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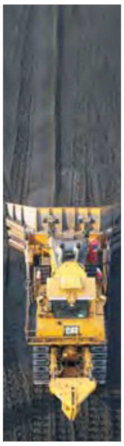
Duralie Open Pit Modification
Environmental Assessment






APPENDIX C

GROUNDWATER ASSESSMENT

YANCOAL
兖煤澳大利亚有限公司

Resource
Strategies

DURALIE COAL MINE EXTENSION PROJECT MODIFICATION

Groundwater Assessment

FOR

Duralie Coal Pty Ltd

BY
W. Minchin, Dr N.P. Merrick and N. Akhter
Heritage Computing Pty Ltd
trading as
HydroSimulations

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A	First Draft	6 June 2014	Initial draft for DCPL and Resource Strategies comment and input
B	Second Draft	4 July 2014	Complete draft
C	Third Draft	6 July 2014	Complete draft
D	Final Draft	10 July 2014	Incorporates Resource Strategies and DCPL comments
E	Final	11 July 2014	Incorporates Resource Strategies comments

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1 INTRODUCTION

This report has been prepared for Duralie Coal Pty Ltd (DCPL), a wholly owned subsidiary of Yancoal Australia Ltd. The report provides a groundwater assessment of the proposed Duralie Open Pit Modification (the Modification).

DCPL owns and operates the mining operations at the Duralie Coal Mine (DCM). The DCM is located approximately 10 kilometres (km) north of the village of Stroud and approximately 20 km south of Stratford in the Gloucester Valley in New South Wales (NSW) **(Figure 1-1).**

Mining operations at the DCM commenced in 2003. In 2008 DCPL lodged an application for the Duralie Extension Project (DEP). The DEP was approved in 2011 by the NSW Land & Environmental Court under section 75J of the *Environmental Planning and Assessment Act, 1979* (EP&A Act) subject to the conditions of Project Approval (08_0203).

The Modification would involve minor changes to the layout of the DCM. The DCM existing/approved surface development areas (including the approximate extent of the open pit and waste rock emplacement) are shown on **Figure 1-2.**

1.1 SCOPE OF WORK

The key tasks for this assessment, with reference to the previous Groundwater Assessment for the DEP (Heritage Computing, 2009) are:

- Description of the hydrogeological setting, including:
  - baseline groundwater data;
  - groundwater regime;
  - groundwater dependent ecosystems;
  - groundwater users;
  - groundwater quality; and
  - analysis of effects of the existing DCM on groundwater levels, pressures and inflows/pumping rates.
- Revision of existing groundwater model for the DCM to account for the Modification (i.e. proposed changes to the mine sequence and pit dimensions).
- Review of potential groundwater impacts associated with the Modification on the following features and receptors:
  - porous and fractured rock and alluvial groundwater systems (during mining and post-mining);
  - surface water resources (i.e. creeks/streams/alluvium);
  - groundwater dependent ecosystems;
  - groundwater users;
  - Biophysical Strategic Agricultural Land (BSAL);
  - consideration of cumulative impacts; and
  - consideration of climate change on groundwater impacts.
- Comparison of predicted groundwater impacts for the Modification with the predicted (Heritage Computing, 2009) and subsequent actual impacts for the approved DCM (i.e. as described in the DEP Groundwater Assessment).
- Comparison of the predicted groundwater impacts of the Modification against the minimal impact considerations in the NSW *Aquifer Interference Policy* (NSW Government, 2012).
- Review of groundwater licensing requirements.

- Review of the groundwater monitoring programme.

Analysis and assessment has been carried out with consideration of the following groundwater-related technical and policy guidelines:

- National Water Quality Management Strategy Guidelines for Groundwater Protection in Australia (Agriculture and Resource Management Council of Australia and Australian and New Zealand Environment and Conservation Council [ARMCANZ/ANZECC]);
- NSW Aquifer Interference Policy (NSW Department of Primary Industries and NSW Office of Water [NOW]), September 2012.
- NSW State Groundwater Policy Framework Document (NSW Department of Land and Water Conservation [DLWC]);
- NSW State Groundwater Quality Protection Policy (DLWC);
- NSW State Groundwater Quantity Management Policy (DLWC) Draft;
- NSW Groundwater Dependent Ecosystem Policy (DLWC);
- Groundwater Modelling Guidelines, namely:
    - Murray-Darling Basin Groundwater Quality. Sampling Guidelines. Technical Report No 3 (Murray-Darling Basin Commission [MDBC]);
    - Australian National Groundwater Modelling Guidelines, published by the National Water Commission (Barnett *et al*, 2012); and
- Draft Guidelines for the Assessment & Management of Groundwater Contamination (NSW Department of Environment and Climate Change [DECC]).

The surface water components of the assessment for the Modification, including consideration of final voids, are provided separately in the Surface Water Assessment (Gilbert and Associates, 2014). That assessment builds on the Surface Water Assessment for the DEP Environmental Assessment (EA) (Gilbert and Associates, 2009).

As part of the assessment process carried out in 2009, an Environmental Risk Assessment was undertaken (SP Solutions, 2009). The following potential groundwater related issue was identified and has been considered in this assessment:

- Seepage of poor quality water from the final void through the waste rock emplacement to Coal Shaft Creek/Mammy Johnsons River.

1.2 THE MODIFICATION

The main activities associated with the Modification include:

- Minor changes to the surface extent of the currently approved open pits to improve geotechnical stability, including a reduction in low wall angles of the Clareval open pit and the removal of the pillar between the Clareval and Weismantel Pits and the associated relocation of existing water diversion infrastructure adjacent to the Clareval pits. The additional surface development extent associated with the Modification (i.e. Modification disturbance area) is shown on **Figure 1-2.**
- Changes to the open pit shells, including an increased maximum pit depth, to reflect the results of recent geological exploration.
- Revised mining sequence (i.e. progression of mining in the Clareval and Weismantel open pits) to account for the revised pit shells and associated dumping requirements (**Figure 1-3**; **Figure 1-4**).
- Increased waste emplacement height in the central portion of the waste emplacement.

1.3 GROUNDWATER MANAGEMENT

The DCM is nominally located within or near the Groundwater Management Areas (GMAs) listed in Table 1-1, as defined by the NOW. These are shown in **Figure 1-5**.

Table 1-1 Groundwater Management Areas near to DCM

Gloucester Basin (within the Draft North Coast Fractured and Porous Rock Groundwater Sources Plan - to be commenced 2014).	Mine located within this GMA.
Karuah Alluvium (to be included within the Lower North Coast Unregulated and Alluvial Plan - to be commenced 2020)*.	This GMA extends within the DCM mining lease.
New England Fold Belt (within the Draft North Coast Fractured and Porous Rock Groundwater Sources Plan - to be commenced 2014).	This GMA is approximately 2.5 km east and west of the DCM.
Manning Alluvium.	At the nearest point, this GMA is located about 12 km north of the DCM.
Hunter River Alluvium.	At the nearest point, this GMA is located about 12 km west of the DCM.

* Karuah Alluvium is not managed within the Karuah River Plan (i.e. only covers surface water)

Because the Draft North Coast Fractured and Porous Rock Groundwater Sources plan has not yet commenced, the DCM and other nearby groundwater users remain managed and licensed under the *Water Act, 1912*.

The Karuah Alluvium GMA is designated as a Coastal (Upriver) Alluvial Water Source. This is relevant to the embargo on new licences (see Section 1.3.1).

Surface Water management occurs under the *Water Sharing Plan for the Karuah River Water Source, 2003*.

1.3.1 GROUNDWATER EMBARGO ZONES

Pursuant to section 113A of the *Water Act, 1912* an embargo on any further applications for sub-surface water licences under Part 5 of the *Water Act, 1912* was declared on 11 April 2008 for the Coastal Floodplain Alluvial Groundwater Sources and Highly Connected Alluvial Groundwater Sources of Coastal Catchments Regional NSW (the alluvial aquifer embargo). As of June 2014, this embargo remains in place[1].

The alluvial aquifer embargo relevantly pertains to:

> *"All the groundwater found in alluvial aquifers located upstream of the tidal limit, and within 500 metres of a 3rd order stream or greater…"*

As described in Section 2.3, Mammy Johnsons River is a 3rd order stream, and the Karuah River a 2nd order stream. It is noted that there are mapped alluvial sediments along Mammy Johnsons River to the east of the DCM. However, there are no mapped alluvial sediments in the Modification additional surface development extent areas (Figure 1-2) (see discussion of geological mapping in Section 2.6).

The embargo therefore includes the alluvium adjacent to the DCM.

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[1] http://www.water.nsw.gov.au/Water-management/Water-availability/Groundwater/avail_ground_embago/default.aspx

1.3.2 GROUNDWATER PRODUCTIVITY

Figure 1-5 also presents NOW's classification of Groundwater Productivity for the purposes of assessment under the NSW Aquifer Interference Policy ('AI Policy') (NSW Government, 2012). Both the Gloucester Basin and New England Fold Belt GMAs are classified as 'Less Productive' groundwater. The various alluvial water sources, including the Karuah Alluvium, are currently classified as 'Highly Productive' groundwater.

1.3.3 BIOPHYSICAL STRATEGIC AGRICULTURAL LAND (BSAL)

BSAL has been mapped across parts of NSW as part of the Strategic Regional Land Use Policy (SRLUP). This policy is aimed at managing potential conflict between extractive and agricultural industries in defined areas of high quality agricultural land. If BSAL is present at a mine project, a 'Gateway' Assessment of groundwater may be required.

Figure 1-5 presents the BSAL for the Upper Hunter area. When the plan was released, it showed areas classified as 'Biophysical Strategic Agricultural Land Mapping' within the DCM mining lease area, despite these areas being previously open pit mined (i.e. prior to the release of the mapping). The area within the southern part of the DCM is aligned with 1:250k geological mapping for the area, which suggests a tongue of alluvium extends north from the Mammy Johnsons River into the DCM. Geology mapping at 1:100k scale (Section 2.6) does not support the mapping of that alluvium.

In any case, the BSAL mapping is relevant to 'greenfield' projects, and to 'brownfield' projects where the mine is proposed to expand beyond the existing lease area. In the case of the DCM, the expansion is within the existing lease area, so the Gateway Assessment is not required[2].

1.4 DEWATERING AND GROUNDWATER LICENCES

Water reporting to the open pit is currently pumped via in-pit sumps to the Main Water Dam (MWD). DCPL holds an existing Bore Licence (20BL168404) that was originally issued under Part V of the *Water Act, 1912* on 23 September 2002, and was renewed in 2007 and again in 2012. It remains valid until September 2017. This licence applies to the excavation, registered as GW080339 on the NSW Bore Database. The licence excerpt relevant to this assessment states:

> *"(8) The volume of groundwater extracted from the works authorised by this licence shall not exceed 300 megalitres in any 12 month period commencing 1st July."*

Groundwater monitoring boreholes at the DCM are licensed under the existing Bore Licence 20BL168539, which sets out conditions of use for the monitoring bores.

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[2] http://www.mpgp.nsw.gov.au/docs/Guideline%20for%20Gateway%20Applicants.pdf

2 HYDROGEOLOGICAL SETTING

2.1 RAINFALL AND EVAPORATION

Rainfall experienced in the DCM area can be described as moderate to high. Rainfall at Stroud Post Office (PO), Meroo (Wards River) and Chichester Dam, the closest Commonwealth Bureau of Meteorology (BoM) rainfall gauges, averages between 1,147 millimetres (mm) to 1,316 mm per year (mm/a). Rainfall measured by the DCM's meteorological station shows lower rainfall (1,059 mm/a), although is a shorter record (2003-09, 2012-14). Average potential (pan) evaporation (based on the Chichester Dam station) is some 2.9 mm per day (mm/d). The average monthly rainfall and potential evaporation statistics from these stations are summarised in **Table 2-1** below and indicate that rainfall over the DCM area is typically lower during the winter months with maxima generally experienced during the summer months.

Table 2-1 Monthly Average Rainfall and Daily Evaporation

MONTH	MONTHLY AVERAGE RAINFALL (mm)				MONTHLY AVERAGE PAN EVAPORATION (mm)	
	STROUD PO[1] (SITE 061071)	MEROO (WARDS RIVER)[2] (SITE 061340)	CHICHESTER DAM[3] (SITE 061151)	DCM MET STATION[4]	CHICHESTER DAM[3]	PATERSON (TOCAL) AWS
JAN	114.8	202.6	166.7	77	140	192.8
FEB	125.5	202.5	182	154	107	150.2
MAR	144.1	150.2	171.6	120	93	130.3
APR	101.6	64.2	100.4	106	69	99.1
MAY	91.7	80	96.9	68	47	73.6
JUN	100.8	108.7	103	87	33	64.2
JUL	75.5	33.4	52.6	46	40	74.1
AUG	64.3	30.1	60.1	44	59	103.8
SEP	62.8	57.3	64.2	55	84	134.5
OCT	78.1	98.6	91.8	58	112	161.8
NOV	85.8	108.8	102	131	123	176.2
DEC	102.8	111.7	124.9	77	152	207.1
ANNUAL	1,147.2	1,241.3	1,316.2	1,023	1,059	1,567.7

Source: BoM, 2014 (http://www.bom.gov.au/climate/data/)

[1] Stroud PO station record 1889 - 2009.

[2] Meroo (Wards River) station record 1970-1977. The observed annual rainfall at Meroo (Wards River) matches well with the historical measurements at Wards River (Moana) (Appendix A of the 2009 EA for the DEP).

[3] Chichester Dam station record 1974-2009.

[4] DCM met station record 2003-June 2009 and June 2012-March 2014.

Actual Evapotranspiration for the region is up to approximately 750 mm/a (BoM, 2014)[3].

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[3] Site-specific values for evapotranspiration were not used in this assessment due to the scale of the area modelled.

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Fluctuations in the groundwater table result from temporal changes in rainfall recharge to aquifers. Typically, changes in the groundwater elevation reflect the deviation between the long term monthly (or yearly) average rainfall, and the actual rainfall, illustrated by the Residual Mass Curve (RMC).

The groundwater levels recorded during periods of rising RMC are expected to increase while those recorded during periods of declining RMC are expected to fall. A plot of RMC at Stroud PO since 1889 is shown in **Figure 2-1A** and a detailed view is shown in **Figure 2-1B** since the commencement of mining at the DCM in 2003. The latter graph shows that the mining operation to date (i.e. since 2003) experienced a significant dry period from mid-2005 to late-2007, with shorter term dry conditions during 2010 and from early-2012 to early-2014. During those periods, pit inflows would be expected to be lower than average. Short duration wetter interludes occurred in 2008, 2009 and 2011. Fluctuations in pit inflow due to rainfall recharge are expected to be much smaller than the dominant influence of mining sequence and geometry.

2.2 TOPOGRAPHY

The DCM is located within an area with significant topographic relief and undulating topography. The Mammy Johnsons River valley runs in an approximately north-south direction and forms the main topographic feature to the east of the DCM (**Figure 2-2**). To the east and south-east of the Mammy Johnsons River, the Buckleys Range is the highest topographical feature in close proximity to the DCM. A second ridgeline to the west of the DCM effectively screens the DCM from The Bucketts Way (**Figure 2-2**). Within the DCM mining area the topography is dominated by the waste rock emplacement and open pits, the valley of Coal Shaft Creek and Tombstone Hill, a locally elevated elongated feature in the north-eastern part of ML 1427 that screens the mining area from the north-east (**Figure 2-2**).

Surface elevations in the area vary from approximately 50 m Australian Height Datum (AHD) to 300 mAHD with ridgelines typically rising between 50 and 150 m above the drainage floor. Elevations range from around 50 mAHD along the river flats of Mammy Johnsons River to 305 mAHD on Peach Tree Mountain to the east of the Mammy Johnsons River. Tombstone Hill is at approximately 130 mAHD (**Figure 2-2**). The ridges that form the western divide between the catchments of Coal Shaft Creek and the Karuah River are typically between 140 and 170 mAHD.

2.3 HYDROLOGY AND DRAINAGE

The DCM is located in the Karuah River catchment and lies just upstream of the confluence of the Karuah River and Mammy Johnsons River. These watercourses are classified as Stream Order 2 and 3 respectively.

Surface water hydrology is addressed in detail in the Surface Water Assessment for this Modification (Gilbert and Associates, 2014). There are two gauging stations on Mammy Johnsons River (known as Pikes Crossing gauging station 209002 [upstream] and Stroud Road gauging station 209004 [downstream]), about 12 km apart in a direct line. The respective catchment areas of the two gauging stations are 156 square kilometres (km^2) and 318 km^2. The DCM lies midway between the two gauging stations.

Recorded flow magnitudes are listed in **Table 2-2** in terms of exceedance probabilities for month-averaged daily flows. The median flow increases from 31 megalitres per day (ML/day) to 45 ML/day going downstream past the DCM. Flow has exceeded 0.9-1.6 ML/day for 90 percent (%) of the time, and 0.08-0.6 ML/day for 95% of the time.

Table 2-2 Exceedance Probability for Month-Averaged Daily Flow in Mammy Johnsons River

EXCEEDANCE PROBABILITY (%)	Pikes Crossing Gauging Station [209002] (ML/day)	Stroud Road Gauging Station [209004] (ML/day)
10	506	1,290
50	31	45
80	2.9	7.8
90	0.9	1.6
95	0.08	0.6

2.4 LAND USE

The DCM is located in a rural area characterised by cattle grazing on native and improved pastures, along with some poultry farming and other agricultural production. The majority of the DCM area has been cleared as part of past land use practices. The DCM and the Stratford Coal Mine (located some 20 km to the north) are the main mining developments in the area. Other land uses in the district include dairying, timber milling, poultry, cropping and recreation.

DCPL owns the land within ML 1427 and ML 1646 and a significant area of surrounding lands. DCPL manages the majority of its landholdings outside ML 1646 and 1427 for agricultural production.

The Modification disturbance area is limited to two relatively small areas (approximately 2.5 hectares in total) along the northern and western extent of the Clareval Open Pit, located within ML 1646 (Figure 1-2).

2.5 GROUNDWATER DEPENDENT ECOSYSTEMS

The NSW State Groundwater Dependent Ecosystems Policy (DLWC, 2002) describes the five broad types of groundwater systems in NSW, each with associated dependent ecosystems as follows:

- **Deep Alluvial Groundwater Systems** – occurring under floodplains of major rivers west of the Great Dividing Range (e.g. Namoi, Macquarie, Lachlan, Murrumbidgee and Murray alluvium).
- **Shallow Alluvial Groundwater Systems** – coastal rivers and higher reaches west of the Great Dividing Range (e.g. Hunter, Peel and Cudgegong alluvium, and beds and lateral bars of the lower Macleay, Bellinger and Nambucca Rivers).
- **Fractured Rock Groundwater Systems** – outcropping and sub-cropping rocks containing a mixture of fractures, joints, bedding planes and faults that contain and submit small and occasionally large amounts of groundwater (e.g. Alstonville Basalt, Molong Limestone and the Young Granite).
- **Coastal Sand Bed Groundwater Systems** – significant sand beds along the coast of NSW (e.g. Botany and Tomago sand beds).
- **Sedimentary Rock Groundwater Systems** – sedimentary rock aquifers including sandstone, shale and coal (e.g. Great Artesian Basin, Sydney Basin and Clarence Moreton Basin).

Groundwater resources in the DCM area are located mainly within the sedimentary rock groundwater systems of the Gloucester Basin.

The NSW State Groundwater Dependent Ecosystems Policy (DLWC, 2002) also recognises the four Australian groundwater dependent ecosystem types (Hatton and Evans, 1998) that can be found in NSW, namely:

- terrestrial vegetation;
- base flows in streams;
- aquifer and cave ecosystems; and
- wetlands.

Further to the commentary in Heritage Computing (2009), a search of the BoM GDE Atlas and relevant legislation has been carried out as part of this study. **Figure 2-3** shows the mapping of features potentially reliant on surface and subsurface expressions of groundwater flow from the BoM GDE Atlas[4]. These are coloured according to the perceived dependency on groundwater inputs (e.g. baseflow). This mapping shows:

- The Karuah River is mapped as a baseflow dependent feature, with the reaches of this river nearest to the DCM identified as having a High' potential for groundwater interaction;
- Areas of terrestrial GDEs (typically gum forest habitat) on the interfluves away from the Karuah River and Mammy Johnsons River. The main areas mapped within the study area are 2 km to the north-east, 3 km south, 3 km southwest and 5 km north of the DCM.

A search of legislation was carried out to identify any High Priority GDEs in the region. Because the Water Sharing Plans (see Section 1.3) are not yet commenced, earlier documents were reviewed. The only High Priority GDEs identified in this region were two sets of karst features ('Gloucester Caves), both of which are located 38 and 40 km north of the DCM.

Based on this data search and analysis, no groundwater dependent ecosystems are known or likely to occur within the DCM mining lease areas (**Figure 2-3**). Based on a review of other literature, e.g. DECCW, 2010, further supported the fact that the DCM is not in close proximity to GDEs identified as High Priority.

2.6 STRATIGRAPHY AND LITHOLOGY

The DCM coal resource is located within the Permian-aged Gloucester Basin in NSW. The DCM is located in the southern closure of the main synclinal structure of the Gloucester Basin and is associated with the coal bearing strata of the Dewrang Group. The Dewrang Group comprises three main stratigraphic units, namely:

- Mammy Johnsons Formation;
- Weismantels Formation; and
- Durallie Road Formation.

The main stratigraphic units in **Figure 2-4** are shown in a geological cross-section of the DCM area in **Figure 2-5**. The outcrop mapping shown in **Figure 2-4** is the 1:100k Dungog map-sheet (*Roberts et al*, 1991). This has been overlain with polygons showing the recently mapped extent of the two mined coal seams (Weismantel and Clareval Seams), as based on DCPL's geological model of the DCM.

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[4] http://www.bom.gov.au/water/groundwater/gde/map.shtml

The Dewrang Group subcrops over a major portion of the DCM and consists of coarse and medium grained sandstones with minor siltstone, conglomerate and coal seams including the Weismantel and Clareval Seams associated with the Weismantels Formation and Durallie Road Formation, respectively (**Figure 2-4**; **Figure 2-5**). The underlying basement rocks are principally volcanics of Early Permian (i.e. Alum Mountain Volcanics) and Carboniferous age that were folded during formation of the Gloucester Basin. The Early Permian and Carboniferous volcanic rocks are typically erosion resistant and form the more prominent ridges to the east and west of the DCM.

Normal and reverse faults are characteristic of the area. The Gloucester Basin is a fault-controlled depositional trough and subsequent compression tectonics have induced folding, which has accentuated the dip of the strata and, in places, resulted in thrust-faulted repetition of the stratigraphic units. The main faulting and fracturing (joints) trend north-south, east-northeast, and west-southwest in the DCM area. Generally the joint spacing in the sandstone is approximately 1 m (Kidd, 1996).

The Modification would not change the nominal coal reserve for the Duralie Extension Project, which based on the planned maximum production rate is approximately 20.5 million tonnes (Mt) of ROM coal.

2.6.1 ALLUVIALS/REGOLITH

A thin, narrow and discontinuous deposit of Quaternary to Recent Age alluvial deposits occurs along the river flats of Mammy Johnsons River. The alluvium consists of silty sands and silts with lenses of gravelly sands and sandy, coarse gravel, particularly towards the base of the alluvium. The gravel lenses correspond to former channel deposits of the river and are evident in the present bed and banks of the river. Monitoring bores in the alluvium are drilled to depths of 5.8 to 10.1 m; other evidence from exploration holes suggests an average thickness of about 9 m for the alluvium, but the maximum thickness is unknown.

2.6.2 MAMMY JOHNSONS FORMATION

The uppermost layer of the Mammy Johnsons Formation is thick shale. Similar to its underlying coal formations, the deeper sections of the Mammy Johnsons Formation comprise coarse grained lithic sandstones. It also hosts minor, poorly developed coal seams.

2.6.3 WEISMANTELS FORMATION

The Weismantels Formation comprises fine to medium grained sandstones over thick shale covering the Weismantel Seam (below) which has a median thickness of 17 m. The Weismantel Seam overburden (comprising Mammy Johnsons Formation and Weismantels Formation) has a median thickness of 34 m.

2.6.4 WEISMANTEL SEAM

The Weismantel Seam was the first of the two main seams to be mined at the DCM and would continue to be mined as part of the Modification. The Weismantel Seam, including any interburden, is generally between 12 and 14 m thick. However, significant reverse faulting causes repetition of the middle and lower sections of the seam resulting in coal thicknesses of up to 42 m. The median coal thickness is 12 m. The Weismantel Seam is divided into working sections on a coal quality basis. The upper 3 to 4 m is generally thermal coal and the lower 7 to 8 m is a mixture of coking coal and thermal coal.

The original DCM pit was located at the southern closure of the regional syncline. The Weismantel open pit has subsequently progressed away from the axis towards the western flank of the syncline (**Figure 2-4**).

The seam is underlain and overlain by massive medium to coarse grained lithic sandstones, conglomerates and minor siltstones. The immediate roof and floor of the Weismantel Seam have a high pyrite content.

2.6.5 DURALLIE ROAD FORMATION

The Durallie Road Formation forms the base of the Dewrang Group and comprises mostly marine sandstones in the south of the Gloucester Basin. The Durallie Road Formation hosts the Clareval Seam (below). The lower Durallie Road Formation (beneath the Clareval Seam) is 200 to 300 m thick.

2.6.6 CLAREVAL SEAM

The Clareval Seam was identified in late 2005 from seismic re-interpretation and was confirmed by an exploration drilling programme. The Clareval Seam is situated at depth typically 160-300 m below (median depth 220 m) and parallel to the Weismantel Seam. This is significantly deeper than the typical 60-80 m depth reported in Heritage Computing (2009), and accordingly the Modification involves deepening of the Clareval open pit in some areas.

The Clareval Seam exhibits many of the same features as the Weismantel Seam (e.g. coal quality trends and seam structure). In the Clareval open pit, the Clareval Seam is typically 8 to 15 m thick. However sequences of 30 m and up to 70 m thickness are known to exist in the north-west (**Figure 2-5**). The median thickness is 10 m.

2.6.7 ALUM MOUNTAIN VOLCANICS

The Alum Mountain Volcanics are a rhyolitic rock unit, which is underlain by undifferentiated rocks of Carboniferous age.

2.7 HYDROGEOLOGY

The deeper aquifer system at the DCM is continuous through the three major geological units (i.e. Mammy Johnsons, Weismantels and Durallie Road Formations) due mainly to the extent of faulting/fracturing/fissures in the DCM area. The various sedimentary rocks at the DCM have low permeability due to their fine grained nature, the predominance of cemented lithic sandstones and the common occurrence of a clayey matrix in the sandstones and conglomerates. The permeability of the aquifer system is related to the frequency of fissures (i.e. spacing) and the degree of opening of individual fissures. Permeability of the aquifer generally decreases with depth of burial as the fissures tighten and become less frequent, with higher permeabilities encountered in the coal seams.

Golder Associates (1982) established that before mining commenced, natural groundwater flow was generally in a southerly direction (**Figure 2-6**). DCPL (1996) extrapolated from this dataset to infer that flow originates in the elevated ground to the west of the open pit (**Figure 2-7**). The trend of the groundwater contours under the higher ground is expected to mimic the topographic contours (**Figure 2-7**). A topographic divide along easting 387000 ISG (or 398700 in MGA94 zone 56) occurs between the mine and the Karuah River in the west. This limits the potential for interaction between the DCM catchment and the Karuah River.

The presence of several free flowing or artesian boreholes on the lower slopes indicates semi-confined conditions due to the presence of siltstone layers, the lower ground elevations along the creek, and the higher elevations of the recharge sources (DCPL, 1996).

The results of previous assessments DCPL (1996), Kidd (1996) and Heritage Computing (2009) indicated groundwater flow would also be toward the pit as mining progresses and that mine dewatering will have little if any measurable impact on the flow conditions in Mammy Johnsons River

Quantification of the impact on flow conditions is undertaken in this assessment.

2.8 GROUNDWATER BORE CENSUS

As of late 2013, according to the NSW Pinneena bore database there are 37 registered bores within 5 km of the DCM, most of which are now owned by DCPL. There are four registered production bores located on privately owned land north of the mining lease (see **Figure 2-8** – one bore is about 3 km, and the others approximately 4-6 km north). Within 15 km there are 68 registered bores. The licensed use of these bores is stock/irrigation/industrial. Bore locations are shown on **Figure 2-8** and NSW Office of Water (NOW) registered bore details are summarised in **Attachment A**. These statistics do not include the works associated with the DCM mine pit, which is also registered on the NSW bore database.

Some of the bores do not have reported/surveyed surface collar levels; therefore groundwater elevations are estimated from approximate ground levels. The majority of historical data from the NOW registered bores is limited to notes on levels and salinity records taken at the time of drilling or installation.

The registered bores have a median depth of approximately 27 m (where recorded), and median depth to water of approximately 13 m with a range in water depths from approximately 2 to 40 m below ground. For the 17 production bores, the median bore yield is approximately 0.7 litres per second (L/s) (minimum = 0.25 L/s and maximum = 9.3 L/s).

DCPL conducted a bore census of privately held bores surrounding the DCM in October 2009 by visiting local landholders. During the bore census, a local landholder indicated that a spring is located to the west of The Bucketts Way, in a drainage line in or near Black Soil Creek (**Figure 2-8**), and west of the groundwater catchment divide described by DCPL (1996) (**Figure 2-7**).

2.9 GROUNDWATER MONITORING

DCM have an overarching Water Management Plan (DCPL, 2013a). The mine's Groundwater Management Plan [GWMP] (DCPL, 2013b) is a sub-plan to the Water Management Plan. Groundwater monitoring is conducted by DCPL under the GWMP.

Groundwater quality sampling and water level monitoring in the general DCM area has historically been undertaken by DCPL and the NOW in accordance with the National Water Quality Management Strategy Guidelines for Groundwater Protection in Australia (ARMCANZ/ANZECC, 1995). Groundwater level and quality monitoring undertaken by DCPL has primarily focused on the Mammy Johnsons River and associated alluvium, Coal Shaft Creek. The focus has also been on areas of proposed or recently completed mining.

Table 2-3 summarises the groundwater monitoring network. Bore locations are plotted on **Figure 2-8**. Water levels in bores DB3W, DB4W (both alluvium) and DB11W are monitored daily, as are the two that monitor the in-pit waste rock emplacement areas (WR1 and WR2).

Water levels at the other bores, as well as water quality at all bores, are monitored on a quarterly basis.

Table 2-3 Groundwater Monitoring Network

Bore ID	Easting	Northing	Ground RL	Bore depth	Screen Top	Screen Bottom	Monitored Formation	Date Drilled
	Zone 56	Zone 56	mAHD	m	mBG	mBG		
DB1W	401424	6426924	62.3	36.9	17.5	36.5	upper Durallie Road Fm	01-Nov-02
DB2W	401445	6426234	63.3	60.6	40.0	60.0	upper Durallie Road Fm	01-Nov-02
DB3W	401762	6426744	52.9	6.35	4.0	5.5	alluvium	01-Jan-03
DB4W	400934	6425507	53.6	41.1	25.0	40.0	upper Durallie Road Fm	01-Nov-02
DB5W	400520	6425172	55.5	41.5	30.0	40.0	upper Durallie Road Fm	01-Nov-02
DB6W	400083	6426344	93.5	40.5	25.0	40.0	upper Durallie Road Fm	01-Nov-02
DB7W	401184	6427783	70	16.0	12.5	15.5	Mammy Johnsons Fm	01-Nov-02
DB8W	400318	6428300	78	50.0			Mammy Johnsons Fm	01-Oct-08
DB9W	400242	6428484	75	51.0	44.0	50.0	Mammy Johnsons Fm	01-Oct-08
DB10W	400127	6428683	75	34.1	28.0	34.0	Mammy Johnsons Fm	01-Oct-08
BH4BW	401599	6426205	53.1	6.31	4.3	5.8	alluvium	01-Jan-03
SI1W	399713	6426032	82.5	17.0	13.4	16.4	lower Durallie Road Fm	01-Jan-04
SI2W	399403	6425974	107.7	36.3	32.7	35.7	lower Durallie Road Fm	01-Jan-04
SI3W	399143	6425781	123.3	28.63	25.2	28.2	lower Durallie Road Fm	01-Jan-04
DB11W	399100	6430300	*	51.0	37.0	50.0	Mammy Johnsons Fm	03-Sep-13
Waste rock dump								
WR1	400776	6425804	*	19.3			Waste rock	
WR2	400990	6426582	*	80.0			Waste rock	

* not yet surveyed

Water quality parameters that are measured at the monitoring bores listed in **Table 2-3** are provided in **Table 2-4**.

Table 2-4 Groundwater Quality Parameters measured at DCM

pH	Total Acidity	Iron (Fe)	Chloride (Cl)
Electrical conductivity (EC)	Total Alkalinity	Magnesium (Mg)	Sulphate (SO4)
Dissolved oxygen (DO)	Sodium (Na)	Aluminium (Al)	Manganese (Mn)
Total Dissolved Solids (TDS)	Calcium (Ca)	Zinc (Zn)	

Groundwater inflows to the pits are inferred by water balance, based on recorded pump volumes from the in-pit sumps (Section 2.12). Field parameters and a suite of water quality parameters are monitored in the sumps on a weekly and monthly basis respectively.

Groundwater quality data is presented in **Attachment BB of Heritage Computing (2009)**. The density, duration and scale of the groundwater monitoring data were considered adequate in 2009 to inform the development of the numerical groundwater model and to conduct an assessment of potential groundwater impacts. More recent data, including from four new monitoring bores, has added to the knowledge of this hydrogeological system.

2.10 GROUNDWATER LEVEL DATA

Analysis of baseline data is as per Heritage Computing (2009). Recent groundwater level data, and the behaviour and trends seen within that, are discussed in Section 2.10.2

2.10.1 BASELINE SPATIAL GROUNDWATER LEVEL DATA

Natural groundwater levels are sustained by rainfall infiltration and are controlled by ground surface topography, geology and surface water elevations. Typically, local groundwater would mound beneath hills and would discharge to incised creeks and rivers. During short events of high surface flow, streams would lose water to the host aquifer, but during recession, the aquifer would discharge water slowly back into the stream from bank storage. Groundwater would flow from elevated to lower-lying terrain.

Based on the available groundwater level data and to gain an impression of the regional water table pattern before mining, a contour map of inferred groundwater levels (**Figure 2-9**) was prepared from groundwater levels at the NOW bores or measured from DCM monitoring boreholes (**Figure 2-8**). The dataset has been supplemented with surface water levels in no-data areas, assuming equivalence between surface water and groundwater levels along drainage lines, and a depth to groundwater of 20 m along ridgelines.

Apart from small changes in detail where groundwater measurements have been made, the overall patterns are insensitive to the assumption made as to the relative levels of surface water and groundwater where they interact. In all cases, the contour maps indicate the same groundwater flow pattern. As groundwater would flow perpendicular to the contours, in general (except for discrete fracture flow), groundwater would generally move from the ridges to the natural surface drainages. The Mammy Johnsons River is a prominent groundwater discharge feature.

The map in **Figure 2-9** is a composite of water levels from different formations. The measurements clustered near the mine are mostly from open holes but would be representative of Weismantel Coal seam heads. The cluster of points to the north-west of the mine are Clareval Seam heads. The three points in the far north are likely to be Weismantels Formation heads.

Despite the uncertainty in the formation sampled, the map in **Figure 2-9** is likely to represent the overall potentiometric head pattern across the area, on the assumption that there is some vertical hydraulic connectivity between formations. The topographic imprint can be expected to be muted with depth below land surface.

Of significance is the direction of groundwater flow due to mining in the nearby DCM open pit. The DCM open pit acts as a groundwater sink, and groundwater nearby maintains a flow direction towards the pit.

2.10.2 BASELINE AND RECENT TEMPORAL GROUNDWATER LEVEL DATA

Groundwater levels have been monitored at some bores since 1997; monitoring at others commenced in January 2003 prior to the commencement of open pit mining (March 2003). Monitoring has also been undertaken at monitoring bores installed after the previous Groundwater Assessment (Heritage Computing, 2009) was conducted.

The figures in this section present groundwater level hydrographs alongside historic monthly rainfall and the RMC (essentially the rainfall trend – see Section 2.1), as well as the calculated river stage at a nearby point on the Mammy Johnsons River. Bore locations are shown on **Figure 2-8**.

Figure 2-10 presents the hydrographs for four bores installed in the alluvium around the southern 'half' of the DCM. Inspection of this data shows or suggests:

- These bores in the alluvium do not exhibit any observable mining effect (mining started in 2003);
- Alluvium groundwater levels are well correlated to the trends in the RMC (including the rise in water levels in DB3W in the period before 2003 (see Stroud PO RMC in **Figure 2-1**), as well as to the shorter-term river level fluctuations (e.g. BH4BW in late 2007 or BH4BW and DB3W in late 2012).

Figure 2-11 presents hydrographs from four bores drilled into the sandstones of the Durallie Road Formation. This figure shows or suggests:

- Bore DB1W, located at least 700 m to the east of the recent mining shows no effect from mining. Water level fluctuations correspond closely with rainfall, in a very similar manner to the responses seen in the alluvium.
- Bore DB5W, located toward the southern edge of the DCM area and down-gradient of the synform closure, shows a mild reduction in groundwater level (approximately 2 m) as mining has moved from the eastern areas of the pit to the western areas of the pit.
- Groundwater levels in the other two bores (DB2W and DB4W) have shown a noticeable effect due to the commencement of mining (in 2003). Bore DB2W is located to the immediate east of the pit between the rail line and Mammy Johnsons River (**Figure 2-8**) and DB4W is located to the south, between the southern edge of the DCM lease and the river.
- Groundwater levels at DB2W and DB4W had also recovered to pre-mining levels by about 2013. The sudden dip and recovery in both hydrographs in late 2013-14 appear to be unreliable data, based on the apparent recovery in subsequent readings.
- DB5W showed recovery by about 2009-10, due to mining moving away and the growth of the waste rock emplacement;

Figure 2-12 focuses on the water level response in the alluvium and rock. The two bores presented, BH4BW and DB2W) are located approximately 265 m apart. BH4BW is close to Mammy Johnsons River; and DB2W to the immediate east of the North Coast Railway adjacent to initial mining. While there is a clear response in the Durallie Road Formation (DB2W) due to the onset of mining in the overlying Weismantel seam, there is no evidence of any effect in the alluvium. By 2013 water levels in the Durallie Road Formation have recovered to their pre-mining (2003) levels. The pre-mining (2003) and recovered (2013-14) Durallie Road Formation water levels are in close agreement with the alluvium water levels.

Figure 2-13 shows hydrographs from bores at elevated locations:

- DB6W is installed in the Durallie Road Formation to the west of the mine pit. This bore is located between the MWD and Auxiliary Dam No. 2 and shows a slight decline in water levels (in line with the RMC) and a recovery in 2009-10. (Possible causes include irrigation, and/or seepage from the Mine Water Dam). Stable water levels through 2010-12 are then followed by a steep decline in water levels (4 m drawdown) into 2014. This is most likely an effect of mining in the Clareval Pit to the north and northeast of this bore.

- BH2W is located to the south-east of the DCM and on the opposite side of the Mammy Johnsons River. This bore is no longer monitored. The groundwater levels in 2009 are similar to those in 2003, and so suggests no mining effect at this location.

Figure 2-14 presents hydrographs from bores located in the DCM irrigation area, just near the MWD (bores SI1W, SI2W, SI3W):

- Water levels at all three bores are stable until 2009.
- Water levels in SI3W remain stable for the whole period, with no apparent correlation to RMC and only minor temporal variation. This bore is the most westerly of the bores, furthest from mining and furthest from the MWD (400 m away).
- SI2W water levels respond strongly to a stress in 2010-13. Initially it was thought it was to the upward trend in the RMC (late 2011-early 2012). However the trend appears to continue after the next decline in the RMC. This bore is close to the MWD, and so the effect could be due to the filling of Auxiliary Dam No. 2.
- Groundwater levels in SI1W also respond to a stress in 2011-12. This could be a response to the high rainfall period seen in the RMC at that time, however could also be due to the operation of Auxiliary Dam No. 2.

Figure 2-15 presents water levels from three bores installed in 2009, at the time the previous Groundwater Assessment was being completed. These bores are installed in the Durallie Road Formation, and all are located to the east of more recent mining in the northern part of the Weismantel pit. This figure shows:

- Conflicting water level behaviour between DB9W and DB10W, and that from DB8W. DB8W shows an apparent recovery or rise in water levels from July 2009 to present day, while the other two show drawdown of around 5-6 m over the same period.
- With mining occurring in the nearby Weismantel pit during the period 2010-14, the drawdown in the Durallie Road Formation is the more likely behaviour. Bores DB9W and DB10W therefore show a clear mining effect, with the greatest drawdown occurring in 2009-10, followed by a flattening of water levels in 2011-14.
- DB8W water levels cannot be explained at this time. See recommendations in Section 6.3.1.

Figure 2-16 presents the recent data from the newest monitoring bore, DB11W. The record is currently too short to make any link between groundwater levels and rainfall or mining stresses.

In summary, a number of bores installed in the Permian strata around the DCM show clear mining effects. Water levels in such bores installed in the south, close to early mining at the DCM but away from more recent mining, have generally recovered to pre-mining levels. There was no mining effect observed in the records from the alluvium bores.

2.11 BASELINE GROUNDWATER CHEMISTRY DATA

The analysis of baseline groundwater chemistry has not been updated from the DEP assessment (in 2009) as mining is well advanced since commencing in 2003. Data at 2009 are retained as adequate representation of baseline chemistry.

Table 2-5 summarises the baseline chemical attributes of all groundwater samples from 1981 to August 2009 taken at monitoring sites and hydrogeological investigation sites by DCPL, Pells Sullivan Meynink and Golder Associates (**Figure 2-7**).

Table 2-5 Chemical Data Summary at Groundwater Monitoring Sites

ANALYTE	UNIT	MEDIAN	MINIMUM	MAXIMUM	AVERAGE
pH	-	6.7	4.4	9.6	6.8
Electrical Conductivity	MicroSiemens per centimetre (µS/cm)	1,874.0	100.0	7,600.0	2,387.1
Sulphate	milligrams per litre (mg/L)	129.0	0.1	813.0	143.3
Calcium	mg/L	83.0	1.0	700.0	138.3
Magnesium	mg/L	53.0	0.4	244.0	62.0
Sodium	mg/L	243.5	15.0	841.0	333.6
Potassium	mg/L	2.35	<0.5	22.0	4.3
Chloride	mg/L	510.0	<5.0	2,400.0	720.7
Iron	mg/L	1.4	0.0	190.0	14.5
Aluminium	mg/L	0.07	<0.01	190.0	6.67
Manganese	mg/L	0.7	<0.001	10.0	0.9
Zinc	mg/L	0.04	<0.005	0.57	0.07
Alkalinity as $CaCO_3$	mg/L	190.0	0.0	710.0	230.5
Total Dissolved Solids	mg/L	1,480.0	156.0	4,110.0	1,416.0

Source: Golder Associates (1981a, 1981b); Pells Sullivan Meynink (1995); DCPL (2009).

The spatial pattern of baseline groundwater salinity is illustrated in **Figure 2-17**. The groundwater is considered moderately brackish, as indicated by a median electrical conductivity (EC) of 1,874 µS/cm and a median salinity (TDS) of 1,480 mg/L. Groundwater salinities range from 100 µS/cm to 7,600 µS/cm, even under the river flats (**Figure 2-17**). Salinity in the narrow thin alluvium is lower, generally less than 1,000 µS/cm, reflecting the higher rates of recharge and shorter residence times and flow paths compared with the underlying strata.

The average EC from bores in the lower Durallie Road Formation (i.e. DB1W, DB2W and DB5W), which incorporates the Clareval seam, is about 2,600 µS/cm.

The pH of groundwater at the DCM is generally within the 6 to 8 range.

The concentrations of trace metals in the groundwater are generally below ANZECC criteria for irrigation and stock uses although in some locations, aluminium concentrations have exceeded the recommended ANZECC 'low risk' trigger level for stock use. In some locations, dissolved iron concentrations have exceeded the recommended ANZECC agricultural irrigation 'short term trigger values'.

2.12 GROUNDWATER INFLOW TO MINE PITS

Groundwater that enters the Weismantel and Clareval Pits is collected in sumps in the pit floor. Some proportion of groundwater that enters the pit will be lost to evaporation before it is collected in those sumps. Water collected in the sumps is pumped to the MWD along with other water captured by the DCM water management system, where it is used for dust suppression or irrigation.

The inferred groundwater inflows are listed in **Table 2-6**. Groundwater inflow is inferred by means of:

- Mine water balance (Gilbert and Associates, 2009 and 2014. This accounts for the measured volume of groundwater pumped from sumps in the pit floor as well as evaporation from the pit walls and floor, groundwater discharge, as well as from the seepage that results from recirculation of water that has been sprayed on the waste emplacement as part of irrigation practices. Gilbert and Associates (2014) estimate that 1.9-3.8 ML/d (700-1400 ML/a) has entered the pit over the last three years sourced from groundwater discharge and seepage from the irrigated in-pit waste rock emplacement. The relative proportions from the two sources is not known.
- Considering previous groundwater modelling for the DCM (Heritage Computing, 2009).

Table 2-6 Inferred Groundwater Inflow Rates

DATE	TOTAL [ML/d]	TOTAL [ML/a]	SOURCE
1/10/2003	0.45	164	Heritage Computing (2009) / Gilbert and Associates (2009)
1/09/2004	0.3	110	
2/09/2004	0.3	110	
1/01/2006	0.21	77	
1/11/2008	0.15	55	

3 HYDROGEOLOGICAL CONCEPTUAL MODEL

A conceptual model of the hydrogeological regime was developed in Heritage Computing (2009) based on the review of existing hydrogeological data as described in Section 2 including:

- Gloucester Basin geology mapping;
- mine-scale geological modelling of the DCM;
- surrounding and regional geological logs;
- relevant data from the NOW register in the NSW Pinneena Groundwater Database;
- geological and hydrogeological assessments undertaken for the DCM (i.e. Golder and Associates, 1981a, 1981b, 1982; DCPL, 1996);
- piezometric data from monitoring bores; and
- slug and pumping tests undertaken by DCPL in 2009.

In addition, some elements of linkage to the surface flow and groundwater (baseflow) interaction mechanisms described in the Surface Water Assessments (Gilbert and Associates, 2009 and 2014) have been considered.

Based on the above, the data supports two groundwater systems:

- shallow groundwater system – associated with alluvium and regolith; and
- deeper groundwater system, including:
    - the Weismantel and Clareval coal seams; and
    - low permeability/disconnected fractured rock/coal measures of the Mammy Johnsons, Weismantels and Durallie Road Formations (**Figure 2-5**).

The two groundwater systems are illustrated in the conceptual model of the region in **Figure 3-1** and **Figure 3-2** developed for the Duralie Extension Project.

The only revisions to the conceptualisation presented in Heritage Computing (2009) are:

- increased vertical separation between the bottom of the Weismantel Seam and the top of the Clareval Seam in the revised DCM geological model (see 2.6.6);
- incorporation of two faults in the vicinity of bores DB8W to DB11W to account for over-prediction of drawdown by the 2009 EA model[5].

Recharge to the groundwater system is from rainfall and from lateral groundwater flow at the boundaries of the study area. Although groundwater levels are sustained by rainfall infiltration, they are controlled by topography, geology and surface water levels. A local groundwater mound develops beneath hills with ultimate discharge to incised creeks and water bodies, and loss by evapotranspiration through outcropping sandstone/shales and vegetation where the water table is within a few metres of the ground surface.

During short events of high surface flow, streams can lose water to the aquifers that host the streams (i.e. leakage), but during recession, the aquifer would discharge water slowly back into the stream from bank storage and slow drainage from the surrounding rock strata (i.e. baseflow). Baseflow is caused by slow drainage of groundwater from the surrounding rock strata or alluvium. In places where mining has occurred, groundwater discharge is expected to occur to the mined pit in proportion to local permeabilities.

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[5] No data at these bores had been acquired at the time of the 2009 Duralie Extension Project EA.

Recharge and potential shallow interflow systems occur within the weathered zone where the syncline outcrops. The recharge zone is focused into the coal seams where the seams subcrop or outcrop. Both underlying coal seams host aquifers with leaky aquitard fractured rock above and below.

At the DCM, geological strata are roughly uniform in thickness and lithology, although they are still very steeply dipping and subject to faulting, fracturing and slippage. The Weismantel Seam is especially uniform in characteristics, and although it has local thickening it can be regarded as a separate entity. The Clareval Seam is believed to be similar, although it increases in apparent thickness at folds. Hydraulic testing to date has focused on the central rock units (i.e. the overlying units of Weismantels Formation). Very little is known about the rock masses between or below the two seams.

The Weismantel Seam groundwater system is unconfined in the area where slug and pump tests were undertaken in 2009 (but is confined in other parts of the DCM), and appears to drain quickly. The seam itself responded very quickly during slug testing but only at the point of disturbance, with marginal effects along strike and no effect on underlying rocks.

The Clareval Seam was fully saturated in the slug and pump test area, being mostly confined at the top and leaky to unconfined at the base. It responded rapidly across the whole seam to disturbance with a clear effect along strike - rapidly inducing flow towards the disturbance point. The small slug disturbances in the Clareval Seam had no effect on the overlying rock and a small influence on the underlying rock.

Data from exploration bore logs (i.e. bores DU021R, DU022R, DU023R and WC225C) indicate that below the alluvials adjacent to Mammy Johnsons River to the east of the North Coast Railway, there are clay/claystone layers varying from 2.5 to 6 m in depth. As clay is a low-permeability stratum these lenses and layers act as minor aquitards. The hydrogeological connection between the subcropping/outcropping coal and the overlying alluvium associated with the Mammy Johnsons River is impeded by these clay lenses.

Irrigation operations at the DCM are designed to maintain moisture of the soil at less than field capacity (Appendix A of the 2009 EA for the DEP), in which case there would be no accession of irrigation water to the groundwater table. The DCM Irrigation Management Plan describes the general principles of irrigation at the DCM:

> *"The irrigation system is to be managed and operated to ensure… irrigation does not cause the soil to become saturated…"*

Therefore, as the numerical model is focused in the saturated zone, irrigation infiltration has not been included as a source of recharge to the groundwater system.

3.1 HYDRAULIC PROPERTIES

Seven active layers are conceptualised in **Figure 3-3** for the purpose of numerical modelling. The major coal measures/sandstone/conglomerate formations (Weismantels Formation and Durallie Road Formations) are split into multiple layers in recognition of their vertical hydraulic gradients and the need to represent the two target coal seams as separate model layers.

Indicative permeabilities for the various stratigraphic units, summarised in **Table 3-1** are informed by:

- Local-scale investigations, namely DCPL slug and pumping; and
- Regional-scale model calibration by Golder Associates (1982) and DCPL (1996)

Golder Associates and DCPL undertook hydrogeological investigations down to the Weismantel Seam.

Figures B-18 to B-22 of Heritage Computing (2009) present the results of field investigations for measurement of hydraulic properties. Some variation in permeability with depth can be expected over the open cut depth interval.

There has been no further permeability testing since Heritage Computing (2009).

Table 3-1 Indicative Hydraulic Properties of Stratigraphic Units

UNIT	HYDROGEOLOGICAL DESCRIPTION	Local-scale Hydraulic Conductivity K_L [m/day]	Regional-scale Hydraulic Conductivity K_L [m/day]
Alluvium	Unconfined aquifer	0.1–5	0.1-5
Coal Measures/sandstones of the Mammy Johnsons and Weismantel Formations	Leaky confined aquifer	0.04–3	10^{-3} –0.3 (to 100 m depth)
Weismantel Seam	Confined / unconfined aquifer	0.08–1.6 0.01–0.5 (to 200 m depth)	10^{-4} –10 (to 200 m depth)
Coal Measures/sandstones of the Durallie Road Formation	Leaky confined aquifer	0.04–3	10^{-4} –0.3 (to 200 m depth)
Clareval Seam	Confined aquifer (top), unconfined aquifer (bottom)	0.036–0.34 0.01–0.5 (to 200 m depth)	10^{-4} –10 (to 200 m depth)
Coal Measures/sandstones of the Durallie Road Formation	Leaky confined aquifer	0.04 - 3	10^{-4} –0.3 (to 200 m depth)
Alum Mountain Volcanics	Confined aquifer	-	-

After: Golder Associates (1982); DCPL (1996, 2009).

The hydraulic property measurements have been used to inform the development of the numerical groundwater model and to obtain initial permeability values. The verification of the groundwater model is discussed in Section 4.5.

4 GROUNDWATER MODELLING

A groundwater model was built as part of the Duralie Mine Extension EA (Heritage Computing, 2009). The predictions made by that model in 2009 have been compared with historical data from 2009 to 2014 as a form of model verification.

Following that process, the model was updated to incorporate a better representation of the actual mine progression from 2009-14 as well as the proposed 2014-19 mine plan for this Modification. The model update also saw revised historical rainfall and evaporation data applied, as well as allowing comparison of modelled groundwater levels at a number of monitoring bores ('targets') added after the 2009 study was completed.

The following sections borrow heavily from the Heritage Computing (2009) report, with any differences between the 2009 study described below.

4.1 MODEL SOFTWARE AND COMPLEXITY

Groundwater modelling has been conducted in accordance with the MDBC Groundwater Flow Modelling Guideline (MDBC 2001) as well as the Australian Groundwater Modelling Guidelines (Barnett *et al.*, 2012). Under the earlier MDBC modelling guideline, the model is best categorised as an Impact Assessment Model of medium complexity. The guide (MDBC, 2001) describes this model type as follows:

"Impact Assessment model - a moderate complexity model, requiring more data and a better understanding of the groundwater system dynamics, and suitable for predicting the impacts of proposed developments or management policies."

Under the more recent (2012) guidelines, this model would be classified as a Confidence Level 2 groundwater model, with the following key indicators (based on Table 2-1 of Barnett *et al.*, 2012):

- Rainfall and evaporation data are available (Level 3);
- Groundwater head observations and bore logs are available but without spatial coverage throughout the model domain (Level 2);
- Stream flow data and baseflow estimates available at a few points (Level 2);
- Seasonal fluctuations not accurately replicated in all parts of the model domain (Level 2);
- Scaled RMS error (refer Chapter 5) or other calibration statistics are acceptable (Level 3); and
- Suggested use is for prediction of impacts of proposed developments in medium value aquifers (Level 2)

Numerical modelling has been undertaken using the Groundwater Vistas (Version 6.58) software interface (Environmental Simulations Inc [ESI], 2010) in conjunction with MODFLOW-SURFACT (Version 3) distributed commercially by Hydrogeologic, Inc. (Virginia, USA). MODFLOW-SURFACT is an advanced version of the popular MODFLOW code developed by the United States Geological Survey (McDonald and Harbaugh, 1988). MODFLOW is the most widely used code for groundwater modelling and is presently considered an industry standard.

MODFLOW-SURFACT is a three-dimensional modelling platform that is able to simulate variably saturated flow and can handle desaturation and resaturation of multiple aquifers without the “dry cell” problems of Standard-MODFLOW. This is pertinent to the dewatering of layers adjacent to open cut coal mines. Standard-MODFLOW can handle this to some extent, but model cells that are dewatered (reduced below atmospheric pressure) are replaced by “dry cells”.

The model complexity is adequate for simulating contrasts in hydraulic properties and hydraulic gradients that may be associated with changes to the groundwater system as a result of the Modification.

4.2 MODEL GEOMETRY

4.2.1 MODEL GRID

The model grid remains unchanged from the model in Heritage Computing (2009).

The model domain is discretised into 212,940 cells arranged into seven layers comprising 260 rows and 117 columns. The dimensions of the model cells are uniformly 50 m in both directions. The model extent as shown in **Figure 4-1** is 5.85 km from west to east and 13 km from south to north, covering an area of approximately 76 km^2.

4.2.2 MODEL LAYERING

The number of model layers remains unchanged from Heritage Computing (2009).

Seven model layers represent the stratigraphic section (**Figure 3-3**). Layer 6 represents the Lower Durallie Road Formation and outcropping Alum Mountain Volcanics to allow the allocation of different permeabilities for outcropping and deeper sections of this formation. Layer 7 hosts the deeper portion of the Alum Mountain Volcanics.

The eastern and western limits of the active model area were chosen to coincide with topographic ridgelines and outcropping Alum Mountain Volcanics.

Representative model cross-sections are displayed in **Figure 4-2** for northing 6,428,525 (MGA) (model row 130) and northing 6,426,275 (MGA) (row 175) (**Figure 4-1**). The cross-sections pass through the Clareval open pit (row 130) and the already-mined portion of the Weismantel pit (row 175). The Weismantel and Clareval seams are respectively Layers 3 and 5.

A revised geological model was provided to HydroSimulations. This has resulted in changes to the groundwater model layer geometry. Most notably, the Clareval Seam is now significantly deeper than in Heritage Computing (2009) – see Section 2.6.6. This has, in turn, pushed deeper layers further down. Additionally, data from the AGL’s Gloucester Gas Project have been used to help control geological elevations at the northern edge of the DCM groundwater model boundary (specifically, Figure 4.6 of Parsons Brinckerhoff, 2013).

The elevations of the top and base of the Weismantel Seam are well defined in the DCM area, and the Clareval Seam is well defined on its western limb. Structure contours have been extrapolated to the north and east to define the stratigraphy throughout the model area, guided by median thicknesses from exploration drilling (as listed in **Figure 3-3**).

4.3 MODEL STRESSES AND BOUNDARY CONDITIONS

The main watercourses in the area (i.e. Mammy Johnsons River and Wards River) are established as “River” cells in model Layer 1 (denoted by blue cells in **Figure 4-3**) using the

MODFLOW RIV package. This allows water exchange in either direction between the stream and the aquifer. The river conductances are proportional to estimated reach lengths in each river cell. The median conductance is 150 square metres per day (m^2/day) with a range from 10 to 450 m^2/day. River stage elevations on Mammy Johnsons River are now transient, based on observed stage data from government (NOW) gauging stations. In Heritage Computing (2009), the river stages were static.

Minor drainage lines were established as "Drain" cells in the model using the MODFLOW DRN package (shown in yellow in **Figure 4-3**). This allows groundwater to discharge to the drainage lines as baseflow. The drain conductances were set at 50 m^2/day.

The model edges are 'no-flow' by default, with general head boundaries where Mammy Johnsons River enters and leaves the active model area in Layer 1. A wider general head boundary is applied across the alluvial extent of Wards River at the northern boundary. Equivalent general heads are applied through the stratigraphic section at the northern boundary.

"Drain" cells are used to represent mining. Invert levels are progressively lowered to the floor of the coal seam, and are set to base levels for layers overlying the mined seam. The drain conductance value (0.2 m^2/day) was determined during calibration.

Rainfall recharge has been imposed as a percentage of actual rainfall (for transient calibration) or long-term average rainfall (for steady-state calibration and prediction simulations) across four zones (**Figure 4-4**):

- Regolith [zone 1];
- Hills [zone 2];
- Alluvium [zone 3]; and
- Subcropping coal seams [zone 4].

The recharge rates were determined during model calibration. Additional recharge zones are defined during predictive simulations for the active mining area (zero recharge) and spoil infiltration (initially zero, then 5% after five years).

There is no active groundwater pumping in the model.

Evapotranspiration is applied uniformly using MODFLOW's linear function, with a maximum rate of 3.7 mm/day and an extinction depth of 1.5 m.

4.4 MODEL VARIANTS

Both steady-state and transient models have been developed:

- Steady-state model of pre-mining conditions: Calibration against the inferred pre-mining groundwater levels in **Figure 2-9**.
- Transient model of the transition from pre-mining to early mining: Calibration against the groundwater hydrographs in **Figure 2-10** to **2-16**.
- Transient predictive model extending to the end of mining.
- Post-mining recovery model.

4.5 MODEL CALIBRATION

In Heritage Computing (2009) the model was calibrated for both steady state and transient (to 2009) conditions. The details of those runs are available in Heritage Computing (2009).

4.5.1 STEADY STATE CALIBRATION

Refer to Section 4.4 of Heritage Computing (2009).

4.5.2 TRANSIENT CALIBRATION

Transient calibration was performed from January 2003 to December 2005 in 12 quarterly periods to replicate the transitional behaviour of key groundwater hydrographs from pre-mining to early mining. In all, 134 target heads were established for 10 sites: DB1W, DB2W, DB3W, DB4W, DB5W, DB6W, BH4BW, DU151R, DU199R, and DU154R. The last three sites had only one target head each but were included to represent the higher heads in the Clareval open pit area. The site locations are shown on **Figure 2-8**.

During the calibration period, rainfall recharge was varied according to measured rainfall, but river stages were invariant with time.

Estimated pit inflow from March 2003 to December 2006 served as an important extra target. Although pit inflow is not measured directly, it has been inferred from a surface water balance model (Gilbert and Associates, 2009), as per Section 2.12.

While automated PEST software was used to get a close match to the pit inflows, the final calibration was fine-tuned manually.

Table 4-1 summarises the hydraulic and storage properties for the stratigraphic section at the end of the 2009 transient calibration. The adopted hydraulic conductivity distributions and the calibrated K_L values are given in Attachment BC of Heritage Computing (2009). The values for K_L are consistent with field estimates listed in **Table 3-1**.

Table 4-1 Calibrated Hydraulic Conductivity and Storage Parameters

ZONE	LAYER	FORMATION	K_L (m/day)	K_T (m/day)	S_S (m^{-1})	Sy (-)
1	1	Regolith	0.5	0.001	$2x10^{-5}$	0.08
2	2	Coal Measures/Sandstones of the Mammy Johnsons and Weismantels formations	0.05	0.000001	$1x10^{-6}$	0.01
3	3	Weismantel Seam	0.15	1	$1x10^{-6}$	0.02
4	4	Coal Measures/Sandstones of the Upper Durallie Road formation	0.1	1	$1x10^{-6}$	0.01
5	5	Clareval Seam	0.05	0.000001	$1x10^{-6}$	0.02
6	7	Coal Measures/Sandstones of the Lower Durallie Road formation	0.05	0.0005	$1x10^{-6}$	0.01
7	1	Alluvium	1	0.0003	$2x10^{-5}$	0.05
8	2, 3, 4, 5	Coal Measures/Sandstones of the Lower Durallie Road formation	0.000001	100^	$1x10^{-6}$	0.005
9	3	Coal Measures/Sandstones of the Mammy Johnsons and Weismantels formations	0.1	1	$1x10^{-6}$	0.005
10	5	Coal Measures/Sandstones of the Upper Durallie Road formation	0.05	0.000001	$1x10^{-6}$	0.005
11	6	Coal Measures/Sandstones of the Lower Durallie Road formation	0.1	0.0001	$1x10^{-6}$	0.005
12	3, 4, 5	Coal Measures/Sandstones of the Mammy Johnsons and Weismantels formations	0.01	0.000001	-	-

^ Forced vertical linkage between phantom layers.

At 2009, the adopted values for rainfall recharge expressed as percentages of long-term average rainfall were:

Regolith [Zone 1]:	2.6%
Hills [Zone 2]:	12%
Alluvium [Zone 3]:	1.0%
Subcropping coal seams [Zone 4]:	0.5%

Additional recharge zones were introduced to represent areas of ground to be mined and to be infilled with spoil (**Figure 4-4**). The adopted rates ranged from 0.5% (zone 5) to 4.4% (zone 10).

When mining passed through one of these extra recharge zones, its rate was set to zero. The rate was not reset during the three-year calibration period as spoil was emplaced due to the time required for spoil to resaturate.

A low mine drain conductance of 0.2 m^2/day proved necessary to match low pit inflows for relatively high longitudinal hydraulic conductivity values.

Infilling mined areas with spoil would have a mitigating effect on pit inflow. At one extreme, the spoil could block further pit inflow from the direction of the area already mined. At the other extreme, the base of the spoil could act as a free-flowing rubble drain. From a modelling point of view, a decision must be made as to how long mine “drain” mechanisms remain active after mining has progressed. After experimentation with several durations, the best calibration result was achieved with a one year activation period. In particular, the partial groundwater recovery noted at bore DB2W could not be reproduced with longer activation times. Also, longer exposure of drains led to pit inflow estimates about double those expected.

4.5.3 MODEL VERIFICATION AND PERFORMANCE

The performance of the model at the end of the 2009 transient calibration can be seen in Heritage Computing (2009). Rather than revisiting the calibration performance here, the results of the model verification exercise are presented instead.

The ability of the model to replicate observed groundwater hydrographs is illustrated in **Figure 4-5** to **Figure 4-9**. The two hydrographs that have clear early-mining responses (DB2W and DB4W) are reproduced well in pattern, although the absolute levels are a little overestimated (**Figure 4-5** and **Figure 4-6**). Nearby alluvial bores (BH4BW and DB3W) show no mining responses in either the simulated or observed hydrographs (**Figure 4-5** and **Figure 4-6**). The DB1W hydrograph could not be matched well (**Figure 4-7**); this bore is located at the junction of three contrasting permeabilities in the model, and its response is very sensitive to changes in hydraulic parameters. The DB6W hydrograph (**Figure 4-7**) follows the observed trend quite well and the absolute levels are reasonable, but observed amplitudes are not reproduced. It is likely that this bore is affected by irrigation activity and/or the construction and operation of mine dams.

There has been a difficulty in calibrating the bores introduced since the calibration for the 2009 EA for the DEP. The model simulates mining effects at bores DB9W and DB10W but tends to overestimate the drawdowns (**Figure 4-8**). Although some faulting is included in the model, it is likely that additional faulting is providing some restriction on the magnitude of drawdown at these locations. The observed data at bore DB8W (Figure 4-8) is regarded as unreliable because it has inconsistent behaviour when compared with nearby bores DB9W and DB10W.

There is an insufficient record at bore DB11W for reliable calibration. The apparent drawdown is reproduced but the model reports substantially lower absolute levels (**Figure 4-9**).

The overall performance of the transient calibration is quantified by the statistics in **Table 4-2**.

Table 4-2 Model Performance at Verification

CALIBRATION STATISTICS	CALIBRATION PARAMETER	
	Calibration (2009)*	Verification (2014)
Number of Data (n)	134	395
Root Mean Square (RMS) (m)	4.0	3.9
Scaled Root Mean Square (SRMS) (%)	6.4	5.9

* from Heritage Computing (2009)

The key statistic are 3.9 mRMS and 5.9% SRMS[6], which is well below the target 10% SRMS suggested in the MDBC flow model guidelines (MDBC, 2001). The verification has a marginally better performance than the 2009 calibration.

A scattergram of simulated versus measured heads in **Figure 4-10** demonstrates good agreement across the whole range of measurements, with the exception of a few outliers.

There is a slight bias towards overestimation at lower elevations and underestimation at higher elevations (**Figure 4-11**).

Simulated pit inflows were calibrated against inferred 'observed' inflows from the last model calibration period (to 2009). This is shown on **Figure 4-12** which shows that the model compared favourably with much of the early data, although is probably overestimating inflow based on the inferred data from the DEP Groundwater Assessment. For the verification period, mine inflow estimates from water balance modelling are too imprecise for groundwater model calibration, as discussed in Section 2.12. Further to that discussion, Gilbert and Associates (2014) state that groundwater discharge of about 300 ML/a is feasible, as inferred from the groundwater model.

4.5.4 TRANSIENT WATER BALANCE

The instantaneous transient water balance across the entire model area is summarised in Table 4-3 at the end of the extended calibration period. The total inflow (recharge) to the aquifer system is approximately 12 ML/day, comprising mainly rainfall recharge (56%), and leakage from the rivers into the aquifer (43%). The dynamic stream leakage is simulated to be about 5.3 ML/day at 2013.

Table 4-3 Simulated Water Balance for the Transient Model

Component	Groundwater Inflow (Recharge) (ML/day)	Groundwater Outflow (Discharge) (ML/day)
Rainfall Recharge	6.8	3.8^
Evapotranspiration	-	6.7
Rivers	5.3	1.0
Creeks	-	0.5
Mine inflow	-	0.6
Boundary Flow	0.12	0.4
TOTAL	**12.2**	**13.0**
Storage	0.8 LOSS	
Discrepancy (%)	0.06	

^ Rejected recharge computed by MODFLOW-SURFACT

Evapotranspiration represents the major outflow of about 52%. Baseflow to the rivers accounts for about 8% of the total discharge at December 2013, with minor creeks accepting about half of that. Of the applied rainfall recharge, 56% is rejected. The computed mine inflow is about 5% of the total groundwater discharge over the model area.

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[6] Excluding unreliable data at DB8W, SI1W, SI2W and SI3W

Net boundary flows are minor but there is a net loss in storage during the July-December 2013 period.

Table 4-4 summarises the hydraulic and storage properties for the stratigraphic section at the end of the updated calibration for comparison with Table 4-1. Only minor changes to five parameters were required for the updated calibration.

Table 4-4 Re-calibration Hydraulic Conductivity and Storage Parameters

ZONE	LAYER	FORMATION	K_L (m/day)	K_T (m/day)	S_S (m^{-1})	Sy (-)
1	1	Regolith	0.5	0.001	$2x10^{-5}$	0.08
2	2	Coal Measures/Sandstones of the Mammy Johnsons and Weismantels formations	0.05	0.000001	$1x10^{-6}$	0.01
3	3	Weismantel Seam	0.15	1	$1x10^{-6}$	0.02
4	4	Coal Measures/Sandstones of the Upper Durallie Road formation	0.1	1	$1x10^{-6}$	0.005[A]
5	5	Clareval Seam	0.01[B]	0.000001	1x10-6	0.005[C]
6	7	Coal Measures/Sandstones of the Lower Durallie Road formation	0.05	0.0005	$1x10^{-6}$	0.01
7	1	Alluvium	1	0.0003	$2x10^{-5}$	0.01[B]
8	2, 3, 4, 5	Coal Measures/Sandstones of the Lower Durallie Road formation	0.000001	100^	$1x10^{-6}$	0.005
9	3	Coal Measures/Sandstones of the Mammy Johnsons and Weismantels formations	0.1	1	$1x10^{-6}$	0.005
10	5	Coal Measures/Sandstones of the Upper Durallie Road formation	0.05	0.000001	$1x10^{-6}$	0.005
11	6	Coal Measures/Sandstones of the Lower Durallie Road formation	0.1	0.0001	$1x10^{-6}$	0.005
12	3, 4, 5	Coal Measures/Sandstones of the Mammy Johnsons and Weismantels formations	0.005[A]	0.000001	-	-

Former values: [A] 0.01; [B] 0.05; [C] 0.02. ^ Forced vertical linkage between phantom layers.

The revised values for rainfall recharge expressed as percentages of long-term average rainfall are:

Regolith [Zone 1]	2.6%
Hills [Zone 2]	10.8%
Alluvium [Zone 3]	0.9%
Subcropping Coal Seams [Zone 4]	0.36%
Spoil Zones	0.36% to 2.7%

4.5.5 TRANSIENT SENSITIVITY ANALYSIS

A substantial sensitivity analysis was conducted in Heritage Computing (2009) for mine drain conductance, mine drain duration and spoil infiltration. In addition, many trial changes in hydraulic conductivity during the calibration process showed extreme sensitivity of pit inflows and hydrographic responses to hydraulic conductivity.

Head-based statistics were found to be similar while pit inflow varied substantially during the sensitivity simulations. Reducing mine drain conductance from 0.3 to 0.2 m^2/day led to a 13% reduction in pit inflow. Temporary activation of mine drains resulted in a 25% reduction in pit inflow. Disabling of newly-placed spoil infiltration made no significant difference over the calibration period.

5 SCENARIO ANALYSIS

5.1 MINE SCHEDULE

Using the hydraulic and storage properties found during transient calibration and a pit activation period of one year, the model was run in transient mode from January 2003 to December 2020. Forty-four continuous stress periods[7] have been applied. The first 16 periods (to December 2006) are each three months in length, while the remainder are six months in length.

The extended calibration period runs from January 2003 to December 2013 (stress periods 1 to 30). The prediction period is taken to commence in January 2014 (stress period 31) and finish in December 2020 (stress period 44). Excavation is assumed to be completed in 2019. The 100 year recovery simulation occupies stress periods 45-64 (20 stress periods).

Rainfall recharge is deactivated in cells where mining is currently active, for a period of five years. It has been estimated that spoil would require roughly this length of time to wet up through the unsaturated zone. After five years, 5% recharge is applied to spoil.[8]

Table 5-1 summarises the stress period setup in the model and the sequencing of six time-variant recharge zones over the mine footprint. The recharge zones are indicated in **Figure 4-4** (as colour-coded polygons).

Rainfall recharge is imposed as a time-varying stress in the model for the stress periods covered by the transient calibration (periods 1 to 31). From then on, long-term average rainfall is the basis for calculating recharge.

Unlike the 2009 model, the water level in the Mammy Johnsons River is also varied during the calibration period, and then held at a constant level in each river cell.

The progression of mining is represented in the model according to the schedule shown in **Figure 5-1**. “Drain” cells are used to represent mining. Invert levels are progressively lowered to the floor of the coal seam, and are set to base levels for layers overlying the mined seam. The drain conductance value (0.2 m^2/day) was determined during calibration.

The mining activity is defined in the model using drain cells within the mined coal seams, with invert levels progressively lowered to the floor of the coal seam. For the Weismantel Seam (Layer 3), drain cells are specified in Layers 1 to 3. For the Clareval Seam (Layer 5), drain cells are specified in Layers 1 to 5.

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[7] A stress period is the time period in the model when all hydrological stresses (e.g. rain recharge, river stage, etc.) remain constant.

[8] To maintain consistency with the EA simulation, spoil permeability has not been specified due to MODFLOW’s restriction at that time to time-invariant properties in a continuous simulation.

Table 5-1 Model Stress Period Setup

PERIOD	DAYS	START Month	START Year	END Month	END Year	PHASE	RCHz5^1	RCHz6^1	RCHz7^1	RCHz8^1	RCHz9^1	RCHz10^1
1	91.3	January	2003	March	2003		0.4%	0.5%	1.2%	1.5%	1.4%	2.7%
2	91.3	April	2003	June	2003		OFF					
3	91.3	July	2003	September	2003							
4	91.3	October	2003	December	2003							
5	91.3	January	2004	March	2004							
6	91.3	April	2004	June	2004							
7	91.3	July	2004	September	2004							
8	91.3	October	2004	December	2004							
9	91.3	January	2005	March	2005			OFF				
10	91.3	April	2005	June	2005							
11	91.3	July	2005	September	2005						VIRGIN	GROUND
12	91.3	October	2005	December	2005							
13	91.3	January	2006	March	2006							
14	91.3	April	2006	June	2006							
15	91.3	July	2006	September	2006							
16	91.3	October	2006	December	2006							
17	182.6	January	2007	June	2007				OFF			
18	182.6	July	2007	December	2007							
19	182.6	January	2008	June	2008							
20	182.6	July	2008	December	2008							
21	182.6	January	2009	June	2009							
22	182.6	July	2009	December	2009		🟩					

(continued next two pages)

Table 5-1. Model Stress Period Setup (continued)

PERIOD	DAYS	START Month	START Year	END Month	END Year	PHASE	RCHz5[1]	RCHz6[1]	RCHz7[1]	RCHz8[1]	RCHz9[1]	RCHz10[1]
23	182.6	January	2010	June	2010		🟩		OPEN PIT	🟦	🟦	🟦
24	182.6	July	2010	December	2010		🟩			OFF	🟦	🟦
25	182.6	January	2011	June	2011		🟩				OFF	🟦
26	182.6	July	2011	December	2011		🟩					🟦
27	182.6	January	2012	June	2012		🟩	🟩				🟦
28	182.6	July	2012	December	2012		🟩	🟩				🟦
29	182.6	January	2013	June	2013		🟩	🟩				🟦
30	182.6	July	2013	December	2013	END TRANSIENT CALIBRATION	🟩	🟩				🟦
31	182.6	January	2014	June	2014		🟩	🟩				OFF
32	182.6	July	2014	December	2014		🟩	🟩				
33	182.6	January	2015	June	2015		🟩	🟩				
34	182.6	July	2015	December	2015		🟩	🟩	🟩 5% SPOIL			
35	182.6	January	2016	June	2016		🟩	🟩	🟩	🟩		
36	182.6	July	2016	December	2016		🟩	🟩	🟩	🟩		
37	182.6	January	2017	June	2017		🟩	🟩	🟩	🟩		
38	182.6	July	2017	December	2017		🟩	🟩	🟩	🟩		
39	182.6	January	2018	June	2018		🟩	🟩	🟩	🟩	🟩	
40	182.6	July	2018	December	2018		🟩	🟩	🟩	🟩	🟩	
41	182.6	January	2019	June	2019		🟩	🟩	🟩	🟩	🟩	
42	182.6	July	2019	December	2019		🟩	🟩	🟩	🟩	🟩	
43	182.6	January	2020	June	2020		🟩	🟩	🟩	🟩	🟩	
44	182.6	July	2020	December	2020	END PREDICTION	🟩	🟩	🟩	🟩	🟩	

Table 5-1. Model Stress Period Setup (continued)

PERIOD	DAYS	START Month	START Year	END Month	END Year	PHASE	RCHz5[1]	RCHz6[1]	RCHz7[1]	RCHz8[1]	RCHz9[1]	RCHz10[1]
45 - 64	36524	January	2021	December	2120	**RECOVERY**	5% SPOIL					100% VOID LAKE

[1] Recharge zones (RCHz) are shown on Figure 4-4. Rainfall in recharge zones is presented as a percentage of actual rainfall to the end of the transient calibration period, after which percentages of long-term average rainfall are applied.

5.2 WATER BALANCE

Simulated water balances for the whole model area are examined in **Table 5-2** at the end of mining (mid- 2018), compared with a no-mining case (the "null" scenario).

At the end of mining (**Table 5-2**), the net flow through the system of about 14 ML/day is dominated by rainfall as the main source of recharge (60%) and evapotranspiration as the main discharge mechanism (53%).

There is no significant difference in component recharge rates between the mining scenario and the null scenario.

At the end of mining, there are minor reductions in groundwater discharge to the rivers (about 0.3 ML/day; 2%) and to the creeks (<0.1 ML/day; 12%) when mine inflow is about 1 ML/day. There is also a reduction in evapotranspiration by 3.5%.

Table 5-2 Simulated Groundwater Balance for the Prediction Model at End of Mining

Component (ML/day)	Inflow (Recharge)		Outflow (Discharge)	
	NO MINING	MINING	NO MINING	MINING
Rainfall Recharge	8.39	8.39	3.54^	3.53^
Evapo-transpiration	-	-	7.81	7.54
Rivers	4.86	4.87	1.09	1.07
Creeks			0.65	0.57
Mine		-	-	1.02
Boundary Flow	0.12	0.12	0.43	0.35
Change in Storage	0.15 LOSS	0.70 LOSS		
TOTAL	**13.5**	**14.1**	**13.5**	**14.1**

^ Rejected recharge computed by MODFLOW-SURFACT.

5.3 PREDICTED PIT INFLOW

The time-varying pit inflow predicted by the model is illustrated in **Figure 5-2** in ML/yr units. Annual totals are presented for groundwater licensing purposes. Note that pit inflow data is presented for both pits (i.e. Weismantel and Clareval open pits). Inflow to the Weismantel open pit is expected to fall from 170 ML/yr to 50-70 ML/yr in 2015-17, and then climb again to about 140 ML/yr in 2018-9, just before the end of mining. Inflow to the Clareval open is expected to increase slowly to a peak of about 200 ML/yr in 2016-7 and then reduce to about 60 ML/yr before the end of mining.

As stated in Section 1.4:

> *"(8) The volume of groundwater extracted from the works authorised by this licence shall not exceed 300 megalitres in any 12 month period commencing 1st July."*

The predicted peak total for both mine pits for the remainder of the mine life is less than the current licensed rate of 300 ML/year (see **Table 5-3**).

Table 5-3 Predicted Annual Pit Inflows

YEAR	TOTAL Pit Inflow [ML/a]	Weismantel Inflow [ML/a]	Clareval Inflow [ML/a]
2013-14	230	172	58
2014-15	206	136	71
2015-16	206	70	136
2016-17	244	47	197
2017-18	**252**	104	148
2018-19	204	142	62

Source: file:///C:\HydroSim\YAN001\Model\Results\PitInflowPrediction.xls

5.4 PREDICTED BASEFLOW EFFECTS

Predicted changes in baseflow and natural river leakage from 2014 onwards have been assessed for relevant Reach 2 (northern) and Reach 3 (southern) of the Mammy Johnsons River. **Figure 4-3** provides reach definitions. River-aquifer exchanges have been compared for transient simulations with and without mining.

The model results for combined reaches are shown in **Figure 5-3**. They reveal that there is expected to be a fairly steady reduction in net baseflow from the groundwater system to the river of about 0.02 ML/day. When the size of the catchment is taken into consideration, the predicted reduction in net groundwater baseflow during mining operations is about 0.00005 megalitres per day per square kilometre (ML/day/km^2) in the Mammy Johnsons River[9]. Accordingly, DCM mining operations have a negligible impact on stream baseflow and natural river leakage of the Mammy Johnsons River.

Table 5-4 expresses the instantaneous river-aquifer flux changes of the Mammy Johnsons River catchment area at the end of mining. The impact is considered negligible.

Table 5-4 Predicted Instantaneous River-Aquifer Flux at End of Mining

Stream	Catchment Area (km^2)	Simulated Flux (ML/day)		Flux Change (ML/day/km^2)
		No Mining	At End of Mining	
Mammy Johnsons River	320	-0.597^	-0.581	0.00005

^ Negative means net baseflow from aquifer to river. There is a predicted reduction in net baseflow of 0.016 ML/day

The simulated fluxes are reported separately for the two reaches of the river in **Figure 5-4** and **Figure 5-5**. For reach 2 (northern) there is a simulated net loss from the river (positive means entering the aquifer). For reach 3 (southern) there is a simulated net gain by the river

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[9] The previous estimate using the 2009 model was 0.00004 ML/day/km^2

(negative means leaving the aquifer). Comparison with the "no mining" scenario indicates that for each reach there is a very minor effect as a result of mining: more leakage from Reach 2, and less baseflow to Reach 3. The magnitudes of the impacts are very small and would not be measureable.

This finding of negligible impact is consistent with the conclusions reached in the original groundwater assessment for the 2009 EA for the DEP.

5.5 SENSITIVITY ANALYSIS

A substantial sensitivity analysis was conducted in Heritage Computing (2009) for the effects of mine drain conductance, mine drain duration, river conductance and the vertical hydraulic conductivity of alluvium on predicted fluxes.

The findings were:

- Drain conductance had a mild effect on pit inflow estimates, while drain activation period had a strong effect.
- There was negligible difference in aquifer-river fluxes in response to changes in river conductance and the vertical hydraulic conductivity of alluvium.
- For all considered cases, the reduction in net baseflow ranged from 0.00002 to 0.00027 ML/day/km^2. Therefore, for all cases, there would be a negligible impact on river-aquifer interaction.

As the predictions of the 2009 model and the current model are very similar, and the model parameterisations are similar, no additional sensitivity analysis was deemed necessary.

5.6 POST-MINING RECOVERY

Inflows to the final open pit voids comprise incident rainfall over the void lake surface, runoff and seepage from the sides of the voids and their adjacent contributing catchment and seepage from coal seam groundwater and waste rock emplacement infiltration.

In the groundwater model, the air space above each final void has been considered to consist of earth that has very high permeability (e.g. 1000 m/day) with unit specific yield, receiving rainfall recharge at 100% and evaporating at 50% of the pan evaporation rate. This is often called a "high-K lake". When these assumptions are made, the groundwater model can give an approximate simulation of the rising free water level in a lake of fixed areal dimension. This enables generation of a seepage-vs-stage relationship for simulation of the final void by surface water modellers, as done in Gilbert and Associates (2014).

Figure 5-6 shows that the groundwater inflow to the combined voids will reduce gradually from about 0.6 ML/day to an equilibrium rate of about 0.1 ML/day. The inflow to the deeper Clareval void will be greater than the inflow to the Weismantel void, which is expected to provide net leakage for about 60 years (years 25-85).

The final void water balance model has been developed by Gilbert and Associates (2014) in consideration of the post-mining seepage rates predicted by groundwater modelling conducted for this assessment.

The predictions in Section 6.1 of Gilbert and Associates (2014) show that the final water level would stabilise in both final voids at levels below the spill level which is about 88 mAHD. The long term water level in the Weismantel final void is predicted to be about 72 mAHD which is some 14 m below the level at which water is predicted to spill over into the adjoining Clareval void (i.e. 86 mAHD). Most of the water level recovery occurs within 50-80 years after mining.

The long term water level in the Clareval final void is predicted to be around 60 m AHD as a result of relatively higher evaporative area of the Clareval final void. It is likely that there would be some groundwater flow between the voids, given the different water levels, which would result in some lowering of longer term levels in the Weismantel final void and correspondingly higher long term water levels in the Clareval final void. The final void water levels would however remain significantly below spill level.

The salinity of water in both voids is predicted to increase slowly over time.

The equilibrium groundwater level contours are given in **Figure 5-7** for the water table, and in **Figure 5-8** for the Clareval Seam (including the replacement spoil within the Clareval excavation area and the Clareval Seam's outside the outcropping seam traces).

At the water table and in deeper layers, the Clareval void lake is predicted to act as a hydraulic sink, receiving groundwater flow from all directions, including from the east and the Weismantel void. The Weismantel void is predicted to act as a flow-through system, with a weak north-west to south or south-easterly gradient, as well as the localised westerly gradient into the Clareval void. Beneath the Weismantel void (Layers 1-3), there would be vertical flow to the void due to an upwards pressure gradient. To the east and north of the Weismantel Seam excavation there is expected to be a permanent upwards hydraulic gradient.

6 IMPACTS ON THE GROUNDWATER RESOURCE

6.1 POTENTIAL IMPACTS ON GROUNDWATER

6.1.1 CHANGES IN HYDRAULIC PROPERTIES

There would be a change in hydraulic properties over the mine footprint where spoil infills the excavation down to the floor of the mined coal seam. As spoil would have a higher permeability than any natural material in this area, with the possible exception of alluvium, there would be associated reductions in hydraulic gradients in accordance with Darcy's Law. As one increases, the other must decrease to maintain the same flow. The flattening of the hydraulic gradient in the spoil material is evident in the spacing of the contours to the south of the pit lakes in **Figure 5-10** and **Figure 5-11**.

Rainfall recharge is expected to be higher in the spoil than in any natural local material.

6.1.2 CHANGES IN GROUNDWATER FLOW AND QUALITY

As mining progresses, the void would act as a groundwater sink. This would cause a temporary change in groundwater flow direction, often reversal of direction, until mining is completed and the aquifer system recovers to a new equilibrium. The final void would remain a groundwater sink for some time, and no impacts to groundwater quality are expected during this time as a result of the final void water quality.

In addition, the average simulated EC of water in the MWD (i.e. irrigation water) ranges between about 2,500 and 4,200 µS/cm (Gilbert & Associates, 2014). Therefore water quality in the surrounding groundwater is in many cases of a poorer quality than what is predicted from irrigation and hence the impact on groundwater from irrigation water is expected to be negligible.

The post-mining groundwater level pattern in **Figure 5-8** shows that the Clareval pit lake acts as a sink, while the Weismantel pit lake would act as flow-through lake system. To the east of the mine footprint, natural groundwater flow direction is expected to be restored to a dominant easterly direction. At the mine itself, the spoil infill would encourage preferential flow in a south-southeast direction. Groundwater would be drawn towards the infill from the west and the north-west.

Because the Clareval void will act as a hydraulic sink, any changes in water quality within that will not result in noticeable changes to water quality in surrounding areas. However the Weismantel void lake will act as a flow through system, with the predominant groundwater flow direction toward the south and south-east, and so there may be an increase in the salinity within the fractured rock and coal measures in this direction. Any increase in salinity would not impact other users of this deeper groundwater system or GDEs, and would not change the existing beneficial use category.

6.1.3 GEOCHEMISTRY

Acid rock drainage (ARD) management at the DCM is managed in accordance with the Potential Acid Forming Material Management Plan (PAFMMP) component of the WMP. This plan comprises the following components:

- Potential acid-forming (PAF) material separation procedures;
- PAF material storage procedures; and
- Monitoring of surface water and groundwater for the control of PAF materials.

Monitoring results from the DCM indicate that the waste rock management methods have been successful in controlling acid release from the open pit floor and waste rock emplacement (Gilbert & Associates, 2014).

The Modification would involve mining of the same material in the open pits, for which the geochemical characteristics were determined for the Duralie Extension Project. As such, no change to the previously identified geochemical characteristics is expected for the Modification, and no changes to existing PAF management practices would be required.

In consideration of the above, it is expected there would be negligible impacts to groundwater quality (either directly or via final pit voids) as a result of PAF material.

6.1.4 PIT INFLOWS

Up to the end of mining, there would be a continuous loss of water from the groundwater system to the mining void. The predictive simulation in Section 5.3 demonstrates that pit inflow is expected to vary between approximately 204 and 252 ML/annum for the remainder of the mine life. These rates are groundwater takes, and do not account for evaporation at seepage faces or pools on the floor of the pit.

6.1.5 POTENTIAL IMPACTS ON REGISTERED PRODUCTION BORES

The maximum regional drawdowns are expected within model Layer 3 (Weismantel seam) and model Layer 5 (Clareval seam). **Figures 5-10** and **5-11** show the drawdown magnitude and pattern for model Layer 3 (Weismantel seam) and Layer 5 (Clareval seam) respectively. Drawdowns are naturally limited to the east, west and south by outcropping volcanics. However, they propagate readily to the north and are in the order of 1 to 2 m in the coal seams at the model boundary.

The drawdowns in the four relatively shallow (18-60 m) private production bores at the northern end of the model area would be much less than the drawdowns in the underlying coal seam, which is probably more than 500 m below ground level. The drawdown in Layer 3 varies from 3 to 7 m at the three bores, but the potentiometric level would remain close to ground level. Therefore, the drawdown in the water level in each bore is expected to be negligible.

The one census spring identified during the 2009 EA bore census is located on the other side of the groundwater divide, to the west of the ridgeline that effectively screens the DCM from The Bucketts Way (**Figure 1-3**). The census spring is most unlikely to be affected by mining.

No other active registered bores (apart from DCPL bores) are known.

6.2 POTENTIAL IMPACTS ON SURFACE WATER BODIES

The drawdown patterns in **Figures 5-10** and **5-11** show substantial reduction in potentiometric head in the aquifers of the deeper groundwater system due east and to the north of the DCM area. However, there is no significant reduction in groundwater levels simulated in the alluvium. This is evidenced by simulated groundwater hydrographs at the alluvial monitoring bores (**Figures 4-5** and **4-6**) which show no mining effect in spite of substantial fluctuations in deeper layers as mining progresses.

This result supports the description of the alluvium/coal seam disconnection in Section 3, where clay lenses below the alluvium (where the coal seams outcrop) would impede any connection between the Mammy Johnsons River and the coal seam or final void.

The predictive simulation in Section 5.4 demonstrates that the net reduction in baseflow to the river is expected to be negligible.

Based on the groundwater level mapping (**Figures 2-6, 2-7 and 2-9**) the Mammy Johnsons River is the primary baseflow receptor for groundwater in the vicinity of the DCM. Given the predicted small influence of mining on Mammy Johnsons River, as discussed above, it follows that potential impacts to other surface water bodies would also be very minor or negligible. For example, Black Soil Creek, located to the northwest of the DCM (see **Figures 2-2 and 2-3**, and see also ‘BSC’ labelled on **Figure 5-8**) is about the same distance from the proposed open pits as the Mammy Johnsons River, but is located beyond a weak groundwater divide (shown on **Figure 5-8**), which will limit the degree of drawdown (see ‘BSC’ on **Figure 5-8**) in the catchment of Black Soil Creek and any associated baseflow capture.

6.2.1 CHANGES IN WATER QUALITY

There are expected to be negligible river-aquifer flux changes to the Mammy Johnsons River catchment area at the end of mining (Section 5.4).

Because the final void in the Weismantel pit is predicted to act as a flow-through system, the saline groundwater would move from the void lake through the spoil toward the south and southeast.

The AI Policy has a Minimal Harm consideration of no increase of more than 1% per activity in long-term average salinity at the point nearest to the activity, where the watercourse is a reliable water source.

There is predicted to be a slow accumulation of salts within the Weismental and Clareval pit lakes and subsequently very slow migration of those salts to the south and southeast from the Weismantel pit only. These could take 120 years to flow from the Weismantel pit lake and contribute to surface water base flows at similar volumetric contributions as current. The 1% water quality threshold criterion is expected to be met for at least 300 years post-mining, and following this period the potential change in surface water quality is expected to be in the order of 1%.

6.2.2 CHANGES IN WATER BALANCE

Numerical modelling has allowed quantification of the relative magnitudes of the major components of the water balance. Pre-mining recharge is dominated by rainfall (62%) and river leakage (36%), while discharge is dominated by evapotranspiration (58%) and baseflow to rivers and creeks (13%). End of mining recharge is expected to be dominated by rainfall (60%) and river leakage (35%), while discharge should be dominated by evapotranspiration (53%) and baseflow to rivers and creeks (12%). Discharge to the mine is estimated to be about 7% of the water budget at the end of mining.

These figures suggest that mining would have a minor effect on the water balance component relativities.

6.2.3 EFFECTS ON SURFACE ECOSYSTEMS

Given the localised disturbance of open pit mining, and the demonstration of inconsequential changes in river leakage or baseflow, no effects on surface ecosystems are anticipated in relation to mining-induced changes to the water system.

6.3 GROUNDWATER MONITORING PROGRAMME

The existing groundwater monitoring network for the mine is summarised in **Table 2-3** and measured water quality parameters are listed in **Table 2-4**. Since the 2009 EA for the DEP, water level data has been monitored at four additional bores (DB8W, DB9W, DB10W and DB11W) and two bores have been drilled adjacent to backfilled open pit (WR1 and WR2).

Consistent with the requirements of Project Approval (08_0203), groundwater monitoring data should be reviewed at regular intervals during the remainder of the mine life and compared against the groundwater modelling predictions in this report.

6.3.1 MONITORING PIEZOMETERS

The existing network is considered adequate for providing information on the dynamics of the groundwater hydraulics and offers an adequate basis for groundwater model calibration. However, as Bore DB8W gives water levels that are inconsistent with DB9W and DB10W, it should be investigated or replaced.

Should the review of monitoring data not correlate well with the predictive modelling results, the existing DCPL monitoring network should be augmented by additional hydraulic property measurements and installed flow meters as mining progresses (**Table 6-1**), as insufficient data are available on waste rock properties.

Table 6-1 Proposed Groundwater Monitoring Programme

PARAMETER	LOCATION
Piezometers	• Existing monitoring bores on-site. • Existing piezometers adjacent to the backfilled open pits.
Groundwater Quality	• At piezometers above.
Hydraulic Property Measurements (Core Sampling and Testing)	• As mining exploration progresses.
Mine Water Balance	• Measurement of volumes extracted from void to MWD, pumped water, coal moisture, etc.

Such data are required to provide information on the recharge rates through spoil, spoil permeabilities, and to validate modelling assumptions and predictions.

6.3.2 GROUNDWATER QUALITY

The groundwater monitoring network should continue to include sampling of water quality on a regular basis, including for at least two years following mining. Water quality samples should also be taken during drilling of any new piezometer and hydrogeological investigation bores.

The existing groundwater quality monitoring should continue to include, but not necessarily be limited to, analysis of the following parameters: pH, dissolved oxygen, EC, TDS, iron, aluminium, magnesium, calcium, sodium, chloride and sulphate. Analysis should be undertaken at a National Association of Testing Authorities (NATA) accredited laboratory. Water quality data should continue to be evaluated as part of the Annual Environmental Management Report (AEMR) processes and should aim to identify any potential mining related impacts.

6.3.3 HYDRAULIC PROPERTY MEASUREMENTS

Core sampling and testing should be conducted during appropriate DCPL drilling within the DCM area, where practicable, to determine aquifer properties within the natural rock strata (e.g. effective porosity, horizontal permeability and vertical permeability). DCPL should create a database of testing data throughout the DCM area, which should be used to validate model parameters and guide potential future groundwater assessments.

6.3.4 MINE WATER BALANCE

Currently, there is inadequate data on actual groundwater inflows to the pits. Estimates of non-runoff components of the water balance are based on pumped hours rather than metered rates. To improve the estimation of the contributions of groundwater inflow and recirculated seepage from the waste rock emplacements to total inflow to the open pit sumps, it is advisable that flow meters be installed to monitor:

- the pumped transfer from the pits to the MWD;
- flow to the irrigation system; and
- flow to the waste emplacement spray irrigation system.

Water balances should be continue to be conducted regularly to account for all monitored volumes and should be reported in the AEMR.

The water balance should be regularly reviewed to confirm groundwater transmission characteristics and modelling predictions. The performance measures and indicators (i.e. trigger levels) and contingency measures specified in the Water Management Plan should continue to be implemented.

7 CLIMATE CHANGE AND GROUNDWATER

Climate change analysis was reported in Heritage Computing (2009) by conducting steady-state simulations at the completion of mining for two scenarios of reduced rainfall recharge: 10% and 20%. The assumed reductions are conservative estimates of the climate change projections offered by CSIRO's OzClim[10] service. Based on these projections, annual rainfall is expected to decline by 60 to 80 mm/a by 2025 (about 5-6%) at the DCM[11], although some more extreme projections available from OzClim suggest a decline of more than 100 mm/a or 15%. In addition, annual average temperatures are projected to increase by about 1°Celsius (relative to 1990) at that time.

The findings were:

- Pit inflow is expected to reduce by about 2% for 10% reduction in rainfall, and by about 7% for 20% less recharge from rainfall.
- Net river-aquifer interaction is expected to worsen by about 1% for 10% reduction in rainfall, and by about 4% for 20% less recharge from rainfall.

As the predictions of the 2009 model and the current model are very similar, and the model parameterisations are similar, no consideration of additional climate change scenarios was deemed necessary.

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[10] http://www.csiro.au/ozclim/home.do

[11] OzClim allows the user to specify a number of criteria. HydroSimulations obtained data for Moderate rainfall decline scenarios, as well as for the Moderate and High Emissions growth scenarios. This represents only a selection of the full range of climate change projections. The High Emissions Growth scenario is considered the most likely (CSIRO and BoM, 2014).
The year 2025 was selected as it is shortly after the proposed cessation of mining.

8 MODEL LIMITATIONS

Although MODFLOW-SURFACT is capable of simulating unsaturated conditions, the focus in this study has been on the saturated part of the groundwater system. Nevertheless, MODFLOW-SURFACT will report groundwater heads (equivalent to negative pore pressures) in dry portions of model layers. Much of model Layer 1 is simulated to be dry.

A former deficiency of MODFLOW-SURFACT was that it did not allow time-varying formation properties (e.g. hydraulic conductivity). In the 2009 study, predictive simulations were continuous for 44 periods from January 2003 to December 2020. The runs were not interrupted for progressive emplacement of waste rock. However, the rainfall recharge through the spoil and the duration of activation of mine drains were varied in time to account in part for the emplacement of waste rock.

Although MODFLOW-SURFACT now has a facility for time-varying formation properties, this was not implemented in order that the changes between the previous and new models could be kept to a minimum.

At this stage the model has adopted laterally uniform properties in layers and uniform rainfall recharge across four zones. As more data are gathered, the spatial distributions of aquifer properties can be refined. At this stage, there is no hydrographic evidence for hydraulic conductivity reduction with depth, but this can be expected as mining proceeds to greater depths. Lower pit inflows can be expected as coal seam permeability reduces with depth.

As there is poor knowledge of formation interface elevations and geometry in the northern half of the model area, predictions in this area should be regarded as indicative only.

Two geological faults are included in the current model that were not part of the 2009 model. The new model does not include other structural features except to the extent that they determine formation thicknesses observed in exploration holes. There is uncertainty as to their size, scale, vertical persistence, locations of smaller structures and whether they are resistive barriers or transmissive conduits. Geological structures are more likely to compartmentalise aquifers and thereby localise drawdown effects and limit pit inflows. By ignoring such structures in the model, predictions of pit inflow would tend to over-estimation, and predicted environmental effects are expected to be conservative.

It is considered that inclusion of additional faults in the model is likely to improve the calibration of the newer bores (DB9W, DB10W and DB11W).

9 CONCLUSIONS

The data supports two groundwater systems:

- shallow groundwater system – associated with alluvium and regolith; and
- deeper groundwater system, including:
    - the Weismantel and Clareval coal seams; and
    - low permeability/disconnected fractured rock/coal measures of the Mammy Johnsons, Weismantels and Durallie Road Formations (**Figure 2-5**).

For mining since 2003, there is strong hydrographic evidence of mining effects on the deeper groundwater system, with no discernible effect on the shallow groundwater system. Based on strong evidence from hydrographic data and field observations, there is expected to be:

- negligible loss of groundwater yield to/from surface stream systems (i.e. Mammy Johnsons River); and
- limited potential for reduction of groundwater yield to other groundwater users, for bores located in the shallow groundwater system.

These observations are consistent with the conclusions of the numerical model, described below.

As would be expected, a lateral hydraulic gradient towards the open pit has developed, and groundwater flow would continue to move toward the pit as mining progresses.

Based on groundwater modelling, there is expected to be:

- negligible drawdown in the aquifers of the shallow groundwater system;
- negligible impact on access to water in known registered production bores licensed to external parties;
- substantial reduction in potentiometric head in the aquifers of the deeper groundwater system due east and to the north of the DCM area;
- negligible loss of groundwater yield to surface stream systems (i.e. Mammy Johnsons River);
- negligible reduction in groundwater contribution to total stream flows, and negligible reduction in natural leakage from streams;
- pit inflow ranging between approximately 204 and 252 ML/annum during the remainder of the mine life, and approximately 204 ML/a at the completion of mining;
- negligible deterioration in groundwater quality as a result of mining, including in the long-term;
- slow recovery of the groundwater system over several decades to a new equilibrium in which the pit lakes would act as flow-through lake systems;
- at equilibrium, natural groundwater flow direction is expected to be restored to a dominant easterly direction to the east of the mine footprint; and
- at equilibrium, the spoil infill is expected to encourage preferential flow in a south-, southeast direction.

Given the large distance to the nearest coal mining (Stratford Coal Mine) and coal seam gas activity (AGL Stage 1), no quantitative cumulative Impact assessment is deemed necessary.

As the *Draft North Coast Fractured and Porous Rock Groundwater Sources* plan has not yet commenced, the interception and use of groundwater at the mine remains managed and licensed under Part V of the Water Act, 1912. DCPL holds an existing Bore Licence for 300 ML/year, for the excavation, that was originally issued in 2002 and was renewed in 2007 and again in 2012. It remains valid until September 2017. The predicted peak groundwater take for the remainder of the mine life is within the current licensed rate of 300 ML/year. No additional licensing is required.

Table 9-1 presents a summary of the relevant criteria specified in the AI Policy.

Table 9-1 Summary of AI Policy Assessment – Gloucester Basin Porous Rock

Aquifer	Gloucester Basin Porous Rock
Category	Less Productive
Level 1 Minimal Impact Consideration	**Assessment**
Water Table Less than or equal to a 10% cumulative variation in the water table, allowing for typical climatic "post-water sharing plan" variations, 40 m from any: high priority groundwater dependent ecosystem; or high priority culturally significant site; listed in the schedule of the relevant water sharing plan. OR A maximum of a 2 m water table decline cumulatively at any water supply work.	The relevant Water Sharing Plan is the 'Greater Metropolitan Groundwater Sources' (dated 1 October 2011). There are no Culturally Significant Sites in the Study Area. Hence there are no known risks of mine development to such sites. The only High Priority GDEs identified in this region are two sets of karst features located about 40 km north of the Duralie Coal mine. As the mine is not in close proximity to GDEs identified as High Priority, the minimal harm considerations of the Aquifer Interference Policy are not infringed. There are four shallow private bores at 4-6 km to the north of the mining lease. As the predicted groundwater drawdown at shallow depths (less than 60 m) is less than 2 m, the minimal harm considerations of the Aquifer Interference Policy are not infringed. **Level 1 minimal impact consideration classification.**
Water pressure A cumulative pressure head decline of not more than a 2m decline, at any water supply work.	No local deep groundwater bores, other than any owned by DCM, will be affected. **Level 1 minimal impact consideration classification.**
Water quality	No predicted change in beneficial use category for local groundwater. "There is predicted to be a slow accumulation of salts within the Weismantel and Clareval pit lakes and subsequently very slow migration of those salts to the south and southeast from the Weismantel pit only. These could take 120 years to flow from the pit lake to the Mammy Johnsons River, and may lead to a greater than 1% increase in average river salinity eventually. However the 1% threshold criterion is expected to be met for at least 300 years post-mining and following this period the potential change in surface water quality is expected to be in the order of 1%. **Level 1 minimal impact classification for 300 years.**

The foregoing groundwater assessment is generally consistent with the assessment undertaken for the 2009 EA for the DEP. Based on the updated modelling results, there is no change to the key assessment outcomes, i.e.:

- Negligible predicted impacts to the shallow alluvial groundwater system in which the Mammy Johnsons River sits, or river leakage/baseflow contributions from/to the Mammy Johnsons River
- Localised increases in groundwater salinity, but that are unlikely to change the beneficial use of the groundwater in this area;
- The 1% water quality threshold criterion is expected to be met for at least 300 years post-mining, and following this period the potential change in surface water quality is expected to be in the order of 1%.
- Negligible impacts to other groundwater users.

10 REFERENCES

Agriculture and Resource Management Council of Australia and New Zealand and Australian and New Zealand Environment and Conservation Council (1995). *National Water Quality Management Strategy Guidelines for Groundwater Protection in Australia*.

Barnett, B., Townley, L.R., Post, V., Evans, R.E., Hunt, R.J., Peeters, L., Richardson, S., Werner, A.D., Knapton, A. and Boronkay, A., 2012. *Australian Groundwater Modelling Guidelines*. Waterlines Report Series No. 82, June 2012.

BoM (2009). "Climate Data Online", Accessed May 2014, <http://www.bom.gov.au/climate/averages/>.

CSIRO and Bureau of Meteorology, 2014. *State of the Climate 2014*. Available at: http://www.csiro.au/Outcomes/Climate/Understanding/State-of-the-Climate-2014.aspx

Department of Land and Water Conservation (2002). *NSW State Groundwater Dependent Ecosystems Policy*. April, 2002. Accessed at: http://www.water.nsw.gov.au/ArticleDocuments/34/groundwater_dependent_ecosystem_policy_300402.pdf.aspx

Department of Environment, Climate Change and Water NSW (2010). *State of the Catchments 2010: Groundwater – Hunter-Central Rivers region*. Accessed at: http://www.environment.nsw.gov.au/resources/soc/huntercentralrivers/10437HUNTCENgwater.pdf

DCPL (1996) *Duralie Coal Environmental Impact Assessment*.

Duralie Coal Pty Ltd (2013a) *Duralie Coal Mine Water Management Plan*. Document WAMP-R02-D, updated September2013. http://www.duraliecoal.com.au/documents/community_environment/WAMP-R02-D.pdf

Duralie Coal Pty Ltd (2013b) *Duralie Coal Mine Groundwater Management Plan*. Document GWMP-R02-C, updated September 2013.

Duralie Coal Pty Ltd (2008b) *Irrigation Management Plan*.

Doherty, J., 2010. *PEST - Model Independent Parameter Estimation*. User Manual 5th Edition. Watermark Numerical Computing.

Environmental Simulations Inc, 2011. *Groundwater Vistas 6*. (Graphical User Interface for MODFLOW and other models). Available at: http://www.groundwatermodels.com/

Gilbert and Associates (2009). *Duralie Extension Project Surface Water Assessment*.

Gilbert and Associates (2014). *Duralie Open Pit Modification Surface Water Assessment*. doc: J0206-51 rg1b. July, 2014.

Golder Associates (1981a). *Geotechnical Investigations for Open Pit Mining, Wards River Area*. Report to BMI Mining Pty Ltd on Gloucester Coal Project. September 1982 Report No 8263-0001-A.

Golder Associates (1981b). *Groundwater Investigations for Open Pit Mining, Wards River Area*. Report to BMI Mining Pty Ltd on Gloucester Coal Project. September 1982 Report No 8263-0001-A.

Golder Associates (1982). *Dewatering Investigations for Open Pit Mining, Wards River Area*. Report to BMI Mining Pty Ltd on Gloucester Coal Project. September 1982 Report No 8263-0001-A.

Hatton, T. and Evans, R. (1998) *Dependence of ecosystems on groundwater and its significance to Australia*. LWRDC Occasional Paper No 12/98.

Hawkins, J.W., 1998. *Hydrogeologic characteristics of surface-mine spoil*. In Coal Mine Drainage Prediction and Pollution Prevention in Pennsylvania, ed. Brady, Smithy and Schueck. Harrisburg, Pennsylvania. Available at: http://www.techtransfer.osmre.gov/nttmainsite/Library/pub/cmdpppp/chapter3.pdf

Heritage Computing, 2009. *A Hydrogeological Assessment of the Duralie Extension Project: Environmental Assessment*. Doc GCL-06-07/HC2009/13, November 2009.

Kidd (1996). *Groundwater Hydrology Background – Part B*, Section 2 of the Duralie Coal Mine Commission of Enquiry.

Mackie, C.D., 2009. *Hydrogeological characterisation of Coal Measures and overview of impacts of coal mining on groundwater systems in the upper Hunter Valley of NSW*. PhD thesis at University of Technology, Sydney.

McDonald, M.G., and Harbaugh, A.W., 1988. *A modular three-dimensional finite-difference ground-water flow model: Techniques of Water-Resources Investigations* of the United States Geological Survey. Book 6. USGS.

Middlemis, H., Merrick, N., and Ross, J., 2001. *Murray-Darling Basin Commission – Groundwater Flow Modelling Guideline*. Report for MDBC. January 2001.

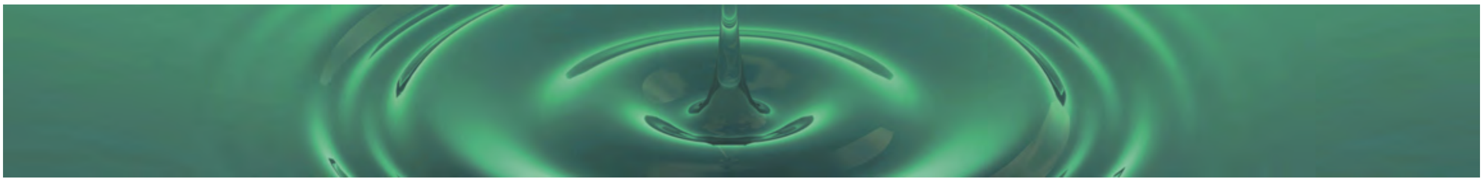
Parsons Brinckerhoff, 2013. Hydrogeological Conceptual Model of the Gloucester Basin. Report for AGL Upstream Investments. June 2013. Available at: http://www.agl.com.au/~/media/AGL/About%20AGL/Documents/How%20We%20Source%20Energy/CSG%20and%20the%20Environment/Gloucester/Assessments%20and%20Reports/2013/Conceptual%20model%20email%20version.pdf

Pells Sullivan Meynink (1995). *Draft Report Hydrometeorological Data Karuah Valley*, Duralie Coal Project.

Roberts J., Engel B., Lennox M. and Chapman J. (editor), 1991, *Dungog 1:100 000 Geological Sheet 9233*, 1st edition. Geological Survey of New South Wales, Sydney.

Smith, B. C., 2001, PEL 285 – *Gloucester Basin Coal Bed Methane Investigations*. Pacific Power Well Completion Report, Stratford 6 (PGSD 6). March 2001. 32p.

State Emergency Service (NSW) (2007) *The Maitland Flood of 2007*. Website: http://www.ses.nsw.gov.au. Date accessed: 10/09/2009.



ATTACHMENT A

Registered Bores near to Duralie Coal Mine

ATTACHMENT A Known registered bores in the vicinity of the Project

Bore ID (Work No)	DCM bore ID	Work Licence	Type	Owner	Easting (zone 56)	Northing (zone 56)	Depth (m)	Year Completed	Property	Groundwater Management Area	Salinity	Bore yield (l/s)	Standing water level (mBG)	Ground elevation or TOC (mAHD)	Distance to DCM mine workings (m)
GW022488			Bore	Private	402721	6414346	25.3	1955		Gloucester Basin	(Unknown)				11400
GW052650		20BL117175	Bore open th	Private	391794	6424674	36.6	1981		New England Fold Belt	(Unknown)				8000
GW054253		20BL114844	Bore	Private	403228	6413304	25	1980		Gloucester Basin	Good				12600
GW047870			Bore open th	Private	399805	6434366	30	1981		Gloucester Basin	(Unknown)				4800
GW051643		20BL112285	Bore open th	Private	403021	6415765	23	1980		Gloucester Basin	Good				10100
GW032846		20BL025489	Bore	Other Govt	399499	6420443	15.2	1970		Gloucester Basin	(Unknown)				5200
GW011316		20BL004470	Well	Private	398447	6434075	18.3	1955		Gloucester Basin	Good Stock				4500
GW011988		20BL005309	Bore	Private	402003	6415663	20.1	1956		Gloucester Basin	(Unknown)				10000
GW078141	DB1W	20BL166741	Bore	Mines	401423	6426930	36.5	1997		Gloucester Basin		0.8	14.09	62.246	500
GW078171			Bore	Mines	401122	6444326	0			Gloucester Basin				133	14900
GW078219		20BL167122	Bore		401700	6418851	31.5	1999	20PT910681	Gloucester Basin		0.526	3		6800
GW079610		20BL167416	Bore	Mines	401228	6444142	0			Gloucester Basin					14700
GW079612		20BL167416	Bore	Mines	401280	6444204	0			Gloucester Basin					14800
GW079614		20BL167416	Bore	Mines	401332	6444235	0			Gloucester Basin					14800
GW079615		20BL167416	Bore	Mines	401366	6444296	0			Gloucester Basin					14900
GW079619	DB2W	20BL166741	Bore	Mines	401444	6426228	60			Gloucester Basin				63.37	100
GW079620		20BL166741	Bore	Mines	401700	6426741	60	1997		Gloucester Basin		5	14.78	55.112	600
GW079621	DB4W	20BL166741	Bore	Mines	400932	6425503	40	1997		Gloucester Basin		1.81	7.26	53.6	200
GW079742		20BL167297	Bore		400597	6420147	30	1999		Gloucester Basin			4		5400
GW200048		20BL166741	Bore	Mines	401589	6425668	6	1996		Karuah Alluvium			5.72		400
GW079746		20BL166741	Bore	Mines	401445	6424619	11	1997		Gloucester Basin					1100
GW079744		20BL166741	Bore	Mines	401618	6425637	9.5	1996		Karuah Alluvium					400
GW079747		20BL166741	Bore	Mines	401717	6426224	7	1996		Gloucester Basin					400
GW079748		20BL166741	Bore	Mines	401717	6426224	10	1996		Gloucester Basin					400
GW079749		20BL166741	Bore	Mines	401928	6426072	10	1996		Gloucester Basin					600
GW079751		20BL166741	Bore	Mines	402269	6425890	9.5	1996		Gloucester Basin					1000
GW079752		20BL166741	Bore	Mines	401583	6426561	9.5	1996		Karuah Alluvium					500
GW079753		20BL166741	Bore	Mines	401319	6426805	7.5	1996		Gloucester Basin					300
GW079761			Well	Private	399996	6443251	13.39	1994		Gloucester Basin			13.39		13700
GW079758			Bore	Private	401497	6440788	0			Gloucester Basin					11500
GW079759			Bore	Private	401176	6438783	0			Gloucester Basin					9400
GW079618			Bore	Mines	401175	6444265	0			Gloucester Basin				130	14800
GW078349			Bore		398789	6416340	22	1996		New England Fold Belt					9400
GW078759		20BL166869	Bore		400610	6419041	22	1998		Gloucester Basin			1.5		6500
GW079049		20BL167416	Bore	Private	401944	6443867	0			Gloucester Basin				124	14600
GW078585		20BL167242	Bore	Private	402432	6417275	19	1999		Gloucester Basin	Good	9.3	3		8500
GW078586		20BL167454	Bore	Private	402152	6413376	33.5	1999		Gloucester Basin		0	9		12300
GW080578		20BL168966	Bore		403063	6414614	33	2004		Gloucester Basin		1	7		11200
GW080508		20BL168893	Bore	Local Govt	404720	6413293	0	2003		New England Fold Belt					12900
GW080509		20BL168893	Bore	Local Govt	404801	6413159	0	2003		New England Fold Belt					13100
GW080288		20BL166921	Bore		400436	6432706	0	2002	20PT910726	Karuah Alluvium					3300
GW064028		20BL135976	Bore	Private	387111	6427087	25.9	1987		New England Fold Belt	1001-3000 ppm				11700
GW066016			Excavation	Private	390494	6428726	2	1991		New England Fold Belt			2		8100

ATTACHMENT A Known registered bores in the vicinity of the Project

Bore ID (Work No)	DCM bore ID	Work Licence	Type	Owner	Easting	Northing	Depth	Year Completed	Property	Groundwater Management Area	Salinity	Bore yield	Standing water level	Ground elevation or TOC	Distance to DCM mine workings
					(zone 56)	(zone 56)	(m)					(l/s)	(mBG)	(mAHD)	(m)
GW067275			(Unknown)	(Unknown)	387366	6425365	10	1991		New England Fold Belt			10	115.8	11800
GW079613		20BL167416	Bore	Mines	401306	6444235	0			Gloucester Basin					14800
GW079617		20BL167416	Bore	Mines	401207	6444274	0			Gloucester Basin					14900
GW079622		20BL166741	Bore	Mines	400517	6425167	40	1997		Gloucester Basin		0.6		55.97	400
GW079750		20BL166741	Bore	Mines	402113	6425889	10.5	1996		Gloucester Basin					800
GW079754		20BL166741	Bore	Mines	401134	6426988	12	1996		Gloucester Basin					300
GW079048		20BL167416	Bore	Mines	401532	6444000	5.97			Gloucester Basin				125	14600
GW050402		20BL111604	Bore	Private	403134	6420263	26	1980		Gloucester Basin	Good				5800
GW080571		20BL169147	Bore	Private	403129	6414366	0	2004		Gloucester Basin					11500
GW080778		20BL168404	Bore		401407	6426825	36.5	2002	20PT910957	Gloucester Basin		0.75	18		400
GW080776		20BL168404	Bore		401342	6426938	40	2002	20PT910957	Gloucester Basin		0.25	9		400
GW080777		20BL168404	Bore		401522	6426872	40	2002	20PT910957	Gloucester Basin		1	22		500
GW080779		20BL168404	Bore		401537	6426751	60	2002	20PT910957	Gloucester Basin		4	40		500
GW080780		20BL168404	Bore		401599	6426842	40	2002	20PT910957	Gloucester Basin		0.3	22		600
GW080781		20BL168404	Bore		401396	6426717	58	2002	20PT910957	Gloucester Basin		0.35	25		300
GW080636		20BL168404	Bore		401453	6426839	35.7	2004	20PT910957	Gloucester Basin		0.25	33.7		400
GW080637		20BL168539	Bore		401520	6424997	16.4	2004		Gloucester Basin			14		800
GW080638		20BL168539	Bore		401416	6425106	28.2	2004		Gloucester Basin					700
GW079050		20BL167416	Bore	Mines	401701	6443473	8.28			Gloucester Basin				125	14100
GW079611		20BL167416	Bore	Mines	401254	6444173	0			Gloucester Basin					14800
GW200049		20BL166741	Bore	Mines	401595	6425329	7	1996		Gloucester Basin					600
GW080484		20BL168934	Bore		402734	6414554	39	2004		Gloucester Basin		2	8.5		11200
GW200244		20BL168404	Bore		402195	6425490	40	2002	20PT910957	Gloucester Basin		0.25	9		1000
GW200431		20BL169316	Bore		403353	6435280	60	2004		New England Fold Belt		0.25	8		7000
GW200432		20BL169271	Bore		398903	6434728	60	2004		Gloucester Basin					5100

C:\HydroSim\YAN001\Tech\Bores\[RegisteredBoreSearch.xlsx]Bores

Figures to accompany

Duralie Coal Mine Extension Modification

Groundwater Assessment

FOR

Duralie Coal Pty Ltd

BY

W. Minchin, Dr N.P. Merrick and N. Akhter
Heritage Computing Pty Ltd
trading as
HydroSimulations

Project number: YAN001
Report: HC2014/012
Date: July 2014

DOCUMENT REGISTER

Revision	Description	Date	Comments
A	First Draft	06 June 2014	Draft to Resource Strategies
B	Second Draft	4 July 2014	Complete Draft
C	Third Draft	6 July 2014	Complete Draft
D	Final Dradt	11 July 2014	Incorporates Resource Strategies and DCPL comments
E	Final		

File:
c:\hydrosim\yan001\wp\figures\hc2014-013d_figures_duraliemod-gwassessment_hydrosim.docx

List of Figures

1 INTRODUCTION

LEGEND

🟩	National Park, Nature Reserve or State Conservation Area
▨	NSW State Forest
—	Mining Lease Boundary
- - -	Mining Lease Application Boundary *
—	Exploration Authorisation 315

* *Subject to Separate Application*

Source: Geoscience Australia (2009); Department of Lands (May 2009); DECC (2009) and DCPL (2009)

DURALIE OPEN PIT MODIFICATION

FIGURE 1-1

Regional Location

GCL-14-23_Mod 2_Section 1_101B

Source: DCPL (2014); AAHatch - Aerial Photography flown April 2009 and July 2013

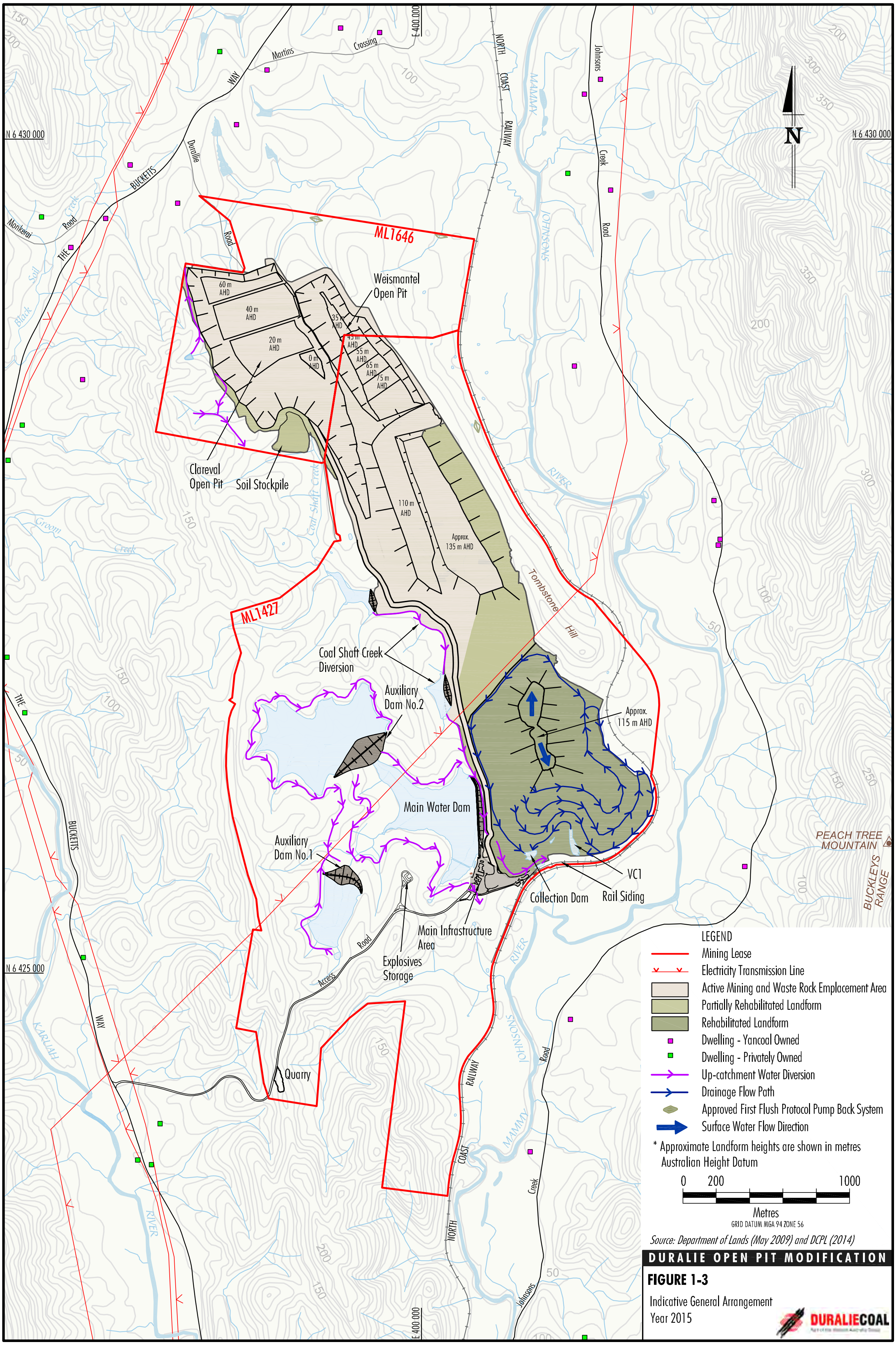
DURALIE OPEN PIT MODIFICATION

FIGURE 1-2

Modification
General Arrangement

DURALIECOAL
Part of the Yancoal Australia Group

GCL-14-23_Mod 2_Section 1_103D

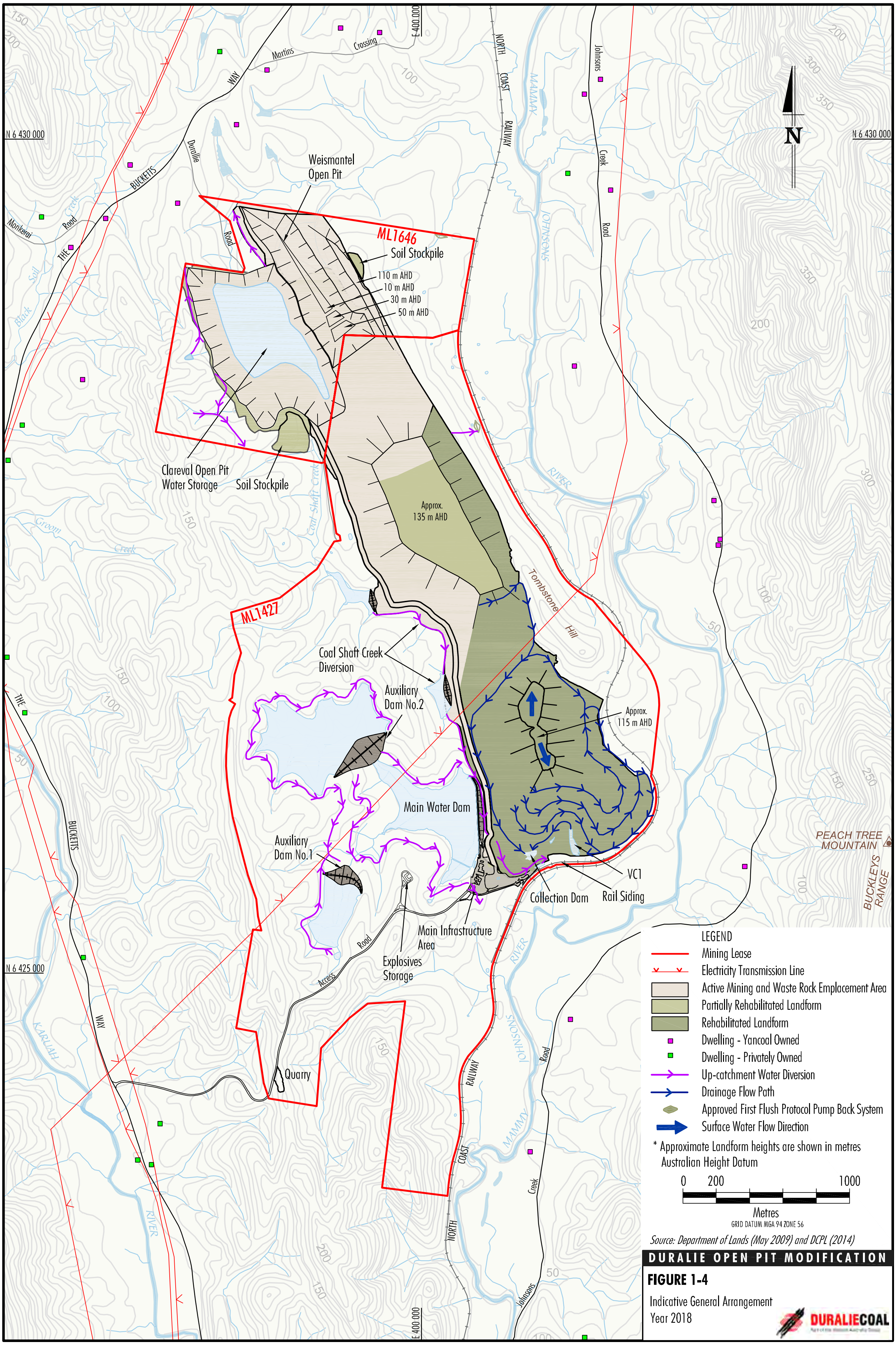


Source: Department of Lands (May 2009) and DCPL (2014)

DURALIE OPEN PIT MODIFICATION

FIGURE 1-3

Indicative General Arrangement
Year 2015



Source: Department of Lands (May 2009) and DCPL (2014)

DURALIE OPEN PIT MODIFICATION

FIGURE 1-4

Indicative General Arrangement
Year 2018

GCL-14-23_Mod 2_GWA_102B

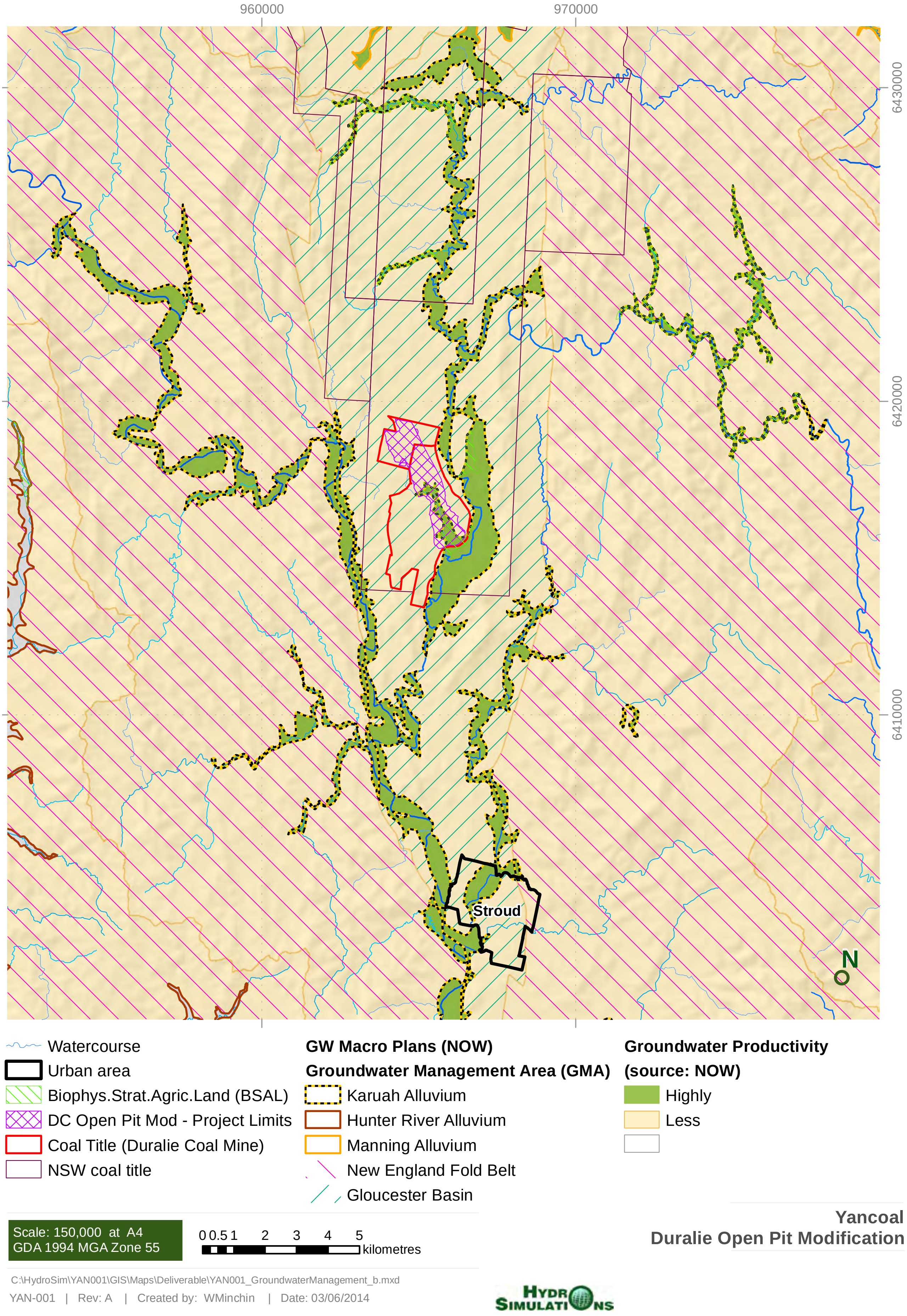


Figure 1-5 Water Management and Regulatory boundaries

2 EXISTING CONDITIONS

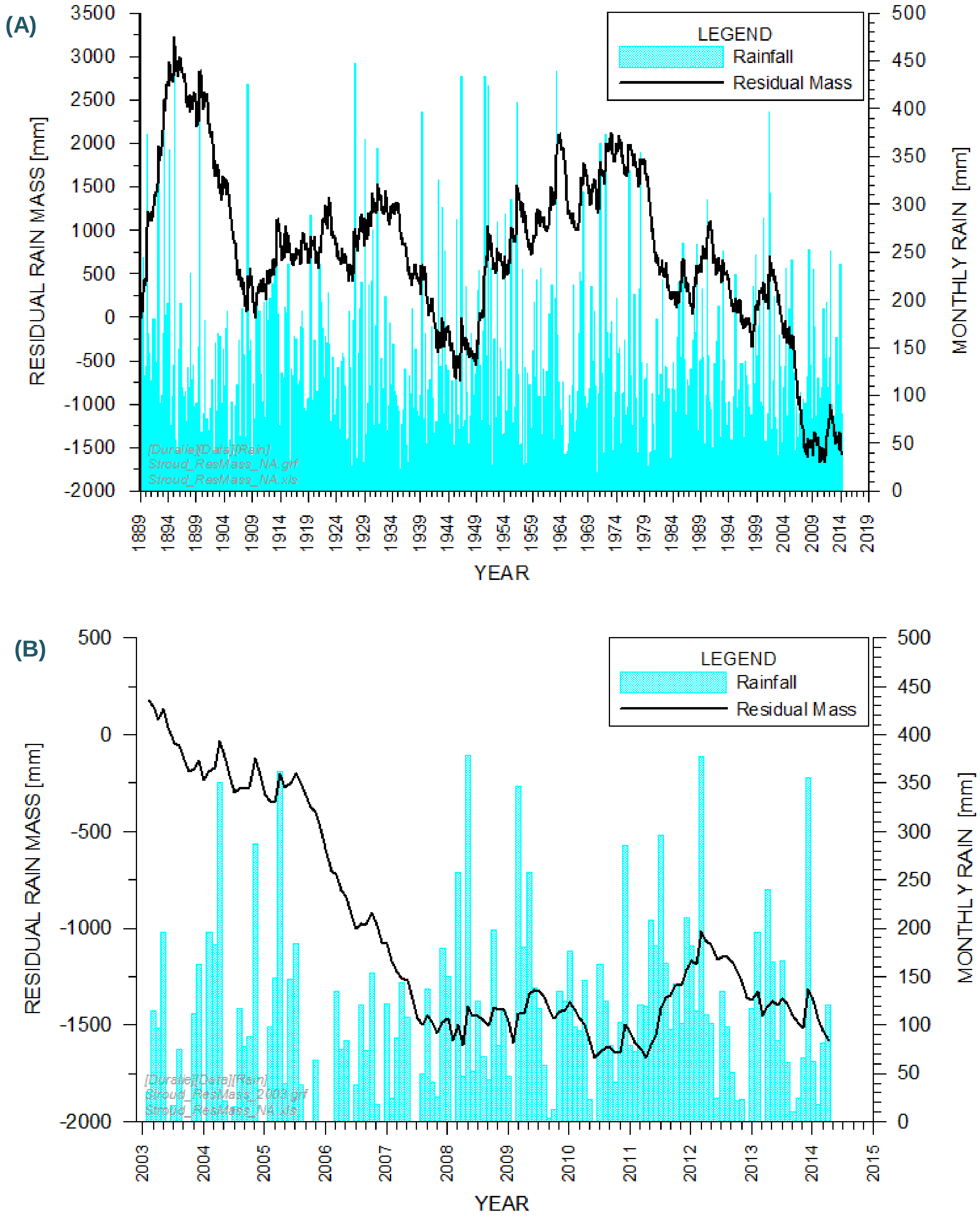
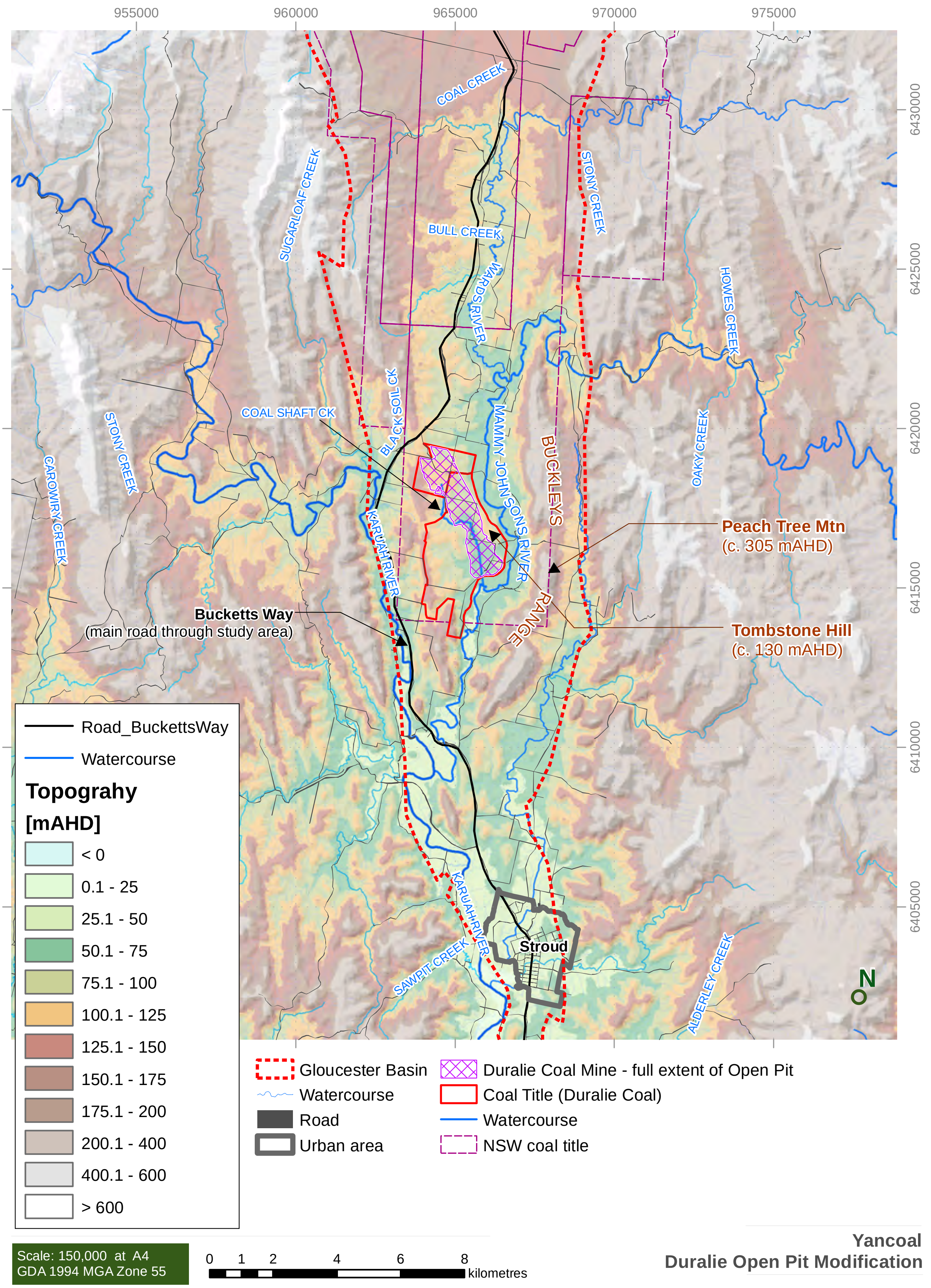


Figure 2-1 Rainfall and Rainfall Residual Mass for A) Stroud PO (since 1889) and B) Stroud PO (since 2003)



Scale: 150,000 at A4
GDA 1994 MGA Zone 55

Yancoal
Duralie Open Pit Modification

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YAN-001 | Rev: A | Created by: WMinchin | Date: 03/06/2014

HydroSimulations

Figure 2-2 Topography and Surface Water Drainage

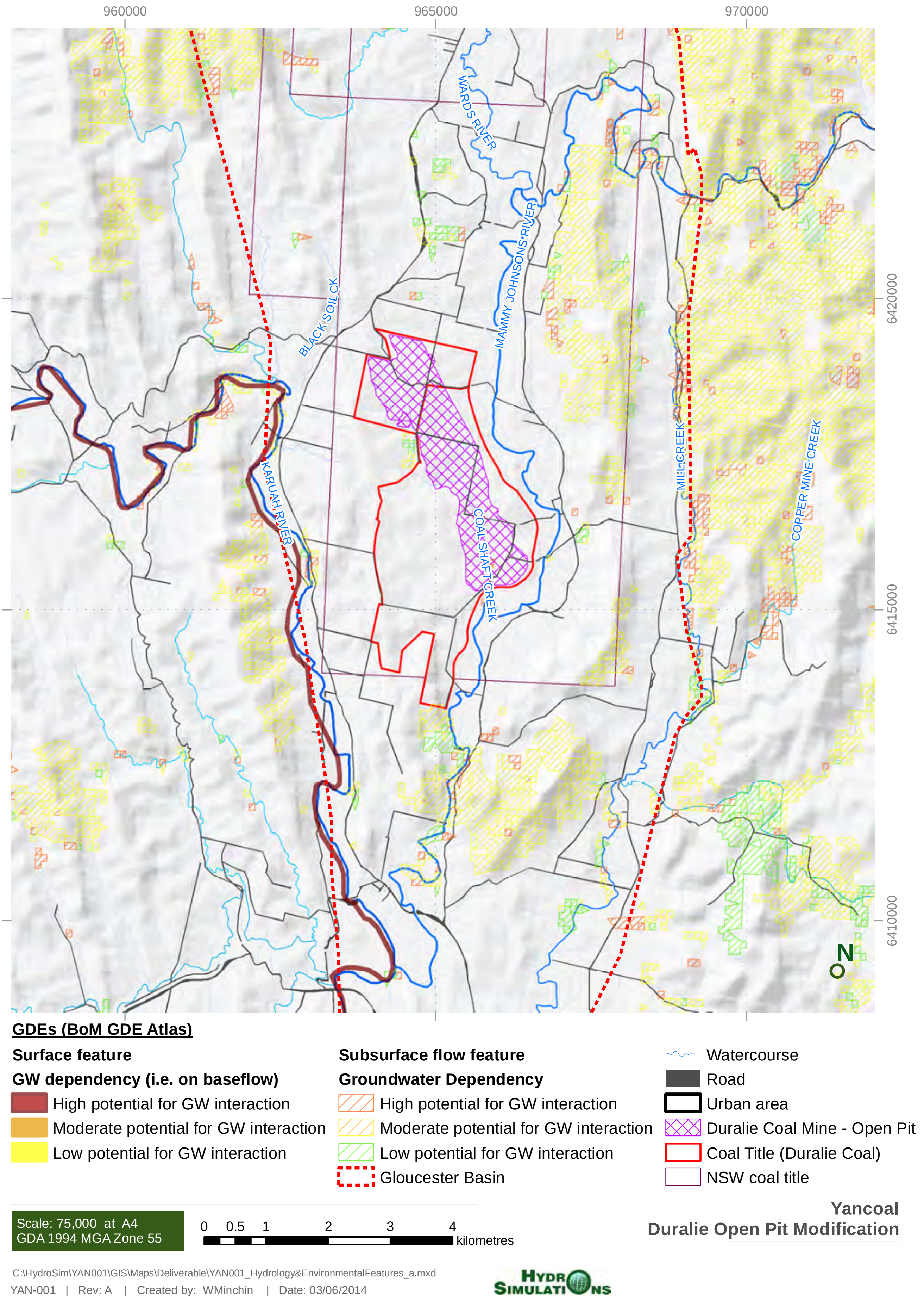


Figure 2-3 Environmental Features

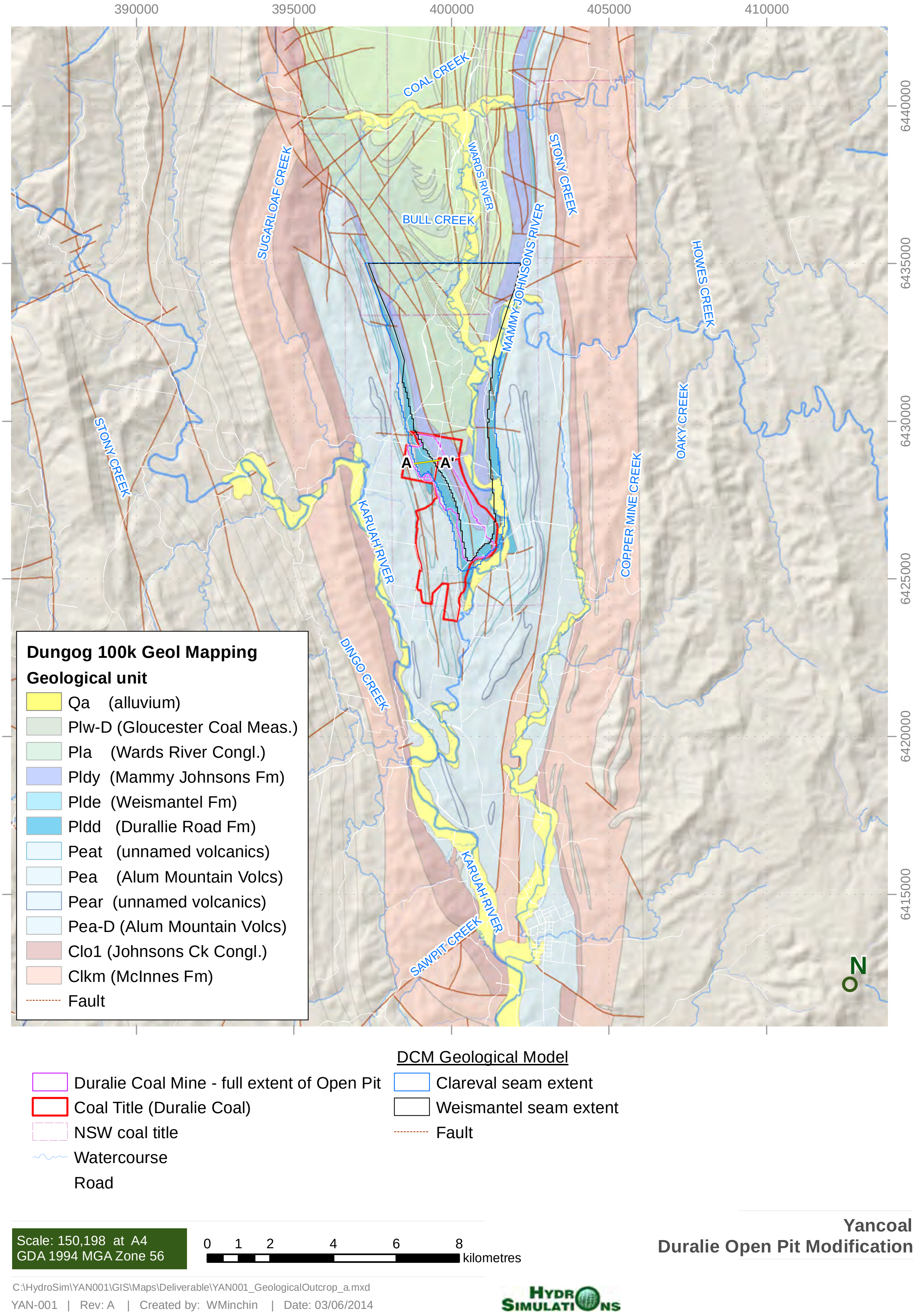
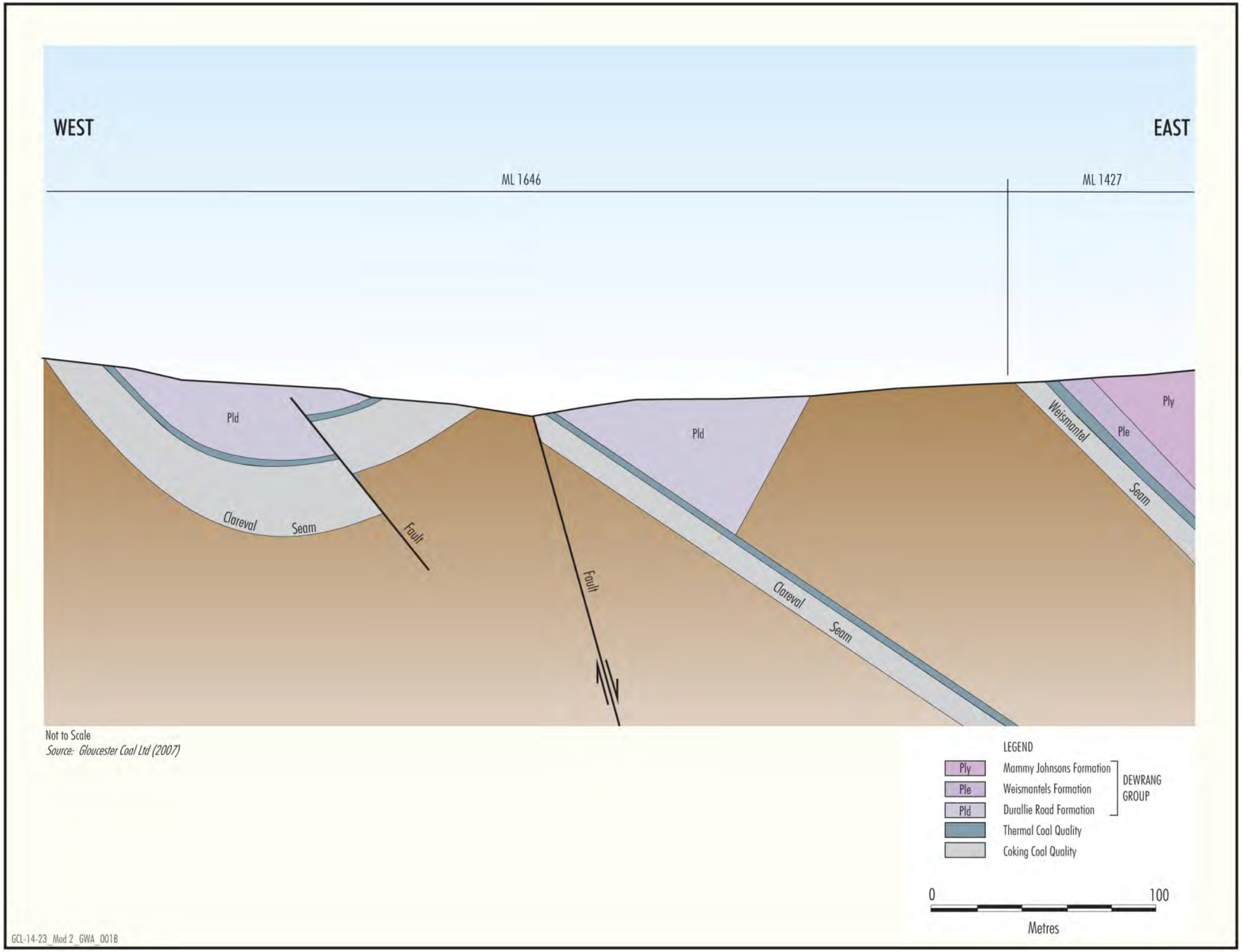


Figure 2-4 Geological Mapping



Not to Scale
Source: Gloucester Coal Ltd (2007)

Figure 2-5 Geological Cross-Section A-A' (through northern part of lease)

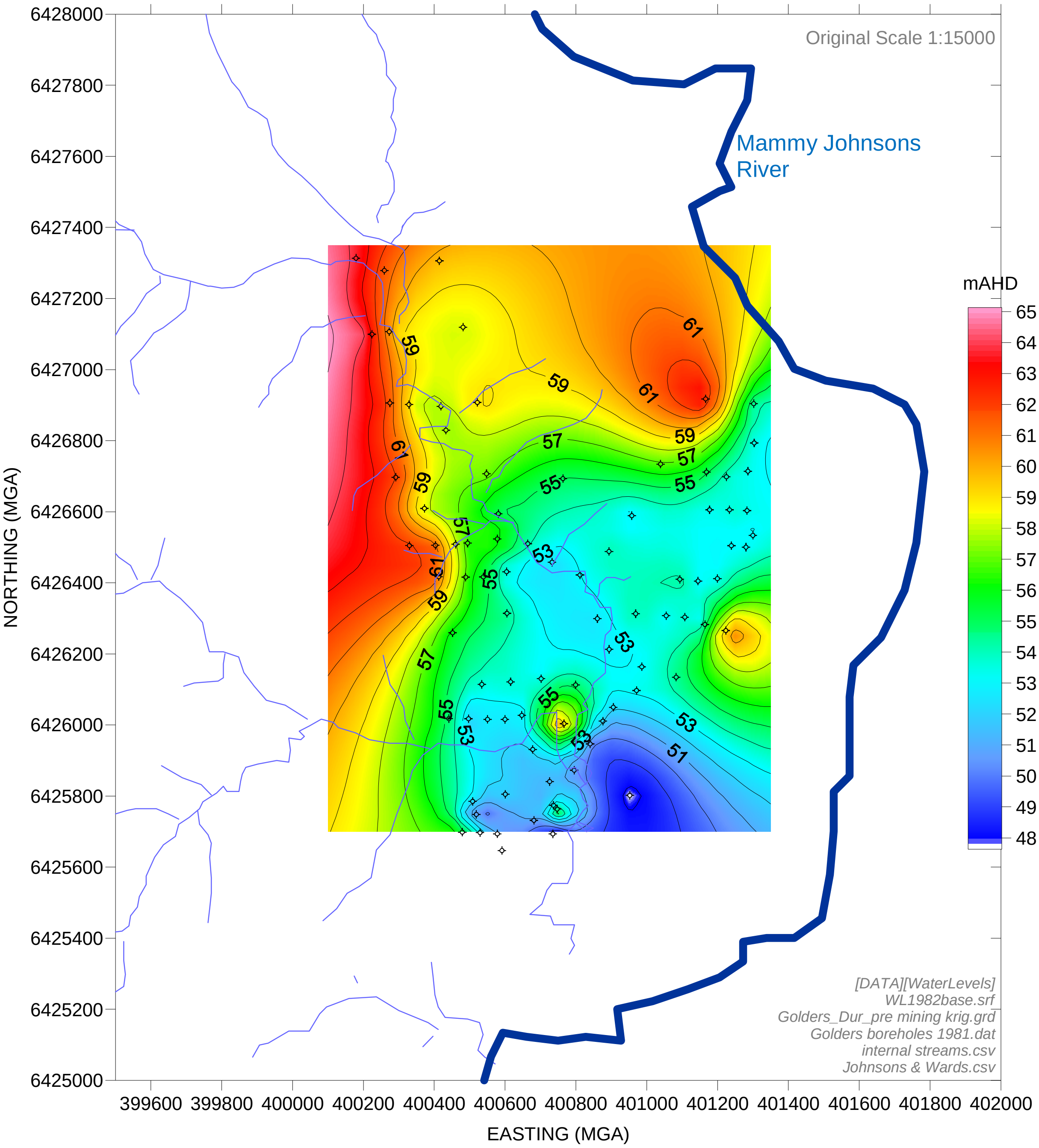
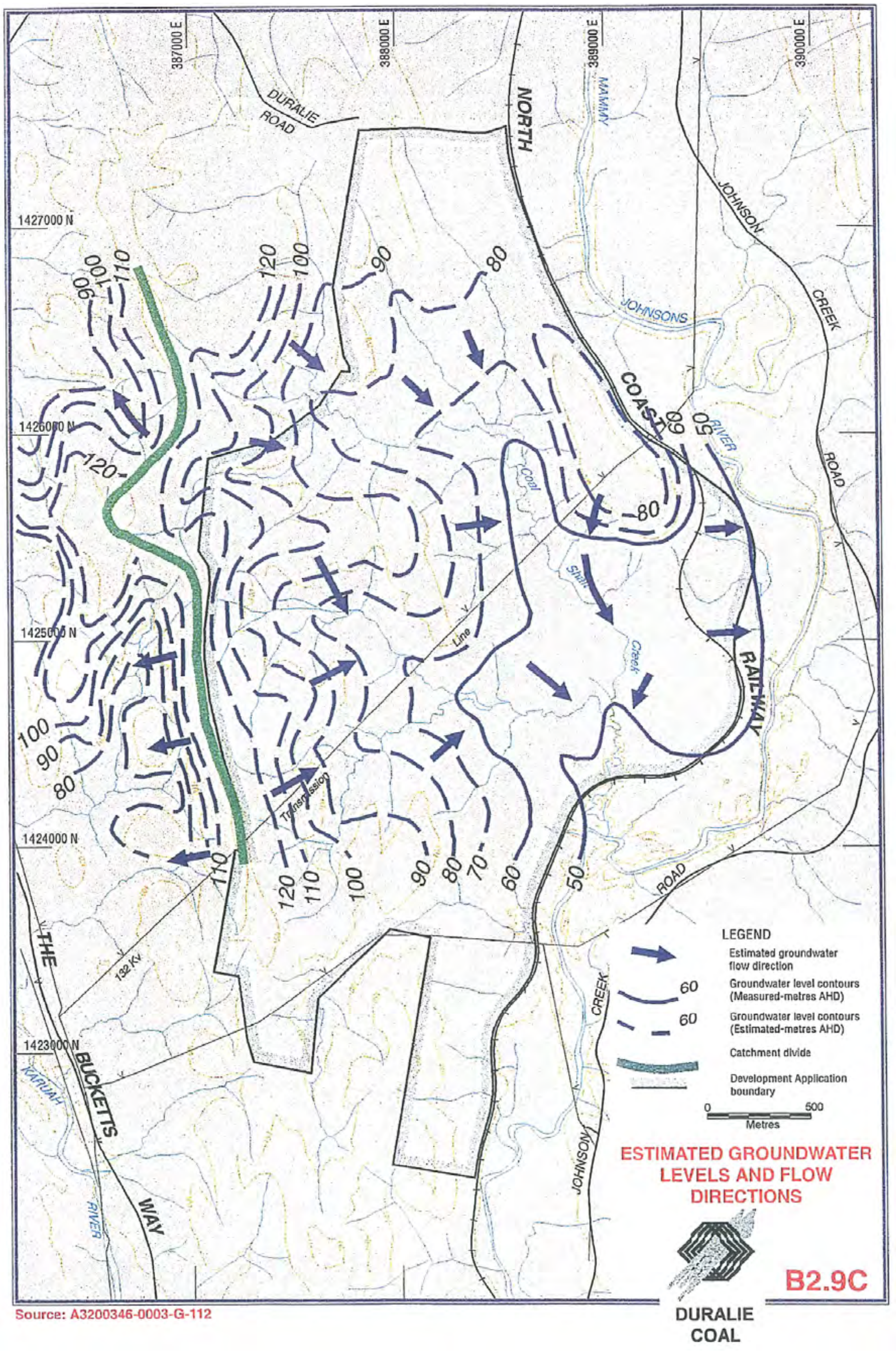


Figure 2-6 Interpreted Pre-Mining Watertable Elevation (mAHD)



Source: A3200346-0003-G-112

Figure 2-7 Inferred Pre-Mining Groundwater Level Contours and Flow Directions [Source: DCPL, 1996]

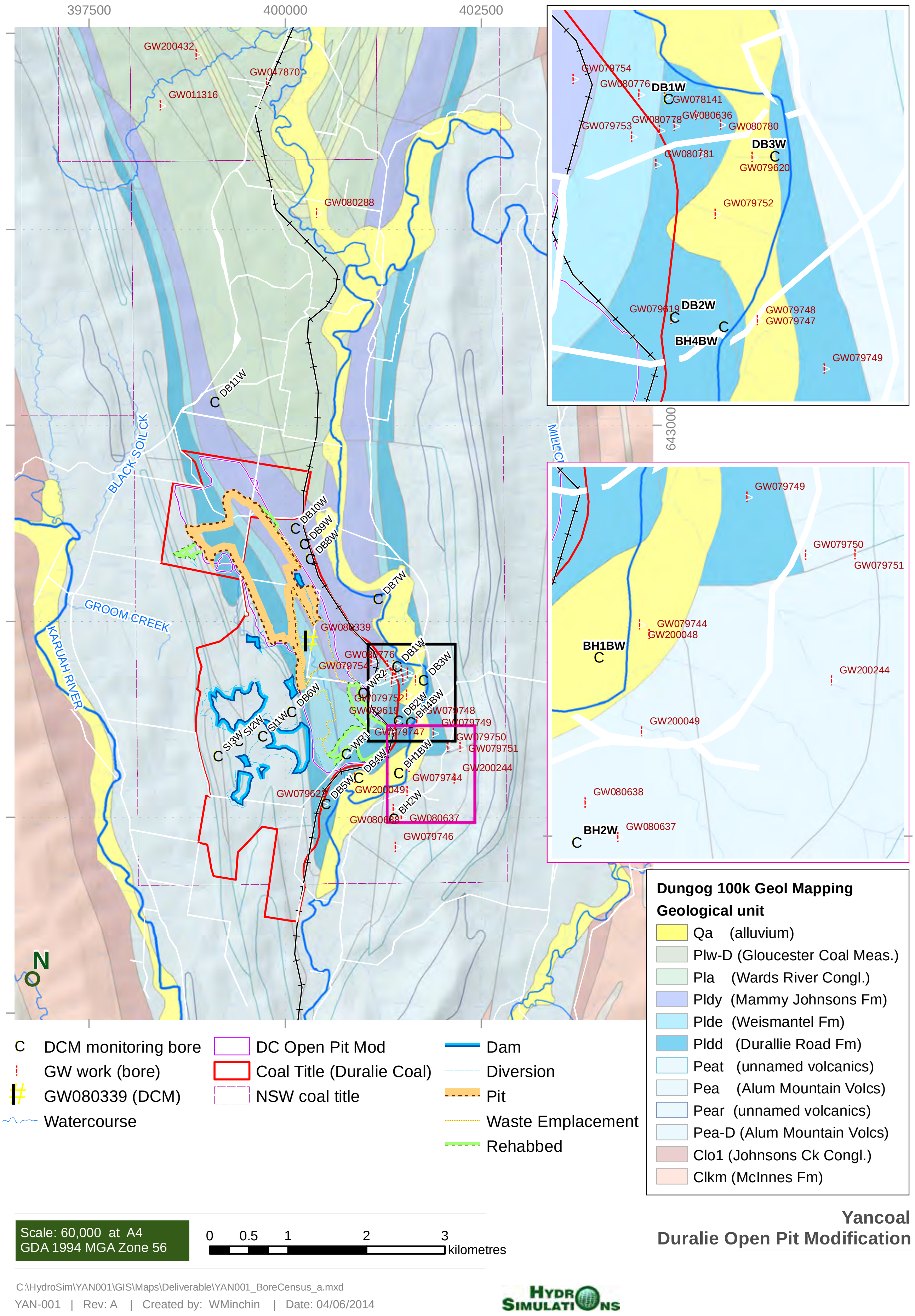


Figure 2-8 Locations of NOW Registered Bores and Groundwater Monitoring Bores

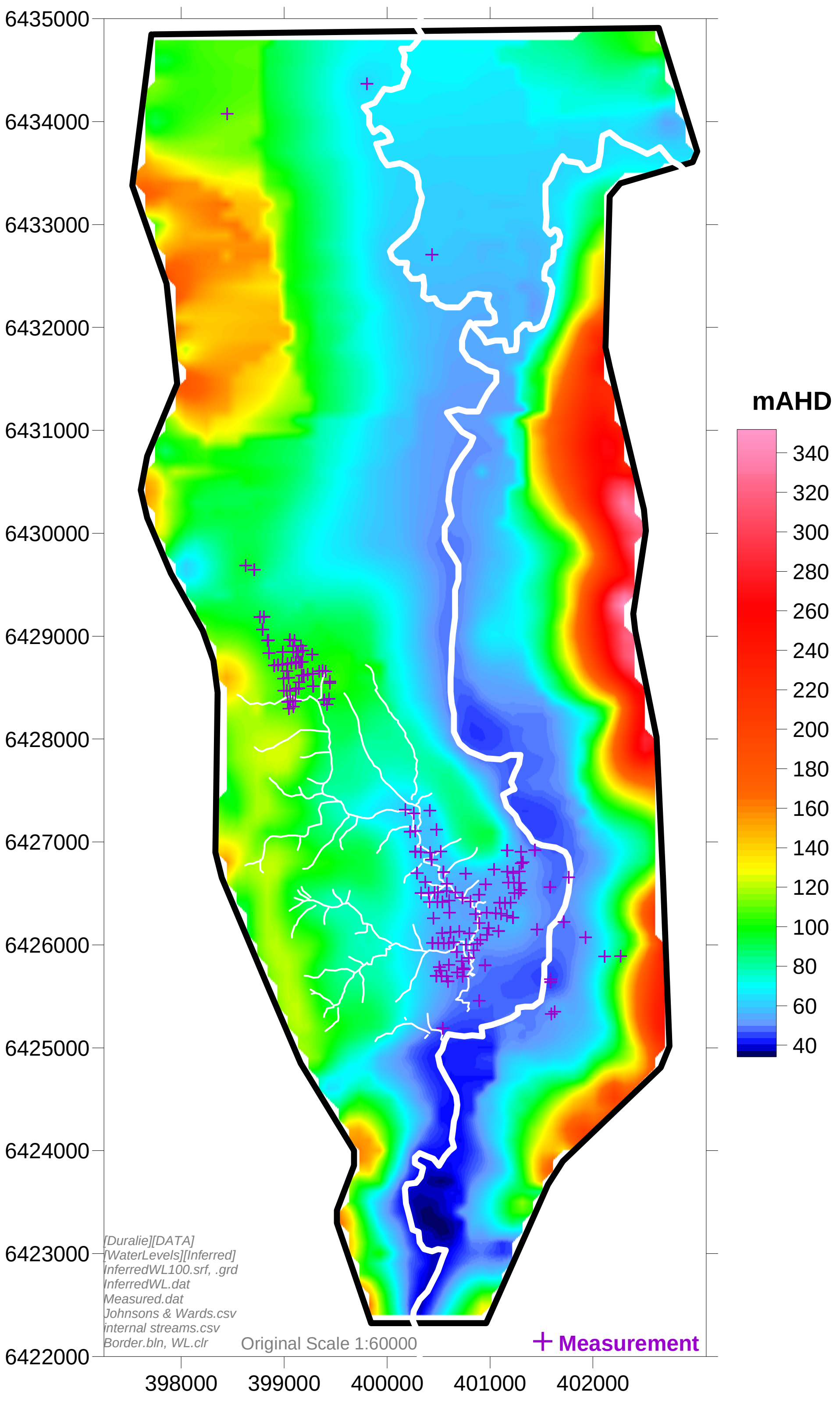
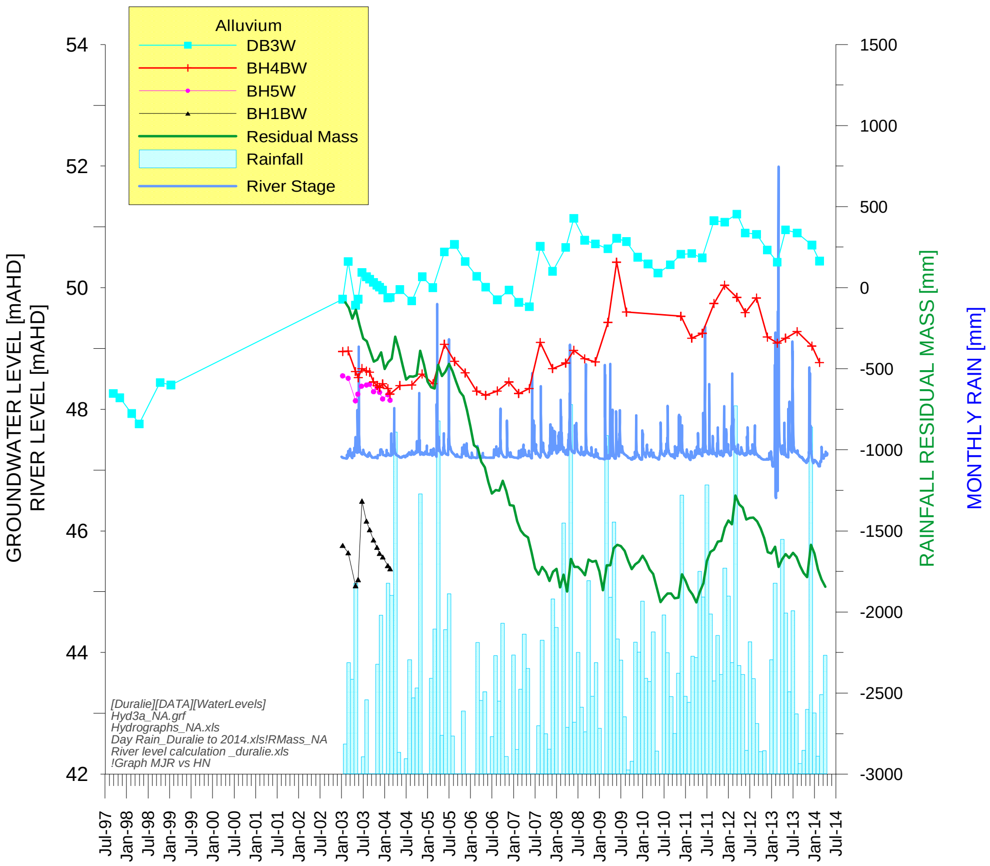


Figure 2-9 Inferred Pre-Mining Groundwater Level Contours (mAHD) for the Entire Model Extent



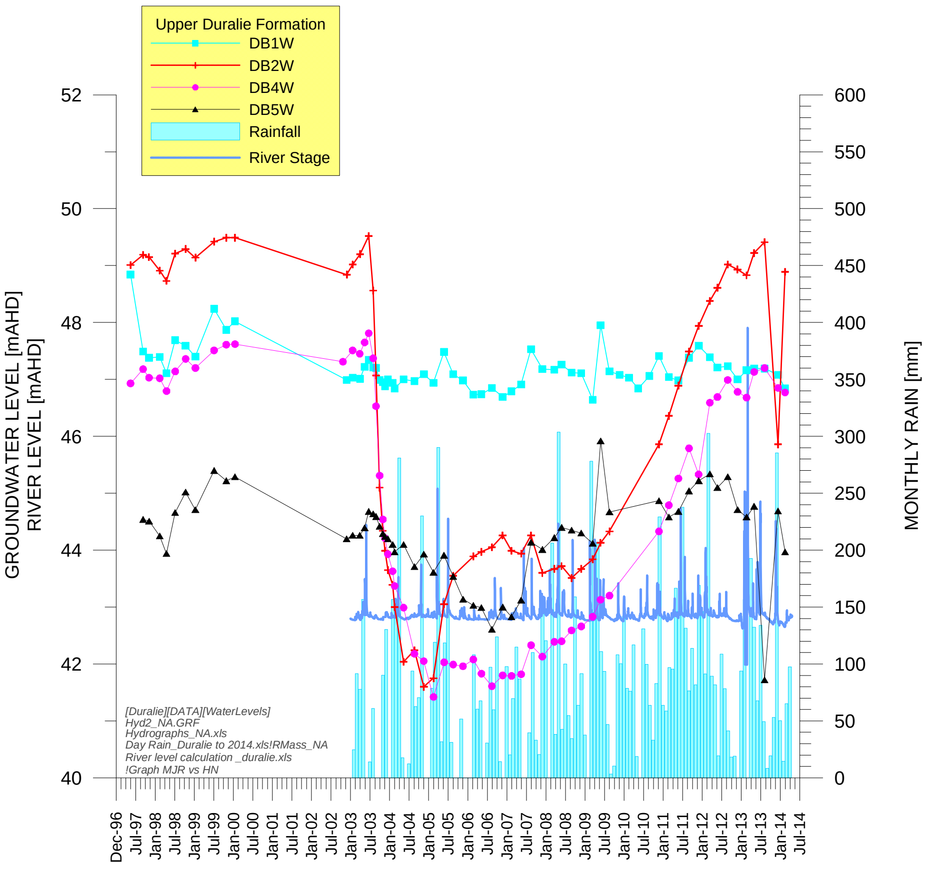


Figure 2-10 Groundwater Level Responses within the Alluvium near Duralie Coal Mine

Figure 2-11 Groundwater Level Responses for the Upper Durallie Road Formation

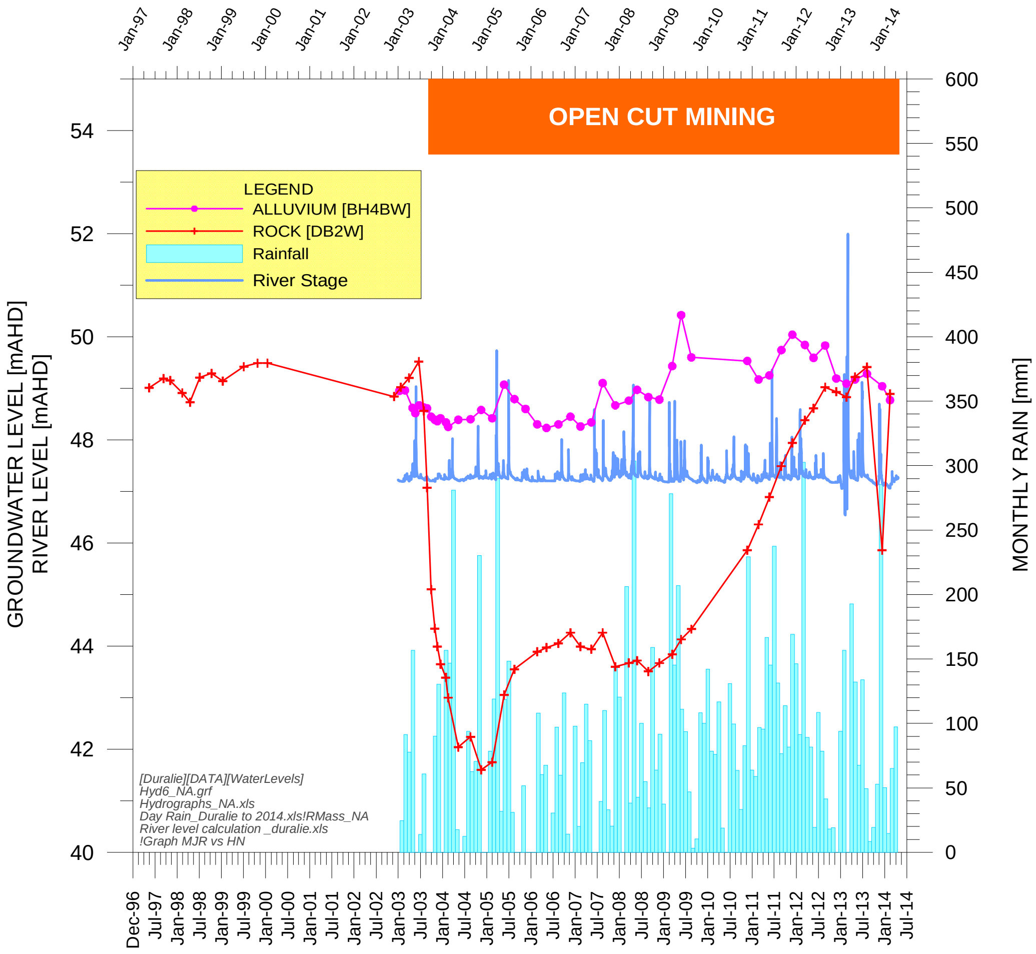


Figure 2-12 Groundwater Level Responses for the Alluvium and Upper Duralie Road Formation

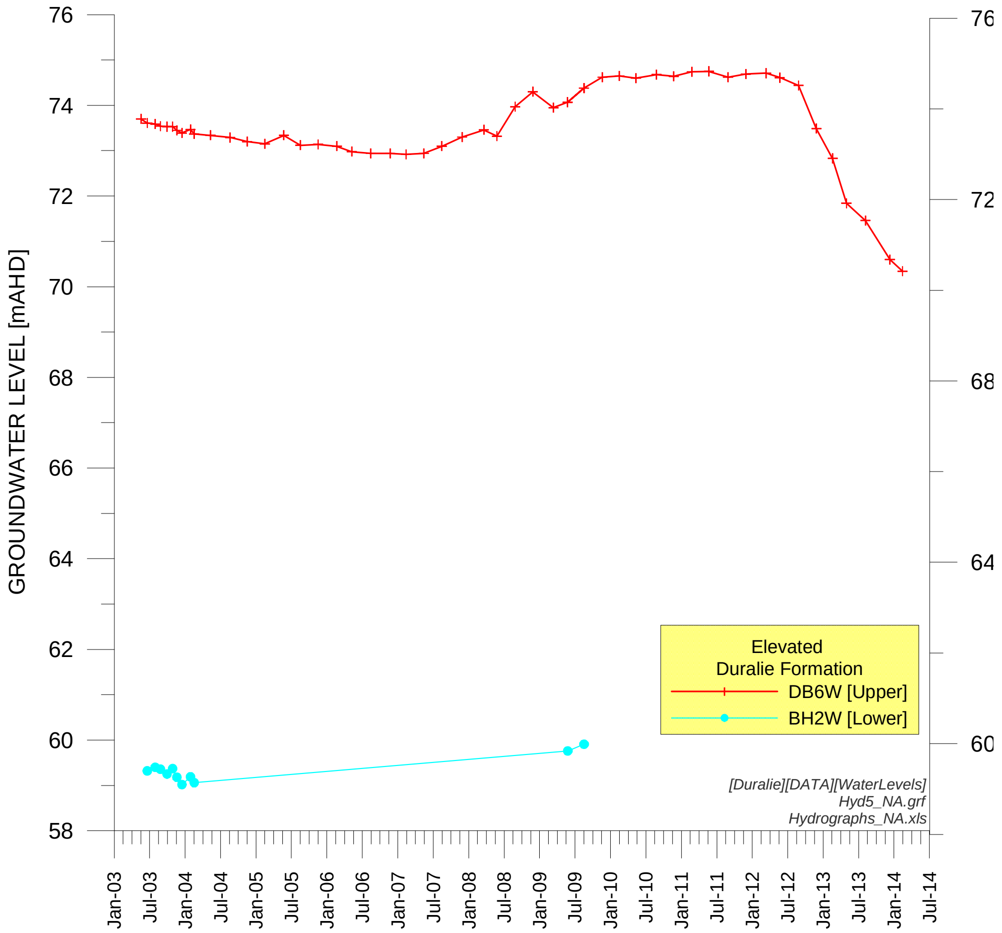


Figure 2-13 Groundwater Level Responses with the Durallie Road Formation on Elevated Land

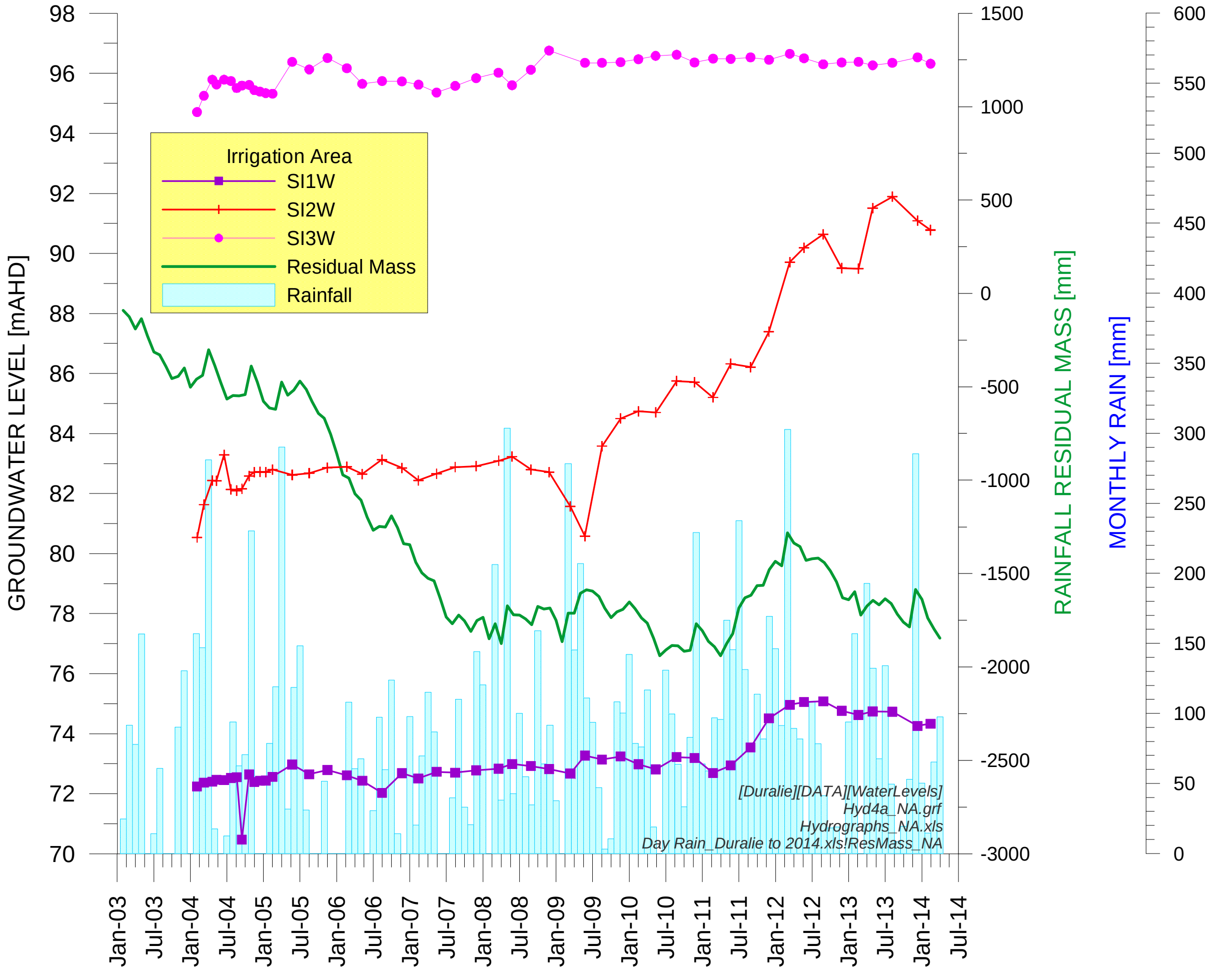


Figure 2-14 Groundwater Level Responses at the Type II Irrigation Area

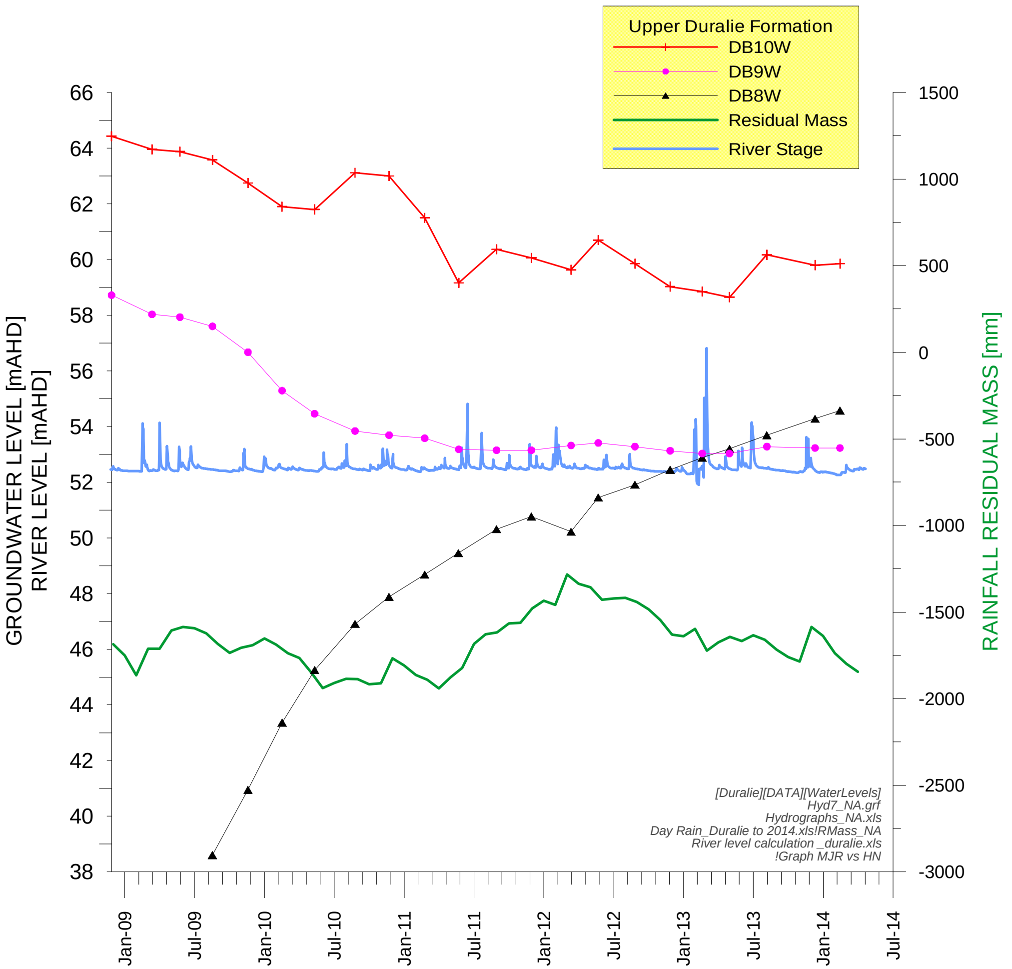


Figure 2-15 Groundwater Level Responses within the Durallie Road Formation to the East of the DCM

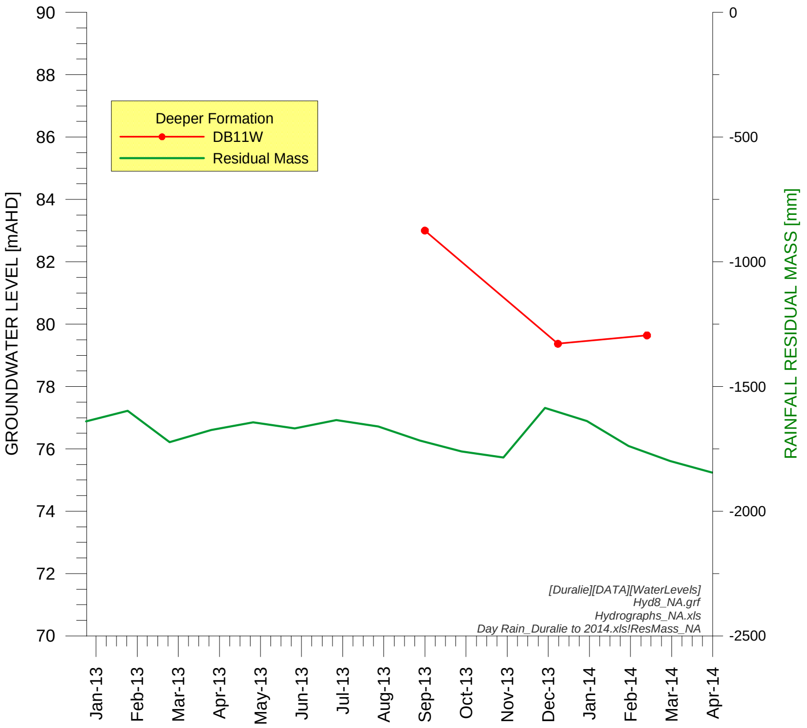
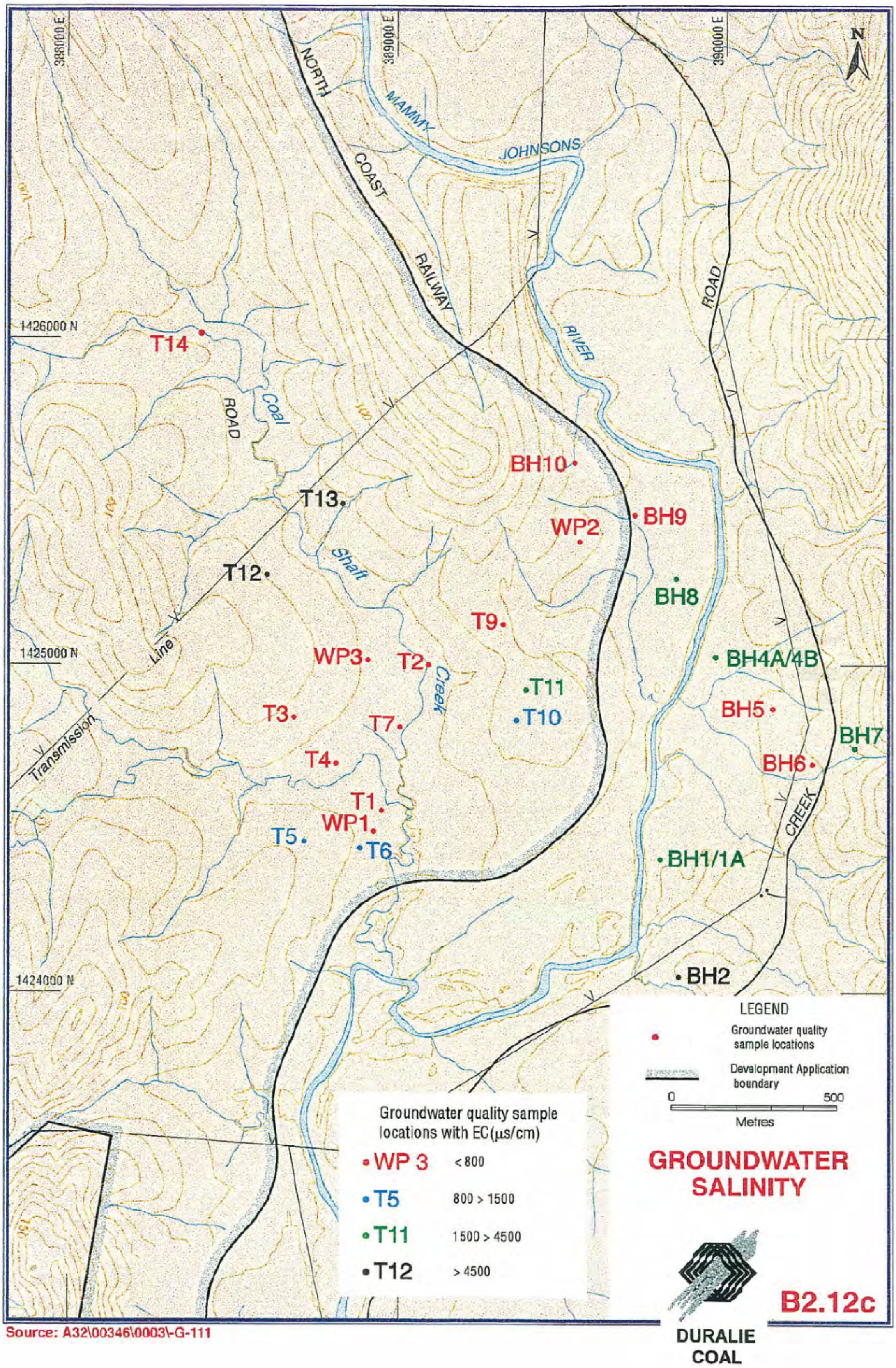


Figure 2-16 Groundwater Level Responses within the Lower Durallie Road Formation to the North of the DCM



Source: A32\00346\0003\-G-111

Figure 2-17 Historic Spatial Distribution for Salinity [EC, uS/cm]

3 HYDROGEOLOGICAL CONCEPTUAL MODEL

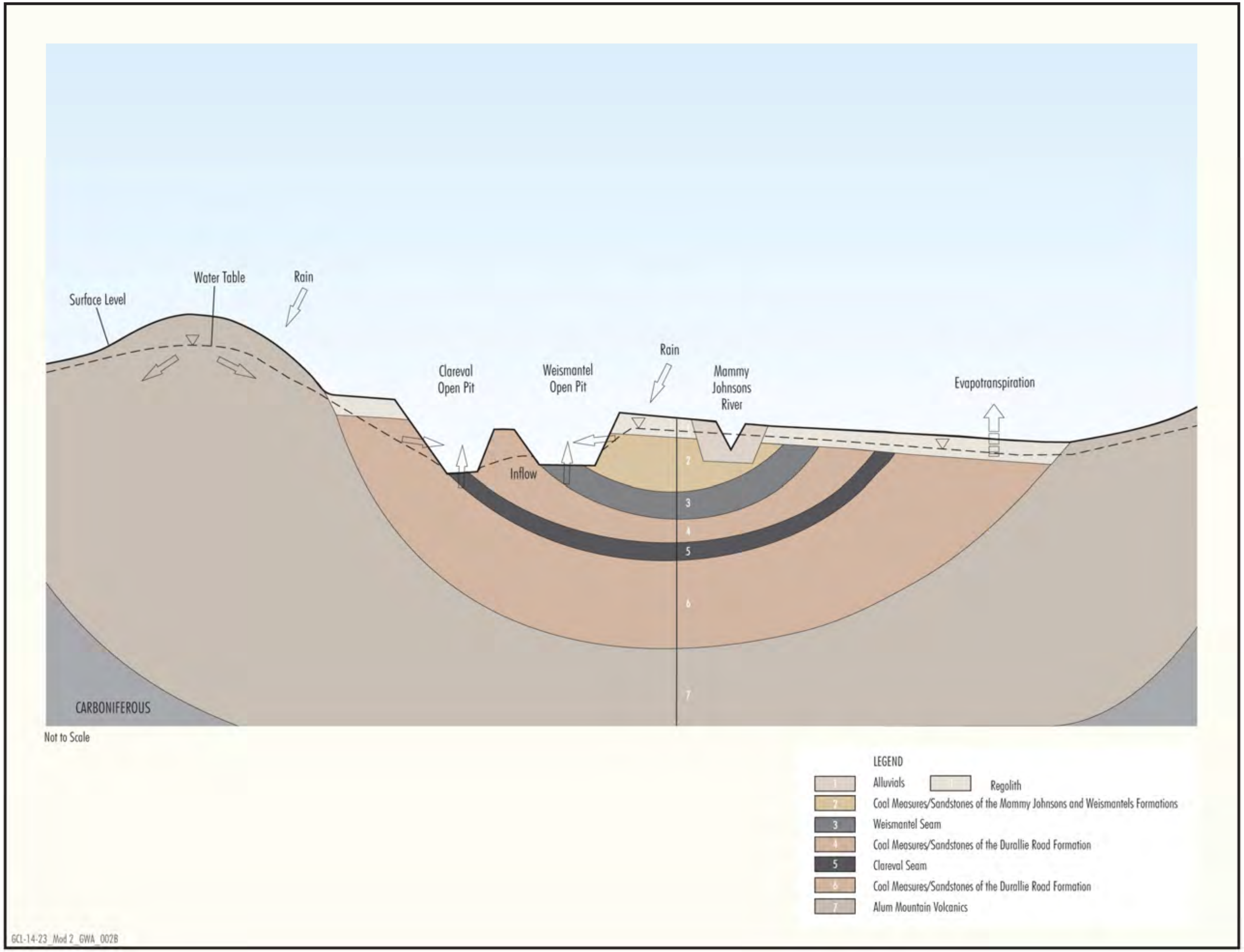


Figure 3-1 Hydrogeological Conceptual Model – South

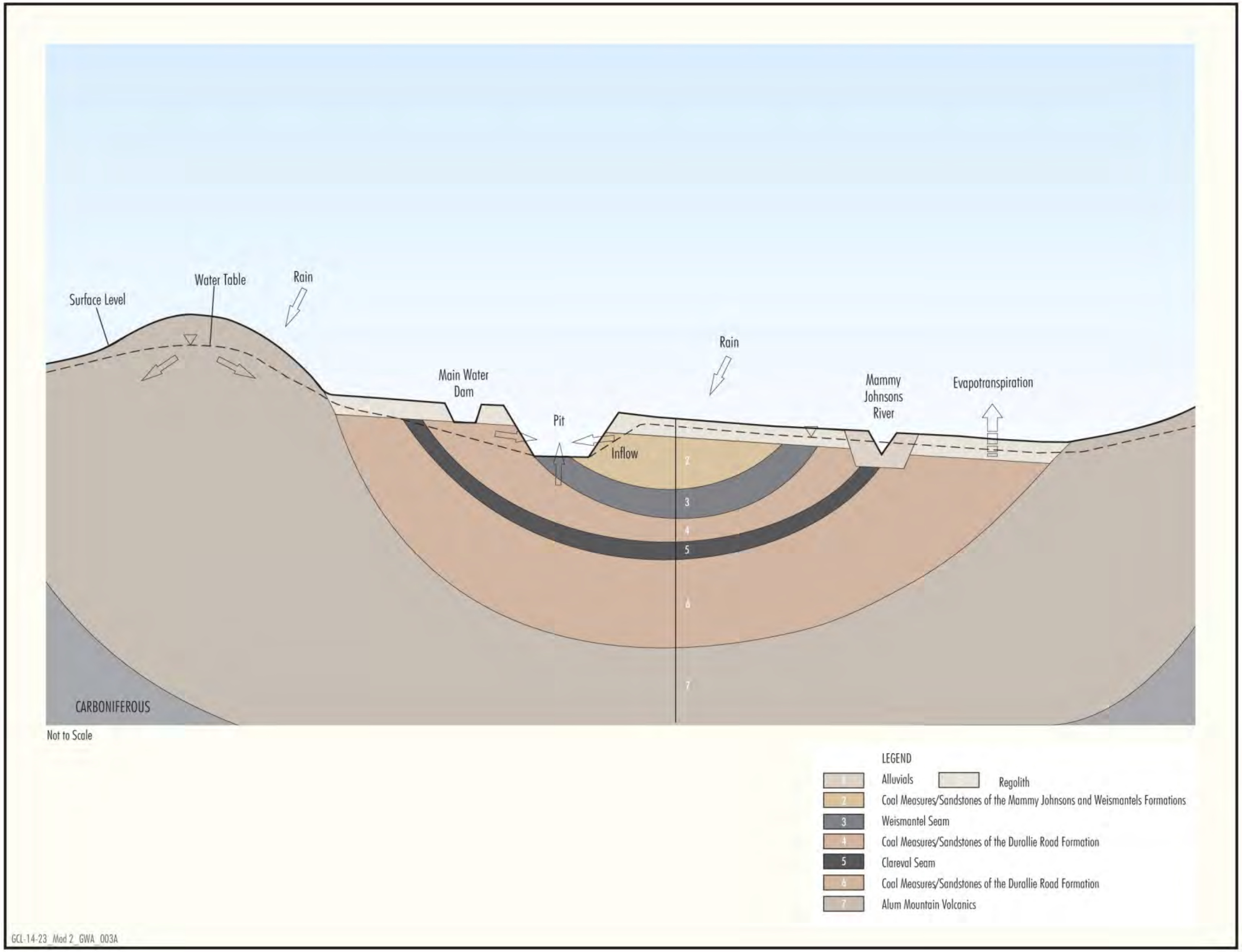
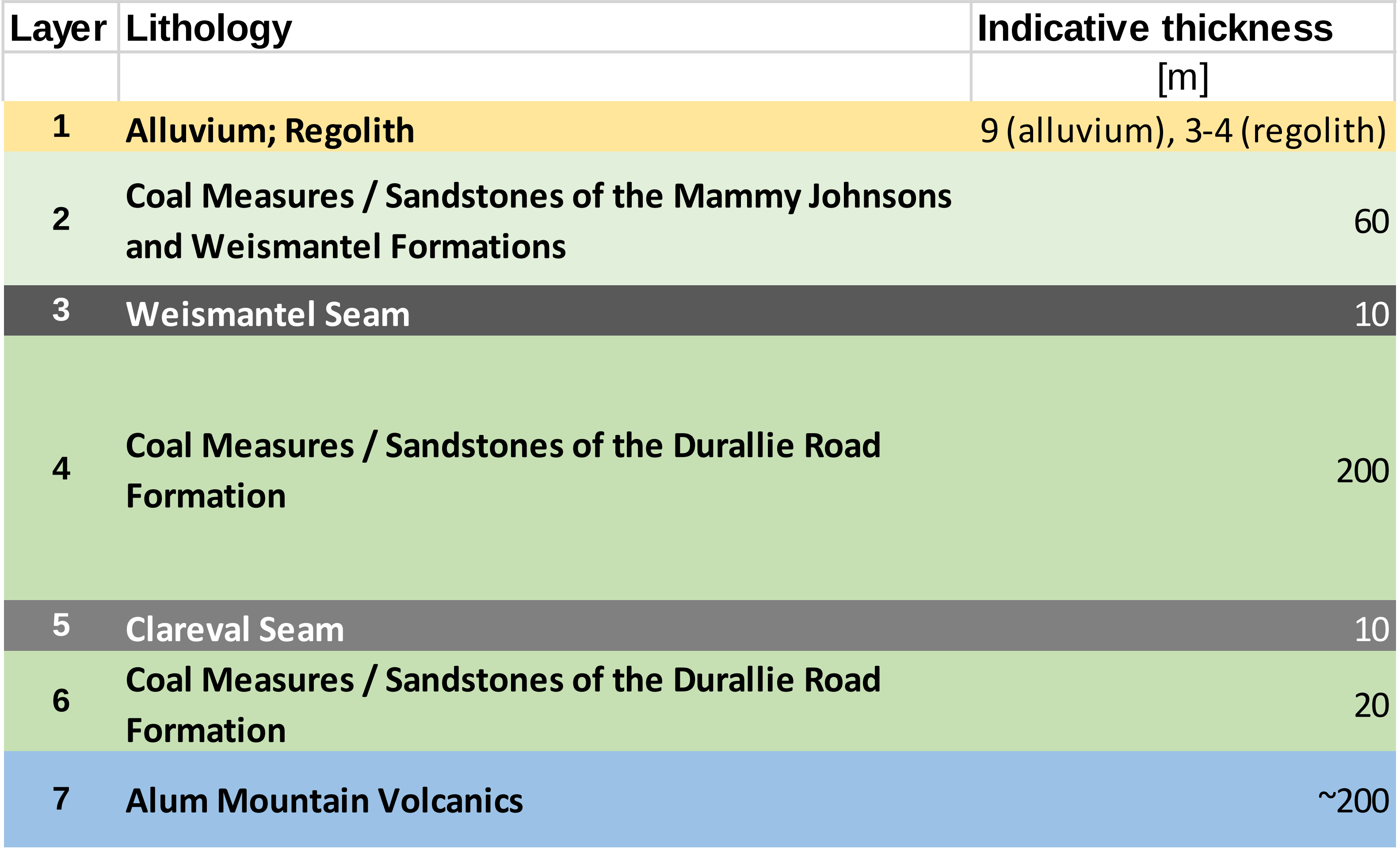


Figure 3-2 Hydrogeological Conceptual Model – North



Layer	Lithology	Indicative thickness [m]
1	Alluvium; Regolith	9 (alluvium), 3-4 (regolith)
2	Coal Measures / Sandstones of the Mammy Johnsons and Weismantel Formations	60
3	Weismantel Seam	10
4	Coal Measures / Sandstones of the Durallie Road Formation	200
5	Clareval Seam	10
6	Coal Measures / Sandstones of the Durallie Road Formation	20
7	Alum Mountain Volcanics	~200

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Figure 3-3 Numerical Model Layers

4 GROUNDWATER SIMULATION MODEL

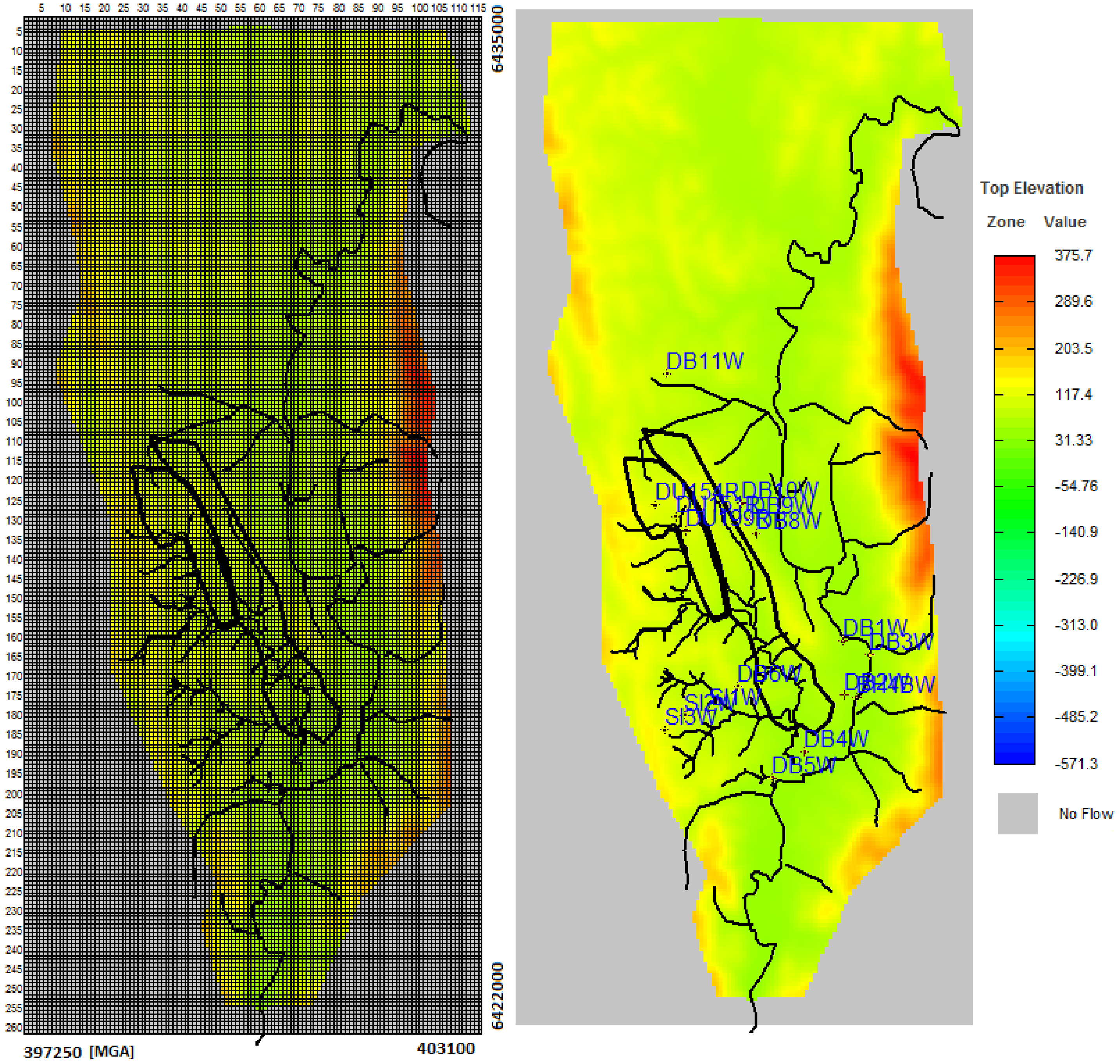
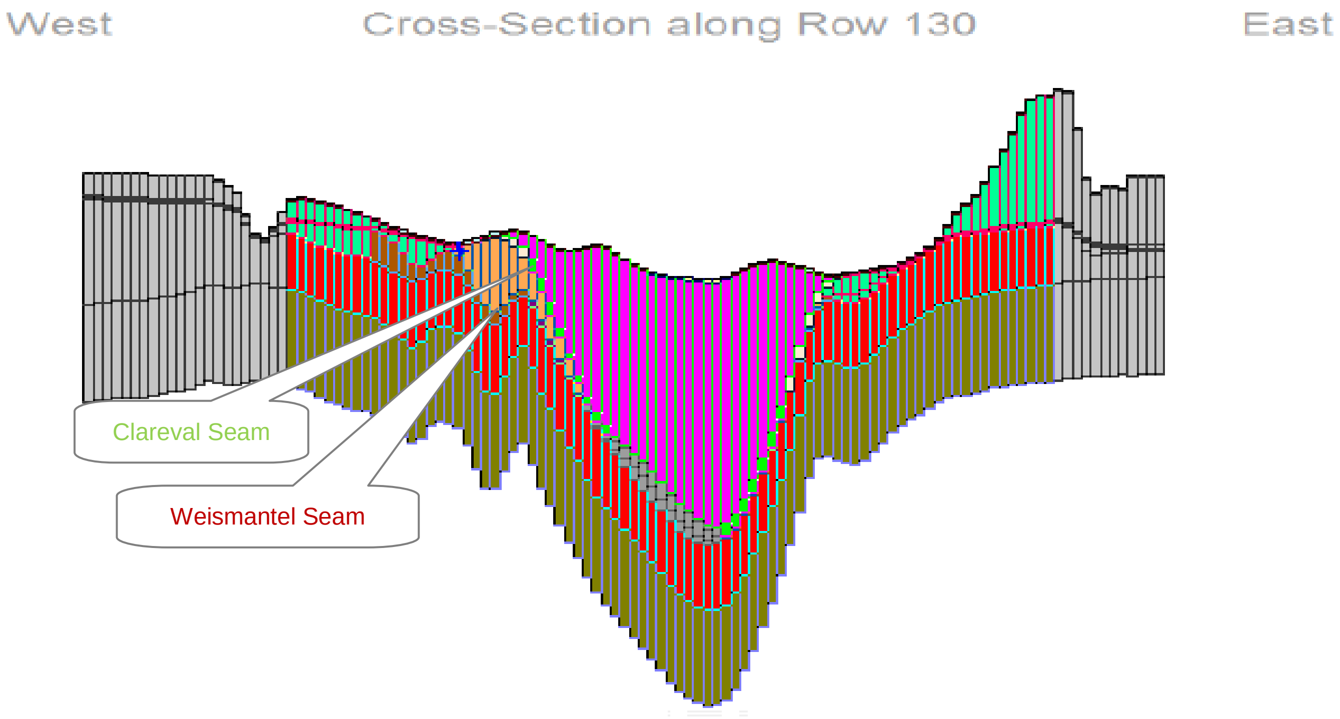


Figure 4-1 Groundwater Model Extent, Surface topography, Drainage Network and Mine Outline



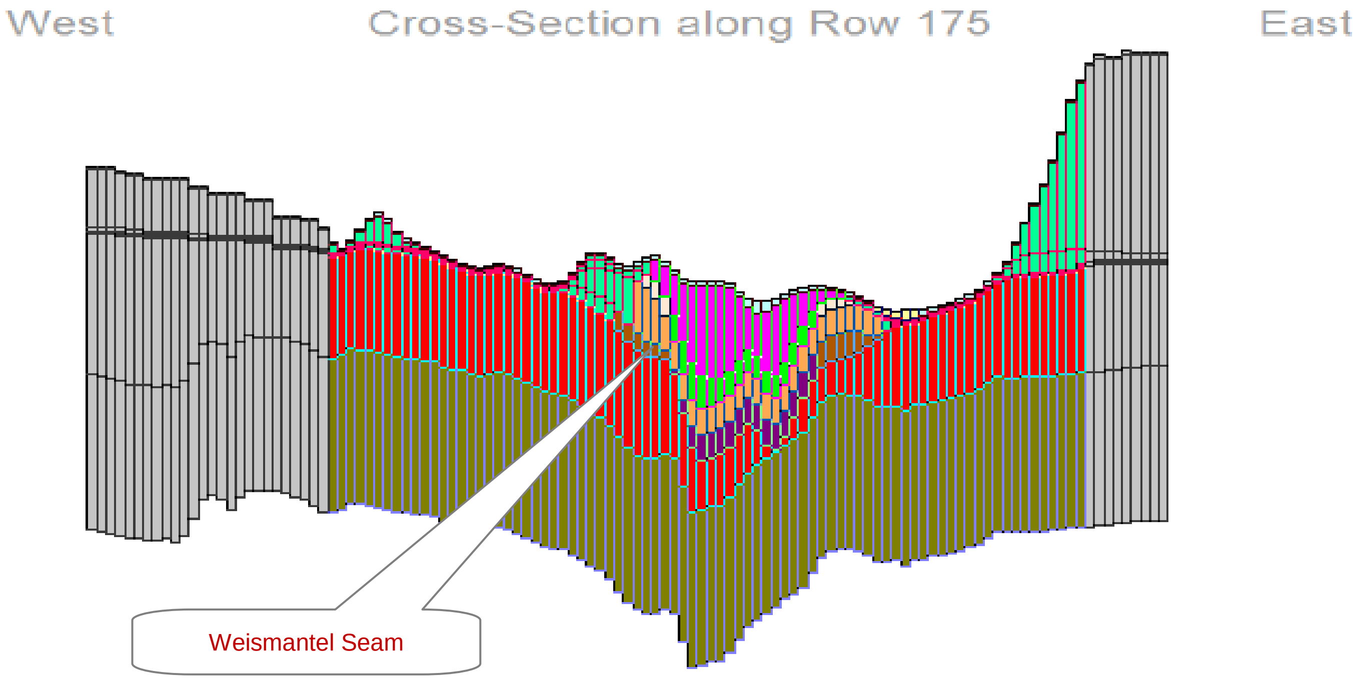


Figure 4-2 Representative Model Cross-Sections through Clareval pit (along Row 130) and through early Weismantel pit (along Row 175)

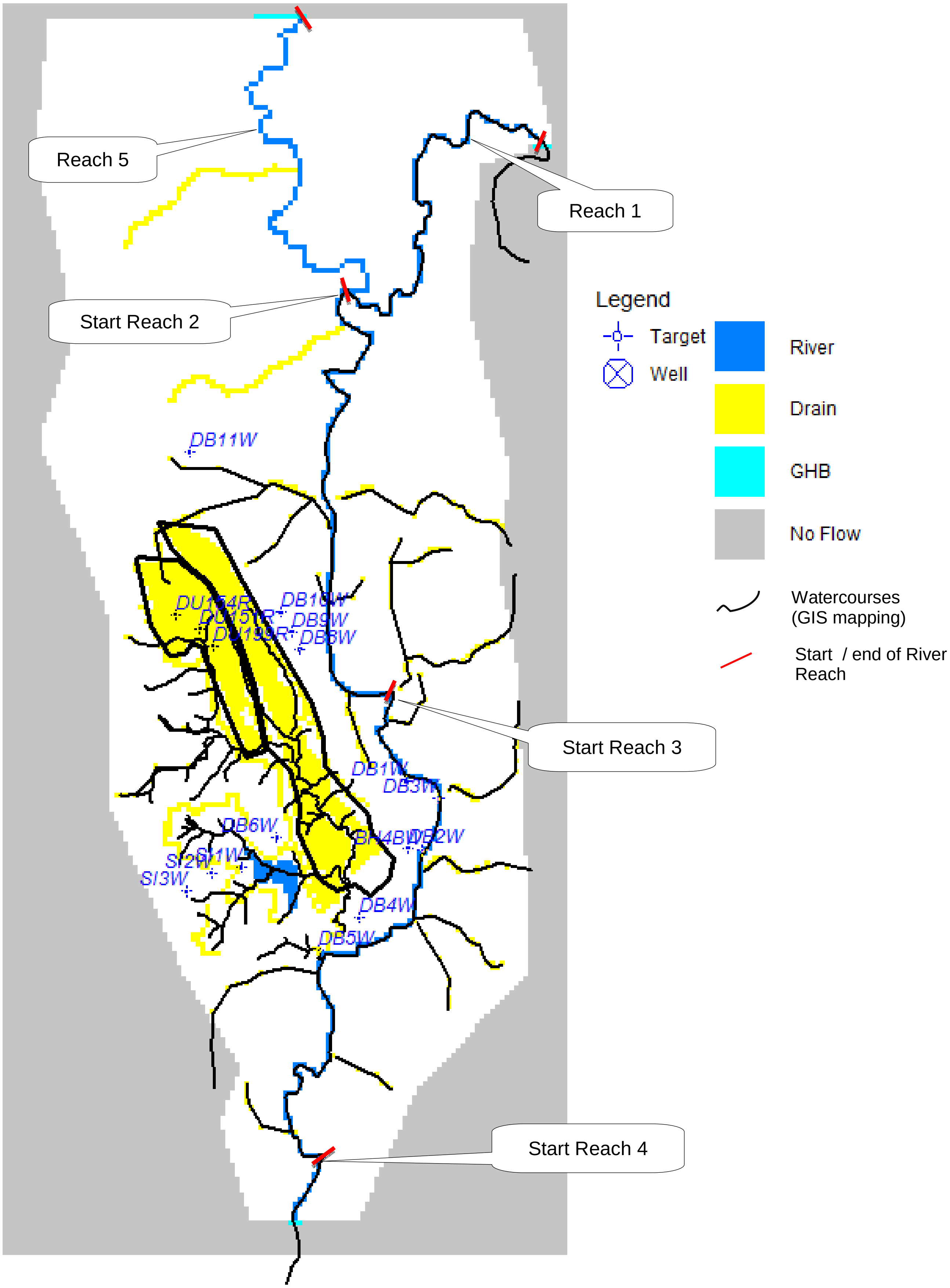


Figure 4-3 Boundary Conditions Applied to Model Layer 1

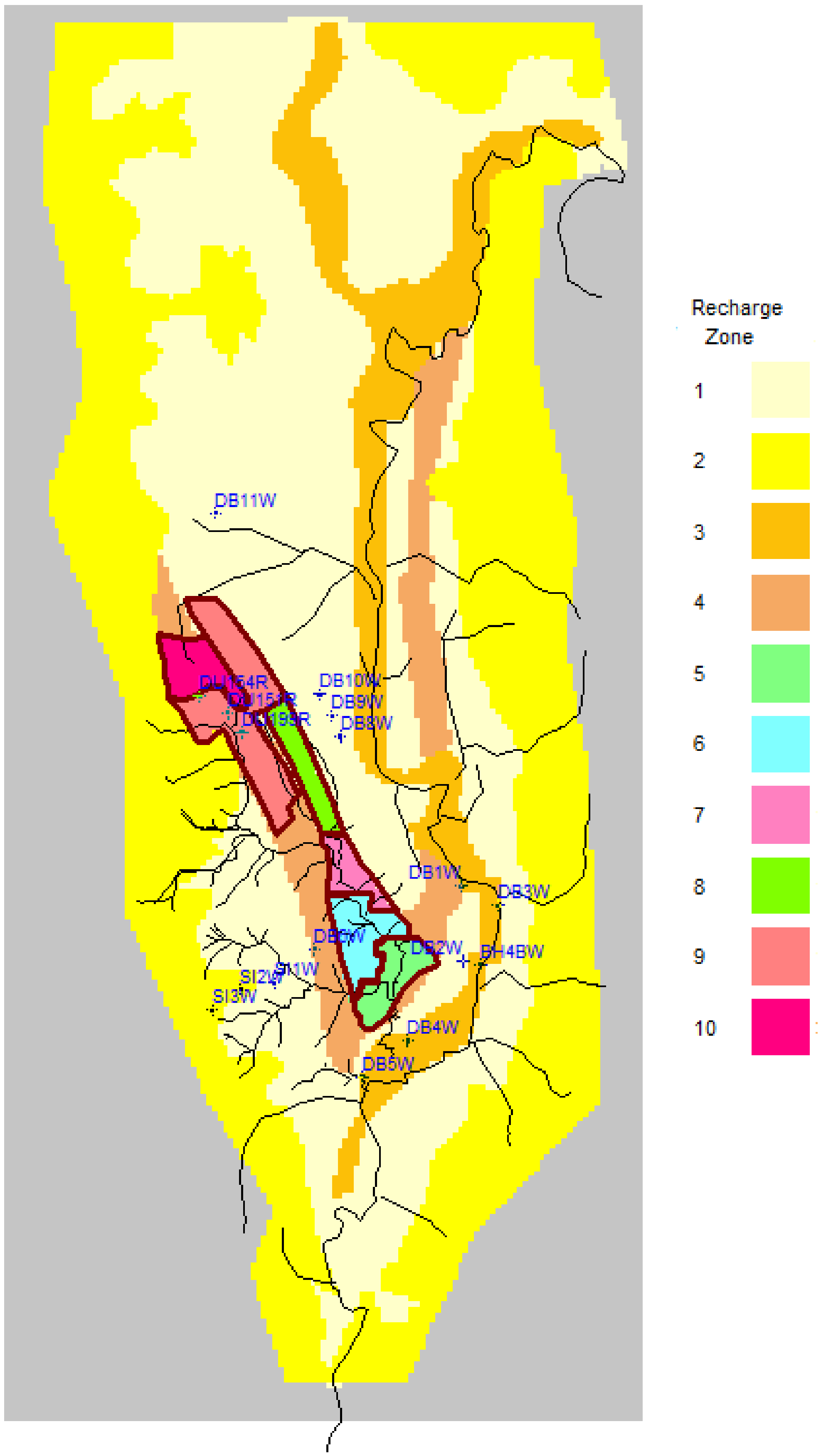


Figure 4-4 Rainfall Recharge Zones

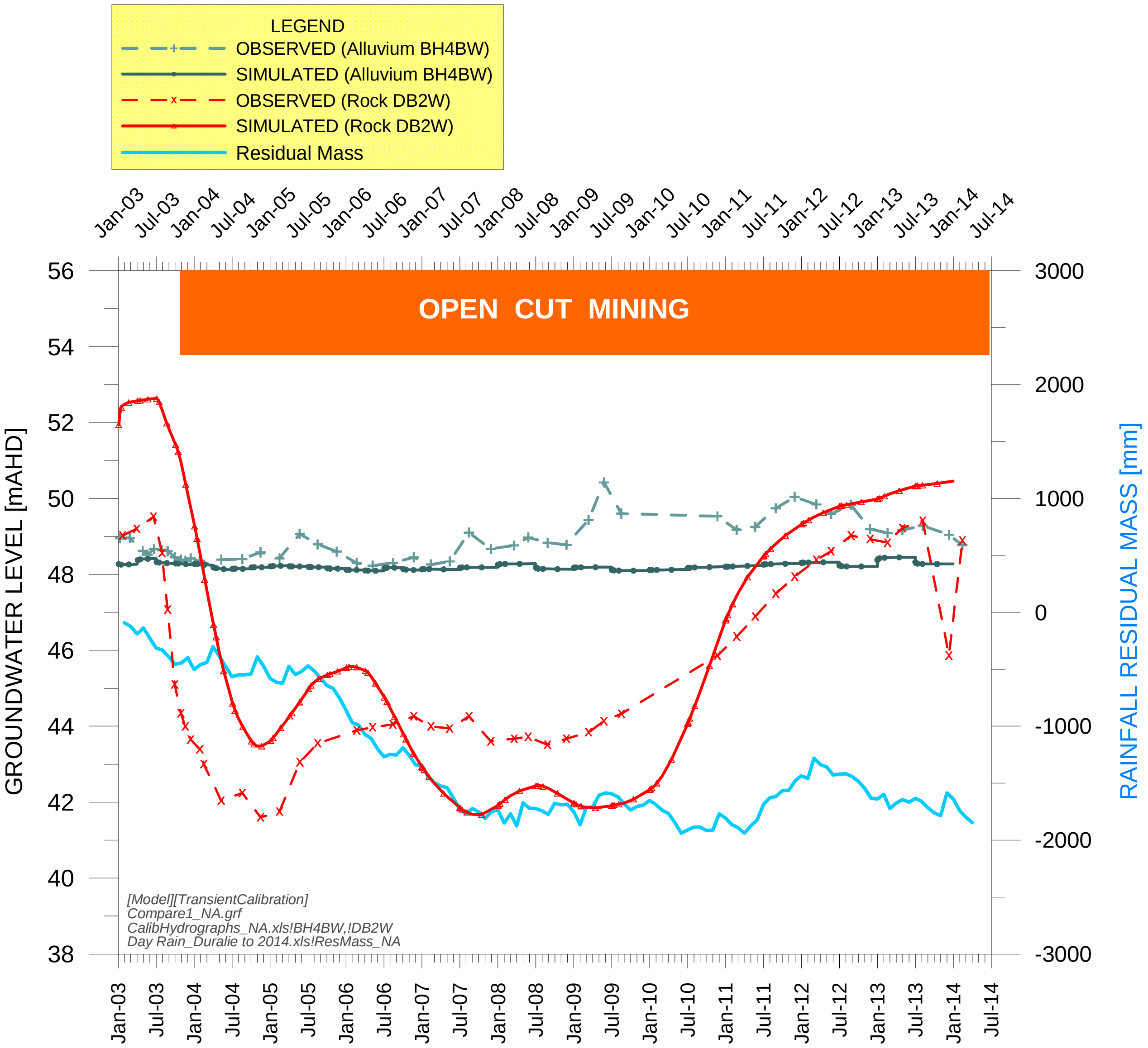


Figure 4-5 Comparison of Simulated and Observed Hydrographs in Alluvium (BH4BW) and Upper Durallie Road Formation (DB2W)

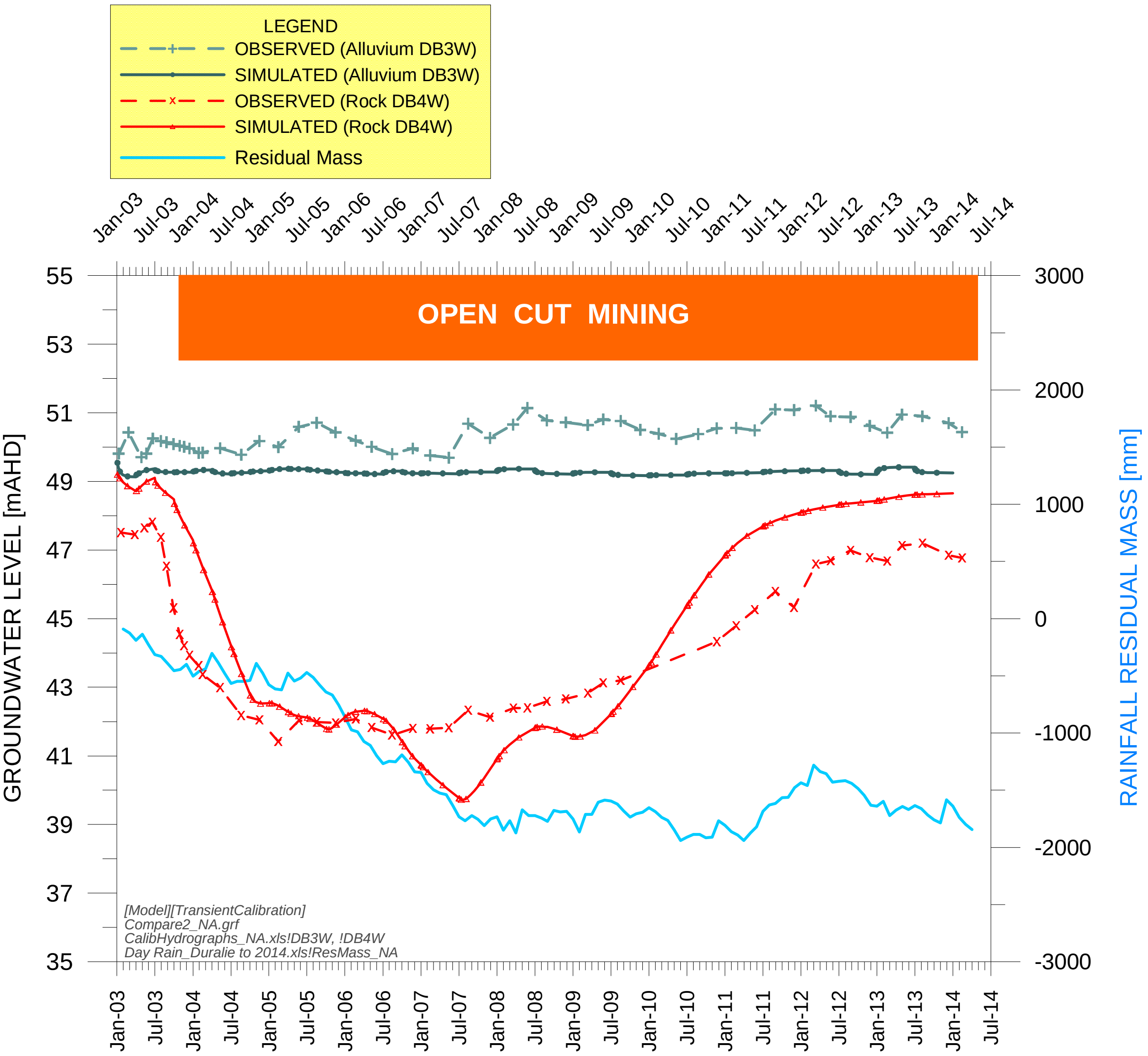


Figure 4-6 Comparison of Simulated and Observed Hydrographs in Alluvium (DB3W) and Upper Duralie Road Formation (DB4W)

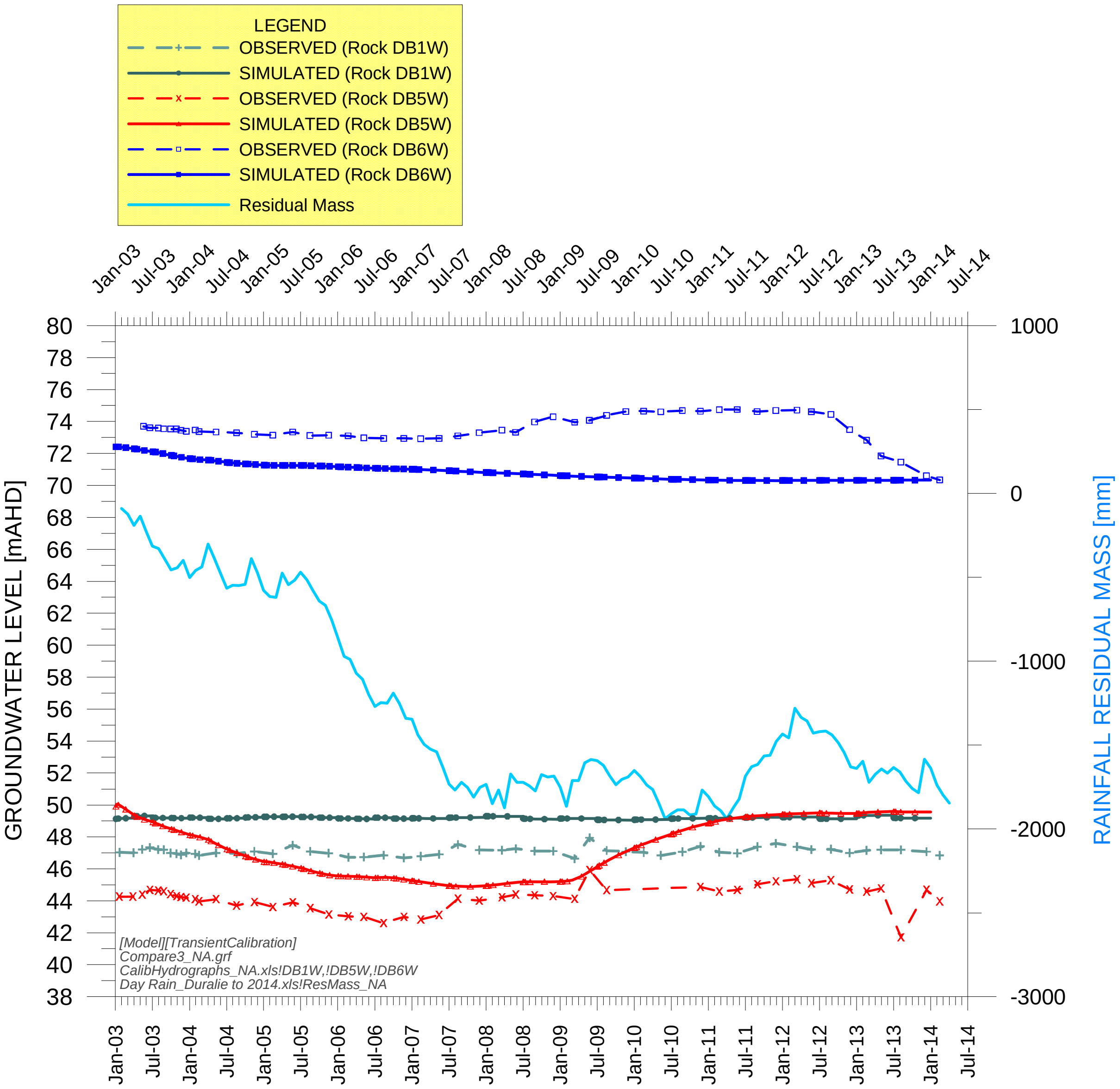


Figure 4-7 **Comparison of Simulated and Observed Hydrographs in Upper Durallie Road Formation (DB1W, DB5W, DB6W)**

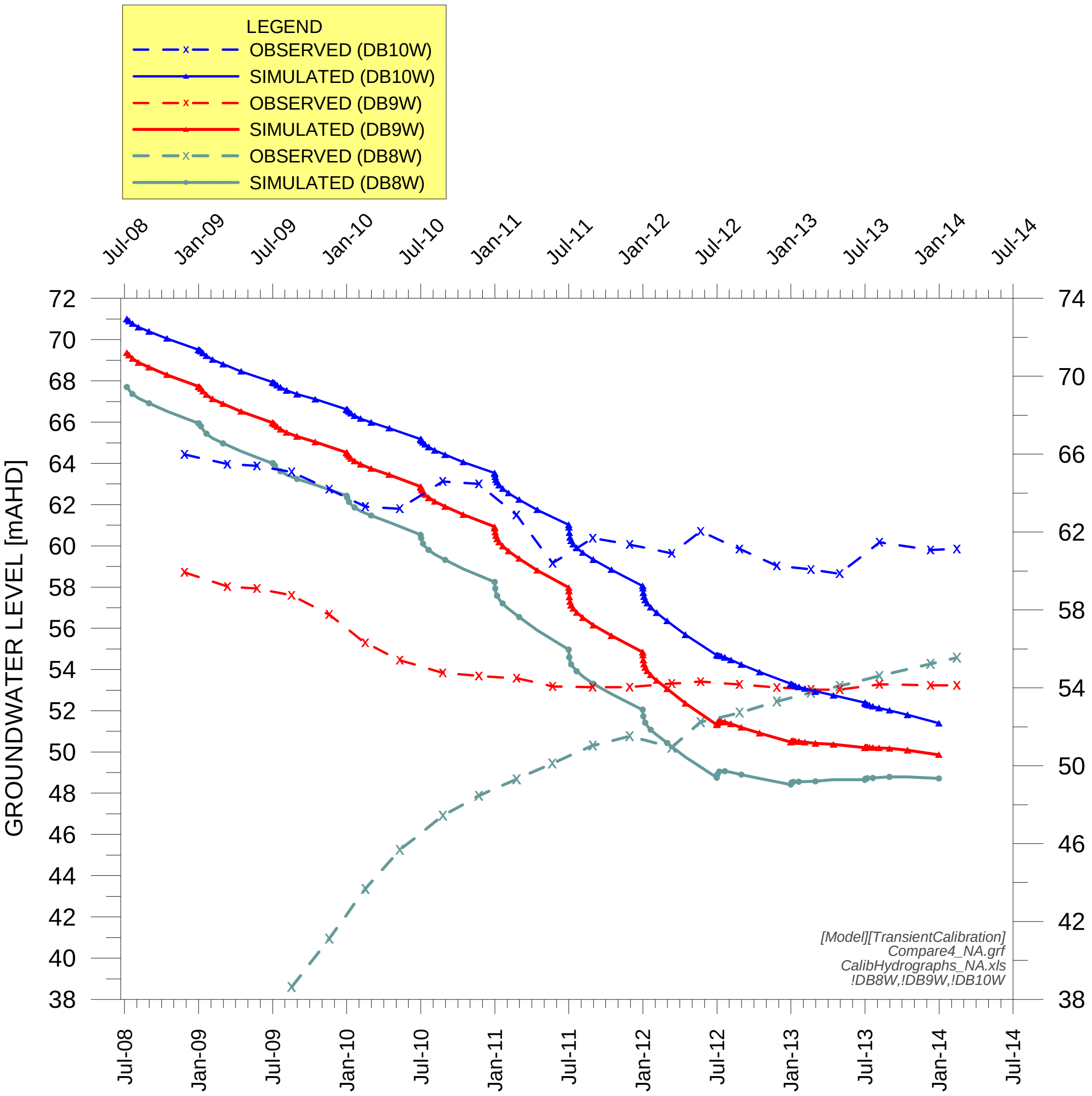


Figure 4-8 Comparison of Simulated and Observed Hydrographs in Upper Durallie Road Formation (DB8W, DB9W, DB10W)

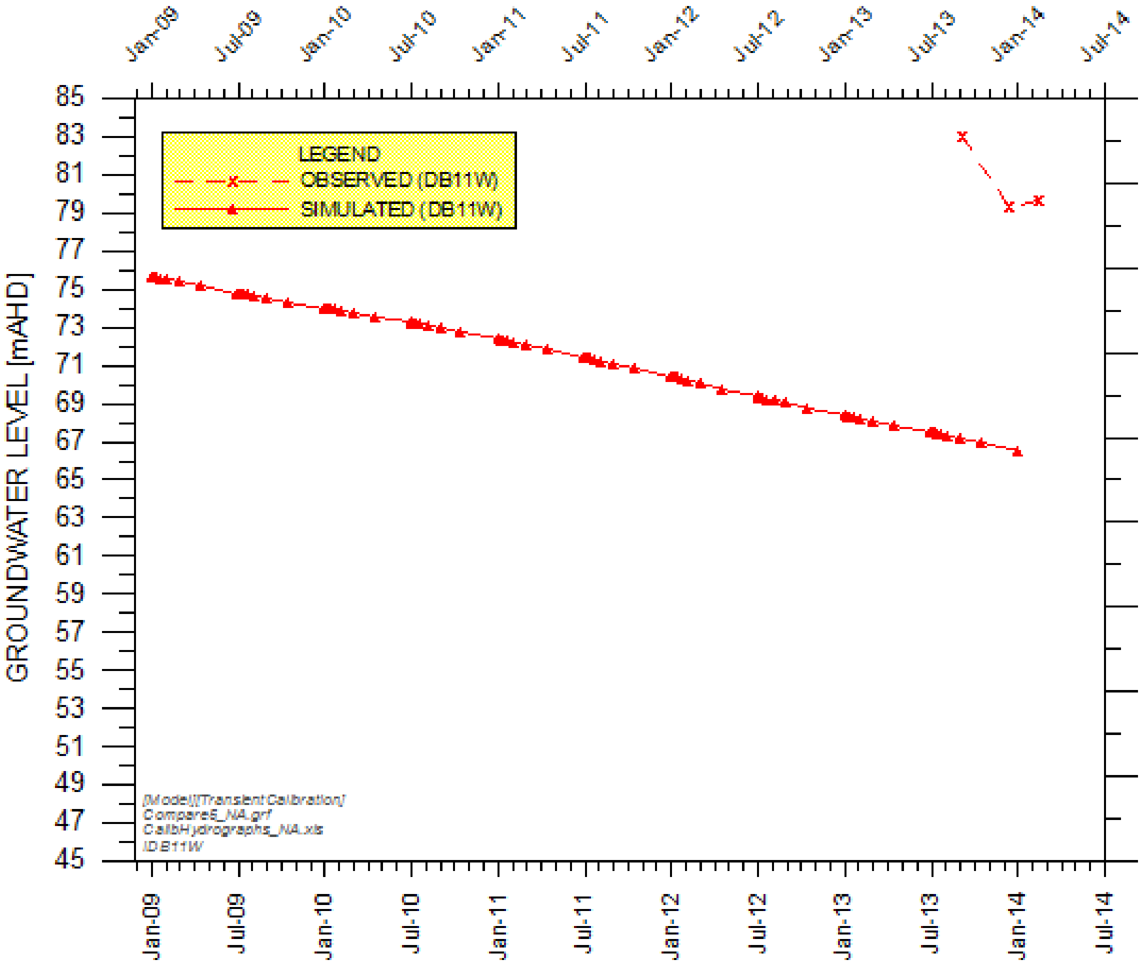


Figure 4-9 Comparison of Simulated and Observed Hydrographs in Upper Durallie Road Formation (DB11W)

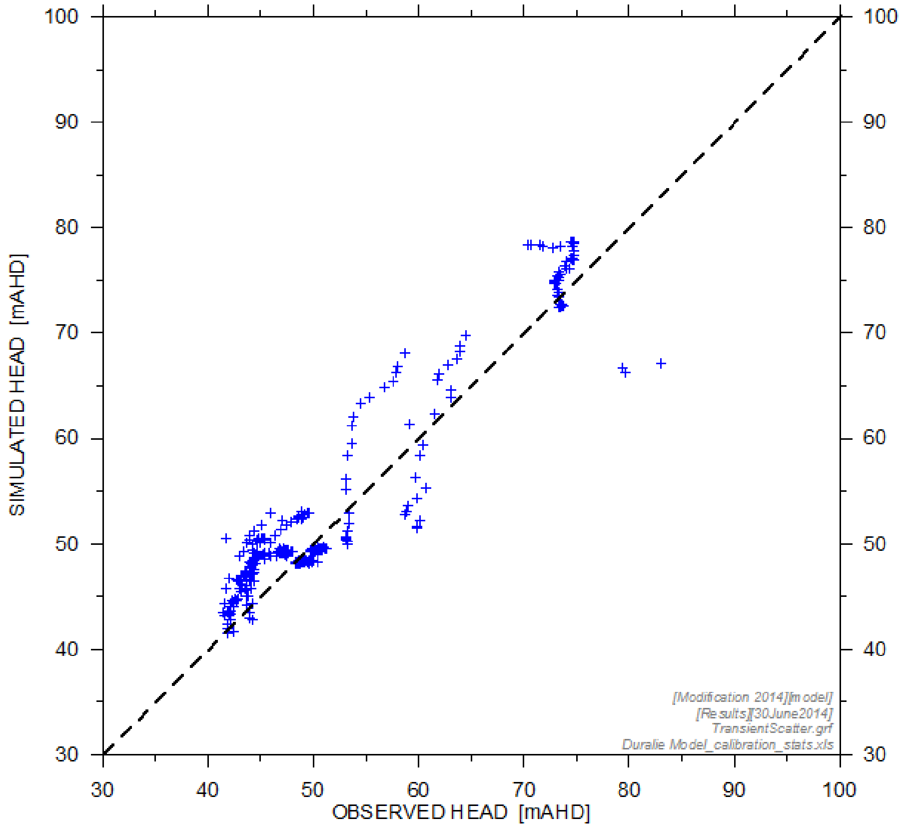


Figure 4-10 Scattergram of Simulated and Observed Heads for Transient Calibration

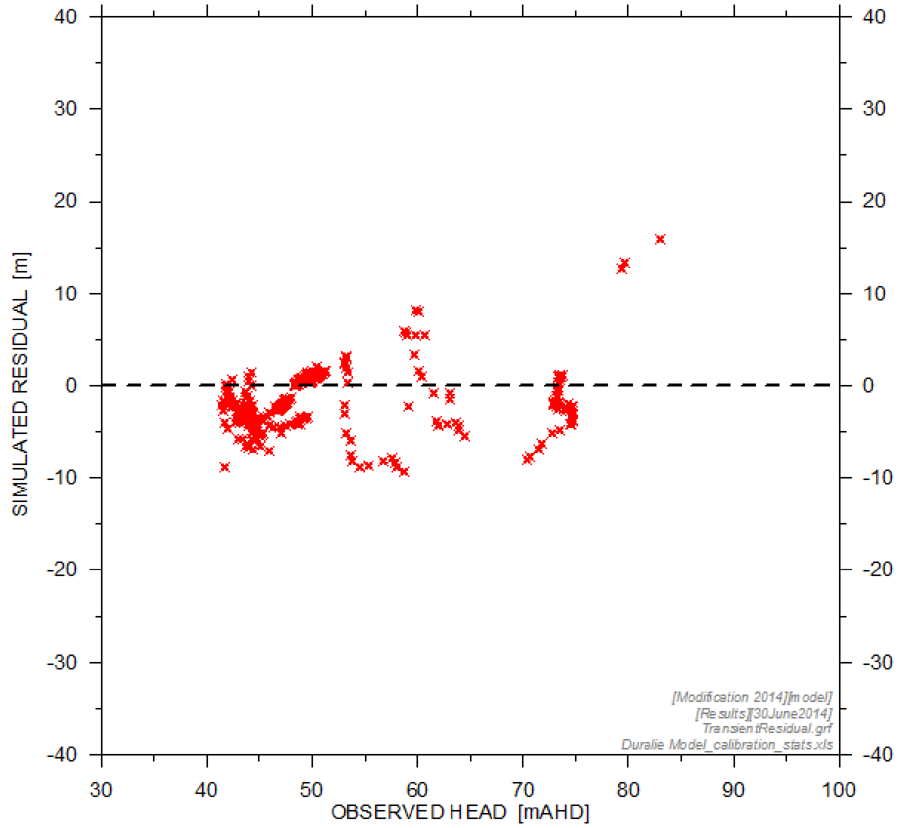


Figure 4-11 Residual between Simulated and Observed Heads for Transient Calibration

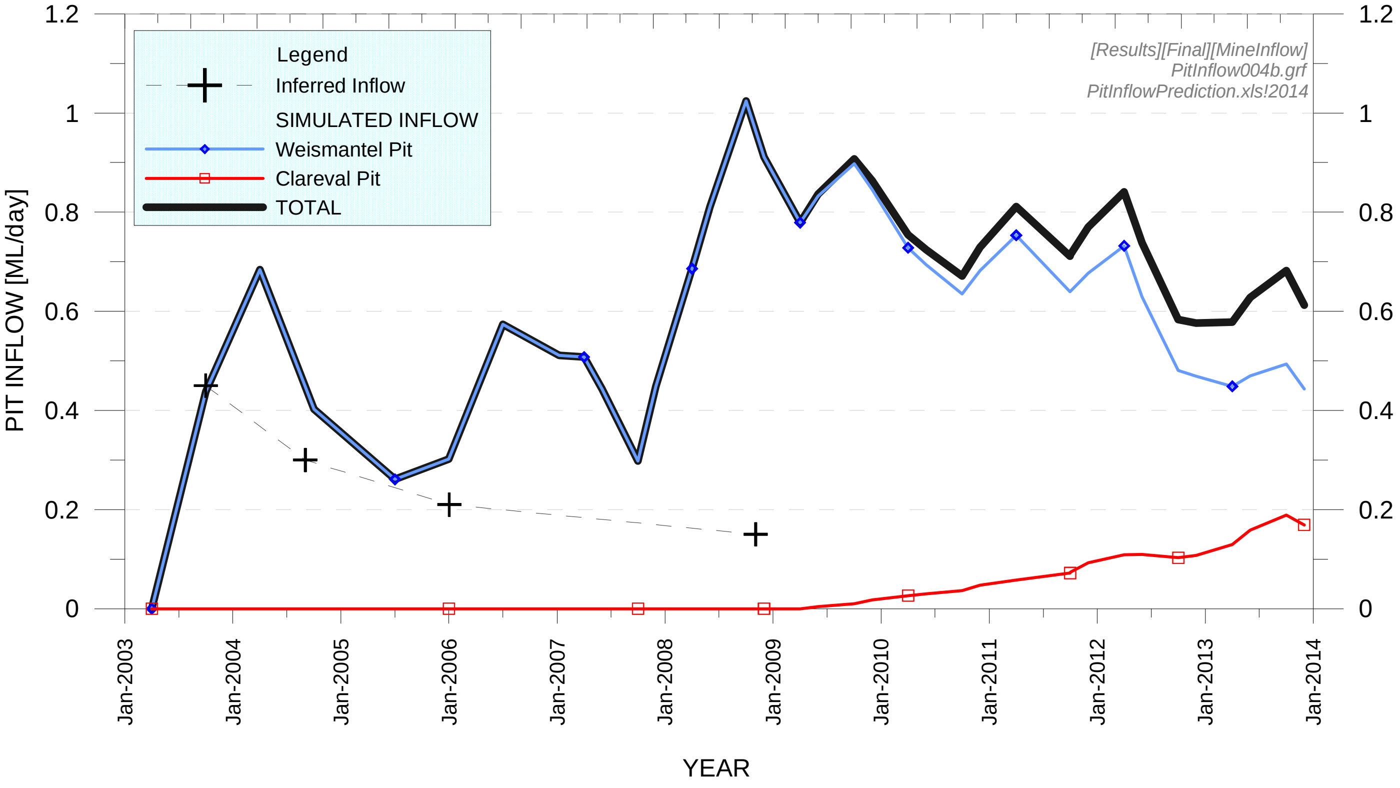


Figure 4-12 Simulated Pit Inflow [ML/d]

5 PREDICTION AND IMPACT ASSESSMENT

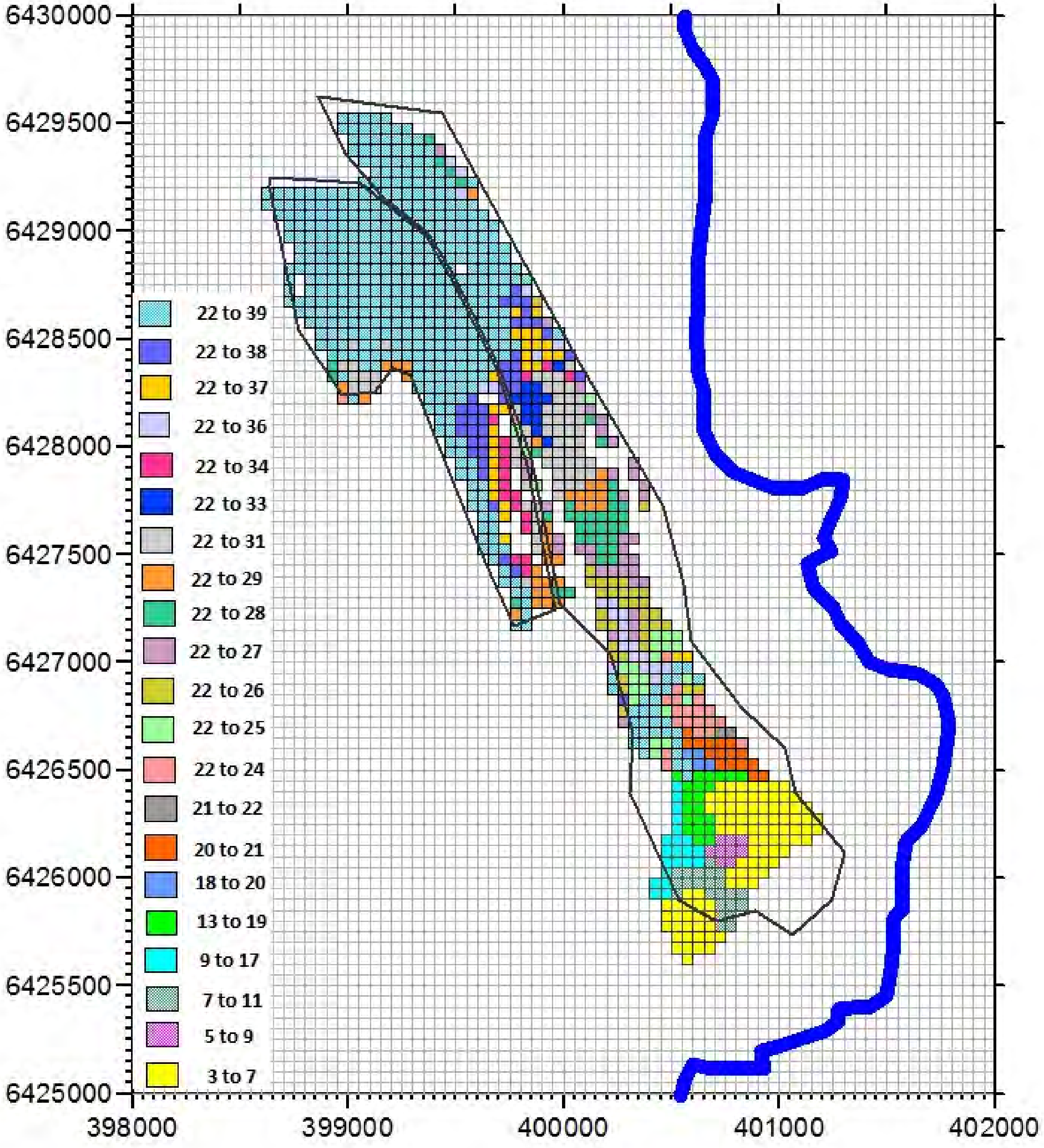


Figure 5-1 Simulated Pit Excavation Schedule in terms of Model Stress Periods

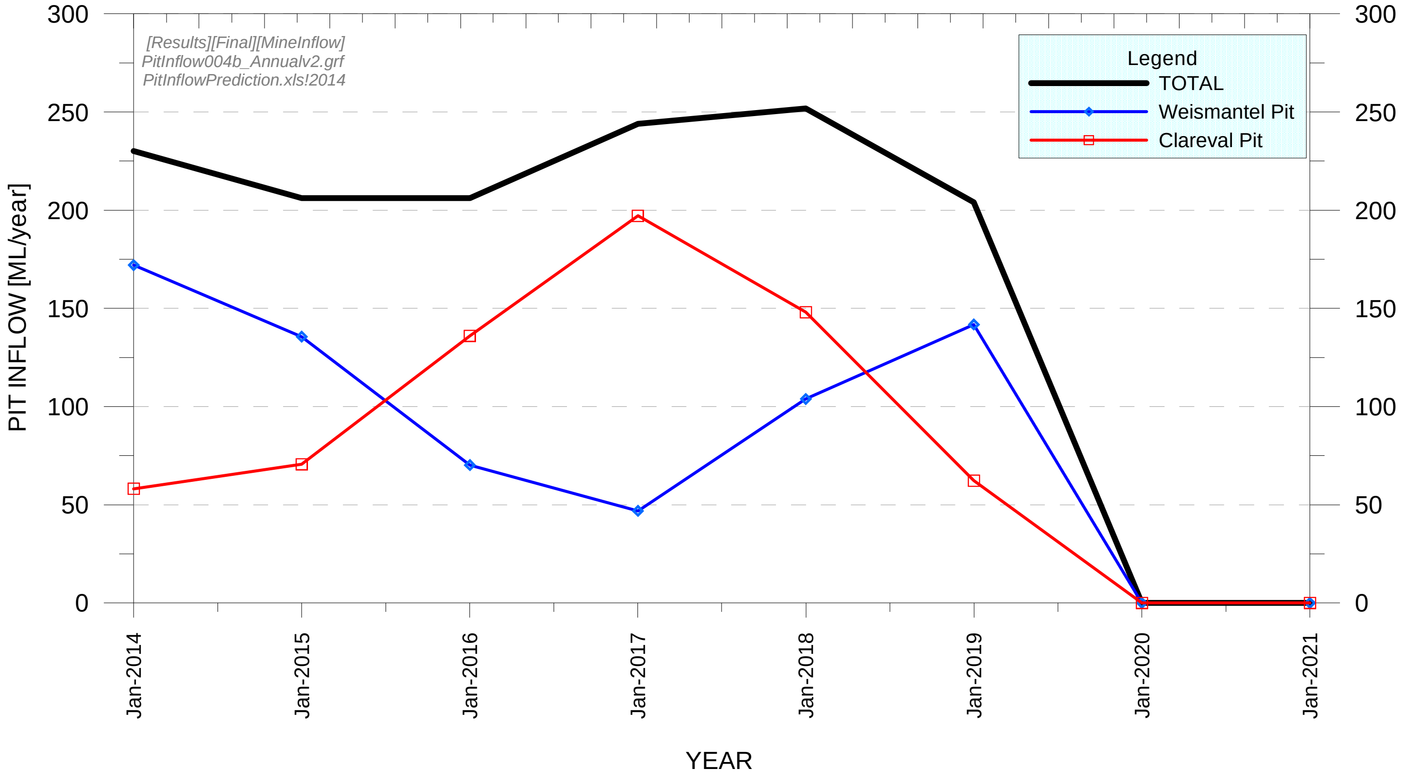


Figure 5-2 Predicted Pit Inflow [ML/yr]

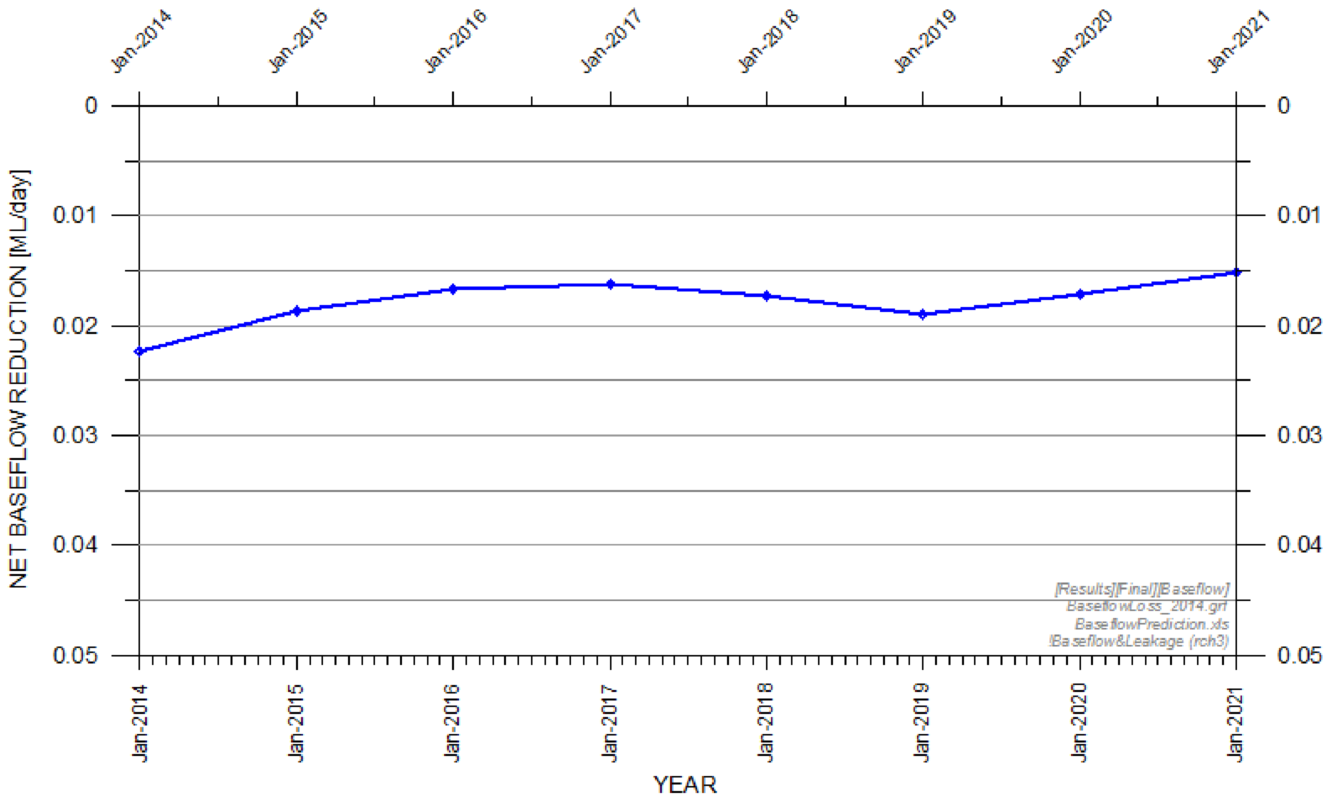


Figure 5-3 Simulated Net Baseflow Reduction to Mammy Johnsons River [ML/day]

[Note: the flows are daily rates averaged over the preceding year for Reaches 2 and 3]

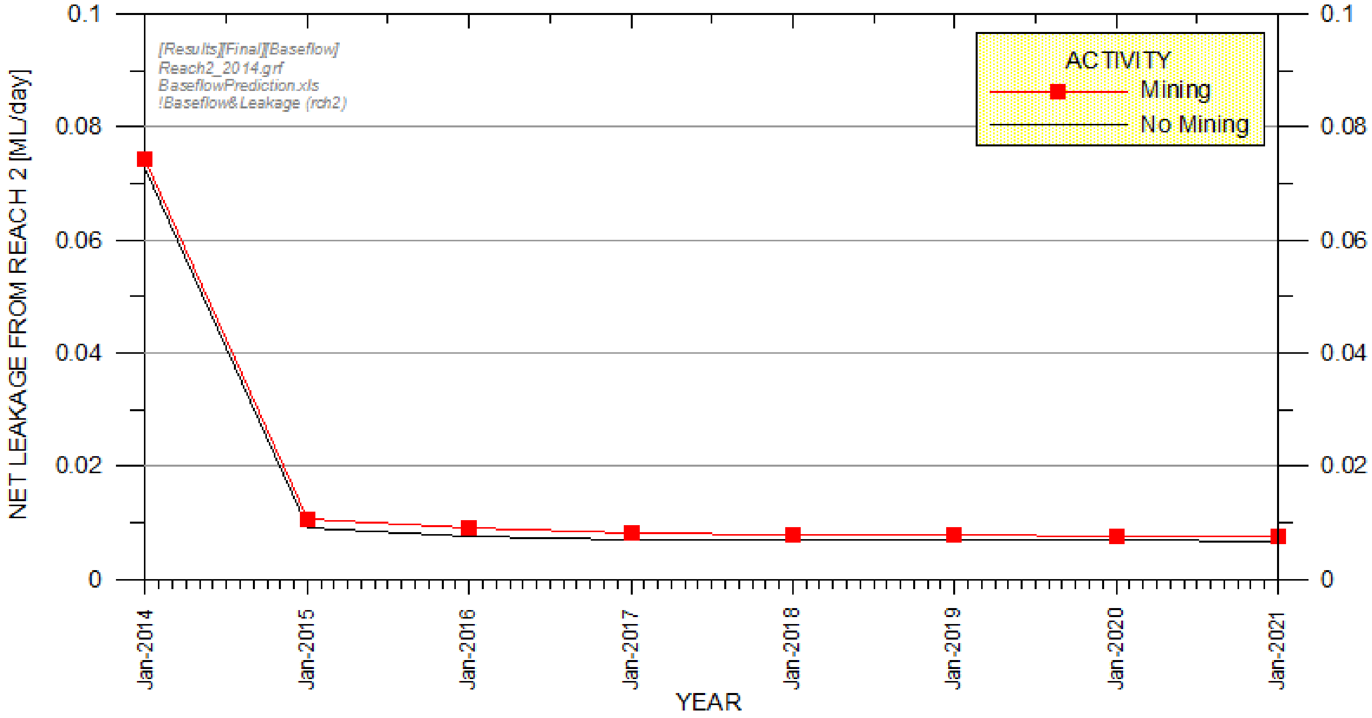


Figure 5-4 Simulated Net Leakage from Mammy Johnsons River Reach 2 [ML/day]

[Note: the flows are daily rates averaged over the preceding year]

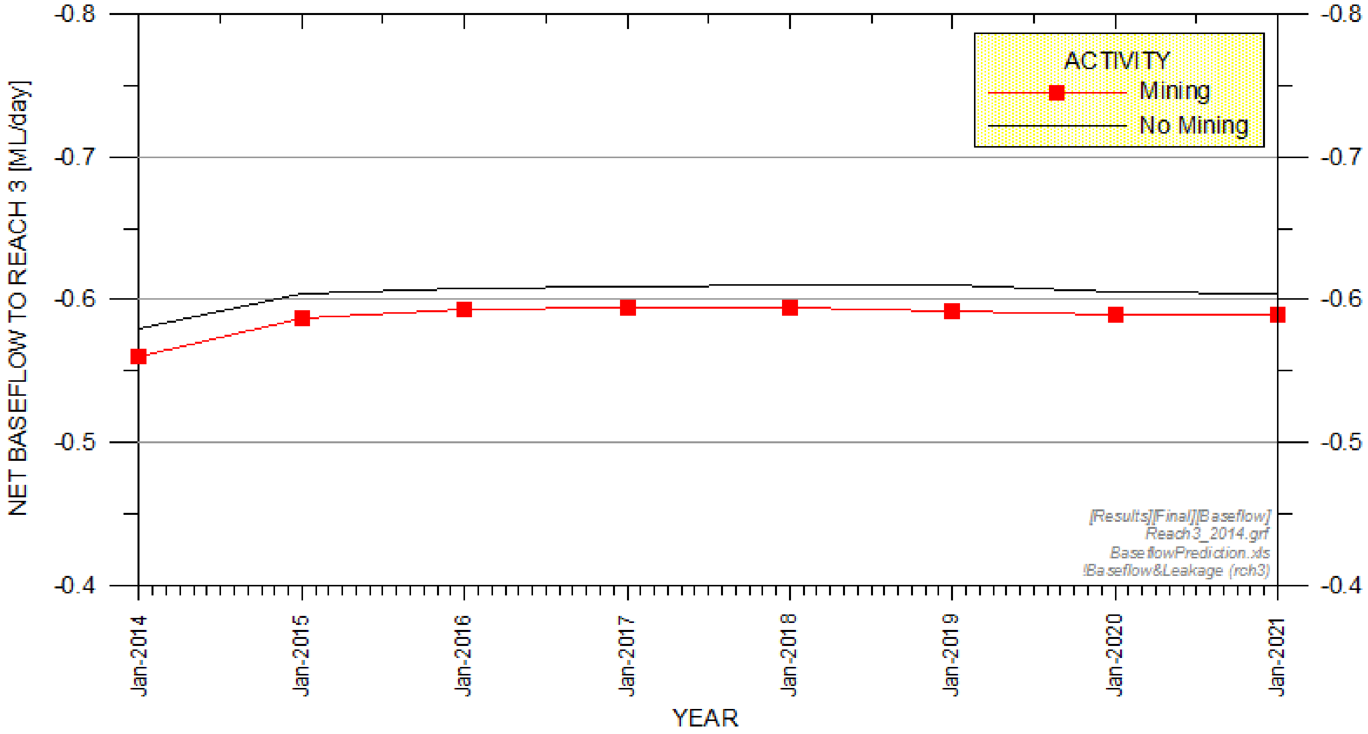


Figure 5-5 Simulated Net Baseflow to Mammy Johnsons River Reach 3 [ML/day]

[Note: the flows are daily rates averaged over the preceding year]

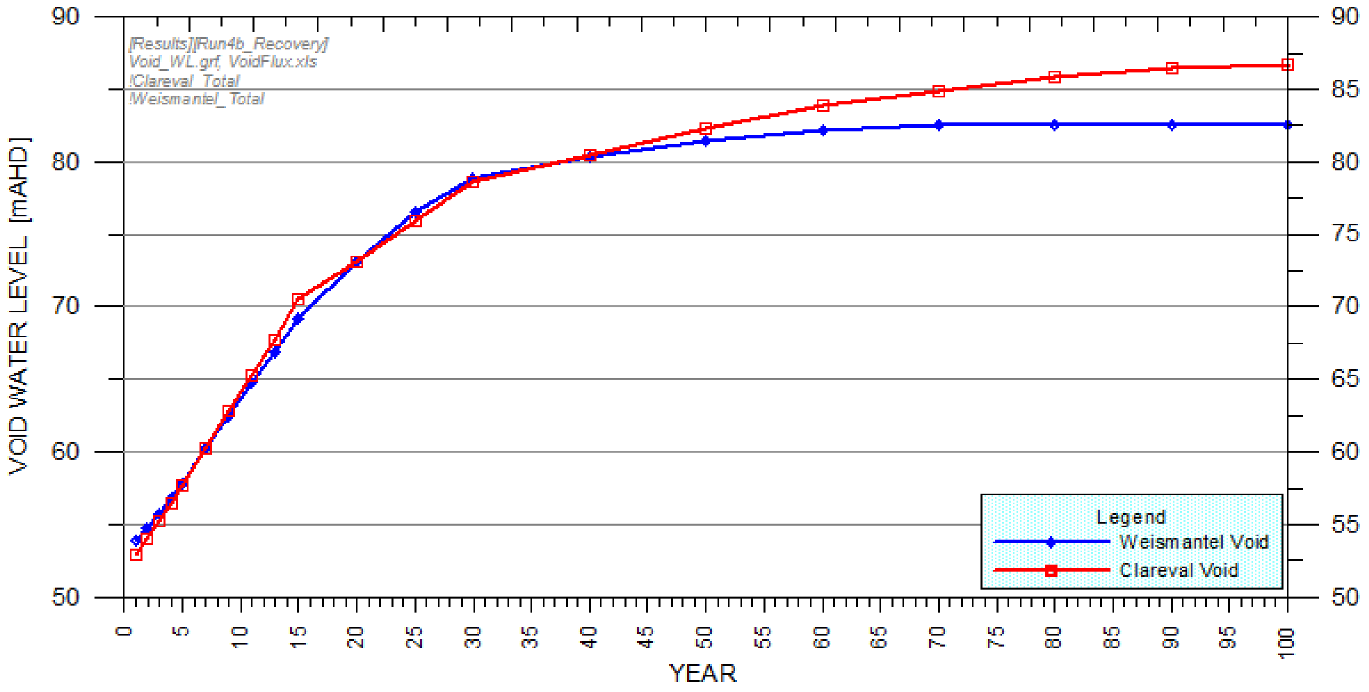


Figure 5-6 Simulated Rise in Water Level in the Two Final Voids

[Note: surface water runoff is not included]

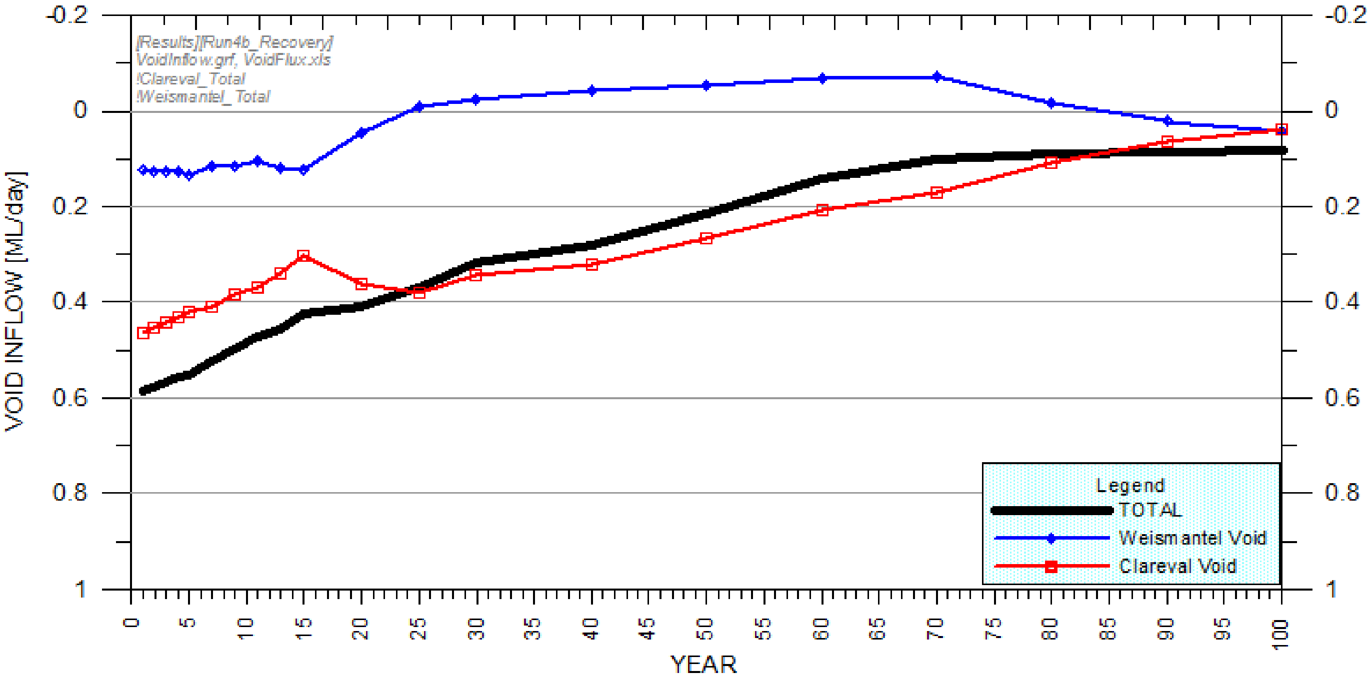


Figure 5-7 Simulated Groundwater Discharge to the Two Final Voids

[Note: surface water runoff is not included]

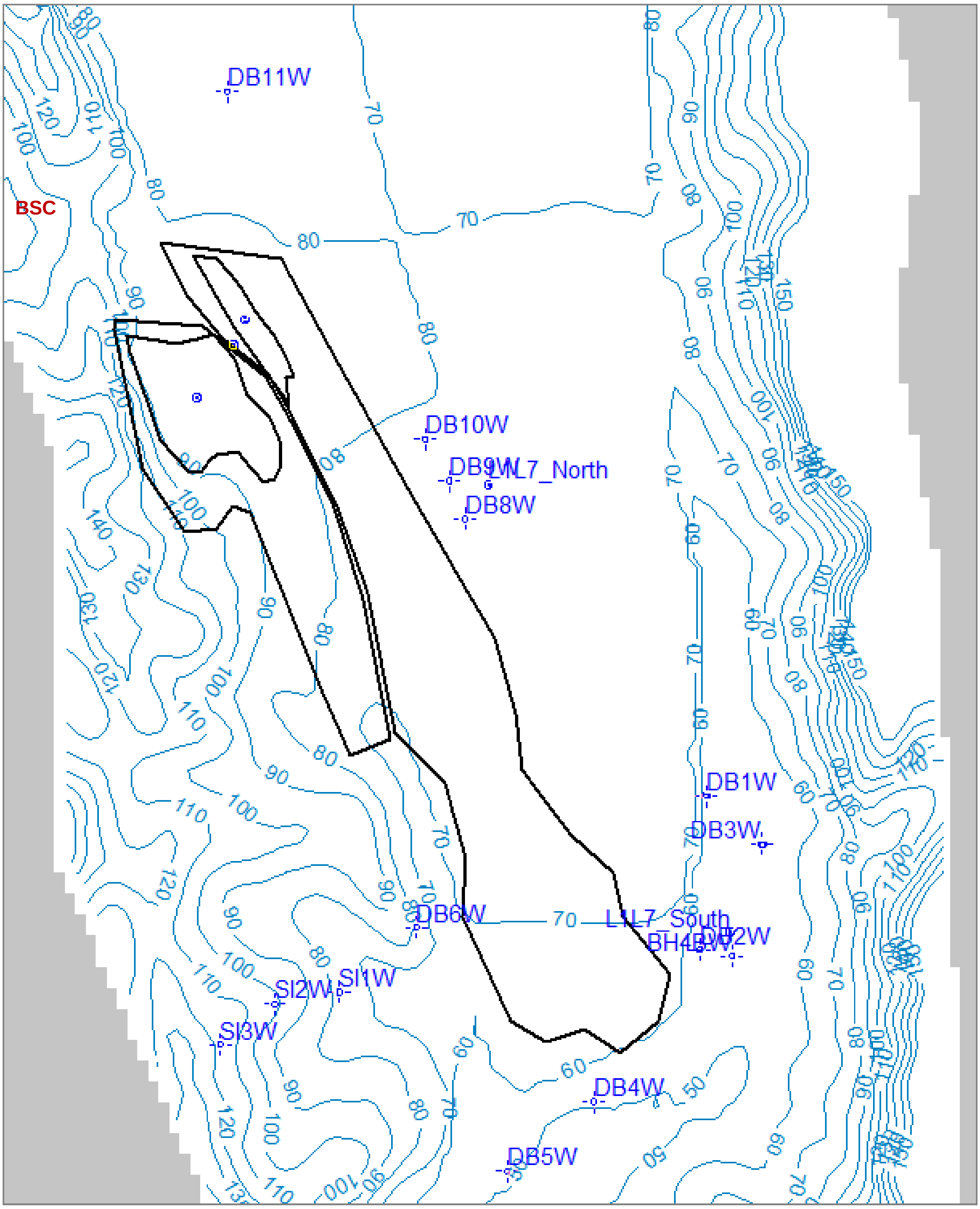


Figure 5-8 Simulated Post-Mining Equilibrium Groundwater Levels in Model Layer 2 [mAHD]

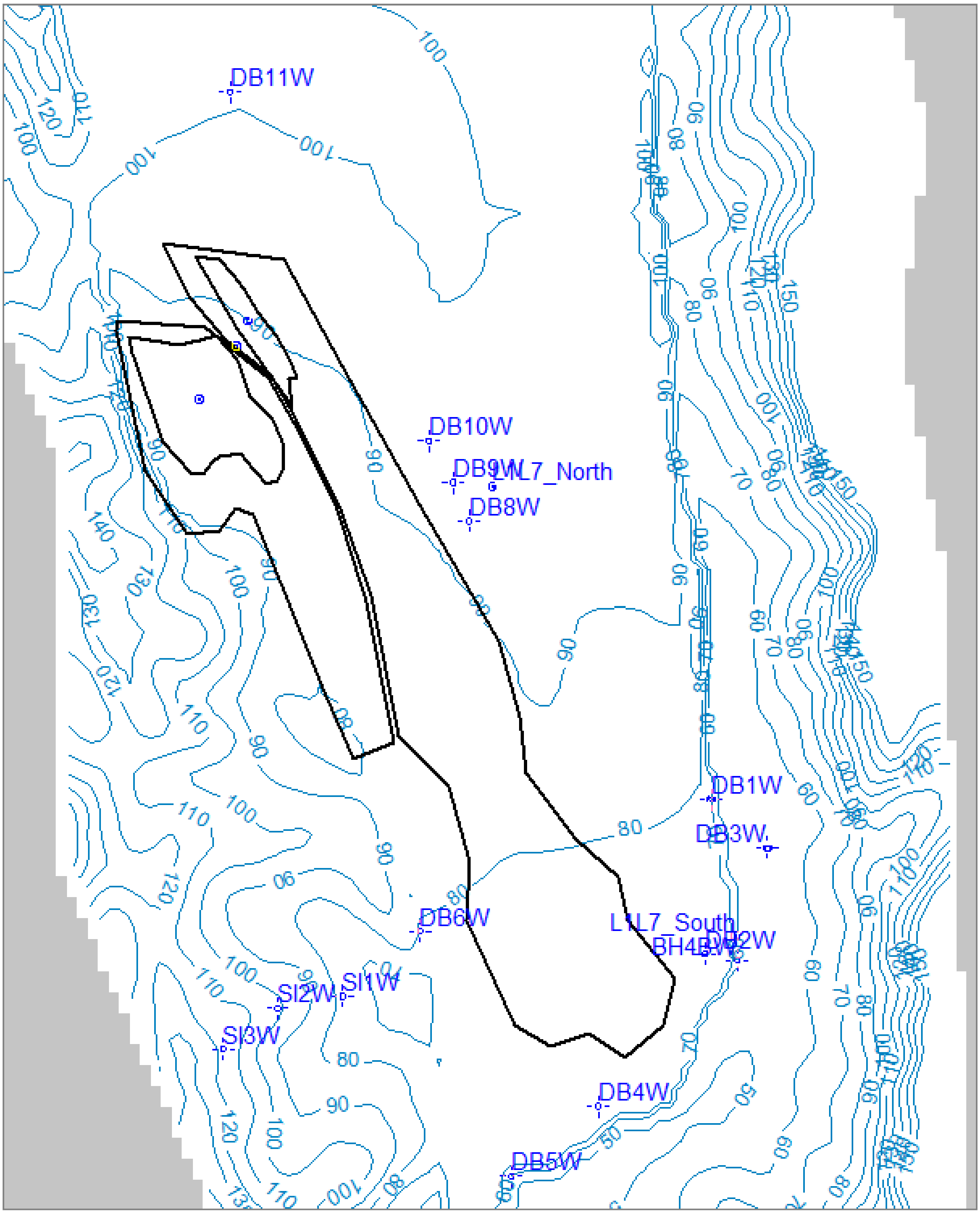


Figure 5-9 Simulated Post-Mining Equilibrium Groundwater Levels in Model Layer 5 [mAHD]

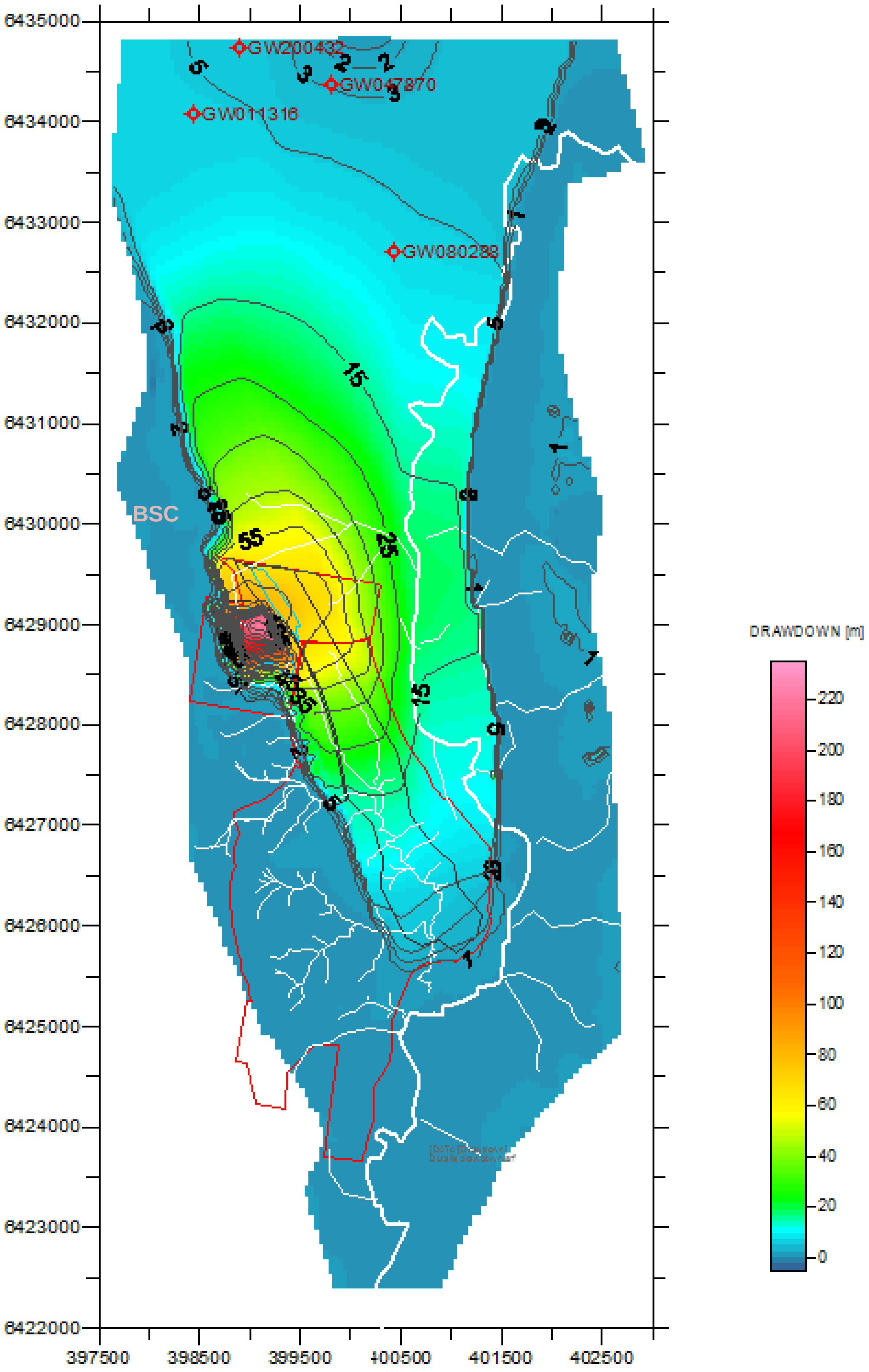


Figure 5-10 Simulated Drawdown in Groundwater Levels at the End of Mining in Model Layer 3 (Weismantel Coal Seam)

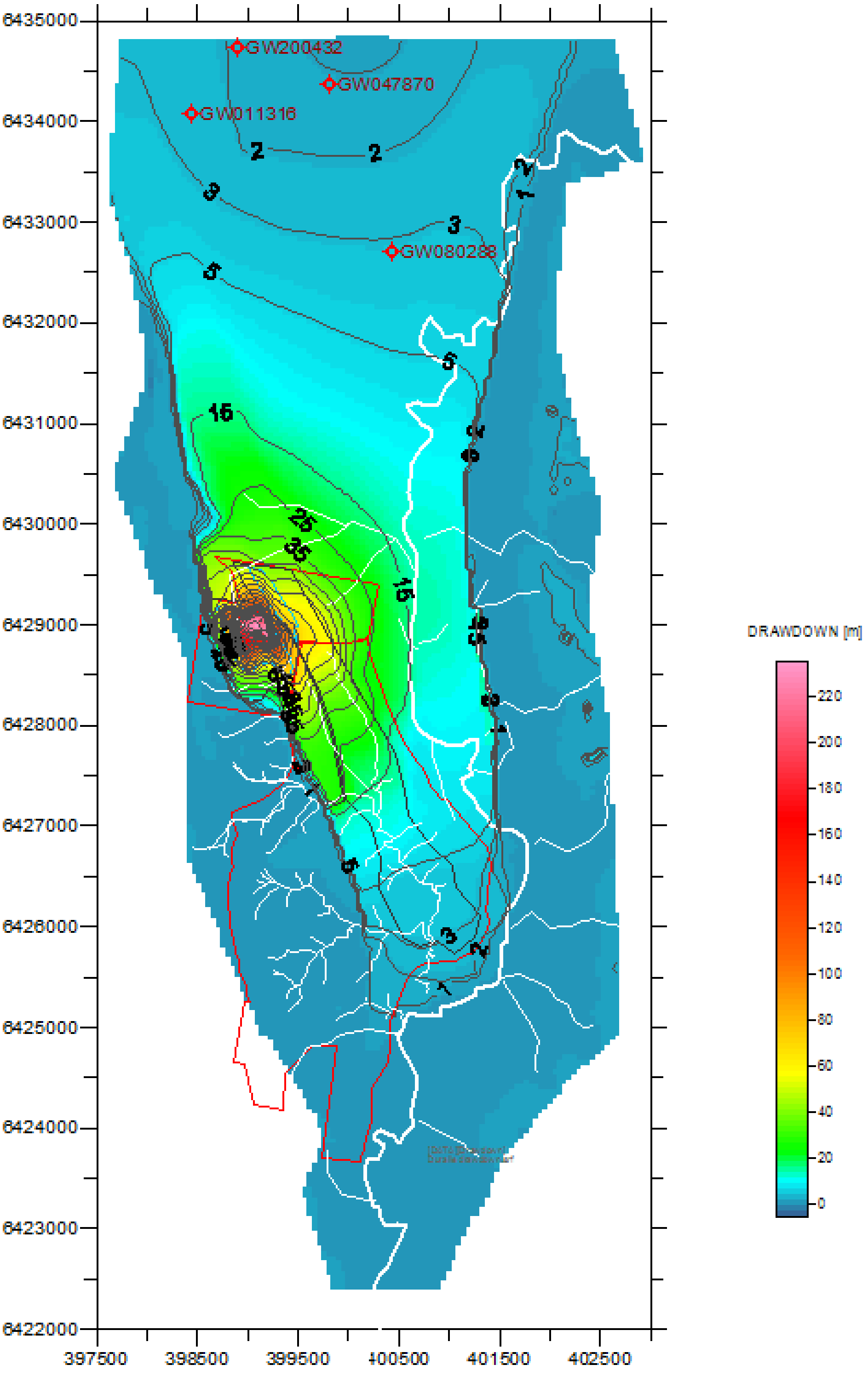


Figure 5-11 Simulated Drawdown in Groundwater Levels at the End of Mining in Model Layer 5 (Clareval Coal Seam)