Centennial Coal

MODIFICATION REPORT

Airly Mine Extension Project

State Significant Development 5581

Modification 3

Volume 2: Part 1 Appendices A – G

October 2019

Centennial Coal
Airly

Airly Mine

SSD 5581 – Modification 3

MODIFICATION REPORT
APPENDICES A – G

Prepared for:

Centennial Airly Pty Limited

Prepared by:

Centennial Coal Company Limited
Level 18, 1 Market St
Sydney NSW 2000

APPENDICES A – G

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APPENDIX – A

Schedule of Land

Airly Mine Extension Project
Schedule of Land

Property ID	Lot/Section No./ Deposited Plan
1	1//1152312
2	4//1152312
3	2//1152312
4	3//1152312
5	5//1152312
6	3/1/758011
7	14//755757
8	1/1/758011
9	4/1/758011
10	154//722292
11	7020//1029319
12	13//755786
13	66//722329
14	68//722329
15	81//755757
16	117//755757
17	112//755757
18	124//755757
19	102//755757
20	94//755757
21	104//755757
22	105//755757
23	95//755757
24	33//755757
25	98//755757
26	91//755757
27	11/1/758011
28	7/3/758011
29	12//1118801
30	7026//1050399
31	7304//1130566

Property ID	Lot/Section No./ Deposited Plan
32	21//1118800
33	20//1118800
34	23//1118800
35	7//1118784
36	10//1118784
37	13//1118784
38	8//1118784
39	16//1118801
40	100//755757
41	7018//1051447
42	7014//1057712
43	83//755757
44	113//755757
45	121//755757
46	7022//1050402
47	67//722329
48	7016//1114802
49	7300//1130496
50	16/2/758011
51	6/2/758011
52	5/2/758011
53	8/1/758011
54	9/1/758011
55	5/3/758011
56	4/3/758011
57	8/3/758011
58	5//755766
59	7023//1050402
60	56//755786
61	3/2/758011
62	1//577478

Property ID	Lot/Section No./ Deposited Plan
63	4//755766
64	1//1007126
65	4/2/758011
66	1//755766
67	12//755786
68	3//755766
69	19//755766
70	5/1/758011
71	51//755786
72	2/1/758011
73	7021//1050431
74	7001//1057060
75	97//755757
76	119//755757
77	22//755786
78	116//755757
79	79//755757
80	109//755757
81	107//755757
82	90//755757
83	126//755757
84	120//755757
85	110//755757
86	108//755757
87	99//755757
88	115//755757
89	6/3/758011
90	1/2/758011
91	1/3/758011
92	2/3/758011
93	3/3/758011

Property ID	Lot/Section No./ Deposited Plan
94	9/3/758011
95	123//755757
96	34//755757
97	10//1118781
98	7303//1130566
99	18//1118800
100	19//1118800
101	22//1118800
102	11//1118784
103	14//1118784
104	13//1118801
105	14//1118801
106	15//1118801
107	24//1118800
108	9//1118784
109	12//1118784
110	101//755757
111	96//755757
112	106//755757
113	78//755757
114	89//755757
115	118//755757
116	82//755757
117	7001//1028024
118	7024//1050402
119	39//755786
120	125//755757
121	80//755757
122	42//755757
123	103//755757
124	7025//1050399

Property ID	Lot/Section No./ Deposited Plan	Property ID	Lot/Section No./ Deposited Plan	Property ID	Lot/Section No./ Deposited Plan	Property ID	Lot/Section No./ Deposited Plan
125	7031//1116097	156	89//755758	187	94//755758	218	38//746912
126	7032//1116097	157	7016//1029387	188	93//755758	219	5//131546
127	7034//1116073	158	7025//1066211	189	7020//1030008	220	18//244899
128	7300//1130282	159	7014//1029387	190	7022//1029388	221	24//755758
129	114//755757	160	9//655050	191	102//1079781	222	8//755758
130	28//755786	161	702//1058325	192	103//1079781	223	C//349704
131	10/1/758011	162	702//1058328	193	7013//1029386	224	1//119590
132	17/2/758011	163	7024//1066211	194	111//755758	225	3//131546
133	2/2/758011	164	7026//1066212	195	7001//1029380	226	45//755758
134	15/2/758011	165	704//1030007	196	13//755758	227	B//349704
135	60//755757	166	11//755757	197	5//986083	228	1//1072590
136	6/1/758011	167	702//1030007	198	17//244899	229	32//755758
137	7/1/758011	168	2//577478	199	39//746912	230	19//244899
138	701//1058328	169	7015//1029387	200	10//132551	231	14//244899
139	4//577478	170	54//755786	201	17//755758	232	110//755758
140	7018//1030008	171	7300//1126380	202	2//131546	233	20//244899
141	71//755758	172	7301//1126380	203	44//755758	234	4//131546
142	100//849168	173	7023//1116918	204	28//755758	235	78//755758
143	7037//1065193	174	7005//1116573	205	37//746912	236	15//755758
144	72//755758	175	7006//1116573	206	25//755758	237	15//244899
145	7021//1030009	176	7024//1116919	207	7002//1029380	238	41//746912
146	65//755786	177	7303//1130728	208	A//349704	239	55//755758
147	3//577478	178	7302//1130590	209	9//755758	240	40//746912
148	7017//1029387	179	1//864999	210	1//346651	241	1//131546
149	701//1030007	180	7004//1029383	211	107//755758	242	22//755758
150	703//1030007	181	2//864999	212	36//755758	243	16//244899
151	701//1058325	182	10//755758	213	16//755758	244	2//927952
152	70//755758	183	22//650039	214	41//755758	245	1//927952
153	7036//1065193	184	7035//1117631	215	23//755758	246	18//1106972
154	63//755758	185	7033//1116073	216	6//131546	247	7010//1021311
155	7027//1066212	186	7013//1057515	217	46//755758	248	1//1115443

Airly Mine Extension Project
Schedule of Land

Property ID	Lot/Section No./ Deposited Plan
249	1//122407
250	42//755758
251	112//755758
252	31//755758
253	26//755758
254	27//755758
255	29//755758
256	30//755758
257	7019//1030008
258	82//755758
259	1//197770
260	126//722134
261	7029//1065275
262	81//755758
263	153//257075
264	142//755757
265	7009//1029698
266	4//755757
267	67//755758
268	17//755757
269	92//755757
270	156//722330
271	102//610704
272	94//755778
273	13//244899
274	86//755757
275	51//755757
276	133//755757
277	85//755757
278	603//615881
279	101//610704

Property ID	Lot/Section No./ Deposited Plan
280	185//755778
281	164//48336
282	2//132549
283	2//379339
284	87//755757
285	35//755758
286	231//1012729
287	159//722293
288	77//755757
289	1//194534
290	2//813231
291	25//665681
292	601//615881
293	2//547497
294	128//755757
295	1//1070723
296	54//755757
297	163//48336
298	47//755758
299	77//755758
300	7015//1057714
301	3//792135
302	58//755757
303	1//132549
304	134//755757
305	1//564345
306	10//755757
307	49//755757
308	135//755757
309	75//755757
310	2//792135

Property ID	Lot/Section No./ Deposited Plan
311	3//709009
312	233//1012729
313	7008//1029698
314	111//755757
315	31//755757
316	55//755757
317	4//709009
318	48//755758
319	6//665679
320	79//755758
321	25//665682
322	141//755757
323	56//755757
324	40//755757
325	3//565109
326	7003//1056614
327	232//1012729
328	132//755757
329	59//755757
330	129//755757
331	4//792135
332	1//831104
333	1//195875
334	157//722330
335	7012//1056868
336	15//755757
337	7028//1029701
338	7029//1075846
339	83//755758
340	70//755757
341	43//755757

Property ID	Lot/Section No./ Deposited Plan
342	7038//1117632
343	158//722293
344	139//755757
345	93//755757
346	7037//1117633
347	7036//1117631
348	137//755757
349	13//755757
350	136//755757
351	20//755757
352	18//755757
353	27//755757
354	41//755757
355	26//755757
356	47//755757
357	24//755757
358	50//755757
359	7002//1058210
360	7302//1130728
361	7304//1130728
362	7028//1065275
363	21//755758
364	35//755786

APPENDIX – B

Communication with Department of Planning, Industry and Environment

Planning and Assessment
Energy and Resources
Contact: Andrew Rode
Tel: 8289 6744
Email: Andrew.Rode@planning.nsw.gov.au

Dr Nagindar Singh
Approvals Coordinator - Centennial Coal Company Limited
100 Miller Road
FASSIFERN NSW 2283

30/08/2019

Dear Dr Singh

Airly Mine Extension Project (SSD 5581) - Modification 3

I refer to your letter dated 28 August 2019 regarding a proposed modification to the Airly Mine Extension Project (SSD 5581).

The Department confirms that the appropriate approval pathway for the modification application would be under Section 4.55(2) of the *Environmental Planning and Assessment Act 1979*.

The Department is satisfied with the issues identified in your letter to be addressed in the Modification Report and the level of assessment you intend to undertake, and requests that the following matters are also addressed:

- **Social impacts** – ensure that the social impact assessment is undertaken in accordance with the Department's *Social Impact Assessment Guideline for State significant mining, petroleum and extractive industry development* (2017);
- **Biodiversity impacts** – determine if the proposal would have any additional impact on biodiversity values on the site by completing Table 1 in Attachment A and including it in the Modification Report; and
- **Stakeholder engagement** – in addition to the public authorities outlined your letter, you should consult with the Resources Regulator, Transport for NSW and the rail operator.

Your next step will be to lodge your Modification Report through your dashboard on our new major projects website (http://www.planningportal.nsw.gov.au/major-projects).

If your proposal is likely to have a significant impact on Matters of National Environmental Significance, it will require an approval under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). This approval would be in addition to any approvals required under NSW legislation and it is your responsibility to contact the Commonwealth Department of the Environment and Energy to determine if an approval under the EPBC Act is required (http://www.environment.gov.au or 6274 1111).

If you have any questions, please contact Andrew Rode on 02 8289 6744 or at andrew.rode@planning.nsw.gov.au.

Yours sincerely,

Stephen O'Donoghue
Director
Resource Assessments

Attachment A

The consent authority is required to consider whether the proposal would affect biodiversity values.

If the proposal is likely to result in expanded impacts or impacts to different biodiversity values not previously assessed, the application must include a Biodiversity Development Assessment Report (BDAR).

Table 1: Effect on biodiversity values

Biodiversity values	Meaning	Relevant or NA* (✓or NA)	Modification interaction with biodiversity values
Vegetation integrity	Degree to which the composition, structure and function of vegetation at a particular site and the surrounding landscape has been altered from a near natural state		*Demonstrate how the proposed modification has been designed to not increase impacts (or to reduce impacts) on the vegetation integrity of identified plant communities within the development site as proposed to be modified. Where identified plant communities have been avoided directly, demonstrate how indirect impacts won't further reduce the natural state of the existing vegetation. Quantitative analysis may be appropriate in some circumstances. Eg:* • *Identify impacted Plant Community Types (PCTs)* • *Identify area of impacted PCTs* • *Estimate vegetation integrity score for PCTs* • *Demonstrate that the impact on each PCT remains the same or is reduced relative to approved impacts* • *Demonstrate that indirect impacts remain the same or are reduced relative to approved impacts*
Vegetation abundance	Occurrence and abundance of vegetation at a particular site		*Where vegetation is present on the development site as proposed to be modified, provide a map on digital aerial photography or the best available imagery showing:* • *native vegetation (including grasslands and other non-woody vegetation types) and non-native vegetation, and* • *the area of land that is likely to be directly impacted by the proposed modification, including related infrastructure such as roads, pipelines, access tracks, temporary material*

Biodiversity values	Meaning	Relevant or NA* (✓ or NA)	Modification interaction with biodiversity values
			stockpiles, asset protection zones and powerlines, if applicable, and • *the area of direct impact previously approved (for comparison).* *Demonstrate how the proposed modification has been designed to not increase impacts, (or to reduce impacts) on native vegetation (including impacts to isolated or cultivated native plants). Quantitative analysis may be appropriate in some circumstances.*
Habitat suitability	Degree to which the habitat needs of threatened species are present at a particular site		*Identify any threatened species or ecological communities or their habitat on the development site as proposed to be modified. In addition to native vegetation, habitat may include non-native vegetation, human made structures, rocks, karst, caves, crevices, cliffs and other geological features of significance.* *Demonstrate how the proposed modification does not increase impacts, or how it reduces impacts, including indirect impacts such as noise, light spill, habitat trampling, weed invasion, on habitat suitability.* *Eg:* • *Identify likely impacted threatened species, ecological communities and their habitats* • *Estimate area of impacted threatened species, ecological communities and their habitats* • *Demonstrate that the estimated impact on threatened species, ecological communities and their habitats remains the same or is reduced relative to approved impacts* • *Demonstrate that indirect impacts remain the same or are reduced relative to approved impacts*
Threatened species abundance	Occurrence and abundance of threatened species or threatened ecological communities, or their habitat, at a		*Identify threatened species or threatened ecological communities (or their habitat) present on the development site as proposed to be modified. Identify their abundance (indicate any abundance already approved for removal under the original development consent).*

Biodiversity values	Meaning	Relevant or NA* (✓ or NA)	Modification interaction with biodiversity values
	particular site		*Demonstrate how the proposed modification does not increase impacts, or how it reduces impacts, on threatened species or threatened ecological community abundance. Ensure all potential impacts are considered including prescribed impacts such as vehicle strikes on threatened species of animals or on animals that are part of a threatened ecological community. Quantitative analysis may be appropriate in some circumstances.*
Habitat connectivity	Degree to which a particular site connects different areas of habitat of threatened species to facilitate the movement of those species across their range		*Identify (on a map where appropriate) and analyse whether the development site as proposed to be modified contributes to habitat connectivity for threatened species. Identify the threatened species that may use the habitat connectivity and how the connectivity facilitates the species' movement across their range.* *Demonstrate how the proposed modification does not increase impacts, or how it reduces impacts, on habitat connectivity for threatened species. Ensure all potential impacts are considered including direct removal of a habitat connection and barriers or deterrents to species movement across the habitat connection.*
Threatened species movement	Degree to which a particular site contributes to the movement of threatened species to maintain their lifecycle		*Identify (on a map where appropriate) and analyse whether the development site as proposed to be modified contributes to threatened species movement that maintains their lifecycle. Identify the threatened species whose lifecycle may rely on movement through the site. ('Habitat connectivity', addressed above, may overlap with this biodiversity value however may be at a larger scale as it considers movement across the species' range. 'Threatened species movement' to maintain a species lifecycle may be at a smaller scale, e.g. where a frog moves across a site to access an adjoining breeding pond).* *Demonstrate how the proposed modification does not increase impacts, or*

Biodiversity values	Meaning	Relevant or NA* (✓ or NA)	Modification interaction with biodiversity values
			how it reduces impacts, on threatened species movement that maintains the species' lifecycle. Ensure all potential impacts are considered including construction and operational impacts.
Flight path integrity	Degree to which the flight paths of protected animals over a particular site are free from interference		*Identify (on a map where appropriate) whether flight paths of protected animals occur over the development site as proposed to be modified. Identify the protected animals with a flight path over the site.* *Demonstrate how the proposed modification does not increase impacts, or how it reduces impacts, on flight path integrity. Ensure all potential impacts are considered including construction and operational impacts.* *For proposed wind farms, demonstrate why turbine strikes are unlikely on protected animals. Modelling may be required.*
Water sustainability	Degree to which water quality, water bodies and hydrological processes sustain threatened species and threatened ecological communities at a particular site		*Identify any threatened species or threatened ecological communities that are sensitive to water quality and/or sustained by water bodies or hydrological processes at the development site as proposed to be modified.* *Demonstrate how the proposed modification has been designed to not increase impacts (or to reduce impacts) on water sustainability for threatened species or threatened ecological communities. Ensure all potential impacts are considered including impacts from subsidence or upsidence resulting from underground mining or other development).*

**Provide reasoning against any NA recorded against any values where it is not relevant (e.g. if the site does not support any natural vegetation or habitat; Site is in a highly urbanized or industrial setting).*

Centennial Coal
Airly

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28 August 2019

Mr Stephen O'Donoghue
A/Director
Resource and Energy Assessments
NSW Department of Planning, Industry & Environment
320 Pitt Street
Sydney NSW 2000

Dear Mr O'Donoghue

Airly Mine Extension Project – Proposed Modification 3
State significant development 5581

I refer to our meeting with the Department on 23 October 2018 to discuss the intention of Centennial Airly Pty Limited (Centennial Airly) to modify Airly Mine's consent SSD 5581 to increase production rate and workforce, and to import water from an external source to meet the identified process water deficit for approved operations. As you would be aware, the importation of water from Charbon Colliery by rail was proposed and approved in Modification 2.

Centennial Airly is now proposing to modify SSD 5581 (Modification 3) to allow for:

- an increase in the run-of-mine (ROM) production rate from the approved 1.8 million tonne per annum (Mtpa) to 3.0 Mtpa
- an increase in workforce from the approved 155 full time equivalent (FTE) personnel to 200 FTE personnel
- an increase in the movement of laden coal trains and water trains leaving the site from the approved average of 2 trains per day to 3 trains per day over any calendar year but maintaining the approved maximum 5 trains per day leaving the site on any day
- underground blasting (or shot-firing) activities for the removal of geological structures in the event they are encountered within the mining areas
- an amendment to the approved 20 year mine schedule for the increased production rate.

No changes are proposed to the approved mining methods, the approved mining zones or the mining area to achieve the increased production rate, however the mining intensity will increase. Accordingly, Airly Modification 3 will not result in any changes to subsidence impacts, and will continue to meet the subsidence impact performance measures included in Schedule 3 Condition 2 (natural and heritage features etc.) and Schedule 3 Condition 3 (built features) of SSD 5581. The proposed modification does not include any physical works or significant changes to the existing underground mine operation or the surface activities.

While the increased production rate will result in a greater process water deficit than identified for the 1.8 Mtpa production rate in Modification 2, there is no proposal to increase the volume of water to be imported from Charbon Colliery from the approved 170 ML/year. Centennial Airly will instead not construct and operate the approved coal preparation plant (CPP) and the reject emplacement area (REA), as beneficiation of ROM coal is not in Airly Mine's current five year business plan. Without the operation of this infrastructure, the 170 ML/year imported water and water available from the onsite sources will be sufficient to meet the process water requirements for the proposed 3 Mtpa production rate. Centennial Airly will review the water requirements for the site at a later stage, should the mine make a decision to construct and operate the CPP and the REA in the future, and will manage the operations, if necessary, to ensure no additional importation of process water is required.

Environment Impact Assessment

A Modification Report will be prepared to support the modification application. The following technical assessments will underpin the Modification Report:

- Groundwater
- Surface water and site water balance
- Air quality and greenhouse gas emissions
- Traffic and transport (road and rail)
- Noise and vibration
- Social
- Economic.

The Modification Report will provide a rationale for the proposed modifications to consent SSD 5581, and will include the strategy to be implemented at Airly Mine to achieve the increased production rate.

Approval Pathway

Section 4.55 of the *Environmental Planning and Assessment Act 1979* (EP&A Act) applies to modifications to Part 4 development consents generally, provided the development as modified is substantially the same development as the development for which consent was originally granted and before that consent as originally granted was modified (if at all).

In determining whether the proposed modification will meet the substantially the same development test, a comparative analysis for changes in:

- development size, scale and footprint
- intensity including rates of production
- project life and hours of operation
- extent, duration and severity of impacts

due to the proposed modification was undertaken. The analyses provided the following conclusions.

1. When considered in insolation, an increase in the annual production to 3 Mtpa, representing a 66% increase from the approved 1.8 Mtpa, may not be considered to be substantially the same development, as the intensity is too great.
2. However, there are numerous qualitative factors which weigh against this conclusion and provide necessary context. These factors comprise the following.
   a) The potential environmental impacts due to the modification elements are expected to be minimal (noise, air quality and greenhouse gas emissions, traffic) while the surface water and groundwater impacts are likely to be lesser than the approved impacts.
   b) There will be no change to subsidence impacts, and the development as modified will meet the subsidence impact performance measures included in Schedule 3 Condition 2 (natural and heritage features etc.) and Schedule 3 Condition 3 (built features) of SSD 5581.
   c) There will be no changes to:
      i) development size, scale and footprint
      ii) daily rates of production
      iii) project life and hours of operation

iv) extent, duration and severity of impacts.

Accordingly, on the above basis, the proposed modification can be considered to meet the substantially the same development test, and therefore the appropriate planning approval pathway is section 4.55(2) of the EP&A Act.

Stakeholder Engagement

Consultation with the local community in regard to the modification was commenced in 2017, and will continue to be undertaken using the Community Consultative Community meetings as the main forum. Consultation with the government agencies will be undertaken via meetings and by letters, and will include consultation with:

- Lithgow City Council
- Environmental Protection Authority
- Water Division, within the Department
- Division of Resources and Geoscience (DRG), within the Department
- National Parks and Wildlife Service
- Roads and Maritime Services.

Issues raised during stakeholder consultation will be addressed in the Modification Report.

Centennial requests the Department confirm:

(i) the proposed approval pathway for the proposed modification

(ii) the adequacy of the technical assessments proposed to underpin the Modification Report.

Please contact me (6355 9814 / 0407 551 405 / nagindar.singh@centennialcoal.com.au), if you require further information.

Yours sincerely

Nagindar Singh
Approvals Coordinator

APPENDIX – C

Hydrogeological Model Report

Centennial Airly Pty Ltd

Airly Mine Mod 3

Hydrogeological Model Report

October 2019

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Appendices

Abbreviations

AHD	Australian height datum
bgl	Below ground level
BOM	Bureau of Meteorology
Centennial Airly	Centennial Airly Pty Limited
CRD	Cumulative rainfall departure
GHB	General head boundary
GHD	GHD Pty Ltd
ha	Hectare
K_h	Horizontal hydraulic conductivity
km	Kilometre
K_v	Vertical hydraulic conductivity
m	Metre
m/day	Metre per day
ML	Megalitre
ML/year	Megalitre per year
Mtpa	Million tonne per annum
ROM	Run of mine
SRMSE	Scaled root mean square error
VWP	Vibrating wire piezometer

Glossary

Alluvial	Deposition from running waters.
Aquifer	A groundwater bearing formation sufficiently permeable to transmit and yield groundwater.
Bord and pillar	Method of underground coal mining where the coal seam is divided into a regular block array (pillars) by driving roadways. In some cases, the pillars are partly removed in a concurrent or later operation.
Bore	Constructed connection between the surface and a groundwater source that enables groundwater to be transferred to the surface either naturally or through artificial means.
Catchment	The land area draining through the main stream, as well as tributary streams, to a particular site.
Cumulative rainfall departure	Monthly accumulation of the difference between the observed monthly rainfall and long-term average monthly rainfall.
Dewatering	The removal or pumping of water from an above or below ground storage, including the mine water within the water collection system of mine workings. Water removed from mine workings is regarded as dewatering unless the workings are flooded and at equilibrium with the surrounding strata (in which case the removal is considered groundwater extraction).
Drawdown	A reduction in piezometric or hydraulic head within an aquifer.
Ephemeral	Stream that is usually dry, but may contain water for rare and irregular periods, usually after significant rain.
Fracture	Cracks within the strata that develop naturally or as a result of underground works.
Groundwater	Subsurface water that occurs in geological formations.
Hydrogeology	The area of geology that deals with the distribution and movement of groundwater in soils and rocks.
Hydrograph	A graph which shows how a water level (either surface or underground) at any particular location changes with time.
Permian age	The youngest geological period of the Palaeozoic era, covering a span between approximately 290 and 250 million years ago.
Quaternary	The most recent geological period spanning from approximately 2.5 million years ago to present.

Recharge	The replenishment of an aquifer by the absorption of water.
Roadway	Underground tunnel constructed to enable access to working face.
Run of mine	Raw coal production (unprocessed).
Strata	Layers of rock above, below and including the coal seam.
Surface water	Water that is derived from precipitation or pumped from underground and may be stored in dams, rivers, creeks and drainage lines.
Triassic	The geological period that spans between approximately 250 and 200 million years ago.

1. Introduction

Airly Mine is an existing underground coal mine owned and operated by Centennial Airly Pty Limited (Centennial Airly). It is located near Capertee village, approximately 40 km north-west of Lithgow on the Castlereagh Highway in the Western Coalfield of NSW, as shown in Figure 1-1.

Airly Mine was first granted Development Consent (DA162/91) for the development of an underground coal mine on 14 April 1993 by the then Minister for Planning following a Commission of Inquiry held in 1993. First coal production for the purposes of developing the main portals and roadways to the underground mine occurred on 14 December 2009.

The Airly Mine Extension Project (SSD_5581) for the continuation of underground mining within the boundaries of ML1331 and within Authorisation 232 (A232) was submitted in September 2014, and approved in December 2016 and allows mining for a period of 20 years. The consent allows Airly Mine to extract up to 1.8 million tonnes per annum (Mtpa) of run of mine (ROM) coal and will lapse on 31 January 2037. Rehabilitation will be undertaken outside this period.

A locality plan showing the Project Approval Area (PAA) boundary is given in Figure 1-1. Coal mining to date at Airly Mine has been bord and pillar mining only within the Lithgow Seam and within the boundary of ML1331.

1.1 Purpose of this report

This hydrogeological model report (HMR) details the recalibration of the existing numerical hydrogeological model, originally developed to inform the Groundwater Impact Assessment (GIA) for the Airly Mine Extension Project. The numerical hydrogeological has been recalibrated using updated monitoring data. The numerical hydrogeological model has been updated and re-run to inform the GIA for a proposed modification to Development Consent SSD_5581 (Modification 3) which proposes to:

- Increase the production rate from the approved 1.8 Mtpa to a maximum rate of 3.0 Mtpa of ROM coal.
- Increase the workforce from the approved 155 full time equivalent (FTE) personnel to 200 FTE personnel.
- Increase the average train movements from the approved two trains per day to three trains per day (maintaining the approved maximum five trains per day) to allow all coal to be transferred offsite at the increased production rate.
- Amend the approved 20 year mine schedule for the increased production rate.

The update of the HMR also included an uncertainty analysis (Section 4.3.1) to meet the requirements of the *Information guidelines for proponents preparing coal seam gas and large coal mining development proposals* (IESC, 2018a) and the *Explanatory Note on Uncertainty Analysis in Groundwater Modelling* (IESC, 2018b). The latter provides additional guidance when undertaking uncertainty analysis.

A hydrogeological risk assessment was undertaken to determine the best approach and level of uncertainty analysis to be undertaken, as discussed in Section 4.3.1. The uncertainty analysis undertaken is commensurate with the level of complexity of the project and the existing hydrogeological environment. It is important to note that the uncertainty analysis undertaken pertains to the model input parameters and outcomes of scenarios investigated, and not the numerical model itself.

The scope and the outcomes of the risk assessment are appended to this report as Appendix A. A summary of the risk assessment is provided in Table 1-1. The risk analysis was undertaken using Centennial's risk management tools. The risk rating provided in Table 1-1 is based on the likelihood of the risk multiplied by the consequence of the risk. More detail regarding the risk assessment process and the calculation of risk is provided in Appendix A.

As required by the NSW Aquifer Interference Policy (DPI, 2012), Dr Noel Merrick (HydroAlgorithmics) is the third party reviewer for the recalibration of the numerical model and the predictive simulations, including the uncertainty analysis.

Table 1-1 Summary of risk assessment

Step	Risk rating	How incorporated into groundwater model
Groundwater Aquifers above Lithgow seam - (including Shallow Quaternary Alluvial Triassic)	Low	Included in the model but no specific action required
Groundwater Aquifers in and immediately above Lithgow seam - Permian	Low	Included in the model but no specific action required
Regional Groundwater - Regional aquifers - Permian below the Lithgow seam and any associated Groundwater Dependent Ecosystems (GDEs)	Low	Included in the model but no specific action required
Groundwater landholder bores	Low	Included in the model but no specific action required.
Groundwater monitoring bores	Medium	Included in the model but no specific action required. Medium risk assigned due to limited redundancies in existing groundwater monitoring network.
Groundwater Dependent Ecosystems	Low	Included in the model but no specific action required
Groundwater licensing	Low	Included in the model but no specific action required
Surface and groundwater connectivity	Low	Included in the model but no specific action required
Groundwater quality	Low	Included in the model but no specific action required
HMR parameters considered in recalibration	Low	Included in the model but no specific action required
Surface water users	Low	Included in the model but no specific action required
Cumulative impacts	Low	Included in the model but no specific action required

1.2 Chronology of model development and review

The chronology of the development of the groundwater model for Airly Mine is as follows:

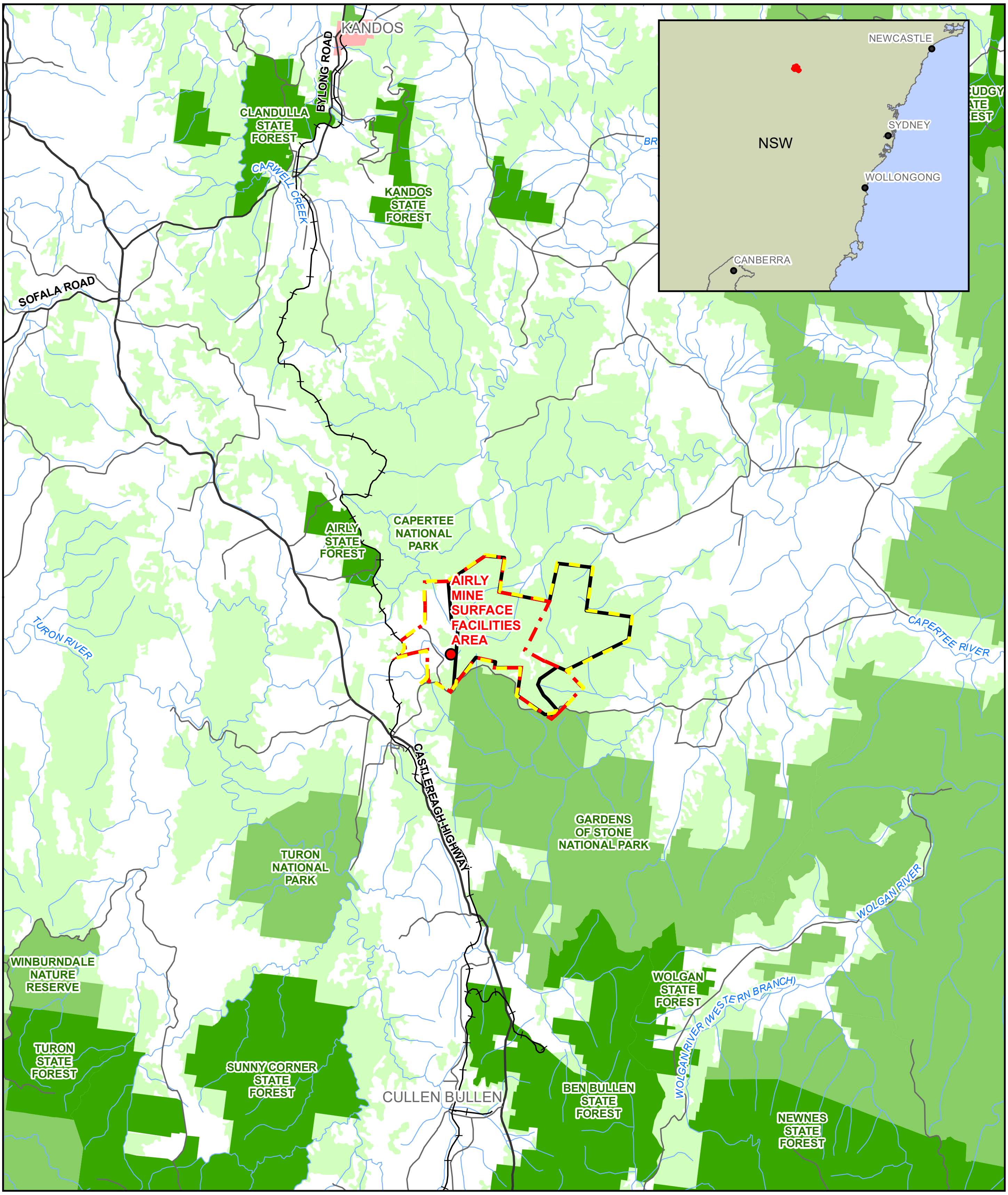
- The original model was developed by GHD in 2013 to inform the GIA for the Airly Mine Extension Project.
- An independent peer review of the original groundwater model was undertaken in 2014 by Dr Noel Merrick (HydroAlgorithmics, 2014).
- Comments from the independent peer review were addressed by GHD and incorporated into the final version of the Hydrogeological Model Report (GHD, 2014).
- The original model was found to over-predict groundwater inflows into the mine workings between 2015 and 2017 and under-predict drawdown in the Lithgow Seam and Marrangaroo Formation at one monitoring location, and was therefore updated by GHD in 2017 to better predict observed flows and drawdown (GHD, 2017).
- The recalibrated model was used to predict groundwater inflows and drawdown associated with the extraction of coal at mining rates of 1.8 million tonnes per annum (Mtpa) and 2.4 Mtpa (GHD, 2017).
- Additional groundwater monitoring locations were installed at Airly Mine in late 2016 and January 2017. Monitoring of these locations commenced in 2017.
- An independent peer review of the recalibrated model was undertaken in 2018 by Dr Noel Merrick (HydroAlgorithmics, 2018).
- The recalibrated model was updated to address comments from the independent model review (HydroAlgorithmics, 2018) and incorporate data from groundwater monitoring locations installed in late 2016 and January 2017.
- An independent peer review of this report was undertaken by Dr Noel Merrick (Appendix D). All outstanding comments from the review have been addressed in this report.

1.3 Assumptions

The report relies on a combination of existing data and site-specific data supplied by the client specifically for the Project including but not limited to:

- Surfaces from the mine geological model.
- Borehole logs and other relevant geological data.
- Bore/piezometer construction details and depth.
- Piezometric head measurements.
- Hydraulic testing data.
- Hydrological (surface water level) data.
- Topographical data.
- Pumping from the production bore was assumed to have negligible impact on groundwater levels in the vicinity of the underground workings as discussed in GHD (2019) and therefore pumping from the production bore was not included in the model.

A numerical groundwater model is a mathematical representation of a complex natural environment where parameters and processes can only be inferred from a finite number of measurements. Simplifications and assumptions are necessary in modelling. Efforts have been made to provide clarity on the data used to support the modelling and associated limitations. Findings presented in this report should be considered in this context.



LEGEND

- Airly Surface Facilities Area
- Project Approval Area SSD_5581
- Mining Lease ML1331
- Authorisation A232
- Existing rail
- Dual carriageway
- Principal road
- Secondary road
- Minor road
- Waterway
- Built up area
- Recreation area
- Forest or shrub
- Nature conservation
- State forest

Paper Size A4

0 1,000 2,000 4,000 6,000 8,000

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

Centennial Airly

Airly Mine
Airly Mine Mod 3
Hydrogeological Model Report

Job Number	22-19275
Revision	0
Date	7 Jun 2019

Locality plan

Figure 1-1

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

G:\22\0105001\GIS\Maps\Deliverables\Western\Airly\2219275\HMR\2219275_HMR001_Locality_A.mxd

Data source: @ Commonwealth of Australia (Geoscience Australia): 250K Topographic Data Series 3 2006; Centennial: Boundaries. Created by: smacdonald

2. Hydrogeological conceptualisation

The original hydrogeological conceptual model is outlined in Section 4 of GHD (2014) with a schematic representation of the local hydrogeology provided in Figure 4-2 of that report and reproduced in this report as Figure 2-1.

The local groundwater sources within the Project Application Area are generally low yielding and predominantly within the Quaternary alluvium, weathered and/or fractured sandstone and coal seams that occur within Mount Airly and Genowlan Mountain. They are classified as 'less productive' in accordance with the criteria specified in the NSW Aquifer Interference Policy (i.e. the yield is typically less than 5 L/s and/or the total dissolved solids concentration is typically greater than 1,500 mg/L). These local groundwater sources are confined to the Project Application Area since their outcrop boundaries occur entirely within this area. As shown in Figure 2-1, these sources are recharged by rainfall and discharge as seepage along the mountain slopes.

The regional groundwater sources occur within the Shoalhaven Group below the target coal seam, as well as within the underlying metamorphic rocks. These sources are also generally low yielding and discontinuous, with higher yields attributable to geological structures.

Further details are provided below.

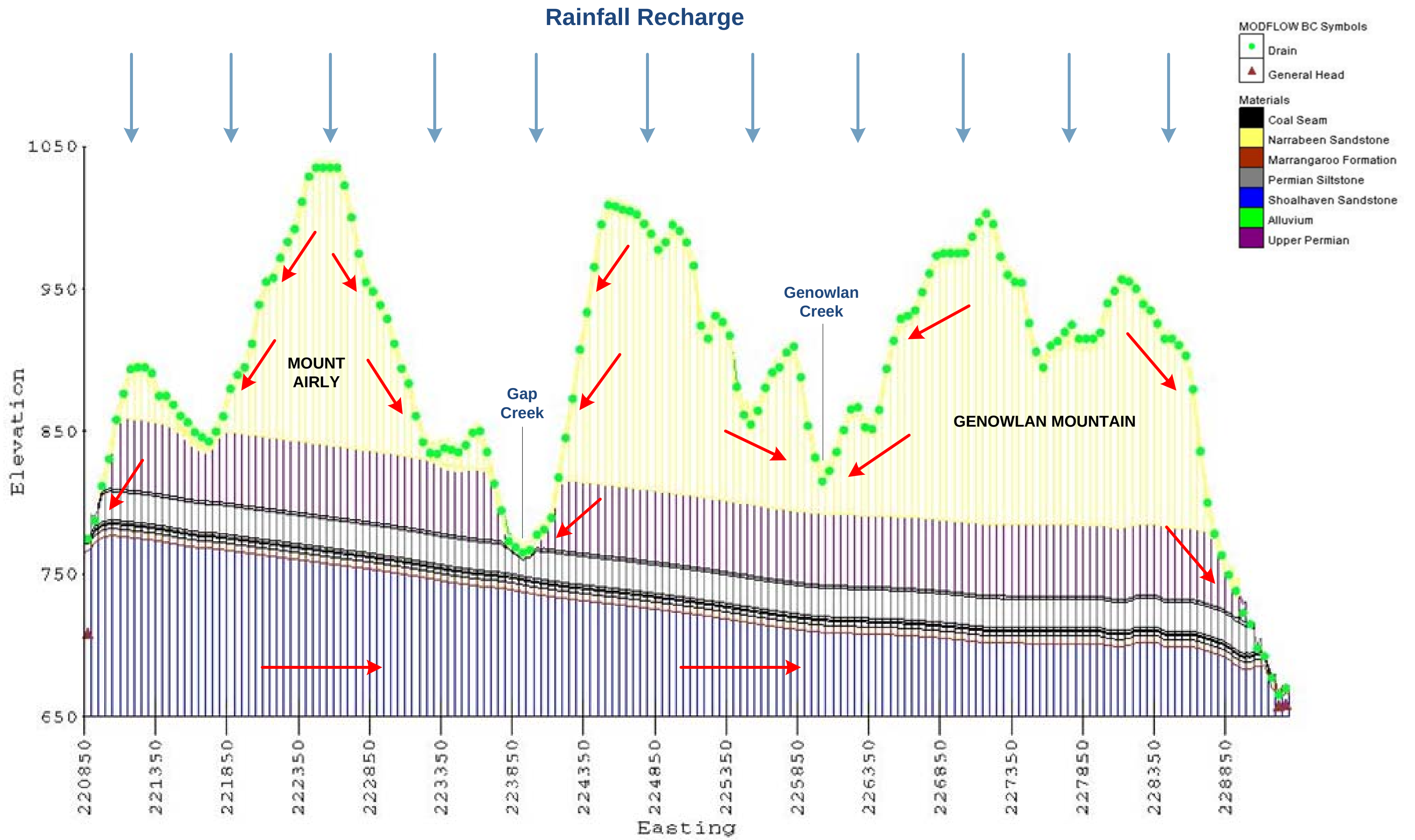
2.1 Rainfall

Daily rainfall data were obtained as SILO Patched Point Data from the Queensland Climate Change Centre of Excellence. SILO Patched Point Data is based on historical data from a particular Bureau of Meteorology (BOM) station with missing data 'patched in' by interpolating with data from nearby stations.

For this assessment, SILO data was obtained for BOM Ilford (Warrangunyah) Station (station number 62031), which is located approximately 29 km north-west of Airly Mine. This station was chosen based on the length and quality of the data record and proximity to the site.

The period of rainfall data used for model calibration extended from January 1901 to May 2018 and is summarised as annual totals in Figure 2-2. Net rainfall recharge for the model was generally applied uniformly across Layer 1 and calculated to be 3.29 x 10^{-5} m/day based on 2% of average annual rainfall.

The SILO dataset from the BOM Ilford (Warrangunyah) Station was also used to generate a cumulative rainfall departure (CRD) curve over the period from 1901 to 2018. The CRD curve has been presented from 2011 to 2018 (period of groundwater monitoring data) in Figure 2-3. A CRD curve is the monthly accumulation of the difference between the observed monthly rainfall and long-term average monthly rainfall. Any increase in the CRD curve reflects above average rainfall while a decrease in CRD curve reflects below average rainfall. The CRD curve only deviates from zero due to atypical (above and below average) rainfall. The CRD curve was generally reducing between 2012 and 2015 with CRD generally increasing during 2016 and again reducing since 2017.



GHD

Groundwater Flow Direction

LOCATION	Airly
SEAM	Lithgow
DRAWN	SM
CHECKED	SG
APPROVED	SG
SCALE	NTS

Airly Mine
Hydrogeological Model Report

Groundwater Conceptual Model for Airly

Centennial Airly

DATE Oct 2013

Figure 2-1

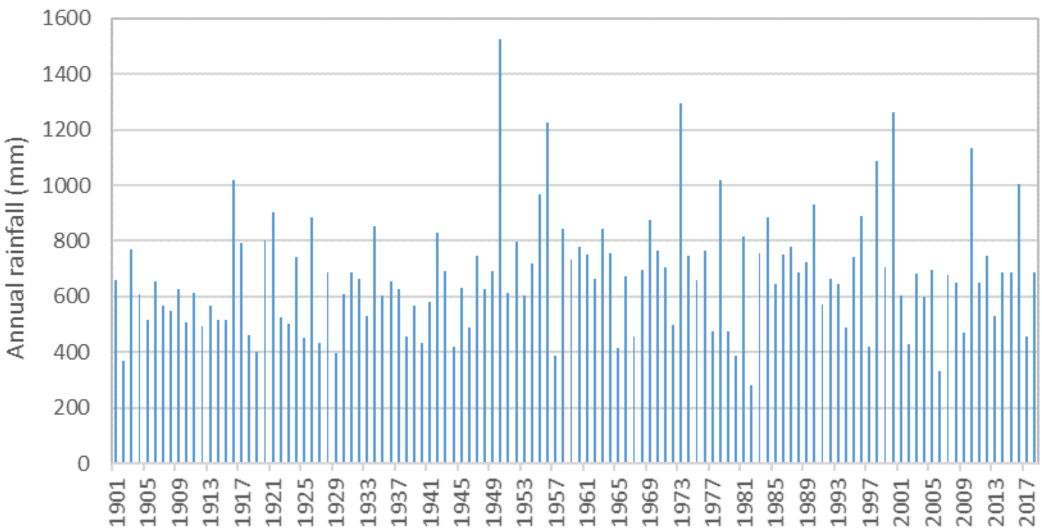


Figure 2-2 Annual rainfall recorded at Illford (Warrangunyah) Station

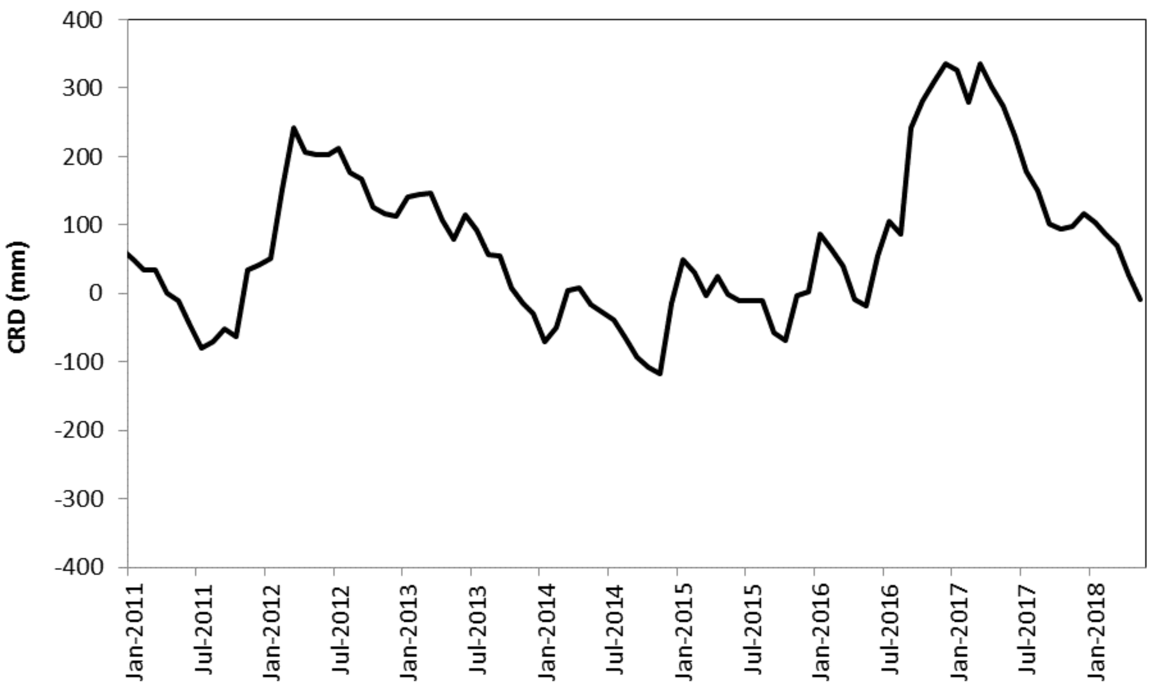


Figure 2-3 Cumulative rainfall departure curve 2011 – 2018

2.2 Hydrology

Watercourses within and in the vicinity of the Development Consent Area include four major sub-catchments areas:

- The Torbane-Oaky Creek sub-catchment.
- The Airly-Coco Creek sub-catchment.
- The Emu Swamp Creek sub-catchment.
- The Gap-Genowlan Creek sub-catchment.

All sub-catchments drain into the Capertee River which flows in a south-easterly direction and is a tributary of the Colo River, which ultimately flows into the Hawkesbury River and Broken Bay. Sub catchments are shown in Figure 3-1 of the GIA (GHD, 2019).

The Gap-Genowlan Creek sub-catchment occupies the largest portion of the Development Consent Area with 1,558 ha draining to the creek system.

Figure 2-4 and Figure 2-5 presents hydrographs of surface water flow at Gap Creek and Genowlan Creek respectively. The hydrographs indicate a behaviour typical of ephemeral creek systems, with the surface water level increasing following episodic rainfall events and effectively falling to zero during dry periods when there is insufficient rainfall and runoff to maintain surface water flow.

Note that streamflow data are not available for 2016 at Genowlan Creek due to a malfunctioning data logger.

The streamflow data do not show any continuous baseflow from a permanent water table but rather indicates that baseflow would generally be short in duration following rainfall events and characteristic of unsaturated, perched flow conditions.

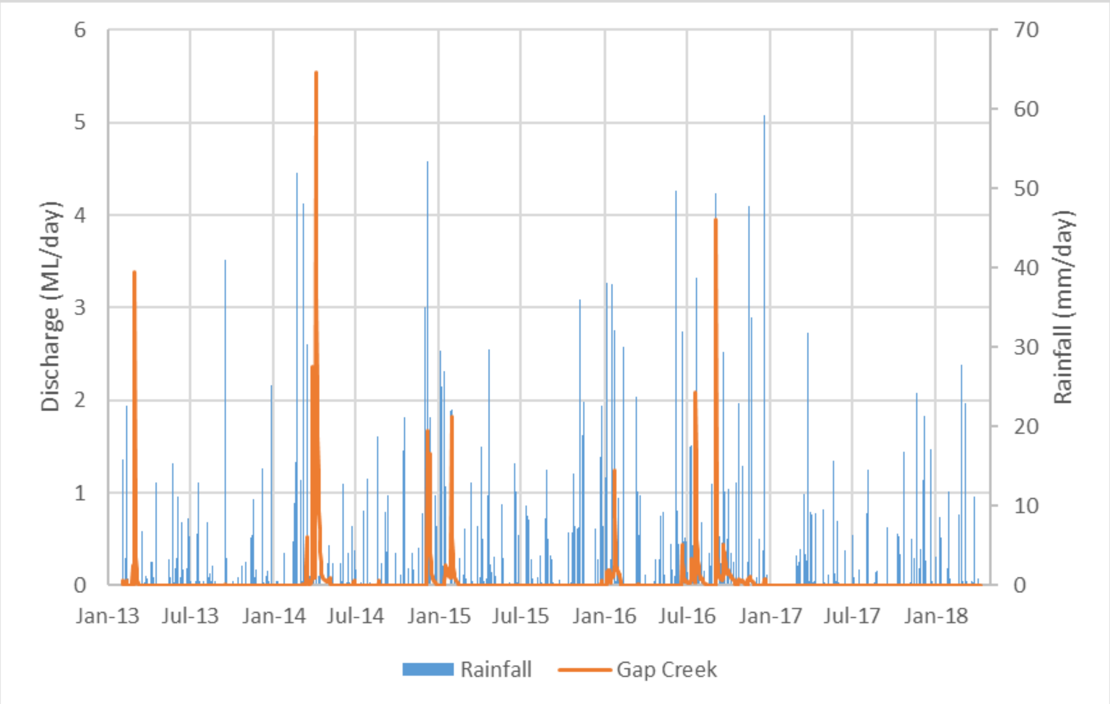


Figure 2-4 Rainfall and streamflow data for Gap Creek

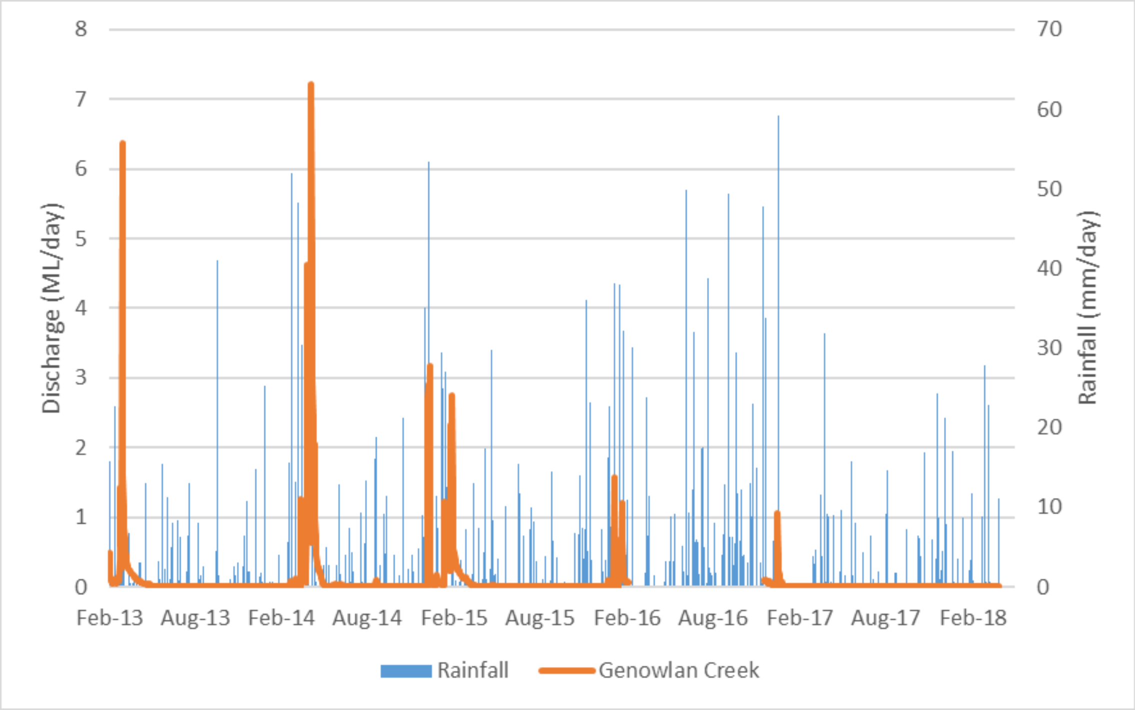


Figure 2-5 Rainfall and streamflow data for Genowlan Creek

2.3 Hydraulic properties

Results of packer testing and falling head testing reported by RPS (2013) indicate the following hydraulic conductivities:

- Narrabeen Sandstone: 0.002–0.15 m/day (based on two packer tests at ARP01, one packer test at ARP02A and one falling head test at ARP03A).
- Lithgow Seam: 0.02–0.08 m/day (based on packer tests at ARP01 and ARP04 and falling head tests at ARP02A and APR03A).

Packer testing reported by GHD (2014) indicates the following hydraulic conductivities:

- Narrabeen Sandstone: 0.00015 m/day (ARP06).
- Lithgow Seam: 0.07 m/day (ARP06).

Additional packer testing undertaken by Highland Drilling and GHD in December 2016 and reported in GHD (2016) indicated the following hydraulic conductivities:

- Marrangaroo Formation: 0.027 m/day (ARP13).
- Upper Shoalhaven Group: 0.0027 (ARP13).

No field testing to estimate aquifer storage properties has been undertaken.

2.4 Groundwater monitoring program

The groundwater monitoring network at Airly Mine primarily targets the localised low yielding groundwater sources within the Quaternary alluvium, weathered and/or fractured sandstone and coal seams that occur within Mount Airly and Genowlan Mountain above the target seam. Some monitoring of the regional groundwater system beyond the outcrop of the target seam is also undertaken.

2.4.1 Groundwater monitoring network

Groundwater level data are available from standpipe monitoring bores and vibrating wire piezometers (VWPs) constructed at Airly Mine. Existing groundwater monitoring location details are summarised in Table 2-1 and locations are shown in Figure 2-6.

Table 2-1 Groundwater monitoring locations

Monitoring type	Location name	Period of data	Ground level (m AHD)	Lithology
VWP	ARP01	June 2012–present Data logger stopped recording values for the Narrabeen Sandstone in December 2015	1027.96	Narrabeen Sandstone (74 m bgl)
				Irondale Seam (238.5 m bgl)
				Lithgow Seam (260 m bgl)
				Marrangaroo Formation (263 m bgl)
	ARP02A	May 2012–present	1022.68	Narrabeen Sandstone (65 m bgl)
				Irondale Seam (243 m bgl)
				Lithgow Seam (266 m bgl)
				Marrangaroo Formation (270 m bgl)
	ARP03A	July 2012–present	1001.66	Narrabeen Sandstone (136 m bgl)
				Middle River Seam (165 m bgl)
				Lithgow Seam (252 m bgl)
				Marrangaroo Formation (257 m bgl)
	ARP04	April 2012–present	762.66	Lithgow Seam (25 m bgl)
				Marrangaroo Formation (28.5 m bgl)

Monitoring type	Location name	Period of data	Ground level (m AHD)	Lithology
				Shoalhaven Siltstone (210.3 m bgl)
	ARP06	June 2013–present	1028.5	Narrabeen Sandstone (230 m bgl)
				Irondale Seam (252 m bgl)
				Lithgow Seam (288 m bgl)
				Marrangaroo Formation (295 m bgl)
	ARP07	July 2013–present	992.6	Middle River Seam (168 m bgl)
				Lithgow Seam (252 m bgl)
	ARP08	September 2013– present	1027.7	Narrabeen Sandstone (183 m bgl)
				Irondale Seam (282.5 m bgl)
	ARP13	December 2016–present [1]	785.6	Shoalhaven Group (120 m bgl)
				Devonian strata (280 m bgl)
	ARP15	January 2017–present [1]	846.7	Lithgow Seam (125 m bgl)
				Shoalhaven Group (200 m bgl)
				Devonian strata (365 m bgl)
Bore/standpipe	AM2B-1	2009–present (quality only)	Unknown	Shoalhaven Group (38–87 m bgl)
	ARP05	August 2012–present	757.22	Gap Creek alluvium (8–11 m bgl)

Monitoring type	Location name	Period of data	Ground level (m AHD)	Lithology
	ARP07	July 2013– present (dry)	992.6	Narrabeen Sandstone (110–119 m bgl)
	ARP08	September 2013– present	1027.7	Lithgow Seam (301–305 m bgl)
	ARP09	June 2013– present (mostly dry)	856.86	Genowlan Creek alluvium (3–4 m bgl)
	ARP11	January 2017– present	750.92*	Permian strata (1.25–15.3 m bgl)
	ARP12	January 2017– present	895.185*	Genowlan Creek alluvium (0.5–2.6 m bgl)
	ARP13SP	January 2017– present	785.74*	Lithgow Seam (67.5–70.5 m bgl)
	ARP14	January 2017– present	783.944*	Genowlan Creek alluvium (0.5–2.3 m bgl)
	ARP15SP	January 2017– present	847.525*	Narrabeen Sandstone (10–16 m bgl)
	Nioka	2013, January 2018 – present (quality only)	Unknown	Permian strata
Seepage	Village Spring	February 2011– present	Unknown	Permian Siltstone
	Mine workings	December 2009– present	N/A	Lithgow Seam

*Elevation for ARP11, ARP12, ARP13SP, ARP14 and ARP15SP is the top of casing elevation

2.4.2 Vibrating wire piezometers

Piezometric head data for VWPs for selected hydrographs utilised as part of model recalibration are plotted in Appendix B. Only those VWPs recording positive pressure have been utilised as part of model recalibration. Generally there is minimal variability in piezometric head over the monitoring period.

Groundwater monitoring data for all VWPs and standpipe monitoring bores is shown in Appendix C. Where mining has approached certain monitoring locations, this has been indicated on the hydrographs. Hydrographs have been annotated to denote VWPs that are recording negative pressure.

Piezometric pressure is generally low and stable at the existing VWP monitoring locations, generally ranging from 0 m to 10 m above the measuring point elevation. The low piezometric pressure is considered to reflect the extensive groundwater seepage/drainage area across the slopes of Mount Airly and Genowlan Mountain.

Decreasing piezometric pressure associated with mining in the Lithgow Seam was observed within the Lithgow Seam and the Marrangaroo Formation at one location (ARP04) during late 2015 and during 2016 (GHD, 2017). Piezometric pressure was observed to fall approximately 7 m at ARP04 in the Lithgow Seam and the Marrangaroo Formation between December 2015 and May 2016. No other groundwater drawdown attributable to mining operations has been observed.

2.4.3 Standpipe monitoring bores

Groundwater hydrographs utilised as part of transient calibration are presented in Appendix B. Groundwater hydrographs for all VWPs and standpipe monitoring bores are presented in Appendix C. Groundwater hydrographs presented in Appendix C have been plotted with the rainfall CRD curve.

Groundwater hydrographs (Figure C-5) indicate that ARP05 installed in the Gap Creek alluvium, and ARP09 (Figure C-9) and ARP12 (Figure C-11) installed within the Genowlan Creek alluvium, are generally dry. Groundwater levels at these alluvial monitoring bores show response to periods of above average rainfall.

Review of groundwater levels at ARP05 indicates a generally decreasing trend between the commencement of monitoring in 2012 and 2016. Mining at Airly Mine under the Gap Creek catchment commenced in 2015. Statistical analysis indicated that the decreasing trend in groundwater level at ARP05 commenced prior to mining in the Gap Creek catchment commencing. Therefore, although the decreasing trend in groundwater level at ARP05 may have some contribution from mining, it is also a continuation of pre-mining trends.

Groundwater levels at ARP14 (Figure C-14), installed in the Genowlan Creek alluvium have remained relatively constant over the period of monitoring.

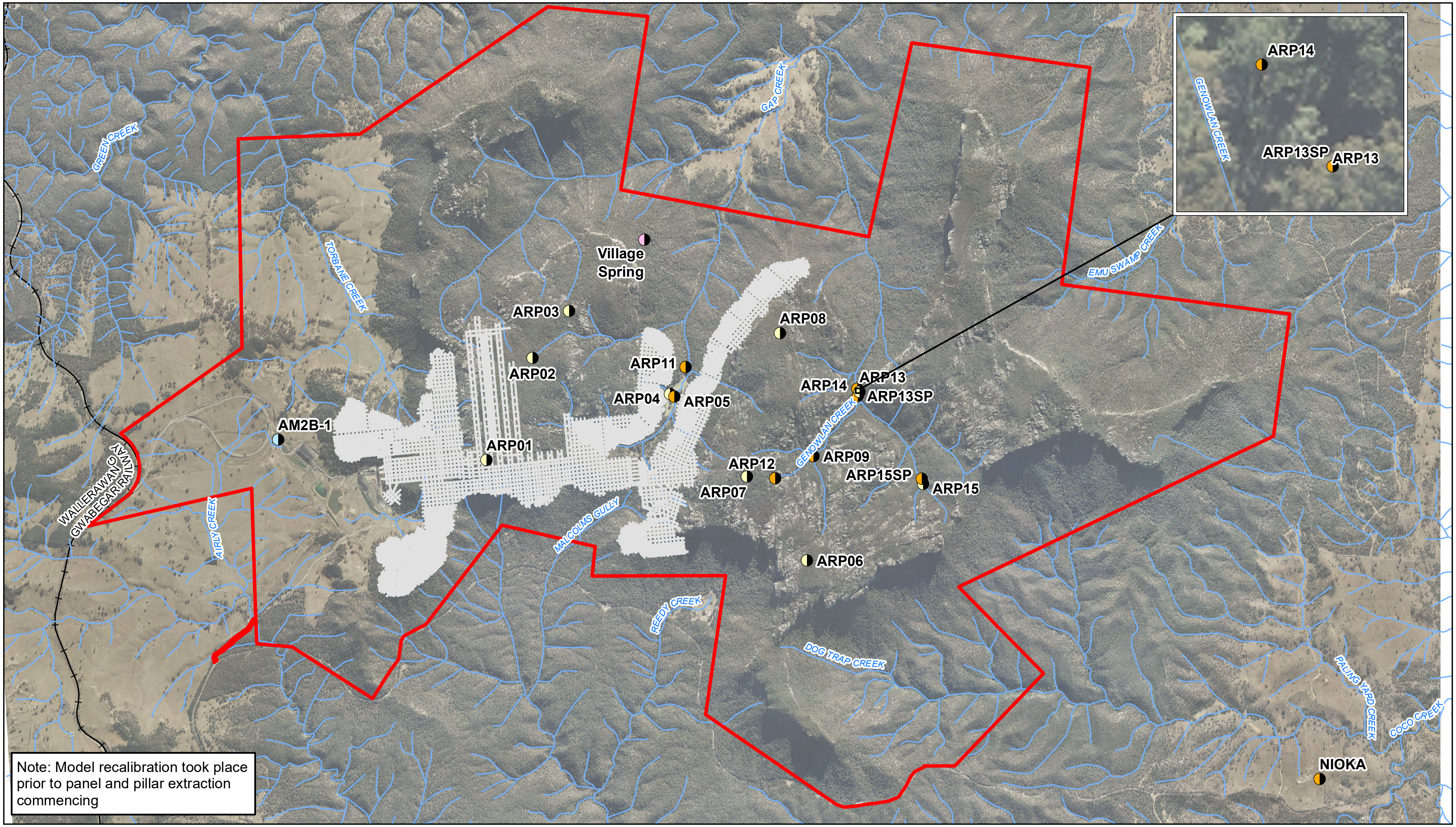
Groundwater levels at ARP11 (Figure C-10), installed in the shallow strata near the Gap Creek alluvium shows a generally decreasing trend throughout 2017 and early 2018. This decreasing trend is potentially related to generally below average rainfall over the monitoring period. Groundwater levels at ARP11 appear to generally fluctuate by up to 0.1 m following rainfall events, with a fluctuation in groundwater level of approximately 0.5 m following rainfall in February 2017.

Groundwater levels at ARP13SP (Figure C-12), installed in the Lithgow Seam, have been very constant over the monitoring period. Groundwater levels at ARP15SP (Figure C-15), installed in the Narrabeen Sandstone, were generally decreasing between the commencement of monitoring in January 2017 and November 2017. Groundwater levels at ARP15SP displayed a response to rainfall with groundwater levels varying up to approximately 2.5 m during late 2017 and during 2018 with two distinct rain responses in 2018.

2.4.4 Groundwater flow directions

Groundwater flow directions in the area of Airly Mine have been interpreted from contours of piezometric heads presented in Figure 2-7, Figure 2-8 and Figure 2-9. The contours are presented separately for the Lithgow Seam, Marrangaroo Formation and the Shoalhaven Group using monitoring data from standpipe bores and VWPs installed in each of these formations. The groundwater level data from 2017 have been used to generate the contours to take advantage of data collected from monitoring locations installed in late 2016 and early 2017. The figures can be considered an approximately synchronous dataset, providing a snapshot of the piezometric surface in 2017.

The contours of the piezometric surface indicate that the groundwater flow direction within the Lithgow Seam, Marrangaroo Formation and Shoalhaven Group is from the west to the east. It should be noted that the eastern extent of the localised groundwater sources within the Lithgow Seam and Marrangaroo Formation is bound by the seepage areas in the vicinity of the seam outcrop. Hence, groundwater within these formations is not hydraulically connected to the regional groundwater to the east of the PAA utilised by private landholders.



Paper Size A4

0 200 400 800 1,200 1,600

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

LEGEND

- Groundwater seepage
- Production bore
- Standpipe monitoring bore
- Vibrating wire piezometer
- Existing workings
- Project Approval Area_SSD_5581
- Waterway

GHD

Airly Mine
Airly Mine Mod 3
Hydrogeological Model Report

Job Number 22-19275
Revision 0
Date 30 Aug 2019

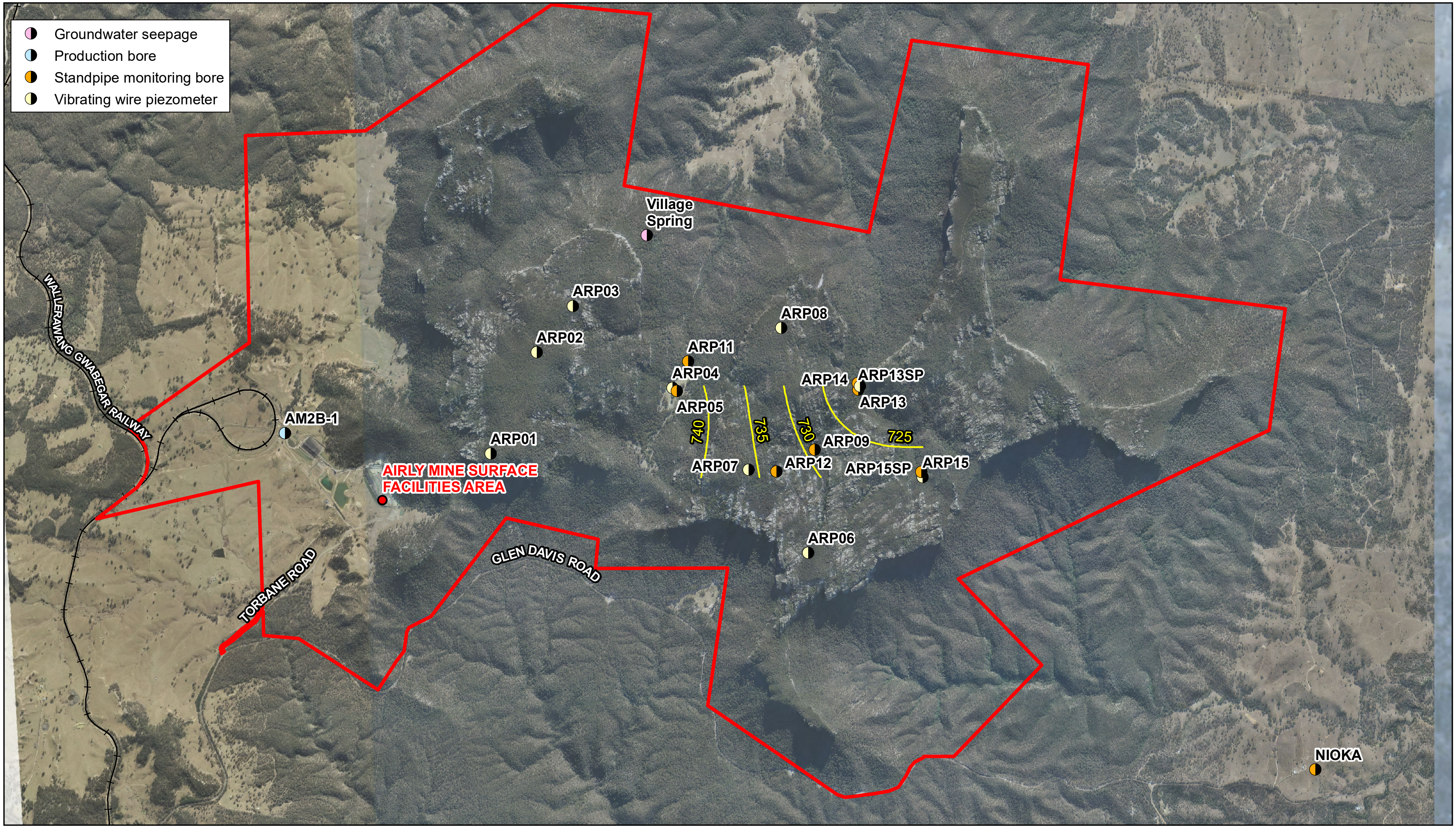
Groundwater monitoring network

Figure 2-6

G:\22\0105001\GIS\Maps\Deliverables\Western\Airly\2219275\HMR\2219275_HMR002_GWMonitoringBores_A.mxd

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

Data source: LPI: DTDB 2012; Centennial: Imagery, monitoring, boundaries, survey. Created by: smacdonald



Paper Size A4

0 300 600 900 1,200

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

LEGEND

- Project Approval Area_SSD_5581
- Airly Surface Facilities Area
- Railway
- Measured Piezometric Contour (m AHD)

GHD

Centennial Airly

Airly Mine
Airly Mine Mod 3
Hydrogeological Model Report

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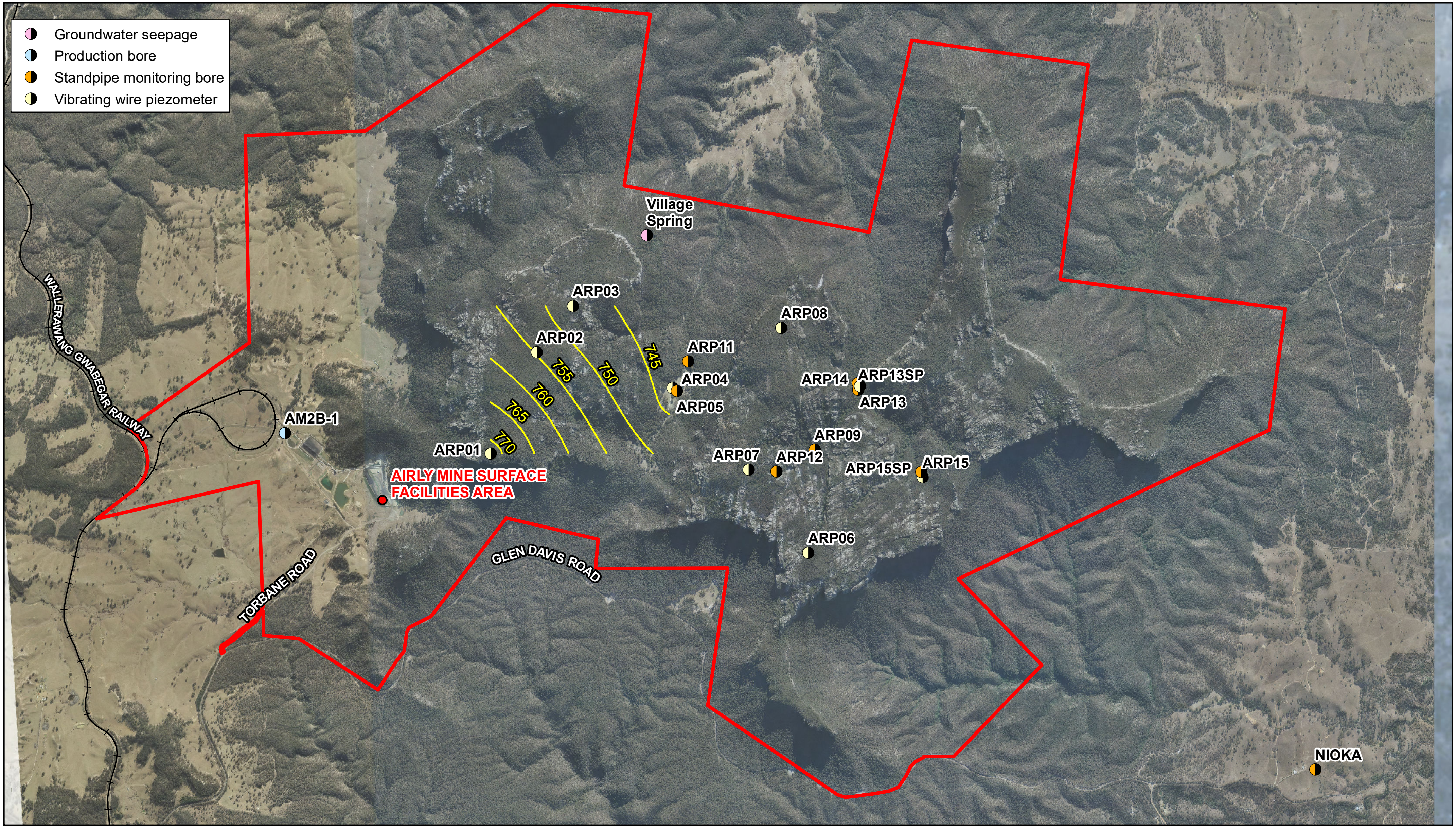
Measured Piezometric Contours
Lithgow Seam

Figure 2-7

G:\22\0105001\GIS\Maps\Deliverables\Western\Airly\2219275\HMR\2219275_HMR003_Contours_Lithgow_A.mxd

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

Data source: LPI: DTDB 2012; Centennial: Aerial Imagery, boundaries, 2013, GHD: groundwater contours, 2017. Created by: igilmore



Paper Size A4

0 300 600 900 1,200

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

LEGEND

- Project Approval Area_SSD_5581
- Airly Surface Facilities Area
- Railway
- Measured Piezometric Contour (m AHD)

GHD

Centennial Airly

Airly Mine
Airly Mine Mod 3
Hydrogeological Model Report

Job Number	22-19275
Revision	0
Date	7 Jun 2019

Measured Piezometric Contours Marrangaroo Formation

Figure 2-8

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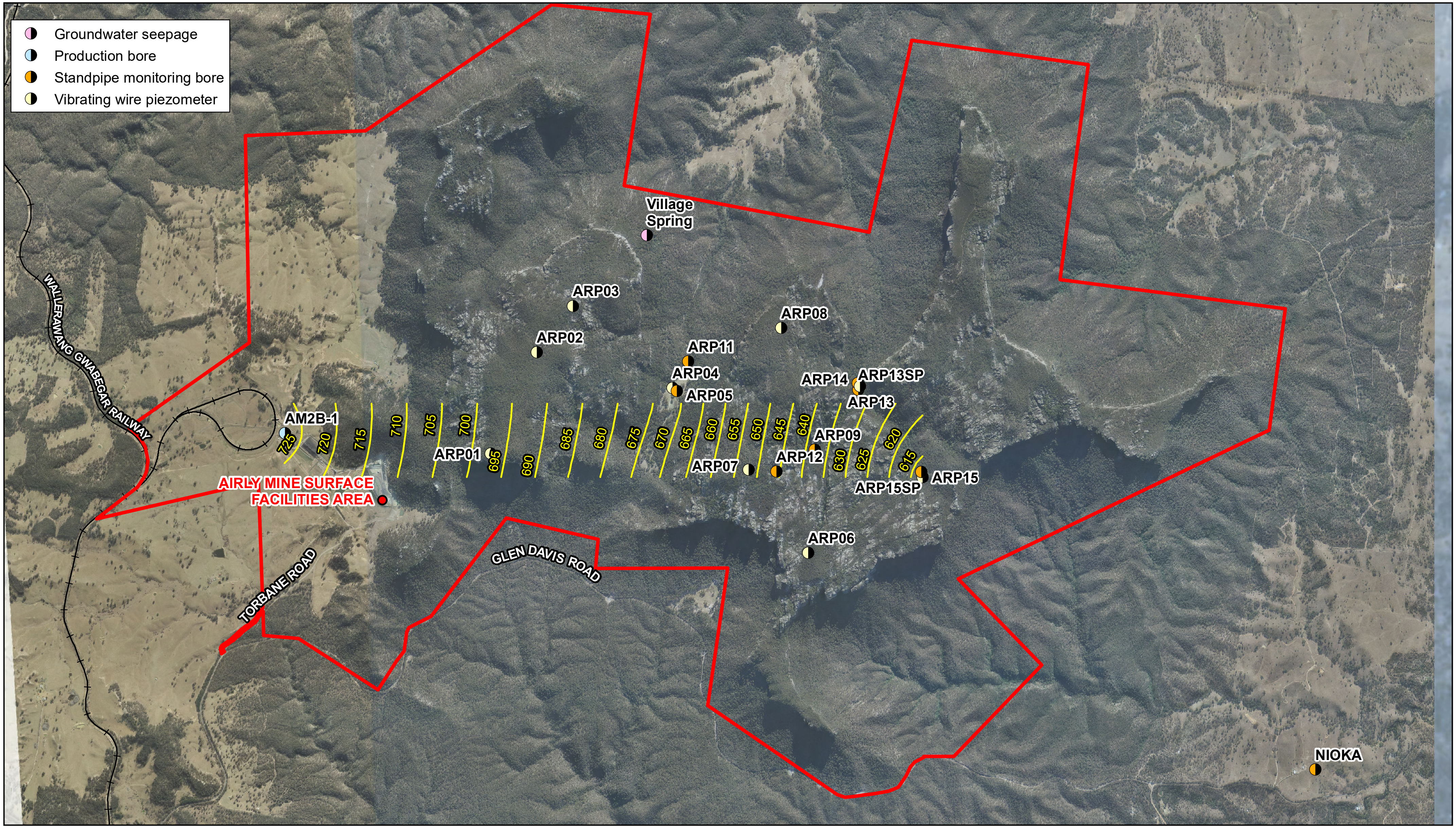
Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

Data source: LPI: DTDB 2012; Centennial: Aerial Imagery, boundaries, 2013, GHD: groundwater contours, 2017. Created by: igilmore



Paper Size A4

0 300 600 900 1,200

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

LEGEND

- Project Approval Area_SSD_5581
- Airly Surface Facilities Area
- Railway
- Measured Piezometric Contour (m AHD)

GHD

Centennial Airly

Airly Mine
Airly Mine Mod 3
Hydrogeological Model Report

Job Number	22-19275
Revision	0
Date	7 Jun 2019

Measured Piezometric Contours Shoalhaven Group

Figure 2-9

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Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

Data source: LPI: DTDB 2012; Centennial: Aerial Imagery, boundaries, 2013, GHD: groundwater contours, 2017. Created by: igilmore

2.4.5 Groundwater seepage

The rate of seepage of groundwater from the Permian strata at Village Spring has been monitored since February 2011. A plot of the daily flow rate at Village Spring is shown in Figure 2-10. It is reported by Centennial Airly that the seep at Village Spring is fed by drainage from the old shale workings, which exist in the mining area identified as the New Hartley Shale Mine Potential Interaction Zone. The New Hartley Shale Mine Potential Interaction Zone is shown in Appendix F.

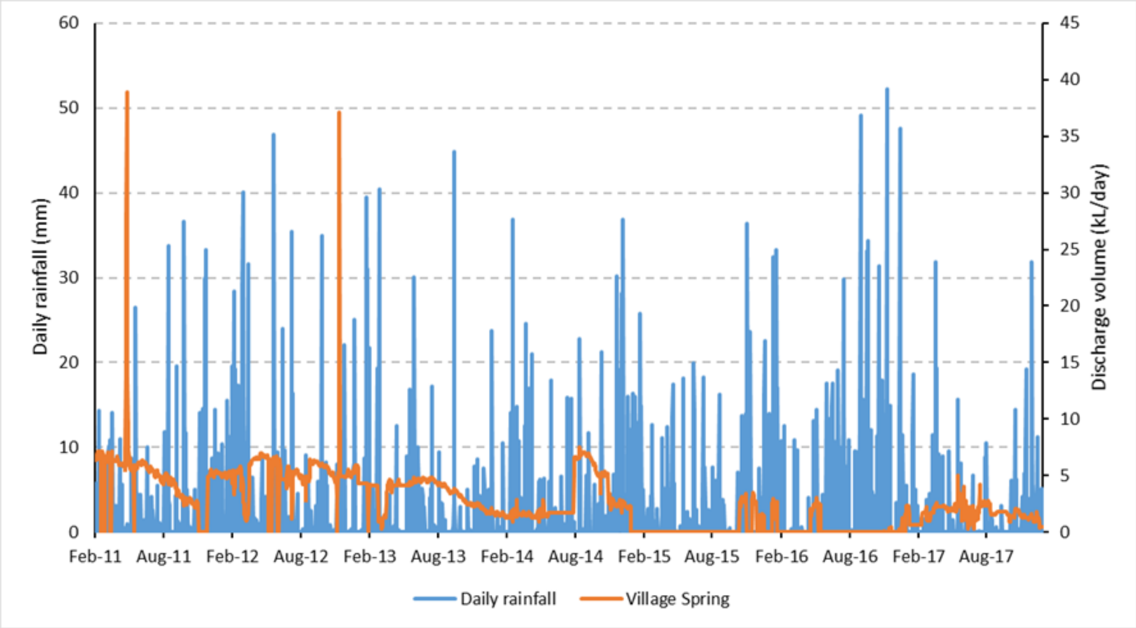


Figure 2-10 Recorded flows at Village Spring

3. Model update and calibration

As discussed in Section 1.2, the existing hydrogeological model was developed by GHD and reported in GHD (2014). This chapter outlines work undertaken as part of the update and recalibration of the hydrogeological model.

The model is considered to generally have the characteristics of class 2 confidence level (i.e. moderate confidence), in accordance with the confidence level classification of the Australian Groundwater Modelling guidelines (Barnett et al, 2012). A comparison of the calibrated model and the AGMG confidence level classifications is shown in Appendix E.

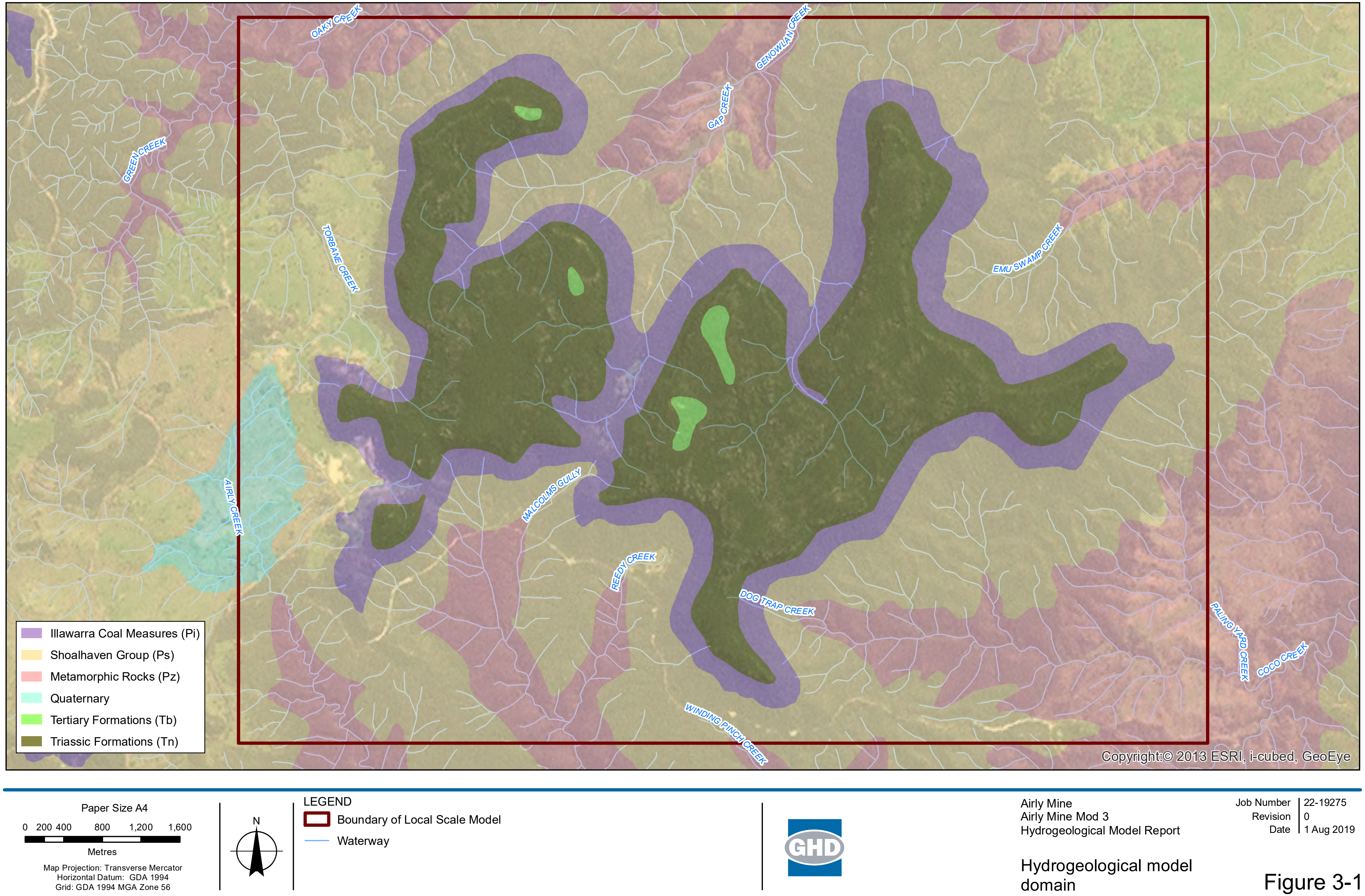
3.1 Model construction

Model construction details for the original model are outlined in Section 5 of GHD (2014). The original model included 10 layers. As part of the previous model update undertaken in 2017 (refer to Section 1.2), layer 10 (Shoalhaven Group) was split into three layers (equal thickness through each column of the grid) to improve the fit between observed and modelled levels for the Shoalhaven Group.

Model layers and top and base elevations are outlined in Table 3-1. The elevation of layers in the model is based on geological data provided by Centennial Airly.

Table 3-1 Model layers

Layer	Description	Top	Base
1	Shallow zone/alluvium	Topographic contours	Topographic contours - 10 m
2	Narrabeen Sandstone	Topographic contours - 10 m	Lithgow Seam roof + 75 m
3	Permian Interburden	Lithgow Seam roof + 75 m	Lithgow Seam roof + 25 m
4	Irondale Seam	Lithgow Seam roof + 25 m	Lithgow Seam roof + 23 m
5	Permian Interburden	Lithgow Seam roof + 23 m	Lithgow Seam roof + 3 m
6	Irondale Seam	Lithgow Seam roof + 3 m	Lithgow Seam roof + 1 m
7	Permian Interburden	Lithgow Seam roof + 1 m	Lithgow Seam roof elevation data
8	Lithgow Seam	Seam elevation data	Seam elevation data
9	Marrangaroo Formation	Lithgow Seam floor elevation data	Lithgow Seam floor - 5 m
10-12	Shoalhaven Group	Lithgow Seam floor - 5 m	450 m AHD



Airly Mine
Airly Mine Mod 3
Hydrogeological Model Report

Job Number	22-19275
Revision	0
Date	1 Aug 2019

Hydrogeological model domain

Figure 3-1

G:\22\0105001\GIS\Maps\Deliverables\Western\Airly\2219275\HMR\2219275_HMR006_ModelBoundary_A.mxd

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

Data source: LPI: DTDB 2012; ESRI: Imagery. Created by: smacdonald

Numerical modelling was undertaken using the MODFLOW-NWT solver with the Upstream Weighting flow package. MODFLOW-NWT is a version of MODFLOW 2005 that provides a different formulation of the groundwater flow equation (Newton formulation) designed to solve models that are non-linear due to unconfined cells or non-linear boundary conditions. MODFLOW 2005 is a three-dimensional finite difference groundwater flow model from the United States Geological Survey and is one of the industry standard codes for numerical groundwater modelling. The model was originally built using the Groundwater Modelling System (GMS) graphical user interface (version 8.2) (GHD, 2014). Update and recalibration of the model was undertaken in GMS graphical user interface version 10.2.

The hydrogeological domain shown in Figure 3-1 covers approximately 75 km^2, extending from N: 6329500 and E: 220000 in the southwest to N: 6337000 and E: 230000 in the northeast. The area has been divided into a grid consisting of 200 columns and 150 rows, generating equally sized cells with dimensions 50 m × 50 m. Active and inactive cells were defined by the available geological data and geological boundaries. The model has 12 layers with 12,632 active cells per layer, giving a total of 151,584 active cells.

3.2 Model recalibration

Model calibration involves changing the values of model parameters within bounds until the model outputs fit historical measurements, such that the model can be accepted as a reasonable representation of the physical system of interest (Barnett et al. 2012). Recalibration of the hydrogeological model was initially undertaken manually under steady state conditions.

The primary calibration targets are observed groundwater levels (heads). Calculated water levels from VWPs with negative water pressures were not used in calibration.

The calibrated steady state heads were used to define the initial conditions for the transient model.

3.2.1 Steady state recalibration results

Steady state recalibration was undertaken through trial and error. Approximately 50 runs have been undertaken as part of this assessment and in GHD (2017).

The lowest scaled root mean square error (SRMSE) obtained (using realistic material properties) for a converging steady state run was 5.3%. The RMS for this model run was 13.6 m. Hydrogeological properties from the best fit steady state run are summarised in Table 3-2. These hydraulic conductivity values are generally in the range of or similar order of magnitude to the field measured values outlined in Section 2.3.

Parameters that required the most changes during calibration were General Head Boundaries (GHBs) and hydraulic conductivity of the Shoalhaven Group, Marrangaroo Formation and Narrabeen Sandstone. GHBs were assigned in Layer 10, 11 and 12 of the model based on groundwater levels at the Airly Mine production bore and groundwater level data from the monitoring bores. GHBs were varied (both up and down) during recalibration.

GHBs in the Shoalhaven Group on the western boundary of the model were set to 650 m AHD. This is approximately equal to monitored groundwater levels in the production bore. GHBs in the Shoalhaven Group (Layer 10, 11 and 12) on the eastern boundary of the model were set to approximately 10 m above the top of Layer 10.

Net rainfall recharge was maintained at 3.29×10^{-5} m/day throughout steady state calibration.

Table 3-2 Hydrogeological properties after steady state calibration

Hydrogeological unit	Model layers	Horizontal hydraulic conductivity (K_h) (m/day)	Vertical hydraulic conductivity (K_v) (m/day)
Shallow zone	Layer 1	0.0548	0.00548
Alluvium	Layer 1	2	0.2
Narrabeen Sandstone	Layer 2	0.0011	0.00011
Coal seams	Layer 4, 6 and 8	0.0548	0.00548
Permian siltstone	Layer 3, 5 and 7	0.00019	0.000019
Marrangaroo Formation	Layer 9	0.0137	0.00137
Shoalhaven Group	Layer 10 and 11	0.00137	0.000137
Deep Shoalhaven Group	Layer 12	0.0548	0.00548

A scatterplot of modelled groundwater levels (best fit steady state run) versus observed levels is shown in Table 3-1. Locations that are dry or have negative water pressure have not been included in the plot.

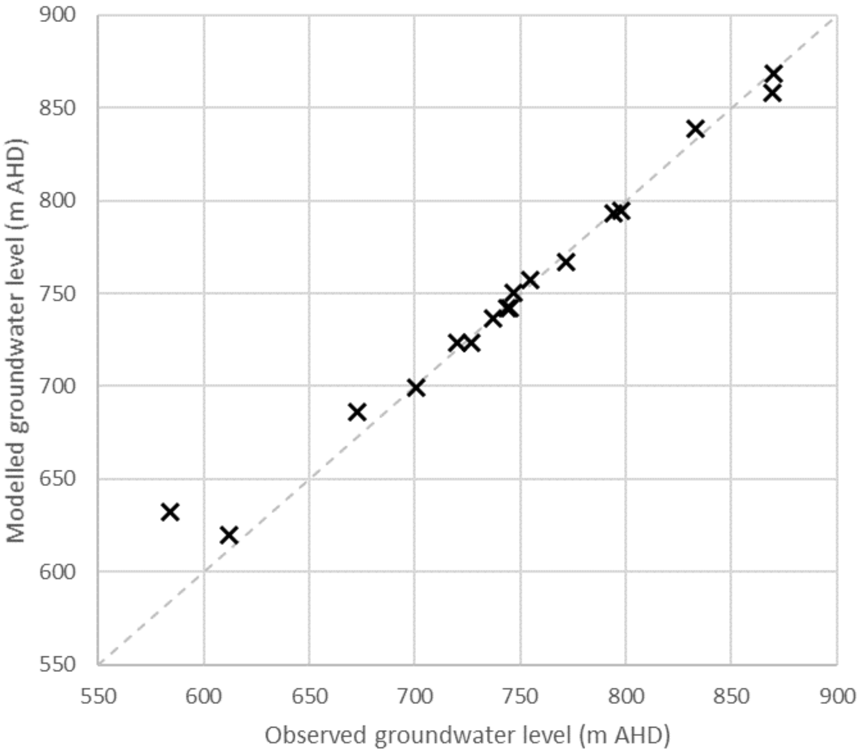


Figure 3-2 Steady state calibration scatterplot

The outlier shown in Figure 3-2 occurs at ARP13 in the Devonian strata. Modelled groundwater levels in the Devonian are partially controlled by GHB values. GHB values in the Devonian have been set with reference to GHB values in the overlying Shoalhaven Group and with reference to observed levels at installations in the Devonian (ARP13 and ARP15). It was not possible to achieve a reasonable fit at both ARP13 and ARP15 without having GHB values that did not match the conceptual model. Therefore GHB values were maintained within the range of expected values which resulted in the poor fit at ARP13 in the Devonian strata.

3.2.2 Steady state flow budget and inter-aquifer flow

The steady state flow budget is shown in Table 3-3. Flow budgets have been calculated for the entire model domain (all zones), alluvium and for the porous and fractured rock aquifers only. The model indicates that there is a net inflow of groundwater from the porous and fractured rock aquifer to the alluvium of approximately 188 ML/year under steady state conditions.

Table 3-3 Steady state flow budget

Model zone	Inputs (ML/year)				Outputs (ML/year)			
	Net Recharge	GHB*	Other Zones	Total	Seepage to surface	GHB*	Other Zones	Total
All zones	503.5	132.3	–	635.8	421.5	214.5	–	636.0
Alluvium	146.7	113.3	259.6	519.6	415.2	34.2	71.2	520.6
Porous and fractured rock	356.8	19.0	71.2	447.1	6.3	180.3	259.6	446.2

* General head boundary

3.2.3 Transient model setup and calibration

The steady state model was converted into a transient model and was initially run from 2011 to 2018 using monthly stress periods and actual rainfall data (with net recharge calculated as 2% of monthly rainfall). The modelled best fit steady state groundwater levels were used as the starting head levels for the transient model. Drain cells were established within Layer 8 to coincide with the development of existing workings within the Lithgow Seam between 2011 and 2018. It is noted that panel extraction has not yet commenced at Airly Mine and therefore no fracturing was applied during the calibration period.

Storage parameters, hydraulic conductivity values and the net recharge coefficient were varied to achieve a best fit between observed hydrographs and modelled groundwater levels. Groundwater inflows into the existing workings were also considered a calibration target, although these have been low (not measureable) to date. Calibrated hydrogeological model properties are presented in Table 3-4. Spatially uniform values for storage parameters and hydraulic conductivity were applied throughout the model. Rainfall recharge was applied uniformly across Layer 1 of the model. Best fit hydraulic conductivity values from transient calibration are generally the same as for steady state calibration with the exception of the value for the deep Shoalhaven Group.

The lowest SRMSE obtained (using realistic material properties) for a converging transient run was 4.1%. The RMS for this run was 10.5 m.

Drain conductance for drains simulating the mine workings was required to be lowered to improve the fit between modelled and observed groundwater inflow into the mine workings. Drain conductance was lowered to 0.02 m^2/day.

A scatterplot of modelled groundwater levels (best fit transient run) versus observed levels is shown in Figure 3-3. Locations that are dry or have negative water pressure were not utilised in model recalibration and therefore have not been included in the plot.

A total of 580 calibration targets were used. Transient calibration targets included monthly monitoring data from four standpipe monitoring bores (ARP11, ARP13SP, ARP14 and ARP15SP) and 13 VWPs at seven locations (ARP01, ARP02, ARP03, ARP04, ARP06, ARP13 and ARP15). Between 10 and 68 data points were used as transient calibration targets at each monitoring point depending on the length of the monitoring dataset available.

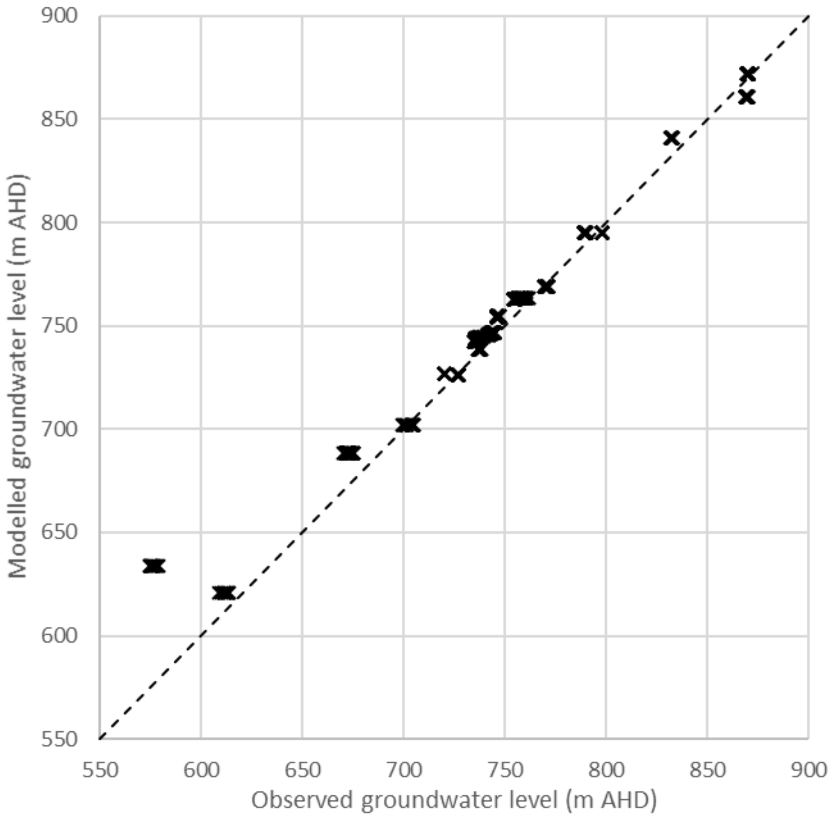


Figure 3-3 Transient calibration scatterplot

The transient calibration scatterplot indicates that the fit between modelled and observed levels at ARP13 in the Devonian strata continue to be an outlier, as discussed in Section 3.2.1. At the majority of bores the model tends to slightly overestimate groundwater levels.

Table 3-4 Calibrated model properties

Hydrogeological unit	Model layer	Horizontal hydraulic conductivity (K_h) (m/day)	Vertical hydraulic conductivity (K_v) (m/day)	Specific yield (unitless)	Specific storage (1/m)
Shallow zone	Layer 1	0.05479	0.005479	0.05	–
Alluvium	Layer 1	2	0.2	0.2	–
Narrabeen Sandstone	Layer 2	0.0011	0.00011	0.2	0.0001
Coal seams	Layer 4, 6 and 8	0.0548	0.00548	0.001	0.00001
Permian siltstone	Layer 3, 5 and 7	0.00019	0.000019	0.001	0.00001
Marrangaroo Formation	Layer 9	0.0137	0.00137	0.001	0.00001
Shoalhaven Group	Layer 10 and 11	0.00137	0.00003	0.001	0.00001
Deep Shoalhaven Group	Layer 12	0.0137	0.0003	0.001	0.00001

Comparison of calibrated model properties shown in Table 3-4 and those presented in GHD (2017) shows increased specific yield for shallow zone (Layer 1), increased hydraulic conductivity and specific yield for alluvium, decreased hydraulic conductivity for Narrabeen Sandstone, increased hydraulic conductivity for Marrangaroo Formation, slightly decreased hydraulic conductivity for Shoalhaven Group (Layer 10 and 11) and increased hydraulic conductivity for deep Shoalhaven Group (Layer 12).

Calibration hydrographs for selected monitoring locations are presented in Appendix B. Hydrographs indicate the model is slightly underestimating drawdown due to mining at ARP04 (in terms of magnitude and rate) within the Lithgow Seam and the Marrangaroo Formation. The modelled levels at ARP04 depressurise over approximately 18 months compared to the relatively sudden observed depressurisation at ARP04. It should be noted that the drawdown observed at ARP04 is within predicted levels approved under development consent SSD_5581.

Updates to the model as part of recalibration included modifying hydraulic conductivity of alluvium and varying rainfall recharge in the alluvium. The model had issues with convergence when rainfall recharge to the alluvium was varied to match the extremes in rainfall (long dry periods followed by short, intense wet events). This has also resulted in a poor calibration hydrograph at ARP15SP as the model does not replicate the short term variation in groundwater level at ARP15SP following above average rainfall events as shown in Appendix B. Additionally, the model currently underestimates the decreasing trend at ARP11.

To investigate the cause of the modelled decreasing trend in groundwater levels at ARP11, a no mining model run was undertaken for the calibration period. As shown in Appendix B, modelled groundwater levels at ARP11 over the calibration period were the same for mining and no mining scenarios. This shows that the modelled decreasing trend at ARP11 is not attributable to mining and is due to a reduction in rainfall recharge.

3.2.4 Lineaments

Lineaments at Airly Mine are shown conceptually in Figure 3-4. Assessment of fracturing and its influence on groundwater is an information requirement in IESC (2018a). Additionally, the Independent Expert Scientific Committee (IESC) recommended that additional assessment of fault zones and their potential impacts on aquifer connectivity and groundwater flow be undertaken as part of the Airly Mine Extension Project (GHD, 2015). While this recommendation of IESC was addressed by GHD (2015), observed drawdown at ARP04 had not yet occurred (refer to Section 2.4.2) and therefore an investigation was undertaken as part of the model recalibration to determine whether the drawdown at ARP04 may be attributable to lineaments that extend from the Devonian basement geology to the surface. ARP04 is located near a lineament identified in the geological structural review for Airly Mine (SRK, 2018). The location of the lineament is shown as Domain D in Figure 3-5.

This lineament has been considered as potentially forming a zone of enhanced hydraulic conductivity or alternatively as a horizontal flow barrier to groundwater flow due to potential discontinuities in geological formations.

To investigate the impact of the alternative conceptualisations on transient calibration, two alternative scenarios were considered for comparison with the best fit model run:

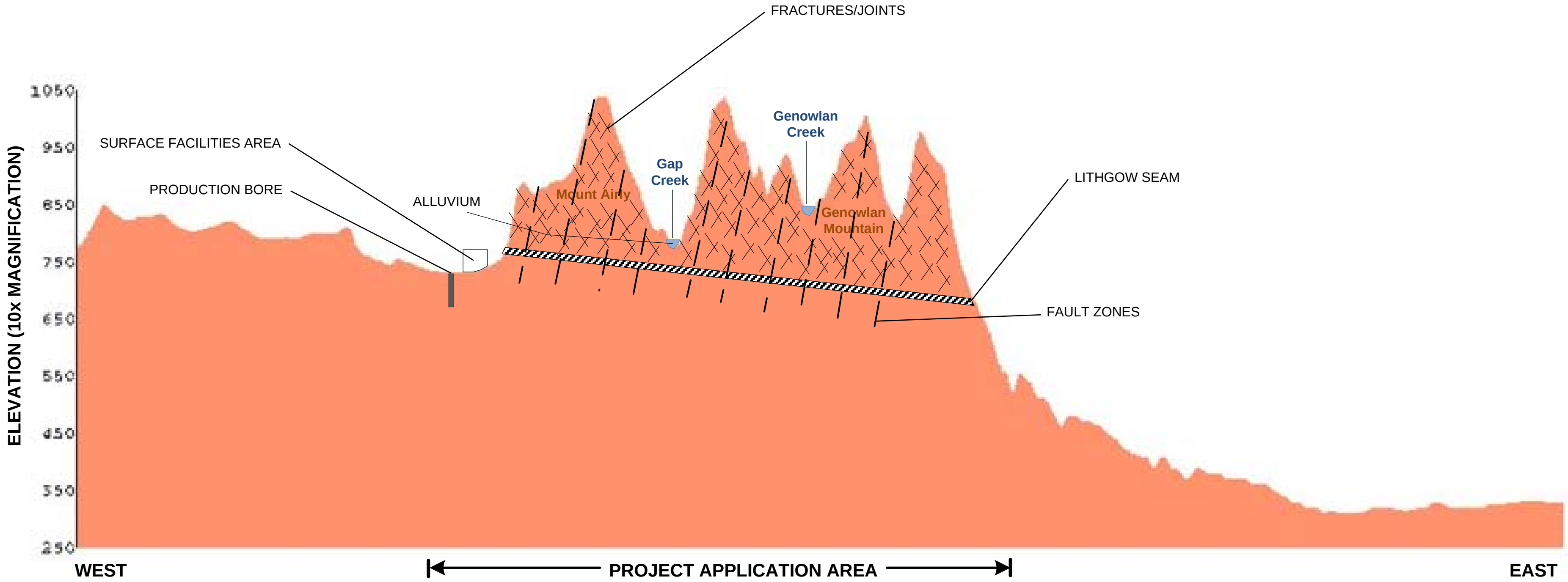
- Area of enhanced hydraulic conductivity from surface (Layer 1) to the Marrangaroo Formation (Layer 9). Horizontal hydraulic conductivities were increased 10 times relative to the best fit model run and vertical hydraulic conductivities were increased 20 times relative to the best fit model run.
- Horizontal low flow boundary from surface (Layer 1) to the Marrangaroo Formation (Layer 9). Horizontal hydraulic conductivities were divided by 100 across the low flow boundary.

The model cells where hydraulic conductivity was enhanced and the horizontal low flow boundary was applied are shown in Figure 3-6. The lineament was modelled at cells shown in orange.

Model results for the best fit transient model run have been compared with model results for the lineament scenarios described above. Observed and modelled groundwater levels at ARP04 are shown in Figure 3-7 and Figure 3-8.

The results indicate that there is negligible difference in modelled groundwater levels at ARP04 or modelled mine inflows due to the inclusion of lineaments. This is shown in Figure 3-7 and Figure 3-8 where model results for the best fit transient model run and for the lineament scenarios described above show the same modelled groundwater level at ARP04. Therefore lineaments were not considered further as part of the assessment.

The lack of difference in modelled groundwater levels between the base case scenario (best fit transient model run) and the two lineament scenarios is likely due to the low groundwater pressure in the Lithgow Seam and the Marrangaroo Formation at Airly, including at ARP04, which is attributable to the extensive groundwater seepage areas along the slopes of Mount Airly and Genowlan Mountain as well as the network of fractures and joints that direct groundwater flow to these areas of outcrop. This process likely dominates the local hydrogeological flow system and, as a result, the majority of local groundwater flow reports to these areas of seepage rather than flowing into mine workings.



Note: Location of faults are conceptual only and do not correspond with locations of faults and joints mapped by SRK (2018).

GHD

→ GROUNDWATER FLOW

LOCATION	Airly
SEAM	NA
DRAWN	SM
CHECKED	SG
APPROVED	SG
SCALE	NTS

Airly Mine
Hydrogeological Model Report

Conceptual cross section showing faults and joints at Airly Mine

Centennial Airly

DATE Jun 2019

Figure 3-4

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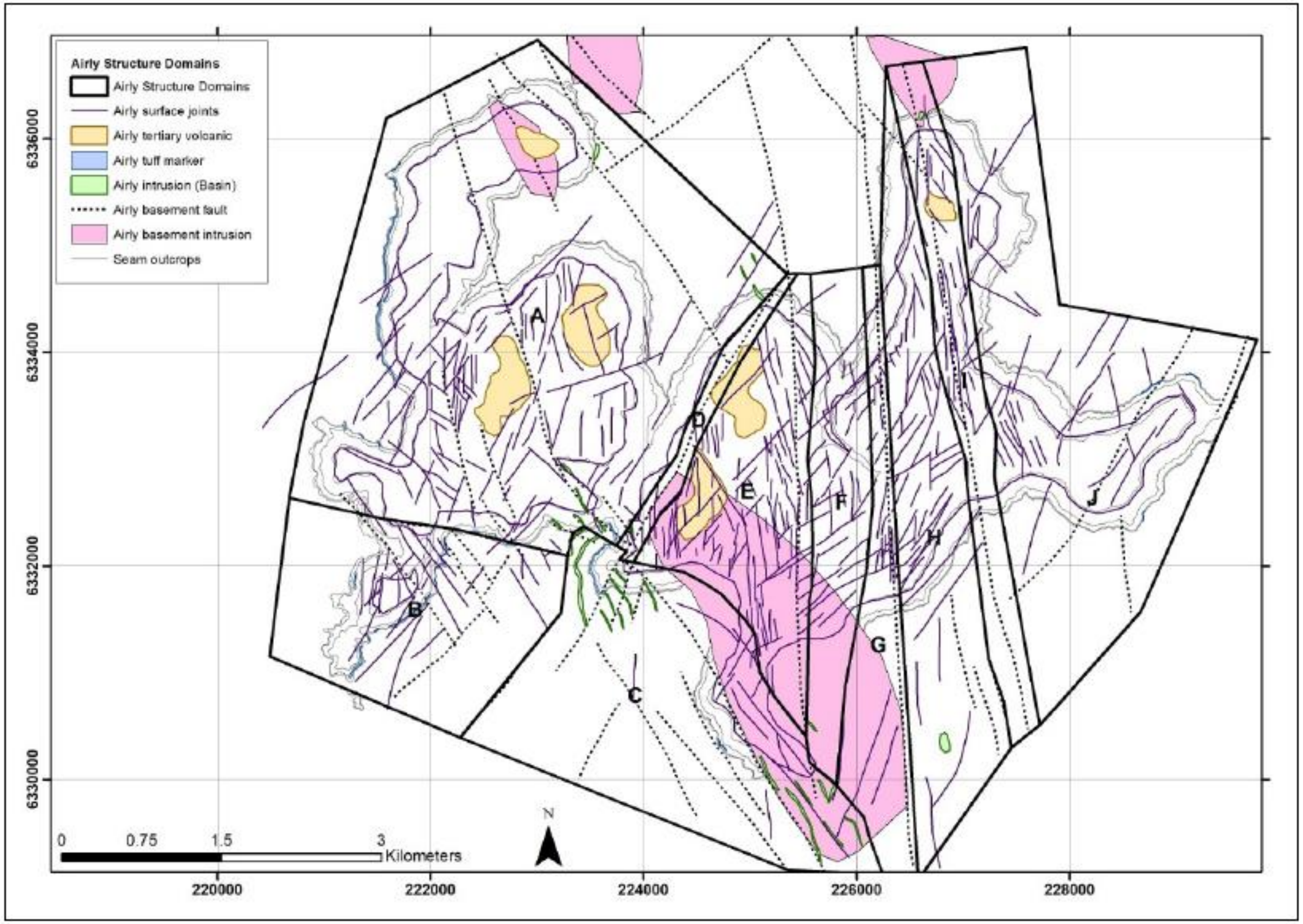

Figure 3-5 **Structural interpretation of basement and surface faults and joints for Airly Mine with seam level structural domains (SRK, 2018)**

Figure 3-6 Modelled lineaments zone and groundwater monitoring locations

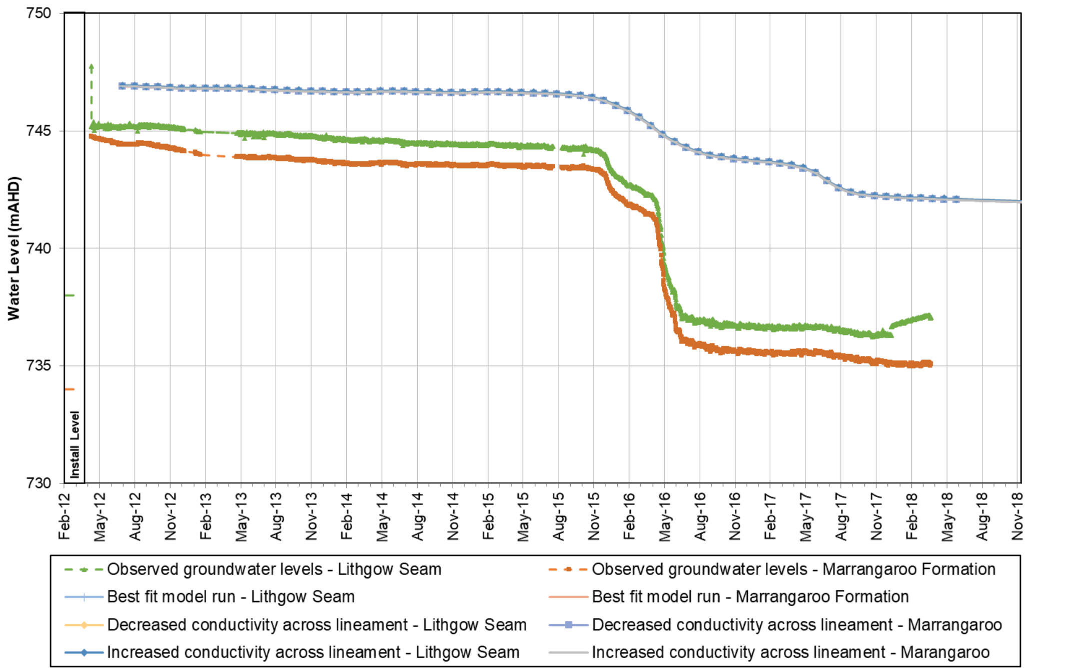

Figure 3-7 Modelled and observed groundwater levels – ARP04 Lithgow Seam and Marrangaroo Formation – lineaments scenario

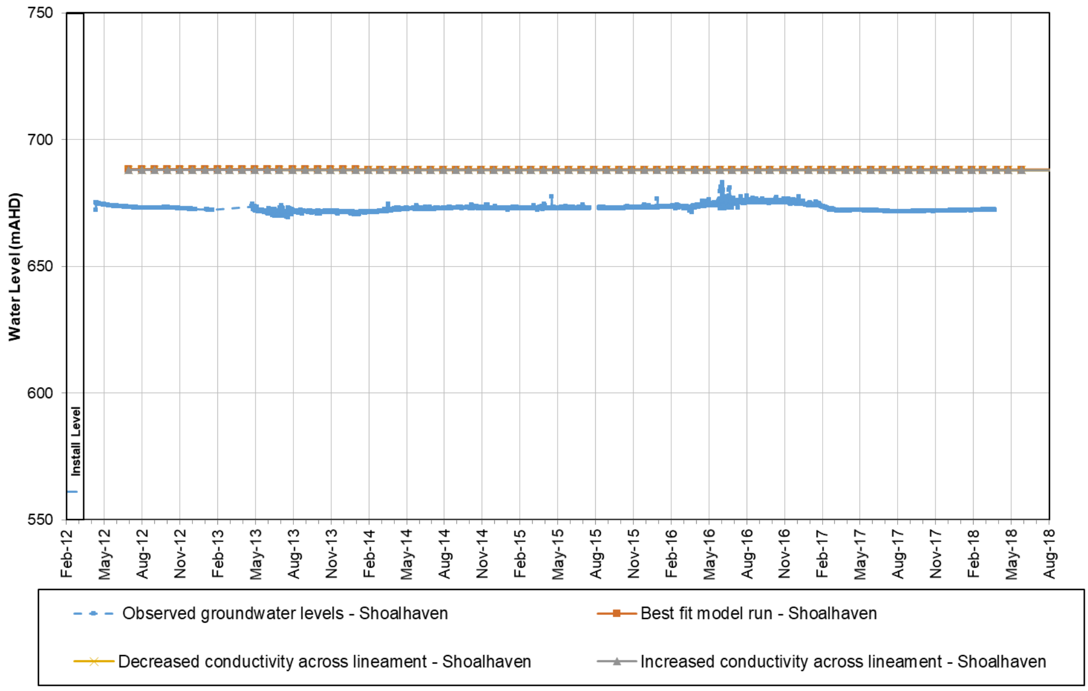

Figure 3-8 Modelled and observed groundwater levels – ARP04 Shoalhaven Group – lineaments scenario

3.2.5 Parameter sensitivity

Key findings from the calibration process are as follows:

- The model is sensitive to adjustment of the specific yield. It was found that the specific yield needed to be reduced to match the drawdown observed at ARP04 and maintain a low groundwater inflow. The modelled drawdown in the Lithgow Seam and Marrangaroo Formation at ARP04 is similar to the observed magnitude, although there is a difference in the rate of drawdown due to the model being based on monthly stress periods and time steps.

- The model is also sensitive to the vertical hydraulic conductivity of the Shoalhaven Group (layers 10-12 of the updated model). In order to reduce the modelled groundwater pressure within the Shoalhaven Group (to better simulate observed pressures), it was necessary to reduce the vertical hydraulic conductivity.
- Modelled groundwater inflows were sensitive to drain conductance. As discussed in Section 3.2.3, observed groundwater inflows have been low (not measureable) to date. Drain conductance was lowered to improve the fit between modelled and observed inflows.

4. Predictive simulations

4.1 Predictive modelling approach

The purpose of the predictive modelling is to estimate the potential future groundwater inflow rates into the mine and to predict the potential magnitude and extent of drawdown of piezometric heads.

For the predictive simulations, the proposed mining of the Lithgow Seam was simulated by extending drain cells throughout Layer 8 of the recalibrated model in accordance with the approved and proposed mining schedule. The approved mining schedule is as per the 1.8 Mtpa mine plan approved in SSD_5581. It was necessary to re-run the model for the approved mine plan and schedule due to the recalibration of the groundwater model. The proposed mining schedule in Modification 3 increases to a maximum rate of 3.0 Mtpa, however there is no increase to the mining footprint or change in the approved subsidence level in any of the approved mining zones. It should be noted that the proposed mining rate is a maximum, and mining will not necessarily be at this maximum rate for every year of mining.

The best fit model parameters from transient calibration (Table 3-4) were adopted for predictive modelling.

The general layout of the five mining zones approved under Airly Mine's consent SSD 5581, including areas approved for panel and pillar mining as well as the New Hartley Shale Mine Potential Interaction Zone, is shown in Appendix F. In addition to the approved subsidence limits included in the Airly Mine Extension Project EIS, the consent SSD 5581 includes restrictions on mining as per Condition 1 under Schedule 3. Under the adopted mining schedule for the 1.8 Mtpa and 3.0 Mtpa scenarios, panel and pillar mining was modelled to commence in 2019.

4.2 Prediction scenarios

Two scenarios were modelled for both the approved and proposed mining conditions. Note that both scenarios were selected to be similar to scenarios assessed by GHD (2014). Details of the scenarios, including any differences with the scenarios assessed by GHD (2014), are outlined below:

- **Scenario 1** assumes that the vertical and horizontal hydraulic conductivity will increase up to a height of 23 m above the panel and pillar mining zone. It is noted that a zero height of fracturing was adopted for Scenario 1 in GHD (2014). However, it was considered by Airly Mine that a height of six times the height of the mine workings is more realistic for a minimum height of fracturing. A height of six times the height of the mine workings (average 3 m) equals 18 m. Due to the thickness of the layers in the model, fracturing was modelled to the top of layer 5. This corresponds to a height of 23 m above the mine workings.
- **Scenario 2** assumes that the vertical and horizontal hydraulic conductivity will increase up to a height of 75 m above the panel and pillar mining zone, which is the maximum height of the fracture zone predicted by Golder Associates (2013). This scenario is identical to Scenario 2 assessed by GHD (2014).

For both Scenario 1 and Scenario 2 the bulk horizontal and vertical hydraulic conductivities within the fracture zone (i.e. Layers 5–7 for Scenario 1 and 3–7 for Scenario 2) have been established in accordance with GHD (2014). Hydraulic conductivity values of 0.41 m/day (horizontal) and 1.6×10^{-4} m/day (vertical) were adopted for the fracture zone as per GHD (2014). Note that, as discussed above, fracturing was only simulated above the panel and pillar zone.

Changing material properties associated with fracturing above the panel and pillar zone were simulated using a stop-start simulation approach.

4.3 Groundwater inflows

Predicted groundwater inflow rates into the underground workings are presented in Figure 4-1. Groundwater inflow rates have been presented for the approved 1.8 Mtpa mining rate and the proposed 3 Mtpa (maximum) mining rate. Groundwater inflow rates have been presented for Scenario 1 and Scenario 2 outlined in Section 4.2.

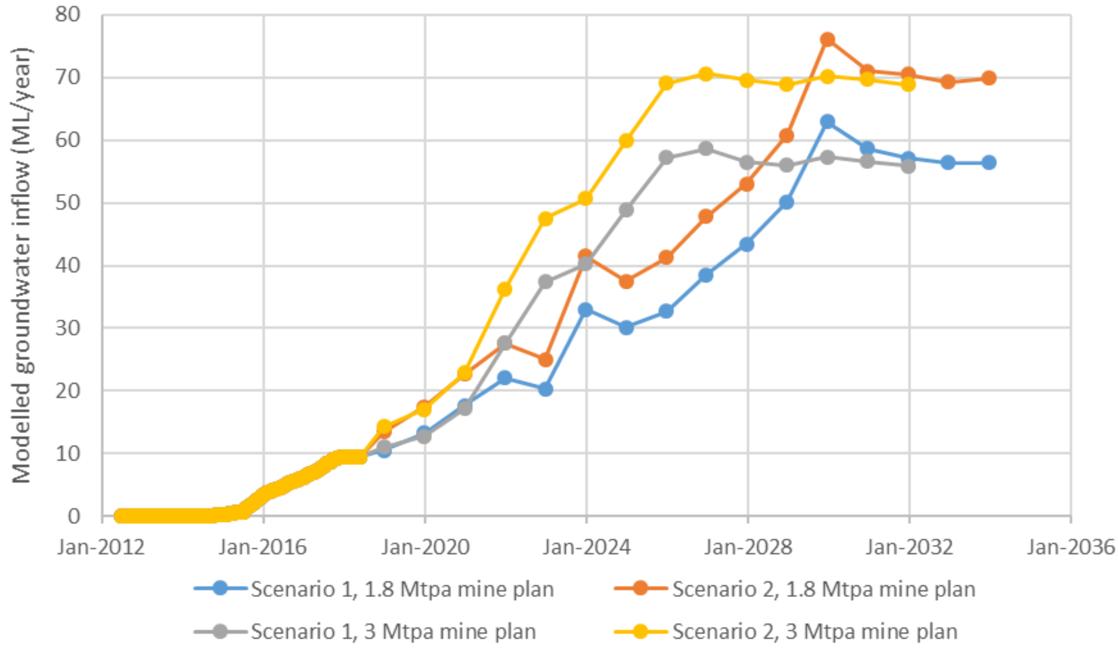

Figure 4-1 Modelled groundwater inflows into mine workings

Under Scenario 1 and the 3 Mtpa mining rate the modelled groundwater inflow rate increases over time to a peak of 59 ML/year in 2027, before gradually decreasing to 57 ML/year in 2031, the final year of mining. Under Scenario 2 and the 3 Mtpa mining rate the modelled groundwater inflow rate increases over time to a peak of 71 ML/year in 2027, before gradually decreasing, to 69 ML/year in 2031, the final year of mining. Note that under the 1.8 Mtpa mining rate, mining is scheduled to finish in 2033.

Under the 3 Mtpa mining rate the peak inflow is predicted to occur earlier than for the 1.8 Mtpa mining rate, however the peak inflow is predicted to be slightly higher for the 1.8 Mtpa mining rate. Mine inflows for both the 1.8 Mtpa mining rate and the 3 Mtpa mining rate are similar at the end of mining as the mine plan has the same footprint for both scenarios. Therefore at the end of mining in both scenarios, groundwater inflow into the mine is occurring into the same mine area resulting in similar inflows.

Groundwater inflows for Scenario 2 are recommended to be adopted for the site water balance assessment as the height of fracturing adopted for this model is more conservative and closer to the 60 m estimate reported recently by Strata2 (2019). With the Scenario 2 predictions, the modelled inflow rate is likely to be greater than the actual inflow rates given that the 75 m height of fracturing over the panel and pillar zone (with void widths of 61 m and inter-panel widths of 35 m) in the model is conservative (David King, pers comm). However, in both scenarios, the peak inflows are so low that it is considered that any groundwater will report only as moisture in run of mine coal, and will be able to be captured and reused as process water. Therefore, the site water balance is expected to be independent of the actual groundwater inflows, in terms of process water demand and off-site discharges.

Modelled mine inflows for both mining scenarios presented in Figure 4-1 are lower than mine inflows modelled by GHD (2014). Mine inflows for Scenario 2 for the 1.8 Mtpa mine plan as modelled by GHD (2014) are shown in Figure 4-2. Mine inflows modelled by the recalibrated model are considerably lower. Observed mine inflows have been low (not measureable) to date and therefore the lower inflows modelled by the recalibrated model are considered to be more realistic.

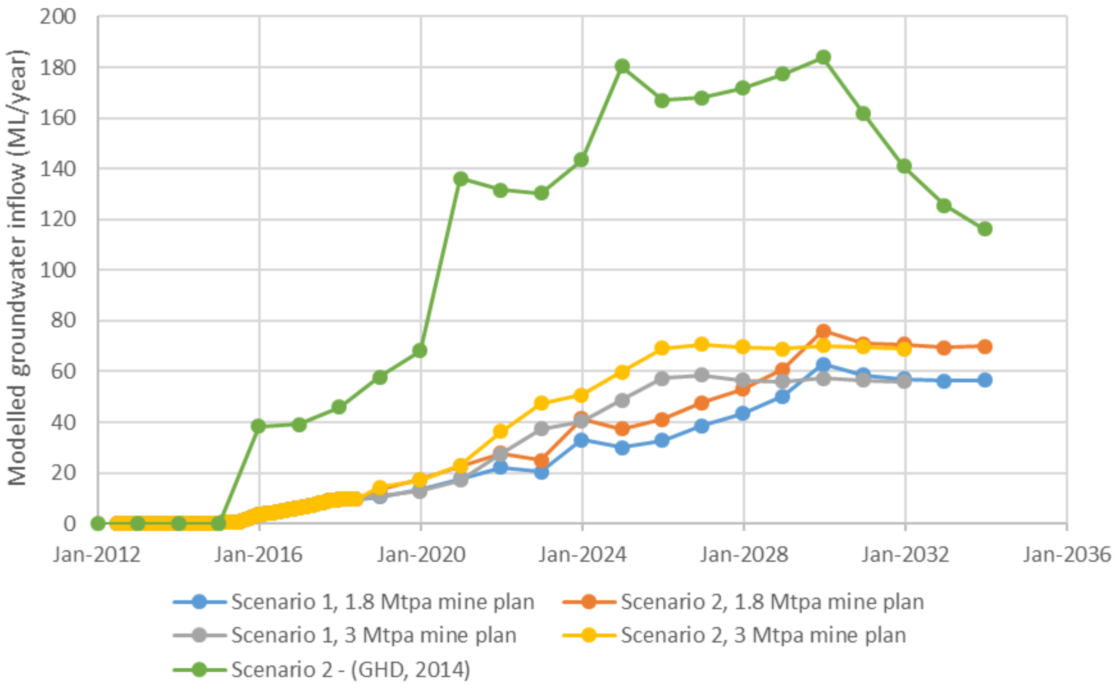

Figure 4-2 1.8 Mtpa mine plan comparison of mine inflow

4.3.1 Uncertainty analysis

Uncertainty analysis for hydrogeological model predictions has been undertaken in accordance with the requirements *Information guidelines for proponents preparing coal seam gas and large coal mining development proposals* (IESC, 2018a) and the *Explanatory Note on Uncertainty Analysis in Groundwater Modelling* (IESC, 2018b).

IESC (2018b) outlines three general approaches to uncertainty analysis with respect to groundwater modelling and these, in order of increasing complexity and computational resource requirements, are: *'(1) scenario analysis with subjective probability, (2) deterministic modelling with linear probability quantification and (3) stochastic modelling with Bayesian probability'*.

Based on risk assessment of the groundwater environment at Airly Mine (summarised in Table 1-1 and Appendix A), the adopted approach for uncertainty analysis was 'scenario analysis with subjective probability'. The risk of impact on the local and regional groundwater environment due to the operation of Airly Mine is considered to be low, based on the limited number of receptors (GDEs and landholder bores), the low connectivity between shallow alluvial groundwater and the coal seam and the adopted mining method.

Based on the adopted methodology, five uncertainty runs were considered as part of uncertainty analysis. In each of these uncertainty runs, model parameters were varied. The hydrogeological model was run for each uncertainty run under steady state and transient conditions. Parameters varied in each uncertainty run are summarised below:

- Uncertainty run 1: rainfall recharge multiplied by 2. Rainfall recharge for this scenario was 6.58×10^{-5} m/day.

- Uncertainty run 2: hydraulic conductivity of coal and Marrangaroo multiplied by 2.
- Uncertainty run 3: hydraulic conductivity of Marrangaroo multiplied by 2, rainfall recharge increased to 1.7% of 90th percentile annual rainfall (to 4.34×10^{-5} m/day), hydraulic conductivity of Lithgow Seam (Layer 8) coal increased by 4.
- Uncertainty run 4: model storage increased ×10, fracture height of 75 m, increased vertical and horizontal hydraulic conductivity of fracture area, increased rainfall recharge.
- Uncertainty run 5: model storage decreased ×10, fracture height of 23 m, reduced vertical and horizontal hydraulic conductivity of fracture area, reduced rainfall recharge.

Note that fracture height was maintained at 23 m for uncertainty runs 1, 2 and 3. Rainfall recharge for the best fit model run and for uncertainty runs 2, 4 and 5 was 3.29×10^{-5} m/day.

Parameters modified as part of the uncertainty analysis were selected with consideration of the likely sensitive model parameters. These parameters were determined based on experience and were subject to critique by the third party reviewer, as required by the NSW Aquifer Interference Policy (DPI, 2012). Model parameters were increased or decreased to provide a range of estimated groundwater inflows.

Model results were analysed to identify potential changes to impacts on groundwater receptors. Calibration statistics were reviewed for each uncertainty run. Calibration statistics were used to identify the likelihood of the selected parameters of each uncertainty run occurring. Model calibration statistics are summarised in Table 4-1.

Table 4-1 Uncertainty analysis – model calibration statistics

Model run	Steady state calibration – Scaled Root Mean Squared Error	Transient calibration – Root Mean Squared Error (m)	Transient calibration – Scaled Root Mean Squared Error
Best fit model run	5.3%	10.5	4.1%
Uncertainty run 1	8.1%	21.7	8.4%
Uncertainty run 2	5.3%	11.2	4.3%
Uncertainty run 3	5.7%	12.4	4.8%
Uncertainty run 4	8.1%	21.8	8.4%
Uncertainty run 5	7.6%	16.5	6.2%

Uncertainty runs that include changing rainfall recharge and storage (run 1, run 4 and run 5) result in large changes in calibration statistics. The poor fit between model results and observed groundwater levels (Table 4-1) indicates that the parameters and associated impacts for these uncertainty runs are not realistic and are unlikely to occur.

Uncertainty runs that include modifying hydraulic conductivities (run 2 and run 3) result in calibration statistics that are similar to the best fit model run. The reasonable fit between model results and observed groundwater levels indicates that these uncertainty runs may provide a reasonable prediction of future impacts from mining.

The modelled groundwater inflows into the mine for each of the uncertainty analysis runs have been compared with modelled groundwater inflows for the best fit model scenario and are shown in Figure 4-3. While run 1 and run 4 result in increased modelled groundwater inflows, the poor calibration statistics indicate parameters associated with these uncertainty runs are not likely to occur.

As panel and pillar mining has not yet commenced at Airly Mine, it is difficult to verify the hydraulic properties of goaf areas. Continued monitoring of groundwater levels and mine inflows following the commencement of panel and pillar mining will provide monitoring data estimating hydraulic properties of goaf areas. Monitoring of the fracture height will be reviewed following extraction of the first four panels within the panel and pillar zone. Further recalibration of the model will be undertaken if required following review of this data.

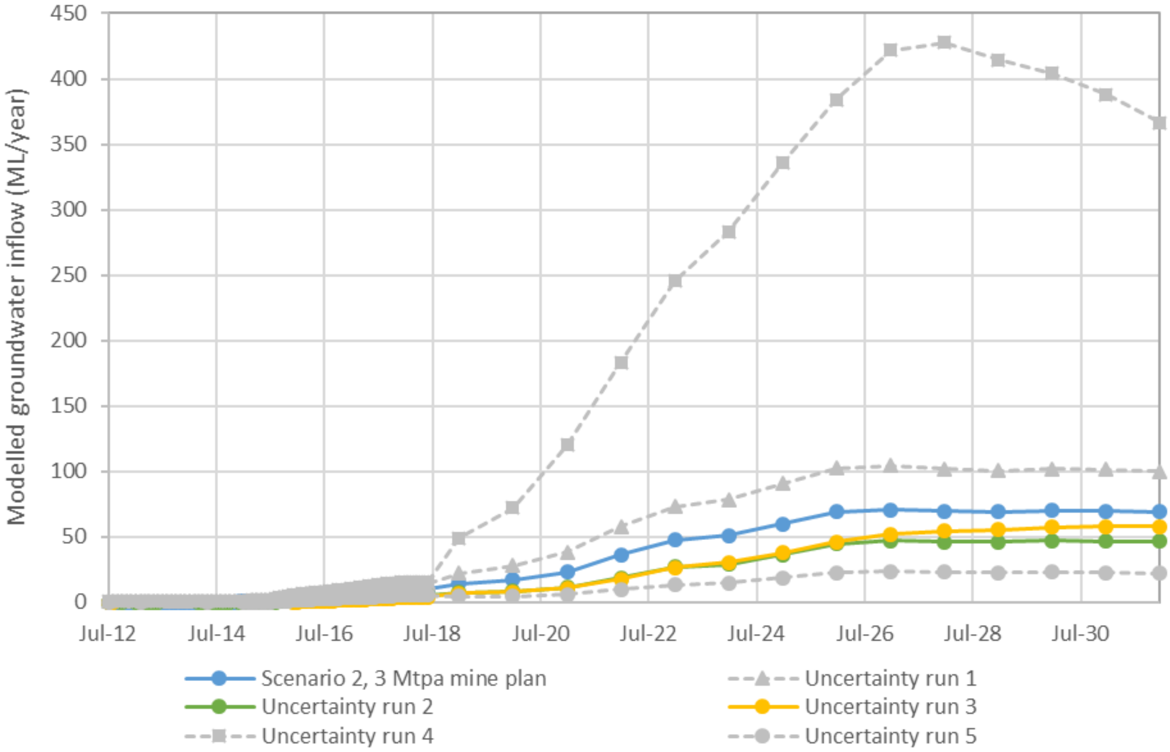

Figure 4-3 Modelled mine inflows – uncertainty analysis

4.4 Flow budget and inter-aquifer flow

The flow budget at final year of mining (year 2031) and the average flow budget over the period of mining (2014 to 2031) is presented in Table 4-2. The transient flow budget applies to the 3 Mtpa mining rate scenario and Scenario 2 fracturing.

Table 4-2 Transient flow budget

Condition	Zone	Inputs (ML/year)					Outputs (ML/year)				
		Recharge	GHB	Storage	Other zones	Total	Drains*	GHB	Storage	Other zones	Total
Average	All zones	503.5	226.5	42.4	–	772.4	449.8	316.5	9.6	–	775.9
	Alluvium	146.7	0.0	9.0	288.7	444.3	395.5	0.0	3.4	46.1	444.9
	Rock	356.8	226.5	33.4	46.1	662.9	54.3**	316.5	6.3	288.7	665.8
End of mining	All zones	503.5	226.7	82.2	–	812.4	475.9	316.2	19.6	–	811.7
	Alluvium	146.7	0.0	16.0	276.0	438.7	385.3	0.0	6.9	46.2	438.5
	Rock	356.8	226.7	66.2	46.2	695.9	90.5***	316.2	12.7	276.0	695.5

Note:
*Outputs from alluvium via drains is seepage to surface and baseflow. Outputs from rock via drains includes mine dewatering and baseflow/seepage to surface.
**Of average transfers from rock aquifers to drains, 40.0 ML/year is mine dewatering and 14.3 ML/year is baseflow.
***Of transfers from rock aquifers to drains, 68.9 ML/year is mine dewatering and 21.6 ML/year is baseflow.

4.5 Drawdown

Groundwater drawdown predictions for the approved (1.8 Mtpa mining rate) and proposed (3 Mtpa mining rate) conditions (and both Scenarios 1 and 2) are included in Appendix G. Groundwater drawdown predictions have been presented for end of mining and for 30 years after the end of mining. A summary of maximum groundwater drawdown (Scenario 2) for approved conditions (EIS and recalibrated model) and proposed conditions is provided in Table 4-3.

The recalibrated model predicts that groundwater drawdown within the shallow zone / alluvium will generally be lower for both approved and proposed conditions compared to the drawdown predicted for approved conditions as part of the EIS (GHD, 2014), with the exception of a small area within Genowlan Creek. This area is not part of the Grotto or Oasis.

The extent of drawdown in the Lithgow Seam and the Marrangaroo Formation is limited by the outcrop of these seams. The drawdown contours show that for both approved and proposed conditions (Scenarios 1 and 2), drawdown in the Lithgow Seam and the Marrangaroo Formation is generally limited to within 300 m of the Project Approval Area. For Scenario 2 drawdown at end of mining for proposed conditions for the Lithgow Seam and the Marrangaroo Formation refer to Figure G-6 and Figure G-7 respectively. For Scenario 2 drawdown at end of mining for approved conditions for the Lithgow Seam and the Marrangaroo Formation refer to Figure G-22 and Figure G-23 respectively.

As shown in Figure G-8 and Figure G-24, drawdown at end of mining in the Upper Shoalhaven Group is generally less than or equal to 1 m at the Project Approval Area boundary for approved and proposed conditions (Scenario 2).

Maximum predicted groundwater drawdown for approved conditions reported as part of the Airly Mine Extension Project (GHD, 2014) is generally lower for the Permian strata and the Shoalhaven Group compared to the predictions by the recalibrated model for approved and proposed conditions. This is due to the process of recalibration of the model, which has modified hydraulic conductivity and storage properties of the strata to better match observed data. As discussed in Section 1.2, the original model (GHD, 2014) was found to under-predict drawdown in the Lithgow Seam and Marrangaroo Formation at one monitoring location (ARP04). In addition, the process of model recalibration involved dividing the bottom layer (regional aquifer) into three layers. As a result, the recalibrated model predicts drawdown in each of these layers whereas the EIS model predicted only bulk (average) drawdown over the entire thickness. As such, predicted drawdown in the upper layer of the Shoalhaven Group in the recalibrated model would be expected to be higher than the overall average drawdown throughout the entire unit within the EIS model.

As shown in Table 4-3, there is minimal difference in predicted drawdown between approved and proposed conditions for the recalibrated model.

Groundwater drawdown predictions and the impacts on groundwater sources are discussed further in Section 6 of the GIA (GHD, 2019).

Table 4-3 Maximum modelled drawdown – Scenario 2

Strata	Approved (GHD, 2014)		Approved (recalibrated model)		Proposed	
	End of mining	30 years after end of mining	End of mining	30 years after end of mining	End of mining	30 years after end of mining
Shallow/ alluvium	3.5 m (Gap Creek) 1.1 m (Genowlan Creek)	Not assessed	2.0 m (Gap Creek) 1.9 m (Genowlan)	0.4 m (Gap Creek and Genowlan Creek)	1.9 m (Gap Creek and Genowlan Creek)	1.0 m (Gap Creek catchment) 0.2 m (Genowlan Creek)
Permian (local)	7.5 m (Permian Siltstone) 6.2 m (Lithgow Seam) 6 m (Marrangaroo)	Not assessed	16.1 m (Lithgow Seam) 16.1 m (Marrangaroo)	0.3 m (Lithgow Seam) 0.3 m (Marrangaroo)	16.5 m (Lithgow Seam) 16.4 m (Marrangaroo)	0.3 m (Lithgow Seam) 0.3 m (Marrangaroo)
Shoalhaven	0.1 m	Not assessed	7.3 m	0.4 m	7.4 m	0.4 m

4.6 Baseflow

Baseflow has been calculated for Gap Creek at the boundary of the Project Approval Area, Genowlan Creek at the boundary of the Project Approval Area and for the confluence of Genowlan Creek and Gap Creek as shown in Figure 4-4, Figure 4-5 and Figure 4-6 respectively. Baseflow has been calculated as flow out of the model via drains assigned across the top of Layer 1 of the model. Refer to Section 4 of GHD (2014b) for additional details regarding model boundary details.

Baseflow for Gap Creek and Genowlan Creek decreases throughout the period of mining. The reduction in baseflow is slightly greater for approved conditions than proposed conditions. The peak in reduction in baseflow occurs slightly later for approved conditions due to the end of mining occurring later. The modelled pre mining baseflow and the minimum modelled baseflow for Gap Creek and Genowlan Creek is summarised in Table 4-4. For comparison, baseflow for the whole of the whole of the model domain is also included in Table 4-4.

Under proposed and approved conditions, after the end of mining, baseflow is modelled to gradually recover to pre-mining rates. Within Gap Creek and Genowlan Creek, baseflow is modelled to return to pre-mining rates within 50 years of the end of mining.

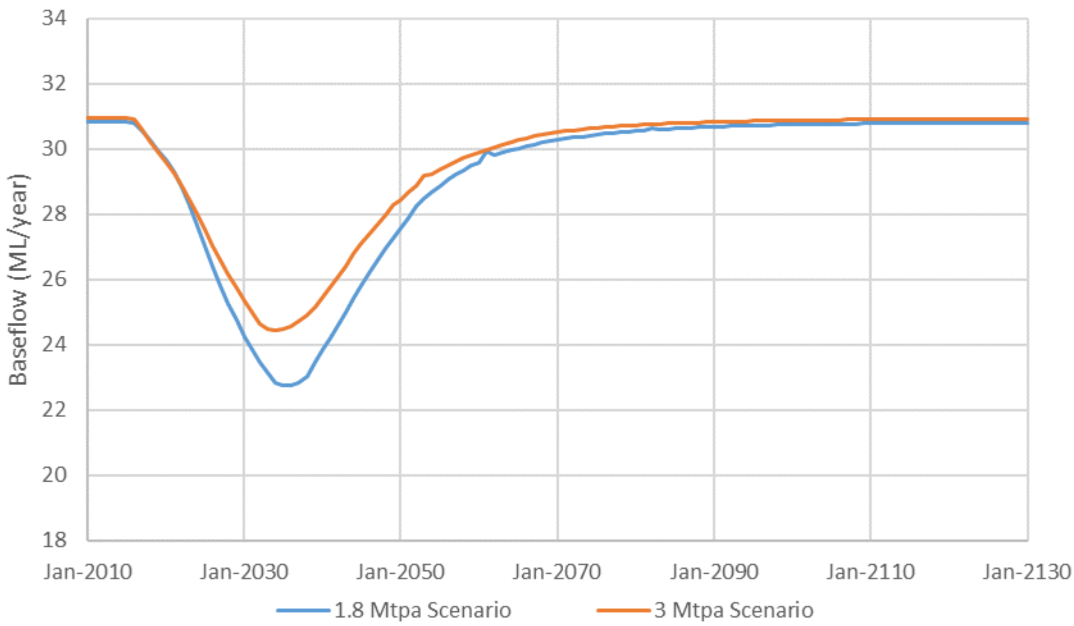

Figure 4-4 Baseflow at Gap Creek at Project Approval Area boundary

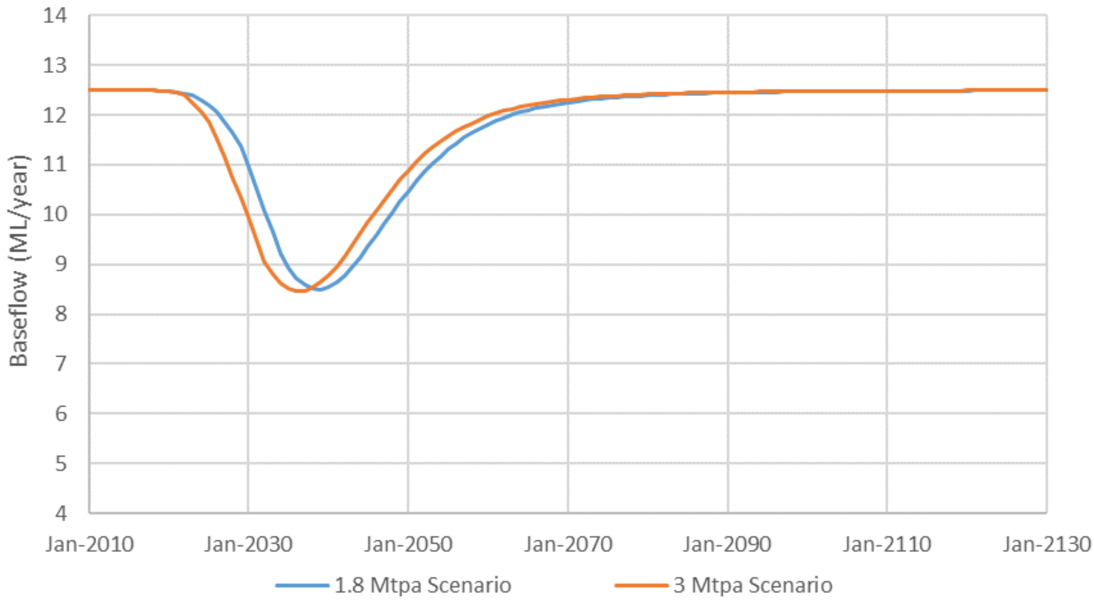

Figure 4-5 Baseflow at Genowlan Creek at Project Approval Area boundary

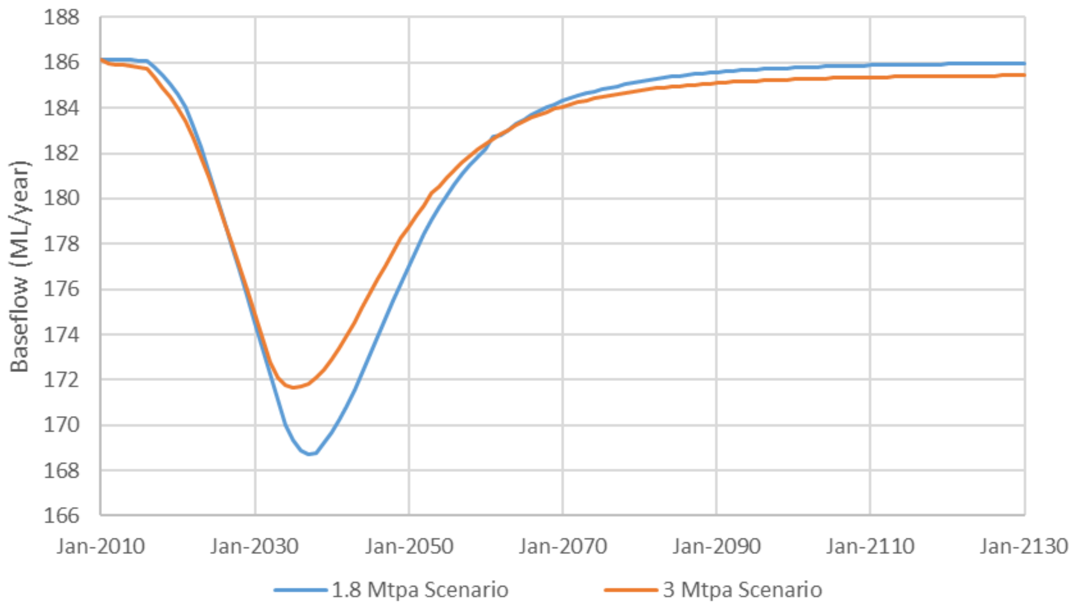

Figure 4-6 Baseflow at confluence of Gap Creek and Genowlan Creek

Table 4-4 Potential changes in baseflow

Location	Approved (GHD, 2014)		Approved (recalibrated model)		Proposed	
	Pre-mining* (ML/year)	Minimum baseflow (ML/year)	Pre-mining* (ML/year)	Minimum baseflow (ML/year)	Pre-mining* (ML/year)	Minimum baseflow (ML/year)
Whole of model domain	581.2	506.1	413.7	393.4	414.2	394.6
Gap Creek at Project Approval Area boundary	32.1	25.9	30.9	22.7 [1]	31.0	24.4 [2]
Genowlan Creek at Project Approval Area boundary	9.2	5.4	12.5	8.5 [3]	12.5	8.5 [4]
Confluence of Gap Creek and Genowlan Creek	198	170.9	186.1	168.7 [5]	186.1	171.7 [6]

*Pre-mining refers to January 2010

1. Value corresponds with the low point of the blue line on Figure 4-4.
2. Value corresponds with the low point of the orange line on Figure 4-4.
3. Value corresponds with the low point of the blue line on Figure 4-5.
4. Value corresponds with the low point of the orange line on Figure 4-5.
5. Value corresponds with the low point blue line on Figure 4-6.
6. Value corresponds with the low point of the orange line on Figure 4-6.

Baseflow presented as part of the Airly Mine Extension Project (GHD, 2014) differs to baseflow calculated from the recalibrated model. This discrepancy is likely due to recalibration of the model and changes in rainfall recharge.

For the recalibrated model, the reduction in baseflow to Gap Creek and Genowlan Creek is greater under approved conditions than for proposed conditions. This reflects modelled baseflow presented in Figure 4-4, Figure 4-5 and Figure 4-6.

5. Conclusions and recommendations

A 3D numerical groundwater flow model of Airly Mine has been developed using industry standard MODFLOW-NWT code. The model has been updated and recalibrated to include additional monitoring data collected at the site since the previous model revision. The model simulates the essential features of the hydrogeological system of the mine including the key hydrostratigraphic units, recharge and discharge mechanisms and spatial and temporal distribution of piezometric heads. The calibrated model parameters are generally consistent with packer testing and falling head testing undertaken at the site and with other sites within the Lithgow region.

Mine inflows modelled by the recalibrated hydrogeological model are considerably lower than mine inflows modelled by GHD (2014), under both approved (1.8 Mtpa) and proposed (3 Mtpa) conditions. Mine inflows modelled by GHD (2014) for approved conditions peak at 184 ML/year. For the recalibrated model peak mine inflows are 71 ML/year and 76 ML/year for proposed and approved conditions respectively. Mine inflows modelled by the recalibrated model are closer to observed mine inflows.

The calibrated model is considered to have the characteristics predominantly of class 2 confidence level (i.e. moderate confidence), in accordance with the confidence level classification of the Australian Groundwater Modelling guidelines (AGMG) (Barnett et al, 2012). A comparison of the calibrated model and the AGMG confidence level classifications is shown in Appendix E. Specific indicators of Class 2 confidence level includes future mining (predictive) period (12 years) of no greater than 10 times the calibration period (6 years). Model confidence would be lower in areas where model calibration would be considered deficient and for predictions of far future conditions post-mining, where the groundwater system slowly recovers towards a new dynamic equilibrium over potentially many tens to hundreds of years. While the existing mining at Airly Mine has provided transient data that provides a sensible basis for projecting potential future effects of mining, there are potential unknowns regarding potential changes of hydrogeological parameters of strata above the panel mining area.

The confidence in model predictions would be improved by ongoing data collection and revision of the numerical model. Predictions of mining-induced effects depend on the monitoring network capturing the stress-response relationship.

It is recommended that surface water and groundwater monitoring continues at Airly Mine. It is recommended that monitoring data continues to be reviewed. Review of monitoring data will allow opportunities to verify model predictions. Model recalibration may be required if observations vary significantly from model predictions.

6. References

Barnett, B., Townley, L.R., Post, V., Evans, R.E., Hunt, R.J., Peeters, L., Richardson, S., Werner, A.D., Knapton, A., Boronkay, A., (2012) *Australian groundwater modelling guidelines*, Waterlines Report Series No. 82, National Water Commission, Canberra, 191 pp. June.

GHD (2014) *Airly Mine Extension Project Hydrogeological Model Report,* prepared by GHD Pty Ltd for Centennial Airly Pty Ltd, document reference 22/16787.

GHD (2015) *Airly Mine Extension Project – Response to Submissions Fault Zone Hydrogeology Assessment,* prepared by GHD Pty Ltd for Centennial Airly Pty Ltd, document reference 22/16787 108405.

GHD (2016) *Airly Mine 2016 Annual Water Monitoring Report,* prepared by GHD Pty Ltd for Centennial Airly Pty Ltd, document reference 22/17890.

GHD (2017) *Airly Mine Hydrogeological Model Recalibration,* prepared by GHD Pty Ltd for Centennial Airly Pty Ltd, document reference 2218803-5851.

GHD (2019) *Airly Mine Mod 3 Groundwater Impact Assessment,* prepared by GHD Pty Ltd for Centennial Airly Pty Ltd, document reference 22/19275.

Golder Associates (2013). *Subsidence Predictions and Impact Assessment for Airly Mine,* prepared by Golder Associates Pty Ltd for Centennial Airly Pty Ltd, document reference 127621105-003.

HydroAlgorithmics (2014) *Airly Mine Extension Project – Groundwater Model Review.*

HydroAlgorithmics (2018) *Airly Mine Groundwater Model Review.*

IESC (2018a) *Information guidelines for proponents preparing coal seam gas and large coal mining development proposals,* Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development.

IESC (2018b) *Draft Explanatory Note on Uncertainty Analysis in Groundwater Modelling,* Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development.

RPS (2013). *Airly Mine – Annual Surface and Groundwater Monitoring Report 2012,* prepared by RPS Aquaterra for Airly Coal Pty Ltd, document reference S102/067b.

SRK (2018) *Structural Risk Review of Airly Mine,* prepared by SRK Consulting (Australasia) Pty Ltd, document reference CCL022.

Strata2 (2019) *Airly Mine Panel and Pillar Mining Zone: Revised Subsidence Estimates and Impacts*, document reference AIR-006-Rev2.

Appendices

Appendix A – Groundwater model risk assessment

1. Background

Airly Mine is an underground coal mine owned and operated by Centennial Airly Pty Limited (Centennial Airly), a wholly owned subsidiary of Centennial Coal Company Limited (Centennial). Centennial is a wholly owned subsidiary of Banpu Public Company Limited. Airly Mine is located near the village of Capertee, approximately 40 km north-west of Lithgow in the Western Coalfield.

Airly Mine currently has approval to extract up to 1.8 million tonnes per annum (Mtpa) of run of mine (ROM) coal from the Lithgow Seam using mining methods that incorporate extraction by first workings, partial pillar extraction or panel and pillar mining. ROM and product coal is transported off site by rail for the export and domestic markets.

Airly Mine operations are currently in the process of undertaking project modifications to increase tonnage and secure their water supply for ongoing mining activities. As part of their increase in tonnage a review/recalibration of the current groundwater model, prepared as part of SSD 12_5581 was undertaken.

As part of the groundwater model update, consideration of the most recent standards was considered. As part of new documents prepared by the IESC on uncertainty analysis in groundwater modelling, a risk assessment methodology is suggested to define how model predictions can aid in decision making during the EIS process. Whilst Airly groundwater interactions are relatively low risk, a risk assessment was undertaken as a trial for implementation of the same process at other sites where groundwater environment risks may be more substational.A risk assessment also forms a recommendation by the independent groundwater technical reviewer.

The level of effort applied to uncertainty analysis is a decision that is a function of the risk being managed.

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2. Objective

The following Hierarchy of Controls offers a framework for considering the effectiveness of controls. Note that the effectiveness of a control that is intended to reduce a risk decreases from top to bottom of the list. In other words, the closer the control type is to the top of the hierarchy, the more potentially effective the control.

·Eliminate the hazard or energy source (do not use the energy)
·Minimise or replace the hazard or energy source (reduce the amount of energy to a less damaging level or replace the energy with another that has less potential negative consequences)
·Control the hazard or energy using engineered devices (ex. Lock outs, chemical containers, mechanical roof support, gas monitors, etc.)
·Control the hazard or energy by using physical barriers (ex. machine guarding, fences or enclosures, etc.)

·Control the hazard or energy with procedures (ex. Isolation procedures, standard operating procedures, etc.)
·Control the hazard or energy with personal protective equipment (ex. hard hats, boots with toe caps, gloves, safety glasses, welding gear, etc.)
·Control the hazard or energy with warnings and awareness (ex. posters, labels, warning signs, verbal warnings, etc.)

The objective of this risk assessment is to facilitate a structured process to enable a critical and objective appraisal of the proposed mining plan for Modification 2 with the groundwater predictions

3. Potential Hazards

Potential hazards identified from the groundwater model may include:
Impacts to GDEs (terrestrial)
Impacts to GDEs (aquatic)
Impacts to nearby water users
Impacts to water quality
Impacts to surface to groundwater connectivity

4a. Boundary Definition

Airly Modification 2 Project extent and 3.0 mtpa mine plan

5. Methods

Risk Assessment Methods
Workplace Risk Assessment and Control (WRAC): Yes
Fault Tree Analysis (FTA):
Safety Integrity Level Analysis to Australian Standard 61508 (SIL):
Bow Tie Analysis (BTA):
Failure Modes and Effects Analysis (FMEA):
Hazard and Operability Analysis (HAZOP):

6. Previous Risk Assessment and other documents to be used and/or referenced

Document Name	Title	Version	Referenced Document Date
HA2018-03 HydroAlgorithmics Interim Review - Airly	Airly Mine Modification - Interim Groundwater Modelling Peer Review	1	17-Mar-2018
2218803-LET-HydrogeologicalModelRecalibration_24July2017	Airly Mine, Hydrogeological Model Recalibration	1	24-Jul-2017
2219275-LET_Airly Groundwater Model Details	Airly Groundwater Model Additional Information for Peer Review	1	05-Feb-2018
2219610-REP-AirlyWater Management Plan-Rev3-18July2018	Airly Water Management Plan	3	18-Jul-2018
Airly MEP EIS_ Appendix E Ground Water	Airly Mine Extension Project Groundwater Impact assessment	2	28-Jul-2014
Airly MEP_Response to Submissions	Response to submissions, Airly Mine Extension Project	1	02-Feb-2015
Airly MEP_Appendix A to supplementary info to RTS	Supplementary Information to Response to Submissions - Appendix A, Response to Submission from Pells Consulting	1	02-Jun-2015

7. Information Required for Risk Assessment

An appreciation for new guideline documents produced by IESC (2018)

8. Venue and Time

Date	Description	Location	Start Time	End Time	Comment
1. 25-Jul-2018	Scoping Study	Fassifern Back Conference Room	9:00 AM	12:00 PM	
2. 14-Aug-2018	Update of scoping study/risk assessment	Fassifern Back Conference Room	9:00 AM	12:00 AM	Addressing gaps in scope identified by Noel Merrick (meeting with NM on Friday 10/8/18)
3.					
4.					

9. Team Selection

Name	Position	Company	Industry Start Date	E-Mail Address	Role	Experience relevant to the role in the risk assessment	Pulse User No.	Attendance			
								1. 25-Jul-2018	2. 14-Aug-2018	3.	4.
Nagindar Singh	Approvals Coordinator	Centennial Coal			Team Member	Approval manager		P	P		
David King	Technical Services Manager	Centennial Coal			Facilitator	Site specialist (mining)		P	P		
Stuart Gray	Principal Hydrogeologist	GHD		Stuart.gray@ghd.com	Consultant	Assessment specialist and modeller		P	P		
Craig Bagnall	Principal Consultant	Catalyst Environmental Management		Craig@catalystem.com.au	Consultant	Assessment specialist		P	A		
Sam Price	Environment and Community Coordinator	Centennial Coal			Team Member	Site specialist (environment)		P	A		
James Wearne	Group Approvals Manager	Centennial Coal			Team Member	Approval manager		P	pr		
Lachlan Hammersley	Water Engineering Manager	Centennial Coal			Risk Assessment Owner	Internal specialist (water)		P	P		

10. WRAC Analysis Incident Builder

Instructions
WRAC Analysis Incident Builder (hover for instructions):

Step	Events				
	Events	caused by	Hazards Causes	resulting in	Consequences Outcomes
1. Groundwater Aquifers above Lithgow seam - (including Shallow Quaternary Alluvial Triassic)	1.1. loss or depressurisation of groundwater that exceed approved impacts	caused by	1. Model conceptualisation does not reflect natural system adequately	resulting in	1. Legal non-compliance
			2. over estimation of model parameters		2. Environmental impact (eg GDEs, flora/fauna)
			3. under estimation of model parameters		3. Social impact
			4. Insufficient baseline data		
			5. Mine design LTA		
			6. Mine design implementation LTA		
			7. Impact of geological structure		
			8. Monitoring LTA		
2. Groundwater Aquifers in and immediately above Lithgow seam - Permian	2.1. loss or depressurisation of groundwater that exceed approved impacts	caused by	1. Model conceptualisation does not reflect natural system adequately	resulting in	1. Legal non-compliance
			2. over estimation of model parameters		2. Environmental impact (eg GDEs, flora/fauna)
			3. under estimation of model parameters		3. Social impact
			4. Insufficient baseline data		

			5. Mine design LTA		
			6. Mine design implementation LTA		
			7. Impact of geological structure		
			8. Monitoring LTA		
3. Regiona Groundwater - Regional aquifers - Permian below the Lithgow seam and any associated GDEs	3.1. loss or depressurisation of groundwater that exceed approved impacts - Shoalhaven	caused by	1. Model conceptualisation does not reflect natural system adequately	resulting in	1. Legal non-compliance
			2. over estimation of model parameters		2. Environmental impact (eg GDEs, flora/fauna)
			3. under estimation of model parameters		3. Social impact
			4. Insufficient baseline data		
			5. Impact of geological structure		
			6. Mine design implementation LTA		
	3.2. loss or depressurisation of groundwater that exceed approved impacts - Devoian	caused by	1. Model conceptualisation does not reflect natural system adequately	resulting in	1. Legal non-compliance
			2. over estimation of model parameters		2. Environmental impact (eg GDEs, flora/fauna)
			3. under estimation of model parameters		3. Social impact
			4. Insufficient baseline data		
			5. Impact of geological structure		
			6. Mine design implementation LTA		
4. Groundwater bores	4.1. Loss or depressurisation of private bores located within or potentiallly affected by mining	caused by	1. Not applicable (none within potentially affected area, ie private	resulting in	1. Environmental impact (eg GDEs, flora/fauna)
					2. Legal non-compliance

			bores are all within the regional aquifers)		3. Social impact
	4.2. Unable to determine compliance	caused by	1. Monitoring LTA	resulting in	1. Environmental impact (eg GDEs, flora/fauna)
			2. Comprimised access to bores (eg lightning strike, vandalisim)		2. Legal non-compliance
					3. Social impact
5. Groundwater Dependent ecosystem	5.1. Other GDES - loss or depressurisation of groundwater that exceeds approved impacts	caused by	1. Model conceptualisation does not reflect natural system adequately	resulting in	1. Environmental impact (eg GDEs, flora/fauna)
			2. over estimation of model parameters		2. Legal non-compliance
			3. under estimation of model parameters		3. Social impact
			4. Insufficient baseline data		
			5. Impact of geological structure		
			6. Mine design implementation LTA		
			7. Mine design LTA		
			8. Monitoring LTA		
	5.2. HIGH PRIORITY GDEs - loss or depressurisation of groundwater that exceeds approved impacts	caused by	1. Not applicable (none identified within NSW AIP/WSP)	resulting in	1. Environmental impact (eg GDEs, flora/fauna)
					2. Legal non-compliance
					3. Social impact
6. Groundwater licensing	6.1. Inadequate licence allocation	caused by	1. Impact of geological structure	resulting in	1. Environmental impact (eg GDEs, flora/fauna)
			2. Mine design implementation LTA		2. Legal non-compliance
			3. Mine design LTA		3. Social impact

			4. over estimation of model parameters		4. Business impact
			5. under estimation of model parameters		
7. Overall site water and salt balance	7.1. groundwater volumes result in a change in the site water and salt balance predicting increase in discharges or salt load	caused by	1. Impact of geological structure	resulting in	1. Business impact
			2. Insufficient baseline data		2. Environmental impact (eg GDEs, flora/fauna)
			3. Mine design implementation LTA		3. Legal non-compliance
			4. Mine design LTA		4. Social impact
			5. Model conceptualisation does not reflect natural system adequately		
			6. Monitoring LTA		
			7. over estimation of model parameters		
			8. under estimation of model parameters		
	7.2. groundwater volumes result in a change in the site water and salt balance predicting reduced water availability or increased salt content	caused by	1. Impact of geological structure	resulting in	1. Environmental impact (eg GDEs, flora/fauna)
			2. Insufficient baseline data		2. Legal non-compliance
			3. Mine design implementation LTA		3. Social impact
			4. Mine design LTA		4. Business impact
			5. Model conceptualisation does not reflect natural system adequately		
			6. Monitoring LTA		
			7. over estimation of model parameters		

			8. under estimation of model parameters		
			9. Production rate requires addtional utilisation of equipment		
8. Surface and groundwater connectivity	8.1. Loss of baseflow from creek systems within mining area	caused by	1. Impact of geological structure	resulting in	1. Environmental impact (eg GDEs, flora/fauna)
			2. Insufficient baseline data		2. Legal non-compliance
			3. Mine design implementation LTA		3. Social impact
			4. Mine design LTA		
			5. Model conceptualisation does not reflect natural system adequately		
			6. Monitoring LTA		
			7. over estimation of model parameters		
			8. under estimation of model parameters		
9. Groundwater quality	9.1. change of beneficial use cateogry of aquifer	caused by	1. Impact of geological structure	resulting in	1. Environmental impact (eg GDEs, flora/fauna)
			2. Mine design implementation LTA		2. Legal non-compliance
					3. Social impact
10. HMR Parameters considered in recalibration	10.1. depressurisation or drawdown exceeding approved predictions	caused by	1. HMR - Storage properties of strata not supported by field investigation	resulting in	1. Environmental impact (eg GDEs, flora/fauna)
			2. HMR - Hydraulic conductivity change as a result of mining		2. Legal non-compliance
			3. HMR - Rainfall data considered based on history and not considering uncertainty		3. Social impact

			4. HMR - Stress testing not sufficient		
11. Surface water users	11.1. loss of surface water to groundwater causes impacts to surface water extractors and water dependent infrastructure/recreation	caused by	1. Impact of geological structure	resulting in	1. Business impact
			2. Insufficient baseline data		2. Environmental impact (eg GDEs, flora/fauna)
			3. Mine design implementation LTA		3. Legal non-compliance
			4. Mine design LTA		4. Social impact
			5. Model conceptualisation does not reflect natural system adequately		
			6. Monitoring LTA		
			7. over estimation of model parameters		
			8. under estimation of model parameters		
	11.2. loss of water from village spring greater than approved	caused by	1. Impact of geological structure	resulting in	1. Business impact
			2. Insufficient baseline data		2. Environmental impact (eg GDEs, flora/fauna)
			3. Mine design implementation LTA		3. Legal non-compliance
			4. Mine design LTA		4. Social impact
			5. Model conceptualisation does not reflect natural system adequately		
			6. Monitoring LTA		
			7. over estimation of model parameters		
			8. under estimation of model parameters		
12. Cumulative impacts			1. inappropriate zone of impact	resulting in	1. Business impact

	12.1. Interactions with external factors	caused by	2. Unexpected activity within defined zone of impact		2. Environmental impact (eg GDEs, flora/fauna)
			3. Constraints on groundwater access		3. Legal non-compliance
					4. Social impact
	12.2. Interactions as a result of the approved project	caused by	1. subsidence occurs outside of predictions	resulting in	1. Business impact
			2. height of fracturing is greater than predictions		2. Environmental impact (eg GDEs, flora/fauna)
					3. Legal non-compliance
					4. Social impact

Scope Confirmation

Approver	Scope Confirmation	Date	Comments
1. Lachlan Hammersley [Lachlan.Hammersley]	Yes	July 25, 2018	

CEY Risk Matrix

CENTENNIAL RISK MATRIX							Likelihood					
							A Certain	B Probable	C Possible	D Remote	E Improbable	Description (D)
Rating	Consequence Note: Consequence may result from a single event or may represent a cumulative impact over a period of 12 months. Use the worst case reasonable consequence if there is more than one.						Common	Has Happened within Centennial	Could Happen & has happened in non-CEY operations	Not Likely	Practically impossible	Probability (Pb)
	Financial Impact to Annual Business Plan (F)	Personal Injury (PI)	Business Interruption (BI)	Legal (L)	Reputation (R)	Environment (E)	Frequent incidents	Regular incidents	Infrequent incidents	Unlikely to occur. Very few recorded or known incidents	May occur in exceptional circumstances. Almost no recorded incidents.	Incident Frequency (IF)
							Operations – within 3 months	Operations – within 2 years	Operations – within 5 years	Operations – within 10 years	Operations – within 30 years	Operations (Op)
							Project – Every project	Project – Every 2 projects	Project – Every 5 projects	Project – Every 10 projects	Project – Every 30 projects	Project (Pr)
5. Catastrophic	>$50m	Multiple Fatalities	> 1month	Prolonged litigation, heavy fines, potential jail term	Prolonged International media attention	Long term impairment habitats/ ecosystem	25 (E)	24 (E)	21 (H)	19 (H)	15 (S)	
4. Major	$10m - $50m	Single Fatality	1 week to 1 month	Major breach/ major litigation	International media attention	Long term effects of ecosystem	23 (E)	22 (E)	18 (H)	14 (S)	10 (M)	
3. Moderate	$1m - $10m	Serious/ Disabling Injury	1 day to 1 week	Serious breach of regulation. prosecution/ fine	National media attention	Serious medium term environmental effects	20 (H)	17 (H)	13 (S)	9 (M)	6 (L)	
2. Minor	$100k - $1m	Lost Time Injury	12 hrs to 1 day	Non-compliance, breaches in regulation	Adverse local public attention	Minor effects to physical environment	16 (S)	12 (S)	8 (M)	5 (L)	3 (L)	
1. Insignificant	<$100k	First Aid Treatment Only	< 12 hrs	Low level compliance issue	Local complaints	Limited physical damage	11 (S)	7 (M)	4 (L)	2 (L)	1 (L)	

CEY Risk Rating Definitions

Risk Rating	Risk Category		Generic Management Actions
22 to 25	E	Extreme	Action is required to eliminate or reduce the risk. If the risk is considered to be ALARP then the decision to accept the risk is to be made by Centennial Coal Chief Executive
17 to 21	H	High	Action is required to eliminate or reduce the risk. If the risk is considered to be ALARP then the decision to accept the risk is to be made by the relevant Centennial Coal Executive General Manager
11 to 16	S	Significant	Action is required to eliminate or reduce the risk. If the risk is considered to be ALARP then the decision to accept the risk is to be made by the Manager of the Centennial Coal Operation
7 to 10	M	Moderate	Action is required to eliminate or reduce the risk. If the risk is considered to be ALARP then the decision to accept the risk is to be made by the Manager of the Centennial Coal Operation
1 to 6	L	Low	Actions to eliminate or further reduce the risk should be considered. If risk is considered to be ALARP then the decision to accept the risk is to be made by the risk assessment owner (no recommended control is required to be created for this)

WRAC Analysis Worksheet

Step	Potential Incident	Current Controls	L	MRC	RR	Recommended Control	Bow Tie Extension
1. Groundwater Aquifers above Lithgow seam - (including Shallow Quaternary Alluvial Triassic)	There is a risk to Operations from ::: loss or depressurisation of groundwater that exceed approved impacts ::: Caused by: Impact of geological structure or Insufficient baseline data or Mine design implementation LTA or Mine design LTA or Model conceptualisation does not reflect natural system adequately or Monitoring LTA or over estimation of model parameters or under estimation of model parameters Resulting in: Environmental impact (eg GDEs, flora/fauna) or Legal non-compliance or Social impact.	1.1.a. Mine method and design does not change. 1.1.b. Mine footprint has not changed 1.1.c. Environmental monitoring program approved 1.1.d. Independent and peer review approved conceptual model 1.1.e. reCalibration of model against mining operational data 1.1.f. Some uncertainty (type 1) has been undertaken	**D** (Pb)	2 (E)	**5 (L)**	1. further independent expert review of deliverables 2. fracture height monitoring to be reviewed following first 4 panels 3. Further consdieration of type 3 uncertainity assessment 4. Consider the impacts of surface to seam geological structures (following definition by the Mine and via a desktop exercise in the first instance)	
2. Groundwater Aquifers in and immediately above Lithgow seam - Permian	There is a risk to Operations from ::: loss or depressurisation of groundwater that exceed approved impacts ::: Caused by: Impact of geological structure or Insufficient baseline data or Mine design implementation LTA or Mine design LTA or Model conceptualisation does not reflect natural system adequately or Monitoring LTA or over estimation of model parameters or under estimation of model parameters	2.1.a. Mine method and design does not change. 2.1.b. Mine footprint has not changed 2.1.c. Environmental monitoring program approved 2.1.d. Independent and peer review approved conceptual model 2.1.e. reCalibration of model against mining operational data	**D** (Pb)	2 (E)	**5 (L)**	1. further independent expert review of deliverables 2. fracture height monitoring to be reviewed following first 4 panels 3. Further consdieration of type 3 uncertainity assessment 4. Consider the impacts of surface to seam geological structures (following definition by the Mine and via a desktop exercise in the first instance)	

	Resulting in: Environmental impact (eg GDEs, flora/fauna) or Legal non-compliance or Social impact.	2.1.f. Some uncertainty (type 1) has been undertaken					
3. Regiona Groundwater - Regional aquifers - Permian below the Lithgow seam and any associated GDEs	There is a risk to Operations from ::: loss or depressurisation of groundwater that exceed approved impacts - Shoalhaven ::: Caused by: Impact of geological structure or Insufficient baseline data or Mine design implementation LTA or Model conceptualisation does not reflect natural system adequately or over estimation of model parameters or under estimation of model parameters Resulting in: Environmental impact (eg GDEs, flora/fauna) or Legal non-compliance or Social impact.	3.1.a. below target seam - outside zone of influence of extraction system 3.1.b. mine design (narrow panel) mitigate fracturing of the floor 3.1.c. observations from mining operation is that water is unlikely to upwell through the floor. 3.1.d. monitoring within shoalhaven zone, piezo pressure is well below the target seam level	**D** (Pb)	2 (E)	**5** **(L)**		
	There is a risk to Operations from ::: loss or depressurisation of groundwater that exceed approved impacts - Devoian ::: Caused by: Impact of geological structure or Insufficient baseline data or Mine design implementation LTA or Model conceptualisation does not reflect natural system adequately or over estimation of model parameters or under estimation of model parameters Resulting in: Environmental impact (eg GDEs, flora/fauna) or Legal non-compliance or Social impact.	3.2.a. Not applicable	**E** (Pb)	1 (E)	**1** **(L)**		

4. Groundwater bores	There is a risk to Operations from ::: Loss or depressurisation of private bores located within or potentiallly affected by mining ::: Caused by: Not applicable (none within potentially affected area, ie private bores are all within the regional aquifers) Resulting in: Environmental impact (eg GDEs, flora/fauna) or Legal non-compliance or Social impact.	4.1.a. Private/Registered bores that exist are within the Devoian zone are disconnected from the groundwater environment intercepted by mining, therefore not applicable	**E** (Pb)	1 (E)	**1** **(L)**		
	There is a risk to Operations from ::: Unable to determine compliance ::: Caused by: Comprimised access to bores (eg lightning strike, vandalisim) or Monitoring LTA Resulting in: Environmental impact (eg GDEs, flora/fauna) or Legal non-compliance or Social impact.	4.2.a. Redundancy in existing monitoring program however only one/two bores across each source	**C** (Pb)	2 (E)	**8** **(M)**	5. Committment to redrill failed or impact bores	
5. Groundwater Dependent ecosystem	There is a risk to Operations from ::: Other GDES - loss or depressurisation of groundwater that exceeds approved impacts ::: Caused by: Impact of geological structure or Insufficient baseline data or Mine design implementation LTA or Mine design LTA or Model conceptualisation does not reflect natural system adequately or Monitoring LTA or over estimation of model parameters or under estimation of model parameters	5.1.a. groundtruthed faculatively GDEs 5.1.b. no change in subsidence profile (<100mm)	**E** (Pb)	2 (E)	**3** **(L)**		

	Resulting in: Environmental impact (eg GDEs, flora/fauna) or Legal non-compliance or Social impact.						
	There is a risk to Operations from ::: HIGH PRIORITY GDEs - loss or depressurisation of groundwater that exceeds approved impacts ::: Caused by: Not applicable (none identified within NSW AIP/WSP) Resulting in: Environmental impact (eg GDEs, flora/fauna) or Legal non-compliance or Social impact.	5.2.a. not applicable (as per WSP)	**E** (Pb)	1 (E)	**1 (L)**		
6. Groundwater licensing	There is a risk to Operations from ::: Inadequate licence allocation ::: Caused by: Impact of geological structure or Mine design implementation LTA or Mine design LTA or over estimation of model parameters or under estimation of model parameters Resulting in: Business impact or Environmental impact (eg GDEs, flora/fauna) or Legal non-compliance or Social impact.	6.1.a. Current licensing covers a 3 times the predicted groundwater inflow. 6.1.b. Significant unallocated portion of catchment water within the Sydney Basin North Source	**E** (Pb)	2 (F)	**3 (L)**		
7. Overall site water and salt balance	There is a risk to Operations from ::: groundwater volumes result in a change in the site water and salt balance predicting increase in discharges or salt load ::: Caused by: Impact of geological structure or Insufficient baseline data or Mine	7.1.a. Nil discharge site 7.1.b. groundwater is currently lost through product coal 7.1.c. Control over water supply sources to the site (eg Water imports, production bore usage).	**B** (Pb)	2 (E)	**12 (S)**	6. Revised Water and Salt Balance (Aug 2018) 7. Management plan revised to enforce a preference system on water sources for the site to mitigate environmental risk. TARPS will also include guidance on appropriate usage of each water source.	

	design implementation LTA or Mine design LTA or Model conceptualisation does not reflect natural system adequately or Monitoring LTA or over estimation of model parameters or under estimation of model parameters Resulting in: Business impact or Environmental impact (eg GDEs, flora/fauna) or Legal non-compliance or Social impact.	7.1.d. Revised EPL has resulted in greater flexibility to site operations					
	There is a risk to Operations from ::: groundwater volumes result in a change in the site water and salt balance predicting reduced water availability or increased salt content ::: Caused by: Impact of geological structure or Insufficient baseline data or Mine design implementation LTA or Mine design LTA or Model conceptualisation does not reflect natural system adequately or Monitoring LTA or over estimation of model parameters or Production rate requires addtional utilisation of equipment or under estimation of model parameters Resulting in: Business impact or Environmental impact (eg GDEs, flora/fauna) or Legal non-compliance or Social impact.	7.2.a. Additional water sources available other than groundwater intercepted by the mine. 7.2.b. Revised EPL has resulted in greater flexibility to site operations	**A** (Pb)	4 (F)	**23 (E)**	8. Determine the water deficit under a range of sensitivities 9. Additional bore to be installed 10. Investigate and seek approval for additional external water	
8. Surface and groundwater connectivity	There is a risk to Operations from ::: Loss of baseflow from creek systems within mining area :::	8.1.a. Groundwater monitoring within both waterways located above mining areas (genowlan, gap creeks)	**D** (Pb)	2 (E)	**5 (L)**		

	Caused by: Impact of geological structure or Insufficient baseline data or Mine design implementation LTA or Mine design LTA or Model conceptualisation does not reflect natural system adequately or Monitoring LTA or over estimation of model parameters or under estimation of model parameters Resulting in: Environmental impact (eg GDEs, flora/fauna) or Legal non-compliance or Social impact.	8.1.b. Mining method does not change from approved					
9. Groundwater quality	There is a risk to Operations from ::: change of beneficial use cateogry of aquifer ::: Caused by: Impact of geological structure or Mine design implementation LTA Resulting in: Environmental impact (eg GDEs, flora/fauna) or Legal non-compliance or Social impact.	9.1.a. Mining method does not change from approved 9.1.b. Closed loop water management system	**E** (Pb)	1 (E)	**1 (L)**		
10. HMR Parameters considered in recalibration	There is a risk to Operations from ::: depressurisation or drawdown exceeding approved predictions ::: Caused by: HMR - Hydraulic conductivity change as a result of mining or HMR - Rainfall data considered based on history and not considering uncertainty or HMR - Storage properties of strata not supported by field investigation or HMR - Stress testing not sufficient	10.1.a. Hydrogeological model prepared to industry standard with limited uncertainity analysis, peer reviewed 10.1.b. Groundwater monitoring program 10.1.c. Limited groundwater volume being measured within mine development to date	**D** (Pb)	2 (L)	**5 (L)**	11. Recalibration following 12 months of panel extraction 12. IESC guidelines being considered for uncertainty, including peer review 13. linearment consdieration	

	Resulting in: Environmental impact (eg GDEs, flora/fauna) or Legal non-compliance or Social impact.	10.1.d. Correlation from actual measured groundwater to model predictions 10.1.e. 12months review undertaken				14. scenario based assessment (at least 5 scenarios as per advice by peer review)	
11. Surface water users	There is a risk to Operations from ::: loss of surface water to groundwater causes impacts to surface water extractors and water dependent infrastructure/recreation ::: Caused by: Impact of geological structure or Insufficient baseline data or Mine design implementation LTA or Mine design LTA or Model conceptualisation does not reflect natural system adequately or Monitoring LTA or over estimation of model parameters or under estimation of model parameters Resulting in: Business impact or Environmental impact (eg GDEs, flora/fauna) or Legal non-compliance or Social impact.	11.1.a. Groundwater and surface water monitoring within both waterways located above mining areas (genowlan, gap creeks) 11.1.b. Mining method does not change from approved	**D** (Pb)	2 (E)	**5 (L)**		
	There is a risk to Operations from ::: loss of water from village spring greater than approved ::: Caused by: Impact of geological structure or Insufficient baseline data or Mine design implementation LTA or Mine design LTA or Model conceptualisation does not reflect natural system adequately or Monitoring LTA or over estimation of model parameters or under estimation of model parameters	11.2.a. Mine design change in 2018 that has resulted in the removal of the Hartely Shale Mine interaction zone	**E** (Pb)	1 (E)	**1 (L)**		

	Resulting in: Business impact or Environmental impact (eg GDEs, flora/fauna) or Legal non-compliance or Social impact.						
12. Cumulative impacts	There is a risk to Operations from ::: Interactions with external factors ::: Caused by: Constraints on groundwater access or inappropriate zone of impact or Unexpected activity within defined zone of impact Resulting in: Business impact or Environmental impact (eg GDEs, flora/fauna) or Legal non-compliance or Social impact.	12.1.a. no known developments within the zone of impact 12.1.b. State conservation area and LEP indicates a rural landuse surrounding zone of impact	**E** (Pb)	1 (E)	**1** **(L)**		
	There is a risk to Operations from ::: Interactions as a result of the approved project ::: Caused by: height of fracturing is greater than predictions or subsidence occurs outside of predictions Resulting in: Business impact or Environmental impact (eg GDEs, flora/fauna) or Legal non-compliance or Social impact.	12.2.a. Mining method does not change 12.2.b. Footprint does not change	**E** (Pb)	1 (E)	**1** **(L)**		

Recommended Controls

Recommended Controls	Place(s) Used	Allocated To	Required By Date	Pulse User No.	PULSE Ref. No.
1. further independent expert review of deliverables	Events: 1.1, 2.1	N Singh	31-Dec-2018		
2. fracture height monitoring to be reviewed following first 4 panels	Events: 1.1, 2.1	Sam Price	30-Jun-2020		
3. Further consdieration of type 3 uncertainity assessment	Events: 1.1, 2.1	N Singh	14-Sep-2018		
4. Consider the impacts of surface to seam geological structures (following definition by the Mine and via a desktop exercise in the first instance)	Events: 1.1, 2.1	David King	27-Aug-2018		
5. Committment to redrill failed or impact bores	Events: 4.2	Sam Price	30-Jun-2020		
6. Revised Water and Salt Balance (Aug 2018)	Events: 7.1	L Hammersley	30-Sep-2018		
7. Management plan revised to enforce a preference system on water sources for the site to mitigate environmental risk. TARPS will also include guidance on appropriate usage of each water source.	Events: 7.1	L Hammersley	28-Jun-2019		
8. Determine the water deficit under a range of sensitivities	Events: 7.2	L Hammersley	31-Aug-2018		
9. Additional bore to be installed	Events: 7.2	Sam Price	31-Oct-2018		
10. Investigate and seek approval for additional external water	Events: 7.2	L Hammersley	31-Oct-2018		
11. Recalibration following 12 months of panel extraction	Events: 10.1	Sam Price	30-Jun-2020		
12. IESC guidelines being considered for uncertainty, including peer review	Events: 10.1	N Singh	14-Sep-2018		
13. linearment consdieration	Events: 10.1	N Singh	14-Sep-2018		

14. scenario based assessment (at least 5 scenarios as per advice by peer review)	Events: 10.1	N Singh	14-Sep-2018		

Appendix B – Modelled and observed groundwater calibration hydrographs

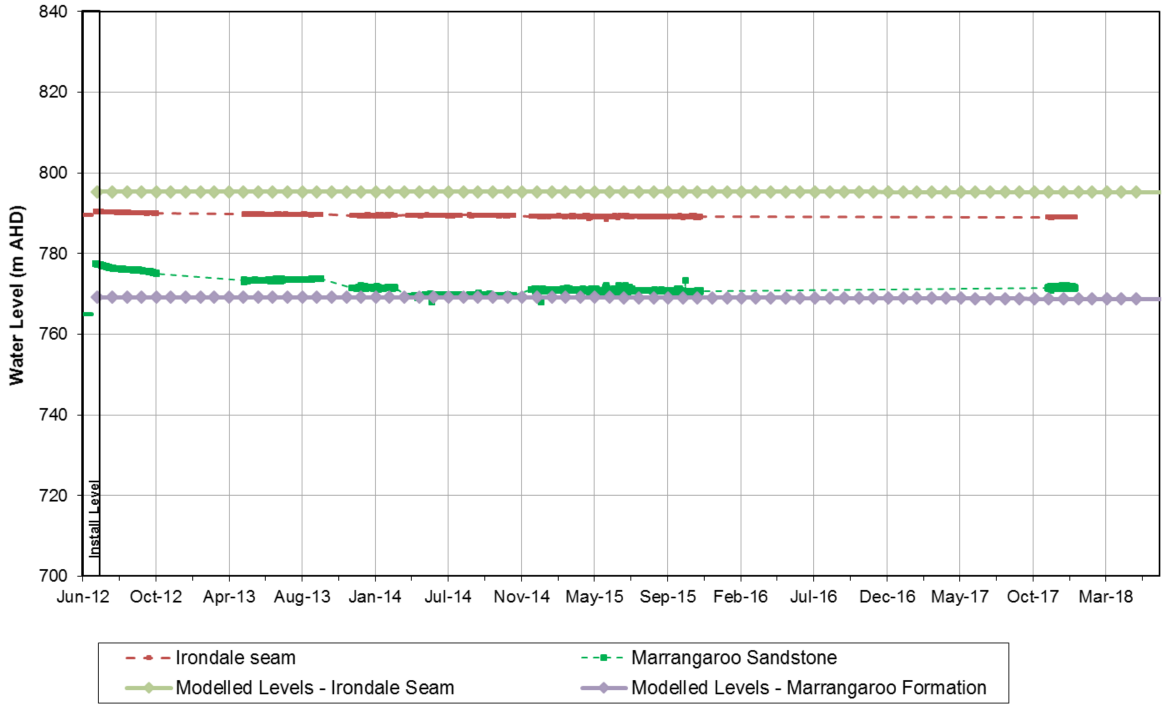

Figure B-1 Modelled and observed hydrographs – ARP01

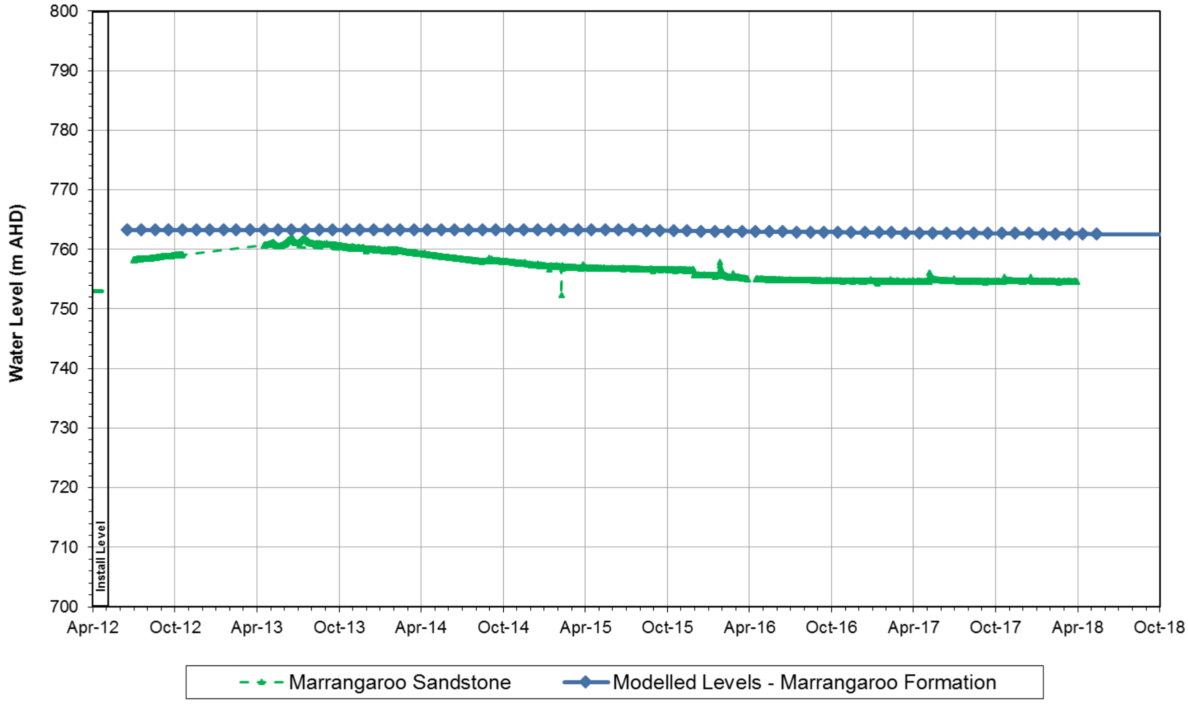

Figure B-2 Modelled and observed hydrographs – ARP02

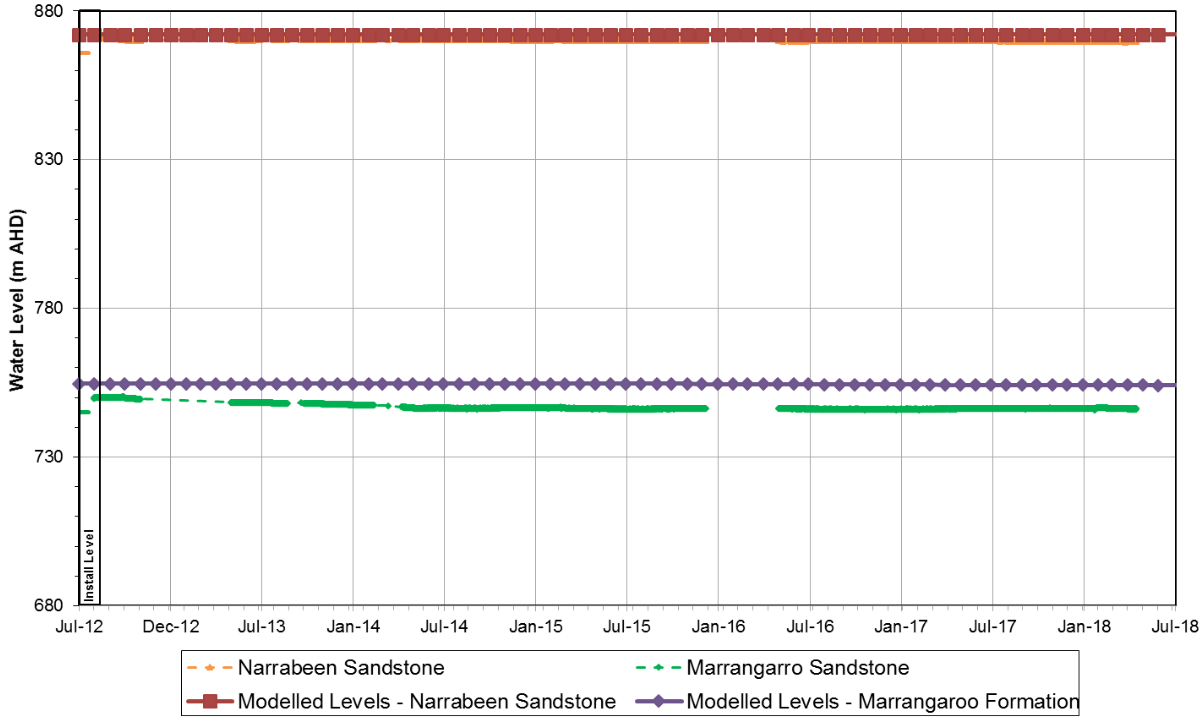

Figure B-3 Modelled and observed hydrographs – ARP03

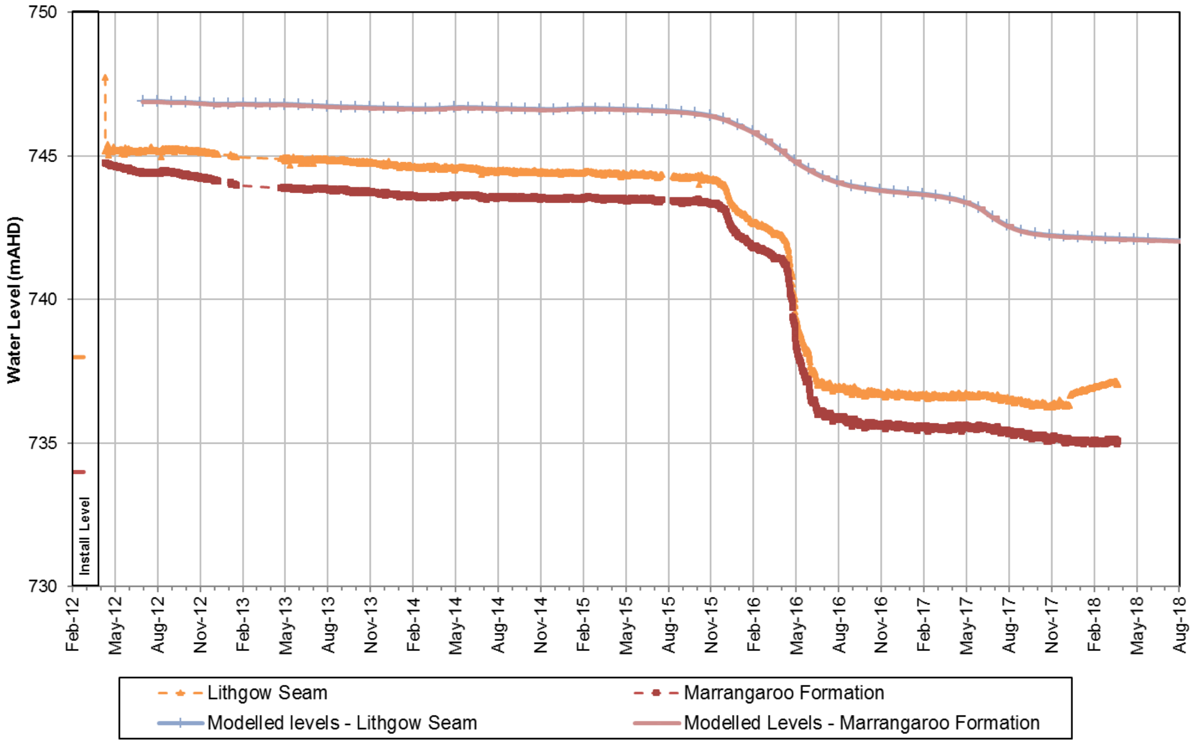

Figure B-4 Modelled and observed hydrographs – ARP04 Lithgow Seam and Marrangaroo Formation

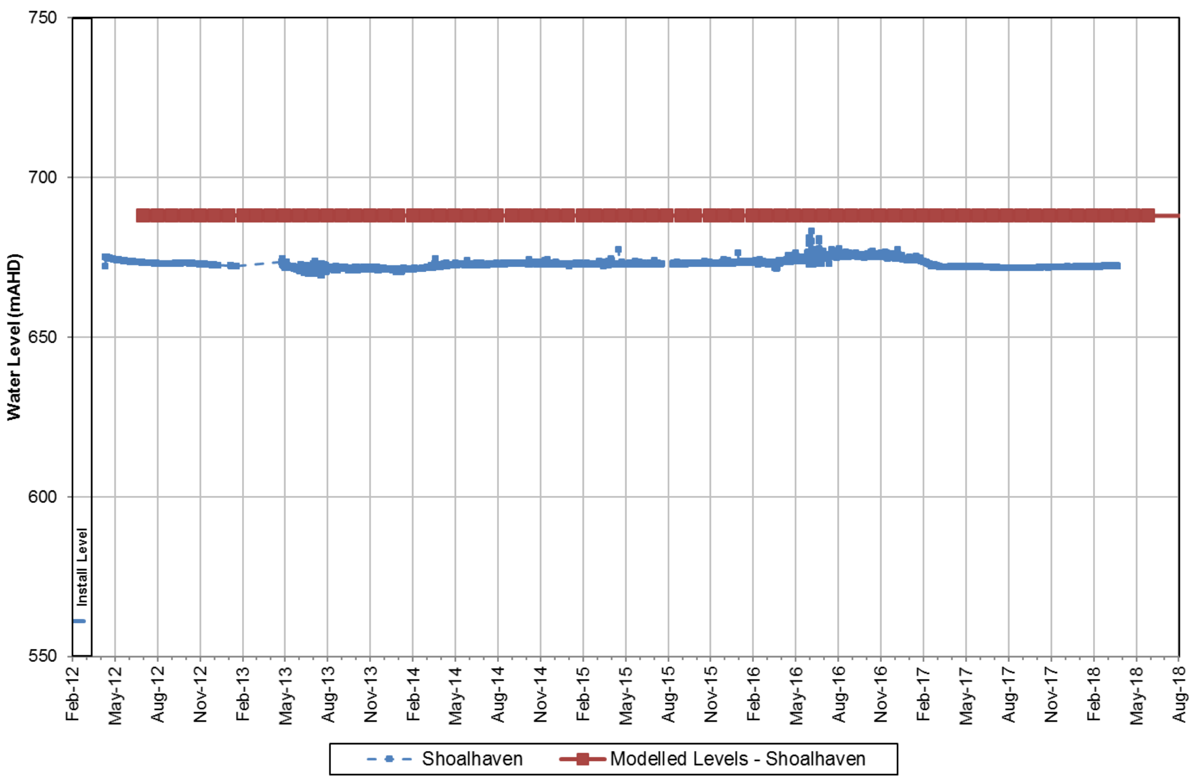

Figure B-5 Modelled and observed hydrographs – ARP04 Shoalhaven Group

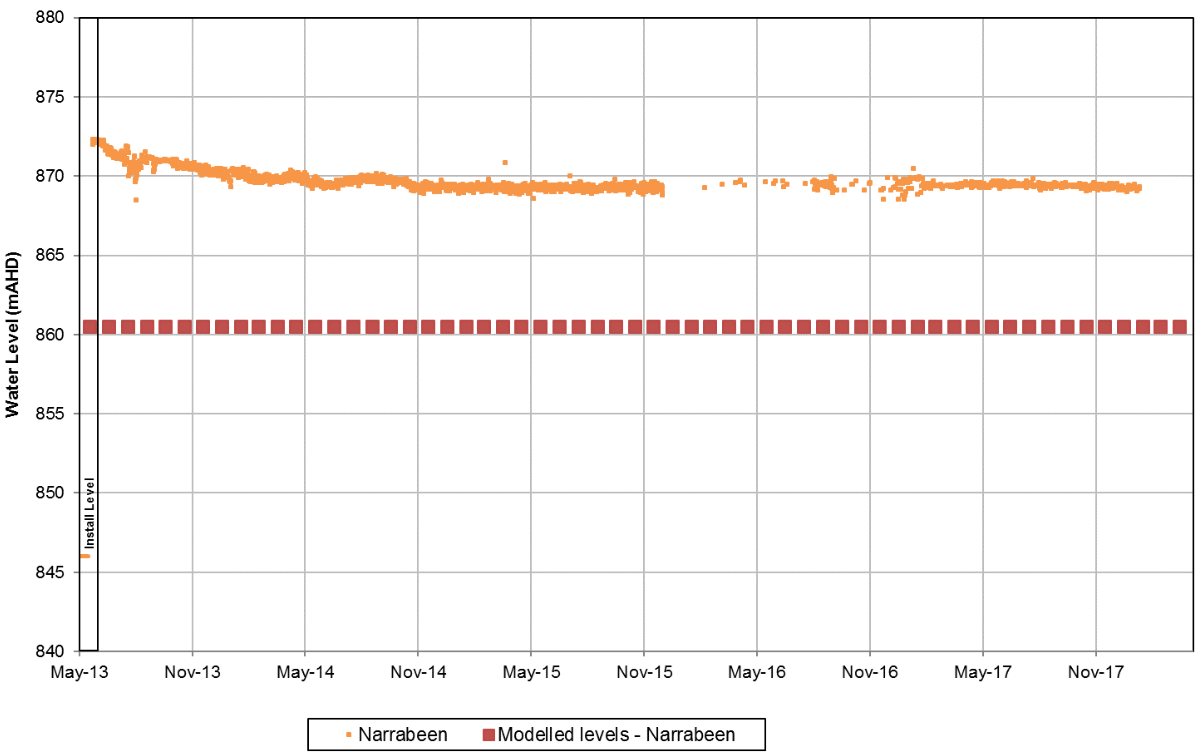

Figure B-6 Modelled and observed hydrographs – ARP06

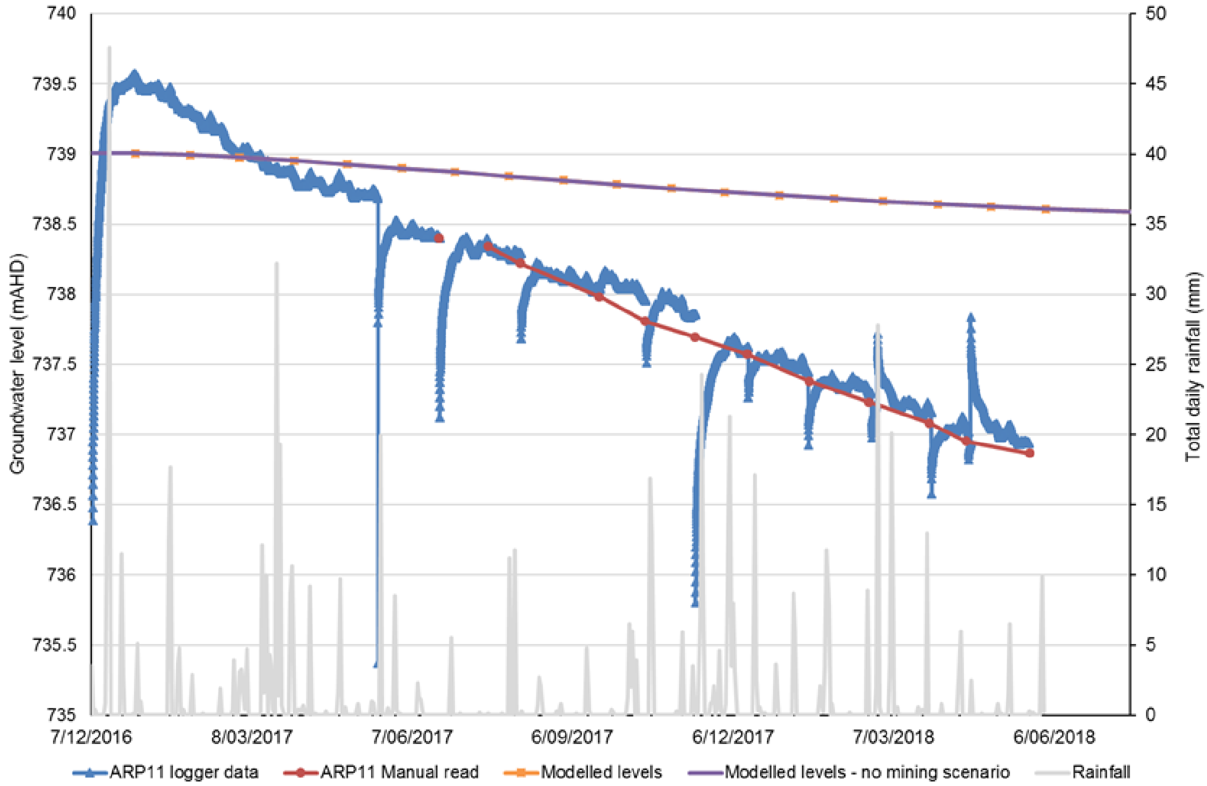

Figure B-7 Modelled and observed hydrographs – ARP11

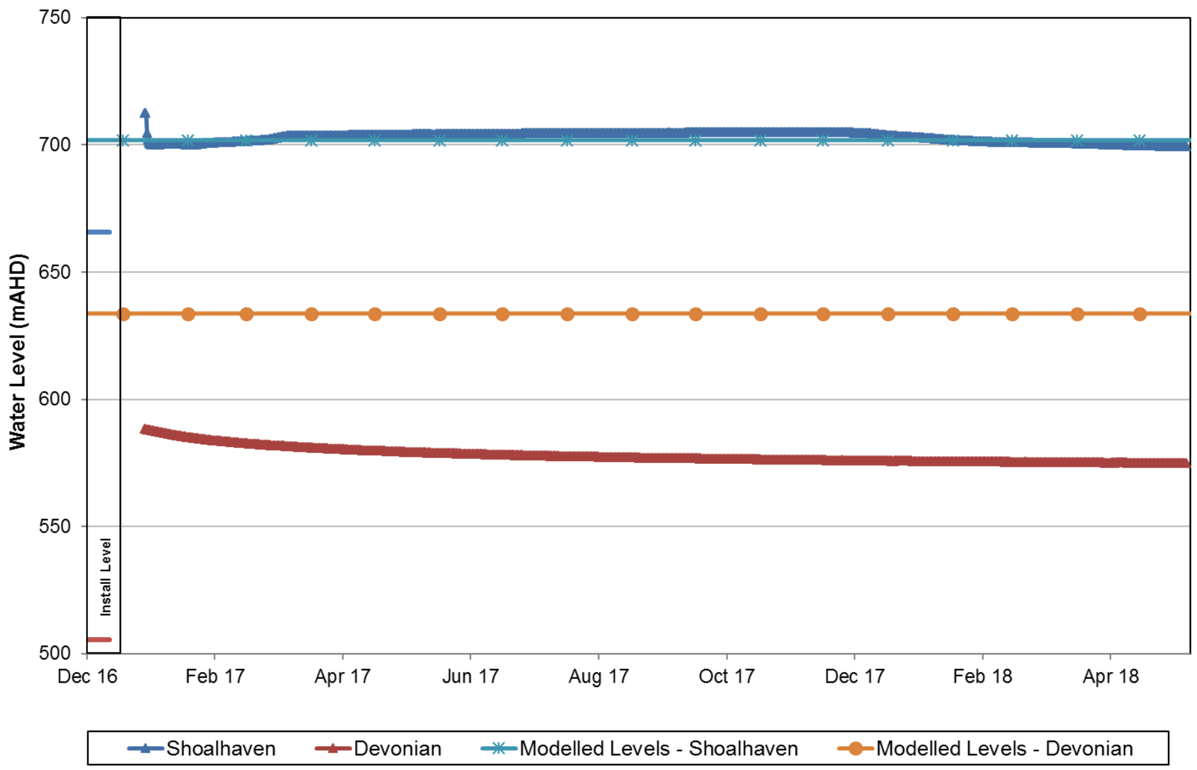

Figure B-8 Modelled and observed hydrographs – ARP13

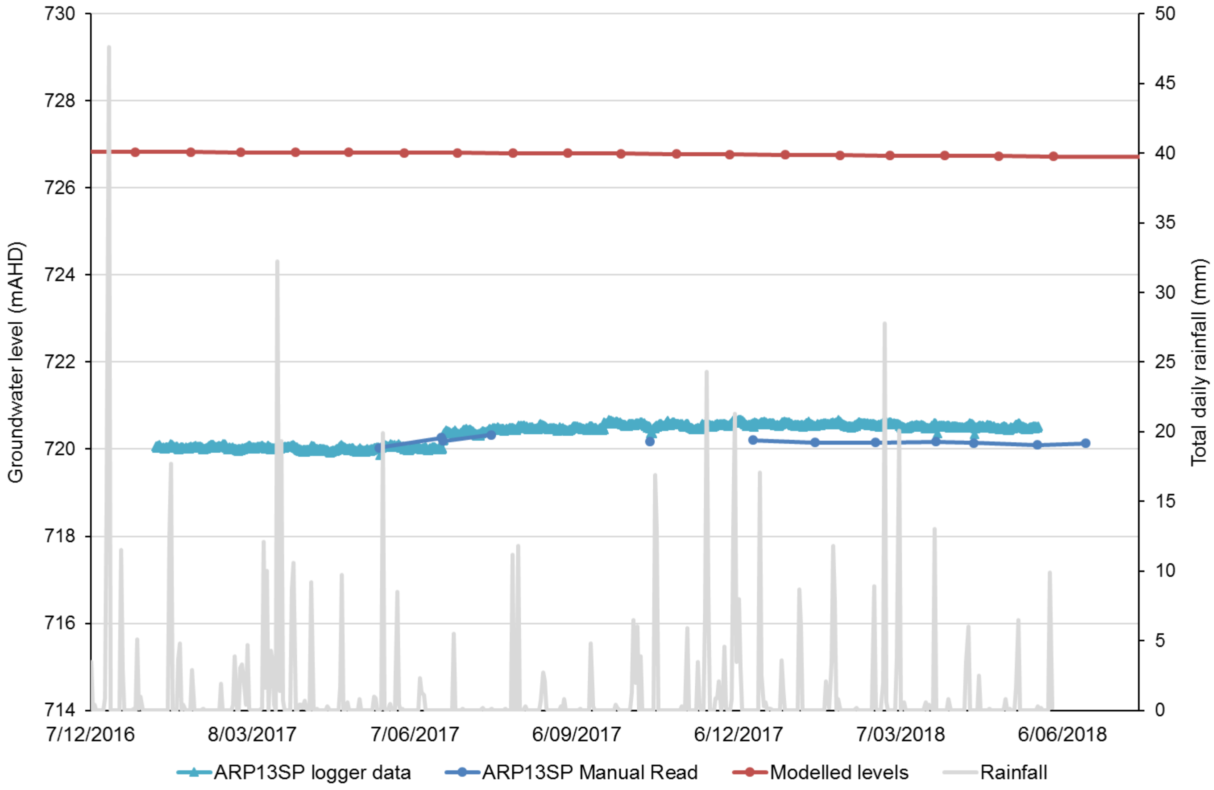

Figure B-9 Modelled and observed hydrographs – ARP13SP

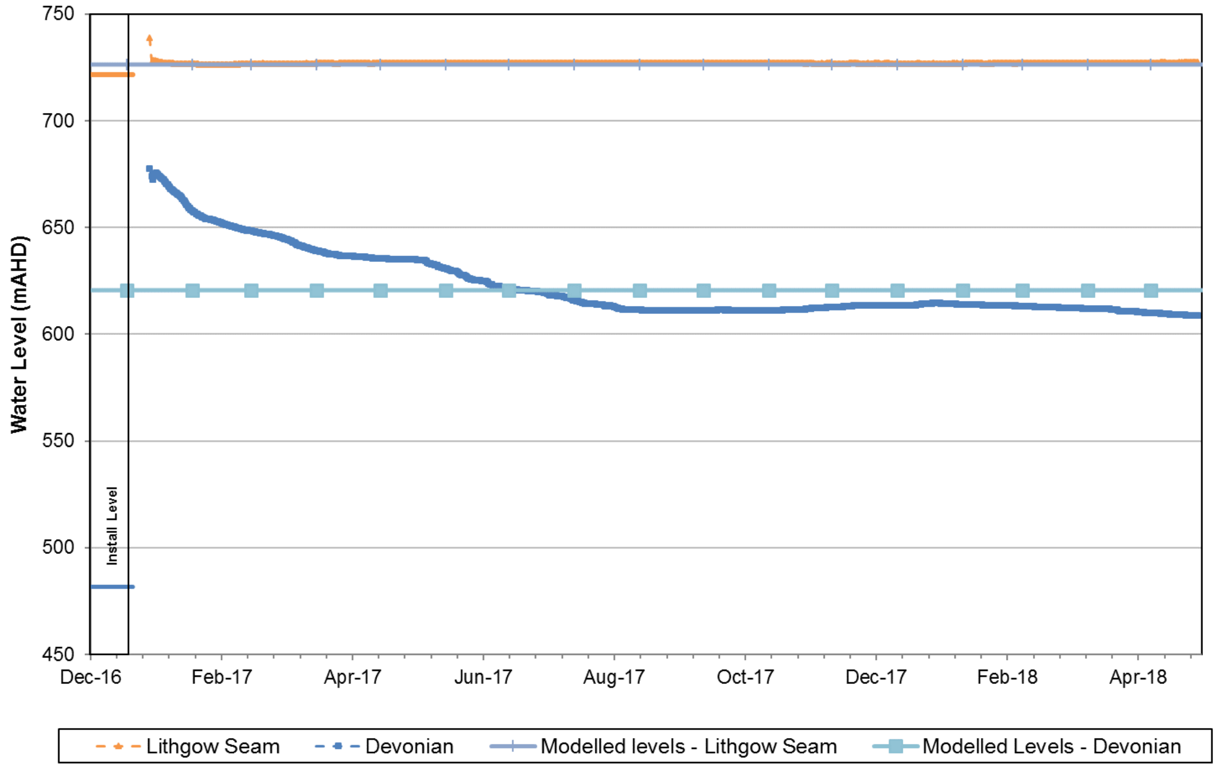

Figure B-10 Modelled and observed hydrographs – ARP15

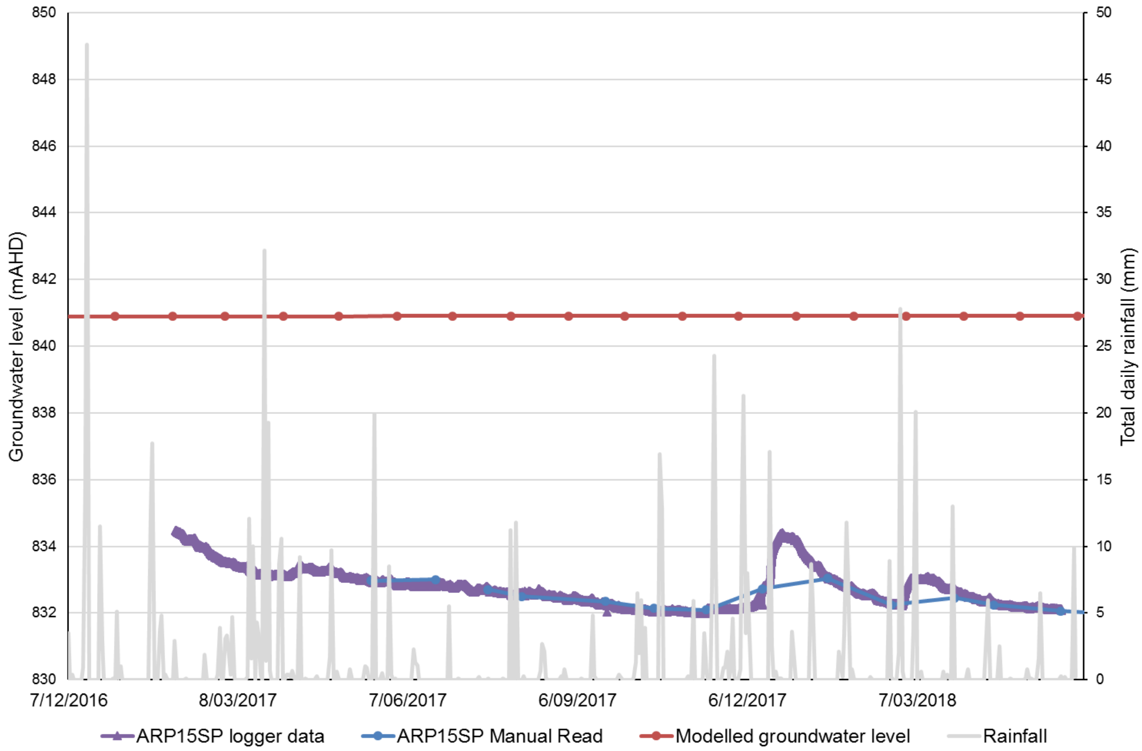

Figure B-11 Modelled and observed hydrographs – ARP15SP

Appendix C – Groundwater hydrographs

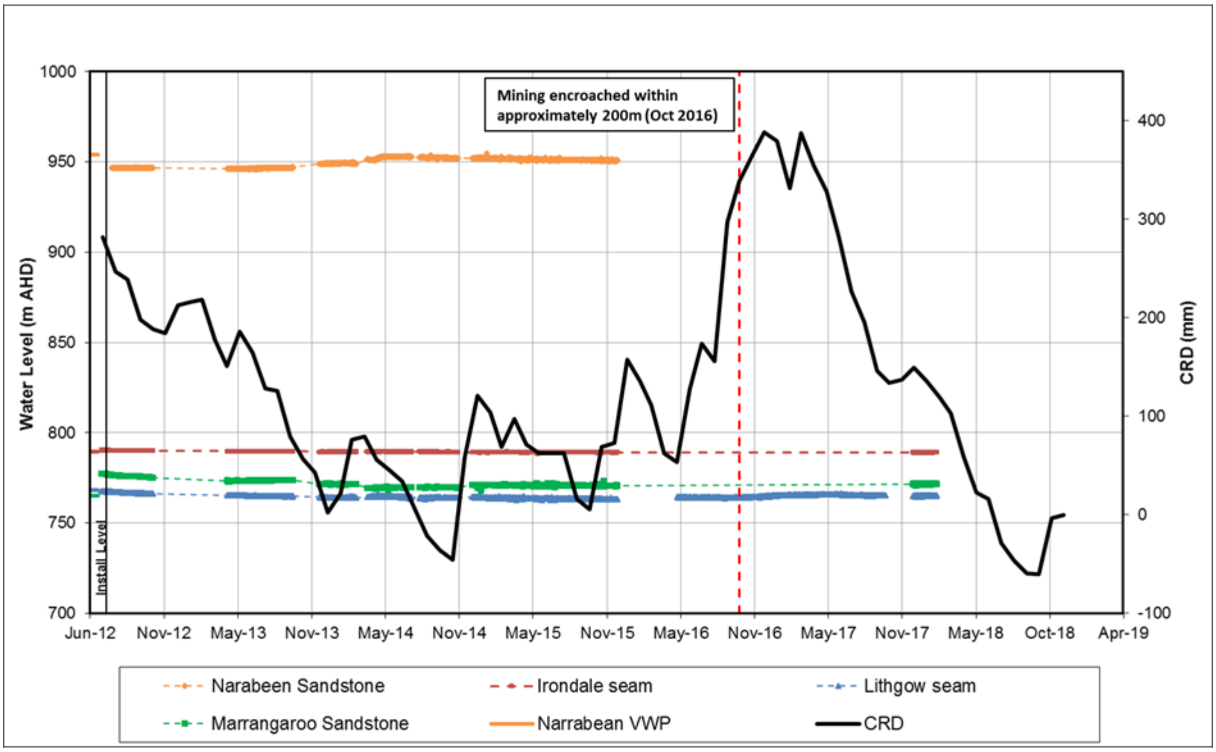

Figure C-1 Observed hydrographs – ARP01

Pressure constantly negative in Narrabeen Sandstone and Lithgow Seam. VWP pressure consistently negative in the Irondale Seam since October 2014.

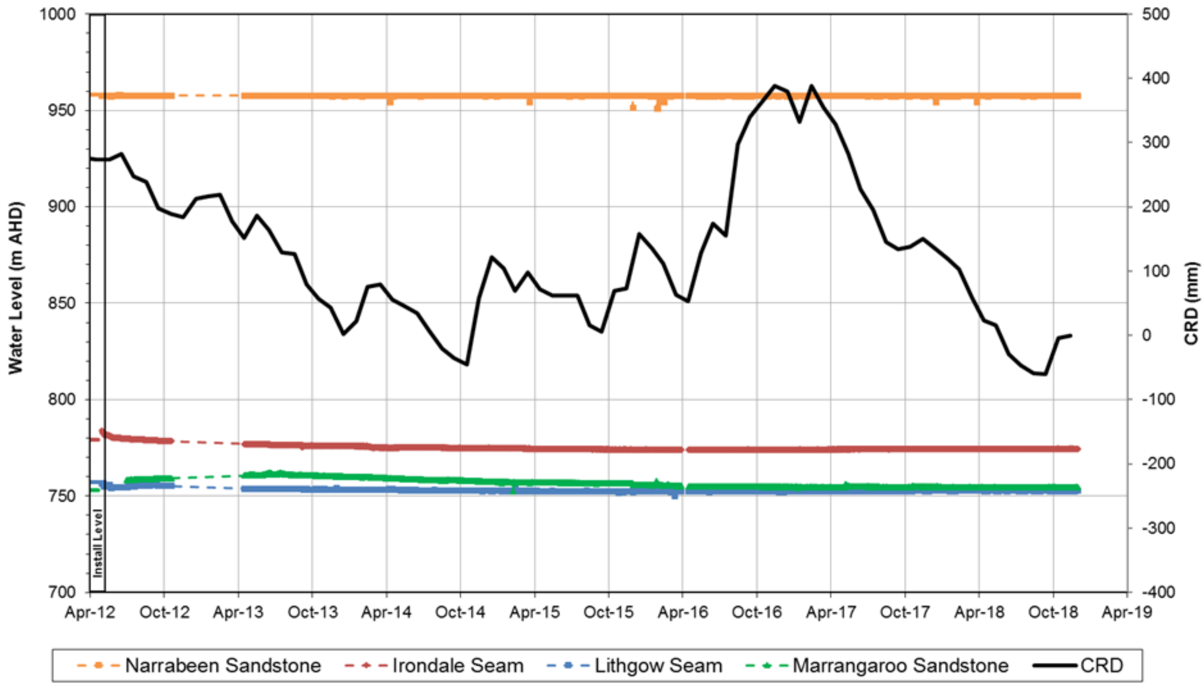

Figure C-2 Observed hydrographs – ARP02

Pressure has been negative at the VWP installed in the Narrabeen Sandstone and Lithgow Seam since installation. Pressure has been negative in the Irondale Seam since July 2012 (two months after installation).

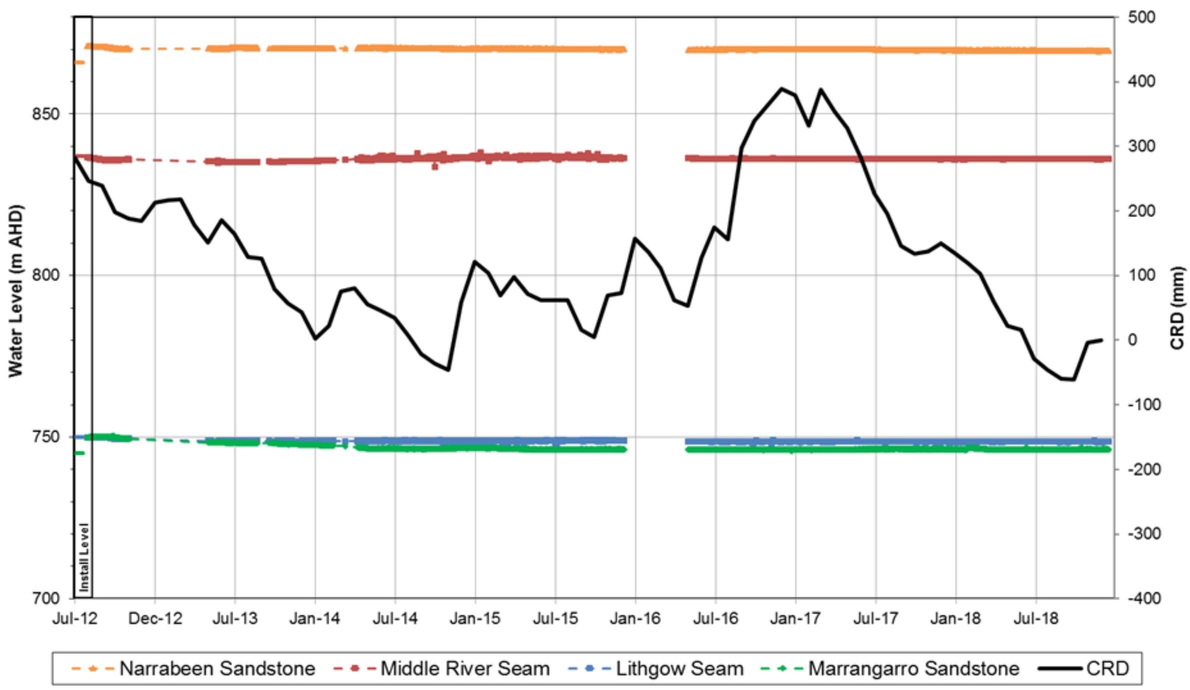

Figure C-3 Observed hydrographs – ARP03

Pressure has typically been negative in the Middle River Seam. Pressure has been negative in the Lithgow Seam since October 2012.

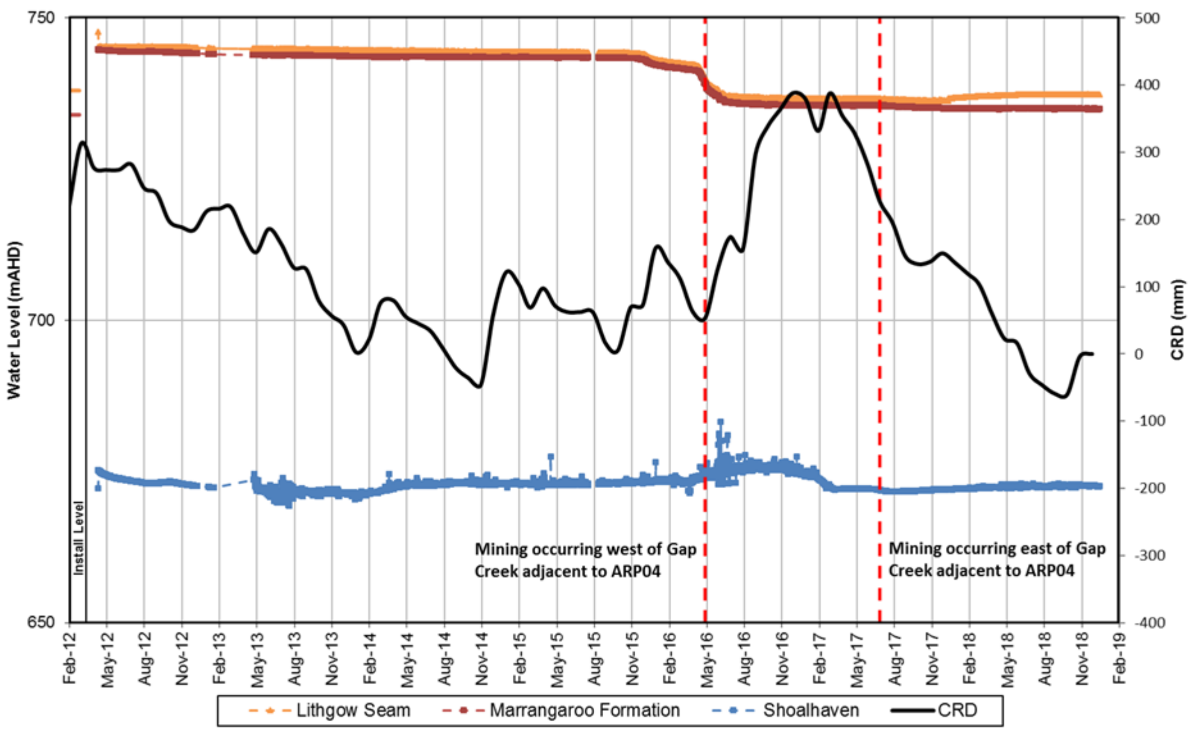

Figure C-4 Observed hydrographs – ARP04

Pressure has been negative in the Lithgow Seam at ARP04 since June 2016.

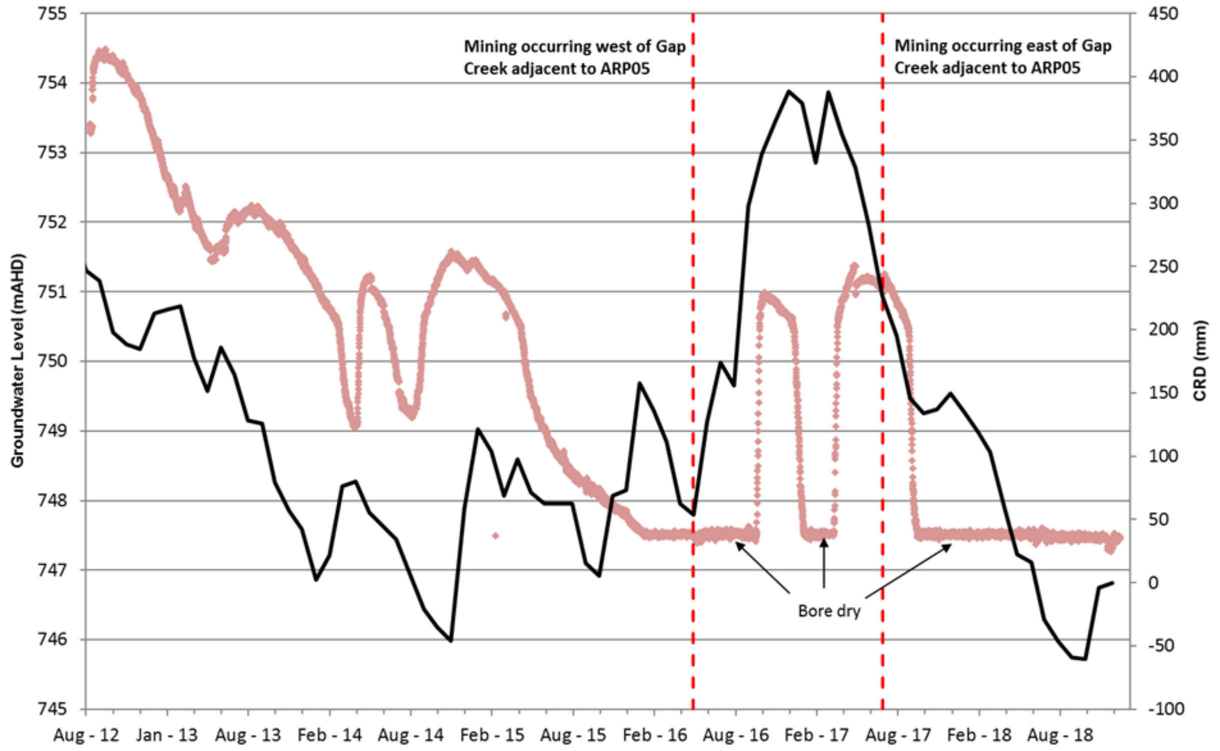

Figure C-5 Observed hydrographs – ARP05

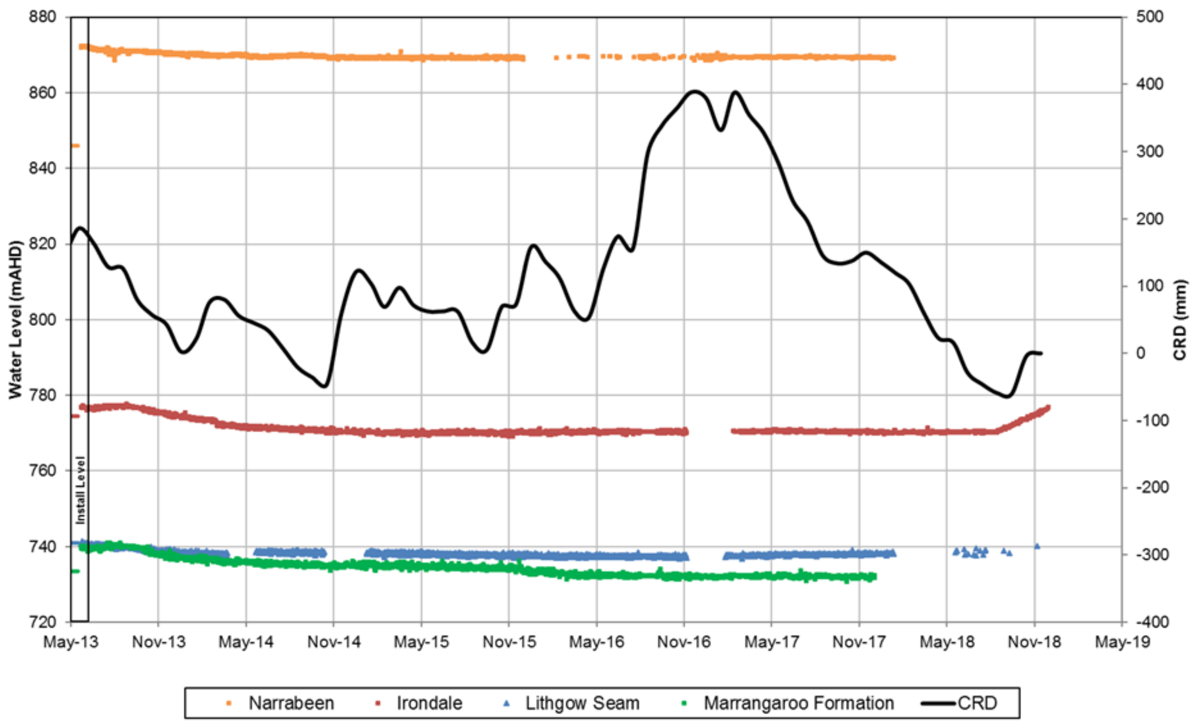

Figure C-6 Observed hydrographs – ARP06

Pressure consistently negative at ARP06 in the Lithgow Seam, in the Irondale Seam since December 2013 and in the Marrangaroo Formation since December 2015.

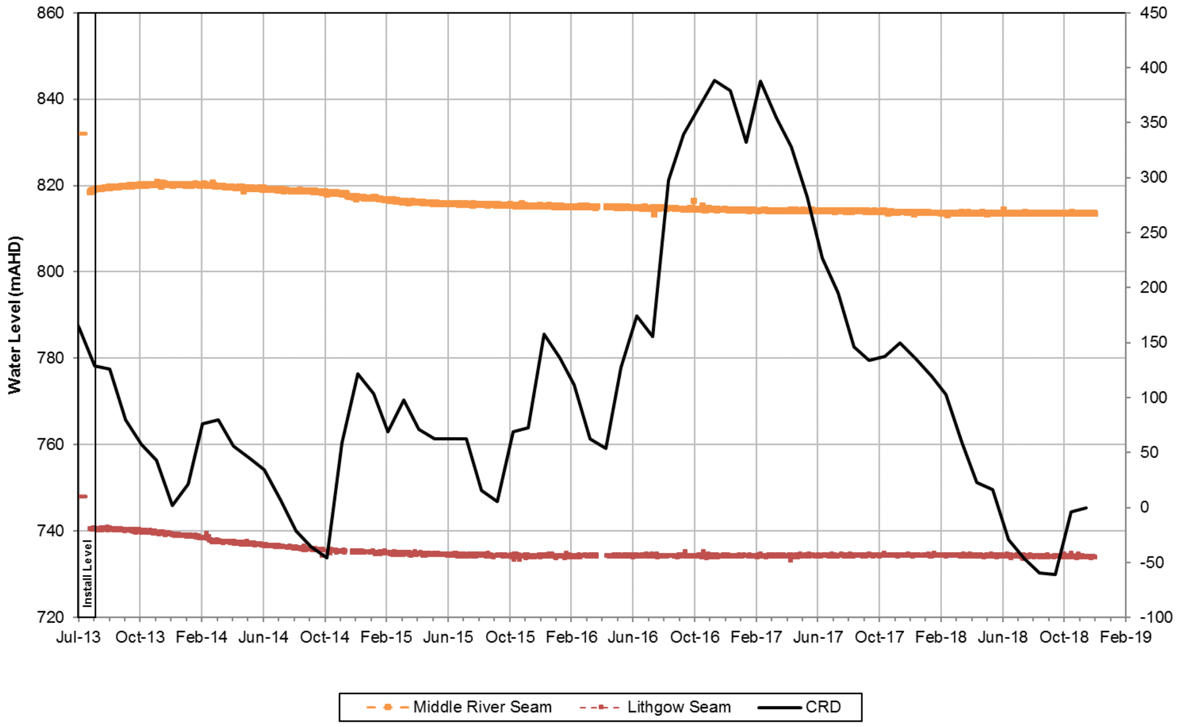

Figure C-7 Observed hydrographs – ARP07

Pressure consistently negative at VWPs installed at ARP07.

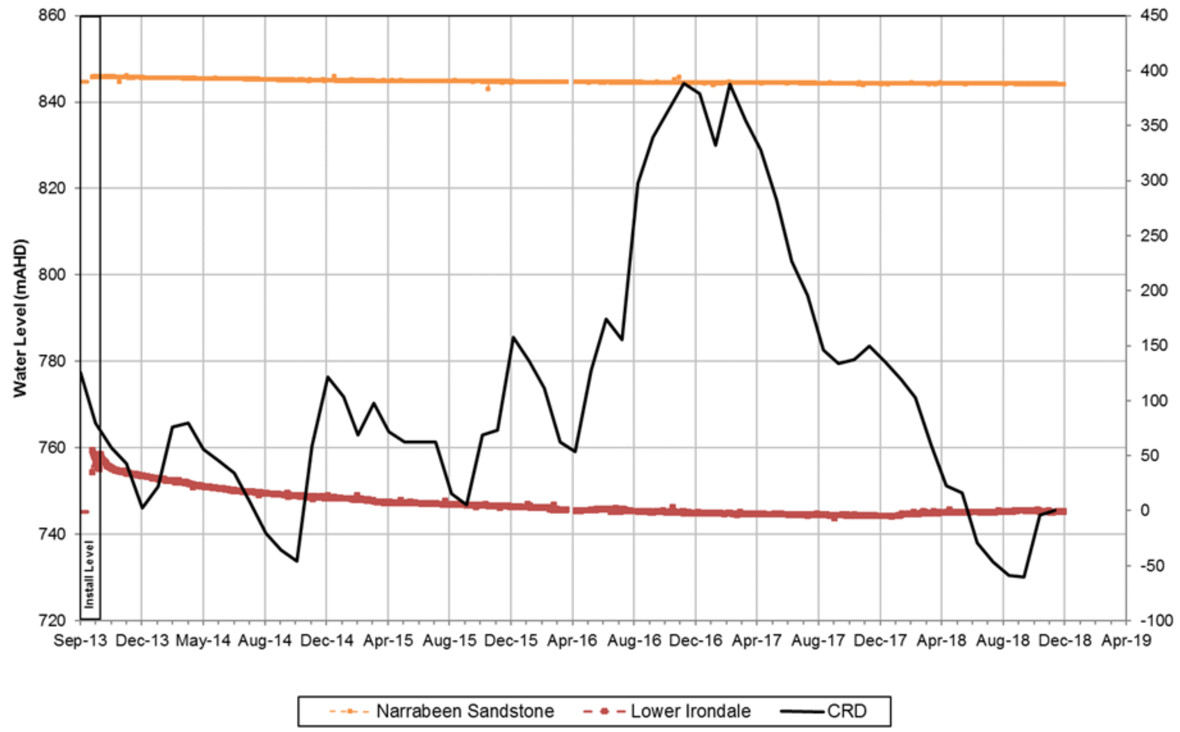

Figure C-8 Observed hydrographs – ARP08

Pressures have been negative at ARP08 in the Narrabeen Sandstone since May 2016 and in the Lower Irondale Seam since November 2016.

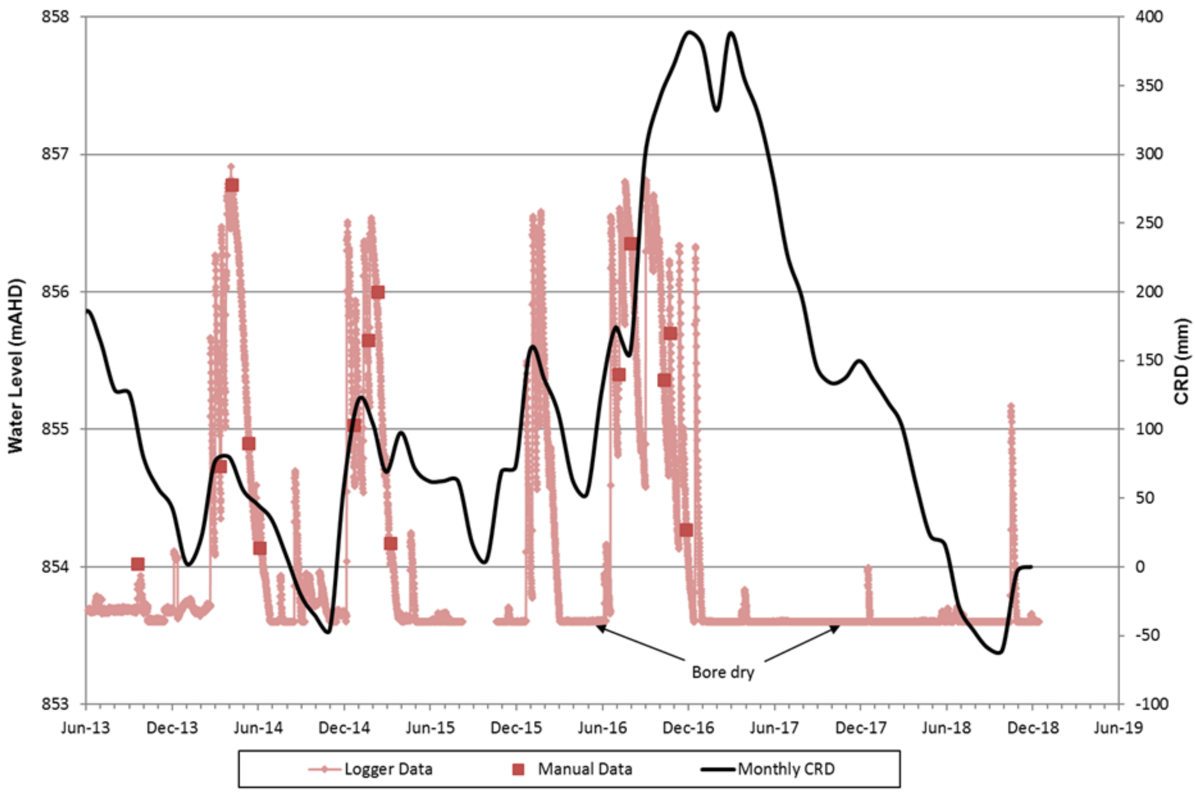

Figure C-9 Observed hydrographs – ARP09

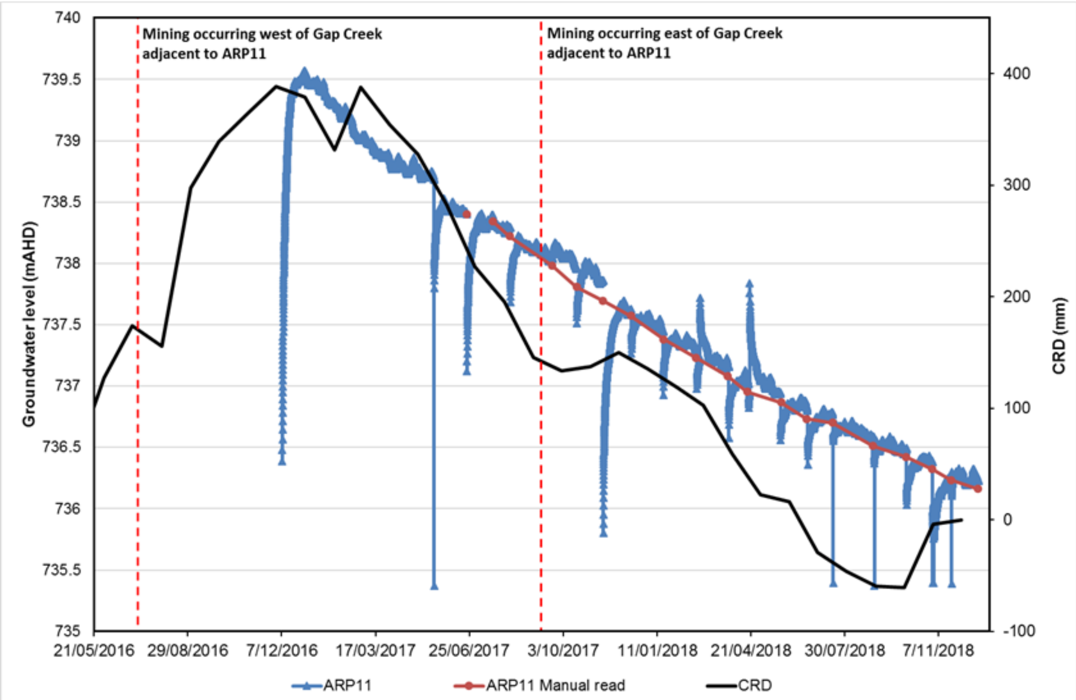

Figure C-10 Observed hydrographs – ARP11

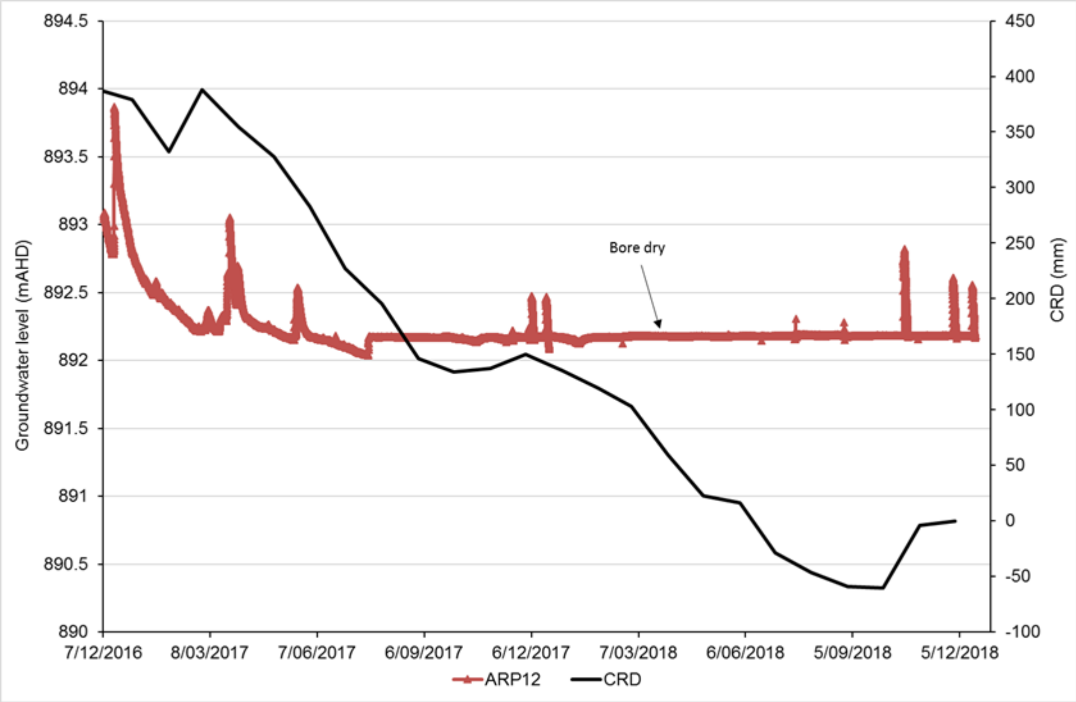

Figure C-11 Observed hydrographs – ARP12

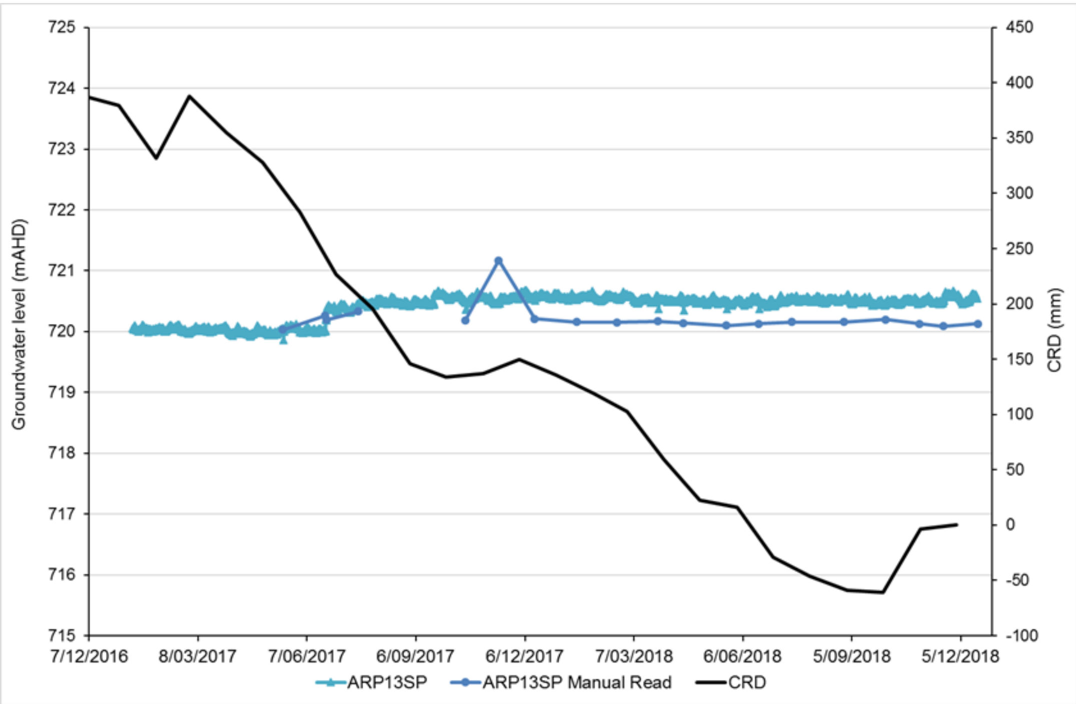

Figure C-12 Observed hydrographs – ARP13SP

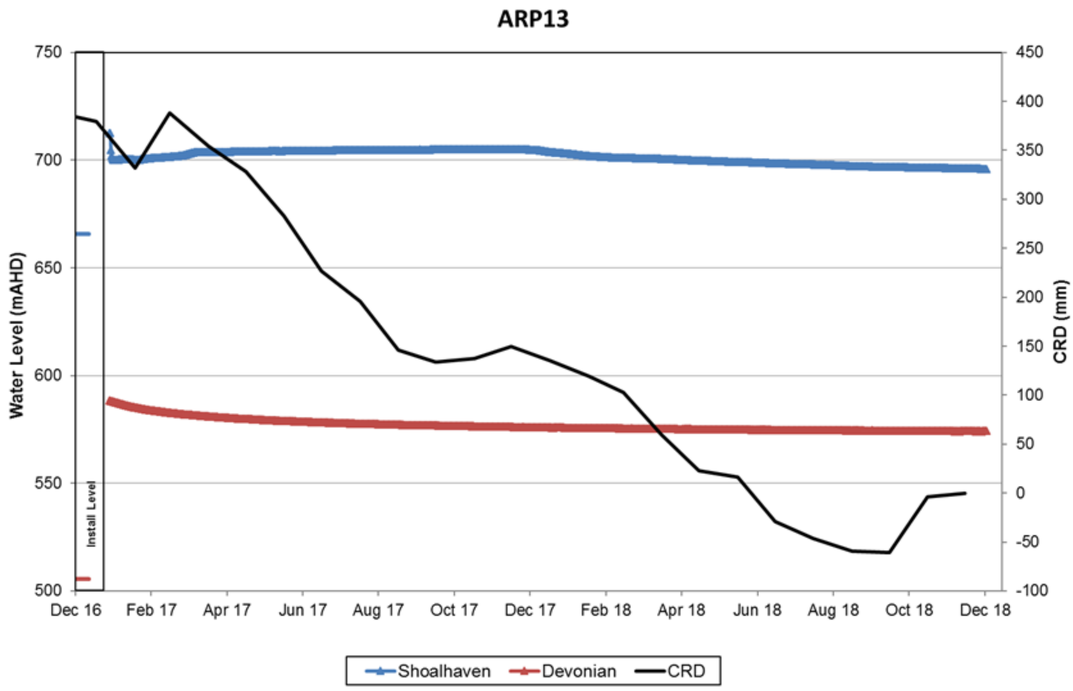

Figure C-13 Observed hydrographs – ARP13

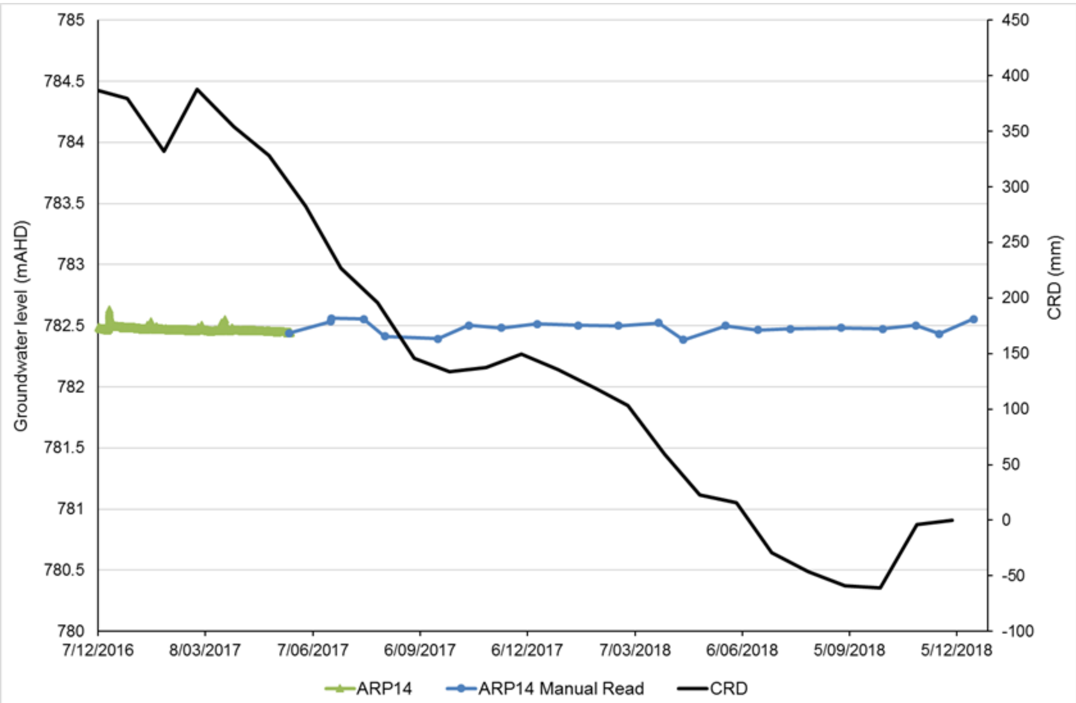

Figure C-14 Observed hydrographs – ARP14

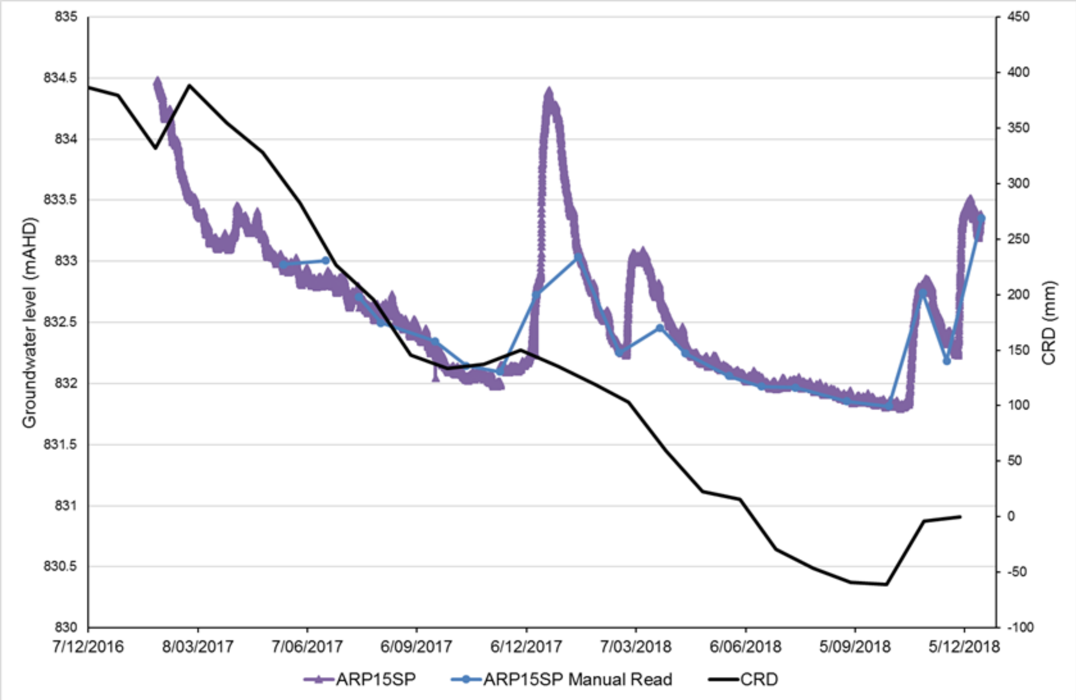

Figure C-15 Observed hydrographs – ARP15SP

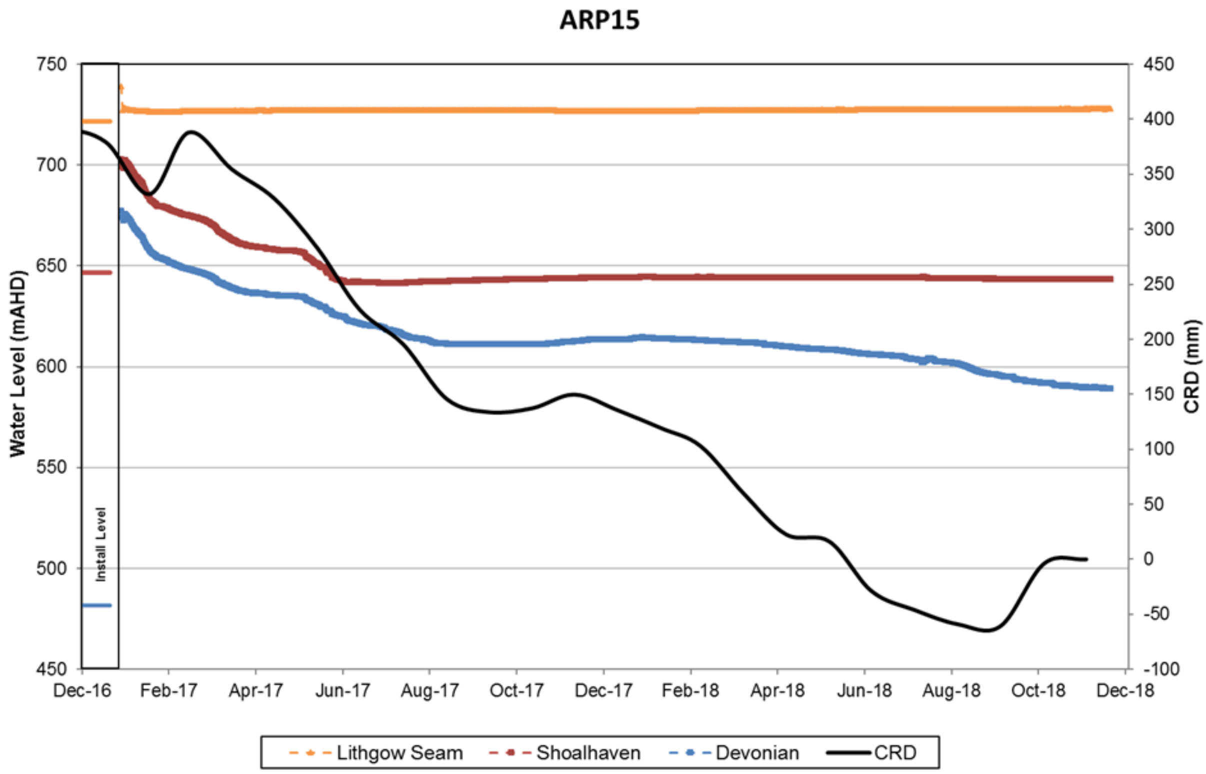

Figure C-16 Observed hydrographs – ARP15

Appendix D – Independent peer review

HydroAlgorithmics Pty Ltd ● ABN 25 163 284 991
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noel.merrick@hydroalgorithmics.com

DATE: 24 July 2019

TO: Nagindar Singh
Approvals Coordinator
Centennial Coal Company Limited
1384 Castlereagh Highway
Lidsdale NSW 2790
Tel: (02) 6355 9814

FROM: Dr Noel Merrick

RE: Airly Mine Modification MOD3 –
Groundwater Assessment Peer Review

YOUR REF: Email 27 February 2019

OUR REF: HA2019/08

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1. Introduction

This report provides a peer review of Modification MOD3 for the Airly Mine. MOD3 seeks an increase in the maximum mining rate from 1.8 Mtpa to 3.0 Mtpa, without any change to the development consent boundary.

An earlier interim review dated 19 March 2019 by HydroAlgorithmics provided comments and notes to allow the groundwater assessment report to be modified to be more complete and more informative. The previous review comments have been addressed satisfactorily.

2. Documentation

The peer review is based on the following two reports:

1. GHD, 2019, Airly Mine Mod 3 Groundwater Impact Assessment. Report 2219275, Rev.B, for Centennial Airly Pty Ltd, July 2019. 53p plus 4 Appendices.
2. GHD, 2019, Airly Mine Mod 3 Hydrogeological Model Report. Report 2219275, Rev.E, for Centennial Airly Pty Ltd, July 2019. 42p plus 7 Appendices.

Document #1 comprises the groundwater impact assessment (GWIA) for the Modification. It has the following sections:

1. Introduction
2. Legislation and policy
3. Site description
4. Existing conditions
5. Impact assessment methodology

6. Impact assessment
7. Mitigation, management and monitoring
8. References.

The Appendices are:

A. Supporting assessment requirements
B. Baseline groundwater data
C. Modelled drawdown contours
D. Airly Mine groundwater risk assessment

Document #2 is the hydrogeological model report (HMR) for the Modification. It has the following sections:

1. Introduction
2. Hydrological conceptualisation
3. Model update and calibration
4. Predictive simulations
5. Conclusions and recommendations
6. References.

The Appendices are:

A. Groundwater model risk assessment
B. Modelled and observed groundwater calibration hydrographs
C. Groundwater hydrographs
D. Independent peer review
E. Australian Groundwater Modelling Guidelines confidence level assessment
F. General layout of mining zones at Airly Mine
G. Modelled drawdown contours

3. Review Methodology

While there are no standard procedures for peer reviews of entire groundwater assessments, there are guidelines for the numerical modelling that underpins the assessment.

There are two accepted guides to the review of groundwater models: (A) the Murray-Darling Basin Commission (**MDBC**) Groundwater Flow Modelling Guideline[1], issued in 2001, and (B) guidelines issued by the National Water Commission (**NWC**) in June 2012 (Barnett *et al.*, 2012[2]). The NWC national guidelines were built upon the original MDBC guide, with substantial consistency in the model conceptualisation, design, construction and calibration principles, and the performance and review criteria, although there are differences in details.

The NWC guide promotes the concept of "model confidence level", which is defined using a number of criteria that relate to data availability, calibration, and prediction scenarios. The NWC guide is almost silent on coal mine modelling and offers no direction on best practice methodology for such applications. There is, however, an expectation of more effort in uncertainty analysis, although the guide is not prescriptive as to which methodology should be adopted.

Guidelines on uncertainty analysis for groundwater models were issued by the Independent Expert Scientific Committee (**IESC**) on Coal Seam Gas and Large Coal Mining Development in February 2018 in draft form and finalised in December 2018[3].

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[1] MDBC (2001). Groundwater flow modelling guideline. Murray-Darling Basin Commission. URL: www.mdbc.gov.au/nrm/water_management/groundwater/groundwater_guides

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

[3] Middlemis H and Peeters LJM (2018) *Uncertainty analysis—Guidance for groundwater modelling within a risk management framework*. A report prepared for the Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development through the Department of the Environment and Energy, Commonwealth of Australia 2018.

The groundwater guides include useful checklists for peer review. This groundwater impact assessment has been reviewed according to the 2-page Model Appraisal checklist[4] in MDBC (2001). This checklist has questions on (1) The Report; (2) Data Analysis; (3) Conceptualisation; (4) Model Design; (5) Calibration; (6) Verification; (7) Prediction; (8) Sensitivity Analysis; and (9) Uncertainty Analysis. Non-modelling components of the groundwater impact assessment are addressed by the first three sections of the checklist.

The review has also considered whether compliance with the minimal harm considerations of the *NSW Aquifer Interference Policy* (AIP) (NSW Government, 2012[5]) has been addressed adequately.

It should be recognised that the effort put into the modelling component of a groundwater impact assessment is very dependent on possible timing and budgetary constraints that are generally not known to a reviewer. However, this is less of an issue with a progressive review.

This review has been conducted progressively since January 2018, with involvement of the peer reviewer through two teleconferences including participation in the risk assessment. An earlier version of the groundwater model was reviewed by HydroAlgorithmics in August 2014.

The detailed assessment of the groundwater modelling is recorded in the peer review checklist in **Table 1**. Supplementary comment is offered in the following sections of this review.

4. GWIA Report

The reason for the groundwater assessment is to provide an update of predicted mine inflows and aquifer interference impacts that would result from increasing the maximum mining production rate from 1.8 to 3.0 Mtpa. The average rates are not dissimilar, as the faster rate is scheduled to complete mining only two years earlier than what has been approved.

Document #1 is a succinct standalone report of about 150 pages in total, providing an adequate groundwater impact assessment in support of the Modification. It commences with a thorough 3-page Executive Summary that addresses each potential impact in turn.

The impacts of *approved* mining have also been updated using a recalibrated model with the benefit of a longer monitoring record and the augmentation of the groundwater monitoring network. The earlier EIS model of 2014 was found to overestimate the inflows recorded from 2015 onwards.

Most mining has been and will be conducted using the bord and pillar technique, with consequent minimal fracturing and subsidence. There is to be some panel mining, but the width of 61m is narrower than in most other longwall mining operations in NSW. The residual pillar width is 57% (35m) of the void width, an unusually high fraction. This limits the height of fracturing and consequent impacts.

A full set of monitoring bore groundwater hydrographs and time-series charts for water quality parameters is provided at Appendix B. While there is substantial discussion on water quality in Section 4.2.2, there is no corresponding discussion on water levels in Section 4.2.1. However, there is commentary in the HGR (Document #2).

Only two monitoring sites have shown a mining effect to date: the effect is definite at site ARP04 and probable at ARP05. **Figure 1** (of this review report) illustrates likely mining effects recorded at ARP05 that are coincident with the definite mining effects at ARP04. The separate mining effects at ARP04 are due to westerly mining followed by easterly mining close to the bore.

[4] The newer guidelines include a more detailed checklist with yes/no answers but without the graded assessments of the 2001 checklist, which this reviewer regards as more informative for readers.

[5] NSW Government, 2012, NSW Aquifer Interference Policy – NSW Government policy for the licensing and assessment of aquifer interference activities. Office of Water, NSW Department of Primary Industries, September 2012.

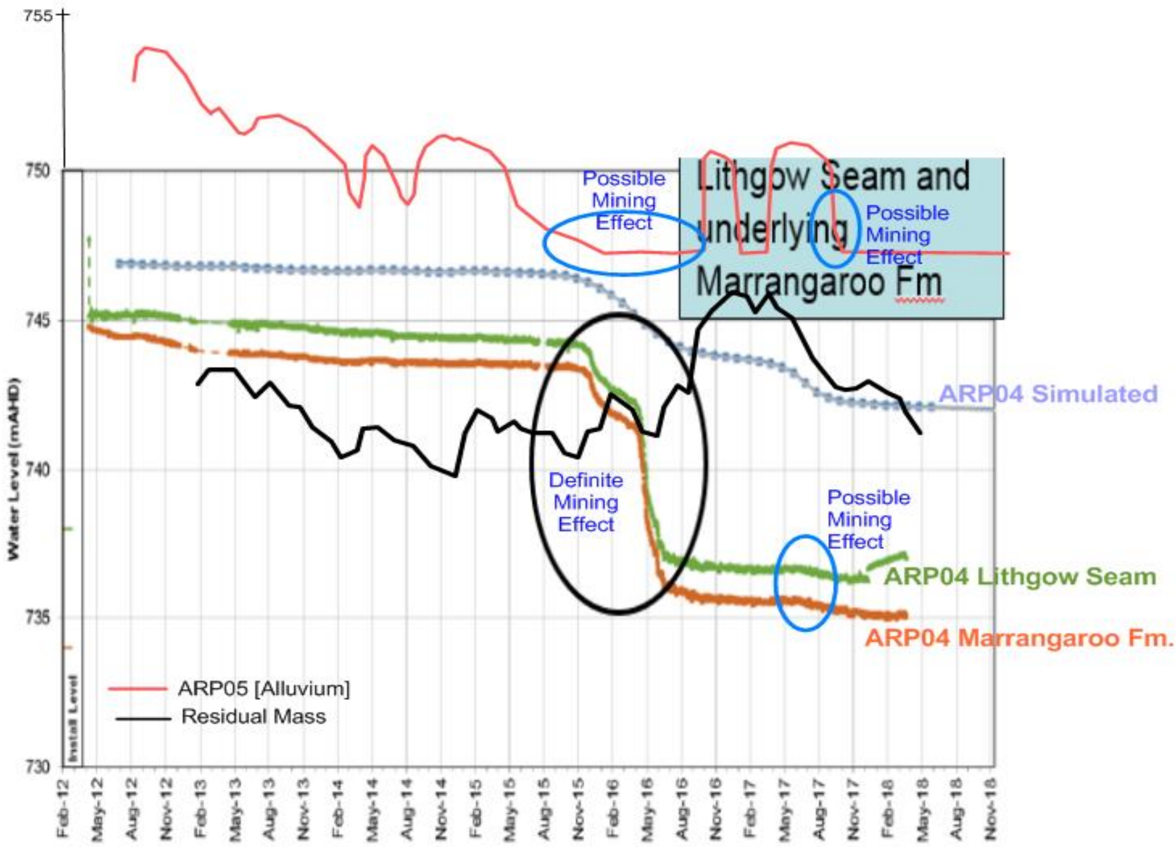


Figure 1. Mining effects evident on hydrographs for Bores ARP04 and ARP05.

The observed declining trend at ARP11 could have been interpreted as a mining effect, being situated between proximal western and eastern mining, but a null-mining run proves conclusively that the response is due entirely to rainfall reduction.

Baseflow impacts are reported in the GWIA report but not in the HGR. While Figures 6-4 to 6-7 are plausible, it is not clear how these results relate to the values reported in Table 6-3. It is also not clear whether the predicted baseflow impacts (being about 10 ML/year at Gap Creek and about 6 ML/year at Genowlan Creek) are significant in terms of normal flow magnitudes (if measureable).

5. HGR Report

Document #2 is a summary modelling report of about 130 pages in total, providing an adequate record of the numerical modelling undertaken in support of the Modification. It is not fully “standalone”, as reference is made to earlier model development in 2014 withour repetition of details. For example, there is no map of the model extent, or of the model grid, and there is no statement on model cell sizes. There is no mention of whether the mine’s production bore is included in the model, but it is shown on the conceptual model disgram.

There is much repetition of material from the GWIR report. While the predicted baseflow impacts are not mentioned here, they do appear in full in the GWIR report. A section should be added to either summarise the baseflow results or refer to the companion report.

Appendix C includes a thorough cause-and-effect analysis of all groundwater hydrographs by comparing measured responses with rainfall trend (the cumulative rainfall departure [CRD] curve) and proximity of mining. There are clear rainfall signatures at many sites, but only two sites with definite (ARP04) and probable (ARP05) mining effects. A feature of the heads dataset is the frequent occurrence of naturally dry holes or effectively zero pressure head at many VWP sensors. Consequently, there is very little natural head available for driving groundwater into the underground mining void. This helps to explain the extremely low mine inflows to date, and supports predictions of minimal impacts.

The earlier EIS model of 2014 was found to overestimate the inflows recorded from 2015 onwards. This has been rectified by recalibration of the model. The report documents the changes that were necessary to reduce mine inflows to more realistic rates.

The model update has achieved better model calibration than recorded for the previous EIS model. Calibration statistics are satisfactory, being 5.3 %RMS and 14 mRMS for steady-state, and 4.1 %RMS and 11 mRMS for transient calibration. A total of 580 transient head targets were used for calibration, at four (of 10) standpipe monitoring sites and 13 VWPs at seven sites. The four standpipe sites should be named. Many monitoring sites are either naturally dry or have zero pressure head and cannot be used quantitatively for calibration. However, qualitative calibration can be checked in Appendix B where all simulated hydrographs are compared with observations.

A non-quantitative control on calibration was the observation of mine inflows too low to be measurable. This is consistent with simulated inflows of about 0.03 ML/day at 2018 and less than 0.2 ML/day during the prediction period.

Of the two fracture height scenarios, Scenario 2 (with fracturing to 75m altitude) is considered more appropriate. Independent calculations by the reviewer suggest a likely height of about 50m to 70m.

The model is said "to have the characteristics of class 2 confidence level". This is defended by completion of a checklist in Appendix E. Counts of the attributes marked in Appendix E indicate that the model is about 5% Class 1, 68% Class 2, and 27% Class 3. The model is mostly Class 2, with elements of the other two classes.

Two lineament simulations, for alternative conduit and barrier fault conceptualisations, demonstrated no evident effects on the hydrograph at ARP04. As noted on Figure 3-5, ARP04 appears to be about 400m west of the lineament. Nearby bores ARP05 and ARP11 are each about 350m west of the fault, and ARP08 is about 200m east of the fault. If the lineament is having any effect, it is not observable at the locations of the installed monitoring bores.

An IESC-compliant uncertainty analysis has been undertaken that accords with the simplest advocated approach using scenario analysis for six model variants. This suggests a narrow range in predicted mine inflows. The simplified approach precludes any estimate of probabilities of occurrence. This "Type 1" approach to uncertainty analysis is appropriate, given the low risk of the Project as documented in the risk assessment in Appendix A.

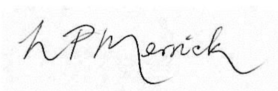
6. Conclusion

The degree of model complexity and modelling effort for this Modification for Airly Mine are considered to be appropriate, as the project is clearly low risk. The geometry of the target coal seam within a truncated topography has resulted in naturally low pressure heads, and the advent of mining causes only minimal further reduction.

Mining to date has demonstrated very low inflows of a magnitude too low to be measurable. The numerical model can be regarded as a reliable predictor of future inflows remaining low.

The reviewer regards this model as being *fit for purpose*, where the purpose is jointly estimation of water take and reduction in groundwater pressure heads.

Yours sincerely



Dr Noel Merrick

Table 1. MODEL APPRAISAL: **Airly Groundwater Model** [Documents #1, #2]

Q.	QUESTION	Not Applicable or Unknown	Score 0	Score 1	Score 3	Score 5	Score	Max. Score (0, 3, 5)	COMMENT
1.0	THE REPORT								
1.1	Is there a clear statement of project objectives in the modelling report?		Missing	Deficient	Adequate	Very Good			Doc#1: S1.6 Doc#2: S1.1
1.2	Is the level of model complexity clear or acknowledged?		Missing	No	Yes				Reference to NWC national guidelines. Class 2 confidence classification substantiated in Appendix E (Dc#2). Appropriate.
1.3	Is a water or mass balance reported?		Missing	Deficient	Adequate	Very Good			Tables of all recharge/discharge components for whole model for steady-state and transient calibration, split into alluvium and rock components.
1.4	Has the modelling study satisfied project objectives?		Missing	Deficient	Adequate	Very Good			Meets objectives
1.5	Are the model results of any practical use?			No	Maybe	Yes			Demonstrates low risk and only minor impacts.
2.0	DATA ANALYSIS								
2.1	Has hydrogeology data been collected and analysed?		Missing	Deficient	Adequate	Very Good			Doc#2: S2.3 (packer, falling head tests)
2.2	Are groundwater contours or flow directions presented?		Missing	Deficient	Adequate	Very Good			Partial coverage. Contours for Lithgow Seam, Marrangaroo Fm and Shoalhaven Group.
2.3	Have all potential recharge data been collected and analysed? (rainfall, streamflow, irrigation, floods, etc.)		Missing	Deficient	Adequate	Very Good			Ephemeral streams
2.4	Have all potential discharge data been collected and analysed? (abstraction, evapotranspiration, drainage, springflow, etc.)		Missing	Deficient	Adequate	Very Good			One mine production bore
2.5	Have the recharge and discharge datasets been analysed for their groundwater response?		Missing	Deficient	Adequate	Very Good			Cause-and-effect analysis based on CRD and mining proximity.
2.6	Are groundwater hydrographs used for calibration?			No	Maybe	Yes			Used 4 of 10 standpipes and 13 VWPs. Many dry.

2.7	Have consistent data units and standard geometrical datums been used?			No	Yes				
3.0	CONCEPTUALISATION								
3.1	Is the conceptual model consistent with project objectives and the required model complexity?		Unknown	No	Maybe	Yes			
3.2	Is there a clear description of the conceptual model?		Missing	Deficient	Adequate	Very Good			
3.3	Is there a graphical representation of the modeller's conceptualisation?		Missing	Deficient	Adequate	Very Good			Doc#1: Figure 3-6. Pre-mining only.
3.4	Is the conceptual model unnecessarily simple or unnecessarily complex?			Yes	No				
4.0	MODEL DESIGN								
4.1	Is the spatial extent of the model appropriate?			No	Maybe	Yes			Unstated dimensions for model extent, no map of outline or grid. 10 layers. Unstated cell sizes.
4.2	Are the applied boundary conditions plausible and unrestrictive?		Missing	Deficient	Adequate	Very Good			Blanket DRNs at surface
4.3	Is the software appropriate for the objectives of the study?			No	Maybe	Yes			MODFLOW-NWT. Minimal description. Relies on reference to 2014 report.
5.0	CALIBRATION								
5.1	Is there sufficient evidence provided for model calibration?		Missing	Deficient	Adequate	Very Good			Steady-state and transient calibration with groundwater level targets, and knowledge of mine inflows too low to be measurable. RMS and %RMS performance statistics and scattergrams for steady-state and transient.
5.2	Is the model sufficiently calibrated against spatial observations?		Missing	Deficient	Adequate	Very Good			Can infer only from scattergrams. Predicted contours are not compared with observed gradients in Figures 2-7 to 2-9 (Doc#2). Simulated vertical head differences are reproduced reasonably at most sites.

5.3	Is the model sufficiently calibrated against temporal observations?		Missing	Deficient	Adequate	Very Good			Observed mining effects are evident only at ARP04 and ARP05. A reasonable match to declining trends is achieved at ARP04. The simulation at ARP15SP does not reproduce two recharge events.
5.4	Are calibrated parameter distributions and ranges plausible?		Missing	No	Maybe	Yes			K, Ss and Sy values are reasonable. Fractured zone Kh and Kv seem constant with altitude,rather than reducing.
5.5	Does the calibration statistic satisfy agreed performance criteria?		Missing	Deficient	Adequate	Very Good			Steady-state model: 5.3 %RMS, 14 mRMS. Transient model: 4.1 %RMS, 11 mRMS
5.6	Are there good reasons for not meeting agreed performance criteria?		Missing	Deficient	Adequate	Very Good			Outlier at ARP13 attributed to assigned GHB heads.
6.0	VERIFICATION								OPTIONAL
6.1	Is there sufficient evidence provided for model verification?	N/A	Missing	Deficient	Adequate	Very Good			
6.2	Does the reserved dataset include stresses consistent with the prediction scenarios?	N/A	Unknown	No	Maybe	Yes			
6.3	Are there good reasons for an unsatisfactory verification?	N/A	Missing	Deficient	Adequate	Very Good			
7.0	PREDICTION								
7.1	Have multiple scenarios been run for climate variability?		Missing	Deficient	Adequate	Very Good			A single average climate has been used – this is sufficient. Naturally low-pressure heads suggest low response to climate variations.
7.2	Have multiple scenarios been run for operational /management alternatives?		Missing	Deficient	Adequate	Very Good			One mine plan. There are no nearby neighbouring mines requiring cumulative impact assessment.
7.3	Is the time horizon for prediction comparable with the length of the calibration / verification period?		Missing	No	Maybe	Yes			Calibration period 8 years (2011-2018). Prediction period 15 years (2019-2033).

7.4	Are the model predictions plausible?			No	Maybe	Yes			Closed basin would constrain drawdown to the mining lease. Drawdown maps are presented of Approved and Proposed at end of mining and 30 years later.
8.0	SENSITIVITY ANALYSIS								
8.1	Is the sensitivity analysis sufficiently intensive for key parameters?		Missing	Deficient	Adequate	Very Good			Investigated for (1) a lineament – no effect; (2) fracturing height – minor effect.
8.2	Are sensitivity results used to qualify the reliability of model calibration?		Missing	Deficient	Adequate	Very Good			RMS statistics for 6 model variants.
8.3	Are sensitivity results used to qualify the accuracy of model prediction?		Missing	Deficient	Adequate	Very Good			For mine inflow predictions only.
9.0	UNCERTAINTY ANALYSIS								
9.1	If required by the project brief, is uncertainty quantified in any way?		Missing	No	Maybe	Yes			Investigation for 6 model variants by scenario analysis [IESC method 1 for low-risk projects}. Appropriate approach. Three realisations decalibrate the model, so are not reliable predictors.
	TOTAL SCORE								PERFORMANCE: %

Appendix E – Australian Groundwater Modelling Guidelines confidence level assessment

Table E-1 Assessment of model confidence level against Australian Groundwater Model Guidelines (Barnett et al, 2012)

Class	Data		Calibration		Prediction		Quantitative indicators	
1 (simple)	✗	Not much	✗	Not possible	✗	Timeframe >> calibration	✗	Timeframe > 10x
	✗	Sparse coverage	✗	Large error statistic	✗	Long stress periods		Stresses > 5x
	✗	No metered usage	✗	Inadequate data spread	✓	Poor/no validation		Mass balance > 1% (or one-off 5%)
	✗	Low resolution						Properties < > field values
	✗	Poor aquifer geometry	✗	Targets incompatible with model purpose	✗	Transient prediction but steady-state calibration		No review by Hydro/ Modeller
	✗	Basic / initial conceptualisation						
2 (impact assessment)	✓	Some	✓	Partial performance	✓	Timeframe > calibration	✓	Time frame = 3–10x
	✓	Ok coverage	✓	Some long term trends wrong	✗	Long stress periods	~	Stresses = 2–5x
	✓	Some data usage / low volumes	✓	Short term record	✗	Ok validation	✗	Mass balance <1%
	~	Baseflow estimates Some K & S measurements	✓	Weak seasonal match	✓	Transient calibration and prediction	✓	Some properties < > field values Review by hydrogeologist
	✓	Some high resolution topographic DEM &/or some aquifer geometry	✗	No use of targets compatible with model purpose (heads & fluxes)	✓	New stresses not in calibration	✗	Some coarse discretisation in key areas of grid or at key times
	✗	Lots, with good coverage	✗	Good performance stats	✗	Timeframe ~ calibration	✗	Timeframe <3x
	✗	Good metered usage info	✗	Most long term trends matched	✓	Similar stress periods	✗	Stresses <2x

Class	Data		Calibration		Prediction		Quantitative indicators	
3 (complex simulator)	✓	Local climate data	✗	Most seasonal matches ok	✗	Good validation	✗	Mass balance <0.5%
	✗	Kh, Kv and Sy measurements from a range of tests	✓	Present day data targets	✓	Calibration & prediction consistent (transient or steady state)	✗	Properties ~ field measurements
	✗	High resolution DEM all areas	✓	Head & flux targets used to constrain calibration	✗	Similar stresses to those in calibration	✓	No coarse discretisation in key areas (grid or time)
	✗	Good aquifer geometry					✓	Review by experienced modeller

Note: achieved attributes are shown with a tick, partially achieved attributes are shown with a tilde and not applicable attributes are shown with a cross

Appendix F – General layout of mining zones at Airly Mine

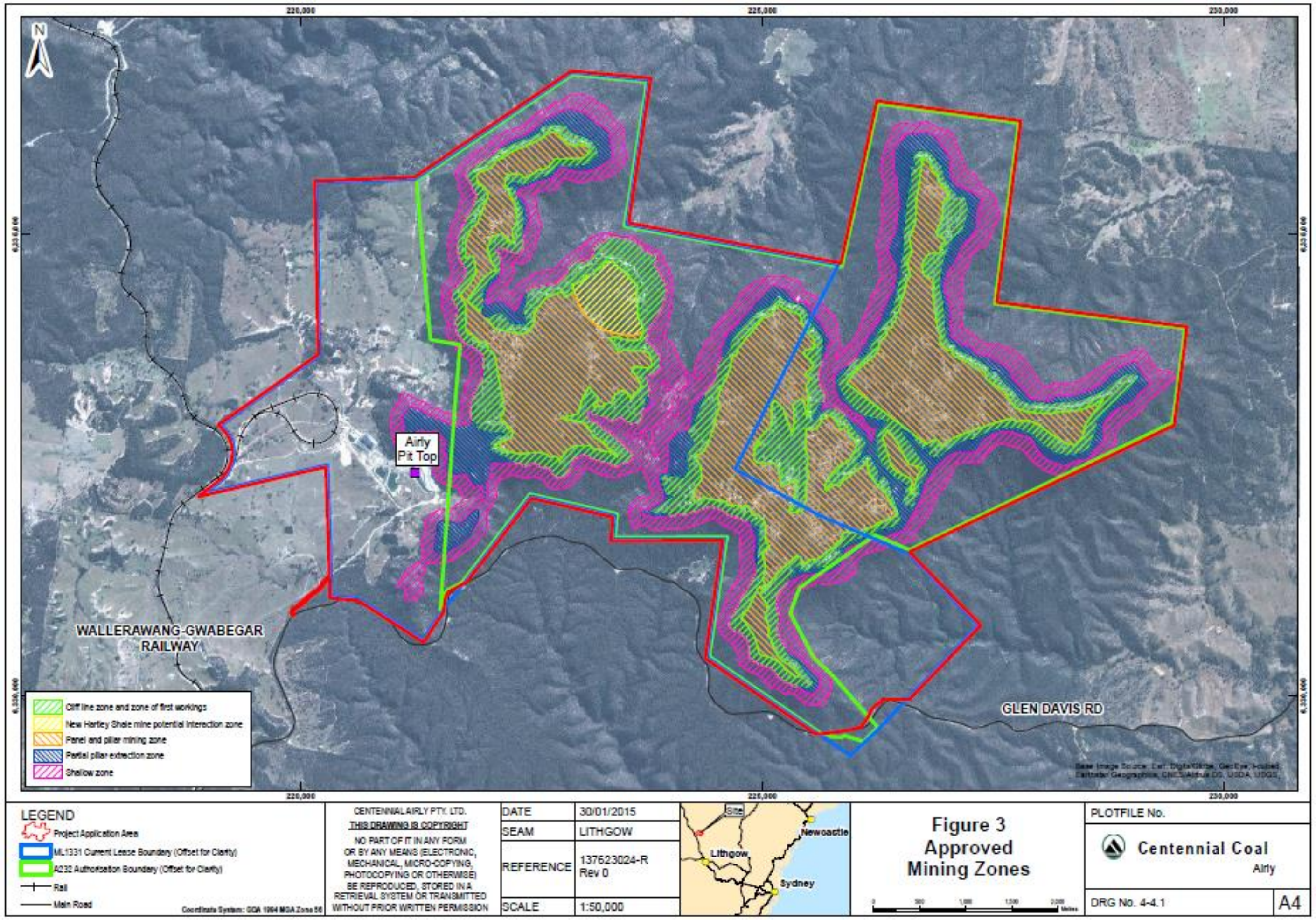
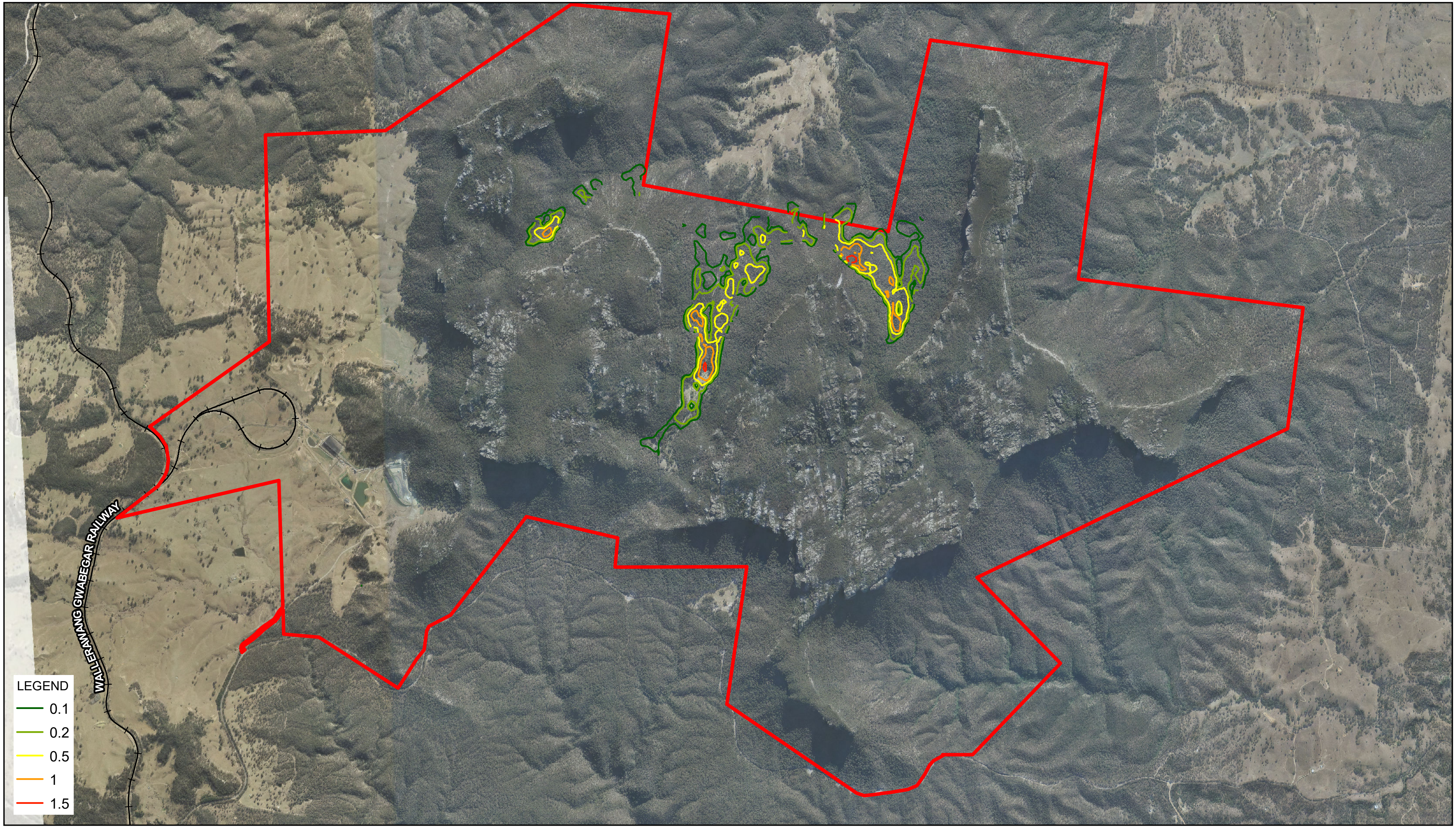


Figure 3 Approved Mining Zones

Appendix G – Modelled drawdown contours



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Metres

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Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

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LEGEND

Project Approval Area SSD_5581

GHD

Centennial Airly

Airly Mine
Airly Mine Mod 3
Hydrogeological Model Report

Drawdown in Shallow Strata
End of mining
3 Mtpa, Scenario 1

Job Number 22-19275
Revision 0
Date 7 Jun 2019

Figure G-1

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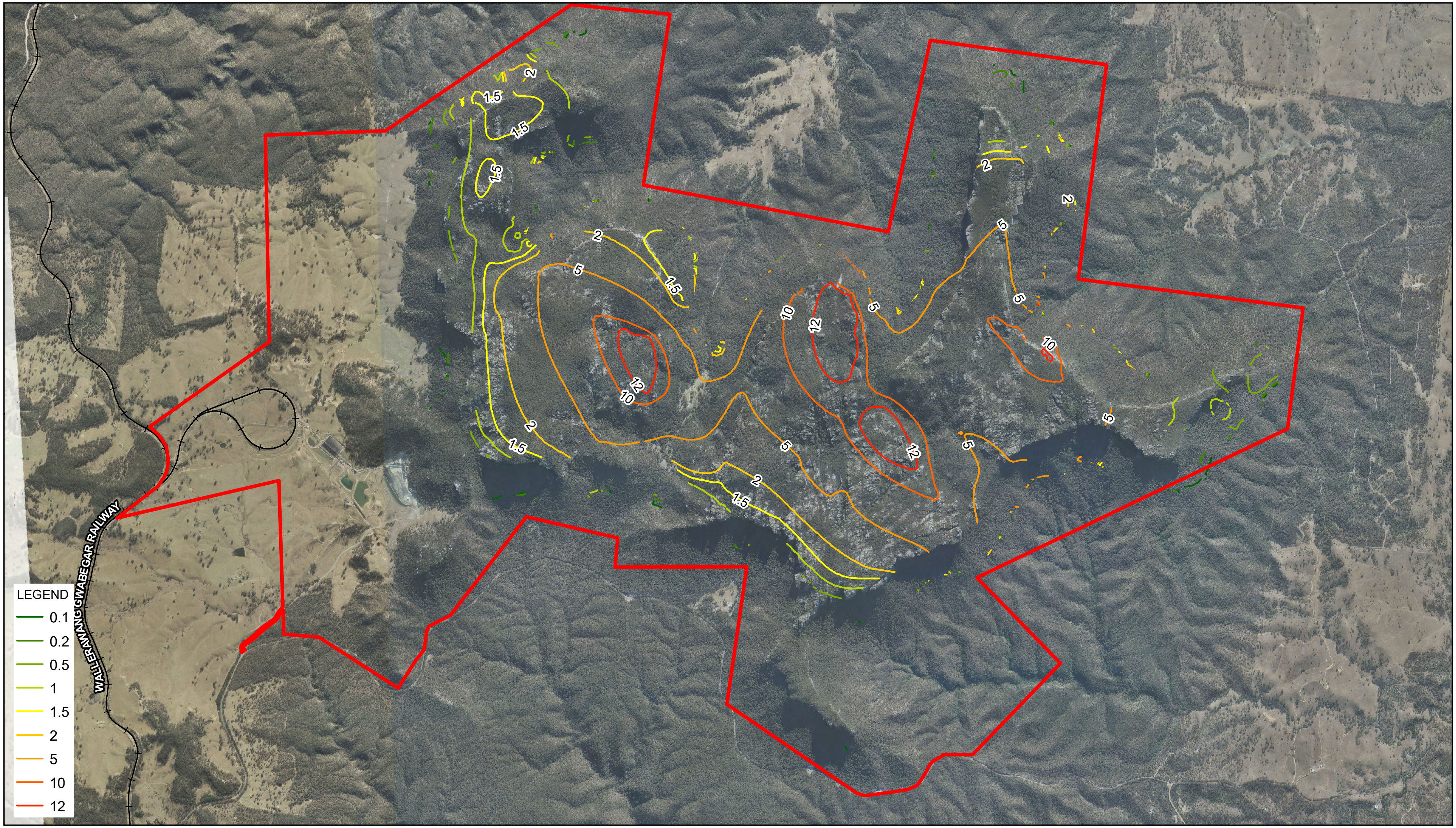
Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

Data source: LPI: DTDB 2012; Centennial: Aerial Imagery, boundaries, 2013, Monitoring Locations, 2017. Created by: fmackay



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Grid: GDA 1994 MGA Zone 56

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LEGEND

Project Approval Area SSD_5581

GHD

Centennial Airly

Airly Mine
Airly Mine Mod 3
Hydrogeological Model Report

Drawdown in Lithgow seam
End of mining
3 Mtpa, Scenario 1

Job Number	22-19275
Revision	A
Date	21 Sep 2018

Figure G-2

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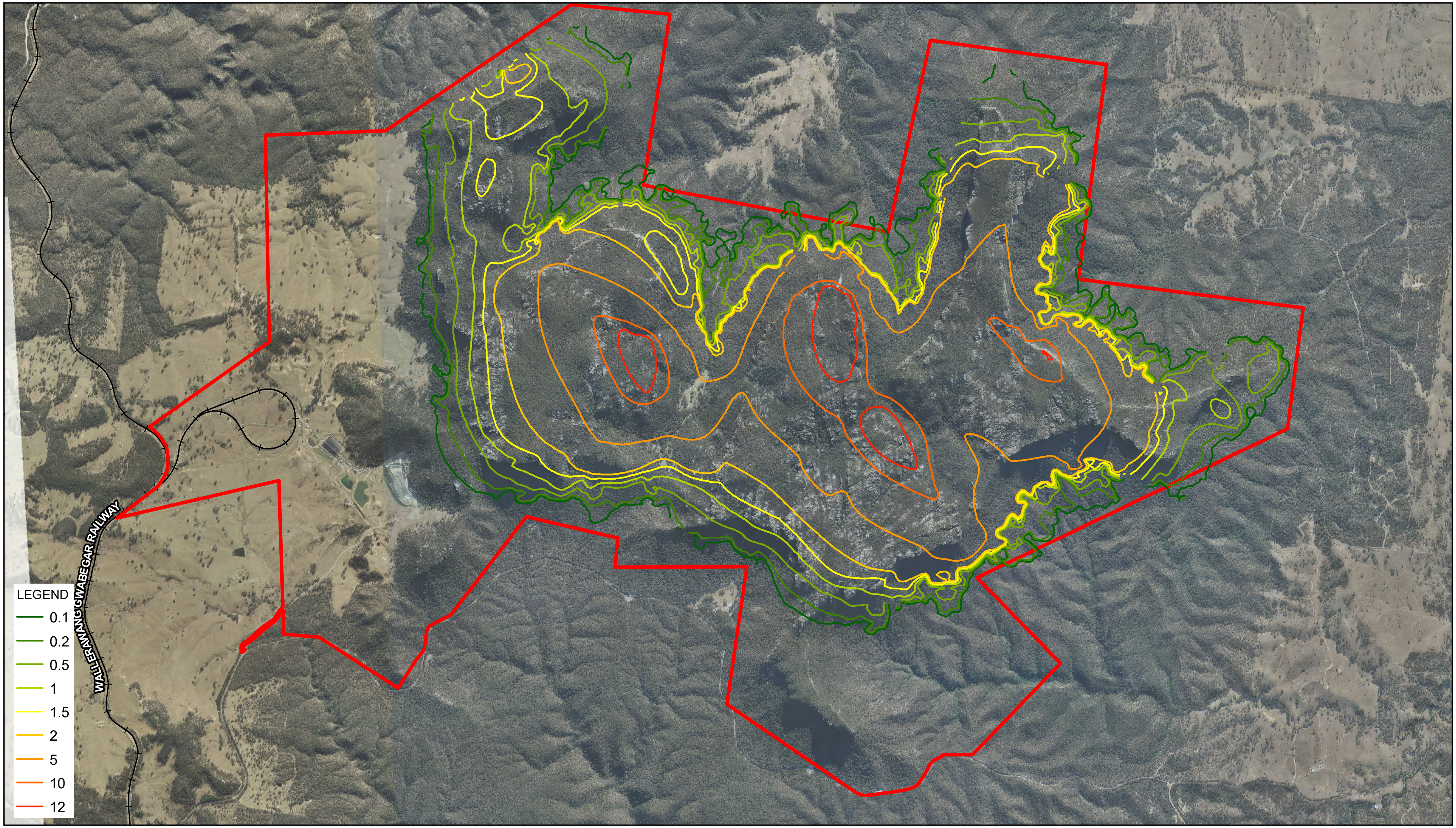

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Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

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LEGEND

Project Approval Area SSD_5581

GHD

Centennial Airly

Airly Mine
Airly Mine Mod 3
Hydrogeological Model Report

Job Number 22-19275
Revision A
Date 30 Jul 2019

Drawdown in Marrangaroo Formation
End of mining
3 Mtpa, Scenario 1

Figure G-3

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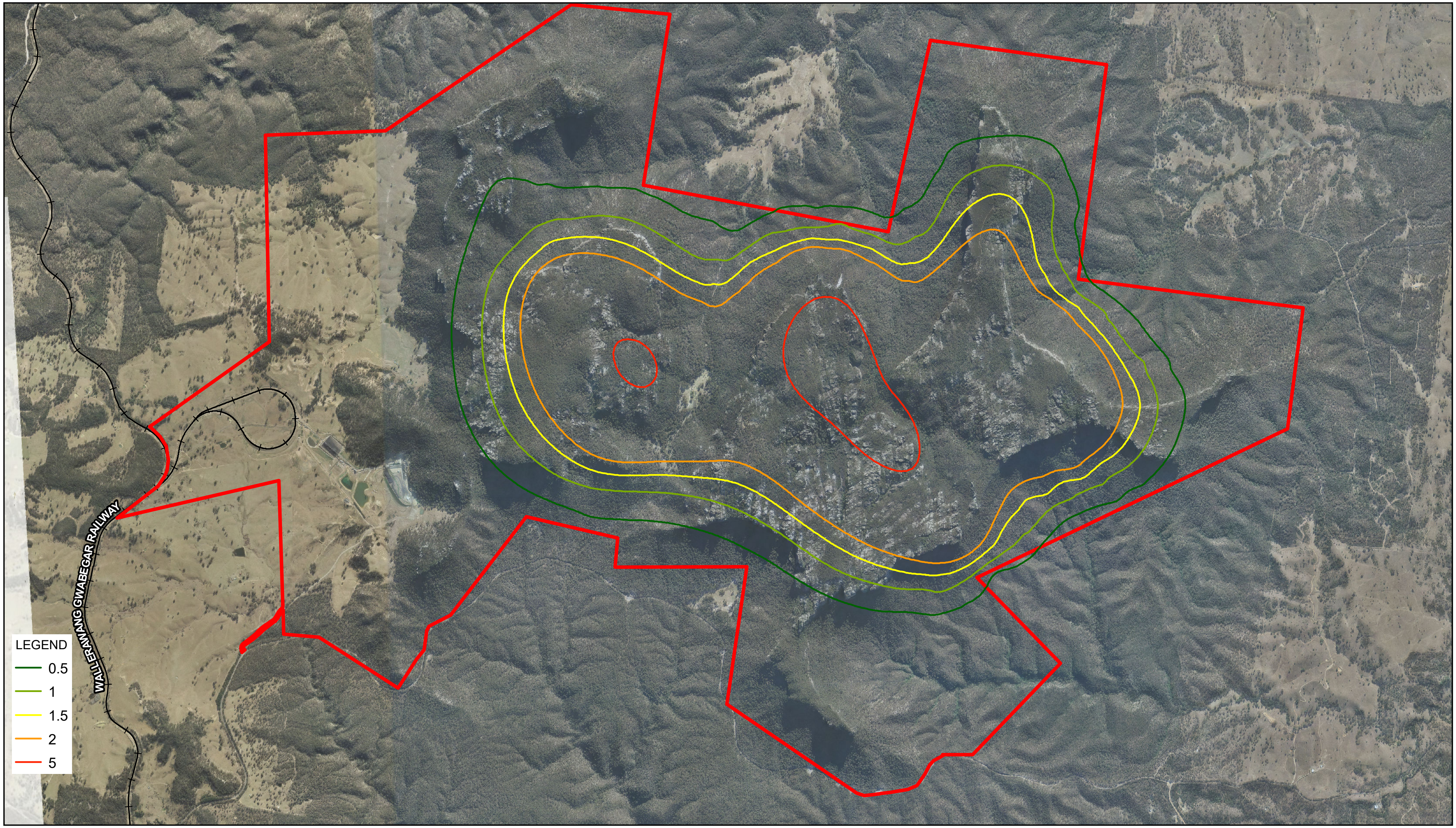
Data source: LPI: DTDB 2012; Centennial: Aerial Imagery, boundaries, 2013, Monitoring Locations, 2017. Created by: fmackay



Paper Size A4

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Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

LEGEND

Project Approval Area SSD_5581

GHD

Centennial Airly

Airly Mine
Airly Mine Mod 3
Hydrogeological Model Report

Job Number 22-19275
Revision A
Date 30 Jul 2019

Drawdown in Upper Shoalhaven Group
End of mining
3 Mtpa, Scenario 1

Figure G-4

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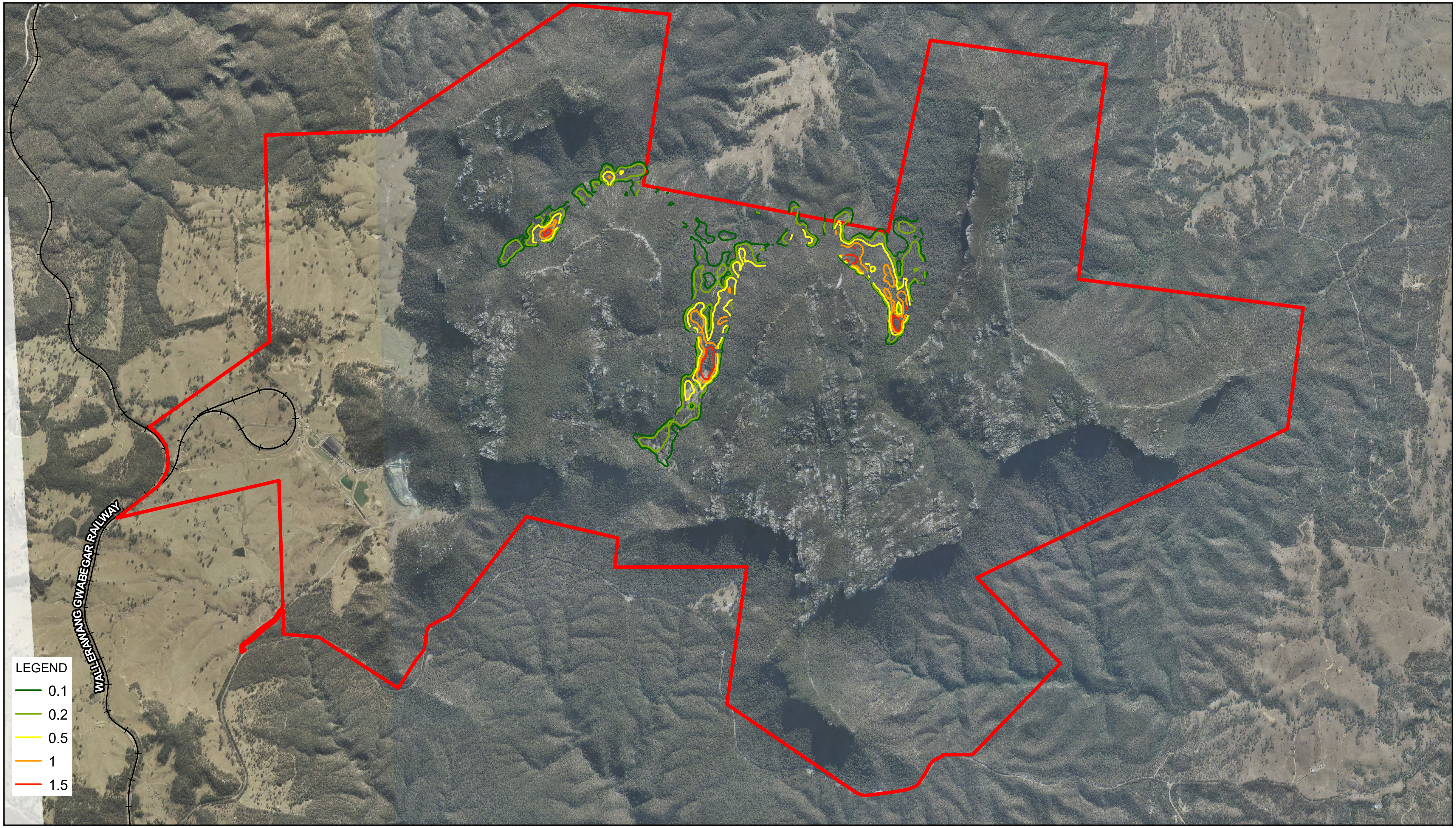
Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

Data source: LPI: DTDB 2012; Centennial: Aerial Imagery, boundaries, 2013, Monitoring Locations, 2017. Created by: fmackay



Paper Size A4

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Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

LEGEND

Project Approval Area SSD_5581

GHD

Centennial Airly

Airly Mine
Airly Mine Mod 3
Hydrogeological Model Report

Drawdown in Shallow Strata
End of mining
3 Mtpa, Scenario 2

Job Number	22-19275
Revision	A
Date	30 Jul 2019

Figure G-5

G:\22\0105001\GIS\Maps\Deliverables\Western\Airly\2219275\HMR\Mod3_AppendixG\2219275_D005_3Mtpa_Scenario2_EOM_Layer01.mxd

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

Data source: LPI: DTDB 2012; Centennial: Aerial Imagery, boundaries, 2013, Monitoring Locations, 2017. Created by: fmackay

Paper Size A4

0 330 660 990 1,320

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

LEGEND

Project Approval Area SSD_5581

GHD

Centennial Airly

Airly Mine
Airly Mine Mod 3
Hydrogeological Model Report

Drawdown in Lithgow seam
End of mining
3 Mtpa, Scenario 2

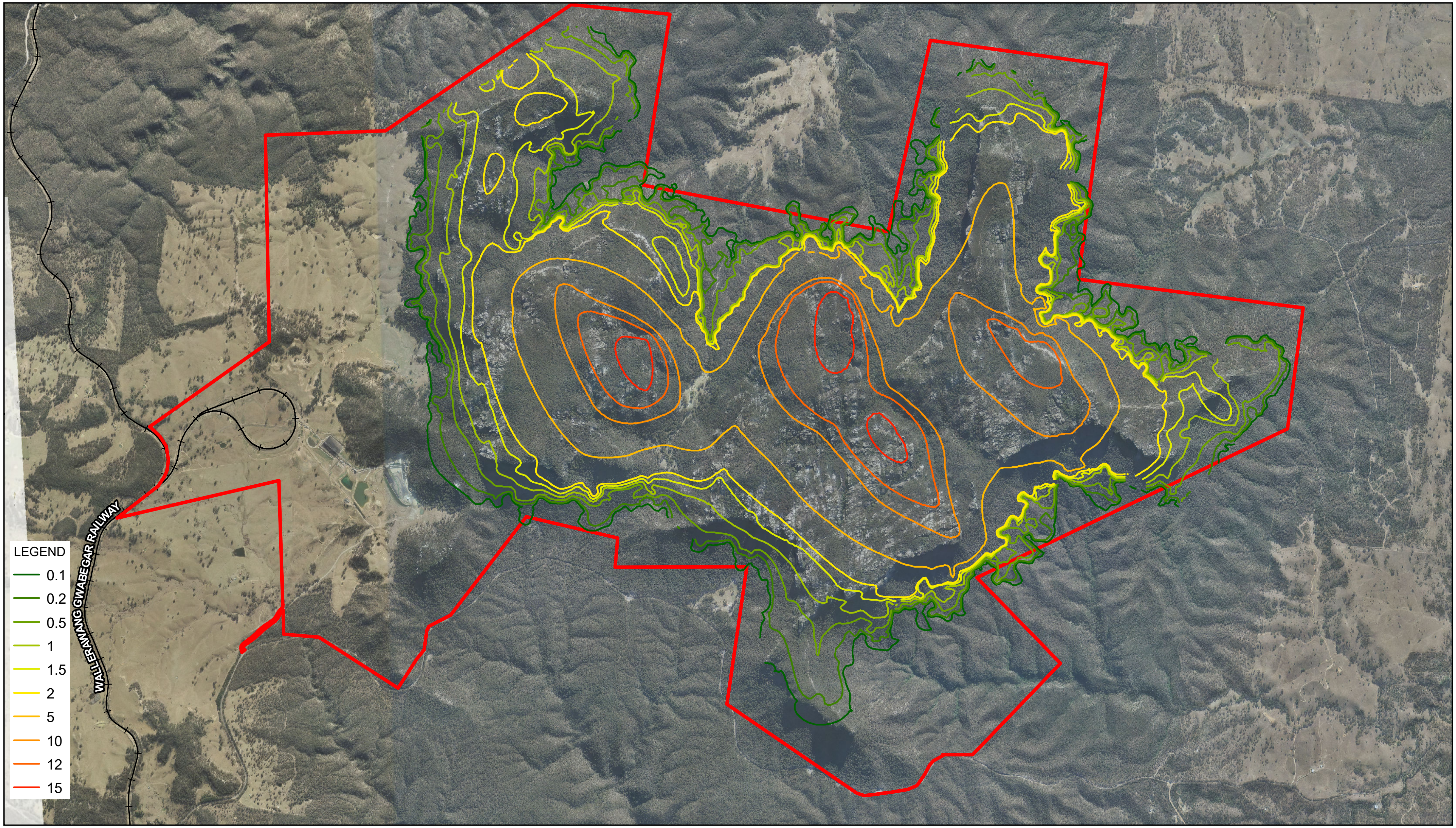
Job Number	22-19275
Revision	A
Date	30 Jul 2019

Figure G-6

G:\22\0105001\GIS\Maps\Deliverables\Western\Airly\2219275\HMR\Mod3_AppendixG\2219275_D006_3Mtpa_Scenario2_EOM_Layer08.mxd

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 T 61 2 4979 9999 F 61 2 4979 9988 E ntlmail@ghd.com W www.ghd.com.au

Data source: LPI: DTDB 2012; Centennial: Aerial Imagery, boundaries, 2013, Monitoring Locations, 2017. Created by: fmackay



Paper Size A4

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Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

LEGEND

Project Approval Area SSD_5581

GHD

Centennial Airly

Airly Mine
Airly Mine Mod 3
Hydrogeological Model Report

Job Number 22-19275
Revision A
Date 30 Jul 2019

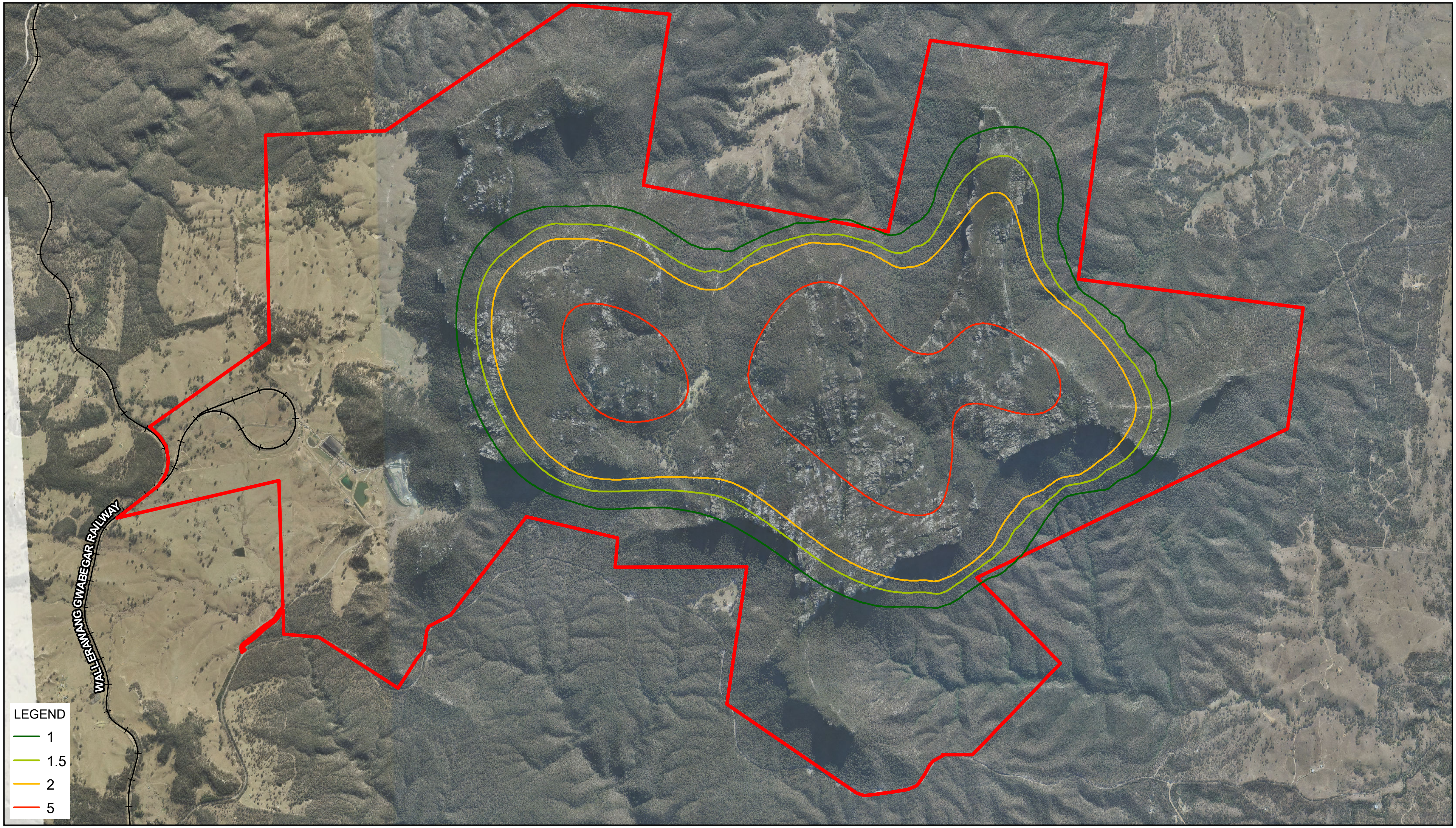
Drawdown in Marrangaroo Formation
End of mining
3 Mtpa, Scenario 2

Figure G-7

G:\22\0105001\GIS\Maps\Deliverables\Western\Airly\2219275\HMR\Mod3_AppendixG\2219275_D007_3Mtpa_Scenario2_EOM_Layer09.mxd

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

Data source: LPI: DTDB 2012; Centennial: Aerial Imagery, boundaries, 2013, Monitoring Locations, 2017. Created by: fmackay



Paper Size A4

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Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

LEGEND

Project Approval Area SSD_5581

GHD

Centennial Airly

Airly Mine
Airly Mine Mod 3
Hydrogeological Model Report

Job Number 22-19275
Revision 0
Date 30 Jul 2019

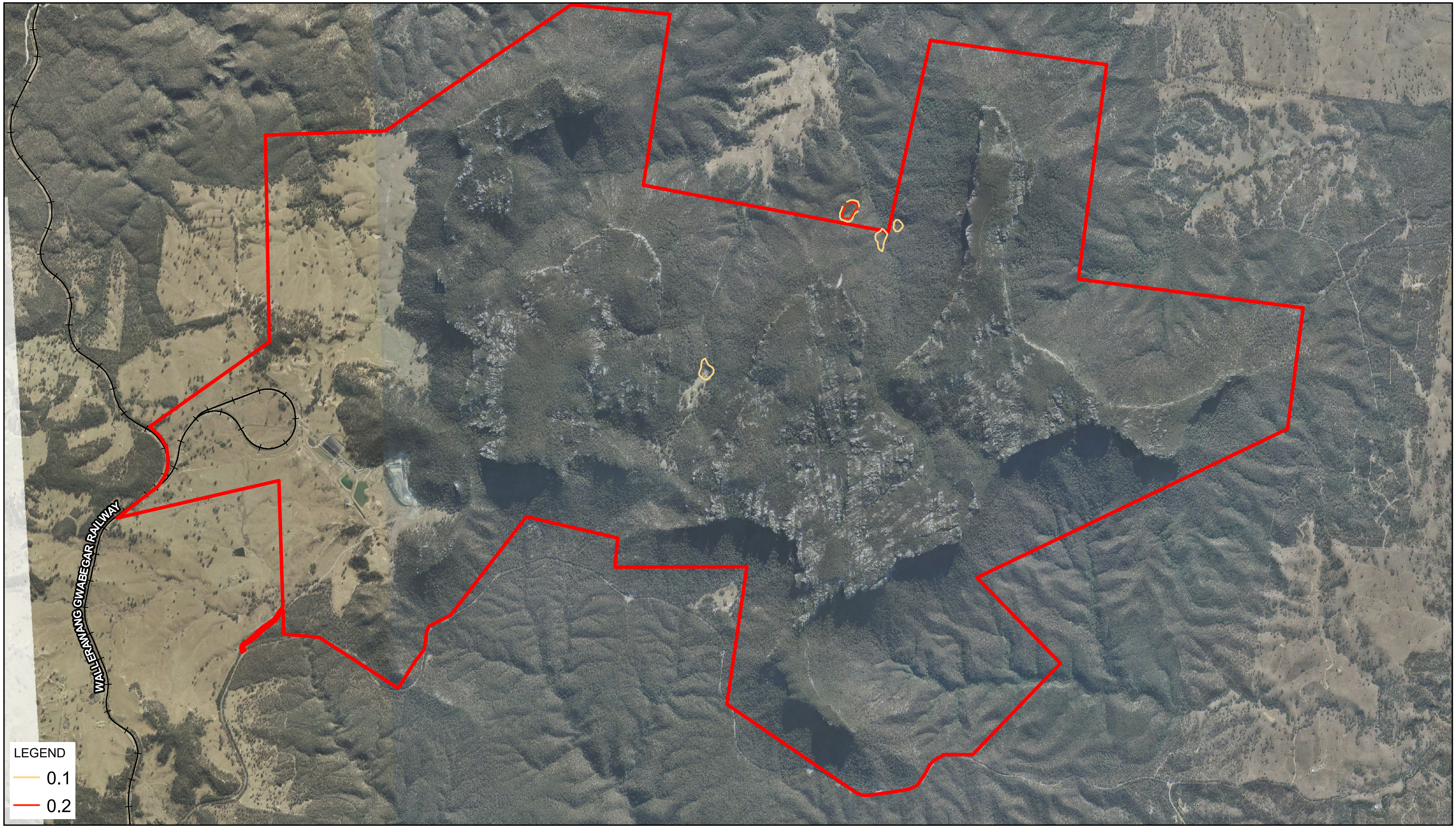
Drawdown in Upper Shoalhaven Group
End of mining
3 Mtpa, Scenario 2

Figure G-8

G:\22\0105001\GIS\Maps\Deliverables\Western\Airly\2219275\HMR\Mod3_AppendixG\2219275_D008_3Mtpa_Scenario2_EOM_Layer10.mxd

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

Data source: LPI: DTDB 2012; Centennial: Aerial Imagery, boundaries, 2013, Monitoring Locations, 2017. Created by: fmackay



Paper Size A4

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Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

LEGEND

Project Approval Area SSD_5581

GHD

Centennial Airly

Airly Mine
Airly Mine Mod 3
Hydrogeological Model Report

Drawdown in Shallow Strata 30 years after mining 3 Mtpa, Scenario 1

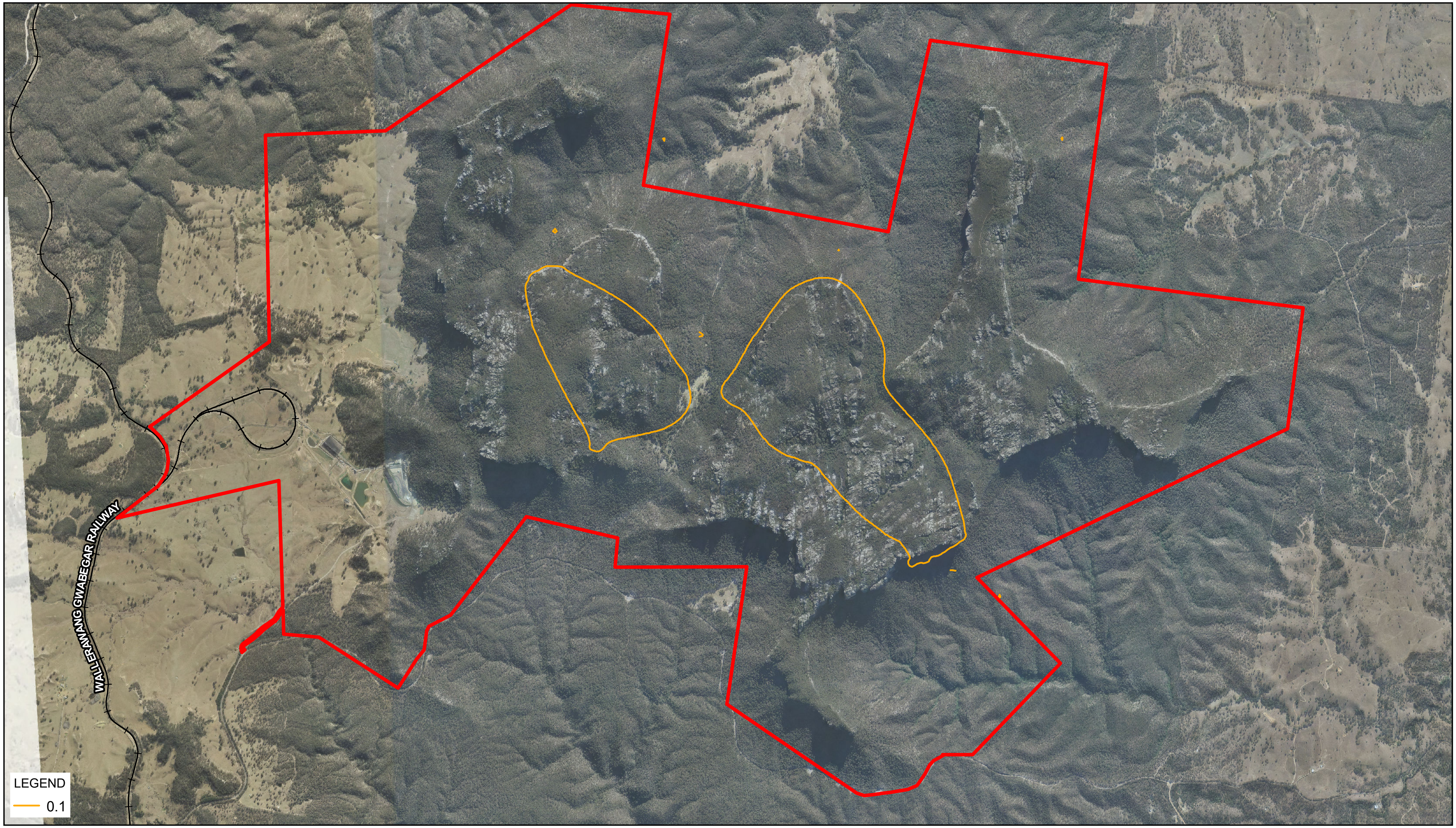
Job Number 22-19275
Revision 0
Date 30 Jul 2019

Figure G-9

G:\22\0105001\GIS\Maps\Deliverables\Western\Airly\2219275\HMR\Mod3_AppendixG\2219275_D009_3Mtpa_Scenario1_30Y_Layer01.mxd

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

Data source: LPI: DTDB 2012; Centennial: Aerial Imagery, boundaries, 2013, Monitoring Locations, 2017. Created by: fmackay



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Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

LEGEND

Project Approval Area SSD_5581

GHD

Centennial Airly

Airly Mine
Airly Mine Mod 3
Hydrogeological Model Report

Drawdown in Lithgow seam
30 years after mining
3 Mtpa, Scenario 1

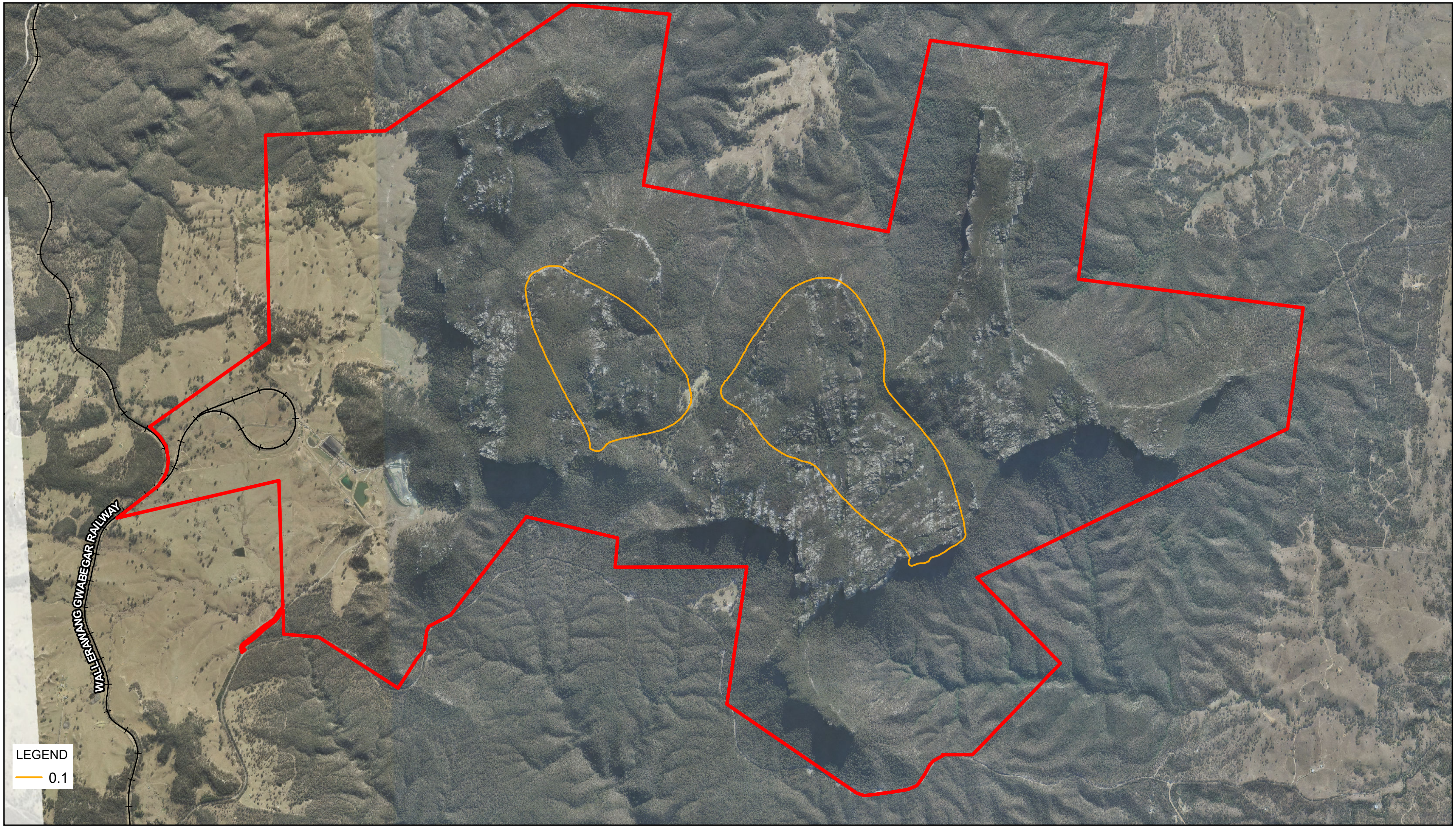
Job Number	22-19275
Revision	0
Date	30 Jul 2019

Figure G-10

G:\22\0105001\GIS\Maps\Deliverables\Western\Airly\2219275\HMR\Mod3_AppendixG\2219275_D010_3Mtpa_Scenario1_30Y_Layer8.mxd

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 T 61 2 4979 9999 F 61 2 4979 9988 E ntlmail@ghd.com W www.ghd.com.au

Data source: LPI: DTDB 2012; Centennial: Aerial Imagery, boundaries, 2013, Monitoring Locations, 2017. Created by: fmackay



Paper Size A4

0 330 660 990 1,320

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

LEGEND

Project Approval Area SSD_5581

GHD

Centennial Airly

Airly Mine
Airly Mine Mod 3
Hydrogeological Model Report

Job Number 22-19275
Revision 0
Date 30 Jul 2019

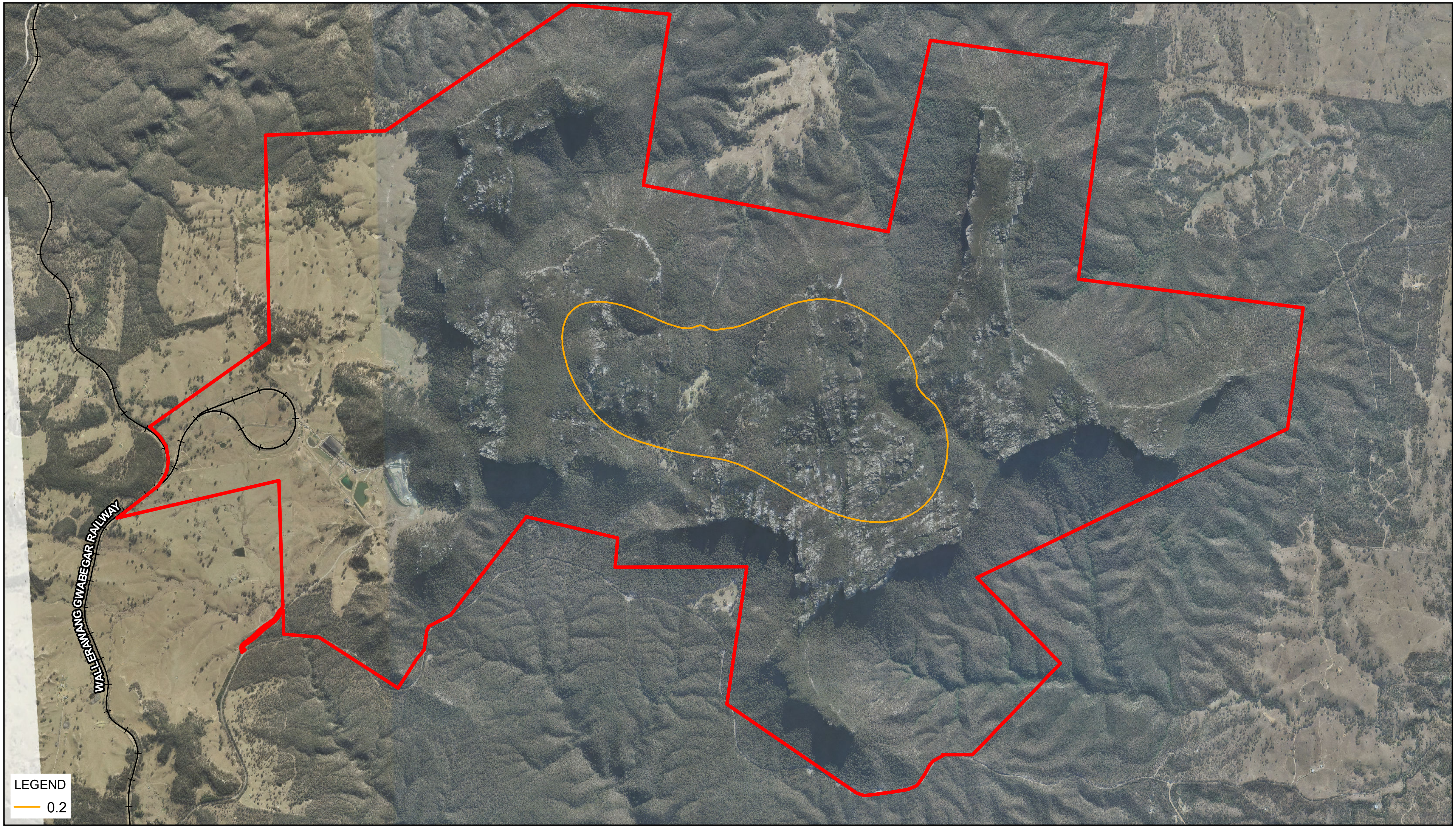
Drawdown in Marrangaroo Formation 30 years after mining 3 Mtpa, Scenario 1

Figure G-11

G:\22\0105001\GIS\Maps\Deliverables\Western\Airly\2219275\HMR\Mod3_AppendixG\2219275_D011_3Mtpa_Scenario1_30Y_Layer9.mxd

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 T 61 2 4979 9999 F 61 2 4979 9988 E ntlmail@ghd.com W www.ghd.com.au

Data source: LPI: DTDB 2012; Centennial: Aerial Imagery, boundaries, 2013, Monitoring Locations, 2017. Created by: fmackay



Paper Size A4

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Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

LEGEND

Project Approval Area SSD_5581

GHD

Centennial Airly

Airly Mine
Airly Mine Mod 3
Hydrogeological Model Report

Job Number | 22-19275
Revision | 0
Date | 30 Jul 2019

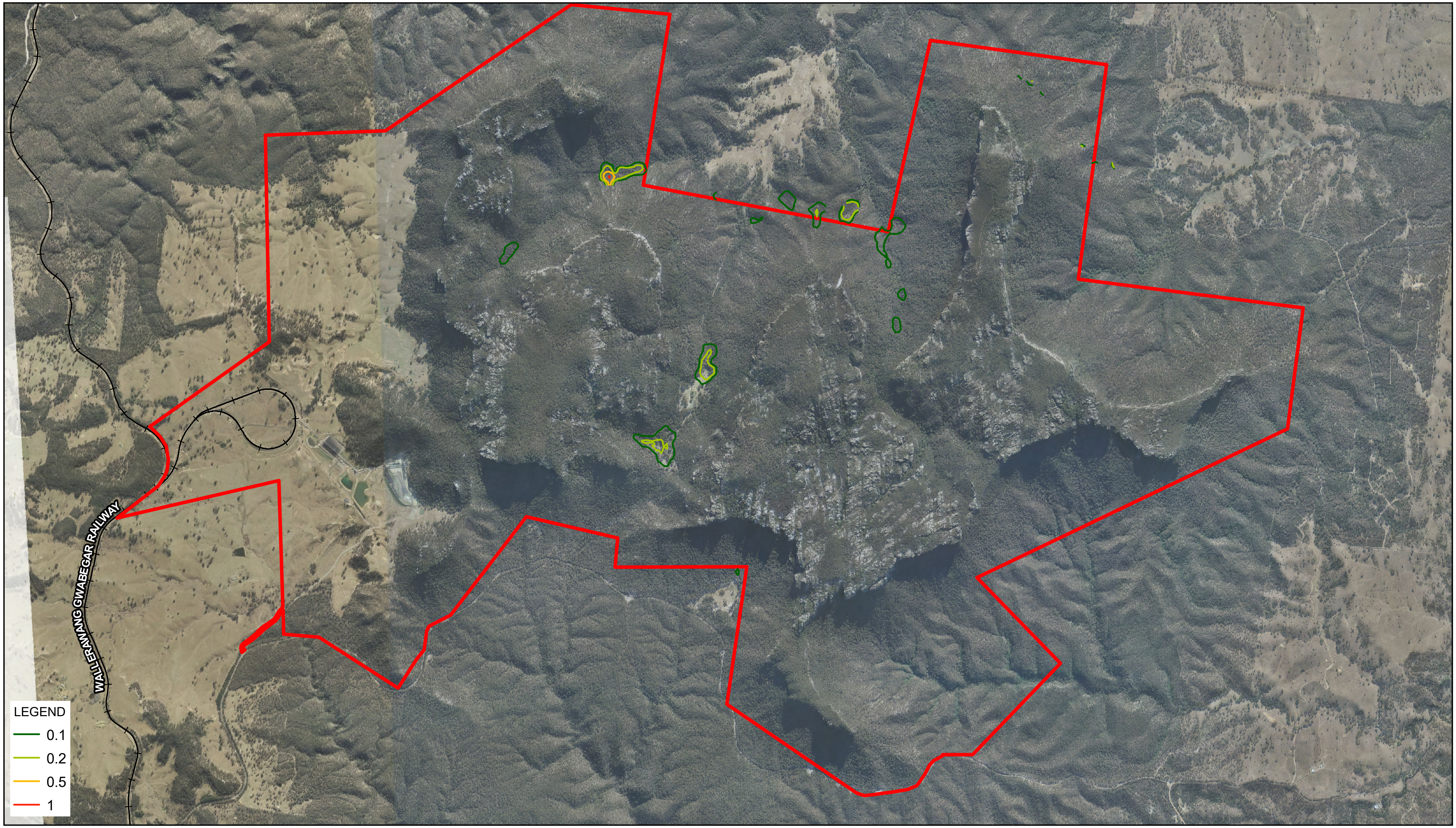
Drawdown in Upper Shoalhaven Group
30 years after mining
3 Mtpa, Scenario 1

Figure G-12

G:\22\0105001\GIS\Maps\Deliverables\Western\Airly\2219275\HMR\Mod3_AppendixG\2219275_D012_3Mtpa_Scenario1_30Y_Layer10.mxd

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

Data source: LPI: DTDB 2012; Centennial: Aerial Imagery, boundaries, 2013, Monitoring Locations, 2017. Created by: fmackay



Paper Size A4

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Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

LEGEND

Project Approval Area SSD_5581

GHD

Centennial Airly

Airly Mine
Airly Mine Mod 3
Hydrogeological Model Report

Drawdown in Shallow Strata
30 years after mining
3 Mtpa, Scenario 2

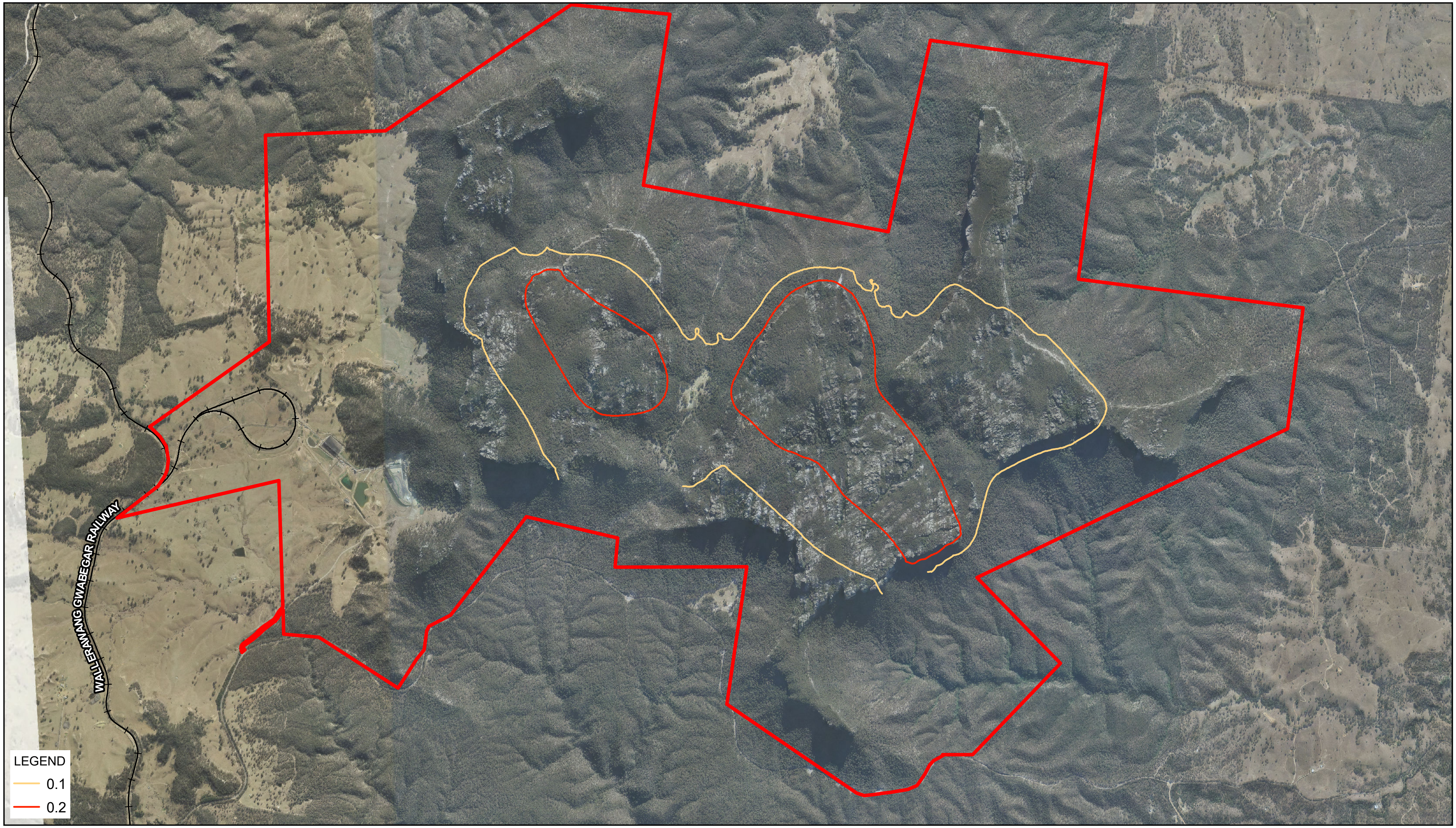
Job Number	22-19275
Revision	0
Date	30 Jul 2019

Figure G-13

G:\22\0105001\GIS\Maps\Deliverables\Western\Airly\2219275\HMR\Mod3_AppendixG\2219275_D013_3Mtpa_Scenario2_30Y_Layer1.mxd

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

Data source: LPI: DTDB 2012; Centennial: Aerial Imagery, boundaries, 2013, Monitoring Locations, 2017. Created by: fmackay



Paper Size A4

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Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

LEGEND

Project Approval Area SSD_5581

GHD

Centennial Airly

Airly Mine
Airly Mine Mod 3
Hydrogeological Model Report

Drawdown in Lithgow seam
30 years after mining
3 Mtpa, Scenario 2

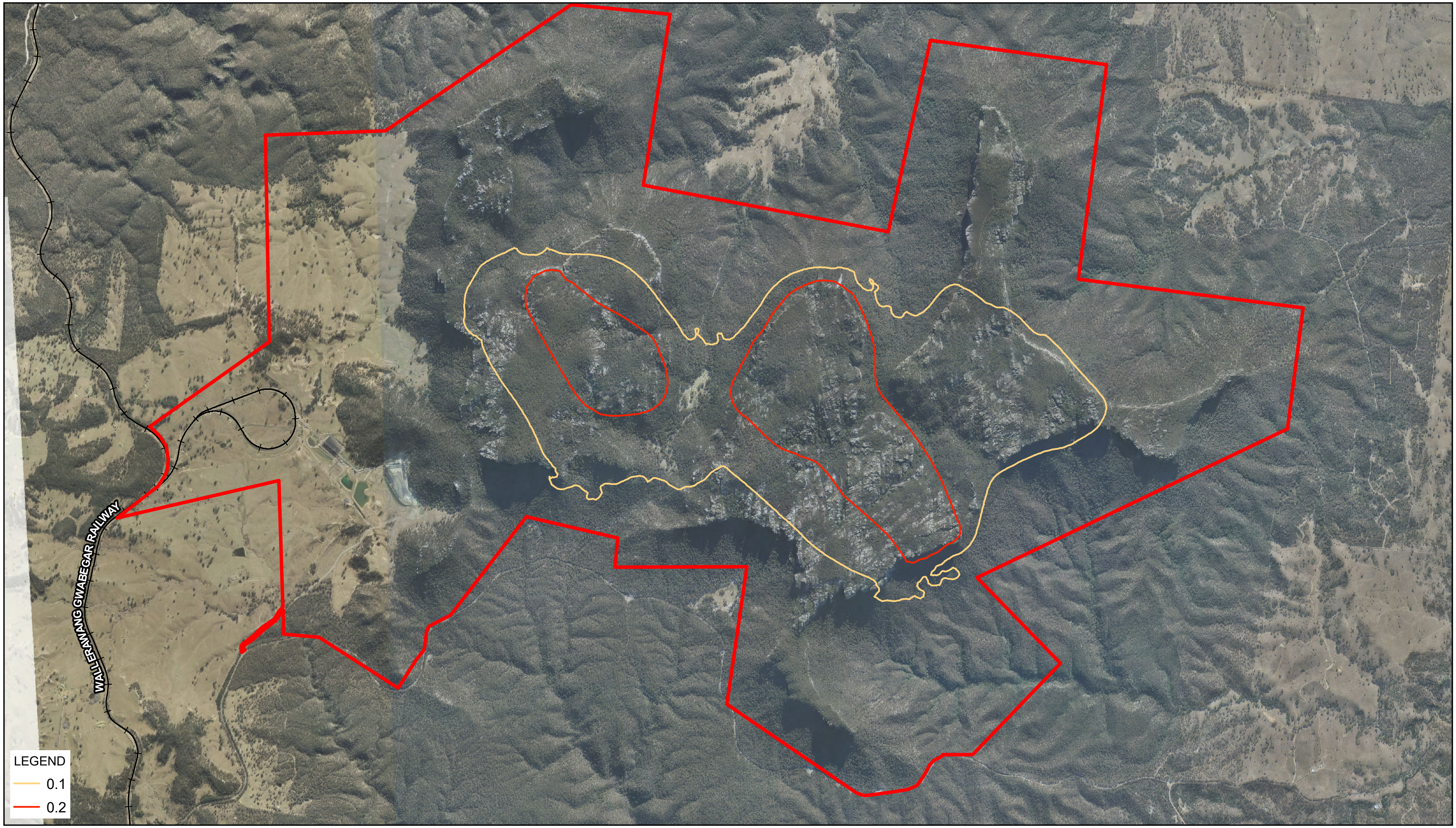
Job Number	22-19275
Revision	0
Date	30 Jul 2019

Figure G-14

G:\22\0105001\GIS\Maps\Deliverables\Western\Airly\2219275\HMR\Mod3_AppendixG\2219275_D014_3Mtpa_Scenario2_30Y_Layer8.mxd

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 T 61 2 4979 9999 F 61 2 4979 9988 E ntlmail@ghd.com W www.ghd.com.au

Data source: LPI: DTDB 2012; Centennial: Aerial Imagery, boundaries, 2013, Monitoring Locations, 2017. Created by: fmackay



Paper Size A4

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Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

LEGEND

Project Approval Area SSD_5581

GHD

Centennial Airly

Airly Mine
Airly Mine Mod 3
Hydrogeological Model Report

Drawdown in Marrangaroo Formation
30 years after mining
3 Mtpa, Scenario 2

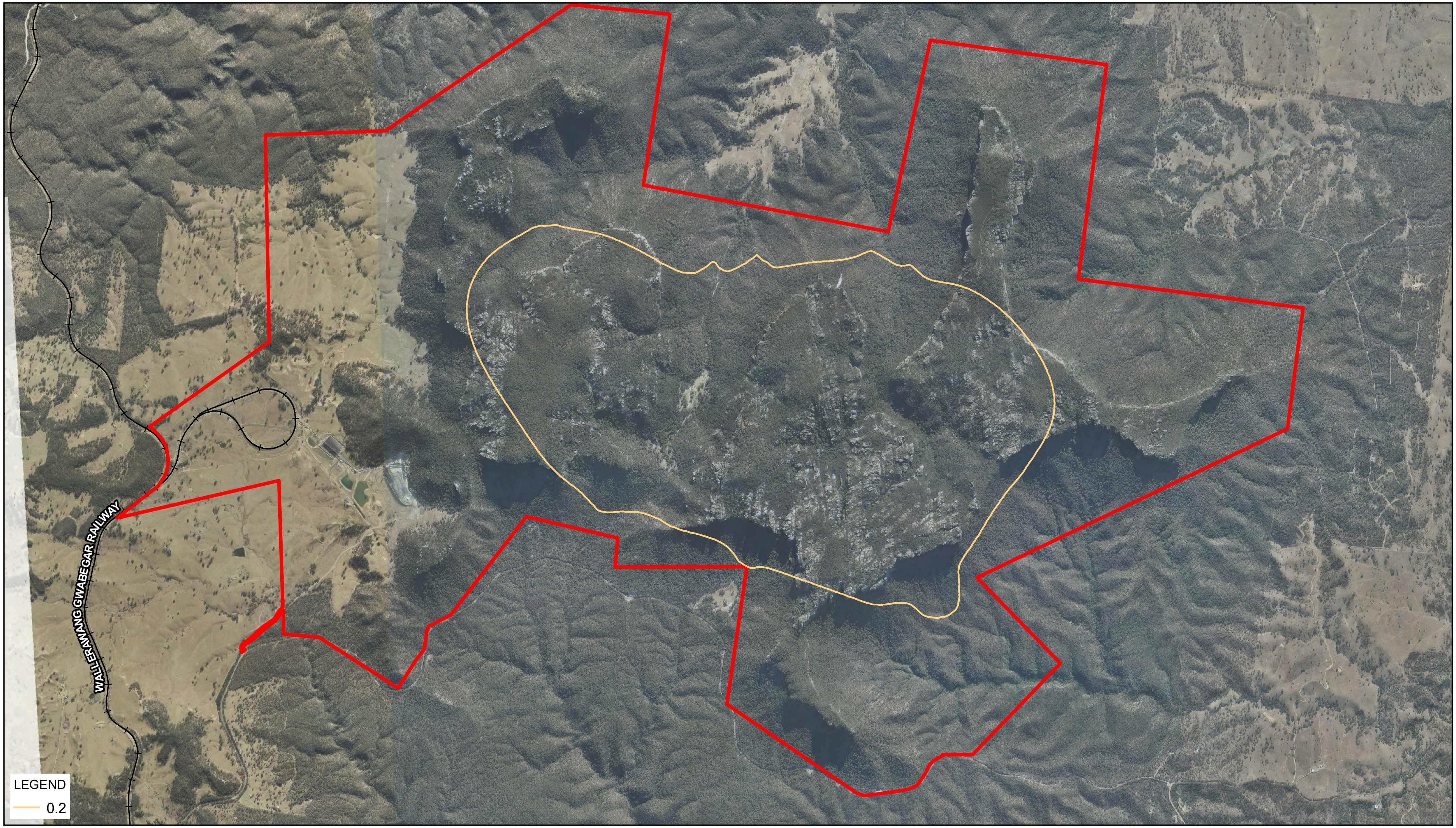
Job Number	22-19275
Revision	0
Date	30 Jul 2019

Figure G-15

G:\22\0105001\GIS\Maps\Deliverables\Western\Airly\2219275\HMR\Mod3_AppendixG\2219275_D015_3Mtpa_Scenario2_30Y_Layer9.mxd

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

Data source: LPI: DTDB 2012; Centennial: Aerial Imagery, boundaries, 2013, Monitoring Locations, 2017. Created by: fmackay



Paper Size A4

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Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

LEGEND

Project Approval Area SSD_5581

GHD

Centennial Airly

Airly Mine
Airly Mine Mod 3
Hydrogeological Model Report

Drawdown in Upper Shoalhaven Group 30 years after mining 3 Mtpa, Scenario 2

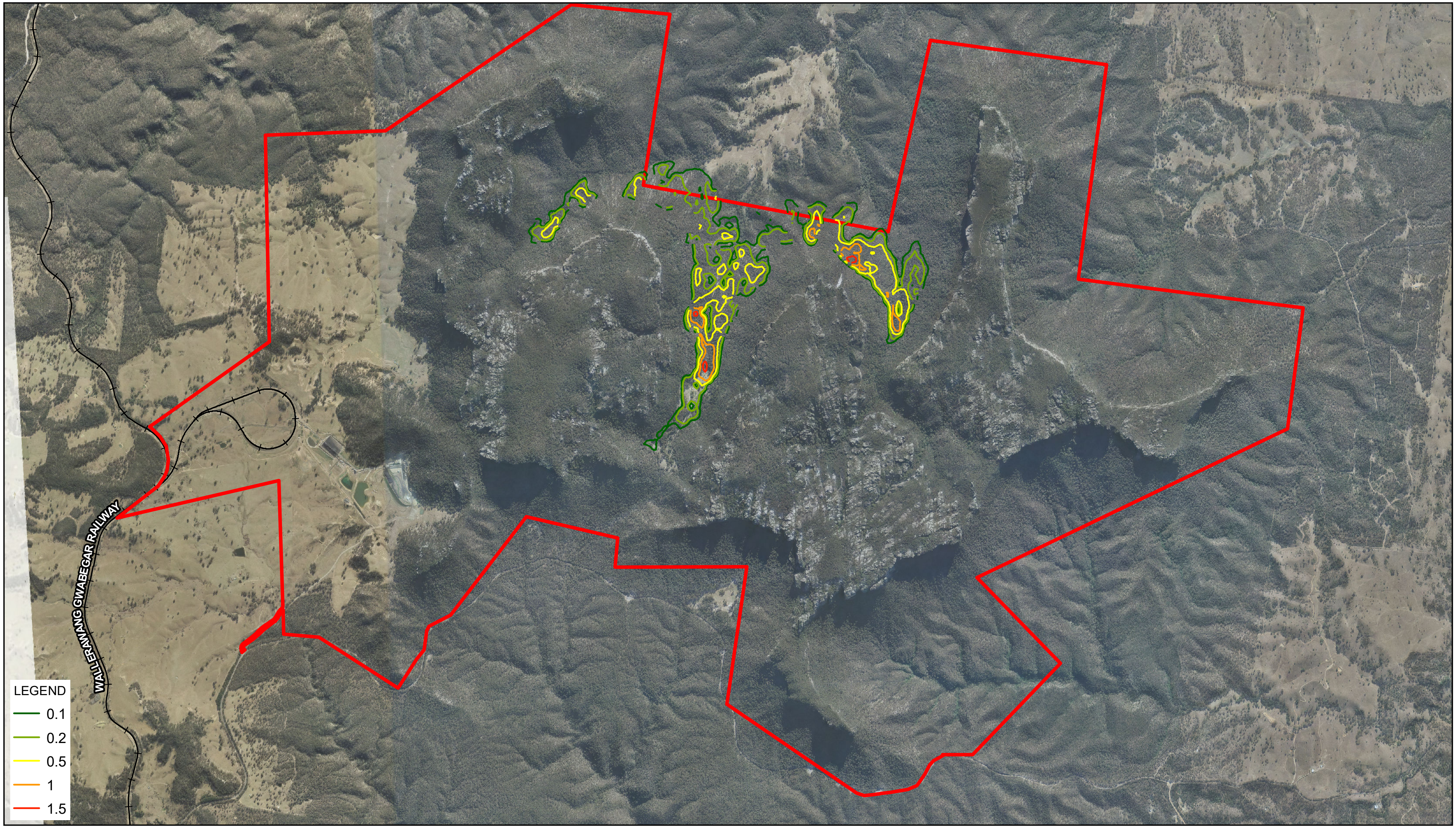
Job Number	22-19275
Revision	0
Date	21 Sep 2018

Figure G-16

G:\22\0105001\GIS\Maps\Deliverables\Western\Airly\2219275\HMR\Mod3_AppendixG\2219275_D016_3Mtpa_Scenario2_30Y_Layer10.mxd

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 T 61 2 4979 9999 F 61 2 4979 9988 E ntlmail@ghd.com W www.ghd.com.au

Data source: LPI: DTDB 2012; Centennial: Aerial Imagery, boundaries, 2013, Monitoring Locations, 2017. Created by: fmackay



Paper Size A4

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Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

LEGEND

Project Approval Area
SSD_5581

GHD

Centennial Airly

Airly Mine
Airly Mine Mod 3
Hydrogeological Model Report

Drawdown in Shallow Strata
End of mining
1-8 Mtpa, Scenario 1

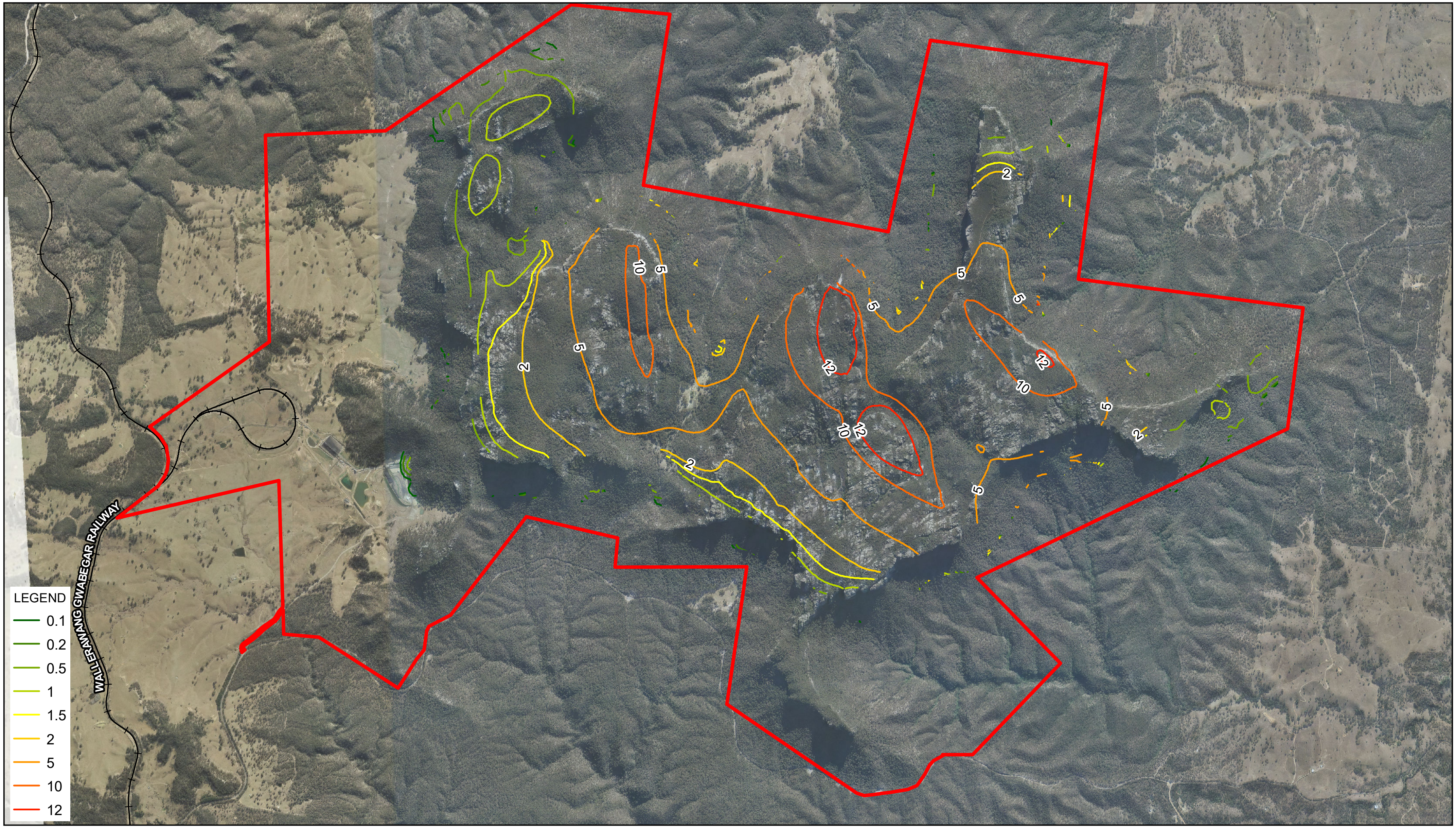
Job Number	22-19275
Revision	A
Date	30 Jul 2019

Figure G-17

G:\22\0105001\GIS\Maps\Deliverables\Western\Airly\2219275\HMR\Mod3_AppendixG\2219275_D017_1-8_Scenario1_EOM_Layer1.mxd

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

Data source: LPI: DTDB 2012; Centennial: Aerial Imagery, boundaries, 2013, Monitoring Locations, 2017. Created by: fmackay



Paper Size A4

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Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

LEGEND

Project Approval Area SSD_5581

GHD

Centennial Airly

Airly Mine
Airly Mine Mod 3
Hydrogeological Model Report

Job Number 22-19275
Revision A
Date 30 Jul 2019

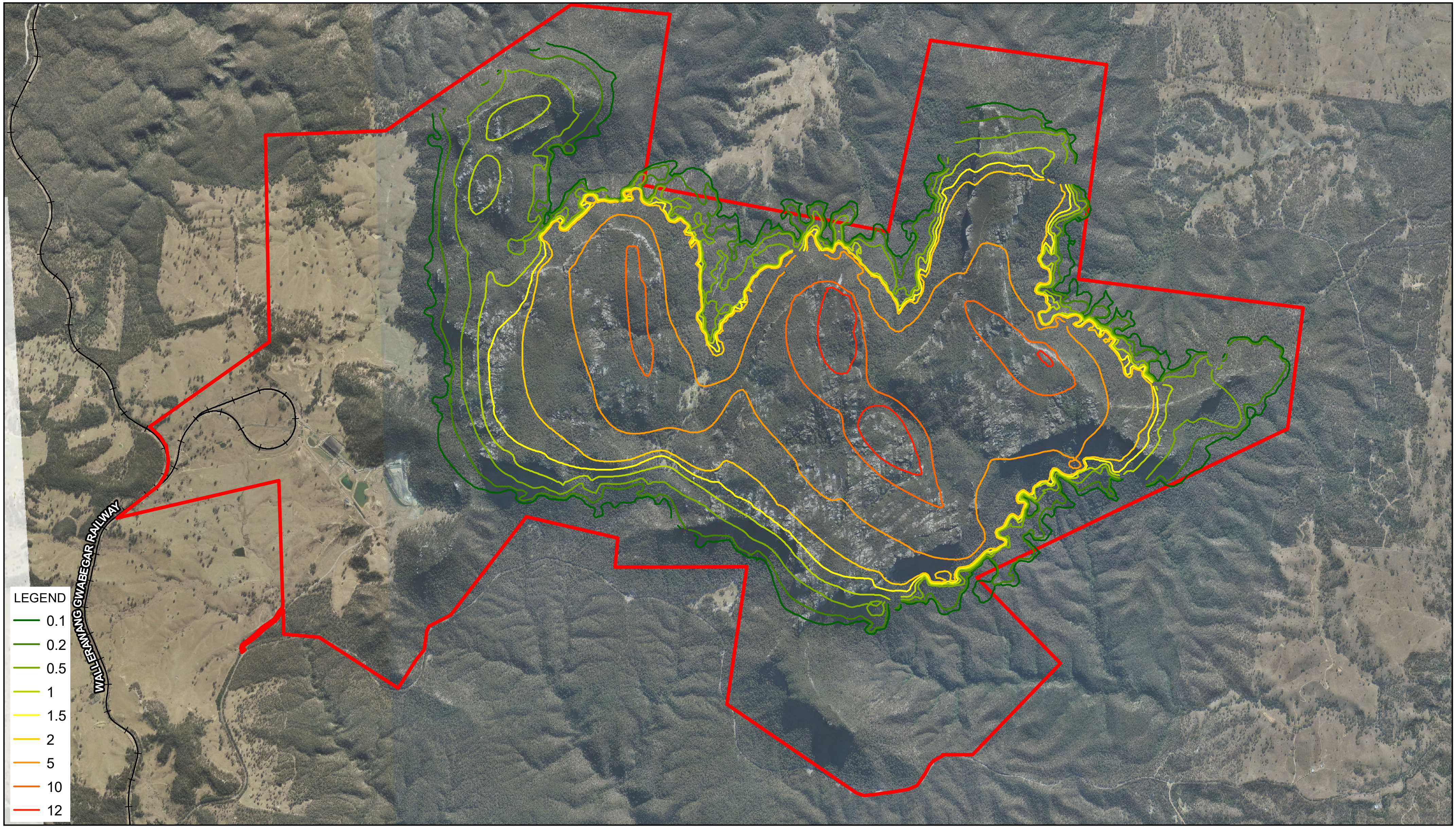
Drawdown in Lithgow seam End of mining 1-8 Mtpa, Scenario 1

Figure G-18

G:\22\0105001\GIS\Maps\Deliverables\Western\Airly\2219275\HMR\Mod3_AppendixG\2219275_D018_1-8_Scenario1_EOM_Layer8.mxd

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

Data source: LPI: DTDB 2012; Centennial: Aerial Imagery, boundaries, 2013, Monitoring Locations, 2017. Created by: fmackay



Paper Size A4

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Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

LEGEND

Project Approval Area SSD_5581

GHD

Centennial Airly

Airly Mine
Airly Mine Mod 3
Hydrogeological Model Report

Job Number 22-19275
Revision A
Date 30 Jul 2019

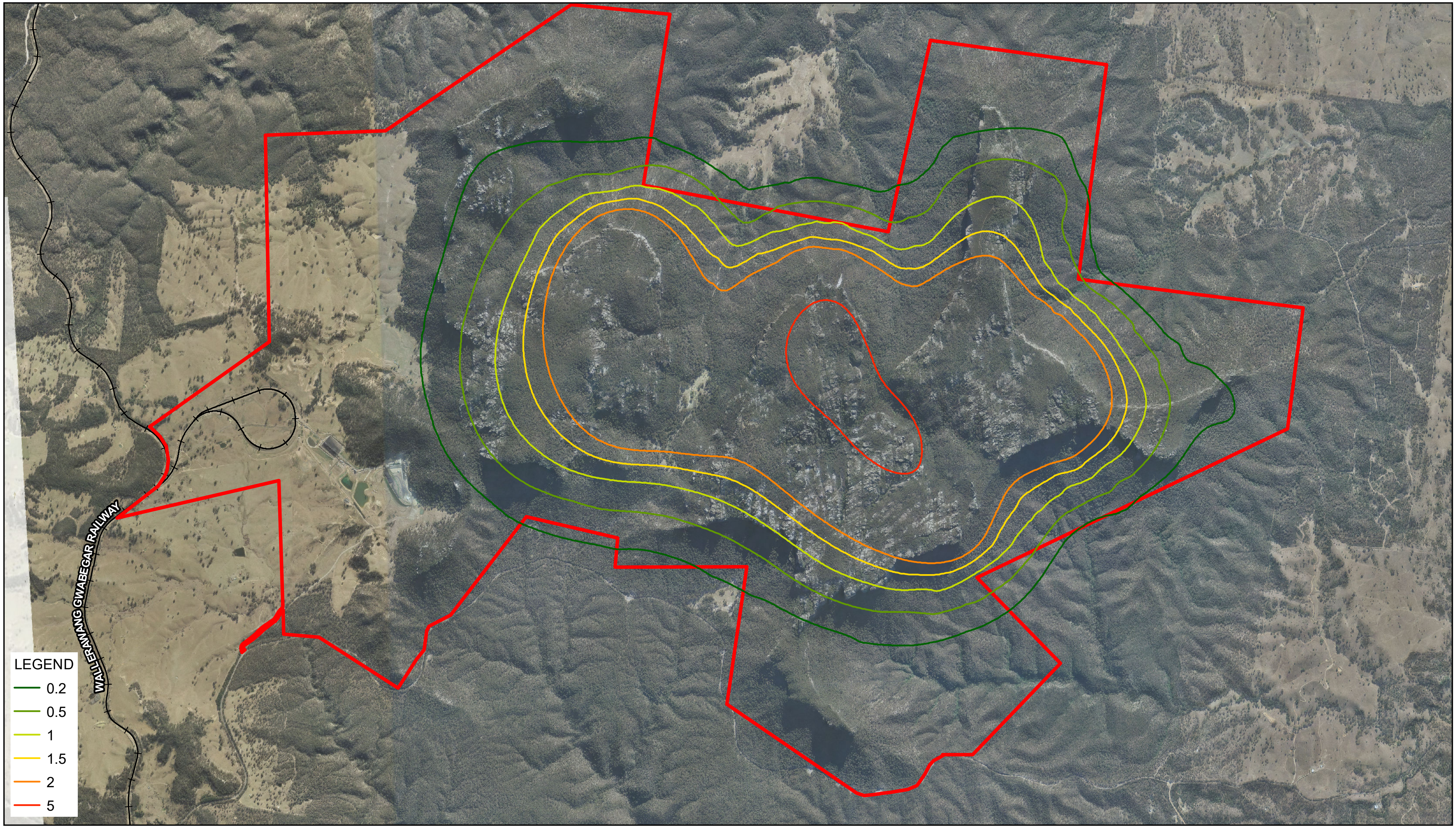
Drawdown in Marrangaroo Formation
End of mining
1-8 Mtpa, Scenario 1

Figure G-19

G:\22\0105001\GIS\Maps\Deliverables\Western\Airly\2219275\HMR\Mod3_AppendixG\2219275_D019_1-8_Scenario1_EOM_Layer9.mxd

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com.au **W** www.ghd.com.au

Data source: LPI: DTDB 2012; Centennial: Aerial Imagery, boundaries, 2013, Monitoring Locations, 2017. Created by: fmackay



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0 330 660 990 1,320

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

LEGEND

Project Approval Area SSD_5581

GHD

Centennial Airly

Airly Mine
Airly Mine Mod 3
Hydrogeological Model Report

Drawdown in Upper Shoalhaven Group
End of mining
1-8 Mtpa, Scenario 1

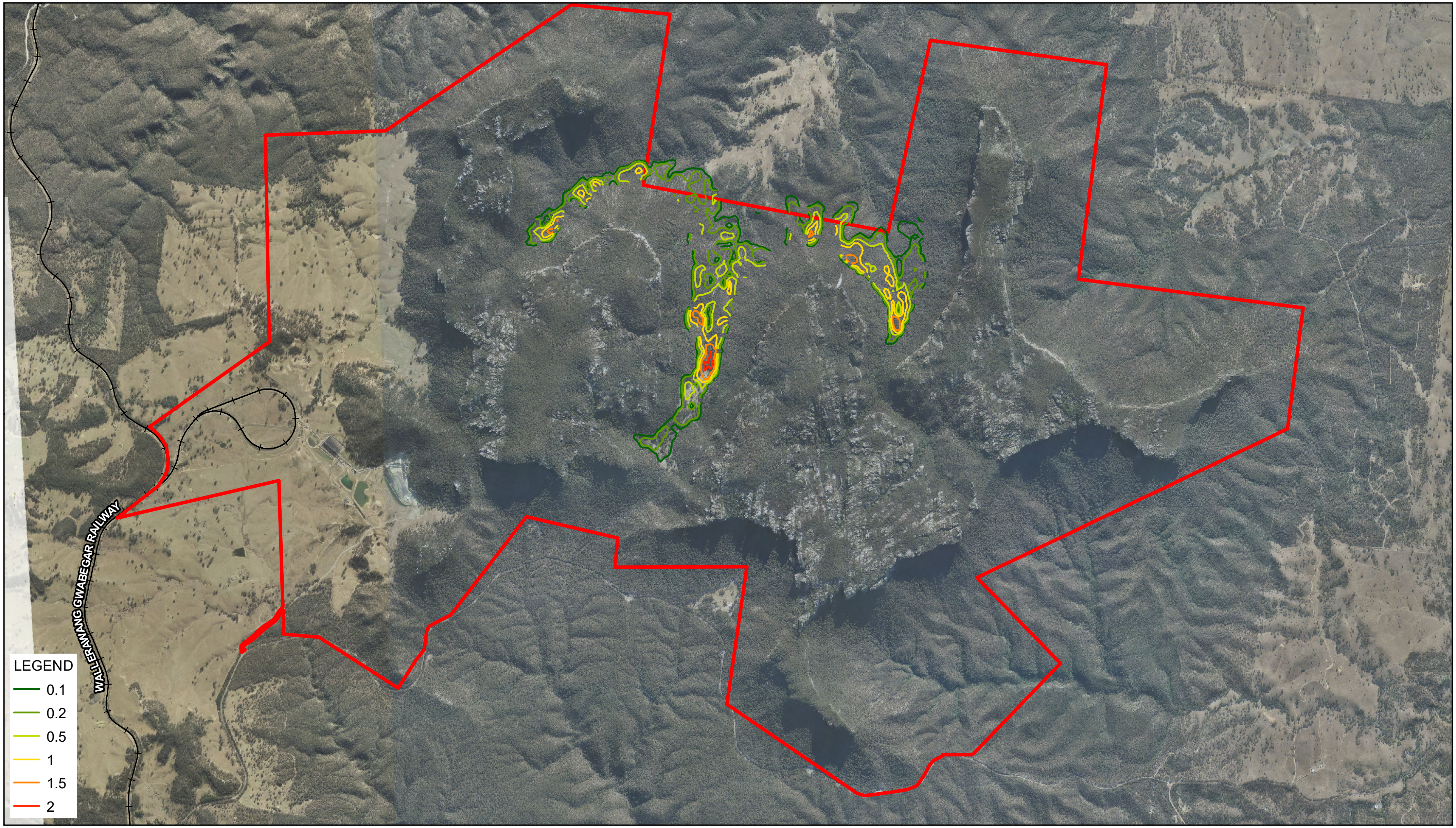
Job Number	22-19275
Revision	A
Date	30 Jul 2019

Figure G-20

G:\22\0105001\GIS\Maps\Deliverables\Western\Airly\2219275\HMR\Mod3_AppendixG\2219275_D020_1-8_Scenario1_EOM_Layer10.mxd

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

Data source: LPI: DTDB 2012; Centennial: Aerial Imagery, boundaries, 2013, Monitoring Locations, 2017. Created by: fmackay



Paper Size A4

0 330 660 990 1,320

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

LEGEND

Project Approval Area SSD_5581

GHD

Centennial Airly

Airly Mine
Airly Mine Mod 3
Hydrogeological Model Report

Drawdown in Shallow Strata
End of mining
1-8 Mtpa, Scenario 2

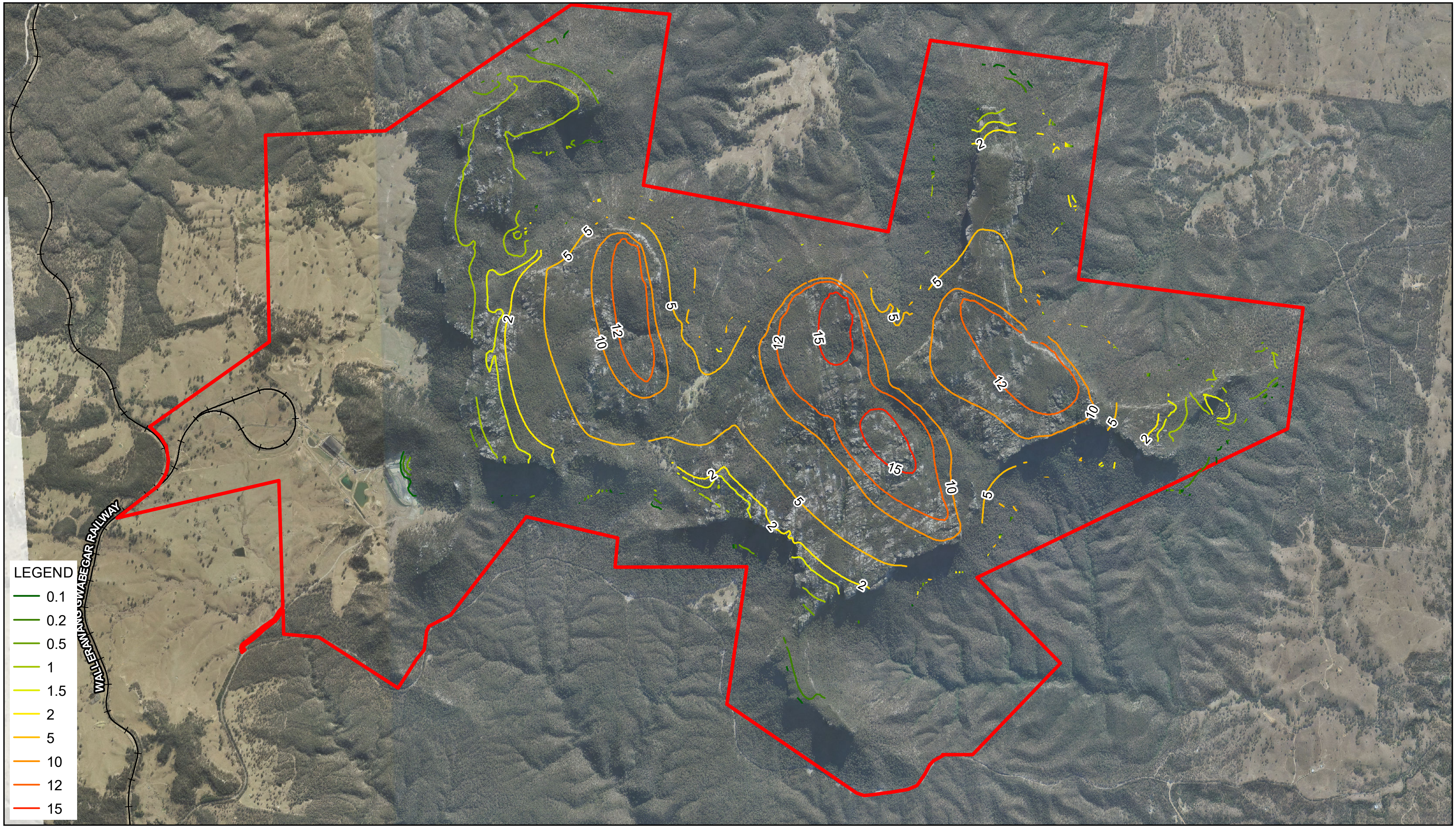
Job Number	22-19275
Revision	A
Date	30 Jul 2019

Figure G-21

G:\22\0105001\GIS\Maps\Deliverables\Western\Airly\2219275\HMR\Mod3_AppendixG\2219275_D021_1-8_Scenario2_EOM_Layer1.mxd

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

Data source: LPI: DTDB 2012; Centennial: Aerial Imagery, boundaries, 2013, Monitoring Locations, 2017. Created by: fmackay



Paper Size A4

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Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

LEGEND

Project Approval Area SSD_5581

GHD

Centennial Airly

Airly Mine
Airly Mine Mod 3
Hydrogeological Model Report

Drawdown in Lithgow seam
End of mining
1-8 Mtpa, Scenario 2

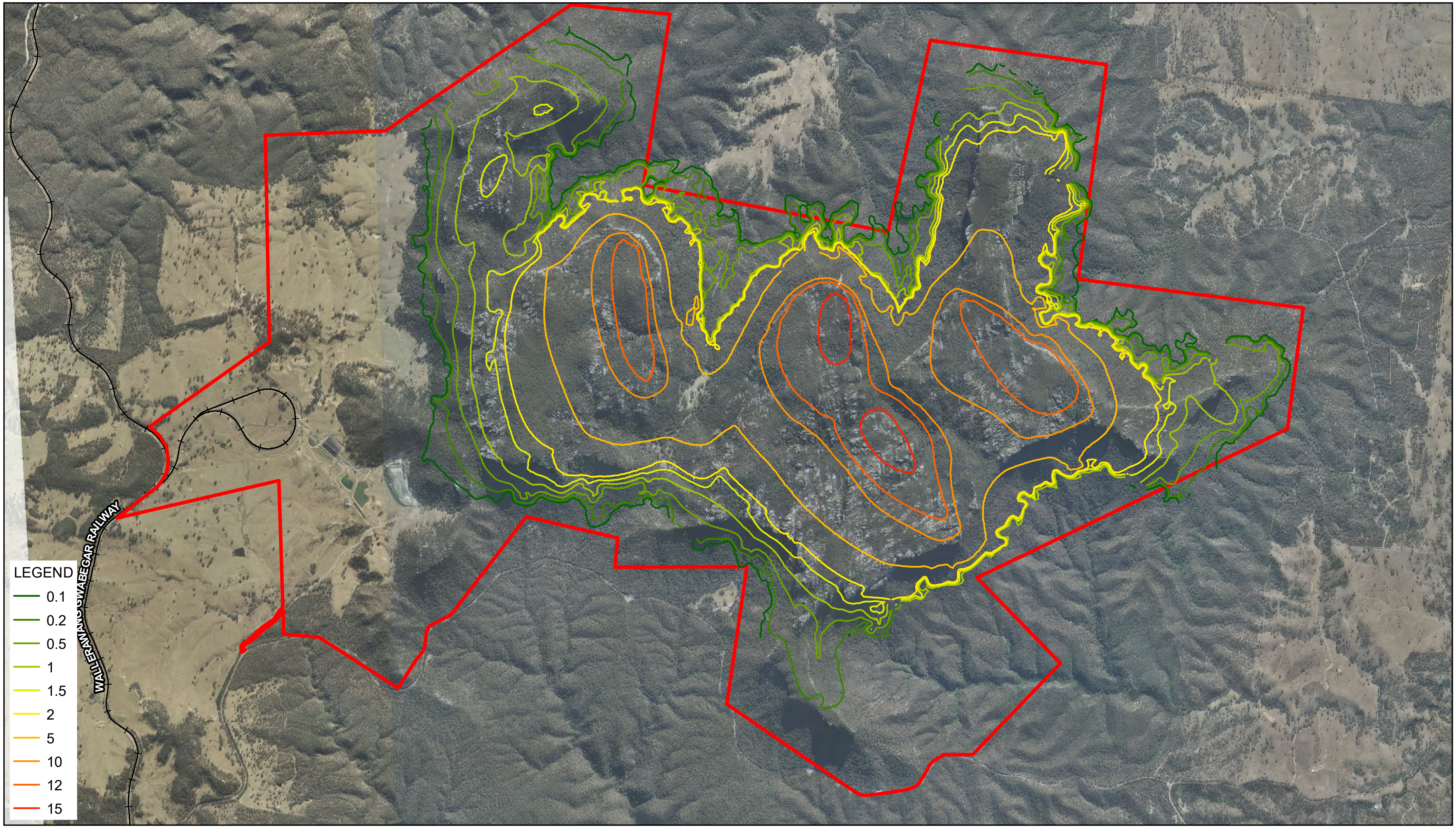
Job Number 22-19275
Revision A
Date 30 Jul 2019

Figure G-22

G:\22\0105001\GIS\Maps\Deliverables\Western\Airly\2219275\HMR\Mod3_AppendixG\2219275_D022_1-8_Scenario2_EOM_Layer8.mxd

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 T 61 2 4979 9999 F 61 2 4979 9988 E ntlmail@ghd.com W www.ghd.com.au

Data source: LPI: DTDB 2012; Centennial: Aerial Imagery, boundaries, 2013, Monitoring Locations, 2017. Created by: fmackay



Paper Size A4

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Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

LEGEND

Project Approval Area SSD_5581

GHD

Centennial Airly

Airly Mine
Airly Mine Mod 3
Hydrogeological Model Report

Job Number 22-19275
Revision A
Date 21 Sep 2018

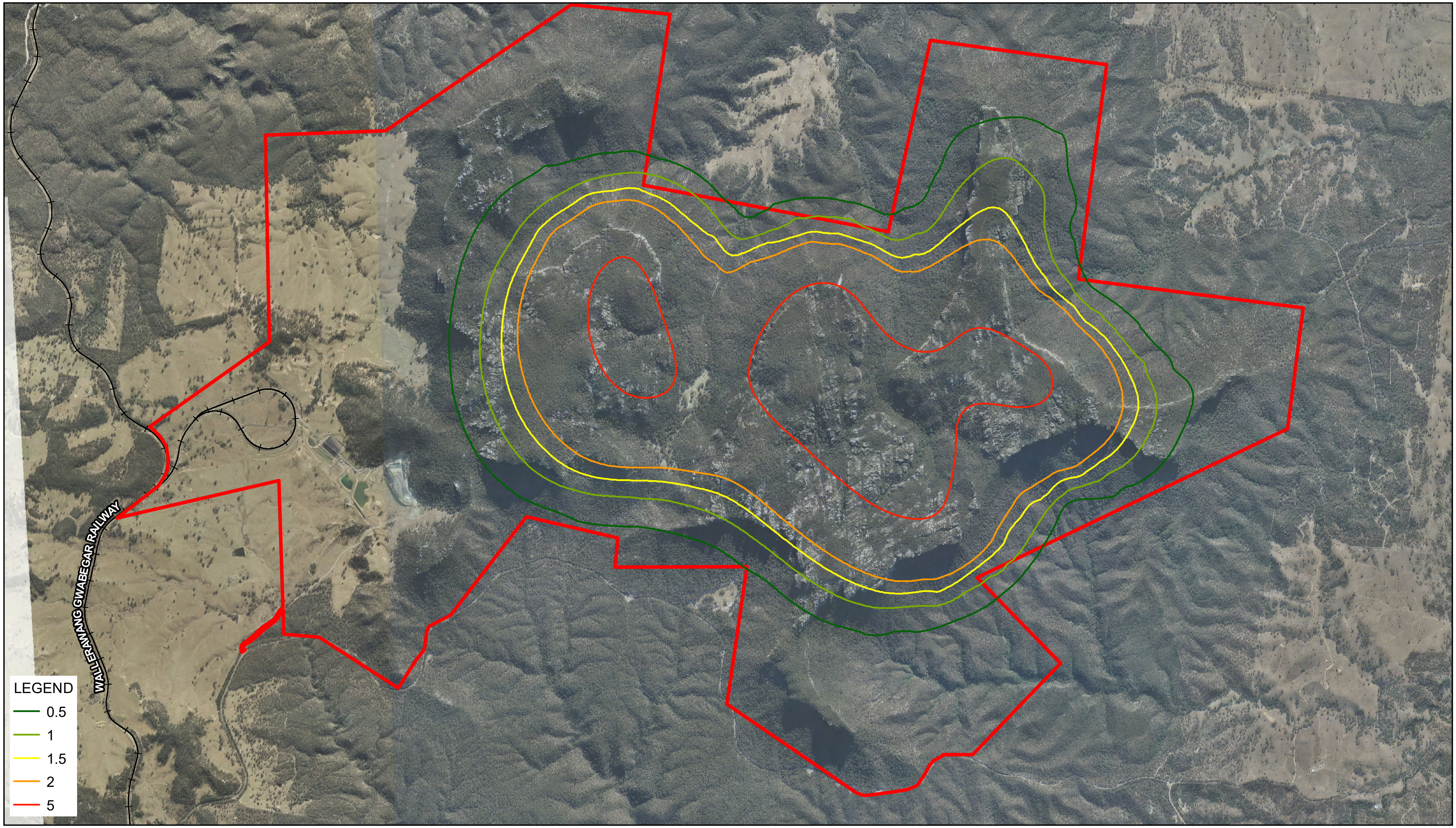
Drawdown in Marrangaroo Formation
End of mining
1-8 Mtpa, Scenario 2

Figure G-23

G:\22\0105001\GIS\Maps\Deliverables\Western\Airly\2219275\HMR\Mod3_AppendixG\2219275_D023_1-8_Scenario2_EOM_Layer9.mxd

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 T 61 2 4979 9999 F 61 2 4979 9988 E ntlmail@ghd.com.au W www.ghd.com.au

Data source: LPI: DTDB 2012; Centennial: Aerial Imagery, boundaries, 2013, Monitoring Locations, 2017. Created by: fmackay



Paper Size A4

0 330 660 990 1,320

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

LEGEND

Project Approval Area SSD_5581

GHD

Centennial Airly

Airly Mine
Airly Mine Mod 3
Hydrogeological Model Report

Job Number 22-19275
Revision A
Date 30 Jul 2019

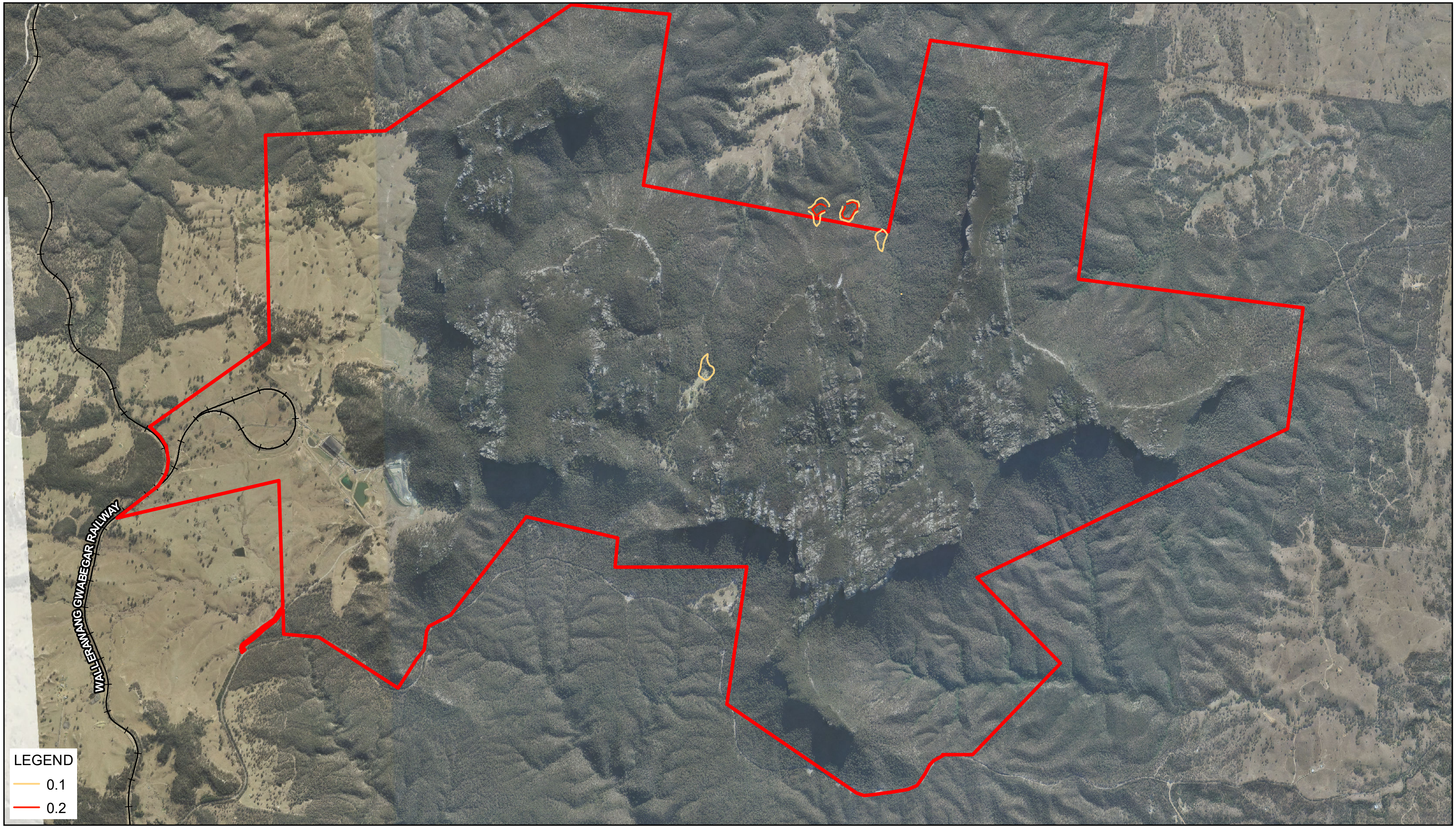
Drawdown in Upper Shoalhaven Group
End of mining
1-8 Mtpa, Scenario 2

Figure G-24

G:\22\0105001\GIS\Maps\Deliverables\Western\Airly\2219275\HMR\Mod3_AppendixG\2219275_D024_1-8_Scenario2_EOM_Layer10.mxd

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 T 61 2 4979 9999 F 61 2 4979 9988 E ntlmail@ghd.com W www.ghd.com.au

Data source: LPI: DTDB 2012; Centennial: Aerial Imagery, boundaries, 2013, Monitoring Locations, 2017. Created by: fmackay



Paper Size A4

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Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

LEGEND

Project Approval Area SSD_5581

GHD

Centennial Airly

Airly Mine
Airly Mine Mod 3
Hydrogeological Model Report

Drawdown in Shallow Strata
30 years after mining
1-8 Mtpa, Scenario 1

Job Number	22-19275
Revision	A
Date	21 Sep 2018

Figure G-25

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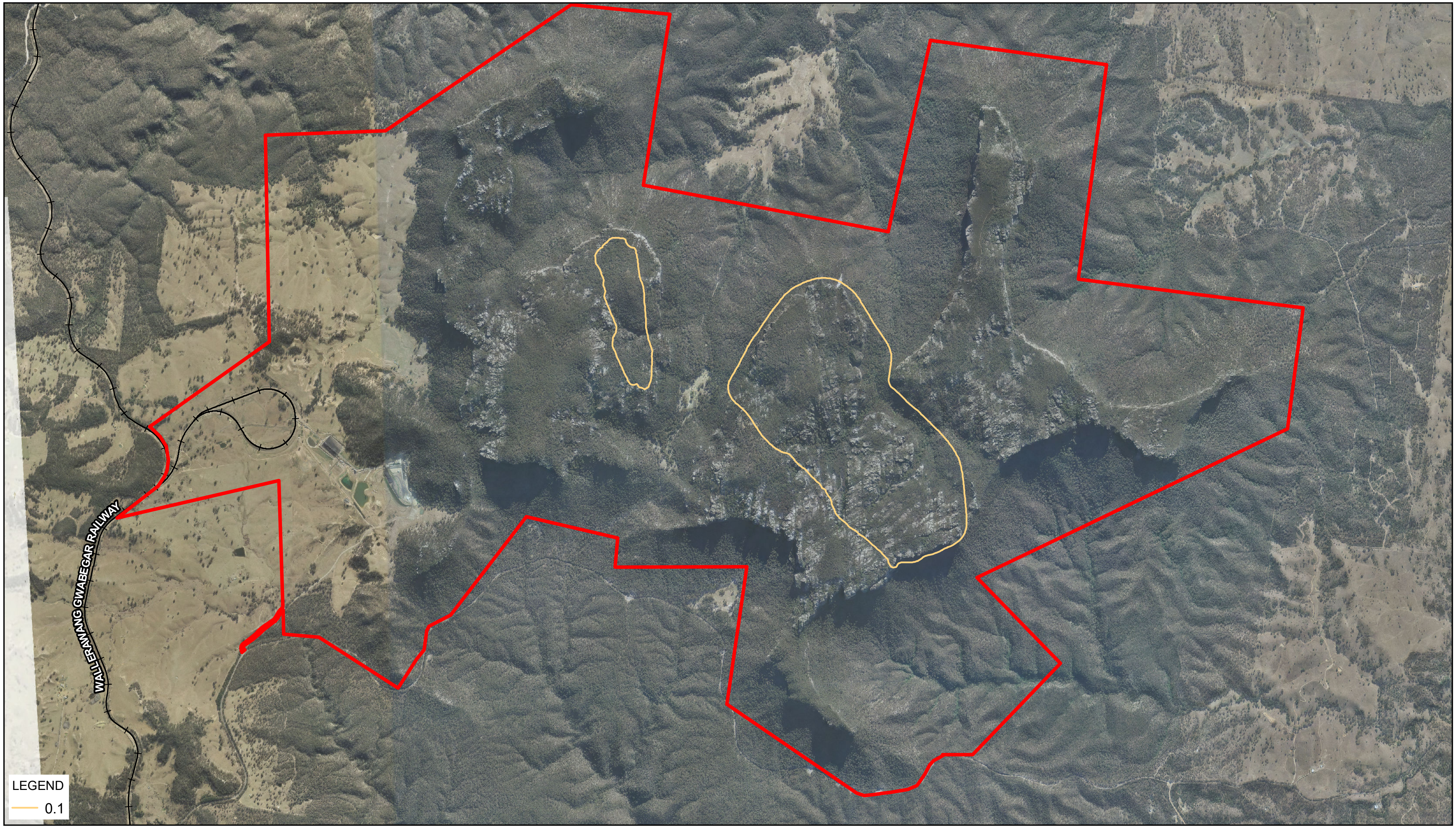

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Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

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LEGEND

Project Approval Area SSD_5581

GHD

Centennial Airly

Airly Mine
Airly Mine Mod 3
Hydrogeological Model Report
Drawdown in Lithgow seam
30 years after mining
1-8 Mtpa, Scenario 1

Job Number 22-19275
Revision A
Date 30 Jul 2019

Figure G-26

G:\22\0105001\GIS\Maps\Deliverables\Western\Airly\2219275\HMR\Mod3_AppendixG\2219275_D026_1-8_Scenario1_30Y_Layer8.mxd

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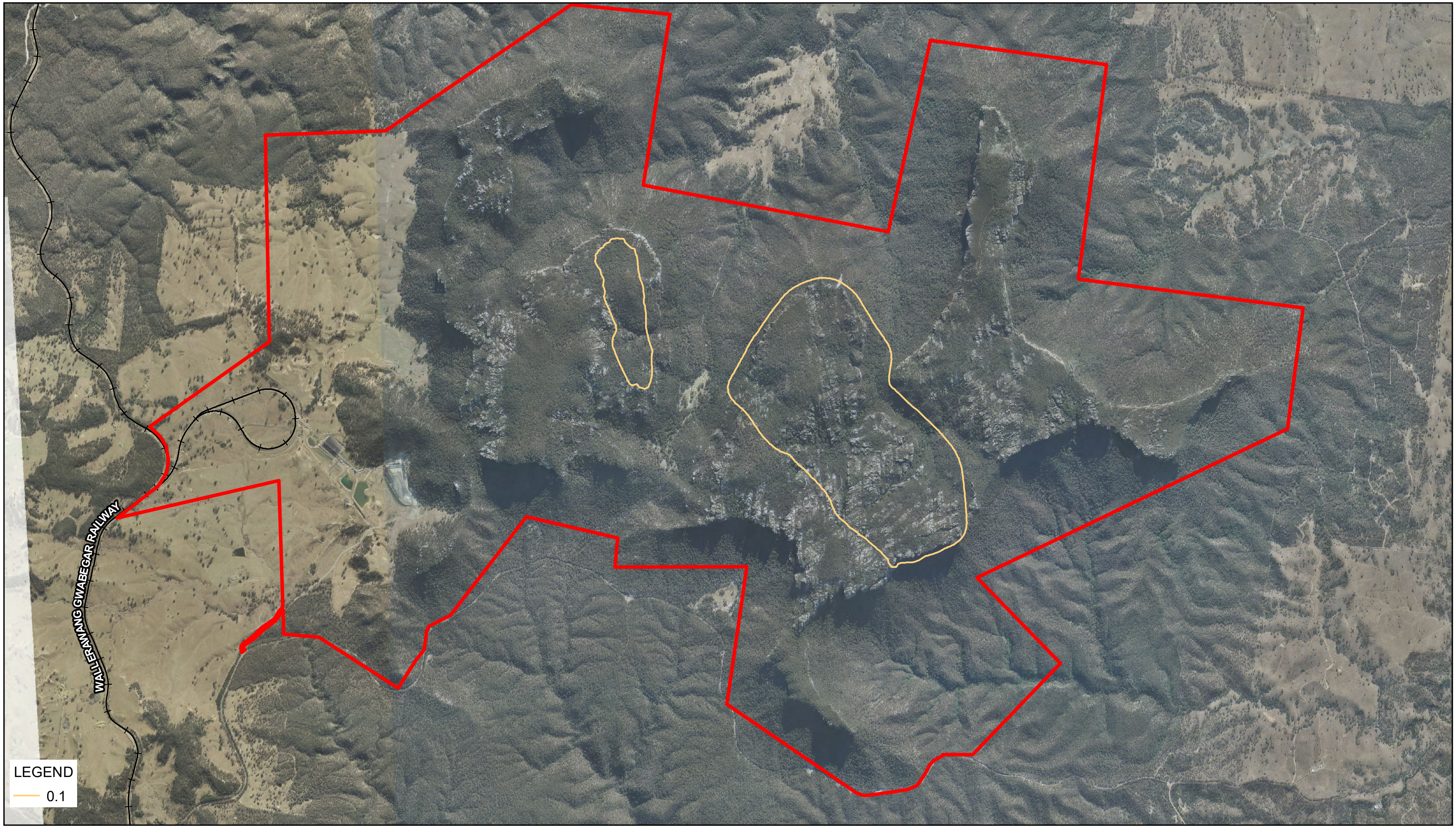
Data source: LPI: DTDB 2012; Centennial: Aerial Imagery, boundaries, 2013, Monitoring Locations, 2017. Created by: fmackay



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Map Projection: Transverse Mercator
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Grid: GDA 1994 MGA Zone 56

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LEGEND

Project Approval Area SSD_5581

GHD

Centennial Airly

Airly Mine
Airly Mine Mod 3
Hydrogeological Model Report

Job Number 22-19275
Revision A
Date 30 Jul 2019

Drawdown in Marrangaroo Formation 30 years after mining 1-8 Mtpa, Scenario 1

Figure G-27

G:\22\0105001\GIS\Maps\Deliverables\Western\Airly\2219275\HMR\Mod3_AppendixG\2219275_D027_1-8_Scenario1_30Y_Layer9.mxd

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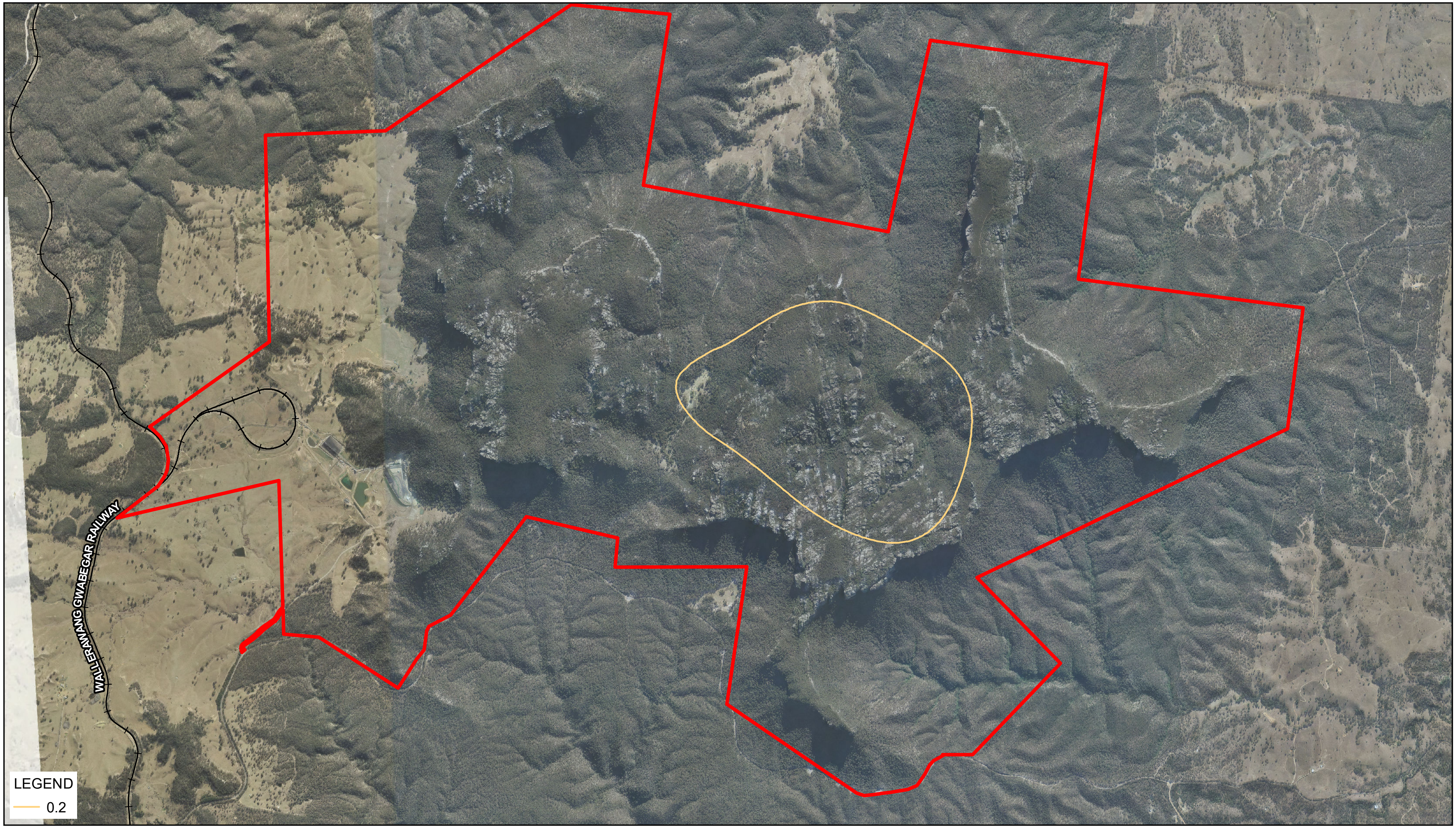
Data source: LPI: DTDB 2012; Centennial: Aerial Imagery, boundaries, 2013, Monitoring Locations, 2017. Created by: fmackay



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Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

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LEGEND

Project Approval Area SSD_5581

GHD

Centennial Airly

Airly Mine
Airly Mine Mod 3
Hydrogeological Model Report

Drawdown in Upper Shoalhaven Group
30 years after mining
1-8 Mtpa, Scenario 1

Job Number 22-19275
Revision A
Date 30 Jul 2019

Figure G-28

G:\22\0105001\GIS\Maps\Deliverables\Western\Airly\2219275\HMR\Mod3_AppendixG\2219275_D028_1-8_Scenario1_30Y_Layer10.mxd

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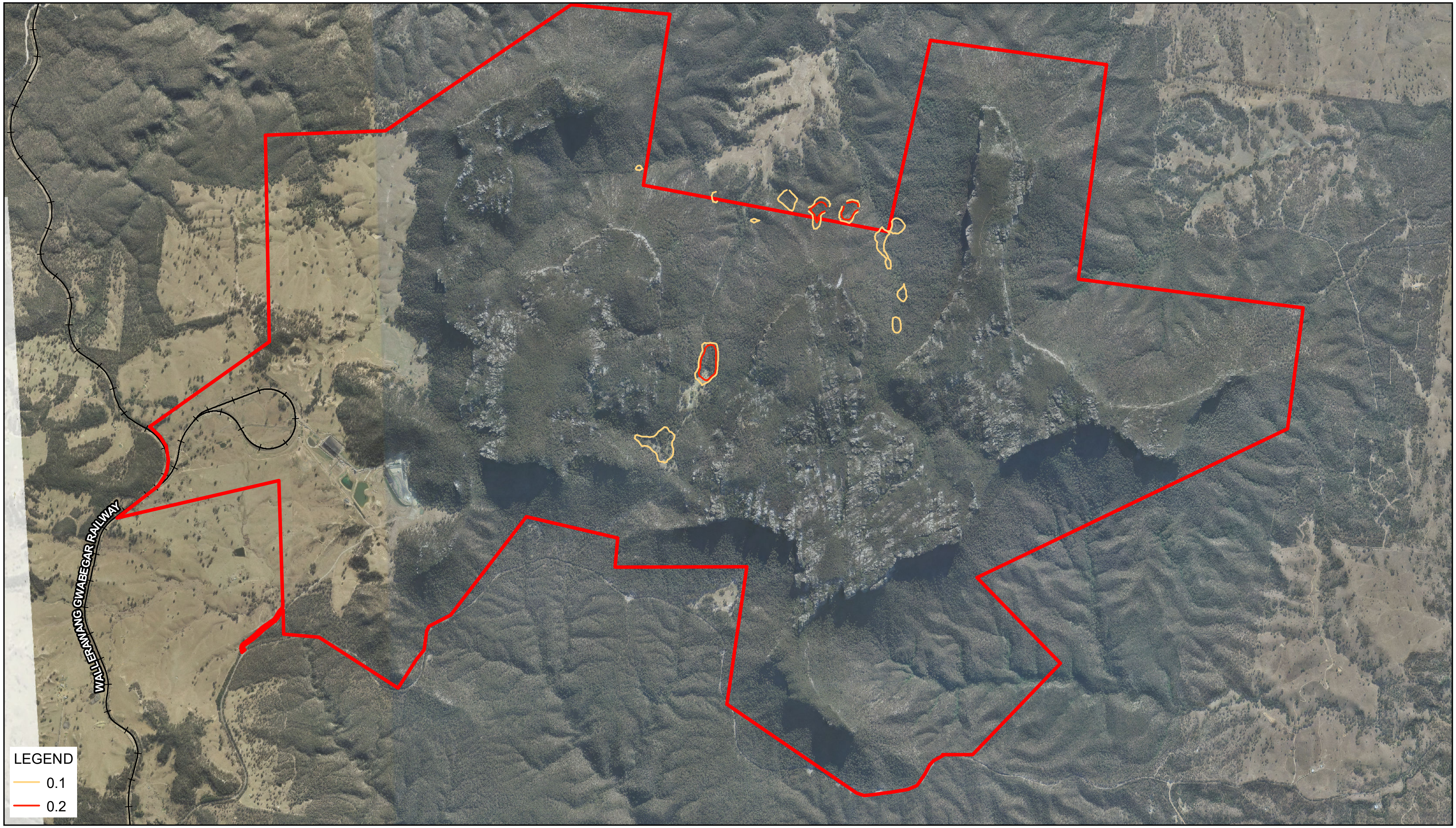
Data source: LPI: DTDB 2012; Centennial: Aerial Imagery, boundaries, 2013, Monitoring Locations, 2017. Created by: fmackay



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Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

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LEGEND

Project Approval Area SSD_5581

GHD

Centennial Airly

Airly Mine
Airly Mine Mod 3
Hydrogeological Model Report

Drawdown in Shallow Strata
30 years after mining
1-8 Mtpa, Scenario 2

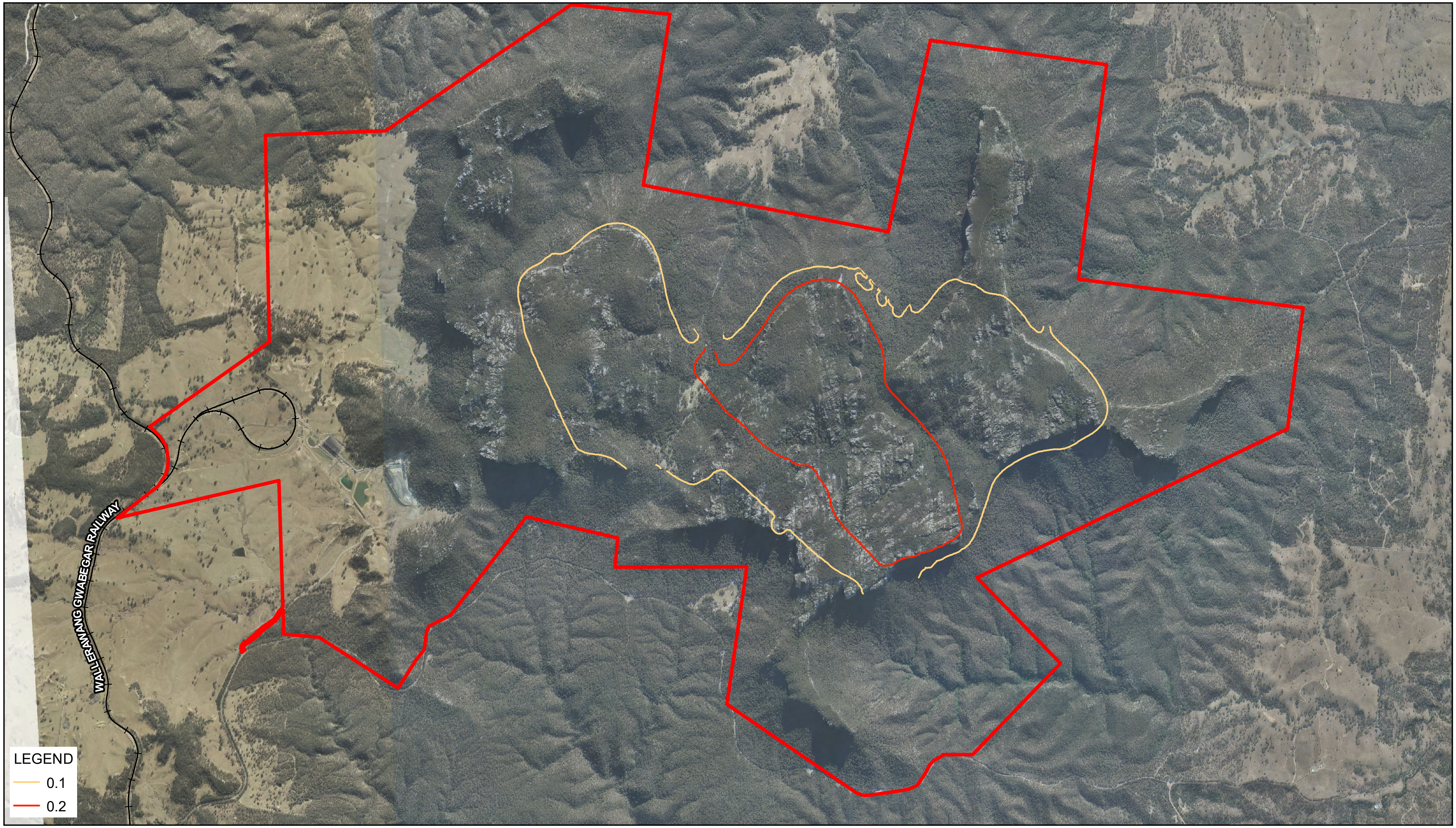
Job Number	22-19275
Revision	A
Date	30 Jul 2019

Figure G-29

G:\22\0105001\GIS\Maps\Deliverables\Western\Airly\2219275\HMR\Mod3_AppendixG\2219275_D029_1-8_Scenario2_30Y_Layer1.mxd

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

Data source: LPI: DTDB 2012; Centennial: Aerial Imagery, boundaries, 2013, Monitoring Locations, 2017. Created by: fmackay



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Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

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LEGEND

Project Approval Area SSD_5581

GHD

Centennial Airly

Airly Mine
Airly Mine Mod 3
Hydrogeological Model Report

Drawdown in Lithgow seam 30 years after mining 1-8 Mtpa, Scenario 2

Job Number 22-19275
Revision A
Date 30 Jul 2019

Figure G-30

G:\22\0105001\GIS\Maps\Deliverables\Western\Airly\2219275\HMR\Mod3_AppendixG\2219275_D030_1-8_Scenario2_30Y_Layer8.mxd

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 T 61 2 4979 9999 F 61 2 4979 9988 E ntlmail@ghd.com W www.ghd.com.au

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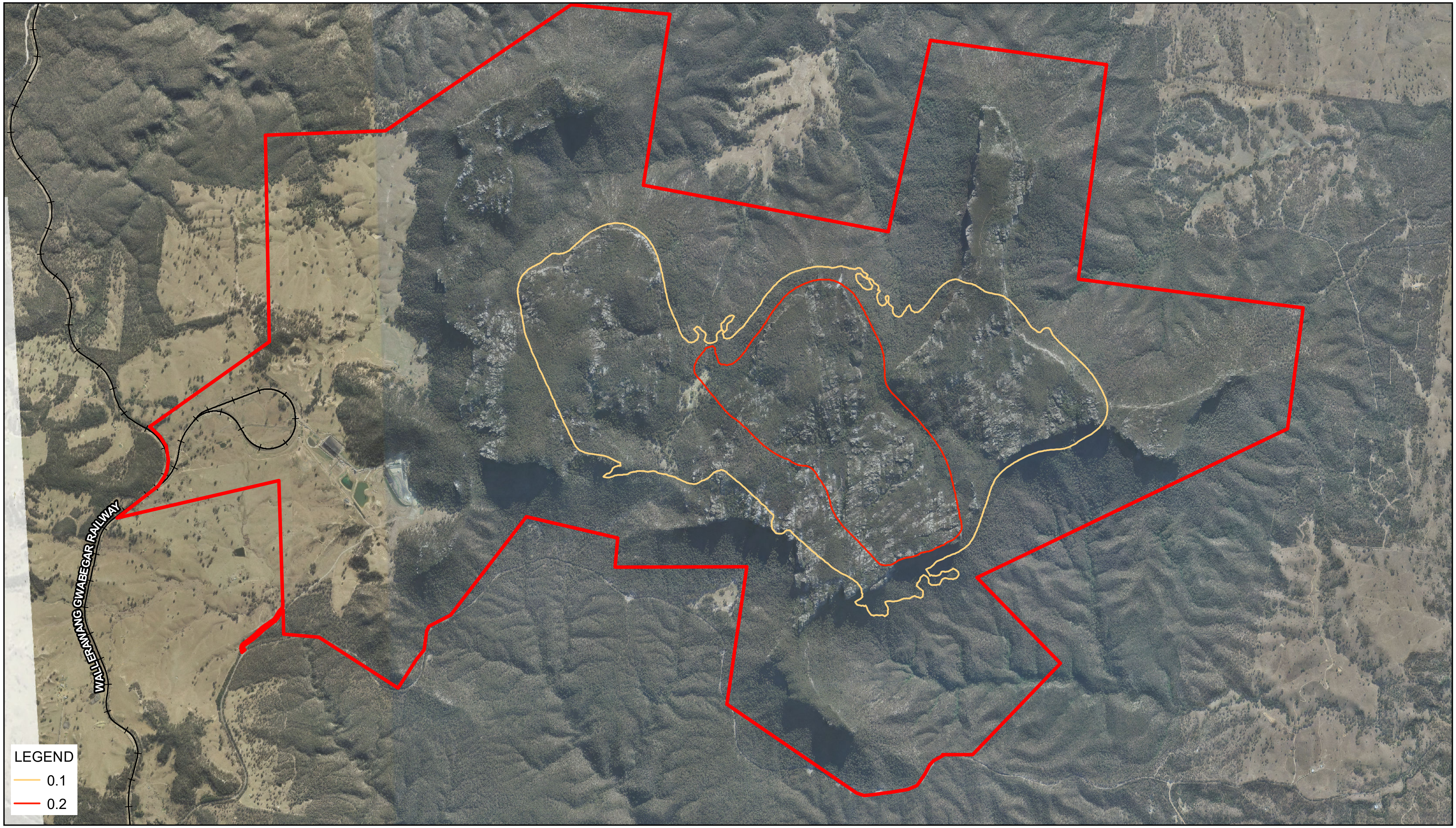

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Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

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LEGEND

Project Approval Area SSD_5581

GHD

Centennial Airly

Airly Mine
Airly Mine Mod 3
Hydrogeological Model Report

Drawdown in Marrangaroo Formation 30 years after mining 1-8 Mtpa, Scenario 2

Job Number	22-19275
Revision	A
Date	30 Jul 2019

Figure G-31

G:\22\0105001\GIS\Maps\Deliverables\Western\Airly\2219275\HMR\Mod3_AppendixG\2219275_D031_1-8_Scenario2_30Y_Layer9.mxd

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 T 61 2 4979 9999 F 61 2 4979 9988 E ntlmail@ghd.com W www.ghd.com.au

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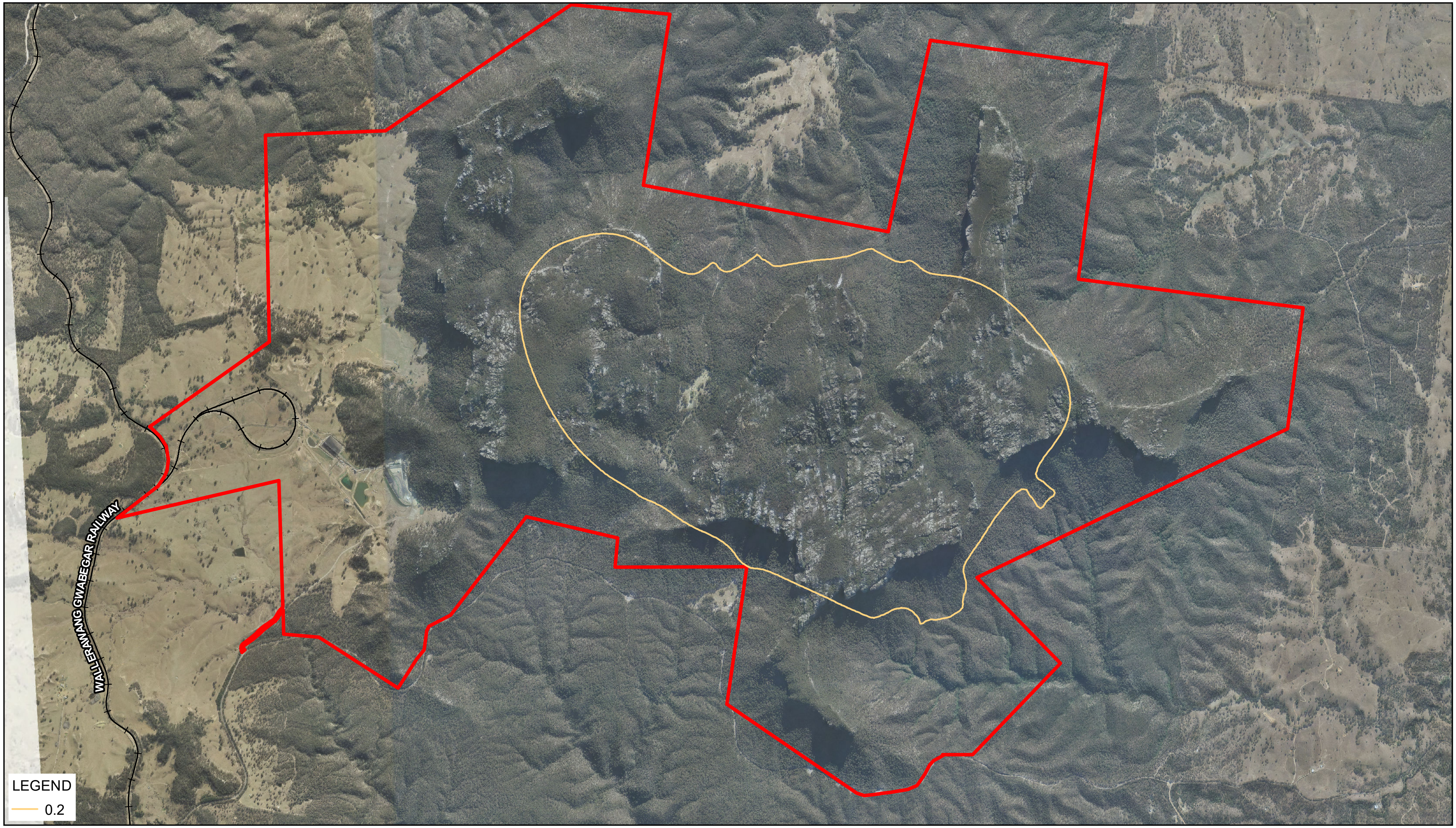

Paper Size A4

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Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

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LEGEND

Project Approval Area SSD_5581

Centennial Airly

Airly Mine
Airly Mine Mod 3
Hydrogeological Model Report

Job Number 22-19275
Revision A
Date 30 Jul 2019

Drawdown in Upper Shoalhaven Group
30 years after mining
1-8 Mtpa, Scenario 2

Figure G-32

G:\22\0105001\GIS\Maps\Deliverables\Western\Airly\2219275\HMR\Mod3_AppendixG\2219275_D032_1-8_Scenario2_30Y_Layer10.mxd

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2219275-62173/https://projects.ghd.com/oc/newcastle1/airlyminemod1groundw/Delivery/Documents/2219275-REP-HMR.docx

Document Status

Revision	Author	Reviewer		Approved for Issue		
		Name	Signature	Name	Signature	Date
0	I Gilmore	S Gray		S Gray		01/10/2019

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Community Consultation Outcomes

APPENDIX – D

Table D1 Matters Raised during Community Consultation

Stakeholder / Issue	Description of Issue	Comments and Modification Report Reference Section
Colo Committee – 17 January 2018		
Historical input by the Colo Committee into Airly Mine matters since 1980 and on the Airly MEP EIS (Appendix 1.2 of SIA)	Colo Committee's efforts and concerns: • promotion of protection of the Mugii Murum-ban SCA • attendance at 1994 Airly Commission of Inquiry for DA 162/91 • mining only under the mesas • foreign owners of Airly Mine proposed two-thirds of coal to be extracted • vast majority of community submissions to PAC argued for greater protection of the biodiversity and geodiversity of the mesas • PAC ignore scientifically based concerns Centennial, NSW Government and DPIE not interested in effective community dialogue or the protection of State's unique heritage.	Extensive consultation has been undertaken with the community since 1998 when Airly Mine commenced trial mining. Consultation with the community was undertaken during the development of Airly MEP and it documented in the EIS. Consultation has been ongoing since the EIS was submitted in 2014 and the Project was approved in December 2016. Consultation for Airly Modification 2 was included in the *Statement of Environmental Effects* (Centennial Coal, 2019a). Extensive consultation has been undertaken for Modification 3, which commenced in January 2018. This table notes the issues raised, provides responses and references to sections of the Modification Report where the issues have been addressed.
Modification 3 concerns	Increased tonnage from 1.8 to 3 Mtpa represents doubling of coal being mined and is ill-advised from a climate change consideration.	A greenhouse gas emissions assessment was undertaken for the modification (**Appendix K**) and summarised in **Section 8.10** of the Modification Report. There will be increases in Scope 1, Scope 2 and Scope 3 emissions. The Scope 1, Scope 2 and Scope emissions will increase as a result of the modification, with the Scope 1 and Scope 2 emissions total contributing to 0.01% of the Australia's greenhouse gas emissions. The modification will contribute to the global climate change proportionally.
	Submission of a new EIS for the increased tonnage.	A new EIS and new SSD application are not required. The proposed modification meets the requirements of a Section 4.55(2) modification, and this was confirmed with DPIE (**Section 1.5** of the Modification Report).
	CCC asked to rubber-stamp the increased production	The CCC is an advisory committee and members are informed of all Airly Mine approvals. Any issues raised by members are addressed in the approvals documents as relevant.
	Virtual doubling of coal is almost certain to lead to cutting corners in terms of environmental protection, leading to greater than predicted	The modification is not proposing to change the conservative mine design philosophy that was presented and approved in the Airly MEP EIS. Secondary approvals via the Extraction Plan process (**Section 4.3.6.2** of the Modification Report). The Extraction Plans are

Stakeholder / Issue	Description of Issue	Comments and Modification Report Reference Section
	subsidence and cliff falls. Will lead to the collapse of the unique Genowlan Point and its biodiversity and geodiversity.	underpinned by an integrated monitoring program designed to confirm the subsidence predictions included in the EIS. The mine is required to meet the subsidence impact performance criteria for natural and heritage features and built features in Condition 2 and Condition 3 under Schedule 3 of SSD 5581.
Capertee Land Care – January 2018		
General comments	Proposal is jobs and wealth for Australia, to be embraced.	Noted
	Lengthy approval process for initial approval and request for expansion months later.	The Airly MEP approval was a protracted process commencing in 2012 and approval was granted in December 2016. In that time Airly Mine's business plan had changed. The increase in production is required for Airly to be an economically viable mine and the 3 Mtpa production rate s in the current five-year business plan.
	Proposal makes the operation more viable for Banpu, by pushing for maximum extraction and maximum profit in the short term.	
	Mine should be closed down. Proposal for increase production is nonsense / outrageous.	Noted.
	Increase in mining quota is outrageous	There is no quota for mining quantities. Mining approvals are granted based on environmental/social/economic benefits/impacts of the proposed production rates, and if the projects are in public interest.
	Third generation farmer and family concerned about any sort of expansion.	The increase in tonnage is unlikely to adversely impact on farmers. Environmental assessments have been undertaken to confirm the potential impacts of the increased tonnage and presented in **Sections 8.2 to 8.9** in the Modification Report. Impacts on downstream water users not measurable (refer **Section 8.3**). No impact on groundwater bores will occur (**Section 8.2**).
	Community member feels Centennial considers them insignificant and considers the approval process a 'palm-greasing exercise' for Centennial to obtain approval.	The consent for the Airly Mine Extension Project was determined by the NSW Planning Assessment Commission (PAC) after a rigorous assessment process which included two public meetings. The community were consulted during the exhibition process for the EIS (through invitation for written submissions) and then again at the public meetings held by NSW PAC (now NSW Independent Planning Commission (IPC)). The community can have their say on the modification through Centennial's consultation sessions, during the exhibition period of the modification and then through the IPC (if the modification is referred to the IPC for determination.

Stakeholder / Issue	Description of Issue	Comments and Modification Report Reference Section
		The Airly Modification 2 was placed on exhibition for two weeks (01 May to 14 May 2019) for submissions, including from the community. The exhibition period was advertised in Lithgow Mercury on 01 May by the Department of Planning, Industry and Environment. Airly Modification 3 will again be exhibited for a minimum of 14 days and will be advertised by the Department in Lithgow Mercury.
Subsidence	Target coal seam at Airly Mine Cliff and pagoda protection in place	Airy Mine's target coal seam is Lithgow seam as that is the economically viable to mine in the area. The mine design utilised is conservative and the mine design philosophy affords protection to the overlying geodiversity including pagodas and cliff lines. The mine design philosophy and adaptive management practices implemented to date to protect the geodiversity is discussed in **Section 4.3.6** of the Modification Report. Subsidence monitoring undertaken to ensure that mining is within the approved limits and performance measures are met is provided in **Section 4.14.3.1** of the Modification Report**.**
	Comparison of Airly Mine's mining techniques with Baal Bone Colliery's mining and impact to a pagoda east of that colliery. Airly's approved mining methods and whether mining under pagodas is approved.	A description of the approved mining zones is provided in **Section 4.3.6** of the Modification Report. A conservative mine design is approved and implemented. Secondary approvals prior to any mining in any of the mining zones via Extraction Plans are required which are prepared in consultation with a wide range of government stakeholders, including an independent expert panel. The mine must meet strict performance consent criteria for natural and heritage features and built features.
Air quality	Dust must increase with increased production	Incremental increases in dust due to the increased production rate have been assessed and discussed in **Section 8.9** of the Modification Report. The short-term and long-term pollutant concentrations are well below the relevant NSW EPA criteria.
	Lack of dust monitors down into the valley	The air quality monitoring at Airly Mine (**Section 4.14.3.5**) is undertaken in accordance with an approved *Airly Mine Air Quality Management Plan*. Dust monitoring in Capertee Valley is not required to be undertaken as air quality impacts from Airly Mine's operations will not extend to the valley under normal weather conditions.
	Public access to monitoring results	Environmental monitoring is reported as required by consent conditions and are available on Centennial Airly website, as discussed in **Section 4.14.2** of the Modification Report. Data requests can be made through the Airly CCC members.
	Covering the product stockpile	Airly Mine is not required to cover the ROM coal stockpile under the consent conditions. The air quality assessment undertaken (Section 8.9) modelled dust and total suspended particulates, PM_{10} and PM2.5 concentrations due to emissions from the stockpile without the

Stakeholder / Issue	Description of Issue	Comments and Modification Report Reference Section
		stockpile being covered. The predictions showed all assessed concentrations would be below the relevant criteria at all identified sensitive receptors. The coal stockpile is kept moist and dust emissions are minimised. Additionally, the air quality is regulated by (i) consent conditions and any exceedances is reported in the *Annual Review* (ii) EPL 12374 conditions and exceedances are reported in the *Annual Return*.
Noise and vibration	Moved to the valley for peace and quiet and purchased property knowing mine was going ahead but not at a larger scale.	The operation of Airly Mine has not resulted in a degradation of the visual amenity of the area. Airly Mine operates within the air quality and noise criteria and no complaints have been received from the community on noise or air quality issues.
	Noise must increase with increased production	A noise impact assessment has been prepared for the Modification Report (**Section 8.7, Appendix J**), and the noise predictions confirm that the Project as modified will continue to meet the consent noise criteria.
	Residence located on Mt Genowlan affected by rumbling noise.	No activities that could result in “rumbling noise” or ground vibration is currently undertaken at Airly Mine.
	Background noise from the mine affects bird calls, including at times when the conditions are “right”.	Airly Mine operates within its consent noise criteria.
Trains movements	Impacts of train movements on residents, farms, landholders and commercial operations along the rail line Covered wagons	The impacts of train movements have been assessed in technical assessments (**Section 8.6**) and in the noise impact assessment (Section 8.7.7). Increasing train movements will not increase rail noise significantly and the operation of the trains at the increased frequency proposed in the modification will continue to meet the *Rail Infrastructure Noise Guideline* (EPA, 2013) nose limits and EPL 13241 noise limits for the Wallerawang-Gwabegar rail line held by John Holland Rail Pty Limited. Coal wagons are not required to be covered as the coal is wet and emissions from the most coal are not likely to be an issue.
Visual	Bright lights left on all night. Visual impact on tourists arriving at night time.	The infrastructure at Airly Mine pit top have directional lights (**Section 4.3.7** of the Modification Report) designed to reduce visual impacts at the night time. The pit top cannot be seen from vantage points generally. The visual impact of the infrastructure was assessed in a Visual Impact Assessment for the Airly MEP EIS, and the visual impact was not assessed as significant. The mine has a complaints line that can be used to lodge a complaint if there are issues with bright lights.
Heritage and biodiversity	Impacts assessed and ascertained	Mining induced impacts on the biodiversity and heritage (natural and cultural) were assessed in the Airly MEP EIS. Airly Mine is required to meet the performance criteria for natural and

Stakeholder / Issue	Description of Issue	Comments and Modification Report Reference Section
		heritage features and built features. To date Airly Mine's subsidence monitoring and monitoring of biodiversity and cultural heritage items with the potential to be impacted by mining have not shown any impacts. The monitoring results are reported in a number of ways, as discussed in **Section 4.14.2** of the Modification Report, and the results are also in the CCC meetings.
Coal preparation plant	Water required in the washery will have devastating effect on the water table. Coal beneficiation at Airly Mine.	Currently no washing of coal occurs at Airly Mine as the approved coal preparation plant (CPP) and the reject emplacement area (REA) are not constructed. The site water balance (Section 8.4) showed that should the washing of coal be undertaken then the site will not have sufficient water in a dry year to operate all activities at 3 Mtpa production rate. The construction of the CPP and REA is not in the current five-year mine plan. Should Airly Mine elect to construct the CPP and the REA in the future then a review of the process water demand will be undertaken (**Section 8.4.6** of the Modification Report).
	Requires confirmation in writing that the washery will not be built. Coal washery to be removed from the consent	The construction of the CPP and REA is not in the current five-year mine plan. Should Airly Mine elect to construct the CPP and the REA in the future then a review of the process water demand will be undertaken (**Section 8.4.6** of the Modification Report).
	Coal washing and tailings dams to be managed using EPA rules.	Noted
	Coal washed to produce low ash coal to meet Japanese import and emissions standards, and to reduce dust during transport by rail and road and comply with EPA's standards.	No coal is washed at the site currently.
	Provided link to the previous EPA's recycling and reuse resource recovery framework, as EPA's standard for onsite coal washery and tailings dam.	Noted
Water	Proposal's impact on water system flowing through the valley.	All potential impacts of the proposed modification have been assessed in this Modification Report. The surface water assessment (**Section 8.3** of the Modification Report, **Appendix F**) concludes that the any changes to stream flow due to mining impacts will not be measurable on one registered surface water user on Genowlan Creek.
	Significant decrease in water system under current condition and problem exacerbated with the modification. Lack of flow to Coco Creek Lack of flows in Genowlan Creek	There has been a dry spell in the Lithgow region and watercourses may not have the flows that are observed in wet years. This is supported by water flow measurements on Genowlan and Gap Creek and correlating with the rainfall data (refer Figure 20), which show that stream flows only occur when there is rainfall. It is noted that Airly Mine has not undermined Genowlan Creek or Coco Creek.

Stakeholder / Issue	Description of Issue	Comments and Modification Report Reference Section
	Genowlan Creek does not even run after heavy rain	
	Electrical conductivity of Airly Creek showing an upward trend, from 2000 µS/com to 4000 µS/cm. Testing of heavy metals in Airly Creek.	Airly Mine undertakes water quality monitoring in accordance with the *Water Management Plan* (refer **Section 4.14.3.2**) at monitoring locations shown in **Figure 13**). Airly Creek is one of the monitoring locations. The Airly Creek has naturally a high electrical conductivity due to the environment. The elevated background EC of the upper Airly Creek catchment is a result of the outcropping Shoalhaven marine sediments. Therefore, the elevated EC readings in Airly Creek are a result of natural outcropped background geology and not from Airly Mine operations. An ANZECC water quality assessment was undertaken in The Airly Modification 2 *Statement of Environmental Effects* (Centennial Coal, 2019a). It is also noted that there are no discharges from the pit top to Airly Creek through implementation of management controls (refer **Section 4.8.1.2**).
	Capertee Valley is totally reliant on groundwater. Compulsory and mandatory testing and measuring of the underground water levels and quality throughout the valley for reliable benchmark for future impacts. Installation and monitoring of 20 bores to be paid by Centennial and monitoring undertaken by a third party. Bore locations to be agreed with the community. Surface water dried up during dry weather and hence increased reliance on bore water	There is no hydraulic connection between the Devonian aquifer which provides bore water to the residents in the valley and the local aquifers above Airly Mine's mining zones which are likely impacted due to mining. This is discussed in **Section 8.2.2.3** of the Modification Report. Airly Mine's current monitoring program already monitors water levels at a private property 'Nioka' (refer **Section 4.8.1.3**). An independent hydrogeologist Joshua Lloyd (ZOIC) was engaged by the Capertee Land Care (paid by Centennial Airly) to review the monitoring. At a presentation to the CCC members on 15 October 2019, Mr Lloyd advised the meeting that water levels groundwater bores in the underlying aquifers are unlikely to be impacted by mining and any water levels changes observed are more likely to be a result of the drought and a lack of rainfall. For this reason, the hydrogeologist's advice was that water level monitoring is unlikely to demonstrate any mining related impacts. He suggested water quality monitoring in 2 bores in two different downstream catchments. This has been accepted by Airly Mine and will become part of Airly Mine's water quality monitoring in the future contingent on access agreements on the identified properties and availability of suitable existing pumping systems (refer **Section 8.14.4**). It is noted that Airly Mine does not extract water from surface watercourses, however does extract water from a production bore, for which it has water access licence for 158 ML/year.
Technical Session 1 – 23 October 2018		
Groundwater	Connectivity and fracturing between upper and lower aquifers	There is no hydraulic connection between the Devonian aquifer which provides bore water to the residents in the valley and the local aquifers above Airly Mine's mining zones which

Stakeholder / Issue	Description of Issue	Comments and Modification Report Reference Section
		are likely impacted due to mining. This is discussed in **Section 8.2.2.3** of the Modification Report.
	Flow monitoring of Airly Creek downstream of operations	Airly Creek is well outside the zone of influence of the Airly mine workings, as such, flow monitoring on Airly Creek is not required. Only water quality monitoring is undertaken in Airly Creek. The water quality and flow monitoring undertaken is described in **Section 4.14.3.2** of the Modification Report. Airly monitors flow in Village Spring, Gap and Genowlan Creeks as well as discharge volume from all Licenced Discharge Points on site. Airly monitors water quality in Airly Creek in comparison to a background representative site that's not influenced by Airly operations. Flow monitors have not been installed to date on Airly Creek because they are unnecessary and the actual installation of a 15-20m concrete weir will cause adverse environmental impacts on the Airly Creek Riparian Zone.
	EC levels in Airly Creek	As discussed above, the elevated background EC of the upper Airly Creek catchment as a result of the outcropping Shoalhaven marine sediments results in the elevated EC readings in Airly Creek not from Airly Mine operations. An ANZECC water quality assessment was undertaken in The Airly Modification 2 *Statement of Environmental Effects* (Centennial Coal, 2019a). It is also noted that there are no discharges from the pit top to Airly Creek through implementation of management controls (refer **Section 4.8.1.2** of the Modification Report).
Technical Session 2 – 28 July 2019		
Water Resources	Springs in Dog Trap Creek	The hydrology of the area is described in **Section 3.8**. there are no springs identified in Dog Trap Creek.
	Descriptions of clean and dirty water separation at the pit top, and whether clean water will continue to flow to Airly Creek	The clean and dirty water separation is described in Section 4.8.1. Clean water continues to flow around the water management infrastructure at the pit top to flow to Airly Creek.
	Frequency and timing of water to be pumped out from underground, and volume of water pumped out from underground to date.	There has not been much mine inflows (measurable) reported as discussed in **Section 4.9**. Mine inflows are entrained in ROM coal and leave the site as coal moisture.
Subsidence	Further extraction from the pillars in the panel and pillar zone after 61 m panels have been extracted.	No further extraction from pillars occurs in the panel and pillar zone after 61 m panels have been extracted.

Stakeholder / Issue	Description of Issue	Comments and Modification Report Reference Section
	Accuracy of Lidar measurements	Discussions on subsidence monitoring undertaken using a wide range of techniques, using LiDAR techniques, is described in **Section 4.14.3.1**.
	Independent audit for mine plan and subsidence	The Extraction Plans are prepared in consultation with Airly Mine's Independent Expert Panel and approved by the DPIE prior to any mining. The Independent Expert Panel also review the subsidence monitoring data as part of the process, described in **Section 4.3.6.2**.
Noise	A lack of C-weighted noise levels in rail impact assessment and for intrusiveness noise for pit top operations.	The rail noise impact assessment guidelines do not require an assessment of C-weighted noise levels. A discussion on the C-weighted noise assessment for the pit top activities is included in the noise impact assessment (**Appendix J**) and discussed in **Section 8.7.4**. No C-weighted noise or low frequency noise assessment is triggered for Airly Mine.
Workforce and employment opportunities for the local community	Airly Mine's policy on employing personnel from the local community Availability of training programs for apprentices Recommend adverts for employment for the local community to be placed in local papers, company website and emails to CV Landcare. List of local contractors to be made available to allow community members to approach them directly for employment.	Annual apprentice recruitments for the company are managed by HVTC on behalf of Centennial Coal, and advertising is undertaken via the following vehicles: • SEEK – advertisements are run for 4 to 6 weeks • HVTC website • Flyers – provided to schools (including local schools) and mine sites for dissemination to potential candidates • Social media. It is noted that advertising through social media has been selected over advertising in local newspapers as this vehicle is more effective in attracting candidates from the targeted younger generation.
GHD Role	Role of GHD in Airly Mine operations and whether independent consultant.	GHD is an external consultancy who have been preparing groundwater and surface water impact assessments for Airly Mine approvals since 2012. The consultancy also prepares management plans for Airly Mine and undertakes water quality and level monitoring and aquatic ecology monitoring.
Technical Session 3 – 11 August 2019		
Mine design	General mining questions including clarification on angle of draw	Questions answered at the meeting. Additional discussion is included in **Section 4.3.6**.

Stakeholder / Issue	Description of Issue	Comments and Modification Report Reference Section
	Visual amenity Safety risks from cliff falls	The modification is not proposing to change the conservative mine design philosophy that was presented and approved in the Airly MEP EIS. Secondary approvals via the Extraction Plan process (**Section 4.3.6.2**). The Extraction Plans are underpinned by an integrated monitoring program designed to confirm the subsidence predictions included in the EIS. The mine is required to meet the subsidence impact performance criteria for natural and heritage features and built features in Condition 2 and Condition 3 under Schedule 3 of SSD 5581. The potential for cliff falls was assessed in the EIS. Given the mine design philosophy will not change in the modification then the risks remain the same as assessed and approved in the EIS.
Water	Water management and monitoring network.	Existing water management at the pit top is described in **Section 4.8**. The surface and groundwater monitoring are undertaken in accordance with the approved *Water Management Plan*. **Section 4.14.2** describes the surface water monitoring at Airy Mine and **Section 4.14.3** describes the groundwater monitoring.
CCC Meeting – 15 October 2019		
Groundwater monitoring	Adequacy of the program in terms of: • Parameters being monitored • Frequency • Methodology • Transparency and reporting	The groundwater monitoring is undertaken in accordance with the approved *Water Management Plan*, which provides for water quality as well as water level monitoring, frequency of monitoring and reporting protocols. **Section 4.14.3** describes the groundwater monitoring at Airly Mine. Airly Mine reports monitoring results at a number of forums. **Section 4.14.2** describes the environmental reporting requirements for the mine.
Monitoring reports	Members require easy to read groundwater monitoring reports	Airly Mine agreed to pay the community's hydrogeologist (ZOIC) to prepare an easy to report groundwater monitoring report based on the annual groundwater monitoring report produced for the site by GHD (refer **Section 8.12.4**).
Explosives	Use and frequency	Explosives for removal of geological structures will only be used when required and this is likely to be infrequently. Proper procedures will be used for the transport, handling and use of explosives in accordance with the *Explosives Control Plan*. Blasting and notification of the blasting activity will be undertaken in accordance with a *Blast Management Plan*.
Subsidence	Impacts and environmental consequences.	The modification is not proposing to change the conservative mine design philosophy that was presented and approved in the Airly MEP EIS. Secondary approvals via the Extraction Plan process (**Section 4.3.6.2**). The Extraction Plans are underpinned by an integrated monitoring program designed to confirm the subsidence predictions included in the EIS. The

Stakeholder / Issue	Description of Issue	Comments and Modification Report Reference Section
		mine is required to meet the subsidence impact performance criteria for natural and heritage features and built features in Condition 2 and Condition 3 under Schedule 3 of SSD 5581.

APPENDIX – E

Groundwater Impact Assessment

Centennial Airly Pty Ltd

Airly Mine Mod 3
Groundwater Impact Assessment

October 2019

Executive summary

Airly Mine is an existing underground coal mine operated by Centennial Airly Pty Limited (Centennial Airly). It is located near Capertee village, approximately 40 km north-west of Lithgow on the Castlereagh Highway in the Western Coalfield of NSW.

Airly Mine commenced trial mining in 1998 under Development Consent DA162/91 granted on 14 April 1993 by the then Minister for Planning for the development of an underground coal mine following a Commission of Inquiry held in 1993. Full scale production commenced in December 2009. The Airly Mine Extension Project (SSD_5581) was approved in December 2016 and allows Airly Mine to extract up to 1.8 million tonnes per annum (Mtpa) of run of mine (ROM) coal for a period of 20 years within the boundaries of ML1331 and Authorisation 232 (A232).

Centennial Airly proposes to modify SSD_5581 (Modification 3) to increase the mining rate from 1.8 to a maximum rate of 3.0 Mtpa of ROM coal and amend the approved 20 year mine schedule for the increased production rate. No change to the development consent boundary is proposed.

This Groundwater Impact Assessment has been prepared to inform the Statement of Environmental Effects (SEE) for Modification 3. It defines the existing hydrogeological environment and sensitive groundwater receptors and assesses impacts on these groundwater receptors, using predictions from the recalibrated hydrogeological model, from the proposed mine plan and schedule based on a maximum mining rate of 3.0 Mtpa (proposed conditions). Predicted impacts under proposed conditions have been compared to predicted impacts under approved conditions from development consent SSD_5581, which involve a mine plan and schedule based on a maximum mining rate of 1.8 Mtpa. Predicted impacts under approved conditions were presented and assessed in the Airly Mine Extension Project Groundwater Impact Assessment (GHD, 2014a). Approved conditions have also been reassessed using the recalibrated hydrogeological model and groundwater impacts have been presented and assessed in this Groundwater Impact Assessment report.

The target seam at Airly Mine is the Lithgow Seam. Until recently mining to date at Airly Mine has been bord and pillar and partial extraction mining methods. This includes workings adjacent to the surface facilities area developed between 2010 and 2012, workings to the east and north of this area developed between 2014 and 2019, as well as the old Torbane Colliery workings. Groundwater inflows into these underground workings have been reported to be low (not measureable) to date. Groundwater impacts associated with these workings and detected to date from the groundwater monitoring network, have been generally isolated to the Lithgow Seam and the underlying Marrangaroo Formation. These impacts are consistent with predictions approved under SSD_5581. Since 24 June 2019, extraction within the panel and pillar zone has been undertaken, and comprises extraction of panels of 61 m void width. To date, no additional mine inflows within this area have been measured.

The local groundwater sources within the development consent boundary are generally low yielding and predominantly within the Quaternary alluvium associated with Gap Creek and Genowlan Creek, weathered and/or fractured sandstone and coal seams that occur within Mount Airly and Genowlan Mountain. They are classified as ‘less productive’ in accordance with the criteria specified in the NSW Aquifer Interference Policy (i.e. the yield is typically less than 5 L/s and/or the total dissolved solids concentration is typically greater than 1,500 mg/L). The local groundwater sources are managed under the Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources and specifically are part of the Sydney Basin North groundwater source. These local groundwater sources are confined to the development consent boundary since their outcrop boundaries occur entirely within this area.

The regional groundwater sources occur within the Shoalhaven Group below the target coal seam, as well as within the underlying Devonian rocks, and extend beyond the Development consent boundary. These groundwater sources are also managed under the Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources and are part of the Sydney Basin North groundwater source. The existing production bore at the Airly Mine surface facilities area is installed within the highly brackish to saline Shoalhaven Group groundwater source. There are a small number of registered users within this source to the west of the development consent boundary. The lower Devonian groundwater source is slightly brackish and supplies numerous registered users to the east of the development consent boundary. The closest registered bores are at least 1 km from the development consent boundary. There is minimal hydraulic connection between the overlying local and regional groundwater sources.

No high priority vegetative groundwater dependent ecosystems (GDEs) have been identified within the development consent boundary, although there is potential for facultative ecosystems existing as moist sheltered gully forests to occur along creek lines. Stygofauna have been collected in low densities and diversity from groundwater bores, with finds limited to two individuals of the obligate stygofauna group Cyclopoida collected at one location (ARP11) installed within shallow sandstone in Spring 2018 and three individuals of obligate stygofauna group Melitidae (an Amphipod) collected at ARP15SP installed in the shallow sandstone in Autumn 2019.

The groundwater sources most likely to provide habitat to stygofauna are the alluvium and Narrabeen Sandstone. Changes to groundwater sources and impacts on these sources as a result of the proposed modification have been predicted using a calibrated three dimensional hydrogeological model. The hydrogeological model was initially developed in 2014 as part of the Airly Mine Extension Project. The hydrogeological model has been updated and recalibrated to include additional monitoring data collected since 2014. The updated model has been used to predict:

- Groundwater inflows as a result of the development of the mine workings.
- Drawdown in groundwater sources.
- Changes in baseflow to watercourses.
- Approximate recovery times in groundwater levels and baseflow.

The recalibrated model has been used to make predictions under both approved (maximum mining rate of 1.8 Mtpa) and proposed (maximum mining rate of 3.0 Mtpa) conditions. Predicted impacts have been assessed against the minimal impact considerations in the NSW Aquifer Interference Policy and have been compared to impacts presented in GHD (2014a).

Maximum groundwater drawdown in Gap Creek alluvium is predicted to be 2 m for approved conditions and slightly less at 1.9 m for proposed conditions based on the recalibrated hydrogeological model. Maximum groundwater drawdown in Genowlan Creek alluvium is predicted to be 1.9 m under both approved and proposed conditions.

Predicted maximum drawdown in Gap Creek alluvium for proposed and approved conditions using the recalibrated model is less than the 3.5 m presented in GHD (2014a). Predicted maximum drawdown in Genowlan Creek alluvium for proposed and approved conditions using the recalibrated model is slightly greater than the 1.1 m presented in GHD (2014a). These variations are attributable to the recalibration of the hydrogeological model rather than due to the proposed change in the mining rate.

Stygofauna to date have been identified in the shallow sandstone, although groundwater monitoring has shown that the extensive natural fracturing of the sandstone results in the seepage of groundwater along the slopes of the mountains and therefore limited groundwater within this strata to support stygofauna. Negligible drawdown is predicted for the Narrabeen Sandstone. Therefore the groundwater source that supports identified stygofauna will not be impacted by mining.

Since there are no identified high priority GDEs (either vegetation or stygofauna) or groundwater supply works (operating under either basic landholder rights or Water Access Licences) in the areas of groundwater drawdown, the predicted impacts are less than the Level 1 minimal impact considerations under the NSW Aquifer Interference Policy and are therefore considered to be acceptable.

Baseflow to creeks from the local groundwater sources is generally low due to the low groundwater pressure, however the hydrogeological model indicates some baseflow occurs in lower reaches. Based on the recalibrated model, at the development consent boundary maximum predicted baseflow reduction to Gap Creek due to groundwater drawdown is 10.9 ML/year under approved conditions and 9.8 ML/year under proposed conditions while maximum baseflow reduction to Genowlan Creek is predicted to be 6.3 ML/year under approved conditions and 6.2 ML/year under proposed conditions. Baseflow reduction to Gap Creek and Genowlan Creek predicted using the recalibrated model is generally higher than presented in GHD (2014a) due to the recalibration of the model rather than due to the proposed change in the mining rate.

Based on the recalibrated model, groundwater inflow to mine workings is predicted to peak at 71 ML/year under proposed conditions, which is slightly less than the 76 ML/year peak under approved conditions. Groundwater flow into mine workings is primarily from local groundwater sources that do not supply private landholder bores located to the east of the Project Application Area. Predicted inflows from the recalibrated model are considerably less than the peak inflow reported in GHD (2014a) of 184 ML/year. These volumes are well below Centennial Airly's existing Water Access Licences for the Sydney Basin North Groundwater Source of 278 ML/year. Therefore the proposed Project will be able to operate in accordance with the rules of the Sydney Basin North groundwater source.

The recalibrated hydrogeological model predicts greater drawdown of Permian strata and the upper Shoalhaven Group (under both approved and proposed conditions) compared to drawdown reported in GHD (2014a). This is attributable to the refinement and recalibration of the model rather than the proposed increase in the mining rate. There is minimal difference in predicted drawdown between approved and proposed conditions for the recalibrated model, and it can be concluded the proposed modification will result in minimal impact on drawdown in the Permian strata and the Shoalhaven Group. The spatial extent of drawdown in porous and fractured rock groundwater sources does not extend far beyond the Project Application Area and there is no drawdown of private landholder bores predicted. In addition, no groundwater impacts are predicted to occur within World Heritage Areas, including the Gardens of Stone National Park, within the resolution of uncertainty associated with modelling predictions and the expected climatic fluctuations. Therefore, residual groundwater impacts under both proposed and approved conditions are considered to be less than the Level 1 criteria under the NSW Aquifer Interference Policy and therefore considered to be acceptable.

The effect of lineaments on groundwater flow and groundwater / surface water interactions was assessed and found to be low (not measureable). The hydrogeological model was used to assess the impact of the Gap Creek lineament zone and indicates that it will not have an influence on groundwater inflows into the mine workings or on groundwater drawdown (and therefore will not impact baseflow). Groundwater pressure within the local groundwater sources is low due to the extensive network of fractures and joints that direct groundwater to seepage areas along the slopes of Mount Airly and Genowlan Mountain. Further, it is noted that mining to date has not impacted surface water flow along Gap Creek which continues to flow after periods of heavy rainfall only and continues to exhibit a similar flow pattern to Genowlan Creek.

There is a production bore installed at the Airly Mine surface site, intended to supplement water supply for mining operations. Pumping testing of the production bore was undertaken in 2009 (Larry Cook & Associates, 2009) and concluded that the safe long-term yield for this bore is 9 L/s. However, the current average yield from the production bore is less than 0.8 L/s, with the flow rate continuing to decrease during 2018 and early 2019. Therefore, it has been assumed that the proposed rate of extraction from the production bore under proposed conditions is up to 25 ML/year (0.8 L/s). Based on the safe long-term yield and the proposed extraction rate, it can be concluded that the operation of the production bore is not expected to result in any additional drawdown in the Shoalhaven Group aquifer. Given that drawdown will not be greater than 2 m at any other water supply work, the impacts are less than the Level 1 minimal impact considerations.

Ongoing groundwater monitoring and management is defined in the Airly Mine Water Management Plan (WMP). The existing groundwater monitoring program is outlined in Section 4 and the WMP. The existing groundwater monitoring program will continue throughout mining and post mining phases. Action will be taken if the Level 1 minimal impact considerations or groundwater trigger values specified in the WMP are exceeded. Responses to exceedances of trigger values will be as per the trigger action response plan specified in the WMP.

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Abbreviations

AHD	Australian height datum
AIP	Aquifer Interference Policy
bgl	Below ground level
BOM	Bureau of Meteorology
Centennial Airly	Centennial Airly Pty Limited
CRD	Cumulative rainfall departure
DPIE-Water	Department of Planning, Industry and Environment – Water
EC	Electrical conductivity
EP&A Act	*Environmental Planning and Assessment Act 1979*
EPL	Environment Protection Licence
GDE	Groundwater dependent ecosystems
GHD	GHD Pty Ltd
GMR WSP	Greater Metropolitan Region Groundwater Sources Water Sharing Plan
GMRU WSP	Greater Metropolitan Region Unregulated River Water Sources Water Sharing Plan
GWIA	Groundwater Impact Assessment
ha	Hectare
IESC	Independent Expert Scientific Committee
kL/day	Kilolitre per day
km	Kilometre
L/s	Litre per second
m	Metre
m/day	Metre per day
mg/L	Milligram per litre
ML	Megalitre
ML/year	Megalitre per year
mm	Millimetre
Mtpa	Million tonne per annum
POEO Act	*Protection of Environment Operations Act 1997*
ROM	Run of Mine
SWIA	Surface Water Impact Assessment

TARP	Trigger action response plan
VWP	Vibrating wire piezometer
WAL	Water Access Licence
WM Act	*Water Management Act 2000*
WMP	Water Management Plan
WSP	Water Sharing Plan
µS/cm	Microsiemens per centimetre

Glossary

Alluvial	Deposition from running waters.
Aquifer	A groundwater bearing formation sufficiently permeable to transmit and yield groundwater.
Australian height datum	A common national surface level datum approximately corresponding to mean sea level.
Bord and pillar	Method of underground coal mining where the coal seam is divided into a regular block array (pillars) by driving roadways. In some cases, the pillars are partly or completely removed in a concurrent or later operation.
Bore	Constructed connection between the surface and a groundwater source that enables groundwater to be transferred to the surface either naturally or through artificial means.
Catchment	The land area draining through the main stream, as well as tributary streams, to a particular site.
Cumulative rainfall departure	Monthly accumulation of the difference between the observed monthly rainfall and long-term average monthly rainfall.
Dewatering	The removal or pumping of water from an above or below ground storage, including the mine water within the water collection system of mine workings. Water removed from mine workings is regarded as dewatering unless the workings are flooded and at equilibrium with the surrounding strata (in which case the removal is considered groundwater extraction).
Drawdown	A reduction in piezometric or hydraulic head within an aquifer.
Ephemeral	Stream that is usually dry, but may contain water for rare and irregular periods, usually after significant rain.
Fracture	Cracks within the strata that develop naturally or as a result of underground works.
Groundwater	Subsurface water that occurs in soils and geological formations.
Hydrogeology	The area of geology that deals with the distribution and movement of groundwater in soils and rocks.
Hydrograph	A graph which shows how a water level (either surface or underground) at any particular location changes with time.
Outcrop	Where the bedrock is exposed at the ground surface.
Overburden	The strata between the coal seam being extracted and the surface.
Permian age	The youngest geological period of the Palaeozoic era, covering a span between approximately 290 and 250 million years ago.
Quaternary	The most recent geological period spanning from approximately 2.5 million years ago to present.

Recharge	The replenishment of an aquifer by the absorption of water.
Roadway	Underground tunnel constructed to enable access to working face.
Run of mine	Raw coal production (unprocessed).
Strata	Layers of rock above, below and including the coal seam.
Subsidence	The vertical difference between the pre-mining surface level and the post-mining surface level at a point.
Surface water	Water that is derived from precipitation or pumped from underground and may be stored in dams, rivers, creeks and drainage lines.
Triassic	The geological period that spans between approximately 250 and 200 million years ago.

1. Introduction

GHD Pty Ltd (GHD) was commissioned by Centennial Airly Pty Limited (Centennial Airly), a wholly owned subsidiary of Centennial Coal Company Limited (Centennial), to prepare a Groundwater Impact Assessment (GWIA) for the proposed Modification 3 of the Airly Mine Extension Project (the Project). This assessment is to form part of Statement of Environmental Effects (SEE) to inform the modification under Part 4, of the *Environmental Planning and Assessment Act 1979* (EP&A Act) to development consent SSD_5581.

1.1 Background

Airly Mine is an existing underground thermal coal mine located near Capertee village, approximately 40 km north-west of Lithgow on the Castlereagh Highway in the Western Coalfield, as shown in Figure 1-1.

Airly Mine was granted Development Consent DA162/91 on 14 April 1993 by the then Minister for Planning for the development of an underground coal mine following a Commission of Inquiry held in 1993.

The development consent DA162/91 allowed Airly Mine to extract up to 1.8 million tonnes per annum (Mtpa) of run of mine (ROM) coal within the mining lease ML1331 and was due to lapse in October 2014. Airly Mine moved to a care and maintenance phase in January 2013 and remained in care and maintenance until March 2014. During the care and maintenance phase extraction activities ceased, however environmental management of the mine was ongoing including ongoing surface water and groundwater monitoring.

Coal production at Airly Mine resumed in March 2014. The expiry date of the consent DA162/91 was extended to beween October 2014 and 31 January 2017 through a number of modifications.

The Airly Mine Extension Project (SSD 5581) was submitted in September 2014, and approved in December 2016. The consent SSD 5581 allows mining for a period of 20 years within the boundaries of ML1331 and Authorisation 232 (A232), and will lapse on 31 January 2037. Rehabilitation will be undertaken outside this period.

A locality plan showing the ML1331 and A232 boundaries is given in Figure 1-1. Mining and exploration activities are currently undertaken within A232, which is also shown in Figure 1-1. Coal mining to date at Airly Mine has been bord and pillar mining only within the Lithgow Seam and between 2014 and 2019 mining was undertaken only within the boundary of ML1331.

1.2 Project description

Centennial Airly has prepared a SEE to support an application seeking to modify development consent SSD-5581 under Part 4 of the EP&A Act.

The Project proposes:

- An increase in the maximum production rate for the approved 1.8 Mtpa to 3.0 Mtpa of ROM coal.
- An increase in the maximum workforce from the approved 155 full time equivalent (FTE) personnel to 200 FTE personnel.
- An increase in the average train movements from the approved two trains per day to three trains per day (maintaining the approved maximum five trains per day) to allow all coal to be transported offsite at the increased production rate.

- Blasting or shot firing to be undertaken in any approved mining zones to remove any geological structure in the event that such a structure is encountered during mining.
- An amendment to the approved 20 year mine schedule for the increased production rate.

1.3 Project Application Area

The Project Application Area corresponds with the development consent boundary and includes:

- The existing ML1331 and A232 boundaries with areas of 2,744 ha and 3,096 ha respectively.
- The extent of the already mined areas.
- The existing Surface Facilities Area comprising:
  - Workforce and materials access.
  - Water management structures.
  - Coal conveyor system, coal stockpile area and coal loading facilities.
- The rail siding and the rail load-out facility.
- Mine access.

There are no proposed changes to mining areas as part of this modification. Proposed mining areas are presented in the *Airly Mine Extension Project Groundwater Impact Assessment* (GHD, 2014a).

The hydrogeological model domain has been identified by hydrogeological and geological boundaries rather than the Project Application Area. Further details regarding the hydrogeological model boundary are provided in Section 5.1.1 of the *Airly Mine Extension Project Hydrogeological Model Report* (GHD, 2014b).

1.4 Proposed and approved project conditions

This GWIA has been prepared to inform the Statement of Environmental Effects (SEE) for Modification 3. It defines the existing hydrogeological environment and sensitive groundwater receptors and assesses impacts on these groundwater receptors, using predictions from the recalibrated hydrogeological model, from the proposed mine plan and schedule based on a maximum mining rate of 3.0 Mtpa (proposed conditions). Predicted impacts under proposed conditions have been compared to predicted impacts under approved conditions from development consent SSD_5581, which involve a mine plan and schedule based on a maximum mining rate of 1.8 Mtpa. Predicted impacts under approved conditions were presented and assessed in the *Airly Mine Extension Project Groundwater Impact Assessment* (AMEP GWIA) (GHD, 2014a). Approved conditions have also been reassessed using the recalibrated hydrogeological model and groundwater impacts have been presented and assessed in this Groundwater Impact Assessment report.

This report compares model results from the recalibrated model (GHD, 2019a) for the approved (1.8 Mtpa) and proposed (3 Mtpa) scenario with approved (1.8 Mtpa) scenario model results reported in the AMEP GWIA (GHD, 2014a). It should be noted that the only valid comparisons are between model predictions for the approved and proposed scenarios using the recalibrated model. This comparison provides a more realistic assessment of the impact of the proposed modification on the hydrogeological environment within the consent boundary and the immediate surroundings encompassing the zone of influence.

1.5 Groundwater management overview

1.5.1 Existing groundwater management

Centennial Airly has a licensed production bore (supply work licence number 10BL603503) located adjacent to the existing rail loop. The bore was installed in 2009 within sandstone and siltstone of the Shoalhaven Group and was licensed to extract up to 158 ML/year of groundwater at a maximum rate of 5 L/s. The bore is a water supply for mining operations at Airly Mine. Limited groundwater has been extracted from the bore. The production bore was first utilised in 2017 (other than for monitoring and testing purposes). Approximately 21.4 ML was extracted from the production bore in 2017 and approximately 37.5 ML was extracted from the production bore in 2018.

Since the commencement of the Water Sharing Plan (WSP) for the Great Metropolitan Region Groundwater Sources in 2011, the volumetric allocation on this bore has been converted to Water Access Licence (WAL) 24386 and the bore works approval was converted to 10WA112537. Centennial Airly purchased an additional groundwater entitlement of 120 ML/year (WAL 36565) in 2013 following a controlled allocation order, bringing Airly Mine's total groundwater extraction entitlement from the Sydney Basin North groundwater source to 278 ML/year.

Baseline groundwater level, pressure and quality monitoring is currently undertaken above the proposed mining zones so that potential impacts on groundwater sources can be assessed in the future. Further details on this monitoring program are provided in Section 4.

To date, the interception of groundwater by the existing mine workings has been low (not measureable). Limited dewatering of the underground has occurred. This dewatering is understood to be surface water transferred from the surface for use in mining operations that has accumulated in the underground workings over time.

1.5.2 Proposed changes to groundwater management

The primary modification to groundwater management associated with the Project is to manage any potential change to groundwater inflow into the mine workings resulting from the proposed increase in mining rate. In accordance with approved project conditions, this groundwater take will be transferred from the workings to the Dirty Water Dam at the surface facilities site for use in coal processing and to meet other water demands throughout the site. However, it is noted that the recalibrated hydrogeological model does not predict that there will be an increase in the peak groundwater inflow rate under proposed conditions.

1.6 Objectives of the groundwater impact assessment

The objective of this GWIA is to assess the potential impacts of the Project on groundwater within the vicinity of the Project and the broader regional environment.

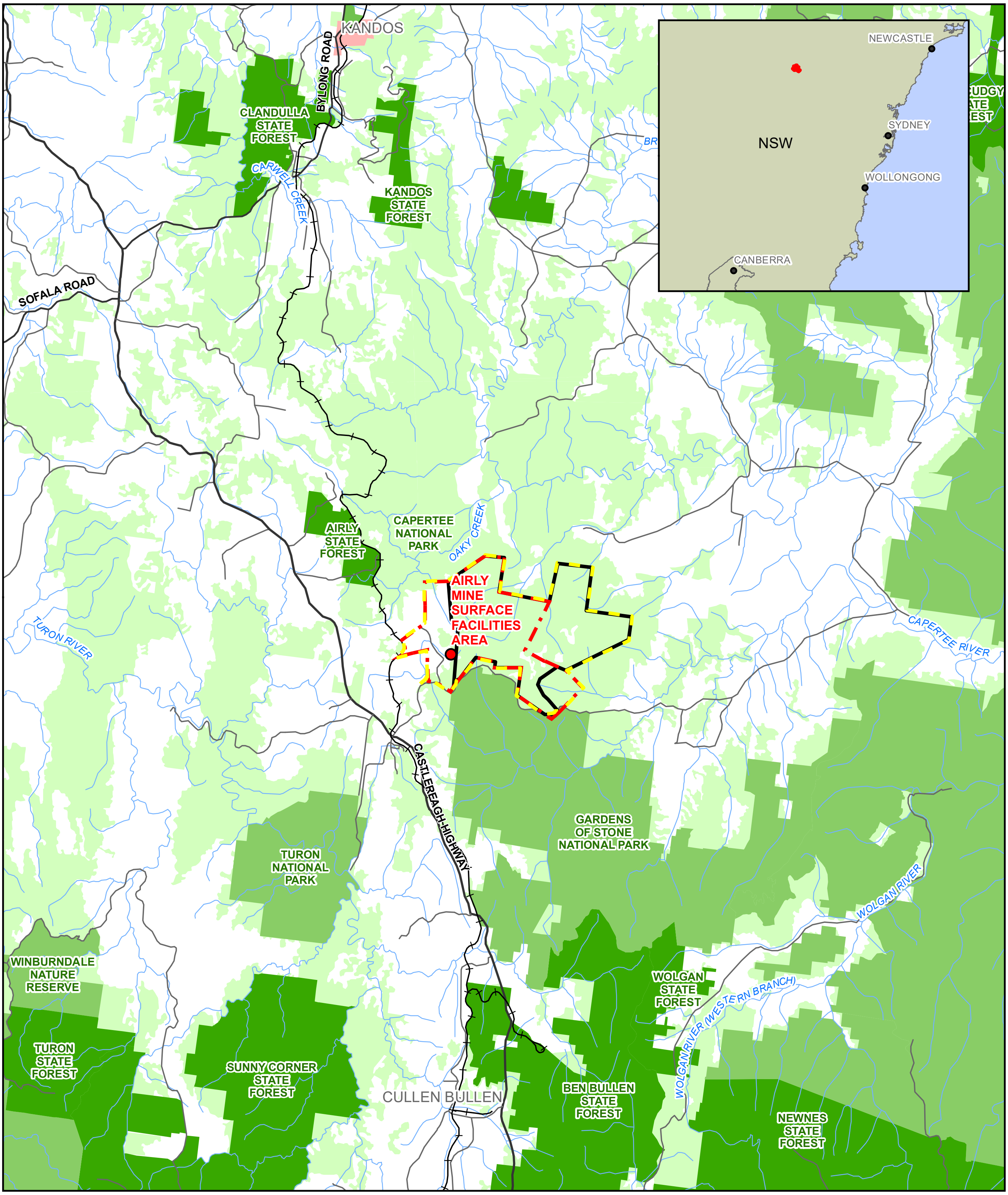
1.7 Scope of work

The GWIA addresses the proposed coal extraction and groundwater supply aspects of the Project and assesses potential impacts on the groundwater sources and users identified in Section 3.

The scope of works for the investigation included:

- A review of available background hydrogeological and mining data.
- Review of relevant statutory requirements and development of impact assessment criteria.

- Identification and description of groundwater sources within the Project Application Area as well as the regional groundwater sources.
- Search of the registered NSW groundwater bores to identify licensed groundwater users in the anticipated radius of groundwater drawdown.
- Identification of potential groundwater dependent ecosystems (GDEs) based on available information.
- Assessment of existing groundwater data (levels and quality) to establish baseline groundwater conditions.
- Update of the existing MODFLOW hydrogeological model to predict potential impacts on groundwater sources (quantity) as a result of the proposed underground workings (addressed in the *Airly Mine Extension Project – Modification 3: Hydrogeological Model Report* (GHD, 2019a)).
- Identification of potential groundwater impacts resulting from the proposed underground workings, based on the NSW Aquifer Interference Policy (AIP) minimal impact considerations.
- Assessment of whether the Project can operate in accordance with the relevant WSP and sufficient groundwater allocation is available.
- Identification of avoidance and adaptive management strategies to minimise and mitigate groundwater impacts.



LEGEND

- Airly Surface Facilities Area
- Project Approval Area SSD_5581
- Mining Lease ML1331
- Authorisation A232
- Existing rail
- Dual carriageway
- Principal road
- Secondary road
- Minor road
- Waterway
- Built up area
- Recreation area
- Nature conservation
- State forest
- Forest or shrub

Paper Size A4

0 1,000 2,000 4,000 6,000 8,000

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Centennial Airly

Airly Mine
Airly Mine Mod 3
Groundwater Impact Assessment

Job Number 22-19275
Revision 0
Date 7 Jun 2019

Locality plan

Figure 1-1

Data source: @ Commonwealth of Australia (Geoscience Australia): 250K Topographic Data Series 3 2006; Centennial: Boundaries. Created by: smacdonald

2. Legislation and policy

The following section provides a brief overview of the legislation, policies and guidelines relevant to this GWIA.

2.1 Legislation

2.1.1 Environment Planning and Assessment Act 1979

The EP&A Act outlines the core legislation relating to planning and development activities in NSW and provides the statutory framework under which development proposals are assessed. The EP&A Act aims to encourage the proper management, development and conservation of resources, environmental protection and ecologically sustainable development.

The GWIA forms part of an SEE to support an application to modify development consent SSD-5581 under Section 4.55 of the EP&A Act for the Project. The Minister for Planning (or delegate) is the determining authority for the Project.

2.1.2 Protection of the Environment Operations Act 1997

The Protection of the Environment Operations Act 1997 (POEO Act) is administered by the EPA, which is an independent statutory authority and the primary environmental regulator for NSW. The objectives of the POEO Act are to protect, restore and enhance the quality of the environment. Some of the mechanisms that can be applied under the POEO Act to achieve these objectives include programs to reduce pollution at the source and monitoring and reporting on environmental quality. The POEO Act regulates and requires licensing for environmental protection, including for waste generation and disposal and for water, air, land and noise pollution.

Under the POEO Act, an Environment Protection Licence (EPL) is required for premises at which a ‘scheduled activity’ is conducted. Schedule 1 of the POEO Act lists activities that are scheduled activities for the purpose of the act. Licence conditions relate to pollution prevention and monitoring and can control the air, noise, water and waste impacts of an activity.

Airly Mine is currently licensed for the scheduled activity of mining for coal and coal works under EPL 12374.

2.1.3 Water Management Act 2000

The *Water Act 1912* has historically been the main legislation for managing water resources in NSW, however is currently being progressively phased out and replaced by water sharing plans (WSPs) under the *Water Management Act 2000* (WM Act). Once a WSP commences, existing licences under the *Water Act 1912* are converted to water access licences (WALs) and to water supply works and use approvals under the WM Act.

The aim of the WM Act is to ensure that water resources are conserved and properly managed for sustainable use benefiting both present and future generations. It is also intended to provide formal means for the protection and enhancement of the environmental qualities of waterways and in-stream uses as well as to provide for protection of catchment conditions.

Water sharing plans

Fresh water sources throughout NSW are managed via WSPs under the WM Act. Provisions within WSPs provide water to support the ecological processes and environmental needs of GDEs and waterways. WSPs also provide how the water available for extraction is shared between the environment, basic landholder rights, town water supplies and commercial uses.

Key rules within the WSPs specify when licence holders can access water and how water can be traded.

The following two WSPs made under Section 50 of the WM Act are relevant to the Project:

- Greater Metropolitan Region Groundwater Sources Water Sharing Plan (GMR WSP).
- Greater Metropolitan Region Unregulated River Water Sources Water Sharing Plan (GMRU WSP).

The WSP boundaries for groundwater are shown in Figure 2-1.

For groundwater, the Project is located within the GMR WSP, which became operational in July 2011. This WSP covers 13 groundwater sources on the east coast of NSW. The Project is located within the Sydney Basin North Groundwater Source.

For surface water, the Project is located within the GMRU WSP, which became operational in July 2011. This WSP covers six water sources which are made up of a total of 87 management zones. The Project is located within the Wywandy Management Zone of the Upper Nepean and Upstream Warragamba Water Source.

2.1.4 Environment Protection and Biodiversity Conservation Act 1999

The Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act) is administered by the Commonwealth Department of the Environment and Energy and provides a legal framework to protect and manage nationally and internationally significant flora, fauna, ecological communities and heritage places defined as 'matters of national environmental significance' (MNES). Any action that "has, will have or is likely to have a significant impact on a matter of national environmental significance" is deemed to be a 'controlled action' and may not be undertaken without prior approval from the Commonwealth Environment Minister, as provided under Part 9 of the EPBC Act. Approval is also required where actions are proposed on, or will affect, Commonwealth land and its environment.

The EPBC Act identifies MNES as:

- World heritage properties.
- National heritage places.
- Wetlands of international importance (Ramsar wetlands).
- Threatened species and ecological communities.
- Migratory species.
- Commonwealth marine areas.
- Nuclear actions (including uranium mining).
- Great Barrier Reef Marine Park.
- A water resource in relation to coal seam gas development and large coal mining development.

The EPBC Act is also relevant to the determination of the ecological value of a groundwater dependent ecosystem (GDE). If a GDE contains a threatened species as listed under the EPBC Act, the GDE is then taken to have a higher ecological value.

Potential impacts on any MNES are subject to assessments of significance pursuant to the EPBC Act Significant Impact Guidelines 1.1 (Department of the Environment, 2013a). If a significant impact is considered likely, a referral under the EPBC Act must be submitted to the Commonwealth Environment Minister.

The Significant Impact Guidelines 1.3 (Department of the Environment, 2013b) includes general criteria for whether an action is likely to have a significant impact on water resources, which are for the possibility for direct or indirect changes to:

- The hydrology of a water resource.
- The water quality of a water resource.

According to the Significant Impact Guidelines 1.3 (Department of the Environment, 2013b), the value of the water resource needs to be confirmed such that impacts from actions can be evaluated on their significance. The guidelines indicate that key factors for evaluating a water resource's value include its utility for all third party users. Third party user categories specific to the Project include:

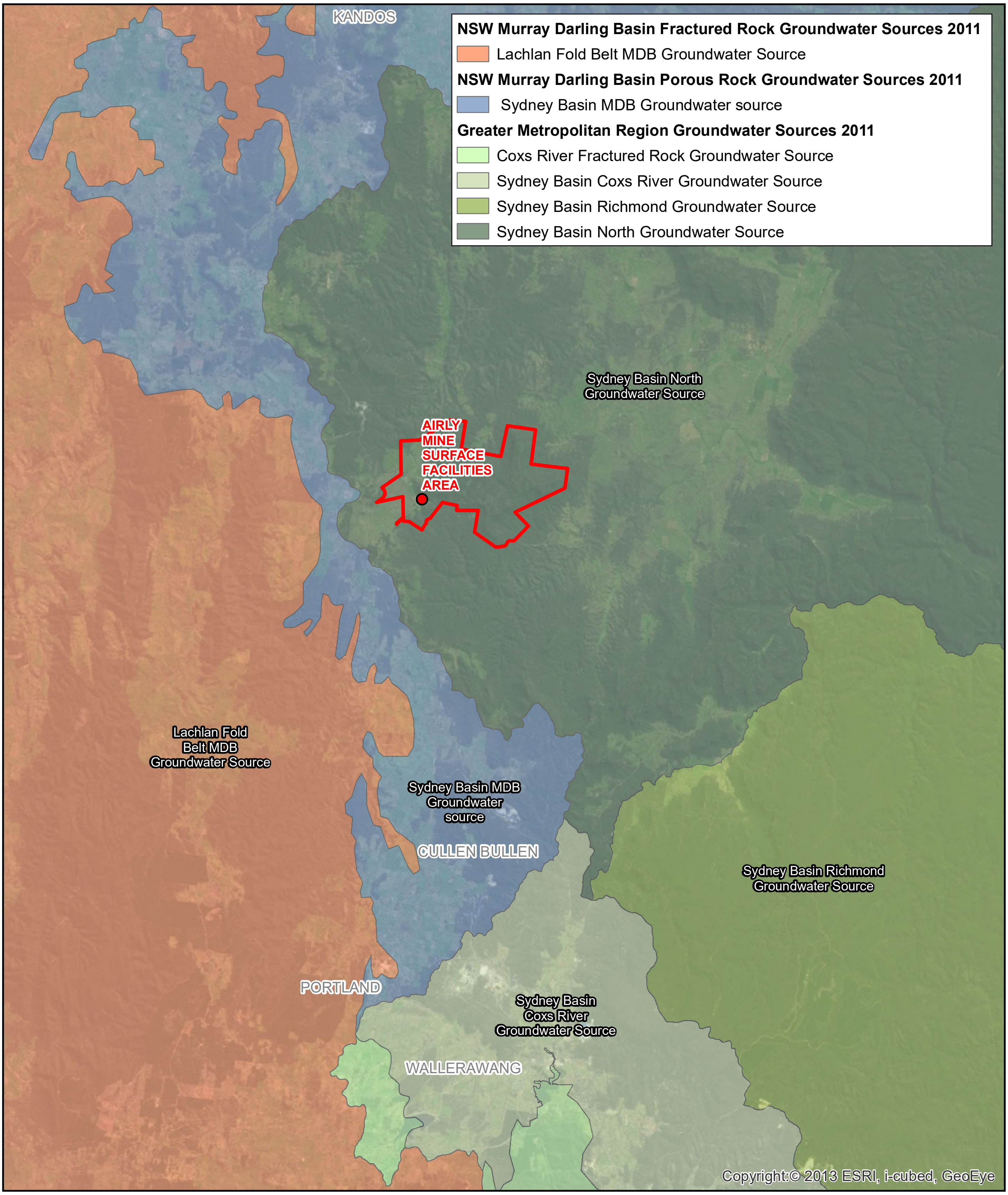
- Provisioning services (e.g. use by other industries and use as drinking water).
- Cultural services (e.g. recreation and tourism, science and education).
- Supporting services (e.g. maintenance of ecosystem function).

If evidence can be provided that proposed actions would not materially affect the availability and quality for third party users, then the likelihood of an action having a significant impact would be reduced (Department of the Environment, 2013b).

An assessment of whether the Project may have a significant impact on any MNES or on the environment of Commonwealth land was undertaken during the EIS investigations and preparation.

Approval for referral 2013/7606 for the Airly Mine Extension Project made under the EPBC Act was granted on 18 May 2017. The approval provides for Centennial Airly to carry out mining operations in accordance with development consent SSD-5581 with conditions relating to the protection of MNES.

The significant impact guideline and IESC checklist relevant to groundwater were completed and provided in Appendix A. The significant impact guideline and IESC checklist relevant to surface water was completed separately and is reported within the *Airly Mine Extension Project – Modification 3 Site water and salt balance assessment* (GHD, 2019b).



LEGEND

- Airly Surface Facilities Area
- Project Approval Area SSD_5581

Paper Size A4

0 1,500 3,000 6,000 9,000 12,000

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

Centennial Airly

Airly Mine
Airly Mine Mod 3
Groundwater Impact Assessment

Job Number	22-19275
Revision	0
Date	7 Jun 2019

Groundwater WSP Boundaries

Figure 2-1

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

G:\22\0105001\GIS\Maps\Deliverables\Western\Airly\2219275\GWIA\2219275_GWIA002_GroundwaterBoundaries_A.mxd

Data source: @ Commonwealth of Australia (Geoscience Australia): 250K Topographic Data Series 3 2006; Centennial: Boundaries. Created by: smacdonald

2.2 Policies

2.2.1 Significant Impact Guidelines for Coal Seam Gas and Large Coal Mines 2013

The *Significant Impact Guidelines for Coal Seam Gas and Large Coal Mines 2013* (DoE) is intended to assist in determining if any action which involves a coal seam gas development or large coal mining development has or is likely to have a significant impact on a water resource.

If the development is likely to have such an impact, the proponent should submit a referral to the Australian Government Department of the Environment and Energy (DEE) for a decision by the Minister on whether assessment and approval is required under the EPBC Act.

An assessment of the Project with respect to management of groundwater, against the *Significant Impact Guidelines for Coal Seam Gas and Large Coal Mines 2013* (DoE) has been undertaken as detailed in Table A-1 in Appendix A.

2.2.2 NSW Aquifer Interference Policy

The NSW Aquifer Interference Policy (AIP) was finalised in September 2012 and clarifies the water licensing and approval requirements for aquifer interference activities in NSW, including the taking of water from an aquifer in the course of carrying out mining.

The Policy outlines the water licensing requirements under the *Water Act 1912* and WM Act. A water licence is required whether water is taken for consumptive use or whether it is taken incidentally by the aquifer interference activity (such as groundwater filling a void), even where that water is not being used consumptively as part of the activity's operation. Under the WM Act, a water licence gives its holder a share of the total entitlement available for extraction from the groundwater source. The WAL must hold sufficient share component and water allocation to account for the take of water from the relevant water source at all times.

Sufficient access licences must be held to account for all water taken from a groundwater or surface water source as a result of an aquifer interference activity, both for the life of the activity and after the activity has ceased. Many mining operations continue to take water from groundwater sources after operations have ceased. This take of water continues until an aquifer system reaches equilibrium and must be licensed.

The NSW AIP requires that potential impacts on groundwater sources, including their users and GDEs, be assessed against minimal impact considerations, outlined in Table 1 of the Policy. If the predicted impacts are less than the Level 1 minimal impact considerations, then these impacts will be considered as acceptable.

The Level 1 minimal impact considerations for less productive groundwater sources are relevant to the groundwater sources at Centennial sites and are as follows:

- **Water table:** less than or equal to 10% cumulative variation in the water table, allowing for typical climatic 'post-water sharing plan' variations, 40 m from any high priority GDE or high priority culturally significant site listed in the schedule of the relevant WSP. A maximum of a 2 m decline cumulatively at any water supply work unless make good provisions should apply.
- **Water pressure:** a cumulative pressure head decline of not more than 40% of the 'post water sharing plan' pressure head above the base of the water source to a maximum of a 2 m decline at any water supply work.
- **Water quality:** any change in the groundwater quality should not lower the beneficial use category of the groundwater source beyond 40 m from the activity. For alluvial water

sources, there should be no increase of more than 1% per activity in the long-term average salinity in a highly connected surface water source at the nearest point to the activity.

2.2.3 NSW State Groundwater Policies

The objective of the NSW State Groundwater Policy Framework Document (NSW Government 1997) is to manage the State's groundwater resources so that they can sustain environmental, social and economic uses for the people of NSW. NSW groundwater policy has three component parts:

- NSW Groundwater Quantity Protection Policy.
- NSW Groundwater Quality Protection Policy.
- NSW Groundwater Dependent Ecosystems Policy.

NSW Groundwater Quantity Management Policy

The principles of this policy include:

- Maintain total groundwater use within the sustainable yield of the aquifer from which it is withdrawn.
- Groundwater extraction shall be managed to prevent unacceptable local impacts.
- All groundwater extraction for water supply is to be licenced. Transfers of licensed entitlements may be allowed depending on the physical constraints of the groundwater system.

NSW Groundwater Quality Protection Policy

The objective of this policy is the ecologically sustainable management of the State's groundwater resources so as to:

- Slow and halt, or reverse any degradation in groundwater resources.
- Direct potentially polluting activities to the most appropriate local geological setting so as to minimise the risk to groundwater.
- Establish a methodology for reviewing new developments with respect to their potential impact on water resources that will provide protection to the resource commensurate with both the threat that the development poses and the value of the resource.
- Establish triggers for the use of more advanced groundwater protection tools such as groundwater vulnerability maps or groundwater protection zones.

NSW Groundwater Dependent Ecosystem Policy

This policy was designed to protect ecosystems which rely on groundwater for survival so that, wherever possible, the ecological processes and biodiversity of these dependent ecosystems are maintained or restored for the benefit of present and future generations.

2.3 Guidelines

2.3.1 Risk Assessment Guidelines for Groundwater Dependent Ecosystems

Risk Assessment Guidelines for Groundwater Dependent Ecosystems (NOW, 2012a) comprises four volumes and provides a conceptual framework for identifying and assessing ecosystems along with worked examples of assessments and discusses the identification of high probability GDEs and also discussed the ecological value of GDEs. The results from this assessment will be used by others to assess potential impacts of GDEs.

2.3.2 Guidelines for Groundwater Protection in Australia

The National Water Quality Management Strategy (NWQMS) provides a national framework for improving water quality in Australia's waterways. The main policy objective of the NWQMS is to achieve sustainable use of the nation's water resources, protecting and enhancing their quality, while maintaining economic and social development.

The Guidelines for Groundwater Protection in Australia (ANZECC, 1995) are part of the NWQMS. The objective of these guidelines is to provide a national framework for the protection of groundwater from contamination. The Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC, 2000a) are identified as a reference for identifying water quality criteria for developing a strategy for protecting groundwater and the aquatic ecosystem to meet a desired end point.

Protection of groundwater is generally easier when the source of contamination is concentrated at a point rather than spread over a broad area. Additionally, environmental protection measures have been developed to manage and minimise pollution from production of waste. These measures for protecting groundwater include waste avoidance, waste reuse, recycling and waste treatment.

Other groundwater protection strategies can include monitoring and review of performance of protection measures.

3. Site description

3.1 Topography and land use

The Project Application Area is characterised by steep and rugged topography, as well as lower lying, undulating areas. The topography of the Project Application Area is dominated by Mount Airly to the west and Genowlan Mountain to the east. Site elevation varies from over 1,000 m to less than 400 m in the south-eastern section of the Project Application Area.

The majority of the Project Application Area consists of rugged unpopulated bushland including the Mugii-Murum-ban State Conservation Area. Past and present land use activities within these areas include shale-oil and diamond mining as well as recreational activities. The Gardens of Stone National Park is located to the south of the Project Application Area while the Capertee Valley extends to the east towards the Wollemi National Park (Figure 1-1).

Existing workings within the Lithgow Seam are situated within the western portion of the Project Application Area in the vicinity of the surface facilities site. Approved workings will generally extend to the east of the existing workings. There are no other current coal mining operations in close proximity to the Project Application Area.

Cleared agricultural land is located to the west, north and east of the Project Application Area. The Castlereagh Highway is situated approximately 3 km to the west of the Project Application Area, while Glen Davis Road, the Airly Mine Access Road and Torbane Road pass through the south-western corner of the Project Application Area.

3.2 Watercourses

Watercourses within the Project Application Area include four major sub-catchment areas:

- The Torbane-Oaky Creek sub-catchment.
- The Airly-Coco Creek sub-catchment.
- The Emu Swamp Creek sub-catchment.
- The Gap-Genowlan Creek sub-catchment.

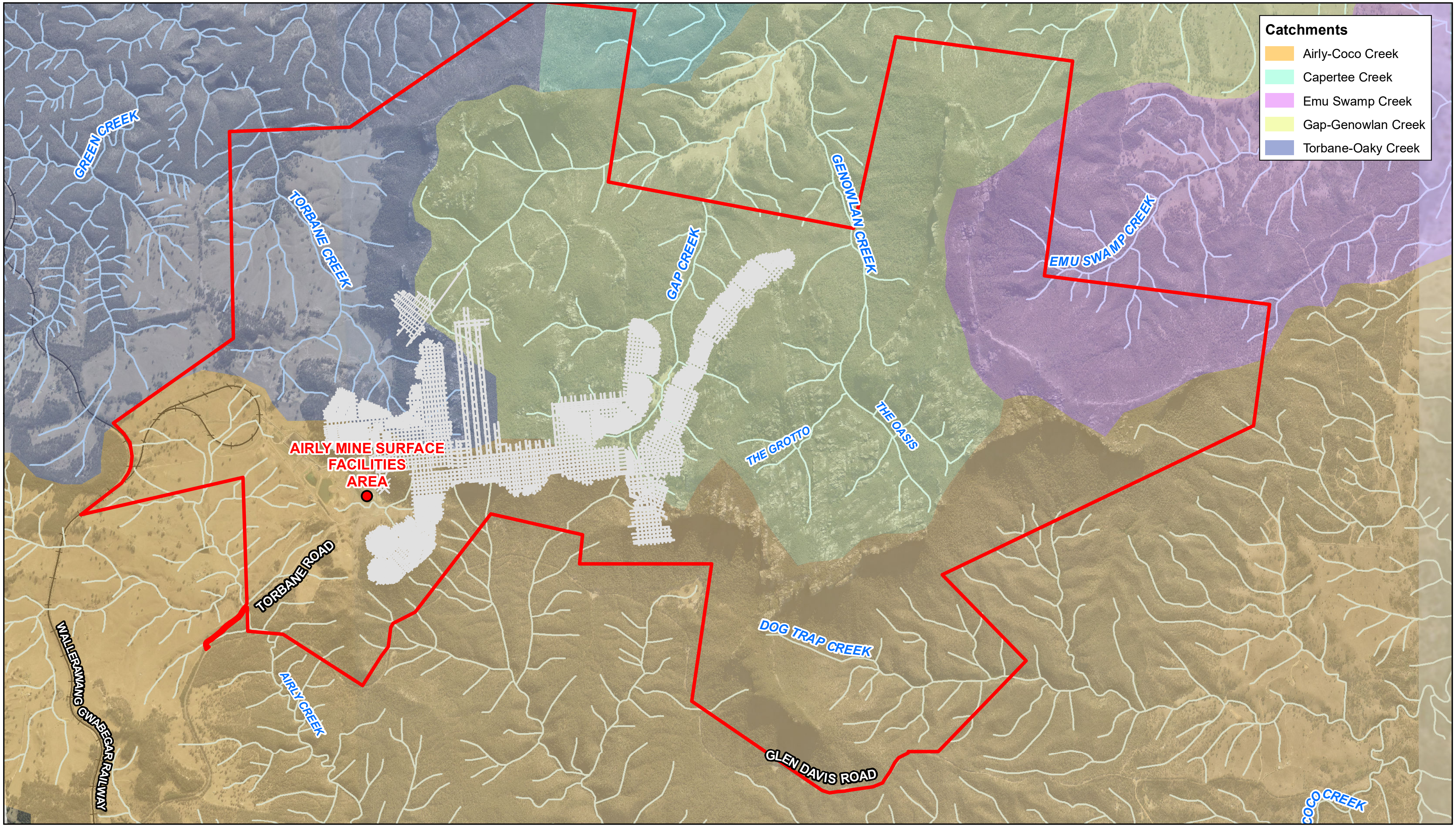
These watercourses are shown in Figure 3-1. Sub-catchment boundaries are shown in Figure 3-1. All sub-catchments drain into the Capertee River (shown in Figure 1-1) which flows in a south-easterly direction and is a tributary of the Colo River, which ultimately flows into the Hawkesbury River and Broken Bay.

All of the streams draining the Project Application Area are ephemeral. Generally, these watercourses flow for relatively brief periods following significant rainfall events. Flows within Airly, Oaky, Coco and Genowlan Creeks become perennial outside the Project Application Area.

3.3 Rainfall

Daily rainfall data were obtained as SILO Patched Point Data from the Queensland Climate Change Centre of Excellence. SILO Patched Point Data is based on historical data from a particular Bureau of Meteorology (BOM) station with missing data 'patched in' by interpolating with data from nearby stations.

For this assessment, SILO data was obtained for BOM Ilford (Warragunyah) Station (station number 62031), which is located approximately 29 km north-west of Airly Mine. This station was chosen based on the length and quality of the data record and proximity to the site.



Paper Size A4

0 375 750 1,125 1,500

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

LEGEND

- Airly Surface Facilities Area
- Project Approval Area SSD_5581
- Existing workings
- Waterway
- Railway

GHD

Centennial Airly

Airly Mine
Airly Mine Mod 3
Groundwater Impact Assessment

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Revision 0
Date 1 Aug 2019

Watercourses at Airly Mine

Figure 3-1

G:\22\0105001\GIS\Maps\Deliverables\Western\Airly\2219275\GWIA\2219275_GWIA003_Watercourses_A.mxd

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 T 61 2 4979 9999 F 61 2 4979 9988 E ntlmail@ghd.com W www.ghd.com.au

Data source: LPI: DTDB 2012; Centennial: Aerial Imagery, boundaries, 2013, Mine Workings, 2012. Created by: fmackay

The period of rainfall data used for this assessment extended from January 1901 to May 2018. The statistics for this rainfall data set are:

- Minimum annual rainfall – 277 mm in 1982.
- Average annual rainfall – 674 mm.
- Median annual rainfall – 659 mm.
- Maximum annual rainfall – 1513 mm in 1950.

The average monthly rainfall was observed to vary from a low of approximately 44 mm in May to a high of approximately 68 mm in January.

The SILO dataset was also used to generate a cumulative rainfall departure (CRD) curve. CRD curve is the monthly accumulation of the difference between the observed monthly rainfall and the long-term average monthly rainfall.

The CRD curve over the period 2011 to 2018 is shown in Figure 3-2. Any increase in the CRD curve reflects above average rainfall while a decrease in CRD curve reflects below average rainfall. A constant (or steady) CRD curve indicates average rainfall.

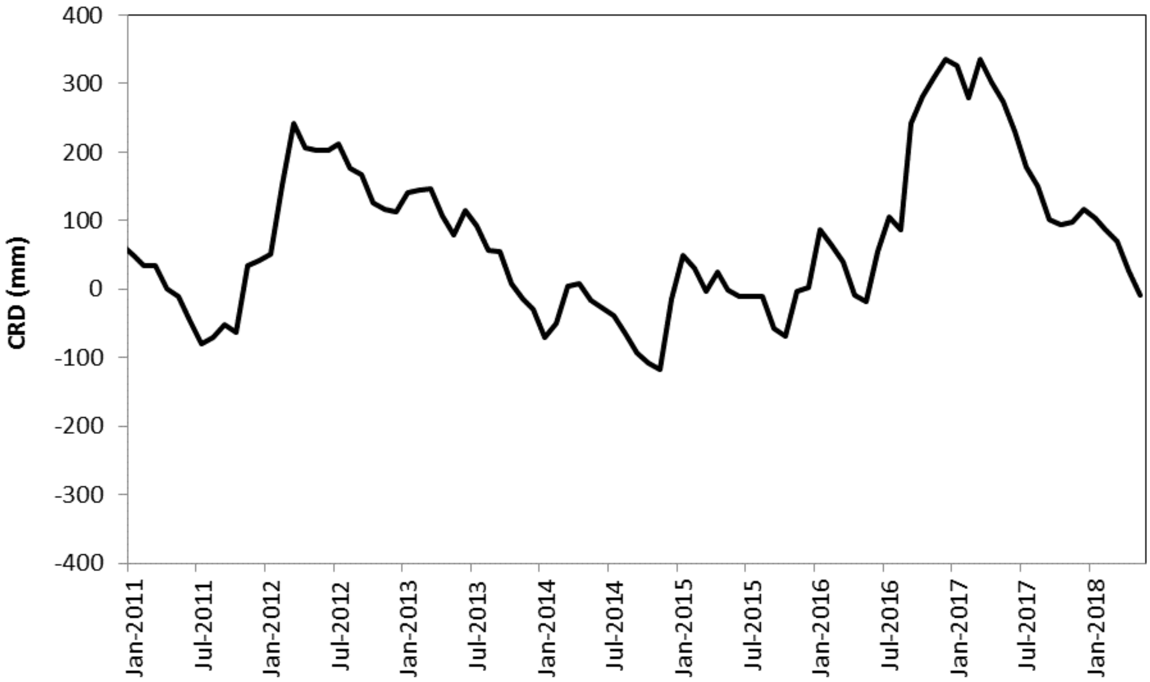


Figure 3-2 Cumulative rainfall departure curve 2011 – 2018

3.4 Geology

The Project Application Area is located within the southern part of the Western Coalfield of NSW, on the western edge of the Sydney Basin. The area is underlain by Triassic sandstone of the Narrabeen Group, which is underlain by the Illawarra Coal Measures.

The stratigraphy at Airly Mine is summarised in Table 3-1. This information has been sourced from the Western Coalfield (Southern Part) Regional Geology 1:100,000 map (NSW Department of Mineral Resources, Edition 1 1992) and exploration logs for Airly Mine. The outcrop geology in the vicinity of the Project Application Area is shown in Figure 3-3 and a cross section of stratigraphy is shown in Figure 3-4.

The Grose sandstone of the Triassic Narrabeen Group outcrops throughout the plateau and cliffs of Mount Airly and Genowlan Mountain, with small areas of Tertiary basalt outcrop at the higher elevations as shown in Figure 3-3. The Triassic strata are up to 200 m thick.

The Permian Illawarra Coal Measures outcrop around the Triassic formations at lower elevations, including the zone between Mount Airly and Genowlan Mountain. The Lithgow Seam, within the lower Illawarra Coal Measures is the target coal seam at Airly Mine. The seam outcrops completely within the Project Application Area and is therefore disconnected from the areas of occurrence of this seam located several kilometres to the south and northwest. The thickness of the Lithgow Seam within the Project Application Area generally ranges between 3 m and 4 m, with an average thickness of 3.4 m. This thickness does not include the lower quality Lidsdale Seam, which occurs immediately above the Lithgow Seam.

The depth of cover above the Lithgow Seam ranges from less than 20 m in areas of outcrop and in the Gap Creek area, up to approximately 310 m. The seam dips gradually to the east at about 1 degree. The average thickness of the Permian overburden is 105 m (Golder Associates, 2013).

Table 3-1 Stratigraphic sequence – Airly Mine

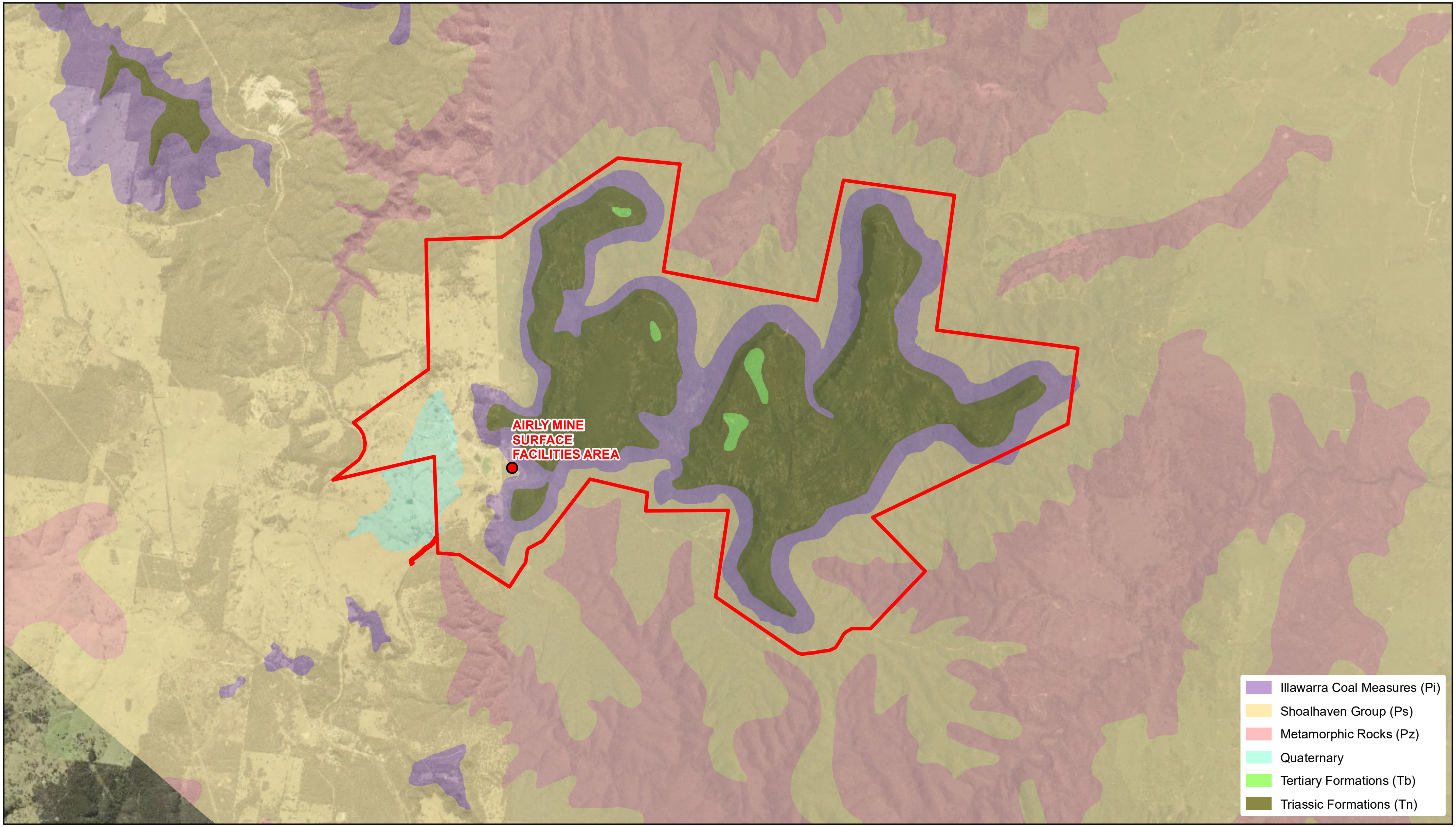
Period	Stratigraphy			Lithology
	Group	Subgroup	Formation	
Quaternary	Alluvium			Silt, clay, sand, gravel
Tertiary				Basalt, dolerite
Triassic	Narrabeen	Grose	Burra-Moko Head Sandstone	Quartz sandstone, red-brown claystone
			Caley Formation	Claystone, shale, quartz sandstone
Permian	Illawarra Coal Measures	Wallerawang	Middle River Coal Gap Sandstone	Coal, lithic sandstone, claystone
		Charbon	Glen Davis Formation Irondale Coal Long Swamp Formation	Sandstone, claystone, coal, mudstone
		Cullen Bullen	Lidsdale Seam Blackmans Flat Conglomerate Lithgow Seam Marrangaroo Formation	Coal, claystone, siltstone, mudstone, conglomerate
	Shoalhaven Group		Berry Siltstone	Siltstone, lithic sandstone conglomerate
Devonian	Metamorphic rocks			Quartzite, shale, sandstone, limestone, tuff

Interbedded siltstone and sandstone of the older Shoalhaven Group outcrop across the surface facilities area and beyond the Project Application Area. Metamorphic rocks also outcrop beyond the Project Application Area in areas of lower elevation.

Based on high resolution aeromagnetic (HRAM) and radiometric data (SRK, 2012), the basement (or pre-Permian) and shallow geology is characterised by the number of NW, NE and NS trending fault and joint features.

The review of structural geological features has been reviewed and updated by SRK (2018). The updated review of geological features identified the potential domains where faults and joints may extend from the basement Devonian strata to the surface. The key domains where there is potential for seam to surface lineaments to occur have been identified as Domain D, F and I as shown in Figure 3-5.

Underground mining has extended past Domain D (referred to locally as the Gap Creek lineament zone). No groundwater inflow was observed during mining in the vicinity of Domain D. There has been no ongoing groundwater inflow following mining in this area. Nevertheless, lineaments have been considered as part of the sensitivity analysis of the hydrogeological modelling as discussed in Section 6.1.4.



LEGEND

- Airly Surface Facilities Area
- Project Approval Area SSD_5581

Centennial Airly

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Date	7 Jun 2019

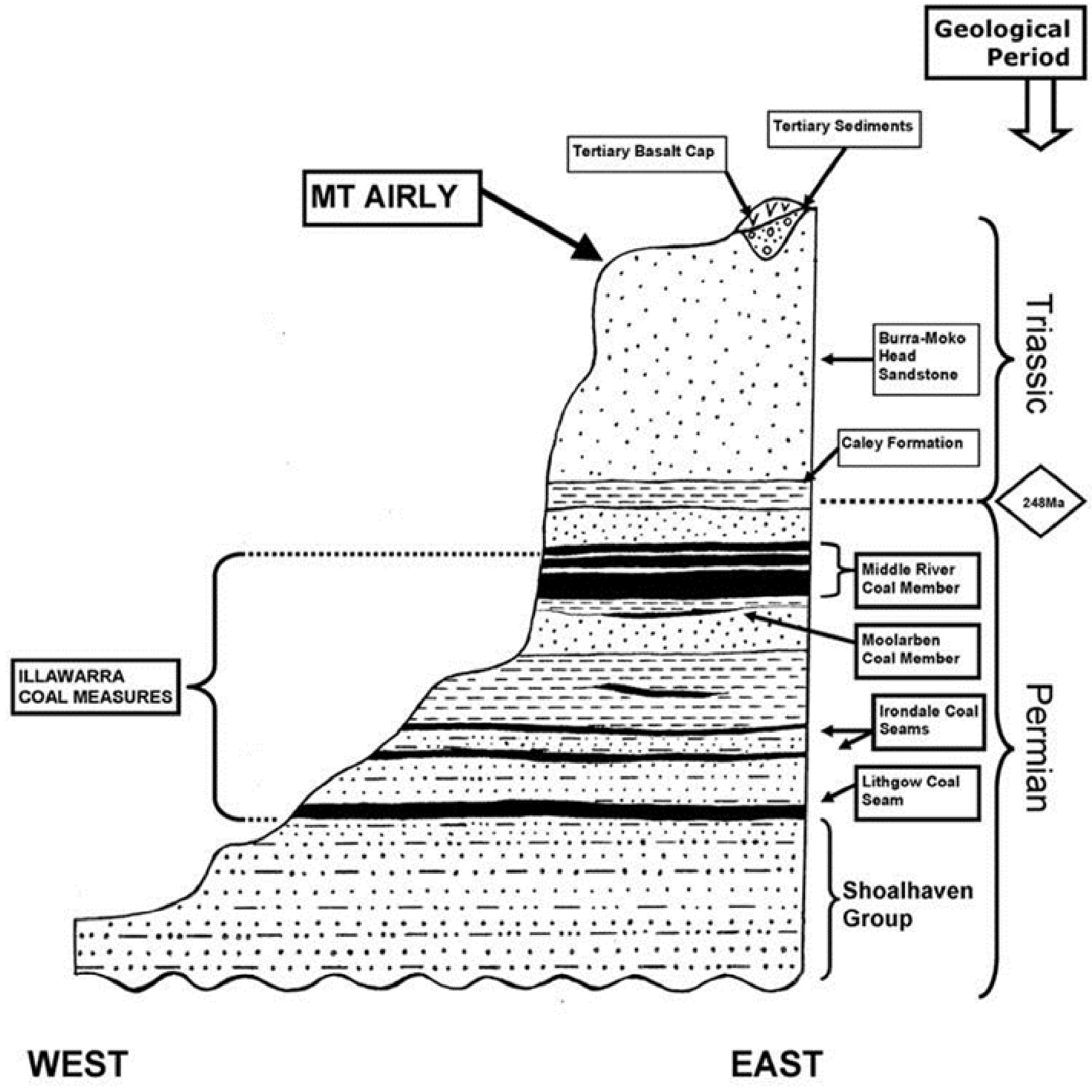
Geological map

Figure 3-3

G:\22\0105001\GIS\Maps\Deliverables\Western\Airly\2219275\GWIA\2219275_GWIA004_GeologicalMap_A.mxd

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

Data source: LPI: DTDB 2012; Aerial Imagery, 2015; Centennial: boundaries,2013; DPI: Geology, 2010. Created by: smacdonald, fmackay



Legend:
Basalt
Gravel and Sand
Coal
Sandstone
Siltstone
Interbedded Sandstone and Siltstone

NB: Not to Scale

LOCATION	Airly
SEAM	NA
DRAWN	SM
CHECKED	SG
APPROVED	SG
SCALE	NTS

Airly Mine Mod 3
Groundwater Impact Assessment

Geological Cross-Section

Centennial Coal

DATE Jun 2019

Figure 3-4

\\ghdnet\ghd\AU\Newcastle\Projects\22\16787\Visio\Groundwater Impact Assessment\Figure3-4_Geological Cross Section.vsd

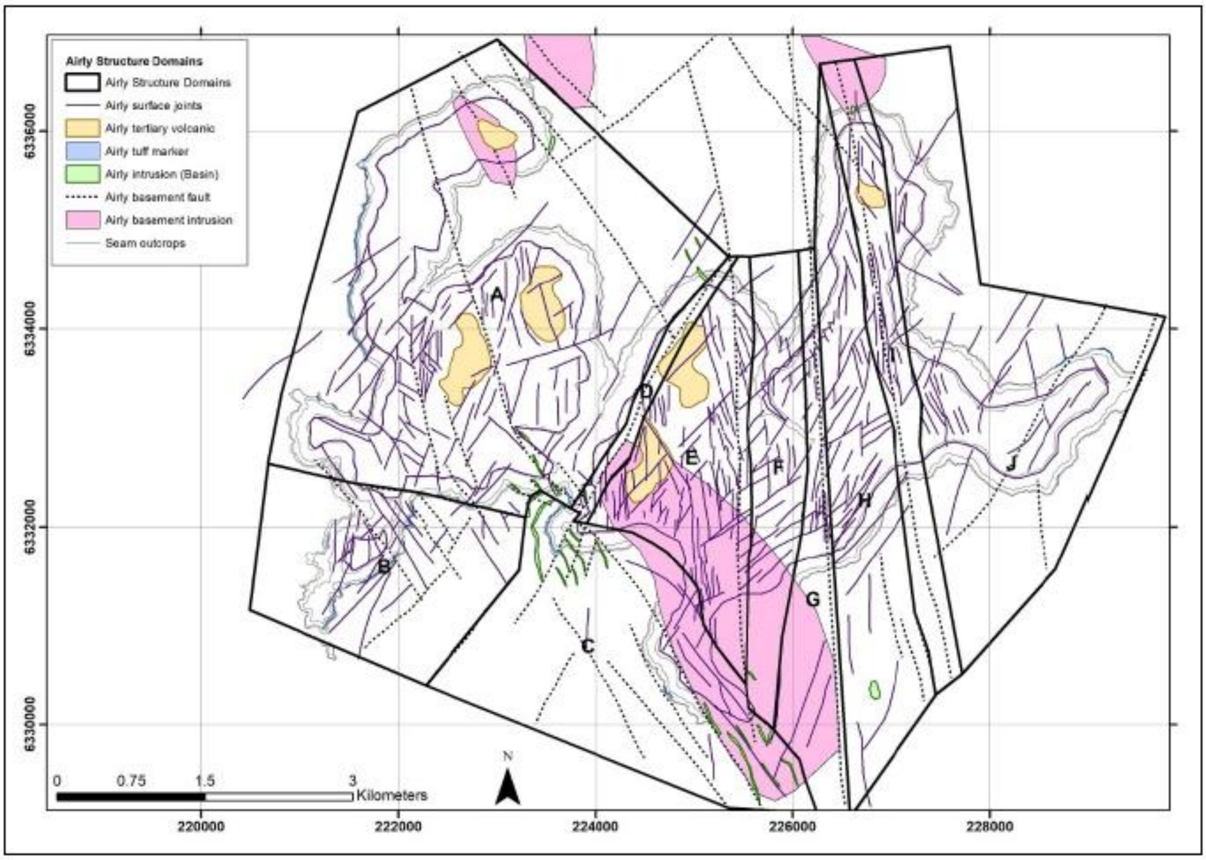


Figure 3-5 Structural interpretation of basement and surface for Airly Mine with seam level structural domains (SRK, 2018)

3.5 Hydrogeology and groundwater sources

The local groundwater sources within the Project Application Area are generally low yielding and predominantly within the Quaternary alluvium, weathered and/or fractured sandstone and coal seams that occur within Mount Airly and Genowlan Mountain. They are classified as 'less productive' in accordance with the criteria specified in the NSW AIP (i.e. the yield is typically less than 5 L/s and/or the total dissolved solids concentration is typically greater than 1,500 mg/L). The local groundwater sources are managed under the WSP for the Great Metropolitan Region Groundwater Sources and specifically are part of the Sydney Basin North groundwater source. These local groundwater sources are confined to the Project Application Area since their outcrop boundaries occur entirely within this area.

The regional groundwater sources occur within the Shoalhaven Group below the target coal seam, as well as within the underlying metamorphic rocks. These groundwater sources are also managed as part of the Sydney Basin North groundwater source, although monitoring data shows there is no connectivity between the local and regional groundwater sources at Airly Mine. A schematic representation of local and regional groundwater flow is shown in Figure 3-6.

3.5.1 Local Groundwater Sources

Alluvium

The alluvium throughout the Project Application Area forms an unconfined shallow aquifer with groundwater ranging in depth from less than 1 m to over 5 m below ground level (bgl), and aquifer thickness generally less than 12 m.

The alluvium associated with Gap Creek and Genowlan Creek is generally a silty sand material and recharged from rainfall as well as inter-aquifer flow from adjacent (primarily Permian) strata. Alluvial groundwater discharges to connected streams.

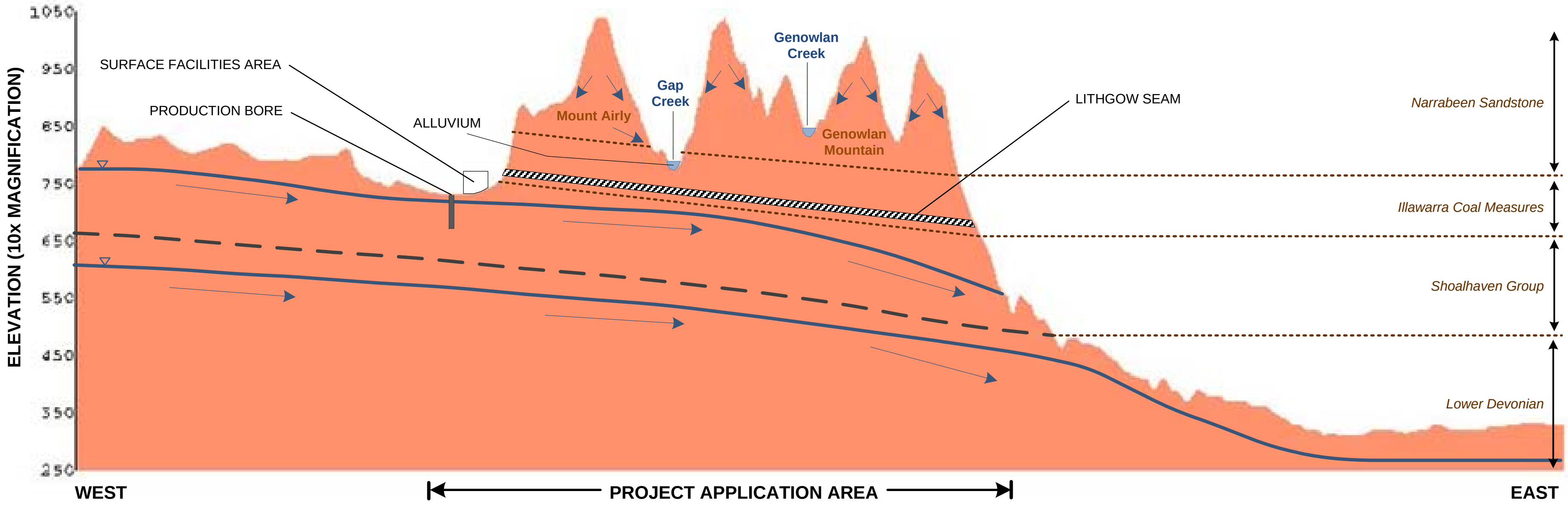
Based on water sampling undertaken at the site, the alluvium is fresh and slightly acidic.

It is understood that areas of Genowlan Creek and Gap Creek are fed relatively consistently by rainfall based flows which emerge from the Quaternary colluvium and alluvium. Although the source for this recharge is rainfall based, anecdotal evidence infers that these rainfall based flows are held in the Quaternary strata and released slowly into the reaches of Genowlan Creek above the 'Grotto' and the 'Oasis' areas (shown in Figure 3-1), as well as in certain reaches of Gap Creek. Flows in the Grotto and Gap Creek vary with rainfall seasonality (as indicated by existing flow gauges) whereas anecdotally the flows through the Oasis are persistent, varying from approximately 2.2 L/s in average conditions to 1 L/s during drought (RPS, 2013). Therefore, as the flows through the Oasis are anecdotally constant, they have been considered a component of baseflow for this assessment.

Porous and fractured rock

The local porous and fractured rock groundwater sources include the Narrabeen Sandstone and coal seams of the Illawarra Coal Measures. These sources are recharged by rainfall via fractures within overlaying strata, and seep out of the side of the mountains or directly into watercourses. With the majority of discharge from these sources being to seepage areas, there is minimal inter-aquifer flow to underlying regional groundwater sources.

Packer testing and falling head testing are reported in the *Airly Mine Extension Project – Modification 3: Hydrogeological Model Report* (GHD, 2019a).



GROUNDWATER FLOW

LOCATION	Airly
SEAM	NA
DRAWN	SM
CHECKED	SG
APPROVED	SG
SCALE	NTS

Airly Mine Mod 3
Groundwater Impact Assessment

Local and Regional Groundwater Flow

Centennial Airly

DATE Jun 2019

Figure 3-6

G:\22\16787\Visio\Groundwater Impact Assessment\Figure3-7_Regional Cross Section.vsd

3.5.2 Regional groundwater sources

Regional groundwater sources occur within strata well below the coal measures and extend beyond the Project Application Area as shown in Figure 3-6.

The upper regional groundwater source occurs within siltstone and sandstone of the Shoalhaven Group. According to the Western Coalfield (Southern Part) Regional Geology 1:100,000 map, this rock formation was deposited in a marine environment and therefore the groundwater is highly brackish to saline. The existing production bore at the Airly Mine surface facilities area is installed within this groundwater source. The recharge area is predominantly to the west of the Project Application Area where the Shoalhaven Group outcrops as shown in Figure 3-3. Groundwater flow is generally to the east.

The lower regional groundwater source occurs within the Devonian metamorphic strata containing shale, sandstone and limestone. The groundwater is slightly brackish and therefore has a lower salt content than the Shoalhaven Group and it is less sulfate dominant. It supplies numerous registered users to the east of the Project Application Area. Recharge areas occur to the north, south and east of the Project Application Area and groundwater flow is generally to the east.

Packer testing undertaken within the regional groundwater sources are summarised in the Hydrogeological Model Report (GHD, 2019a).

Groundwater quality monitoring data consistently indicates that there would be minimal inter-aquifer hydraulic connection between the upper and lower regional groundwater sources, based on differences in groundwater chemistry. As shown in the Piper Diagram in Figure 3-7, the Devonian groundwater (as represented by ‘Nioka’) is a calcium bicarbonate/sulfate type water and clearly different to the Shoalhaven Group (as represented by ‘Production Bore’) which is magnesium sulfate type water and the local groundwater sources (represented by ARP05, ARP11, ARP13SP, ARP14 and ARP15SP) which are of sodium/calcium bicarbonate/chloride type.

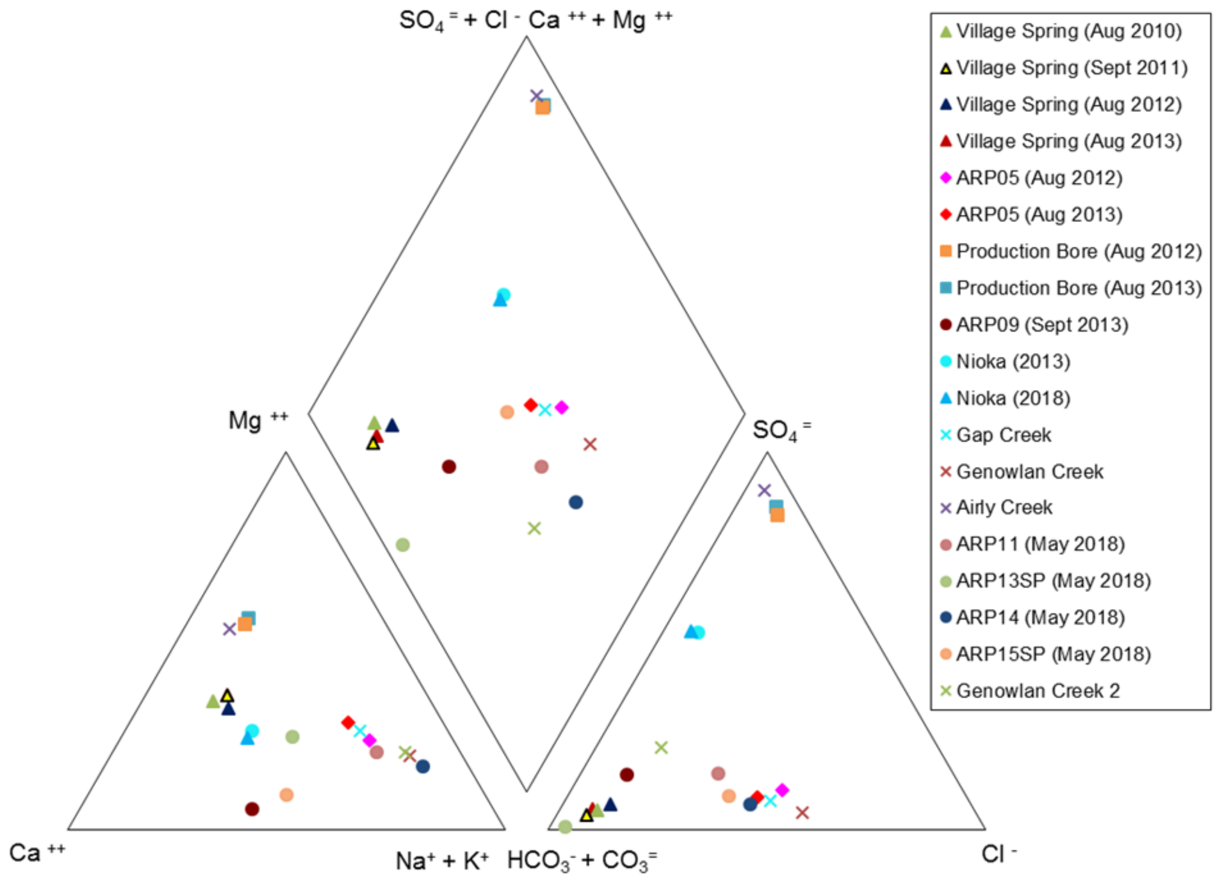


Figure 3-7 Piper Diagram

3.6 Registered landholder bores

A search of the database of registered groundwater bores managed by WaterNSW (2018) to identify registered bores within a 5 km radius of the Project Application Area. The search identified 40 bores, with the majority (30 bores) being registered for domestic, irrigation and/or stock use, nine bores registered as monitoring bores and one registered as a test bore. Bore details and locations are outlined in Appendix B.

The registered domestic and stock bores that were identified primarily extract groundwater from the lower regional groundwater source (sandstone and conglomerate formations) to the east of Airly Mine, with yields generally less than 2.5 L/s. Some registered bores are also located within Genowlan Creek alluvium to the north-east. The closest registered bores are at least 1 km from the Airly Mine development consent boundary.

The search identified three registered landholder bores located to the west of Airly Mine. Based on the depth (6.4 metres) and location in the vicinity of a creek line, registered bore GW035684 is likely located in the alluvium. Based on the location and bore depth, GW061562 and GW055643 are likely installed in the Shoalhaven Group.

There are ten registered bores within the development consent boundary. All of these are owned by Centennial Airly; one is a former test bore (GW068640) and the remainder are Airly Mine monitoring bores.

As discussed in Section 1.5.1, Airly Mine has a licensed production bore. The production bore was not identified in the search of the database of registered groundwater bores. The location of the production bore is shown in Figure 4-1.

3.7 Groundwater dependent ecosystems

RPS (2014) reports that GDEs are likely to occur within the shallow alluvial aquifer zones where groundwater levels are shallow and exist as moist sheltered gully forests. They are unlikely to be entirely groundwater dependent and are termed 'facultative' ecosystems. The GDEs that may exist within the Project Application Area are not listed as high priority GDEs in the WSP.

Minimal stygofauna have been detected in groundwater samples collected to date, limited to two individuals of one obligate stygofauna group (Cyclopoida) collected at one location (ARP11) installed within shallow sandstone in Spring 2018 (GHD, 2019c) and three individuals of obligate stygofauna group Melitidae (an Amphipod) collected at ARP15SP installed within the Narrabeen Sandstone in Autumn 2019. The groundwater sources most likely to provide habitat to stygofauna are the alluvium and Narrabeen Sandstone (Cardno, 2014).

3.8 Summary of sensitive groundwater resources

The GWIA focusses on potential impacts of the Project on the following sensitive groundwater resources:

- Alluvium and Quaternary strata: provides baseflow to Gap Creek and Genowlan Creek (including the Grotto and Oasis areas), potential habitat to vegetation and stygofauna GDEs and is a groundwater source to a small number of users along Genowlan Creek downstream of the Project Application Area.
- Narrabeen Sandstone: local groundwater source within the Project Application Area that provides a potential habitat to stygofauna and feeds seepage areas/springs.
- Illawarra Coal Measures: local groundwater sources within the Project Application Area that provide baseflow to Gap Creek and Genowlan Creek and feed seepage areas/springs such as the Village Spring.
- Shoalhaven Group: a highly brackish to saline regional groundwater source providing a small proportion of water supply requirements to Airly Mine.
- Devonian Metamorphic Strata: a slightly brackish regional groundwater source that provides the majority of registered groundwater users to the east of the Project Application Area.

3.8.1 Existing groundwater impacts

The coal mining to date at Airly Mine has been bord and pillar mining only within the Lithgow Seam. This includes both the recent workings adjacent to the surface facilities area developed between 2010 and 2012 and between 2014 and 2018, as well as the old Torbane Colliery workings. These workings are shown in Figure 4-1. Groundwater inflows into these workings have been low (not measureable). Groundwater impacts associated with these workings and detected to date from the groundwater monitoring network, have been isolated to the Lithgow Seam and the underlying Marrangaroo Formation (occurred in late 2015 and early 2016). These impacts are consistent with predictions approved under SSD_5581.

There are also old shale workings within the Glen Davis Formation, developed between the late 1800s to early 1900s beneath the northern end of the Mount Airly plateau. These workings resulted in some cracking to the surface and the drainage of overlying groundwater sources (primarily Narrabeen Sandstone) into the old workings. It is reported that the seep at Village

Spring is fed by drainage from the old shale workings. Based on groundwater monitoring undertaken at Airly Mine it appears that recovery of groundwater pressure within the Narrabeen Sandstone has taken place over time, most likely due to the infilling of old cracks.

4. Existing conditions

4.1 Monitoring program details

The existing groundwater monitoring program at Airly Mine includes vibrating wire piezometers (VWPs), sampling of groundwater bores and flow monitoring of groundwater seepage. All VWPs and standpipe monitoring bores are continuously logged for piezometric head and groundwater levels.

Existing monitoring location details are outlined in Table 4-1. Locations are shown in Figure 4-1.

It is considered that the spatial coverage of groundwater monitoring bores is adequate for the purpose of predicting and monitoring groundwater impacts associated with the Project. The local groundwater sources are limited in extent by outcrop boundaries (shown in Figure 4-2 of GHD (2014b)) creating a 'closed' hydrogeological system of rainfall recharge and seepage within the Project Application Area. This limits the required spatial coverage of groundwater monitoring bores to gain an understanding of the hydrogeological system. Piezometric head at many monitoring locations is low or negative.

Table 4-1 Groundwater monitoring locations

Monitoring type	Location name	Period of data	Ground level (m AHD)	Lithology
VWP	ARP01	June 2012–present Data logger stopped recording values for the Narrabeen Sandstone in December 2015	1027.96	Narrabeen Sandstone (74 m bgl)
				Irondale Seam (238.5 m bgl)
				Lithgow Seam (260 m bgl)
				Marrangaroo Formation (263 m bgl)
	ARP02A	May 2012–present	1022.68	Narrabeen Sandstone (65 m bgl)
				Irondale Seam (243 m bgl)
				Lithgow Seam (266 m bgl)
				Marrangaroo Formation (270 m bgl)
	ARP03A	July 2012–present	1001.66	Narrabeen Sandstone (136 m bgl)
				Middle River Seam (165 m bgl)

Monitoring type	Location name	Period of data	Ground level (m AHD)	Lithology
				Lithgow Seam (252 m bgl)
				Marrangaroo Formation (257 m bgl)
	ARP04	April 2012–present	762.66	Lithgow Seam (25 m bgl)
				Marrangaroo Formation (28.5 m bgl)
				Shoalhaven Siltstone (210.3 m bgl)
	ARP06	June 2013–present	1028.5	Narrabeen Sandstone (230 m bgl)
				Irondale Seam (252 m bgl)
				Lithgow Seam (288 m bgl)
				Marrangaroo Formation (295 m bgl)
	ARP07	July 2013–present	992.6	Middle River Seam (168 m bgl)
				Lithgow Seam (252 m bgl)
	ARP08	September 2013– present	1027.7	Narrabeen Sandstone (183 m bgl)
				Irondale Seam (282.5 m bgl)
	ARP13	December 2016– present [1]	785.6	Shoalhaven Group (120 m bgl)
				Devonian strata (280 m bgl)
	ARP15	January 2017–present [1]	846.7	Lithgow Seam (125 m bgl)
				Shoalhaven Group (200 m bgl)

Monitoring type	Location name	Period of data	Ground level (m AHD)	Lithology
				Devonian strata (365 m bgl)
Bore/standpipe	AM2B-1	2009–present (quality only)	Unknown	Shoalhaven Group (38–87 m bgl)
	Old Production bore	May 2017 – present	737.3	Shoalhaven Group
	ARP05	August 2012–present	757.22	Gap Creek alluvium (8–11 m bgl)
	ARP07	July 2013–present (dry)	992.6	Narrabeen Sandstone (110–119 m bgl)
	ARP08	September 2013– present	1027.7	Lithgow Seam (301–305 m bgl)
	ARP09	June 2013–present (mostly dry)	856.86	Genowlan Creek alluvium (3–4 m bgl)
	ARP11	January 2017–present	750.92*	Permian strata (1.25–15.3 m bgl)
	ARP12	January 2017–present	895.185*	Genowlan Creek alluvium (0.5–2.6 m bgl)
	ARP13SP	January 2017–present	785.74*	Lithgow Seam (67.5–70.5 m bgl)
	ARP14	January 2017–present	783.944*	Genowlan Creek alluvium (0.5–2.3 m bgl)
	ARP15SP	January 2017–present	847.525*	Narrabeen sandstone (10–16 m bgl)
	Nioka	2013, January 2018 – present (quality only)	Unknown	Permian strata
Seepage	Village Spring	February 2011–present	Unknown	Permian Siltstone
	Mine workings	December 2009–present (negligible)	N/A	Lithgow Seam

*Elevation for ARP11, ARP12, ARP13SP, ARP14 and ARP15SP is the top of casing elevation

4.2 Baseline monitoring results

4.2.1 Groundwater level and pressures

Groundwater levels observed at standpipe monitoring bores and pressures observed at VWPs are summarised in Appendix B.

4.2.2 Groundwater quality

Monthly groundwater samples have been collected from the production bore (AM2B-1). Monitoring bore ARP05 is periodically dry and samples have been collected on a monthly basis when this bore is not dry. Three samples to date have been collected at ARP09, while the standpipes at ARP07 and ARP12 have been consistently dry since installed. Water within ARP08 is understood to be residual water from drilling.

Groundwater quality time series data and a Piper Diagram of major ion concentrations are shown in Appendix B.

Production bore AM2B-1

The production bore extracts groundwater from the Shoalhaven Group for use in operations at Airly Mine.

Based on the monitoring data, groundwater from the Shoalhaven Group is slightly acidic and highly brackish to saline. The groundwater is very hard and of magnesium sulfate type. This water type corresponds to that of Airly Creek.

Dissolved iron, manganese, nickel and zinc concentrations consistently exceed ANZECC/ARMCANZ (2000) default trigger values for the protection of 95% freshwater aquatic ecosystems. Considering the electrical conductivity (EC) and metal concentrations, this groundwater source is considered suitable for stock watering and industrial use. Water management systems at the surface facilities area ensure that groundwater from the production bore is not discharged directly to Airly Creek. Due to the relatively poor quality of groundwater extracted from the production bore Airly Mine is investigating external sources of water.

ARP05

Alluvial monitoring bore ARP05 is an open standpipe screened within sandy alluvium associated with Gap Creek.

Groundwater quality time series data for ARP05 as well as a Piper Diagram of major ion concentrations are also shown in Appendix B. Based on the monitoring data, the alluvial groundwater at this location is fresh and slightly acidic.

The alluvial groundwater at ARP05 is a sodium – chloride/bicarbonate type water as shown in the Piper Diagram in Appendix B. The water type is similar to that of Gap Creek, suggesting that there is connection between the alluvial groundwater and Gap Creek. All dissolved metal concentrations at ARP05 have been below ANZECC/ARMCANZ (2000) default trigger values for the protection of 95% freshwater aquatic ecosystems with the exception of dissolved copper and dissolved zinc. Dissolved nickel concentrations also exceeded ANZECC/ARMCANZ (2000) default trigger values for the protection of 95% freshwater aquatic ecosystems on two occasions. Based on the available water quality data, this alluvial groundwater source is considered suitable for environmental protection as well as domestic and agricultural use.

ARP09

Monitoring bore ARP09 is installed within Genowlan Creek alluvium downstream of the Grotto. The standpipe has been dry for most of the monitoring period with the exception of small temporary responses to rainfall in the order of 0.1 m to 0.3 m.

Based on the three samples collected to date, the groundwater is fresh and slightly acidic and of calcium bicarbonate type. As shown in the Piper Diagram in Appendix B, there is a notable difference in water type between ARP09 and Genowlan Creek surface water suggesting that there is minimal connection between the alluvial groundwater at ARP09 and Genowlan Creek.

Dissolved metal concentrations were below ANZECC/ARMCANZ (2000) default trigger values for the protection of 95% freshwater aquatic ecosystems with the exception of dissolved copper and zinc. This groundwater source would be considered suitable for environmental protection as well as domestic and agricultural use.

ARP11

Monitoring bore ARP11 is installed within sediments above the outcropping Narrabeen Sandstone/Permian coal measures. ARP11 is located near Gap Creek.

Based on monitoring data, groundwater at ARP11 is slightly brackish and very slightly acidic. Water type at ARP11 is sodium – bicarbonate/chloride. As shown in the Piper Diagram in Appendix B, water type at ARP11 differs from water type at ARP05 and Gap Creek. This difference may be attributable to the location of ARP11, installed in the weathered sediments above Gap Creek.

Dissolved chromium, copper, iron and zinc exceed ANZECC/ARMCANZ (2000) default trigger values for the protection of 95% freshwater aquatic ecosystems. Dissolved lead concentration also exceeded ANZECC/ARMCANZ (2000) default trigger values for the protection of 95% freshwater aquatic ecosystems on one occasion.

ARP13SP

Monitoring bore ARP13SP is installed within the Lithgow Seam. Based on monitoring data, groundwater at ARP13SP is slightly brackish and generally slightly basic and of sodium/calcium – bicarbonate water type. As shown in the Piper Diagram in Appendix B, water type at ARP13SP differs from all other monitoring locations. This difference is likely attributable to ARP13SP being the only monitoring bore installed within the Lithgow Seam.

Dissolved metal concentrations were below ANZECC/ARMCANZ (2000) default trigger values for the protection of 95% freshwater aquatic ecosystems with the exception of dissolved copper, iron and zinc.

ARP14

ARP14 is installed with Genowlan Creek alluvium.

Based on monitoring data, the groundwater at ARP14 is generally fresh and slightly acidic and of sodium – bicarbonate/chloride water type. As shown in in the Piper Diagram in Appendix B, there is a notable difference in water type between ARP14 and Genowlan Creek surface water (monitored at the Grotto) and Genowlan Creek 2 surface water. This indicates that there is minimal connection between surface water within Genowlan Creek and groundwater at ARP14.

Dissolved metal concentrations were below ANZECC/ARMCANZ (2000) default trigger values for the protection of 95% freshwater aquatic ecosystems with the exception of dissolved copper, iron and zinc. This groundwater source would be considered suitable for environmental protection as well as domestic and agricultural use.

ARP15SP

ARP15SP is installed within the Narrabeen Sandstone. Based on monitoring data, groundwater at ARP15SP is fresh and varies from slightly acidic to slightly basic. Water type at ARP15SP is calcium/sodium – chloride/bicarbonate. As shown in the Piper Diagram in Appendix B, water type at ARP15SP differs from all other monitoring locations. This difference is likely attributable to ARP15SP being the only standpipe monitoring bore installed within the Narrabeen Sandstone that has encountered groundwater.

The majority of sampled dissolved metals including cadmium, chromium, copper, iron, lead, nickel and zinc were above ANZECC/ARMCANZ (2000) default trigger values for the protection of 95% freshwater aquatic ecosystems.

4.2.3 Groundwater seepage

Village Spring

The rate of seepage of groundwater from the Permian strata at Village Spring has been monitored since February 2011. A plot of the daily groundwater seepage rate at Village Spring is shown in Appendix B. Between February 2011 and August 2013, the average rate of seepage at Village Spring was approximately 4.8 kL/day. Between September 2013 and December 2014, the average rate of seepage from Village Spring was 2.8 kL/day. From January 2015 onwards, flow data observation at Village Spring has been intermittent due to vandalism and a malfunctioning datalogger. When data have been available from 2015 onwards, the typical rate of seepage has been between 1 kL/day and 2 kL/day.

As shown in Appendix B, the water at Village Spring is fresh and slightly alkaline and of calcium/magnesium-bicarbonate type. The majority of dissolved metal concentrations are generally below the limit of recording of laboratory analysis with the exception of manganese, nickel and zinc. The majority of dissolved metal concentrations are below ANZECC/ARMCANZ (2000) default trigger values for the protection of 95% freshwater aquatic ecosystems with the exception of dissolved zinc. It is most likely that this seepage is coming from the old shale workings rather than from natural groundwater seepage.

Mine workings

The seepage of groundwater into the existing Lithgow Seam workings has been reported to be low (not measureable) by Centennial Airly. There has been limited dewatering of the underground workings to date. Calculations indicate that this water is predominately water transferred from the surface that has accumulated in the underground workings over a number of years.

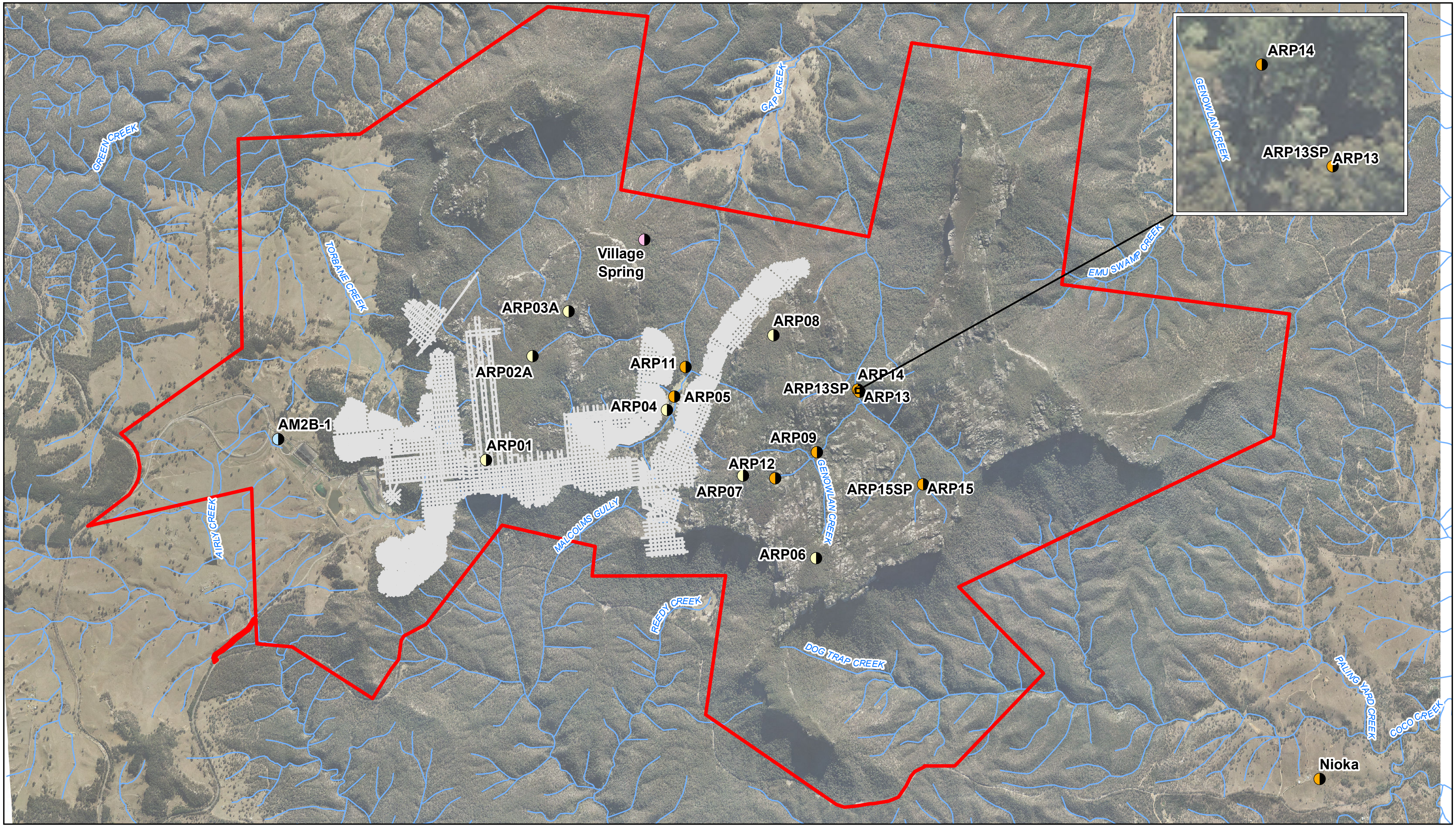
Creek baseflow

The seepage of groundwater into Gap Creek and Genowlan Creek is minimal and is generally not detected at the existing surface water flow gauges on these creeks except possibly during rainfall periods.

4.2.4 Sampling of private bores

The private registered bore GW103410 (Nioka) was sampled in December 2013 and January 2014 to characterise the quality of the lower Devonian regional aquifer. Private registered bore GW103410 was monitored on a quarterly basis during 2018 with quarterly monitoring to continue. The bore is located to the south-east of the Project Application Area as shown in Figure 4-1.

The groundwater at this location is slightly alkaline and slightly brackish. As shown by the Piper Diagram in Appendix B, the groundwater is calcium – bicarbonate/sulfate dominant and therefore considerably different from Shoalhaven Group groundwater.



Paper Size A4

0 200 400 800 1,200 1,600

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

LEGEND

- Groundwater seepage
- Production bore
- Standpipe monitoring bore
- Vibrating wire piezometer
- Project Approval Area SSD_5581
- Existing workings
- Waterway

Airly Mine
Airly Mine Mod 3
Groundwater Impact Assessment

Job Number 22-19275
Revision 0
Date 7 Jun 2019

Groundwater monitoring network

Figure 4-1

G:\22\0105001\GIS\Maps\Deliverables\Western\Airly\2219275\GWIA\2219275_GWIA005_GWMonitoringBores_A.mxd

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

Data source: LPI: DTDB 2012; Centennial: Imagery, monitoring, boundaries, survey. Created by: smacdonald

5. Impact assessment methodology

Potential groundwater impacts from the Project on the sensitive groundwater sources identified in Section 3.8 have been predicted by construction and calibration of a numerical hydrogeological model. Impacts have been assessed in accordance with the criteria from the NSW AIP.

5.1 Impact prediction

The hydrogeological model was initially developed as part of the Airly Mine Extension Project. The development of the hydrogeological model is outlined in the *Airly Mine Extension Project Hydrogeological Model Report* (GHD, 2014b). The hydrogeological model has been updated and recalibrated since the approval of SSD_5581, accounting for updated monitoring data. The recalibrated hydrogeological model has been independently reviewed by Dr Noel Merrick. Details of the update and recalibration of the hydrogeological model are outlined in GHD (2019a).

The recalibrated hydrogeological model was used to predict for both 1.8 Mtpa and 3.0 Mtpa production rate scenarios:

- Groundwater inflows as a result of the development of the mine workings.
- Drawdown in groundwater sources.
- Changes in baseflow.
- Approximate recovery times in groundwater levels and baseflow.

5.1.1 Approved and proposed conditions

The recalibrated model has been used to make predictions under both approved (maximum mining rate of 1.8 Mtpa) and proposed (maximum mining rate of 3.0 Mtpa) conditions. Predicted impacts have been compared to impacts presented in GHD (2014a) for approved conditions based on the original model. However, it should be noted that the only valid comparison is between the proposed 3.0 Mtpa scenario and the approved 1.8 Mtpa scenario using the recalibrated model.

5.1.2 Predictive simulations

Two scenarios were modelled for both the approved (1.8 Mtpa mining rate) and proposed (3 Mtpa mining rate) conditions. These scenarios (1 and 2) are detailed in the *Hydrogeological Model Report* (GHD, 2019a). As outlined in GHD (2019a), Scenario 2 predictions have been adopted for this groundwater impact assessment as well as for the site water balance assessment for the Project. This is because the height of fracturing adopted for Scenario 2 (i.e. 75 m) is more conservative than Scenario 1 (height of fracturing 23 m) and closer to the 60 m estimate reported recently by Strata2 (2019). With the Scenario 2 predictions, the modelled inflow rate is likely to be greater than the actual inflow rates given that the 75 m height of fracturing over the panel and pillar zone (with void widths of 61 m and inter-panel widths of 35 m) in the model is conservative (David King, pers comm). With the commencement of the extraction of the 61 m void width panels in June 2019 and the completion of this panel in August 2019, it has been reported that there have been no measurable mine inflows (David King, pers comm).

In addition to running the model using best fit model parameters, uncertainty analysis was undertaken using a range of parameters to determine a range of possible groundwater inflows into the mine for the proposed (3 Mtpa) case.

A review of the potential effect of lineaments on groundwater predictions and groundwater / surface water interactions has also been undertaken, including modelling of the Gap Creek lineament zone to assess the effect on groundwater levels and inflows into mine workings.

5.2 Impact assessment criteria

The AIP requires that potential impacts on the groundwater sources, including their users and GDEs, be assessed against minimal impact considerations, outlined in Table 1 of the Policy. If the predicted impacts are less than the minimal impact considerations, then these impacts will be considered as acceptable. The Level 1 minimal impact considerations have been adopted for this groundwater impact assessment and are outlined in Section 2.2.2.

6. Impact assessment

6.1 Impact prediction

6.1.1 Groundwater flows

Predicted groundwater inflow rates into the underground workings are presented in Figure 6-1. Using the recalibrated hydrogeological model groundwater inflow rates have been presented for the approved 1.8 Mtpa mining rate and the proposed 3 Mtpa mining rate. Groundwater inflows have been presented for Scenario 2 only as outlined in Section 5.1.2.

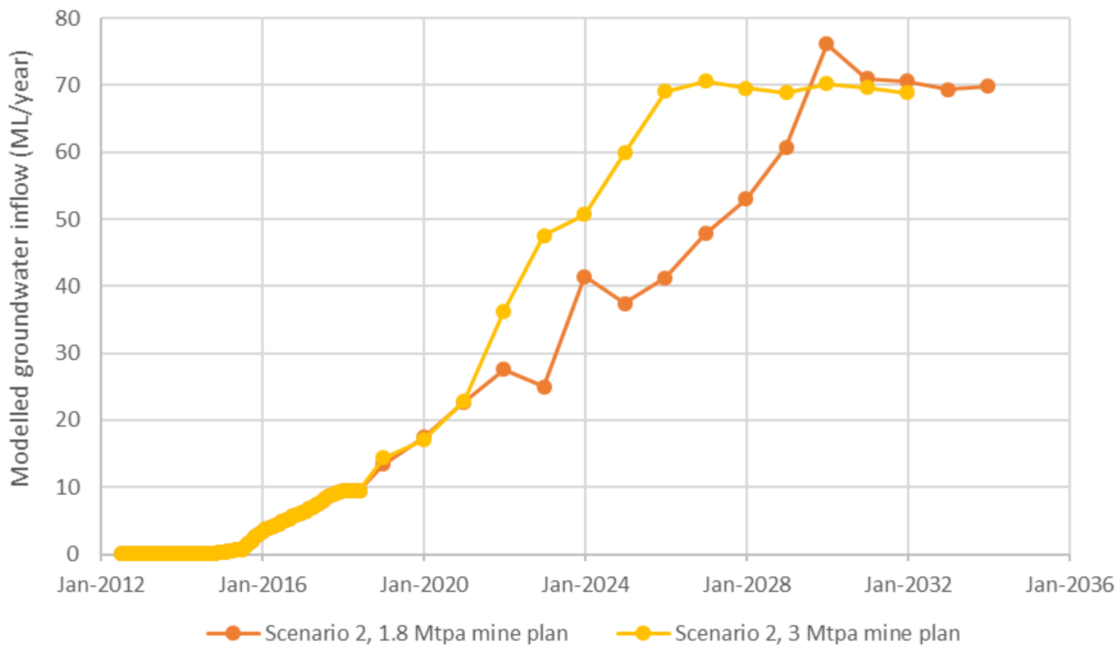


Figure 6-1 Modelled groundwater inflows into mine workings

Under Scenario 2 and the 3 Mtpa mining rate the modelled groundwater inflow rate increases over time to a peak of 71 ML/year in 2027, before gradually decreasing, to 69 ML/year in 2031, the final year of mining.

Under the proposed 3 Mtpa mining rate the peak inflow is predicted to occur earlier than for the approved 1.8 Mtpa mining rate, however the peak inflow is predicted to be slightly higher for the 1.8 Mtpa mining rate (76 ML/year). Note that under the 1.8 Mtpa mining rate, mining is scheduled to finish in 2033. Mine inflows for both the 1.8 Mtpa mining rate and the 3 Mtpa mining rate are similar at the end of mining as the mine plan has the same footprint for both scenarios. Therefore at the end of mining in both scenarios, groundwater inflow into the mine is occurring into the same mine area resulting in similar inflows.

Modelled mine inflows for approved and proposed conditions as presented in Figure 6-1 are lower than mine inflows modelled by GHD (2014a). Mine inflows for Scenario 2 for the 1.8 Mtpa mine plan as modelled by GHD (2014a) are shown in Figure 6-2. Mine inflows modelled by the recalibrated model are considerably lower. Observed mine inflows have been low (not measureable) to date and therefore the lower inflows modelled by the recalibrated model are considered to be more realistic.

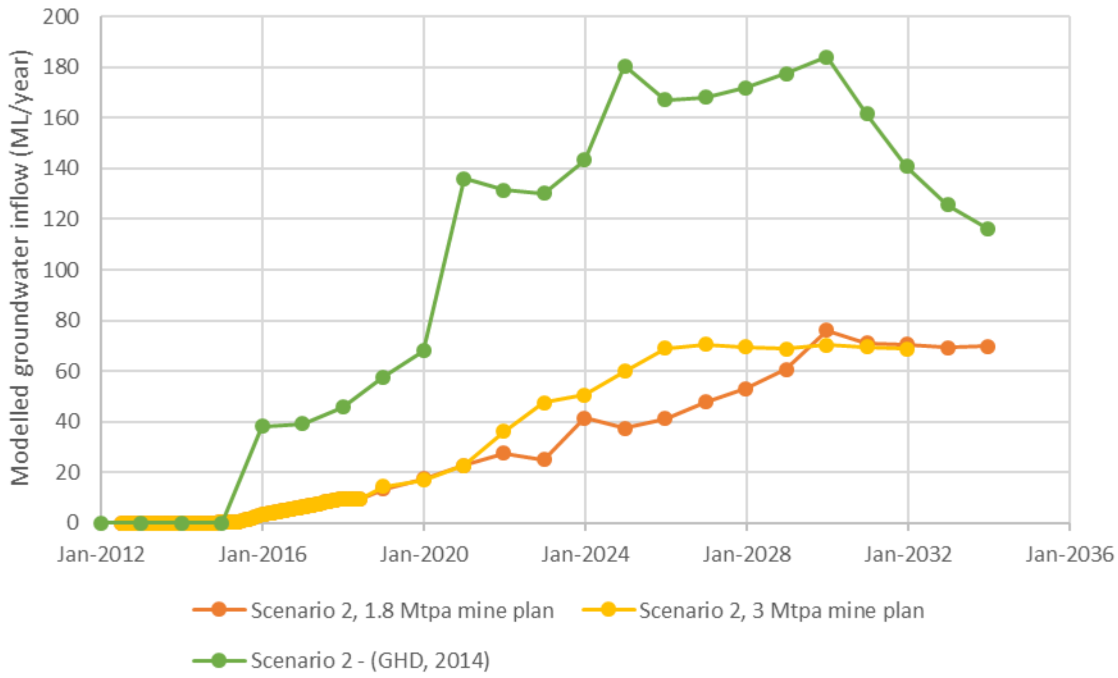


Figure 6-2 Comparison with predicted mine inflows modelled by GHD (2014)

Uncertainty analysis

Uncertainty analysis of groundwater inflow predictions has been undertaken in accordance with the requirements of the *Information guidelines for proponents preparing coal seam gas and large coal mining development proposals* (IESC, 2018a) and the *Explanatory Note on Uncertainty Analysis in Groundwater Modelling* (IESC, 2018b).

IESC (2018b) outlines three general approaches to uncertainty analysis with respect to groundwater modelling and these, in order of increasing complexity and computational resource requirements, are: *'(1) scenario analysis with subjective probability, (2) deterministic modelling with linear probability quantification and (3) stochastic modelling with Bayesian probability'*.

Based on the risk assessment of the groundwater environment at Airly Mine (summarised in Appendix D), the adopted approach for uncertainty analysis was 'scenario analysis with subjective probability'. The risk of impact on the local and regional groundwater environment due to the operation of Airly Mine is considered to be low, based on the limited number of receptors (GDEs and landholder bores), the low connectivity between shallow alluvial groundwater and the coal seam and the adopted mining method.

Based on the adopted methodology, five uncertainty runs were considered as part of uncertainty analysis of groundwater inflows. Uncertainty runs were undertaken for proposed conditions only. In each of these uncertainty runs, model parameters were varied. The hydrogeological model was run for each uncertainty run under steady state and transient conditions. Parameters varied in each uncertainty run are summarised below:

- Uncertainty run 1: rainfall recharge multiplied by 2. Rainfall recharge for this scenario was 6.58×10^{-5} m/day.
- Uncertainty run 2: hydraulic conductivity of coal and Marrangaroo multiplied by 2.
- Uncertainty run 3: hydraulic conductivity of Marrangaroo multiplied by 2, rainfall recharge increased to 1.7% of 90th percentile annual rainfall (to 4.34×10^{-5} m/day), hydraulic conductivity of Lithgow Seam (Layer 8) coal increased by 4.

- Uncertainty run 4: model storage increased ×10, fracture height of 75 m, increased vertical and horizontal hydraulic conductivity of fracture area, increased rainfall recharge.
- Uncertainty run 5: model storage decreased ×10, fracture height of 23 m, reduced vertical and horizontal hydraulic conductivity of fracture area, reduced rainfall recharge.

Note that fracture height was maintained at 23 m for uncertainty runs 1, 2 and 3. Rainfall recharge for the best fit model run and for uncertainty runs 2, 4 and 5 was 3.29×10^{-5} m/day.

Parameters modified as part of the uncertainty analysis were selected with consideration of the likely sensitive model parameters. These parameters were determined based on experience and were subject to critique by the third party reviewer, as required by the NSW AIP (DPI, 2012). Model parameters were increased or decreased to provide a range of estimated groundwater inflows.

Model results were analysed to identify potential changes to impacts on groundwater receptors. Calibration statistics were reviewed for each uncertainty run. Calibration statistics were used to identify the likelihood of the selected parameters of each uncertainty run occurring. Model calibration statistics are summarised in Table 6-1

Table 6-1 Uncertainty analysis – model calibration statistics

Model run	Steady state calibration – Scaled Root Mean Squared Error	Transient calibration – Root Mean Squared Error (m)	Transient calibration – Scaled Root Mean Squared Error
Best fit model run	5.3%	10.5	4.1%
Uncertainty run 1	8.1%	21.7	8.4%
Uncertainty run 2	5.3%	11.2	4.3%
Uncertainty run 3	5.7%	12.4	4.8%
Uncertainty run 4	8.1%	21.8	8.4%
Uncertainty run 5	7.6%	16.5	6.2%

Uncertainty runs that include changing rainfall recharge and storage (run 1, run 4 and run 5) result in large changes in calibration statistics. The poor fit between model results and observed groundwater levels (Table 6-1) indicates that the parameters and associated impacts for these uncertainty runs are not realistic and are unlikely to occur.

Uncertainty runs that include modifying hydraulic conductivities (run 2 and run 3) result in calibration statistics that are similar to the best fit model run. The reasonable fit between model results and observed groundwater levels indicates that these uncertainty runs may provide a reasonable prediction of future impacts from mining. Peak groundwater inflow for the best fit model is 71 ML/year, peak inflow for run 2 is 47.1 ML/year and peak inflow for run 3 is 57.7 ML/year.

The modelled groundwater inflows into the mine for each of the uncertainty analysis runs have been compared with modelled groundwater inflows (under proposed conditions) for the best fit model scenario and are shown in Figure 6-3. While run 1 and run 4 result in increased modelled groundwater inflows, the poor calibration statistics indicate parameters associated with these uncertainty runs are not likely to occur.

As panel and pillar mining has not yet commenced at Airly Mine, it is difficult to verify the hydraulic properties of goaf areas. Continued monitoring of groundwater levels and mine inflows following the commencement of panel and pillar mining will provide monitoring data estimating hydraulic properties of goaf areas. Monitoring of the fracture height will be reviewed following extraction of the first four panels within the panel and pillar zone. Further recalibration of the model will be undertaken if required following review of this data.

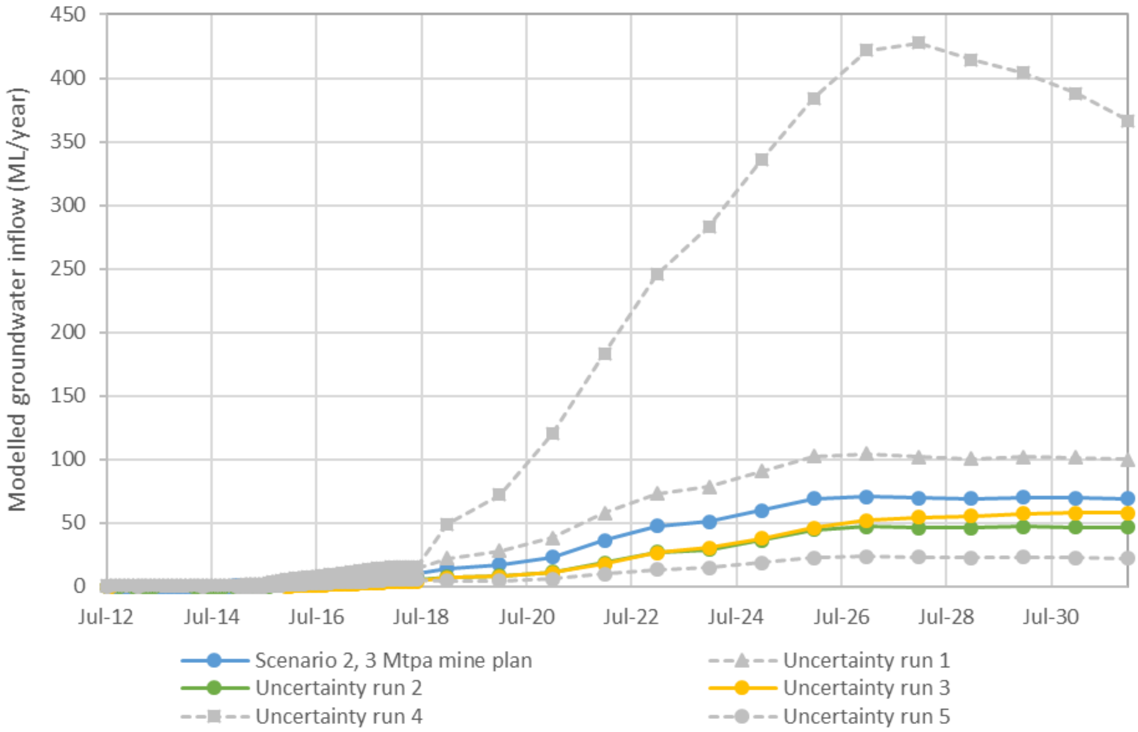


Figure 6-3 Modelled mine inflows – uncertainty analysis

6.1.2 Groundwater drawdown and recovery

Groundwater drawdown predictions for the approved (1.8 Mtpa mining rate) and proposed (3 Mtpa mining rate) conditions (Scenario 2 only) are included in Appendix C. Groundwater drawdown predictions have been presented for end of mining and for 30 years after the end of mining. A summary of maximum groundwater drawdown for approved conditions (EIS and recalibrated model) and proposed conditions is provided in Table 6-2.

The recalibrated model predicts that maximum groundwater drawdown within the shallow zone / alluvium will generally be lower for both approved and proposed conditions (up to 2.0 m) compared to the drawdown predicted for approved conditions as part of the EIS (GHD, 2014), with the exception of a small area within Genowlan Creek. This area is not part of the Grotto or Oasis. Under proposed conditions, groundwater drawdown within Gap Creek alluvium is predicted to peak at 1.9 m. Drawdown within Genowlan Creek is also expected to peak at 1.9 m. Under approved conditions, the recalibrated model predicts that groundwater drawdown within Gap Creek alluvium will peak at 2.0 m, which is slightly greater than under proposed conditions. Drawdown within Genowlan Creek is expected to peak at 1.9 m under approved conditions. The slightly greater drawdown under approved conditions is attributable to the longer period of mining and dewatering of the mine, allowing additional time for the drawdown to occur.

The extent of drawdown in the Lithgow Seam and the Marrangaroo Formation is limited by the outcrop of these seams. The drawdown contours show that for both approved and proposed conditions, drawdown in the Lithgow Seam and the Marrangaroo Formation is generally limited to within 300 m of the Project Application Area. For drawdown at end of mining for proposed conditions for the Lithgow Seam and the Marrangaroo Formation refer to Figure C-2 and Figure C-3 respectively. For drawdown at end of mining for approved conditions for the Lithgow Seam and the Marrangaroo Formation refer to Figure C-10 and Figure C-11 respectively.

As shown in Figure C-4 and Figure C-12, drawdown at end of mining in the Upper Shoalhaven Group is generally less than or equal to 1 m at the Project Application Area boundary for approved and proposed conditions with maximum drawdown up to approximately 7 m within the Project Application Area.

Maximum predicted groundwater drawdown for approved conditions reported as part of the Airly Mine Extension Project (GHD, 2014b) is generally lower for the Permian strata and the Shoalhaven Group compared to the predictions by the recalibrated model for approved and proposed conditions as shown in Table 6-2. This is due to the process of recalibration of the model, which has modified hydraulic conductivity and storage properties of the strata to better match observed data. As discussed in Section 1.2 of GHD (2019a), the original model (GHD, 2014b) was found to under-predict drawdown in the Lithgow Seam and Marrangaroo Formation at one monitoring location (ARP04). In addition, the process of model recalibration (GHD, 2019a) involved dividing the bottom layer (regional aquifer) into three layers. As a result, the recalibrated model predicts drawdown in each of these layers whereas the EIS model predicted only bulk (average) drawdown over the entire thickness. As such, predicted drawdown in the upper layer of the Shoalhaven Group in the recalibrated model would be expected to be higher than the overall average drawdown throughout the entire unit within the EIS model.

As shown in Table 6-2, there is minimal difference in predicted drawdown between approved and proposed conditions for the recalibrated model.

Groundwater recovery

Groundwater drawdown contours for 30 years after the end of mining have been prepared to examine groundwater recovery after the end of mining.

Comparison of drawdown in the alluvium/shallow strata for proposed conditions between the end of mining (Figure C-1) and 30 years after the end of mining (Figure C-5) indicate that within 30 years after the end of mining, drawdown in the alluvium/shallow zone will almost completely recover, with only isolated areas of groundwater drawdown remaining at this time. Under proposed conditions, following 30 years after the end of mining maximum drawdown of 1 m is predicted in the Gap Creek catchment and maximum drawdown of 0.2 m is predicted in the Genowlan Creek catchment. Assuming median rainfall, groundwater drawdown in the Gap Creek and Genowlan Creek will have recovered by 1.0 m to 1.7 m from maximum by 2062. Under approved conditions, groundwater drawdown in the Gap Creek and Genowlan Creek will have recovered by 1.5 m to 1.6 m from maximum by 2064.

Groundwater is predicted to largely recover in the Lithgow Seam 30 years after the end of mining. Comparison of drawdown contours within the Lithgow Seam for end of mining (Figure C-2) and 30 years after mining (Figure C-6), indicate that by 2032 the radius of depressurisation within the Lithgow Seam is greatly reduced and levels have almost recovered to pre-mining levels with maximum drawdown of 0.3 m at this time (Table 6-2).

Similarly to the Lithgow Seam, groundwater has largely recovered in the Marrangaroo Formation 30 years after the end of mining. Comparison of groundwater drawdown for within the Marrangaroo Formation at the end of mining (Figure C-3) and 30 years after mining (Figure C-7) indicate that within 30 years after the end of mining the radius of depressurisation within the Marrangaroo Formation has greatly reduced and levels have almost recovered to pre-mining levels with maximum drawdown of 0.4 m at this time (Table 6-2).

As shown in Figure C-8 and Figure C-16, drawdown 30 years after the end of mining in the Upper Shoalhaven Group is generally less than or equal to 0.2 m at the Project Application Area boundary for approved and proposed conditions (Scenario 2).

Overall, similar groundwater recovery is predicted under both approved and proposed conditions based on the recalibrated model (Table 6-2).

Table 6-2 Maximum modelled drawdown – Scenario 2

Strata	Approved (GHD, 2014)		Approved (recalibrated model)		Proposed	
	End of mining	30 years after end of mining	End of mining	30 years after end of mining	End of mining	30 years after end of mining
Shallow/alluvium	3.5 m (Gap Creek) 1.1 m (Genowlan Creek)	Not assessed	2.0 m (Gap Creek) 1.9 m (Genowlan)	0.4 m (Gap Creek and Genowlan Creek)	1.9 m (Gap Creek and Genowlan Creek)	1.0 m (Gap Creek catchment) 0.2 m (Genowlan Creek)
Permian (local)	7.5 m (Permian Siltstone) 6.2 m (Lithgow Seam) 6 m (Marrangaroo)	Not assessed	16.1 m (Lithgow Seam) 16.1 m (Marrangaroo)	0.3 m (Lithgow Seam) 0.3 m (Marrangaroo)	16.5 m (Lithgow Seam) 16.4 m (Marrangaroo)	0.3 m (Lithgow Seam) 0.3 m (Marrangaroo)
Shoalhaven	0.1 m	Not assessed	7.3 m	0.4 m	7.4 m	0.4 m

6.1.3 Baseflow

Flow budgets for proposed and approved conditions have been compared in order to assess potential changes in baseflow as a result of the Project. The flow budget has been shown for Scenario 2 for the final year of mining (2031) for the 3 Mtpa mine plan (proposed conditions) and the final year of mining (2033) for the 1.8 Mtpa mine plan (approved conditions). The average flow budget over the period of mining has also been presented for each scenario. The flow budget table is shown in Table 6-3.

Comparison of flow budgets for proposed and approved conditions indicates baseflow to watercourses from the alluvium, and seepage to the surface from outcropping rock is slightly greater at the end of mining under proposed conditions. This is indicated by the higher flows for outputs via drains as shown in Table 6-3.

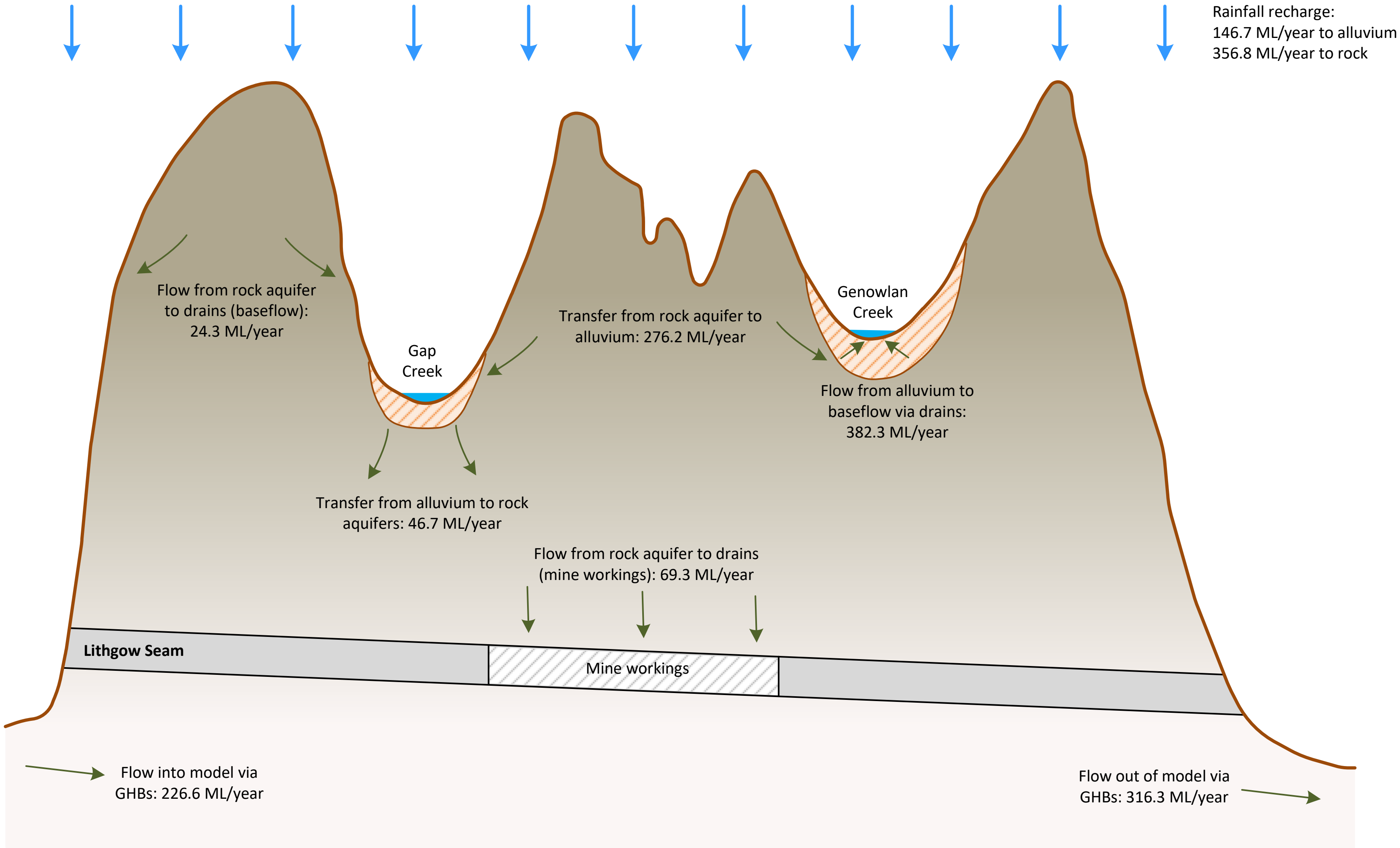
The flow budget is presented in a schematic for approved conditions at end of mining in Figure 6-4 and for proposed conditions at end of mining in Figure 6-5.

Table 6-3 Transient flow budget

Condition	Zone	Inputs (ML/year)					Outputs (ML/year)				
		Recharge	GHB	Storage	Other zones	Total	Drains [1]	GHB	Storage	Other zones	Total
Approved conditions Average	All zones	503.5	226.5	45.4	–	775.4	449.8	316.5	9.6	–	775.9
	Alluvium	146.7	0.0	17.1	290.1	453.9	402.7	0.0	5.3	46.2	454.2
	Rock	356.8	226.5	28.3	46.2	657.8	47.1 [2]	316.4	4.3	290.1	657.9
Approved conditions End of mining	All zones	503.5	226.7	82.2	–	812.4	475.9	316.2	19.6	–	811.7
	Alluvium	146.7	0.0	25.4	276.2	448.3	382.3	0.0	18.6	46.7	447.6
	Rock	356.8	226.6	56.8	46.7	686.9	93.6 [3]	316.3	1.0	276.2	687.1
Proposed conditions Average	All zones	503.5	226.5	42.4	–	772.4	449.8	316.5	9.6	–	775.9
	Alluvium	146.7	0.0	9.0	288.7	444.3	395.5	0.0	3.4	46.1	444.9
	Rock	356.8	226.5	33.4	46.1	662.9	54.3 [4]	316.5	6.3	288.7	665.8
Proposed conditions End of mining	All zones	503.5	226.7	82.2	–	812.4	475.9	316.2	19.6	–	811.7
	Alluvium	146.7	0.0	16.0	276.0	438.7	385.3	0.0	6.9	46.2	438.5
	Rock	356.8	226.7	66.2	46.2	695.9	90.5 [5]	316.2	12.7	276.0	695.5

Notes:
1. Outputs from alluvium via drains is seepage to surface and baseflow. Outputs from rock via drains includes mine dewatering and baseflow/seepage to surface.
2. Of average transfers from rock aquifers to drains, 34.9 ML/year is mine dewatering and 12.2 ML/year is baseflow.
3. Of transfers from rock aquifers to drains, 69.3 ML/year is mine dewatering and 24.3 ML/year

is baseflow.
4. Of average transfers from rock aquifers to drains, 40 ML/year is mine dewatering and 14.3 ML/year is baseflow.
5. Of transfers from rock aquifers to drains, 68.9 ML/year is mine dewatering and 21.6 ML/year is baseflow.



Legend

Alluvium

Groundwater flow

Centennial Airly
Airly Mine Mod 3
Groundwater Impact Assessment

Flow Budget
Approved conditions - End of mining

Project No. 22-19275
Revision No. 0
Date 31/07/2019

FIGURE 6-4

Created by: Suzanne MacDonald

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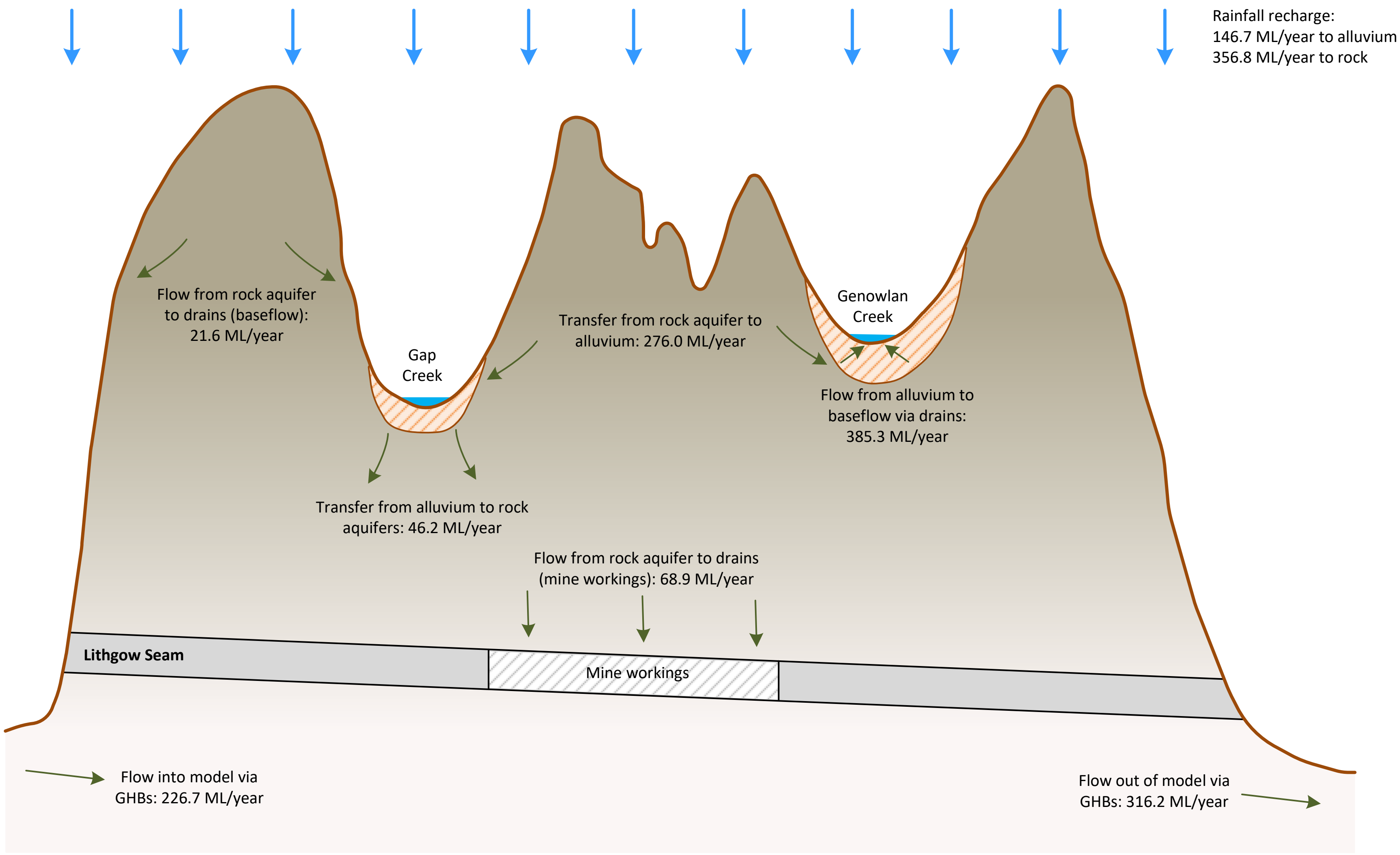

Legend

Alluvium

Groundwater flow

Centennial Airly
Airly Mine Mod 3
Groundwater Impact Assessment

Flow Budget
Proposed conditions - End of mining

Project No. 22-19275
Revision No. 0
Date 31/07/2019

FIGURE 6-5

Created by: Suzanne MacDonald

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Baseflow has been calculated for Gap Creek at the boundary of the Project Application Area, Genowlan Creek at the boundary of the Project Application Area and for the confluence of Genowlan Creek and Gap Creek as shown in Figure 6-6, Figure 6-7 and Figure 6-8 respectively. Baseflow has been calculated as flow out of the model via drains assigned across the top of Layer 1 of the model. Refer to Section 4 of GHD (2014b) for additional details regarding model boundary details.

Baseflow for Gap Creek and Genowlan Creek decreases throughout the period of mining. The reduction in baseflow is slightly greater for approved conditions than proposed conditions. The peak in reduction in baseflow occurs slightly later for approved conditions due to the end of mining occurring later. The modelled pre mining baseflow and the minimum modelled baseflow for Gap Creek and Genowlan Creek is summarised in Table 6-4. For comparison, baseflow for the whole of the whole of the model domain is also included in Table 6-4.

Under proposed and approved conditions, after the end of mining, baseflow is modelled to gradually recover to pre-mining rates. Within Gap Creek and Genowlan Creek, baseflow is modelled to return to pre-mining rates within 50 years of the end of mining.

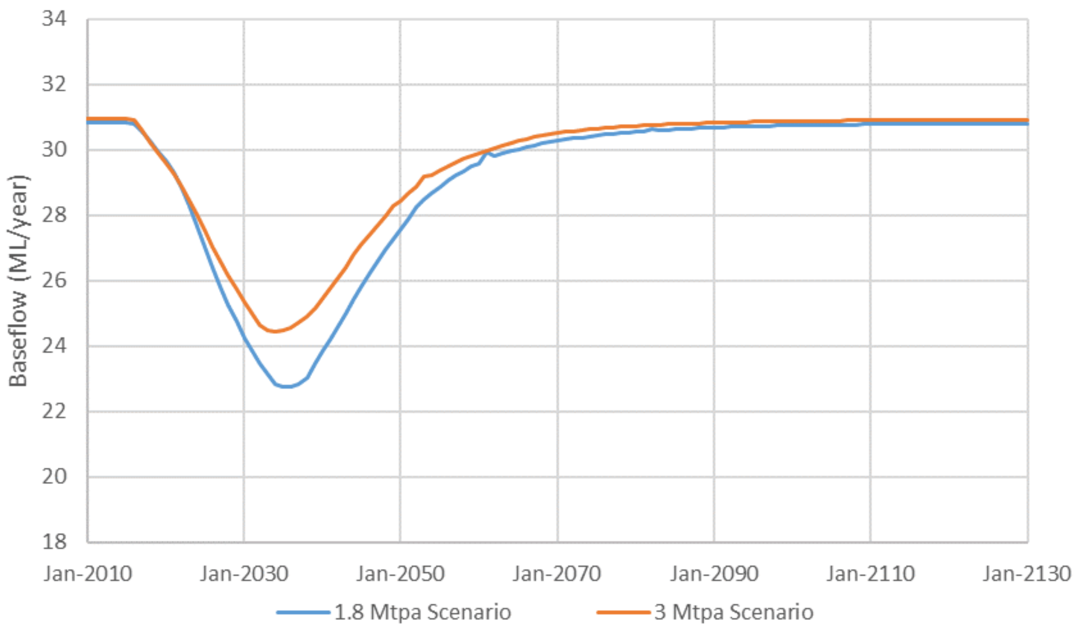

Figure 6-6 Baseflow at Gap Creek at Project Application Area boundary

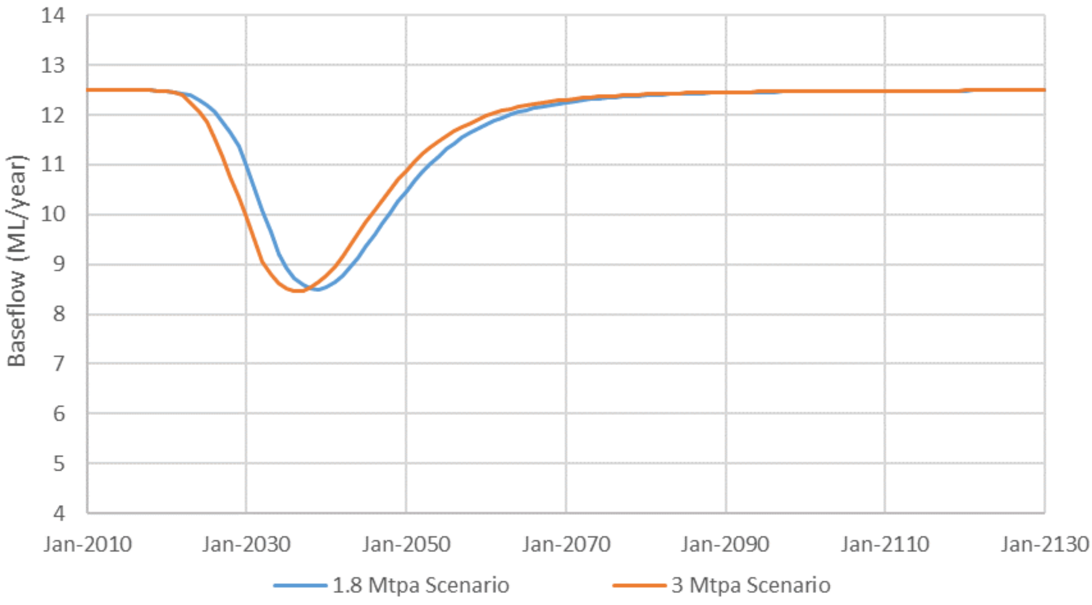

Figure 6-7 Baseflow at Genowlan Creek at Project Application Area boundary

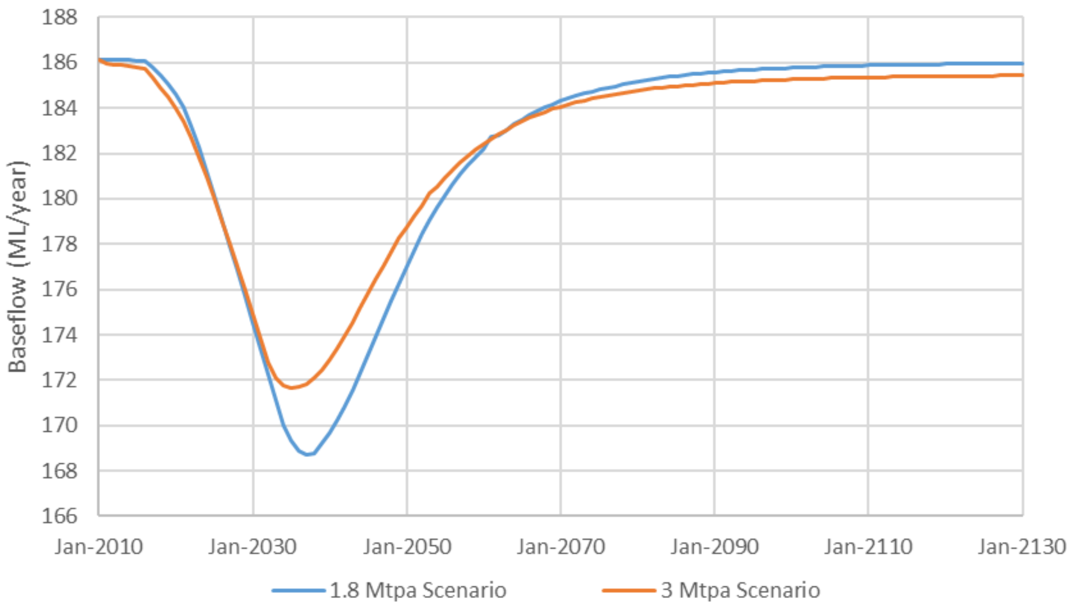

Figure 6-8 Baseflow at confluence of Gap Creek and Genowlan Creek

In addition to the predicted change in baseflow, Table 6-4 also provides an indication of the predicted reduction in total annual flows (i.e. including catchment runoff) as a result of changes in baseflow for average rainfall conditions in the Gap Creek and Genowlan Creek catchment.

In order to evaluate the impact of the change in baseflow on total annual flow it was assumed that catchment runoff was equal to 5% of the mean annual rainfall. This method was adopted in GHD (2014c). As discussed in GHD (2014c), annual runoff is likely to be more than 5% of annual rainfall due to the rocky nature and steep topography of the catchment. Therefore, the estimated reduction of total annual flow is conservative (i.e. impacts are likely to be less than indicated.

Table 6-4 Potential changes in baseflow

Location	Approved (GHD, 2014)			Approved (recalibrated model)			Proposed		
	Pre-mining* (ML/year)	Minimum baseflow (ML/year)	Estimated reduction of total annual flow (under average rainfall conditions)	Pre-mining* (ML/year)	Minimum baseflow (ML/year)	Estimated reduction of total annual flow (under average rainfall conditions)	Pre-mining* (ML/year)	Minimum baseflow (ML/year)	Estimated reduction of total annual flow (under average rainfall conditions)
Whole of model domain	581.2	506.1	Not assessed	414	393.4	Not assessed	414	394.6	Not assessed
Gap Creek at Project Application Area boundary	32.1	25.9	3.4%	30.9	22.7 [1]	4.5%	31.0	24.4 [2]	3.6%
Genowlan Creek at Project Application Area boundary	9.2	5.4	2.1%	12.5	8.5 [3]	2.2%	12.5	8.5 [4]	2.2%
Confluence of Gap Creek and Genowlan Creek	198	170.9	3.3%	186.1	168.7 [5]	2.1%	186.1	171.7 [6]	1.8%

*Pre-mining refers to January 2010

1. Value corresponds with the low point of the blue line on Figure 6-6.

2. Value corresponds with the low point of the orange line on Figure 6-6.
3. Value corresponds with the low point of the blue line on Figure 6-7.
4. Value corresponds with the low point of the orange line on Figure 6-7.
5. Value corresponds with the low point blue line on Figure 6-8.
6. Value corresponds with the low point of the orange line on Figure 6-8.

Baseflow and reduction to total annual flow presented as part of the Airly Mine Extension Project (GHD, 2014) differs to baseflow and total annual flow calculated from the recalibrated model. This discrepancy is due to recalibration of the model and changes in rainfall recharge.

For the recalibrated model, the reduction in baseflow and total annual flow to Gap Creek and Genowlan Creek is greater under approved conditions than for proposed conditions. This reflects modelled baseflow presented in Figure 6-6, Figure 6-7 and Figure 6-8.

6.1.4 Lineaments

As discussed in the review of geology in Section 3.4, the geological structural review for Airly Mine (SRK, 2018) identified the potential for lineaments that extend from the Devonian basement geology to the surface. The interpretation of the geological review identified domains D, F and I (Figure 3-5) as areas where there is potential for seam to surface lineaments to occur. Domain D is typically referred to locally as the Gap Creek lineament.

Assessment of fault zones and their potential impacts on aquifer connectivity, groundwater / surface water interactions and groundwater flow was initially undertaken as part of the Response to Submissions for the Airly Mine Extension Project (GHD, 2015). The analysis undertaken has shown that lineaments have a minimal effect on groundwater at Airly Mine based on the following lines of evidence:

- There is a downward vertical flow gradient at all groundwater monitoring locations, including those in the vicinity of mapped fault zone areas. Vertical equilibration of piezometric head would be expected within a conductive fault zone.
- Horizontal groundwater flow gradients do not appear to be affected across mapped fault zones.
- The network of fractures and joints within the Triassic and Permian strata is considered to have a greater influence on groundwater flow than fault zones. These fractures direct groundwater to seepage areas and account for the relatively low piezometric head throughout Mount Airly and Genowlan Mountain, the water loss during drilling and packer testing and the unsaturated conditions in the Lithgow Seam (GHD, 2015).

Underground mining has already extended through the Gap Creek lineament zone. Observations from the underground workings indicate that there was no observable groundwater inflow during mining in this lineament zone or any groundwater inflow into this area of the mine workings since this time. Further, it is noted that mining to date has not impacted surface water flow along Gap Creek which continues to flow after periods of heavy rainfall only and continues to exhibit a similar flow pattern to Genowlan Creek. Hence there is no evidence to date that lineaments enhance the risk of impact to surface water flow due to underground mining at Airly.

The Gap Creek lineament zone has been considered in the hydrogeological model as part of alternative conceptualisations of the hydrogeological environment. The lineament zone has been considered as potentially forming a zone of enhanced hydraulic conductivity or alternatively as a horizontal flow barrier to groundwater flow due to potential discontinuities in geological formations.

As these changes were initially only implemented as part of the calibration run, they were initially only implemented in the Gap Creek lineament zone (Figure 3-5). Further details regarding the inclusion of lineaments is included in GHD (2019a).

Results of model runs that include lineaments indicate that there is negligible difference to modelled groundwater levels, groundwater baseflow or modelled mine inflows due to the inclusion of lineaments. Therefore lineaments were not considered further in predictive analysis.

6.2 Impact assessment

The assessment of potential impacts on the sensitive groundwater resources identified in Section 3.8 from proposed and approved mining conditions is detailed in this section.

6.2.1 Alluvium groundwater sources

The alluvium and Quaternary groundwater sources include Gap Creek and Genowlan Creek alluvium as well as the Quaternary groundwater sources in the upper Genowlan Creek area (known as the Oasis).

Water table

As discussed in GHD (2019a), drawdown attributable to mining has been estimated by running the model throughout the period of mining and 100 years after completion of mining to model groundwater drawdown and groundwater level recovery.

It should be noted that observations at ARP05, ARP09 and ARP12 installed in the Gap Creek and Genowlan Creek alluvium are generally dry with groundwater observed following periods of above average rainfall. As the predictive scenarios use an annual time-step they do not accurately simulate the wetting and drying of the alluvium strata and the drawdown predictions provided do not reflect the generally dry alluvium. It is predicted that this periodic wetting and drying of the alluvium will continue throughout the mining period.

Under proposed conditions, groundwater drawdown within Gap Creek alluvium is predicted to peak at 1.9 m. Drawdown within Genowlan Creek is also expected to peak at 1.9 m. Under approved conditions, the recalibrated model predicts that groundwater drawdown within Gap Creek alluvium will peak at 2.0 m, which is slightly greater than under proposed conditions. Drawdown within Genowlan Creek is expected to peak at 1.9 m under approved conditions. The slightly greater drawdown under approved conditions is attributable to the longer period of mining and dewatering of the mine, allowing additional time for the drawdown to occur.

The areas where groundwater drawdown is expected to occur within the alluvium/shallow zone strata are shown in Figure C-1 in Appendix C. No drawdown is predicted in the Grotto or Oasis areas. All drawdown within Gap Creek and Genowlan Creek alluvium is predicted to occur within 300 m of the Project Application Area.

The differences in modelled drawdown in the alluvium/shallow zone as shown in Appendix C and modelled drawdown as previously shown in GHD (2014a) are due to recalibration of the hydrogeological model.

Within the alluvial groundwater sources, since there are no identified high priority GDEs (either vegetation or stygofauna) or groundwater supply works (operating under either basic landholder rights or Water Access Licences) in the areas of groundwater drawdown, the predicted impacts are less than the Level 1 minimal impact considerations under the AIP and are therefore considered to be acceptable.

Since these groundwater sources are unconfined, the criterion for ‘Water Pressure’ does not apply.

Groundwater quality

The existing beneficial use categories for Gap Creek and Genowlan Creek alluvium are environmental protection as well as domestic and agricultural use.

Under both approved and proposed conditions, it is not expected that the predicted localised drawdown will change these categories either within the Project Application Area or further down gradient. Between August 2012 and March 2014, the groundwater level at ARP05 (Gap

Creek alluvium) fell by approximately 5.3 m likely due to a combination of climatic conditions and potentially mining influence. Over this time period, there was no noticeable change in groundwater quality. Therefore, it is not expected that groundwater drawdown will result in an increase in salinity in connected surface waters (Gap Creek and Genowlan Creek).

The beneficial use category of the alluvial groundwater is not expected to change within or outside the Project Application Area and the level of impact is less than the Level 1 minimal impact considerations under the AIP.

Baseflow

Baseflow to Genowlan Creek and Gap Creek will decrease during the period of mining under approved and proposed conditions. Under proposed conditions, the maximum reduction in baseflow at the boundary of the Project Application Area is 6.6 ML/year and 4.0 ML/year in Gap Creek and Genowlan Creek respectively. Under proposed conditions, reduction in total annual flow under average rainfall conditions at the boundary of the Project Application Area is 3.6% and 2.2% in Gap Creek and Genowlan Creek respectively. Under proposed conditions the maximum reduction in baseflow and total flow will occur in 2032, 1 year after the end of mining.

The maximum reduction in baseflow at the boundary of the Project Application Area is slightly greater under approved conditions. Under approved conditions, the maximum reduction in baseflow at the boundary of the Project Application Area is 10.9 ML/year and 6.3 ML/year in Gap Creek and Genowlan Creek respectively. Under approved conditions, reduction in total annual flow under average rainfall conditions at the boundary of the Project Application Area is 4.5% and 2.2% in Gap Creek and Genowlan Creek respectively. Under approved conditions the maximum reduction in baseflow and total flow will occur in 2034, 1 year after the end of mining. The slightly greater loss of baseflow under approved conditions is attributable to the longer period of mining and dewatering of the mine, allowing additional time for loss in baseflow to occur.

The differences in loss of baseflow presented in Table 6-4 and that previously shown in GHD (2014a) are due to recalibration of the hydrogeological model.

Cumulative impacts

There are no other mining operations or groundwater extraction/interception activities in the area that impact the alluvial and Quaternary groundwater sources.

6.2.2 Porous and fractured rock groundwater sources

The Narrabeen Sandstone, Illawarra Coal Measures and Shoalhaven Group groundwater sources are considered to be ‘less productive’ under the AIP since the yields are typically less than 5 L/s and/or the groundwater salinity exceeds 1,500 mg/L.

Modelled drawdown contours for proposed conditions are shown in Appendix C. The drawdown contours indicate the expected zone of groundwater impact under proposed and approved conditions.

Water pressure

Depressurisation of the Narrabeen Sandstone is expected to be negligible (not measureable) under both approved and proposed conditions throughout most of the strata, although there may be some localised drawdown at the interface with the underlying Permian strata of up to 2.1 m under both conditions.

Based on the recalibrated model, maximum depressurisation of the Permian strata of the Illawarra Coal Measures overlying and including the Lithgow Seam is 16.5 m under proposed conditions, which is slightly greater than the maximum of 16.1 m for approved conditions.

Maximum depressurisation of the underlying Marrangaroo Formation of 16.4 m is predicted under proposed conditions and up to 16.1 m under approved conditions. The slightly greater drawdown under proposed conditions is considered to be attributable to panel and pillar mining occurring earlier under proposed conditions.

The differences in modelled depressurisation in the Permian strata as shown in Appendix C and modelled depressurisation as previously shown in GHD (2014a) are due to recalibration of the hydrogeological model rather than changes to the mining rate.

As detailed in GHD (2019a), the peak groundwater inflow into the mine workings is predicted to be 70.6 ML/year under proposed conditions and 76.1 ML/year under approved conditions. Over 99% of this groundwater is expected to come from the overlying Permian strata and the remaining portion from the underlying Marangaroo Formation. Peak inflows under approved conditions are modelled to be slightly higher than compared to proposed conditions due to the length of time mining occurs and slight changes to the mine plan. Predicted groundwater inflows from the recalibrated model are considerably less than inflows predicted by the original model in GHD (2014a).

Maximum depressurisation of the underlying Shoalhaven Group regional groundwater source of up to 7.4 m is predicted under proposed conditions and up to 7.3 m under approved conditions. Maximum depressurisation occurs within the Project Application Area. Depressurisation of less than 0.2 m is predicted at the boundary of the Gardens of Stone National Park under both approved and proposed conditions. This minor depressurisation predicted at the boundary of the Gardens of Stone National Park is within the resolution of uncertainty associated with modelling predictions and the expected climatic fluctuations. No drawdown of regional groundwater is expected to extend to private landholder bores to the east of the Project Application Area. Depressurisation in the Shoalhaven Group due to mining does not extend to the Airly Mine production bore or landholder bores to the west of Airly Mine.

Stygofauna have been identified at ARP11 and ARP15SP in the shallow Narrabeen Sandstone, although groundwater monitoring has shown that the extensive natural fracturing of the sandstone results in the seepage of groundwater along the slopes of the mountains and therefore limited groundwater within this strata to support stygofauna. Negligible drawdown is predicted in the Narrabeen Sandstone due to mining. Therefore the groundwater source that supports identified stygofauna will not be impacted by mining.

Since there are no high priority vegetation GDEs or groundwater supply works (operating under either basic landholder rights or Water Access Licences) in the areas of groundwater drawdown and no drawdown in the groundwater source that supports identified stygofauna, the predicted impacts are less than the Level 1 minimal impact considerations under the AIP and are therefore considered to be acceptable.

Since these groundwater sources are confined, the criterion for 'Water Table' does not apply.

Production bore

As discussed in Section 1.5.1, Airly Mine currently uses groundwater extracted from the production bore for mining operations. The production bore extracts groundwater from the Shoalhaven Group.

Recent drought conditions at Airly Mine have increased reliance on the production bore to supplement process water supply. The volume of water extracted from the production bore is limited by water approvals to 5 L/s (158 ML/year), which is based on the sustainable yield of the bore calculated from the pumping tests undertaken at the time of installation. However, the current average yield is less than 0.8 L/s, with the flow rate continuing to decrease during 2018 and early 2019. Based on the existing extraction rates observed on site, the peak extraction from the production bore under proposed conditions is expected to be approximately 25 ML/year (0.8 L/s).

Pumping testing of the production bore was undertaken in 2009 (Larry Cook & Associates, 2009) and concluded that the safe long-term yield for this is 9 L/s. At this rate it was found that there would be no drawdown or groundwater quality impacts on receptors or other users. It can therefore be concluded from this pump testing that the operation of the production bore at the expected 0.8 L/s is not expected to result in any drawdown. Given that drawdown will not be greater than 2 m at any other water supply work, the impacts are less than the Level 1 minimal impact considerations.

Village Spring

As discussed in Section 3.8.1, Village Spring is fed by seepage from old shale workings. The old shale workings are located in the Glen Davis Formation. As shown in Table 3-1, the Glen Davis Formation is located in the Permian strata above the Irondale Coal Seam. The old shale workings are located in the New Hartley Shale Mine potential interaction zone.

As discussed in GHD (2014c), based on groundwater monitoring undertaken at Airly Mine it appears that recovery of groundwater pressure within the Narrabeen Sandstone above the old shale workings has taken place over time, most likely due to the infilling of old cracks. As assessed in GHD (2014c), mining in the New Hartley Shale Mine potential interaction zone has the potential to induce further cracking of the strata. As previously assessed in GHD (2014c), the cracking may affect the Village Spring seep and therefore there is a possibility that discharges from Village Spring will decrease or cease as a result of proposed mining.

Since mining within the New Hartley Shale Mine potential interaction zone is no longer proposed by Centennial Airly, this would reduce the likelihood of cracking of strata in this zone and would reduce the likelihood of impacts on Village Spring.

Groundwater quality

The predicted drawdown in the less productive porous and fractured rock groundwater sources is not expected to result in the interaction between salty or poor quality groundwater (i.e. Permian and Shoalhaven Group) and fresh high quality groundwater (alluvium, Narrabeen Sandstone, Devonian regional groundwater) under proposed conditions. Since the poorer quality regional groundwater (Shoalhaven Group) is located above the higher quality Devonian groundwater, the minor depressurisation of the upper Shoalhaven Group that is predicted due to mining of the overlying Lithgow Seam will not impact groundwater levels or quality of the underlying Devonian. Further, any hydraulic connection that may currently exist between the Shoalhaven Group groundwater and Devonian groundwater due to lineaments (which is considered to be limited based on the water quality assessment) will not be enhanced due to mining since the mining occurs well above this zone. Overall, it is not expected that the beneficial use category of the porous and fractured rock groundwater will change under approved or proposed conditions.

Cumulative impacts

The extents of the Narrabeen Sandstone and Illawarra Coal Measures groundwater sources are limited to the Project Application Area. There are no other mining operations or groundwater extraction/interception activities in the area that impact these sources.

The modelled impact on the Shoalhaven Group due to underground mining does not extend to the production bore. Therefore there are no cumulative drawdown or groundwater quality impacts from the operation of the production bore and the coal extraction activities.

6.3 Water sharing plan licensing requirements

Groundwater extraction and interception from the GMR WSP Sydney Basin North Groundwater Source over the life of the Project (proposed conditions) is as follows:

- Groundwater inflows into the underground mine workings, which are predicted to peak at up to 71 ML/year in year 2027 under proposed conditions (modelling Scenario 2). The groundwater inflow is primarily from the Illawarra Coal Measures. The majority of groundwater inflow is expected to be realised as increased ROM coal moisture rather than free water pumped from the underground workings.
- Groundwater extraction from the Shoalhaven Group via the existing production bore, which is expected be up to 25 ML/year during the project. This volume is based on current extraction from the production bore. It is possible that this extraction will decrease over time to zero.
- Inherent (or in situ) coal moisture, which forms part of the ROM coal moisture, which is predicted to be 75 ML/year (GHD, 2019b) during mining operations. This inherent coal moisture is conservatively considered in addition to groundwater inflows into the underground mine workings. As discussed above, as groundwater inflows are expected to be realised as increased coal moisture, peak ROM coal moisture is predicted to be 146 ML/year.

Overall, extraction and interception from the Sydney Basin North groundwater source over the life of the Project is expected to peak at 171 ML/year. Given that most of this volume is expected as ROM coal moisture and that the water balance model predicts that the site will be in water deficit under almost all climatic conditions considered (GHD, 2019b), this total is not expected to vary significantly due to climatic conditions over the life of the Project. In any case, these peak volumes are well below Centennial Airly's existing WAL for the Sydney Basin Groundwater Source of 278 ML/year.

7. Mitigation, management and monitoring

7.1 Mitigation and management measures

A regional water management plan (GHD, 2016) has been developed to provide an overview of the water management requirements across Centennial's western operations. A site-specific water management plan for Airly Mine (GHD, 2018) has also been developed to address specific water management requirements for the site.

The water management plans ensure the operation of the mine, with respect to water, meets all relevant regulatory requirements. The regional water management plan and site-specific water management plan will be considered for review every three years or as a result of any regulatory requirements, any significant changes to water management practices or the development of any new mining areas.

Subsidence monitoring will inform remedial actions during panel and pillar extraction. Monitoring will determine if any remedial drainage works are required to maintain surface water drainage channels. Any works within the drainage channels will need to be undertaken in consultation with DPIE-Water and potentially National Parks and Wildlife Services (NPWS).

Trigger action response plans (TARPs) are provided in the site-specific water management plan (GHD, 2018). These TARPs should be referenced to determine the appropriate actions in response to any impacts of the Project identified as part of the monitoring program. Generally, responses include investigation and monitoring, determination of the risk of the impact and remedial measures to be implemented. The TARPs also include reporting, training and personnel responsibilities.

7.2 Monitoring

A comprehensive groundwater and surface water monitoring program has been developed by Airly Mine. The site-specific water management plan (GHD, 2018) provides the details of the groundwater and surface water monitoring programs.

The water monitoring programs include:

- Groundwater level and quality.
- Groundwater seepage rates and quality.
- Surface water quality, flow and watercourse stability.

The main objective of monitoring is to ensure that implemented water management measures function as designed and provide data for assessment of potential impacts on water sources.

7.3 Reporting and reviews

Reporting at Centennial involves a number of internal and external reporting procedures that comply with regulatory and operational requirements. For Airly Mine, reporting includes an *Annual Review*, an Annual Return for EPL 12374, results of environmental monitoring, incident reporting and complaints record.

The hydrogeological model for Airly Mine will be reviewed and revised if required every three years. The review of the hydrogeological model will include a comparison of modelling results and monitoring predictions.

8. References

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Appendices

Appendix A – Supporting assessment requirements

Table A-1 Significant Impact Test

Impact guideline	Triggers an impact	Comment
Hydrogeological characteristics		
A significant impact on the hydrological characteristics of a water resource may occur where there are, as a result of the action: a) changes in the water quantity, including the timing of variations in water quantity	Yes	Drawdown of up to 16.5 m is predicted to occur within the Permian Illawarra Coal Measures overlying and including the Lithgow Coal Seam. Drawdown of up to 16.4 m is predicted to occur within the Marrangaroo Formation. Drawdown of up 7.4 m is predicted to occur within the Shoalhaven Group. Alluvial groundwater systems are periodically dry due to climatic factors. This variability is expected to continue during mining. Note this drawdown does not impact on any groundwater receptors including licenced bores or GDEs.
b) changes in the integrity of hydrological or hydrogeological connections, including substantial structural damage (e.g. large scale subsidence)	No	Estimates indicate vertical and horizontal hydraulic conductivity will increase up to a height of 60 m above the panel and pillar mining zone Strata2 (2019). This fracture height does not extend into the shallow alluvium groundwater.
c) changes in the area or extent of a water resource	Yes	Drawdown of up to 16.5 m is predicted to occur within the Permian Illawarra Coal Measures overlying and including the Lithgow Coal Seam. Drawdown of up to 16.4 m is predicted to occur within the Marrangaroo Formation. Drawdown of up 7.4 m is predicted to occur within the Shoalhaven Group. Alluvial groundwater systems are periodically dry due to climatic factors. This variability is expected to continue during mining.

		Note this drawdown does not impact on any groundwater receptors including licenced bores or GDEs.
Water quality		
A significant impact on water resource may occur where, as a result of the action: a) there is a risk that the ability to achieve relevant local or regional water quality objectives would be materially compromised, and as a result the action: i. creates risks to human or animal health or to the condition of the natural environment as a result of the change in water quality	No	As discussed in Section 6.2.1 and Section 6.2.2, proposed operations are not predicted to result in observable change in groundwater quality. Surface water aspects are addressed in GHD (2019b).
ii. substantially reduces the amount of water available for human consumptive uses or for other uses, including environmental uses, which are dependent on water of the appropriate quality	No	No change in groundwater quality due to the project. Surface water aspects are addressed in GHD (2019b).
iii. causes persistent organic chemicals, heavy metals, salt or other potentially harmful substances to accumulate in the environment	No	No change in groundwater quality due to the project. Surface water aspects are addressed in GHD (2019b).
iv. seriously affects the habitat or lifecycle of a native species dependent on a water resource, or	No	GDEs are considered to be 'facultative' ecosystems (RPS, 2014). Minimal stygofauna have been detected in groundwater samples collected to date, limited to two individuals of one obligate stygofauna group (Cyclopoida) collected at one location (ARP11) (GHD, 2019c) and three individuals of obligate stygofauna group Melitidae (an Amphipod) collected at ARP15SP installed in the shallow sandstone in Autumn 2019.
v. causes the establishment of an invasive species (or the spread of an existing invasive species) that is harmful to the ecosystem function of the water resource, or	N/A	N/A
b) there is a significant worsening of local water quality (where current local water quality is superior to local or regional water quality objectives), or	No	As discussed in Section 6.2.2, mining operations is not predicted to result in increased interaction between salty or poor quality

		groundwater (i.e. Permian and Shoalhaven Group) and fresh high quality groundwater (alluvium, Narrabeen Sandstone, Devonian regional groundwater). Surface water aspects are addressed in GHD (2019b).
c) high quality water is released into an ecosystem which is adapted to a lower quality of water.	No	As discussed in Section 6.2.2, mining operations is not predicted to result in increased interaction between salty or poor quality groundwater (i.e. Permian and Shoalhaven Group) and fresh high quality groundwater (alluvium, Narrabeen Sandstone, Devonian regional groundwater). Surface water aspects are addressed in GHD (2019b).

Table A-2 Consolidated IESC Checklist

Element	Assessed within GWIA or GHD (2019b)
Background Data and Modelling Identification of the water related assets Identification of the geological formation/aquifer to which groundwater dependent ecosystems (GDEs) are connected Location of springs and other groundwater dependent ecosystems A site specific water balance complemented by a regional water balance A description of the water resources of the site A description of the geology and hydrogeology at a local and regional level, including definition of the geological sequence The depth to aquifers and standing water levels, hydro-chemical characteristics A description of the likely recharge sources for each aquifer, details of discharges from each aquifer, direction of groundwater flow and contours of groundwater elevations for all aquifers Surface water assessment and model, including hydrology and water quality parameters Relevant information to describe the existing state of water related ecosystems	Yes
Water and Salt Balance	Not relevant

Element	Assessed within GWIA or GHD (2019b)
A site specific water balance and a site specific salt balance, complemented by a regional balance of both water and salt covering the larger area of potential impact. An assessment of the changes to any water storage or flow of water in the system as a result of the project, including changes to salt loads.	
Assessment of the likely significant impacts on water resources and water related assets Consideration of the State based policies and guidelines Predicted change to both local and regional water balances Impacts associated with surface water diversions Estimates of the quantity and quality of operational discharges of water, including emergency discharges Indication of the vulnerability to contamination and the likely impacts on the identified water assets Consideration of the impacts of water management infrastructure on the biodiversity assets Assessment of the cumulative impact of the project with past, present and known future projects Proposed mitigation measures for each identified impact	Yes
Assessment of cumulative impacts The cumulative impact assessment needs to consider all past, present and known future projects, undertaking with regard to the regional water balance. Catchment and regional scale information Total existing and planning licensed and extracted water for consumptive, industrial and agricultural purposes in the surface catchment and groundwater system Existing water quality guidelines, targets, environmental flow objectives and requirements for the ecosystems of the surface and groundwater systems The proportional increase in water resource use and impacts as a consequence of the proposal The overall level of risk to water related assets that combine probability of occurrence with severity of impact of all past, present and known future projects	Yes
Ongoing management and monitoring Plan of management is to be included that focuses on the avoid, mitigate, manage and offset principles Clearly defined monitoring objectives Maps/figures demonstrating location of bores, their purpose and distribution such that impacts to groundwater gradients, flow directions, recharge processes, quality and water levels in each aquifer	Yes

Element	Assessed within GWIA or GHD (2019b)
Variables such as water levels, EC, pH and other quality parameters to be measured and the interval for measurement An ANZECC water quality assessment and the development of guideline trigger values	

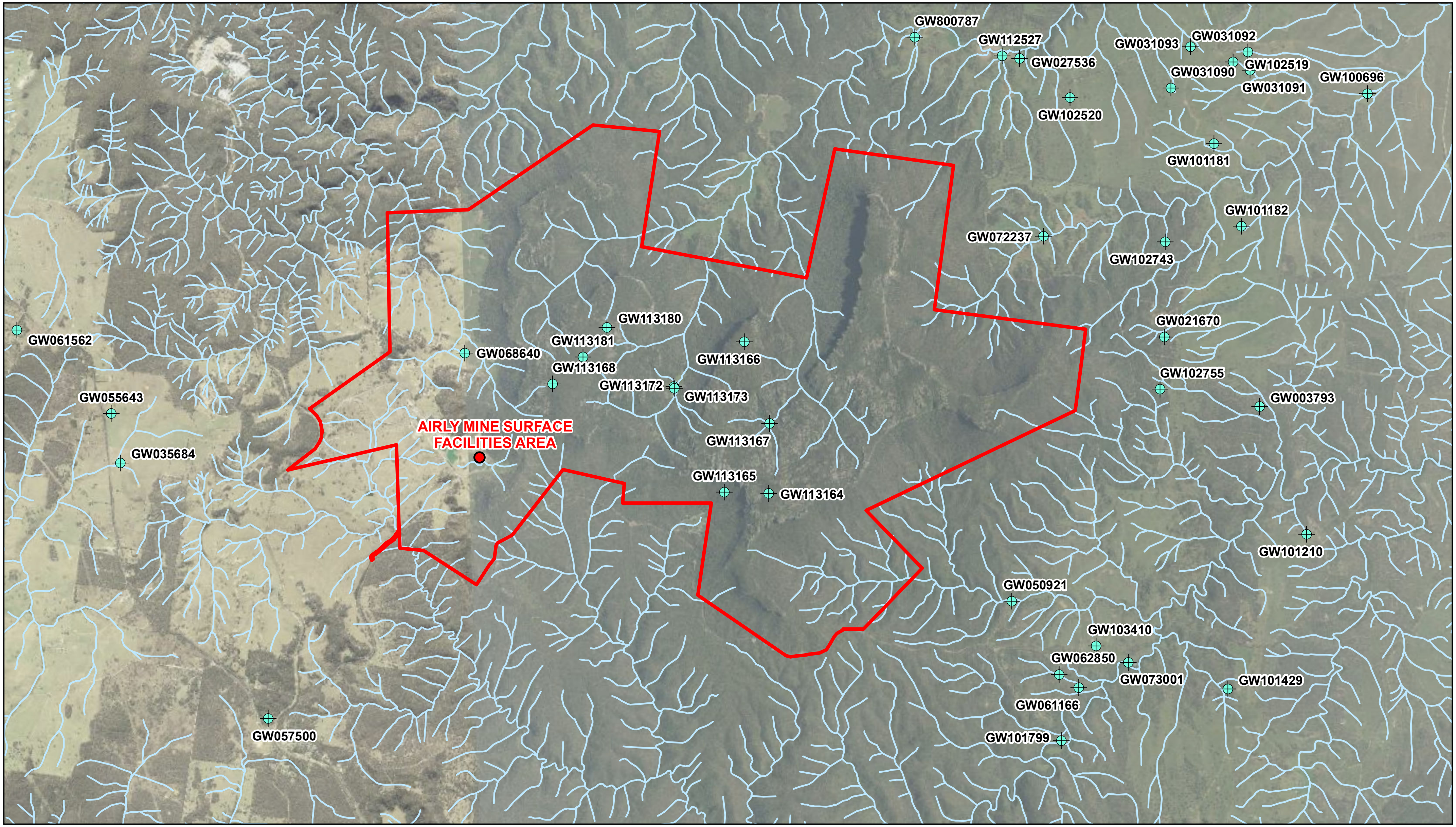
Appendix B – Baseline groundwater data

B.1 Groundwater bore database search

Bore	Licence	Location		Use	Depth (m)	SWL (bgl)	Salinity	Yield (L/s)	Aquifer
		m N	m E						
GW003793	–	6332960	232004	Stock	39.6	–	–	–	Boulders/rock/porphyry
GW021670	10BL013665	6333911	230707	Stock	92.9	50.5	Unknown	0.38	Sandstone/shale/sandstone limestone/andesite
GW027536	10BL020891	6337711	228733	Domestic/stock	5.7	–	–	–	–
GW031090	10BL023864	6337305	230795	Stock	92.9	48.7	Stock	0.15	Shale/limestone water supply
GW031091	10BL023863	6337551	231879	Stock	54.8	–	–	–	–
GW031092	10BL023865	6337796	231846	Stock	32	14.6	Stock	0.25	Limestone decomposed/limestone conglomerate
GW031093	10BL023866	6337868	231065	Stock	100.5	–	–	–	Limestone conglomerate
GW035684	80BL029547	6332387	776371	Stock	6.4	–	–	–	–
GW042703	10BL105058	6341429	222760	Domestic/irrigation/stock	8	5	0–500 ppm	20.83	Clay/gravel water supply
GW050921	10BL109475	6330307	228627	Stock	10.5	4.1	Good	0.25	Sandstone boulder/clay gravel/sandstone siltstone/sand gravel
GW055643	10BL120830	6333068	776287	Domestic/stock	38.1	12.2	Good	0.10–0.30	Clay/shale sandy/shale
GW057500	80BL125680	6328790	778189	Domestic	30	10	Unknown	1.26	Overburden/shale
GW061166	10BL132888	6329130	229541	Domestic/stock	47.5	6.1	Good	0.5	Clay/shale
GW061562	80BL134157	6334274	775075	Domestic/stock	70	29	Good	0.22–9.00	Shale/sandstone/conglomerate

Bore	Licence	Location		Use	Depth (m)	SWL (bgl)	Salinity	Yield (L/s)	Aquifer
		m N	m E						
GW062850	–	6329308	229277	Irrigation	15	–	–	–	Limestone/fissure
GW068640	10BL141250	6333693	221173	Test bore	78.5	19.08	1990	1.00–2.15	Clayey sand and gravel/siltstone/sandstone/quartz/shale
GW072237	10BL154338	6335284	229060	Domestic/irrigation/stock	55	17	Fresh	2.00–6.00	Sandy gravel/shale
GW073001	–	6329474	230214	Domestic/stock	24	9	–	0.5	Weathered basalt/blue basalt
GW100696	10BL155172	6337232	233478	Domestic/stock	6	–	–	–	Sand/gravel
GW101181	–	6336551	231387	Domestic/stock	33	5	Good	2.5	Conglomerate
GW101182	10BL158364	6335420	231755	Domestic/stock	40	12	Good	2	Clay/conglomerate
GW101210	10BL158255	6331220	232649	Domestic/stock	91.4	–	–	–	Clay and boulders/granite
GW101429	10BL157957	6329110	231573	Domestic/stock	64	39.6	–	3.79	Sandstone/shale
GW101799	10BL157241	6328406	229304	Domestic	30	7	Brackish	0.25–0.38	Weathered shale/shale
GW102519	10BL159353	6337661	231646	Domestic/stock	93	66	–	2	Shale/granite
GW102520	10BL159354	6337175	229423	Domestic/stock	42	22	Good	0.8	Shale/granite
GW102743	10BL159493	6335206	230723	Domestic/stock	49	7.5	Good	1.43	Shale soft/shale hard
GW102755	10BL159449	6333200	230648	Domestic/stock	42	26	6,000 ppm	0.5	Soft shale/hard grey shale
GW103410	10BL159909	6329698	229776	Domestic/stock	106	54	–	0.38	Shale/limestone
GW112527	10BL604088	6337744	228496	Domestic/stock	42	6	–	5	Siltstone

Bore	Licence	Location		Use	Depth (m)	SWL (bgl)	Salinity	Yield (L/s)	Aquifer
		m N	m E						
GW800787	80BL236772	6338000	227305	Domestic/stock	41	14	Fresh	0.08–1.56	Sandstone/shale
GW113168	10BL604518	6333269	222372	Monitoring bore	–	–	–	–	–
GW113181	10BL604520	6333638	222783	Monitoring bore	–	–	–	–	–
GW113180	10BL604520	6334042	223113	Monitoring bore	–	–	–	–	–
GW113173	10BL604521	6333235	224023	Monitoring bore	–	–	–	–	–
GW113172	10BL604521	6333209	224030	Monitoring bore	–	–	–	–	–
GW113166	10BL605352	6333846	224983	Monitoring bore	–	–	–	–	–
GW113167	10BL605352	6332729	225330	Monitoring bore	–	–	–	–	–
GW113165	10BL605352	6331793	224713	Monitoring bore	–	–	–	–	–
GW113164	10BL605352	6331775	225314	Monitoring bore	–	–	–	–	–



Paper Size A4

0 600 1,200 1,800 2,400

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

LEGEND

- Airly Surface Facilities Area
- Waterway
- Project Approval Area SSD_5581
- Registered Groundwater Bores

Centennial Airly

Airly Mine
Airly Mine Mod 3
Groundwater Impact Assessment

Job Number	22-19275
Revision	0
Date	7 Jun 2019

Registered Groundwater Bores Figure B-1

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Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

Data source: LPI: DTDB 2012; Centennial: Aerial Imagery, boundaries, 2013. NSW-OoW: groundwater bores, 2013. Created by: fmackay

B.2 Groundwater hydrographs

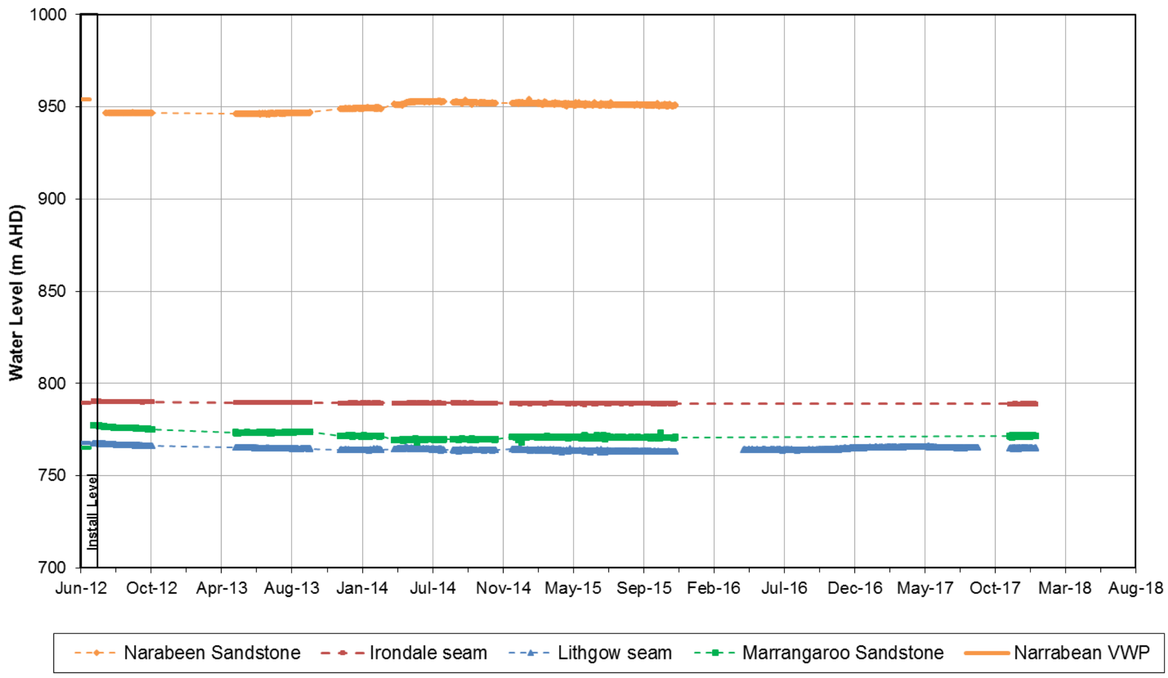


Figure B-2 Groundwater level recorded in ARP01

Pressure consistently negative in Narrabeen Sandstone and Lithgow Seam. VWP pressure consistently negative in the Irondale Seam since October 2014.

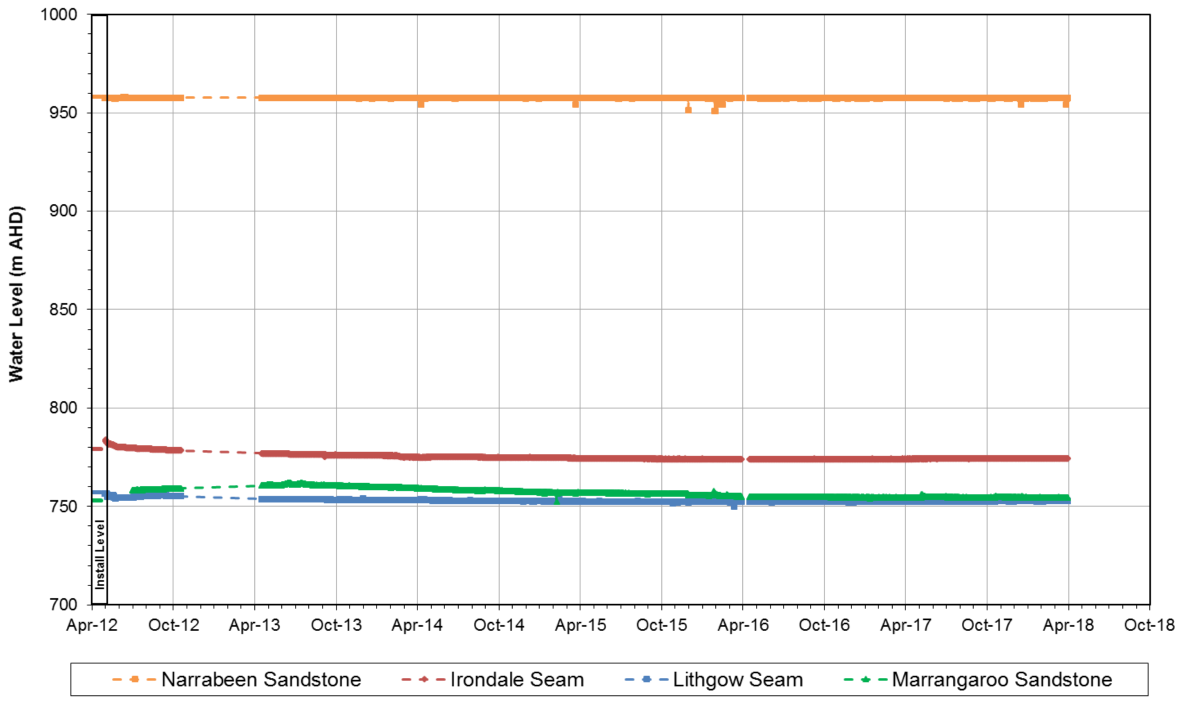


Figure B-3 Groundwater level recorded in ARP02

Pressure has been negative at the VWP installed in the Narrabeen Sandstone and Lithgow Seam. Pressure has been negative in the Irondale Seam since July 2012 (two months after installation).

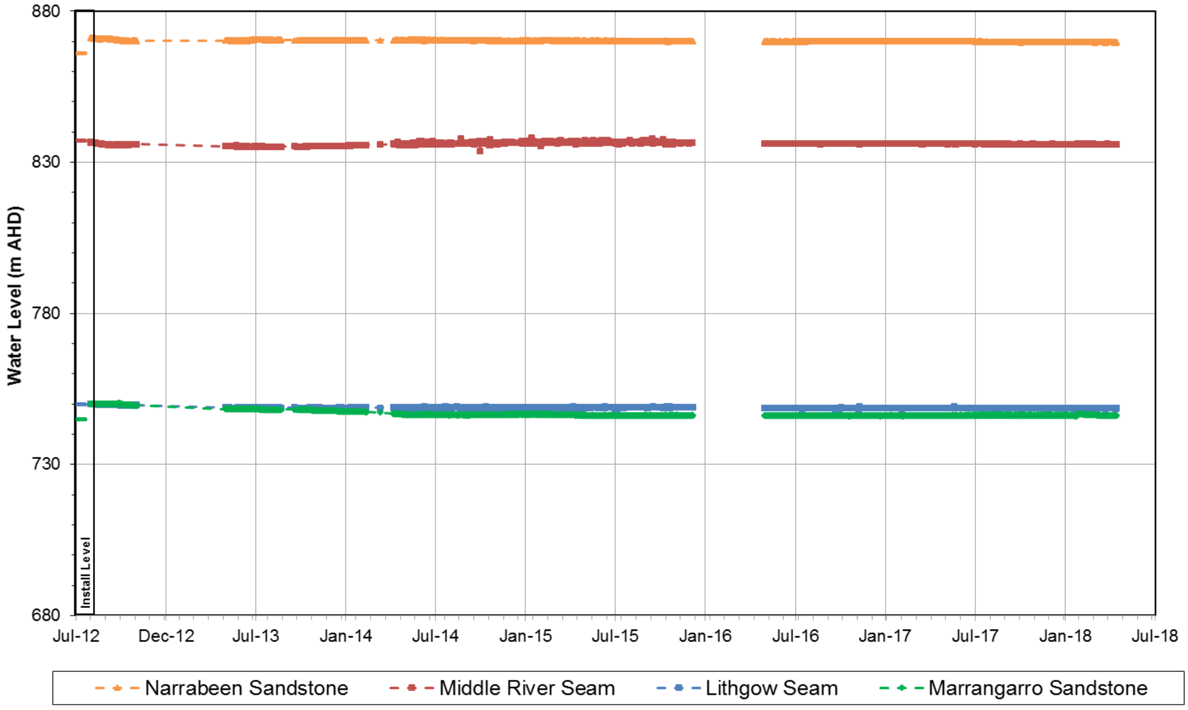


Figure B-4 Groundwater level recorded in ARP03

Pressure has typically been negative in the Middle River Seam. Pressure has been negative in the Lithgow Seam since October 2012 (approximately two months after undermining).

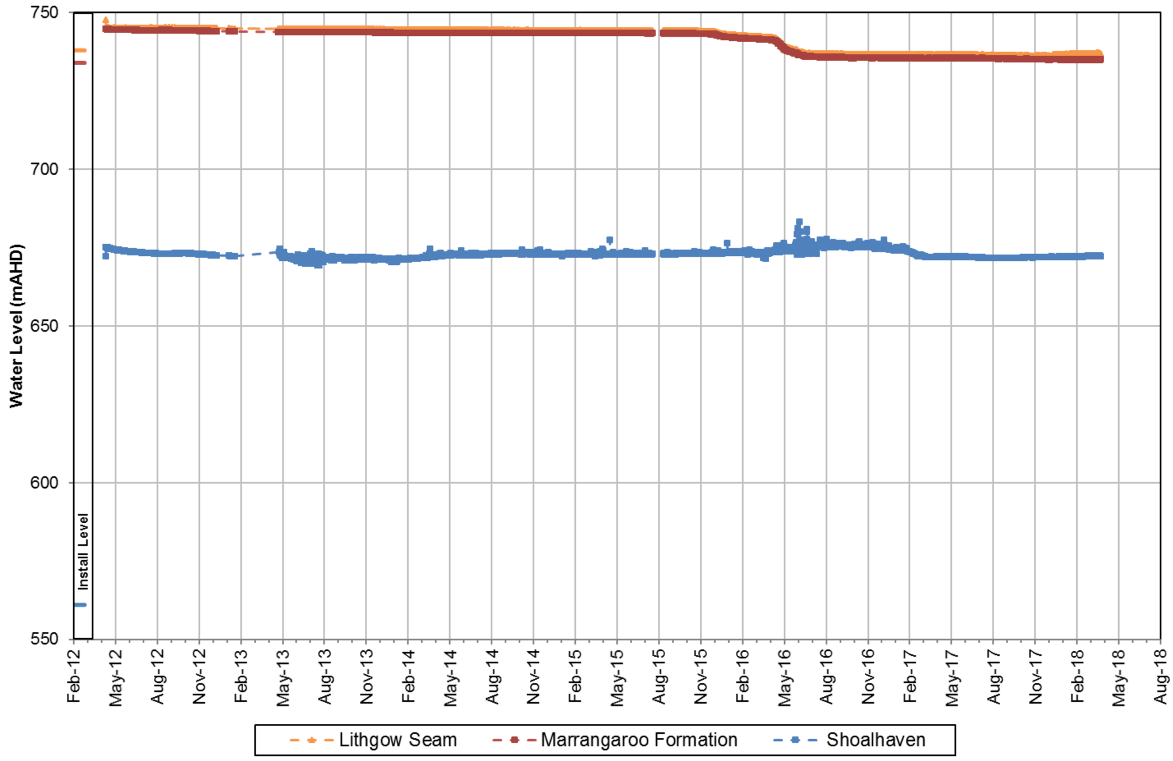


Figure B-5 Groundwater level recorded in ARP04

Pressure has been negative in the Lithgow Seam at ARP04 since June 2016.

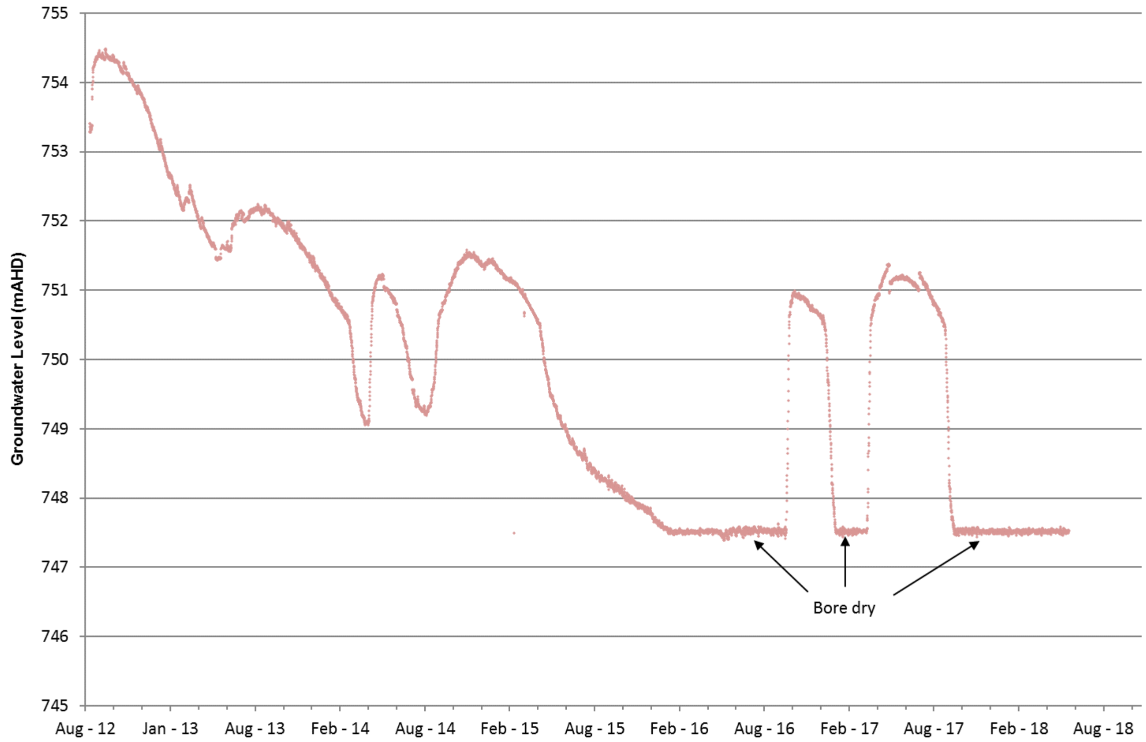


Figure B-6 Groundwater level recorded in ARP05

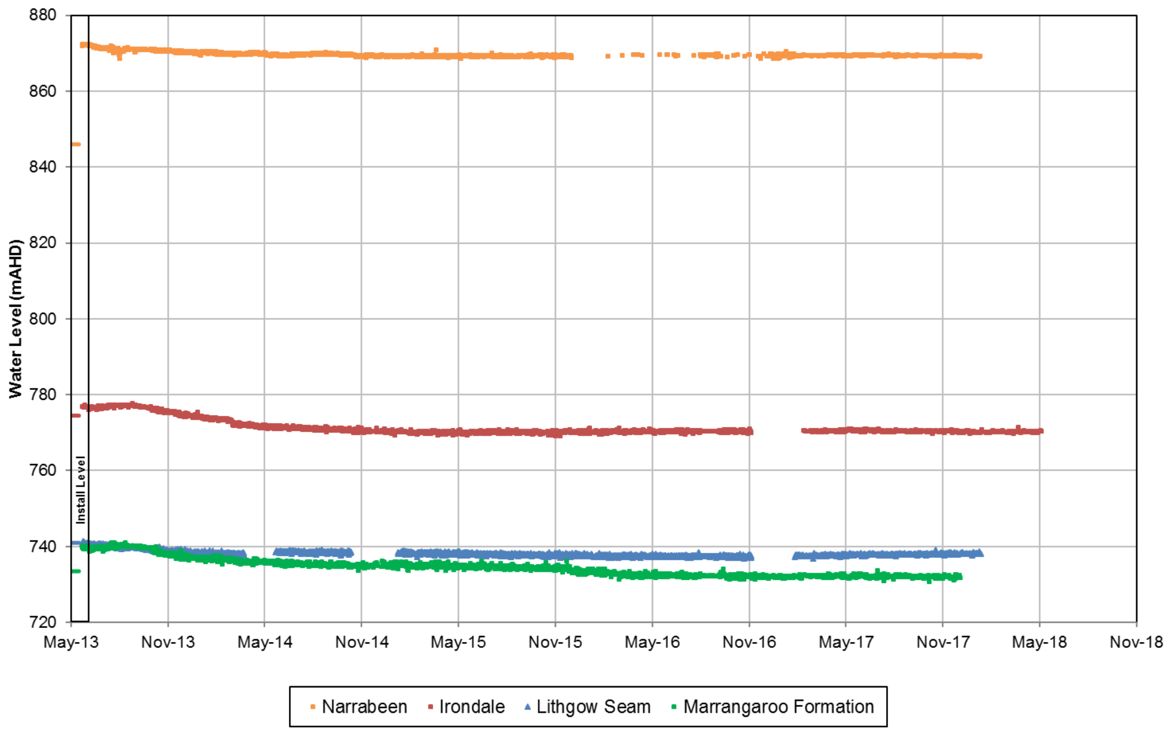


Figure B-7 Groundwater level recorded in ARP06

Pressure consistently negative at ARP06 in the Lithgow Seam, in the Irondale Seam since December 2013 and in the Marrangaroo Formation since December 2015.

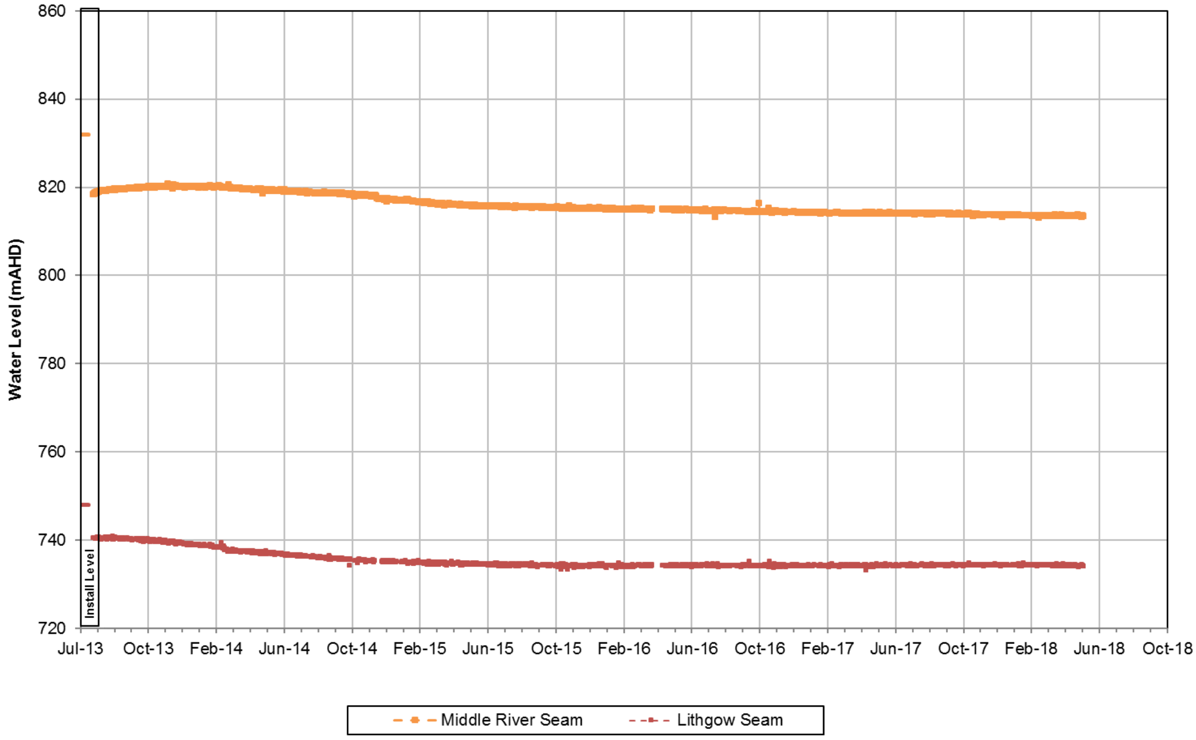


Figure B-8 Groundwater level recorded in ARP07

Pressure consistently negative at VWPs installed at ARP07.

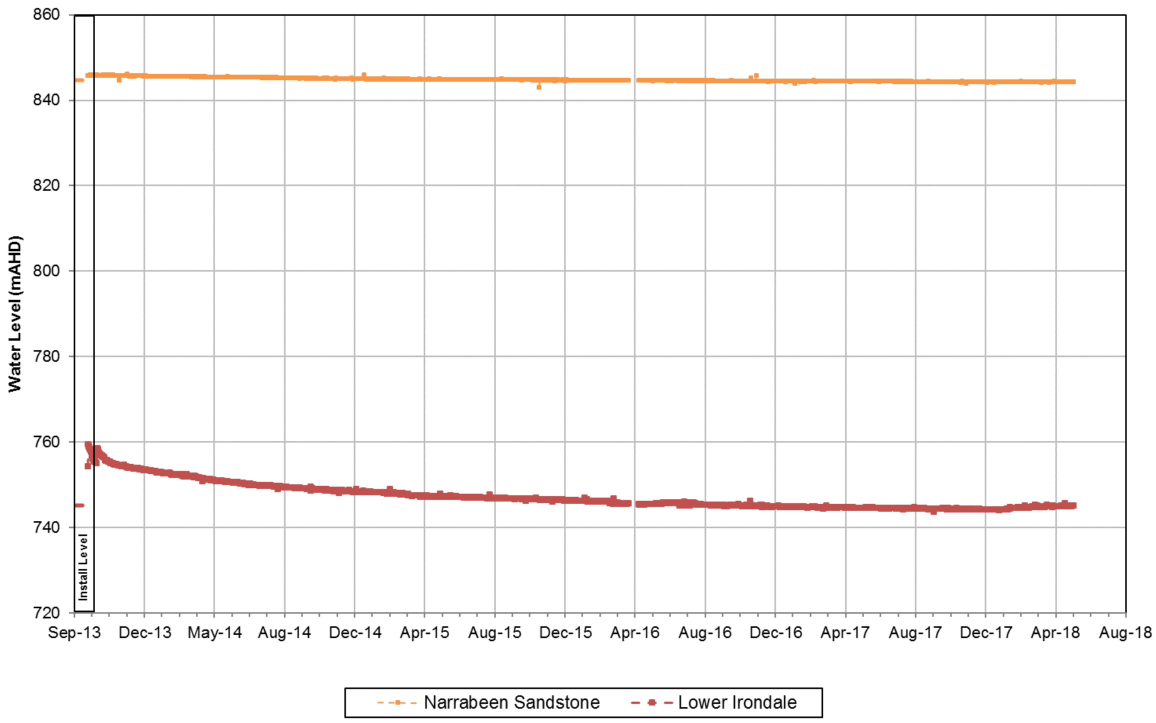


Figure B-9 Groundwater level recorded in ARP08

Pressures have been negative at ARP08 in the Narrabeen Sandstone since May 2016 and in the Lower Irondale Seam since November 2016.

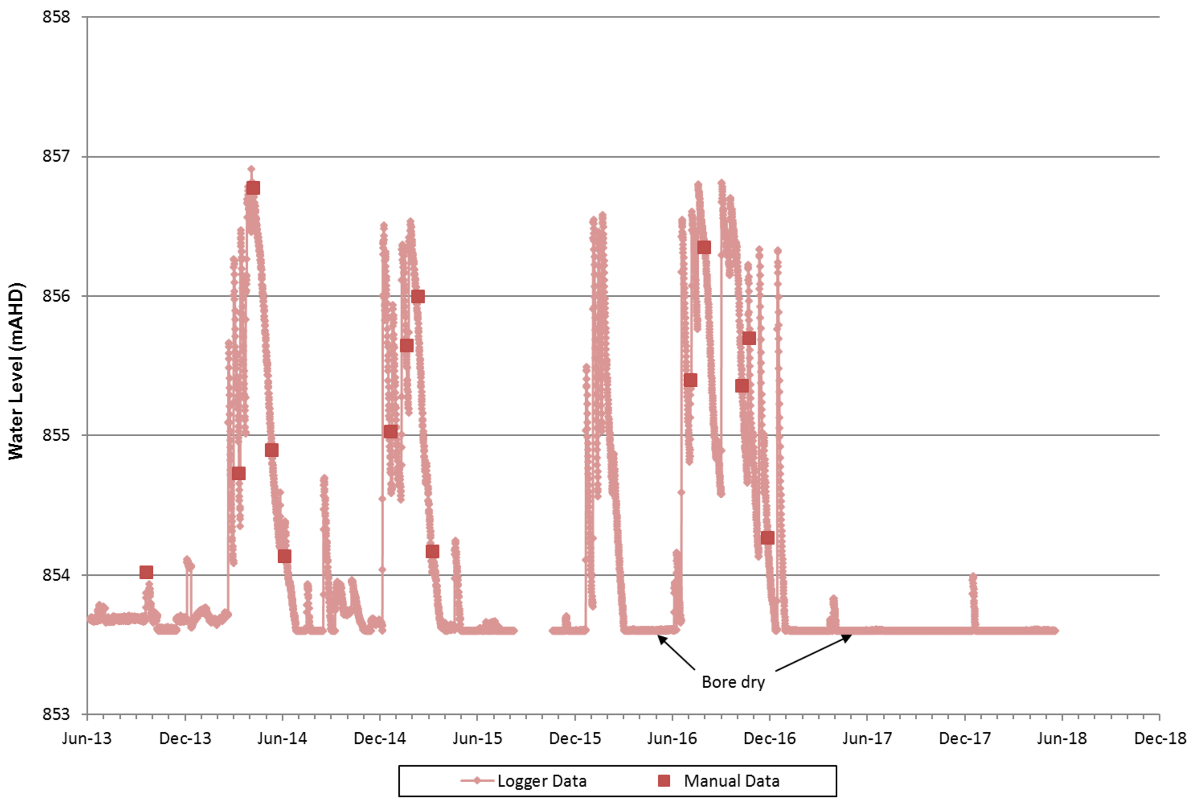


Figure B-10 Groundwater level recorded in ARP09

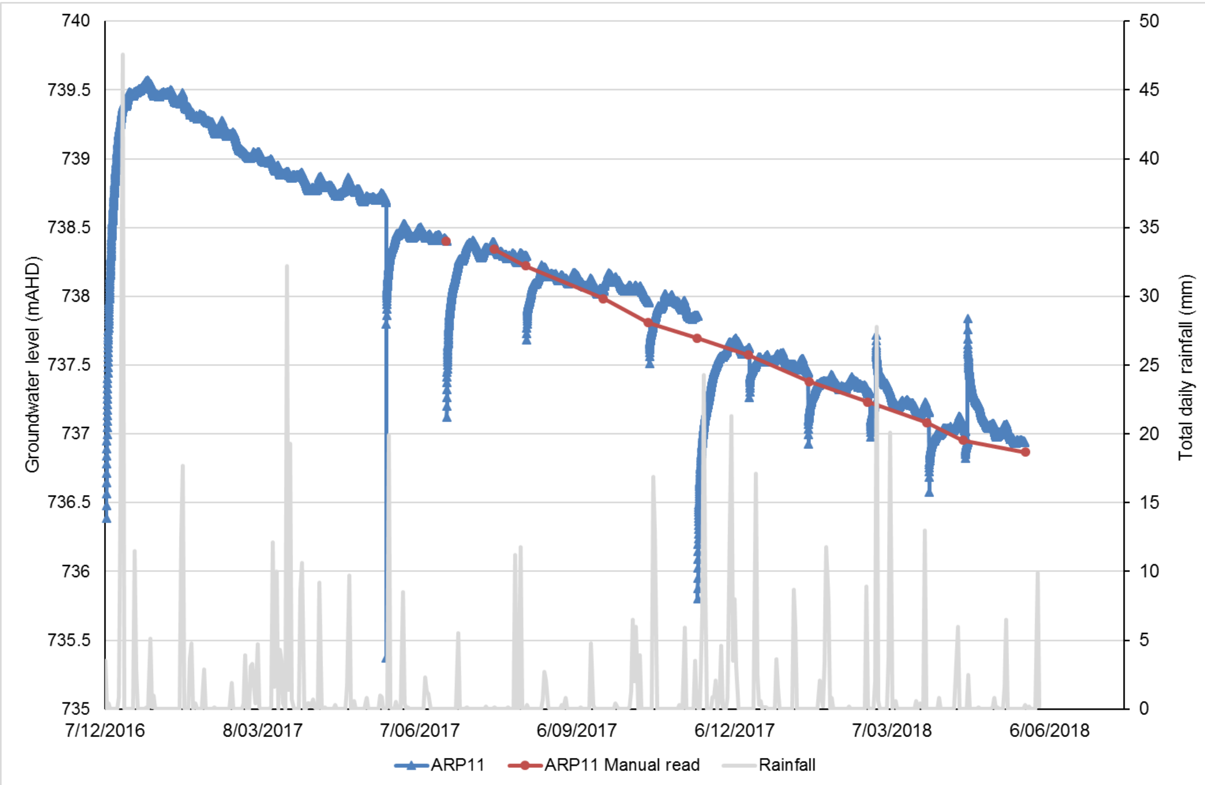


Figure B-11 Groundwater level recorded in ARP11

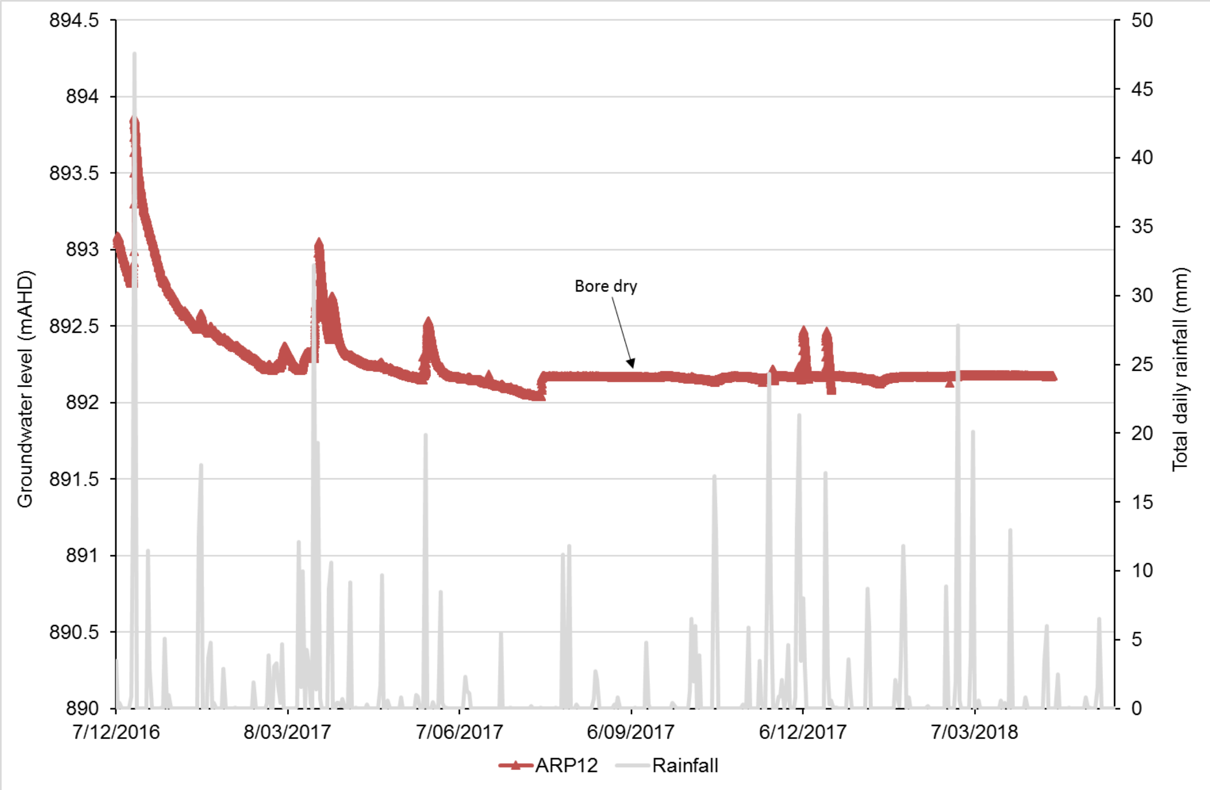


Figure B-12 Groundwater level recorded in ARP12

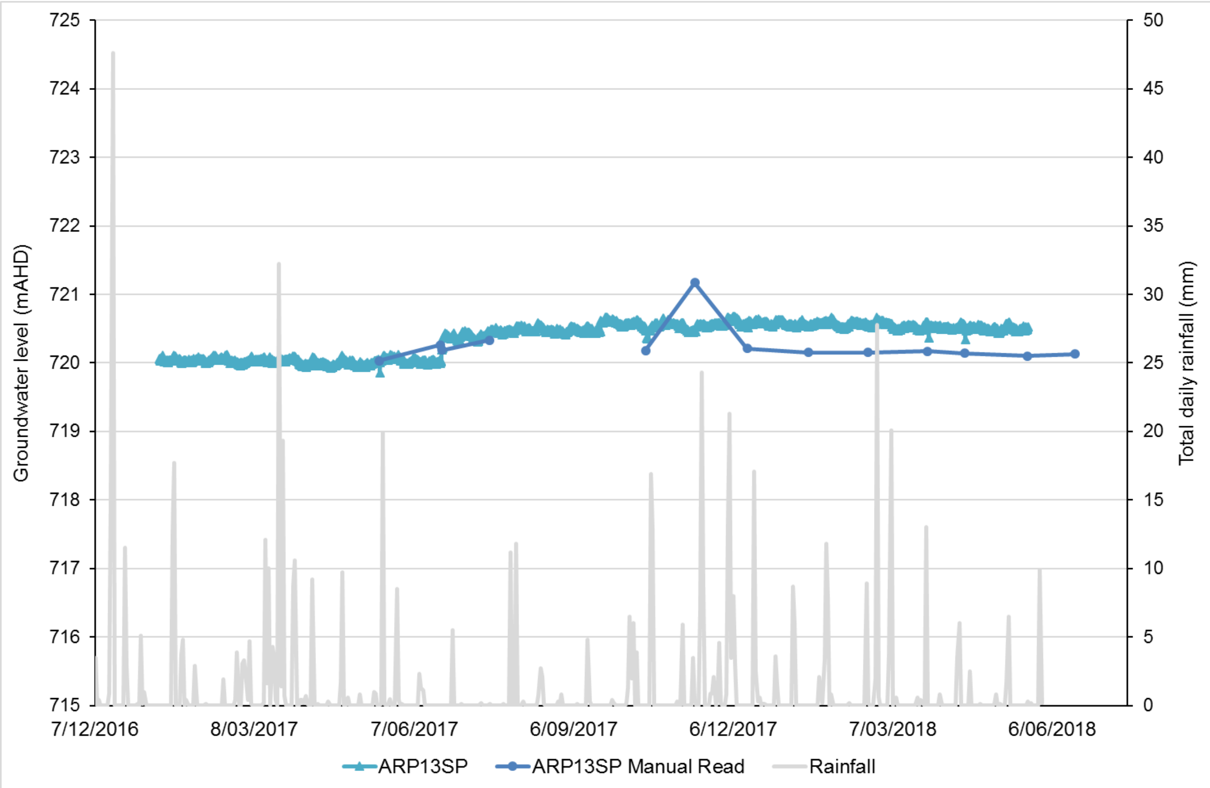


Figure B-13 Groundwater level recorded in ARP13SP

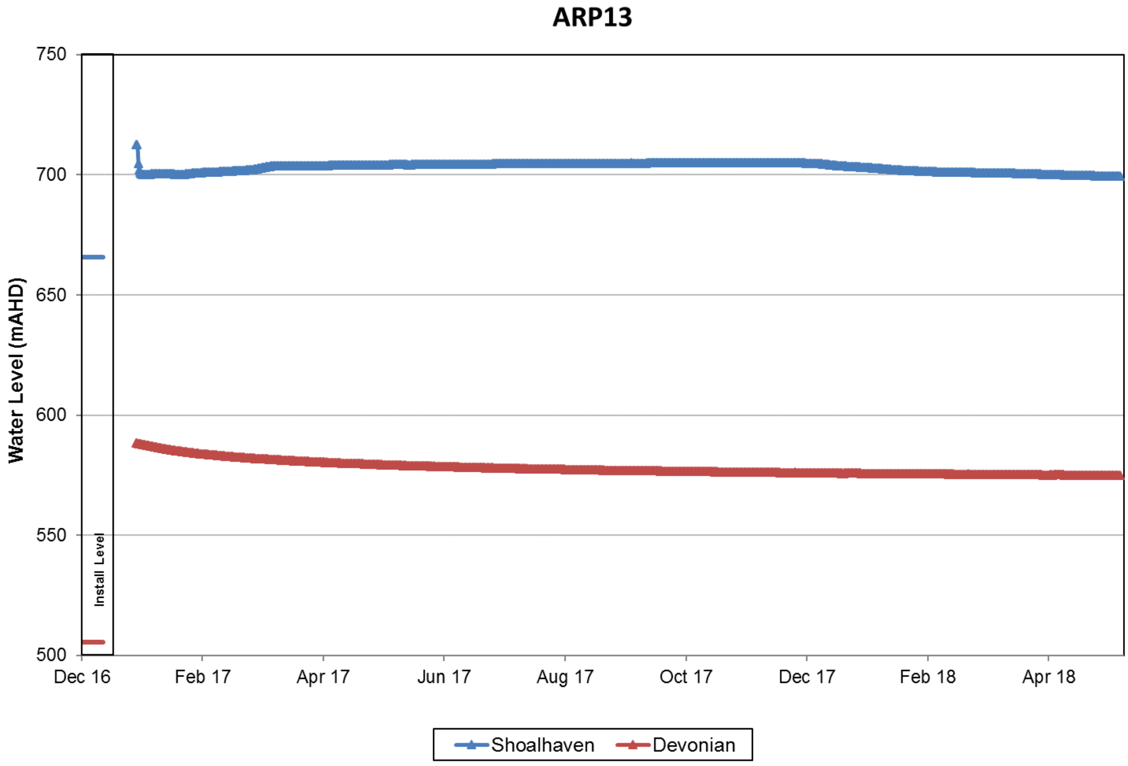


Figure B-14 Groundwater level recorded in ARP13

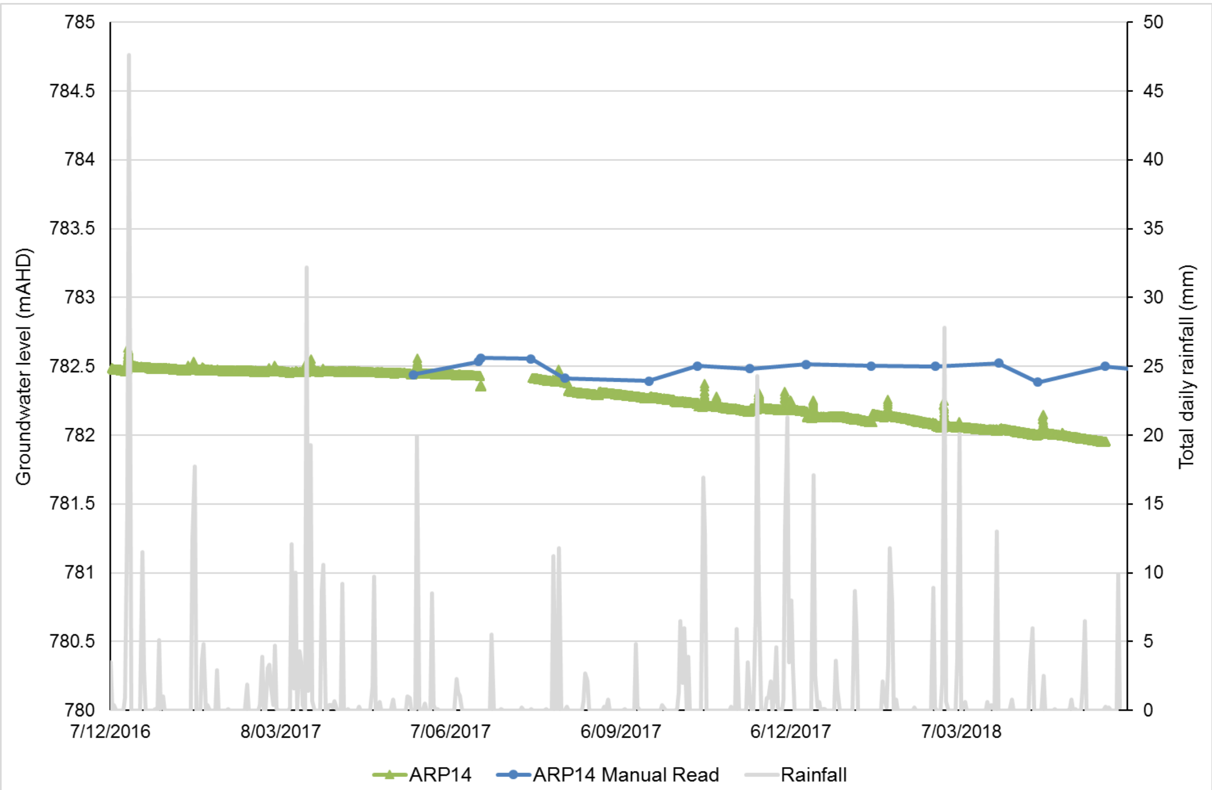


Figure B-15 Groundwater level recorded in ARP14

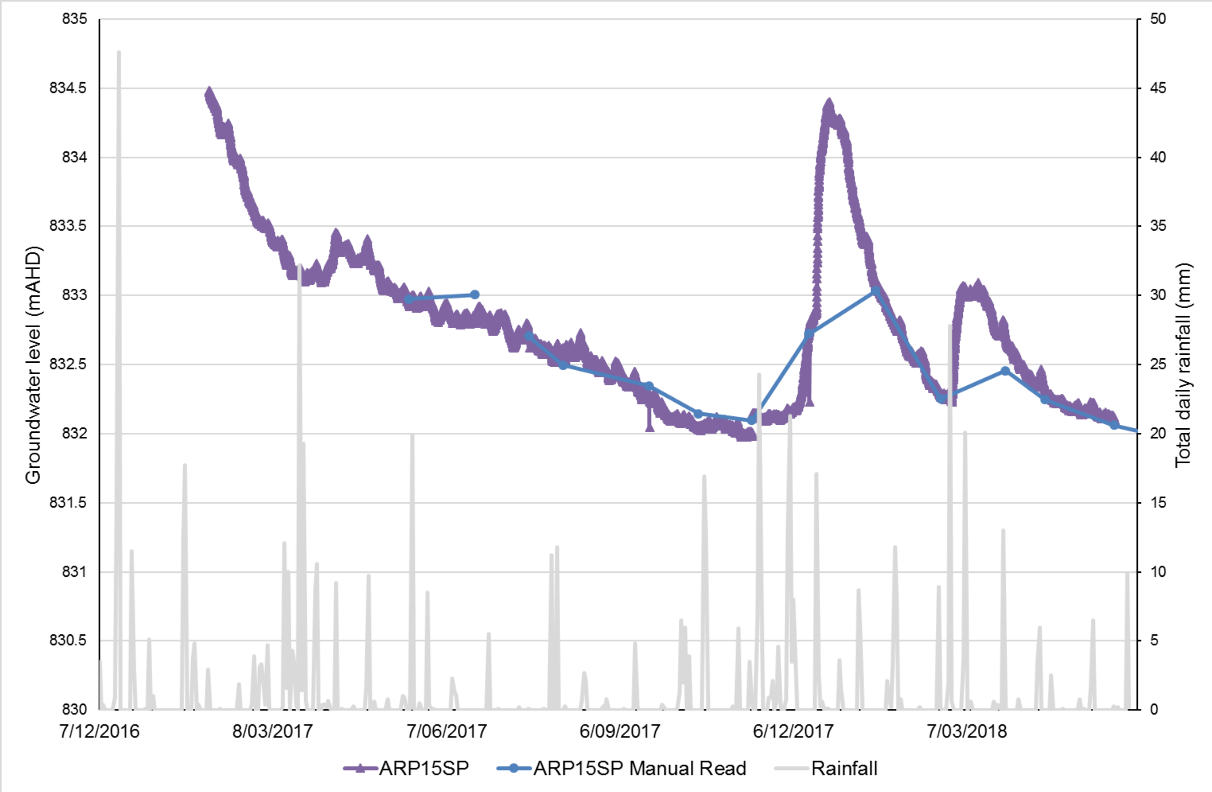


Figure B-16 Groundwater level recorded in ARP15SP

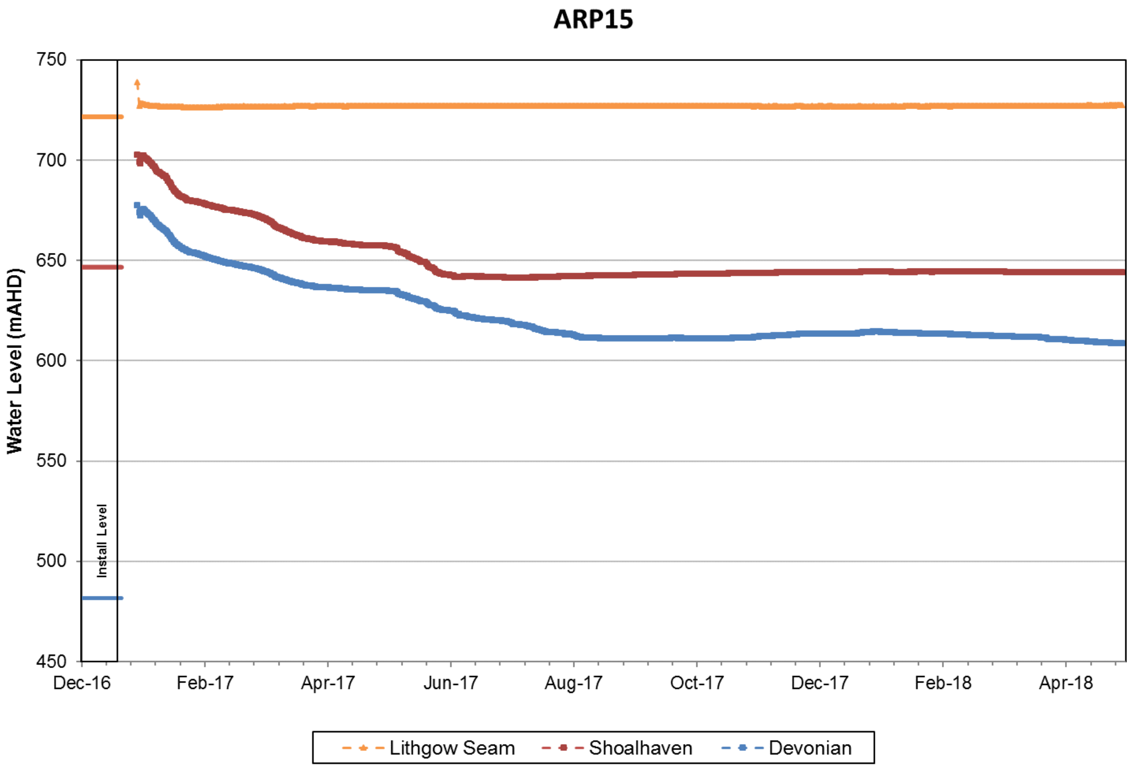


Figure B-17 Groundwater level recorded in ARP15

Pressures have been negative at ARP15 in the Shoalhaven Group since June 2017.

B.3 Groundwater quality

Physicochemical parameters

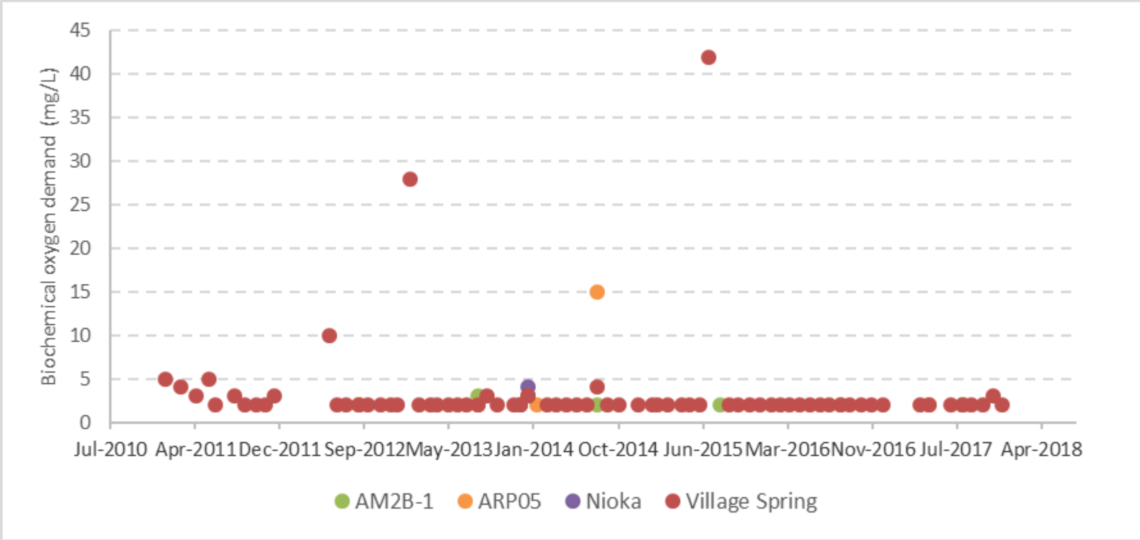


Figure B-18 Biochemical oxygen demand monitored in groundwater

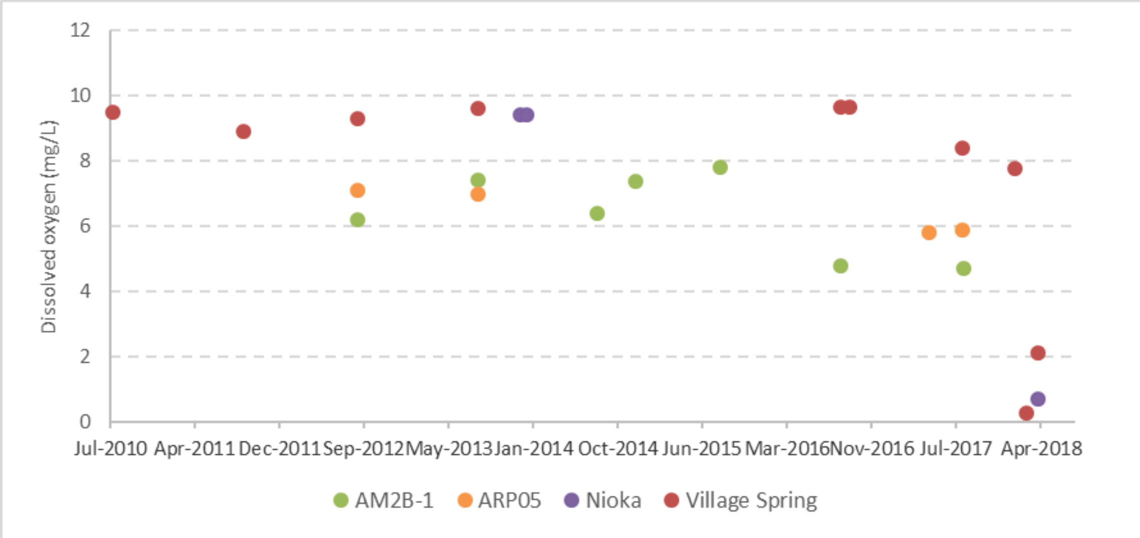


Figure B-19 Dissolved oxygen monitored in groundwater

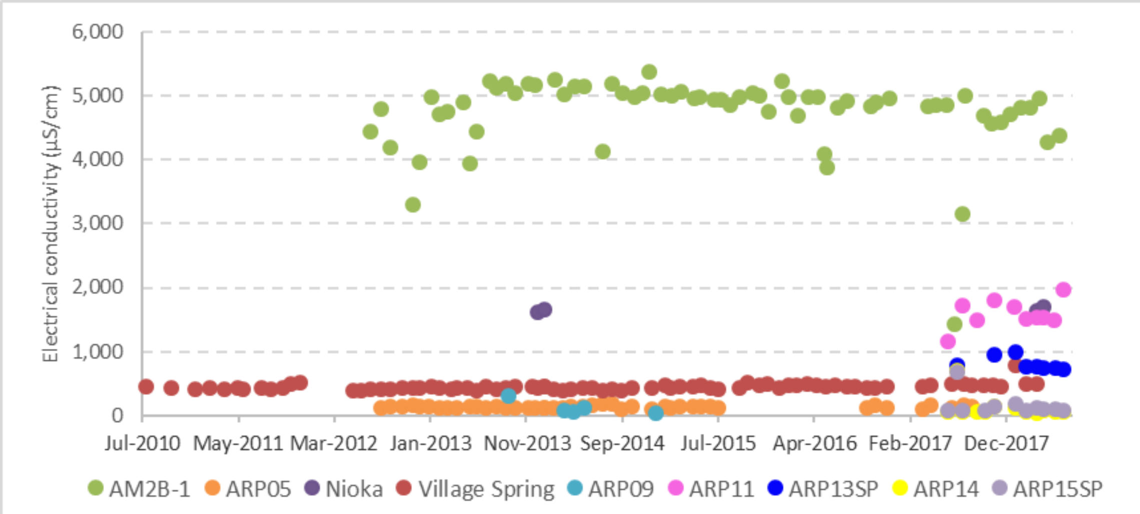


Figure B-20 Electrical conductivity monitored in groundwater

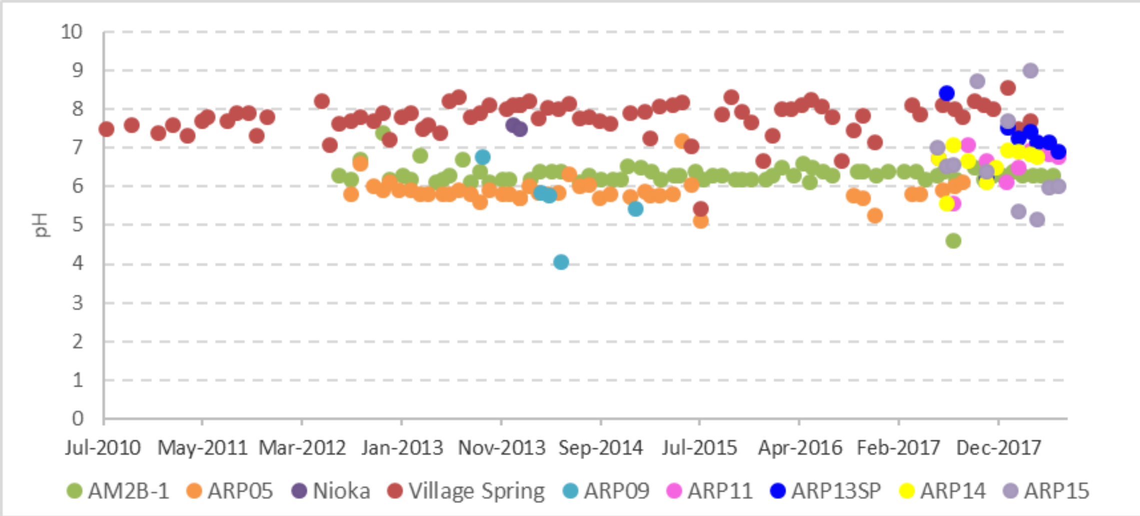


Figure B-21 pH monitored in groundwater

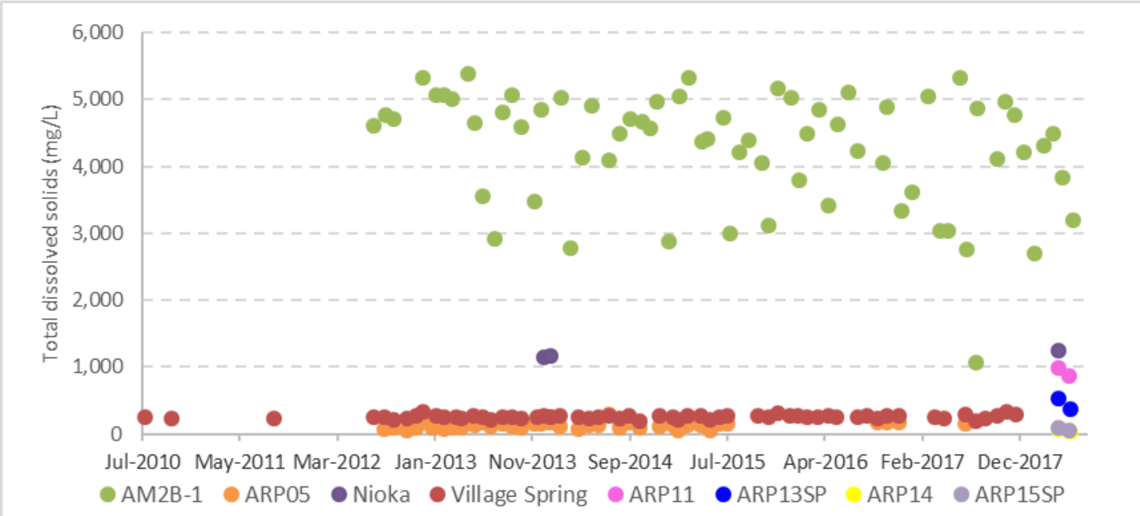


Figure B-22 Total dissolved solids monitored in groundwater

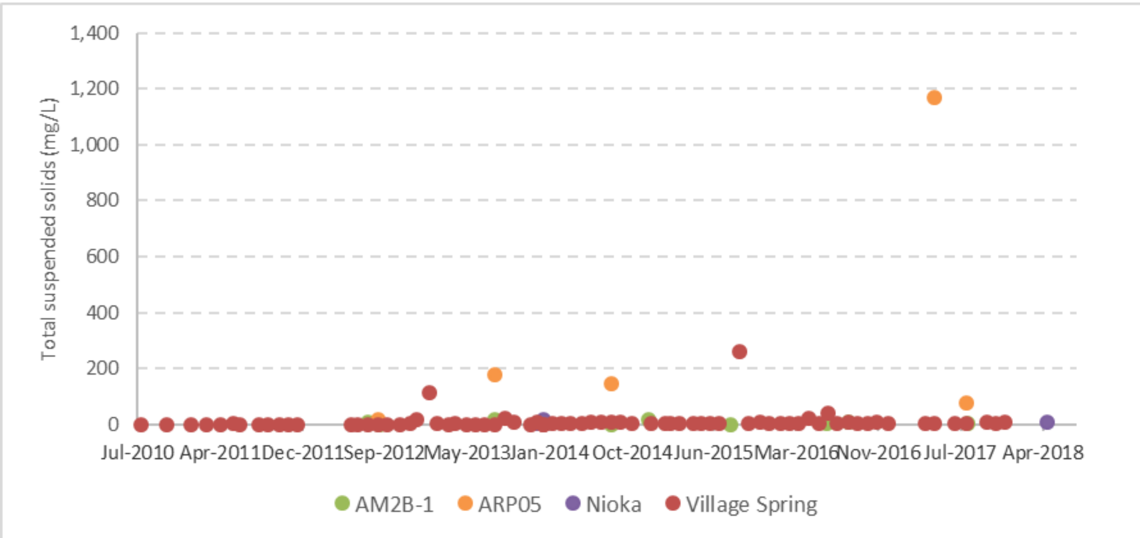


Figure B-23 Total suspended solids monitored in groundwater

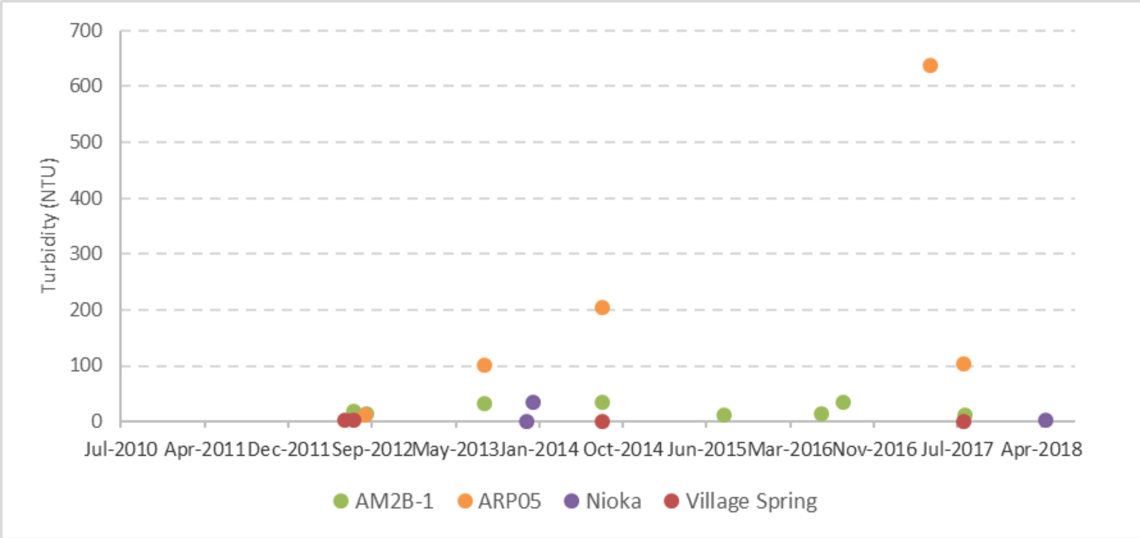


Figure B-24 Turbidity monitored in groundwater

Nutrients

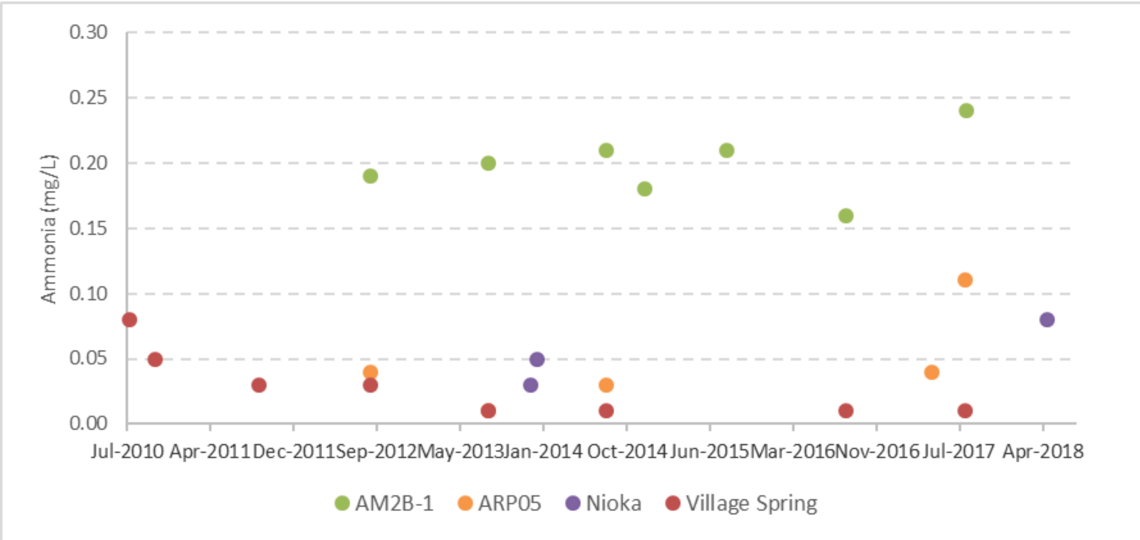


Figure B-25 Ammonia monitored in groundwater

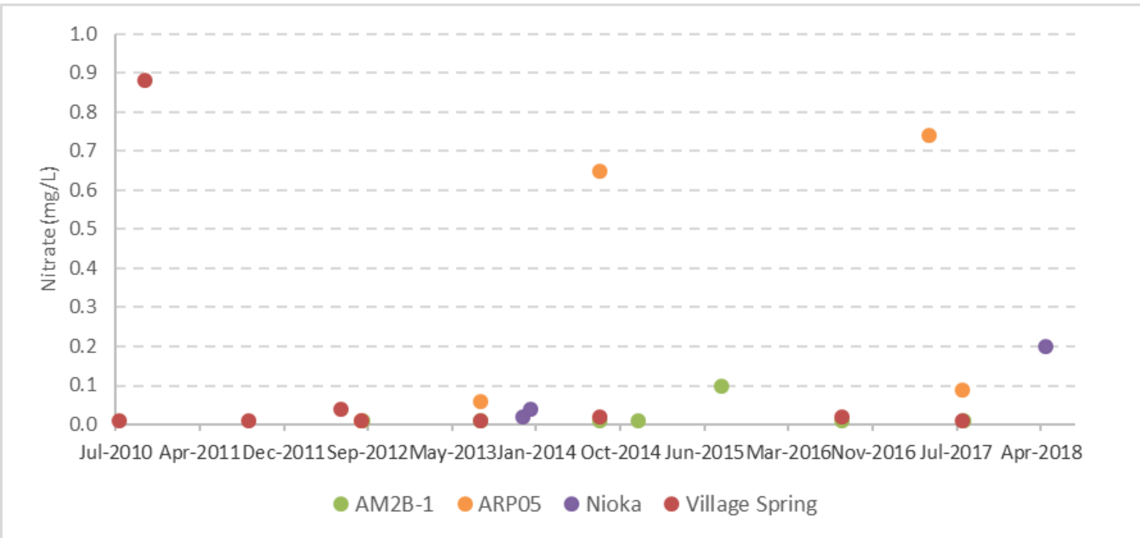


Figure B-26 Nitrate monitored in groundwater

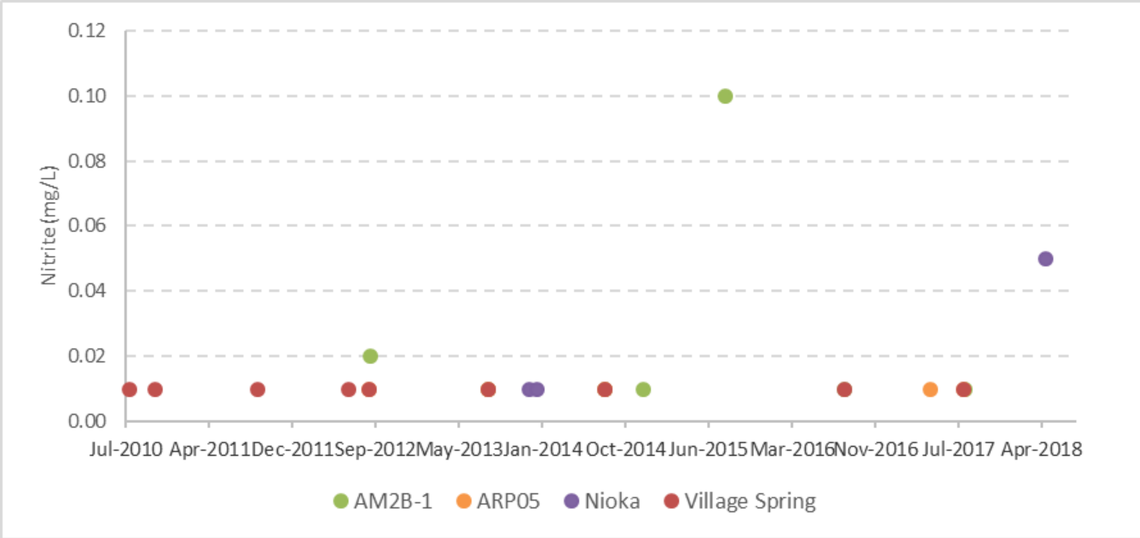


Figure B-27 Nitrite monitored in groundwater

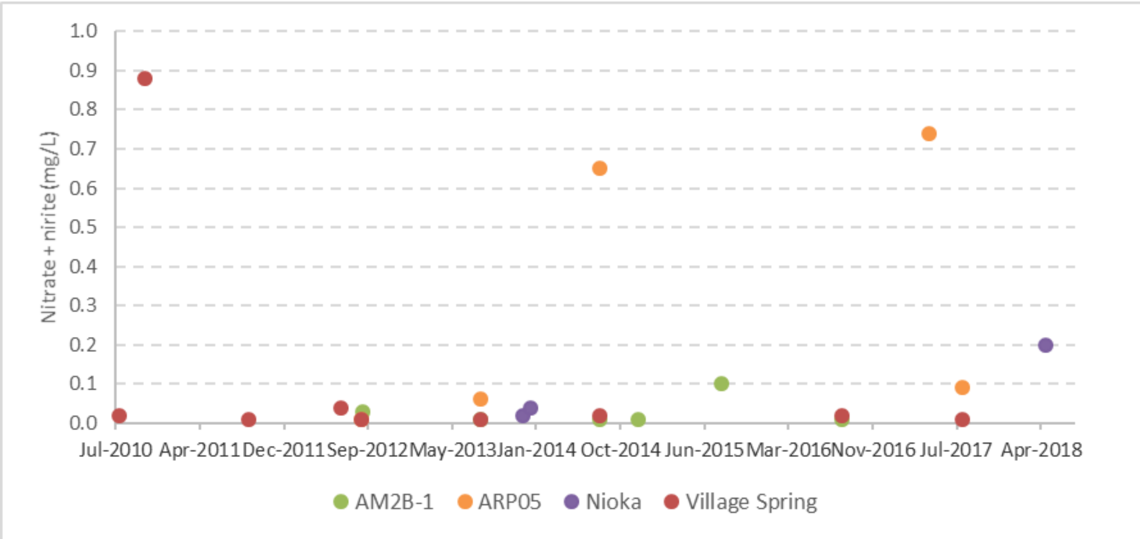


Figure B-28 Nitrate + nitrite monitored in groundwater

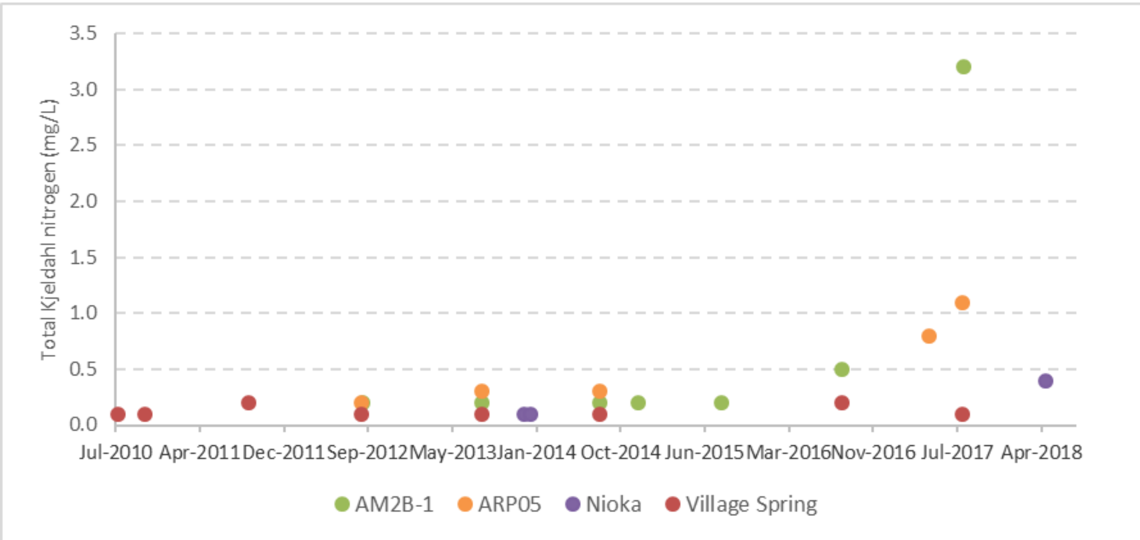


Figure B-29 Total Kjeldahl nitrogen monitored in groundwater

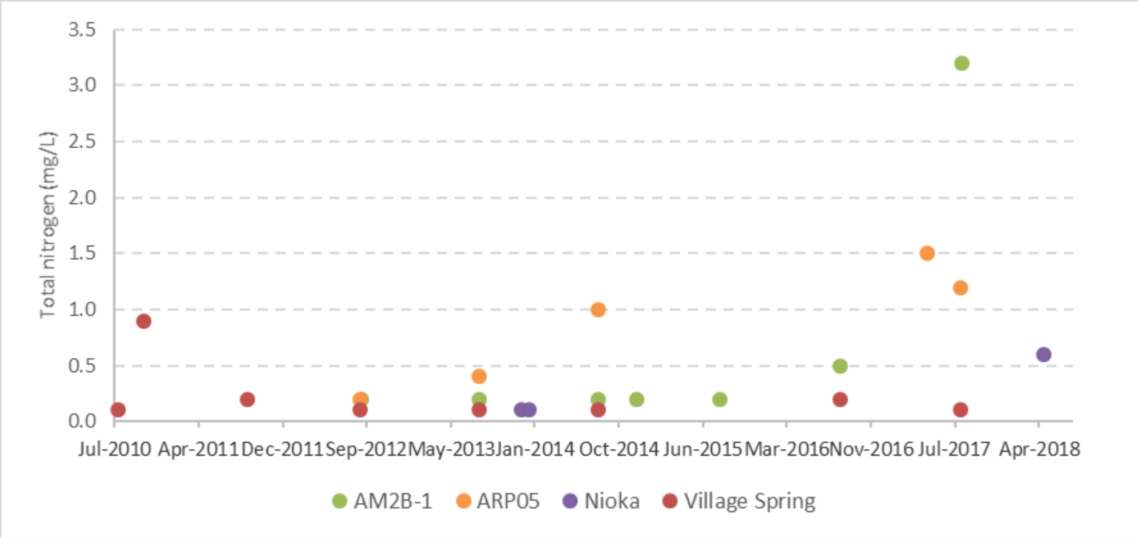


Figure B-30 Total nitrogen monitored in groundwater

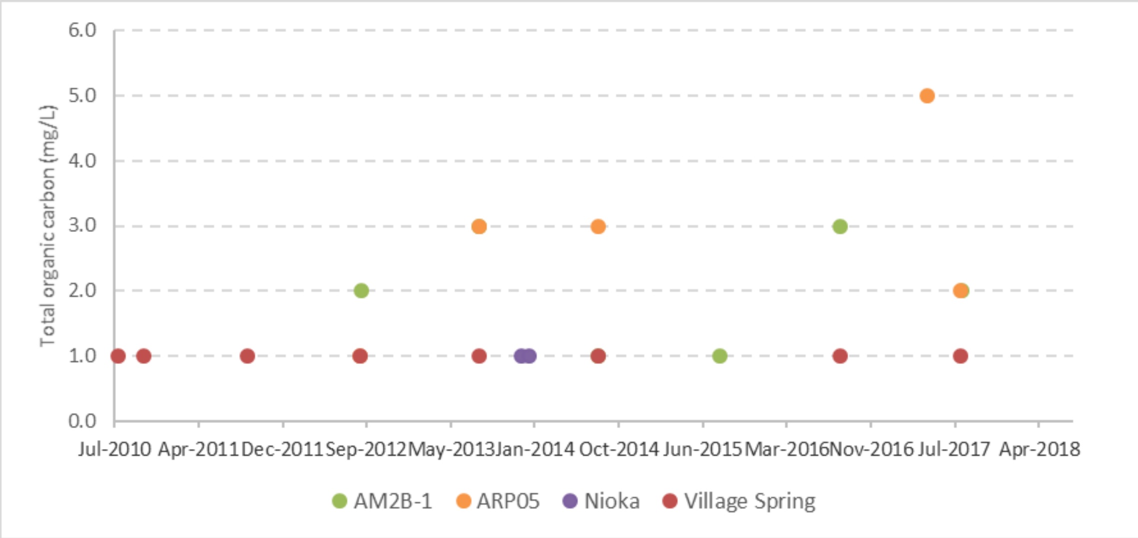


Figure B-31 Total organic carbon monitored in groundwater

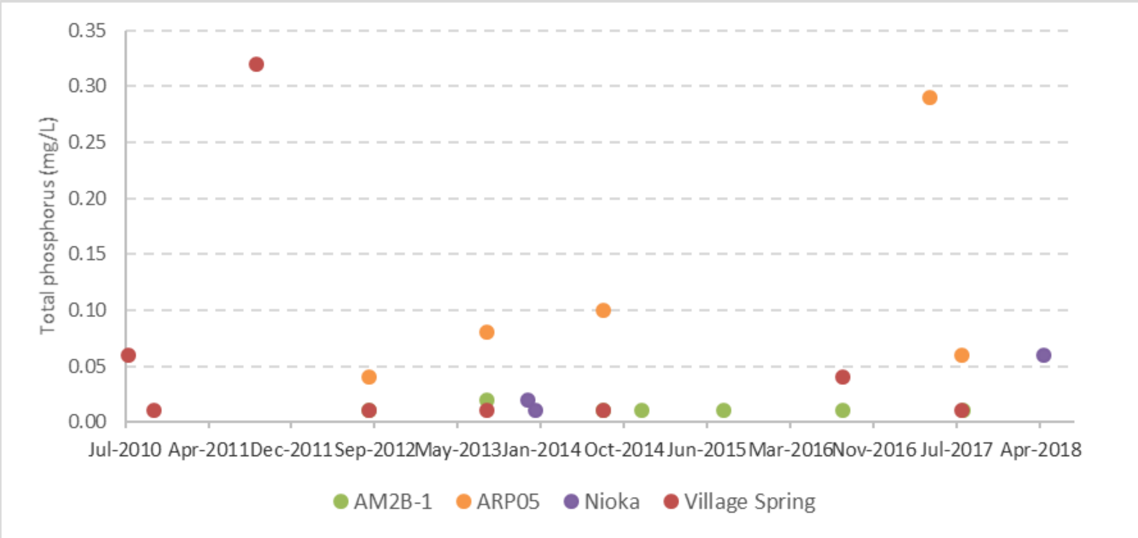


Figure B-32 Total phosphorus monitored in groundwater

Major ions

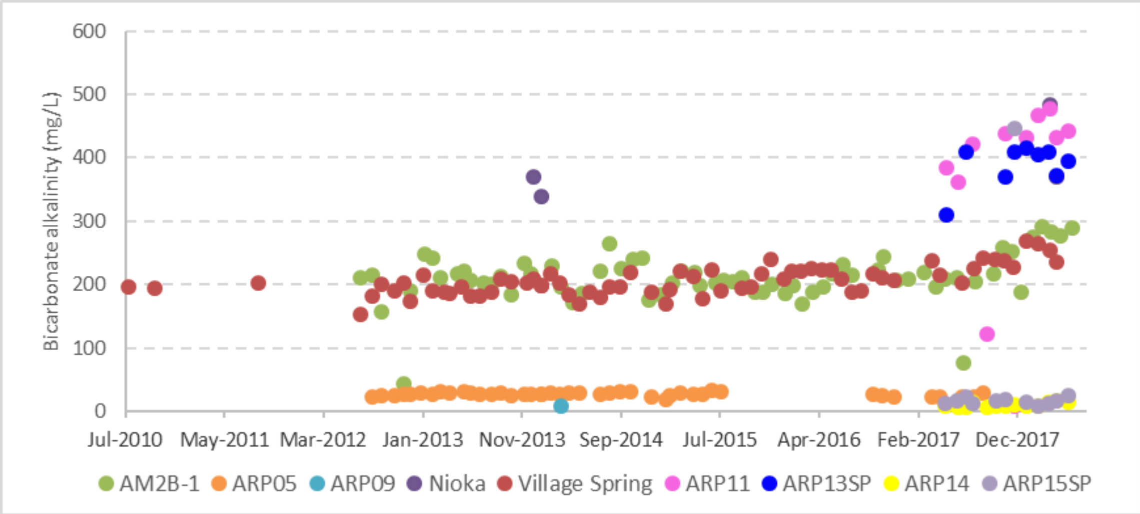


Figure B-33 Bicarbonate alkalinity monitored in groundwater

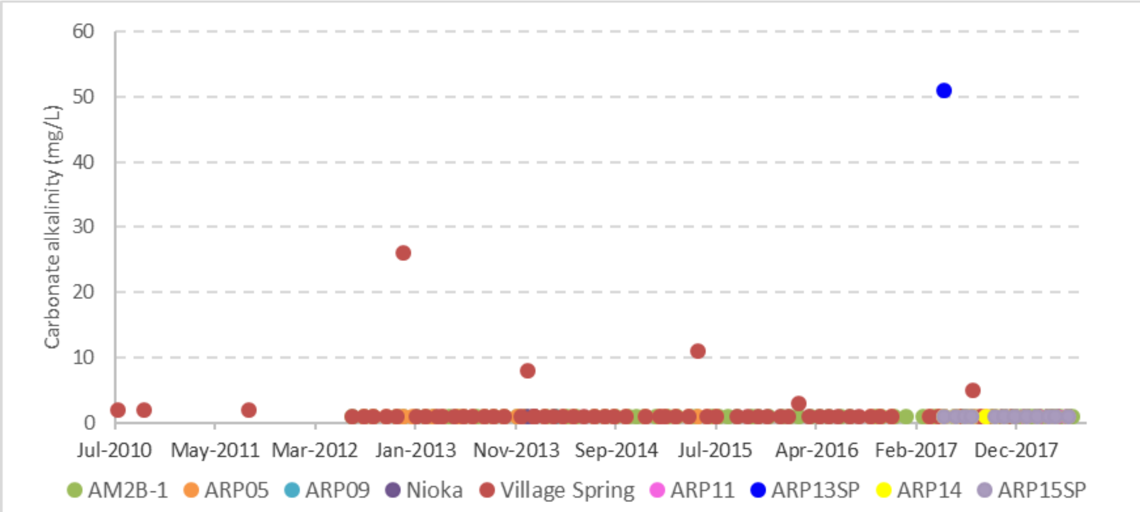


Figure B-34 Carbonate alkalinity monitored in groundwater

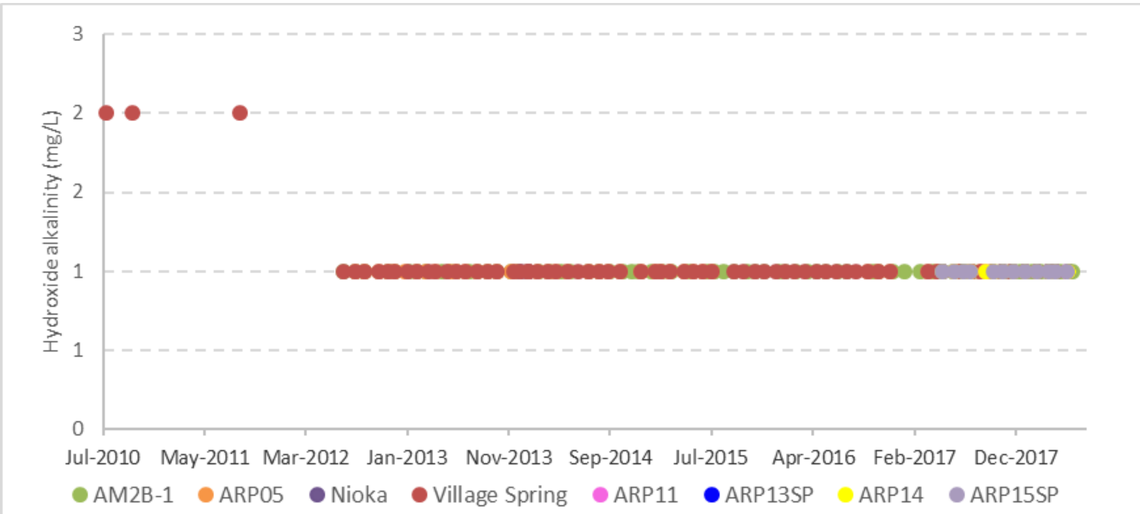


Figure B-35 Hydroxide alkalinity monitored in groundwater

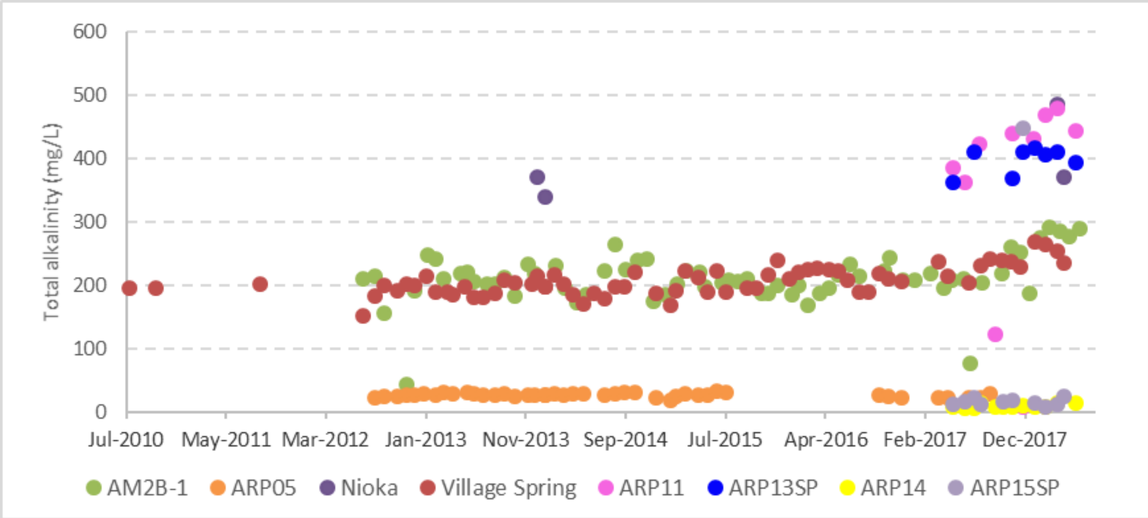


Figure B-36 Total alkalinity monitored in groundwater

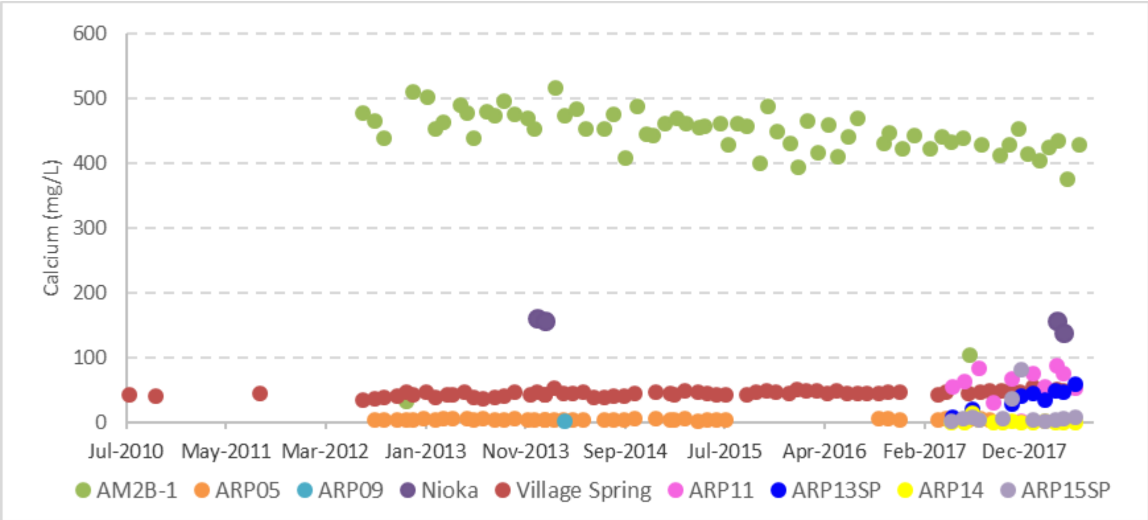


Figure B-37 Calcium monitored in groundwater

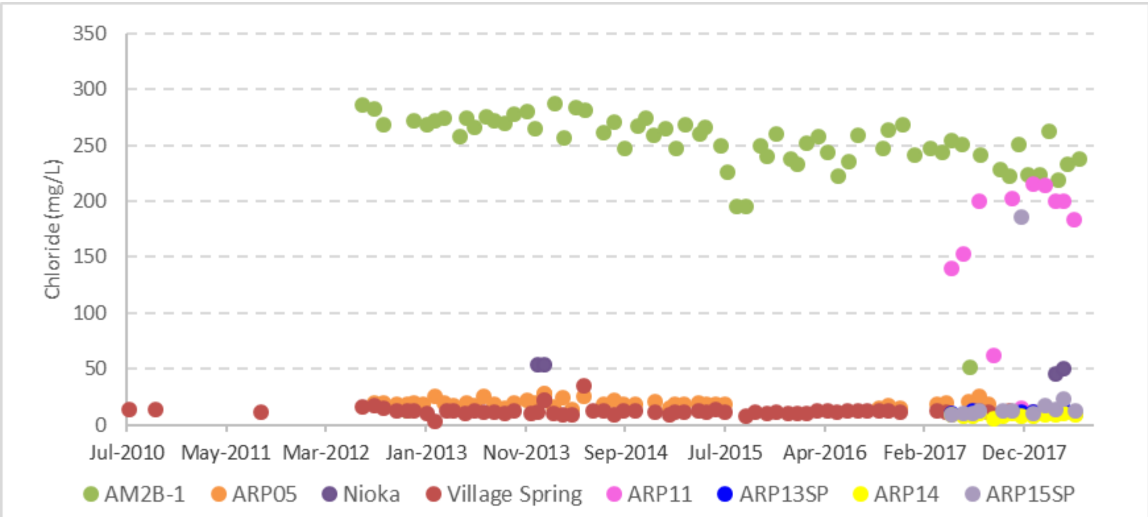


Figure B-38 Chloride monitored in groundwater

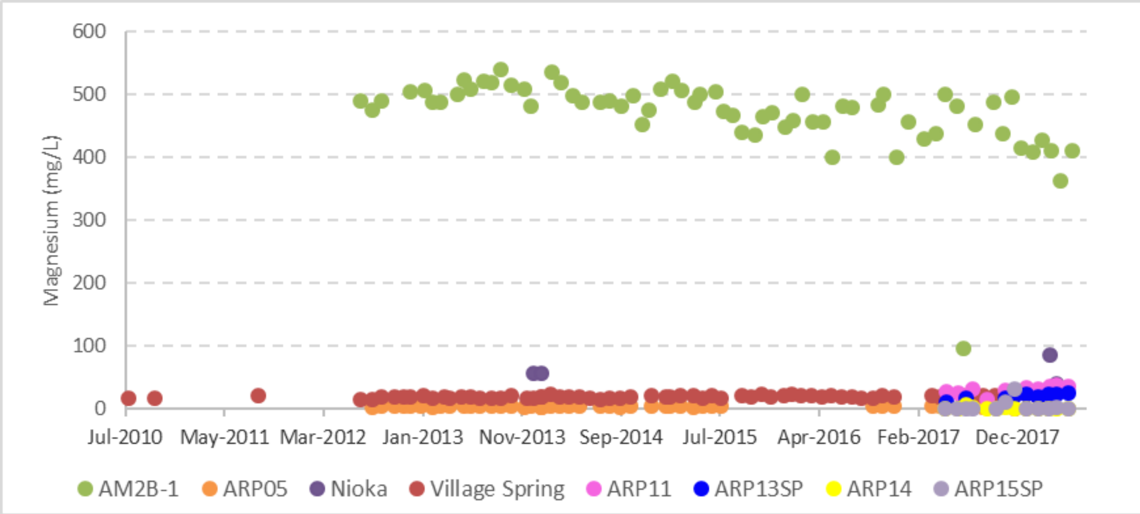


Figure B-39 Magnesium monitored in groundwater

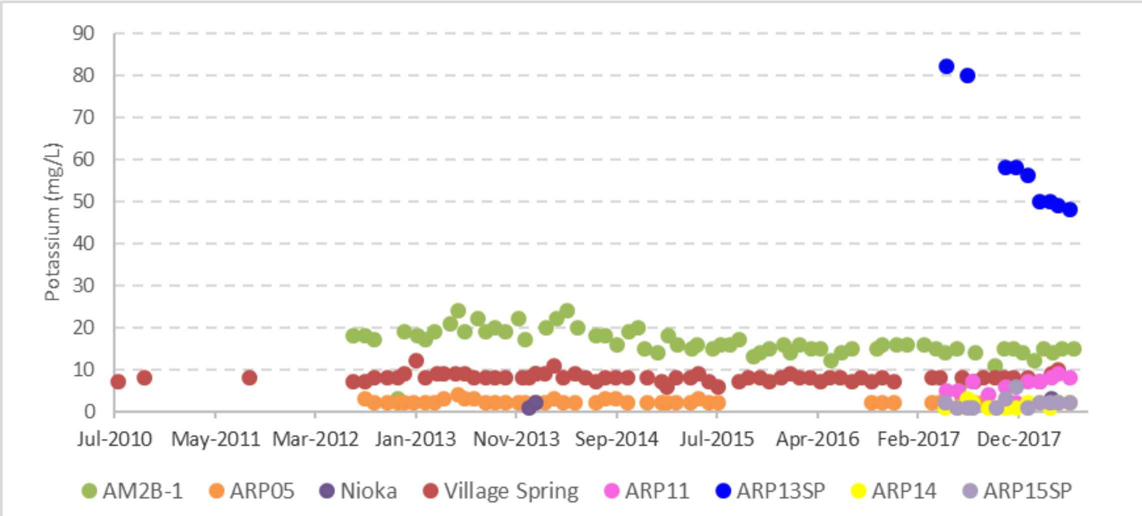


Figure B-40 Potassium monitored in groundwater

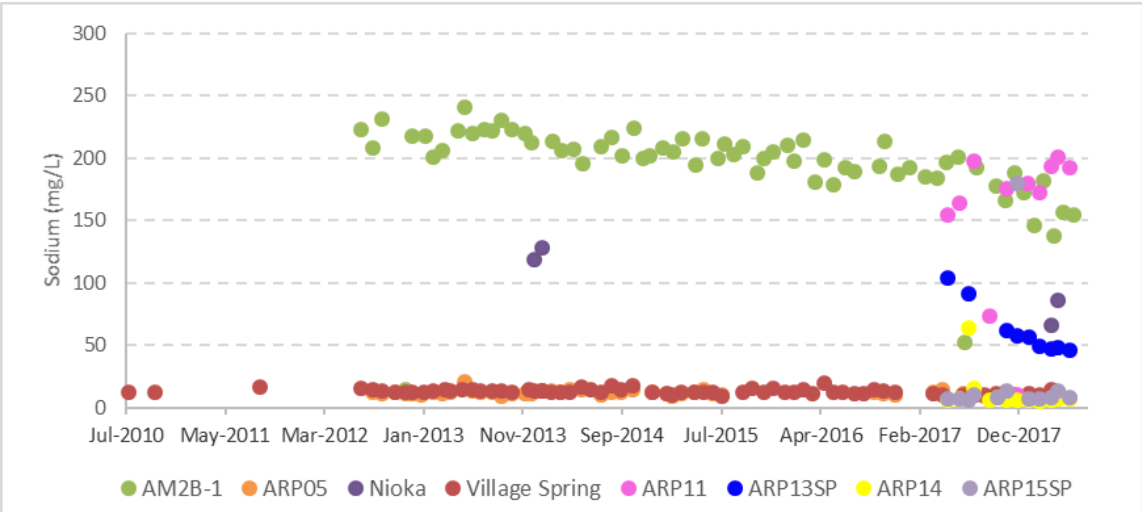


Figure B-41 Sodium monitored in groundwater

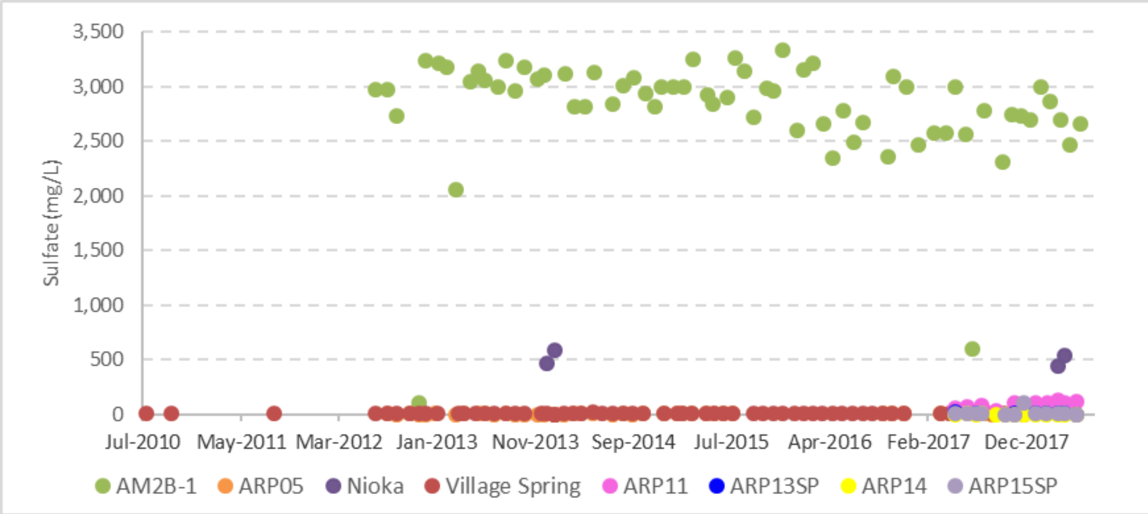


Figure B-42 Sulfate monitored in groundwater

Metals

Note that time series graph for mercury has not been shown as all results have been below the LOR.

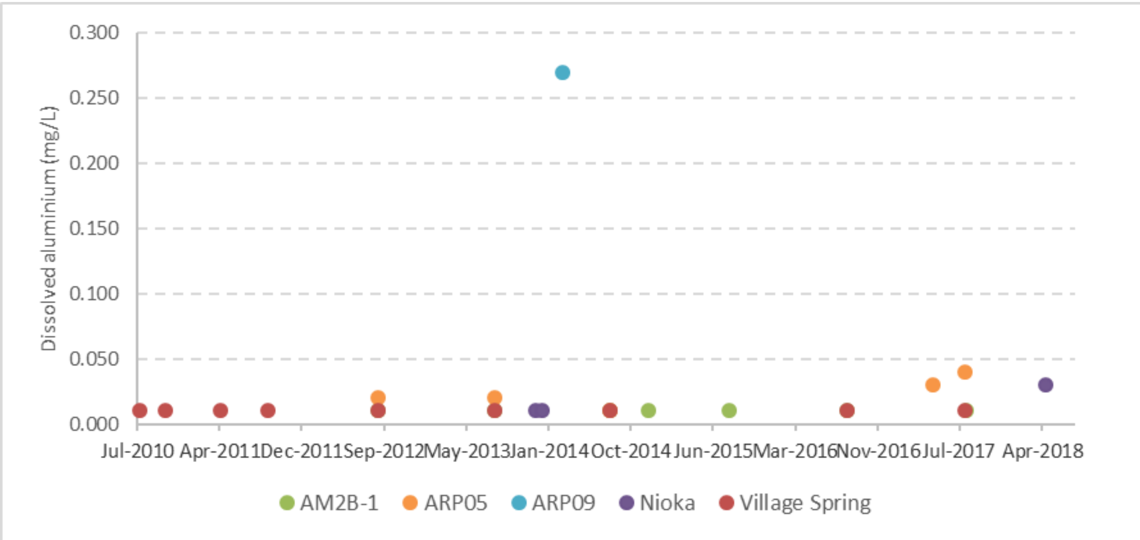


Figure B-43 Dissolved aluminium monitored in groundwater

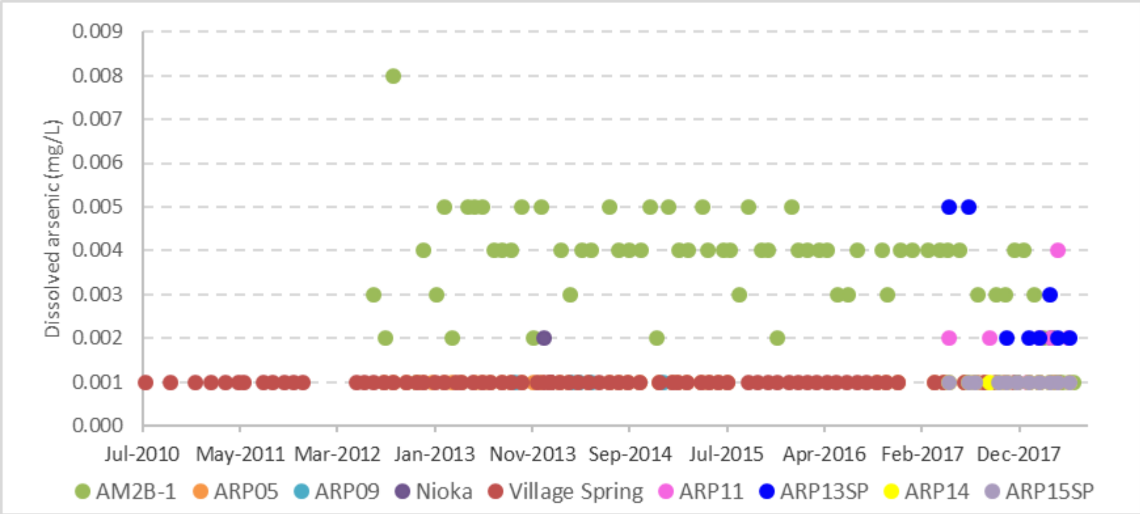


Figure B-44 Dissolved arsenic monitored in groundwater

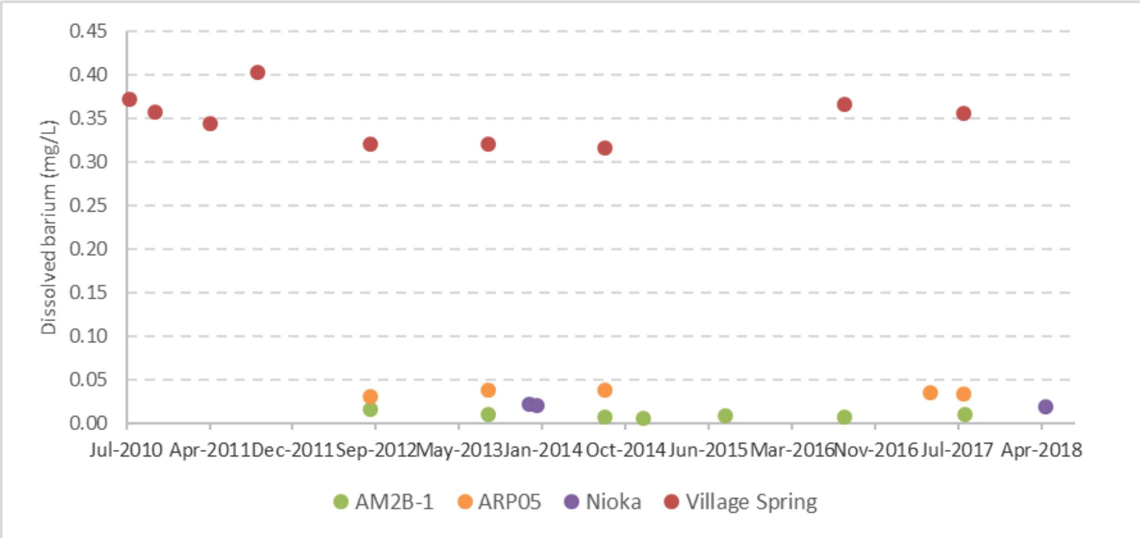


Figure B-45 Dissolved barium monitored in groundwater

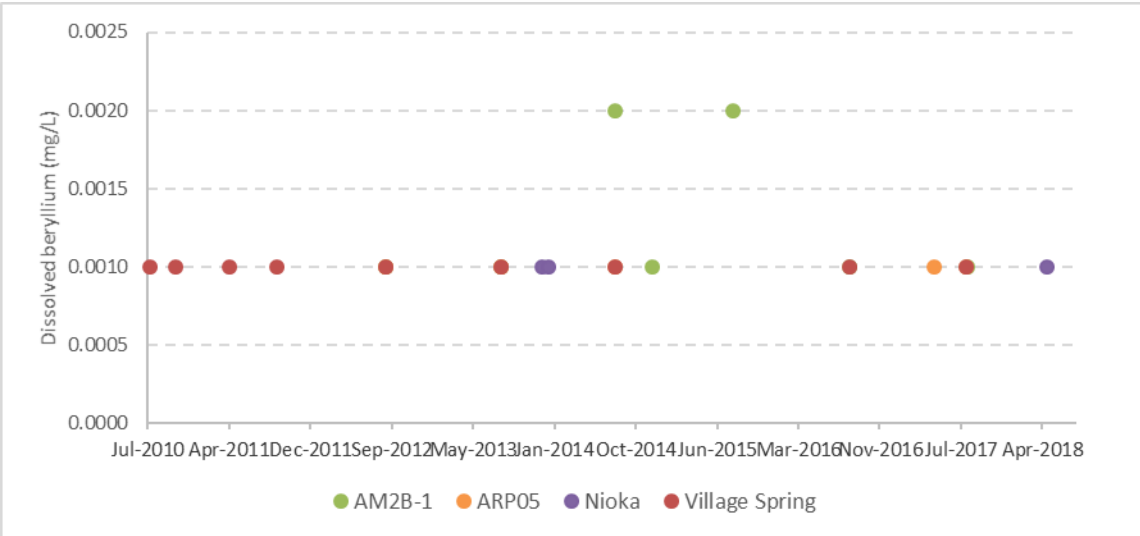


Figure B-46 Dissolved beryllium monitored in groundwater

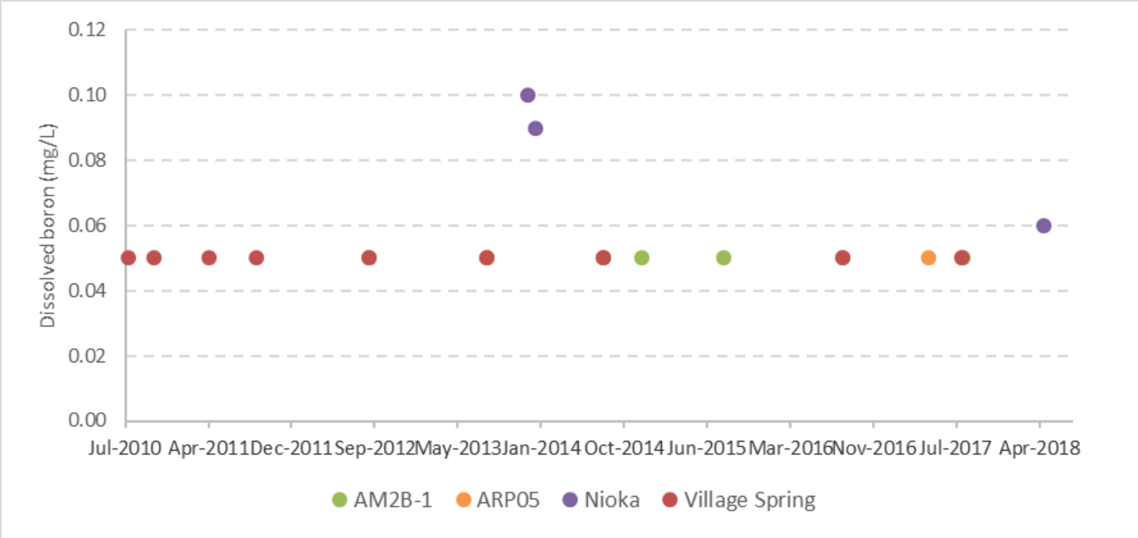


Figure B-47 Dissolved boron monitored in groundwater

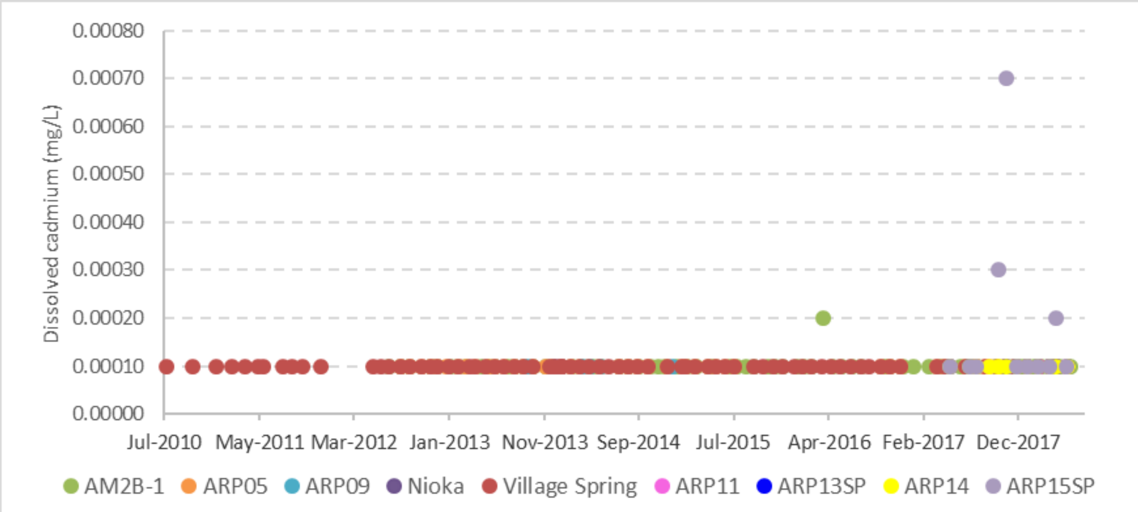


Figure B-48 Dissolved cadmium monitored in groundwater

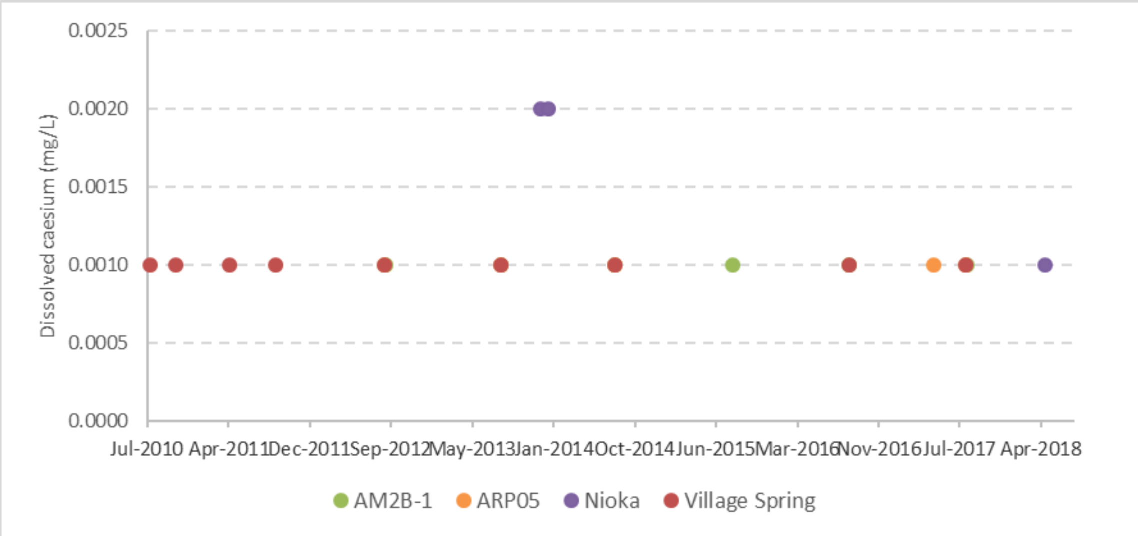


Figure B-49 Dissolved caesium monitored in groundwater

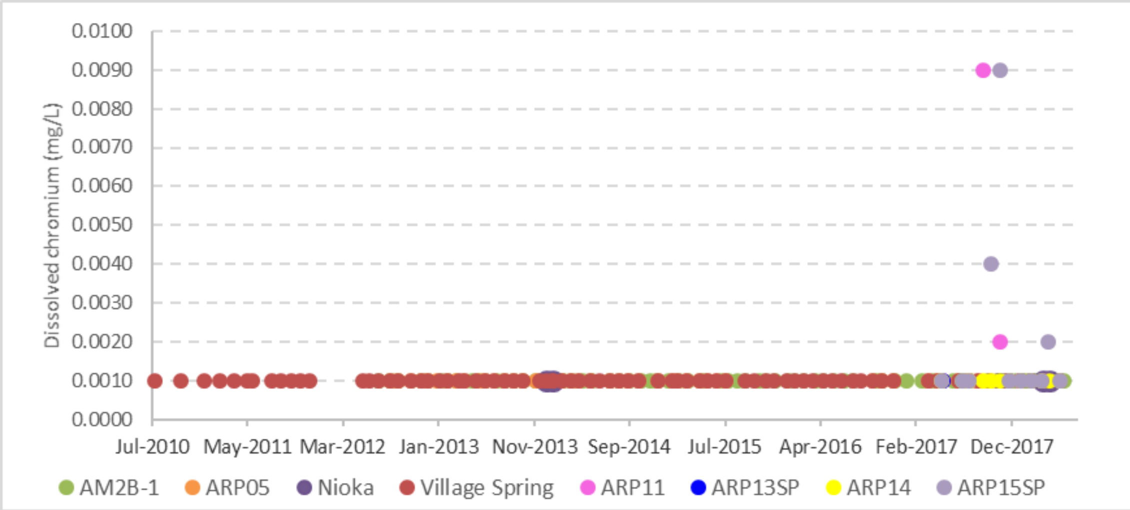


Figure B-50 Dissolved chromium monitored in groundwater

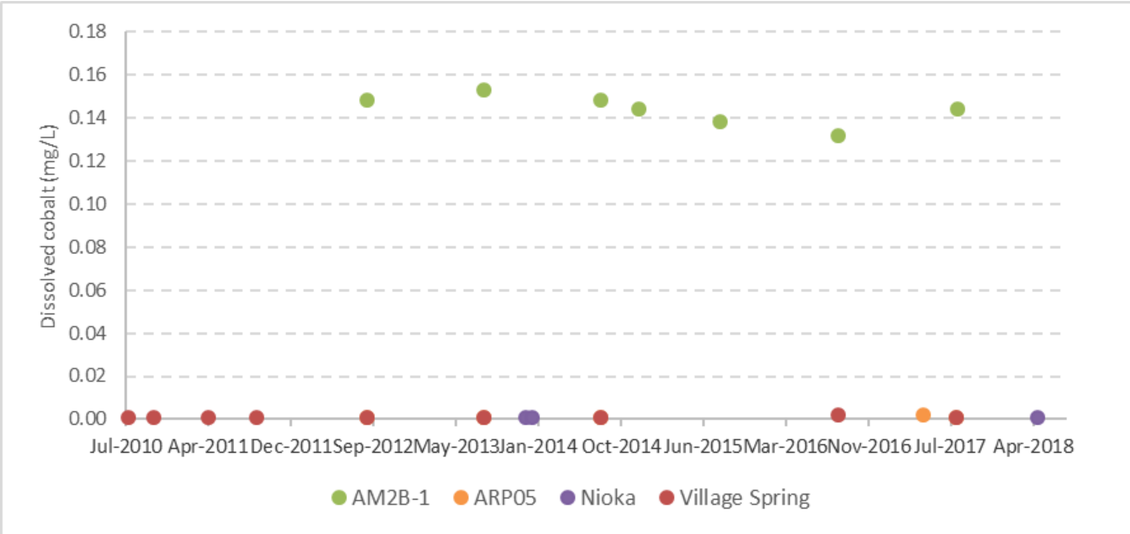


Figure B-51 Dissolved cobalt monitored in groundwater

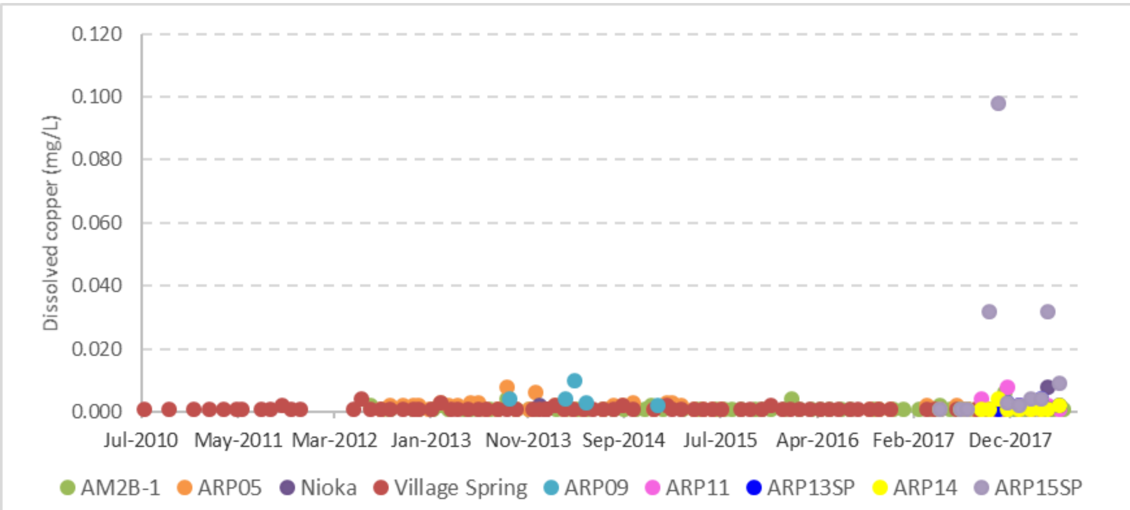


Figure B-52 Dissolved copper monitored in groundwater

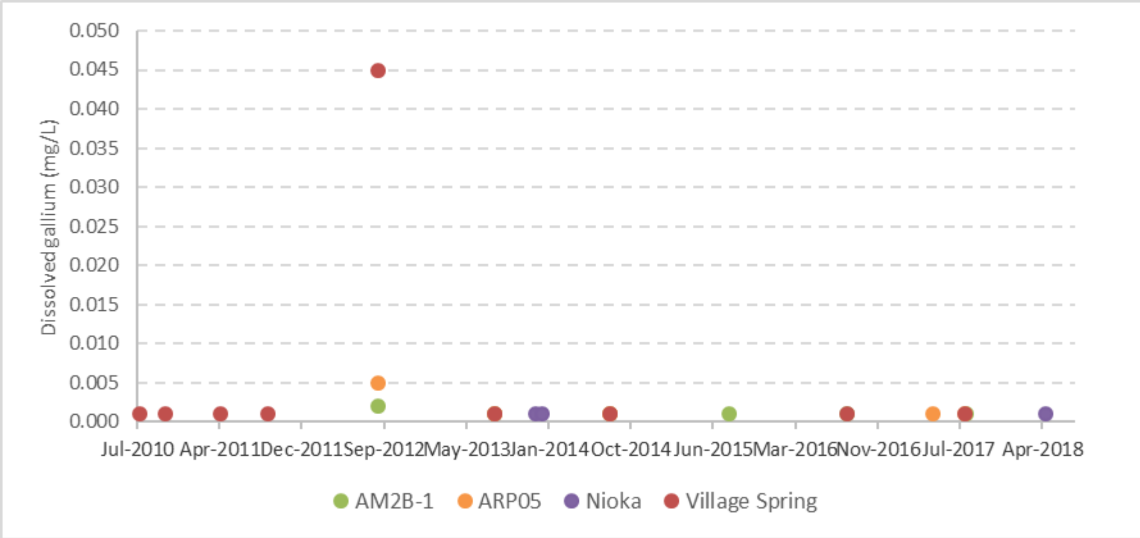


Figure B-53 Dissolved gallium monitored in groundwater

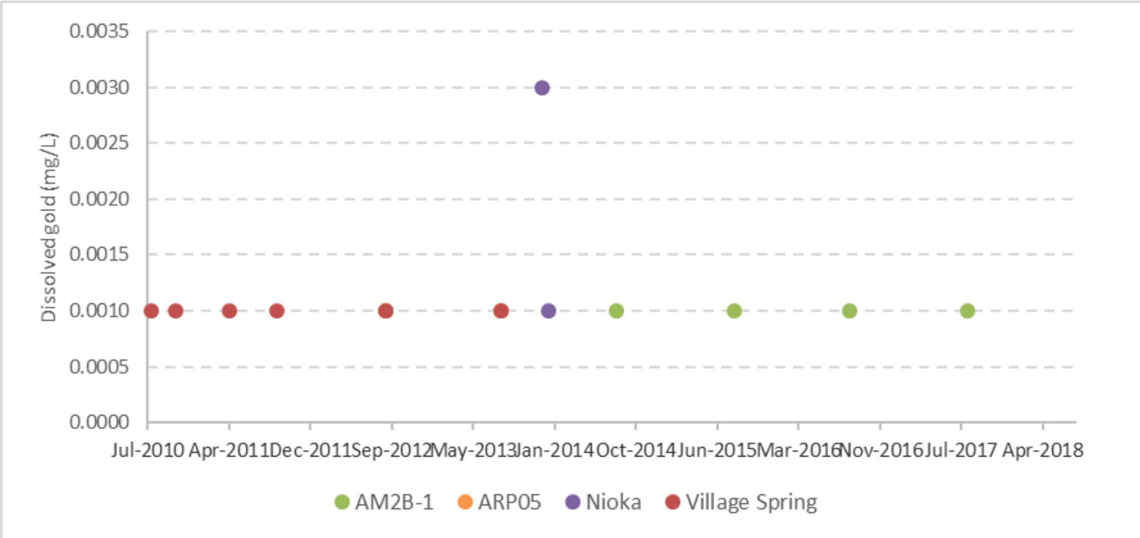


Figure B-54 Dissolved gold monitored in groundwater

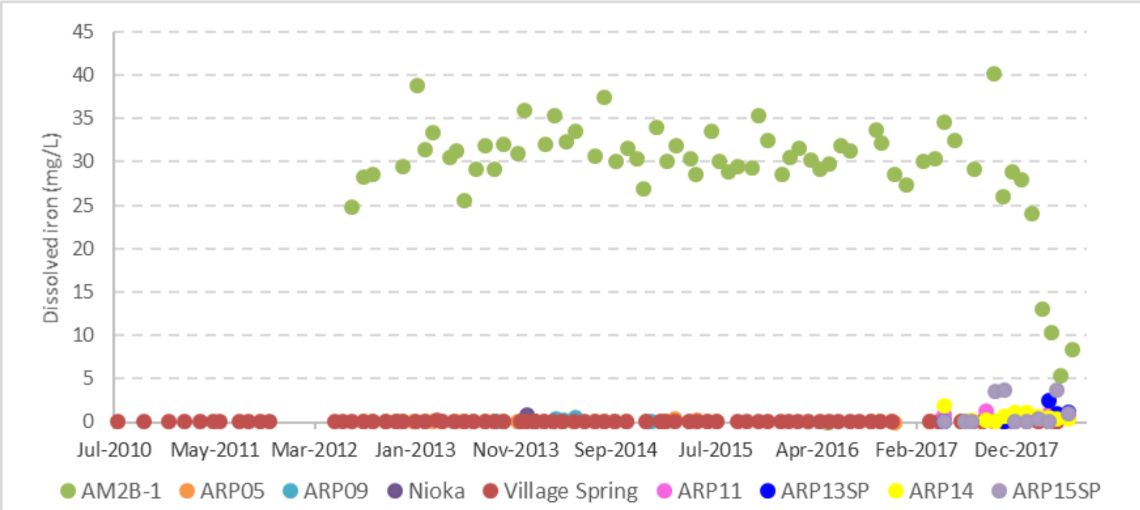


Figure B-55 Dissolved iron monitored in groundwater

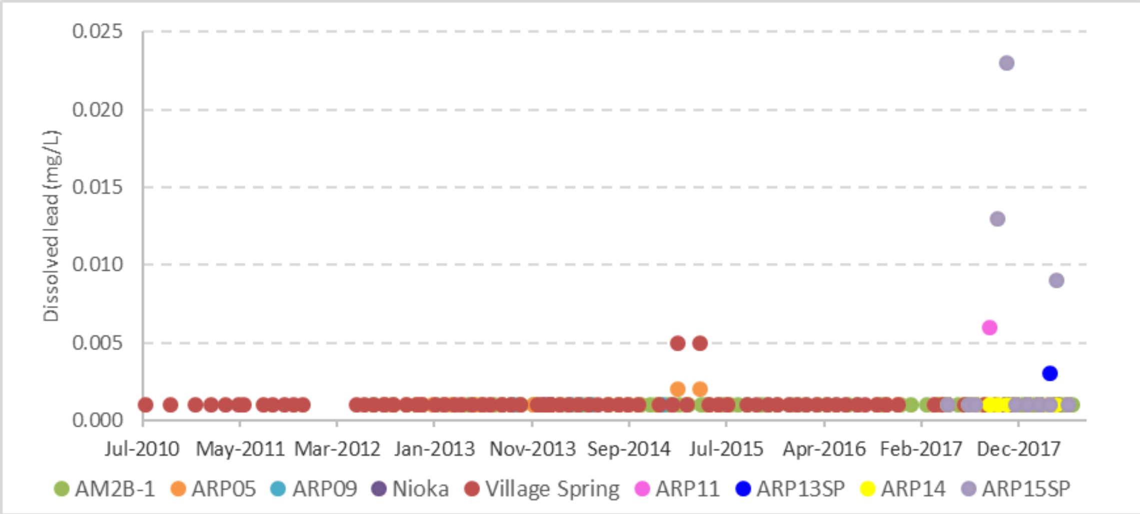


Figure B-56 Dissolved lead monitored in groundwater

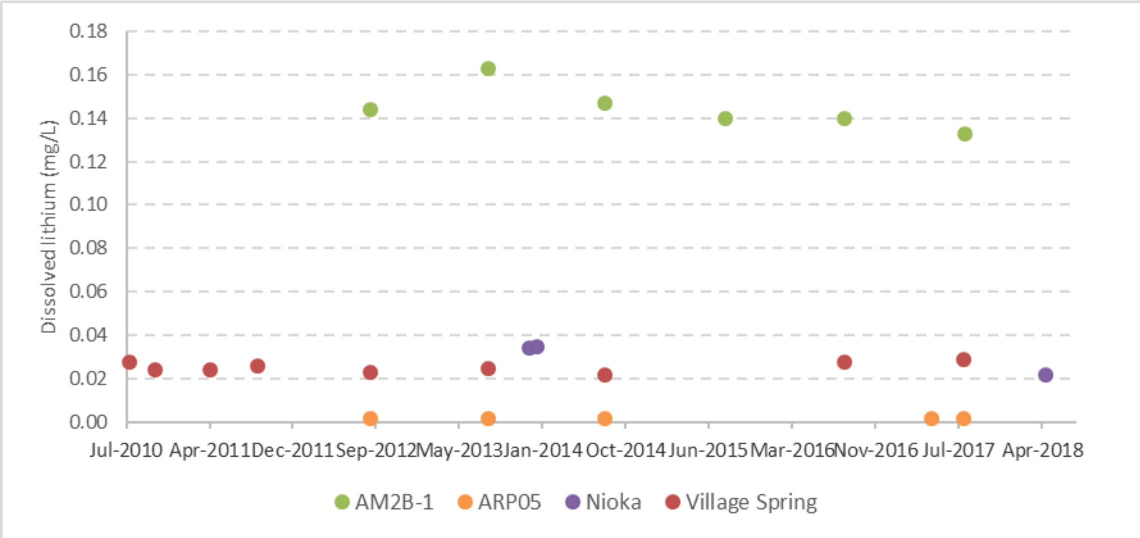


Figure B-57 Dissolved lithium monitored in groundwater

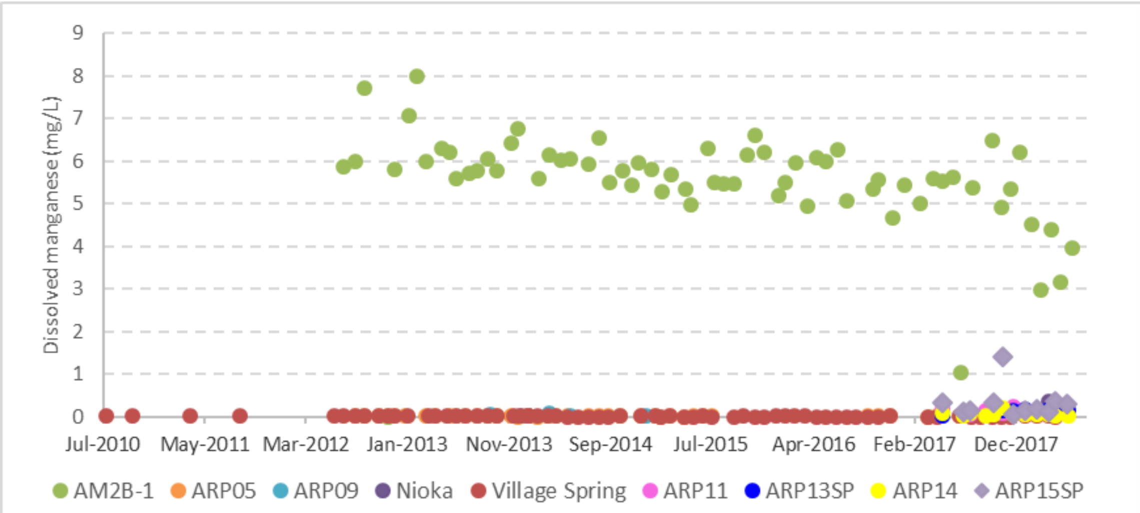


Figure B-58 Dissolved manganese monitored in groundwater

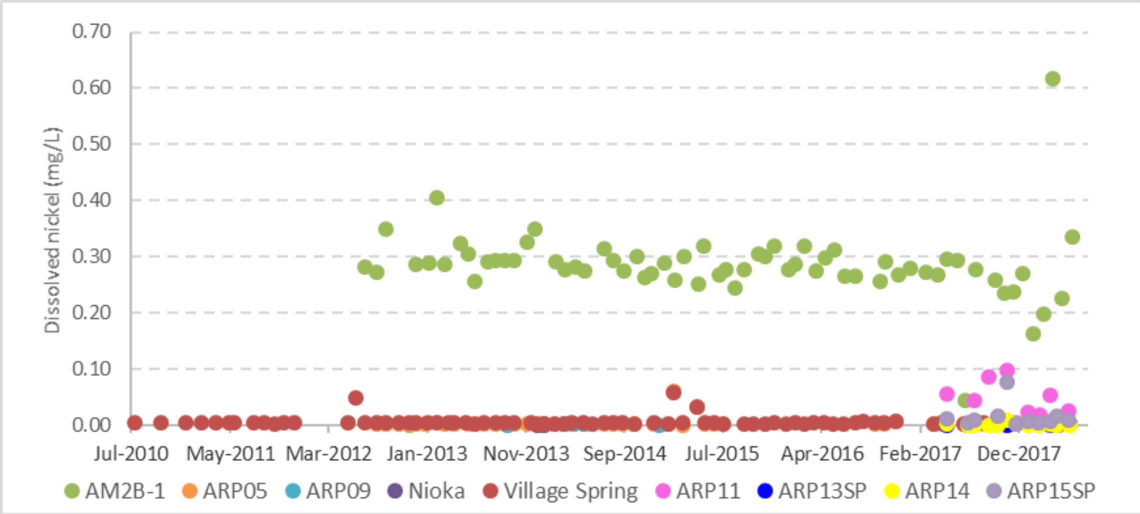


Figure B-59 Dissolved nickel monitored in groundwater

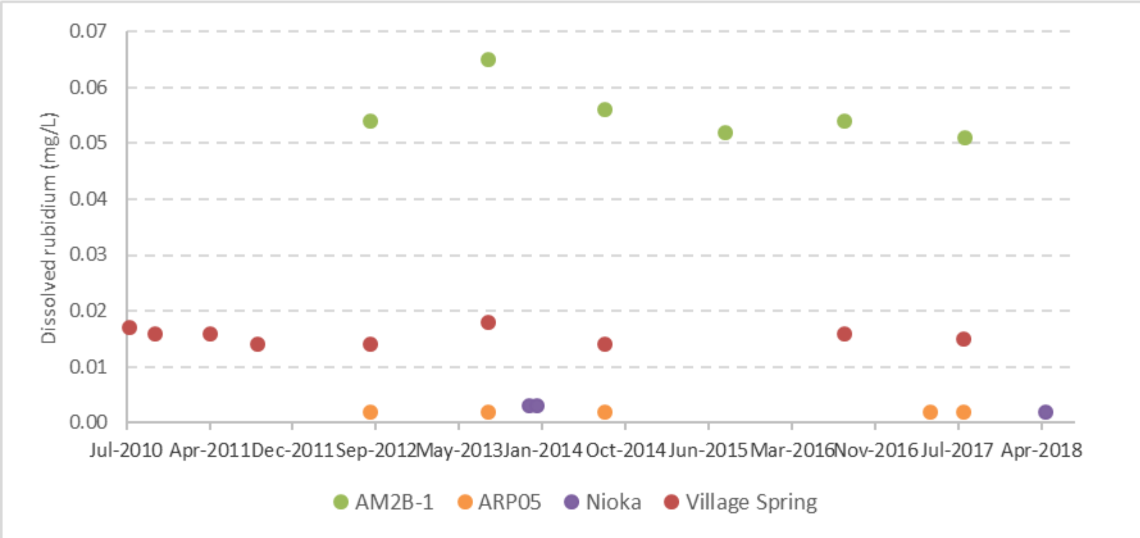


Figure B-60 Dissolved rubidium monitored in groundwater

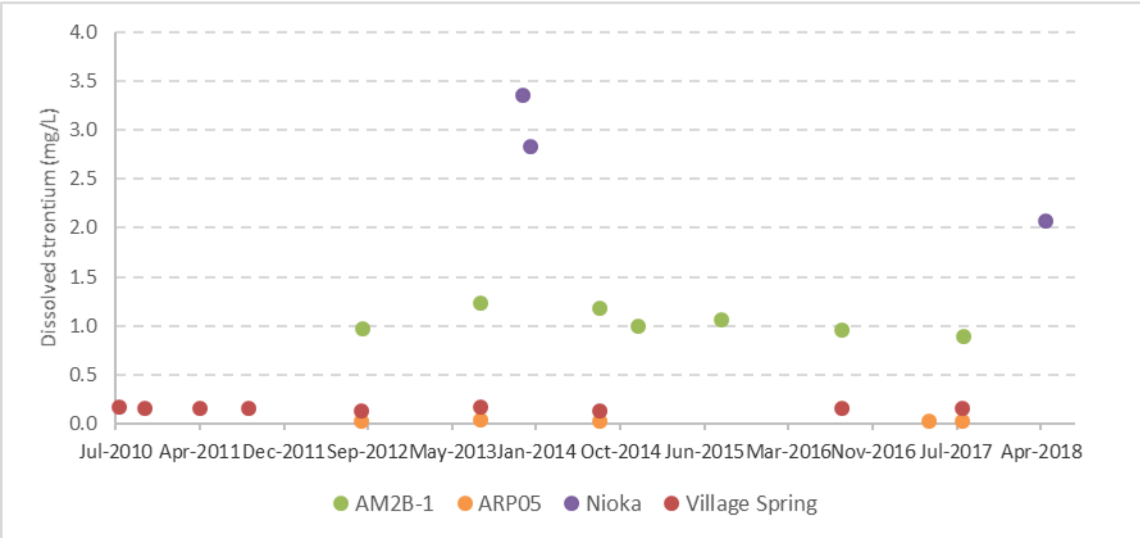


Figure B-61 Dissolved strontium monitored in groundwater

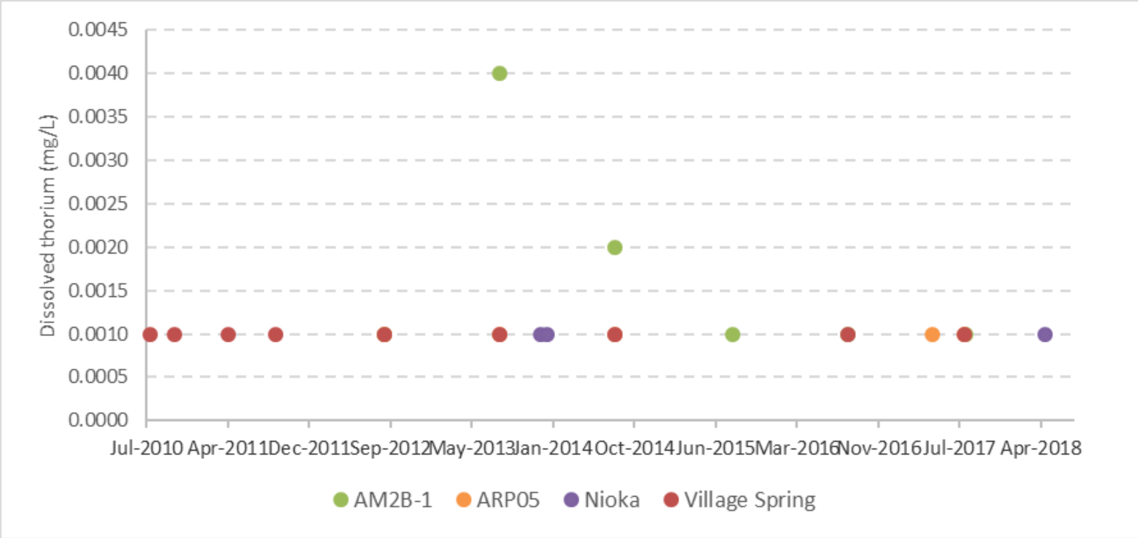


Figure B-62 Dissolved thorium monitored in groundwater

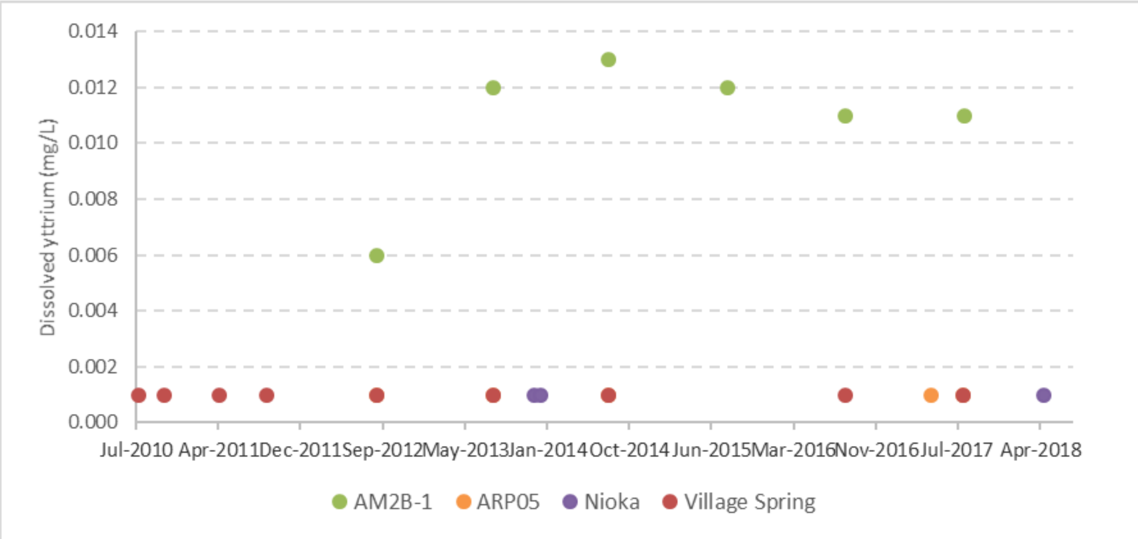


Figure B-63 Dissolved yttrium monitored in groundwater

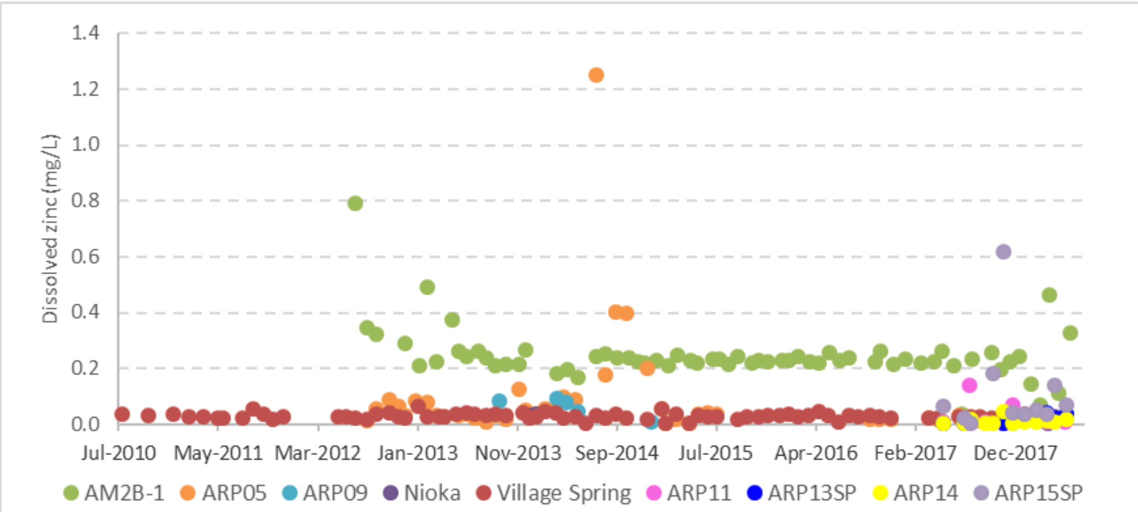


Figure B-64 Dissolved zinc monitored in groundwater

Other parameters

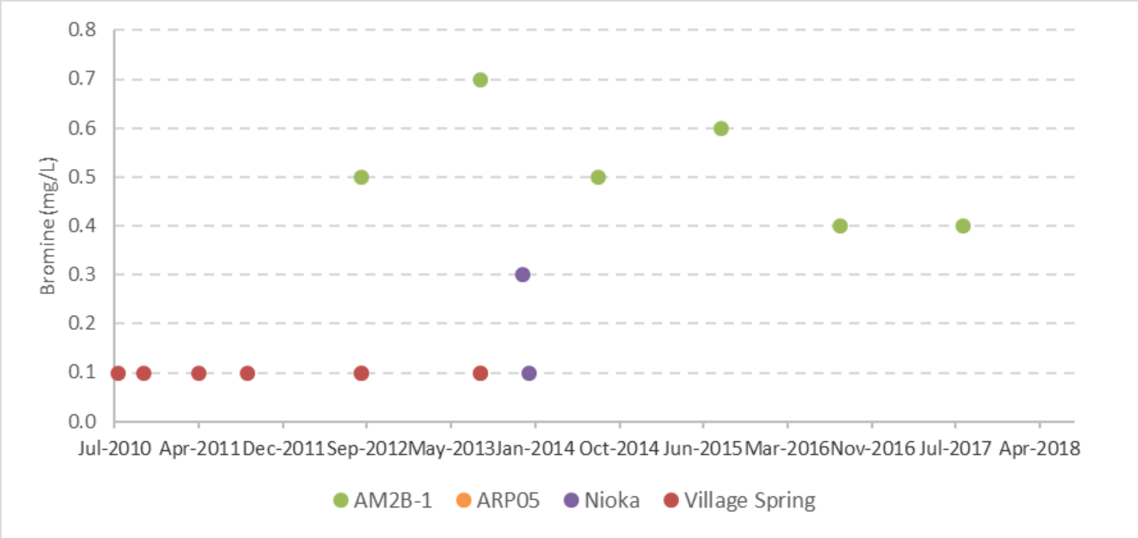


Figure B-65 Bromine monitored in groundwater

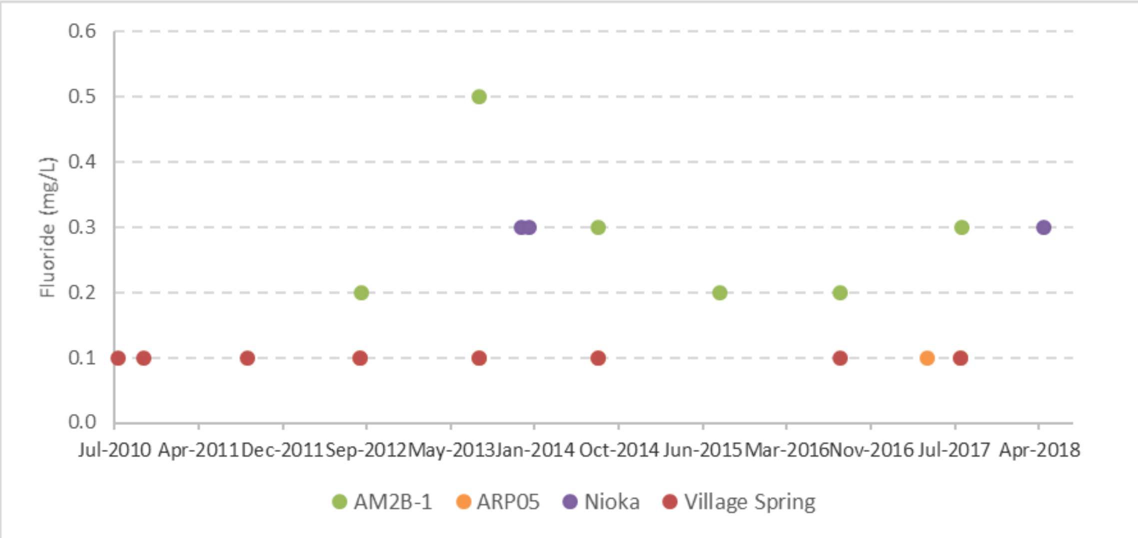


Figure B-66 Fluoride monitored in groundwater

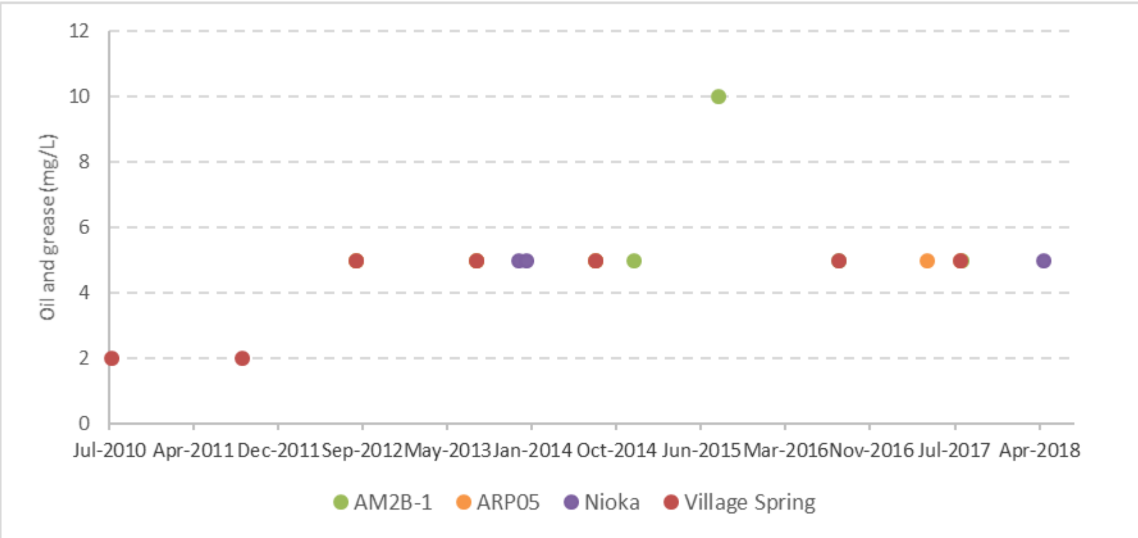


Figure B-67 Oil and grease monitored in groundwater

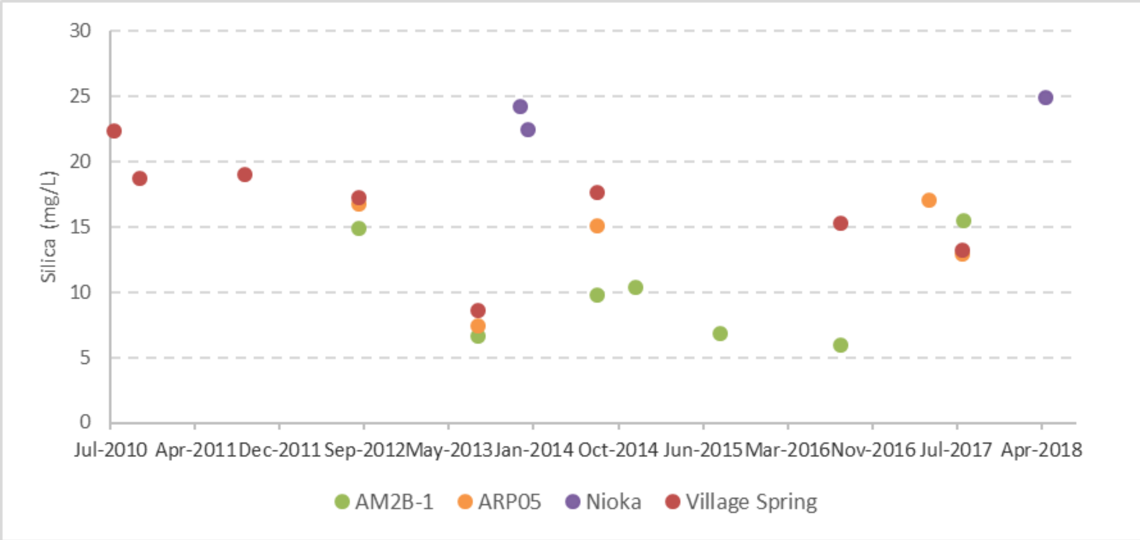


Figure B-68 Silica monitored in groundwater

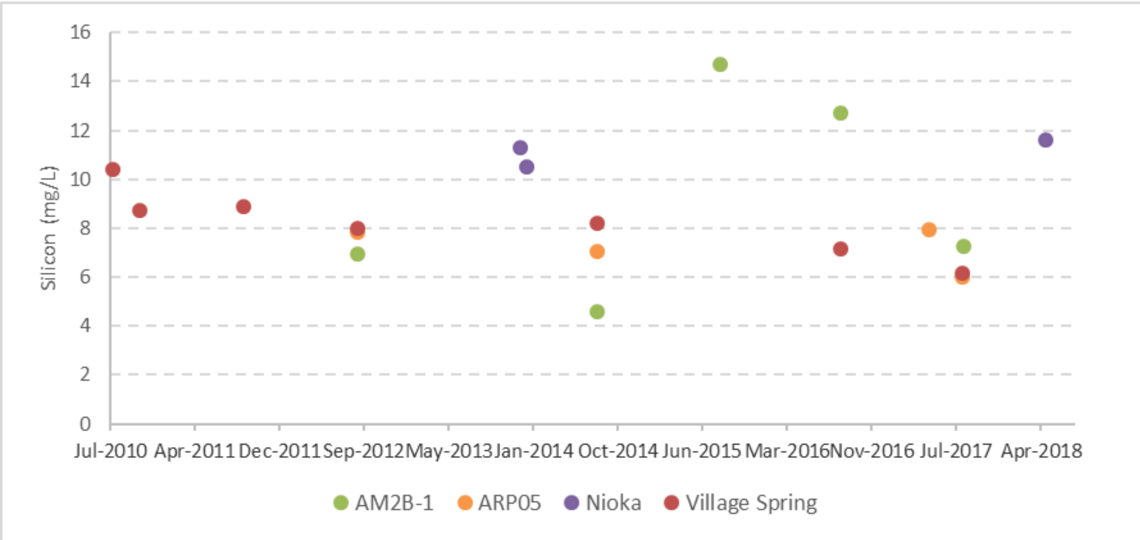
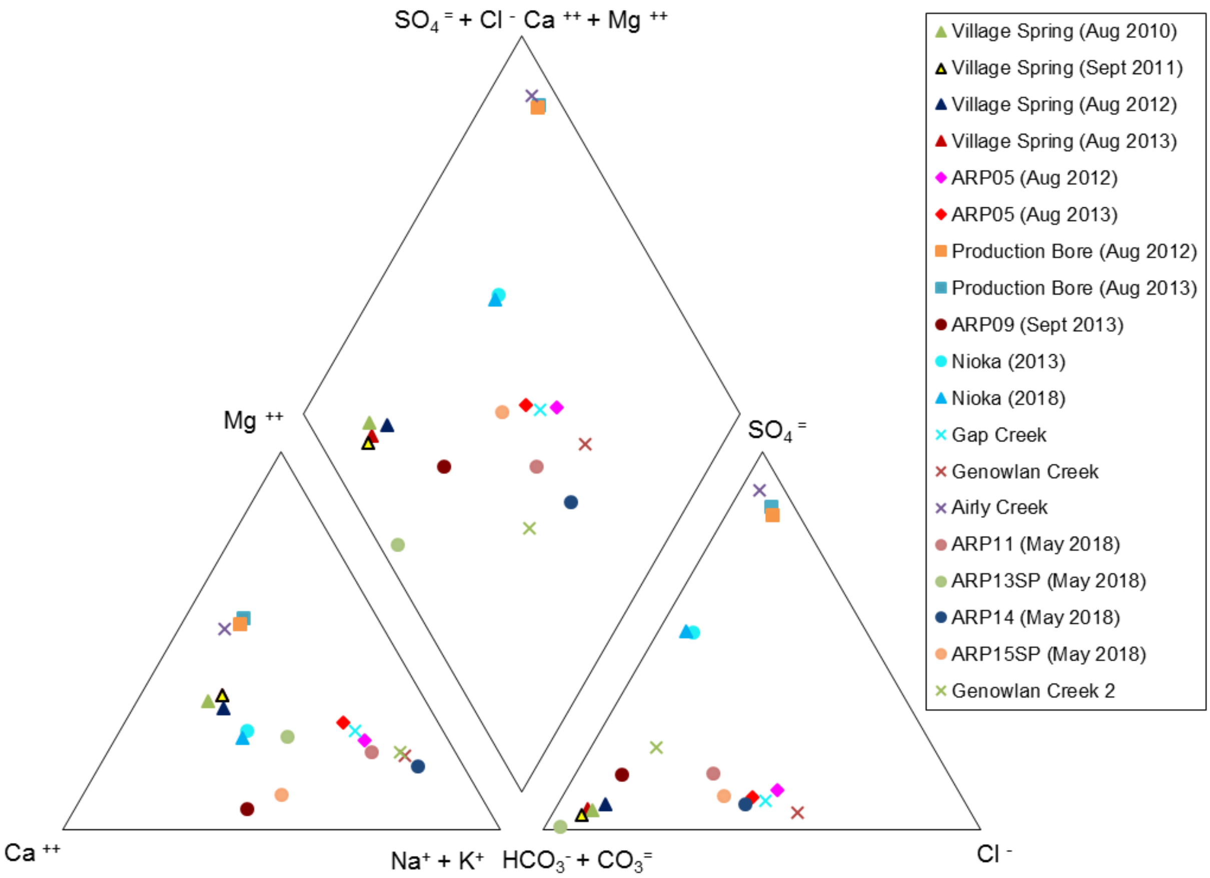
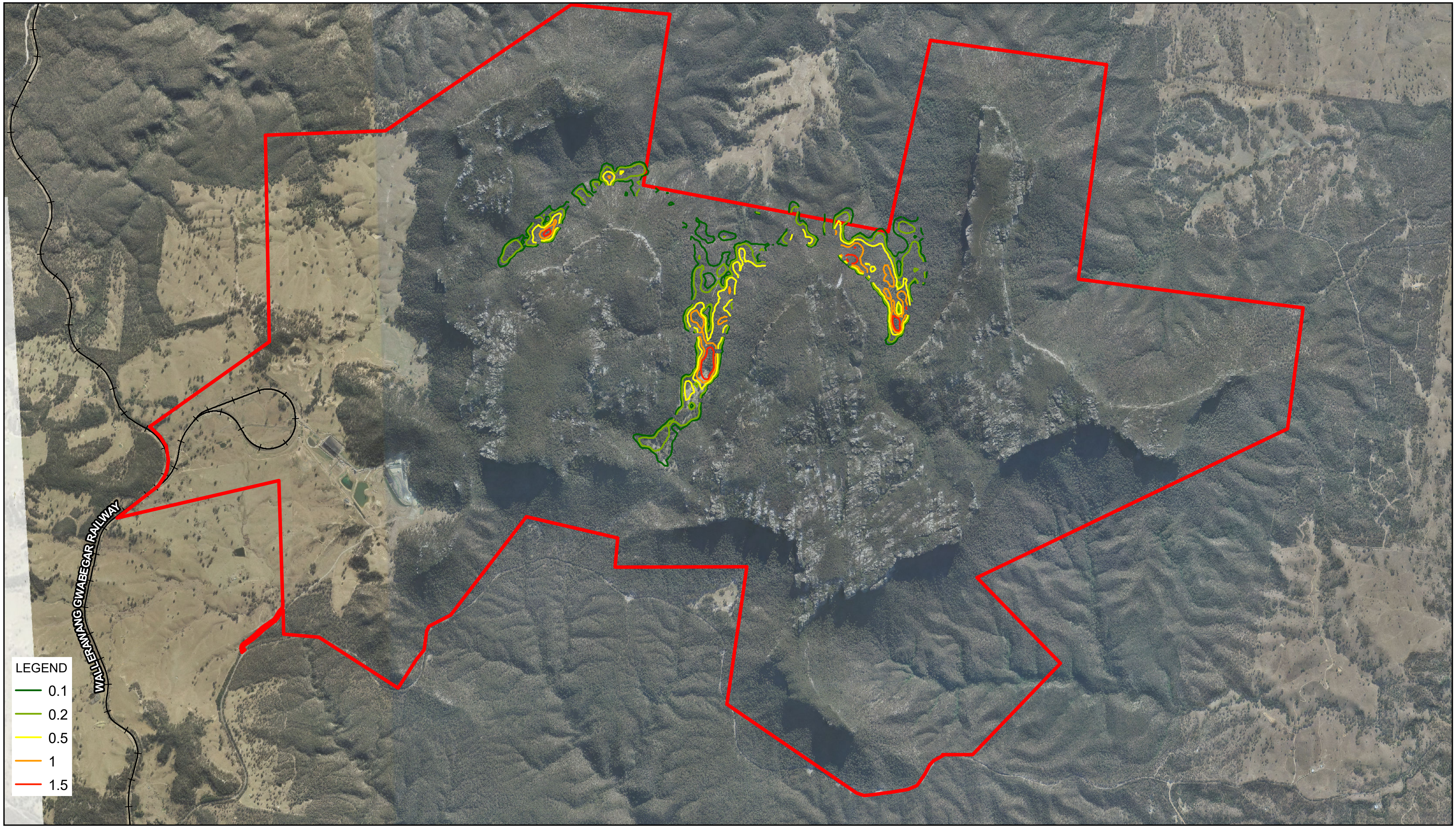


Figure B-69 Silicon monitored in groundwater

Piper diagram



Appendix C – Modelled drawdown contours



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Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

LEGEND

Project Approval Area SSD_5581

GHD

Centennial Airly

Airly Mine
Airly Mine Mod 3
Groundwater Impact Assessment

Drawdown in Shallow Strata
End of mining
3 Mtpa, Scenario 2

Job Number 22-19275
Revision A
Date 30 Jul 2019

Figure C-1

G:\22\0105001\GIS\Maps\Deliverables\Western\Airly\2219275\GWIA\Appendix\2219275_D005_3Mtpa_Scenario2_EOM_Layer01.mxd

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 T 61 2 4979 9999 F 61 2 4979 9988 E ntlmail@ghd.com W www.ghd.com.au

Data source: LPI: DTDB 2012; Centennial: Aerial Imagery, boundaries, 2013, Monitoring Locations, 2017. Created by: fmackay

Paper Size A4

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Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

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LEGEND

Project Approval Area SSD_5581

GHD

Centennial Airly

Airly Mine
Airly Mine Mod 3
Groundwater Impact Assessment

Drawdown in Lithgow seam
End of mining
3 Mtpa, Scenario 2

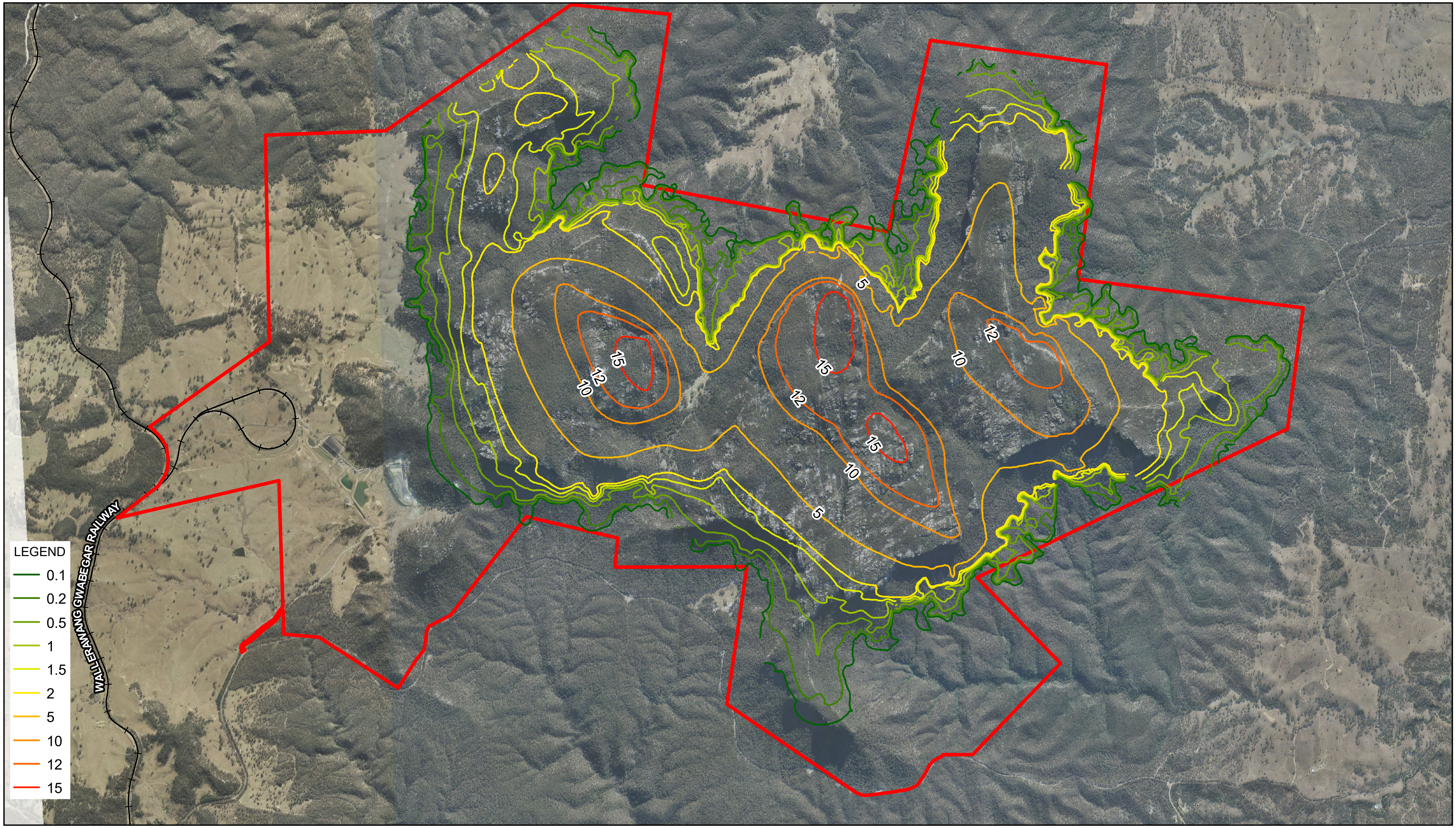
Job Number	22-19275
Revision	A
Date	30 Jul 2019

Figure C-2

G:\22\0105001\GIS\Maps\Deliverables\Western\Airly\2219275\GWIA\Appendix\2219275_D006_3Mtpa_Scenario2_EOM_Layer08.mxd

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

Data source: LPI: DTDB 2012; Centennial: Aerial Imagery, boundaries, 2013, Monitoring Locations, 2017. Created by: fmackay



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Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

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Project Approval Area SSD_5581

GHD

Centennial Airly

Airly Mine
Airly Mine Mod 3
Groundwater Impact Assessment

Job Number 22-19275
Revision A
Date 30 Jul 2019

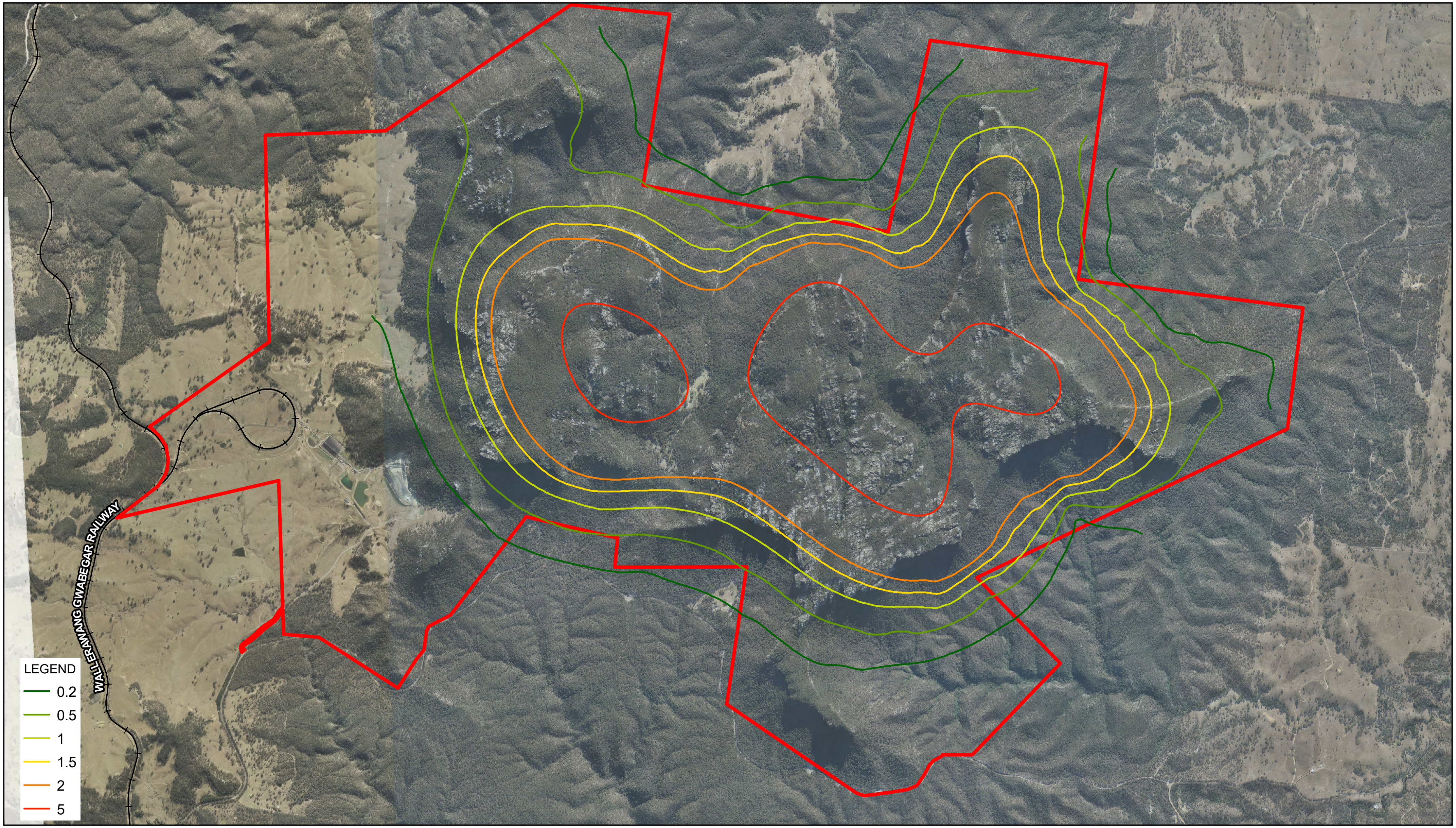
Drawdown in Marrangaroo Formation End of mining 3 Mtpa, Scenario 2

Figure C-3

G:\22\0105001\GIS\Maps\Deliverables\Western\Airly\2219275\GWIA\Appendix\2219275_D007_3Mtpa_Scenario2_EOM_Layer09.mxd

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

Data source: LPI: DTDB 2012; Centennial: Aerial Imagery, boundaries, 2013, Monitoring Locations, 2017. Created by: fmackay



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Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

LEGEND

Project Approval Area SSD_5581

GHD

Centennial Airly

Airly Mine
Airly Mine Mod 3
Groundwater Impact Assessment

Job Number 22-19275
Revision 0
Date 30 Jul 2019

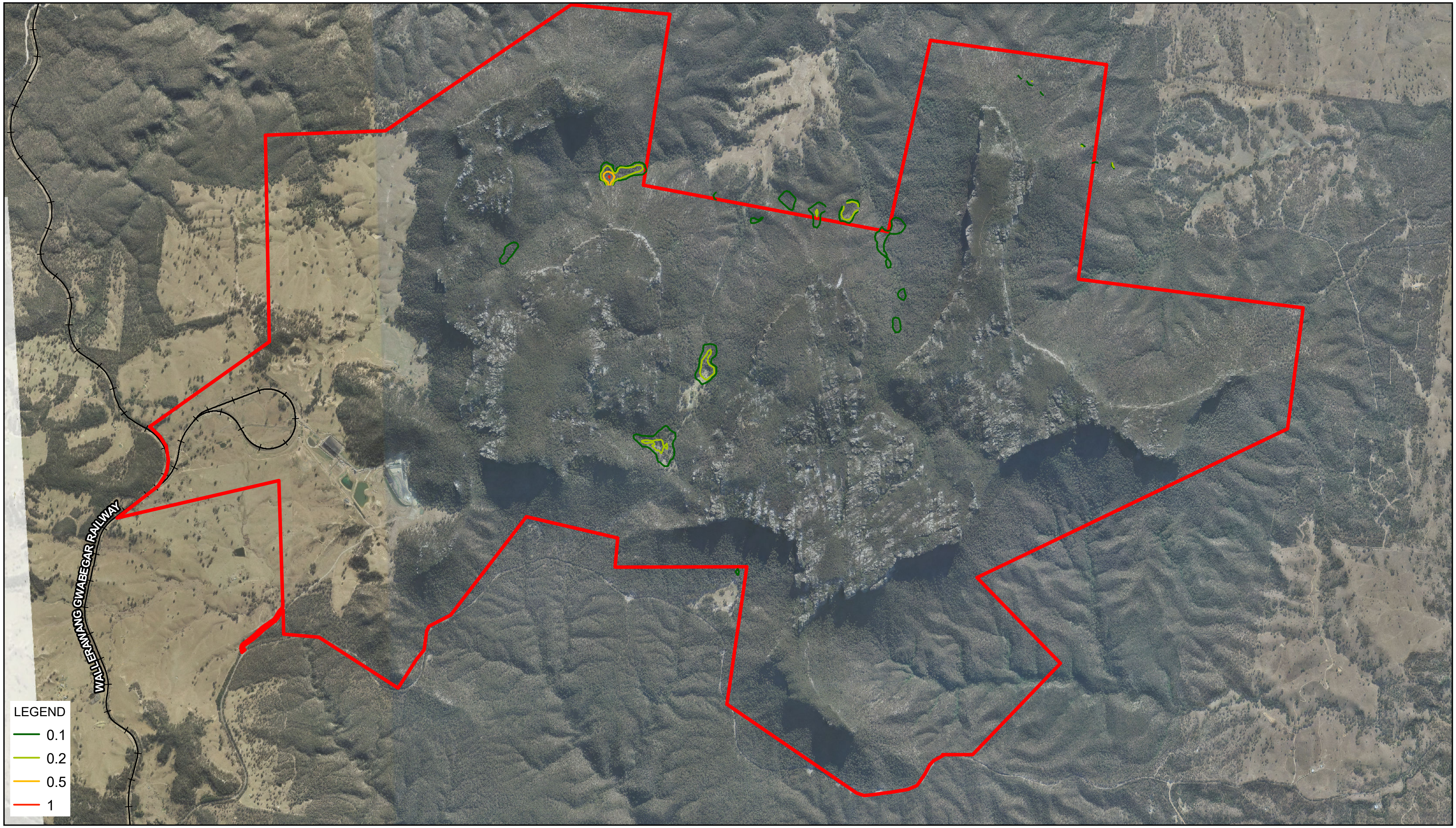
Drawdown in Upper Shoalhaven Group
End of mining
3 Mtpa, Scenario 2

Figure C-4

G:\22\0105001\GIS\Maps\Deliverables\Western\Airly\2219275\GWIA\Appendix\2219275_D008_3Mtpa_Scenario2_EOM_Layer10.mxd

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

Data source: LPI: DTDB 2012; Centennial: Aerial Imagery, boundaries, 2013, Monitoring Locations, 2017. Created by: fmackay



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Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

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LEGEND

Project Approval Area SSD_5581

GHD

Centennial Airly

Airly Mine
Airly Mine Mod 3
Groundwater Impact Assessment

Drawdown in Shallow Strata 30 years after mining 3 Mtpa, Scenario 2

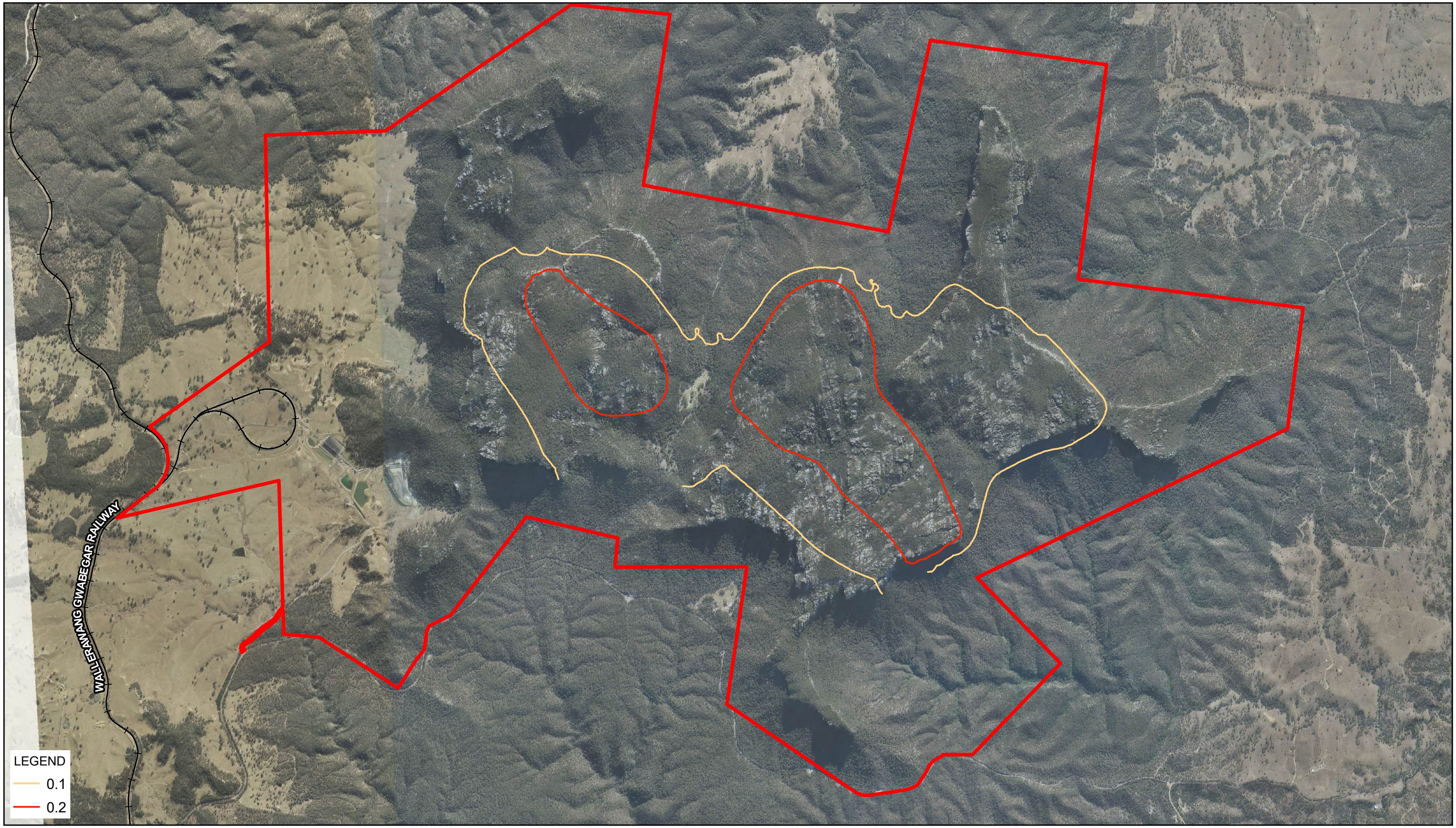
Job Number	22-19275
Revision	0
Date	30 Jul 2019

Figure C-5

G:\22\0105001\GIS\Maps\Deliverables\Western\Airly\2219275\GWIA\Appendix\2219275_D013_3Mtpa_Scenario2_30Y_Layer1.mxd

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

Data source: LPI: DTDB 2012; Centennial: Aerial Imagery, boundaries, 2013, Monitoring Locations, 2017. Created by: fmackay



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Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

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Project Approval Area SSD_5581

Centennial Airly

Airly Mine
Airly Mine Mod 3
Groundwater Impact Assessment

Drawdown in Lithgow seam
30 years after mining
3 Mtpa, Scenario 2

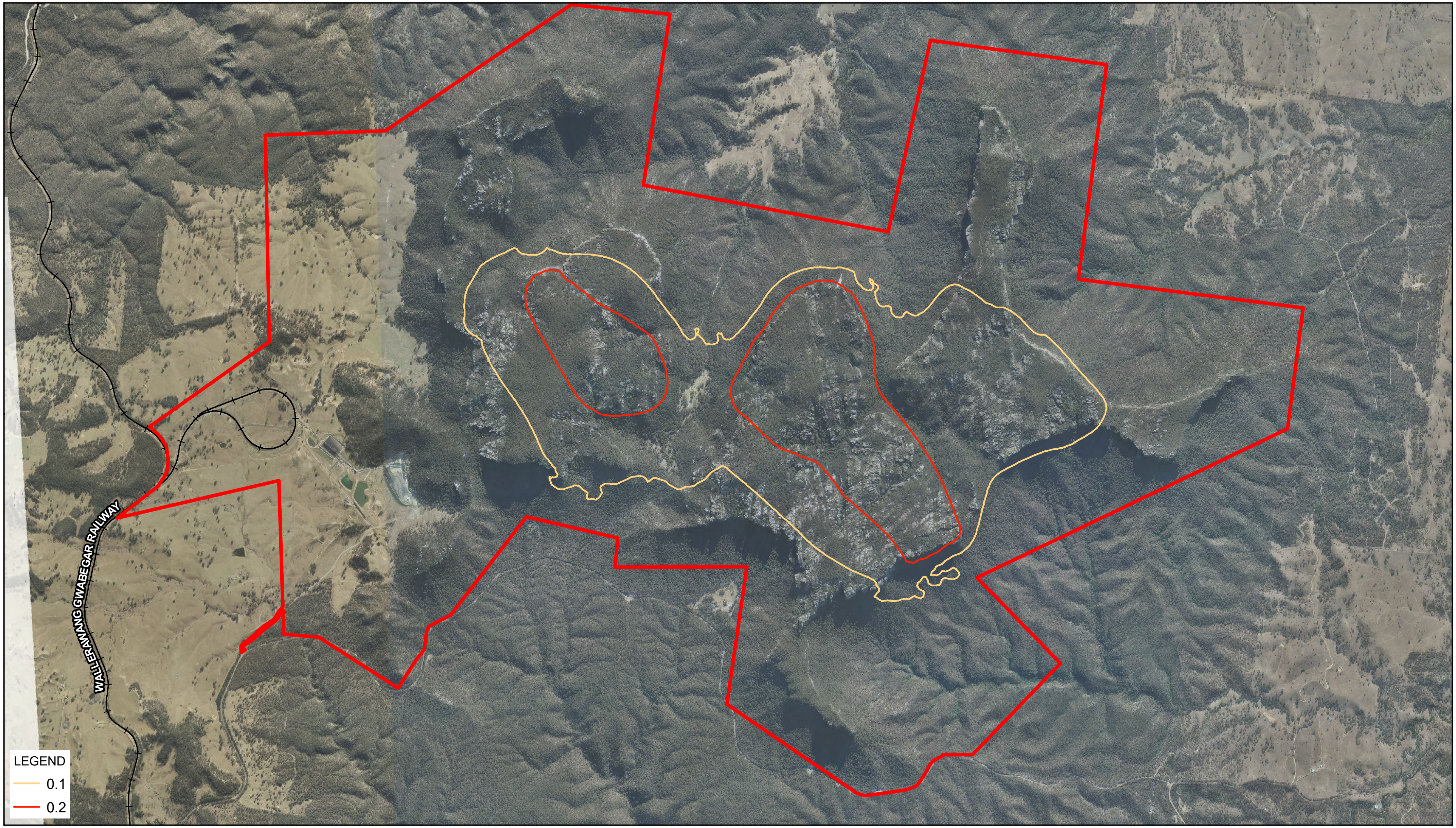
Job Number	22-19275
Revision	0
Date	30 Jul 2019

Figure C-6

G:\22\0105001\GIS\Maps\Deliverables\Western\Airly\2219275\GWIA\Appendix\2219275_D014_3Mtpa_Scenario2_30Y_Layer8.mxd

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

Data source: LPI: DTDB 2012; Centennial: Aerial Imagery, boundaries, 2013, Monitoring Locations, 2017. Created by: fmackay



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Metres

Map Projection: Transverse Mercator
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LEGEND

Project Approval Area SSD_5581

GHD

Centennial Airly

Airly Mine
Airly Mine Mod 3
Groundwater Impact Assessment

Job Number 22-19275
Revision 0
Date 30 Jul 2019

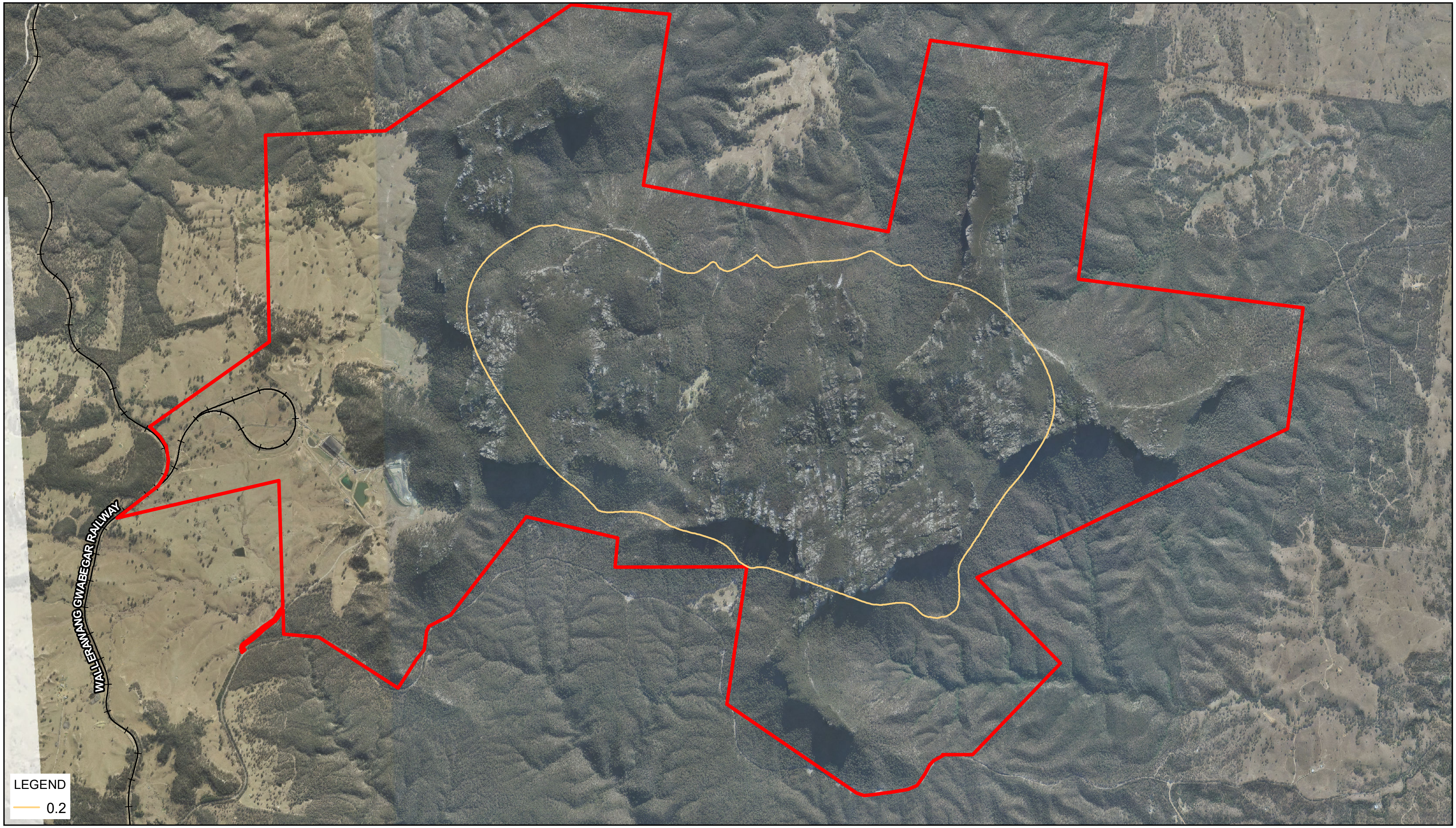
Drawdown in Marrangaroo Formation
30 years after mining
3 Mtpa, Scenario 2

Figure C-7

G:\22\0105001\GIS\Maps\Deliverables\Western\Airly\2219275\GWIA\Appendix\2219275_D015_3Mtpa_Scenario2_30Y_Layer9.mxd

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

Data source: LPI: DTDB 2012; Centennial: Aerial Imagery, boundaries, 2013, Monitoring Locations, 2017. Created by: fmackay



Paper Size A4

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Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

LEGEND

Project Approval Area SSD_5581

GHD

Centennial Airly

Airly Mine
Airly Mine Mod 3
Groundwater Impact Assessment

Job Number 22-19275
Revision 0
Date 30 Jul 2019

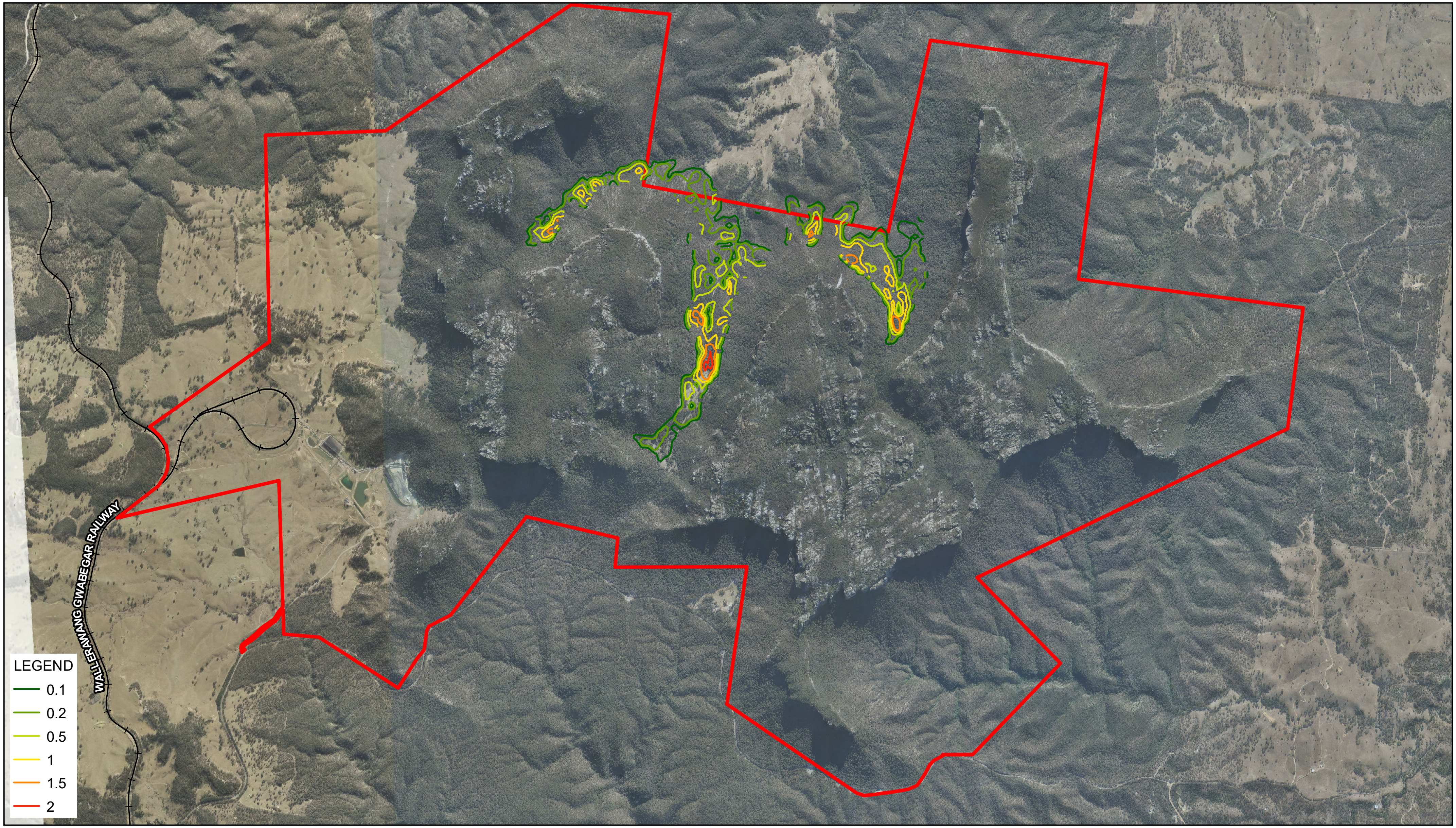
Drawdown in Upper Shoalhaven Group
30 years after mining
3 Mtpa, Scenario 2

Figure C-8

G:\22\0105001\GIS\Maps\Deliverables\Western\Airly\2219275\GWIA\Appendix\2219275_D016_3Mtpa_Scenario2_30Y_Layer10.mxd

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 T 61 2 4979 9999 F 61 2 4979 9988 E ntlmail@ghd.com W www.ghd.com.au

Data source: LPI: DTDB 2012; Centennial: Aerial Imagery, boundaries, 2013, Monitoring Locations, 2017. Created by: fmackay



Paper Size A4

0 330 660 990 1,320

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

LEGEND

Project Approval Area SSD_5581

GHD

Centennial Airly

Airly Mine
Airly Mine Mod 3
Groundwater Impact Assessment
Drawdown in Shallow Strata
End of mining
1-8 Mtpa, Scenario 2

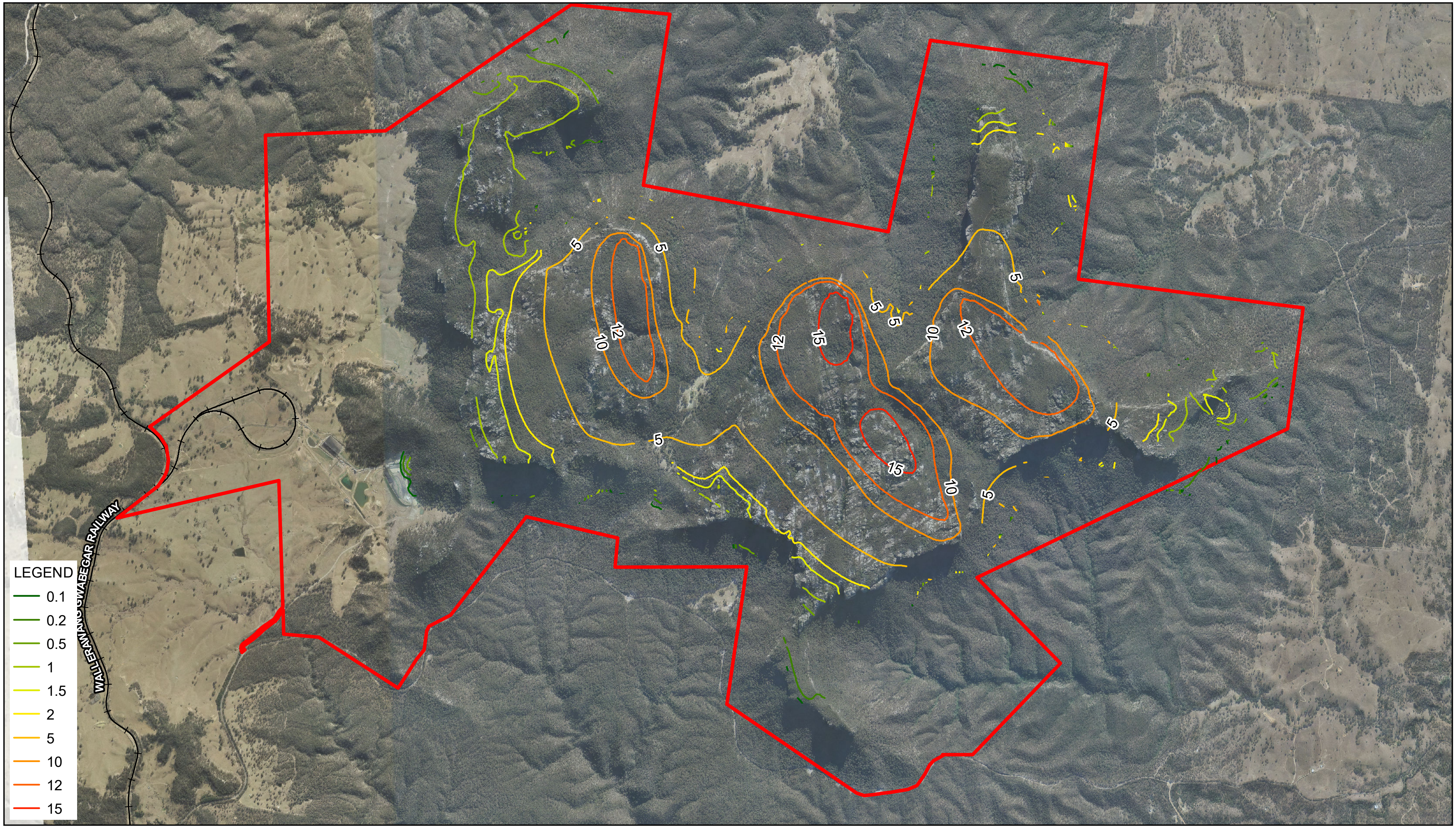
Job Number 22-19275
Revision A
Date 30 Jul 2019

Figure C-9

G:\22\0105001\GIS\Maps\Deliverables\Western\Airly\2219275\GWIA\Appendix\2219275_D021_1-8_Scenario2_EOM_Layer1.mxd

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 T 61 2 4979 9999 F 61 2 4979 9988 E ntlmail@ghd.com W www.ghd.com.au

Data source: LPI: DTDB 2012; Centennial: Aerial Imagery, boundaries, 2013, Monitoring Locations, 2017. Created by: fmackay



Paper Size A4

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Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

LEGEND

Project Approval Area SSD_5581

GHD

Centennial Airly

Airly Mine
Airly Mine Mod 3
Groundwater Impact Assessment
Drawdown in Lithgow seam
End of mining
1-8 Mtpa, Scenario 2

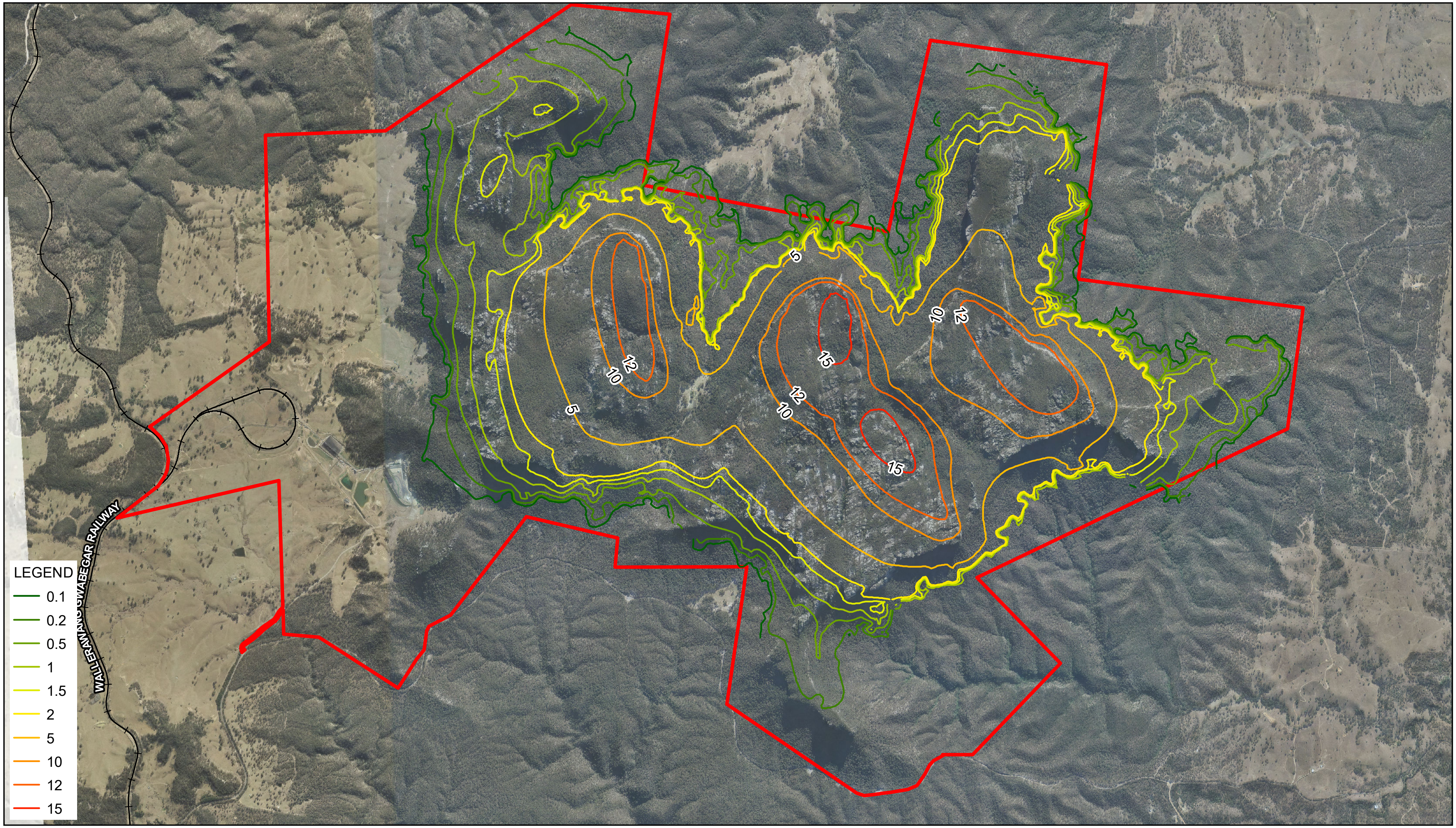
Job Number	22-19275
Revision	A
Date	30 Jul 2019

Figure C-10

G:\22\0105001\GIS\Maps\Deliverables\Western\Airly\2219275\GWIA\Appendix\2219275_D022_1-8_Scenario2_EOM_Layer8.mxd

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

Data source: LPI: DTDB 2012; Centennial: Aerial Imagery, boundaries, 2013, Monitoring Locations, 2017. Created by: fmackay



Paper Size A4

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Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

LEGEND

Project Approval Area SSD_5581

GHD

Centennial Airly

Airly Mine
Airly Mine Mod 3
Groundwater Impact Assessment

Job Number 22-19275
Revision A
Date 30 Jul 2019

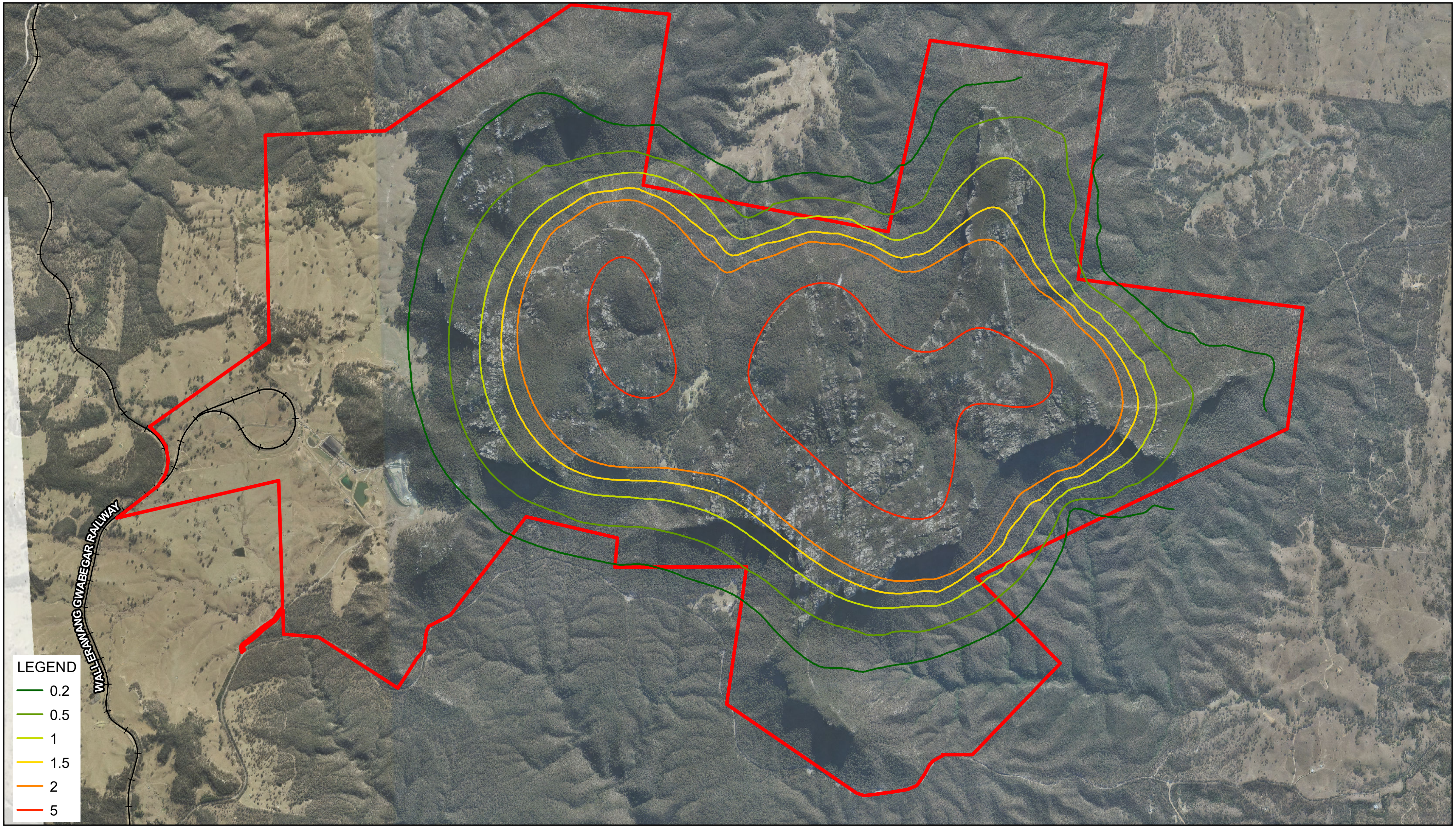
Drawdown in Marrangaroo Formation End of mining 1-8 Mtpa, Scenario 2

Figure C-11

G:\22\0105001\GIS\Maps\Deliverables\Western\Airly\2219275\GWIA\Appendix\2219275_D023_1-8_Scenario2_EOM_Layer9.mxd

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

Data source: LPI: DTDB 2012; Centennial: Aerial Imagery, boundaries, 2013, Monitoring Locations, 2017. Created by: fmackay



Paper Size A4

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Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

LEGEND

Project Approval Area SSD_5581

GHD

Centennial Airly

Airly Mine
Airly Mine Mod 3
Groundwater Impact Assessment

Job Number 22-19275
Revision A
Date 30 Jul 2019

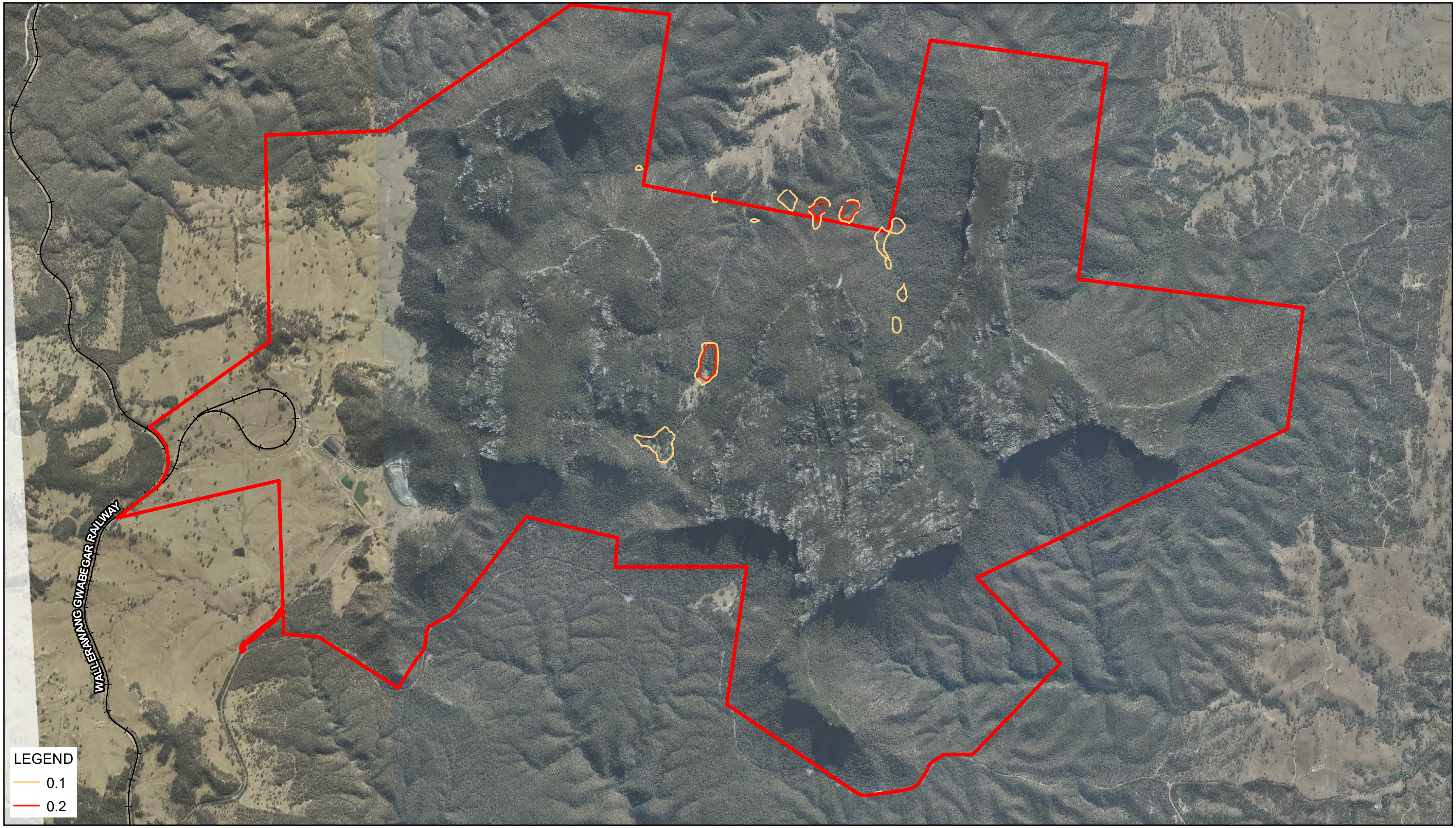
Drawdown in Upper Shoalhaven Group End of mining 1-8 Mtpa, Scenario 2

Figure C-12

G:\22\0105001\GIS\Maps\Deliverables\Western\Airly\2219275\GWIA\Appendix\2219275_D024_1-8_Scenario2_EOM_Layer10.mxd

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

Data source: LPI: DTDB 2012; Centennial: Aerial Imagery, boundaries, 2013, Monitoring Locations, 2017. Created by: fmackay



Paper Size A4

0 330 660 990 1,320

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

LEGEND

Project Approval Area SSD_5581

GHD

Centennial Airly

Airly Mine
Airly Mine Mod 3
Groundwater Impact Assessment

Drawdown in Shallow Strata
30 years after mining
1-8 Mtpa, Scenario 2

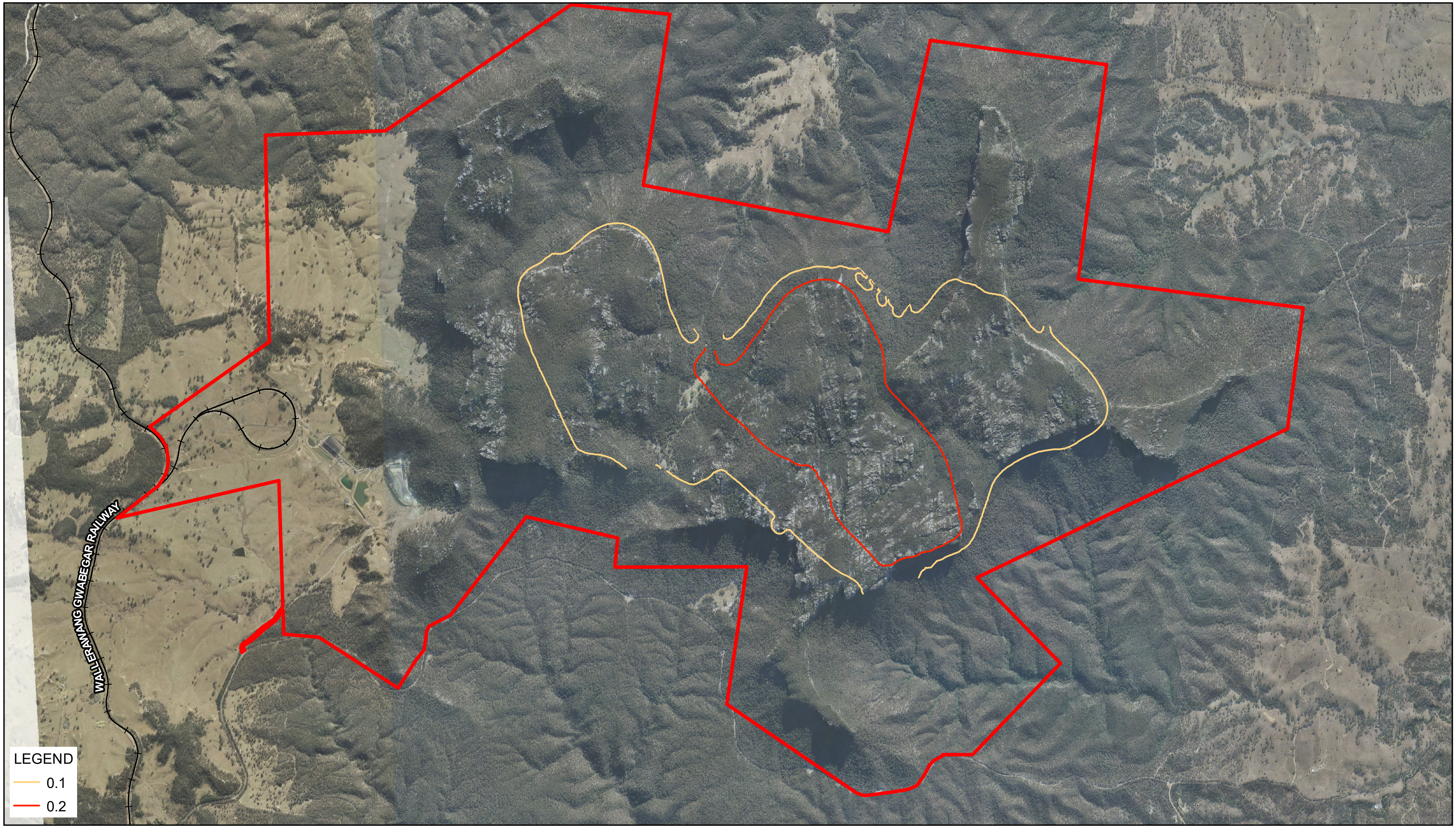
Job Number	22-19275
Revision	A
Date	21 Sep 2018

Figure C-13

G:\22\0105001\GIS\Maps\Deliverables\Western\Airly\2219275\GWIA\Appendix\2219275_D029_1-8_Scenario2_30Y_Layer1.mxd

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

Data source: LPI: DTDB 2012; Centennial: Aerial Imagery, boundaries, 2013, Monitoring Locations, 2017. Created by: fmackay



Paper Size A4

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Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

LEGEND

Project Approval Area SSD_5581

Centennial Airly

Airly Mine
Airly Mine Mod 3
Groundwater Impact Assessment
Drawdown in Lithgow seam
30 years after mining
1-8 Mtpa, Scenario 2

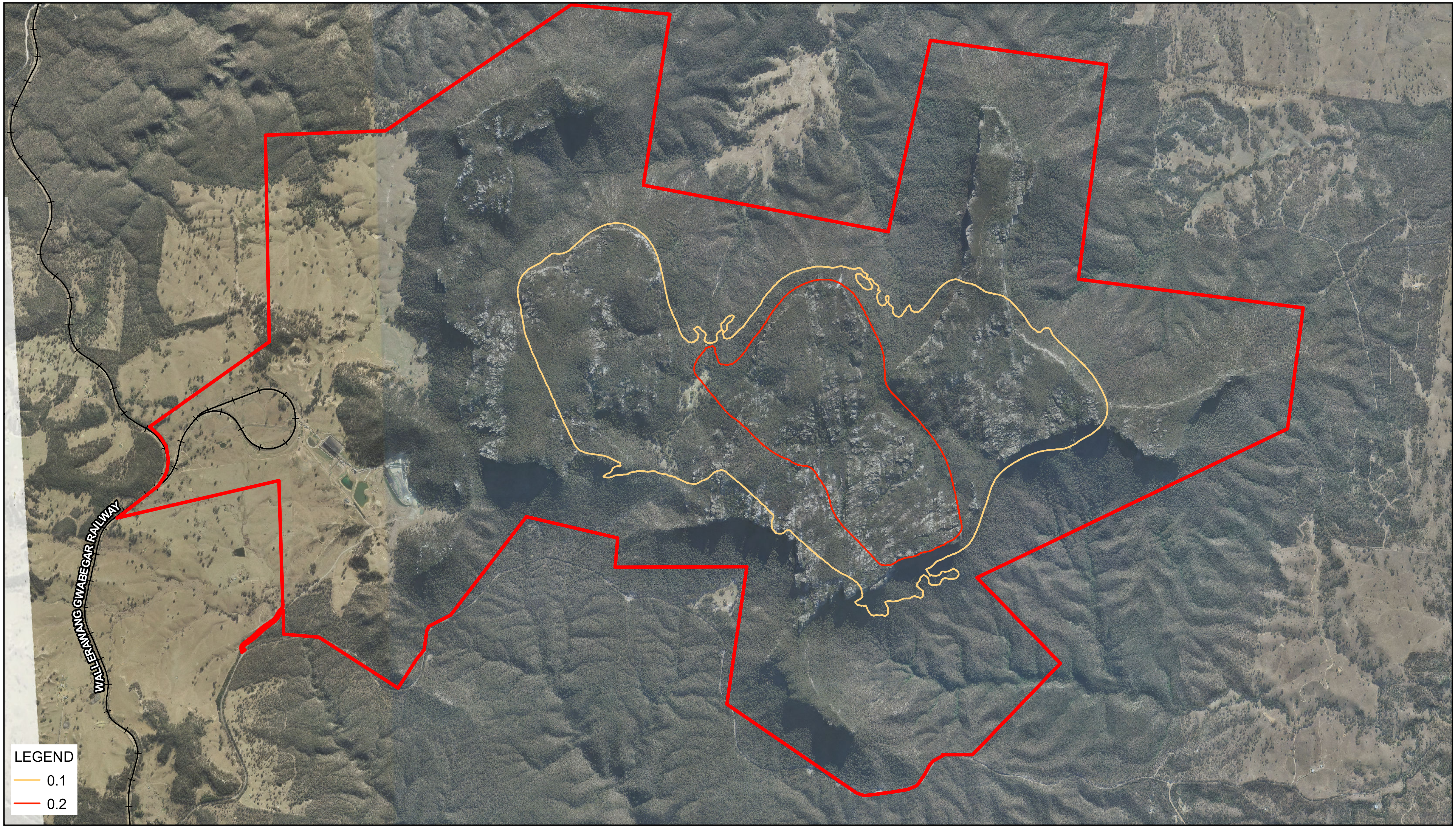
Job Number 22-19275
Revision A
Date 21 Sep 2018

Figure C-14

G:\22\0105001\GIS\Maps\Deliverables\Western\Airly\2219275\GWIA\Appendix\2219275_D030_1-8_Scenario2_30Y_Layer8.mxd

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 T 61 2 4979 9999 F 61 2 4979 9988 E ntlmail@ghd.com W www.ghd.com.au

Data source: LPI: DTDB 2012; Centennial: Aerial Imagery, boundaries, 2013, Monitoring Locations, 2017. Created by: fmackay



Paper Size A4

0 330 660 990 1,320

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

LEGEND

Project Approval Area SSD_5581

GHD

Centennial Airly

Airly Mine
Airly Mine Mod 3
Groundwater Impact Assessment

Job Number	22-19275
Revision	A
Date	30 Jul 2019

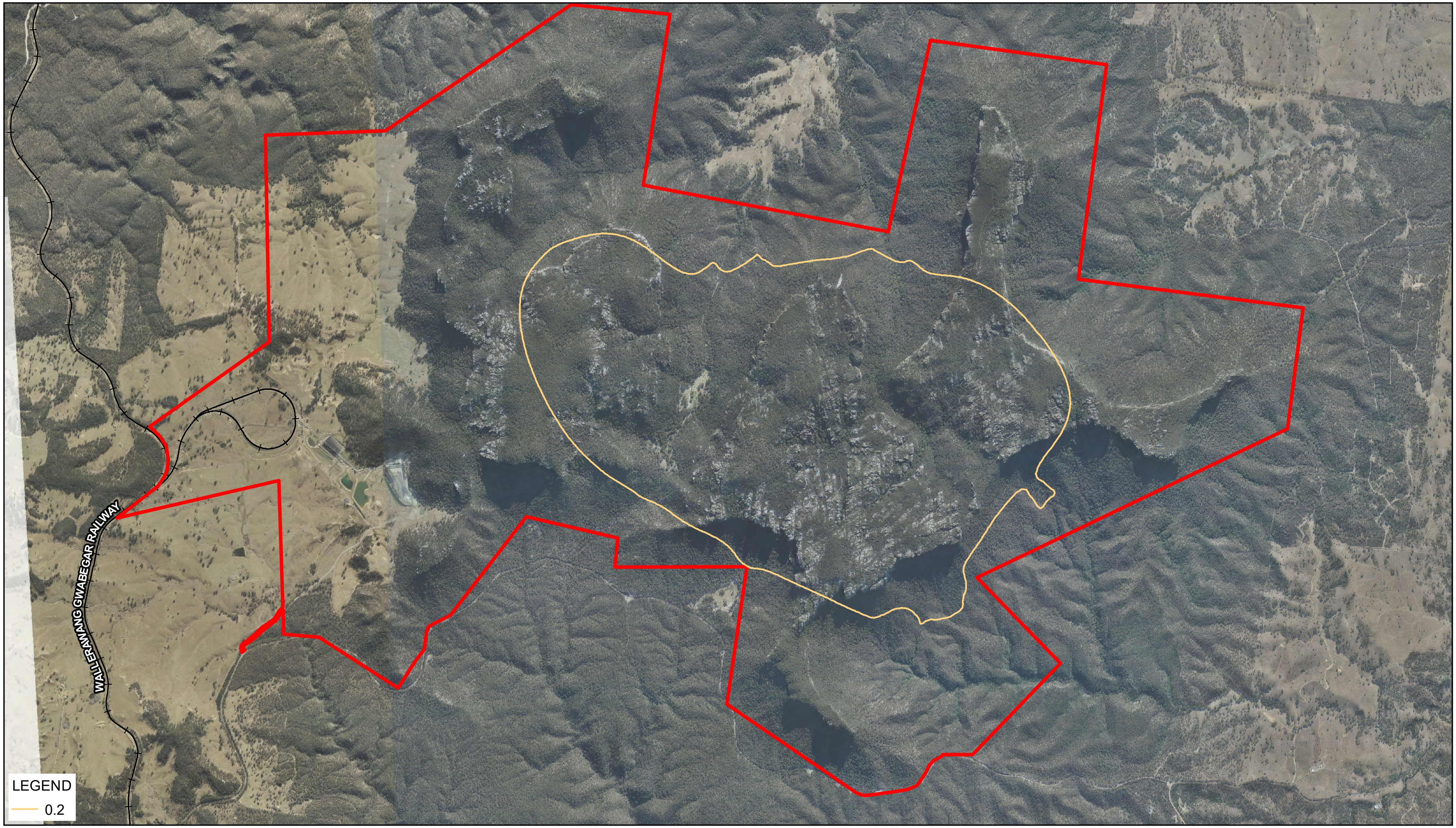
Drawdown in Marrangaroo Formation 30 years after mining 1-8 Mtpa, Scenario 2

Figure C-15

G:\22\0105001\GIS\Maps\Deliverables\Western\Airly\2219275\GWIA\Appendix\2219275_D031_1-8_Scenario2_30Y_Layer9.mxd

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com.au **W** www.ghd.com.au

Data source: LPI: DTDB 2012; Centennial: Aerial Imagery, boundaries, 2013, Monitoring Locations, 2017. Created by: fmackay



Paper Size A4

0 330 660 990 1,320

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

LEGEND

Project Approval Area SSD_5581

GHD

Centennial Airly

Airly Mine
Airly Mine Mod 3
Groundwater Impact Assessment

Job Number 22-19275
Revision A
Date 30 Jul 2019

Drawdown in Upper Shoalhaven Group 30 years after mining 1-8 Mtpa, Scenario 2

Figure C-16

G:\22\0105001\GIS\Maps\Deliverables\Western\Airly\2219275\GWIA\Appendix\2219275_D032_1-8_Scenario2_30Y_Layer10.mxd

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 T 61 2 4979 9999 F 61 2 4979 9988 E ntlmail@ghd.com W www.ghd.com.au

Data source: LPI: DTDB 2012; Centennial: Aerial Imagery, boundaries, 2013, Monitoring Locations, 2017. Created by: fmackay

Appendix D – Airly Mine groundwater risk assessment

1. Background

Airly Mine is an underground coal mine owned and operated by Centennial Airly Pty Limited (Centennial Airly), a wholly owned subsidiary of Centennial Coal Company Limited (Centennial). Centennial is a wholly owned subsidiary of Banpu Public Company Limited. Airly Mine is located near the village of Capertee, approximately 40 km north-west of Lithgow in the Western Coalfield.

Airly Mine currently has approval to extract up to 1.8 million tonnes per annum (Mtpa) of run of mine (ROM) coal from the Lithgow Seam using mining methods that incorporate extraction by first workings, partial pillar extraction or panel and pillar mining. ROM and product coal is transported off site by rail for the export and domestic markets.

Airly Mine operations are currently in the process of undertaking project modifications to increase tonnage and secure their water supply for ongoing mining activities. As part of their increase in tonnage a review/recalibration of the current groundwater model, prepared as part of SSD 12_5581 was undertaken.

As part of the groundwater model update, consideration of the most recent standards was considered. As part of new documents prepared by the IESC on uncertainty analysis in groundwater modelling, a risk assessment methodology is suggested to define how model predictions can aid in decision making during the EIS process. Whilst Airly groundwater interactions are relatively low risk, a risk assessment was undertaken as a trial for implementation of the same process at other sites where groundwater environment risks may be more substational.A risk assessment also forms a recommendation by the independent groundwater technical reviewer.

The level of effort applied to uncertainty analysis is a decision that is a function of the risk being managed.

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2. Objective

The following Hierarchy of Controls offers a framework for considering the effectiveness of controls. Note that the effectiveness of a control that is intended to reduce a risk decreases from top to bottom of the list. In other words, the closer the control type is to the top of the hierarchy, the more potentially effective the control.

·Eliminate the hazard or energy source (do not use the energy)
·Minimise or replace the hazard or energy source (reduce the amount of energy to a less damaging level or replace the energy with another that has less potential negative consequences)
·Control the hazard or energy using engineered devices (ex. Lock outs, chemical containers, mechanical roof support, gas monitors, etc.)
·Control the hazard or energy by using physical barriers (ex. machine guarding, fences or enclosures, etc.)

·Control the hazard or energy with procedures (ex. Isolation procedures, standard operating procedures, etc.)
·Control the hazard or energy with personal protective equipment (ex. hard hats, boots with toe caps, gloves, safety glasses, welding gear, etc.)
·Control the hazard or energy with warnings and awareness (ex. posters, labels, warning signs, verbal warnings, etc.)

The objective of this risk assessment is to facilitate a structured process to enable a critical and objective appraisal of the proposed mining plan for Modification 2 with the groundwater predictions

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3. Potential Hazards

Potential hazards identified from the groundwater model may include:
Impacts to GDEs (terrestrial)
Impacts to GDEs (aquatic)
Impacts to nearby water users
Impacts to water quality
Impacts to surface to groundwater connectivity

4a. Boundary Definition

Airly Modification 2 Project extent and 3.0 mtpa mine plan

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5. Methods

Risk Assessment Methods
Workplace Risk Assessment and Control (WRAC): Yes
Fault Tree Analysis (FTA):
Safety Integrity Level Analysis to Australian Standard 61508 (SIL):
Bow Tie Analysis (BTA):
Failure Modes and Effects Analysis (FMEA):
Hazard and Operability Analysis (HAZOP):

6. Previous Risk Assessment and other documents to be used and/or referenced

Document Name	Title	Version	Referenced Document Date
HA2018-03 HydroAlgorithmics Interim Review - Airly	Airly Mine Modification - Interim Groundwater Modelling Peer Review	1	17-Mar-2018
2218803-LET-HydrogeologicalModelRecalibration_24July2017	Airly Mine, Hydrogeological Model Recalibration	1	24-Jul-2017
2219275-LET_Airly Groundwater Model Details	Airly Groundwater Model Additional Information for Peer Review	1	05-Feb-2018
2219610-REP-AirlyWater Management Plan-Rev3-18July2018	Airly Water Management Plan	3	18-Jul-2018
Airly MEP EIS_ Appendix E Ground Water	Airly Mine Extension Project Groundwater Impact assessment	2	28-Jul-2014
Airly MEP_Response to Submissions	Response to submissions, Airly Mine Extension Project	1	02-Feb-2015
Airly MEP_Appendix A to supplementary info to RTS	Supplementary Information to Response to Submissions - Appendix A, Response to Submission from Pells Consulting	1	02-Jun-2015

7. Information Required for Risk Assessment

An appreciation for new guideline documents produced by IESC (2018)

8. Venue and Time

Date	Description	Location	Start Time	End Time	Comment
1. 25-Jul-2018	Scoping Study	Fassifern Back Conference Room	9:00 AM	12:00 PM	
2. 14-Aug-2018	Update of scoping study/risk assessment	Fassifern Back Conference Room	9:00 AM	12:00 AM	Addressing gaps in scope identified by Noel Merrick (meeting with NM on Friday 10/8/18)
3.					
4.					

9. Team Selection

Name	Position	Company	Industry Start Date	E-Mail Address	Role	Experience relevant to the role in the risk assessment	Pulse User No.	Attendance			
								1. 25-Jul-2018	2. 14-Aug-2018	3.	4.
Nagindar Singh	Approvals Coordinator	Centennial Coal			Team Member	Approval manager		P	P		
David King	Technical Services Manager	Centennial Coal			Facilitator	Site specialist (mining)		P	P		
Stuart Gray	Principal Hydrogeologist	GHD		Stuart.gray@ghd.com	Consultant	Assessment specialist and modeller		P	P		
Craig Bagnall	Principal Consultant	Catalyst Environmental Management		Craig@catalystem.com.au	Consultant	Assessment specialist		P	A		
Sam Price	Environment and Community Coordinator	Centennial Coal			Team Member	Site specialist (environment)		P	A		
James Wearne	Group Approvals Manager	Centennial Coal			Team Member	Approval manager		P	pr		
Lachlan Hammersley	Water Engineering Manager	Centennial Coal			Risk Assessment Owner	Internal specialist (water)		P	P		

10. WRAC Analysis Incident Builder

Instructions
WRAC Analysis Incident Builder (hover for instructions):

Step	Events				
	Events	caused by	Hazards	resulting in	Consequences
			Causes		Outcomes
1. Groundwater Aquifers above Lithgow seam - (including Shallow Quaternary Alluvial Triassic)	1.1. loss or depressurisation of groundwater that exceed approved impacts	caused by	1. Model conceptualisation does not reflect natural system adequately	resulting in	1. Legal non-compliance
			2. over estimation of model parameters		2. Environmental impact (eg GDEs, flora/fauna)
			3. under estimation of model parameters		3. Social impact
			4. Insufficient baseline data		
			5. Mine design LTA		
			6. Mine design implementation LTA		
			7. Impact of geological structure		
			8. Monitoring LTA		
2. Groundwater Aquifers in and immediately above Lithgow seam - Permian	2.1. loss or depressurisation of groundwater that exceed approved impacts	caused by	1. Model conceptualisation does not reflect natural system adequately	resulting in	1. Legal non-compliance
			2. over estimation of model parameters		2. Environmental impact (eg GDEs, flora/fauna)
			3. under estimation of model parameters		3. Social impact
			4. Insufficient baseline data		

			5. Mine design LTA		
			6. Mine design implementation LTA		
			7. Impact of geological structure		
			8. Monitoring LTA		
3. Regiona Groundwater - Regional aquifers - Permian below the Lithgow seam and any associated GDEs	3.1. loss or depressurisation of groundwater that exceed approved impacts - Shoalhaven	caused by	1. Model conceptualisation does not reflect natural system adequately	resulting in	1. Legal non-compliance
			2. over estimation of model parameters		2. Environmental impact (eg GDEs, flora/fauna)
			3. under estimation of model parameters		3. Social impact
			4. Insufficient baseline data		
			5. Impact of geological structure		
			6. Mine design implementation LTA		
	3.2. loss or depressurisation of groundwater that exceed approved impacts - Devoian	caused by	1. Model conceptualisation does not reflect natural system adequately	resulting in	1. Legal non-compliance
			2. over estimation of model parameters		2. Environmental impact (eg GDEs, flora/fauna)
			3. under estimation of model parameters		3. Social impact
			4. Insufficient baseline data		
			5. Impact of geological structure		
			6. Mine design implementation LTA		
4. Groundwater bores	4.1. Loss or depressurisation of private bores located within or potentiallly affected by mining	caused by	1. Not applicable (none within potentially affected area, ie private	resulting in	1. Environmental impact (eg GDEs, flora/fauna)
					2. Legal non-compliance

			bores are all within the regional aquifers)		3. Social impact
	4.2. Unable to determine compliance	caused by	1. Monitoring LTA	resulting in	1. Environmental impact (eg GDEs, flora/fauna)
			2. Comprimised access to bores (eg lightning strike, vandalisim)		2. Legal non-compliance
					3. Social impact
5. Groundwater Dependent ecosystem	5.1. Other GDES - loss or depressurisation of groundwater that exceeds approved impacts	caused by	1. Model conceptualisation does not reflect natural system adequately	resulting in	1. Environmental impact (eg GDEs, flora/fauna)
			2. over estimation of model parameters		2. Legal non-compliance
			3. under estimation of model parameters		3. Social impact
			4. Insufficient baseline data		
			5. Impact of geological structure		
			6. Mine design implementation LTA		
			7. Mine design LTA		
			8. Monitoring LTA		
	5.2. HIGH PRIORITY GDEs - loss or depressurisation of groundwater that exceeds approved impacts	caused by	1. Not applicable (none identified within NSW AIP/WSP)	resulting in	1. Environmental impact (eg GDEs, flora/fauna)
					2. Legal non-compliance
					3. Social impact
6. Groundwater licensing	6.1. Inadequate licence allocation	caused by	1. Impact of geological structure	resulting in	1. Environmental impact (eg GDEs, flora/fauna)
			2. Mine design implementation LTA		2. Legal non-compliance
			3. Mine design LTA		3. Social impact

			4. over estimation of model parameters		4. Business impact
			5. under estimation of model parameters		
7. Overall site water and salt balance	7.1. groundwater volumes result in a change in the site water and salt balance predicting increase in discharges or salt load	caused by	1. Impact of geological structure	resulting in	1. Business impact
			2. Insufficient baseline data		2. Environmental impact (eg GDEs, flora/fauna)
			3. Mine design implementation LTA		3. Legal non-compliance
			4. Mine design LTA		4. Social impact
			5. Model conceptualisation does not reflect natural system adequately		
			6. Monitoring LTA		
			7. over estimation of model parameters		
			8. under estimation of model parameters		
	7.2. groundwater volumes result in a change in the site water and salt balance predicting reduced water availability or increased salt content	caused by	1. Impact of geological structure	resulting in	1. Environmental impact (eg GDEs, flora/fauna)
			2. Insufficient baseline data		2. Legal non-compliance
			3. Mine design implementation LTA		3. Social impact
			4. Mine design LTA		4. Business impact
			5. Model conceptualisation does not reflect natural system adequately		
			6. Monitoring LTA		
			7. over estimation of model parameters		

			8. under estimation of model parameters 9. Production rate requires addtional utilisation of equipment		
8. Surface and groundwater connectivity	8.1. Loss of baseflow from creek systems within mining area	caused by	1. Impact of geological structure 2. Insufficient baseline data 3. Mine design implementation LTA 4. Mine design LTA 5. Model conceptualisation does not reflect natural system adequately 6. Monitoring LTA 7. over estimation of model parameters 8. under estimation of model parameters	resulting in	1. Environmental impact (eg GDEs, flora/fauna) 2. Legal non-compliance 3. Social impact
9. Groundwater quality	9.1. change of beneficial use cateogry of aquifer	caused by	1. Impact of geological structure 2. Mine design implementation LTA	resulting in	1. Environmental impact (eg GDEs, flora/fauna) 2. Legal non-compliance 3. Social impact
10. HMR Parameters considered in recalibration	10.1. depressurisation or drawdown exceeding approved predictions	caused by	1. HMR - Storage properties of strata not supported by field investigation 2. HMR - Hydraulic conductivity change as a result of mining 3. HMR - Rainfall data considered based on history and not considering uncertainty	resulting in	1. Environmental impact (eg GDEs, flora/fauna) 2. Legal non-compliance 3. Social impact

			4. HMR - Stress testing not sufficient		
11. Surface water users	11.1. loss of surface water to groundwater causes impacts to surface water extractors and water dependent infrastructure/recreation	caused by	1. Impact of geological structure	resulting in	1. Business impact
			2. Insufficient baseline data		2. Environmental impact (eg GDEs, flora/fauna)
			3. Mine design implementation LTA		3. Legal non-compliance
			4. Mine design LTA		4. Social impact
			5. Model conceptualisation does not reflect natural system adequately		
			6. Monitoring LTA		
			7. over estimation of model parameters		
			8. under estimation of model parameters		
	11.2. loss of water from village spring greater than approved	caused by	1. Impact of geological structure	resulting in	1. Business impact
			2. Insufficient baseline data		2. Environmental impact (eg GDEs, flora/fauna)
			3. Mine design implementation LTA		3. Legal non-compliance
			4. Mine design LTA		4. Social impact
			5. Model conceptualisation does not reflect natural system adequately		
			6. Monitoring LTA		
			7. over estimation of model parameters		
			8. under estimation of model parameters		
12. Cumulative impacts			1. inappropriate zone of impact	resulting in	1. Business impact

	12.1. Interactions with external factors	caused by	2. Unexpected activity within defined zone of impact		2. Environmental impact (eg GDEs, flora/fauna)
			3. Constraints on groundwater access		3. Legal non-compliance
					4. Social impact
	12.2. Interactions as a result of the approved project	caused by	1. subsidence occurs outside of predictions	resulting in	1. Business impact
			2. height of fracturing is greater than predictions		2. Environmental impact (eg GDEs, flora/fauna)
					3. Legal non-compliance
					4. Social impact

Scope Confirmation

Approver	Scope Confirmation	Date	Comments
1. Lachlan Hammersley [Lachlan.Hammersley]	Yes	July 25, 2018	

CEY Risk Matrix

CENTENNIAL RISK MATRIX							Likelihood					
							A Certain	B Probable	C Possible	D Remote	E Improbable	Description (D)
Rating	Consequence Note: Consequence may result from a single event or may represent a cumulative impact over a period of 12 months. Use the worst case reasonable consequence if there is more than one.						Common	Has Happened within Centennial	Could Happen & has happened in non-CEY operations	Not Likely	Practically impossible	Probability (Pb)
	Financial Impact to Annual Business Plan (F)	Personal Injury (PI)	Business Interruption (BI)	Legal (L)	Reputation (R)	Environment (E)	Frequent incidents	Regular incidents	Infrequent incidents	Unlikely to occur. Very few recorded or known incidents	May occur in exceptional circumstances. Almost no recorded incidents.	Incident Frequency (IF)
							Operations – within 3 months	Operations – within 2 years	Operations – within 5 years	Operations – within 10 years	Operations – within 30 years	Operations (Op)
							Project – Every project	Project – Every 2 projects	Project – Every 5 projects	Project – Every 10 projects	Project – Every 30 projects	Project (Pr)
5. Catastrophic	>$50m	Multiple Fatalities	> 1month	Prolonged litigation, heavy fines, potential jail term	Prolonged International media attention	Long term impairment habitats/ ecosystem	25 (E)	24 (E)	21 (H)	19 (H)	15 (S)	
4. Major	$10m - $50m	Single Fatality	1 week to 1 month	Major breach/ major litigation	International media attention	Long term effects of ecosystem	23 (E)	22 (E)	18 (H)	14 (S)	10 (M)	
3. Moderate	$1m - $10m	Serious/ Disabling Injury	1 day to 1 week	Serious breach of regulation. prosecution/ fine	National media attention	Serious medium term environmental effects	20 (H)	17 (H)	13 (S)	9 (M)	6 (L)	
2. Minor	$100k - $1m	Lost Time Injury	12 hrs to 1 day	Non-compliance, breaches in regulation	Adverse local public attention	Minor effects to physical environment	16 (S)	12 (S)	8 (M)	5 (L)	3 (L)	
1. Insignificant	<$100k	First Aid Treatment Only	< 12 hrs	Low level compliance issue	Local complaints	Limited physical damage	11 (S)	7 (M)	4 (L)	2 (L)	1 (L)	

CEY Risk Rating Definitions

Risk Rating	Risk Category		Generic Management Actions
22 to 25	E	Extreme	Action is required to eliminate or reduce the risk. If the risk is considered to be ALARP then the decision to accept the risk is to be made by Centennial Coal Chief Executive
17 to 21	H	High	Action is required to eliminate or reduce the risk. If the risk is considered to be ALARP then the decision to accept the risk is to be made by the relevant Centennial Coal Executive General Manager
11 to 16	S	Significant	Action is required to eliminate or reduce the risk. If the risk is considered to be ALARP then the decision to accept the risk is to be made by the Manager of the Centennial Coal Operation
7 to 10	M	Moderate	Action is required to eliminate or reduce the risk. If the risk is considered to be ALARP then the decision to accept the risk is to be made by the Manager of the Centennial Coal Operation
1 to 6	L	Low	Actions to eliminate or further reduce the risk should be considered. If risk is considered to be ALARP then the decision to accept the risk is to be made by the risk assessment owner (no recommended control is required to be created for this)

WRAC Analysis Worksheet

Step	Potential Incident	Current Controls	L	MRC	RR	Recommended Control	Bow Tie Extension
1. Groundwater Aquifers above Lithgow seam - (including Shallow Quaternary Alluvial Triassic)	There is a risk to Operations from ::: loss or depressurisation of groundwater that exceed approved impacts ::: Caused by: Impact of geological structure or Insufficient baseline data or Mine design implementation LTA or Mine design LTA or Model conceptualisation does not reflect natural system adequately or Monitoring LTA or over estimation of model parameters or under estimation of model parameters Resulting in: Environmental impact (eg GDEs, flora/fauna) or Legal non-compliance or Social impact.	1.1.a. Mine method and design does not change. 1.1.b. Mine footprint has not changed 1.1.c. Environmental monitoring program approved 1.1.d. Independent and peer review approved conceptual model 1.1.e. reCalibration of model against mining operational data 1.1.f. Some uncertainty (type 1) has been undertaken	**D** (Pb)	2 (E)	**5 (L)**	1. further independent expert review of deliverables 2. fracture height monitoring to be reviewed following first 4 panels 3. Further consdieration of type 3 uncertainity assessment 4. Consider the impacts of surface to seam geological structures (following definition by the Mine and via a desktop exercise in the first instance)	
2. Groundwater Aquifers in and immediately above Lithgow seam - Permian	There is a risk to Operations from ::: loss or depressurisation of groundwater that exceed approved impacts ::: Caused by: Impact of geological structure or Insufficient baseline data or Mine design implementation LTA or Mine design LTA or Model conceptualisation does not reflect natural system adequately or Monitoring LTA or over estimation of model parameters or under estimation of model parameters	2.1.a. Mine method and design does not change. 2.1.b. Mine footprint has not changed 2.1.c. Environmental monitoring program approved 2.1.d. Independent and peer review approved conceptual model 2.1.e. reCalibration of model against mining operational data	**D** (Pb)	2 (E)	**5 (L)**	1. further independent expert review of deliverables 2. fracture height monitoring to be reviewed following first 4 panels 3. Further consdieration of type 3 uncertainity assessment 4. Consider the impacts of surface to seam geological structures (following definition by the Mine and via a desktop exercise in the first instance)	

	Resulting in: Environmental impact (eg GDEs, flora/fauna) or Legal non-compliance or Social impact.	2.1.f. Some uncertainty (type 1) has been undertaken					
3. Regiona Groundwater - Regional aquifers - Permian below the Lithgow seam and any associated GDEs	There is a risk to Operations from ::: loss or depressurisation of groundwater that exceed approved impacts - Shoalhaven ::: Caused by: Impact of geological structure or Insufficient baseline data or Mine design implementation LTA or Model conceptualisation does not reflect natural system adequately or over estimation of model parameters or under estimation of model parameters Resulting in: Environmental impact (eg GDEs, flora/fauna) or Legal non-compliance or Social impact.	3.1.a. below target seam - outside zone of influence of extraction system 3.1.b. mine design (narrow panel) mitigate fracturing of the floor 3.1.c. observations from mining operation is that water is unlikely to upwell through the floor. 3.1.d. monitoring within shoalhaven zone, piezo pressure is well below the target seam level	**D** (Pb)	2 (E)	**5** **(L)**		
	There is a risk to Operations from ::: loss or depressurisation of groundwater that exceed approved impacts - Devoian ::: Caused by: Impact of geological structure or Insufficient baseline data or Mine design implementation LTA or Model conceptualisation does not reflect natural system adequately or over estimation of model parameters or under estimation of model parameters Resulting in: Environmental impact (eg GDEs, flora/fauna) or Legal non-compliance or Social impact.	3.2.a. Not applicable	**E** (Pb)	1 (E)	**1** **(L)**		

4. Groundwater bores	There is a risk to Operations from ::: Loss or depressurisation of private bores located within or potentiallly affected by mining ::: Caused by: Not applicable (none within potentially affected area, ie private bores are all within the regional aquifers) Resulting in: Environmental impact (eg GDEs, flora/fauna) or Legal non-compliance or Social impact.	4.1.a. Private/Registered bores that exist are within the Devoian zone are disconnected from the groundwater environment intercepted by mining, therefore not applicable	**E** (Pb)	1 (E)	**1** **(L)**		
	There is a risk to Operations from ::: Unable to determine compliance ::: Caused by: Comprimised access to bores (eg lightning strike, vandalisim) or Monitoring LTA Resulting in: Environmental impact (eg GDEs, flora/fauna) or Legal non-compliance or Social impact.	4.2.a. Redundancy in existing monitoring program however only one/two bores across each source	**C** (Pb)	2 (E)	**8** **(M)**	5. Committment to redrill failed or impact bores	
5. Groundwater Dependent ecosystem	There is a risk to Operations from ::: Other GDES - loss or depressurisation of groundwater that exceeds approved impacts ::: Caused by: Impact of geological structure or Insufficient baseline data or Mine design implementation LTA or Mine design LTA or Model conceptualisation does not reflect natural system adequately or Monitoring LTA or over estimation of model parameters or under estimation of model parameters	5.1.a. groundtruthed faculatively GDEs 5.1.b. no change in subsidence profile (<100mm)	**E** (Pb)	2 (E)	**3** **(L)**		

	Resulting in: Environmental impact (eg GDEs, flora/fauna) or Legal non-compliance or Social impact.						
	There is a risk to Operations from ::: HIGH PRIORITY GDEs - loss or depressurisation of groundwater that exceeds approved impacts ::: Caused by: Not applicable (none identified within NSW AIP/WSP) Resulting in: Environmental impact (eg GDEs, flora/fauna) or Legal non-compliance or Social impact.	5.2.a. not applicable (as per WSP)	**E** (Pb)	1 (E)	**1** **(L)**		
6. Groundwater licensing	There is a risk to Operations from ::: Inadequate licence allocation ::: Caused by: Impact of geological structure or Mine design implementation LTA or Mine design LTA or over estimation of model parameters or under estimation of model parameters Resulting in: Business impact or Environmental impact (eg GDEs, flora/fauna) or Legal non-compliance or Social impact.	6.1.a. Current licensing covers a 3 times the predicted groundwater inflow. 6.1.b. Significant unallocated portion of catchment water within the Sydney Basin North Source	**E** (Pb)	2 (F)	**3** **(L)**		
7. Overall site water and salt balance	There is a risk to Operations from ::: groundwater volumes result in a change in the site water and salt balance predicting increase in discharges or salt load ::: Caused by: Impact of geological structure or Insufficient baseline data or Mine	7.1.a. Nil discharge site 7.1.b. groundwater is currently lost through product coal 7.1.c. Control over water supply sources to the site (eg Water imports, production bore usage).	**B** (Pb)	2 (E)	**12** **(S)**	6. Revised Water and Salt Balance (Aug 2018) 7. Management plan revised to enforce a preference system on water sources for the site to mitigate environmental risk. TARPS will also include guidance on appropriate usage of each water source.	

	design implementation LTA or Mine design LTA or Model conceptualisation does not reflect natural system adequately or Monitoring LTA or over estimation of model parameters or under estimation of model parameters Resulting in: Business impact or Environmental impact (eg GDEs, flora/fauna) or Legal non-compliance or Social impact.	7.1.d. Revised EPL has resulted in greater flexibility to site operations					
	There is a risk to Operations from ::: groundwater volumes result in a change in the site water and salt balance predicting reduced water availability or increased salt content ::: Caused by: Impact of geological structure or Insufficient baseline data or Mine design implementation LTA or Mine design LTA or Model conceptualisation does not reflect natural system adequately or Monitoring LTA or over estimation of model parameters or Production rate requires addtional utilisation of equipment or under estimation of model parameters Resulting in: Business impact or Environmental impact (eg GDEs, flora/fauna) or Legal non-compliance or Social impact.	7.2.a. Additional water sources available other than groundwater intercepted by the mine. 7.2.b. Revised EPL has resulted in greater flexibility to site operations	**A** (Pb)	4 (F)	**23 (E)**	8. Determine the water deficit under a range of sensitivities 9. Additional bore to be installed 10. Investigate and seek approval for additional external water	
8. Surface and groundwater connectivity	There is a risk to Operations from ::: Loss of baseflow from creek systems within mining area :::	8.1.a. Groundwater monitoring within both waterways located above mining areas (genowlan, gap creeks)	**D** (Pb)	2 (E)	**5 (L)**		

	Caused by: Impact of geological structure or Insufficient baseline data or Mine design implementation LTA or Mine design LTA or Model conceptualisation does not reflect natural system adequately or Monitoring LTA or over estimation of model parameters or under estimation of model parameters Resulting in: Environmental impact (eg GDEs, flora/fauna) or Legal non-compliance or Social impact.	8.1.b. Mining method does not change from approved					
9. Groundwater quality	There is a risk to Operations from ::: change of beneficial use cateogry of aquifer ::: Caused by: Impact of geological structure or Mine design implementation LTA Resulting in: Environmental impact (eg GDEs, flora/fauna) or Legal non-compliance or Social impact.	9.1.a. Mining method does not change from approved 9.1.b. Closed loop water management system	**E** (Pb)	1 (E)	**1 (L)**		
10. HMR Parameters considered in recalibration	There is a risk to Operations from ::: depressurisation or drawdown exceeding approved predictions ::: Caused by: HMR - Hydraulic conductivity change as a result of mining or HMR - Rainfall data considered based on history and not considering uncertainty or HMR - Storage properties of strata not supported by field investigation or HMR - Stress testing not sufficient	10.1.a. Hydrogeological model prepared to industry standard with limited uncertainity analysis, peer reviewed 10.1.b. Groundwater monitoring program 10.1.c. Limited groundwater volume being measured within mine development to date	**D** (Pb)	2 (L)	**5 (L)**	11. Recalibration following 12 months of panel extraction 12. IESC guidelines being considered for uncertainty, including peer review 13. linearment consdieration	

	Resulting in: Environmental impact (eg GDEs, flora/fauna) or Legal non-compliance or Social impact.	10.1.d. Correlation from actual measured groundwater to model predictions 10.1.e. 12months review undertaken				14. scenario based assessment (at least 5 scenarios as per advice by peer review)	
11. Surface water users	There is a risk to Operations from ::: loss of surface water to groundwater causes impacts to surface water extractors and water dependent infrastructure/recreation ::: Caused by: Impact of geological structure or Insufficient baseline data or Mine design implementation LTA or Mine design LTA or Model conceptualisation does not reflect natural system adequately or Monitoring LTA or over estimation of model parameters or under estimation of model parameters Resulting in: Business impact or Environmental impact (eg GDEs, flora/fauna) or Legal non-compliance or Social impact.	11.1.a. Groundwater and surface water monitoring within both waterways located above mining areas (genowlan, gap creeks) 11.1.b. Mining method does not change from approved	**D** (Pb)	2 (E)	**5** **(L)**		
	There is a risk to Operations from ::: loss of water from village spring greater than approved ::: Caused by: Impact of geological structure or Insufficient baseline data or Mine design implementation LTA or Mine design LTA or Model conceptualisation does not reflect natural system adequately or Monitoring LTA or over estimation of model parameters or under estimation of model parameters	11.2.a. Mine design change in 2018 that has resulted in the removal of the Hartely Shale Mine interaction zone	**E** (Pb)	1 (E)	**1** **(L)**		

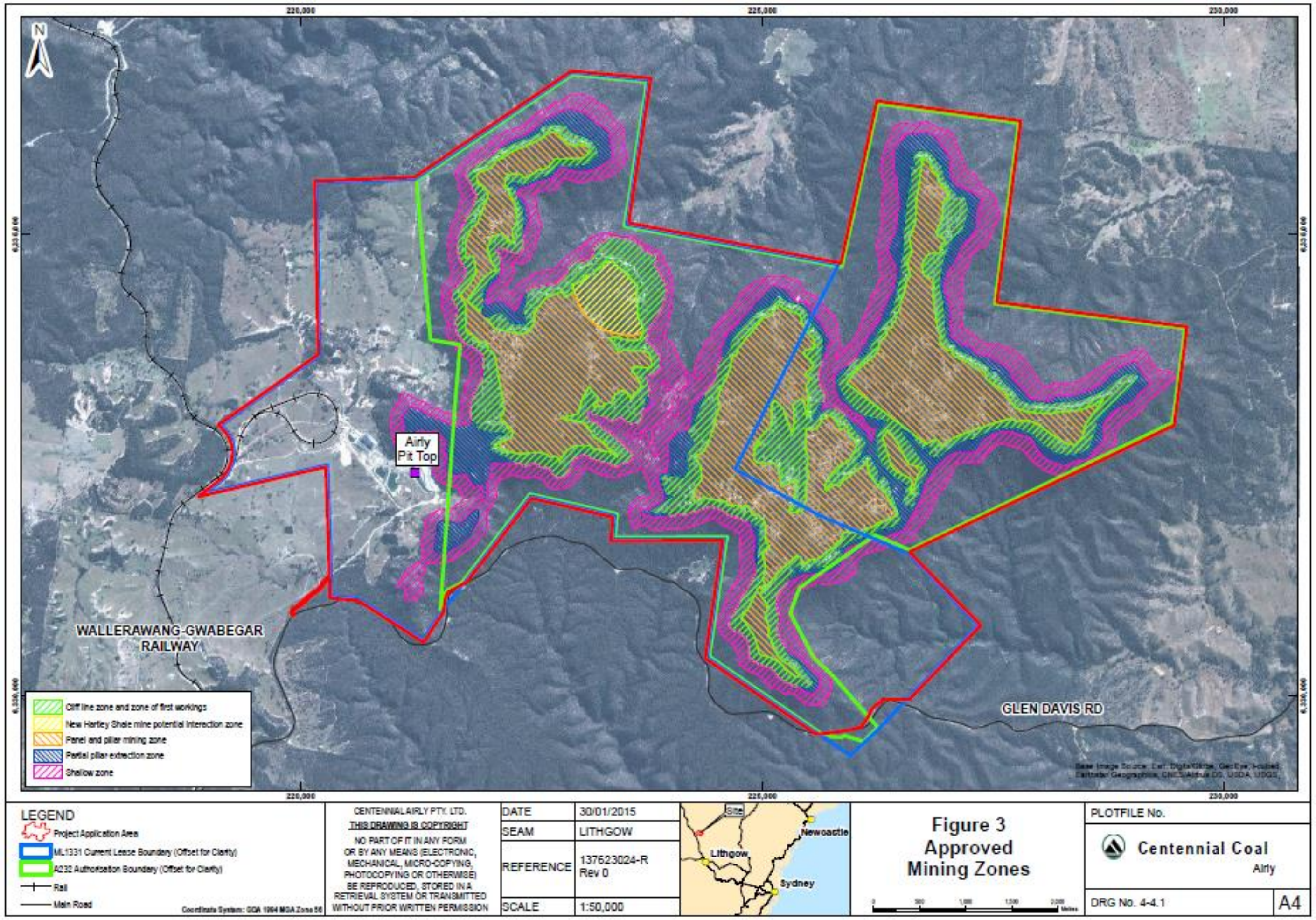
	Resulting in: Business impact or Environmental impact (eg GDEs, flora/fauna) or Legal non-compliance or Social impact.						
12. Cumulative impacts	There is a risk to Operations from ::: Interactions with external factors ::: Caused by: Constraints on groundwater access or inappropriate zone of impact or Unexpected activity within defined zone of impact Resulting in: Business impact or Environmental impact (eg GDEs, flora/fauna) or Legal non-compliance or Social impact.	12.1.a. no known developments within the zone of impact 12.1.b. State conservation area and LEP indicates a rural landuse surrounding zone of impact	**E** (Pb)	1 (E)	**1** **(L)**		
	There is a risk to Operations from ::: Interactions as a result of the approved project ::: Caused by: height of fracturing is greater than predictions or subsidence occurs outside of predictions Resulting in: Business impact or Environmental impact (eg GDEs, flora/fauna) or Legal non-compliance or Social impact.	12.2.a. Mining method does not change 12.2.b. Footprint does not change	**E** (Pb)	1 (E)	**1** **(L)**		

Recommended Controls

Recommended Controls	Place(s) Used	Allocated To	Required By Date	Pulse User No.	PULSE Ref. No.
1. further independent expert review of deliverables	Events: 1.1, 2.1	N Singh	31-Dec-2018		
2. fracture height monitoring to be reviewed following first 4 panels	Events: 1.1, 2.1	Sam Price	30-Jun-2020		
3. Further consdieration of type 3 uncertainity assessment	Events: 1.1, 2.1	N Singh	14-Sep-2018		
4. Consider the impacts of surface to seam geological structures (following definition by the Mine and via a desktop exercise in the first instance)	Events: 1.1, 2.1	David King	27-Aug-2018		
5. Committment to redrill failed or impact bores	Events: 4.2	Sam Price	30-Jun-2020		
6. Revised Water and Salt Balance (Aug 2018)	Events: 7.1	L Hammersley	30-Sep-2018		
7. Management plan revised to enforce a preference system on water sources for the site to mitigate environmental risk. TARPS will also include guidance on appropriate usage of each water source.	Events: 7.1	L Hammersley	28-Jun-2019		
8. Determine the water deficit under a range of sensitivities	Events: 7.2	L Hammersley	31-Aug-2018		
9. Additional bore to be installed	Events: 7.2	Sam Price	31-Oct-2018		
10. Investigate and seek approval for additional external water	Events: 7.2	L Hammersley	31-Oct-2018		
11. Recalibration following 12 months of panel extraction	Events: 10.1	Sam Price	30-Jun-2020		
12. IESC guidelines being considered for uncertainty, including peer review	Events: 10.1	N Singh	14-Sep-2018		
13. linearment consdieration	Events: 10.1	N Singh	14-Sep-2018		

14. scenario based assessment (at least 5 scenarios as per advice by peer review)	Events: 10.1	N Singh	14-Sep-2018		

Appendix E – General layout of mining zones at Airly Mine



220,000
225,000
230,000
N
Airly
Pit Top
WALLERAWANG-GWABEGAR
RAILWAY
GLEN DAVIS RD
Cliff line zone and zone of first workings
New Hartley Shale mine potential interaction zone
Panel and pillar mining zone
Partial pillar extraction zone
Shallow zone
LEGEND
Project Application Area
ML1331 Current Lease Boundary (Offset for Clarity)
A232 Authorisation Boundary (Offset for Clarity)
Rail
Main Road
Coordinate System: GDA 1994 MGA Zone 56
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DATE 30/01/2015
SEAM LITHGOW
REFERENCE 137623024-R Rev 0
SCALE 1:50,000
Site
Newcastle
Lithgow
Sydney
Figure 3
Approved
Mining Zones
PLOTFILE No.
Centennial Coal
Airly
DRG No. 4-4.1
A4

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The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report. GHD disclaims liability arising from any of the assumptions being incorrect.

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The opinions, conclusions and any recommendations in this report are based on information obtained from, and testing undertaken at or in connection with, specific sample points. Site conditions at other parts of the site may be different from the site conditions found at the specific sample points.

GHD

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2219275-94504/https://projects.ghd.com/oc/newcastle1/airlyminemod1groundw/Delivery/Documents/2219275-REP-GWIA_SG.docx

Document Status

Revision	Author	Reviewer		Approved for Issue		
		Name	Signature	Name	Signature	Date
0	I Gilmore	S Gray		S Gray		01/10/2019

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Surface Water Assessment

APPENDIX – F

2 October 2019

Nagindar Singh
Approvals Coordinator
Centennial Airly Pty Ltd

By email: Nagindar.Singh@centennial.com.au

Our ref: 22-SO-1120441763-6
Your ref:

Dear Nagindar

Airly Mine Extension Project - Modification 3
Baseflow impact assessment - Genowlan and Gap Creek

Centennial Airly Pty Limited (Centennial Airly) engaged GHD Pty Ltd (GHD) to investigate the potential impact of Modification 3 of the Airly Mine Extension Project on baseflow in Gap Creek and Genowlan Creek. Changes to baseflow were estimated from the recalibrated hydrogeological model for the Airly Mine Extension Project (GHD 2019)[1]. This letter is subject to limitations set out in Attachment B.

1 Site description

Airly Mine is an underground coal mine owned and operated by Centennial Airly. The mine is located near the village of Capertee, approximately 40 km north-west of Lithgow in the Western Coalfield. In part, Airly Mine underlies the headwaters of Genowlan Creek including its tributary Gap Creek. Centennial Airly have monitored flow in Genowlan and Gap Creek using a continuous flow gauge and data logger since 2013. The location of the Gap Creek and Genowlan Creek flow gauges in comparison to the Project approval area is shown in Attachment A.

Attachment A also shows the downstream course of Genowlan Creek to the Capertee River. A search of lots within 2 km of Genowlan and Gap Creek using the *NSW Water Register* (WaterNSW 2019)[2] identified one downstream surface water user on Genowlan Creek. The works approval and associated water access licence are summarised in Table 1.

Table 1 Downstream water users

Lot/DP	Approval number	Work	Use purpose	WAL number	WAL share components	Category
Lot 5, DP 755786 Lot 9, DP 755786	10CA104516	50 mm centrifugal pump	Irrigation	26203	41.00	Unregulated river

[1] GHD (2019) Airly Mine Extension Project – Modification 3: Groundwater Impact Assessment (2219275). Report prepared by GHD Pty Ltd for Centennial Airly Pty Ltd.

[2] WaterNSW (2019) NSW Water Register. Retrieved from https://waterregister.waternsw.com.au/water-register-frame

WAL 26203 is an unregulated river category in the Capertee River Management Zone of the Hawkesbury and Lower Nepean Rivers Water Source.

2 Available data

The analysis considered observed streamflow at Gap Creek and Genowlan Creek stream gauges and site rainfall data from January 2013 to July 2019. Streamflow and observed rainfall are shown on Figure 1.

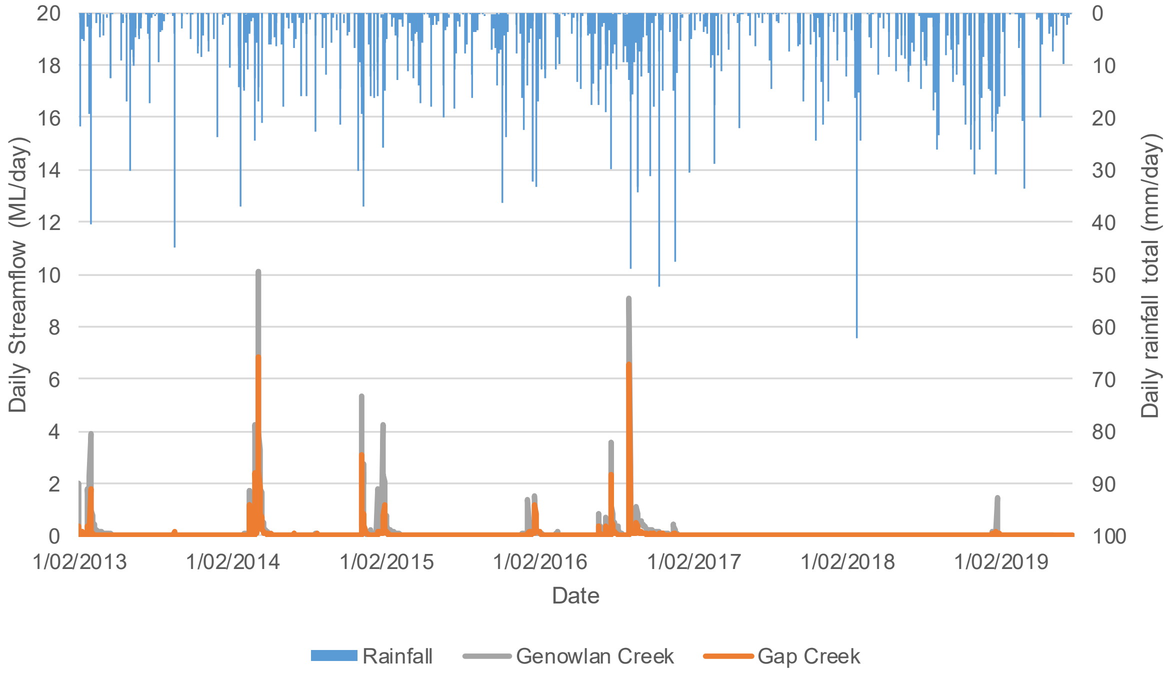


Figure 1 Available streamflow and rainfall data

Figure 1 shows that brief periods of streamflow occur during and following rainfall events, before quickly receding to no-flow condition during periods where there is insufficient rainfall and runoff to maintain surface water flow. One flow event has been observed in both Genowlan and Gap Creek since late 2016 (in February 2019). The absence of observed flow is consistent with below average rainfall during this period and unlikely to be associated with mining at Airly Mine.

3 Impact of baseflow reduction analysis on Gap and Genowlan Creek

The potential impact of baseflow reduction in Gap and Genowlan Creek from Modification 3 has been assessed using the available observed flows of both creeks and the baseflow reduction estimates from the recalibrated hydrogeological model. Four scenarios were considered:

- Existing conditions: based on observed stream gauge data. This assumes that observed data to date is representative of the pre mining case from GHD (2019). Given that no baseflow reductions are expected in Genowlan Creek until after 2020, and predicted baseflow reduction in Gap Creek for 2019 is minor compared to the maximum reduction in about 2035, this is considered an adequate approximation.
- Approved (GHD 2014)[3]: Based on the predicted baseflow reductions presented as part of the 2014 EIS for the 1.8 million tonnes per annum (Mtpa) coal production rate.
- Approved (recalibrated model): based on the approved maximum mining rate of 1.8 Mtpa with the recalibrated hydrogeological model from GHD (2019).
- Proposed: maximum mining rate of 3.0 Mtpa with the recalibrated hydrogeological model from GHD (2019).

Table 2 summarises the predicted baseflow reduction for each scenario, based on GHD (2014) and GHD (2019), expressed as daily averages.

Table 2 Estimated baseflow reduction

Location	Approved (GHD, 2014) (ML/day)	Approved (recalibrated model) (ML/day)	Proposed (ML/day)
Gap Creek at Project Application Area boundary	0.010	0.022	0.018
Genowlan Creek at Project Application Area boundary	0.010	0.011	0.011
Genowlan Creek at Gap Creek confluence	0.074	0.048	0.040

Table 2 shows that there are some differences between the approved (GHD 2014) case and approved (recalibrated model), for the 1.8 Mtpa production rate at all 3 locations, however, these are associated with the recalibration of the groundwater model.

Table 2 shows that baseflow reductions under proposed conditions are expected to less than or equal to baseflow reductions under approved conditions (recalibrated). The minor differences are not significant and relate to the different mining schedules between the 1.8 Mtpa (approved) and 3.0 Mtpa (proposed)

[3] GHD (2014) Airly Mine Extension Project Groundwater Impact Assessment, prepared by GHD Pty Ltd for Centennial Airly Pty Limited.

production rates from the recalibrated model although the mining footprint remains unchanged, as discussed in GHD (2019)[4].

The predicted baseflow reductions in Table 2 were applied to the observed stream flow record presented in Figure 1 to assess the potential impacts on flow regime using flow duration curves. For the purpose of this assessment, the stream gauges were assumed to be sufficiently close to the Project Application Area boundary, such that the estimated baseflow reduction was comparable to the observed streamflow. The flow duration curves for Gap Creek and Genowlan Creek are shown in Figure 2 and Figure 3 respectively. The approved (GHD, 2014) case has been included for completeness and is not comparable with the approved (recalibrated model) and proposed case.

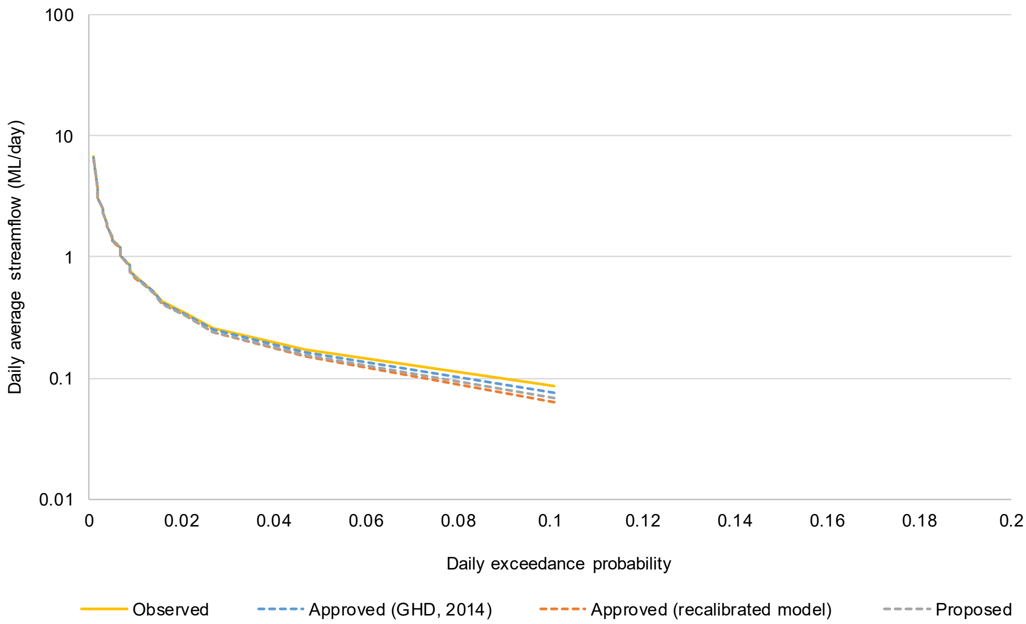


Figure 2 Potential impact on Gap Creek flow regime

Figure 2 shows that Gap Creek has measurable surface flow on about 10% of days, ranging in the order of 0.1 ML/day to 10 ML/day. Some reduction in baseflow and measurable flows days are expected as a result of approved mining at Airly Mine. The reduction is slightly less (that is, not significantly) for proposed conditions compared to approved conditions.

[4] GHD (2019) Airly Mine Extension Project – Modification 3: Groundwater Impact Assessment (2219275). Report prepared by GHD Pty Ltd for Centennial Airly Pty Ltd.

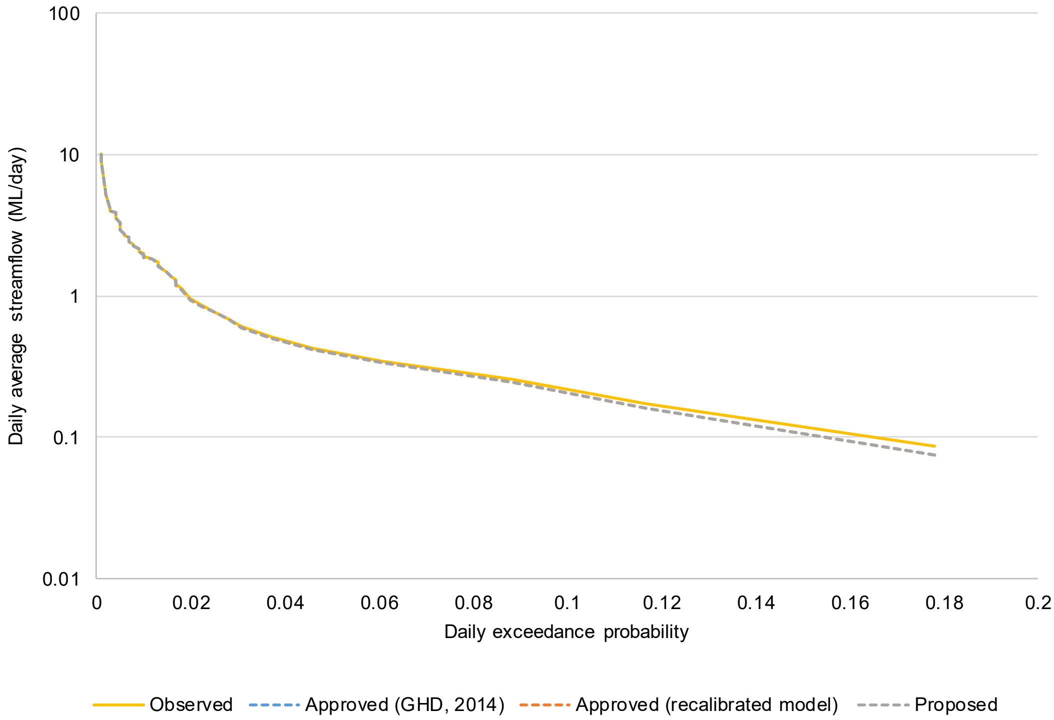


Figure 3 Potential impact on Genowlan Creek flow regime

Figure 3 shows that Genowlan Creek has measurable surface flow on about 18% of days, ranging in the order of 0.1 ML/day to 10 ML/day. Some reduction in baseflow and measurable flows days are expected as a result of approved mining at Airly Mine. No change to this potential reduction is expected under proposed conditions compared to approved conditions.

4 Conclusion

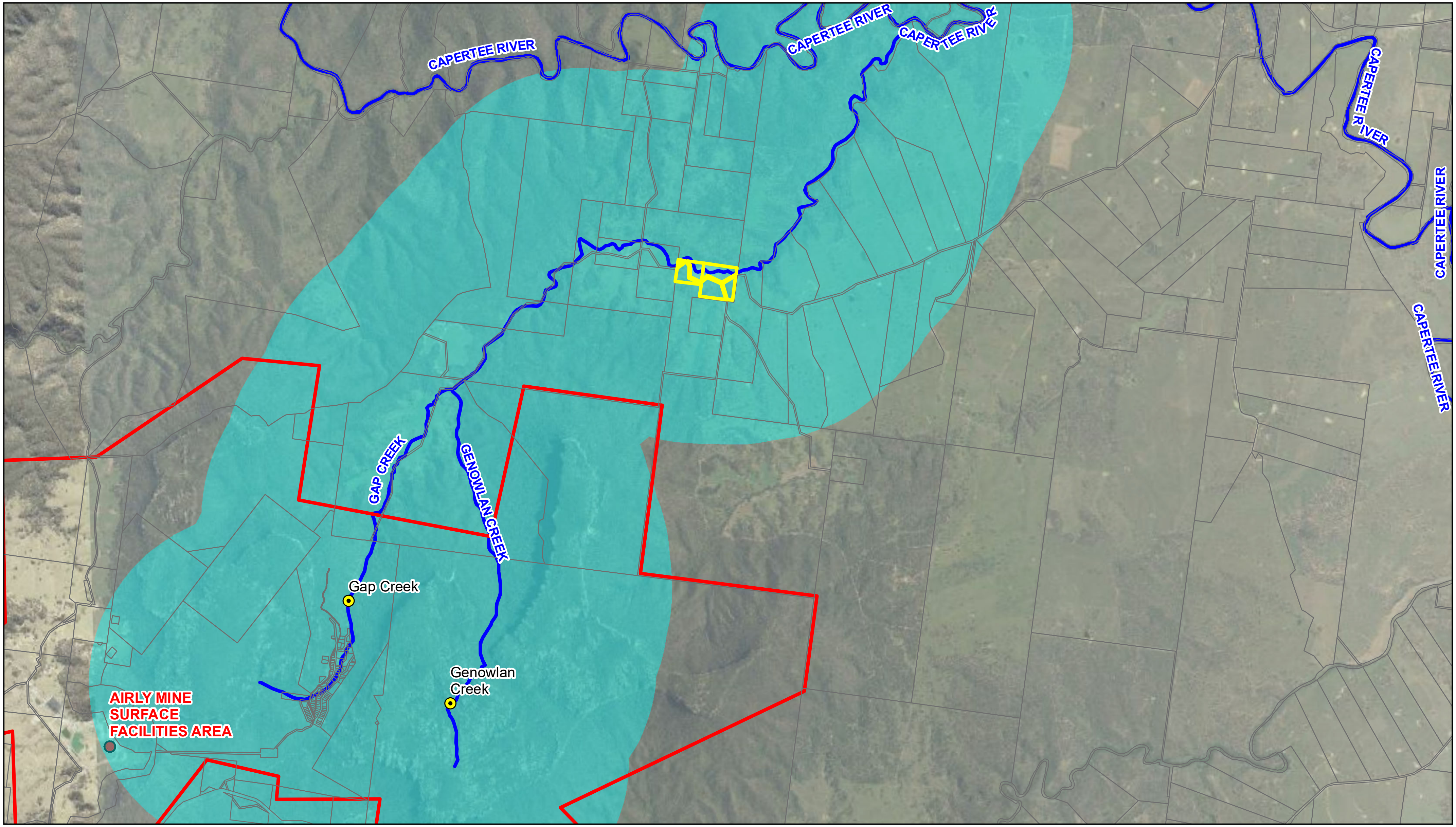
Overall, the potential impact of Modification 3 of the Airly Mine Extension Project on baseflow in Gap Creek and Genowlan Creek is expected to be slightly less than approved conditions, based on the recalibrated groundwater model predictions. The differences are small between the two conditions and the impact of the proposed modification on the hydrological environment downstream from the mining area within the Genowlan Creek catchment is not expected to be significant. The proposed modification can therefore be considered equivalent to the potential impacts of approved operations at Airly Mine.

One surface water user downstream of Airly Mine on Genowlan Creek was identified. No measurable impacts on downstream surface water users are expected as a result of Modification 3 of the Airly Mine Extension Project.

It is recommended that the existing monitoring of streamflow in Gap Creek and Genowlan Creek at Airly Mine be continued.

Sincerely

Tyler Tinkler
Water Engineer
+61 2 4979 9061



Paper Size A4

0 525 1,050 1,575 2,100

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

LEGEND

- Project approval area SSD_5581
- Downstream watercourse
- Flow gauge
- Cadastre
- Downstream water user search area
- Downstream surface water user

Centennial Airly

Centennial Airly Pty Ltd
Airly Mine Extension Project - Modification 3
Baseflow assessment
Genowlan and Gap Creek

Job Number 2220276
Revision 0
Date 9 Aug 2019

Flow gauges and downstream water users

Figure 4

\\ghdnet\ghd\AU\Newcastle\Projects\22\0105001\GIS\Maps\Deliverables\Western\Airly\2220276\Baseflow\2220276_BF001_DownstreamWaterUsers_0.mxd

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

Data source: LPI: DTDB 2012; Centennial: Aerial Imagery, boundaries, 2013, Mine Workings, 2012. Created by: fmackay, kpsroba

Attachment B: Limitations

This report has been prepared by GHD for Centennial Airly Pty Ltd and may only be used and relied on by Centennial Airly Pty Ltd for the purpose agreed between GHD and the Centennial Airly Pty Ltd as set out in Section 1 of this report.

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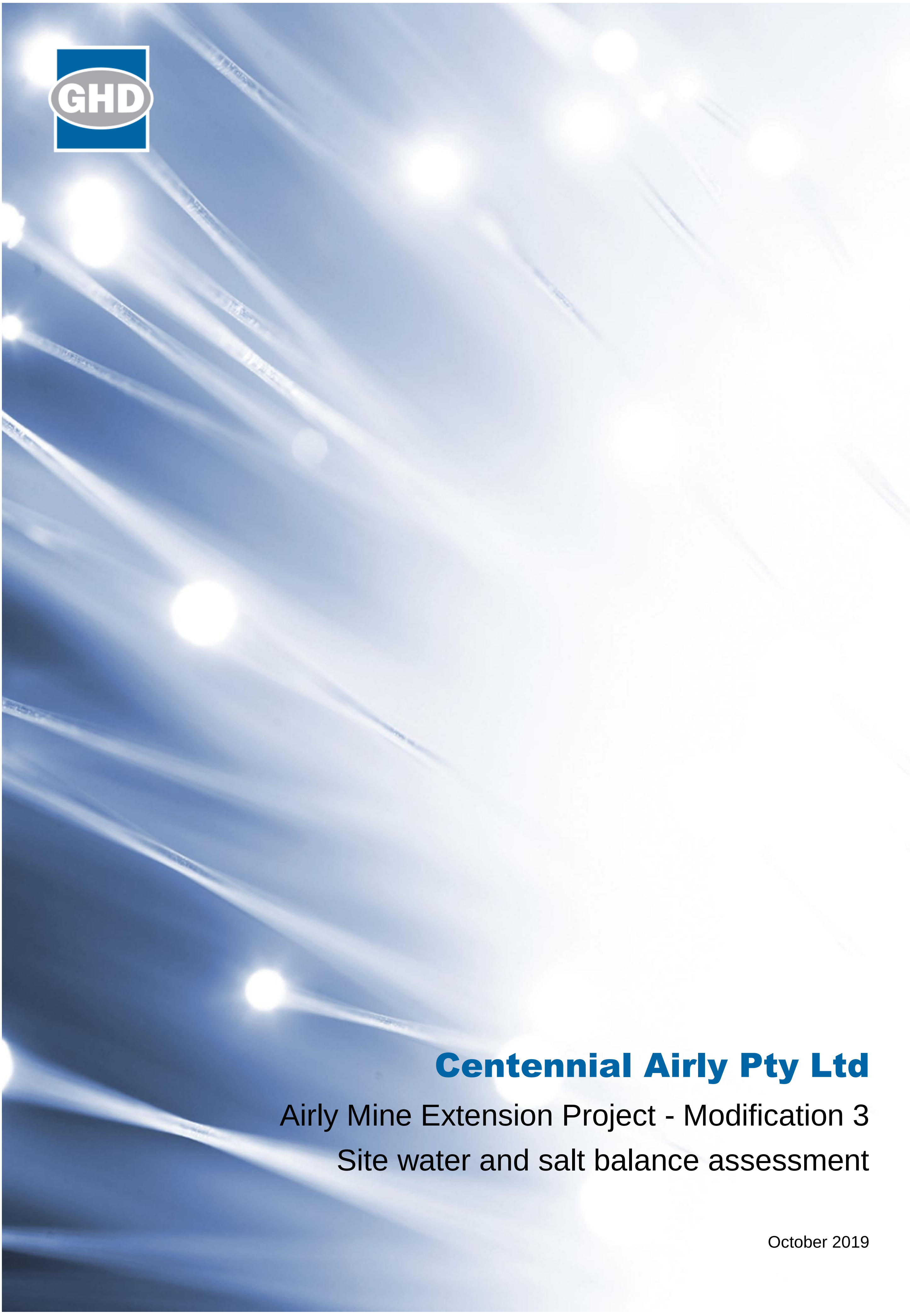
APPENDIX – G

Site Water and Salt Balance Assessment



Centennial Airly Pty Ltd

Airly Mine Extension Project - Modification 3

Site water and salt balance assessment

October 2019

Executive summary

Airly Mine is an existing underground coal mine operated by Centennial Airly Pty Limited (Centennial Airly), a wholly owned subsidiary of Centennial Coal Company Limited (Centennial). It is located near Capertee village, approximately 40 km north-west of Lithgow on the Castlereagh Highway in the Western Coalfield of NSW.

The Airly Mine Extension Project (SSD_5581) was approved in December 2016 and allows Airly Mine to extract up to 1.8 million tonnes per annum of run of mine coal for a period of 20 years within the boundaries of Mining Lease 1331 and Authorisation 232. Centennial Airly recently received approval to modify SSD_5581 (Modification 2) to import up to 170 ML/year of water to supply operations at the mine from nearby Charbon Colliery. Centennial Airly proposes to modify SSD_5581 (Modification 3) to increase the approved maximum production rate at Airly Mine from 1.8 to 3.0 million tonnes per annum of run of mine coal, increase the workforce from 155 to 200 full time equivalent personnel and increase the number of trains leaving the site from an average of 2 trains per day to 3 trains per day over a calendar year.

This site water and salt balance assessment has been prepared to inform the Modification Report for Modification 3 to SSD_5581. It assesses the impact of the proposed modification, relative to the conditions as currently approved at Airly Mine in terms of site water management and the site water and salt balance.

Water management at Airly Mine

The water management system at Airly Mine includes five dams and associated infrastructure that capture runoff from the surface facilities area and supply operations at the mine, along with a production bore that extracts groundwater. In 2018, the existing production bore only yielded about a quarter of the licence allocation, and the average yield continues to fall. Modification 2 provided Centennial Airly with a reliable source of water from Charbon Colliery to supply operations. No change to water management at Airly Mine is proposed as part of the Project.

Water and salt balance

A site water and salt balance model has been developed for Airly Mine. Discharges from Airly Mine are only expected as a result of rare rainfall events, which exceed the criteria specified in Airly Mine’s Environment Protection Licence 12374 (EPL 12374). Water and salt balance modelling indicates that no increase in the frequency or magnitude of potential off-site discharges, nor a deterioration in the water quality of potential discharges, are expected as a result of the proposal.

A Coal Preparation Plant and Rejects Emplacement Area are approved at Airly Mine, but there are no current plans to construct or operate these. Water balance modelling indicates that the approved importation of up to 170 ML/year of water from Charbon Colliery is sufficient to meet the process water requirements of the proposed production increase. However in the event that the Coal Preparation Plant and Rejects Emplacement Area are constructed and operated, water balance modelling indicates that up to an additional 42 ML/year is expected to be required at Airly Mine. In that case, a review of the water requirements should be undertaken.

Conclusion

The proposal is not expected to result in an increase in the frequency or magnitude, nor a deterioration of water quality, of potential discharges. Given the recommended mitigation and management measures, no measurable change in the potential impacts on Airly Creek, downstream water users, or cumulative impacts are expected with respect to surface water. Water balance modelling indicates that the on-site water sources and the approved importation of up to 170 ML/year of water from Charbon Colliery are sufficient to meet the process water requirements of the proposed production increase if the approval Coal Preparation Plant and Rejects Emplacement Area are not constructed.

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Glossary

Australian Height Datum	A common national surface level datum approximately corresponding to mean sea level
average recurrence interval	The average or expected value of the periods between exceedances of a given rainfall total accumulated over a given duration
beneficiate	Treat, or wash, (a raw material) to improve its properties
box cut	Small open cut built to supply a secure and safe entrance as access to a slope to an underground mine
calibration	In computer modelling, the process of testing different model parameters for the fit of model results to observations
catchment	The land area draining through the main stream, as well as tributary streams, to a particular site
clean water	Waters within a site that have not come into physical contact with sediment, coal or mined carbonaceous material
coal fines	Fine material from coal
coal handling plant	A facility where coal is crushed and screened
coal moisture	The water within and entrained in coal
coal preparation plant	A facility where coal is beneficiated
coarse coal rejects	Waste material from a coal preparation plant that with relatively large particle size
confluence	The location where two streams meet and merge
design storm	A hypothetical rainfall event used for design purposes
dewatering	Transfer of water from underground workings to the surface
dirty water	Waters within a site that have come into contact with coal or mined carbonaceous material or otherwise contain an elevated sediment load
disturbed areas	Areas where vegetation is not present that are likely to generate sediment laden runoff
electrical conductivity	A measure of the concentration of dissolved salts in water
ephemeral	Stream that is usually dry, but may contain water for rare and irregular periods, usually after significant rain
evaporation	The process where liquid water turns into vapour in the air
fine coal rejects	Waste material from a coal preparation plant that with relatively small particle size
fresh water sources	Water on the land; not ocean water
groundwater	Subsurface water that occurs in soils and geological formations
in situ coal moisture	The moisture entrained in coal in the seam prior to extraction
licensed discharge points	A location where a licensed operation discharges water to the environment in accordance with conditions stipulated within the site environment protection licence
mass balance	A mathematical model that balances inflows and outflows in order to obey the law of conservation of mass
mean	The average, sum of values divided by the number of values
median	The middle value, such that there is an equal number of higher and lower values, also referred to as the 50th percentile
normalised root mean square error	A measure of goodness of fit, a small number indicates a better fit
perennial	A watercourse or part of a watercourse that has continuous flow throughout the year
process water	Water used for the operation of the mine

product coal	Coal that is transport off-site for sale
production bore	A bore used to extract water from the ground
Quaternary	The most recent geological period spanning from approximately 2.5 million years ago to present
rejects emplacement area	A facility for containing coal rejects
run of mine coal	Coal in its unprocessed state, following mining but before processing
runoff	The amount of rainfall which actually ends up as streamflow, also known as rainfall excess
sediment	Soil or other particles that settle to the bed of lakes, rivers, oceans and other waters
subsidence	The vertical difference between the pre-mining surface level and the post-mining surface level at a point
topography	The shape of the surface of the earth
train loader	A facility to load coal into rail wagons
Triassic	The geological period that spans between approximately 250 and 200 million years ago
wastewater	Liquid waste discharged by a community or industry

Abbreviations

AHD	Australian Height Datum
AMEP	Airly Mine Extension Project
BOM	Bureau of Meteorology
Centennial Airly	Centennial Airly Pty Limited
Centennial	Centennial Coal Company Limited
EC	electrical conductivity
EIS	environmental impact statement
EPA	Environment Protection Authority
EPBC Act	*Environment Protection and Biodiversity Act 1999*
EP&A Act	*Environmental Planning and Assessment Act 1979*
EPL	environment protection licence
FTE	full time equivalent
CHP	coal handling plant
CPP	coal preparation plant
LDP	licensed discharge point
GHD	GHD Pty Ltd
GMRU WSP	Greater Metropolitan Region Unregulated River Water Sources Water Sharing Plan
GWIA	Groundwater Impact Assessment
ha	hectare
IESC	Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development
kL/day	kilolitre per day
km	kilometre
L/s	litre per second
m	metre
mg/L	milligram per litre
ML	megalitre (one million litres)
ML/year	megalitre per year
mm	millimetre
MNES	matters of national environmental significance
Mtpa	million tonne per annum
NWQMS	National Water Quality Management Strategy
POEO Act	*Protection of Environment Operations Act 1997*
REA	rejects emplacement area
ROM	run of mine
SILO	Scientific Information for Land Owners
SSGV	site-specific guideline values
TARP	trigger action response plan
WAL	water access licence

WM Act	*Water Management Act 2000*
WMP	water management plan
WSP	water sharing plan
µS/cm	microsiemens per centimetre

1. Introduction

GHD Pty Ltd (GHD) was commissioned by Centennial Airly Pty Limited (Centennial Airly), a wholly owned subsidiary of Centennial Coal Company Limited (Centennial), to prepare a site water and salt balance assessment for Modification 3 to State significant development consent SSD_5581 for Airly Mine (the Project). This assessment forms part of a Modification Report to support a modification application under section 4.55 (2) of the *Environmental Planning and Assessment Act 1979* (EP&A Act).

1.1 Background

Airly Mine is an underground coal mine owned and operated by Centennial Airly. The mine is located near the village of Capertee, approximately 40 km north-west of Lithgow in the Western Coalfield. The location of the mine is shown in Figure 1-1.

Airly Mine was first granted development consent DA162/91 for the development of an underground coal mine in April 1993. The Airly Mine Extension Project (AMEP) for the continuation of underground mining within the boundaries of Mining Lease 1331 and Authorisation 232 was submitted in September 2014. The AMEP was approved in December 2016 by the then NSW Planning Assessment Commission for a period of 20 years, with rehabilitation to be undertaken after this period. Airly Mine's development consent SSD_5581 provides approval to extract up to 1.8 million tonnes per annum (Mtpa) of run of mine (ROM) coal from the Lithgow Seam. Airly Mine is also approved to construct and operate a coal preparation plant (CPP) and reject emplacement area (REA) to beneficiate up to 1.8 Mtpa of ROM coal, however neither have been constructed to date. ROM and product coal is transported off-site by rail for the export and domestic markets.

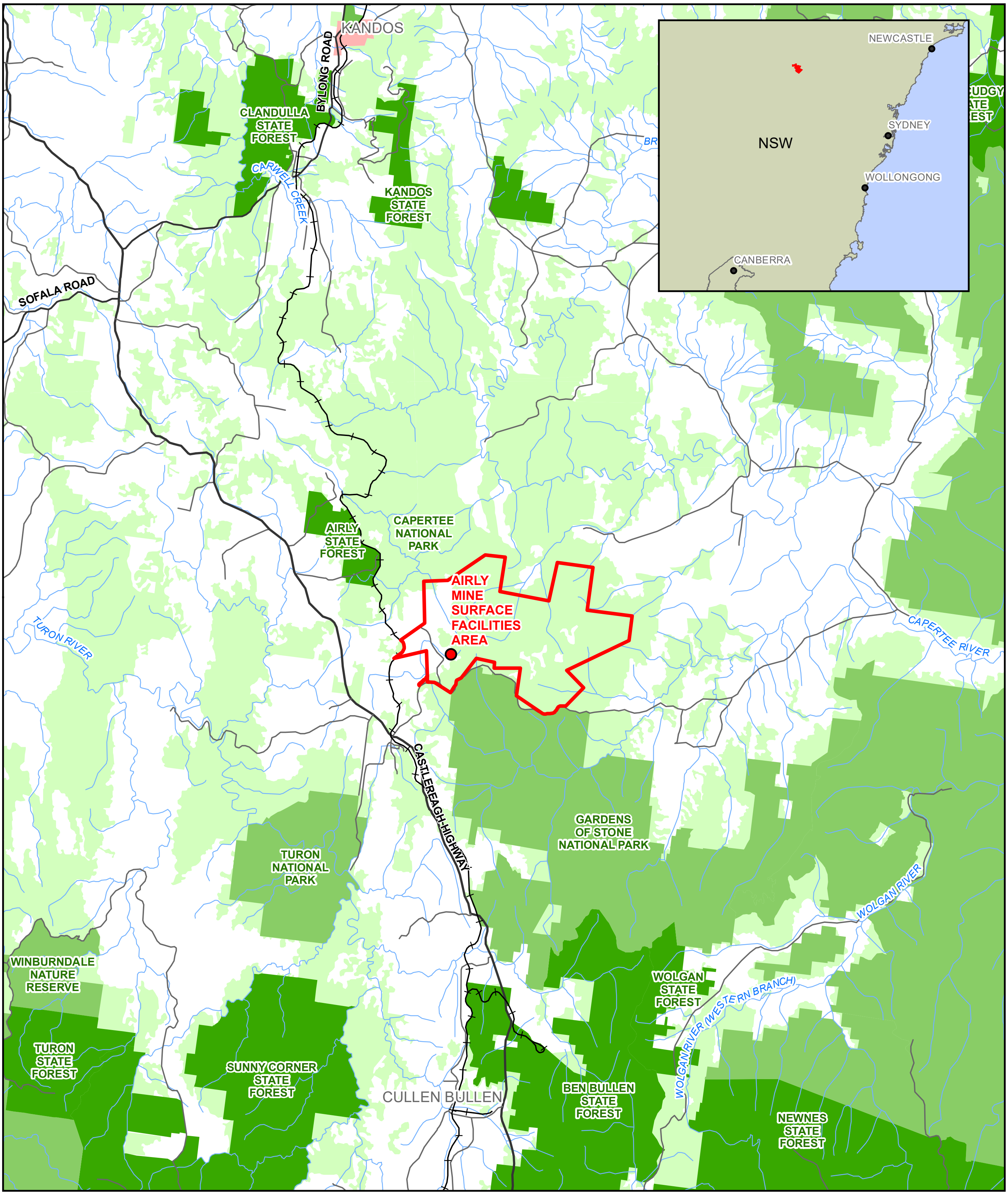
In April 2019, Centennial proposed a modification (MOD 2) to SSD_5581, to allow the importation of up to 170 ML/year of water from nearby Charbon Colliery. MOD 2 was approved by the Department of Planning and Environment in July 2019.

1.2 Overview of site operations

Airly Mine comprises an underground mine and a surface facilities area. The development consent boundary, existing workings and location of the surface facilities area (pit top) are shown in Figure 1-2. The features of the surface facilities area associated with operations at Airly Mine are provided in Figure 1-3 and include water management and pollution control infrastructure, underground mining access, a coal handling plant (CHP) (including a coal crusher), rail loop and train loader used to load coal for export from the site and workshop and administration infrastructure. Figure 1-3 also shows the concept design of the approved REA and the CPP.

The Rail Loop Pollution Control Dam shown in Figure 1-3 is currently being designed and constructed. It does not form part of the water management system at Airly Mine and does not form part of the Project.

The water management system at Airly Mine includes the collection of runoff from disturbed and undisturbed areas in dams and infrequent discharges of water to Airly Creek through licensed discharge points (LDPs). Water used for activities associated with mining, including dust suppression, vehicle and plant washdown and underground mining, is currently sourced from the surface water catchment of the surface facilities area and a production bore. Water supply from clean water runoff and the production bore is minimised by reuse and recirculation of water on site.



LEGEND

Project approval area SSD_5581	Recreation area	Dual carriageway
Waterway	Nature conservation	Principal road
Existing rail	State forest	Secondary road
Built up area	Forest or shrub	Minor road

Paper Size A4

0 1 2 4 6 8

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Centennial Airly

Centennial Airly Pty Ltd
Airly Mine Extension Project - Modifcation 3
Site water and salt balance assessment

Job Number 2220276
Revision 0
Date 04 Sep 2019

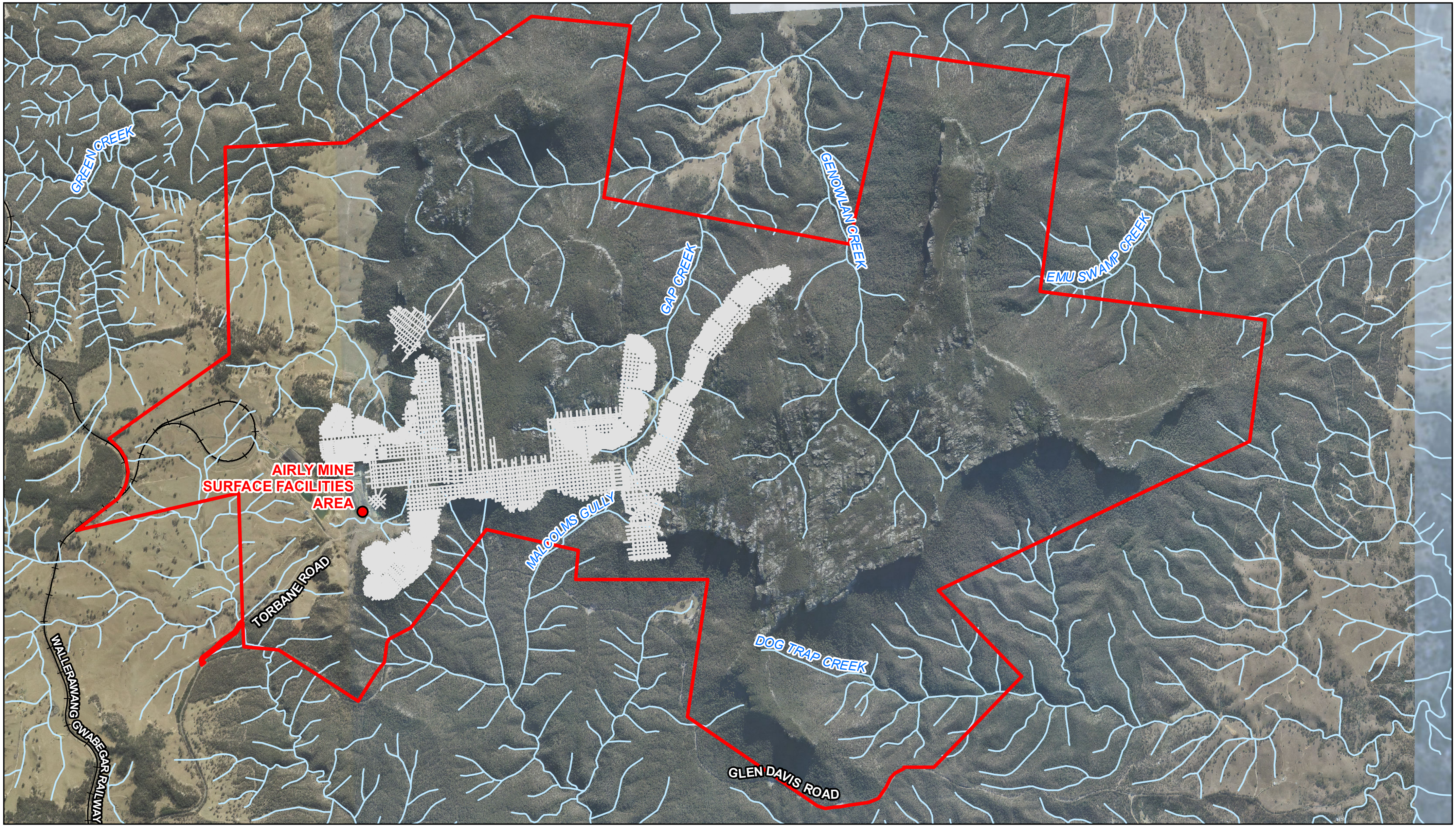
Locality plan

Figure 1-1

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

\\ghdnet\ghd\AU\Newcastle\Projects\22\0105001\GIS\Maps\Deliverables\Western\Airly\2220276\SWIA\2220276_SWIA001_Locality_0.mxd

Data source: @ Commonwealth of Australia (Geoscience Australia): 250K Topographic Data Series 3 2006; Centennial: Boundaries. Created by: smacdonald, kpsroba



Paper Size A4

0 375 750 1,125 1,500

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

LEGEND

Project approval area SSD_5581

Railway

Existing workings

Waterway

GHD

Centennial Airly

Centennial Airly Pty Ltd
Airly Mine Extension Project - Modification 3
Site water and salt balance assessment

Job Number 2220276
Revision 0
Date 14 June 2019

Site features

Figure 1-2

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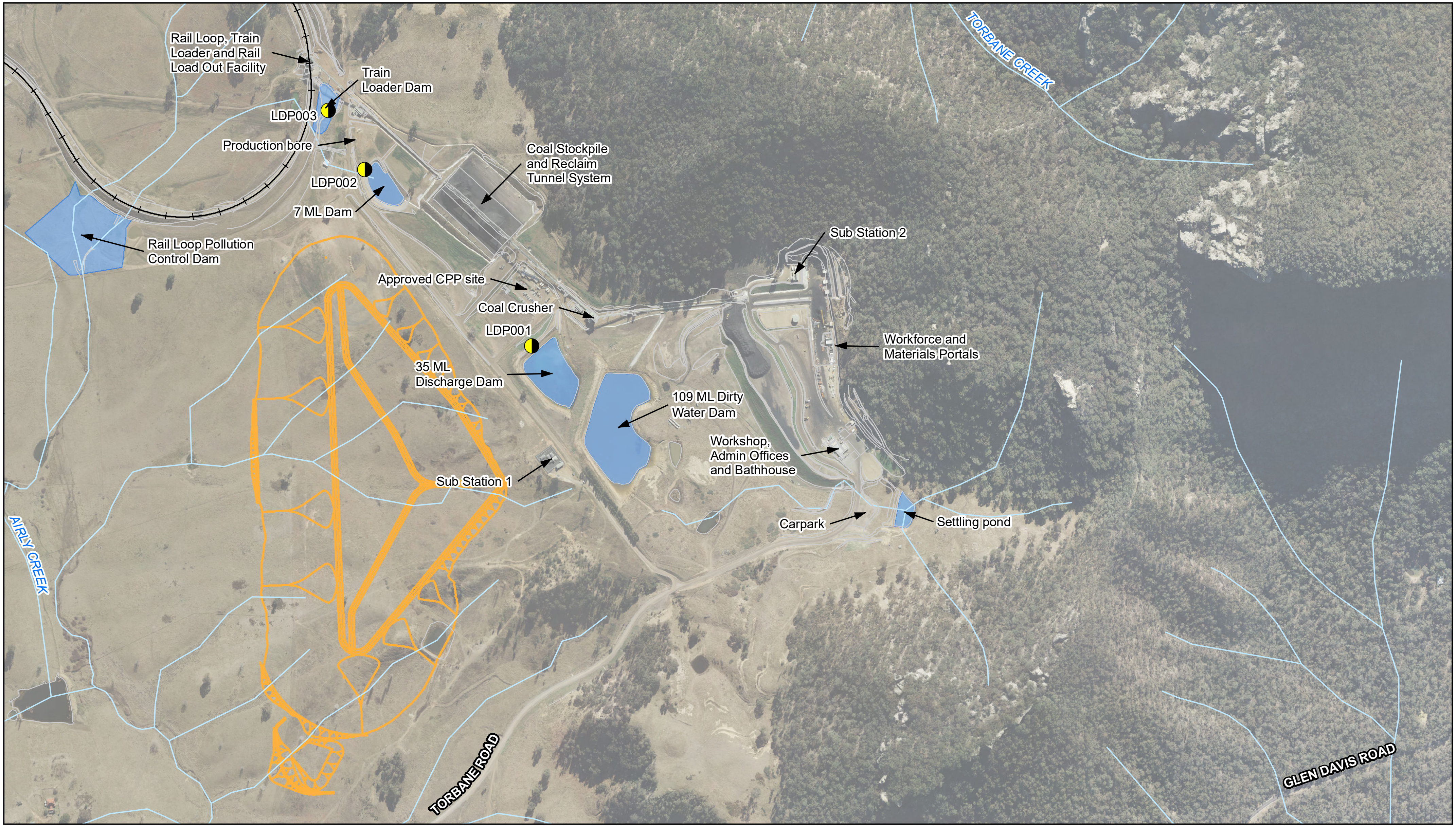
Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

Data source: LPI: DTDB 2012; Centennial: Aerial Imagery, boundaries, 2013, Mine Workings, 2012. Created by: fmackay, kpsroba



Paper Size A4

0 75 150 225 300

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

LEGEND

- LDP location
- Waterway
- Infrastructure
- Rail Loop
- Surface water storage
- Approved REA concept design

Centennial Airly

Centennial Airly Pty Ltd
Airly Mine Extension Project - Modification 3
Site water and salt balance assessment

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Revision 0
Date 14 June 2019

Surface facilities area features

Figure 1-3

\\ghdnet\ghd\AU\Newcastle\Projects\22\0105001\GIS\Maps\Deliverables\Western\Airly\2220276\SWIA\2220276_SWIA003_SurfaceFacilitiesArea_0.mxd

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

Data source: LPI: DTDB 2012; Centennial: Aerial Imagery, Infrastructure, 2013. Created by: fmackay, tmorton, kpsroba

1.3 Import of water from Charbon Colliery

The recently approved MOD 2 was motivated by a review of the site water balance for Airly Mine that identified a deficit in process water supply as a result of:

- Revised groundwater inflow predictions being significantly less than included in the AMEP hydrogeological model report (GHD 2014a) and the groundwater impact assessment (GHD 2014b).
- Current below average rainfall conditions limiting the surface water runoff captured on site.
- Reduced reliability of the production bore as a supplementary water supply.

1.3.1 Groundwater inflows

The predictions of groundwater inflows into the underground workings that were included in the groundwater impact assessment for the AMEP (GHD 2014b), have recently been revised using additional monitoring data in accordance with the requirements of the site's *Water Management Plan* (WMP) (Centennial Coal 2018). GHD (2019b) presents the results of the update and recalibration of the hydrogeological model for the mine using additional monitoring data collected since the AMEP was approved. The groundwater inflows predicted by the recalibrated hydrogeological model peak at 76 ML/year in 2030 for the case presented for the recently approved MOD 2 (GHD 2019a) and at 71 ML/year in 2027 under proposed conditions. In both cases this is significantly less than the maximum inflow of 183 ML/year predicted for the AMEP (GHD 2014a), submitted in 2014 in support of the EIS for the application for SSD_5581. The groundwater inflows presented in this assessment differ slightly from those presented in MOD 2 (GHD 2019a) due to a correction to the interpolation method.

The seepage of groundwater into the existing underground workings has been reported by Centennial Airly to be low (not measurable) and not sufficient to require regular mine dewatering. Monitoring results indicate that groundwater inflow volumes and process water used in underground operations is entrained in the ROM coal. As a result, all groundwater inflows and additional water is removed from the site as product coal moisture, with no water available to be reclaimed and reused as process water. Given the reduced groundwater inflows predicted by the recalibrated hydrogeological model, no mine inflows are expected to be able to be relied on for reuse as process water in the future.

1.3.2 Surface water runoff

Surface water runoff from across the site is captured within several dams and transferred to the main collection dam, the 109 ML Dirty Water Dam, prior to use in underground mining operations, dust suppression, machinery washdown and staff amenities. Harvested runoff is currently the primary water supply for operations at Airly Mine. A recent prolonged period of below average rainfall has reduced the volume of water stored on site, as the process water demand is currently greater than the rate of runoff harvested.

1.3.3 Production bore

Recent drought conditions at Airly Mine have increased reliance on the production bore to supplement process water supply. The volume of water extracted from the production bore is limited by water approvals to 5 L/s (158 ML/year), which is based on the sustainable yield of the bore calculated from the pumping tests undertaken at the time of installation. However, the current average yield is less than 0.8 L/s, with the flow rate continuing to decrease during 2018 and early 2019. Investigations to assess the reliability of the production bore as a supplementary source of process water suggest that it is unlikely that flow rates will increase.

Given the declining trend in yield, the Shoalhaven Group groundwater source is not currently considered to be a reliable source of water.

1.4 Project description

As part of the Project, the annual coal production rate and workforce at Airly Mine is proposed to increase. No change to the existing mining infrastructure is proposed, however the ECOMAX system, currently rated for 150 FTE personnel, will require an upgrade when the workforce number exceeds 150 FTE personnel.

The Project proposes to:

- Increase in the run-of-mine (ROM) production rate from the approved 1.8 million tonne per annum (Mtpa) to 3.0 Mtpa.
- Increase in workforce from the approved 155 full time equivalent (FTE) personnel to 200 FTE personnel.
- Increase in the movement of laden coal trains and water trains leaving the site from the approved average of 2 trains per day to 3 trains per day over any calendar year but maintaining the approved maximum 5 trains per day leaving the site on any day.
- Include underground blasting (or shot-firing) activities for the removal of geological structures in the event they are encountered within the mining areas.

1.5 Objectives and scope of work

The objective of this assessment is to determine the potential impacts of the Project on the surface water environment within the vicinity of the Project and the broader regional environment. Since no change to the mining method is proposed, the potential impacts of subsidence above mined areas are not expected to change as a result of the Project. Thus, the assessment of the potential impacts of the Project on surface water resources is limited to operations at the surface facilities area (this assessment) and potentially flows in Gap and Genowlan Creek, discussed in GHD (2019c).

The scope of work for this assessment includes:

- Review existing assessments and data relevant to the Project
- Review relevant statutory requirements
- Establish the baseline conditions for water management system
- Identify components of the Project with potential to affect the surface water environment
- Undertake an assessment of the potential impacts of the Project on the site water and salt balance
- Determine any licensing requirements for the Project
- Develop measures to avoid, minimise and mitigate potential impacts of the Project and recommend management, monitoring and reporting requirements

2. Regulatory context

2.1 Legislation

2.1.1 Environmental Planning and Assessment Act 1979

The EP&A Act is the core legislation relating to planning and development activities in NSW and provides the statutory framework under which development proposals are assessed. The EP&A Act aims to encourage the proper management, development and conservation of resources, environmental protection and ecologically sustainable development.

This assessment forms part of a Modification Report to support an application to modify development consent SSD-5581 under section 4.55 (2) of the EP&A Act. The Minister for Planning (or delegate) is the determining authority for the Project.

2.1.2 Protection of the Environment Operations Act 1997

The *Protection of the Environment Operations Act 1997* (POEO Act) is administered by the NSW Environment Protection Authority (EPA), which is an independent statutory authority and the primary environmental regulator for NSW. The objectives of the POEO Act are to protect, restore and enhance the quality of the environment. Some of the mechanisms that can be applied under the POEO Act to achieve these objectives include programs to reduce pollution at the source and monitoring and reporting on environmental quality. The POEO Act regulates and requires licensing for environmental protection, including for waste generation and disposal and for water, air, land and noise pollution.

Under the POEO Act, an environment protection licence (EPL) is required for premises at which a ‘scheduled activity’ is conducted. Schedule 1 of the POEO Act lists activities that are scheduled activities for the purpose of the Act. Licence conditions relate to pollution prevention and monitoring and can control the air, noise, water and waste impacts of an activity.

Currently, Centennial Airly holds EPL 12374 that authorises coal mining and coal works. Water is licensed to be discharged from the site through the following LDPs:

- LDP001 – discharge to Airly Creek via the 35 ML Discharge Dam
- LDP002 – discharge to Airly Creek via the 7 ML Dam
- LDP003 – discharge to Airly Creek via the Train Loader Dam

Water quality concentration limits for LDP001, LDP002 and LDP003 specified by EPL 12374 are provided in Table 2-1. No volumetric discharge limits at the LDPs are specified by EPL 12374.

Table 2-1 Water quality concentration limits for licensed discharge points

Parameter	Units	LDP001		LDP002 and LDP003
		90th percentile	100th percentile	100th percentile
Physicochemical parameters				
Electrical conductivity (EC)	µS/cm	2244		
pH	pH units		6.5–9.0	6.5–9.0
Total suspended solids (TSS)	mg/L		50	50
Turbidity	NTU		40	40

Parameter	Units	LDP001		LDP002 and LDP003
		90th percentile	100th percentile	100th percentile
Nutrients				
Ammonia	mg/L		0.32	
Total nitrogen	mg/L	2		
Total phosphorus	mg/L	0.5		
Dissolved metals				
Arsenic	mg/L		0.024	
Copper	mg/L		0.013	
Nickel	mg/L		0.1	
Zinc	mg/L		0.072	
Other parameters				
Oil and grease	mg/L		10	10

The water quality limits presented in Table 2-1 do not apply when the discharge for LDP001, LDP002 or LDP003 occurs solely as a result of rainfall measured at the site exceeding 44 mm over any consecutive five day period. A 44 mm rainfall depth is defined by *Managing Urban Stormwater: Soils and Construction Volume 1* (the 'Blue Book'; Landcom 2004) as the rainfall depth for a 95th percentile, five day rainfall event for the Central Tablelands consistent with the storage capacity (recommended minimum design criteria) for Type D sediment retention basins for mines (Landcom 2008).

Condition O4 of EPL 12374 requires the design storage capacity of the 35 ML Discharge Dam, 7 ML Dam and Train Loader Dam to be maintained by dewatering within 15 days (for the 35 ML Discharge Dam) or five days (for the 7 ML Dam and Train Loader Dam) following rainfall. Maintenance is required on all dams as necessary to retain the design storage capacity.

2.1.3 Water Management Act 2000

The *Water Act 1912* has historically been the main legislation for managing water resources in NSW, however is currently being progressively phased out and replaced by water sharing plans (WSPs) under the *Water Management Act 2000* (WM Act). Once a WSP commences, existing licences under the *Water Act 1912* are converted to water access licences (WALs), water supply works and use approvals under the WM Act.

The aim of the WM Act is to ensure that water resources are conserved and properly managed for sustainable use benefiting both present and future generations. It is also intended to provide formal means for the protection and enhancement of the environmental qualities of waterways and in-stream uses as well as to provide for protection of catchment conditions.

Water sharing plans

Fresh water sources throughout NSW are managed via WSPs under the WM Act. Provisions within WSPs provide water to support the ecological processes and environmental needs of groundwater dependent ecosystems and waterways. WSPs also regulate how the water available for extraction is shared between the environment, basic landholder rights, town water supplies and commercial uses. Key rules within the WSPs specify when licence holders can access water and how water can be traded.

The site is covered by two WSPs made under Section 50 of the WM Act, which are the Greater Metropolitan Region Unregulated River Water Sources WSP and the Greater Metropolitan Region Groundwater Sources WSP. Each WSP consists of several water sources that are regulated by a water extraction entitlement.

Airly Mine currently holds two WALs under the WM Act for the extraction of groundwater. A total of 278 ML/year is licensed for extraction from the Sydney Basin North groundwater source as part of the WSP for the Greater Metropolitan Region Groundwater Sources. WAL 24386 (158 ML/year) licenses the take of water from the production bore (water supply work approval 10WA112537), which is used to supplement water for use in mining activities. WAL 36565 (120 ML/year) licenses the extraction of water from the underground workings to the 109 ML Dirty Water Dam (miscellaneous works approval 10MW119324).

Basic landholder rights

Under the WM Act, extraction of water for basic landholder rights is protected by allocating and prioritising water for basic landholder rights. There are three types of basic landholder rights in NSW under the WM Act:

- Domestic and stock rights
- Native title rights
- Harvestable rights

Domestic and stock rights

Landholders are entitled to take water from a river, estuary or lake which fronts their land or from an aquifer which is underlying their land for domestic consumption and stock watering, without the need for a licence. However, a water supply work approval is required to construct a dam or a groundwater bore.

Native title rights

Anyone who holds native title with respect to water, as determined by the *Native Title Act 1993*, can take and use water for a range of purposes, including personal, domestic and non-commercial communal purposes.

Harvestable rights

Landholders are entitled to collect a portion of runoff from their property and store it in one or more dams up to a certain size, known as a 'harvestable right', which is determined from the total contiguous area of land ownership. In the Central and Eastern Divisions of NSW (where the Project is located), landholders may capture and use up to 10% of the average regional runoff for their property without requiring a licence under the WM Act. The maximum harvestable right is the total volume of runoff that a landholder is entitled to use without requiring a licence. If the maximum harvestable right for a site is exceeded, licensing for the volume of water extracted from the surface water source exceeding the harvestable right is required under the WM Act.

The surface water assessment for the AMEP (GHD 2014c) found that, based on the contiguous area of property under ownership of Centennial Airly at the Airly Mine site of 1710 ha, the maximum harvestable right for Airly Mine (10% of the average rainfall runoff of the total area) was 128 ML/year. The capacity of existing dams (excluding dams located in the surface facilities area, which are exempt) was estimated to be approximately 70 ML, and therefore, the remaining harvestable rights for the Project are 58 ML/year (45% of the total). The predicted volume of clean catchment runoff captured by the mine water management system was estimated to be 28 ML/year. As this volume is within the maximum harvestable rights, there is no requirement for licensing of clean catchment runoff by Centennial Airly under the WM Act.

2.1.4 Environment Protection and Biodiversity Conservation Act 1999

The *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) is administered by the Commonwealth Department of the Environment and Energy (DEE) and provides a legal framework to protect and manage nationally important flora, fauna, ecological communities and heritage places defined as 'matters of national environmental significance' (MNES). The EPBC Act identifies water resources, in relation to large coal mining development, as a MNES.

An action that 'has, will have or is likely to have a significant impact on a matter of national environmental significance' is deemed a 'controlled action' and may not be undertaken without prior approval from the Commonwealth Environment Minister. Approval under the EPBC Act is also required where actions are proposed on, or will effect, Commonwealth land and its environment.

The AMEP is a controlled action under the EPBC Act and the approval for referral 2013/7606 was granted on 18 May 2017. This approval has effect until 31 March 2047. The water resources trigger is one of the controlling provisions in this approval. The approval provides for Centennial Airly to carry out mining operations in accordance with development consent SSD_5581 with conditions relating to the protection of MNES.

The Project was determined, though an assessment of the Project against the significant impact criteria defined by the *Significant Impacts Guidelines 1.3* (DoE 2013a), as not likely to have a significant impact on any MNES listed under the EPBC Act (refer to Section 6.3) and consequently the Project is not required to be referred to the Commonwealth Department of Environment and Energy under the EPBC Act.

2.2 Guidelines

2.2.1 Significant impact guidelines

The significant impact guidelines provide over-arching advice on determining whether an action is likely to have a significant impact on a MNES protected by the EPBC Act and requires referral to the Commonwealth Department of the Environment and Energy for assessment and approval. Potential impacts on any MNES are subject to assessments of significance pursuant to the *Significant Impact Guidelines 1.1* (DoE 2013b). If a significant impact is considered likely, a referral under the EPBC Act must be submitted to the Commonwealth Environment Minister.

The *Significant Impact Guidelines 1.3* (DoE 2013a) includes significant impact criteria to assist in determining whether the impacts on a water resource from a proposed action associated with a coal seam gas or large coal mining development are likely to be significant, and therefore whether the action will require referral, assessment and approval. An action is likely to have a significant impact on a water resource if there is the possibility that it will directly or indirectly result in changes to the hydrology or water quality of a water resource.

The significant impact criteria defined by the *Significant Impact Guidelines 1.3* (DoE 2013a) are presented in Section 6.3, along with where each aspect has been assessed in this assessment.

2.2.2 IESC information guidelines

The Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development (IESC) is a statutory body established under the EPBC Act in 2012. The IESC provides independent scientific advice to Australian government regulators on proposed coal seam gas or large coal mining developments that are likely to have a significant impact on water resources. Information guidelines (IESC 2018) outline the information requirements of the IESC to adequately assess a proposal and provide scientific advice on the potential water-related impacts.

This assessment has been undertaken based on the information guidelines specified by the IESC (2018). Appendix A presents the information requirements as well as where each requirement has been addressed in this assessment.

2.2.3 Australian and New Zealand Guidelines for Fresh and Marine Water Quality

The *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZG 2018) provide guidance for assessing and managing ambient water quality in a wide range of water resource types and according to specified environmental values, such as aquatic ecosystems, primary industries, recreation and drinking water. A revised *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZG 2018) was published in 2018 after a scientific review of the ANZECC (2000) guidelines. The Water Quality Management Framework (ANZG 2018) provides the key requirements for determining appropriate guideline values or performance criteria to evaluate the results of water quality monitoring programs.

The ANZG (2018) guideline adopts a risk-based approach to assessing ambient water quality by providing the framework to tailor water quality guidelines to local environmental conditions. Guideline values provided by ANZG (2018) can be modified into regional, local or site-specific guideline values (SSGVs) by taking into account factors such as the variability of the particular ecosystem, soil types, rainfall and level of exposure to contaminants. Guideline values are applied to the receiving environment at the edge of the mixing zone and do not apply to mine water at the point of discharge.

2.2.4 Managing Urban Stormwater: Soils and Construction

Managing Urban Stormwater: Soils and Construction – Volume 1 (Landcom 2004) outlines the basic principles for the design, construction and implementation of sediment and erosion control measures to improve stormwater management and mitigate the impacts of land disturbance activities on soils and receiving waters. This document relates particularly to urban development sites; however, it is relevant to the Project as it provides guidance on the configuration of erosion and sedimentation controls required during construction.

Additional guidelines on specific aspects of development and the application of erosion and sediment controls are also available. *Managing Urban Stormwater: Soils and Construction – Volume 2E Mines and Quarries* (DECC 2008) provides specific guidelines, principles and minimum design standards for good management practice in erosion and sediment control during the construction and operation of mines and quarries.

2.2.5 NSW Water Quality and River Flow Objectives

The *NSW Water Quality and River Flow Objectives* (DECCW 2006) are the agreed environmental values and long-term goals for each catchment in NSW. The objectives are intended to be considered in assessing and managing the potential impacts of activities on waterways.

The Project lies in the Hawkesbury-Nepean River catchment. There are no environmental objectives for the Hawkesbury-Nepean River, as, at the time of the objectives were approved, the Healthy Rivers Commission had completed a public enquiry and recommended water quality objectives for the catchment. These objectives were for nutrients, namely 0.035 mg/L for total phosphorus and 0.7 mg/L for total nitrogen. (NSW Government, 2001: Table 2, p. 22). These trigger levels are less stringent than the ANZG (2018) guideline levels for upland rivers (refer to Section 2.2.3).

3. Site description

3.1 Climate

A historical record of rainfall and evaporation data was obtained from the Scientific Information for Land Owners (SILO) database hosted by the Science Division of the Queensland Government's Department of Environment and Science. SILO point data consist of interpolated estimates based on historically observed data from Bureau of Meteorology (BOM) stations. For this assessment, SILO data was obtained for the grid point centred at -33.10N, 150.00E, which includes the Airly Mine surface facilities area.

Figure 3-1 presents the distribution of annual total rainfall and evaporation (Mortons Lake evaporation) from the SILO dataset between January 1889 and December 2018. Figure 3-1 also compares SILO rainfall to site-based rainfall recorded between 2011 and 2018.

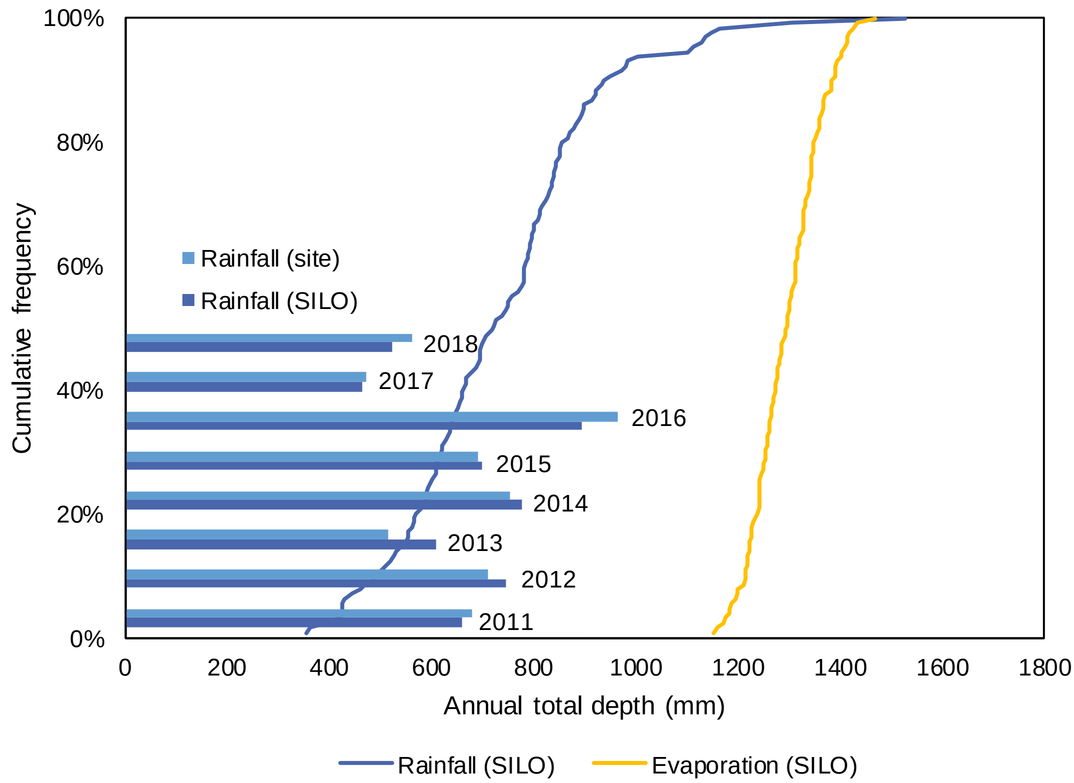


Figure 3-1 Annual rainfall and evaporation totals at Airly Mine

Figure 3-1 shows that annual rainfall totals have ranged from 347 mm (for 1982) to 1530 mm (for 1950), with a median of 721 mm and average of 731 mm. Annual evaporation totals have an average of 1296 mm, corresponding to an average annual moisture deficit (the difference between rainfall and evaporation) of 565 mm. The lower left corner of Figure 3-1 compares the annual rainfall totals observed at the site weather station against the SILO dataset. There is an adequate match between the site and SILO data (normalised root mean square error of 7%) indicating that the SILO dataset provides an adequate representation of the potential rainfall variability at the site. In recent years, both dry conditions (8th percentile in 2017) and wet conditions (91st percentile in 2016) have been experienced at the site.

Average monthly rainfall and evaporation totals were determined from the SILO dataset and are presented in Figure 3-2.

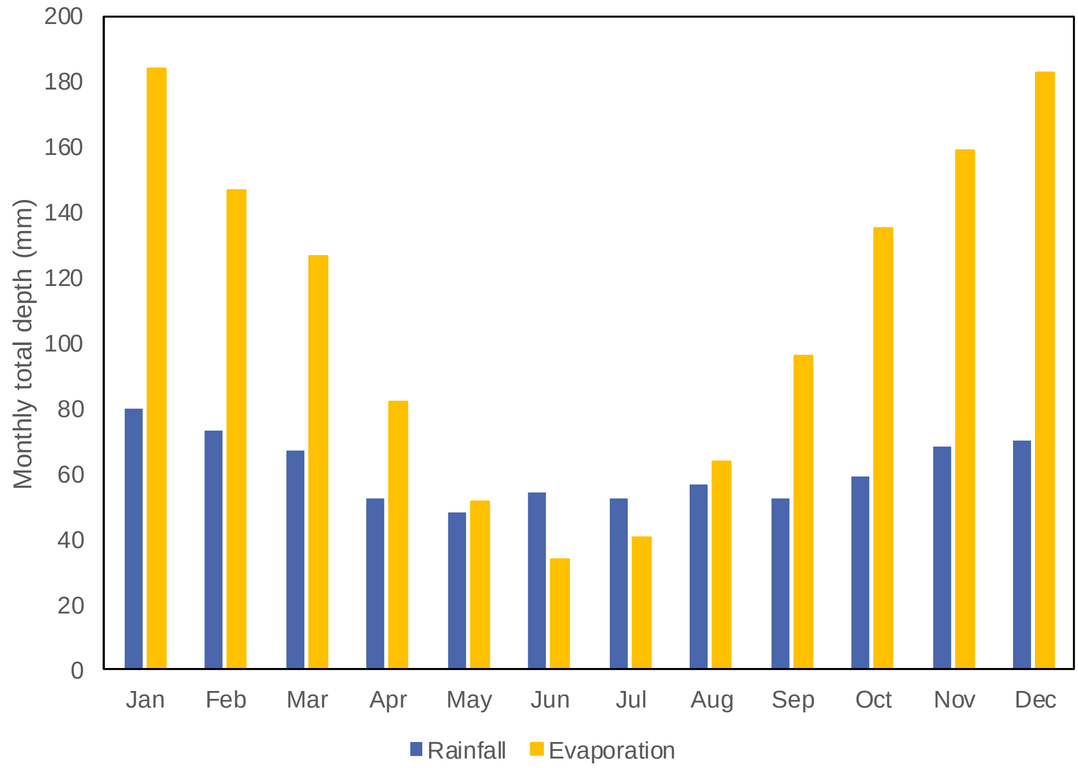


Figure 3-2 Average monthly rainfall and evaporation totals at Airly Mine

Figure 3-2 shows that evaporation varies seasonally, being higher in summer than in winter. There is also a similar, but less pronounced, seasonal variation in monthly rainfall totals. This seasonal variation is typical of the mild and cool temperature climate of the site.

3.2 Topography

Airly Mine is characterised by steep and rugged topography, as well as lower lying, undulating areas. The topography of the Project Application Area is dominated by Mount Airly to the west and Genowlan Mountain to the east. Site elevation varies from over 1000 m Australian Height Datum (AHD) to less than 750 m AHD in the south-eastern section of the site. The Airly Mine surface facilities area is located at the foot of Mount Airly at an elevation of about 780 m AHD.

3.3 Geology

Airly Mine is located within the southern part of the Western Coalfield of NSW, on the western edge of the Sydney Basin. The area is underlain by Triassic sandstone of the Narrabeen Group, which is underlain by the Illawarra Coal Measures.

The stratigraphy at Airly Mine is summarised in Table 3-1. This information has been sourced from the *Western Coalfield (south) Regional 1:100,000 Geology Map* (Yoo 1992) and exploration logs for Airly Mine. The outcrop geology in the vicinity of Airly Mine is shown in Table 3-1.

Table 3-1 Stratigraphic sequence

Period	Stratigraphy			Lithology
	Group	Subgroup	Formation	
Quaternary	Alluvium			Silt, clay, sand, gravel
Tertiary				Basalt, dolerite
Triassic	Narrabeen	Grose	Burra-Moko Head Sandstone	Quartz sandstone, red-brown claystone
			Caley Formation	Claystone, shale, quartz sandstone
Permian	Illawarra Coal Measures	Wallerawang	Middle River Coal Gap Sandstone	Coal, lithic sandstone, claystone
		Charbon	Glen Davis Formation Irondale Coal Long Swamp Formation	Sandstone, claystone, coal, mudstone
		Cullen Bullen	Lidsdale Seam Blackmans Flat Conglomerate Lithgow Seam Marrangaroo Formation	Coal, claystone, siltstone, mudstone, conglomerate
	Shoalhaven Group		Berry Siltstone	Siltstone, lithic sandstone conglomerate
Devonian	Metamorphic rocks			Quartzite, shale, sandstone, limestone, tuff

The Grose sandstone of the Triassic Narrabeen Group outcrops throughout the plateau and cliffs of Mount Airly and Genowlan Mountain, with small areas of Tertiary basalt outcrop at the higher elevations. The Triassic strata are up to 200 m thick.

The Permian Illawarra Coal Measures outcrop around the Triassic formations at lower elevations, including the zone between Mount Airly and Genowlan Mountain. The Lithgow Seam within the lower Illawarra Coal Measures is the target coal seam at Airly Mine. The seam outcrops completely within the site boundary and is therefore disconnected to the areas of occurrence of this seam located several kilometres to the south and north-west. The thickness of the Lithgow Seam ranges between 3 m and 4 m with an average thickness of 3.4 m.

The depth of cover above the Lithgow Seam ranges from less than 20 m in areas of outcrop and in the Gap Creek area, up to approximately 310 m. The seam dips gradually to the east at around 1 degree. The average thickness of the Permian overburden is 105 m (Golder Associates 2013).

Interbedded siltstone and sandstone of the older Shoalhaven Group outcrop across the surface facilities area and beyond the Airly Mine boundary. Metamorphic rocks also outcrop beyond the site in areas of lower elevation.

3.4 Hydrology

Airly Mine lies within the Capertee River catchment, which is part of the Greater Hawkesbury/Nepean catchment. The Capertee River flows in a south-east direction to its confluence with the Wolgan River to form the Colo River, which ultimately contributes to the Hawkesbury River and Broken Bay.

There are four major creek systems located within the development consent boundary, as shown in Figure 1-2:

- Airly-Coco Creek (which includes Dog Trap Creek)
- Emu Swamp Creek
- Gap-Genowlan Creek
- Torbane-Oaky Creek

The Airly Creek system drains the southern sector of the site and joins Coco Creek within the Gardens of Stone National Park approximately 10 km south-east of the surface facilities area. Coco Creek flows out of the Gardens of Stone National Park for approximately 20 km before joining the Capertee River.

Surface runoff from a small area of the north-east of the site drains to Emu Swamp Creek, which flows in a north-east direction and joins the Capertee River approximately 10 km downstream.

Surface runoff from the northern sections of the site drains into Gap Creek and Genowlan Creek. The two creeks, which are groundwater fed in parts, drain northwards approximately 2 km before converging into the greater Genowlan Creek. Genowlan Creek continues to drain in a north-east direction until its confluence with the Capertee River approximately 8 km downstream. The Gap-Genowlan Creek sub-catchment occupies the largest portion of the site, with 1558 ha draining to the creek system.

The north-west section of the site area is drained by the Torbane-Oaky Creek system. Torbane Creek joins Oaky Creek approximately 2 km downstream of the site.

All of the watercourses draining the Airly Mine development consent boundary are ephemeral. Generally, these watercourses flow for relatively brief periods following significant rainfall events. Flows within Airly Creek, Oaky Creek, Coco Creek and Genowlan Creek become perennial outside the development consent boundary.

4. Methodology

4.1 Potential impacts

The objective of this assessment is to identify and assess the significance of the potential impacts of the Project on the site water and salt balance at Airly Mine. The identification of potential impacts enables the development of measures to avoid or mitigate impacts. The following potential impacts to surface water systems as a result of the Project were identified:

- Changes to site water management
- Changes to the site water and salt balance

4.2 Water and salt balance

A water and salt balance assessment was undertaken of the water management system for Airly Mine, including inflows, outflows and net change in storage. A site water and salt balance was previously developed in GoldSim for the AMEP (GHD 2014), which is revised regularly to assist in the management and reporting of water use at the site. The changes to the site water and salt balance are described in Section 4.2.1 and are reflected in the existing conditions at the site in 2018 (described in Section 4.2.2).

Airly Mine does not currently operate at its approved production rate and not all approved activities are undertaken. For the purpose of the impact assessment, an approved conditions scenario (described in Section 4.2.3) was established and used as the basis of comparison to the proposed conditions under the Project (described in Section 4.2.4).

4.2.1 Background

A site water and salt balance model was developed in GoldSim for the EIS for the AMEP *Surface Water Impact Assessment* (GHD 2014). Since the time of the EIS, the site water and salt balance model has been updated to reflect:

- New site information, including dust suppression estimates, catchment and runoff model parameters. A summary of the changes to the current water and salt balance model compared to the model developed for the AMEP (GHD 2014) is provided in Appendix B.
- The revised groundwater inflows into the underground workings predicted by the recalibrated hydrogeological modelling for the both the approved 1.8 Mtpa and the proposed 3 Mtpa production rates (GHD 2019b).
- The degraded reliability and average flow rates from the production bore. The average flow rate under existing conditions has continually reduced and the production bore is considered unreliable under the approved and proposed conditions.
- The approved importation of up to 170 ML/year of water from Charbon Colliery by rail haulage to be unloaded at the Rail Loader Dam and transferred to the 35 ML Discharge Dam.

These updates to the site water and salt balance model are reflected in approved and proposed conditions in this assessment. Differences between the conditions are described in the following sections.

4.2.2 Existing conditions

Airly Mine does not currently operate at its full approved production rate and not all approved activities are undertaken. The existing conditions site water and salt balance reflects the actual conditions experience in 2018, including:

- Observed rainfall at Airly Mine.
- Production of 906 308 t of ROM coal.
- Workforce of 125 fulltime equivalent (FTE) personnel.
- The average flow rate from production bore has reduced throughout the year to below 0.8 L/s. A total of 39 ML was extracted from the production bore in 2018.
- The approved CPP and REA were not included as they have not yet been constructed.

4.2.3 Approved conditions

The approved conditions represent the baseline scenario where all approved activities are undertaken, using the updated water and salt balance model. This effectively simulates a “do nothing” scenario for Airly Mine and is used to provide a comparison to the proposed conditions.

The approved conditions site water and salt balance has assumed:

- The existing water management system and the approved operation of the CPP and REA. This includes the REA Dam at the toe of the REA and a planned LDP for potential discharges from the REA Dam (referred to as “planned REA LDP”).
- Approved maximum production rate of 1.8 Mtpa of ROM coal.
- Approved maximum workforce of 155 FTE personnel.
- Approved importation of up to 170 ML/year of water from Charbon Colliery by rail haulage to be unloaded at the Rail Loader Dam and transferred to the 35 ML Discharge Dam. This transfer was modelled to occur as required when the surface water storages were simulated to be less than 75% full. The transfer of water was limited to up to one train per work day, with up to 30 containers of 26,000 L capacity each able to be delivered to Airly Mine. The median EC of LDP4 (Charbon Colliery) discharge of 2320 µS/cm (GHD 2019a) was adopted as the modelled EC of the transfer from Charbon Colliery.

The CPP would require process water to operate, sourced from the existing water management system. Water for the CPP would be supplied by the 35 ML Discharge Dam via the Process Water Tank, with a water recycling system reducing the net demand of the CPP by returning approximately 80% of the water supplied to the 109 ML Dirty Water Dam.

The processing of ROM coal in the CPP is expected to produce approximately 20% waste reject material, consisting of both coarse and fine material that would be emplaced in the REA. Surface water runoff from the REA and contributing natural catchment would be collected by internal sediment collection storages and external sediment ponds before being recirculated in the surface water management system to the 109 ML Dirty Water Dam for reuse.

4.2.4 Proposed conditions

Proposed conditions reflect the changes proposed as part of the Project. Proposed conditions for the purpose of the site water balance modelling were similar to approved conditions, except for the increase in maximum production rate from 1.8 to 3 Mtpa ROM coal and increase in workforce from 155 FTE to 200 FTE personnel.

The approved CPP and REA are not in the current five year plan at Airly Mine, and therefore two proposed scenarios have been considered:

- Proposed conditions A: the approved CPP and REA are not constructed or operational.
- Proposed conditions B: the approved CPP and REA are constructed and operational.

The Project has the potential to require water at Airly Mine in excess of what is able to be reliably supplied from existing water sources. Therefore, a deficit is modelled to exist under proposed conditions when process water demand exceeds the available water supplies. The difference between water required (i.e. the outflows from the Process Water Tank) and the water available (i.e. the inflow to the Process Water Tank) was used to quantify the deficit for the site. For the purpose of the salt balance, the EC of water supplied from the Process Water Tank was assumed to be equal to the median observed EC of the 35 ML Discharge Dam (which supplies the Process Water Tank) and was adopted as representative of process water at Airly Mine.

4.2.5 Modelling methodology

The water management schematic for the water management system at Airly Mine is presented in Figure 4-1. The model represents the water and salt cycle as a series of elements, each containing pre-set rules and data, that are linked together to simulate the interaction of these elements within the water and salt cycle. The water and salt balance model was simulated over projected life of the mine, from existing conditions in 2018 until 2037, and selected outputs from the modelled system were statistically summarised.

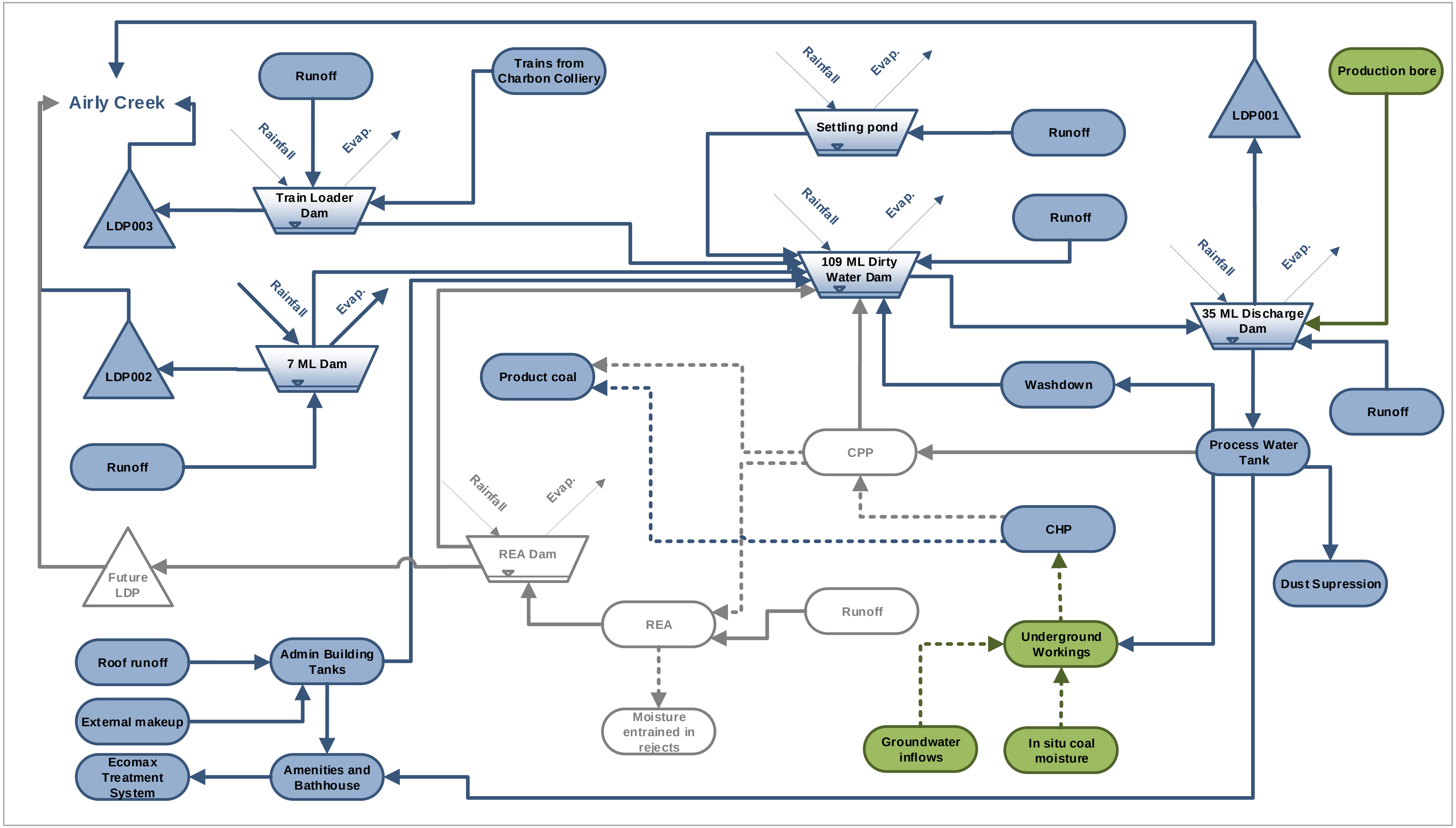
The salt balance model was developed as an extension of the water balance model, with expected concentrations of salt applied to water inflows into the system. Transfers of the resulting salt loads were modelled throughout the site. The mass and concentration of salt within particular storages was established such that a mass balance was achieved after allowing for salt discharged via extraction and overflows.

To assess the impact of rainfall on the site, modelling for the approved and proposed conditions was completed by using a historical time series of daily rainfall data extending over 130 years, from January 1889 to December 2018 (refer Section 3.1). A total of 130 simulations were applied, with each simulation modelling a different rainfall pattern from the record.

The results presented in this assessment include the average annual transfers between water management elements as well as the 10th percentile and 90th percentile values. The purpose of displaying the three results for each water transfer is to show the average transfer volume and an indication of the range of values expected due to possible variation in rainfall.

The 10th percentile represents the value at which 10% of the modelled outputs were less than this value. Similarly, the 90th percentile represents the value at which 90% of the modelled outputs were less than this value.

The 10th and 90th percentile results are not the same as the “dry” and “wet” year results presented in this assessment. The “dry” and “wet” year results are based on an equilibrium modelling approach with the driest and wettest rainfall year on record (347 mm in 1982 and 1530 mm in 1950 respectively; refer to Section 3.1) being repeated continuously as the simulated rainfall.



Legend

- Underground storage
- Underground process
- Surface storage
- Surface process
- Licensed discharge point
- Entrained moisture
- Surface water flow
- Groundwater flow
- Approved conditions

GHD

Centennial Airly Pty Ltd
Airly Mine Extension Project – Modification 3
Site water and salt balance assessment

Water management schematic

Project No. 2220276
Revision No. 0
Date 01/10/2019

FIGURE 4-1

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5. Existing environment

5.1 Water management

The water management system at Airly Mine is comprised of clean surface, dirty surface, amenities, waste and underground water elements. Sources of water at the site include:

- Direct rainfall onto storages
- Catchment runoff
- External water supply (for bathhouse and amenities)
- Groundwater inflows to the underground workings

The primary water demands are for underground mining operations, surface dust suppression, machinery washdown, fire-fighting storage and staff amenities.

The layout of the existing surface water management system at the surface facilities area is shown in Figure 5-1, including the catchment of the approved REA, based on the concept design. A schematic of the overall water cycle is provided in Figure 5-2.

5.1.1 Clean surface water management system

Surface water runoff from areas where there is no coal storage, transportation, handling or processing or any disturbance is considered to be clean water, as it is unlikely to be contaminated with coal fines or sediment. Runoff is diverted around dirty water and coal-contact catchments to avoid mixing. The clean surface water management system diverts runoff from natural (undisturbed) and impervious catchments, such as areas of vegetation, sealed roads and sealed car parks.

The 35 ML Discharge Dam is the main clean water storage at Airly Mine. The dam receives surface water runoff from the northern perimeter clean water drainage system and piped transfers and overflows from the 109 ML Dirty Water Dam. Water is supplied to the Process Water Tank from the 35 ML Discharge Dam. Overflows from the dam discharge through LDP001 to Airly Creek.

5.1.2 Dirty surface water management system

Dirty water is runoff from disturbed areas and areas likely to contain suspended sediment, oils, grease and hydrocarbons. This typically includes workshop and fuel storage areas. Coal-contact water is runoff from catchments where coal storage, transportation, handling or processing occurs and is managed within the dirty water management system.

The dirty water management structures at Airly Mine form the basis of sediment control at the site. Dirty water runoff (coal-contact and sediment-laden water) is managed by a number of dirty water storages which enable suspended solids to settle out of the water column. Small primary dams trap coarse sediment, which overflow into the 109 ML Dirty Water Dam where fine sediments settle. The dirty water management structures are regularly de-silted to maximise available storage capacity.

Sediment-laden water from the eastern hardstand area is directed via diversion bunds to an active filter pond, where it is managed and released to the 109 ML Dirty Water Dam if capacity is available.

Settling Pond

The Settling Pond receives surface water runoff from contributing catchments east of the surface facilities area. Overflows from the Settling Pond are directed to the 109 ML Dirty Water Dam.

7 ML Dam

The 7 ML Dam receives surface water runoff from the conveyor and stockpile areas. The water level in the dam is maintained low by pumping water to the 109 ML Dirty Water Dam. During high rainfall events, overflows from the 7 ML Dam discharge through LDP002 into Airly Creek.

Train Loader Dam

The Train Loader Dam receives surface water runoff from the train loading area and is supplied with water from Charbon Colliery by rail haulage. The water level in the dam is maintained low by pumping water to the 109 ML Dirty Water Dam. During high rainfall events, overflows from the Train Loader Dam discharge through LDP003 into Airly Creek.

109 ML Dirty Water Dam

The 109 ML Dirty Water Dam receives surface water runoff from the eastern hardstand area, including the mine entrance area and emergency stockpile, and from the northern perimeter clean water drainage system. Overflows from the Settling Pond and Administration Buildings Tanks, water pumped from the 7 ML Dam and Train Loader Dam and extractions from the production bore are also directed into the 109 ML Dirty Water Dam.

Water is supplied from the 109 ML Dirty Water Dam to the 35 ML Discharge Dam via a pontoon mounted pipe, with water drawn from the surface of the dam. Overflows are also directed to the 35 ML Discharge Dam.

5.1.3 Underground water management system

The underground water management system at Airly Mine consists of the underground mine workings and groundwater extraction through a production bore. Mining operations are supplied water by the Process Water Tank (part of the dirty surface water management system).

Groundwater inflows

As discussed in Section 1.3, the seepage of groundwater into the underground workings has been reported by Centennial Airly to be low (not measurable) and not sufficient to require regular mine dewatering. Monitoring data indicates that all groundwater inflows and additional process water used in underground operations is entrained in ROM coal. As a result, no groundwater inflows are available to be reclaimed and reused as process water.

Production bore

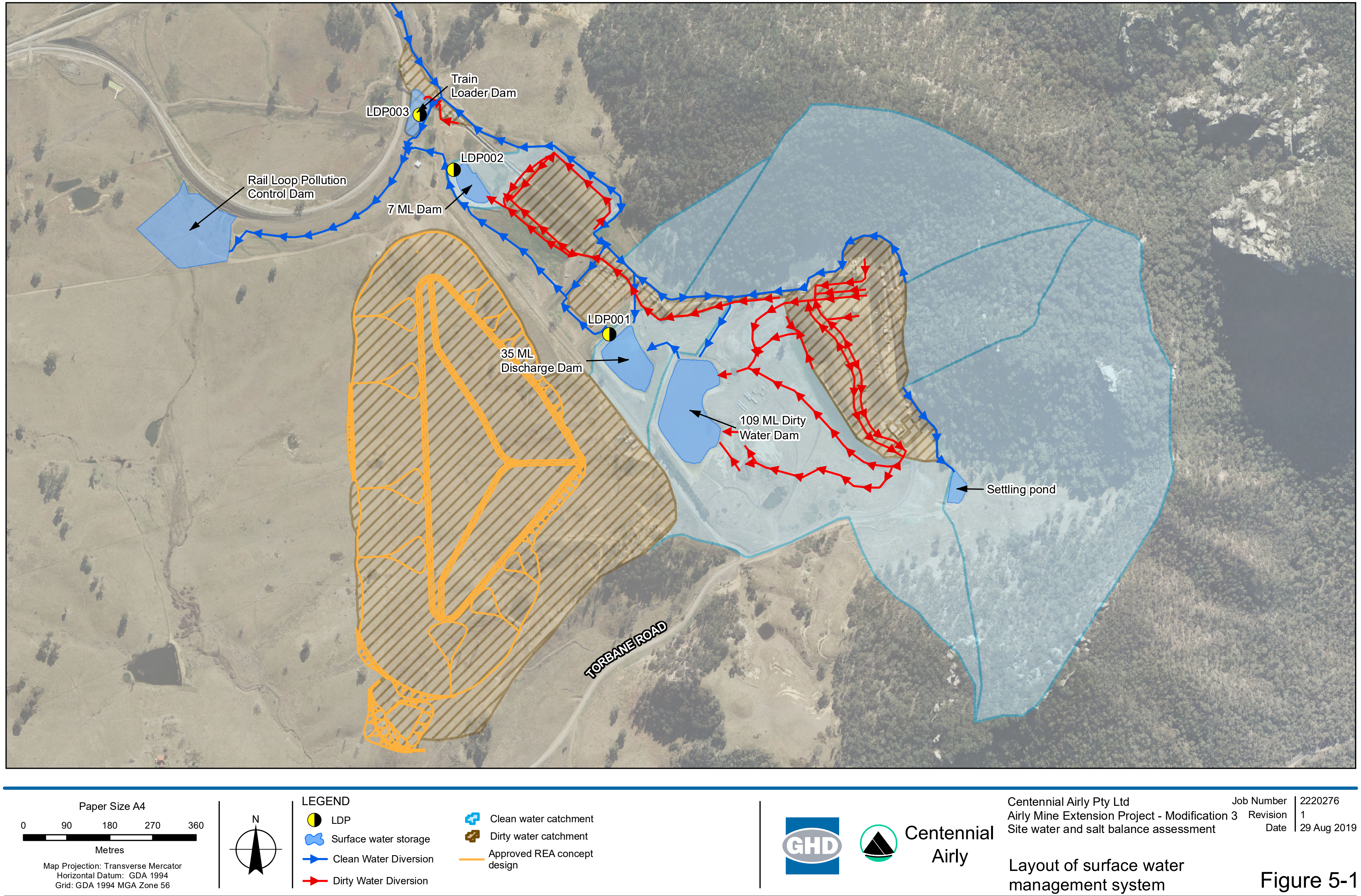
Airly Mine was granted approval for groundwater extraction through the production bore (WAL 24386 and water supply works approval 10WA112537) in 2011. As discussed in Section 1.3 below average rainfall conditions at Airly Mine have increased reliance on the production bore to supplement process water supply. Extraction from the production bore, other than for monitoring purposes, commenced in 2017, with approximately 21 ML extracted during the latter part of 2017. In 2018, the maximum actual extraction rate achieved from the production bore has been limited to 2 L/s, with a total of 39 ML extracted through the year, however the average flow rate has reduced to below 0.8 L/s in late 2018, and continues to decrease over time. The actual extraction rates achieved are considerably less than the sustainable yield of the bore calculated from the pumping tests undertaken at the time of installation, which are the basis for the water supply works approval limit of 5 L/s and the WAL of 158 ML/year.

Investigations to assess the reliability of the production bore as a supplementary source of process water suggest that it is unlikely that flow rates will increase and be sustained for the life of mine operations (GHD 2019a). Given the declining trend in yield, the Shoalhaven Group groundwater source is not currently considered to be a reliable source of water.

The water quality of the production bore is poor compared to the surface water at Airly Mine, with higher EC (median of 4920 µS/cm) and elevated dissolved nickel concentrations (median of 0.28 mg/L). Prolonged use of the production bore is expected to result in an increase in EC and dissolved nickel concentrations in the 35 ML Discharge Dam at Airly Mine, as has begun to be observed during 2018 (GHD 2019a).

5.1.4 Amenities and wastewater management system

As Airly Mine is not connected to a municipal water supply, drinking water is supplied by bottled water. Water for amenities is harvested from the rooftops of the administration and facilities buildings and supplemented by trucked water. Wastewater from the administration buildings and bathhouse is directed to the Ecomax effluent treatment system for disposal via soil infiltration. The existing capacity of this effluent treatment system is for 150 personnel.



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Centennial Airly

Layout of surface water management system

Figure 5-1

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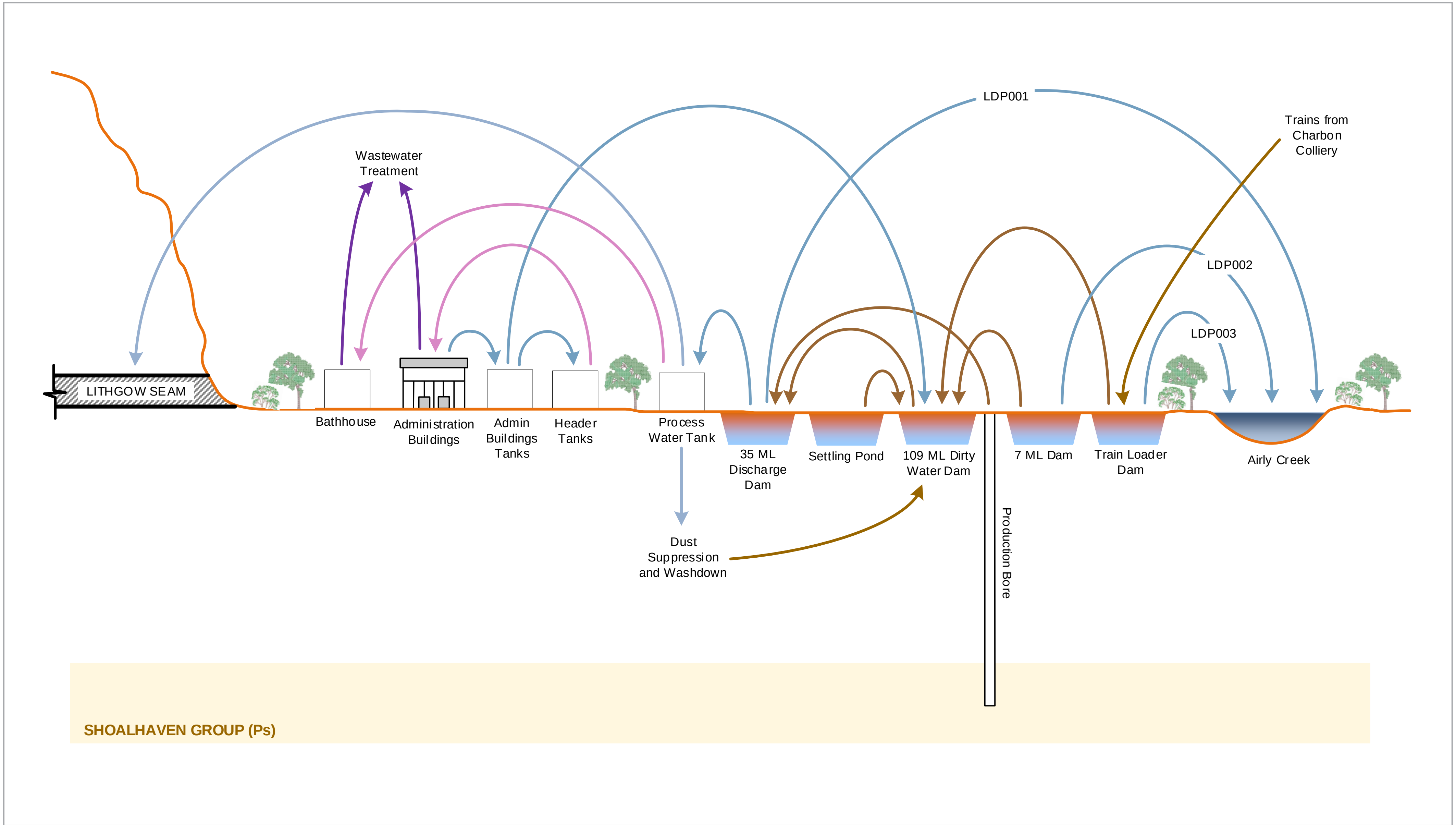
Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

Data source: LPI: DTDB 2012; Centennial: Aerial Imagery, Infrastructure, 2013. Created by: fmackay, tmorton, kpsroba



Legend

- Clean Water
- Underground Water
- Dirty Water
- Wastewater
- Amenities Water

Centennial Airly Pty Ltd
Airly Mine Extension Project – Modification 3
Site water and salt balance assessment

Water cycle schematic
Approved conditions

Project No. **2220276**
Revision No. **0**
Date **01/10/2019**

FIGURE 5-2

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5.2 Water and salt balance – existing conditions

5.2.1 Water balance

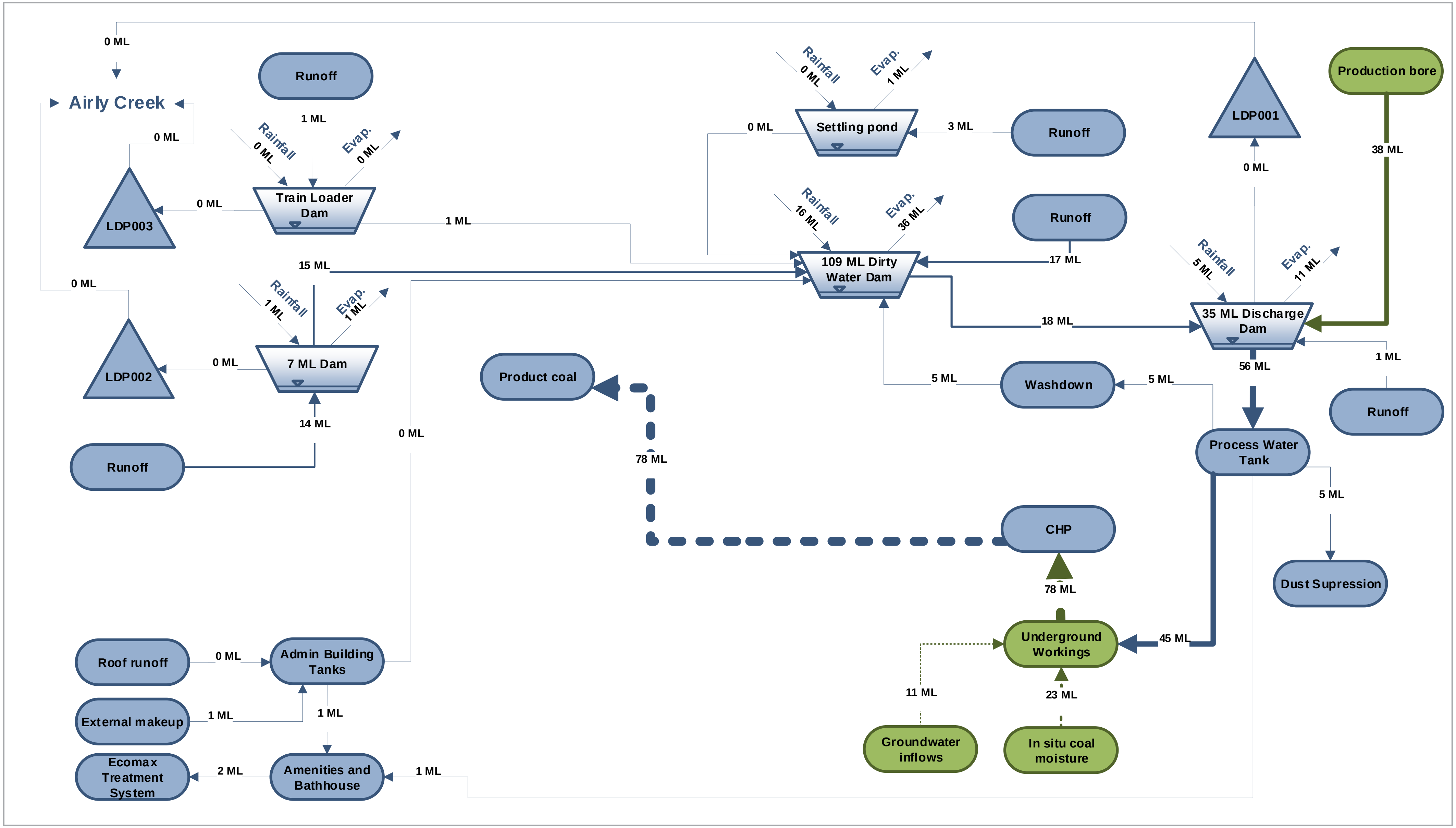
The water and salt balance at Airly Mine was simulated based on the observed data in 2018 (refer to Section 4.2.2). The annual water balance for existing conditions during 2018 is shown in Figure 5-3 and summarised in Table 5-1. The results shown are modelled results (rounded to 1 ML/year), based on the available site observations and modelled estimates where flows could not be directly measured.

Table 5-1 Annual water balance – existing conditions (2018)

	Volume (ML/year)
INPUTS	
Direct rainfall onto storages and catchment runoff	57
External potable water supply	1
Groundwater inflows into underground workings	10
Extraction from production bore	38
In situ coal moisture	23
TOTAL INPUTS	**129**
OUTPUTS	
Evaporation	49
Dust suppression	5
Sewage to Ecomax effluent treatment system	2
Discharge through LDP001	0
Discharge through LDP002	0
Discharge through LDP003	0
Product coal moisture	78
TOTAL OUTPUTS	**134**
CHANGE IN STORAGE	
Surface water storages	-5
Underground workings	0
TOTAL CHANGE IN STORAGE	**-5**
BALANCE	
Inputs – outputs – change in storage	0

Table 5-1 shows that during 2018, direct rainfall onto storages and catchment runoff was the largest input at Airly Mine while product coal moisture was the largest output. Figure 5-3 shows that product coal moisture includes groundwater inflows and in situ coal moisture that reported as ROM coal moisture and cannot be recovered. The balance of product coal moisture was from underground mining. This water was sourced from the production bore, direct rainfall and catchment runoff, after allowing for evaporation losses and dust suppression usage. Some water was lost as sewage, which includes external makeup to the administration building tanks.

Table 5-1 shows that during 2018, water storage volumes at Airly Mine fell by about 5 ML, despite extractions from the production bore being at the highest achievable rates throughout the year (due to rounding, modelled extractions were about 1% lower than observed). This drop in storage volumes reflects the below average rainfall, lower than predicted groundwater inflows and degrading reliability of the production bore described in Section 1.3.



Legend

Underground storage	Surface process	Surface water flow
Underground process	Licensed discharge point	Groundwater flow
Surface storage	Entrained moisture	X (X, X) Mean (10th percentile, 90th percentile)

GHD

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Airly Mine Extension Project – Modification 3
Site water and salt balance assessment

Water management schematic
Annual water transfers
Existing conditions (2018)

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Date 02/10/2019

FIGURE 5-3

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5.2.2 Salt balance

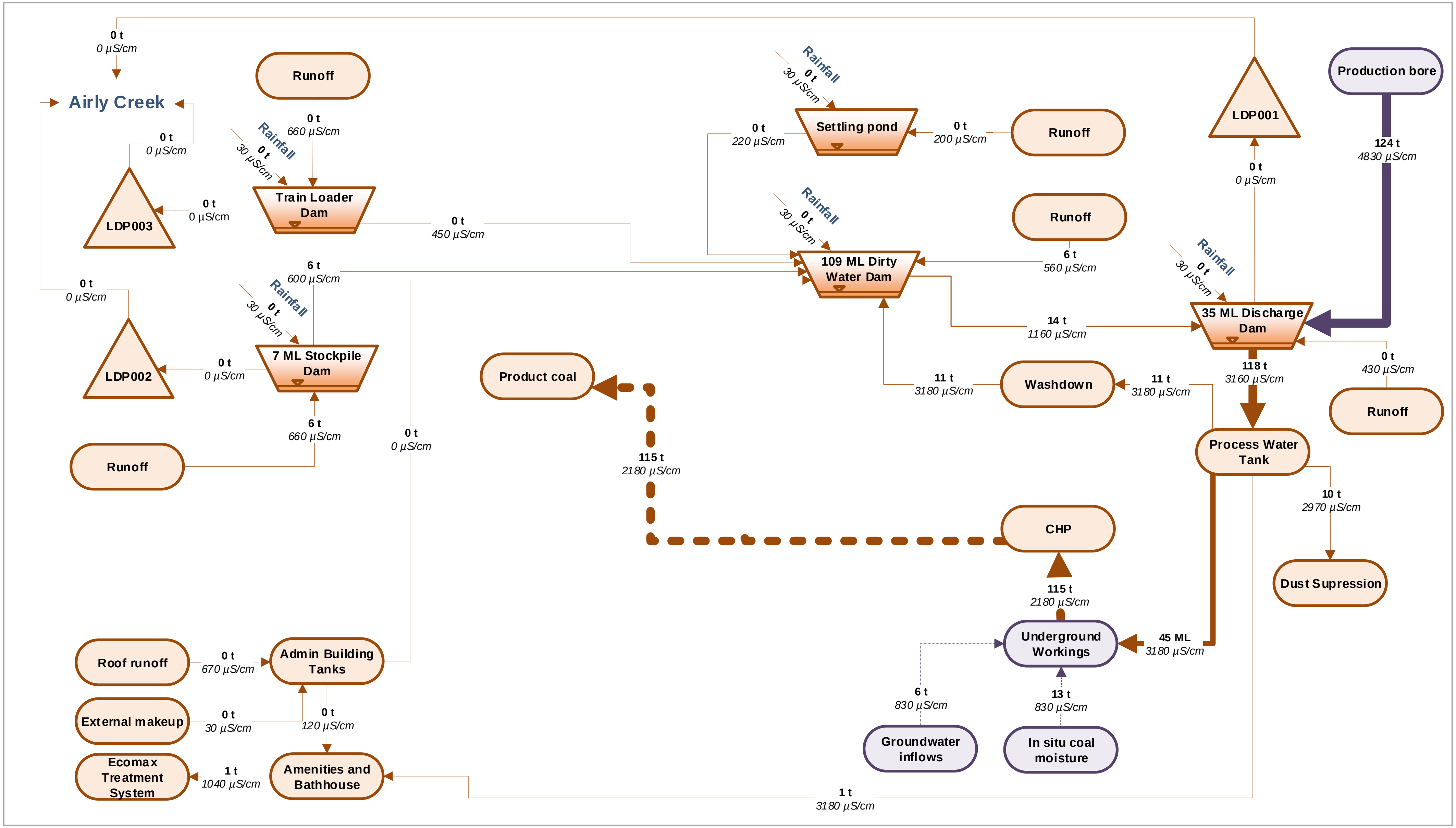
The annual salt balance for existing conditions during 2018 is shown in Figure 5-4 and summarised in Table 5-2. The results shown are modelled results (rounded to 1 tonne/year), based on the available site observations and modelled estimates where flows could not be directly measured.

Table 5-2 Annual salt balance – existing conditions (2018)

	Mass (tonne/year)
INPUTS	
Direct rainfall onto storages and catchment runoff	14
External water supply	0
Groundwater inflows into underground workings	5
Extraction from production bore	124
In situ coal moisture	13
TOTAL INPUTS	**156**
OUTPUTS	
Evaporation	0
Dust suppression	10
Sewage to Ecomax effluent treatment system	1
Discharge through LDP001	0
Discharge through LDP002	0
Discharge through LDP003	0
Product coal moisture	114
TOTAL OUTPUTS	**125**
CHANGE IN STORAGE	
Surface water storages	31
Underground workings	0
TOTAL CHANGE IN STORAGE	**31**
BALANCE	
Inputs – outputs – change in storage	0

Table 5-2 shows that during 2018, extraction from the production bore was the largest input of salt at Airly Mine and product coal moisture the largest output. Figure 5-4 shows that the salt in product coal moisture includes salt in groundwater inflows and in situ coal moisture that report in ROM coal moisture. The balance of salt in product coal moisture was from the production bore, direct rainfall and catchment runoff, after allowing for dust suppression usage. Relatively minor amounts were lost as sewage, which includes external makeup to the administration building tanks.

Table 5-2 shows that, overall during 2018, the salt balance estimates that salt in water storages at Airly Mine increased by about 30 tonne. This is largely attributable to the below average rainfall conditions and the use of the production bore. This increasing trend in salt in storages is reflected in the trends in water quality observed at the site (GHD 2019a).



Legend

Underground storage	Surface process	Surface water flow
Underground process	Licensed discharge point	Groundwater flow
Surface storage	Entrained moisture	X (X, X) XX — Mean (10th percentile, 90th percentile) Mean EC

Centennial Airly Pty Ltd
Airly Mine Extension Project – Modification 3
Site water and salt balance assessment

Water management schematic
Annual salt transfers
Existing conditions (2018)

Project No. 2220276
Revision No. A
Date 13/06/2019

FIGURE 5-4

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5.3 Water and salt balance – approved conditions

The water and salt balance model (refer to Section 4.2) was used to estimate the annual transfers between the water cycle components under approved conditions. As discussed in Section 4.2.3, the approved conditions modelling assumed production at the maximum approved rate of 1.8 Mtpa of ROM coal and construction of the approved CPP and REA. The approved conditions modelling was used to quantify the simulated deficit in process water at Airly Mine.

The results presented are based on the predicted site conditions in 2030. This year was chosen as it is when groundwater inflows into the underground workings are predicted to peak.

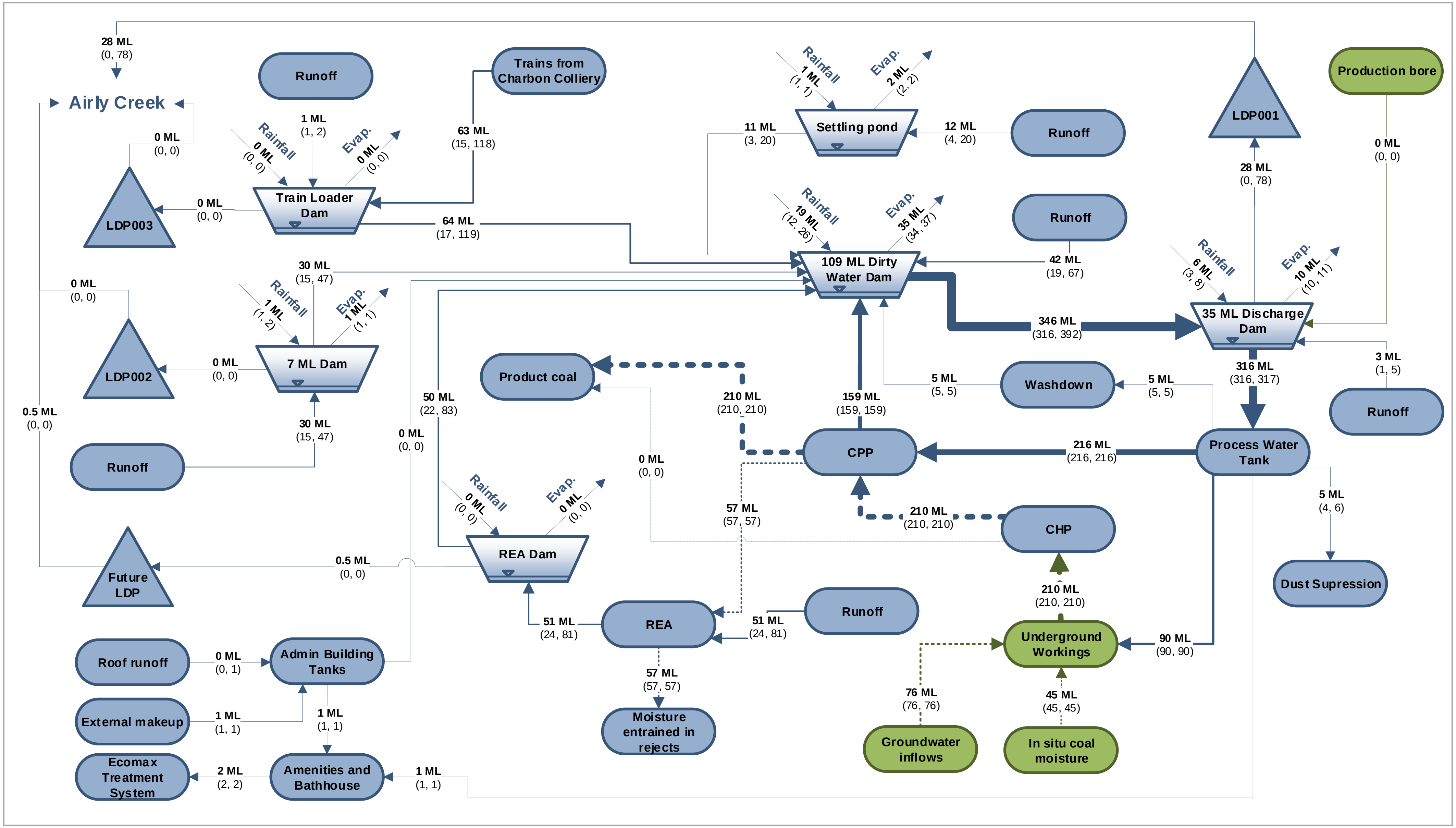
5.3.1 Water balance

A summary of the annual water balance results is provided in Figure 5-5 and Table 5-3. Results are rounded to the nearest 1 ML/year, except for discharges via the planned REA LDP, for consistency with previous assessments (GHD 2019a).

Table 5-3 Annual water balance – approved conditions (2030)

Water management element	Approved conditions (ML/year)		
	Average (mean)	"Dry" year	"Wet" year
Direct rainfall onto storages and catchment runoff	165	34	724
External potable water supply	1	1	0
Groundwater inflows into underground workings	76	76	76
Extraction from production bore	0	0	0
In situ coal moisture	45	45	45
Transfer from Charbon Colliery	63	168	0
TOTAL INPUTS	**351**	**324**	**845**
Evaporation	49	49	54
Dust suppression	5	6	4
Sewage to Ecomax effluent treatment system	2	2	2
Discharge through LDP001	28	0	517
Discharge through LDP002	0	0	0
Discharge through LDP003	0	0	0
Discharge through planned REA LDP	0.5	0	0
Product coal moisture	210	210	210
Moisture retained in rejects	57	57	57
TOTAL OUTPUTS	**351**	**324**	**845**
Surface water storages	0	0	0
Underground water storages	0	0	0
TOTAL CHANGE IN STORAGE	**0**	**0**	**0**
Inputs – outputs – change in storage	0	0	0

Table 5-3 shows that, for the approved conditions, Airly Mine will require 63 ML/year, on average, and 168 ML/year for the "dry" year, from Charbon Colliery to maintain a sufficient supply of water for the approved production and activities (including the approved CPP and REA).



Legend

Underground storage	Surface process	Surface water flow
Underground process	Licensed discharge point	Groundwater flow
Surface storage	Entrained moisture	X (X, X) — Mean (10th percentile, 90th percentile)

GHD

Centennial Airly Pty Ltd
Airly Mine Extension Project – Modification 3
Site water and salt balance assessment

Water management schematic
Annual water transfers
Approved conditions (2030)

Project No. 2220276
Revision No. 0
Date 01/10/2019

FIGURE 5-5

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Direct rainfall onto storages and catchment runoff

Table 5-3 shows that, on average, the largest source of water into the Airly Mine water management system was predicted to be direct rainfall and catchment runoff. Under the “dry” year and “wet” scenarios, rainfall and runoff are substantially lower and higher respectively.

External potable water supply and sewage to Ecomax treatment system

In the “wet” year, roof runoff collected is forecast to be sufficient to reduce the requirement for external potable water makeup. The sewage volumes are expected to be unchanged with rainfall conditions.

Groundwater inflows into underground workings

Groundwater inflows are expected to be unchanged with rainfall conditions.

Extraction from production bore

As discussed in Section 1.3, the production bore is not currently considered a reliable source of water and was not modelled to supply process water to Airly Mine for the approved conditions.

Coal moisture

Water associated with the product coal moisture was forecast to be the largest output from the site, on average. Coal moisture fluxes are expected to be insensitive to rainfall conditions.

Evaporation

Evaporation is expected to be slightly higher in the “wet” year, as the surface water storages are expected to be slightly fuller and have a generally larger open water surface area.

Dust suppression

Dust suppression was modelled under the approved conditions to demand 5 ML/year. Dust suppression is expected to be higher in “dry” years and lower in “wet” years, reflecting the difference in the frequency of rain days.

Discharge

Under approved conditions, discharges via LDP001 are only expected due to rare rainfall events. Discharges via LDP001 are expected to higher in the “wet” year and no discharges are predicted in the “dry” year. No discharges through LDP002 or LDP003 are simulated to occur under the approved conditions.

The REA Dam was designed to capture the 1% annual exceedance probability, 72 hour rainfall event (GHD 2019a). Therefore, discharges through the planned REA LDP are expected to occur only as a result of rainfall that exceeds this criteria. One overflow from the REA Dam of approximately 31 ML was modelled to occur in response to a large rainfall event in the historical rainfall dataset, which recorded over 270 mm over five consecutive days in March 1926. This discharge event is reflected in the 0.5 ML/year discharge on average for the approved conditions. No discharges from the REA Dam were predicted to occur for the “wet” year, as these results were based on the wettest rainfall year on record (1530 mm in 1950; refer to Section 3.1), which did not record any rainfall events over the design criteria for the REA Dam.

Figure 5-6 presents the percentiles of the daily flow rates predicted to discharge through LDP001 under approved conditions for all 130 historical rainfall patterns modelled. For clarity, the results are shown with a logarithmic vertical axis and therefore values of 0 ML/day are not plotted. The horizontal axis shows the proportion of days that a given off-site discharge volume was simulated not to occur, for example 99% daily percentile corresponds to only discharges occurring on 1% of days.

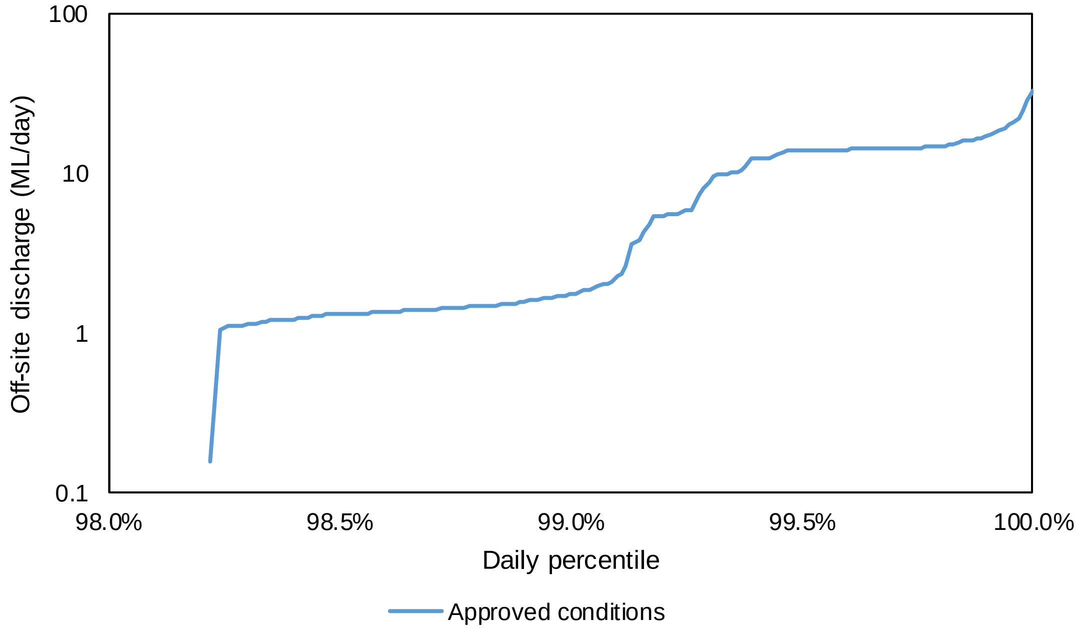
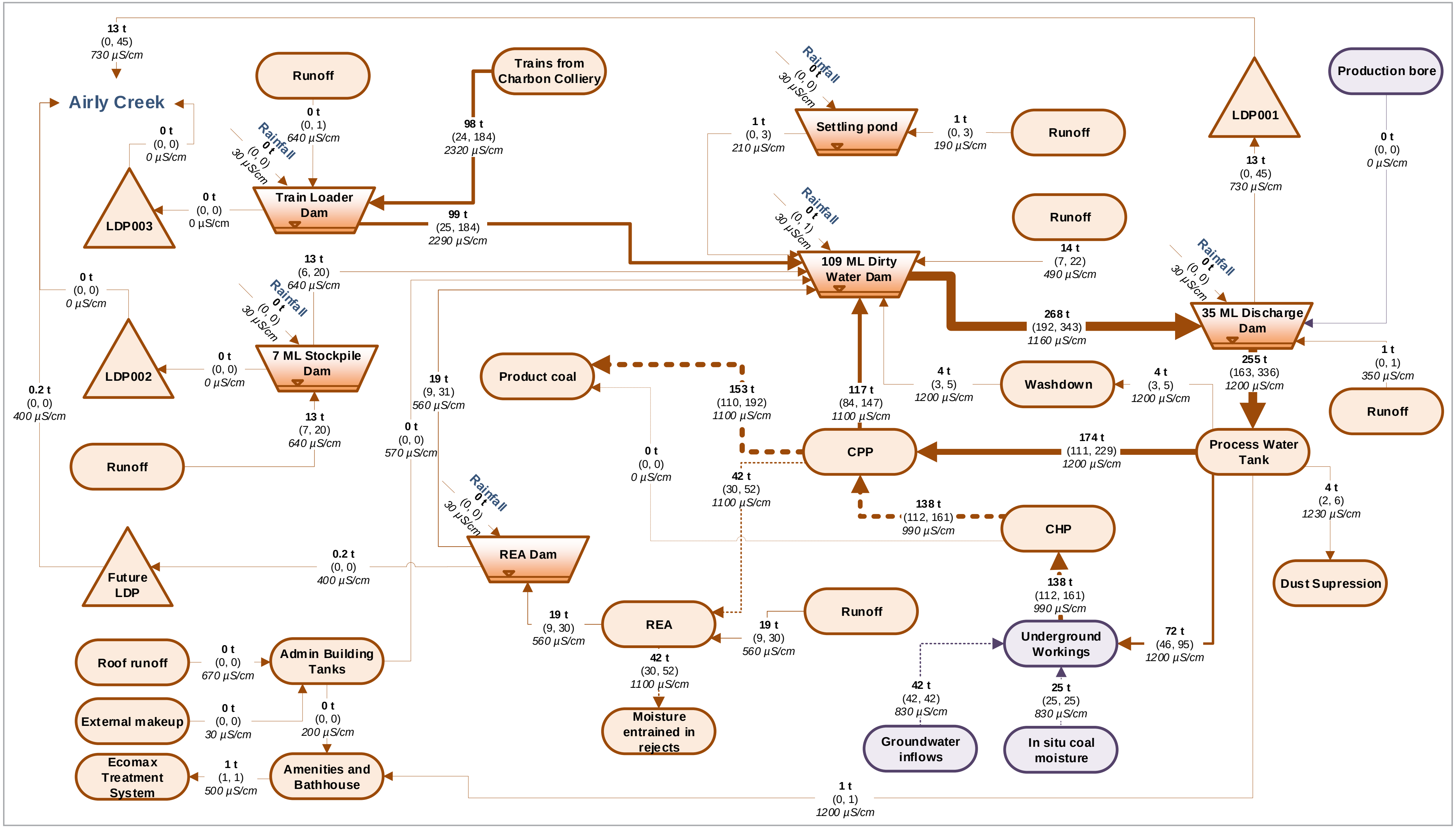


Figure 5-6 Predicted daily LDP001 discharges – approved conditions

Discharges off-site through LDP001 to Airly Creek are expected to occur only due to rare rainfall events. All discharges modelled under approved conditions were predicted to occur as a result of rainfall events exceeding 44 mm over five days, which is the rainfall depth for a 95th percentile, five day rainfall event design criteria for the 35 ML Discharge Dam (refer Section 2.1.2). Discharges were predicted to occur on less than 2% of days modelled, with the maximum daily discharge estimated to be about 30 ML/day.

5.3.2 Salt balance

As discussed in Section 4.2, the salt balance model was developed as an extension of the water balance model with expected concentrations of salt applied to water inflows into the system. From the results shown in Figure 5-7, inputs and outputs for the salt balance under the approved conditions in 2030 are summarised in Table 5-4. Results are rounded to the nearest 1 tonne/year, except for discharges via the planned REA LDP, for consistency with previous assessments (GHD 2019a).



Legend

- Underground storage
- Underground process
- Surface storage
- Surface process
- Licensed discharge point
- Entrained moisture
- Surface water flow
- Groundwater flow
- X: Mean; (X, X): (10th percentile, 90th percentile); XX: Mean EC

Centennial Airly Pty Ltd
Airly Mine Extension Project – Modification 3
Site water and salt balance assessment

Water management schematic
Annual salt transfers
Approved conditions (2030)

Project No. 2220276
Revision No. 0
Date 01/10/2019

FIGURE 5-7

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Table 5-4 Annual salt balance - approved conditions (2030)

Water management element	Approved conditions (tonne/year)		
	Average (mean)	"Dry" year	"Wet" year
Direct rainfall onto storages and catchment runoff	49	10	179
External potable water supply	0	0	0
Groundwater inflows into underground workings	42	42	42
Extraction from production bore	0	0	0
In situ coal moisture	25	25	25
Transfer from Charbon Colliery	98	260	0
TOTAL INPUTS	**213**	**336**	**245**
Evaporation	0	0	0
Dust suppression	4	9	1
Sewage to Ecomax effluent treatment system	1	1	1
Discharge through LDP001	13	0	147
Discharge through LDP002	0	0	0
Discharge through LDP003	0	0	0
Discharge through planned REA LDP	0.2	0	0
Product coal moisture	154	254	76
Moisture retained in rejects	42	71	21
TOTAL OUTPUTS	**213**	**335**	**245**
Surface water storages	0	0	0
Underground water storages	0	0	0
TOTAL CHANGE IN STORAGE	**0**	**0**	**0**
Inputs – outputs – change in storage	0	0	0

Table 5-4 shows that the sources and sinks for the salt balance at Airly Mine are broadly similar to the water balance shown in Table 5-3.

Direct rainfall onto storages and catchment runoff

On average, a major source of salt into the water management system for the approved conditions is direct rainfall onto storages and catchment runoff. This is lower and higher in the "dry" year and "wet" year case respectively, in proportion with rainfall.

External potable water supply and sewage to Ecomax treatment system

In all cases, the salt in external potable water supply is less than 0.5 tonne/year and relatively minor. The salt in sewage was insensitive to rainfall conditions.

Groundwater inflows into underground workings

The salt associated with groundwater inflows is the second largest input into the water management system, and is independent of rainfall conditions.

Extraction from production bore

In the approved conditions, the production bore is not considered a reliable source of water and therefore no inputs to the water management system are modelled. Therefore, the production bore does not contribute any salt to the site salt balance under the approved conditions.

Coal moisture

Salt associated with in situ coal moisture is expected to be independent of rainfall. Salt associated with the product coal moisture was forecast to be the largest output from the site. Salt entrained in product coal and rejects moisture are expected to be higher for the “dry” year due to less dilution by rainfall and catchment runoff, and lower in the “wet” year, due to greater dilution.

Evaporation

In all cases, no salt was modelled to be lost via evaporation.

Dust suppression

Salt lost via dust suppression was relatively minor. In the “dry” year, the mass lost was slightly higher, due to less dilution by rainfall and catchment runoff, and slightly lower in the “wet” year, due to greater dilution.

Discharge

Some salt is expected to be associated with average discharges via LDP001. In the “wet” year, the mass of salt discharged is higher than the average, however this is less than proportional to difference in water flows shown in Table 5-3, due to dilution within the water management system. No discharges were simulated in the “dry” year.

In all cases, no discharges were simulated via LDP002 or LDP003. The mass of salt discharged via the planned REA LDP from the REA Dam was about 0.2 tonne/year on average under approved conditions.

Figure 5-8 presents the percentiles of the EC corresponding to the daily volume of water predicted to be discharged through LDP001 into Airly Creek under approved conditions (as shown in Figure 5-6). EC was modelled to range from approximately 300 µS/cm up to a maximum of about 1600 µS/cm.

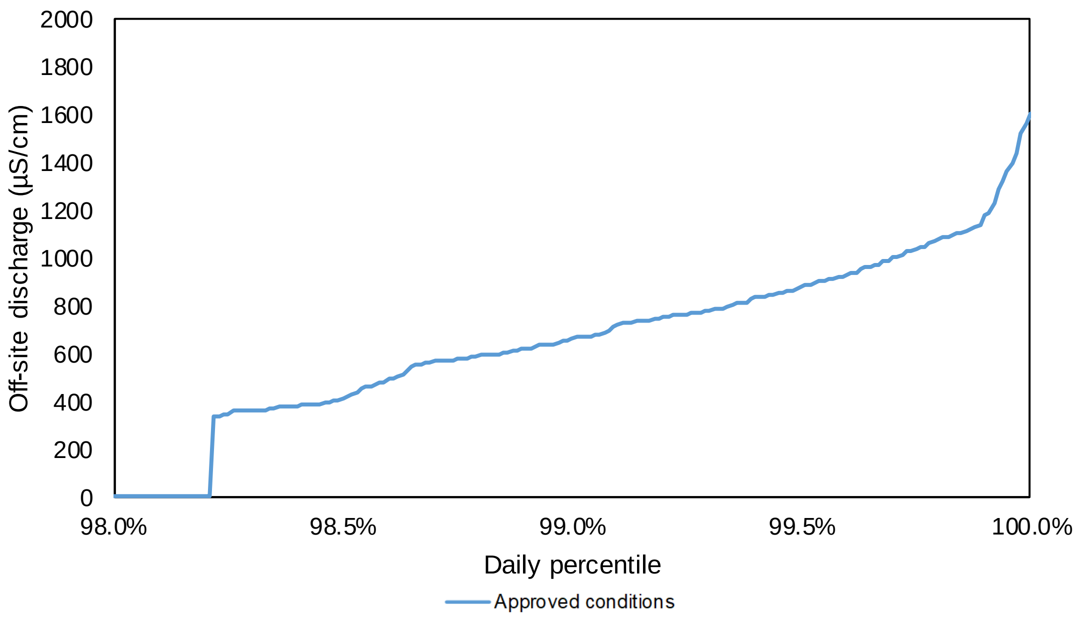


Figure 5-8 Predicted electrical conductivity of daily LDP001 discharges – approved conditions

6. Impact assessment

6.1 Water management system

As part of the Project, the production rate and workforce at Airly Mine is proposed to be increased. This includes an increase in the maximum production rate from 1.8 to 3 Mtpa ROM coal and in workforce from 155 FTE to 200 FTE personnel. No change to the existing mining infrastructure is proposed, however the ECOMAX effluent treatment system will be upgraded to accommodate the 200 FTE personnel when its existing capacity of 150 FTE personnel is exceeded.

6.2 Water and salt balance

The water and salt balance model (refer to Section 4.2) was used to estimate the annual transfers between the water cycle components under the proposed conditions.

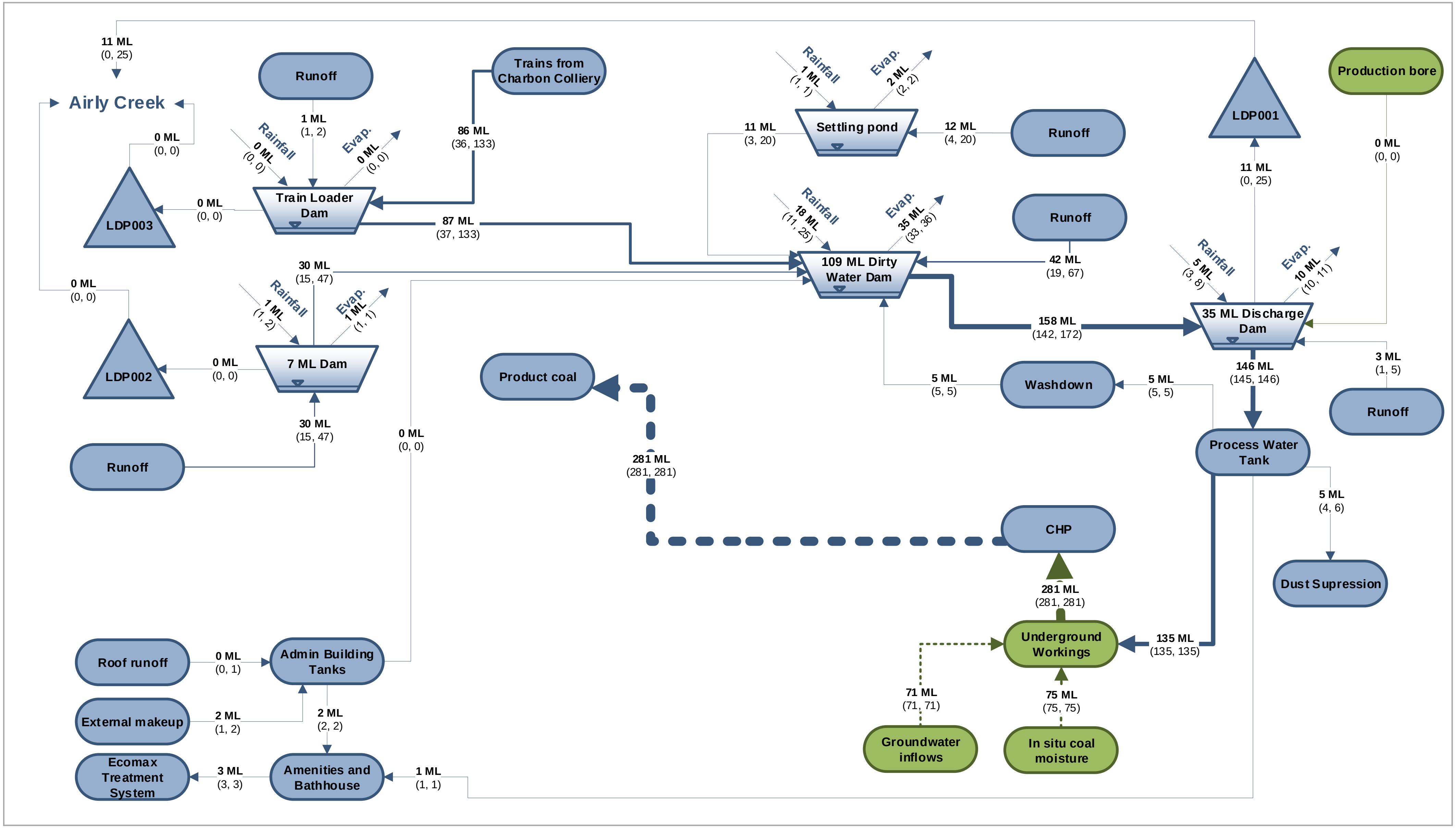
As described in Section 4.2.4, the construction and the operation of the approved CPP and REA are not in the current five year plan at Airly Mine, and therefore two proposed scenarios have been considered:

- Proposed conditions A: the approved CPP and REA are not constructed or operational.
- Proposed conditions B: the approved CPP and REA are constructed and operational.

The results presented are based on the predicted site conditions in 2030 for approved conditions and 2027 for proposed conditions. These years represent the peaks, respectively, in predicted groundwater inflows into the underground workings for the approved and proposed conditions.

6.2.1 Water balance

The forecast annual water transfers for proposed conditions are presented in Figure 6-1 and Figure 6-2, which may be compared to the approved conditions results shown in Figure 5-5. The average annual inputs and outputs for the water balance for the approved and proposed conditions are summarised in Table 6-1. Results are rounded to the nearest 1 ML/year, except for discharges via the planned REA LDP, for consistency with previous assessments (GHD 2019a).



Legend

Underground storage	Surface process	Surface water flow
Underground process	Licensed discharge point	Groundwater flow
Surface storage	Entrained moisture	X (X, X) Mean (10th percentile, 90th percentile)

GHD

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Airly Mine Extension Project – Modification 3
Site water and salt balance assessment

Water management schematic
Annual water transfers
Proposed conditions A (2030)

Project No. 2220276
Revision No. 0
Date 01/10/2019

FIGURE 6-1

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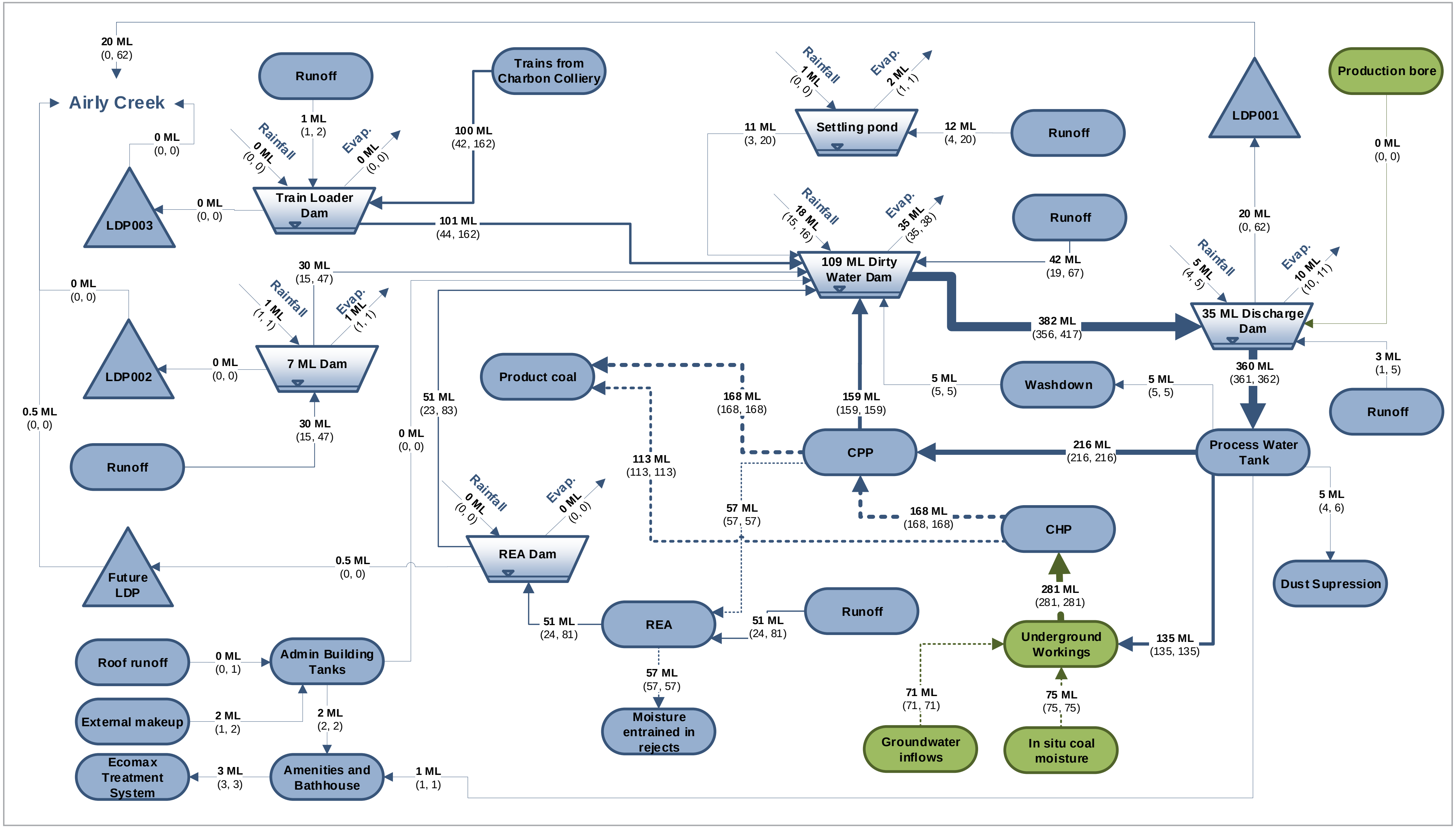

Legend

- Underground storage
- Underground process
- Surface storage
- Surface process
- Licensed discharge point
- Entrained moisture
- Surface water flow
- Groundwater flow
- X (X, X) Mean (10th percentile, 90th percentile)

GHD

Centennial Airly Pty Ltd
Airly Mine Extension Project – Modification 3
Site water and salt balance assessment

Water management schematic
Annual water transfers
Proposed conditions B (2030)

Project No. 2220276
Revision No. 0
Date 01/10/2019

FIGURE 6-2

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Table 6-1 Average annual water balance – approved conditions (2030) and proposed conditions (2027)

Water management element	Approved conditions	Proposed conditions A	Proposed conditions B	Approved conditions	Proposed conditions A	Proposed conditions B	Approved conditions	Proposed conditions A	Proposed conditions B
	Average (mean) (ML/year)			"Dry" year (ML/year)			"Wet" year (ML/year)		
INPUTS									
Rainfall and catchment runoff	165	114	165	34	25	34	724	500	724
External potable water supply	1	2	2	1	2	2	0	1	1
Groundwater inflows	76	71	71	76	71	71	76	71	71
Extraction from production bore	0	0	0	0	0	0	0	0	0
In situ coal moisture	45	75	75	45	75	75	45	75	75
Transfer from Charbon Colliery	63	86	100	168	165	170	0	0	0
TOTAL INPUTS	**351**	**347**	**413**	**324**	**337**	**351**	**845**	**647**	**870**
OUTPUTS									
Evaporation	48	48	48	49	47	47	54	54	54
Dust suppression	5	5	5	6	6	6	4	4	4
Sewage to Ecomax system	2	3	3	2	3	3	2	3	3
Discharge through LDP001	28	11	20	0	0	0	517	306	472
Discharge through LDP002	0	0	0	0	0	0	0	0	0
Discharge through LDP003	0	0	0	0	0	0	0	0	0
Discharge through planned REA LDP	0.5	NA	0.5	0	NA	0	0	NA	0
Product coal moisture	210	281	281	210	281	281	210	281	281
Moisture retained in rejects	57	0	57	57	0	57	57	0	57
TOTAL OUTPUTS	**351**	**347**	**414**	**324**	**337**	**393**	**845**	**647**	**870**
CHANGE IN STORAGE									
Surface water storages	0	0	0	0	0	0	0	0	0
Underground water storages	0	0	0	0	0	0	0	0	0
TOTAL CHANGE IN STORAGE	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
BALANCE									
Deficit	0	0	1	0	0	42	0	0	0

Overall, Table 6-1 shows that, on average, the proposed increases to production and workforce is forecast to be able to be accommodated with the approved transfer of up to 170 ML/year from Charbon Colliery in the case where the CPP and REA are not constructed or operational (proposed conditions A). In the case where the CPP and REA are constructed and operational (proposed conditions B), the proposed production increase is forecast to result in a process water deficit of up to 42 ML/year in a “dry” year. No increases to potential off-site discharges are expected as a result of the Project.

Direct rainfall and catchment runoff

Direct rainfall and catchment runoff is, on average, the major inflow of water at Airly Mine in all cases. Rainfall and runoff are expected to be lower under proposed conditions A than approved or proposed conditions B, due to the absence of the catchment of the approved REA and REA Dam. In all conditions, rainfall and runoff are lower in “dry” years and higher in “wet” years.

External potable water supply and sewage to Ecomax system

The proposed increase in workforce from 155 to 200 FTE is expected to have a proportional increase in the external potable water supply and sewage to Ecomax system, however these changes are small compared to the overall water balance.

Groundwater inflows

Based on the predictions of the hydrogeological model (GHD 2019a), the peak groundwater inflows are expected to be slightly lower under proposed conditions than approved conditions. This is not expected to affect the overall water balance, as all groundwater inflows are expected to report as product coal moisture. Groundwater inflows are expected to be unchanged with rainfall conditions.

Extraction from production bore

As discussed in Section 1.3, the production bore is not currently considered a reliable source of water and was not modelled to supply process water to Airly Mine for the proposed conditions.

Coal moisture

The proposed increase in production rate is expected to result in a proportional increase in the in situ coal moisture. Losses to moisture retained in rejects are only expected when the CPP and REA are constructed and operational. The proposed increase in production rate is also expected to increase to product coal moisture. After accounting for in situ coal moisture and groundwater inflows, the increase is slightly less than proportional to the increased production rate, as the panel and pillar mining method planned to be used is expected to be slightly more water efficient than the currently continuous mining method.

Evaporation and dust suppression

Evaporation and dust suppression losses are not expected to be significantly affected by the Project.

Discharge

On average, discharges via LDP001 as a result of rare rainfall events are forecast to decrease as a result of the Project. This is due to the modelled increase in process water use corresponding to the proposed increase in production resulting in water storage at Airly Mine being simulated to be lower on average.

No discharges through LDP002 or LDP003 are forecast to occur under approved conditions or proposed conditions. No change to the forecast discharges via the planned REA LDP are expected as a result of the Project.

Figure 6-3 presents the daily LDP001 discharges predicted for the approved and proposed conditions for all 130 historical rainfall patterns modelled. The horizontal axis shows the proportion of days that a given off-site discharge volume was simulated not to occur, for example 99% daily percentile corresponds to discharges only occurring on 1% of days. For clarity, the results are shown with a logarithmic vertical axis and therefore values of 0 ML/day are not plotted.

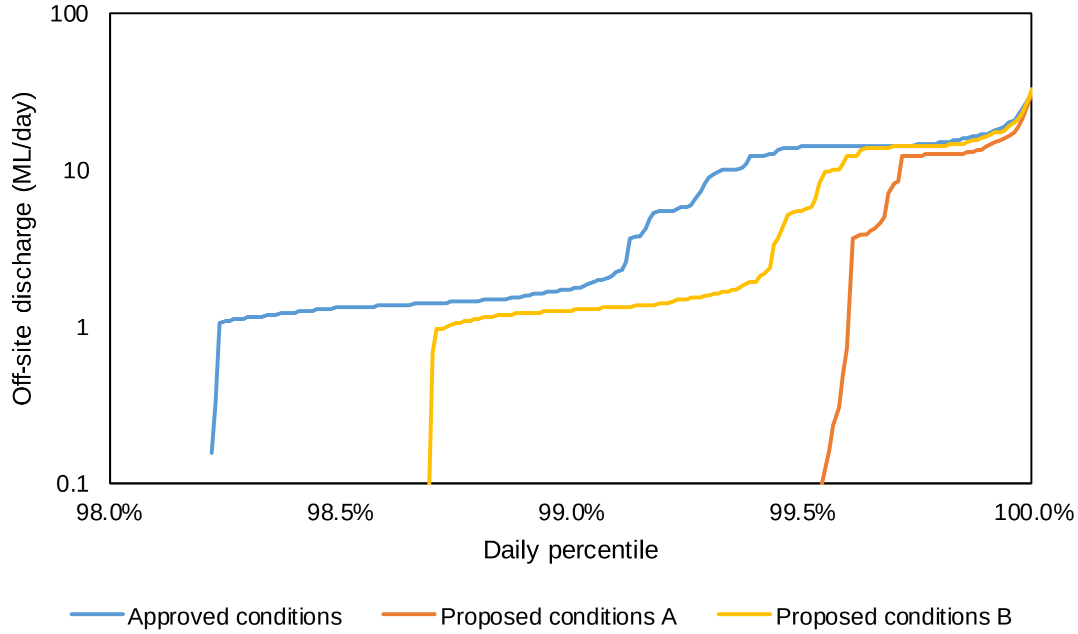


Figure 6-3 Impact on predicted daily LDP001 discharges

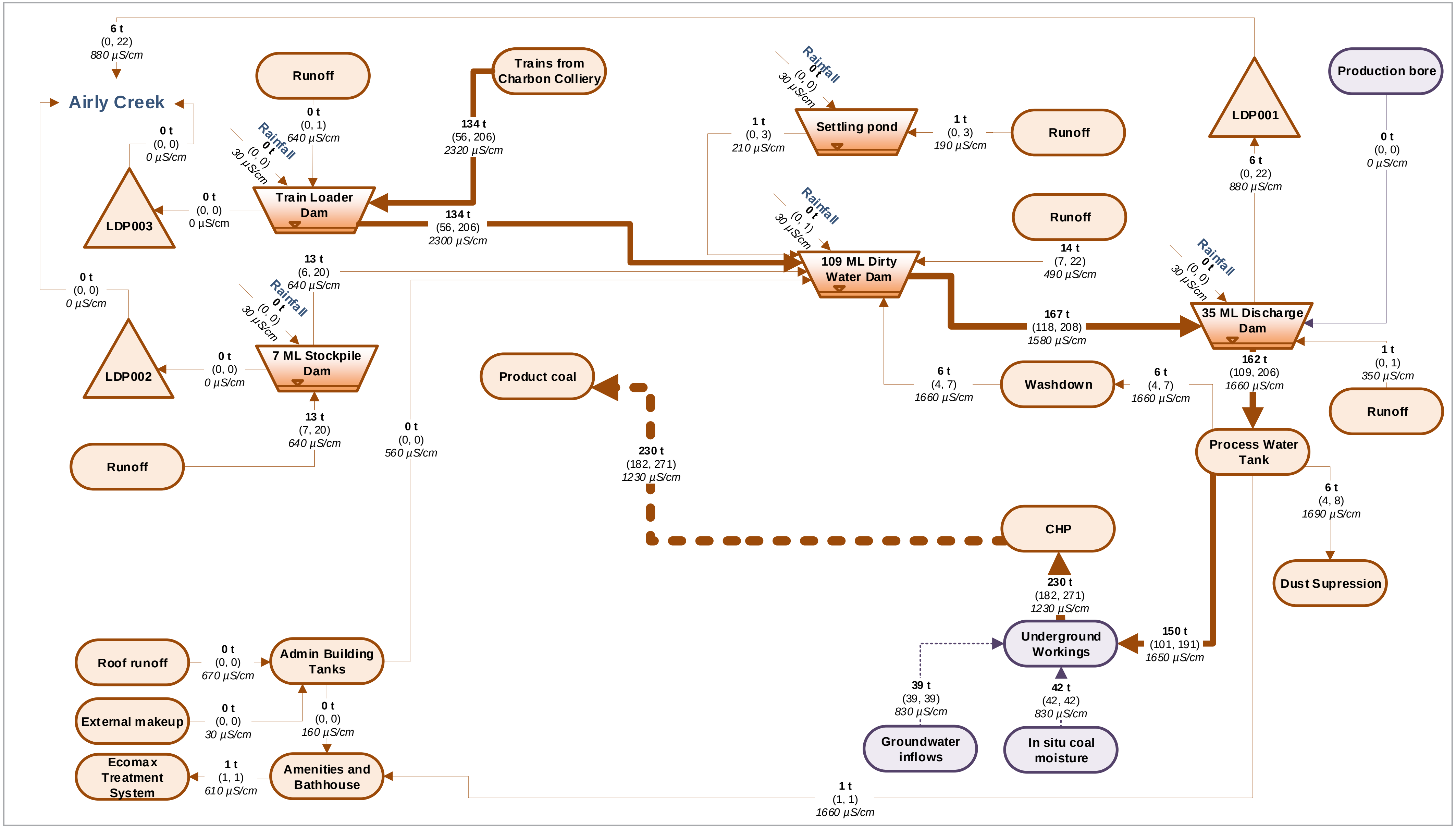
Figure 6-3 shows that the already rare discharges are forecast to be less frequent (shift to the right) as a result of the Project (or conversely a rarer rainfall event is required for a discharge to occur). This is due to the modelled increase in process water usage due to the proposed increase in maximum production rate, and therefore it is concluded that no increases in the potential for off-site discharge are expected as a result of the Project.

Discharges off-site through LDP001 to Airly Creek occur due to rare rainfall events for the proposed conditions. All discharges modelled were predicted to occur as a result of rainfall events exceeding 44 mm over five days, which is the rainfall depth for a 95th percentile, five day rainfall event design criteria for the 35 ML Discharge Dam (refer Section 2.1.2). Discharges were predicted to occur on less than 2% of days modelled, with the maximum daily discharge estimated to be about 30 ML/day.

The water balance model results did not forecast transfers from Charbon Colliery (for the proposed conditions) at the same time as discharges through LDP001, since discharges would occur only when the site water storages were filled by rainfall runoff, in which case water transfers from Charbon Colliery would not occur, as the storages would be more than 75% full.

6.2.2 Salt balance

The predicted annual salt transfers for the proposed conditions are presented in Figure 6-4 and Figure 6-5, which may be compared to Figure 5-7 for the approved conditions. The average annual inputs and outputs for the salt balance for the approved conditions and proposed conditions are compared in Table 6-2, consistent with the water balance results presented in Section 6.2.1. Results are rounded to the nearest 1 tonne/year, except for discharges via the planned REA LDP, for consistency with previous assessments (GHD 2019a).



Legend

Underground storage	Surface process	Surface water flow
Underground process	Licensed discharge point	Groundwater flow
Surface storage	Entrained moisture	X (X, X) XX: Mean (10th percentile, 90th percentile) Mean EC

Centennial Airly Pty Ltd
Airly Mine Extension Project – Modification 3
Site water and salt balance assessment

Water management schematic
Annual salt transfers
Proposed conditions A (2030)

Project No. 2220276
Revision No. 0
Date 01/10/2019

FIGURE 6-4

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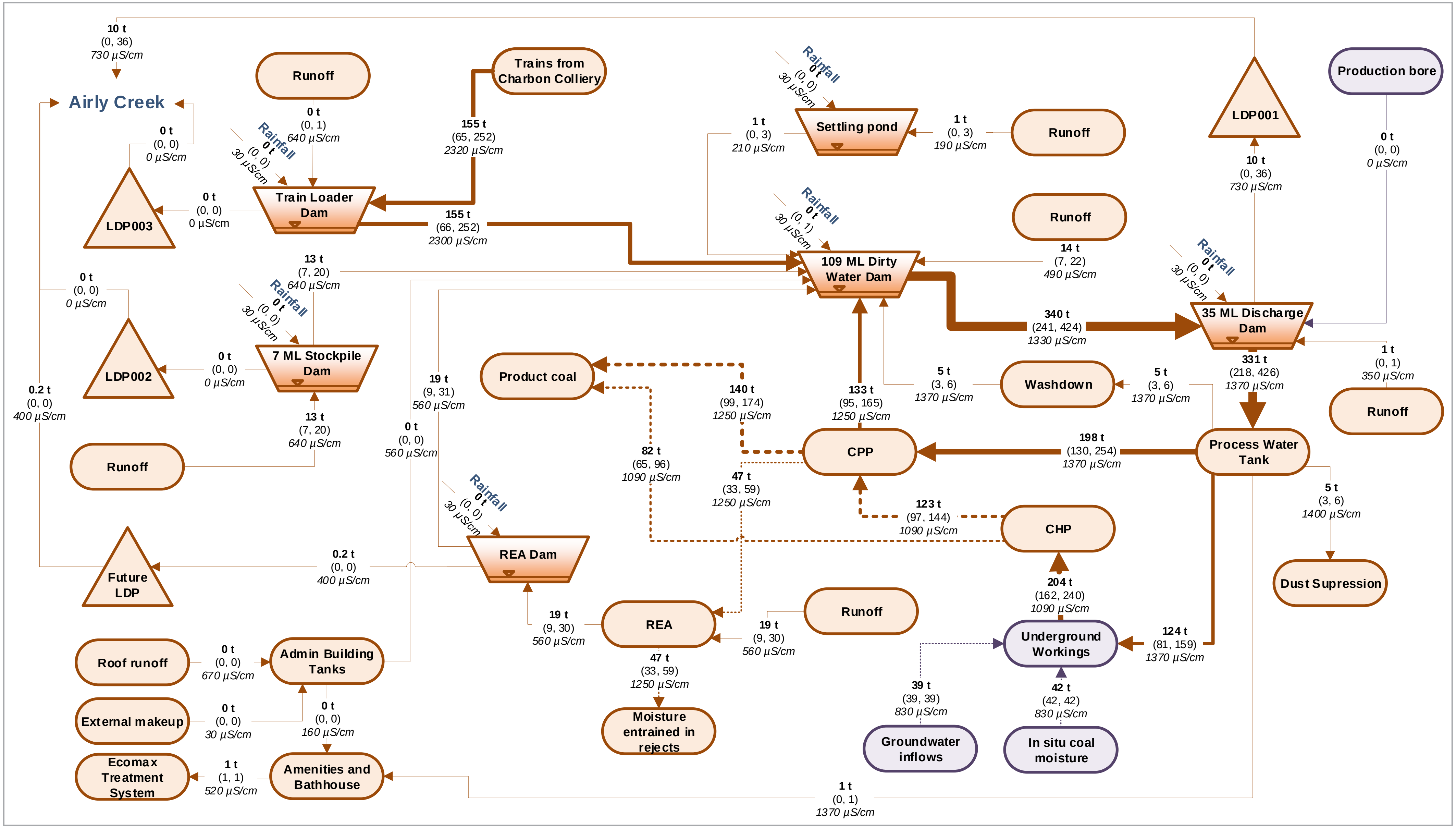

Legend

Underground storage	Surface process	Surface water flow
Underground process	Licensed discharge point	Groundwater flow
Surface storage	Entrained moisture	X (X, X) XX — Mean (10th percentile, 90th percentile) Mean EC

GHD

Centennial Airly Pty Ltd
Airly Mine Extension Project – Modification 3
Site water and salt balance assessment

Water management schematic
Annual salt transfers
Proposed conditions B (2030)

Project No. 2220276
Revision No. 0
Date 01/10/2019

FIGURE 6-5

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Table 6-2 Average annual salt balance – approved conditions (2030) and proposed conditions (2027)

Water management element	Approved conditions	Proposed conditions A	Proposed conditions B	Approved conditions	Proposed conditions A	Proposed conditions B	Approved conditions	Proposed conditions A	Proposed conditions B
	Average (mean) (tonne/year)			"Dry" year (tonne/year)			"Wet" year (tonne/year)		
INPUTS									
Rainfall and catchment runoff	49	30	49	10	6	10	179	111	179
External potable water supply	0	0	0	0	0	0	0	0	0
Groundwater inflows	42	39	39	42	39	39	42	39	39
Extraction from production bore	0	0	0	0	0	0	0	0	0
In situ coal moisture	25	42	42	25	42	42	25	42	42
Transfer from Charbon Colliery	98	134	155	260	256	264	0	0	0
TOTAL INPUTS	**213**	**244**	**284**	**336**	**343**	**355**	**245**	**191**	**260**
OUTPUTS									
Evaporation	0	0	0	0	0	0	0	0	0
Dust suppression	4	6	5	9	11	8	1	1	1
Sewage to Ecomax system	1	1	1	1	2	1	1	1	1
Discharge through LDP001	13	6	10	0	0	0	147	76	132
Discharge through LDP002	0	0	0	0	0	0	0	0	0
Discharge through LDP003	0	0	0	0	0	0	0	0	0
Discharge through planned REA LDP	0.2	NA	0.2	0	NA	0	0	NA	0
Product coal moisture	154	230	222	254	330	304	76	114	106
Moisture retained in rejects	42	0	47	71	0	67	21	0	20
TOTAL OUTPUTS	**213**	**244**	**285**	**336**	**343**	**379**	**245**	**191**	**260**
CHANGE IN STORAGE									
Surface water storages	0	0	0	0	0	0	0	0	0
Underground water storages	0	0	0	0	0	0	0	0	0
TOTAL CHANGE IN STORAGE	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
BALANCE									
Deficit	0	0	1	0	0	24	0	0	0

Table 6-2 shows that the Project is expected to result in generally higher salinity in the process water at Airly Mine, based on the conservative salinity assumptions used in the modelling (refer to Section 4.2.4), due to the increase reliance on transfers from Charbon Colliery. However, as discharges are forecast to be lower on average, due the increase process water consumption, potential discharges of salt are forecast to be lower as a result of the Project.

Figure 6-6 presents the daily percentiles of the EC corresponding to the volume of water predicted to be discharged through LDP001 into Airly Creek for approved and proposed conditions. The horizontal axis shows the proportion of days that a given off-discharge volume was simulated not to occur, for example 98% daily percentile corresponds to only occurring on 2% of days.

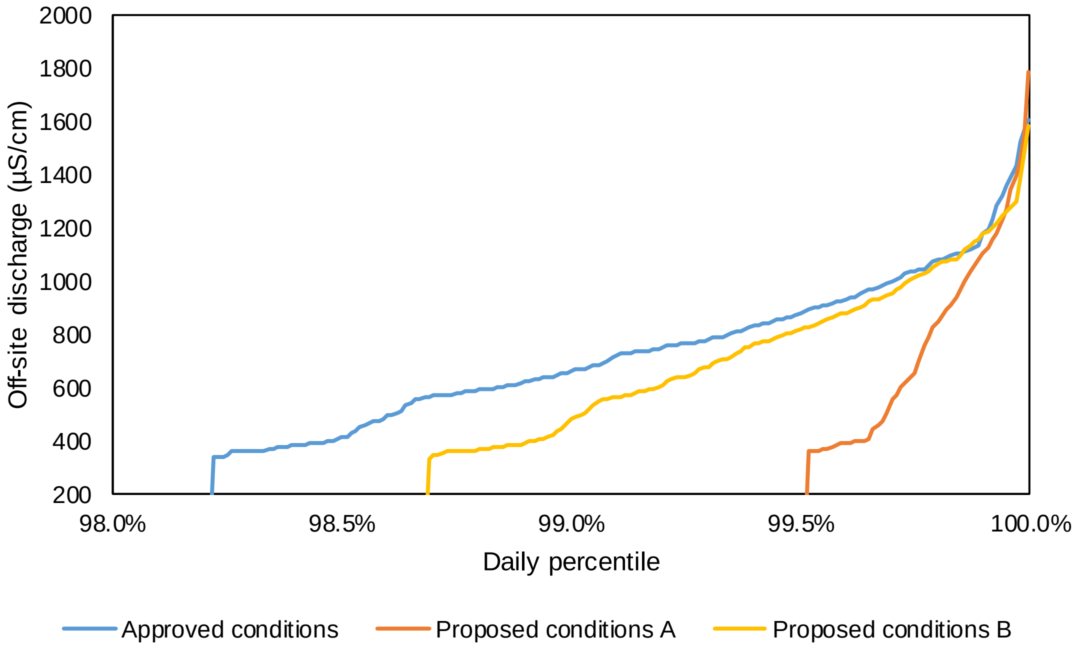

Figure 6-6 Impact on predicted electrical conductivity of daily LDP001 discharges

Figure 6-6 shows that the EC range of potential off-site discharges is not expected to change as a result of the Project. So while Figure 6-3 shows the off-site discharge is expected to be no more frequent as a result of Project, Figure 6-6 shows that potential off-site discharges are not expected to have any higher EC as a result of the Project.

6.3 Significant impact criteria

The significant impact criteria defined by the *Significant Impact Guidelines 1.3* (DoE 2013a) are presented in Table 6-3, along with where each aspect has been assessed in this assessment, which has been undertaken based on the information guidelines specified by the IESC (2018). Appendix A presents the information requirements as well as where each requirement has been addressed in this assessment.

Table 6-3 Significant impact criteria

Impact criteria	Comment
Hydrological characteristics	
Changes in the water quantity, including the timing of variations in water quantity.	No impact. No change to extraction from water resources is proposed (refer to Section 6.1). The proposal is not expected to result in any increase in off-site discharge (refer to Section 6.2.1).

Impact criteria	Comment
Changes in the integrity of hydrological or hydrogeological connections, including substantial structural damage.	No impact. No change to extent of the underground or surface parts of the site are proposed (refer to Section 1.3).
Changes in the area or extent of a water resource.	No impact. No change to the approved surface water catchments of the surface facilities area are proposed (refer to Section 1.3).
Water quality	
Substantially reduces the amount of water available for human consumptive uses or for other uses, including environmental uses, which are dependent on water of the appropriate quality.	No changes to water extraction at Airly Mine are proposed. No increase to off-site discharges quantities are expected.
Creates risk to human or animal health or to the condition of the natural environment as a result of the change in water quality.	No impact. The results of the salt balance modelling indicates that the Project is not expected to result in an increase of the salinity of potential off-site discharges. As no change to the water sources at Airly Mine are proposed, this indicates that no deterioration in the water quality of potential off-site discharges or potential for establishment of invasive species are expected as a result of the Project.
Causes persistent organic chemicals, heavy metals, salt or other potentially harmful substances to accumulate in the environment.	
There is a significant worsening of local water quality (where current local water quality is superior to local or regional water quality objectives).	
Seriously affects the habitat or lifestyle of a native species dependent on a water resource.	
Causes the establishment of an invasive species (or the spread of an existing invasive species) that is harmful to the ecosystem function of the water resource.	
High quality water is released into an ecosystem which is adapted to a lower water quality.	Not applicable. No increase to the frequency or magnitude of potential off-site discharges are expected (refer to Section 6.2.1). The quality of water in the water management system at Airly Mine is not considered high (GHD 2019a).

6.4 Downstream water users

The surface water impact assessment for Modification 2 (GHD 2019a) identified three lots as licensed for surface water users downstream of the Airly Mine surface facilities area. As the Project is not expected to result in any measurable impacts to water quantity or quality downstream of Airly Mine, no impact on downstream water users are expected.

6.5 Cumulative impacts

As the Project is not expected to result in any measurable impacts to water quantity or quality downstream of Airly Mine, and given that there are no other developments in the vicinity of Airly Mine, cumulative impacts are unlikely to occur as a result of the Project.

7. Mitigation, management and licensing

7.1 Discharge avoidance

The following management measures will be implemented to minimise the risk of discharge to Airly Creek:

- The importation of water from Charbon Colliery will only be undertaken as required when surface water storages are less than 75% full at Airly Mine, such that 25% freeboard is maintained at all times at Airly Mine.
- The water level in surface water storages will be continuously monitored.
- The water level in surface water storages will be maintained with sufficient freeboard to contain the 95th percentile, five day rainfall event of 44 mm.

A review of the size of surface water storages and transfer systems (pipelines and pumps) should be undertaken to ensure that the surface water management system is sufficient to capture the 95th percentile, five day rainfall event without uncontrolled discharges off-site.

7.2 Inspections

Centennial Airly undertake site inspections of the water management structures at the surface facilities area weekly as a minimum. The surface water storages are inspected for capacity, structural integrity and effectiveness. Maintenance of any erosion and sediment control structures will be implemented when visual defects are observed. Sediment accumulated within storages will be removed as required to maintain water storage capacity.

7.3 Licensing

No changes to extraction or use of water at Airly Mine are proposed. Therefore no changes to any licences held for Airly Mine are required by the Project.

7.4 Water management plans

A regional water management plan (Centennial Coal 2016) provides an overview of the water management requirements across Centennial's operations in the Western Coalfield. A site-specific water management plan for Airly Mine (Centennial Coal 2018) has also been developed to address the specific water management requirements for the mine. An extraction plan (including a water management plan) is also required for specific mine workings prior to extraction.

The water management plans ensure that the operation of the mine, with respect to water, meets all relevant regulatory requirements. The regional and site-specific water management plans are reviewed every three years or as a result of any regulatory requirements, any significant changes to water management practices or the development of new mining areas. Following approval of the Project, the site-specific water management plan will be updated to include the new water management strategy.

Trigger action response plans (TARPs) are provided in the site-specific water management plan. These TARPs provide guidance on the immediate actions that should be taken in response to any impacts of the Project identified as part of the monitoring program. Generally, responses include investigation and monitoring, determination of the risk of impact and remedial measures to be implemented. The TARPs also include reporting, training and personnel responsibilities. A review of the TARPs within the water management plans for Airly Mine will be undertaken.

7.5 Monitoring

A comprehensive surface water monitoring program has been developed by Airly Mine. The water management plan (Centennial Coal 2018) provides the details of the surface water monitoring program. Monitoring includes water quality and level of water storages at the surface facilities area and water quality, flow and stability of watercourses surrounding the surface facilities area. The main objective of monitoring is to ensure that the implemented water management measures function as designed. Observations from the surface water monitoring will be used to report on the site water balance for each calendar year as part of the annual review.

No changes to the monitoring program at Airly Mine are required as a result of the Project.

8. Summary

This assessment considers the overall water management system associated with Airly Mine and the potential impacts of the Project on the site water and salt balance at Airly Mine. A summary of the existing/approved conditions and potential impacts under proposed conditions is provided in Table 8-1.

Table 8-1 Summary of potential impacts

Component	Existing/approved conditions	Potential impacts
Water balance	• Airly Mine is approved to import up to 170 ML/year of water from Charbon Colliery to supply operations. • Off-site discharges are only expected as a result of rare rainfall events in excess of the 95th percentile, five day event (44 mm of rainfall in 5 days).	• No increase in the likelihood of potential off-site discharges, compared to approved conditions.
Salt balance	• The main salt influx at Airly Mine is forecast to be in water transferred from Charbon Colliery. • The main outflow of salt from Airly Mine, on average, is forecast to be salt within the moisture entrained in product coal.	• No increase in the likely salinity of potential off-site discharges, compared to approved conditions.

9. References

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Centennial Coal (2016) Western Operations: Regional Water Management Plan, prepared by GHD Pty Ltd for Centennial Coal Company Limited.

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DECCW (2006) *NSW Water Quality and River Flow Objectives*, NSW Department of Environment, Climate Change and Water, available at https://www.environment.nsw.gov.au/ieo/

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IESC (2018) *Information guidelines for proponents preparing coal seam gas and large coal mining development proposals*, Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development.

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GHD (2019c) Airly Mine Extension Project – Modification 3: Baseflow impact assessment – Genowland and Gap Creek. Report prepared by GHD Pty Ltd for Centennial Airly Pty Ltd.

Landcom (2004) Managing Urban Stormwater: Soils and Construction – Volume 1, 4th edition.

NSW Government (2001), Statement of Joint Intent for the Hawkesbury Nepean River System.

Appendices

Appendix A – Supporting assessment requirements

IESC information requirements (IESC 2018)

Assessment requirement	Where addressed
Surface water	
Context and conceptualisation	
Describe the hydrological regime of all watercourses, standing waters and springs across the site including: • geomorphology, including drainage patterns, sediment regime and floodplain features; • spatial, temporal and seasonal trends in streamflow and/or standing water levels; • spatial, temporal and seasonal trends in water quality data (such as turbidity, acidity, salinity, relevant organic chemicals, metals, metalloids and radionuclides); and, • current stressors on watercourses, including impacts from any currently approved projects.	Section 3.4
Describe the existing flood regime, including flood volume, depth, duration, extent and velocity for a range of annual exceedance probabilities. Provide flood hydrographs and maps identifying peak flood extent, depth and velocity. This assessment should be informed by topographic data that has been acquired using lidar or other reliable survey methods with accuracy stated.	Not relevant.
Provide an assessment of the frequency, volume, seasonal variability and direction of interactions between water resources, including surface water/ groundwater connectivity and connectivity with sea water.	Not relevant.
Analytical and numerical modelling	
Provide conceptual models at an appropriate scale, including water quality, stores, flows and use of water by ecosystems.	Section 4.2.
Describe and justify model assumptions and limitations, and calibrate with appropriate surface water monitoring data.	Section 4.2.
Use methods in accordance with the most recent publication of Australian Rainfall and Runoff (Ball et al. 2016).	Not relevant.
Provide an assessment of the risks and uncertainty inherent in the data used in the modelling, particularly with respect to predicted scenarios.	Section 4.2.
Develop and describe a program for review and update of the models as more data and information becomes available.	Section 7.
Provide a detailed description of any methods and evidence (e.g. expert opinion, analogue sites) employed in addition to modelling.	Not relevant.
Impacts to water resources and water-dependent assets	
Describe all potential impacts of the proposed project on surface waters. Include a clear description of the impact to the resource, the resultant impact to any assets dependent on the resource (including water-dependent ecosystems such as riparian zones and floodplains), and the consequence or significance of the impact. Consider: • Impacts on streamflow under the full range of flow conditions. • Impacts associated with surface water diversions. • Impacts to water quality, including consideration of mixing zones. • The quality, quantity and ecotoxicological effects of operational discharges of water (including saline water), including potential emergency discharges, and the likely impacts on water resources and water-dependent assets. • Landscape modifications such as subsidence, voids, post rehabilitation landform collapses, on-site earthworks (including disturbance of acid-forming or sodic soils, roadway and pipeline networks) and how these could affect surface water flow, surface water quality, erosion, sedimentation and habitat fragmentation of water-dependent species and communities.	Section 4.1.

Assessment requirement	Where addressed
Discuss existing water quality guidelines, environmental flow objectives and requirements for the surface water catchment(s) within which the development proposal is based.	Section 2.
Identify processes to determine surface water quality guidelines and quantity thresholds which incorporate seasonal variation but provide early indication of potential impacts to assets.	Not relevant. SSGVs already defined.
Propose mitigation actions for each identified significant impact.	Section 7.
Describe the adequacy of proposed measures to prevent or minimise impacts on water resources and water-dependent assets.	Section 7.
Describe the cumulative impact of the proposal on surface water resources and water-dependent assets when all developments (past, present and reasonably foreseeable) are considered in combination.	Not relevant.
Provide an assessment of the risks of flooding (including channel form and stability, water level, depth, extent, velocity, shear stress and stream power), and impacts to ecosystems, project infrastructure and the final project landform.	Not relevant.
Data and monitoring	
Identify monitoring sites representative of the diversity of potentially affected water-dependent assets and the nature and scale of potential impacts, and match with suitable replicated control and reference sites (BACI design) to enable detection and monitoring of potential impacts.	Not relevant, no change to existing monitoring program proposed or required.
Develop and describe a surface water monitoring program that will collect sufficient data to detect and identify the cause of any changes from established baseline conditions, and assess the effectiveness of mitigation and management measures. The program will: • include baseline monitoring data for physico-chemical parameters, as well as contaminants (e.g. metals); • comparison of physico-chemical data to national/regional guidelines or to site-specific guidelines derived from reference condition monitoring if available; and, • identify baseline contaminant concentrations and compare these to national guidelines, allowing for local background correction if required.	
Ensure water quality monitoring complies with relevant National Water Quality Management Strategy (NWQMS) guidelines (ANZECC/ARMCANZ 2000) and relevant legislated state protocols (e.g. QLD Government 2013).	
Describe the rationale for selected monitoring parameters, duration, frequency and methods, including the use of satellite or aerial imagery to identify and monitor large-scale impacts.	
Identify data sources, including streamflow data, proximity to rainfall stations, data record duration and describe data methods, including whether missing data have been patched.	
Develop and describe a plan for ongoing ecotoxicological monitoring, including direct toxicity assessment of discharges to surface waters where appropriate.	
Identify dedicated sites to monitor hydrology, water quality, and channel and floodplain geomorphology throughout the life of the proposed project and beyond.	
Water and salt balance, and water quality	
Provide a quantitative site water balance model describing the total water supply and demand under a range of rainfall conditions and allocation of water for mining activities (e.g. dust suppression, coal washing etc.), including all sources and uses.	Section 5.3 and Section 6.2
Provide estimates of the quality and quantity of operational discharges under dry, median and wet conditions, potential emergency discharges due to unusual events and the likely impacts on water-dependent assets.	

Assessment requirement	Where addressed
Describe the water requirements and on-site water management infrastructure, including modelling to demonstrate adequacy under a range of potential climatic conditions.	
Provide salt balance modelling that includes stores and the movement of salt between stores, and takes into account seasonal and long-term variation.	
Cumulative impacts	
Context and conceptualisation	
Provide cumulative impact analysis with sufficient geographic and temporal boundaries to include all potentially significant water-related impacts.	Not applicable. No significant cumulative impact identified.
Consider all past, present and reasonably foreseeable actions, including development proposals, programs and policies that are likely to impact on the water resources of concern in the cumulative impact analysis. Where a proposed project is located within the area of a bioregional assessment consider the results of the bioregional assessment.	
Impacts	
Provide an assessment of the condition of affected water resources which includes: • identification of all water resources likely to be cumulatively impacted by the proposed development; • a description of the current condition and quality of water resources and information on condition trends; • identification of ecological characteristics, processes, conditions, trends and values of water resources; • adequate water and salt balances; and, • identification of potential thresholds for each water resource and its likely response to change and capacity to withstand adverse impacts (e.g. altered water quality, drawdown).	Not applicable. No significant cumulative impact identified.
Assess the cumulative impacts to water resources considering: • the full extent of potential impacts from the proposed project, (including whether there are alternative options for infrastructure and mine configurations which could reduce impacts), and encompassing all linkages, including both direct and indirect links, operating upstream, downstream, vertically and laterally; • all stages of the development, including exploration, operations and post closure/decommissioning; • appropriately robust, repeatable and transparent methods; • the likely spatial magnitude and timeframe over which impacts will occur, and significance of cumulative impacts; and, • opportunities to work with other water users to avoid, minimise or mitigate potential cumulative impacts.	
Mitigation, monitoring and management	
Identify modifications or alternatives to avoid, minimise or mitigate potential cumulative impacts. Evidence of the likely success of these measures (e.g. case studies) should be provided.	Not applicable. No significant cumulative impact identified.
Identify cumulative impact environmental objectives.	
Identify measures to detect and monitor cumulative impacts, pre and post development, and assess the success of mitigation strategies.	
Describe appropriate reporting mechanisms.	
Propose adaptive management measures and management responses.	
Final landform and voids – coal mines	
Identify and consider landscape modifications (e.g. voids, on-site earthworks, and roadway and pipeline networks) and their potential effects on surface water flow, erosion, sedimentation and habitat fragmentation of water-dependent species and communities.	Not applicable. No final

Assessment requirement	Where addressed
Provide an assessment of the long-term impacts to water resources and water-dependent assets posed by various options for the final landform design, including complete or partial backfilling of mining voids. Assessment of the final landform for which approval is being sought should consider: • groundwater behaviour – sink or lateral flow from void. • water level recovery – rate, depth, and stabilisation point (e.g. timeframe and level in relation to existing groundwater level, surface elevation). • seepage – geochemistry and potential impacts. • long-term water quality, including salinity, pH, metals and toxicity. • measures to prevent migration of void water off-site. For other final landform options considered sufficient detail of potential impacts should be provided to clearly justify the proposed option.	void proposed.
Assess the adequacy of modelling, including surface water and groundwater quantity and quality, lake behaviour, timeframes and calibration.	
Provide an evaluation of stability of void slopes where failure during extreme events or over the long term (for example due to aquifer recovery causing geological heave and landform failure) may have implications for water quality.	
Evaluate mitigating inflows of saline groundwater by planning for partial backfilling of final voids.	
Assess the probability of overtopping of final voids with variable climate extremes, and management mitigations.	

Appendix B – Water and salt balance model parameters

Since the 2014 EIS, the site water and salt balance model has been regularly updated to reflect improved site information. In particular, the following changes to the model have occurred:

- Adoption of groundwater inflow predictions from revised hydrogeological modelling
- Recognition that reduced predicted groundwater inflows are likely to report only as ROM coal moisture and not require dewatering from the underground to the surface
- The production bore contributes to 35 ML Discharge Dam, rather than the 109 ML Dirty Water Dam
- Reduction in the production bore extraction rate
- Reduction in dust suppression demands to match actual site usage
- Detailed stage storage relationships for surface water storages based on bathymetry and survey
- Adjustments to catchment areas and land use to reflect improved survey and aerial imagery as well as changes in site water management system (in particular the 7 ML Dam catchment)
- Updates to salinity (EC) parameters based on observed monitoring data

The modelling parameters are compared in Table B-1, the changes to storage geometry and catchment areas are summarised in Table B-2 and Table B-3 respectively. Changes to the runoff model parameters are summarised in Table B-4.

Table B-1 Modelling parameters

Category	Parameter	Original model (proposed conditions in GHD 2014)	Current model
Production	ROM extraction rate	1.8 Mtpa	1.8 Mtpa
	Site personnel	155 FTE	155 FTE
Amenities	Drinking water usage	2.2 L/day/FTE	2.2 L/day/FTE
	Shower usage	11.3 L/day/FTE	11.3 L/day/FTE
	Toilet usage	26.5 L/day/FTE	26.5 L/day/FTE
Mining support operations	Underground mining operations	80 L/tonne ROM coal	50 L/tonne ROM coal (approved) 45 L/tonne ROM coal (proposed)
	CPP water demand (gross)	120 L/tonne ROM coal	120 L/tonne ROM coal
	Dust suppression	100 ML/year	5 ML/year
	Washdown	5 ML/year	5 ML/year
Coal moisture	In situ coal moisture	2.5%	2.5%
	ROM coal moisture	8%	Varies with groundwater inflows
	Beneficiated coal moisture	9%	Varies with groundwater inflows
	Coarse rejects moisture	9%	9%
	Fine rejects moisture	26%	26%
Coal processing	Product coal mass fraction	80%	80%
	Coarse rejects mass fraction	15%	15%

Category	Parameter	Original model (proposed conditions in GHD 2014)	Current model
	Fine rejects mass fraction	5%	5%
Maximum transfer rates	Train Loader Dam to 109 ML Dirty Water Dam	5 L/s	5 L/s (existing conditions/baseline conditions) 100 L/s (proposed conditions)
	7 ML Dam to 109 ML Dirty Water Dam	48 L/s	48 L/s
	Production bore extraction	9 L/s up to 278 ML/year	5 L/s up to 158 ML/year
	REA Dam to 109 ML Dirty Water Dam	25 L/s	20 L/s
Salinity data	Rainfall	20 µS/cm	30 µS/cm
	Clean catchment runoff	185 µS/cm	120 µS/cm
	Coal-contact runoff	653 µS/cm	450 µS/cm
	Groundwater inflows into underground workings	900 µS/cm	830 µS/cm
	Groundwater extracted from production bore	4626 µS/cm	4830 µS/cm

Table B-2 Storage capacities

Storage	Original model (GHD 2014)	Current model
7 ML Dam	7 ML	7.24 ML
Train Loader Dam	0.78 ML	6 ML
Settling Pond	3 ML	3 ML
109 ML Dirty Water Dam	109 ML	98.08 ML
35 ML Discharge Dam	35 ML	22.88 ML
Process Water Tank	0.746 ML	0.746 ML
Administration Buildings Tank	0.14 ML	0.19 ML
Header Tanks	0.04 ML	0.04 ML
REA Dam	52.4 ML	52.4 ML

Table B-3 Catchment area data

Storage	Original model (GHD 2014)				Revised model			
	Catchment area (ha)	Vegetated catchment (%)	Impervious catchment (%)	Disturbed/ compacted catchment (%)	Catchment area (ha)	Vegetated catchment (%)	Impervious catchment (%)	Disturbed/ compacted catchment (%)
7 ML Dam – without CPP	5.7	29	71	0	14.1	38	62	0
7 ML Dam – with CPP	7.2	23	77	0	14.1	38	62	0
Train Loader Dam	0.4	0	100	0	0.5	36	64	0
Settling Pond	32.8	86	14	0	33.0	99	1	0
109 ML Dirty Water Dam	53.1	75	25	0	56.8	85	15	0
35 ML Discharge Dam	5.9	90	10	0	6.7	95	5	0
Administration Buildings Tank	0.2	0	100	0	0.1	0	100	0
REA Dam	45.0	40	0	60	46.6	71	1	28

Table B-4 AWBM parameters

Parameter	Original model (GHD 2014)			Revised model		
	Vegetated catchment	Impervious catchment	Disturbed/ compacted catchment	Vegetated catchment	Impervious catchment	Disturbed/ compacted catchment
A_1, A_2, A_3	0.134, 0.433, 0.433	1.0, 0.0, 0.0	0.134, 0.433, 0.433	0.134, 0.433, 0.433	1.0, 0.0, 0.0	0.134, 0.433, 0.433
C_1, C_2, C_3	18.0, 182.88, 365.76 ($C_{average}$ = 240)	7.0, 0.0, 0.0	7.0, 14.0, 30.0	18.0, 182.9, 365.8 ($C_{average}$ = 240)	7.0, 0.0, 0.0	0.7, 7.6, 15.2 ($C_{average}$ = 10)
BFI	0.0	0.0	0.0	0.3	0.0	0.3
K_b	0.813	0.813	0.813	0.98	0.0	0.98
K_s	0.5	0.0	0.5			

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Document Status

Revision	Author	Reviewer		Approved for Issue		
		Name	Signature	Name	Signature	Date
0	T Tinkler	S Gray	S Gray	S Gray	S Gray	2/10/2019

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