Donaldson Coal Pty Limited

ABEL UNDERGROUND MINE PART 3A ENVIRONMENTAL ASSESSMENT

Appendix G

Abel Coal Project Groundwater Assessment

DONALDSON COAL PTY LIMITED

ABEL COAL PROJECT
GROUNDWATER ASSESSMENT

BY

PETER J DUNDON

21 JULY 2006

05-0163-R01E

CONTENTS

TABLES

FIGURES

APPENDICES

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 kL/d	Duration min	Transmissivity m^2/d	Average Hydraulic Conductivity m/d	Average Hydraulic Conductivity m/s	Storativity	Comments
<u>Abel Piezometers:</u>											
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 x 10^{-6}	-	Interrupted test
			30 May 2006	Constant Rate	10	120	0.4	0.06	7 x 10^{-7}	-	Early data
							0.08	0.01	1.5 x 10^{-7}		Late data
C072B	42-45	Alluvium / weathered Permian	20 March 2006	Constant Rate	13	30	1.2	0.4	5 x 10^{-6}	-	
C078A	87-90 and 96-99	Donaldson Seam	2 June 2006	Constant Rate	2	120	0.4	0.07	8 x 10^{-7}	-	
C078B	18-24	Alluvium / weathered Permian	30 May 2006	Constant Rate	11	60	0.2	0.07	8 x 10^{-7}	-	
C081B	14-20	Alluvium / weathered Permian	22 March 2006	Constant Rate	13	75	2.4	0.4	4 x 10^{-6}	-	
C082	14-20	Alluvium / weathered Permian	22 March 2006	Constant Rate	13	160	0.3	0.05	6 x 10^{-7}	-	
C087	12-18	Alluvium / weathered Permian								-	No test – pumped dry in 4 minutes
<u>Bloomfield Monitoring Bores:</u>											
BL03A	?		14 April 2006	Slug test	-	-	-	1.3	1.6 x 10^{-5}	-	
BLO4	?		14 April 2006	Slug Test	-	-	-	0.02	3 x 10^{-7}	-	
BL05	?		14 April 2006	Slug Test	-	-	-	0.04	5 x 10^{-7}	-	
BL07	?		13 April 2006	Slug Test	-	-	-	2.3	3 x 10^{-5}	-	
<u>Donaldson Piezometers:</u>											
DPZ1	16.5-26.9	L Donaldson and Big Ben Seams	31 July 1997	Slug Test	-	-	-	0.08	9.6 x 10^{-7}	-	
	17.4-17.6	Mudstone	4 Sept 1997	Lab K Test	-	-	-	0.0003	3 x 10^{-9}	-	Kh
								0.0001	1 x 10^{-9}	-	Kv
	18.5-18.6	Mudstone	4 Sept 1997	Lab K Test	-	-	-	0.0037	4 x 10^{-8}	-	Kh
								0.0008	9 x 10^{-9}	-	Kv
DPZ4	12.8-13.0	Interbedded sandstone / mudstone	4 Sept 1997	Lab K Test	-	-	-	0.0015	2 x 10^{-8}	-	Kh
								0.0005	5 x 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 x 10^{-8}	-	Kh
								0.0002	2 x 10^{-9}	-	Kv
	35.7-35.9	Interbedded sandstone / mudstone	4 Sept 1997	Lab K Test	-	-	-	0.0014	1.6 x 10^{-8}	-	Kh
								0.0001	1 x 10^{-9}	-	Kv
	37.0-37.2	Sandstone (very coarse)	4 Sept 1997	Lab K Test	-	-	-	1.3	1.5 x 10^{-5}	-	Kh
								0.19	2.2 x 10^{-6}	-	Kv
DPZ7	22.9-34.9	L Donaldson Seam	30 June 1997	Slug Test	-	-	-	0.002	1.4 x 10^{-8}	-	
	18.4-18.6	Sandstone	4 Sept 1997	Lab K Test	-	-	-	0.0015	1.7 x 10^{-8}	-	Kh
								0.0009	1 x 10^{-8}	-	Kv
DPZ8	22-32	L Donaldson and Big Ben Seams	30 June 1997	Slug Test	-	-	-	0.17	1.9 x 10^{-6}	-	
DPZ9	12.5-36.5	U/L Donaldson and Big Ben Seams	30 June 1997	Slug Test	-	-	-	0.02	2.3 x 10^{-7}	-	
DPZ14	24-32	Buchanan and Ashtonfield Seams	26 July 2001	Slug Test	-	-	-	0.7	8 x 10^{-6}	-	Early data (Gravel pack?)
								0.02	2.5 x 10^{-7}	-	Late data (formation?)
DPZ15	41-47	Buchanan and Ashtonfield Seams	26 July 2001	Slug Test	-	-	-	0.3	3 x 10^{-6}	-	Early data (Gravel pack?)
								0.009	1 x 10^{-7}	-	Late data (formation?)
DPZ16	21-24	Ashtonfield Seam	26 July 2001	Slug Test	-	-	-	0.4	4 x 10^{-6}	-	Early data (Gravel pack?)
								0.04	3 x 10^{-7}	-	Late data (formation?)
Tasman:											
ODO003	113-131	Fassifern Seam	7 December 2001	Slug Test	-	-	-	0.002	2 x 10^{-8}	-	
TAS011	26-38	Fassifern Seam	7 December 2001	Slug Test	-	-	-	1.25	1.5 x 10^{-5}	-	
TAS012	90.5-105.5	Overburden above Fassifern	7 December 2001	Slug Test	-	-	-	0.15	1.7 x 10^{-6}	-	Early data (Gravel pack?)
			7 December 2001	Slug Test	-	-	-	0.3	4 x 10^{-6}	-	Late data (formation?)
TAS014a	38-50	Fassifern Seam	7 December 2001	Slug Test	-	-	-	0.25	3 x 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 @ 25°C	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

Layer		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	0.15	0.001	0.0001	0.01
	Alluvium	6.0	0.0005	0.0001	0.1
4	Interburden above LD/UD seam (undisturbed)	Under confinement: 0.001	0.0001	0.00001	0.005
		At outcrop/Under Alluvium: 0.0005 - 0.01	under swamp: 0.00001		
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

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

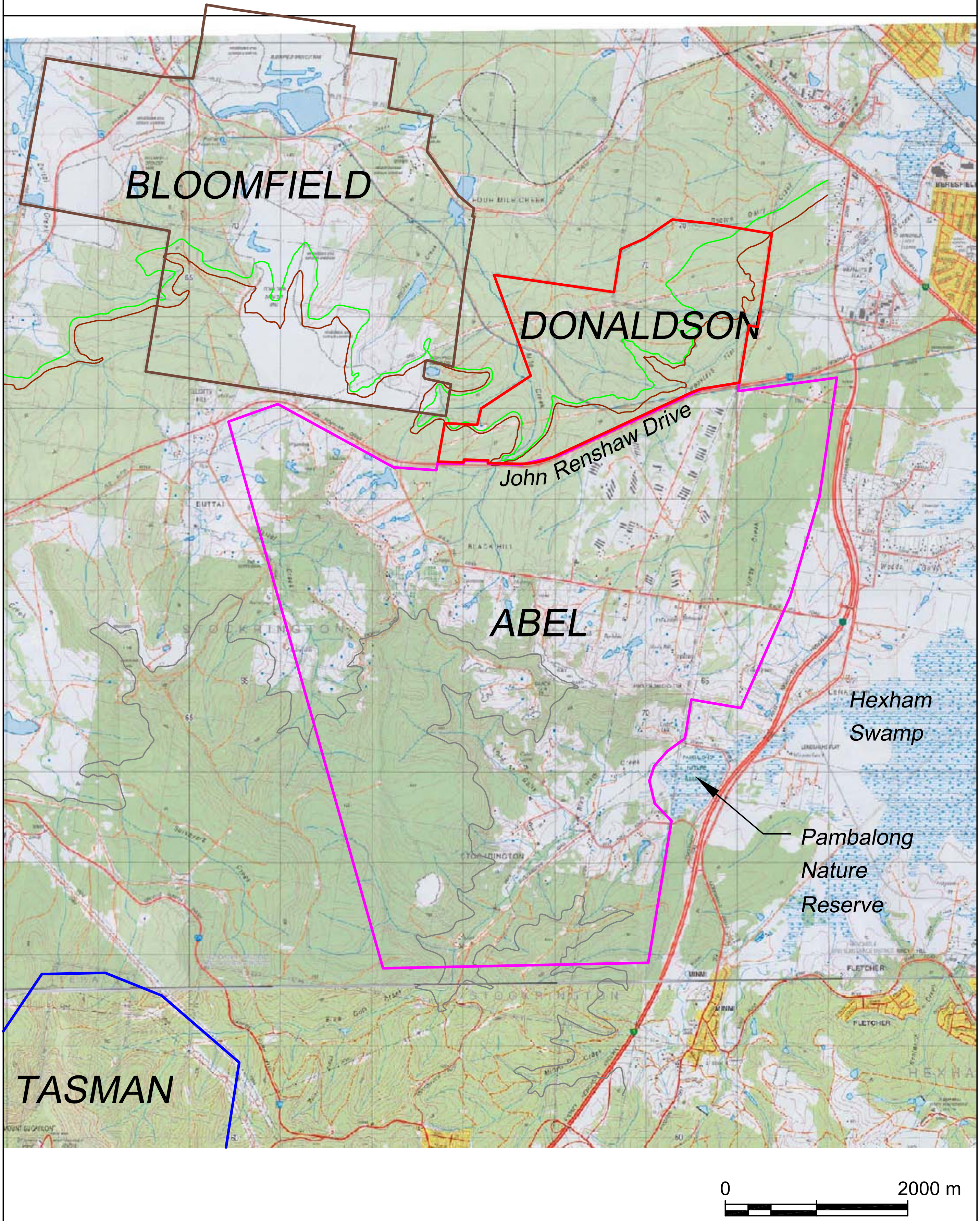
Evans and Peck, 2006. *Surface Water Assessment and Outline Water Management Plan.*

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

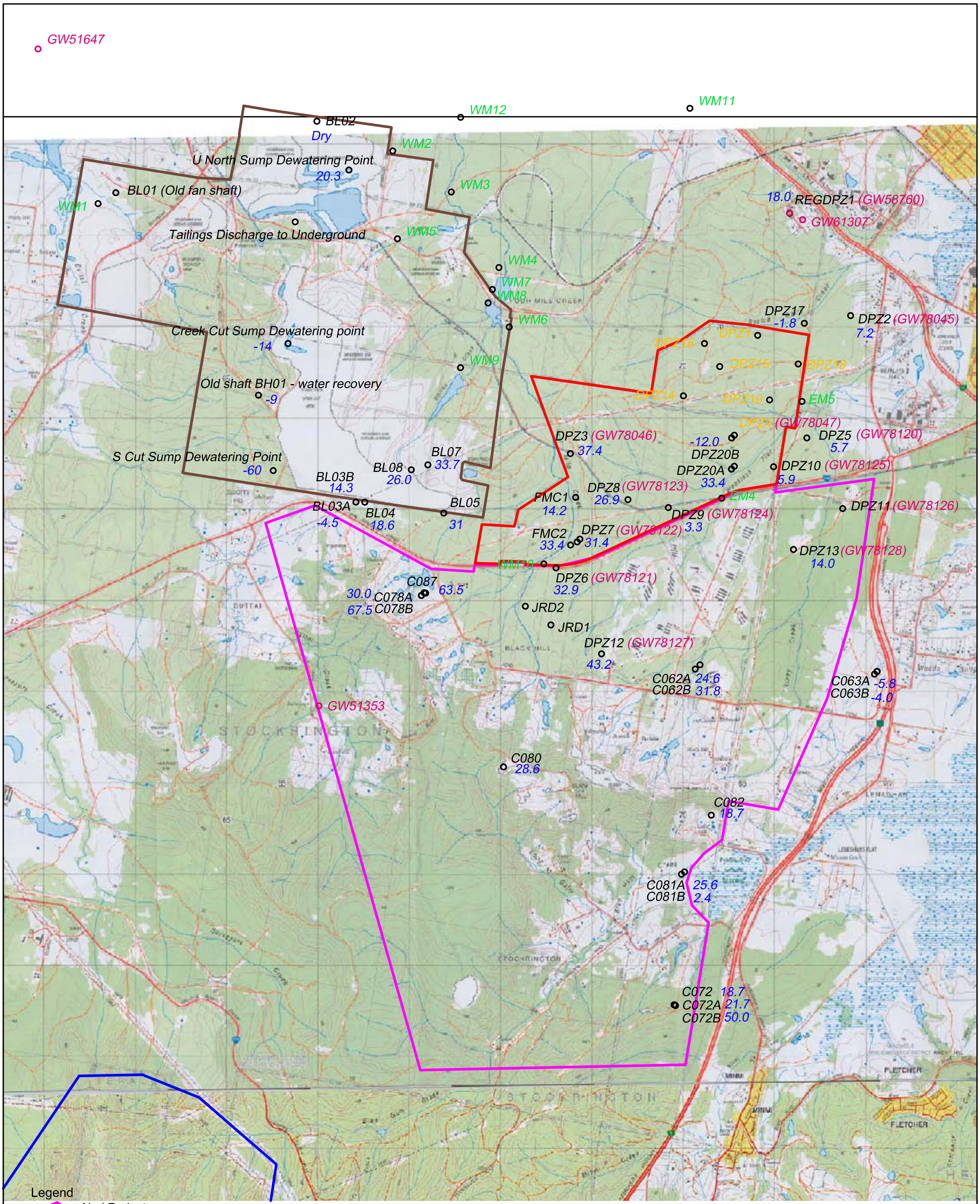
Middlemis, H et al, 2001. *Groundwater flow modelling guideline.* Murray-Darling Basin Commission. URL: www.mdbc.gov.au/nrm/water_management/groundwater/groundwater_guides

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



Legend
- Abel Project
- Tasman Project
- Bloomfield Project
- Donaldson Project

Date:	23/07/06	Scale:	as shown	**Donaldson Coal Pty Ltd**	
Initials:	PJD	Job No:	05-0163	**Abel Coal Project** **Project Locality**	
Drawing No:	05-0163-008_A	Rev:	A		
Peter Dundon & Associates Pty Limited					**Figure 1**



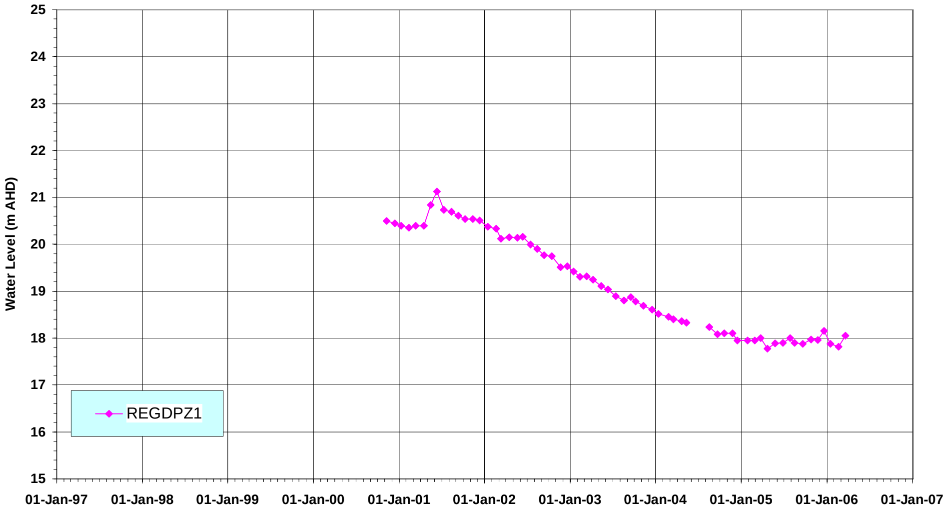
Legend

- 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
- 28.5 Groundwater Level (mAHD)

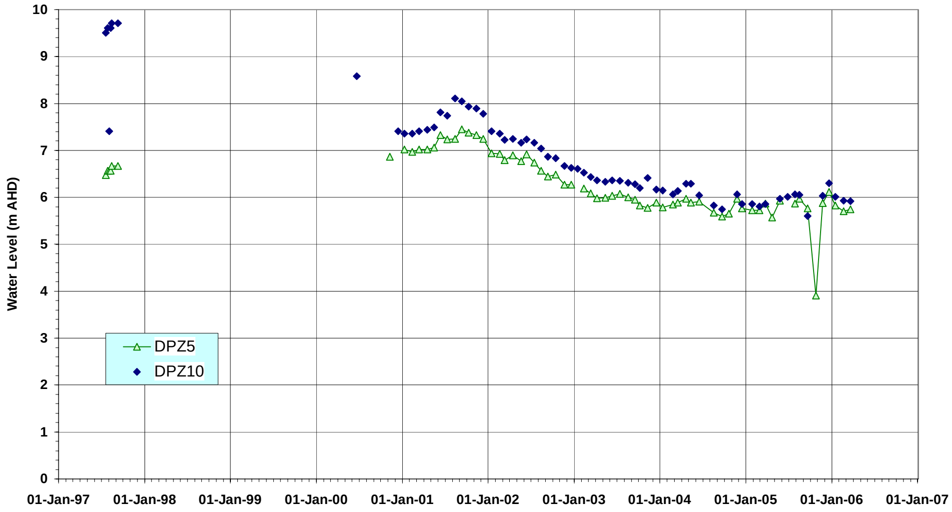
0 2000 m

Date:	23 July 2006	Scale:	as shown	**Donaldson Coal Pty Ltd**
Initials:	PJD	Job No:	05-0163	**Abel Coal Project** **Bore Location Plan**
Drawing No:	05-0163-005_E	Rev:	Rev E	
Peter Dundon & Associates Pty Limited				**Figure 2**

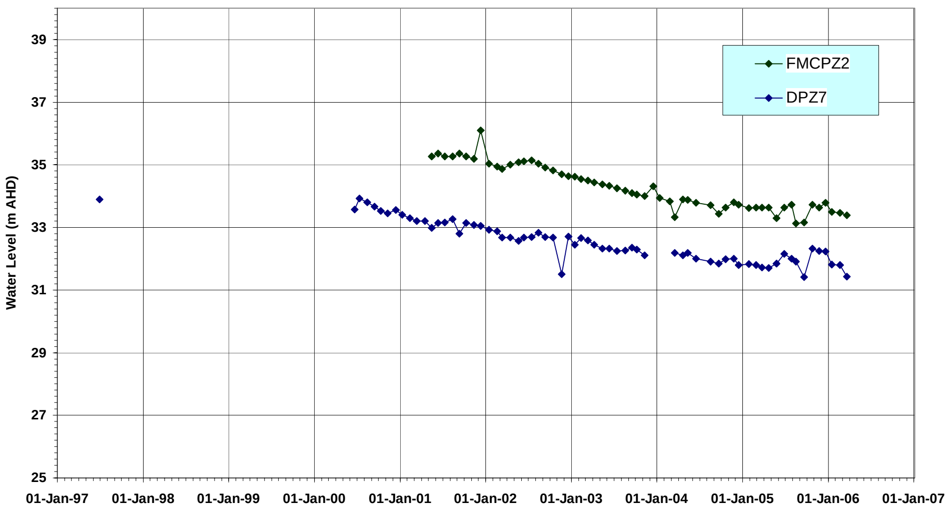
WATER LEVEL HYDROGRAPHS - REGDPZ1



WATER LEVEL HYDROGRAPHS - DPZ5 and DPZ10

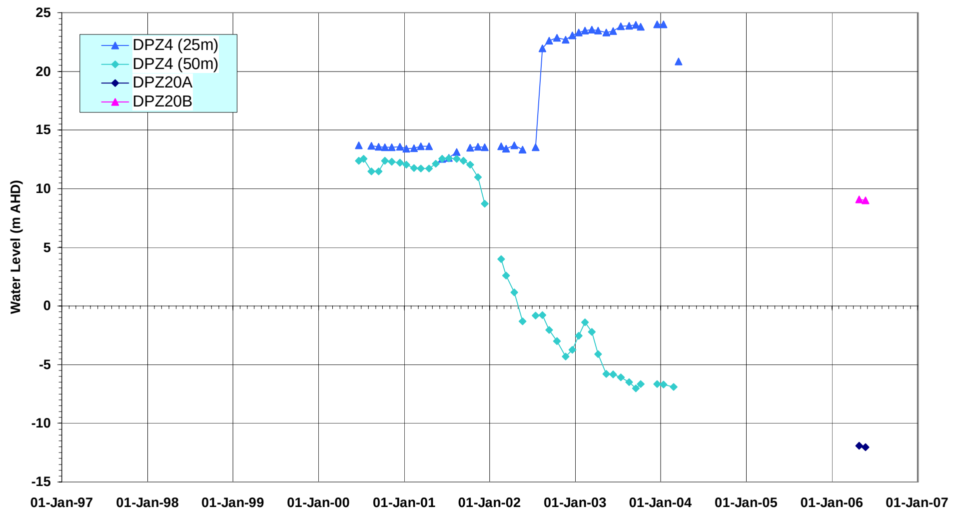


WATER LEVEL HYDROGRAPHS - FMCPZ2 and DPZ7

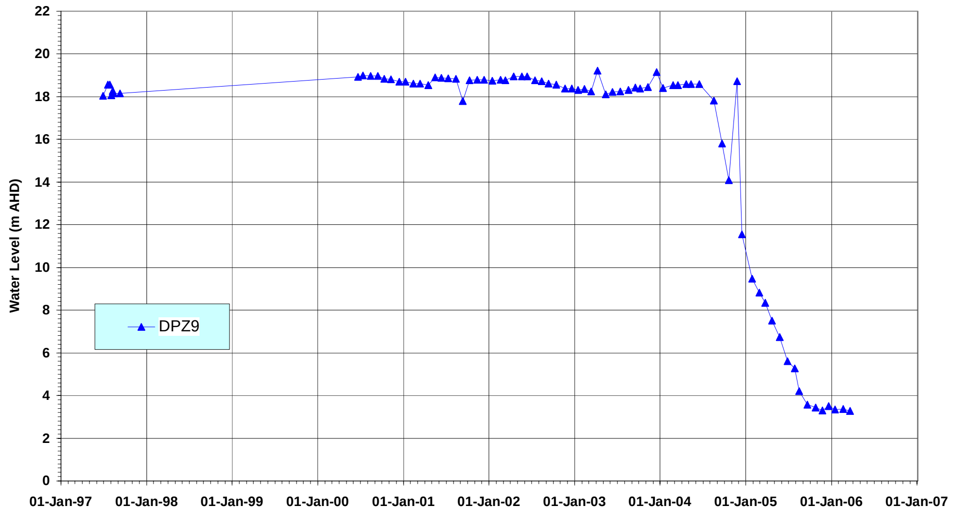


Date:	12 June 2006	Scale:	as indicated	**Donaldson Coal Pty Ltd**
Initials:	PJD	Job No:	05-0163	**ABEL COAL PROJECT PIEZOMETER HYDROGRAPHS - REGIONAL PIEZOMETERS**
Drawing No:	05-0163-105	Rev:	0	
Peter Dundon & Associates Pty Limited				**Figure 3**

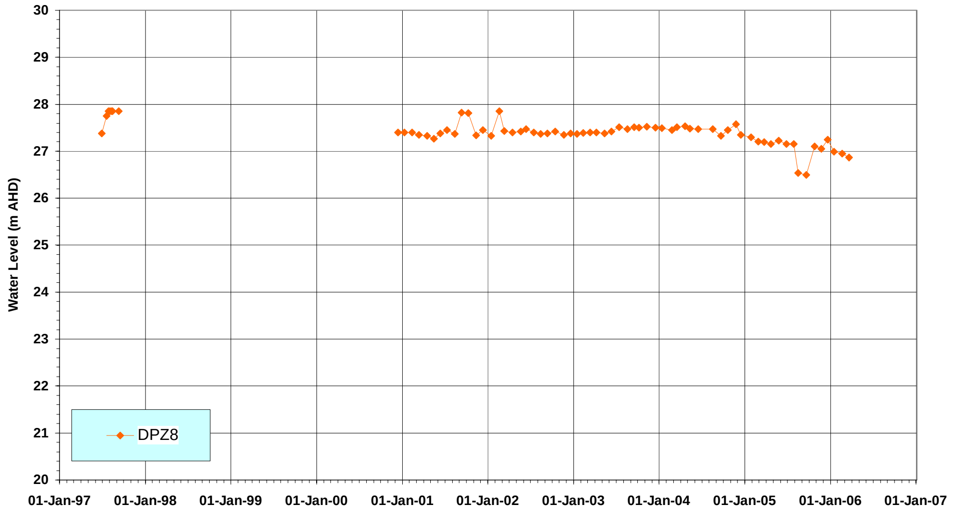
WATER LEVEL HYDROGRAPHS - DPZ4 and DPZ20



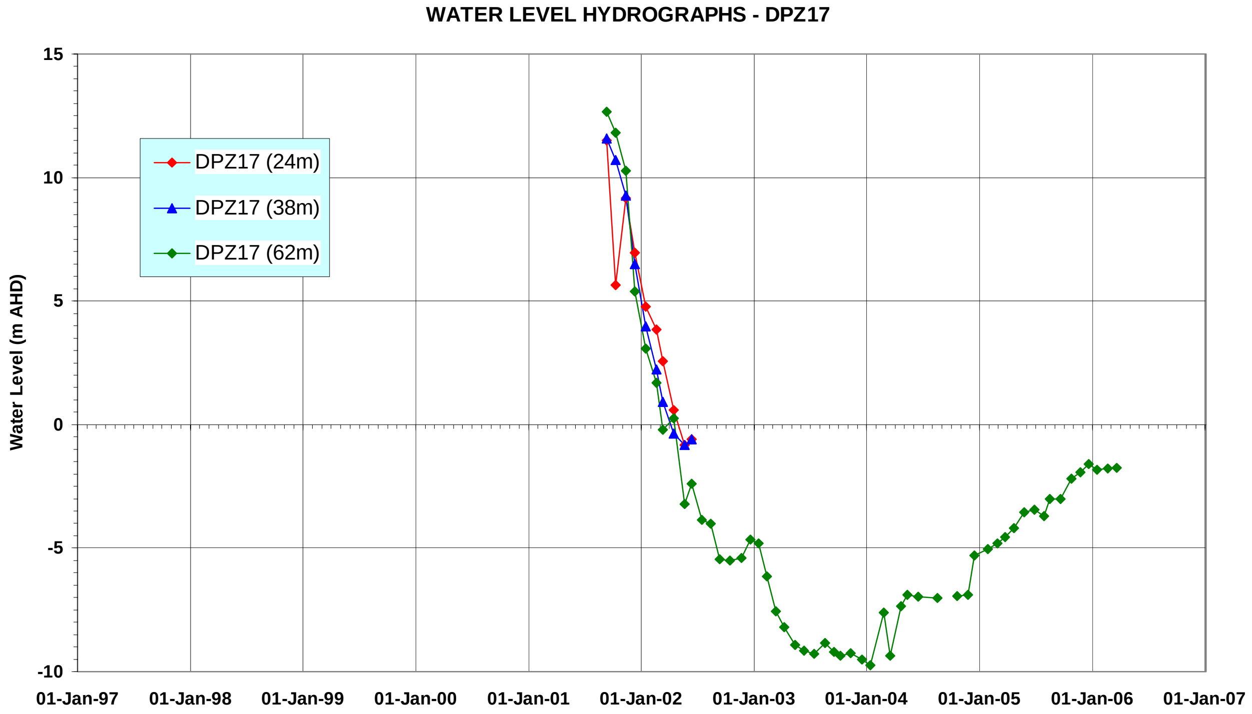
WATER LEVEL HYDROGRAPHS - DPZ9



WATER LEVEL HYDROGRAPHS - DPZ8



Date: 12 June 2006	Scale: as indicated	**Donaldson Coal Pty Ltd**
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**

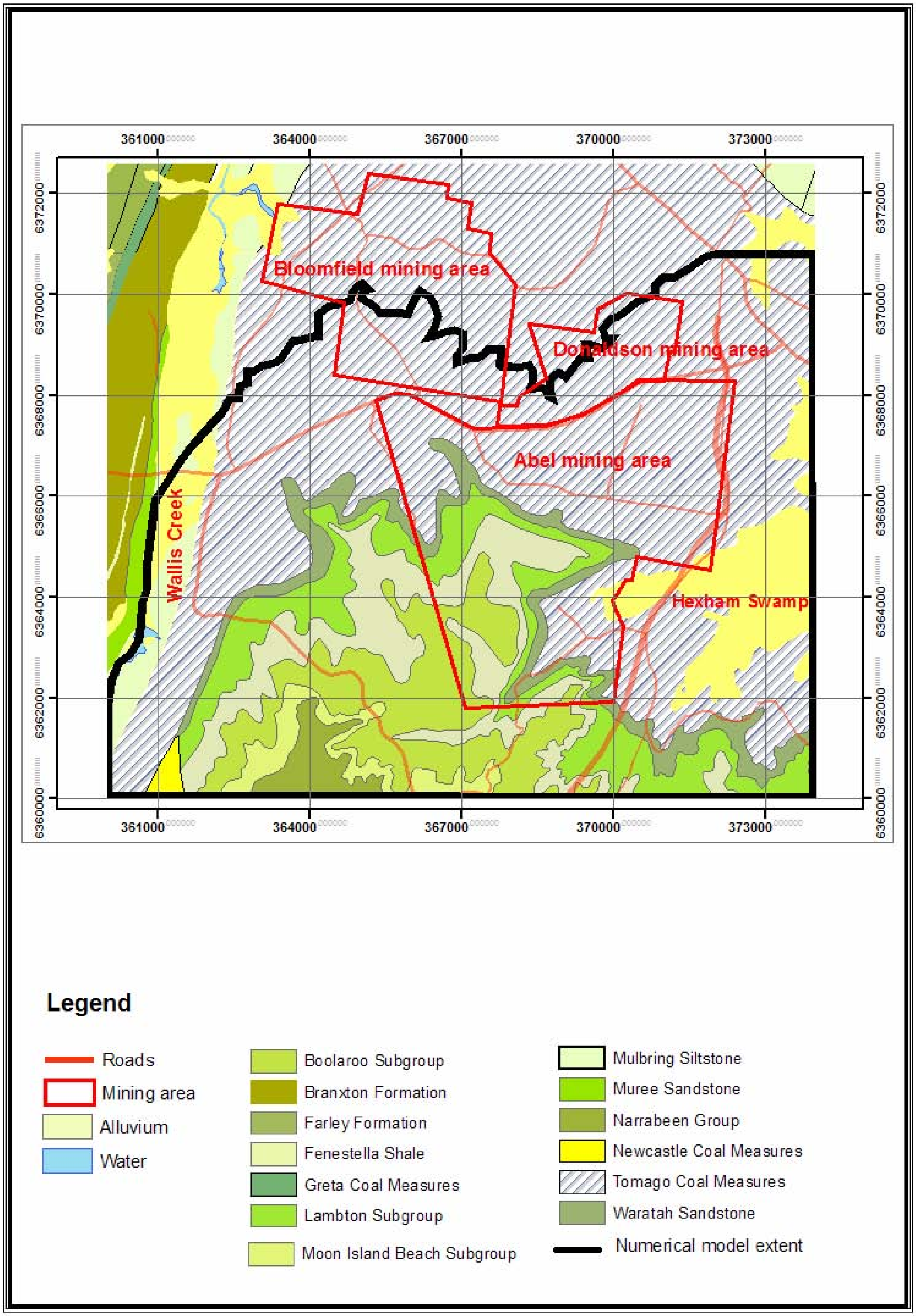


Figure 6: Regional Geology

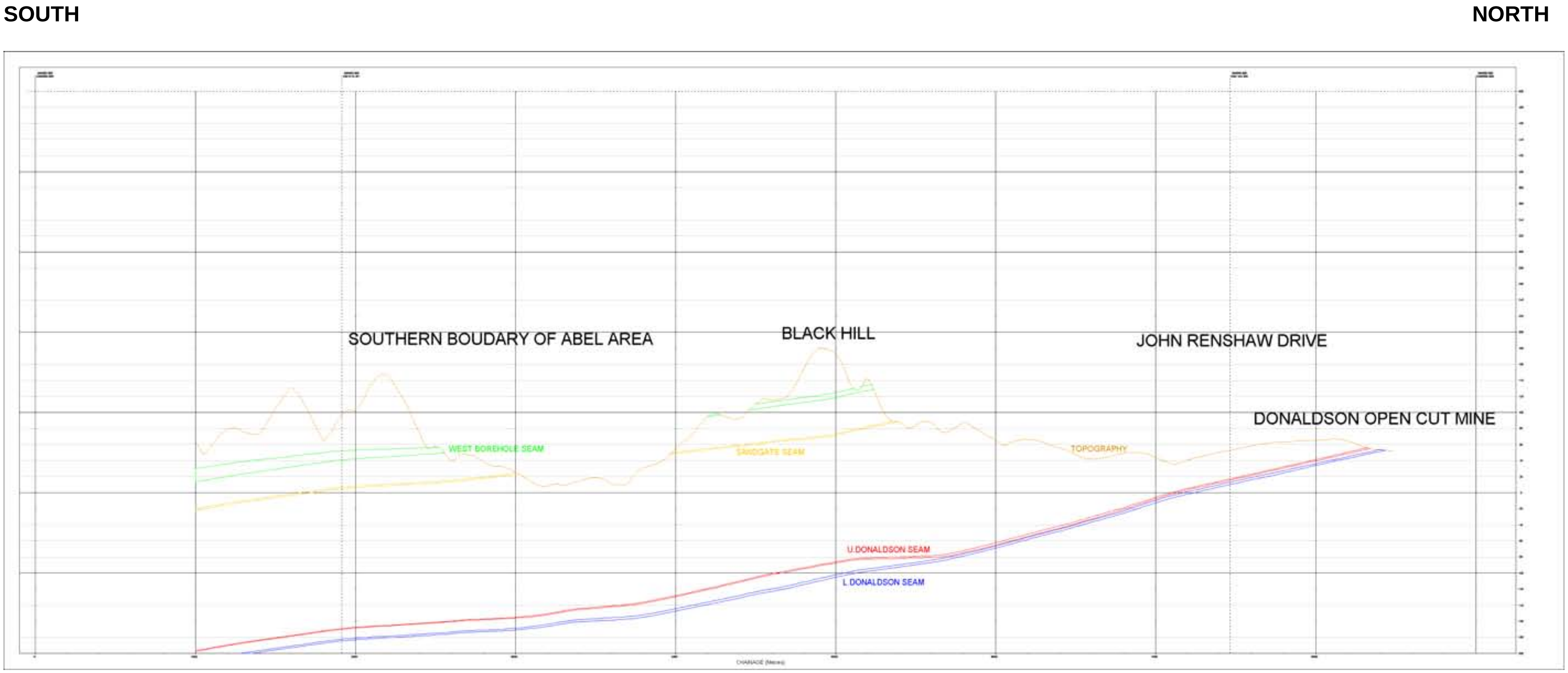
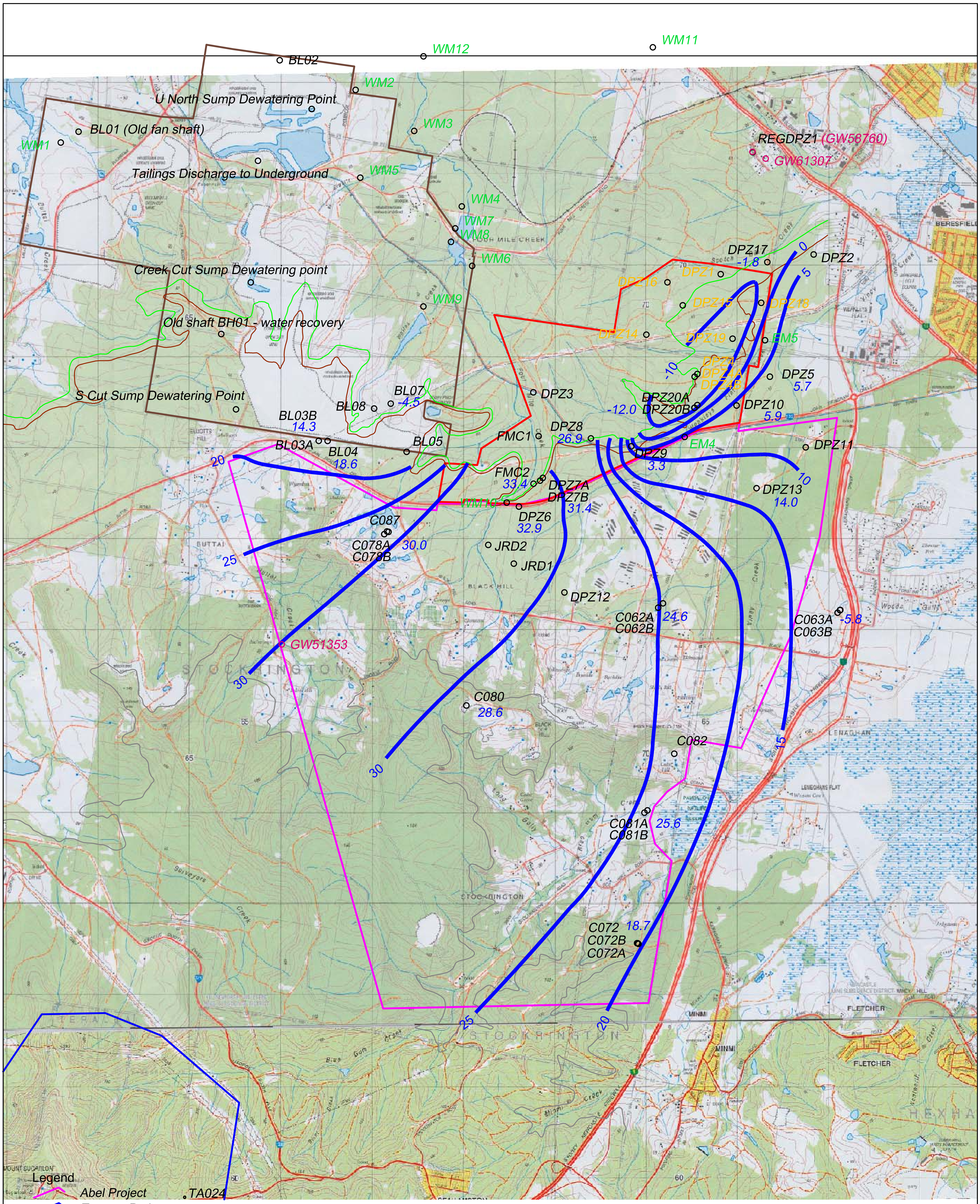


Figure 7: North-South Geological Cross-Section Through Abel Project Area



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

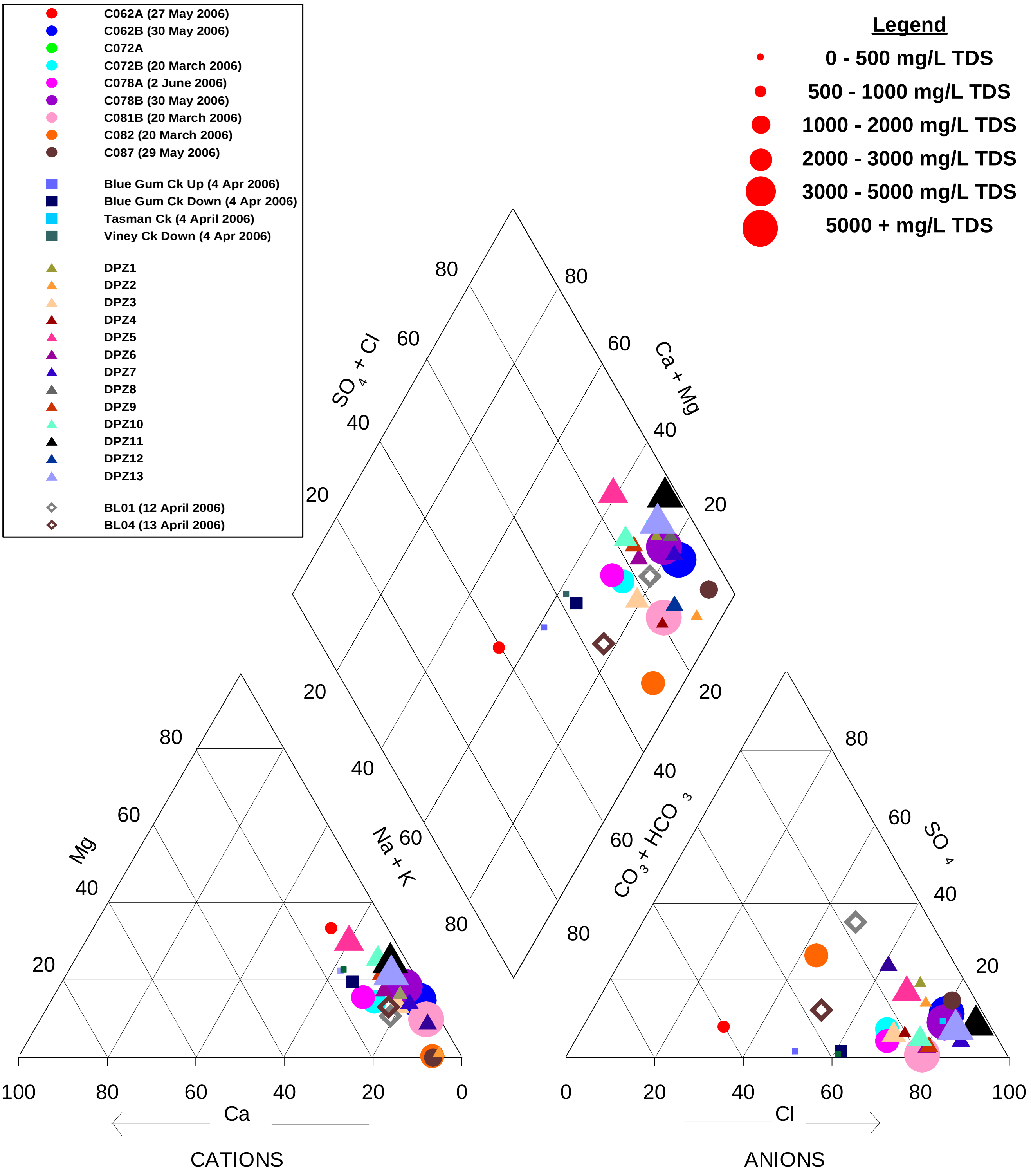
Date:	23 July 2006	Scale:	as shown
Initials:	PJD	Job No:	05-0163
Drawing No:	05-0163-005_C	Rev:	Rev C

Peter Dundon & Associates Pty Limited

Donaldson Coal Pty Ltd

Abel Coal Project
Interpreted Groundwater Contours
for the Donaldson Seam

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		PROJECT	ABEL COAL PROJECT
DRAWN PJD	DATE 14 June 2006	TITLE	PIPER TRILINEAR DIAGRAM GROUNDWATER v SURFACE WATER
CHECKED	DATE		
SCALE As Shown	Dwg 05-0163-115 A4	PROJECT No 05-0163	Figure 9

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

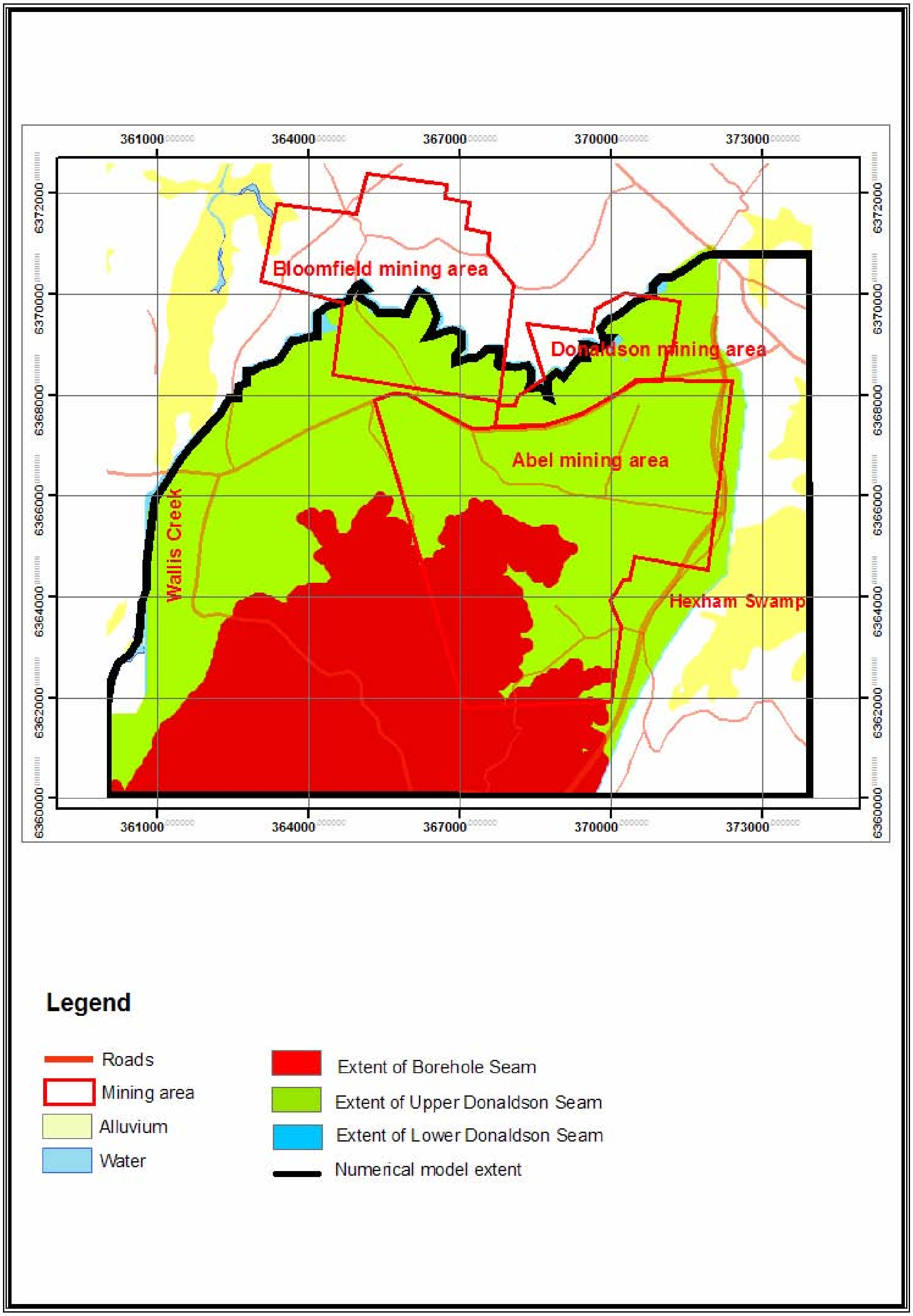


Figure 10: Groundwater Flow Model Area

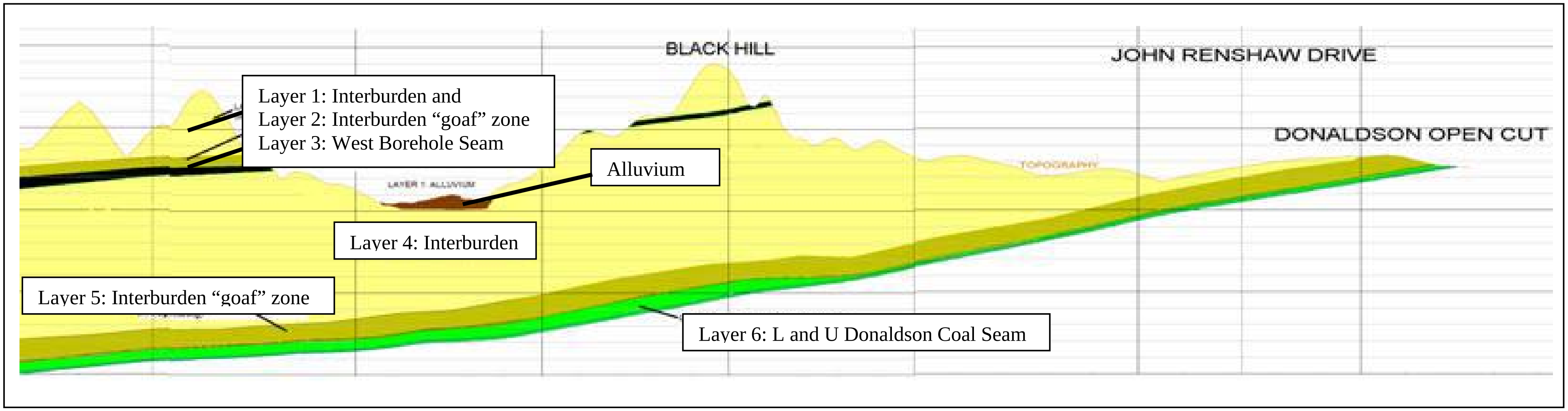


Figure 11: Groundwater Model Layer Definition

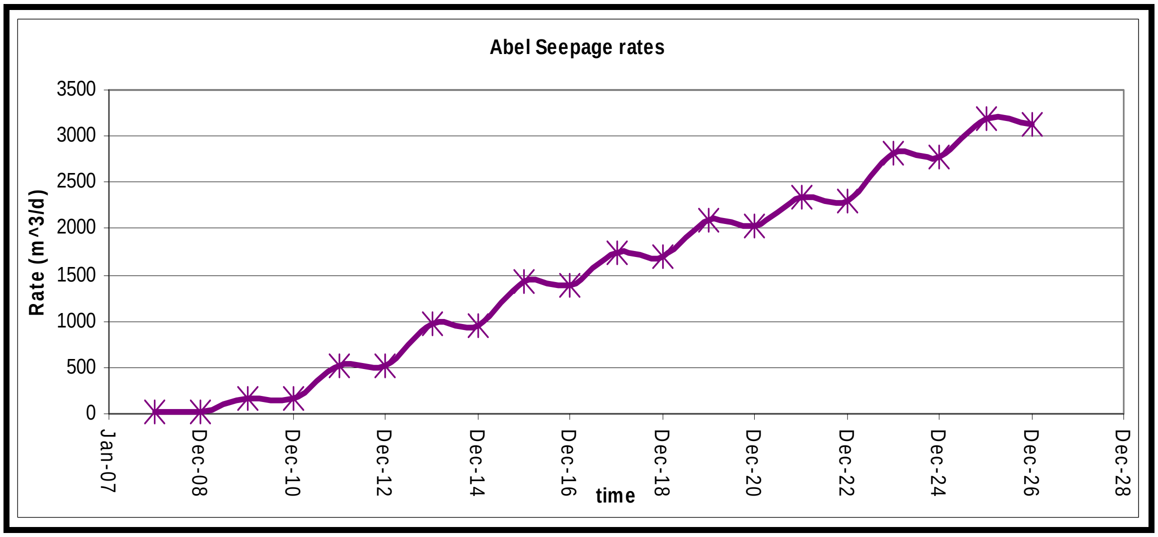
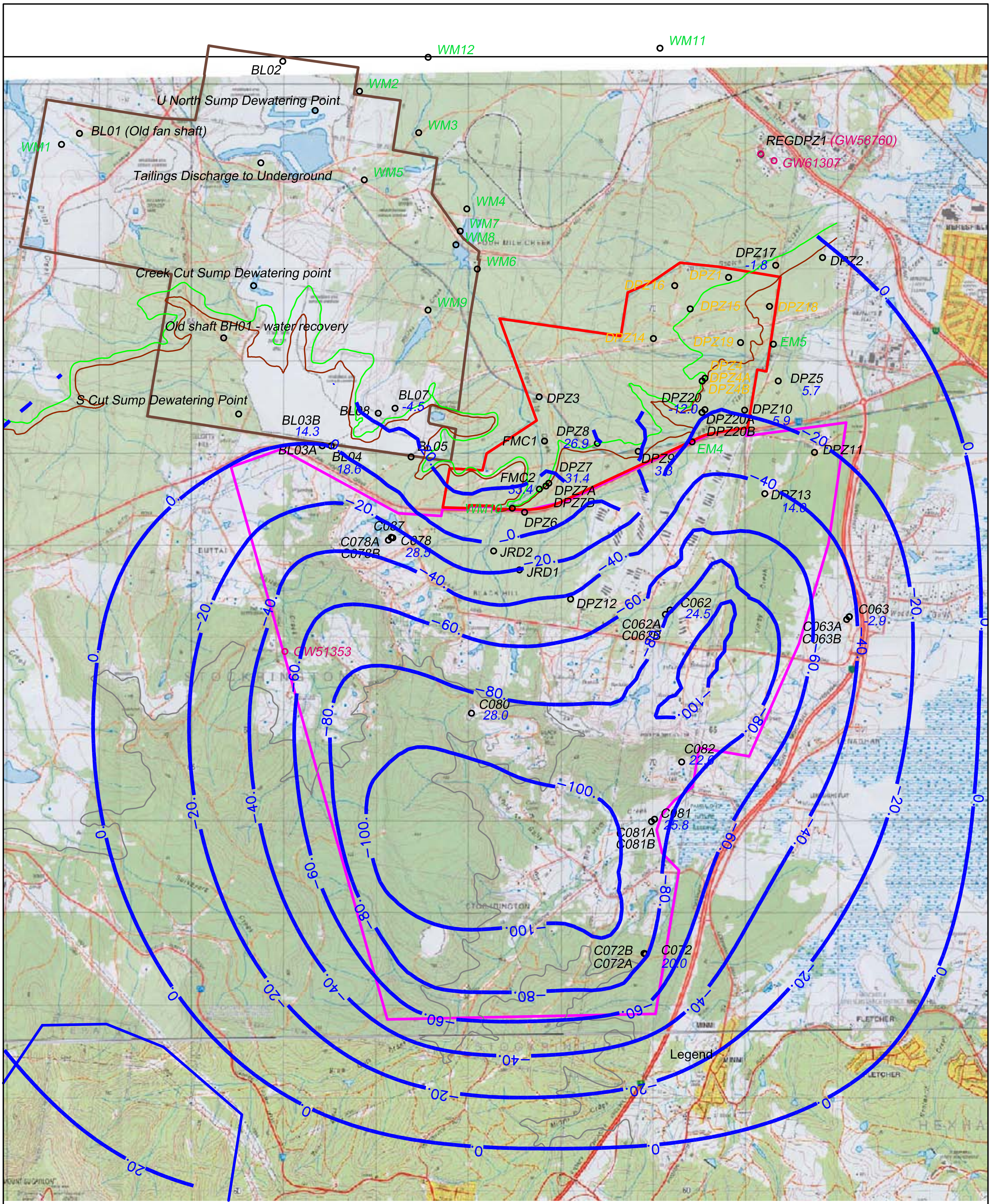


Figure 12: Predicted Groundwater Inflow Rates to the Abel Mine



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

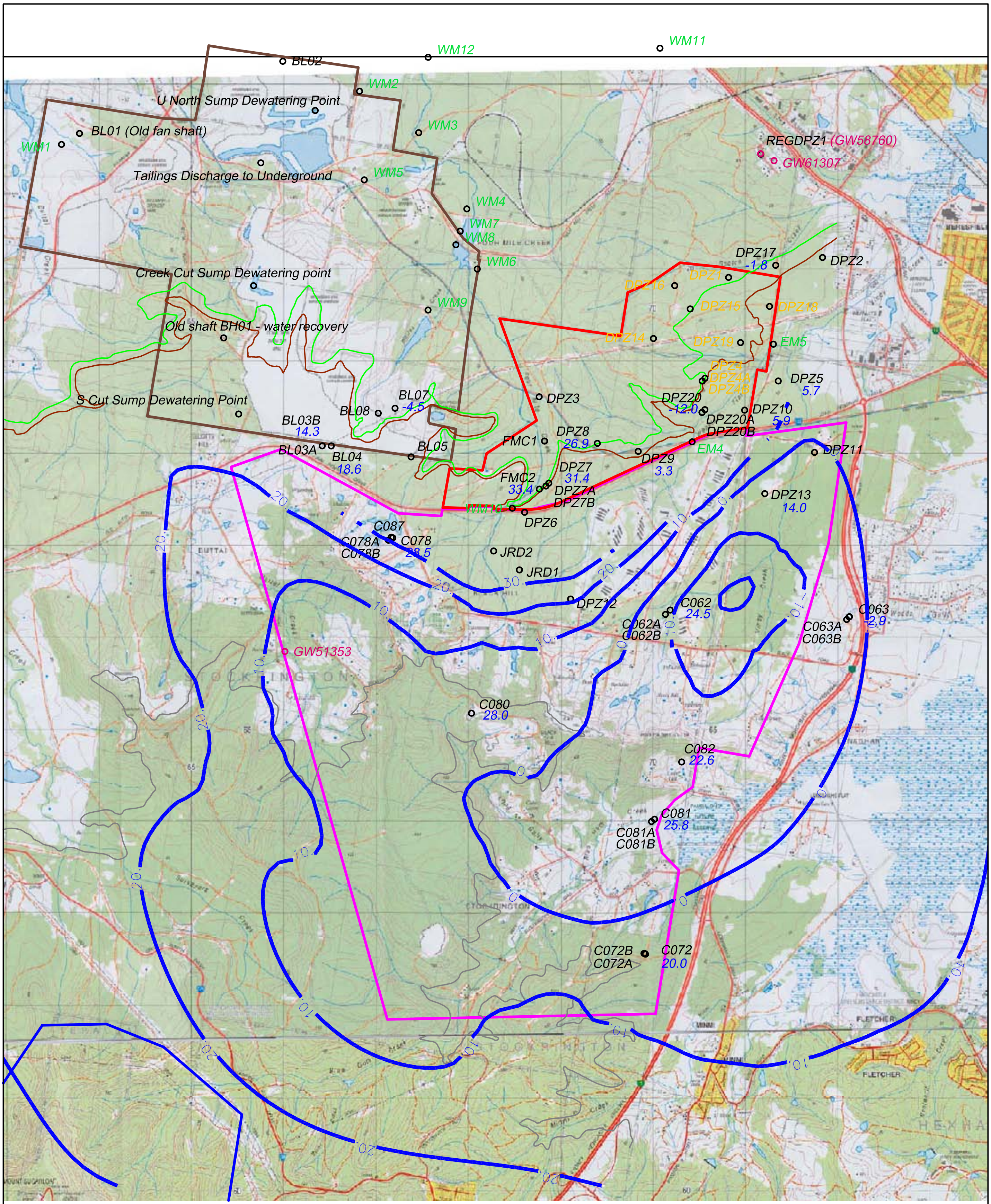
Date:	23/07/06	Scale:	as shown
Initials:	PJD	Job No:	05-0163
Drawing No:	05-0163-010_B	Rev:	B

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**