privately owned bores. To be conservative, the predicted drawdown was based on maximum predicted depressurisation across all layers within the HBSS and Bulgo Sandstone. It is noted that there is a lack of clear pre and post mining to validate predictions as there is only exploration and environmental piezometers for reference. Consequently, the results are considered conservative since depressurisation has been attributed to mining where in fact a component of the depressurisation is likely to be caused by landowner bore groundwater abstraction. As shown in **Table 12** negligible depressurisation was predicted for most of the landholder bores, except GW072874 and GW105534 which have a predicted 3 m and 4 m depressurisation in the lower HBSS due to mining at Longwalls 709 to 711 and 905, respectively.

The incremental depressurisation of the Appin Mine presents the total impacts of the Approved + Project mining at Appin and the incremental depressurisation of the Project presents the impacts of the mining at Longwalls 709 to 711 and 905 only.

This study predicted the depressurisation for privately owned bores due to Appin Mine by subtracting the Approved + Project Appin Mine water levels from the NULL Appin Mine Run water levels shown in **Table 12**. The findings are:

- negligible depressurisation was predicted for landholder bores within the shallow surficial strata (model layer 1);
- between 8 m to 24 m of depressurisation at five bores within the upper HBSS;
- between 4 m to 20 m of depressurisation at six bores within the lower HBSS; and
- 112 m drawdown at one bore within the Bulgo Sandstone.

For bores located directly above mined longwalls, there is a risk of damage to bore casing from subsidence related movement, as previously discussed by Heritage Computing (2009).

While no drawdown is predicted within the surficial strata as part of the groundwater assessment, the subsidence assessment did identify potential for surface cracking along Navigation Creek (Refer **Section 2.5**). This has the potential for localised impacts on Navigation Creek surface water flow, which may influence recharge to the alluvium within proximity to the Project and potentially landholder bores accessing alluvial groundwater in this particular area (i.e. GW100289). Local geological structures such as fracturing and shearing could cause significantly greater depressurisation at individual bores.

Table 12 Predicted Change in Maximum Predicted Drawdown (m) at Landholder Bores

Work ID	Bore Type	Geology	Cumulative Maximum Depressurisation (m)	Incremental Maximum Depressurisation (m) due to Appin Mine	Incremental Maximum Depressurisation (m) due to Project
GW026516	Water Supply, Stock, Irrigation (BH Reg); IRAG (NGIS)	Unconsolidated Clay/Silt	10	0	0
GW112481*	Industrial (BH Reg); INDS (NGIS)	Bulli Coal Seam	633	0	0
GW072196	Domestic (BH Reg); HUSE (NGIS)	Unknown. Information on depth, likely HBSS	0	0	0
GW110550	Stock, Domestic (BH Reg); HUSE (NGIS)	Sandstone and Shale from Open Hole to TD	327	0	0
GW111727	Stock, Domestic (BH Reg); HUSE (NGIS)	-	261	0	0
GW104347	Stock, Domestic (BH Reg); HUSE (NGIS)	Sandstone from Open Hole to TD	285	0	0
GW107791	Stock, Domestic (BH Reg); HUSE (NGIS)	Sandstone from Open Hole to TD	231	0	0
GW105376	Stock, Domestic (BH Reg); HUSE (NGIS)	Sandstone from Open Hole to TD	219	0	0
GW105325	Stock, Domestic, Recreation (BH Reg); RECN (NGIS)	Sandstone and Shale from Open Hole to TD	159	0	0
GW104661	Stock, Domestic (BH Reg); HUSE (NGIS)	Sandstone from Open Hole to TD	215	1	0
GW104766	Stock, Domestic (BH Reg); HUSE (NGIS)	Sandstone and Shale from Open Hole to TD	192	0	0
GW062945	Stock, Domestic (BH Reg); HUSE (NGIS)	Sandstone from Open Hole to TD	150	0	0

Work ID	Bore Type	Geology	Cumulative Maximum Depressurisation (m)	Incremental Maximum Depressurisation (m) due to Appin Mine	Incremental Maximum Depressurisation (m) due to Project
GW102584	Stock, Domestic (BH Reg); HUSE (NGIS)	Sandstone from Open Hole to TD	60	20	0
GW110671	Stock, Domestic (BH Reg); HUSE (NGIS)	Sandstone, Shale and Granite from Open hole to TD	184	0	0
GW101986	Stock, Domestic (BH Reg); HUSE (NGIS)	Sandstone in open hole section	189	0	0
GW104602	Stock (BH Reg); STOK (NGIS)	Sandstone and Claystone from Open hole to TD	188	2	0
GW105574	Stock, Domestic (BH Reg); HUSE (NGIS)	Sandstone, Clay and Shale from Surface	185	0	0
GW105534	Stock, Domestic (BH Reg); HUSE (NGIS)	Sandstone and Slate from open hole to TD	151	4	4
GW104154	Stock, Domestic (BH Reg); HUSE (NGIS)	Sandstone and Shale from Open Hole to TD	165	24	0
GW072874	Stock, Domestic (BH Reg); HUSE (NGIS)	Sandstone, Siltstone and Shale from Open Hole to TD	149	4	3
GW101437	Farming (BH Reg); IRAG (NGIS)	Sandstone and Shale from Open Hole to TD	128	22	0
GW108907	Stock, Domestic (BH Reg); HUSE (NGIS)	Sandstone and Shale from Open Hole to TD	173	0	0
GW102144	Stock, Domestic (BH Reg); HUSE (NGIS)	Sandstone and Shale from Open Hole to TD	163	0	0
GW112437	Stock, Domestic (BH Reg); HUSE (NGIS)	Sandstone and Shale from Open Hole to TD	113	1	0

Work ID	Bore Type	Geology	Cumulative Maximum Depressurisation (m)	Incremental Maximum Depressurisation (m) due to Appin Mine	Incremental Maximum Depressurisation (m) due to Project
GW108312	Test Bore (BH Reg); INDS (NGIS)	Sandstone from Slots and Open Hole to TD	156	20	0
GW112381	Stock, Domestic (BH Reg); HUSE (NGIS)	Sandstone from Open Hole to TD	152	1	1
GW102043	Stock, Domestic (BH Reg); HUSE (NGIS)	Sandstone, Siltstone and Clay from Open Hole to TD.	152	6	0
GW104068	Stock, Domestic (BH Reg); HUSE (NGIS)	Sandstone, Siltstone and Shale from Open Hole to TD	151	6	0
GW105531	Stock, Domestic (BH Reg); HUSE (NGIS)	Sandstone and Shale from Open Hole to TD	141	0	0
GW111781	Domestic (BH Reg); HUSE (NGIS)	Sandstone from Open Hole to TD	134	0	0
GW106675	Stock, Domestic (BH Reg); HUSE (NGIS)	Sandstone and Shale from Open Hole to TD	132	0	0
GW034425	Waste Disposal (BH Reg); WSUP, INDS (NGIS)	Sandstone from Open Hole to TD	70	0	0
GW017315	Water Supply, Farming / General Purpose (BH Reg); WSUP (NGIS)	-	0	0	0
GW035033	Stock (BH Reg); STOK (NGIS)	Sandstone and Shale from Open Hole to TD	84	1	0
GW102619	Stock, Domestic, Irrigation (BH Reg); IRAG (NGIS)	Sandstone and Shale from Open Hole to TD	70	0	0

Work ID	Bore Type	Geology	Cumulative Maximum Depressurisation (m)	Incremental Maximum Depressurisation (m) due to Appin Mine	Incremental Maximum Depressurisation (m) due to Project
GW101133	Stock, Domestic (BH Reg); HUSE (NGIS)	Sandstone, Siltstone and Ironstone from Open Hole to TD	67	1	0
GW102798	Stock, Domestic, Farming (BH Reg); IRAG (NGIS)	Sandstone from Open Hole to TD	57	2	0
GW100673	Stock (BH Reg); STOK (NGIS)	-	7	0	0
GW105339	Stock, Domestic, Irrigation (BH Reg); HUSE (NGIS)	Sandstone and Shale from Open Hole to TD	1	1	0
GW100289	Stock, Domestic (BH Reg); HUSE (NGIS)	Bore is Screened in Gravel	30	0	0
GW108990	Test Bore (BH Reg); HUSE (NGIS)	-	2	0	0
GW111637	Monitoring Bore (BH Reg); MON (NGIS)	-	1	1	0
GW111638	Monitoring Bore (BH Reg); MON (NGIS)	-	1	1	0
GW111636	Monitoring Bore (BH Reg); MON (NGIS)	-	12	12	0
GW111634	Monitoring Bore (BH Reg); MON (NGIS)	-	8	8	0
GW105942	Test Bore (BH Reg); MON (NGIS)	Shale and Clay from Open Hole to TD	0	0	0
GW108193	Test Bore (BH Reg); MON (NGIS)	Clay and Shale from Open Hole to TD	0	0	0

Note: * Water supply bore, part of the AGL Camden CSG project

The above predictions from the Regional Groundwater Model relate to changes in groundwater levels and pressures due to regional depressurisation from the proposed mining. Local subsidence effects such as shear and localised fracturing of a bore can result in additional changes to groundwater level at that location.

4.3.5 Potential Impacts on Surface Water Bodies

There are no predicted impacts on surface water bodies due to depressurisation of the coal measures as part of the Project. This is because there is no predicted drawdown due to the Project within the upper layers (layer 1 to layer 5) to induce downward seepage or reduce baseflow contributions. These findings are consistent with the impact assessment conclusions for BSO by Heritage Computing (2009).

Localised temporal changes in surface water flow and quality related to subsidence is discussed in the Surface Water Assessment report.

4.3.6 Impacts on Water Quality

The Project does not include any surface activities or direct abstraction or interaction with the HBSS groundwater source. Therefore, impacts on the water quality within the HBSS are unlikely.

The height of fracture calculations indicate longwall mining as part of the Project could result in fracturing from the Bulli Seam to the Scarborough Sandstone and in some localised areas the Bulgo Sandstone (lower). Increased iron staining has been observed and is attributed to groundwater becoming oxidised while in contact with fresh fractures or shears. Additional fracturing can also cause the liberation of formation gas particularly deeper bores such as these intersecting the Bulgo Sandstone. Post closure, this could create hydraulic connection between the confined Permian coal measures and overlying Narrabeen Group. As discussed in **Section 2.6.3**, the Bulgo Sandstone is generally moderately saline with sodium-bicarbonate type water and can be suitable for some stock water supply and short-term irrigation. However, the Bulgo Sandstone has limited usage within the region, with preferential use of the shallower HBSS.

There is limited data on water quality within the coal measures at Appin, but regionally it is characterised as moderately saline to saline. The impact on groundwater salinity within the hydrostratigraphic units above the Bulli Seam due to cracking is unknown since there is little water quality information available in these units including the Coalcliff Sandstone, Wombarra Claystone, Scarborough Sandstone and Stanwell Park Claystone. Water leakage from the upper units to the lower units will be partially restricted as the Stanwell Park Claystone and Wombarra Claystone units will continue to act as aquitards, which may be impacted by some minor cracking. Ongoing monitoring of site mine water representative of the Permian coal measures should be conducted and incorporated for ongoing mine closure planning and management.

5 Recommendations - Monitoring

5.1 Appin Mine Monitoring Network

Groundwater monitoring will be conducted in accordance with a Groundwater Monitoring Plan (GWMP) that will be prepared in consultation with the regulator. The GWMP will include full details on how, when and what groundwater parameters will be monitored across Appin Mine and surrounds. A groundwater management plan is to be prepared to describe the requirements for ongoing groundwater management at Appin. The groundwater management plan will be prepared in consultation with DPIE -Water and include the groundwater monitoring plan.

Table 13 presents the proposed monitoring network and program for the Project, and **Figure 41** shows the bore locations. This includes indicative locations for proposed bores. In addition, it is recommended that monthly monitoring of mine water inflows (water quality) is conducted to monitor groundwater quality within the local Permian coal measures. Groundwater criteria have been developed and are discussed in **Section 5.3**.

Three exploration bores (S1913, S1941 and S1954) have been fitted with vibrating wire piezometers with 10 piezometers in bores S1913 and S1941 and 13 piezometers in S1954. Each piezometer monitors water pressure on an hourly interval and transmits data automatically via FTP. These bores are suitable for coding with an alarm as part of the assessment criteria (**Section 0**). Bore S1936 has only one remaining piezometer operational (65m) as all other piezometers have sheared. This bore is not suitable for alarming without a logger upgrade to the FTP. Data from the remaining piezometer is captured manually via irregular site visits. Exploration bore S2157 has 10 piezometers, however their condition is unknown as the bore is not fitted with a FTP and access has not been possible since 2015. Renewed access to this site is currently being negotiated. This bore is not suitable for alarming without a logger upgrade to the FTP.

The existing monitoring bores are vibrating wire piezometers (VWP) each with multiple sensors monitoring water pressure at hourly intervals with data transmitted automatically to a File Transfer Protocol (FTP). Four additional monitoring bores are proposed to be constructed to monitor groundwater levels in the alluvium (Proposed bore 1) and Hawkesbury Sandstone (Proposed bore 2, 3 and 4). Proposed monitoring bores 1, 3 and 4 are to be completed as VWPs installed to the depth and within the lithology as outlined in **Table 13**. Proposed bore 2 is to be constructed as an open piezometer to calibrate the nearby VWPs and to collect groundwater quality samples.

In Area 10 selected exploration bores are proposed to be converted to VWP in the mining area and further afield to monitor the effects of mining on groundwater pressure in multiple hydrostratigraphic units.

Table 13 Proposed Project Monitoring Program

Bore ID	Type	Easting	Northing	Ground Level	Screen/ Sensor	Geology	Purpose	SWL (mAHD)		WQ	
								Frequency	Trigger	Frequency	Trigger
S1913	VWP (EX)	289028	6218729	117.04	65	HBSS		Hourly	-	N/A	-
					137	HBSS		Hourly	74	N/A	-
					194	HBSS		Hourly	47	N/A	-
					274	BGSS		Hourly	-	N/A	-
					358	BGSS		Hourly	-	N/A	-
					447	BGSS		Hourly	112	N/A	-
					473	SBSS		Hourly	119	N/A	-
					486	SBSS		Hourly	-	N/A	-
					505	SBSS		Hourly	127	N/A	-

Bore ID	Type	Easting	Northing	Ground Level	Screen/ Sensor	Geology	Purpose	SWL (mAHD)		WQ	
					559.5	BUCO	VWP immediately north of Project (LW711). Verify predicted water level impacts and early identification of adverse impacts not previously predicted.	Hourly	70	N/A	-
S1936	VWP (AD)	291547	6217768	148.14	65	HBSS	VWP within 1 km of Project (LW709). Verify predicted water level impacts and early identification of adverse impacts not previously predicted	Irregular	85	N/A	-
					123.8	HBSS		Broken	-	N/A	-
					192	HBSS		Broken	36	N/A	-
					278	BGSS		Broken	-10	N/A	-
					347.8	BGSS		Broken	-10	N/A	-
					422.5	BGSS		Broken	-46	N/A	-
					456.2	SBSS		Broken	-50	N/A	-
					462.1	SBSS		Broken	-25	N/A	-
					468	SBSS		Broken	-	N/A	-
					556.1	BUCO		Broken	-400	N/A	-
S1941	VWP (EX)	287181	6216341	148.82	65	HBSS	VWP within 200 m of Project (LW905). Verify predicted water level impacts and early identification of adverse impacts not previously predicted	Hourly	108	N/A	-
					126.5	HBSS		Hourly	75	N/A	-
					201.6	HBSS		Hourly	40	N/A	-
					284.3	BGSS		Hourly	65	N/A	-
					355.7	BGSS		Hourly	85	N/A	-
					432	BGSS		Hourly	80	N/A	-
					463	SBSS		Hourly	-	N/A	-
					472.8	SBSS		Hourly	8.5	N/A	-
					487.5	SBSS		Hourly	-5	N/A	-
					555.4	BUCO		Hourly	-400	N/A	-
					596	WWCO		Hourly	-242	N/A	-
S1954	VWP (EX)	285466	6216904	310	36	BrSh	VWP within 1 km of Project (LW711). Verify predicted water level impacts and early identification of adverse impacts not previously predicted	Hourly	-	N/A	-
					85	BrSh		Hourly	-	N/A	-
					100.5	BrSh		Hourly	-	N/A	-
					138.5	UnSS		Hourly	-	N/A	-
					145.3	UnSS		Hourly	-	N/A	-
					181	AsSh		Hourly	-	N/A	-
					205	AsSh		Hourly	-	N/A	-
					245	HBSS		Hourly	-	N/A	-
					273.1	HBSS		Hourly	-	N/A	-
					316.3	HBSS		Hourly	-	N/A	-
					359.4	HBSS		Hourly	67	N/A	-
					392.5	HBSS		Hourly	-	N/A	-
					742.9	BUCO		Hourly	-200	N/A	-
S2157	VWP (AD)	283212	6215968	224.45	82.5	WNSH	VWP approximately 3 km west of Project (LW711). Verify predicted water level impacts and early identification of adverse impacts not previously predicted	Currently not sampled	-	N/A	-
					135	HBSS			105*	N/A	-
					207	HBSS			-	N/A	-
					284	HBSS			90*	N/A	-
					368	BGSS			-	N/A	-
					418	BGSS			165*	N/A	-
					468	BGSS			160*	N/A	-
					518	SPCS			-	N/A	-
					568	SBSS			165*	N/A	-
					626.9	BUCO			160*	N/A	-

Bore ID	Type	Easting	Northing	Ground Level	Screen/ Sensor	Geology	Purpose	SWL (mAHD)		WQ	
Proposed1	MB PRP	~289029	~6218741	117	~15	Qa	Near VWP S1913, to characterise alluvial groundwater conditions and monitor trends.	Q	TBC	Q	EC, pH TBC
Proposed2	MB PRP	~289028	~6218740	117	~135	HBSS	Near VWP S1913, to verify VWP levels in HBSS and monitor groundwater quality.	Q	-	Q	EC, pH TBC
Proposed3	MB PRP	287167	6216341	148	~126	HBSS	Near VWP S1941, to verify VWP levels in HBSS and monitor groundwater quality.	Q	-	Q	EC, pH TBC
Proposed4	MB PRP	291600	6217756	148	~123	HBSS	Near VWP S1936, to verify VWP levels in HBSS and monitor groundwater quality.	Q	-	Q	EC, pH TBC

Note: *MB – Monitoring bore (open standpipe)* *PRP – Proposed*

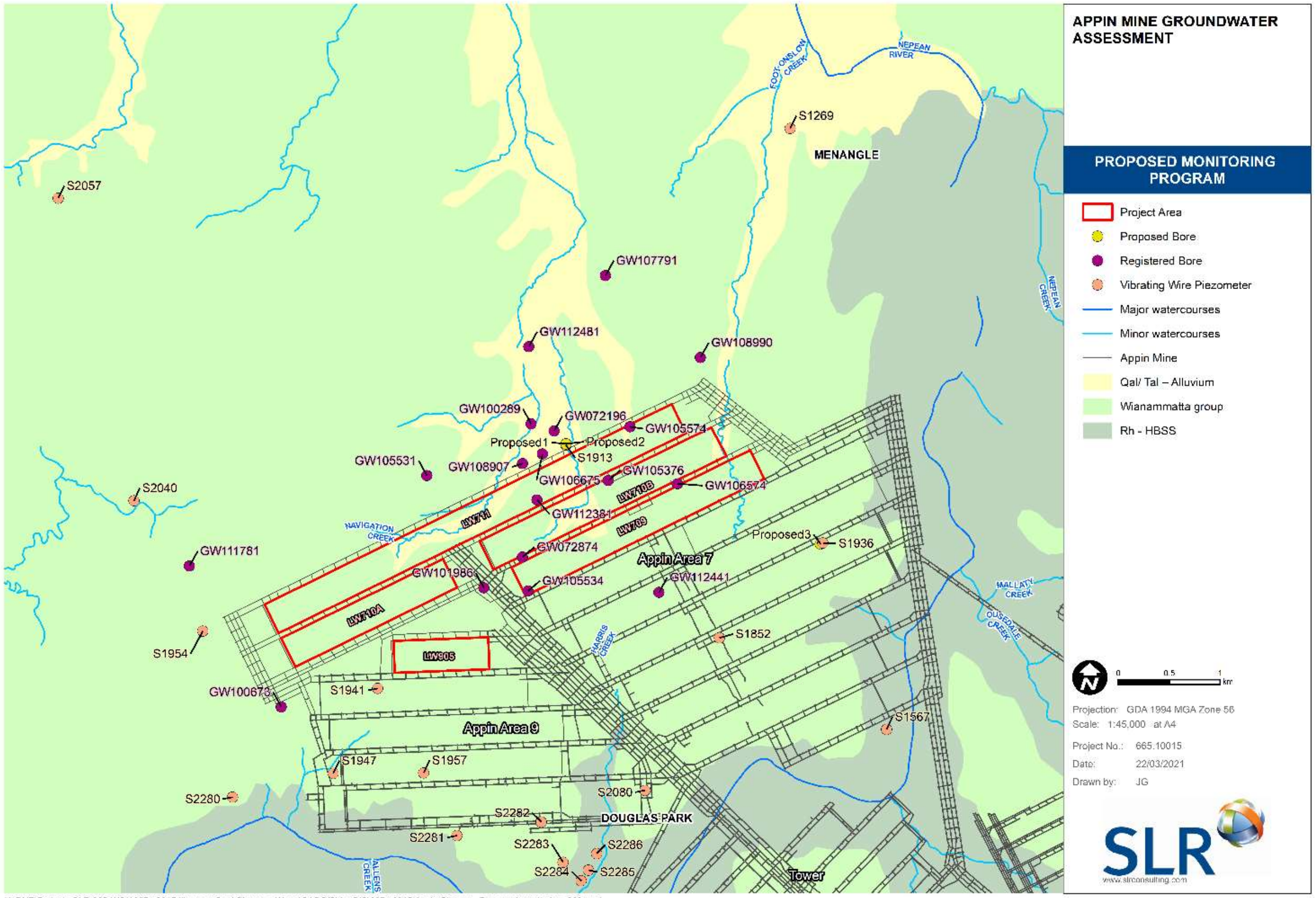
Q – Quarterly *Daily – based on VWP sensor data*

TBC – to be confirmed once sufficient data has been collected following bore installation

Coordinates in metres (GDA94 - MGA zone 56)

(*) Note: S2157 requires manual data pickup, but due to land access issues, data has not been picked up since 2015 and the status of the piezometers in this drill hole cannot be confirmed at this stage.

Qa – Quaternary alluvium *BrSh – Wianamatta Bringelly Shale* *UnSS – Wianamatta - Minchinbury Sandstone*
AsSh – Wianamatta – Ashfield Shale *HBSS – Hawkesbury Sandstone* *BGSS – Bulgo Sandstone*
CCSS – Coal Cliff Sandstone *SBSS – Scarborough Sandstone* *BUCO – Bulli Coal Seam*
WWCO - Wongawilli Coal Seam *LDSS – Loddon Sandstone*



H:\BNF\Projects-SLR\665-WOL\665.10015 Illawarra Coal Closure - Water\CADGIS\ArcGIS\665.10015 Appin Closure - Proposed monitoring_002.mxd

Figure 41 Proposed Monitoring Network

5.2 Appin Monitoring Program

Manual groundwater level monitoring should be conducted for all monitoring bores, with data loggers installed within selected bores to gather temporal variations in water levels. Data should also continue to be downloaded from the existing VWPs, pressure readings recorded and converted to groundwater elevations within a central database.

Ongoing monitoring will enable natural groundwater level fluctuations (such as responses to rainfall) to be distinguished from potential groundwater level impacts due to depressurisation resulting from the Project. Ongoing monitoring of groundwater levels can also be used to assess the extent and rate of depressurisation against model predictions.

It is recommended that a monitoring program is conducted in accordance with a Groundwater Monitoring Plan (GWMP). The following actions are recommended to support on-going groundwater monitoring:

- Establishment of a central groundwater monitoring database;
- Water level and quality results from the monitoring network should be included in annual reviews;
- Monitoring data (groundwater levels, discharges and water quality) is reviewed and compared to targets (predicted) as described in the modelling actions above on a five yearly basis; and
- Where access is available monitor landowner bores.
- If a landowner bore is suitable undertake the following:
  - Install a datalogger to automatically record water levels;
  - Install a flow meter on landowner water extraction bores to monitor usage;
  - Conduct an annual water quality analyses including pH and electrical conductivity (EC) as well as laboratory analysis as outlined below; and
  - Annual manual groundwater level monitoring with an electronic dip meter to calibrate the dataloggers where access is available.

Groundwater quality sampling should be conducted to detect any changes in groundwater quality during and post mining.

Water quality monitoring should include field analysis of pH and EC, as well as annual sampling for laboratory analysis of a full suite of analytes, including:

- physio-chemical indicators – pH, electrical conductivity, total dissolved solids;
- major ions – calcium, fluoride, magnesium, potassium, sodium, chloride, sulphate;
- total alkalinity as $CaCO_3$, HCO_3, CO_3; and
- dissolved and total metals – aluminium, arsenic, barium, boron, beryllium, cadmium, chromium, cobalt, copper, iron, lead, manganese, mercury, molybdenum, nickel, selenium, strontium, silver, vanadium and zinc.

5.3 Criteria Assessment

Proposed groundwater trigger criteria for the Project are presented in **Table 14**. Groundwater assessment levels at monitoring bores are based on the numerical model predicted change in groundwater levels, as outlined in **Table 13**. Investigation into groundwater level trends should be undertaken if there are three consecutive readings outside of the proposed trigger level. Investigation should include review of climate trends, the quality of the data/condition of the monitoring point, as well as water level and quality trends at other relevant bores to identify the cause for the change in levels beyond those predicted.

Water quality assessments proposed for the four proposed bores, three within the HBSS and one within the alluvium. It is proposed that assessments of field pH and electrical conductivity (EC) be used for early detection of potential adverse changes in water quality. Indicative assessment levels for the HBSS bores have been included based on the 5th and 95th percentile for pH and 95th percentile for EC from site baseline data (**Section 2.6.3**). These assessment levels are indicative only and should be reviewed following bore installation and collection of data to ensure they are applicable and capable of early detection of potential impacts.

Table 14 Proposed Appin Mine Assessment Criteria

Type	Proposed Assessment Criteria
Groundwater Levels	Three consecutive readings are outside of the proposed individual bore/sensor as specified in **Table 13**.
Quaternary Alluvium Water Quality	Three consecutive readings for pH outside of the 5th and 95th percentile and EC outside of the 95th percentile of baseline data for Quaternary alluvium at Proposed Bore 1, to be determined from baseline data.
Hawkesbury Sandstone Water Quality	Three consecutive readings for pH outside of the 5th and 95th percentile of baseline site data of 6.4 and 11.9 for Proposed Bore 2 to Proposed Bore 4. Three consecutive readings for EC outside the 95th percentile of baseline site data of 6,458 µS/cm for Proposed Bore 2 to Proposed Bore 4.

There is available baseline data for alluvial water quality from the Navigation Creek site (NAV1) that would be used to establish surface water quality assessment levels. Water level and quality results from the monitoring network should be included in an annual review. An assessment of water level and quality is undertaken in the relevant End of Panel Report. This information is summarised in the Annual Review. The reporting should include a review comparing predicted and observed levels and vertical head profiles to identify any potential adverse changes beyond those predicted. The review should include a comparison to climate trends and surface water monitoring results to identify any changes in the surface water and groundwater interactions, where relevant. The annual review or End of Panel Review should also identify if any additional monitoring sites are required, or if optimisation of the existing monitoring sites should be undertaken.

5.4 Landholder Bore Monitoring

If accessible, and landholder access is granted, it is recommended that landholder bores within the immediate vicinity of the Appin Mine are monitored for water levels, quality and details on bore usage be noted. **Table 15** presents a summary of landholder bores above and in the vicinity of the Appin Mine, with available details on the bore construction, likely geology and recommended monitoring frequency. The location of the bores is shown in **Figure 41**. It should be noted that this is indicative only and would be dependent on landholder access.

It is recommended that the construction of bore GW100289 be verified to confirm if it is within alluvium or the Wianamatta Group. Currently, GW106574 has nested piezometers installed at depths of 65 m, 129 m and 190 m.

Table 15 Proposed Landholder Bore Monitoring

Bore ID	Easting	Northing	Elevation (mAHD)	Total Depth (mbgl)	Screen (mbgl)	Use	Geology	SWL	WQ
GW108990	290347	6219588	108.75		-	Domestic	Unknown (likely HBSS)	A	A
GW100289	288686	6218937	124.22	30	Slots (12 – 18)	Stock and Domestic	Wianamatta? Or alluvium?	D/Q	Q
GW072874	288601	6217630	140.9	189	OH (45 – TD)	Stock and Domestic	Upper HBSS	D/Q	Q
GW100673	286235	6216160	154.16	104	-	Stock	Upper HBSS	GS	A
GW101986	288223	6217328	174.71	210	OH (103 – TD)	Stock and Domestic	Upper HBSS	Q	A
GW105531	287664	6218430	150.51	210	OH (33 – TD)	Stock and Domestic	Upper HBSS	A	A
GW105534	288655	6217297	167.82		OH (72 – TD)	Stock and Domestic	Upper HBSS	D/Q	Q
GW106675	288797	6218642	124.43	183	OH (43 – TD)	Stock and Domestic	Upper HBSS	Q	A
GW111781	285334	6217542	-	305	OH (120 – TD)	Domestic	Upper HBSS	A	A
GW112381	288743	6218191	-	152	OH (72 – TD)	Stock and Domestic	Upper HBSS	D/Q	Q
GW105376	289443	6218380	151.54	218.5	OH (102 – TD)	Stock and Domestic	Lower HBSS	D/Q	Q
GW105574	289656	6218908	125.42	210	OH (Surface – TD)	Stock and Domestic	Lower HBSS	D/Q	Q
GW106574	290123	6218350	140.52	238	OH (6 – TD)	Domestic	Lower HBSS	D/Q	Q
GW107791	289415	6220392	114.32	OH (81 – 231)	-	-	Lower HBSS	A	A
GW108907	288602	6218547	125.78	210	OH (72 – TD)	Stock and Domestic	Lower HBSS	Q	A
GW108990	290347	6219588	108.75	-	-	-	NA	A	A
GW072196	288911	6218867	118.01	-	-	Domestic	HBSS?	A	A
GW110671	288717	6216340	141.86	240	OH (28 – TD)	Stock and Domestic	Lower HBSS	GS	A

Note: A – Annual Q - Quarterly
D – Daily water levels from datalogger if it can be installed within landholder bore
D/Q – Daily water levels and quarterly manual dipped water level readings to verify logger performance
GS – Bores are already monitored with piezometer data presented on the Geosensing website

Bores GW100673 and GW110671 are currently monitored as piezometers. Pending individual site evaluation, it is recommended that a datalogger be installed within the other 16 bores above the mine workings to monitor time series groundwater levels. In addition, quarterly manual groundwater level and quality monitoring should be conducted in these bores. As the registered bores are used for groundwater supply the water levels would be influenced by bore usage.

It is recommended that annual water quality analysis include field parameters of pH and electrical conductivity (EC) as well as laboratory analysis as outlined in **Section 5.2**.

6 Conclusions

IMC are proposing to continue extracting coal from Longwalls 709, 710A, 710B, 711 in Appin Area 7 and Longwall 905 in Area 9 and require EP approval prior to the commencement of secondary extraction. Groundwater modelling has been conducted to predict potential impacts to the local hydrogeological system to support the EP approval process.

The groundwater model was developed utilising existing numerical groundwater models developed by SLR (2021) and Hydrosimulations, 2018 and Heritage Computing, 2009. The model extends approximately 52 km from west to east and approximately 43 km from north to south, covering an area of approximately 2,070 km^2, centred on the Appin Mine. The model consists of 18 layers, simulating extraction from the Bulli Seam and potential impacts in the overlying hydrostratigraphy.

Based on the groundwater modelling, there is expected to be:

- Peak mine inflows are not predicted to change when compared to the approved mining plan. Predicted inflows from Longwalls 709 to 711 and 905 will result in up to 0.63 ML/day (230.88 ML/year) of groundwater inflows;
- Depressurisation of aquifers beneath the Bald Hill Claystone, including the Lower HBSS, Bulgo Sandstone and Scarborough Sandstone is likely to occur. Depressurisation is predicted to extend up to 1.7 km from the proposed longwall panels. The extent and magnitude of drawdown is consistent with previous predictions by Heritage Computing (2009);
- There is negligible predicted impacts on surface water bodies including stream inflows due to depressurisation of the coal measures. This is because there is no predicted drawdown within the upper layers, above the Bald Hill Claystone to induce downward seepage or reduce baseflow contributions;
- Within the 49 registered bores within a 5 km radius of the Project there will be some predicted drawdown ranging from negligible drawdown in the within the shallow strata up to 122 m of drawdown predicted in a bore within the Bulgo Sandstone above Longwall707. Depressurisation within the HBSS is predicted to range between 4 and 24 m depending on the distance from the longwall panels. The predicted impacts on landholder bores are consistent with previous predictions by Heritage Computing (2009) for BSO;
- The Project does not include any surface activities or direct abstraction or interaction with the HBSS groundwater source. Therefore, impacts on the water quality within the HBSS are unlikely. Although there is limited data on water quality within the coal measures at Appin, ongoing monitoring of site mine water representative of the Permian coal measures is recommended; and
- The groundwater data analysis, based on currently available records, has shown that there are no observed material impacts from longwall mining beyond what was foreseen for the cumulative impacts described in the BSO study by Heritage Computing (2009).

A groundwater monitoring program is recommended in accordance with a Groundwater Monitoring Plan (GWMP) that will be prepared in consultation with the regulator. The GWMP will include details on how, when and what groundwater parameters will be monitored across the Project area and surrounds. Monitoring will include groundwater level monitoring of mine bores and landowner bores (subject to gaining access), groundwater and surface water quality monitoring, with results compared to trigger levels to assist in recommending any additional management or mitigation measures.

7 References

AGL, 2013. *Hydrogeological Summary of the Camden Gas Project area*, January 2013.

AGL, 2018. *Groundwater Management Plan for the Camden Gas Project report – version 5.0*, DCS_CM_MP_HSE_023, July 2018.

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 Series No. 82, June 2012.

Bureau of Meteorology (BoM), 2013, Weather and Climate data, http://www.bom.gov.au/climate/data, Accessed March 2020.

CSIRO, 2015; Soil and Landscape Grid National Soil Attribute Maps – Depth of Regolith. https://data.csiro.au/collections/collection/CIcsiro:11393v1#collection/CIcsiro:11393v006.

Ditton, S. and Merrick, N, 2014, A New Subsurface Fracture Height Prediction Model for Longwall Mines in the NSW Coalfields. Geological Society of Australia, 2014 Australian Earth Sciences Convention (AESC), Sustainable Australia. Abstract No 03EGE-03 of the 22nd Australian Geological Convention, Newcastle City Hall and Civic Theatre, Newcastle, New South Wales. July 7 - 10. Page 136.

Harries, 1997. *Acid mine drainage in Australia: Its extent and potential future liability. Department of the Environment.* 1997

Heritage Computing 2009, *Bulli Seam Operations Groundwater Assessment*, A Hydrogeological Assessment in support of the Bulli Seam Operations Environmental Assessment for Illawarra Coal Holdings Pty Ltd, HC2009/5, July 2009

HGEO,2019. *Investigation into the height of fracturing above extracted longwalls in Area 3, Dendrobium.* Report January 2020.

Holla and Barclay 2000, subsidence in the southern coalfield, NSW, Australia. New South Wales Dept. of Mineral Resources

HydroSimulations 2018; Appin Mine inflow report to estimate altered groundwater ingress into updated Appin Mine Area 7 and 9 mine plan proposed long walls. Report No HS2018/20, dated 10 April.

MSEC 2021; Subsidence Predictions and Impact Assessments, Subsidence Predictions and Impact Assessments for the Natural and Built Features due to the Extraction of the Proposed Longwalls 709, 710A, 710B, 711 and 905 at Appin Colliery, prepared for Illawarra Metallurgical Coal, dated July.

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

Price and Wright, 2016. Water Quality Impact from the Discharge of Coal Mine Wastes to Receiving Streams: Comparison of Impacts from an Active Mine with a Closed Mine. Water, Air and Soil Pollution 2016.

Rumbaugh J.O and Rumbaugh D.B., 2011; Tutorial Manual for Groundwater Vistas, Version 6. Environmental Simulations.

SILO-Australian climate data from 1889 to yesterday, rainfall and Potential Evaporation, https://www.longpaddock.qld.gov.au/silo/point-data, Accessed June 2020.

State of Queensland, 2020. SILO (Scientific Information for Land Owners) database of Australian climate data. © The State of Queensland 1995 - 2020, https://silo.longpaddock.qld.gov.au, Accessed March 2020.

Wright I.A., Paciuszkiewicz K. and Belmer N.,2018. *Increased Water Pollution After Closure of Australia's Longest Operating Underground Coal Mine: a 13-Month Study of Mine Drainage, Water Chemistry and River Ecology.* Water, Air Soil Pollutant 229, 55.

APPENDIX A

Groundwater Monitoring Network

Mine Bore ID	Site ID	Type (Status)	Easting (m)	Northing (m)	Ground Level (mAHD)	Sensor/ Screen Depth (mbgl)	Stratigraphy	Data Range
S1913	Appin West (EAW5)	VWP (EX)	289028	6218729	117.04	65	HBSS	2008 – 2018
						137	HBSS	2008 - 2018
						194	HBSS	2008 - 2018
						274	BGSS	2008 - 2018
						358	BGSS	2008 - 2019
						447	BGSS	2008 - 2019
						473	SBSS	2008 - 2019
						486	SBSS	2008 - 2019
						505	SBSS	2008 - 2019
						559.5	BUCO	2008 - 2019
S1936	Appin West 07 (EAW7)	VWP (AD)	291547	6217768	148.14	65	HBSS	2008 - 2019
						123.8	HBSS	2008 - 2014
						192	HBSS	2008 - 2014
						278	BGSS	2008 - 2014
						347.8	BGSS	2008 - 2014
						422.5	BGSS	2008 - 2014
						456.2	SBSS	2008 - 2014
						462.1	SBSS	2008 - 2014
						468	SBSS	2008 - 2014
						556.1	BUCO	2008 - 2012
S1941	Appin West 09 (EAW9)	VWP (EX)	287181	6216341	148.82	65	HBSS	2009 - 2020
						126.5	HBSS	2009 - 2020
						201.6	HBSS	2009 - 2020
						284.3	BGSS	2009 - 2020
						355.7	BGSS	2009 - 2020
						432	BGSS	2009 - 2020
						463	SBSS	2009 - 2020
						472.8	SBSS	2009 - 2020
						487.5	SBSS	2009 - 2020
						555.4	BUCO	2009 - 2020
						596	WWCO	2009 - 2014
S1954	Appin West 18 (EAW18)	VWP (EX)	285466	6216904	310	36	BrSh	2009 - 2019
						85	BrSh	2009 - 2019
						100.5	BrSh	2009 - 2019
						138.5	UnSS	2009 - 2019
						145.3	UnSS	2009 - 2019
						181	AsSh	2009 - 2019
						205	AsSh	2009 - 2012
						245	HBSS	2009 - 2019
						273.1	HBSS	2009 - 2019
						316.3	HBSS	2009 - 2019
						359.4	HBSS	2009 - 2019
						392.5	HBSS	2009 - 2019
						742.9	BUCO	2009 - 2019
S1993	West Cliff	VWP (EX)	296778	6217610	164.39	35	HBSS	2009 - 2020
						86.5	HBSS	2009 - 2020
						168	HBSS	2009 - 2020
						230.9	BGSS	2009 - 2020
						319	BGSS	2009 - 2020
						412	BGSS	2009 - 2020
						435	SBSS	2009 - 2020
						441.5	SBSS	2009 - 2020

Mine Bore ID	Site ID	Type (Status)	Easting (m)	Northing (m)	Ground Level (mAHD)	Sensor/ Screen Depth (mbgl)	Stratigraphy	Data Range
						448	SBSS	2009 - 2020
						508.2	BUCO	AD
S1996	North to Cataract Lake	VWP (EX)	298772	6207843	381.65	82	HBSS	2010 - 2020
						159	HBSS	
						219	BGSS	
						274	BGSS	
						313	BGSS	
						355	SBSS	
						373	SBSS	
						380	SBSS	
						439	CCSS	
						478	BUCO	
S1997	West to Metropolitan Mine	VWP (EX)	306997	6212764	370.17	24	HBSS	2010 - 2020
						68.5	HBSS	
						132	HBSS	
						218	BGSS	
						292.5	BGSS	
						372	BGSS	
						429	SBSS	
						441.5	SBSS	
						454	SBSS	
						504.5	CCSS	
						511.63	BUCO	
S2036	North to Cataract Lake	VWP (EX)	300016	6206725.5	358.76	374.2511.63	BUCO	2017 - 2020
						411.2	WWCO	
S2040	Appin Area 9	VWP (AD)	284789	6218183	251.45	773	BUCO	2009 - 2014
S2057	North to Appin Area 9	VWP (AD)	284047	6221149	137.4	691	LDSS	2010 - 2013
S2080	Appin West 58 (EAW58)	VWP (EX)	297111	6216174	125.9	65	HBSS	2010 - 2019
						95	HBSS	2010 - 2019
						170	HBSS	2010 - 2019
						241	BGSS	2010 - 2019
						326.5	BGSS	2010 - 2019
						417	BGSS	2010 - 2019
						440	SBSS	2010 - 2019
						447	SBSS	2010 - 2019
						454	SBSS	2010 - 2019
						499	CCSS	2010 - 2019
S2087	West Cliff	VWP (AD)	295752	6217627.5	192.97	55	HBSS	2010
						95	HBSS	
						185	HBSS	
						238	BGSS	
						313.5	BGSS	
						394	BGSS	
						419	SBSS	
						440	SBSS	
S2149	Appin Area 8	VWP (EX)	282415	6215044	153.46	65	HBSS	2011 - 2020
						121.5	HBSS	2011 - 2020
						203	HBSS	2011 - 2020
						262	BGSS	2011 - 2020
						326	BGSS	2011 - 2020
						395	BGSS	2011 - 2020

Mine Bore ID	Site ID	Type (Status)	Easting (m)	Northing (m)	Ground Level (mAHD)	Sensor/ Screen Depth (mbgl)	Stratigraphy	Data Range
						429.5	SBSS	2011 - 2020
						515.7	BUCO	2011 - 2020
						525.4	BACO	2011 - 2020
						541.4	CHCO	2011 - 2020
S2157	Appin Area 8	VWP (AD)	283212	6215968	224.45	82.5	WNSH	2013 - 2015
						135	HBSS	
						207	HBSS	
						284	HBSS	
						368	BGSS	
						418	BGSS	
						468	BGSS	
						518	SPCS	
						568	SBSS	
						626.9	BUCO	
S2158	Appin Area 8	VWP (EX)	283778	6212690	138.92	44	HBSS	2012 - 2020
						65	HBSS	
						111.6	HBSS	
						158.2	HBSS	
						218.9	BGSS	
						295.4	BGSS	
						377	BGSS	
						404	SBSS	
						473	BUCO	
						511	UWWCO	
						516.5	LWWCO	
						528	ACCO	
S2160	Appin Area 8	VWP (AD)	284717	6213651	133.4	44	HBSS	2012 - 2017
						87	HBSS	2012 - 2017
						164	HBSS	2012 - 2017
						226	BGSS	2012 - 2017
						273	BGSS	2012 - 2017
						320.5	BGSS	2012 - 2017
						367.8	SPCS	2012 - 2017
						415	SBSS	2012 - 2017
						479.6	BUCO	2012 - 2017
						486	BACO	2012 - 2017
S2165	North to Appin Area 7	VWP (EX)	288766	6226269	66.95	40	WNSH	2012 - 2020
						116	HBSS	
						112	HBSS	
						168.5	HBSS	
						257	HBSS	
						328	BGSS	
						414.2	BGSS	
						500.4	BGSS	
						586.5	SPCS	
						672.7	SBSS	
						694.7	BUCO	
						713.6	BACO	
						765	WWCO	
S2173	North to Appin Area 7	VWP (EX)	287589	6223237	110.22	76	WNSH	2012 - 2020
						91.5	WNSH	
						116	HBSS	

Mine Bore ID	Site ID	Type (Status)	Easting (m)	Northing (m)	Ground Level (mAHD)	Sensor/ Screen Depth (mbgl)	Stratigraphy	Data Range
						198	HBSS	
						285	HBSS	
						369	BGSS	
						451	BGSS	
						533	BGSS	
						554	SPCS	
						596.8	SBSS	
S2177	Appin Area 10	VWP (EX)	291122	6225144	70	44	HBSS	2013 - 2020
						80	HBSS	
						150.2	HBSS	
						220.3	HBSS	
						283.6	BGSS	
						358.9	BGSS	
						434.2	BGSS	
						462.1	SPCS	
						510	SBSS	
						621.1	BUCO	
S2280	Harris Creek 6	VWP (EX)	296752	6216617	129.86	60	HBSS	2014 - 2020
						99	HBSS	2014 - 2020
S2281	Harris Creek 7	VWP (EX)	289028	6218729	125.15	61	HBSS	2014 - 2020
						99	HBSS	2014 - 2020
S2282	Harris Creek	VWP (EX)	288787	6215032	133.01	60	HBSS	2015 - 2020
						100	HBSS	2015 - 2020
S2283	Harris Creek	VWP (EX)	288999	6214636	127.1	60	HBSS	2015 - 2018
						100	HBSS	2015 - 2018
S2284	Harris Creek	VWP (EX)	289176	6214454	110.45	60	HBSS	2015 - 2020
						100	HBSS	2015 - 2020
S2285	Harris Creek	VWP (EX)	289248	6214558	113.33	60	HBSS	2015 - 2020
						100	HBSS	2015 - 2020
S2286	Harris Creek	VWP (EX)	289329	6214721	114.55	60	HBSS	2015 - 2020
						100	HBSS	2015 - 2020
WC_54	West Cliff Area 5	MB (EX)	291547	6217768	206.49	46.8	HBSS	2014 - 2020
WC_95	West Cliff Area 5	MB (EX)	287181	6216341	228.68	20.24	HBSS	2014 - 2020
A3GW1	A3GW1a	MB (AD)	292997	6210540	209.4	62	HBSS	2006 - 2011
	A3GW1b					38.5	HBSS	2005 - 2012
	A3GW1c					9.9	HBSS	2005 - 2012
A3GW2	A3GW2a	MB (AD)	293674	6210776	215	59.6	HBSS	2006 - 2012
	A3GW2b					28.3	HBSS	2006 - 2012
	A3GW2c					9.9	HBSS	2006 - 2012
A3GW3	A3GW3a	MB (AD)	293974	6210832	219.7	70	HBSS	2006 - 2012
	A3GW3b					27	HBSS	2006 - 2010
	A3GW3c					9.9	HBSS	2006 - 2012
A3GW4	A3GW4a	MB (AD)	293640	6209537	236	84	HBSS	2005 - 2012
	A3GW4b					29.9	HBSS	2005 - 2012
A3GW5	A3GW5a	MB (AD)	294222	6210572	228.1	77	HBSS	2006 - 2010
	A3GW5b					50.75	HBSS	2006 - 2011
	A3GW5c					10	HBSS	2006 - 2011
A3GW6	A3GW6a	MB (AD)	294482	6209688	240.9	74.5	HBSS	2006 - 2012
	A3GW6b					47.5	HBSS	2006 - 2012
	A3GW6c					9.85	HBSS	2006 - 2012

Mine Bore ID	Site ID	Type (Status)	Easting (m)	Northing (m)	Ground Level (mAHD)	Sensor/ Screen Depth (mbgl)	Stratigraphy	Data Range
A3GW7	A3GW7a	MB (AD)	292988	6210942	226.6	75	HBSS	2006 - 2011
	A3GW7b					56.5	HBSS	2006 - 2011
	A3GW7c					25	HBSS	2006 - 2012
A3GW8	A3GW8a	MB (AD)	293646	6209862	228.5	53	HBSS	2005 - 2012
	A3GW8b					22.8	HBSS	2005 - 2012
	A3GW8c					8.3	HBSS	2005 - 2012
GR27	S1428	MB (AD)	297111	6216174	217.57	30.1	HBSS	2001 - 2020
GR28	S1429	MB (AD)	296752	6216617	206.9	24.31	HBSS	2001 - 2020
GR59	S1481	MB (AD)	296850	6213349	227.95	-	-	2002 - 2011
GR60	S1482	MB (AD)	296865	6213317	227.97	-	-	2002 - 2011
GR61	S1483	MB (AD)	296863	6213272	227.3	-	-	2002 - 2011
GR62	S1484	MB (AD)	296854	6213250	224.11	-	-	2002 - 2011
GR63	S1485	MB (AD)	296860	6213185	225.75	-	-	2002 - 2011
GR64	S1486	MB (AD)	296873	6213409	234.12	-	-	2002 - 2011
GR70	-	MB	296778	6217610	186.54	28.88	HBSS	2014 - 2019
NGW3	-	MB (AD)	6216750	275027	123.087	72.1	Shale / sandstone	2004 - 2015
NGW4	-	MB (AD)	6216826	275790	125.244	78.75	Sandstone	2004 - 2015
NGW5	-	MB (AD)	6216327	276124	110.85	66.45	Sandstone	2004 - 2015
NGW6	-	MB (AD)	6216681	276403	116.45	66.75	Sandstone	2004 - 2015
NGW7	-	MB (AD)	6216591	277027	124.333	69.18	Sandstone	2004 - 2013
NGW9	-	MB (AD)	6217131	277737	124.333	69.19	Sandstone	2004 - 2012
NGW10	-	MB (AD)	6217333	276952	123.252	69.5	Sandstone	2004 - 2013
NGW11	-	MB (AD)	6217625	277105	127.336	72.15	Sandstone	2004 - 2013

Coordinates in metres (GDA94 - MGA zone 56) monitoring bore/open standpipe
GW – Georges River Bores
HBSS – Hawkesbury Sandstone
BUCO – Bulli Coal Seam
UnSS – Wianamatta - Minchinbury Sandstone
LDSS – Loddon Sandstone
VWP – Vibrating Wire Piezometer
EX – Existing
AGW – Cataract River Bores
BGSS – Bulgo Sandstone
WWCO - Wongawilli Coal Seam
AsSh – Wianamatta – Ashfield Shale
MB – monitoring bore/open standpipe MB – AD – abandoned and destroyed
NGW – Nepean River Bores
SBSS – Scarborough Sandstone
BrSh – Wianamatta (WnSh)– Bringelly Shale
CCSS – Coal Cliff Sandstone

APPENDIX B

Water Quality Data

Analyte		NHMRC Drinking water	ANZECC (2000) Fresh Water Aquatic	ANZECC (2000) Short term irrigation	ANZECC (2000) Long term irrigation	ANZECC (2000) Stock Water	Nepean River (Surface water)	Wianamatta Group	Hawkesbury Sandstone	Bulgo Sandstone
pH (Field)	Av.	6.5 - 8.5b	6.5 – 8.5	6.0 - 8.5	6.0 - 8.5	-	7.7	8.1	8.0	7.4
	Med.						7.7	7.9	7.5	7.2
	Min.						5.6	7.1	4.8	4.2
	Max.						9.8	9.7	13.1	12.8
	Pop.						3561	19	205.0	48.0
EC (Field)	Av.	-	120 - 300	-	-	-	321	4354	2653	4379
	Med.						244	4750	2063	4950
	Min.						12	7	7	7
	Max.						5596	9310	15820	10070
	Pop.						3575	19	206	48
TDS	Av.	600b	-	-	-	3,000 - 13,000*	173	2917^	1778^	2934^
	Med.						135	**3183^**	1382^	**3317^**
	Min.						10	5^	5^	4^
	Max.						1460	6238^	10599^	6747^
	Pop.						1738	19	206	48
Chloride	Av.	250b	-	-	-	-	41	979	548	114
	Med.						33	675	233	122
	Min.						14	289	22	16
	Max.						724	2820	8530	332
	Pop.						1761	23	213	60
Calcium	Av.	-	-	-	-	1,000	5	42	76	60
	Med.						4	36	70	50
	Min.						1	7	1	1
	Max.						83	108	384	190
	Pop.						1763	23	212	60
Sodium	Av.	180b	-	-	-	-	48	1018	336	1203
	Med.						34	**1050**	**261**	**1300**
	Min.						11	162	20	63
	Max.						**362**	1930	1390	2230
	Pop.						1763	23	213	60
Magnesium	Av.	-	-	-	-	-	5	15	52	24
	Med.						4	14	30	22
	Min.						1	6	1	4

Analyte		NHMRC Drinking water	ANZECC (2000) Fresh Water Aquatic	ANZECC (2000) Short term irrigation	ANZECC (2000) Long term irrigation	ANZECC (2000) Stock Water	Nepean River (Surface water)	Wianamatta Group	Hawkesbury Sandstone	Bulgo Sandstone
	Max.						112	34	332	48
	Pop.						1763	23	194	60
Sulphate	Av.	500a / 250b	-	-	-	1,000 – 2,400 (pigs)	5	2	11	5
	Med.						4	1	5	3
	Min.						1	1	2	2
	Max.						100	4	38	9
	Pop.						252	3	13	3
Potassium	Av.	-	-	-	-	-	4	36	151	33
	Med.						3	23	16	29
	Min.						1	11	3	3
	Max.						17	318	7190	106
	Pop.						1763	23	213	60
Fluoride	Av.	1.5a	-	2	1	2	0.2	0.5	0.2	0.2
	Med.						0.1	0.5	0.2	0.2
	Min.						0.1	0.2	0.1	0.1
	Max.						0.3	0.9	1.3	0.6
	Pop.						201	7	68.0	24.0
Bicarbonate	Av.	-	-	-	-	-	81	1140	540	2834
	Med.						55	789	374	2900
	Min.						1	252	29	1360
	Max.						399	2810	2570	4430
	Pop.						1754	1140	540	2834
Iron (t)	Av.	0.3b	-	10	0.2	-	0.3	1.5	2.0	3.8
	Med.						**0.3**	**1.4**	**1.1**	**1.9**
	Min.						0.01	0.01	0.03	0.03
	Max.						12.2	4	19	12
	Pop.						1766	20	186	55
Aluminium (d)	Av.	0.2b c	0.055	20	5	5	0.1	0.1	0.4	0.01
	Med.						0.1	0.03	0.02	0.01
	Min.						0.01	0.01	0.01	0.01
	Max.						5.2	0.5	7.6	0.2
	Pop.						1766	14	101	50
Arsenic (d)	Av.	0.01a	As (III) 0.024	2	0.1	0.5	0.003	0.004	0.007	0.004
	Med.						0.001	0.002	0.003	0.003

Analyte		NHMRC Drinking water	ANZECC (2000) Fresh Water Aquatic	ANZECC (2000) Short term irrigation	ANZECC (2000) Long term irrigation	ANZECC (2000) Stock Water	Nepean River (Surface water)	Wianamatta Group	Hawkesbury Sandstone	Bulgo Sandstone
	Min.		As (V) 0.013				0.001	0.001	0.001	0.001
	Max.						0.2	0.010	0.061	0.013
	Pop.						1764	18	173	60
Barium (d)	Av.						0.2	7.2	2.3	16.8
	Med.						0.2	**6.0**	1.08	**15.50**
	Min.	2a	-	-	-	-	0.1	3.1	0.03	0.4
	Max.						0.2	17.0	14.5	38.8
	Pop.						5.0	19	205	58
Boron (d)	Av.						0.2	-	-	-
	Med.						0.8	-	-	-
	Min.	4a	0.37	refer to guideline	0.5	7 (cattle)	0.0	-	-	-
	Max.						4.9	-	-	-
	Pop.						45.0	-	-	-
Cadmium (d)	Av.						0.0001	-	-	-
	Med.						0.0001	-	-	-
	Min.	0.002a	0.0002	0.05	0.01	0.01	0.0001	-	-	-
	Max.						0.0001	-	-	-
	Pop.						2.0	-	-	-
Chromium (d)	Av.	0.05a					0.001	-	-	-
	Med.		CrIII – ID				0.001	-	-	-
	Min.		Cr(VI) 0.001	1	0.1	1	0.001	-	-	-
	Max.						0.001	-	-	-
	Pop.						2	-	-	-
Copper (d)	Av.						0.001	0.001	0.002	0.007
	Med.						0.001	0.001	0.002	0.001
	Min.	2a / 1b	0.0014	5	0.2	1 (cattle)	0.001	0.001	0.001	0.001
	Max.						0.03	0.005	0.006	0.17
	Pop.						1764	16	18	31
Iron (d)	Av.						0.3	-	-	-
	Med.						0.3	-	-	-
	Min.	-	-	-	-	-	0.0	-	-	-
	Max.						12.2	-	-	-
	Pop.						1766	-	-	-
	Av.	0.01a	0.0034	5	2	0.1	0.001	0.04	0.24	0.7

Analyte		NHMRC Drinking water	ANZECC (2000) Fresh Water Aquatic	ANZECC (2000) Short term irrigation	ANZECC (2000) Long term irrigation	ANZECC (2000) Stock Water	Nepean River (Surface water)	Wianamatta Group	Hawkesbury Sandstone	Bulgo Sandstone
Lead (d)	Med.						0.001	0.001	0.04	0.7
	Min.						0.001	0.001	0.001	0
	Max.						0.05	0.7	1.4	1.4
	Pop.						1764	16	7	2
Manganese (d)	Av.	0.5a / 0.1b	1.9	10	0.2	-	0.04	0.1	0.1	0.04
	Med.						0.03	0.03	0.1	0.02
	Min.						0.001	0.01	0.001	0.001
	Max.						1.6	0.3	0.7	0.5
	Pop.						1766	18	145	45
Mercury (d)	Av.	-	0.0006	0.002	0.002	0.002	0.0001	-	-	-
	Med.						0.0001	-	-	-
	Min.						0.0001	-	-	-
	Max.						0.0001	-	-	-
	Pop.						2	-	-	-
Nickel (d)	Av.	0.02a	0.011	2	0.2	1	0.006	0.001	0.005	0.003
	Med.						0.003	0.001	0.002	0.002
	Min.						0.001	0.001	0.001	0.001
	Max.						0.1	0.002	0.09	0.02
	Pop.						1764	20	136	47
Selenium (d)	Av.	0.01a	Total – 0.011 SeIIV - ID	0.05	0.02	0.02	0.01	0.01	0.009	0.007
	Med.						**0.01**	**0.01**	**0.01**	0.009
	Min.						0.02	0.005	0.006	0.001
	Max.						0.1	0.01	0.01	0.01
	Pop.						1764	16	3	3
Zinc (d)	Av.	3b	0.008	2	2	20	0.01	0.14	0.044	0.058
	Med.						0.01	0.006	0.003	0.010
	Min.						0.004	0.003	0.003	0.001
	Max.						0.24	2.5	1.4	2.4
	Pop.						1764	20	116	54

Note Values below the limit of reporting were set at the limit for the calculations

** Maximum concentration at which good condition might be expected, with 13,000 mg/L for sheep, 5,000 mg/L for beef cattle, 4,000 mg/L for dairy cattle, 6,000 mg/L for horses and 3,000 mg/L for pigs and poultry.*

a NHMRC Health Guidelines for Drinking Water (2015)

b NHMRC Aesthetic Guidelines for Drinking Water (2015)

c NHMRC acid-soluble aluminium concentrations (2015) *(d) dissolved metals*

Av. Average; Med. Median

^ Calculated based on field EC

APPENDIX C

Registered Bores in the Appin Mine Area

Bore ID	Easting	Northing	Elevation (mAHD)	Year Drilled	Total Depth (mbgl)	Screen (mbgl)	SWL (mbgl)	EC/ Salinity	Status	Use	Geology	Comment
GW017315	286642	6220354	140.51	1938	36.5	OH (0.9 – TD)	-	3001-7000 ppm	Current	Farming – General Use	-	-
GW026516	289037	6220994	96.21	1965	10	-	-	-	Test Hole (Unknown)	Irrigation	Unconsolidated Clay, Silt and Shale	WBZ 4.5 m (Clay)
GW034425	289184	6215603	121	1972	70.1	OH (12 – TD)	-	Good	non-operational	Waste Disposal	Sandstone	WBZ (Sandstone) 9.1 - 10.6 m (SWL 4.7 m, Yield 0.03 L/s) WBZ (Sandstone) 21.3 - 24.3 m (SWL 14.6 m, Yield 0.04 L/s) WBZ (Sandstone) 64 - 69.4 m (SWL 14.6 m, Yield 0.63 L/s)
GW035033	288045	6214961	129.67	1973	131	OH (20.4 – TD)	-	-	Current	Stock	Sandstone and Shale	WBZ (Sandstone/Shale) 17.6 - 17.7 m (SWL 17.6 m, Yield 0.13 L/s) WBZ (Sandstone) 54.8 - 55.1 m (SWL 54.8 m, Yield 0.23 L/s)
GW062945	287960	6221031	115.28	1986	150	OH (86.9 – TD)	-	Fresh	Current	Stock, Domestic and Farming	Sandstone	WBZ (Fractured Shale) 29.6 - 30.8 m (SWL 15 m, Yield 1.2 L/s) WBZ (Sandstone) 101.3 - 101.7 m (SWL 85 m, Yield 0.2 L/s) WBZ (Sandstone) 144.8 - 145.9 m (SWL 40 m, Yield 0.7 L/s)
GW072196	288911	6218867	118.01	2006	-	-	-	-	Current	Domestic	-	Drilled in mapped alluvium (NGIS) potentially in HBSS
GW072874	288601	6217630	140.9	1992	189	OH (45 – TD)	-	Good	Current	Stock and Domestic	Sandstone, Shale and Siltstone	WBZ (Gravels) 6 - 7 m (Yield 0.2 L/s) WBZ (Shale) 30 - 36 m (Yield 0.1 L/s) WBZ (Sandstone) 80 - 85 m (Yield 0.3 L/s) WBZ (Siltstone) 98 - 104 m (Yield 0.1 L/s) WBZ (Sandstone) 164 - 170 m (Yield 0.2 L/s) WBZ (Sandstone) 176 - 189 m (Yield 1.4 L/s)

Bore ID	Easting	Northing	Elevation (mAHD)	Year Drilled	Total Depth (mbgl)	Screen (mbgl)	SWL (mbgl)	EC/ Salinity	Status	Use	Geology	Comment
GW100289	288686	6218937	124.22	1994	30	Slots (12 – 18) OH (18 - TD)	10	Good	Current	Stock and Domestic	Gravel (Slots) Shale (OH)	WBZ (Gravel) (Yield 0.3 L/s, SWL 10 m)
GW100673	286235	6216160	154.16	1995	104	-	49	Good	Current	Stock	-	Yield: 0.6 L/s (BH Reg), Work Summary (Unavailable)
GW101133	289443	6214100	117.02	1997	96	OH (5.5 – TD)	61	1100 mg/L	Current	Stock and Domestic	Sandstone, Ironstone and Siltstone	WBZ (Sandstone) 78.5 - 78.8 m (Yield 1.8 L/s, SWL 61 m)
GW101437	291642	6216361	135.89	1997	128	OH (6 – TD)	75	2500 mg/L	Current	Farming	Sandstone and Shale	WBZ (Sandstone and Shale) 119 – 121 m (Yield: 0.7 L/s, SWL 75 m, Salinity 2500 mg/L)
GW101986	288223	6217328	174.71	1998	210	OH (103 – TD)	82	-	Current	Stock and Domestic	Sandstone	WBZ (Sandstone) 119 - 120 m (SWL 82 m , Yield 0.25 L/s) WBZ (Sandstone) 132 - 133 m (SWL 82 m, Yield 0.31 L/s) WBZ (Sandstone) 146 - 148 m (SWL 82 m, Yield 0.05 L/s) WBZ (Sandstone) 173 - 179 m (SWL 82 m, Yield 0.05 L/s)
GW102043	289777	6214659	125.56	1999	192	OH (11.6 – TD)	104	260 mg/L	Current	Stock and Domestic	Sandstone, Siltstone and Clay	WBZ (Sandstone) 40 - 41 m (Yield 0.1 L/s, Salinity 291 mg/L) WBZ (Sandstone) 161.5 - 162 m (Yield 0.2 L/s, Salinity 260 mg/L)
GW102144	285921	6221466	143.24	1992	182	OH (17 – TD)	6	-	Current	Stock and Domestic	Sandstone and Shale	NGIS reports northing as 6220466, BH Reg lists as 6221466 WBZ (Shale) 114 - 115 m (SWL 6 m, Yield 0.07 L/s) WBZ (Shale) 140 - 140.4 m (SWL 6 m, Yield 0.06 L/s) WBZ (Sandstone) 162 - 163 m (SWL 6 m, Yield 0.13 L/s) WBZ (Sandstone) 168 - 168.6 m (SWL 6 m, Yield 0.12 L/s)

Bore ID	Easting	Northing	Elevation (mAHD)	Year Drilled	Total Depth (mbgl)	Screen (mbgl)	SWL (mbgl)	EC/ Salinity	Status	Use	Geology	Comment
GW102584	289626	6216445	136.76	1999	186	OH (29.5 – TD)	-	1300 mg/L	Grouted	Stock and Domestic	Sandstone	WBZ (Sandstone) 54 - 60 m (Yield 0.1 L/s, Salinity 1370 mg/L) WBZ (Sandstone) 64 - 70 m (Yield 0.1 L/s, Salinity 1190 mg/L) WBZ (Sandstone) 108 - 112 m (Yield 0.2 L/s, Salinity 1300 mg/L) WBZ (Sandstone) 144 - 150 m (Yield 0.2 L/s, Salinity 1300 mg/L, SWL 60 m) WBZ (Sandstone) 177 - 179 m (Yield 0.9 L/s, Salinity 1300 mg/L)
GW102619	287887	6220525	124.74	1999	224	OH (95 – TD)	95	-	Current	Stock, Domestic, Farming and Irrigation	Sandstone and Shale	WBZ (Sandstone) 38 - 39 m (Yield 0.13 L/s, SWL 24 m) WBZ (Sandstone) 81 - 83 m (Yield 0.75 L/s) WBZ (Shale) 145 - 150 m (Yield 0.25 L/s, SWL 95 m) WBZ (Sandstone) 165 - 200 m (Yield 0.75 L/s, SWL 95 m) WBZ (Sandstone) 200 - 225 m (Yield 0.75 L/s, SWL 95 m)
GW102798	289990	6214783	127.16	See comment	122	OH (3 – TD)	148	700 mg/L	Current	Farming, Stock and Domestic	Sandstone	WBZ (Sandstone) 95 - 96 m (Yield 0.25 L/s) WBZ (Sandstone) 103 - 104 m) (SWL 148 m, Yield 1 L/s, Salinity 700 mg/L)
GW104068	289519	6214530	118.66	2001	180	OH (12 – TD)	62	1000 mg/L	Current	Stock and Domestic	Sandstone, Siltstone and Shale	WBZ (Sandstone) 95 - 118 m (Yield 0.52 L/s, Salinity 990 mg/L, SWL 62 m) WBZ (Sandstone) 152 - 153 m (Yield 0.26 L/s, Salinity 1000 mg/L, SWL 62 m) WBZ (Sandstone) 163 - 164 m (Yield 0.88 L/s, Salinity 1000 mg/L, SWL 62 m)
GW104154	291233	6216088	134.69	2000	165	OH (18 – TD)	74	-	Current	Stock and Domestic	Sandstone and Shale	WBZ (Sandstone) 116 - 117 m (Yield 0.7 L/s) WBZ (Sandstone) 134 - 135 m (Yield 0.9 L/s) WBZ (Sandstone) 160 - 161 m (Yield 1.3 L/s, SWL 74 m)

Bore ID	Easting	Northing	Elevation (mAHD)	Year Drilled	Total Depth (mbgl)	Screen (mbgl)	SWL (mbgl)	EC/ Salinity	Status	Use	Geology	Comment
GW104347	284012	6217884	199.9	2002	298	OH (145 – TD)	110	Brackish	Current	Stock and Domestic	Sandstone	WBZ (Sandstone) 195 - 196 m (Yield 0.3 L/s, SWL 110 m) WBZ (Sandstone) 207 - 208 m (Yield 0.4 L/s, SWL 110 m) WBZ (Sandstone) 273 - 274 m (Yield 0.2 L/s, SWL 110 m)
GW104602	289054	6216338	133.52	Unknown	231	OH (101.5 – TD)	42	Fresh	Current	Stock	Sandstone and Clay	WBZ (Shale) 29.9 - 30 m (Yield 0.13 L/s, Salinity 2500 mg/L, SWL 27 m) WBZ (Sandstone) 161 - 161.5 m (Yield 0.75 L/s, SWL 42 m) WBZ (Sandstone) 213 - 213.15 m (Yield 0.75 L/s, SWL 42 m)
GW104661	289118	6216661	140.74	2003	219.3	OH (42 – TD)	68	Fresh	Grouted	Stock and Domestic	Sandstone	WBZ (Sandstone) 113 - 113.1 m (Yield 0.38 L/s, SWL 68 m) WBZ (Sandstone) 154 - 154.1 m (Yield 0.53 L/s, SWL 68 m) WBZ (Sandstone) 197 - 197.1 m (Yield 0.53 L/s, SWL 68 m) WBZ (Sandstone) 212 - 212.15 m (Yield 1.05 L/s, SWL 68 m)
GW104766	287663	6220995	117.31	2002	192	OH (29.5 – TD)	82	662 mg/L	Current	Stock and Domestic	Sandstone and Shale	WBZ (Sandstone) 121.5 - 123 m (Yield 0.2 L/s, Salinity 860 mg/L) WBZ (Sandstone) 128.5 - 129 m (Yield 0.15 L/s, Salinity 850 mg/L) WBZ (Sandstone) 175 - 176 m (Yield 0.1 L/s, Salinity 740 mg/L) WBZ (Sandstone) 184 - 187 m (Yield 0.15 L/s, Salinity 662 mg/L, SWL 82 m)
GW105325	287685	6221474	111.02	2001	159	OH (122 - TD)	-	2000 mg/L	Current	Stock, Domestic and Recreation	Sandstone and Shale	WBZ (Shale) 72 - 73 m (Yield 0.3 L/s, Salinity 2000 mg/L) WBZ (Shale) 121 - 122 m (Yield 0.5 L/s, Salinity 1800 mg/L) WBZ (Sandstone) 130 - 137 m (Yield 1.2 L/s, Salinity 2000 mg/L)

Bore ID	Easting	Northing	Elevation (mAHD)	Year Drilled	Total Depth (mbgl)	Screen (mbgl)	SWL (mbgl)	EC/ Salinity	Status	Use	Geology	Comment
GW105339	291919	6218356	129	2003	238	OH (30 – TD)	-	-	Grouted	Stock, Domestic and Recreation	Sandstone and Shale	WBZ (Sandstone) 139 - 140 m (Yield 0.25 L/s) WBZ (Sandstone) 183 - 184 m (Yield Unknown)
GW105376	289443	6218380	151.54	2002	218.5	OH (102 – TD)	76	Fresh	Current	Stock and Domestic	Sandstone	WBZ (Sandstone) 180 - 180.1 m (Yield 1.13 L/s, SWL 76 m) WBZ (Sandstone) 191 - 191.2 m (Yield 1.63 L/s, SWL 76 m) WBZ (Sandstone) 204 - 204.2 m (Yield 1.5 L/s, SWL 76 m)
GW105531	287664	6218430	150.51	2003	210	OH (33 – TD)	79	2070 mg/L	Current	Stock and Domestic	Sandstone and Shale	WBZ (Sandstone) 96.2 - 96.8 m (Yield 0.2 L/s, Salinity 2070 mg/L) WBZ (Sandstone) 110.5 - 113 m (Yield 0.20 L/s, Salinity 2450 mg/L) WBZ (Sandstone) 175.5 - 177 m (Yield 0.15 L/s, Salinity 2190 mg/L) WBZ (Sandstone) 188 - 188.2 m (Yield 0.15 L/s, Salinity 2070 mg/L)
GW105534	288655	6217297	167.82	1905	See comment	OH (72 – TD)	92	Fresh	Current	Stock and Domestic	Sandstone and Slate	NGIS lists -total depth as 207, BH Reg lists as 201 WBZ (Sandstone) 113 - 113.1 m (Yield 0.1 L/s, SWL 92 m) WBZ (Sandstone) 161 - 161.1 m (Yield 0.5 L/s, SWL 92 m) WBZ (Sandstone) 188 - 188.1 m (Yield 0.68 L/s, SWL 92 m) WBZ (Sandstone) 197 - 197.1 m (Yield 0.42 L/s, SWL 92 m)
GW105574	289656	6218908	125.42	2003	210	OH (Surface – TD)	-	3630	Current	Stock and Domestic	Sandstone, Clay and Shale	WBZ (Shale) 27 - 28.5 m (Yield 0.5 L/s, Salinity 2960 mg/L) WBZ (Sandstone) 85 - 86 m (Yield 0.5 L/s, Salinity 2840 mg/L) WBZ (Shale) 145 - 147 m (Yield 0.45 L/s, Salinity 3630 mg/L)

Bore ID	Easting	Northing	Elevation (mAHD)	Year Drilled	Total Depth (mbgl)	Screen (mbgl)	SWL (mbgl)	EC/ Salinity	Status	Use	Geology	Comment
GW105942	282545	6218791	307.01	2002	214	OH (Surface – TD)	11	Fresh	Unknown	Test Bore	Shale and Clay	WBZ (Shale) 18 - 18.1 m (Yield 0.03 L/s, SWL 11 m) WBZ (Shale) 64 - 64.1 m (Yield 0.13 L/s, SWL 11 m)
GW106574	290123	6218350	140.52	2002	238	OH (6 – TD)	-	3000 mg/L	Grouted	Domestic	Sandstone and Shale	WBZ (Sandstone) 115 - 116 m (Yield 0.2 L/s, Salinity 1400 mg/L) WBZ (Sandstone) 133 - 114 m (Yield 0.55 L/s, Salinity 3000 mg/L)
GW106675	288797	6218642	124.43	2003	183	OH (43 – TD)	20	Fresh	Current	Stock and Domestic	Sandstone and Shale	WBZ (Sandstone) 60 - 60.1 m (Yield 1 L/s, SWL 42 m) WBZ (Sandstone) 83 - 83.1 m (Yield 0.9 L/s, SWL 42 m) WBZ (Sandstone) 145 - 145.1 m (Yield 1.1 L/s, SWL 42 m) WBZ (Sandstone) 162 - 162.15 m (Yield 1.05 L/s, SWL 42 m)
GW107791	289415	6220392	114.32	2003	231	OH (81 – TD)	37	Fresh	Current	Stock and Domestic	Sandstone	WBZ (Sandstone) 128 - 128.2 m (Yield 0.85 L/s, SWL 37 m) WBZ (Sandstone) 151 - 151.1 m (Yield 0.28 L/s, SWL 37 m) WBZ (Sandstone) 162 - 162.1 m (Yield 0.15 L/s, SWL 37 m) WBZ (Sandstone) 217 - 217.2 m (Yield 0.53 L/s, SWL 37 m) WBZ (Sandstone) 222 - 222.25 m (Yield 1.2 L/s, SWL 37 m)
GW108193	282555	6218724	308.35	2002	214	OH (Surface – TD)	16	2800 mg/L	Unknown	Test Bore	Clay and Shale	WBZ (Shale) 17.8 - 18 m (Yield 0.03 L/s, SWL 16 m) WBZ (Shale) 63.8 - 64 m (Yield 0.13 L/s, SWL 16 m, Salinity 2800 mg/L)

Bore ID	Easting	Northing	Elevation (mAHD)	Year Drilled	Total Depth (mbgl)	Screen (mbgl)	SWL (mbgl)	EC/ Salinity	Status	Use	Geology	Comment
GW108312	291534	6217750	144.97	2004	175	Slots (78 – 84 - No WBZ listed at this depth) OH (85 – TD)	84	500 mg/L	Current	Industrial	Sandstone (Slots and OH to TD)	WBZ (Sandstone) 119 - 120 m (Yield 0.1 L/s, SWL 84 m, Salinity 1200 mg/L) WBZ (Sandstone) 156 - 157 m (Yield 0.16 L/s, Salinity 500 mg/L)
GW108907	288602	6218547	125.78	2007	210	OH (72 – TD)	40	1200 mg/L	Current	Stock and Domestic	Sandstone and Shale	WBZ (Sandstone/Shale) 62 - 64 (Yield 0.8 L/s, Salinity 3000 mg/L) WBZ (Sandstone) 126 - 130 m (Yield 1 L/s, SWL 40 , Salinity 1830 mg/L) WBZ (Sandstone) 186 - 188 m (Yield 1.4 L/s, SWL 40 m, Salinity 1300 mg/L) WBZ (Shale) 206 - 208 m (Yield 1.8 L/s, SWL 40 m, Salinity 1200 mg/L)
GW108990	290347	6219588	108.75	2008	See comment	-	-	-	Current	Domestic	-	NGIS lists total depth as 150 m, BH Reg lists as 0;
GW110550	283788	6218949	249.41	2009	See comment	OH (2.5 – TD)	200	670 mg/L	Current	Stock and Domestic	Sandstone and Shale	NGIS lists total depth as 336 m; BH Reg lists as 339 m WBZ (Sandstone) 277 - 279 m (Yield 0.5 L/s, Salinity 800 mg/L) WBZ (Sandstone) 310 - 312 m (Yield 0.6 L/s, Salinity 616 mg/L) WBZ (Sandstone) 320 - 322 m (Yield 0.75 L/s, SWL 200 m, Salinity 670 mg/L)
GW110671	288717	6216340	141.86	2010	240	OH (28 – TD)	82	400 mg/L	Current	Stock and Domestic	Sandstone, Shale and Granite	WBZ (Sandstone) 72 - 72.2 m (Yield 0.05 L/s, SWL 82 m, Salinity 400 mg/L) WBZ (Sandstone) 150 - 150.3 m (Yield 0.1 L/s) WBZ (Sandstone) 166 - 166.2 m (Yield 0.9 L/s) WBZ (Sandstone) 211 - 211.1 m (Yield 0.15 L/s)
GW111634	290819	6215923	128.36	2004	72.14	-	-	-	Active	Monitoring Bore	-	No construction or geology information
GW111636	291580	6216015	125.72	2004	78.75	-	-	-	Active	Monitoring Bore	-	No construction or geology information

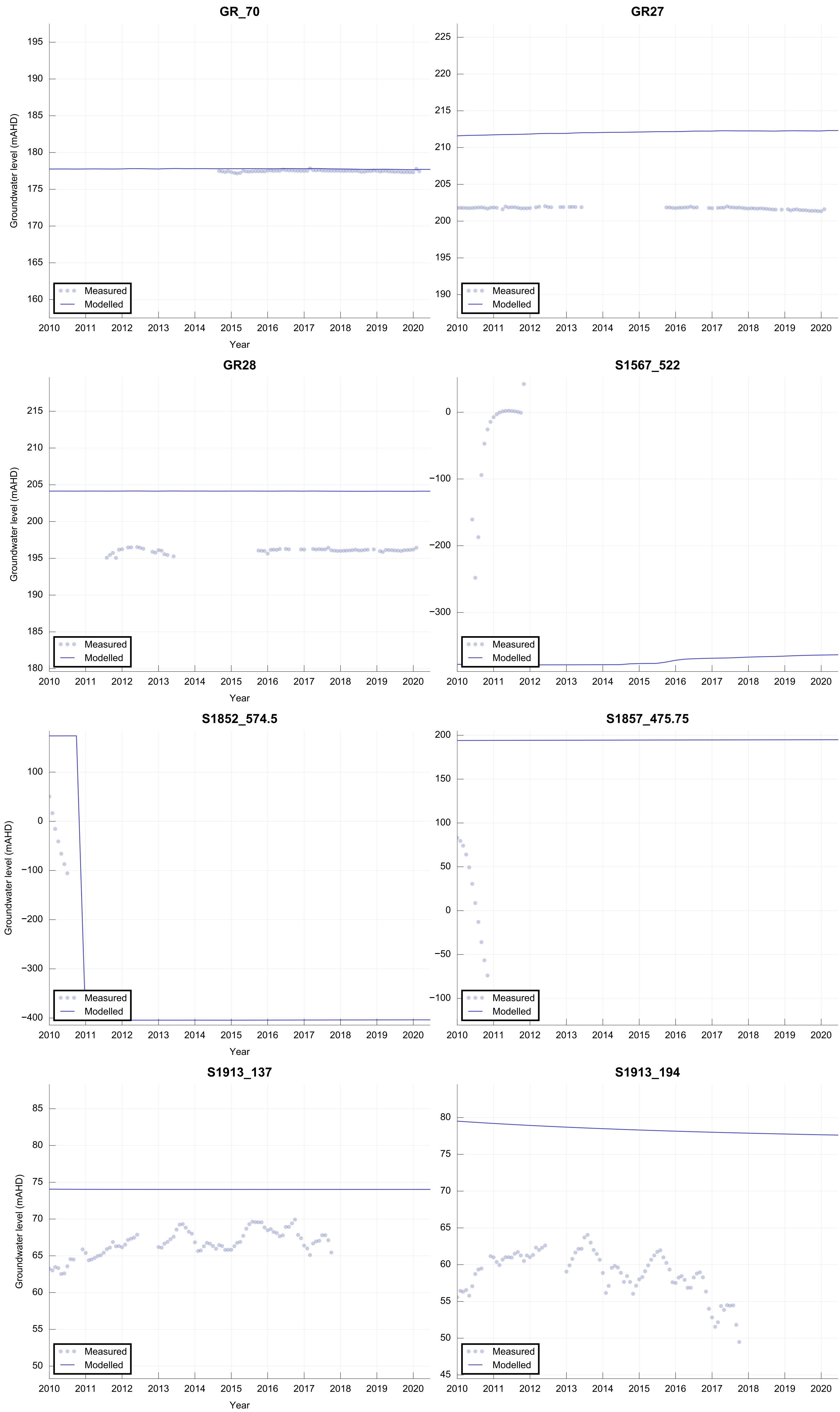
Bore ID	Easting	Northing	Elevation (mAHD)	Year Drilled	Total Depth (mbgl)	Screen (mbgl)	SWL (mbgl)	EC/ Salinity	Status	Use	Geology	Comment
GW111637	291924	6215523	115.57	2004	78.75	-	-	-	-	Monitoring Bore	-	No construction or geology information
GW111638	292197	6215881	119.03	2004	78.75	-	-	-	-	Monitoring Bore	-	No construction or geology information
GW111727	287506	6221188	-	2004	261	OH (Surface – TD)	150	Salty	Current	Stock and Domestic	-	Yield: 1 L/s (BH Reg) No information on geology
GW111781	285334	6217542	-	2005	305	OH (120 – TD)	185	Fresh	Current	Domestic	Sandstone	Yield: 1 L/s (BH Reg) WBZ (Sandstone) 243 - 243.05 m (Yield 0.2 L/s, SWL 185 m) WBZ (Sandstone) 283 - 283.01 m (Yield 1 L/s, SWL 185 m)
GW112381	288743	6218191	-	2010	152	OH (72 – TD)	70	Fresh	Current	Stock and Domestic	Sandstone	WBZ (Sandstone) 102 - 102.5 m (Yield 0.1 L/s, SWL 70 m) WBZ (Sandstone) 142 - 142.05 m (Yield 0.5 L/s)
GW112437	288659	6215538	-	2010	156	OH (72 – TD)	63	1500 mg/L	Current	Stock and Domestic	Sandstone and Shale	WBZ (Sandstone) 50 - 50.05 m (Yield 0.25 L/s, SWL 63 m, Salinity 3200 mg/L) WBZ (Sandstone) 62 - 62.05 m (Yield 0.19 L/s, SWL 63 m, Salinity 3200 mg/L) WBZ (Sandstone) 141 - 141.5 m (Yield 1.9 L/s, SWL 63 m, Salinity 1500 mg/L)
GW112441	289940	6217284	-	2010	294	OH (60 – TD)	70	400	Grouted	Stock and Domestic	Sandstone	WBZ (Sandstone) 113 - 113.05 m (Yield 0.1 L/s, SWL 70 m, Salinity 400 mg/L) WBZ (Sandstone) 136 - 136.05 m (Yield 0.2 L/s) WBZ (Sandstone) 140 - 140.05 m (Yield 0.2 L/s) WBZ (Sandstone) 225 - 225.01 m (Yield 0.1 L/s)
GW112481	288663	6219694	-	2007	633.2	-	-	-	-	Industrial	-	No construction or geology information

Datum: GDA94/MGA Zone 56

OH – Open Hole *TD – Total Depth* *WBZ – Water Bearing Zone*

APPENDIX D

Calibration Hydrographs


GR_70
GR27
GR28
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S1852_574.5
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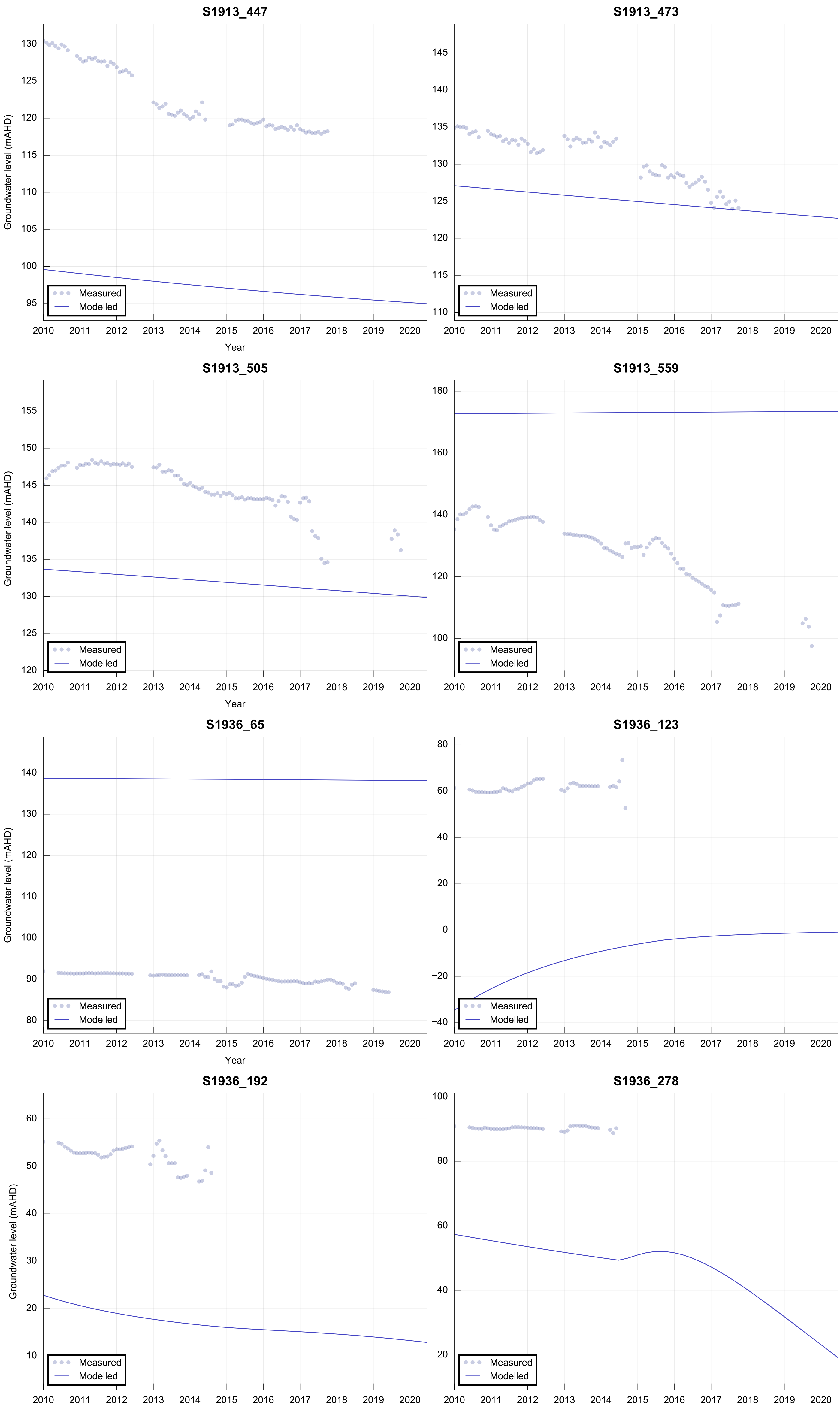
S1913_194
Groundwater level (mAHD)
Year
Measured
Modelled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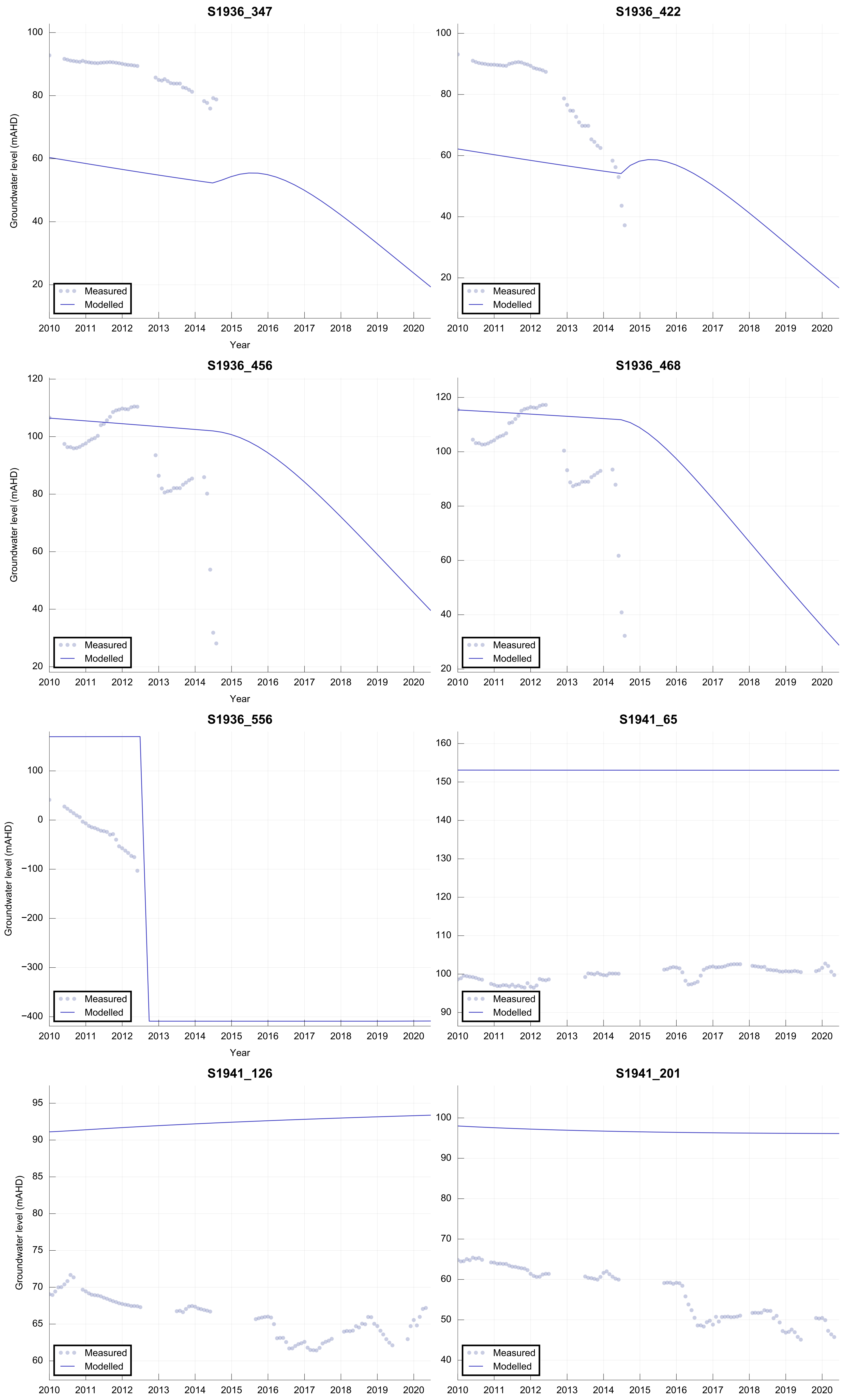
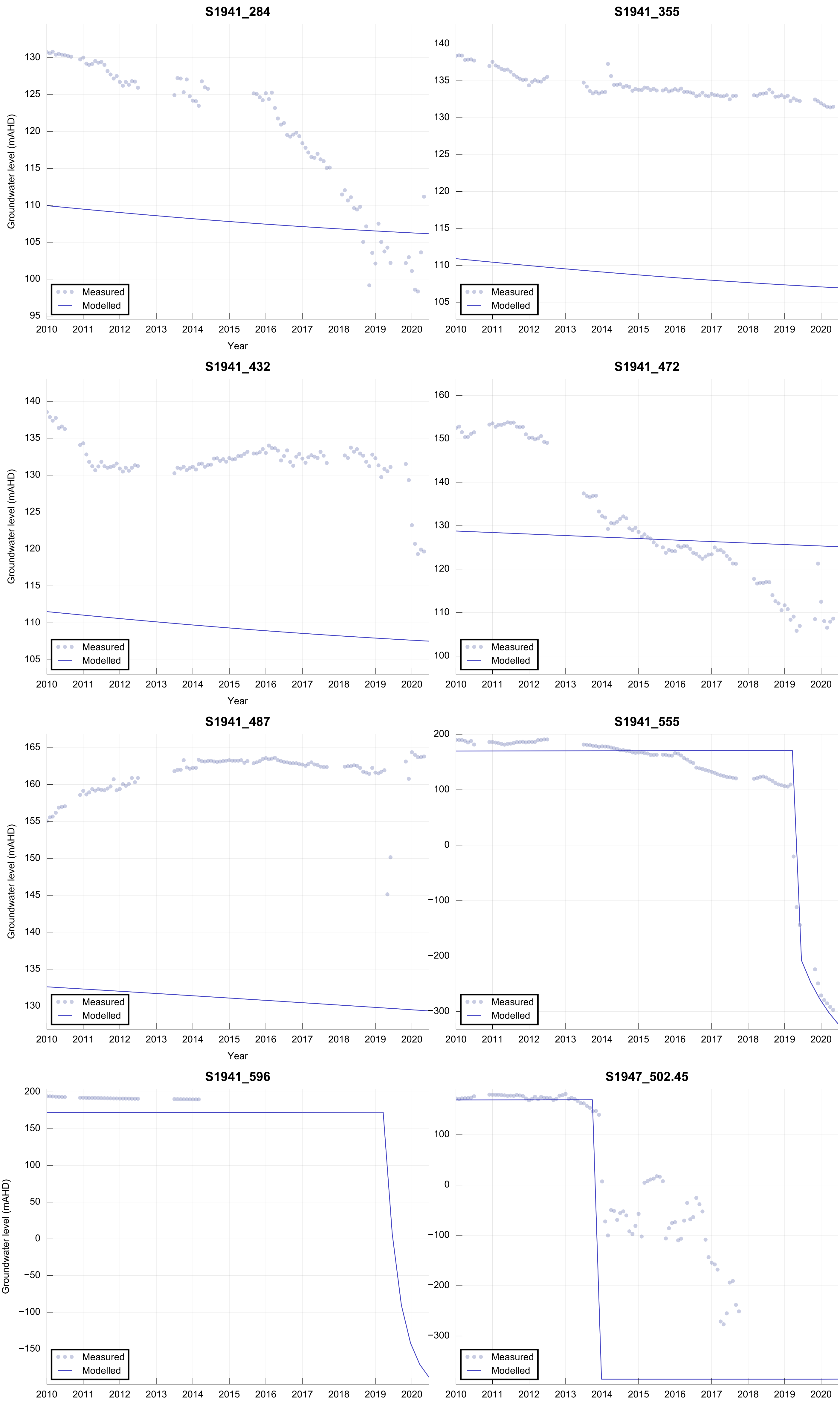
S1913_473
S1913_505
S1913_559
S1936_65
S1936_123
S1936_192
S1936_278
Groundwater level (mAHD)
Year
Measured
Modelled
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020


S1936_347
S1936_422
S1936_456
S1936_468
S1936_556
S1941_65
S1941_126
S1941_201
Groundwater level (mAHD)
Year
Measured
Modelled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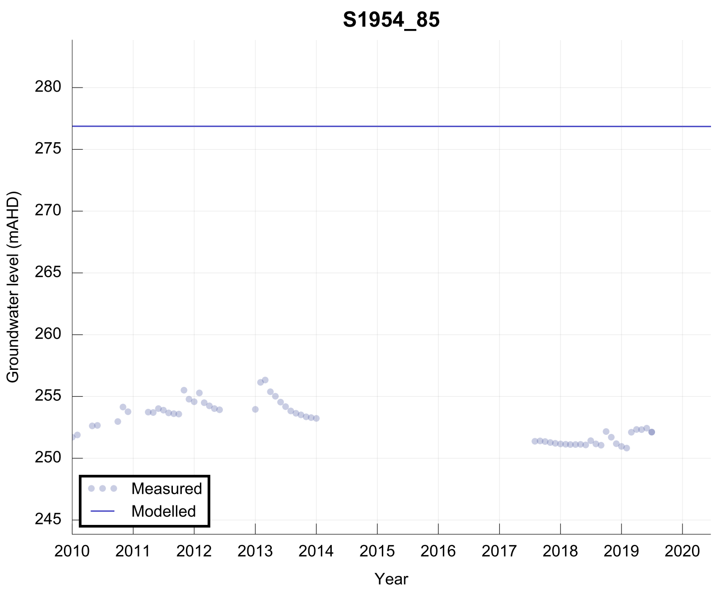
S1941_355
S1941_432
S1941_472
S1941_487
S1941_555
S1941_596
S1947_502.45
Groundwater level (mAHD)
Year
Measured
Modelled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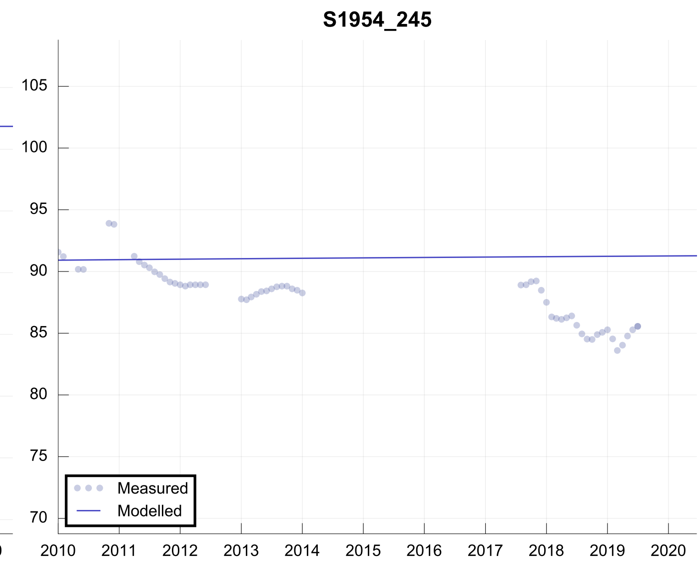
Groundwater level (mAHD)
Year
Measured
Modelled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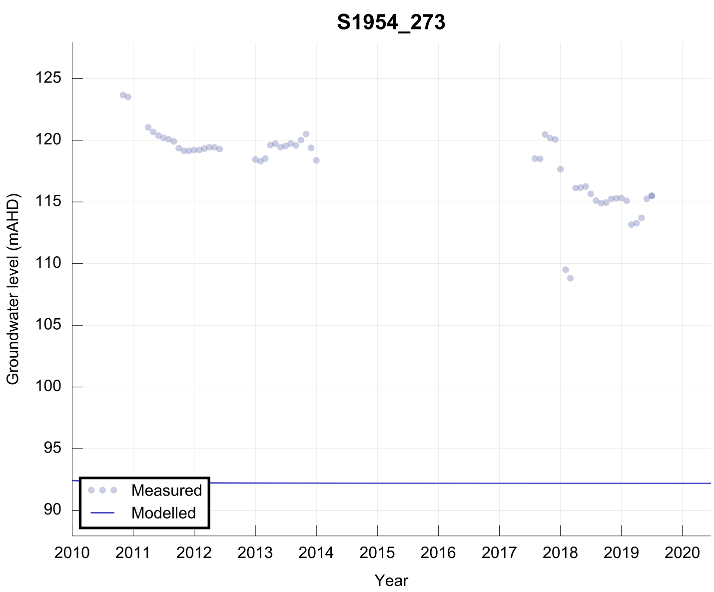
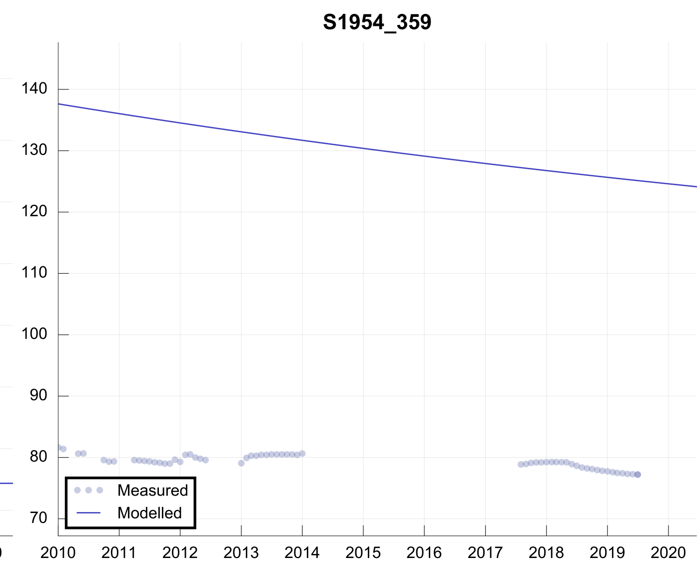
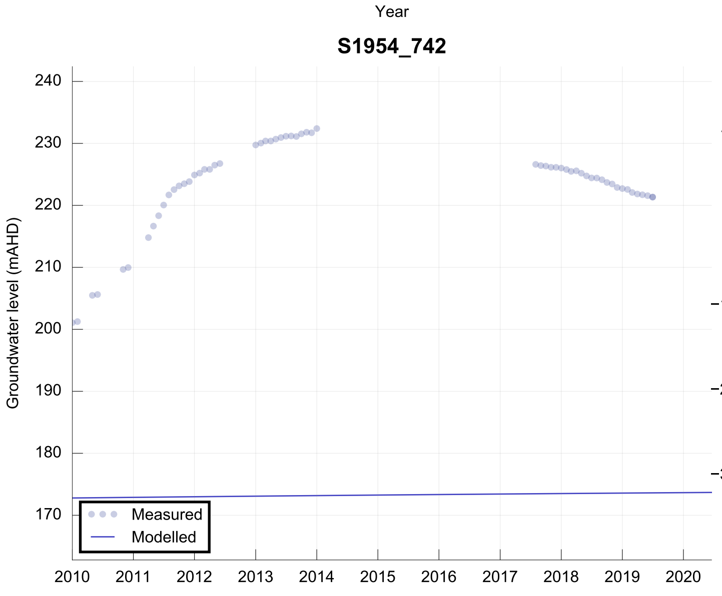
Measured
Modelled


S1954_273
Groundwater level (mAHD)
Year
Measured
Modelled


S1954_359
Measured
Modelled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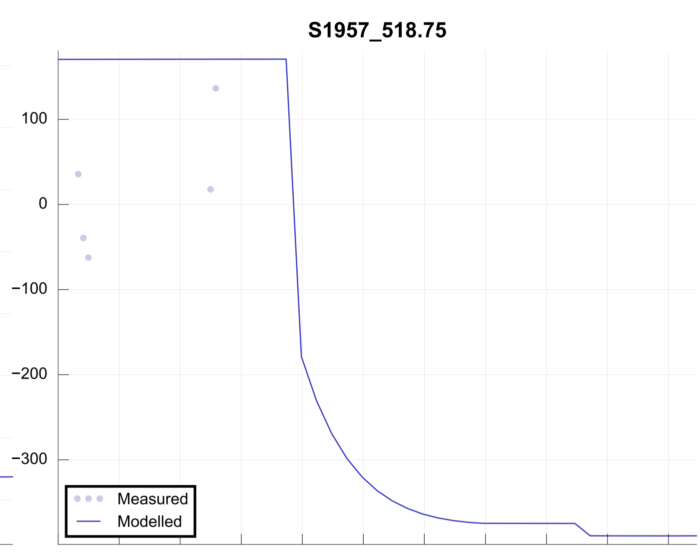
Groundwater level (mAHD)
Year
Measured
Modelled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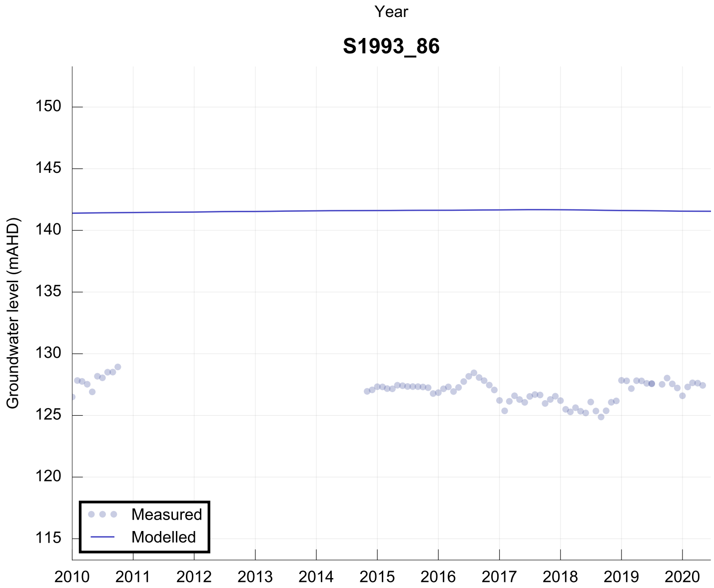
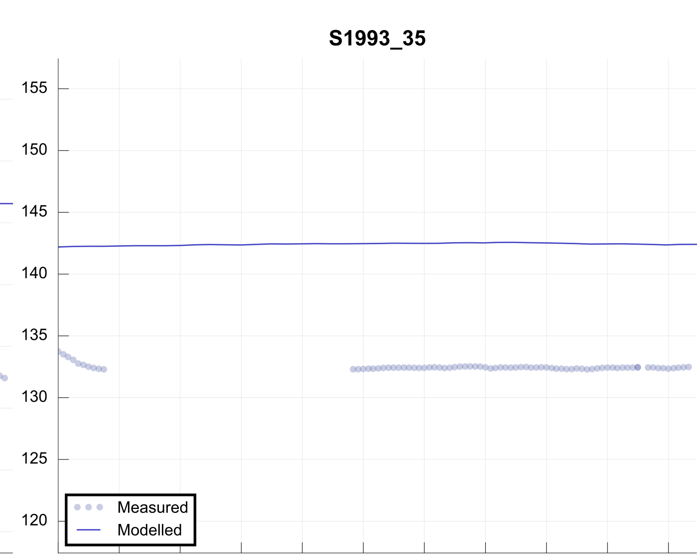
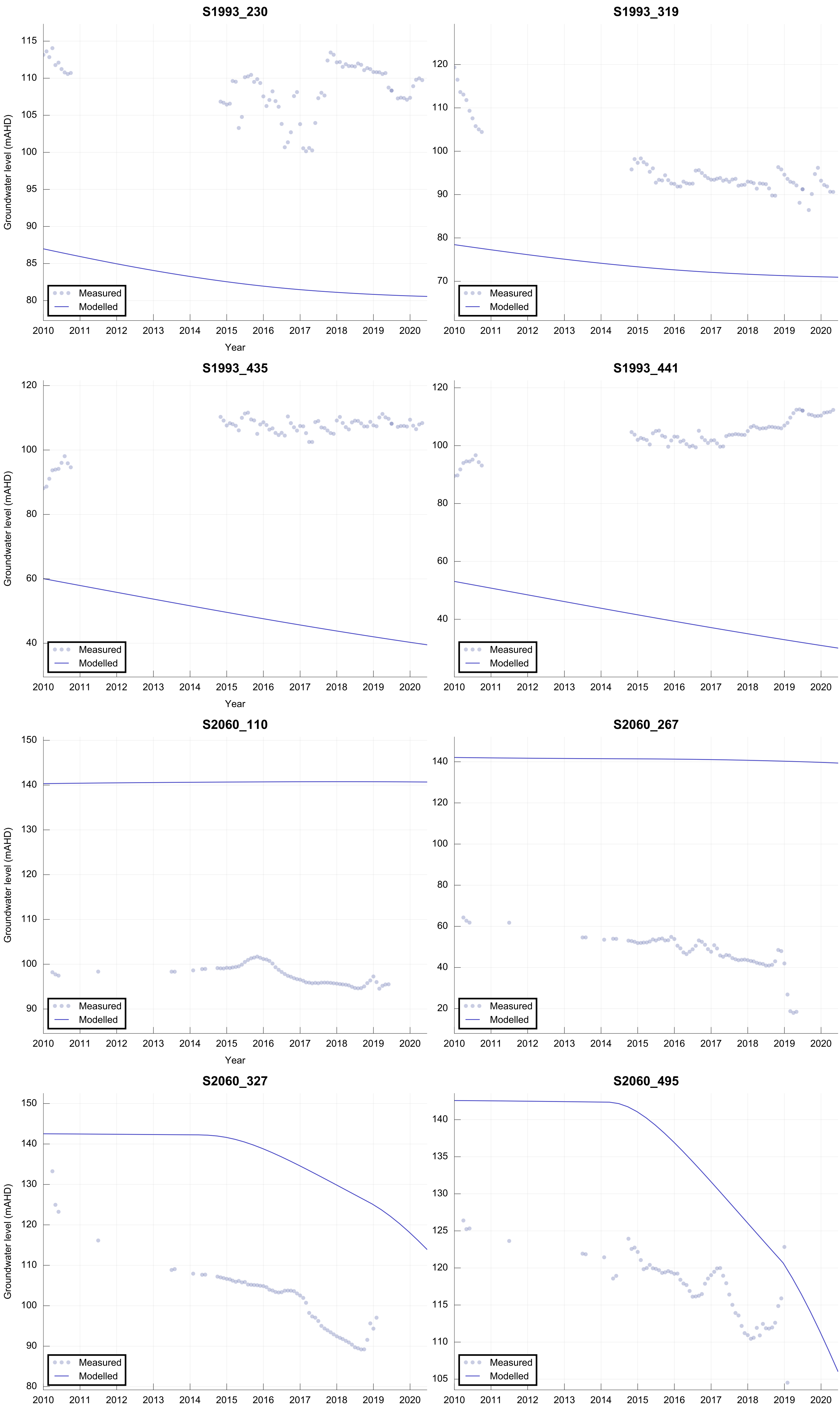
Measured
Modelled


S1993_86
Groundwater level (mAHD)
Year
Measured
Modelled


S1993_35
Measured
Modelled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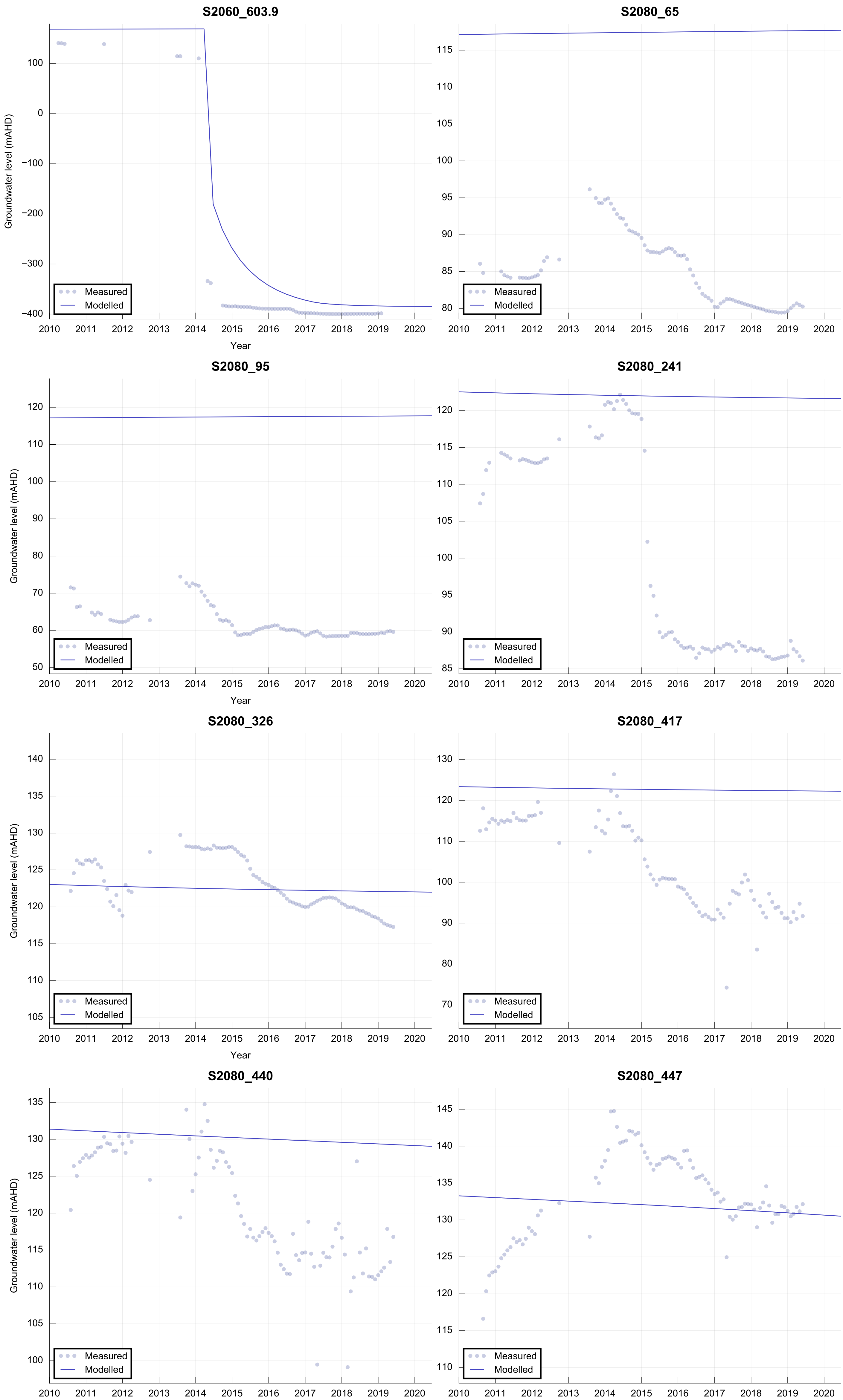
S1993_319
S1993_435
S1993_441
S2060_110
S2060_267
S2060_327
S2060_495
Groundwater level (mAHD)
Year
Measured
Modelled
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020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S2080_95
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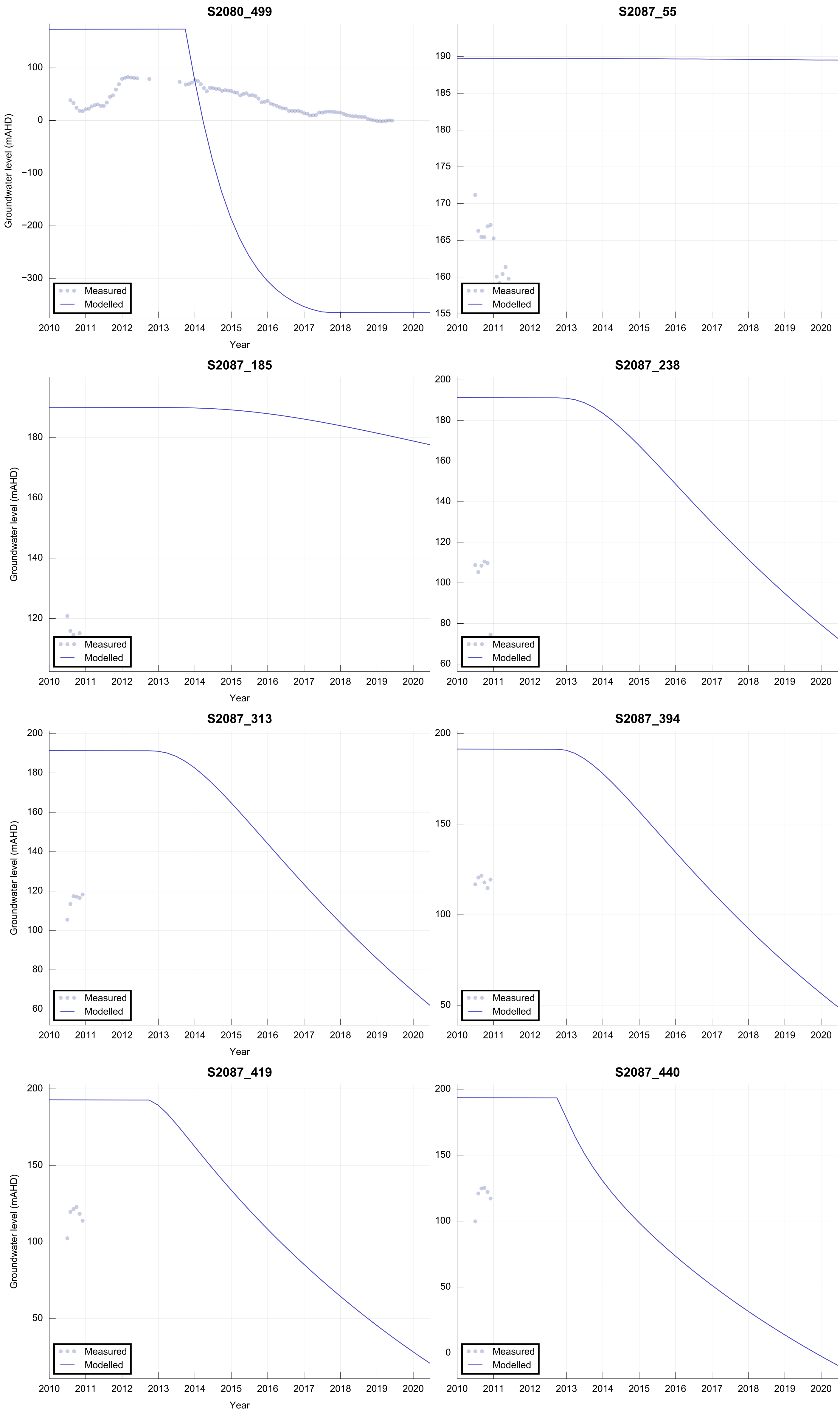
S2080_326
S2080_417
S2080_440
S2080_447
Groundwater level (mAHD)
Year
Measured
Modelled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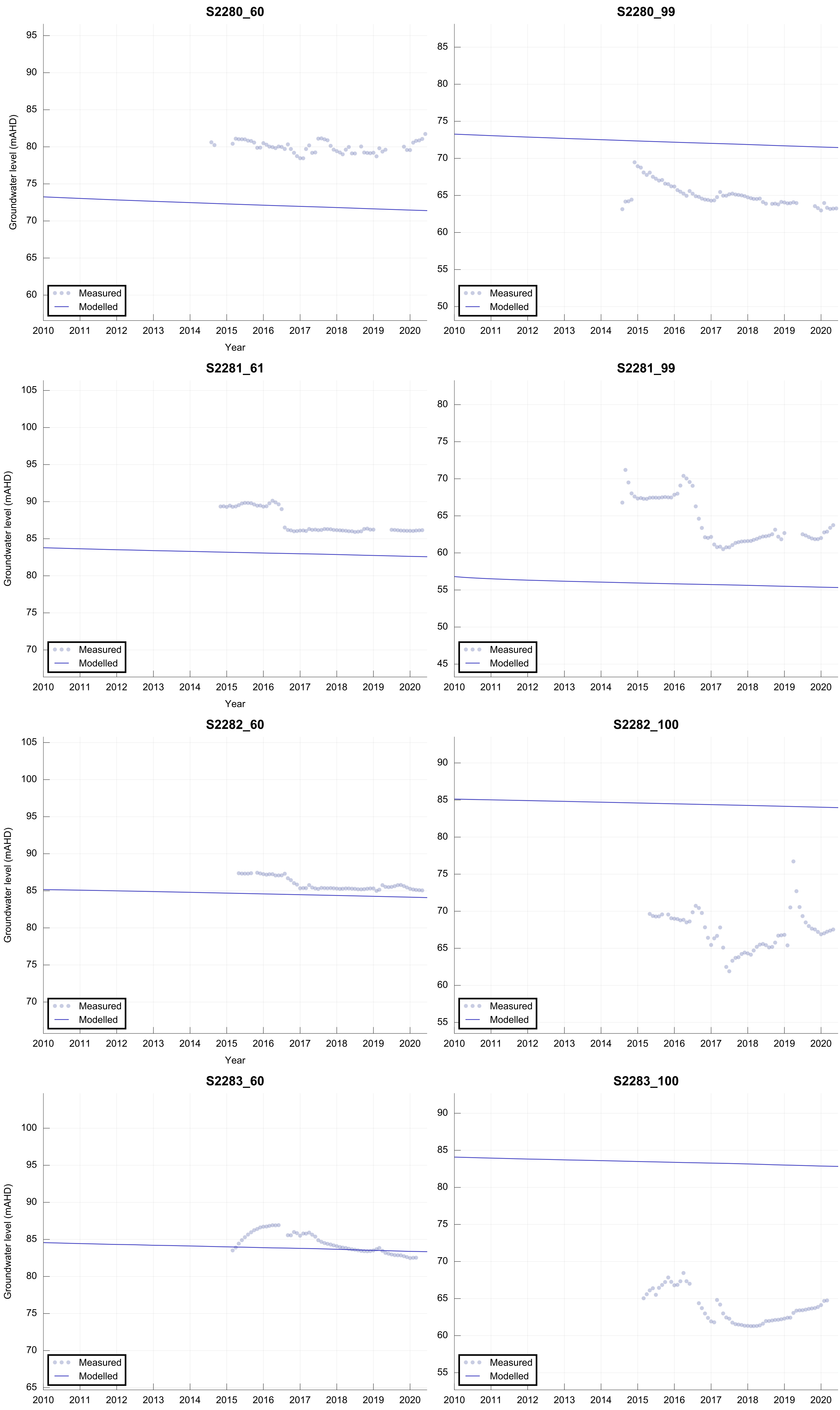
S2087_185
S2087_238
S2087_313
S2087_394
S2087_419
S2087_440
Groundwater level (mAHD)
Year
Measured
Modelled
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020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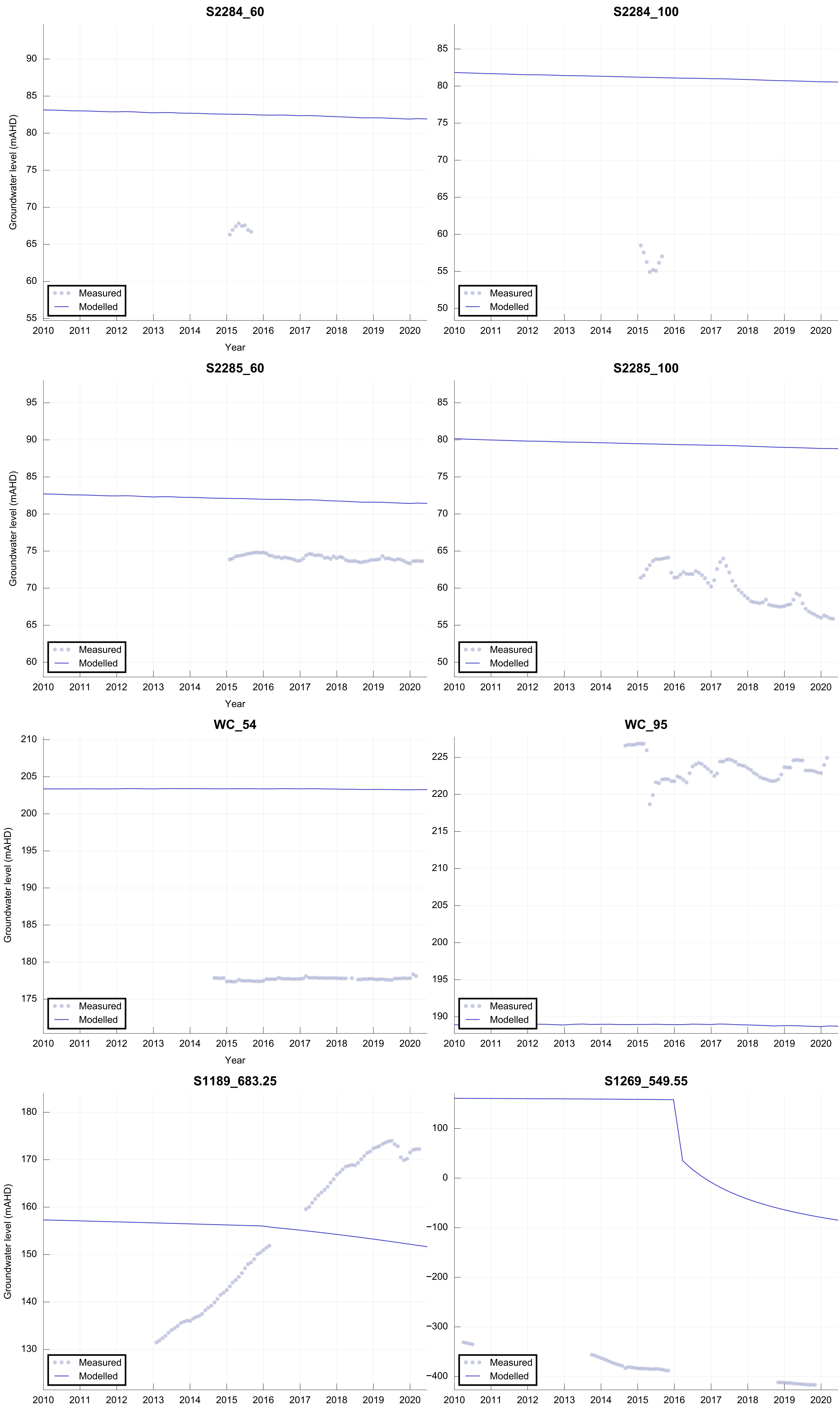
S2280_99
S2281_61
S2281_99
S2282_60
S2282_100
S2283_60
S2283_100
Groundwater level (mAHD)
Year
Measured
Modelled
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020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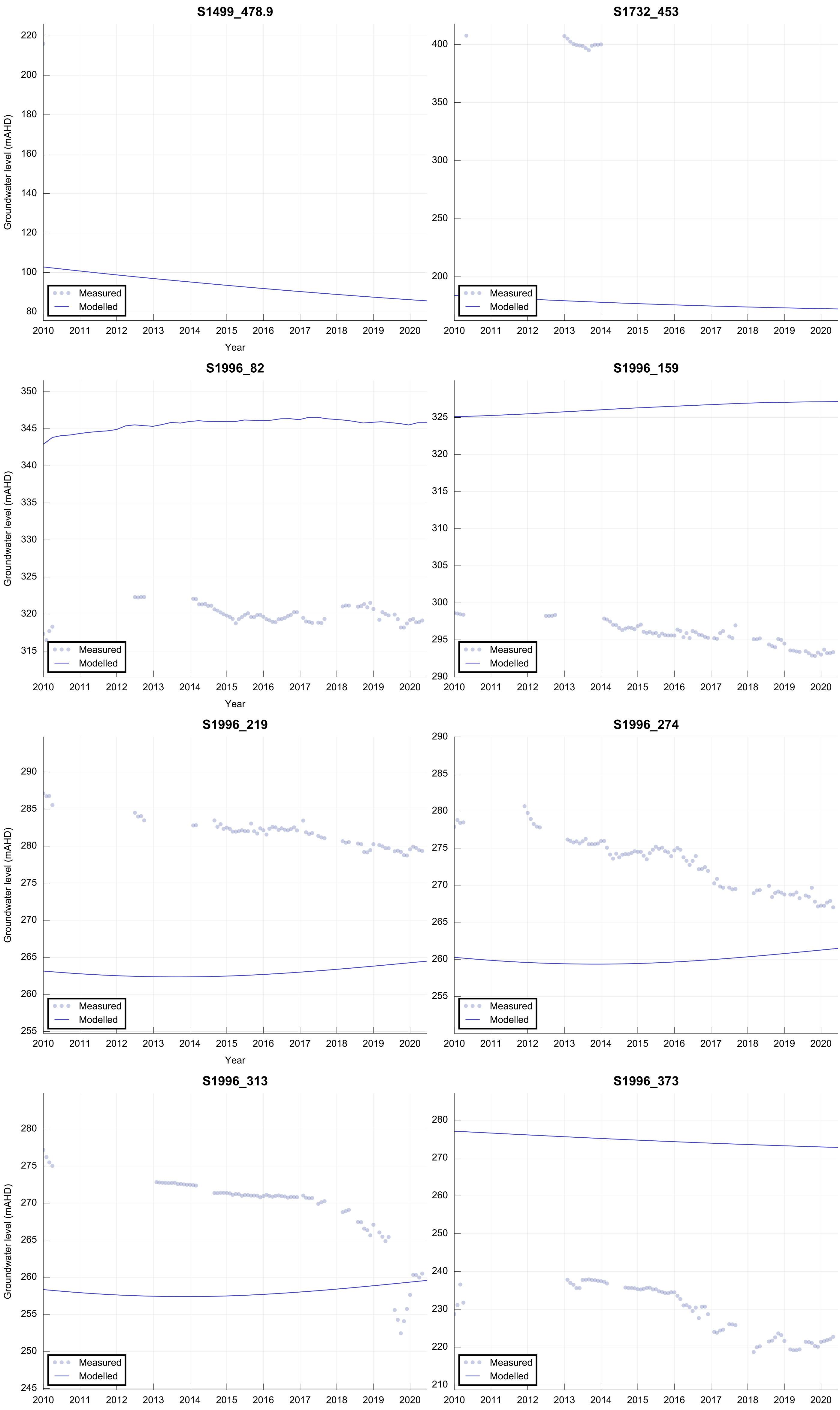
S2284_100
S2285_60
S2285_100
WC_54
WC_95
S1189_683.25
S1269_549.55
Groundwater level (mAHD)
Year
Measured
Modelled
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020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S1996_219
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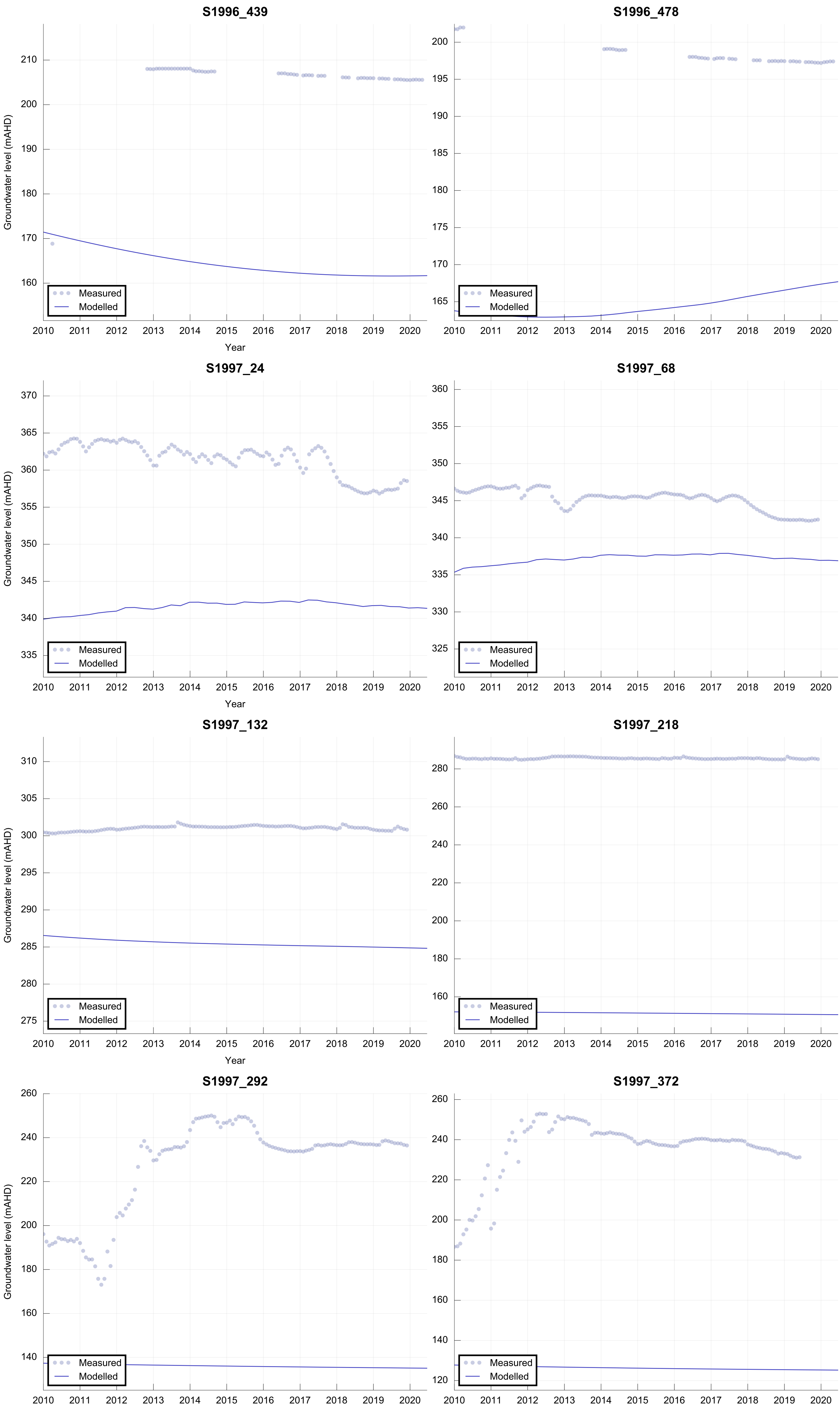
S1996_313
S1996_373
Groundwater level (mAHD)
Year
Measured
Modelled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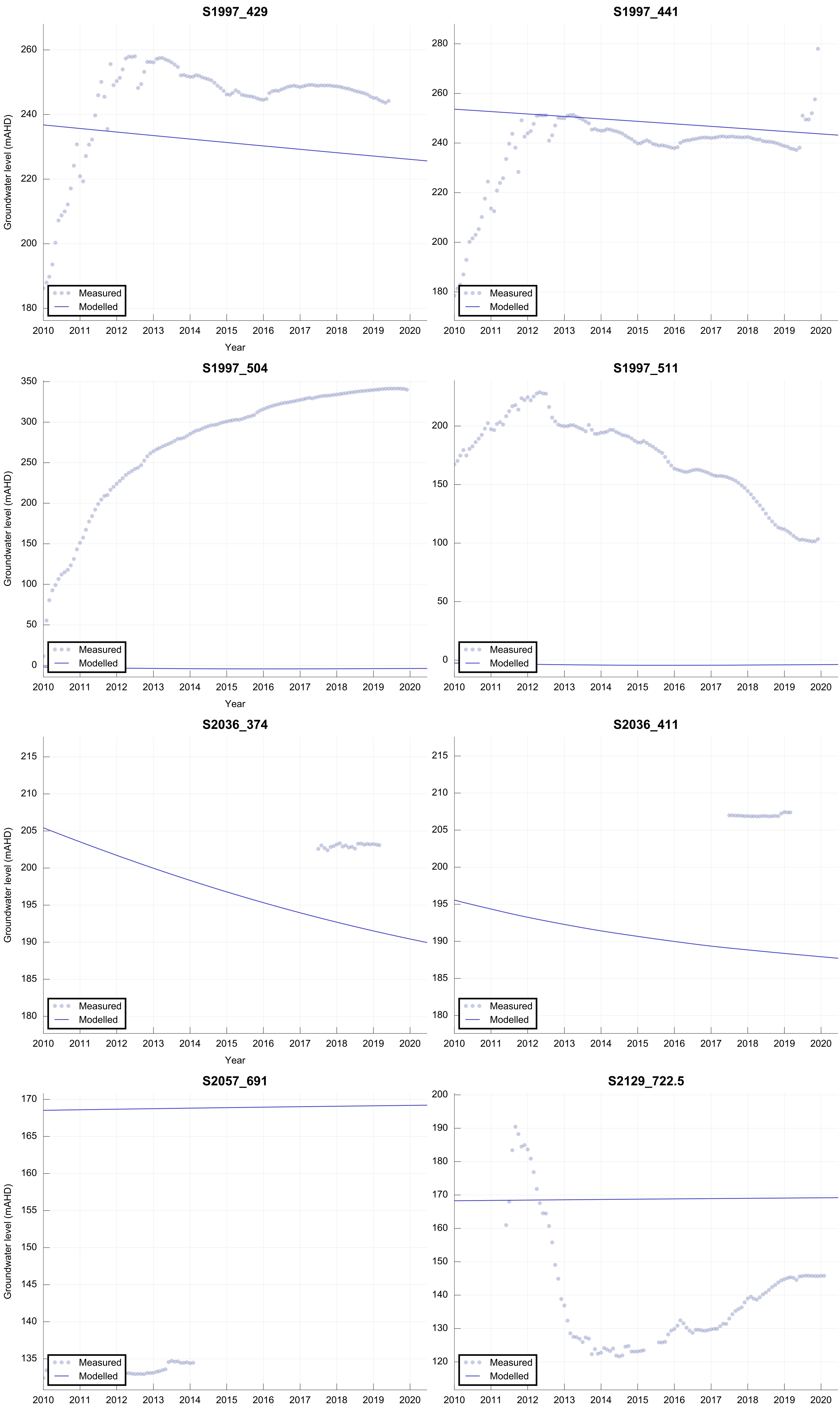
S1997_68
S1997_132
S1997_218
S1997_292
S1997_372
Groundwater level (mAHD)
Year
Measured
Modelled
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020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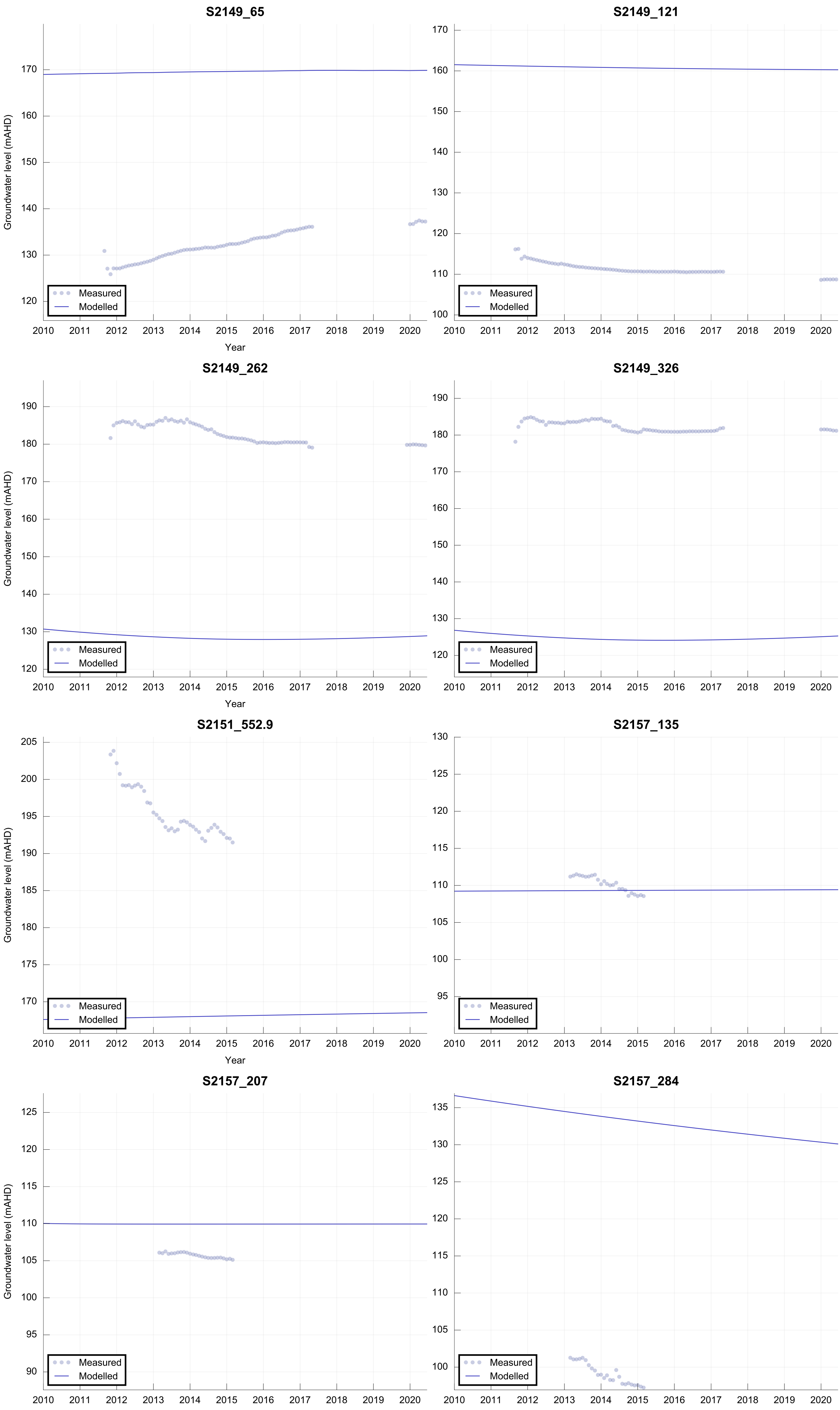
S2036_411
S2057_691
S2129_722.5
Groundwater level (mAHD)
Year
Measured
Modelled
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020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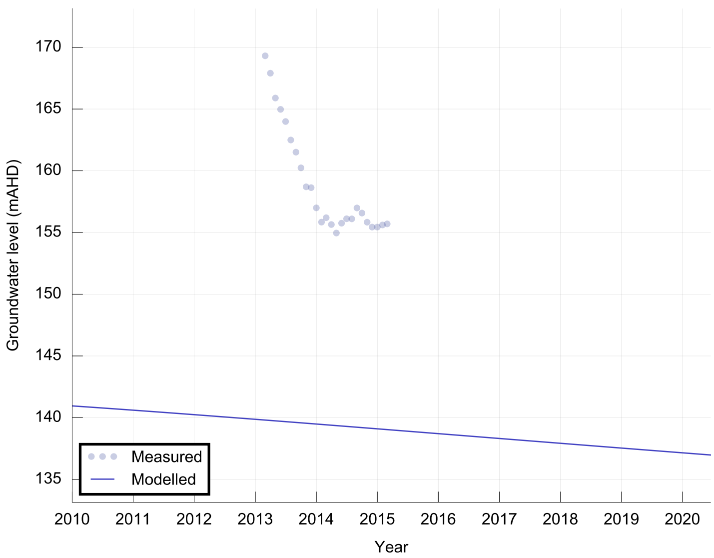
S2149_326
S2151_552.9
S2157_135
S2157_207
S2157_284
Groundwater level (mAHD)
Year
Measured
Modelled
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020

S2157_368



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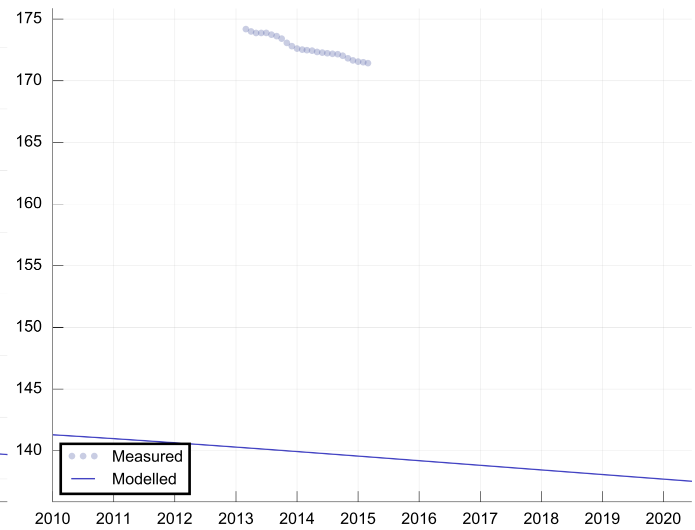

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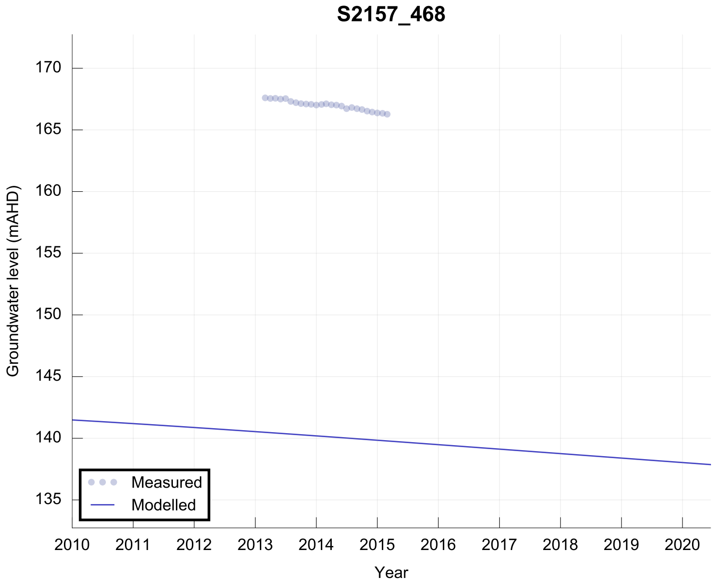

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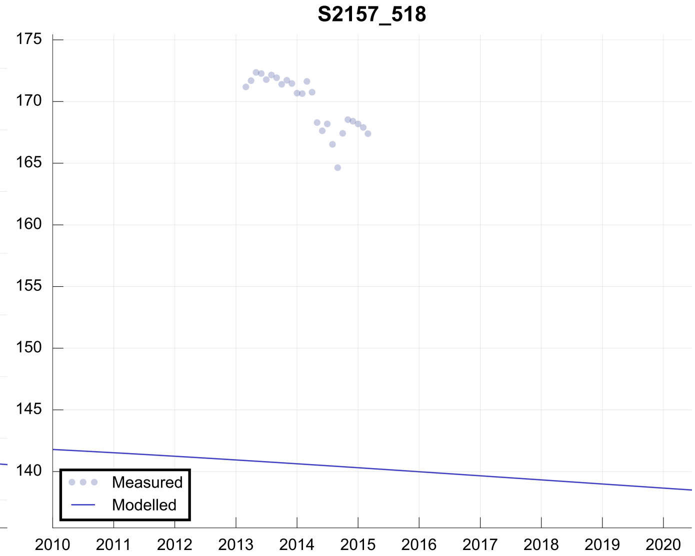

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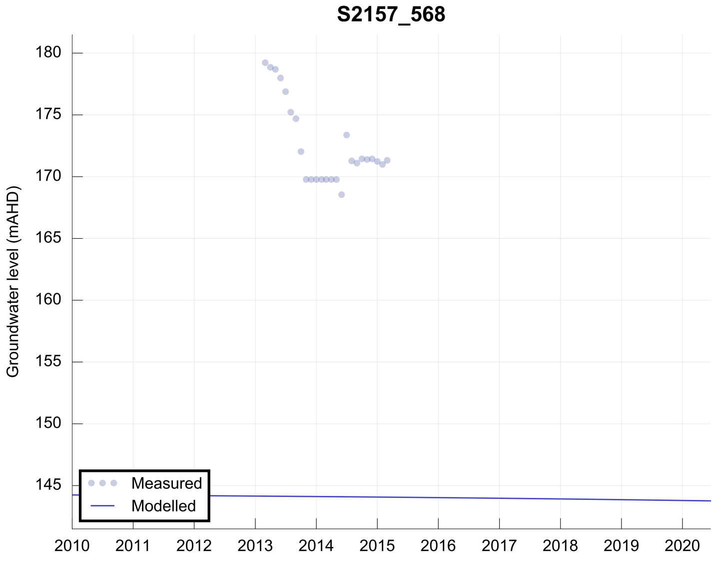

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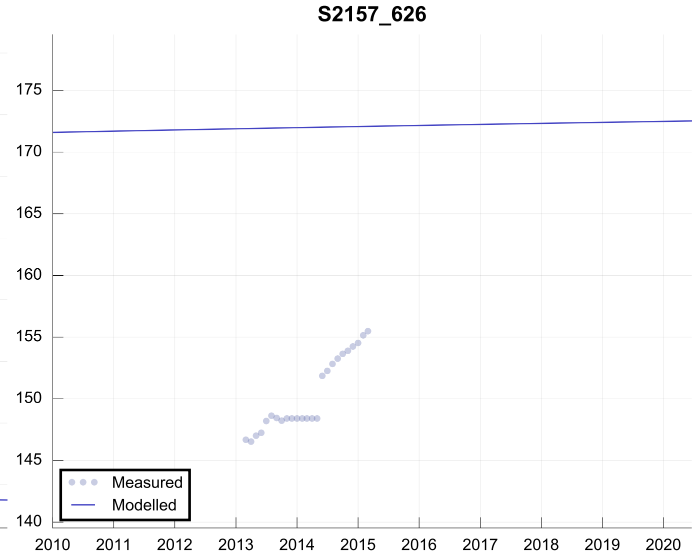

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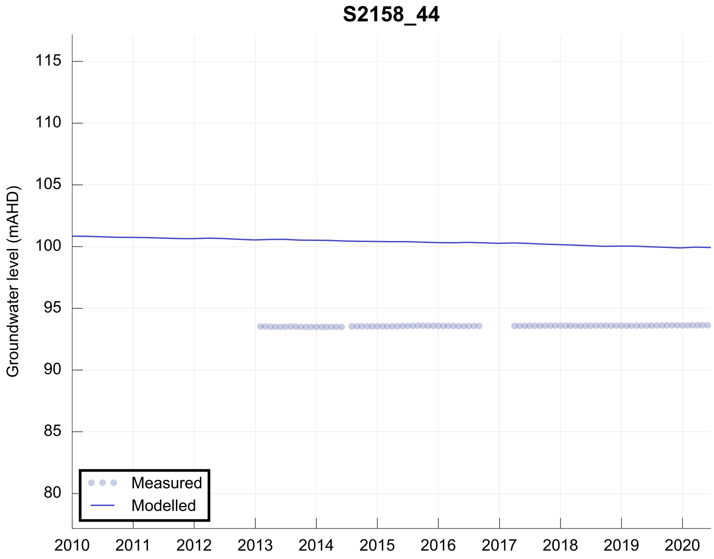

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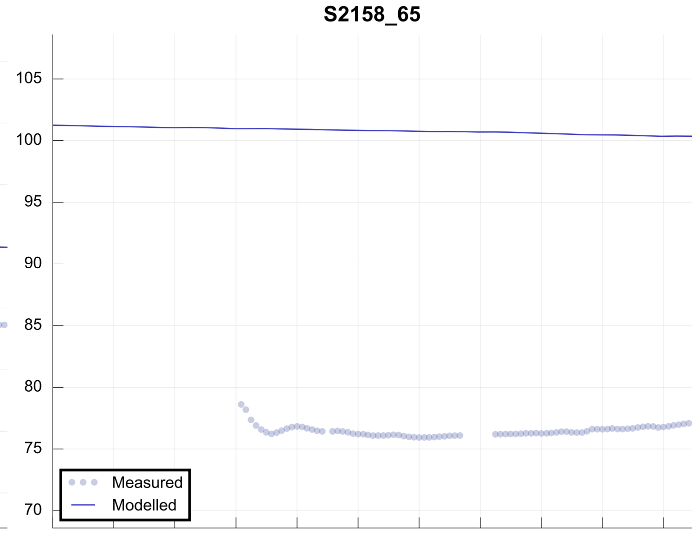

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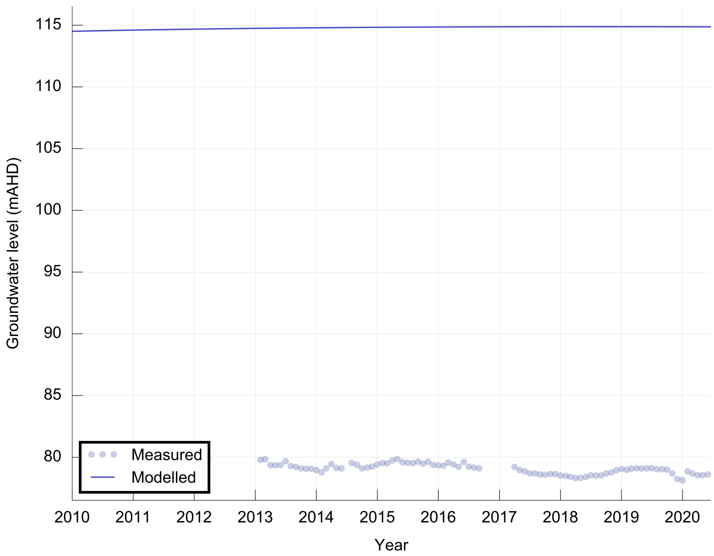
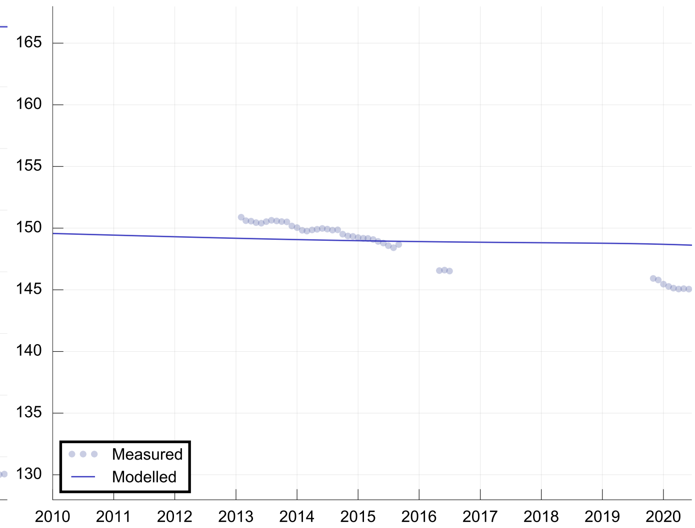
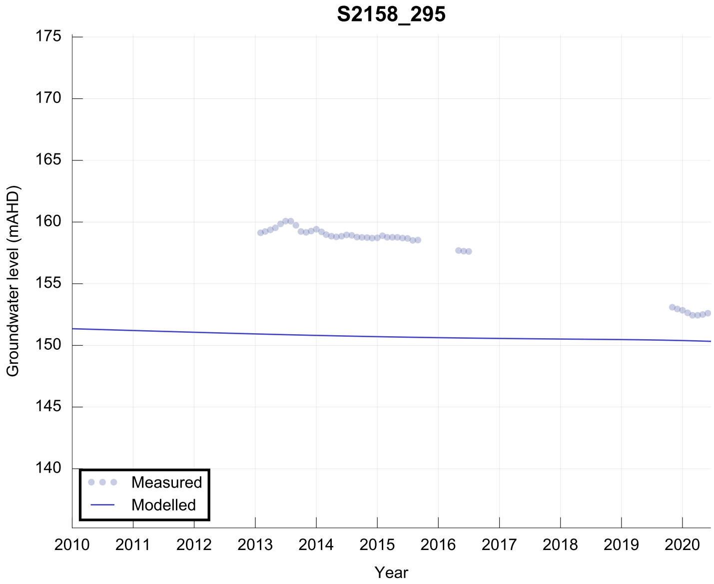


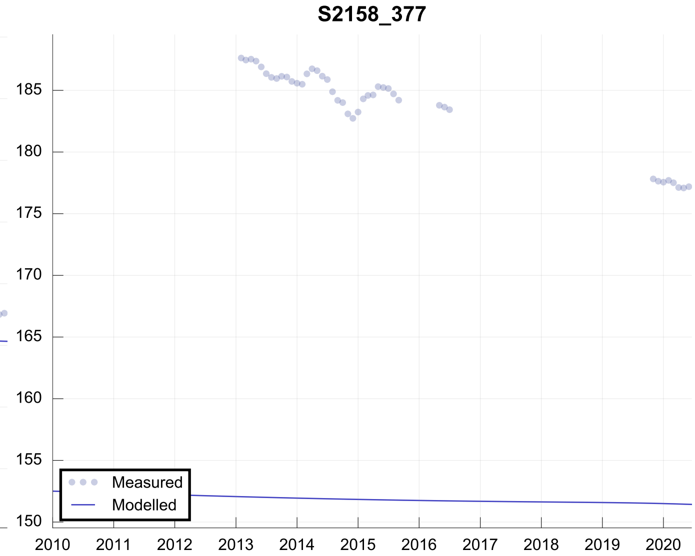
S2158_218



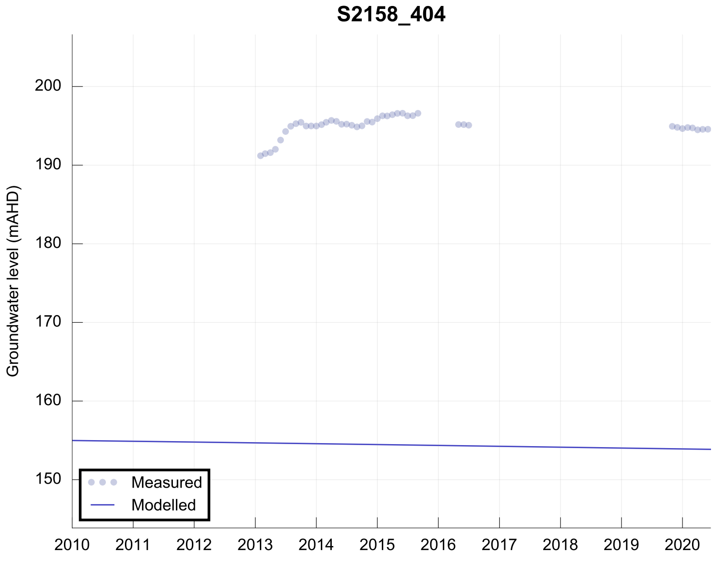
S2158_295



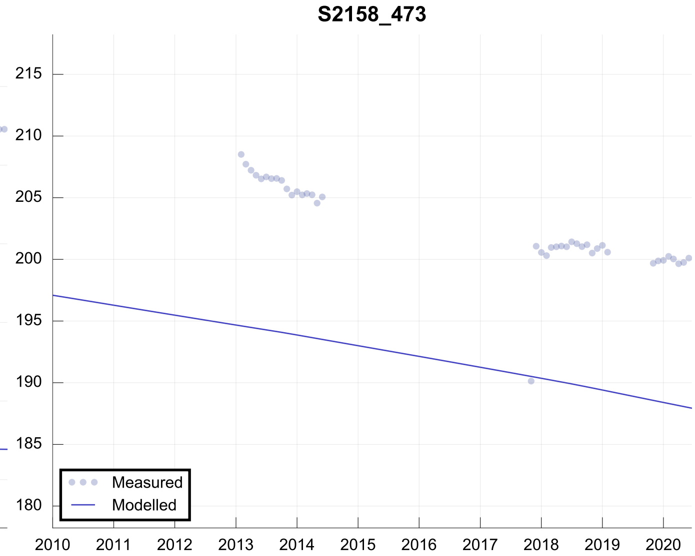
S2158_377



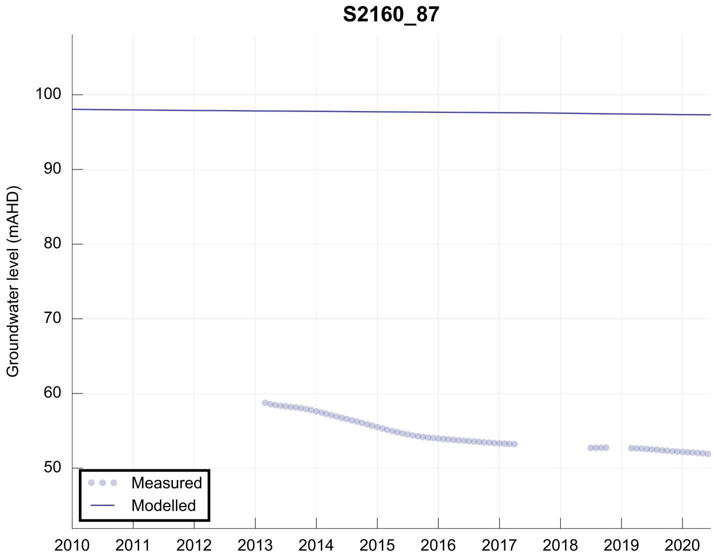
S2158_404



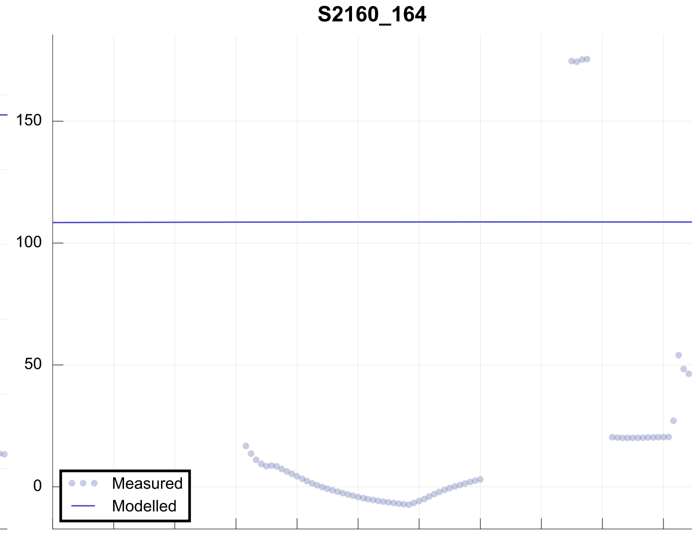
S2158_473

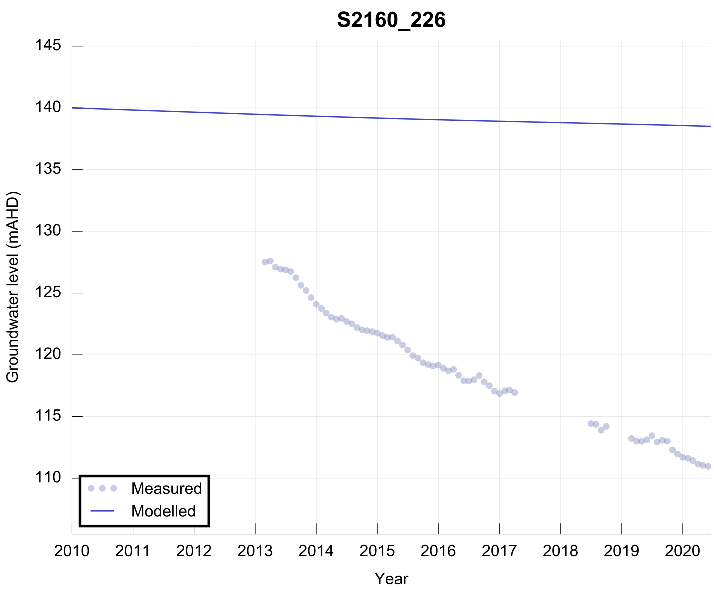


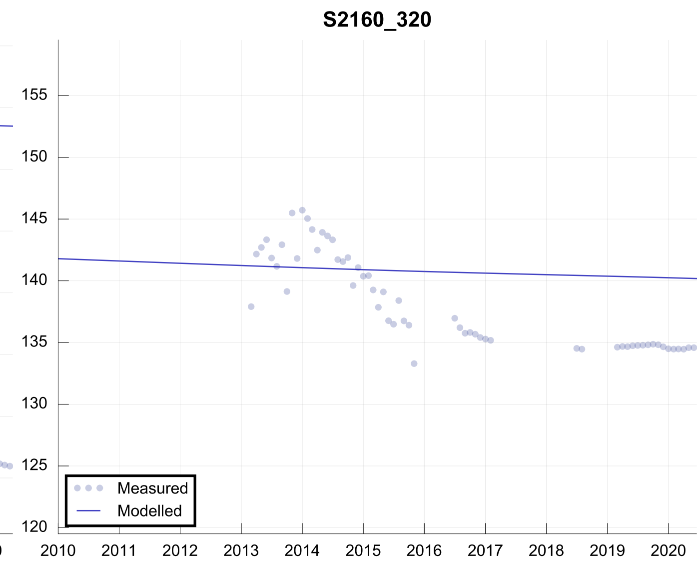
S2160_87

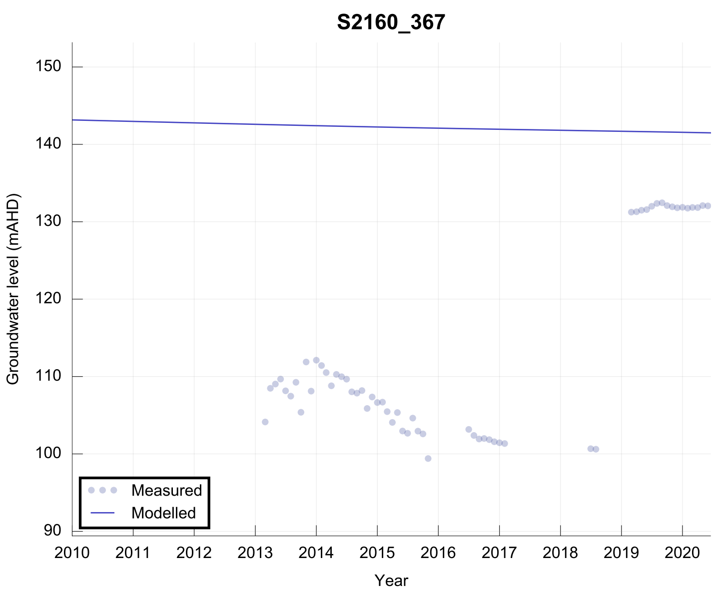


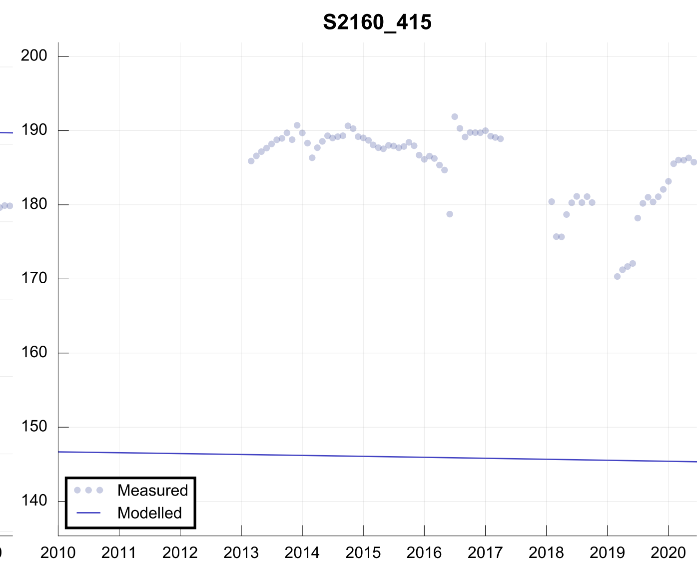
S2160_164

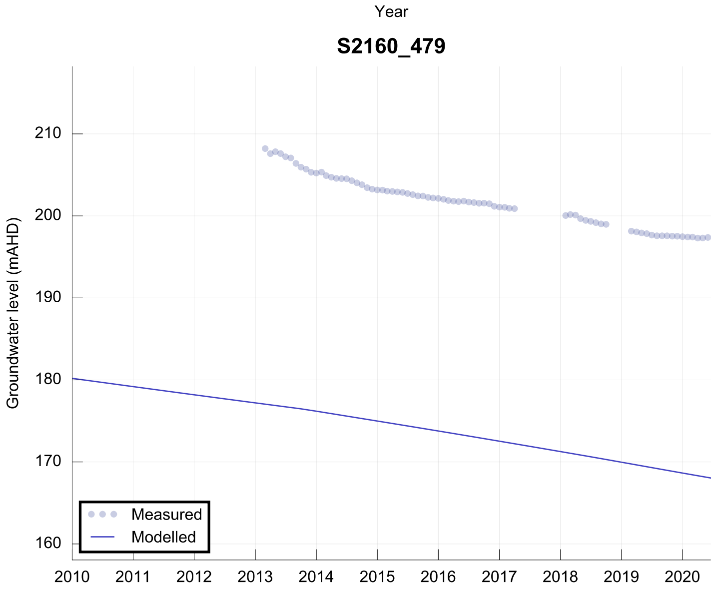


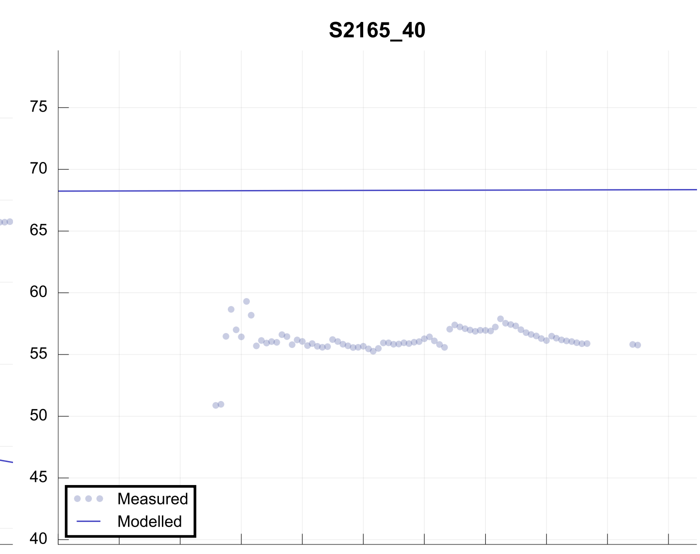

S2160_226
Groundwater level (mAHD)
145
140
135
130
125
120
115
110
Measured
Modelled
2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020
Year

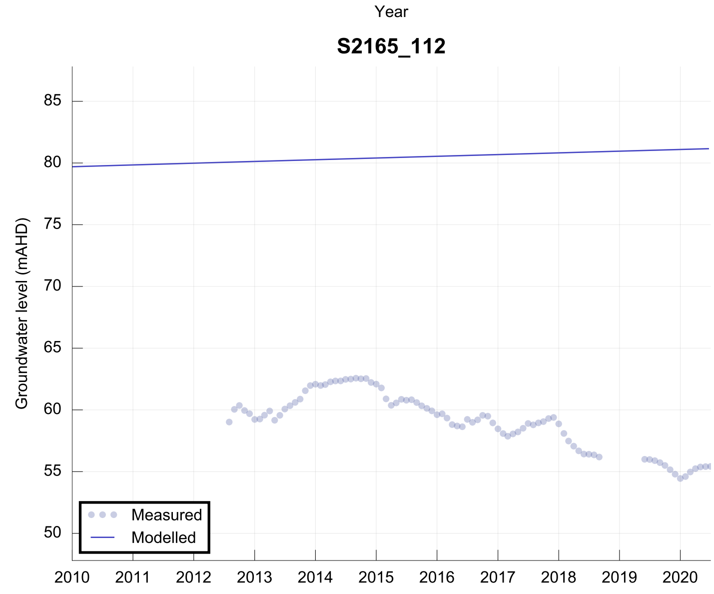

S2160_320
155
150
145
140
135
130
125
120
Measured
Modelled
2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020

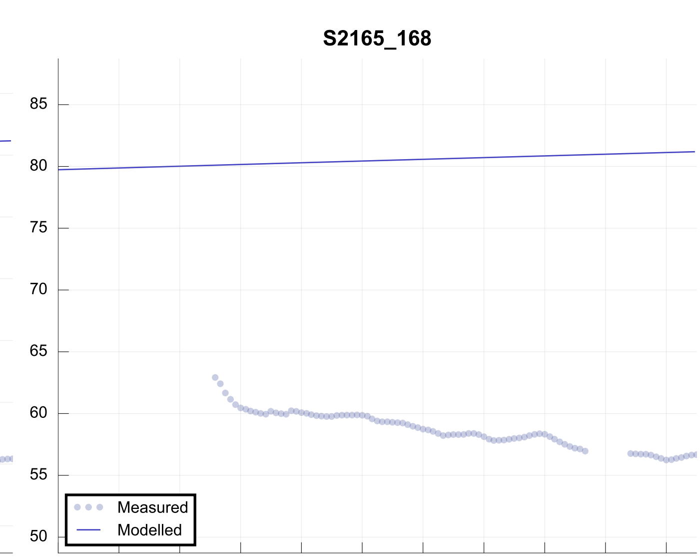

S2160_367
Groundwater level (mAHD)
150
140
130
120
110
100
90
Measured
Modelled
2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020
Year

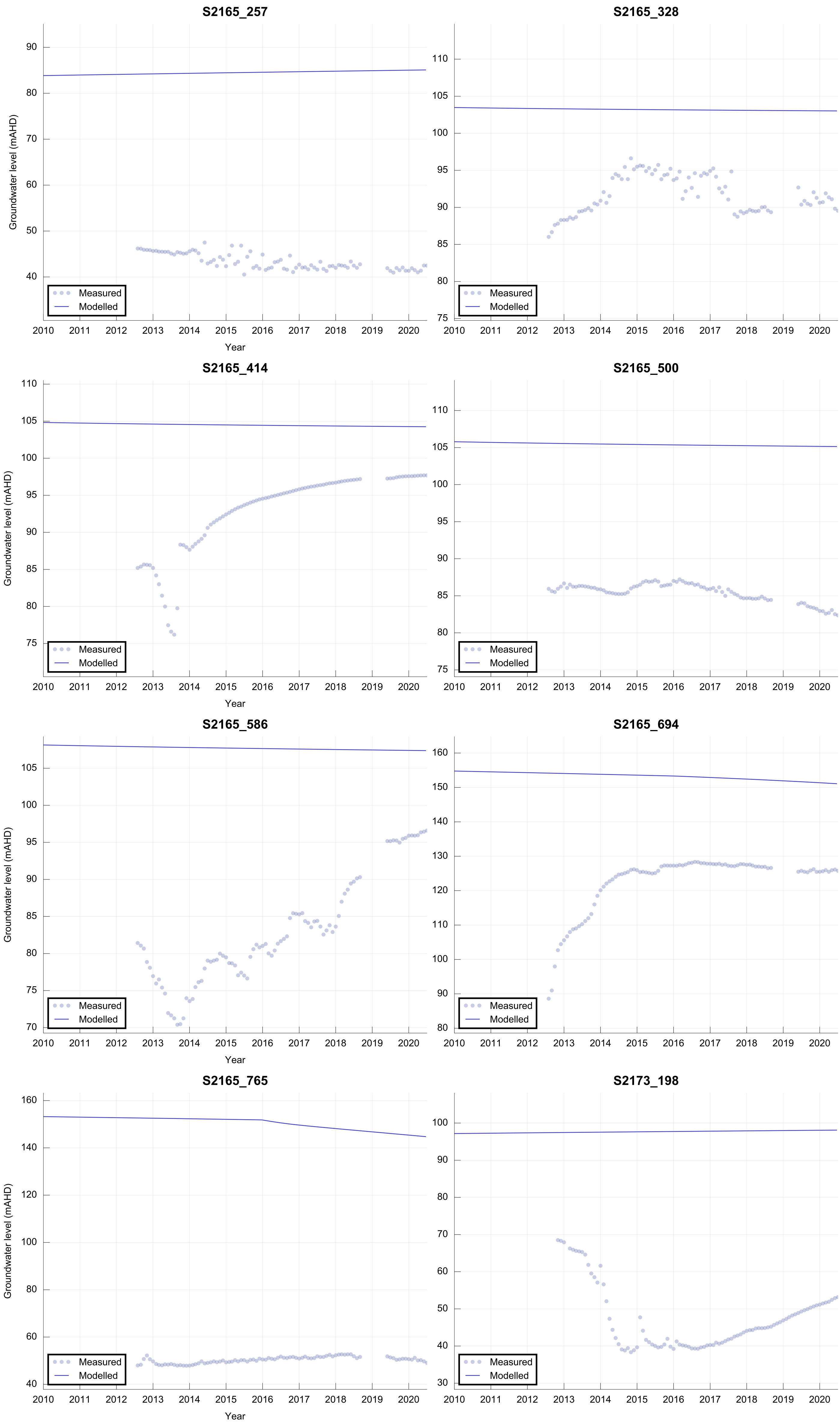

S2160_415
200
190
180
170
160
150
140
Measured
Modelled
2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020

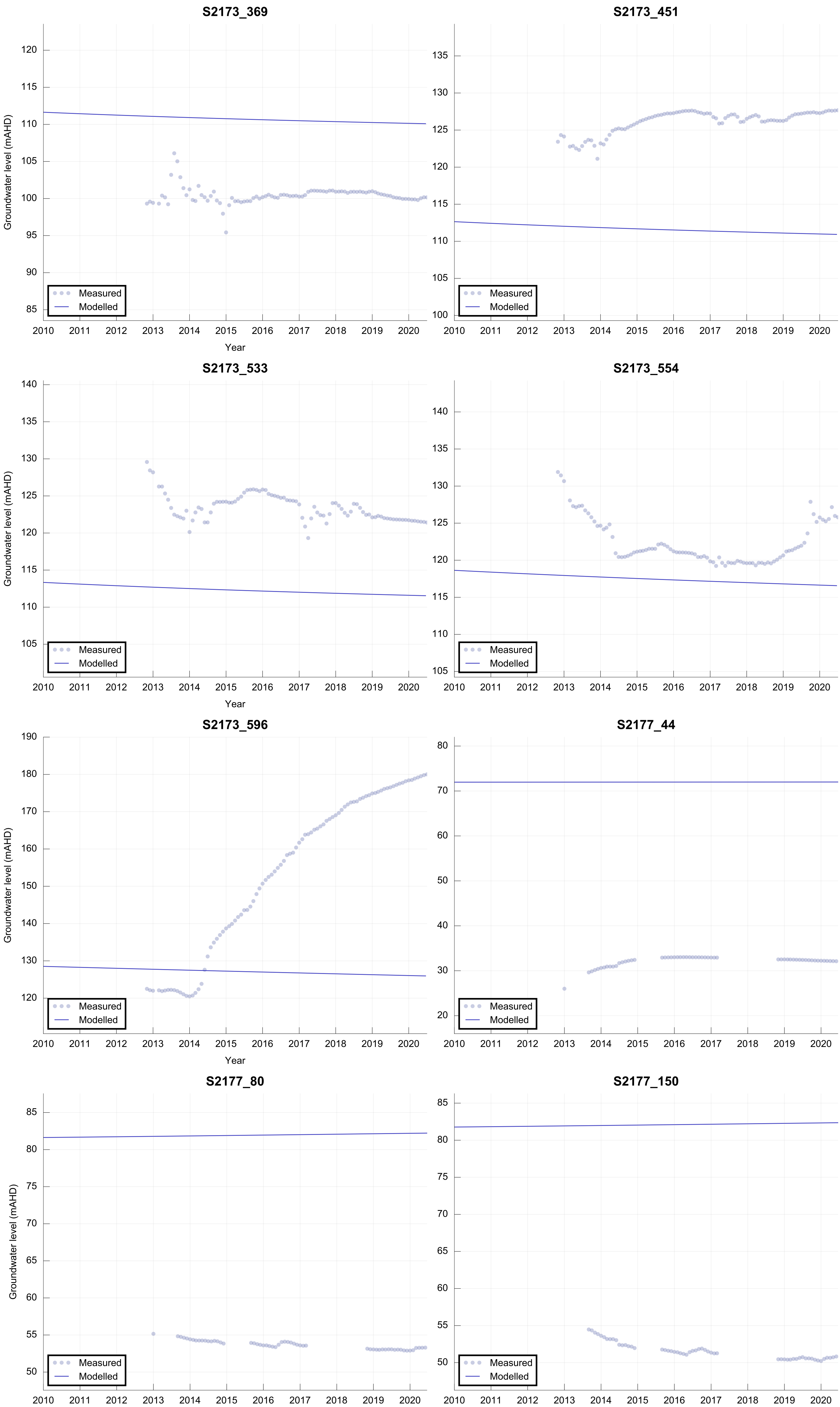

S2160_479
Groundwater level (mAHD)
210
200
190
180
170
160
Measured
Modelled
2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020
Year

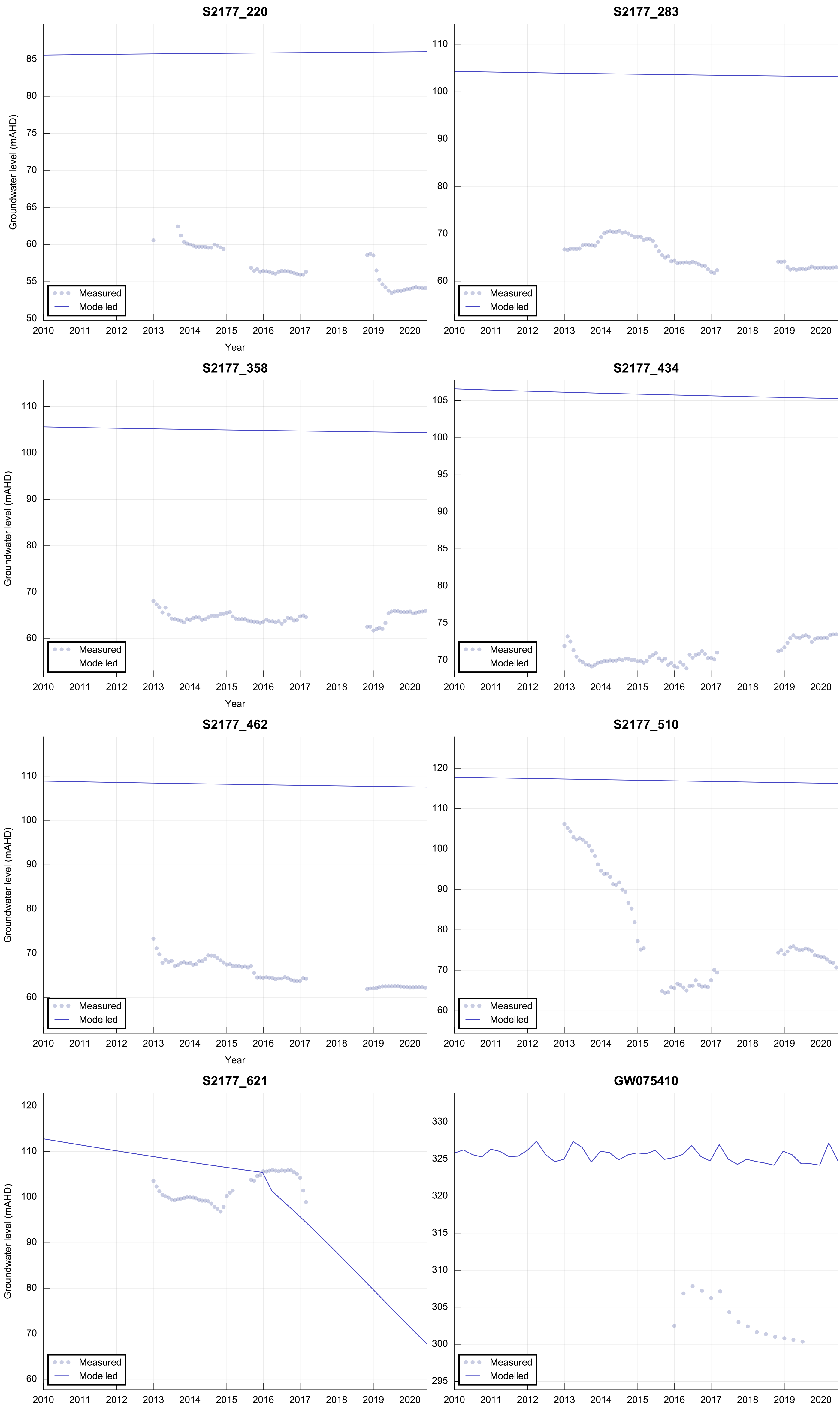

S2165_40
75
70
65
60
55
50
45
40
Measured
Modelled
2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020

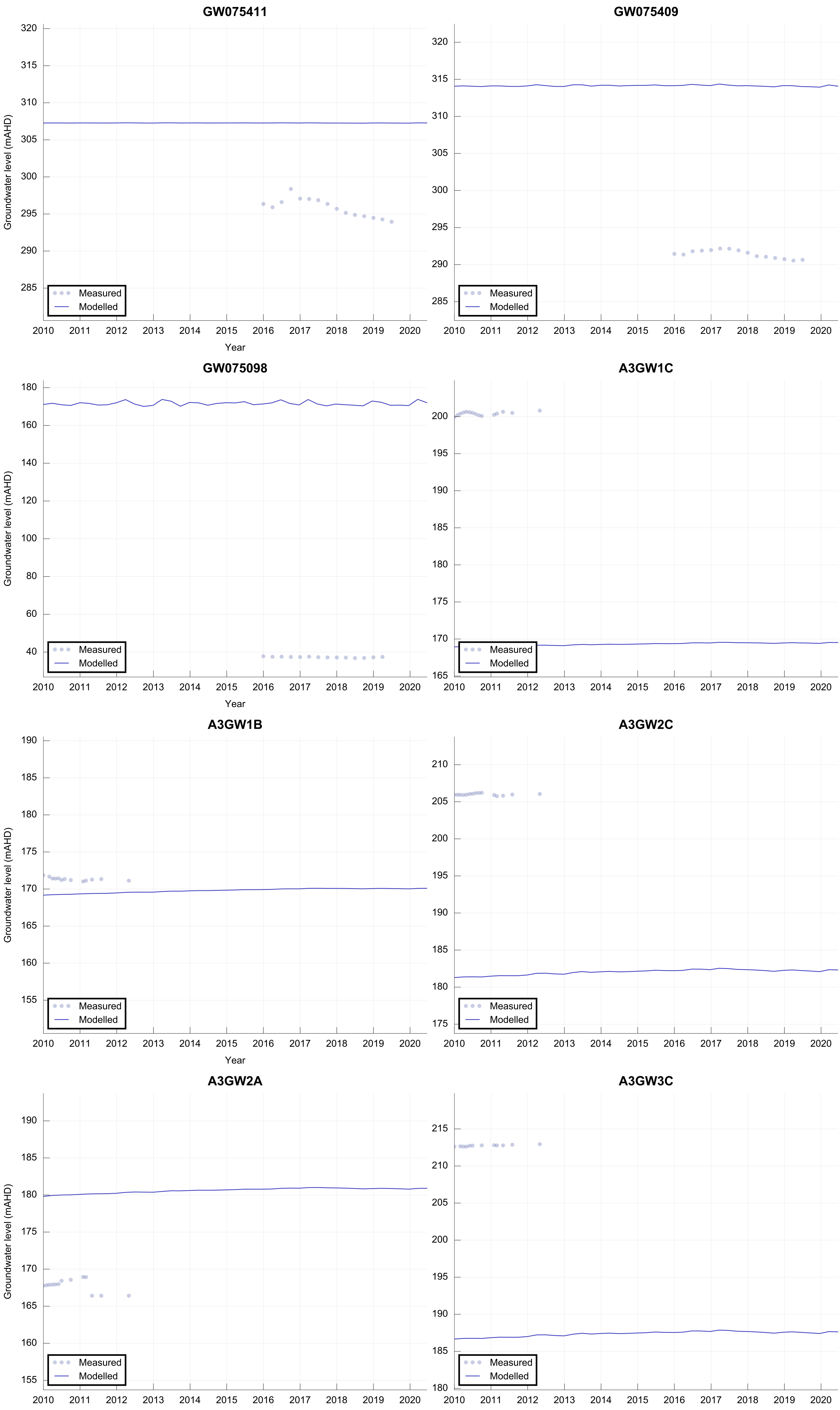

S2165_112
Groundwater level (mAHD)
85
80
75
70
65
60
55
50
Measured
Modelled
2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020
Year


S2165_168
85
80
75
70
65
60
55
50
Measured
Modelled
2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020

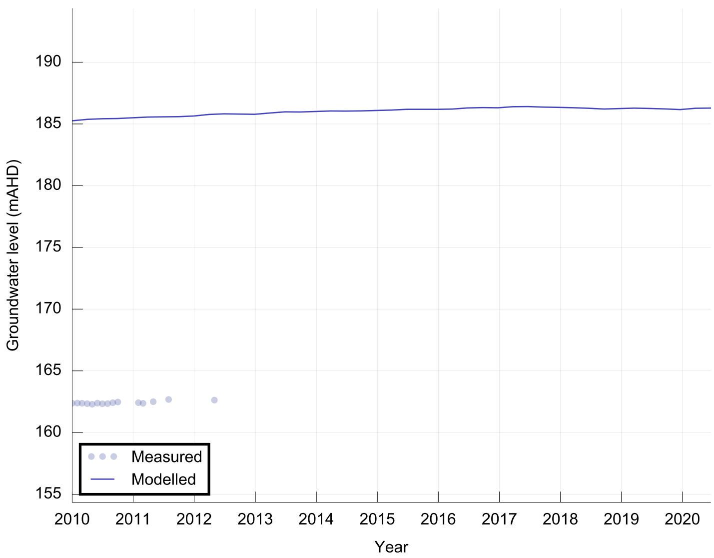

S2165_257
S2165_328
S2165_414
S2165_500
S2165_586
S2165_694
S2165_765
S2173_198
Groundwater level (mAHD)
Year
Measured
Modelled


S2173_369
S2173_451
S2173_533
S2173_554
S2173_596
S2177_44
S2177_80
S2177_150
Groundwater level (mAHD)
Year
Measured
Modelled
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020

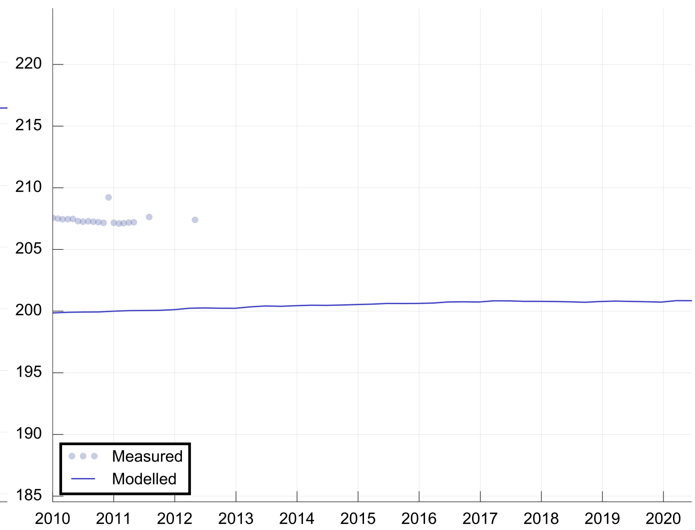

S2177_220
S2177_283
S2177_358
S2177_434
S2177_462
S2177_510
S2177_621
GW075410
Groundwater level (mAHD)
Year
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
Measured
Modelled


GW075411
GW075409
GW075098
A3GW1C
A3GW1B
A3GW2C
A3GW2A
A3GW3C
Groundwater level (mAHD)
Year
Measured
Modelled
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020

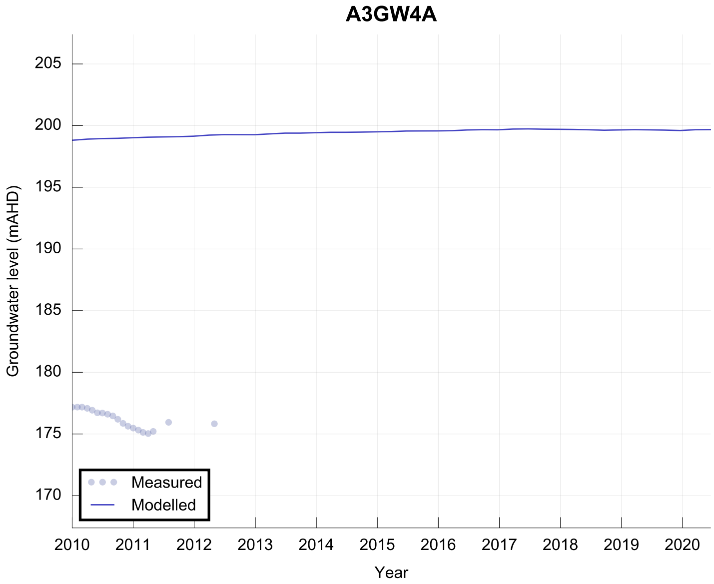
A3GW3A



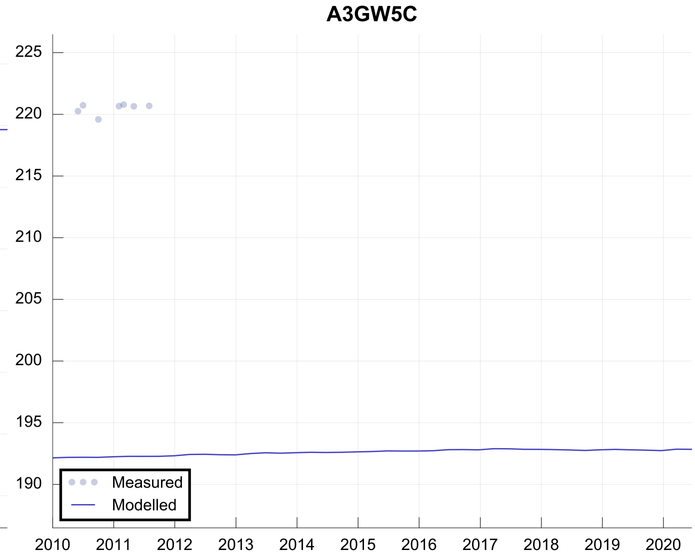
A3GW4B



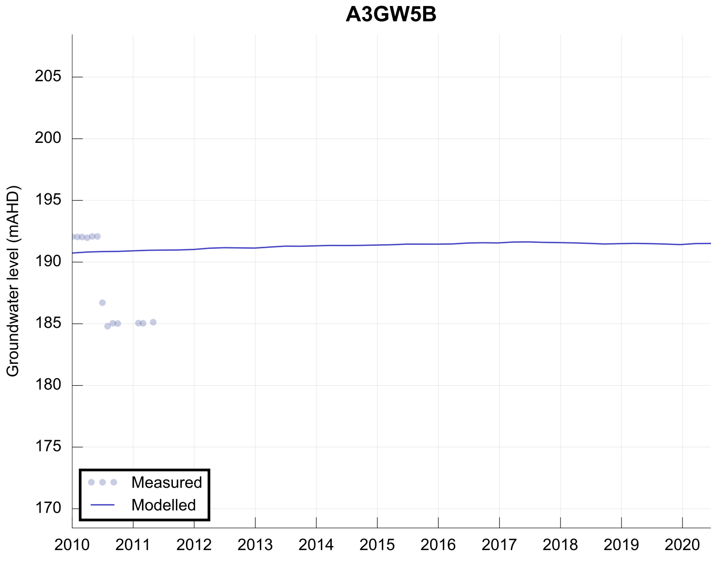
A3GW4A



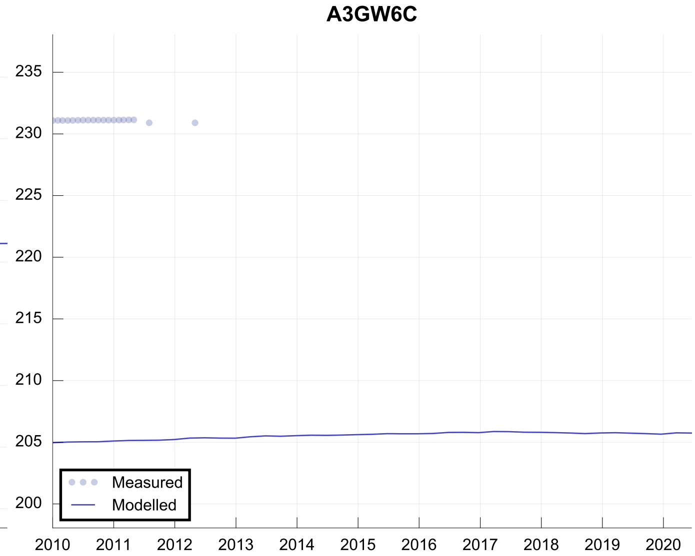
A3GW5C



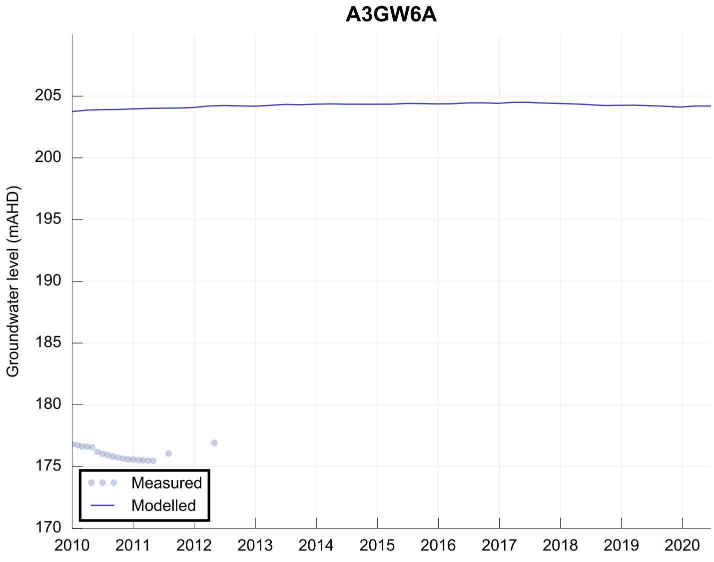
A3GW5B



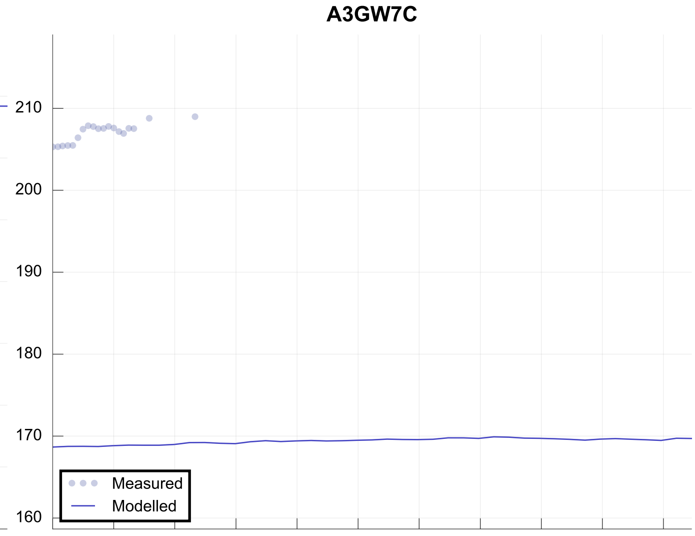
A3GW6C

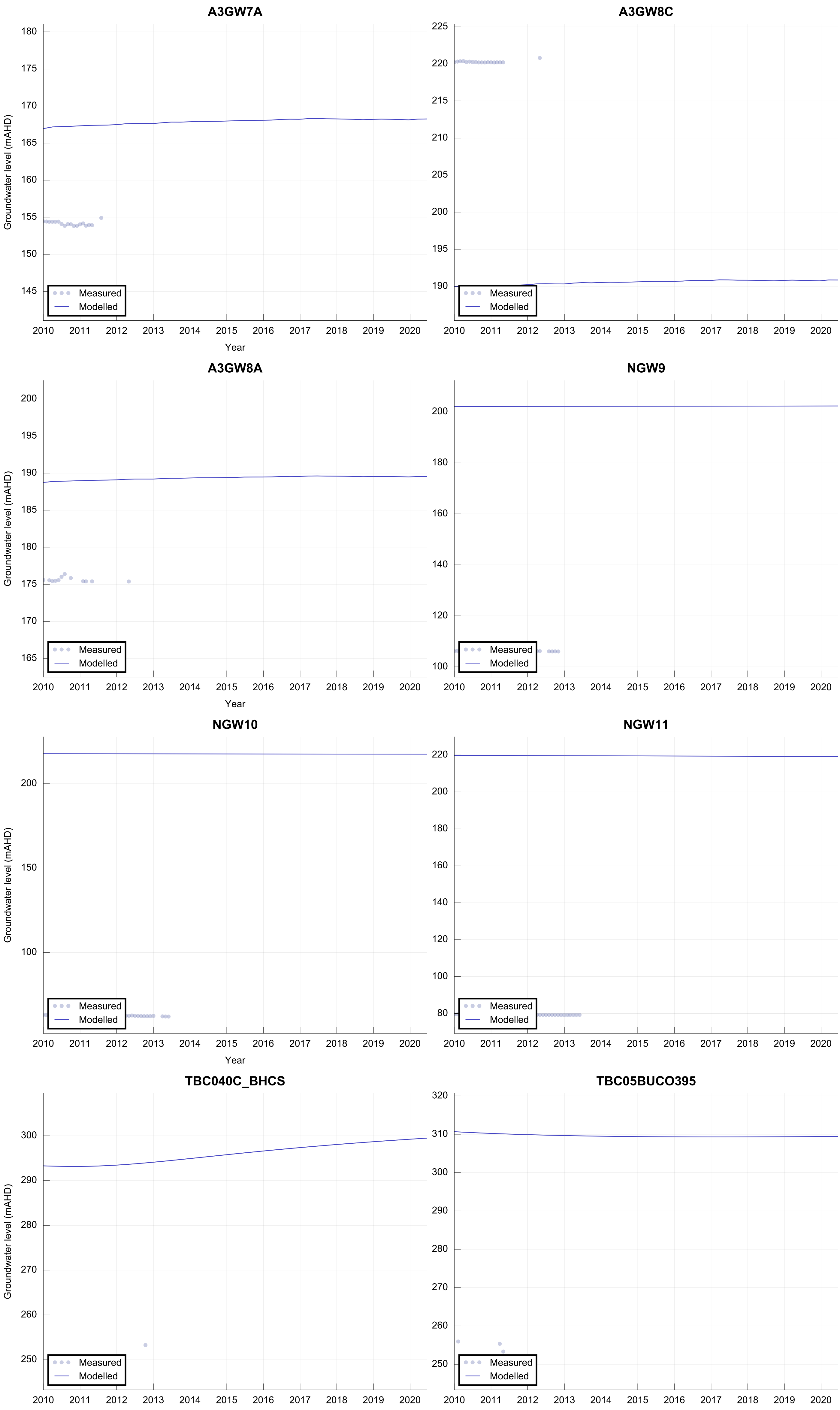


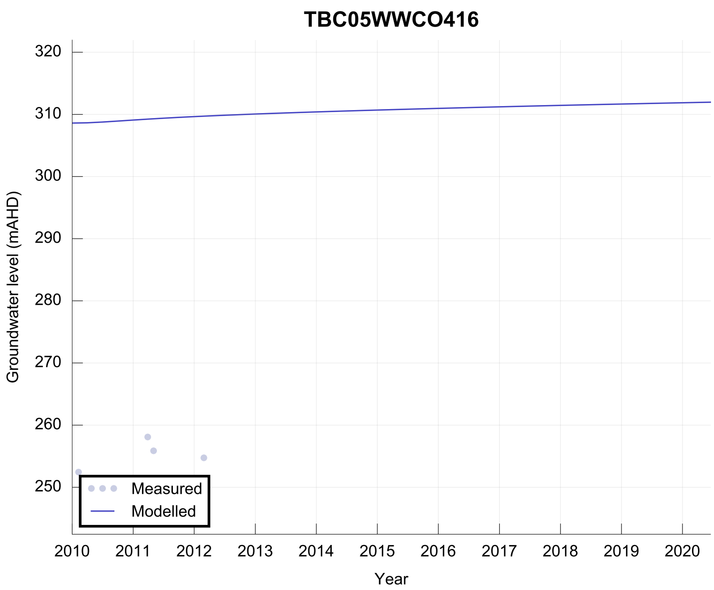
A3GW6A

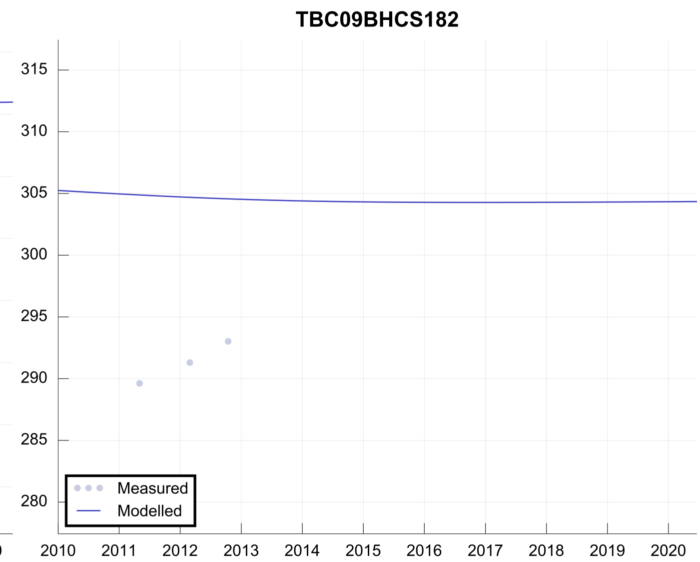


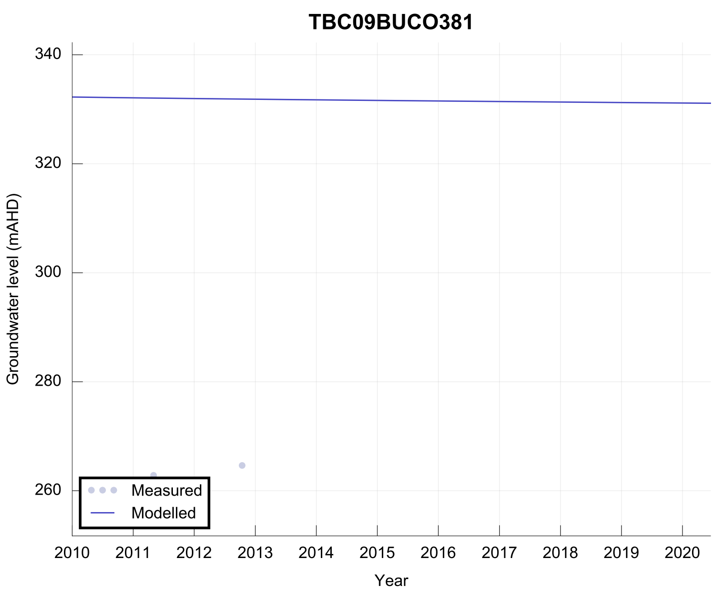
A3GW7C

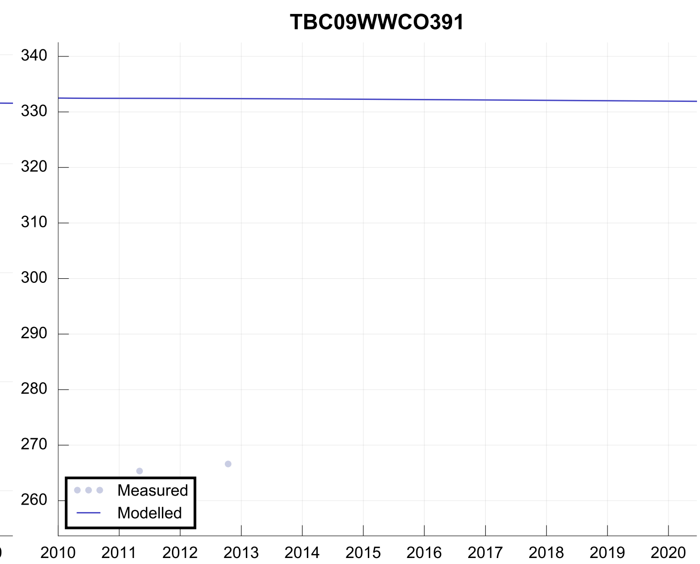


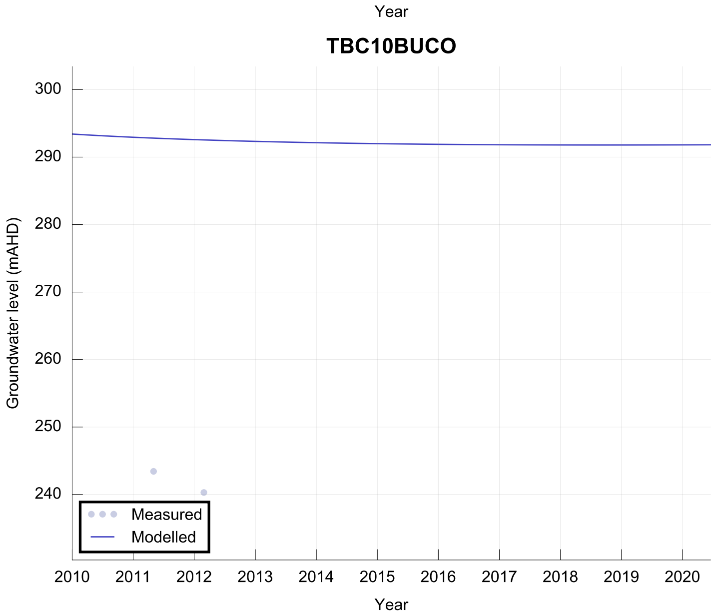

A3GW7A
A3GW8C
A3GW8A
NGW9
NGW10
NGW11
TBC040C_BHCS
TBC05BUCO395
Groundwater level (mAHD)
Year
Measured
Modelled
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020

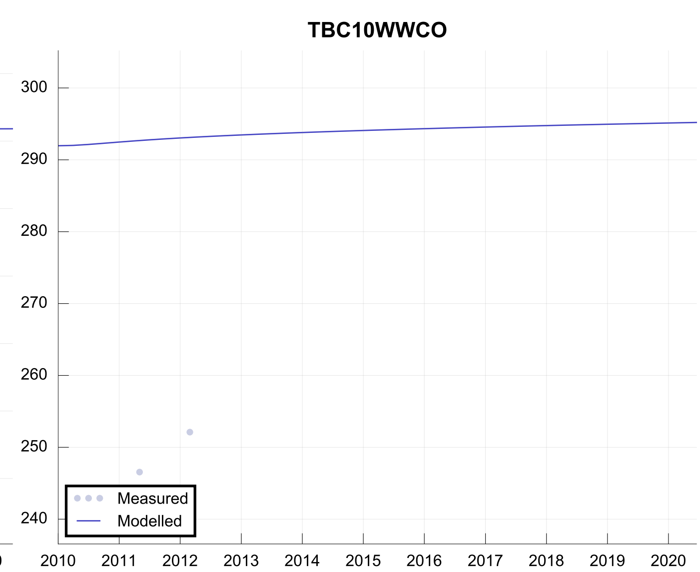

TBC05WWCO416
Groundwater level (mAHD)
320
310
300
290
280
270
260
250
Measured
Modelled
2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020
Year

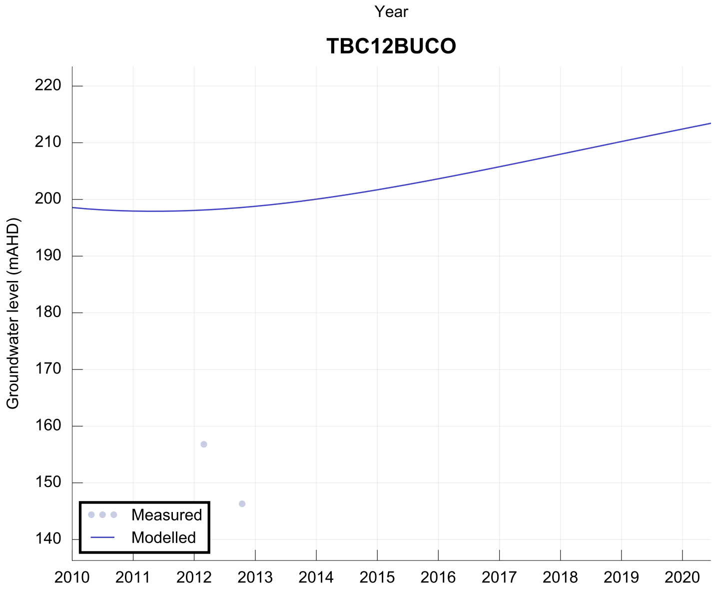

TBC09BHCS182
315
310
305
300
295
290
285
280
Measured
Modelled
2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020

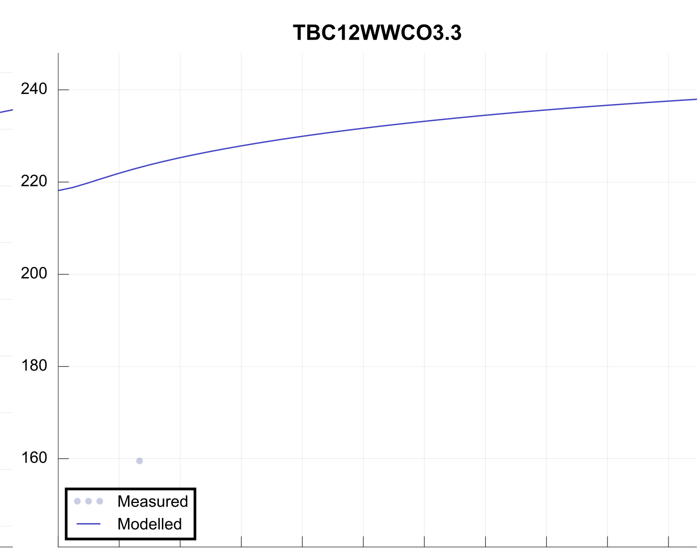

TBC09BUCO381
Groundwater level (mAHD)
340
320
300
280
260
Measured
Modelled
2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020
Year


TBC09WWCO391
340
330
320
310
300
290
280
270
260
Measured
Modelled
2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020

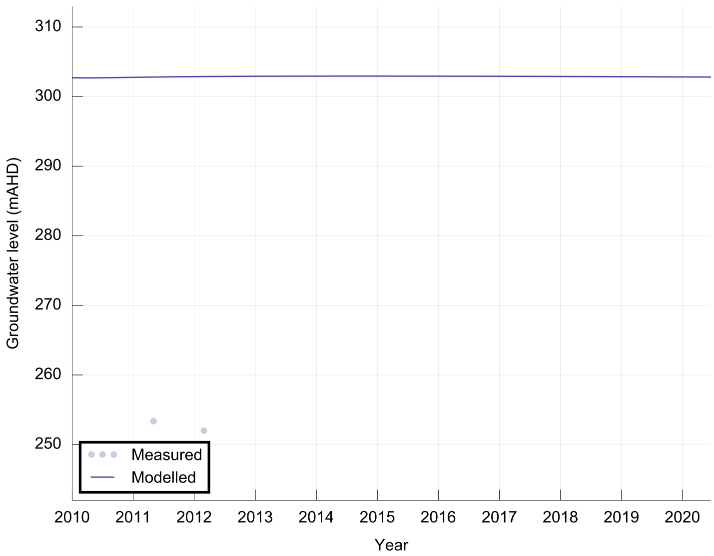

TBC10BUCO
Groundwater level (mAHD)
300
290
280
270
260
250
240
Measured
Modelled
2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020
Year


TBC10WWCO
300
290
280
270
260
250
240
Measured
Modelled
2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020

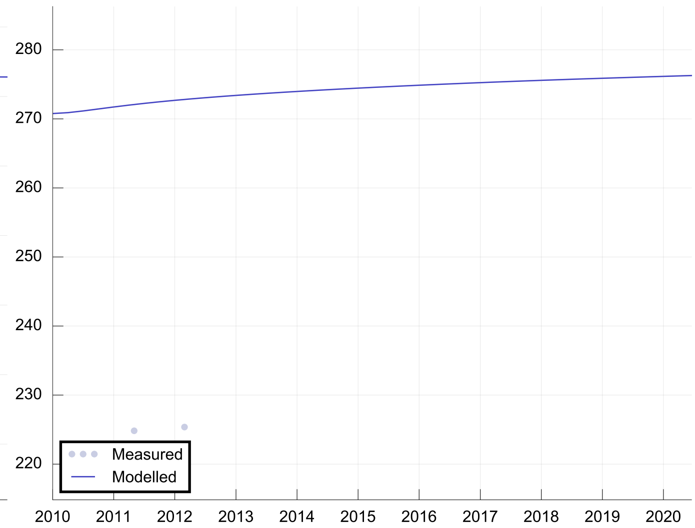

TBC12BUCO
Groundwater level (mAHD)
220
210
200
190
180
170
160
150
140
Measured
Modelled
2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020
Year


TBC12WWCO3.3
240
220
200
180
160
Measured
Modelled
2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020

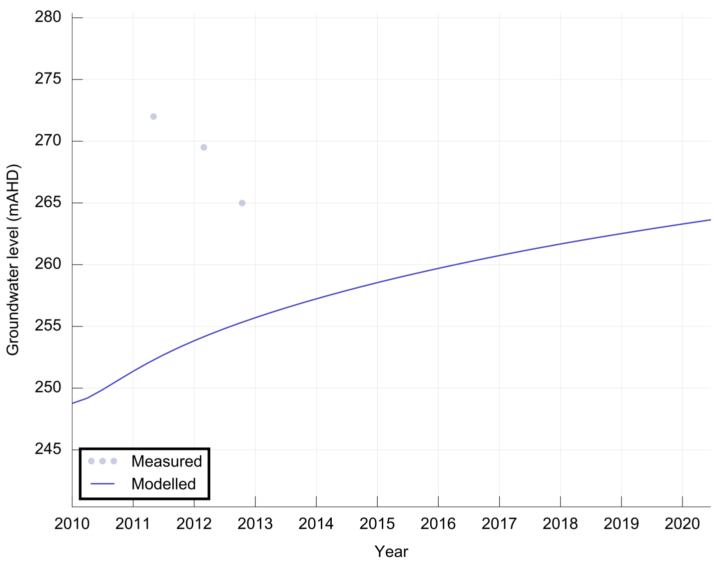
TBC14WWCO7.8



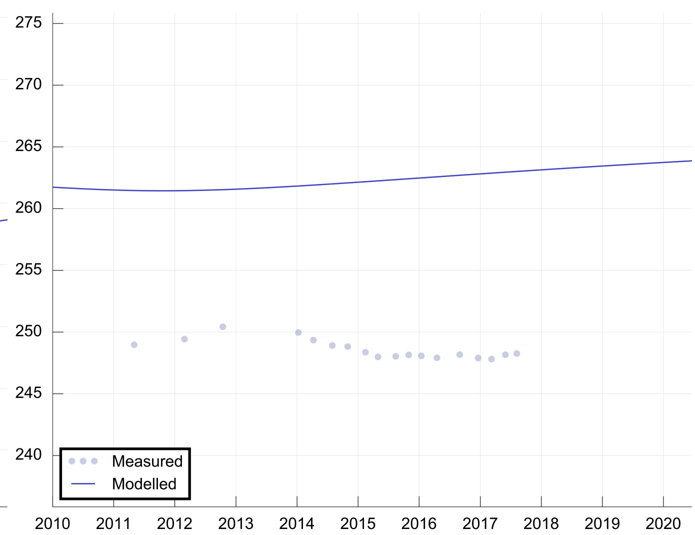
TBC15WWCO2.5



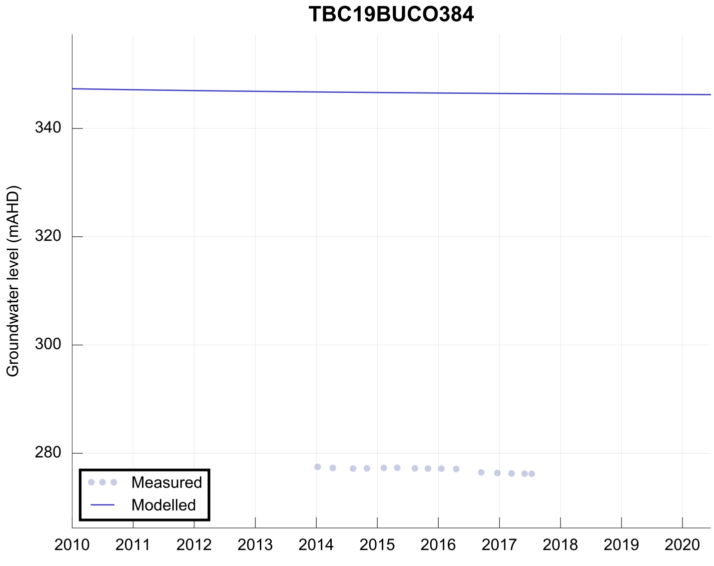
TBC16WWCO8.5



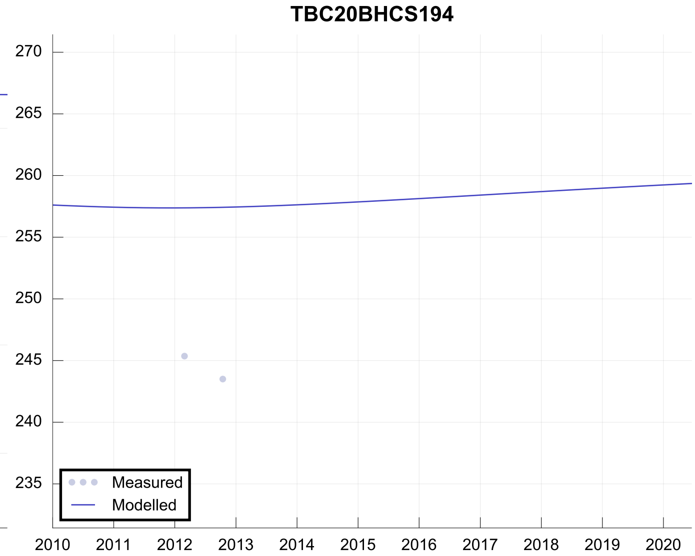
TBC18BHCS179



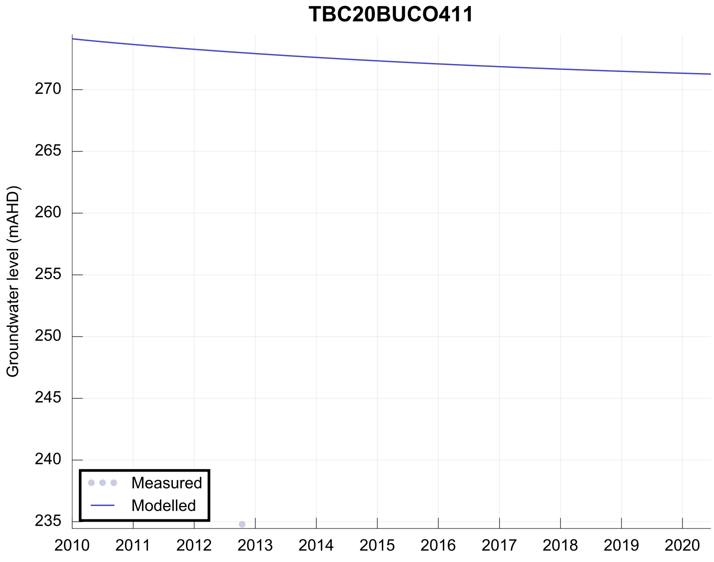
TBC19BUCO384



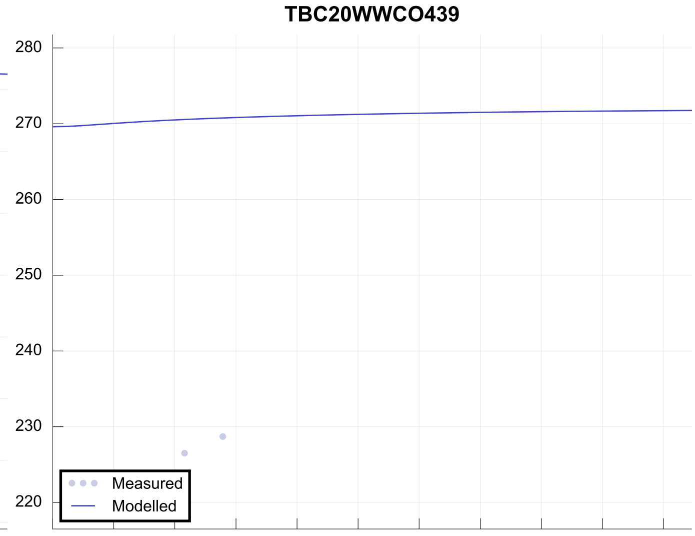
TBC20BHCS194

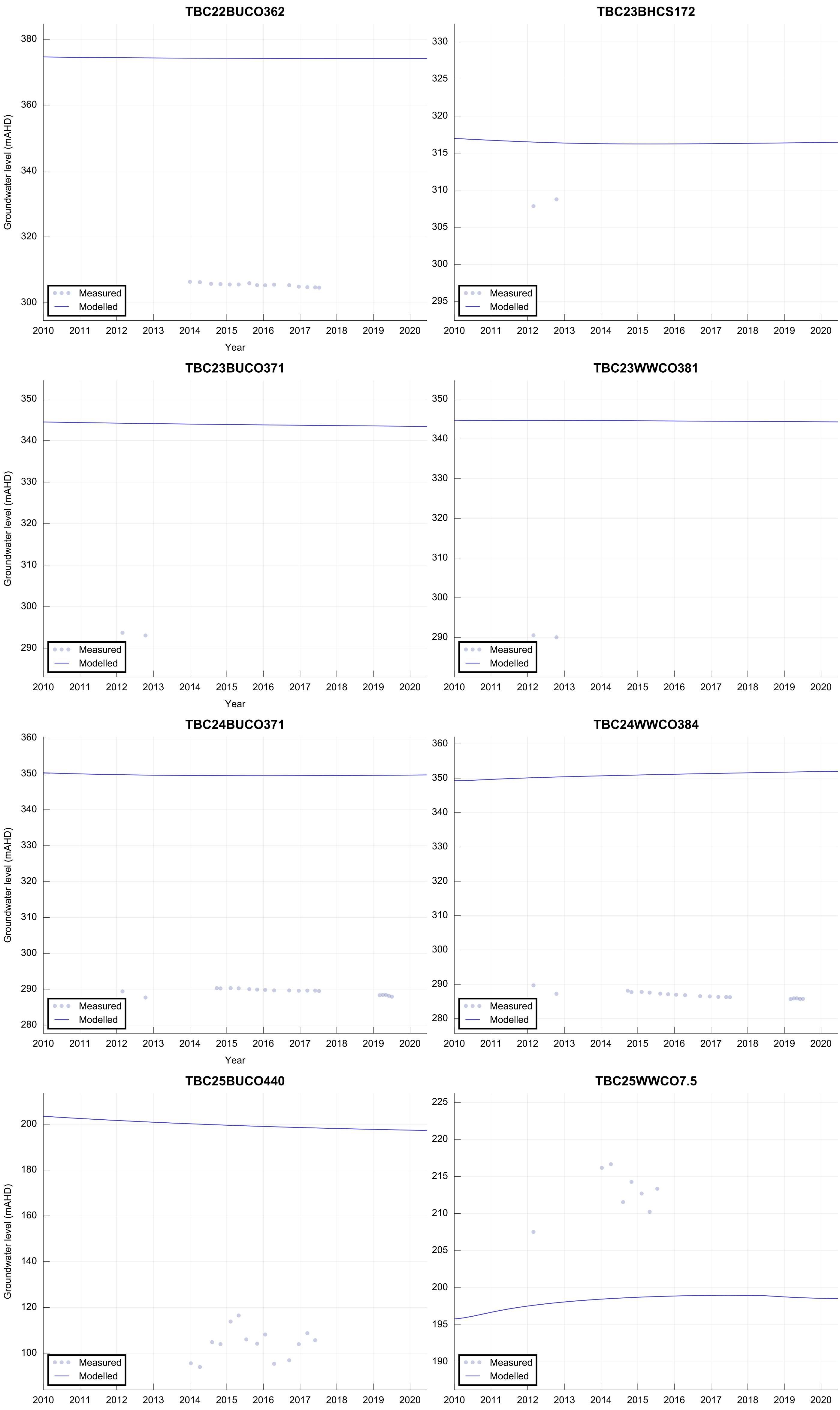


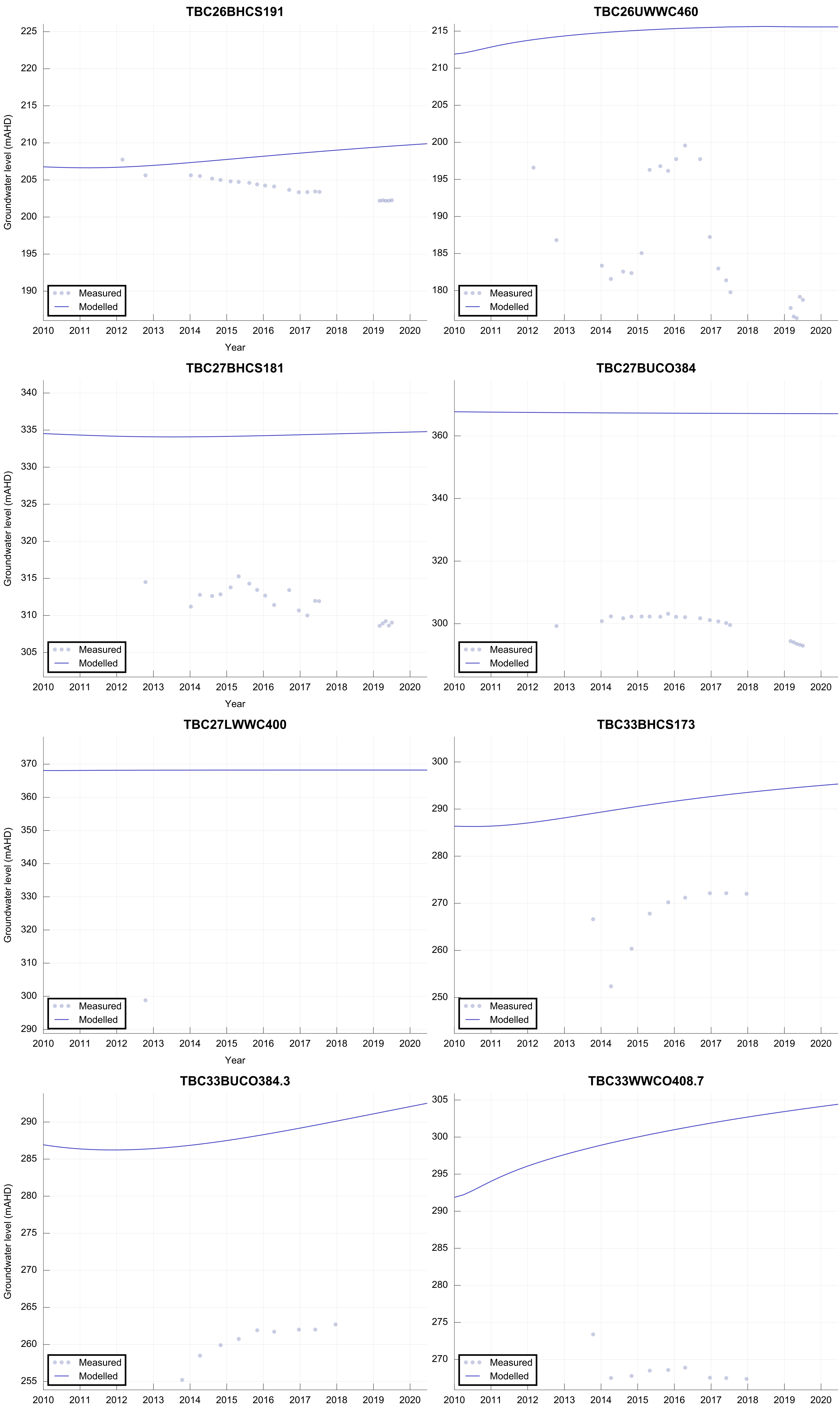
TBC20BUCO411



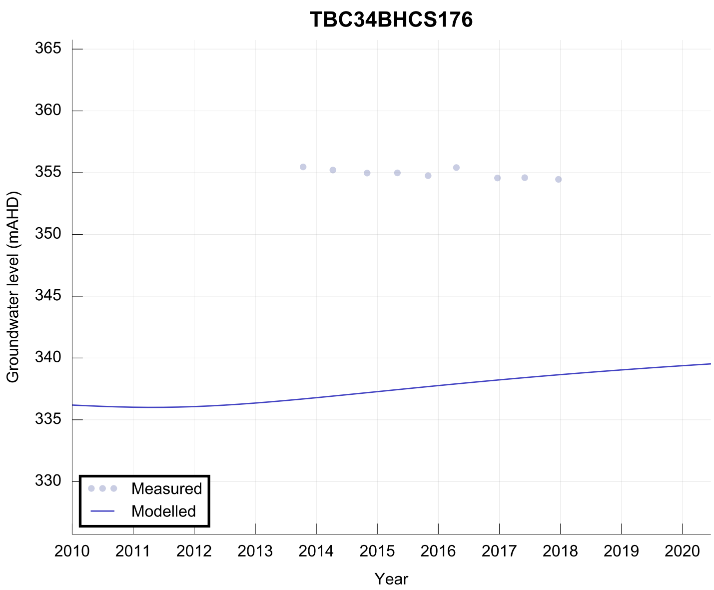
TBC20WWCO439

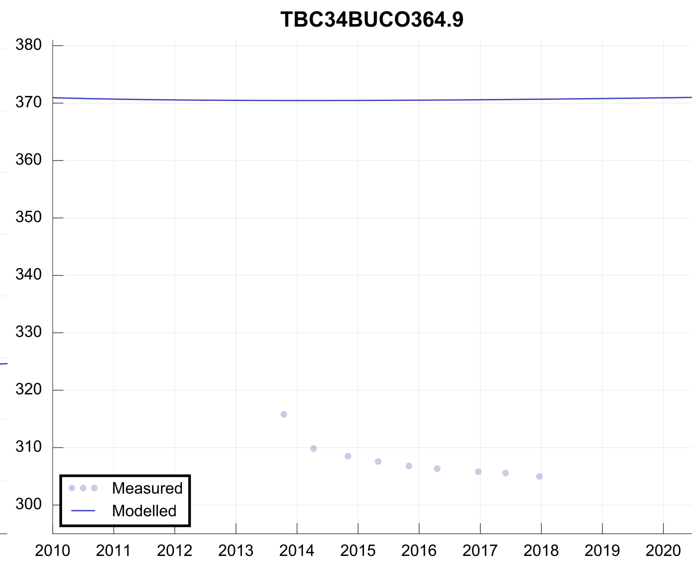


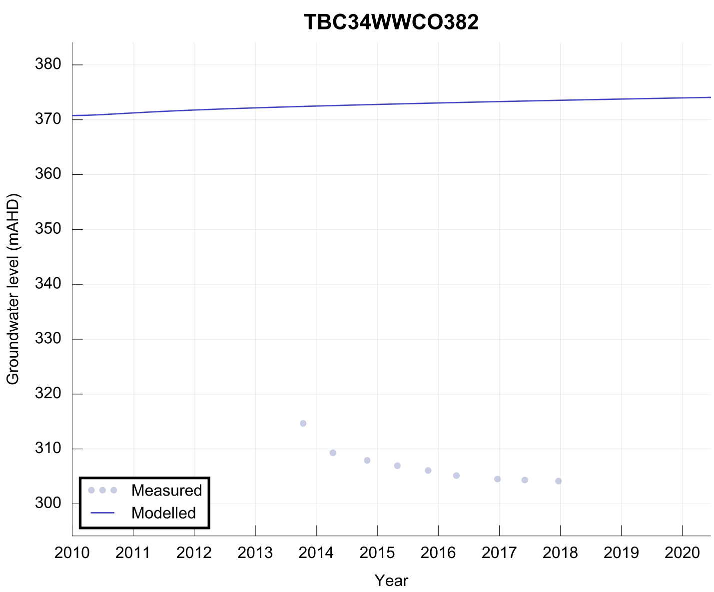

TBC22BUCO362
TBC23BHCS172
TBC23BUCO371
TBC23WWCO381
TBC24BUCO371
TBC24WWCO384
TBC25BUCO440
TBC25WWCO7.5
Groundwater level (mAHD)
Year
Measured
Modelled

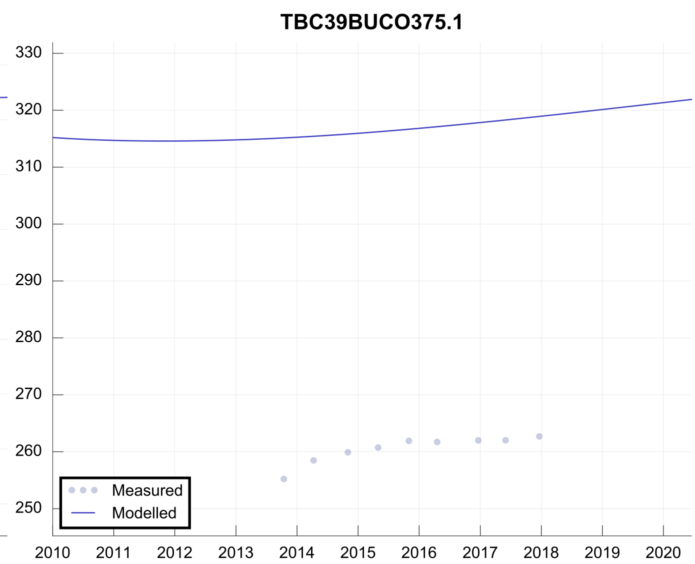


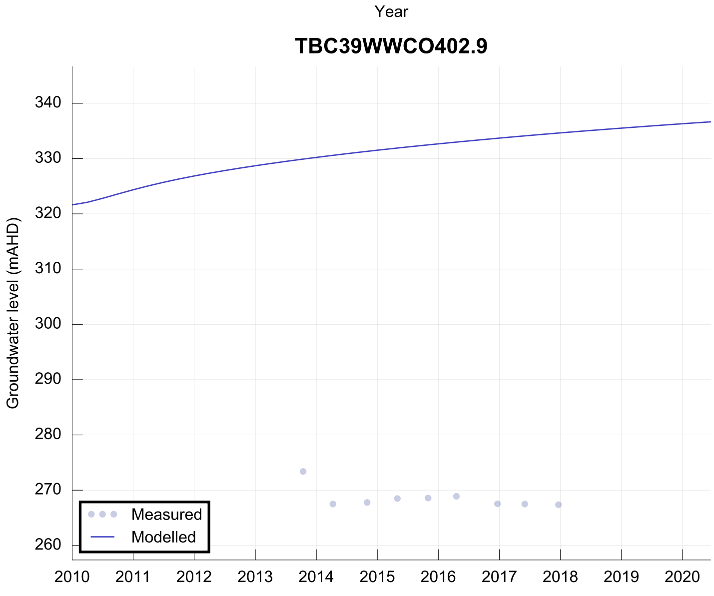
TBC26BHCS191
TBC26UWWC460
TBC27BHCS181
TBC27BUCO384
TBC27LWWC400
TBC33BHCS173
TBC33BUCO384.3
TBC33WWCO408.7
Groundwater level (mAHD)
Year
Measured
Modelled

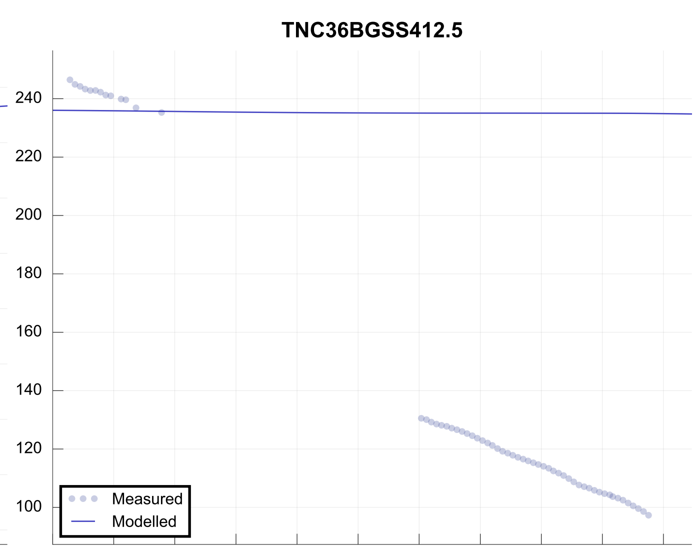

TBC34BHCS176
Groundwater level (mAHD)
365
360
355
350
345
340
335
330
2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020
Year
Measured
Modelled

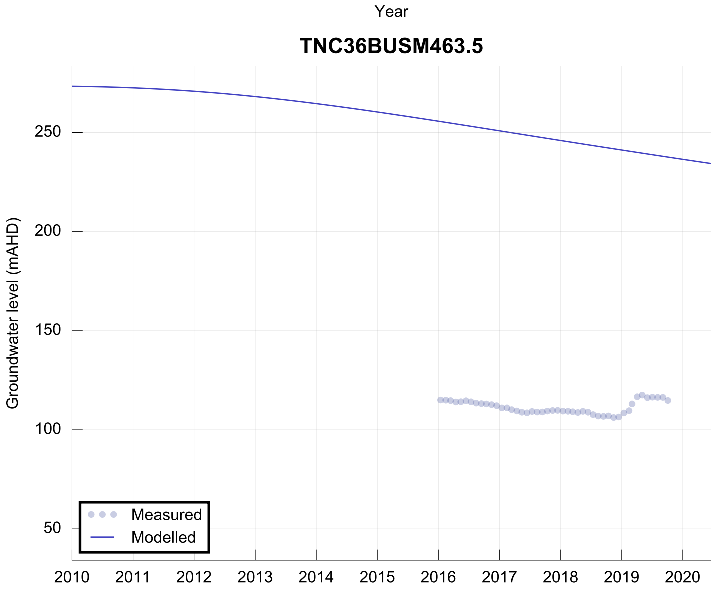

TBC34BUCO364.9
380
370
360
350
340
330
320
310
300
2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020
Measured
Modelled

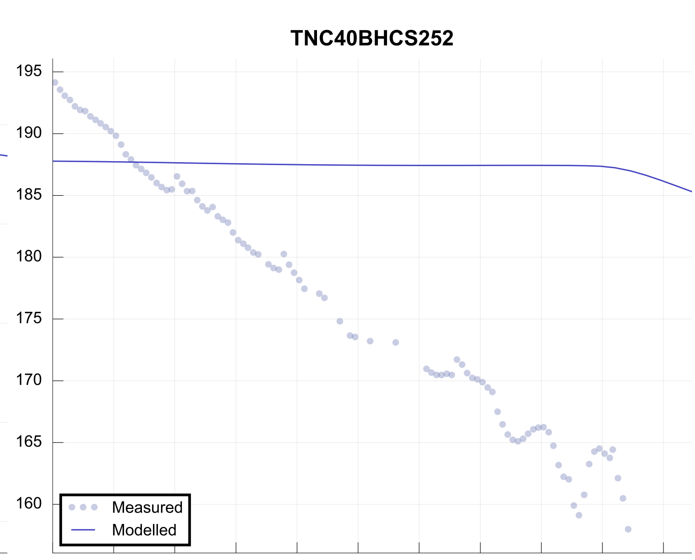

TBC34WWCO382
Groundwater level (mAHD)
380
370
360
350
340
330
320
310
300
2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020
Year
Measured
Modelled

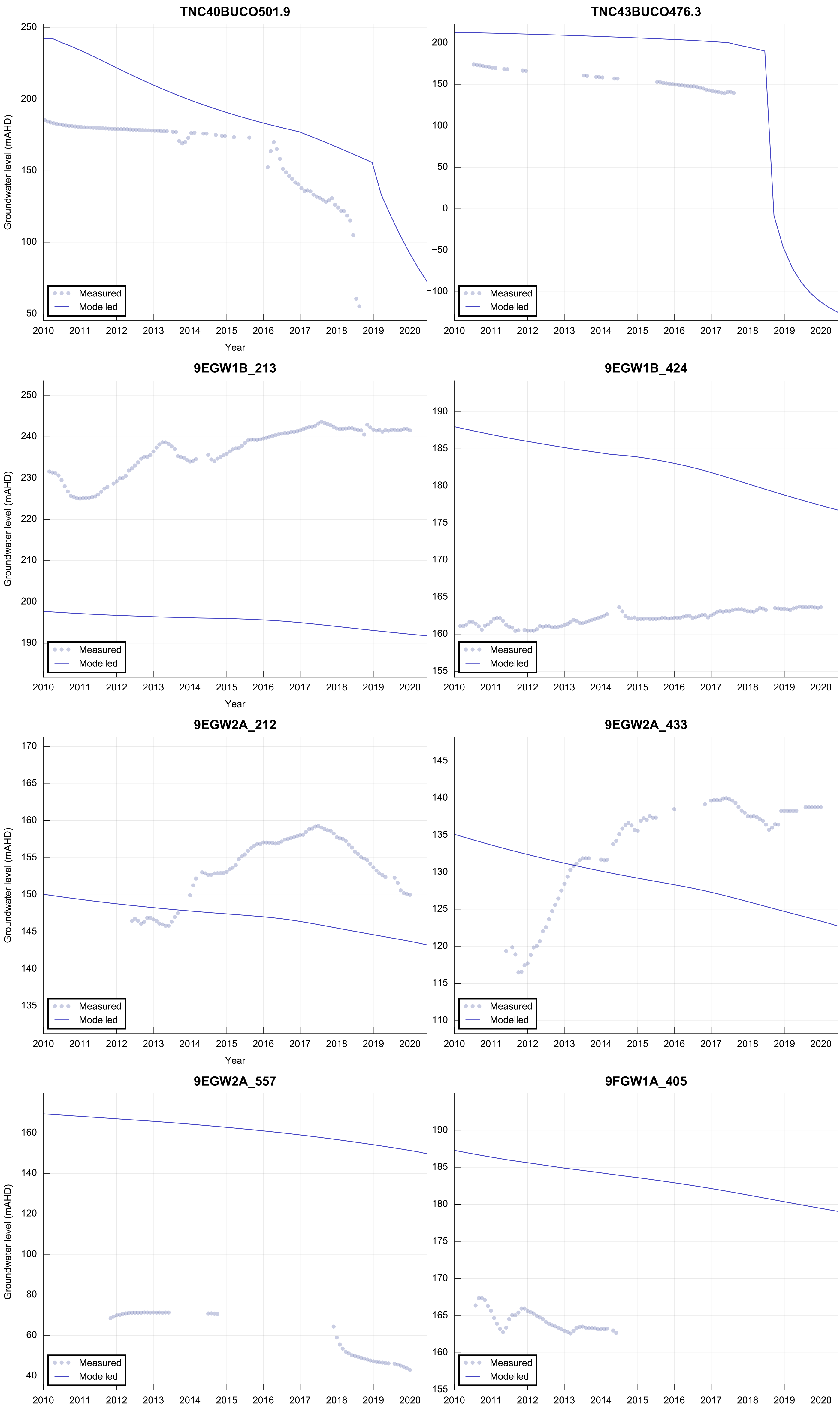

TBC39BUCO375.1
330
320
310
300
290
280
270
260
250
2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020
Measured
Modelled


TBC39WWCO402.9
Groundwater level (mAHD)
340
330
320
310
300
290
280
270
260
2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020
Year
Measured
Modelled


TNC36BGSS412.5
240
220
200
180
160
140
120
100
2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020
Measured
Modelled


TNC36BUSM463.5
Groundwater level (mAHD)
250
200
150
100
50
2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020
Year
Measured
Modelled


TNC40BHCS252
195
190
185
180
175
170
165
160
2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020
Measured
Modelled


TNC40BUCO501.9
TNC43BUCO476.3
9EGW1B_213
9EGW1B_424
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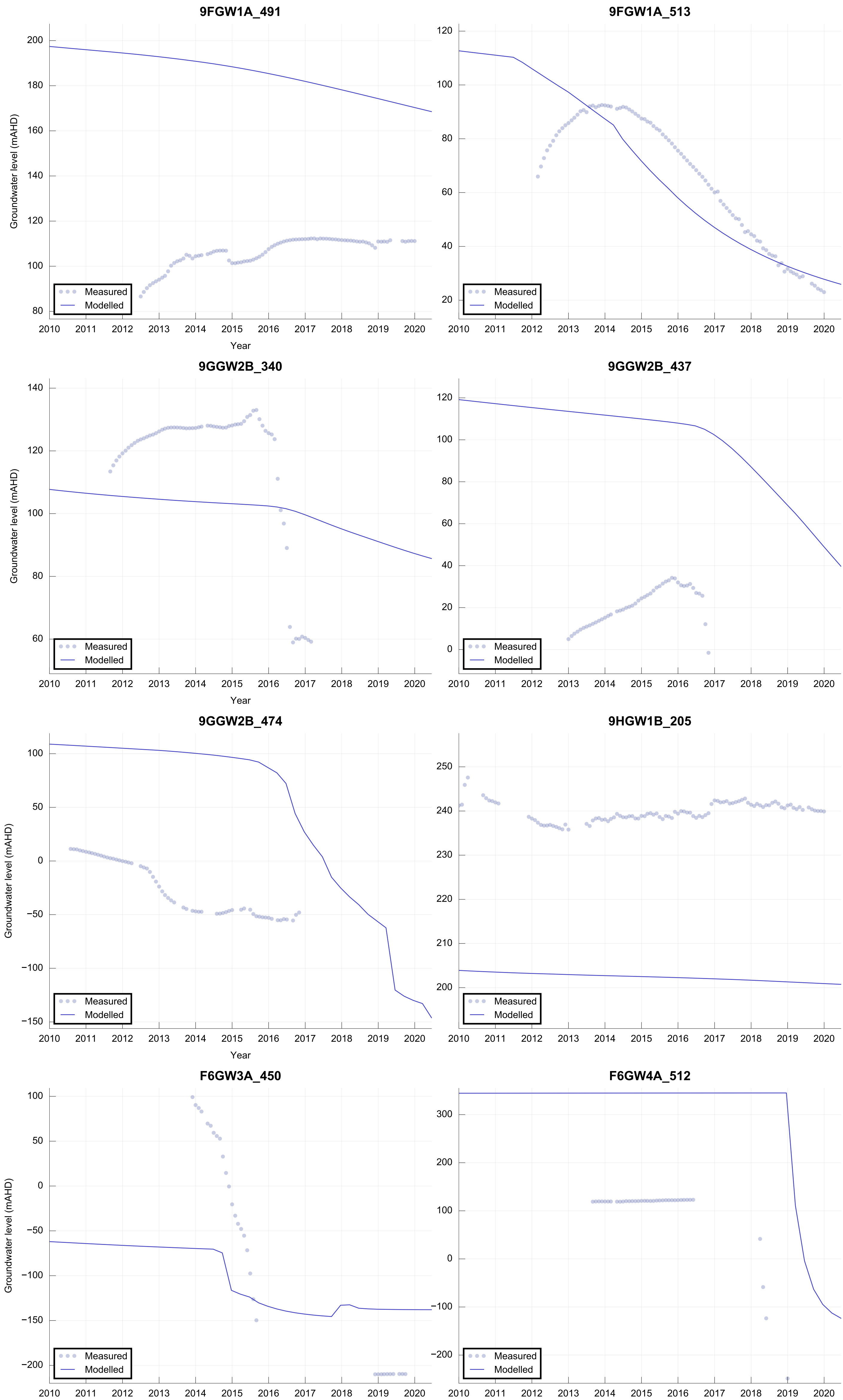
Year
Measured
Modelled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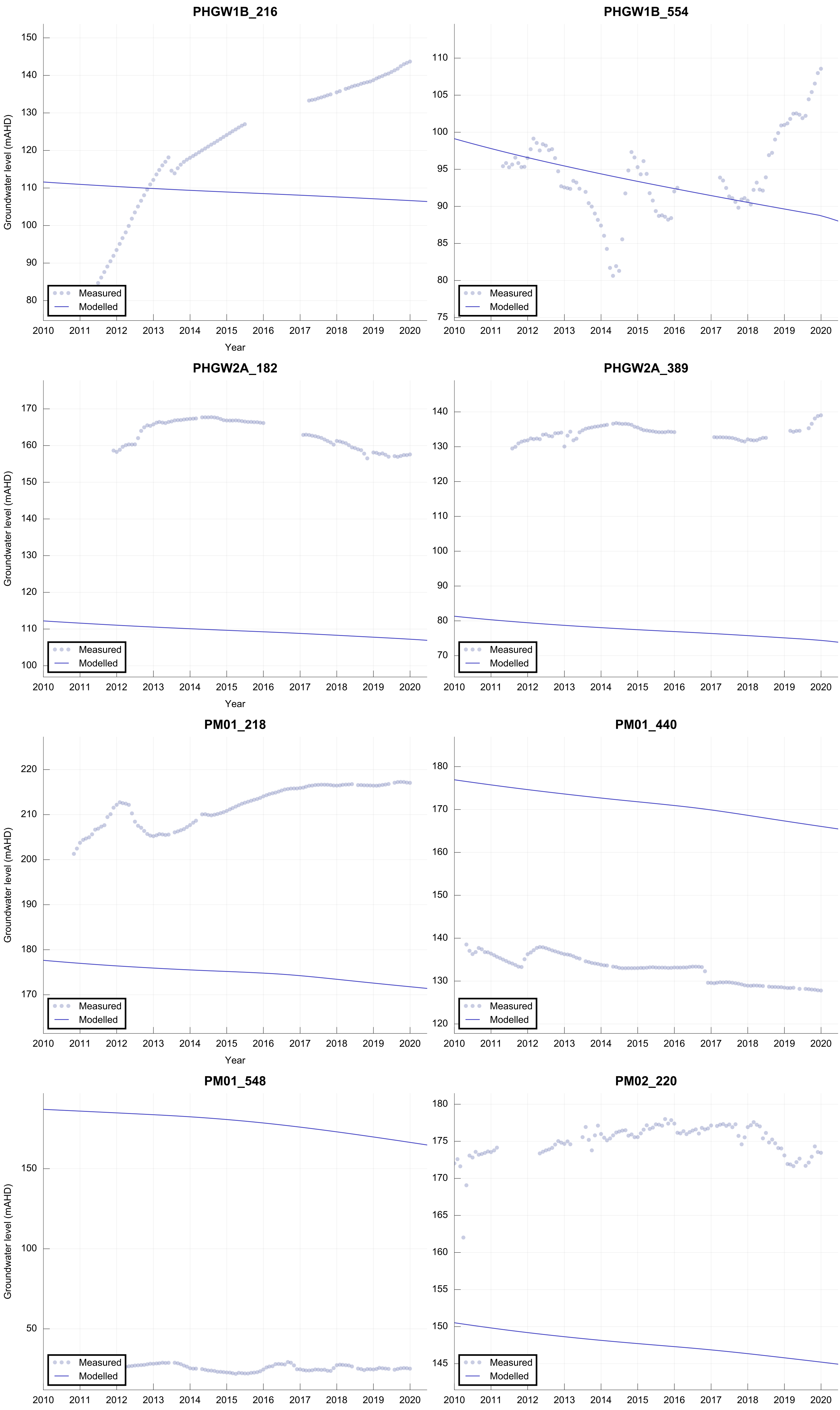
Year
Measured
Modelled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PHGW2A_389
PM01_218
PM01_440
PM01_548
PM02_220
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Year
Measured
Modelled
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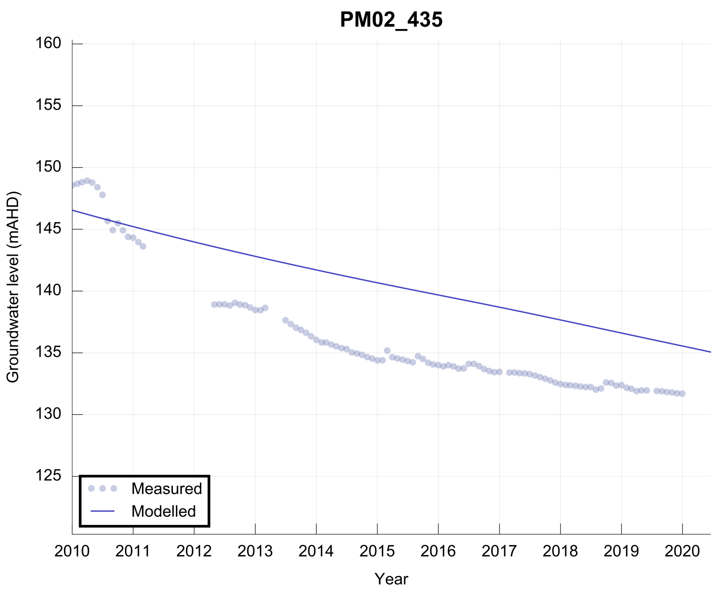
2012
2013
2014
2015
2016
2017
2018
2019
2020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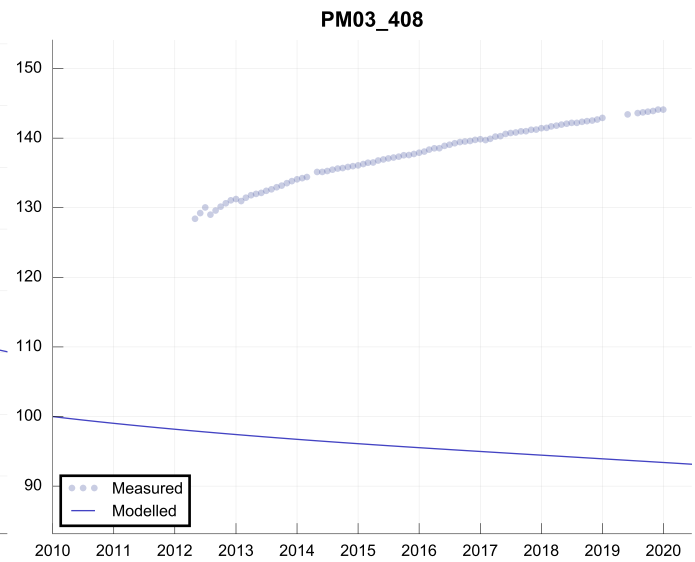
Year
Measured
Modelled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130
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110
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2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
Measured
Modelled

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Appendix B – Appin Longwalls 709 to 711 and 905 Surface Water Impact Assessment (SLR 2021b)

APPIN MINE EXTRACTION PLAN

Surface Water Assessment
Longwalls 709 to 711 and 905

Prepared for:

South 32 - Illawarra Metallurgical Coal

SLR Ref: 630.30102-R01
Version No: -v2.0
April 2021

SLR

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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 South 32 - Illawarra Metallurgical Coal (the Client). Information reported herein is based on the interpretation of data collected, which has been accepted in good faith as being accurate and valid.

This report is for the exclusive use of the Client. No warranties or guarantees are expressed or should be inferred by any third parties. This report may not be relied upon by other parties without written consent from SLR.

SLR disclaims any responsibility to the Client and others in respect of any matters outside the agreed scope of the work.

DOCUMENT CONTROL

Reference	Date	Prepared	Checked	Authorised
630.30102-R01-v.2.0	21 April 2021	Duncan Barnes / Emily Curtis	Paul Delaney	Paul Delaney
630.30102-R01-v.1.1	16 April 2021	Duncan Barnes / Emily Curtis	Paul Delaney	Paul Delaney
630.30102-R01-v.1.0	10 February 2021	Duncan Barnes / Emily Curtis	Paul Delaney	Paul Delaney
630.30102-R01-v.5	5 February 2021	Duncan Barnes / Emily Curtis	Paul Delaney	Paul Delaney

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TABLES

FIGURES

PHOTOS

1 Introduction

The Appin Mine is located approximately 25 kilometres (km) north-west of Wollongong. Appin Mine is owned and operated by Illawarra Metallurgical Coal (IMC), a subsidiary of South32 Limited (South32). The existing mining operations are undertaken in accordance with Project Approval 08_0150 for the Bulli Seam Operations (BSO), granted in December 2011 and modified in October 2016 to incorporate the Appin Ventilation Shaft No. 6 Approval.

IMC is currently extracting Longwall 708B in Appin Area 7 and Longwall 903 in Area 9. In accordance with the BSO Approval Condition 5, an Extraction Plan (EP) is required to be prepared prior to commencement of secondary extraction. The EP outlines the proposed management, mitigation, monitoring and reporting of potential impacts from the secondary extraction of approved longwalls at Appin Mine. IMC will seek EP approval for Longwalls 709, 710A, 710B, 711 and 905 (the Project).

SLR Consulting Australia Pty Ltd (SLR) was engaged by South32 to complete a technical review of the surface water impacts for the Project (Longwalls 709, 710A, 710B, 711 and 905) and recommend management and mitigation strategies. This report presents the methodology and results of this work.

1.1 Project Description

The Project relates to Longwalls 709, 710A, 710B, 711 and 905 within Areas 7 and 9 of the approved BSO. The location of these longwalls are presented in **Figure 1**. The proposed mining includes:

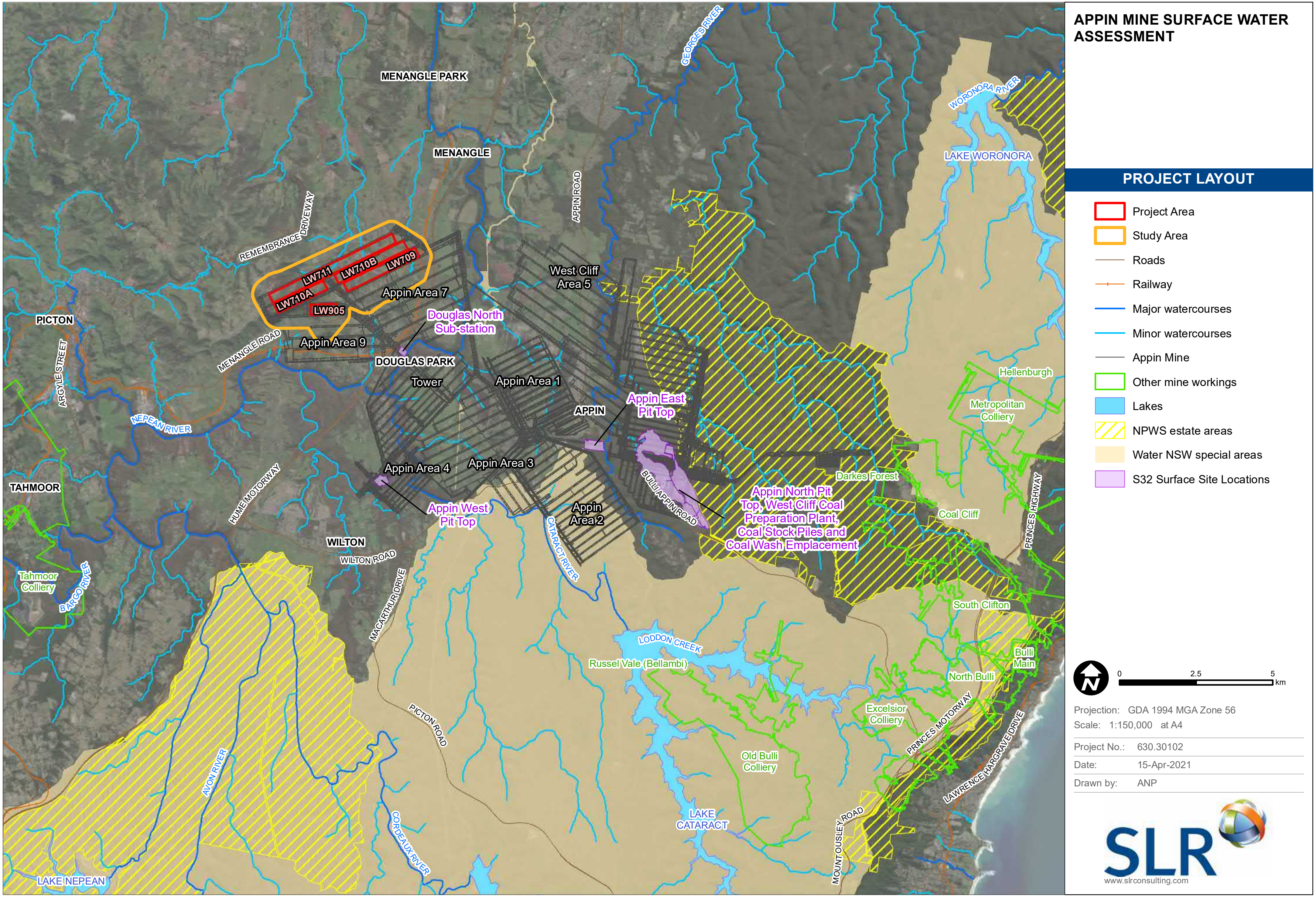
- Longwall 709 – Planned to be mined from December 2021 to June 2023, panel width of 319 metres (m) and average extraction height of 3.02 m;
- Longwall 710A – Planned to be mined from June 2023 to February 2024, panel width of 319 m and average extraction height of 3.10 m;
- Longwall 710B – Planned to be mined from March 2024 to December 2024, panel width of 319 m and average extraction height of 3.00 m;
- Longwall 711 – Planned to be mined from December 2024 to May 2026, panel width of 319 m and average extraction height of 3.15 m; and
- Longwall 905 – Planned to be mined from July 2022 to December 2022, panel width of 319 m and average extraction height of 3.03 m.

1.2 Study Area

The general Study Area consist of the 600 m boundary based on the likely extent of predicted subsidence due to mining of the proposed longwalls defined within the Subsidence Assessment (MSEC, 2021). The extent of the Study Area has been calculated by combining the areas bound by the following limits:

- A 35° angle of draw line; and
- Predicted 20mm subsidence contour.

The investigation also considers effects caused within the general Study Area to major downstream waterways i.e. The Nepean River and downstream effects of tributaries within the Study Area i.e. Foot Onslow Creek, Navigation Creek and Harris Creek.



H:\WOL\Projects-SLR-WOL\630-NTL\630.30102.00000 Appin SW Man Plan LW709 905\06 SLR Data\01 CADGIS\GIS\SLR63030102_G1_Site layout_002.mxd

1.3 Approved Operations

Appin Mine extracts coal from the Bulli Coal Seam within the Permian aged Illawarra Coal Measures via the longwall mining method. The Appin Mine refers to the current and previous mine areas, which comprises the formerly Tower Colliery and West Cliff Mine.

The Appin Mine includes Area 1, Area 2, Area 3, Area 4, Area 5, Area 7 and Area 9 (**Figure 1**). The current active mining is in Area 7 and Area 9. It should be noted that the approved Area 9 is more extensive than the currently mined Area 9, as shown in **Figure 1**. A summary of the mine areas, years mined, and current status is shown in **Table 1**.

Table 1 Appin Mine Areas and Timing

Mine Area	Longwall Panels	Date From	Date To	Date Approved To	Status/ Comment
Tower	1 - 20	1978	2002	-	Historic mining
Appin Area 1	1 - 12	1969	1986	-	Currently used for underground mine water storage (White Panel), transferred from current mining areas.
Appin Area 2	12 - 29	1986	1997	-	Historic mining
Appin Area 3	301 - 302	1998	2007	-	Historic mining
Appin Area 4	401 - 408	1998	2007	-	Currently used for underground mine water storage, transferred from current mining areas.
West Cliff Area 5	1 - 38	1983	2016	2040 (BSO)	Historic mining
Appin Area 7	701 - 714	2007	Present	2040 (BSO)	Active Mining
Appin Area 9	901 - 910	2016	Present	2040 (BSO)	Active Mining

1.4 Camden Gas Project

The AGL Camden Gas Project is on Petroleum Production Lease (PPL) 1 to 6 and Petroleum Exploration Licence (PEL2), at the northern end of Appin Mine. The Camden Gas Project has been in operation since 2001, with production to cease by 2023. AGL hold two Water Access Licenses (24856 and 24736) and Works and Use Approvals (10WA112288 and 10WA112294) with a current total allocation of 30 ML/year (15ML allocated from the Sydney Basin Central Groundwater Source and 15 ML allocated from the Sydney Basin Nepean Groundwater Source) (AGL, 2018). The Camden Gas Project comprises 144 wells (92 currently active, 41 have been rehabilitated) targeting the Bulli and Balgownie seams north of the Project.

2 Environmental Setting

2.1 Climate and Topography

Daily rainfall observations have been recorded by IMC since 2014 at Appin East, Appin North, Appin West (part) and at the Ventilation Shaft No.6. However, due to the short period of monitoring, long-term BoM site data associated to the SILO point grid has been used for this assessment of the Project. There are several Bureau of Meteorology (BoM) stations in the area with long-term data, including Darkes Forest (068024), Cataract Dam (068016), Wedderburn (068159) and Douglas Park (068200). The BoM data was obtained from SILO point grid (Latitude -34.20 Longitude 150.75) located between Douglas Park and Appin and used to evaluate the climatic conditions at Appin Mine. The data was obtained through the Scientific Information for Landowners (SILO) database, from January 1890 to September 2020. Based on the SILO data, the long-term (1890 to 2020) average yearly rainfall for the Project Area is 986 mm/yr.

Figure 2 shows the long-term rainfall trends based on the SILO data, as defined by the cumulative departure from mean or cumulative rainfall deficit curve. This shows the historical occurrence of dry periods (downward rainfall trend), wetter than average periods (upward rainfall trend). The recent April 2017 to December 2019 rainfall deficit is assessed by BoM as the 'lowest on record'.

Potential evaporation (PE) is also available from BoM. Long-term average PE is approximately 1576 mm/yr at Appin, and slightly lower at Wollongong on the coast (1520 mm/yr). Actual evapotranspiration (ET) at Appin is approximately 922 mm/yr. A comparison of the average daily rainfall and PE for each month is presented in **Figure 3**. This shows that in July there is a slight rainfall excess, with a rainfall deficit in all other months.

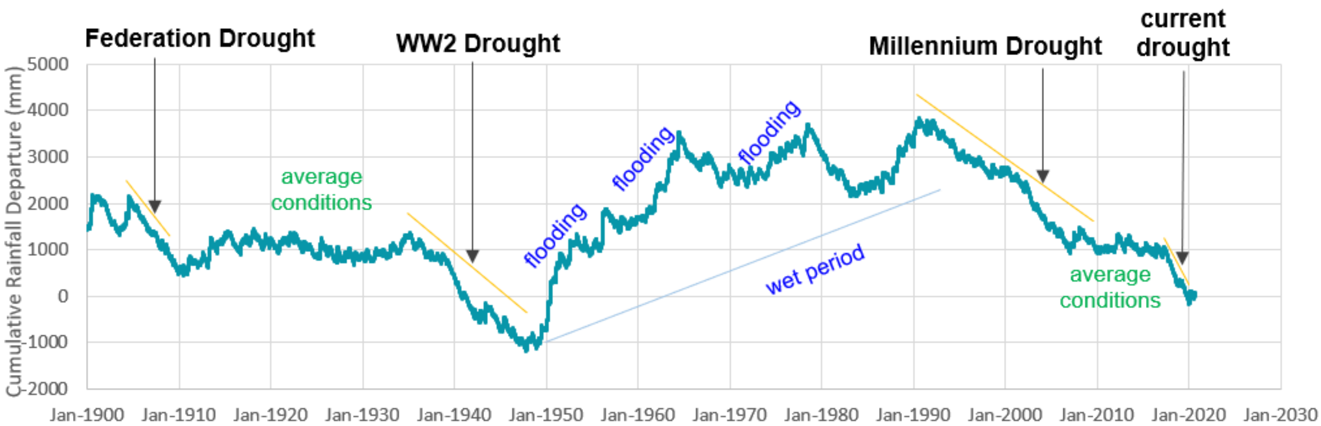


Figure 2 Cumulative Rainfall Departure

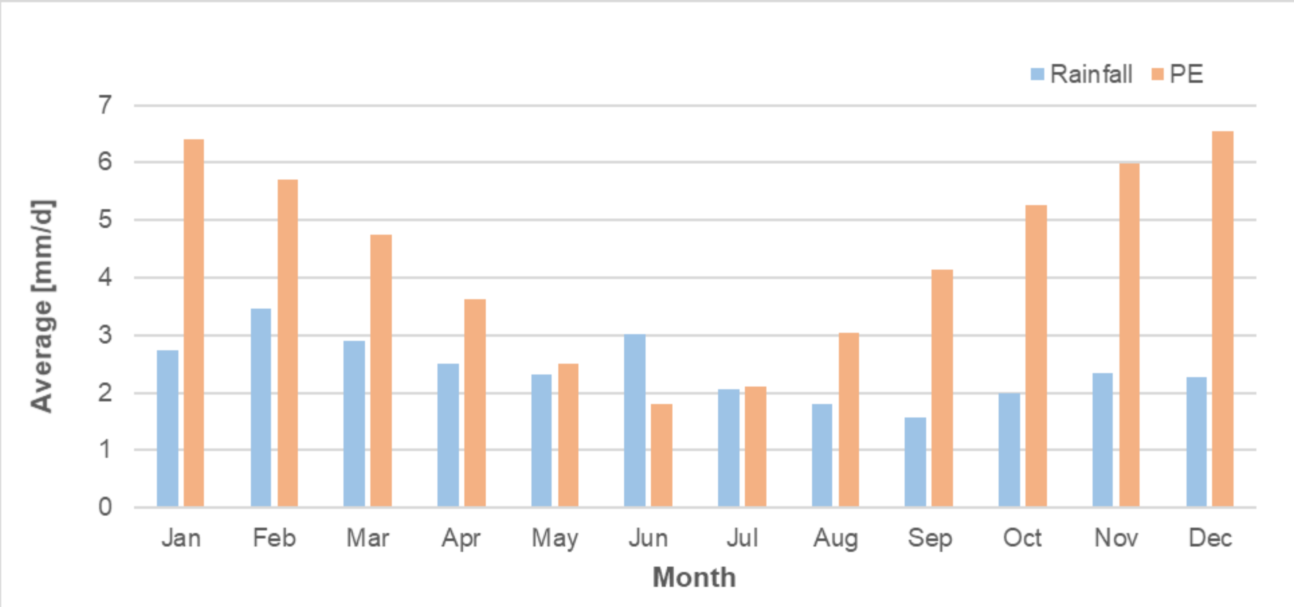
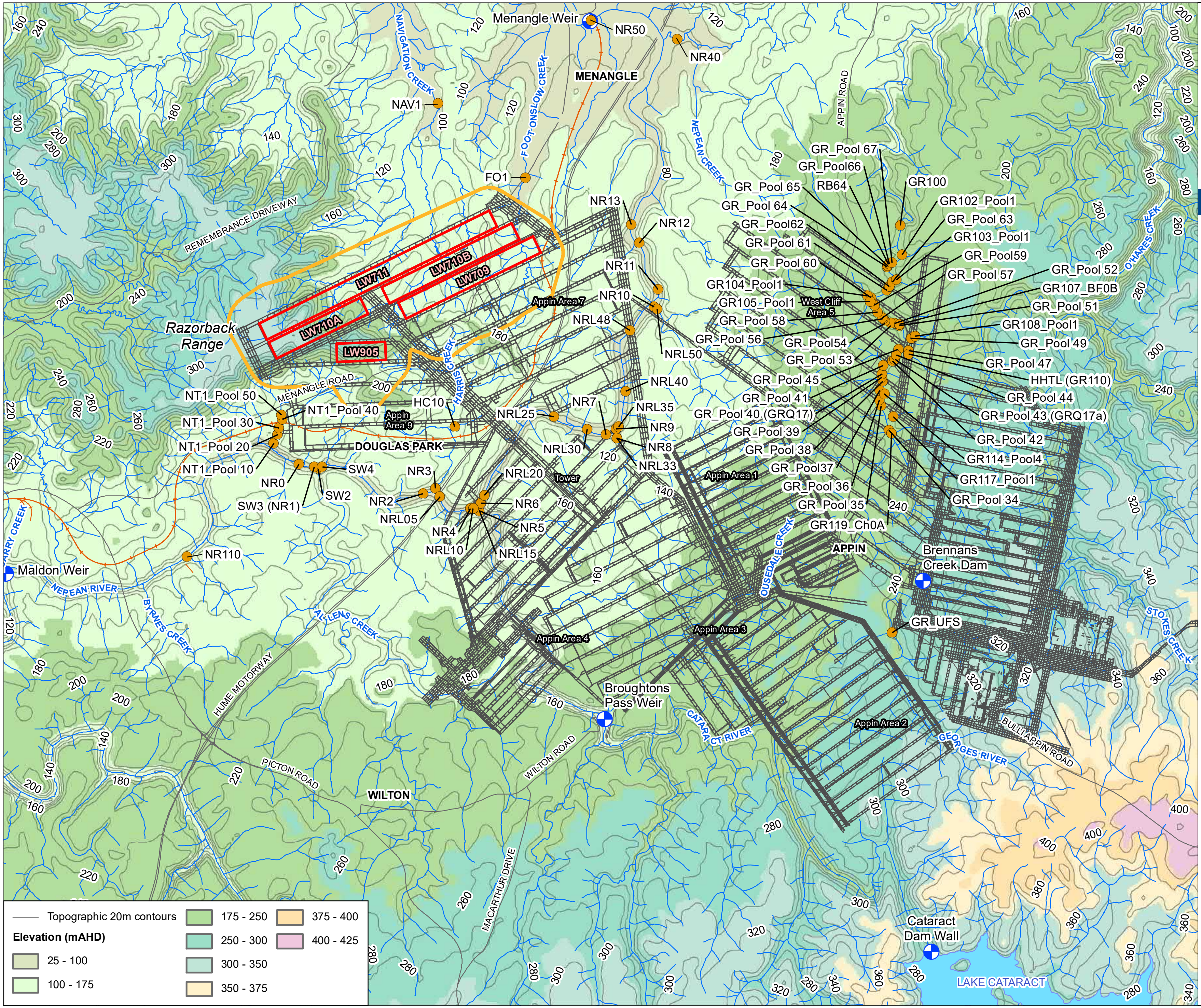


Figure 3 Average Daily Rainfall and Potential Evaporation

2.2 Topography

Appin Mine is located to the west of the Woronora Plateau and the Cumberland Plain inland of the Illawarra Escarpment approximately 25 km northwest of Wollongong, NSW. Topography within the Project Area ranges from 100 m AHD to 320 m AHD, with the topographic high associated with Razorback Range on the western part of the Project Area (**Figure 4**).

On the plateau to the north the topography generally slopes to the north or northwest, toward the center of the Sydney Basin. The topography of the eastern part (West Cliff Area 5) falls from 250 m AHD to 130 m AHD while the western area slopes gently from approximately 250 m AHD (south along the Nepean Valley) to 60 m AHD near Menangle Park to the north.



APPIN MINE SURFACE WATER ASSESSMENT

TOPOGRAPHY AND DRAINAGE

- Project Area
- Study Area
- Dams
- Surface water monitoring
- Roads
- Railway
- Appin Mine
- Watercourses
- Lakes

0 0.5 1 km

Projection: GDA 1994 MGA Zone 56
Scale: 1:90,000 at A4

Project No.:	630.30102
Date:	15-Apr-2021
Drawn by:	ANP

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2.3 Geology

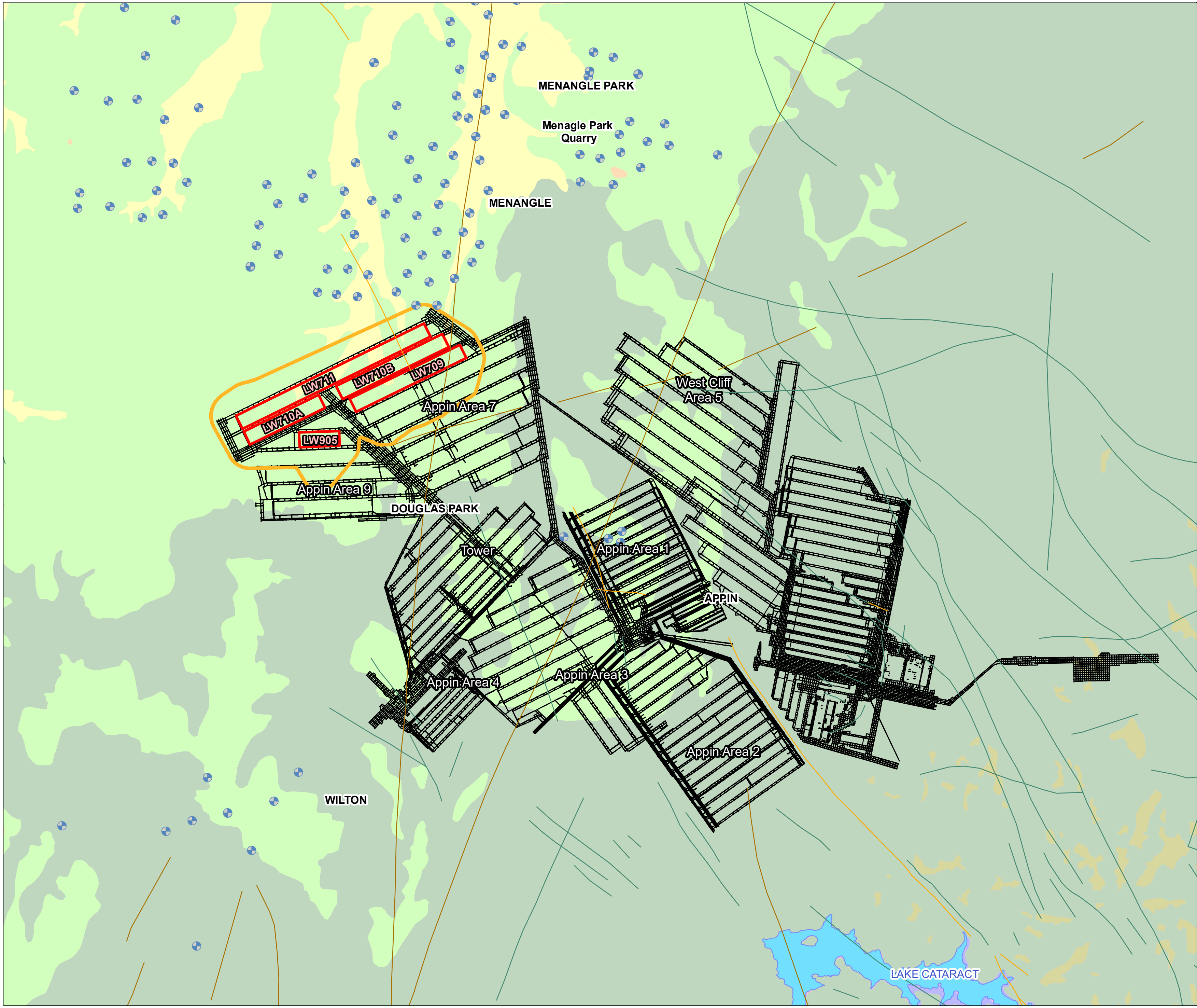
Appin Mine is located within the Southern Coalfield of the Sydney Basin. The stratigraphy of the Southern Sydney Basin is shown in **Figure 5**, based on the Southern Coalfield 1:100,000 geological map (Moffitt 1999).

The Triassic Wianamatta Group is present at surface across the site (**Figure 5**) and ranges in thickness from less than 10 m to 200 m at Razorback Range. Quaternary floodplain alluvium is also mapped as being present on the northern side of the Project Area, localised along Nepean River and its tributaries (i.e. Navigation Creek).

The Hawkesbury Sandstone (HBSS) is also present at surface and underlies the Wianamatta Group where it is present. The HBSS comprises bedded sandstone units and is around 170 m thick (MSEC, 2021). The HBSS is incised along the major rivers (i.e. Nepean River) and contributes baseflow. The HBSS is underlain by the Triassic sandstones, siltstones and claystones of the Narrabeen Group. This includes the Bulgo Sandstone, Scarborough Sandstone and Coal Cliff Sandstone, as well as the Bald Hill Claystone, Stanwell Park Claystone and Wombarra Claystone.

Permian aged Illawarra Coal Measures underlie the Narrabeen Group. The Illawarra Coal Measures consist of interbedded sandstone, shale and coal seams, with a thickness of approximately 200 m to 300 m. The Bulli Seam is the primary economic sequence of interest at Appin Mine. Within the Project Area the Bulli Seam is around 2.8 m to 3.3 m thick and around 530 m to 750 m below surface (MSEC, 2021).

The major geological structures (faults) in the region include the Nepean Fault Zone, O'Hares Fault and J-Line Fault. Within the Project Area (Area 7 and 9) there are a series of NNW-SSE orientated dykes and minor faults (MSEC, 2021). However, previous mining through these structures at LW703 to LW706 and LW901 to LW903 did not cause any change in vertical subsidence (MSEC, 2021). In addition, since the 1970s in-seam drilling has been undertaken in advance of all development underground. No hydraulically charged structures were intersected at Appin Mine during the in-seam drilling process or progression of mining.



APPIN MINE SURFACE WATER ASSESSMENT

GEOLOGY

- Project Area
- Study Area
- CSG Wells
- Appin Mine
- Fault
- Dyke
- Lineament
- Lakes
- Qal/ Tal – Alluvium
- Wianamatta group
- Rh - HBSS

0 0.5 1 km

Projection: GDA 1994 MGA Zone 56
Scale: 1:110,000 at A4

Project No.: 665.10015
Date: 15-Apr-2021
Drawn by: JG

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2.4 Hydrogeology

Existing hydrogeology information is provided in the Groundwater Impact Assessment that was prepared for the Project by SLR in 2021. This Groundwater Impact Assessment included groundwater modelling to predict potential impacts to the local hydrogeological system to support the EP approval process. The assessment found that depressurisation of aquifers beneath the Bald Hill Claystone, including the Lower HBSS, Bulgo Sandstone and Scarborough Sandstone is likely to occur. Predicted peak mine inflows are not expected to change compared to the approved mining plan with up to 0.65 ML/day predicted groundwater inflows from the proposed longwalls.

Although some impacts to groundwater are predicted, the assessment concluded that there are negligible predicted impacts on surface water bodies including stream inflows due to depressurisation of the coal measures. This is because there is negligible predicted depressurisation within the upper layers, above the Bald Hill Claystone to induce downward seepage or reduce baseflow contributions. While negligible depressurisation is predicted within the surficial strata as part of the groundwater assessment, the subsidence assessment identified the potential for fracturing to develop along the creeks and tributaries due to the mining of the proposed Longwalls 709 to 711 and 905. Fracturing will predominately occur where the creeks and tributaries are located directly above the mining area. Impacts can also occur outside the mining area, with minor and isolated fracturing occurring at distances up to approximately 400 m outside the longwalls, as previously observed at Appin Colliery and elsewhere in the Southern Coalfield. Changes in shallow groundwater as a result of fracturing, dilatation and shear of shallow strata can result in changes to surface water bodies and shallow groundwater, where they are connected. This has the potential for localised impacts on surface water flow in creeks and tributaries, which may influence recharge to the alluvium within proximity to the Project.

While the assessment predicts no substantial depressurisation within the upper layers, during mining of recent adjacent longwalls some minor reduction in standing water levels in the stratigraphy above the Bulgo Sandstone was observed in groundwater monitoring. However, groundwater gradient towards the Nepean River is maintained. Additionally, IMC have observed declines in standing water levels in the upper and lower HBSS in landowner boreholes that have been mined under. It is suspected that changes in shallow groundwater are a result of fracturing, dilatation and shear of shallow strata. The data is observational only at this time as the baseline monitoring time period is short; therefore the pre-mining data is not able to be compared with the post mining data at this time.

The groundwater data analysis also concluded that there are no observed material impacts from longwall mining beyond what was foreseen for the cumulative impacts described in the BSO study by Heritage Computing (2009).

2.5 Surface Water and Drainage

2.5.1 Major Rivers

Appin Mine is located within the Georges River and the Hawkesbury-Nepean catchments. Major rivers in the area include the Nepean River, Cataract River, Stonequarry Creek and Georges River (**Figure 4**). The rivers within the Appin Mine area generally flow in a northerly direction and have perennial flows influenced by dam releases and baseflow contributions from the incised HBSS.

Summary details for each of the main rivers near the Project are included in **Table 2**.

Table 2 Major River System at Appin Mine

River	Characteristics	Surface Water Flow
Nepean River	Regulated flows from upstream dams and baseflow contributions where incised into Hawkesbury Sandstone. Present across surface of Appin Mine area (Area 7).	Main government stream gauge 212216 (Nepean River at Camden Weir), as well as 212238 (Menangle Weir) and 212208 (Maldon Weir). Plus IMC Nepean River (NR) monitoring. Flows in a northerly direction, with flow of around 310 ML/day (Maldon Weir) since 2010.
Cataract River	Regulated flows from Lake Cataract. Present across surface of Appin Mine area (Area 4 and Tower).	Main government stream gauge 212230 (Cataract River at Broughtons Pass), as well as 212231 (Jordans Crossing) and 212232 (Cataract Dam). Flows in a northerly direction towards Nepean River, with flow of around 92 ML/day (Broughton Pass Weir) since 2010, with surface water elevations generally around 130 m AHD to 132 m AHD.
Stonequarry Creek	Stonequarry Creek Management Area at north-west side of Area 9.	Government stream gauge 212053 (Stonequarry Creek at Picton). Flows in a general southerly direction to the Nepean River near Maldon. Flow around 22 ML/day (Picton) since 2010, with surface water elevations generally around 148 m AHD.
Georges River	Regulated flows from upstream dam (Brennans Creek Dam). Present across surface of Appin Mine area (West Cliff area).	IMC monitoring of pool levels along Georges River (GR_POOL). River flows in a northerly direction, with flow of around 4.2 ML/day (Brennans Creek Dam) since 2010.

There are no drinking water catchment areas, or declared special areas within the Study Area. The closest river is the Nepean River, which is 1.5 km south of the Project footprint (MSEC, 2021). The Hawksbury-Nepean Catchment covers approximately 21,400 km^2 (DPIE, 2020). Water flows from the Nepean River are derived from a number of sources and include flows from catchment areas, licensed discharges, including Appin and Tahmoor Collieries, and runoff from agricultural and urban areas. Flows from catchment areas contribute the majority of base water flow into the river (Ecoengineers, 2012).

Natural flow within the Nepean River and its associated watercourses have been significantly altered by water storages such as dams and weirs. Some natural catchment flows are retained by large storage dams upstream of Appin Mine for the purpose of the Sydney water supply system. Water is also retained by numerous farm dams within the local part of the Nepean River catchment, particularly around the Project Area.

The Hawksbury-Nepean basin is considered an unregulated system as the water storages do not regulate flows downstream. They do not capture then release water into the river downstream for extraction by users (DPIE, 2020). Based on available information, two licensed extraction pumps are known to draw water from the Nepean River upstream of the Douglas Park Causeway, only one of which is located within the general Project Area (Ecoengineers, 2012). The majority of unregulated river access licences within the Hawksbury-Nepean catchment are for irrigation purposes, extraction also takes place largely through basic landholder rights, which do not require a licence (DPIE, 2016).

A significant portion of the Nepean River catchment has been cleared for housing, agriculture and industry. Chemical nutrient runoff from residences, farms and industries and treated waste from several sewage treatment plants have contributed to degraded water quality within the Nepean River, including excess nutrients and algae growth (WSU, 2017).

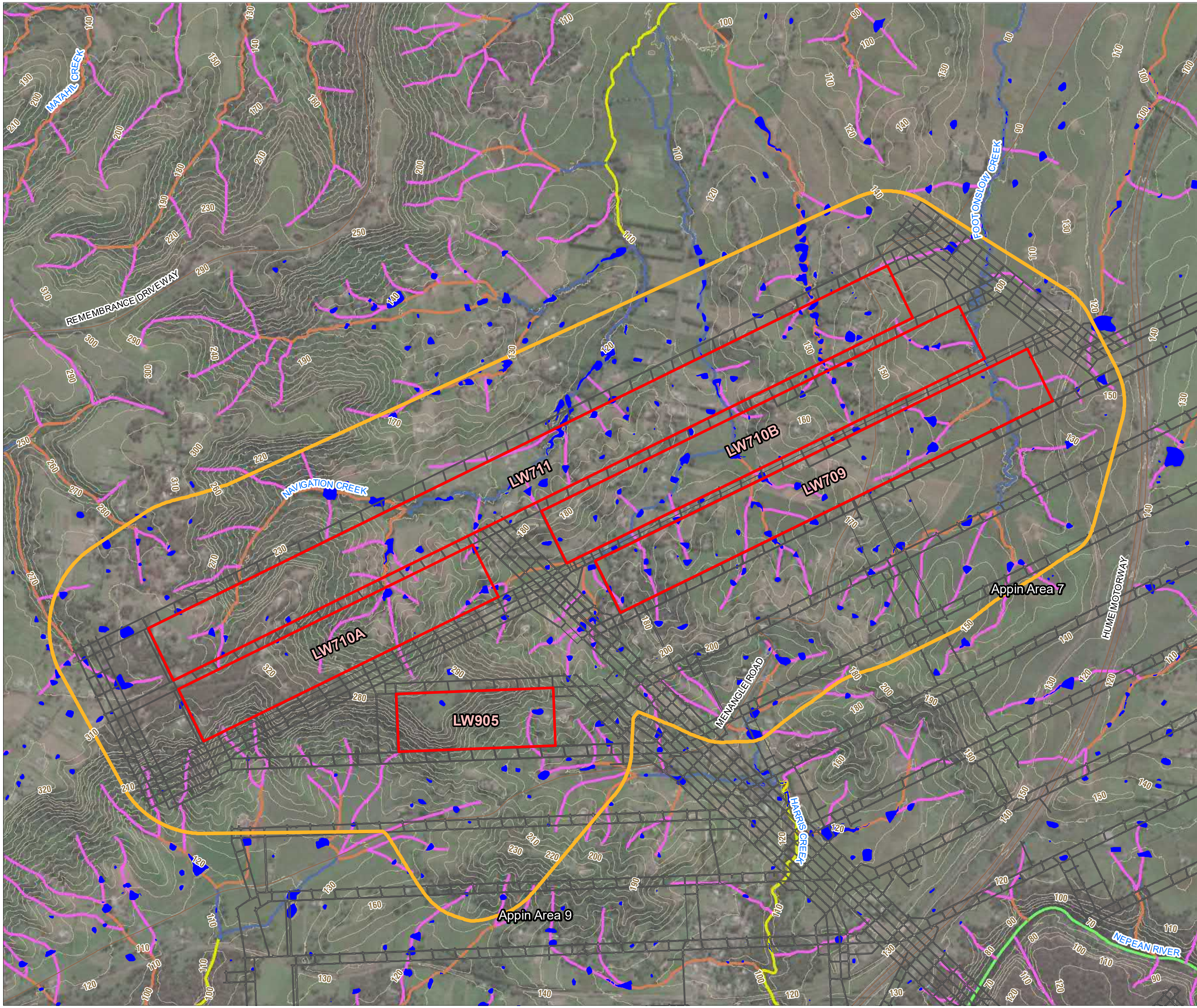
2.5.2 Watercourses within the Project Area

Minor creeks and tributaries of the Nepean River are present across the Appin Mine area. This includes the headwaters of Navigation Creek, Navigation Creek Tributary 1, Foot Onslow Creek and Harris Creek that are third order streams within the Study Area, see **Figure 6** .

Watercourses within the Study Area have upper reaches with shallow incisions into the surface soils, which have been derived from the Wianamatta Group, and steep natural gradients ranging from 2-40%. The lower reaches of these creeks have substantial incisions into the surface soils, with exposed sandstone platforms in the bases and rock outcropping in the valley sides. Natural gradients of third order streams range from 0.5-4%.

Watercourses within the Study Area contribute to a small portion of the total Hawkesbury-Nepean Catchment (<0.2%) with runoff from predominately cleared, agricultural land with small pockets of remnant vegetation. The creeks are largely ephemeral, but pools have naturally formed in some areas. Like the receiving Nepean River, flows within ephemeral creeks have been altered by farm dams which intersect the drainage lines at a number of locations. Runoff from within the catchments is influenced by input of nutrients from adjacent farmland and salinity from the marine sediments of the Wianamatta Shale.

Impacts to water related ecosystems with these watercourses are discussed as part of the Terrestrial Ecology Impact Assessment (Niche, 2021) and Aquatic Ecology Impact Assessment (Cardno, 2021).



APPIN MINE SURFACE WATER ASSESSMENT

WATERCOURSES WITHIN THE PROJECT AREA

- Project Area
- Study Area
- Roads
- Appin Mine
- 10m Contour (NSW SS, 2019)
- Farm Dam

Strahler Stream Order (WaterNSW)

- 1
- 2
- 3
- 4
- 7

0 0.5 1 km

Projection: GDA 1994 MGA Zone 56
Scale: 1:28,000 at A4

Project No.: 630.30102
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2.5.2.1 Navigation Creek

Navigation Creek (**Photo 1**) is a third order stream that is situated directly above Longwall 711, with a third order tributary (Navigation Creek Tributary 1) also directly above Longwalls 709, 710A and 711. A total length of Navigation Creek (including Navigation Creek Tributary 1) of 2.9 km is located within the Project Area with an additional 1.4 km within the Study Area. The upper reaches of Navigation Creek are located within the Study Area and flow north to its confluence with the Nepean River approximately 9.8 km downstream of the Project. The catchment area of Navigation Creek to its confluence with the Nepean River is approximately 24.9 km^2.

Navigation Creek is ephemeral and likely only flows during periods of extended, moderate or high rainfall. The headwaters of Navigation Creek are located within the Project Area with first and second order streams within the steep ridgeline of remnant bushland to the northwest of Appin Mine. The majority of the remaining catchment, including that of the third order stream, is comprised of agricultural land. Navigation Creek is predominantly highly disturbed and in poor condition. Stream banks are often steep with vegetation often consisting of weeds, and areas of minimal vegetation with evidence of erosion and scouring. Some pools have naturally established along the reaches, however the majority of the upper reaches consist of depressions and minor drainage lines intersected by a number of farm dams with little to no signs of flow. Any surface water flows from the upper reaches are predominantly captured within these established farm dams with runoff likely to only contribute to the downstream Nepean River during periods of extended or significant flow. Hence, the influence of this watercourse on flow and water quality within the Nepean River is minimal.

Photo 1 Navigation Creek (Source: IMC)

2.5.2.2 Foot Onslow Creek

Foot Onslow Creek (**Photo 2**) is a third order stream that is situated directly above Longwalls 708B, 709 and 710A. A total length of 1.5 km is located within the Project Area with an additional 2.2 km within the Study Area. The upper reaches of Foot Onslow Creek are located within the Study Area and flow north to its confluence with the Nepean River approximately 3.8 km downstream of the Project. The catchment area of Foot Onslow Creek to its confluence with the Nepean River is approximately 8.5 km^2.

Foot Onslow Creek is ephemeral and likely only flows during periods of extended, moderate or high rainfall. Foot Onslow Creek exists as a third order creek within the Project Area, with some minor first and second order streams. Within the Study Area the watercourse resides chiefly within agricultural land. Foot Onslow Creek is predominantly highly disturbed and in poor condition. Stream banks show areas of significant scouring and erosion with steep to near vertical walls. On shallower banks vegetation consist primarily of grassland and weeds. Stream bed material consists of loose sediment with grass and reed growth in some locations. Surface water flows from the upper reaches are predominantly captured within a number of established farm dams with runoff likely to contribute to the Nepean River during periods of extended or significant flow only. Hence, the influence of this watercourse on flow and water quality within the Nepean River is minimal.

Photo 2 Foot Onslow Creek (Source: IMC)

2.5.2.3 Harris Creek

Harris Creek (**Photo 3**) is a third order stream within 600 m of Longwall 905 and adjacent to the previously mined Longwall 706. A total length of 0.4 km is located within the Study Area. The upper reaches of Harris Creek are located within the Study Area and flow south to its confluence with the Nepean River approximately 3.6 km downstream of the Project. The catchment area of Navigation Creek to its confluence with the Nepean River is approximately 5.2 km^2.

Harris Creek is ephemeral and likely only flows during periods of extended, moderate or high rainfall. Only first order parts of Harris Creek exists within the Project Area within a steep ridgeline of agricultural land and remnant vegetation. The upper reaches of Harris Creek are predominantly disturbed with depressions and minor drainage lines which are intersected by a number of farm dams. Harris Creek becomes a third order stream adjacent to the Project Area and passes under a culvert at Menangle Road. Downstream of the Project, Harris Creek flows through a rural residential area before discharging to the Nepean River. Where Harris Creek is a third order stream the drainage line is shallow with well-vegetated banks. Natural pools have established in some areas. Surface water flows are limited due to catchment size in addition to flows from upper reaches predominantly captured within established farm dams. Runoff is likely to contribute to the Nepean River during period of extended or significant flow only and is expected to be minimal. Hence, the influence of this watercourse on flow and water quality within the Nepean River is minimal.

Photo 3 Harris Creek (Source: IMC)

3 Baseline Surface Water Monitoring

Surface water monitoring is conducted at the main rivers at government stream gauges (Meldon, Menangle and Broughtons Weirs). IMC also conduct monitoring of surface water levels and quality at the major rivers as well as creeks and tributaries across the site and to the north. This includes monitoring of ponded water (pools) along Georges River and Nepean River.

River stage levels for Nepean River, Cataract River and Stonequarry Creek are shown in **Figure 7**, along with IMC observation data for one of the Georges River pools (GR_POOL63). The river levels generally correlate with rainfall trends (CRD), but also show influence from dam releases/regulation where water levels rise during periods of below average rainfall.

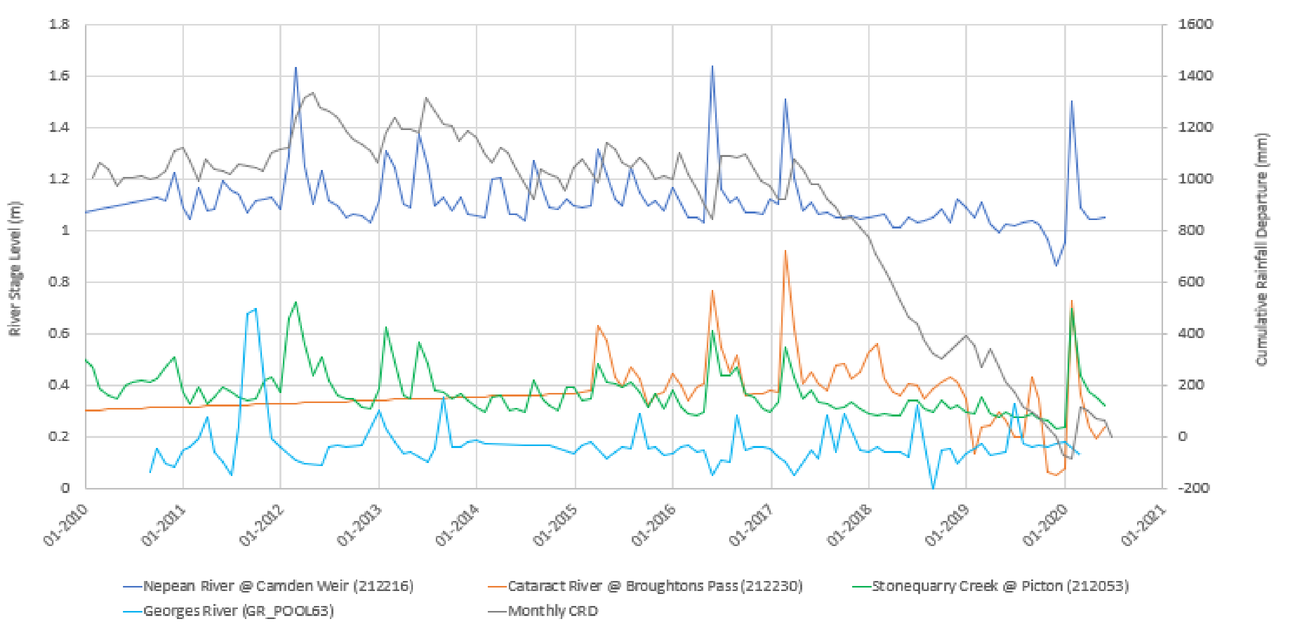


Figure 7 Surface Water Stages

Surface water monitoring has been undertaken at the site for a baseline period between 2002 – 2020. A summary of average water quality monitored at the site surface water monitoring points is included in **Table 3.** The results show that the major rivers have contributions from dam releases, and are incised into the HBSS (i.e. Nepean River, Cataract River and Georges River) and generally contain fresh (low salinity) water. In contrast the minor tributaries, particularly those that occur where the Wianamatta Group is present at surface (i.e. Navigation Creek), have more brackish water quality and higher total dissolved solids (TDS).

Table 3 Summary of Surface Water Monitoring at Appin Mine

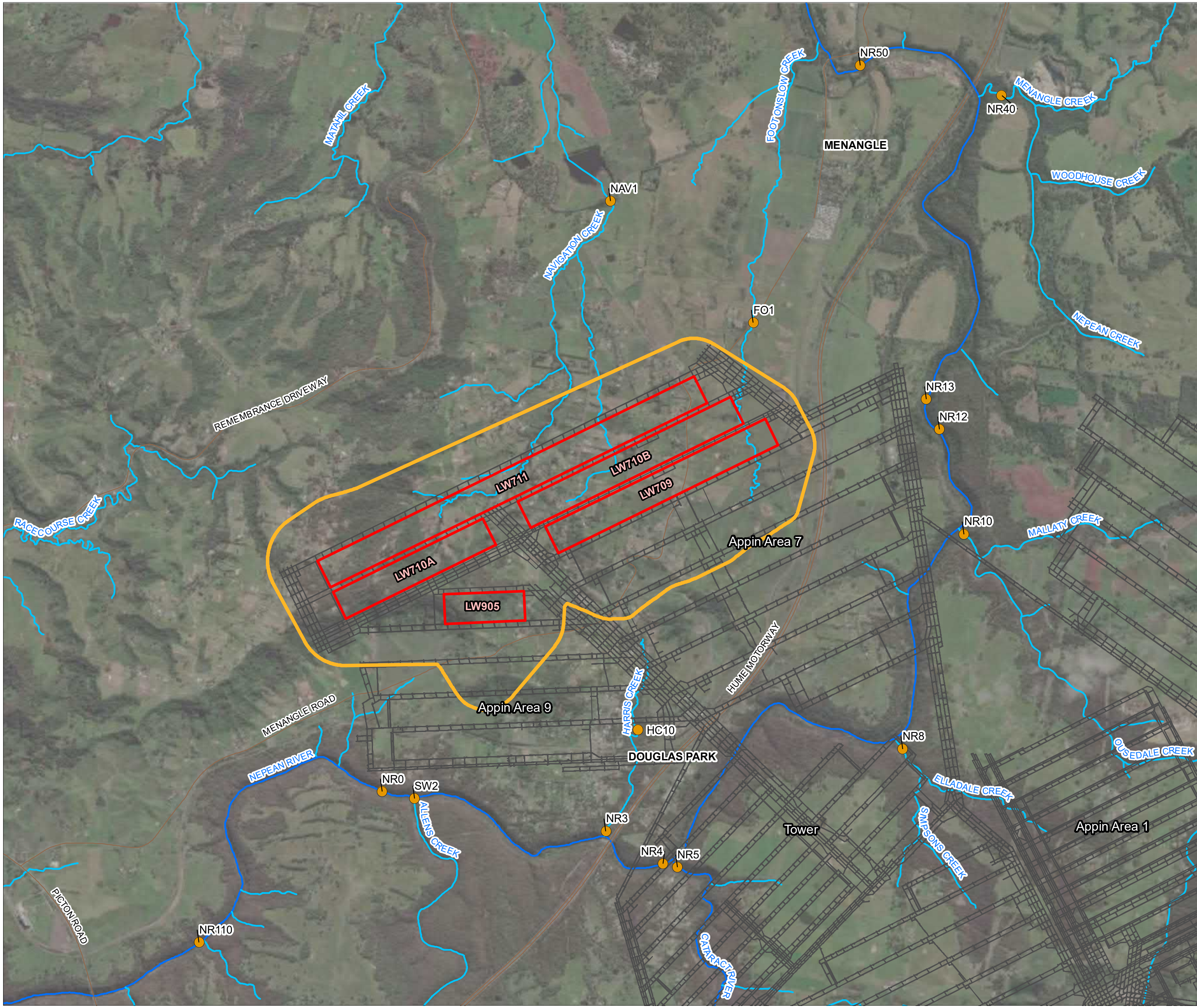
River	Average EC (µS/cm)	pH	TDS (mg/L)	Monitoring Period
Nepean River	309	8	172	2002 - Present
Cataract River	168	7	97	2002 - Present
Georges River	929	7	538	2008 - Present
Ousedale Creek	1478	8	801	2002 - Present
Menangle Creek	1373	8	725	2003 - Present
Elladale Creek	1632	8	904	2002 - Present
Allens Creek	743	8	397	2003 - Present
Navigation Creek	2565	8	1470	2006 - Present
Harris Creek	1490	8	872	2002 - Present / 2010 - Present
Foot Onslow Creek	1616	8	909	2008 - Present

There is an adequate baseline of water quality data to fully characterise water quality conditions prior to the commencement of mining in the Project Area. This includes monitoring locations within the Study Area, as well as monitoring locations in downstream waterways. There are no watercourses which flow into the Project Area, with the headwaters of Harris, Navigation and Foot Onslow Creeks being within the Project Area.

Locations of water quality monitoring sites relevant to this report are considered as shown in **Figure 8** and include:

- **Nepean River** – NR110, NR0, SW2, NR4, NR5, NR8, NR10, NR12, NR13, NR40, NR50;
- **Navigation Creek** – NAV1;
- **Foot Onslow Creek** – FO1; and
- **Harris Creek** – HC10, NR3.

Average water quality for salinity (EC), pH, Dissolved Oxygen (DO), TDS, Total Iron (Fe) and Total Manganese (Mn) over the baseline period for each watercourse at the existing water quality monitoring sites are shown in **Table 4** along with the standard deviation.



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APPIN MINE SURFACE WATER ASSESSMENT

LONGWALLS 709 – 711 AND 905 SURFACE WATER MONITORING

- Project Area
- Study Area
- Surface water monitoring
- Roads
- Major watercourses
- Minor watercourses
- Appin Mine

N

0 0.5 1 km

Projection: GDA 1994 MGA Zone 56
Scale: 1:55,000 at A4

Project No.:	630.30102
Date:	15-Apr-2021
Drawn by:	ANP

SLR
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Table 4 Baseline Water Quality Data

River	EC (µS/cm)		pH		DO (%)		TDS (mg/L)		Fe (mg/L)		Mn (mg/L)	
	Average	St.Dev.	Average	St.Dev.	Average	St.Dev.	Average	St.Dev.	Average	St.Dev.	Average	St.Dev.
Nepean River												
NR110	319	147	7.9	0.3	90.5	14.8	171	76	0.3	0.2	0.03	0.02
NR0	378	173	7.9	0.5	89.5	13.2	208	89	0.3	0.2	0.03	0.02
NR4	223	104	7.6	0.4	85.7	18.4	128	57.8	0.4	0.2	0.03	0.01
NR12	186	67	7.4	0.3	87.2	10.1	107	39	0.4	0.1	0.03	0.01
NR13	182	55	7.4	0.3	85.7	12.6	105	31	0.4	0.1	0.03	0.01
NR50	296	240	7.6	0.4	84.1	19.7	167	135	0.4	0.4	0.05	0.09
Allens Creek - Perturbation												
SW2	704	299	8.1	0.4	95.7	18.4	394	151	0.5	0.4	0.02	0.02
Cataract River - Perturbation												
NR5	169	118	7.2	0.5	73.1	29.6	97	61	0.7	0.8	0.08	0.12
Elladale Creek - Perturbation												
NR8	1640	1229	7.6	0.3	72.4	20.5	909	696	0.8	0.5	0.32	0.82
Ousedale Creek - Perturbation												
NR10	1486	1007	7.8	0.5	91.4	13.9	805	548	0.6	1.4	0.05	0.32
Menangle Creek - Perturbation												
NR40	1376	772	7.7	0.4	54.1	31.7	727	411	2.1	2.0	1.1	1.6
Foot Onslow Creek												
FO1	1616	901	8.0	0.4	73.5	22.3	909	525	1.5	2.0	0.3	0.4
Navigation Creek												

River	EC (µS/cm)		pH		DO (%)		TDS (mg/L)		Fe (mg/L)		Mn (mg/L)	
	Average	St.Dev.	Average	St.Dev.	Average	St.Dev.	Average	St.Dev.	Average	St.Dev.	Average	St.Dev.
NAV1	2565	1943	7.6	0.4	27.8	21.4	1470	1124	5.1	6.0	1.8	1.0
Harris Creek												
HC10	1561	688	7.9	0.3	81.5	25.0	935	425	0.7	2.3	0.2	0.4
NR3	1550	956	7.9	0.3	53.1	26.9	864	531	0.7	1.1	0.5	0.9

Comparison between rainfall trends and the Nepean River surface water quality over time is presented in **Figure** 9. The Nepean River at Appin Mine has a long-term EC average of 291 µS/cm and median of 244 µS/cm, with no significant change between its upstream (NR0 and NR110) and downstream (NR50) segment. The peaks in volume discharge correlate to above average rainfall conditions over time, which freshen water in the river system.

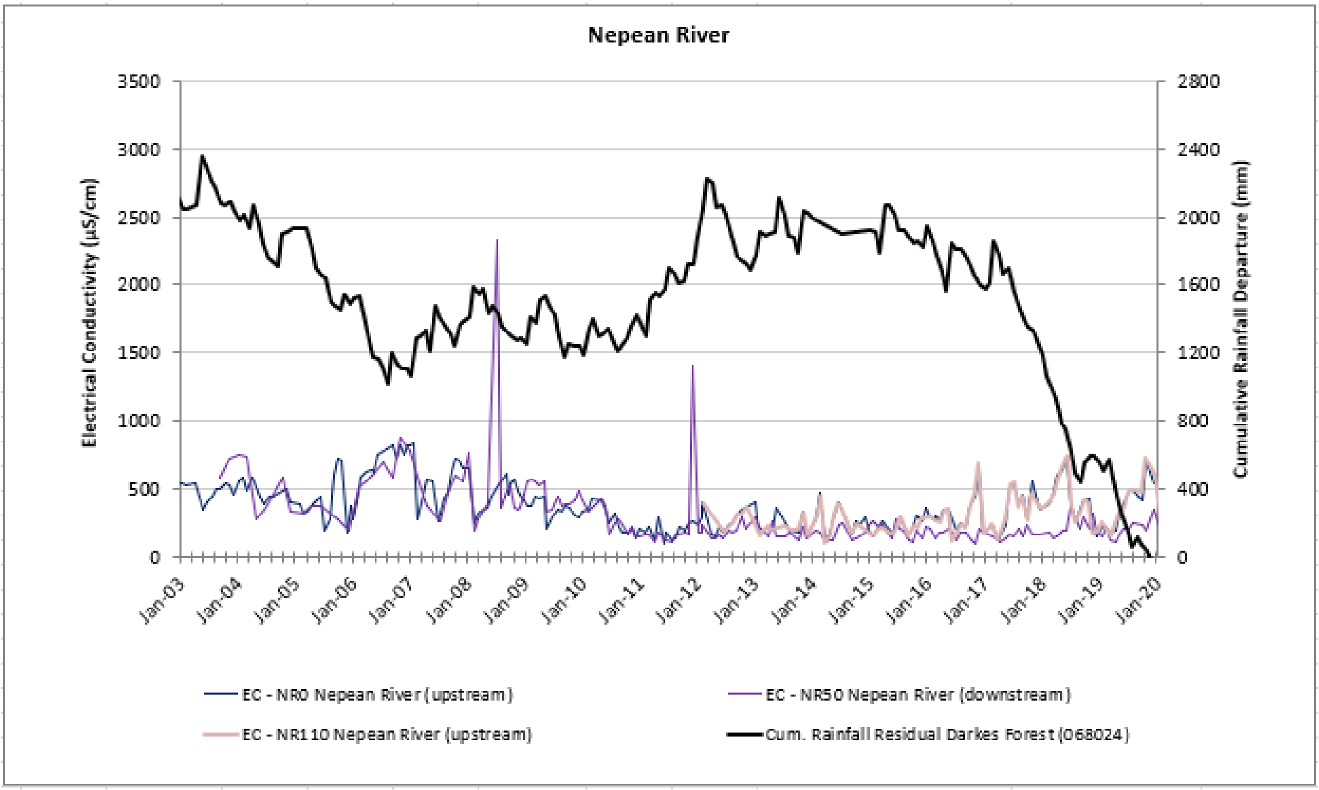

Figure 9 Water Quality along the Nepean River

In comparison **Figure 10** shows the surface water quality of creeks and tributaries within the Study Area over time. The long-term average EC of these watercourses is significantly higher than that of the Nepean River due to the occurrence of the Wianamatta Group at the surface. The salinity of waters within these shale catchment creeks is principally driven by the presence of the anion sodium (Na^+) and cation bicarbonate (HCO_3^-). Bicarbonate is well known to be the principle and most variable driver of salinity based ecotoxicity in such waters. These watercourses have also been observed to provide a consistent input of Fe and Mn to the Nepean River. The oxidation and precipitation of input Fe and Mn, which is enhanced by high pH levels of these streams, increases the ratio of bicarbonate to carbonate ions, ultimately, increasing the ecotoxicity due to salinity (Ecoengineers, 2012). The high variability of salinity over time is typical of ephemeral creeks, with higher salinity typically associated with low flows.

High pH values in the 8.2 – 9.4 pH range can be found within the Nepean River and ephemeral creeks surrounding the Project Area which is not unexpected due to land use dominated to farmland with pre-existing Total Phosphorus (TP) and Total Nitrogen (TN) inputs from fertilisation and livestock waste pollution in catchments draining into the watercourses predominantly during large rainfall events (Ecoengineers, 2012).

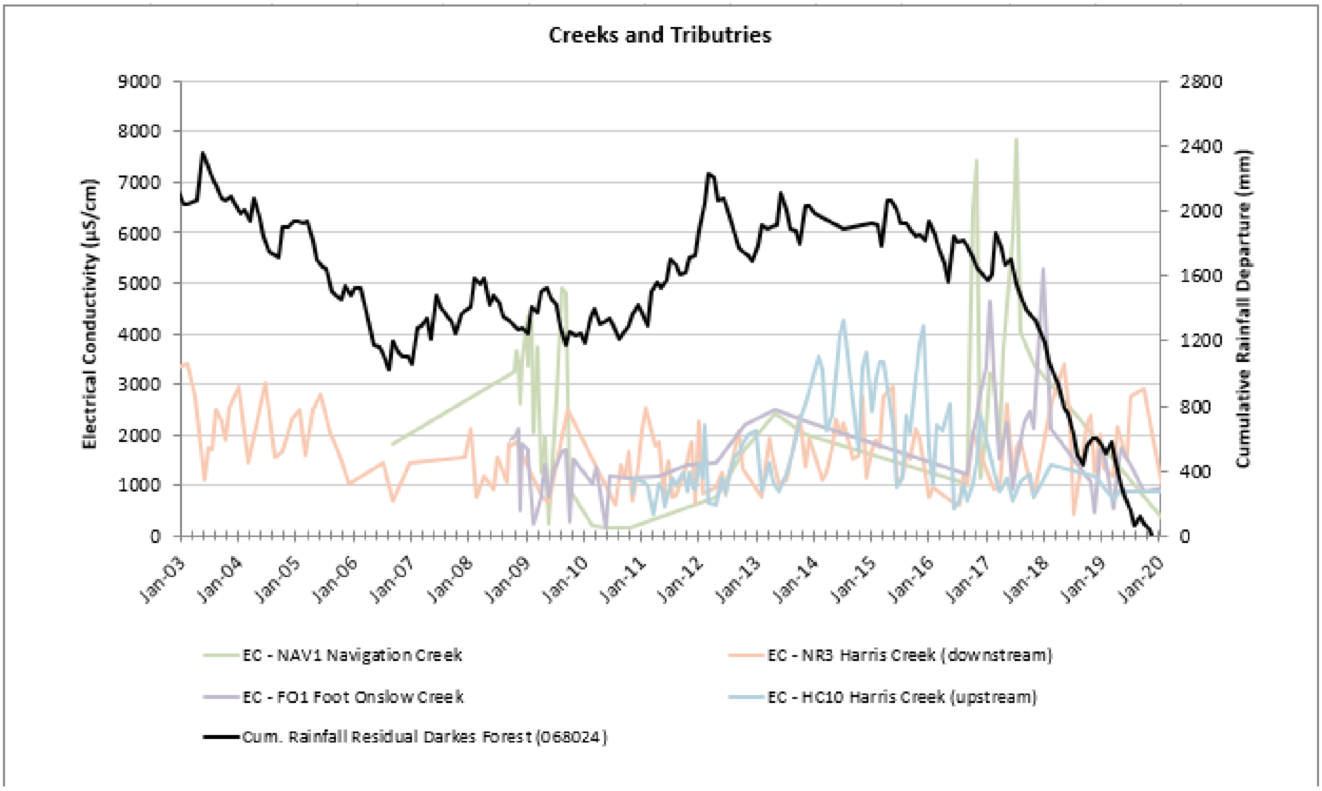

Figure 10 Water Quality in Creeks and Tributaries

4 Predicted Mine Subsidence

Above Longwalls 709 to 711 and 905 in the Bulli Seam, the depth of cover is between 530 m to 750 m. Watercourses located directly above and within 600 m of the proposed longwall panels, which represents the minimum extent for assessment of valley-related effects, are Navigation Creek, Navigation Creek Tributary 1, Foot Onslow Creek and Harris Creek. The closest river is the Nepean River which is located 1.5 km from the Project. Potential subsidence impacts to the creeks and watercourses directly above and adjacent (within 600 m) to longwalls have been assessed by MSEC (2021).

The maximum predicted total vertical subsidence for the existing, approved and proposed longwalls is 1,550 mm and maximum predicted total tilt is 7 mm/m (MSEC, 2021). Maximum predicted subsidence effects for rivers and third order creeks above or adjacent to the Project are listed in **Table 5**. The maximum predicted subsidence effects on the third order creeks (i.e. Navigation, Foot Onslow and Harris) is 1,400 mm vertical subsidence, comprising a predicted 550 mm upsidence and 800 mm total closure. The maximum predicted subsidence effects on the Nepean River due to the Project is less than 20 mm vertical subsidence, upsidence and closure (MSEC, 2021).

Table 5 Maximum predicted subsidence in Rivers, Creeks and Tributaries

Name	Maximum predicted vertical subsidence (mm)	Maximum predicted upsidence (mm)	Maximum predicted total closure (mm)
Rivers			
Nepean River	<20	<20	<20
Creeks and Tributaries			
Foot Onslow Creek	1400	300	250
Harris Creek	500	350	300
Navigation Creek	950	350	475
Navigation Creek Tributary 1	1350	550	800

The assessment by MSEC (2021) found cracking in the creek bed and fracturing of shallow (10 m to 20 m depth) bedrock for the creeks could develop due to the Project, particularly in areas immediately above the longwall panels. Surface tension cracks are also likely to occur, typically with widths in the order of 25 mm to 50 mm.

MSEC (2021) found localised ponding could develop in some isolated locations. However, there are no predicted reversals of stream grade due to the Project, and no large-scale adverse changes in levels of ponding or scouring of banks along creeks due to subsidence related tilt.

5 Surface Water Impact Assessment

5.1 Stream Flow Impact Assessment

Watercourses may experience dilation fracturing as a result of longwall mining. This is most likely to occur in streams located directly above the mining area. However, impacts can occur outside the mining area at distances up to 400 m outside the longwall, typically this is minor and isolated fracturing (MSEC, 2021). Where fracturing occurs, a portion of stream flow may be diverted via the fracture to the dilated strata below the stream bed resulting in a reduction in water flow. Diversion of surface water flow is more likely to occur during times of low flow as during heavy rainfall the majority of runoff is likely to flow over the fractured bed rather than diverting to the dilated strata below (MSEC, 2021). Therefore, there is the potential to reduce continuity of flow between pools during dry weather.

A total length of 4.2 km of the upper reaches of third order streams, discussed in Section 4, lie above the proposed longwall area with an additional 2.6 km within the Study Area. The Project will not extract from directly beneath or within 600 m of the Nepean River and thus the Nepean River is not expected to experience any fracturing as a result of the Project. Similarly, flows contributed to the Nepean River from the ephemeral watercourses within the Study Area are minimal and thus changes to flow within these streams is expected to have negligible impact on flows within the Nepean River.

Based on previous experience of mining beneath creeks and tributaries within the Southern Coalfield, it is likely that some fracturing will occur along watercourses, particularly those located above or adjacent to the proposed longwalls (MSEC, 2021). However, such watercourses are ephemeral and surface water flows only occur for short periods during and after rainfall events. During the mining of previous longwalls within Appin Area 7 and 9 ephemeral creeks with comparable predicted subsidence movements to those of third order creeks within the Study Area showed no reported observed fracturing that has resulted in surface water flow diversion. The assessment by MSEC (2021) found that although fracturing along streams may occur it is unlikely that there would be a significant loss of surface water yield from the catchment.

Nevertheless, monitoring of these creeks and the Nepean River to assess impacts is proposed (refer to Section 6) and trigger action response plans (TARPs) have been developed to manage impacts should they occur (refer to Section 7).

5.2 Stream Pools Impact Assessment

Longwall mining can result in increased levels of ponding in locations where the mining-induced tilts oppose and are greater than the natural drainage line gradients that exist before mining.

No adverse effect on stream pools is anticipated as a result of subsidence induced tilt due to the low predicted subsidence and the minimal predicted change in stream tilt (7mm/m). The predicted mining-induced tilt for creeks above and adjacent to the proposed longwalls is less than the average gradients with no predicted reversal of stream grade. Therefore, it is unlikely that any large-scale changes to ponding levels will occur, however, it is possible that minor localised increases in ponding could develop (MSEC, 2021). Any impacts resulting from changes in surface water flows due to tilt are expected to be small in comparison to those which occur during natural flooding conditions (MSEC, 2021).

Where dilation fracturing, discussed in Section 5.1, occurs within the pools of ephemeral watercourses a portion of streamflow may be diverted via the fracturing resulting in reduction in water level in the surface water system as they drain via the bed fractures. Small pools have formed naturally along the reaches of ephemeral streams within the Study Area, however, as discussed in Section 5.1, no significant loss of catchment yield is expected as a result of the proposed longwalls.

Furthermore, the Groundwater Impact Assessment (SLR, 2021) found that the Project is not predicted to induce downward seepage or reduced baseflow contributions in surface water bodies, including stream pools, as there is no predicted depressurisation within the upper layers. It is predicted that although the lower seams will be depressurised the depressurisation will not extend upwards and therefore not affect groundwater levels in the upper layers. The subsidence assessment identified the potential for fracturing to develop along the creeks and tributaries due to the mining of the proposed Longwalls 709 to 711 and 905, as discussed in Section 5.1. Fracturing will predominately occur where the creeks and tributaries are located directly above the mining area. Impacts can also occur outside the mining area, with minor and isolated fracturing occurring at distances up to approximately 400 m outside the longwalls, as previously observed at Appin Colliery and elsewhere in the Southern Coalfield. Changes in shallow groundwater as a result of fracturing, dilatation and shear of shallow strata can result in changes to surface water bodies and shallow groundwater, where they are connected.

MSEC (2021) determined that the risk of significant loss of stream flow and water levels within pools due to creek bed fracturing is low. Nevertheless, there is potential for fracturing of creek beds to reduce flows along ephemeral creeks during dry periods or periods of light rainfall. This potential impact will be monitored by:

- Routine inspection of creek lines for signs of fracturing; and
- Monitoring water levels in pools.

Water level monitoring of pools is planned (refer to Section 6.2) and TARPs have been developed to assess the need for management and remediation (refer to Section 7). In the unlikely event of significant impact to stream pools within ephemeral watercourses, remediation would be conducted where remediation is technically feasible and necessary.

5.3 Channel Stability Impact Assessment

Where subsidence induced fracturing or mining induced tilts are significant it is possible that bed and bank stability could be adversely affected with an associated loss of riparian vegetation. However, within the Study Area the predicted subsidence is unlikely to result in widespread impacts on stream stability.

Predicted subsidence impacts are expected to result in only small changes to the stream bed profile. As a result, changes in bed gradients are not likely to cause significant ponding or scouring of the banks. Any potential impacts on streams above and adjacent to the proposed longwalls are therefore expected to be minor and localised. Potential changes in surface water flows due to the Project are expected to be very small in comparison to flows which occur during heavy rainfall.

It is also noted that the streams in the Project Area are not intended to be relocated or reinstated, and that no instream structures are proposed.

Monitoring of creeks for potential instability as a result of mining is proposed (refer to Section 6) and TARPs will be in place to manage impacts should they occur and assess the need for remediation (refer to section 7).

5.4 Water Quality Impact Assessment

The Project is not anticipated to have any significant impacts on surface water quality as a result of mining the proposed longwalls. The Project does not include any direct abstraction of surface water nor is it expected to cause significant changes to flow regime and bank scouring, as outlined above. However, the occurrence of ferruginous springs has been observed occasionally when mining areas of the Bulli Seam, therefore is considered in the following section.

The Project includes associated minor activities on the land surface consisting of monitoring activities, rehabilitation and associated access tracks within the Study Area. Although These access tracks and rehabilitation areas will be managed with best practice runoff controls which comply with the 'Blue Book' (Managing Urban Stormwater: Soils and Construction Vol.1, 4th edition and Vol.2E Mines and Quarries (Landcom, 2004 and DECC, 2008)) to minimise the risk of adverse impacts to water quality of downstream areas. Water quality monitoring in downstream waterways will also be undertaken. With appropriate controls in place, it is considered that these surface activities will have minimal impacts to surface water quality. Ventilation shafts associated with the Project are included under this EP, however, is an activity that will require controls to prevent water quality impacts in the respective areas.

Water quality monitoring is planned on watercourses downstream of the Project Area; and continued monitoring of the Nepean River upstream of the confluences of those watercourses (refer to Section 6.1). TARPs have been developed to assess the need for management and remediation (refer to Section 7).

5.4.1 Ferruginous Springs

Induction or exacerbation of ferruginous/saline springs is believed to result from strata dilation and bed separation leading to increased storage of perched groundwater, especially at and near to the interface between Wianamatta Shale and underlying HBSS. The experience in the Southern Coalfield is that such springs do not occur in terrain where Wianamatta Shale and shale-derived soils do not outcrop (Ecoengineers, 2012).

The interface between the Hawkesbury Sandstone and the Wianamatta Shale sequences appears likely to undergo a mine subsidence-induced permeability enhancement along the sub-horizontal interface between these units due to dilation and bed separation induced by subsidence (Ecoengineers, 2012).

The shale, being marine sediment, continues to contain traces of connate water with an elevated (seawater composition) salt load and a significant load of major cations on cation exchange sites in ratios that are still relatively similar to that of seawater. These are displaced by protons in weakly acidic infiltrating meteoric water, so increases in salinity are predicted to occur from the subcrop of the basal interface between the shale and the underlying Hawkesbury Sandstone. The shale also contains a high concentration of finely disseminated crystalline iron (Fe) and manganese (Mn) oxides (after siderite and rhodocrosite). An elevated dissolved Fe and Mn load, largely due to microbiologically-mediated reductive dissolution of Fe and Mn oxides and oxyhydroxides within the base of the weathered shale during saturation (Lovley and Phillips, 1986), is expected from waters that become stored in the catchment of any spring.

The liberation of contaminants from subsidence induced fracturing in watercourses, with resulting localised and transient water quality impacts, has the potential to impact aquatic biota. This is particularly the case where increased iron precipitation occurs. Streams that are acidic and have low alkalinity are more likely to be impacted as these surface water systems have less buffering capacity against changes to pH (Niche, 2014).

The inducement of ferruginous springs due to mining has been occasionally observed in Bulli Seam mining areas especially along margins of outcropping Wianamatta Shale. As described in the previous Assessment of Water Quality for longwalls 705-710 (Ecoengineers, 2008) ephemeral creeks that overly the Project are more prone to arise or be enhanced due to their position within the Wianamatta Shale formation in the upper reaches. However, mining of previous longwalls within Appin Area 7 and 9 has not led to induction of any detectable ferruginous springs in the walls of the Nepean River or adjacent tributaries. It is therefore considered that there is a low likelihood of ferruginous springs induced by the mining of the proposed Longwalls 709 to 711 and 905.

Although it is possible that ferruginous saline springs may be induced or enhanced in the catchment directly overlying the longwalls, impacts are expected to be minor based on the findings of this assessment and the of the previous assessment of Longwalls 705-710 (Ecoengineers, 2008) and the Assessment of Area 9 Longwalls 901-904 (Ecoengineers, 2012), including the following principles:

- Streams above or adjacent to longwalls are slightly alkaline, as described in **Table 4**, and therefore have a greater buffer capacity against changes to pH;
- The consequence of springs within the ephemeral creeks would be insignificant to ecological health of downstream pools due to the reduced habitat that has resulted from existing effects of local agricultural land uses on stream water quality;
- Ephemeral flows in Harris Creek do not constitute a significant input to downstream rivers; and
- Ephemeral flows in Navigation and Foot Onslow Creeks would have negligible influence on the downstream Nepean River due to the significant distance waters from any springs would need to flow to reach the river.

Furthermore, the arise or enhancement of ferruginous springs are not predicted within the Subsidence Impact Assessment (MSEC, 2021) and Groundwater Impact Assessment (SLR, 2021).

Nevertheless, monitoring of these creeks to assess impacts is proposed (refer to Section 6) and trigger action response plans (TARPs) have been developed to manage impacts should they occur (refer to Section 7).

5.5 Surface Water Related Infrastructure Impact Assessment

5.5.1 Farm Dams

There are 241 farm dams located within and adjacent to the Project Area, 106 of which are located directly above the proposed longwalls. The locations of these farm dams are shown on **Figure 6**.

Farm dams located directly above the proposed mining area could experience cracking in their bases or walls due to mining-induced curvatures and strains. The predicted changes in freeboard for farm dams are small, varying from less than 50 mm to 200 mm. It is unlikely that the dams would experience adverse impacts on the storage capacities due to these small changes in freeboard (MSEC, 2021).

There is extensive experience of mining directly beneath farm dams in the Southern Coalfield, which indicates that the incidence of impacts on these features is low. Farm dams are commonly constructed with cohesive materials in the bases and walls which can absorb the conventional subsidence movements typically experienced in the Southern Coalfield without the development of substantial cracking. Non-conventional movements can result in localised cracking and deformations at the surface and, where coincident with farm dams, could result in adverse impacts (MSEC, 2021).

There are no predicted impacts on surface water bodies due to depressurisation of the coal measures as part of the Project. This is because there is no predicted drawdown from the lower stratigraphic units to the surface due to the Project to induce downward seepage or reduce baseflow contributions, as discussed further in the Groundwater Assessment undertaken by SLR in 2021. These findings are consistent with the impact assessment conclusions for BSO by Heritage Computing (2009).

It is predicted that impact to farm dams from mining Longwalls 709 to 711 and 905 will be unlikely. However, where subsidence results in loss of water from dams due to cracking and/or tilt, these impacts will be managed and compensated in accordance with the *Coal Mine Subsidence Compensation Act 2017* and/or an alternate water supply would be provided as required by Condition 14 of the BSO Project Approval (Compensatory Water Supply) in consultation with the landowner.

5.5.2 Culverts

Three culverts exist in the vicinity of the Project that convey flows under the Main Southern Railway embankment located to the east of the proposed longwalls. No culverts are located within the extents of the proposed longwalls. The railway culverts consist of a brick arch culvert and two concrete culverts. The culverts are expected to have already experienced vertical subsidence up to 1350 mm due to previous mining, and only low level additional movements are predicted as a result of the Project with a maximum predicted additional vertical subsidence of 150 mm. These small additional vertical movements are not considered likely to result in significant impacts to the culverts. Subsidence related management strategies are captured within the subsidence assessment by MSEC (2021).

5.6 Surface Gas Emissions Impact Assessment

Longwall mining can result in fracturing of the strata above the extracted area and/or relative movement of strata along pre-existing joint planes. This may result in the liberation of methane and other gases from the strata to the surface. The emission of such gases typically occurs within deep river valleys, although some gas emissions have also been observed in creeks and water bores. If substantial gas emissions occur at the surface, there is potential for aquatic and terrestrial dieback. Such dieback is rare and has only occurred in one location in the Southern Coalfield.

Gas emissions typically occur in isolated locations and are most vigorous when an area is directly mined beneath. However, gas emissions do occur in areas that have not been directly mined beneath. Gas emissions have previously been observed during the mining of Tower Longwalls 17 and 20 and Appin Longwalls 701-703 within the Nepean River indicated by both visual observation of gas release and dissolved oxygen (DO) sag (Ecoengineers, 2012). However, those dissolved oxygen sags could be principally attributed to inputs of dissolved iron from Cataract River in Nepean River and/or pulses of available nutrients in stormwater runoff from agricultural land on both sides of Nepean River (Ecoengineers, 2012). Nevertheless, some minor sagging attributable to reduction in dissolved oxygen in the river due to microbiological consumption of dissolved methane around gas releases by natural aerobic methanotrophic could not be ruled out. End of Panel reports of the most recent extraction area, Appin Area 9 longwalls 901-902, found that minor gas emissions were identified at a number of gas release zones in the Nepean River as a consequence of longwall mining, although the impacts are considered to be minor (HGEO, 2019).

Considering the previous observations regarding the potential for surface gas emissions and the nature of streams within the Study Area, it is considered unlikely that the Project will result in significant impacts to watercourses due to the release of surface gas emissions. The Project is located 1.5 km from the Nepean River where observed gas release zones are located. Previous DO sagging due to mining of longwalls has been a result of mining within close proximity to the river valley with no substantial impacts noted within ephemeral waterways. Creeks within the Study Area are ephemeral and predominantly within the upper reaches of the catchment. Hence, if gas releases were to occur into the water column there is insufficient time for any substantial amount of gas to dissolve into the water (HECONS, 2019). Thus, due to the nature of flows within these areas it is expected that if gas emissions occur the impacts would be negligible. Similarly, no potential surface gas emissions are predicted within the subsidence report.

6 Surface Water Monitoring

Appin Mine operates under the approved Water Management Plan (2020) which has been prepared to detail the control measures, compliance procedures, monitoring programs, evaluation protocols, notification and communication processes for water management for Appin Mine.

A Subsidence Management Plan (SMP) or EP are then developed to describe the measures and procedures which are site specific for the active mining area (currently Appin Area 9 Longwalls 901-904 EP (2014)).

6.1 Surface Water Quality Monitoring

Baseline water quality monitoring is occurring in the Nepean River upstream and adjacent to the proposed Longwalls 709 to 711 and 905. Monitoring also occurs in creeks within the Study Area in Harris Creek, Navigation Creek and Foot Onslow Creek.

Existing baseline water quality monitoring is discussed in Section 3.

A series of control sites at tributaries of the Nepean River are utilised to allow for a more quantitative understanding of any effects in the Nepean River which may be related to creeks outside the Longwalls 709 to 711 and 905 mining area, and provide a means of ensuring that the TARPs for the established impact sites are reasonable and not triggered by upstream effects unrelated to the mining of the proposed longwalls. A monitoring point (NR4) is included to assess the influence of any potential impacts within Harris Creek on the Nepean River.

The location, parameters and frequency of monitoring points considered relevant to this Project are described in **Table 6**. However, current monitoring within the Nepean River undertaken as part of the existing WMP should continue as required.

Table 6 Longwall 709 to 711 and 905 Surface Water Quality Monitoring

Location	ID	Frequency	Parameters
Nepean River	Upstream and at Junctions: NR110 SW2 NR4 NR5 NR8 NR10 NR40 Adjacent: NR12 NR13 Downstream: NR50	• Monthly baseline prior to mining • Monthly observations and field analysis during mining • Monthly detailed laboratory analysis during mining • Monthly monitoring for 2 years post mining (or as otherwise required/approved) • If required as a result of assessment of mining impacts	Field Measurements of: - Temperature - pH - ORP - DO - EC - Time - General Comments - Photo records Laboratory analysis of: - pH - EC - SO_4 filtered - Fe total - Na filtered - K filtered - Ca filtered - Cl filtered - DOC - Pb filtered - Ni filtered - Zn filtered - Fe filtered - Mn filtered - As filtered - Br filtered - Cu filtered - I filtered - Se filtered - NO_x-N - NH_3-N - TKN - TP - TRP - TDS - CH_4* - Trace Phenols* - Sulfide*
Navigation Creek	NAV1	• Monthly monitoring prior to mining of longwall underlying watercourses or mining of any immediately adjacent longwall • Monthly monitoring following the development of incremental subsidence for each longwall that will impact on the feature	
Foot Onslow Creek	FO1		
Harris Creek	HC10 NR3		

** Analytes tested at closest downstream sample site following Level 2 and above trigger for gas release*

6.2 Surface Water Flow and Level Monitoring

Flow monitoring within the Nepean River is currently undertaken upstream and downstream of the proposed longwalls via Maldon, Menangle and Broughtons Pass Weirs. Water levels and observational impacts in the Nepean River are also monitored. Observational monitoring of creeks within the Study Area should also be undertaken.

The location of the Maldon, Menangle and Broughtons Pass gauging sites is included in **Figure 4**. These flow monitoring stations are ideally located on the Nepean River, being directly upstream and downstream of the approved BSO footprint. Flow monitoring on the Cataract River at Broughtons Pass Weir measures the flow of the major tributary input to Nepean River between the two Nepean River flow stations.

The Longwall 707-710 Environmental Management Plan (IMC, 2015) and Area 9 Longwalls 901-904 WMP (2014) provides details of the proposed data analysis and approach associated with Areas 7 and 9 flow and water level monitoring. Daily flow records for Maldon, Menangle and Broughtons Pass weirs from 1990 have been assessed in order to study the dry weather recessions in the Nepean River adjacent to the proposed mining areas. The difference in flows should be equivalent to runoff from all catchments between these two weirs responding to local rainfall minus any abstractions by licensed pumps in the River.

The approach to monitoring of flow for the longwalls is proposed to be the same as for mining of the previous Appin Area 7 and 9 longwalls.

The Nepean River is a ‘gaining river’ in terms of surface water - groundwater interaction. The potential for infiltration of water into the groundwater system is very low as the Nepean River lies in a well incised gorge which represents the regional low point in the piezometric surface. The potential for sub-bed diversion of surface water is very low as the Nepean River is flooded and the gradient is very flat, significantly removing the effects of gravity to force surface flow through any fracture network that develops. Water levels in the Nepean River and its tributaries are monitored using observations and measured benchmarks. The water level is recorded before, during and after mining and is assessed against catchment rainfall and discharges from the WaterNSW controlled weirs. This method of monitoring has been used for the previous Appin Areas 7 and 9 longwalls with no impacts to the water levels of the Nepean River observed during the period of extraction. Monitoring of water levels currently undertaken within the Nepean River should continue throughout the Project.

No water level monitoring is currently undertaken within the creeks and tributaries, specifically Navigation Creek, Foot Onslow Creek and Harris Creek. It is recommended that water level monitoring be established at sites shown in **Figure 11** and described in **Table 7**, and be undertaken prior to mining and following the development of incremental subsidence. Due to the ephemeral nature of creeks within the Study Area, continuous water flow monitoring is problematic. The potential impact of creek bed fracturing on environmental flows will be monitored via regular inspection for the presence of fracturing in the stream bed and observation of water levels within pools. No suitable pools for automated monitoring were identified on Navigation and Foot Onslow Creeks.

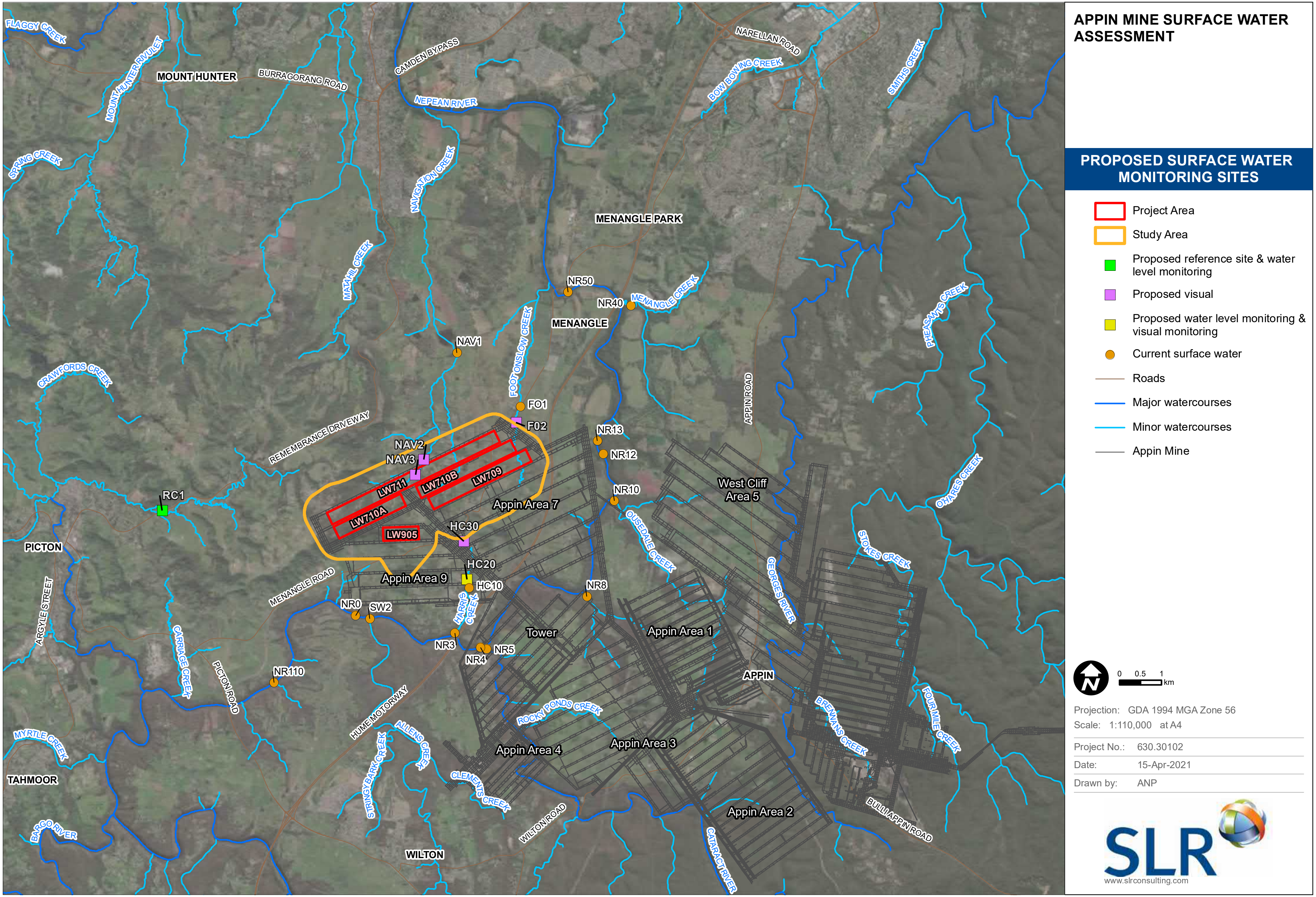

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Table 7 Longwall 709 to 711 and 905 Surface Water Flow and Level Monitoring

Location	ID	Frequency	Parameters
Nepean River	Water Level Monitoring: continue current monitoring. Water Flow Monitoring: • Maldon Weir • Broughtons Pass Weir • Menangle Weir	• Data sourced from Water NSW	• River flows at weirs
Navigation Creek	NAV1, NAV2, NAV3	• Prior to mining of longwall underlying watercourses or mining of any immediately adjacent longwall, and following the development of incremental subsidence for each longwall that will impact on the feature; • Monthly measurement of pool levels; and • Annual inspection (visual assessment) of creek line condition.	• Measurement of pool water levels # compared with baseline (Harris Creek only); • Inspection for potential fracturing for observable loss of surface water flow (Navigation, foot Onslow and Harris Creeks); and • Visual assessment as described in Section 6.3 below.
Foot Onslow Creek	FO1, FO2		
Harris Creek	HC20, HC30		
Racecourse Creek (Reference Site)	RC1		

 # Where a suitable benchmark exists

6.3 Observational Monitoring of Watercourse Condition

Implementation of observational monitoring of watercourse condition is recommended prior, during and following mining of the proposed longwalls. Assessment should include:

- Erosion/sedimentation compared with baseline;
- Signs of impacts (e.g. cracking, vegetation changes, increased erosion, changes in water colour etc);
- Impacts determined from comparing photo points taken prior to, during and post mining;
- Iron or salinity staining (e.g. orange or white staining in water or on banks/seeps);
- Water cloudiness; and
- Evidence of springs.

Monitoring should be undertaken along Navigation Creek, Foot Onslow Creek and Harris Creek within the mining area (including a 600m buffer) annually (where access permits), with photo points at locations such as: NAV1, NAV2, NAV3, FO1, FO2, HC10, HC20, HC30, NR3 (**Figure 11**).

A reference site should be established in a similar ephemeral creek in order to assist in distinguishing natural and mining induced changes. Monitoring may be undertaken at a historical monitoring site within Racecourse Creek (RC1), see **Figure 11**.

7 Management and Mitigation Strategies

The predicted impacts for the Nepean River, Navigation Creek, Foot Onslow Creek and Harris Creek and other watercourses and drainage lines within the area are nil to negligible and mitigation measures are unlikely to be required for any of these predicted impacts.

Where there are impacts to farm dams these would be managed and compensated in accordance with the C*oal Mine Subsidence Compensation Act 2017* and/or an alternate water supply would be provided in consultation with the landowner as required by Condition 14 of the BSO Project Approval (Compensatory Water Supply).

TARPs have been developed to manage potential impacts to surface water in the Project Area. IMC will review the need to implement additional management and mitigation measures during routine monitoring and during the finalisation of BFMP's with affected landholders.

7.1 Trigger Action Response Plan (TARP)

A TARP has been developed for the management of surface water within the Project. The primary goal of this TARP is to monitor risks and then mitigate, control or eliminate the risk using the appropriate management action. The TARP is provided in **Table 8**.

It is recommended that, following commencement of the Project, water quality TARPs for pH, EC, DO, Total Fe and Total Mn be implemented for the proposed monitoring sites based on the principles described in **Table 8**. However, both the upstream (NR110) monitoring site and a series of sites within tributaries of the Nepean River are utilised to indicate perturbation at the proposed Longwall 709 to 711 and 905 impact monitoring sites within the Nepean River. This provides a means of distinguishing upstream effects unrelated to the mining of the proposed longwalls. Hence, the following premise should apply:

- A TARP at River site NR0 should only be considered to have been triggered whenever a two standard deviation change (from the long term mean) is not exhibited for the same parameter at the upstream site NR110.
- A TARP at River site NR4 should only be considered to have been triggered whenever a two standard deviation change (from the long term mean) is not exhibited for the same parameter at the upstream sites NR110 or SW2 (monitors for upstream perturbation from Allens Creek).
- A TARP at River site NR12 and NR13 should only be considered to have been triggered when an equivalent change (from the long term mean) in excess of two standard deviations is not exhibited for the same water quality analyte at the upriver sites; NR110, SW2, NR5, NR8 or NR10 (monitors upstream perturbation from Allens Creek, Cataract River, Elladale Creek and Ousedale Creek).
- A TARP at River site NR50 should only be considered to have been triggered when an equivalent change (from the long term mean) in excess of two standard deviations is not exhibited for the same water quality analyte at the upriver sites; NR110, SW2, NR5, NR8, NR10 or NR40 (monitors upstream perturbation from Allens Creek, Cataract River, Elladale Creek, Ousedale Creek and Menangle Creek).

Table 8 Appin Proposed Longwalls 709 to 711 and 905 Trigger Action Response Plan (TARP)

Monitoring	Trigger	Action
Surface Water Quality		
Nepean River Upriver Site N110 will be used for cross-checking upriver perturbation impacting the proposed longwall monitoring sites. Control Site: N110 (Upstream perturbations) SW2 (Upstream perturbations from Allens Creek) NR5 (Upstream perturbations from Cataract River)	**Level 1**[1] Impact monitoring sites: • pH reduction greater than 1 standard deviation but less than 2 standard deviation from pre-mining mean resulting from the mining for two consecutive months • DO reduction greater than 1 standard deviation but less than 2 standard deviation from pre-mining mean resulting from the mining for two consecutive months • Identification of strata gas plume of flow rate <3000 L/min [2] • Trend analysis (completed in End of Panel Report) shows deviation from baseline post mining.	• Continue monitoring program; • Investigate if impact is caused by or associated with mining; • Report impacts to key stakeholders; and • Summarise impacts and record.

Monitoring	Trigger	Action
NR8 (Upstream perturbations from Elladale Creek) NR10 (Upstream perturbations from Ouesdale Creek) NR40 (Upstream perturbation from Menangle Creek) Impact Sites: NR0 NR4 (assess influence from Harris Creek) NR12 NR13 NR50 **Creeks and Tributaries** Impact Sites: NAV1 FO1 HC10	**Level 2**[1] Impact monitoring sites: • pH reduction greater than 2 standard deviation from pre-mining mean resulting from the mining for two consecutive months • DO reduction greater than 2 standard deviation from pre-mining mean resulting from the mining for two consecutive months • EC increases greater than 2 standard deviation from pre-mining mean resulting from the mining for two consecutive months • Identification of strata gas plume of flow rate >3000 L/min[2] • Trend analysis (completed in End of Panel Report) shows significant deviation from baseline post mining.	Actions as stated for Level 1 plus: • Review monitoring program • Notify relevant specialists (South32 IMC) and seek advice on Corrective Management Actions (CMAs) • Develop and implement CMAs if necessary and approved Gas Emission Plume: • Estimate gas emission flow rates. Re-estimate should significant change be observed • Take sample of plume (if possible) for: - chemical composition - dissolved methane from exactly above gas plume and at established downriver monitoring sites - dissolved sulphide and total phenols from exactly above gas plume and at nearest downriver monitoring site(s)

Monitoring	Trigger	Action
NR3	**Level 3**[1] Impact monitoring sites: Level 2-type reduction in water quality resulting from the mining observed for six consecutive months	Actions as stated for Level 2 plus: • Notify DPIE, DPIE Water & Resource Regulator and any other relevant specialist • Consultation with key stakeholders • Collect laboratory samples and analyse for: – pH, EC, Total Fe and Mn – Suite of Filterable metals – Dissolved methane, sulphide and total phenols (if relevant) • Develop any CMAs as soon as practically possible (pending stakeholder availability) and seek any approvals required to implement • Review the relevant TARP and Management Plan in consultation with key stakeholders
Surface Water Level and Flow		
Nepean River Visual observations along the Nepean River adjacent to the active mining area	**Level 1**[1] Observation of areas of dry and/or flooded riverbed in comparison to baseline observations and flows, for less than two consecutive months.	• Continue monitoring program • Investigate if impact is caused by or associated with mining • Report impacts to key stakeholders • Summarise impacts and record

Monitoring	Trigger	Action
	Level 2(1) Observation of areas of dry and/or flooded riverbed in comparison to baseline observations and flows, for more than two consecutive months.	Actions as stated for Level 1 plus: • Review monitoring program • Notify relevant specialists (South32 IMC) and seek advice on CMAs • Develop and implement CMAs if necessary and approved
	Level 3(1) Observation of areas of dry and/or flooded riverbed in comparison to baseline observations and flows, for six consecutive months.	Actions as stated for Level 2 plus: • Notify relevant government agencies, other resource managers and relevant technical specialists and seek advice on any CMA required • Site visit with key stakeholders if required • Develop any CMAs as soon as practically possible (pending stakeholder availability) and seek any approvals required to implement • Review the relevant TARP and Management Plan in consultation with key stakeholders
Creeks and Tributaries Visual observations along: Navigation Creek Foot Onslow Creek Harris Creek	**Level 1**(1) • Fracturing with no observable loss of surface water flow • Fracturing with no reduction in pool water level when compared to baseline period	• Continue monitoring program • Investigate if impact is caused by or associated with mining • Report impacts to key stakeholders • Summarise impacts and record

SLR

Monitoring	Trigger	Action
	Level 2[1] • Fracturing resulting in loss of surface flow in some creeks or tributary • Fracturing resulting in water loss from some permanent pools • Reduced water retention time in pools	Actions as stated for Level 1 plus: • Review monitoring program • Notify relevant specialists (South32 IMC) and seek advice on Corrective Management Actions • Develop and implement Corrective Management Actions if necessary and approved
	Level 3[1] • Fracturing resulting in total loss of surface flow in all sections of a creek or tributary • Fracturing resulting in total water loss from all permanent pools in the mining area • Reduced water retention time in all pools in the mining area	Actions as stated for Level 2 plus: • Notify relevant government agencies, other resource managers and relevant technical specialists and seek advice on any CMA required • Site visit with key stakeholders if required • Develop any CMAs as soon as practically possible (pending stakeholder availability) and seek any approvals required to implement • Review the relevant TARP and Management Plan in consultation with key stakeholders
Surface Water Creek Stability		
Creeks and Tributaries Observations made in: Navigation Creek Foot Onslow Creek Harris Creek	**Level 1**[1] • Fracturing resulting in minimal change in stream bed or bank stability compared to baseline. • No impact on turbidity	• Continue monitoring program • Investigate if impact is caused by or associated with mining • Report impacts to key stakeholders • Summarise impacts and record

Monitoring	Trigger	Action
	Level 2[(1)] • Fracturing resulting in minor decrease in stream stability compared to baseline period. • Minor increase in turbidity	Actions as stated for Level 1 plus: • Review monitoring program • Notify relevant specialists (South32 IMC) and seek advice on CMAs • Develop and implement Corrective Management Actions if necessary and approved
	Level 3[(1)] • Fracturing resulting in major decrease in stream bed or bank stability compared to baseline. • Significant increase in turbidity	Actions as stated for Level 2 plus: • Notify relevant government agencies, other resource managers and relevant technical specialists and seek advice on any CMA required • Site visit with key stakeholders if required • Develop any CMAs as soon as practically possible (pending stakeholder availability) and seek any approvals required to implement • Review the relevant TARP and Management Plan in consultation with key stakeholders
Surface Water Other Observations		
Creeks and Tributaries Observations made in: Navigation Creek Foot Onslow Creek Harris Creek	**Level 1**[(1)] Minor increase iron staining, algal growth, or other visible water related parameters resulting from the mining for consecutive months determined by comparing baseline photos with photos during the mining period.	• Continue monitoring program • Investigate if impact is caused by or associated with mining • Report impacts to key stakeholders • Summarise impacts and record

Monitoring	Trigger	Action
	Level 2[1] Notable increase iron staining, algal growth, or other visible water related parameters resulting from the mining for consecutive months determined by comparing baseline photos within photos during the mining period.	Actions as stated for Level 1 plus: • Review monitoring program • Notify relevant specialists (South32 IMC) and seek advice on Corrective Management Actions • Develop and implement Corrective Management Actions if necessary and approved
	Level 3[1] Significant increase iron staining, algal growth, or other visible water related parameters resulting from the mining for consecutive months determined by comparing baseline photos within photos during the mining period.	Actions as stated for Level 2 plus: • Notify relevant government agencies, other resource managers and relevant technical specialists and seek advice on any CMA required • Site visit with key stakeholders if required • Develop any CMSa as soon as practically possible (pending stakeholder availability) and seek any approvals required to implement • Review the relevant TARP and Management Plan in consultation with key stakeholders

(1) These may be revised in consultation with DPIE and Other key stakeholders.
(2) If strata gas emission plumes are detected – particularly coinciding with low river flow and significant gas evolution.

8 Conclusions

IMC are proposing to continue extracting coal from Longwalls 709, 710A, 710B, 711 in Appin Area 7 and Longwall 905 in Area 9 and require EP approval prior to the commencement of secondary extraction. A Surface Water Assessment has been undertaken to predict potential impacts to the local surface water system to support the EP approval process.

Based on the assessment, there is expected to be:

- A low risk of broadscale fracturing of local creek beds within the Study Area. Some localised fracturing is probable, however no significant loss of catchment yield is anticipated. It is possible that environmental flows during periods of low rainfall could be impacted, and this potential impact will be monitored by pool level monitoring. No fracturing is anticipated within the Nepean River;
- No adverse effect on stream pools as a result of subsidence induced tilt are anticipated as a result of the Project with no reversal of stream grades; some localised ponding may occur however effects are expected to be negligible;
- Although impacts to groundwater are expected, the Project is not predicted to induce downward seepage or reduced baseflow contributions in surface water bodies, including stream pools, as there is no predicted depressurisation from the upper layers to deep strata. It is predicted that although the lower seams will be depressurised the depressurisation will not extend upwards and therefore not affect groundwater levels in the upper layers (SLR, 2021);
- Changes in shallow groundwater as a result of fracturing, dilatation and shear of shallow strata can result in changes to surface water bodies and shallow groundwater, where they are connected.
- No significant adverse impacts to channel stability are anticipated as subsidence is predicted to have minor impacts on stream bed profile;
- No significant impacts on surface water quality are predicted to occur as the Project includes only minor surface activities comprising vent shafts and associated access tracks, the Project does not include direct abstraction of surface water, and subsidence is not expected to cause significant changes to flow regime and bank scouring;
- The likelihood of the occurrence or enhancement of ferruginous springs in considered to be low due to previous mining experience within the area, however, if this were to occur the effects are anticipated to be minor; and
- Any impacts due to gas release as a result of mining the proposed longwalls are likely to be minor due to previous observations regarding potential surface gas emissions and the nature of creeks above and adjacent to the proposed longwalls.

A Water Management Plan (WMP) will be prepared in consultation with Biodiversity Conservation and Science Directorate, WaterNSW and DPIE Water in accordance with Condition 5(h) of the BSO Approval. It is recommended that the WMP include the recommendations in this assessment.

9 References

AGL, 2013. *Hydrogeological Summary of the Camden Gas Project area*, January 2013.

AGL, 2018. Groundwater Management Plan, July 2018.

Bureau of Meteorology (BoM), 2013. Weather and Climate data, http://www.bom.gov.au/climate/data, Accessed March 2020.

DPIE, 2016. *Water Sharing Plan Greater Metropolitan Region Unregulated River Water Sources: Background document for amended plan 2016 incorporating Kangaroo River Management Zone.* Department of Industries – Water Report June 2016.

DPIE, 2020. *Water in NSW: Hawksbury Nepean, https://www.industry.nsw.gov.au/water/basins-catchments/snapshots/hawksbury-nepean, Accessed December 2020.*

Ecoengineers, 2008. *Assessment of Surface Water Flow and Quality Effects: Appin Colliery Longwalls 705 to 710*. Report May 2008

Ecoengineers, 2012. *Assessment of Surface Water Flow and Quality Effects: Appin Colliery Longwalls 901 to 904*. Report June 2012

Heritage Computing 2009, *Bulli Seam Operations Groundwater Assessment*, A Hydrogeological Assessment in support of the Bulli Seam Operations Environmental Assessment for Illawarra Coal Holdings Pty Ltd, HC2009/5, July 2009

HGEO, 2019. *Appin Mine: Area 9 Longwall 902 End of Panel Surface Water and groundwater monitoring review.* Report August 2019.

Lovely D. R., and Phillips E. J. P., 1986. *Organic matter materialization with the reduction of ferric iron in anaerobic sediments*. Appl. Environ. Microbiol. 51:683-689

HECONS, 2019. *Tahmoor Mine Extraction Plan LW W1 – W2 Surface Water Technical Report (DRAFT).* TCCO Report, dated May 2019.

IMC, 2014. *Appin Area 9 Longwalls 901 to 904 Extraction Plan: Annex C Water Management Plan.* Report, dated September 2014.

IMC, 2015. *Longwall 707 to 710 Environmental Management Plan*. Report, dated August 2015.

IMC, 2020. *Appin Mine Water Management Plan.* Report number IMCMP0235, dated July 2020.

MSEC 2021; Subsidence Predictions and Impact Assessments, Subsidence Predictions and Impact Assessments for the Natural and Built Features due to the Extraction of the Proposed Longwalls 709, 710A, 710B, 711 and 905 at Appin Colliery, prepared for Illawarra Metallurgical Coal, dated February.

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

Niche, 2014. *Tahmoor North Longwalls 21 to 37 Aquatic Ecology Assessment*. Report December 2014.

SILO-Australian climate data from 1889 to yesterday, rainfall and Potential Evaporation, https://www.longpaddock.qld.gov.au/silo/point-data, Accessed November 2020.

SLR Consulting, 2021. *Appin Mine Extraction Plan: Groundwater Impact Assessment.* Report April 2021.

State of Queensland, 2020. SILO (Scientific Information for Land Owners) database of Australian climate data. © The State of Queensland 1995 - 2020, https://silo.longpaddock.qld.gov.au, Accessed March 2020.

Western Sydney University (WSU), 2017. *The Health of River Systems: Hawkesbury-Nepean River Watch Education and Sustainability Tools,* https://www.westernsydney.edu.au/harwest/harwest, Accessed December 2020.

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Appendix C – Hydrographs

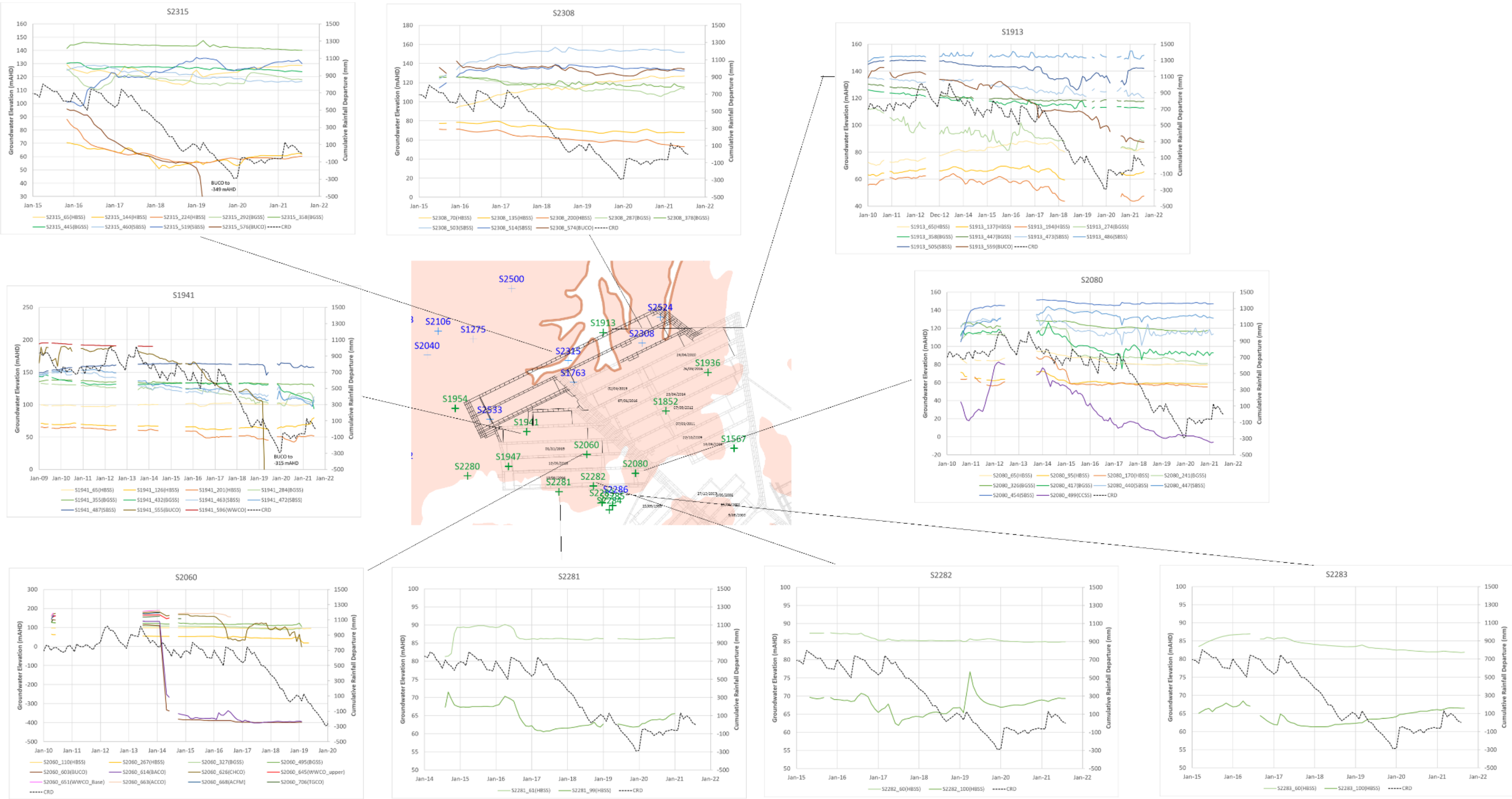

Figure 4 Bore locations and Hydrographs

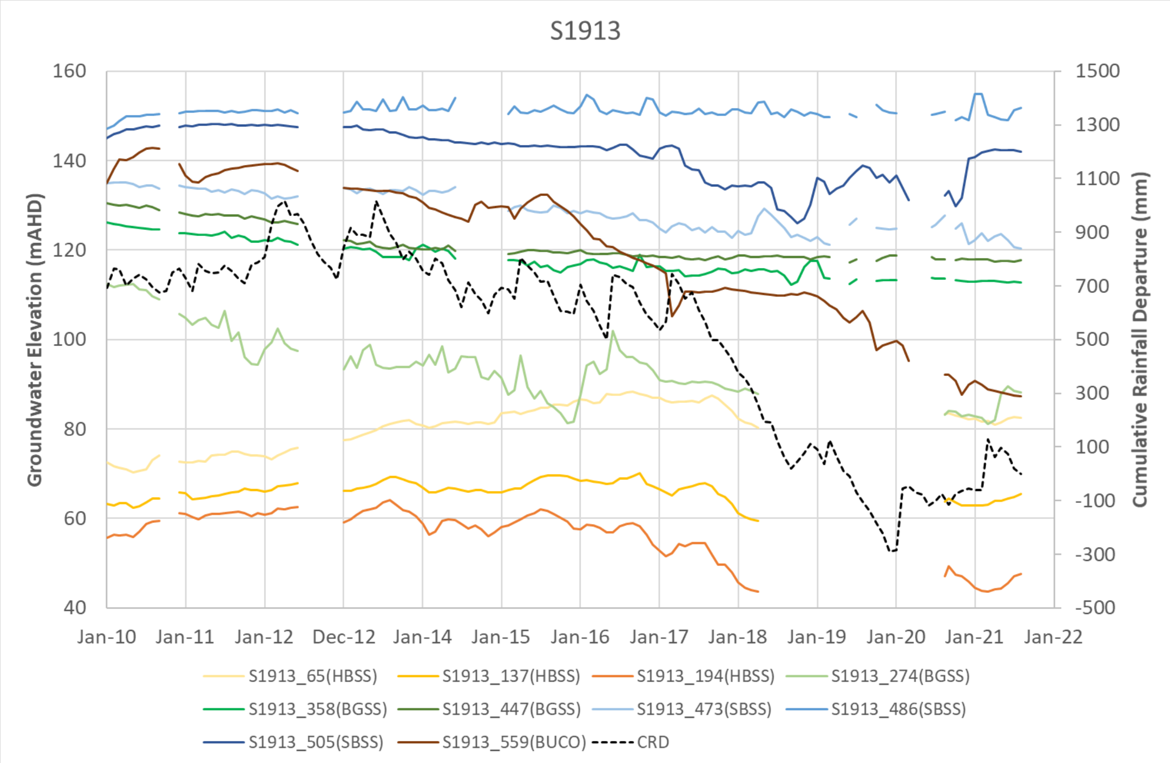

Figure 5 Hydrograph – S1913

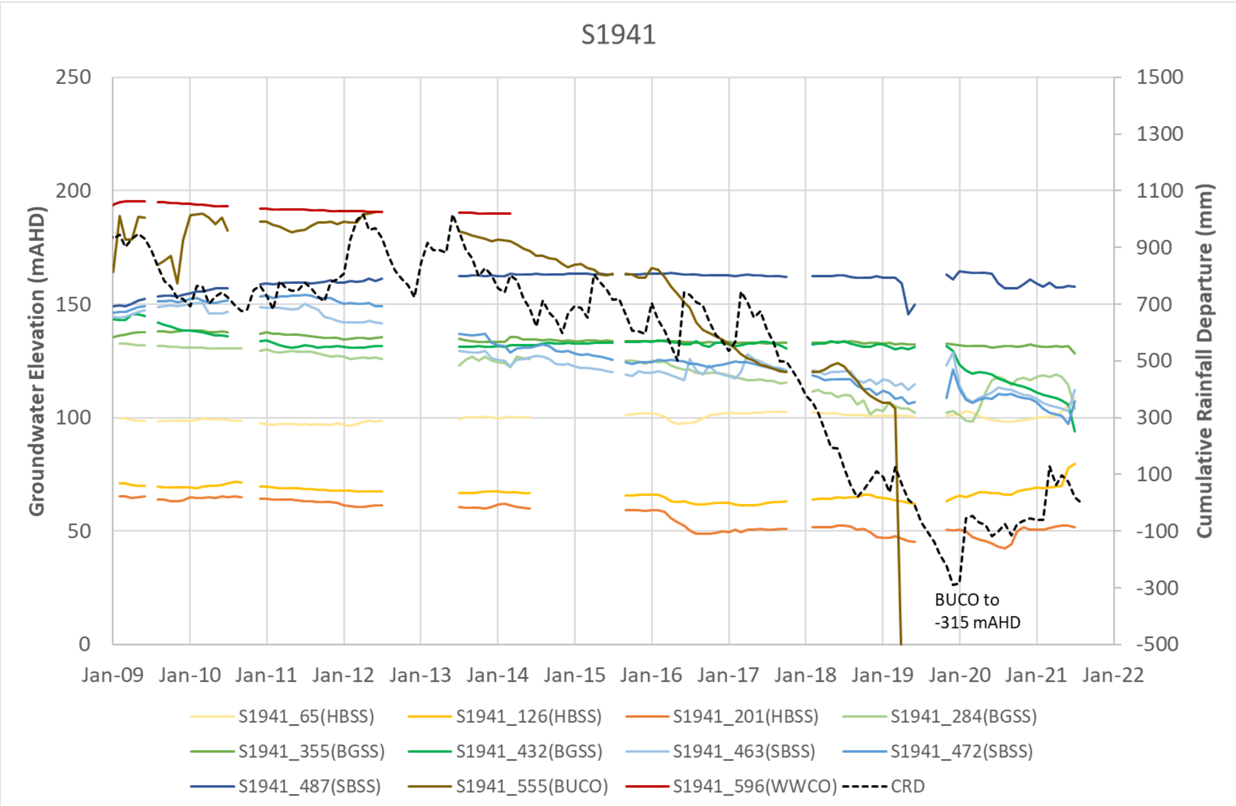

Figure 6 Hydrograph – S1941

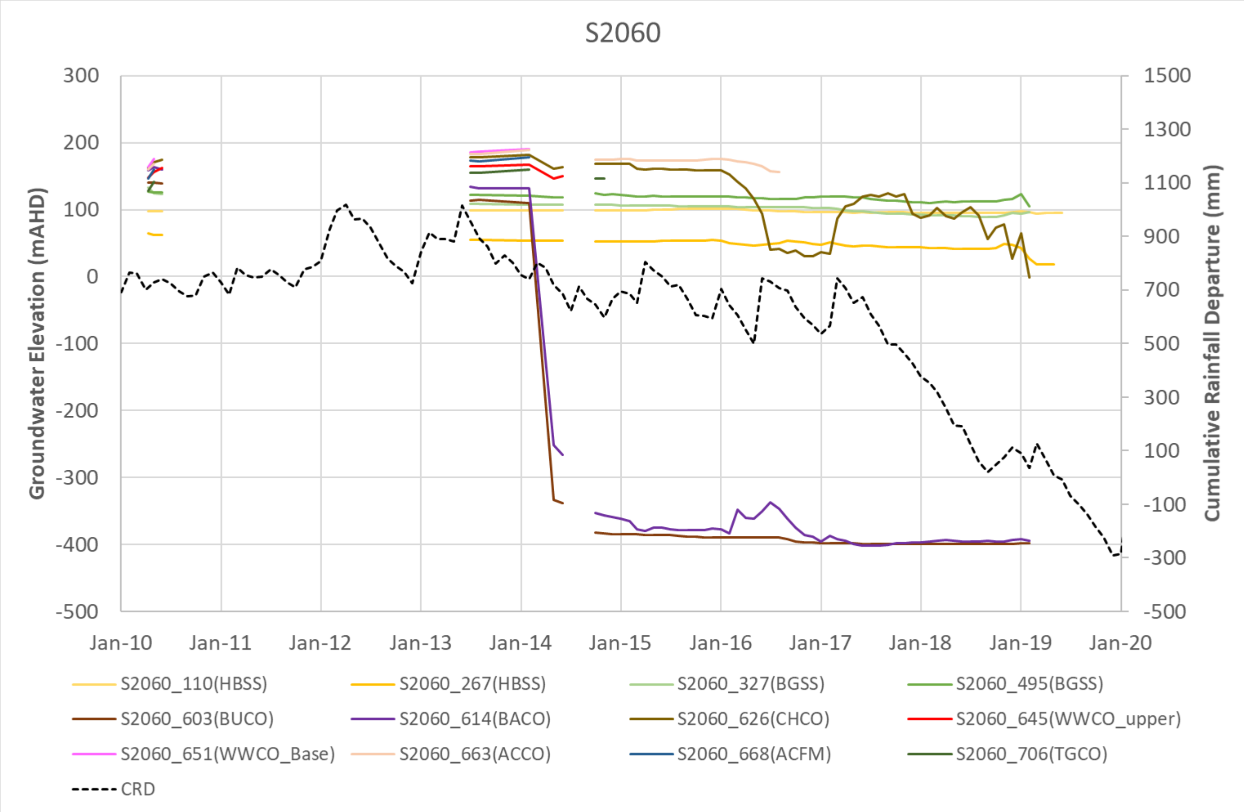

Figure 7 Hydrograph – S2060

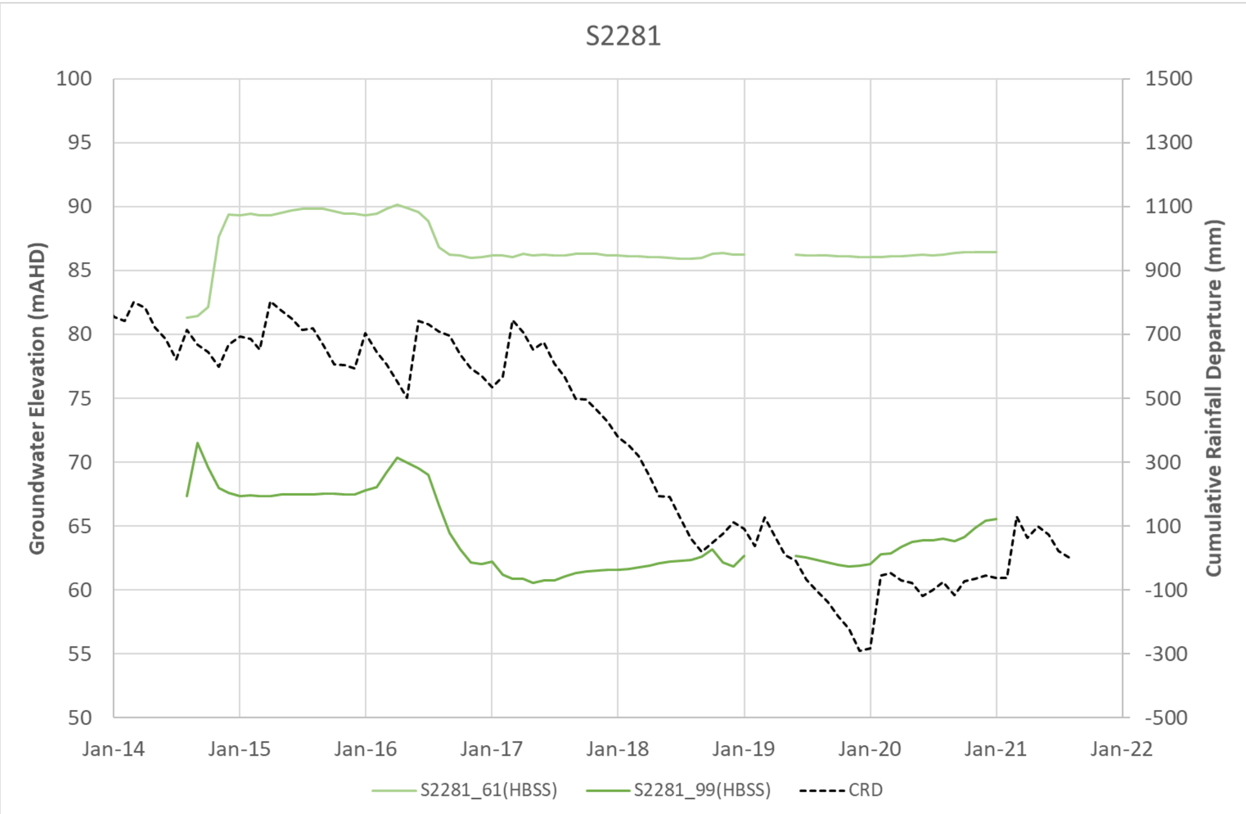

Figure 8 Hydrograph – S2281

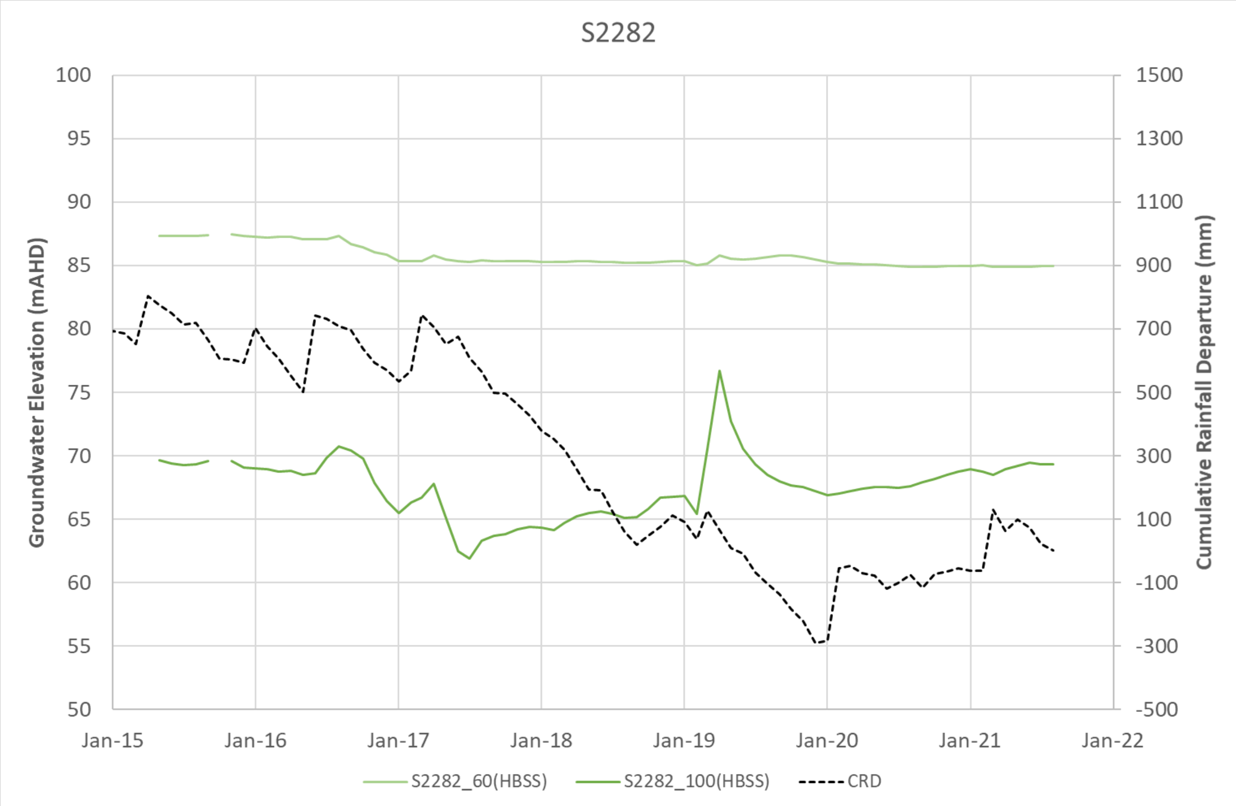

Figure 9 Hydrograph – S2282

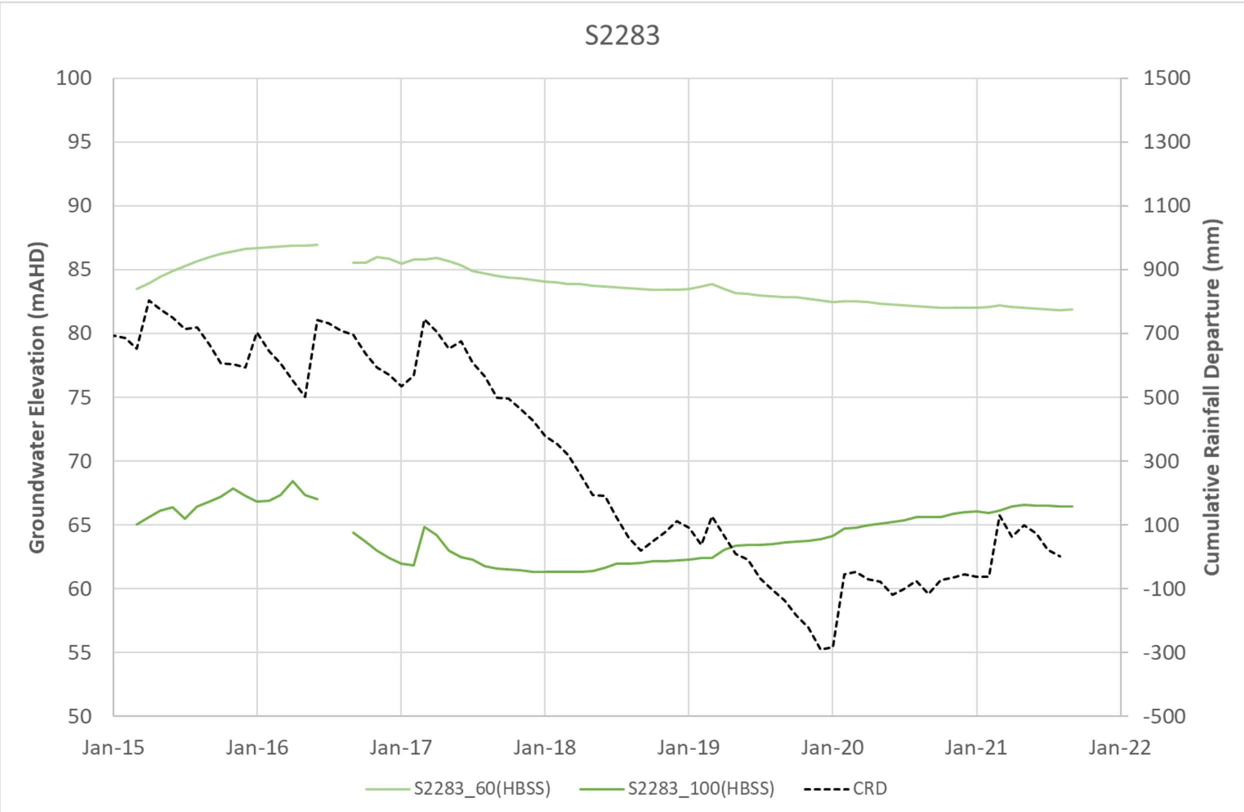

Figure 10 Hydrograph – S2283

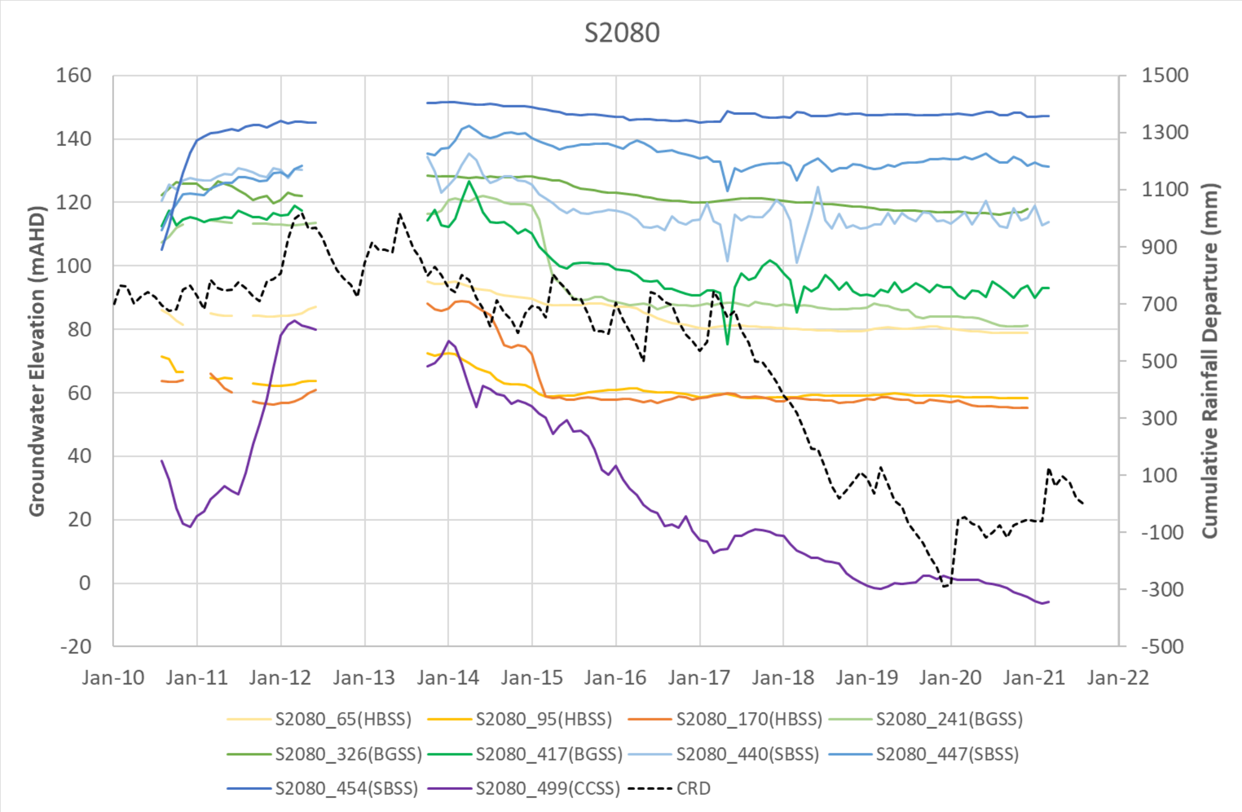

Figure 11 Hydrograph – S2080

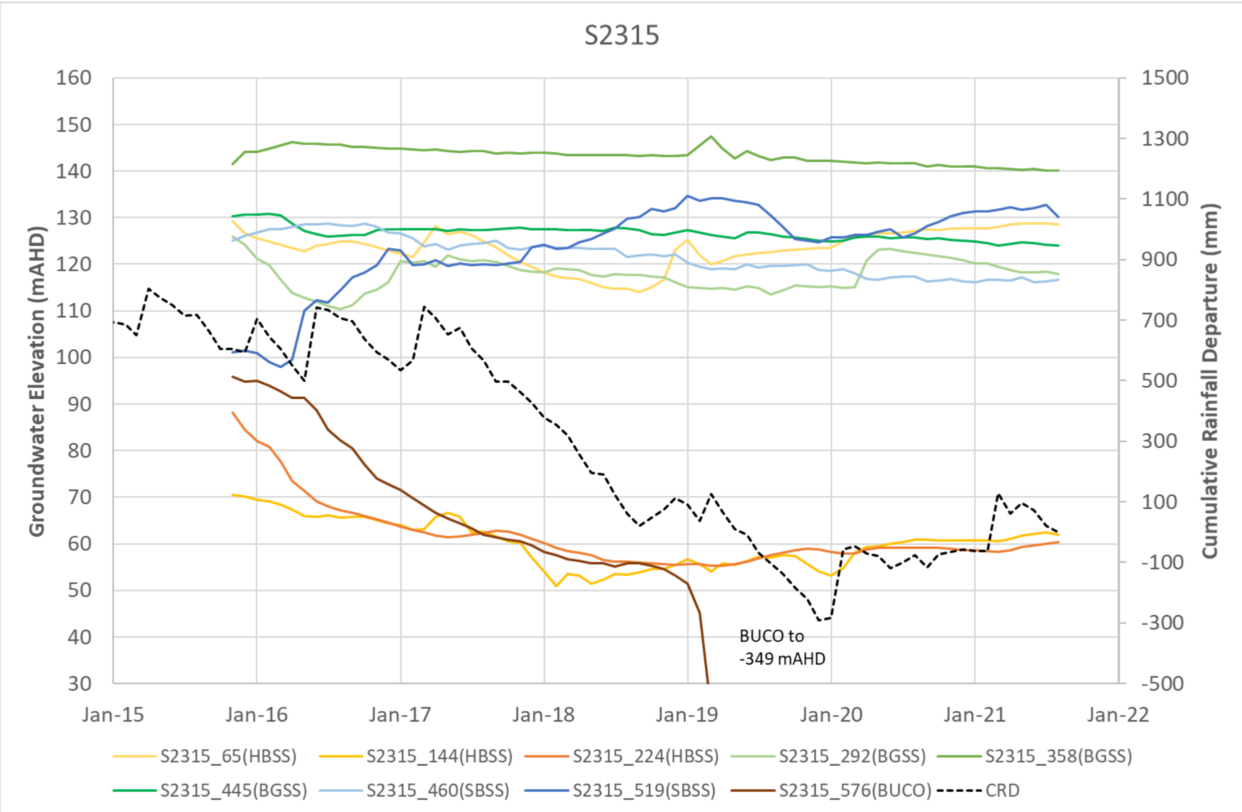

Figure 12 Hydrograph – S2315

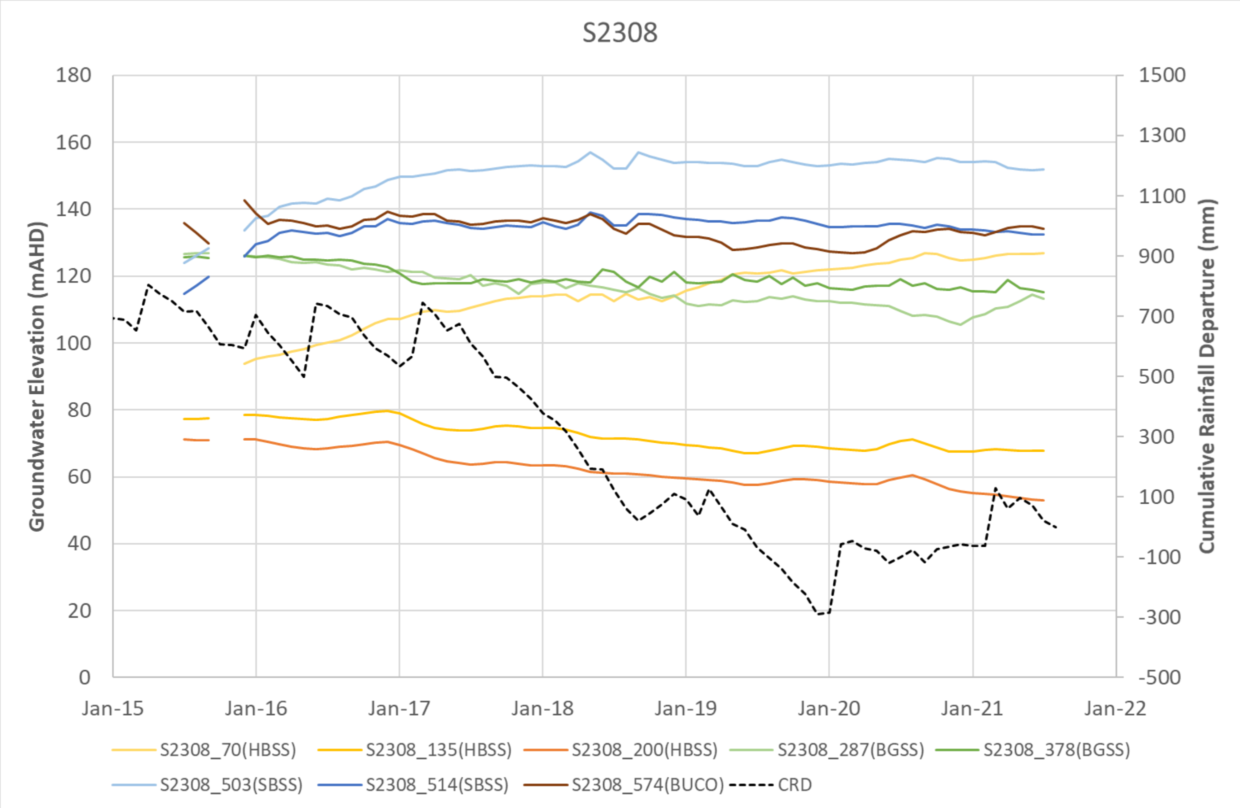

Figure 13 Hydrograph – S2308