Australasian Groundwater and
Environmental Consultants Pty Ltd

Report on

Boggabri, Tarrawonga, Maules Creek Complex Numerical Model Update

Prepared for
Boggabri Coal Operations Pty Ltd

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Report on

Boggabri, Tarrawonga, Maules Creek Complex Numerical Model Update

1 Introduction

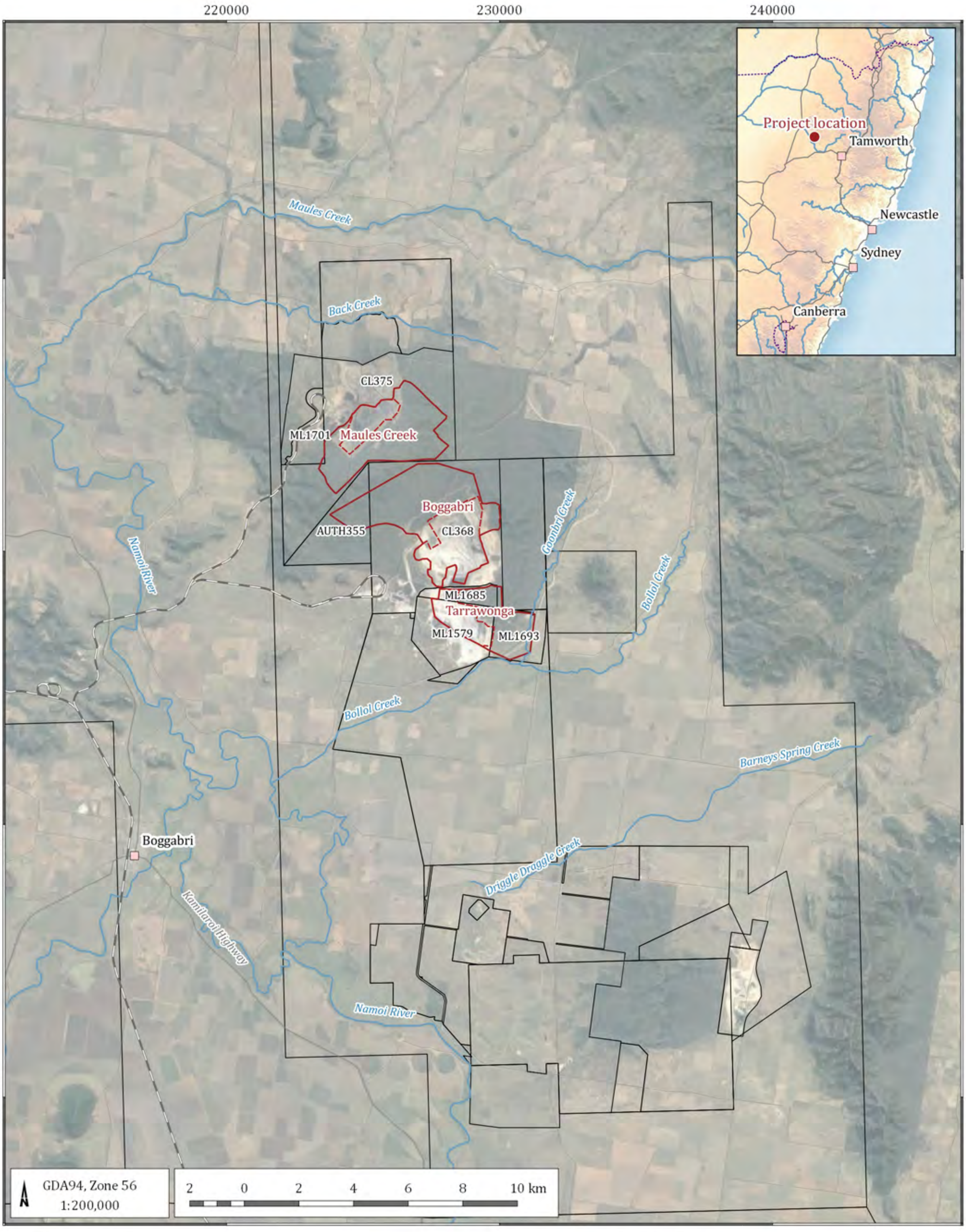
The Boggabri, Tarrawonga, Maules Creek (BTM) mining complex comprises three adjacent open cut coal mines located in the Gunnedah Basin, approximately 15 km northeast of the township of Boggabri in north-western NSW (Figure 1.1). The mines are owned and operated as follows:

- Boggabri Mine – operated by Boggabri Coal Operations Pty Ltd (BCOPL), a joint venture between Idemitsu Australia Resources through its subsidiary company Boggabri Coal Pty Ltd (80%), Chugoku Electric Power Australia Resources Pty Ltd (10%), and NS Boggabri Pt Ltd (10%);
- Tarrawonga Mine – operated by Tarrawonga Coal Pty Ltd (TCPL), a joint venture between Whitehaven Coal Mining Ltd (70%) and Boggabri Coal Pty Ltd (30%); and
- Maules Creek Mine – operated by Maules Creek Joint Venture (MCJV), a joint venture between Whitehaven Coal Mining Ltd (75%), ICRAMC Pty Ltd (15%), and J-Power (10%).

Conditions of approval for the mining operations require that the impacts to groundwater predicted by numerical models are verified against observed datasets every three years. The three mining approvals were granted at different times and the three year review periods are not currently aligned.

BCOPL initially engaged Australasian Groundwater and Environmental Consultants Pty Ltd (AGE) to verify the results of the model against recent groundwater level and mine pit seepage records from Boggabri Mine as it has reached the review date. As Boggabri is between Tarrawonga and Maules Creek Mines which creates cumulative impacts, an agreement to generate a cumulative model using data from all three sites was reached.

This report describes the process of verifying the model against site measurements and the subsequent calibration and simulation processes.



LEGEND

- Populated place
- Major road
- Minor road
- Rail
- Major drainage
- Current mining extent
- Mine maximum open cut outlines
- Mining lease

BTM model update (G1850A)

Site location

AGE

DATE 29/03/2017

FIGURE No: **1.1**

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:/Projects/G1850A.BTM_Model/3_GIS/Workspaces/001_Deliverable1/01.01_G1850A_Site location.qgs

2 Objectives and scope of work

Each of the mines within the BTM complex is approved under Section 75J of the *Environmental Planning & Assessment Act 1979*. The approval is subject to conditions that must be adhered to in order to:

- prevent, minimise and/offset adverse environmental impacts;
- set standards and performance measures for acceptable environmental performance;
- require regular monitoring and reporting; and
- provide for the ongoing environmental management of the project.

The Project Approval documents set out conditions for all aspects of the project, i.e. noise, blasting, air quality, biodiversity, heritage, water. Schedule 3 within the Project Approval outlines Environmental Performance Conditions that relate to groundwater. Each of the BTM complex mines are required by conditions to prepare *"a Groundwater Management Plan, which includes .....a program to validate the groundwater model for the project, including an independent review of the model every 3 years, and comparison of monitoring results with modelled predictions."*

The objective of the project was to satisfy the above condition by determining if the groundwater model that represents mining within the BTM complex provides valid predictions of impacts on the groundwater regime, and if necessary to update the model to improve its predictive capability. To achieve this objective, the scope of work was broken into the following main tasks:

- verification;
- updates to numerical model;
- calibration;
- predictions and uncertainty; and
- reporting.

The following report describes the results of each of the above tasks.

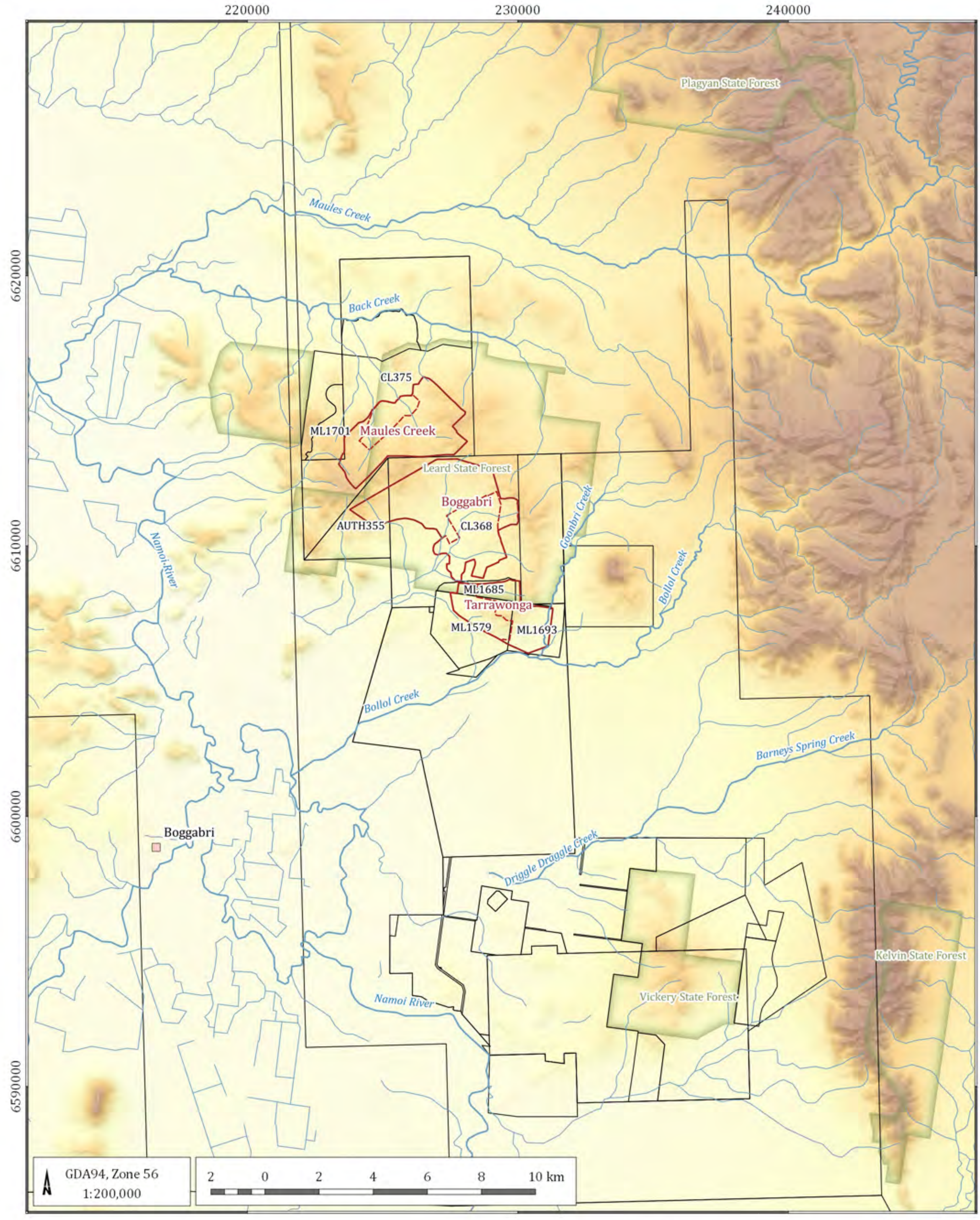
3 Regional setting

3.1 Topography, drainage and land use

The topography of the region is characterised by wide and flat alluvial plains bounded by wooded hills and ridgelines. The topography is controlled by the underlying geology that is comprised of outcropping volcanic and sedimentary sequences overlain by alluvial sediments in low lying areas. The BTM complex is located within an area of hills that rise to approximately 400 mAHD, about 150 m above the surrounding flood plains (Figure 3.1).

The hills and slopes of the BTM complex are drained by a series of generally westerly flowing ephemeral creeks that meander across floodplains and discharge to the Namoi River. The Namoi River is about 8 km to 10 km west of the BTM mines and is the most significant water feature within the Namoi Valley. Tributaries of the Namoi River include Maules Creek to the north of the BTM complex and Bollol Creek to the south. These tributaries flow in a westerly direction and also have large broad but gently sloping flood plains connecting to the Namoi River flood plain.

The BTM mines lie partially or wholly within the Leard State Forest area. The predominant land uses in the BTM region are forestry and mining in the hills and agriculture on the flood plains. The Namoi River alluvial floodplain (Figure 3.1) supports an array of agricultural enterprises including cotton, wheat and cattle grazing. The catchment is farmed using supplementary irrigation sourced from the regulated Namoi River or alluvial groundwater.



LEGEND

- Populated place
- Major drainage
- Minor drainage
- Current mining extent
- Mine maximum open cut outlines
- Mining lease
- State forest

Elevation (mAHD)

- 200
- 300
- 400
- 500
- 800
- 1000

BTM model update (G1850A)

Topography

AGE

DATE 29/03/2017

FIGURE No: **3.1**

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.; G:/Projects/G1850A.BTM_Model/3_GIS/Workspaces/001_Deliverable1/03.01_G1850A_Topography.qgs

3.2 Climate and recharge

The climate in the vicinity of the Project Boundary is characterised by hot summers with regular thunderstorms and mild dryer winters. Rainfall records collected by the Bureau of Meteorology (BoM) were obtained from the Boggabri Post Office which is located approximately 19 km to the south-west of the BTM complex. Long term evaporation data was obtained for the BoM site at Gunnedah Resource Centre, approximately 40 km to the south of BTM. Interpolated synthetic climate data was also obtained for the BTM complex from a SILO data drill. The SILO data contains potential crop evapotranspiration rates generated by the Penman-Monteith formula. The locations of the three sites (GDA94 Z56) are as follows:

- Boggabri PO: 217,051 mE, 6,599,297mN, Elev 245 mAHD;
- Gunnedah Resource Centre: 236,591 mE, 6,675,179mN, Elev 307 mAHD; and
- SILO data drill: 226,737 mE, 6,611,265 mN, Elev 498 mAHD.

Table 3.1 summarises the average monthly rainfall and evaporation rates recorded at the above sites.

Table 3.1 Summary of climate averages

Month	Mean monthly rainfall (mm)		Mean monthly pan evaporation (mm)		Mean monthly FAO56 EVT (mm)
	Boggabri PO	SILO	Gunnedah resource centre	SILO	SILO
January	77.3	81.1	238.7	253.8	192
February	63	67.6	192.1	205.6	158.9
March	44.1	49.5	186	193.2	144.7
April	33.7	36.4	129	131	100.1
May	41.3	43.9	83.7	82.1	69.6
June	43	45.4	57	56.2	49.4
July	41.7	46	58.9	61.3	53.8
August	37.4	42.7	86.8	87.6	72.4
September	38.2	41.5	120	126.1	100.4
October	50.1	52.3	167.4	176.9	140.2
November	60.3	63.5	201	213.6	166.6
December	65.7	66.8	241.8	252.4	189.3
Annual Mean/Total	**595.8**	**636.7**	**1762.4**	**1839.8**	**1437.4**

Table 3.1 shows that the mean annual rainfall and evaporation is similar at Boggabri and at the north at the BTM complex. More detailed examination of the daily rainfall records are more variable and reflects the influence of localised storms across the catchment. The consistently higher monthly rainfall indicated by the SILO data drill at the BTM complex compared to Boggabri may reflect the higher elevation of the mining area at 498 mAHD compared to 245 mAHD at the township of Boggabri.

Evaporation rates exceed mean rainfall throughout the year, with the highest moisture deficits occurring in summer. Pan evaporation rates are consistently higher than FAO56 EVT rates, reflecting the higher energy required to remove water from partially unsaturated ground.

Monthly rainfall records were used to calculate the Cumulative Rainfall Deficit (CRD – also referred to as the rainfall residual mass) for both rainfall locations. The CRD in Figure 3.2 shows periods of below average rainfall as rising trends and below average with declining trends. The calculated CRD is shown back to 2006 when mining was approved to commence within the BTM complex at Boggabri Mine.

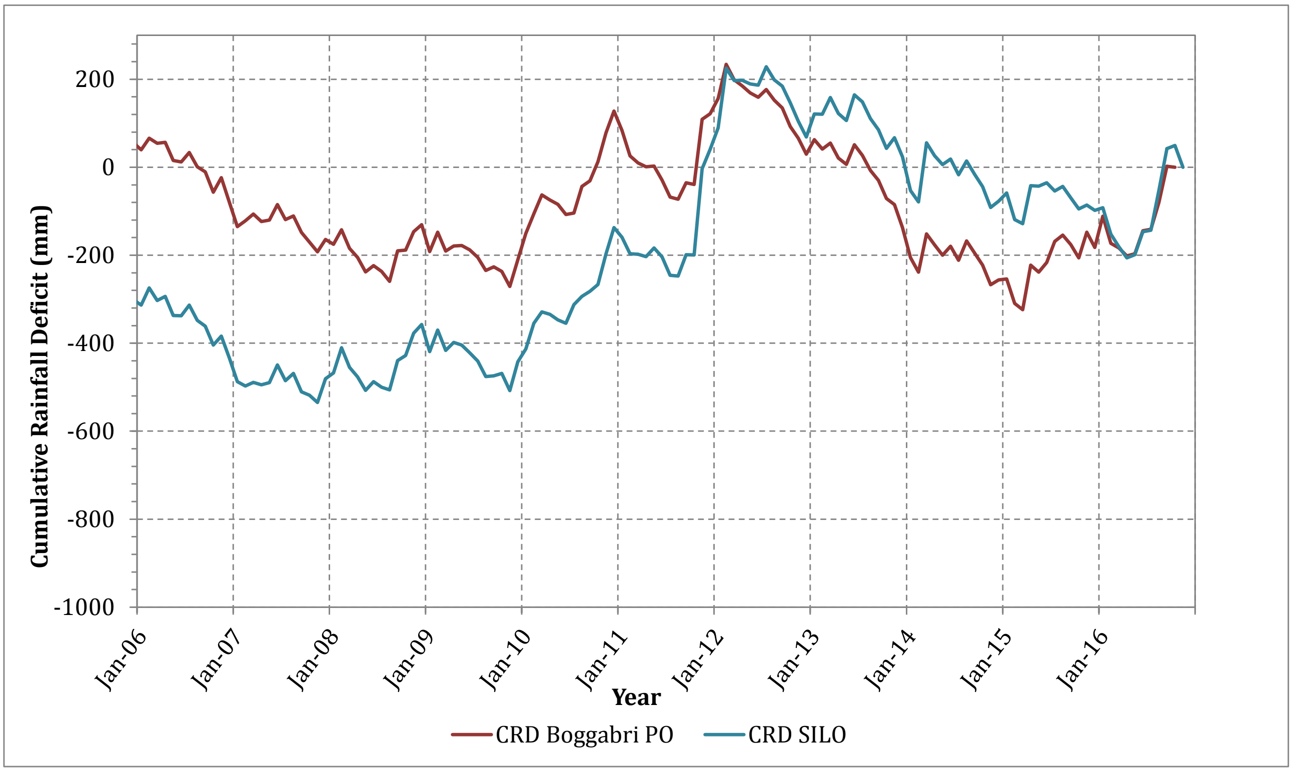


Figure 3.2 Cumulative rainfall deficit

Of most interest is the three to four year period of generally below average rainfall occurring between 2012 and 2016. The four year period was followed by significant rainfall in mid-2016 that returned a rising trend to the CRD. These trends are of relevance as groundwater levels tend to correlate with the CRD, and therefore groundwater levels would be expected to be declining over the 2012 to 2016 period. This period also coincide with all three mines within the BTM complex operating in unison from 2014.

Rainfall is the principal means for recharge to groundwater in the study area. The amount of water that will eventually reach the aquifers depends upon the rate and duration of rainfall, the antecedent soil moisture, the water table depth, and the properties of the soil and vegetation.

Simplistic soil moisture balances were used to determine periods where rainfall recharge of the groundwater systems was likely. Two estimates of recharge were made using the BoM and SILO data and with the assumptions in the soil moisture balance summarised in Table 3.2.

Table 3.2 Data sources for soil moisture balance

Soil moisture balance inputs	Estimate 1	Estimate 2
Daily rainfall	Boggabri Post Office	SILO
Evaporation	Monthly average from Gunnedah Resource Centre	SILO EVT
Soil storage capacity	35 mm/d	50 mm/d
Recharge cap	25 mm/d	25 mm/d

Figure 3.3 and Figure 3.4 show the estimated recharge events for the period 2006 to 2016 whilst mining has been active in the region, and compares against selected alluvial groundwater levels. The monitoring bores shown on the charts were selected because electronic water level loggers are installed in these bores and have measured water levels on a daily basis. Water levels in other alluvial government bores are only manually dipped and therefore do not have sufficient measurements to detect responses to recharge events. The figures indicate groundwater levels generally rise in a subdued manner following recharge events.

Average rainfall-recharge estimated from the moisture balance calculations is in the region of 35 mm/year to 50 mm/year. The majority of this recharge is generated from a small number of discrete rainfall events each year. Recharge estimates for the two methods show similar responses although the short terms are variable.

Section 8.2.6 describes how the estimated rainfall recharge rates from the SILO datasets were used to update and recalibrate the groundwater model.

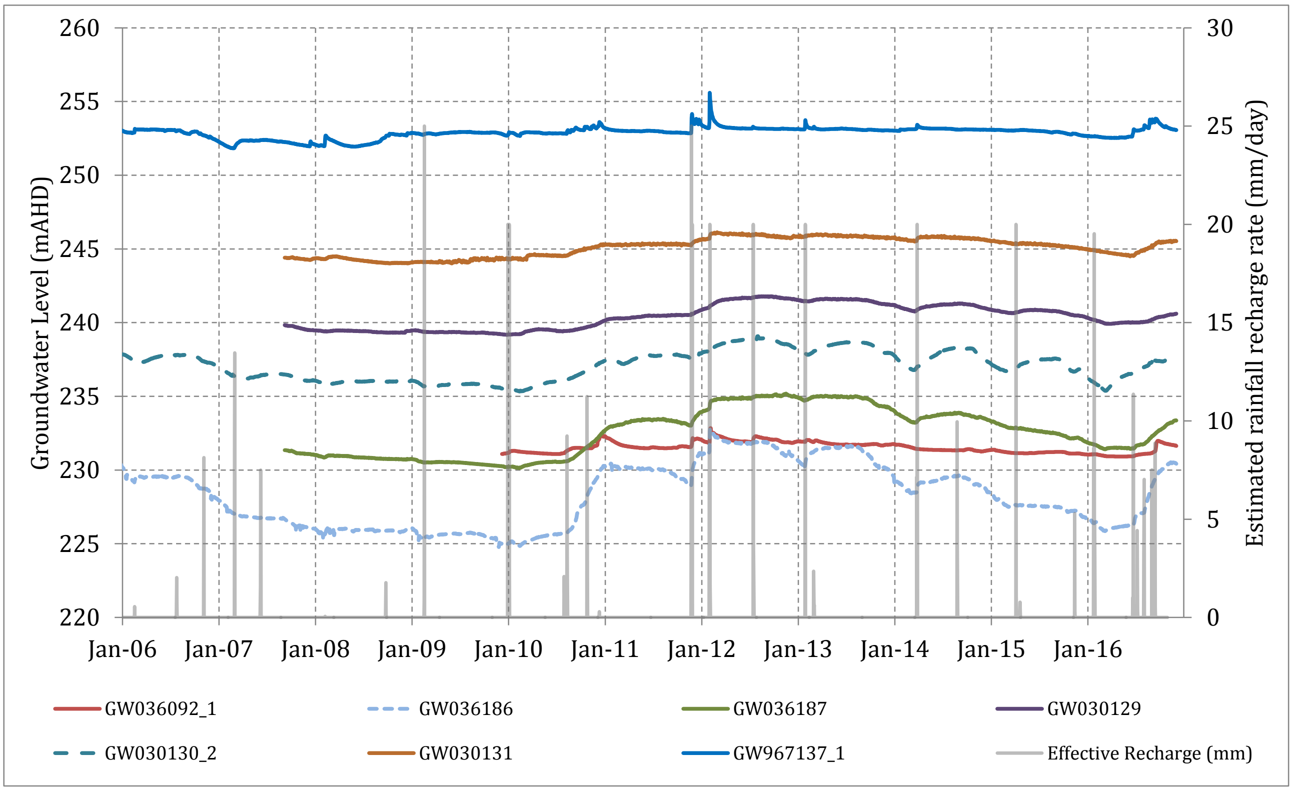


Figure 3.3 Estimated rainfall-recharge events and alluvial groundwater levels (BoM stations)

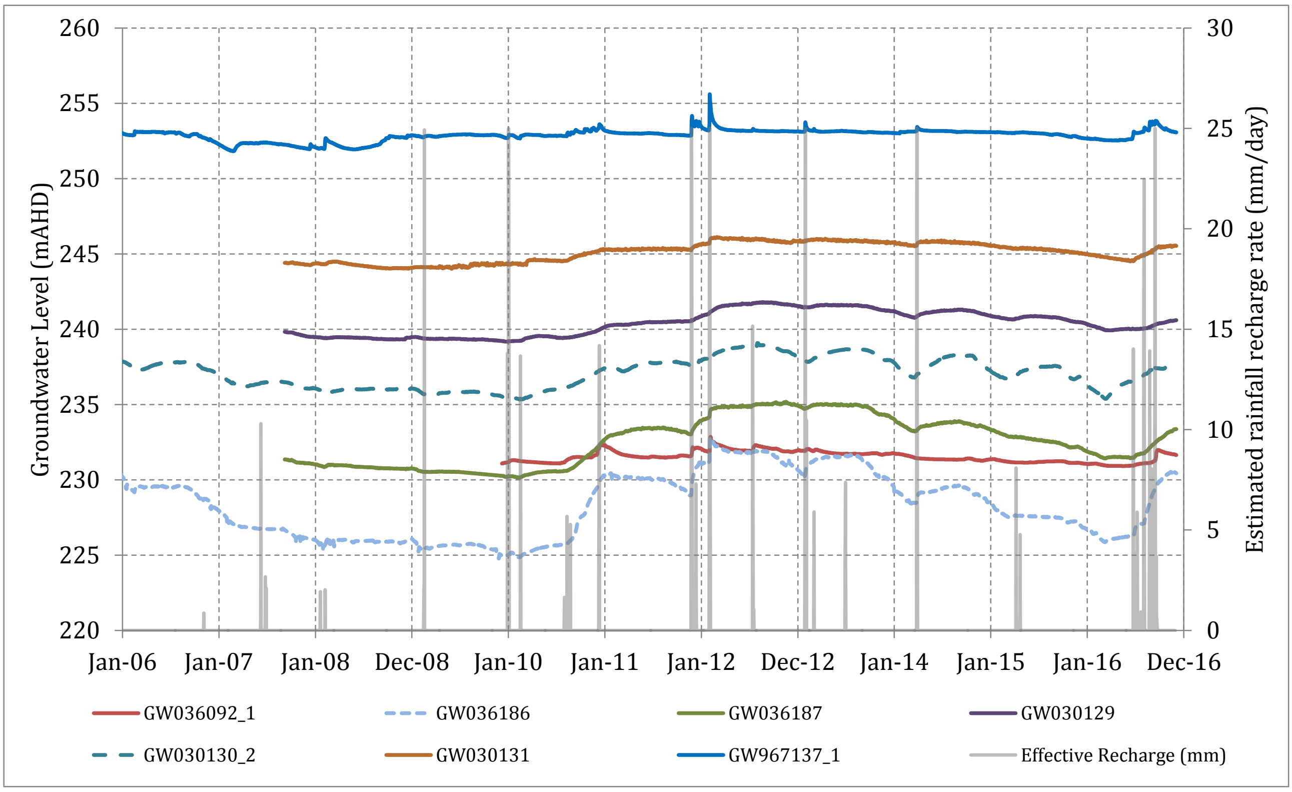


Figure 3.4 Estimated rainfall-recharge events and alluvial groundwater levels (SILO datasets)

3.3 Geology

The BTM coal deposits are early Permian in age and located in the Maules Creek sub-basin of the Gunnedah Basin. The Maules Creek sub-basin is underlain by the Boggabri Volcanics, and is physically separated from the western Mullaley sub-basin of the larger Gunnedah Basin by a basement ridge formed by the Boggabri Volcanics (Figure 3.5), which primarily consists of dacitic to rhyolitic basalt and pyroclastic rocks.

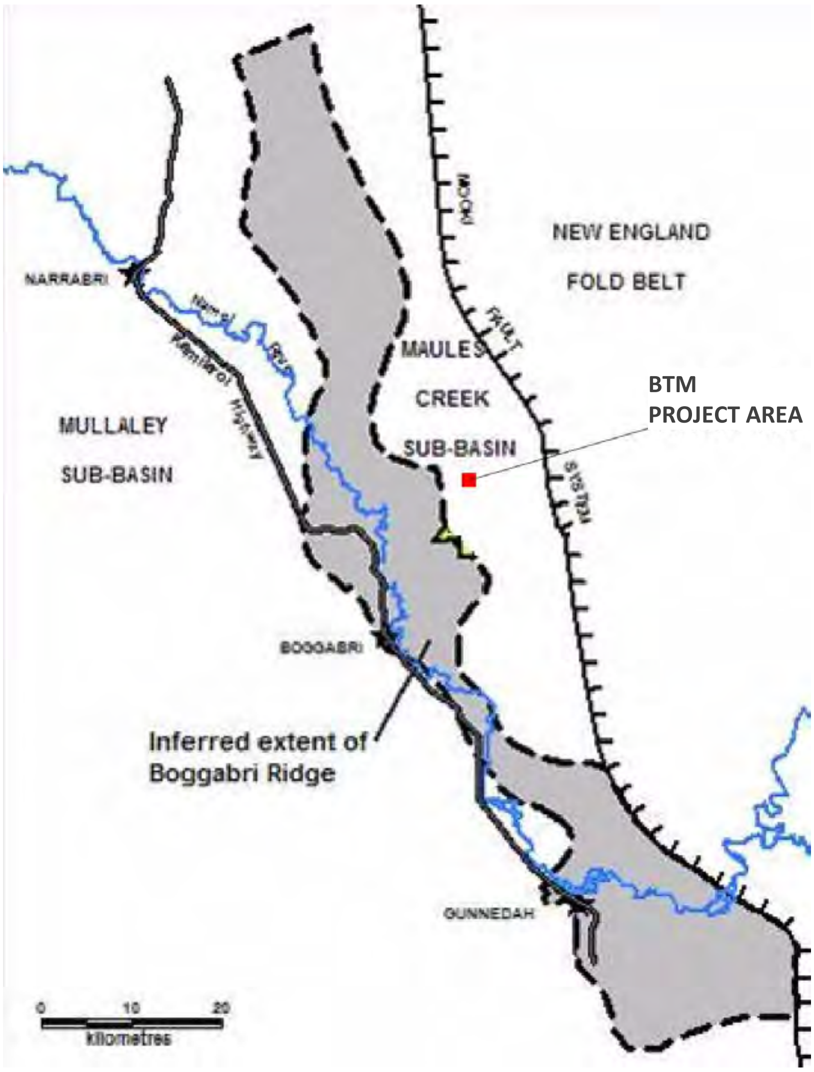
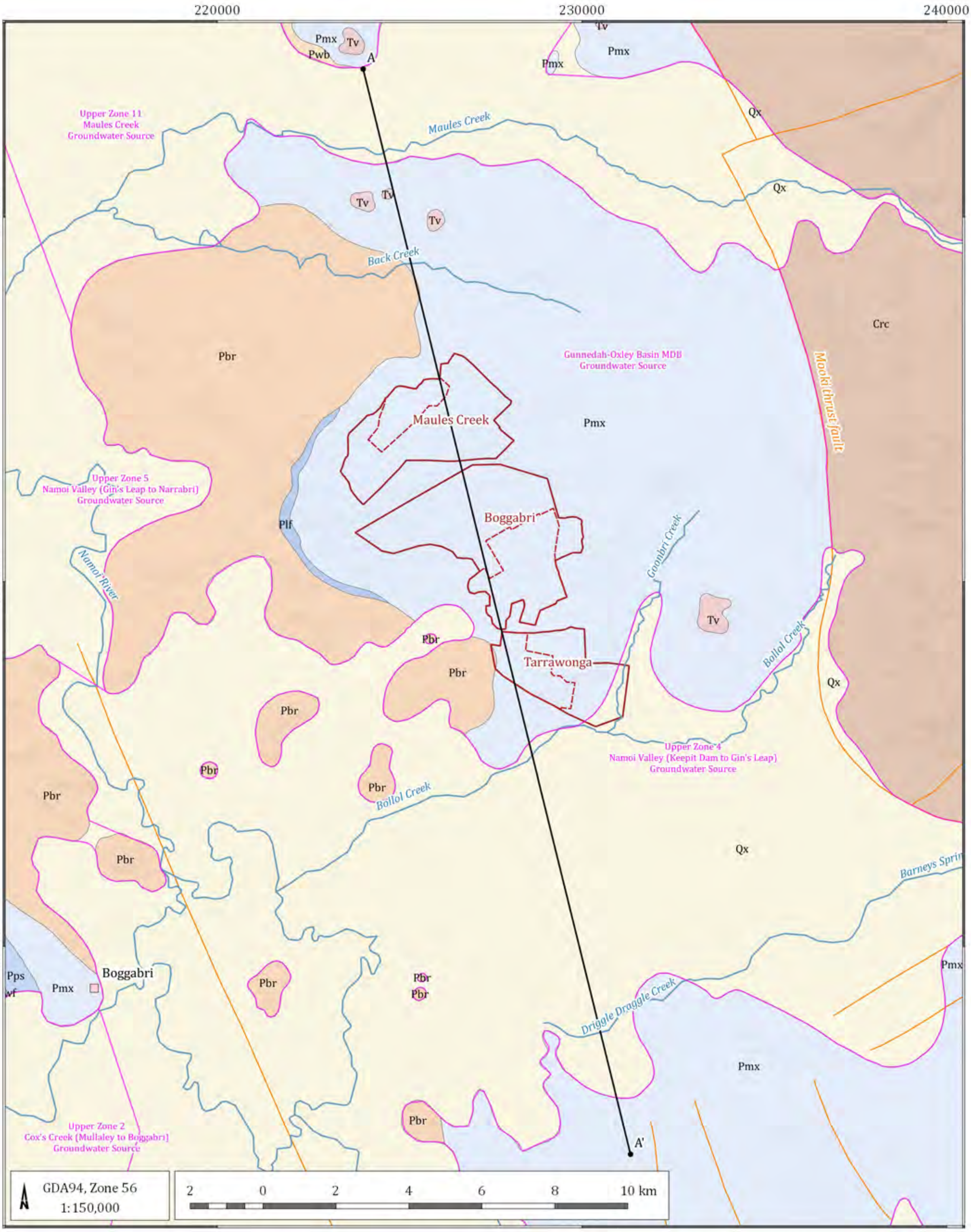


Figure 3.5 Maules Creek sub-basin

The Boggabri Volcanics were subject to extensive erosion and weathering during the very early Permian resulting in the formation of an irregular palaeo-topography onto which the coal deposits were laid. A large area of the Permian bedrock is covered with an extensive blanket of unconsolidated alluvial Cainozoic sediments as shown in the regional geology map published by the then Department of Mineral Resources (Pratt 1998) which is reproduced in Figure 3.6. The Cainozoic sediments can be subdivided into two distinct aquifers being the basal Gunnedah Formation and the overlying surficial Narrabri Formation.

The Maules Creek Formation forms a regular layered easterly dipping sedimentary sequence that gradually thickens to the east to over 800 m at the Mooki Thrust Fault. The Maules Creek Formation consists predominantly of conglomerate and sandstone, with minor siltstone, claystone and intercalated coal seams. The Maules Creek Formation underlies the Cainozoic sediments to the north and south of the BTM complex. To the west the Cainozoic sediments are underlain by the Boggabri Volcanics.

The generalised stratigraphy of the Maules Creek mining area is shown graphically in Figure 3.7. A total of 15 coal seams have been formally identified within the Maules Creek mining lease. The thicknesses of the seams varies between 0.5 m and 5.0 m. The Maules Creek Mine is approved to extract from all seams, the Boggabri Coal Mine from the Upper Braymont to Merriown seams and the Tarrawonga Mine to the floor of the Nagero seam.



LEGEND

- Populated place
- Major drainage
- Section location
- Current mining extent
- Mine maximum open cut outlines
- Namoi Groundwater Management areas

Gunnedah Coalfield rock unit (1:100k)

- Qx - Quaternary Sediments
- Tv - Tertiary Volcanics
- Pmx - Maules Creek and Goonbri formations
- Plf - Leard Formation
- Pbr - Boggabri Volcanics
- Cbc - Currabubula Formation
- Crc - Rocky Creek Conglomerate
- Fault

BTM model update (G1850A)

Regional geology

AGE

DATE 29/03/2017

FIGURE No: **3.6**

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.; Geology - © New South Wales Department of Mineral Resources 2002
G:/Projects/G1850A.BTM_Model/3_GIS/Workspaces/001_Deliverable1/03.06_G1850A_Regional geology.qgs

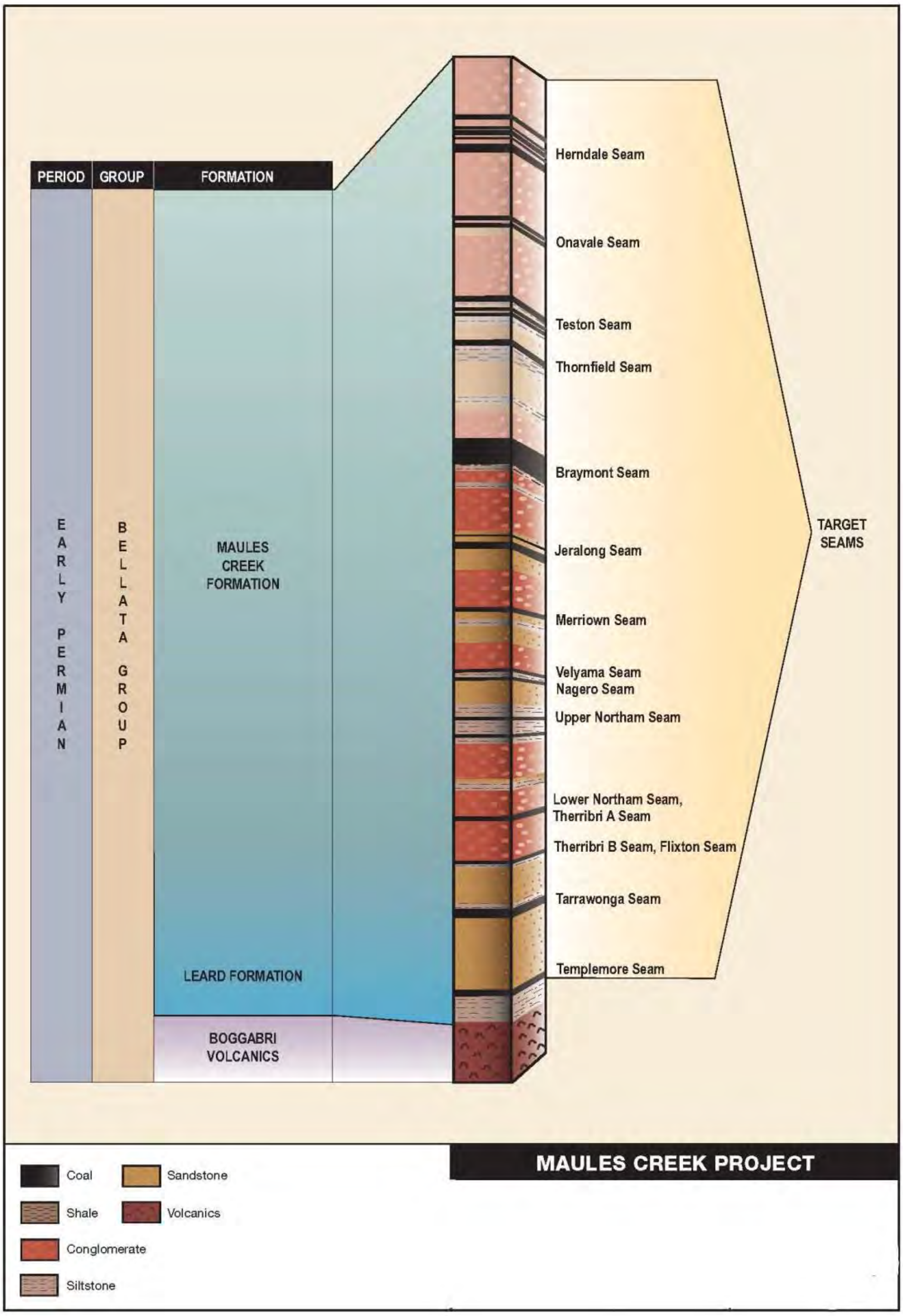


Figure 3.7 Generalised Stratigraphy after Hansen Bailey (2010)

A conceptual cross section running approximately north – south through the mining area and showing the relationships between the major geological units and the mining voids is provided as Figure 3.8. The location of the section line is shown on Figure 3.6.

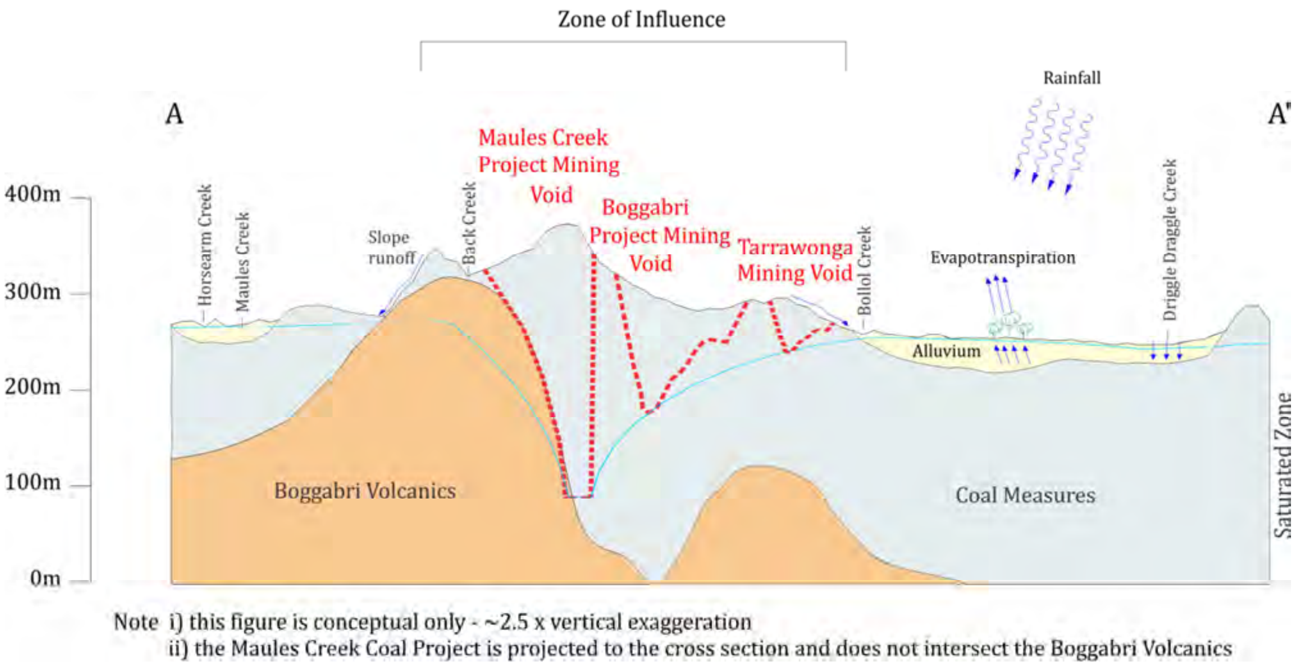


Figure 3.8 Conceptual geological cross section

3.4 Hydrogeology

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

- hydrogeologically "tight" and hence very low yielding to essentially dry sandstone, and conglomerate that comprise the majority of the Maules Creek Formation strata;
- low to moderately permeable coal seams which are the prime water bearing strata within the Maules Creek Formation; and
- the underlying Boggabri Volcanics that act as a low permeability basement to the sedimentary units.

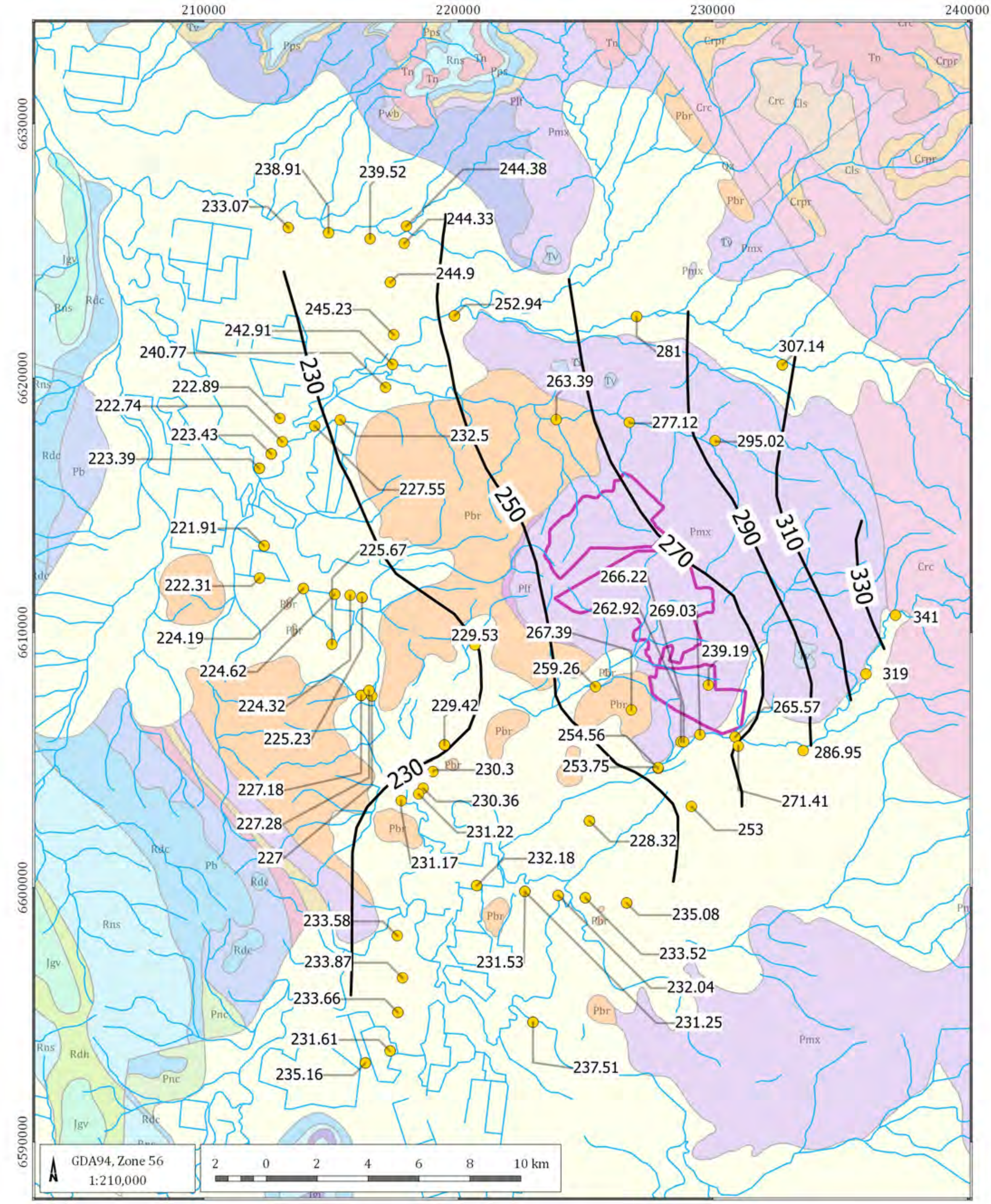
Alluvial plains are present in areas surrounding the BTM complex, existing to the:

- North: Maules Creek alluvial aquifer;
- South: Bollol, Driggle Draggle and Barneys Spring Creeks; and
- West: Namoi River.

The alluvial aquifers that underlie the alluvial plains are part of the Upper Namoi Alluvial Aquifer Zones shown previously in Figure 3.6. The Maules Creek alluvial aquifer is within zone 11, Bollol, Driggle Draggle and Barneys Spring Creeks in zone 4 and the Namoi River alluvial aquifer in zone 5. The boundary between zones 4 and 5 is at Gins Leap.

Bore yields in the alluvial aquifers are highly variable and dependent on the nature and thickness of the sediment intersected when drilling. The bores show a very wide range in yields, from less than 1 L/s up to a maximum of 175 L/s.

Regional groundwater flow directions were determined by examining the water level measured in 2015/2016 from the monitoring network. Figure 3.9 shows the interpolated groundwater levels, and indicates a general westerly groundwater flow direction



LEGEND

- Bore ID and Observed groundwater level (MAHD)
- Drainage
- Mine outline

BTM model update (G1850A)

Shallow groundwater levels and flow directions (2015 to 2016)

AGE

DATE 13/08/2018

FIGURE No: **3.9**

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:\Projects\G1850A.BTM_Model\3_GIS\Workspaces\004_ReportUpdate\G1850A_fig09.03_flow_lines.qgs

4 Mining history

4.1 Boggabri

Construction of the Boggabri Coal Mine commenced in 2005 with the first coal delivered to the ROM coal pad in October 2006. The current method of open cut mining allows coal extraction to occur in the uppermost seams in the Maules Creek sequence including the Braymont, Bollol Creek, Jeralong and Merriown. The Project is currently approved to extract up to 8.6 Mtpa ROM coal until 31st December 2033. The approved mining area for the Boggabri Mine is shown on Figure 4.1 and the coal volumes produced to date are provided in Table 4.1.

Table 4.1 Product coal produced to date (source Boggabri MOP, March 2016)

Calendar year	Product coal produced (Mt)
2006	0.24
2007	1.49
2008	1.47
2009	1.56
2010	2.11
2011	2.65
2012	3.34
2013	4.66
2014	5.49
2015	6.63
2016	Not available

4.2 Tarrawonga

The Tarrawonga Mine is located immediately to the south of the Boggabri Mine. Tarrawonga commenced coal production within ML 1579 during 2006. Extraction occurs from the Braymont to Nagero seams in the Maules Creek sequence using truck and excavator methods. An expansion to the original mining area was approved in 2013. The Project is currently approved to extract up to 3 Mtpa ROM coal until the end of December 2030. The approved mining area for the Tarrawonga Mine is shown on Figure 4.1 and the ROM coal volumes produced to date are provided in Table 4.2.

Towards the end of the approved mining the pit will expand into an area of alluvium adjacent to Goonbri creek, and a low permeability cut off wall will be installed to reduce the potential for groundwater in the alluvium to seep into the pit. The Goonbri Creek will also be diverted to flow in a new channel on the outside of the low permeability barrier and overlying flood bund.

Table 4.2 ROM coal produced 2010-2016 (source Tarrawonga Coal Annual Reviews, Whitehaven 2016a)

Calendar year	ROM coal produced (Mt)
2010/11	1.58
2011/12	1.74
2012/13	1.95
2013/14	1.85
2014/15	2.38
2015/16	2.24

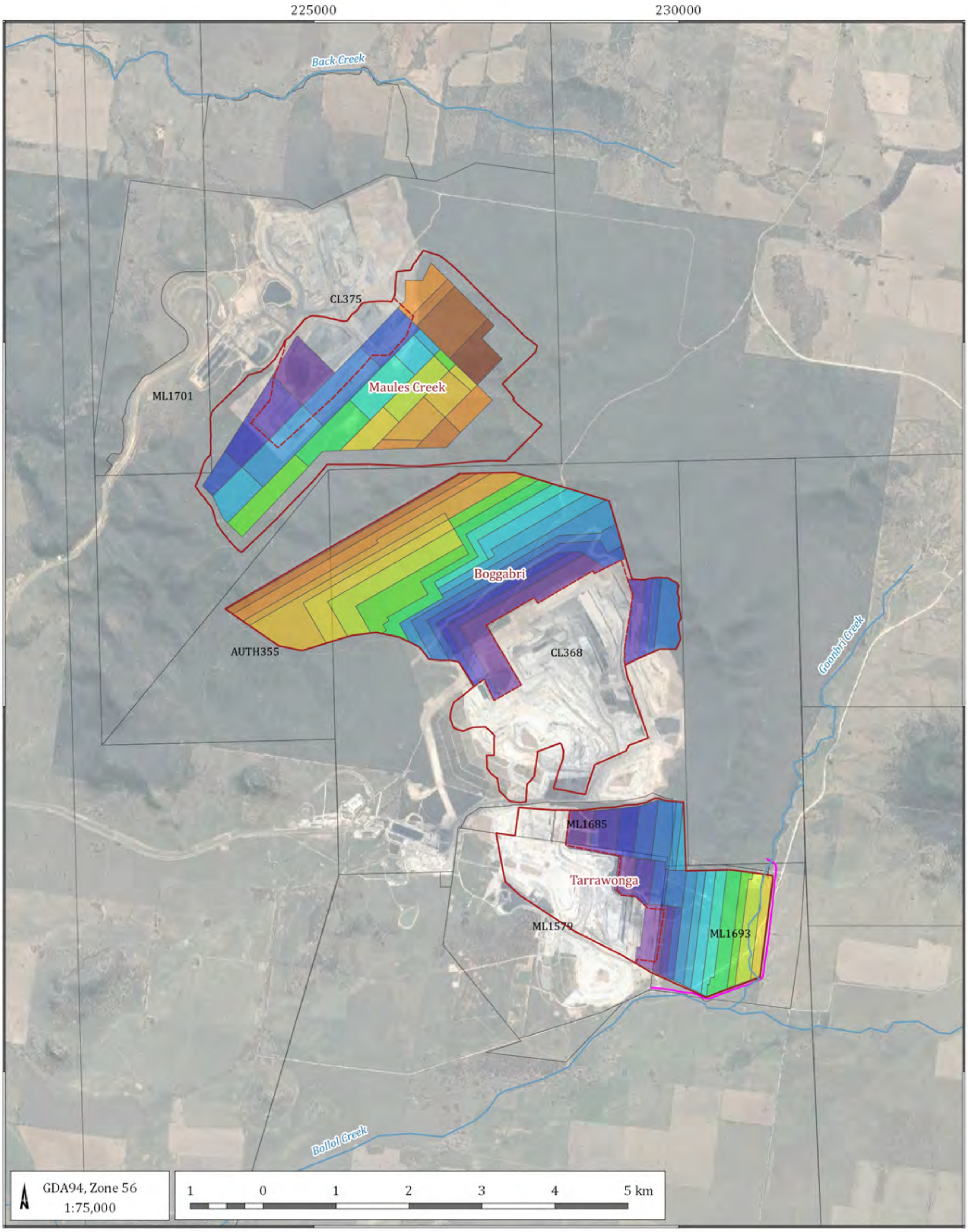
4.3 Maules Creek

The Maules Creek Mine is located to the north of the Boggabri Mine. The mined areas could come within 200 m of each other by the end of approved mining. Commercial production started from Maules Creek in mid-2015. The Project is currently approved to extract up to 13 Mtpa ROM coal until the end of December 2034. Maules Creek is approved to extract from the Maules Creek sequence down to the Templemore seam. The approved mining area for the Maules Creek Mine is shown on Figure 4.1 and the coal volumes produced to date are provided in Table 4.3.

Table 4.3 Coal produced to date (source Maules Creek 2015 Annual Review, Whitehaven 2016b)

Calendar year	ROM coal produced	Saleable product
2014	0.09 Mt	0.05 Mt
2015	5.82 Mt	5.34 Mt
2016	7.8 Mt*	--

***Note*: * Taken from Whitehaven Coal website**



LEGEND

- Populated place
- Tarrawonga low permeability barrier location
- Major road
- Minor road
- Rail
- Major drainage
- Current mining extent
- Mine maximum open cut outlines
- Mining lease

Mining (Years)

2017, 2018, 2019, 2020, 2021, 2022, 2023, 2024, 2025, 2026, 2027, 2028, 2029, 2030, 2031, 2032, 2033, 2034, 2035

BTM model update (G1850A)

Approved mining areas 2016

AGE

DATE 29/03/2017

FIGURE No: **4.1**

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:/Projects/G1850A.BTM_Model/3_GIS/Workspaces/001_Deliverable1/04.01_G1850A_Approved mining areas 2016.qgs

5 Regional groundwater monitoring network

Monitoring bores and vibrating wire piezometers (VWP) have been installed in a series of separate campaigns within the BTM complex. Each of the mines within the BTM complex have a network of baseline monitoring bores around the mining area to detect local impacts on groundwater levels. In addition to this there is a network installed further from the mining areas within in the wider region designed to detect any cumulative impacts from the BTM complex.

Appendix A contains a summary table describing the details of all the monitoring bores at the BTM complex. Figure 5.1 shows the location of each of the bores. Where an array of multiple vibrating wire pressure (VWP) sensors are installed within a single borehole then only the primary bore ID is shown. The sections below describe the various campaigns undertaken to install the monitoring bores.

5.1 'IBC' series

Prior to the commencement of the Boggabri Coal Mine, Parsons Brinkerhoff (2005) undertook a baseline groundwater assessment that included installation of monitoring bores, permeability testing and groundwater modelling of the first 6 years of the mine life. This project included the installation of the 'IBC' series of bores around the mining area that comprised seven bores targeting coal seams and volcanic basement.

5.2 'MW' series

The 'MW' series of bores was installed at Tarrawonga Mine in 2006 as part of baseline investigations prior to mining.

5.3 'BCS' series

The 'BCS' series of bores along Bollol Creek to the east of the mining area was installed by Tarrawonga Mine. Whilst the installation date is not known, water level records are available for these bores from 2007. These bores are relatively shallow and less than 50 m in depth targeting shallow alluvium or rock.

5.4 'MAC' series

The 'MAC' series was established around the Maules Creek Mine in 2010 to gather information on the groundwater regime for the Environmental Assessment. This baseline data was used to develop and calibrate a numerical model in order to predict the impacts of mining on the groundwater regime. The bores were installed within former exploration holes, with a total of eight groundwater monitoring bores and four vibrating wire piezometers (VWP) constructed. Most of the 'MAC' series monitoring bores and all the VWPs were damaged or destroyed by the progress of mining or by protestors.

5.5 'RB' series

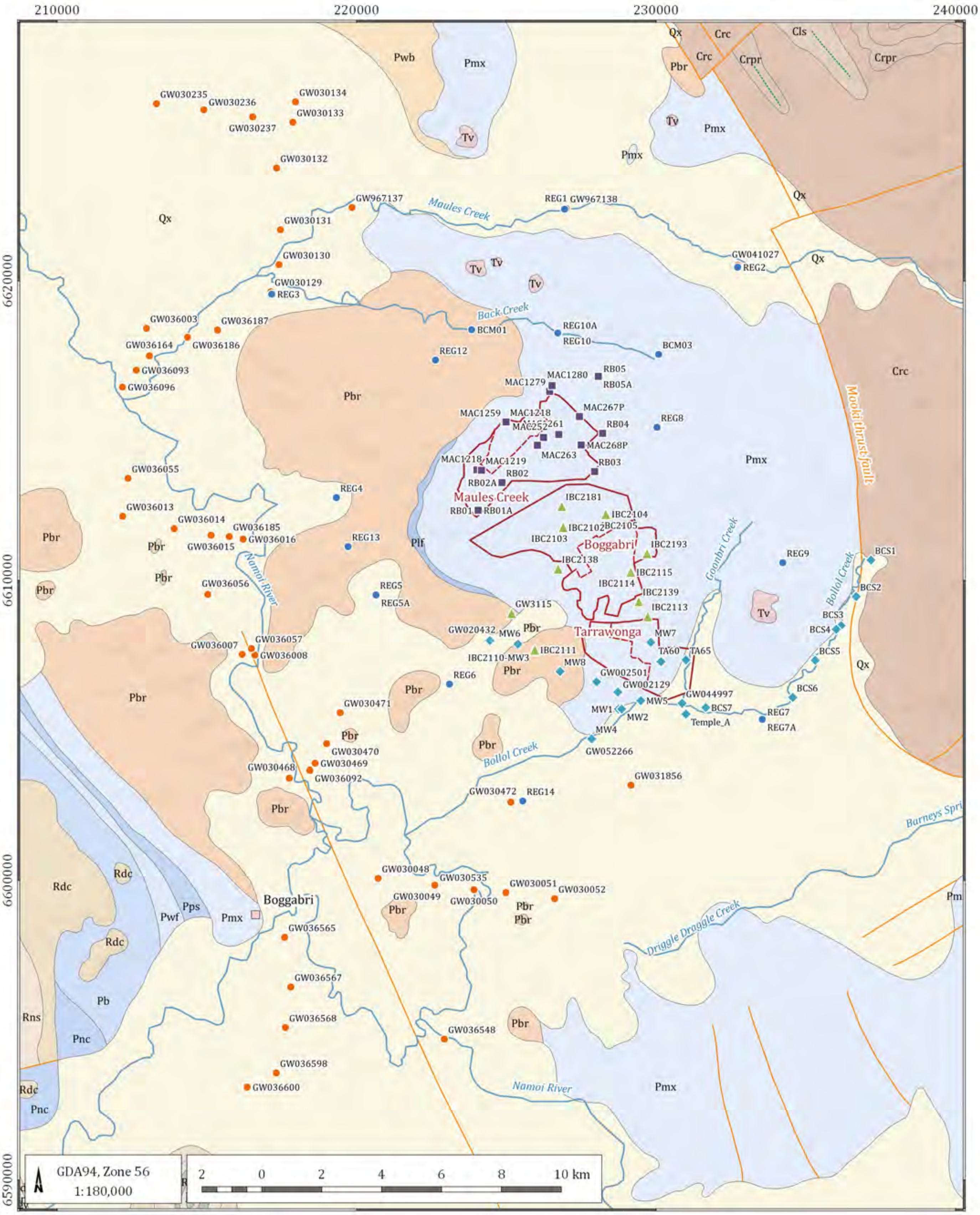
The 'RB' series of bores were designed to replace the damaged 'MAC' series and installed between October 2013 and February 2014. The 'RB' series comprises three groundwater monitoring bores and five nested vibrating wire piezometers (VWP).

5.6 'REG' and 'BCM' series

The 'REG' series comprises twelve groundwater monitoring bores and six nested vibrating wire piezometers (VWP) designed to detect cumulative impacts from the BTM complex. Of these bores, BCM1, BCM3 and REG10A were installed along Back Creek to assess the potential for shallow groundwater and the presence of a Groundwater Dependent Ecosystems (GDE).

5.7 'GW' bores

The NSW Department of Primary Industries – Water (DPI Water) maintain a network of monitoring bores within the Namoi Valley alluvium that surrounds the BTM complex. The purpose of these bores is to monitor groundwater levels and quality within the Narrabri and Gunnedah Formations. These bores all have the prefix 'GW' and are shown in Figure 5.1.



LEGEND

- Populated place

Monitoring bore

Group
- Boggabri mine
- Tarrawonga mine
- Maules Creek mine
- Cumulative monitoring bores
- GW registered bores

HIERARCHY
- Current mining extent
- Mine maximum open cut outlines

Gunnedah Coalfield rock unit (1:100k)

LETT_SYMB
- Tn - Tertiary Nandewar Volcanics
- Pps - Porcupine Formation
- Pmx - Maules Creek and Goonbri formations
- Pwb - Werrie Basalt
- ?Pbr - Boggabri Volcanics
- Cls - Lark Hill Formation

Fault

BTM model update (G1850A)

Regional groundwater monitoring network

AGE

DATE 31/07/2018

FIGURE No: **5.1**

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.; Geology - © New South Wales Department of Mineral Resources 2002
G:\Projects\G1850A.BTM_Model\3_GIS\Workspaces\001_Deliverable1\05.01_G1850A_Regional groundwater monitoring network.qgs

6 Previous modelling work

Parsons Brinkerhoff (2005) developed the first groundwater model for the Boggabri Coal Mine as part of the project approval process. The model was later updated by Parsons Brinkerhoff (2008). This model was later converted to MODFLOW SURFACT by AGE (2010) as part of the 'Continuation of Boggabri Mine Project'. The early models were relatively simplistic with limited detail on the coal seam surfaces in the Maules Creek sub-basin. This was because at that time there was little public information on the architecture of the coal seams outside the Boggabri Coal Mine area, particularly under the alluvial flood plain surrounding the site. The early numerical models therefore did not represent the coal seams directly, but lumped the coal seams into layers with interburden material with uniform transmissivity, equivalent to that within the coal seams proposed to be mined.

During development of the Maules Creek project, to the north of Boggabri Coal Mine, it was recognised that due to the close proximity of the Maules Creek Project, Boggabri Coal Mine and the Tarrawonga Project, that cumulative impacts needed to be quantified. This led to a data sharing agreement between the mining companies. Combined geological models allowed the coal seams to be better defined across the mining areas and under the alluvial plains. The groundwater model developed for the Boggabri Coal Mine was then updated with this data and used to simulate the entire mining complex for the Maules Creek Project.

An outcome of the approvals process was the installation of a network of bores to monitor cumulative impacts on the flood plain surrounding the ridge area where mining occurs. The cumulative monitoring bore network, known as the BTM network, representing Boggabri, Tarrawonga and Maules Creek Mines was installed between November 2013 and January 2014 under the supervision of Maules Creek Mine geologists. At this time, the Maules Creek groundwater numerical model was also updated by AGE (2014).

Heritage Computing (2012) developed a model for the Tarrawonga Coal Project that utilised the geological layers developed during the data sharing process. Boggabri Mine also commissioned Parsons Brinckerhoff (2015) to develop a model of the alluvial aquifer. The purpose of the model was to assess the impact of installing a borefield within the Namoi River alluvium to the west of the Boggabri Ridge to supply 'make up' water to the mine. The model represented the alluvium and basement volcanics but not the Permian coal measures. The model was also smaller than the regional scale models developed for approvals (12.1 km x 17.3 km (209.33 km^2)).

7 Verification of existing model

7.1 Verification process

The most recent version of the groundwater model for the BTM complex is described by AGE (2014). This version of the model used water levels measured within the alluvium dating back to 1992, and from the Permian back to 2006 to calibrate the groundwater model. Additional groundwater level measures collected from 2013 to 2016 are now available that can be used to verify the ability of the model to predict changes in groundwater levels. The verification process involved comparing:

- measured groundwater levels and trends in the monitoring bore and vibrating wire piezometer (VWP) network with the model predictions; and
- estimates of pit inflow from site water balances with model predictions.

The match between the measured data and simulations will never be exact, because numerical models contain many simplifying assumptions to account for natural environmental processes. Determining the adequacy of a model to predict impacts is largely a subjective process. For the purposes of the BTM complex it was considered a 'validated' model should generally replicate the:

- major changes in groundwater levels due to climatic events;
- drawdown in the groundwater systems due to the advancing mine face; and
- groundwater inflow to the active mining areas.

The sections below describe the processes of comparing the 2013 to 2016 data to the predictions of the 2014 groundwater model.

7.2 Water levels

Appendix B contains hydrographs that compare the measured groundwater levels with the levels predicted by the 2014 numerical model. It can be seen from the hydrographs within Appendix B that the model does not perfectly replicate the water levels measured in the monitoring bores over the observation period. This is typical for groundwater models which are a simplified representation of environmental processes. The sections below discuss the ability of the model to replicate water levels within the alluvium, Permian coal measures and Boggabri Volcanics basement.

7.2.1 Alluvial bores

The alluvial bores have continued with the trends shown up to 2013.

There are two clear trends in the DPI- Water monitoring bores installed within the Namoi Valley alluvium that have continued during the 2013 to 2016 verification period. These are, either a cyclic water level influenced by pumping from irrigation bores, or relatively stable water levels in areas beyond the influence of pumping bores.

The groundwater model uses represents abstraction from licensed bores at average rates calculated using data available between 2003 and 2005. The hydrographs within Appendix B for the 'GW' bores generally show the model represents pumping cycles where these are being observed within the monitoring network. The hydrographs suggest the model continues to broadly represent water level behaviour and trends within the alluvium during the 2013 to 2016 verification period.

7.2.2 Permian bores in mining areas

7.2.2.1 Braymont-Jeralong-Merriown seams

The Braymont, Jeralong, and Merriown coal seams are represented within the numerical model as a single layer which has the equivalent thickness of the three seams combined from the base of the Merriown seam. Groundwater levels in these seams are monitored at sites throughout the mining leases and to the east of the mines. All the BTM complex mines will extract these coal seams, with the floor of the Boggabri pit at the floor of the Merriown seam.

Measurements from the Boggabri Mine monitoring bores intersecting these seams (nine of the IBC bores) [IBC2102, 2103, 2104, 2105, 2113, 2114, 2115, 2138, 2139] indicates groundwater level have been declining since 2006. The groundwater model also generally replicates this trend, although the quality of the match with each bore varies. The modelled and measured groundwater levels match well in both time and elevation for some monitoring bores, whilst other sites show a modelled decline that is greater or less than the measured change. This is expected to be due details of the mine plans or hydraulic properties not represented within the numerical model.

The modelled groundwater levels match the measured levels within the monitoring bores at the Maules Creek Mine reasonably well, but the correlation degrades for the VWPs. There are a significant number of coal seams and plys within the BTM complex that cannot be practically represented within the groundwater model due to size limitations. To address this issue the model uses a simplified representation of the geology and groups multiple coal seams into single 'super seam' layers. This approach can result in two VWPs which monitor different seams being allocated within the same model layer i.e. VWP1 which is installed within the Braymont seam, and VWP2 which is in the Merriown seam are both in layer 6 of the numerical model. In this case as the VWPs have recorded different water level trends it is not possible for the numerical model to match both responses well. The model often underestimates the absolute water levels by over 20 m, although overall trends can be similar to those observed.

VWP sites in the cumulative monitoring network show similar responses to the VWPs in the Maules Creek sites. The model under predicts water levels at many of the sites.

There are two VWP sensors at Tarrawonga that are located within the Jeralong and Merriown seams. The model generally replicates the trend drawdown observed within the Jeralong seam, but does not predict the rate of drawdown observed within the Merriown seam. The exact reason the model does not represent the drawdown well east of Tarrawonga Mine is not known, but may relate to variability in hydraulic properties that are not represented within the model.

7.2.2.2 Velyama to Flixton seams

The model also combines the coal seams from the Velyama to Flixton seams into a single layer. The sites monitoring these seams are concentrated around the Maules Creek and Tarrawonga Mines. There are also some sites within the cumulative monitoring network to the east of the BTM complex monitoring groundwater within these seams.

The water levels simulated by the numerical model match the absolute level and trends for the MAC series bores around the Maules Creek Mine reasonably. The correlation is poorer at the 'RB' series VWPs, which did not have a significant data record when the model was last updated in 2014.

The model generally records a systematic error with modelled water levels for the 'REG' series bores being too high to the north of BTM complex, and too low to the east and south. The model also predicts water levels are also rising at many of the sites in these areas, whereas the observed water levels are gently falling.

7.2.3 Bores in Boggabri Volcanics

There are seven BTM cumulative network bores (REG3, REG4, REG5, REG6, REG12, REG13, REG14) and a small number of other bores to the east of Tarrawonga Mine that are completed within the Boggabri Volcanics.

The 'REG' series bores were installed in 2014. Those in the volcanics have recorded relatively stable groundwater levels with no significant decline evident over the last three years. Only REG3 and REG14 have recorded seasonal fluctuations, and there is no evidence of drawdown induced by mining. The model generally fails to reproduce the absolute water levels with simulated levels in some bores higher (5) and lower (2) than the measured levels. The measured and the simulated groundwater levels typically differ by about 10 m.

The datum elevation for bore GW3115 has been adjusted since the model was last run in 2013. The revised observed water level is lower and much closer to the modelled starting elevation. The observed level also remains flat, whereas the modelled water levels show a gradual fall from 2006 to 2016. This suggests the modelled hydraulic parameters or recharge rates within the model are not appropriate.

Two other bores installed within the Boggabri Volcanics with time variant datasets are IBC2110-MW3 and IBC2111 (Figure 7.1). Observed water levels have been rising at both locations since 2006. Levels often increase in steps rather than smoothly and there is a strong correlation with the CRD. These sites are located close to surface water storage areas associated with the Coal Handling and Preparation Plant (CHPP) and rail loading facility for Boggabri and Tarrawonga. It is possible that the bores are responding to enhanced infiltration from these artificial ponded areas. These facilities are not represented within the numerical model.

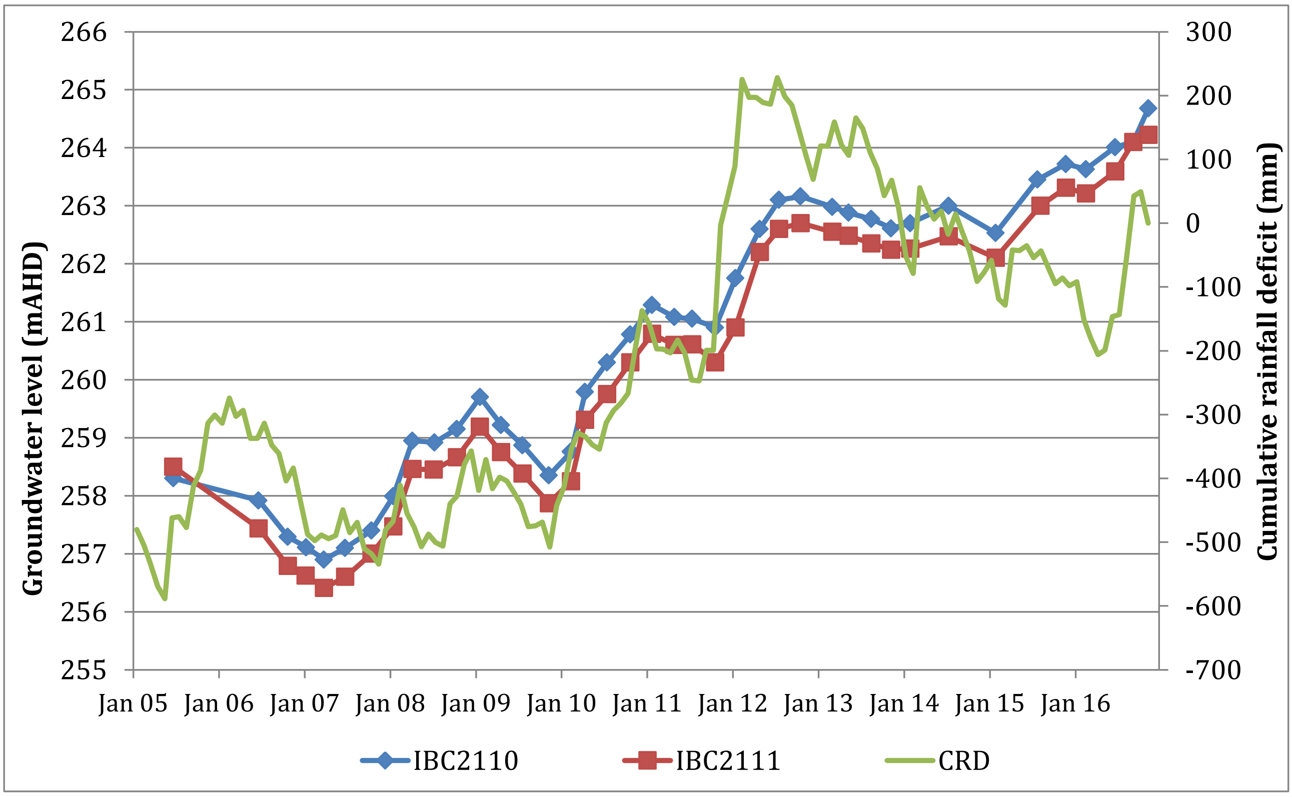


Figure 7.1 Water levels in the IBC Boggabri Volcanics bores vs CRD

7.3 Mining inflows

The mines within the BTM complex do not direct intersect any productive aquifers and therefore the volume of groundwater entering the mining area is not large. Within the BTM complex groundwater is not problematic for mining activities and is commonly evident only as damp evaporating seeps in active mine faces. The volume of groundwater taken from groundwater ingress is impossible to directly measure because it is not collected at a single point, and is subject to range of processes including evaporation, mixing with surface runoff and adhering to mined materials. There are two main methods which can be used to estimate the volume of groundwater intercepted during mining. Firstly groundwater flow models (numerical & analytical) that attempt to represent the groundwater flow processes directly, and secondly water budget models that indirectly estimate the volume of groundwater entering mining areas.

The mines within the BTM complex have utilised both numerical models and groundwater inflows to estimate the volume of groundwater intercepted by mining. These estimates are documented in the Annual Reviews prepared for each mine and are summarised in the sections below.

7.3.1 Boggabri

The Annual Review for the Boggabri Mine provides estimates of groundwater inflow to the mining areas for the calendar years of 2014 and 2015 as follows:

- 2014: 0.69 ML/d to 0.75 ML/d (224 – 274 ML/yr); and
- 2015: 0.51 ML/d to 0.57 ML/d (186 – 208 ML/yr).

The Annual Review indicates the total amount of water entering the mining area, which is comprised of groundwater and rainfall/runoff, averaged 4.46 ML/d in 2014 and 3.88 ML/d in 2015. This indicates the groundwater inflows were generally a small portion of the site water balance.

7.3.2 Tarrawonga

The Tarrawonga Mine uses the numerical groundwater flow model developed for the project EIS to estimate the groundwater removed from the mine. The 2015/2016 Annual Review concluded that the inflow from the porous rock groundwater system into the mine was less than the 0.5 ML/d average predicted in the EA for the same pit extent. No inflow estimates were provided in the 2014/2015 Annual Review other than commenting that the majority of water inflows to the open pit were from surface water. Total water take from the pit, including surface water runoff, was estimated at 224 ML for the 2015 annual reporting period.

7.3.3 Maules Creek

The Maules Creek Mine is relatively shallow and much of the active mining area is not expected to have intercepted the regional water table. There were small seepages observed in 2016 when the mine reached the Braymont coal seam. These seepages were removed from the pit through in-pit evaporation, with no active pumping required. The 2015 Annual Review estimated the groundwater take for 2015 to be less than 5 ML/yr.

7.3.4 Predicted inflows

The 2014 groundwater model estimated groundwater inflows for the three mines at a similar time to present day to be approximately:

- Boggabri: 1 ML/d to 1.5 ML/d;
- Tarrawonga: 0 ML/d to 0.05 ML/d; and
- Maules Creek: 0.1 ML/d to 0.7 ML/d.

Table 7.1 below shows the estimates of groundwater inflow for each mine, and the inflows predicted by the 2014 version of the groundwater model.

Table 7.1 Comparison of observed and predicted groundwater inflows

Site	Predicted inflow (ML/d)	Observed inflow (ML/d)
Boggabri	1 – 1.5	0.5 – 0.75
Tarrawonga	0 – 0.05	<0.5
Maules Creek	0.1 - 0.7	<0.01

Table 7.1 shows the model predicts higher volumes of groundwater inflow to the Boggabri and Maules Creek Mine compared to the estimates from the water balance models. In contrast the groundwater inflow to the Tarrawonga Mine shows closer agreement.

When interpreting the results in Table 7.1 it is important to note that the groundwater model represents groundwater removed by pumping, and water that does not report to pumping sumps because it evaporates from the highwall, or is bound as moisture with coal and spoil. In contrast the water balance method only estimates the volume of water that flows into the mine water circuit. Both methods are therefore not directly comparable due to differing underlying assumptions. Whilst estimates are different, the agreement is considered relatively good given the differences in the methodologies.

7.4 Conclusions

As noted in Section 7.1 for the purposes of the BTM complex a 'validated' numerical model should generally replicate the

- major changes in groundwater levels due to climatic events;
- drawdown in the groundwater systems due to the advancing mine face; and
- groundwater inflow to the active mining areas.

The review indicates that at a high level the model does achieve these requirements. There is however room to improve the match between measured and modelled groundwater levels, particularly around each of the mines.

The ability of the numerical model to replicate measured groundwater levels can be assessed by calculating the Scaled Root Mean Square Error (SRMS). The 2014 model achieved a RMS of 5.5% for the period 2006 to 2013. Since this time additional bores have been installed adjacent to the mining areas along the ridge line and in the alluvial plain. Whilst the SRMS was not recalculated with the new data collected since 2013 and the new monitoring bore sites it is clear that given the differences discussed above that the SRMS would increase. The calibration of the model was therefore adjusted to improve the match, particularly at the newer monitoring sites installed since the model was last updated. The sections below describe the updates to the model and updated predictions of drawdown and inflow.

8 Groundwater model update

8.1 Model development

8.1.1 Model code

The 2014 groundwater model was updated from MODFLOW SURFACT to MODFLOW-USG (Panday *et al*., 2015). MODFLOW-USG allows for use of an unstructured mesh, meaning that the cells in the model are not restricted to rectangular shapes. Small cells can be used in the area of interest to represent different features (such as geological boundaries, streams, observation wells, mining voids) with larger cells outside these areas where refinement is not required. This produces an optimal model grid, aiding numerical stability and limiting the number of cells. In addition, model layering does not need to be continuous over the model domain, and layers can terminate where geological units pinch out or outcrop such as the Permian coal measures along the Boggabri Ridge. Flow transfer processes between systems such as bedrock and alluvial groundwater systems can therefore be more accurately represented.

The input files for the MODFLOW-USG model were created using Fortran code and a MODFLOW-USG edition of the Groundwater Data Utilities by Watermark Numerical Computing. The model mesh was generated using Algomesh.

8.1.2 Geometry and boundary conditions

The extent of the model was almost identical to the 2014 Maules Creek groundwater model, with minor changes along the eastern boundary (Figure 8.1). The north-west corner of the grid was located at 212,150 mE and 6,632,450 mN (MGA94, Z56). The model was centred on the BTM complex and extended 28.5 km x 39.6 km, covering an area of approximately 961 km^2. The cells located to the east of the Mooki Fault, where the coal seams are not present were made inactive and excluded from the simulation.

The model mesh comprised two types of cells, being rectangular cells aligned with the primary direction of mining for each of BTM mines, and voronoi polygons for the remainder of the model area, as also shown on Figure 8.1. The model cell size varied from:

- 100 m x 50 m cells within the mining areas;
- 200 m x 200 m cells along the major creeks and rivers within the model domain;
- approximately 115 m diameter cells in a buffer zone surrounding the mining area where the majority of monitoring bores are located; and
- up to approximately 650 m diameter cells in areas distant from all the boundaries and potential areas of interest.

A second buffer zone with refined cells was also assigned in the area of the proposed low permeability barrier (LPB) along the eastern and southern edge of the approved Tarrawonga open cut void.

The number of cells varied from 6,429 to 19,292 per layer because of truncation of layers with non-continuous units. The total number of model cells in the model was 214,786.

The 2014 version of the model domain contained 12 layers, which was increased to 19 layers. Table 8.1 summaries the layers and the geological unit represented. The additional layers were added to better represent the base of the Tarrawonga Mine, which is at the floor of the Nagero seam, and to further subdivide the interburden. Each of the 2014 model layers representing interburden layers were split into two layers of equal thickness.

Table 8.1 Model layers

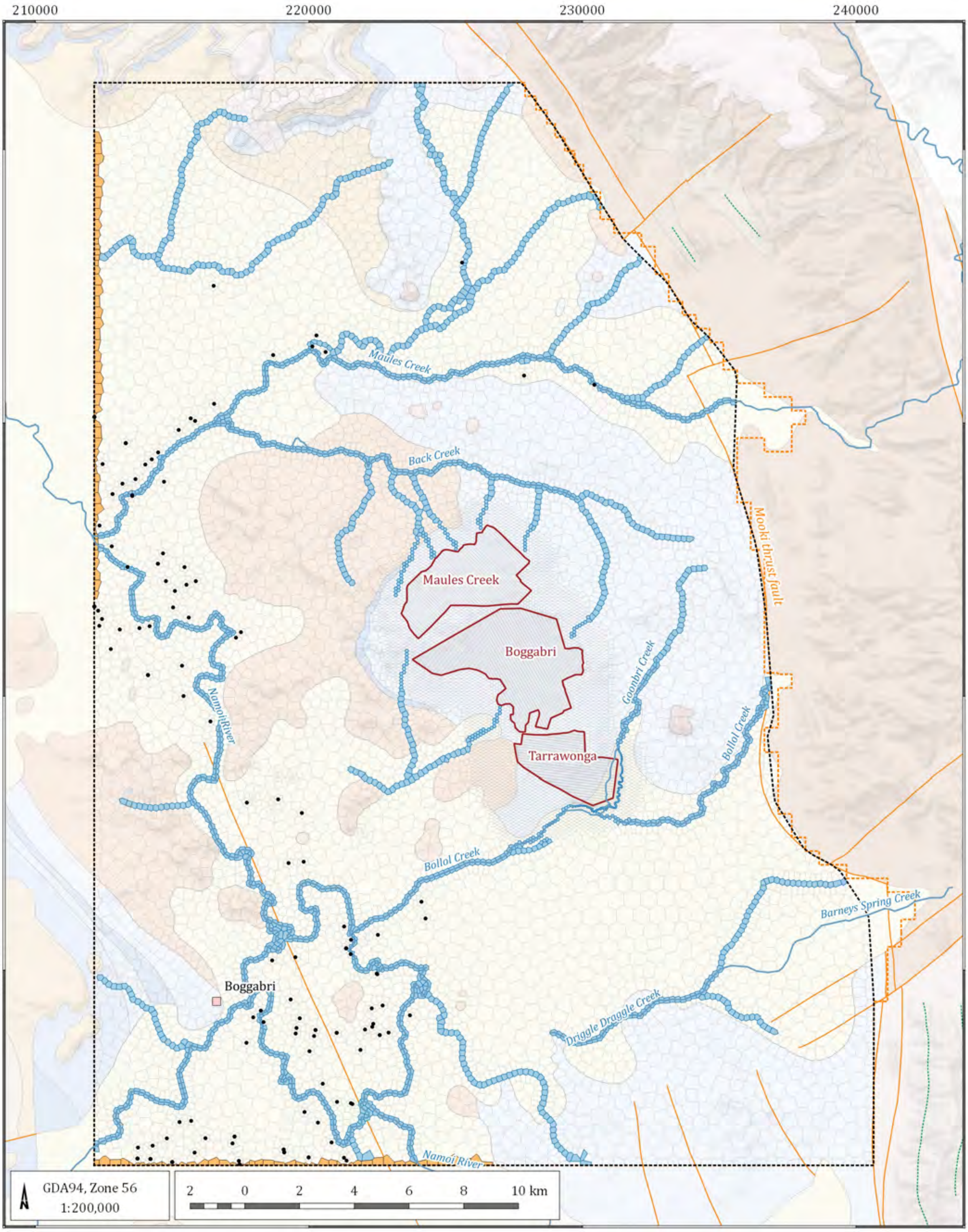
Model layer		Geological unit
2014 model	2016 model	
1	1	Narrabri Fm (alluvial), Weathered Permian
2	2	Gunnedah Fm (alluvial)
3	3	Interburden
3	4	Interburden
4	5	Herndale Seam
4	5	Onavale Seam
4	5	Teston Seam
4	5	Thornfield Seam
5	6	Interburden
5	7	Interburden

Model layer		Geological unit
2014 model	2016 model	
6	8	Braymont Seam
6	8	Jeralong Seam
6	8	Merriown Seam (Base of Boggabri Mine)
7	9	Interburden
7	10	Interburden
8	11	Velyama Seam
8	11	Nagero Seam (Base of Tarrawonga Mine)
7	12	Interburden
7	13	Interburden
8	14	Upper Northam Seam
8	14	Lower Northam Seam
8	14	Therribri A Seam
8	14	Therribri B Seam, Flixton Seam
9	15	Interburden
9	16	Interburden
10	17	Tarrawonga Seam
10	17	Templemore Seam (Base of Maules Creek Mine)
11	18	Interburden
12	19	Basalt

The following boundary conditions were assigned within the model:

- a "no flow" boundary along the Mooki Thrust Fault zone marking the eastern boundary of the model;
- constant head (CHD) boundaries in layers 1 and 2:
  - at 234 mAHD along the southern boundary of the model to represent flow of groundwater into the model through the alluvial aquifer; and
  - at 224 mAHD on the western boundary to represent outflow from the model through the alluvial aquifer.
- "no-flow" boundaries were set along the remainder of the northern, western and southern boundaries at an arbitrary distance considered beyond the influence of the mining operations.

Figure 8.2 shows the model mesh in a three dimensional view.



LEGEND

- Populated place
- Abstraction bore
- Major drainage
- Mine maximum open cut outlines
- Model extent 2016
- Model extent 2014
- Constant head cell
- River cell
- Mesh

Gunnedah Coalfield rock unit (1:100k)

- Qx - Quaternary Sediments
- Tv - Tertiary Volcanics
- Pmx - Maules Creek and Goonbri formations
- Plf - Leard Formation
- Pbr - Boggabri Volcanics
- Cbc - Currabubula Formation
- Crc - Rocky Creek Conglomerate
- Fault

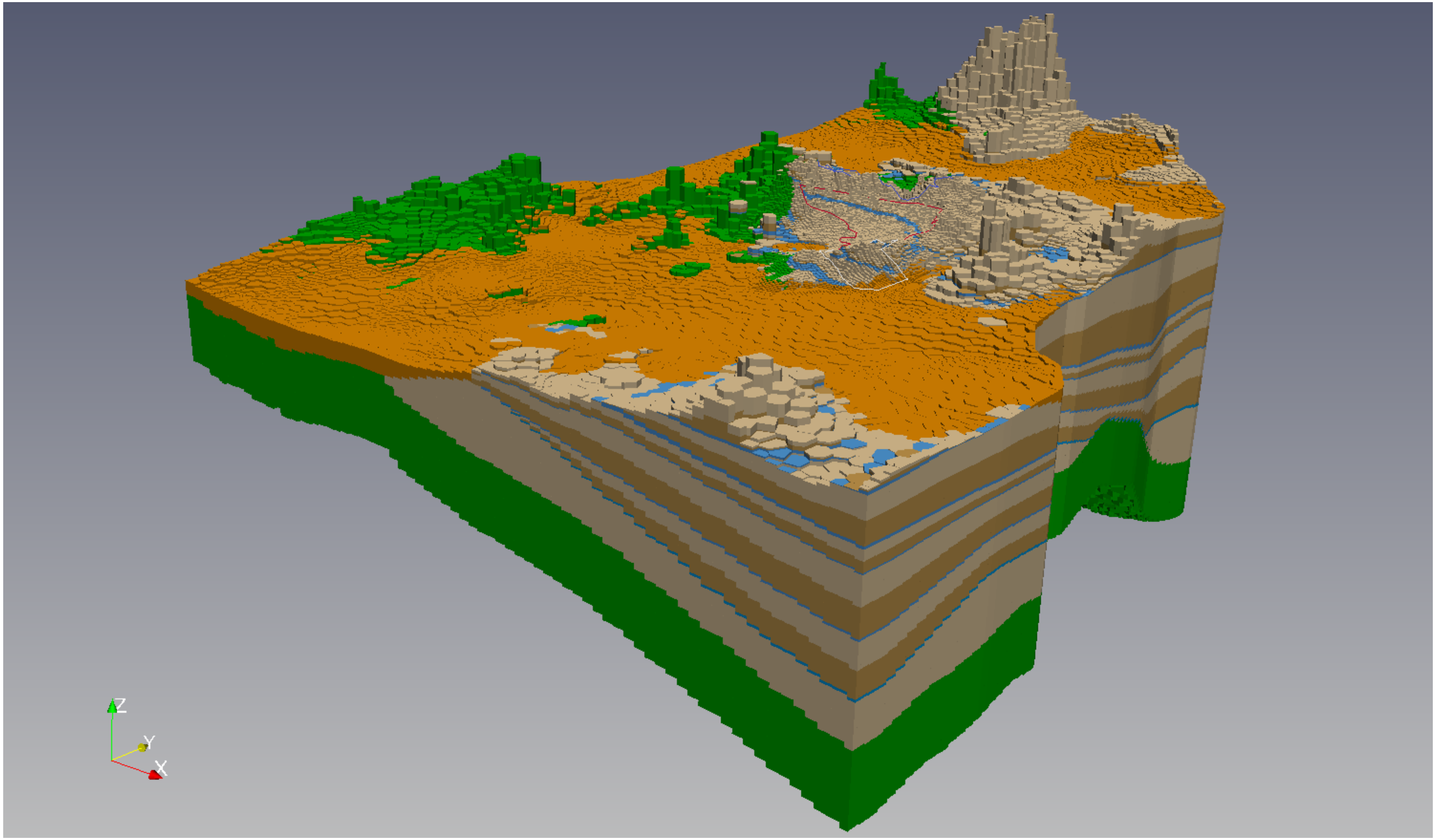
BTM model update (G1850A)

Model domain and mesh

DATE 29/03/2017

FIGURE No: **8.1**

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:/Projects/G1850A.BTM_Model/3_GIS/Workspaces/001_Deliverable1/08.01_G1850A_Model domain and mesh.qgs



3D model domain and layering

Figure 8.2

BTM model update (G1850A)

AGE

8.1.3 Other packages

8.1.3.1 Recharge and evapotranspiration

Recharge was applied to model layer 1, with differing rates for each geological unit. Recharge zones were assigned for the Permian coal measures, Boggabri Volcanics, alluvium, break of slope and the Boggabri-Tarrawonga CHPP area. Section 8.2.6 summarises the calibrated recharge rate for each zones.

Evapotranspiration was set at a maximum rate of 1,821 mm/yr, reducing linearly to an extinction depth of 1.3 m below ground surface.

8.1.3.2 Wells

Private abstraction from irrigation bores was represented in the model using the MODFLOW well package. Actual abstraction for each quarter previously provided by NSW government during previous iterations of the model was maintained to represent pumping from private bores for the period 2006 to 2010. An attempt was made to obtain updated abstraction records for each bore from NSW Department of Industries – Land and Water for the periods 2010 and 2016, but the data was not obtained in time for this model update. Instead an average abstraction rate was assigned to each bore calculated using abstraction recorded from between 2003 and 2005.

8.1.3.3 Rivers and creeks

The Namoi River and major ephemeral creeks were represented using the MOFLOW river package. The bed levels for the rivers were set by subtracting the assumed river depth from the topographic surface. The river bed depth was assumed based on previous observations of the area.

The Namoi River and Lower Maules Creek were assigned a bed elevation 5 m below ground level. Other surface drainages, such as Bollol Creek, were assigned with a 0.5 m incision into the landscape. The Namoi River, Maules Creek downstream of Elfin Crossing and an upstream section of the Bollol Creek were assigned a positive head of water in the river, that is, they are able to recharge the aquifer. The other surface drainage lines in the model were assigned a water level equal to the base elevation, hence they can only simulate the “drainage” of water out of the aquifer where and when the groundwater levels are high enough. The proposed diverted alignment of Goonbri Creek was represented in the model from the commencement of the calibration period in 2006. The water table within the model was below the base of Goonbri Creek and therefore the calibration was not considered sensitive to the creek location as it does not interact with shallow groundwater.

8.1.3.4 Drains

The model represents mining using the MODFLOW drain package. During the model runs, drain cells were used to simulate the effect of historic and future mining. A nominally high drain conductance of 100 m^2/day was applied to the drain cells. For the historical mines at Boggabri and Tarrawonga the locations of drain cells were determined using the shape of the empty mining voids, with the size of the mine increasing each year. Drain cells were set in all layers from the base of the void to ground surface, allowing pre-stripping and benching to be represented. For Maules Creek the mine was set to progress according to the mine plan provided in the project EIS, with a revised start date of January 2014. The mine progression at Boggabri and Tarrawonga was updated to reflect the actual progress of mining achieved since the last update to the groundwater model in 2014.

8.2 Model calibration

8.2.1 Approach

The objective of the calibration process was to improve the simulated groundwater levels and flows. The calibration was accomplished by finding a set of model parameters that produces simulated water levels and fluxes that most closely matches field measured.

The model was calibrated in two stages. Firstly, a steady state model was manually calibrated to reproduce groundwater levels prior to mining at the BTM complex. The water levels were used as starting conditions for transient calibration. A transient model was then set up for the calibration process using PEST. Each transient calibration run commenced by running the steady state model using the adopted hydraulic parameters to obtain the starting water levels. The transient model used for calibration was set up with 44 quarterly (91.3 days) stress periods, representing the period from January 2006 to December 2016.

PEST was used to systematically adjust the model properties to obtain the best match between modelled and measured water levels. The software makes small adjustments to the parameter set within bounds determined by the user in order to match the observed and simulated data. PEST adjusted the following properties in the model:

- horizontal and vertical hydraulic conductivity;
- percentage of recharge to each recharge zone; and
- storage properties - specific yield and specific storage.

PEST was applied to zonal properties with single values per layer, i.e there was no spatial variability in model parameters.

At the completion of the model simulation the final combination of model parameters was manually checked to ensure that they remained consistent with the conceptual understanding of the area.

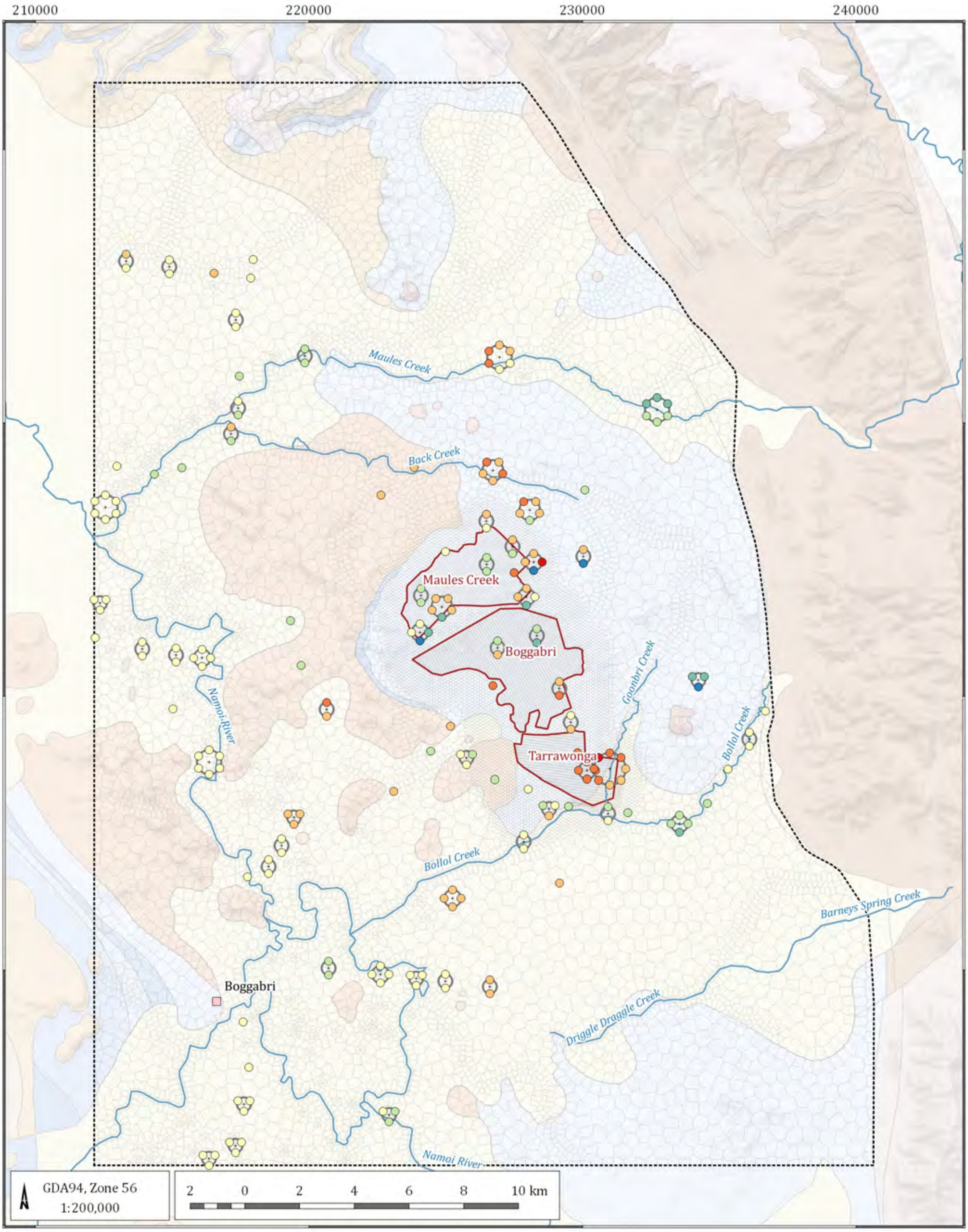
8.2.2 Groundwater level targets

One of the key objectives whilst calibrating the transient model was to represent the declining water levels measured within the Permian coal seams between 2006 and 2016 due to mining at the BTM complex. Water level measurements from a total of 194 individual bores and VWPs were used to calibrate the model. Figure 8.3 shows the residuals for each observation bore which is the average difference between observed and modelled water levels over the period of record. Where there are multiple bores or VWPs in one location a circle showing the residuals for each separate monitoring point is provided. The aim of the calibration was to make the average residuals as close to zero as possible, which indicates that the two datasets are matching well. This is shown on the map using white circles. If the residual map shows a negative value (orange) then the observed heads are on average lower than the modelled water levels. Conversely if the residual map shows a positive value (blue) then the observed heads are on average higher than the modelled water levels.

The variable nature of the sub-surface means observed and modelled water levels will never perfectly match. During calibration, effort is made to remove systematic errors with positive or negative residuals. The residuals map also helps identify bores with anomalous data.

Appendix C contains hydrographs for each of the monitoring bores showing the measured and model simulated groundwater levels between 2006 and 2016. The hydrographs indicate the model is reproducing the general trend of reducing water levels around the mining area. The most significant exception was the measurements from the VWP strings within TA60 and TA65 east of the Tarrawonga Mine, which have recorded declining water levels that could not be matched well by the model.

The reasons for the discrepancies at the Tarrawonga VWPs are unclear. There are extremely high drawdowns reported for the deeper VWP sensors despite them being some distance from the active mining face. It is possible that the coal is highly fractured and therefore highly permeable in this area of the complex. It is also be possible that the actual VWP installs were different to those shown on the bore construction drawing. It is recommended this issue is further investigated.



LEGEND

- Populated place
- Major drainage
- Mine maximum open cut outlines
- Model extent
- Mesh

Gunnedah Coalfield rock unit (1:100k)

- Qx - Quaternary Sediments
- Tv - Tertiary Volcanics
- Pmx - Maules Creek and Goonbri formations
- Plf - Leard Formation
- Pbr - Boggabri Volcanics
- Cbc - Currabubula Formation
- Crc - Rocky Creek Conglomerate

Residuals

- -105 - -40
- -40 - -15
- -15 - -3
- -3 - 3
- 3 - 15
- 15 - 40
- 40 - 100

BTM model update (G1850A)

Transient model residuals

AGE

DATE 04/12/2017

FIGURE No: **8.3**

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:/Projects/G1850A.BTM_Model/3_GIS/Workspaces/001_Deliverable1/08.03_G1850A_Transient model residuals.qgs

8.2.3 Observation bore statistics

Figure 8.4 shows a scattergram of observed and simulated groundwater levels from the transient model for the period 2006 to 2016. The sites are coloured according to their origin.

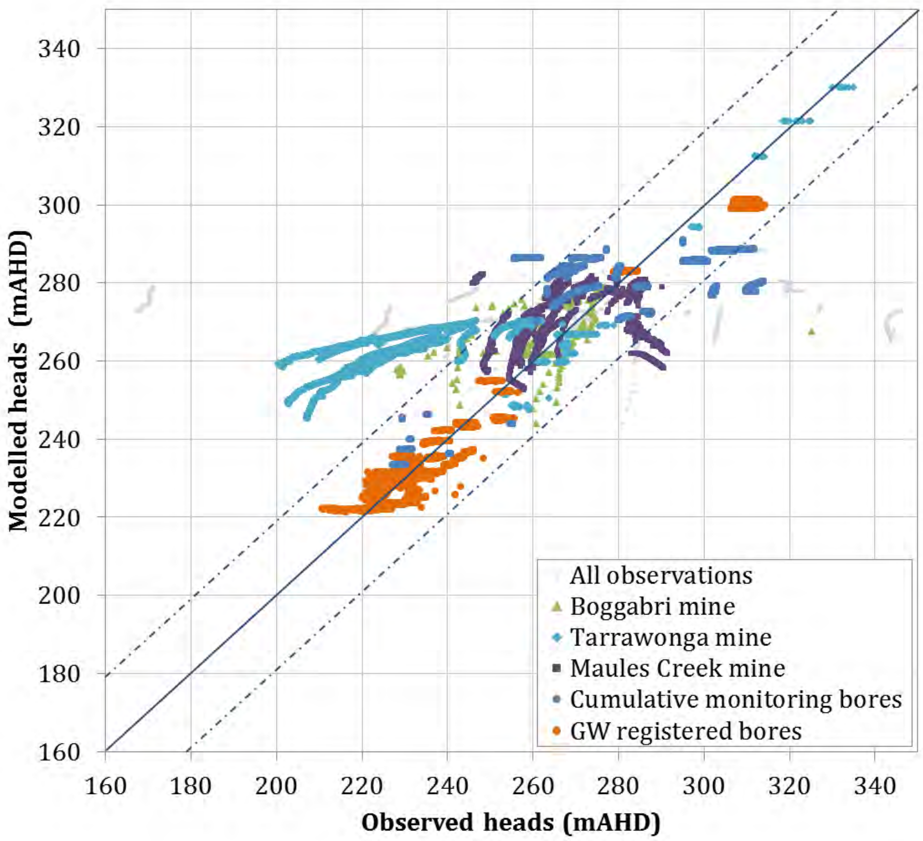


Figure 8.4 Scattergram showing observed and modelled water levels

The majority of data points for the DPI Water registered bores plot close to the 1:1 line. The most obvious outliers on the plot are the Tarrawonga VWP sites, which have a large observed range but only a small modelled range; and the Maules Creek sites which have a small observed range and a larger modelled range. The Maules Creek bores start close to the 1:1 line then drift away.

The mismatch between the measured and modelled groundwater levels at the Maules Creek monitoring bores is considered to be due to the mining progression represented within the model. The mine plan for Maules Creek was based on the EIS, and therefore represented mining deeper than has actually occurred. The data points shown in grey were anomalous for their particular location and were not used during the calibration process.

The Root Mean Square (RMS) error calculated for the calibrated transient model was 26 m. The ratio of RMS (26 m) to the total head change across the calibration points (209.8 m) indicated a Scaled RMS of 9.1%. This is within the suggested limit suggested in the Australian Modelling Guidelines (Barnett, 2012) target of less than 10%.

8.2.4 Groundwater inflows

Figure 8.5 shows the modelled inflows to each of the mining areas during the calibration period.

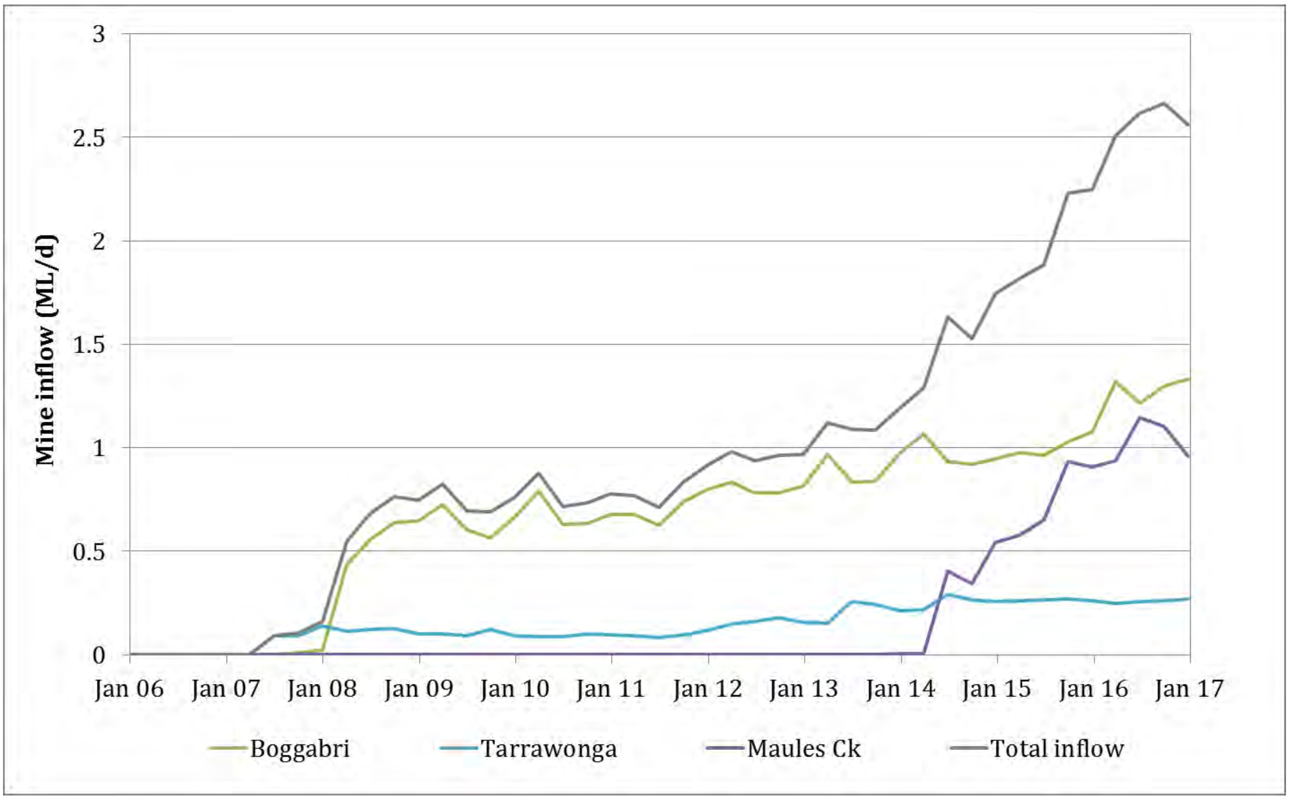


Figure 8.5 Modelled inflows to mining areas

The model predicts the groundwater inflow to each of the mines increases steadily as the footprint of the mining area expands. As discussed in Section 7.3, due to the relatively low permeability of the geological units exposed within the mining areas it is not possible to measure the actual groundwater inflow. The only option to assess the validity of the model predictions are to compare with other estimates from water balance methods. The latest annual reports indicate the following inflows for the BTM complex mines:

- Boggabri: 0.5 ML/d to 0.75 ML/d
- Tarrawonga: <0.5 ML/d
- Maules Creek: <0.01 ML/d

The modelled inflows are close to the observed inflows for Boggabri and within the correct magnitude for Tarrawonga. Inflows for Maules Creek are noticeably higher than observed. As discussed previously this is expected to be a result of representing a mine plan for Maules Creek that has the mine extracting from seams which lie below the water table, whereas in reality the mine is currently much shallower.

8.2.5 Hydraulic properties

Table 8.2 summarises the optimal hydraulic properties from the calibration process.

Table 8.2 Calibrated hydraulic parameters

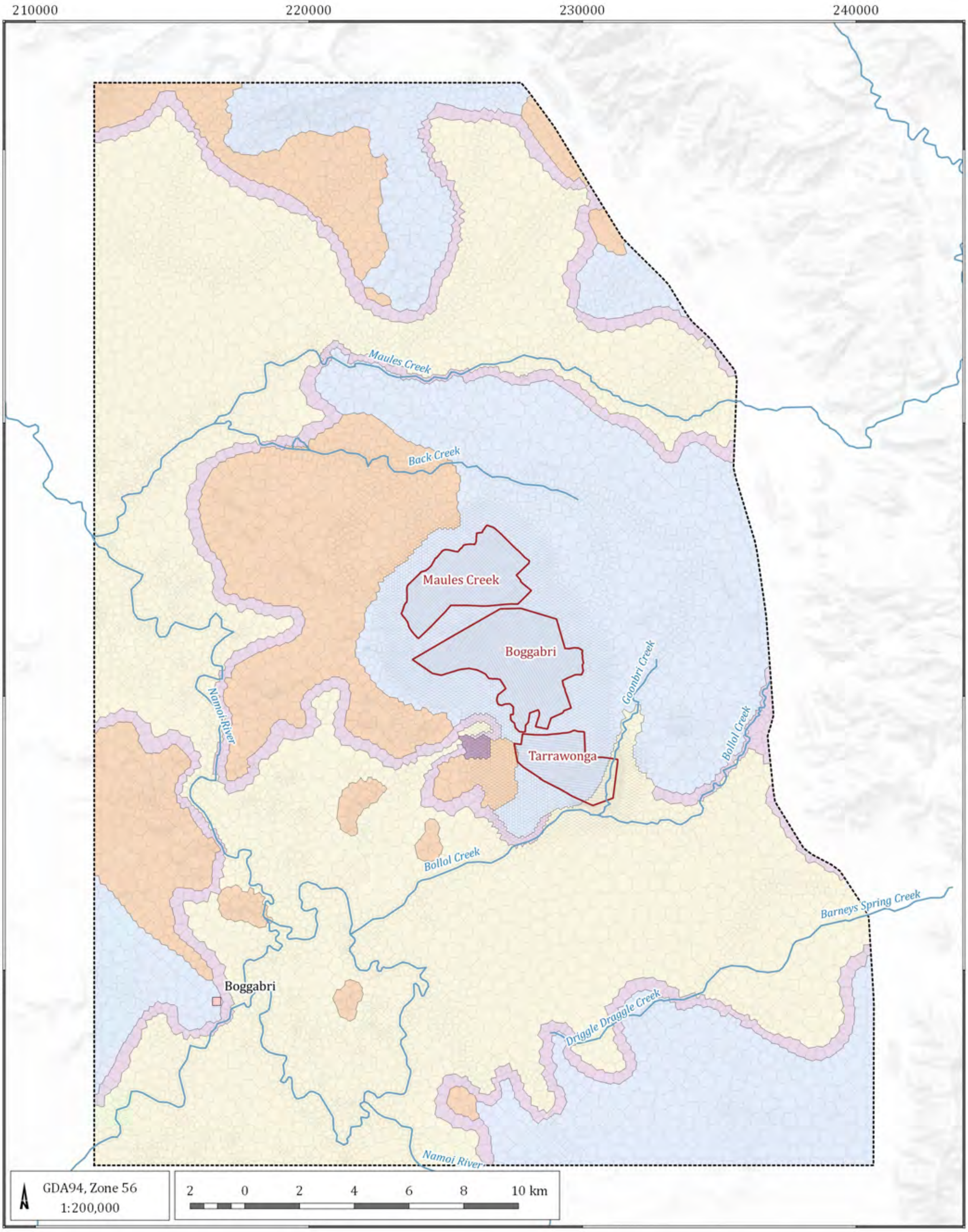
Geology	Hydraulic conductivity (m/day)		Storage properties	
	horizontal (Kh)	vertical (Kv)	specific yield (-)	specific storage (m^{-1})
Narrabri Formation	2.30	3.29×10^{-1}	5.20×10^{-2}	1.46×10^{-5}
Gunnedah Formation	6.44	9.22×10^{-1}	5.20×10^{-2}	1.46×10^{-3}
Weathered Permian	6.12×10^{-3}	8.76×10^{-4}	1.00×10^{-3}	1.00×10^{-5}
Weathered volcanics	1.45×10^{-3}	2.07×10^{-4}	1.00×10^{-3}	1.00×10^{-5}
Interburden	1.00×10^{-3}	3.96×10^{-5}	1.50×10^{-4}	5.00×10^{-7}
Coal Seams	4.45×10^{-1}	7.00×10^{-3}	7.50×10^{-3}	5.00×10^{-5}
Boggabri Volcanics	1.00×10^{-4}	1.15×10^{-5}	1.50×10^{-3}	1.50×10^{-5}

The calibrated horizontal hydraulic conductivity for the Narrabri Formation (2.3 m/day) is slightly lower than the value used in the 2014 model but remains higher than the value used in the Boggabri borefield model (Parsons Brinkerhoff, 2015). The calibrated value for the Gunnedah Formation (6.44 m/day) is within the previous range used in 2014. Vertical hydraulic conductivity was higher in the Narrabri and similar in the Gunnedah. The specific yield was at comparable values for the Narrabri and the Gunnedah.

The calibrated horizontal hydraulic conductivity of the Permian coal seams and interburden were slightly higher than the values adopted in previous versions of the model. This result is expected to have been influenced by the drawdown observed in the network and the mine plans represented in the model. The Boggabri Volcanics decreased to similar values as the Boggabri borefield model. This was necessary for the model to match the observed water levels within the Boggabri Volcanics that did not record any obvious depressurisation attributable to mining. Vertical hydraulic conductivity and storage values decreased slightly for all of the bedrock units.

8.2.6 Recharge

Recharge to the model domain was based on the soil moisture balance described in Section 3.2. The recharge rate estimated from the soil moisture balance was then applied at differing rates to the alluvium, Permian, Boggabri Volcanics, break of slope, and an additional small zone next to the Boggabari - Tarrawonga CHPP. Figure 8.6 shows each of the recharge zones.



LEGEND

- Populated place
- Major drainage
- Mine maximum open cut outlines
- Model extent

Recharge zones

- Zone 1 - Alluvium
- Zone 2 - Permian
- Zone 3 - Boggabri volcanics
- Zone 4 - Break of slope
- Zone 5 - Boggabri-Tarrawonga CHPP

BTM model update (G1850A)

Recharge zones

AGE

DATE 29/03/2017

FIGURE No: **8.6**

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:/Projects/G1850A.BTM_Model/3_GIS/Workspaces/001_Deliverable1/08.06_G1850A_Recharge zones.qgs

Figure 8.7 shows the recharge rates in mm/year applied to each recharge zone within the model. The rainfall recharge rates generally decreased when compared to previous iterations of the groundwater model. This was a necessary adjustment to allow lower values of hydraulic conductivity in some of the model layers and replication of water level observations. The figure shows the highest rates of recharge occur within the alluvium and at the edge of the alluvium at the break of slope. Recharge is about 100 times lower within the Permian coal measures and 1000 times lower to the Boggabri Volcanics.

The small separate zone within the alluvium around the Boggabri-Tarrawonga CHPP was introduced to account for a conceptual increase in the recharge generated by the construction of several shallow ponds in this area of the site. Nearby groundwater monitoring suggested that the ponds were enhancing recharge and causing groundwater levels to rise more than expected. However, during the calibration process to optimise the correlation between measured and modelled groundwater levels PEST decreased recharge in this zone to less than background levels. The conceptualisation of this area will require further review before the next model recalibration.

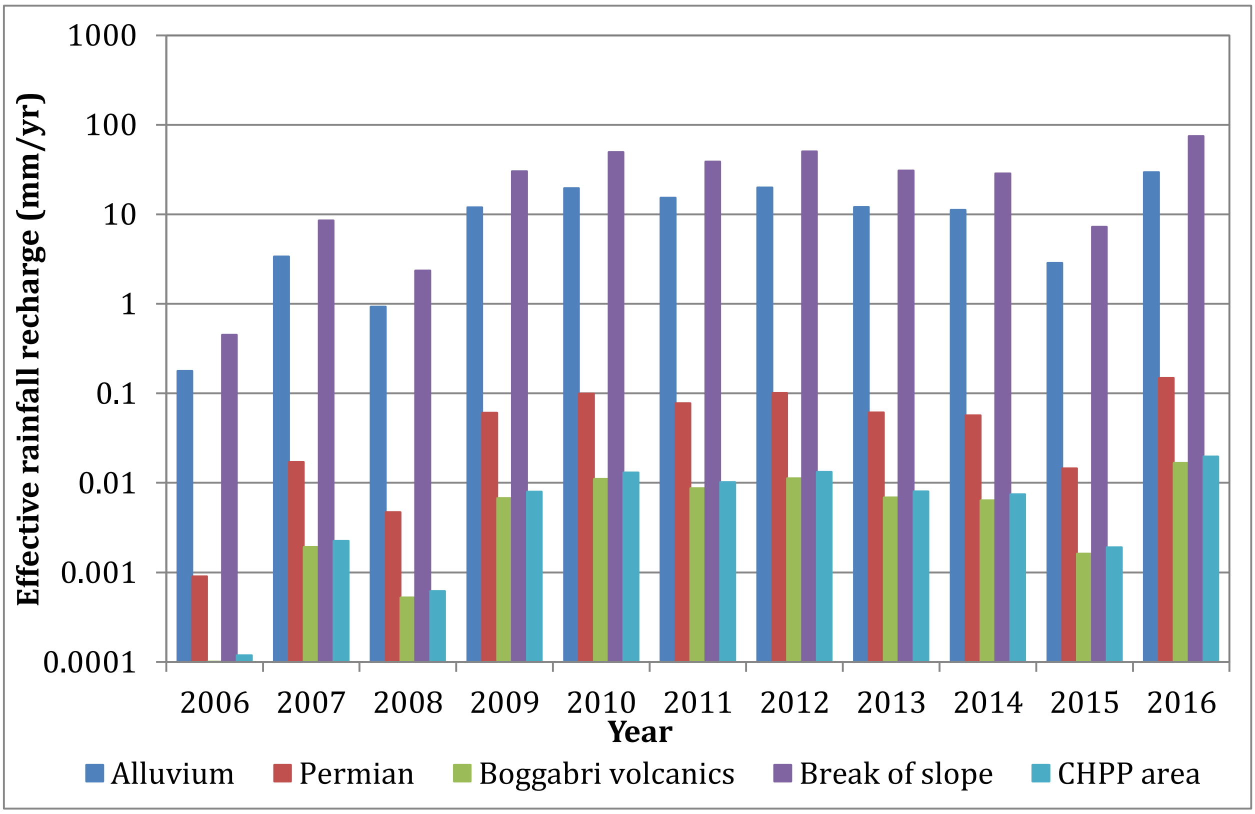


Figure 8.7 Calibrated recharge rates

8.2.7 Water budget

Table 8.3 summarises the average values for the model water budget over the calibration period.

Table 8.3 Transient water budget

Parameter	Input (ML/day)			Output (ML/day)		
	minimum	average	maximum	minimum	average	maximum
Rainfall recharge	0.0	20.1	175.6	-	-	-
River leakage	9.2	9.2	9.3	0.0	0.05	0.2
Evapotranspiration	-	-	-	1.5	2.0	3.4
Fixed head	8.7	19.2	49.0	3.8	4.6	6.1
Wells	-	-	-	4.3	39.1	115.9
Drains	-	-	-	0.0	1.0	2.7
Storage	0.8	18.9	58.8	0.0	20.7	150.6
TOTAL IN/OUT	-	67.5	-	-	67.5	-

The water budget indicates water enters the model domain on average via:

- 20.1 ML/day rainfall recharge across the active model area (961 km^2);
- 9.2 ML/day from river transmission leakage; and
- 19.2 ML/day inflow from sections of the Upper Namoi alluvial system outside the model domain.

Groundwater discharge from the model is via:

- 0.05 ML/day discharges into rivers and creeks;
- 2.0 ML/day is lost to evapotranspiration;
- 4.6 ML/day is removed through flow to the Namoi Valley alluvium outside the model domain;
- 39.1 ML/day is removed from the aquifer via private pumping bores; and
- 1.0 ML/day on average seeps into the mining voids.

Figure 8.8 shows the transient water budget graphically.

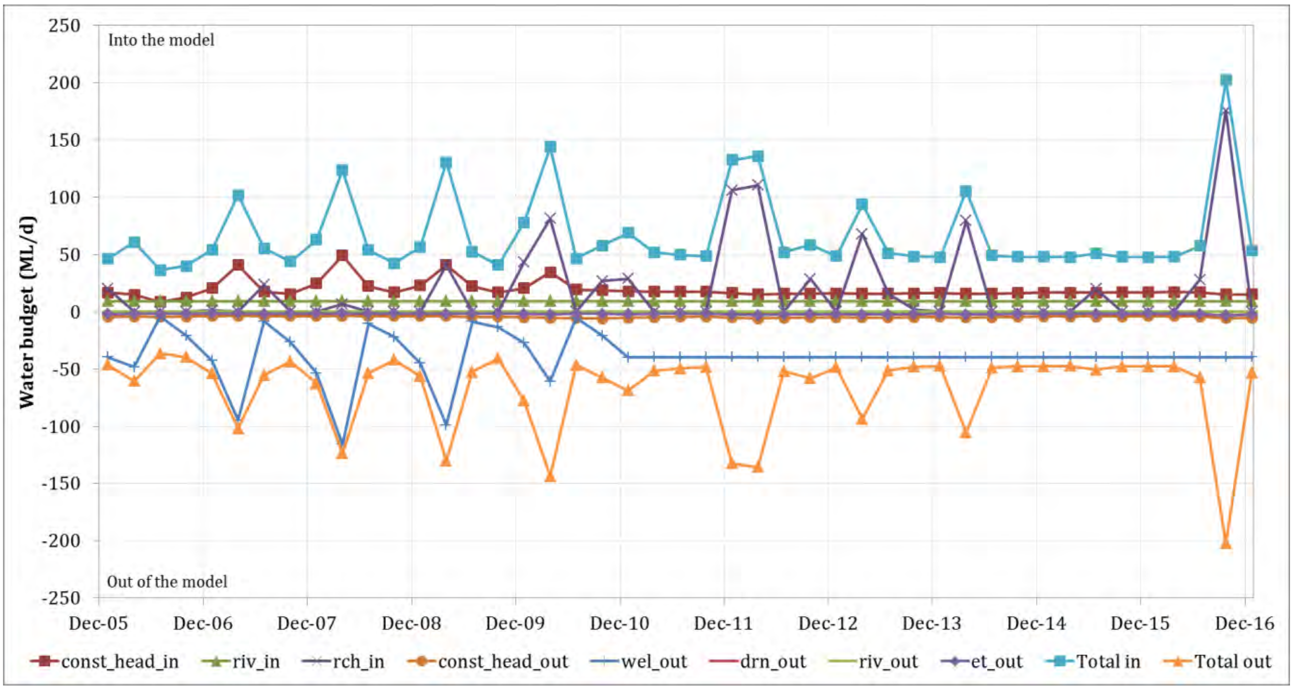


Figure 8.8 Water budget graph

The cumulative mass balance error, that is, the difference between calculated model inflows and outflows, at the completion of the calibration run was -1.73%. The maximum percent discrepancy for individual time steps within the transient model run is 0.14%. This maximum error is within acceptable limits for adequate numerical convergence (<2%: Australian Modelling Guidelines – Barnett [2012]).

8.3 Predictive simulations

8.3.1 Model setup

The predictive modelling was completed by extending the calibrated model. The predictive model was set up with quarterly stress periods (91.3 days) from January 2017 to December 2029. December 2029 was adopted as the end of predictions as this is when the first of the BTM mines (Tarrawonga) is expected to close based on current approvals.

The time variant model packages were extended to the end of the simulation. The evapotranspiration, river and constant head packages were extended using the same uniform values adopted in the calibration model. The well and recharge packages were extended by repeating the average quarterly rates assigned within the calibration model.

The future mining schedules were provided by each of the mines within the BTM complex and processed into quarterly stress periods. Similar to the historical model the drain cells used to simulate mining remained active for the entire simulation. The drain cells were set to the base of the lowest coal seam being mined. For Boggabri Mine this was layer 8, layer 11 for Tarrawonga Mine and from layer 11 to layer 17 for Maules Creek depending on the area being mined.

The planned low permeability barrier adjacent to the Tarrawonga Mine was represented from 2024 using the time-variant materials package. The barrier was installed through model layers 1 and 2 (alluvium) and assigned a hydraulic conductivity of 0.001 m/day (1 x 10^{-8} m/s) as adopted in the site EIS (Heritage Computing 2012).

8.3.2 Mining phase water budget summary

Figure 8.9 shows the budget for the components of the predictive model. Positive values indicate water entering the model and negative numbers represent water leaving. Table 8.4 summarises the average values for the model water budget over the predictive period.

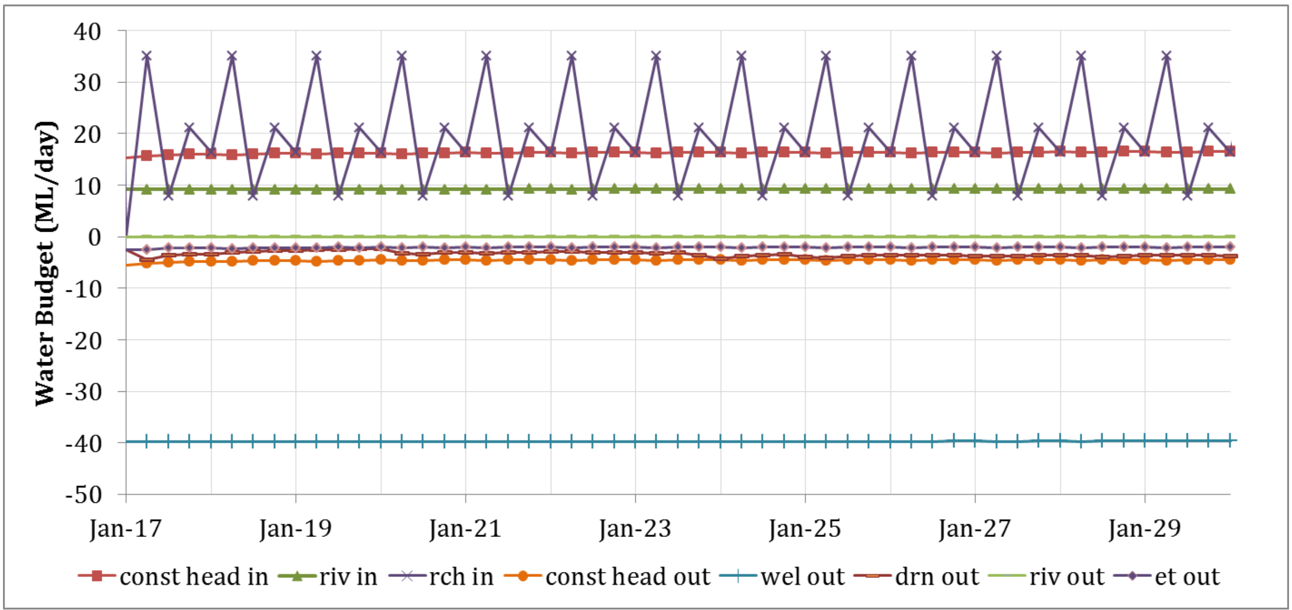


Figure 8.9 Predictive model cumulative water budget

Table 8.4 Transient predictive model water budget

Parameter	Input (ML/day)			Output (ML/day)		
	minimum	average	maximum	minimum	average	maximum
Rainfall recharge	7.9	20.1	35.1	-	-	-
River leakage	9.2	9.2	9.2	0.02	0.03	0.10
Evapotranspiration	-	-	-	2.0	2.1	2.4
Fixed head	15.6	16.3	16.5	4.4	4.5	5.2
Wells	-	-	-	39.6	39.7	39.8
Drains	-	-	-	2.4	3.4	4.4
Storage	2.0	7.7	18.2	0.0	3.6	13.5
TOTAL IN/OUT	-	53.3	-	-	53.3	-

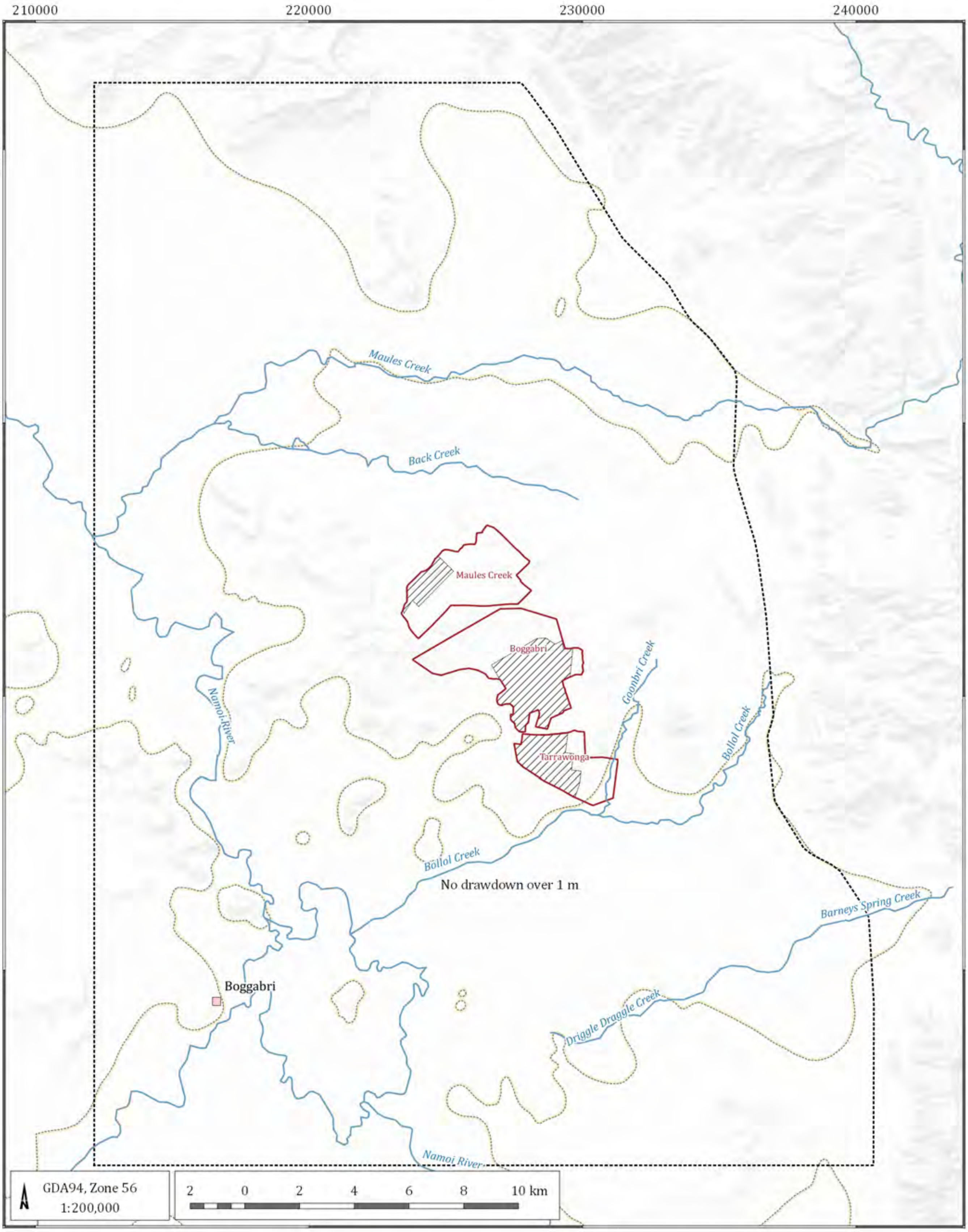
Figure 8.9 shows the influence of the mining, as represented by flows to the drain cells are a relatively small component of the water balance at the scale of the regional model. The cumulative mass balance error at the completion of the predictive run was 0.003%. The maximum percent discrepancy for individual time steps within the transient model run is 0.03%. This maximum error is within acceptable limits for adequate numerical convergence (<2%: Australian Modelling Guidelines – Barnett [2012]).

8.3.3 Piezometric surface/water table levels

The updated model was used to simulate drawdown at 2019, which is when the next update for the groundwater model is required, and at 2029, which is the last year when all three BTM mines are approved to be operating at the same time. Figure 8.10 to Figure 8.15 show the cumulative drawdown for the following model layers at 2019 and 2029.

- layer 1: Narrabri Formation alluvium;
- layer 2: Gunnedah Formation alluvium; and
- layer 8: Merriown coal seam.

The figures show the model predicts only limited drawdown within the alluvial groundwater systems as a result of mining. The drawdown is confined to the zones of alluvium that that have infilled valleys immediately adjacent to the active mining areas at Boggabri and Tarrawonga Mine.



LEGEND

- Populated place
- Major drainage
- Mine maximum open cut outlines
- Mine extent to 2019
- Model extent
- Alluvium

Drawdown (m)

- 1
- 2
- 5
- 10
- 20
- 50
- 100
- 200
- 500
- Drawdown contour (m)

BTM model update (G1850I)

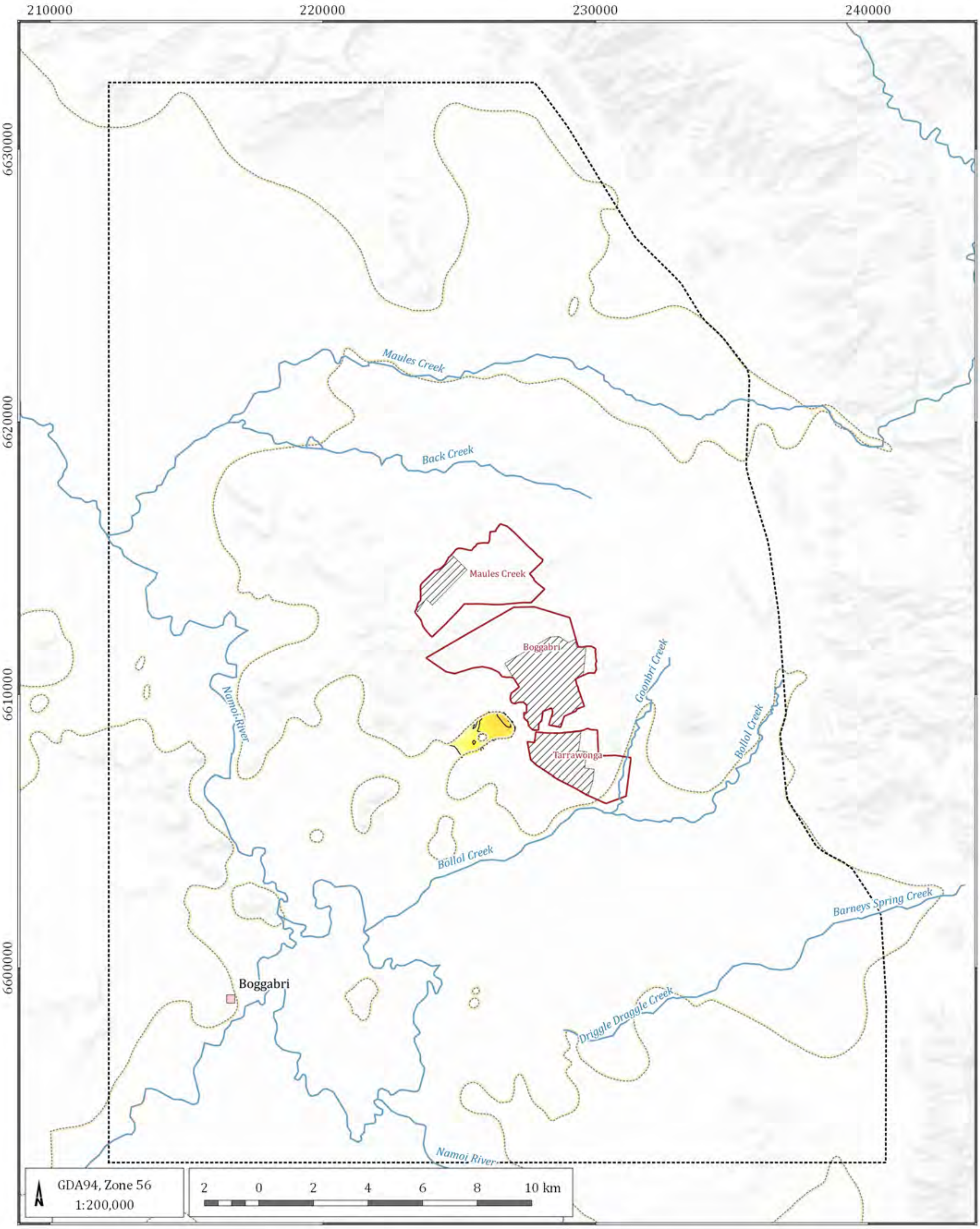
Simulated drawdown at end 2019
Layer 1 - Narrabri alluvium

AGE

DATE 25/07/2018

FIGURE No: **8.10**

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:/Projects/G1850I.BTM_peer_review_responses/3_GIS/Workspaces/001_Deliverable1/08.10-15_G1850I_Simulated drawdown.qgs



LEGEND

- Populated place
- Major drainage
- Mine maximum open cut outlines
- Mine extent to 2019
- Model extent
- Alluvium

Drawdown (m)

- 1
- 2
- 5
- 10
- 20
- 50
- 100
- 200
- 500
- Drawdown contour (m)

BTM model update (G1850I)

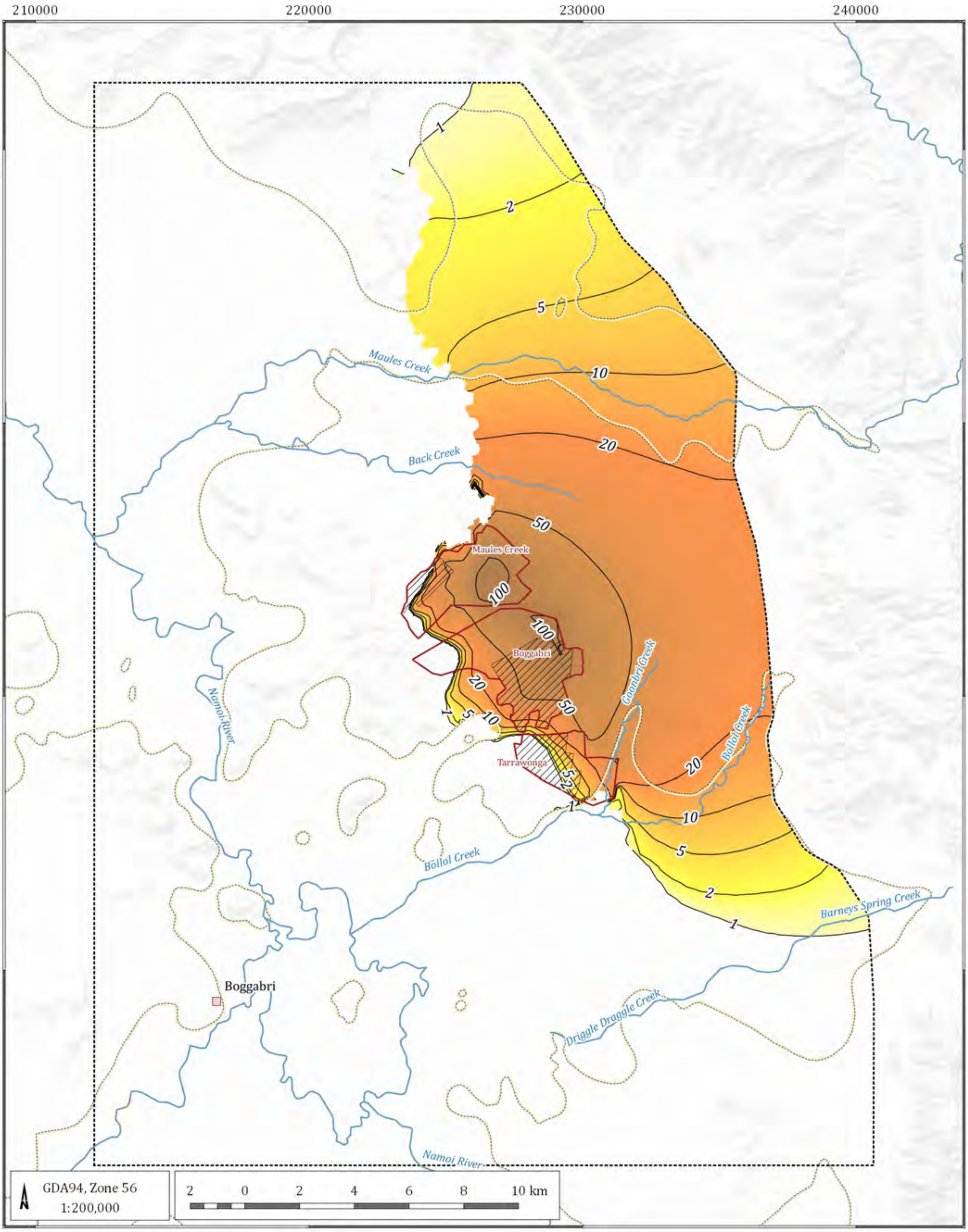
Simulated drawdown at end 2019
Layer 2 - Gunnedah alluvium

AGE

DATE 25/07/2018

FIGURE No: **8.11**

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:/Projects/G1850I.BTM_peer_review_responses/3_GIS/Workspaces/001_Deliverable1/08.10-15_G1850I_Simulated drawdown.qgs



LEGEND

- Populated place
- Major drainage
- Mine maximum open cut outlines
- Mine extent to 2019
- Model extent
- Alluvium

Drawdown (m)

- 1
- 2
- 5
- 10
- 20
- 50
- 100
- 200
- 500
- Drawdown contour (m)

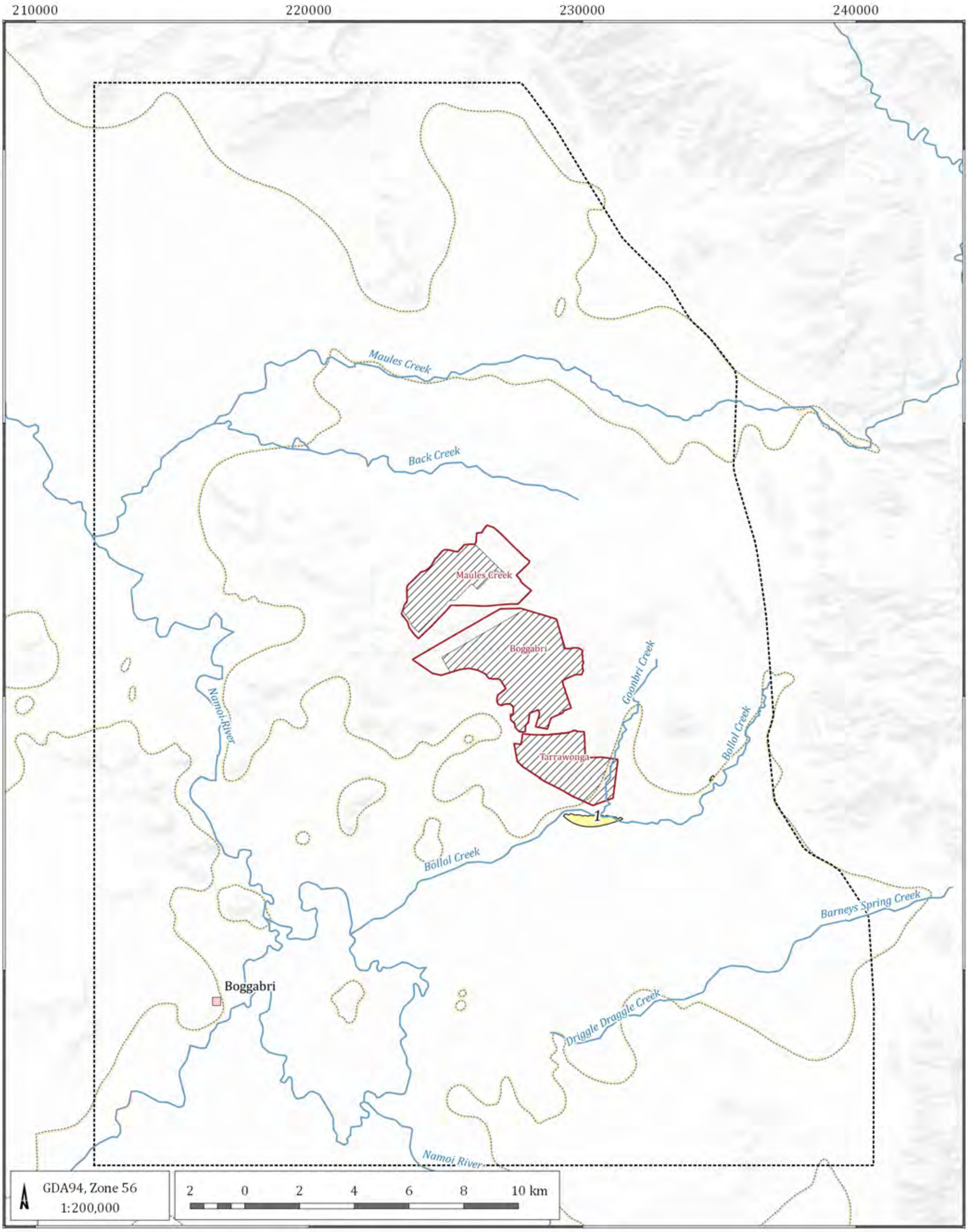
BTM model update (G1850I)

Simulated drawdown at end 2019
Layer 8 - Merriown seam

DATE 25/07/2018

FIGURE No: **8.12**

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:/Projects/G1850I.BTM_peer_review_responses/3_GIS/Workspaces/001_Deliverable1/08.10-15_G1850I_Simulated drawdown.qgs



LEGEND

- Populated place
- Major drainage
- Mine maximum open cut outlines
- Mine extent to 2029
- Model extent
- Alluvium

Drawdown (m)

- 1
- 2
- 5
- 10
- 20
- 50
- 100
- 200
- 500
- Drawdown contour (m)

BTM model update (G1850I)

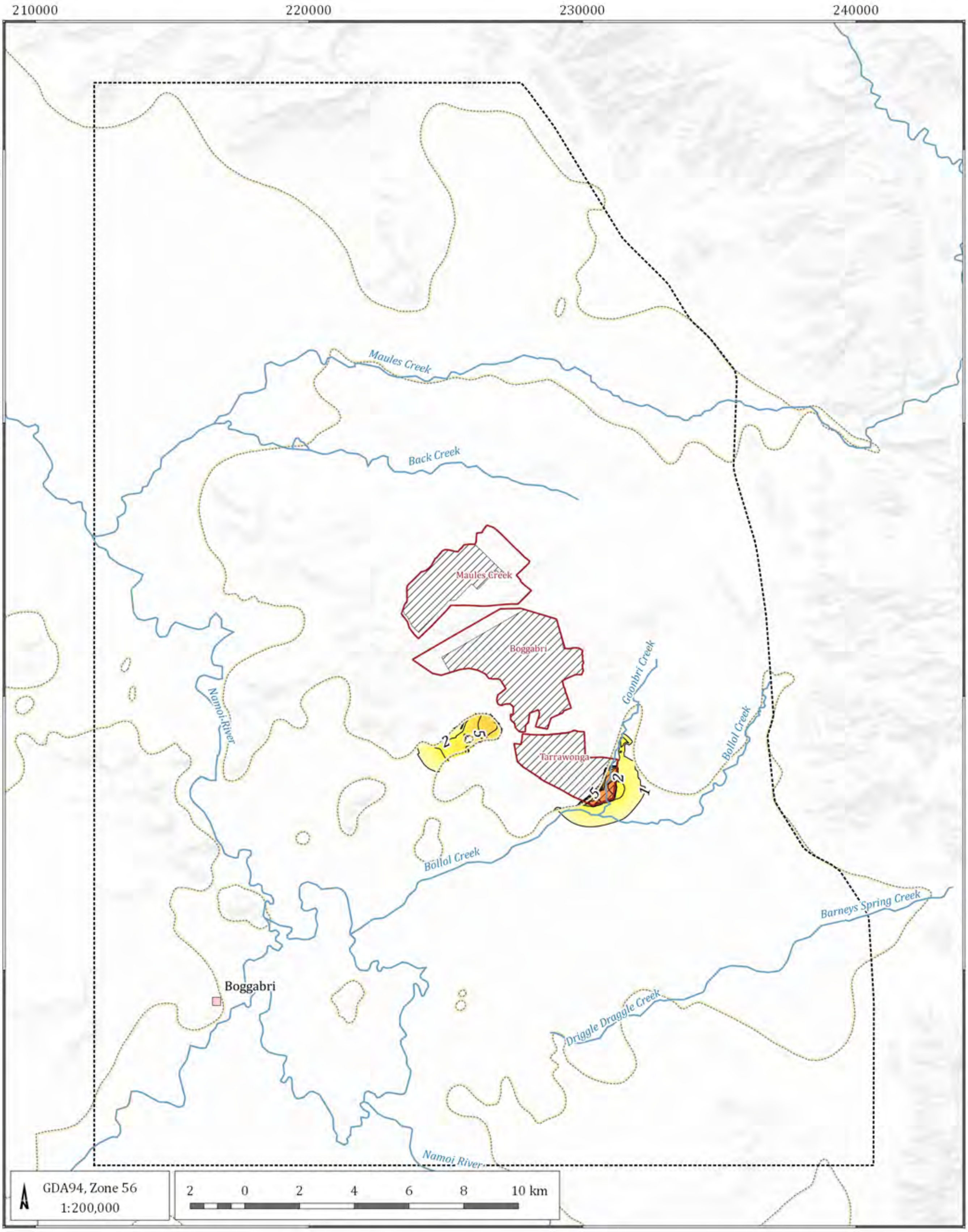
Simulated drawdown at end 2029
Layer 1 - Narrabri alluvium

AGE

DATE 25/07/2018

FIGURE No: **8.13**

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:/Projects/G1850I.BTM_peer_review_responses/3_GIS/Workspaces/001_Deliverable1/08.10-15_G1850I_Simulated drawdown.qgs



LEGEND

- Populated place
- Major drainage
- Mine maximum open cut outlines
- Mine extent to 2029
- Model extent
- Alluvium

Drawdown (m)

- 1
- 2
- 5
- 10
- 20
- 50
- 100
- 200
- 500
- Drawdown contour (m)

BTM model update (G1850I)

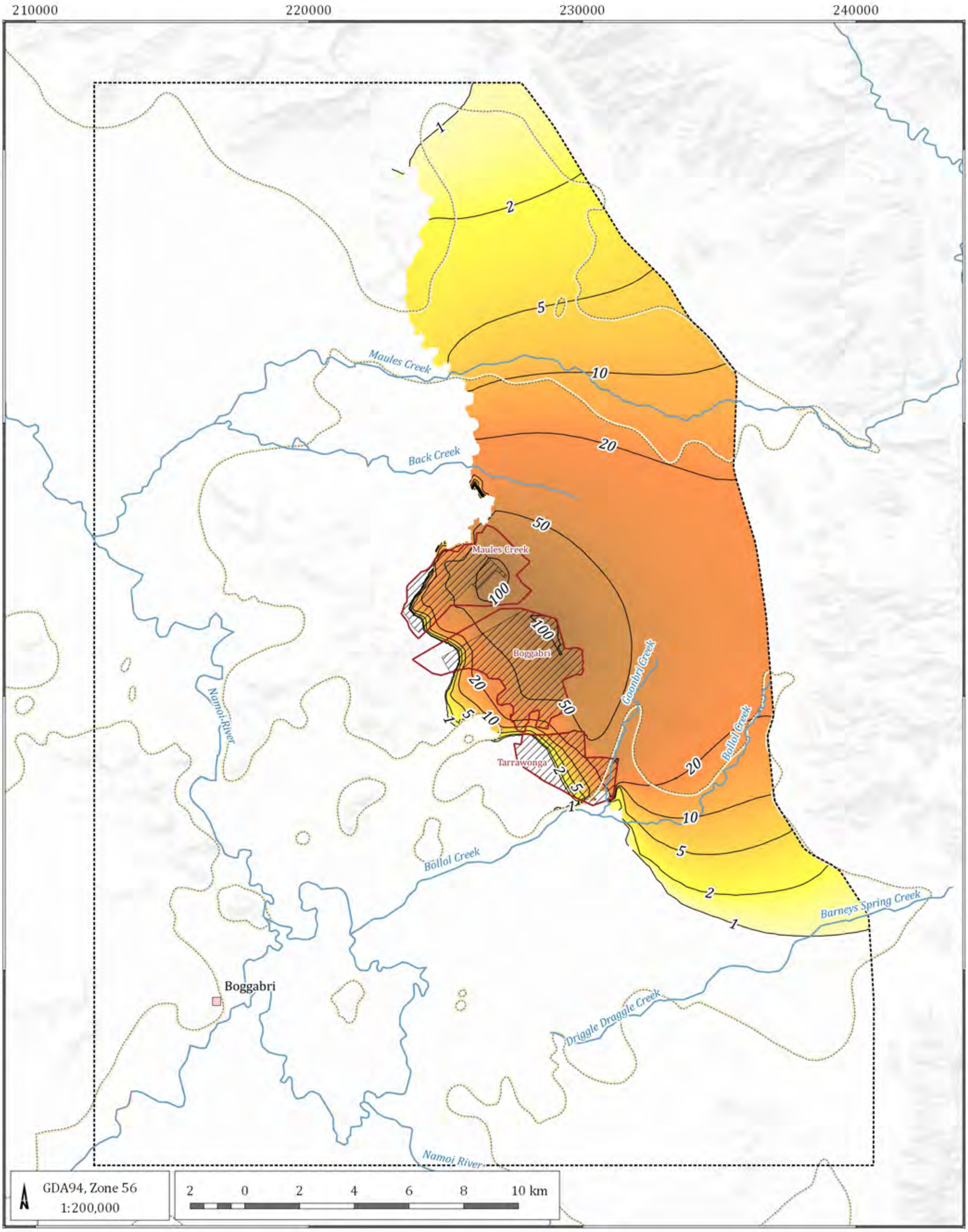
Simulated drawdown at end 2029
Layer 2 - Gunnedah alluvium

AGE

DATE 25/07/2018

FIGURE No: **8.14**

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:/Projects/G1850I.BTM_peer_review_responses/3_GIS/Workspaces/001_Deliverable1/08.10-15_G1850I_Simulated drawdown.qgs



LEGEND

- Populated place
- Major drainage
- Mine maximum open cut outlines
- Mine extent to 2029
- Model extent
- Alluvium

Drawdown (m)

- 1
- 2
- 5
- 10
- 20
- 50
- 100
- 200
- 500
- Drawdown contour (m)

BTM model update (G1850I)

Simulated drawdown at end 2029
Layer 8 - Merriown seam

AGE

DATE 25/07/2018

FIGURE No: **8.15**

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:/Projects/G1850I.BTM_peer_review_responses/3_GIS/Workspaces/001_Deliverable1/08.10-15_G1850I_Simulated drawdown.qgs

In contrast to the alluvium, the drawdown within the Merriown coal seams is predicted by the model to reach the eastern and northern boundaries by 2019. When the drawdown predicted by the updated model is compared with predictions from the 2014 version there are notable differences. Previous reports (AGE 2011, AGE 2014) do not present figures for drawdown within the Merriown seam, however the drawdown within layer 2 in the previous reports is similar to drawdown predicted within the coal seams.

The drawdown predicted by the updated model is less extensive to the west and does not extend into the Boggabri Volcanics, but is more extensive towards the east reaching the model boundary. These differences are expected to be a result of:

- changing from MODFLOW SUFACT to MODFLOW USG that allowed pinching out of the coal seams towards the west where they do not exist;
- a simplified approach to representing rainfall recharge (use of the pseudo soil option); and
- the more permeable hydraulic conductivity values determined from the calibration process.

The previous version of the numerical model, which utilised MODFLOW SURFACT, did not allow for pinching out of the coal seams and the alluvium. When these geological units did not exist in the 2014 model, the thickness of the layer was reduced to 1 m and the hydraulic properties changed to reflect the geological unit that existed in that area. This approach still allows for some lateral flow into the layer at the outcrop area, whereas this does not occur in reality. The updated version of the model using MODFLOW SURFACT allows for no flow into the layer at the limit of the formation. The result of this is that drawdown extends further towards the east, as water does not enter the layer from the west.

When interpreting the predicted drawdown it is important to note that faults are known to exist to the north and south of the BTM complex, but are not represented within the numerical model. It is expected that depressurisation and drawdown within the coal seams will not propagate beyond the faults which offset and terminate the coal seams against lower permeability interburden.

Whilst the drawdown is predicted to be more extensive within the coal seams it does not increase the drawdown predicted within the Namoi Valley alluvium (Narrabri and Gunnedah Formation) which is predicted to be similar, or less extensive than previous versions of the numerical model. The drawdown is confined to the alluvial areas immediately adjacent to the active mining at Boggabri and Tarrawonga Mines.

The drawdown predicted by the model represents the cumulative impact on the groundwater regime generated by all three mines operating together. Appendix D contains a series of figures that show how each mine contributes proportionally to the total drawdown and cumulative impact. The figures show the proportion of each mine to the cumulative impact is most significant within the active mining area and reduces with distance from the mine. The figures also show that the proportion for each mine changes with time, as mining depth and location progresses.

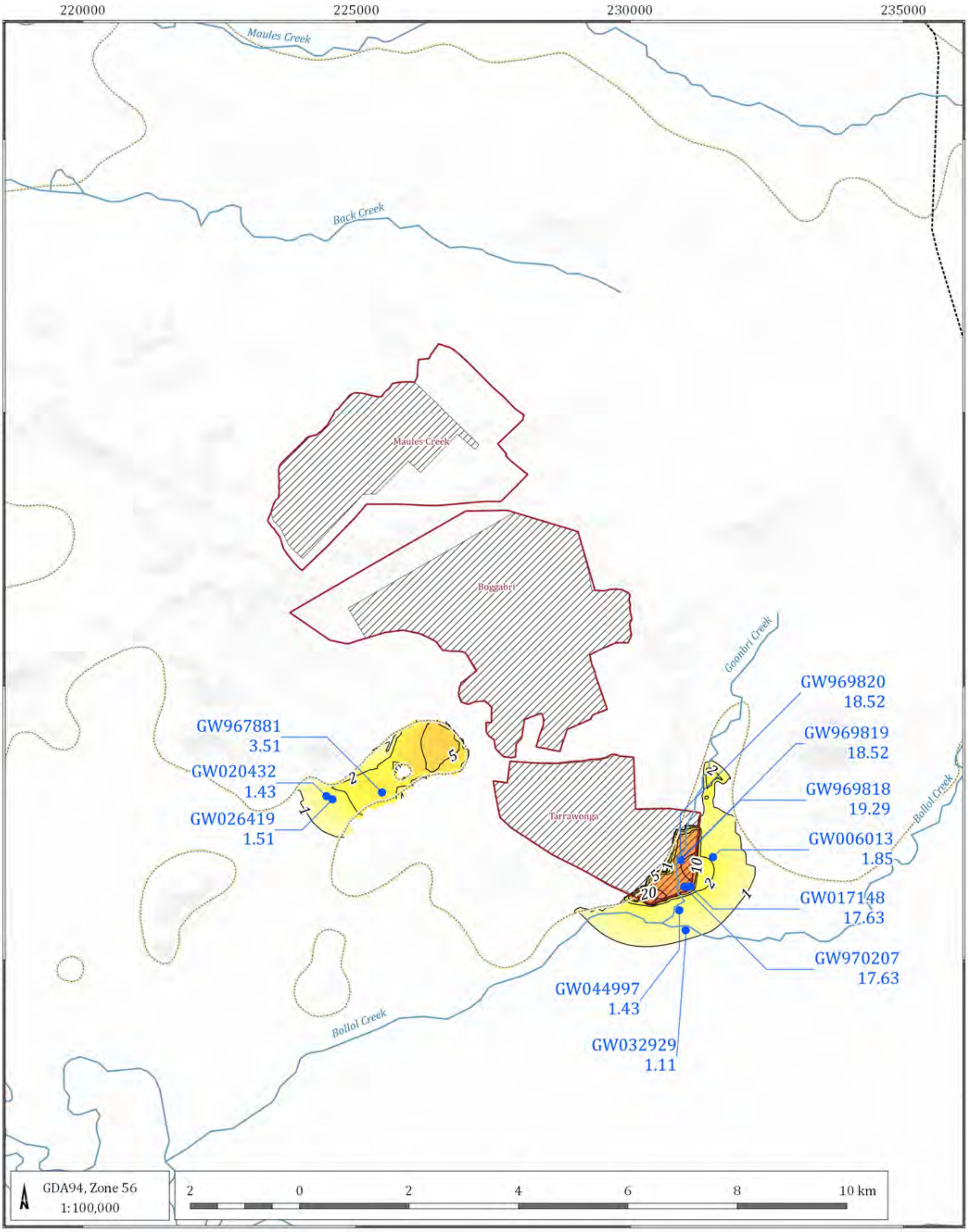
The proportion of drawdown attributed to each mine was estimated by running the model with each BTM complex mine operating in isolation, and then calculating a factor for each cell in the model. This factor was then used to apportion the cumulative drawdown to each individual mine.

8.3.4 Impact on groundwater users

Figure 8.16 shows the drawdown predicted within the alluvium (layer 2) by 2029 and the locations of bores registered on the NSW government groundwater database (PINEENA). This figure shows that the monitoring bores with the largest drawdown are located within the footprint of the Tarrawonga pit, which will be mined through by 2029. Table 8.5 summarises the details for the bores outside of the mine footprints and within the predicted zone of drawdown at 2029..

Table 8.5 Bores within predicted drawdown zone at 2029

Station	Latitude	Longitude	Depth completed (m)	Purpose	Land owner	Predicted drawdown in layer 2 at 2029 (m)
GW967881	-30.6286	150.1359	32	monitoring	unknown	3.5
GW006013	-30.6407	150.1986	103.6	stock	Tarrawonga	1.9
GW026419	-30.6295	150.1264	60	unknown	unknown	1.5
GW020432	-30.629	150.1253	48.8	unknown	Unknown	1.4
GW044997	-30.6493	150.192	45.7	stock	Tarrawonga	1.4
GW032929	-30.6526	150.1931	42.7	stock	Tarrawonga	1.1



LEGEND

- Populated place
- Major drainage
- Mine maximum open cut outlines
- Model extent
- Mine extent 2029
- Alluvium
- Registered bore

Drawdown (m)

- 1
- 2
- 5
- 10
- 20
- 50
- 100
- 200
- 500
- Drawdown contour (m)

BTM model update (G1850A)

Simulated drawdown at end 2029
Layer 2 - Gunnedah Formation and registered water bores

DATE: 31/07/2018

FIGURE No: **8.16**

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:/Projects/G1850A.BTM_Model/3_GIS/Workspaces/001_Deliverable1/08.16_G1850A_Simulated drawdown at end 2029 - Layer 2 - Gunnedah Formation and registered water bores_.qgs

8.3.5 Mine inflow

The AIP requires the accounting for all groundwater taken, either directly or indirectly from groundwater systems. Groundwater intercepted from the BTM mining area is considered a direct take from the Permian groundwater system. The discussion below refers to the volume of groundwater intercepted by mining from the Permian groundwater systems. This includes groundwater that cannot be pumped because it evaporates, groundwater that is bound to coal/spoils as well as groundwater that flows into sumps for pumping.

Figure 8.17 shows the volume of groundwater predicted to be directly intercepted by mining at the BTM complex within each of the mining areas. Table 8.6 summarises the annual volumes of groundwater directly intercepted within each of the BTM complex mines.

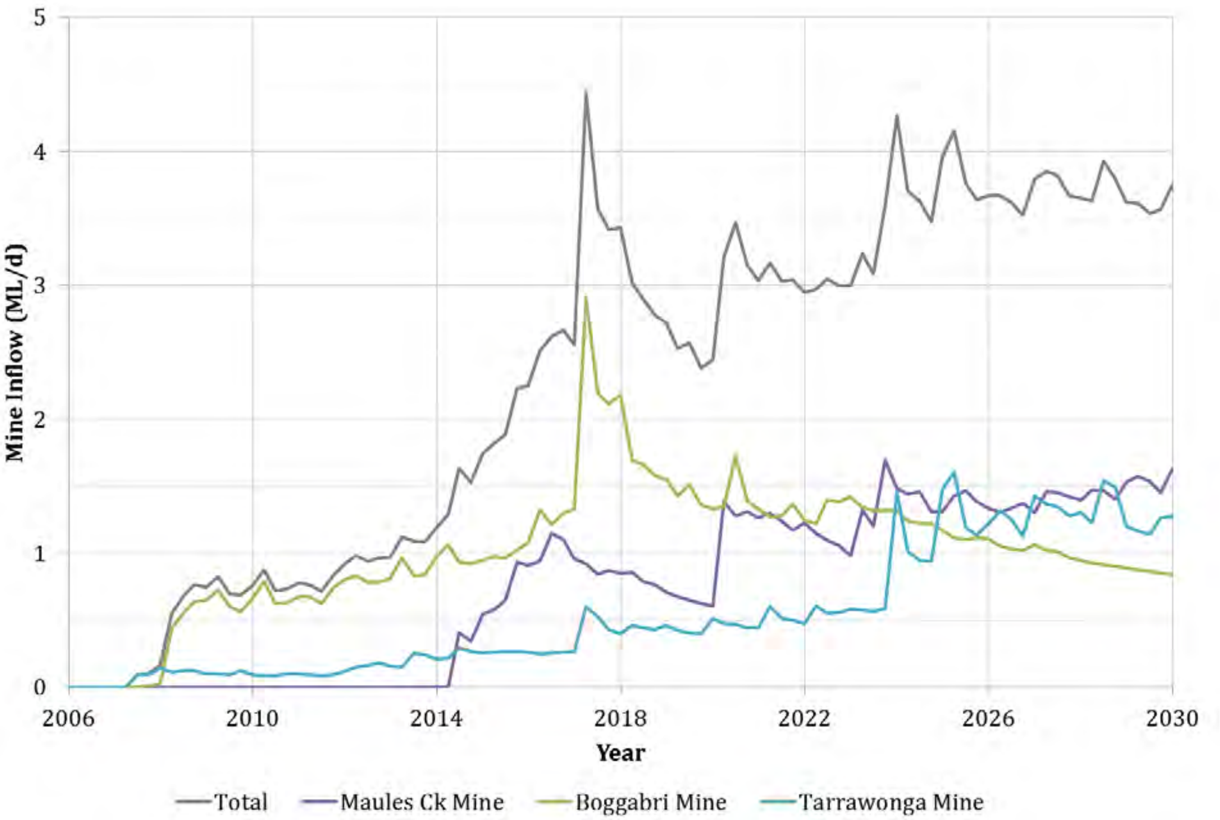


Figure 8.17 Predicted seepage into the BTM mining voids

Table 8.6 Predicted total volume of groundwater intercepted within each mining area

Year	Predicted volume of groundwater intercepted from mining areas (ML/year)		
	Boggabri	Tarrawonga	Maules Creek
2017	858	179	319
2018	592	164	285
2019	513	160	233
2020	529	168	478
2021	471	191	450
2022	495	210	391
2023	483	291	521
2024	443	400	504
2025	406	470	513
2026	381	468	485
2027	361	483	524
2028	331	499	537
2029	313	443	565

Figure 8.17 shows the volume of groundwater intercepted by the BTM complex gradually rises as the footprint of mining grows, peaking around 4.3 ML/day by 2023. The peak in predicted inflows during 2017 for Boggabri Mine is an artefact of merging the historical and predictive mining progressions. To transition from the actual to predictive mine plans requires a large amount of modelled mining to occur during 2017. The peak inflow in 2017 is therefore unlikely to actually occur. Whilst there is an upward trend in groundwater intercepted by the BTM complex, the volume predicted to be intercepted by each mining area varies. The initial volumes of groundwater intercepted by the Maules Creek Mine are expected to be an overestimate as the model represents deeper mining proposed during the EIS that did not occur at the time proposed. The volume of groundwater intercepted by Boggabri Mine is predicted to gradually reduce from 2018 as the mine begins to move parallel to the strike of the coal seam, and as cumulative effects for the deeper adjacent Tarrawonga and Maules Creek Mines increase.

The volume of groundwater intercepted by the mining areas is relatively comparable to previous versions of the model.

8.3.6 Water licensing

Within the region, groundwater is managed under the *Water Sharing Plan for the Murray Darling Basin Porous Rock Groundwater Sources* (porous rock WSP) and the *Water Sharing Plan for the Namoi Unregulated and Alluvial Water Sources* (alluvial WSP). The AIP requires mines account for water taken directly from the excavated groundwater systems, as well as flows of water indirectly influenced by pressure changes in adjacent water sources not directly mined. The BTM complex mines hold Water Access Licenses (WALs) to account for the groundwater directly and indirectly intercepted by mining.

Table 8.7 and Table 8.8 summarise the WALs held by the BTM complex mines from each of the water management units.

Table 8.7 Water access licenses and total entitlement within each mining area (porous rock WSP)

Mine	Water access licenses [1] (ML/year)	Total entitlement (ML/year)
Boggabri	WAL 29473 – 177.5 units WAL 29562 – 700 units	877.5
Tarrawonga	WAL 31084 - 250 units WAL 29548 – 50 units	300
Maules Creek	WAL 29467 – 6 units WAL 29588 – 300 units WAL 36641 – 800 units	1106

Note: *[1] Gunnedah - Oxley Basin NSW Murray Darling Basin Porous Rock Groundwater Sources*

Table 8.8 Water access licenses and total entitlement within each mining area (alluvial WSP)

Mine	Water access licenses (ML/year)	Zone	Total entitlement (ML/year)
Boggabri	WAL 15037 WAL 24103 WAL 12767 WAL 12691 WAL 36547 WAL 37519	4 4 4 4 4 4	953
Boggabri	no entitlement	11	-
Tarrawonga	tbc	4	453
Tarrawonga	no entitlement	11	-
Maules Creek	WAL 27385	4	38
Maules Creek	WAL 12811	5	135
Maules Creek	WAL 12479	11	78

Table 8.9 presents the predicted volume of groundwater removed by each mine from each management zone under the alluvial WSP.

Five variants of the groundwater model were created to estimate the volume of water intercepted from the alluvial aquifers by each mine. The first version of the model did not represent any mining activities occurring over time. The second of the models was the base model representing mining at all of the three operations within the BTM complex. A further three variants were then created that represented only mining at each of the operations separately. The model with all mining was then run to calculate the change in groundwater flow to the alluvial zones compared to the model with no mining.

The change in groundwater flow to the alluvial zones for each of the models with only one mine operating was also calculated. The calculated change in flow from each of the three models with only one mine were then combined to determine the proportion of impact attributable to each operations. The time varying factor for each mine was then applied to the change in flow calculated by the model with all three mines operating to estimate the proportion of the cumulative impact attributable to each operation.

Table 8.9 Predicted groundwater volume indirectly intercepted from alluvial aquifer zones

Year	Volume requiring licensing under alluvial WSP (ML/year)					
	Boggabri		Tarrawonga		Maules Creek	
	Zone 4	Zone 11	Zone 4	Zone 11	Zone 4	Zone 11
Entitlement[1]	953	0	453	0	38	78
2017	65	**2**	14	0	25	1
2018	68	**3**	19	**1**	33	1
2019	76	**4**	24	**1**	34	2
2020	66	**4**	21	**1**	**60**	4
2021	67	**5**	27	**2**	**64**	5
2022	76	**7**	32	**3**	**60**	6
2023	67	**7**	38	**4**	**72**	8
2024	64	**8**	57	**7**	**73**	9
2025	64	**8**	73	**9**	**80**	10
2026	69	**9**	85	**11**	**88**	12
2027	71	**10**	95	**13**	**103**	14
2028	73	**10**	110	**15**	**119**	16
2029	81	**11**	115	**15**	**146**	20

Notes: *[1] Total number of units for water access licenses held from each alluvial WSP management zone*

Bold text indicates when predicted 'water take' exceeds available entitlements

Table 8.9 shows the total volume of entitlements held by the BTM mines (1,444 ML) in zone 4 of the alluvial WSP exceeds the combined 'water take' from this zone predicted by the numerical model. However when the individual entitlements are compared with the predictions from the numerical model, there is predicted to be a potential shortage at Maules Creek Mine from 2020 onwards. Transfer of water entitlements between the BTM mines would ensure each operation remains within its entitlement for zone 4.

The combined volume of water entitlements held within zone 11 (78 ML) is less than zone 4, with only Maules Creek Mine holding entitlements for this zone. The model predicts take from zone 11 for all three mines despite Boggabri and Tarrawonga being geographically further from zone 11 than Maules Creek. Hydrogeologically the three pits are essentially acting as a single large pit. The geographic location of each individual pit is therefore of lesser importance to the propagation of cumulative impacts. It is important to note that the predicted indirect water take reflects a reduction in the Permian inflows to the alluvium rather than a flow out of the alluvium into the Permian.

This total volume of entitlements in zone 11 of the alluvial WSP also exceeds the combined 'water take' predicted for this zone by the numerical model. If individual entitlements are compared with predictions from the numerical model, there has been a potential shortage at Boggabri Mine since 2017 and Tarrawonga Mine since 2018, as the mines do not hold any water entitlements for this zone. However, transfer of water entitlements from Maules Creek would ensure each operation remains within its entitlement for this zone.

Maules Creek Mine also holds a WAL with an entitlement of 135 ML within zone 5. The alluvial WSP zones 2 and 5 occur in the model area, but are not predicted to be impacted by the mining at any of the operations so are not included within the above tables.

The volumes of water required to be accounted for under the porous rock WSP were estimated as follows:

a) the groundwater directly intercepted by each mining area by drain cells (representing dewatering of the mining voids) was extracted from the model (refer Table 8.6);
b) the indirect change in groundwater flux from the porous rock WSP into the alluvial WSP area due to mining activities was extracted from the model – this volume of water was assigned as 'water take' from the alluvial WSP; and
c) the alluvial 'water take' was subtracted from the drain cell flux directly into the mining areas to calculate the 'water take' from the porous rock WSP (a minus b).

This method prevents double accounting of 'water take' from the porous rock with the 'water take' from the alluvial WSPs. Table 8.10 below presents the total volume of groundwater removed from the porous rock WSP, and the corrected volume to prevent double accounting of alluvial groundwater in the porous rock 'water take'.

Table 8.10 Predicted volume of groundwater intercepted within each mining area within porous rock WSP

Year	Total volume of groundwater intercepted from mining areas (ML/year)			Volume requiring licensing under porous rock WSP (ML/year)		
	Boggabri	Tarrawonga	Maules Creek	Boggabri	Tarrawonga	Maules Creek
Entitlement[1]	-	-	-	877.5	300	1106
2017	858	179	319	791	165	293
2018	592	164	285	521	145	251
2019	513	160	233	434	135	197
2020	529	168	478	459	145	414
2021	471	191	450	399	162	381
2022	495	210	391	411	175	325
2023	483	291	521	408	248	441
2024	443	400	504	371	**335**	423
2025	406	470	513	334	**388**	422
2026	381	468	485	302	**371**	384
2027	361	483	524	280	**375**	406
2028	331	499	537	248	**374**	401
2029	313	443	565	221	**312**	399

Notes: *[1] Total number of units for water access licenses held from porous rock WSP*
Bold text indicates when predicted 'water take' exceeds available entitlements

Table 8.10 shows all the BTM complex mines hold sufficient WALs to account for the peak volume of groundwater predicted to be intercepted by mining from the porous rock WSP. Cumulatively the BTM complex holds 2,283.5 ML of WALs, with the predicted annual volume of groundwater intercepted by the complex from the porous rock to be at or below 1249 ML for the period 2017 to 2029.

If individual entitlements are compared with predictions from the numerical model, there is a potential shortage at Tarrawonga Mine, with the predicted take above 300 ML/year at 2024. However, transfer of water entitlements from the other two mines would ensure Tarrawonga remains within their entitlement for this zone.

8.4 Uncertainty analysis

Groundwater models represent complex environmental systems and processes in a simplified manner. This means that predictions from groundwater models, likely so many other environmental models are inherently uncertain. The preceding sections highlight uncertainties in model inputs and the necessary simplifications within models to represent natural systems. National modelling guidelines encourage the acknowledgement of uncertainty and suggest methods to formulate predictions in which uncertainties are minimised. Barnett *et al* (2012) recommend uncertainty in model predictions can be quantified using linear or non-linear methods. A non-linear uncertainty analysis was undertaken to quantify the magnitude of uncertainty in the future impacts predicted by the model. The analysis was undertaken in accordance with the methods presented by Doherty (2015).

8.4.1 Development of uncertainty analysis

The uncertainty analysis tested the influence of changing multiple parameters within the model at the same time, rather than the standard sensitivity analysis where only one parameter is changed at a time. The analysis method chosen was a calibrated constrained non-linear analysis using a normal distribution around the calibrated parameter set. In total 200 versions of the model were run. Of these 200 runs 87 were rejected as they either failed to converge or had become sufficiently uncalibrated (a phi higher than 1.5 times the calibrated value). Appendix E contains histograms showing the distribution of posterior parameters utilised in the 133 models that were used for the uncertainty analysis.

8.4.2 Uncertainty in predicted cumulative groundwater inflows to mining voids

Figure 8.18 shows the range in the predicted total volume of groundwater intercepted by the BTM mines. The figure shows the 5th, 20th, 50th, 80th, and 95th percentile inflows determined from the 133 models utilised for the uncertainty analysis. The results indicate the uncertainty is on average +40% to -80% of the calibrated base case model. That is, the volume of groundwater intercepted each year could be one and a half times or four fifths of the predicted base case. Figure 8.19 shows the volume of groundwater intercepted by each of the BTM mining areas.

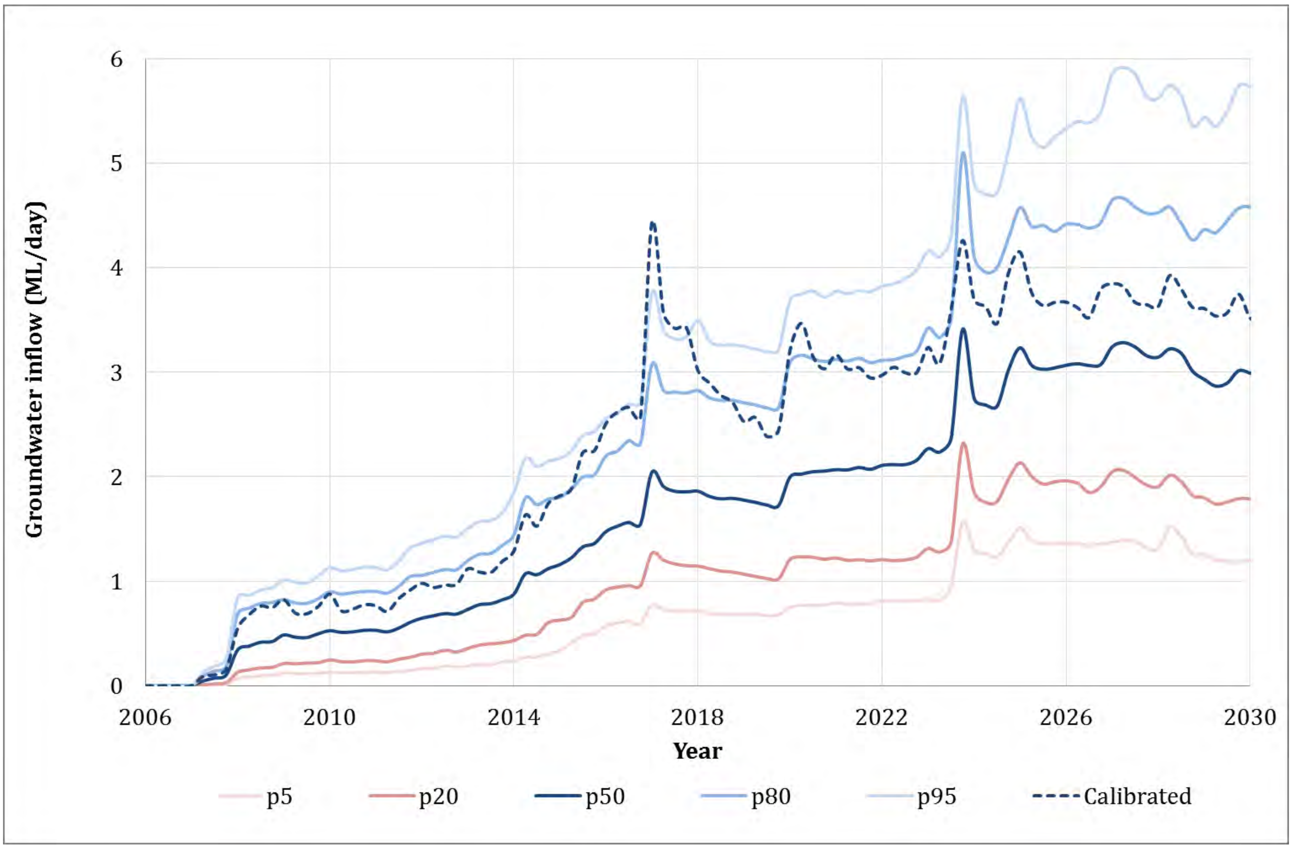


Figure 8.18 Uncertainty of cumulative inflow to BTM mining voids

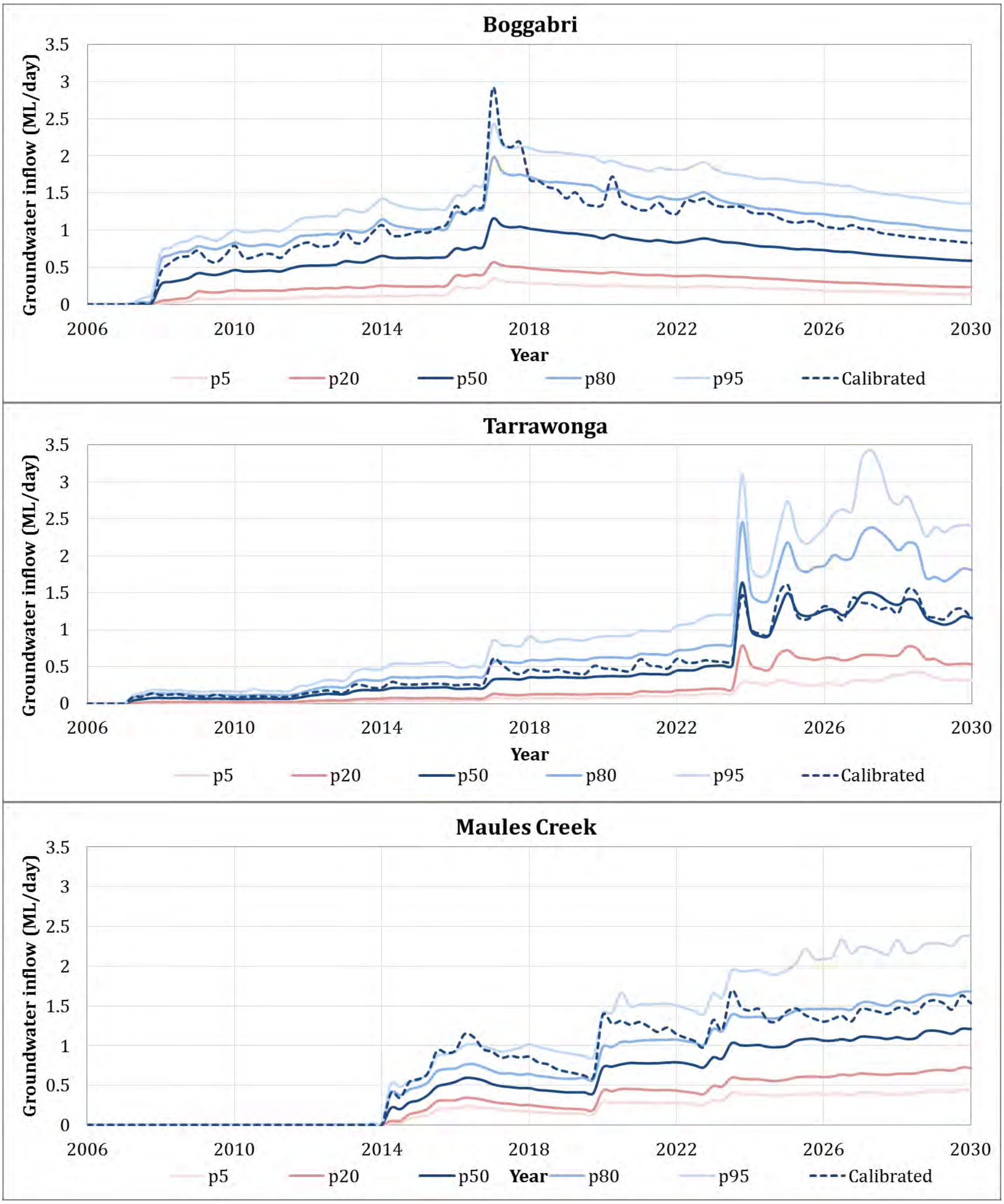


Figure 8.19 Uncertainty in predicted volume intercepted by each mine

8.4.3 Uncertainty in predicted drawdown

To illustrate the level of uncertainty in the extent of drawdown predicted by the model, the 1 m drawdown contour line was compared for the 5th, 50th and 95th percentile drawdowns from the uncertainty analysis. The figures within Appendix F show the uncertainty in the extent of the 1 m drawdown contour line for within the alluvium in layer 1 (Narrabri) and layer 2 (Gunnedah) and the Merriown seam (layer 8) at the end of 2019 and 2029.

8.5 Model confidence level classification

The Australian Groundwater Modelling Guidelines (Barnett *et al*., 2012) developed a system to classify the confidence-level for groundwater models. Models are classified as either Class 1, Class 2 or Class 3 in order of increasing confidence (i.e. Class 3 has the highest level of confidence). Several factors are considered in determining the model confidence level:

- available data;
- calibration procedures;
- consistency between calibration and predictive analysis; and
- level of stresses.

Table 8.11 below is a check list to classify the confidence level for the model. The table shows the model generally achieves aspects of Class 2 and Class 3 confidence level criteria. It does this by simulating a similar calibration period to the predictive model, replicating seasonal responses to surface water/rainfall interaction (where included), and meeting calibration and model error statistics.

Table 8.11 Model confidence level classification

Class		Data		Calibration		Prediction		Quantitative Indicators
1 (Simple)	×	Not much	×	Not possible	×	Timeframe >> calibration	×	Timeframe > 10x
	×	Sparse coverage	×	Large error statistic	×	Long stress periods	×	Stresses > 5x
	×	No metered usage	×	Inadequate data spread	×	Poor/no validation	×	Mass balance > 1% (or one-off 5%)
	×	Low resolution	×	Targets incompatible with model purpose	×	Transient prediction but steady-state calibration	×	Properties < > field values
	×	Poor aquifer geometry					×	No review by Hydro/Modeller
2 (Impact Assessment)	✓	Some	×	Partial performance	✓	Timeframe > calibration	×	Time frame = 3-10x
	✓	Ok coverage	✓	Some long term trends wrong	×	Long stress periods	✓	Stresses = 2-5x
	~	Some usage data/ low volumes	✓	Short term record	✓	Ok validation	✓	Mass balance <1%
	~	Baseflow estimates Some K & S measurements	×	Weak seasonal match	✓	Transient calibration and prediction	✓	Some properties < > field values Review by Hydrogeologist
	✓	Some high resolution topographic DEM &/or some aquifer geometry	×	No use of targets compatible with model purpose (heads & fluxes)	✓	New stresses not in calibration	×	Some coarse discretisation in key areas of grid or at key times
3 (Complex Simulator)	✓	Lots, with good coverage	✓	Good performance stats	✓	Timeframe ~ calibration	✓	Timeframe <3x
	~	Good metered usage info	×	Most long term trends matched	✓	Similar stress periods	×	Stresses <2x
	~	Local climate data	✓	Most seasonal matches ok	×	Good validation	✓	Mass balance <0.5%
	~	Kh, Kv & Sy measurements from range of tests	✓	Present day data targets	✓	Calibration & prediction consistent (transient or steady state)	×	Properties ~field measurements
	~	High resolution DEM all areas	✓	Head & Flux targets used to constrain calibration	✓	Similar stresses to those in calibration	✓	No coarse discretisation in key areas (grid or time)
	✓	Good aquifer geometry					✓	Review by experienced Modeller

9 Conclusions and recommendations

The numerical model for the BTM complex was reviewed and verified against monitoring data collected since 2013. It was determined that adjustment of the model parameters would improve the calibration statistics for the model. Prior to further calibration the model was imported into MODFLOW USG to allow the geological units to be me more accurately represented.

Further calibration of the model aimed at reproducing the water level trends observed within the BTM complex monitoring bore network. The calibration resulted in increasing the coal seam hydraulic conductivity.

The recalibrated model predicted more extensive drawdown within the coal seams, but only limited and localised drawdown within the alluvium, consistent with previous versions of the model.

The mines cumulatively have sufficient water licenses to account for groundwater intercepted by mining in the areas managed under the *Water Sharing Plan for the NSW Murray-Darling Basin Porous Rock Groundwater Sources*.

The mines cumulatively also have sufficient water licenses to account for water indirectly removed from zone 4 and 11 of the alluvial aquifers managed under the *Water Sharing Plan for the Namoi Unregulated and Alluvial Water Sources*.

It is recommended that:

- the conditions of consent for the BTM complex mines are aligned to allow the numerical model to be updated at the same time every three years;
- the BTM complex consider creating a shared cloud database for storage of groundwater data collected from the monitoring network;
- the factors influencing drawdown recorded by the VWPs within TA60 and TA65 at Tarrawonga be further investigated;
- geological fault systems known to occur to the north and south of the BTM mining complex be represented within the next version of the numerical model;
- the potential for enhanced recharge in the Boggabri/Tarrawonga CHPP area be further investigated; and
- the mines consider transferring water entitlements between each other as necessary to account for the potential individual shortage in zones 4 and 11.

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Appendix A Monitoring bore locations

Bore ID	Type [1]	Status	Network	Easting (GDA94Z56)	Northing (GDA94Z56)	GL (mAHD)	Bore depth (m)	Screen/sensor depth (mbgl)	Target geology
BCM01	SP	Active	Maules Creek	223841	6618371	273.39	10	6.75 - 9.75	Alluvium
BCM03	SP	Active	Maules Creek	230085	6617546	305.02	10	6.75 - 9.75	Alluvium
BCS1	Private	Unknown	Tarrawonga	237177	6610679	343			Alluvium
BCS2	Private	Unknown	Tarrawonga	236682	6609459	331	16.2		Alluvium
BCS3	Private	Unknown	Tarrawonga	236179	6608490	323	45.7		Alluvium
BCS4	Private	Unknown	Tarrawonga	236016	6608368	323	39		Alluvium
BCS5	Private	Unknown	Tarrawonga	235314	6607331	314			Alluvium
BCS6	Private	Unknown	Tarrawonga	234563	6606093	302			Alluvium
BCS7	Private	Unknown	Tarrawonga	231656	6605754	281.3			Alluvium
GW002129	Private	Active	Tarrawonga	228724	6606271				Coal Aquifer in Mine Lease
GW002501	Private	Active	Tarrawonga	228013	6606613	291.1			Interburden. Model has weathered and volcanics only
GW020432	Private	Active	Tarrawonga	224451	6607991	265			Volcanics
GW031856	Private	Active	Tarrawonga	229157	6603179				Alluvial
GW044997	Private	Active	Tarrawonga	230870	6605895				Alluvial
GW052266	Private	Active	Tarrawonga	227848	6604674				Alluvial
GW3115	Private	Active	Boggabri	225174	6608903				Boggabri Volcanics
IBC2102	SP	Active	Boggabri	226892	6611771	322	85	78-82	Merriown Coal Seam
IBC2103	SP	Active	Boggabri	226898	6611773	321.8	59	50-56	Jeralong Coal Seam
IBC2104	SP	Active	Boggabri	228336	6612215	331.1	87	80-84	Braymont Coal Seam
IBC2105	SP	Active	Boggabri	228321	6612212	331.4	160	151-157	Merriown Coal Seam
IBC2110-MW3	SP	Active	Boggabri	225939	6607684	272.8	100	91-97	Boggabri Volcanics
IBC2111	SP	Active	Boggabri	225950	6607683	272.7	45	36-42	Boggabri Volcanics
IBC2113	SP	Destroyed	Boggabri	229720	6608797	343.4	96.8		Merriown Coal Seam
IBC2114	SP	Destroyed	Boggabri	229146	6610283	324.8	86	77-83	Bollol Creek Coal Seam
IBC2115	SP	Destroyed	Boggabri	229155	6610279	325	111.5	103-107	Merriown Coal Seam
IBC2138	SP	Destroyed	Boggabri	226725	6610387	294.5	66	57-63	Merriown Coal Seam
IBC2139	SP	Destroyed	Boggabri	229421	6609296	319.4	92.79	83-89	Merriown Coal Seam
BC2181	SP	Active	Boggabri	226848	6612477	335.2	114	105-111	Merriown Coal Seam
BC2193	SP	Destroyed	Boggabri	229699	6610899	340	96.3	87-93	Braymont Coal Seam
M267P_V1	VWP	Destroyed	Maules Creek	227440	6615472	404.76	299	151.5	Braymont
M267P_V2	VWP	Destroyed	Maules Creek	227440	6615472	404.76	299	256.5	Velyama, Upper Northam

Bore ID	Type [1]	Status	Network	Easting (GDA94Z56)	Northing (GDA94Z56)	GL (mAHD)	Bore depth (m)	Screen/sensor depth (mbgl)	Target geology
MAC1218	SP	Destroyed	Maules Creek	224015	6613693	360.4	110	107 – 110	Nagero Upper
MAC1219	SP	Destroyed	Maules Creek	224172	6613678	369.61	163	107 – 110	Jeralong/Merriown
MAC1259	SP	Destroyed	Maules Creek	224948	6615277	316.15	98	94 – 97	
MAC1261	SP	Destroyed	Maules Creek	226750	6614872	381.48	180	161 – 164	Braymont
MAC1279	SP	Active	Maules Creek	226446	6616312	326.05	144	70 – 73	Jeralong
MAC1280	SP	Active	Maules Creek	226525	6616503	322.5	146	56 – 59	Interburden between Braymont seams
MAC1283	SP	Destroyed	Maules Creek	224989	6615291	317.42	91	61 – 64	Velyama
MAC252	SP	Destroyed	Maules Creek	226240	6614772	340.98	98.5	92.5 – 98.5	Braymont
MAC263_V1	VWP	Destroyed	Maules Creek	226037	6614513	347.46	-	105	Braymont
MAC263_V2	VWP	Destroyed	Maules Creek	226037	6614513	347.46	-	183	Velyama Nagero Seam, Upper Northam
MAC268P	VWP	Destroyed	Maules Creek	227498	6614521	415.97	-	280	Velyama Nagero Seam, Upper Northam
MW1	SP	Active	Tarrawonga	228743	6605702	269.51	56	52-56	Permian Coal Measures
MW2	SP	Active	Tarrawonga	228851	6605704	269.72	7	4-7	Alluvial
MW4	SP	Active	Tarrawonga	227848	6604708	262.67	20	17-20	Alluvial
MW5	SP	Active	Tarrawonga	229488	6605985	271.32	8.3	5.3-8.3	Alluvial
MW6	SP	Active	Tarrawonga	225385	6607871	264.41	32	29-32	Alluvial
MW7	SP	Active	Tarrawonga	229823	6607932	344.32	105	102-105	Permian Sediments
MW8	SP	Active	Tarrawonga	226795	6606958	280.93	26	23-26	Permian Sediments
RB01_V1	VWP	Active	Maules Creek	224058	6612333	433.05	-	97	Braymont
RB01_V2	VWP	Active	Maules Creek	224058	6612333	433.05	-	140	Merriown
RB01_V3	VWP	Active	Maules Creek	224058	6612333	433.05	-	194.5	Flixton
RB01A	SP	Active	Maules Creek	224058	6612341	432.41	220.5	213.5 - 219.5	Templemore
RB02_V1	VWP	Active	Maules Creek	224860	6613267	398.17	-	110.5	Braymont
RB02_V2	VWP	Active	Maules Creek	224860	6613267	398.17	-	162	Merriown
RB02_V3	VWP	Active	Maules Creek	224860	6613267	398.17	-	226	Nagero
RB02_V4	VWP	Active	Maules Creek	224860	6613267	398.17	-	229.5	Northam
RB02A	SP	Active	Maules Creek	224853	6613266	398.08	234	227 - 233	Nagero
RB03_V1	VWP	Active	Maules Creek	227947	6613635	407.89	-	164	Braymont
RB03_V2	VWP	Active	Maules Creek	227947	6613635	407.89	-	242	Merriown
RB03_V3	VWP	Active	Maules Creek	227947	6613635	407.89	-	289	Nagero

Bore ID	Type [1]	Status	Network	Easting (GDA94Z56)	Northing (GDA94Z56)	GL (mAHD)	Bore depth (m)	Screen/sensor depth (mbgl)	Target geology
RB03_V4	VWP	Active	Maules Creek	227947	6613635	407.89	-	317	Templemore
RB04_V1	VWP	Active	Maules Creek	228213	6614910	437.53	-	209	Braymont
RB04_V2	VWP	Active	Maules Creek	228213	6614910	437.53	-	272.5	Merriown
RB04_V3	VWP	Active	Maules Creek	228213	6614910	437.53	-	309	Nagero
RB04_V4	VWP	Active	Maules Creek	228213	6614910	437.53	-	339	Lower Northam
RB05A	SP	Active	Maules Creek	228065	6616810	328.1	246.5	239 - 245	Merriown
REG1_V1	VWP	Active	Cumulative	226946	6622396	286.17	-	118.7	Jeralong
REG1_V2	VWP	Active	Cumulative	226946	6622396	286.17	-	134.5	Merriown
REG1_V3	VWP	Active	Cumulative	226946	6622396	286.17	-	193.5	Nagero
REG1_V4	VWP	Active	Cumulative	226946	6622396	286.17	-	281.5	Therribri
REG10_V1	VWP	Active	Cumulative	226723	6618261	287.12	-	55	Braymont
REG10_V2	VWP	Active	Cumulative	226723	6618261	287.12	-	144.2	Merriown
REG10_V3	VWP	Active	Cumulative	226723	6618261	287.12	-	178	Nagero
REG10_V4	VWP	Active	Cumulative	226723	6618261	287.12	-	185.5	Upper Northam
REG10A	SP	Active	Cumulative	226717	6618260	287.12	10	6.75 - 9.75	Alluvium
REG12	SP	Active	Cumulative	222632	6617358	285.61	48.3	38.4 - 44.4	Boggabri Volcanics
REG13	SP	Active	Cumulative	219713	6611129	277.08	133	128 - 132	Boggabri Volcanics
REG14	SP	Active	Cumulative	225547	6602649	250.18	102	90 - 96	Basement
REG2_V1	VWP	Active	Cumulative	232722	6620459	317.01	-	60	Braymont
REG2_V2	VWP	Active	Cumulative	232722	6620459	317.01	-	120	Jeralong
REG2_V3	VWP	Active	Cumulative	232722	6620459	317.01	-	200	Merriown
REG2_V4	VWP	Active	Cumulative	232722	6620459	317.01	-	260	Therribri
REG3	SP	Active	Cumulative	217164	6619558	241.6	57	50.50 - 56.50	Boggabri Volcanics
REG4	SP	Active	Cumulative	219323	6612763	259.95	72.5	65.5 - 71.5	Boggabri Volcanics
REG5	SP	Active	Cumulative	220649	6609521	252.17	78.7	72.2 - 78.2	Boggabri Volcanics
REG5A	SP	Active	Cumulative	220646	6609514	252.03	22	18 – 21	Alluvium
REG6	SP	Active	Cumulative	223100	6606534	250.65	96	88.0 – 94.0	Boggabri Volcanics
REG7_V1	VWP	Active	Cumulative	233543	6605348	291.62	-	67.5	Braymont
REG7_V2	VWP	Active	Cumulative	233543	6605348	291.62	-	148.2	Merriown
REG7_V3	VWP	Active	Cumulative	233543	6605348	291.62	-	242.5	Nagero
REG7A	SP	Active	Cumulative	233545	6605359	291.71	36	24 - 30	Alluvium
REG9_V1	VWP	Active	Cumulative	234233	6610591	346.81	-	115.8	Braymont
REG9_V2	VWP	Active	Cumulative	234233	6610591	346.81	-	175.2	Merriown

Bore ID	Type [1]	Status	Network	Easting (GDA94Z56)	Northing (GDA94Z56)	GL (mAHD)	Bore depth (m)	Screen/sensor depth (mbgl)	Target geology
REG9_V3	VWP	Active	Cumulative	234233	6610591	346.81	-	268	Nagero
TEMPLE_A	Private	Active	Tarrawonga	230997	6605537				
REG8_V1	VWP	Active	Cumulative	230030	6615113	341.6	-	91.5	Braymont
REG8_V2	VWP	Active	Cumulative	230030	6615113	341.6	-	221	Merriown
REG8_V3	VWP	Active	Cumulative	230030	6615113	341.6	-	274	Nagero
RB05_V1	VWP	Active	Cumulative	228071	6616813	328.4	-	107	Braymont
RB05_V2	VWP	Active	Cumulative	228071	6616813	328.4	-	213	Jeralong
RB05_V3	VWP	Active	Cumulative	228071	6616813	328.4	-	280	Nagero
RB05_V4	VWP	Active	Cumulative	228071	6616813	328.4	-	390	Templemore
TA60_V1	VWP	Active	Tarrawonga	230164	6607286	317.46	-	69	Velyama interburden
TA60_V2	VWP	Active	Tarrawonga	230164	6607286	317.46	-	89	Velyama interburden
TA60_V3	VWP	Active	Tarrawonga	230164	6607286	317.46	-	109	Velyama seam
TA60_V4	VWP	Active	Tarrawonga	230164	6607286	317.46	-	118	Velyama-Nagero interburden
TA65_V1	VWP	Active	Tarrawonga	230997	6607344	287.08	-	30	Jeralong overburden
TA65_V2	VWP	Active	Tarrawonga	230997	6607344	287.08	-	35	Jeralong seam
TA65_V3	VWP	Active	Tarrawonga	230997	6607344	287.08	-	47	Jeralong-Merriown Interburden
TA65_V4	VWP	Active	Tarrawonga	230997	6607344	287.08	-	56	Merriown Seam
TA65_V5	VWP	Active	Tarrawonga	230997	6607344	287.08	-	97	Velyama-Nagero Interburden
TA65_V6	VWP	Active	Tarrawonga	230997	6607344	287.08	-	110	Nagero Seam
TA65_V7	VWP	Active	Tarrawonga	230997	6607344	287.08	-	136	Nagero-Upper Northam Interburden
TA65_V8	VWP	Active	Tarrawonga	230997	6607344	287.08	-	153	Upper Northam Seam

Note 1 : SP - Standpipe, VWP - Vibrating wire piezometer, Private - Private bore, construction details often uncertain

Bore ID	Type [1]	Status	Network	Easting (GDA94Z56)	Northing (GDA94Z56)	GL (mAHD)	Bore depth (m)	Screen/sensor depth (mbgl)	Target geology
GW030048_1	SP - Nested (2)	Active	DPI Water	220717	6600067	241.9	53.6	11.6-17.7	Alluvium
GW030048_2	SP - Nested (2)	Active	DPI Water	220717	6600067	241.9	53.6	34.4-35.9	Alluvium
GW030049_1	SP - Nested (3)	Active	DPI Water	222611	6599839	243	74.7	19.2-20.4	Alluvium
GW030049_2	SP - Nested (3)	Active	DPI Water	222611	6599839	243	74.7	25.9-28.9	Alluvium
GW030049_3	SP - Nested (3)	Active	DPI Water	222611	6599839	243	74.7	57.6-61.9	Alluvium
GW030050_1	SP - Nested (3)	Active	DPI Water	223919	6599684	242.7	143.9	29.9-34.5	Alluvium
GW030050_2	SP - Nested (3)	Active	DPI Water	223919	6599684	242.7	143.9	49.4-50.9	Alluvium
GW030050_3	SP - Nested (3)	Active	DPI Water	223919	6599684	242.7	143.9	97.5-105.7	Alluvium
GW030051_1	SP - Nested (2)	Active	DPI Water	224986	6599589	244.2	67.1	17.7-18.6	Alluvium
GW030051_2	SP - Nested (2)	Active	DPI Water	224986	6599589	244.2	67.1	55.2-56.7	Alluvium
GW030052_1	SP - Nested (2)	Active	DPI Water	226612	6599387	248.4	97.5	19.8-21.3	Alluvium
GW030052_2	SP - Nested (2)	Active	DPI Water	226612	6599387	248.4	97.5	25.9-27.4	Alluvium
GW030129_1	SP	Active	DPI Water	217135	6619637	247.97	62.5	23.2-24.4	Alluvium
GW030130_1	SP - Nested (2)	Active	DPI Water	217409	6620543	248.45	103	15.2-16.2	Alluvium
GW030130_2	SP - Nested (2)	Active	DPI Water	217409	6620543	248.45	103	54.9-56.7	Alluvium
GW030131_1	SP	Active	DPI Water	217455	6621709	250.73	22	16.8-18.3	Alluvium
GW030132_1	SP - Nested (2)	Active	DPI Water	217325	6623769	251	64.3	8.2-9.4	Alluvium
GW030132_2	SP - Nested (2)	Active	DPI Water	217325	6623769	251	64.3	32.6-34.1	Alluvium
GW030133_1	SP	Active	DPI Water	217869	6625298	254.2	107.3	46.6-47.5	Alluvium
GW030134_1	SP	Active	DPI Water	217958	6625978	254.8	106.7	14.6-17.4	Alluvium
GW030235_1	SP - Nested (2)	Active	DPI Water	213314	6625918	241.4	87.2	25-26.5	Alluvium
GW030235_2	SP - Nested (2)	Active	DPI Water	213314	6625918	241.4	87.2	50.9-52.7	Alluvium
GW030236_1	SP - Nested (2)	Active	DPI Water	214894	6625713	245.31	57.3	12.8-15.2	Alluvium
GW030236_2	SP - Nested (2)	Active	DPI Water	214894	6625713	245.31	57.3	54.3-55.8	Alluvium
GW030237_1	SP	Active	DPI Water	216529	6625478	249.9	70.1	64-65.5	Alluvium
GW030468_1	SP	Active	DPI Water	217752	6603407	240.39	45.7	21.3-24.4	Alluvium
GW030469_1	SP	Active	DPI Water	218612	6603896	239.8	38.8	24.3-27.4	Alluvium
GW030470_1	SP - Nested (2)	Active	DPI Water	218998	6604550	240.2	30.8	10.4-16.2	Alluvium
GW030470_2	SP - Nested (2)	Active	DPI Water	218998	6604550	240.2	30.8	19.8-22.8	Alluvium
GW030471_1	SP - Nested (3)	Active	DPI Water	219451	6605582	239.6	49.7	16.4-18.9	Alluvium
GW030471_2	SP - Nested (3)	Active	DPI Water	219451	6605582	239.6	49.7	24.4-30.5	Alluvium
GW030471_3	SP - Nested (3)	Active	DPI Water	219451	6605582	239.6	49.7	41.5-44.5	Alluvium
GW030472_1	SP - Nested (3)	Active	DPI Water	225148	6602611	248	106.7	23.8-25	Alluvium
GW030472_2	SP - Nested (3)	Active	DPI Water	225148	6602611	248	106.7	57.3-59.7	Alluvium
GW030472_3	SP - Nested (3)	Active	DPI Water	225148	6602611	248	106.7	94.5-101.5	Alluvium

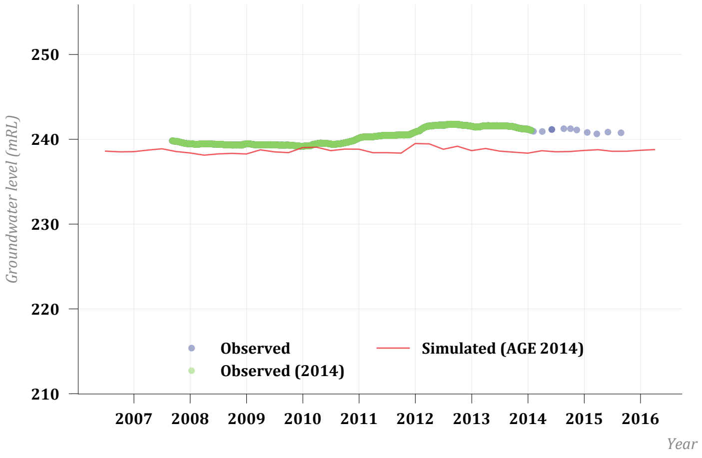
Bore ID	Type [1]	Status	Network	Easting (GDA94Z56)	Northing (GDA94Z56)	GL (mAHD)	Bore depth (m)	Screen/sensor depth (mbgl)	Target geology
GW030535_1	SP	Active	DPI Water	222609	6599838	241	75	54.9-60.6	Alluvium
GW036003_1	SP	Active	DPI Water	212979	6618417	233.8	121.4	97.5-101	Alluvium
GW036007_1	SP - Nested (3)	Active	DPI Water	216176	6607527	235.8	51.5	16.5-22.6	Alluvium
GW036007_2	SP - Nested (3)	Active	DPI Water	216176	6607527	235.8	51.5	29.6-32.6	Alluvium
GW036007_3	SP - Nested (3)	Active	DPI Water	216176	6607527	235.8	51.5	37.8-39.8	Alluvium
GW036008_1	SP	Active	DPI Water	216599	6607505	235.1	61	18.3-21.3	Alluvium
GW036013_1	SP	Active	DPI Water	212185	6612140	233.9	49.7	18.9-21.9	Alluvium
GW036014_1	SP - Nested (2)	Active	DPI Water	213905	6611728	235.3	65.5	18.3-21.3	Alluvium
GW036014_2	SP - Nested (2)	Active	DPI Water	213905	6611728	235.3	65.5	39.6-45.7	Alluvium
GW036015_1	SP - Nested (2)	Active	DPI Water	215140	6611506	236	74.1	19.8-22.8	Alluvium
GW036015_2	SP - Nested (2)	Active	DPI Water	215140	6611506	236	74.1	50.3-53.4	Alluvium
GW036016_1	SP - Nested (3)	Active	DPI Water	216209	6611379	237.1	89.3	22.9-27.4	Alluvium
GW036016_2	SP - Nested (3)	Active	DPI Water	216209	6611379	237.1	89.3	42.7-45.7	Alluvium
GW036016_3	SP - Nested (3)	Active	DPI Water	216209	6611379	237.1	89.3	73.1-76.2	Alluvium
GW036055_1	SP - Nested (3)	Active	DPI Water	212363	6613407	233.6	93.6	27.4-30.5	Alluvium
GW036055_2	SP - Nested (3)	Active	DPI Water	212363	6613407	233.6	93.6	45.7-48.8	Alluvium
GW036055_3	SP - Nested (3)	Active	DPI Water	212363	6613407	233.6	93.6	60.9-64	Alluvium
GW036056_1	SP	Active	DPI Water	215028	6609534	237.2	44.2	25.3-28.3	Alluvium
GW036057_1	SP - Nested (2)	Active	DPI Water	216487	6607724	236.3	98.5	39.6-42.7	Alluvium
GW036057_2	SP - Nested (2)	Active	DPI Water	216487	6607724	236.3	98.5	73.2-76.2	Alluvium
GW036092_1	SP	Active	DPI Water	218436	6603669	238.69	30.8	19.8-22.8	Alluvium
GW036093_1	SP - Nested (3)	Active	DPI Water	212641	6617021	232	89.3	21.3-24.3	Alluvium
GW036093_2	SP - Nested (3)	Active	DPI Water	212641	6617021	232	89.3	51.8-54.8	Alluvium
GW036093_3	SP - Nested (3)	Active	DPI Water	212641	6617021	232	89.3	66.8-70.1	Alluvium
GW036096_1	SP - Nested (2)	Active	DPI Water	212177	6616456	233.3	74.7	21.3-24.3	Alluvium
GW036096_2	SP - Nested (2)	Active	DPI Water	212177	6616456	233.3	74.7	39.6-42.6	Alluvium
GW036164_1	SP	Active	DPI Water	213080	6617499	233.4	111.3	103.6-106.6	Alluvium
GW036185_1	SP	Active	DPI Water	215746	6611466	234.6	115.8	91.4-94.5	Alluvium
GW036186_1	SP	Active	DPI Water	214351	6618121	239.07	67.1	22.8-25.9	Alluvium
GW036187_1	SP	Active	DPI Water	215353	6618358	261.32	42.7	25.6-28.3	Alluvium
GW036548_1	SP - Nested (3)	Active	DPI Water	222929	6594698	245.6	124	19-23	Alluvium
GW036548_2	SP - Nested (3)	Active	DPI Water	222929	6594698	245.6	124	57-61	Alluvium
GW036548_3	SP - Nested (3)	Active	DPI Water	222929	6594698	245.6	124	87.5-93.5	Alluvium
GW036565_1	SP	Active	DPI Water	217594	6598099	242.7	34	15-17	Alluvium
GW036567_1	SP	Active	DPI Water	217801	6596440	243.5	38	25-29	Alluvium

Bore ID	Type [1]	Status	Network	Easting (GDA94Z56)	Northing (GDA94Z56)	GL (mAHD)	Bore depth (m)	Screen/sensor depth (mbgl)	Target geology
GW036568_1	SP - Nested (3)	Active	DPI Water	217621	6595084	244.1	89	26.5-30.5	Alluvium
GW036568_2	SP - Nested (3)	Active	DPI Water	217621	6595084	244.1	89	42-46	Alluvium
GW036568_3	SP - Nested (3)	Active	DPI Water	217621	6595084	244.1	89	60-64	Alluvium
GW036598_1	SP - Nested (3)	Active	DPI Water	217315	6593569	245.3	134	25-31	Alluvium
GW036598_2	SP - Nested (3)	Active	DPI Water	217315	6593569	245.3	134	74-79	Alluvium
GW036598_3	SP - Nested (3)	Active	DPI Water	217315	6593569	245.3	134	123-129	Alluvium
GW036600_1	SP - Nested (3)	Active	DPI Water	216345	6593096	246.97	141.5	13-15	Alluvium
GW036600_2	SP - Nested (3)	Active	DPI Water	216345	6593096	246.97	141.5	100-105	Alluvium
GW036600_3	SP - Nested (3)	Active	DPI Water	216345	6593096	246.97	141.5	122-127	Alluvium
GW041027_1	Piezometer	Active	DPI Water	232730	6620523	318.45	83.5	8.3-14.3	Alluvium
GW967137_1	SP - Nested (2)	Active	DPI Water	219846	6622452	258.79	84	8-11	Alluvium
GW967137_2	SP - Nested (2)	Active	DPI Water	219846	6622452	258.79	84	64-75	Alluvium
GW967138_1	SP - Nested (2)	Active	DPI Water	227001	6622422	288.55	89.6	7-10	Alluvium
GW967138_2	SP - Nested (2)	Active	DPI Water	227001	6622422	288.13	89.6	71-77	Alluvium

Appendix B 2014 model verification hydrographs

L01 Northwest - Alluvium

GW030129_1



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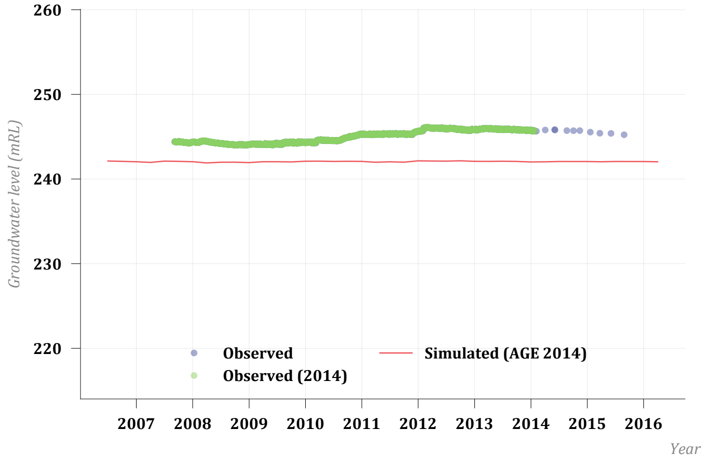

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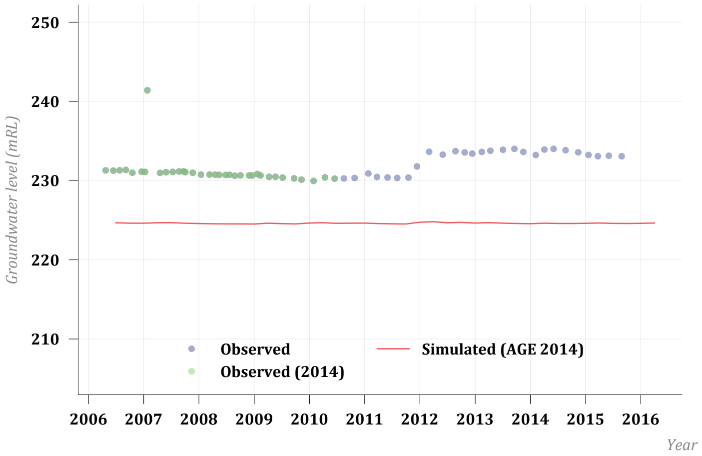
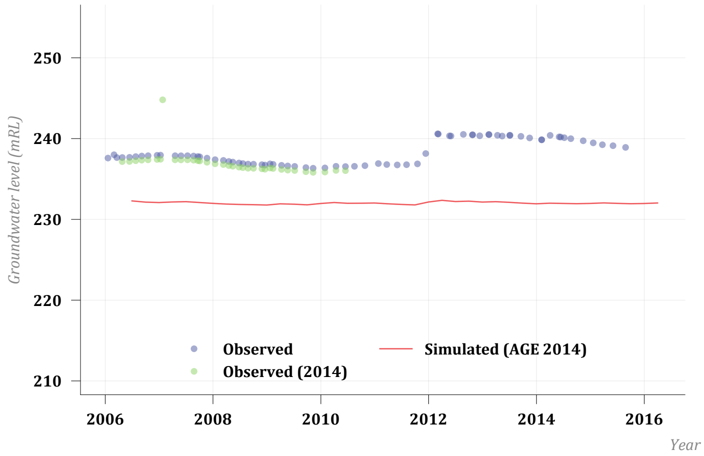


GW030236_1



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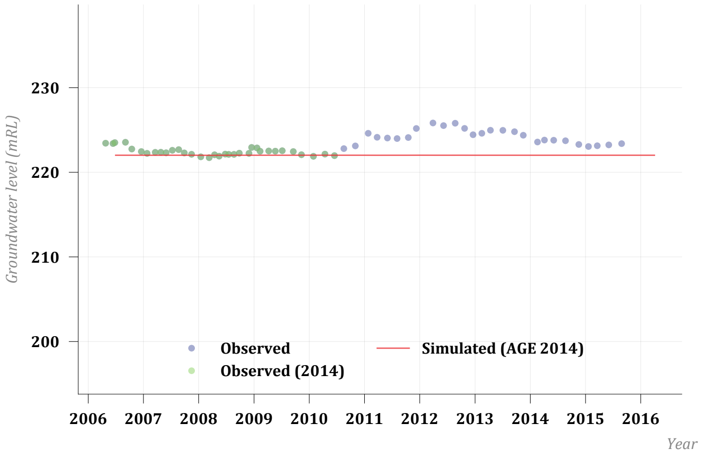

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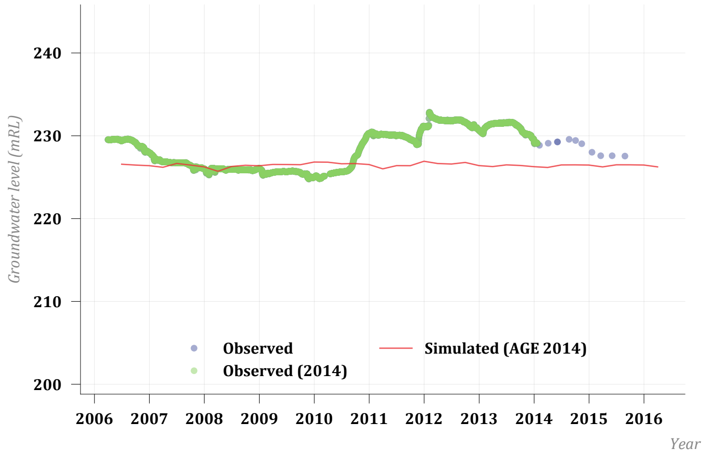
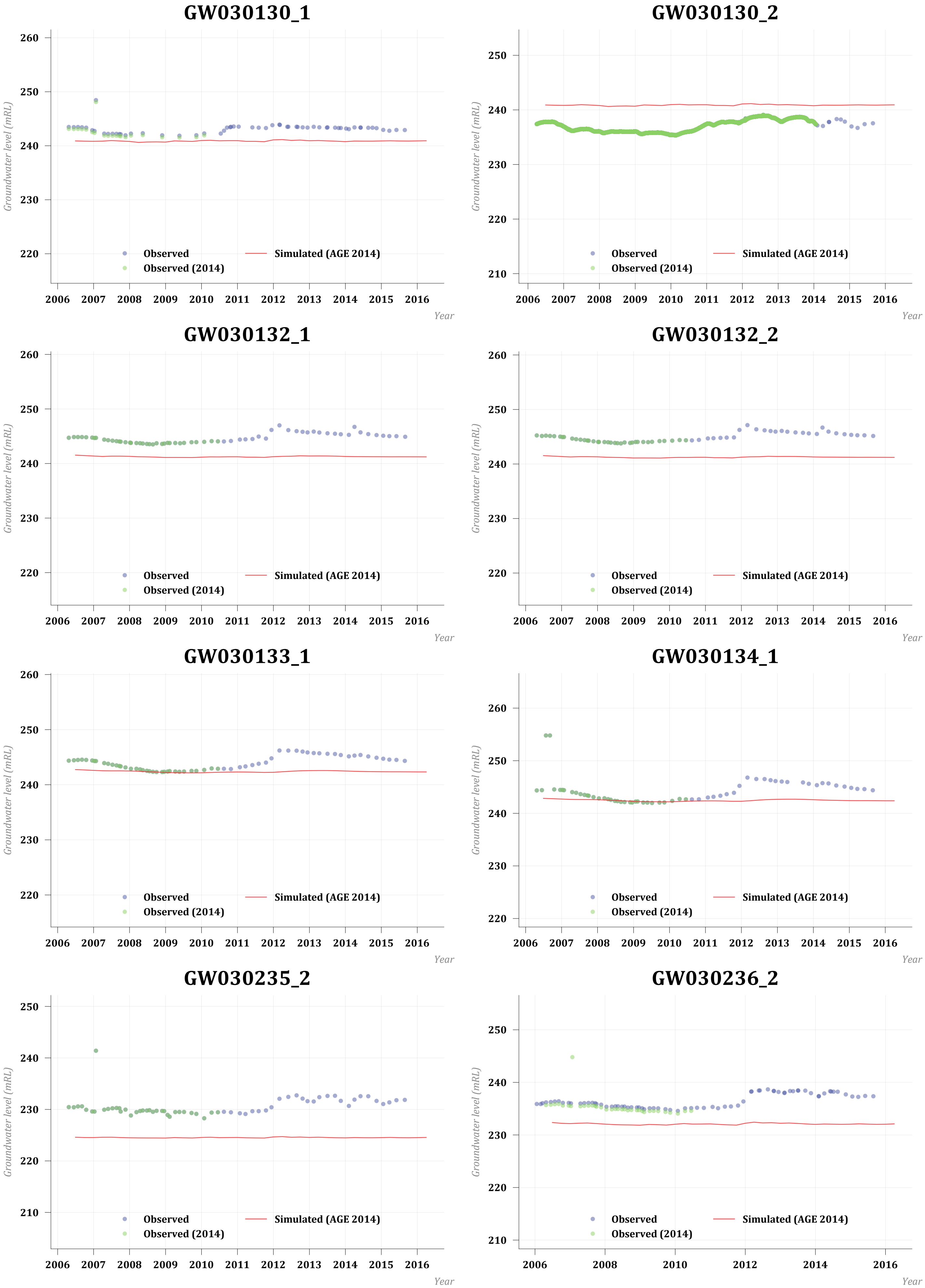
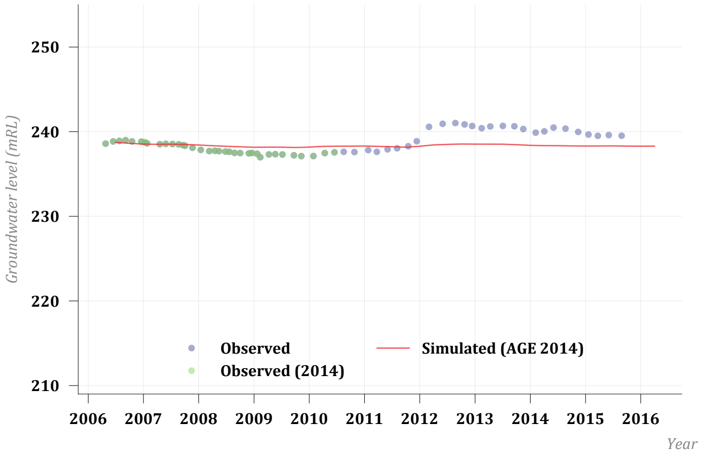


L02 Northwest - Alluvium



L02 Northwest - Alluvium

GW030237_1



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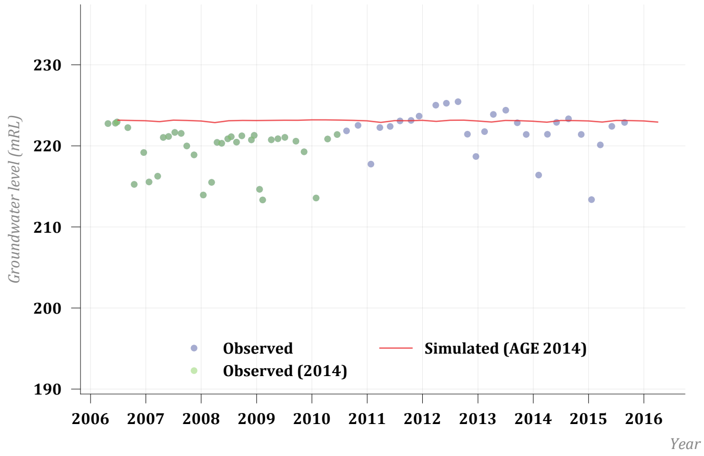

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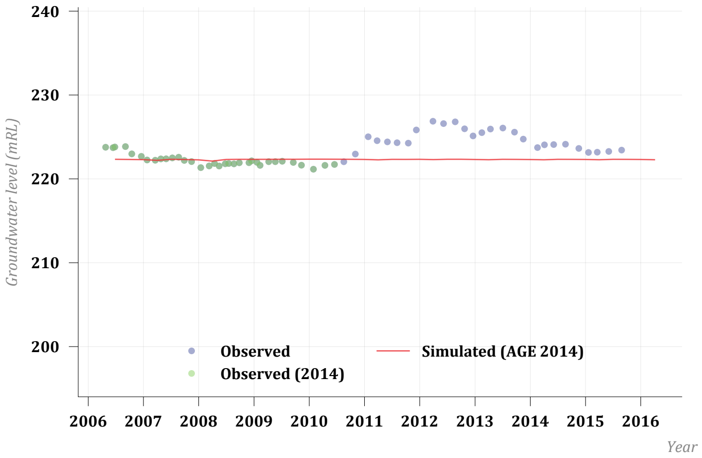

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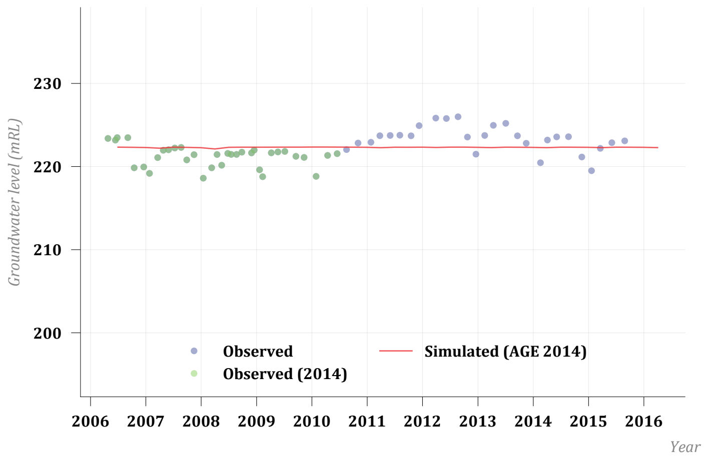

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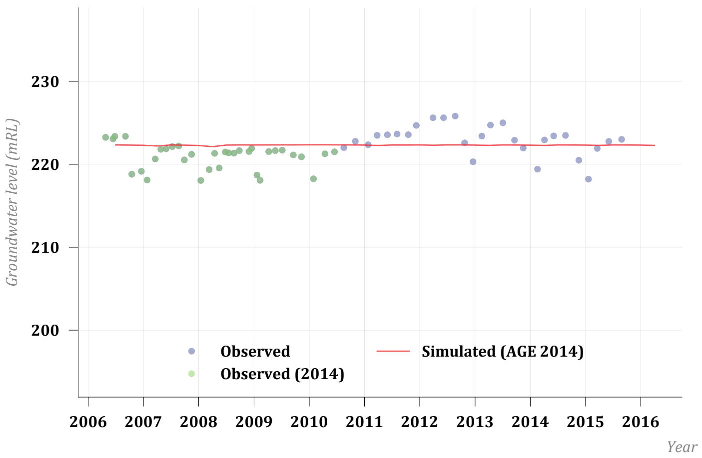

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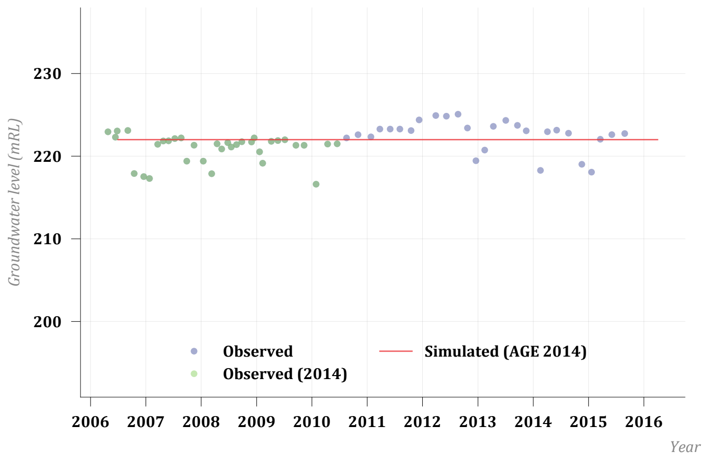

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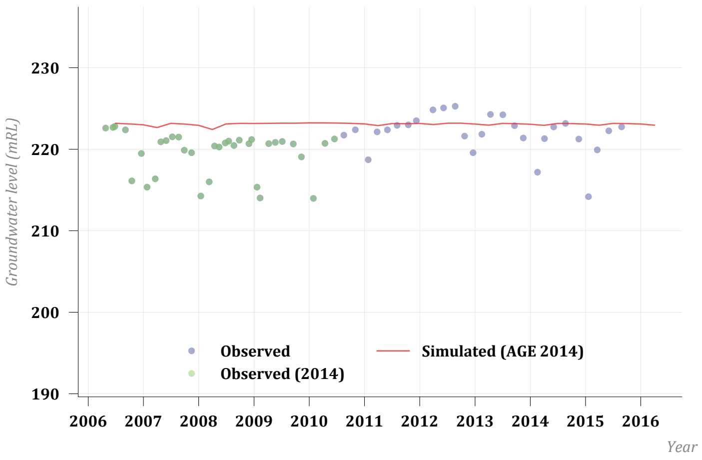

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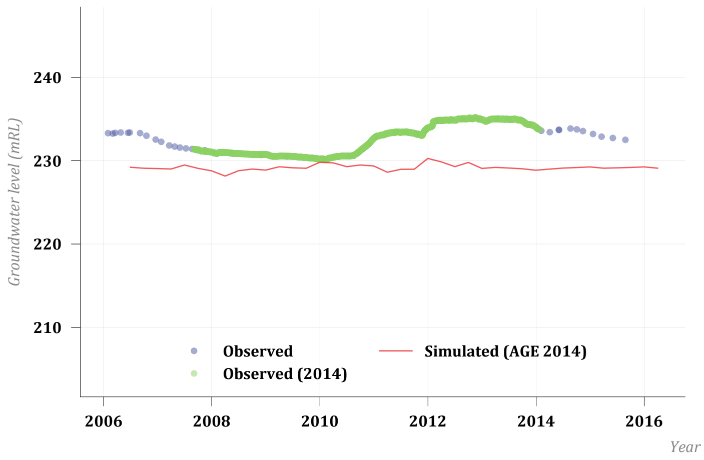
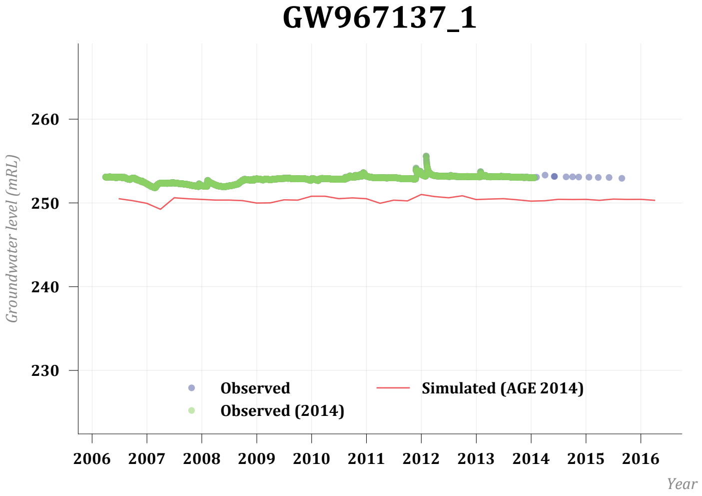
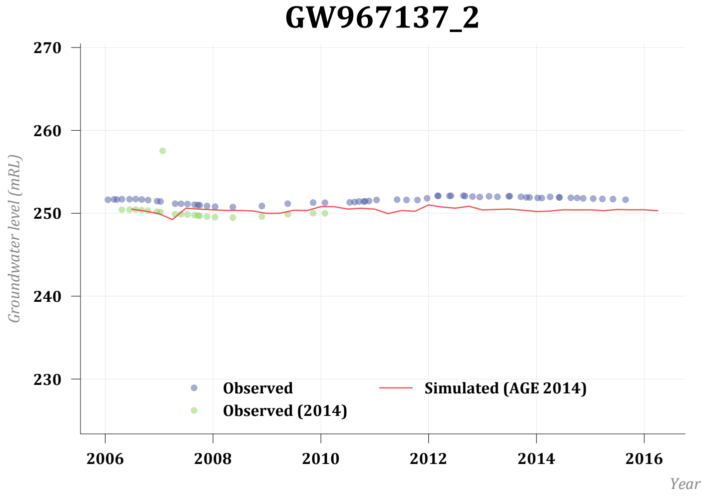
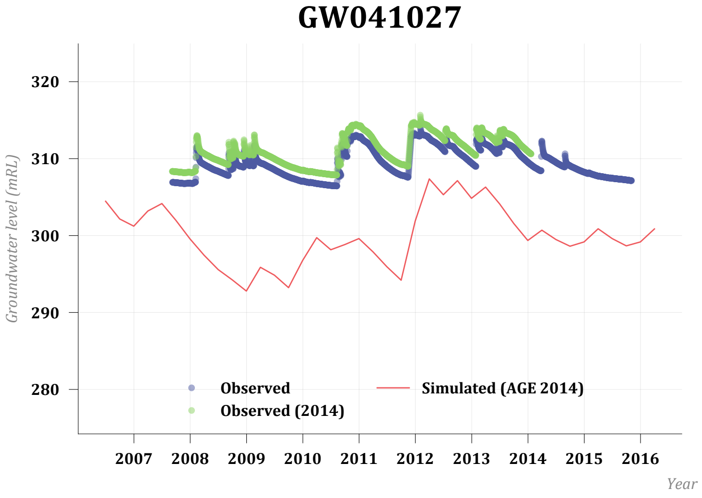


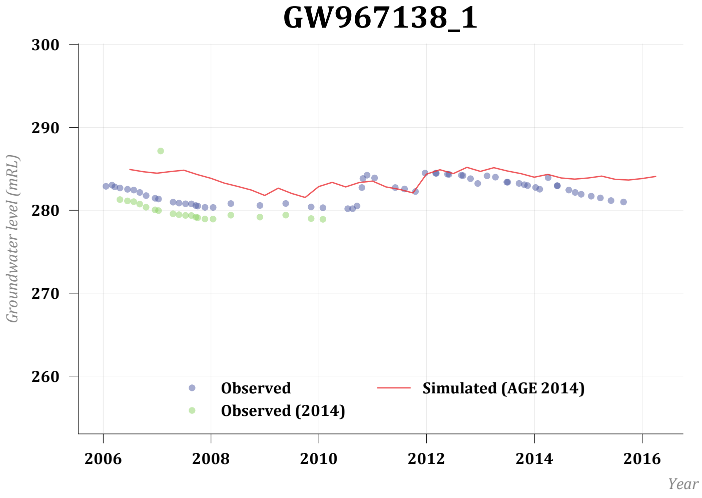
L02 Northwest - Alluvium





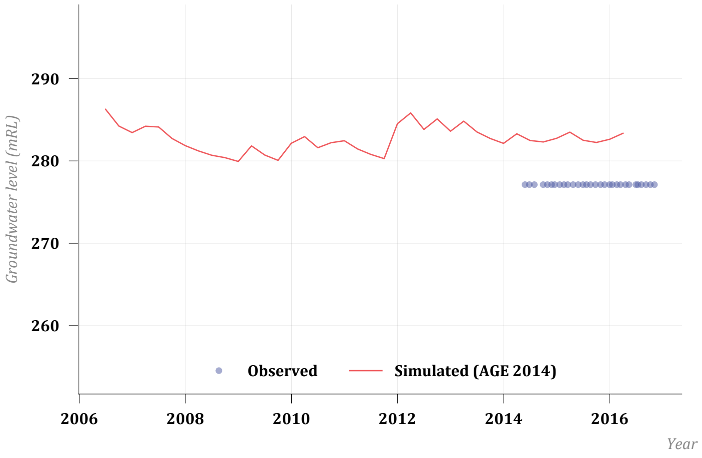
L01 North - Alluvium



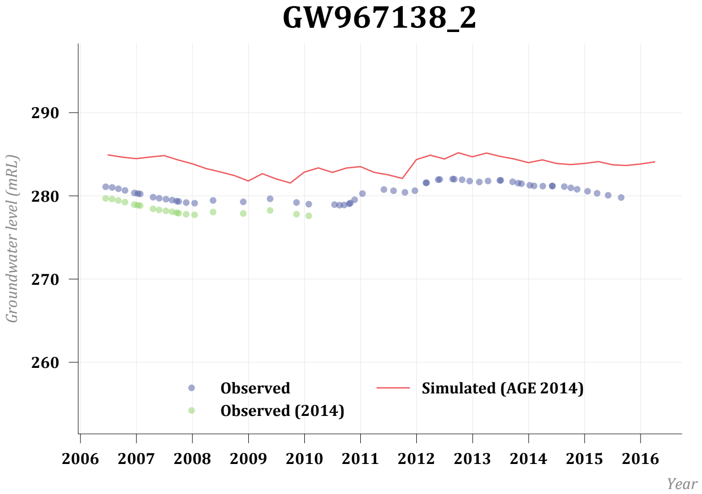


L01 North - Alluvium [Mod:L01PermianReg]

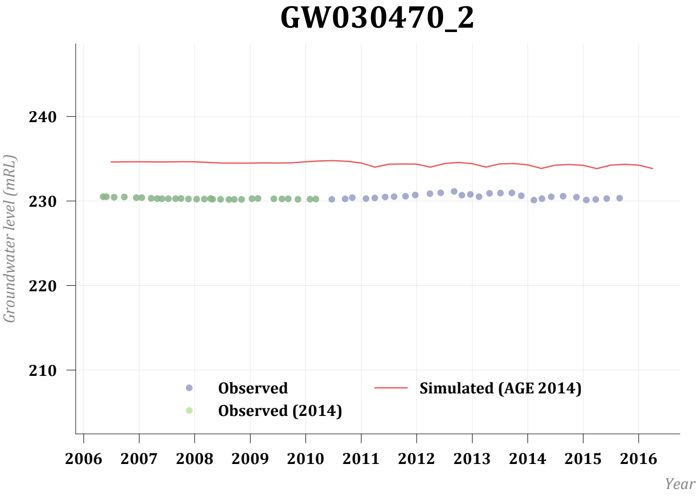
REG10A



L02 North - Alluvium

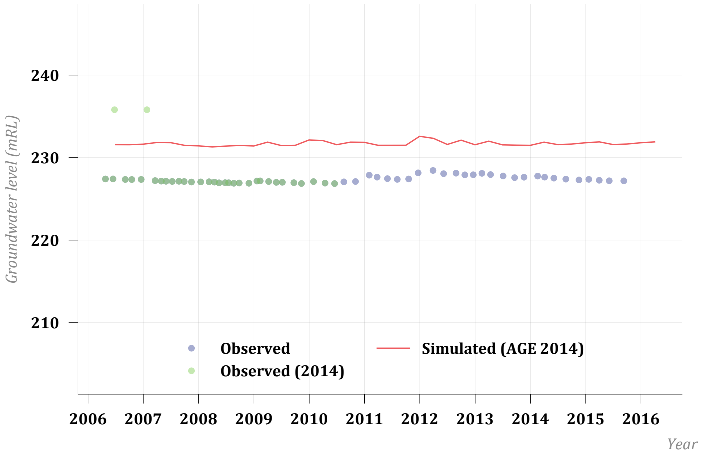


L01 West - Alluvium



L02 West - Alluvium

GW036007_1



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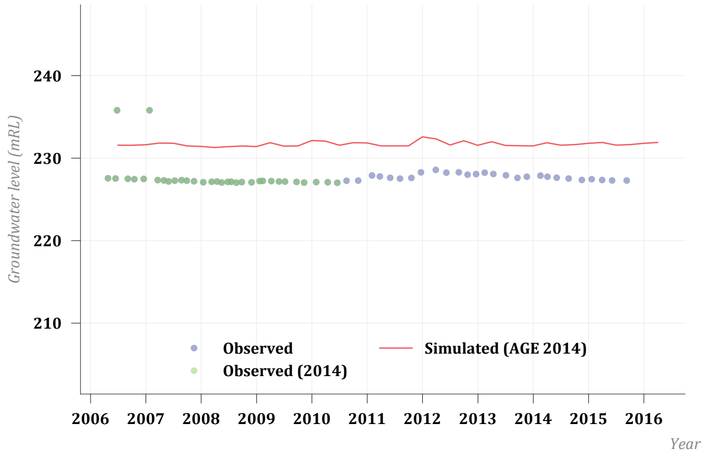

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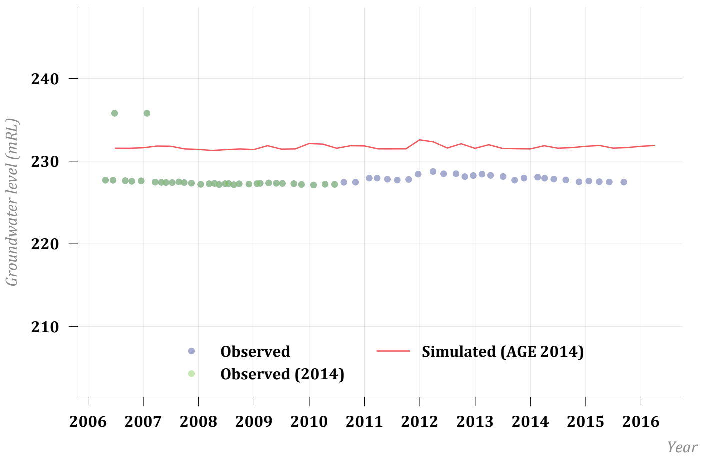

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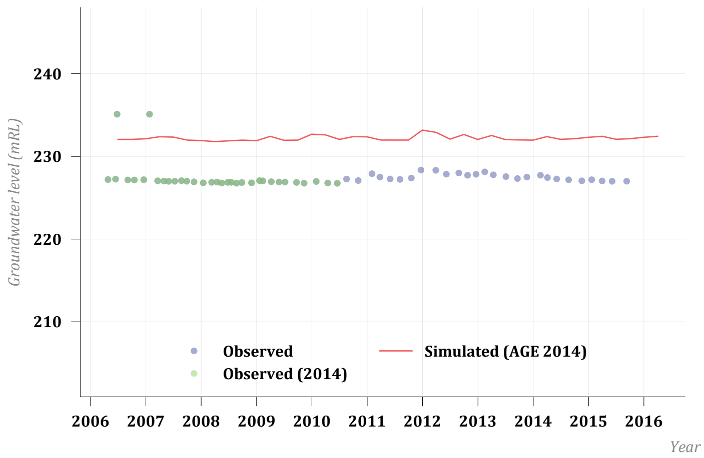

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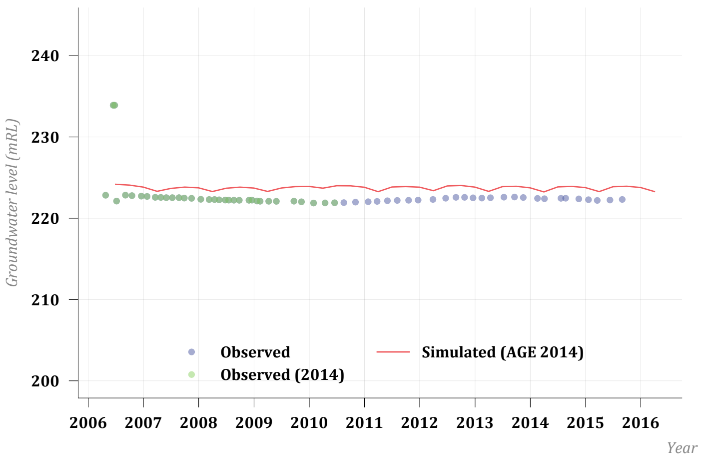
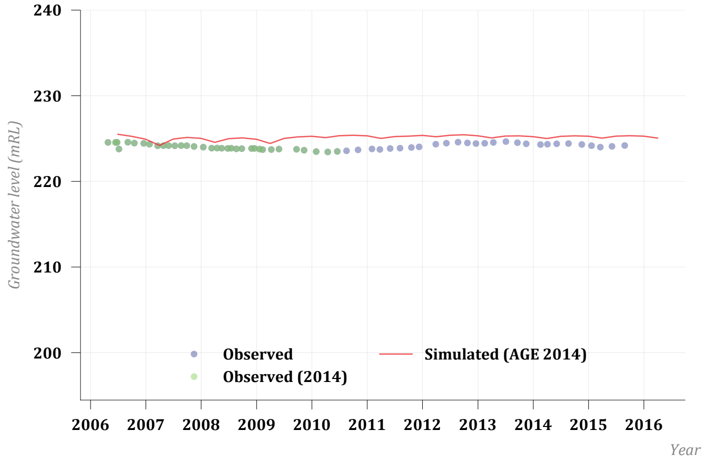
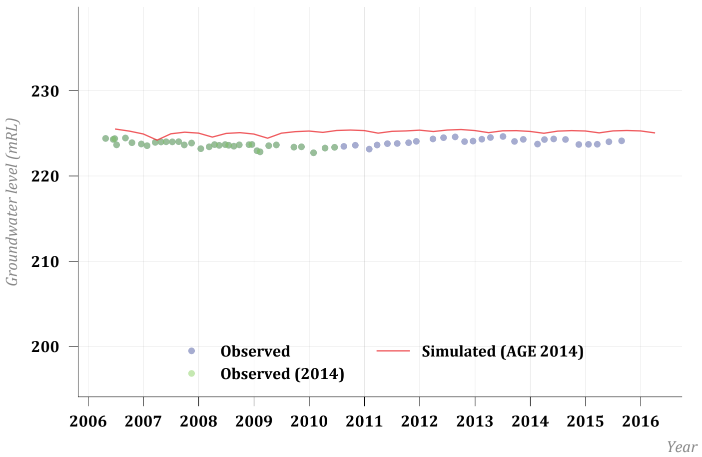


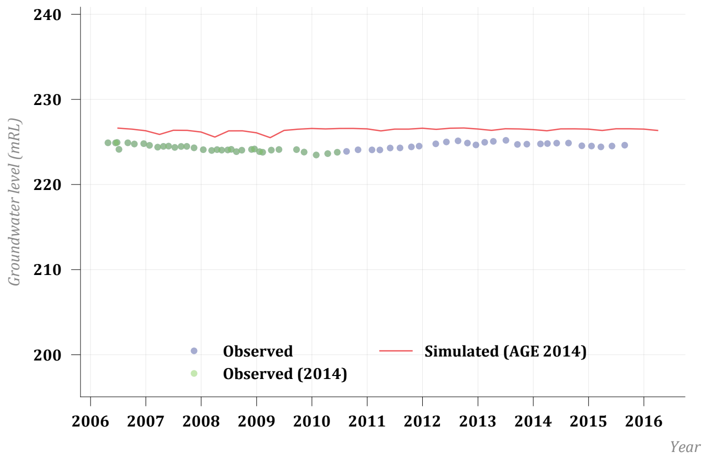
GW036014_1



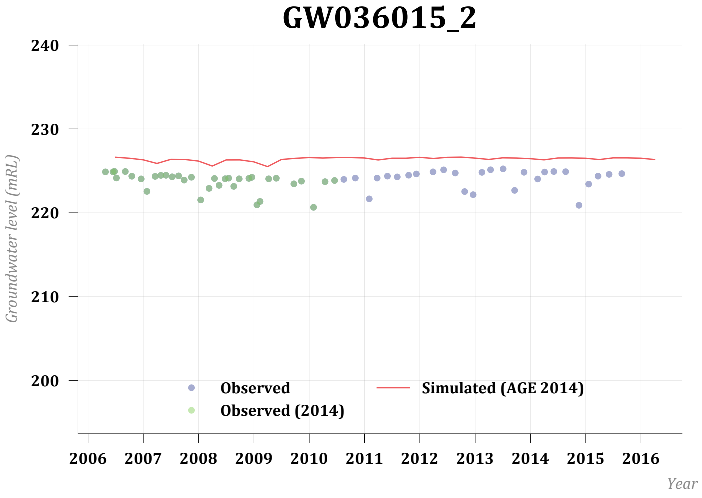
GW036014_2

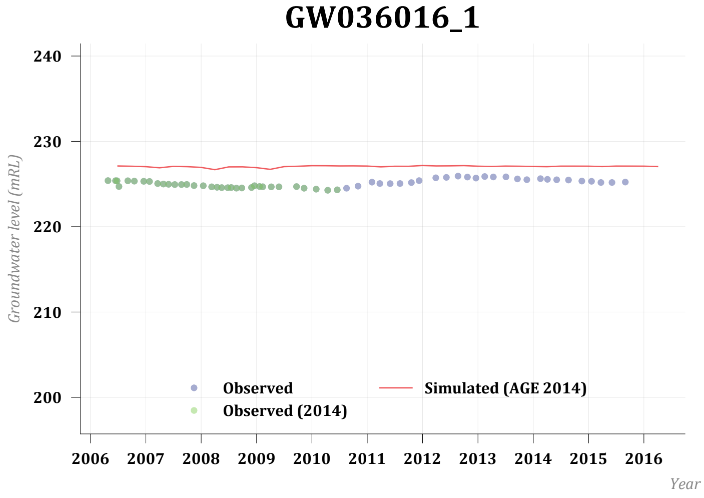


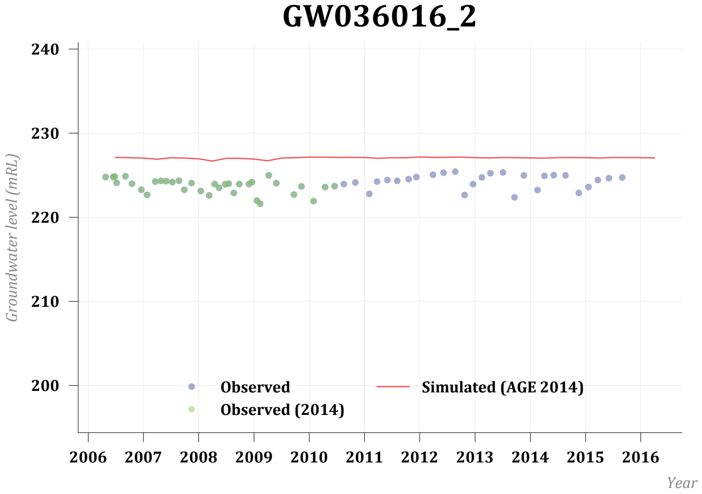
GW036015_1

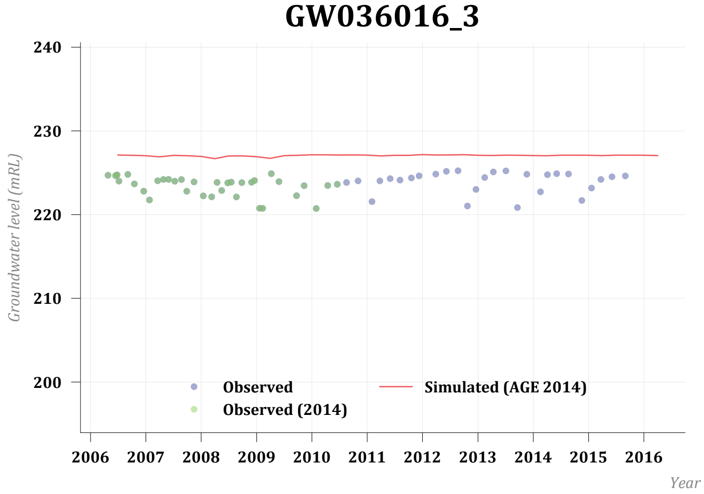


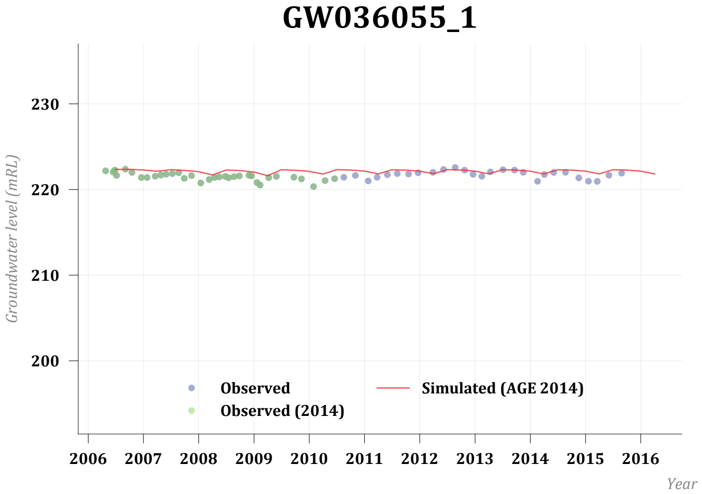
L02 West - Alluvium

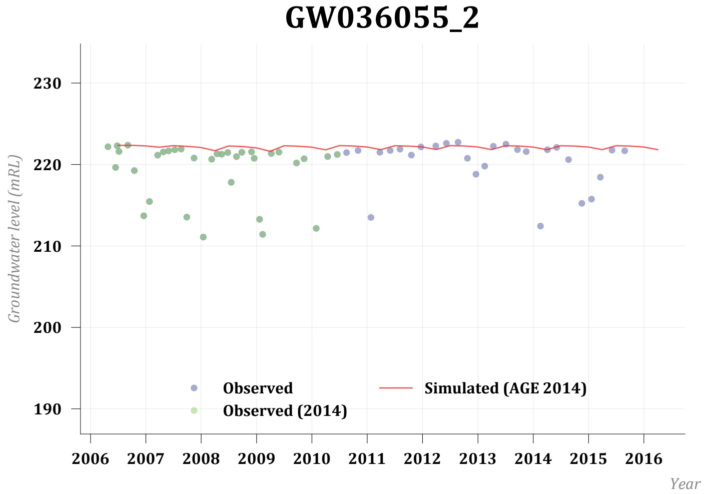


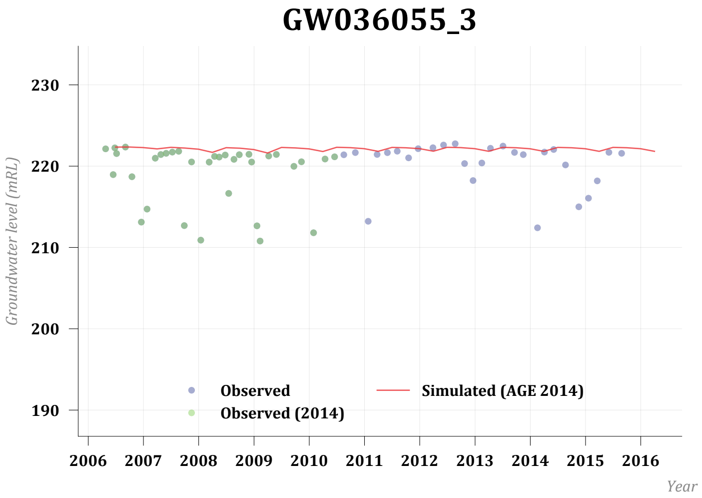


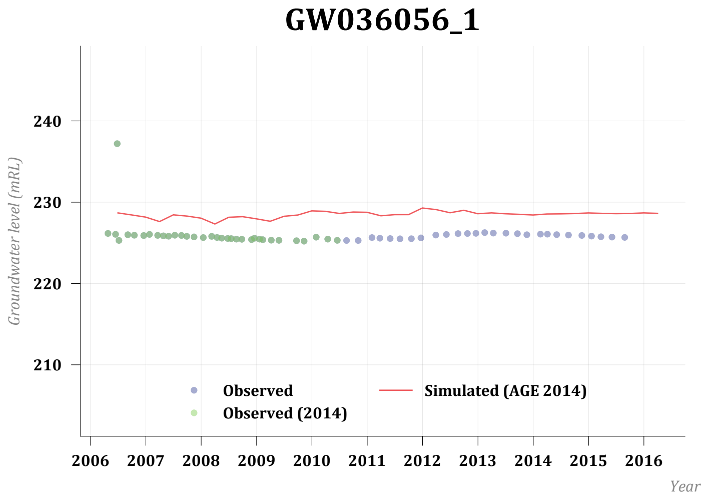




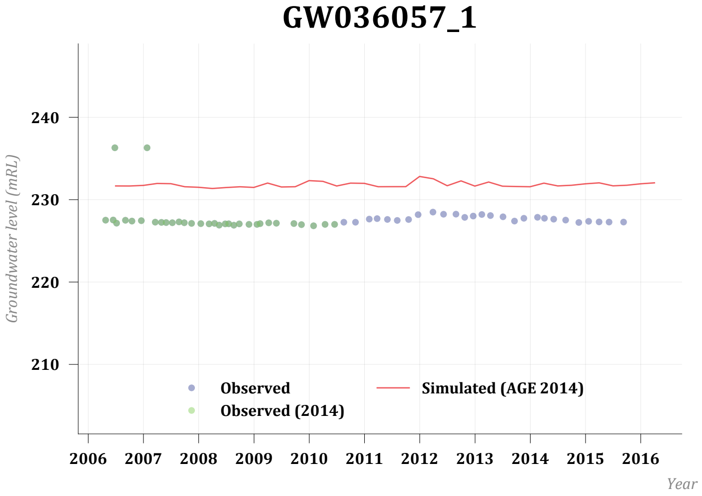


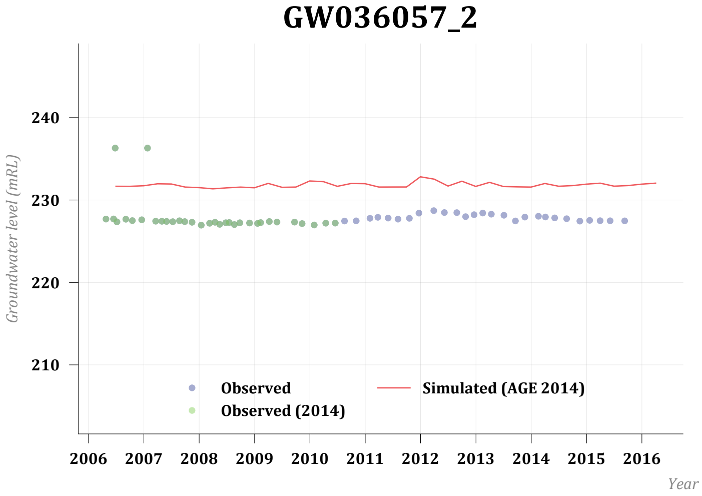


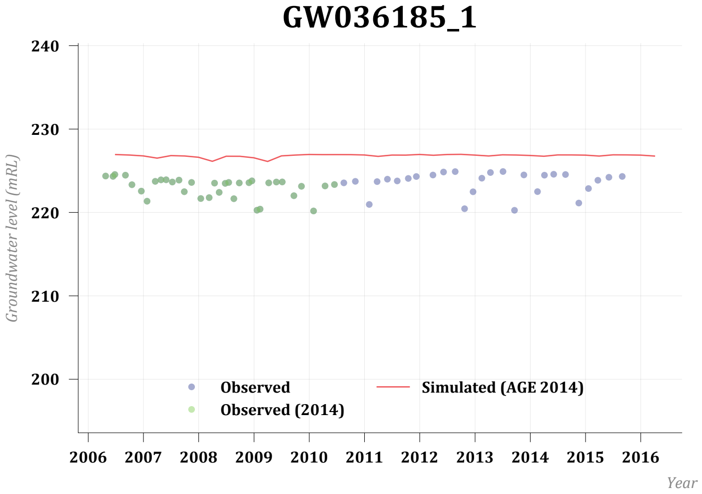


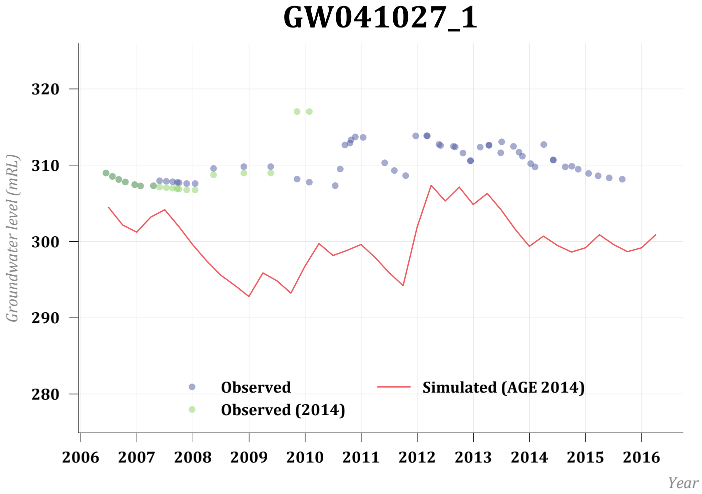


L02 West - Alluvium

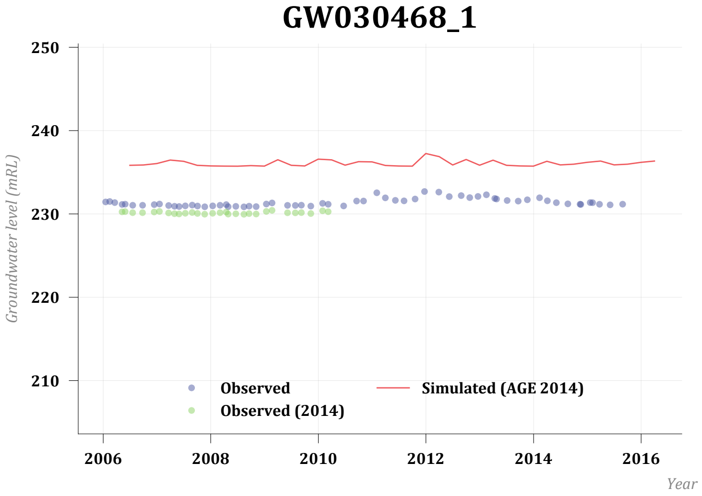


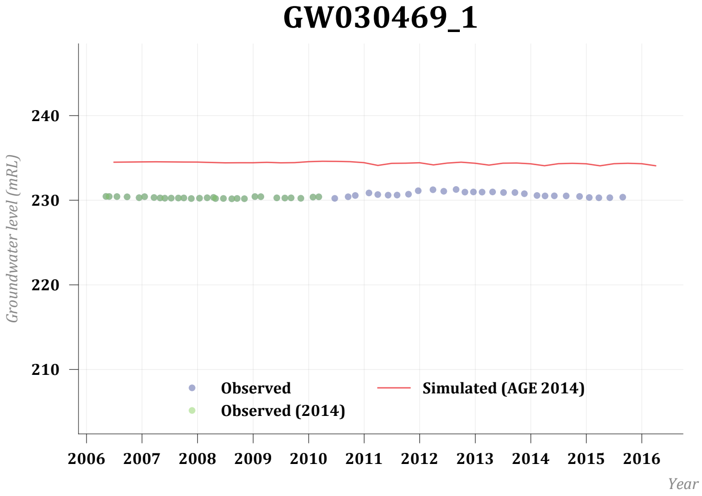


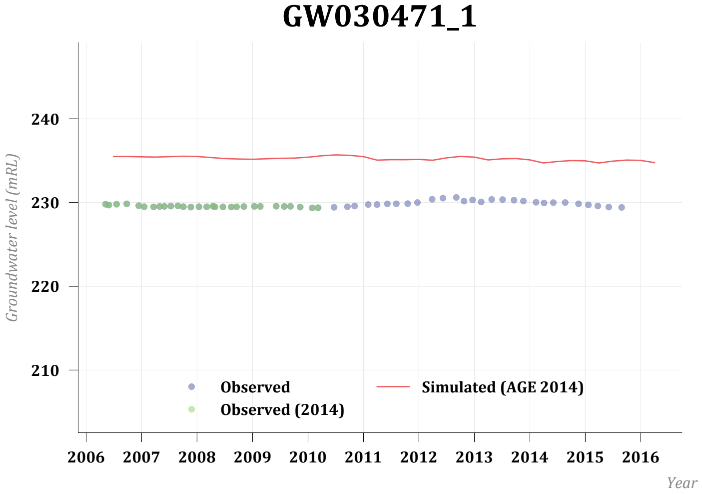


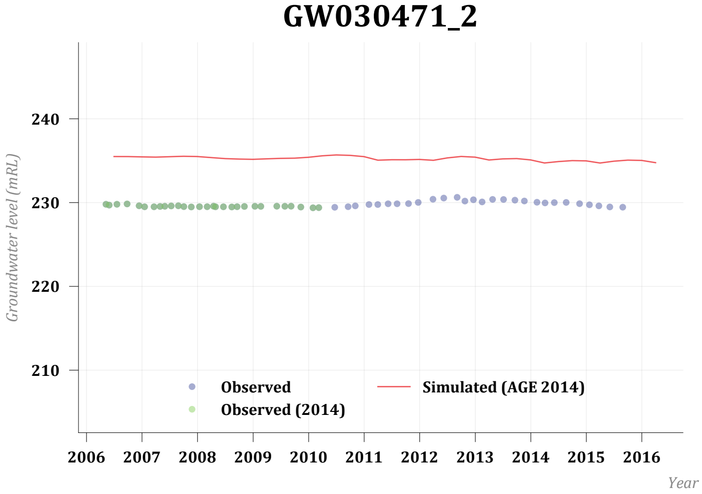


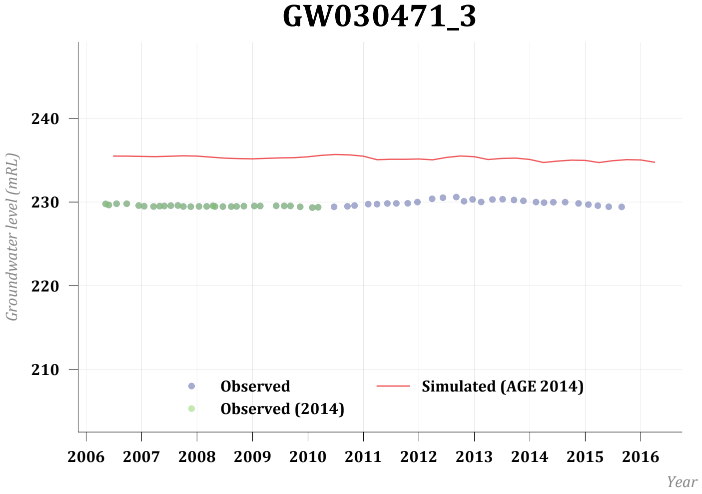
L02 Central West - Alluvium

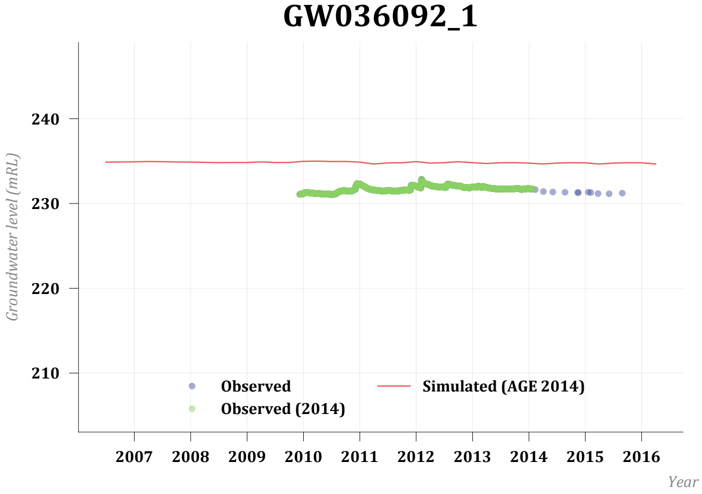


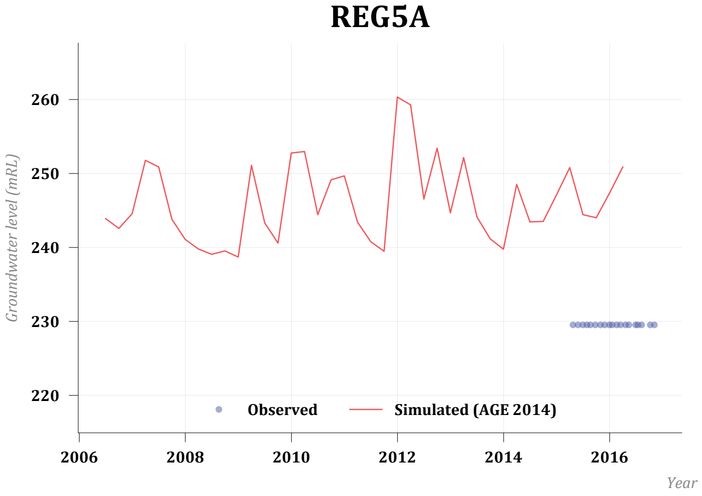






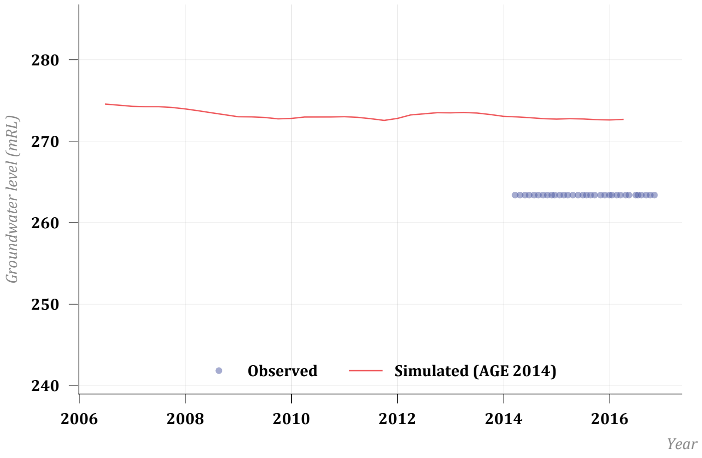






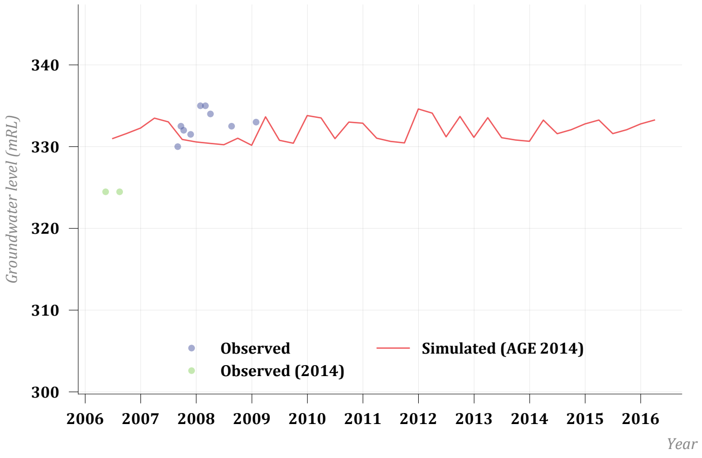
L02 Central North - Alluvium [Mod:L01PermianReg]

BCM01

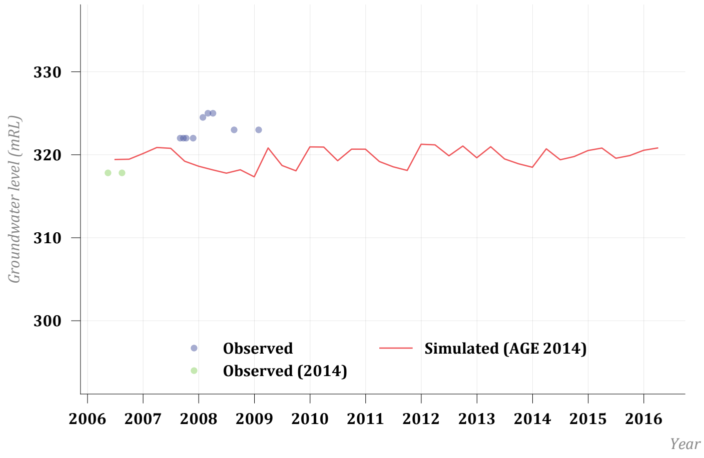


L02 East - Alluvium

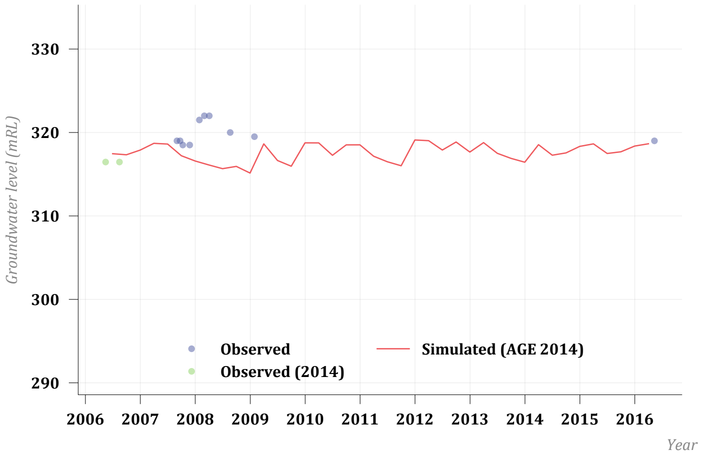
BCS2



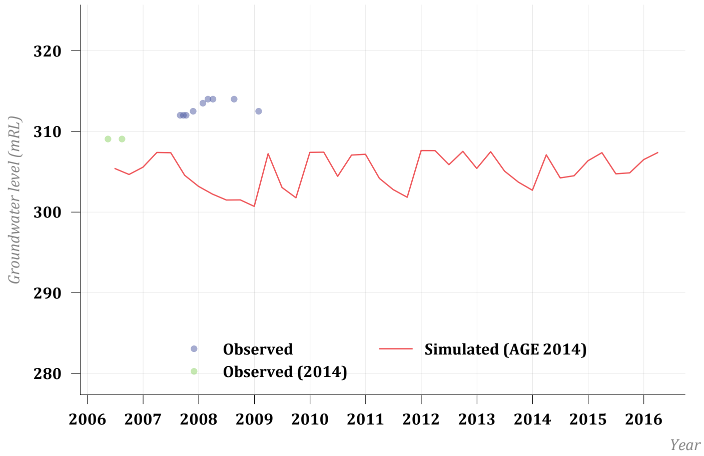
BCS3



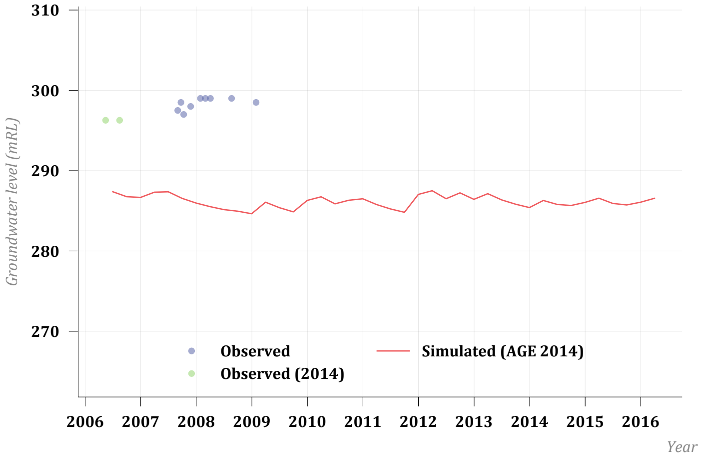
BCS4



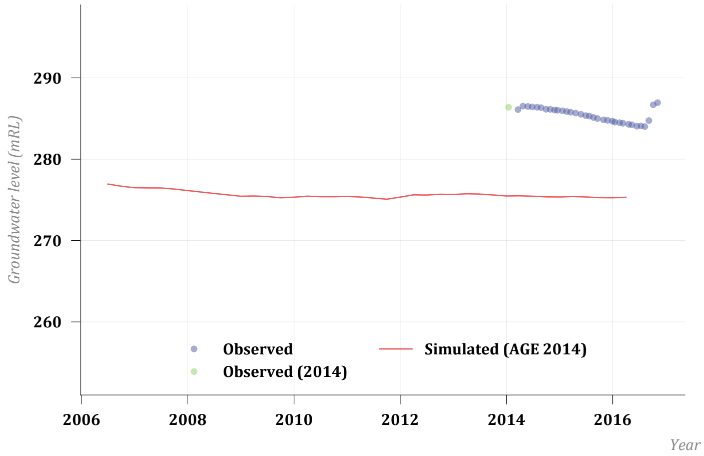
BCS5



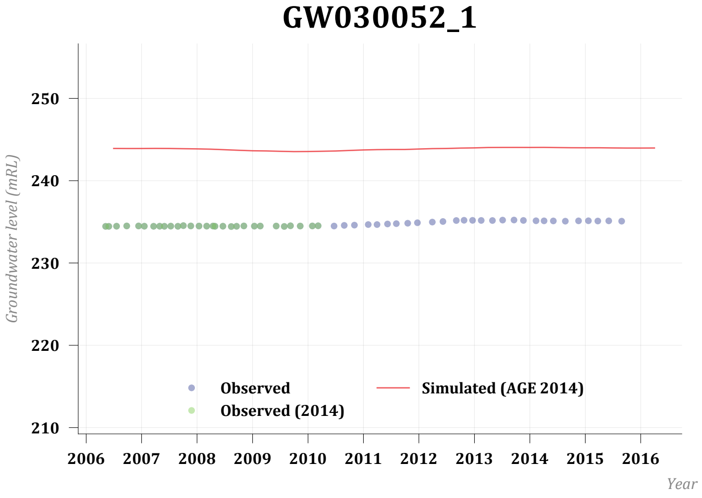
BCS6

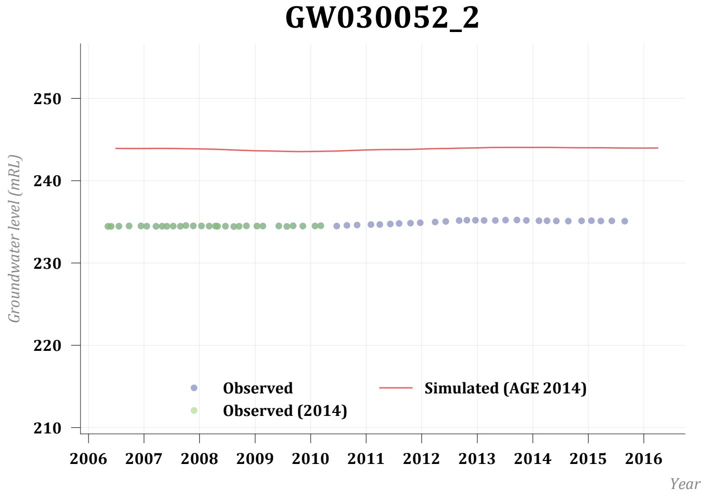


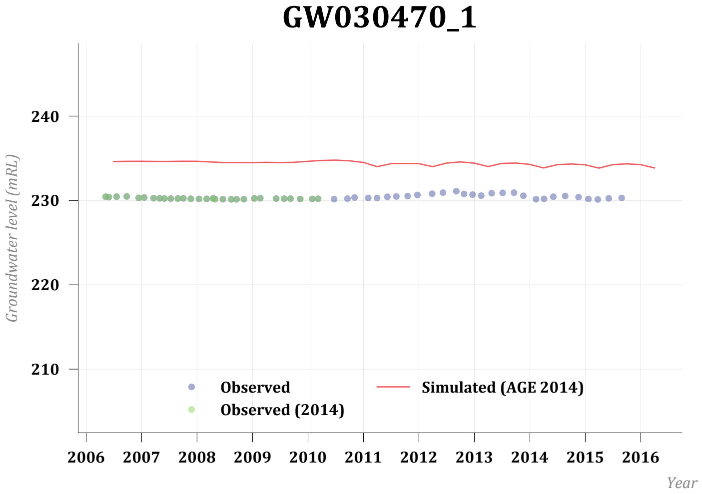
REG7A



L01 Central South - Alluvium

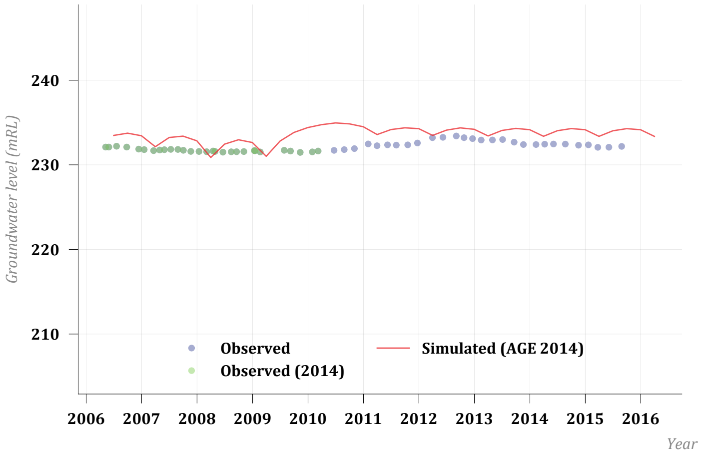






L02 Central South - Alluvium

GW030048_1



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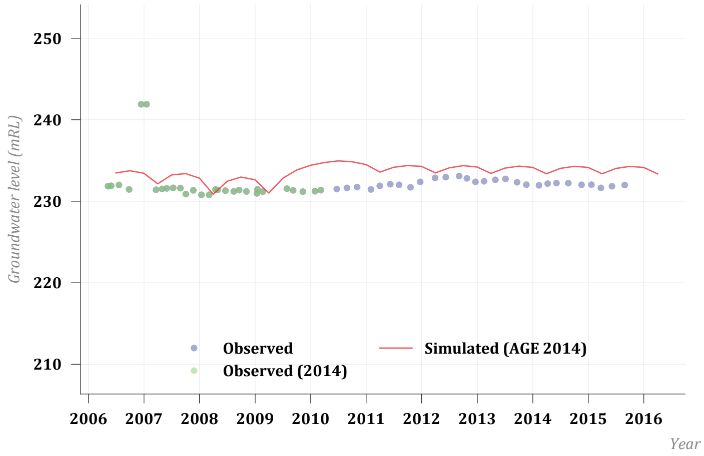

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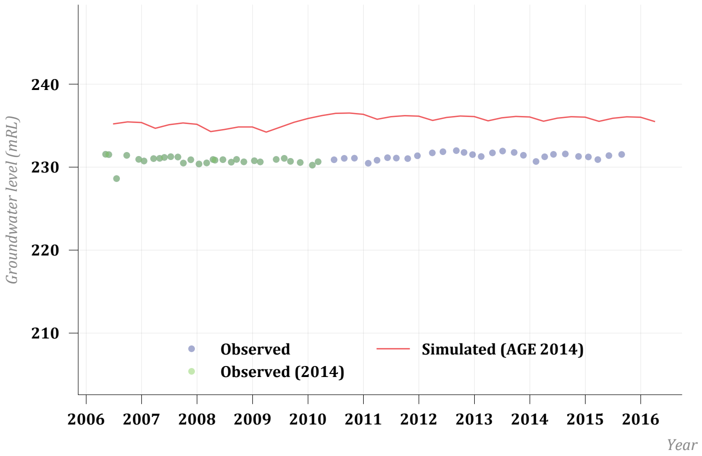

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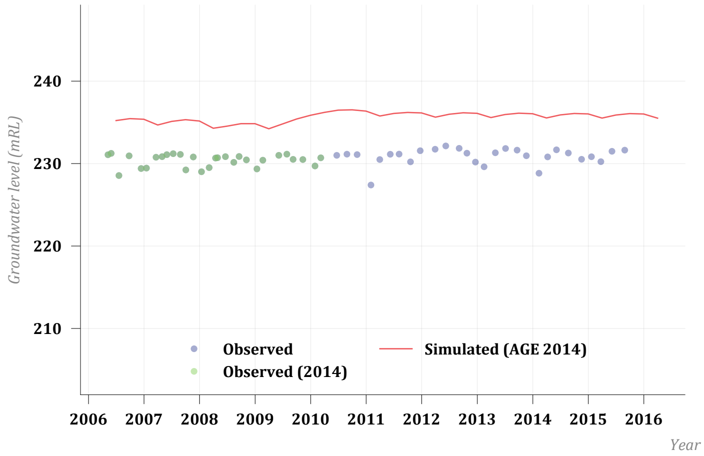

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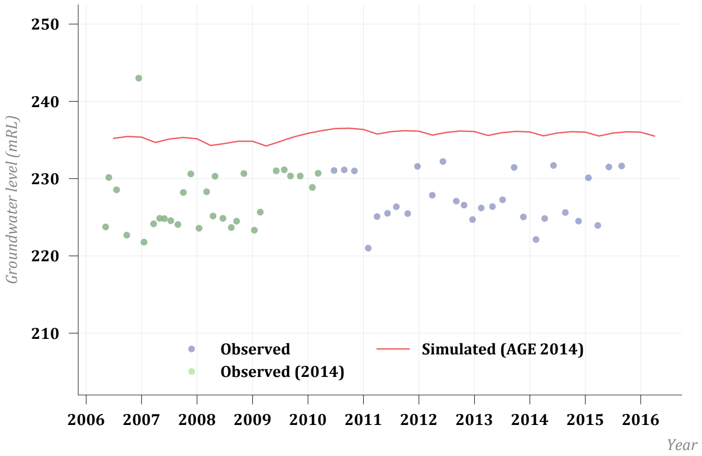
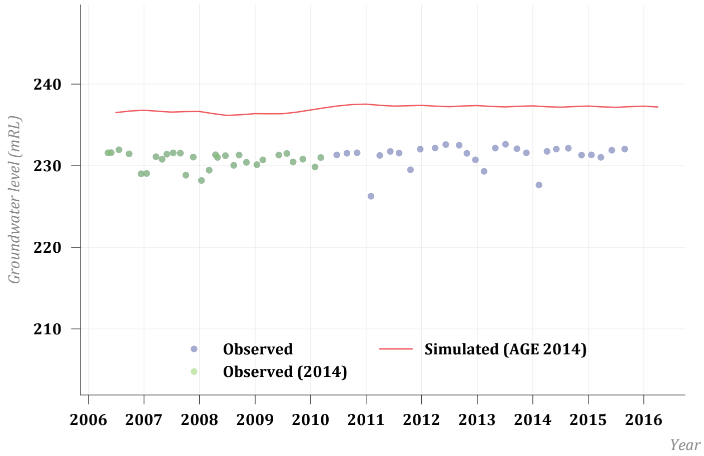


GW030050_1



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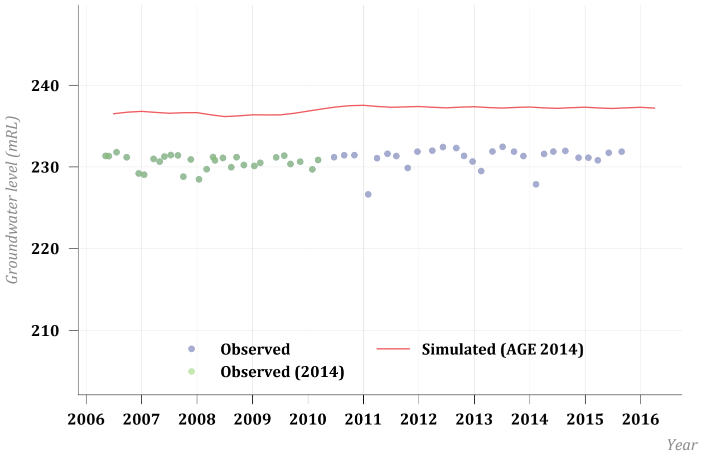

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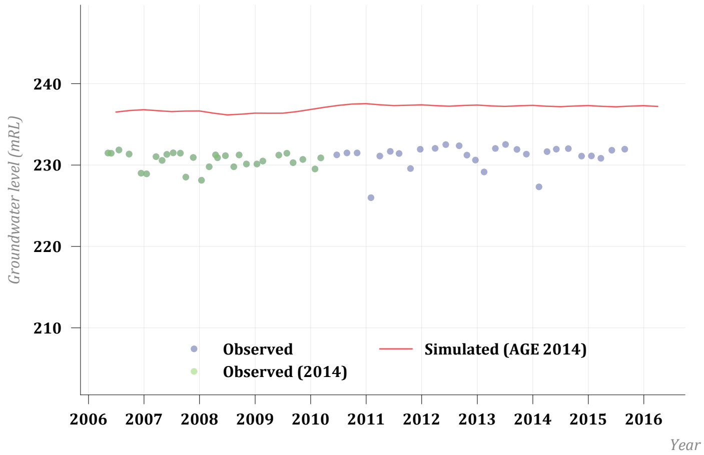
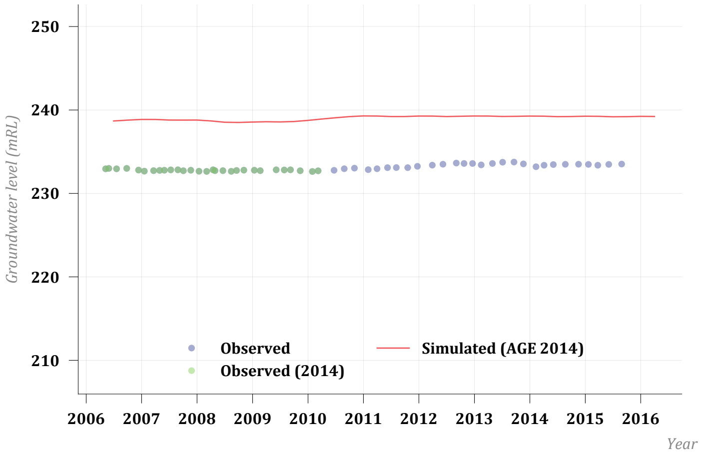


L02 Central South - Alluvium

GW030051_1



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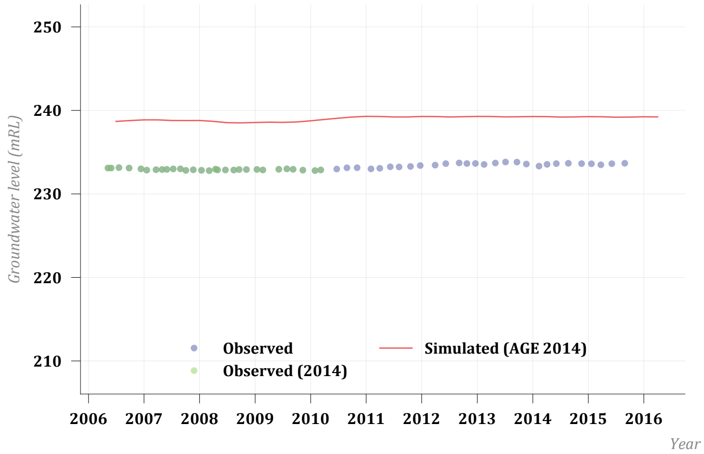

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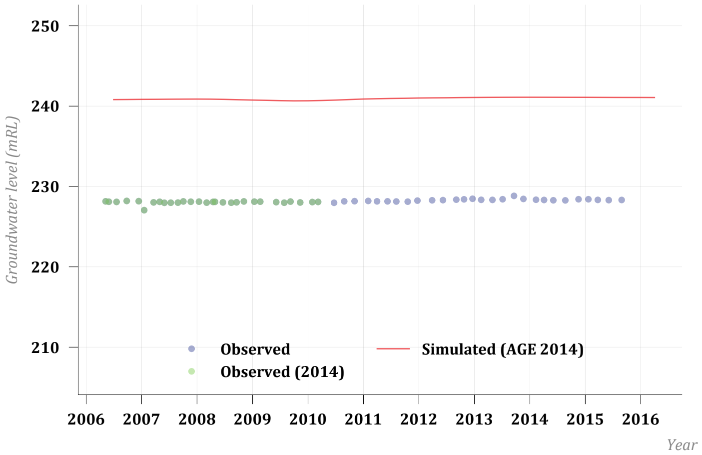

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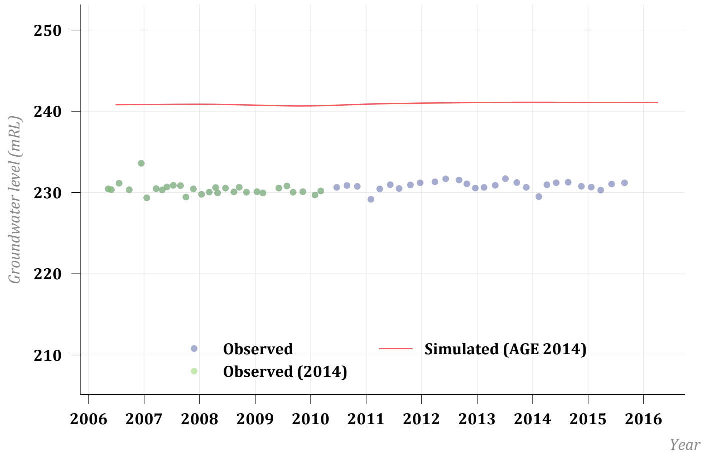

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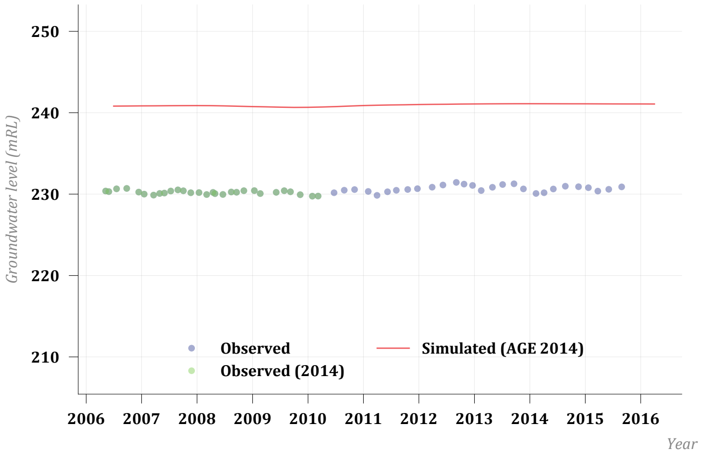
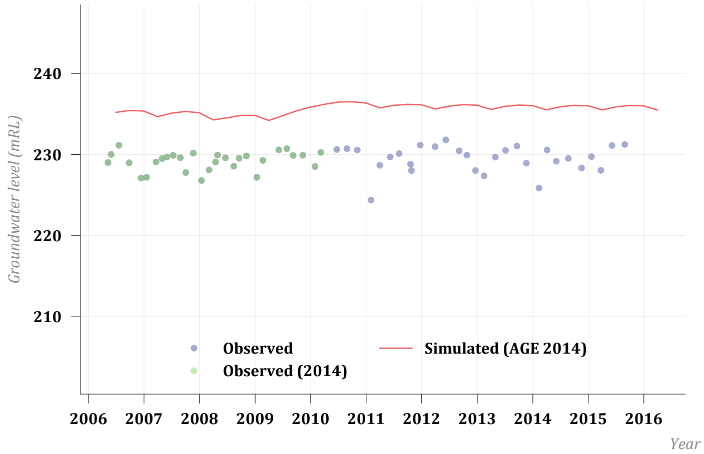
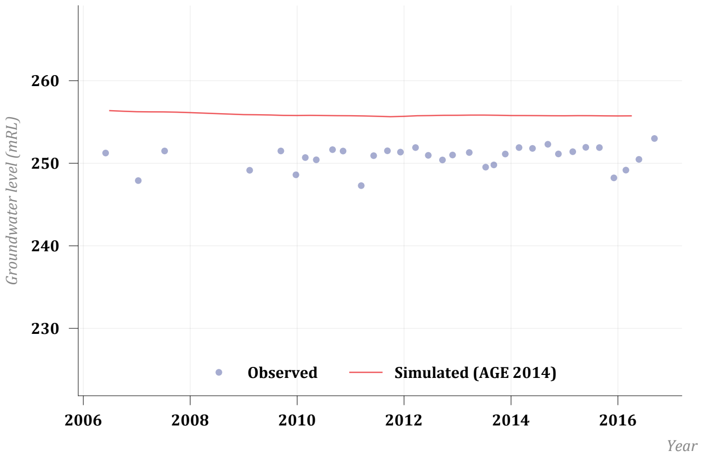


GW030535_1



GW031856



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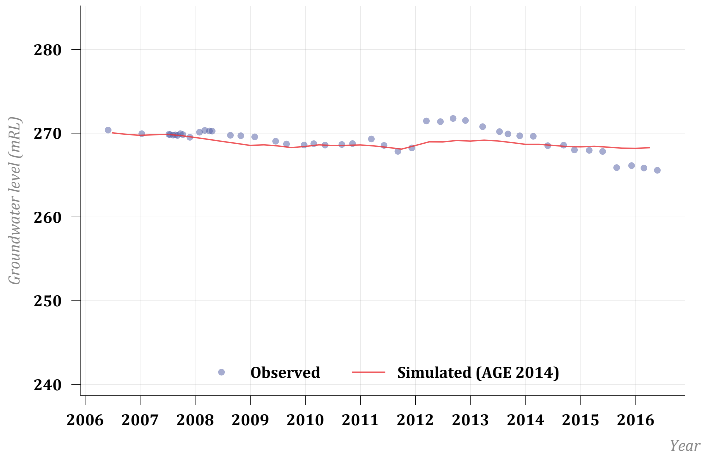
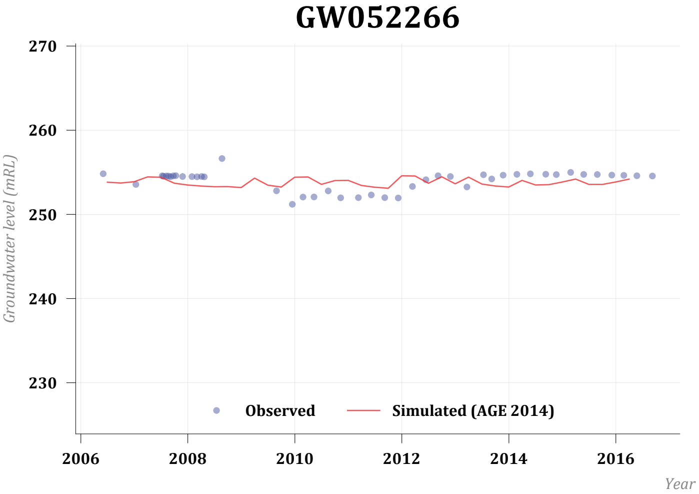
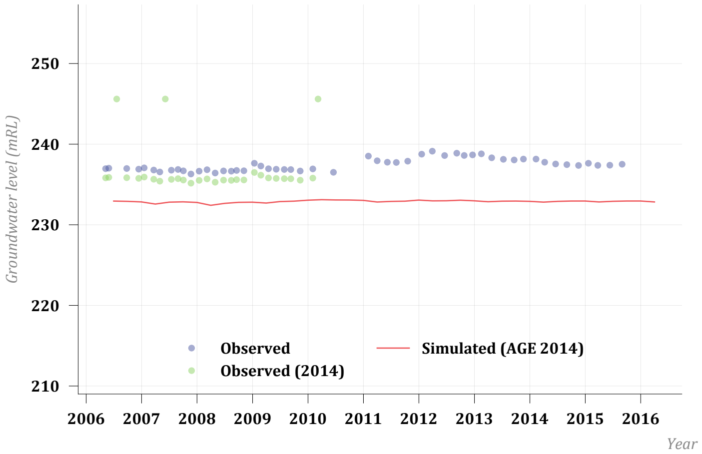


L02 Central South - Alluvium

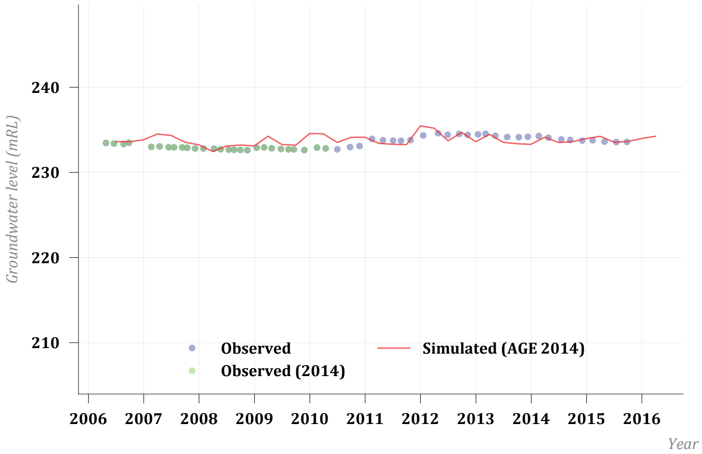


L01 Southwest - Alluvium

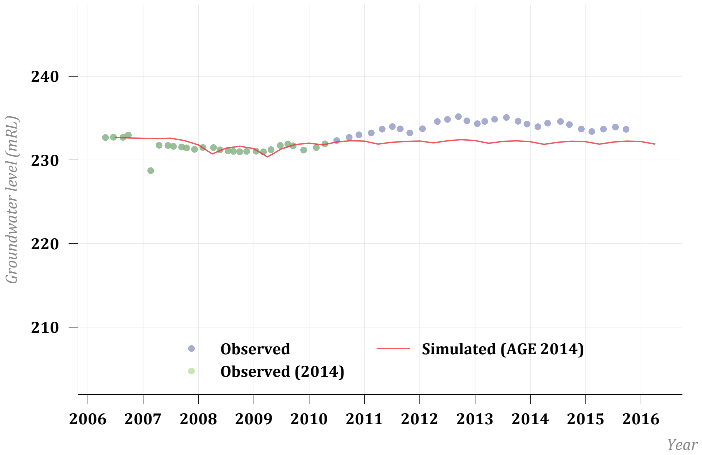
GW036548_1



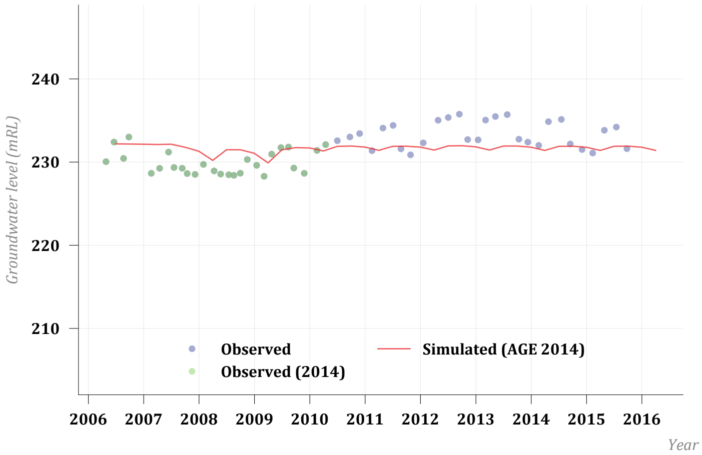
GW036565_1



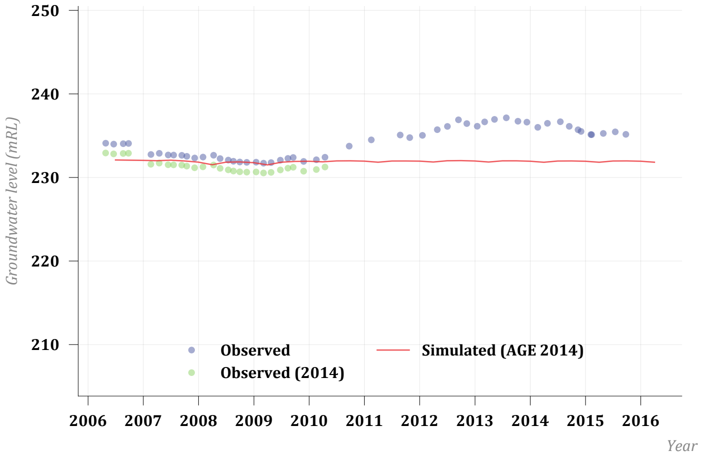
GW036568_1



GW036598_1

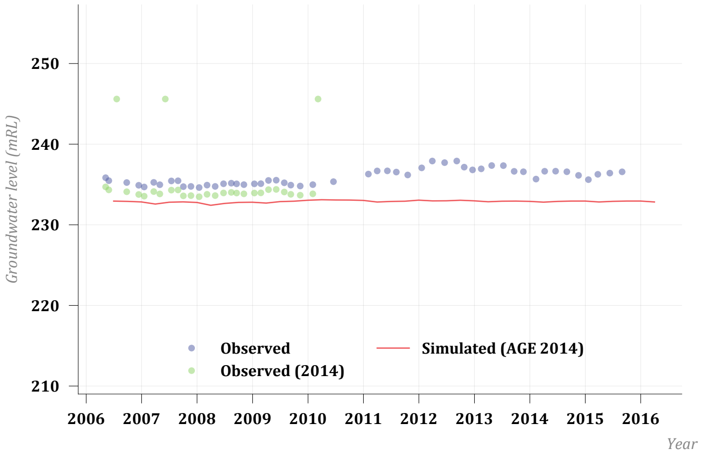


GW036600_1

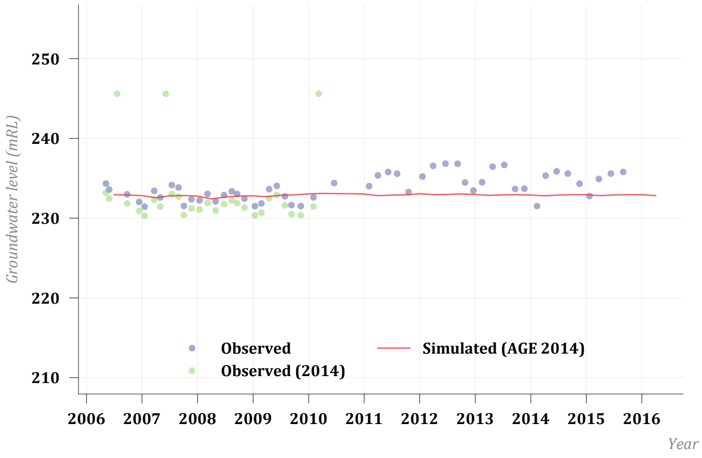


L02 Southwest - Alluvium

GW036548_2



GW036548_3



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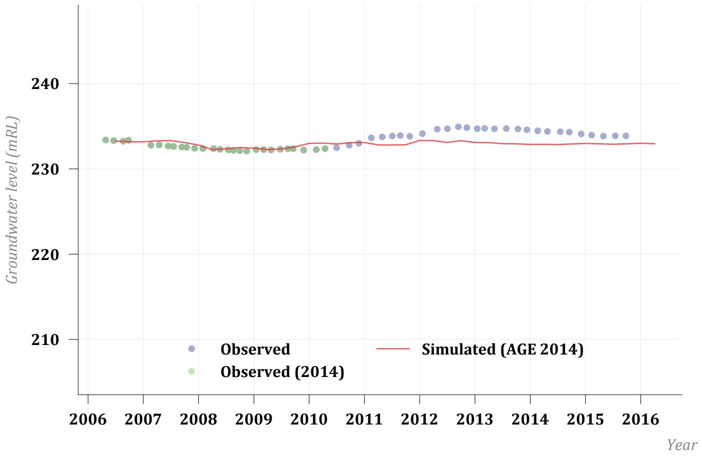

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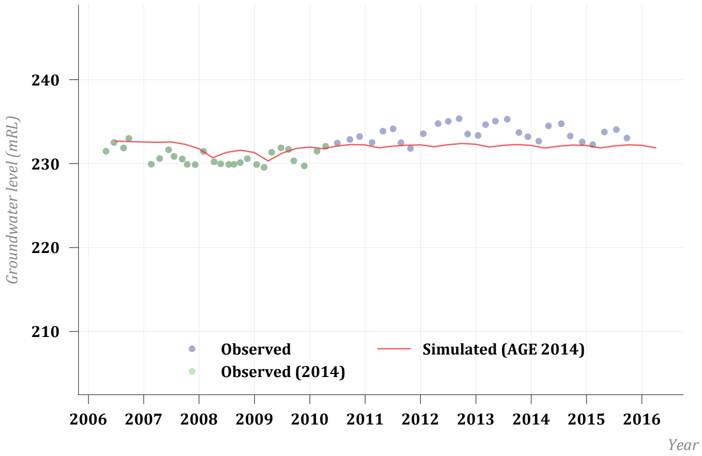

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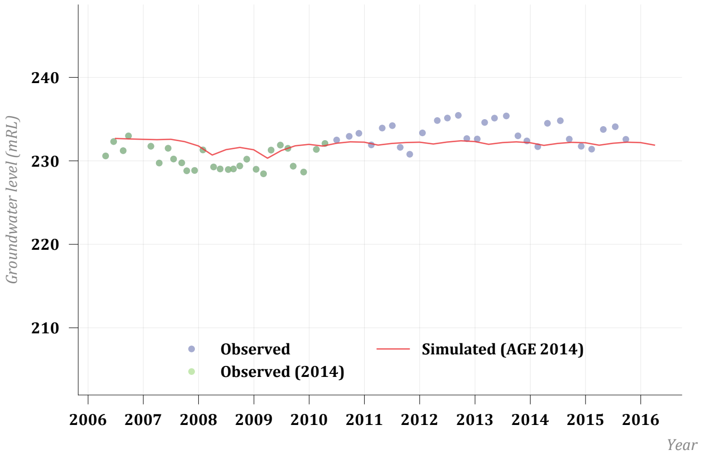

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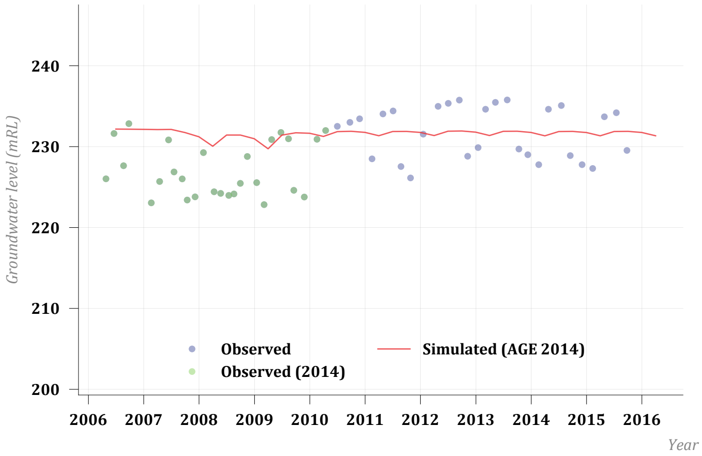

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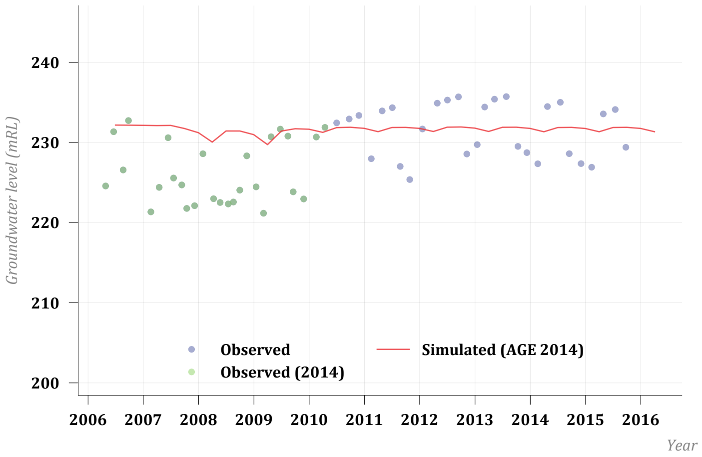

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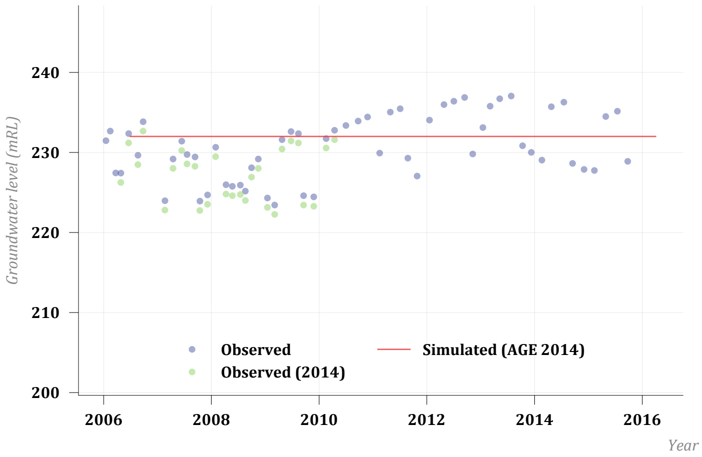
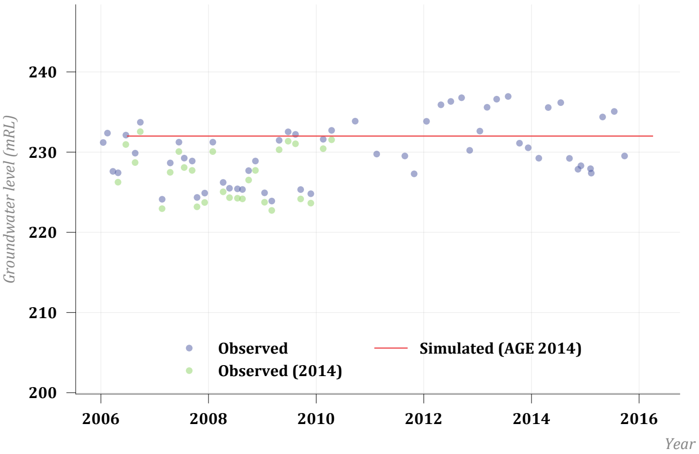


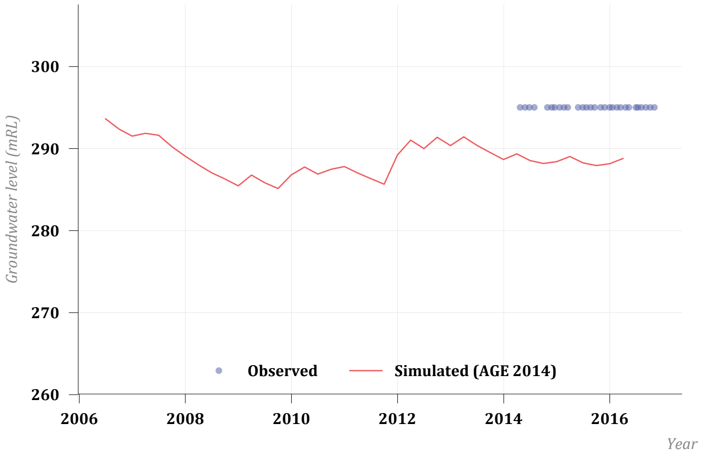
L02 Southwest - Alluvium

GW036600_3



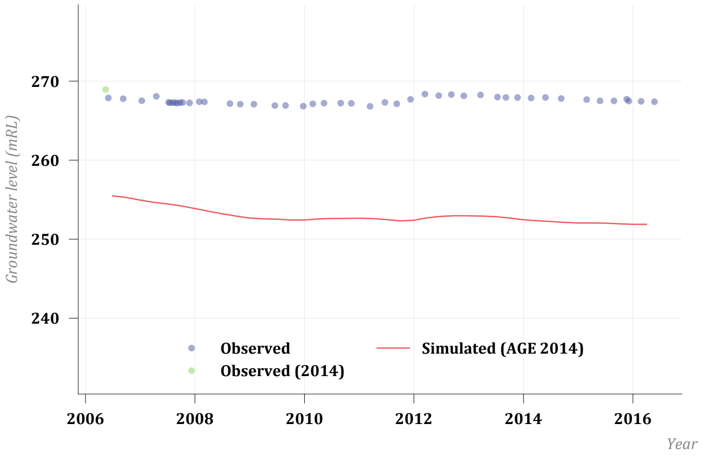
L01 MaulesCk Surroundings - Alluvium [Mod:L01PermianReg]

BCM03



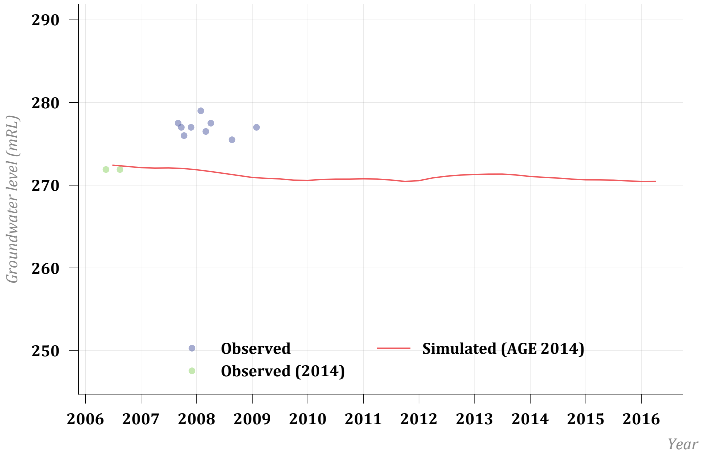
L01 Tarrawonga Surroundings - Permian Regolith

MW8

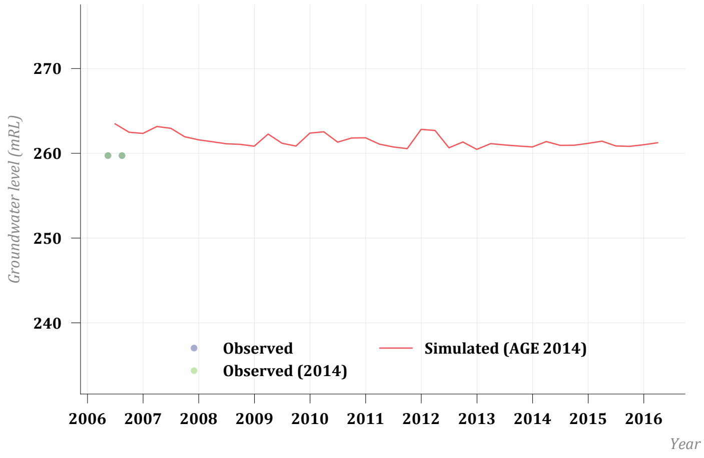


L02 Tarrawonga Surroundings - Alluvium

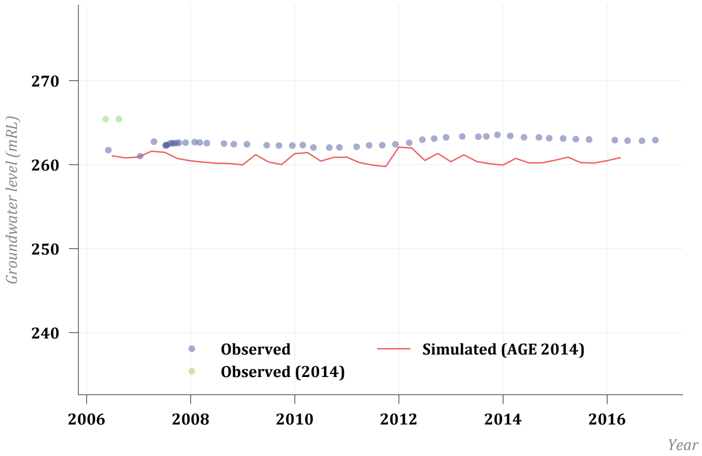
BCS7



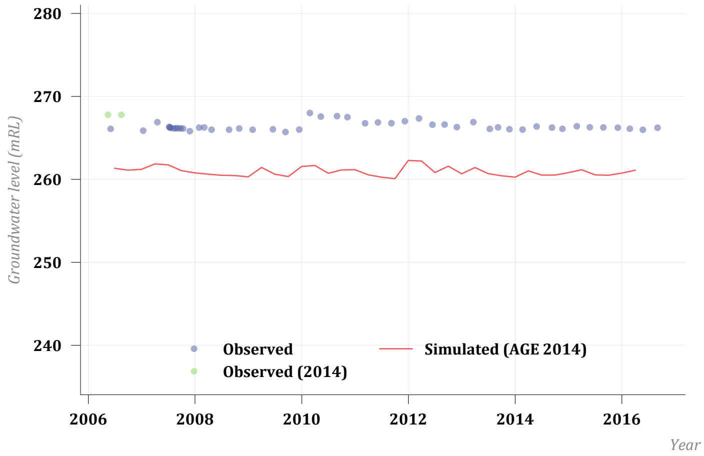
GW002129



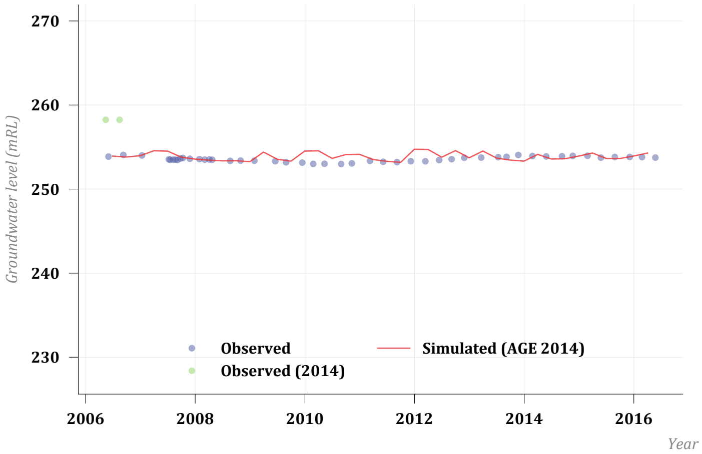
MW1



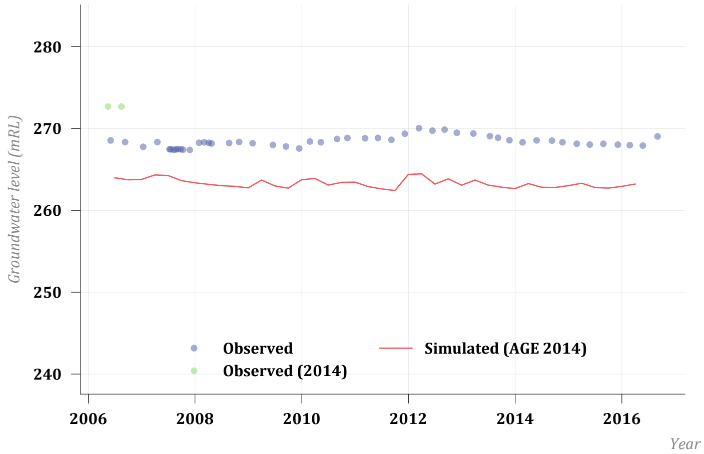
MW2



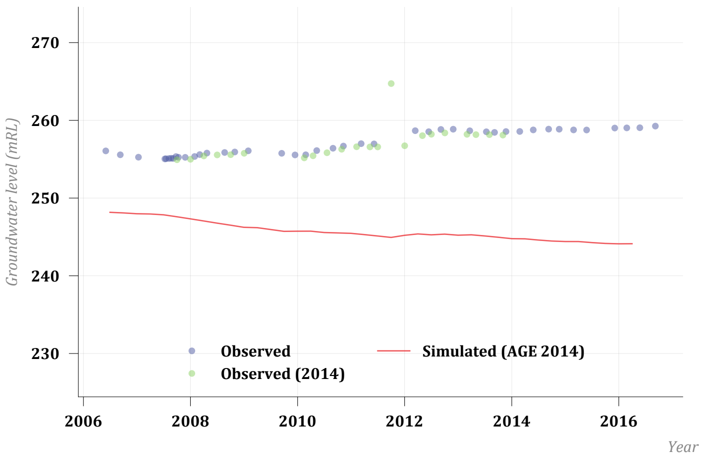
MW4



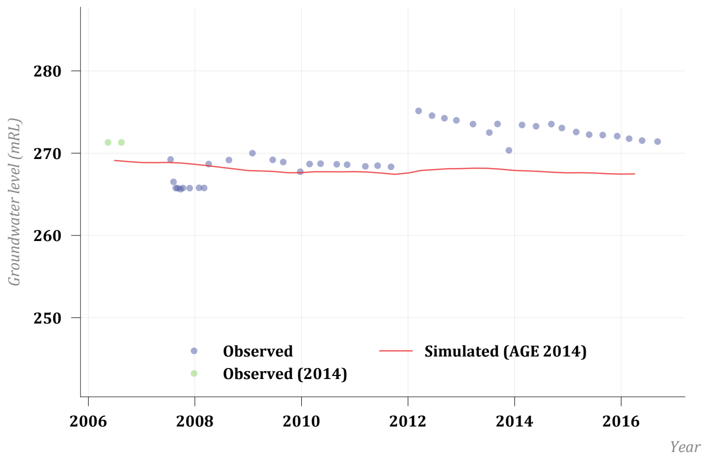
MW5



MW6

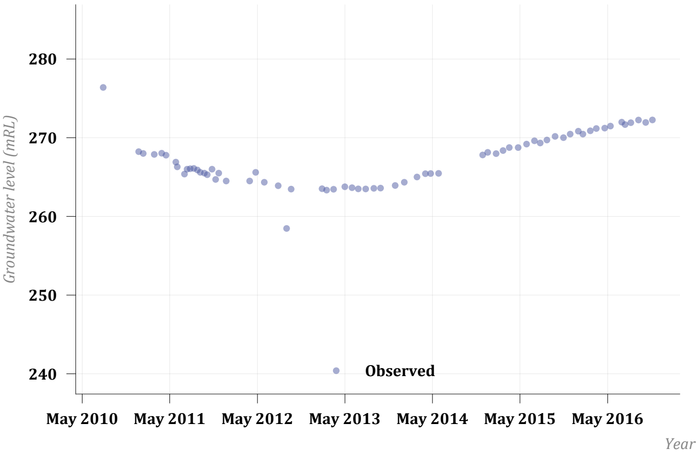


TEMPLE_A

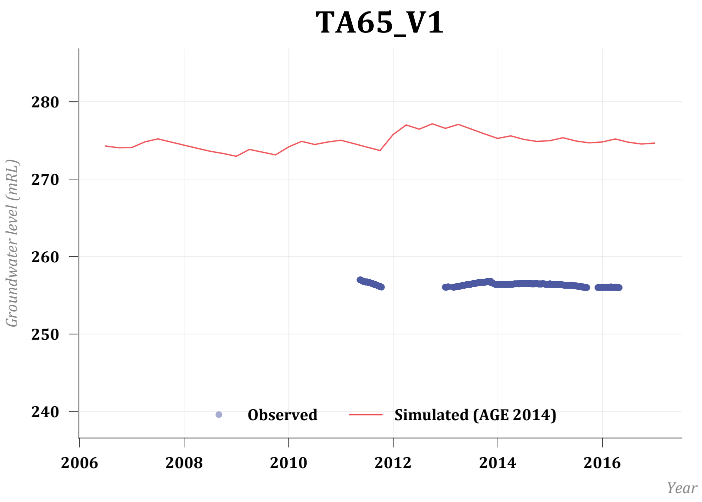


L06 MaulesCk Surroundings - Interburden

MAC1280

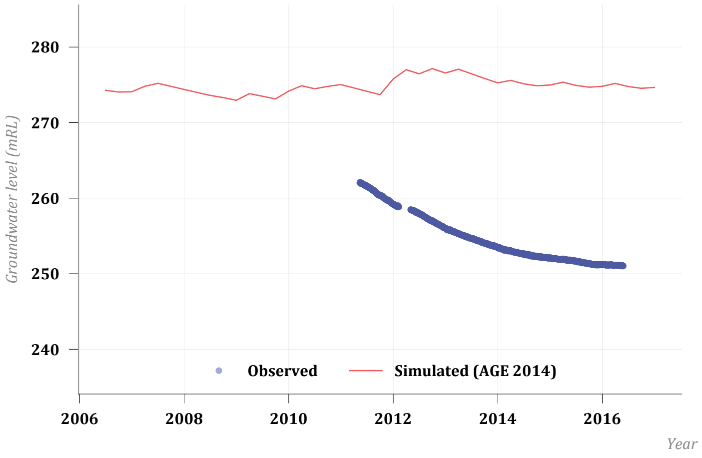


L06 Tarrawonga Pit - Interburden

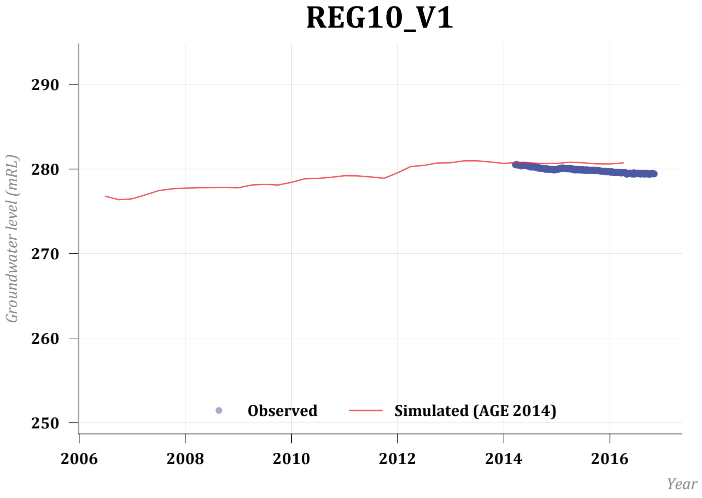


L07 Tarrawonga Pit - Interburden

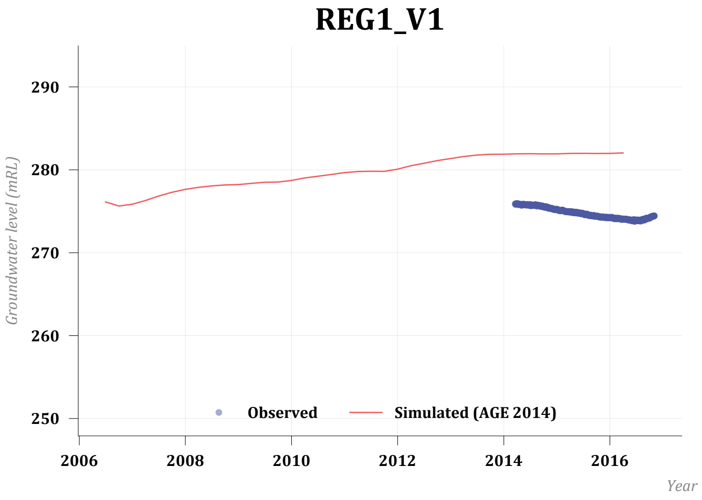
TA65_V3



L08 North - Braymont

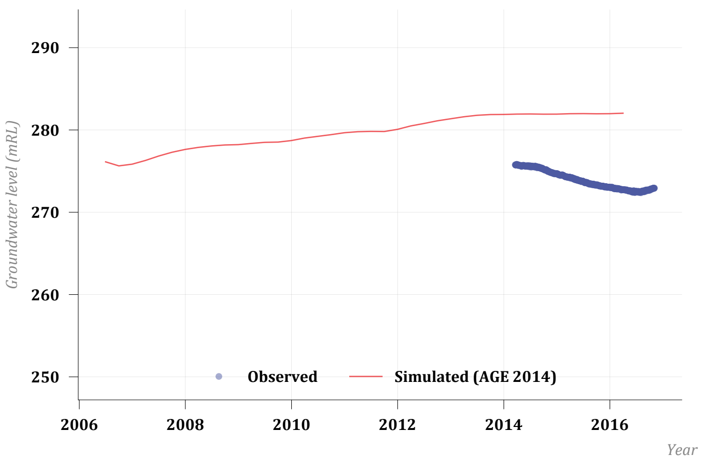


L08 North - Jeralong

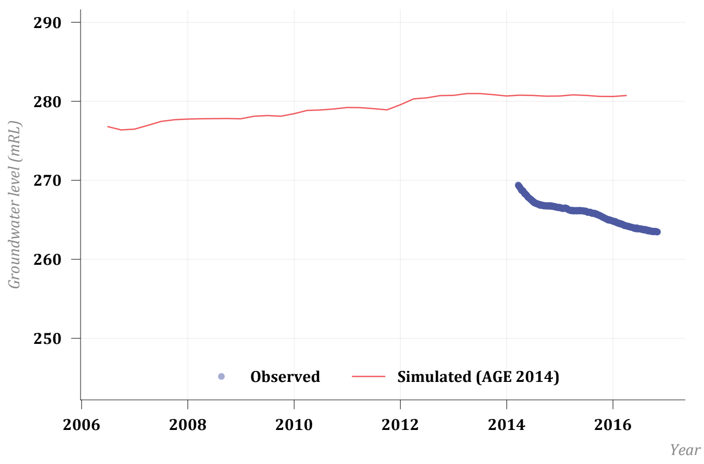


L08 North - Merriown

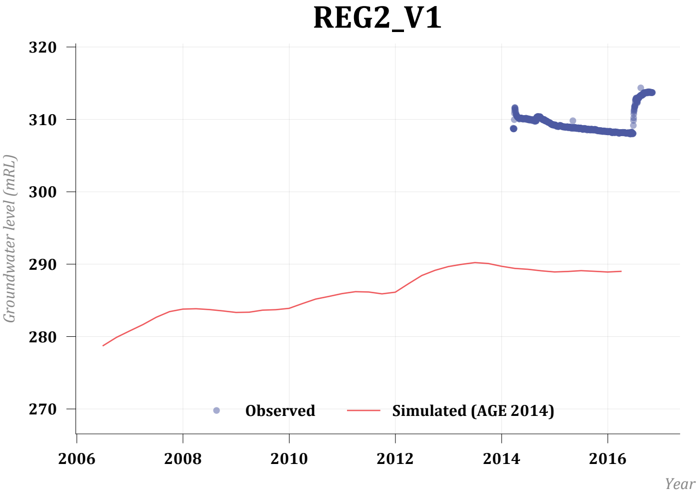
REG1_V2



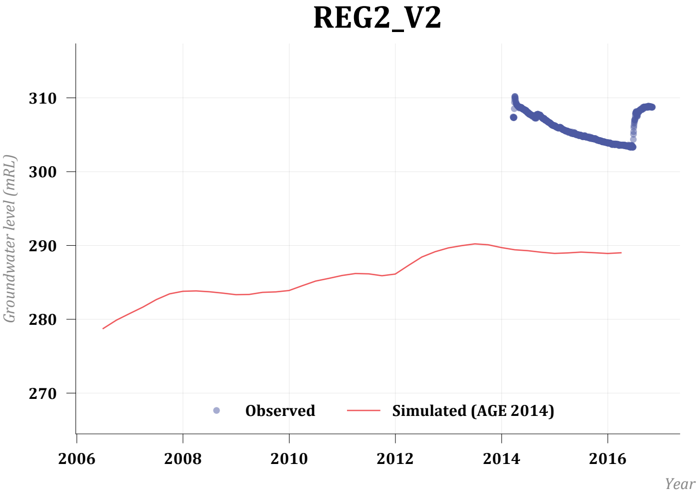
REG10_V2



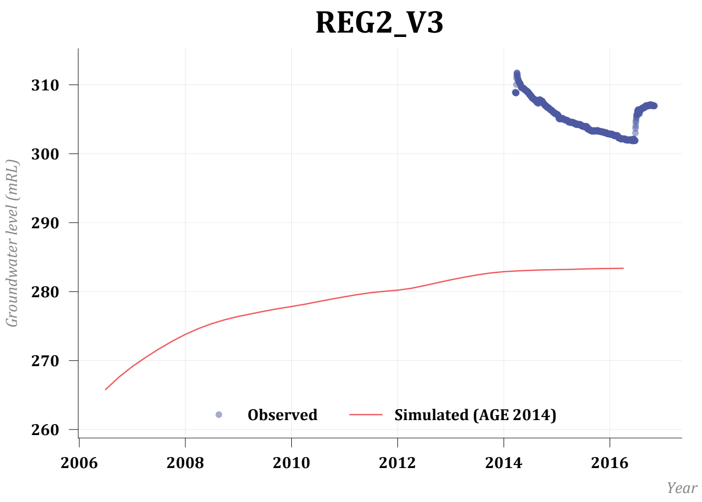
L08 Northeast - Braymont



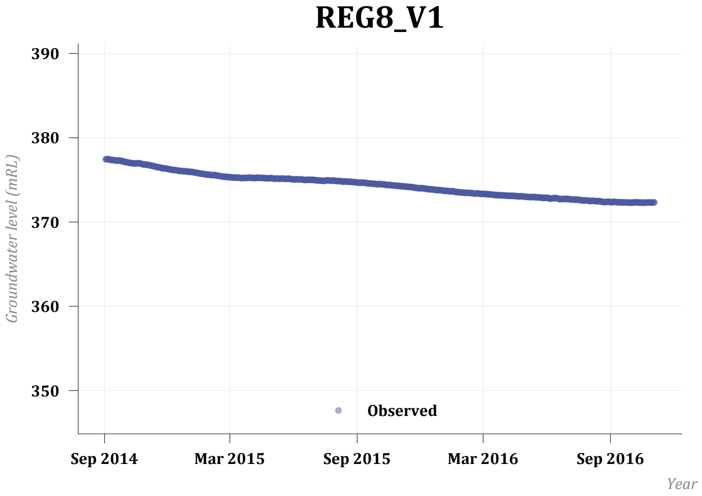
L08 Northeast - Jeralong

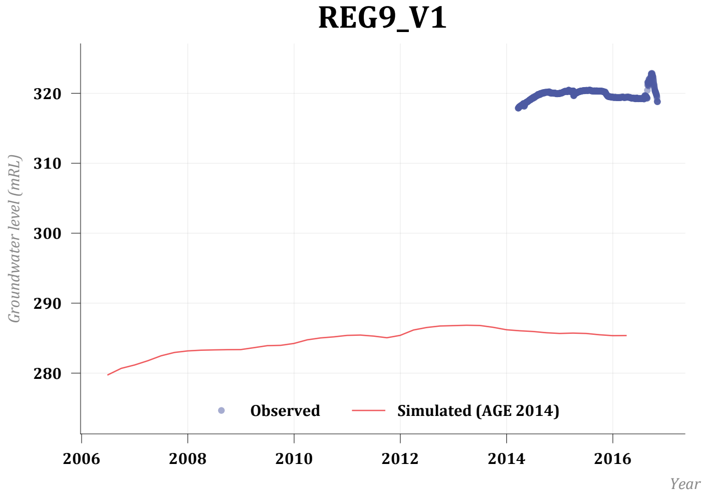


L08 Northeast - Merriown

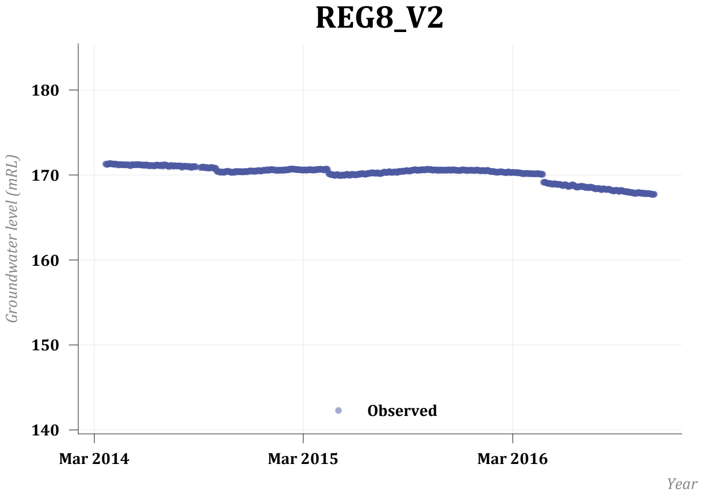


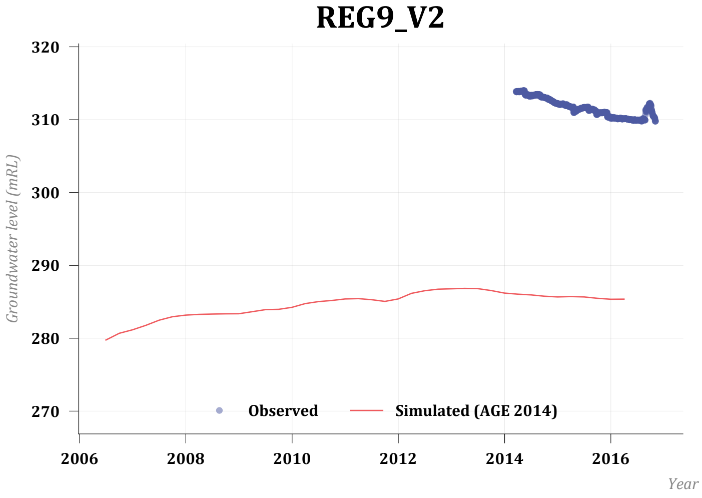
L08 East - Braymont



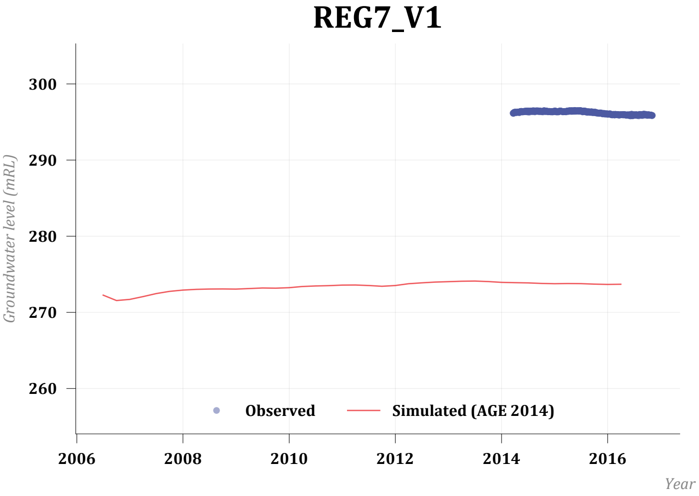


L08 East - Merriown



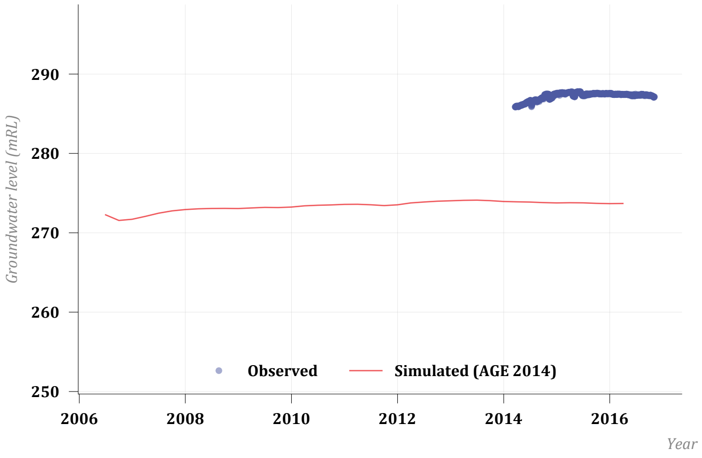


L08 Southeast - Braymont

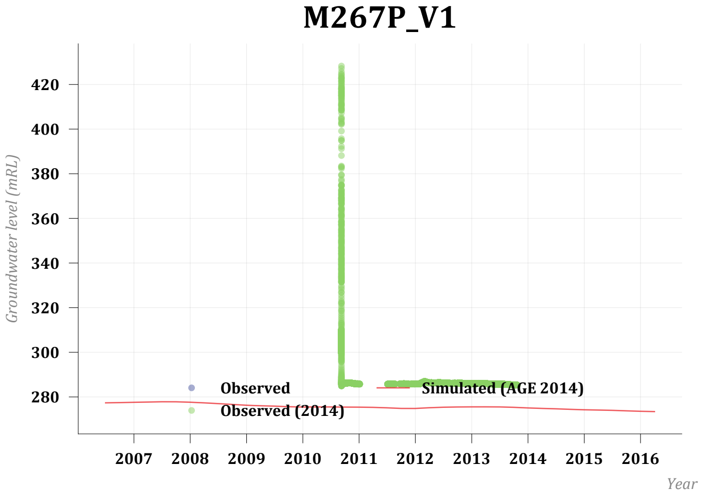


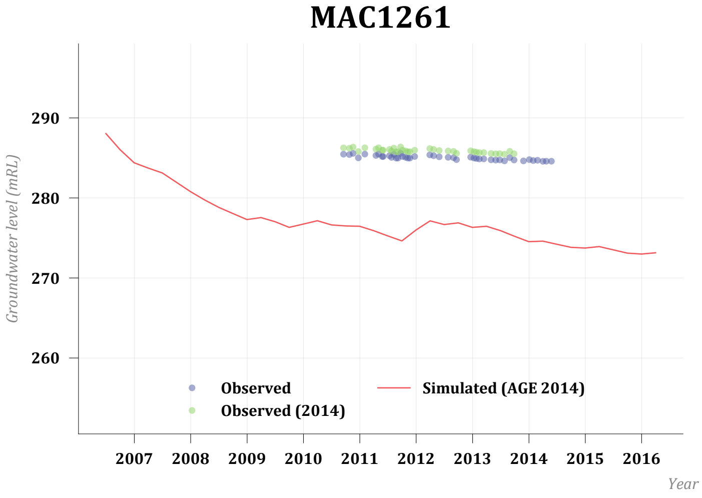
L08 Southeast - Merriown

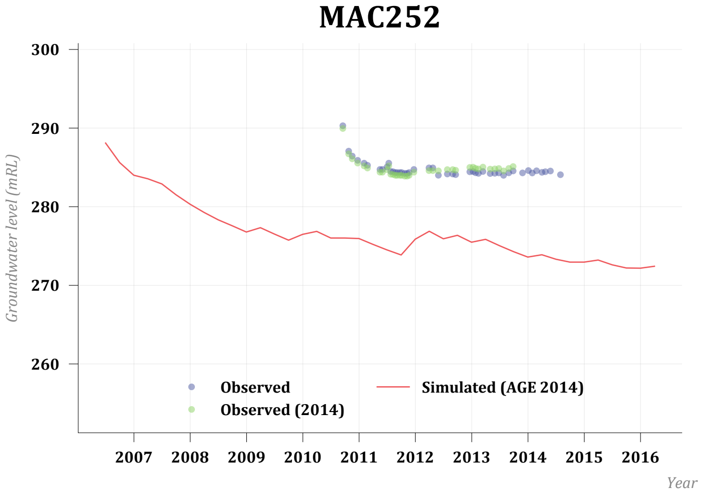
REG7_V2

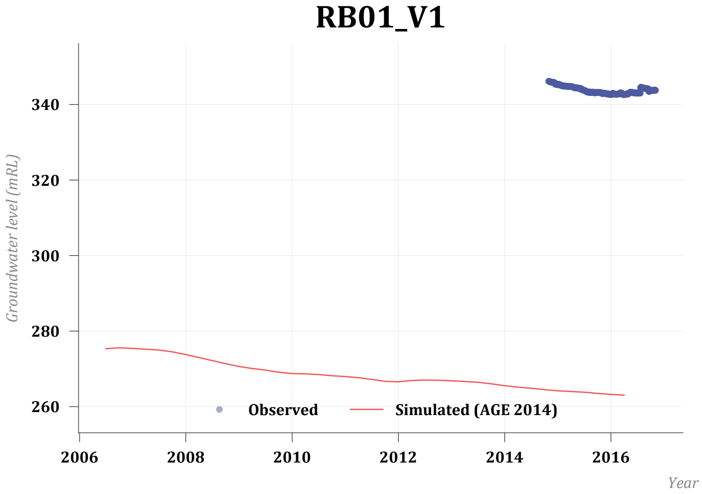


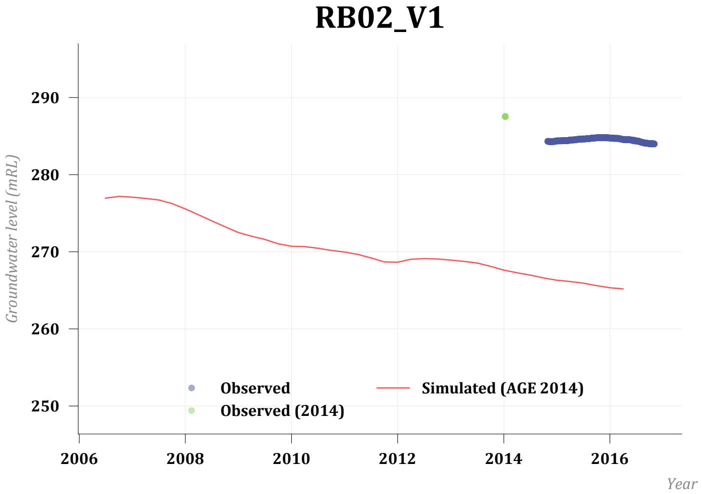
L08 MaulesCk Pit - Braymont





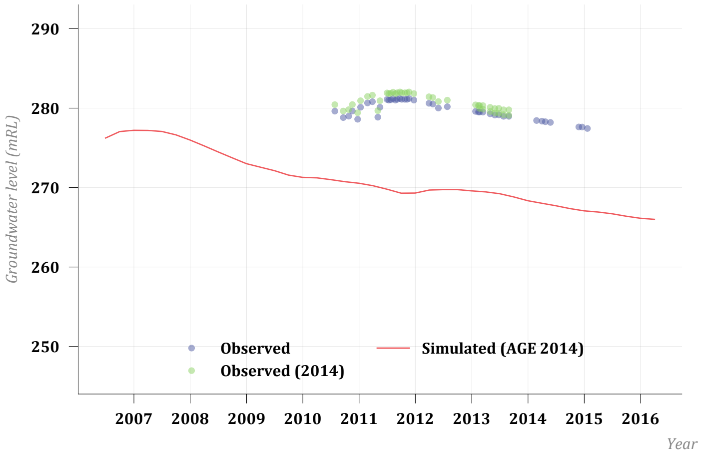




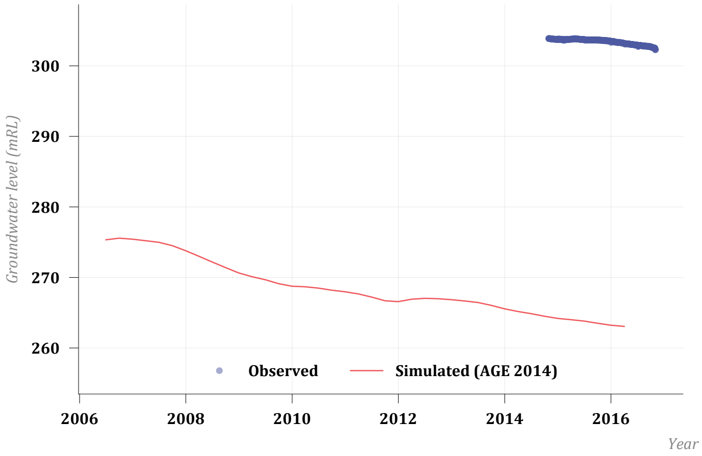


L08 MaulesCk Pit - Merriown

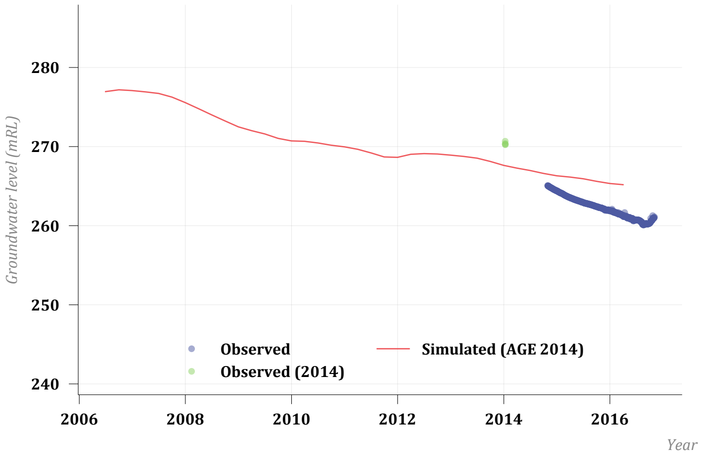
MAC1219



RB01_V2

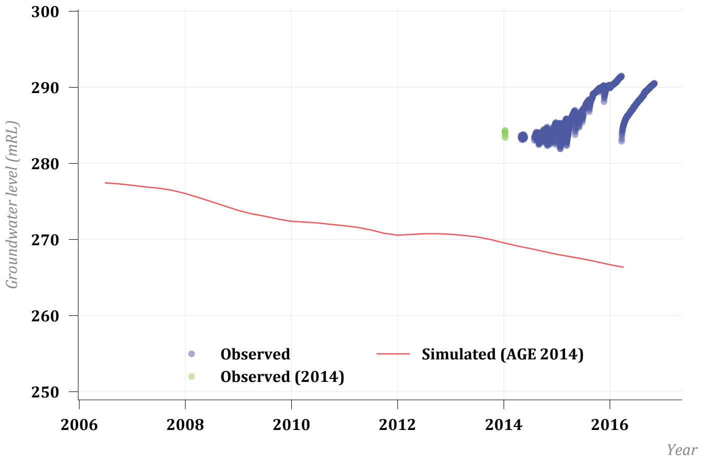


RB02_V2

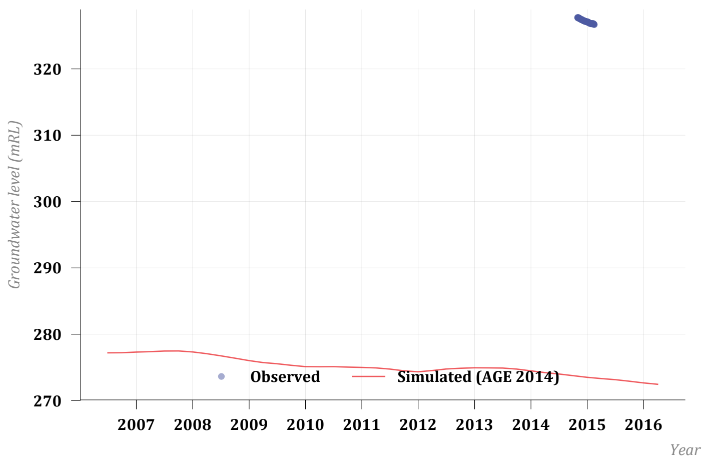


L08 MaulesCk Surroundings - Braymont

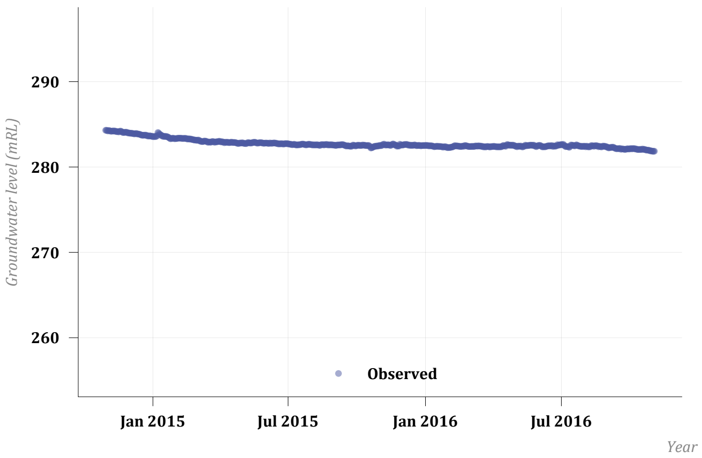
RB03_V1



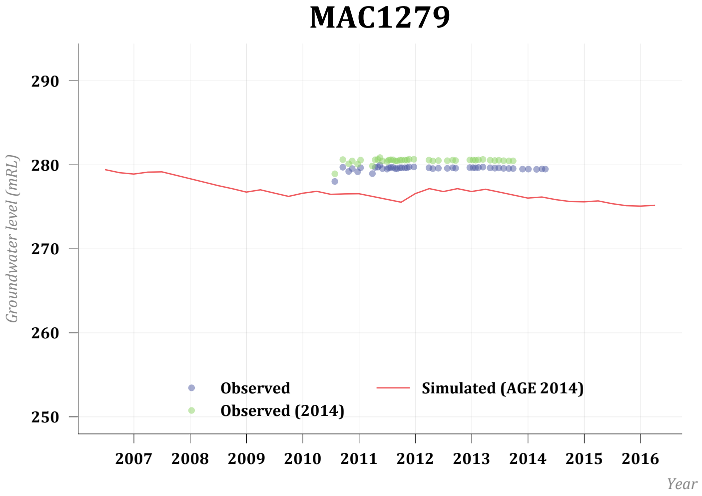
RB04_V1

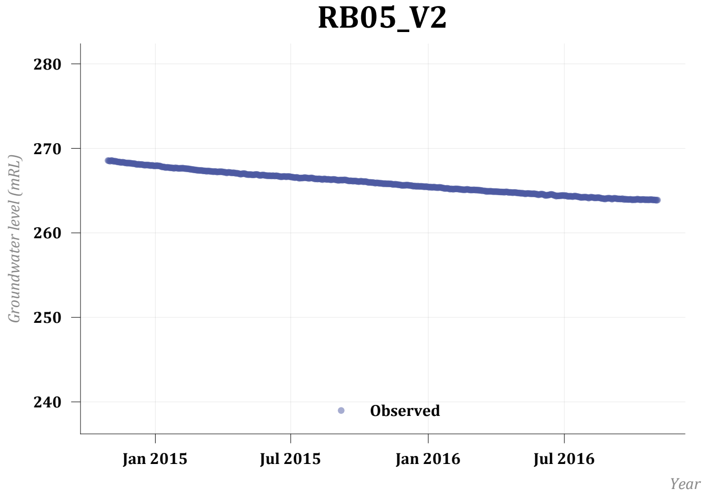


RB05_V1



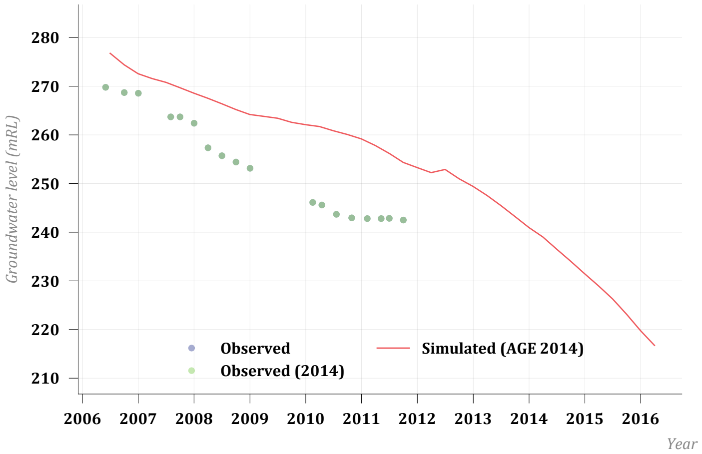
L08 MaulesCk Surroundings - Jeralong





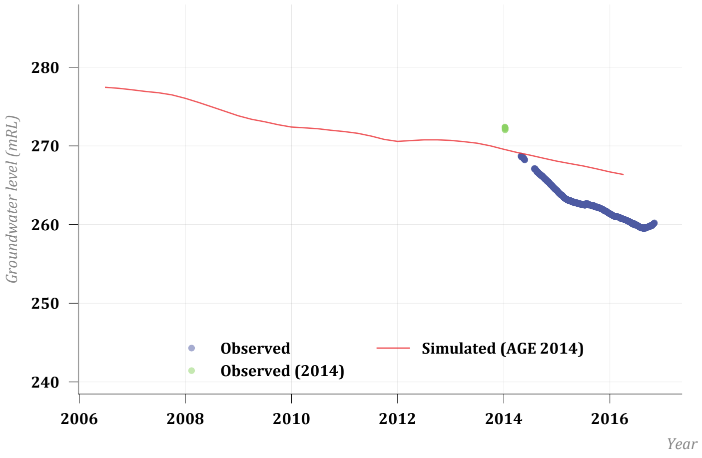
L08 Boggabri Pit - Bollol Creek Seam

IBC2114

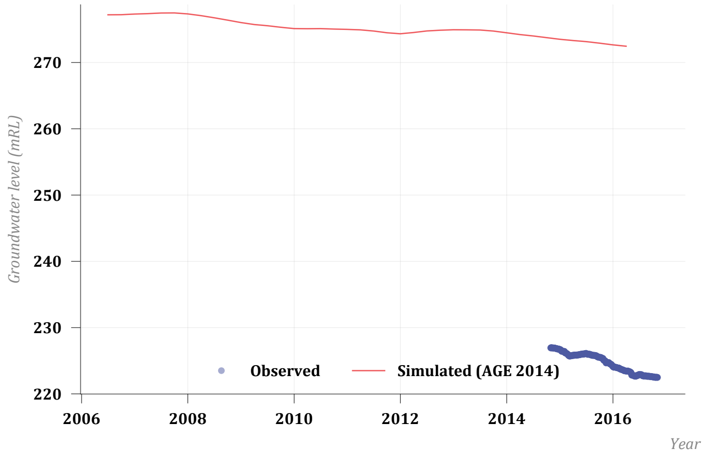


L08 MaulesCk Surroundings - Merriown

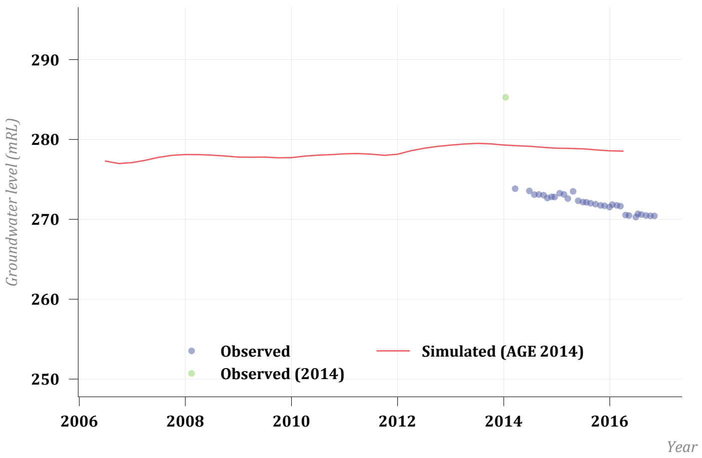
RB03_V2



RB04_V2

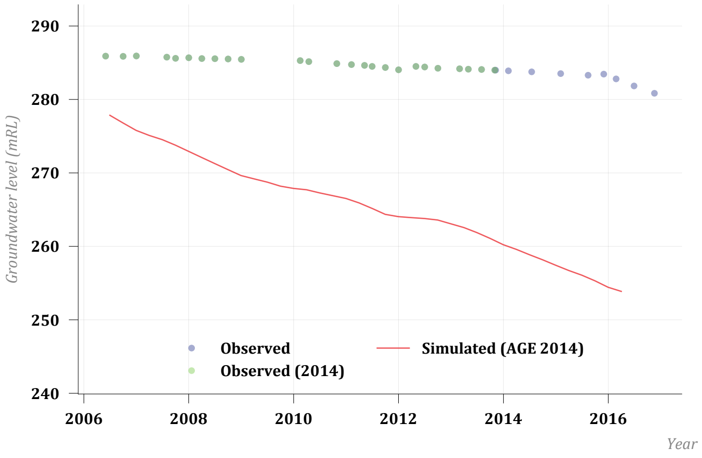


RB05A

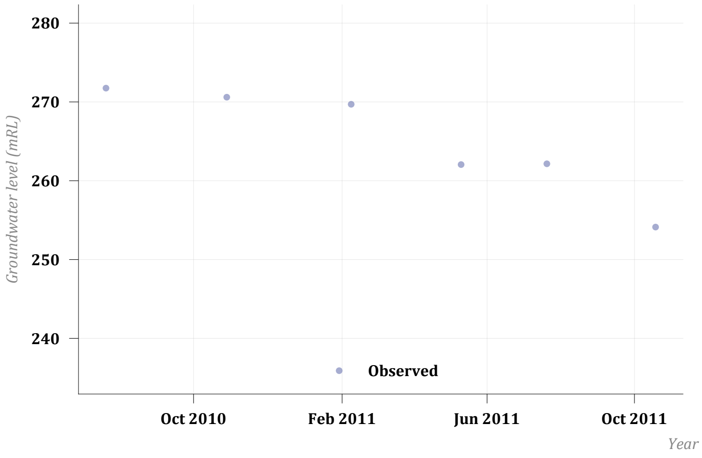


L08 Boggabri Pit - Braymont

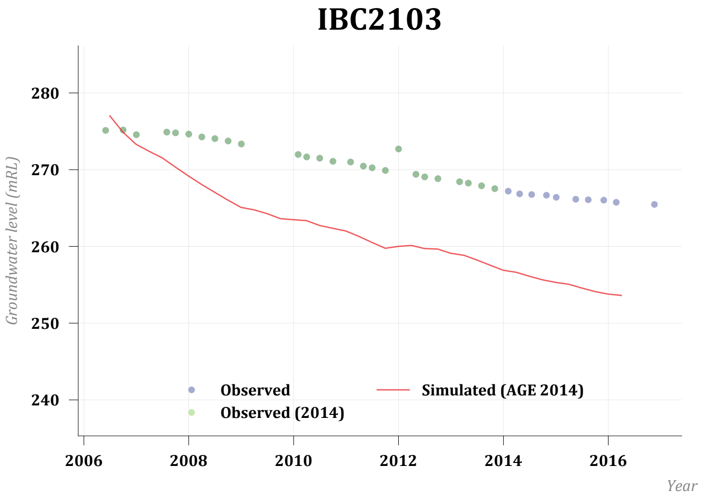
IBC2104



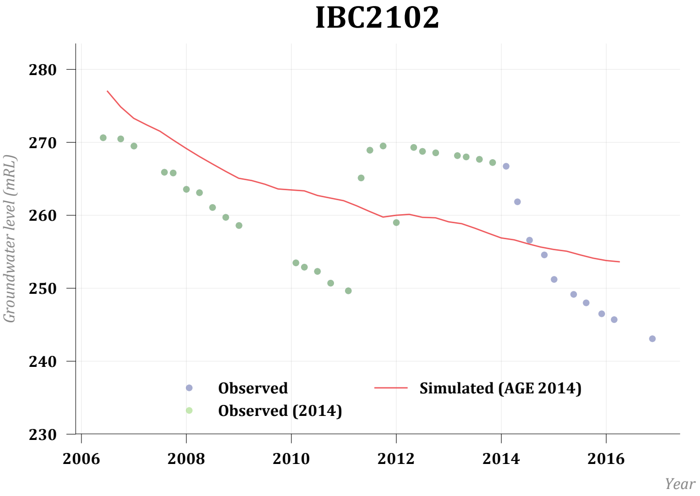
IBC2193

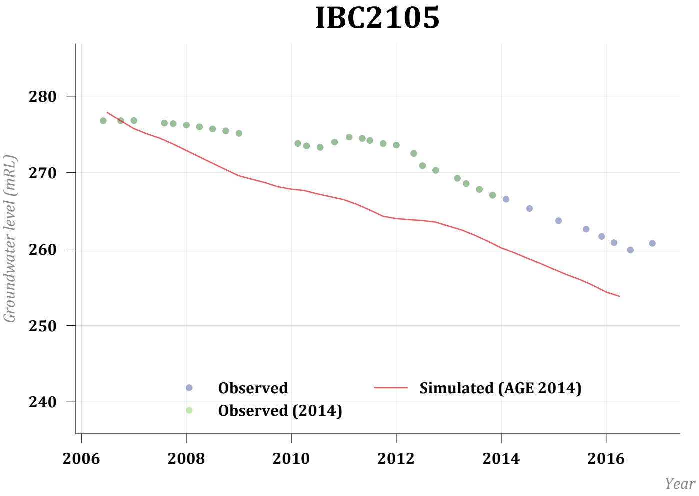


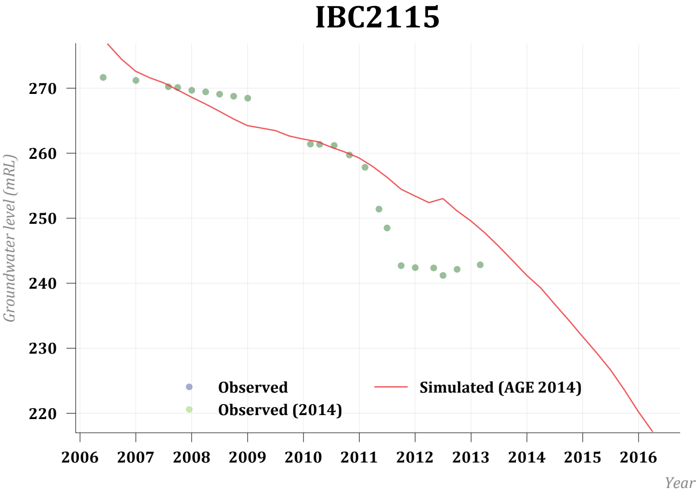
L08 Boggabri Pit - Jeralong

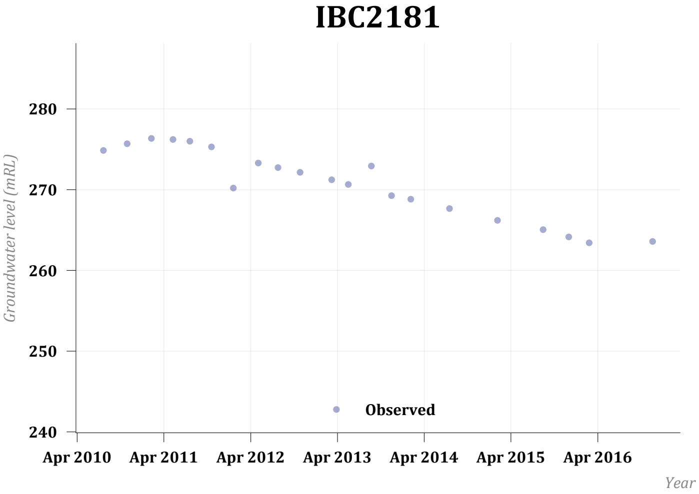


L08 Boggabri Pit - Merriown



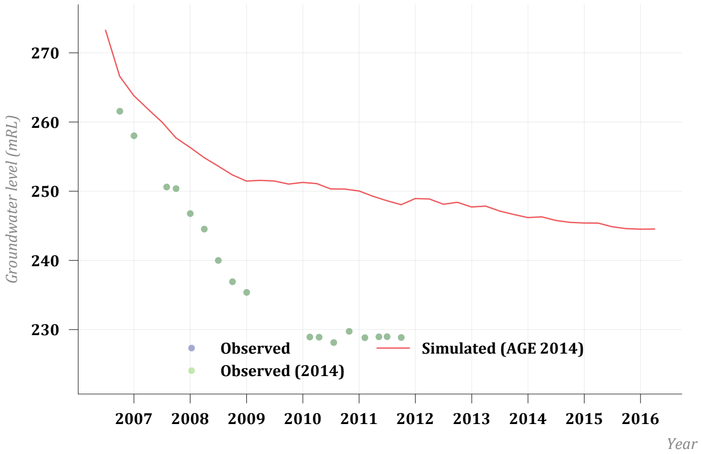




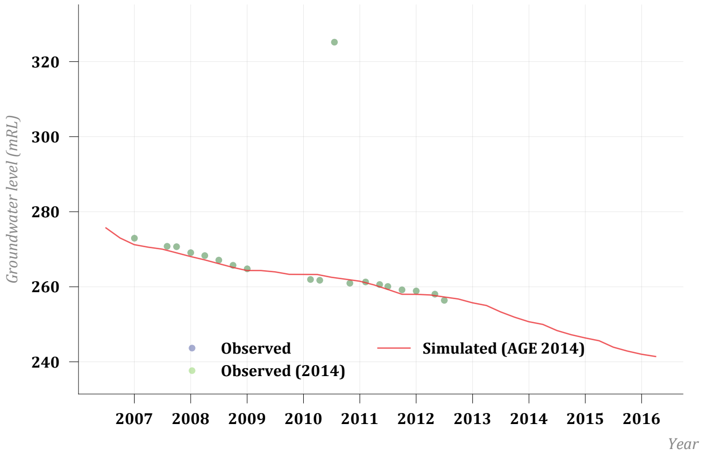


L08 Boggabri Surroundings - Merriown

IBC2138

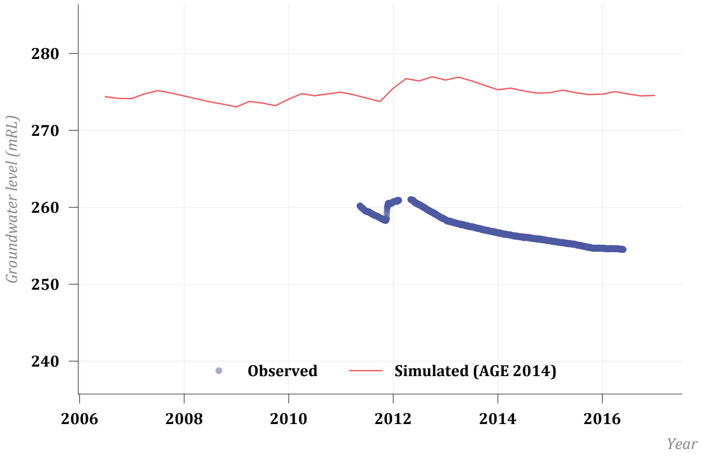


IBC2139

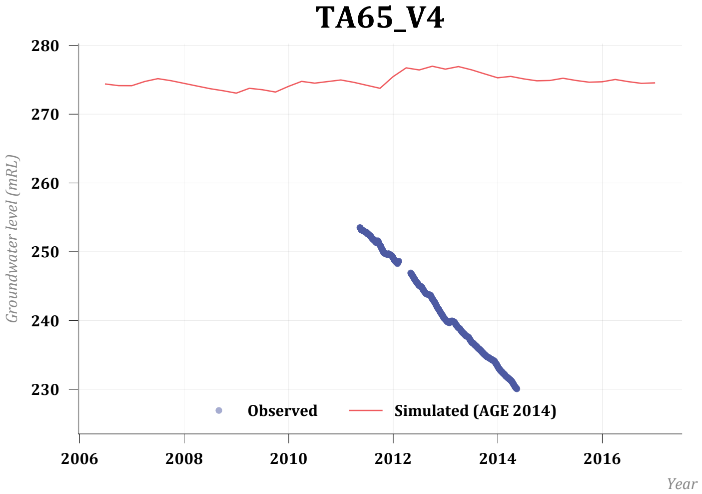


L08 Tarrawonga Pit - Jeralong

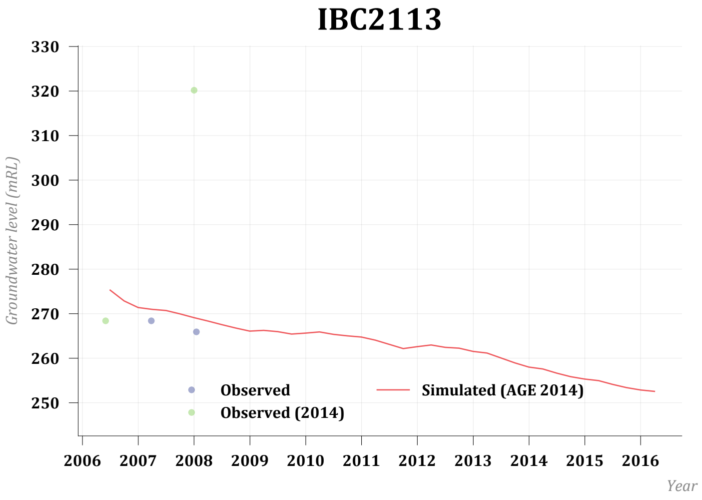
TA65_V2



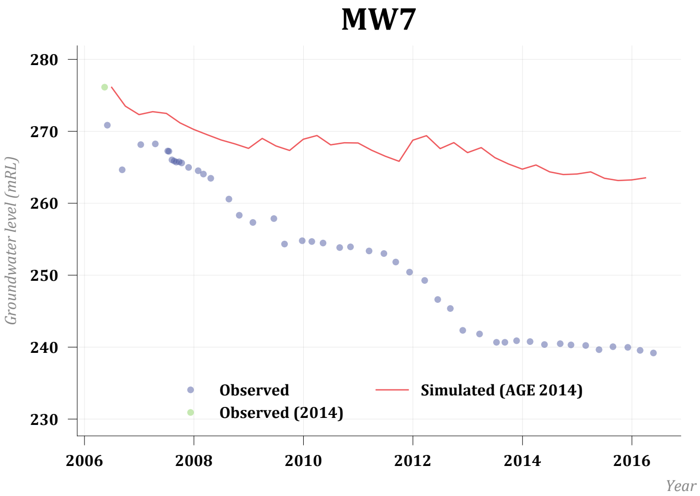
L08 Tarrawonga Pit - Merriown

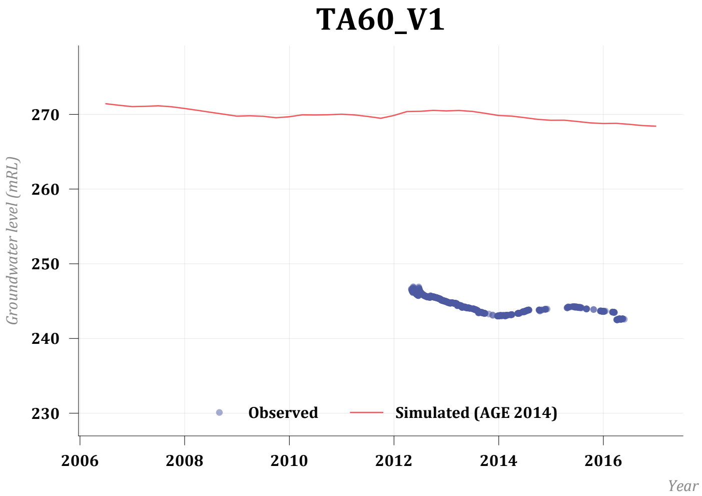


L08 Tarrawonga Surroundings - Merriown

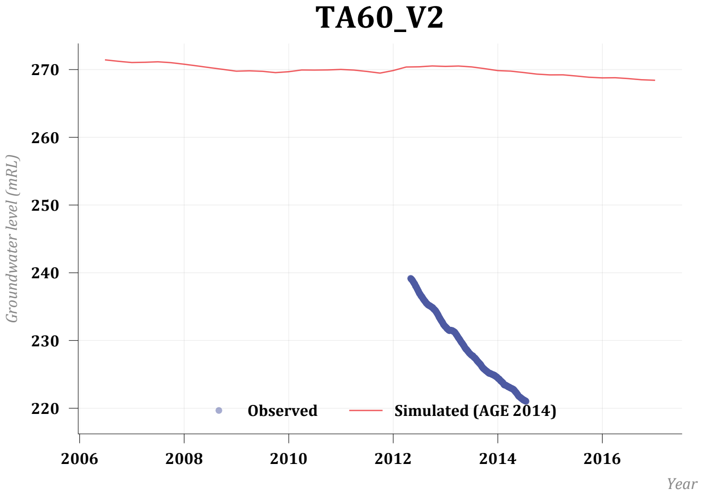


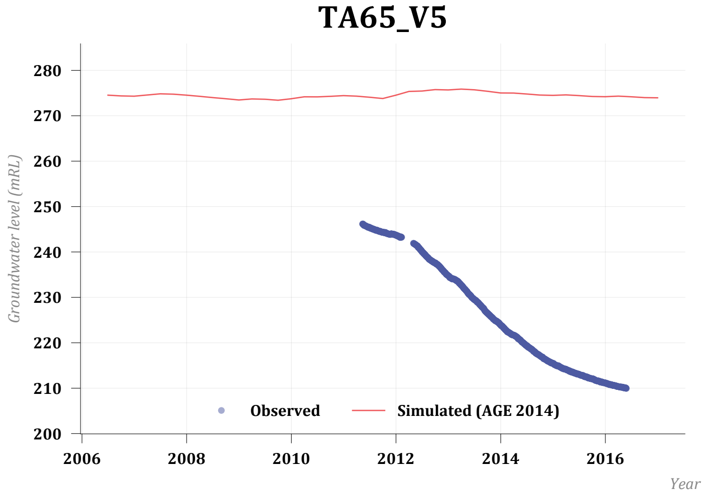
L09 Tarrawonga Pit - Interburden





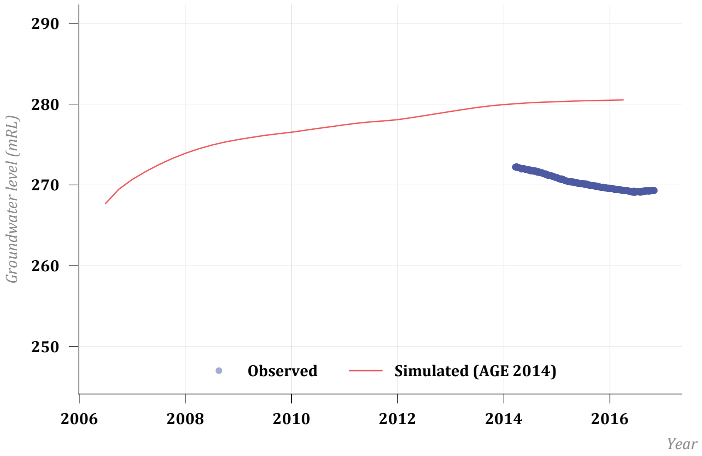
L10 Tarrawonga Pit - Interburden



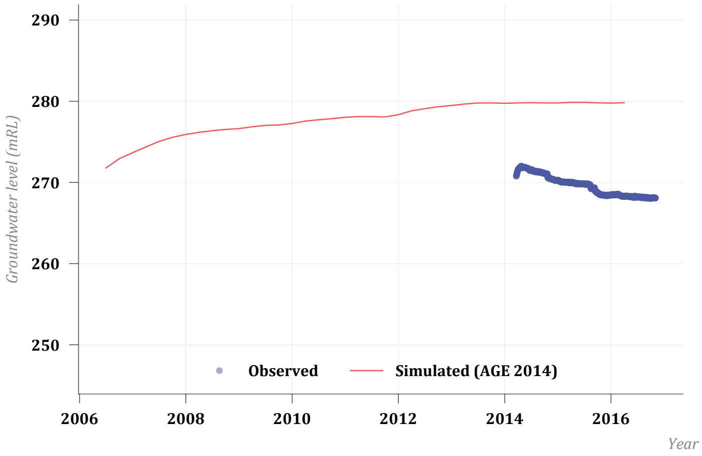


L11 North - Nagero

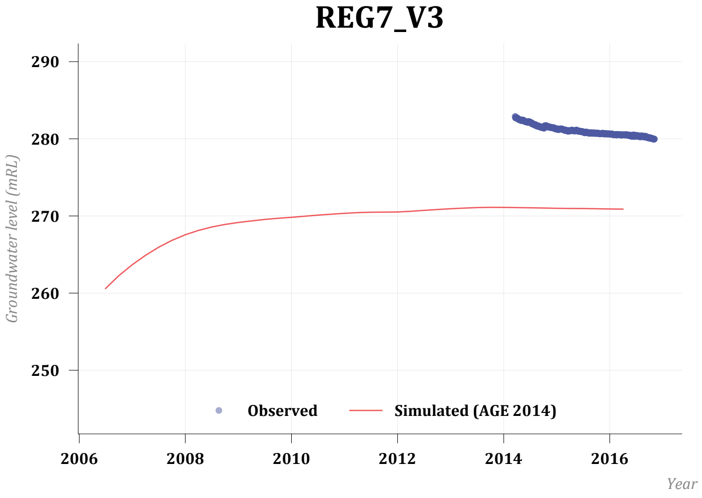
REG1_V3

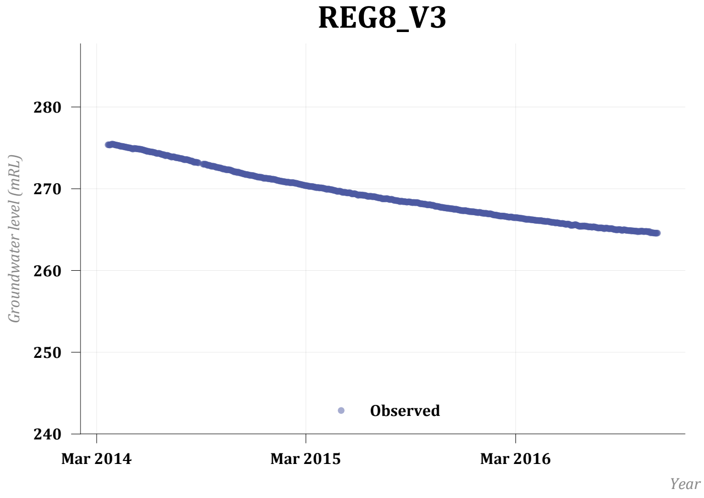


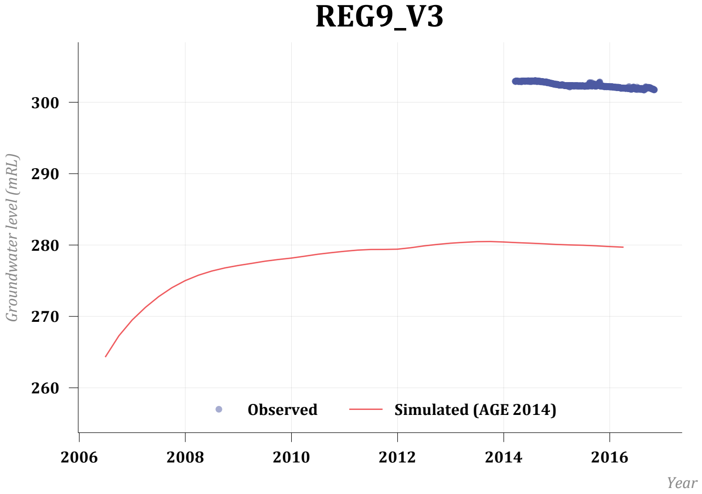
REG10_V3



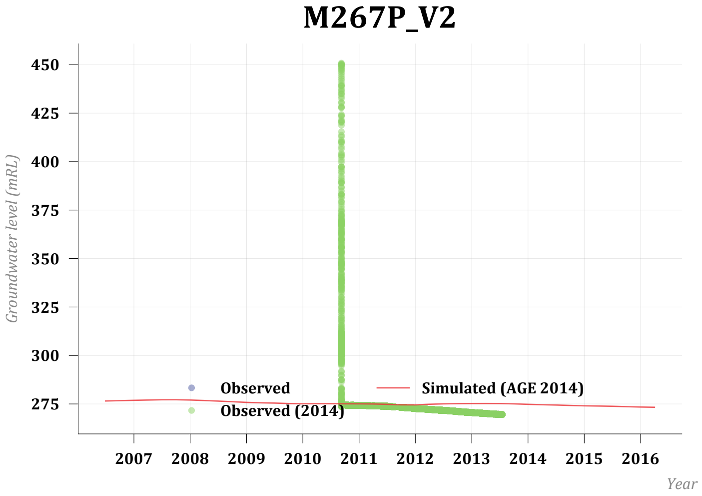
L11 East - Nagero

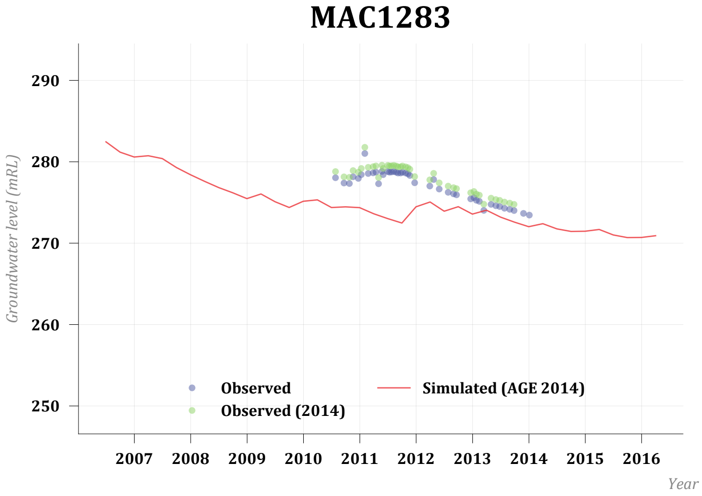


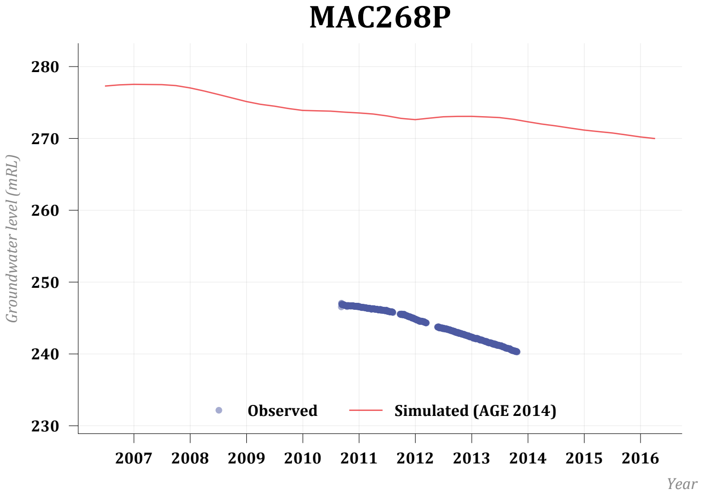




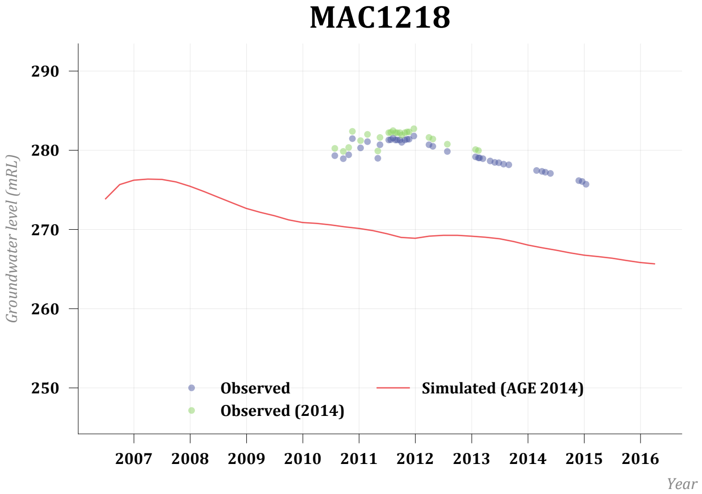
L11 MaulesCk Pit - Velyama

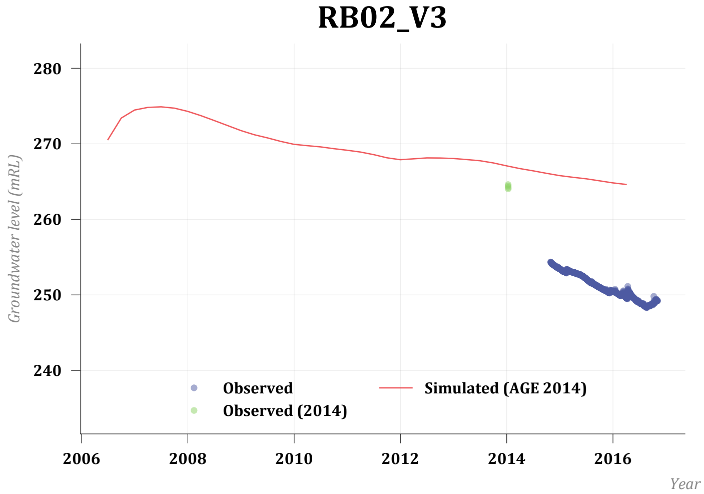


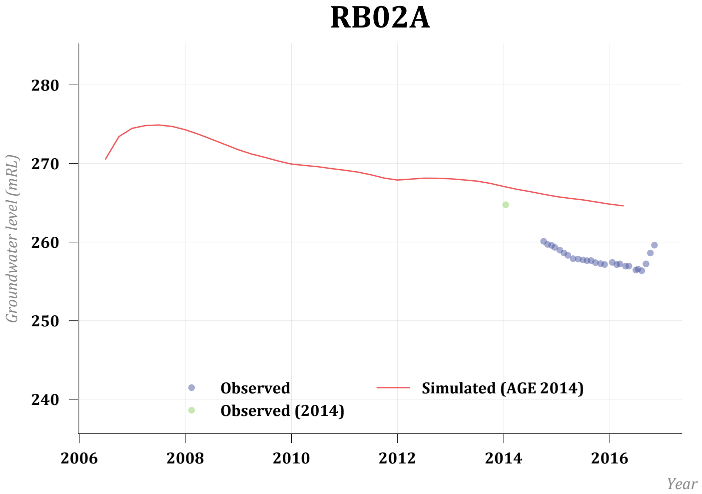




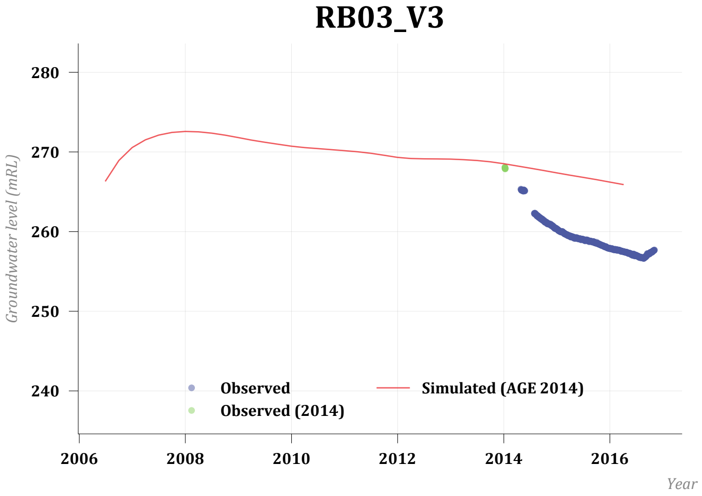
L11 MaulesCk Pit - Nagero

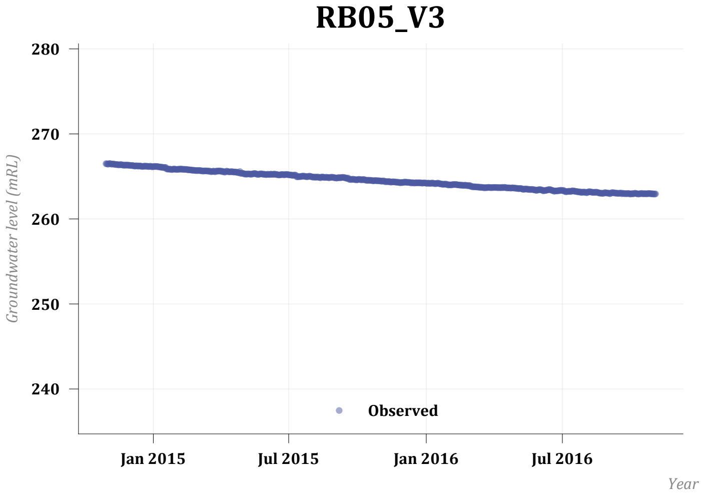






L11 MaulesCk Surroundings - Nagero

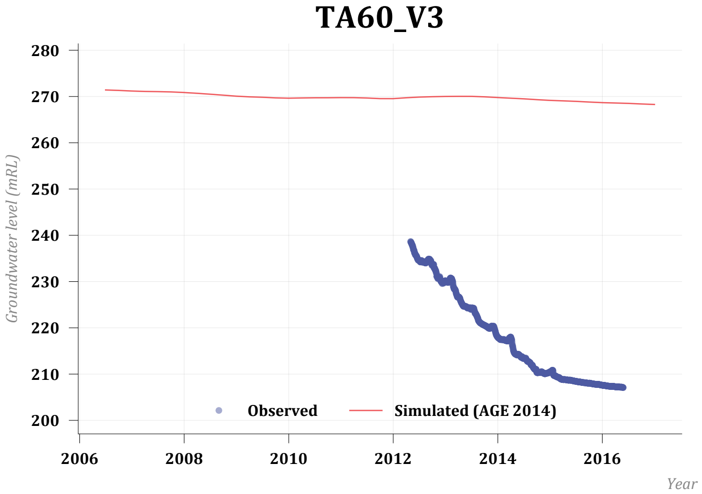




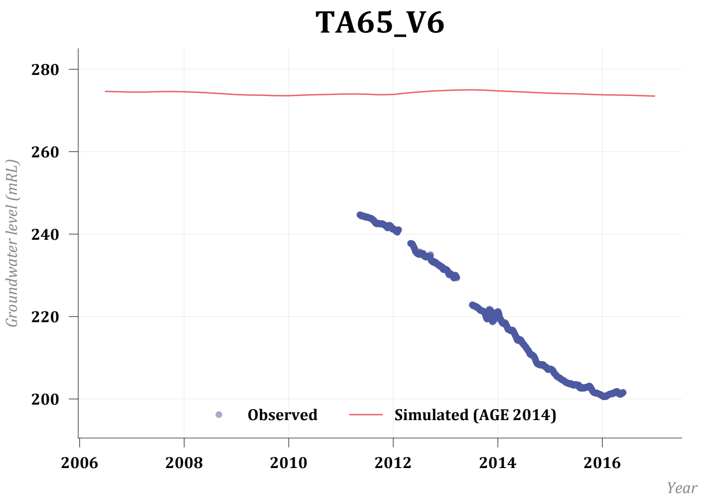
L11 MaulesCk Surroundings - Nagero [Mod:L08]

RB04_V3

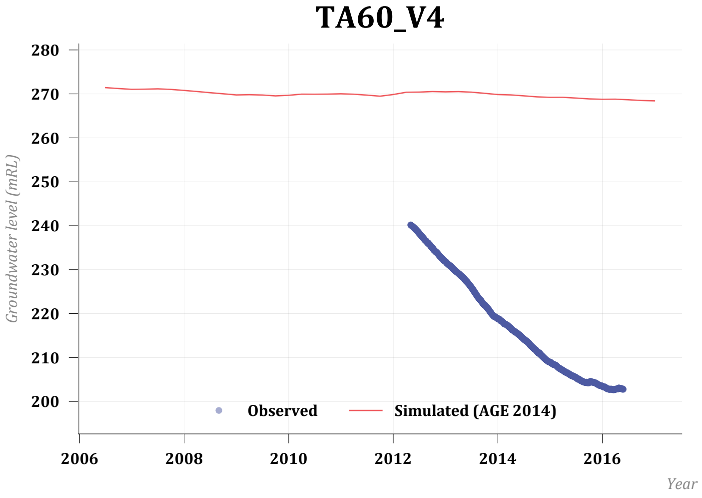
L11 Tarrawonga Pit - Velyama

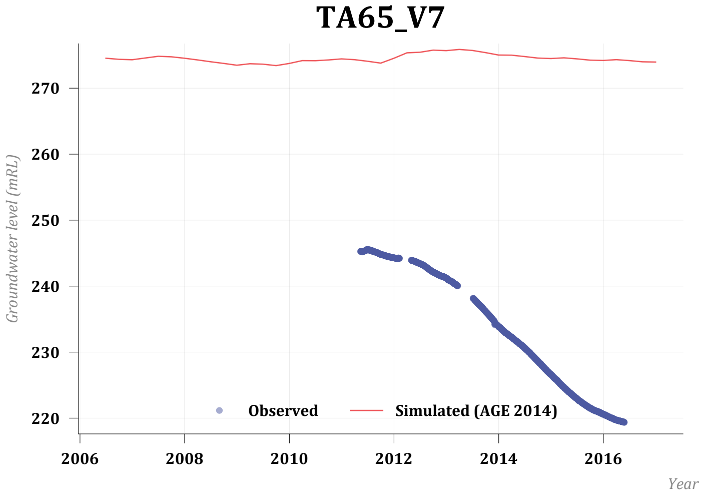


L11 Tarrawonga Pit - Nagero

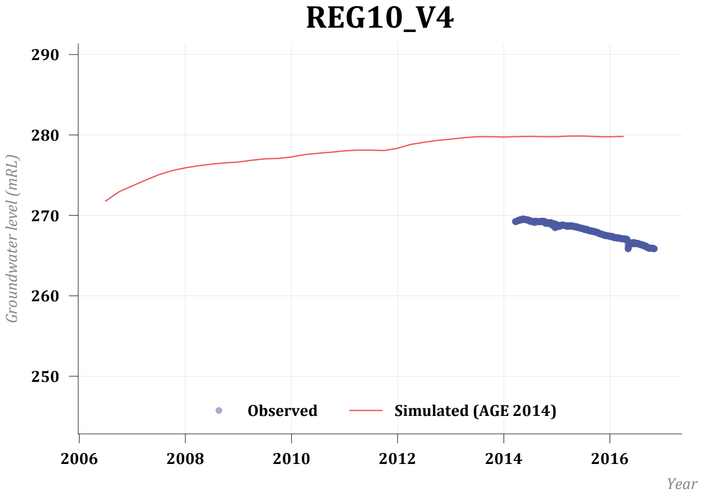


L12 Tarrawonga Pit - Interburden

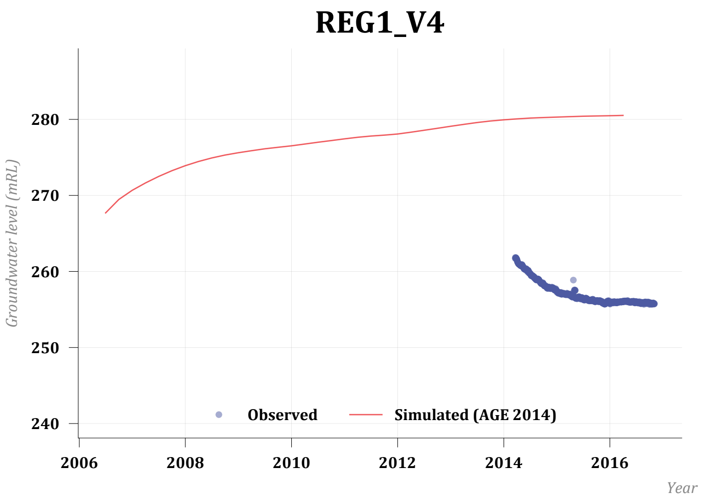




L14 North - Northam

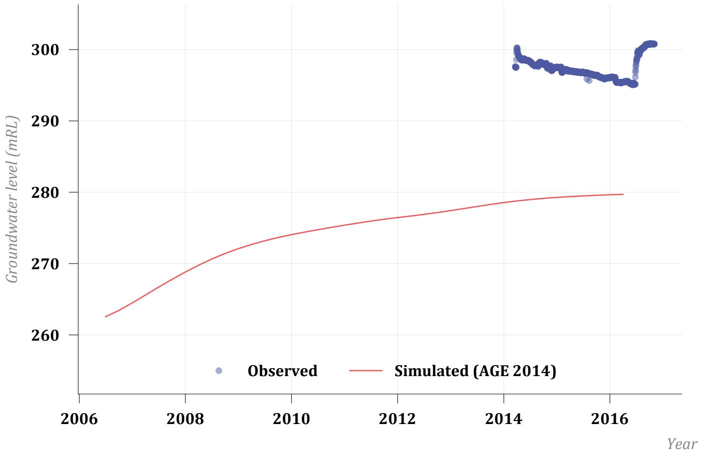


L14 North - Therribri

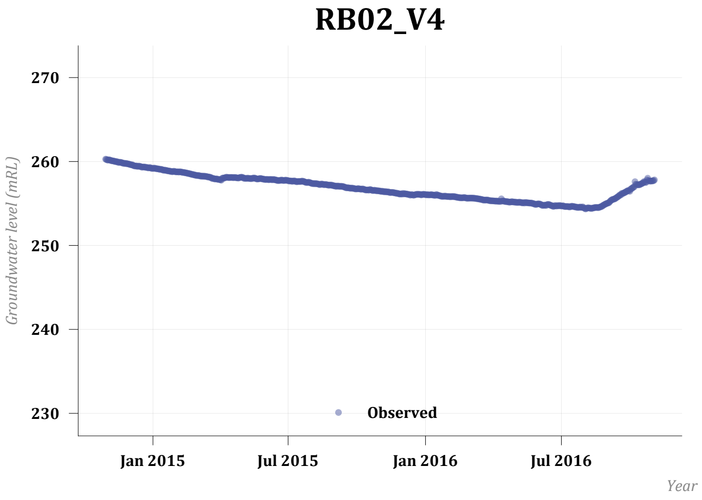


L14 Northeast - Therribri

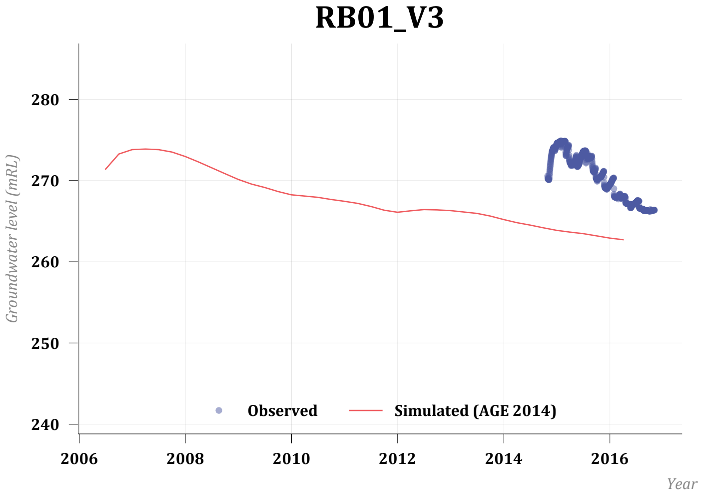
REG2_V4



L14 MaulesCk Pit - Northam

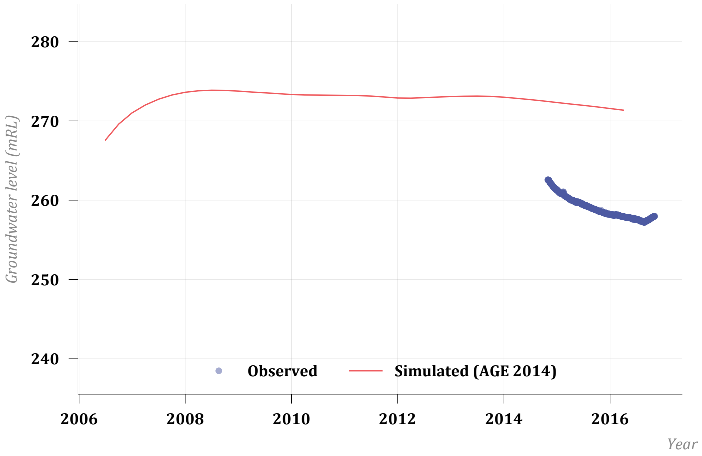


L14 MaulesCk Pit - Flixston

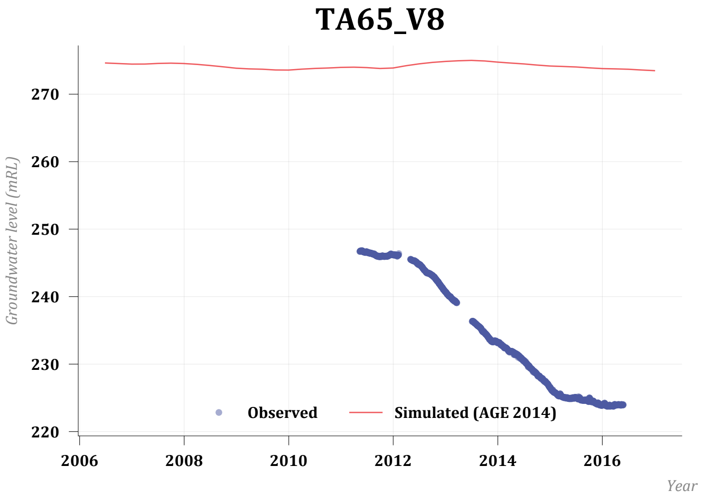


L14 MaulesCk Surroundings - Northam [Mod:L08]

RB04_V4

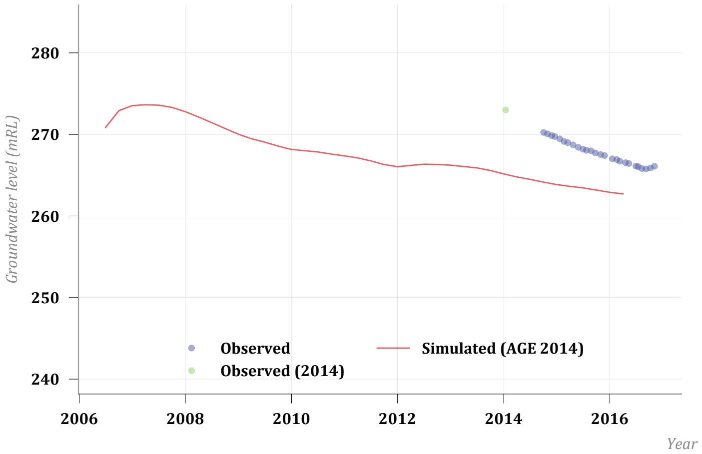


L14 Tarrawonga Pit - Northam

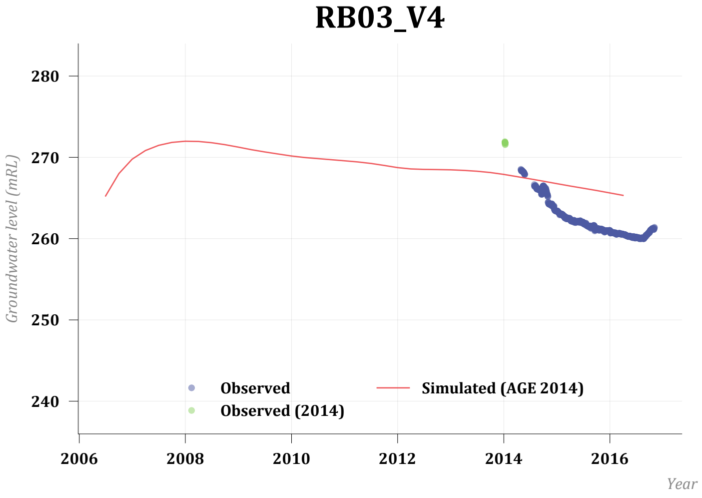


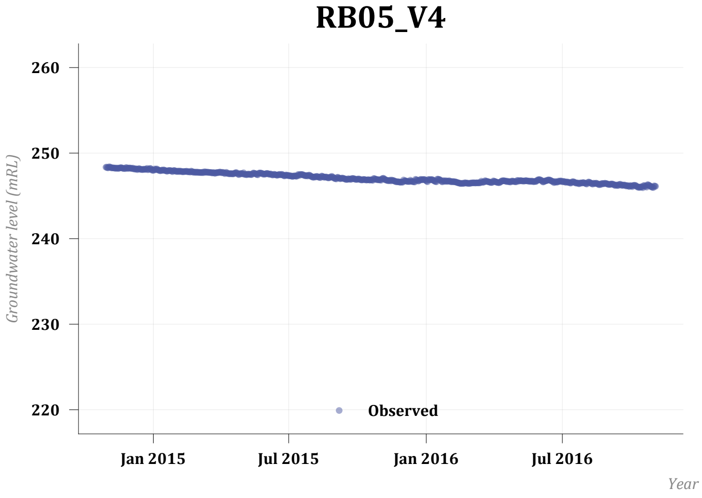
L17 MaulesCk Pit - Templemore

RB01A



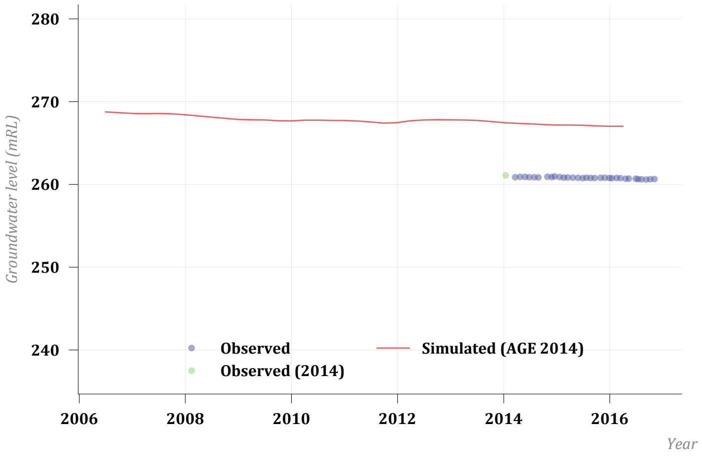
L17 MaulesCk Surroundings - Templemore



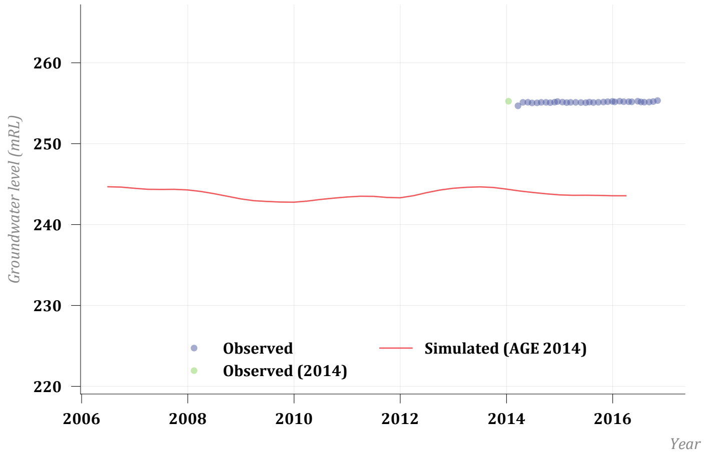


L19 West - Basalt

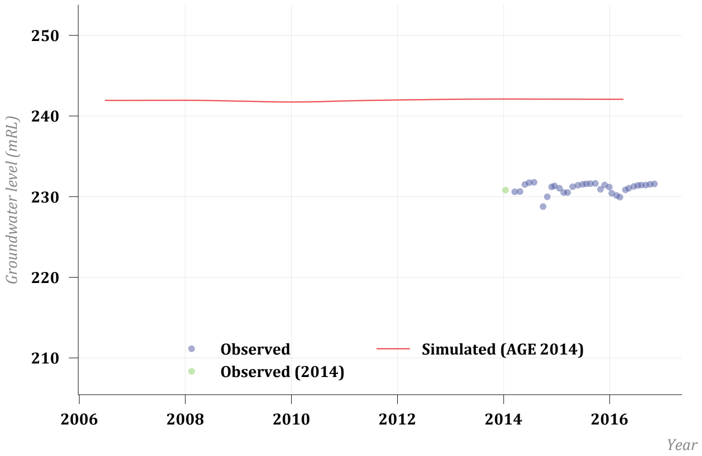
REG12



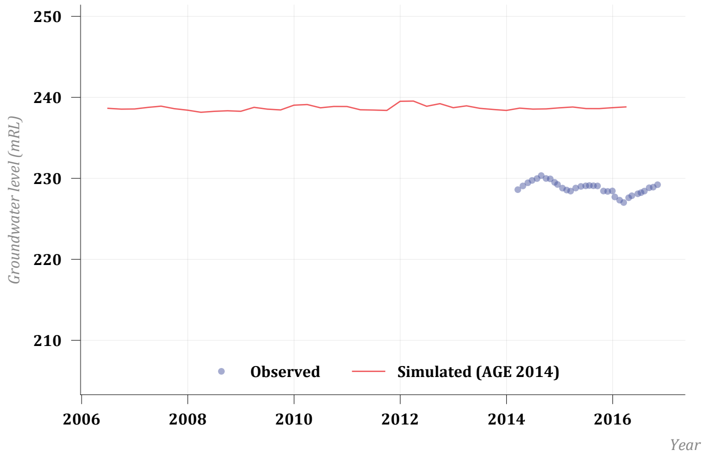
REG13



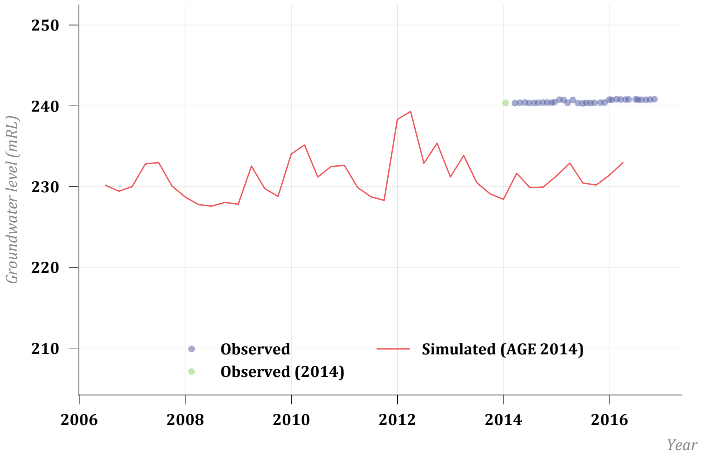
REG14



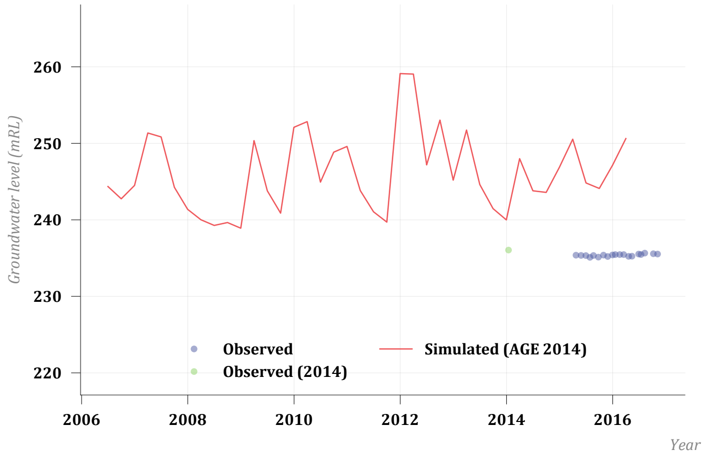
REG3



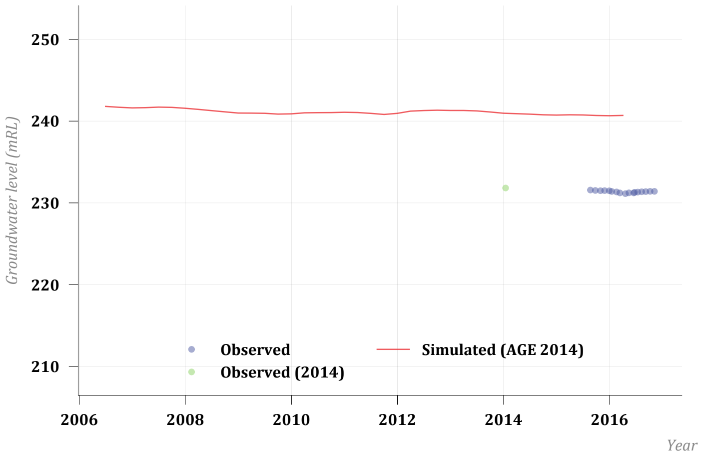
REG4



REG5

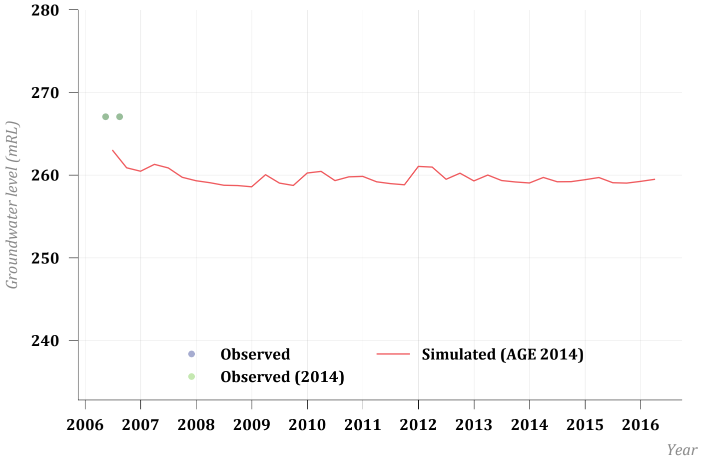


REG6

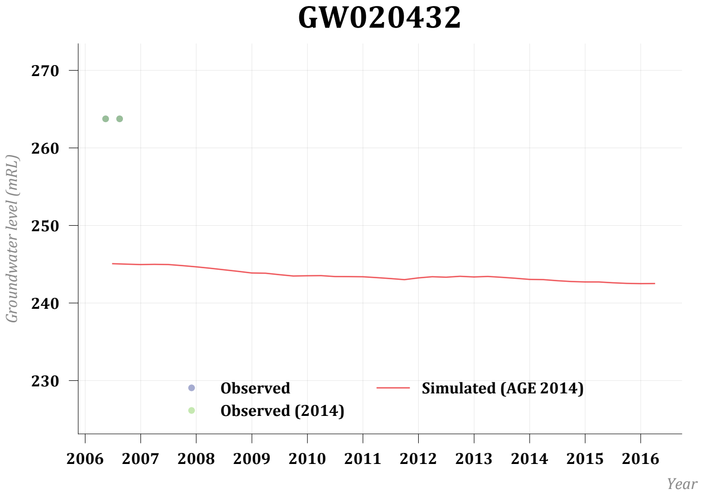


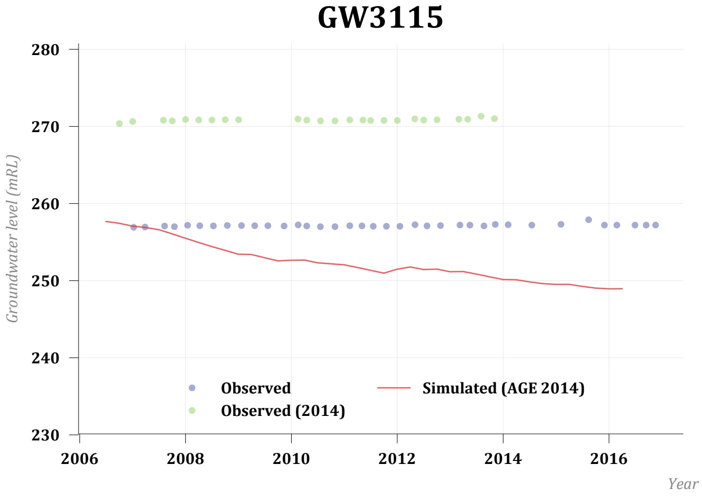
Tarrawonga Surroundings - Interburden [Mod:L19Basalt]

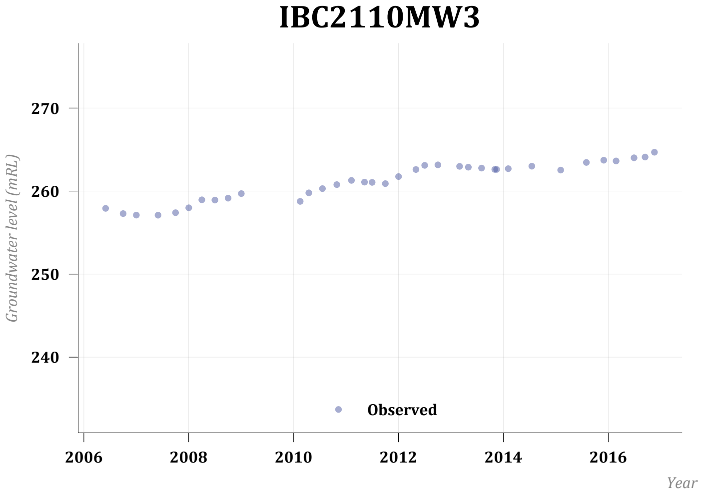
GW002501

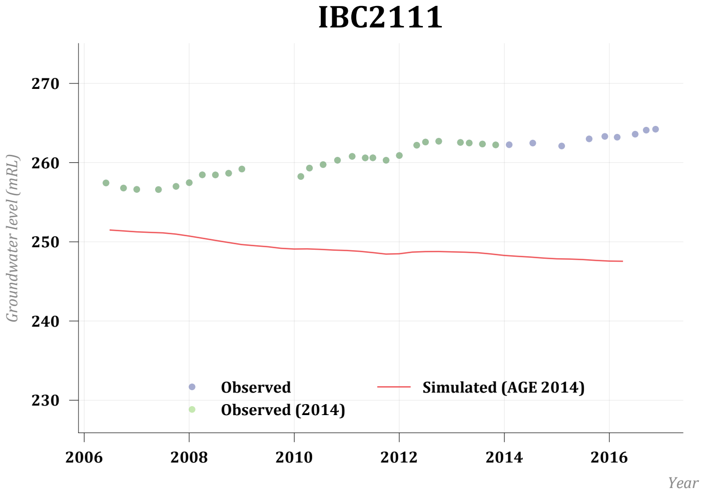


L19 Central West - Basalt



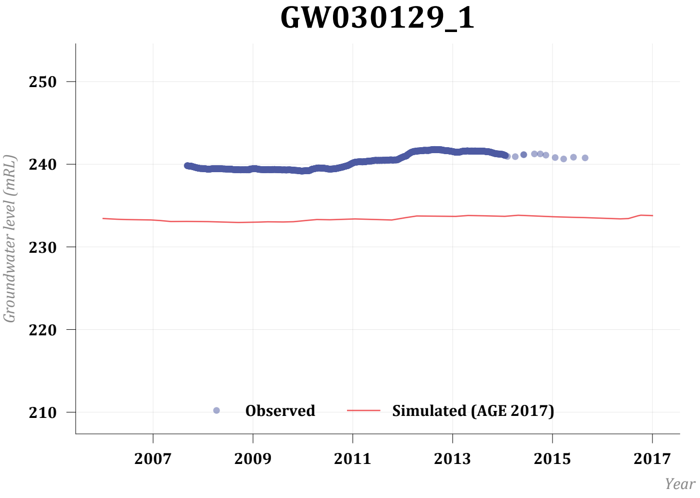


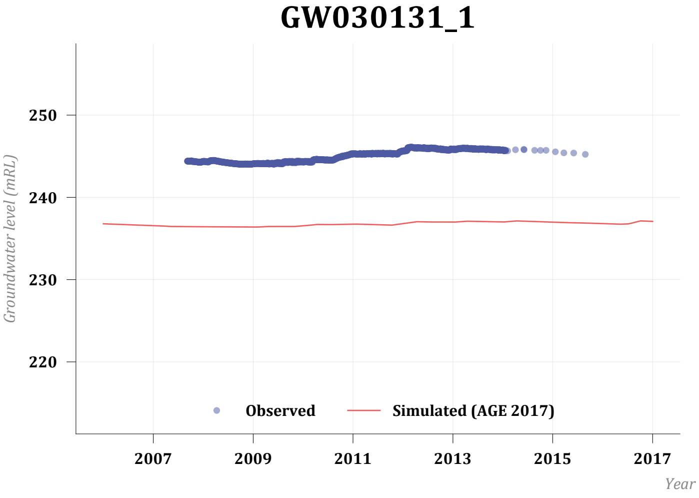


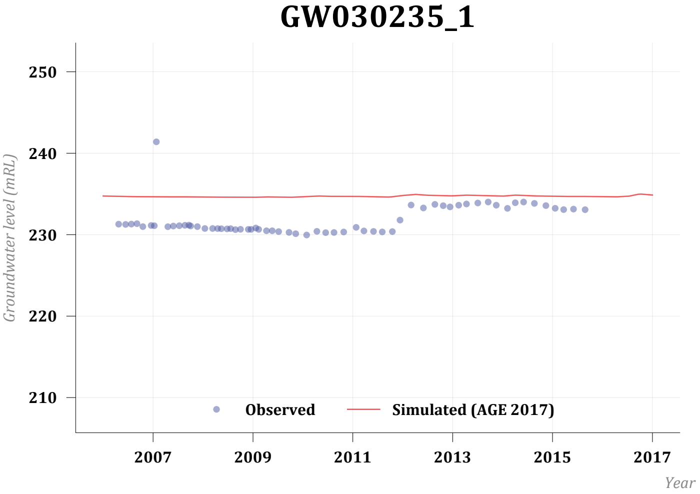


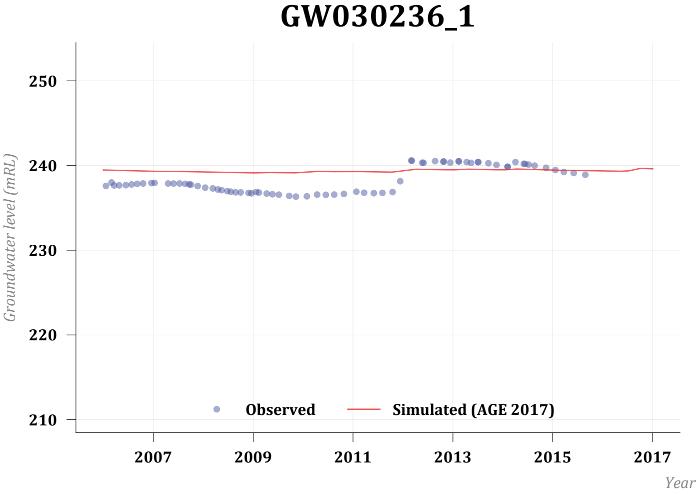
Appendix C Calibrated model hydrographs

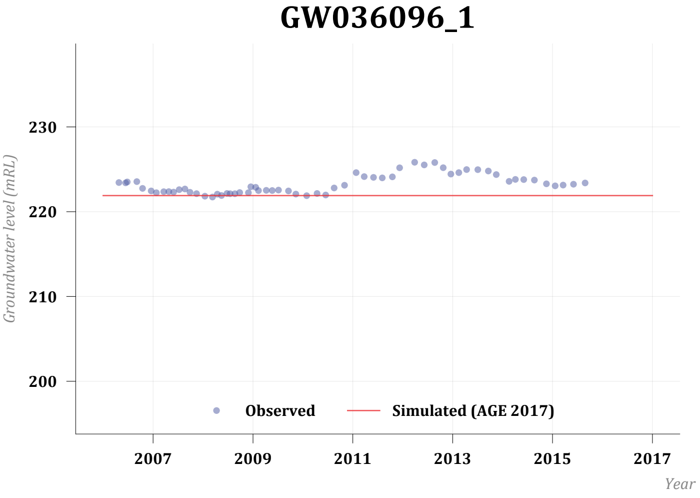
L01 Northwest - Alluvium

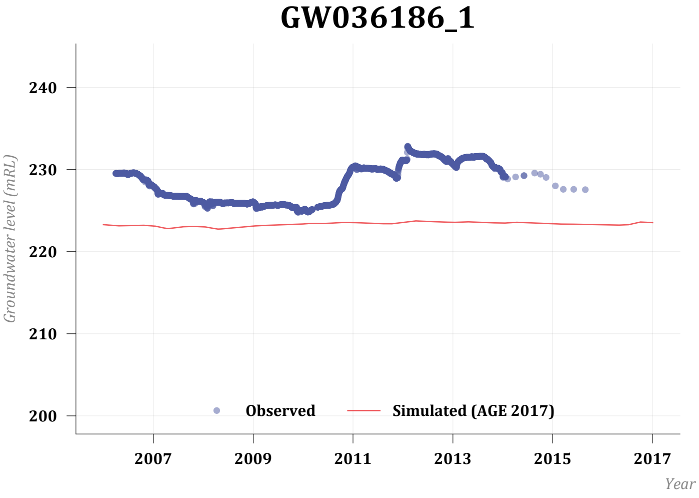






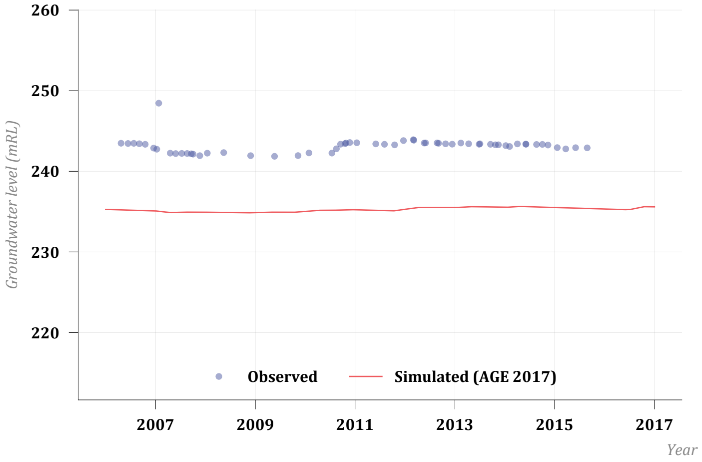




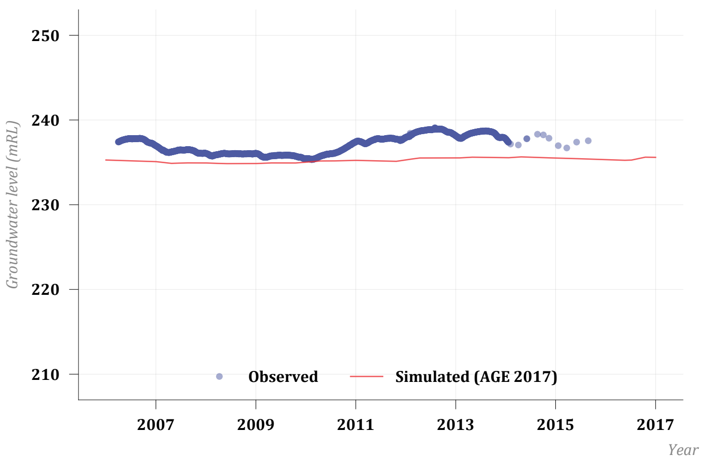


L02 Northwest - Alluvium

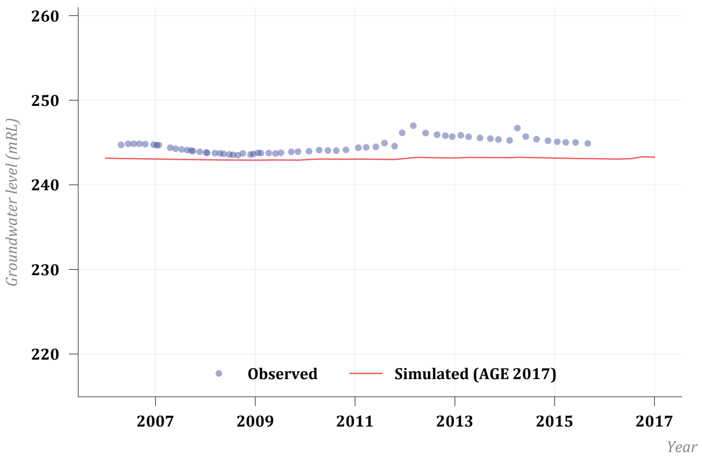
GW030130_1



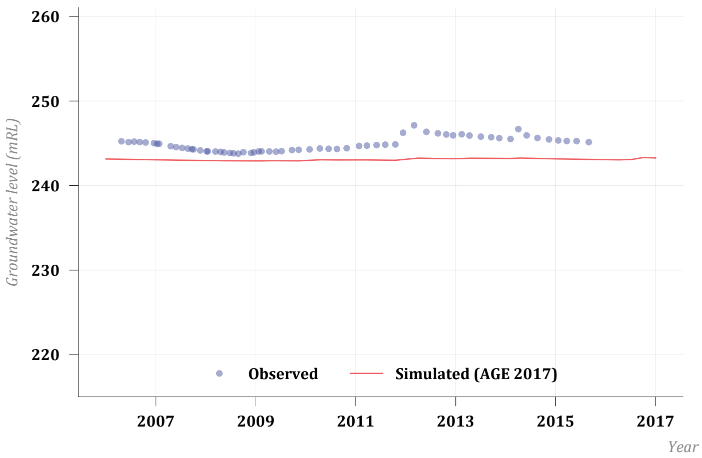
GW030130_2



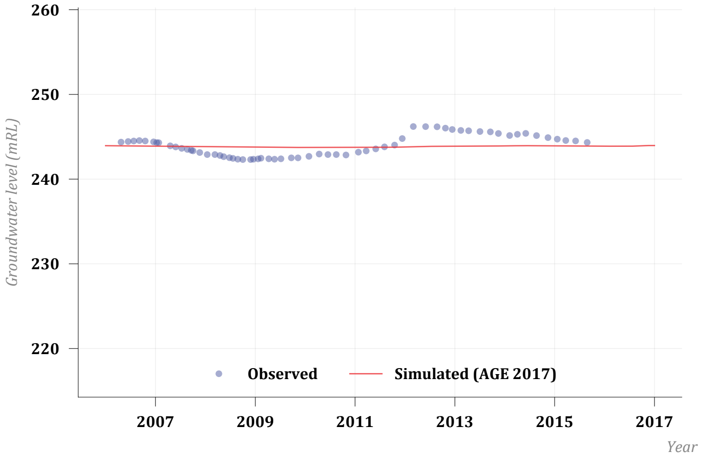
GW030132_1



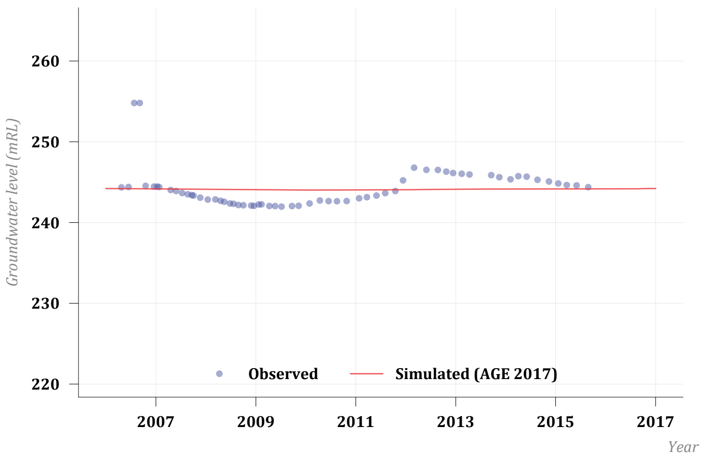
GW030132_2



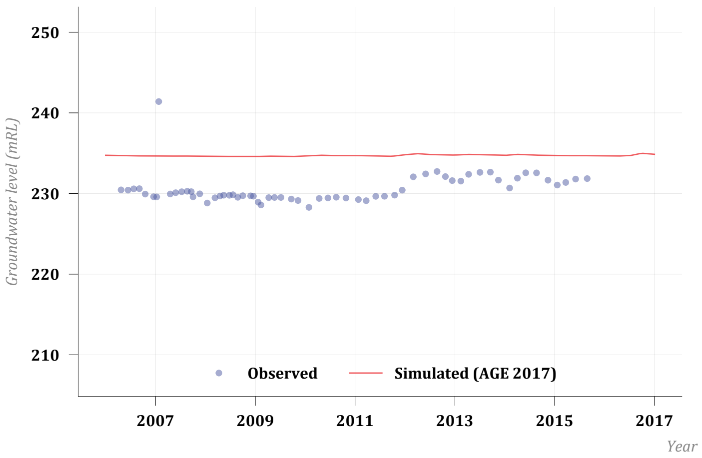
GW030133_1



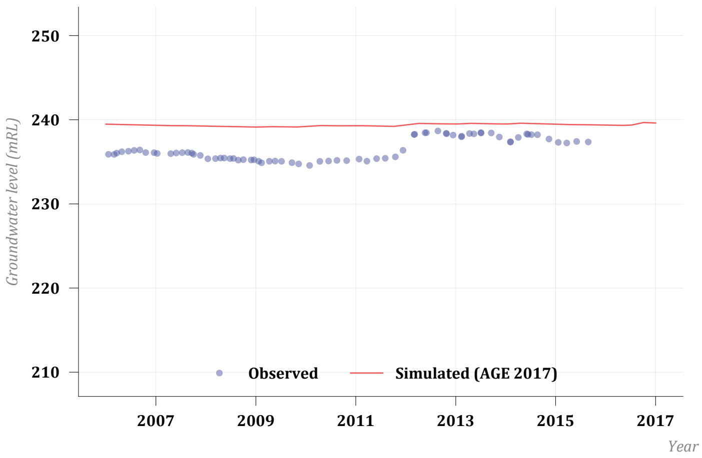
GW030134_1



GW030235_2

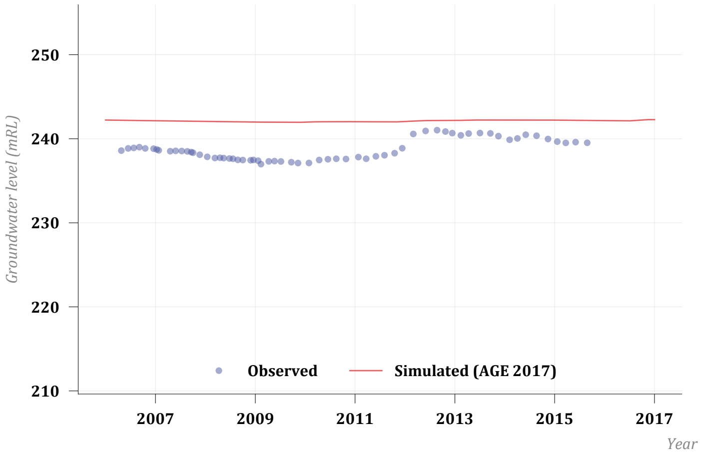


GW030236_2

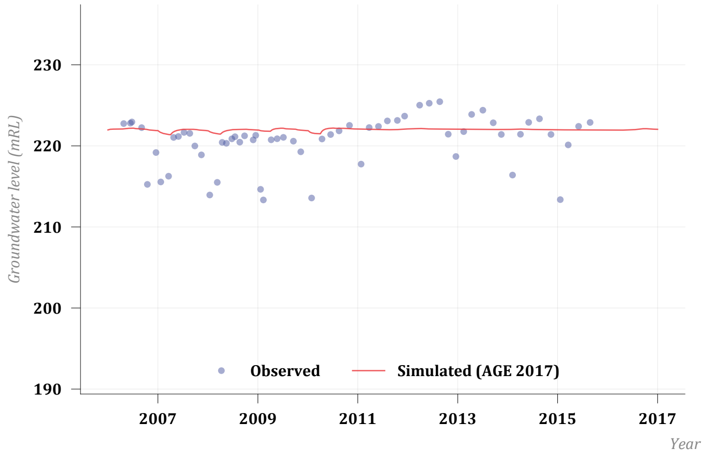


L02 Northwest - Alluvium

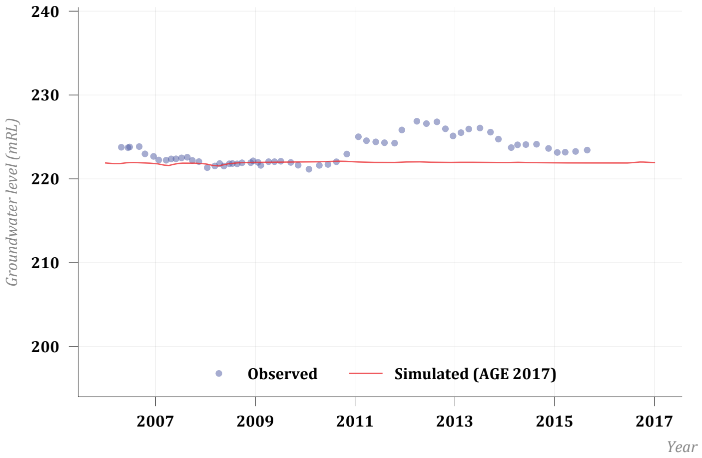
GW030237_1



GW036003_1



GW036093_1



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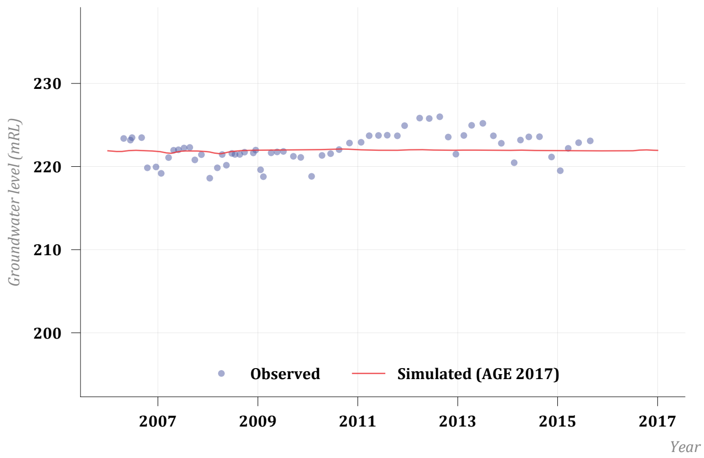
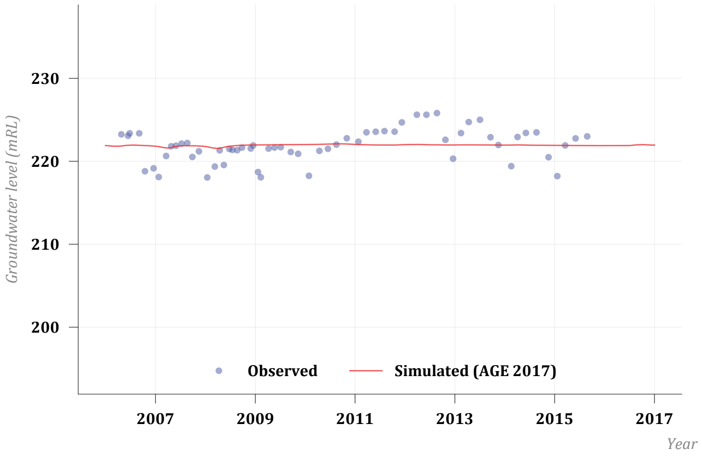
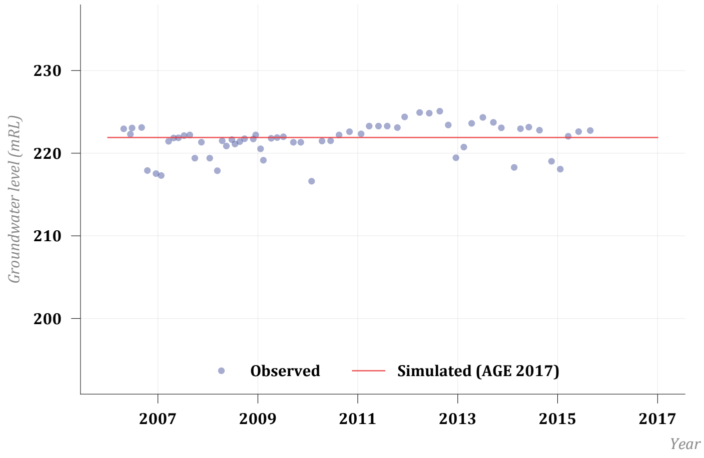


GW036093_3



GW036096_2



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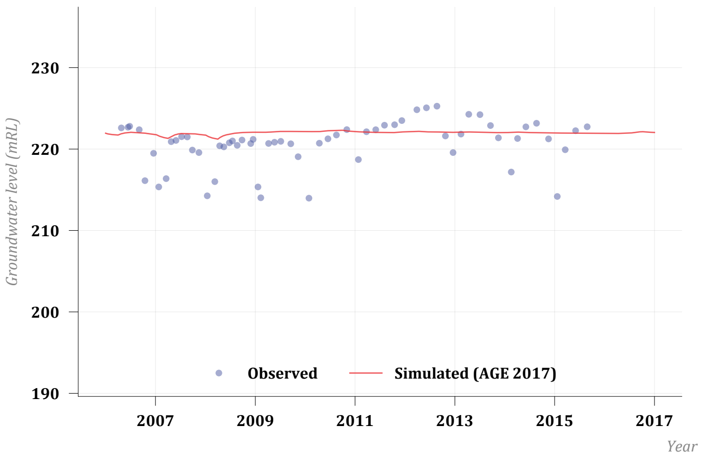
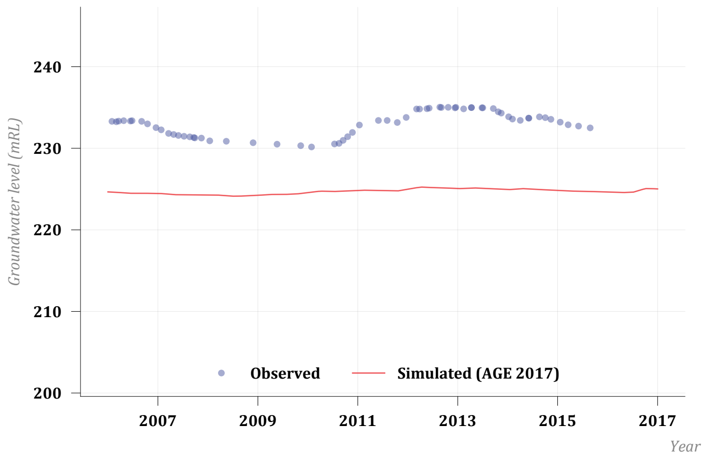
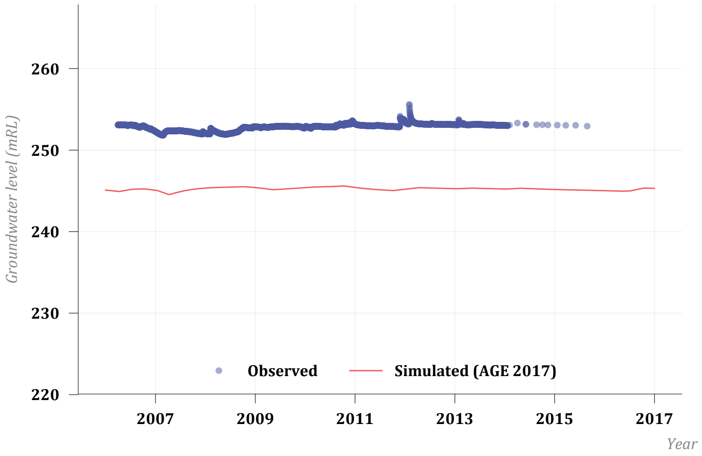


GW036187_1

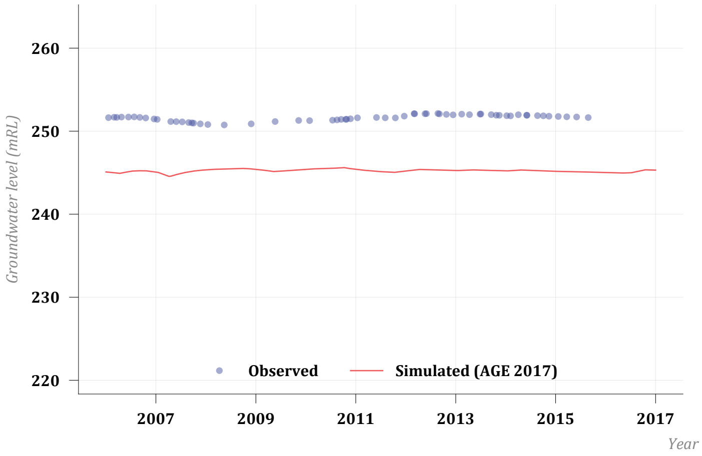


L02 Northwest - Alluvium

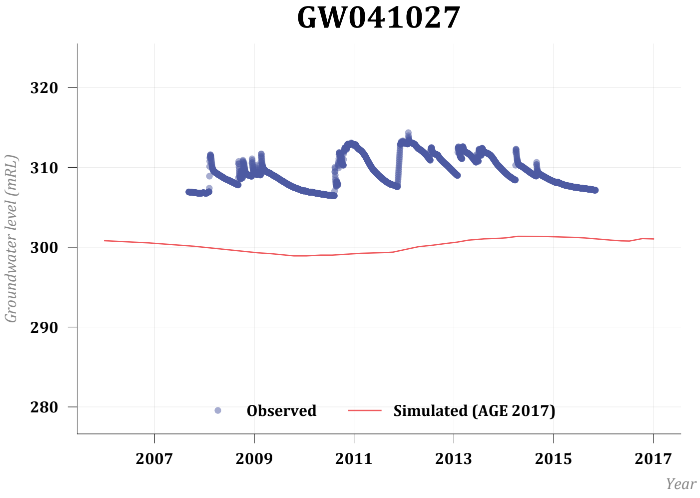
GW967137_1

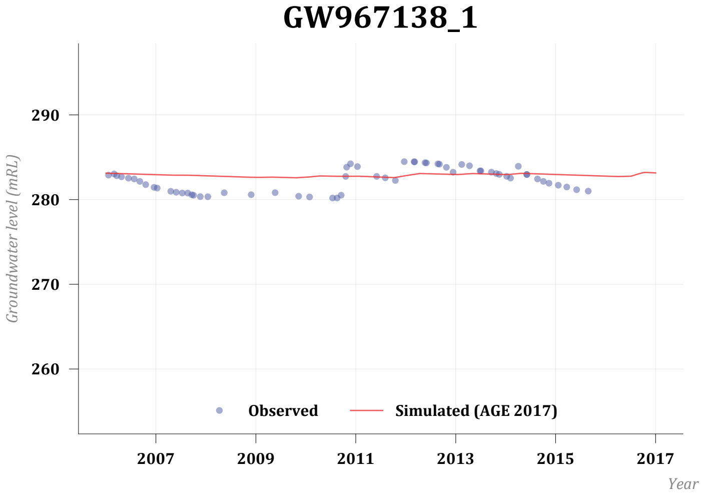


GW967137_2



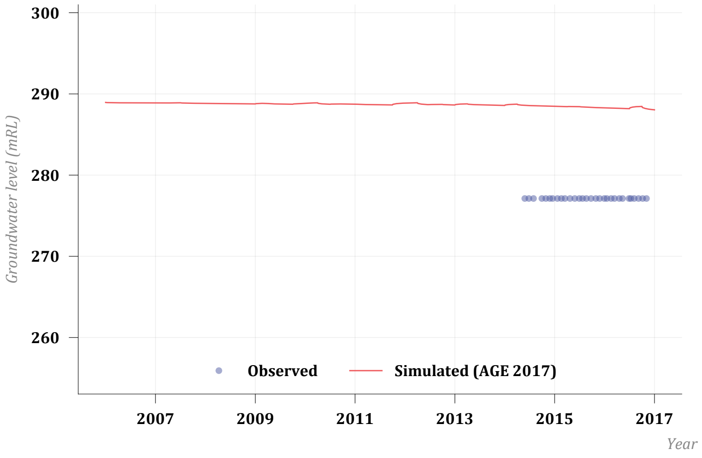
L01 North - Alluvium





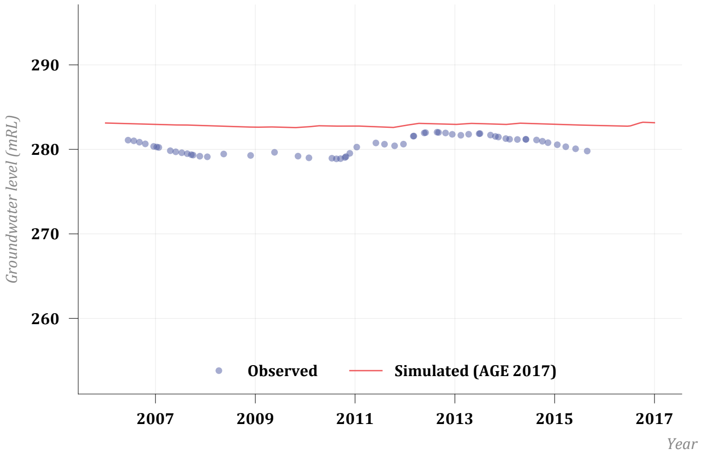
L01 North - Alluvium [Mod:L01PermianReg]

REG10A

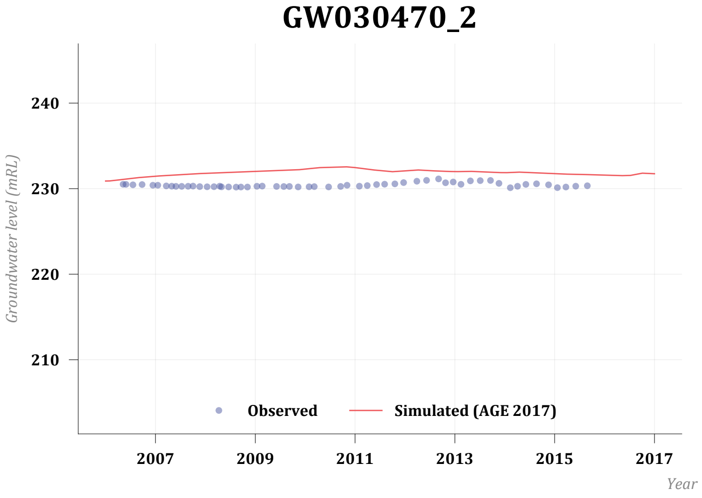


L02 North - Alluvium

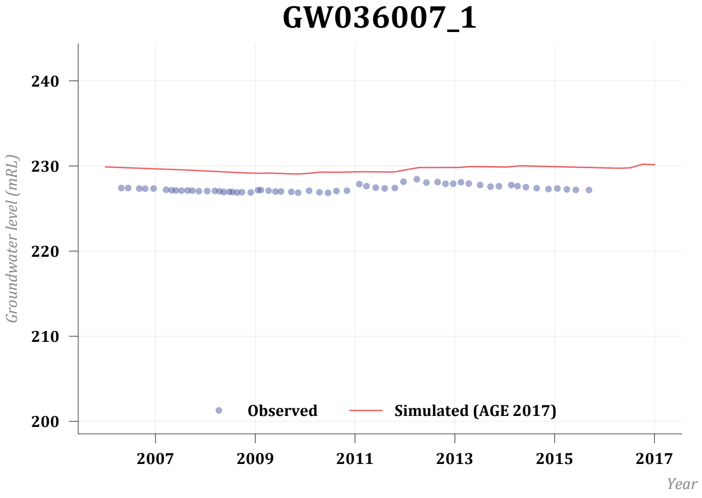
GW967138_2

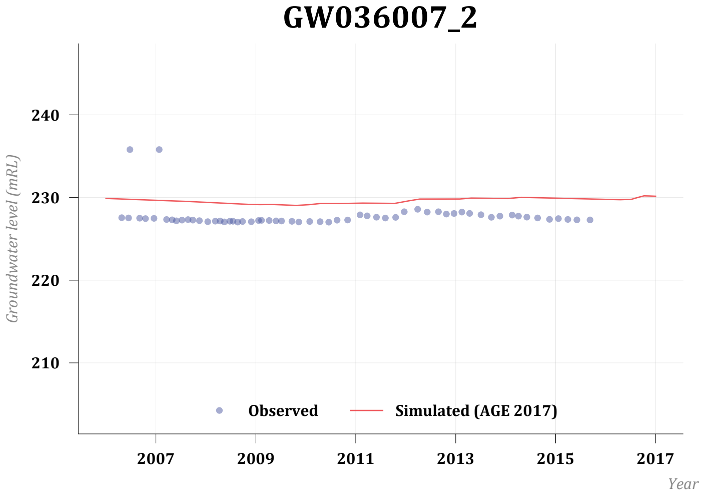


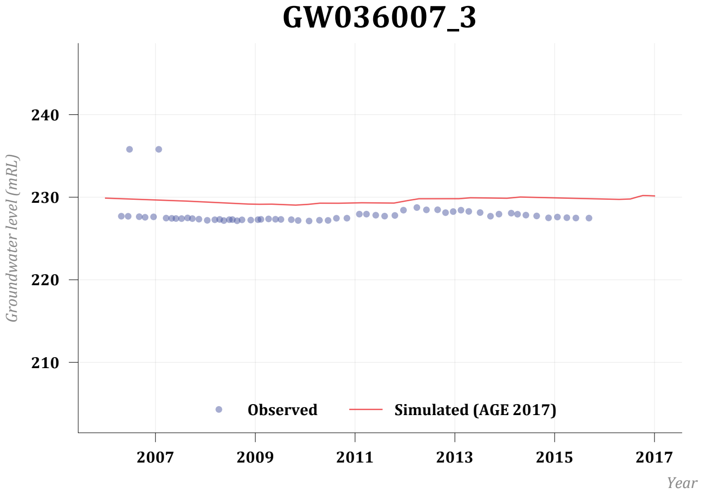
L01 West - Alluvium

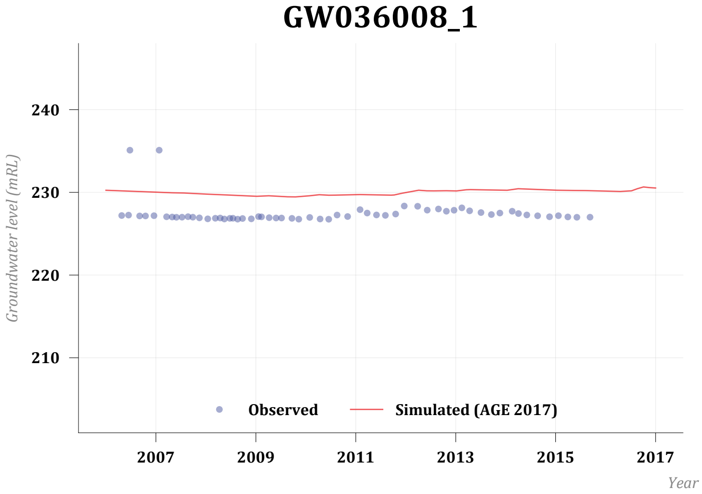


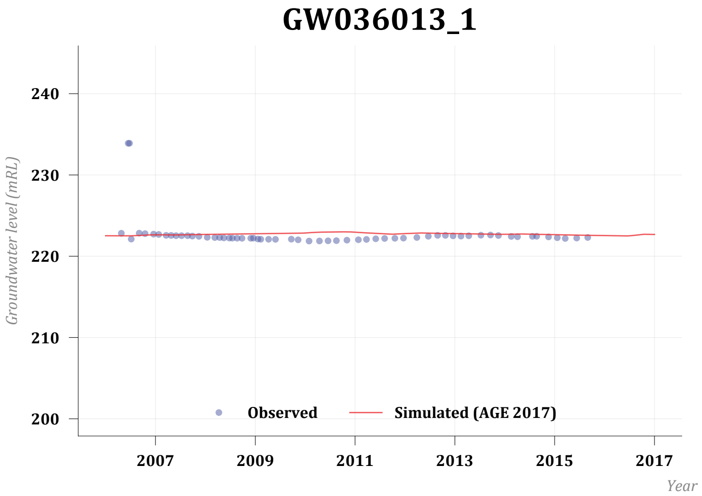
L02 West - Alluvium

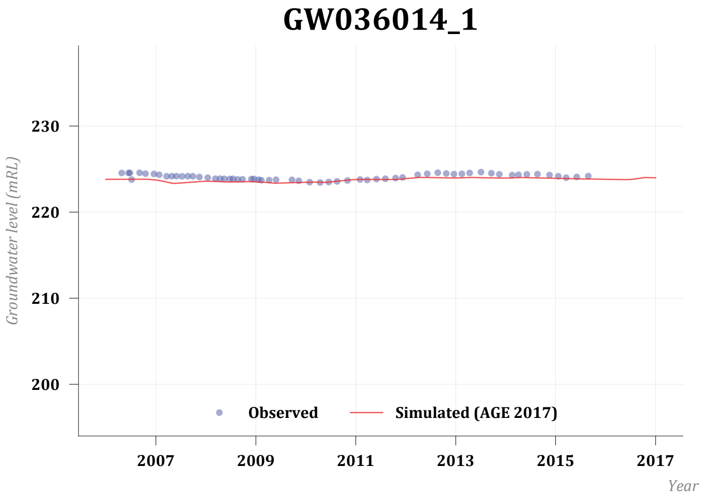


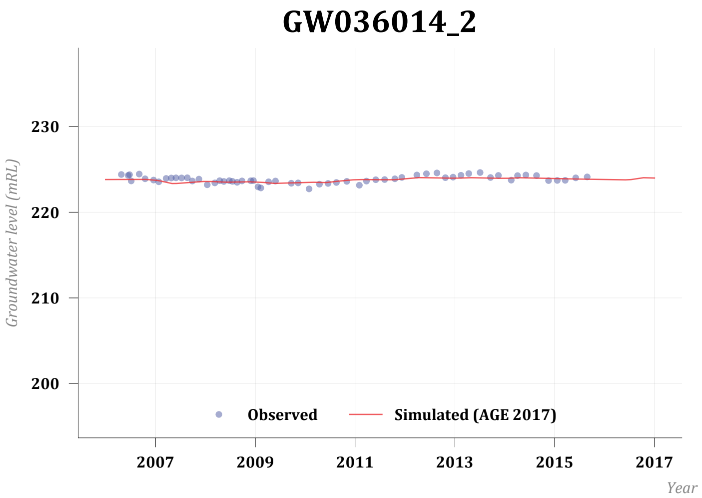


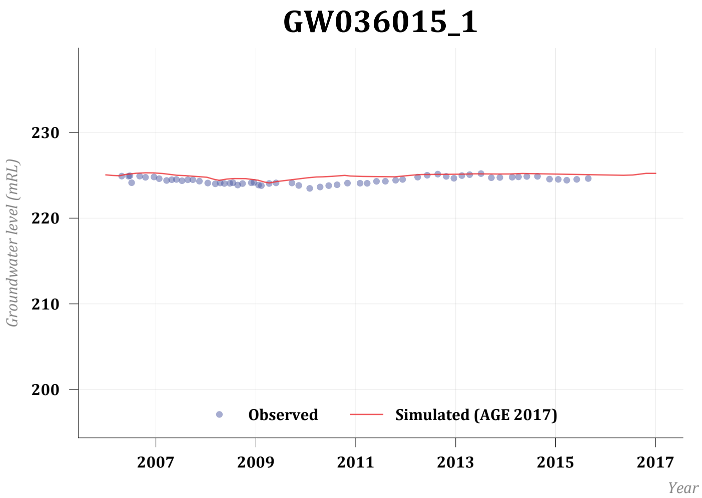






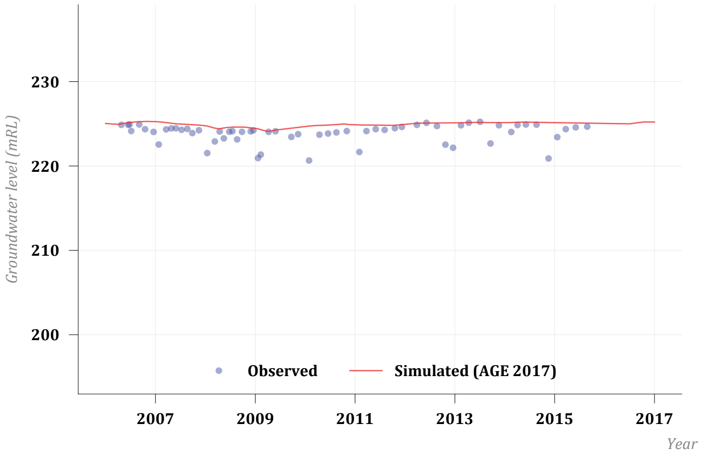




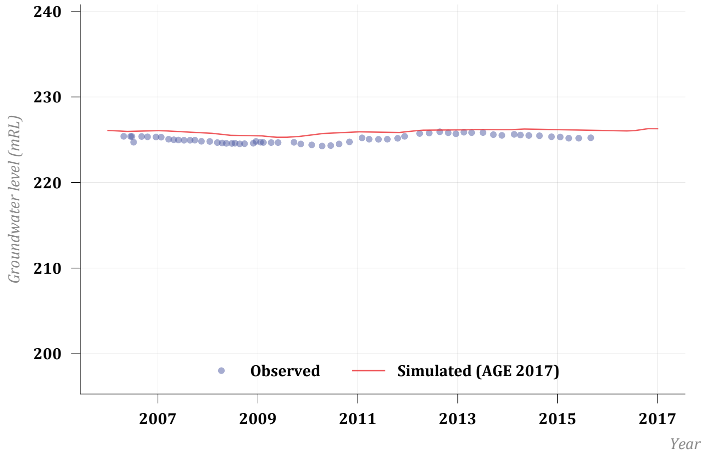


L02 West - Alluvium

GW036015_2



GW036016_1



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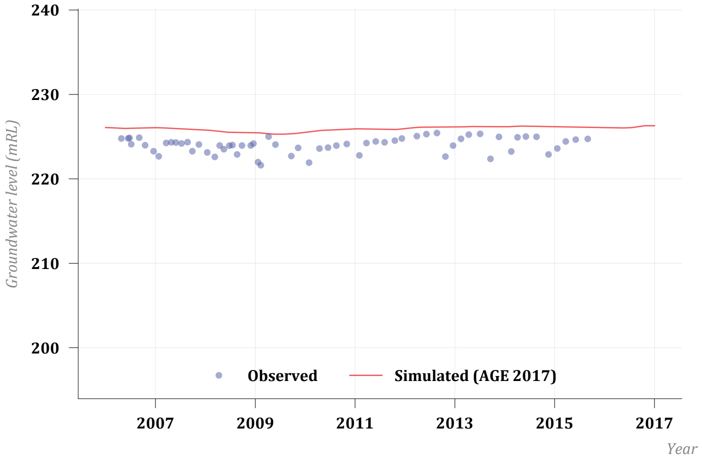

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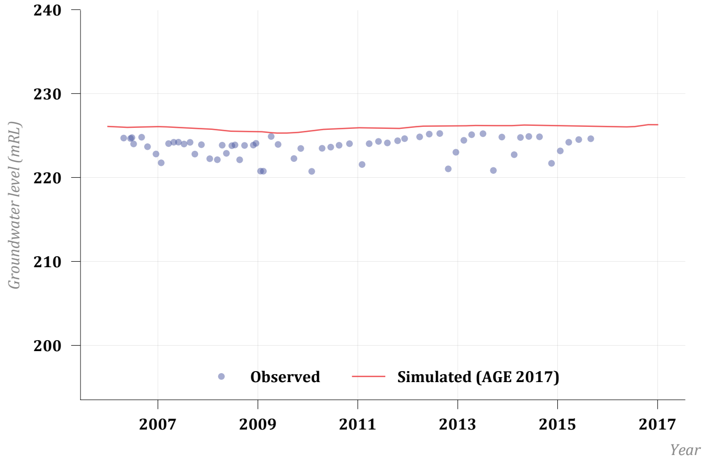

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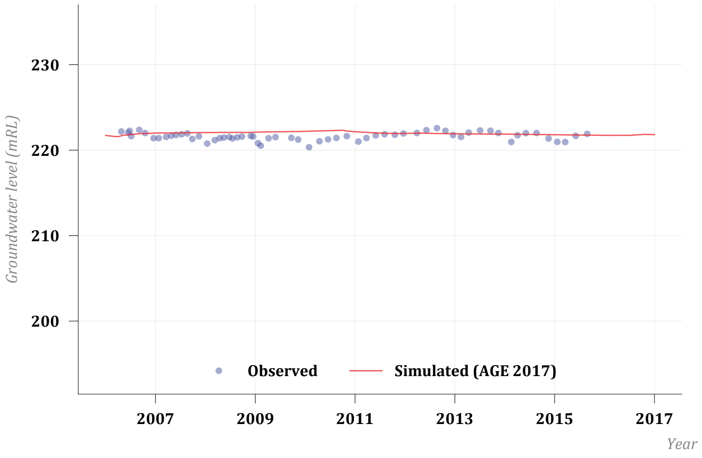

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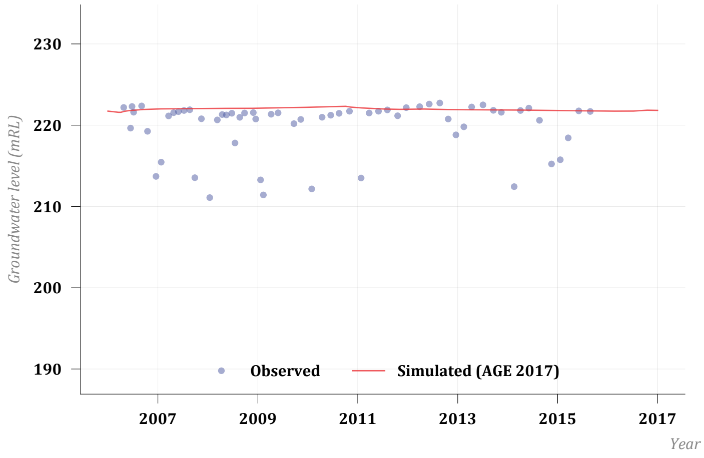

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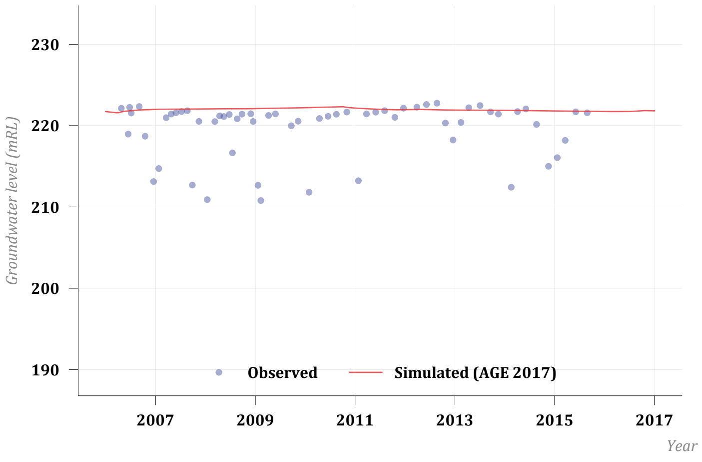

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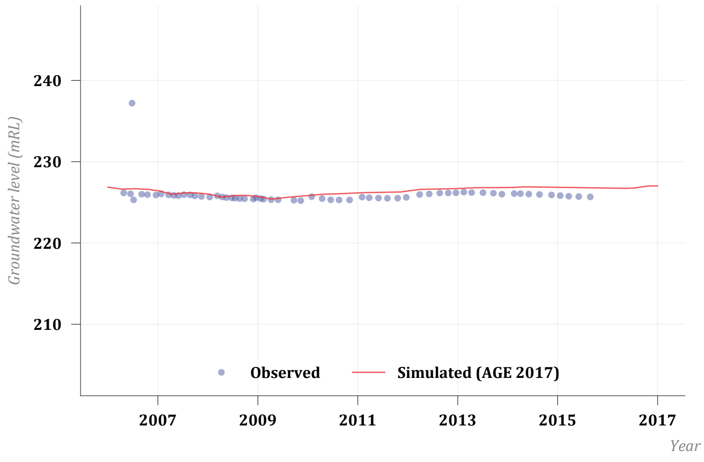
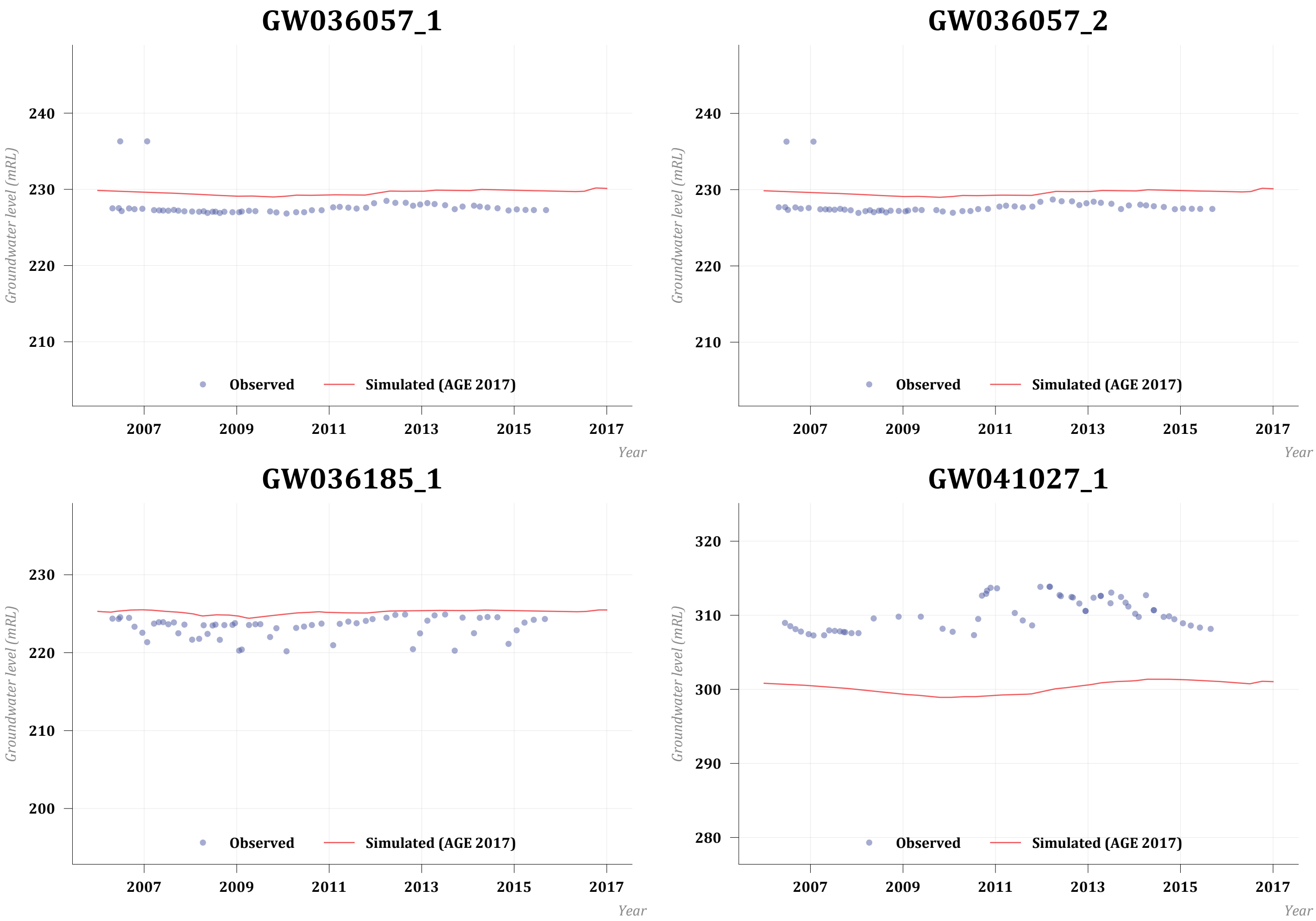
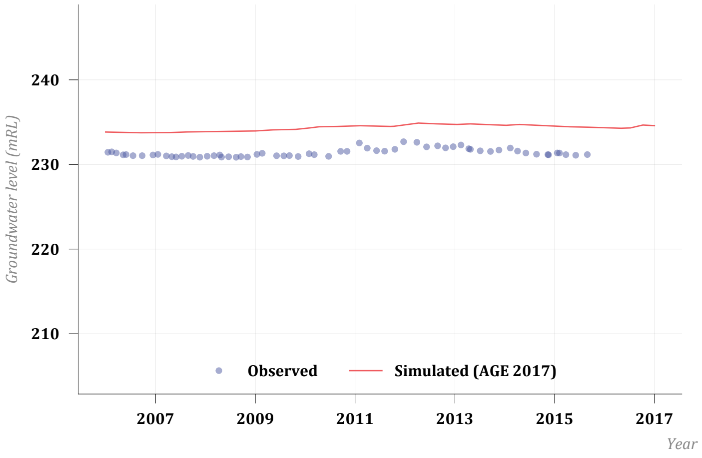


L02 West - Alluvium



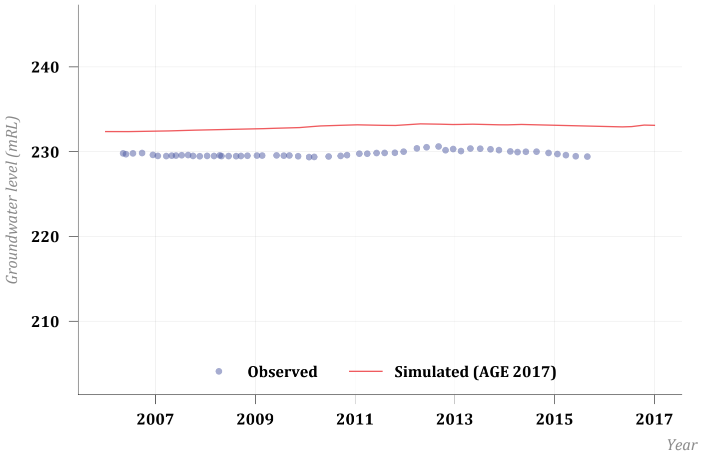
L02 Central West - Alluvium

GW030468_1



GW030469_1

GW030471_1



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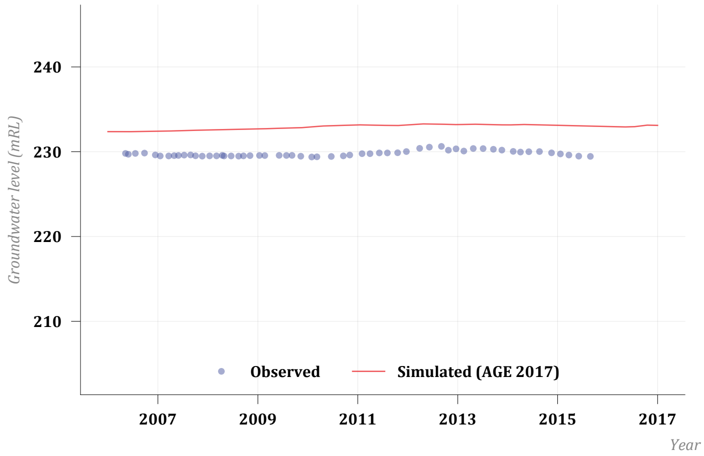
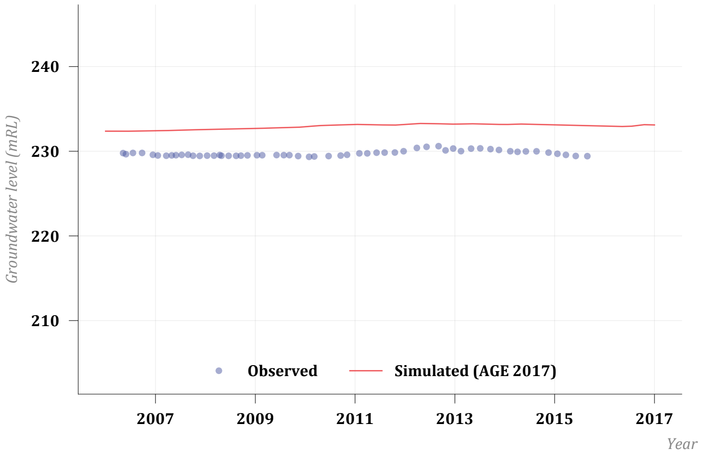
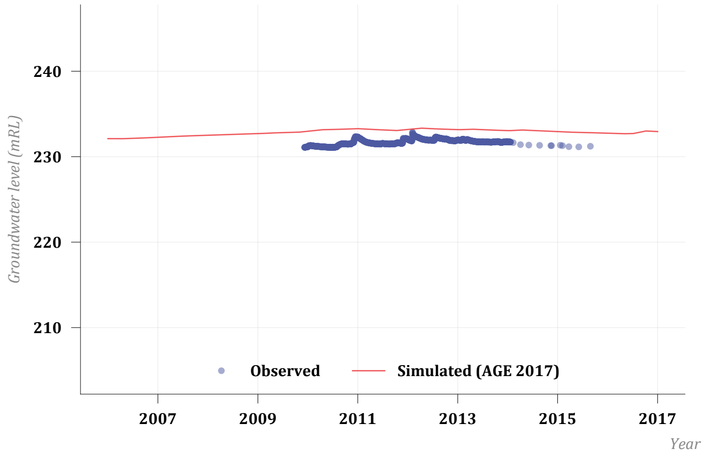


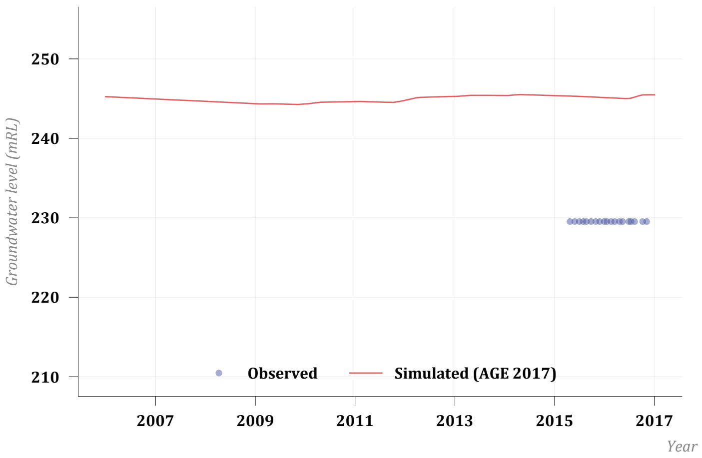
GW030471_3



GW036092_1

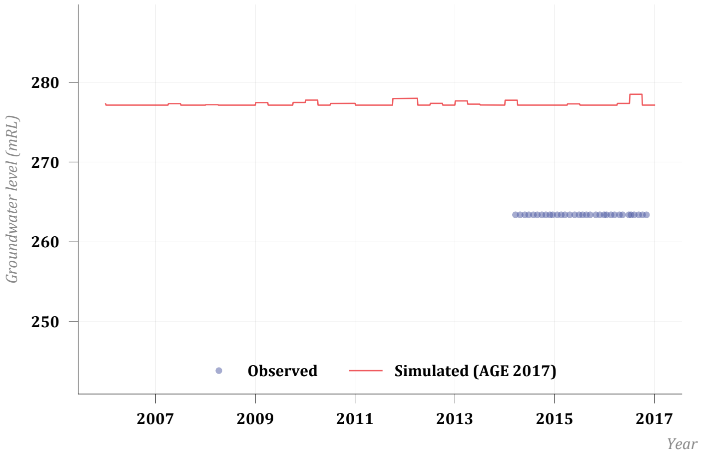


REG5A

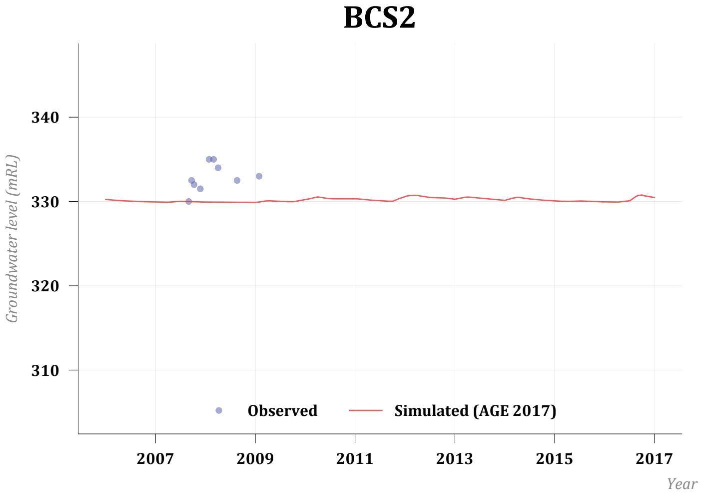


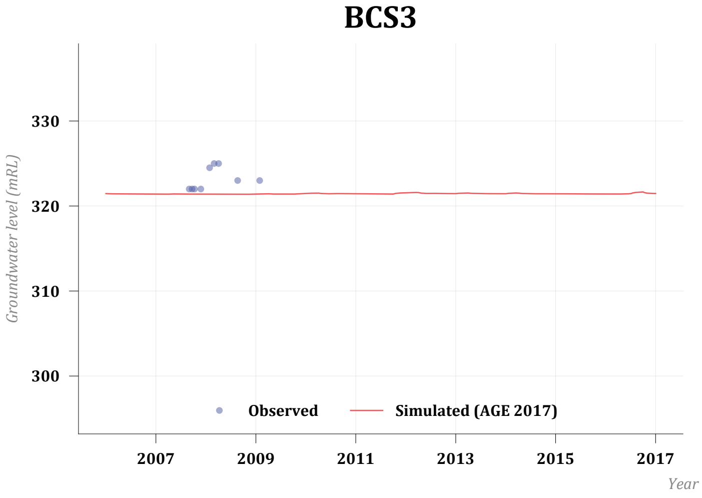
L02 Central North - Alluvium [Mod:L01PermianReg]

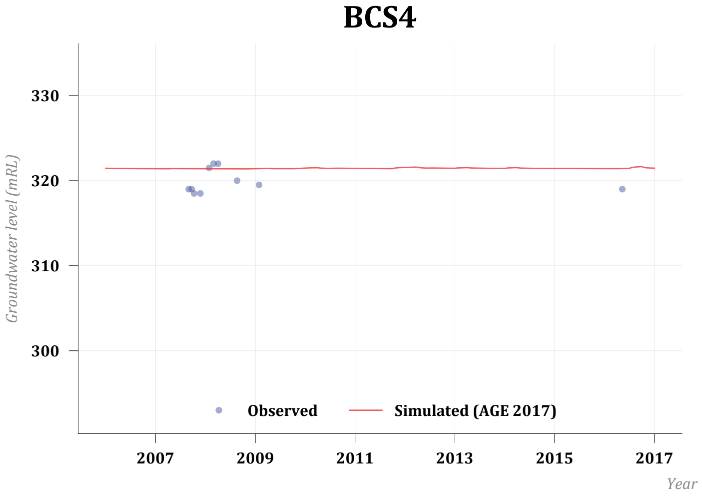
BCM01

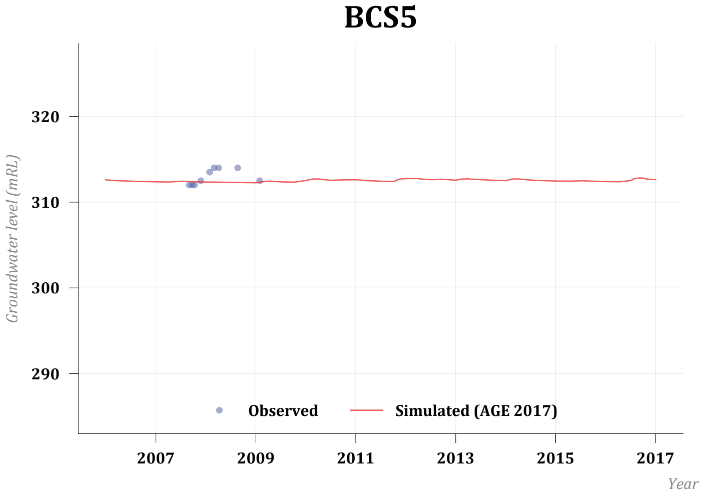


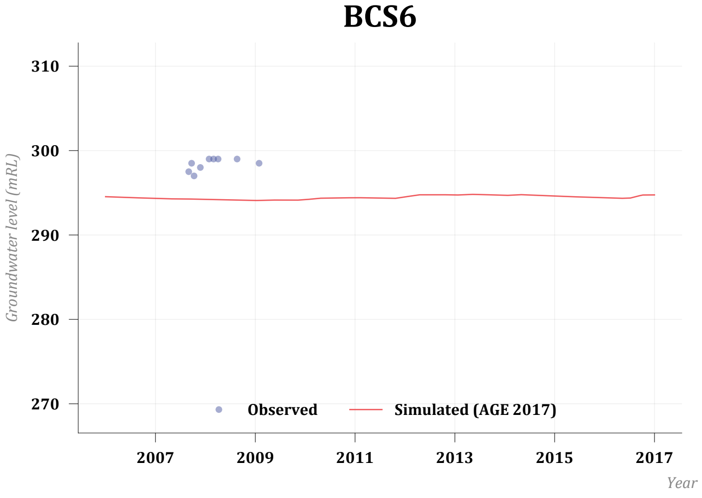
L02 East - Alluvium

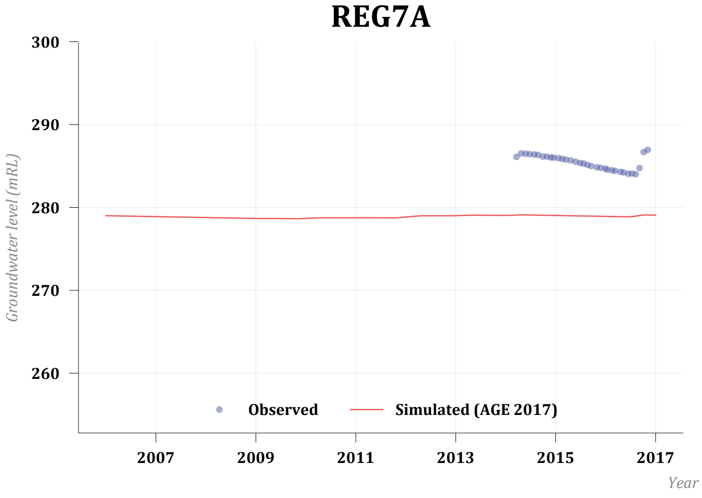




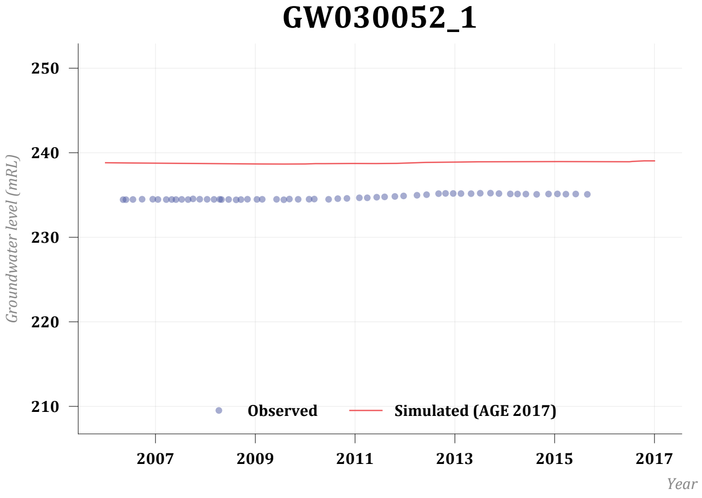


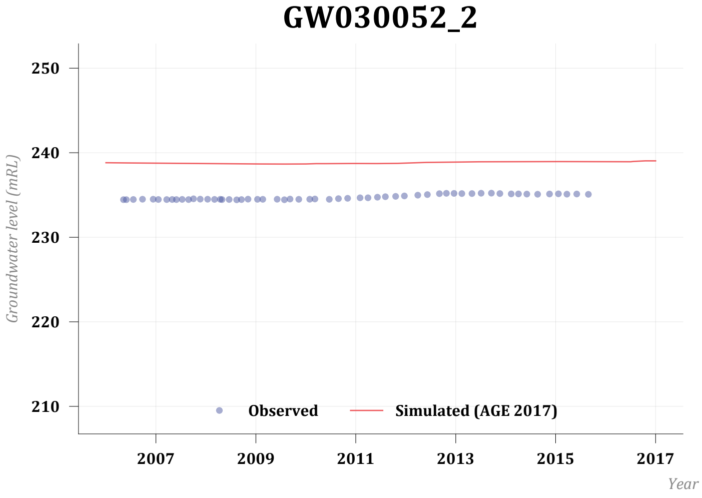


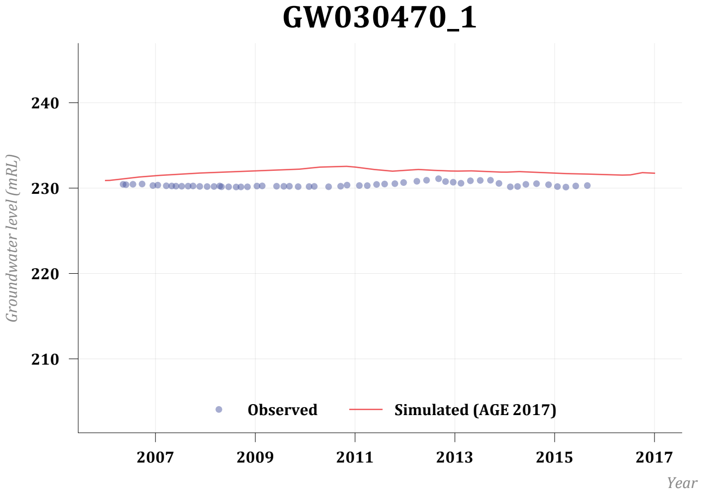




L01 Central South - Alluvium

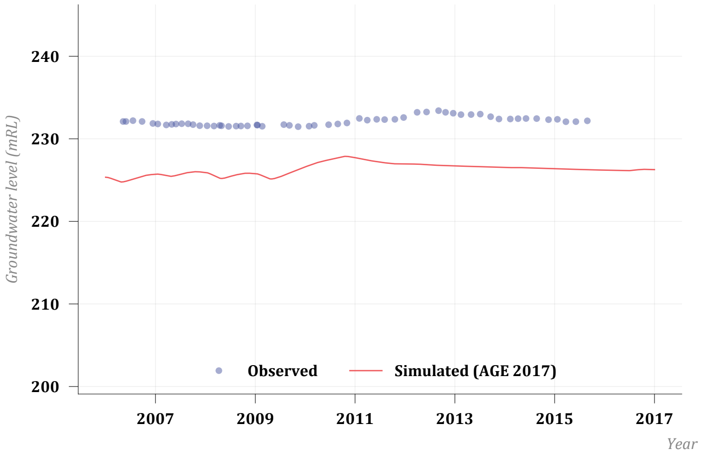






L02 Central South - Alluvium

GW030048_1



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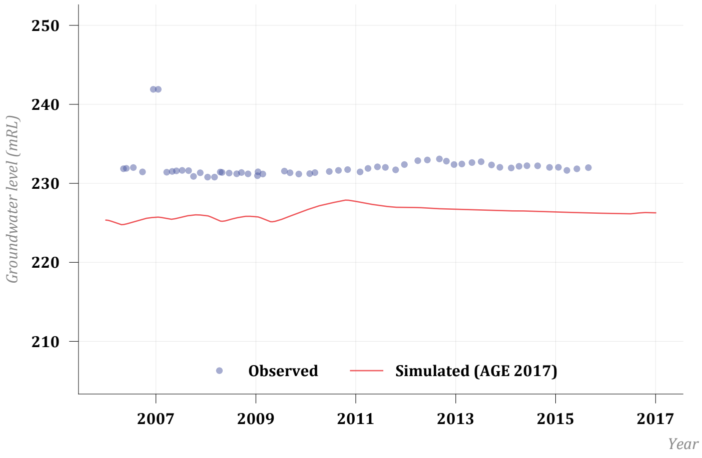

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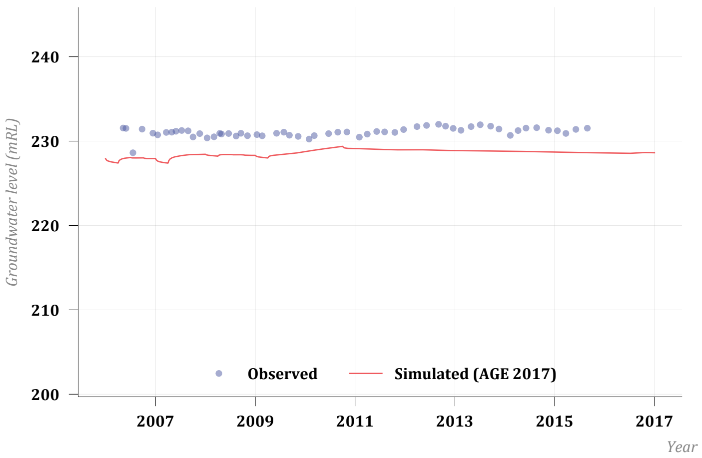

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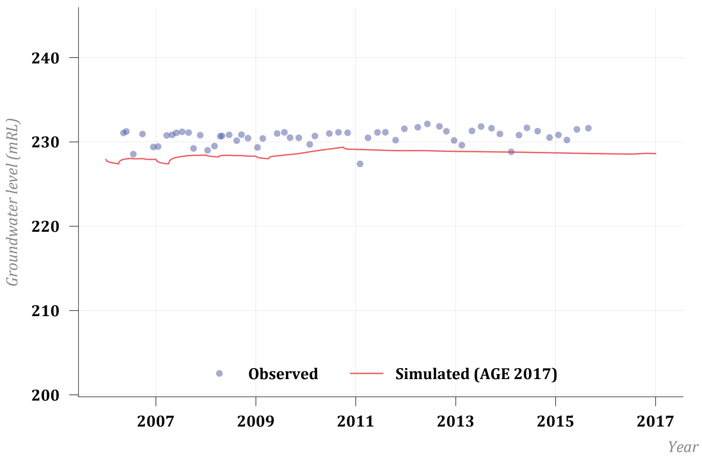

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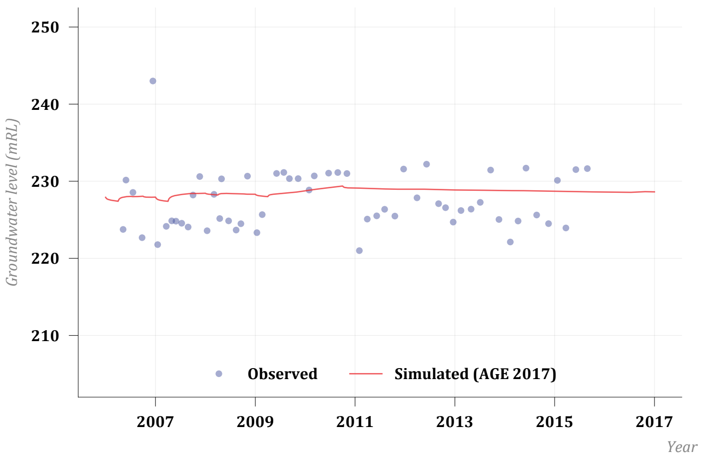

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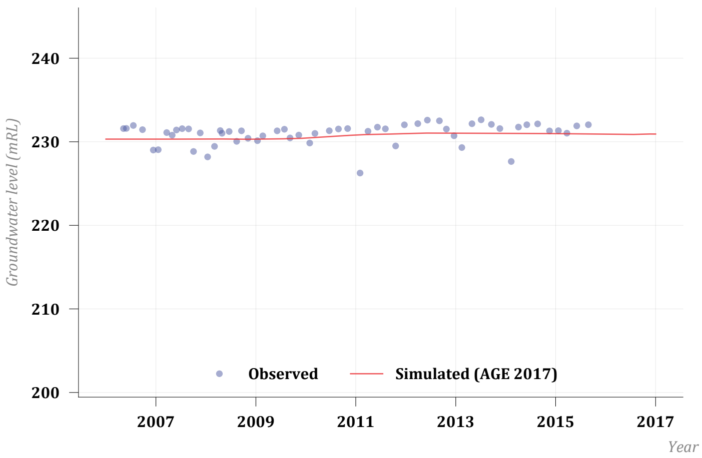

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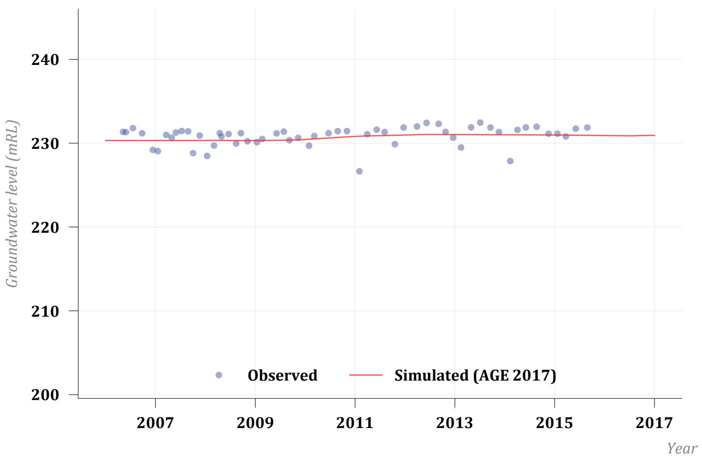

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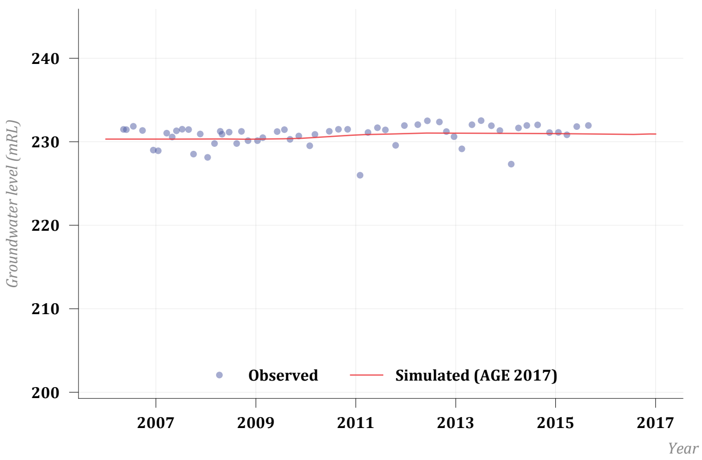
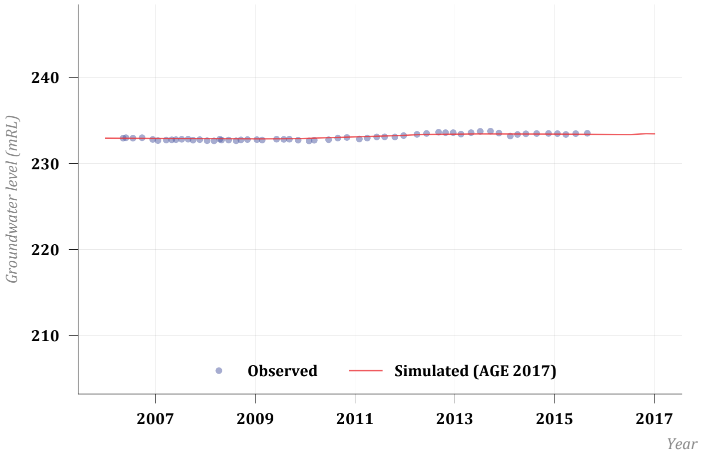


L02 Central South - Alluvium

GW030051_1



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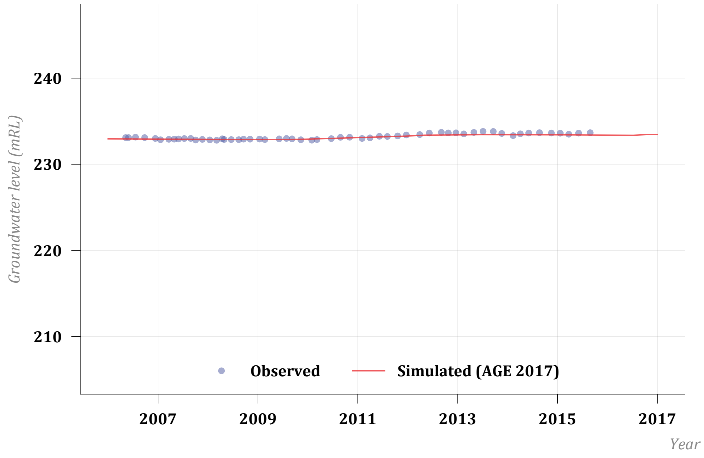
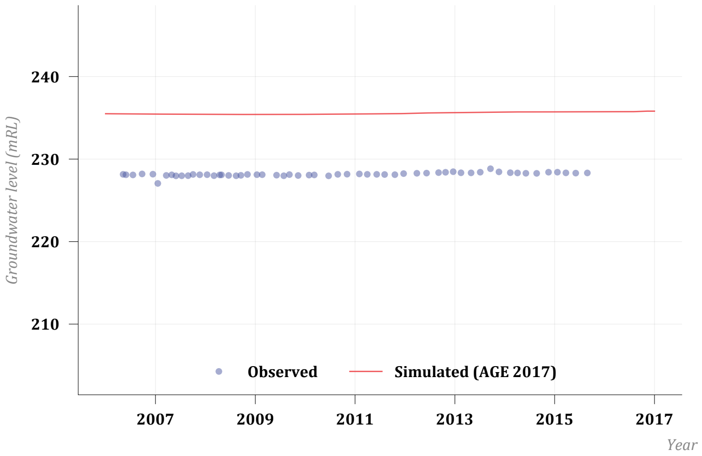


GW030472_1



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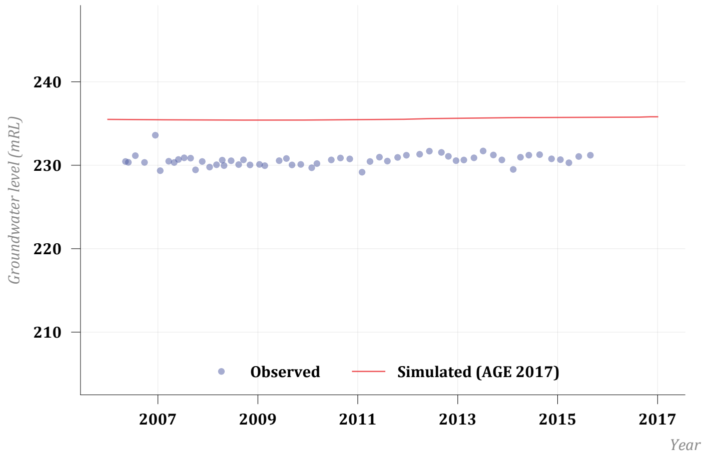

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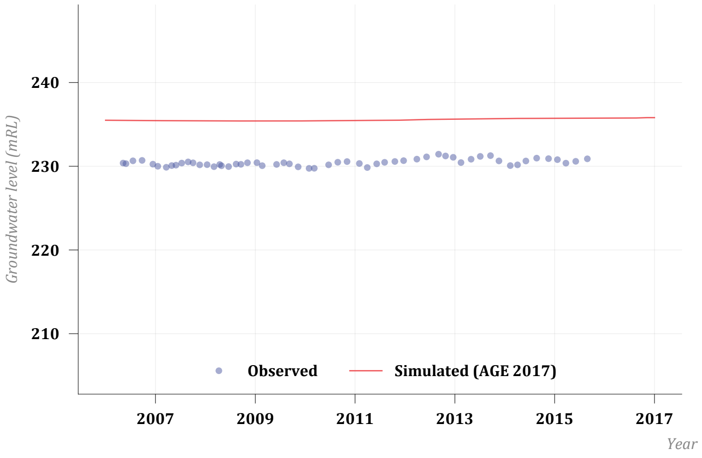

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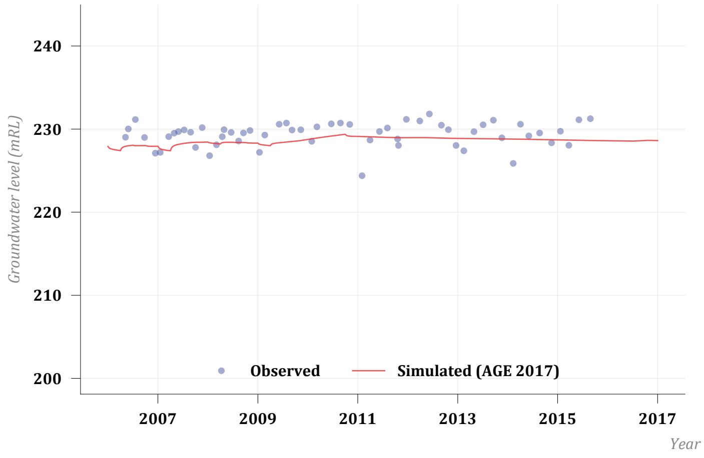

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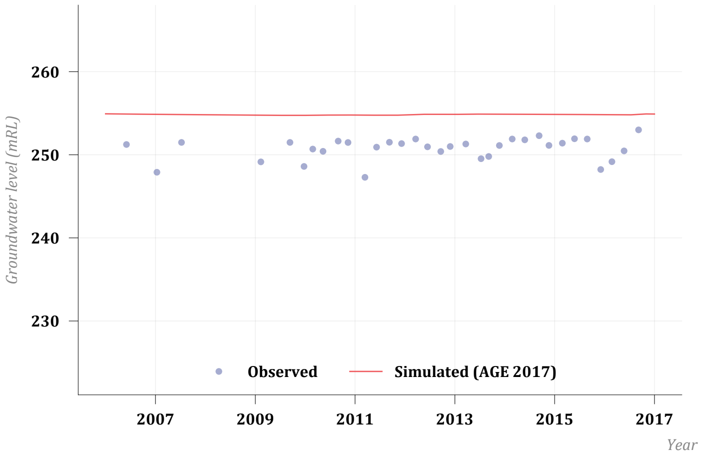

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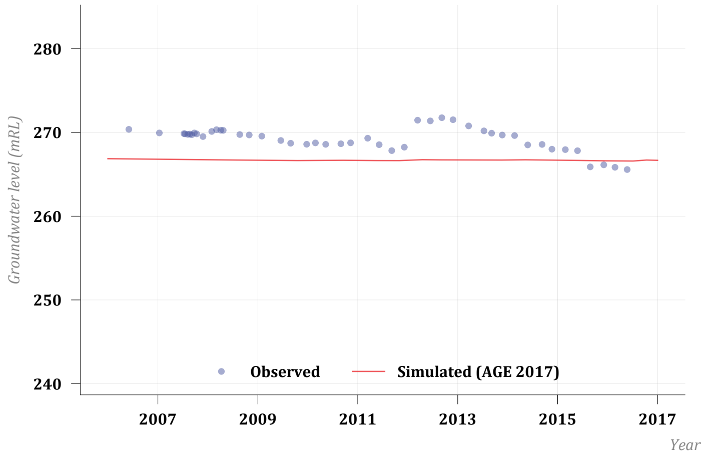
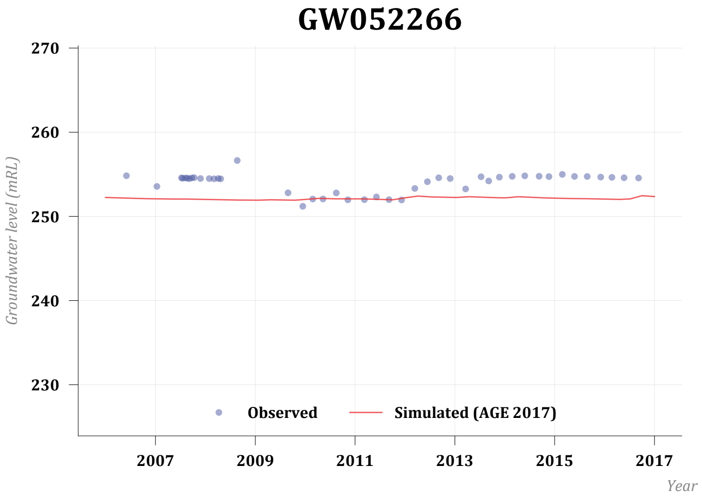
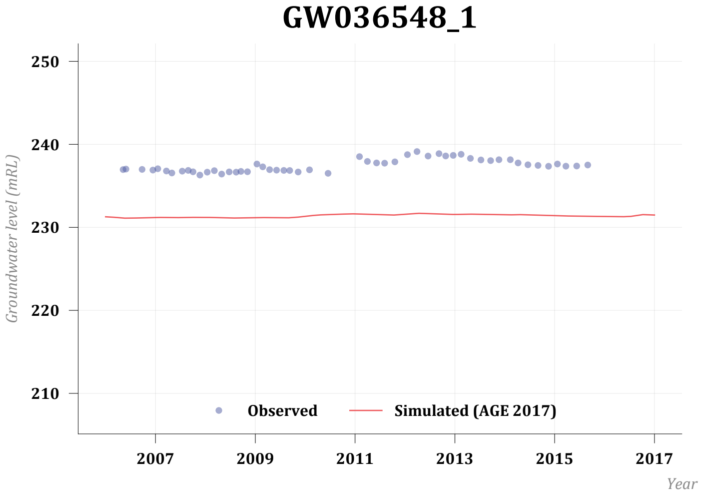
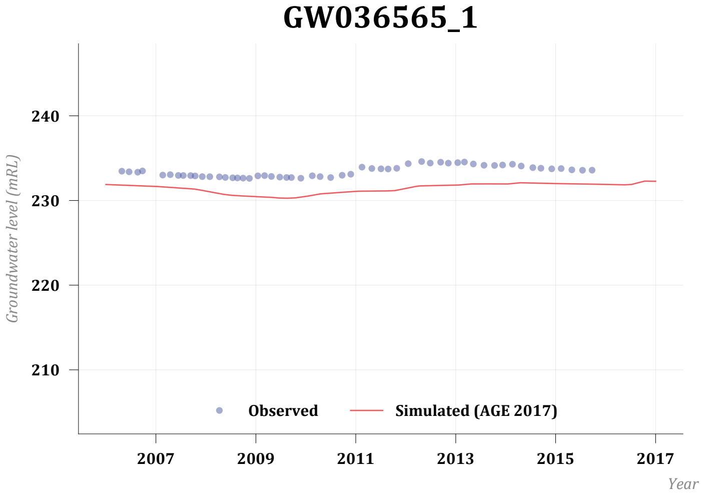


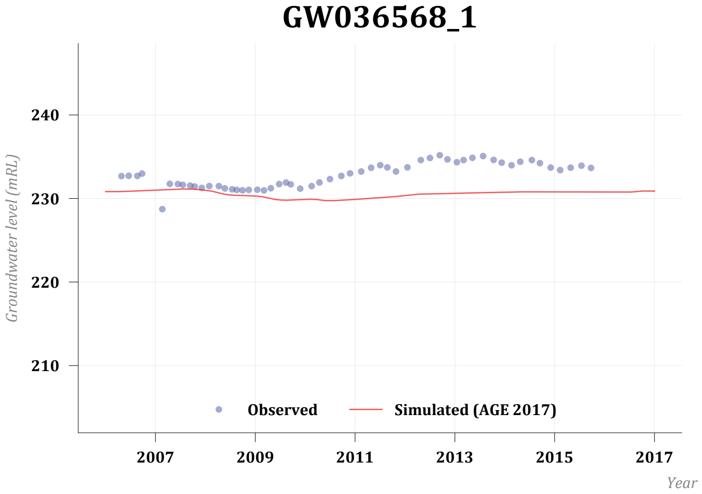
L02 Central South - Alluvium

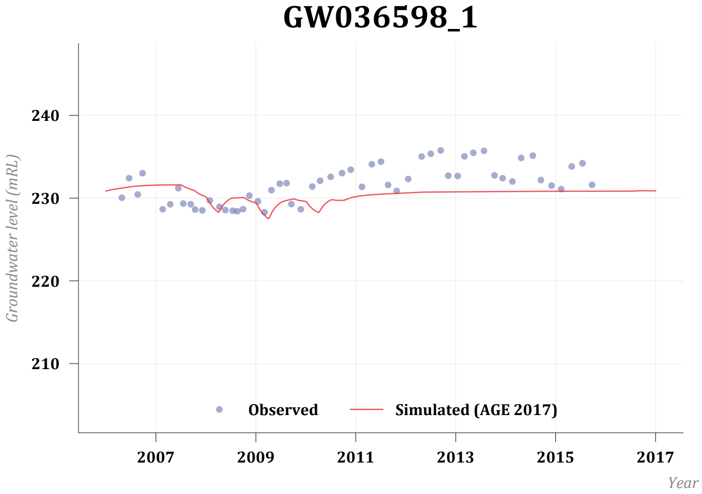


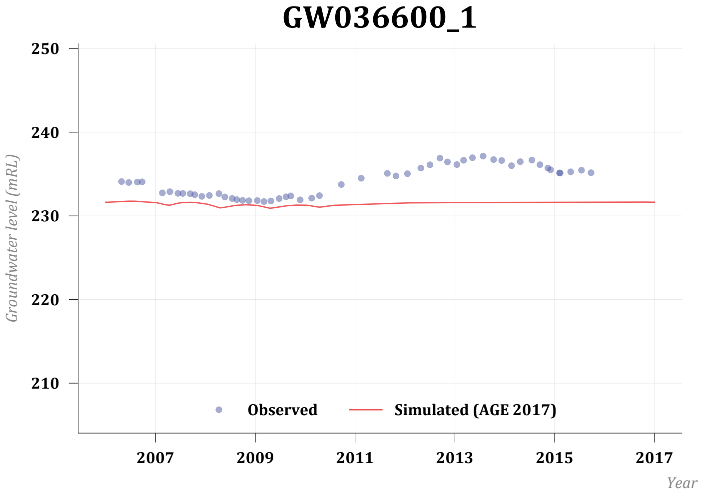
L01 Southwest - Alluvium





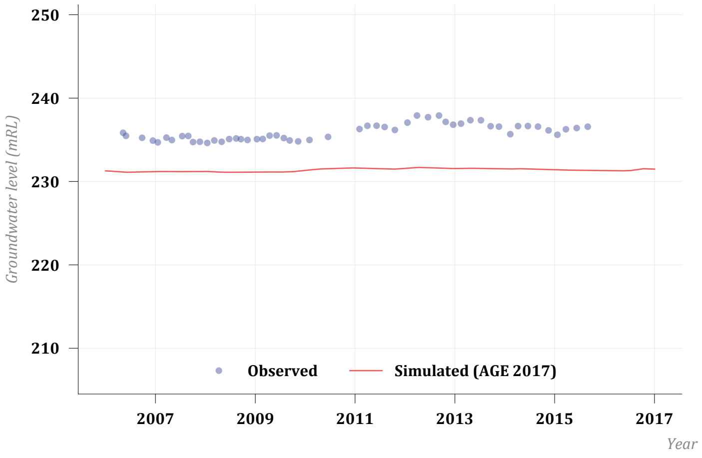






L02 Southwest - Alluvium

GW036548_2



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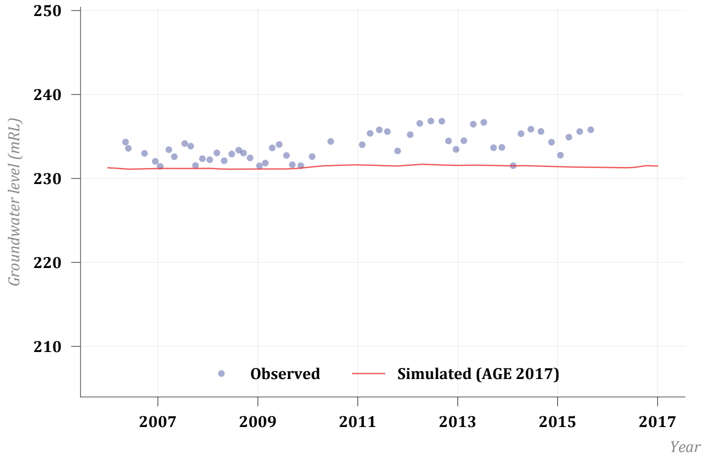

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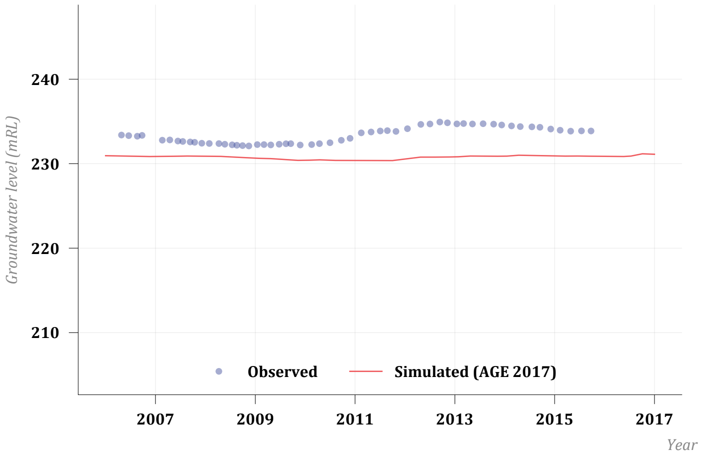
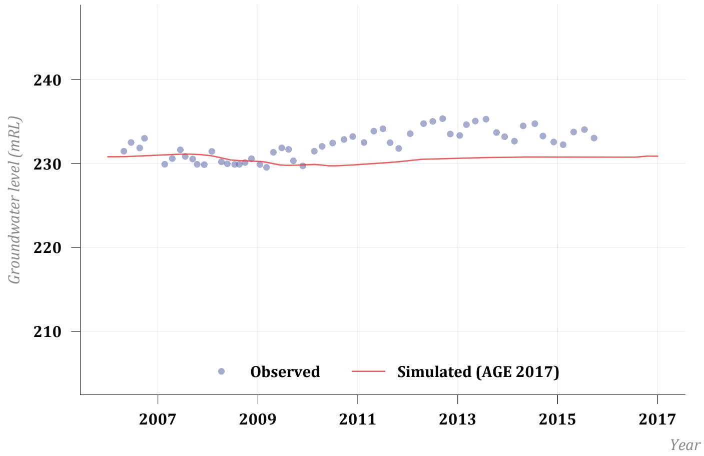


GW036568_2



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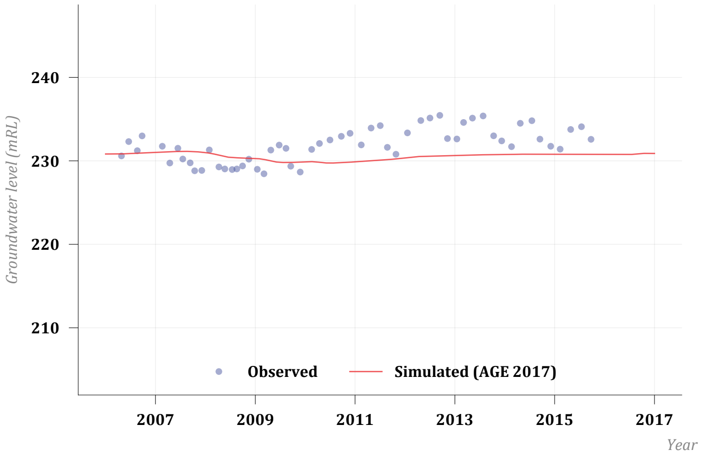

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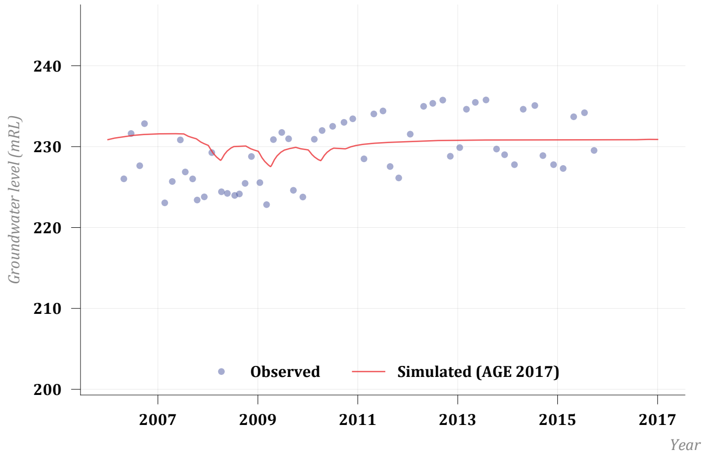
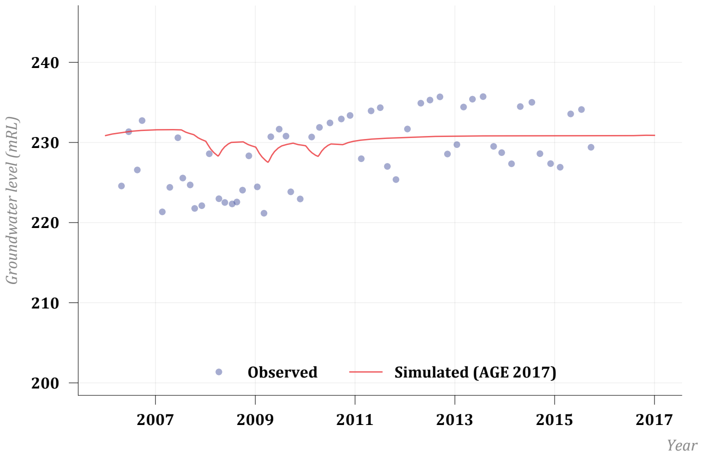


GW036598_3



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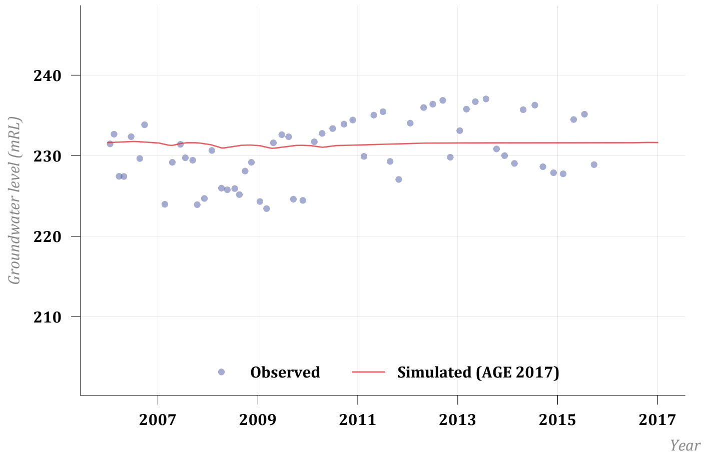
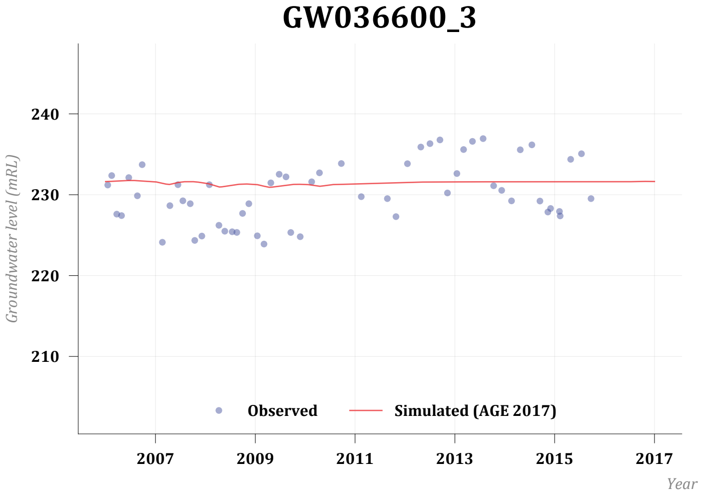
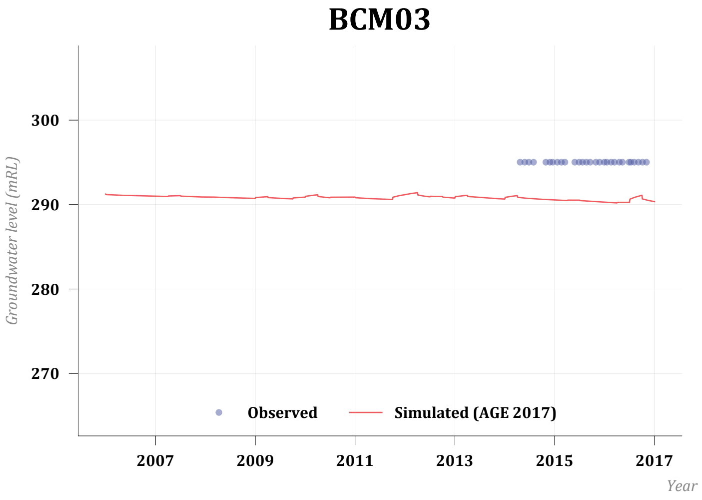


L02 Southwest - Alluvium

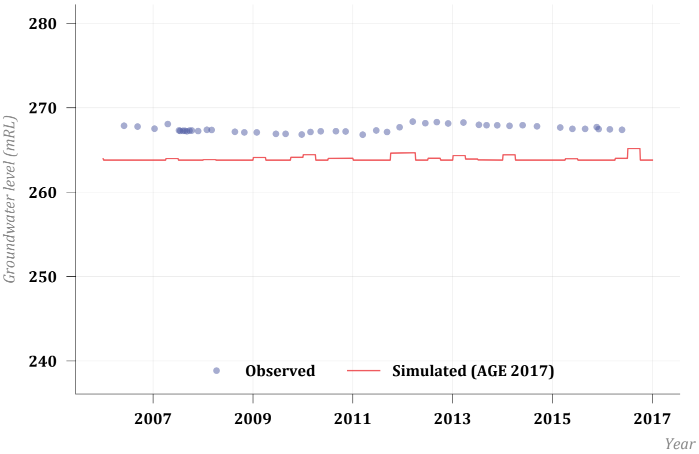


L01 MaulesCk Surroundings - Alluvium [Mod:L01PermianReg]



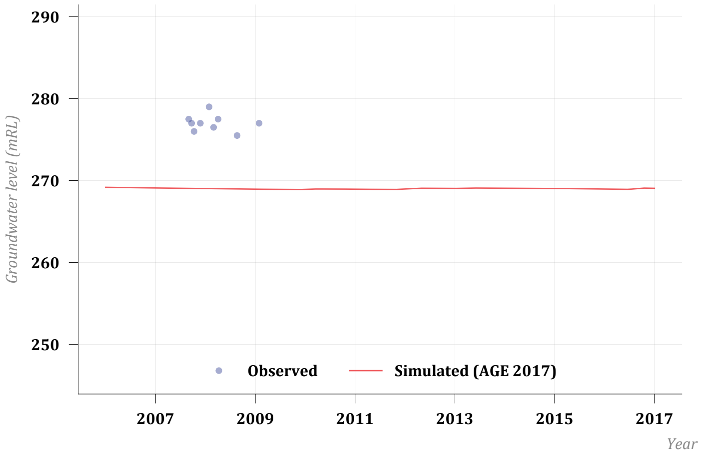
L01 Tarrawonga Surroundings - Permian Regolith

MW8

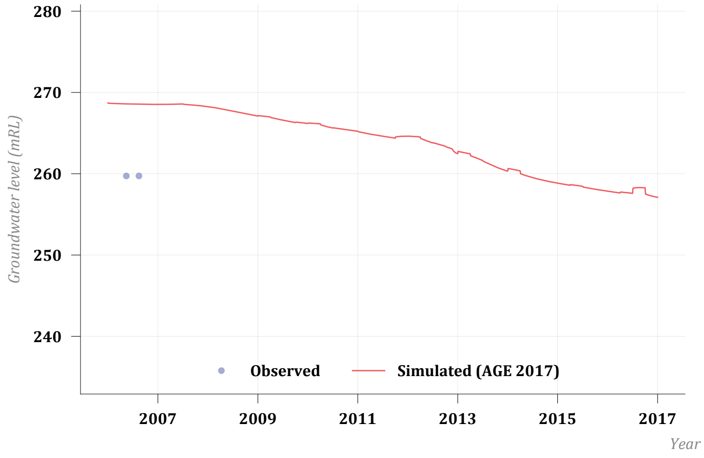


L02 Tarrawonga Surroundings - Alluvium

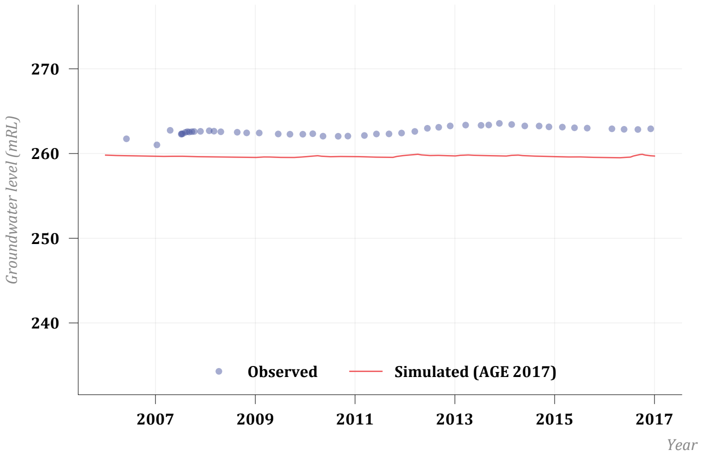
BCS7



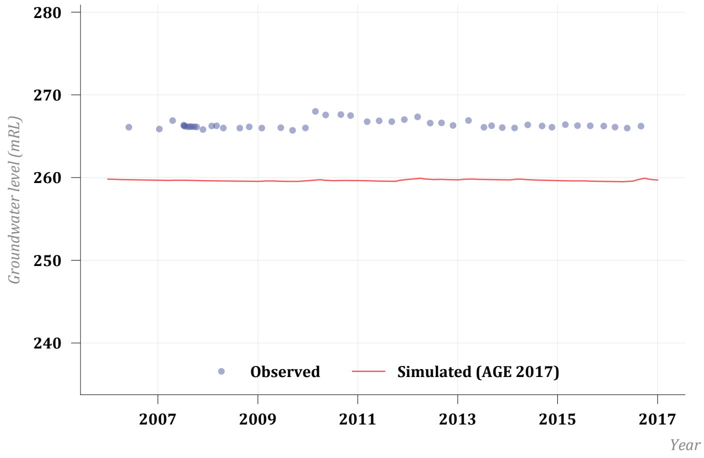
GW002129



MW1



MW2



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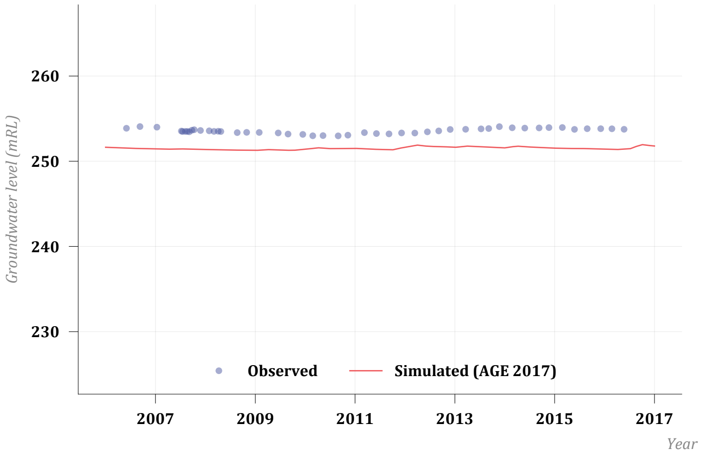

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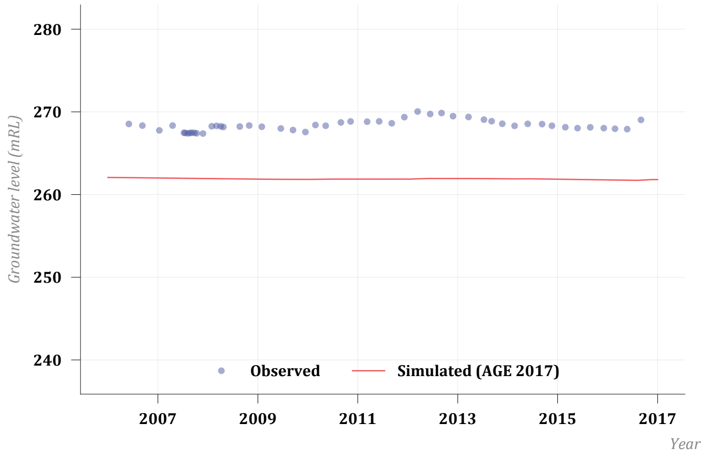

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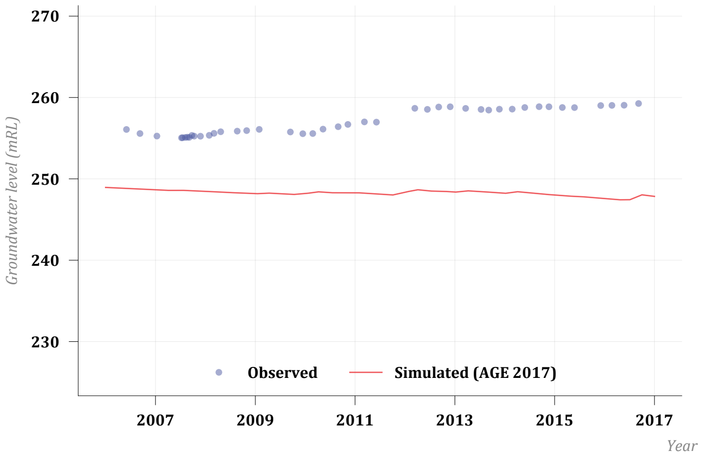
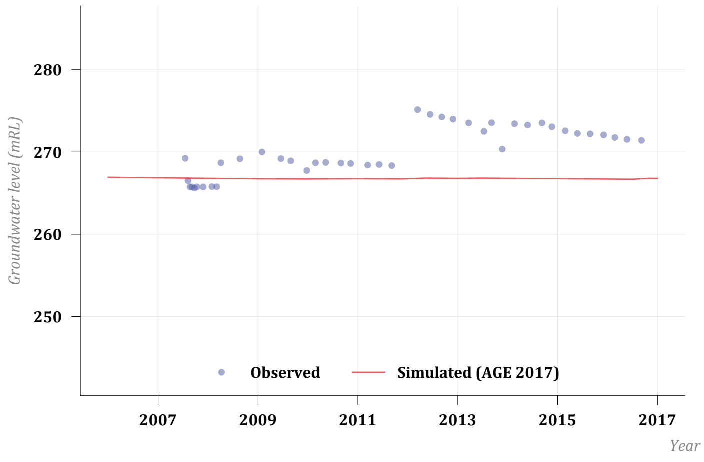
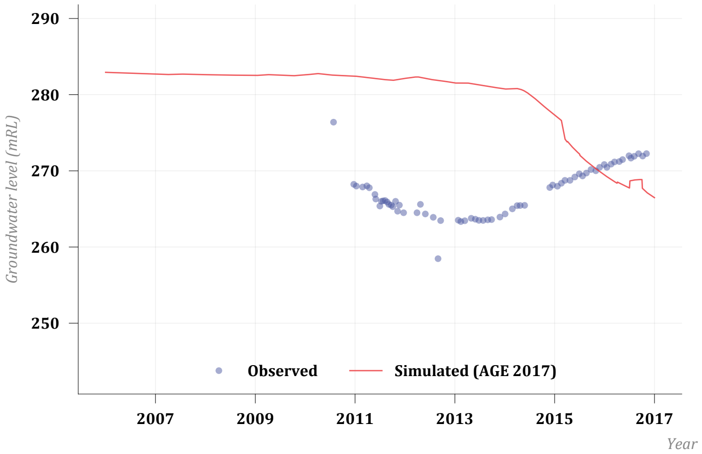


TEMPLE_A



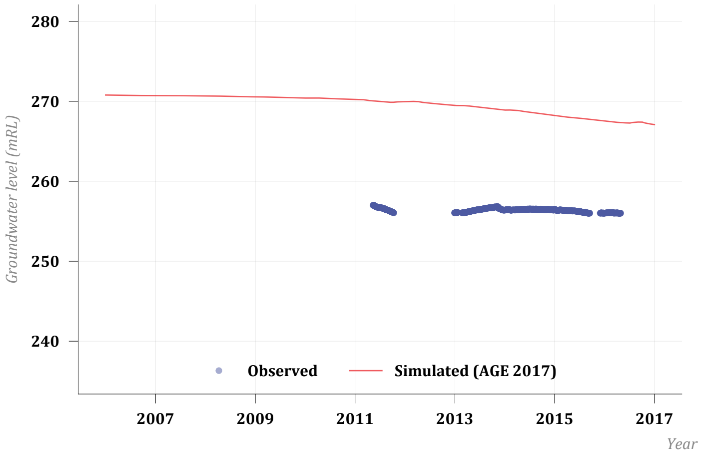
L06 MaulesCk Surroundings - Interburden

MAC1280



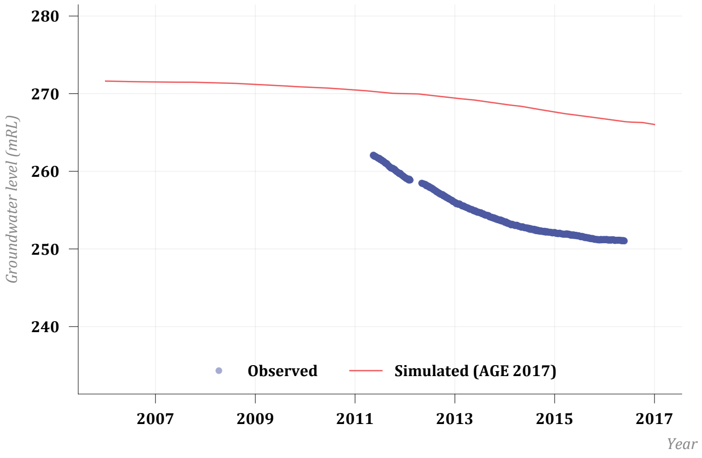
L06 Tarrawonga Pit - Interburden

TA65_V1

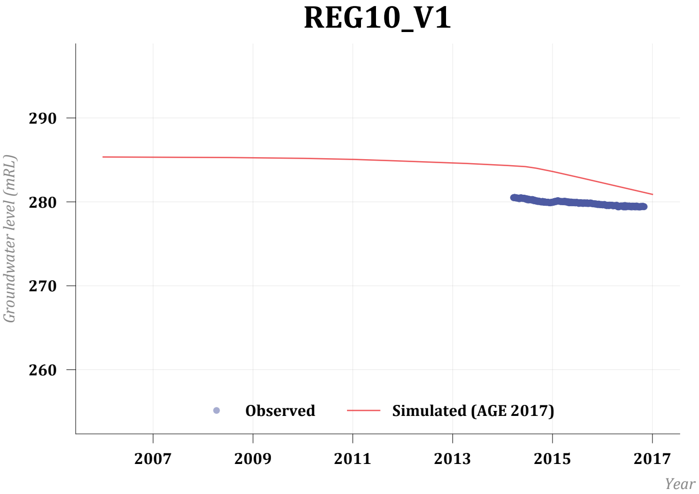


L07 Tarrawonga Pit - Interburden

TA65_V3

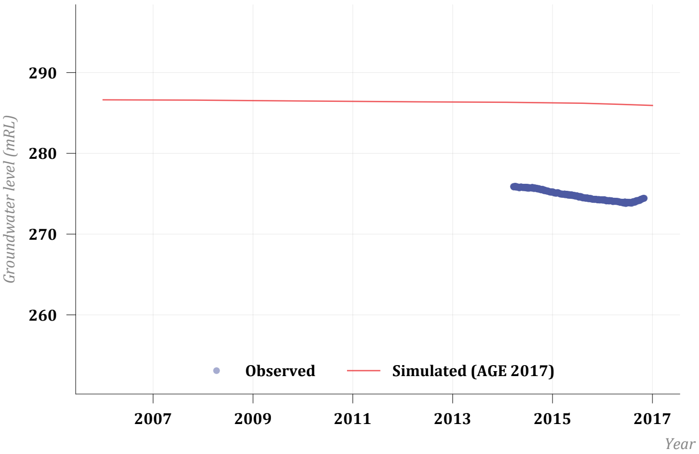


L08 North - Braymont

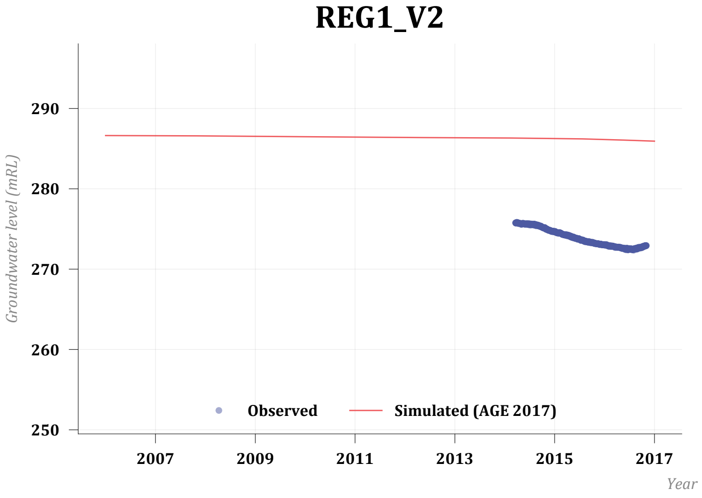


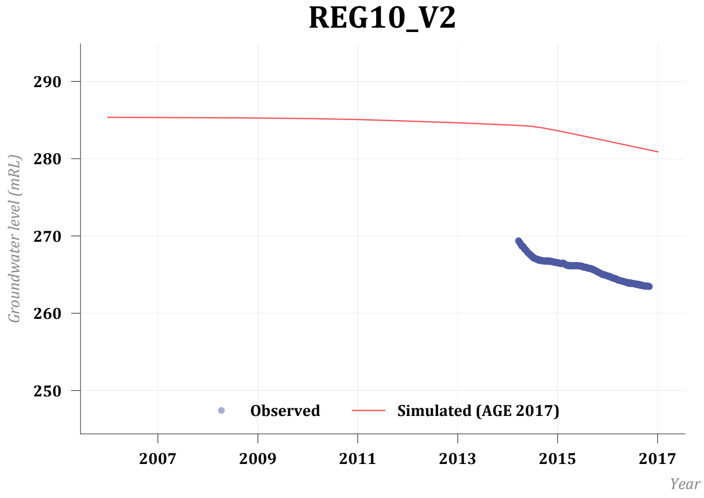
L08 North - Jeralong

REG1_V1



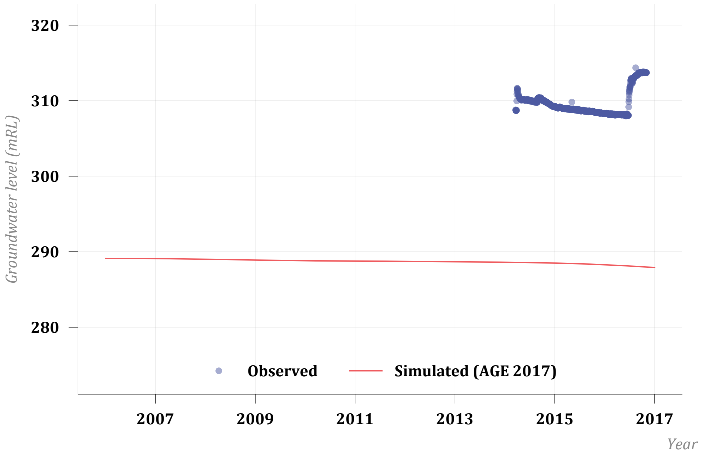
L08 North - Merriown





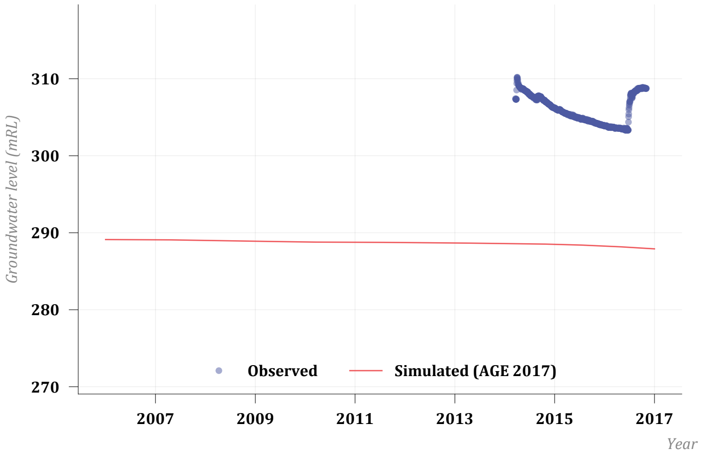
L08 Northeast - Braymont

REG2_V1



L08 Northeast - Jeralong

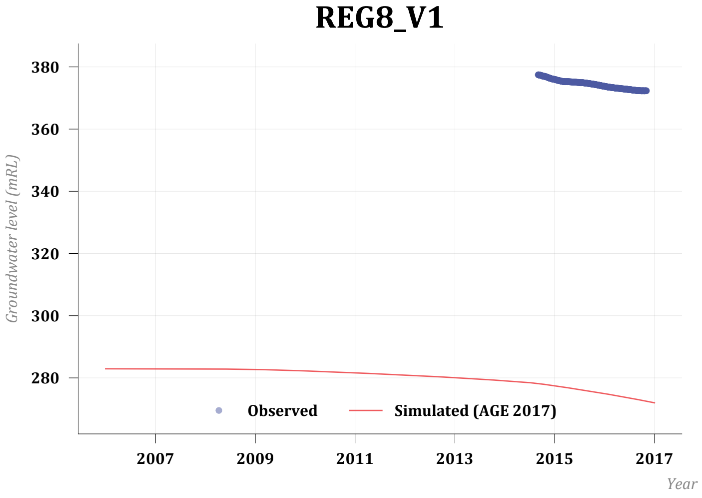
REG2_V2

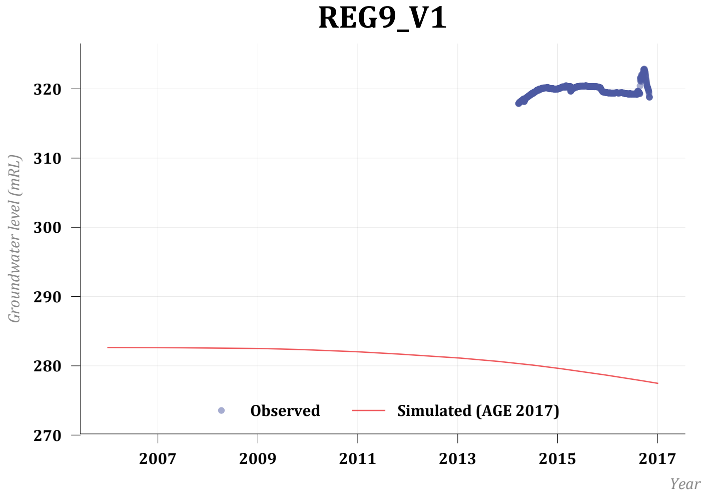


L08 Northeast - Merriown

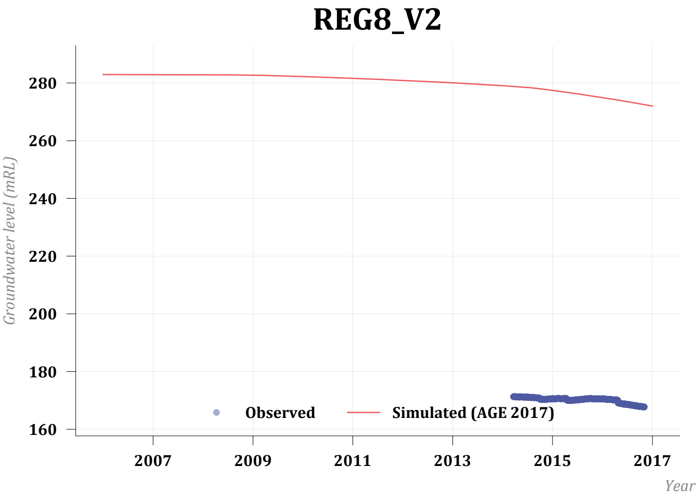
REG2_V3

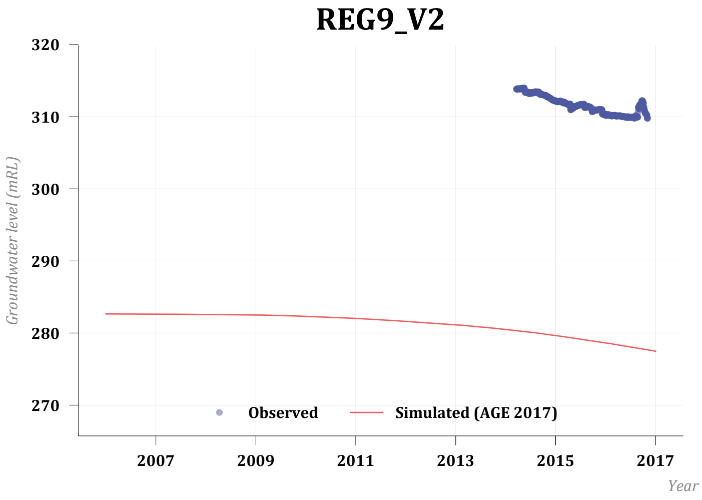
L08 East - Braymont



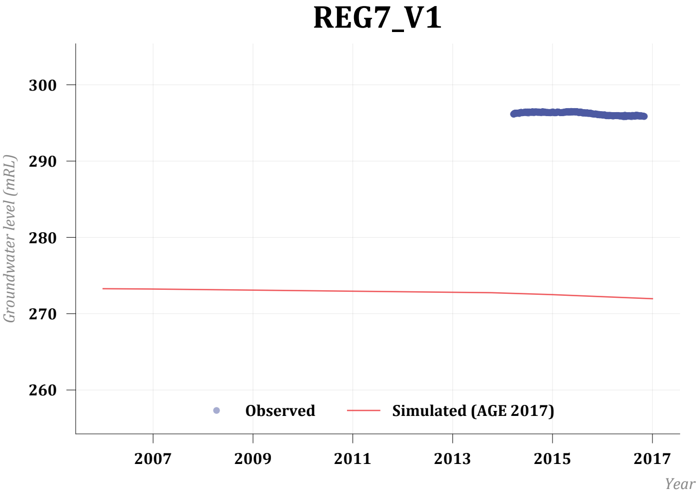


L08 East - Merriown

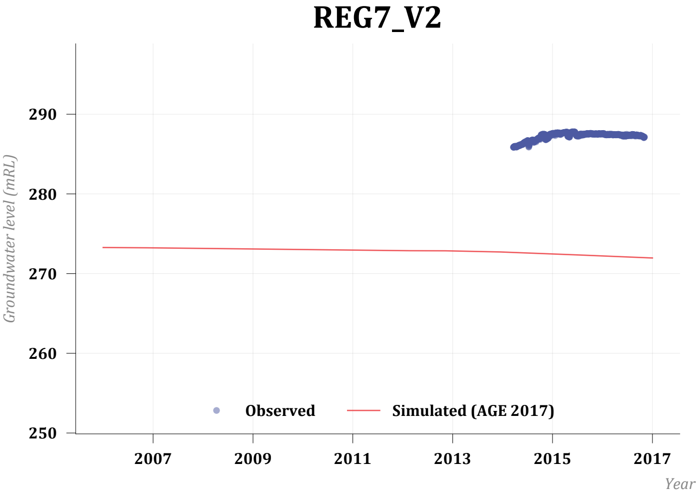




L08 Southeast - Braymont

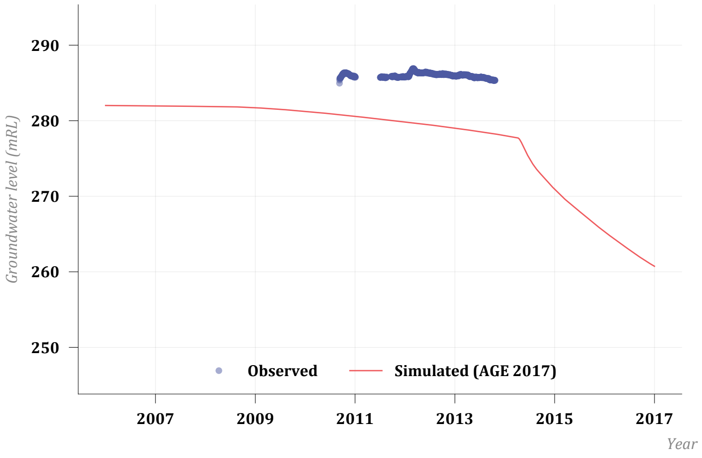


L08 Southeast - Merriown

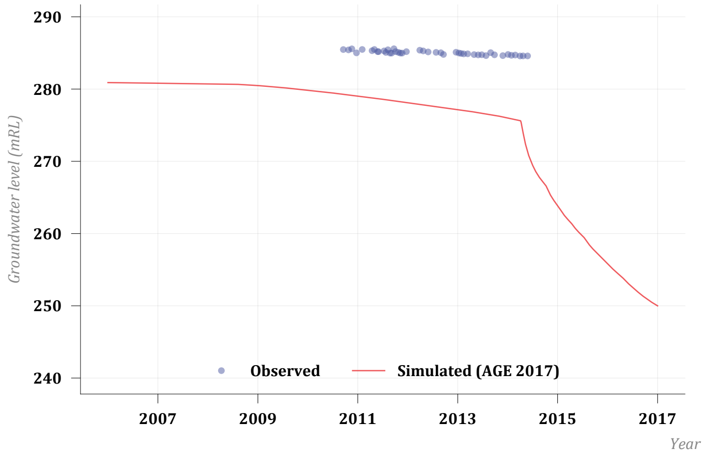


L08 MaulesCk Pit - Braymont

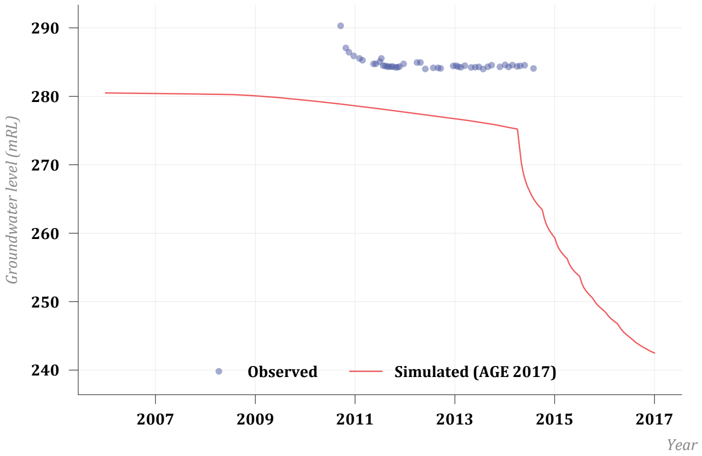
M267P_V1



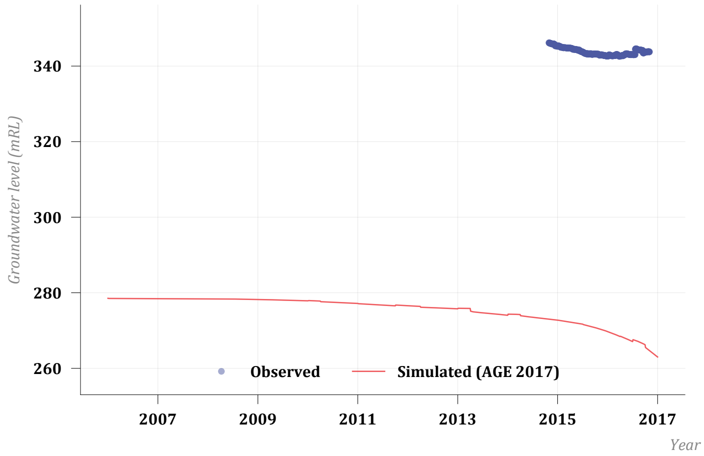
MAC1261



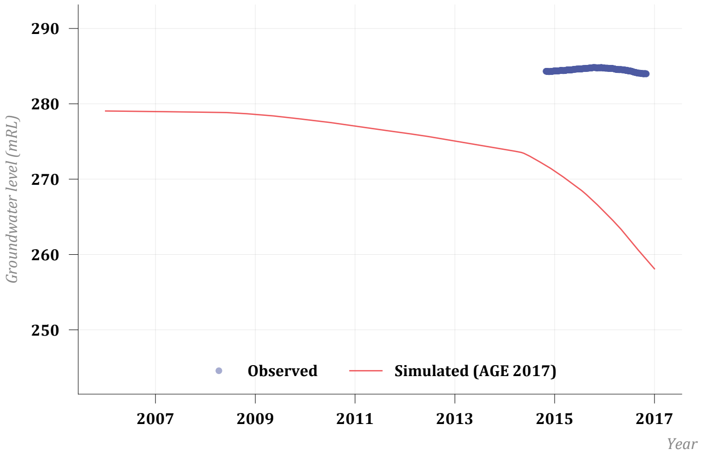
MAC252



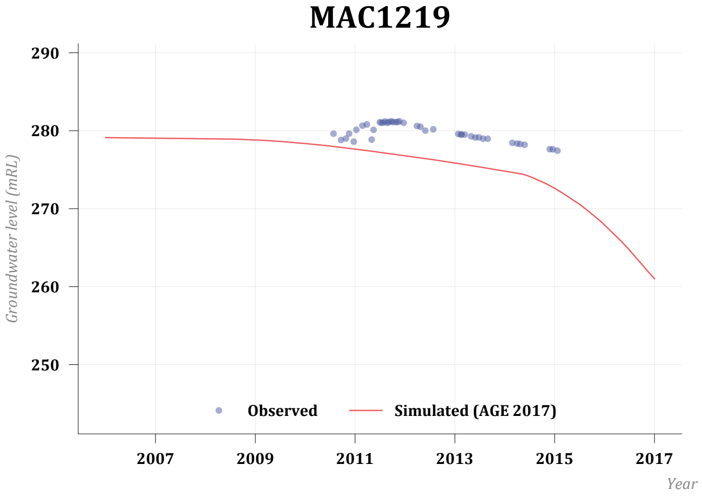
RB01_V1

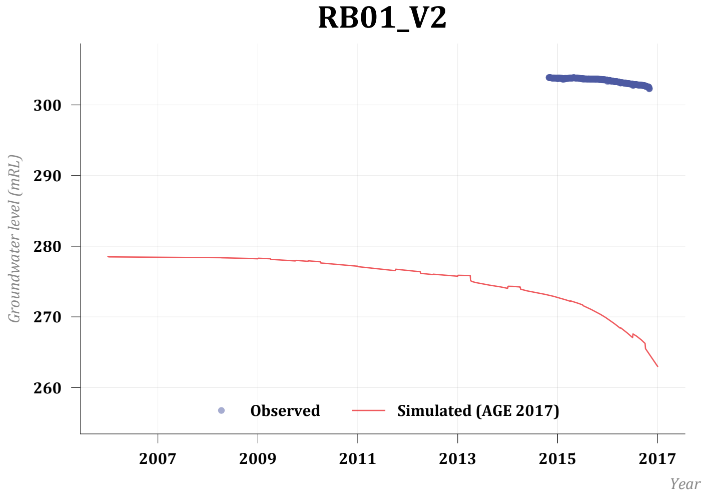


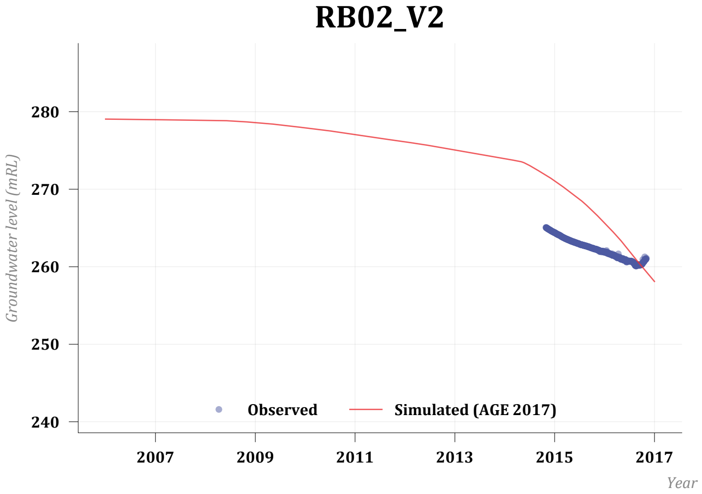
RB02_V1



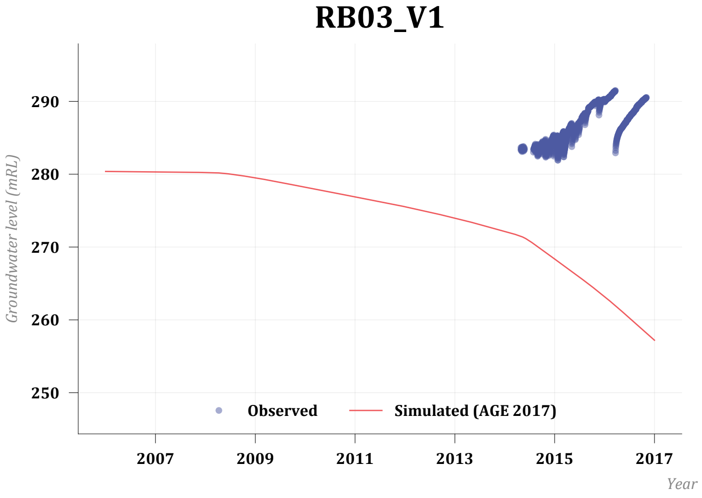
L08 MaulesCk Pit - Merriown

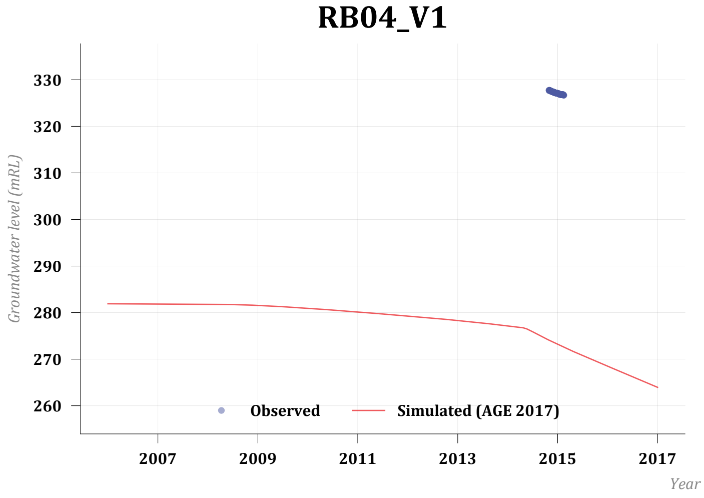


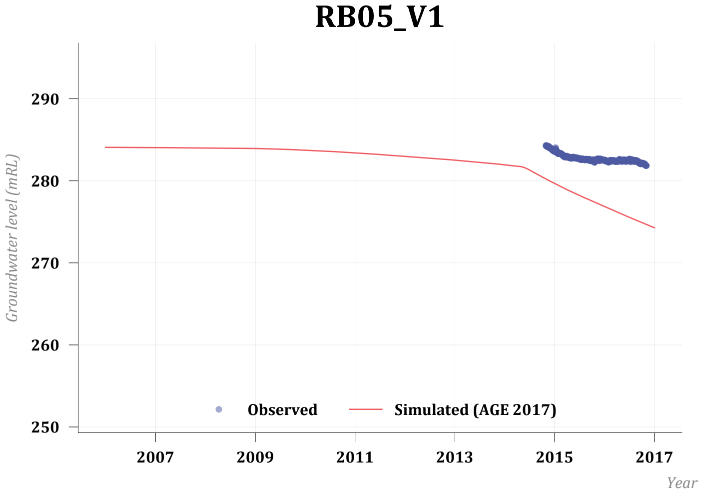




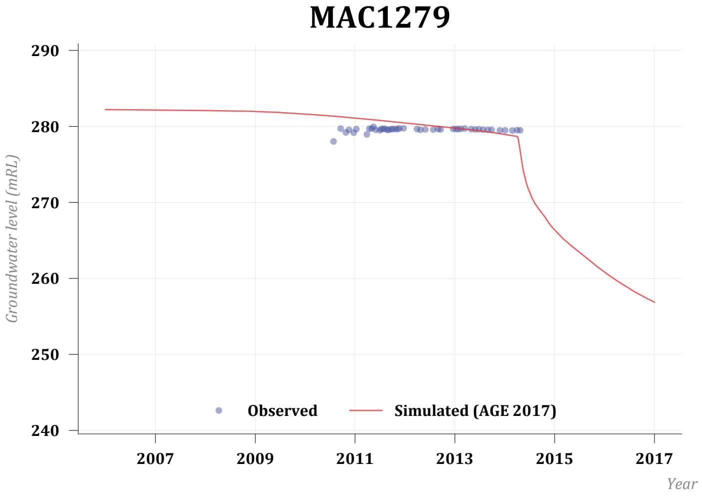
L08 MaulesCk Surroundings - Braymont

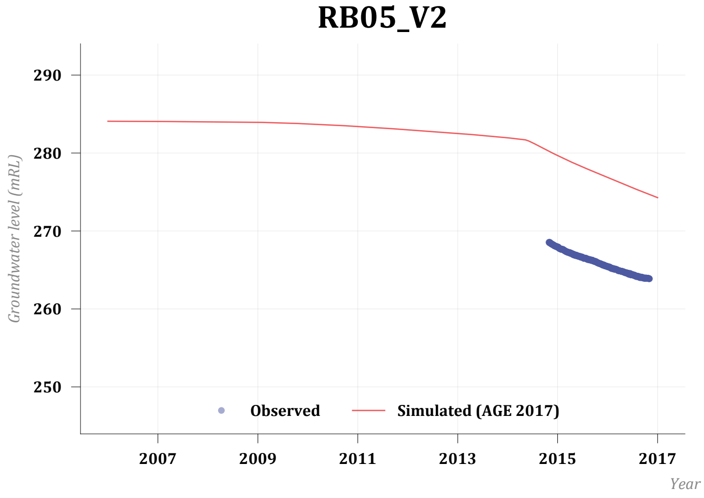




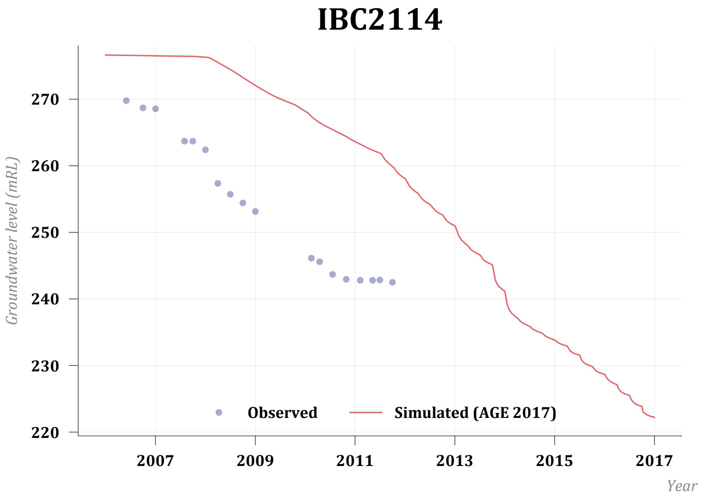


L08 MaulesCk Surroundings - Jeralong



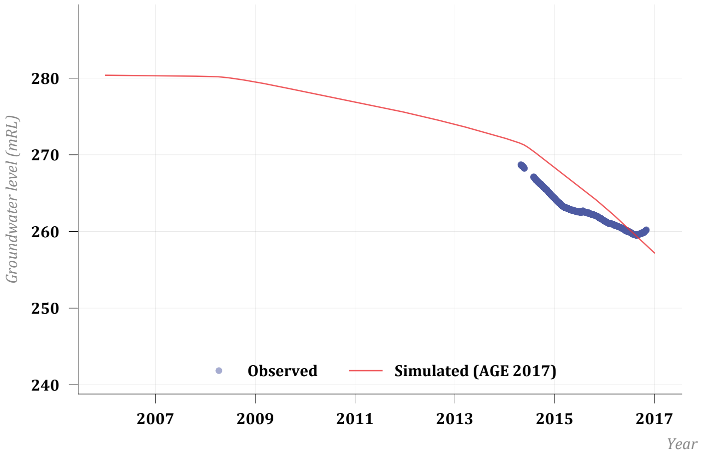


L08 Boggabri Pit - Bollol Creek Seam

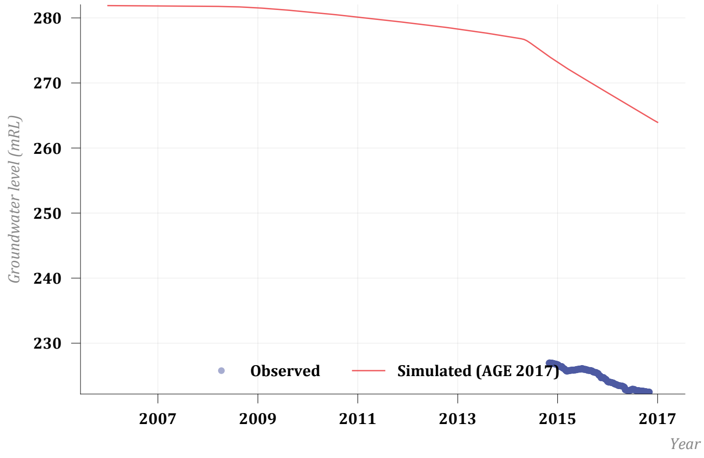


L08 MaulesCk Surroundings - Merriown

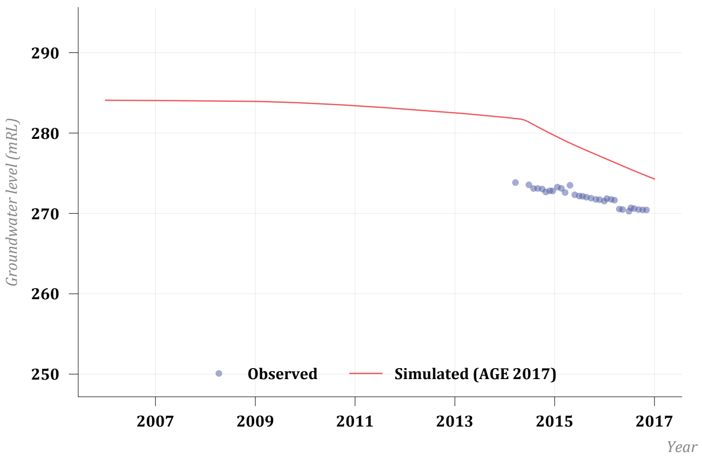
RB03_V2



RB04_V2

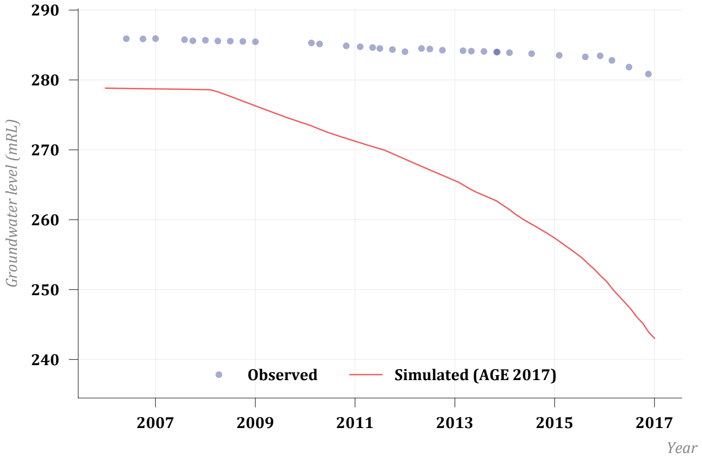


RB05A

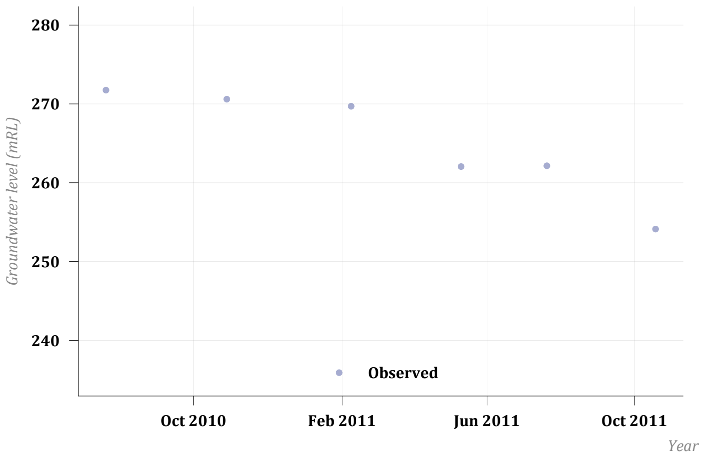


L08 Boggabri Pit - Braymont

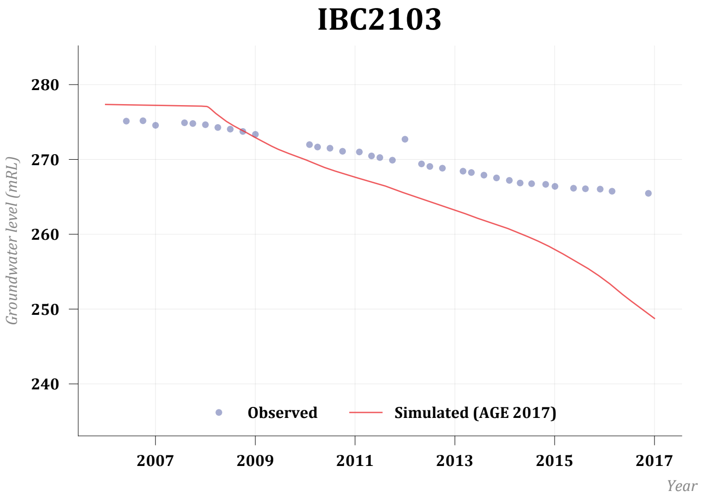
IBC2104



IBC2193

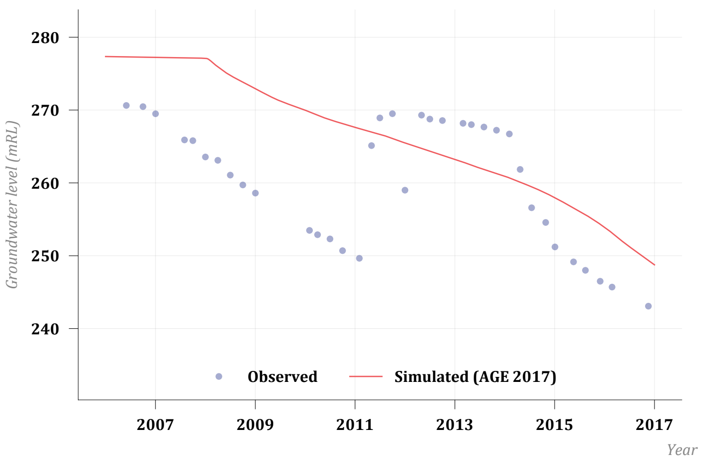


L08 Boggabri Pit - Jeralong

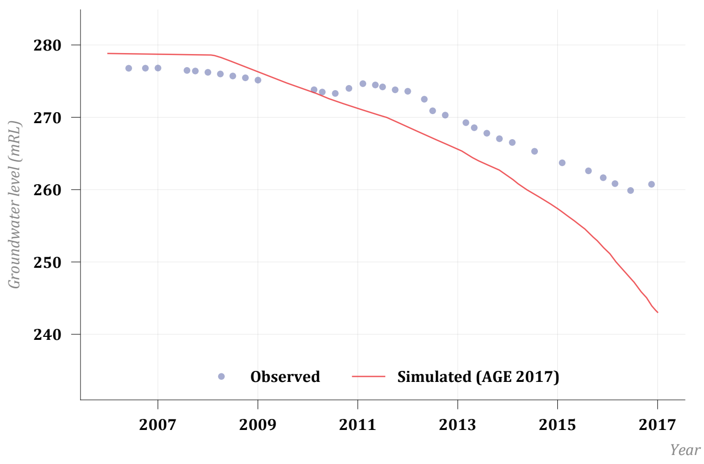


L08 Boggabri Pit - Merriown

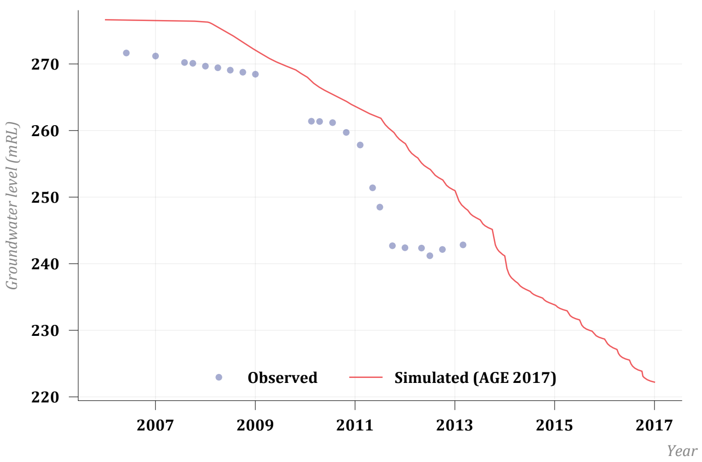
IBC2102



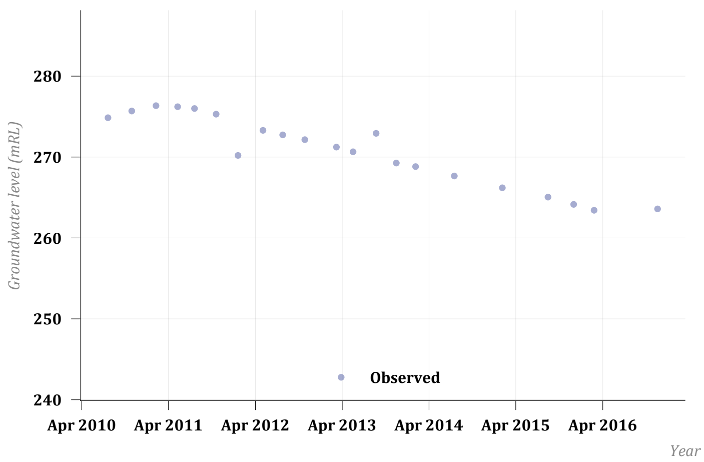
IBC2105



IBC2115

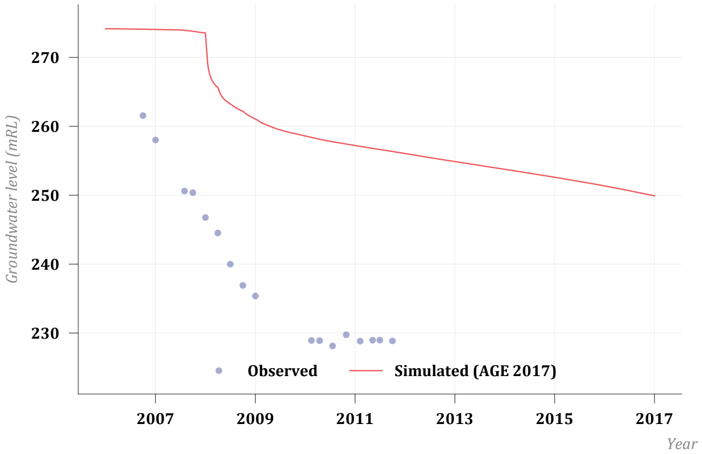


IBC2181

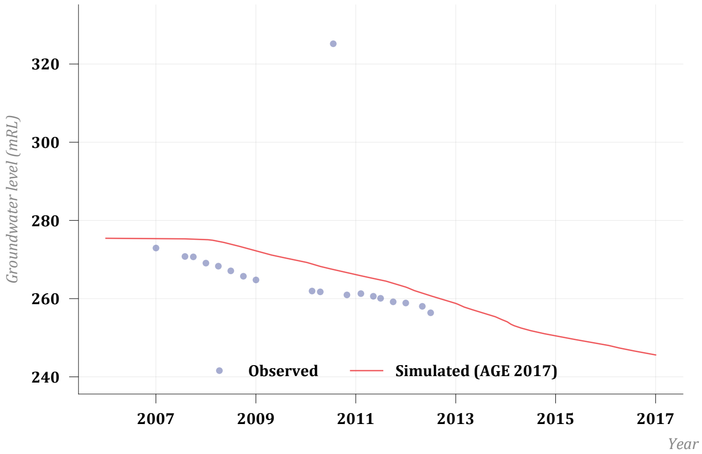


L08 Boggabri Surroundings - Merriown

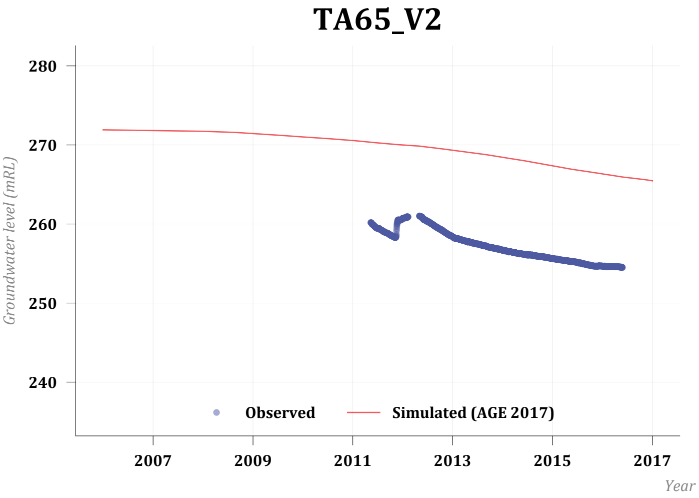
IBC2138



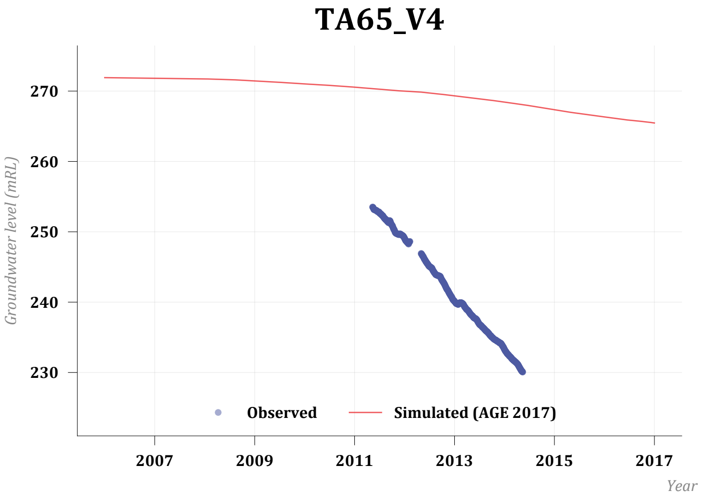
IBC2139



L08 Tarrawonga Pit - Jeralong

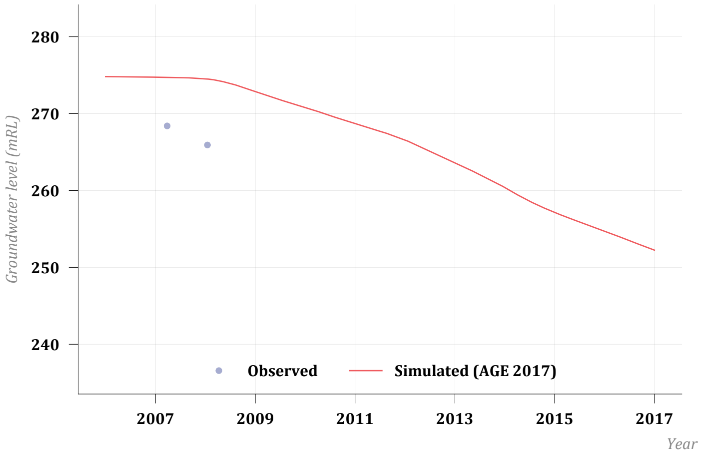


L08 Tarrawonga Pit - Merriown



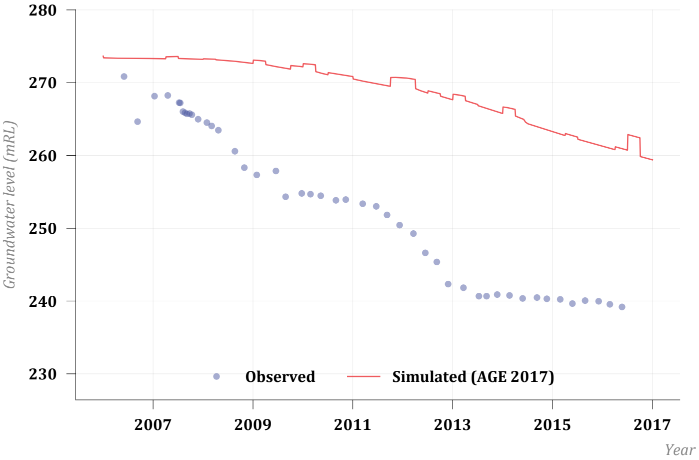
L08 Tarrawonga Surroundings - Merriown

IBC2113

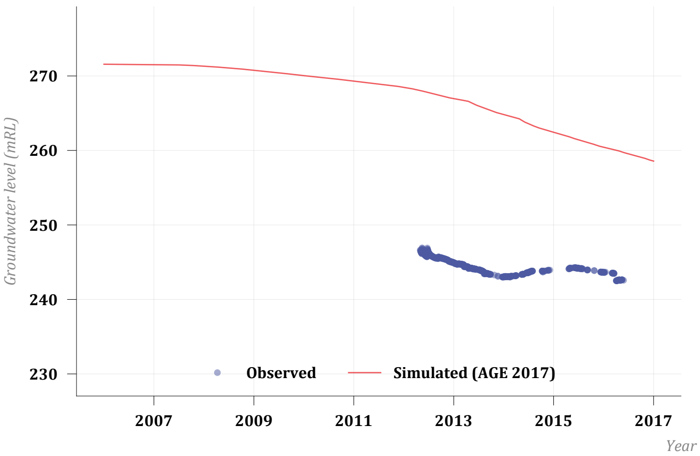


L09 Tarrawonga Pit - Interburden

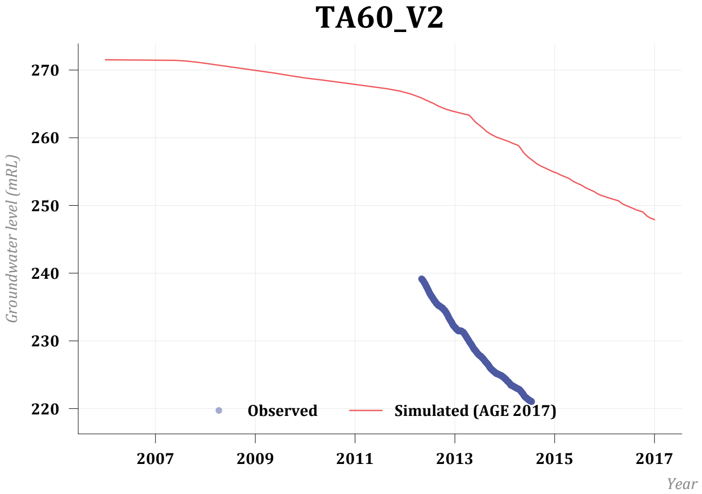
MW7

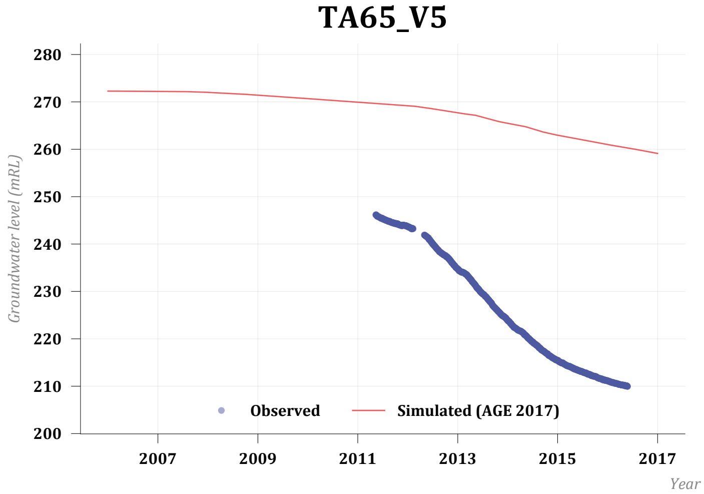


TA60_V1



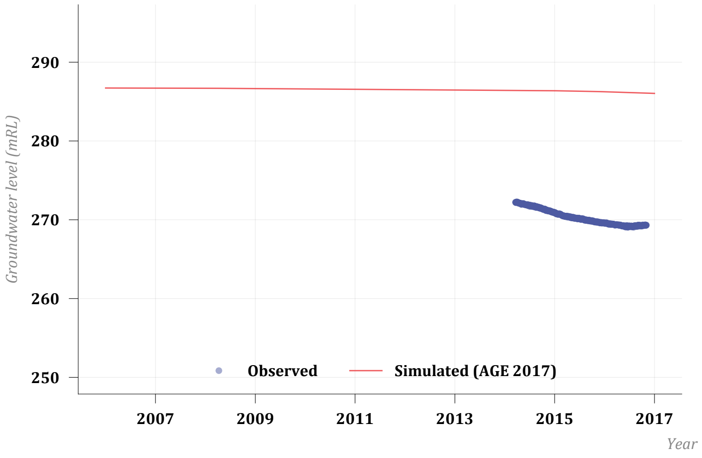
L10 Tarrawonga Pit - Interburden



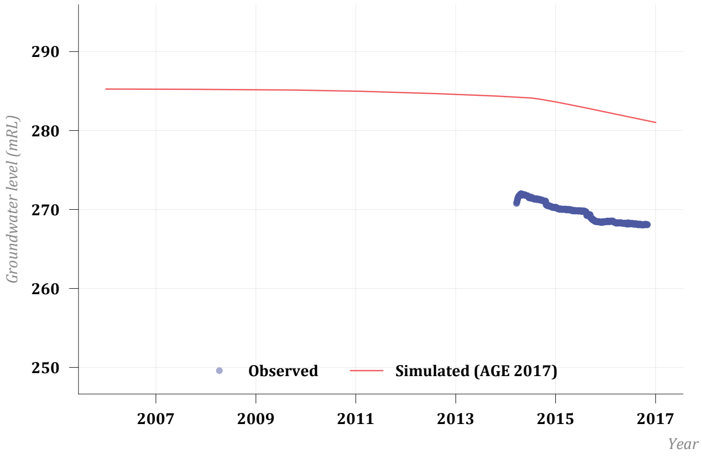


L11 North - Nagero

REG1_V3

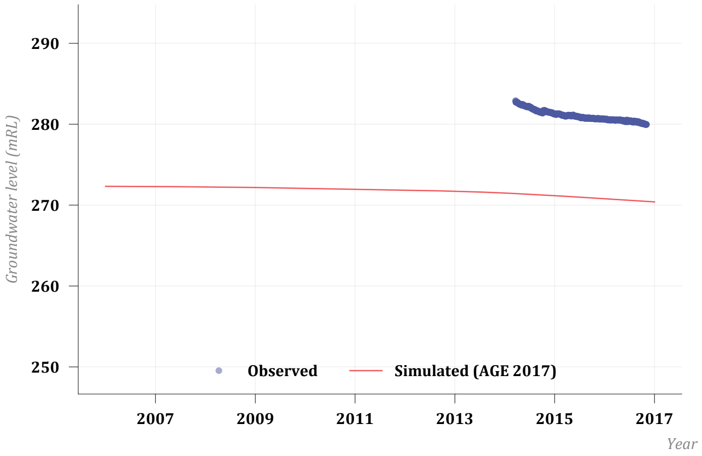


REG10_V3

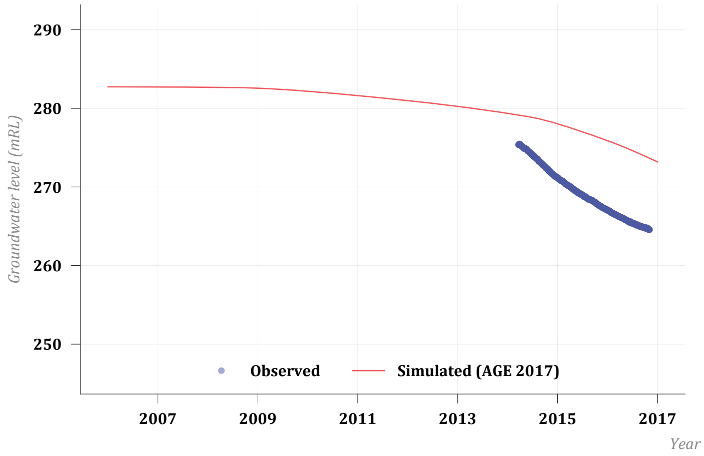


L11 East - Nagero

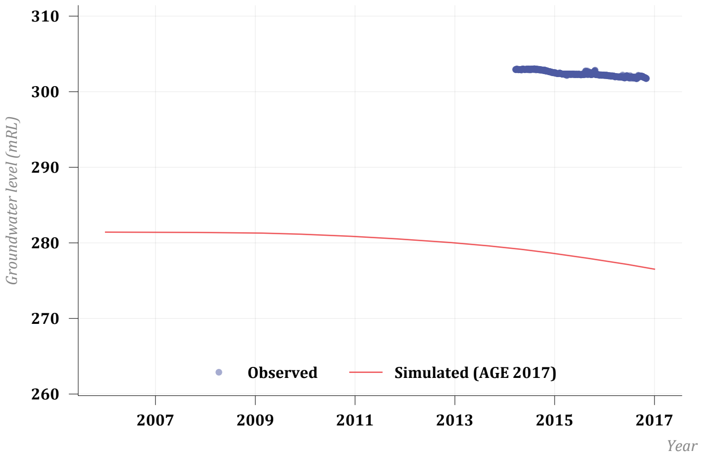
REG7_V3



REG8_V3



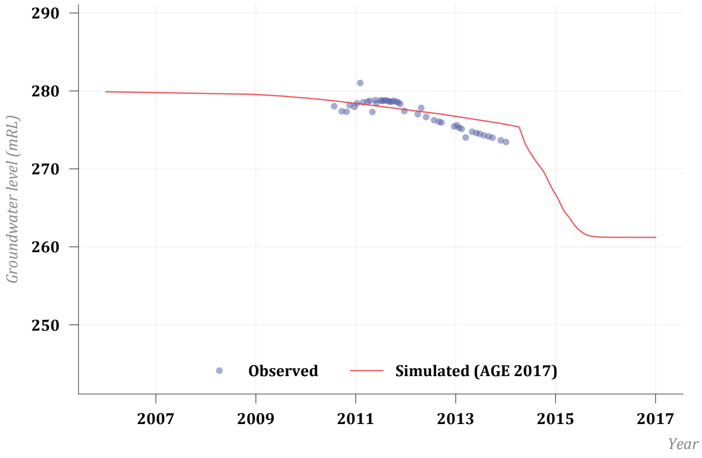
REG9_V3



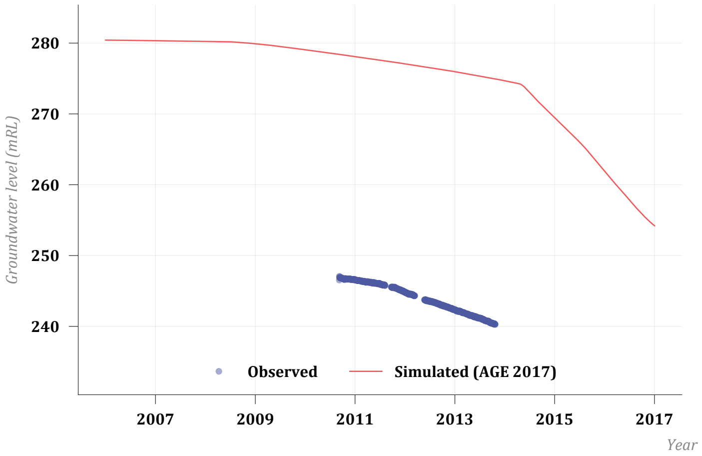
L11 MaulesCk Pit - Velyama

M267P_V2

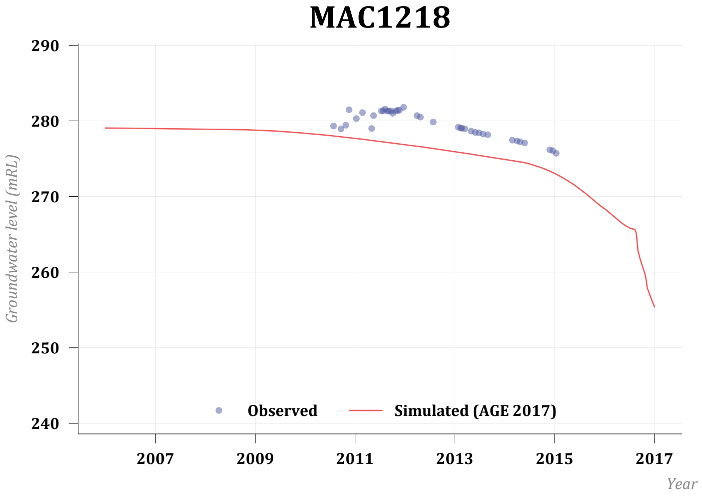
MAC1283

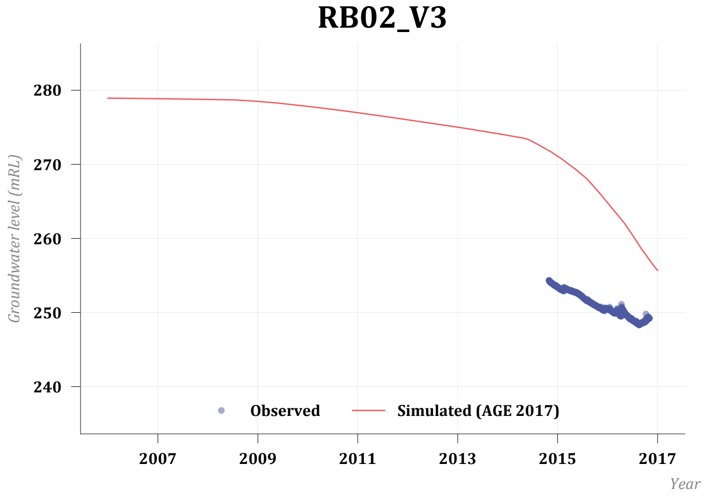


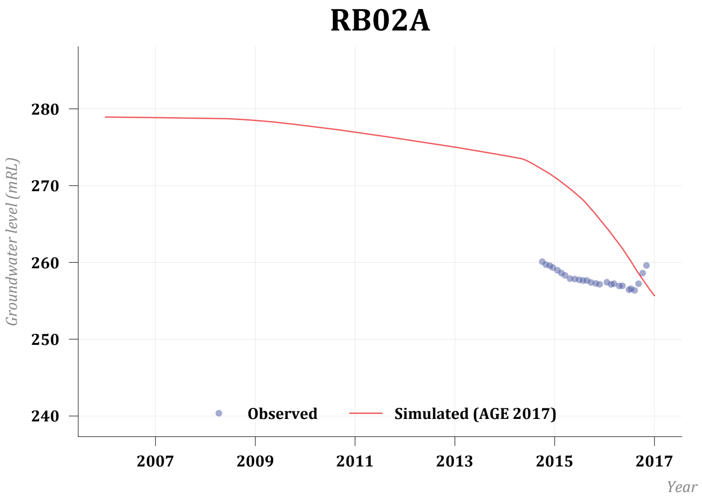
MAC268P



L11 MaulesCk Pit - Nagero

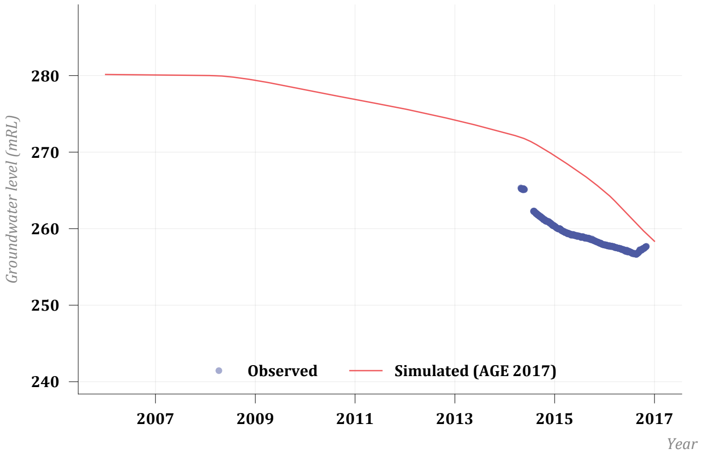




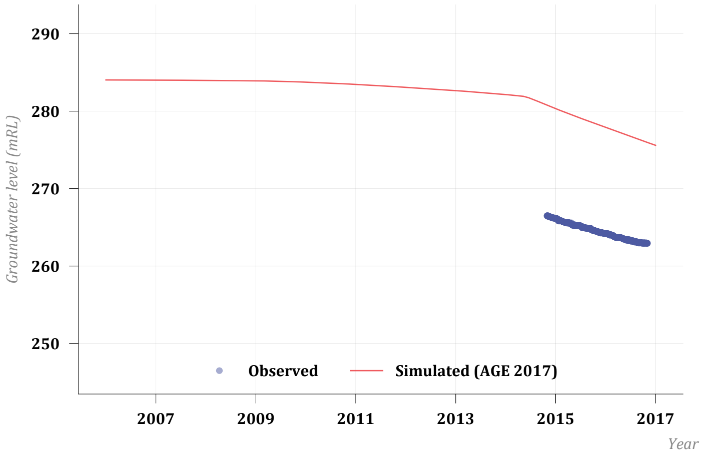


L11 MaulesCk Surroundings - Nagero

RB03_V3

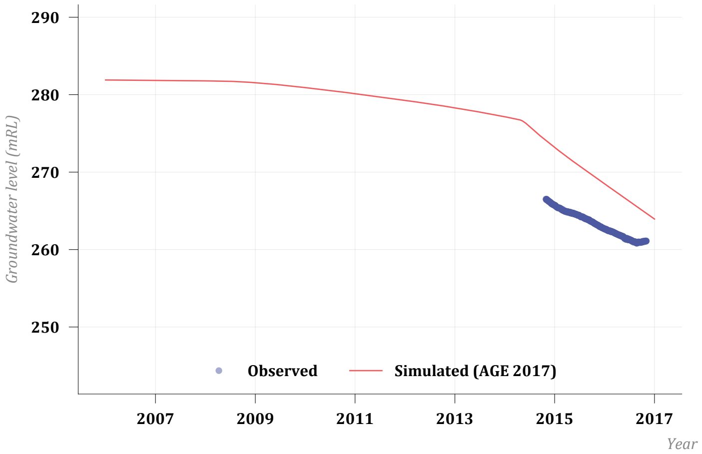


RB05_V3

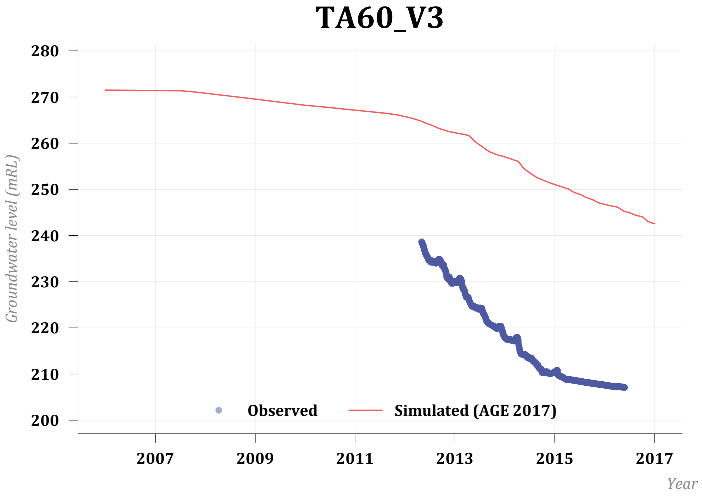


L11 MaulesCk Surroundings - Nagero [Mod:L08]

RB04_V3

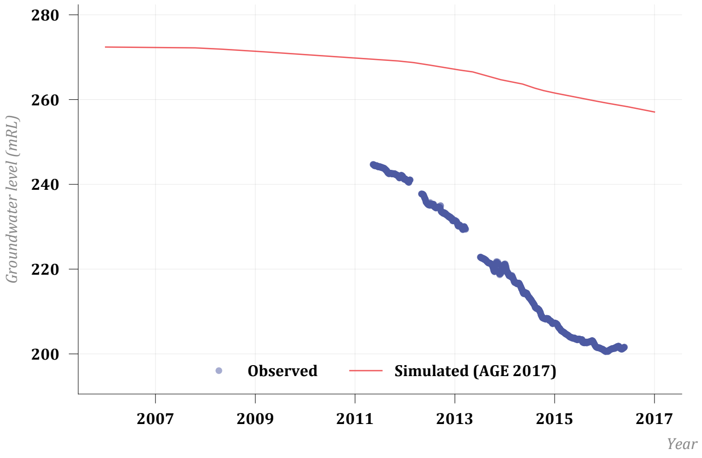


L11 Tarrawonga Pit - Velyama

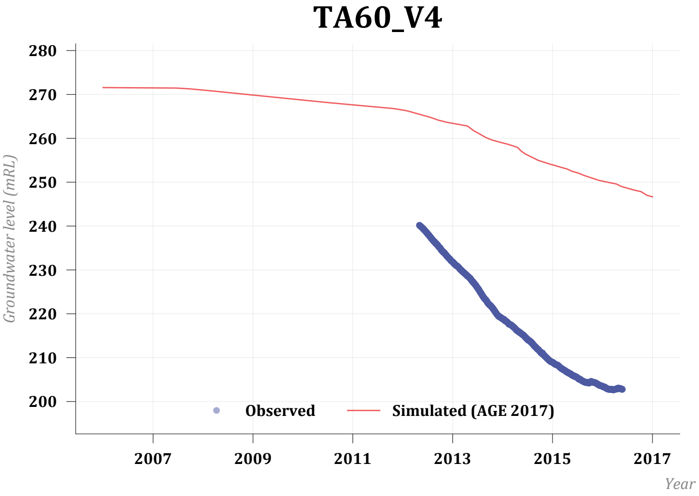


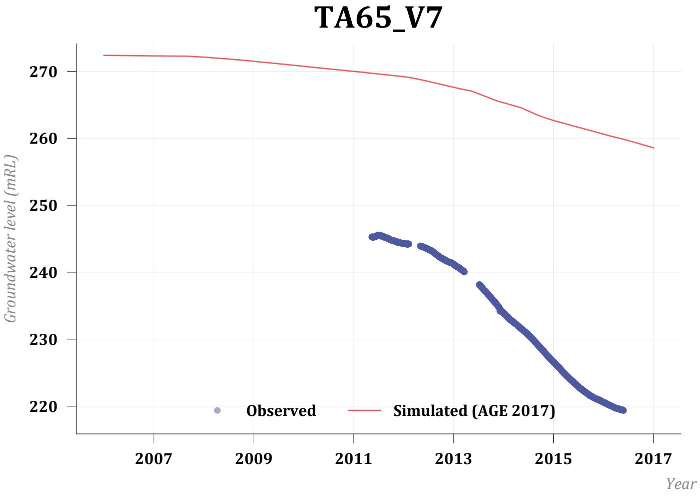
L11 Tarrawonga Pit - Nagero

TA65_V6



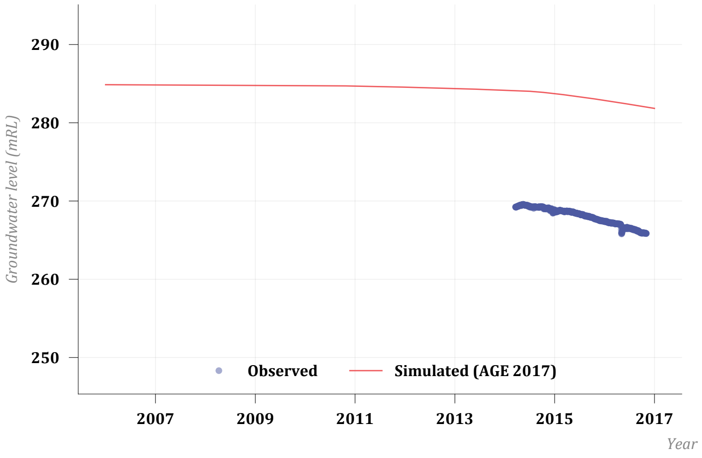
L12 Tarrawonga Pit - Interburden





L14 North - Northam

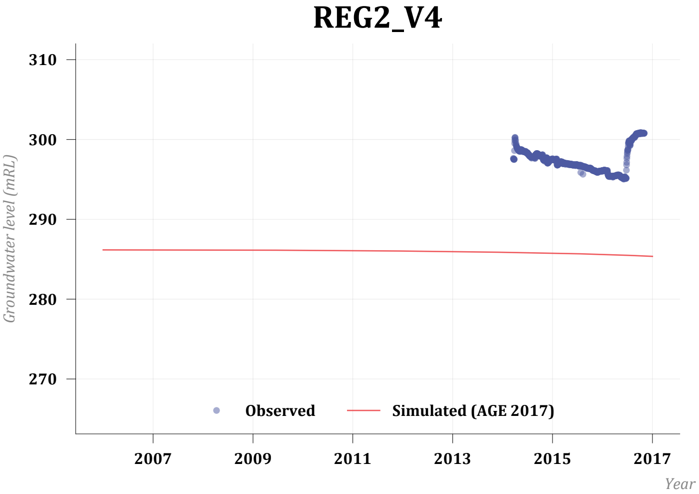
REG10_V4



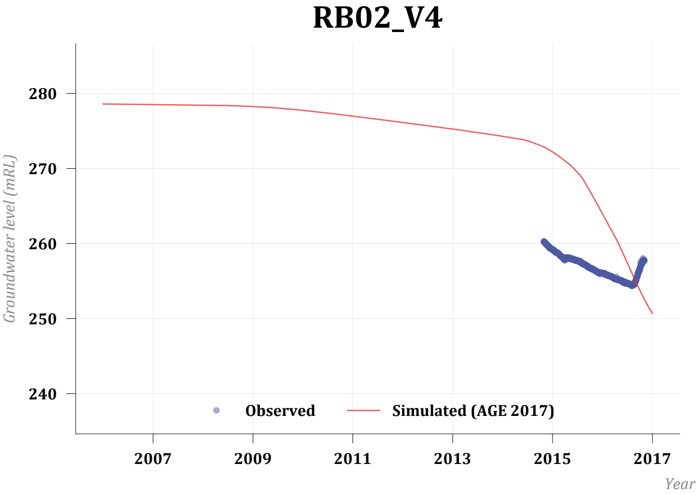
L14 North - Therribri

REG1_V4

L14 Northeast - Therribri

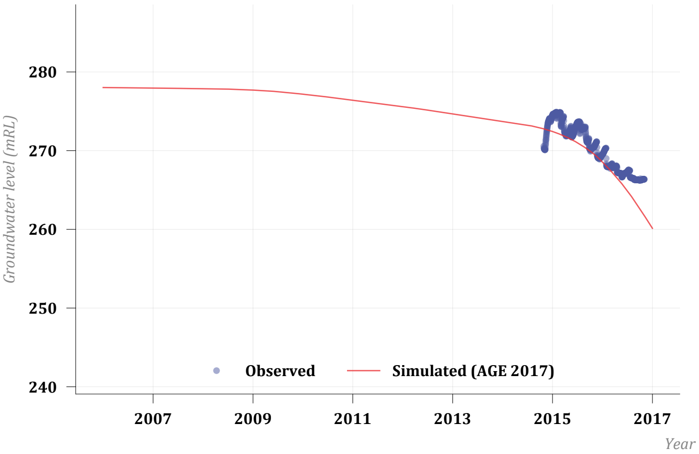


L14 MaulesCk Pit - Northam



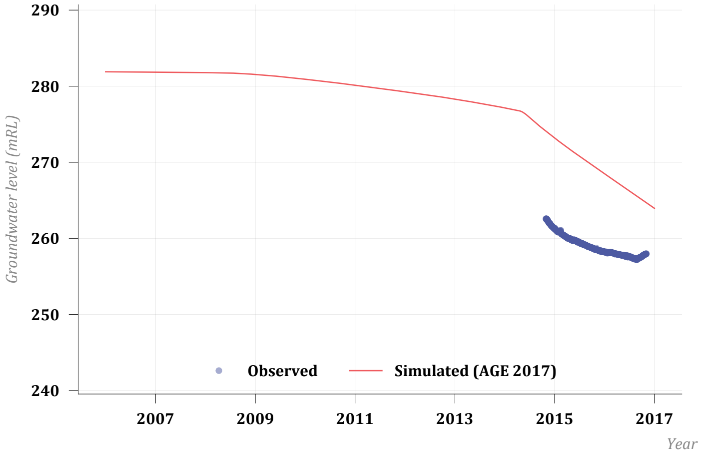
L14 MaulesCk Pit - Flixston

RB01_V3



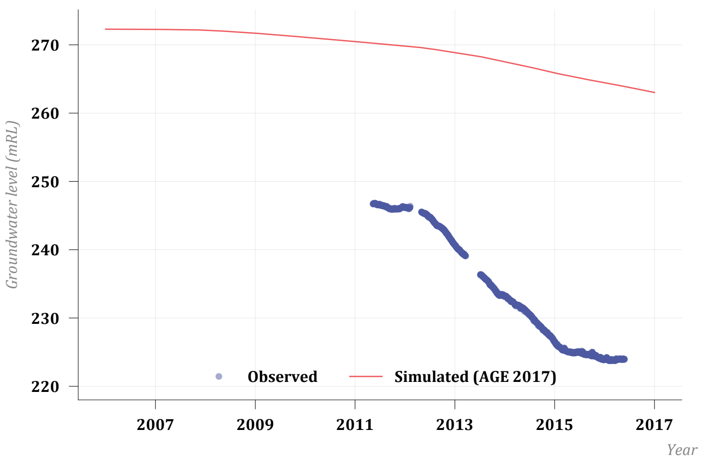
L14 MaulesCk Surroundings - Northam [Mod:L08]

RB04_V4



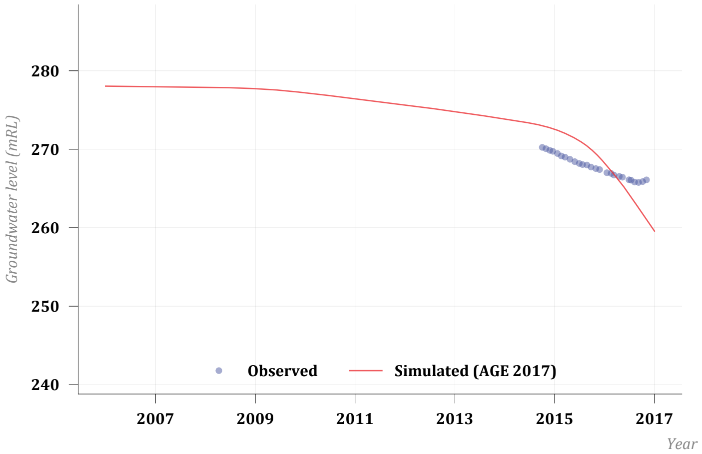
L14 Tarrawonga Pit - Northam

TA65_V8

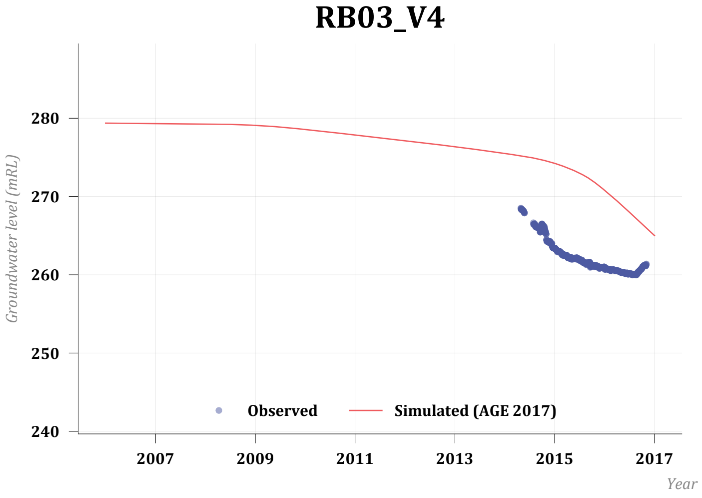


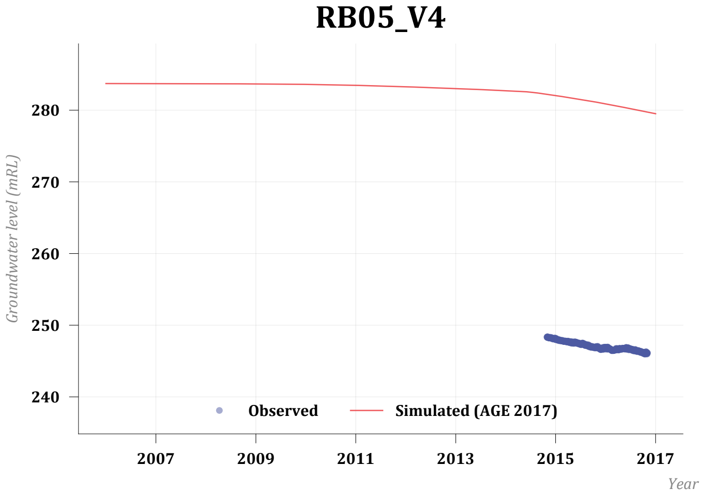
L17 MaulesCk Pit - Templemore

RB01A



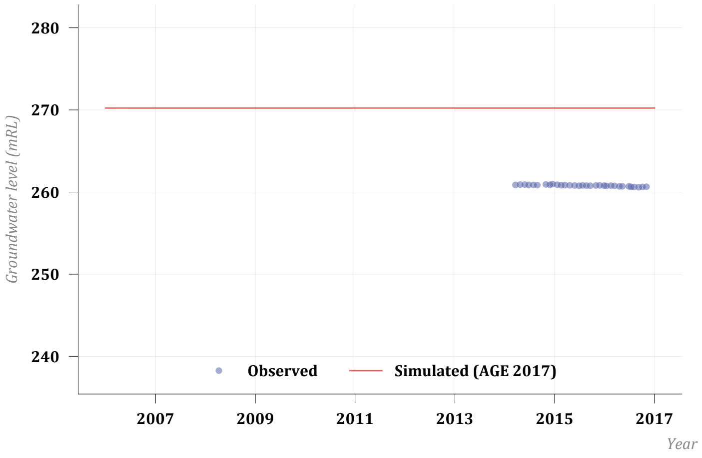
L17 MaulesCk Surroundings - Templemore





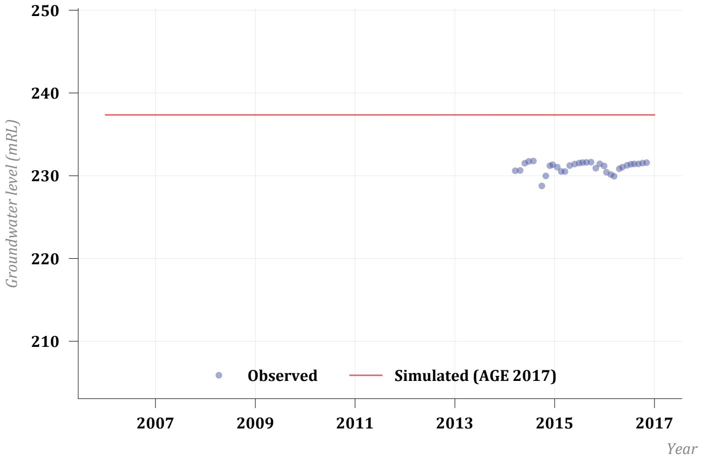
L19 West - Basalt

REG12

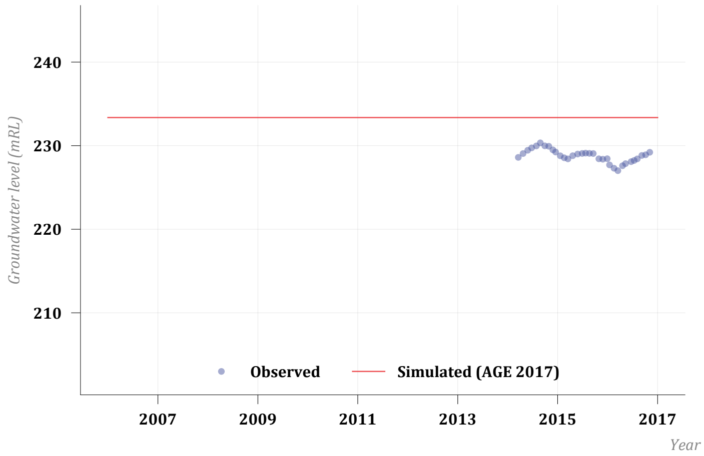


REG13

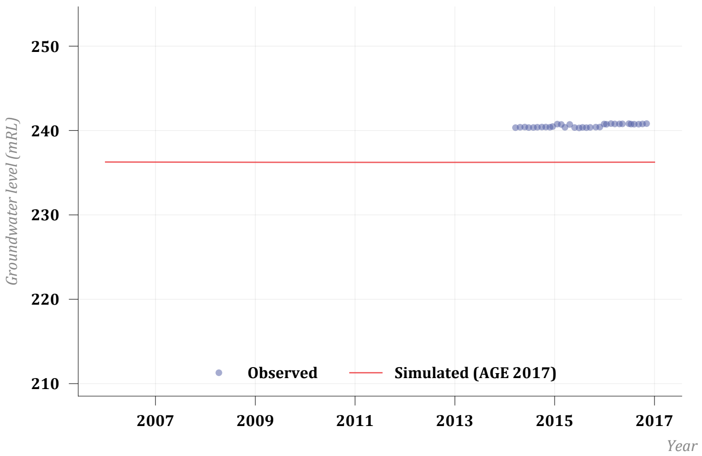
REG14



REG3

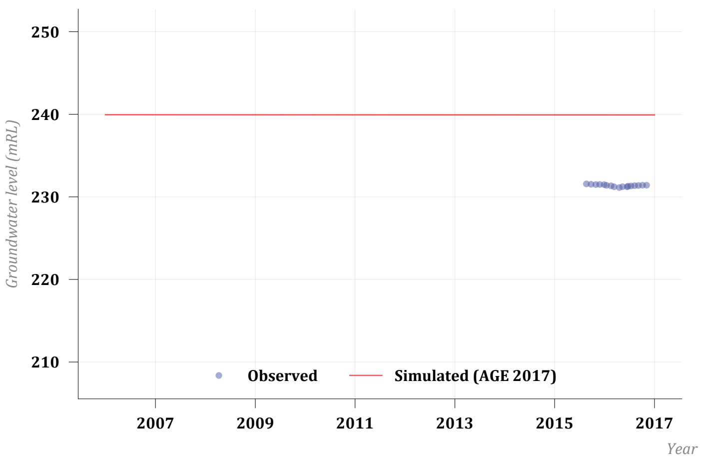


REG4



REG5

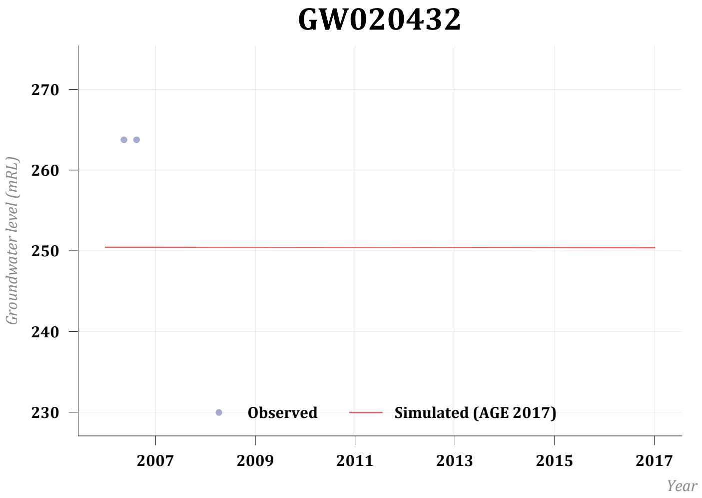
REG6

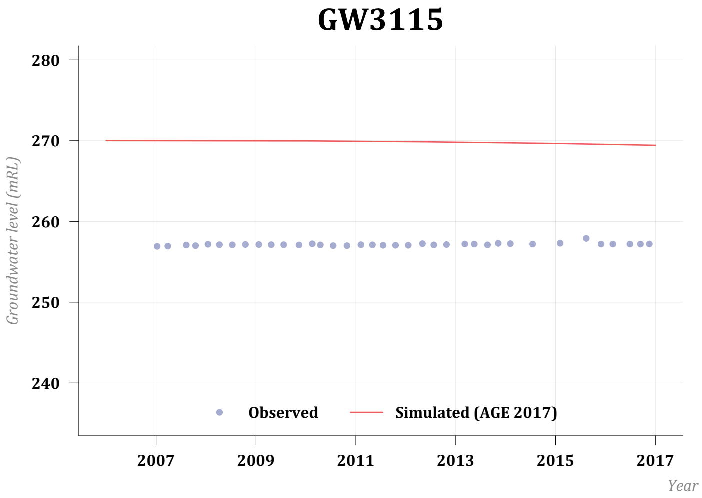


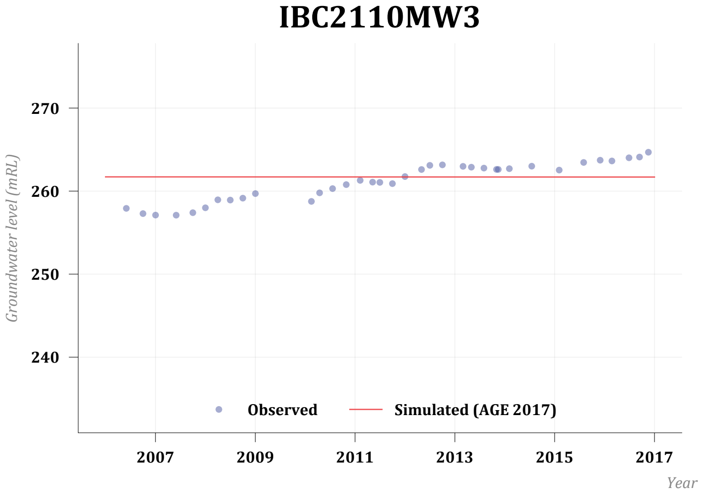
Tarrawonga Surroundings - Interburden [Mod:L19Basalt]

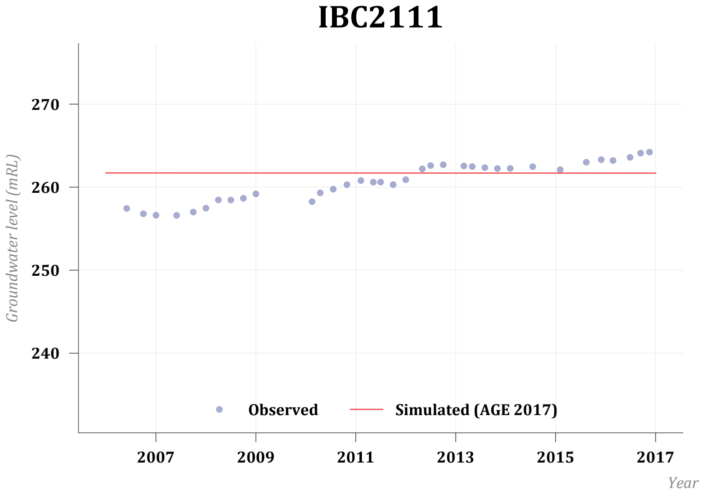
GW002501

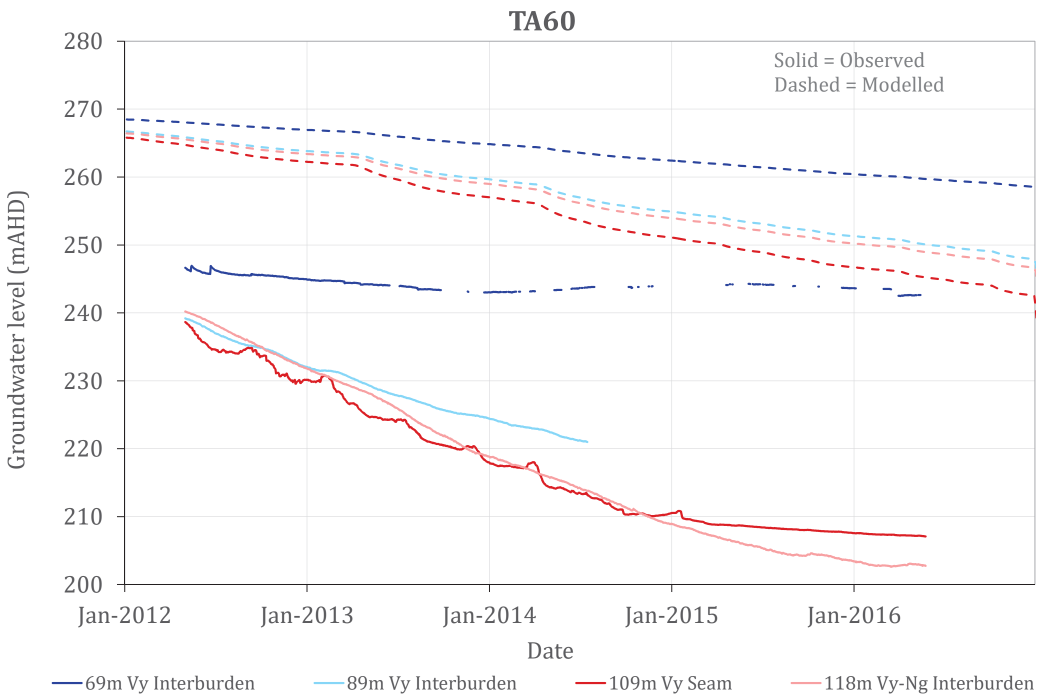
L19 Central West - Basalt

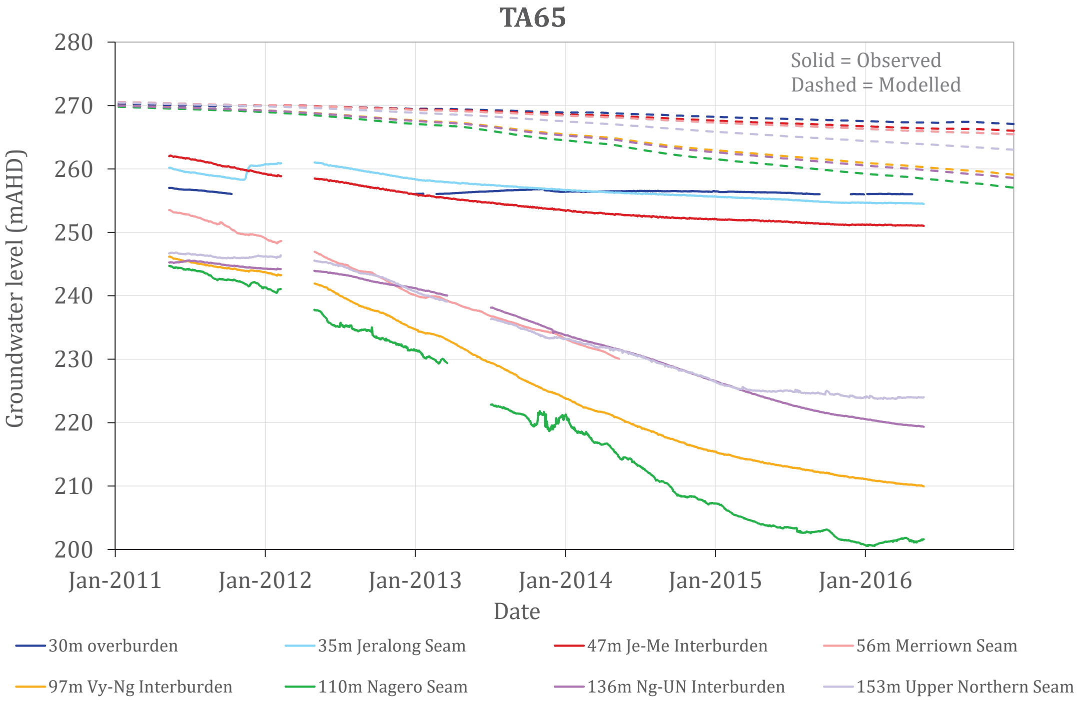


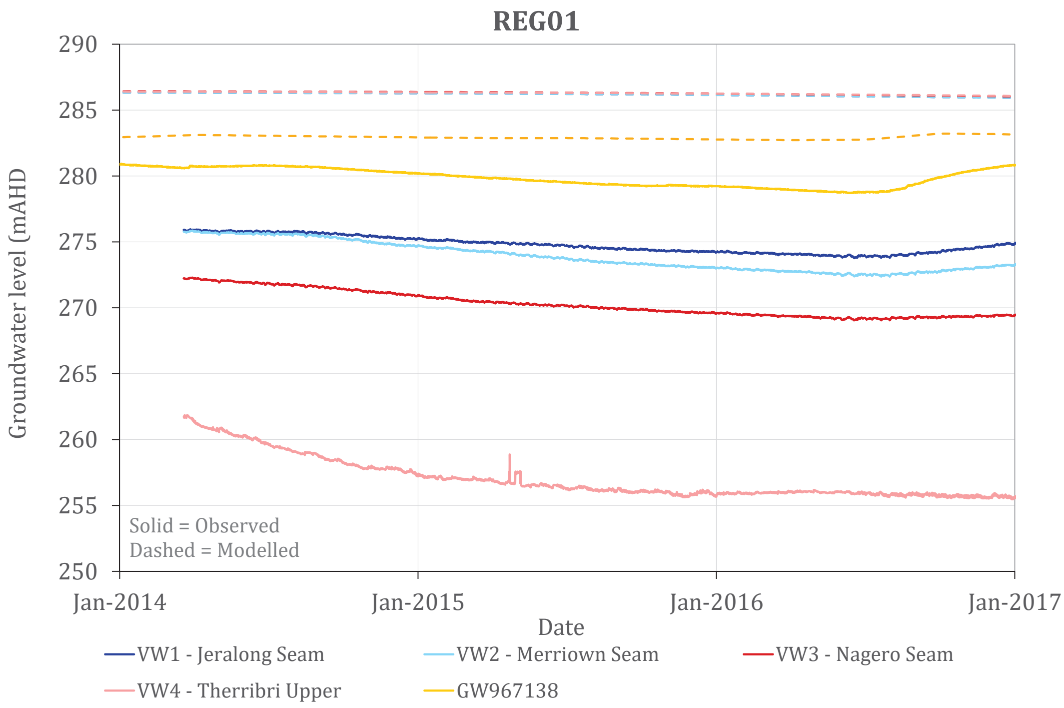


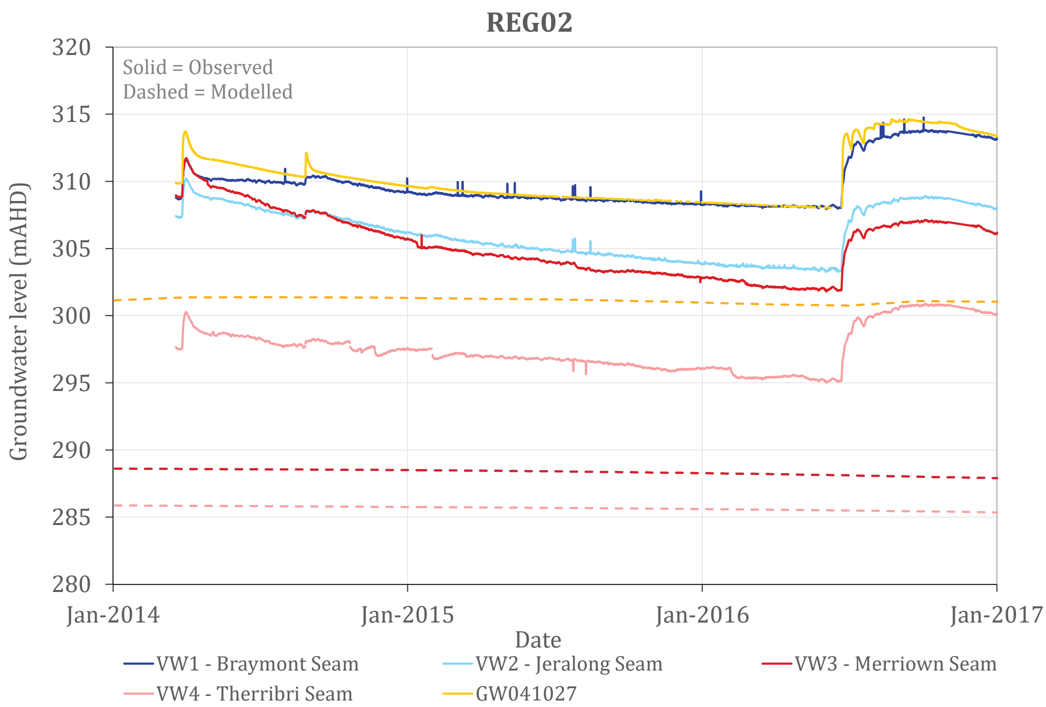


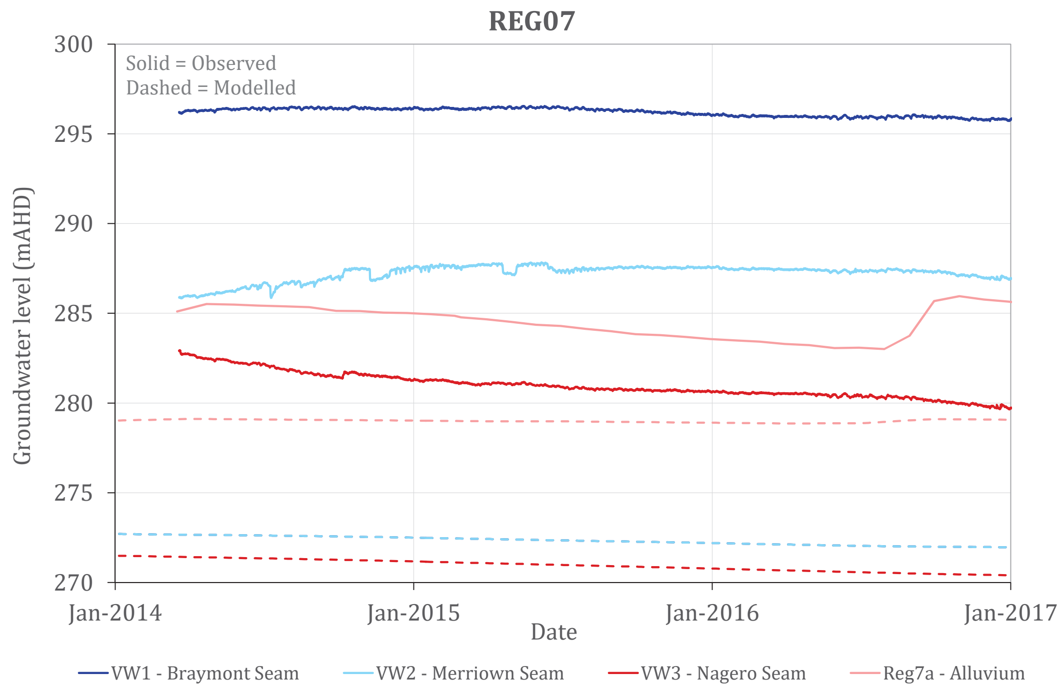


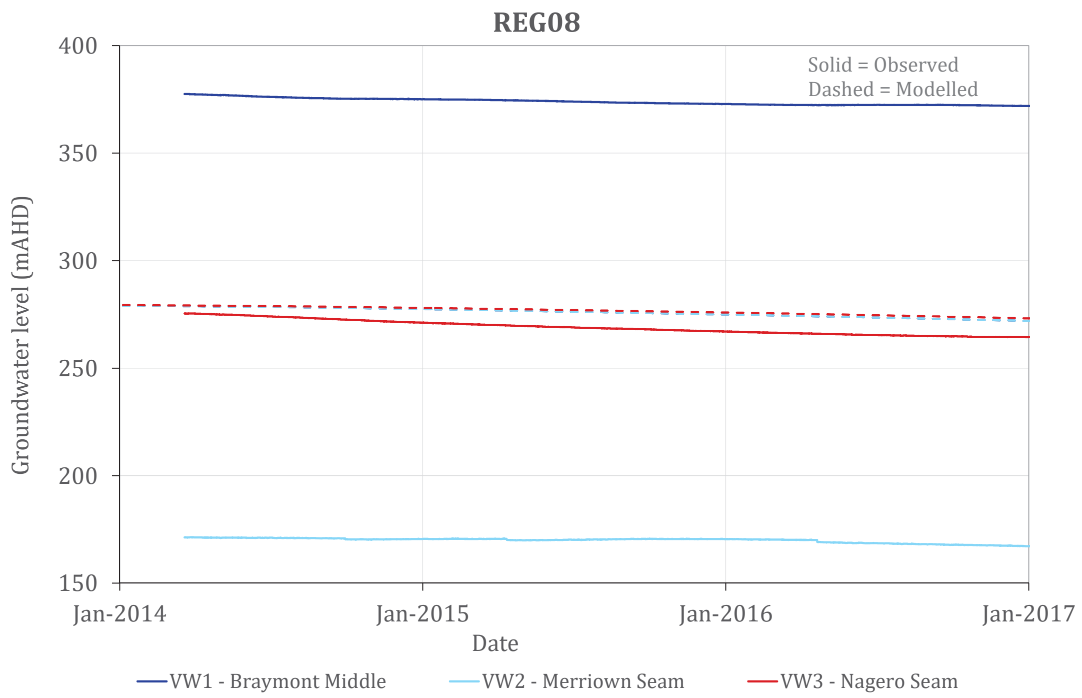

TA60
Solid = Observed
Dashed = Modelled
Groundwater level (mAHD)
280
270
260
250
240
230
220
210
200
Jan-2012
Jan-2013
Jan-2014
Jan-2015
Jan-2016
Date
69m Vy Interburden
89m Vy Interburden
109m Vy Seam
118m Vy-Ng Interburden

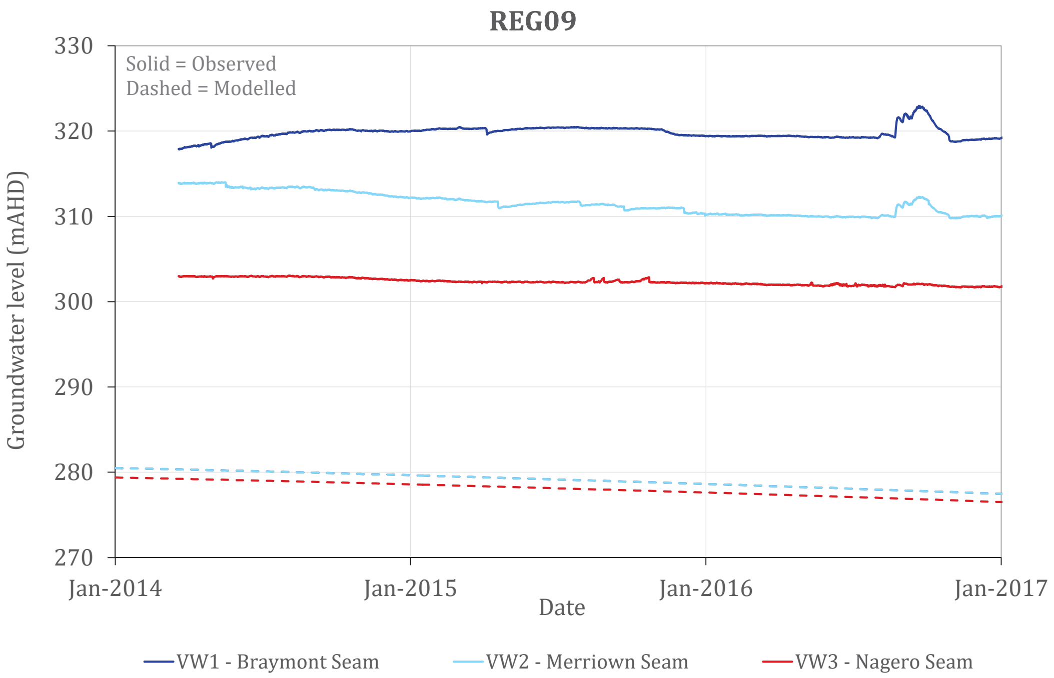

TA65
Solid = Observed
Dashed = Modelled
Groundwater level (mAHD)
280
270
260
250
240
230
220
210
200
Jan-2011
Jan-2012
Jan-2013
Jan-2014
Jan-2015
Jan-2016
Date
30m overburden
35m Jeralong Seam
47m Je-Me Interburden
56m Merriown Seam
97m Vy-Ng Interburden
110m Nagero Seam
136m Ng-UN Interburden
153m Upper Northern Seam

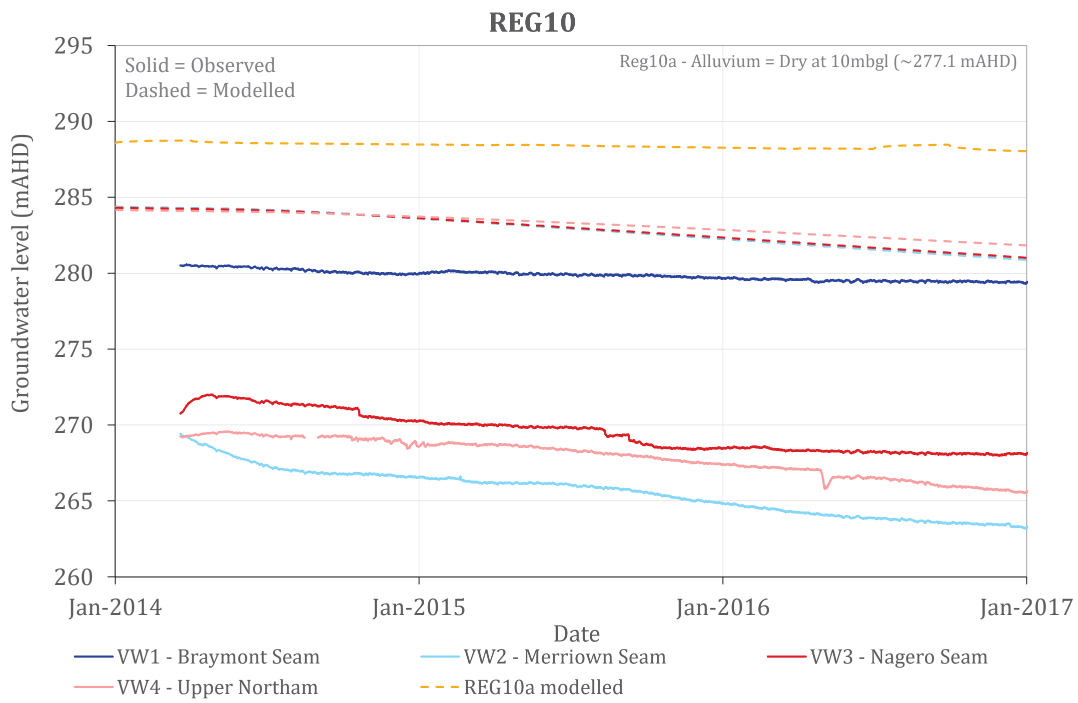

REG01
Groundwater level (mAHD)
290
285
280
275
270
265
260
255
250
Solid = Observed
Dashed = Modelled
Jan-2014
Jan-2015
Jan-2016
Jan-2017
Date
VW1 - Jeralong Seam
VW2 - Merriown Seam
VW3 - Nagero Seam
VW4 - Therribri Upper
GW967138

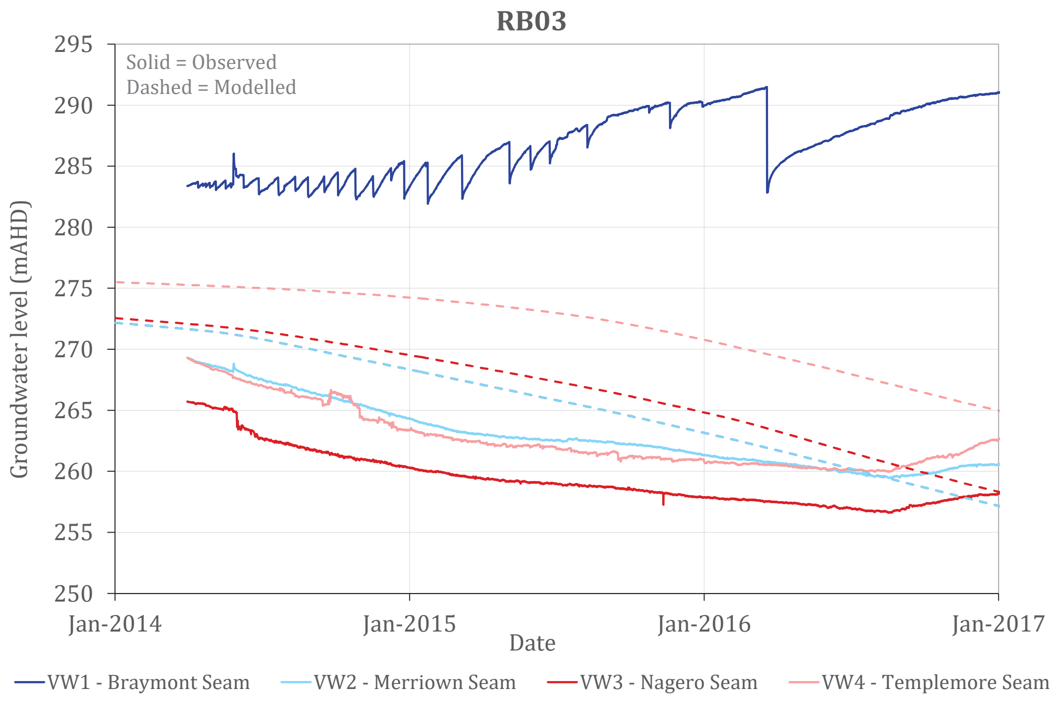

REG02
Groundwater level (mAHD)
320
315
310
305
300
295
290
285
280
Solid = Observed
Dashed = Modelled
Jan-2014
Jan-2015
Jan-2016
Jan-2017
Date
VW1 - Braymont Seam
VW2 - Jeralong Seam
VW3 - Merriown Seam
VW4 - Therribri Seam
GW041027

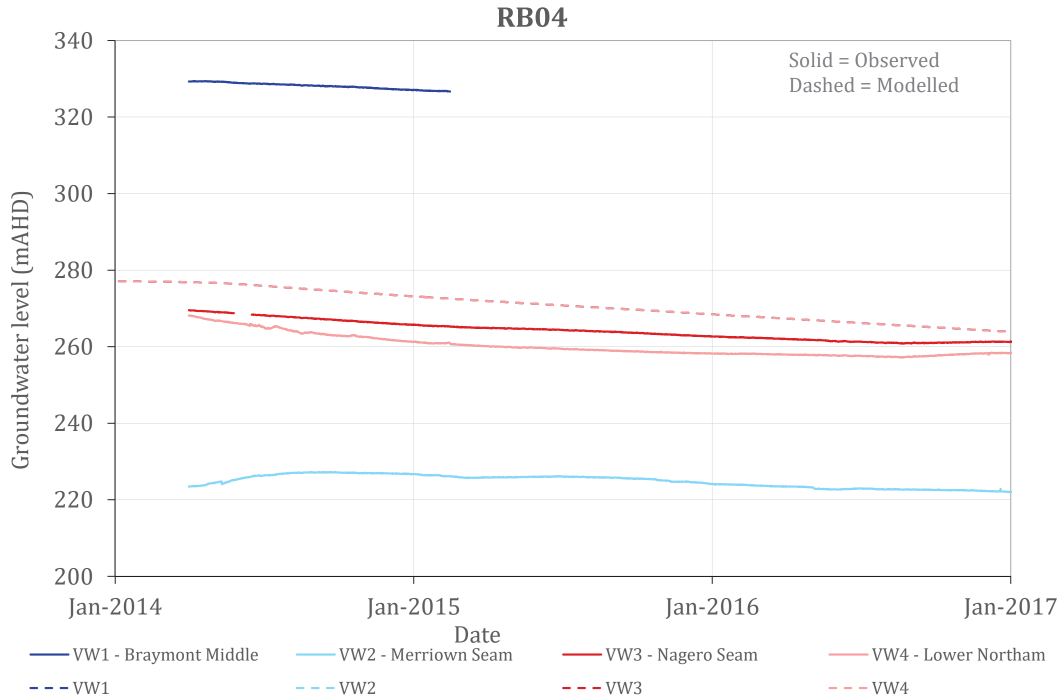

REG07
Solid = Observed
Dashed = Modelled
Groundwater level (mAHD)
300
295
290
285
280
275
270
Jan-2014
Jan-2015
Jan-2016
Jan-2017
Date
VW1 - Braymont Seam
VW2 - Merriown Seam
VW3 - Nagero Seam
Reg7a - Alluvium

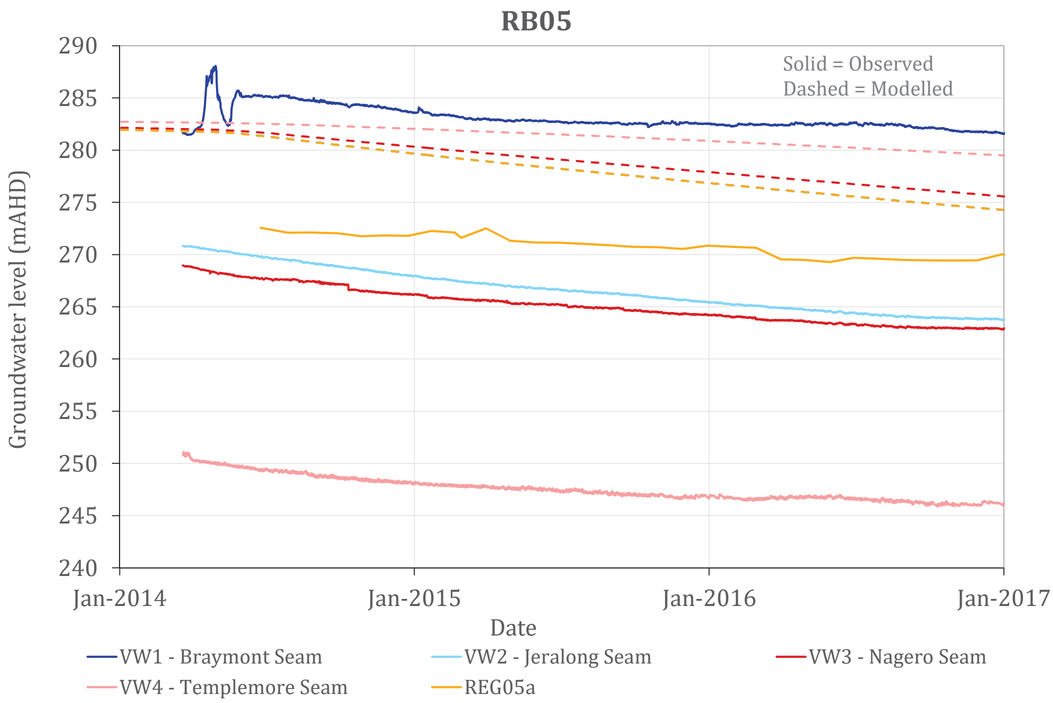

REG08
Solid = Observed
Dashed = Modelled
Groundwater level (mAHD)
400
350
300
250
200
150
Jan-2014
Jan-2015
Jan-2016
Jan-2017
Date
VW1 - Braymont Middle
VW2 - Merriown Seam
VW3 - Nagero Seam


REG09
Solid = Observed
Dashed = Modelled
Groundwater level (mAHD)
330
320
310
300
290
280
270
Jan-2014
Jan-2015
Jan-2016
Jan-2017
Date
VW1 - Braymont Seam
VW2 - Merriown Seam
VW3 - Nagero Seam


REG10
Solid = Observed
Dashed = Modelled
Reg10a - Alluvium = Dry at 10mbgl (~277.1 mAHD)
Groundwater level (mAHD)
295
290
285
280
275
270
265
260
Jan-2014
Jan-2015
Jan-2016
Jan-2017
Date
VW1 - Braymont Seam
VW2 - Merriown Seam
VW3 - Nagero Seam
VW4 - Upper Northam
REG10a modelled

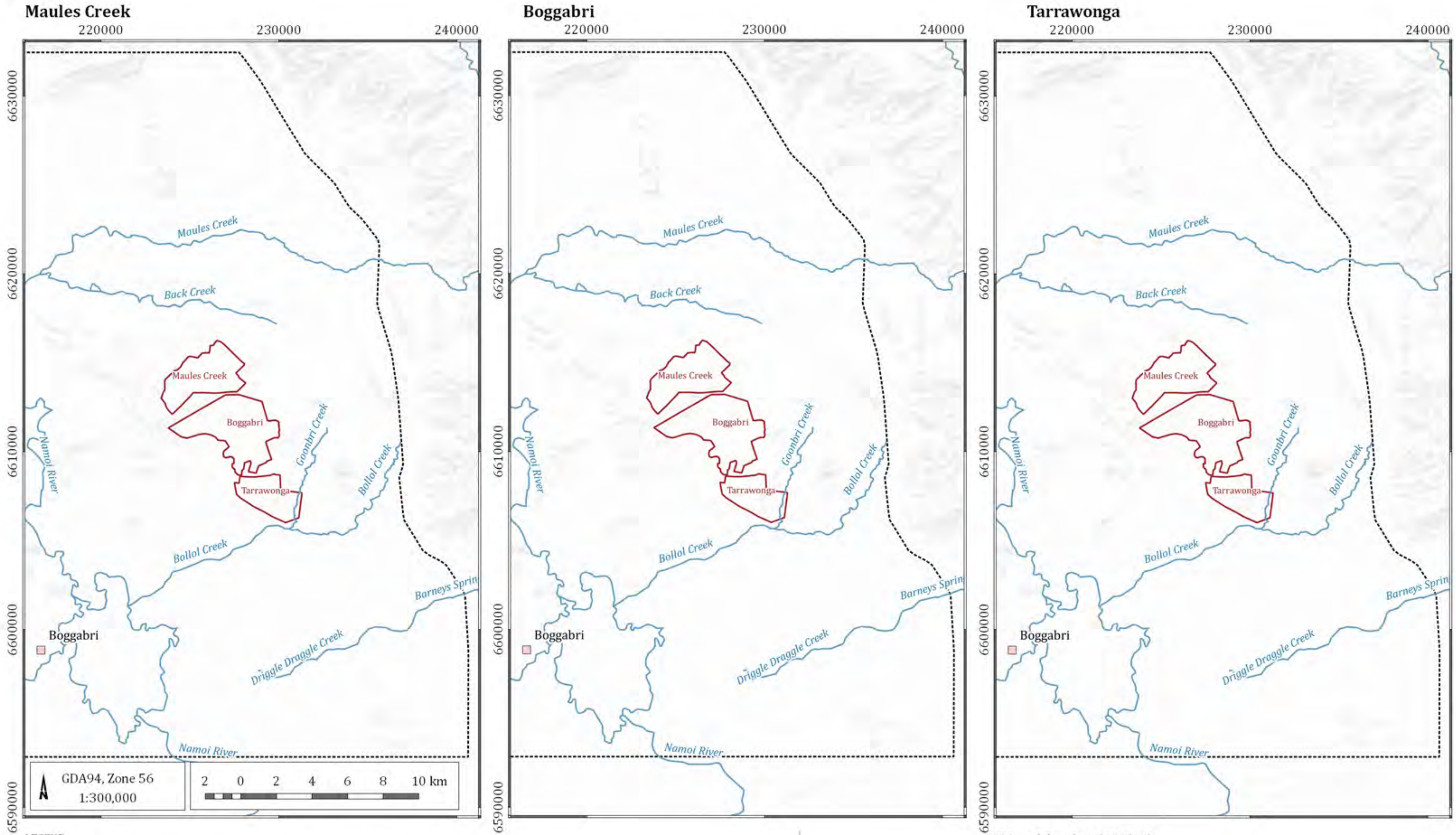

RB03
Solid = Observed
Dashed = Modelled
Groundwater level (mAHD)
295
290
285
280
275
270
265
260
255
250
Jan-2014
Jan-2015
Jan-2016
Jan-2017
Date
VW1 - Braymont Seam
VW2 - Merriown Seam
VW3 - Nagero Seam
VW4 - Templemore Seam


RB04
Solid = Observed
Dashed = Modelled
Groundwater level (mAHD)
340
320
300
280
260
240
220
200
Jan-2014
Jan-2015
Jan-2016
Jan-2017
Date
VW1 - Braymont Middle
VW2 - Merriown Seam
VW3 - Nagero Seam
VW4 - Lower Northam
VW1
VW2
VW3
VW4



RB05
Solid = Observed
Dashed = Modelled
Groundwater level (mAHD)
290
285
280
275
270
265
260
255
250
245
240
Jan-2014
Jan-2015
Jan-2016
Jan-2017
Date
VW1 - Braymont Seam
VW2 - Jeralong Seam
VW3 - Nagero Seam
VW4 - Templemore Seam
REG05a

Appendix D Drawdown proportion for each mine



BTM model update (G1850A)

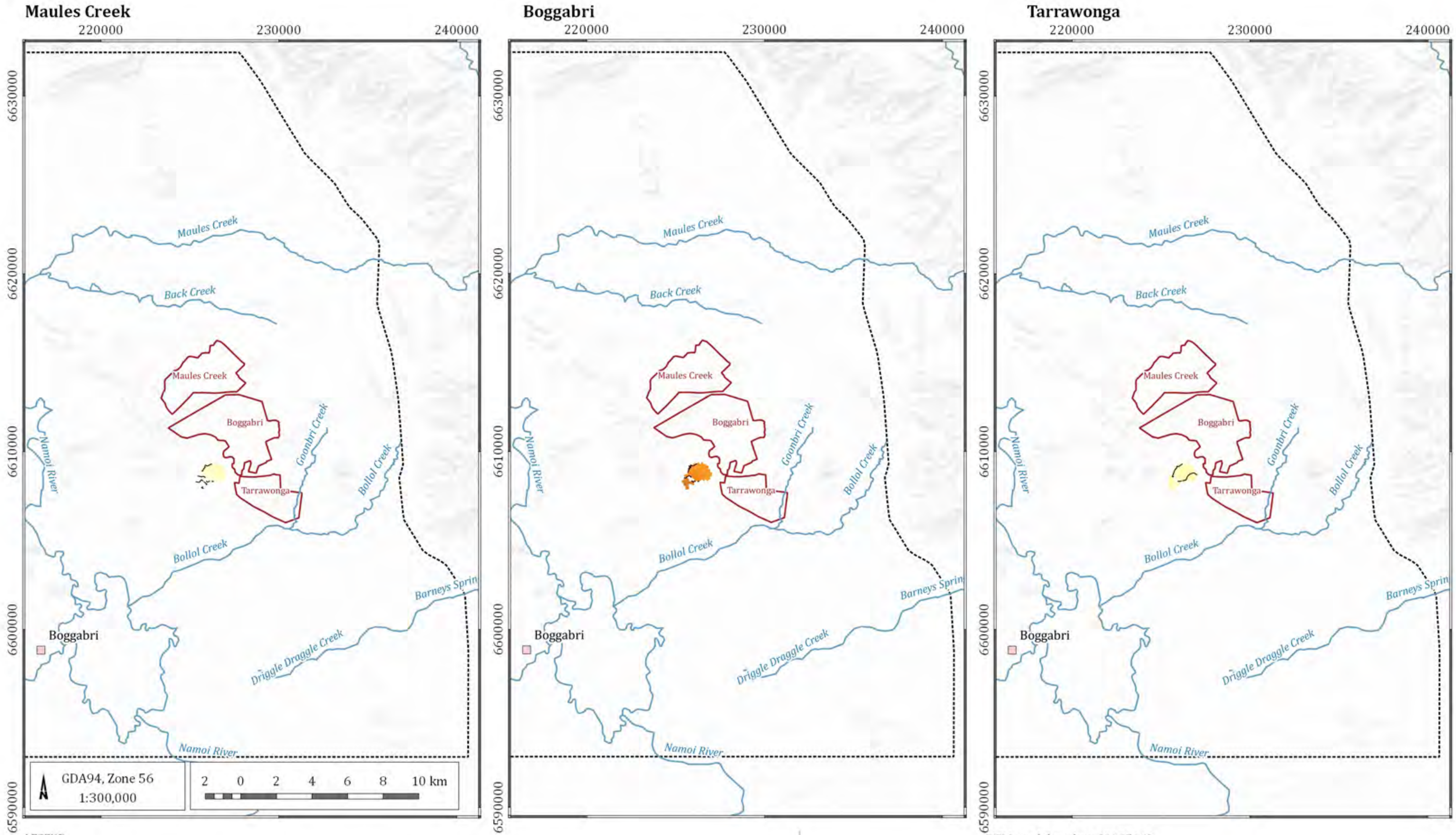
AGE

Percentage of simulated drawdown attributed to each mine at end 2019 - Layer 1 - Narrabri alluvium

DATE
29/03/2017

FIGURE No:
D.1

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:/Projects/G1850A.BTM_Model/3_GIS/Workspaces/001_Deliverable1/D.01-06_G1850A_Percentage of simulated drawdown attributed to each mine.qgs



LEGEND

- Populated place
- Major drainage
- Mine maximum open cut outlines
- Model extent

Drawdown contribution percentage

0	60
10	70
20	80
30	90
40	100
50	Drawdown contribution percentage contour

BTM model update (G1850A)

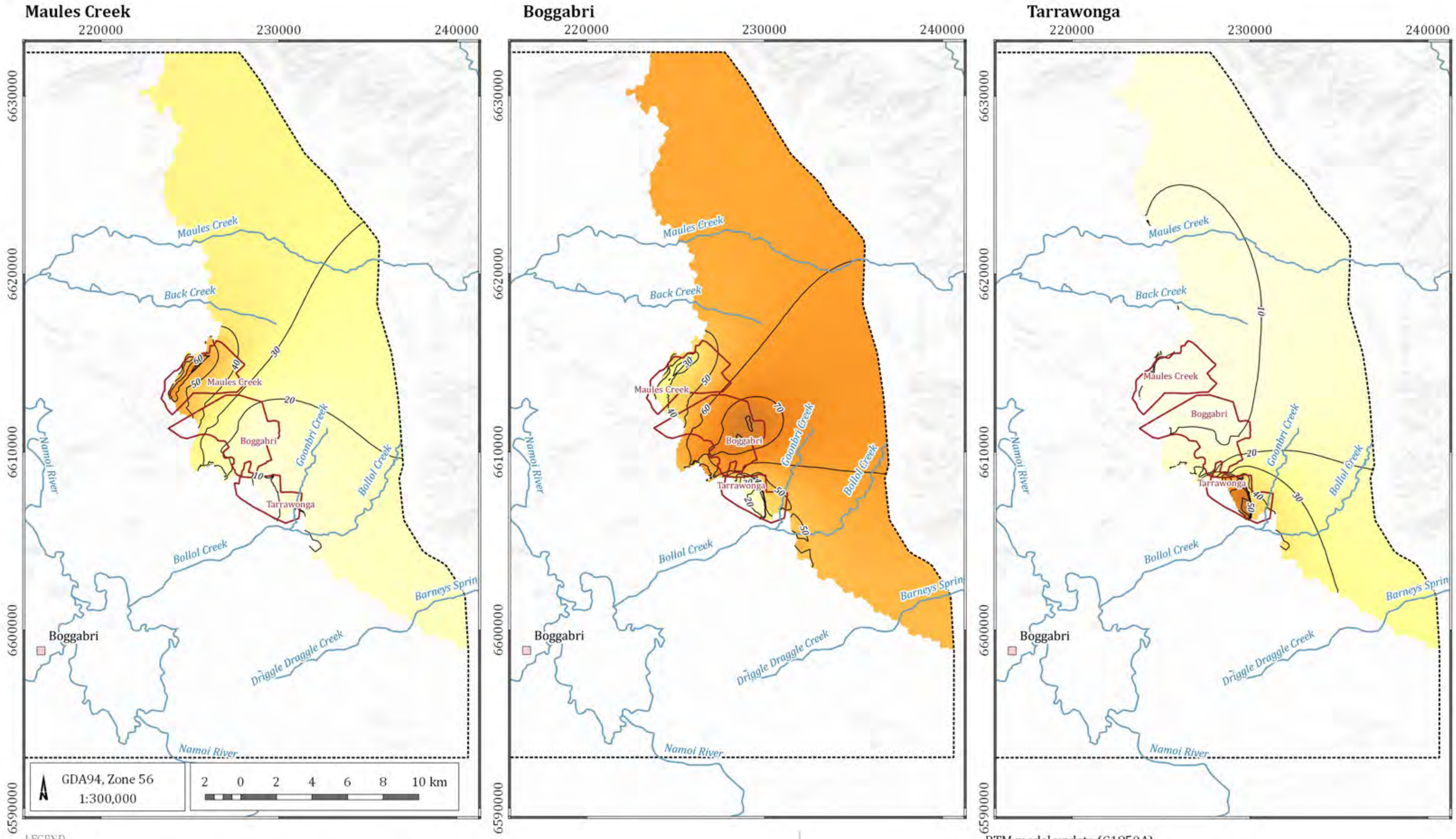
AGE

Percentage of simulated drawdown attributed to each mine at end 2019 - Layer 2 - Gunnedah alluvium

DATE
29/03/2017

FIGURE No:
D.2

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:/Projects/G1850A.BTM_Model/3_GIS/Workspaces/001_Deliverable1/D.01-06_G1850A_Percentage of simulated drawdown attributed to each mine.qgs



LEGEND

- Populated place
- Major drainage
- Mine maximum open cut outlines
- Model extent

Drawdown contribution percentage

0, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100

Drawdown contribution percentage contour

AGE

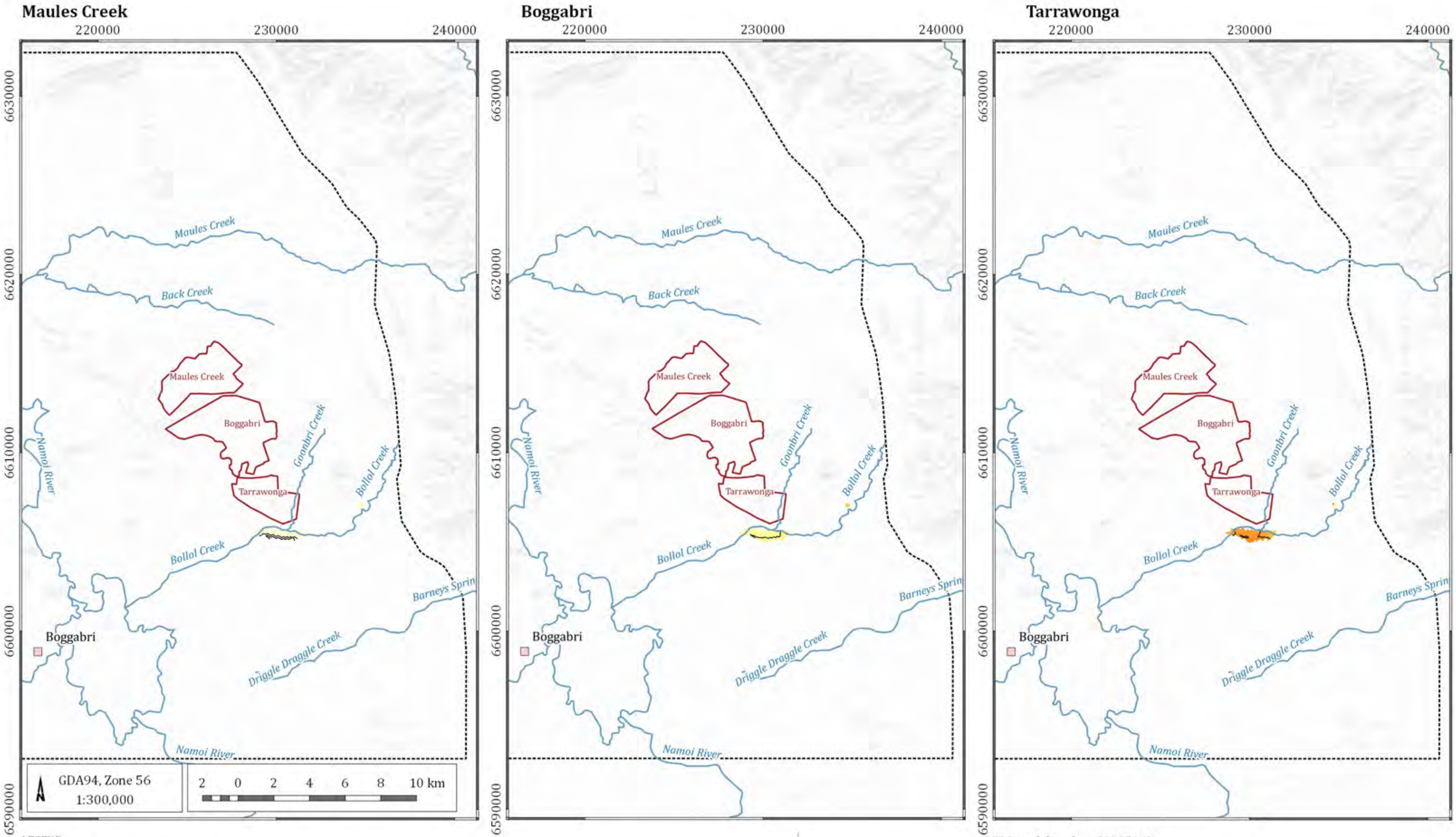
BTM model update (G1850A)

Percentage of simulated drawdown attributed to each mine at end 2019 - Layer 8 - Merriown seam

DATE
29/03/2017

FIGURE No:
D.3

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:/Projects/G1850A.BTM_Model/3_GIS/Workspaces/001_Deliverable1/D.01-06_G1850A_Percentage of simulated drawdown attributed to each mine.qgs



LEGEND

- Populated place
- Major drainage
- Mine maximum open cut outlines
- Model extent

Drawdown contribution percentage

0, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100

— Drawdown contribution percentage contour

BTM model update (G1850A)

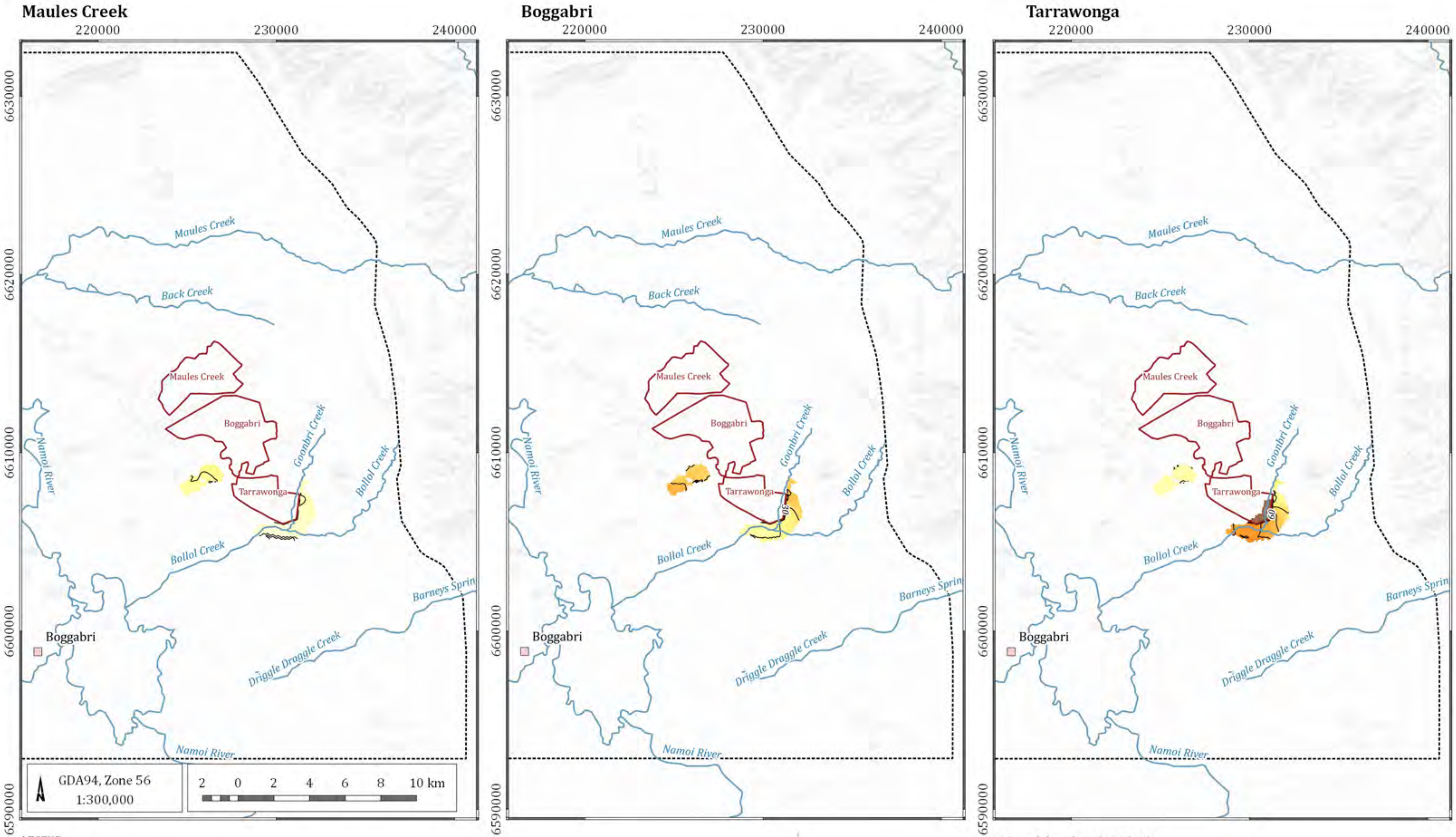
AGE

Percentage of simulated drawdown attributed to each mine at end 2029 - Layer 1 - Narrabri alluvium

DATE
29/03/2017

FIGURE No:
D.4

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:/Projects/G1850A.BTM_Model/3_GIS/Workspaces/001_Deliverable1/D.01-06_G1850A_Percentage of simulated drawdown attributed to each mine.qgs



LEGEND

- Populated place
- Major drainage
- Mine maximum open cut outlines
- Model extent

Drawdown contribution percentage

0, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100

Drawdown contribution percentage contour

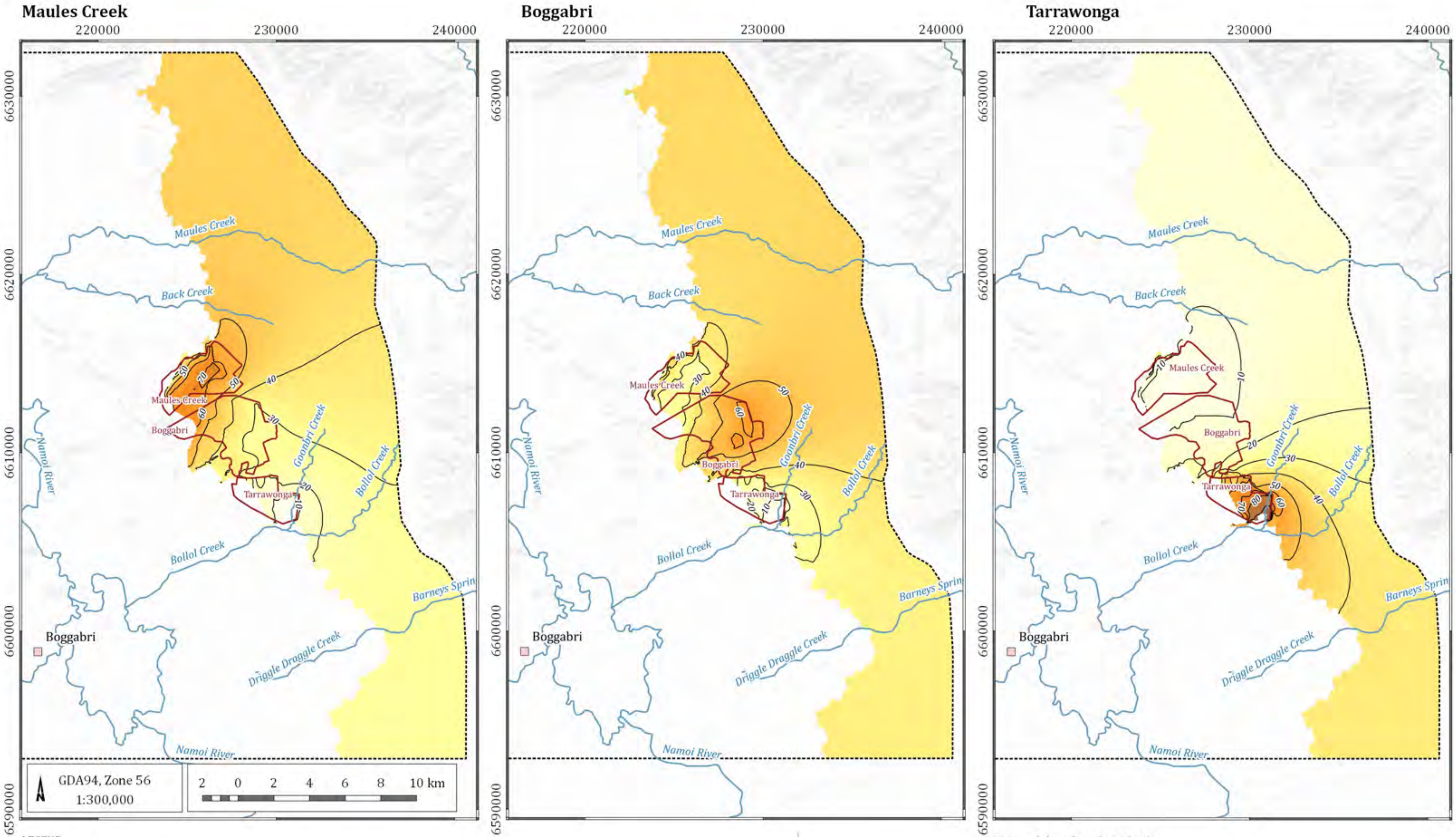
BTM model update (G1850A)

Percentage of simulated drawdown attributed to each mine at end 2029 - Layer 2 - Gunnedah alluvium

DATE
29/03/2017

FIGURE No:
D.5

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:/Projects/G1850A.BTM_Model/3_GIS/Workspaces/001_Deliverable1/D.01-06_G1850A_Percentage of simulated drawdown attributed to each mine.qgs



LEGEND

- Populated place
- Major drainage
- Mine maximum open cut outlines
- Model extent

Drawdown contribution percentage

0, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100

Drawdown contribution percentage contour

BTM model update (G1850A)

AGE

Percentage of simulated drawdown attributed to each mine at end 2029 - Layer 8 - Merriown seam

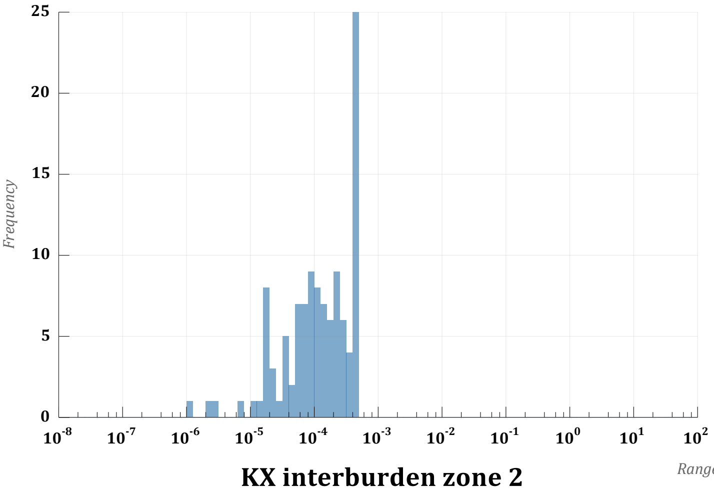
DATE
29/03/2017

FIGURE No:
D.6

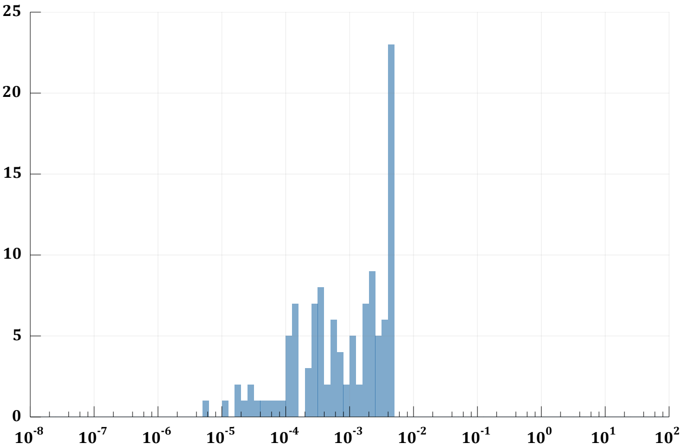
Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:/Projects/G1850A.BTM_Model/3_GIS/Workspaces/001_Deliverable1/D.01-06_G1850A_Percentage of simulated drawdown attributed to each mine.qgs

Appendix E Parameter ranges for uncertainty analysis

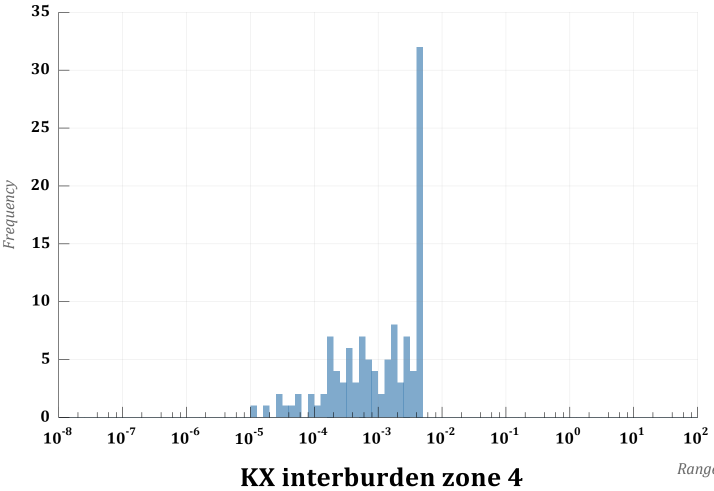
KX basalt



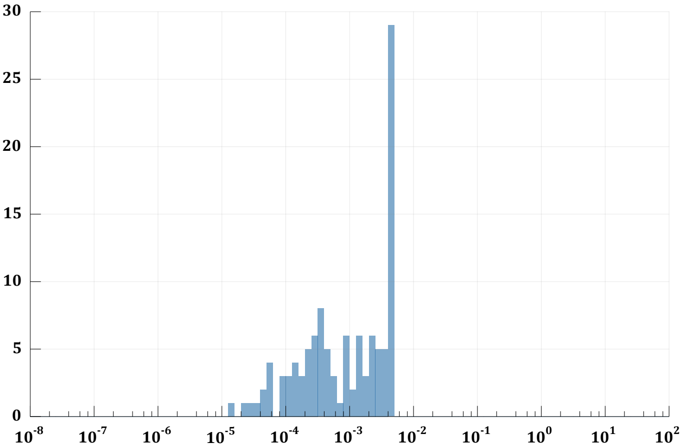
KX interburden zone 1



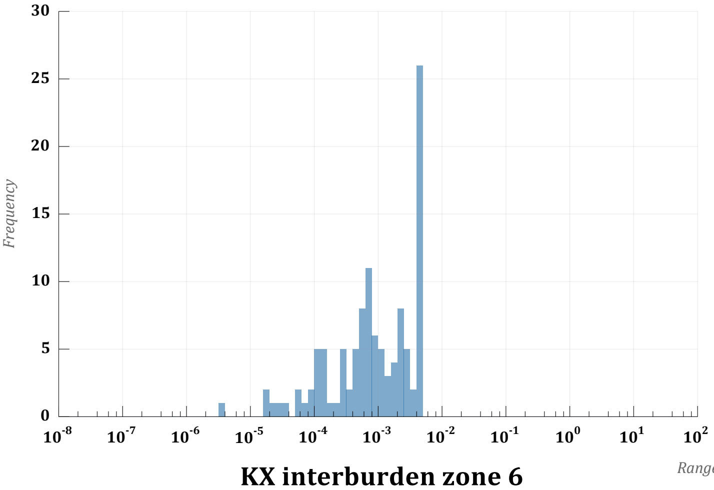
KX interburden zone 2



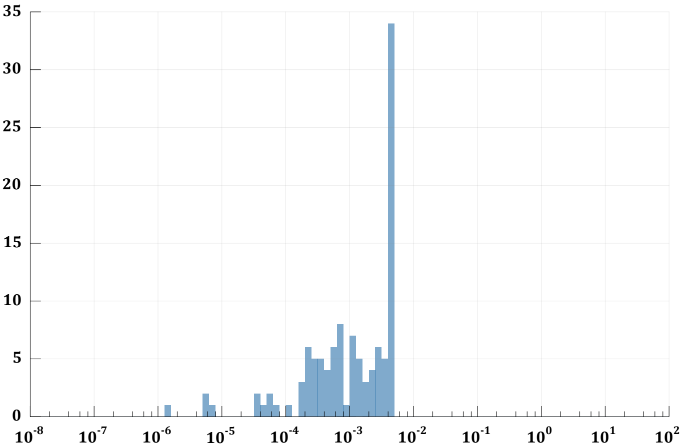
KX interburden zone 3



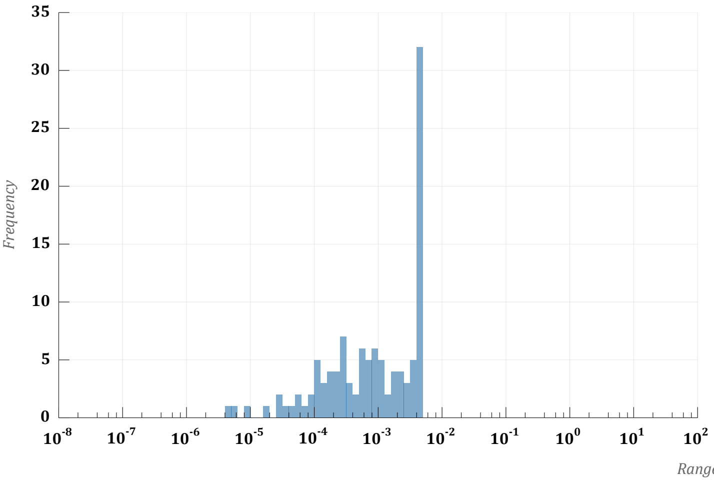
KX interburden zone 4



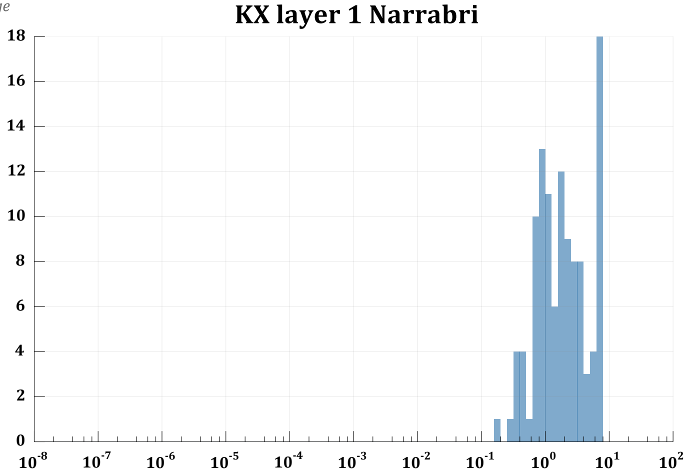
KX interburden zone 5

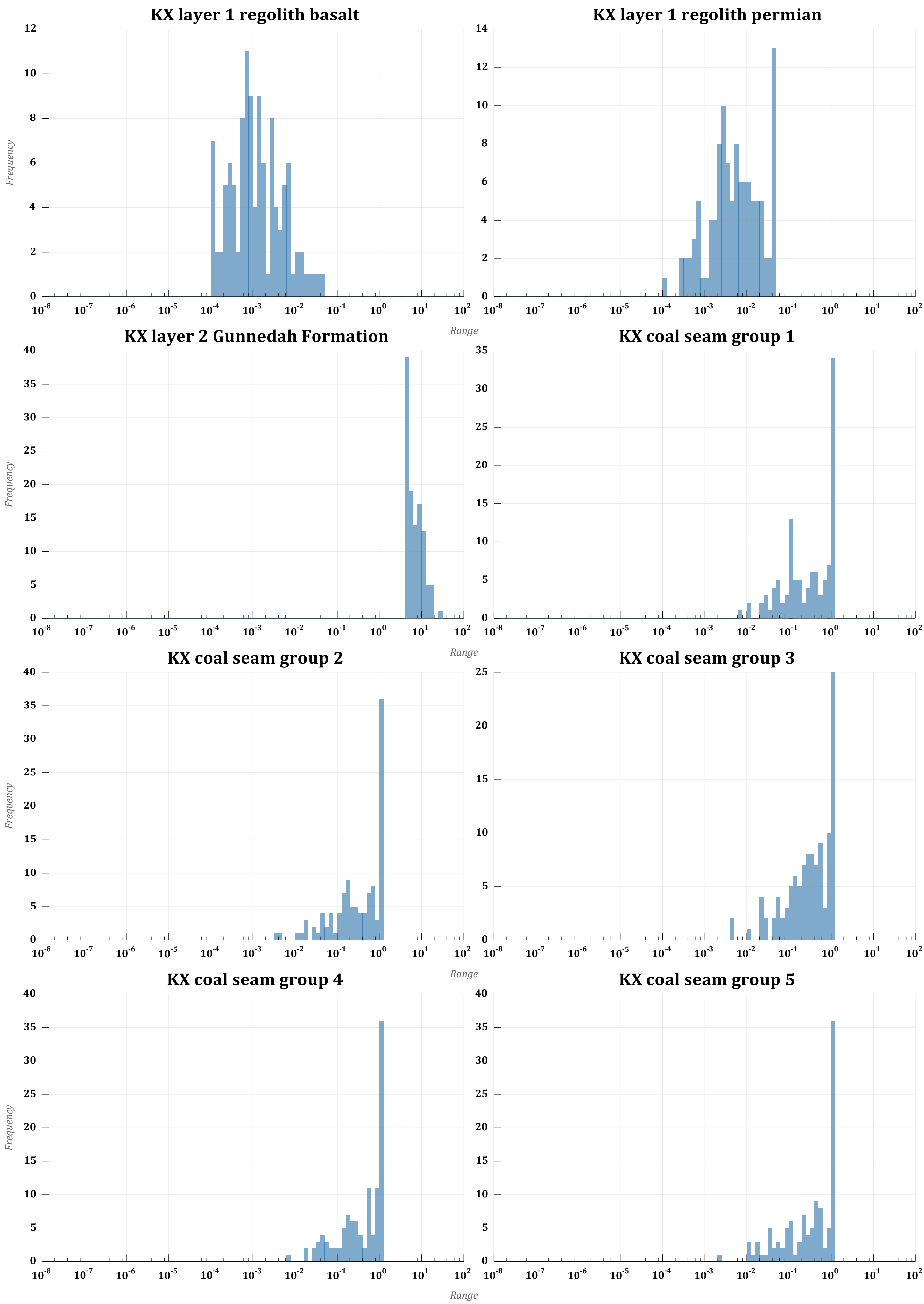


KX interburden zone 6

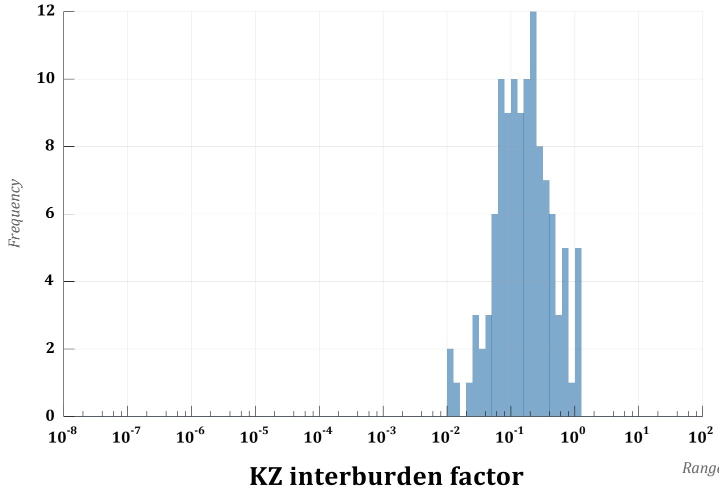


KX layer 1 Narrabri

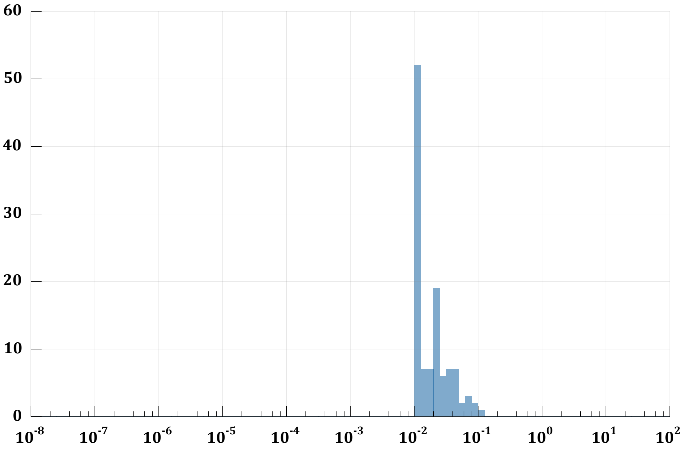



KX layer 1 regolith basalt
KX layer 1 regolith permian
KX layer 2 Gunnedah Formation
KX coal seam group 1
KX coal seam group 2
KX coal seam group 3
KX coal seam group 4
KX coal seam group 5
Frequency
Range

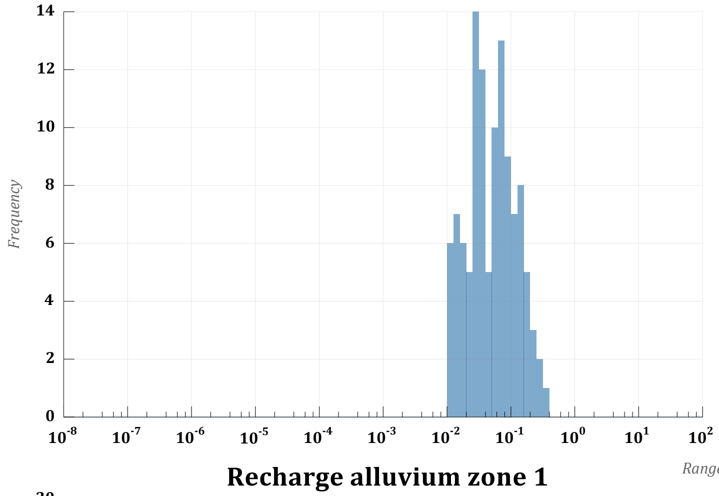
KZ basalt factor



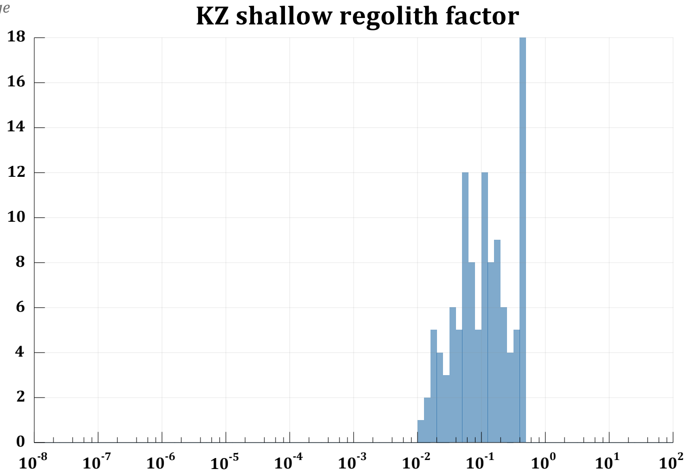
KZ coal factor



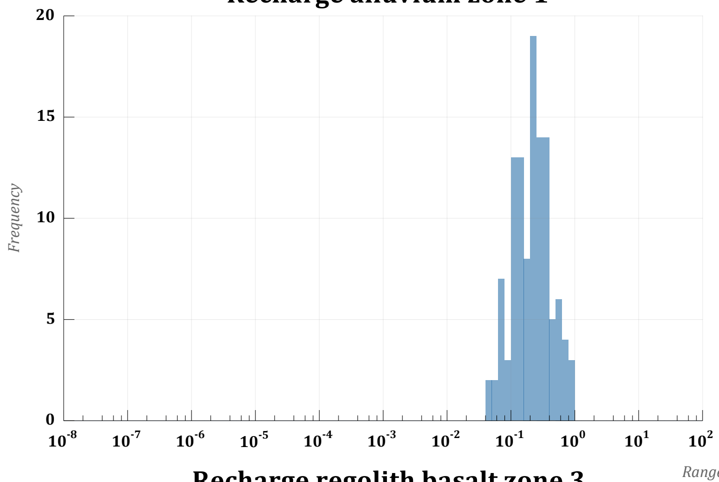
KZ interburden factor



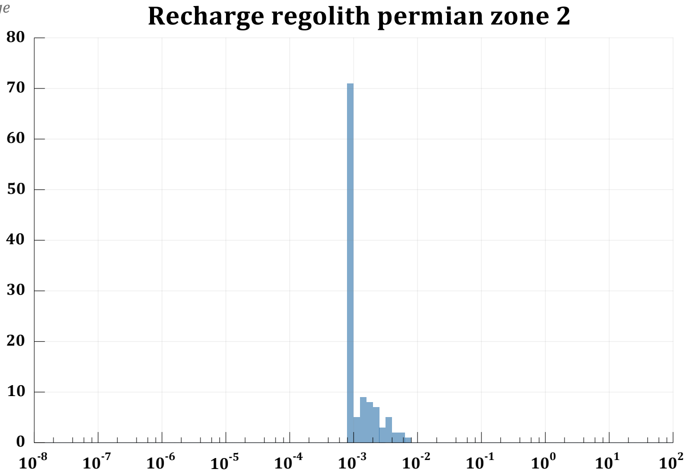
KZ shallow regolith factor



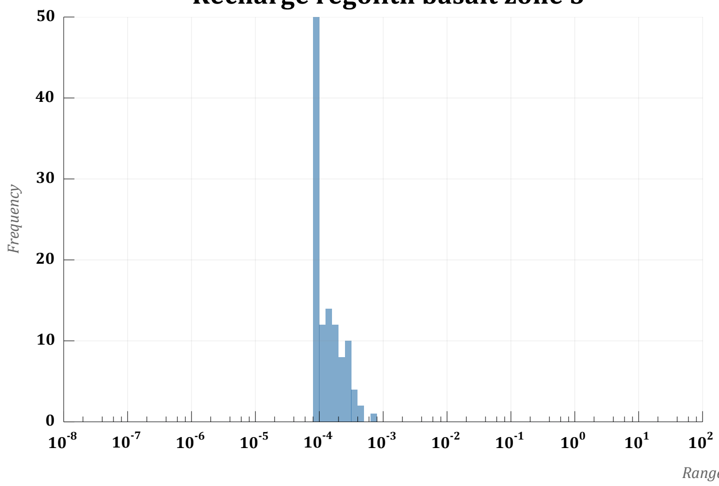
Recharge alluvium zone 1



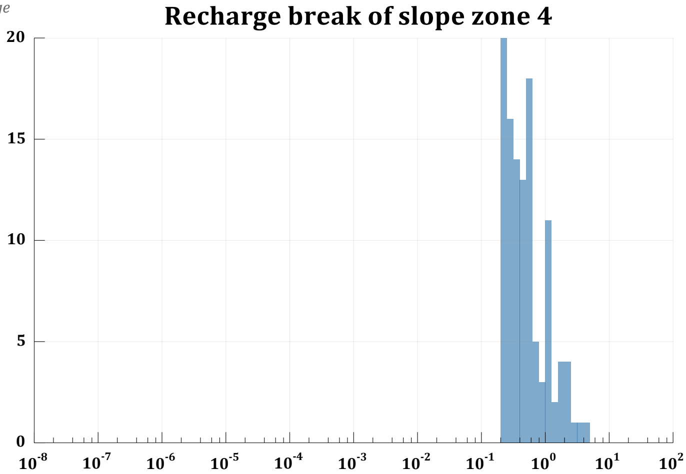
Recharge regolith permian zone 2



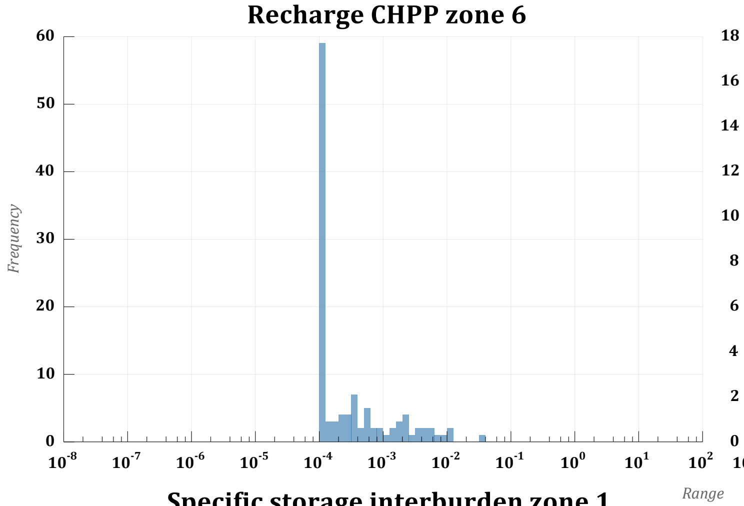
Recharge regolith basalt zone 3



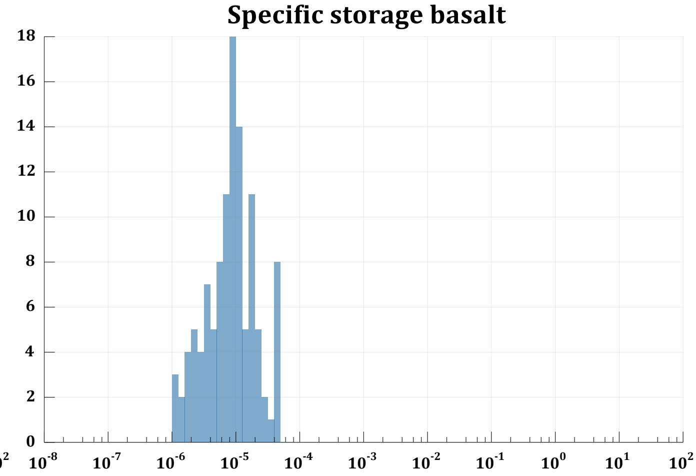
Recharge break of slope zone 4



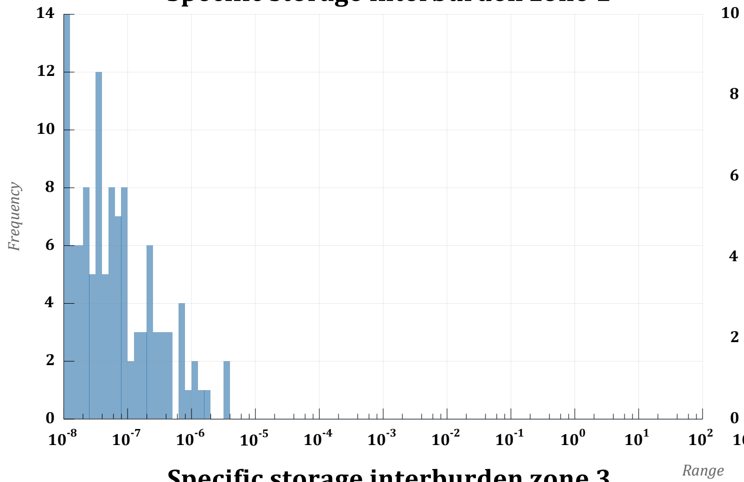
Recharge CHPP zone 6



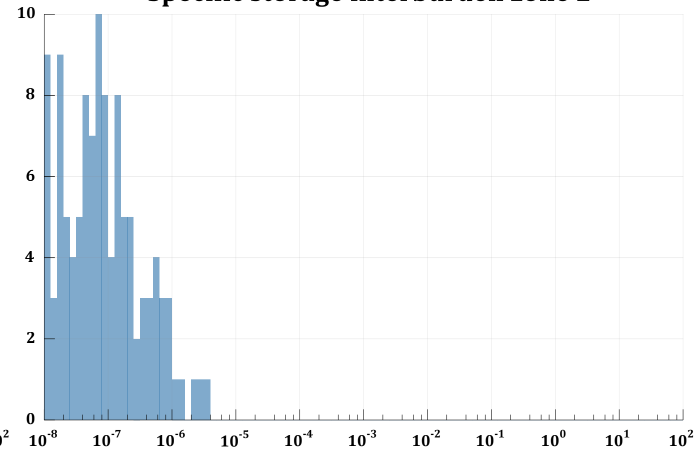
Specific storage basalt



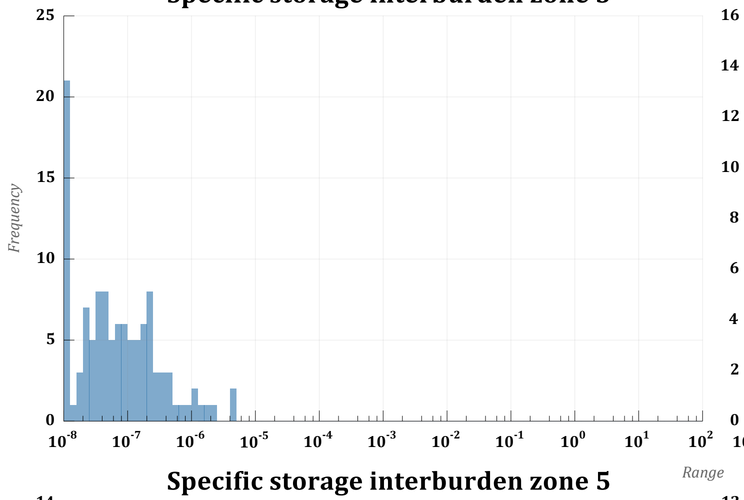
Specific storage interburden zone 1



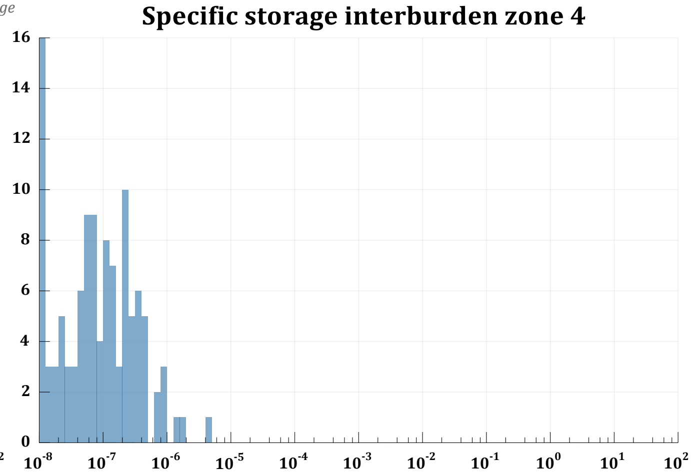
Specific storage interburden zone 2



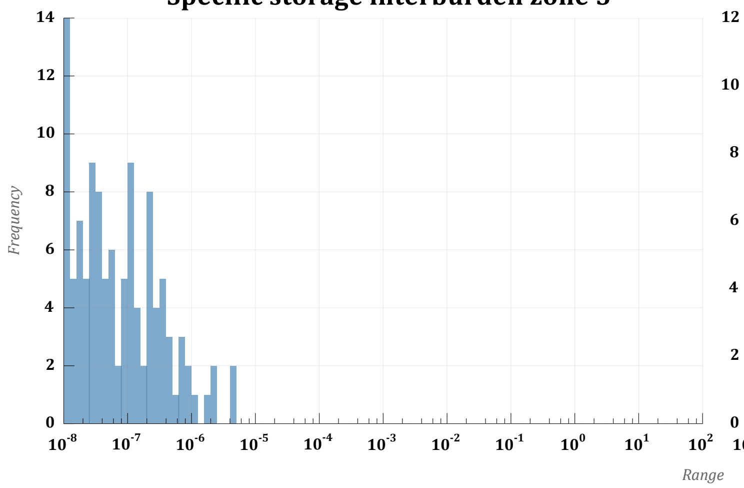
Specific storage interburden zone 3



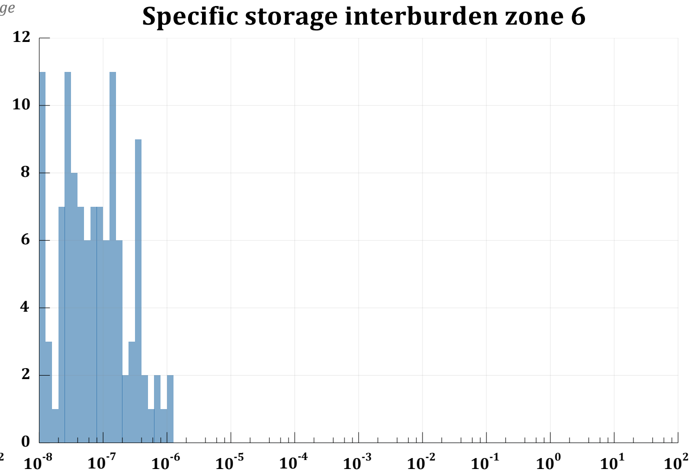
Specific storage interburden zone 4



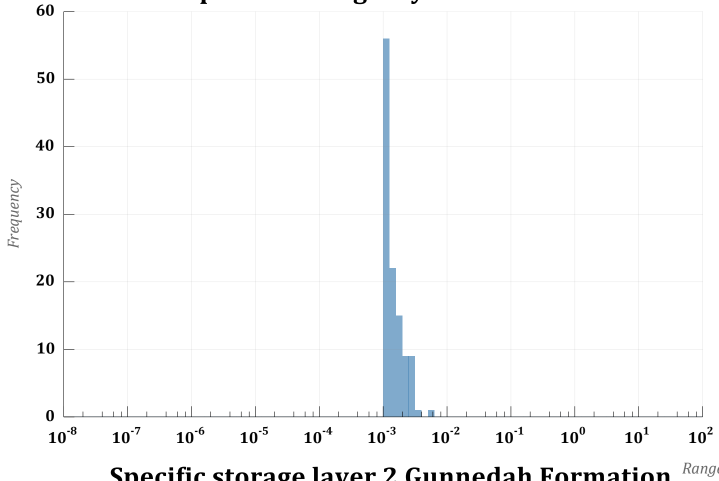
Specific storage interburden zone 5



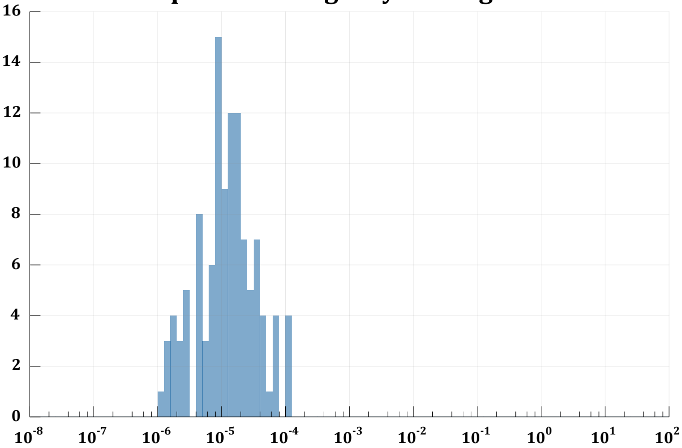
Specific storage interburden zone 6



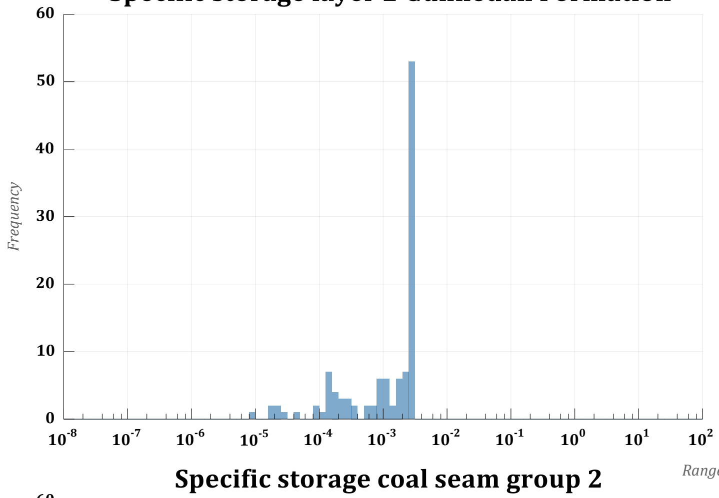
Specific storage layer 1 Narrabri



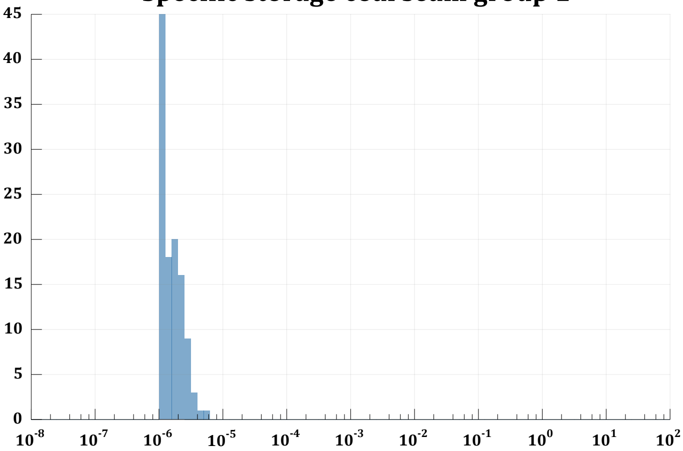
Specific storage layer 1 regolith



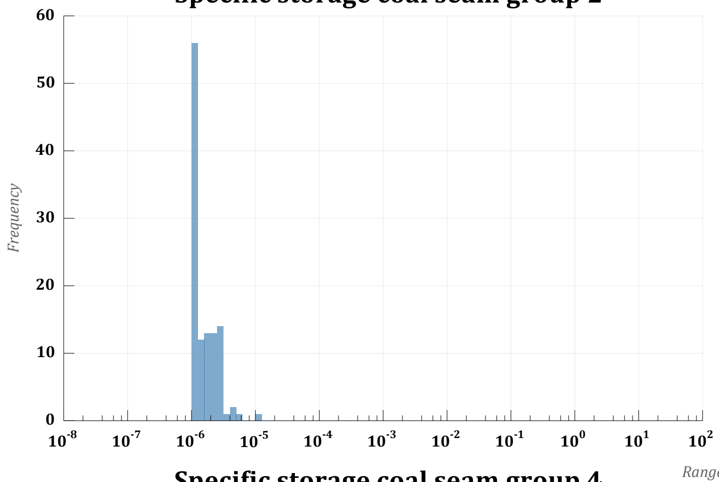
Specific storage layer 2 Gunnedah Formation



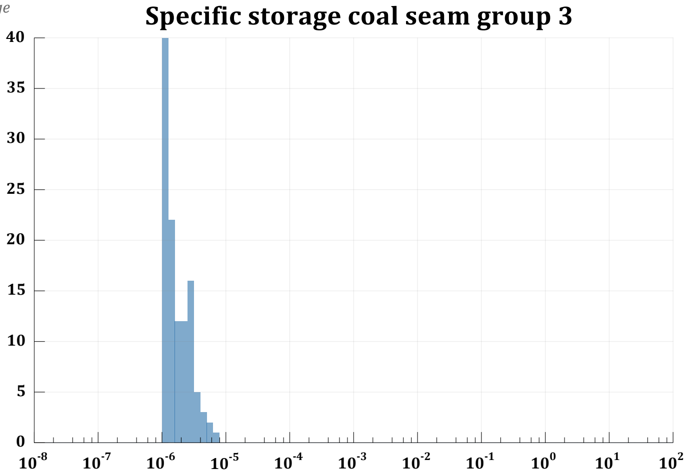
Specific storage coal seam group 1



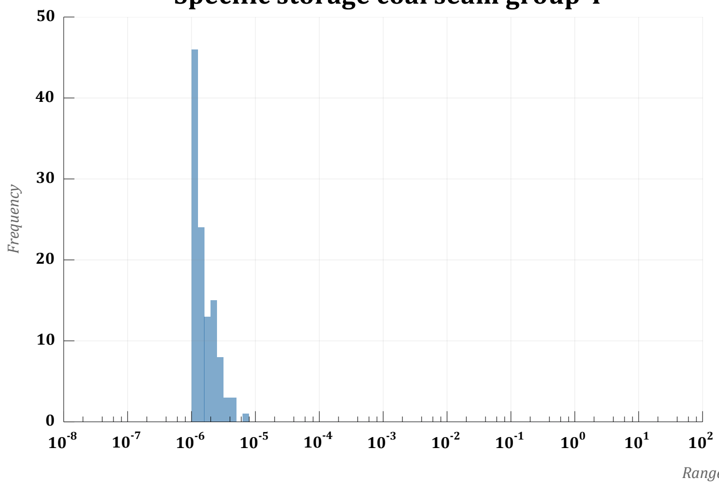
Specific storage coal seam group 2



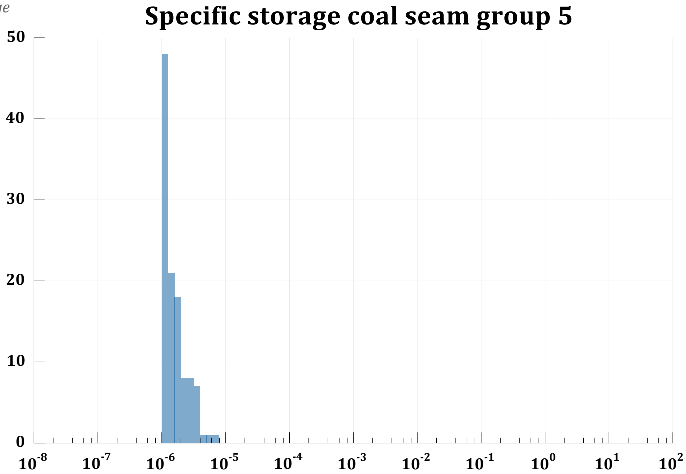
Specific storage coal seam group 3

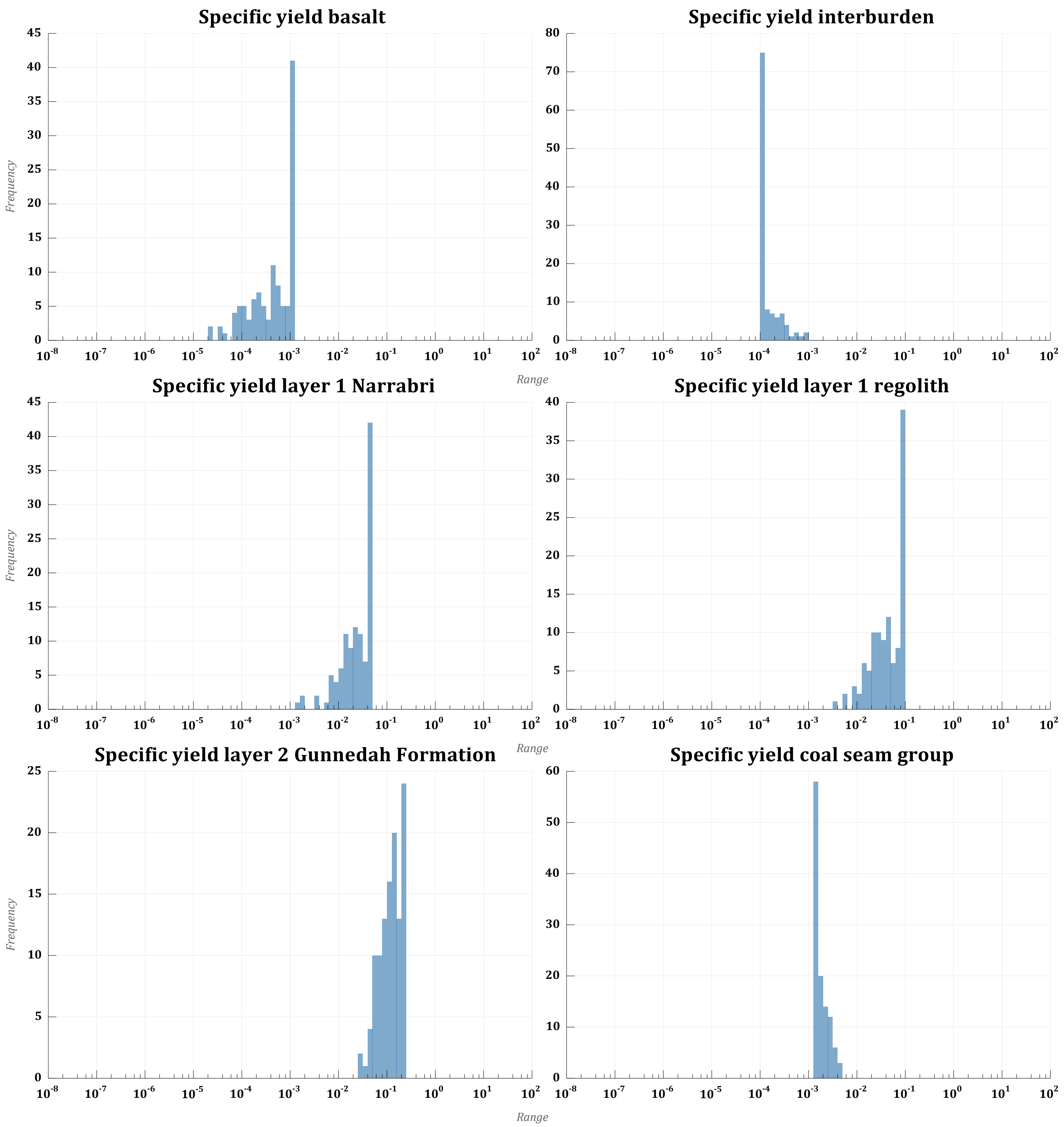


Specific storage coal seam group 4



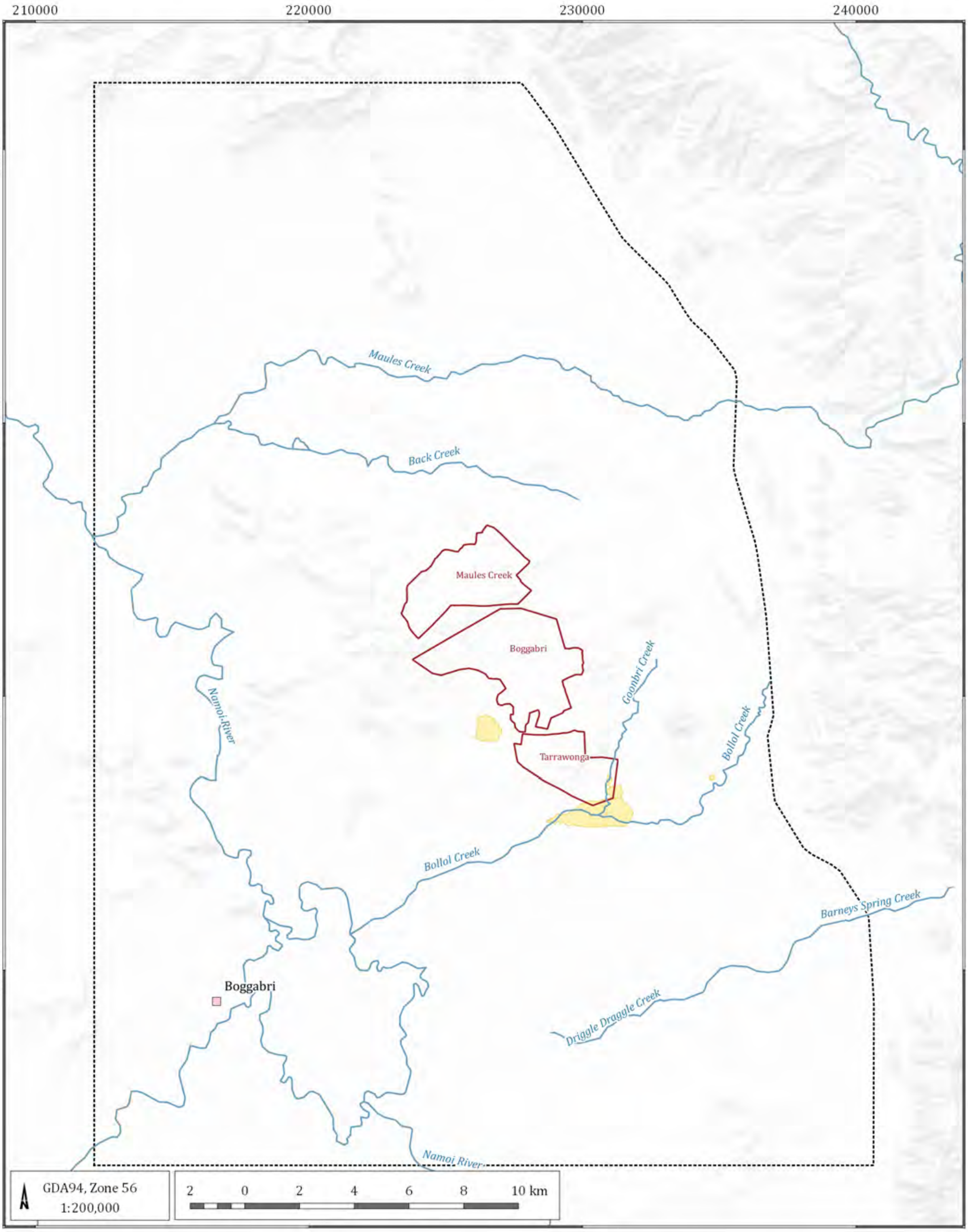
Specific storage coal seam group 5





Specific yield basalt
Specific yield interburden
Specific yield layer 1 Narrabri
Specific yield layer 1 regolith
Specific yield layer 2 Gunnedah Formation
Specific yield coal seam group
Frequency
Range
10^{-8} 10^{-7} 10^{-6} 10^{-5} 10^{-4} 10^{-3} 10^{-2} 10^{-1} 10^{0} 10^{1} 10^{2}

Appendix F Drawdown uncertainty figures



LEGEND

- Populated place
- Major drainage
- Mine maximum open cut outlines
- Model extent

Uncertainty in drawdown higher than 1 m

- 95th percentile
- 50th percentile
- 5th percentile

BTM model update (G1850A)

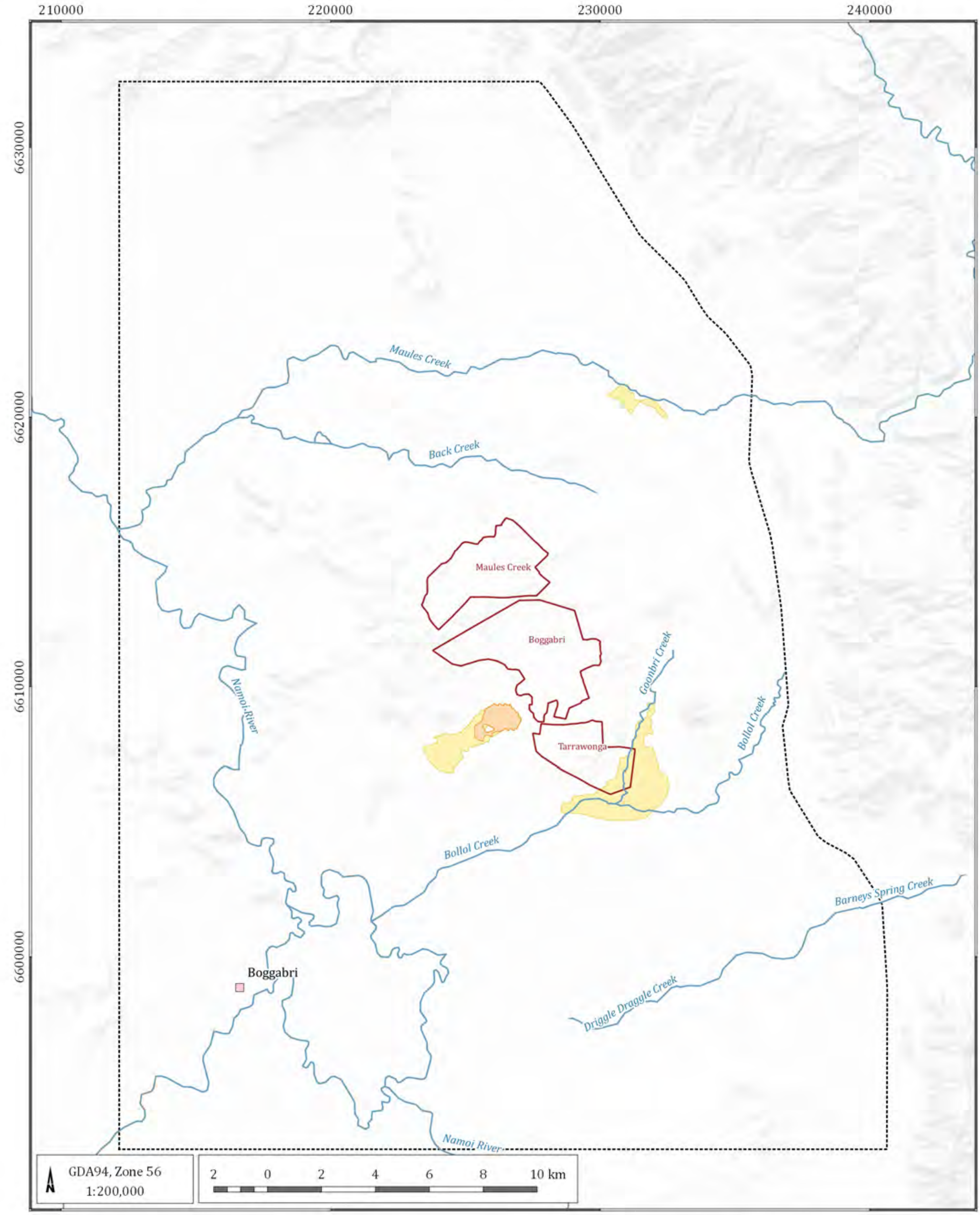
Uncertainty in predicted drawdown at end of 2019 - Layer 1 - Narrabri alluvium

AGE

DATE 06/12/2017

FIGURE No: **F.1**

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:/Projects/G1850A.BTM_Model/3_GIS/Workspaces/001_Deliverable1/F.01-06_G1850A_Uncertainty in predicted drawdown.qgs



LEGEND

- Populated place
- Major drainage
- Mine maximum open cut outlines
- Model extent

Uncertainty in drawdown higher than 1 m

- 95th percentile
- 50th percentile
- 5th percentile

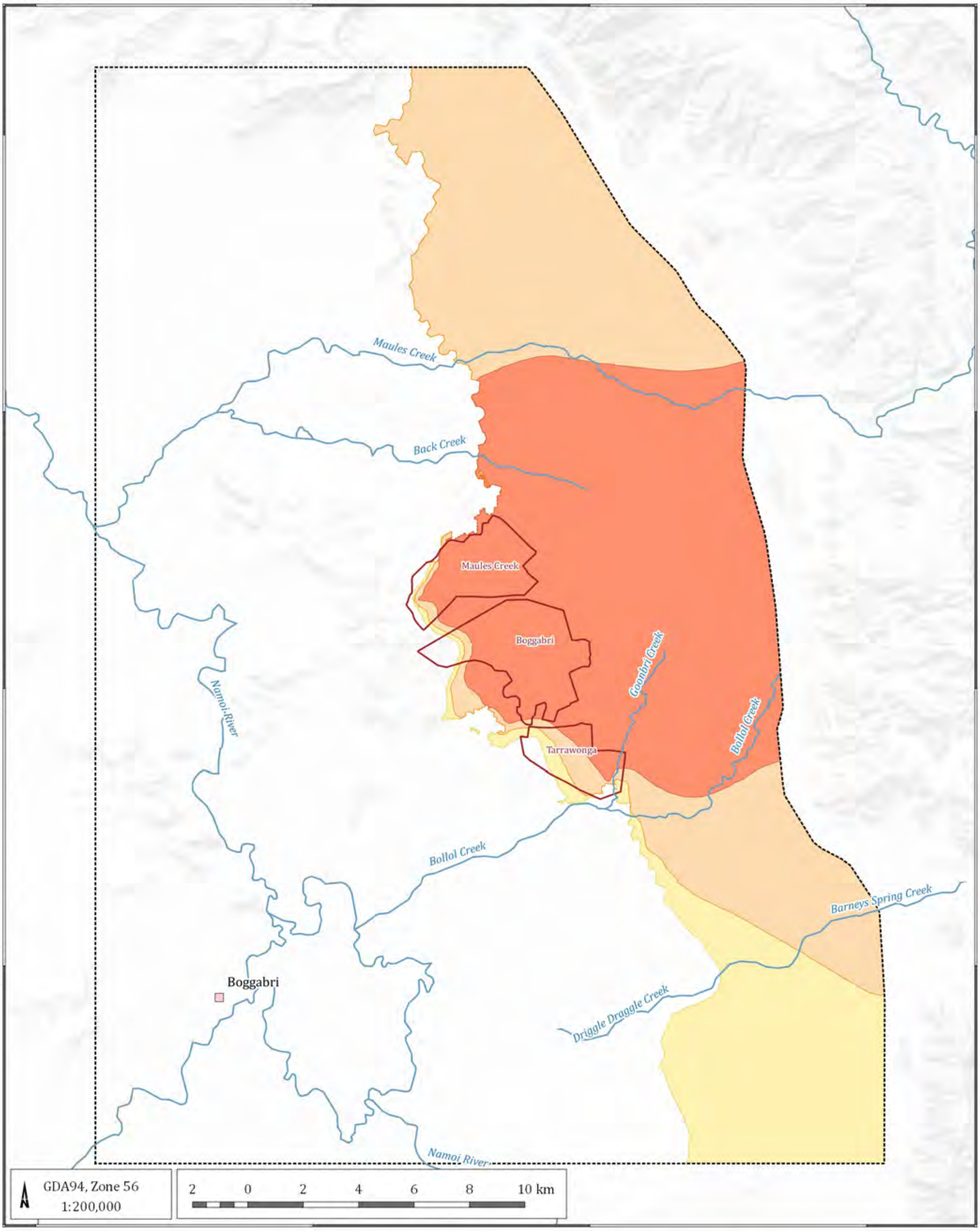
BTM model update (G1850A)

Uncertainty in predicted drawdown at end of 2019 - Layer 2 - Gunnedah alluvium

AGE

DATE 06/12/2017

FIGURE No: **F.2**



LEGEND

- Populated place
- Major drainage
- Mine maximum open cut outlines
- Model extent

Uncertainty in drawdown higher than 1 m

- 95th percentile
- 50th percentile
- 5th percentile

BTM model update (G1850A)

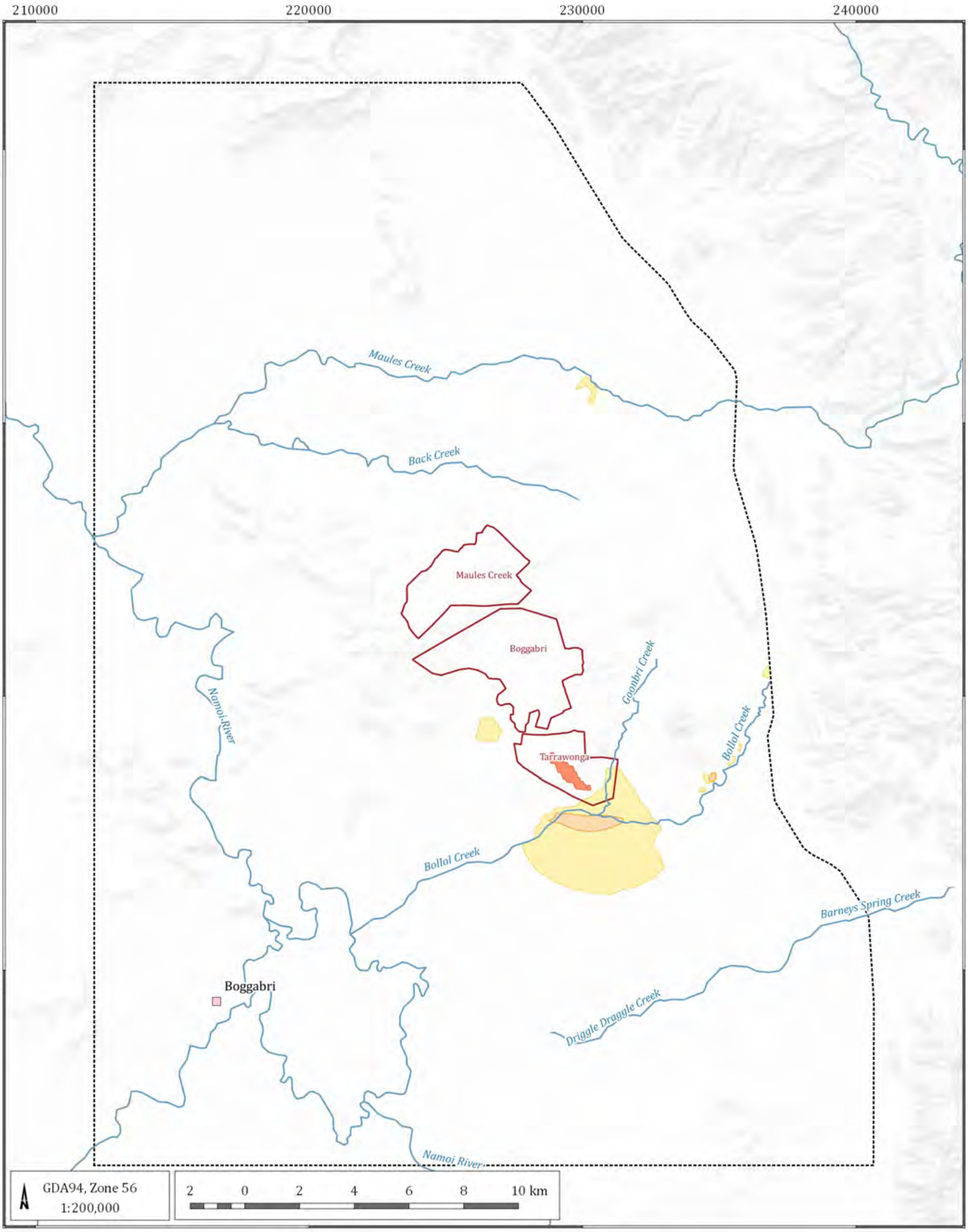
Uncertainty in predicted drawdown at end of 2019 - Layer 8 - Merriown seam

AGE

DATE 06/12/2017

FIGURE No: **F.3**

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:/Projects/G1850A.BTM_Model/3_GIS/Workspaces/001_Deliverable1/F.01-06_G1850A_Uncertainty in predicted drawdown.qgs



LEGEND

- Populated place
- Major drainage
- Mine maximum open cut outlines
- Model extent

Uncertainty in drawdown higher than 1 m

- 95th percentile
- 50th percentile
- 5th percentile

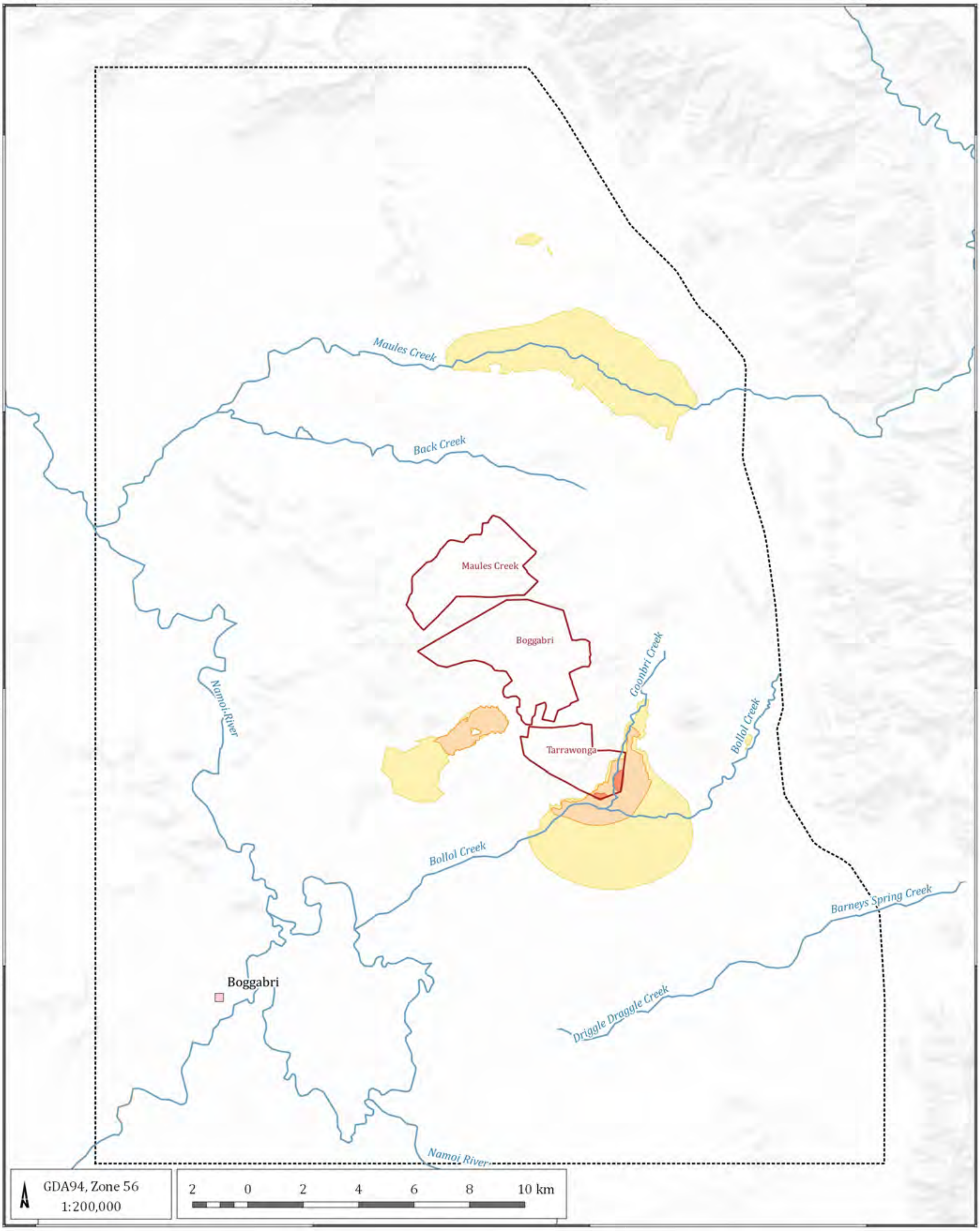
BTM model update (G1850A)

Uncertainty in predicted drawdown at end of 2029 - Layer 1 - Narrabri alluvium

DATE 06/12/2017

FIGURE No: **F.4**

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:/Projects/G1850A.BTM_Model/3_GIS/Workspaces/001_Deliverable1/F.01-06_G1850A_Uncertainty in predicted drawdown.qgs



LEGEND

- Populated place
- Major drainage
- Mine maximum open cut outlines
- Model extent

Uncertainty in drawdown higher than 1 m

- 95th percentile
- 50th percentile
- 5th percentile

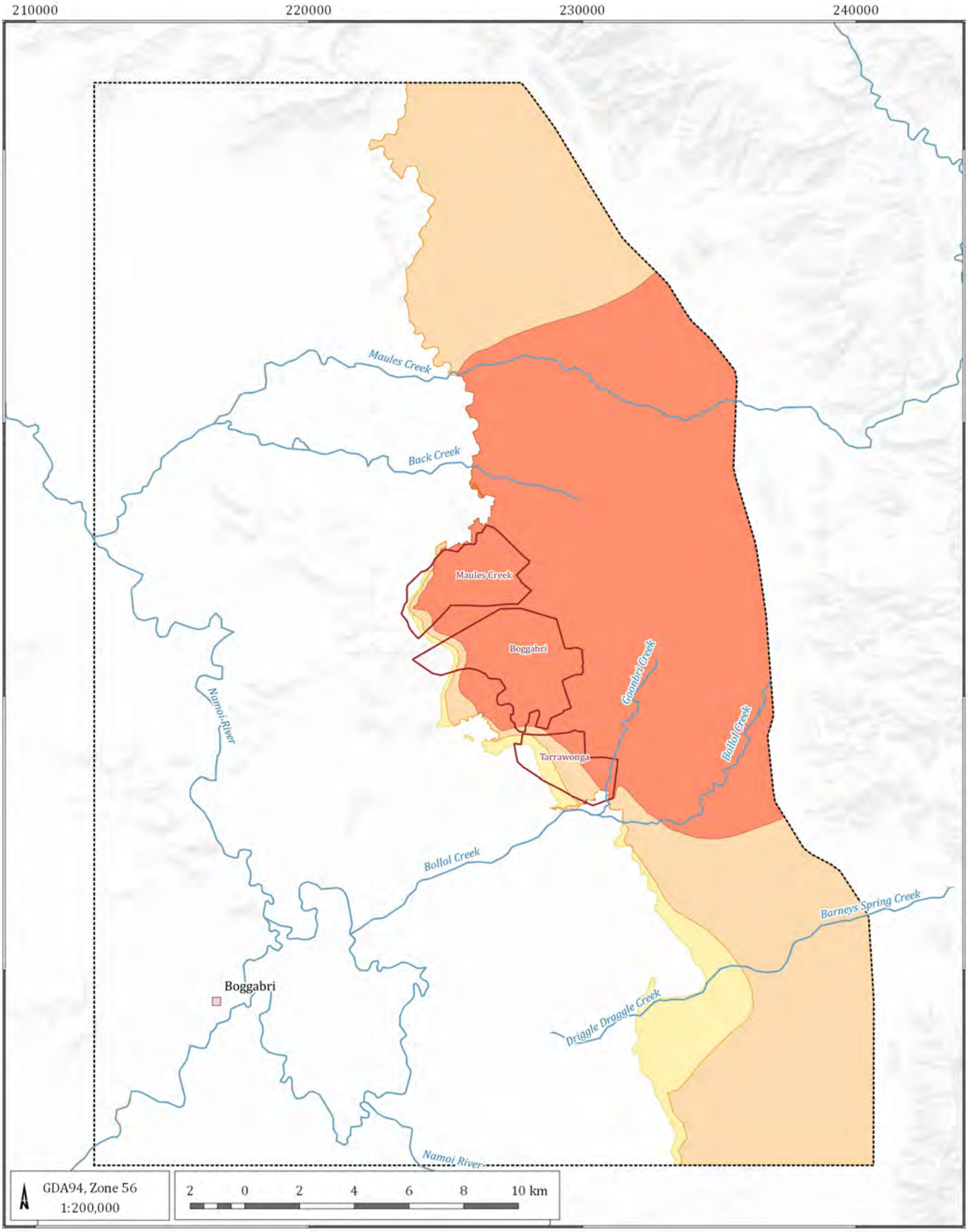
BTM model update (G1850A)

Uncertainty in predicted drawdown at end of 2029 - Layer 2 - Gunnedah alluvium

AGE

DATE 06/12/2017

FIGURE No: **F.5**



LEGEND

- Populated place
- Major drainage
- Mine maximum open cut outlines
- Model extent

Uncertainty in drawdown higher than 1 m

- 95th percentile
- 50th percentile
- 5th percentile

BTM model update (G1850A)

Uncertainty in predicted drawdown at end of 2029 - Layer 8 - Merriown seam

AGE

DATE 06/12/2017

FIGURE No: **F.6**

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:/Projects/G1850A.BTM_Model/3_GIS/Workspaces/001_Deliverable1/F.01-06_G1850A_Uncertainty in predicted drawdown.qgs