Abel Mine SMP Area 1 Application-Written Report

APPENDIX C

Abel Coal Project Groundwater Assessment

Peter Dundon and Associates Pty Ltd

Abel Underground Mine Part 3A Environmental Assessment

DONALDSON COAL PTY LIMITED

ABEL COAL PROJECT
GROUNDWATER ASSESSMENT

BY

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21 JULY 2006

05-0163-R01E

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1 INTRODUCTION

1.1 Project Overview

Donaldson Coal Pty Ltd ('Donaldson') currently owns and operates Donaldson Open Cut Mine, located approximately 23 km north-west of Newcastle (**Figure 1**). This open cut mine has approval to operate until 2012 when it is considered current reserves will be exhausted. Donaldson proposes to develop a new underground mine known as Abel south from the high wall of Donaldson Open Cut Mine. The mine will utilise existing areas of disturbance within the Donaldson Mine Lease for surface infrastructure and the existing Bloomfield Coal Handling and Preparation Plant (CHPP), rail loader and rail loop for coal processing and loading.

The proposed Abel Underground Mine will have a production capacity of approximately 4.5 million tonnes per annum run-of-mine (ROM) coal over 20 years. The proposed method of extraction will be high productivity, continuous miner based bord and pillar systems, and pillar extraction techniques.

The Abel mining lease area (**Figure 1**) extends southwards from John Renshaw Drive towards George Booth Drive and is bounded on the eastern side by the F3 Freeway and the western side by a geological feature in the vicinity of Buttai Creek. The eastern boundary also excludes the Pambalong Nature Reserve.

Abel Underground Mine will extract coal from the Upper and Lower Donaldson coal seams. These seams dip downwards towards the south across the site at approximately 5 degrees. Mine access will be from the Donaldson high wall north of John Renshaw Drive. Underground mining will commence on the southern side of John Renshaw Drive and progress southwards. ROM coal will be transported via conveyor through the high wall to the existing Bloomfield Coal Handling and Preparation Plant (CHPP) where it will be processed and loaded onto rail.

The Abel Project Area consists of the area of generally disturbed land north of John Renshaw Drive within the existing Donaldson and Bloomfield mining leases, and the underground area south of John Renshaw Drive that consists of low undulating forested hills with patches of cleared land with rural/residential properties. The ridgeline associated with Black Hill runs east-west through the Project Area, with tributaries of Buttai Creek, Viney Creek/Weakleys Flat Creek and Four Mile Creek draining northwards from this ridgeline. The Long Gully/Blue Gum Creek system drains the southern side of the ridgeline eastwards towards Pambalong Nature Reserve. Some limited cliff-lines and steeper gullies are located along sections of the ridge.

1.2 Interaction with Neighbouring Mines

Donaldson Open Cut Mine

Donaldson Open Cut Mine has consent to operate until 2012. The areas of Donaldson Mine that will be required for the Abel Underground Mine to operate are included in this Development Application for Abel Underground Mine. These include:

- existing Donaldson Coal private roads for coal haulage to Bloomfield, and the approved access road from John Renshaw Drive;
- selected areas of active and future mining that will be used for Abel surface facilities; and
- elements of the existing Donaldson dirty water management system.

The existing Donaldson final landform and rehabilitation plans will be amended to address the required modifications to cater for the Abel Underground Mine.

Donaldson currently delivers 2.5 million tonnes per annum ROM coal to the Bloomfield CHPP, however this amount is planned to decrease as Abel production increases.

Tasman Underground Mine

Tasman Underground Mine, to the south of George Booth Drive and Abel Underground Mine, was approved in 2004 for a maximum extraction of 960,000 tonnes per annum ROM coal.

Coal from Tasman Underground Mine (which is currently under construction) will be trucked to Bloomfield Coal Handling and Preparation Plant and Rail Loading facility for processing. Trucks will use approved roads through Donaldson Open Cut Mine to Bloomfield.

Bloomfield Coal Handling and Preparation Plant (CHPP) and Rail Loading Facility

The Bloomfield CHPP and rail loading facility will be used for the processing of coal from Abel Underground Mine. The CHPP and rail loading facility also handles coal from Donaldson Open Cut, Bloomfield and Tasman Mines. Bloomfield currently has a licence under the *Protection of the Environment Operations Act 1997* to process 3.5 million tonnes per annum of product coal (approximately 5 million tonnes per annum ROM coal). An increase in capacity of 30 percent is required to cater for Abel coal.

The Bloomfield Coal Handling and Preparation Plant (CHPP) is also used, and will continue to be used, to process coal from other sources, including from the Bloomfield Group operations.

1.3 Objectives of Groundwater Study

The broad objectives of the study were to:

- To assess and describe the existing groundwater environment in the vicinity of the proposed Abel project

- To identify key potential risks to the environment from the proposal

- To evaluate the potential impacts of the proposal on the regional and local groundwater resources, incorporating any necessary management and mitigation strategies

- To assess the residual post-project impacts and any ongoing management requirements.

The study has been undertaken with reference to the following relevant policies:

- NSW State Rivers and Estuaries Policy
- NSW Wetlands Management Policy
- NSW Groundwater Policy Framework Document – General
- NSW Groundwater Quantity Management Policy
- NSW Groundwater Quality Protection Policy
- NSW Groundwater Dependent Ecosystem Policy,

and the following relevant best practice guidelines:

- Groundwater Flow Modelling Guideline (Middlemis, 2001)
- Independent Inquiry into the Hunter River System (Healthy Rivers Commission, 2002)
- Guidelines for Management of Stream/Aquifer Systems in Coal Mining Developments – Hunter Region (DNR, 2005).
- Groundwater Monitoring Guidelines for Mine Sites within the Hunter Region (DIPNR, 2003).

2 GROUNDWATER INVESTIGATIONS

2.1 Summary

A series of piezometers were installed across the lease area, to enable separate sampling, testing and monitoring of the Donaldson coal seams, and the overburden and interburden sediments, both within the shallow northern part of the deposit, and downdip at the southern end. Some bores were also installed along strike to the east. A number of shallow piezometers were also installed around the Pambalong Nature Reserve.

Each piezometer was designed to monitor a specific depth interval. Both open standpipe piezometers and vibrating wire piezometers were used. Standpipes were mainly used for shallow piezometers, with the casing/screen annulus sealed above and below, to enable the specific screened zone to be separately sampled and tested. Deeper piezometers usually consisted of vibrating wire piezometers encased in fully-grouted holes.

A hydraulic testing program was carried out on the standpipe piezometers, comprising either slug tests or short duration pumping tests, to determine aquifer permeabilities.

Water samples have been collected from each piezometer during hydraulic testing. The samples were submitted to a NATA-registered laboratory for comprehensive analysis of physical properties and the major inorganic parameters.

The specific investigations carried out for the Abel project were supplemented by relevant parts of earlier studies carried out for the Donaldson Open Cut mine. Ongoing monitoring of groundwater levels and groundwater and surface water quality has provided additional valuable information.

A limited testing program was also carried out on existing bores on the Bloomfield project site.

The hydrogeological investigations (including modelling) have also been undertaken with reference to the *Guidelines for Management of Stream/Aquifer Systems in Coal Mining Developments – Hunter Region* (DNR, 2005), with the model developed in accordance with the best practice guidelines on groundwater flow modelling (Middlemis et al, 2001).

2.2 Census of Existing Groundwater Usage

A search of the Department of Natural Resources groundwater bore database has been made to identify existing licensed bores within approximately 10km of the project. Summary details of the 16 licensed bores within 10km of the project are presented in **Appendix A**. Locations are shown on **Figure 2**.

Most of the licensed water supply bores are located to the north of the project, beyond the subcrop line of the Donaldson seams and the overlying coal measures sediments. They will thus not be impacted by the project.

Only one stock/domestic bore is recorded within the zone of potential groundwater impact from the project, ie bore GW51353, which is located on the western boundary of the mining lease (**Figure 2**). This bore is reported to be 50m deep, with a water level at 15m, yielded 0.2 L/s and has a salinity in the range 3000-7000 ppm.

All other licensed bores within the project vicinity are monitoring bores around the Donaldson Open Cut.

2.3 Piezometers

Fourteen (14) piezometers have been installed specifically for the Abel project. These are supplemented by 30 piezometers previously installed for the Donaldson project, 9 piezometers at the Tasman project to the south, and 8 monitoring bores/shafts on the Bloomfield lease. Piezometer locations are shown on **Figure 2**. All piezometers have been consolidated into an integrated regional monitoring network encompassing all four coal operations.

Completion details of the piezometers are listed in **Table 1**. Summary bore logs for the fourteen new Abel piezometers and the Donaldson piezometers are presented in **Appendix B**. A Bore Licence application has been lodged for all the new piezometers.

Piezometers were constructed in existing coal exploration drillholes, which had generally been drilled at 100 or 125mm diameter.

Standpipe piezometers were constructed by installation of 50mm diameter PVC casing, with PVC screens set adjacent to the desired monitoring interval in the bore, then placing a gravel pack around the screen and a bentonite seal in the annulus above the screened zone. The rest of the annulus above the bentonite seal was then backfilled with cement grout using a tremie pipe from the surface. Vibrating wire piezometers were installed by securing them to the cementing tremie pipe at the desired depth level and the hole then fully grouted back to the surface.

The piezometers have been completed at the surface with a concrete block to prevent ingress of surface runoff or contamination, and secured within a padlocked steel monument.

The piezometers were located and designed to allow a geographic spread of monitoring locations across the project area, and also to allow separate monitoring of aquifers in both the Donaldson coal seams and the overburden sediments, as well as in the shallow surficial aquifer.

Table 1: Groundwater Piezometers and Other Monitoring Bores

Piezometer	MGA Coordinates		Surface RL (mAHD)	Depth (m)	Screen / Vibrating Wire Piezometer (m)	Elevation of Donaldson Seams (m AHD)	Screen / Piezometer Relative to Donaldson Seam (m)	Water Level			Aquifer Formation	Status
	E	N						Date	m BGL	m AHD		
CO62A	370143	6366248	36	157	124-118	-95 to -86	0	27/03/06	11.4	24.6	Donaldson Seam	Active
CO62B	370143	6366248	36	157	87-81	-95 to -86	+35	27/03/06	4.2	31.8	Overburden	Active
CO63A	372109	6366193	19	255	197	-169 to -144	-34	27/03/06	27.0	-8.0	?Donaldson Seam	Active
CO63B	372109	6366193	19	255	130	-169 to -144	+33	27/03/06	24.9	-5.9	Overburden	Active
CO72	369927	6362562	63	318	264	-188 to -176	0	27/03/06	44.3	18.7	Donaldson Seam	Active
CO72A	369919	6362569	63		168	-188 to -176	+71	23/03/06	41.3	21.7	Overburden	Active
CO72B	369911	6362570	63		45-42	-188 to -176	+194	27/03/06	13.0	50.0	Alluvium/weathered Permian	Active
CO78A	367140	6367054	77	101	99-96 and 90-87	-32 to -22	0	26/04/06	48.6	28.4	Donaldson Seam	Active
CO78B	367140	6367054	77	24	24-18	-32 to -22	+75	28/03/06	9.5	67.5	Alluvium/weathered Permian	Active
CO80	368040	6365176	177	300	280	-106 to -95	0	27/03/06	148.4	28.6	Donaldson Seam	Active
CO81A	369992	6364001	2.3	225	149.7	-160 to -141	0	27/03/06	-23.9	26.0	Donaldson Seam	Active
CO81B	369992	6364001	2.3	20	20-14	-160 to -141	+124	27/03/06	0.3	2.0	Alluvium/weathered Permian	Active
CO82	370319	6364647	34	20	20-14	-151 to -132	+146	27/03/06	15.3	18.7	Alluvium/weathered Permian	Active
C087	367187	6367079	74	18.3	18.3-12.3	-32 to -22	+78	26/04/06	10.5	63.5	Alluvium/weathered Permian	Active
DPZ1	370828	6369904	23.08	30	16.5-26.9	+2 to +19	0	11/07/01	10.8	12.2	Lower Donaldson and Big Ben Seams	Mined out
DPZ2	371847	6370120	22.3	30	15.8-27.8	?	+5	16/12/04	15.1	7.2	Beresfield Seam	Active
DPZ3	368774	6368609	49.1	30	6.8-18.8	absent	? -20	17/08/05	12.4	36.7	Undifferentiated coal measures below Lower Donaldson Seam	Active
DPZ4A	370542	6368780	35.0	23	18.7-22.7	-8 to +10	+2	17/03/04	14.15	20.86	Beresfield Seam	Mined out
DPZ4B	370542	6368780	35.0	49	24.9-49.2	-8 to +10	0	26/02/04	41.92	-6.91	Upper and Lower Donaldson and Big Ben Seams	Mined out
DPZ5	371367	6368780	12.8	24	6-18	?	? +20	17/08/05	6.83	5.97	Undifferentiated coal measures above Donaldson Seams	Active
DPZ6			57.7	43	26.7-42.5	+19 to +26	0	14/08/02	13.64	31.02	Upper and Lower Donaldson Seams	Not read - unreliable
DPZ7A	368848	6367641	55.4	18	12.9-16.9	+29 to +36	+3	11/07/01	16.9	38.5	Overburden above Upper Donaldson	Not read since 2001
DPZ7B	368848	6367641	55.4	41	22.9-34.9	+29 to +36	0	17/08/05	23.5	31.9	Lower Donaldson	Active
DPZ8	369375	6368074	51.8	33	22.2-32.2	+29 to +39	0	17/08/05	25.3	26.5	Lower Donaldson and Big Ben Seams	Active

Table 1: Groundwater Piezometers and Other Monitoring Bores

Piezometer	MGA Coordinates		Surface RL (mAHD)	Depth (m)	Screen / Vibrating Wire Piezometer (m)	Elevation of Donaldson Seams (m AHD)	Screen / Piezometer Relative to Donaldson Seam (m)	Water Level			Aquifer Formation	Status
	E	N						Date	m BGL	m AHD		
DPZ9	369848	6368017	36.4	40	12.5-36.5	+9 to +21	0	17/08/05	32.1	4.2	Upper and Lower Donaldson and Big Ben Seams	Active
DPZ10	371002	6368464	19.8	30	11.8-29.8	?	? +20	17/08/05	13.8	6.0	Beresfield Seam	Active
DPZ11	371760	6368006	19.0	30	17.5-29.5	?	? +30	-	-	-	Overburden above Upper Donaldson	Lost
DPZ12	369115	6366415	59.5	24	6-18	?	? +60	17/08/05	16.8	42.7	Overburden above Upper Donaldson	Active – erratic readings
DPZ13	371221	6367558	21.5	30	18-30	?	? +40	17/08/05	7.3	14.2	Overburden above Upper Donaldson	Active
DPZ14			47.4	32	23.9-31.8	+36 to +44	-13	13/03/02	29.2	18.2	Buchanan and Ashtonfield Seams	Mined out
DPZ15			43.4	50	40.5-47.3	+19 to +42	-16	20/02/02	36.9	6.5	Buchanan and Ashtonfield Seams	Mined out
DPZ16			26.8	27	21.1-24.0	+22 to +24	-17	13/03/02	18.1	8.7	Ashtonfield Seam	Mined out
DPZ17-24m								13/06/02	15.9	-0.6		Not read since 2002
DPZ17-38m								13/06/02	15.9	-0.6		Not read since 2002
DPZ17-62m								17/08/05	18.3	-3.0		Active
DPZ18-72m								16/04/02	33.2	-2.7		Mined out
DPZ18-90m								16/04/02	32.8	-2.3		Mined out
DPZ19-56m								13/03/02	26.3	-4.1		Mined out
DPZ19-73m								13/03/02	25.4	-3.2		Mined out
DPZ20A	370541	6368439	20.1	51	11.5-17.5			23/05/06	11.1	9.0	Surficial aquifer – creek bed level	Active
DPZ20B	370540	6368439	20.1	51	44			23/05/06	32.2	-12.0	Big Ben Seam	Active
FMC1												
FMC2												
JRD1	368560	6366731										
JRD2	368280	6366936										
REGDPZ1												Regional licensed bore (GW58760)
ODO003												Blocked
TAS009a			293.94	227	215-227	-	-	3/07/01	158	135.9		Blocked

Table 1: Groundwater Piezometers and Other Monitoring Bores

Piezometer	MGA Coordinates		Surface RL (mAHD)	Depth (m)	Screen / Vibrating Wire Piezometer (m)	Elevation of Donaldson Seams (m AHD)	Screen / Piezometer Relative to Donaldson Seam (m)	Water Level			Aquifer Formation	Status
	E	N						Date	m BGL	m AHD		
TAS009b			293.94	227	185-190	-	-	3/07/01	143.4	150.5		Blocked
TAS010			318.39	236	199.5-211.5	-	-	3/07/01	200	118.4		? Active
TAS011			106.74	38	26-38	-	-	3/07/01	24.8	81.9		? Active
TAS012			199.15	149	90.5-105.5	-	-	3/07/01	97.8	101.4		? Active
TAS013			113.02	44	32-44	-	-	3/07/01	40.5	72.5		? Active
TAS014a			148.23	50	38-50	-	-	3/07/01	39.6	108.5		Blocked
TAS014b			148.23	50	24.5-30	-	-	3/07/01	Dry	Dry		Blocked
TAS24	364951	6359786		146	135	-	-					Active
BL01 (Old fan shaft)	363789	6371466	16.1			-	-					
BL02	365994	6372249	26.7			-	-		Dry	Dry		Blocked by tree roots
BL03A	366422	6368077	63.6	72		-	-	14/04/06	69.0	-4.5		
BL03B	366422	6368077		53		-	-	14/04/06	50.2	+14.3		
BL04	366519	6368076	61.5	52		-	-	14/04/06	43.7	+18.6		
BL05	367385	6367957	75.4	46		-	-	14/04/06	? 45	+31		
BL07	367211	6368485	57.6	26		-	-	13/04/06	24.6	+33.7		Partially blocked at 15m
BL08	367029	6368431	52.3	49		-	-	13/04/06	27.0	+26.0		

2.4 Groundwater Levels

Groundwater levels are monitored approximately monthly in all piezometers on the Donaldson and Abel project areas. Overall, there are almost 9 years of relevant groundwater level monitoring records extending from July 1997 to the present time. The earliest records were collected during the pre-project investigations for the Donaldson mine in 1997. Routine monthly monitoring at Donaldson commenced in June 2000, prior to the commencement of mining in the Donaldson open cut in January 2001.

There has been less frequent monitoring of the Tasman and Bloomfield bores. Tasman piezometers were monitored between July 2000 and October 2002, however they represent a hydraulically separate aquifer system. The Tasman mine is proposing to extract coal from the Fassifern Seam, which is more than 300m stratigraphically above the Donaldson seams targeted by the Abel project.

All relevant water level hydrographs are shown in **Appendix C**.

The hydrographs show the effects of seasonal and long term climatic changes in groundwater levels. The Donaldson bores also show the effects of pit dewatering and the onset of post-mining recovery of groundwater levels. Dewatering of the Donaldson mine is achieved by allowing free drainage of groundwater to a sump at the low point in the active mining area, and pumping from the sump to one of several water supply dams within the Donaldson mine area, for use primarily for dust suppression. Mining commenced at the north-eastern end of the deposit, and has progressed westwards to approximately the centre of the lease at the present time.

In summary, the hydrographs show:

- The effects of the protracted period of below average rainfalls between 2001 and 2005, illustrated by the hydrograph for regional monitoring bore REGDPZ1 and other bores remote from the mine development – FMCPZ2, DPZ5, DPZ7 and DPZ10 (**Figure 3**).

- The progressive impacts of the Donaldson mine dewatering (**Figure 4**), with the piezometers near the eastern end of the lease responding first (eg DPZ4B, which first responded to dewatering in October 2001) and those further west responding later as the pit advanced to the west (eg DPZ9 – first response in August 2004; and DPZ8 – first response in December 2004).

- The commencement of recovery of groundwater levels in some of the eastern bores, as the centre of mining has moved further west, and the eastern end of the pit has been progressively backfilled with waste rock, eg DPZ17-62m (**Figure 5**). By March 2006, the groundwater level has recovered by more than 8m from the lowest level reached in January 2004.

2.5 Hydraulic Testing

A hydraulic testing program was carried out on the new standpipe piezometers, comprising either slug tests or short duration pumping tests using low capacity sampling pumps, to determine aquifer permeabilities. The pumping tests were all of relatively short duration, generally 120 minutes or less.

Pumping tests or slug tests were also carried out on four bores on the Bloomfield site.

Details of the hydraulic testing program carried out are summarised in **Table 2**. The results of previous testing carried out on the Donaldson and Tasman piezometers are also included in the table. The results of all testing are presented in **Appendix D**.

Table 2: Hydraulic Testing Program – Piezometers and Monitoring Bores

Piezometer / Test Bore	Test Interval	Aquifer / Lithology	Date of Test	Type of Test	Pumping Rate	Duration min	Transmissivity	Average Hydraulic Conductivity		Storativity	Comments
					kL/d		m^2/d	m/d	m/s		
Abel Piezometers:											
C062A	118-124	Donaldson Seam	27 May 2006	Constant Rate	7.5	15	-	-	-	-	Reached pump inlet in 15 minutes
			30 May 2006	Slug Test	-	-	-			-	
C062B	81-87	Overburden	27 May 2006	Constant Rate	2	5	0.7	0.1	1×10^{-6}	-	Interrupted test
			30 May 2006	Constant Rate	10	120	0.4	0.06	7×10^{-7}	-	Early data
							0.08	0.01	1.5×10^{-7}		Late data
C072B	42-45	Alluvium / weathered Permian	20 March 2006	Constant Rate	13	30	1.2	0.4	5×10^{-6}	-	
C078A	87-90 and 96-99	Donaldson Seam	2 June 2006	Constant Rate	2	120	0.4	0.07	8×10^{-7}	-	
C078B	18-24	Alluvium / weathered Permian	30 May 2006	Constant Rate	11	60	0.2	0.07	8×10^{-7}	-	
C081B	14-20	Alluvium / weathered Permian	22 March 2006	Constant Rate	13	75	2.4	0.4	4×10^{-6}	-	
C082	14-20	Alluvium / weathered Permian	22 March 2006	Constant Rate	13	160	0.3	0.05	6×10^{-7}	-	
C087	12-18	Alluvium / weathered Permian								-	No test – pumped dry in 4 minutes
Bloomfield Monitoring Bores:											
BL03A	?		14 April 2006	Slug test	-	-	-	1.3	1.6×10^{-5}	-	
BLO4	?		14 April 2006	Slug Test	-	-	-	0.02	3×10^{-7}	-	
BL05	?		14 April 2006	Slug Test	-	-	-	0.04	5×10^{-7}	-	
BL07	?		13 April 2006	Slug Test	-	-	-	2.3	3×10^{-5}	-	
Donaldson Piezometers:											
DPZ1	16.5-26.9	L Donaldson and Big Ben Seams	31 July 1997	Slug Test	-	-	-	0.08	9.6×10^{-7}	-	
	17.4-17.6	Mudstone	4 Sept 1997	Lab K Test	-	-	-	0.0003	3×10^{-9}	-	Kh
								0.0001	1×10^{-9}	-	Kv
	18.5-18.6	Mudstone	4 Sept 1997	Lab K Test	-	-	-	0.0037	4×10^{-8}	-	Kh
								0.0008	9×10^{-9}	-	Kv
DPZ4	12.8-13.0	Interbedded sandstone / mudstone	4 Sept 1997	Lab K Test	-	-	-	0.0015	2×10^{-8}	-	Kh
								0.0005	5×10^{-9}	-	Kv

Table 2: Hydraulic Testing Program – Piezometers and Monitoring Bores

Piezometer / Test Bore	Test Interval	Aquifer / Lithology	Date of Test	Type of Test	Pumping Rate	Duration min	Transmissivity	Average Hydraulic Conductivity		Storativity	Comments
					kL/d		m^2/d	m/d	m/s		
	20.0-20.2	Mudstone	4 Sept 1997	Lab K Test	-	-	-	0.0015	2×10^{-8}	-	Kh
								0.0002	2×10^{-9}	-	Kv
	35.7-35.9	Interbedded sandstone / mudstone	4 Sept 1997	Lab K Test	-	-	-	0.0014	1.6×10^{-8}	-	Kh
								0.0001	1×10^{-9}	-	Kv
	37.0-37.2	Sandstone (very coarse)	4 Sept 1997	Lab K Test	-	-	-	1.3	1.5×10^{-5}	-	Kh
								0.19	2.2×10^{-6}	-	Kv
DPZ7	22.9-34.9	L Donaldson Seam	30 June 1997	Slug Test	-	-	-	0.002	1.4×10^{-8}	-	
	18.4-18.6	Sandstone	4 Sept 1997	Lab K Test	-	-	-	0.0015	1.7×10^{-8}	-	Kh
								0.0009	1×10^{-8}	-	Kv
DPZ8	22-32	L Donaldson and Big Ben Seams	30 June 1997	Slug Test	-	-	-	0.17	1.9×10^{-6}	-	
DPZ9	12.5-36.5	U/L Donaldson and Big Ben Seams	30 June 1997	Slug Test	-	-	-	0.02	2.3×10^{-7}	-	
DPZ14	24-32	Buchanan and Ashtonfield Seams	26 July 2001	Slug Test	-	-	-	0.7	8×10^{-6}	-	Early data (Gravel pack?)
								0.02	2.5×10^{-7}	-	Late data (formation?)
DPZ15	41-47	Buchanan and Ashtonfield Seams	26 July 2001	Slug Test	-	-	-	0.3	3×10^{-6}	-	Early data (Gravel pack?)
								0.009	1×10^{-7}	-	Late data (formation?)
DPZ16	21-24	Ashtonfield Seam	26 July 2001	Slug Test	-	-	-	0.4	4×10^{-6}	-	Early data (Gravel pack?)
								0.04	3×10^{-7}	-	Late data (formation?)
Tasman:											
ODO003	113-131	Fassifern Seam	7 December 2001	Slug Test	-	-	-	0.002	2×10^{-8}	-	
TAS011	26-38	Fassifern Seam	7 December 2001	Slug Test	-	-	-	1.25	1.5×10^{-5}	-	
TAS012	90.5-105.5	Overburden above Fassifern	7 December 2001	Slug Test	-	-	-	0.15	1.7×10^{-6}	-	Early data (Gravel pack?)
			7 December 2001	Slug Test	-	-	-	0.3	4×10^{-6}	-	Late data (formation?)
TAS014a	38-50	Fassifern Seam	7 December 2001	Slug Test	-	-	-	0.25	3×10^{-6}	-	

2.6 Water Sampling and Analysis

Water samples have been collected from the Abel standpipe piezometers and Bloomfield monitoring bores, and submitted to NATA-accredited laboratory ALS Environmental for detailed chemical analysis. Electrical conductivity (EC) and pH were measured in the field at the time of sampling.

The laboratory analysis results are presented in **Table 3**. Water analysis results from previous sampling of the Donaldson and Tasman bores are included in **Table 3**.

The main water quality characteristics of groundwater from within the Abel lease area are as follows:

Salinity

Salinity is variable, ranging from 518 to 13000 mg/L total dissolved solids (TDS).

pH

pH is close to neutral. Two samples with reported pH in the range 11-12 (C082 and C087) are believed to be affected by residual affects of cement grout.

Dissolved Metals

Limited sampling of dissolved metals revealed generally low concentrations relative to ANZECC (2000) freshwater ecosystem protection guidelines. Dissolved iron concentrations are relatively high in some samples.

Nutrients

Limited sampling for nutrients revealed concentrations ranging from 0.3 to 13 mg/L ammonia (as N). The 13mg/L was reported from one of the cement-affected bores (C082).

2.7 Surface Water Quality

Surface water samples were collected from five sites on and near the Abel project lease and subjected to laboratory analysis. The results are presented in **Table 3**, together with a summary of relevant previous water quality monitoring on the Tasman and Donaldson projects.

Table 3: Groundwater Sample Analysis Results
(page 1 of 2)

Bore/Stream				C062A	C062B	C072A	C072B	C078A	C078B	C081B	C082	C087	Blue Gum Upstream	Blue Gum Downstream	Tasman Creek	Viney Creek Downstream
Parameter	**Units**	**LOR**	**ANZECC (2000) Guideline Value for Freshwater Ecosystem Protection**	**27-May-06**	**30-May-06**		**20-Mar-06**	**30-May-06**	**30-May-06**	**20-Mar-06**	**20-Mar-06**	**29-May-06**	**04-Apr-06**	**04-Apr-06**	**04-Apr-06**	**04-Apr-06**
pH Value		**0.01**		7.26	6.64		7.19	6.94	7.23	7.36	12.20	11.90	6.90	6.90	5.40	6.70
Sodium Adsorption Ratio				2.48	34.02		12.59	10.91	34.65	35.86	22.59	28.94	2.29	4.46	3.38	2.42
Conductivity @ 25ºC	µS/cm	**1**		904	10200		3800	3140	23400	10300	2770	3220	275	860	240	355
Total Dissolved Solids (TDS)	mg/L	**1**		518	8890		2460	2070	13000	7440	2230	1980	185	575	160	235
Total Suspended Solids (TSS)	mg/L												266	20	1260	13
Calcium	mg/L	**1**		21	68		103	109	163	70	27	42	9.6	26	3.6	11
Magnesium	mg/L	**1**		34	266		73	72	499	137	<1	<1	8.2	21	10	10
Sodium	mg/L	**1**		79	2780		683	598	3950	2240	439	681	40	126	55	46
Potassium	mg/L	**1**		40	33		16	12	45	45	8	24	3.5	10	5	8.8
Hydroxide Alk as $CaCO_3$	mg/L	**1**		<1	<1		<1	<1	<1	<1	146	87				
Carbonate Alk as $CaCO_3$	mg/L	**1**		<1	<1		<1	<1	<1	<1	119	88	<2	<2	<2	<2
Bicarbonate Alk as $CaCO_3$	mg/L	**1**		249	686		539	515	1220	1210	265	<1	61	145	9	88
Sulphate	mg/L	**1**		62	888		160	84	1070	46	323	235	<2	6	8	<2
Chloride	mg/L	**1**		92.2	4620		1100	1010	6970	3550	388	930	46	170	50	99
Aluminium - Filtered	mg/L	**0.1/0.01**	**0.055**				0.01			<0.01	1.46					
Arsenic - Filtered	mg/L	**0.01/0.001**	**0.013**				<0.001			0.011	0.006					
Cadmium - Filtered	mg/L	**0.005/0.0001**	**0.0002**				<0.0001			<0.0001	<0.0001					
Chromium - Filtered	mg/L	**0.01/0.001**	**ID**				0.002			0.001	0.002					
Copper - Filtered	mg/L	**0.01/0.001**	**0.0014**				<0.001			<0.001	0.004					
Lead - Filtered	mg/L	**0.01/0.001**	**0.0034**				<0.001			<0.001	<0.001					
Manganese - Filtered	mg/L	**0.01**	**1.9**				1.29			0.539	<0.001					
Nickel - Filtered	mg/L	**0.01/0.001**	**0.011**				0.008			0.003	0.006					
Selenium - Filtered	mg/L	**0.01**	**0.005**				<0.01			<0.01	<0.01					
Silver - Filtered	mg/L	**0.001**	**0.00005**				<0.001			0.001	<0.001					
Zinc - Filtered	mg/L	**0.01/0.001**	**0.008**				0.006			<0.005	<0.005					
Boron - Filtered	mg/L	**0.1/0.01**	**0.37**				0.12			0.99	0.07					
Iron - Filtered	mg/L	**0.1**	**ID**				1.56			2.13	<0.05					
Mercury - Filtered	mg/L	**0.0001**	**0.00006**				<0.0001			<0.0001	<0.0001					
Ammonia as N	mg/L	**0.01**	**0.9**				0.283			4.02	13.4					
Nitrite as N	mg/L	**0.01**					<0.01			<0.01	0.042					
Nitrate as N	mg/L	**0.01**	**0.7**				0.085			<0.01	0.116					
Total Kjeldahl Nitrogen as N	mg/L	**0.1**					3.3			7.2	15					
Total Phosphorus as P	mg/L	**0.01**					0.04			0.23	0.14					
Reactive Phosphorus as P	mg/L	**0.01**					0.034			0.035	0.029					
Total Cations (reported)	meq/L	**0.01**		8.24	162		41.2	40.5	243		21.6	34.6				
Total Anions (reported)	meq/L	**0.01**		8.3	147		45.1	37.7	222		23	32.4				
Anion-Cation Difference (reported)	meq/L	**0.01**		0.38%	4.93%		4.47%	3.59%	4.58%		3.06%	3.40%				
Allowable Anion-Cation Difference (reptd)	meq/L	**0.01**		2.00%	5.00%		5.00%	5.00%	5.00%		5.00%	5.00%				
Anion-Cation Difference (reported)	%															
Allowable Anion-Cation Difference (reptd)	%															
Total Cations (calculated)	meq/L	**0.01**		8.30	147.05		41.26	37.68	222.16	114.00	20.73	32.33	2.98	8.76	3.52	114.00
Total Anions (calculated)	meq/L	**0.01**		8.87	162.53		45.13	40.53	243.28	125.00	22.97	31.13	2.56	7.82	1.76	125.00
% Difference (calculated)	%	**0.01**		-3.28%	-5.00%		-4.48%	-3.64%	-4.54%	4.88%	-5.12%	1.90%	7.67%	5.69%	33.44%	4.88%
Allowed % Difference (calculated)	%	**0.01**		2.00%	2.00%		2.00%	2.00%	2.00%	2.00%	5.00%	2.00%	2.00%	2.00%	2.00%	2.00%

Table 3: Groundwater Sample Analysis Results
(page 2 of 2)

Bore/Stream				DPZ1	DPZ2	DPZ3	DPZ4	DPZ5	DPZ6	DPZ7	DPZ8	DPZ9	DPZ10	DPZ11	DPZ12	DPZ13	BL01	BL04
Parameter	**Units**	**LOR**	**ANZECC (2000) Guideline Value for Freshwater Ecosystem Protection**															
pH Value		**0.01**															6.58	7.11
Sodium Adsorption Ratio				7.26	19.12	17.45	13.51	9.09	11.30	11.59	9.28	8.61	11.03	27.56	19.60	23.52	13.22	13.72
Conductivity @ 25°C	µS/cm	**1**				5300	1700		3800	2300	1900	2600			3300		2700	2970
Total Dissolved Solids (TDS)	mg/L	**1**		770	900	2500	850	3600	1800	1100	1000	1200	2600	16000	1600	8900	2020	2110
Total Suspended Solids (TSS)	mg/L																	
Calcium	mg/L	**1**		9	11	81	8.6	99	56	18	18	32	49	140	19	130	67	76
Magnesium	mg/L	**1**		33	2.5	96	19	190	71	36	34	61	140	700	36	400	41	61
Sodium	mg/L	**1**		210	270	980	310	670	540	370	290	360	670	3600	630	2400	557	662
Potassium	mg/L	**1**		5.1	7.9	21	7.7	17	15	8.6	8.6	10	9.7	27	8.4	16	11	19
Hydroxide Alk as $CaCO_3$	mg/L	**1**															<1	<1
Carbonate Alk as $CaCO_3$	mg/L	**1**		0	0	0	0	0	0	0	0	0	0	0	0	0	<1	<1
Bicarbonate Alk as $CaCO_3$	mg/L	**1**		70	90	590	160	440	300	85	60	190	410	310	210	640	288	753
Sulphate	mg/L	**1**		130	110	170	52	540	56	47	75	39	130	1100	330	690	573	247
Chloride	mg/L	**1**		340	410	1300	410	1500	1000	620	510	660	1300	7300	600	4900	573	757
Aluminium - Filtered	mg/L	**0.1/0.01**	**0.055**															
Arsenic - Filtered	mg/L	**0.01/0.001**	**0.013**															
Cadmium - Filtered	mg/L	**0.005/0.0001**	**0.0002**															
Chromium - Filtered	mg/L	**0.01/0.001**	**ID**															
Copper - Filtered	mg/L	**0.01/0.001**	**0.0014**															
Lead - Filtered	mg/L	**0.01/0.001**	**0.0034**															
Manganese - Filtered	mg/L	**0.01**	**1.9**															
Nickel - Filtered	mg/L	**0.01/0.001**	**0.011**															
Selenium - Filtered	mg/L	**0.01**	**0.005**															
Silver - Filtered	mg/L	**0.001**	**0.00005**															
Zinc - Filtered	mg/L	**0.01/0.001**	**0.008**															
Boron - Filtered	mg/L	**0.1/0.01**	**0.37**															
Iron - Filtered	mg/L	**0.1**	**ID**	11	5	0.14	5.6	0.09	0.18	3.9	16	19	<0.06	7.2	0.39	<0.06		
Mercury - Filtered	mg/L	**0.0001**	**0.00006**															
Ammonia as N	mg/L	**0.01**	**0.9**															
Nitrite as N	mg/L	**0.01**																
Nitrate as N	mg/L	**0.01**	**0.7**															
Total Kjeldahl Nitrogen as N	mg/L	**0.1**																
Total Phosphorus as P	mg/L	**0.01**																
Reactive Phosphorus as P	mg/L	**0.01**																
Total Cations (reported)	meq/L	**0.01**															31.3	38.1
Total Anions (reported)	meq/L	**0.01**															33.8	41.5
Anion-Cation Difference (reported)	meq/L	**0.01**																
Allowable Anion-Cation Difference (reptd)	meq/L	**0.01**																
Anion-Cation Difference (reported)	%																4.00%	4.32%
Allowable Anion-Cation Difference (reptd)	%																	
Total Cations (calculated)	meq/L	**0.01**																
Total Anions (calculated)	meq/L	**0.01**																
% Difference (calculated)	%	**0.01**																
Allowed % Difference (calculated)	%	**0.01**																

3 DESCRIPTION OF THE EXISTING HYDROGEOLOGICAL ENVIRONMENT

3.1 Climate

Rainfall

The nearest long-term Bureau of Meteorology rain gauging stations to the Abel Project are listed in **Table 4**.

Table 4: Bureau of Meteorology Stations

Station No.	Location	Latitude	Longitude
61008	Campbells Hill (16 km NNE)	32.7000 S	151.5000 E
61009	Cessnock Post Office (20.4 km WNW)	32.8272 S	151.3661 E
61034	East Maitland Bowling Club (13.3 km NNE)	32.7483 S	151.5833 E
61223	Maryville (19 km East)	32.9131 S	151.7500 E
61242	Cessnock – Nulkaba (22 km WNW)	32.8093 S	151.3490 E

Analysis of the daily rainfall data since 1902 (ie. 99 years) from the nearest meteorological station at East Maitland, 5 km north of the proposed surface infrastructure development for the Abel Project, provides the following key characteristics shown in **Table 5**.

Table 5: Long Term Rainfall Data for East Maitland Station 61034

Rainfall	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Mean (mm)	89	94	96	87	70	84	58	52	55	65	62	81	895
Mean No of Raindays	7.9	7.8	7.7	7.7	6.7	7.5	6.6	6.2	6.2	7.4	6.5	6.4	85

The annual rainfall at the East Maitland site exhibits a moderate seasonal pattern with the highest mean rainfall occurring during the December to June period and lower rainfall between July and November. No evaporation data is available from the East Maitland meteorological station.

Evapotranspiration

Average annual potential evapotranspiration for the Project area is around 1470 mm.

Table 6: Average Monthly Potential Evapotranspiration Rates for the Project Area (mm)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total
mm	182	143	127	96	68	57	67	93	120	149	167	200	1470

Average of Cessnock and Paterson Stations - Source: Bureau of Meteorology (2001)

A comparison between monthly average rainfall and monthly average potential evapotranspiration over the year, indicates that on average the area has an excess evaporative capacity over rainfall in all months. There is variability in monthly rainfall and there would be periods when rainfall could exceed evapotranspiration during the winter months.

3.2 Geology

The project area is underlain by Permian Tomago and Newcastle Coal Measures (**Figure 6**). The target coal seam of the proposed Abel mine is the Donaldson Seam, which divides into separate Upper and Lower units in the southern half of the lease. Sediments above and below the coal seams comprise predominantly interbedded mudstone, siltstone and sandstone. The strata dip generally towards the south and south-east, although the structure is complicated by the presence of faults.

Surface topography is generally in the range 15 to 150 mAHD in the Abel area.

The West Borehole Seam is present only in the southern part of the Abel mining lease (**Figure 6**), and was the subject of previous mining. It is stratigraphically about 200m above the Donaldson Seam, on average 7.7 m thick, and crops out in the south-west of the project area. Due to the dip of the strata, the seam reaches depths of over 200 m below surface in the south of the study area, while it is absent due to erosion in the north (**Figure 7**).

Other coal seams of lesser importance between the West Borehole and Donaldson seams include the Sandgate, Buttai and Beresfield seams.

The Upper and Lower Donaldson seams are on average 1.5 and 2.2 m thick, respectively. The seams are present throughout the proposed Abel mining area and outcrop at about 800 m north of the site. Due to the southerly dip, the seams reach depths of about -360 mAHD in the south of the study area (**Figure 7**).

Around the Pambalong Nature Reserve, Hexham Swamp and the floodplain of the Hunter River to the east of the site, the bedrock is overlain by Quaternary alluvial deposits including gravel, sand, silt and clay. Alluvial development extends upstream from Pambalong for some distance along the lower reaches of Blue Gum Creek and Long Gully. To the west, alluvial sediments also occur along Wallis Creek. Elsewhere, minor intermittent occurrences of localised alluvium can be found in association with creek-lines.

The upper part of the Permian sequence is moderately to highly weathered to depths of up to 20-30 m.

3.3 Hydrogeology

Overall, the coal measures are poorly permeable, but in the study area permeability is generally highest in the coal seams and areas of significant fracturing or faulting. The interbedded sandstones and siltstones are of lower permeability (generally by at least one order of magnitude) and offer very limited intergranular porosity and little secondary permeability and storage in joints.

Groundwater also occurs in the alluvial overburden, which comprises mainly swamp, floodplain and estuarine sediments. There is believed to be very limited hydraulic connectivity between the alluvium and the coal measures.

The colluvium / weathered bedrock zone constitutes a minor aquifer up to about 20-30 m thick which blankets most of the area. Groundwater occurs locally within this zone and represents a discontinuous unconfined aquifer, that is believed to be in hydraulic connection locally with the surface stream system, but is hydraulically isolated from deeper groundwater within the Permian coal measures sequence.

A summary of representative aquifer properties of the hydrogeological units in the study area is given in **Table 7**. These are based on hydraulic testing on the Abel site, supplemented by previous investigations in the Tasman and Donaldson Mining area and experience in other parts of the Hunter Valley coalfields.

Table 7: Hydraulic Parameters of Hydrogeological Units

Units	Horizontal Hydraulic Conductivity (m/d)	Confined Storativity	Unconfined Specific Yield
Coal Seams	0.01 to 0.1	0.0001	0.01
Interburden (undisturbed)	0.001	0.00001	0.005
Interburden (disturbed through mining)	0.1 to 10	0.0001	0.01 to 0.05
Colluvium / weathered coal measures sediments	0.1 to 0.5	-	0.05
Alluvium	1 to 5	-	0.1

Horizontal hydraulic conductivity is considered to be at least 10 times higher than vertical hydraulic conductivity. This is generally supported by the results of laboratory testing on samples collected at the Donaldson site in 1997 (**Table 2**) which showed horizontal/vertical ratios of between 1.7 and 14 in solid rock samples. Much higher ratios are expected for bulk rock mass hydraulic conductivity, when fractures and bedding plane partings are included.

It is likely that enhanced hydraulic conductivity exists within the previously mined areas of the West Borehole seam, and disturbed overburden strata.

The extent and nature of subsidence and cracking associated with mining of the West Borehole seam is not known, nor is the extent to which the workings have become re-saturated following cessation of mining. However it is likely that there is a body of groundwater within the residual mine voids and fractured overburden, and that this zone would have a substantially higher hydraulic conductivity than the undisturbed coal measures sediments.

Groundwater flow within the coal measures is overall controlled by the recharge-discharge process, with recharge occurring to coal seams and other permeable zones where they outcrop in areas of elevated terrain, and then slow movement down-dip or along strike to areas of lower topography, with ultimate discharge probably to the ocean. There is believed to be a smaller component of vertical downward flow across the bedding within the coal measures.

Groundwater level contours for the Donaldson Seam show an overall pattern of flow to the east, south and west from a central ridge which extends southwards from the Donaldson project, and the flow pattern is largely independent of the local topography (**Figure 8**). The contours also show the influence of dewatering in the Donaldson Mine area with a prominent cone of depression located to the north of John Renshaw Drive.

A similar flow pattern is apparent generally for the rest of the coal measures. Groundwater levels are about 5 – 10 m higher in the overburden above the Donaldson Seam. There is a consistent pattern of lower pressure heads with depth in the coal measures.

However, groundwater levels in the near surface material, which includes alluvium, colluvium and weathered bedrock, show a much closer relationship to the local topography. Near surface groundwater levels in shallow piezometers C072B, C078B and C087 reported groundwater levels of 50, 67 and 63 mAHD respectively (**Table 2**), in each case about 30-40 m higher than water levels in the Donaldson Seam at the same sites (ie C072VW, C072A, C078A and C087). However, the near surface groundwater level in bore C081B is 2.0 mAHD, which is 24m lower than the pressure head in the Donaldson Seam at the same location (C081A).

The groundwater levels in the deeper coal measures are not influenced by local topography, but rather by the elevations of the recharge zones (ie in updip areas where they outcrop). By contrast, the surficial groundwater levels are locally influenced, as they are recharged by infiltration of local rainfall and downward percolation to the water table.

Flow within the deeper coal measures is therefore believed to be more regionally controlled, whereas flow within the near-surface material is subject to local topographic influences.

The close correlation between groundwater levels in the alluvium around the wetlands of Pambalong Nature Reserve and the swamp water levels indicate that the alluvium and the swamp are in good hydraulic connection. However, the distinct lack of correlation between the deeper groundwater levels and the swamp levels show that there is negligible hydraulic connection between the swamps and the deeper groundwater.

3.4 Recharge and Discharge

Rainfall recharge occurs to both the coal seams where they outcrop, and to the alluvial aquifers. The alluvial aquifers are likely to be in hydraulic continuity with Hexham Swamp in the east and Wallis Creek to the west of the Abel mining area. During periods of high stream flow, surface water courses are likely to contribute to recharge to these alluvial aquifers. However, stream flows from rainfall runoff are reported to be short-lived after rainfall events.

The coal seams, where covered by overburden, are recharged mainly by flow along the bedding from elevated areas where the beds are exposed in outcrop, with minimal downward percolation through the overburden. After reaching the water table, flow is predominantly down-gradient along the more permeable horizons, but also with a smaller component of continuing downward flow to recharge underlying coal seam aquifers.

Rainfall recharge rates within the hard rock outcrop area are believed to be relatively low (below 10 mm/yr). However, where alluvial deposits occur, recharge rates may be as high as 100mm/yr.

Natural groundwater discharge occurs through evaporation, seepage and baseflow contributions to creeks, rivers and Hexham Swamp, where aquifer horizons outcrop in low lying areas. However, most natural discharge is believed to occur by slow downdip migration within the coal measures strata to the south and east, with ultimate discharge to the ocean.

3.5 Existing Groundwater Usage

Due to the generally high salinity and low bore yields, there is almost no existing groundwater abstraction in the study area other than for coal mine dewatering (Donaldson, Bloomfield, etc). Occasional small stock water supplies are drawn from near surface groundwater, such as the DNR registered bore GW51353 discussed in **Section 2.2**.

Incidental use of groundwater from the coal measures is believed to occur. A landholder south of John Renshaw Drive reported that groundwater inflow was observed to occur from a shallow coal seam (believed to be the Sandgate Seam) intersected during excavation of a dam. The salinity is reported to be too high for beneficial use, unless it is blended with low salinity surface runoff in the dam.

3.6 Groundwater Quality

The quality of groundwater sampled from within the Abel lease is variable, with total dissolved solids (TDS) ranging from less than 518 mg/L to 13,000 mg/L. The highest salinities are reported from the surficial groundwater, ie the colluvium / weathered Permian (13,000 mg/L TDS in C078B, and 7440 mg/L TDS in C081B) and the overburden (8890 mg/L TDS in C062B). The lowest reported salinity of 518 mg/L was from the Donaldson Seam at bore C062A.

The salinities reported from the Donaldson open cut area are also variable. They represent a broad spectrum of lithologies, including the coal seams (Donaldson Seam and others above and below) and various levels within the coal measures overburden. Salinities ranged from 770 to 16,000 mg/L TDS.

pH is close to neutral. Two samples reporting pH values of 11-12 (C082 and C087) are believed to be affected by the residual effects of cement grout.

The groundwater samples have been plotted on a Piper Trilinear diagram (**Figure 9**), which allows each sample to be plotted at a unique point on the basis of the relative concentrations of the major ions in solution – the cations calcium, magnesium, sodium and potassium, and the anions carbonate/bicarbonate, sulphate and chloride. This plot allows an assessment of the recharge-discharge processes, and also allows a comparison of water samples derived from different environments within the hydrological cycle. It can also be used to assess the possible mixing of waters from different sources.

Recently-recharged water tends to plot closer to the left-hand apex of the diamond field in the Piper diagram, and waters further from the source of recharge closer to the right-hand side.

Figure 9 is a composite plot of the groundwater samples from the Abel project area, and the Donaldson and Bloomfield sites, together with surface water samples collected from Blue Gum Creek, Tasman Creek (a Blue Gum Creek tributary on the Tasman project site) and Viney Creek close to the lease boundaries. The plot shows the Blue Gum Creek surface waters and the groundwater sample from bore C062A plotting near the centre of the Piper diamond, whereas the remaining groundwater samples and the surface water sample from Tasman Creek are grouped close to the right hand side of the diagram. It is interpreted that the Tasman Creek sample, despite its relatively low salinity, probably contains a significant component of groundwater baseflow, whereas the other surface samples are probably largely runoff.

3.7 Groundwater-Surface Water Interaction

Groundwater in the alluvium associated with Pambalong Nature Reserve and Hexham Swamp is believed to be in direct hydraulic connection with the surface water in these wetlands, based on close correlation between the surface water and groundwater levels. There is believed to be relatively free interchange of water between the alluvium and the surface water bodies, with the groundwater discharging to the surface water at most times, and possibly the in the reverse direction for short periods following periods of heavy rainfall.

The limited occurrences of localised surficial groundwater in the colluvium / weathered bedrock are believed to be in reasonable hydraulic connection with the high level streams, and there is expected to be some interchange of water between the creek-beds and the shallow weathered bedrock beneath. These localised occurrences of surficial groundwater do not represent a significant or regionally extensive aquifer system, and should really be considered to be an integral part of the surface water flow system.

On the other hand, there is believed to be minimal interaction between the surface drainage system (including the alluvial and other surficial groundwater), and the deeper groundwater within the coal measures. Likewise, there is believed to be limited interaction between groundwater in the alluvium and deeper groundwater in the coal measures.

4 ASSESSMENT OF POTENTIAL IMPACTS OF THE PROPOSAL ON THE GROUNDWATER SYSTEM

4.1 The Mining Proposal

The Abel project comprises a proposed underground mining operation in which coal will be recovered from the Donaldson and Ashtonfield Seams, as a down-dip extension from the Donaldson Open Cut.

The entry to the mine will be by way of a portal from the highwall of the Donaldson open cut, on the northern side of John Renshaw Drive. A number of roadways will be driven under John Renshaw Drive with normal underground mining commencing on the southern side of John Renshaw Drive and progressing southwards.

The mining method proposed for the Abel Underground Mine is a bord and pillar system with secondary extraction using high productivity continuous miners. This mining method has been selected to enable long term stable pillars to be left behind to provide surface protection where there is no other option to manage subsidence.

4.2 Groundwater Flow Model

A numerical groundwater flow model based on the MODFLOW package has been used to assess the potential impacts of the proposed mining operation. A detailed account of the modelling carried out for the Abel project is presented in **Appendix E**.

The modelling has been reviewed by an independent peer reviewer, Dr Noel Merrick. A copy of Dr Merrick's review report is also presented in **Appendix E**.

The model area of about 120 km^2 is shown in **Figure 10**. It includes the Abel and Donaldson mining areas and part of the Bloomfield operation, and extends to the north and west as far as the outcrop line of the Lower Donaldson seam, which is represented in the model using a no-flow boundary. The southern model boundary has been set at Northing 6,360,000, about 1.8 km south of the Abel mining area. At this latitude, the coal seam aquifers are overlain by considerable thickness of overburden – the Lower Donaldson seam occurs at a depth of about 240 m below surface in the west, increasing to over 400 m depth towards the east.

The depth of the coal seam aquifer units along the southern boundary warrants that only limited flow occurs across it. Additionally, it has been set far enough south to avoid any interference with the mining activities to be simulated in the Abel mining area to the north. This boundary has been represented numerically using a head-dependent flux (using MODFLOW's

General Head Boundary “GHB” package), with water level set to observed heads.

In model layers representing the coal seams and interburden material, the eastern boundary has been represented using GHB cells, as some groundwater flow may occur across the boundary towards the sea. This flow however is believed to be minimal with seams buried under more than 200 m of overburden at this location.

The eastern model boundary is located within Hexham Swamp at Easting 374000, about 2 km east of the N3 Freeway. The Hexham Swamp area (including the Pambalong Nature Reserve) has been represented using river cells, allowing water to flow into or leak out of the swamp according to the difference in heads between the aquifer and swamp.

For the steady state model, Wallis Creek has been represented using river cells to allow for stream-aquifer interaction due to leakage from the creek and/or baseflow from the alluvial aquifer. Smaller creeks, where flow is known to occur only through minor baseflow and after rainfall events, are represented using drain cells to allow for the predominant process of groundwater discharge (baseflow) to these minor streams. Such creeks included in the numerical model are Buttai Creek, Blue Gum Creek, Weakleys Flat Creek, Viney Creek and Four Mile Creek.

The cell size throughout the model is a uniform 100m by 100m.

The hydrogeology has been represented numerically with a 6 layer model (**Figure 11**), where coal seams and interburden are represented independently. Alluvial deposits are not represented as a specific single layer but are included in layers 1 to 6 according to their location and surface elevation.

Summary of model layers:

Layer 1: Interburden (undisturbed)
Layer 2: Interburden (disturbed “goaf” interburden section after mining)
Layer 3: West Borehole Seam
Layer 4: Interburden (undisturbed)
Layer 5: Interburden (disturbed “goaf” interburden section after mining)
Layer 6: Upper and Lower Donaldson Seams including the interburden between the seams.

The interburden above coal seams has been divided into two parts. The lower unit, a “goaf” zone of about 50 metres thickness immediately above the coal seams, represents the interburden where subsidence during and after mining may result in increased vertical and horizontal hydraulic conductivity (ie Layers 2 and 5). The upper unit represents the undisturbed interburden sediments (ie Layers 1 and 4). This delineation of a 50m “disturbed” layer above the mined seam is based on the likely continuous fracturing heights of 29m to 66m above the workings predicted by Strata Engineering (2006).

As the Lower and Upper Donaldson Seams are separated by a relatively thin interburden layer and are believed to act as a single hydrogeological unit, they are represented by one model layer.

Layers 1 to 3 are only present in the model within the area of occurrence of the West Borehole seam. Alluvium where it occurs has been represented in the uppermost active model layer, which is Layer 3 (ie alluvium is only present in areas where there is no West Borehole Seam).

Underground mining and dewatering activity has been represented in the model using drain cells within the mined coal seams (Layer 6). These have been emplaced where workings occur and progress in accordance with the mine plan requiring a transient model set-up.

Although the hydraulic properties of the coal seams and the overlying goaf would change following mining, MODFLOW does not permit these properties to be changed during a simulation. Therefore, for the base dewatering predictions, aquifer parameters were not changed progressively in the cells representing mined coal seams or the overlying goaf cells. However, for the post-mining recovery model run, aquifer properties of the interburden above the mine workings (Layer 5) have been changed to reflect the increased permeability of goaf zones. The effect of the change in hydraulic properties as mining proceeds has been evaluated in the sensitivity modelling (discussed in **Section 4.4**).

Given the current hydrogeological knowledge, using drain cells to model the underground development progressively down-dip is believed to adequately represent the flow processes. The drain conductance values used in the model have been derived during the modelling process, comparing the predicted leakage rates into the workings with the results of analytical calculations of inflow.

4.3 Model Calibration

The Abel groundwater model was run firstly in steady-state ("long term average") mode. Pre-mining conditions were simulated for the Abel mining lease area, while Donaldson mine dewatering north of John Renshaw Drive was included using drain cells. The modelled abstraction rate from Donaldson amounted to about 70 m^3/d, which is slightly lower than, but comparable to, the reported volumes being pumped at Donaldson.

Parameters of the calibrated steady-state model run are detailed in **Table 8** and are graphed in **Appendix E**. The calibrated model has a scaled RMS error of 6.07% and simulated water levels fit the observed pattern well (**Appendix E**).

The model simulates a vertical hydraulic gradient from higher to lower model layers within the coal and interburden layers, with lowest water levels being measured in the Donaldson Seam. Water levels in the Hexham swamp area are simulated to be around 1 to 4 mAHD, being perched and with very limited hydraulic connectivity to the layers below. The model has been calibrated to reflect the observed vertical hydraulic gradients by varying the vertical hydraulic conductivity.

Table 8: Abel Model Parameters after Calibration

<table>
<tr><th colspan="2">Layer</th><th>Kh [m/d]</th><th>Kv [m/d]</th><th>Confined S*</th><th>Unconfined Sy*</th></tr>
<tr><td>1</td><td>Interburden above WB seam (undisturbed)</td><td>0.001</td><td>0.0001</td><td>0.00001</td><td>0.005</td></tr>
<tr><td>2</td><td>Interburden above WB seam (undisturbed)</td><td>0.001</td><td>0.0001</td><td>0.00001</td><td>0.005</td></tr>
<tr><td rowspan="2">3</td><td>WB seam</td><td>0.15</td><td>0.001</td><td>0.0001</td><td>0.01</td></tr>
<tr><td>Alluvium</td><td>6.0</td><td>0.0005</td><td>0.0001</td><td>0.1</td></tr>
<tr><td rowspan="2">4</td><td rowspan="2">Interburden above LD/UD seam (undisturbed)</td><td>Under confinement: 0.001</td><td>0.0001</td><td rowspan="2">0.00001</td><td rowspan="2">0.005</td></tr>
<tr><td>At outcrop/Under Alluvium: 0.0005 - 0.01</td><td>under swamp: 0.00001</td></tr>
<tr><td>5</td><td>Interburden above LD/UD seam (undisturbed)</td><td>0.001
At outcrop : 0.005</td><td>0.00005</td><td>0.00001</td><td>0.005</td></tr>
<tr><td>6</td><td>LD/UD seam</td><td>0.1 – 0.001</td><td>0.001</td><td>0.0001</td><td>0.01</td></tr>
</table>

* only applicable for the transient model runs

The steady-state water balance is summarised in **Table 9**.

Table 9: Steady State Water Balance

	Recharge	Evapotranspiration	Drains (dewatering at Donaldson/Bloomfield and flow into creeks)	River flows	Flows across boundaries
Inflows into model [m^3/d]	1785	-	-	16.4	8.45
Outflows [m^3/d]	-	22	149	1402	236

Recharge was applied at rates of 1.5 to 3 mm/yr generally, except for the alluvium areas, which received 100mm/yr. Evapotranspiration is active in low lying area such as around creeks and the swamp area to the east, and operates at maximum rates of 250 mm/yr.

Due to limited detailed knowledge of pumping rates and schedules in the Bloomfield and Donaldson mine areas, the impact of these operations on the water table has been simulated in a simplistic way, using drain cells set to observed water levels in the area.

4.4 Predictive Modelling and Sensitivity Analysis

Having achieved satisfactory calibration of the model in steady-state mode, the groundwater model was applied to prediction simulations of mining from 2007 onwards as envisaged by the Abel mine plan. The model setup for the predictive modelling runs is described in detail in **Appendix E**.

The transient dewatering model comprised 11 stress periods. The duration of each stress period is detailed in **Table 10**. At 2027, a post-mining recovery model run was set up to simulate the recovery of the groundwater levels after mining operations have ceased.

Underground mining and dewatering activity is represented in the dewatering model using drain cells within the mined coal seam (Layer 6). These are emplaced where workings occur and progress in accordance with the mine plan. The drain conductivity has been set to double the Kv of the overlying interburden (ie resulting in a drain conductance of 0.01 m^2/d) in the actively mined area. This changes to a 5 times higher drain conductance (ie 0.05 m^2/d) for already mined out areas, to reflect the increased permeability of “goaf” zones above the mine workings.

Table 10: Stress Period Set-up of the Dewatering Model Run

Stress period	Time	Features implemented in the model
1	Jan 2007 – Dec 2007	The box-cut is being introduced north of John Renshaw Drive.
2	Jan 2008 – Dec 2009	Underground mining in Abel. Open cut mining in Donaldson progresses towards Abel portal
3	Jan 2010 – Dec 2011	Underground mining in Abel. Open cut mining in Donaldson progresses towards Abel portal
4	Jan 2012 – Dec 2013	Underground mining in Abel. Open cut mining in Donaldson has progressed to Abel portal and then ceases
5 to 11	Jan 2014 – Dec 2027	Underground mining in Abel progresses down-dip according to mine plan

For the post-mining recovery model run, aquifer properties of the interburden above the mine workings (Layer 5) have been changed to reflect the increased permeability of “goaf” zones, while drain cells have been switched off (**Table 11**).

Predicted groundwater inflow rates to the mine workings over time are shown in **Figure 12**. Seepage into the mine commences at 2008 and increases with the progressively enlarged underground mine area. By 2027, when the mine reaches its largest extent, a mine inflow rate of 3100 m^3/d is predicted. This is accompanied by a drawdown in hydraulic heads in the Donaldson Seam of about 60 m at the fringes of the mining lease and about 120 m in the centre of the area (**Figure 13**).

Figure 14 shows a less pronounced cone of depression in the undisturbed interburden above the Donaldson seam (model layer 4). The predicted maximum decline in heads is about 30 metres (ie to -10mAHD).

Table 11: Set-up of the Dewatering and Recovery Models

Layer		Dewatering run	Recovery run
1 to 2	Interburden above WB seam	No change to steady state model	No change to steady state model
3	Alluvium WB seam	No change to steady state model	No change to steady state model
4	Interburden above LD/UD (undisturbed)	No change to steady state model	No change to steady state model
5	Interburden above LD/UD (disturbed)	No change to steady state model	Aquifer parameters changed to reflect disturbed interburden (i.e. Kh, Kv times 100)
6	LD/UD seam	Introduction of drain cells in accordance with the mine plan. Drain conductance in actively mined area: 0.01 m^2/d, in mined-out areas: 0.05m^2/d	No change to steady state model. Drain cells are switched off.

A complete set of water table maps from 2008 onwards is presented in **Appendix E**. Prediction hydrographs for selected piezometer locations are also presented in **Appendix E**.

Following on from the dewatering phase, the recovery of the water table after mining ceases (ie after 2027) was simulated over a period of 60 years. Pressure heads in the Donaldson Seam are predicted to recover to 80% of the pre-mining levels within 6 years after cessation of mining. Undisturbed overburden groundwater levels show a much slower rate of recovery due to their lower permeability, and also show an apparent incomplete recovery. This is due to the increase in permeability of the goaf zone above the mined areas. The water balance flow volumes also show a return to pre-mining levels.

The results of the recovery modelling are presented in more detail in **Appendix E**.

The modelling predicts an insignificant decline in water levels in the alluvium around Pambalong Nature Reserve in the East, reaching a maximum of about 12 cm by 2029, ie 2 years after completion of mining, before commencing a post-mining recovery back to pre-mining levels (see Figures19 and 23 in **Appendix E**).

To assess the level of uncertainty in the modelling results, sensitivity analysis was carried out on the dewatering model, to derive upper and lower bounds for seepage rates into the mine workings over time, and the associated drawdown and recovery impacts.

The critical model parameter that most influences the seepage rate into the mine workings is the applied drain conductance. To establish its influence on model results, the drain conductance was systematically changed within a plausible range. **Table 12** summarises the sensitivity runs undertaken and the parameters applied.

Table 12: Summary of Sensitivity Modelling Runs

	Kh/Kv	S/Sy	Drain conductance (m^2/d)
Dewatering model	As per steady state model	See **Table 8**	Drain conductance: actively mined: $0.01m^2/d$, mined-out area: $0.05\ m^2/d$
Sensitivity Run 1	Parameters of dewatering model	Parameters of dewatering model	Drain conductances ÷ 2 (i.e. 0.001/0.025)
Sensitivity Run 2	Parameters of dewatering model	Parameters of dewatering model	Drain conductances x 2 (i.e. 0.02/0.1)
Sensitivity Run 3	Parameters of dewatering model	Parameters of dewatering model	Drain conductances ÷ 5 (i.e. 0.002/0.01)
Sensitivity Run 4	Kh/Kv x 100	Parameters of dewatering model	Parameters of dewatering model
Sensitivity Run 5	Parameters of dewatering model	Parameters of dewatering model	Drain conductances x 5 (i.e. 0.05/0.25)

The sensitivity analysis shows that predicted inflow rates to the mine workings increase with higher drain conductances, as the resistance to flow between interburden and mine workings is reduced. For the applied range of parameters, seepage rates were calculated to be in the order of 1500 m^3/d to 4500 m^3/d. For the highest drain conductance applied, the accompanying maximum reduction in piezometric heads in the Donaldson Seam is about 170 metres, which is regarded as the upper limit of likely drawdowns, based on experience in other areas of underground mine workings.

The model was then also run introducing the "goaf" zone parameters (ie higher vertical and horizontal permeability values) in the interburden above the Donaldson coal seam to establish the influence of enhanced permeability during mining.

Using disturbed aquifer properties during the prediction run (ie vertical and horizontal hydraulic conductances increased by two orders of magnitude) results in higher inflow rates and demonstrates the strong dependence of seepage volumes on the geological structure present.

In conclusion, the sensitivity analysis established a likely range of groundwater inflow rates to be expected in the Abel underground mine, which is between 1500 m^3/d and 4500 m^3/d. Based on experience of drawdowns observed in other underground mining operations, drawdowns of 100 to 150 m are plausible, which narrows the most likely rate of seepage to around 3100 m^3/d or 3.1 ML/day, based on the assumed aquifer properties.

It also should also be pointed out that, during the dewatering simulation, the cone of depression caused by the mining activity encroaches on the model boundaries. This is not ideal, as models should preferably extend beyond the zone of influence of any aquifer stresses to avoid boundary interference effects. However, the model was properly restricted to the area of detailed geological information. To reduce boundary effects in the chosen model area, the model design involved general-head boundaries, which were implemented to allow inflow and outflow over the model boundaries in response to changes in piezometric heads. This approach is believed to be adequate given the lack of information on layer geometry and heads on a more regional scale and ensures that the current model boundaries minimise any effect on model results.

As mining will be confined to shallow updip areas in the early years, a considerable amount of additional monitoring data will be collected from regional monitoring bores to enable improved assessment of model boundary impacts prior to mining approaching the southern and eastern model boundaries at depth.

4.5 Potential Impacts on Surficial Groundwater and Surface Water

Under present (pre-mining) conditions, there is a clear lack of hydraulic connection between the surface and near surface water resources, and the deeper groundwater within the Permian coal measures, as evidenced by the large differences in groundwater levels. The near surface groundwater levels are strongly influenced by local topography (ie local recharge and local discharge), whereas the deeper groundwater in the coal measures is responding to regional influences (ie recharge updip where the aquifers outcrop and discharge down-dip).

Thus the near-surface groundwater levels tend to mirror the topography, whereas the deeper groundwater levels show a more consistent pattern across the area, irrespective of the local topography. This is best illustrated at the site of piezometers C081A and C081B near Pambalong Nature Reserve (**Figure 2**), with C081A showing a water level (pressure head) in the Donaldson seam about 24 m above ground level, and C081B showing a water level almost at ground level in the alluvium.

The subsidence studies (Strata Engineering, 2006) have indicated that continuous cracking is likely to result in hydraulic connection for a distance of between 29 and 66 m above the proposed Abel workings, (or a credible worst case of 58 to 123 m in the event of adverse conditions). In the area of shallow cover depth in the northern part of the Abel project area, in the region shown hatched on **Figure …**, Strata Engineering predict that direct hydraulic connection may extend to the surface. However, elsewhere throughout the lease area, the depth of cover is such that direct hydraulic connection with the surface is not expected to occur.

The area of potential direct hydraulic connection to the surface does not contain any regionally significant alluvium.

As shown by the predictive modelling, there is potential for leakage of groundwater from higher levels in the Permian coal measures above the predicted zone of continuous cracking, but this would occur by natural leakage through the relatively low permeability strata, and not by the creation of a direct fracture-induced pathway.

4.6 Potential Impacts on Pambalong Nature Reserve and Hexham Swamp

As discussed above in **Section 4.5**, the prevailing groundwater levels in the coal measures beneath Pambalong Nature Reserve indicate that there is negligible hydraulic connection between the Donaldson Seam aquifer and the surface wetland. The depth of cover above the Upper Donaldson seam in this vicinity is around 150m.

The Pambalong Nature Reserve has been totally excluded from the proposed Abel mining area. Further, it is not proposed to mine by total extraction methods beneath the Blue Gum Creek alluvial valley that extends south-westwards from Pambalong. The closest proposed area of total extraction mining to Pambalong Nature Reserve is approximately 300m laterally from the north-western margin of the wetland. This is beyond the buffer zone required by the DNR Guideline for mining near streams and alluvial aquifers (DNR, 2005). As a result, negligible subsidence impacts are predicted to occur beneath the Pambalong wetland.

Strata Engineering (2006) have predicted that the maximum extent of continuous sub-surface fracturing above the Donaldson seam at the closest point to Pambalong Nature Reserve would be around 50 m, or a credible worst case height of around 120 m above the seam level in the event of adverse conditions. On this basis, it is not expected that the sub-surface cracking will allow direct hydraulic interconnection between the workings and the surface or any near-surface groundwater in the vicinity of Pambalong Nature Reserve.

This is supported by the groundwater model predictions. The groundwater modelling has predicted that drawdown in the alluvial aquifer at the location of piezometer C081B, near the western side of Pambalong Nature Reserve, would reach 10cm by the conclusion of mining in 2027, and would reach a maximum of 12cm by 2029 before starting to recover back to the pre-mining water levels. This predicted drawdown would occur by indirect flow, ie by leakage through the low permeability coal measures strata beneath the alluvium. A 10-12cm drawdown is much less than the seasonal variation in water levels that has been observed even in the short period of monitoring of bore C081B (Figure C2 in **Appendix C**).

4.7 Potential Impacts on Groundwater Quality

It is expected that the quality of groundwater inflows to the Abel underground mine will initially be similar to the current groundwater inflow to the Donaldson open cut, with TDS around 1500-2000 mg/L and pH around 7. Over time, a gradual increase in salinity may occur, to an eventual salinity of around 3000-4000 mg/L TDS.

It is proposed to maintain a no-discharge water management strategy for the project, with all water derived from groundwater inflows to be either used for coal washing, dust suppression or other project uses, or contained in storage within the project area. No water releases are anticipated, so it is expected that the project will not have any adverse impacts on surface water quality.

Following completion of the project and recovery of groundwater levels, groundwater levels will remain below ground level in the vicinity of the mine portal, and there is not expected to be any ongoing discharge of mine water.

In the event that there is any reduction in groundwater baseflow contribution to the surface streams within the predicted subsidence impact areas, the impact on water quality in the streams would be beneficial, as the groundwater quality is commonly poorer than the quality of surface runoff.

4.8 Potential Impacts of Proposed Tailings Disposal

Coal from the Bloomfield and Donaldson projects is currently processed through a coal washery plant located on the Bloomfield project site. Tailings from the washery are discharged into former underground workings via a former shaft located in the northern part of the lease (**Figure 2**). Prior to 2003, tailings were deposited into the U open cut north of the present discharge point (**Figure 2**).

Water is recovered from the tailings by pumping from a downdip borehole BH01 located about 2 km south of the discharge shaft (**Figure 2**). The water pumped from BH01 would comprise water segregating from the deposited tailings and groundwater inflows. This recovery point is believed to represent a local sump for groundwater in the Bloomfield lease area.

The water level is regularly monitored in BH01, and the hydrograph (**Figure 15**) shows that the water level has been consistently between about -5 and -15 mAHD since 2001.

Additional groundwater sumps exist in the open cuts, and water is currently pumped from sumps in the U Cut, Creek Cut and S Cut (**Figure 2**). The sump in S Cut near the southern boundary of the Bloomfield lease is located at an RL of -60 mAHD. This is believed to be the primary groundwater “sink” for the lease area. Groundwater levels in nearby bores BL03A and BL03B are currently at -4.5 and +14.3 mAHD respectively, which are more than 15m lower than the water level in the closest Abel bore measuring water level in the coal measures (C078A about 1 km to the south – see **Figure 2**).

The current practice of tailings disposal and recovery of water from BH01, as well as the sump pumping from the open cuts, in particular S Cut, is maintaining a groundwater “sink” within the Bloomfield lease. Thus groundwater currently flows generally towards the lease, and there is believed to be no off-site discharge of tailings leachate or other contaminated groundwater.

It is proposed to process the Abel coal through the Bloomfield coal washery, as well as continued processing of coal from Donaldson and Bloomfield. Tasman project coal will also be processed here as well when it comes on stream. The expansion of the coal washery to accommodate the additional throughput will require additional water supply, which will be partly derived from groundwater inflows to Abel, but will require continued pumping from BH01 and from the open cut sumps. Thus the additional volume of tailings disposal in the former underground workings will be offset by additional water abstractions from borehole BH01, maintaining this location as a groundwater "sink", and groundwater will continue to flow inwards towards the Bloomfield lease.

In the event that the remaining underground storage capacity for tailings is exhausted, it is proposed to revert to open cut disposal again. Sufficient storage is available in the underground workings and open cuts to accommodate tailings for the proposed life of the Abel project (Evans and Peck, 2006).

5 MONITORING AND MANAGEMENT RECOMMENDATIONS

It is recommended that the monitoring program currently operating at the Donaldson mine be continued and expanded to include the Abel, Tasman and Bloomfield areas, as an integrated monitoring system covering all four sites. It should also be integrated with the surface water monitoring program.

The groundwater monitoring program would include:

- Monthly measurement of water levels in a representative network of piezometers. Initially, all piezometers currently available would be monitored, however it is recommended that the representativeness of the piezometers be reviewed after the first two years of the project, and an appropriate suite of piezometers be selected on the basis of this review for ongoing monitoring. All piezometers located around Pambalong Nature Reserve would continue to be monitored through the life of the project.

- Quarterly sampling of all standpipe piezometers, for laboratory analysis of electrical conductivity (EC), total dissolved solids (TDS) and pH.

- Annual collection of water samples from all standpipe piezometers for laboratory analysis of a broader suite of parameters

    ◊ Physical properties (EC, TDS and pH)
    ◊ Major cations and anions
    ◊ Nutrients
    ◊ Dissolved metals

- Weekly measurement of the volume of mine water pumped from the underground workings. Separate inflow rates should be monitored if tow or more separate mining areas are active at any time.

- Weekly measurement on site of the EC, TDS and pH of the mine water pumped from the underground workings.

Additional regional monitoring piezometers are recommended in the following areas to resolve some of the existing hydrogeological uncertainties and to provide a more comprehensive monitoring network near the sensitive ecosystems:

- Multi-level piezometers to the north and west of Pambalong Nature Reserve, to provide additional data on groundwater pressures in the intervening strata between the Donaldson seams and the alluvium (supplementing the existing data from piezometers C081A and B and C082).

- Multi-level piezometers along the eastern side of the Abel project area, located at nominally 3 sites between the F3 Freeway and the lease boundary, to resolve the apparent anomalous water levels below sea level at C063A and B, and to provide additional data on groundwater pressures in the intervening strata between the Donaldson seams and the Hexham Swamp alluvium.

- Multi-level piezometers near the western and southern boundaries of the Abel project area to provide information on groundwater pressures at various depths, as this area currently lacks monitoring points. These piezometers would also aim to provide information on the current status of groundwater in the West Borehole seam near the former workings, prior to mining of the Donaldson seams approaching that area.

The additional Pambalong and Hexham Swamp monitoring bores should be installed prior to commencement of coal extraction. The western piezometers should be installed at least five years prior to mining reaching that part of the lease, ie by around 2013.

A comprehensive monitoring program is also recommended to assess the development of sub-surface fracturing above the underground mining areas. It is recommended that a monitoring network of multi-level piezometers and extensometers be installed above the first 4 or 5 extraction panels, which will be near the northern-central and north-eastern part of the project area. This is the area with shallowest cover depths (**Figure …**). The monitoring network will aim to verify the predicted fracture heights as reported by Strata Engineering (2006), and the associated impacts on groundwater levels/pressures and hydraulic properties of the strata.

The subsidence/fracturing monitoring piezometer network should comprise the following:

- Multi-level piezometers situated centrally within the extraction panels (at least 2 locations per panel) with vibrating wire piezometers set at nominally 30m intervals from the surface down to 30m above the Upper Donaldson roof level.

- Shallow standpipe piezometers adjacent to each of the above multi-level piezometers, set to the base of the colluvium/weathered bedrock zone, to monitor any impact on the surficial unconfined aquifer. Standpipe piezometers will allow repeat hydraulic testing and water quality sampling, as well as water level monitoring.

The above monitoring network would be implemented prior to commencement of each extraction panel, and would be monitored closely before, during and after extraction. Based on the monitoring results during extraction of the first 4 or 5 panels, an appropriate ongoing monitoring program would be developed for the subsequent deeper panels as the mining progresses downdip.

It is also recommended that the following response plan be implemented in the event of significant unforeseen variances from the predicted inflow rates and/or groundwater level impacts:

- Additional sampling and/or water level measurements to confirm the variance from expected behaviour.

- Immediate referral to a competent hydrogeologist for assessment of the significance of the variance from expected behaviour. The review hydrogeologist would be requested to recommend an appropriate remedial action plan or amendment to the mining or water management approach. If appropriate, this recommended action plan would be discussed with DNR and other agencies for endorsement.

It is further recommended that at the end of the second year of underground mining, a comprehensive review be undertaken of the performance of the groundwater system. This would include re-running the groundwater model in transient calibration mode, to verify that the actual inflow rates and groundwater level impacts are in accordance with the model predictions described in this report. If necessary, further adjustment would be made to the model at that time, and new forward predictions of mine inflows and water level impacts would be undertaken.

The groundwater model used for the simulation of impacts from the proposed Abel mine has been limited to the Donaldson seams and the coal measures stratigraphically overlying them. Thus the model does not extend north of the sub-crop line of the Lower Donaldson Seam, and does not therefore include all of the Bloomfield mining operation. This limitation was considered adequate for the purpose of predicting impacts from the Abel project.

The model does include the existing Donaldson open cut, however that operation has been simulated in a simplified fashion, rather than detailed simulation of the westward advance of the open cut and progressive backfilling with waste.

There is currently a groundwater depression centred on the deepest part of current mining in the open cuts near the southern boundary of the Bloomfield lease, and a lesser depression centred on the water recovery bore into the former underground Big Ben workings which are the current depository for tailings from the coal washery. Hence the Bloomfield operation constitutes a regional groundwater sink.

Following the lodgement of the Abel Project environmental assessment documents, it is proposed to expand the current groundwater model to include deeper layers and an expanded area, that will incorporate the Bloomfield operations and areas of possible groundwater impact around Bloomfield. It is proposed to calibrate this expanded model with ongoing monitoring data from Bloomfield, and more detailed simulation of the Donaldson mining and backfilling.

6 CONCLUSIONS

The groundwater investigations carried out for the Abel Coal Project have led to the following principal conclusions:

- Groundwater is present in most lithologies in the area, but significant permeability is generally only present in association with fracturing and cleat development in the principal coal seams in the Permian coal measures. Lesser permeability may be present locally in interburden siltstones, mudstones and sandstones, and in the surficial alluvium / colluvium.

- Groundwater quality is variable, with salinity ranging from around 500 to more than 13000 mg/L total dissolved solids (TDS). pH is generally close to neutral.

- Groundwater levels in the Permian coal measures including the Donaldson Coal Seams generally fall to the east and west from a central ridge extending south from the Donaldson mine area, and range from around 35 mAHD near the central northern end of the project area to around 10-15 mAHD along the eastern boundary, and around 15-20m at the north-western corner. The groundwater levels in the Permian coal measures are unrelated to the local topography, and are frequently artesian (ie above ground level) in low-lying areas.

- Surficial groundwater levels in the alluvium / colluvium, probably including the thin upper highly weathered zone of the Permian coal measures are strongly controlled by the local topography, and appear to be unrelated to the groundwater in the underlying less weathered Permian coal measures. Thus the surficial groundwater water levels are above the Permian groundwater levels in elevated locations and below the Permian levels in low-lying areas.

- The dewatering operations at the Donaldson mine have caused a noticeable cone of drawdown in groundwater levels, ranging up to more than 30m (ie to around –15 mAHD) along the southern margin of the open cut. The cone of drawdown has extended only a short distance into the north-eastern part of the Abel lease area.

- The Donaldson mine dewatering appears to have had negligible impact on groundwater levels in the alluvium/colluvium, or in the Permian coal measures lithologies that are stratigraphically above the zones that have been directly intersected by the open cut.

- A less pronounced cone of depression has developed around the Bloomfield mining operations, most of which are situated north of the Donaldson Seam subcrop line. Near the southern boundary of the Bloomfield lease, mine dewatering appears to have resulted in drawdown in groundwater levels to around –30 mAHD.

- Dewatering will be required as part of the proposed mine developments. Modest groundwater inflows are predicted to the Abel underground mine, based on the most likely set of assumed hydraulic parameters. The total groundwater inflow rate is predicted to increase steadily through the project life, reaching a maximum of 3 ML/d by the 20 year mark.

- Sensitivity modelling suggests that the maximum inflow rates could be between about 1.5 and 4.5 ML/d.

- Initial average water quality of groundwater inflows to the Abel underground mine is expected to be similar to that currently entering the Donaldson open cut, with TDS around 1500-2000 mg/L and pH around 7. Over time, a steady increase in salinity may occur, to an eventual salinity of around 3000-4000 mg/L TDS.

- The dewatering associated with the proposed Abel mine is predicted to locally impact groundwater levels in the Donaldson Seam and the immediately overlying coal measures sediments. Drawdowns to below –100 mAHD are predicted for the sediments above the centre of mining activity as it progresses through the lease.

- There is believed to be negligible hydraulic interconnection between the Donaldson seams and the Hexham Swamp / Pambalong Nature Reserve. Limited connection was simulated in the groundwater modelling to assess a possible worst case condition. Drawdowns of just 10 cm at the completion of extraction, and a maximum of 12 cm two years after completion, and then recovery back to pre-mining levels, were predicted by the groundwater model for the alluvium adjacent to Pambalong Nature Reserve, and less beneath the main Hexham Swamp region to the east of the F3 freeway. In practice, no impact is expected.

- Recovery of groundwater levels after completion of mining have been assessed by 60 years of post-mining simulations. Pressure heads in the Donaldson Seam are predicted to recover to 80% of the pre-mining levels within 6 years after cessation of mining. Undisturbed overburden groundwater levels show a much slower rate of recovery due to their lower permeability, and also show an apparent incomplete recovery.

- Localised changes to the relative proportions of surface flow and surficial groundwater baseflow may occur as a result of subsidence effects. However, these two components should properly be considered as component parts of the surface water system, and are predicted to remain unconnected to the deeper groundwater.

- No adverse impacts on surface water quality are expected.

- No existing groundwater supplies are expected to be impacted.
- No adverse impacts are expected on any groundwater dependent ecosystems (GDEs).

7 GLOSSARY OF TERMS

aquifer	A saturated permeable unit of rock or soil which is able to transmit significant quantities of water under ordinary hydraulic gradients.
aquitard	A saturated unit of rock or soil that is capable of transmitting water to and between aquifers, but is not sufficiently permeable to allow water to flow into a bore a rate that will allow the bore to be pumped at a useful rate.
bedrock	In this report, bedrock refers to the geological unit that underlies the geological units that are active media for the movement of groundwater.
discharge	Groundwater discharge from an aquifer is the loss of water from the aquifer, either by natural processes (such as evapotranspiration, outflow to the ocean or other water body, or to another aquifer) or by artificial means (such as pumped extraction). Under conditions of dynamic equilibrium, the average rate of natural discharge from an aquifer is usually equivalent to the average long-term rate of recharge. See “recharge”.
DNR	Department of Natural Resources, formerly known as Department of Infrastructure, Planning and Natural Resources (DIPNR) or Department of Land and Water Conservation (DLWC).
drawdown	The lowering of the water level or the potentiometric head in an aquifer due to the removal of water from a nearby bore or excavation.
drain conductance	When the Drain Package has been used in a MODFLOW groundwater model to simulate open mine workings, the drain conductance term (units of m^2/d) represents the ease with which water can leak from an aquifer into the mine opening. It is an empirical term usually determined by calibration to field data. In the modelling described in this report, the open cuts and underground longwall panels have been represented by drain cells.
ephemeral	Temporary or seasonal.
groundwater	Water that occurs beneath the water table in rock or soil that is fully saturated.

groundwater modelling	Use of mathematical functions to simulate the flow of water below the ground surface.
groundwater table	See "water table".
head	The head in an aquifer is the height above a reference datum of the surface of a column of water that can be supported by the hydraulic pressure in the aquifer against atmospheric pressure. It equates to the elevation of the water table above the datum, and is the sum of the *elevation* head, or the elevation of the point of measurement, and the *pressure* head, or the pressure of the water at that point relative to atmospheric pressure.
hydraulic conductivity (K)	A measure of the ability of a rock or soil to transmit water under a prevailing hydraulic gradient. It has the units of metres/day. In this report, the term is used synonymously with the term "permeability". Hydraulic conductivity is often anisotropic, and the horizontal hydraulic conductivity (Kh) is usually higher than the vertical hydraulic conductivity (Kv).
hydraulic testing	Testing to determine the hydraulic properties (hydraulic conductivity, storativity, etc) of aquifers. Tests used in this study included pumping tests and slug tests.
hydraulic gradient	The change in head per unit distance in a particular direction, usually the direction of maximum change, perpendicular to the groundwater contours (equipotentials).
hydrogeological unit	A unit of rock or soil which has reasonably consistent hydraulic properties of permeability and storage
hydrograph	A linear plot of water level versus time.
infiltration	Movement of water through the surface of the ground into the saturated or unsaturated zone beneath.
lithology	A term used to describe the physical nature and characteristics of a rock or soil.
MODFLOW	A modular three-dimensional groundwater flow model which was developed by the USGS (McDonald and Harbaugh, 1988).

monitoring piezometer	Bore drilled in a location and constructed specifically to enable the sampling and ongoing measurement of groundwater levels, pressure changes and groundwater quality. It is ideally constructed so as to minimise the potential for contamination or interference from external influences, and to enable accurate and reliable sampling and hydraulic measurements from a specific aquifer or zone within an aquifer.
permeability	The permeability of a rock or soil is a measure of the ease with which fluids can flow through it, and is independent of the properties of the fluid. In this report, the term is used synonymously with the term "hydraulic conductivity".
Permian	Last period of the Paleozoic Era, 280 – 225 million years BP.
porosity	The proportion of a volume of rock or soil that is occupied by voids, or the ratio of the total void space to the total rock or soil volume. For the movement or release of water, only the proportion of porosity that is interconnected is significant, and is referred to as the "effective" porosity, which is often very much less than the total porosity. In a saturated material, the porosity comprises two components – the proportion of porosity that will freely drain under gravity, known as the specific yield, and the proportion that will not drain under gravity, known as the specific retention.
potentiometric surface	An imaginary surface defined by the heads at all points within a particular plane in an aquifer. Where the vertical component of hydraulic gradient is much smaller than the horizontal component, the potentiometric surface can be said to apply to the aquifer as a whole.
pumping test	Test carried out to determine hydraulic properties of the aquifer (hydraulic conductivity, storativity, etc).
recharge	Groundwater recharge is the addition of water to an aquifer, either by direct infiltration at the ground surface, by percolation through an unsaturated zone, or by inflow of discharge from another aquifer.

runoff	The portion of rainfall precipitation which collects on the surface and flows to surface streams.
saturated zone	That part of a soil or rock in which all the interconnected voids are filled with water under pressure equal to or greater than atmospheric pressure. The top of the saturated zone is defined by the surface at which the water pressure is equal to atmospheric pressure. [Parts of the saturated zone may be temporarily unsaturated due to air entrapment; likewise, in parts of the "unsaturated zone" the voids may be all filled with water, but at less than atmospheric pressure.]
slug test	A type of permeability test conducted by introducing to (or removing from) a bore, a known volume of water and monitoring the progressive return of the water level in the bore back to its former level.
specific yield	The volume of water that will freely drain under gravity from a unit volume of a saturated soil or rock per unit change in head.
storage coefficient	The volume of water that will drain freely from a unit volume of saturated soil or rock per unit change in head, by means of elastic compression of the aquifer fabric and decompression of the water.
storativity	A general term for both specific yield (gravity storage term) and storage coefficient (elastic storage term).
transmissivity	The rate at which water is transmitted through a unit width of an aquifer under a unit hydraulic gradient. It is equal to the product of the average hydraulic conductivity and the saturated thickness of the aquifer. It is expressed in units of metres^2/day.
water table	The surface within an unconfined aquifer at which the water pressure is equal to atmospheric pressure. It is defined by the level to which water would rise in a bore which just penetrates the top of the aquifer.

8 REFERENCES

Australian and New Zealand Environment and Conservation Council (ANZECC) / Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ), 2000. *Australian and New Zealand Guidelines for Fresh and Marine Water Quality.*

Bureau of Meteorology, 2001. *Climatic Atlas of Australia*.

Department of Infrastructure, Planning and Natural Resources (DIPNR), 2003. *Groundwater Monitoring Guidelines for Mine Sites Within the Hunter Region.* Rept prepared by J Williams, Sept 2003.

Department of Natural Resources (DNR), 2005. *Guidelines for Management of Stream/Aquifer Systems in Coal Mining Developments – Hunter Region*.

ESI, 2004. *Groundwater Vistas*. Version 4 User's Manual. URL: www.groundwatermodels.com

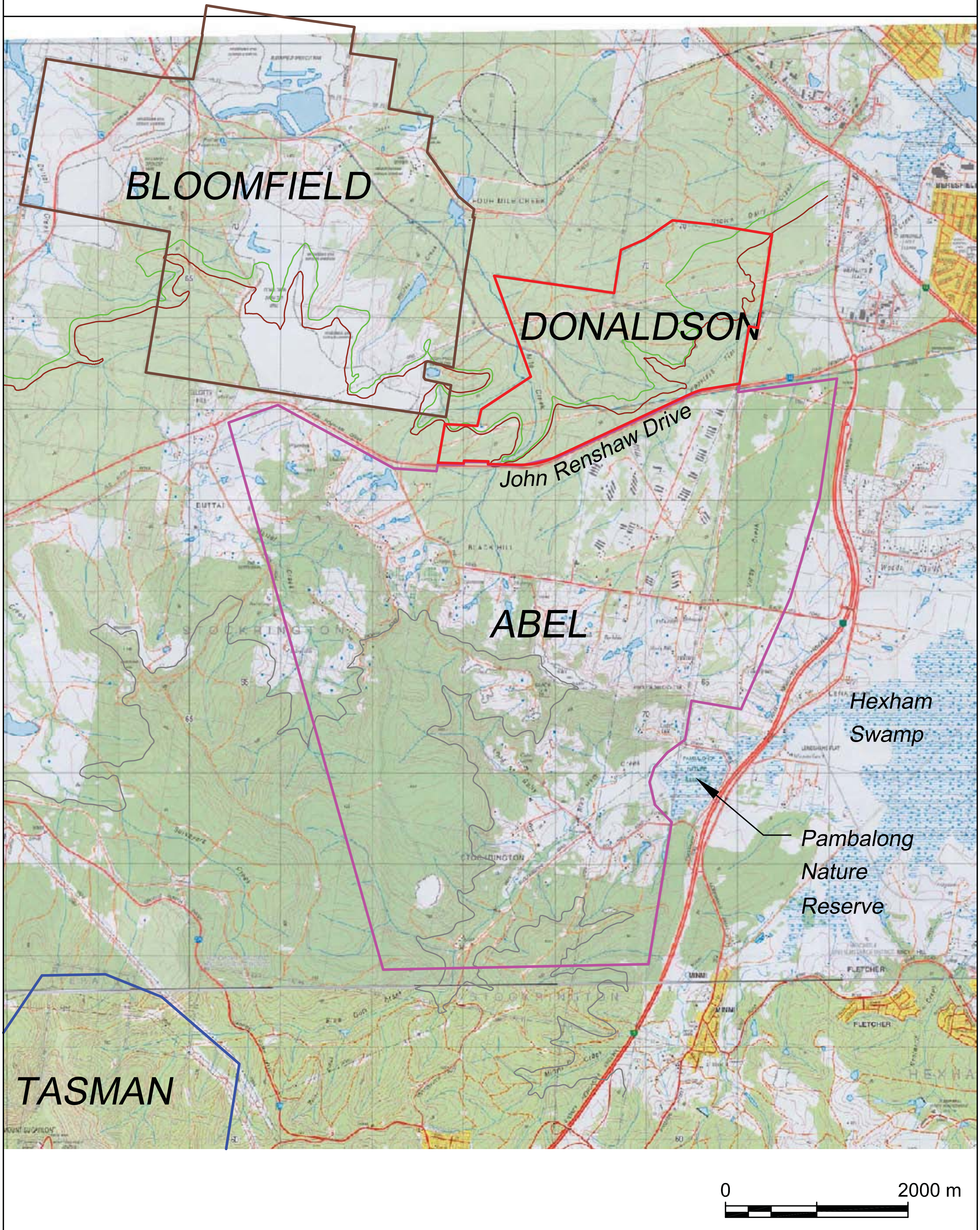
Evans and Peck, 2006. *Surface Water Assessment and Outline Water Management Plan.*

Healthy Rivers Commission, 2002. *Independent Inquiry into the Hunter River System.*

IES, 2006. *Processing MODFLOW Pro* Version 7.0.15 User's Manual. URL: http://www.iesinet.com/products/desktop_pmwin.php

Middlemis, H et al, 2001. *Groundwater flow modelling guideline.* Murray-Darling Basin Commission. URL: www.mdbc.gov.au/nrm/water_management/groundwater/groundwater_guides

Strata Engineering, 2006. *Mine Subsidence Impact Assessment for the Proposed Mine Layout and Extraction Panels, Abel Underground Mine.*



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Drawing No: 05-0163-008_A	Rev: A	
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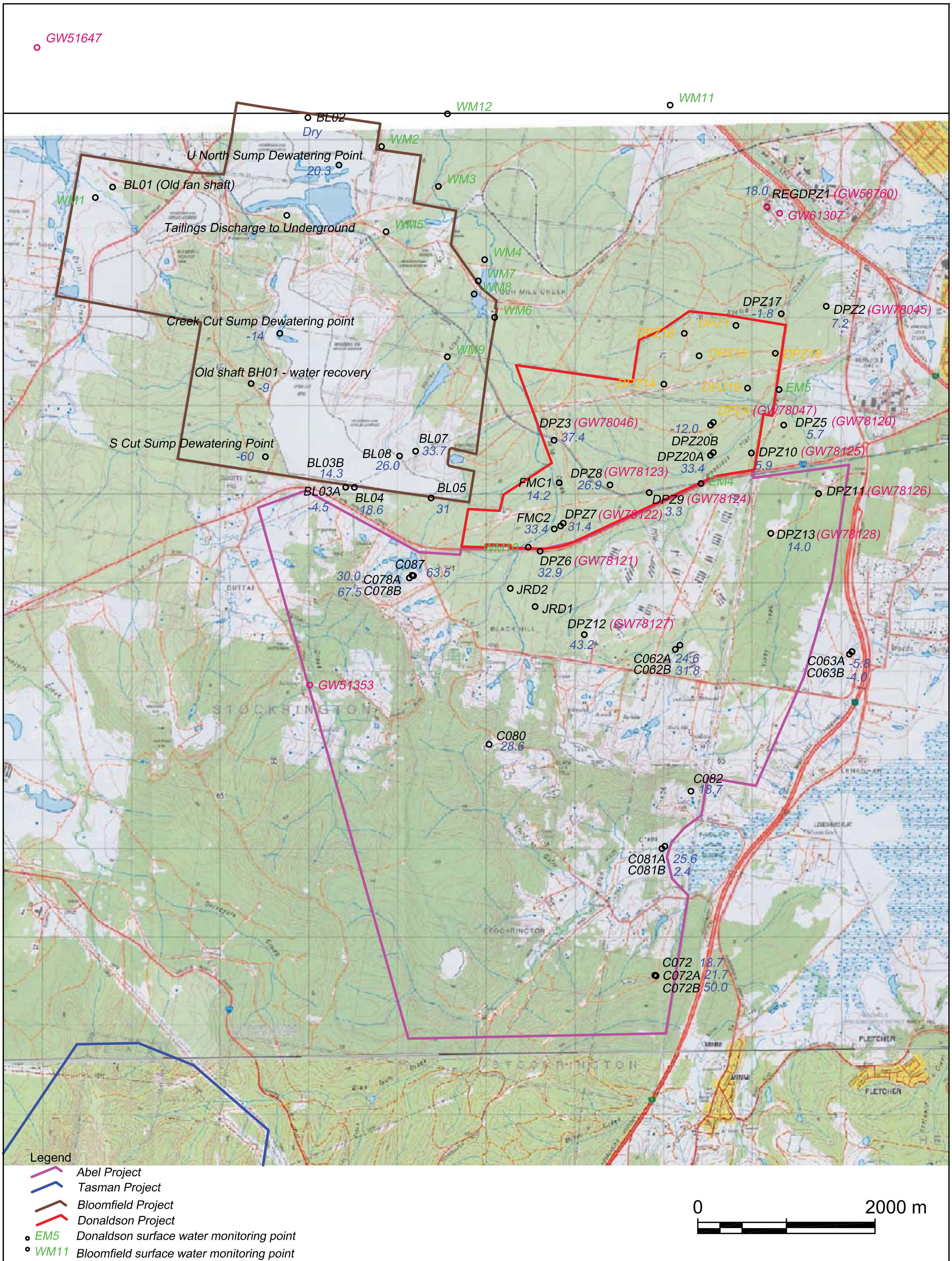

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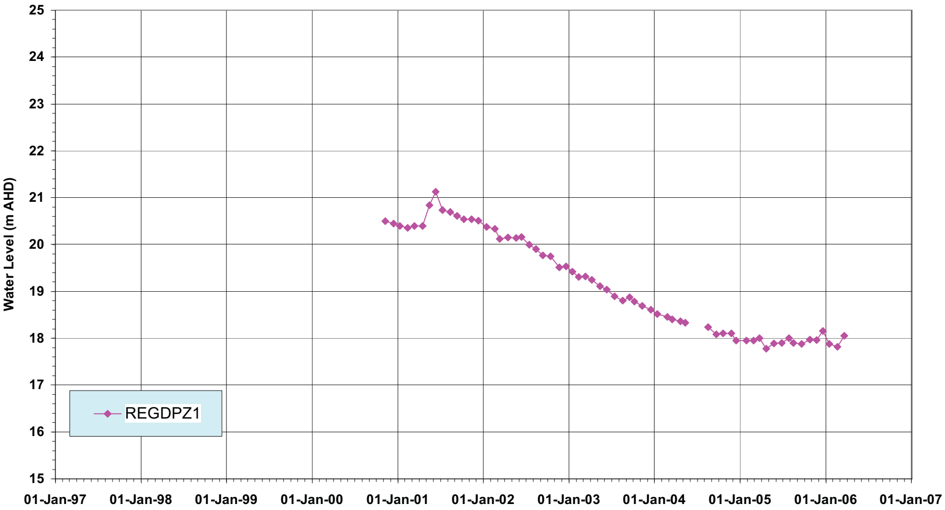
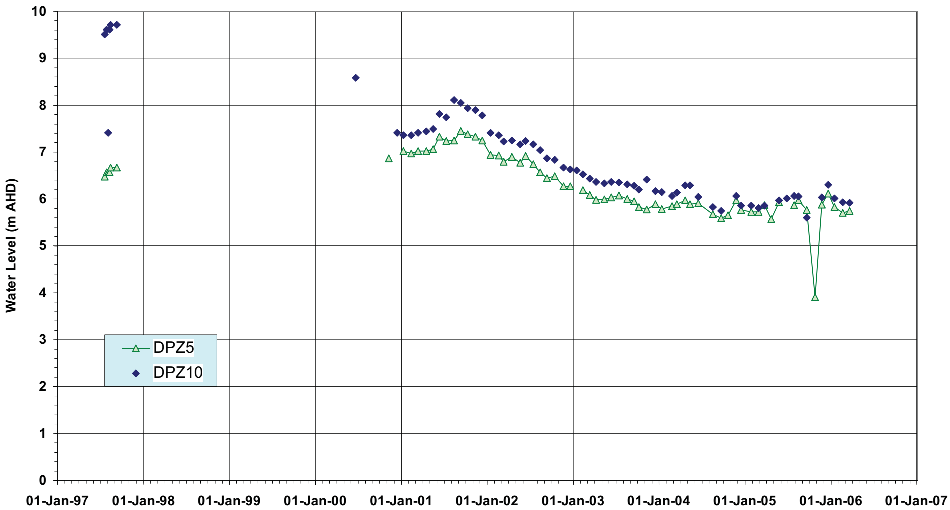
Initials:	PJD	Job No:	05-0163	**Abel Coal Project**
Drawing No:	05-0163-005_E	Rev:	Rev E	**Bore Location Plan**
Peter Dundon & Associates Pty Limited				**Figure 2**

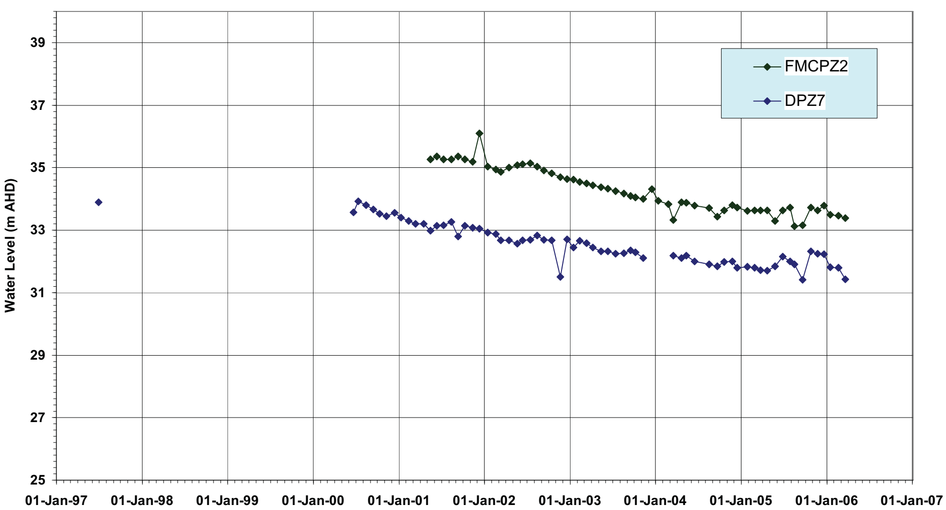
WATER LEVEL HYDROGRAPHS - REGDPZ1



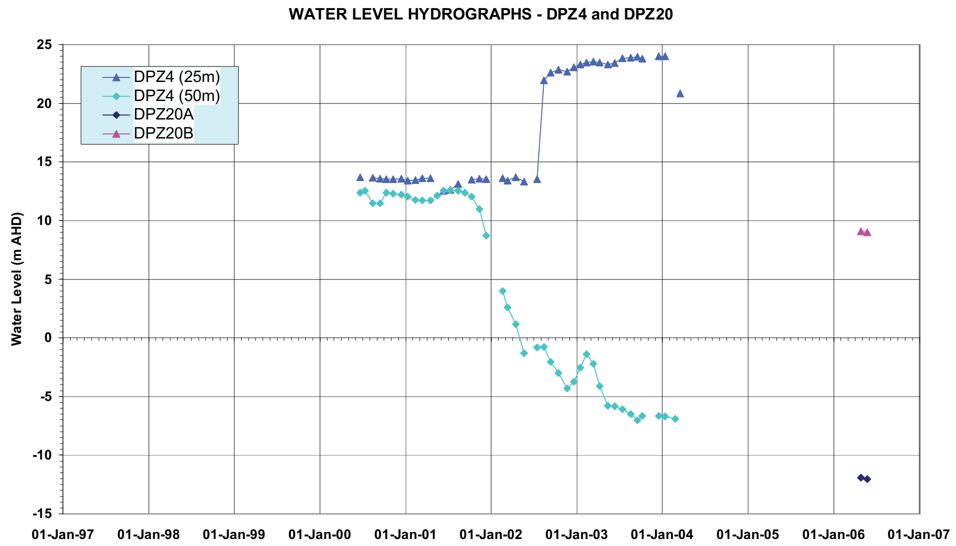
WATER LEVEL HYDROGRAPHS - DPZ5 and DPZ10

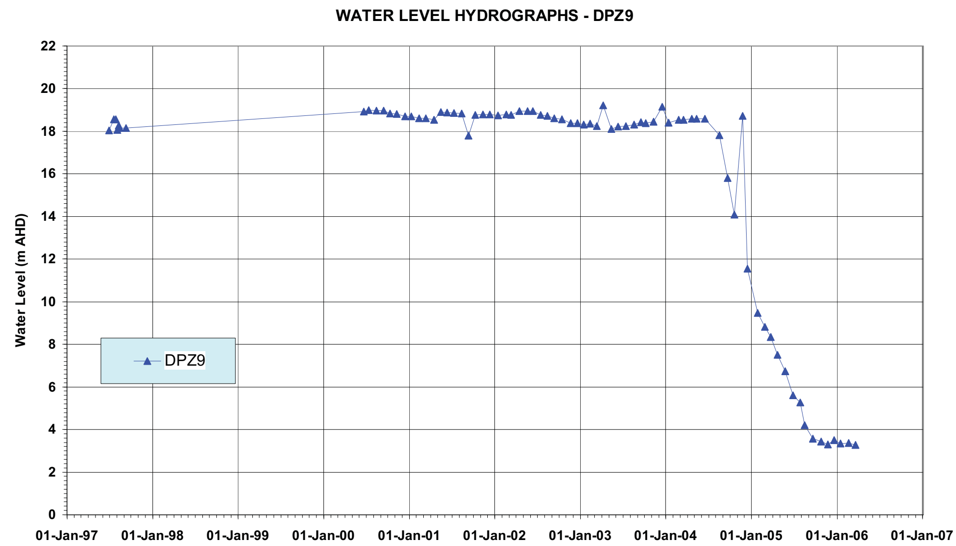


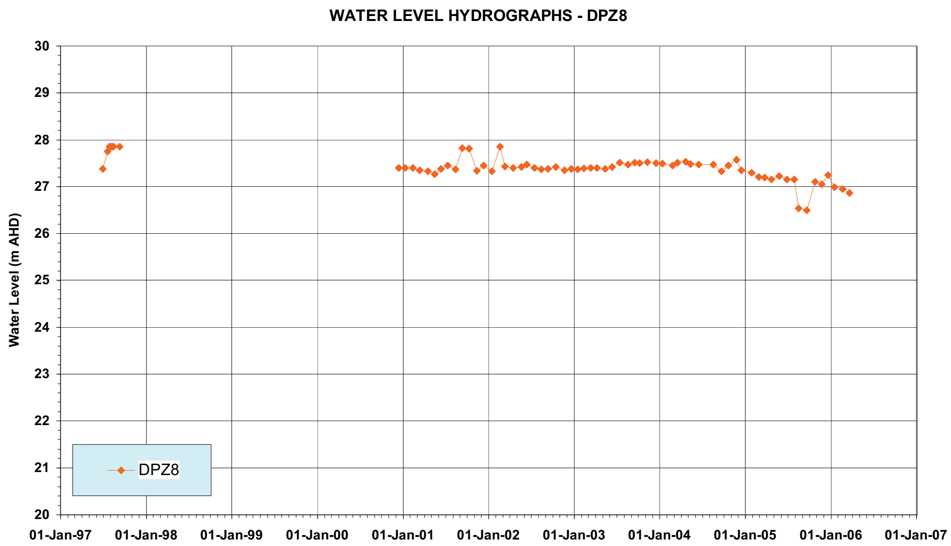
WATER LEVEL HYDROGRAPHS - FMCPZ2 and DPZ7



Date: 12 June 2006	Scale: as indicated	**Donaldson Coal Pty Ltd**
Initials: PJD	Job No: 05-0163	**ABEL COAL PROJECT PIEZOMETER HYDROGRAPHS - REGIONAL PIEZOMETERS**
Drawing No: 05-0163-105	Rev: 0	
Peter Dundon & Associates Pty Limited		**Figure 3**







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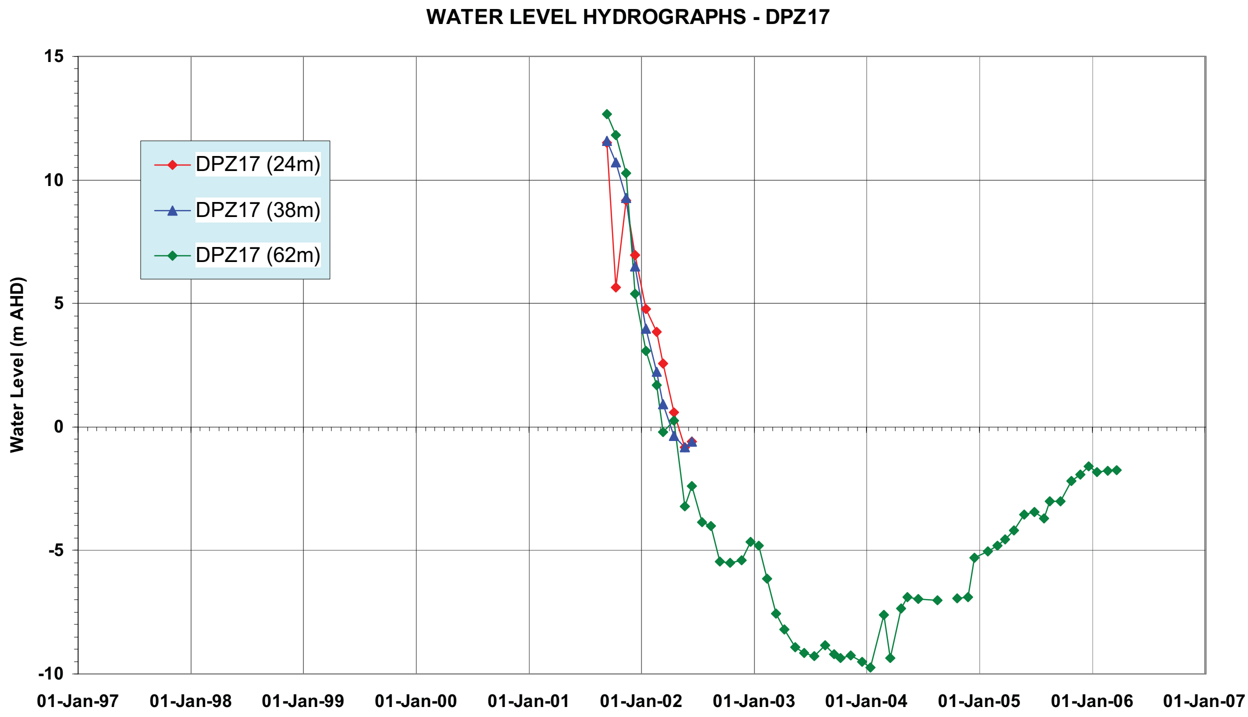
Initials: PJD	Job No: 05-0163	**ABEL COAL PROJECT PIEZOMETER HYDROGRAPHS - IMPACTS OF DONALDSON DEWATERING**	
Drawing No: 05-0163-106	Rev: 0		
Peter Dundon & Associates Pty Limited			**Figure 4**



Date: 18 July 2006	Scale: as indicated	**Donaldson Coal Pty Ltd**
Initials: PJD	Job No: 05-0163	**ABEL COAL PROJECT PIEZOMETER HYDROGRAPHS - IMPACTS OF DONALDSON POST-MINING RECOVERY**
Drawing No: 05-0163-107_A	Rev: A	
Peter Dundon & Associates Pty Limited		**Figure 5**

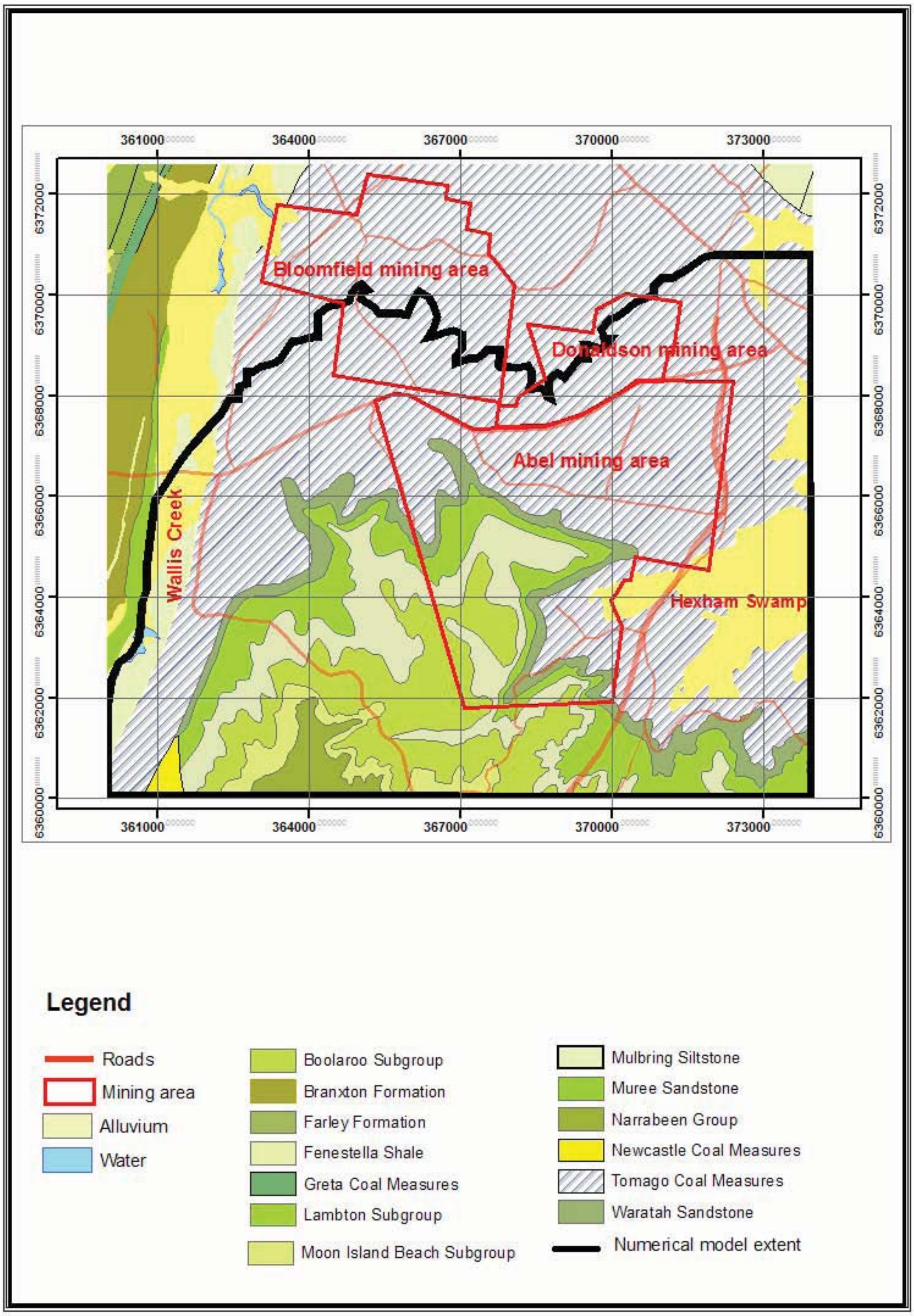


Figure 6: Regional Geology

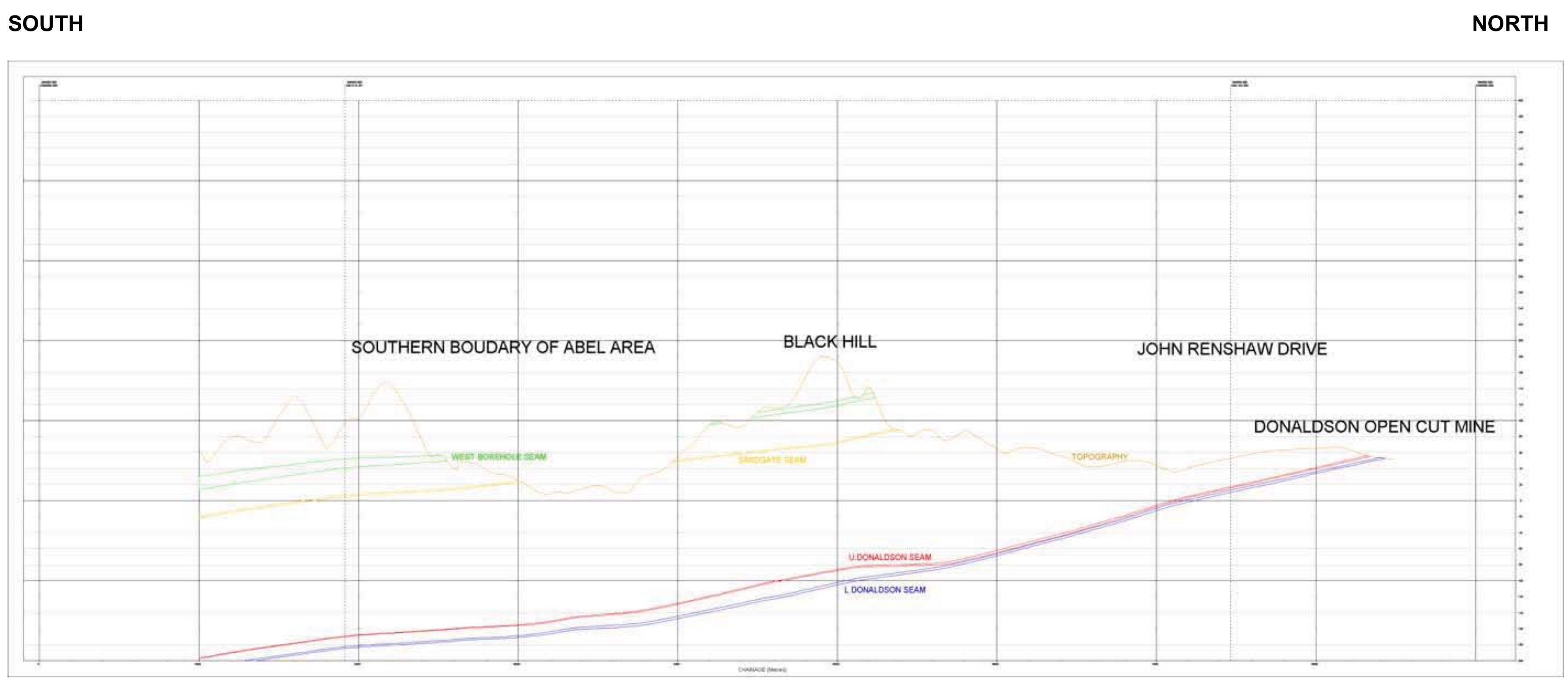
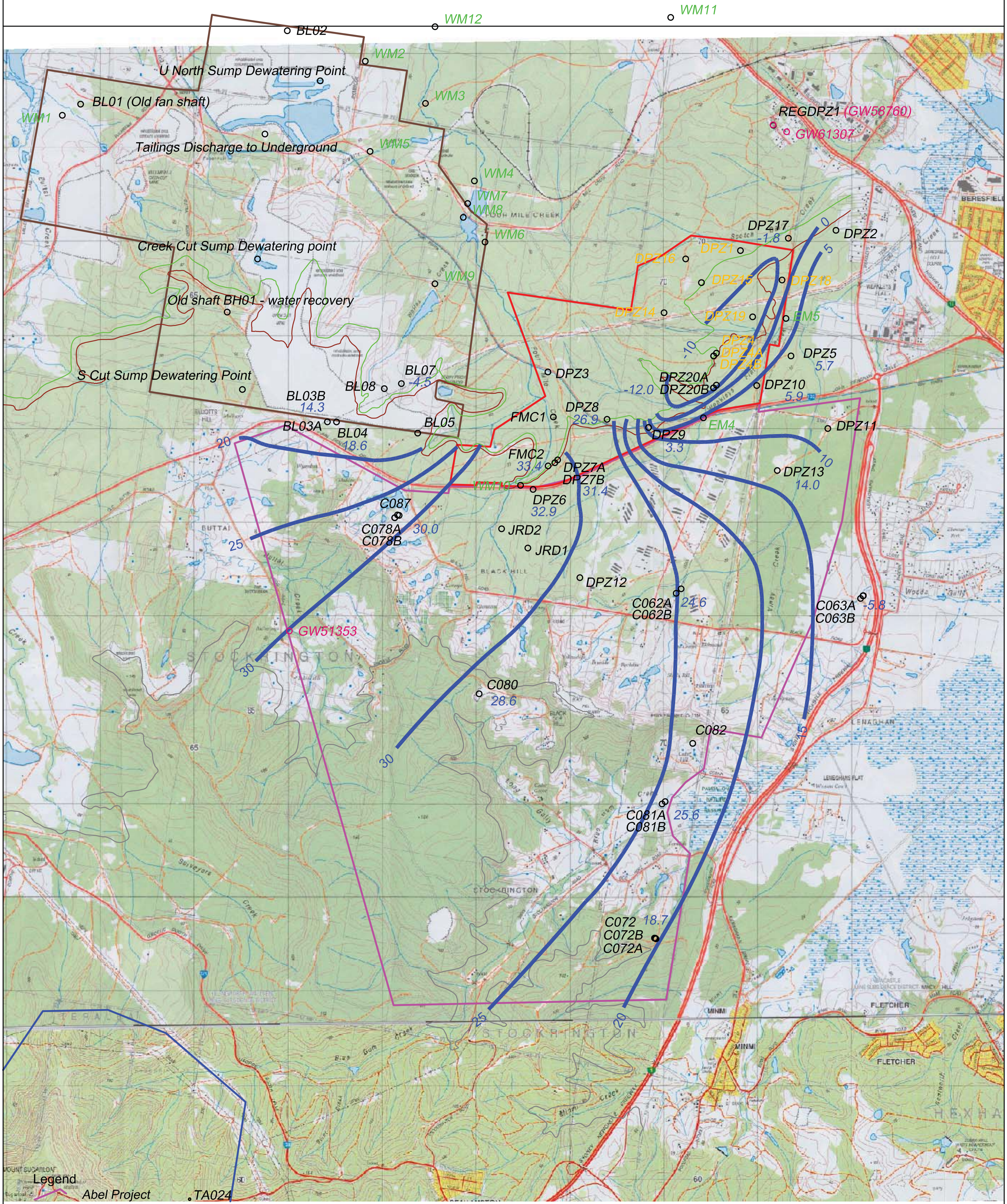


Figure 7: North-South Geological Cross-Section Through Abel Project Area



Legend

Abel Project

Tasman Project

Bloomfield Project

Donaldson Project

EM5 Donaldson surface water monitoring point

WM11 Bloomfield surface water monitoring point

BL02 Bloomfield borehole/piezometer

C063 Abel piezometer

DPZ13 Donaldson piezometer

DPZ18 Donaldson piezometer - lost to mining activity

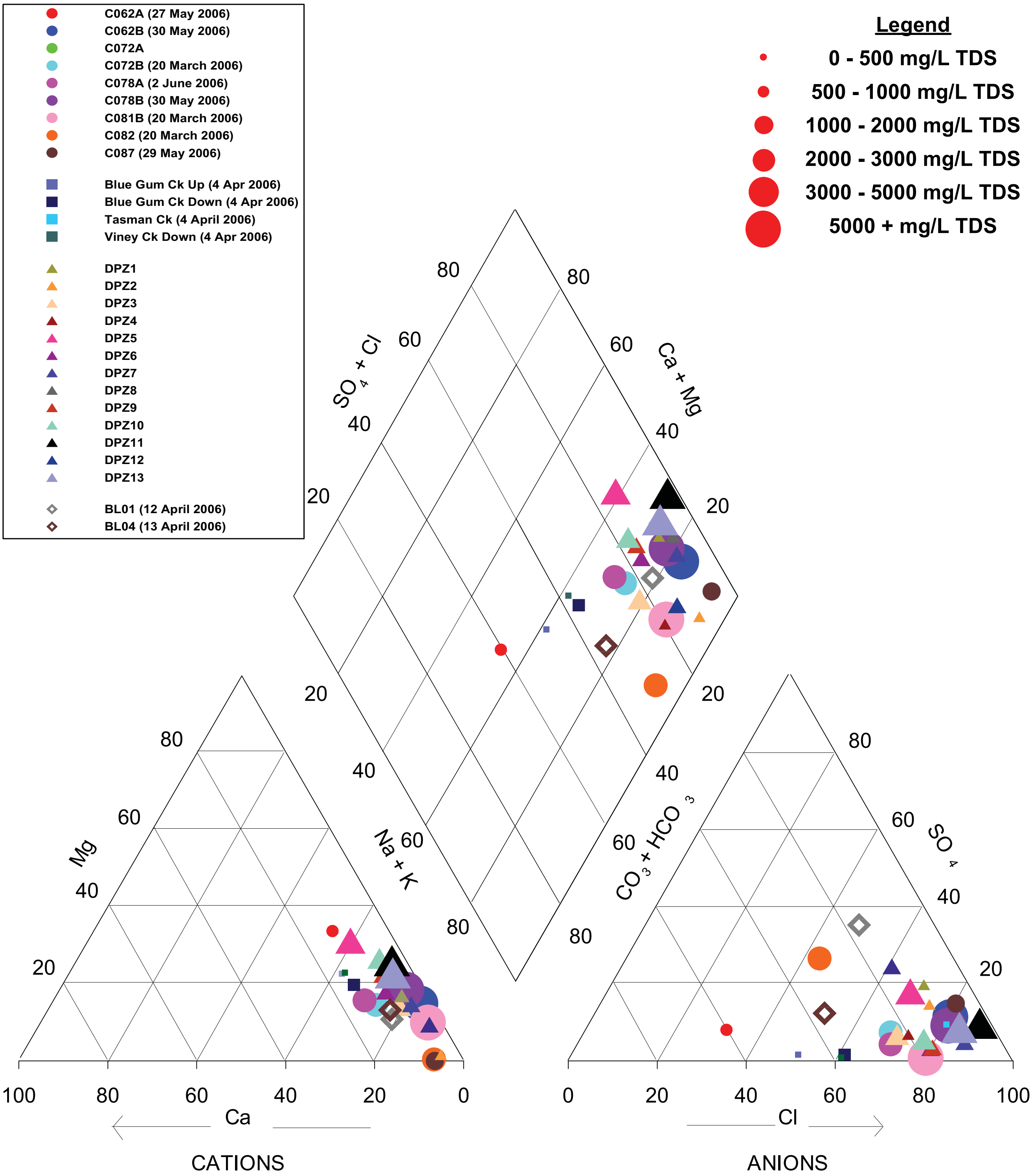
(GW78045) DNR Registered Bore

28.7 Groundwater Level (mAHD)

5 Groundwater Contour (mAHD)

0 2000 m

Date: 23 July 2006	Scale: as shown	Donaldson Coal Pty Ltd
Initials: PJD	Job No: 05-0163	Abel Coal Project Interpreted Groundwater Contours for the Donaldson Seam
Drawing No: 05-0163-005_C	Rev: Rev C	
Peter Dundon & Associates Pty Limited		Figure 8



Peter Dundon and Associates Pty Ltd 12 Dakara Close Pymble NSW 2073 ph 61 2 9440 2666 fx 61 2 94493193 mb 0418 476 799 pjdundon@ozemail.com.au	CLIENT Donaldson Coal Pty Ltd DRAWN PJD / DATE 14 June 2006 CHECKED / DATE SCALE As Shown / Dwg 05-0163-115 / A4	PROJECT **ABEL COAL PROJECT** TITLE **PIPER TRILINEAR DIAGRAM** **GROUNDWATER v SURFACE WATER** PROJECT No 05-0163	**Figure 9**

c:\...\05-0163\Piper\piper.grt

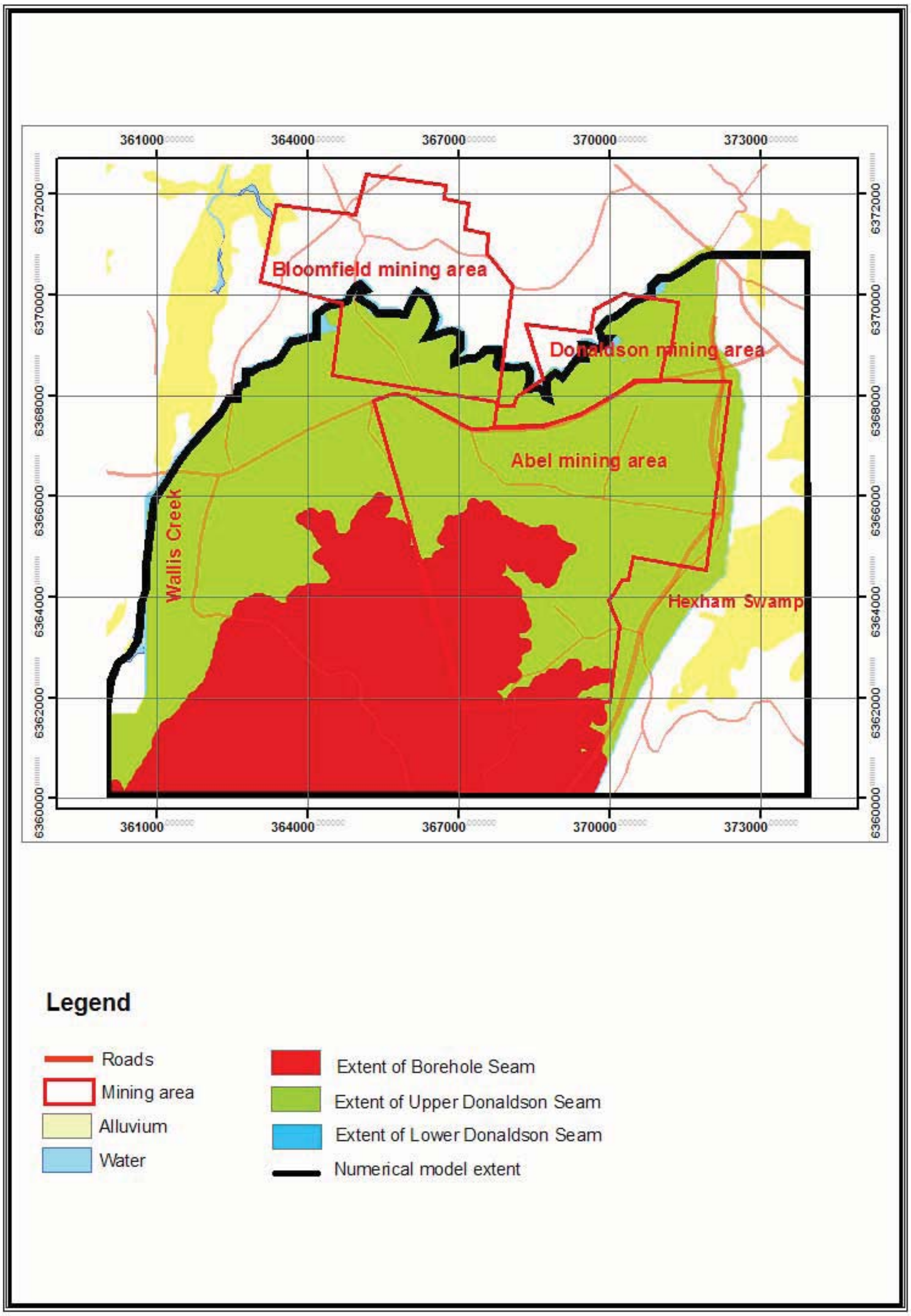


Figure 10: Groundwater Flow Model Area

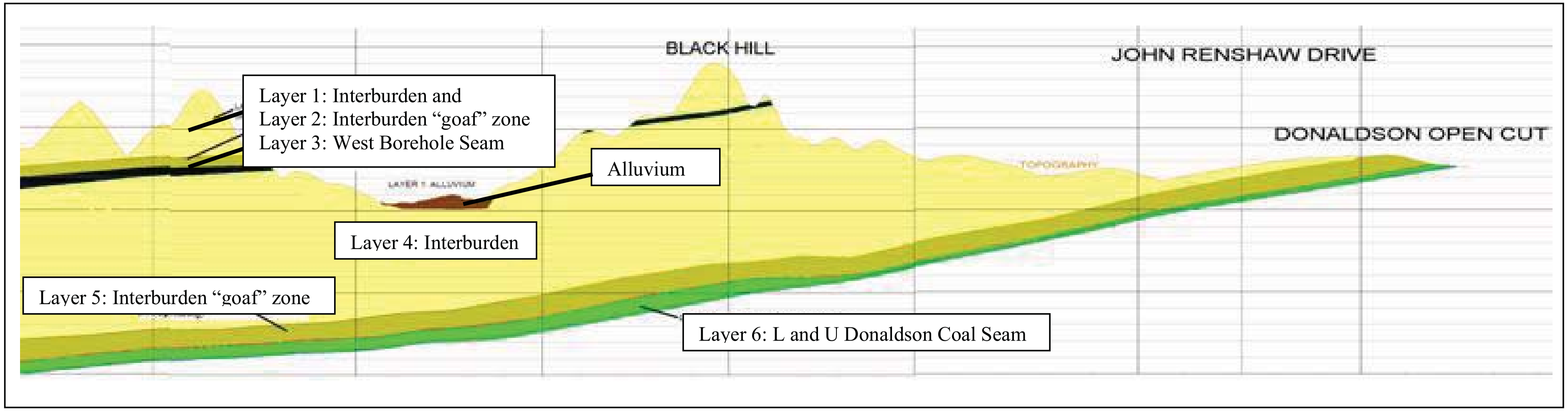


Figure 11: Groundwater Model Layer Definition

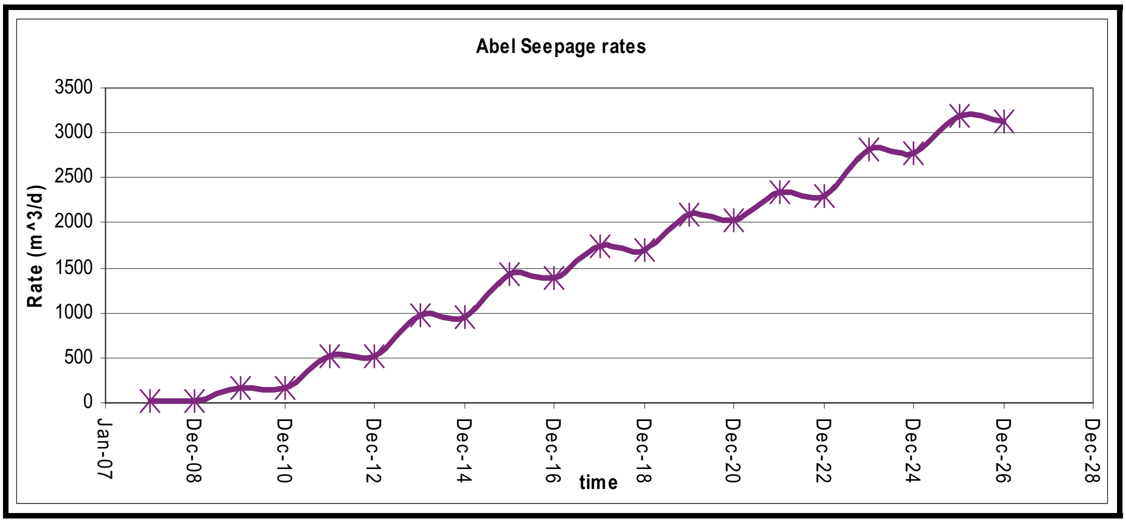


Figure 12: Predicted Groundwater Inflow Rates to the Abel Mine

Legend

- Abel Project
- Tasman Project
- Bloomfield Project
- Donaldson Project
- EM5 Donaldson surface water monitoring point
- WM11 Bloomfield surface water monitoring point
- BL02 Bloomfield borehole/piezometer
- C063 Abel piezometer
- DPZ13 Donaldson piezometer
- DPZ18 Donaldson piezometer - lost to mining activity
- (GW78045) DNR Registered Bore
- 28.7 Groundwater Level (mAHD)
- 5 Groundwater Contour (mAHD)
- West Borehole Seam subcrop line
- Upper Donaldson Seam subcrop line
- Lower Donaldson Seam subcrop line

0 2000 m

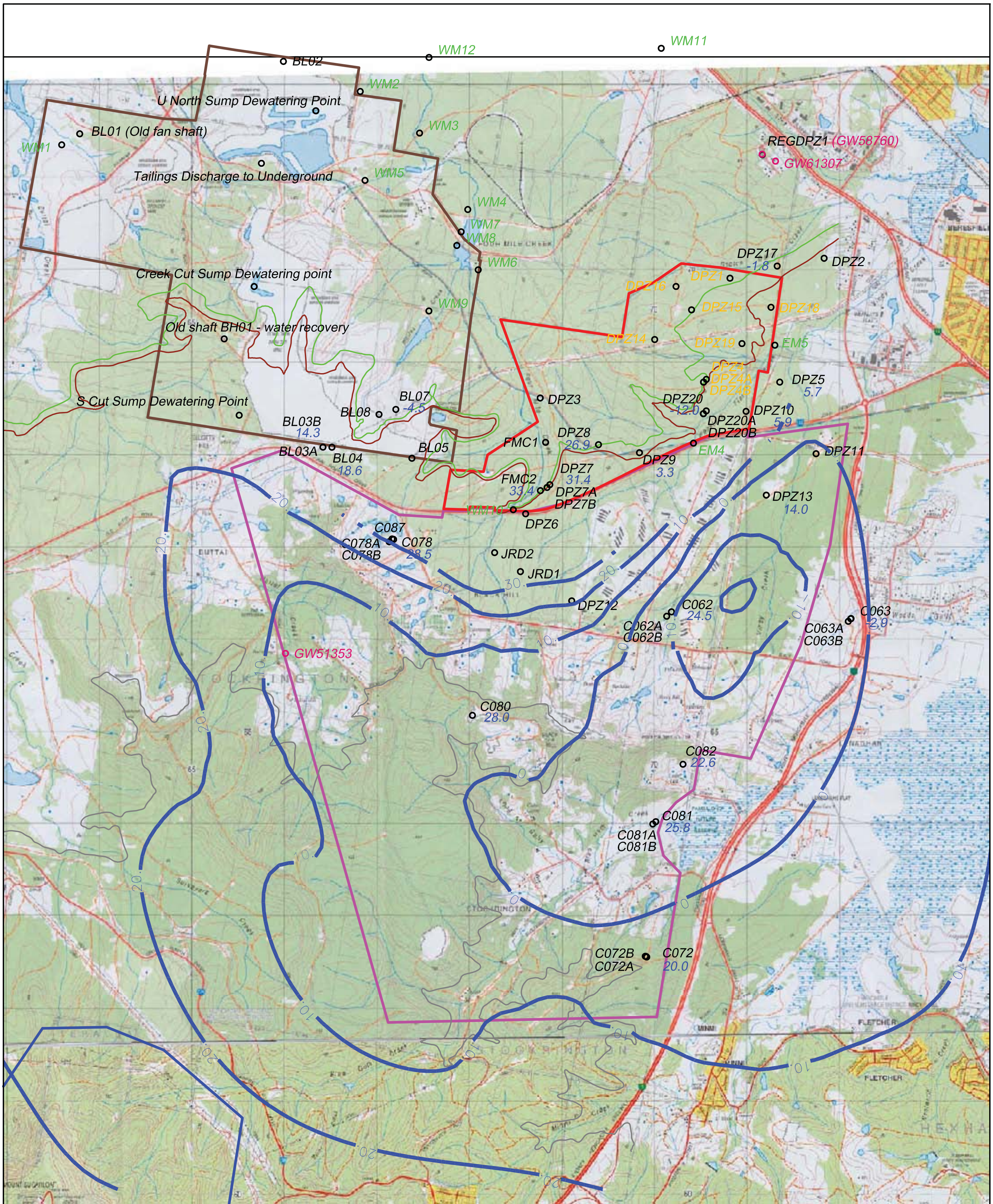
Date:	23/07/06	Scale:	as shown
Initials:	PJD	Job No:	05-0163
Drawing No:	05-0163-010_B	Rev:	B

Peter Dundon & Associates Pty Limited

Donaldson Coal Pty Ltd

Abel Coal Project
Predicted Groundwater Levels in Donaldson Seam (Layer 6) at 2027

Figure 13



Legend

- Abel Project
- Tasman Project
- Bloomfield Project
- Donaldson Project
- EM5 Donaldson surface water monitoring point
- WM11 Bloomfield surface water monitoring point
- BL02 Bloomfield borehole/piezometer
- C063 Abel piezometer
- DPZ13 Donaldson piezometer
- DPZ18 Donaldson piezometer - lost to mining activity
- (GW78045) DNR Registered Bore

- 28.7 Groundwater Level (mAHD)
- 5 Groundwater Contour (mAHD)
- West Borehole Seam subcrop line
- Upper Donaldson Seam subcrop line
- Lower Donaldson Seam subcrop line

0 2000 m

Date:	23 July 2006	Scale:	as shown	**Donaldson Coal Pty Ltd**
Initials:	PJD	Job No:	05-0163	**Predicted Groundwater Levels in the Undisturbed Overburden (Layer 4) at 2027**
Drawing No:	05-0163-009_B	Rev:	Rev B	
Peter Dundon & Associates Pty Limited				**Figure 14**

APPENDIX A

DNR LICENSED BORES WITHIN 10 KM OF ABEL PROJECT

Date/Time :15-Feb-2006 03:02 PM
User :RWASKI
Report :RMGW001D.QRP
Executable :S:\G5\PROD32\Ground.exe
Exe Date :18-Apr-2005
System :Groundwater
Database :Edbp

NSW Government
DEPARTMENT OF NATURAL RESOURCES

DEPARTMENT OF NATURAL RESOURCES
Work Summary

GW051353 *Converted From HYDSYS*

License :20BL114994

Work Type : Bore open thru rock
Work Status :(Unknown)
Construct. Method : Rotary
Owner Type : Private

Authorised Purpose(s)
DOMESTIC
STOCK

Intended Purpose(s)
DOMESTIC
STOCK

Commenced Date :
Completion Date :01-Nov-1980
Final Depth : 49.70 m
Drilled Depth : 49.70 m

Contractor Name :
Driller :

Property : - ROBIN HILL
GWMA : -
GW Zone : -
Standing Water Level :
Salinity : 3001-7000 ppm
Yield :

Site Details

Site Chosen By

	County	Parish	Portion/Lot DP
Form A :	NORTHUMBERLAND	STOCKRINGTON	99
Licensed :	NORTHUMBERLAND	STOCKRINGTON	39

Region :20 - HUNTER
River Basin :210 - HUNTER RIVER
Area / District :
CMA Map :9232-3N BERESFIELD
Grid Zone :56/1 **Scale :**1:25,000

Elevation :
Elevation Source :(Unknown)
Northing :6365625
Easting :365880
Latitude (S) :32° 50' 21"
Longitude (E) :151° 34' 1"

GS Map :0053C4 **AMG Zone :**56 **Coordinate Source :**GD.,ACC.MAP

Construction

Negative depths indicate Above Ground Level;H-Hole;P-Pipe;OD-Outside Diameter;ID-Inside Diameter;C-Cemented;SL-Slot Length;A-Aperture;GS-Grain Size;Q-Quantity

H	P	Component	Type	From (m)	To (m)	OD (mm)	ID (mm)	Interval	Details
1	1	Casing	P.V.C.	-0.30	1.50	114			Driven into Hole

Water Bearing Zones

From (m)	To (m)	Thickness (m)	WBZ Type	S.W.L. (m)	D.D.L. (m)	Yield (L/s)	Hole Depth (m)	Duration (hr)	Salinity (mg/L)
22.60	23.10	0.50	Fractured	15.20		0.12			(Unknown)
24.90	25.20	0.30	Fractured	15.20		0.20			(Unknown)

Drillers Log

From (m)	To (m)	Thickness(m)	Drillers Description	Geological Material	Comments
0.00	0.50	0.50	Topsoil	Topsoil	
0.50	3.60	3.10	Sandstone Yellow	Sandstone	
3.60	3.90	0.30	Ironstone Shale	Ironstone	
3.90	10.70	6.80	Sandstone White	Sandstone	
3.90	10.70	6.80	Shale Seams	Shale	
10.70	11.90	1.20	Coal	Coal	
11.90	14.00	2.10	Sandstone Hard	Sandstone	
14.00	15.80	1.80	Shale	Shale	
15.80	22.60	6.80	Sandstone White	Sandstone	
22.60	25.60	3.00	Shale Water Supply	Shale	
25.60	49.70	24.10	Shale Black	Shale	

Remarks

***** End of GW051353 *****

DEPARTMENT OF NATURAL RESOURCES
Work Summary

GW078045

License : 20BL166663

	Authorised Purpose(s)	Intended Purpose(s)
	MONITORING BORE	MONITORING BORE

Work Type : Bore
Work Status : (Unknown)
Construct. Method : Backhoe
Owner Type :

Commenced Date : **Final Depth :** 30.50 m
Completion Date : 14-Nov-1997 **Drilled Depth :** 30.50 m

Contractor Name : McDERMOTT DRILLING
Driller : DODDS

Property : - N/A **Standing Water Level :**
GWMA : 017 - HUNTER **Salinity :**
GW Zone : - **Yield :**

Site Details

Site Chosen By	County	Parish	Portion/Lot DP
Geologist	Form A : NORTHUMBERLAND	ALNWICK	LOT 23 DP 532814
	Licensed : NORTHUMBERLAND	ALNWICK	23 532814

Region : 20 - HUNTER **CMA Map :**
River Basin : **Grid Zone :** **Scale :**
Area / District :

Elevation : **Northing :** 6369702 **Latitude (S) :** 32° 48' 11"
Elevation Source : **Easting :** 371697 **Longitude (E) :** 151° 37' 48"

GS Map : **AMG Zone :** 56 **Coordinate Source :**

Construction

Negative depths indicate Above Ground Level;H-Hole;P-Pipe;OD-Outside Diameter;ID-Inside Diameter;C-Cemented;SL-Slot Length;A-Aperture;GS-Grain Size;Q-Quantity

H	P	Component	Type	From (m)	To (m)	OD (mm)	ID (mm)	Interval	Details
1		Hole	Hole	0.00	30.50	96			Open Hole - Water
1	1	Opening	Screen	15.80	27.80				
1	1	Opening	Slots - Horizontal	15.80	27.80	55			PVC; SL: 12mm; A: 5mm
1		Annulus	Waterworn/Rounded	5.00	30.50				Ungraded; GS: 4-5mm

Water Bearing Zones

From (m)	To (m)	Thickness (m)	WBZ Type	S.W.L. (m)	D.D.L. (m)	Yield (L/s)	Hole Depth (m)	Duration (hr)	Salinity (mg/L)
17.30	30.50	13.20		17.30			30.50		

Drillers Log

From (m)	To (m)	Thickness(m)	Drillers Description	Geological Material	Comments
0.00	2.00	2.00	SANDSTONE	Sandstone	
2.00	16.00	14.00	SILTSTONE/MUDSTONE	Siltstone	
16.00	16.50	0.50	COAL	Coal	
16.50	20.40	3.90	SILTSTONE/MUDSTONE	Siltstone	
20.40	20.90	0.50	COAL	Coal	
20.90	25.00	4.10	MUDSTONE	Mudstone	
25.00	30.50	5.50	SILTSTONE	Siltstone	

Remarks

***** End of GW078045 *****

DEPARTMENT OF NATURAL RESOURCES
Work Summary

GW078046

License : 20BL166664

Work Type : Bore
Work Status : (Unknown)
Construct. Method : Backhoe
Owner Type :

Authorised Purpose(s)
MONITORING BORE

Intended Purpose(s)
MONITORING BORE

Commenced Date :
Completion Date : 14-Nov-1997

Final Depth : 30.40 m
Drilled Depth : 30.40 m

Contractor Name : McDERMOTT DRILLING
Driller : DODDS

Property : - N/A
GWMA : 017 - HUNTER
GW Zone : -

Standing Water Level :
Salinity :
Yield :

Site Details

Site Chosen By
Geologist

	County	Parish	Portion/Lot DP
Form A :	NORTHUMBERLAND	STOCKRINGTON	LOT 92 DP 755260
Licensed :	NORTHUMBERLAND	STOCKRINGTON	92 755260

Region : 20 - HUNTER
River Basin :
Area / District :

CMA Map :
Grid Zone :
Scale :

Elevation :
Elevation Source :

Northing : 6368552
Easting : 368512

Latitude (S) : 32° 48' 47"
Longitude (E) : 151° 35' 45"

GS Map :
AMG Zone : 56
Coordinate Source :

Construction

Negative depths indicate Above Ground Level;H-Hole;P-Pipe;OD-Outside Diameter;ID-Inside Diameter;C-Cemented;SL-Slot Length;A-Aperture;GS-Grain Size;Q-Quantity

H	P	Component	Type	From (m)	To (m)	OD (mm)	ID (mm)	Interval	Details
1		Hole	Hole	0.00	30.40	96			Open Hole - Water
1	1	Opening	Screen	6.80	18.80				
1	1	Opening	Slots - Horizontal	6.80	18.80	55			PVC; SL: 12mm; A: 5mm
1		Annulus	Waterworn/Rounded	6.00	30.40				Ungraded; GS: 4-5mm

Water Bearing Zones

From (m)	To (m)	Thickness (m)	WBZ Type	S.W.L. (m)	D.D.L. (m)	Yield (L/s)	Hole Depth (m)	Duration (hr)	Salinity (mg/L)
13.60	30.40	16.80		13.60			30.40		

Drillers Log

From (m)	To (m)	Thickness(m)	Drillers Description	Geological Material	Comments
0.00	9.20	9.20	SILTSTONE/MUDSTONE	Siltstone	
9.20	9.40	0.20	COAL	Coal	
9.40	11.20	1.80	SILTSTONE	Siltstone	
11.20	11.60	0.40	COAL	Coal	
11.60	30.40	18.80	SILTSTONE/SANDSTONE	Siltstone	

Remarks

***** End of GW078046 *****

DEPARTMENT OF NATURAL RESOURCES
Work Summary

GW078047

License :20BL166665

Work Type : Bore
Work Status :(Unknown)
Construct. Method :
Owner Type :

Authorised Purpose(s)
MONITORING BORE

Intended Purpose(s)
MONITORING BORE

Commenced Date :
Completion Date :14-Nov-1997

Final Depth : 54.30 m
Drilled Depth : 54.30 m

Contractor Name : McDERMOTT DRILLING
Driller :

Property : - N/A
GWMA :017 - HUNTER
GW Zone : -

Standing Water Level :
Salinity :
Yield :

Site Details

Site Chosen By
Driller

	County	Parish	Portion/Lot DP
Form A :	NORTHUMBERLAND	STOCKRINGTON	PT LOT 13 DP 755260
Licensed :	NORTHUMBERLAND	STOCKRINGTON	13 755260

Region :20 - HUNTER
River Basin :
Area / District :

CMA Map :
Grid Zone :
Scale :

Elevation :
Elevation Source :

Northing :6368611
Easting :370644

Latitude (S) :32° 48' 46"
Longitude (E) :151° 37' 7"

GS Map :
AMG Zone :56
Coordinate Source :

Construction

Negative depths indicate Above Ground Level;H-Hole;P-Pipe;OD-Outside Diameter;ID-Inside Diameter;C-Cemented;SL-Slot Length;A-Aperture;GS-Grain Size;Q-Quantity

H	P	Component	Type	From (m)	To (m)	OD (mm)	ID (mm)	Interval	Details
1		Hole	Hole	0.00	54.30	96			
1	1	Opening	Screen	25.20	49.20				
1	1	Opening	Slots - Horizontal	25.20	49.20	55			PVC; SL: 24mm; A: 5mm
1		Annulus	Waterworn/Rounded	24.90	49.20				Ungraded; GS: 4-5mm

Water Bearing Zones

From (m)	To (m)	Thickness (m)	WBZ Type	S.W.L. (m)	D.D.L. (m)	Yield (L/s)	Hole Depth (m)	Duration (hr)	Salinity (mg/L)
22.80	54.30	31.50		22.80			54.30		

Drillers Log

From (m)	To (m)	Thickness(m)	Drillers Description	Geological Material	Comments
0.00	6.50	6.50	[illegible]	[illegible]one	
6.50	12.00	5.50	SANDSTONE	Sandstone	
12.00	14.60	2.60	SILTSTONE/MUDSTONE	Siltstone	
14.60	15.40	0.80	COAL	Coal	
15.40	24.90	9.50	SILTSTONE	Siltstone	
24.90	27.70	2.80	COAL	Coal	
27.70	32.30	4.60	SILTSTONE/SANDSTONE	Siltstone	
32.30	33.40	1.10	COAL	Coal	
33.40	39.30	5.90	SANDSTONE	Sandstone	
39.30	39.90	0.60	COAL	Coal	
39.90	41.10	1.20	SILTSTONE/SANDSTONE	Siltstone	
41.10	43.50	2.40	COAL	Coal	
43.50	45.10	1.60	CLAYSTONE	Claystone	
45.10	49.40	4.30	COAL	Coal	
49.40	54.30	4.90	SILTSTONE	Siltstone	

Remarks

***** End of GW078047 *****

DEPARTMENT OF NATURAL RESOURCES
Work Summary

GW078120

License : 20BL166666

Work Type : Bore
Work Status : (Unknown)
Construct. Method :
Owner Type :

Authorised Purpose(s)	Intended Purpose(s)
MONITORING BORE	MONITORING BORE

Commenced Date :
Completion Date : 14-Nov-1997

Final Depth : 24.00 m
Drilled Depth : 24.00 m

Contractor Name : McDERMOTT DRILLING
Driller :

Property : - N/A
GWMA : 017 - HUNTER
GW Zone : -

Standing Water Level :
Salinity :
Yield :

Site Details

Site Chosen By
Geologist

	County	Parish	Portion/Lot DP
Form A :	NORTHUMBERLAND	HEXHAM	LOT 115 DP 240782
Licensed :	NORTHUMBERLAND	HEXHAM	115 240782

Region : 20 - HUNTER
River Basin :
Area / District :

CMA Map :
Grid Zone :
Scale :

Elevation :
Elevation Source :

Northing : 6368400
Easting : 371037

Latitude (S) : 32° 48' 53"
Longitude (E) : 151° 37' 22"

GS Map :
AMG Zone : 56
Coordinate Source :

Construction

Negative depths indicate Above Ground Level;H-Hole;P-Pipe;OD-Outside Diameter;ID-Inside Diameter;C-Cemented;SL-Slot Length;A-Aperture;GS-Grain Size;Q-Quantity

H	P	Component	Type	From (m)	To (m)	OD (mm)	ID (mm)	Interval	Details
1		Hole	Hole	0.00	24.00	96			Open Hole - Water
1	1	Opening	Screen	6.00	18.00				
1	1	Opening	Slots - Horizontal	6.00	18.00	55			PVC; SL: 12mm; A: 5mm
1		Annulus	Waterworn/Rounded	2.00	24.00				Ungraded; GS: 4-5mm

Water Bearing Zones

From (m)	To (m)	Thickness (m)	WBZ Type	S.W.L. (m)	D.D.L. (m)	Yield (L/s)	Hole Depth (m)	Duration (hr)	Salinity (mg/L)
6.10	24.00	17.90		6.10			24.00		

Drillers Log

From (m)	To (m)	Thickness(m)	Drillers Description	Geological Material	Comments
0.00	14.00	14.00	SILTSTONE/MUDSTONE	Siltstone	
14.00	16.00	2.00	SANDSTONE	Sandstone	
16.00	24.00	8.00	MUDSTONE/SHALE	Mudstone	

Remarks

***** End of GW078120 *****

DEPARTMENT OF NATURAL RESOURCES
Work Summary

GW078121

License : 20BL166667

Authorised Purpose(s) MONITORING BORE
Intended Purpose(s) MONITORING BORE

Work Type : Bore
Work Status : (Unknown)
Construct. Method :
Owner Type :

Commenced Date :
Completion Date : 14-Nov-1997
Final Depth : 43.00 m
Drilled Depth : 43.00 m

Contractor Name : McDERMOTT DRILLING
Driller :

Property : - N/A
GWMA : 017 - HUNTER
GW Zone : -

Standing Water Level :
Salinity :
Yield :

Site Details

Site Chosen By
Geologist

	County	Parish	Portion/Lot DP
Form A :	NORTHUMBERLAND	STOCKRINGTON	LOT 10 DP 11875
Licensed :	NORTHUMBERLAND	STOCKRINGTON	10 11875

Region : 20 - HUNTER
River Basin :
Area / District :
CMA Map :
Grid Zone :
Scale :

Elevation :
Elevation Source :
Northing : 6367073
Easting : 368479
Latitude (S) : 32° 49' 35"
Longitude (E) : 151° 35' 43"

GS Map :
AMG Zone : 56
Coordinate Source :

Construction

Negative depths indicate Above Ground Level;H-Hole;P-Pipe;OD-Outside Diameter;ID-Inside Diameter;C-Cemented;SL-Slot Length;A-Aperture;GS-Grain Size;Q-Quantity

H	P	Component	Type	From (m)	To (m)	OD (mm)	ID (mm)	Interval	Details
1		Hole	Hole	0.00	43.00	96			Open Hole - Water
1	1	Opening	Screen	26.70	42.50				
1	1	Opening	Slots	26.70	42.50	55			PVC; SL: 15.8mm
1		Annulus	Waterworn/Rounded	2.00	43.00				Ungraded; GS: 4-5mm

Water Bearing Zones

From (m)	To (m)	Thickness (m)	WBZ Type	S.W.L. (m)	D.D.L. (m)	Yield (L/s)	Hole Depth (m)	Duration (hr)	Salinity (mg/L)
22.30	43.00	20.70		22.30			43.00		

Drillers Log

From (m)	To (m)	Thickness(m)	Drillers Description	Geological Material	Comments
0.00	14.00	14.00	SILTSTONE/SHALE	Siltstone	
14.00	16.00	2.00	SANDSTONE	Sandstone	
16.00	20.00	4.00	SILTSTONE/SHALE	Siltstone	
20.00	22.00	2.00	SANDSTONE	Sandstone	
22.00	25.40	3.40	SILTSTONE/SHALE	Siltstone	
25.40	25.90	0.50	COAL	Coal	
25.90	32.10	6.20	SANDSTONE	Sandstone	
32.10	32.60	0.50	COAL	Coal	
32.60	33.90	1.30	SANDSTONE	Sandstone	
33.90	35.60	1.70	COAL	Coal	
35.60	36.20	0.60	SANDSTONE	Sandstone	
36.20	37.00	0.80	COAL	Coal	
37.00	38.20	1.20	SANDSTONE/SILTSTONE	Sandstone	
38.20	38.60	0.40	COAL	Coal	
38.60	43.00	4.40	SILTSTONE	Siltstone	

Remarks

***** End of GW078121 *****

DEPARTMENT OF NATURAL RESOURCES
Work Summary

GW078122

License : 20BL166668

Work Type : Bore
Work Status : (Unknown)
Construct. Method :
Owner Type :

Authorised Purpose(s) MONITORING BORE
Intended Purpose(s) MONITORING BORE

Commenced Date :
Completion Date : 14-Nov-1997
Final Depth : 35.40 m
Drilled Depth : 35.40 m

Contractor Name : McDERMOTT DRILLING
Driller :

Property : - N/A
GWMA : 017 - HUNTER
GW Zone : -

Standing Water Level :
Salinity :
Yield :

Site Details

Site Chosen By		County	Parish	Portion/Lot DP
Geologist	Form A :	NORTHUMBERLAND	STOCKRINGTON	LOT 10 DP 11875
	Licensed :	NORTHUMBERLAND	STOCKRINGTON	10 11875

Region : 20 - HUNTER
River Basin :
Area / District :

CMA Map :
Grid Zone :
Scale :

Elevation :
Elevation Source :

Northing : 6367474
Easting : 368526
Latitude (S) : 32° 49' 22"
Longitude (E) : 151° 35' 45"

GS Map :
AMG Zone : 56
Coordinate Source :

Construction

Negative depths indicate Above Ground Level;H-Hole;P-Pipe;OD-Outside Diameter;ID-Inside Diameter;C-Cemented;SL-Slot Length;A-Aperture;GS-Grain Size;Q-Quantity

H	P	Component	Type	From (m)	To (m)	OD (mm)	ID (mm)	Interval	Details
1		Hole	Hole	0.00	35.40	96			Open Hole - Water
1	1	Opening	Screen	19.50	35.00				
1	1	Opening	Slots - Horizontal	19.50	35.00	55			PVC; SL: 15.5mm; A: 5mm
1		Annulus	Waterworn/Rounded	19.20	35.40				Ungraded; GS: 4-5mm

Water Bearing Zones

From (m)	To (m)	Thickness (m)	WBZ Type	S.W.L. (m)	D.D.L. (m)	Yield (L/s)	Hole Depth (m)	Duration (hr)	Salinity (mg/L)
23.10	51.30	28.20		23.10			35.40		

Drillers Log

From (m)	To (m)	Thickness(m)	Drillers Description	Geological Material	Comments
0.00	12.00	12.00	SANDSTONE/SILTSTONE	Sandstone	
12.00	12.40	0.40	COAL	Coal	
12.40	16.00	3.60	SILTSTONE	Siltstone	
16.00	19.50	3.50	SANDSTONE	Sandstone	
19.50	20.90	1.40	COAL	Coal	
20.90	22.00	1.10	SANDSTONE	Sandstone	
22.00	23.60	1.60	COAL	Coal	
23.60	24.40	0.80	SANDSTONE	Sandstone	
24.40	26.60	2.20	COAL	Coal	
26.60	28.00	1.40	SILTSTONE/CLAYSTONE	Siltstone	
28.00	31.70	3.70	COAL	Coal	
31.70	35.40	3.70	SANDSTONE	Sandstone	

Remarks

***** End of GW078122 *****

DEPARTMENT OF NATURAL RESOURCES
Work Summary

GW078123

License : 20BL166669

Authorised Purpose(s): MONITORING BORE
Intended Purpose(s):

Work Type : Bore
Work Status : (Unknown)
Construct. Method :
Owner Type :

Commenced Date :
Completion Date : 14-Nov-1997
Final Depth : 33.00 m
Drilled Depth : 33.00 m

Contractor Name : McDERMOTT DRILLING
Driller :

Property : - N/A
GWMA : 017 - HUNTER
GW Zone : -

Standing Water Level :
Salinity :
Yield :

Site Details

Site Chosen By		County	Parish	Portion/Lot DP
Geologist	Form A :	NORTHUMBERLAND	STOCKRINGTON	LOT 92 DP 755260
	Licensed :	NORTHUMBERLAND	STOCKRINGTON	92 755260

Region : 20 - HUNTER
River Basin :
Area / District :
CMA Map :
Grid Zone :
Scale :

Elevation :
Elevation Source :
Northing : 6367975
Easting : 369170
Latitude (S) : 32° 49' 6"
Longitude (E) : 151° 36' 10"

GS Map :
AMG Zone : 56
Coordinate Source :

Construction

Negative depths indicate Above Ground Level;H-Hole;P-Pipe;OD-Outside Diameter;ID-Inside Diameter;C-Cemented;SL-Slot Length;A-Aperture;GS-Grain Size;Q-Quantity

H	P	Component	Type	From (m)	To (m)	OD (mm)	ID (mm)	Interval	Details
1		Hole	Hole	0.00	33.00	96			Other
1	1	Opening	Screen	20.20	32.20				
1	1	Opening	Slots - Horizontal	20.20	32.20	55			PVC; SL: 12mm; A: 5mm
1		Annulus	Waterworn/Rounded	12.50	32.20				Ungraded; GS: 4-5mm

Water Bearing Zones

From (m)	To (m)	Thickness (m)	WBZ Type	S.W.L. (m)	D.D.L. (m)	Yield (L/s)	Hole Depth (m)	Duration (hr)	Salinity (mg/L)
24.40	33.00	8.60		24.40			33.00		

Drillers Log

From (m)	To (m)	Thickness(m)	Drillers Description	Geological Material	Comments
0.00	13.20	13.20	SANDSTONE/SILTSTONE	Sandstone	
13.20	15.30	2.10	COAL	Coal	
15.30	17.00	1.70	SILTSTONE	Siltstone	
17.00	17.90	0.90	COAL/SANDSTONE	Coal	
17.90	19.00	1.10	SILTSTONE	Siltstone	
19.00	19.70	0.70	COAL/SANDSTONE	Coal	
19.70	20.80	1.10	SANDSTONE	Sandstone	
20.80	23.20	2.40	COAL	Coal	
23.20	25.50	2.30	SANDSTONE/CLAYSTONE	Sandstone	
25.50	29.70	4.20	COAL	Coal	
29.70	33.00	3.30	SANDSTONE/SILTSTONE	Sandstone	

Remarks

***** End of GW078123 *****

DEPARTMENT OF NATURAL RESOURCES
Work Summary

GW078124

License : 20BL166670

Work Type : Bore
Work Status : (Unknown)
Construct. Method :
Owner Type :

Authorised Purpose(s)
MONITORING BORE

Intended Purpose(s)
MONITORING BORE

Commenced Date :
Completion Date : 14-Nov-1997

Final Depth : 40.00 m
Drilled Depth : 37.00 m

Contractor Name : McDERMOTT DRILLING
Driller :

Property : - N/A
GWMA : 017 - HUNTER
GW Zone : -

Standing Water Level :
Salinity :
Yield :

Site Details

Site Chosen By
Geologist

	County	Parish	Portion/Lot DP
Form A :	NORTHUMBERLAND	STOCKRINGTON	PT LOT 13 DP755260
Licensed :	NORTHUMBERLAND	STOCKRINGTON	13 755260

Region : 20 - HUNTER
River Basin :
Area / District :

CMA Map :
Grid Zone :
Scale :

Elevation :
Elevation Source :

Northing : 6367829
Easting : 369744

Latitude (S) : 32° 49' 11"
Longitude (E) : 151° 36' 32"

GS Map :
AMG Zone : 56
Coordinate Source :

Construction

Negative depths indicate Above Ground Level;H-Hole;P-Pipe;OD-Outside Diameter;ID-Inside Diameter;C-Cemented;SL-Slot Length;A-Aperture;GS-Grain Size;Q-Quantity

H	P	Component	Type	From (m)	To (m)	OD (mm)	ID (mm)	Interval	Details
1		Hole	Hole	0.00	40.00	96			Open Hole - Water
1	1	Opening	Screen	12.50	36.50				
1	1	Opening	Slots - Horizontal	12.50	36.50	55			PVC; SL: 24mm; A: 55mm
1		Annulus	Waterworn/Rounded	11.10	40.00				Ungraded; GS: 4-5mm

Water Bearing Zones

From (m)	To (m)	Thickness (m)	WBZ Type	S.W.L. (m)	D.D.L. (m)	Yield (L/s)	Hole Depth (m)	Duration (hr)	Salinity (mg/L)
18.60	40.00	21.40		18.60			40.00		

Drillers Log

From (m)	To (m)	Thickness(m)	Drillers Description	Geological Material	Comments
0.00	8.10	8.10		Mudstone	
8.10	8.60	0.50	coal	Coal	
8.60	10.00	1.40	siltstone	Siltstone	
10.00	15.50	5.50	sandstone	Sandstone	
15.50	17.20	1.70	coal	Coal	
17.20	18.30	1.10	sandstone	Sandstone	
18.30	19.20	0.90	coal	Coal	
19.20	20.00	0.80	mudstone	Mudstone	
20.00	24.50	4.50	siltstone	Siltstone	
24.50	27.70	3.20	coal	Coal	
27.70	29.90	2.20	sandstone/claystone	Sandstone	
29.90	33.30	3.40	coal	Coal	
33.30	37.00	3.70	mudstone	Mudstone	

Remarks

***** End of GW078124 *****

DEPARTMENT OF NATURAL RESOURCES
Work Summary

GW078125

License : 20BL166671

Work Type : Bore
Work Status : (Unknown)
Construct. Method :
Owner Type :

Authorised Purpose(s)	Intended Purpose(s)
MONITORING BORE	MONITORING BORE

Commenced Date :
Completion Date : 14-Nov-1997

Final Depth : 30.00 m
Drilled Depth : 30.00 m

Contractor Name : McDERMOTT DRILLING
Driller :

Property : - N/A
GWMA : 017 - HUNTER
GW Zone : -

Standing Water Level :
Salinity :
Yield :

Site Details

Site Chosen By	County	Parish	Portion/Lot DP
Geologist	Form A : NORTHUMBERLAND	STOCKRINGTON	PT LOT 13 DP755260
	Licensed : NORTHUMBERLAND	STOCKRINGTON	13 755260

Region : 20 - HUNTER
River Basin :
Area / District :

CMA Map :
Grid Zone :
Scale :

Elevation :
Elevation Source :

Northing : 6368274
Easting : 370831

Latitude (S) : 32° 48' 57"
Longitude (E) : 151° 37' 14"

GS Map :
AMG Zone : 56
Coordinate Source :

Construction

Negative depths indicate Above Ground Level;H-Hole;P-Pipe;OD-Outside Diameter;ID-Inside Diameter;C-Cemented;SL-Slot Length;A-Aperture;GS-Grain Size;Q-Quantity

H	P	Component	Type	From (m)	To (m)	OD (mm)	ID (mm)	Interval	Details
1		Hole	Hole	0.00	30.00	96			Open Hole - Water
1	1	Opening	Screen	11.80	29.80				
1	1	Opening	Slots - Horizontal	11.80	29.80	55			PVC; SL: 18mm; A: 5mm
1		Annulus	Waterworn/Rounded	5.00	30.00				Ungraded; GS: 4-5mm

Water Bearing Zones

From (m)	To (m)	Thickness (m)	WBZ Type	S.W.L. (m)	D.D.L. (m)	Yield (L/s)	Hole Depth (m)	Duration (hr)	Salinity (mg/L)
10.20	30.00	19.80		10.20			30.00		

Drillers Log

From (m)	To (m)	Thickness(m)	Drillers Description	Geological Material	Comments
0.00	19.00	19.00	siltstone/sandstone	Siltstone	
19.00	24.00	5.00	sandstone	Sandstone	
24.00	26.50	2.50	siltstone/sandstone	Siltstone	
26.50	26.90	0.40	coal	Coal	
26.90	30.00	3.10	siltstone/sandstone	Siltstone	

Remarks

***** End of GW078125 *****

DEPARTMENT OF NATURAL RESOURCES
Work Summary

GW078126

License : 20BL166672

Work Type : Bore
Work Status : (Unknown)
Construct. Method :
Owner Type :

Authorised Purpose(s) MONITORING BORE
Intended Purpose(s) MONITORING BORE

Commenced Date :
Completion Date : 14-Nov-1997
Final Depth : 30.00 m
Drilled Depth : 30.00 m

Contractor Name : McDERMOTT DRILLING
Driller :

Property : - BERESFIELD
GWMA : 017 - HUNTER
GW Zone : -

Standing Water Level :
Salinity :
Yield :

Site Details

Site Chosen By		County	Parish	Portion/Lot DP
Geologist	Form A :	NORTHUMBERLAND	HEXHAM	LOT 117 DP 568625
	Licensed :	NORTHUMBERLAND	HEXHAM	30 870411

Region : 20 - HUNTER
River Basin :
Area / District :

CMA Map :
Grid Zone :
Scale :

Elevation :
Elevation Source :

Northing : 6367547
Easting : 371751
Latitude (S) : 32° 49' 21"
Longitude (E) : 151° 37' 49"

GS Map :
AMG Zone : 56
Coordinate Source :

Construction

Negative depths indicate Above Ground Level;H-Hole;P-Pipe;OD-Outside Diameter;ID-Inside Diameter;C-Cemented;SL-Slot Length;A-Aperture;GS-Grain Size;Q-Quantity

H	P	Component	Type	From (m)	To (m)	OD (mm)	ID (mm)	Interval	Details
1		Hole	Hole	0.00	30.00	96			Open Hole - Water
1	1	Opening	Screen	17.50	29.50				
1	1	Opening	Slots - Horizontal	17.50	29.50	55			PVC; SL: 12mm; A: 5mm
1		Annulus	Waterworn/Rounded	2.00	30.00				Ungraded; GS: 4-5mm

Water Bearing Zones

From (m)	To (m)	Thickness (m)	WBZ Type	S.W.L. (m)	D.D.L. (m)	Yield (L/s)	Hole Depth (m)	Duration (hr)	Salinity (mg/L)
9.00	30.00	21.00		9.00			30.00		

Drillers Log

From (m)	To (m)	Thickness(m)	Drillers Description	Geological Material	Comments
0.00	7.00	7.00		[illegible]one	
7.00	17.10	10.10	siltstone/mudstone	Siltstone	
17.10	17.80	0.70	coal	Coal	
17.80	19.50	1.70	siltstone/claystone	Siltstone	
19.50	19.90	0.40	coal	Coal	
19.90	30.00	10.10	siltstone/mudstone	Siltstone	

Remarks

***** End of GW078126 *****

DEPARTMENT OF NATURAL RESOURCES
Work Summary

GW078127

License : 20BL166673

Work Type : Bore
Work Status : (Unknown)
Construct. Method :
Owner Type :

Authorised Purpose(s)	Intended Purpose(s)
MONITORING BORE	MONITORING BORE

Commenced Date :
Completion Date : 14-Nov-1997

Final Depth : 30.00 m
Drilled Depth : 30.00 m

Contractor Name : McDERMOTT DRILLING
Driller :

Property : - NOT KNOWN
GWMA : 017 - HUNTER
GW Zone : -

Standing Water Level :
Salinity :
Yield :

Site Details

Site Chosen By
Geologist

	County	Parish	Portion/Lot DP
Form A :	NORTHUMBERLAND	STOCKRINGTON	LOT 82 DP 627798
Licensed :	NORTHUMBERLAND	STOCKRINGTON	82 627799

Region : 20 - HUNTER
River Basin :
Area / District :

CMA Map :
Grid Zone :
Scale :

Elevation :
Elevation Source :

Northing : 6366216
Easting : 368933

Latitude (S) : 32° 50' 3"
Longitude (E) : 151° 36' 0"

GS Map :
AMG Zone : 56
Coordinate Source :

Construction

Negative depths indicate Above Ground Level;H-Hole;P-Pipe;OD-Outside Diameter;ID-Inside Diameter;C-Cemented;SL-Slot Length;A-Aperture;GS-Grain Size;Q-Quantity

H	P	Component	Type	From (m)	To (m)	OD (mm)	ID (mm)	Interval	Details
1		Hole	Hole	0.00	30.00	96			Open Hole - Water
1	1	Opening	Screen	14.30	26.30				
1	1	Opening	Slots - Horizontal	14.30	26.30	55			PVC; SL: 12mm; A: 5mm
1		Annulus	Waterworn/Rounded	1.00	30.00				Ungraded; GS: 4-5mm

Water Bearing Zones

From (m)	To (m)	Thickness (m)	WBZ Type	S.W.L. (m)	D.D.L. (m)	Yield (L/s)	Hole Depth (m)	Duration (hr)	Salinity (mg/L)
16.60	30.00	13.40		16.60			30.00		

Drillers Log

From (m)	To (m)	Thickness(m)	Drillers Description	Geological Material	Comments
0.00	13.00	13.00	siltstone/mudstone	Siltstone	
13.00	17.00	4.00	mudstone	Mudstone	
17.00	30.00	13.00	siltstone/mudstone	Siltstone	

Remarks

***** End of GW078127 *****

DEPARTMENT OF NATURAL RESOURCES
Work Summary

GW078128

License : 20BL166674

Authorised Purpose(s): MONITORING BORE
Intended Purpose(s): MONITORING BORE

Work Type : Bore
Work Status : (Unknown)
Construct. Method :
Owner Type :

Commenced Date :
Completion Date : 14-Nov-1997
Final Depth : 30.00 m
Drilled Depth : 30.00 m

Contractor Name : McDERMOTT DRILLING
Driller :

Property : - BERESFIELD
GWMA : 017 - HUNTER
GW Zone : -

Standing Water Level :
Salinity :
Yield :

Site Details

Site Chosen By: Geologist

	County	Parish	Portion/Lot DP
Form A :	NORTHUMBERLAND	HEXHAM	LOT 117 DP 568625
Licensed :	NORTHUMBERLAND	HEXHAM	30 870411

Region : 20 - HUNTER
River Basin :
Area / District :
CMA Map :
Grid Zone :
Scale :

Elevation :
Elevation Source :
Northing : 6366733
Easting : 370773
Latitude (S) : 32° 49' 47"
Longitude (E) : 151° 37' 11"

GS Map :
AMG Zone : 56
Coordinate Source :

Construction

Negative depths indicate Above Ground Level;H-Hole;P-Pipe;OD-Outside Diameter;ID-Inside Diameter;C-Cemented;SL-Slot Length;A-Aperture;GS-Grain Size;Q-Quantity

H	P	Component	Type	From (m)	To (m)	OD (mm)	ID (mm)	Interval	Details
1		Hole	Hole	0.00	30.00	96			Open Hole - Water
1	1	Opening	Screen	18.00	30.00				
1	1	Opening	Slots - Horizontal	18.00	30.00	55			PVC; SL: 12mm; A: 5mm
1		Annulus	Waterworn/Rounded	1.70	8.00				Ungraded; GS: 4-5mm

Water Bearing Zones

From (m)	To (m)	Thickness (m)	WBZ Type	S.W.L. (m)	D.D.L. (m)	Yield (L/s)	Hole Depth (m)	Duration (hr)	Salinity (mg/L)
7.80	30.00	22.20		7.80			30.00		

Drillers Log

From (m)	To (m)	Thickness(m)	Drillers Description	Geological Material	Comments
0.00	8.00	8.00	[illegible]	[illegible]one	
8.00	9.00	1.00	shale	Shale	
9.00	12.00	3.00	siltstone	Siltstone	
12.00	12.80	0.80	shale	Shale	
12.80	13.40	0.60	coal	Coal	
13.40	30.00	16.60	siltstone/mudstone	Siltstone	

Remarks

*** End of GW078128 ***

DEPARTMENT OF NATURAL RESOURCES
Work Summary

GW078161 - PGMW1

License : 20BL153302

Authorised Purpose(s)	**Intended Purpose(s)**
MONITORING BORE	MONITORING BORE

Work Type : Bore
Work Status : (Unknown)
Construct. Method : Other
Owner Type : Local Govt

Commenced Date :
Completion Date : 03-Nov-1993
Final Depth : 84.00 m
Drilled Depth : 84.00 m

Contractor Name : intertech drilling
Driller : 1489 BARDEN, Colin Leslie

Property : - N/A
GWMA : -
GW Zone : -
Standing Water Level :
Salinity :
Yield :

Site Details

Site Chosen By	**County**	**Parish**	**Portion/Lot DP**
Geologist	**Form A :** NORTHUMBERLAND	HEXHAM	LOT 3 DP800035
	Licensed : NORTHUMBERLAND	HEXHAM	34 800036

Region : 20 - HUNTER
River Basin : 210 - HUNTER RIVER
Area / District :
CMA Map : 9232-3S WALLSEND
Grid Zone : 56/1 **Scale :** 1:25,000

Elevation :
Elevation Source :
Northing : 6359302
Easting : 372560
Latitude (S) : 32° 53' 49"
Longitude (E) : 151° 38' 16"

GS Map : **AMG Zone :** 56 **Coordinate Source :** GIS - Geographic Information System

Construction

Negative depths indicate Above Ground Level;H-Hole;P-Pipe;OD-Outside Diameter;ID-Inside Diameter;C-Cemented;SL-Slot Length;A-Aperture;GS-Grain Size;Q-Quantity

H	P	Component	Type	From (m)	To (m)	OD (mm)	ID (mm)	Interval	Details
1		Hole	Hole	0.00	84.00	153			Down Hole Hammer
1	1	Casing	PVC Class 18	-0.50	61.00	60.3			C: 50-56m; Screwed; Seated on Bottom
1	1	Casing	PVC Class 18	-0.50	84.00	60.3			C: 61-76m; Screwed; Seated on Bottom
1	1	Opening	Screen	57.00	60.00	60.3			PVC Class 18; A: .5mm; Screwed
1	1	Opening	Screen	80.00	83.00	60.3			PVC Class 18; A: .5mm; Screwed
1		Annulus	(Unknown)	56.00	61.00				Graded
1		Annulus	(Unknown)	76.00	84.00				Graded

Water Bearing Zones

From (m)	To (m)	Thickness (m)	WBZ Type	S.W.L. (m)	D.D.L. (m)	Yield (L/s)	Hole Depth (m)	Duration (hr)	Salinity (mg/L)

(No Water Bearing Zone Details Found)

Drillers Log

From (m)	To (m)	Thickness(m)	Drillers Description	Geological Material	Comments
0.00	4.00	4.00	Overburden - Surface Coal Pump	Overburden	
4.00	40.00	36.00	Sand - Siltstone (Grey)	Sand	
40.00	41.50	1.50	Coal Seam	Coal Bands	
41.50	57.00	15.50	Sand - Siltstone (Grey) Some small fractures	Sand	
57.00	60.00	3.00	Coal Seam	Coal Bands	
60.00	80.00	20.00	Sand - Siltstone (Grey)	Sand	
80.00	83.00	3.00	Coal Seam	Coal Bands	
83.00	84.00	1.00	Sand - Siltstone (Grey)	Sand	

Remarks

Form A Remarks:
Newcastle City Council, Sumerhill Waste Management Centre, PGMW1.

***** End of GW078161 *****

DEPARTMENT OF NATURAL RESOURCES
Work Summary

GW079059

License : 20BL153300

Work Type : Bore
Work Status : Equipped - bore used for obs
Construct. Method : Rotary - Percussion (Down Hole Hammer)
Owner Type : D.W.R. (NSW Dept Infrastructure, Planning & Nat Re

Authorised Purpose(s)	Intended Purpose(s)
MONITORING BORE	MONITORING BORE

Commenced Date : **Final Depth :**
Completion Date : 21-May-2000 **Drilled Depth :**

Contractor Name :
Driller :

Property : - N/A **Standing Water Level :**
GWMA : - **Salinity :**
GW Zone : - **Yield :**

Site Details

Site Chosen By		County	Parish	Portion/Lot DP
Hydrogeologist	Form A :			
	Licensed :	NORTHUMBERLAND	HEXHAM	34 800036

Region : 20 - HUNTER **CMA Map :**
River Basin : 210 - HUNTER RIVER **Grid Zone :** **Scale :**
Area / District :

Elevation : 56.00 m (A.H.D.) **Northing :** 6359311 **Latitude (S) :** 32° 53' 49"
Elevation Source : Est. Contour 4-8M. **Easting :** 372588 **Longitude (E) :** 151° 38' 16"

GS Map : **AMG Zone :** 56 **Coordinate Source :**

Construction

Negative depths indicate Above Ground Level;H-Hole;P-Pipe;OD-Outside Diameter;ID-Inside Diameter;C-Cemented;SL-Slot Length;A-Aperture;GS-Grain Size;Q-Quantity

H	P	Component	Type	From (m)	To (m)	OD (mm)	ID (mm)	Interval	Details

(No Construction Details Found)

Water Bearing Zones

From (m)	To (m)	Thickness (m)	WBZ Type	S.W.L. (m)	D.D.L. (m)	Yield (L/s)	Hole Depth (m)	Duration (hr)	Salinity (mg/L)

(No Water Bearing Zone Details Found)

Drillers Log

From (m)	To (m)	Thickness(m)	Drillers Description	Geological Material	Comments

Remarks

Form A Remarks:
NEWCASTLE CITY COUNCIL
MINMI
PGMW1a and PGMW1b at the 1 location.
Summerhill Waste facility

***** End of GW079059 *****

DEPARTMENT OF NATURAL RESOURCES
Work Summary

GW079065

License : 20BL153300

Work Type : Bore
Work Status : (Unknown)
Construct. Method :
Owner Type :

Authorised Purpose(s)
MONITORING BORE

Intended Purpose(s)
MONITORING BORE

Commenced Date :
Completion Date :

Final Depth :
Drilled Depth :

Contractor Name :
Driller :

Property : - N/A
GWMA : -
GW Zone : -

Standing Water Level :
Salinity :
Yield :

Site Details

Site Chosen By		County	Parish	Portion/Lot DP
	Form A :			
	Licensed :	NORTHUMBERLAND	HEXHAM	34 800036

Region : 20 - HUNTER
River Basin :
Area / District :

CMA Map :
Grid Zone :
Scale :

Elevation :
Elevation Source :

Northing : 6359943
Easting : 372557.431

Latitude (S) : 32° 53' 28"
Longitude (E) : 151° 38' 16"

GS Map :
AMG Zone : 56
Coordinate Source :

Construction

Negative depths indicate Above Ground Level;H-Hole;P-Pipe;OD-Outside Diameter;ID-Inside Diameter;C-Cemented;SL-Slot Length;A-Aperture;GS-Grain Size;Q-Quantity

H	P	Component	Type	From (m)	To (m)	OD (mm)	ID (mm)	Interval	Details

(No Construction Details Found)

Water Bearing Zones

From (m)	To (m)	Thickness (m)	WBZ Type	S.W.L. (m)	D.D.L. (m)	Yield (L/s)	Hole Depth (m)	Duration (hr)	Salinity (mg/L)

(No Water Bearing Zone Details Found)

Drillers Log

From (m)	To (m)	Thickness(m)	Drillers Description	Geological Material	Comments

Remarks

Form A Remarks:
NEWCASTLE CITY COUNCIL
MINMI
PGMW5
Summerhill Waste Management Facility

***** End of GW079065 *****

***** End of Report *****

APPENDIX B

PIEZOMETER CONSTRUCTION LOGS

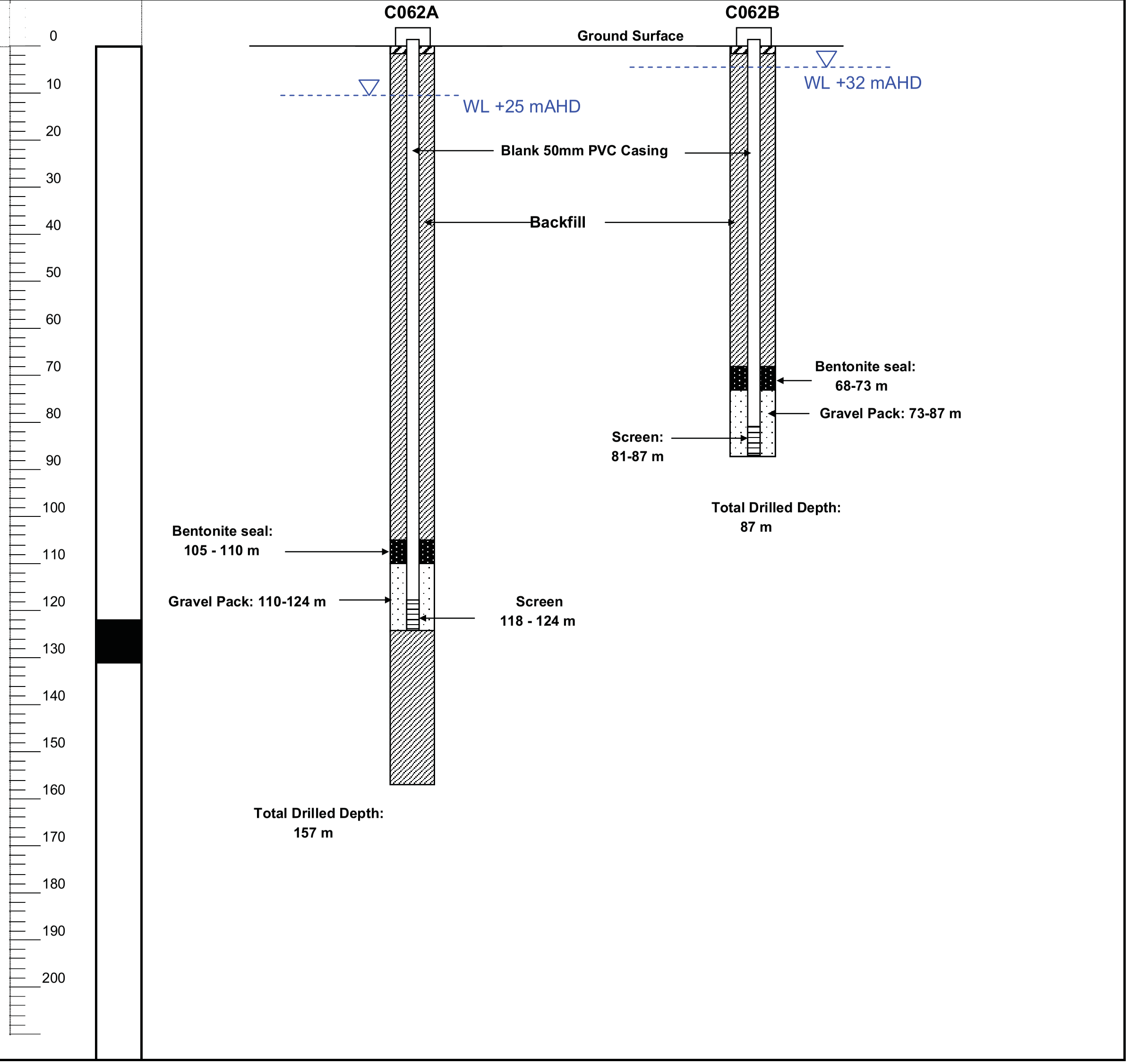
Peter Dundon and Assoc.
Logging Sheet

BORES: C062A and C062B

						Project No:	05-0163
Client:	Bore:	Elevation (GL):	Elevation (TOC):	Stickup:	Drilling Contractor:	Date Started:	Date Finished:
Donaldson Coal Pty Ltd	**C062A**	**36 mAHD**		**.. m**			
Locationt:	**C062B**	**36 mAHD**		**.. m**			
Abel Coal Project							
			Hole depths: **As shown**			Supervised By:	

Description | **Depth (metres)** | **Well Construction Details:**

Donaldson Seams

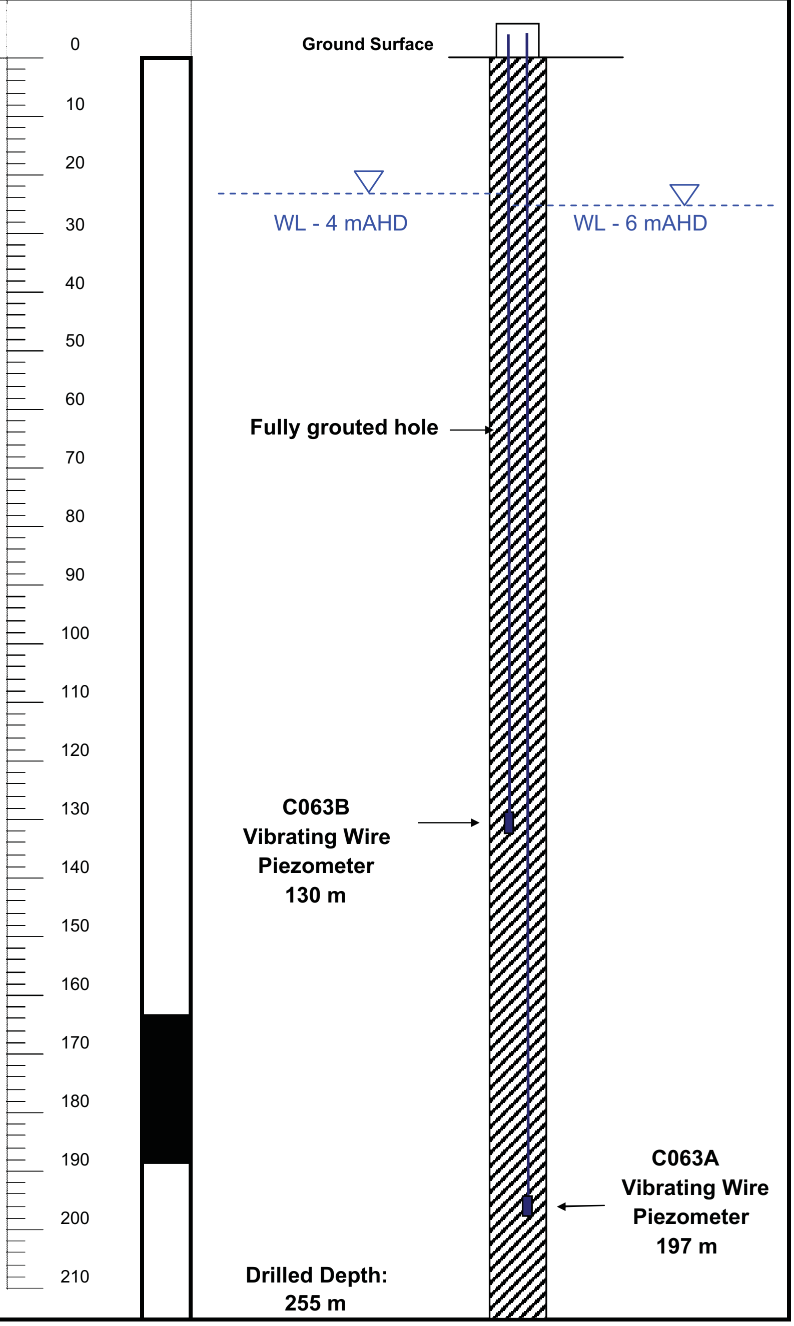


Peter Dundon and Assoc.
Logging Sheet

BORE: C063A and C063B

		Project No:	05-0163
Client: **Donaldson Coal Pty Ltd**	Elevation (GL):	19.67 mAHD	
	Elevation (TOC):	… mAHD	
Location: **Abel Coal Project**	Stickup:	… m	
	Hole Depth:	255 m	
Drilling Contractor:	Date Started:		Supervised By:
	Date Completed:		

Description	Depth (metres)	Well Construction Details:
Upper Donaldson Seam	170	
Lower Donaldson Seam	185	

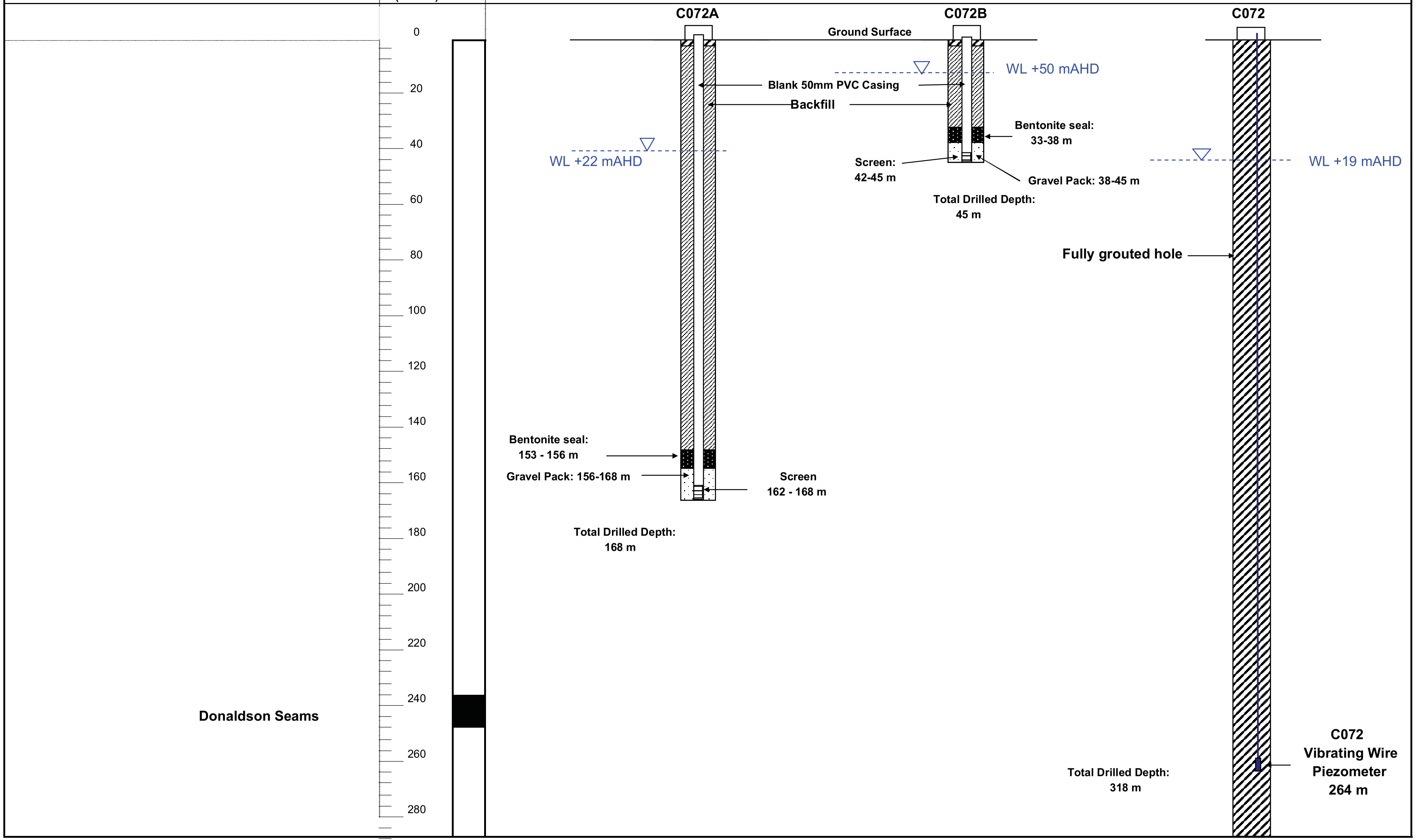


Peter Dundon and Assoc.
Logging Sheet

BORES: C072, C072A and C072B

						Project No:	05-0163
Client:	Bore:	Elevation (GL):	Elevation (TOC):	Stickup:	Drilling Contractor:	Date Started:	Date Finished:
Donaldson Coal Pty Ltd	**C072**	**63 mAHD**		**.. m**			
Locationt:	**C072A**	**63 mAHD**		**.. m**			
Abel Coal Project	**C072B**	**63 mAHD**					
			Hole depths: **As shown**			Supervised By:	

Description	Depth (metres)	Well Construction Details:

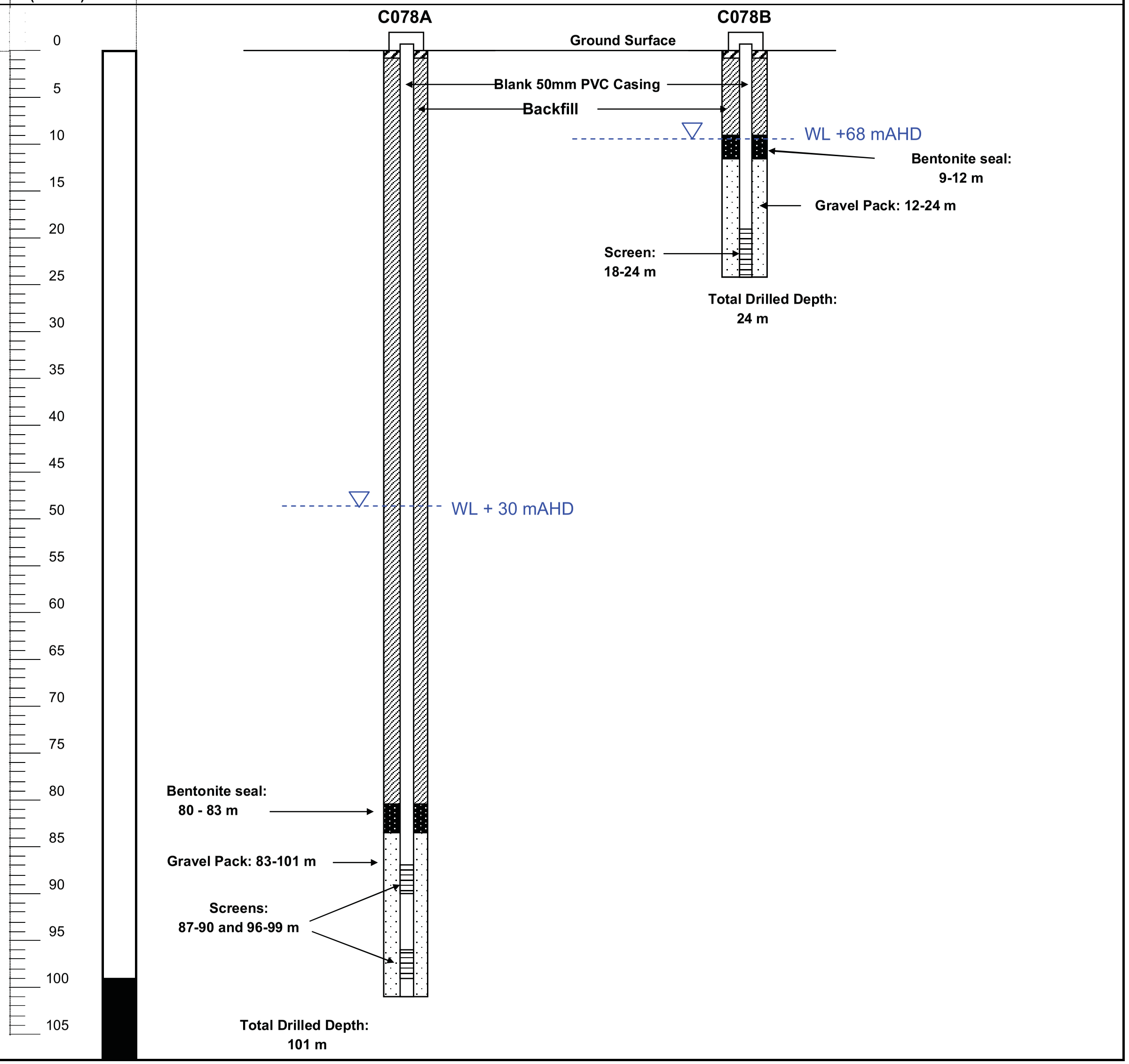


Peter Dundon and Assoc.
Logging Sheet

BORES: C078A and C078B

						Project No:	05-0163
Client:	Bore:	Elevation (GL):	Elevation (TOC):	Stickup:	Drilling Contractor:	Date Started:	Date Finished:
Donaldson Coal Pty Ltd	**C078A**	**77 mAHD**		**.. m**			
Locationt:	**C078B**	**77 mAHD**		**.. m**			
Abel Coal Project							
			Hole depths: **As shown**			Supervised By:	

Description	Depth (metres)	Well Construction Details:
Donaldson Seams	0–105	

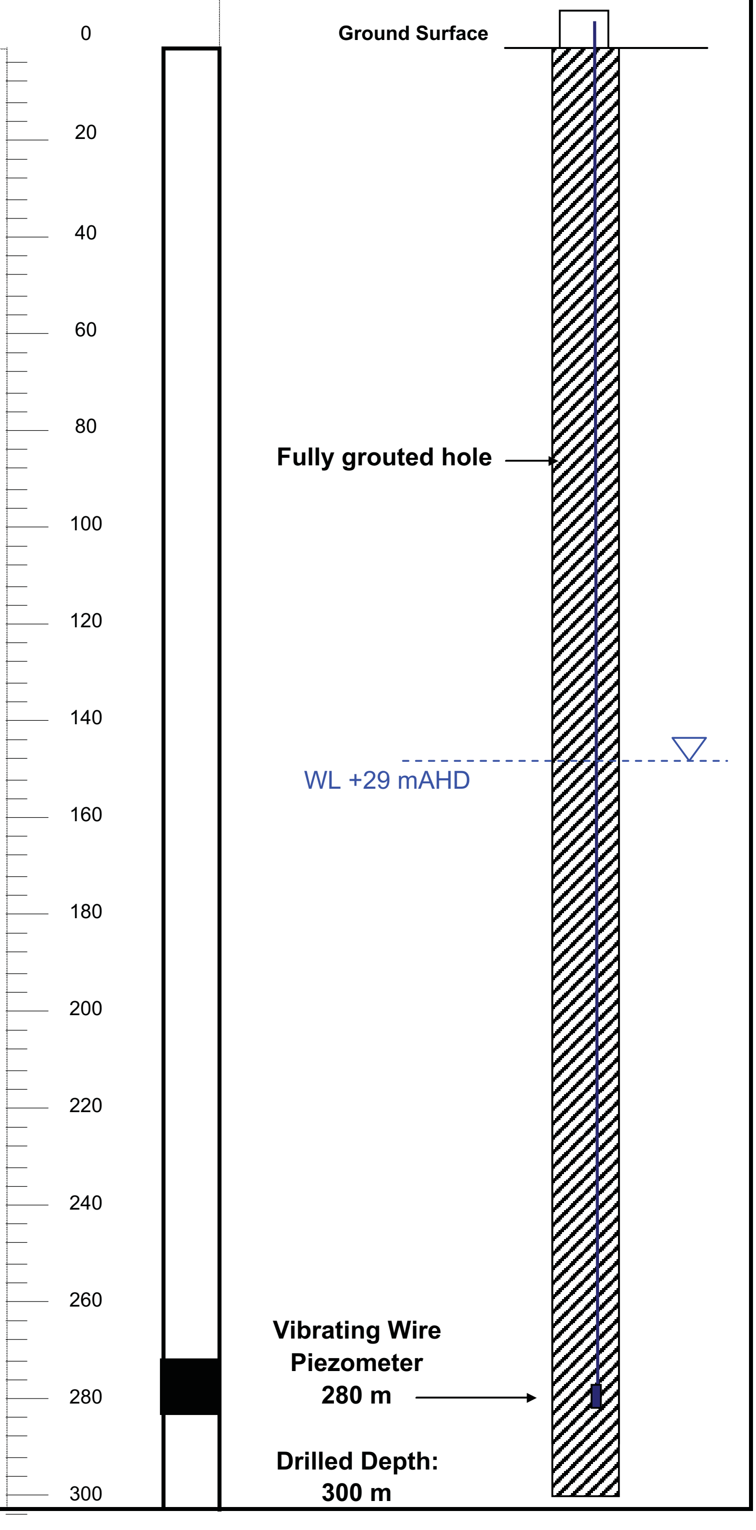


Peter Dundon and Assoc.
Logging Sheet

BORE: C080

		Project No:	**05-0163**
Client: **Donaldson Coal Pty Ltd**	Elevation (GL):	**177 mAHD**	
	Elevation (TOC):	**… mAHD**	
Location: **Abel Coal Project**	Stickup:	**… m**	
	Hole Depth:	**300 m**	
Drilling Contractor:	Date Started:		Supervised By:
	Date Completed:		

Description	Depth (metres)	Well Construction Details:
Donaldson Seams	280	

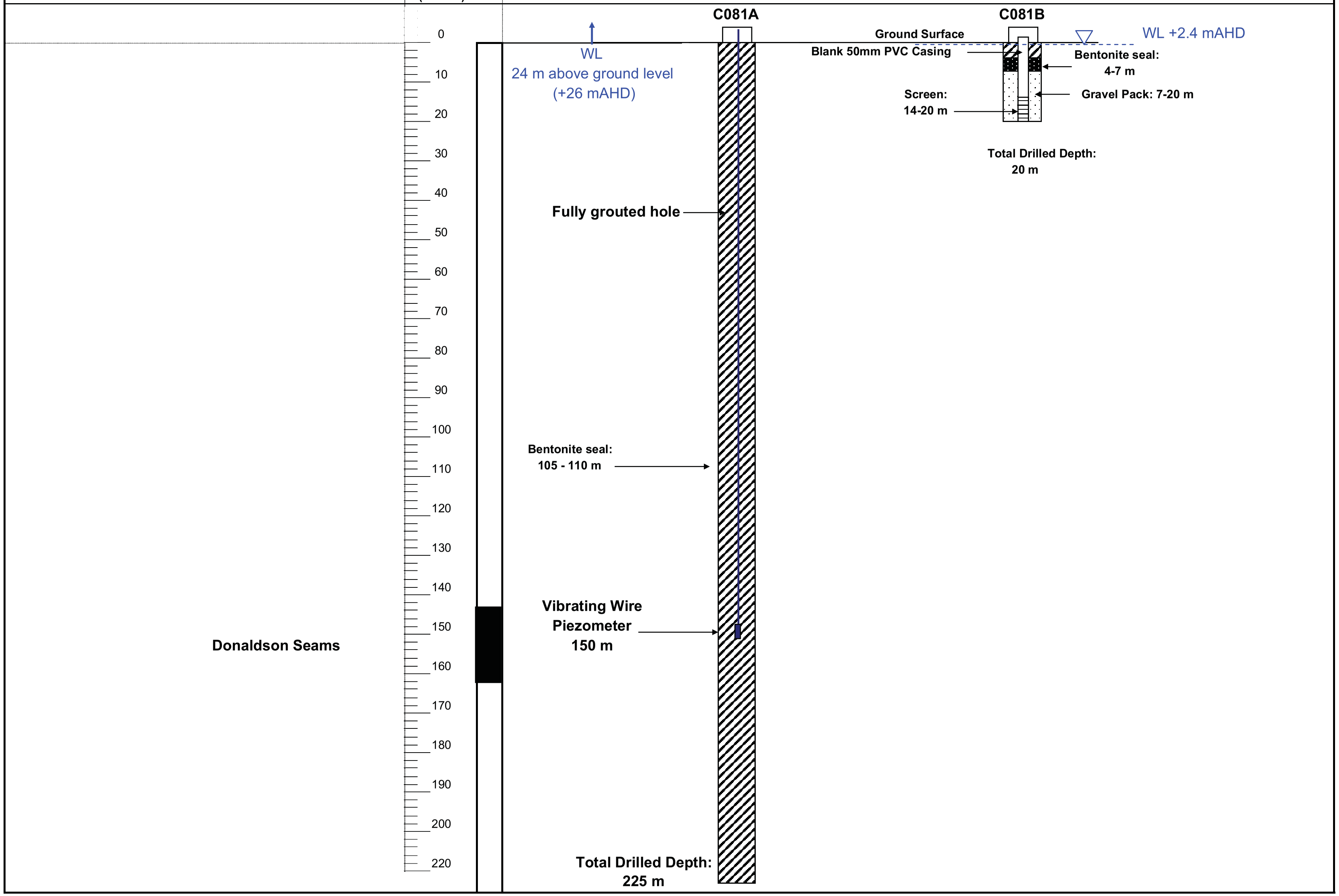


Peter Dundon and Assoc.
Logging Sheet

BORES: C081A and C081B

						Project No:	05-0163
Client:	Bore:	Elevation (GL):	Elevation (TOC):	Stickup:	Drilling Contractor:	Date Started:	Date Finished:
Donaldson Coal Pty Ltd	**C081A**	**2.3 mAHD**		**.. m**			
Locationt:	**C081B**	**2.3 mAHD**		**.. m**			
Abel Coal Project							
			Hole depths: **As shown**			Supervised By:	

Description	Depth (metres)	Well Construction Details:

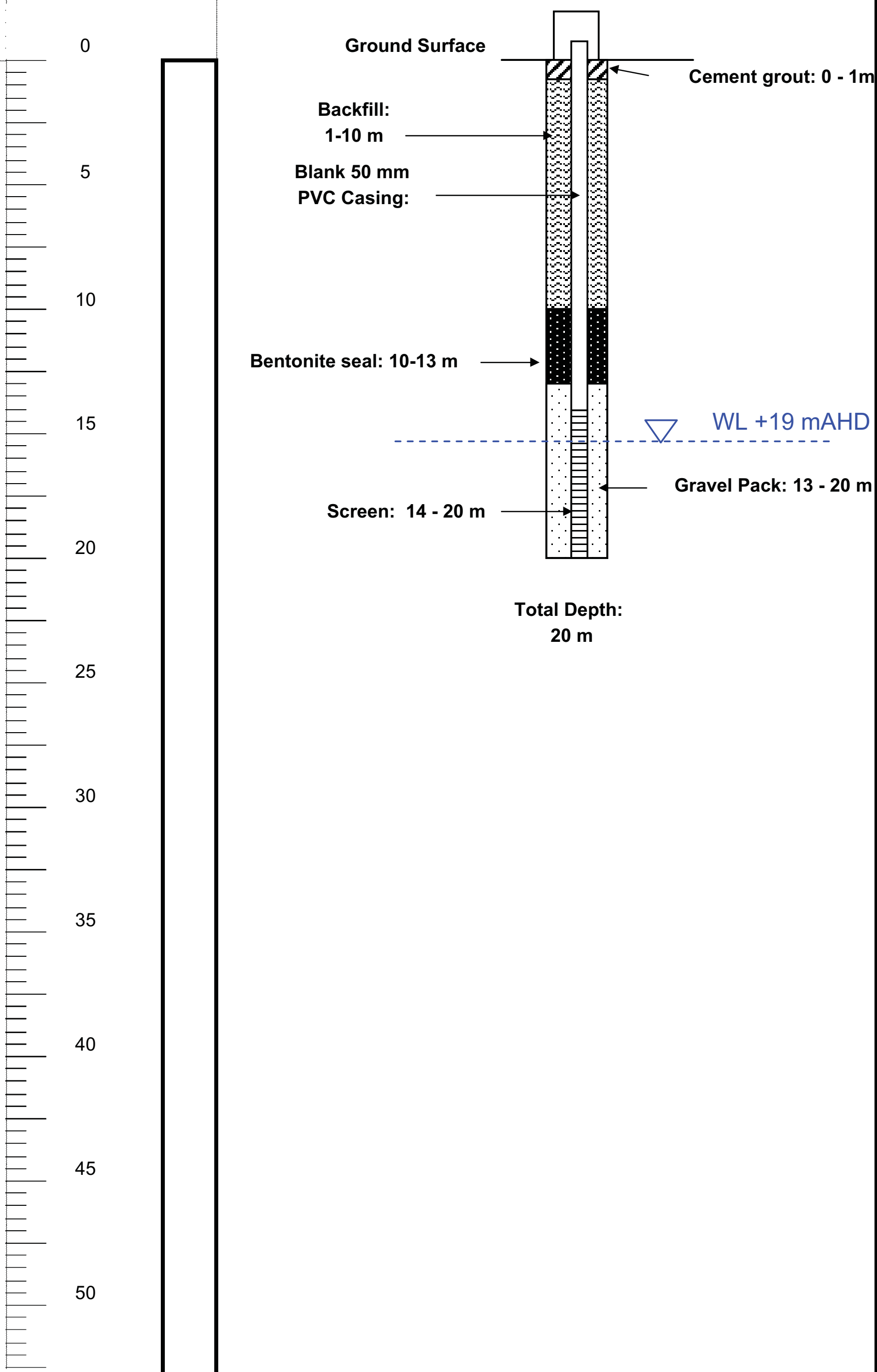


Peter Dundon and Assoc.
Logging Sheet

BORE: C082

		Project No:	05-0163
Client: **Donaldson Coal Pty Ltd**	Elevation (GL):	34 mAHD	
	Elevation (TOC):	… mAHD	
Location: **Abel Coal Project**	Stickup:	… m	
	Hole Depth:	20 m	
Drilling Contractor:	Date Started:		Supervised By:
	Date Completed:		

Description	Depth (metres)	Well Construction Details:

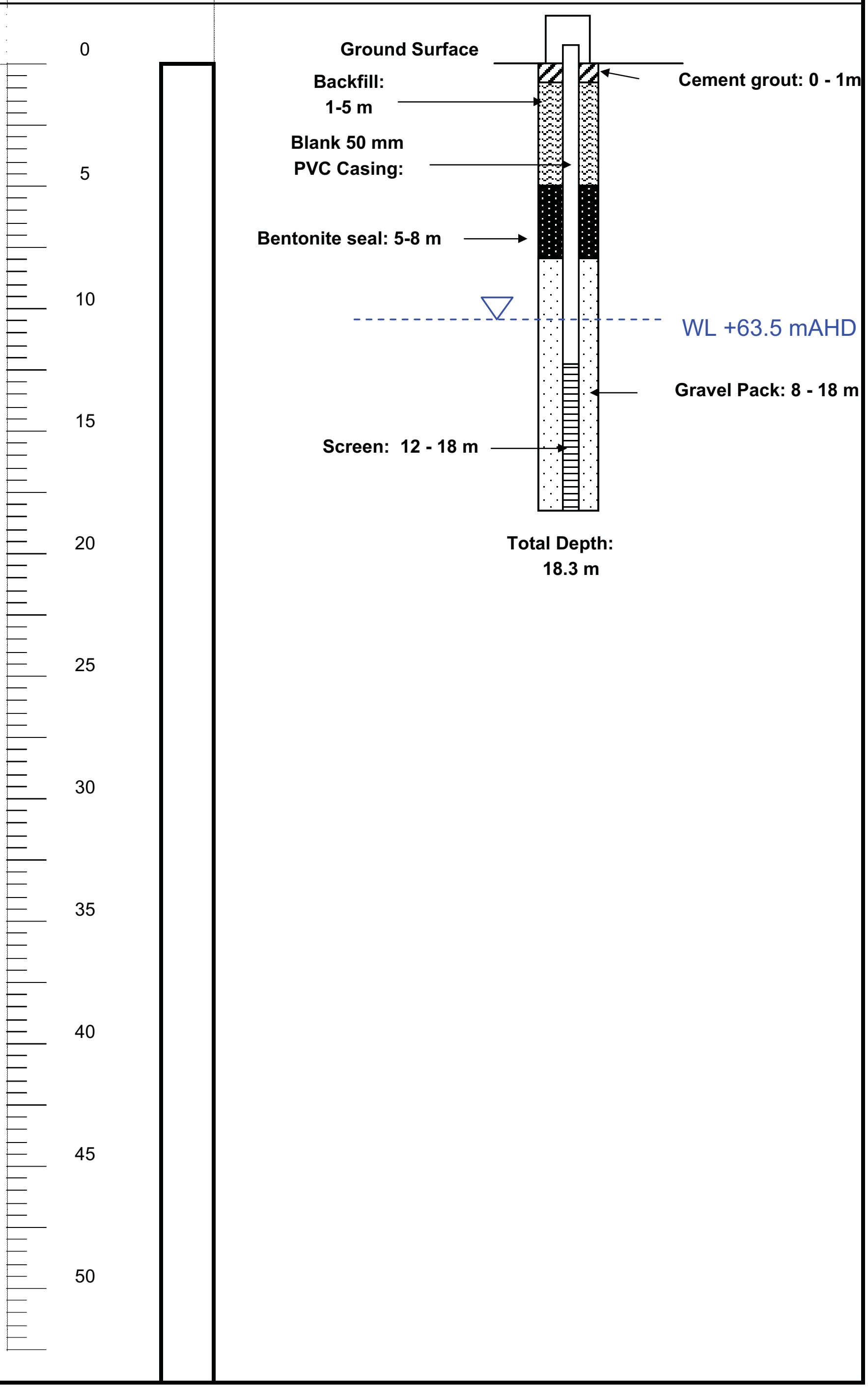


Peter Dundon and Assoc.
Logging Sheet

BORE: C087

			Project No:	**05-0163**
Client: **Donaldson Coal Pty Ltd**	Elevation (GL):	**74 mAHD**		
	Elevation (TOC):	**… mAHD**		
Location: **Abel Coal Project**	Stickup:	**… m**		
	Hole Depth:	**18.3 m**		
Drilling Contractor:	Date Started:		Supervised By:	
	Date Completed:			

Description	Depth (metres)	Well Construction Details:



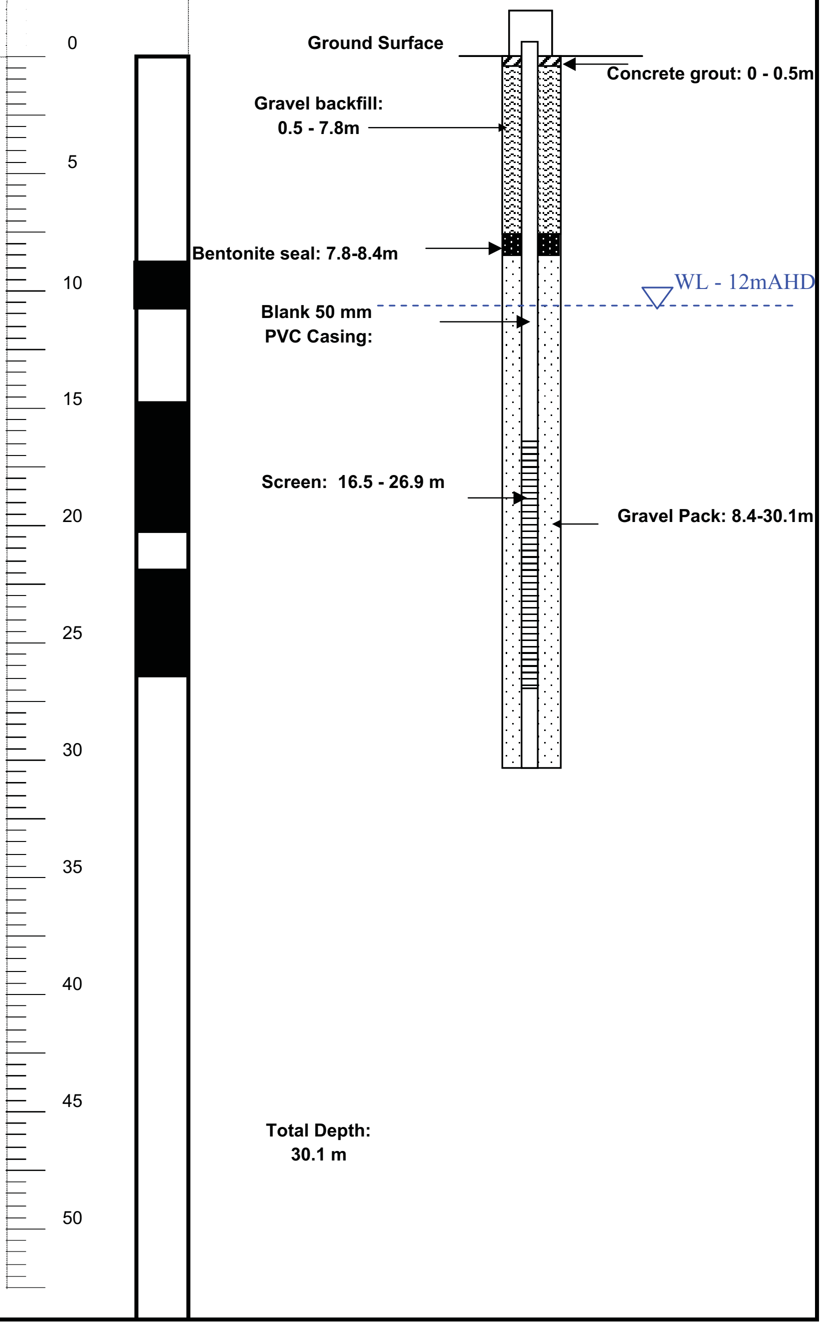
Peter Dundon and Assoc.

Logging Sheet

BORE: DPZ1

		Project No:	05-0163
Client: **Donaldson Coal Pty Ltd**	Elevation (GL):	23.08mAHD	
	Elevation (TOC)	23.56mAHD	
Location: **Abel Coal Project**	Stickup:	0.48m	
	Hole Depth:	30.1m	
Drilling Contractor:	Date Started:		Supervised By:
	Date Completed		

Description	Depth (metres)	Well Construction Details:
Upper Donaldson Seam	10	
Lower Donaldson Seam	20	
Big Ben Seam	25	



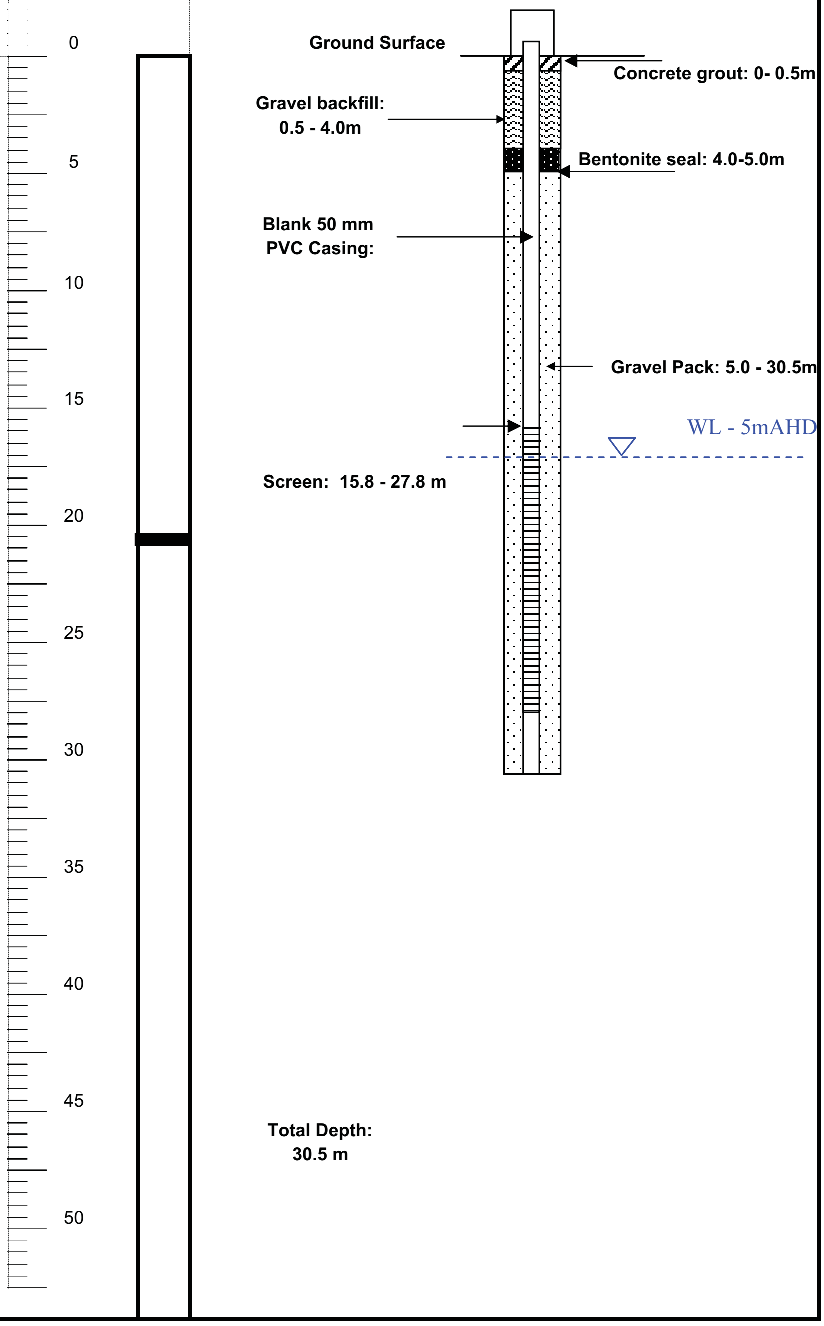
Peter Dundon and Assoc.

Logging Sheet

BORE: DPZ2

			Project No:	05-0163
Client: **Donaldson Coal Pty Ltd**	Elevation (GL):	22.3 mAHD		
	Elevation (TOC)	23.37mAHD		
Location: **Abel Coal Projecy**	Stickup:	1.07m		
	Hole Depth:	30.5m		
Drilling Contractor:	Date Started:		Supervised By:	
	Date Completed			

Description	Depth (metres)	Well Construction Details:
Beresfield Seam		

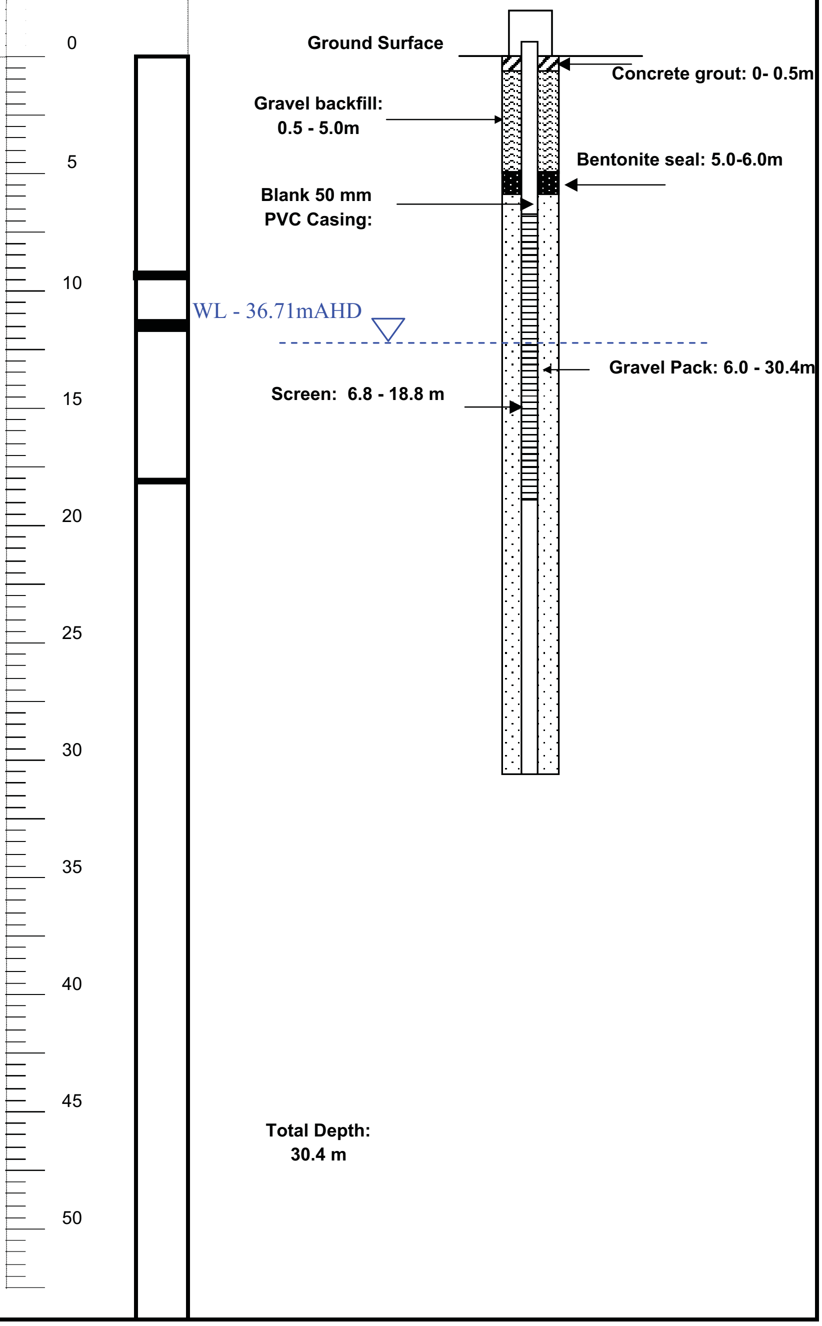


Peter Dundon and Assoc.
Logging Sheet

BORE: DPZ3

		Project No:	**05-0163**
Client: **Donaldson Coal Pty Ltd**	Elevation (GL):	**49.09mAHD**	
	Elevation (TOC)	**49.62 mAHD**	
Location: **Abel Coal Project**	Stickup:	**0.53m**	
	Hole Depth:	**30.4m**	
Drilling Contractor:	Date Started:		Supervised By:
	Date Completed		

Description	Depth (metres)	Well Construction Details:
Undifferentiated Coal (approx. 10 m)		
Undifferentiated Coal (approx. 12 m)		
Undifferentiated Coal (approx. 18 m)		

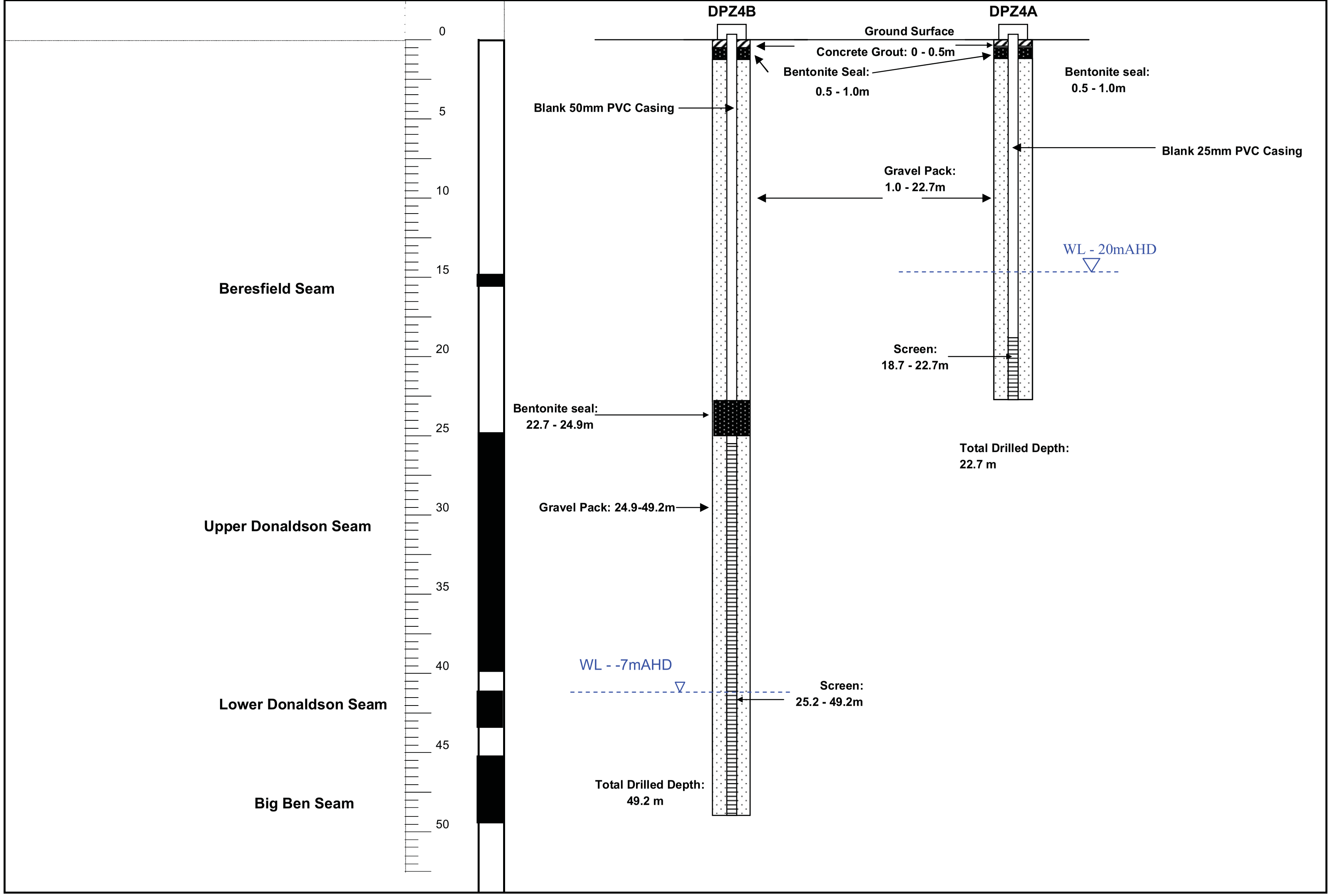


Peter Dundon and Assoc.
Logging Sheet

BORES: DPZ4A and DPZ4B

Client:	Bore:	Elevation (GL):	Elevation (TOC):	Stickup:	Drilling Contractor:	Project No: 05-0163	
						Date Started:	Date Finished:
Donaldson Coal Pty Ltd	DPZ4A	35.01mAHD	35.74 mAHD	0.73m			
Locationt: Abel Coal Project	DPZ4B	35.01mAHD	35.74 mAHD	0.73m			
			Hole depths: As shown			Supervised By:	

Description	Depth (metres)	Well Construction Details:



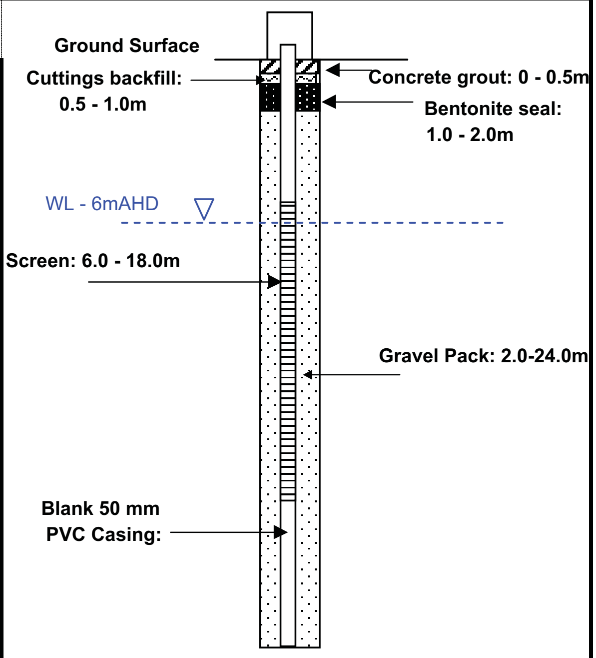
Peter Dundon and Assoc.

Logging Sheet

BORE: DPZ5

			Project No:	05-0163
Client: **Donaldson Coal Pty Ltd**	Elevation (GL):	12.8 mAHD		
	Elevation (TOC	13.58mAHD		
Location: **Abel Coal Project**	Stickup:	0.78m		
	Hole Depth:	24.0m		
Drilling Contractor: **Mitchell Drilling**	Date Started:	1 July 2005	Supervised By:	
	Date Complete(	9 July 2005		A Price

Description	Depth (metres)	Well Construction Details:
	0 5 10 15 20 25 30 35 40 45 50	



Total Depth:
24.0 m

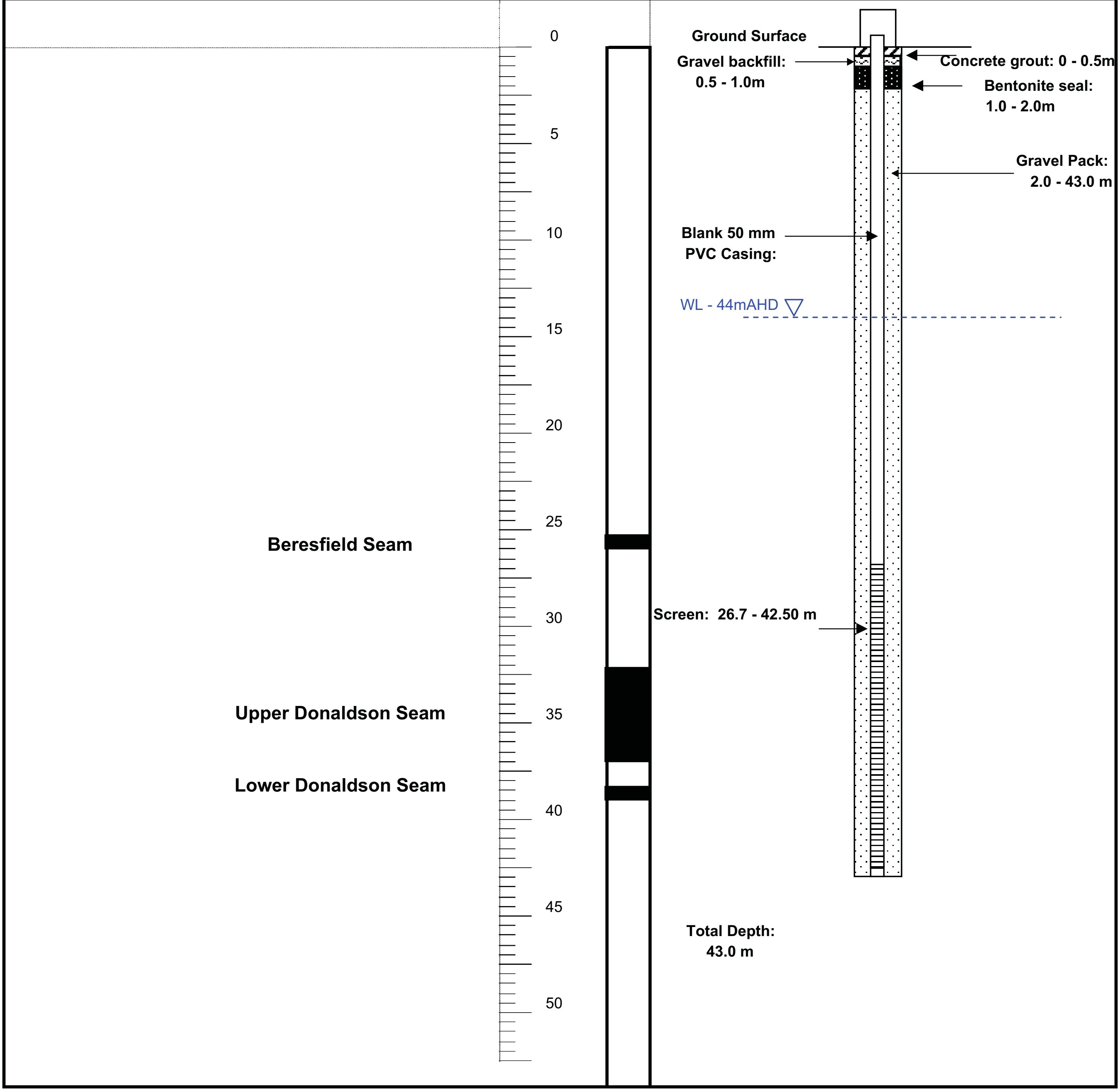
Peter Dundon and Assoc.

Logging Sheet

BORE: DPZ6

		Project No:	**05-0163**
Client: **Donaldson Coal Pty Ltd**	Elevation (GL):	**57.7 mAHD**	
	Elevation (TOC	**58.3mAHD**	
Location: **Abel Coal Project**	Stickup:	**0.6m**	
	Hole Depth:	**43.0m**	
Drilling Contractor:	Date Started:		Supervised By:
	Date Complete(		

Description	**Depth (metres)**	**Well Construction Details:**



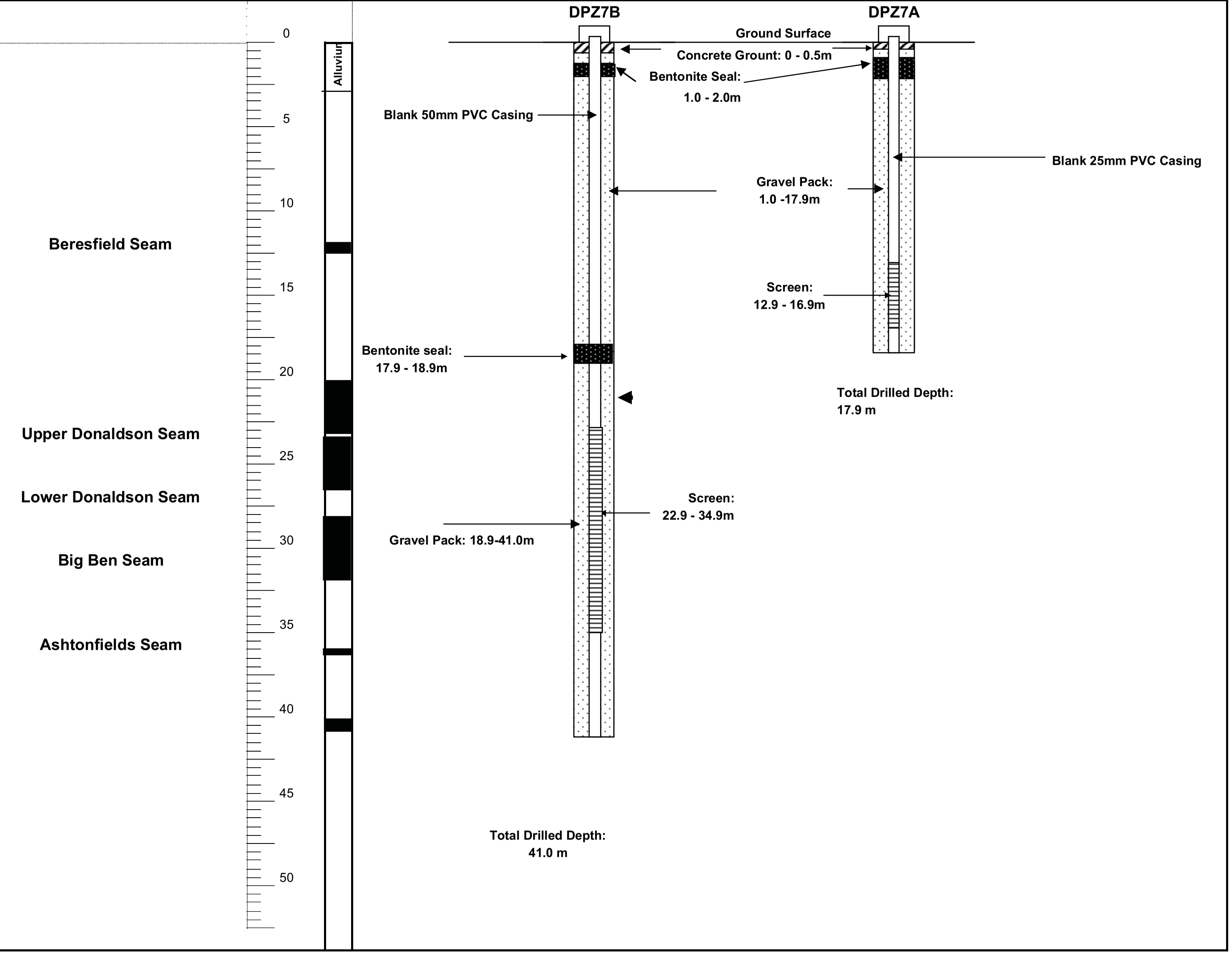
Peter Dundon and Assoc.
Logging Sheet

BORES: DPZ7A and DPZ7B

Project No:	05-0163

Client:	Bore:	Elevation (GL):	Elevation (TOC):	Stickup:	Drilling Contractor:	Date Started:	Date Finished:
Donaldson Coal Pty Ltd	DPZ7A	428.270 mAHD	428.44 mAHD	0.78m			
Location:	DPZ7B	428.404 mAHD	428.63 mAHD	0.78m			
Abel Coal Project							
			Hole depths: As shown			Supervised By:	

Description	Depth (metres)	Well Construction Details:



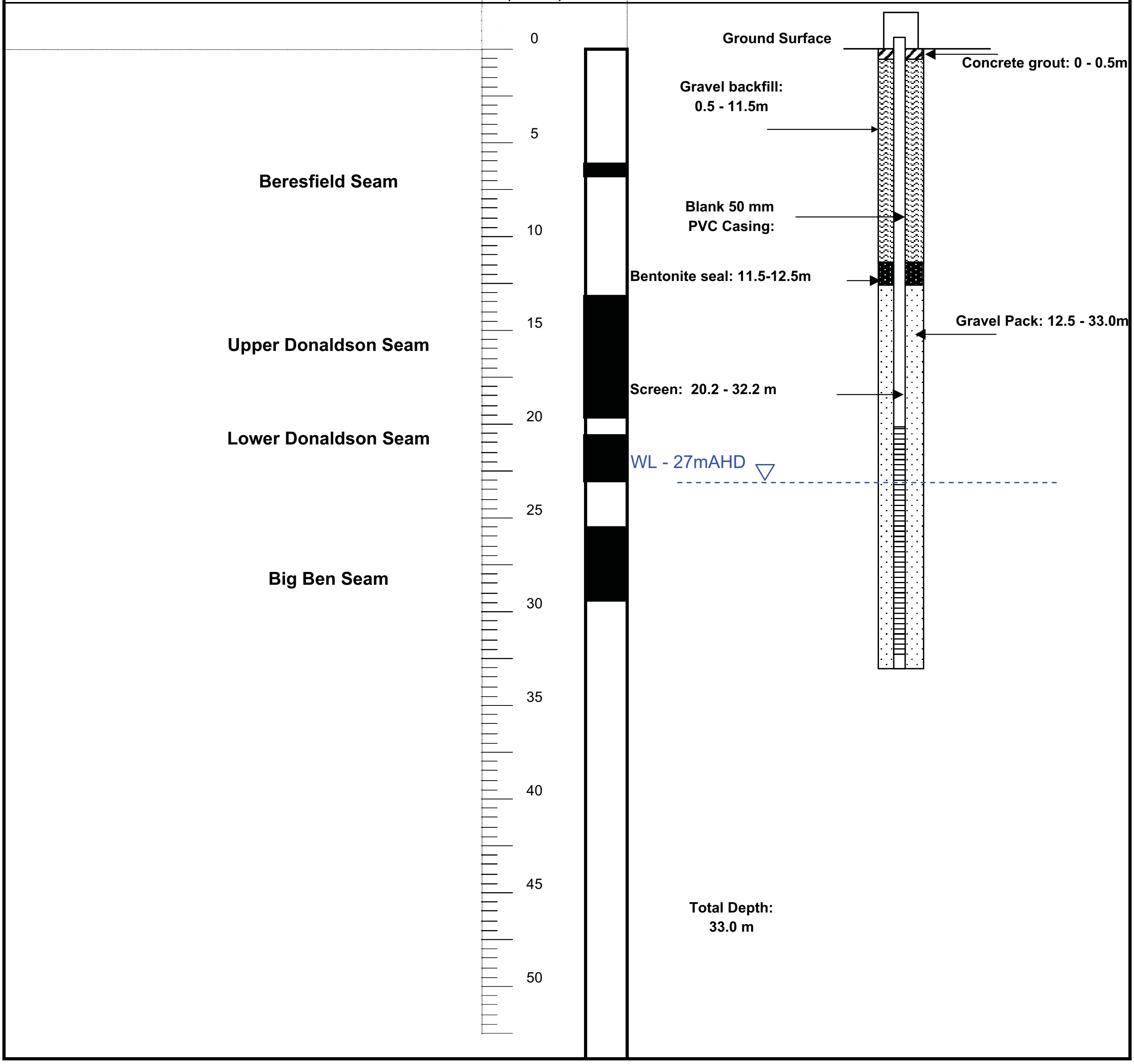
Peter Dundon and Assoc.

Logging Sheet

BORE: DPZ8

		Project No:	**05-0163**
Client: **Donaldson Coal Pty Ltd**	Elevation (GL):	**51.8 mAHD**	
	Elevation (TOC)	**52.43 mAHD**	
Location: **Abel Coal Project**	Stickup:	**0.63m**	
	Hole Depth:	**33.0m**	
Drilling Contractor:	Date Started:		Supervised By:
	Date Completed		

Description	Depth (metres)	Well Construction Details:



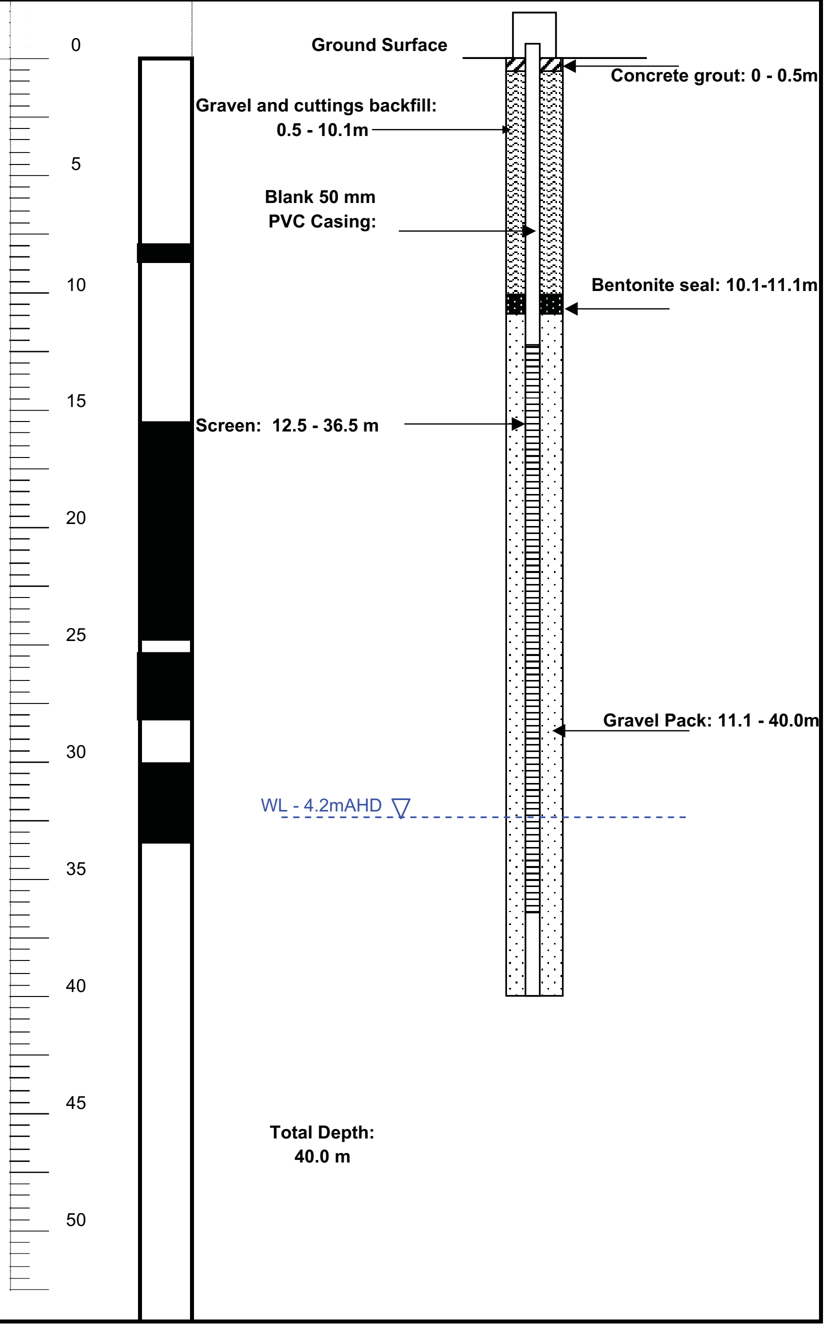
Peter Dundon and Assoc.

Logging Sheet

BORE: DPZ9

		Project No:	05-0163
Client: **Donaldson Coal Pty Ltd**	Elevation (GL):	36.36 mAHD	
	Elevation (TOC)	36.85 mAHD	
Location: **Abel Coal Project**	Stickup:	0.49m	
	Hole Depth:	40.0m	
Drilling Contractor:	Date Started:		Supervised By:
	Date Completed		

Description	Depth (metres)	Well Construction Details:
Beresfield Seam		
Upper Donaldson Seam		
Lower Donaldson Seam		
Big Ben Seam		

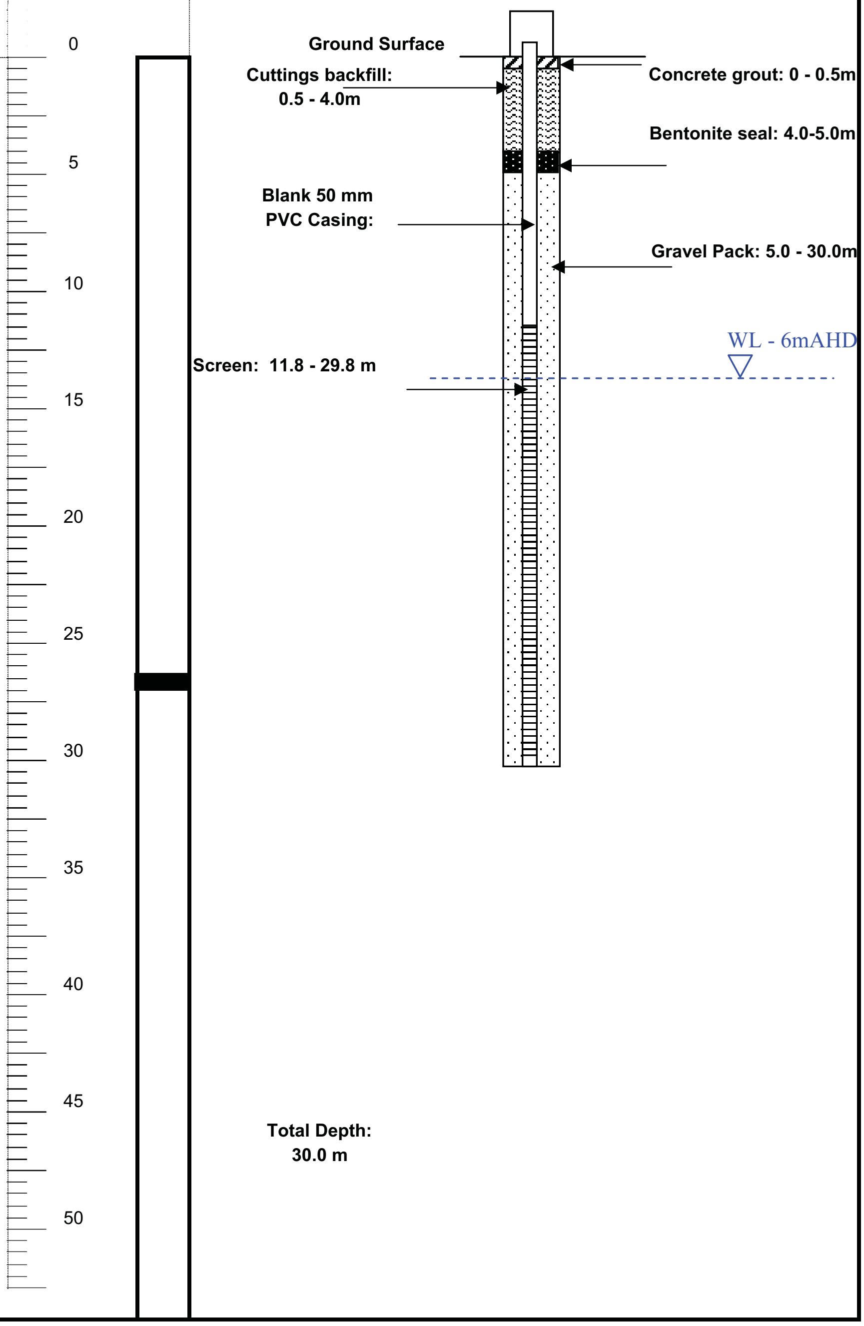


Peter Dundon and Assoc.
Logging Sheet

BORE: DPZ10

		Project No:	**05-0163**
Client: **Donaldson Coal Pty Ltd**	Elevation (GL):	**19.81 mAHD**	
	Elevation (TOC)	**20.1 mAHD**	
Location: **Abel Coal Project**	Stickup:	**0.29m**	
	Hole Depth:	**30.0m**	
Drilling Contractor:	Date Started:		Supervised By:
	Date Completed		

Description	Depth (metres)	Well Construction Details:
Beresfield Seam		



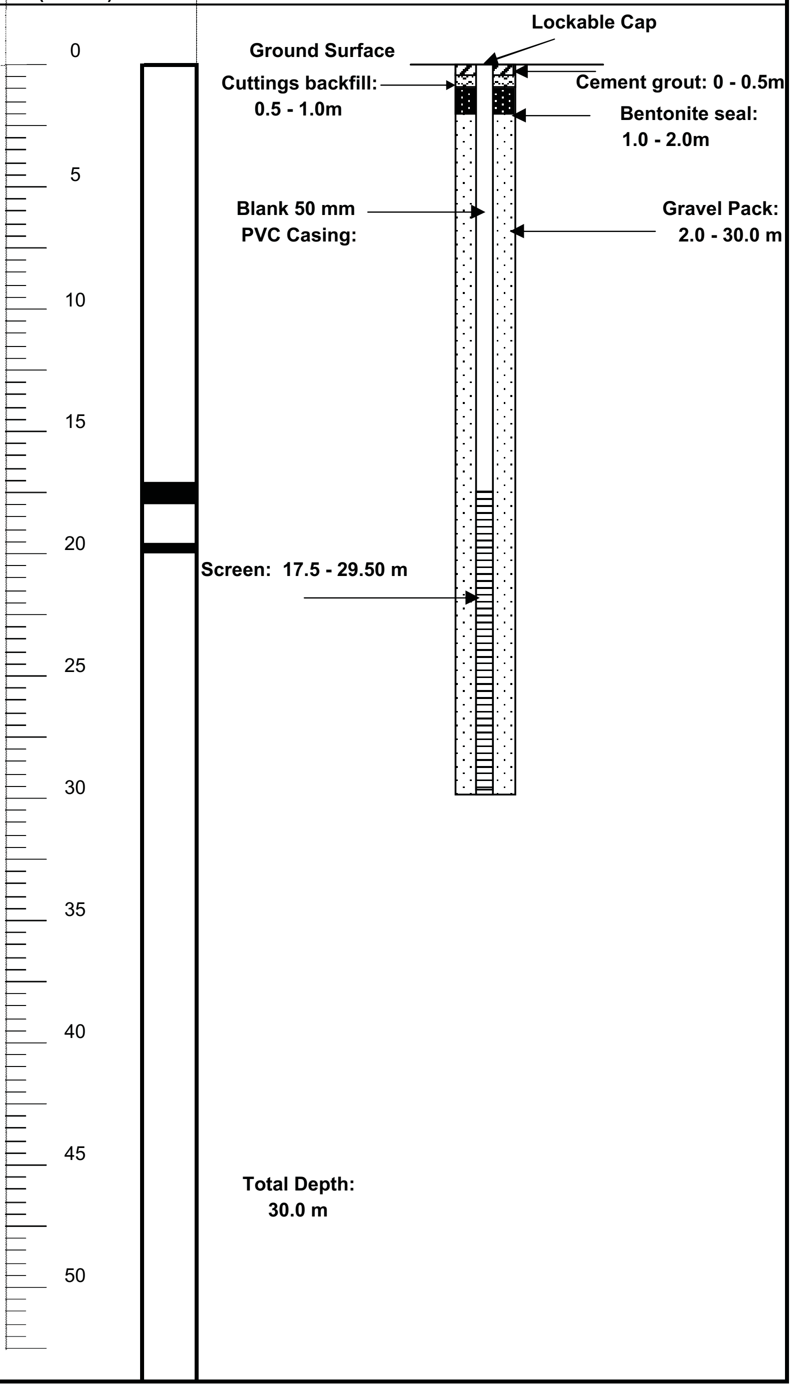
Peter Dundon and Assoc.

Logging Sheet

BORE: DPZ11

		Project No:	05-0163
Client:	Elevation (GL):	19 mAHD	
Donaldson Coal Pty Ltd	Elevation (TOC	19 mAHD	
Location:	Stickup:	0m	
Abel Coal Project	Hole Depth:	30.0m	
Drilling Contractor:	Date Started:		Supervised By:
	Date Complete		

Description	Depth (metres)	Well Construction Details:
Undifferentiated Coal		
Undifferentiated Coal		



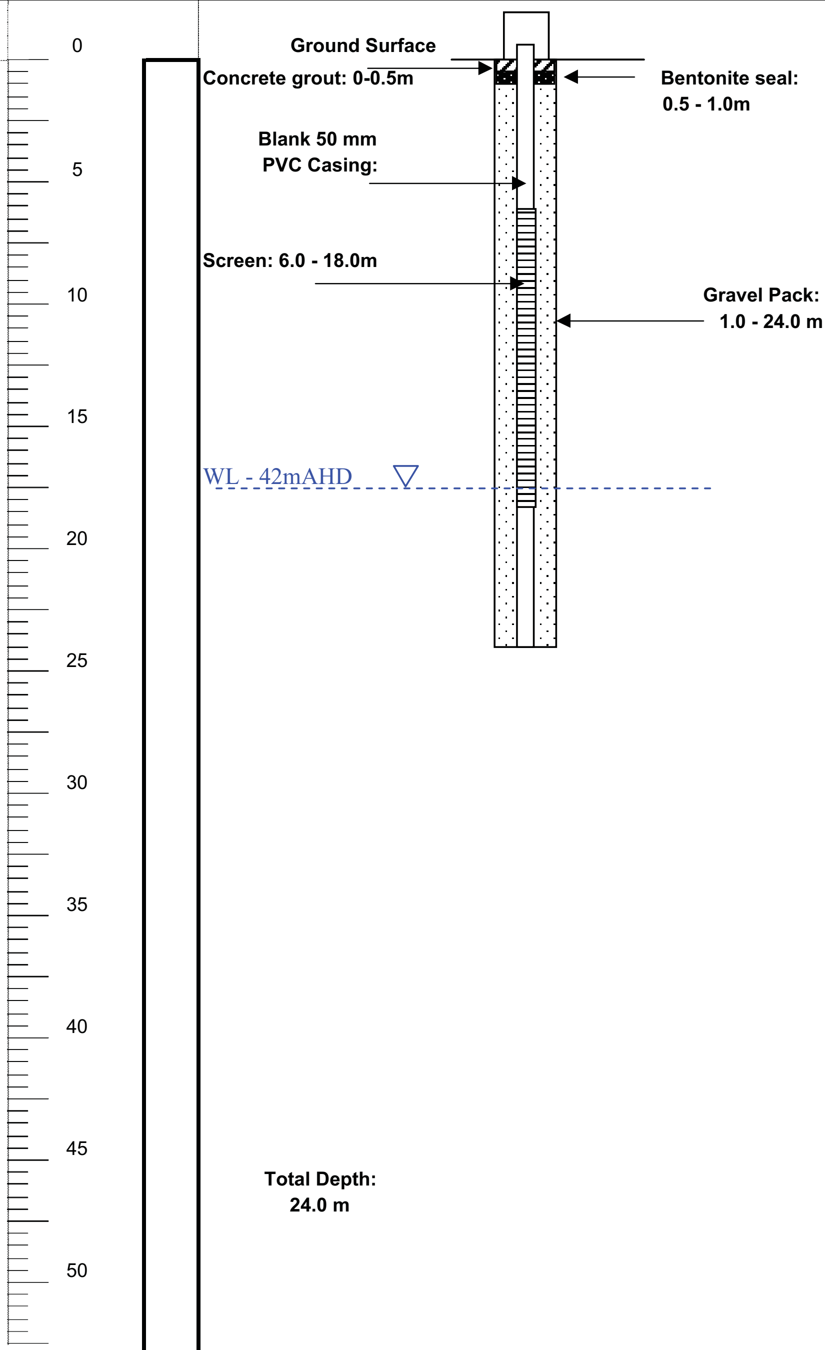
Peter Dundon and Assoc.

Logging Sheet

BORE: DPZ12

		Project No:	05-0163
Client: **Donaldson Coal Pty Ltd**	Elevation (GL):	**59.5mAHD**	
	Elevation (TOC	**60 mAHD**	
Location: **Abel Coal Project**	Stickup:	**0.5m**	
	Hole Depth:	**24.0m**	
Drilling Contractor:	Date Started:		Supervised By:
	Date Complete		

Description	Depth (metres)	Well Construction Details:



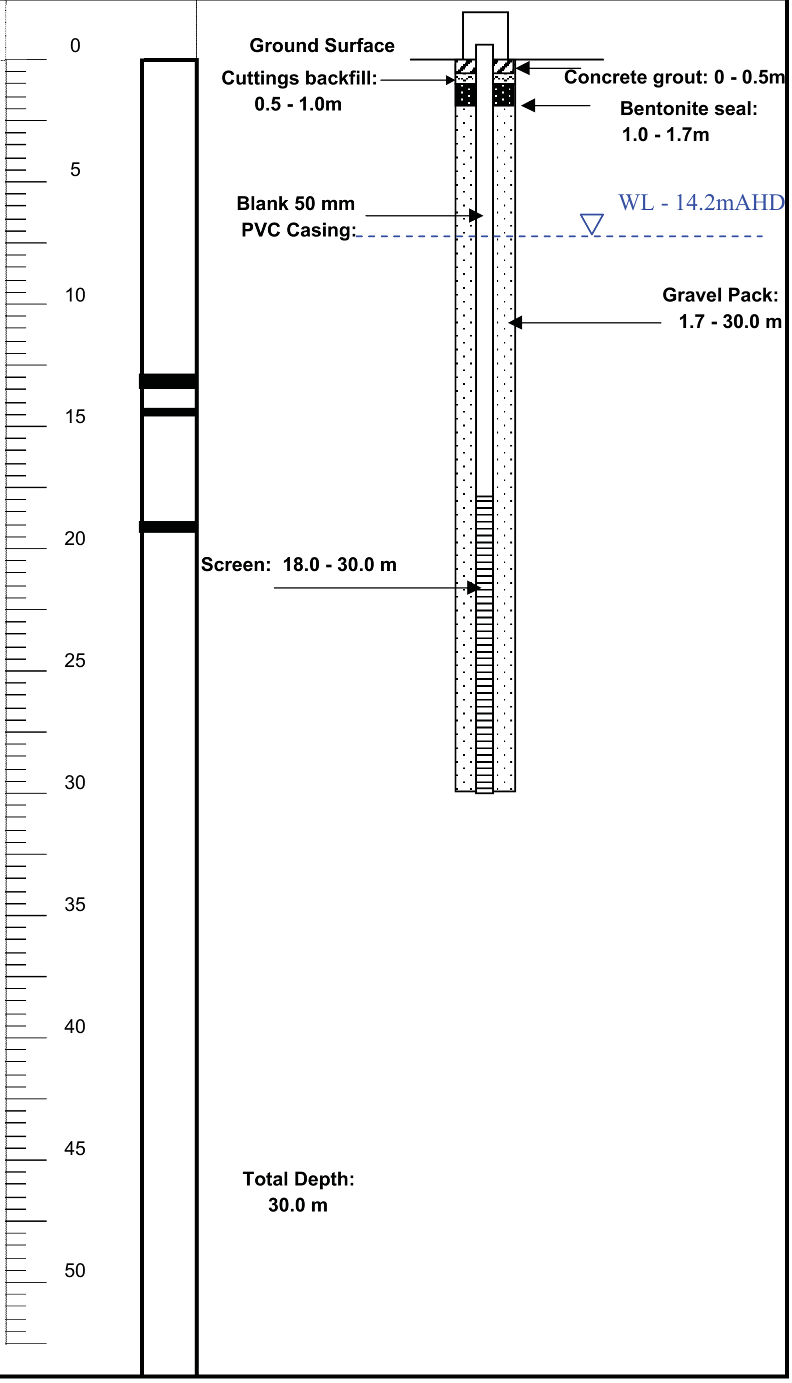
Peter Dundon and Assoc.

Logging Sheet

BORE: DPZ13

		Project No:	05-0163
Client: Donaldson Coal Pty Ltd	Elevation (GL): 21.48 mAHD Elevation (TOC 21.97 mAHD		
Location: Abel Coal Project	Stickup: 0.49m Hole Depth: 30.0m		
Drilling Contractor:	Date Started: Date Complete		Supervised By:

Description	Depth (metres)	Well Construction Details:
Undifferentiated Coal Undifferentiated Coal Undifferentiated Coal		



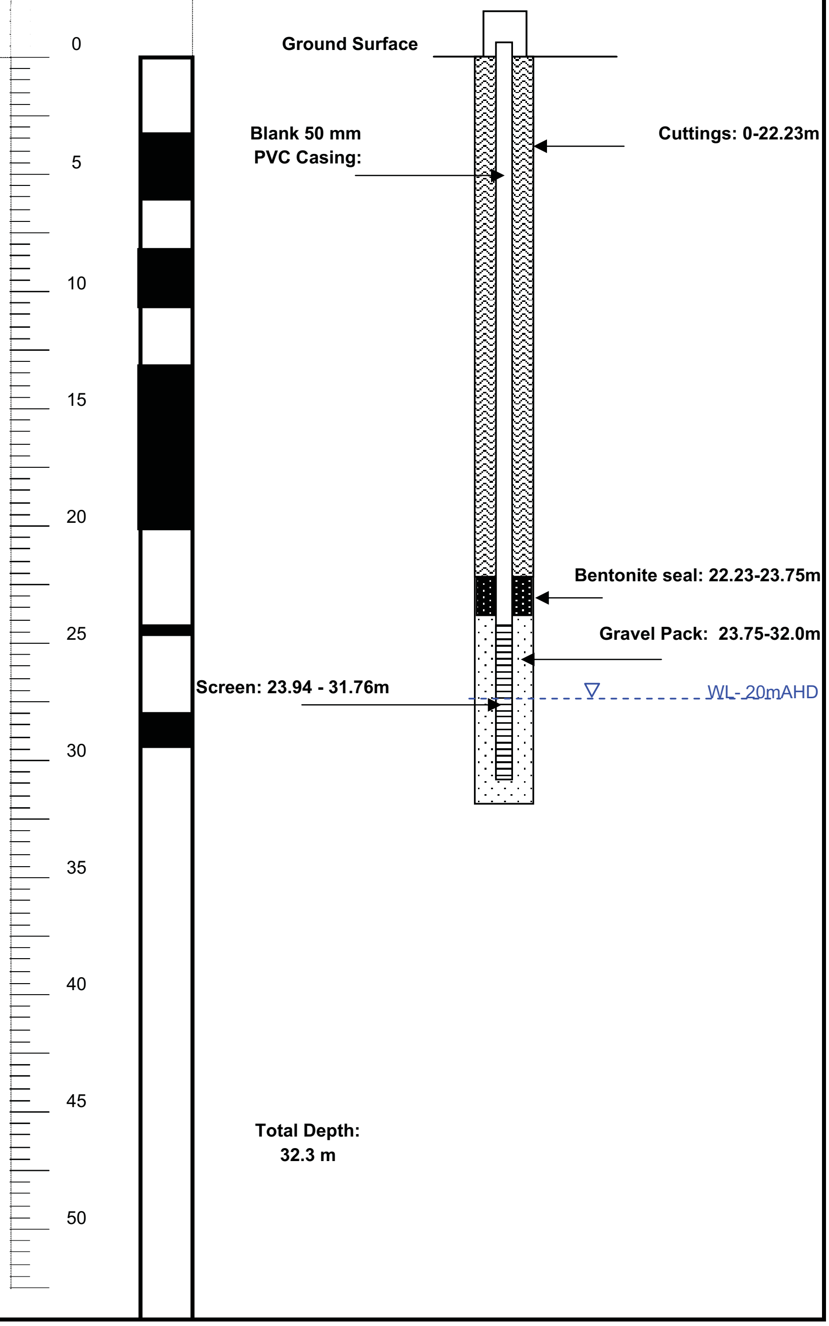
Peter Dundon and Assoc.

Logging Sheet

BORE: DPZ14

		Project No:	**05-0163**
Client: **Donaldson Coal Pty Ltd**	Elevation (GL):	**47.44 mAHD**	
	Elevation (TOC)	**47.94 mAHD**	
Location: **Abel Coal Project**	Stickup:	**0.5m**	
	Hole Depth:	**32.3**	
Drilling Contractor:	Date Started:		Supervised By:
	Date Completed		

Description	Depth (metres)	Well Construction Details:
Upper Donaldson Seam		
Lower Donaldson Seam		
Big Ben Seam		
R Buchanan Seam		
S Ashtonfields Seam		

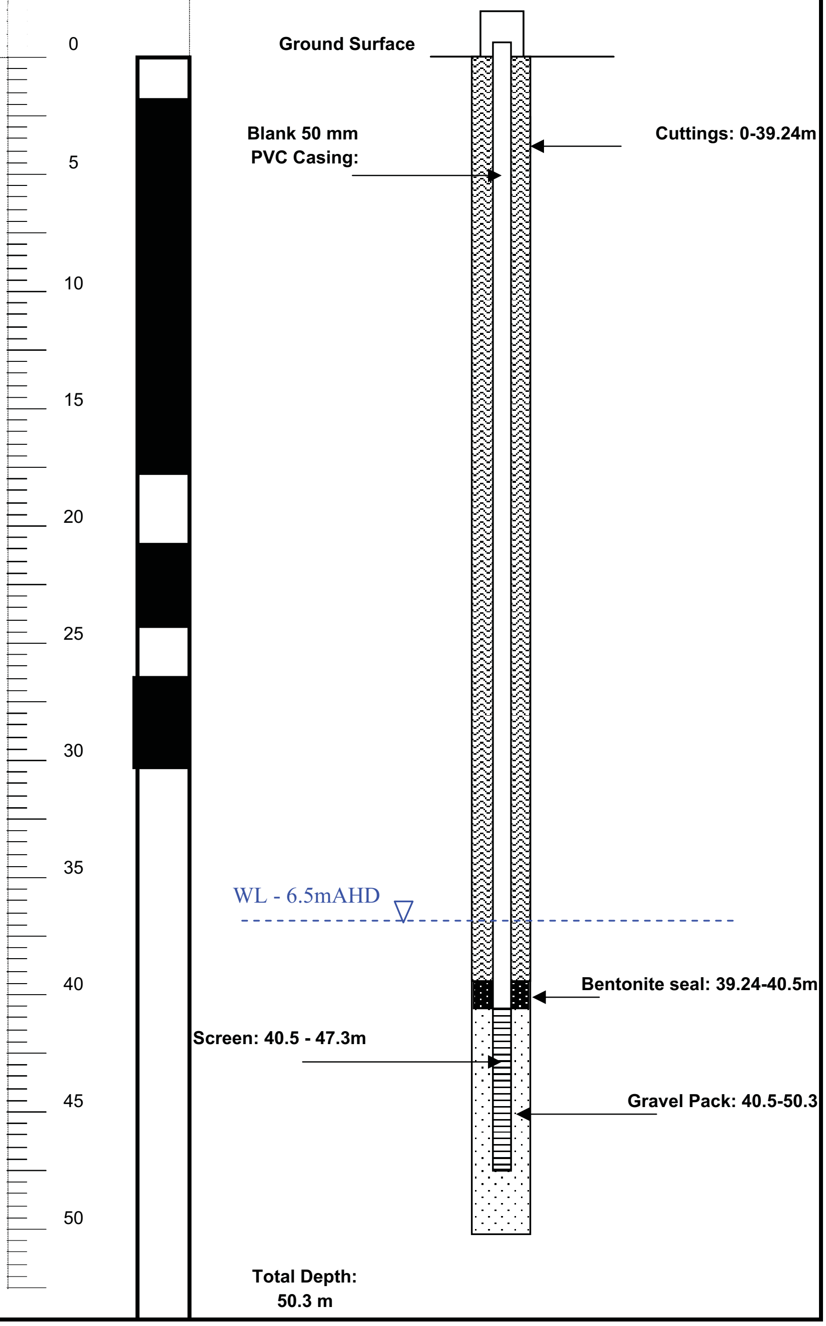


Peter Dundon and Assoc.
Logging Sheet

BORE: DPZ15

			Project No:	05-0163
Client: **Donaldson Coal Pty Ltd**	Elevation (GL):	43.4mAHD		
	Elevation (TOC)	43.9 mAHD		
Location: **Abel Coal Project**	Stickup:	0.5m		
	Hole Depth:	50.3		
Drilling Contractor:	Date Started:		Supervised By:	
	Date Completed			

Description	Depth (metres)	Well Construction Details:
Upper Donaldson Seam		
Lower Donaldson Seam		
Big Ben Seam		



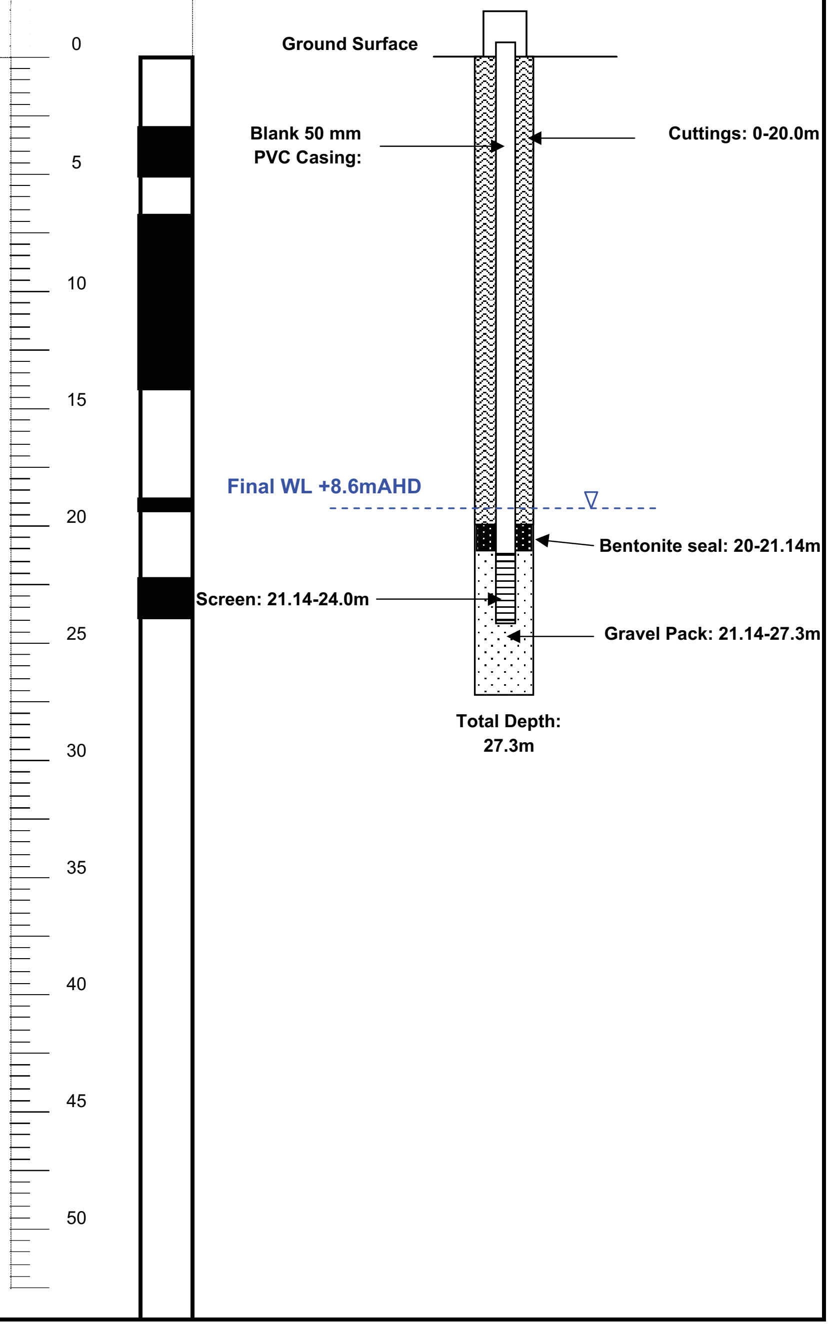
Peter Dundon and Assoc.

Logging Sheet

BORE: DPZ16

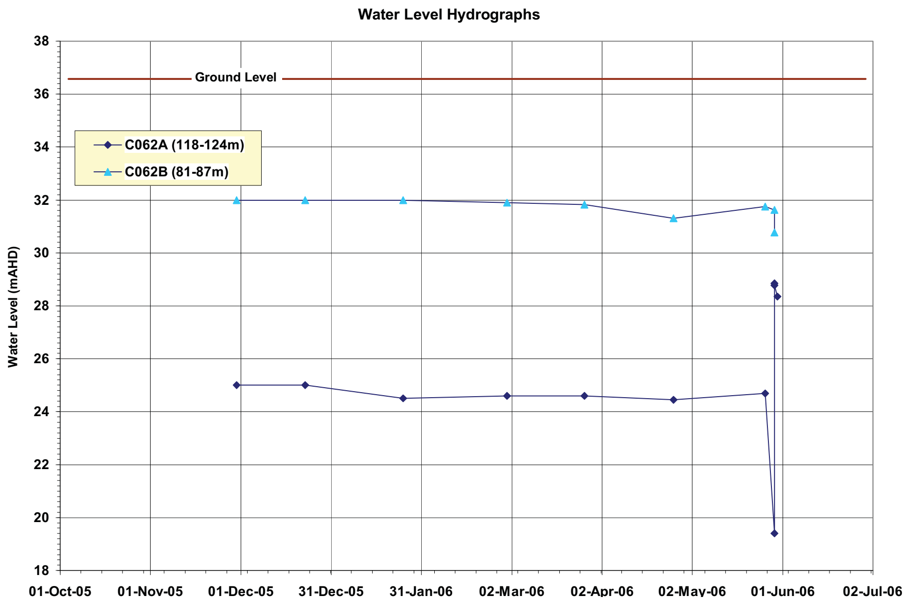
		Project No:	**05-0163**
Client: **Donaldson Coal Pty Ltd**	Elevation (GL):	**26.83 mAHD**	
	Elevation (TOC)	**27.33 mAHD**	
Location: **Donaldson Coal Project**	Stickup:	**0.5m**	
	Hole Depth:	**27.3 m**	
Drilling Contractor:	Date Started:		Supervised By:
	Date Completed		

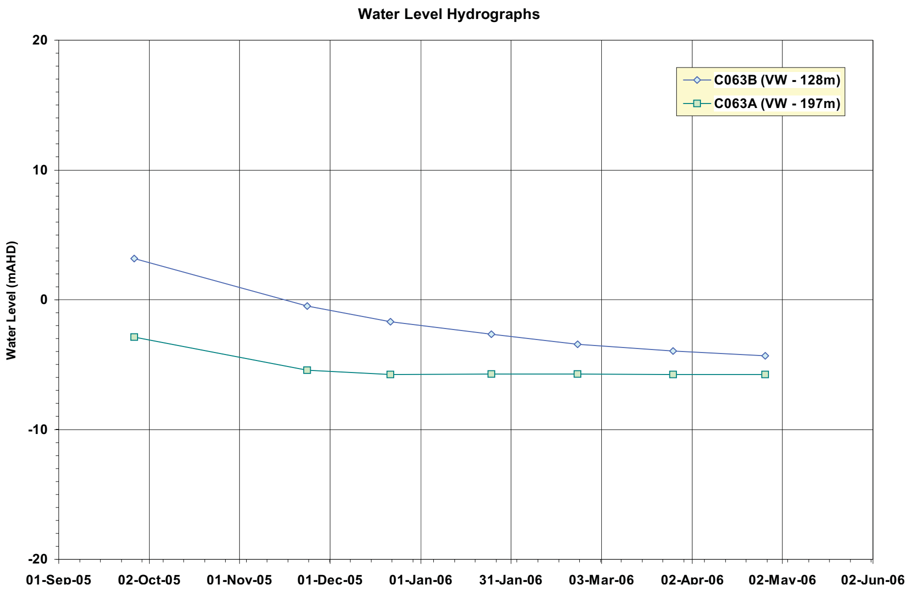
Description	**Depth (metres)**	**Well Construction Details:**
Lower Donaldson Seam		
Big Ben Seam		
Buchanan Seam		
Ashtonfield Seam		

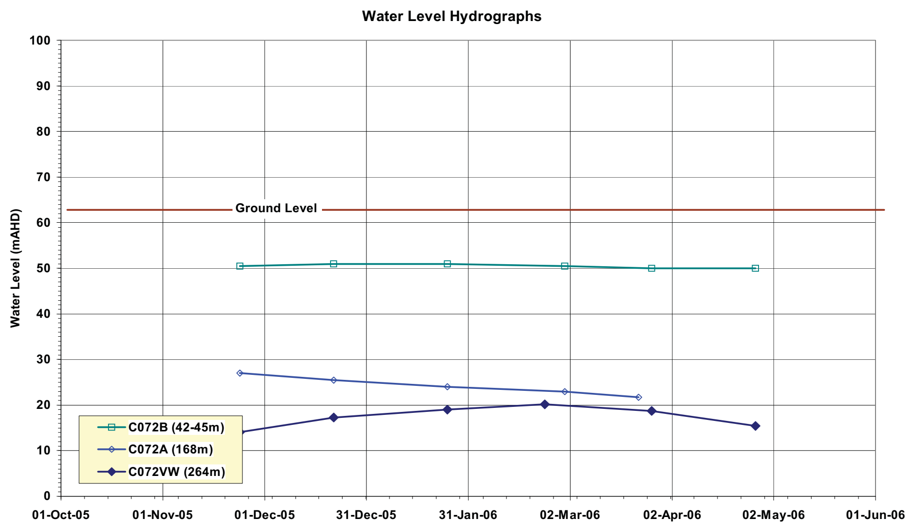


APPENDIX C

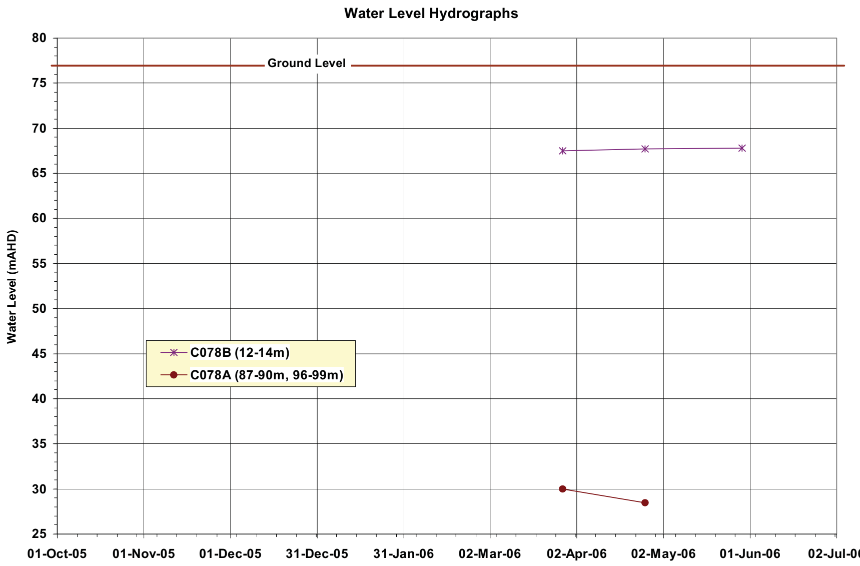
GROUNDWATER LEVEL HYDROGRAPHS

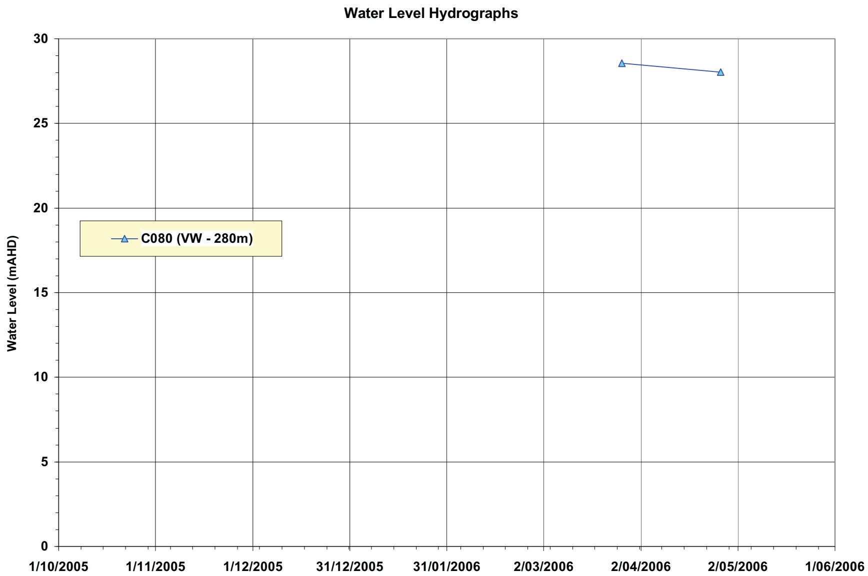


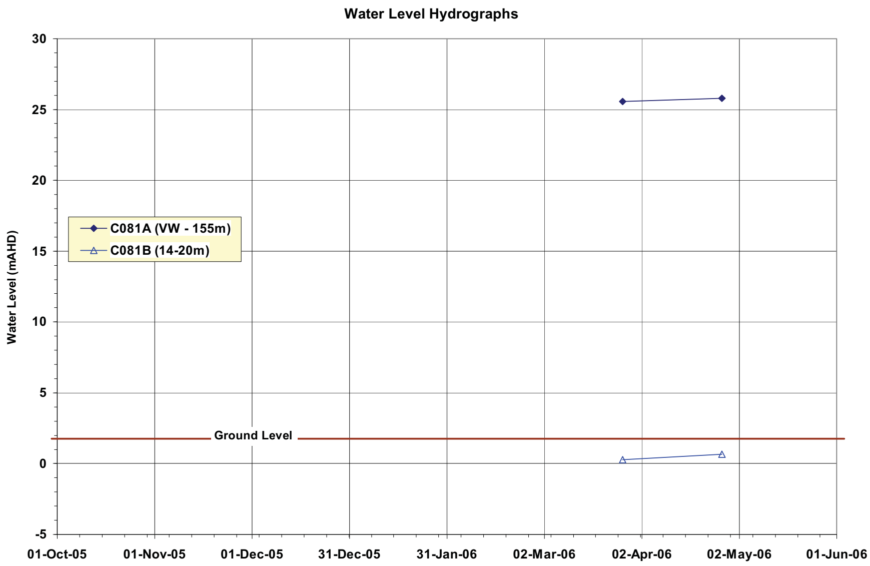




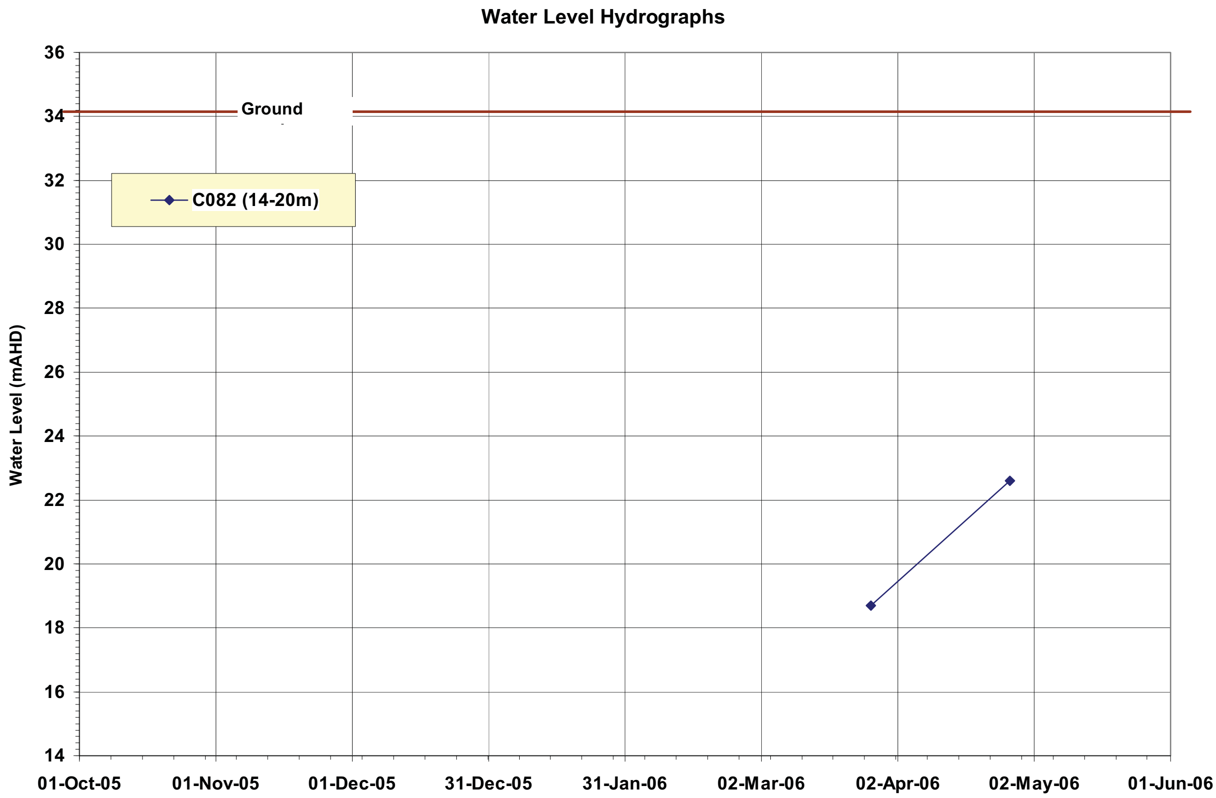
Date: 12 June 2006	Scale: as indicated	**Donaldson Coal Pty Ltd**
Initials: PJD	Job No: 05-0163	**ABEL COAL PROJECT PIEZOMETER HYDROGRAPHS - C062, C063, C072**
Drawing No: 05-0163-101	Rev: 0	
Peter Dundon & Associates Pty Limited		**Figure C1**

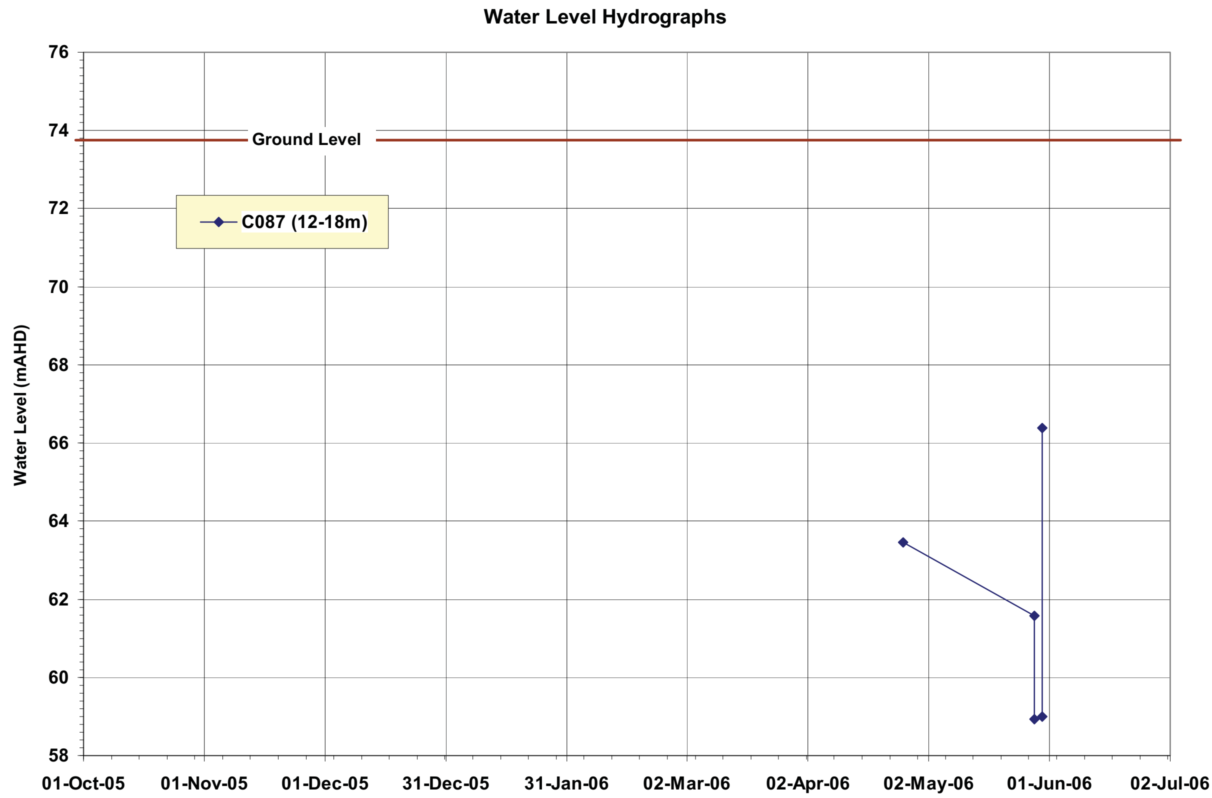






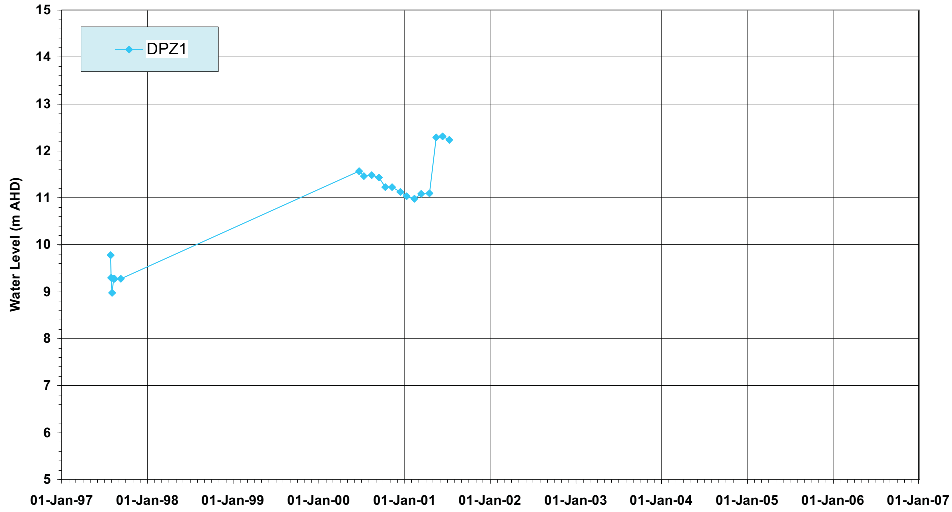
Date: 12 June 2006	Scale: as indicated	**Donaldson Coal Pty Ltd**
Initials: PJD	Job No: 05-0163	**ABEL COAL PROJECT PIEZOMETER HYDROGRAPHS - C078, C080, C081**
Drawing No: 05-0163-102	Rev: 0	
Peter Dundon & Associates Pty Limited		**Figure C2**



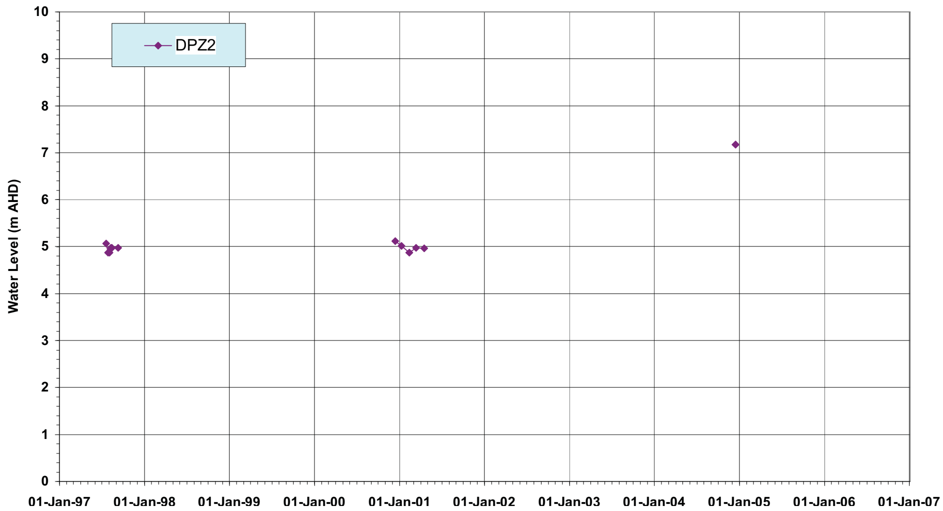


Date: 12 June 2006	Scale: as indicated	**Donaldson Coal Pty Ltd**
Initials: PJD	Job No: 05-0163	**ABEL COAL PROJECT PIEZOMETER HYDROGRAPHS - C082, C087**
Drawing No: 05-0163-103	Rev: 0	
Peter Dundon & Associates Pty Limited		**Figure C3**

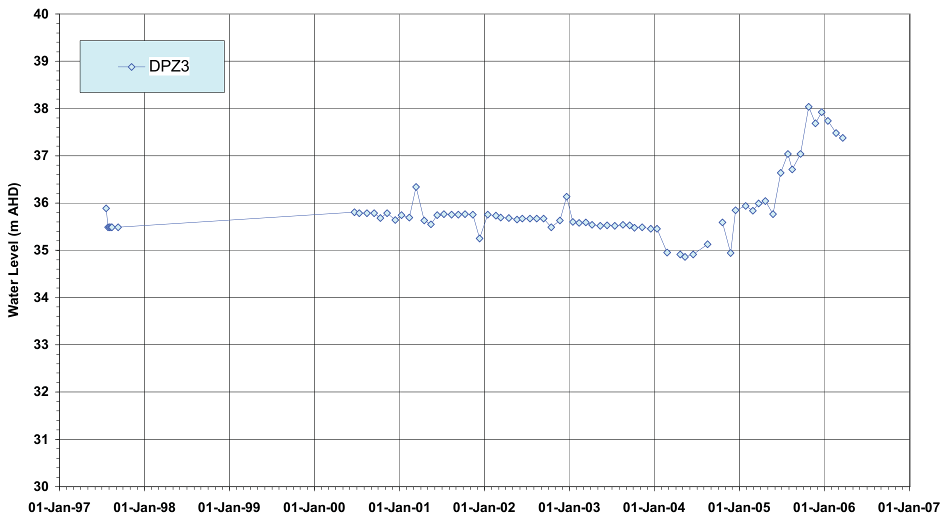
WATER LEVEL HYDROGRAPHS - DPZ1



WATER LEVEL HYDROGRAPHS - DPZ2

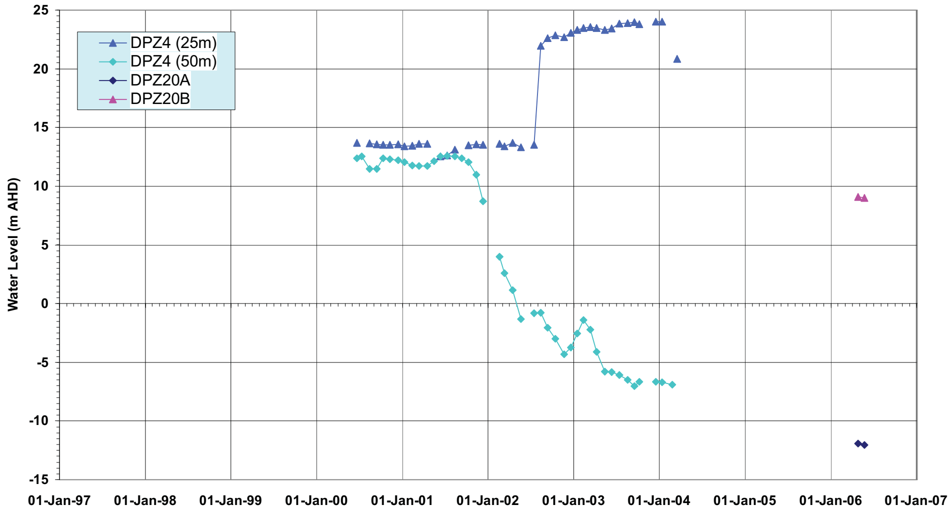


WATER LEVEL HYDROGRAPHS - DPZ3

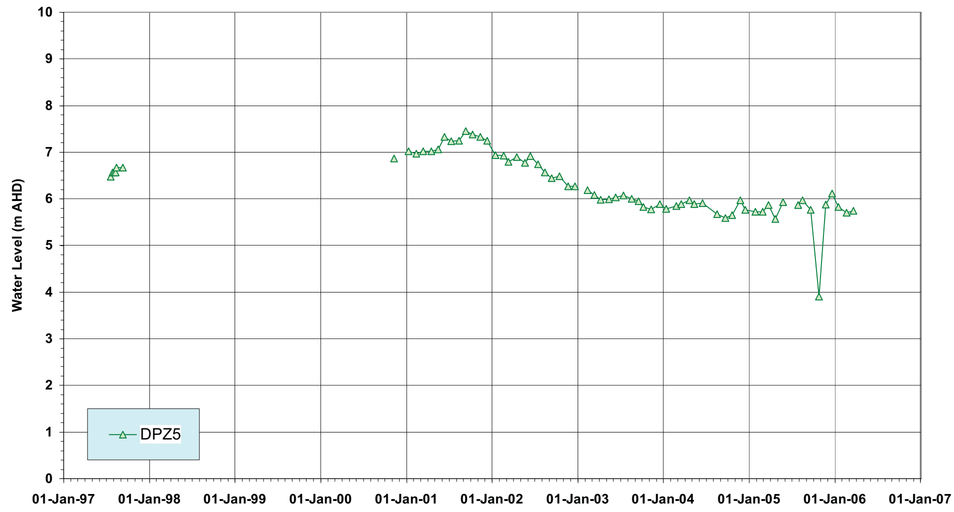


Date: 12 June 2006	Scale: as indicated	**Donaldson Coal Pty Ltd**
Initials: PJD	Job No: 05-0163	**ABEL COAL PROJECT PIEZOMETER HYDROGRAPHS - DONALDSON PIEZOMETERS**
Drawing No: 05-0163-108	Rev: 0	
Peter Dundon & Associates Pty Limited		**Figure C4**

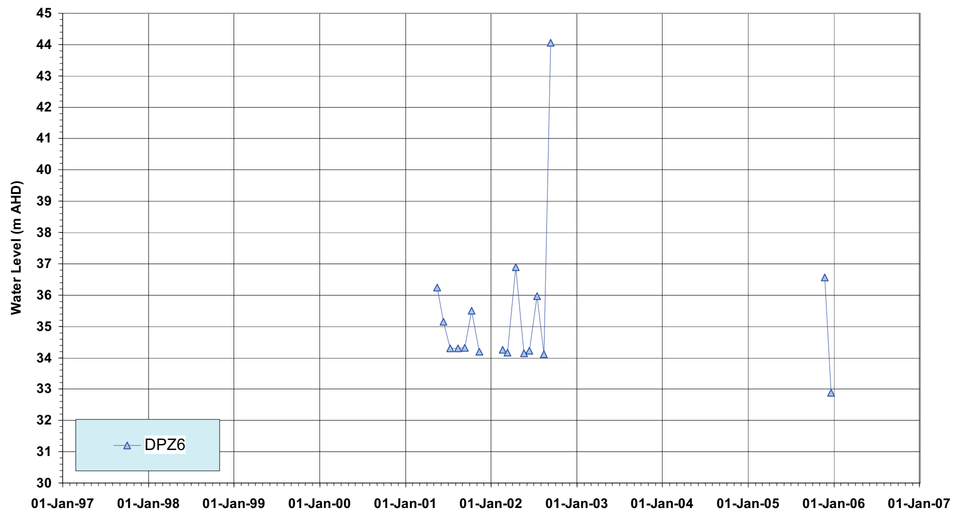
WATER LEVEL HYDROGRAPHS - DPZ4 and DPZ20



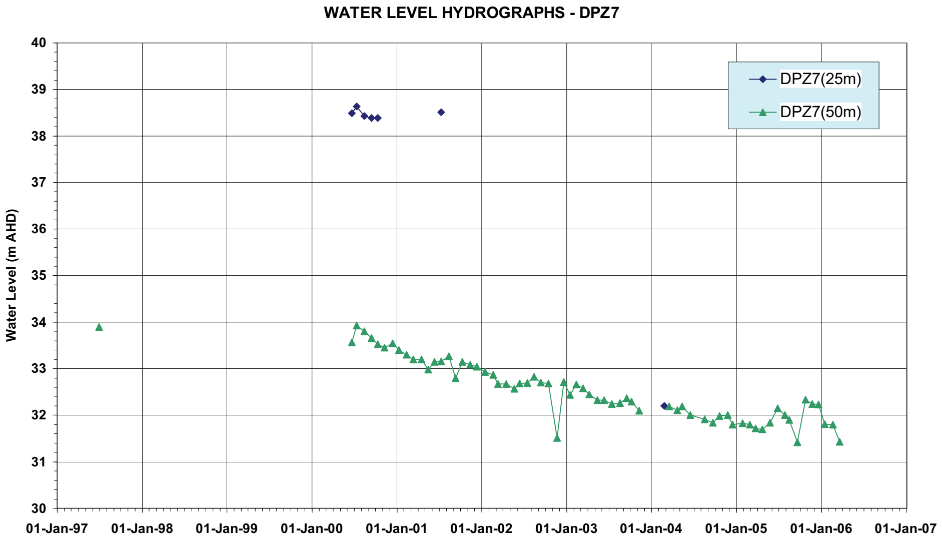
WATER LEVEL HYDROGRAPHS - DPZ5

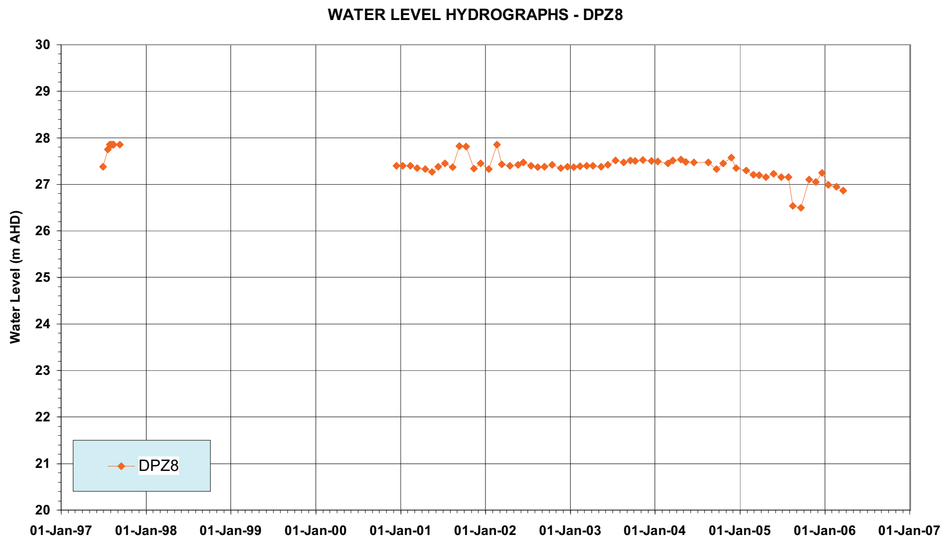


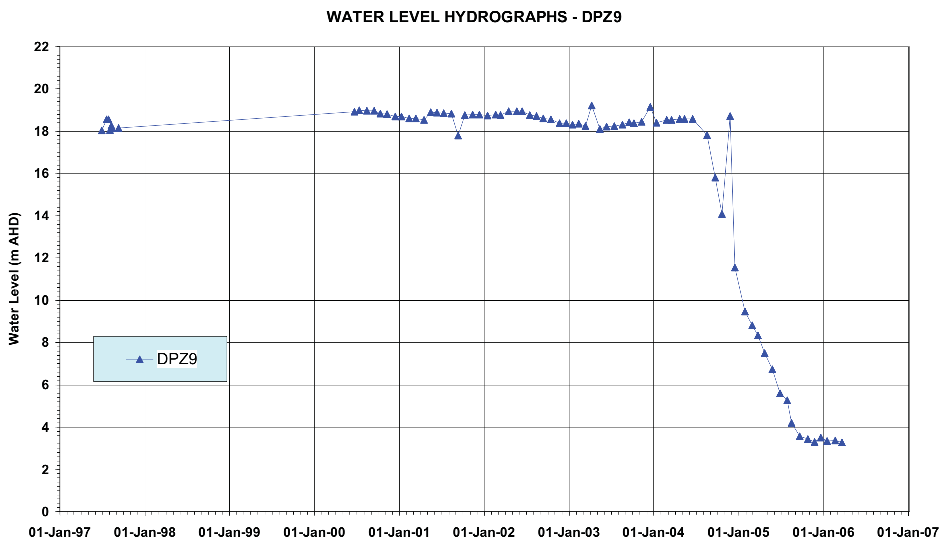
WATER LEVEL HYDROGRAPHS - DPZ6



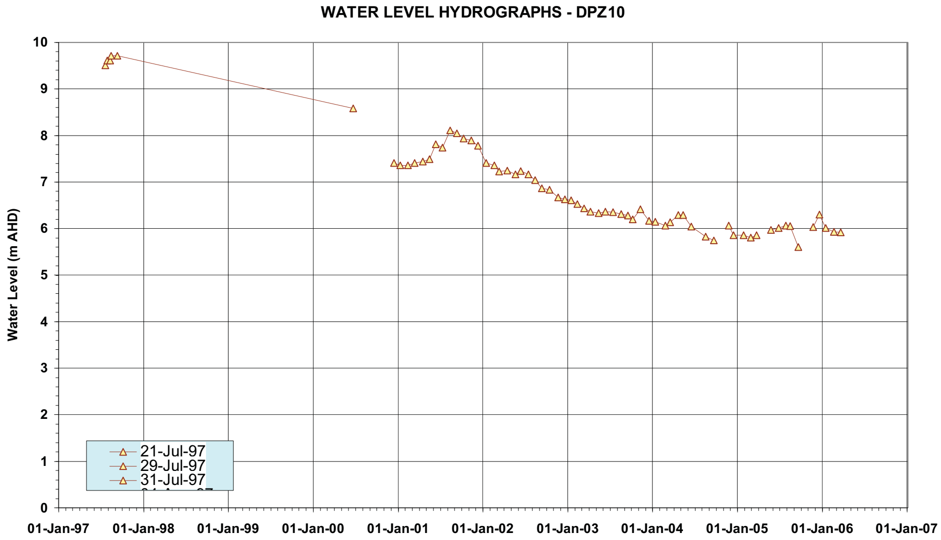
Date: 12 June 2006	Scale: as indicated	**Donaldson Coal Pty Ltd**
Initials: PJD	Job No: 05-0163	**ABEL COAL PROJECT PIEZOMETER HYDROGRAPHS - DONALDSON PIEZOMETERS**
Drawing No: 05-0163-109	Rev: 0	
Peter Dundon & Associates Pty Limited		**Figure C5**

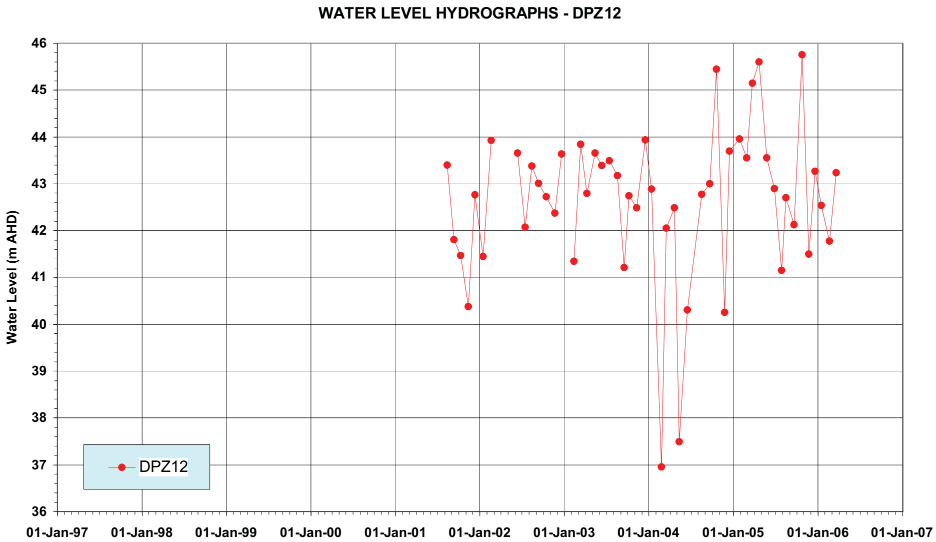


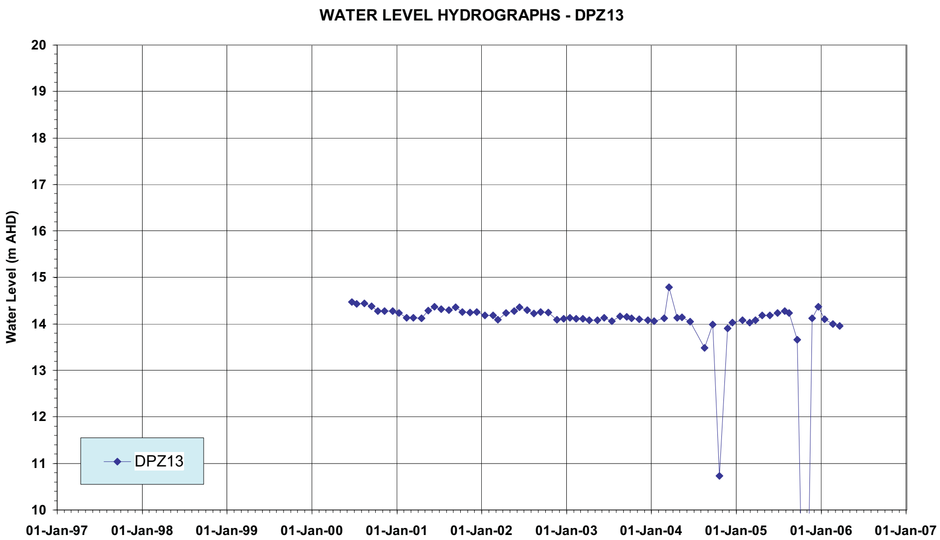




Date: 12 June 2006	Scale: as indicated	**Donaldson Coal Pty Ltd**
Initials: PJD	Job No: 05-0163	**ABEL COAL PROJECT PIEZOMETER HYDROGRAPHS - DONALDSON PIEZOMETERS**
Drawing No: 05-0163-110	Rev: 0	
Peter Dundon & Associates Pty Limited		**Figure C6**

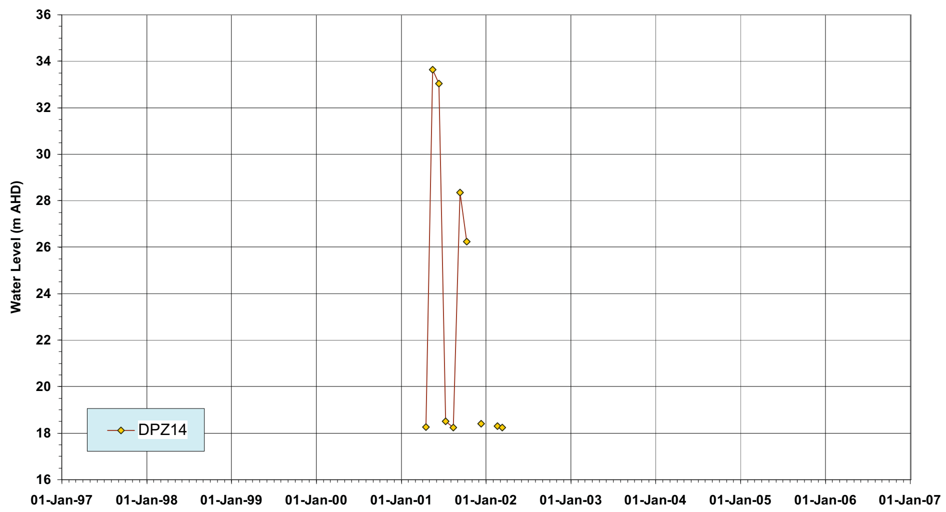




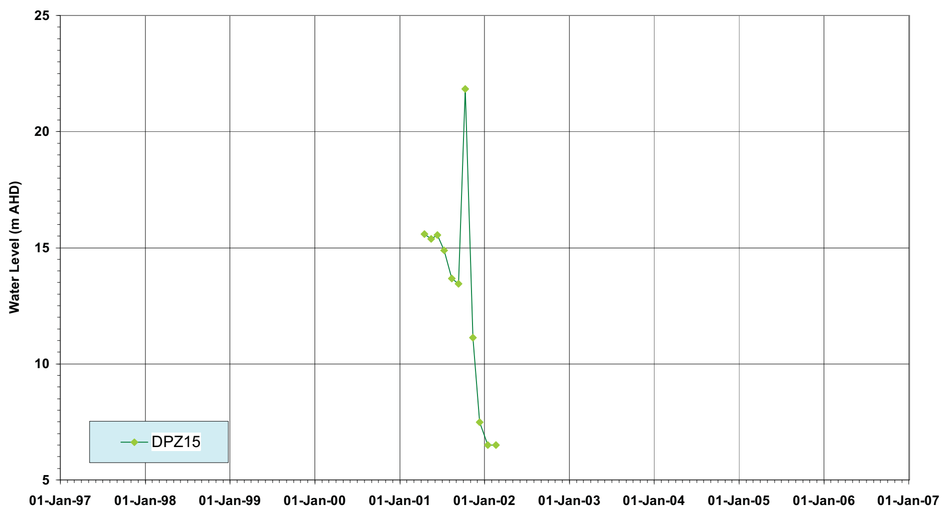


Date: 12 June 2006	Scale: as indicated	**Donaldson Coal Pty Ltd**
Initials: PJD	Job No: 05-0163	**ABEL COAL PROJECT PIEZOMETER HYDROGRAPHS - DONALDSON PIEZOMETERS**
Drawing No: 05-0163-111	Rev: 0	
Peter Dundon & Associates Pty Limited		**Figure C7**

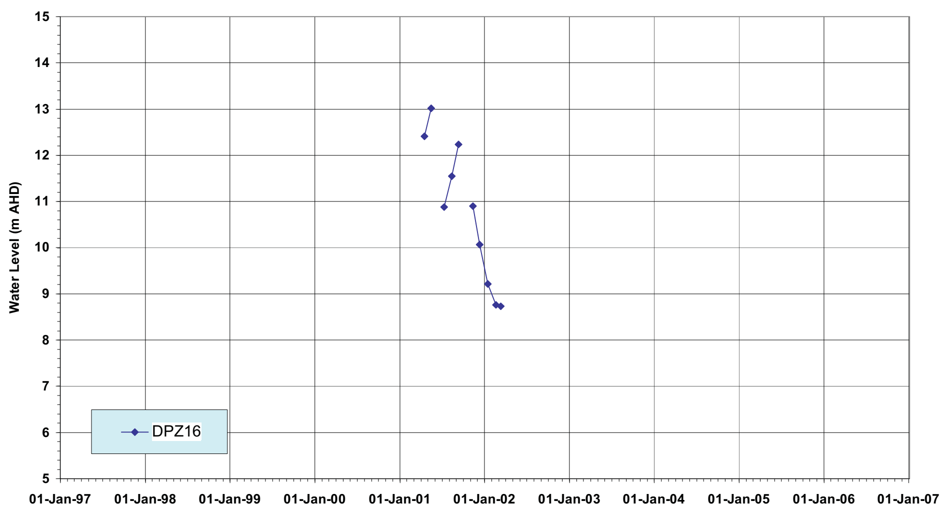
WATER LEVEL HYDROGRAPHS - DPZ14



WATER LEVEL HYDROGRAPHS - DPZ15

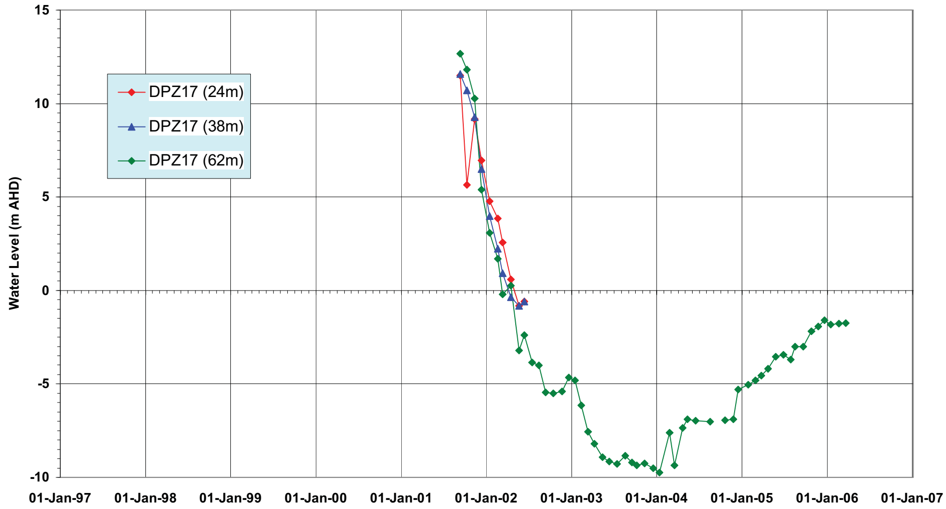


WATER LEVEL HYDROGRAPHS - DPZ16

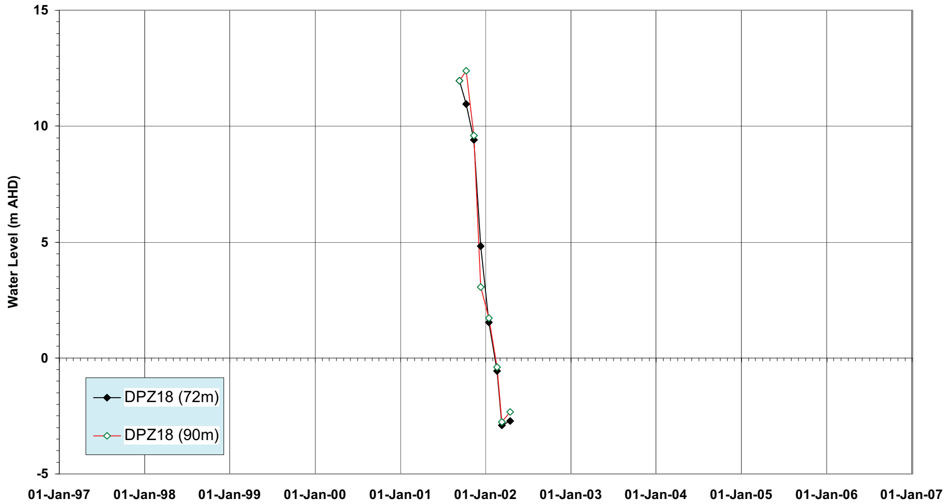


Date: 12 June 2006	Scale: as indicated	**Donaldson Coal Pty Ltd**
Initials: PJD	Job No: 05-0163	**ABEL COAL PROJECT PIEZOMETER HYDROGRAPHS - DONALDSON PIEZOMETERS**
Drawing No: 05-0163-112	Rev: 0	
Peter Dundon & Associates Pty Limited		**Figure C8**

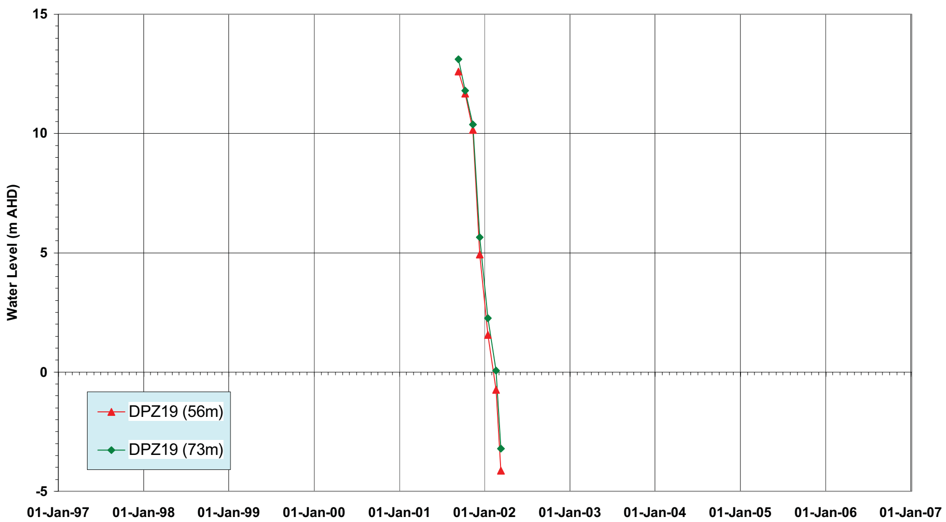
WATER LEVEL HYDROGRAPHS - DPZ17



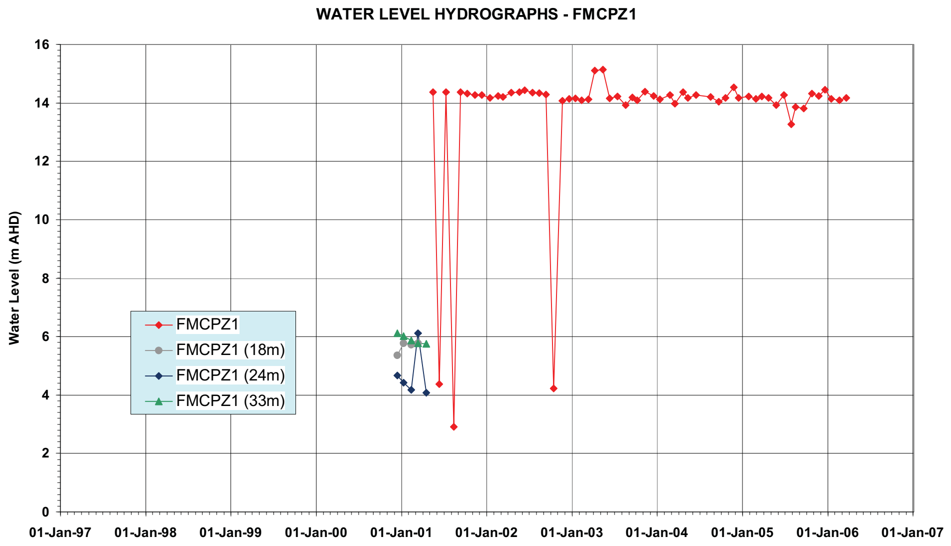
WATER LEVEL HYDROGRAPHS - DPZ18

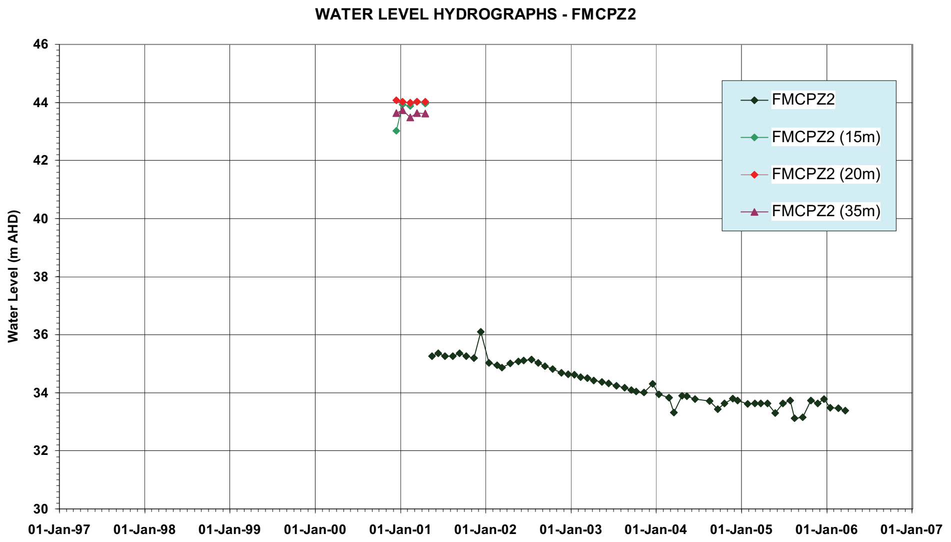


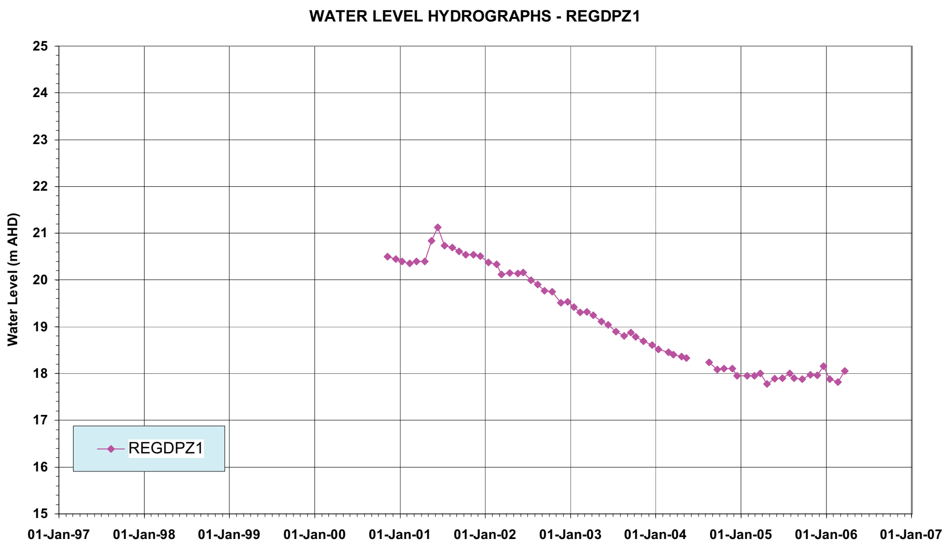
WATER LEVEL HYDROGRAPHS - DPZ19



Date: 12 June 2006	Scale: as indicated	**Donaldson Coal Pty Ltd**
Initials: PJD	Job No: 05-0163	**ABEL COAL PROJECT PIEZOMETER HYDROGRAPHS - DONALDSON PIEZOMETERS**
Drawing No: 05-0163-113	Rev: 0	
Peter Dundon & Associates Pty Limited		**Figure C9**



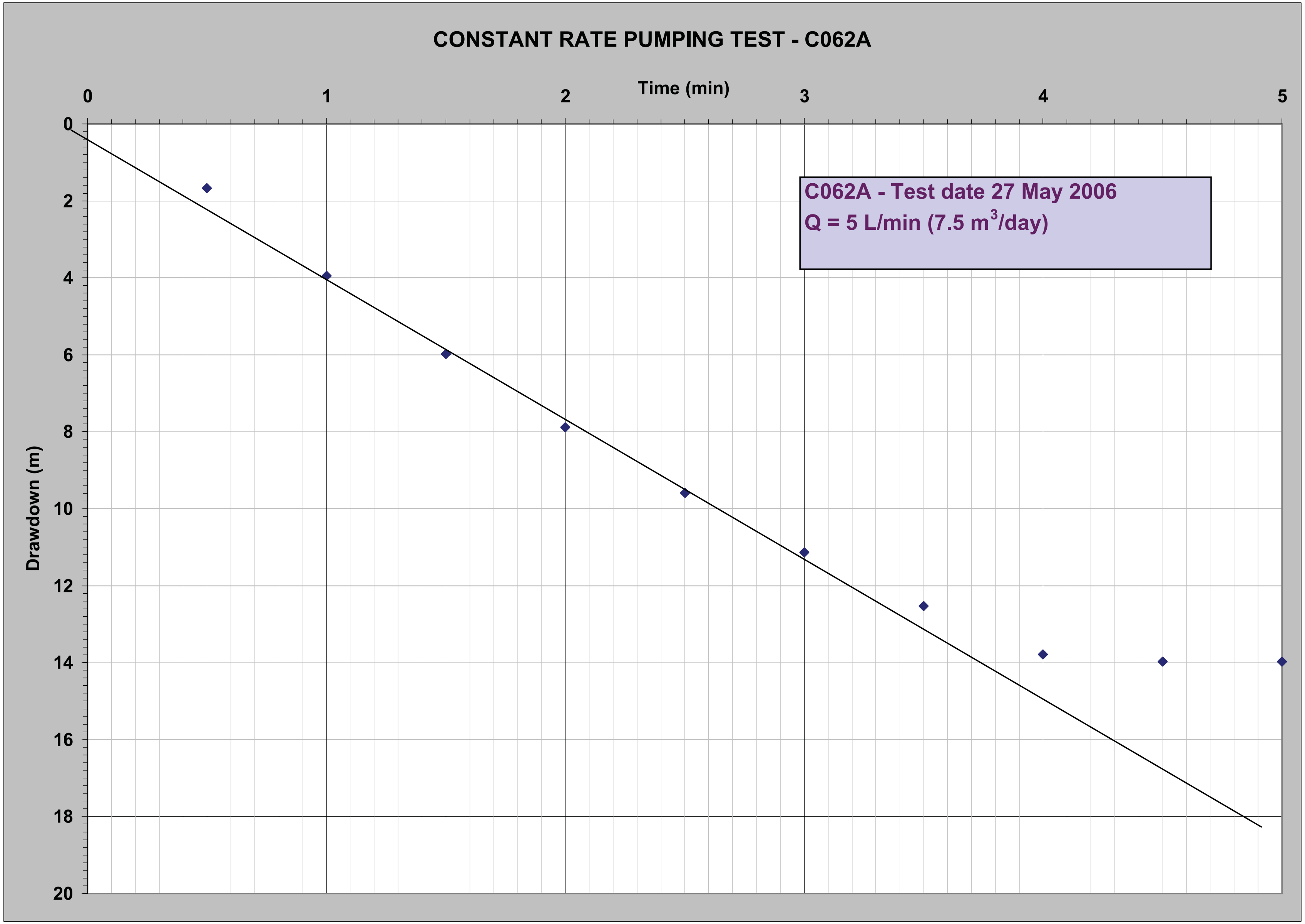




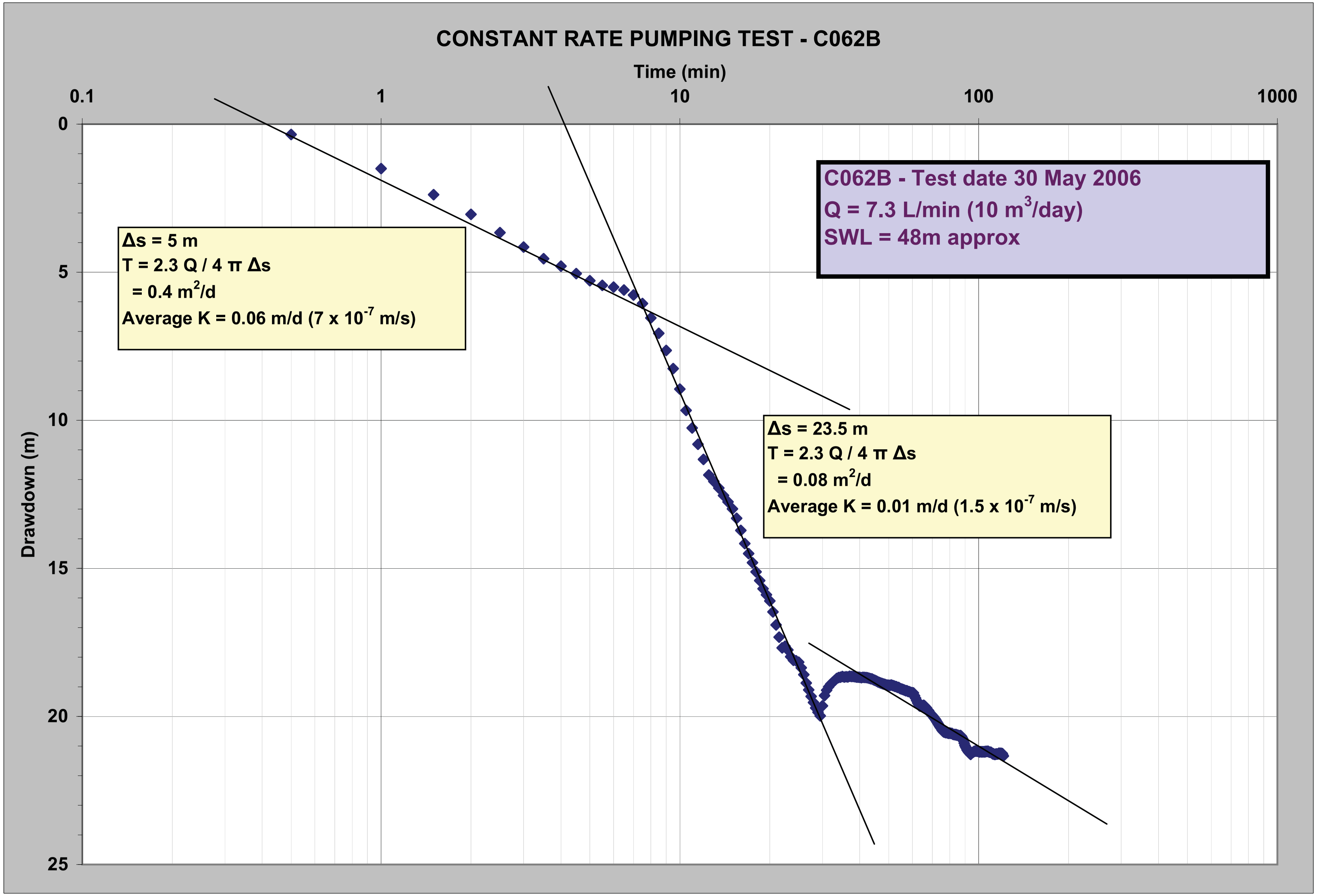
Date: 12 June 2006	Scale: as indicated	**Donaldson Coal Pty Ltd**
Initials: PJD	Job No: 05-0163	**ABEL COAL PROJECT PIEZOMETER HYDROGRAPHS - DONALDSON PIEZOMETERS**
Drawing No: 05-0163-114	Rev: 0	
Peter Dundon & Associates Pty Limited		**Figure C10**

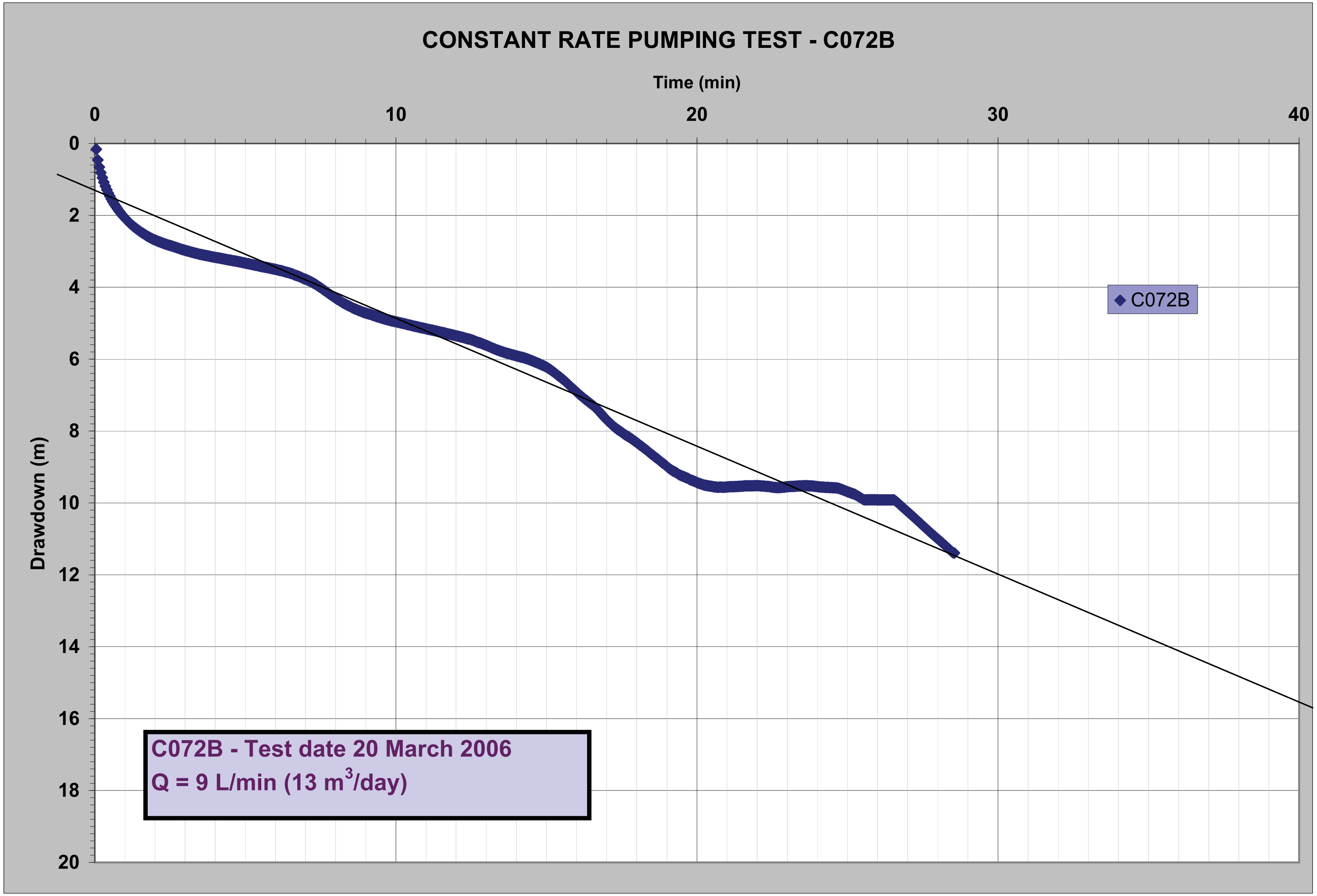
APPENDIX D

HYDRAULIC TESTING RESULTS

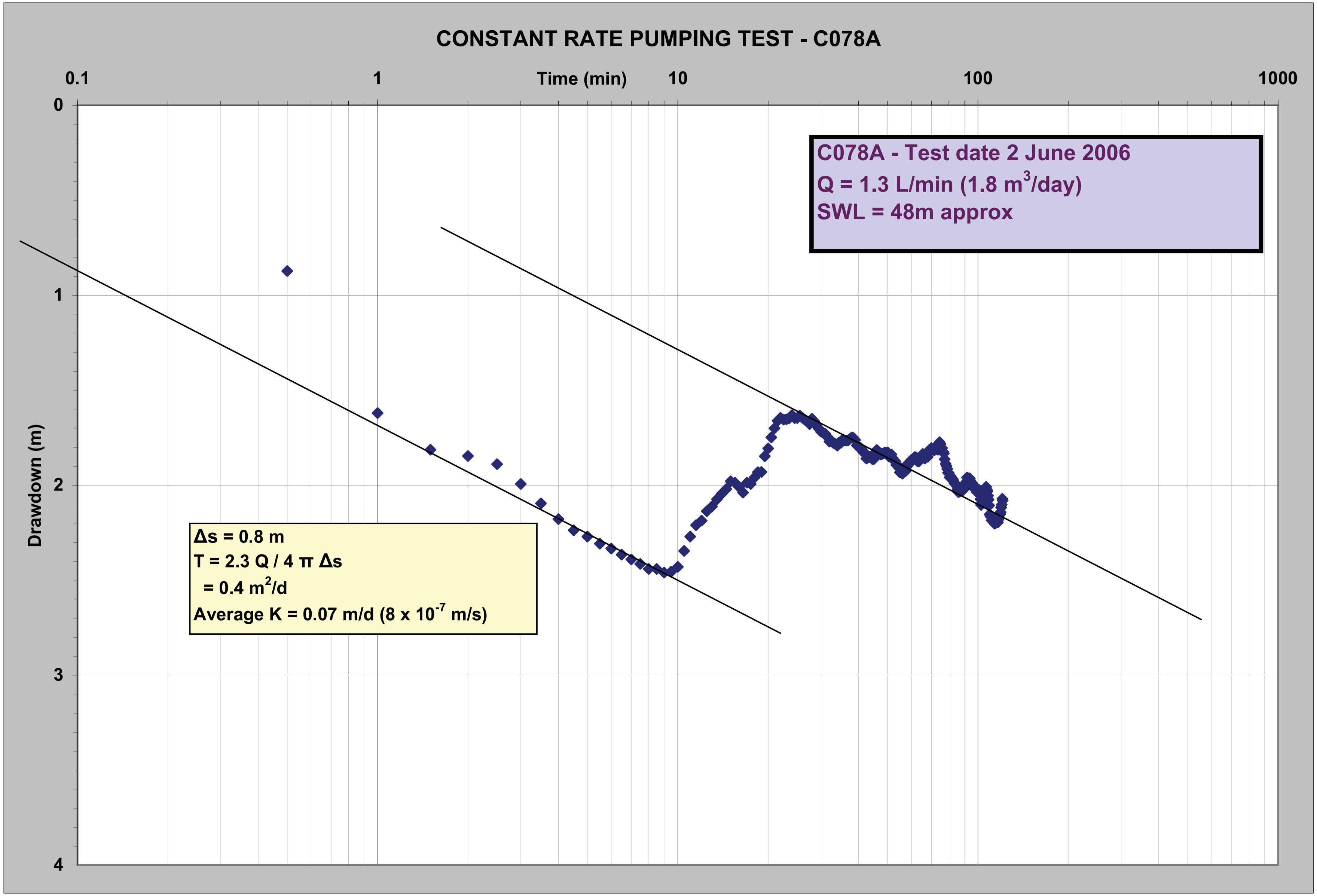


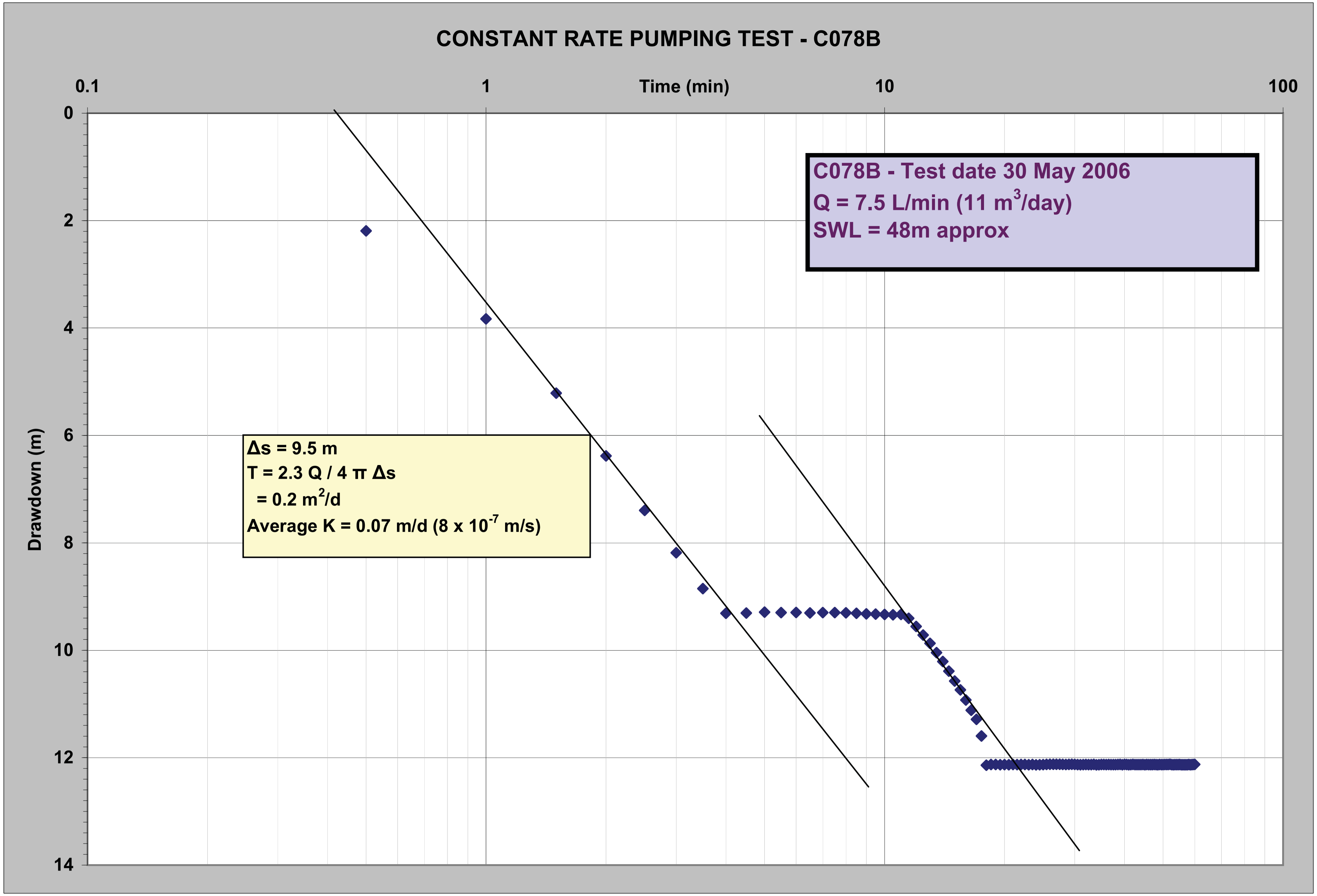
CONSTANT RATE PUMPING TEST - C062A
Time (min)
0
1
2
3
4
5
Drawdown (m)
0
2
4
6
8
10
12
14
16
18
20
C062A - Test date 27 May 2006
Q = 5 L/min (7.5 m3/day)

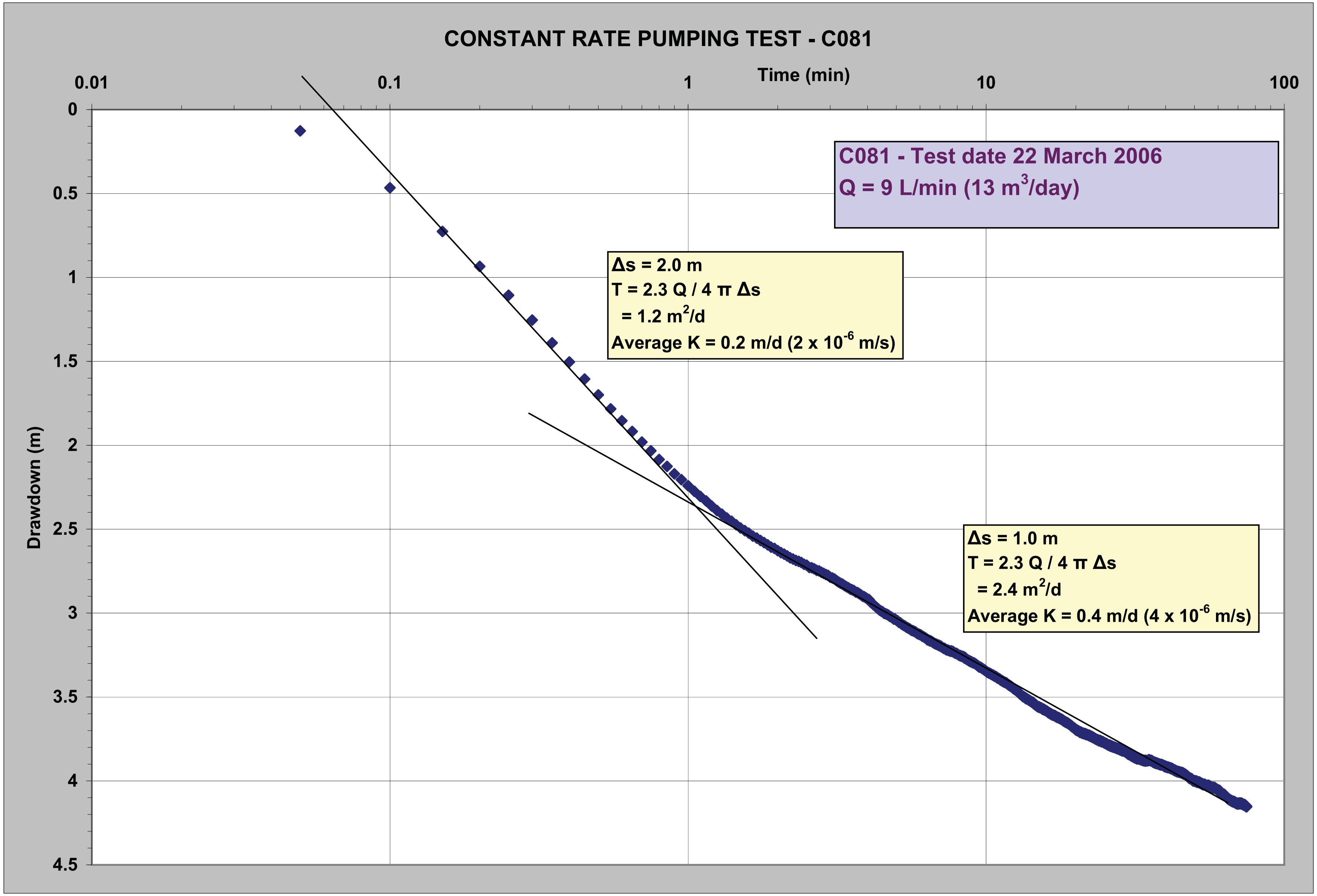

CONSTANT RATE PUMPING TEST - C062B
Time (min)
0.1
1
10
100
1000
Drawdown (m)
0
5
10
15
20
25
C062B - Test date 30 May 2006
Q = 7.3 L/min (10 m^3/day)
SWL = 48m approx
Δs = 5 m
T = 2.3 Q / 4 π Δs
= 0.4 m^2/d
Average K = 0.06 m/d (7 x 10^{-7} m/s)
Δs = 23.5 m
T = 2.3 Q / 4 π Δs
= 0.08 m^2/d
Average K = 0.01 m/d (1.5 x 10^{-7} m/s)

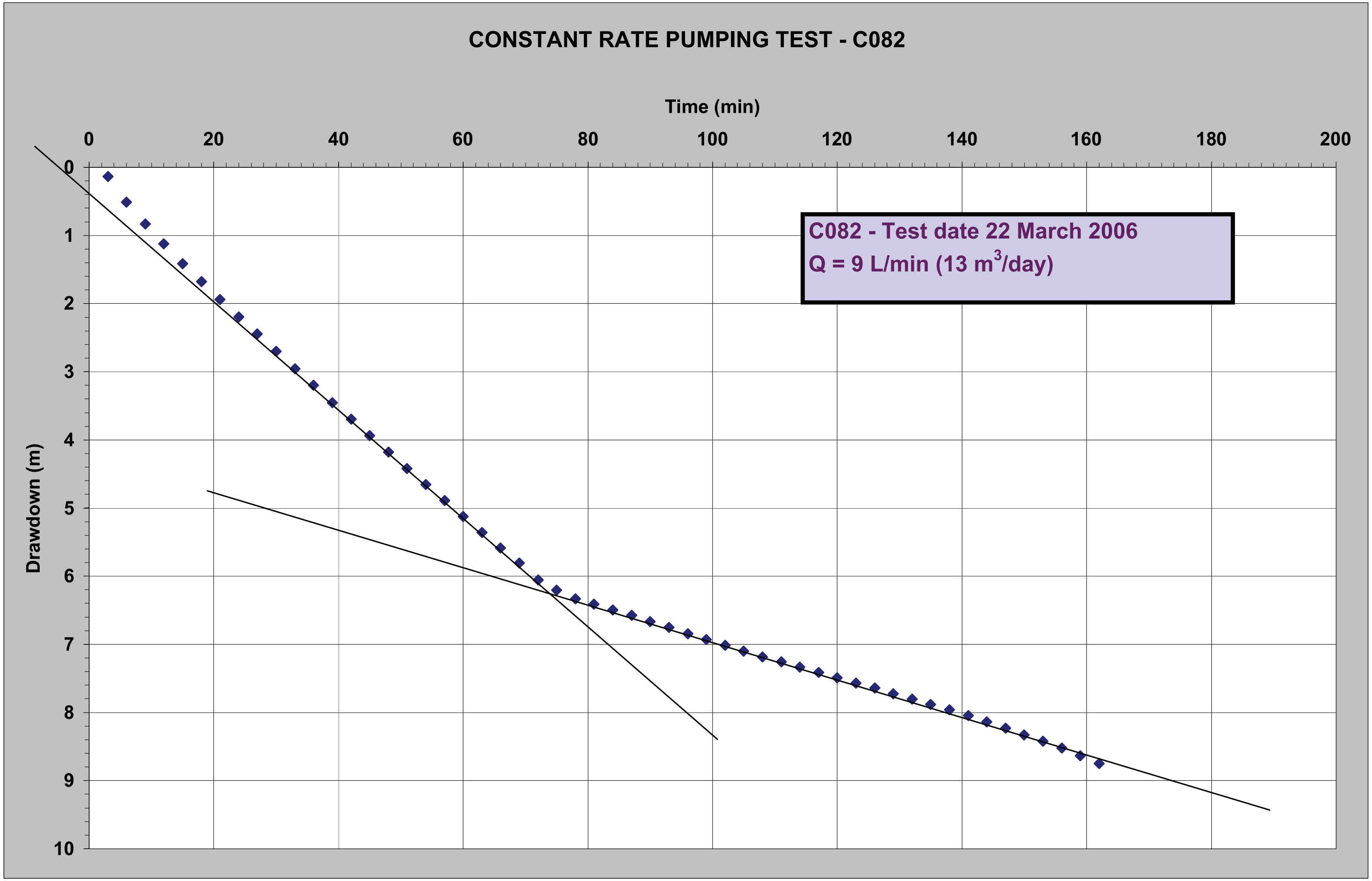


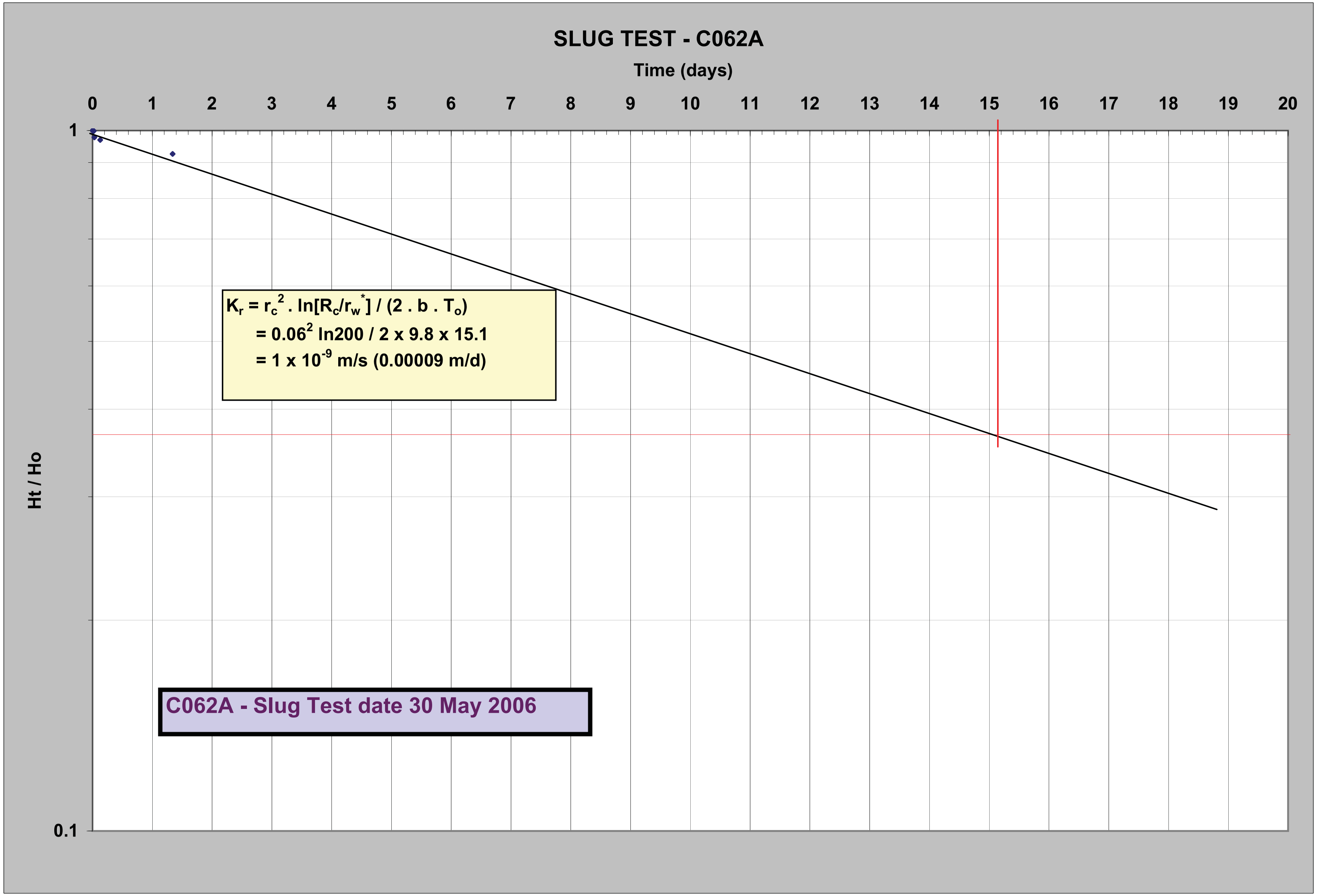
CONSTANT RATE PUMPING TEST - C072B
Time (min)
0
10
20
30
40
Drawdown (m)
0
2
4
6
8
10
12
14
16
18
20
C072B
C072B - Test date 20 March 2006
Q = 9 L/min (13 m3/day)


CONSTANT RATE PUMPING TEST - C078A
Time (min)
0.1
1
10
100
1000
Drawdown (m)
0
1
2
3
4
C078A - Test date 2 June 2006
Q = 1.3 L/min (1.8 m³/day)
SWL = 48m approx
Δs = 0.8 m
T = 2.3 Q / 4 π Δs
= 0.4 m²/d
Average K = 0.07 m/d (8 x 10⁻⁷ m/s)

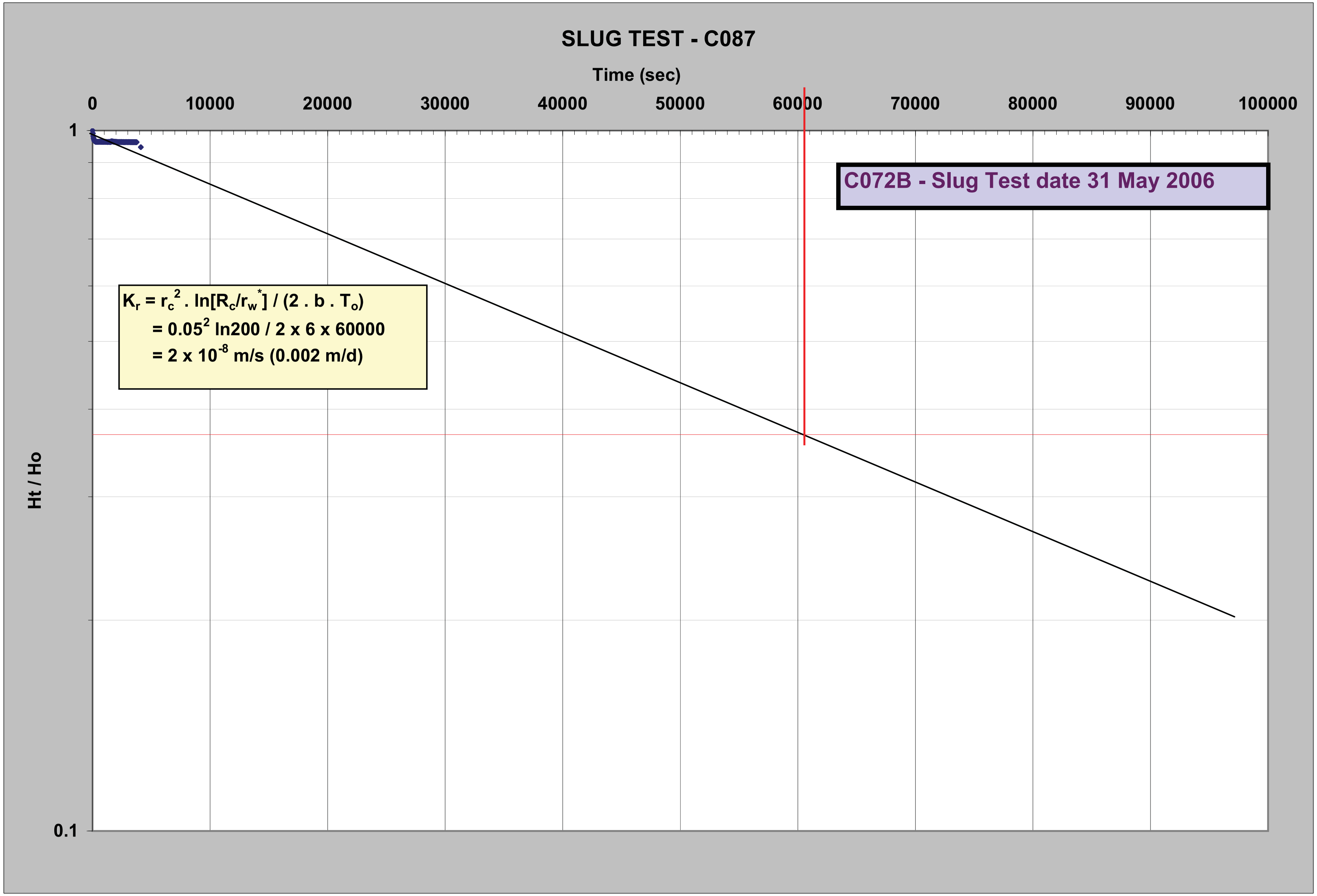

CONSTANT RATE PUMPING TEST - C078B
Time (min)
0.1
1
10
100
Drawdown (m)
0
2
4
6
8
10
12
14
C078B - Test date 30 May 2006
Q = 7.5 L/min (11 m³/day)
SWL = 48m approx
Δs = 9.5 m
T = 2.3 Q / 4 π Δs
= 0.2 m²/d
Average K = 0.07 m/d (8 x 10⁻⁷ m/s)


CONSTANT RATE PUMPING TEST - C081
Time (min)
0.01
0.1
1
10
100
Drawdown (m)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
C081 - Test date 22 March 2006
Q = 9 L/min (13 m3/day)
Δs = 2.0 m
T = 2.3 Q / 4 π Δs
= 1.2 m2/d
Average K = 0.2 m/d (2 x 10-6 m/s)
Δs = 1.0 m
T = 2.3 Q / 4 π Δs
= 2.4 m2/d
Average K = 0.4 m/d (4 x 10-6 m/s)


CONSTANT RATE PUMPING TEST - C082
Time (min)
0
20
40
60
80
100
120
140
160
180
200
Drawdown (m)
0
1
2
3
4
5
6
7
8
9
10
C082 - Test date 22 March 2006
Q = 9 L/min (13 m3/day)



SLUG TEST - C062A
Time (days)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
1
0.1
Ht / Ho
$K_r = r_c^2 . \ln[R_c/r_w^*] / (2 . b . T_o)$
$= 0.06^2 \ln200 / 2 \times 9.8 \times 15.1$
$= 1 \times 10^{-9}$ m/s (0.00009 m/d)
C062A - Slug Test date 30 May 2006


SLUG TEST - C087
Time (sec)
0
10000
20000
30000
40000
50000
60000
70000
80000
90000
100000
1
0.1
Ht / Ho
C072B - Slug Test date 31 May 2006
$K_r = r_c^2 . \ln[R_c/r_w^*] / (2 . b . T_o)$
$= 0.05^2 \ln 200 / 2 \times 6 \times 60000$
$= 2 \times 10^{-8}$ m/s (0.002 m/d)

APPENDIX E

GROUNDWATER MODELLING REPORT

PETER DUNDON & ASSOCIATES

GROUNDWATER MODELLING OF IMPACTS OF ABEL UNDERGROUND MINING OPERATION
FINAL

JULY 2006

Ilka Wallis	Hugh Middlemis
Senior Hydrogeologist	**Principal Water Resources Engineer**

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20 July, 2006

VALIDITY STATEMENT

We certify that we have prepared this modelling study and to the best of our knowledge it contains all available, current information relevant to the proposed development.

The modelling assessment does not, through its presentation or omission of information, materially mislead.

Study review: Hugh Middlemis
Principal Water Resources Engineer

Study preparation: Ilka Wallis
Senior Hydrogeologist/Modeller

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Executive Summary

A groundwater model of the proposed Abel underground coal mine in the Hunter Valley of New South Wales has been developed by Aquaterra Simulations for Peter Dundon and Associates, who were engaged to undertake hydrogeological investigations to support the preparation of an EA for the Abel Coal Mine Project.

The model was developed to predict the potential impacts of the underground mining on groundwater levels in the area and on surface water resources including Pambalong Nature Reserve and Hexham Swamp; and to assess the potential inflow into the mine workings during operation.

A 6-layered MODFLOW finite-difference model was set up, based on the most up to date data on geology and hydrogeology in the area. Calibration of the model was undertaken in steady-state mode and a good fit between observed and simulated water levels was achieved. The calibrated model was then used in predictive mode, simulating the impacts of mining at Abel from 2008 to 2027 and a simulation of recovery was undertaken thereafter.

Uncertainties exist in various model input parameters which lead to limitations of the model, and are detailed in the report. Uncertainties which are believed to have the greatest effect on simulated drawdowns and seepage influx rates into the mine, were evaluated through sensitivity analysis.

Based on the model predictions and sensitivity runs, drawdowns in the coal measures are expected to be in the order of 60 metres at the margins of the Abel mining lease area and up to 120 metres in the centre of the lease. The best estimate for the maximum rate of mine inflow at the end of mining is 3 ML/day, with a likely upper limit of 4.5 ML/day.

The impact of mining on the alluvium adjacent to Pambalong Nature Reserve is predicted to be a drawdown of about 10 cm. However, predicted water levels around Hexham Swamp are sensitive to the applied vertical permeability underneath the swamp.

Model results presented in this report are regarded as current best estimates based on the available data. Due to inherent uncertainties in input parameters such as recharge and evaporation and inhomogenities of the subsurface model results should be used with some caution and predicted seepage rates and drawdowns regarded as indicative, order-of-magnitude estimates. Ongoing monitoring is essential to confirm the predictions as mining progresses

SECTION 1 - INTRODUCTION

The Abel Coal Mine Project is a proposed underground mining operation located near Black Hill in the Hunter Valley of NSW, about 20 km NW of Newcastle, and about 10km south of Maitland. The project site is located just west of the F3 Freeway and immediately south of John Renshaw Drive (Figure 1).

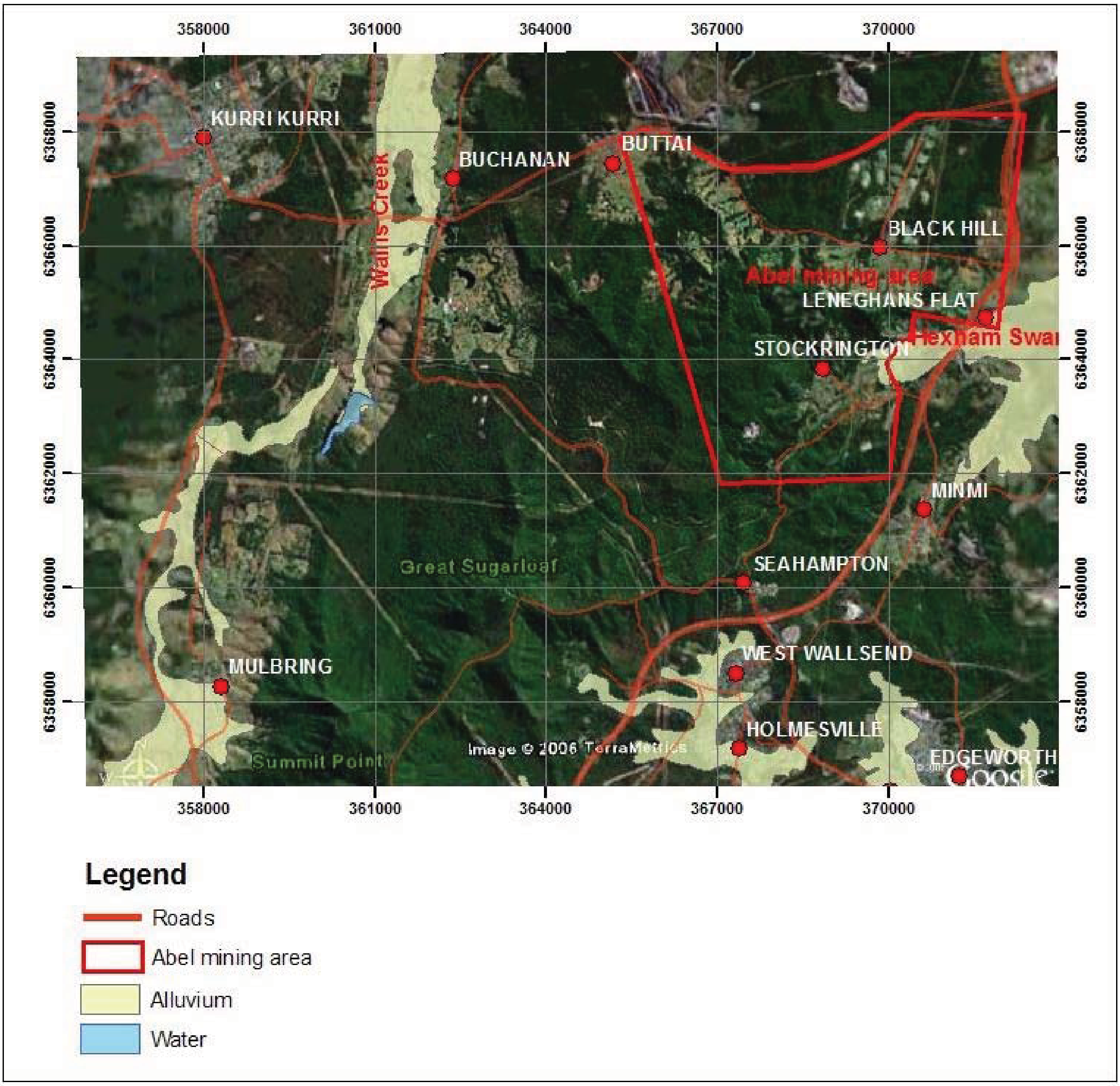


Figure 1 Location of study area

The Abel Coal Mine Project has engaged Peter Dundon and Associates to undertake hydrogeological investigations to support the preparation of an EIS. As part of these investigations, Peter Dundon and Associates has engaged Aquaterra to develop a numerical groundwater flow model. The modelling studies are to investigate the potential impacts of the underground mining activity on the local aquifers and the surface water courses in the area, and Pambalong Nature Reserve and Hexham Swamp to the east. It will also be used to estimate potential water ingress into the underground workings during the life of the mine through vertical leakage.

The main **objectives** of the Abel Coal Groundwater Model are to:

(i) predict the potential impacts of the underground mining on groundwater levels in the area and on surface water resources, including Pambalong Nature Reserve and Hexham Swamp; and

(ii) assess the potential inflow into the mine workings during operation.

SECTION 2 - CONCEPTUAL HYDROGEOLOGY

The conceptual hydrogeological model for the area is based to a large degree on investigations undertaken by Peter Dundon and Associates and is summarized below.

2.1 GEOLOGY

The project area is underlain by Permian Tomago and Newcastle Coal Measures (Figure 2). The target coal seam of the proposed Abel mine is the Donaldson Seam, which divides into separate Upper and Lower units in the southern half of the lease. Sediments above and below the coal seams comprise predominantly interbedded mudstone, siltstone and sandstone. The strata dip generally towards the south and south-east, although the structure is complicated by the presence of faults (Figure 3).

Surface topography in the Abel project area ranges from less than 5 to more than 180 mAHD (Figure 5).

The West Borehole Seam is present only in the southern part of the Abel mining lease (Figure 4), and was the subject of previous mining. It is stratigraphically about 200m above the Donaldson Seam, on average 7.7 m thick, and crops out in the south-west of the project area. Due to the dip of the strata, the seam reaches depths of over 200 m below surface in the south of the study area, while it is absent due to erosion in the north (Figure 6).

The Upper and Lower Donaldson seams are on average 1.5 and 2.2 m thick, respectively. The seams are present throughout the proposed Abel mining area and crop out about 800 m north of the site. Due to the southerly dip, the seams reach depths of about -360 mAHD in the south of the study area (Figure 7 and Figure 8).

Around the Hexham Swamp and the floodplain of the Hunter River to the east of the site, the bedrock is overlain by Quaternary alluvial deposits including gravel, sand, silt and clay. To the west, alluvium also occurs along Wallis Creek.

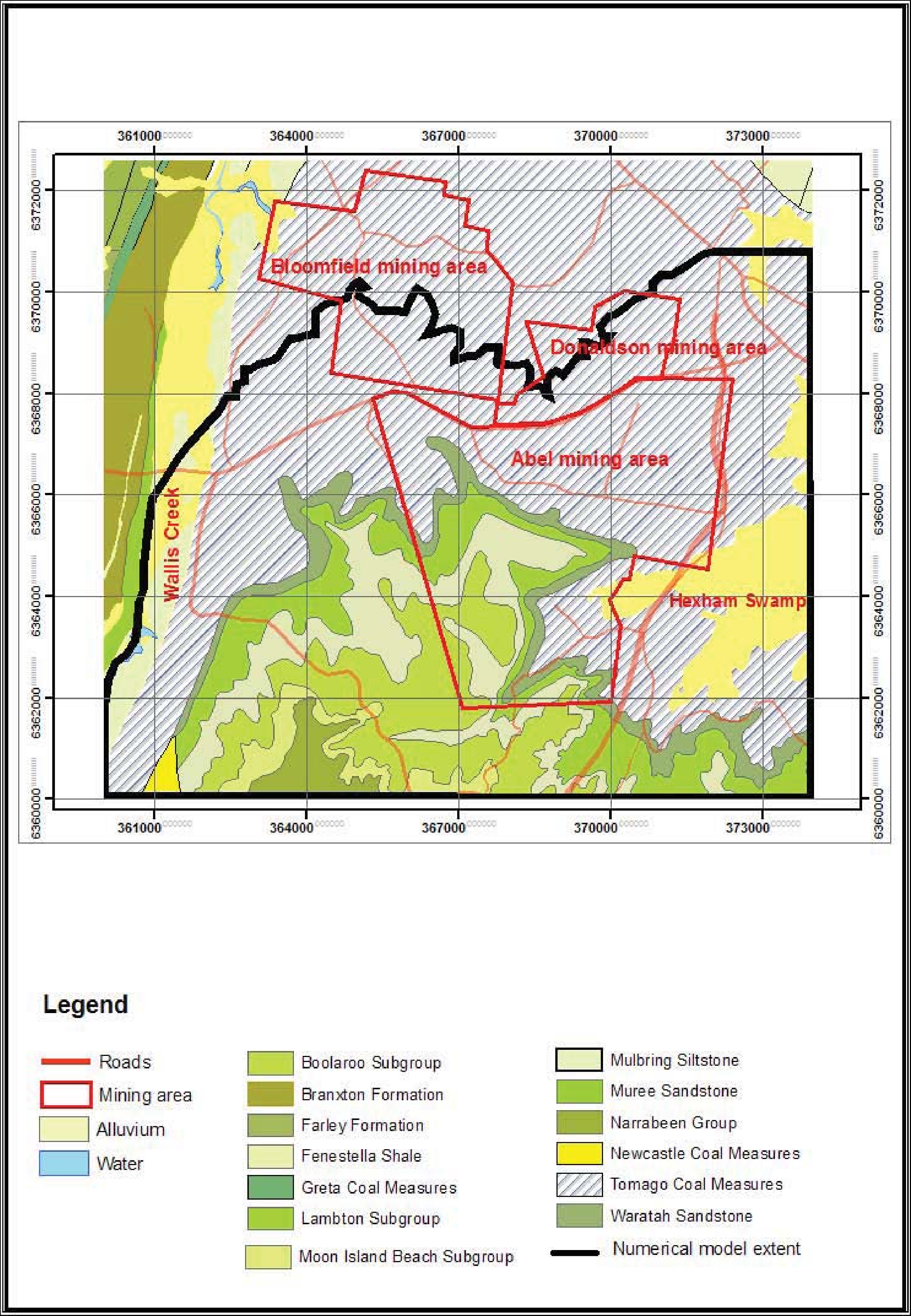
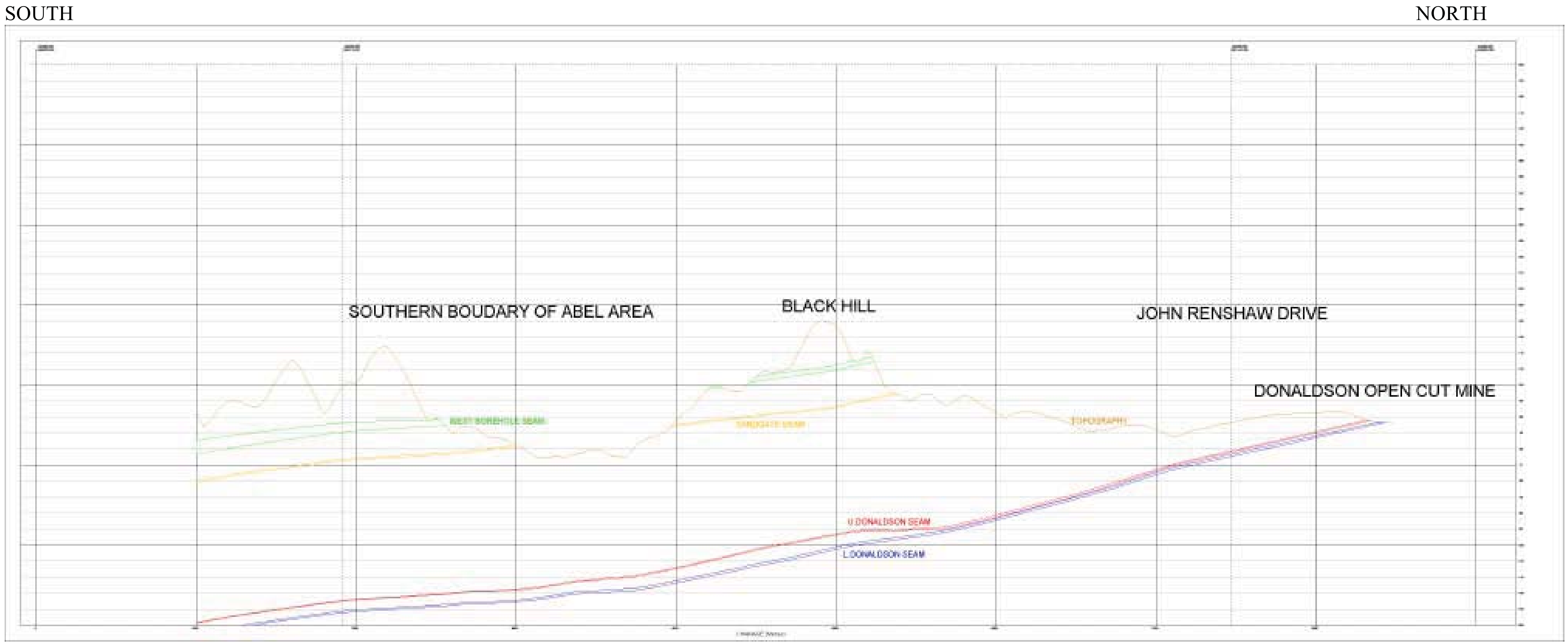


Figure 2 **Geological map of the study area**

Figure 3 **Cross section through Abel mining area from north to south (courtesy of Ellemby Resources Pty Ltd)**



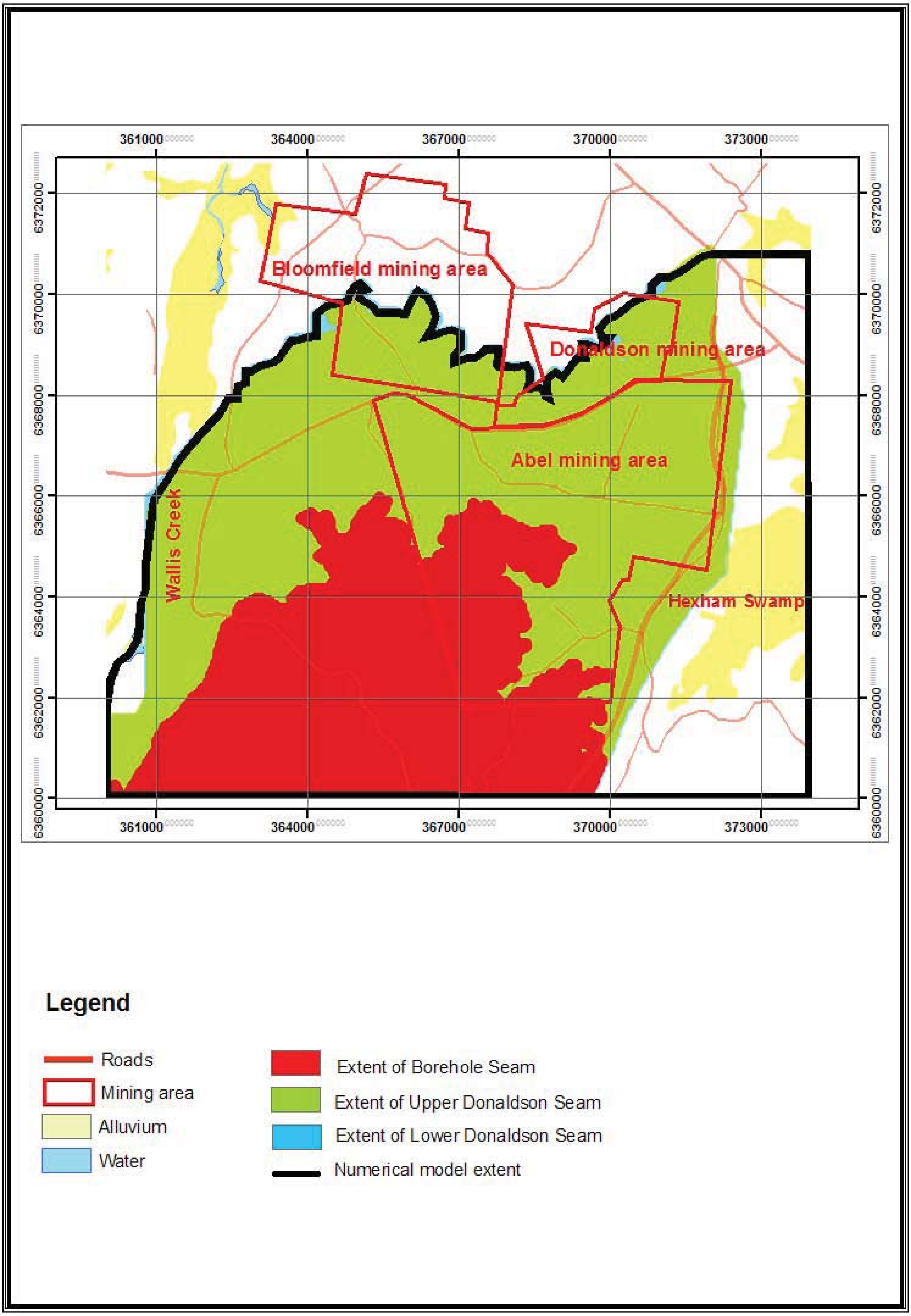


Figure 4 Extent of the West Borehole coal seam and the Lower and Upper Donaldson seams.

(Note: seams extend further to the East than indicated on the map, but data is not available for this area)

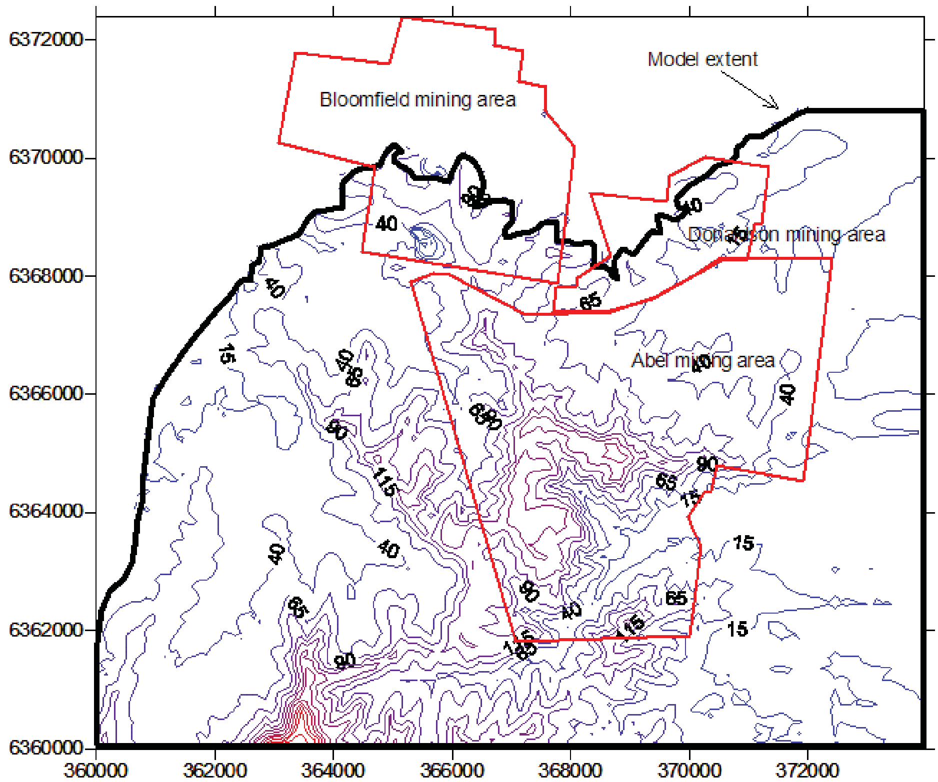


Figure 5 **Topographical contour map of the study area (mAHD)**

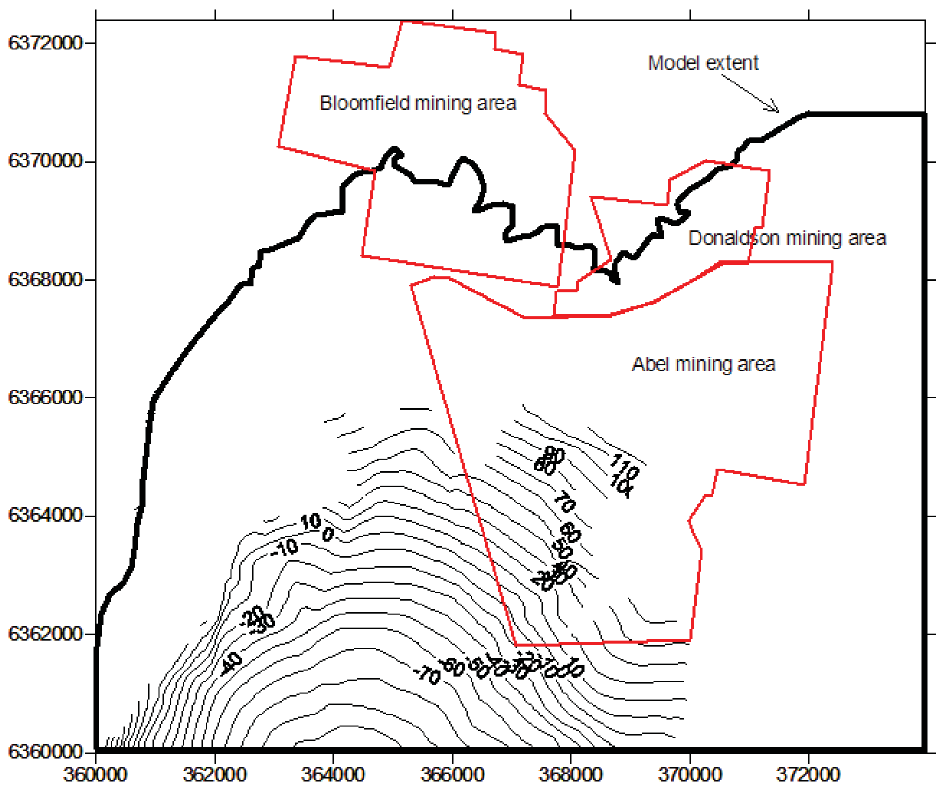


Figure 6 **Contour map of the West Borehole coal seam floor elevation (mAHD)**

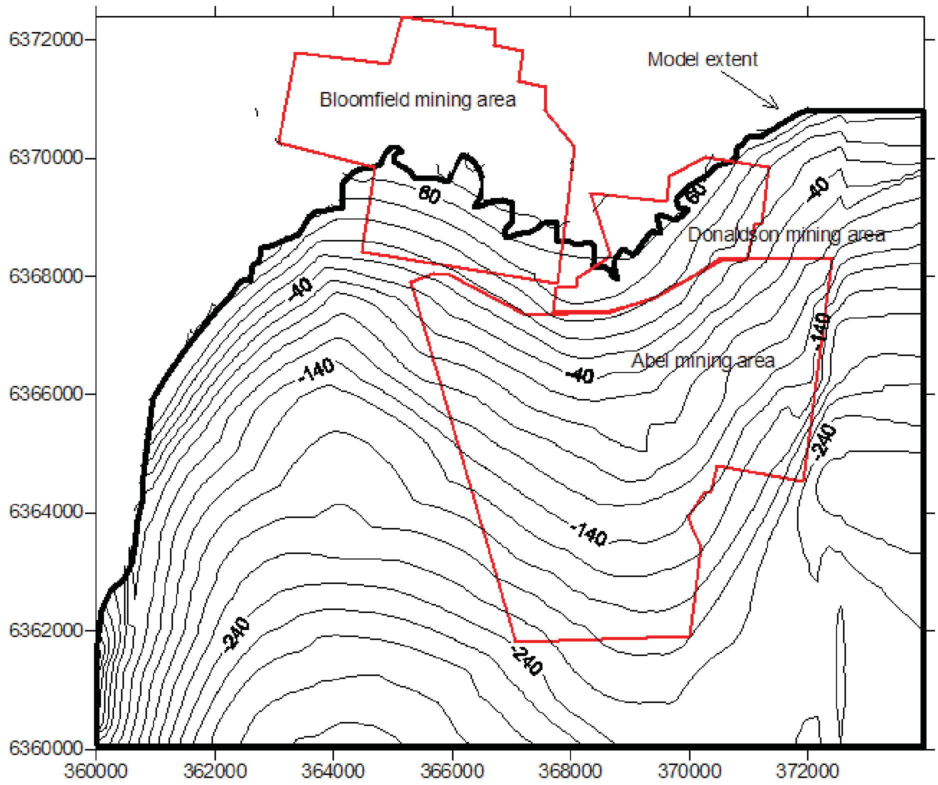


Figure 7 **Contour map of the Upper Donaldson coal seam floor elevation (mAHD)**

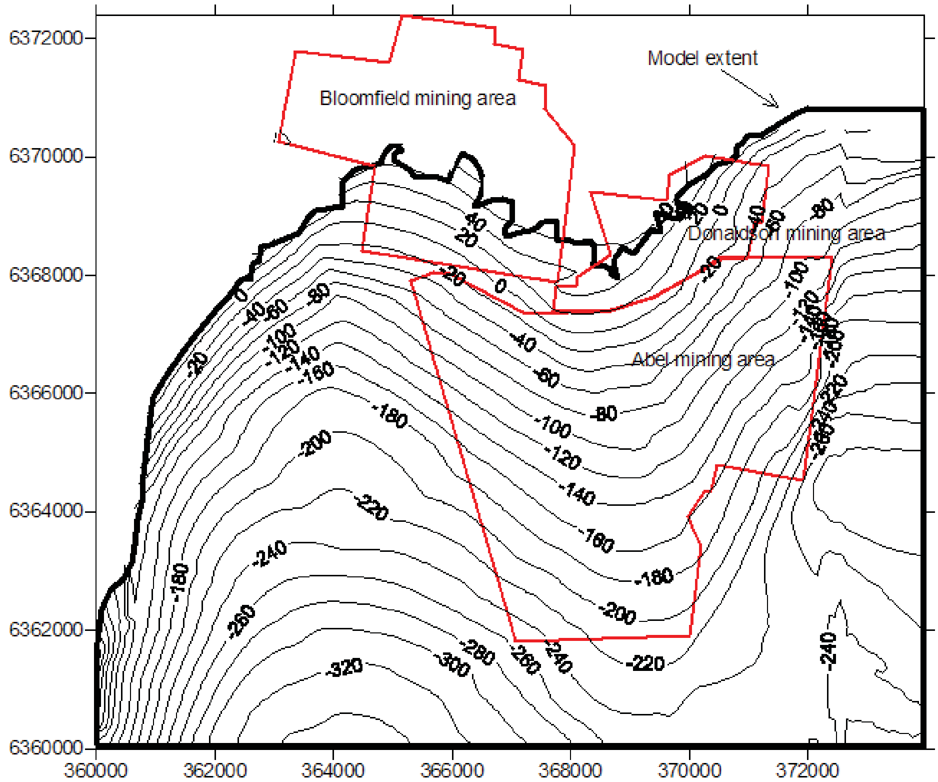


Figure 8 **Contour map of the Lower Donaldson coal seam floor elevation (mAHD)**

2.2 HYDROGEOLOGY

Overall, the coal measures are poorly permeable, but in the study area permeability is generally highest in the coal seams and areas of significant fracturing or faulting. The interbedded sandstone and siltstones are of lower permeability (by at least one order of magnitude) and offer very limited intergranular porosity and little secondary permeability and storage in joints.

Groundwater also occurs in the alluvium, which comprises mainly swamp, floodplain and estuarine sediments. Groundwater also occurs locally in the shallow weathered Permian, which extends to depths of 10-20 metres, and is more closely related hydrogeologically to the alluvium than to the deeper groundwater in the Permian coal measures. Groundwater levels measured in the alluvium and weathered Permian are quite variable, because the water levels are generally related to the local topographic elevations (eg C081B and C082 at low-lying sites; and C087, C078B and C072 at higher level sites - see Table 6). The alluvium around Pambalong Nature Reserve and Hexham Swamp is in hydraulic continuity with the swamp.

The potentiometric head within the Lower and Upper Donaldson Coal seams is regionally-controlled, shows a more consistent pattern across the project area, and is unrelated to the local topographic elevation. The deep piezometer C081A shows that the Donaldson seams at this site is fully artesian with a water level more than 20 metres above ground level[1], and 25 metres higher than the alluvium water level in the shallow piezometer C081B (Table 6). At more elevated sites, deeper piezometers show the groundwater levels to be up to 40m lower than the near-surface groundwater. Water levels within the coal measures show a progressive decline with depth.

The large head differences between the shallow groundwater and deeper Permian groundwater levels, and the presence of artesian groundwater in the Permian in low-lying areas, are both indications of limited hydraulic connectivity between the alluvium/weathered overburden and the deeper coal measures.

A summary of representative aquifer properties of the hydrogeological units in the study area is given in Table 1. These are based on limited hydraulic testing on the Abel site, supplemented by previous investigations in the Tasman and Donaldson mining areas, and experience in other parts of the Hunter Valley coalfields.

Table 1 Parameters of hydrogeological units

Units	Horizontal Hydraulic Conductivity (m/d)	Confined Storativity	Unconfined Specific Yield
Coal Seams	0.01 to 0.1	0.0001	0.01
Interburden (undisturbed)	0.001	0.00001	0.005
Interburden (disturbed through mining)	0.1 to 10	0.0001	0.01 to 0.05
Alluvium	5 to 1 m/d	0.0001	0.1

[1] Water levels above ground surface in deeper piezometers generally occur only in low-lying areas, because the groundwater is confined, and is under pressure. The water level in a bore represents the groundwater pressure or head within the part of the aquifer that is screened, and the head is controlled by the elevation of the recharge zone for that horizon, usually some distance updip where that particular horizon outcrops.
In the unconfined alluvium or weathered bedrock aquifers, the water level represents the level of saturation. A bore water level at the same elevation as the ground surface would be accompanied by seepage or boggy conditions around the bore.

Horizontal hydraulic conductivities in the coal measures are believed to be at least 10 times the vertical hydraulic conductivities.

Groundwater within the coal measures is controlled by the recharge discharge process, with highest groundwater levels in the northern parts of the lease area where the coal measures outcrop. Groundwater levels generally fall to the south and south-east in the direction of groundwater flow downdip to the locations of primary discharge. There is believed to be a component of lateral flow in the Coal Measures out of the model area over the southern and eastern boundaries. The rate of flow across the model boundaries is believed to be limited due to the substantial burial of the coal seams under extensive cover of overburden material (several hundred metres thick).

Data on water levels within the Abel mining lease area is summarised in Section 4. Additional water level records are available for the area around the Donaldson Mining lease just to the north of the Abel mining area. The data indicates the influence of dewatering in the Donaldson Mine area with a cone of depression located to the north of John Renshaw Drive (see Section 4).

2.3 RECHARGE

Long term records of rainfall data are available for the station at the East Maitland Bowling Club (32.7483S, 151.5833E; about 10 km NNE of the Abel mining area). Table 2 lists the mean monthly and annual rainfall, based on more than 100 years of daily rainfall data since 1902.

Table 2 Mean monthly rainfall at East Maitland Bowling Club

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Mean (mm)	89.0	94.1	96.5	87.4	70.3	84.2	58.1	52.2	54.8	65.5	61.6	81.3	895.0

Rainfall recharge occurs to both the coal seams where at outcrop, and to the surficial alluvium/weathered Permian aquifer system. The alluvial aquifers are believed to be in hydraulic continuity with Pambalong Nature Reserve and Hexham Swamp in the east, and with Wallis Creek to the west of the Abel mining area. During periods of high stream flow, surface water courses are likely to contribute to recharge to these alluvial aquifers. However, stream flows from rainfall runoff are reported to be short-lived after rainfall events.

The coal seams are recharged in areas of outcrop and shallow subcrop by direct infiltration of rainfall. Where covered by overburden, the coal seams are recharged primarily by lateral flow down-gradient from the outcrop areas, possibly also with a smaller component of downward percolation through the less permeable overlying sediments.

Rainfall recharge rates within the hard rock outcrop area are believed to be relatively low (i.e. below 10 mm/yr). However, where alluvial deposits occur, recharge rates may be as high as 100 mm/yr. Rainfall recharge occurs in practice as an intermittent process, related to specific larger rainfall events. However, for the steady-state (“long term average”) groundwater model, rainfall recharge has been modelled by applying constant assumed effective recharge rates to the alluvium and hard-rock areas, rather than a time-dependent recharge mechanism. If, at a later stage the model is upgraded with transient (time-varying) history-match capability, the recharge rate may be varied according to the seasonal change in rainfall and evaporation.

2.4 GROUNDWATER DISCHARGE

In outcrop or shallow subcrop areas, groundwater discharge from the coal measures can occur through evaporation, seepage and spring flow where the water table intersects the land surface, and through baseflow contributions to creeks, rivers and the Hexham Swamp, including discharge to the alluvium where it occurs. Away from outcrop, discharge from the coal measures occurs by slow down-dip flow along bedding or other zones of enhanced permeability to the south and south-east to areas where the groundwater heads are lower, with ultimate discharge probably to the ocean.

Groundwater discharge from the alluvium and shallow weathered bedrock can occur by evapotranspiration, seepage and discharge to creeks or to the wetlands of Pambalong Nature Reserve and Hexham Swamp.

Due to the high groundwater salinity and low bore yields, there is almost no existing groundwater abstraction in the study area other than for coal mine dewatering (Donaldson, Bloomfield, etc).

Average A Class pan evaporation data is available for Cessnock (32.8093S 151.3490E, about 20 km WNW of Abel mining area) and Paterson, and provide the closest data to the Abel mining area. Table 3 summarises mean monthly evaporation rates, based on a 34 year period.

Table 3 Mean daily evaporation data for Cessnock and Paterson Stations (mm)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Cessnock	5.7	5.0	4.0	3.0	2.0	1.6	1.8	2.6	3.6	4.4	5.2	5.9
Paterson	6.0	5.2	4.2	3.4	2.4	2.2	2.5	3.4	4.4	5.2	5.9	7.0

The data presented in Table 2 and Table 3 indicates that evaporation exceeds mean monthly rainfall during the summer period, while it is comparable or slightly above rainfall during winter. If the model were upgraded for transient (history match) calibration, then it would be appropriate to specify recharge as a seasonal process.

Evaporation is included in the model using the Evapotranspiration (EVT) package of MODFLOW. The EVT parameter values adopted were a constant rate of 250 mm/yr and an extinction depth of 5 m, which allows E_T to be active in areas of shallow water table, such as in areas of low topography along surface water courses such as Wallis Creek and the Hexham Swamp area.

2.5 SURFACE DRAINAGE

The land surface within the Abel mining lease area is located within the lower section of the Hunter River catchment and consists of low undulating hills. There are several surface water catchments in the study area, with associated creeks being generally ephemeral, with the possible exception of Wallis Creek to the west.

The western part of the Abel mining area lies within the Buttai Creek Catchment, which drains westwards into Wallis Creek and then into Hunter River east of Maitland. Wallis Creek is characterized by substantial alluvial deposits developed along the river bed. Such deposits are also present in the east, around Hexham Swamp, which is partly tidal, and which also receives drainage from the Long Gully/Blue Gum Creek catchment from the southern part of the study area. A ridgeline associated with Black Hill running east-west through the proposed underground mine lease area results in drainage directed to the north and north-east from this ridgeline via the Weakleys Flat Creek, Viney Creek and Four Mile Creek catchments to the Hunter River.

The numerical model incorporates river/aquifer interactions, to enable quantification of the impacts of groundwater pumping on surface water features. This is important to assess whether mining is likely to lower water levels and reduce baseflow to permanent streams, although it should be noted that the streams in the Abel project area are mainly ephemeral because baseflow support is relatively short, and extensive periods of no flow occur naturally.

2.6 ESTIMATE OF DRAINAGE INTO MINE WORKINGS USING ANALYTICAL SOLUTIONS

One aim of the modelling study at Abel is to estimate likely seepage rates from the overlying interburden into the Abel underground workings over the life of the mine. Underground mining and dewatering activity will be represented in the model using drain cells within the mined coal seams (Layer 6, see Section 4). Drain cells will be emplaced where workings occur and progress in accordance to the mine plan requiring a transient model set-up. At the same time, the aquifer properties of the interburden above the workings (Layer 5, see Section 4) will change with time to reflect the increased permeability of goaf zones. The drain conductance should reflect the resistance to flow between the interburden material and the mine void. This is a critical model parameter which determines the simulated seepage inflow into the workings and care needs to be taken to select appropriate permeabilities. Therefore, leakage rates into the workings will be calculated on the basis of analytical methods to support the selection of drain conductances in the numerical model.

A commonly used analytical method of predicting seepage into open voids (such as tunnels) is the method of Goodman et al. (1965). It is an approximate formula based on theory modified by laboratory experimental results, and predicts groundwater inflow into a drained tunnel based on several simplifying assumptions :

- homogeneous and isotropic permeability
- steady flow
- circular tunnel cross section, held at constant hydraulic potential

These simplifications are in most cases not met entirely, however, the obtained solutions are still valuable for rough estimations. Also, the high level of uncertainty with respect to the highly non-homogenous distribution of hydraulic conductivity in the subsurface does not allow for anything more than a rough estimation of seepage. Nevertheless, the solution will serve as a first approximation, but should be regarded as an upper limit.

The equation proposed by Goodman et al., (1965) for calculation of groundwater inflow during tunnel driving is:

$$q = \frac{1}{\sqrt{t}}\sqrt{\frac{KH^3Sy}{3}}$$

where: q = inflow [m^3/day], t = time [day], K = hydraulic conductivity [m/day], H = depth of void below initial water table [m], Sy = specific yield.

Table 4 presents the long-term leakage rates per metre length of mine opening for a range of aquifer parameters, which also highlights the sensitivity of the seepage calculation to aquifer properties. Figure 9 presents the results in graphical format for varying length of the underground workings. The results indicate that seepage into the workings is likely to be in the order of 0.0024 m^3/day per metre length of workings for a Kv of 0.0001 m/d, given the generally deep burial and the consequent likely low permeability of the interburden through which leakage may occur. If highly conductive geologic formations (eg faults or fracture zones) are encountered during mining they could produce inflows greater than the predicted values. There are no infinitely large sources of water, such as a lake, over the proposed mine. Accordingly, the only long-term source of water is likely to be infiltration of precipitation.

For the purpose of the numerical modelling, a leakage rate in the order of 0.0024 m^3/d, corresponding to an assumed interburden permeability of 0.0001 m/d, will serve as a guide on the to expected seepage volumes. Accordingly, a leakage volume of about 9.6 ML/day can be calculated for the entire Abel underground mine area. This is regarded as an upper limit, or worst-case scenario for full drainage of the overlying bedrock.

Table 4 Long term seepage rates per metre length of mine workings for a range of aquifer parameters

Kv interburden [m/d]	Sy	Depth of mine below water table [m]	Seepage [m^3/d]	Seepage [L/s]
0.01	0.005	50	0.0239	0.000277
0.001	0.005	50	0.0076	0.000087
0.0001	0.005	50	0.0024	0.000028
0.00001	0.005	50	0.0008	0.000009
0.000001	0.005	50	0.0002	0.000003

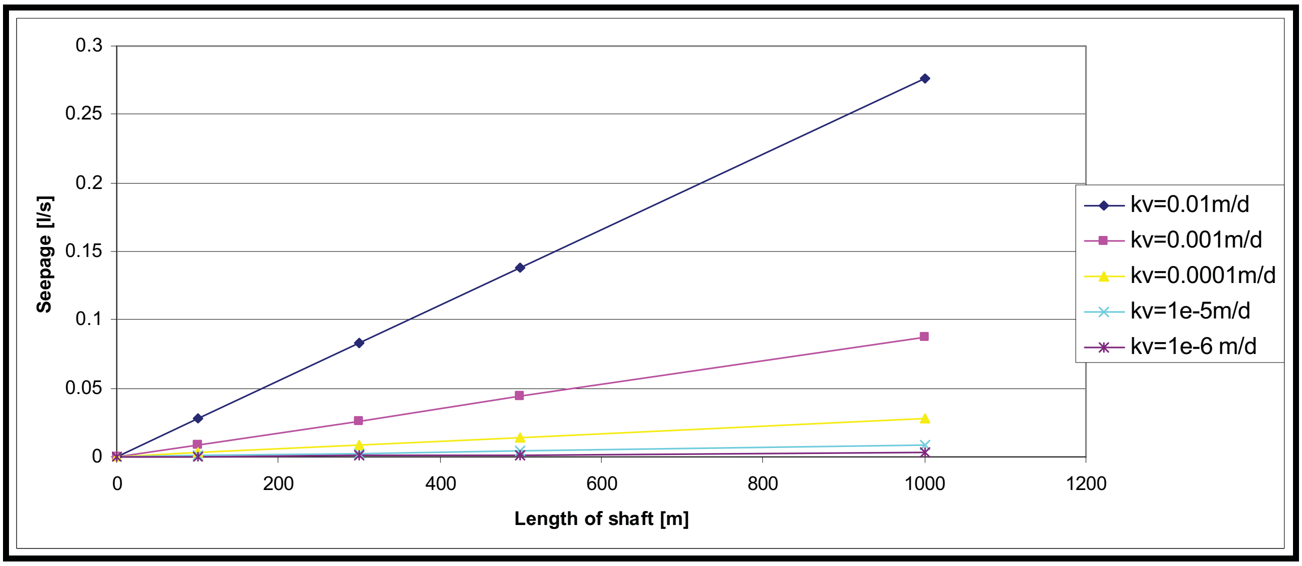


Figure 9 Long term seepage rates for various length of mine workings and various aquifer parameters.

SECTION 3 IMPLEMENTATION OF CONCEPTUALISATION IN MODEL

3.1 MODEL SELECTION AND COMPLEXITY

The MODFLOW numerical groundwater flow modelling package has been used for this study, operating under the Processing Modflow for Windows software package (IES), and also the Vistas software package (ESI).

The MODFLOW numerical code is adequate for this study, particularly due to its industry-leading modules for simulating surface water and groundwater interaction. Perhaps as importantly for future capabilities, there have been recent advances in the development of other modules. Already available modules include a package for density-coupled flow (SEAWAT), in case density (salinity) effects may (eventually) become significant in the case of the mine post-closure. MODHMS is a module with which saturated/unsaturated flow conditions can be simulated which could become important for the simulation of unsaturated underground workings in surrounding saturated rock.

The degree of model complexity required to accomplish the study objectives is a key issue (MDBC, 2001). In this case, a **medium complexity model** was required for impact assessment purposes and to support the feasibility and bankability aspects of the Abel project.

The hydrogeological investigations (including modelling) were also undertaken with reference to the 'Guidelines for Management of Stream/Aquifer Systems in Coal Mining Developments – Hunter Region' (DNR, April 2005), with the model developed in accordance with the best practice guidelines on groundwater flow modelling (MDBC, 2001). The Dept of Planning report on *Coal Mining Potential in the Upper Hunter Valley - Strategic Assessment* (October 2005) has also influenced the methodologies applied to these investigations.

3.2 MODEL EXTENT, BOUNDARIES, LAYERS AND GRID

The model area of about 120 km^2 is shown in Figure 4. It includes the Abel mining area and extends to the north and west as far as the outcrop line of the Lower Donaldson seam, which is represented using a no-flow boundary. The southern boundary has been set at Northing 6,360,000, about 1.8 km south of the Abel mining area. At this latitude, the coal seam aquifers are under considerable overburden: the lower Donaldson seam occurs at a depth of about 240 m below surface in the west, increasing to over 400 m depth towards the east. The depth of the coal seam aquifer units along this boundary warrants that only limited flow occurs across it. Additionally, it has been set far enough south to avoid any interference with the mining activities to be simulated in the Abel mining area to the north. This boundary will be represented numerically using a head-dependent flux (using Modflow's General Head Boundary "GHB" package), with water level set to observed heads.

In model layers representing the coal seams and interburden material, the eastern boundary is represented using GHB cells, as some groundwater flow may occur across the boundary towards the sea. This flow however is believed to be minimal with seams buried under more than 200 m of overburden at this location.

The eastern model boundary is located within the Hexham Swamp at Easting 374,000, about 2 km east of the F3 Freeway. The Hexham Swamp area will be represented using river cells, allowing water to flow into and leak out of the swamp according to the difference in heads in the aquifer and swamp.

For the steady state model, Wallis Creek is represented using river cells to allow for stream-aquifer interaction due to leakage from the creek and/or baseflow from the alluvial aquifer. Smaller creeks, where flow is known to occur only through minor baseflow and after rainfall events, are represented using drain cells to allow for the predominant process of groundwater discharge (baseflow) to these minor streams. Such creeks included in the numerical model are: Buttai Creek, Blue Gum Creek, Weakleys Flat Creek, Viney Creek and Four Mile Creek. The representation of surface watercourses may be revised during future modelling work when more data on their interaction with the groundwater system becomes available.

The cell size throughout the model is uniform at 100m by 100m, however further grid refinement is possible at any time. A total of 109 rows and 140 columns are used.

The hydrogeological model can be represented numerically with a 6 layer model (Figure 10), where coal seams and interburden are represented independently. Alluvial deposits are not represented as a specific layer but are included in layers 1 to 6 according to their location and surface elevation.

Summary of model layers:

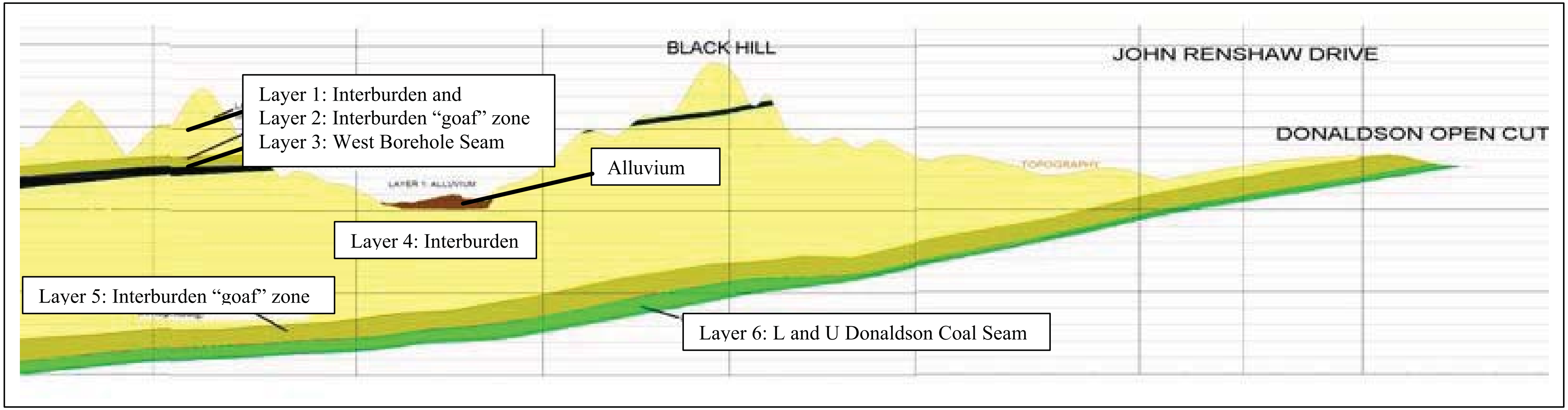
Layer 1: Interburden (to represent the undisturbed interburden)
Layer 2: Interburden (to represent the disturbed "goaf" interburden section after mining)
Layer 3: West Borehole Coal Seam
Layer 4: Interburden (to represent the undisturbed interburden)
Layer 5: Interburden (to represent the disturbed "goaf" interburden section after mining)
Layer 6: Upper and Lower Donaldson Seam including the narrow interburden between the seams.

The interburden above coal seams is to be divided into two parts. The basal unit, a "goaf" zone of about 50 metres thickness above the coal seams, represents the interburden where subsidence during and after mining may result in increased vertical and horizontal hydraulic conductivity. The remaining part represents the undisturbed interburden sediments. As the Lower and Upper Donaldson Seams are separated by a thin interburden layer of only 10.7 m average thickness and are believed to act as one hydrogeological unit, they are represented by one model layer.

Underground mining and dewatering activity will be represented in the model using drain cells within the mined coal seams (Layer 6). These will be emplaced where workings occur and progress in accordance to the mine plan requiring a transient model set-up. For the post-mining recovery model run, aquifer properties of the interburden above the mine workings (Layer 5) will be changed to reflect the increased permeability of goaf zones. For the dewatering predictions, aquifer parameters will not change with time.

Given the current hydrogeological knowledge, using drain cells to model the underground development progressively down-dip is believed to adequately represent the flow processes. Future modelling should seek to refine the approach, perhaps using Modflow-Surfact to represent the dewatering conditions with more detail. The drain conductance should reflect the resistance to flow between the interburden material and the mined-out seam. This is a critical model parameter which determines the simulated seepage inflow into the workings and care needs to be taken to select appropriate permeabilities. Leakage rates into the workings will be compared to the results of analytical methods (see Section 2.6) to support the selection of drain conductances in the numerical model.

Figure 10 Model layers in the Abel model



SECTION 4 MODEL CALIBRATION

4.1 CALIBRATION APPROACH

The groundwater model will be set up and run initially in steady state mode. Calibration will be based on the available water level data matching what is deemed to be a long term average water table level. No long term transient water level records are available, and at this stage, transient model calibration is not possible due to the lack of detailed time series data.

Model calibration performance will be demonstrated in quantitative (head value matches) and qualitative (pattern-matching) terms, by:

- contour plans of modelled head, with posted spot heights of measured head
- hydrographs of the water balance components
- scatter plots of modelled versus measured head, and the associated statistical measure of the scaled root mean square (SRMS) value.

The scaled RMS value is the RMS error term divided by the range of heads across the site and it forms the major quantitative performance indicator. Given uncertainties in the overall water balance volumes (eg it is difficult to directly measure evaporation and baseflow into the creeks), it is proposed that a 10% scaled RMS value would be an appropriate target for this project, with an ideal target for long term model refinement suggested as 5% or lower. This approach is consistent with the Australian best practice groundwater modelling guideline (MDBC, 2001).

Having achieved acceptable calibration of the model, the model will be used for predictive transient modelling (Section 6) to assess the impact of progressive underground mining on the water balance in the study area. Particular interest will be placed on the regional change in groundwater levels during mining and after mine closure, on changes in flows to surface water courses, including Pambalong Nature Reserve and Hexham Swamp, and on the potential water ingress into the mine workings through vertical leakage during the life of the mine.

4.2 CALIBRATION POINTS

There are several observation boreholes covering different depths within the geological profile available from the Donaldson Mine area which fall within the Abel groundwater model area. Boreholes, which have not been lost to mining and are within the model area have been used for model calibration. As the model includes the Donaldson and Bloomfield mining operations, calibration was based on the current water levels, i.e. mining water levels. Where water levels are available from various depths at the same location, but fall within one model layer, the longest records of water levels were used. Table 5 and Table 6 summarise the bores used for model calibration, with their location shown in Figure 11.

The vertical hydraulic gradients within the same geological unit, as seen from some of the piezometer readings, cannot be represented in the model due to the vertical discretisation being restricted to one to two model layers per geological unit. Bore C063 was discarded, as the reported water levels below sea level appear erroneous. Bores C078B, C087, C072B, and C082 represent water levels in the shallow weathered Permian (pers. comm. Peter Dundon), a unit not explicitly represented in the model. Bore C081B represents the water level in the alluvium close to Pambalong Nature Reserve.

No long term water levels are available for those bores.

In total, the model is calibrated using 17 piezometer points and in addition the match between the simulated water table and the observed water table map can be assessed at Figure 12.

Table 5 Existing observation points around the Donaldson Mining area

(location of bores is shown in Figure 11)

Name	Surface Level (mAHD)	Depth of Piezo (m)	Level of Base of Piezo (mAHD)	Average water level (mAHD)	Typical level before mining (mAHD)	Typical current level (ie mining-influenced) (mAHD)	Number of records
DPZ2	22.27	27.8	-5.53	4.97	5.0	7.0	11
DPZ4B*					12.4	-6.9	
DPZ5	12.77	18	-5.23	6.39	6.9	6.0	60
DPZ7@50*	55.4	41	37.4	32.60	33.9	31.9	59
DPZ8*	51.75	32.2	19.55	27.44	27.4	26.5	62
DPZ9*	36.36	36.5	-0.14	17.02	18.9	4.2	68
DPZ10	19.81	29.8	-9.99	7.00	8.6	6.0	61
DPZ13	21.48	30	-8.52	14.13	14.5	14.2	62
DPZ17@62*	15.25			-4.26	12.7	-3.0	46

* = Water levels of the Lower and Upper Donaldson coal seam

Table 6 Piezometers in the Abel mining lease area

(location of bores is shown in Figure 11)

Bore_Name	Easting	Northing	Average WL (mAHD)	Min WL (mAHD)	Max WL (mAHD)	Screen (mAHD)	Penetrated geol. unit
C062A(SP)	370143	6366248	24.69	24.45	25.00	124-118	UD seam
C062B(SP)	370143	6366248	31.84	31.30	32.00	87-81	Interburden above UD
C063A(VW) [2]	372109	6366193	-5.47	-6.00	-3.04	197	Below LD seam
C063B(VW) [2]	372109	6366193	-2.08	-4.51	+3.21	128	Interburden above UD
C072A(SP)	369919	6362569	24.25	21.73	27.00	168	Interburden above UD
C072B(SP) [1]	369911	6362570	50.51	50.01	51.00	45-42	Colluvium/weathered Permian
C072(VW)	369927	6362562	17.46	14.12	20.13	264	LD and UD seam
C078A(SP)	367140	6367054	29.22	28.44	30.00	99-96 and 90-87	LD and UD seam
C078B(SP) [1]	367140	6367054	67.60	67.48	67.72	24-18	Colluvium/weathered Permian
C080(VW)	368040	6365176	28.29	28.03	28.56	280	LD seam
C081A(VW)	369992	6364001	26.07	25.96	26.18	155	Base of LD seam
C081B(SP)	369992	6364001	1.84	1.65	2.02	20-14	Alluvium - Pambalong Nature Reserve
C082(SP) [1]	370319	6364647	20.66	18.70	22.61	20-14	Colluvium/weathered Permian
C087(SP) [1]	367187	6367079	63.46	63.46	63.46	18.3-12.3	Colluvium/weathered Permian

[1] discarded for purpose of model calibration as water levels represent shallow, possibly perched water table in the shallow colluvium/weathered Permian, a unit not explicitly represented in the model;
[2] discarded for purpose of model calibration as water levels appear erroneous.

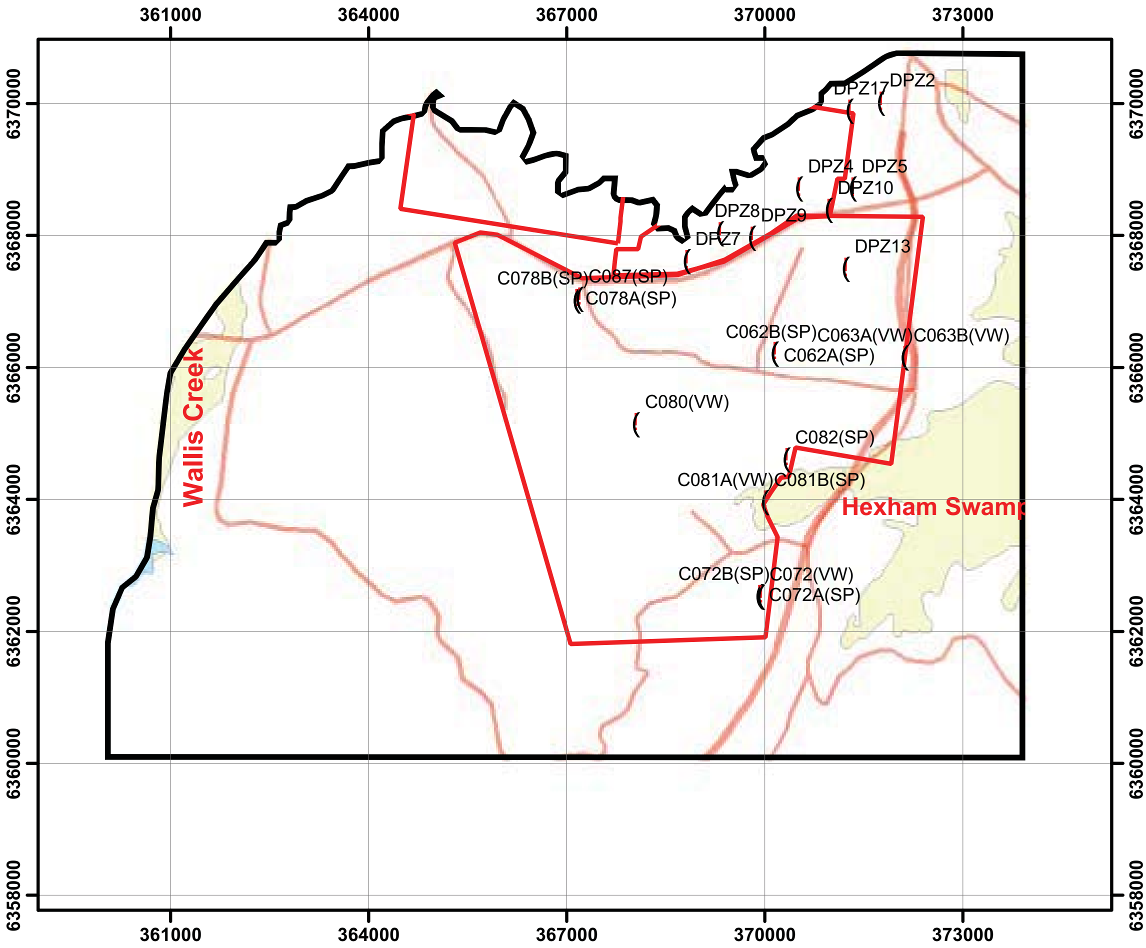


Figure 11 **Location of calibration points within the model area**

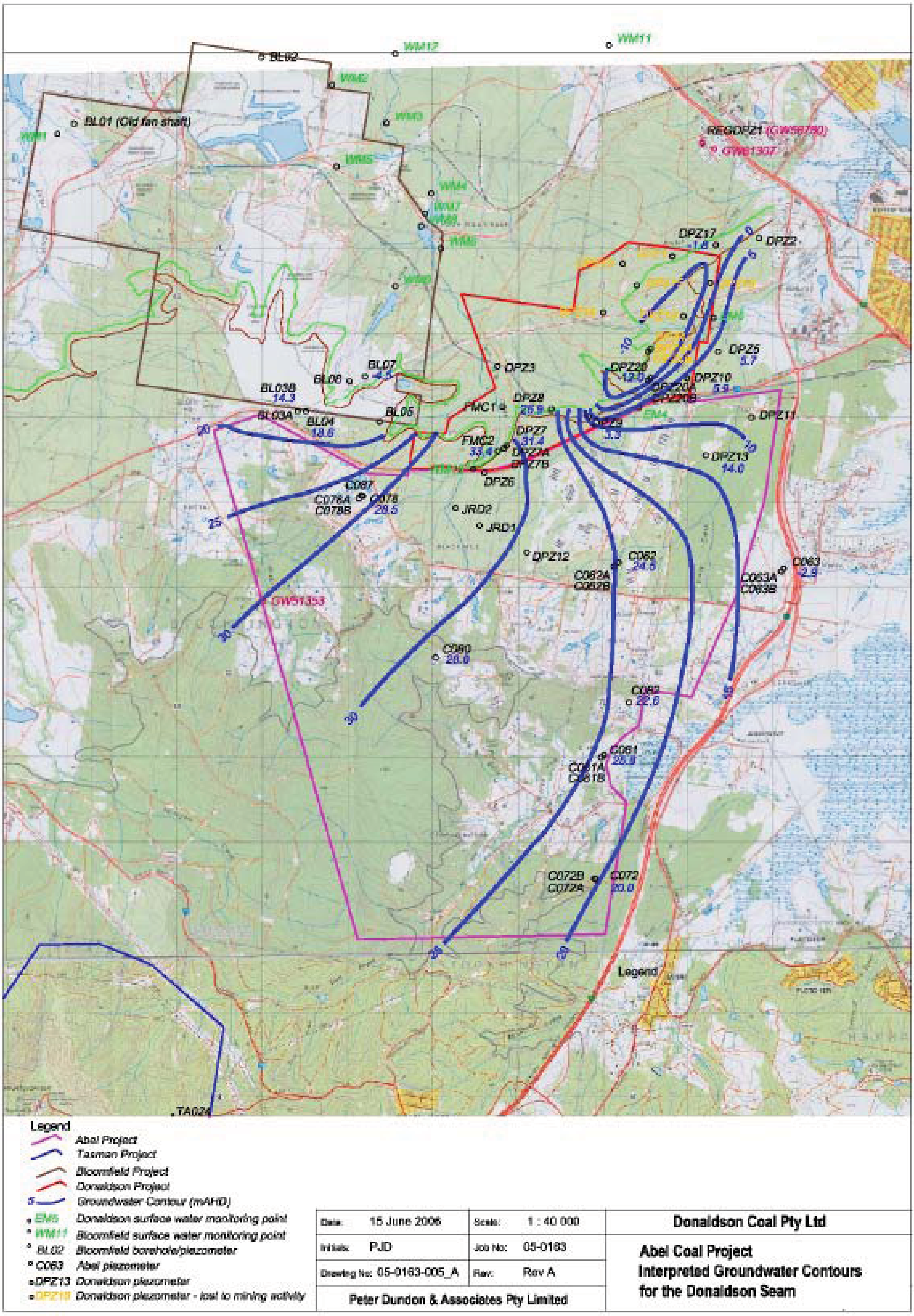


Figure 12 Sketch of water levels in the Lower and Upper Donaldson Coal seam (courtesy of Peter Dundon)

SECTION 5 STEADY STATE MODEL

The Abel groundwater model was run firstly in steady-state (“long term average”) mode. Pre-mining conditions were simulated for the Abel mining lease area, while Donaldson mine dewatering was included using drain cells north of the John Renshaw Drive.

Parameters of the steady-state model run after calibration are detailed in Table 7 and are graphed in Appendix A. The calibrated model has a scaled RMS error of 6.07% (Table 9) and simulated water levels fit the observed pattern well (Figure 13 and Figure 14). Figure 14 and Figure 15 show the simulated water levels for the Lower and Upper Donaldson Coal seam and the interburden above the coal. The model simulates a vertical hydraulic gradient from higher to lower model layers within the coal and interburden layers, with lowest water levels being measured in the Donaldson coal seam. Water levels in the vicinity of Pambalong Nature Reserve are simulated to be around 1 to 5 mAHD (C081B observed: 1.84mAHD), being perched and with very limited hydraulic connectivity to the layers below. However, the simulated water table in the swamp is sensitive to the underlying vertical hydraulic conductivity. In general, the model has been calibrated to reflect the observed vertical hydraulic gradient by varying the vertical hydraulic conductivity. Data on the vertical head gradients are, however, quite sparse, including the area around Hexham Swamp, where simulated vertical head gradients cannot be verified by field data. However, the simulated head gradient around the swamp is consistent with the head differences observed at other locations in the model area.

The steady-state water balance is summarised in Table 8. The main inflow component to the model area is recharge, with most water being lost to the rivers and creeks and some groundwater also discharging over the model boundaries towards the south and south-east. Discharge due to mining at Bloomfield and Donaldson mines is simulated to be around 150 m^3/d. The modelled groundwater discharge into Donaldson mine amounts to about 70 m^3/d, which is slightly lower, but comparable to the estimated discharge volumes from Donaldson mine at 2002 of 160 m^3/d (Hughes Trueman and Dundon, 2003). An exact match is not attempted, as the discharge rate at 2002 (i.e. 160 m^3/d) is not measured, but estimated roughly on the basis of total hours of pumping and the rated capacity of the pump, with some allowance made for surface water inflows. It is not possible to apply a high level of confidence to the calculated inflow rate, however it is the best information available and the model is able to simulate inflow rates in the same order of magnitude.

Table 7 Abel Model parameters after calibration

Layer	Geological unit	Kh [m/d]	Kv [m/d]	Confined S*	Unconfined Sy*
1	Interburden above WB seam (undisturbed)	0.001	0.0001	0.00001	0.005
2	Interburden above WB seam (undisturbed)	0.001	0.0001	0.00001	0.005
3	WB seam/Alluvium	0.15 Alluvium = 6.0	0.001 Alluvium= 0.0005	0.0001	0.01 Alluvium = 0.1
4	Interburden above LD/UD seam (undisturbed)	Under confinement: 0.001 At outcrop/Under Alluvium: 0.0005 - 0.01	0.0001 under swamp: 0.00001	0.00001	0.005
5	Interburden above LD/UD seam (undisturbed)	0.001 At outcrop : 0.005	0.00005	0.00001	0.005
6	LD/UD seam	0.1 – 0.001	0.001	0.0001	0.01

* only applicable for the transient model runs

Recharge was applied at rates of 1.5 to 3 mm/yr generally, except for the alluvium areas, which received 100mm/yr. Evapotranspiration is active in low lying areas such as around creeks and the swamp area to the east and operates at maximum rates of 250 mm/yr.

Due to limited data on pumping rates and schedules in the Bloomfield and Donaldson mine areas, the impact of these operations on the water table has been simulated in a simplistic way, using drain cells set to observed water levels in the area.

Table 8 Steady state water balance [m^3/d]

	Recharge	ET	Drains (dewatering @ Donaldson/Bloomfield and flow into creeks)	River flows (Wallis Creek and Hexham Swamp)	Flows across boundaries
Inflows into model [m^3/d]	1785	-	-	16.4	8.45
Outflows [m^3/d]	-	22	149	1402	236

Table 9 Steady state model statistics

CALIBRATION PARAMETERS		VALUE	
Sum of Residuals	SR		m
Scaled Mean Sum of Residuals	SMSR	-0.31	%
Root Mean Square	RMS	2.57	m
Scaled RMS	SRMS	6.07	%
Root Mean Fraction Square	RMFS	53.58	%
Scaled RMFS	SRMFS	21.41	%
Coefficient of Determination	CD	0.95	

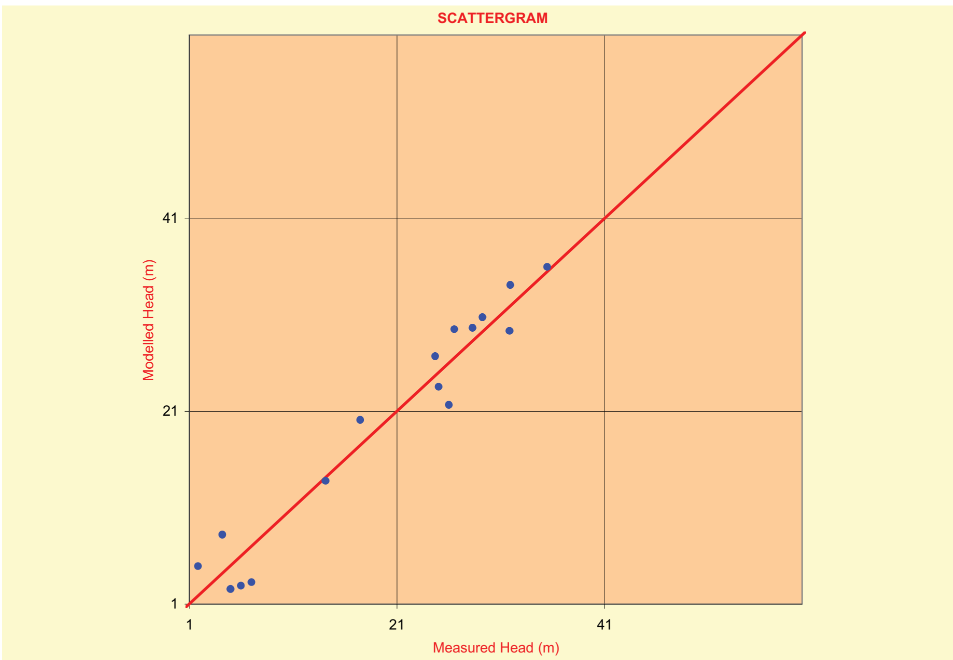


Figure 13 Observed vs. simulated water levels

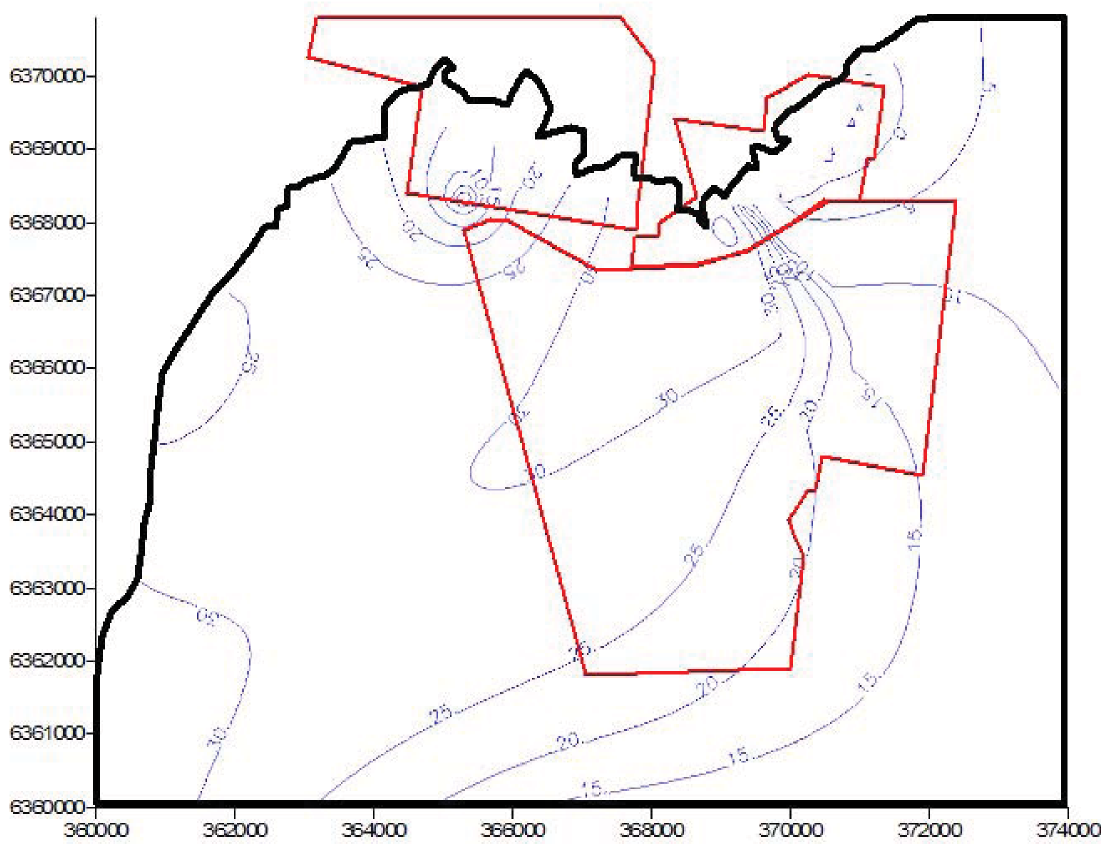


Figure 14 Water level map for the LD/UD coal layer (Layer 6)

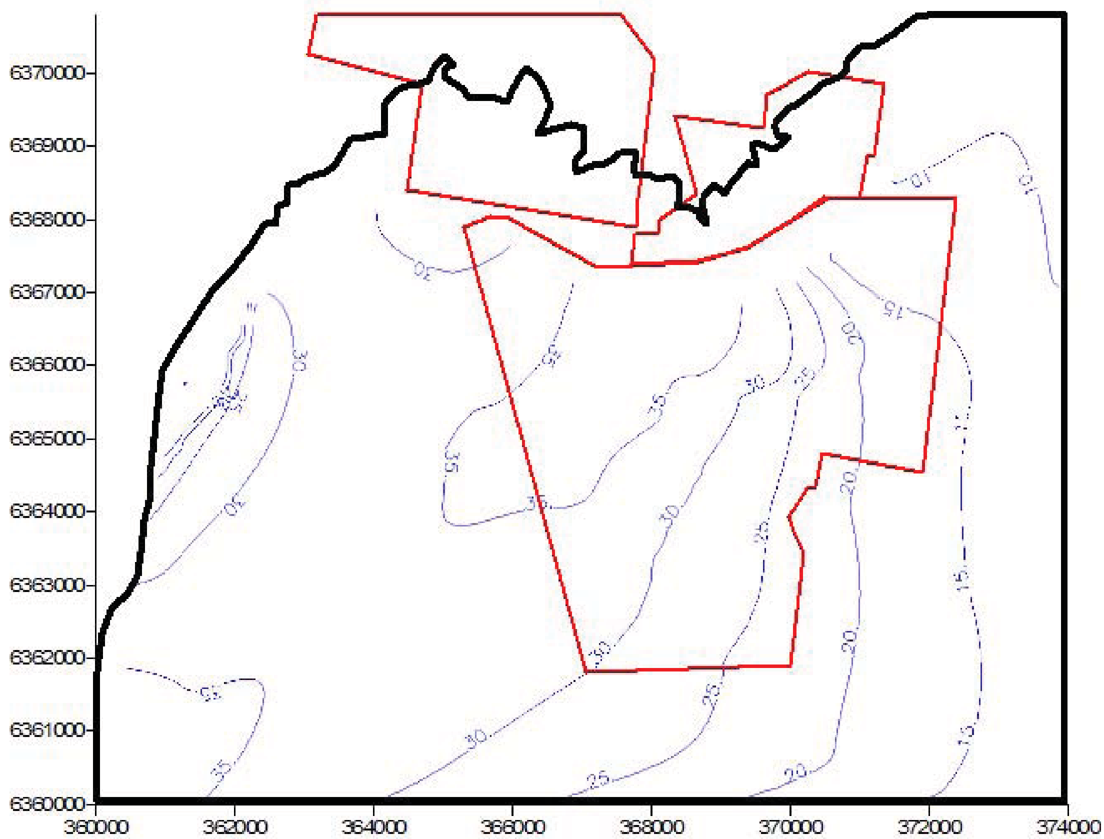


Figure 15 Water level map for the interburden above the Donaldson Coal seam (Layer 4)

6.1 SET UP OF DEWATERING PREDICTION MODEL

Having achieved calibration of the model in steady-state mode, the Abel groundwater model was applied to prediction simulations of mining actions from 2007 onwards as envisaged by the Abel mine plan (Figure 16).

The transient dewatering model comprises 11 stress periods. The duration and start and end date of each stress period are detailed in Table 10. At 2027 a post mining recovery model run is set up to simulate the recovery of the water levels after mining operations have ceased.

Underground mining and dewatering activity is represented in the dewatering model using drain cells within the mined coal seam (Layer 6). These are emplaced where workings occur and progress in accordance to the mine plan. The available mine schedule summarises mine progress within two year time steps, which has been replicated in the model by applying stress periods of 730 days length. Panels are assumed to be excavated instantly at the start of each stress period. This is a simplification of the actual mining progress, which is continuous rather than step-wise, and may lead to a slight overestimate of the actual drainage volumes, as model cells are “mined” in advance of what will occur in reality. The drain conductivity has been set to double the Kv of the overlying interburden (i.e. resulting in a drain conductance of 0.01 m^2/d) in the actively mined area. This changes to a 5 times higher drain conductance (i.e. 0.05 m^2/d) for already mined out areas, to reflect the increased permeability of “goaf” zones above the mine workings. For the post-mining recovery model run, aquifer properties of the interburden above the mine workings (Layer 5) have been changed to reflect the increased permeability of “goaf” zones, while drain cells are switched off (Table 11).

Table 10 Stress period set-up of the dewatering run

Stress period	Time	Features implemented in the model
1*	Jan 2007 – Dec 2007	The drop-cut is being introduced north of the John Renshaw Drive and progressively deepened to base of coal.
2*	Jan 2008 – Dec 2009	Underground mining in Abel. Open cut mining in Donaldson progresses towards Abel portal
3*	Jan 2010 – Dec 2011	Underground mining in Abel. Open cut mining in Donaldson progresses towards Abel portal
4*	Jan 2012 – Dec 2013	Underground mining in Abel. Open cut mining in Donaldson has progressed to Abel portal and then ceases
5 to 11*	Jan 2014 – Dec 2027	Underground mining in Abel progresses down-dip according to mine plan

* All stress periods are divided into 200 time steps

Table 11 Set-up of the dewatering and recovery models

Layer		Dewatering run	Recovery run
1 to 4	Interburden, Alluvium and West Borehole seam and undisturbed interburden above LD/UD	No change to steady state model	No change to steady state model
5	Interburden above LD/UD seam (disturbed)	No change to steady state model	Aquifer parameters changed to reflect disturbed interburden (i.e. Kh, Kv times 100)
6	LD/UD seam	Introduction of drain cells in accordance with the mine plan. Drain conductance in actively mined area: 0.01 m^2/d, in mined-out areas: 0.05m^2/d	No change to steady state model. Drain cells are switched off.

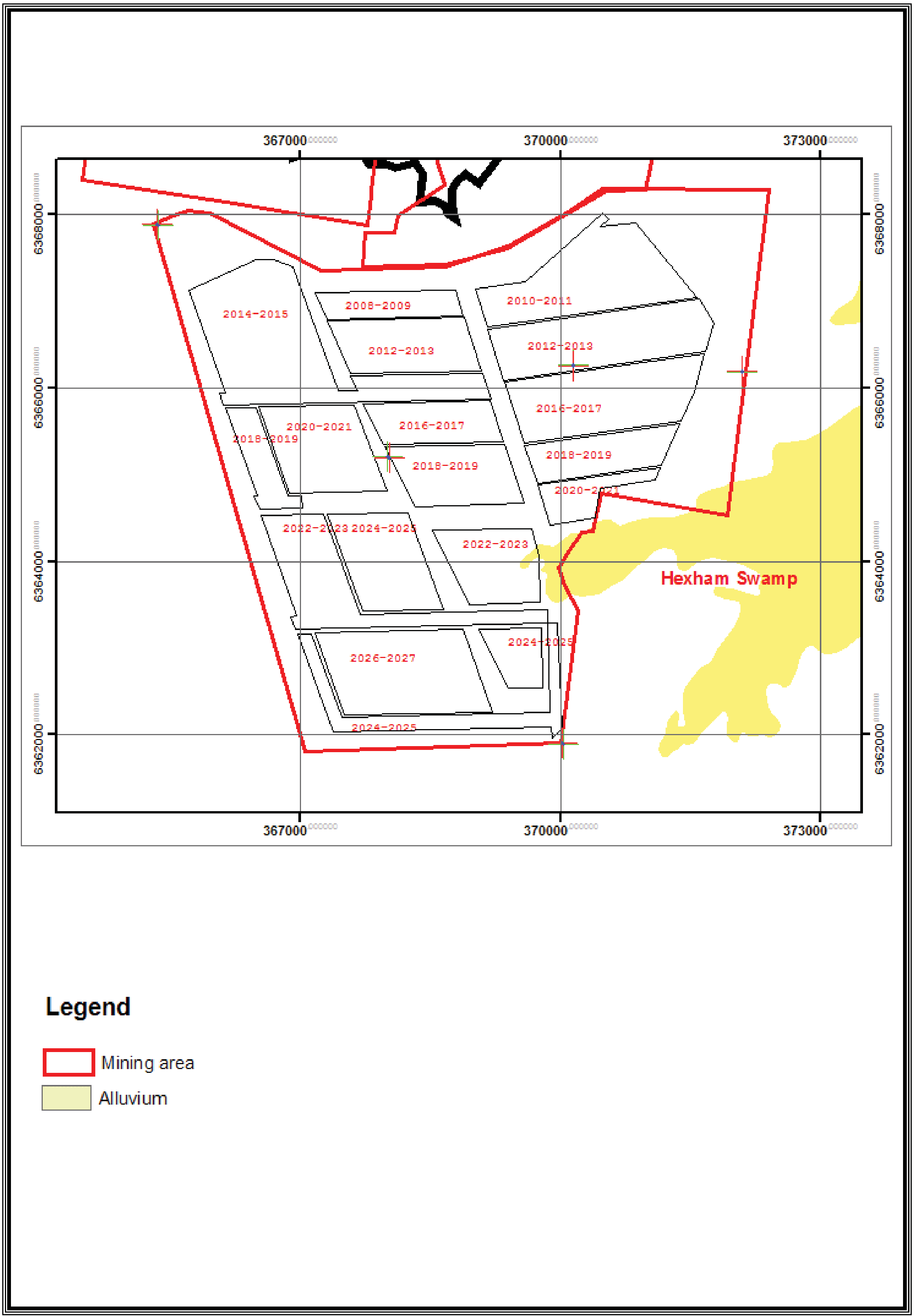


Figure 16 **Mine plan for the Abel mining lease area**

6.2 RESULTS OF PREDICTION MODEL AND RECOVERY MODEL RUNS

The results of the dewatering run are presented in form of piezometric head maps in Figure 17 and Figure 18 for the year 2027 (i.e. end of mining). A complete set of water table maps from 2008 onwards is presented in Appendix B. Selected hydrographs (C072, C080, C082, C081a, C081b, C062b, see Figure 11 for location) are shown in Figure 19, while the seepage rates in the mine workings over time are shown in Figure 20. The water balance over time for the entire dewatering model is summarised in Table 12 and shown in Figure 21.

Seepage into the mine works starts at 2008 and increases with the progressively enlarged underground mine area (Figure 20). By 2027, at the largest extent of the mine, a seepage rate of 3100 m^3/d is predicted to enter the mine workings. Accordingly, the cumulative seepage volume increases with time from zero to $11.6x10^3$ ML at 2027. This is accompanied by a drawdown in hydraulic heads in the coal layer of about 60 metres at the fringes of the mining lease, increasing to a maximum of about 120 metres in the centre of the area. Figure 18 shows the influence of the mining operations on the undisturbed interburden above the Donaldson seam (model layer 4). While a cone of depression is clearly present in year 2027, drawdowns in this formation are much less significant with a maximum decline in heads of about 30 metres (i.e. -10mAHD). Hydrograph C081b (Figure 19) demonstrates the impact of the underground mine on the water levels in the alluvium around Hexham Swamp in the East. There is an insignificant decline in predicted water levels for the swamp, which remains at about 10 cm at 2027.

Following on from the dewatering model, the recovery of the water table after mining ceases (i.e. after 2027) was simulated over a period of 60 years (Figure 22 and Figure 23). Hydrographs show the recovery of heads in the mining lease area with the sharpest adjustment recorded in the coal layer within the first few years after mining closure. Pressure heads above the Donaldson Coal recover to within 80% of the pre-mining level after 6 years of recovery. Undisturbed interburden water levels show a much slower recovery due to their low permeabilities and show an apparent incomplete recovery. This is caused by the introduction of “goaf” zone aquifer parameters at the beginning of the recovery model run. The 100 times higher aquifer permeabilities in the disturbed interburden material forces a reduction in heads. The same reason causes a temporary artificial reduction in water levels in the first 3 years in observation bores penetrating the interburden material.

The water balance flow volumes also show a return to pre-mining levels. Inflow over the model boundaries reduces by 80% in the first 6 years while outflow over the model boundaries increases and approaches pre-mining levels at the end of the recovery model run.

It should be noted that this is a predictive modelling exercise. Due to limited observation data in the Abel area, there is considerable uncertainty about the behaviour of the aquifer under stress induced through mining. Results are based on the best available data at present, however, they cannot be robustly verified at this stage and hence predicted seepage rates and drawdowns should be used with caution. When transient observation data becomes available on the decline of water levels at the start of the underground mining, model results should be compared to observed data and, if necessary, the model adjusted accordingly.

Due to the degree of uncertainty, sensitivity analysis was carried out on the dewatering model and this is reported in Section 6.3, to derive the “likely range” of seepage rates for the mine workings over time.

It is also pointed out that, during the dewatering simulation, the cone of depression caused by the mining activity encroaches on the model boundaries. This is not ideal, as models should preferably extend beyond the zone of influence of any aquifer stresses to avoid boundary interference effects. However, the model was properly restricted to the area of detailed geological information. To reduce boundary effects in the chosen model area, the model design involved general-head boundaries, which were implemented to allow inflow and outflow over the model boundaries in response to changes in piezometric heads. This approach is believed to be adequate given the lack of information on layer geometry and heads on a more regional scale and ensures that the current model boundaries minimise any effect on model results. Ellemby Resources have committed to future modelling studies, in which an enlarged model domain is envisaged, comprising all mining operations, i.e. Bloomfield, Donaldson, Abel and Tasman, which should address the current limitation on model boundary locations.

Table 12 Transient water balance

	Model Water Balance Inputs (m^3/d)					**Model Water Balance Outputs** (m^3/d)							
	Release from Storage	**River discharge to the aquifer**	**Flow across boundaries**	**Recharge**	**Total in**	**Replenishment of storage**	**River/creek/ swamp baseflow**	**ET**	**Flow across boundaries**	**Abel dewatering**	**Bloomfield/ Donaldson dewatering**	**Total out**	**% Errors**
31/12/08	71	16.4	18.7	1784	1890	18.0	1446	22.1	216	19.7	140	1862	0.01
31/12/09	61	16.4	18.7	1784	1880	12.6	1442	22.1	216	19.5	139	1851	0.01
31/12/10	165	16.4	19.6	1784	1985	43.8	1424	22.0	208	175	88.9	1961	0.01
31/12/11	153	16.4	19.7	1784	1972	37.1	1421	21.9	207	172	87.5	1946	0.01
30/12/12	395	16.4	48.0	1784	2243	67.9	1415	21.8	186	524	0.0	2216	0.01
30/12/13	364	16.4	50.4	1784	2215	59.4	1413	21.7	182	511	0.0	2187	0.01
30/12/14	729	16.4	90.2	1784	2620	32.1	1409	21.4	166	983	0.0	2611	0.00
30/12/15	687	16.5	94.8	1784	2582	27.1	1405	21.2	158	955	0.0	2567	0.00
29/12/16	1070	16.5	120	1784	2990	9.9	1401	20.7	135	1420	0.0	2987	0.00
29/12/17	1011	16.5	125	1784	2937	6.5	1398	20.4	125	1379	0.0	2928	0.00
29/12/18	1267	16.5	195	1784	3263	4.2	1394	19.8	95.1	1748	0.0	3261	0.00
28/12/19	1197	16.6	206	1784	3204	3.3	1391	19.4	84.6	1701	0.0	3199	0.00
27/12/20	1508	16.6	255	1784	3563	3.1	1388	18.7	53.9	2097	0.0	3561	0.00
27/12/21	1406	16.7	273	1784	3480	3.0	1384	18.2	40.4	2039	0.0	3485	0.00
27/12/22	1615	16.7	341	1784	3757	3.2	1380	17.5	18.3	2349	0.0	3768	0.00
27/12/23	1534	16.8	364	1784	3698	2.5	1376	16.8	14.6	2294	0.0	3704	0.00
26/12/24	1870	16.8	537	1784	4207	2.2	1372	16.0	10.7	2822	0.0	4222	0.00
26/12/25	1792	16.9	556	1784	4149	3.0	1368	15.2	8.8	2766	0.0	4160	0.00
26/12/26	2008	16.9	740	1784	4548	3.1	1363	14.2	7.0	3183	0.0	4571	0.00
26/12/27	1924	17.0	762	1784	4487	2.6	1360	13.4	5.9	3123	0.0	4504	0.00

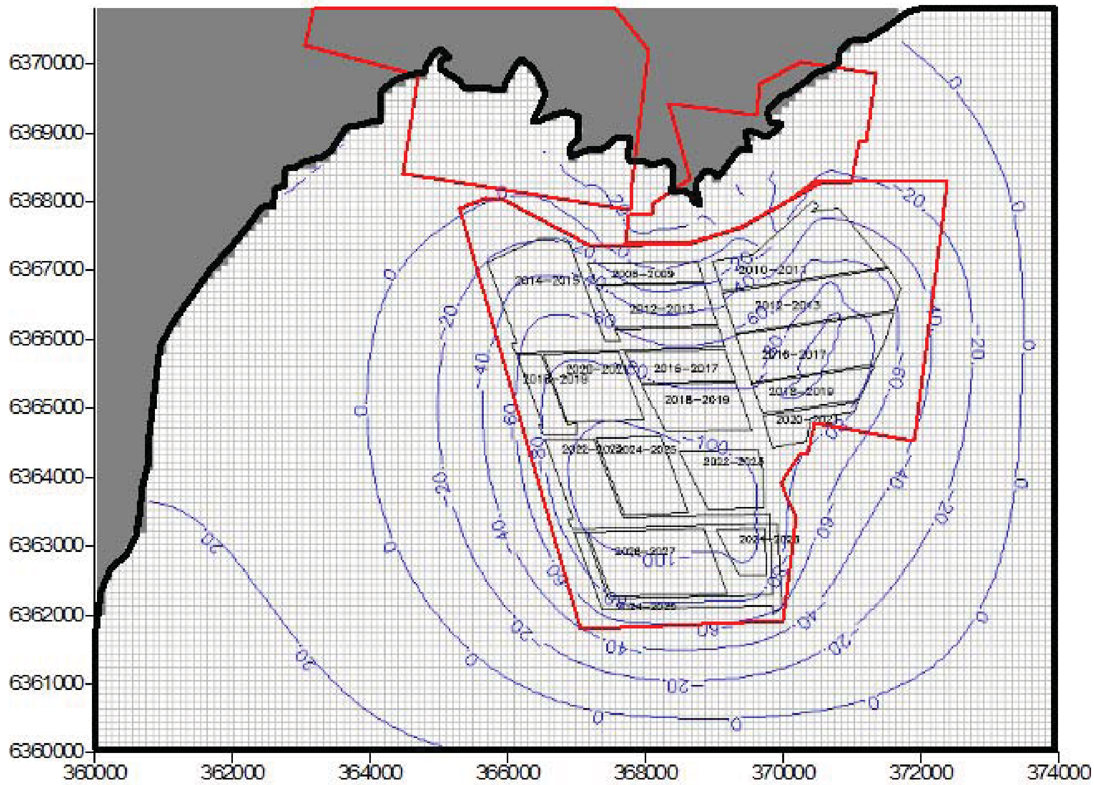


Figure 17 Predicted pressure heads (mAHD) above the Donaldson coal at 2027, the end of mining operations (Layer 6)

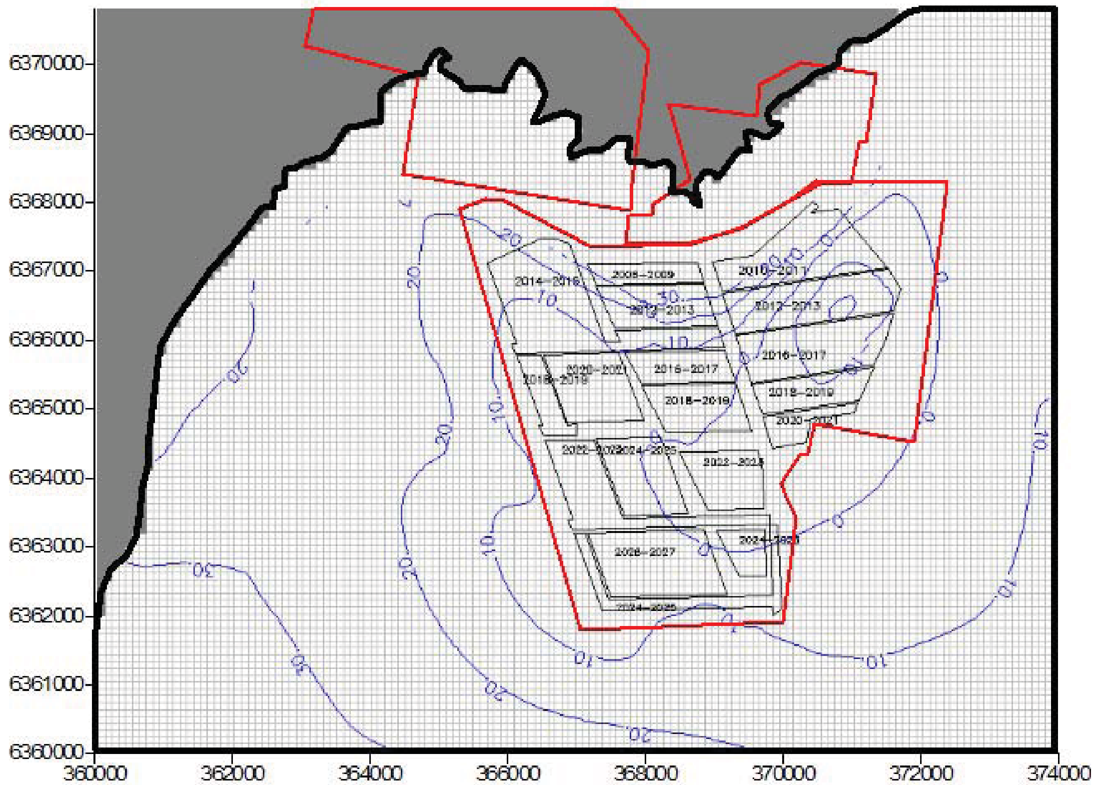


Figure 18 Predicted piezometric contours at 2027 (mAHD) in the undisturbed interburden (Layer 4)

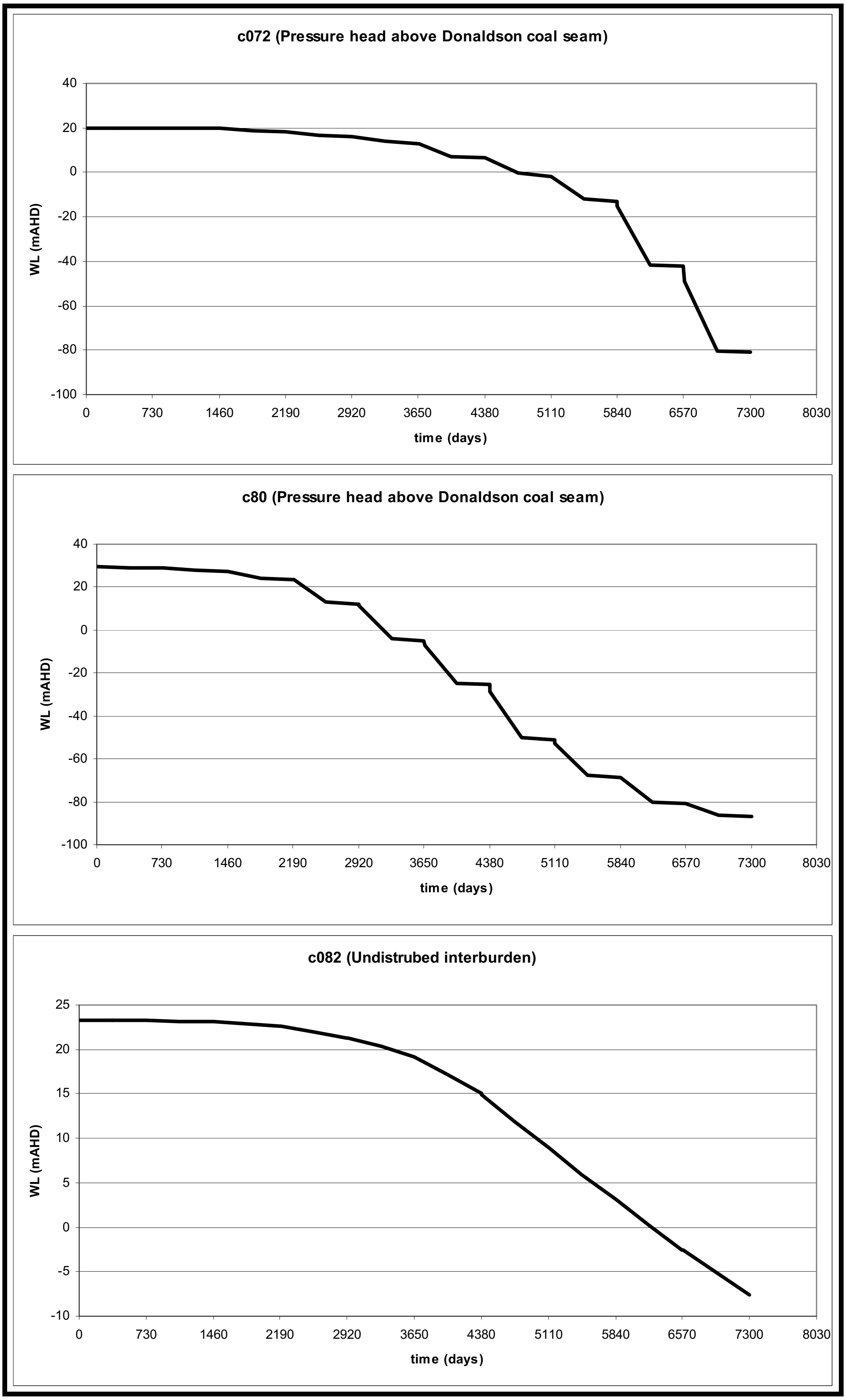


Figure 19 Selected hydrographs showing the decline in piezometric heads in the Abel mining lease area

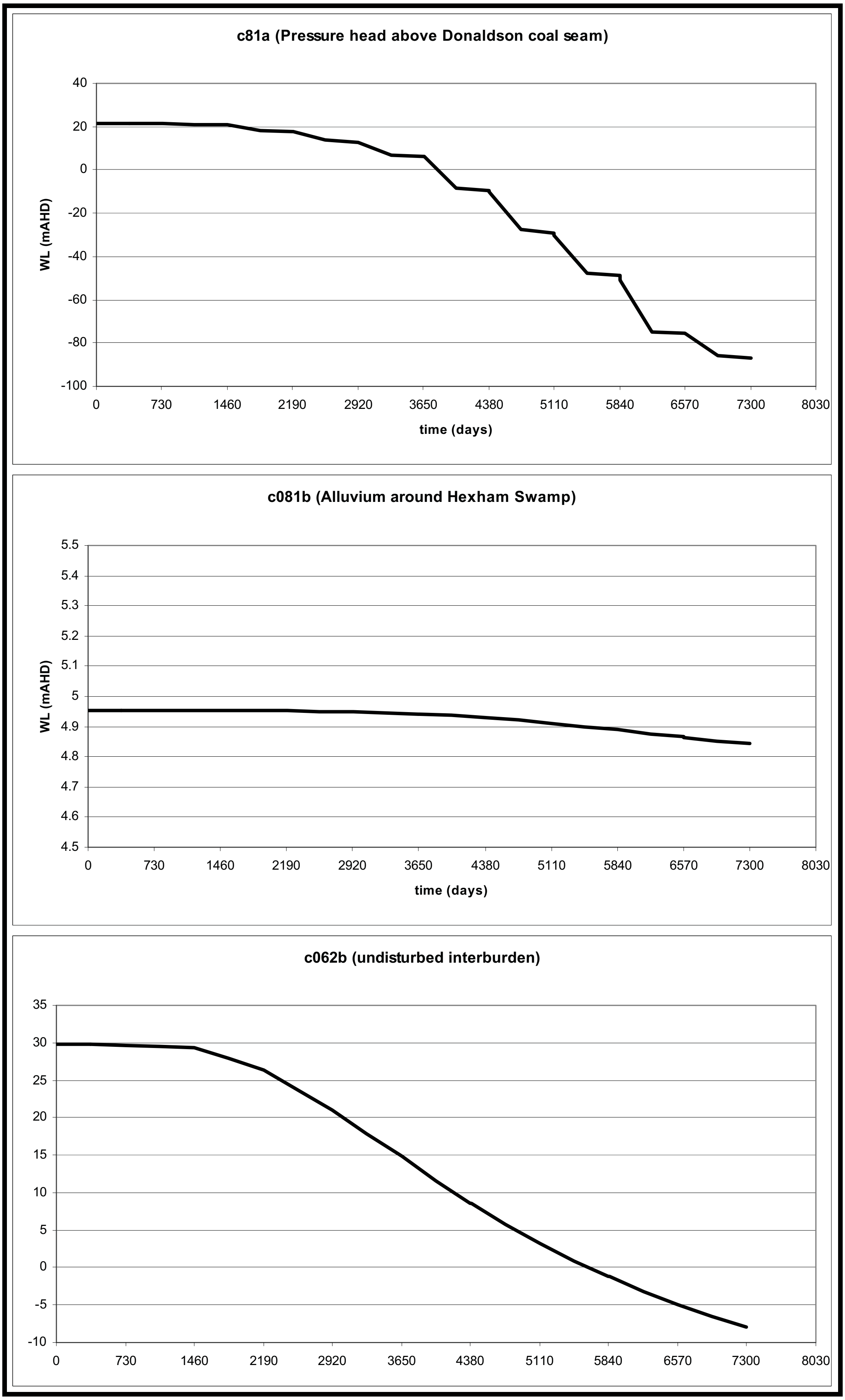


Figure 19 continued

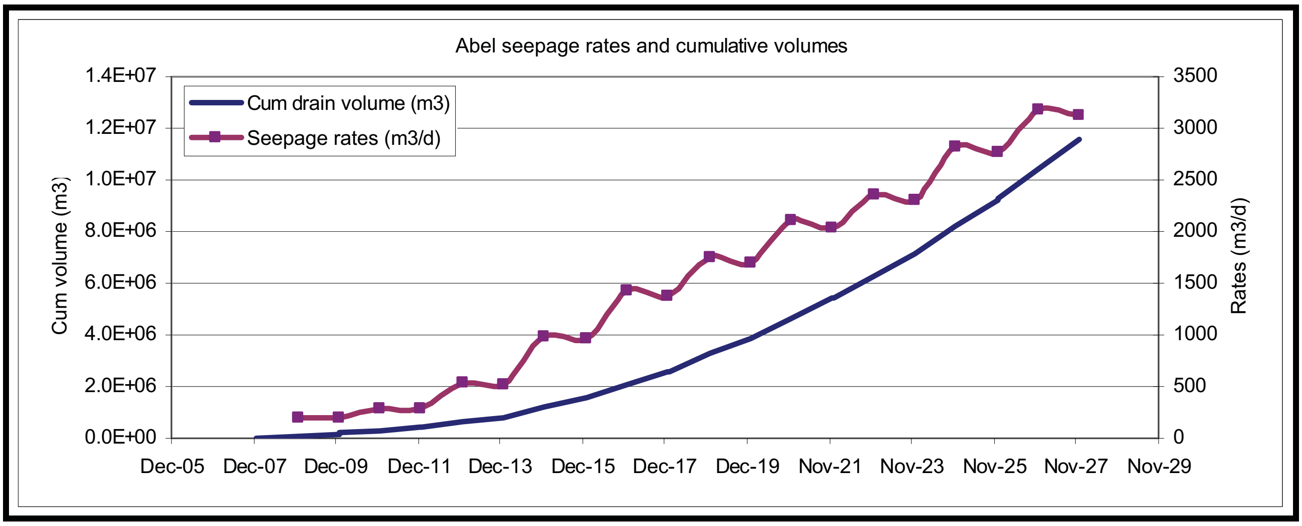


Figure 20 **Rates and cumulative seepage volumes into the Abel mine workings over time**

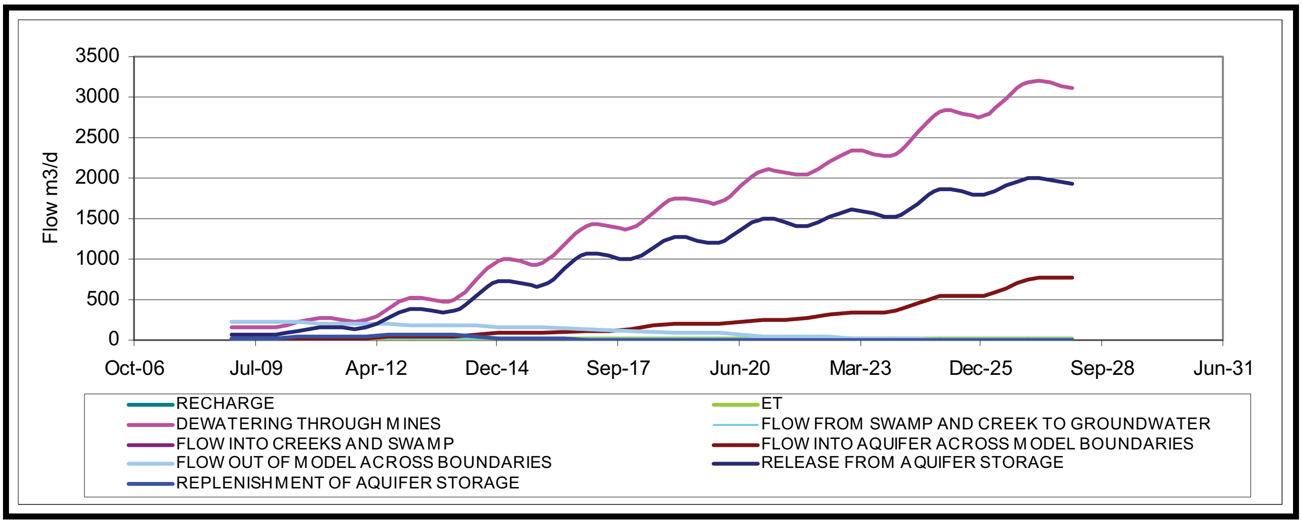


Figure 21 **Water balance of the dewatering model run over time**

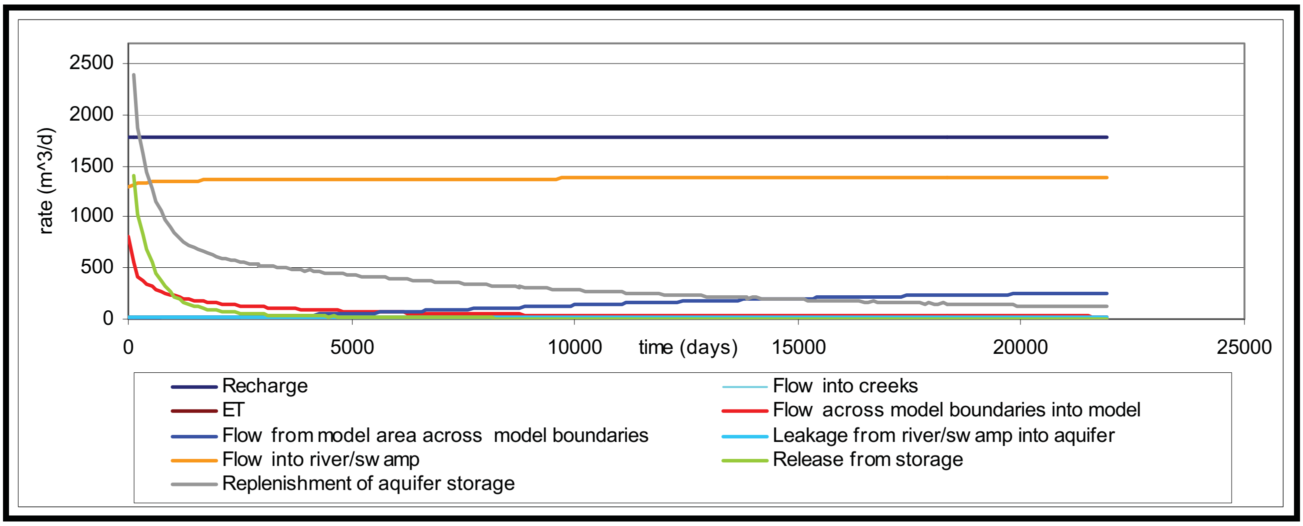


Figure 22 **Water balance of the recovery model run over time**

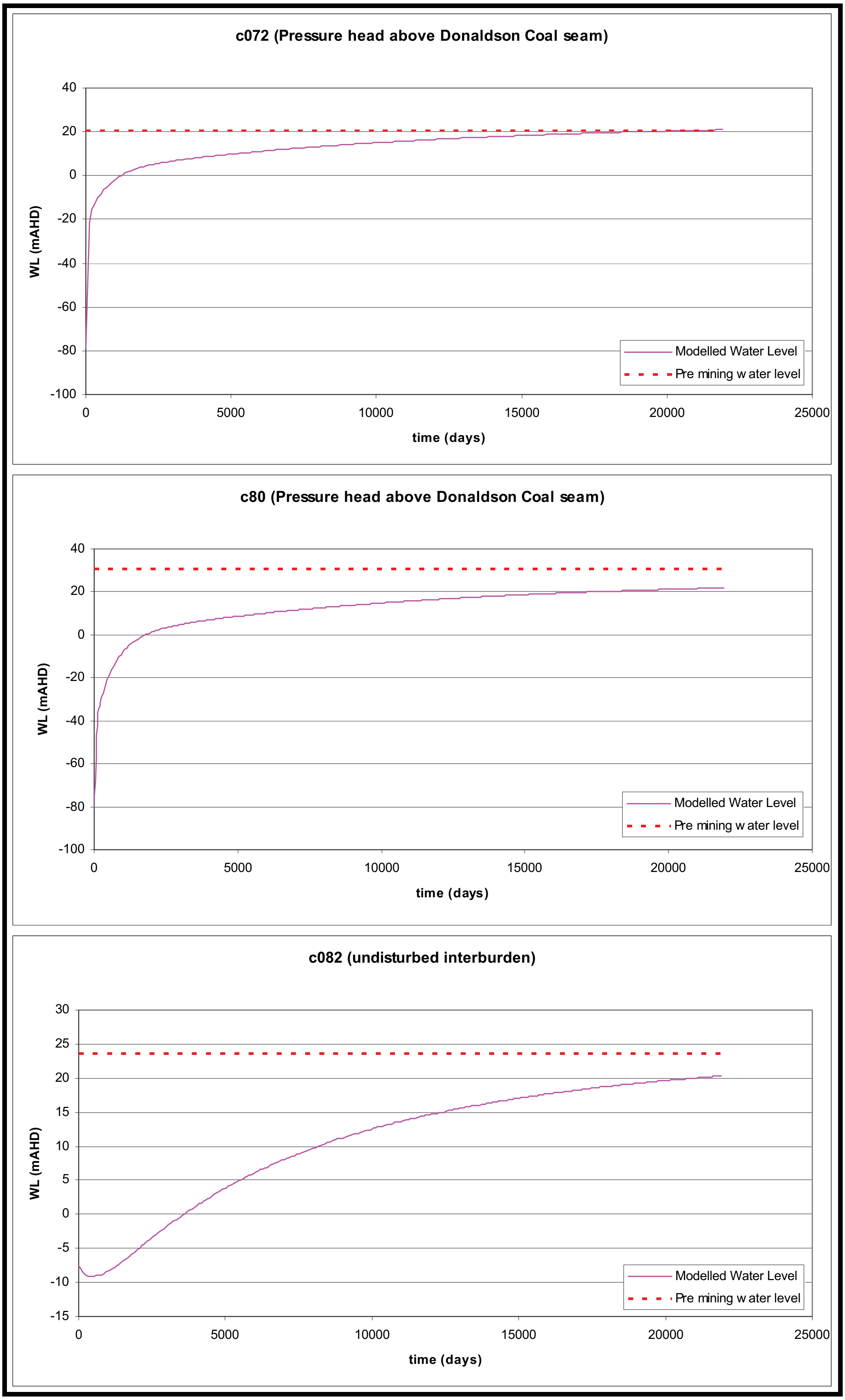


Figure 23 **Recovery of piezometric heads in the Abel mining lease area after mining**

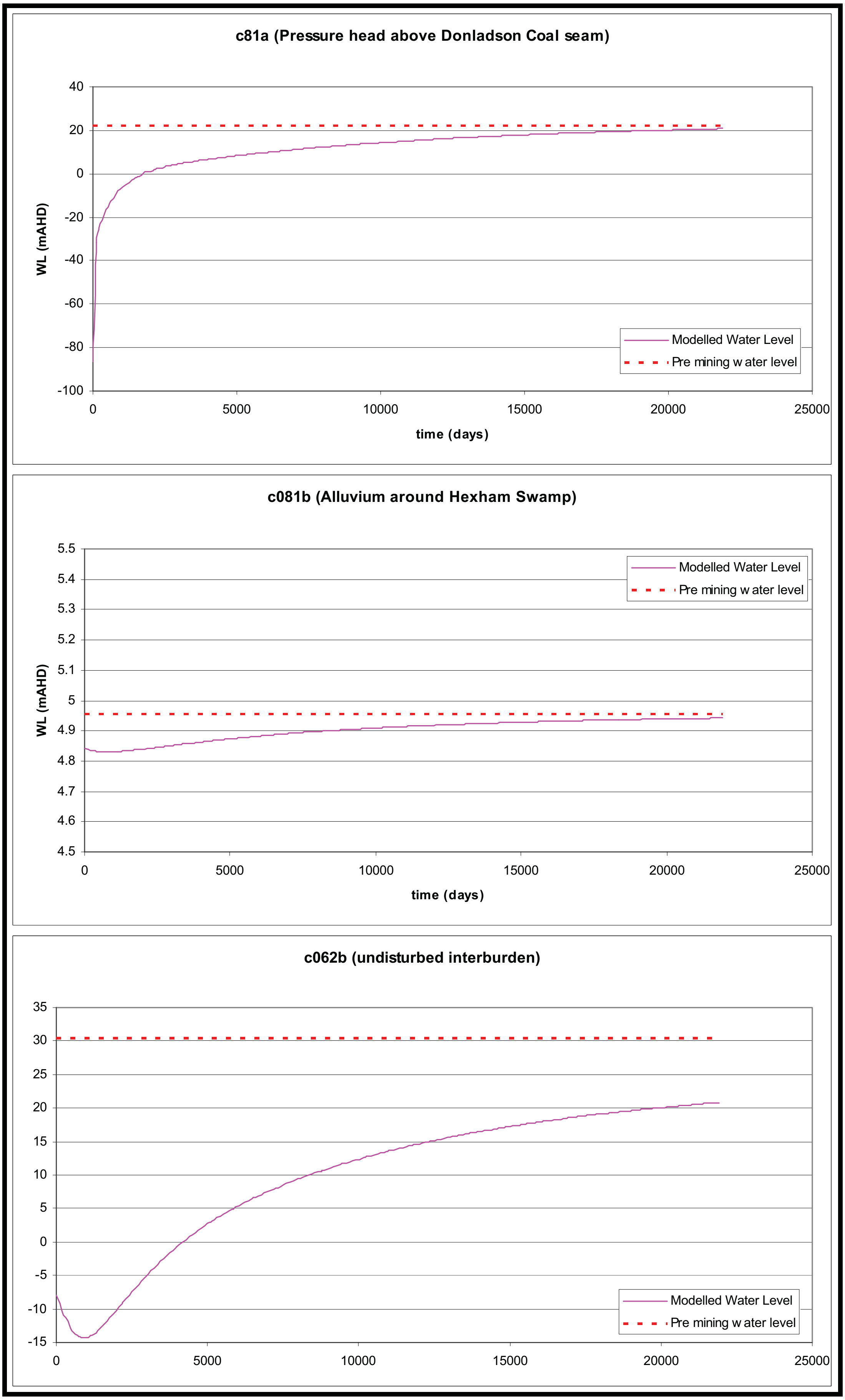


Figure 23 continued

After completion of the prediction model, a new mine plan was devised by Ellemby Resources. The new mine plan is almost identical to the old mine plan used in this modeling study, except for an extension of the mined area in the north-east corner of the Abel mining lease area by about 800 metres.

While the numerical model has not been re-run using the new mine plan, it is believed that the predicted drawdowns and seepage rates will not change significantly under the new mining proposal. Drawdowns will extend further towards the NE and also the simulated seepage rates will be slightly higher. The additional drawdown will be experienced mainly in the coal layer and the interburden above the coal. Overall, it is anticipated that the impact of the additional dewatering will be small with regards to drawdowns and seepage influx into the mine workings, due to the very limited additional mining area compared to the already simulated underground mine extent.

6.3 SENSITIVITY ANALYSIS

Due to the degree of uncertainty of the dewatering prediction results, sensitivity analysis was carried out on the dewatering model. This gives information on the uncertainty of the model results caused by uncertainty in the estimates of aquifer parameters and stresses, and leads to a “likely range” of seepage rates into the mine workings.

To a large degree, the critical model parameter that influences the seepage rate into the mine workings is the applied drain conductance. To establish its influence on model results, the drain conductance was systematically changed within a plausible range. Table 13 summarises the sensitivity runs undertaken and the parameters applied. The model was also run introducing the “goaf” zone parameters (i.e. higher vertical and horizontal permeability values) in the interburden above the Donaldson coal seam to establish the influence of enhanced permeability during mining. The results of these runs are demonstrated in Figure 24 and Figure 26.

Table 13 Summary of sensitivity runs

	Kh/Kv	S/Sy	Drain conductance (m^2/d)
Dewatering model	As per steady state model	See Table 7	Drain conductance: actively mined: $0.01 m^2/d$, mined-out area: $0.05 m^2/d$
Sensitivity Run 1	Parameters of dewatering model	Parameters of dewatering model	Drain conductances ÷ 2 (i.e. 0.005/0.025)
Sensitivity Run 2	Parameters of dewatering model	Parameters of dewatering model	Drain conductances x 2 (i.e. 0.02/0.1)
Sensitivity Run 3	Parameters of dewatering model	Parameters of dewatering model	Drain conductances ÷ 5 (i.e. 0.002/0.01)
Sensitivity Run 4	Kh/Kv x 100	Parameters of dewatering model	Parameters of dewatering model
Sensitivity Run 5	Parameters of dewatering model	Parameters of dewatering model	Drain conductances x 5 (i.e. 0.05/0.25)

The sensitivity analysis shows that predicted seepage rates into the mine workings increase with higher drain conductances, as the resistance to flow between interburden and mine workings is reduced. For the applied range of parameters, seepage rates are calculated to be in the order of 1500 m^3/d to 4500 m^3/d. For the highest drain conductance applied, the accompanying maximum reduction in piezometric heads is about 170 metres, which is regarded as the upper limit of likely drawdowns, based on experience in other areas of underground mine workings. Also, Figure 25 shows a “saturation effect” whereby the increase in mine seepage rates due to an increase in drain conductance tapers off for higher multipliers, supporting a likely upper limit of about 4.5 ML/d. This is consistent with the results obtained using the Goodman equation, which delivered a "worst-case" seepage rate of about 9.6ML/day for full drainage of the overlying rock.

Using disturbed aquifer properties during the prediction run (i.e. vertical and horizontal hydraulic conductances increased by two orders of magnitude) results in higher leakage rates and demonstrates the strong dependence of seepage volumes on the geological structure present. However, the increase in the goaf zone parameters results in an increase in the final mine seepage rate of only 14%, also supporting a likely upper limit of seepage rates of about 4.5 ML/d.

In conclusion, the sensitivity analysis established a likely range of seepage rates to be expected in the Abel mining lease area, which is between 1500 m^3/d and 4500 m^3/d. Based on experience of drawdowns observed in other underground mining operations, drawdowns of 100 to 150 metres are plausible, which narrows the most likely rate of seepage to around 3100 m^3/d or 3.1 ML/day, based on the assumed aquifer properties.

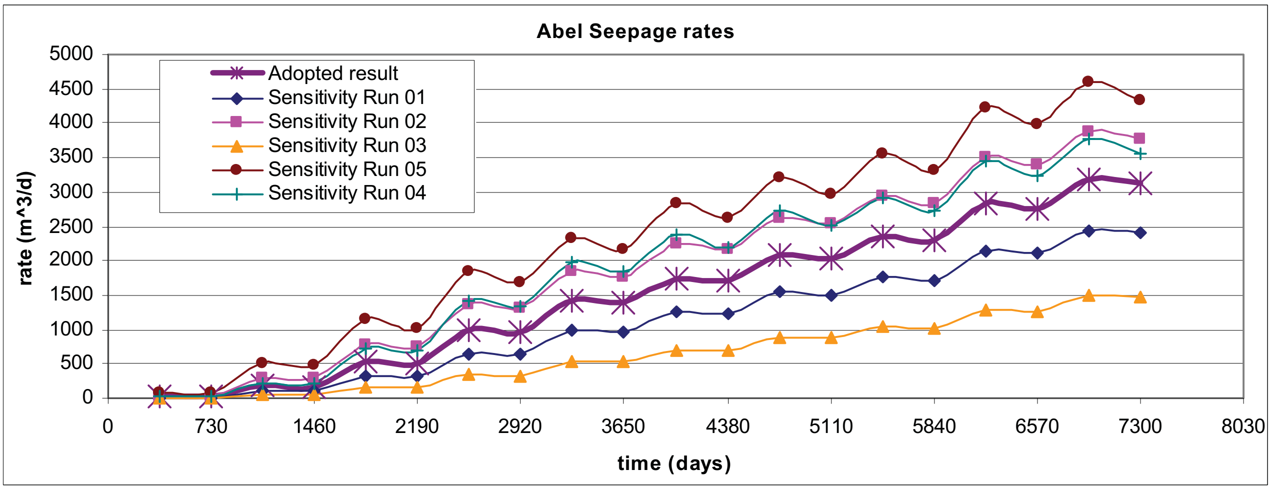


Figure 24 Seepage rates into the Abel under ground mine over time for various model sensitivity runs

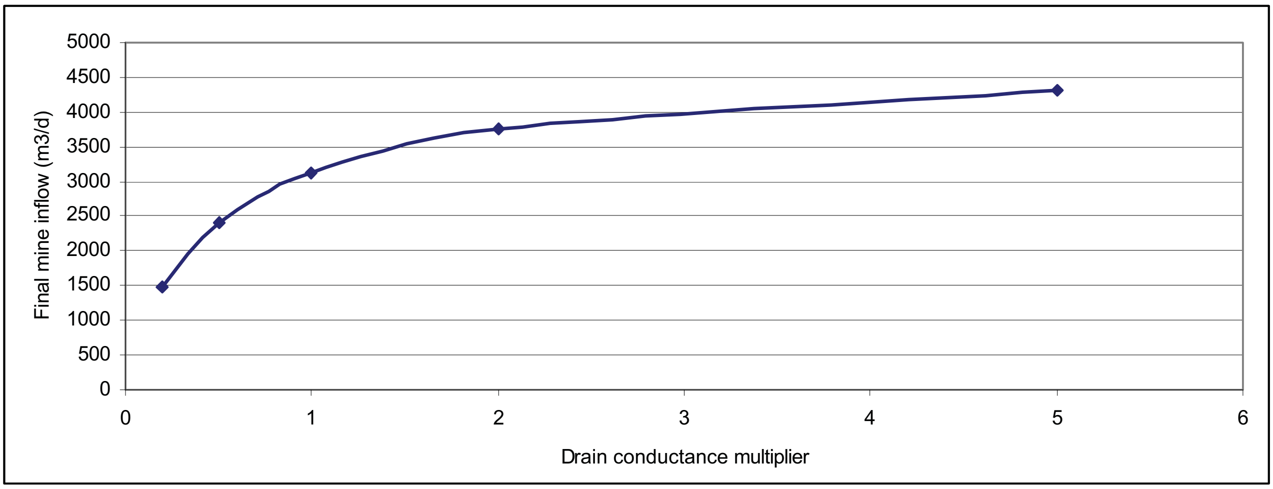


Figure 25 Sensitivity of final mine inflows to varying mine drain conductance

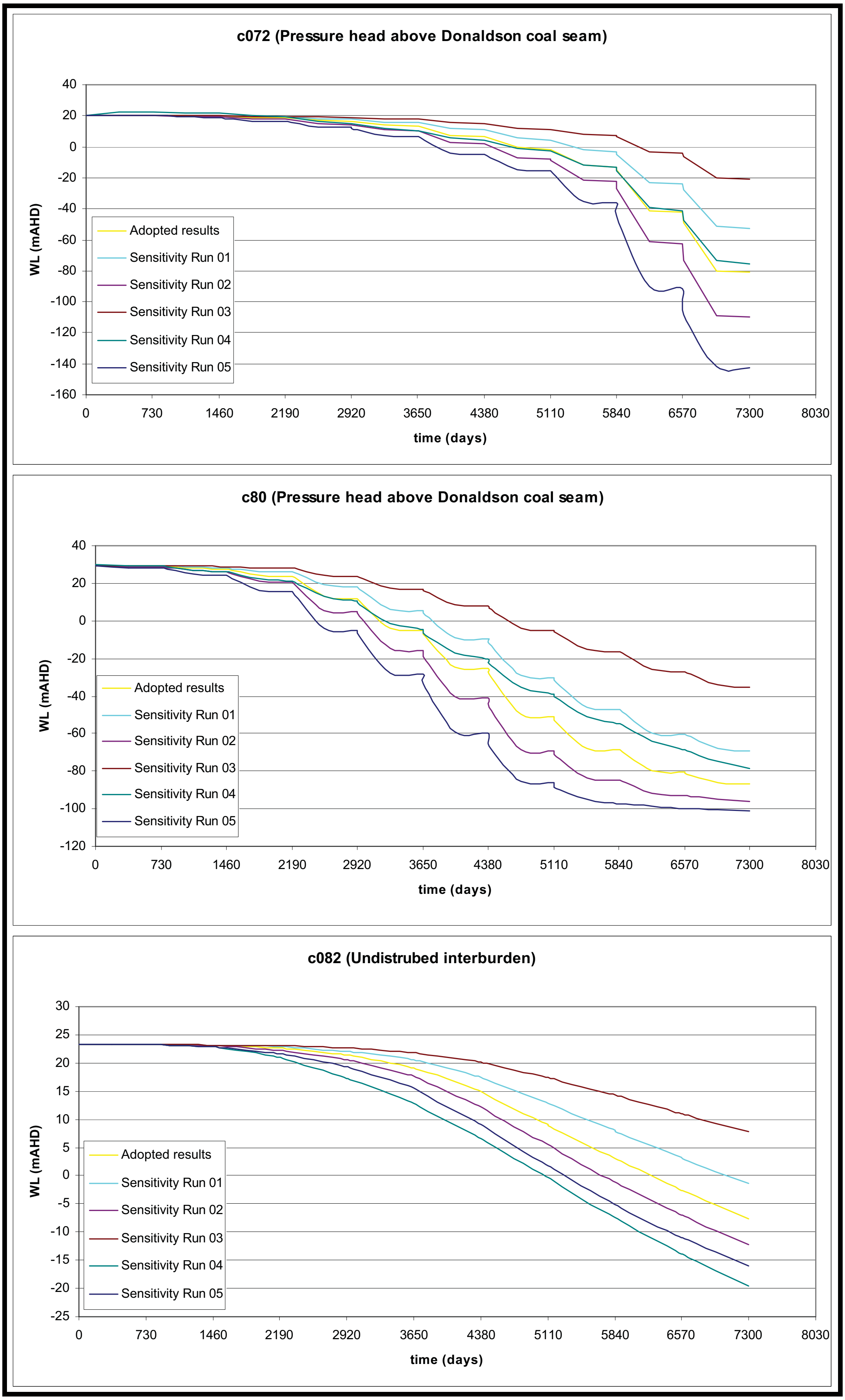


Figure 26 Selected hydrographs showing the decline in water levels over time during mining operations

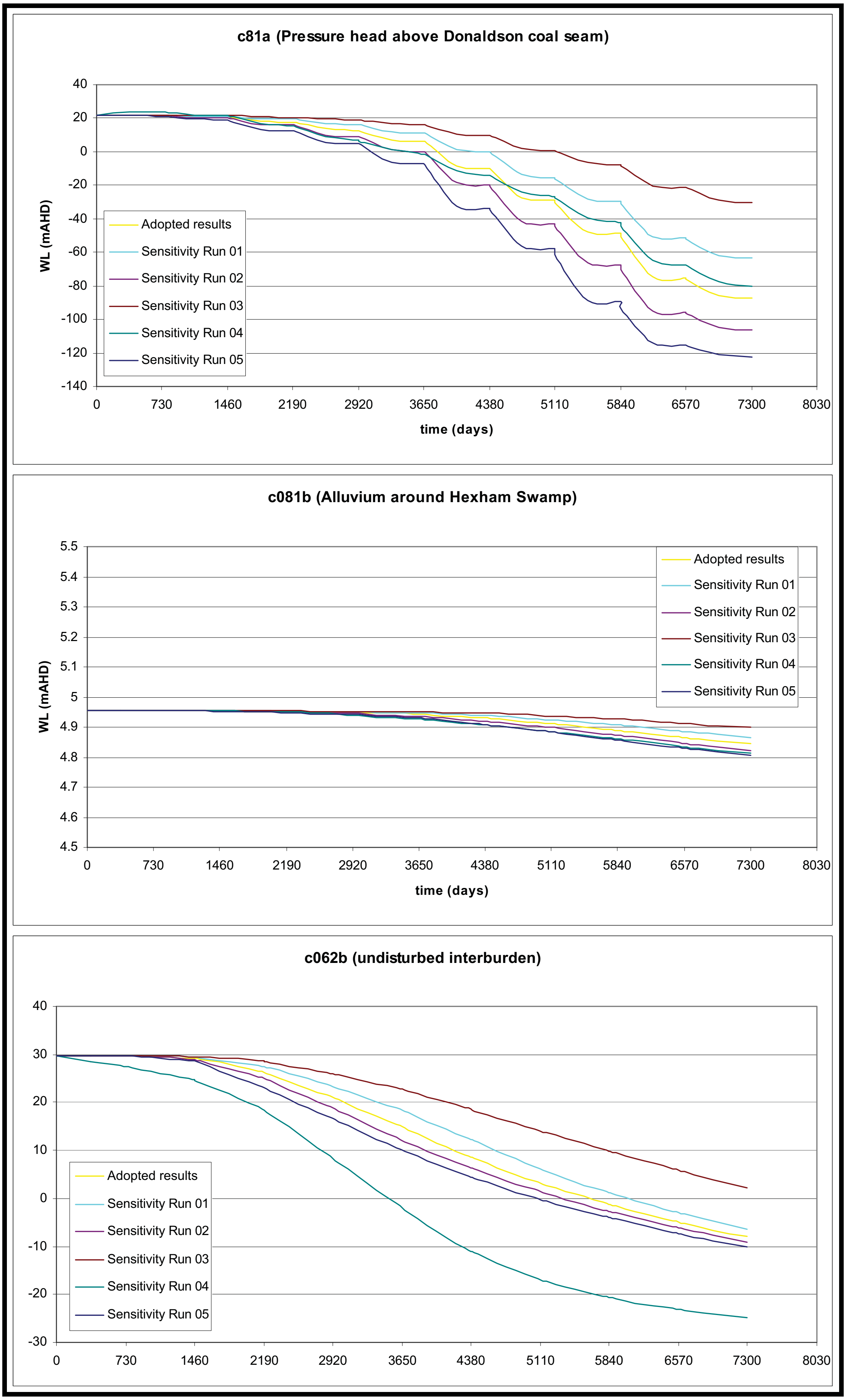


Figure 26 continued

SECTION 7 MODEL LIMITATIONS

Due to uncertainties in model input parameters, certain limitations of the numerical model apply, which need to be taken into consideration. These are summarised below:

- The model layer set-up is based on available bore log data, supplied by Ellemby Resources. The layer information extends to about 372000 Easting. The model however extends another 2 km to the east and some inaccuracies in layer elevations might occur in this area as elevation data has been extrapolated out.
- Little data was available on surface water flows in the area and all creeks except for Wallis Creek have been implemented as drain features, i.e. the creeks are assumed to be influent. Wallis Creek and the Pambalong/Hexham Swamp area have been implemented through a river feature with stage levels being kept constant. Once more data becomes available, representation of surface features in the model could become more detailed.
- Recharge and ET are being kept constant at median yearly rates and seasonal or climatic variability is not included in the model. If required, this feature could be added to the model in future. There is uncertainty about actual recharge rates to the interburden material and coal, where they occur at outcrop and to the alluvial deposits in the study area. Recharge values have been changed within a plausible range to obtain a calibrated model, but values cannot be verified. The maximum possible rate of evaporation in the model is 250mm/yr, acting in areas of shallow (<5m) water levels. This is a best estimate, but could be improved with some site-specific data on vegetation type and/or water use characteristics.
- There is a high level of uncertainty with respect to the distribution of hydraulic conductivity in the subsurface in the vertical as well as horizontal direction. Conductivities do not change with depth to reflect progressive burial of coal and interburden. If more data becomes available in future through pump test analysis and/or water level measurements, the model should be adjusted if necessary.
- The steady state model was calibrated on the basis of 17 water level observation points, located mainly in the Donaldson and Abel mining lease area. There is little data available on water levels in the east of the model area, including along model boundaries and the calibration should be revisited once more data becomes available.
- 6 model layers allow the simulation of vertical head gradients in the model area. Heads are averaged over one model layer and the resolution of heads with depth cannot be as detailed as observed in the field using the current model configuration. Further model refinement is possible in future, including layer refinement, which should be based on improvements in hydrogeological understanding and ongoing monitoring and assessment.
- At present there is insufficient data for a transient model calibration in the Abel area. Transient model calibration is desirable for model verification, especially as the model is currently run in predictive mode without verification. At this stage, model predictions are best estimates and have a degree of uncertainty as the sensitivity model runs demonstrate. If transient data on water levels becomes available in future, model results should be compared to actual dewatering rates and head declines and the model adjusted if necessary.

- During the dewatering simulation the simulated cone of depression caused by the mining activity encroaches on the model boundaries. This is not ideal, as models should preferably extend beyond the zone of influence of any aquifer stresses to avoid boundary interference effects. However, the model was properly restricted to the area of detailed geological information. To reduce boundary effects in the chosen model area, general-head boundaries were specified to allow inflow and outflow over the model boundaries in response to changes in piezometric heads. Possible future model upgrades should ideally include an enlarged model area and revisions to model boundaries.
- Due to very limited data on historical pumping volumes and locations at the Bloomfield and Donaldson mining operations, these have been included in the model in a simplistic way, using drain features to simulate the approximate depression in heads in these areas.
- Uncertainties exist on the “resistance to flow” between the interburden and the underground mine void, simulated in the model using a drain conductance. The uncertainty has been addressed by running sensitivity model runs, varying the conductance to establish the effect on model results. It is expected that the conductance increases with mining as the rock mass gets disturbed, however the increase in permeability is a best-guess at this stage.

In conclusion, the model results can be regarded as a current best estimate based on the available data. Due to the uncertainties listed above, the predicted seepage rates and drawdowns should be regarded as indicative, order-of-magnitude estimates.

SECTION 8 CONCLUSIONS

The Abel Coal groundwater model was used to predict the potential impacts of the underground mining on groundwater levels in the Abel mining lease area and surrounds and on surface water resources including Pambalong Nature Reserve and Hexham Swamp; and to assess the potential inflow into the mine workings during operation. The following conclusions can be drawn:

- In the study area, groundwater occurs mainly within the coal seams, and within the alluvium and the upper weathered Permian. Groundwater levels show strong variation with depth. Within the Upper and Lower Donaldson Seam, a consistent pattern of pressure heads are observed that is independent of local topography. Heads vary between about 20 mAHD in the south-east, rising to about 30 mAHD in the north-west. The interburden above the Donaldson seams exhibits a similar broadly consistent water level pattern but with generally higher water levels, reflecting the low permeable properties of the unit.

- Water levels reported in alluvium and the colluvium/weathered Permian are more variable, and are closely related to the local topographic elevations. Thus the surficial groundwater levels are higher than the coal measures in elevated areas, and lower than the coal measures in low-lying locations. The head differences also indicate that the hydraulic connectivity between the alluvium/weathered overburden and the coal measures is likely to be limited and the shallow aquifer is possibly immune from direct impacts due to mining.

- The hydrogeological and geological system was implemented into a 6 layer MODFLOW model and calibrated in steady-state mode. The calibrated model has a scaled RMS error of 6.07% and simulated water levels fit the observed pattern well. The model simulates a vertical hydraulic gradient from higher to lower model layers within the coal and interburden layers, with lowest water levels being measured in the Donaldson coal seam, consistent with field observations.

- The modelled groundwater discharge into Donaldson mine was used as another calibration measure for the steady-state model and amounts to about 70 m^3/d, which is slightly lower, but comparable to the (roughly) estimated discharge volumes from Donaldson mine at 2002 of 160 m^3/d.

- Simulated water levels in the Pambalong Nature Reserve area compare well with observed values and suggest a perched water table with very limited hydraulic connectivity to the layers below. The simulated water table in the swamp is sensitive to the underlying vertical hydraulic conductivity.

- Having achieved acceptable steady-state model calibration, a transient dewatering model was set-up to simulate dewatering due to mining from 2008 to 2027. At 2027, a post mining recovery model run was set up to simulate the recovery of the water levels after mining operations have ceased.

- The dewatering model simulates the seepage flux into the mine workings over time. By 2027, at the largest extent of the mine, a seepage rate of 3100 m^3/d is predicted to enter the mine workings. Accordingly, the cumulative seepage volume increases with time from zero to about 12000 ML at 2027. This is accompanied by a drawdown in hydraulic heads in the coal layer of about 60 metres at the fringes of the mining lease, increasing to a maximum of about 120 metres in the centre of the area.

- The predicted drawdown is much less significant in the interburden above the coal seams and a maximum decline in heads in this undisturbed formation of about 30 metres is simulated.
- Pambalong Nature Reserve exhibits an insignificant decline in predicted water levels, which reaches a maximum of about 10 cm at 2027.
- Sensitivity analysis was carried out on the dewatering model to establish the impact of model parameter uncertainties on predicted seepage rates. Six sensitivity runs established a likely range of seepage rates to be expected in the Abel mining lease area, which is between 1500 m^3/d and 4500 m^3/d.
- The model is based on the most up to date data. However, various uncertainties in input parameters result in certain model limitations, which are outlined in detail in the report. The most important limitation to date is the lack of time-series data, i.e. the model is not able to be calibrated in transient mode and the reaction of the aquifer to large stresses is unknown at this time.
- The model results can be regarded as a best estimate based on the currently available data. Predicted seepage rates and drawdowns should be regarded as indicative, order-of-magnitude estimates.

SECTION 9 REFERENCES

Bureau of Meteorology (2001). Climatic Atlas of Australia.

DNR (April 2005). Guidelines for Management of Stream/Aquifer Systems in Coal Mining Developments – Hunter Region.

ESI (2000-2004). *Groundwater Vistas*. Version 4 User's Manual. URL: www.groundwatermodels.com

IES (2006). *Processing MODFLOW Pro* Version 7.0.15 User's Manual. URL: http://www.iesinet.com/products/desktop_pmwin.php

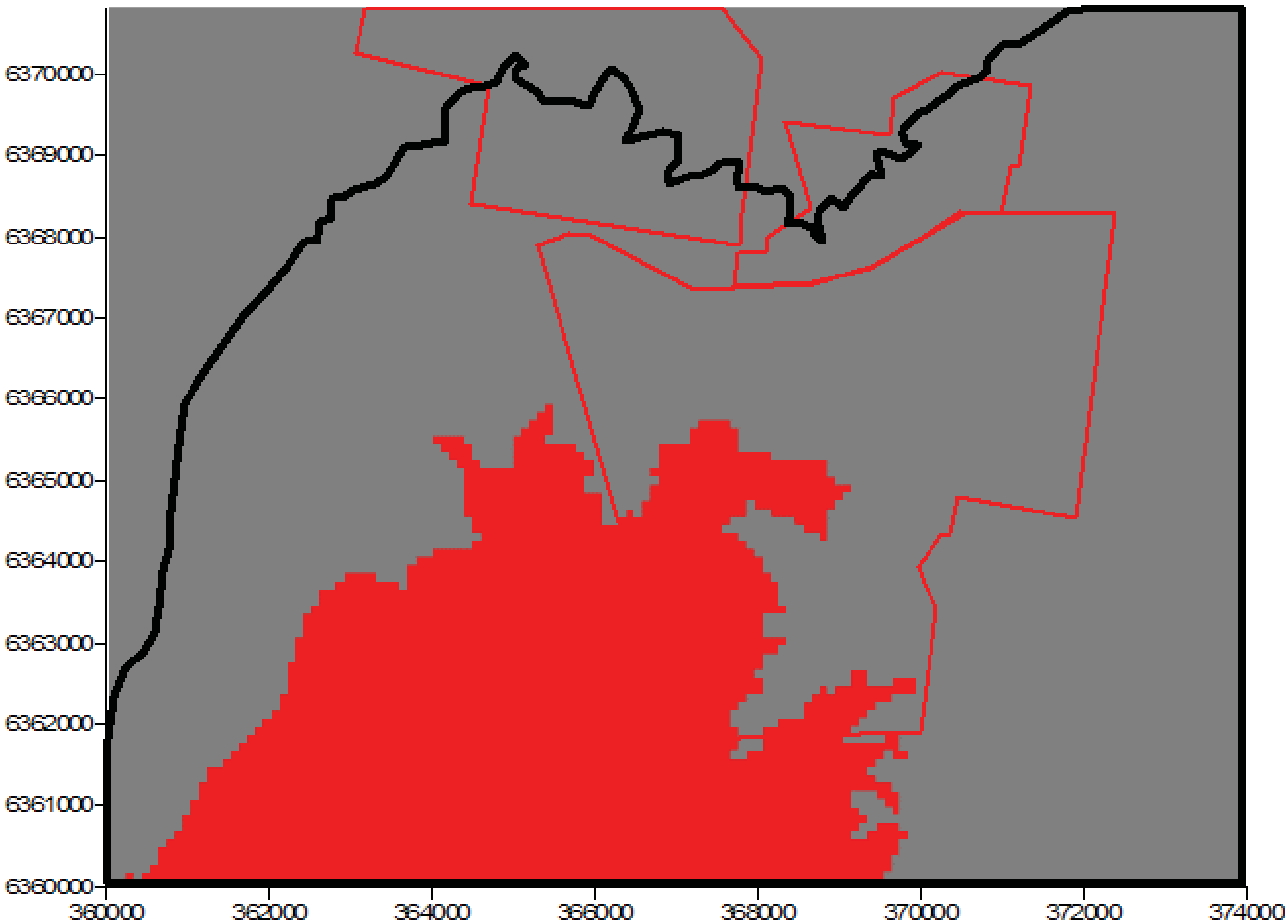
MDBC (2001). Groundwater flow modelling guideline. Murray-Darling Basin Commission. URL: www.mdbc.gov.au/nrm/water_management/groundwater/groundwater_guides

Goodman et al (1965) Groundwater inflows during tunnel driving. Eng. Geol 2. pp. 39-56.

APPENDIX A

MODEL INPUT DATA

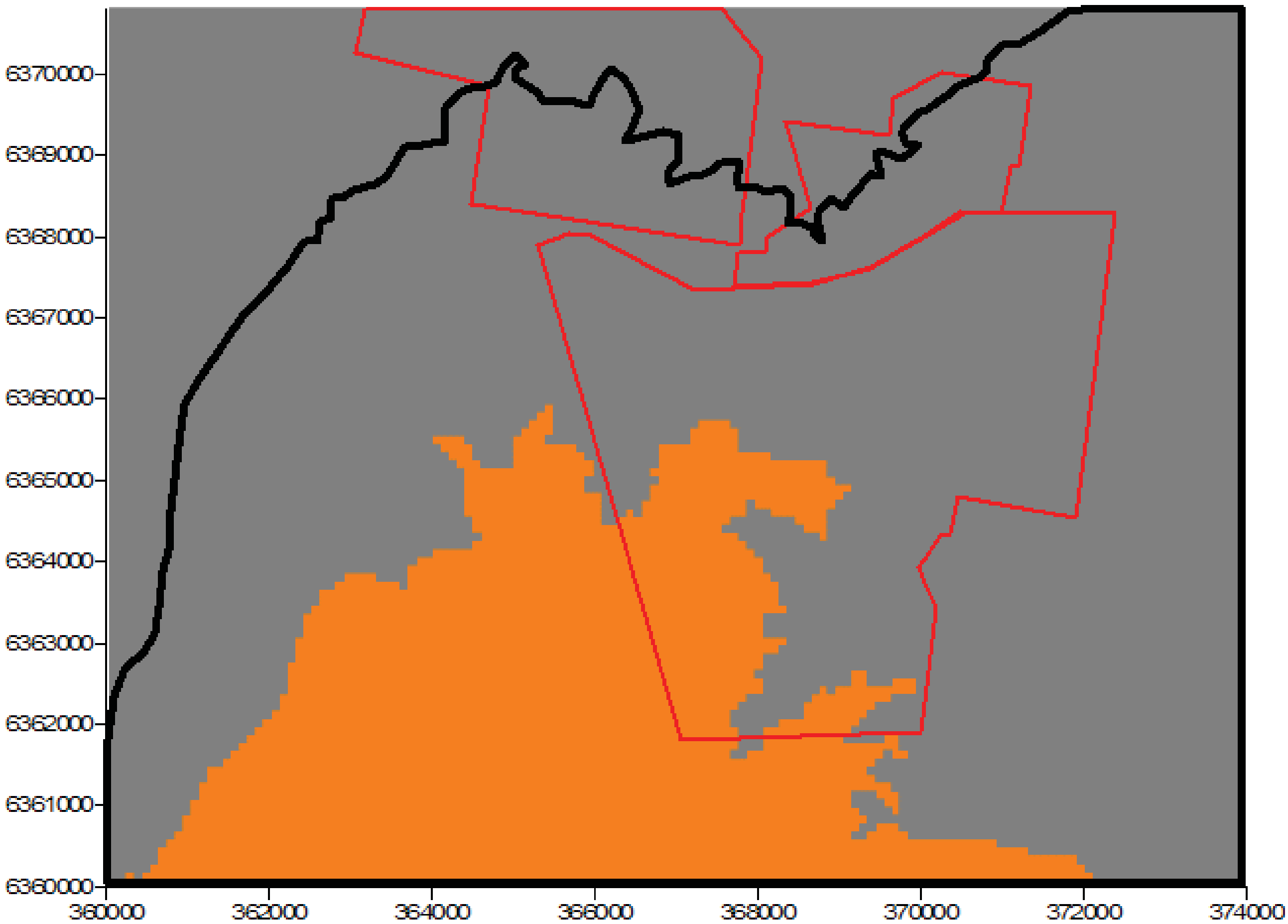
HYDRAULIC CONDUCTIVITY – L1



	Geological unit	Kh [m/d]	Kv [m/d]	S	Sy
Layer 1	Interburden above WB seam (undisturbed)	0.001	0.0001	0.00001	0.005

GREY COLOUR = INACTIVE

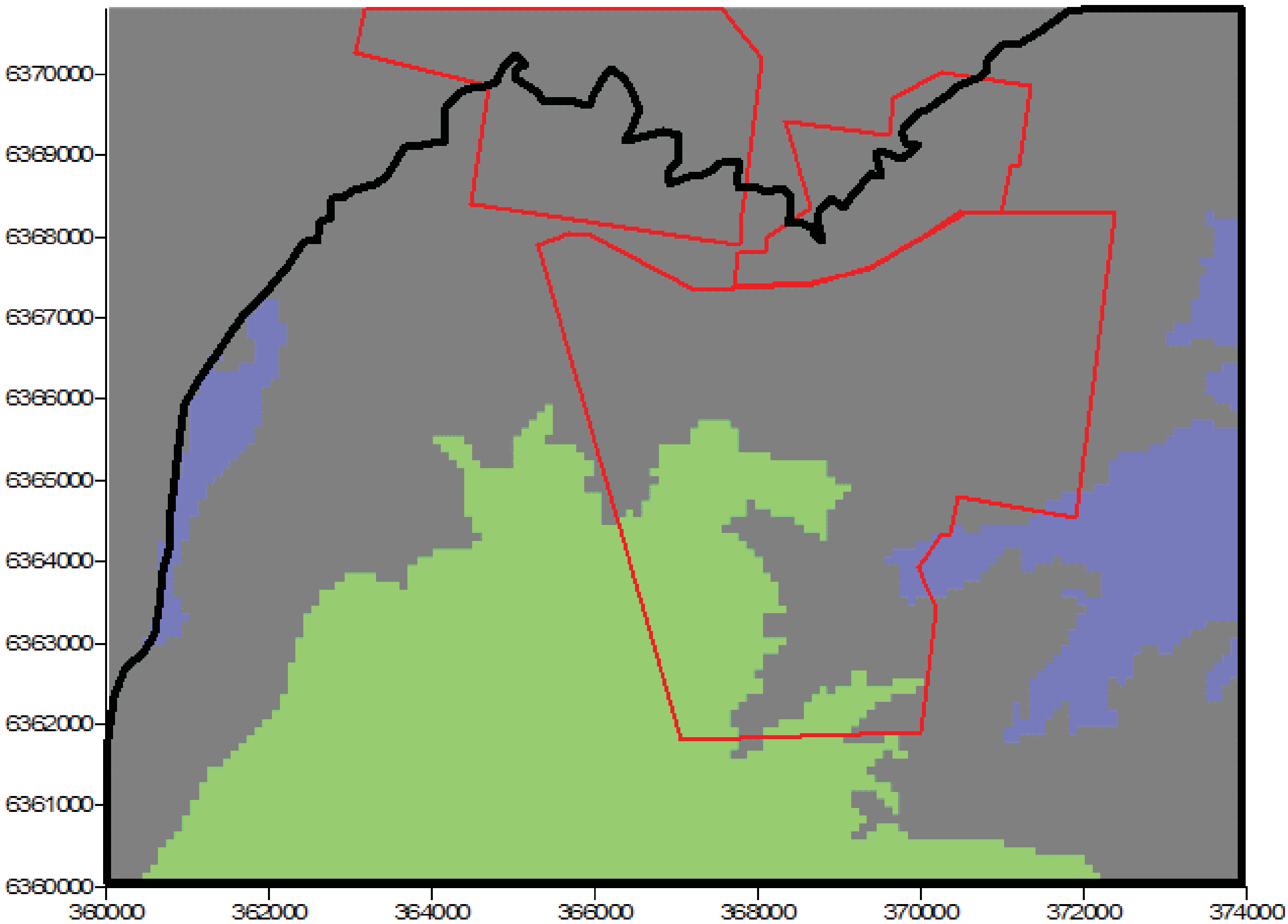
HYDRAULIC CONDUCTIVITY – L2



	Geological unit	Kh [m/d]	Kv [m/d]	S	Ss
Layer 2	Interburden above WB seam (undisturbed)	0.001	0.0001	0.00001	0.005

GREY COLOUR = INACTIVE

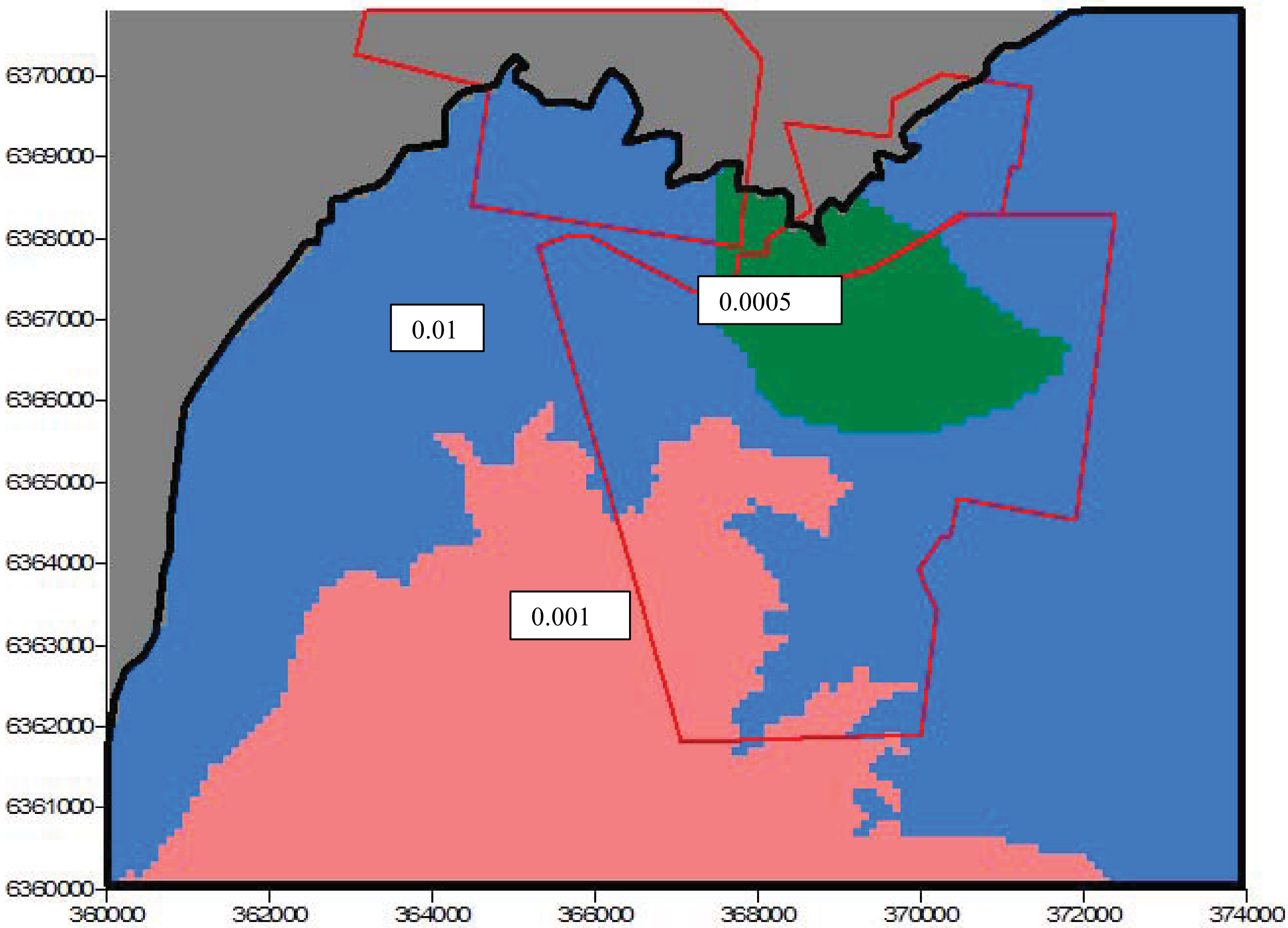
HYDRAULIC CONDUCTIVITY – L3



	Geological unit	Kh [m/d]	Kv [m/d]	S	Ss
Layer 3	WB seam/Alluvium	0.15 Alluvium = 6.0	0.001 Alluvium= 0.0005	0.0001	0.01 Alluvium = 0.1

GREY COLOUR = INACTIVE

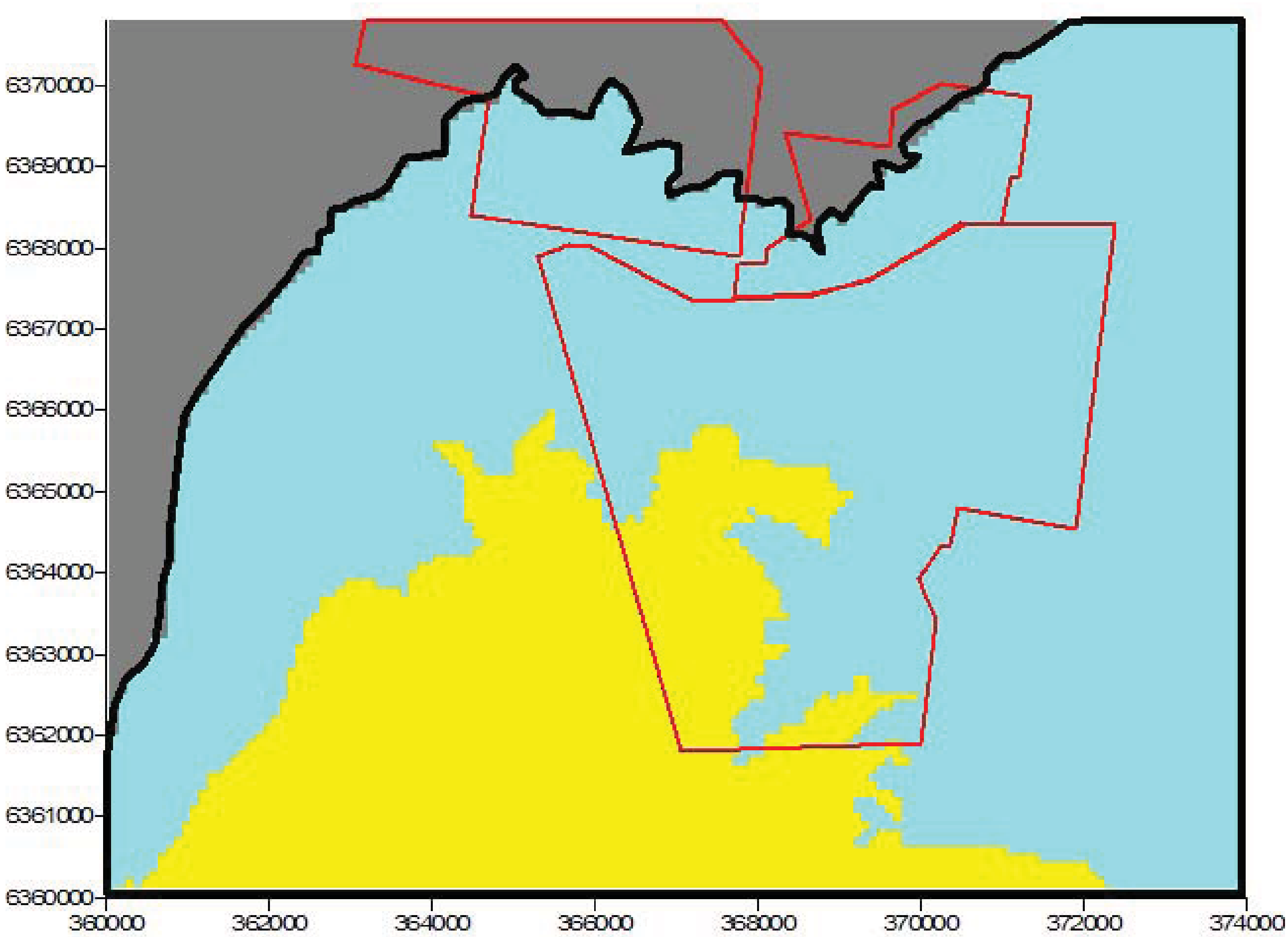
HYDRAULIC CONDUCTIVITY – L4



	Geological unit	Kh [m/d]	Kv [m/d]	S	Ss
Layer 4	Interburden above LD/UD seam (undisturbed)	Under confinement: 0.001 At outcrop/Under Alluvium: 0.0005 - 0.01	0.0001 under swamp: 0.00001	0.00001	0.005

GREY COLOUR = INACTIVE

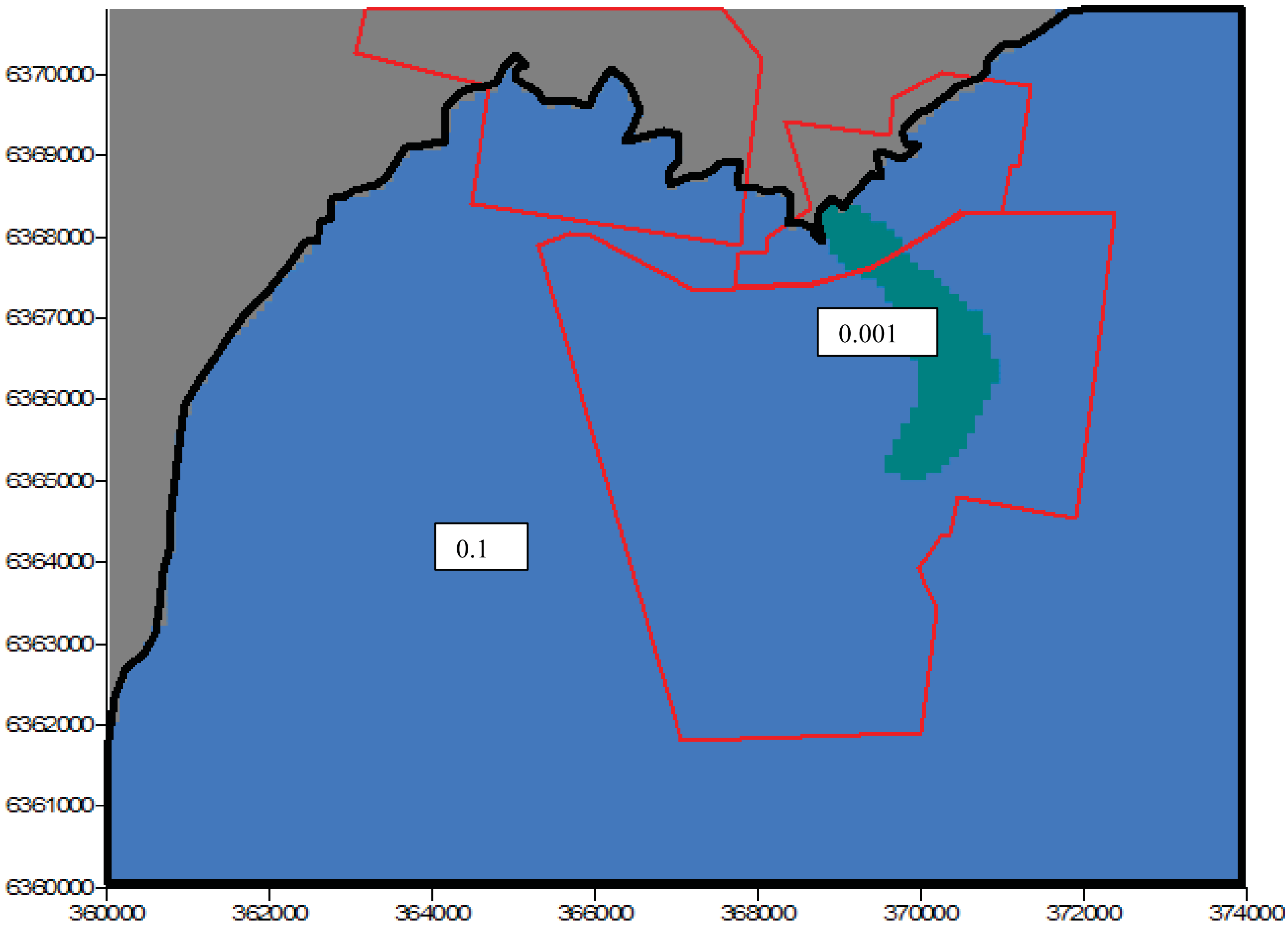
HYDRAULIC CONDUCTIVITY – L5



	Geological unit	Kh [m/d]	Kv [m/d]	S	Ss
Layer 5	Interburden above LD/UD seam (undisturbed)	0.001 At outcrop : 0.005	0.00005	0.00001	0.005

GREY COLOUR = INACTIVE

HYDRAULIC CONDUCTIVITY – L6



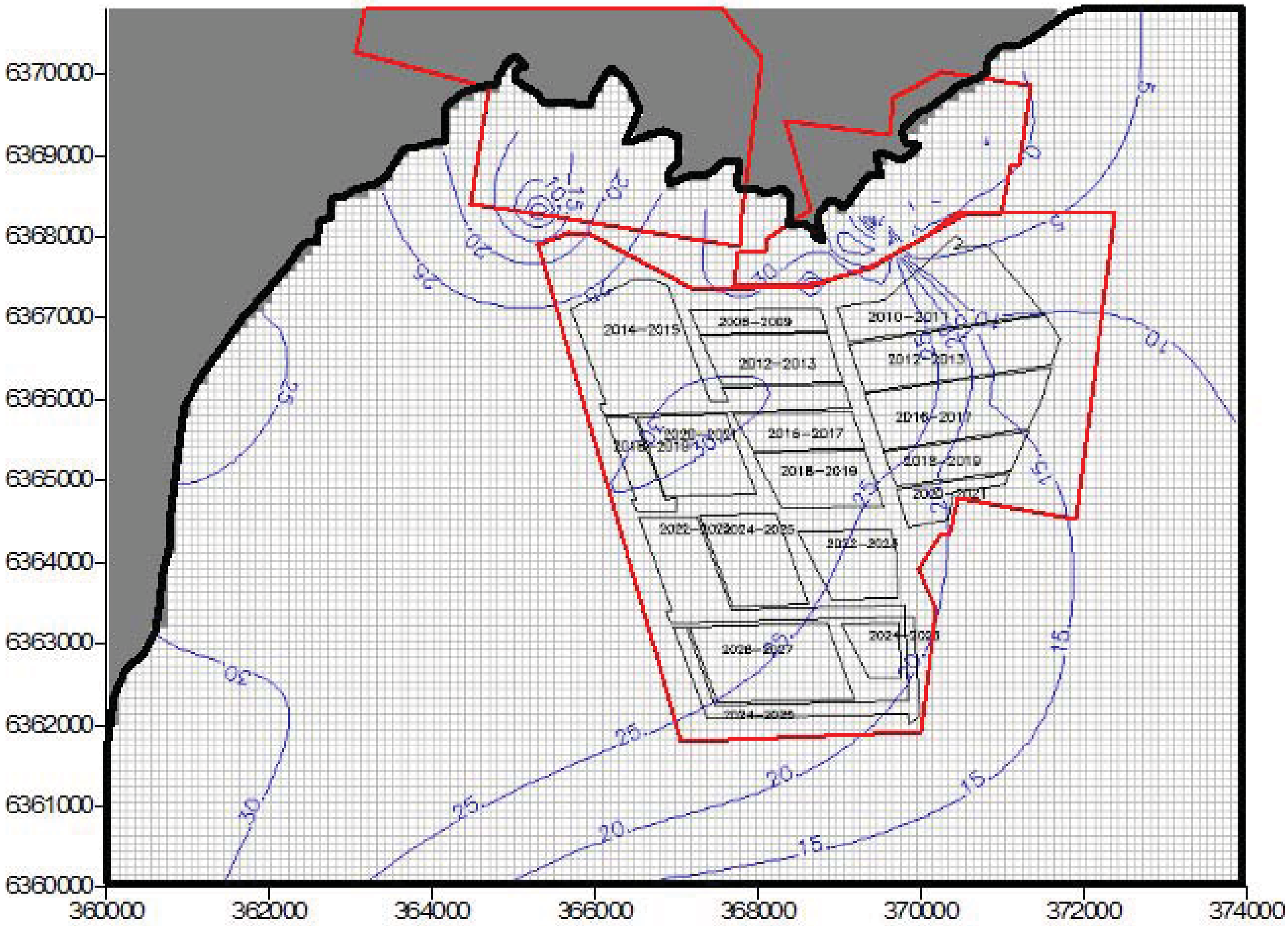
	Geological unit	Kh [m/d]	Kv [m/d]	S	Ss
Layer 6	LD/UD seam	0.1 – 0.001	0.001	0.0001	0.01

GREY COLOUR = INACTIVE

APPENDIX B

PIEZOMETRIC PRESSURE ABOVE DONALDSON COAL DURING MINING

DECEMBER 2009



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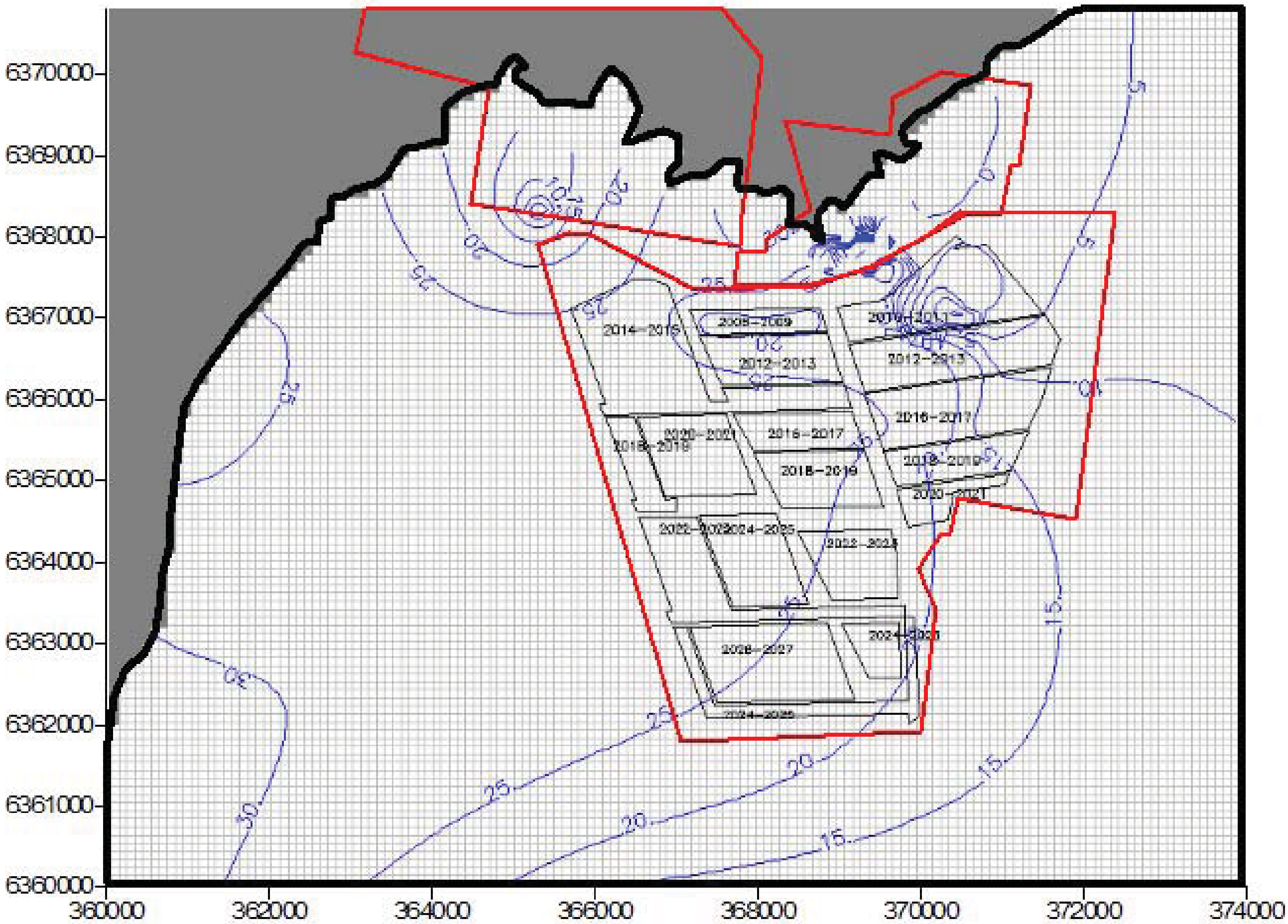

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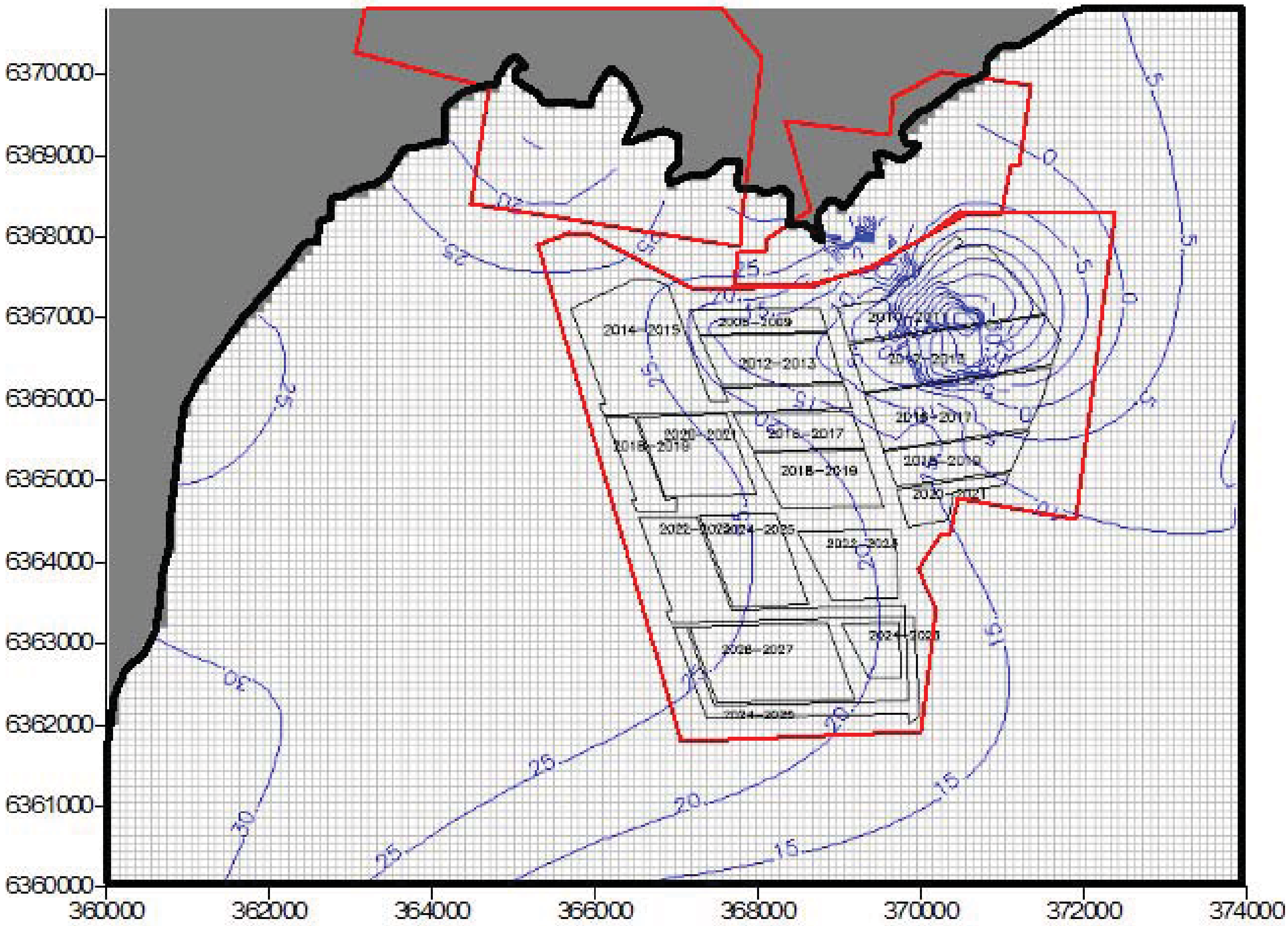

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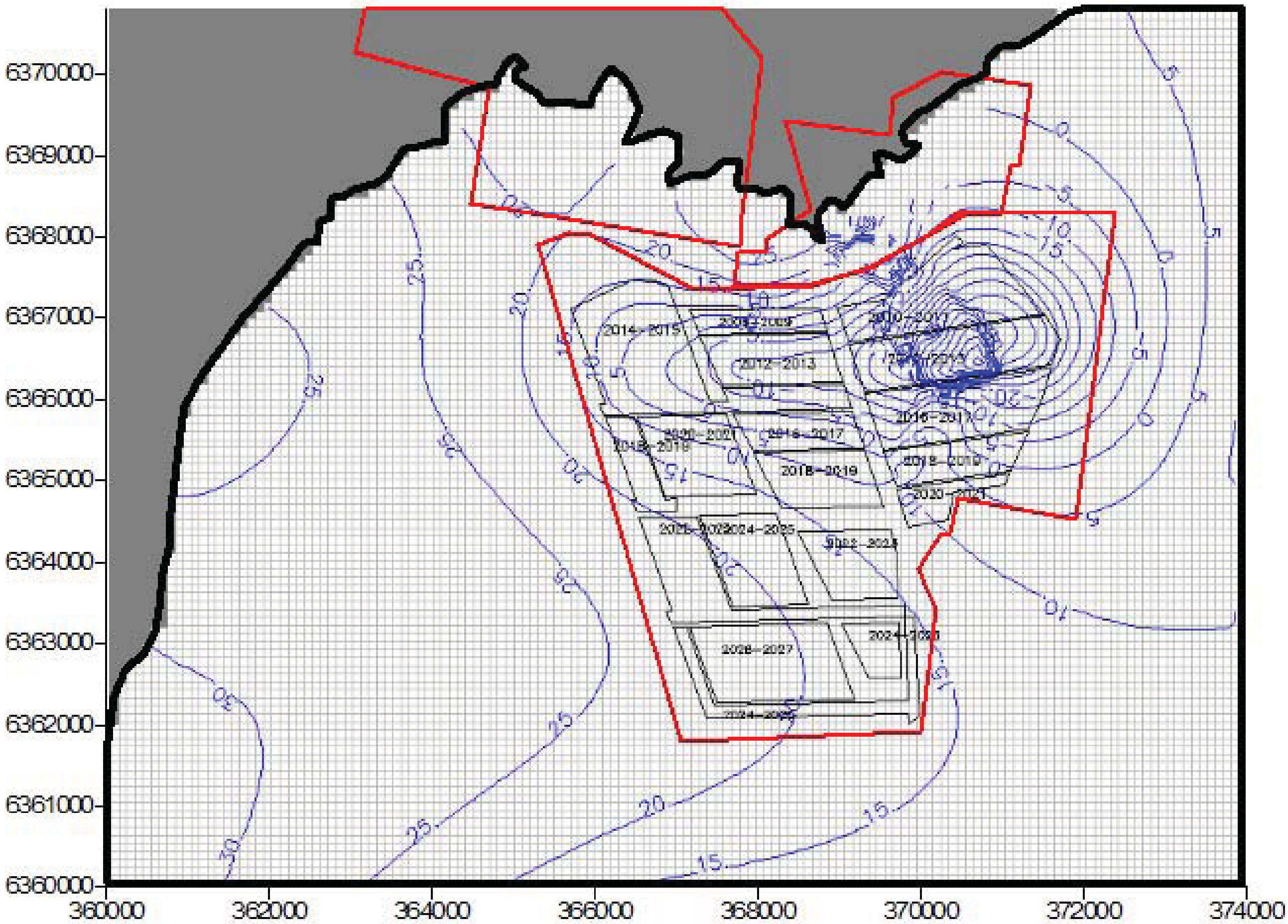

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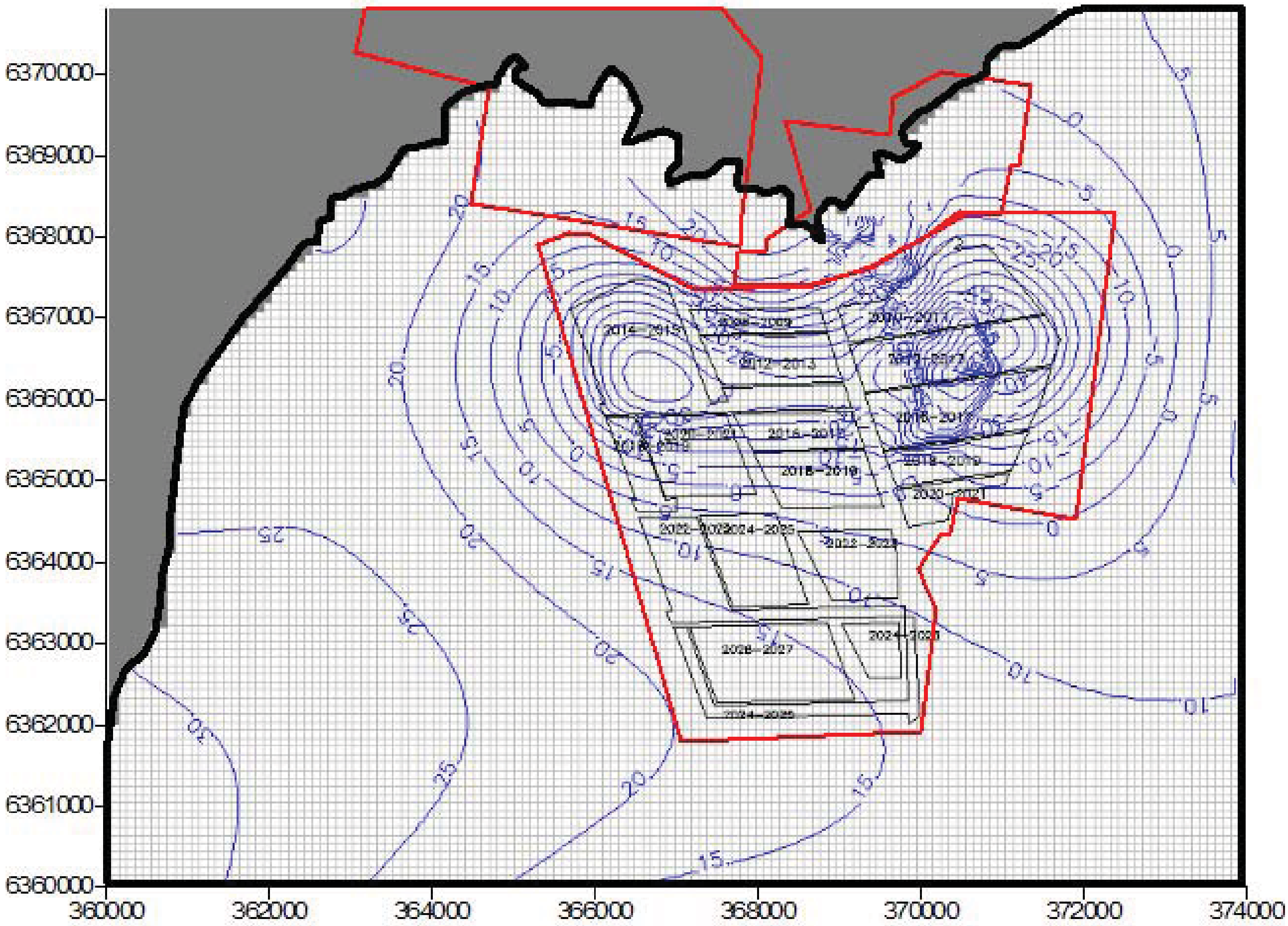

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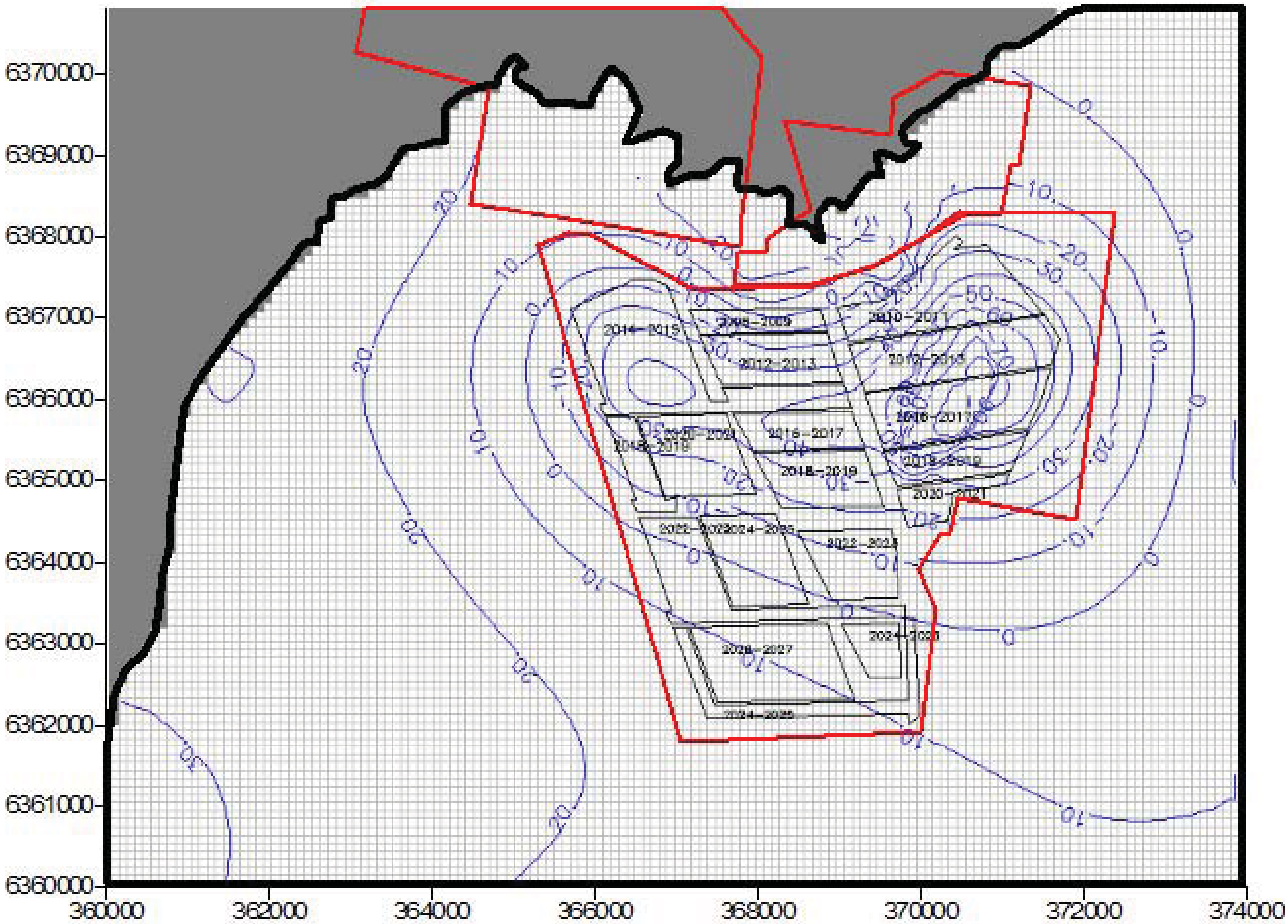

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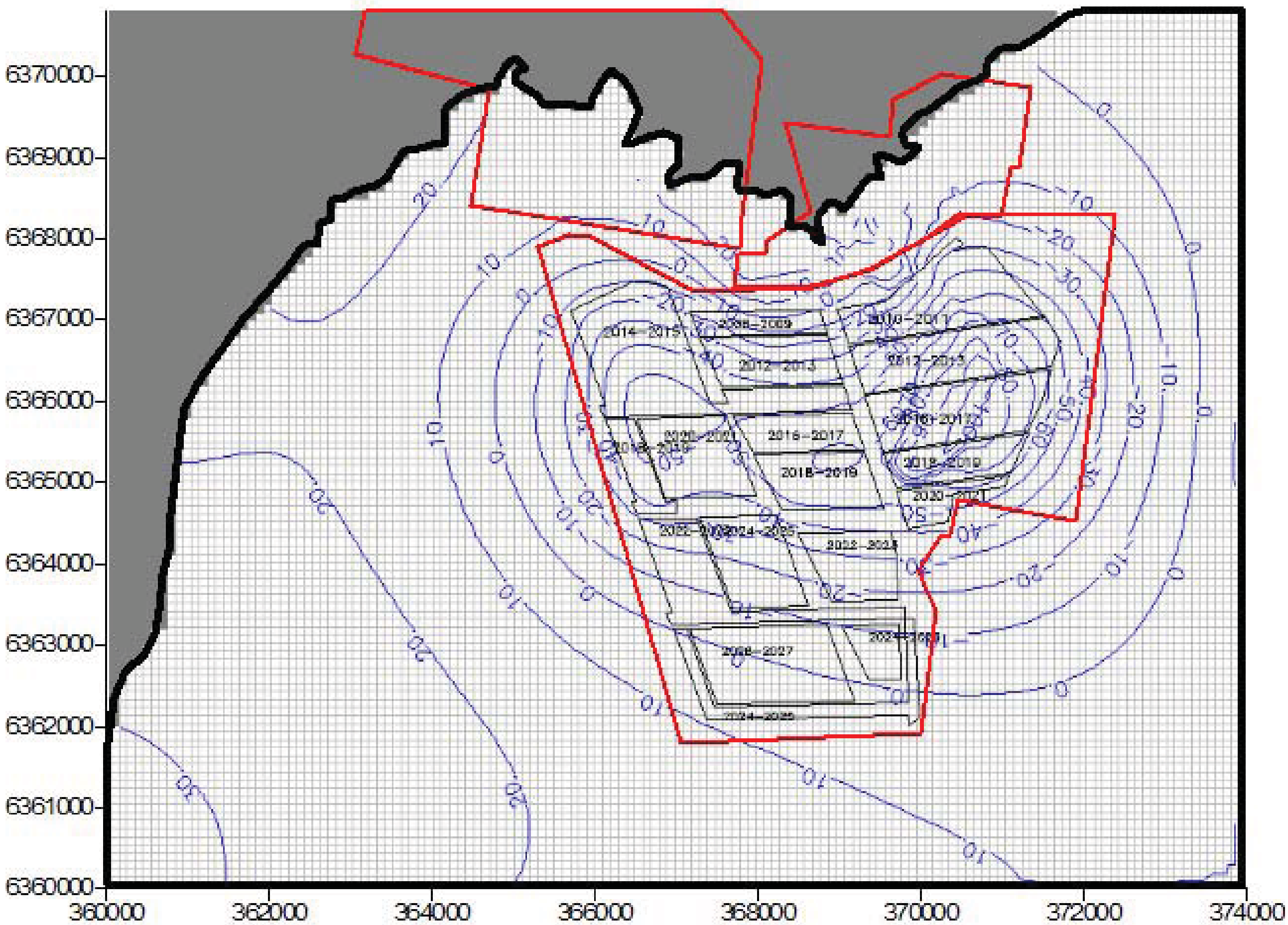

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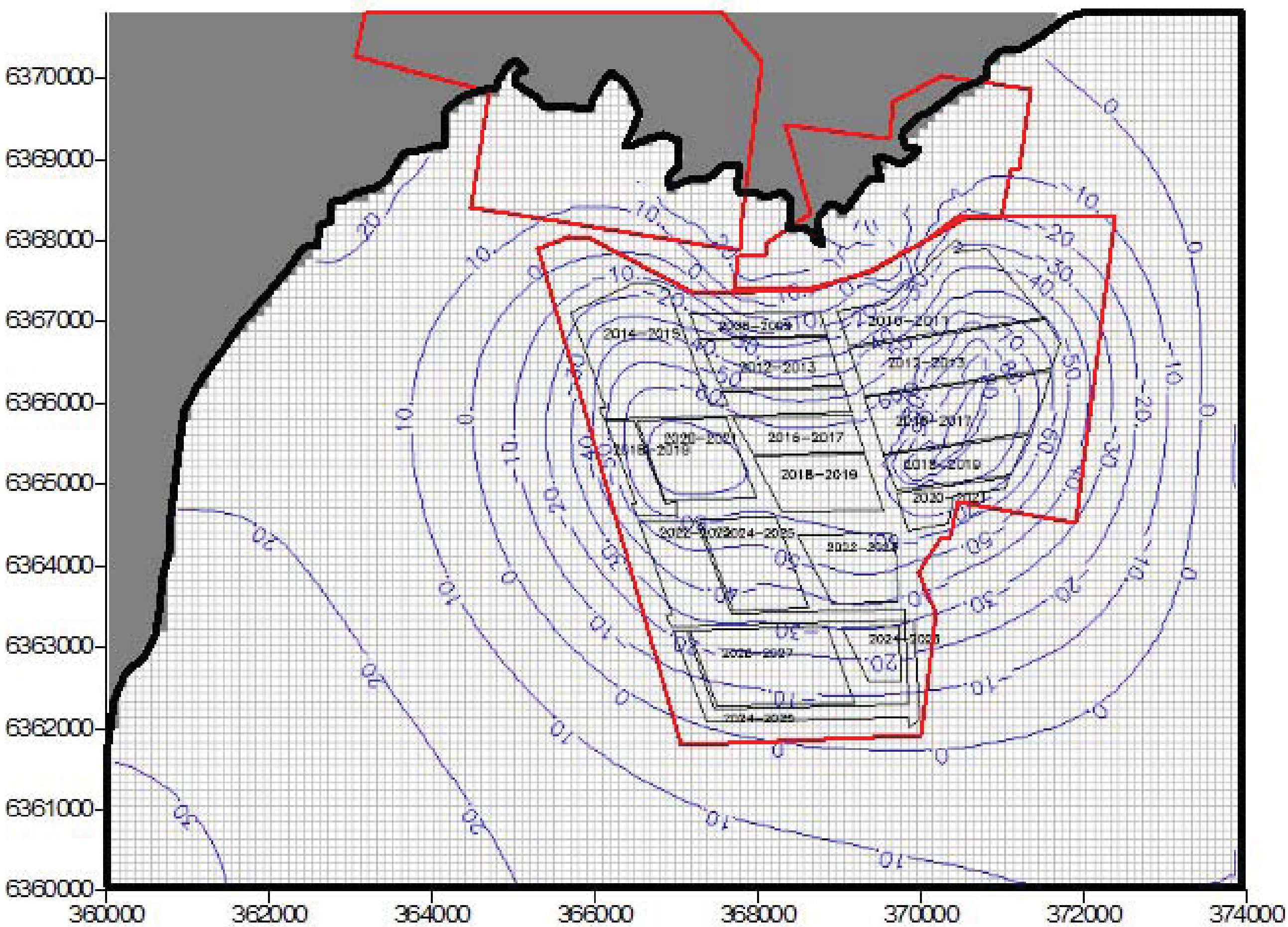

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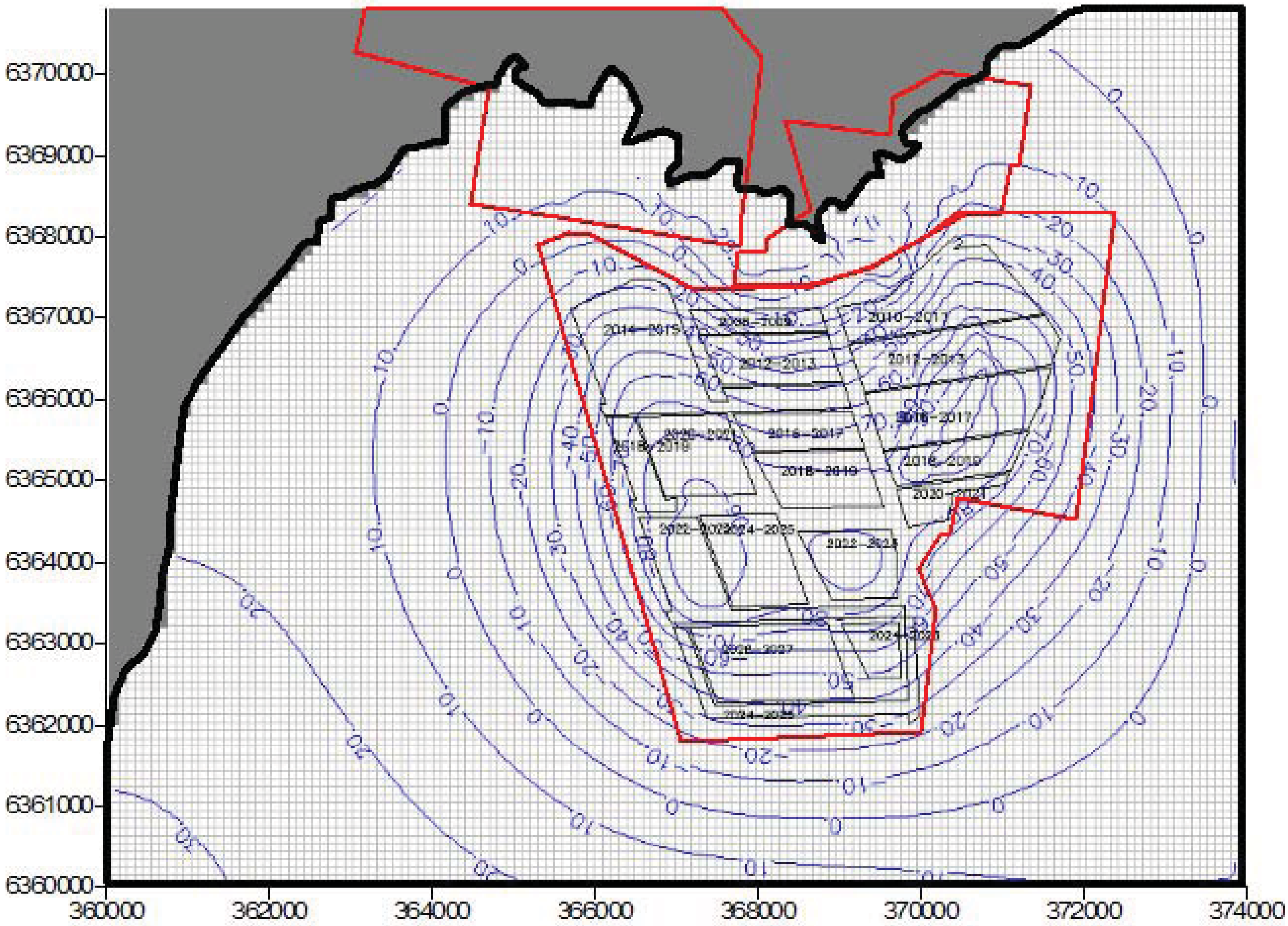

DECEMBER 2027