MOOLARBEN COAL PROJECT

APPENDIX 5

Groundwater Assessment

MOOLARBEN COAL MINES PTY LIMITED

MOOLARBEN COAL PROJECT
GROUNDWATER ASSESSMENT

BY

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EXECUTIVE SUMMARY

Groundwater investigations have been carried out to develop an understanding of the groundwater environment in the vicinity of the proposed Moolarben Coal Project, and to make an assessment of the potential impacts of the project on the groundwater resources and existing groundwater users including groundwater dependent ecosystems.

It is proposed to develop three open cut mines (Open Cuts 1 to 3) and an underground mine (Underground 4), within EL6288, which is located about 40 km north of Mudgee in central western New South Wales. Coal will be recovered from the Ulan coal seam, which is the lowermost and most significant of the coal seams in the Permian Illawarra Coal Measures in the western coalfields.

The Permian coal measures occur in outcrop in the southern part of EL6288, and dip to the north-east, being progressively overlain by increasing thickness of Triassic Narrabeen Group sediments. The Permian coal measures are underlain by Early Permian Shoalhaven Group, and in turn by volcanic and granitic basement rocks.

Open Cuts 1 to 3 are located in the southern part of EL6288, where the Ulan seam is relatively shallow. The open cuts are bounded on their western side by the outcrop limit, and on the eastern side by increasing cover depth.

Underground 4 is located in the northern part of the EL area, which is characterised by increasing overburden cover depth. Underground 4 is bounded to the west and north by Goulburn River, to the east by the Goulburn River National Park and to the south by the alluvial valley of Bora Creek. The existing Ulan open cut and underground mines are located to the west of Moolarben's Underground 4.

Quaternary alluvium is present in association with the Moolarben Creek and Lagoon Creek catchment which drains the south-western part of the area, and flows northwards to become the Goulburn River. Goulburn River then flows northwards across firstly Permian and then Triassic rocks with limited associated alluvium, before heading east through the Goulburn River National Park area.

There is also an apparently west-flowing Tertiary paleochannel alluvium, remnants of which have been identified by drilling in two locations, one adjacent to Moolarben Creek and the other beneath Bora Creek. The Tertiary paleochannel is up to 48 m deep, and appears to be unconnected hydraulically with the present drainage system or the Quaternary alluvium.

Groundwater occurs within most lithologies represented in the area. The principal aquifer is the Ulan seam and other parts of the Permian coal measures sequence, with mainly secondary permeability due to fracturing, jointing and cleats within the coal. Other useful aquifers include the Triassic Narrabeen Group and weathered granite basement. Minor groundwater potential also exists in the Quaternary and Tertiary alluvium.

Six regional hydrogeological units are identified:

- Quaternary alluvium
- Tertiary alluvium
- Triassic Narrabeen Group
- Permian Coal Measures, including the Ulan Seam
- Permian Shoalhaven Group
- Basement granite and volcanics.

Additionally, there are a large number of natural springs and seepages throughout the area, some of which have been developed for water supplies with modest yields. A number of farm dams are also believed to be at least partly groundwater-fed. The springs, seepages and groundwater-fed dams are believed to be part of a surficial groundwater system, which is quite shallow and blankets the hard rock units. It is locally recharged by rainfall infiltration and is closely related to the surface drainage system, and is largely unrelated to the underlying Triassic and Permian aquifer systems.

The groundwater investigation commenced with a census of bores, wells, springs/soaks and groundwater-fed dams, and a search of the DNR groundwater bore database, to establish existing groundwater use in the area. A network of 42 piezometers was installed across the study area, establishing an effective geographic spread of monitoring points in the major hydrogeological units. An ongoing baseline monitoring program was implemented, comprising monthly measurements of water levels and three-monthly sampling of groundwater for laboratory analysis from all piezometers. Finally, four test production bores were constructed, and extended pumping tests carried out to determine aquifer hydraulic properties. Short pumping tests were also carried out on the piezometers.

The groundwater investigation has been integrated with parallel studies undertaken by other specialists, especially those relating to surface water, terrestrial and aquatic ecology, and underground mine subsidence.

Within the main Permian coal measures aquifer, groundwater flows generally to the north-east, although the flow pattern has been disturbed by an extensive depression in groundwater levels around the Ulan coal mines. Groundwater levels range from 500 mAHD in the south-west to 380 mAHD at the northern end of EL6288.

Dewatering will be required to enable the Moolarben mining project to take place, as the Ulan Seam is generally below the water table. However, the Ulan seam is only partly saturated across most of Open Cuts 1 and 3, and is virtually dry within Open Cut 2.

Aquifer hydraulic conductivities are quite variable, as the permeability is fracture related, but the average is around 2-3 m/d in the Permian coal measures, which is about 1-2 orders of magnitude higher than in either the alluvium and basement units.

Groundwater quality is good in the northern part of EL6288, with low salinity (less than 600 mg/L total dissolved solids) and neutral pH, whereas in the southern part of EL6288, quality is more variable, with salinity ranging up to 7000 mg/L, and pH varying between about 3 and 7. Thus the quality of groundwater inflows to Underground 4 is expected to be generally good, while inflows to Open Cuts 1 and 2 is expected to be variable to poor.

A numerical groundwater model of the groundwater system was set up, using MODFLOW software. The model was first calibrated against the present distribution of groundwater levels, and was then used to simulate the proposed mining operation to enable prediction of potential impacts of the project on the groundwater, surface water, existing users and groundwater dependent ecosystems. A model simulation of the mining operation was run for the proposed 15 year project life, and for a period of 45 years after project completion to predict the post-project recovery of groundwater levels.

Ongoing independent review and final endorsement of the groundwater modelling was provided by Dr Noel Merrick, Director of the National Centre for Groundwater Management.

Using the groundwater model, it is predicted that groundwater inflows to the Underground 4 mine will range from 0.3 ML/d in Year 1 to 6.5 ML/d in the final year of mining. Groundwater inflow rates to the open cuts are predicted to be much lower, ranging up to 0.4 ML/d in Open Cut 1 and less than 0.1 ML/d in Open Cut 3, with negligible inflows to Open Cut 2.

The predicted total inflows are sufficient to meet the project’s water demand in Years 2 and 12 to 16. In other years there will be a shortfall, which reaches a maximum of 5.8 ML/d in Year 9, which will be met by sourcing water from adjacent mines if available, or otherwise by pumping from up to 16 dewatering/water supply bores located along the eastern boundary of Underground 4. Testing has indicated that individual bore yields of 0.3-0.4 ML/d are sustainable, and that a borefield could sustain a total production rate of at least 7ML/d.

The model-predicted groundwater level impacts include extensive lowering of groundwater levels in the Ulan seam, and to a lesser extent in the overlying coal measures. Drawdown impacts due to the Moolarben project are predicted to extend a distance of approximately 20 km by the completion of mining, with drawdown of about 5 m in the Ulan Seam 10 km east of Underground 4, and about 0.5 m in the upper section of the Permian coal measures at this same distance.

Minimal impact on the overlying Triassic aquifer system is predicted, with a maximum drawdown of between 0.4 and 0.5 m in a region to the east of Underground 4. No drawdown impact is predicted to occur in the Quaternary or Tertiary alluvium.

Based on post-project recovery modelling, groundwater levels in the Permian coal measures are predicted to have fully recovered within 10-20 years after project completion. A small residual drawdown of up to about 3 m is predicted to remain within the Triassic Narrabeen Group aquifer system at 45 years after completion.

Five seeps and/or groundwater-fed dams within or close to the open cut footprints will be lost as a result of the project. A further 19 groundwater-fed dams or soaks, located within Murragamba Valley, are within an area where the Permian coal measures aquifer is predicted to become dry during the mining operation, but is expected to recover fully after project completion. They may dry up temporarily as a result, although it is believed that they are more likely to be fed by the surficial aquifer system, which is believed to be unconnected with the underlying deeper Permian aquifer, and may therefore remain unaffected.

The licensed potable/fire water supply bore used by UCML, which is believed to be located above the Underground 4 mine area, is expected to be significantly impacted by the Moolarben dewatering. An additional drawdown of 30 m is predicted. A number of UCML monitoring bores located west of Underground 4 are also predicted to experience additional drawdowns of between 18 and 44 m.

Two licensed domestic bores which are drawing water from the Triassic Narrabeen Group aquifer system could be minimally affected by the drawdown impacts from the mining project. Additional drawdowns of up to 0.2 m and 1.8 m are predicted at the Elward and Mullins-Imrie bores respectively.

Strata Engineering have predicted that subsurface cracking from the goaf zone in Underground 4 may extend up to about 50 to 75 m above the longwall panels, with a 5 percent chance that continuous cracking might extend as high as 75 to 90 m, ie to close to the base of the Triassic sediments in the northern part of Underground 4. Sub-surface cracking is not expected to extend fully to the surface or to connect with surface cracking, except possibly at the very southern end of Underground 4, where the overburden cover depth is less.

The subsurface cracking is expected to enhance permeability within the Permian coal measures in the zone of continuous cracking above the goaf, but is not expected to affect the permeability of higher coal measures or the overlying Triassic. Nor is subsurface cracking expected to affect the Drip, and other similar springs and seepage zones along the Goulburn River, which are derived from perched aquifers within the Triassic sequence and are totally reliant on rainfall infiltration above and up-gradient of the seep zones.

Surface cracking within the subsidence zone above Underground 4 may impact on one ephemeral spring/seepage near the northern end of the mine. Any impact is likely to be a re-routing of subsurface flow leading to emergence at a different location than at present. Similar springs and seepages nearby, including the Drip, will be unaffected by surface cracking, as they are located outside the subsidence zone.

Small final pit voids will remain at the northern end of Open Cut 1 and the southern end of Open Cut 3. The Open Cut 1 void is expected to extend to more than 40 m below pre-mining groundwater level. It is proposed to use this void for storage of water derived from underground inflows in excess of project water requirements in the later years of the project, after first sealing the Ulan Seam outcrop around the void to limit recirculation of this water back downdip to the underground workings.

The Open Cut 3 final void is expected to extend no more than 5 m below the pre-mining groundwater level, and due to evaporative effects is unlikely to result in a permanent water body.

A robust ongoing monitoring program of groundwater level and groundwater quality monitoring has been recommended. In addition, a subsidence monitoring program has been recommended to monitor the development of both surface and subsurface cracking above the longwall panels of Underground 4, and to detect any impacts on groundwater levels and quality.

Mitigation and response measures have also been outlined in the report.

It has also been recommended that periodic reviews of the project impacts and performance of the groundwater management program be carried out, including a post-audit review of the performance of the groundwater flow model two years after project commencement and every five years thereafter.

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1 INTRODUCTION

The Moolarben Coal Project area (EL 6288) is located east of the village of Ulan in NSW in the Western Coal Fields of New South Wales, around 40 km north of Mudgee and 25km east of Gulgong. Immediately west of EL6288 is the existing Ulan Coal Mine and to the east is the Wilpinjong Coal Mine which is currently under construction.

Moolarben Coal Mines Pty Ltd is proposing the development of a coal mining project within EL 6288. The proposed project will comprise a series of open cut and underground mines together with a coal preparation plant, coal handling and storage facilities, rail loop and train loading system, and associated mine infrastructure and services. The development of the mines will be staged, and open cut and underground mines will operate concurrently.

EL6288 covers 11,000ha (110 km^2) and comprises Coal Authorisation A309, the northwest portion of A449, the eastern residual area of A428, plus untitled ground between the Ulan Colliery holding and A309.

EL6288 is characterised by substantial topographic relief, with the land elevation ranging from approximately 370m RL in the Goulburn River valley to 600m RL on the ranges. Goulburn River runs through the north of EL6288, and forms a natural extraction limit for the coal resource.

Landforms in the southern half of EL6288 comprise forested upland ridges, dissected plateaus, and lowlands consisting of cleared valleys of Moolarben, Lagoon, Murragamba and Bora Creeks. The northern half of EL6288 comprises largely forested upland ridges and dissected plateaus, with limited cleared lowland areas associated with Goulburn River and its tributary streams.

The major commercial activities are farming and underground and open-cut coal-mining. The valley floors support agricultural activity, which includes sheep and cattle grazing, some lucerne cultivation and apiaries. Adjoining national parks include the Goulburn River National Park to the northeast and the Munghorn Gap Nature Reserve to the southeast.

Three open cut mine areas (Open Cuts 1, 2 and 3) are proposed for development. The open-cut mine pit limits are defined by physical constraints (cover depth to the east), economic constraints (including the Gulgong to Sandy Hollow rail line and the Ulan-Cassilis Road to the north, and Moolarben Creek to the south-east) and geological constraints (edge of the sedimentary basin to the west and wash-outs and sub-crops internally). All proposed open cut areas are bounded on the eastern side by increasing overburden cover.

The Underground 4 mine limits are defined by both surface constraints (principally Goulburn River and the boundary of the Goulburn River National Park) and depth of cover.

2 GROUNDWATER INVESTIGATIONS

2.1 Summary

A series of piezometers were installed across EL6288, to enable separate sampling, testing and monitoring of the target Ulan coal seam and other important hydrogeological units, and to provide a broad network of test and monitoring sites both within and outside the proposed mining areas.

Most piezometers were installed in existing exploration drill-holes. However, in some areas where coal exploration drillholes were not available, particularly in the northern half of EL6288, new bores were specifically drilled for the piezometer installations. Each piezometer was designed with a gravel-packed screen at a specific depth interval, with an annular seal above and below, to enable the specific screened zone to be separately sampled and tested.

A hydraulic testing program was carried out on the piezometers, comprising either slug tests or short duration pumping tests with low capacity sampling pumps, to determine aquifer hydraulic conductivity (permeability).

Four test bores were also constructed at three sites to provide hydraulically efficient bores that could be pumped for longer duration and at higher pumping rates than could be achieved using the sampling pumps in piezometers. These were test pumped for periods of either 2 or 3 days, at pumping rates likely to be required for both dewatering and water supply purposes. The test bores are suitably constructed for use in the coal project as dewatering and/or water supply bores.

An ongoing groundwater baseline monitoring program has been established, involving both water levels and water quality.

Groundwater levels have been measured monthly in all piezometers and tests bores since installation, to assess the fluctuations in groundwater levels, and responses to recharge and natural discharge processes.

Water samples have been collected from each piezometer quarterly following installation. The samples are submitted to a NATA-registered laboratory for comprehensive analysis of the major physical and inorganic parameters, nutrients, and a screening suite of heavy metals.

A field census of existing known bores, wells, springs, soaks and possible spring-fed dams was conducted in the project area. Landholders within the range of potential impact from the project were approached to determine any current or past use of groundwater, and other natural expressions of groundwater on their properties, such as springs.

The locations of all investigations (piezometers, test bores and census locations) are shown on **Figure 1**.

2.2 Census of Existing Groundwater Occurrences

A field census of existing known bores, wells, springs, soaks and possible spring-fed dams was conducted in the project area.

Each landholder within and close to the proposed development area was approached to identify all current or past groundwater use on their property, and the location of any known natural springs and soaks. Each site was visited, sampled and photographed, construction and other details provided by the landholder were recorded, and the location and elevation of each site determined by GPS. Measurements of electrical conductivity and pH were made in the field, and a sample collected for more extensive laboratory analysis.

Locations of all sites identified through this survey are shown on **Figure 2**. This figure also shows the elevation of the water level at the site, and the measured EC and pH. Some properties in the central and northern part of EL6288 have not yet been inspected, but it is proposed that the survey will be carried out on all properties, subject to landholder consent, prior to commencement of the project.

The small holdings west of the Mudgee-Cassilis Road were not visited, as these are considered to be well beyond the potential for groundwater impacts from the project. However, a number of probable bores, pumps and windmills observed on these properties from the roadside have also been plotted on **Figure 2**.

All information has been recorded to form a baseline for future monitoring of potential impacts of the proposal. The census locations are summarised in **Appendix A.** The complete records of each census site, including survey details, photographs and water quality details, and presented in Dundon (2006).

2.3 Search of DNR Groundwater Bore Database

A search of DNR's groundwater bore database has revealed the presence of 72 existing registered bores and wells within 10 km of the proposed Moolarben mining area (**Figure 3**).

Summary construction details and other information for each registered bore are presented in **Appendix E**.

2.4 Piezometers

Forty-two (42) piezometers have been installed within the project area. The number and locations of the piezometers are consistent with DNR's groundwater monitoring guideline for mine sites in the Hunter catchment (DIPNR, 2003). Completion details of all piezometers and production bores are listed in **Table 1**. Locations are shown on **Figure 4**.

Piezometers were mostly constructed in an existing coal exploration drillhole, which had generally been drilled at 100 or 125mm diameter. New holes drilled specifically as piezometers were drilled at either 150 mm or 200 mm diameter. 50mm diameter PVC casing was installed, with PVC screens set adjacent to the desired monitoring interval in the bore, the annulus was gravel packed, and a bentonite seal set in the annulus above the screened zone. The rest of the annulus above the bentonite seal was then backfilled with cement grout. 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 designed to establish a geographic spread of monitoring locations across the project area, and also to allow separate monitoring, sampling and testing of aquifers in the Ulan coal seam and in the overburden and underburden sediments. Some were installed at locations within the coal deposit, others at locations outside of it, either up dip (west), down dip (east), or along strike to the north-west and south-east.

A Bore Licence application has been lodged for all piezometers.

Bore logs for the piezometers are presented in **Appendix B**. Pertinent construction details are summarised in **Table 1**.

2.5 Test / Production Bores

Four test / production bores have been constructed at three sites. The test bores were drilled under Bore Licence No 20BL169899, issued under Part 5 of the *Water Act 1912*. Locations are shown on **Figure 4**.

Test bores have been cased with 150mm PVC casing, with PVC screens set at selected depth intervals. The annulus is gravel packed around the screens, and sealed above with a bentonite seal, and above that with cement grout.

The test bores have been constructed so as to be suitable for use during the proposed mining operation as water supply or dewatering bores. All are located outside of areas currently proposed for longwall extraction.

Bore logs for the test bores are included in **Appendix B**. Pertinent construction details are summarised in **Table 1**.

Table 1: Groundwater Monitoring Piezometers and Test Bores

Piezometer / Test Bore	**MGA Coordinates**		**Top of Casing Elevation**	**Ground Level / Concrete**	**Depth Drilled**	**Aquifer Screened**	**Screen Interval**	**Water Quality**		**Water Level Jan- Feb 2006**	
	East	**North**	**(m AHD)**	**(m AHD)**	**(m)**		**(m below GL)**	**TDS (mg/L)**	**pH**	**(m below TOC)**	**(m AHD)**
Existing Bores, Springs:											
Pinemount Spring (OB01)	?	?				?		56	5.4	Flowing	?
Croydon Bore (OB02)	763817.945	6415647.277	495.046			?		1200	7.0	Flowing	495.04
OB03	762806.328	6417649.187	480.082	479.761		?		890	6.8	8.17	471.91
OB04	?	?				?		330	3.8	4.91	?
New Piezometers:											
PZ3	762714.340	6417963.684	474.918	474.592	21.35	Ulan Seam	9-15	500	6.1	4.18	470.74
PZ4	762251.428	6416655.068	517.398	517.087	32.35	Ulan Seam	20-26	2700	6.9	Dry	Dry
PZ17	760774.015	6419352.482		472.154	15	Blackmans Flat Fm (below Ulan Seam)	6-9			Dry	Dry
PZ18	760087.773	6422135.904		456.843	15	Ulan Seam and sediments below	6-9	390	4.6	4.37	452.48
PZ30	760007.731	6424852.513	432.928	432.928	30	Conglomerate (below Ulan Seam)	18-24	420	6.2	23.36	409.57
PZ31A	759547.262	6423722.850	456.794	456.794	30	Conglomerate (below Ulan Seam)	18-24			Dry	Dry
PZ39	763831.926	6424258.593	428.385	428.101	90.35	Ulan Seam overburden	57-60	300	6.0	10.14	418.25
PZ40A	763928.968	6423745.494		428.270	45	Ulan Seam overburden	38-44		5.7	9.00	419.27
PZ40B	763928.490	6423743.303		428.404	15.7	Weathered Ulan Seam overburden	9-15	250	6.3	8.51	419.89
PZ41A	763517.558	6423253.587		432.595	80.8	Conglomerate (below Ulan Seam)	77-80	3400	6.3	65.90	366.70
PZ41B	763522.980	6423258.223		432.773	69.8	Ulan Seam	66-69	2300	7.1	7.96	424.81
PZ43A	760457.765	6417102.236		510.408	30	Ulan Seam overburden	26-29	1500	6.6	20.27	490.14
PZ43B	760455.992	6417101.625		510.385	19	Weathered Permian sediments above Ulan Seam	15-18	3000	4.1	16.45	493.94
PZ44	759906.057	6417069.043		491.300	24	Ulan Granite	20-23	2300	6.5	11.25	480.05
PZ50A	762532.160	6422847.539	449.758	449.468	70	Ulan Seam	63-69	1300	7.6	61.78	387.98
PZ50B	762531.073	6422847.795	449.871	449.544	45	Ulan Seam overburden	38-44	1300	7.6	17.66	432.22
PZ50C	762530.083	6422848.307	449.632	449.492	12	Alluvium	8-11	990	7.5	10.06	439.77
PZ52	764832.176	6425912.414	419.560	419.430	39	? Tertiary paleochannel alluvium	24-30	270	6.6	1.65	417.91
PZ53	761716.526	6425481.291		446.915	51	Ulan Seam overburden	47-50	490	7.5	47.20	399.72
PZ55	758772.967	6423995.287		429.464	15.1	Alluvium	11-14	350	6.7	7.31	422.16
PZ58	761616.387	6418359.992	478.083	477.847	12	Alluvium	8-11	7800	4.9	10.21	467.88
PZ72A	764661.286	6415236.131		509.982	35.9	Ulan Seam overburden	27-33	850	7.9	11.91	498.08
PZ72C	764664.197	6415235.074		510.108	14	Alluvium	10-13	2000	7.9	5.67	504.44
PZ74	762689.043	6415585.829		531.221	34.8	Ulan Seam overburden	31-34	3300	7.6	29.79	501.44

Table 1: Groundwater Monitoring Piezometers and Test Bores

Piezometer / Test Bore	MGA Coordinates		Top of Casing Elevation	Ground Level / Concrete	Depth Drilled	Aquifer Screened	Screen Interval	Water Quality		Water Level Jan- Feb 2006	
	East	North	(m AHD)	(m AHD)	(m)		(m below GL)	TDS (mg/L)	pH	(m below TOC)	(m AHD)
PZ101A	762654.823	6431452.031	403.465	402.418	131	Ulan Seam	120-129	720	8.5	36.75	374.72
PZ101B	762645.956	6431445.472	403.284	402.591	60	Ulan Seam overburden	54-60	580	8.0	39.02	364.27
PZ102A	761117.858	6429149.821	408.537	408.027	128	Permian sediments below Ulan Seam	116-125	430	8.3	52.67	355.87
PZ102B	761116.747	6429146.759	408.229	407.767	86	Ulan Seam	80-86	600	7.9	52.97	355.26
PZ103AR	762409.96	6429260.850	425.205	425.115	128	Ulan Seam	118-127	270	8.1	68.79	356.42
PZ103B	762397.25	6429264.130	425.000	424.850	87	Ulan Seam overburden	81-87			55.85	369.15
PZI04	766831.511	6426451.205	438.919	438.577	160	Ulan Seam	151-160	410	7.7	58.67	380.25
PZ105A	763988.151	6431610.057	388.934	388.490	115	Ulan Seam overburden	87.5-96.5	270	7.8	29.38	359.23
PZ105B	763986.588	6431606.567	389.052	388.736	64	Ulan Seam overburden	58-64	240	7.4	11.92	377.13
PZ106A	765127.853	6418274.794	510.687	510.492	131.5	Ulan Seam overburden	87.5-96.5	400	7.7	83.12	427.57
PZ106B	765124.096	6418279.022	510.907	510.718	41	Weathered Ulan Seam overburden	29-35	480	7.4	7.90	503.01
PZ107	762812.568	6419869.062	499.361	498.998	125	Ulan Seam	78-80	360	7.0	66.65	432.71
PZ108R	763133.682	6434792.879	419.463	419.366	227	Ulan Seam overburden	221 - 227	150	6.7	86.41	333.05
PZ109	766122.993	6435558.148	437.115	436.983	254	Ulan Seam overburden	246-252	330	9.5	52.68	384.44
PZ110	762001.817	6427216.372	428.717	728.387	134.5	Ulan Seam floor Shoalhaven Group	100.5 – 103.5 (108.5 – 111.5 (117.5 – 120.5 (126.5 – 129.5	480	6.0	62.49	366.23
PZ111	767081.925	6423095.507	404.783	404.553	83	Ulan Seam	71 - 77	650	6.6	25.00	379.78
PZ112A	766136.870	6419519.476	485.643	485.403	93	Ulan Seam	84 - 90	1400	6.6	93.75	391.89
PZ112B	766138.611	6419516.567	485.674	485.294	12	?Alluvium	6 - 12	4300	5.5	5.08	480.59
Test Production Bores:											
TB52A	764822.839	6425907.571	419.279	419.226	112	Ulan Seam overburden Ulan Seam	47-53 108-114	180	6.5	11.84	407.44
TB52B	764824.876	6425910.631	419.456	419.231	38	Alluvium	31-37	78	6.1	2.79	416.64
TB103	762415.44	6429260.680	425.195	424.925	100	Ulan Seam overburden	76-79 82-85 94-97	290	7.3	55.93	369.27
TB105	763980.813	6431610.839	388.780	388.600		Ulan Seam overburden Ulan Seam	78-84 126-132	310	6.9	29.25	359.53

2.6 Groundwater Levels

Groundwater levels have been monitored monthly in all piezometers, commencing in February 2005 with the first piezometers installed. Water level hydrographs are shown in **Appendix C**.

Most hydrographs have shown limited change in groundwater level with time, as illustrated by **Figure 5**, which is a composite plot of piezometer hydrographs. However, several bores show some change with time.

At sites where two or more piezometers have been installed, the shallower piezometer usually reports a higher water level than the deeper piezometer, viz:

- PZ41A-B (**Figure 6**) which show a markedly higher water level in the Ulan Seam than in the immediately underlying sediments;
- PZ50A-C, where the three piezometers installed in the Ulan Seam, the Ulan overburden and the shallow alluvium respectively, show progressively higher water levels (**Figure 6**);
- PZ52 and TB52A-B (**Figure 7**) showing groundwater levels higher in the Tertiary paleochannel alluvium than in the underlying Permian;
- PZ72A-C (**Figure 7**) showing a higher water level in the Recent alluvium than in the underlying Permian; and
- PZ103A-B and TB103 (**Figure 8**), and PZ105A-B and TB105 (**Figure 8**) and PZ106A-B (**Figure 8**), all of which show the same pattern of lower water levels at depth.

However, the hydrographs for piezometers PZ40A-B (**Figure 9**) and PZ102A-B (**Figure 9**) show the opposite trend, with higher water levels observed in the deeper piezometers. In the case of PZ102A and B, it is likely that the groundwater level in the Ulan seam (PZ102B) is depressed relative to the underlying coal measures due to the impacts of dewatering at the Ulan coal mine to the west.

The head difference between piezometers in the Ulan Seam and the rest of the Permian sediments is generally not very great, indicating a reasonable degree of hydraulic interconnection within the Permian Coal Measures sequence.

However, there appears to be a lack of hydraulic interconnection between the Coal Measures and the underlying Shoalhaven Group sediments. The water level in PZ41A is almost 60m higher than the water level in PZ41B, even though the two piezometers are located just metres apart and with a stratigraphic difference of only 8m between the intervals screened in the two bores. PZ41A is screened at 66-69m in the Ulan Seam (water level 425m AHD), while PZ41B is screened at 77-80m in the immediately underlying Conglomerate (water level at 366m AHD). The substantial head difference indicates a lack of hydraulic interconnection between the Ulan Seam and the underlying sediments (see **Figure 6**, and **Figure C9** in **Appendix C**).

A contour plan of groundwater levels within the Ulan Coal Seam across the project site is presented on **Figure 10**. The contours have been extended to incorporate the Ulan Coal Mines monitoring data, incorporating the most recent data available from UCML's 2005 Annual Environmental Management Report (UCML, 2006). Groundwater level contours from the Wilpinjong EIS (Resource Strategies, 2005) have also been incorporated in **Figure 10**.

Groundwater levels from the Ulan Seam and the immediate roof sediments have been used to construct these contours. Groundwater levels in these units are reasonably consistent, suggesting reasonable hydraulic continuity within the Permian coal measures. In most locations, the groundwater levels are quite different in the underlying Shoalhaven Group sediments beneath the Ulan Seam, and likewise in the overlying Triassic and Tertiary/Quaternary alluvium units.

Groundwater level contours for the near surface groundwater system, incorporating groundwater in the alluvium and the shallow weathered bedrock zone, have been constructed largely from the springs and soaks identified in the groundwater census. These contours are presented on **Figure 11**. They show a general conformance with the surface topography, and are clearly unrelated to the groundwater contours in the deeper Permian coal measures.

2.7 Hydraulic Testing

A hydraulic testing program was carried out on the piezometers, comprising either slug tests or short duration pumping tests using low capacity sampling pumps, to determine aquifer hydraulic conductivity values. The piezometer pumping tests were all of relatively short duration, mostly 60 minutes, with one test lasting 120 minutes. These tests were adequate for determining site-specific aquifer hydraulic properties, but were too short to evaluate aquifer geometry or regional hydraulic continuity.

Longer duration pumping tests were carried out on the four test/production bores using a higher capacity submersible pump, with the tests lasting for up to 4320 minutes (72 hours) duration.

Details of the hydraulic testing program carried out are summarised in **Table 2**. The results of all tests are presented in **Appendix D**.

Table 2: Hydraulic Testing Program – Piezometers and Test Bores

Piezometer / Test Bore	Screened Interval	Aquifer	Date of Test	Type of Test	Pumping Rate kL/d	Duration	Transmissivity m^2/d	Average Hydraulic Conductivity m/d	Average Hydraulic Conductivity m/s	Comments
Test / Production Bores:										
TB52A	47 – 53	Ulan Seam overburden	27 February 2006	Constant Rate	345	480 min	40	3.3	3.9 x 10^{-5}	Single boundary effect
				Recovery			40	3.3	3.9 x 10^{-5}	
	108 – 114	Ulan Seam	3 March 2006	Constant Rate	345	2880 min	35	2.9	3.4 x 10^{-5}	Multiple boundary effects
				Recovery			37	3.1	3.6 x 10^{-5}	
TB52B	31 – 37	Tertiary paleochannel alluvium	22 February 2006	Constant Rate	175	420 min	6.1	1.0	1.2 x 10^{-5}	
				Recovery			6.1	1.0	1.2 x 10^{-5}	
TB103R	76 – 79 82 – 85 94 – 97	Ulan Seam overburden	24 February 2006	Constant Rate	300	2880 min	38	4.2	4.9 x 10^{-5}	Multiple boundary effects
TB105	78 – 84 126 – 132	Ulan Seam overburden Ulan Seam	3 March 2006	Constant Rate	345	4320 min	45	3.8	5.8. x 10^{-5}	Multiple boundary effects and leakage
Piezometers:										
PZ3	9 – 15	Ulan Seam	-							Inaccessible for testing
PZ4	20 – 26	Ulan Seam	-							Dry
PZ17	6 – 9	Blackmans Flat Fm	-							Dry
PZ18	6 – 9	Ulan Seam and floor	-							
PZ30	18 – 24	Cgl	1 April 2006	Constant Rate	?	35 min	?	?	?	
PZ31A	18 – 24	Cgl								Dry
PZ39	57 – 60	Ulan Seam overburden	4 April 2006	Constant Rate	13.3	180 min	3.0	1.0	1.2 x 10^{-5}	
				Recovery			3.5	1.2	1.4 x 10^{-5}	
PZ40A	34 – 44	Ulan Seam overburden	3 November 2005	Slug	-	-	-	14	3.5 x 10^{-4}	
PZ40B	9 – 15	Weathered Ulan Seam overburden	3 November 2005	Constant Rate	9.9	64 min	0.22	0.04	4.2 x 10^{-7}	
							1.6	0.3	3.1 x 10^{-6}	
				Recovery			0.18	0.03	3.5 x 10^{-7}	
							2.25	0.4	4.3 x 10^{-7}	

Table 2: Hydraulic Testing Program – Piezometers and Test Bores

Piezometer / Test Bore	Screened Interval	Aquifer	Date of Test	Type of Test	Pumping Rate	Duration	Transmissivity	Average Hydraulic Conductivity	Average Hydraulic Conductivity	Comments
					kL/d		m^2/d	m/d	m/s	
PZ41A	77 – 80	Cgl	8 December 2005	Slug	-	-	-	0.06	7.4 x 10^{-7}	
PZ41B	66 – 69	Ulan Seam	8 December 2005	Constant Rate	16	70 min	17	5.7	6.6 x 10^{-5}	? Delayed yield effect
PZ43A	26 – 29	Ulan Seam overburden	7 December 2005	Constant Rate	9.1	30 min	3.3	1.1	1.3 x 10^{-5}	
PZ43B	15 – 18	Weathered Ulan Seam overburden	7 December 2005	Slug	-	-	-	0.19	2.2 x 10^{-6}	
PZ44	20 – 23	Ulan Granite	7 December 2005	Constant Rate	11	30 min	0.8	0.3	3.1 x 10^{-6}	
PZ50A	63 – 69	Ulan Seam	11 April 2006	Slug	-	-	-	0.05	6.2 x 10^{-7}	
PZ50B	38 – 44	Ulan Seam overburden	3 March 2006	Constant Rate	9.6	180 min	2.5	0.4	4.9 x 10^{-6}	
PZ50C	8 – 11	Alluvium	11 April 2006	Slug	-	-	-	1.4	1.7 x 10^{-5}	
PZ52	24 – 30	Tertiary paleochannel alluvium	8 December 2005	Constant Rate	16	30	1.5	0.25	2.9 x 10^{-6}	
PZ53	47 – 50	Ulan Seam overburden	9 April 2006	Slug	-	-	-	4.0	4.8 x 10^{-5}	
								0.2	1.9 x 10^{-6}	
PZ55	11 – 14	Alluvium	1 April 2006	Slug	-	-	-	0.9	1.0 x 10^{-5}	
								0.3	3.3 x 10^{-6}	
PZ58	8 – 11	Alluvium	7 December 2005	Slug	-	-	-	0.21	2.5 x 10^{-6}	
								0.05	5.7 x 10^{-7}	
PZ72A	27 – 33	Ulan Seam overburden	11 April 2006	Constant Rate	8.6	120 min	8.3	1.4	1.6 x 10^{-5}	
				Recovery			10	1.7	2.0 x 10^{-5}	
PZ72C	10 – 13	Alluvium	31 March 2006	Constant Rate	16.0	180 min	6.1	2.0	2.4 x 10^{-5}	
				Recovery			9.2	3.0	3.5 x 10^{-5}	
PZ74	31 – 34	Ulan Seam overburden	-							
PZ101A	120 – 129	Ulan Seam	7 December 2005	Slug	-	-	-	?		
PZ101B	54 – 60	Ulan Seam overburden	7 December 2005	Slug	-	-	-	0.006	6.8 x 10^{-8}	
PZ102A	116 – 125	Ulan Seam overburden	7 December 2005	Slug	-	-	-	0.22	2.6 x 10^{-6}	
PZ102B	80 – 86	Ulan Seam	7 December 2005	Slug	-	-	-	11	1.2 x 10^{-4}	
								0.18	2.1 x 10^{-6}	

Table 2: Hydraulic Testing Program – Piezometers and Test Bores

Piezometer / Test Bore	Screened Interval	Aquifer	Date of Test	Type of Test	Pumping Rate	Duration	Transmissivity	Average Hydraulic Conductivity	Average Hydraulic Conductivity	Comments
					kL/d		m^2/d	m/d	m/s	
PZ103AR	118 – 127	Ulan Seam	8 April 2006	Slug	-	-	-	0.5	5.9 x 10^{-6}	
PZ103B	81 – 87	Ulan Seam overburden	8 April 2006	Slug	-	-	-	0.0003	3.0 x 10^{-9}	
PZI04	151 – 160	Ulan Seam	8 December 2005	Slug	-	-	-	0.29	3.3 x 10^{-6}	
PZ105A	87.5 – 96.5	Ulan Seam overburden	4 April 2006	Slug	-	-	-	?	?	
PZ105B	58 – 64	Ulan Seam overburden	29 March 2006	Constant Rate	12	180 min	0.5	0.09	1.0 x 10^{-6}	
				Recovery			1.7	0.3	3.4 x 10^{-6}	
PZ106A	87.5 – 96.5	Ulan Seam overburden	8 April 2006	Slug	-	-	-	0.005	6.0 x 10^{-8}	
PZ106B	29 – 35	Weathered Ulan Seam overburden	30 March 2006	Constant Rate	15	180 min	5	0.8	9.6 x 10^{-6}	
				Recovery			6.1	1.0	1.2 x 10^{-5}	
PZ107	78 – 80	Ulan Seam	8 April 2006	Slug	-	-	-	0.13	1.6 x 10^{-6}	
								0.03	3.6 x 10^{-7}	
PZ108R	221 – 227	Ulan Seam overburden	9 April 2006	Slug	-	-	-	0.004	4.9 x 10^{-8}	
PZ109	246 – 252	Ulan Seam overburden	8 April 2006	Slug	-	-	-	0.26	3.0 x 10^{-6}	
			8 April 2006	Slug	-	-	-	0.3	3.5 x 10^{-6}	
PZ110	100.5 – 103.5 108.5 – 111.5 117.5 – 120.5 126.5 – 129.5	Ulan Seam Sst	23 May 2006	Slug	-	-	-	6.8	8 x 10^{-5}	
PZ111	71 – 77	Ulan Seam	23 May 2006	Constant Rate	9	100 min	3.0	0.5	6 x 10^{-6}	
				Recovery			3.7	0.6	7 x 10^{-6}	
PZ112A	84 – 90	Ulan Seam	-							
PZ112B	6 – 12	Alluvium	-							

2.8 Water Sampling and Analysis

Water samples have been collected routinely from all piezometers and test bores quarterly since each bore was completed. The first sampling was carried out in February 2005.

Electrical conductivity (EC) and pH were measured in the field at the time of sampling, and the collected samples were submitted to Ecowise Environmental’s NATA-registered laboratories in Mudgee and/or Canberra. The laboratory analysis comprised physical properties, the major cations and anions, nutrient parameters and a screening suite of heavy metals. The laboratory results are presented in **Table 3**.

Table 3: Groundwater Sample Laboratory Analysis Results
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Bore / Well / Spring / Soak				PZ03						PZ04						PZ18					
Parameter	Units	LOR	ANZECC (2000) Guideline Value for Freshwater Ecosystem Protection	25-Feb-05 1150	24-May-05 1045	31-Aug-05	21-Nov-05	03-Mar-06	29-May-06	25-Feb-05 1125	23-May-05 1730	31-Aug-05	21-Nov-05	03-Mar-06	29-May-06	11-Mar-05 1530	24-May-05 1350	31-Aug-05	21-Nov-05	03-Mar-06	29-May-06
pH Value (field)		0.01		6.90	6.40	6.30	6.20	7.20	6.10	7.20	6.70	7.40	6.80	8.00	6.90	4.40	3.90	4.10	4.60	4.20	4.60
pH Value (lab)																					
Conductivity (field)	µS/cm	0			1930	1890	1800	1440	1160		4540	4350	4670	4590	4430		1060	440	670	490	480
Conductivity @ 25°C	µS/cm	1		1700	1700	1700	1600	1300	1000	4400	4300	4200	4300	4300	4300	600	960	410	520	400	450
Total Suspended Solids (TSS)	mg/L	2			11		33	14	9		15		72	52	72		15		120	73	350
Total Dissolved Solids (TDS)	mg/L	1		1000	980	950	880	640	500	2900	2700	2700	2700	2600	2700	500	570	490	600	500	390
Calcium	mg/L	1		56	57	55	50	9.4	4.7	180	170	160	150	160	160	0.3	0.4	0.2	0.9	0.4	1.2
Magnesium	mg/L	1		63	70	66	66	40	27	210	210	210	200	210	200	8.4	14	4.3	8.2	5.6	5.6
Sodium	mg/L	1		160	160	180	170	150	120	330	440	430	440	400	460	80	130	56	73	68	64
Potassium	mg/L	1		15	16	13	14	8.1	6.8	72	68	55	63	64	65	2.7	4	1.6	2.4	1.9	2
Hydroxide as CaCO3	mg/L	1																			
Carbonate as CaCO3	mg/L	1		<1	<1	<1	<2	<2	<2	<1	<1	<1	<2	<2	<2	<1	<1	<1	<2	<2	<2
Bicarbonate as CaCO3	mg/L	1		366	361	338	340	120	100	824	878	804	840	830	820	<1	<1	<1	4	32	5
Chloride	mg/L	1		260	270	220	230	310	240	760	710	860	750	890	760	140	210	82	120	91	110
Sulphate	mg/L	1		130	120	110	120	42	30	440	400	490	430	500	500	46	87	28	55	33	37
Fluoride	mg/L	0.1		0.55	0.58	0.57	0.47	0.22	0.2	0.67	0.69	0.92	0.68	0.79	0.65	0.09	0.1	0.15	0.21	0.16	0.12
Cyanide	mg/L	0.01	0.007	0.04	<0.001	<0.01	<0.01	<0.01	<0.01	0.07	<0.001	<0.01	<0.01	<0.01	<0.01	<0.01	<0.001	<0.01	<0.01	<0.01	<0.01
Aluminium - Filtered	mg/L	0.005	0.055	0.04	<0.005	<0.02	<0.02	<0.02	<0.02	0.31	0.007	0.03	0.03	0.02	<0.02	4.6	0.94	0.48	0.95	0.75	0.35
Arsenic - Filtered	mg/L	0.001	0.013	0.002	<0.001	<0.001	<0.001	<0.001	<0.001	0.005	<0.001	0.001	0.001	<0.001	<0.001	0.017	0.009	0.004	0.003	0.003	0.004
Boron - Filtered	mg/L	0.01	0.37	<0.01	<0.01	0.02	0.01	0.03	0.02	0.08	0.03	0.05	0.04	0.05	0.05	0.05	0.07	0.03	0.1	0.03	0.04
Cadmium - Filtered	mg/L	0.00005	0.0002	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	0.00006	<0.00005	0.00005	0.00008	<0.00005	<0.00005	0.00041	0.0003	<0.00005	<0.00005	0.00011	<0.00005
Chromium - Filtered	mg/L	0.002	ID	<0.002	0.006	<0.002	<0.002	<0.001	0.001	0.013	0.005	<0.002	<0.002	0.001	<0.001	0.002	<0.002	<0.002	<0.002	0.001	0.001
Cobalt - Filtered	mg/L	0.001		0.0005	0.0004	0.0004	0.0027	0.0038	0.0012	0.0066	0.0013	0.0008	0.0022	0.0005	0.0006	0.019	0.043	0.0014	0.0009	0.001	0.0008
Copper - Filtered	mg/L	0.0005	0.0014	<0.002	0.0017	0.001	0.0009	<0.00005	<0.00005	0.002	0.0052	0.0027	0.003	0.0023	0.0022	0.005	0.0014	0.0019	0.0031	0.0022	0.0022
Iron - Filtered	mg/L	0.01	ID	5.2	0.4	0.85	0.65	15	2	0.81	0.11	0.03	<0.01	0.02	<0.01	3.4	5.2	0.68	0.56	0.57	0.66
Lead - Filtered	mg/L	0.00005	0.0034	0.0002	<0.00005	0.00048	0.0036	0.00018	0.00006	0.012	0.0033	0.041	0.017	0.00023	0.05	0.012	0.0052	0.0013	0.015	0.0014	0.012
Manganese - Filtered	mg/L	0.001	1.9	0.19	0.22	0.19	0.38	0.76	0.49	0.77	0.63	0.033	0.46	0.21	0.46	0.017	0.014	0.002	0.006	0.007	0.009
Mercury - Filtered	mg/L	0.0001	0.00006	<0.0001	<0.0001	0.0002	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0002	<0.0001	0.0001	<0.0001	<0.0001	<0.0001	0.0002	<0.0001	<0.0001	<0.0001
Nickel - Filtered	mg/L	0.001	0.011	0.003	0.002	0.002	<0.001	<0.001	<0.001	0.016	0.01	0.008	0.015	0.011	0.016	0.033	0.075	0.004	0.003	0.004	0.002
Selenium - Filtered	mg/L	0.001	0.005	<0.001	<0.001	<0.001	0.002	<0.001	<0.001	0.002	<0.001	<0.001	0.002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Silver - Filtered	mg/L	0.001	0.00005	0.003	<0.001	<0.001	<0.001	<0.001	<0.001	0.008	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Zinc - Filtered	mg/L	0.005	0.008	0.013	0.01	<0.005	0.013	0.013	<0.005	0.081	0.02	0.079	0.069	0.039	0.12	0.16	0.38	0.012	0.18	0.017	0.013
Ammonia as N	mg/L	0.01	0.9	0.19	0.19	0.24	0.22	0.16	0.18	0.51	0.44	0.02	0.01	<0.01	0.02	0.58	0.57	0.37	0.14	0.29	0.35
Nitrate as N	mg/L	0.01	0.7	<0.01	<0.01	<0.01	0.02	0.04	0.01	0.06	<0.01	0.1	0.03	0.06	0.07	<0.01	<0.01	<0.01	0.07	0.02	0.05
Total Nitrogen as N	mg/L			0.25	0.23	0.23	0.42	0.11	<0.5	1.6	0.87	0.36	0.64	0.4	0.29	1.4	0.79	1.2	1.4	1.3	1.5
Reactive Phosphorus as P	mg/L	0.01		0.02	0.01	0.03	<0.01	0.04	<0.01	0.02	0.03	0.02	<0.01	0.03	<0.01	0.02	0.02	0.04	0.02	0.05	0.01
Total Phosphorus as P	mg/L	0.01		0.04	0.05	0.05	0.07	0.05	0.03	0.09	0.05	0.05	0.04	0.1	0.02	0.24	0.04	0.18	0.24	0.17	0.22
Total Anions (reported)	meq/L	0.01				15.20	15.80	12.00	9.39			50.50	46.90	52.00	48.20			2.90	4.64	3.90	3.97
Total Cations (reported)	meq/L	0.01				16.40	15.70	11.30	7.96			45.40	44.70	44.00	46.10			2.93	4.12	3.60	3.43
% Difference (reported)	%	0.01																			
Allowed % Difference	%	0.01																			
Total Cations (calculated)	meq/L	0.01		15.32	15.97	16.34	15.68	10.49	7.85	42.45	46.64	45.37	44.69	44.30	46.11	4.25	6.93	2.84	3.96	3.49	3.36
Total Anions (calculated)	meq/L	0.01		17.35	17.33	15.25	15.78	12.02	9.39	47.07	45.90	50.53	46.90	52.10	48.24	4.93	7.76	2.92	4.61	3.89	3.97
% Difference (calculated)	%	0.01		-6.23%	-4.08%	3.44%	-0.33%	-6.78%	-8.95%	-5.15%	0.79%	-5.38%	-2.41%	-8.10%	-2.26%	-7.32%	-5.63%	-1.31%	-7.63%	-5.51%	-8.43%
Allowed % Difference (calculated)	%	0.01		5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%
Sodium Adsorption Ratio				3.49	3.36	3.87	3.72	4.76	4.71	3.96	5.33	5.26	5.53	4.90	5.72	5.86	7.39	5.71	5.29	6.03	5.46

Table 3: Groundwater Sample Laboratory Analysis Results
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Bore / Well / Spring / Soak				PZ30				PZ39				PZ40A	PZ40B				PZ41A			PZ41B			
Parameter	Units	LOR	ANZECC (2000) Guideline Value for Freshwater Ecosystem Protection	28-Oct-05	20-Nov-05	03-Mar-06	29-May-06	31-Aug-05	21-Nov-05	03-Mar-06	29-May-06	07-Feb-06	31-Aug-05	21-Nov-05	03-Mar-06	29-May-06	28-Oct-05	14-Feb-06	28-Apr-06	31-Aug-05	21-Nov-05	31-Jan-06	28-Apr-06
pH Value (field)		0.01		6.30	6.20	6.20	6.20	6.20	6.20	7.30	6.00	5.70	5.60	6.00	7.10	6.30	6.00	5.00	6.30	6.60	6.20	6.70	7.10
pH Value (lab)																							
Conductivity (field)	µS/cm	0		860	1110	880	950	2190	1430	970	680	1450	590	710	610	600	6590	6470	6100	3070	3270	6810	3770
Conductivity @ 25°C	µS/cm	1		760	760	770	740	2100	1200	830	530		650	570	530	500	5800	6100	6000	2800	2900	6100	3700
Total Suspended Solids (TSS)	mg/L	2		20	170	110	150		39	9	47			130	6	45	22	730	97		69	42	98
Total Dissolved Solids (TDS)	mg/L	1		450	450	440	420	1300	670	420	300		380	300	260	250	3700	3700	3400	1600	1700	3300	2300
Calcium	mg/L	1		53	50	55	51	82	46	35	23		10	11	14	15	150	71	87	46	46	77	59
Magnesium	mg/L	1		11	11	11	11	90	40	25	12		7.9	10	11	11	190	210	210	78	82	210	110
Sodium	mg/L	1		63	64	71	65	160	81	67	43		83	64	61	53	600	720	150	310	320	690	380
Potassium	mg/L	1		18	19	18	18	13	13	10	8.1		5	8.7	11	11	42	41	28	24	27	43	22
Hydroxide as CaCO3	mg/L	1																					
Carbonate as CaCO3	mg/L	1		<2	<2	<2	<2	<1	<2	<2	<2		<1	<2	<2	<2	<2	<2	<2	<1	<2	<2	<2
Bicarbonate as CaCO3	mg/L	1		180	170	180	160	144	120	95	39		23	66	100	95	140	<2	<2	45	29	53	58
Chloride	mg/L	1		98	81	94	97	560	300	210	130		180	130	97	90	1900	1900	2000	900	810	1900	1100
Sulphate	mg/L	1		61	56	61	65	35	13	3	12		8.8	19	11	12	25	140	150	76	85	190	64
Fluoride	mg/L	0.1		0.68	0.7	0.75	0.66	0.34	0.22	0.15	0.12		<0.05	0.13	<0.05	0.11	0.56	0.11	0.09	0.35	0.36	0.15	0.29
Cyanide	mg/L	0.01	0.007	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Aluminium - Filtered	mg/L	0.005	0.055	<0.02	<0.02	0.02	0.02	<0.02	<0.02	<0.02	0.02		<0.02	<0.02	<0.02	<0.02	0.03	<0.02	0.07	<0.02	<0.02	<0.02	0.04
Arsenic - Filtered	mg/L	0.001	0.013	<0.001	0.001	<0.001	<0.001	0.003	<0.001	<0.001	<0.001		0.001	<0.001	<0.001	<0.001	<0.001	0.002	<0.001	<0.001	<0.001	0.011	<0.001
Boron - Filtered	mg/L	0.01	0.37	0.02	0.02	0.04	0.02	0.03	0.01	0.02	0.02		0.02	<0.01	0.03	0.03	0.05	0.06	<0.01	0.06	0.04	0.13	<0.01
Cadmium - Filtered	mg/L	0.00005	0.0002	0.00033	0.00017	0.00008	<0.00005	0.00008	<0.00005	<0.00005	<0.00005		0.00007	<0.00005	<0.00005	<0.00005	<0.00005	0.00028	0.0003	0.00016	<0.00005	<0.00005	<0.00005
Chromium - Filtered	mg/L	0.002	ID	<0.001	<0.002	0.001	<0.001	0.003	<0.002	<0.001	0.001		<0.002	<0.002	<0.001	0.002	0.001	0.001	0.001	<0.002	<0.002	<0.002	0.001
Cobalt - Filtered	mg/L	0.001		0.052	0.0057	0.058	0.044	0.18	0.0008	0.0003	0.0005		0.0065	0.0039	0.0005	0.0004	0.011	0.23	0.18	0.062	0.057	0.13	0.0052
Copper - Filtered	mg/L	0.0005	0.0014	0.0018	0.0005	0.0006	0.0005	0.0017	<0.0005	<0.0005	<0.0005		0.0006	<0.0005	<0.0005	<0.0005	0.0007	0.0052	0.0024	0.0008	0.0006	0.0013	<0.0005
Iron - Filtered	mg/L	0.01	ID	0.09	0.6	16	1.8	4.1	1.6	9	6.9		7	0.48	17	12	11	41	9.2	33	80	130	27
Lead - Filtered	mg/L	0.00005	0.0034	0.0034	0.006	0.0021	0.00029	0.011	0.00083	<0.0005	0.002		0.044	0.00007	<0.00005	0.0009	<0.00005	0.0099	0.034	0.00037	0.00069	<0.00005	<0.00005
Manganese - Filtered	mg/L	0.001	1.9	2.2	2.2	2.2	1.7	3.8	1.5	0.65	0.17		0.18	0.12	0.14	0.15	2.8	3.5	3.5	2.1	2.2	4.3	2.7
Mercury - Filtered	mg/L	0.0001	0.00006	<0.0001	<0.0001	<0.0001	<0.0001	0.0001	<0.0001	<0.0001	<0.0001		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Nickel - Filtered	mg/L	0.001	0.011	0.06	0.063	0.075	0.062	0.07	<0.001	0.002	0.001		0.006	<0.001	0.001	0.001	0.028	0.35	0.25	0.097	0.086	0.2	0.009
Selenium - Filtered	mg/L	0.001	0.005	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Silver - Filtered	mg/L	0.001	0.00005	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Zinc - Filtered	mg/L	0.005	0.008	0.084	0.12	0.08	0.052	0.65	<0.005	0.006	0.018		0.037	0.011	0.006	0.013	0.02	0.61	0.71	0.53	0.035	0.029	0.14
Ammonia as N	mg/L	0.01	0.9	0.29	0.26	0.34	0.29	0.23	0.05	0.13	0.2		0.08	0.07	0.13	0.1	0.16	1.7	1.7	0.85	0.95	1.2	1.1
Nitrate as N	mg/L	0.01	0.7	<0.2	<0.01	0.02	0.03	<0.01	0.01	0.01	0.02		<0.01	<0.01	0.01	0.02	<0.2	<0.01	0.03	<0.01	<0.01	<0.01	<0.01
Total Nitrogen as N	mg/L			0.39	0.47	0.35	0.33	0.34	0.36	0.13	0.37		0.12	0.08	0.13	0.2	0.42	1.8	2.5	0.86	0.62	<2.5	2.6
Reactive Phosphorus as P	mg/L	0.01		0.02	<0.01	0.03	<0.01	0.02	<0.01	0.03	<0.01		0.01	<0.01	0.03	<0.01	0.02	0.01	0.02	0.01	<0.01	0.02	0.02
Total Phosphorus as P	mg/L	0.01		0.03	0.22	0.11	0.03	0.02	0.05	0.02	0.04		0.01	0.14	0.02	0.04	0.04	1.6	0.07	0.08	0.05	<0.01	0.1
Total Anions (reported)	meq/L	0.01		7.60	6.87	7.50	7.29	19.40	11.10	7.90	4.70		5.72	5.37	5.00	4.69	56.90	56.50	59.50	27.90	25.20	58.60	33.50
Total Cations (reported)	meq/L	0.01		6.80	6.72	8.00	6.84	19.00	9.53	7.50	4.59		5.26	4.41	5.40	4.89	51.00	55.40	54.00	24.60	28.00	59.20	32.50
% Difference (reported)	%	0.01																					
Allowed % Difference	%	0.01																					
Total Cations (calculated)	meq/L	0.01		6.75	6.67	7.20	6.74	18.79	9.44	6.97	4.21	0.00	4.89	4.38	4.54	4.24	50.29	53.19	28.86	22.81	23.65	52.23	29.09
Total Anions (calculated)	meq/L	0.01		7.63	6.85	7.52	7.29	19.40	11.13	7.88	4.70	0.00	5.72	5.38	4.96	4.69	56.92	56.55	59.58	27.87	25.20	58.61	33.52
% Difference (calculated)	%	0.01		-6.13%	-1.32%	-2.18%	-3.92%	-1.61%	-8.21%	-6.14%	-5.43%	#DIV/0!	-7.86%	-10.29%	-4.48%	-5.01%	-6.18%	-3.07%	-34.74%	-9.98%	-3.17%	-5.76%	-7.09%
Allowed % Difference (calculated)	%	0.01		2.00%	2.00%	2.00%	2.00%	5.00%	5.00%	5.00%	5.00%	5.00%	2.00%	2.00%	2.00%	2.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%
Sodium Adsorption Ratio				2.06	2.14	2.29	2.15	2.90	2.11	2.11	1.81	#DIV/0!	4.76	3.36	2.96	2.54	7.68	9.71	1.98	6.46	6.55	9.24	6.75

Table 3: Groundwater Sample Laboratory Analysis Results

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Bore / Well / Spring / Soak				PZ43A				PZ43B				PZ44				PZ50A			PZ50B			PZ50C			
Parameter	Units	LOR	ANZECC (2000) Guideline Value for Freshwater Ecosystem Protection	31-Aug-05	21-Nov-05	03-Mar-06	29-May-06	31-Aug-05	21-Nov-05	03-Mar-06	29-May-06	31-Aug-05	21-Nov-05	03-Mar-06	29-May-06	28-Oct-05	07-Feb-06	28-Apr-06	28-Oct-05	07-Feb-06	28-Apr-06	28-Oct-05	21-Nov-05	07-Feb-06	28-Apr-06
pH Value (field)		0.01		6.50	6.70	6.50	6.60	3.80	3.90	3.40	4.10	6.40	6.40	7.50	6.50	6.00	6.10	7.60	6.10	6.20	7.50	6.10	5.70	5.50	7.10
pH Value (lab)																									
Conductivity (field)	µS/cm	0		2900	2760	2810	2640	5090	4920	4390	4790	2930	3200	3150	3170	1340	2170	2420	1410	1470	1610	950	910	870	660
Conductivity @ 25°C	µS/cm	1		2500	2500	2500	2500	5100	4600	4000	4500	2800	2800	2900	2900	1300	2000	2200	1300	1300	1700	730	770	770	640
Total Suspended Solids (TSS)	mg/L	2			56	76	210		270	240	340		60	52	39	180	220	390	79	210	71	89	800	250	260
Total Dissolved Solids (TDS)	mg/L	1		1700	1600	1600	1500	3600	3100	2600	3000	2200	2300	2300	2300	820	1100	1300	790	670	990	380	430	400	320
Calcium	mg/L	1		140	130	140	140	52	22	12	23	450	420	430	480	36	58	67	33	39	61	4.3	3.7	3.1	4.5
Magnesium	mg/L	1		200	170	180	180	190	120	100	130	79	82	88	84	42	85	100	41	44	71	16	17	18	16
Sodium	mg/L	1		110	110	120	110	670	640	610	460	95	97	110	110	100	180	190	120	130	140	93	94	110	82
Potassium	mg/L	1		32	38	38	38	79	73	64	77	41	45	46	46	13	14	12	13	15	12	3.9	3.9	3.6	3.9
Hydroxide as CaCO3	mg/L	1																							
Carbonate as CaCO3	mg/L	1		<1	<2	<2	<2	<1	<2	<2	<2	<1	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Bicarbonate as CaCO3	mg/L	1		602	660	650	660	<1	<2	<2	<2	444	450	440	430	110	380	350	110	240	300	37	33	38	46
Chloride	mg/L	1		510	340	360	350	840	770	810	830	230	290	300	270	270	450	490	250	310	360	180	160	180	140
Sulphate	mg/L	1		420	260	270	270	1500	1000	950	1000	900	1100	1200	1000	69	56	61	62	2	36	43	53	49	38
Fluoride	mg/L	0.1		1.1	0.89	0.9	0.84	1.1	0.63	0.52	0.58	0.3	0.35	0.34	0.26	0.36	0.51	0.44	0.27	0.36	0.35	0.11	0.23	0.15	0.21
Cyanide	mg/L	0.01	0.007	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Aluminium - Filtered	mg/L	0.005	0.055	<0.02	<0.02	0.12	<0.02	16	10	8.1	11	<0.02	<0.02	0.03	<0.02	<0.02	<0.02	0.03	0.03	<0.02	0.03	<0.02	<0.02	<0.02	<0.02
Arsenic - Filtered	mg/L	0.001	0.013	<0.001	0.038	0.02	0.06	0.002	0.004	0.016	0.025	0.003	0.002	0.002	0.007	<0.001	<0.001	0.004	0.001	<0.001	0.002	<0.001	<0.001	<0.001	<0.001
Boron - Filtered	mg/L	0.01	0.37	0.02	0.02	0.02	0.02	0.07	0.05	0.05	0.06	0.02	0.02	0.02	0.01	0.02	0.02	<0.01	0.02	0.02	<0.01	<0.01	<0.01	<0.01	<0.01
Cadmium - Filtered	mg/L	0.00005	0.0002	<0.00005	<0.00005	<0.00005	<0.00005	0.0027	0.0018	0.0014	0.0014	0.00009	<0.00005	<0.00005	<0.00005	0.00011	<0.0005	<0.0005	<0.00005	<0.0005	<0.0005	0.00016	<0.00005	0.00005	<0.00005
Chromium - Filtered	mg/L	0.002	ID	<0.002	<0.002	0.001	0.001	0.004	0.002	0.002	0.003	<0.002	<0.002	0.001	0.001	<0.001	0.002	0.001	<0.001	0.005	0.004	0.001	<0.002	0.001	0.001
Cobalt - Filtered	mg/L	0.001		0.016	0.0011	0.021	0.0009	0.59	0.49	0.27	0.36	0.0021	0.0021	0.0037	0.0013	0.0066	0.0015	0.0006	0.0091	0.0014	0.001	0.0054	0.0042	0.0027	0.0016
Copper - Filtered	mg/L	0.0005	0.0014	0.0007	0.0015	0.0012	0.0012	0.03	0.021	0.019	0.015	0.0006	0.0015	0.002	0.0017	0.0007	0.0008	0.0016	0.0007	<0.0005	<0.0005	0.0026	0.001	0.0013	0.0014
Iron - Filtered	mg/L	0.01	ID	0.01	0.48	3.6	0.07	10	4.1	0.43	5.1	0.01	10	5.9	0.29	1.5	4	0.25	1.4	0.61	6.1	0.09	0.46	0.01	0.06
Lead - Filtered	mg/L	0.00005	0.0034	0.008	0.0056	<0.00005	0.0022	0.54	0.22	0.031	0.12	0.00047	0.0019	0.00026	0.0005	0.00043	0.0033	0.0001	0.00016	0.0025	0.0004	0.0015	0.0054	0.0072	0.0024
Manganese - Filtered	mg/L	0.001	1.9	0.2	0.71	0.58	0.34	0.7	0.32	0.2	0.33	0.48	0.47	0.65	0.59	0.29	0.25	0.21	0.24	0.31	0.29	0.086	0.079	0.044	0.053
Mercury - Filtered	mg/L	0.0001	0.00006	0.0001	<0.0001	<0.0001	<0.0001	0.0001	<0.0001	0.0002	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0002	<0.0001	<0.0001	0.0001	<0.0001	<0.0001	<0.0001	0.0002	<0.0001
Nickel - Filtered	mg/L	0.001	0.011	0.02	0.006	0.042	0.009	0.87	0.65	0.42	0.49	0.002	0.002	0.016	0.018	0.006	0.005	0.004	0.007	0.004	0.004	0.005	0.004	0.003	0.002
Selenium - Filtered	mg/L	0.001	0.005	<0.001	0.002	<0.001	<0.001	0.002	0.004	<0.001	0.002	<0.001	0.002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	0.001	<0.001
Silver - Filtered	mg/L	0.001	0.00005	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Zinc - Filtered	mg/L	0.005	0.008	0.062	0.007	0.005	0.1	3.5	3	2.3	2.8	0.025	0.015	0.024	0.009	0.29	0.099	0.03	0.19	<0.005	0.016	0.074	0.036	0.048	0.029
Ammonia as N	mg/L	0.01	0.9	0.22	0.13	0.32	0.36	0.23	0.11	0.13	0.08	0.21	0.14	0.25	0.27	0.11	0.05	0.1	0.41	<0.01	<0.01	0.01	<0.01	<0.01	0.03
Nitrate as N	mg/L	0.01	0.7	0.01	0.01	0.02	0.02	1.1	1.2	0.97	0.85	0.01	0.01	0.02	0.02	<0.2	0.09	<0.01	<0.2	<0.01	0.01	2.4	2.1	3.2	2.1
Total Nitrogen as N	mg/L			0.89	0.65	0.36	1.1	2.3	2.7	2.7	2.5	0.41	0.58	0.46	0.51	0.38	3.7	0.45	0.64	1.3	1.7	2.9	3.2	3.8	2.7
Reactive Phosphorus as P	mg/L	0.01		0.01	<0.01	0.03	<0.01	0.03	0.01	0.04	<0.01	0.01	<0.01	0.02	0.02	0.01	0.01	0.02	0.01	0.01	0.02	0.01	<0.01	<0.01	0.01
Total Phosphorus as P	mg/L	0.01		0.82	0.07	0.11	0.24	0.24	0.36	0.14	0.39	0.12	0.13	0.11	0.07	0.17	0.47	0.33	0.04	0.26	0.11	0.1	0.85	0.37	0.32
Total Anions (reported)	meq/L	0.01		35.20	28.20	29.00	28.70	54.90	42.60	43.00	44.20	34.10	40.10	42.00	37.00	11.20	21.50	22.10	10.50	13.6	16.9	6.90	6.51	6.86	5.81
Total Cations (reported)	meq/L	0.01		29.10	25.30	28.00	27.60	51.70	42.10	38.00	35.30	34.10	33.60	35.00	36.80	10.00	18.30	21.20	10.60	11.60	16.90	5.70	5.80	6.54	5.51
% Difference (reported)	%	0.01																							
Allowed % Difference	%	0.01																							
Total Cations (calculated)	meq/L	0.01		29.04	26.23	27.98	27.55	49.39	40.68	37.00	33.82	34.13	33.07	34.66	36.82	9.93	18.07	20.14	10.57	11.60	15.28	5.68	5.77	6.51	5.21
Total Anions (calculated)	meq/L	0.01		35.16	28.19	28.77	28.68	54.95	42.58	42.67	44.27	34.10	40.08	42.24	37.03	11.25	21.45	22.09	10.54	13.58	16.90	6.71	6.28	6.86	5.66
% Difference (calculated)	%	0.01		-9.53%	-3.61%	-1.38%	-2.02%	-5.33%	-2.29%	-7.12%	-13.39%	0.05%	-9.57%	-9.86%	-0.28%	-6.22%	-8.55%	-4.61%	0.14%	-7.86%	-5.03%	-8.37%	-4.19%	-2.58%	-4.16%
Allowed % Difference (calculated)	%	0.01		5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	2.00%	5.00%	5.00%	5.00%
Sodium Adsorption Ratio				1.40	1.50	1.58	1.45	9.66	11.89	12.63	8.22	1.09	1.13	1.26	1.22	2.68	3.52	3.44	3.30	3.39	2.89	4.62	4.60	5.29	4.06

Table 3: Groundwater Sample Laboratory Analysis Results
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Bore / Well / Spring / Soak				TB52A	TB52B		PZ52				PZ53				PZ55			PZ58		
Parameter	Units	LOR	ANZECC (2000) Guideline Value for Freshwater Ecosystem Protection	29-May-06	31-Jan-06	29-May-06	28-Oct-05	17-Nov-05	31-Jan-06	28-Apr-06	28-Oct-05	17-Nov-05	31-Jan-06	28-Apr-06	28-Oct-05	31-Jan-06	28-Apr-06	28-Oct-05	31-Jan-06	28-Apr-06
pH Value (field)		0.01		6.50	7.10	6.10	5.80	5.80	6.60	6.70	6.50	6.30	7.20	7.50	5.30	6.30	6.70	3.80	4.70	4.90
pH Value (lab)																				
Conductivity (field)	µS/cm	0		380	160	160	350	320	240	150	1000	930	1050	1000	250	330	240	8120	9400	10030
Conductivity @ 25°C	µS/cm	1		350	140	140	300	250	280	140	880	870	890	890	190	200	220	7600	9300	10000
Total Suspended Solids (TSS)	mg/L	2		16	120	15	10000	2200	560	170	390	110	28	59	120	480	310	15000	190	530
Total Dissolved Solids (TDS)	mg/L	1		180	160	78	270	1500	270	91	480	470	490	490	280	250	350	5900	7200	7800
Calcium	mg/L	1		22	1.1	3	3.2	12	2.1	3	59	61	56	61	0.7	1.8	5.3	48	83	80
Magnesium	mg/L	1		9.7	0.86	2	2.7	5.9	2.1	2	31	32	30	33	1.1	1.6	1.9	260	320	330
Sodium	mg/L	1		20	6.9	16	49	17	23	17	49	54	52	51	27	33	28	940	1100	1300
Potassium	mg/L	1		10	0.8	1.6	1.5	4.5	1.3	1.1	23	23	21	22	1.2	1.4	1.4	23	13	5.8
Hydroxide as CaCO3	mg/L	1																		
Carbonate as CaCO3	mg/L	1		2	<1	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Bicarbonate as CaCO3	mg/L	1		110	31	25	49	48	36	37	260	260	280	270	13	20	33	<2	<2	<2
Chloride	mg/L	1		40	23	24	61	47	24	24	110	110	110	110	32	33	37	1600	2000	2200
Sulphate	mg/L	1		1	2	1	14	28	1	<1	27	32	28	29	13	18	20	2100	2500	3100
Fluoride	mg/L	0.1		0.21	0.16	0.11	0.71	0.43	0.19	0.14	0.26	0.27	0.19	0.25	0.1	0.2	0.19	3.7	2.9	3.3
Cyanide	mg/L	0.01	0.007	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Aluminium - Filtered	mg/L	0.005	0.055	<0.02	0.37	0.02	0.049	<0.02	0.2	0.04	<0.02	<0.02	<0.02	<0.02	0.07	0.05	0.05	97	160	150
Arsenic - Filtered	mg/L	0.001	0.013	<0.001	0.001	<0.001	0.001	0.003	0.003	<0.001	0.001	0.004	0.001	0.002	<0.001	0.003	<0.001	<0.001	<0.001	<0.001
Boron - Filtered	mg/L	0.01	0.37	0.02	<0.01	0.01	0.13	0.06	0.01	<0.01	0.01	0.01	0.01	<0.01	0.02	0.01	0.01	0.01	0.09	0.14
Cadmium - Filtered	mg/L	0.00005	0.0002	<0.00005	<0.00005	<0.00005	<0.00005	0.00027	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	0.00005	0.00015	0.00009	0.0049	0.0058	0.0064
Chromium - Filtered	mg/L	0.002	ID	<0.001	<0.002	0.001	0.001	<0.001	<0.002	<0.001	0.001	<0.0005	0.006	0.001	0.001	<0.002	0.001	0.016	0.021	0.022
Cobalt - Filtered	mg/L	0.001		0.0008	0.0002	<0.0002	0.0004	<0.0002	0.0002	0.0002	0.0006	0.0006	0.0005	0.0009	0.0017	0.0016	0.0021	0.93	0.99	0.94
Copper - Filtered	mg/L	0.0005	0.0014	<0.0005	0.0006	0.001	0.0006	0.0026	0.0013	<0.0005	<0.0005	0.001	0.0005	<0.0005	0.0006	0.001	0.0005	0.54	0.5	0.28
Iron - Filtered	mg/L	0.01	ID	4.1	0.47	0.28	0.22	<0.01	0.03	0.91	2.4	3.3	6	3.5	0.03	0.02	0.21	5.1	14	0.74
Lead - Filtered	mg/L	0.00005	0.0034	0.0011	0.0026	0.012	0.00054	<0.00005	0.00068	0.005	0.0001	0.0059	0.0017	0.00026	0.00039	0.00026	0.0047	0.53	0.37	0.43
Manganese - Filtered	mg/L	0.001	1.9	0.14	0.008	0.027	0.042	0.003	0.014	0.033	0.048	0.063	0.06	0.045	0.078	0.24	0.13	1.2	2.4	2.2
Mercury - Filtered	mg/L	0.0001	0.00006	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0009	0.0007	0.0014
Nickel - Filtered	mg/L	0.001	0.011	0.002	<0.001	0.001	<0.001	0.002	<0.001	<0.001	<0.001	0.002	0.002	0.005	0.002	0.003	0.003	1	1.3	1.4
Selenium - Filtered	mg/L	0.001	0.005	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.004	<0.001
Silver - Filtered	mg/L	0.001	0.00005	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Zinc - Filtered	mg/L	0.005	0.008	0.009	<0.005	0.025	0.075	0.07	<0.005	0.014	0.038	0.02	0.034	0.098	0.02	0.035	0.052	5.4	6.8	6.9
Ammonia as N	mg/L	0.01	0.9	0.18	<0.01	0.02	0.02	0.03	0.01	0.06	0.08	0.3	0.04	0.1	0.02	<0.01	<0.01	0.02	0.19	<0.01
Nitrate as N	mg/L	0.01	0.7	0.01	<0.01	<0.01	<0.2	<0.2	<0.01	0.01	<0.2	<0.2	0.01	0.01	<0.2	<0.01	0.02	<0.2	<0.01	0.03
Total Nitrogen as N	mg/L			0.19	1.7	0.27	8	3.9	1.4	0.51	0.43	0.53	0.34	0.43	0.64	0.42	0.97	0.64	1.3	1.7
Reactive Phosphorus as P	mg/L	0.01		<0.01	0.01	<0.01	0.02	0.01	0.02	0.02	0.01	<0.01	0.01	0.02	0.02	0.01	0.02	0.02	0.02	0.02
Total Phosphorus as P	mg/L	0.01		0.13	0.26	0.03	0.77	2.3	0.59	0.12	0.08	0.17	0.07	0.87	0.12	0.6	0.44	0.12	0.09	1.3
Total Anions (reported)	meq/L	0.01		3.33	1.30	1.20	3.00	2.87	1.42	1.42	8.90	8.97	9.28	9.11	1.40	1.71	2.12	88.80	108.00	126.00
Total Cations (reported)	meq/L	0.01		3.24	1.10	1.07	2.60	1.94	1.34	1.32	8.30	8.80	8.39	9.31	1.30	1.70	2.12	76.00	97.20	112.00
% Difference (reported)	%	0.01																		
Allowed % Difference	%	0.01																		
Total Cations (calculated)	meq/L	0.01		2.31	0.45	1.05	2.55	1.94	1.31	1.08	8.21	8.61	8.06	8.54	1.33	1.69	1.67	65.26	78.65	87.84
Total Anions (calculated)	meq/L	0.01		1.21	1.31	1.20	2.99	2.87	1.42	1.44	8.86	8.96	9.28	9.10	1.43	1.71	2.12	88.90	108.51	126.64
% Difference (calculated)	%	0.01		31.20%	-49.18%	-6.51%	-7.93%	-19.33%	-3.88%	-14.11%	-3.79%	-2.00%	-7.04%	-3.19%	-3.71%	-0.37%	-11.73%	-15.33%	-15.96%	-18.09%
Allowed % Difference (calculated)	%	0.01		2.00%	2.00%	2.00%	2.00%	5.00%	5.00%	5.00%	2.00%	5.00%	5.00%	5.00%	2.00%	5.00%	5.00%	5.00%	5.00%	5.00%
Sodium Adsorption Ratio				0.89	1.20	1.76	4.88	1.00	2.69	1.87	1.29	1.39	1.39	1.31	4.69	4.31	2.66	11.86	12.26	14.33

Table 3:   Groundwater Sample Laboratory Analysis Results
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Bore / Well / Spring / Soak				PZ72A			PZ72C			PZ74				PZ101A			PZ101B		
Parameter	Units	LOR	ANZECC (2000) Guideline Value for Freshwater Ecosystem Protection	28-Oct-05	31-Jan-06	28-Apr-06	28-Oct-05	31-Jan-06	28-Apr-06	28-Oct-05	21-Nov-05	31-Jan-06	28-Apr-06	17-Nov-05	07-Feb-06	28-Apr-06	17-Nov-05	07-Feb-06	28-Apr-06
pH Value (field)		0.01		6.40	7.40	7.90	6.80	7.70	7.90	6.50	6.40	7.30	7.60	7.10	7.00	8.50	7.00	6.60	8.00
pH Value (lab)																			
Conductivity (field)	µS/cm	0		1950	1820	1700	3540	3560	3710	5170	5120	5140	4930	1060	1330	1320	1020	1140	1030
Conductivity @ 25°C	µS/cm	1		1700	1600	1500	3400	3400	3500	4800	4700	4700	4700	860	1200	1200	790	1000	960
Total Suspended Solids (TSS)	mg/L	2		140	12	7	380	58	31	450	410	220	230	78	54	120	250	86	160
Total Dissolved Solids (TDS)	mg/L	1		940	840	850	1800	2000	2000	3500	3200	3300	3300	500	730	720	440	600	580
Calcium	mg/L	1		54	80	78	67	69	70	340	330	340	340	60	110	110	53	83	70
Magnesium	mg/L	1		59	58	57	140	160	160	190	200	200	200	21	26	26	19	28	26
Sodium	mg/L	1		150	140	130	380	430	420	380	400	390	380	65	72	73	59	76	76
Potassium	mg/L	1		15	17	14	12	11	8.9	63	62	62	48	20	31	35	20	19	17
Hydroxide as CaCO3	mg/L	1																	
Carbonate as CaCO3	mg/L	1		<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Bicarbonate as CaCO3	mg/L	1		55	390	370	630	640	630	740	450	750	750	290	310	390	270	440	390
Chloride	mg/L	1		340	290	240	620	770	700	880	850	820	870	100	120	130	84	85	83
Sulphate	mg/L	1		76	78	78	210	220	220	690	700	670	710	29	180	62	14	43	13
Fluoride	mg/L	0.1		0.87	0.65	0.8	1.2	1	1.2	0.34	0.22	0.2	0.26	0.9	0.72	0.75	1.2	0.52	0.67
Cyanide	mg/L	0.01	0.007	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Aluminium - Filtered	mg/L	0.005	0.055	0.04	0.03	0.51	0.03	<0.02	0.07	0.04	<0.02	0.03	0.09	0.04	0.05	0.03	<0.02	0.02	0.02
Arsenic - Filtered	mg/L	0.001	0.013	0.019	<0.001	0.002	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	0.003	<0.001	0.006	0.044	0.018	0.027
Boron - Filtered	mg/L	0.01	0.37	0.02	0.02	<0.01	0.02	<0.01	<0.01	0.03	0.02	0.02	<0.01	0.04	0.03	0.03	0.05	0.04	0.03
Cadmium - Filtered	mg/L	0.00005	0.0002	<0.00005	<0.00005	<0.00005	<0.00005	0.00012	<0.00005	0.00019	<0.00005	0.00006	0.00017	0.00009	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005
Chromium - Filtered	mg/L	0.002	ID	0.001	<0.002	<0.001	<0.002	0.003	0.003	0.001	<0.002	0.003	0.001	0.002	0.002	0.004	0.001	0.001	0.001
Cobalt - Filtered	mg/L	0.001		0.0088	0.0004	0.0003	0.0016	0.0005	0.0005	0.0021	0.0008	0.0008	0.0008	0.0014	0.0006	0.0006	0.0043	0.0048	0.0019
Copper - Filtered	mg/L	0.0005	0.0014	0.0009	0.0005	<0.0005	0.0012	0.0026	0.0012	0.0051	0.0029	0.0022	0.0026	0.0046	0.0008	0.0008	<0.0005	0.0007	0.0005
Iron - Filtered	mg/L	0.01	ID	0.29	1.4	1.9	0.05	0.02	<0.01	0.8	2.2	2.1	<0.01	0.5	0.09	0.25	0.23	0.51	0.48
Lead - Filtered	mg/L	0.00005	0.0034	0.01	0.00009	0.00013	0.0085	0.00061	0.00056	0.0053	0.001	0.0013	0.011	0.0012	0.002	0.0081	0.03	0.0019	0.0047
Manganese - Filtered	mg/L	0.001	1.9	0.066	0.073	0.081	0.054	0.028	0.034	0.16	0.079	0.077	0.093	0.12	0.14	0.15	0.087	1.7	1.8
Mercury - Filtered	mg/L	0.0001	0.00006	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0001	<0.0001
Nickel - Filtered	mg/L	0.001	0.011	0.009	0.002	0.003	<0.001	0.003	0.005	0.002	0.003	0.012	0.012	0.004	0.005	0.005	0.024	0.019	0.016
Selenium - Filtered	mg/L	0.001	0.005	<0.001	<0.001	<0.001	0.002	0.008	0.002	<0.001	0.002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Silver - Filtered	mg/L	0.001	0.00005	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Zinc - Filtered	mg/L	0.005	0.008	0.03	0.014	0.017	0.019	0.005	0.013	0.12	0.025	0.052	0.11	0.035	<0.005	0.033	0.067	<0.005	0.032
Ammonia as N	mg/L	0.01	0.9	0.16	0.31	0.33	<0.01	<0.01	<0.01	0.46	0.4	0.37	0.48	<0.01	<0.01	0.18	0.22	0.19	0.14
Nitrate as N	mg/L	0.01	0.7	<0.2	<0.01	<0.01	<0.2	0.94	0.96	0.5	<0.01	<0.01	0.02	<0.2	<0.01	0.02	<0.2	<0.01	0.02
Total Nitrogen as N	mg/L			0.62	0.28	0.39	1	1	0.98	2.1	0.69	0.52	1.3	2.1	2.5	3.3	3.3	2.3	2.5
Reactive Phosphorus as P	mg/L	0.01		0.01	<0.01	0.02	0.02	0.02	0.02	0.01	<0.01	0.01	0.01	0.02	0.07	0.03	0.33	0.02	0.02
Total Phosphorus as P	mg/L	0.01		0.14	0.04	<0.01	0.41	0.04	<0.01	0.62	0.37	0.36	0.27	0.5	0.37	0.46	1.3	0.47	0.51
Total Anions (reported)	meq/L	0.01		12.30	17.60	15.80	34.50	39.10	37.00	54.00	47.60	52.10	54.30	9.23	13.30	12.80	8.09	12.10	10.40
Total Cations (reported)	meq/L	0.01		14.50	15.40	15.50	32.00	35.60	36.40	51.00	52.10	52.10	55.10	8.09	11.60	13.20	7.32	10.30	10.40
% Difference (reported)	%	0.01																	
Allowed % Difference	%	0.01																	
Total Cations (calculated)	meq/L	0.01		14.46	15.29	14.59	31.70	35.59	35.15	50.74	51.90	51.97	51.18	8.06	11.55	11.70	7.29	10.24	9.37
Total Anions (calculated)	meq/L	0.01		11.21	17.60	15.79	21.90	39.09	36.92	39.23	47.54	52.07	54.31	9.22	13.33	12.75	8.06	12.09	10.41
% Difference (calculated)	%	0.01		12.63%	-7.03%	-3.93%	18.27%	-4.69%	-2.45%	12.79%	4.38%	-0.10%	-2.97%	-6.71%	-7.13%	-4.31%	-5.03%	-8.28%	-5.22%
Allowed % Difference (calculated)	%	0.01		5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%
Sodium Adsorption Ratio				3.36	2.91	2.73	6.06	6.49	6.33	4.09	4.29	4.15	4.04	1.84	1.60	1.63	1.77	1.84	1.97

Table 3: Groundwater Sample Laboratory Analysis Results
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Bore / Well / Spring / Soak				PZ102A		PZ102B			TB103	TB103R		PZ103A		PZ104		TB105		PZ105A			PZ105B		
Parameter	Units	LOR	ANZECC (2000) Guideline Value for Freshwater Ecosystem Protection	07-Feb-06	28-Apr-06	17-Nov-05	31-Jan-06	28-Apr-06	16-Nov-05	07-Feb-06	29-May-06	07-Feb-06	28-Apr-06	31-Jan-06	28-Apr-06	03-Mar-06	29-May-06	11-Jan-06	31-Jan-06	28-Apr-06	11-Jan-06	31-Jan-06	28-Apr-06
pH Value (field)		0.01		7.40	8.30	7.00	7.70	7.90	7.30	6.80	6.60	7.00	8.10	7.40	7.70	7.80	6.90	6.80	6.80	7.80	7.60	7.90	7.40
pH Value (lab)																							
Conductivity (field)	µS/cm	0		620	810	1360	1250	1200	740	730	650	470	490	840	710	540	640	380	380	500	620	660	460
Conductivity @ 25°C	µS/cm	1		550	620	1100	1100	1100	560	600	560	430	430	710	660	500	580	330	330	460	560	540	420
Total Suspended Solids (TSS)	mg/L	2		48	16	130	89	69	270	75	47	79	42	230	230	3	23	71	11	110	3300	31	60
Total Dissolved Solids (TDS)	mg/L	1		370	430	600	610	600	290	350	290	280	270	420	410	270	310	200	190	270	320	300	240
Calcium	mg/L	1		26	33	59	56	58	37	45	37	22	25	31	33	22	29	13	11	24	44	38	23
Magnesium	mg/L	1		4.6	4	24	25	25	16	18	17	4.5	5.8	16	16	9.9	12	5.6	5.7	7.7	19	16	8
Sodium	mg/L	1		74	74	100	100	100	65	41	34	40	32	78	58	52	60	34	36	46	42	40	34
Potassium	mg/L	1		14	18	19	18	18	15	17	11	18	24	8.4	10	10	13	3.6	3	7.2	8.4	6.9	6.2
Hydroxide as CaCO3	mg/L	1																					
Carbonate as CaCO3	mg/L	1		<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Bicarbonate as CaCO3	mg/L	1		180	160	230	240	250	160	260	150	110	130	160	180	150	200	41	45	140	220	200	88
Chloride	mg/L	1		42	55	180	180	200	89	73	81	58	51	110	92	69	66	67	71	57	50	58	77
Sulphate	mg/L	1		54	68	21	25	10	10	8	5	20	7	10	5	3	1	15	4	6	14	3	5
Fluoride	mg/L	0.1		2.2	2.1	1.5	1.3	1.4	1.3	0.53	0.38	0.56	0.53	0.8	1.1	0.86	1.1	0.16	0.14	0.87	0.49	0.3	0.23
Cyanide	mg/L	0.01	0.007	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Aluminium - Filtered	mg/L	0.005	0.055	0.05	0.03	0.02	0.02	0.02	<0.02	<0.02	<0.02	0.02	0.02	0.04	0.05	<0.005	<0.02	<0.02	0.02	0.03	<0.02	<0.02	0.02
Arsenic - Filtered	mg/L	0.001	0.013	0.003	0.004	0.001	<0.001	<0.001	<0.001	0.002	<0.001	0.002	0.002	0.002	0.001	<0.001	0.002	0.001	0.003	0.002	0.009	0.005	0.004
Boron - Filtered	mg/L	0.01	0.37	0.01	0.01	0.03	0.03	0.03	0.03	0.02	0.03	0.02	0.02	0.03	0.03	0.05	0.06	0.01	0.01	0.02	0.03	0.03	0.01
Cadmium - Filtered	mg/L	0.00005	0.0002	<0.00005	<0.00005	0.00005	<0.00005	<0.00005	<0.00005	0.00011	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005
Chromium - Filtered	mg/L	0.002	ID	0.001	0.001	0.002	0.003	0.002	0.001	0.002	0.001	0.004	0.001	0.002	0.001	<0.001	0.001	0.002	<0.002	<0.001	0.002	<0.002	0.001
Cobalt - Filtered	mg/L	0.001		<0.0002	<0.0002	0.0021	0.0012	0.0003	0.0003	0.0087	0.0015	0.0002	0.0003	0.0034	0.0016	0.0059	0.0011	0.013	0.01	0.0016	0.0008	0.0004	0.003
Copper - Filtered	mg/L	0.0005	0.0014	0.0015	0.0008	0.0011	<0.0005	0.0006	<0.0005	0.0014	0.0006	0.0011	<0.0005	<0.0005	0.0006	<0.0005	<0.0005	<0.0005	<0.0005	0.0006	0.0007	<0.0005	<0.0005
Iron - Filtered	mg/L	0.01	ID	0.03	0.03	0.07	0.81	0.33	<0.01	0.16	6.9	0.12	0.17	0.53	0.7	<0.01	2.8	1.2	2.6	0.26	<0.01	0.28	2.3
Lead - Filtered	mg/L	0.00005	0.0034	0.011	0.022	0.0013	0.0021	0.00069	<0.00005	0.0015	0.0028	0.0084	0.0019	0.00099	0.0032	0.0014	0.00041	0.00011	0.0005	0.003	0.00008	0.00016	0.0028
Manganese - Filtered	mg/L	0.001	1.9	0.01	0.011	0.11	0.1	0.1	0.044	0.19	0.16	0.018	0.017	0.2	0.16	0.13	0.12	0.2	0.23	0.087	0.11	0.14	0.27
Mercury - Filtered	mg/L	0.0001	0.00006	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Nickel - Filtered	mg/L	0.001	0.011	0.001	0.002	0.008	0.002	0.002	0.002	0.013	0.006	0.002	0.002	0.01	0.006	0.039	0.004	0.078	0.063	0.009	0.004	0.001	0.014
Selenium - Filtered	mg/L	0.001	0.005	<0.001	<0.001	0.002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Silver - Filtered	mg/L	0.001	0.00005	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Zinc - Filtered	mg/L	0.005	0.008	0.016	0.034	0.1	0.012	0.007	<0.005	0.16	0.099	0.059	<0.005	0.007	0.022	0.01	<0.005	0.15	0.29	0.03	<0.005	0.006	0.011
Ammonia as N	mg/L	0.01	0.9	0.03	<0.01	0.11	0.09	0.1	0.36	0.25	0.18	0.02	0.24	1.2	0.98	0.38	0.28	<0.01	<0.01	0.43	0.06	0.11	0.2
Nitrate as N	mg/L	0.01	0.7	<0.01	<0.01	0.4	0.02	0.03	<0.2	<0.01	0.01	<0.01	0.01	<0.01	0.01	<0.2	0.01	<0.01	<0.01	0.03	0.01	<0.01	<0.01
Total Nitrogen as N	mg/L			3.8	0.7	1	1	1	0.47	3.2	0.2	1.2	0.76	2.2	3.1	0.49	0.47	2.1	0.43	1.4	<5	0.17	0.94
Reactive Phosphorus as P	mg/L	0.01		0.03	0.02	0.01	<0.01	0.02	0.03	0.01	<0.01	0.02	0.02	0.02	0.02	0.03	<0.01	0.02	0.01	0.02	0.02	0.02	0.02
Total Phosphorus as P	mg/L	0.01		0.09	0.05	0.21	0.1	0.05	<0.01	0.06	0.05	0.1	0.01	0.65	1.1	0.01	0.07	0.17	0.01	0.13	2.1	0.04	0.07
Total Anions (reported)	meq/L	0.01		5.91	6.17	10.10	10.40	10.90	5.92	7.43	5.39	4.25	4.19	6.51	6.30	5.00	5.86	3.00	3.01	4.54	6.10	5.70	4.04
Total Cations (reported)	meq/L	0.01		5.26	6.02	9.77	9.71	10.30	6.40	5.95	5.38	3.68	4.11	6.51	6.91	4.50	5.53	2.70	2.80	4.39	5.90	5.15	4.06
% Difference (reported)	%	0.01																					
Allowed % Difference	%	0.01																					
Total Cations (calculated)	meq/L	0.01		5.25	5.66	9.75	6.40	5.85	6.37	5.94	5.00	3.67	3.73	6.47	5.74	4.43	5.38	2.68	2.66	4.02	5.80	5.13	3.44
Total Anions (calculated)	meq/L	0.01		5.91	6.16	10.11	22.57	23.13	5.92	7.42	5.39	4.25	4.18	6.51	6.30	5.01	5.88	3.02	2.99	4.53	6.10	5.70	4.03
% Difference (calculated)	%	0.01		-5.85%	-4.31%	-1.80%	-55.83%	-59.65%	3.72%	-11.05%	-3.67%	-7.36%	-5.71%	-0.29%	-4.61%	-6.11%	-4.47%	-5.98%	-5.76%	-6.02%	-2.50%	-5.23%	-7.91%
Allowed % Difference (calculated)	%	0.01		5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%
Sodium Adsorption Ratio				3.52	3.24	2.77	0.70	0.28	2.25	1.31	1.16	2.03	1.50	2.84	2.07	2.31	2.37	1.99	2.20	2.09	1.33	1.37	1.56

Table 3: Groundwater Sample Laboratory Analysis Results
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Bore / Well / Spring / Soak				PZ106A		PZ106B		PZ107		PZ108		PZ108R	PZ109	PZ110		PZ111		PZ112A	PZ112B	
Parameter	Units	LOR	ANZECC (2000) Guideline Value for Freshwater Ecosystem Protection	07-Feb-06	28-Apr-06	07-Feb-06	28-Apr-06	07-Feb-06	28-Apr-06	07-Feb-06	03-Mar-06	29-May-06	29-May-06	02-May-06	29-May-06	02-May-06	29-May-06	11-May-06	10-May-06	29-May-06
pH Value (field)		0.01		5.80	7.70	5.00	7.40	5.80	7.00	6.40	7.40	6.70	9.50	6.60	6.00	7.00	6.60	6.60	5.90	5.50
pH Value (lab)																				
Conductivity (field)	µS/cm	0		2390	720	1330	990	2190	630	660	770	280	690	5470	1040		1300	2200	5900	7550
Conductivity @ 25°C	µS/cm	1		2300	660	1200	870	2000	610	570	660	250	650	860	920	1200	1200	2170	5830	7300
Total Suspended Solids (TSS)	mg/L	2		420	94	32	21	300	160	18	15	85	82	87	51	48	8	2700	100	130
Total Dissolved Solids (TDS)	mg/L	1		1200	400	630	480	1100	360	360	350	150	330	490	480	720	650	1400	3600	4300
Calcium	mg/L	1		72	34	20	11	110	26	40	29	13	6.6	40	39	73	61	120	93	74
Magnesium	mg/L	1		51	11	26	17	66	12	14	29	4.7	7.7	26	26	31	28	61	130	160
Sodium	mg/L	1		220	58	140	110	140	54	41	59	21	76	60	64	87	130	210	930	1200
Potassium	mg/L	1		20	19	8.7	5	30	17	7.3	3.4	5.2	35	11	21	20	18	30	31	35
Hydroxide as CaCO3	mg/L	1																		
Carbonate as CaCO3	mg/L	1		<2	<2	<2	<2	<2	<2	<2	<2	<2	48	<2	<2	<2	<2	<2	<2	<2
Bicarbonate as CaCO3	mg/L	1		210	110	46	30	250	100	100	210	72	42	95	120	130	350	150	58	41
Chloride	mg/L	1		590	140	310	230	410	120	60	84	33	100	210	210	300	150	570	1600	2200
Sulphate	mg/L	1		42	4	34	30	170	12	90	10	2	65	14	15	17	51	64	470	480
Fluoride	mg/L	0.1		0.13	0.21	0.06	0.12	0.23	0.18	0.26	0.26	0.14	0.54	0.2	0.24	0.34	2.8	0.27	0.13	0.15
Cyanide	mg/L	0.01	0.007	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.001	<0.01	<0.01	<0.01
Aluminium - Filtered	mg/L	0.005	0.055	<0.02	0.05	<0.02	0.03	<0.02	0.04	0.02	<0.02	0.06	0.05	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.02
Arsenic - Filtered	mg/L	0.001	0.013	<0.001	0.001	0.001	0.001	<0.001	0.008	0.005	<0.001	<0.001	<0.001	<0.001	<0.001			0.006	<0.001	<0.001
Boron - Filtered	mg/L	0.01	0.37	0.02	0.04	0.02	0.02	0.02	0.04	0.01	0.02	0.06	0.02	0.03	0.02	0.03	0.04	0.09	0.05	0.02
Cadmium - Filtered	mg/L	0.00005	0.0002	<0.00005	<0.00005	0.0001	<0.00005	0.00007	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	0.00035	<0.00005	<0.00005	<0.00005	0.00015	0.00022	0.00043
Chromium - Filtered	mg/L	0.002	ID	<0.001	0.003	<0.001	0.002	<0.001	0.002	0.004	<0.001	0.001	0.001	<0.001	<0.001	<0.001	0.001	0.001	0.001	0.002
Cobalt - Filtered	mg/L	0.001		0.037	0.0016	0.021	0.015	0.032	0.0036	0.0039	0.004	0.001	<0.0002	0.028	0.03	0.02	0.001	0.012	0.003	0.089
Copper - Filtered	mg/L	0.0005	0.0014	0.0008	0.0011	0.0019	0.0014	0.0014	0.0014	0.0014	0.0007	0.0026	0.0007	0.0008	0.0005	0.0014	0.0005	0.0019	0.0023	0.0023
Iron - Filtered	mg/L	0.01	ID	0.04	1.4	0.36	4.4	2	1.1	<0.01	4	1.5	0.04	7.3	3.2	0.25	0.08	0.01	0.01	0.14
Lead - Filtered	mg/L	0.00005	0.0034	0.0085	0.013	0.0026	0.0018	0.0015	0.018	0.0023	0.0035	0.044	0.0063	0.00025	0.0078	0.009	<0.00005	0.0061	0.00034	0.0012
Manganese - Filtered	mg/L	0.001	1.9	1.3	0.15	0.8	0.5	0.83	0.25	0.078	0.16	0.07	0.002	0.89	0.9	1	0.089	0.53	0.18	2.8
Mercury - Filtered	mg/L	0.0001	0.00006	<0.0001	0.0002	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0003
Nickel - Filtered	mg/L	0.001	0.011	0.067	0.005	0.034	0.028	0.084	0.009	0.009	0.025	0.004	0.001	0.1	0.1	0.04	0.003	0.039	0.043	0.15
Selenium - Filtered	mg/L	0.001	0.005	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Silver - Filtered	mg/L	0.001	0.00005	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Zinc - Filtered	mg/L	0.005	0.008	0.13	0.074	0.13	0.026	0.11	0.29	0.013	0.3	0.056	0.013	0.47	0.48	0.21	<0.005	0.41	0.22	0.19
Ammonia as N	mg/L	0.01	0.9	<0.01	<0.01	<0.01	0.02	0.43	0.16	1.6	0.01	0.28	0.57	0.1	0.2	0.27	0.22	0.3	0.04	0.19
Nitrate as N	mg/L	0.01	0.7	<0.01	0.01	<0.01	<0.01	0.04	0.02	0.03	0.02	0.05	0.03	0.18	0.02	0.29	0.01	0.07	1.2	0.34
Total Nitrogen as N	mg/L			2.5	2.1	0.32	0.57	1.5	3.6	2.4	0.09	2.8	1.5	0.54	0.31	0.89	<0.5	3.1	2.4	1.1
Reactive Phosphorus as P	mg/L	0.01		0.01	0.01	<0.01	0.02	0.01	0.01	0.01	0.02	0.01	0.03	0.01	0.01	0.01	<0.01	0.02	0.03	<0.01
Total Phosphorus as P	mg/L	0.01		0.29	0.13	0.02	0.05	0.09	0.24	0.03	0.02	0.22	0.12	<0.01	0.05	<0.01	0.02	4.3	0.09	0.07
Total Anions (reported)	meq/L	0.01		21.70	6.23	10.40	7.71	20.10	5.64	5.56	6.80	2.41	5.97	8.13	8.63	11.40	12.30	20.40	56.10	72.80
Total Cations (reported)	meq/L	0.01		17.90	6.33	9.47	7.30	17.90	5.75	5.12	6.70	2.17	5.17	7.43	7.58	10.50	11.50	18.80	53.70	70.00
% Difference (reported)	%	0.01																		
Allowed % Difference	%	0.01																		
Total Cations (calculated)	meq/L	0.01		17.87	5.61	9.45	6.86	17.78	5.07	5.12	6.49	2.08	5.16	7.03	7.41	10.49	11.46	20.91	56.58	69.95
Total Anions (calculated)	meq/L	0.01		21.71	6.23	10.37	7.71	20.10	5.63	5.56	6.77	2.41	4.21	6.26	6.28	8.86	5.33	17.45	54.96	72.10
% Difference (calculated)	%	0.01		-9.71%	-5.24%	-4.66%	-5.85%	-6.14%	-5.28%	-4.18%	-2.17%	-7.33%	10.12%	5.80%	8.25%	8.43%	36.49%	9.01%	1.45%	-1.51%
Allowed % Difference (calculated)	%	0.01		5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	2.00%	2.00%	5.00%	5.00%	5.00%	5.00%	5.00%
Sodium Adsorption Ratio				4.85	2.21	4.86	4.85	2.61	2.20	1.42	1.85	1.27	4.76	1.82	1.95	2.15	3.46	3.89	14.61	17.98

Table 3: Groundwater Sample Laboratory Analysis Results

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Bore / Well / Spring / Soak				OB01						OB02						OB03					OB04			
Parameter	Units	LOR	ANZECC (2000) Guideline Value for Freshwater Ecosystem Protection	22-Mar-05	23-May-05	31-Aug-05	22-Nov-05	02-Mar-06	29-May-06	22-Mar-05	24-May-05	31-Aug-05	22-Nov-05	02-Mar-06	29-May-06	22-Mar-05	31-Aug-05	22-Nov-05	02-Mar-06	29-May-06	31-Aug-05	22-Nov-05	02-Mar-06	29-May-06
				NR	1445					NR	0915					1445								
pH Value (field)		0.01		5.90	4.80	4.80	4.70	6.40	5.40	6.40	7.10	7.30	6.80	7.90	7.00	6.10	6.20	6.10	7.70	6.80	3.80	3.50	4.80	3.80
pH Value (lab)																								
Conductivity (field)	µS/cm	0		100	130	140	180	180	300	2060	2240	2140	2280	2130	2190	2060	2260	2210	2120	2080	420	500	460	490
Conductivity @ 25°C	µS/cm	1		110	92	110	92	94	92	1900	2000	2000	2000	1900	2000	1900	2200	2000	2900	1800	400	450	460	470
Total Suspended Solids (TSS)	mg/L	2		<2	<2	<2	4	2	<2	3	4	3	6	4	<2	36	35	19	28	21	20	3	2	3
Total Dissolved Solids (TDS)	mg/L	1		78	50	52	100	51	56	1100	1100	1200	1200	1100	1200	1100	1200	1100	880	890	320	340	320	330
Calcium	mg/L	1		4.3	0.6	0.5	0.7	0.5	0.4	120	110	120	100	100	110	37	36	36	32	34	2.4	2.6	3.5	4.6
Magnesium	mg/L	1		1.5	1.6	1.4	1.5	1.6	1.6	82	81	85	74	74	80	53	62	55	47	47	3.6	3.7	3.9	6.8
Sodium	mg/L	1		11	11	9.6	10	10	11	170	150	180	140	150	170	230	280	190	180	210	44	42	45	54
Potassium	mg/L	1		0.9	0.9	0.8	0.9	0.8	0.8	24	21	17	19	18	19	15	18	17	20	19	6.4	6.4	6.3	6.9
Hydroxide as CaCO3	mg/L	1																						
Carbonate as CaCO3	mg/L	1		<1	<1	<1	<2	<2	<2	<1	<1	<1	<2	<2	<2	<1	<1	<2	<2	<2	<1	<2	<2	<2
Bicarbonate as CaCO3	mg/L	1		10	<1	<1	10	25	6	334	363	348	370	350	350	218	214	200	330	310	<1	<2	<2	<2
Chloride	mg/L	1		22	21	22	23	22	22	340	330	400	320	350	380	390	520	390	390	370	61	57	61	65
Sulphate	mg/L	1		<1	<1	<1	<1	2	1	150	150	150	130	150	160	110	130	120	55	47	40	44	41	43
Fluoride	mg/L	0.1		0.12	<0.05	<0.05	<0.05	<0.05	0.06	0.61	0.62	0.63	0.59	0.65	0.56	0.35	0.35	0.32	0.25	0.19	0.11	0.11	0.12	<0.05
Cyanide	mg/L	0.01	0.007	<0.01	<0.001	<0.01	<0.01	<0.01	<0.01	<0.01	<0.001	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Aluminium - Filtered	mg/L	0.005	0.055	<0.005	0.089	0.07	0.08	0.1	0.09	<0.005	<0.005	<0.02	<0.02	<0.005	<0.02	0.017	<0.02	0.04	0.014	<0.02	2.1	2	2	2.1
Arsenic - Filtered	mg/L	0.001	0.013	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.002	<0.001	<0.001	0.002	<0.001	<0.001	0.002	<0.001	0.002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Boron - Filtered	mg/L	0.01	0.37	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	0.03	0.02	0.02	0.02	<0.01	0.03	0.03	0.02	0.02	0.07	0.07	0.07	0.07
Cadmium - Filtered	mg/L	0.00005	0.0002	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	0.00008	<0.00005	<0.00005	<0.00005	0.00015	0.00031	0.00014	<0.00005	<0.00005	0.00012	0.0001	0.00008	0.00007
Chromium - Filtered	mg/L	0.002	ID	<0.002	<0.002	<0.002	<0.002	<0.01	<0.01	0.014	<0.002	<0.002	<0.002	<0.001	<0.001	<0.002	<0.002	<0.002	0.001	<0.001	<0.002	<0.002	0.001	0.001
Cobalt - Filtered	mg/L	0.001		0.0015	0.0028	0.0029	0.0032	0.0033	0.0029	0.0004	<0.0002	0.0002	0.0002	0.0002	0.0002	0.0038	0.0055	0.0049	0.0006	0.0009	0.0092	0.0091	0.0096	0.0084
Copper - Filtered	mg/L	0.0005	0.0014	0.0012	0.004	0.011	0.022	0.013	0.015	0.0015	0.0013	0.0008	0.0014	0.0021	0.0012	0.0065	0.0013	0.0014	0.0007	<0.0005	0.0067	0.007	0.006	0.0058
Iron - Filtered	mg/L	0.01	ID	<0.01	<0.01	<0.01	0.02	0.07	0.11	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	3.4	1.8	7.7	0.51	0.4	0.68	0.64	0.88	1.2
Lead - Filtered	mg/L	0.00005	0.0034	<0.00005	0.00009	0.00055	0.0023	0.0019	0.00076	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	0.002	0.0002	0.0014	0.00017	0.00008	0.097	0.13	0.075	0.044
Manganese - Filtered	mg/L	0.001	1.9	0.012	0.0089	0.013	0.01	0.011	0.01	0.075	0.017	0.1	0.089	0.057	0.017	0.35	0.35	0.32	0.33	0.34	0.08	0.072	0.09	0.11
Mercury - Filtered	mg/L	0.0001	0.00006	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0003	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0002	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0001
Nickel - Filtered	mg/L	0.001	0.011	0.003	0.004	0.005	0.004	0.006	0.005	0.003	<0.001	<0.001	<0.001	0.004	0.005	0.012	0.015	0.014	0.004	0.004	0.018	0.018	0.02	0.017
Selenium - Filtered	mg/L	0.001	0.005	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.004	<0.001	<0.001	<0.001	<0.001	<0.001	0.004	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Silver - Filtered	mg/L	0.001	0.00005	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Zinc - Filtered	mg/L	0.005	0.008	<0.005	0.011	0.019	0.016	0.017	0.019	<0.005	<0.005	<0.005	0.022	0.009	0.007	0.096	0.12	0.14	0.005	0.005	0.089	0.1	0.091	0.079
Ammonia as N	mg/L	0.01	0.9	<0.01	0.02	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.35	0.41	0.39	25	0.33	1.7	0.38	0.04	0.07
Nitrate as N	mg/L	0.01	0.7	0.13	0.11	0.12	0.12	<0.2	0.12	0.29	0.3	0.29	0.28	0.4	0.28	1.4	0.31	0.88	0.31	<0.2	5	6.5	7.3	6.6
Total Nitrogen as N	mg/L			0.15	0.15	0.14	0.16	0.16	<0.5	0.33	0.37	0.35	0.33	0.39	0.55	2	0.83	1.1	28	36	7.7	7.9	8	7.7
Reactive Phosphorus as P	mg/L	0.01		<0.01	0.01	0.01	<0.01	0.02	<0.01	<0.01	0.01	0.01	<0.01	0.02	0.01	0.05	0.02	0.01	2.1	1.7	0.1	0.11	0.14	0.14
Total Phosphorus as P	mg/L	0.01		<0.01	<0.01	<0.01	0.01	0.01	<0.01	0.01	0.02	<0.01	0.02	0.02	<0.01	0.6	0.16	0.07	3.4	3.9	0.18	0.18	0.2	0.18
Total Anions (reported)	meq/L	0.01					0.86	1.16	0.77				19.10	20.00	21.10			17.60	18.00	18.70		2.99	3.09	3.22
Total Cations (reported)	meq/L	0.01					0.63	0.67	0.67				17.70	18.10	20.00			15.50	17.00	17.70		2.91	2.89	3.62
% Difference (reported)	%	0.01																						
Allowed % Difference	%	0.01																						
Total Cations (calculated)	meq/L	0.01		0.84	0.66	0.58	0.62	0.61	0.65	20.74	19.21	21.24	17.65	18.06	19.95	16.59	19.54	15.02	13.80	15.18	2.49	2.42	2.61	3.31
Total Anions (calculated)	meq/L	0.01		0.84	0.63	0.66	0.87	1.16	0.76	19.39	19.69	21.36	19.13	19.99	21.05	17.65	21.65	17.50	18.74	17.61	2.57	2.56	2.61	2.77
% Difference (calculated)	%	0.01		0.00	0.02	-0.07	-0.17	-0.31	-0.08	3.37%	-1.21%	-0.27%	-4.01%	-5.07%	-2.67%	-3.08%	-5.14%	-7.62%	-15.17%	-7.40%	-1.58%	-2.79%	-0.01%	8.97%
Allowed % Difference (calculated)	%	0.01		0.01	0.01	0.01	0.01	0.01	0.01	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%
Sodium Adsorption Ratio				1.16	1.68	1.58	1.55	1.55	1.74	2.93	2.65	3.07	2.59	2.77	3.01	5.68	6.56	4.65	4.74	5.48	4.20	3.92	3.93	3.74

3 DESCRIPTION OF THE EXISTING HYDROGEOLOGICAL ENVIRONMENT

3.1 Climate

Rainfall

Based on the Bureau of Meteorology (BOM) climate monitoring data collected at Ulan Post Office Station No. 062036 and Ulan (Mittaville) Station No. 062045 between 1901 and 2004, the average annual rainfall is approximately 640 millimetres (**Table 4**).

On average the distribution of the rainfall throughout the year is relatively uniform, but is slightly higher in the summer months. The heaviest daily falls have also generally been recorded during summer (December – February). Rainfall intensity is locally affected by the orographic influence of the Great Dividing Range.

Table 4: Average Rainfall Data - BOM Ulan PO (Station 062036) and Ulan Mittaville (Station 062045)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
062036	73.9	61.7	52.7	41.8	46.2	44.7	47.7	48.7	43.3	55.8	56.2	66.6	637.7
062045	84.3	67.7	67.7	30.9	46.6	39.4	37.5	44.0	44.4	69.9	49.8	61.4	644.5

Source: Bureau of Meteorology (2005)

Evapotranspiration

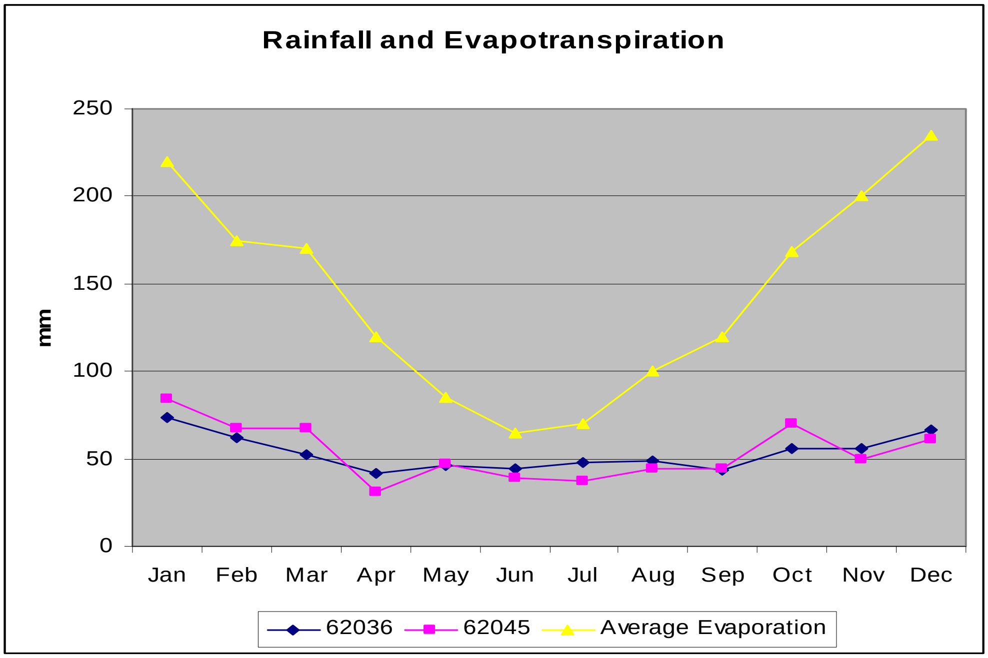
Average annual potential evapotranspiration for the Project area is around 1728 mm.

Table 5: 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	220	175	170	120	85	65	70	100	120	168	200	235	1,728

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 and can therefore be classified as having a semi-arid climate. There is variability in monthly rainfall and there would be periods when rainfall could exceed evapotranspiration during the winter months.



3.2 Geology

3.2.1 Regional Setting and Stratigraphy

Moolarben's EL6288 is located in the Western Coalfield, which occupies the northwest margin of the Sydney-Gunnedah-Bowen Basin in NSW. This coalfield contains the Illawarra Coal Measures of mid to late Permian age. Triassic sandstones and conglomerates of the Narrabeen Group overlie the coal measures, which in turn overlie either Late Permian marine sediments (Shoalhaven Group) in the east, or Carboniferous Ulan Granite and Rylstone Volcanics in the west.

The coal measures contain a number of coal seams, however the Ulan Seam is the only seam of economic significance. This seam occurs at the base of the coal measures and is considered to be the northern equivalent of the Lidsdale seam (Bayly, 1999), which is mined further south at Lithgow.

Small intrusives and remnant basalt flows of Tertiary and possibly Jurassic age have been observed in outcrop in the Murragamba and Wilpinjong valleys, and are intersected in some bores.

Unconsolidated Quaternary and partially consolidated Tertiary gravel, sand, and clays also occur in places as Quaternary valley alluvium or Tertiary paleochannel fills.

3.2.2 General Geological Description of EL6288

The coal measures comprise a well bedded sequence of claystone, mudstone, siltstone, tuff, sandstone and coal. These sedimentary units unconformably on-lap the basement and strike in a northwest direction with dips of between 1 and 2 degrees to the northeast.

In the northern half of EL6288, the Illawarra Coal Measures, which are generally 100 to 120m thick, are preserved by up to 60m of plateau-forming Triassic sandstone. The contact between the Permian and Triassic is marked by an erosional unconformity. Erosion during early Triassic time had largely removed the last episodes of Late Permian coal measure sedimentation in the region.

Along the valley floors in the south and central south parts of the licence, the coal measures have also been eroded by more recent events. An east-west trending Tertiary paleochannel has been identified in the central south. This channel is up to 48m deep, and comprises poorly sorted quartzose sediments, semi-consolidated in a clayey matrix. Investigations further south and west suggest that this channel is part of a larger system that emanated from the north. Exposures of the channel in the Goulburn River diversion, and just north of the Ulan airstrip reveal cross bedding suggestive of a southerly flow direction (Johnstone, 2005).

3.3 Hydrogeological Units

Six main hydrogeological units are present in the project area, viz:

- Quaternary alluvium
- Tertiary paleochannel alluvium
- Triassic Narrabeen Group sediments (sandstone and conglomerate)
- Permian coal measures sediments (claystone, mudstone, siltstone, sandstone, coal and tuff), including the Ulan Coal Seam
- Permian Shoalhaven Group sediments (conglomerate and sandstone)
- Basement (Ulan Granite, Gulgong Granite, Rylstone Volcanics).

The regional distribution of these hydrogeological units, based largely on the published geological map (Watkins, et al, 1999) is shown on **Figure 12**. The Shoalhaven Group is not depicted on **Figure 12**, as this unit does not occur in outcrop, except possibly for limited outcrops along the western margin of the Permian basin within the Moolarben Creek valley.

The only significant permeability occurs in the Ulan Seam and some parts of the overburden coal measures sediments within the Permian, and the Tertiary paleochannel alluvium. Minor zones of higher permeability also occur in parts of the Triassic sequence, although the Triassic is believed to be saturated only in the northern part of EL6288, commencing at the very northern end of the proposed Underground 4 longwalls. Similarly, minor zones of permeability also occur in the underlying Shoalhaven Group sediments.

All other units contain moderate to low permeability and are believed to support localised groundwater use. Many of the springs and seepages observed throughout the area are supported by low permeability units within the Permian coal measures or the Shoalhaven Group sediments. In the northern part of EL6288, the springs and seepage zones within the Triassic Narrabeen Group sediments observed along Goulburn River and in its tributary streams are the surface expressions of perched aquifers, representing local accumulations of groundwater above less permeable horizons (massive sandstones or shale layers).

The Quaternary alluvium is mostly poorly developed, and does not generally constitute a useful aquifer for water supply purposes, although it is believed to contribute to supporting groundwater-dependent ecosystems both locally and downstream within the Hunter River system catchment.

The Tertiary paleochannel alluvium is believed to be unconnected with the present drainage, and is possibly a remnant of a former westwards-flowing paleo-drainage. In the Bora Creek valley immediately south of the proposed Underground 4 mine, it was found to be mostly dry when drilled.

3.4 Groundwater Occurrence

Groundwater has been recognised as occurring within each of the following regimes:

- Localised aquifers within the unconsolidated Quaternary alluvium associated with the present drainage system;
- Paleochannel aquifer system comprising valley-fill alluvium within remnant Tertiary age paleodrainage system;
- Aquifers within the Triassic Narrabeen Group sediments;
- Aquifers within the Permian coal measures, principally the Ulan Seam;
- Limited aquifer potential in the Shoalhaven Group sediments; and
- Aquifers in weathered basement granites.

In outcrop, towards the south of EL6288, the coal measures aquifer is unconfined, and in places dry. Minor artesian occurrences and springs have been observed from at or below the seam floor level in low-lying areas in the southern part of the EL.

Throughout EL6288, there are two regionally persistent zones where lost circulation is encountered in drilling (Johnstone, 2005). These more transmissive zones occur at the boundary between the Permian and Triassic and just above the C marker of the Ulan Coal Seam.

Drilling indicates shallow weathering ranging from 4 to 18m, and generally less than 10m. However, in the central and southern part of the licence the seam has been partially eroded by southwest flowing Tertiary channels. These ancient drainage features are up to 48m thick and have themselves been eroded by and in places superimposed by more recent weathering and sedimentation associated with the Goulburn River and Wilpinjong Creek. In places the channels have completely washed out the Ulan Coal, and replaced the seam and Permian overburden with poorly sorted and semi-lithic sandy gravel, clay and silcrete.

3.5 Aquifer Hydraulic Conductivities

Hydraulic testing of piezometers and test bores has revealed the following range of hydraulic conductivity values for the principal hydrogeologic units:

Table 6: Hydraulic Testing Results - Aquifer Hydraulic Conductivity

Unit	No Tests	Hydraulic Conductivity (m/d)		Comments
		Range	Mean	
Recent alluvium	3	0.05 – 3.0	0.9	
Paleochannel alluvium	2	0.25 – 1.0	0.6	
Triassic Narrabeen sediments	0	-	-	
Permian coal measures – overburden	21	0.03 – 14	2.2	Northern part of EL6288
		0.0003 – 7	2.3	Southern part of EL6288
Permian coal measures – Ulan Seam	15	0.05 – 5.7	2.9	Northern part of EL6288
		0.3 – 11	2.1	Southern part of EL6288
Shoalhaven Group	2	0.06 – 0.00002	0.03	2 other sites dry
Basement – granite, volcanics	1	0.3	0.3	

3.6 Current Groundwater Use

The census of local groundwater usage on properties around EL6288 conducted between May 2005 and February 2006 identified a small number of bores or wells, a few springs and soaks, and a large number of dams believed by the landowners to be spring-fed. The water sources identified are shown on **Figure 2**, and summary details are provided in **Appendix A**.

A search of the DNR database was undertaken to identify registered bores and wells in the Project locality. The records indicate that there are 72registered bores and wells within approximately 10 km of the Project area. Summary details of the registered bores are presented in **Appendix E.**

Around 10 ML/d of groundwater is extracted for dewatering of the Ulan coal mine operations (UCML, 2006). Approximately 5 ML/d of water excess to mine requirements is disposed of by means of irrigation on the Bobadeen property to the north of Ulan Coal Mines and north-west of EL6288 (UCML, 2005).

A further 0.24 ML/d is extracted from a water supply bore PC1C, which according to UCML (2006) is located close to Millers Dam on the eastern side of the Ulan-Cassilis road, to provide potable water, fire water and other mining requirements. The DNR database does not show any registered bore east of the Ulan-Cassilis road, however this may be due to erroneous grid coordinates in the database.

The map attached to bore licence 20BL168008 in Appendix 3 of UCML (2004) shows the licensed bore to be west of the Ulan-Cassilis Road, between the road and Goulburn River. According to the DNR database records, this bore is registered number GW059034, and was drilled in January 1981 to a depth of 89m and is cased to 72m, with stainless steel screens at 41-47m and 60-66m depth. Based on the driller's log, the bore is probably completed in Permian coal measures, probably including the Ulan Seam. The bore location is shown on **Figure 3**, at the coordinates listed in the DNR database.

3.7 Groundwater Flow Pattern

The surficial (near-surface) groundwater flow pattern is closely related to the surface topography (**Figure 11**). This groundwater is believed to be derived by local infiltration of rainfall into the near-surface alluvium, colluvium and highly weathered bedrock zone, and flow is largely confined within this shallow layer, with local discharge to the surface stream system, often emerging mid-slope in springs or seepage zones. The shallow groundwater is believed to be largely unrelated to the flow system in the deeper Permian sediments.

The contours of groundwater level for the Permian coal measures aquifer system shown on **Figure 10** indicate that groundwater levels generally fall to the north and north-east. Groundwater levels range from around 500 m AHD near the southern end of EL6288 to around 380 m AHD at the very northern end.

However, the flow pattern has been extensively impacted by the dewatering extractions at Ulan. Groundwater levels in the Permian have been drawn down to below 260 m AHD close to the UCML underground workings, at the north-western corner of EL6288. Historical water levels shown in the UCML bore hydrographs suggest that prior to mine dewatering groundwater levels in the Permian Coal Measures in the northern part of EL6288 were probably around 400-420 mAHD.

The earliest available water levels from the UCML piezometers are from PB2, PB3, PB5 and PP9 in January 1982 (UCML, 2003). PB2 and PB3 are located just west of the Ulan-Cassilis road, adjacent to the northern half of Underground 4, and PB5 and PP9 are about 1 km west of Underground 4, between Ulan's open cut and underground mines (**Figure 10**). PB2 and PB3 are screened in the Permian coal measures above the Ulan Seam, while PB5 and PP9 are completed in both the Ulan Seam and the Permian coal measures above.

These bores reported water levels between 390 and 400 mAHD in January 1982. By 2004, the water levels in PB5 and PP9, which are screened in the

Ulan Seam, had fallen to around 350 mAHD, a fall of about 45m. Water levels in PB2 and PB3, which are screened only in the overlying coal measures, had fallen to around 360-365 mAHD, a fall of about 30m (**Figure 13**). Drawdowns would likely be much greater downdip to the north, closer to the most-northerly advance of UCML's longwall. The hydrograph for UCML PZ04 (**Figure 13**) suggests that total drawdown could have been as much as 120m by the end of 2005.

By extrapolation, it is interpreted that residual drawdown in groundwater levels in the Ulan Seam and the overlying Permian sediments along the western margin of Underground 4 would currently be between about 40m at the southern end and 50m at the northern end.

The UCML monitoring data indicate that up to the end of 2005, the dewatering of the Ulan Seam and the overlying Permian coal measures has had limited or negligible impacts on groundwater levels in the Triassic sediments. Monitoring of water levels in two private bores on Mr Elward's property near the northern end of EL6288 indicates that there has been negligible change in water level in the Triassic sediments, but more than 50 m drawdown in the underlying Permian (**Figure 14**).

3.8 Recharge and Discharge

Groundwater recharge occurs by infiltration of rainfall and locally-collected runoff, hence the Permian and Triassic aquifers are primarily recharged in the elevated areas of rock outcrop. Where the hard rock aquifers underlie the Tertiary or Quaternary alluvium, recharge may also occur to the hard rock aquifers by downward percolation from the overlying alluvium, supplementing the primary recharge derived from direct infiltration of rainfall into the rock in areas of outcrop up-gradient.

The groundwater contours suggest that, apart from the impact of Ulan mine dewatering, groundwater is flowing through the Permian aquifer system in a north-easterly direction, generally towards the central part of the basin. Local discharges take place wherever an aquifer unit within the Permian sediments outcrops, such as on hillsides or the flanks of creeks and gullies. The ultimate discharge point for groundwater flow within the Permian is likely to be some considerable distance downgradient, perhaps on the north-eastern side of the dissected plateau, in any locality where the topography falls below the level of the main zones of permeability within the Permian.

The groundwater levels in the Permian coal measures in bores close to Goulburn River are below the riverbed level. The Permian is thus not contributing to baseflow in the Goulburn River itself, although there are small contributions to baseflow of relatively saline Permian groundwater in the upper reaches of Moolarben and Lagoon Creeks. Goulburn River is believed to be more closely related to groundwater in the Triassic sediments that outcrop beneath and adjacent to the river. Water discharging at The Drip and similar seepages nearby is derived from perched groundwater in the Triassic sediments.

Groundwater flow within the alluvium is believed to generally follow the surface topography, with a similar flow direction and flow pattern to surface runoff. Groundwater discharge occurs generally locally, as springs or stream-bed baseflow contributions.

Groundwater flow direction in the east-west Tertiary paleochannel beneath the Bora Creek valley south of Underground 4 is believed to be to the west, but at some depth below the Quaternary alluvium, and hydraulically separated from it.

3.9 Groundwater Quality

Groundwater quality is variable within the project area. The highest recorded groundwater salinity was 7800 mg/L, in a sample from PZ58. This piezometer is screened in a Tertiary alluvium “washout” west of the current course of Moolarben Creek (**Figure 12**).

The pH of the groundwater is also variable, with recorded pH values ranging from 3.4 to 7.9. Three samples reporting pH values above 10 are believed to have been still affected by cement from bore construction at the time of sampling, and are not representative of natural groundwater conditions.

The low pH groundwater was all reported from the southern part of EL6288, with pH generally between 3 and 6 in the Moolarben Creek – Lagoon Creek catchment. Groundwater in the Murragamba Valley catchment is slightly acidic, with pH generally between 5.5 and 6.5. In the northern half of EL6288, pH is close to neutral, generally in the range 6.5 to 7.5.

Salinity

The salinity of the groundwater is variable, with total dissolved solids (TDS) ranging from less than 200 mg/L to more than 7000 mg/L. In the northern part of EL6288, salinities are less than 600 mg/L TDS. However, salinity is more variable in the southern half of EL6288, with pockets of higher salinity occurring within the Murragamba Valley catchment and in the southern part of the Moolarben Creek – Lagoon Creek catchment.

The higher salinities reported at surface water monitoring points SW7, SW8 and SW9 on Lagoon and Moolarben Creeks are consistent with the higher groundwater salinities reported from this part of EL6288. This also suggests that groundwater baseflow has been a significant component of total flow during the period of baseline monitoring.

pH

The groundwater generally has a near-neutral or slightly acidic pH, in the range 5.5 to 8.5. However, low pH waters were reported from a number of locations in the southern part of EL6288, viz

- PZ18 – pH range 3.9 to 4.6 (6 samples)
- PZ43B – pH range 3.4 to 4.1 (4 samples)
- PZ58 – pH range 3.8 to 4.9 (3 samples)
- OB01 – pH range 4.7 to 6.4 (6 samples)
- OB04 – pH range 3.5 to 4.8 (4 samples).

Dissolved Metals

Moderately elevated dissolved metals concentrations have been reported in the groundwater generally through the area. Dissolved metals significantly above ANZECC (2000) guideline values for freshwater ecosystem protection are detailed in **Table 7**.

Dissolved iron concentrations are also frequently elevated in the groundwater, with reported concentrations covering a wide range from <0.01 to 150 mg/L. The higher concentrations are generally found in the southern part of the Moolarben EL6288. Average dissolved iron levels in the groundwater in the southern part of EL6288, south of the Ulan-Wollar Road, is around 2.5-3.0 mg/L, whereas in the northern part of EL6288, average concentration is around 0.9 mg/L.

Nutrients

Generally ammonia concentrations are below the ANZECC (2000) freshwater ecosystem protection guideline value (0.9 mg/L), with minor exceedences reported from bores PZ41A (average 1.2 mg/L), PZ41B (average 1.0 mg/L) and PZ104 (1.1 mg/L). Nitrate concentrations are also generally below the ANZECC (2000) ecosystem guideline (0.7 mg/L) – minor exceedences are reported from PZ43B (average 1.1 mg/L) and PZ112B (1.2 mg/L). The higher concentrations reported from PZ50C (average 2.5 mg/L) and OB04 (average 6.3 mg/L) probably reflect local contamination from either fertilisers or animal wastes.

Groundwater – Major Ion Composition

Major ion composition has been analysed with the aid of Piper trilinear plots. These plots allow each water analysis to be plotted as a unique point based on the relative concentrations of the major cations (calcium, magnesium, sodium and potassium) and major anions (carbonate, bicarbonate, sulphate and chloride). These plots allow assessment of recharge and discharge processes, and can provide indications of mixing of waters from different sources, and to assess likely trends under sustained long-term pumping.

The laboratory analysis results for the Moolarben piezometers and test/production bores are plotted on four Piper diagrams (**Figures 14** to **17**). Bores from the southern part of EL6288 are plotted on **Figures 14** to **16**. Bores from the northern part of EL6288, including the vicinity of the proposed Underground 4, are plotted on **Figure 17**.

Table 7: Dissolved Metals – Significant Exceedences of ANZECC (2000) Freshwater Ecosystem Protection Guidelines

Metal	Guideline (mg/L)	Bore	Reported Concentrations	
			Range (mg/L)	Average (mg/L)
Aluminium	0.055	PZ18	0.48 – 4.6	1.5
		PZ43B	8.1 – 16	11.3
		TB52B	0.37	0.37
		PZ103B	0.23 – 0.57	0.40
		PZ109	0.39	0.39
		OB02	2.0 – 2.1	2.0
Arsenic	0.013	No significant exceedences – maximum reported average value 0.029 (PZ101A)		
Boron	0.37	No reported concentrations above guideline		
Cadmium	0.0002	PZ43B	0.0014 – 0.0027	0.0020
		PZ58	0.0049 – 0.0064	0.0057
Copper	0.0014	PZ43B	0.019 – 0.030	0.023
		PZ58	0.28 – 0.54	0.44
		OB01	0.0012 – 0.022	0.010
Lead	0.0034	PZ43B	0.031 – 0.54	0.26
		TB52A	0.19	0.19
		PZ58	0.37 – 0.53	0.44
		PZ102A	0.010 – 0.022	0.014
		PZ103B	0.064 – 0.17	0.12
		OB04	0.075 – 0.13	0.10
Manganese	1.9	No significant exceedences – guideline value slightly exceeded at PZ30 (average 2.2 mg/L); PZ39 (2.0 mg/L); PZ41A (3.3 mg/L); PZ41B (2.6 mg/L); PZ58 (1.9 mg/L).		
Mercury	0.00006	PZ58	0.0007 – 0.0014	0.0010
Nickel	0.011	PZ41A	0.028 – 0.35	0.21
		PZ43B	0.47 – 0.87	0.66
		PZ58	1.0 – 1.4	1.2
Selenium	0.005	No exceedences – maximum reported average value 0.004 (PZ72C)		
Silver	0.00005	PZ03	<0.001 – 0.003	0.0006
		PZ04	<0.001 – 0.008	0.0016
Zinc	0.008	PZ18	0.012 – 0.38	0.15
		PZ30	0.080 – 0.12	0.095
		PZ41A	0.02 – 0.71	0.45
		PZ41B	0.029 – 0.53	0.73
		PZ43B	2.3 – 3.5	2.9
		PZ50A	0.03 – 0.29	0.14
		PZ58	5.4 – 6.9	6.4
		PZ105A	0.01 – 0.29	0.16
		PZ106A	0.074 – 0.13	0.10
		PZ107	0.11 – 0.29	0.20
		PZ108	0.013 – 0.3	0.16
		OB03	0.005 – 0.14	0.09
		OB04	0.089 – 0.10	0.09

In addition to displaying the relative ionic composition, these plots also provide broad indication of salinity, with the plotted symbols sized according to representative salinity ranges. Visual comparison of **Figure 17** (ie the northern part of EL6288) with the other three Piper plots (**Figures 14** to **16**) reveals the much lower salinity of the groundwater in the northern part of the project area.

3.10 Groundwater-Surface Water Interaction

There is abundant evidence in the large number of springs and seeps that the groundwater discharges to the surface throughout the area. However, with few exceptions, the volumes of individual spring and seep discharges are very small. Many seeps were only visible as patches of dampness or lush grass. The flow rate of the largest spring flow observed in the study area is estimated at less than 0.1 L/s. Nevertheless, the accumulation of groundwater discharges is sufficient to maintain semi-perennial flow in the major tributaries and virtually permanent flow in Goulburn River (either visible flow or flow within the sandy stream bed). Landowners report that a number of spring-fed dams are able to maintain permanent water through extended dry periods due to groundwater seepage.

Groundwater baseflow comprised a significant component of total streamflow during the period of baseline monitoring. This is reflected by a close relationship in the water salinity and major ion chemistry between the groundwater and the surface water during periods of lower rainfall. Thus, in the Moolarben Creek – Lagoon Creek catchment, the surface water quality is generally saline like the typical groundwater from that area. The water quality in the Goulburn River is much less saline than that in the Moolarben Creek – Lagoon Creek system, indicating that the river probably derives most of its baseflow from other tributaries in which the groundwater is presumably of better quality, eg Ryans Creek and Sportsmans Hollow Creek, both of which drain granitic catchments to the west of the Permian basin margin (**Figure 12**).

The salinity of surface flow in Lagoon Creek at site SW7 showed a marked seasonal variation, with a range from 1500 to 4100 mg/L TDS (**Figure 19**). The highest salinities occurred in February 2005 and June 2006, and the lowest in November 2005. A similar pattern was observed at site SW8 on Moolarben Creek, with salinity ranging from 6400 mg/L TDS in February 2005 to 1500 mg/L TDS in September 2005 (**Figure 19**). The higher salinities occurred during the drier part of the baseline monitoring period, ie early in 2005 and early 2006, when presumably surface runoff component was lower, and the bulk of the streamflow was derived from groundwater baseflow.

The water quality in Goulburn River over the same period was at much lower salinity, with a recorded range from 210 to 470 mg/L TDS at SW1 and from 300 to 560 mg/L at SW2 (**Figure 19**). In the case of Goulburn River, the highest salinities were reported in October 2005, and the lowest in early 2005 and early 2006. This pattern is the reverse of that seen in the Moolarben Creek and Lagoon Creek catchments, suggesting that the dominant component of groundwater baseflow reporting to Goulburn River during the drier early part of the baseline monitoring period was derived from areas where the prevailing groundwater salinity is lower than the typical salinity of surface runoff.

Plate 1: Goulburn River North of Underground 4 – Flow Mostly Within the River-bed Gravels

4 MINING PROPOSAL

4.1 Mining Schedule

Mining is proposed to commence in the 2007-2008 year. In this report, Mining Years have been defined as follows:

Mining Year 0	2006-2007
Mining Year 1	2007-2008
Mining Year 2	2008-2009
Mining Year 3	2009-2010
Mining Year 4	2010-2011
Mining Year 5	2011-2012
Mining Year 6	2012-2013
Mining Year 7	2013-2014
Mining Year 8	2014-2015
Mining Year 9	2015-2016
Mining Year 10	2016-2017
Mining Year 11	2017-2018
Mining Year 12	2018-2019
Mining Year 13	2019-2020
Mining Year 14	2020-2021
Mining Year 15	2021-2022

4.2 Open Cuts 1 to 3

Mining is planned to commence at the southern end of Open Cut 1, then progress to the north-eastern end, with extraction to cease in Year 6 (2012-2013). Between Years 6 and 8, Open Cut 2 will be mined, starting at the northern end and progressing southwards. The southernmost Open Cut 3 will be mined from north to south between Years 8 and 10 (**Figure 20**).

Overburden will initially be placed outside the pits, being used initially for the construction of noise and visibility barriers and other infrastructure works. However, once void space becomes available, in-pit dumping of waste will occur, starting in the southern end of Open Cut 1 during Year 2. Rehabilitation of the mine areas will proceed progressively following mining and waste backfilling.

Limited dewatering will be required in Open Cuts 2 and 3, as the Ulan Seam and overlying sediments are only partly saturated through most of that area. The Ulan Seam is also partly dewatered in parts of the north-west of Open Cut 1, due to the regional effects of dewatering operations at the Ulan mine.

4.3 Underground 4

Construction of the two access declines to Underground 4 (**Figure 20**) is proposed to commence during Mining Year 0 (2006-2007). Coal extraction is proposed to commence in Year 2 (2008-2009), and to continue through until the 2021-22 year (Mining Year 15).

Dewatering pumping will need to commence prior to the decline construction, to ensure safe construction conditions. The groundwater level in the Ulan Seam in the vicinity of the declines is currently around 365 mAHD, compared with a seam floor elevation of around 300 mAHD. Groundwater levels will therefore need to be lowered by approximately 65 m during Year 1.

The declines are proposed to commence from boxcuts constructed within paleochannel alluvium, which is mostly unsaturated, but may yield some groundwater inflow in the lowest parts of the channel. The paleochannel alluvium aquifer is perched above, and hydraulically separated from, the underlying Permian coal measures.

Longwall mining is the proposed underground mining method.

4.4 Coal Preparation Plant

Coal washing is proposed, with a washery plant to be constructed in the infrastructure area between Underground 4 and Open Cut 1. Coal stockpiles will also be maintained in this area, for transport off-site by rail.

Other infrastructure facilities are proposed for this area as well (**Figure 20**).

4.5 Water Supply

The projected annual water demands for the Project are listed in **Table 8**.

The proposed approach to sourcing water for the project is to make use first of all groundwater mine inflows and runoff from disturbed mine areas, and recycling of water from the tailings storage. Any remaining water shortfall would be obtained from surplus water generated by nearby coal projects if available, or alternatively from local groundwater sources.

During Year 1, and then from Year 3 to Year 11, it is predicted that mine water inflows will be less than water demand. It is proposed that the water demand shortfall in those years will be met by pumping from production bores adjacent to the Underground 4 area. A production borefield is proposed to be installed along the eastern side of Underground 4, to supplement the existing production bores TB52A, TB103 and TB105 (**Figure 21**). This borefield will facilitate advance dewatering as well as meet the water supply shortfall in Years 1 and 3-11.

Table 8: Water Demand

Mine Year	Water Requirement		Comments
	ML/d	ML/a	
Year 0	0.6	208	Construction and development, including declines for UG4
Year 1	2.7	1000	
Year 2	4.0	1458	
Year 3	4.1	1510	
Year 4	6.3	2291	
Year 5	6.9	2500	Full production rate 12 Mtpa ROM
Year 6	6.9	2500	
Year 7	6.9	2500	
Year 8	6.9	2500	
Year 9	6.9	2500	
Year 10	6.9	2500	
Year 11	6.9	2500	Open cut mining completed
Year 12	2.6	937	
Year 13	2.3	833	
Year 14	2.3	833	
Year 15	2.3	833	
Year 16	0.1	52	Part year of production

5 GROUNDWATER IMPACTS OF THE PROJECT

5.1 Assessment of Groundwater Impacts

The impacts of the project on the groundwater resources have been assessed with the aid of a numerical groundwater flow model.

A three-dimensional finite difference model was used, based on the MODLFOW code (McDonald and Harbaugh, 1988) operating under the Processing MODFLOW Pro software package (IES, 2006), and also the Groundwater Vistas software package (ESI, 2004). The model was set up to simulate groundwater conditions over a 1600 km^2 area, to encompass the area of potential impact of both the Moolarben project and the adjoining Ulan and Wilpinjong projects.

The model structure, modelling approach, model calibration and the results of simulations are detailed in **Appendix F**, and summarised below. The assessment of potential impacts is discussed in detail in the following sections.

The modelling has been subjected to an independent review by Associate Professor Noel Merrick at all stages of the modelling process. Dr Merrick's review report is also included in **Appendix F**.

5.2 Model Design

The domain and boundaries of the model are shown in **Figure 22**.

The model domain covers an area of approximately 1600 km^2, with the southwestern corner defined by Cooyal Creek and the north-eastern corner bounded by the Goulburn River near Comiala Flat.

The southern boundary is aligned approximately with a topographic divide, except for the south-western corner, which is aligned with Cooyal Creek and set as a drain (outflow) feature, with underlying head-dependent flow boundaries to represent deep groundwater outflow down-gradient. The northern boundary has been set beyond the Goulburn River to reduce potential boundary effects, and is set up as a no-flow condition.

The Goulburn River forms the eastern boundary condition for the shallow system (represented using the River package for leakage to or from the groundwater system), with deeper layers using head-dependent flow boundaries to represent deep groundwater outflow down-gradient.

The main part of the western boundary is set as no flow as it is aligned with areas of basement outcrop, and the northern end is aligned with a topographic divide that runs approximately parallel with Ulan Creek.

Rainfall recharge has been set to vary spatially depending on topography and the nature of the surficial material.

The Goulburn River has been simulated using MODFLOW's River package, with the stage elevations set to topography and river bed depth set to 0.2m below the stage. Drains have been used to represent all the tributaries in the area including Moolarben, Lagoon, Murragamba, Cumbo, Wilpinjong and Wollar Creeks. These creeks are believed to be ephemeral, draining the shallow groundwater system, and thus the creek features in the model do not generally represent a potential source of groundwater recharge. Drain elevations of the creeks have been set consistent with surface topography.

Historical pumping in the area began at the Ulan Coal mine as early as 1924, but it is believed that regular and substantial pumping did not commence until 1957. The Ulan Coal pumping operations have been broadly represented in the model by means of drain features, as there is limited information available in the public record on abstraction rates and specific pumping locations. The limited data on historical pumping rates and groundwater levels recorded in UCML's Annual Environmental Management Reports has been used to help calibrate the model.

Pumped abstractions for water supply or dewatering have been represented by a combination of model features, including drains, pumping wells with specified rates, and using the evapotranspiration feature to represent dewatering at maximum specified pumping rates initially, with automatic reduction in pumping as dewatering targets are achieved.

A uniform cell size of 100 x 100m has been used.

The model comprises five (5) layers:

- Layer 1 - Alluvial deposits and Narrabeen Group mainly, but also representing Illawarra Coal Measures and Basement where they occur in outcrop
- Layer 2 - Illawarra Coal Measures containing interbedded coal, siltstone and mudstones, and basement lithologies in areas of outcrop
- Layer 3 - Illawarra Coal Measures containing interbedded coal, siltstone and mudstones, and basement lithologies in areas of outcrop
- Layer 4 - Ulan Coal Seam, and basement lithologies in areas of outcrop
- Layer 5 - Shoalhaven Group and basement outcrop.

The top elevation of Layer 1 has been interpolated from surface topography with a base elevation for the alluvium (where it occurs) set to 5 metres below the surface, except in the east-west paleochannel south of UG4, where up to 40m of alluvium has been simulated.

The top and base of the Ulan Coal Seam (Layer 4) within EL6288 have been interpolated from the Moolarben geological model. These layer elevations have been extended regionally using information from the Wilpinjong groundwater model, using data provided by Wilpinjong Coal Mines, and from the logs of regional drillholes, together with spot level and general dip information provided by the 1:100,000 geological map.

The basement (Layer 5) has an assumed thickness of 100m. The Illawarra Coal Measures (Layers 2 and 3) have been assumed to be up to 100 metres thick, extending upwards from the top of the Ulan Coal Seam (Layer 4), with the topography data used to identify cut-throughs in low-lying areas. Layers 2 and 3 have been set with equal thickness, which allows for a disturbed unit (the goaf above longwall panels) immediately above the Ulan Coal Seam (Layer 3), and an undisturbed unit (Layer 2) above that.

Figures 23 and **24** are cross-sections taken from the initial model setup as a result of applying the above layering methodology. **Figure 23** shows the cross section through the proposed open cuts at Moolarben and Wilpinjong, while **Figure 24** shows the layer arrangement near the proposed Moolarben underground operation. The modelled transects show the Ulan Coal Seam dipping to the east with the seam 0–10 m below the surface at Moolarben Pit 2 and 30–40 m below surface at Wilpinjong, and about 70–180 m below the surface at the Moolarben underground, with a goaf unit of about 50m thickness.

5.3 Calibration Modelling

The model was initially run in steady state mode, to calibrate the model against the present observed groundwater conditions. However, because of the ongoing transient impacts of dewatering pumping from Ulan Coal's open cut and underground mines, the present observed groundwater levels do not represent an equilibrium condition. Further there is limited information on the groundwater conditions that applied before Ulan dewatering commenced. Consequently, the steady state calibration can only be approximate. Hence, in addition to the steady state runs, further calibration was achieved during the subsequent transient modelling, in which an attempt was made to simulate Ulan Coal's past dewatering pumping and the resultant impacts on groundwater levels.

An acceptable calibration was achieved when the transient simulation produced conformance with the gross pumped extractions and the resultant head distribution around the Ulan mines. It was considered that the model could then be used with confidence to predict future impacts from the proposed Moolarben mining operations.

Through the calibration process, there was some refinement of the hydraulic parameter values assumed in the model. The final parameter distribution adopted for subsequent predictive modelling is illustrated in **Appendix F**, and summarised in **Table 9**.

The model has been set up to include the Ulan and Wilpinjong projects as well as Moolarben. Hydraulic properties derived from calibration of the historic pumping and groundwater level impacts at Ulan have been used in the Ulan area and generally also in the Moolarben Underground 4 area, where hydraulic testing has confirmed similar conditions to those applying at Ulan. The initial hydraulic properties adopted for the Wilpinjong area of the model are biased towards those reported in the Wilpinjong EIS (Resource Strategies, 2005).

Table 9: Calibrated Model Aquifer Parameters

Main Layer	Aquifer/Aquitard	T (m^2/d)	K_h (m/d)	K_v (m/d)	Unconfined S_y	Confined S
1, 2 & 3	Alluvial deposits	-	0.7-1.5	0.005-0.15	0.20	n/a
1	Triassic Narrabeen Group	-	0.1	0.001	0.05	5e-05
2	Permian Coal Measures (coal seams present; undisturbed)	-	0.06-0.8	0.0007	0.05	5e-05
3	Permian Coal Measures (coal seams absent; undisturbed)	-	0.01-0.8	0.00001-0.0004	0.05	5e-05
4	Ulan Coal Seam (undisturbed)	-	1.7-3.0	0.00015-0.025	0.05	5e-05
5	Sandstone	1-5		0.0000025-0.1	0.05	5e-05
4 & 5	Basement Granite or Volcanics (T in layer 5 only)	0.1	0.001	0.00001	0.05	5e-05

5.4 Impact Prediction Modelling

The transient simulation described in **Section 5.3** above was continued through the full proposed mine life of the Moolarben Project. In addition to the Moolarben proposals, the adjoining Ulan and Wilpinjong projects were included in the simulation.

Mine plans for the Wilpinjong project were assumed to be in accordance with the plans outlined in the Wilpinjong EIS (Resource Strategies, 2005). At Ulan, it was assumed that underground mining would continue northwards and north-westwards from the point reached in 2005, at a similar production rate, generally in accordance with the mining layout presented in UCML's 2005 AEMR (UCML, 2006).

Initial predictive simulations were run with all groundwater extractions assumed to derive from direct inflow into the mine workings, with no pumping from external dewatering bores.

The simulation predicted that there would be a shortfall between the dewatering discharge and the water demand during Year 1, and from Year 3 to Year 11 of the Moolarben project. The predicted shortfall ranges up to 2129 ML (5.8 ML/d) in Year 9 (2015-16). During Year 2, and Years 12 to 16, the mine water inflows were predicted to be in excess of water demand.

Accordingly, a further simulation was run, with the additional water requirement assumed to be derived from external production/dewatering bores along the eastern boundary of Underground 4 (see **Section 5.5**). Makeup pumping was also included in the model for both the Ulan and Wilpinjong projects, in accordance with historical records in the case of Ulan and with the Wilpinjong EIS in the case of Wilpinjong.

The groundwater inflows and pumping rates predicted from the final simulation are listed in **Table 10**. The table shows the results of the simulation through the past eight years of dewatering from the Ulan mine, and through to the planned completion of the Wilpinjong project, five years after the completion of mining at Moolarben.

The predicted inflow rates at Ulan are possibly higher than the actual rates of groundwater inflow. It is apparent (UCML, 2006) that there is a component of recycled water in the total pumping rates from the Ulan underground workings, and the true rate of groundwater inflow is uncertain.

During model calibration, the hydraulic parameters in the Moolarben model were amended to try to generate inflow rates at Ulan that matched the reported pumping rates from underground. Since it is unclear from the available UCML reports (UCML, 2005 and 2006) how much of the total pumpage from underground is groundwater inflow and how much is recycled water from the up-dip open cut, it was therefore considered prudent to take a conservative approach, and the model was considered suitable for predictive purposes when it was predicting inflow rates comparable with the total pumping rates indicated by the available reporting.

Anecdotal evidence indicates that groundwater inflow rates to the Ulan underground mine were around 3ML/d in the early stages of underground mining. Prior to that time, UCML pumped about 3 ML/d from a borefield of five production bores located above the southern part of Moolarben's proposed Underground 4 mine. It is understood that this rate was the maximum sustainable rate from the borefield. This pumping rate is consistent with the model prediction of between 2 and 4 ML/d from the southern part of Underground 4 during Years 2 to 8 of the Moolarben project (ie 2008-2015).

Nevertheless, as the model possibly over-predicts past inflow rates to Ulan underground, the future inflow rates predicted by the model may be over-estimates, not only in respect of Ulan, but also at Moolarben and possibly at Wilpinjong. However, due to the uncertainties regarding actual Ulan rates, this approach is considered appropriate.

The apparent oscillation in predicted inflow rates at Ulan is due to the assumption made in the model that longwall panels would alternate between east and west of the central access headings as the mine progresses northwards. If a different mining pattern is followed, a different pattern of inflow rates would be predicted, but generally within the same range.

Table 10: Predicted Annual Groundwater Abstractions (ML/a) – Moolarben, Ulan and Wilpinjong Projects

Mine Year	Period	Moolarben Mine Water Inflows				Moolarben Pumping Bores	Ulan		Wilpinjong
		OC 1	OC 2	OC 3	UG 4		OC	UG	OC
	1997-90	-	-	-	-	-	613	53	-
	1990-92	-	-	-	-	-	26	1818	-
	1992-94	-	-	-	-	-	8	2180	-
	1994-96	-	-	-	-	-	13	2206	-
	1996-98	-	-	-	-	-	23	2621	-
	1998-00	-	-	-	-	-	30	2839	-
	2000-02	-	-	-	-	-	36	3307	-
	2002-04	-	-	-	-	-	43	3453	-
	2004-06	-	-	-	-	-	45	3711	-
0	2006-07	-	-	-	113	95	42	3944	230
1	2007-08	0	-	-	83	917	41	4185	823
2	2008-09	0	-	-	1472	-	30	3181	876
3	2009-10	0	-	-	1282	228	16	4123	628
4	2010-11	4	-	-	1035	1252	8	3023	588
5	2011-12	116	-	-	821	1563	3	4214	646
6	2012-13	139	0	-	639	1722	2	2990	600
7	2013-14	-	0	-	527	1973	2	3974	1618
8	2014-15	-	0	0	733	1767	2	2940	250
9	2015-16	-	-	0	371	2129	2	4064	313
10	2016-17	-	-	0	679	1821	2	2765	647
11	2017-18	-	-	-	902	1598	2	4004	1077
12	2018-19	-	-	-	1479	-	2	2892	3077
13	2019-20	-	-	-	1925	-	2	3992	2106
14	2020-21	-	-	-	2255	-	2	2888	1491
15	2021-22	-	-	-	2402	-	2	4034	1340
16	2022-23	-	-	-	-	55	2	2914	1194
	2023-24	-	-	-	-	-	2	3151	1197
	2024-25	-	-	-	-	-	-	-	1280
	2025-26	-	-	-	-	-	-	-	1282
	2026-27	-	-	-	-	-	-	-	1226

It is predicted that negligible inflows will occur to Open Cut 2, and only very minor inflows to Open Cut 3. Initial inflows to Open Cut 1 will be very low, but they will progressively increase as Open Cut 1 advances further downdip to the north, reaching a predicted maximum of 0.4 ML/d in Year 6.

Inflows to Underground 4 are predicted to be relatively modest in Year 1, when activity will include the construction of the access declines and initial roadway development underground for longwall panel 1. Inflows increase markedly once longwall extraction commences in Year 2. Inflow rates are predicted to be relatively steady for the next few years while coal extraction is taking place in the southern half of Underground 4. The inflow rates are predicted to increase progressively once mining moves to the northern end of Underground 4, reaching a maximum of 6.6 ML/d in the final year of mining.

As indicated above, the model is considered conservative because of the assumptions made in respect of historical dewatering rates at Ulan based on uncertainty and the sparseness of the data. Further, the model is also considered to be conservative because the Permian coal measures aquifer has been assumed in the model to be laterally hydraulically continuous. However, the 2-3 day pumping tests all showed the evidence of barrier boundaries in the aquifer system. It is certain that these boundaries will act to partly compartmentalise the aquifer system, at least locally, which could reduce the groundwater inflow rates necessary to achieve dewatering. The boundaries could also limit the lateral extent of drawdowns. However, it is not certain whether the boundaries will be effective on a regional scale.

Again drawing on the Ulan experience, anecdotal evidence indicated that the major Spring Gully Fault that marks the eastern limit of Ulan's underground workings (**Figure 12**) was expected to act as a barrier to groundwater flow, but the drawdown impacts observed to the eastern side of this fault suggest that at best the fault is acting as only a partial barrier. UCML (2006) report that a 7-day pumping test conducted in November 2005 to test the hydraulic behaviour of the Spring Gull Fault also confirmed that the fault is not acting as either a barrier or a conduit to flow. Accordingly, it was considered prudent to take the conservative assumption that there would be no barriers to flow within the coal measures aquifer.

These two conservative assumptions (ie the adoption of higher inflow rates at Ulan and no barrier boundaries within the coal measures aquifer) may mean that the predicted inflow rates to the Moolarben Underground 4 mine are over-estimated, by as much as 50 percent. However, it is considered prudent to take this approach until more recent information from Ulan is available, and until some history of pumping from Moolarben is available.

5.5 Makeup Water Supply

Predicted mine water inflows are expected to be sufficient to meet the project's water demand only in Years 2 and 12-16 (**Table 10**). The predicted shortfall in Year 1 and Years 3 to 11 will need to be made up from additional pumping or from alternative sources.

It is recommended that in Years 1 and 3 to 11, the additional water required for the project be obtained if possible be sourcing surplus water from the Ulan operations, or if that source is not available, then from production bores located around the eastern side of the Underground 4 mine. This would have the additional benefit of assisting advance dewatering of Underground 4.

It is considered that individual bore yields would be in the order of 0.3 – 0.4 ML/d, so up to 16 dewatering bores would be required. The existing bores TB52A, TB103 and TB105 would form part of the borefield.

In the event that the groundwater inflow rates to Moolarben Underground 4 have been significantly over-estimated, and the additional shortfall cannot be provided from Ulan or Wilpinjong, it may be necessary to develop additional water supply pumping bores. These could be located at other sites around the perimeter of Underground 4, or alternatively in Permian coal measures aquifers along Murragamba valley, down-dip from Open Cuts 1-3, or in the vicinity of bore TB52A.

The pumping test results from bores TB103 and TB105, and indicative airlift yields during drilling of piezometers at other locations in the northern and central parts of EL6288, indicate that there is sufficient capacity in the aquifer system to sustain a total extraction rate (ie combined rate from mine inflows and external dewatering bores) of at least 7 ML/d, sufficient to meet the project's peak demand of 2500 ML/a. The production bores are each considered capable of sustaining pumping at rates of 0.3-0.4 ML/d, even allowing for the multiple boundary effects, so that the total supply could be met if necessary from a borefield of up to 20 production bores.

5.6 Groundwater Level Impacts

The dewatering required for the Moolarben coal project will have an impact on regional groundwater levels.

5.6.1 Permian Coal Measures

Groundwater levels in the Ulan Seam and the overlying Permian coal measures have already experienced significant drawdown in response to abstractions from UCML's open cut and underground mines, as illustrated by the extensive cone of depression around the Ulan mines on **Figure 10**.

Predicted Ulan Seam water levels at 2022, the end of the Moolarben coal project, are shown on **Figure 25**. Total predicted drawdowns in this aquifer at 2022 are shown on **Figure 26**.

Figures 25 and **26** show the cumulative effects of all three mining operations. There is a prominent depression over the Moolarben Underground 4 mine area. The depression over the Ulan underground mine is predicted to have moved further north as the centre of mining there has moved north, and there is a zone of draw-up, due to recovery of water levels around the 2006 centre of pumping. There is also a less prominent region of depression centred on the Wilpinjong project.

The predicted drawdown effect due to the Moolarben project alone is shown on **Figure 27**. This has been derived from comparing the predicted drawdowns due to all three projects and that predicted by running the model without the Moolarben project, ie with just Ulan and Wilpinjong operating. The difference between the two predictions has been assumed to represent the Moolarben impacts.

Figure 27 shows a prominent cone of depression developed over Underground 4, and the Ulan seam is also predicted to be substantially dry around the Open Cuts, apart from a small area at the northern end of Open Cut 1. The Ulan Seam is also predicted to be dry across much of the western parts of the Murragamba Valley area, to the east of the Open Cuts and south-east from Underground 4. The regional drawdown impact in the Ulan Seam from the Moolarben project is predicted to extend to about 20 km to the east of Underground 4, with approximately 5m drawdown at 10 km.

Drawdown impacts in the Permian Coal Measures above the Ulan Seam are predicted to be much less than those for the Ulan Seam – for example in model Layer 2, the undisturbed Permian coal measures, the predicted drawdown due to Moolarben at 10km east of Underground 4 is just 0.5 m.

5.6.2 Triassic Narrabeen Group

The project simulation also predicted maximum drawdowns of between 0 and 0.6 m in Layer 1 in the northern part of EL6288 (**Figure 28**). As for the Permian aquifer, this plot has been derived by comparing the predicted change in Triassic water levels due to all three coal projects, and a prediction based on just Ulan and Wilpinjong, with the difference assumed to represent the drawdowns due to Moolarben alone. Note that the Triassic is either absent or dry over most of the area occupied by the Moolarben coal project, with only the very northern part of Underground 4 overlain by saturated Triassic. The edge of saturation is seen on **Figure 28** as a NW-SE trending line that crosses Underground 4 near its northern end. This line marks the edge of the predicted drawdown contours.

Figure 28 shows a region of drawdown between 0.4 m and 0.5 m to the east of Underground 4, and smaller drawdowns extending further to the east, with 0.25 m drawdown at a distance of 8 km east of Underground 4.

These results are consistent with observations at Ulan, which reportedly have shown no or minimal drawdown impacts of Ulan Seam dewatering on groundwater levels in the Triassic.

5.6.3 Tertiary and Quaternary Alluvium

The limited occurrence of Quaternary alluvium within the immediate vicinity of the Moolarben mine development areas was included in the model, although it is underlain mostly by bedrock granites, and even where underlain by Permian coal measures, they are predicted to be substantially dry. The alluvium of the Moolarben-Lagoon Creeks catchment is therefore not directly affected by the dewatering operations, as discussed in more detail in **Section 5.10**.

The Tertiary paleochannel alluvium has not been represented in the model, due to its limited occurrence, its dry condition in the area to the south of Underground 4, and the apparent lack of hydraulic connection with the

Quaternary alluvium in the Moolarben Creek valley, based on water quality and water level evidence. The potential impact of the project on the Tertiary alluvium is discussed in more detail in **Sections 5.10** and **5.11**.

5.7 Sensitivity Modelling

Because of the uncertainties associated with the model input parameters, a series of sensitivity runs was undertaken, to assess the implications of possible errors in the assumed model parameters. The sensitivity runs involved successive changes to key hydraulic parameters. The range of sensitivity runs carried out is summarised in **Table 11**.

The results of sensitivity modelling are discussed in detail in **Appendix F**. In summary, the runs that gave the closest correlation with historical Ulan mine groundwater inflow rates (based on best available information in the public record) while still achieving an acceptable scaled RMS error of less than 10 percent, were the runs that assumed a lower horizontal hydraulic conductivity in the Ulan Seam. The particular run which was adopted as the base case was the run that best matched the known distribution of groundwater levels.

It is acknowledged that this results in a moderate over-prediction of inflow rates to the Ulan mine over the past 5-10 years, and may therefore also be over-predicting the likely inflow rates to the Moolarben operations. The higher scaled RMS error associated with the "low" case runs is most likely due to imperfect hydraulic parameter assignment.

Although the hydraulic conductivity of Layer 4 (Ulan Seam) and Layer 3 (disturbed zone of Permian Coal Measures immediately above the longwall panels post-mining) would increase significantly as a result of subsidence and goaf formation above the mined out panels, it was not possible to incorporate a progressive increase in hydraulic conductivity as each mine cell is mined out, as this parameter cannot be altered within a simulation. Consequently, the hydraulic conductivity was held unchanged through the full base case simulation.

In order to assess the impact of higher conductivity in the affected cells, a "goaf" sensitivity run was included in the sensitivity modelling in which the conductivity in all Layer 3 and 4 cells coinciding with the longwall panels was set to two orders of magnitude (100 times) higher than the base case for the full simulation. The storativity value was also set to 0.01 for these cells.

The results of this sensitivity run showed that the change to higher conductivity may increase the inflow rates by up to about 25 percent above the base case predictions.

Table 11: Summary of Parameters Adjusted in Sensitivity Analysis

Parameter Adjusted			**Low**	**Base Case**	**High**
Layer 4 Horizontal Hydraulic Conductivity (m/d)	Parameter values assigned	Ulan	1	**3**	10
		Moolarben and Wilpinjong	0.5	**1.7**	5.5
	Predicted Moolarben Inflow Rates (ML/d)	**Year 3**	2.7	**4.0**	6.9
		Year 15	4.9	**6.6**	14.6
Layers 3/4/5 Vertical Hydraulic Conductivity (m/d)	Layer 3	Ulan	10^{-6}	**2.5 x 10^{-6}**	10^{-3}
		Moolarben	10^{-5} or 4 x 10^{-5}	**10^{-5} or 1 x 10^{-4}**	10^{-2} or 4 x 10^{-2}
	Layer 4	Ulan	6 x 10^{-5}	**1.5 x 10^{-4}**	6 x 10^{-2}
		Moolarben	1 x 10^{-2} or 8 x 10^{-5}	**2.5 x 10^{-2} or 2 x 10^{-4}**	1 or 8 x 10^{-2}
	Layer 5	Ulan	10^{-6}	**2.5 x 10^{-6}**	10^{-3}
		Moolarben	10^{-6}	**2.5 x 10^{-6}**	10^{-3}
	Predicted Moolarben Inflow Rates (ML/d)	**Year 3**	2.7	**4.0**	12.1
		Year 15	5.9	**6.6**	27.2
Drain Conductance (m^2/d)	Values assigned	Underground	1	**4**	10
		Open Cut	100	**1000**	10000
	Predicted Moolarben Inflow Rates (ML/d)	**Year 3**	2.9	**4.0**	5.8
		Year 15	6.3	**6.6**	9.7
Drain Setup			-	**Drains active only in drive and current panel**	**Drains remain active in all mined cells**
	Predicted Moolarben Inflow Rates (ML/d)	**Year 3**	**-**	**4.4**	**4.5**
		Year 15	**-**	**6.6**	**9.6**

5.8 Groundwater Level Recovery Post-Mining

The groundwater flow model has been run for a period of 45 years after cessation of mining, to simulate the post-project recovery of groundwater levels. The predicted head distribution at the completion of mining was adopted as starting condition for the recovery simulations.

For the post-mining recovery simulation, the aquifer parameters for the cells corresponding to the goaf above the mined panels were altered at both Ulan and Moolarben underground mines to reflect the higher hydraulic conductivities of the goaf zone. Goaf hydraulic conductivities were set to 100 times the base case values, and storativity to 0.10. Likewise, the parameters for the residual pit voids at Ulan and Wilpinjong were also adjusted. Pit voids were assigned a hydraulic conductivity of 10000 m/d and storativity of 0.99, and the evaporation rate was set to 50% of pan value (or 0.00237 m/d). It was assumed in the modelling that all three Moolarben pits will be backfilled with waste to above the pre-mining groundwater level, although in reality there will be small residual voids at the northern end of Open Cut 1 and the very southern end of Open Cut 3.

The results of the post-mining recovery simulation show that within 10-20 years after completion of mining, groundwater levels are predicted to have recovered to pre-mining (ie pre-1987) levels in the Permian coal measures. Some remaining residual drawdown is predicted to still be present at Wilpinjong, due to the evaporation effect from the residual pit lakes proposed to remain in place after project completion.

By 2067, there is no residual drawdown in any of the Permian coal measures layers, ie the Ulan Seam and the overlying coal measures. However, small residual drawdowns are predicted to be still present in the Triassic aquifer.

Figure 29 shows the predicted net residual drawdown in the Triassic aquifer at 2067, nominally 45 years after completion of the Moolarben project. This plot shows the residual drawdown impact from all three coal projects at 2067. Both Ulan and Wilpinjong are also expected to be completed long before that date. **Figure 29** shows a region of residual drawdown ranging up to about 3 m to the east of Underground 4.

The recovery simulation results are presented in detail in **Appendix F**.

5.9 Groundwater and Surface Water Quality Impacts

The initial average groundwater quality of mine inflows (and pumped extractions) for each of the four proposed mining areas is expected to be similar to the chemical composition shown in **Table 12**.

These initial average qualities have been determined by simple averaging of the water analyses from all bores within the vicinity of each of the four mining areas. It is expected that there will be some modification from year to year within each area, and the Open Cuts in particular may see annual fluctuations above and below the above averages due to the spatial variability in water quality. In the case of Underground 4, there is likely to be a slight increase in salinity and a similar accompanying change in some of the other quality parameters, as slightly more saline water is drawn in from the south. The increase over time may see an increase in salinity in the order of 25% above the initial average salinity.

The dewatering is not expected to have an adverse impact on water quality in the surface water system. In the case of Open Cuts 2 and 3, the dewatering may slightly reduce the volume of the groundwater baseflow component as a percentage of total flow. This will result in a corresponding albeit slight improvement in the average water quality of Moolarben Creek and Lagoon Creek, which should also have a flow-on effect to the water quality in Goulburn River.

Table 12: Average Mine Inflow Water Quality

Parameter	Average Concentration (as mg/L unless otherwise specified)			
	OC1	OC2	OC3	UG4
pH	6.45	4.24	6.52	7.41
Total Dissolved Solids	415	532	2047	420
Total Suspended Solids	180	69	581	228
Electrical Conductivity (µS/cm)	643	578	3157	717
Calcium	40	0.4	106	46
Magnesium	16	8.1	123	16
Sodium	49	81	320	60
Potassium	15	2.5	27	16
Carbonate as $CaCO_3$	<2	<1	<2	<2
Bicarbonate as $CaCO_3$	167	18	477	208
Sulphate	82	129	601	95
Chloride	35	50	440	27
Cyanide	<0.01	<0.01	<0.01	<0.01
Aluminium	0.05	1.54	18.02	0.03
Arsenic	0.002	0.007	0.004	0.008
Boron	0.02	0.06	0.04	0.03
Cadmium	0.00015	0.00027	0.00111	0.00015
Chromium	0.002	0.002	0.007	0.00
Cobalt	0.0124	0.0131	0.0865	0.0043
Copper	0.0008	0.0027	0.0450	0.0011
Iron	3.22	2.08	2.49	0.89
Lead	0.0025	0.0070	0.0604	0.0050
Manganese	0.726	0.009	0.352	0.289
Mercury	<0.0001	0.0002	<0.0001	<0.0001
Nickel	0.024	0.024	0.135	0.018
Selenium	<0.001	<0.001	0.003	0.002
Silver	<0.001	<0.001	0.006	<0.001
Zinc	0.058	0.150	0.662	0.085
Ammonia	0.18	0.39	1.64	0.18
Nitrate	0.02	0.05	1.17	0.08
Reactive Phosphorus	0.02	0.03	0.09	0.04
Total Phosphorus	0.27	0.17	0.30	0.32

5.10 Potential Impacts on Alluvium in Moolarben Creek – Lagoon Creek Catchment

The distribution of alluvium in the Moolarben Creek – Lagoon Creek catchment is shown on **Figure 12**. Two types of alluvium are recognised:

- Quaternary alluvium, as mapped on the published Gulgong 1:100,000 geological map (Watkins, et al, 1999);

- Paleochannel alluvium of probable Tertiary age.

Moolarben Creek has a well-defined incised channel in the southern part of the catchment, where the creek is situated close to the escarpment rising up to the sandstone plateau. Approximately level with the northern end of the western boundary of Munghorn Creek Nature Reserve (**Figure 12**), Moolarben Creek ceases to occupy a well-defined channel, and fans out across a broad plain towards Lagoon Creek to the west.

The mapped Quaternary alluvium comprises a section along this defined channel of Moolarben Creek to the south, and a much more extensive alluvium associated with Lagoon Creek and extending downstream to the north. No alluvium is mapped through the central portion of Moolarben Creek where it fans out broadly across the valley towards the confluence with Lagoon Creek.

From drilling results, it is believed that the Quaternary alluvium has a maximum depth of about 5-10m around Lagoon Creek, but may be much shallower adjacent to Moolarben Creek.

The Tertiary paleochannel alluvium is recognised on the basis of drilling information rather than surface expression. The known extent of Tertiary paleochannel alluvium consists of a NW-SE trending zone situated between the proposed Open Cut 3 and Moolarben Creek. From drilling results, the paleochannel alluvium extends to a maximum depth of approximately 30m.

<u>Open Cut 3:</u>

The mining of coal from the proposed Open Cut 3 (**Figure 12**) is not expected to impact directly on either Moolarben Creek or the Quaternary alluvium. The proposed open cut is located well away from the creek, and in most areas, the lowest floor elevation of the open cut will be at or above the creek-bed level in Moolarben Creek.

There is a small section at the very southern end of Open Cut 3, where the pit extends by up to about 5 m below the expected groundwater level within the Permian Coal Measures. The open cut at this location is 600 m from Moolarben Creek, but is very close to the tributary Spring Creek (**Figure 12**). The mining may lead to a temporary reduction in groundwater levels in the vicinity of this low point in Open Cut 3, but by only of the order of about 5 m. The groundwater level in this area is currently about 10 m below the ground surface at Spring Creek, so an increase to 15 m as a result of mining is not expected to have a material impact on loss of surface flow from Spring Creek, or from any associated alluvium.

Figure 30 shows a series of cross-sections across the Moolarben Creek valley in the area of Open Cut 3. The locations of the sections are shown on **Figure 12**. The sections show the proposed pit outlines relative to Moolarben Creek and the Quaternary alluvium, as defined by the drillholes shown on the sections. Where groundwater was intersected, the water table elevation is also shown on the sections.

The outline of the Tertiary paleochannel alluvium shown on the sections on **Figure 30** has been interpreted from the drilling results. Open Cut 3 will intersect the Tertiary paleochannel, but at elevations above the water table. Piezometer PZ58 located close to Section 4 (**Figure 12**) is completed in the Tertiary alluvium, and reports a water level around 468 mAHD. This level has been projected on to Section 4, and shows that the water table is about 10m lower than the lowest proposed floor level of Open Cut 3 (**Figure 30**). It is noted also that the groundwater intersected by PZ58 is also highly saline, with a TDS of over 7000 mg/L, and a pH of approximately 4 (**Table 3**).

Groundwater levels indicated from drilling results on Sections 2 and 3 are also below the lowest nearby pit floor levels. The alluvium drilled on Section 1 was reported to be dry.

In conclusion, Open Cut 3 is predicted to have no impact on surface flow in Moolarben Creek or on groundwater levels or quality in the alluvium associated with Moolarben Creek. Open Cut 3 is also more than 750m from the edge of the Lagoon Creek alluvium at its closest point, and the pit floor level will be more than 20m above the creek-bed level. Open Cut 3 will have no direct impact on flows or quality in Lagoon Creek.

Open Cut 2:

Open Cut 2 is located well to the east of the edge of alluvium associated with Moolarben and Lagoon Creeks, with the separation being 200m at its closest point. The Ulan Seam in this part of the deposit is only partly saturated, and in some places is entirely above the water table. This open cut is also located very close to the basin margin, and the published geological map (Watkins. Et al, 1999) shows granite basement outcrop between the pit margin and the edge of the alluvium (see also **Figure 12**).

Based on the relatively shallow depth of coal in Open Cut 2, the low water table level, the lateral separation of at least 200m between the proposed pit and the edge of the alluvium, and the occurrence of granite outcrop between the pit and the alluvium, it is predicted that Open Cut 2 will have no direct impact on surface water flow or quality in Moolarben Creek and Lagoon Creek, or on groundwater levels or quality in the alluvium associated with those creeks.

Open Cut 1:

Open Cut 1 is proposed to encroach into the mapped alluvium along part of its north-western edge (**Figure 12**). That part of the pit is adjacent to the main Goulburn River valley, downstream of the confluence of Moolarben Creek with Sportsmans Hollow Creek, when it becomes known as the Goulburn River, and is discussed in more detail in the following section, **Section 5.11**.

The southern part of Open Cut 1 is proposed to approach no closer than 200m to the edge of alluvium associated with Moolarben Creek. At this closest point, the pit floor level will be at an elevation of around 450 mAHD, compared with a creek-bed level of around 430 mAHD. Two piezometers have been drilled in this area – PZ31A within the outline of Open Cut 1, and PZ55 near the edge of the alluvium on the eastern side of Moolarben Creek (**Figure 12**). PZ31A penetrated the Ulan Seam, the underlying Marrangaroo Conglomerate and granite basement; it is screened in Marrangaroo Conglomerate at 432-444 mAHD; and is dry. PZ55 is screened in alluvium, and has a groundwater level at 422 mAHD.

Based on the relative pit floor levels and the alluvium groundwater level, together with the separation between the pit and the edge of the alluvium, it is predicted that Open Cut 1 will have no direct impact on surface water flow or quality in Moolarben Creek, or on groundwater levels or quality in the Moolarben Creek alluvium.

5.11 Potential Impacts on Goulburn River Alluvium

The published geological map (Watkins et al, 1999) shows alluvium associated with the Goulburn River valley extending only as far as the confluence with Bora Creek (see also **Figure 12**). Thereafter, the present course of Goulburn River, including both the original course and the diversion around Ulan Open Cut, is incised initially into the Permian and further north into Triassic rocks, with only limited alluvial development.

Open Cut 1 is proposed to encroach into the area of mapped Quaternary alluvium, but it has been found by drilling to be only a few metres thick in this area, and dry. Likewise, Underground 4 is proposed to encroach within the mapped boundary of the alluvium within the Bora Creek catchment. The Quaternary alluvium has been found to be dry in that area as well.

The Quaternary alluvium is underlain by up to 40-50 m of Tertiary paleochannel alluvium (**Figure 31**), however this has been revealed by drilling to be largely dry as well. It is expected that this paleochannel alluvium will be intersected by the pit, but as it is dry, the mining is not expected to have any direct impact on the groundwater system.

The presence of both Quaternary and Tertiary alluvium in the Bora Creek valley between Underground 4 and Open Cut 1 is shown on Sections 9 and 10 on **Figure 31**. The locations of Sections 7-10 are shown on **Figure 12**. The base level of the Tertiary paleochannel appears to be at around 375 mAHD, compared with a base level of the Goulburn River diversion at the confluence with Bora Creek of about 405 mAHD. However, drilling has shown the Tertiary alluvium to be dry on these two sections. Sections 7 and 8 on **Figure 31** show that the Tertiary alluvium is saturated further to the east, with the groundwater level close to ground surface at PZ52 (elevation 418 mAHD).

Groundwater levels are also very low in the Permian coal measures, as revealed by the piezometers in this vicinity PZ31A, PZ30 PZ53 and PZ110 (**Figure 12**). The Ulan Seam is dry (ie above the water table) in PZ31A (see **Section 5.11**), and in PZ30. The groundwater level in coal measures above the Ulan Seam in PZ53 (**Figure 12**) is at 400 mAHD, compared with the bed level of the Goulburn River diversion nearby of around 410-415 mAHD. The water level in PZ110, which is screened in both the Ulan Seam and the underlying Marrangaroo sandstone, is at 366 mAHD, that is below the base of the nearby Tertiary paleochannel (**Figure 31**).

It is not clear whether the low groundwater levels in both the alluvium and the Permian coal measures in this area is a natural feature or is due to the residual effects of dewatering of the Ulan Open Cut to the northwest.

As the groundwater levels are already well below the base level of the Goulburn River, it is predicted that the mining in Open Cut 1 and in Underground 4 will have no impact on flow or quality in Goulburn River. There is apparently no groundwater present in the Quaternary alluvium, and groundwater levels in the Tertiary alluvium, if present at all, are also well below both the Goulburn River bed level and the base of the associated Quaternary alluvium. Groundwater levels in the Permian coal measures at the southern end of Underground 4 are already lower than the base of the Tertiary paleochannel alluvium.

5.12 Potential Impacts of Subsidence, Surface Cracking and Subsurface Cracking from Longwall Mining in Underground 4 Area

The potential subsidence resulting from longwall mining in the Underground 4 area is described by Strata Engineering (2006). Strata Engineering predicts that subsidence is likely to occur in areas directly overlying the longwall extraction panels, with a magnitude of up to 2.4 m.

Strata Engineering also describes the subsurface cracking that is likely to develop above the longwall panels due to the subsidence and goaf formation. They have predicted that subsurface cracking could propagate upwards from the top of the coal extraction zone for a height that varies between approximately 46 and 74 m depending on the location within the Underground 4 mining area and the depth of overburden cover. These predictions represent the mean or 50 percent confidence level. Cover depth will vary from 85 m at the southern end of Longwall 4 to about 200 m at the northern end.

The most likely heights of subsurface cracking predicted by Strata Engineering have been plotted on two cross-sections (Sections 5 and 6) depicting the subsurface profile at the northern end of Underground 4, where the underground workings are proposed to come closest to Goulburn River and the Drip. The locations of the cross-sections are shown on **Figure 12**. These cross-sections (**Figures 32** and **33**) show that subsurface cracking is not expected to extend as high as the top of the Permian Coal Measures, and therefore will not penetrate into the overlying Triassic Narrabeen Group sediments.

Strata Engineering have also determined a plausible worst case height of sub-surface cracking, representing the 95 percent confidence level, which is about 75 m near the southern end of Underground 4 and about 90 m near the northern end. This plausible worst case height of subsurface cracking is also shown on Sections 5 and 6 (**Figures 32** and **33**). This extends up to approximately the base of the Triassic sediments at the northern end of Underground 4. There is no Triassic above the Permian coal measures at the southern end of Underground 4.

It is also likely that surface cracking will potentially develop in areas affected by subsidence (Strata Engineering, 2006). Surface cracks up to 50 to 250 mm in width could occur immediately above goaf areas (ie within the angle of draw extending out from the longwall panel areas). Strata Engineering predict that such cracks could extend to depths of 2 to 5 m, but would not connect with sub-surface cracking extending up from the goaf, except possibly in the shallow cover areas at the southern end of Longwall 4. Connection between the subsurface cracking and the surface cracking is not expected to occur in any areas where the Permian coal measures are overlain by Triassic Narrabeen Group sediments. The clear separation between surface cracking and subsurface cracking at the northern end of Longwall 4 near the Drip is shown on Section 5 (**Figure 32**) and Section 6 (**Figure 33**).

The potential impacts of subsidence effects on the groundwater system and groundwater users, including groundwater dependent ecosystems, are discussed below in **Sections 5.13** and **5.14**.

5.13 Potential Impacts on Existing Groundwater Users

Potential impacts on groundwater dependent ecosystems are discussed in **Section 5.14**. This section of the report addresses the potential impacts on existing extractive use by landholders, identified from either:

- Registered and/or licensed groundwater bores and wells; or
- The census of landholders' use, which included in addition to bores and wells, the use of springs, seepages and possible groundwater fed dams or soaks.

The DNR registered and/or licensed bores and wells in the project vicinity are shown on **Figure 3**, and detailed in **Appendix E**. These have been obtained from a search of the DNR database on 1 August 2006. The results of the census of groundwater use are shown on **Figure 2**, and detailed in **Appendix A**.

A UCML production bore believed to be located in the vicinity of Open Cut 4 is not identifiable from the DNR database search, which included no bores east of the Ulan-Cassilis Road in this area. UCML (2006) describes bore PC1C as being near Millers Dam east of the road, but does not show the bore location on any plan. As discussed in **Section 3.6**, the coordinates in the DNR database put this bore west of the road, between the road and Goulburn River, but it is likely that the coordinates in the database are incorrect.

The average production rate from this bore is reported by UCML (2006) to be 0.24 ML/d. It is believed to be screened in the Permian coal measures, possibly including the Ulan Seam.

A number of unregistered water supply bores were revealed by the census survey in the Moolarben Creek valley. They include domestic water supply bores at the Croydon and Fernmount properties (SP7 and SP12 on **Figure 2**); Hay Shed bore (SP39); and Clarkes Gully bore (SP42). All are still in use. A number of abandoned wells were also identified, including the following unregistered wells – SP20, SP27 and SP28 on the Swords property, SP60 (inside Munghorn Gap Nature Reserve), and a dry well SP70 on the Simpson property.

The potential impacts of the project on existing bores, wells, springs, soaks and possible groundwater fed dams identified from either the census survey or the DNR database search is summarised in **Table 13**. In this assessment, all groundwater features listed in **Table 13**, apart from those that have been abandoned due to damage or disrepair, have been considered to be potential water supply sources, even though it is clear that many are not used and are unlikely to ever be used for water supply purposes. This includes a number of registered UCML monitoring bores.

5.13.1 Alluvium

It is predicted that none of the Quaternary alluvium water supply sources will be impacted by the project.

There are no existing groundwater supplies associated with the Tertiary paleochannel alluvium.

Table 13: Predicted Impacts on Existing Bores, Wells, Springs, Soaks and Groundwater-Fed Dams

Registered No	Licence No	Census No	MGA Coords		Landholder	Bore/ well	Authorised Purpose	Depth (m)	Aquifer	Predicted Drawdown Impact (m)	
			E	N						End of Mining (2022)	45 years After Closure (2067)
GW047111	20BL107324		756435	6419900	P Ban	Bore		12	Granite	No impact	
GW047172	20BL107323		756065	6419786	P Ban	Bore		15	Granite	No impact	
GW073038	20BL166333		767380	6414181	G C & E M Batty	Bore		42	Permian coal measures	0	0
-	-	SP58	764034	6420061	B W & H J Best	Soak	Stock		Permian coal measures	0.8	0
-	-	SP59	764087	6419456	B W & H J Best	Seep	Stock		Permian coal measures	0.6	0
-	-	SP50	763347	6421268	S M Birt & K M Hayes	Soak	Stock		Permian coal measures	0	0
-	-	SP51	762981	6421831	S M Birt & K M Hayes	Dam/soak	Stock		Permian coal measures	May dry up	0
-	-	SP52	762988	642004	S M Birt & K M Hayes	Dam/soak	Stock		Permian coal measures	May dry up	0
-	-	SP53	762023	6422573	S M Birt & K M Hayes	Dam/soak	Stock		Permian coal measures	May dry up	0
-	-	SP54	762546	6422672	S M Birt & K M Hayes	Dam/soak	Stock		Permian coal measures	May dry up	0
-	-	SP55	762616	6422722	S M Birt & K M Hayes	Dam/soak	Stock		Permian coal measures	May dry up	0
-	-	SP56	762639	6422687	S M Birt & K M Hayes	Dam/soak	Stock		Permian coal measures	May dry up	0
-	-	SP57	763173	6420815	S M Birt & K M Hayes	Dam/soak	Stock		Permian coal measures	0	0
GW013368	20BL005420		761169	6413589	K O Bishop	Bore	Stock / domestic	19	? Alluvium	No impact	
GW023203	20BL015692		757410	6414170	W D & M S Bryant	Well	Stock	8	Alluvium	No impact	
GW023216	20BL015693		757001	6414081	W D & M S Bryant	Well	Stock	11	Alluvium	No impact	
-	-	SP61	763023	6420894	M Carlisle	Dam/soak	Stock		Permian coal measures	0	0
GW052583	20BL113120	SP65	759314	6416285	D Chinner	Bore	Stock	33	Granite	No impact	
-	-	SP66	759014	6416275	D Chinner	Dam/soak	Stock		Quaternary alluvium	No impact	
-	-	SP67	759034	6416285	D Chinner	Dam/soak	Stock		Quaternary alluvium	No impact	
-	-	SP68	759549	6416252	D Chinner	Dam/soak	Stock		Quaternary alluvium	No impact	
GW059766	20BL130632		755914	6418905	K J & B J Condran	Bore	Domestic	31	Granite	No impact	
GW070856	20BL150485		759834	6416078	M Cox	Bore	Stock / domestic	55	?Granite	No impact. Abandoned bore.	
GW078082	20BL166624		757681	6416385	R Cox	Bore	Stock / domestic	23	Granite	No impact	
-	-	SP30	757511	6416779	R Cox	Dam	Stock		Granite	No impact	

Table 13: Predicted Impacts on Existing Bores, Wells, Springs, Soaks and Groundwater-Fed Dams

Registered No	Licence No	Census No	MGA Coords		Landholder	Bore/ well	Authorised Purpose	Depth (m)	Aquifer	Predicted Drawdown Impact (m)	
			E	N						End of Mining (2022)	45 years After Closure (2067)
-	-	SP31	757409	6416426	R Cox	Dam	Stock		Granite	No impact	
-	-	SP32	759472	6418031	R Cox	Soak	Stock		Quaternary alluvium	No impact	
GW050592	20BL113124	SP33	758378	6416637	R Cox	Bore	Stock/domestic		Granite	No impact. Abandoned bore.	
-	-	SP34	758959	6415907	R Cox	Dam/soak	Stock		Quaternary alluvium	No impact	
-	-	SP35	759098	6415615	R Cox	Dam/soak	Stock		Quaternary alluvium	No impact	
-	-	SP36	760216	6414796	R Cox	Dam/soak	Stock		Permian coal measures	0	0
-	-	SP37	760220	6414788	R Cox	Dam/soak	Stock		Permian coal measures	0	0
-	-	SP38	760393	6413980	R Cox	Dam/soak	Stock		Permian coal measures	0	0
-	-	SP39	760584	6414547	R Cox	Bore	Stock		Permian coal measures	0	0
-	-	SP41	760643	6414671	R Cox	Dam/soak	Stock		Permian coal measures	0	0
-	-	SP42	761334	6414996	R Cox	Bore	Stock		Permian coal measures	0	0
-	-	SP44	761163	6416324	R Cox	Dam/soak	Stock		Permian coal measures	0	0
-	-	SP45	760703	6415854	R Cox	Dam/soak	Stock		Quaternary alluvium	No impact	
-	-	SP46	759614	6415930	R Cox	Dam/soak	Stock		Quaternary alluvium	No impact	
GW070638		SP47	758165	6416275	R Cox	Bore	Domestic	45	Granite	No impact	
GW064580	20BL137225		764114	6438510	M J Cundy	Bore	Stock / domestic	70	Triassic Narrabeen Gp	0	0
-	-	SP62	763043	6423288	C & H Davies	Dam/soak	Stock		Permian coal measures	May dry up	0
-	-	SP63	763078	6423185	C & H Davies	Dam/soak	Stock		Permian coal measures	May dry up	0
GW043432	20BL102183	SP64	762994	6423288	C & H Davies	Soak/well	Stock / domestic		Permian coal measures	Abandoned, unreliable supply	
GW047195	20BL107487	SP83	762564	6434758	E H Elward	Bore (dry)	Stock/domestic	107	Permian coal measures	Already dewatered by Ulan dewatering.	
GW047495	20BL107537	SP84	762683	6425945	E H Elward	Bore	Domestic	149	Triassic Narrabeen Gp	0.2	0
GW073376			756069	6417363	H M Graham	Bore		36	Granite	No impact	
GW059683	20BL122034		757764	6423645	L K Hoare	Bore	Stock / domestic	62	Granite	No impact	
GW078174	20BL152584		757585	6423655	L K Hoare	Bore		84	Granite	No impact	
GW053215	20BL118263		756054	6417895	B J & K Howe	Bore	Domestic,	23	Granite	No impact	

Table 13: Predicted Impacts on Existing Bores, Wells, Springs, Soaks and Groundwater-Fed Dams

Registered No	Licence No	Census No	MGA Coords		Landholder	Bore/ well	Authorised Purpose	Depth (m)	Aquifer	Predicted Drawdown Impact (m)	
			E	N						End of Mining (2022)	45 years After Closure (2067)
							irrigation, stock				
GW059514	20BL131263		755934	6419485	B G Jackson	Bore	Stock / domestic	20	Granite	No impact	
GW067674	?				B G Jackson	Bore	Stock / domestic	30	Granite	No impact	
GW078314	20BL166146		767956	6435662	G R & R A King	Bore		99	Granite	No impact	
GW025262	20BL0224743		756198	6415670	P Libertis	Bore	Domestic, irrigation	126	Granite	No impact	
-	-	SP79	762473	6412035	C Mayberry	Spring			Triassic Narrabeen Gp	No impact	
-	-	SP7	763817	6415947	E Mayberry	Bore	Stock		Permian coal measures	0	0
-	-	SP12	761122	6415475	E Mayberry	Bore	Stock/Domestic		Permian coal measures	0	0
-	-	SP14	761172	6415310	E Mayberry	Dam	Stock		Permian coal measures	0	0
-	-	SP15	761222	6415168	E Mayberry	Dam	Stock		Permian coal measures	0	0
-	-	SP16	760973	6415294	E Mayberry	Dam	Stock		Permian coal measures	0	0
-	-	SP17	761485	6415530	E Mayberry	Dam	Stock		Permian coal measures	0	0
-	-	SP98			E Mayberry	Spring			Triassic Narrabeen Gp	No impact	
-	-	SP99			E Mayberry	Dam	Stock		Permian coal measures?	0	0
-	-	SP100			E Mayberry	Dam	Stock		Permian coal measures?	0	0
-	-	SP8	763776	6417524	K & R Mayberry	Dam/soak	Stock		Permian coal measures	0	0
-	-	SP9	763813	6417794	K & R Mayberry	Soak			Permian coal measures	0	0
-	-	SP10	763166	6417592	K& R Mayberry	Soak			Quaternary alluvium	0	0
-	-	SP11	763451	6417178	K & R Mayberry	Soak			Quaternary alluvium	0	0
GW051741	20BL113001		756724	6418366	R C Menchin	Bore	Stock / domestic	27	Sandstone	No impact	
GW800279	80BL236762	SP49	765214	6431985	J Mullins & C Imrie	Bore	Domestic	24	Triassic Narrabeen Gp	0.2	0.8
-	-	SP81	764094	6432635	J Mullins & C Imrie	Spring			Triassic Narrabeen Gp	No impact	
-	-	SP93	765557	6431343	J Mullins & C Imrie	Goulburn R			Surface water	No impact	
-	-	SP95	764474	6431648	J Mullins & C Imrie	Spring/seep			Triassic Narrabeen Gp	No impact	
-	-	SP96	764227	6431823	J Mullins & C Imrie	Goulburn R			Surface water	No impact	

Table 13: Predicted Impacts on Existing Bores, Wells, Springs, Soaks and Groundwater-Fed Dams

Registered No	Licence No	Census No	MGA Coords		Landholder	Bore/ well	Authorised Purpose	Depth (m)	Aquifer	Predicted Drawdown Impact (m)	
			E	N						End of Mining (2022)	45 years After Closure (2067)
GW059519	20BL125780		756034	6419085	P T J & S E Nagle	Bore	Stock / domestic	24	? Granite	No impact	
GW046670	20BL105865		755884	6418679	M & E Petrovics	Bore	Stock / domestic	19	Granite	No impact	
GW057084	20BL124673		756329	6418750	B D & D M Rayner	Bore	Domestic	42	Granite	No impact	
-	-	SP1	759268	6417079	D & Y Rayner	Dam	Stock		Quaternary alluvium	No impact	
-	-	SP2	759486	6417425	D & Y Rayner	Soak			Quaternary alluvium	No impact	
-	-	SP3	759621	6417909	D & Y Rayner	Soak			Quaternary alluvium	No impact	
-	-	SP4	761489	6417051	D & Y Rayner	Dam	Stock		Permian coal measures	Will be mined out	
-	-	SP5	761435	6418308	D & Y Rayner	Dam	Stock		Quaternary alluvium	0	0
-	-	SP6	760339	6416803	D & Y Rayner	Dam	Stock/Domestic		Marrangaroo conglomerate	No impact	
GW023210	20BL015691		757818	6414855	C & L Schmidt	Well	Stock	8	Alluvium/Granite	No impact	
GW802260	80BL242378		758094	6415817	C & L Schmidt	Bore		42	Granite	No impact	
GW070657	80BL152122		755940	6419842	J E Simpson	Bore		32	Granite	No impact	
-	-	SP69	763692	6425140	T R & N C Simpson	Dam	Stock		Permian coal measures	May dry up	0
-	-	SP70	763692	6425140	T R & N C Simpson	Well (dry)			Permian coal measures	May dry up	0
-	-	SP71	763843	6425191	T R & N C Simpson	Dam	Stock		Permian coal measures	May dry up	0
-	-	SP72	762741	6424915	T R & N C Simpson	Dam	Stock		Triassic Narrabeen Gp	0	0
-	-	SP73	763707	6424278	T R & N C Simpson	Spring/seep			Permian coal measures	May dry up	0
-	-	SP85	764843	6425945	Splitters Hollow Pty Ltd	Dam/soak	Stock		Tertiary alluvium?	0	0
-	-	SP86	766226	6426537	Splitters Hollow Pty Ltd	Dam/soak	Stock		Permian coal measures	May dry up	0
GW055488	20BL113009		756284	6415385	R & D Sprigg	Bore	Stock	11	?	No impact	
GW063717	20BL135331		763650	6412985	D & J Stokes	Well	Stock / domestic	3.4	?	No impact	
-	-	SP18	760047	6421881	M & P Swords	Dam	Stock		Marrangaroo conglomerate	May dry up	Dry
-	-	SP19	759789	6421886	M & P Swords	Seep	Stock		Permian coal measures	May dry up	Dry
-	-	SP20	760911	6420739	M & P Swords	Spring/well	Stock		Permian coal measures	Will be mined out	

Table 13: Predicted Impacts on Existing Bores, Wells, Springs, Soaks and Groundwater-Fed Dams

Registered No	Licence No	Census No	MGA Coords		Landholder	Bore/ well	Authorised Purpose	Depth (m)	Aquifer	Predicted Drawdown Impact (m)	
			E	N						End of Mining (2022)	45 years After Closure (2067)
-	-	SP21	760513	6419753	M & P Swords	Soak	Stock		Marrangaroo conglomerate	No impact	
-	-	SP22	761339	6418879	M & P Swords	Seep	Stock		Permian coal measures	0	0
-	-	SP23	761905	6418879	M & P Swords	Seep	Stock		Permian coal measures	0	0
-	-	SP24	759948	6418791	M & P Swords	Soak	Stock		Quaternary alluvium	No impact	
-	-	SP25	759689	6418905	M & P Swords	Dam/soak	Stock		Quaternary alluvium	No impact	
-	-	SP26	759698	6419038	M & P Swords	Dam/soak	Stock		Quaternary alluvium	No impact	
-	-	SP27	759560	419105	M & P Swords	Seep/well	Stock		Quaternary alluvium	No impact	
-	-	SP28	759517	6419929	M & P Swords	Well			Quaternary alluvium	No impact	
-	-	SP29	759247	6420605	M & P Swords	Soak	Stock		Quaternary alluvium	No impact	
GW043930	20BL102022		756232	6417099	J Szymkarczuk	Bore		35	Granite	No impact	
-	-	SP87	763685	6426320	M & J Transport	Dam	Stock		Surface water	No impact	
-	-	SP88	763760	6426259	M & J Transport	Dam	Stock		Surface water	No impact	
-	-	SP89	763770	6426361	M & J Transport	Dam	Stock		Surface water	No impact	
-	-	SP90	764040	6426486	M & J Transport	Dam/soak	Stock		Surficial	0	0
-	-	SP91	763513	6426657	M & J Transport	Dam	Stock		Surface water	No impact	
-	-	SP92	763865	6426907	M & J Transport	Dam/soak	Stock		Surficial	0	0
-	-	SP74	761386	6422350	B J & M R Wallis	Dam	Stock		Permian coal measures	0	0
-	-	SP75	761397	6422157	B J & M R Wallis	Dam	Stock		Permian coal measures	0	0
-	-	SP76	761293	6422238	B J & M R Wallis	Dam	Stock		Permian coal measures	0	0
-	-	SP80	763656	6431196	J Westwood	Spring (dry)			Triassic Narrabeen Gp	0	0
-	-	SP82	761869	6430503	J Westwood	Dam/soak	Stock		Permian coal measures	May dry up	0
GW079745			763189	6435869	J Williams	Bore		34	? Jurassic/Triassic	No impact	
GW078317			764390	6436463	J Williams	Bore	Domestic	?	? Triassic	? No impact	
GW078371	20BL167677		760914	6430335	UCML	Bore		6	Alluvium	No impact	
GW078372	20BL167677		760764	6430435	UCML	Bore		2.0	Alluvium	No impact	
GW078373	20BL167677		760782	6429634	UCML	Bore		4.8	Alluvium	No impact	
GW078374	20BL167677		761109	6430535	UCML	Bore		2.2	Alluvium	No impact	

Table 13: Predicted Impacts on Existing Bores, Wells, Springs, Soaks and Groundwater-Fed Dams

Registered No	Licence No	Census No	MGA Coords		Landholder	Bore/ well	Authorised Purpose	Depth (m)	Aquifer	Predicted Drawdown Impact (m)	
			E	N						End of Mining (2022)	45 years After Closure (2067)
GW012015			759793	6429114	UCML	Bore	Coal exploration	76	Permian coal measures	Backfilled	
GW012016			760198	6429108	UCML	Bore	Coal exploration	76	Permian coal measures	18	0
GW024774			765415	6423890	UCML	Bore	Coal exploration	91	Permian coal measures	10	0
GW034640	20BL027911		765173	6422294	UCML	Bore	Stock / domestic	70	Permian coal measures	7	0
GW038112	20BL102747		759958	6429118	UCML	Bore	Irrigation	81	Permian coal measures	Collapsed	
GW057326	20BL124955		760644	6429565	UCML	Bore	Test / monitoring	73	Permian coal measures	Abandoned bore	
GW057327	20BL124956		760046	6429771	UCML	Bore	Test / monitoring	62	Permian coal measures	19	0
GW057329	20BL124958		761171	6429878	UCML	Bore	Test / monitoring	93	Permian coal measures	36	0
GW059037	20BL121131		760254	6429710	UCML	Bore	Industrial	70	Permian coal measures	22	0
GW059038	20BL121129		760664	6429475	UCML	Bore	Industrial	73	Permian coal measures	27	0
GW065949			760854	6427185	UCML	Bore		57	Permian coal measures	Mined out – Ulan O C	
GW065950			759204	6425693	UCML	Bore		81	? Granite	No impact	
GW200094	20BL167677		758717	6426606	UCML	Bore			Permian coal measures	0	0
-	-	SP77	759943	6422203	UCML	Dam	Stock		Permian coal measures	May dry up	0
-	-	SP78	757921	6422254	UCML	Dam	Stock		Granite	No impact	
GW010013			760602	6428295	Crown Land	Bore	Coal exploration	61	Permian coal measures	Mined out – Ulan O C	
GW024773			762645	643950	Crown Land	Bore	Coal exploration	126	Permian coal measures	44	0
GW057328	20BL124957		761894	6430860	Crown Land	Bore	Test / monitoring	115	Permian coal measures	Abandoned bore	
GW059034	20BL121127		760934	6429235	Crown Land	Bore	Industrial	72	Permian coal measures	30	0
GW059035	20BL121128		761039	6429765	Crown Land	Bore	Industrial	80	Permian coal measures	33	0
GW059036	20BL121130		761634	6430395	Crown Land	Bore	Industrial	109	Permian coal measures	42	0
GW065948			760864	6428910	Crown Land	Bore		95	Permian coal measures	28	0
GW065995			760934	6428773	Crown Land	Bore		105	Permian coal measures	26	0
GW049542	20BL110252		758106	6425092	? Ulan Village	Bore	Domestic	31	Granite	No impact	
GW080350	20BL168215		758378	6425115	? Ulan Village	Bore			Granite	No impact	
GW060608	20BL131820		769534	6436675	DP250311 / 3	Bore	Stock / domestic	63	Basalt	No impact	
GW053778	20BL117431		768304	6437705	DP250311 / 18	Bore	Domestic, irrigation, stock	93	Sandstone	0	0

Table 13: Predicted Impacts on Existing Bores, Wells, Springs, Soaks and Groundwater-Fed Dams

Registered No	Licence No	Census No	MGA Coords		Landholder	Bore/ well	Authorised Purpose	Depth (m)	Aquifer	Predicted Drawdown Impact (m)	
			E	N						End of Mining (2022)	45 years After Closure (2067)
GW073549	20BL166215		756471	6424018	DP592376 / 1	Bore	Test / monitoring	53	Granite	No impact	
GW073550	?				DP40917 / 279	Bore	Test / monitoring	53	Granite	No impact	
GW030626			762554	6438985	DP750736 / 61	Bore	Stock / domestic	105.2	Permian coal measures	Hole backfilled	
GW030631	20BL027210		762458	6438996	DP750736 / 61	Bore	Stock / domestic	122	Triassic Narrabeen Gp	0	0
GW034454	20BL027654		763695	6438051	DP750736 / 61	Bore	Stock	61	Triassic Narrabeen Gp	0	0
GW052802	20BL113133		756364	6423610	DP809642 / 1	Bore	Irrigation	46	Granite	No impact	
-	-	SP60	763023	6420894	Munghorn Gap N R	Well			Permian coal measures		
-	-	SP94	764674	6431991	Goulburn River N P	Goulburn R			Surface water	No impact	
-	-	SP97	764257	6431667	Goulburn River N P	Spring/seep			Triassic Narrabeen Gp	0.3	

5.13.2 Triassic Narrabeen Group

There are two bores on properties close to Underground 4 which are believed to be capable of drawing water supplies from Triassic (and/or Jurassic) aquifers, and five others at greater distance beyond the range of potential drawdown impact. The two bores potentially within the zone of impact are on the Mullins-Imrie and Elward properties, and are listed in **Table 13**. The predicted maximum drawdown impacts in each case is 0.2 m at the completion of mining, and 0.8 m in the case of the Mullins-Imrie bore 45 years after completion, as detailed in **Table 13**.

There are no Triassic groundwater sources within the potential impact zone of Open Cuts 1-3. Two springs on Mayberry properties to the south of Open Cut 3 are well beyond the range of potential impact.

5.13.3 Permian Coal Measures

Existing springs and dams or soaks which derive water from the Permian coal measures within the region of predicted drawdown impact of the proposed open cuts and/or underground mine may be impacted to varying degrees by the proposal. Any such springs or soaks which actually lie within the open cut extraction areas are expected to be permanently removed, but those which are not mined out are expected to return to their pre-project condition within 10-20 years after completion of mining, as the regional groundwater levels recover.

Based on the groundwater model simulations, it is possible that such Permian water supplies situated within about 5 km of the open cuts or the perimeter of Underground 4 may be reduced or lost temporarily during the project. This is a conservative opinion, as it is not clear that the springs and soaks are derived from the deeper Permian groundwater. It is more likely that they are supported by the perched surficial groundwater system, which is not hydraulically connected with the deeper Permian and will not be impacted by dewatering pumping.

Water sources derived from Permian coal measures aquifers that will be physically removed as they lie within or very close to the proposed open cut footprints include:

- None within Open Cut 1;
- Abandoned well (SP20), groundwater-fed dams (SP18 and SP77) and a small hillside seep (SP19) within or close to Open Cut 2 (**Plates 2** to **5**); and
- A groundwater-fed dam (SP4) in Open Cut 3 (**Plate 6**).

Plate 2: Abandoned well (SP20) – within Open Cut 2 footprint

Plate 3: Groundwater-fed dam (SP18) – just west of Open Cut 2

Plate 4: Hillside seep (SP19) – 200 m west of Open Cut 2

Plate 5: Dam / soak (SP77) – just west of Open Cut 2 western boundary

Plate 6: Groundwater-fed dam (SP4) – within Open Cut 3 footprint

The licensed UCML potable / fire water supply bore (GW059034) located near the western boundary of Underground 4 (**Figure 3**) is expected to be significantly impacted by the Moolarben project. It is predicted that the groundwater level in the Permian coal measures in the vicinity of this bore will be lowered by an additional 42 m due to the Moolarben project by the completion of mining in 2022. This drawdown would be expected to require the provision of a replacement supply to UCML.

The southern Elward bore (GW047195) is already dry, presumably as a result of Ulan dewatering.

The two Mayberry domestic water supply bores, SP7 and SP12 at Croydon and Fernmount houses respectively, both apparently unregistered and unlicensed, are predicted to be unaffected by the dewatering of Open Cut 3. SP7 is at a lower elevation than the base level of mining in Open Cut 3, and SP12 is believed to be drawing from levels stratigraphically below the Ulan

Seam, either from the basal units of the Coal Measures or from the underlying Shoalhaven Group.

No other existing water supply bores drawing from Permian Coal Measures aquifers are predicted to be impacted (see **Table 13**). A number of monitoring bores are predicted to experience drawdown or additional drawdown as a result of the Moolarben project.

There are a number of springs, seeps and groundwater-fed dams, identified in **Table 13**, which are within the region of predicted drawdown impacts, and may possibly be affected by the dewatering. It is not certain that they will be affected, as many are believed to be fed by near-surface perched aquifers which are dependent on local recharge and discharge patterns, and are expected to be unaffected by dewatering of the underlying deeper Permian sediments. Nevertheless, monitoring is recommended, and any which are used for water supply that suffer impact from the project would need to be replaced from an alternative water supply source.

5.13.4 Granite and Other Basement Units

There is expected to be no impact by the Moolarben project on groundwater users from the areas to the west of the basin margins, that is all bores, wells and soaks situated west of the subcrop line of the Permian sediments. This includes all the properties in the small lots around Ridge Road on the western side of the Mudgee-Cassilis Road, as well as those properties situated on granite or volcanics on the eastern side of the road.

It is possible that some dams/soaks located within the basin margin are deriving water from basement aquifers, as the basin sediments are quite this near the margins of the basin. However, if that is the case, none are expected to be impacted by the project.

5.14 Potential Impacts on Groundwater Dependent Ecosystems

The assessment of potential impacts of the project on groundwater dependent ecosystems (GDEs) has been carried out in accordance with the NSW Groundwater Dependent Ecosystems policy (DLWC, 2002). The assessment has also made reference to the Australian Government document on environmental water requirements of GDEs (Sinclair Knight Merz, 2001).

Groundwater dependent ecosystems (GDEs) are defined by ARMCANZ/ANZECC (1996) as ecosystems which have their species composition and their natural ecological processes determined by groundwater.

Terrestrial and aquatic ecological surveys of the Moolarben coal project area have identified two types of ecosystem that are partly or wholly dependent on groundwater (Moolarben Biota, 2006). They include:

- Localised vegetation assemblages below small groundwater seepages from the Triassic Narrabeen Group sediments.
- Flora and fauna along creeklines, in which flow is maintained for at least part of the year by upstream groundwater discharges.

Vegetation along walls in the Drip Area on the Goulburn River, and other similar seepage zones nearby, is probably the only known vegetation that is uniquely sourcing water from groundwater. These groundwater seepages derive from the Triassic Narrabeen Group aquifer system. The discharges represent small flows from perched aquifer horizons above less permeable units within the Triassic sediments (eg **Plate 7**), and are reliant on localised recharge from rainfall above and up-gradient from the discharge points. These individual aquifer horizons are not regionally extensive units.

Plate 7: The Drip - Groundwater Seepages from Perched Aquifers of the Triassic Narrabeen Group

These seepages are totally supported by rainfall infiltrating into the natural ground surface above and upgradient from the discharge points. The water percolates downwards through both intergranular and fracture porosity until it reaches a relatively less permeable layer (massive sandstone or shale layer) allowing water to accumulate as a perched aquifer and flow along the top of the less permeable layer until it reaches either an open sub-vertical joint allowing further downwards percolation, or the ground surface at a cliff or scarp where it can emerge as seepage.

There is no possibility that these high level seepages such as the Drip are derived from groundwater under pressure rising from depth. For that to occur, the recharge zones for that deeper groundwater would need to be at a much higher elevation than the Drip, but the area is close to a regional topographic high, being near the top of the Great Dividing Range. There is no locality at sufficiently high elevation within feasible distance of the project site to be able to influence deep groundwater to emerge at elevations such as the Drip.

The relationship of these seepage zones to the regional groundwater system is illustrated on the cross-sections on **Figures 31** and **32**. The Drip and other similar seepages visible on the cliffs along Goulburn River to the north of the Underground 4 mining area are derived from perched aquifers situated well above any aquifers hydraulically connected with the proposed underground workings, and are also situated outside the area of potential impact from either subsidence or subsurface cracking (**Figure 32**). They are also located outside the area capable of potential impact from surface cracking (Strata Engineering, 2006). Consequently, the Drip and other similar seepage zones along Goulburn River will not be affected by either subsidence or mine dewatering associated with the Moolarben Coal Project.

Similar but much smaller seepages can be found from waterfall scarps at the head of gullies draining from the sandstone plateaux to the south and north of Goulburn River. These are generally ephemeral seepages, and the vegetation assemblages in the gullies downstream/downslope from these seepage zones would also be partly dependent on surface runoff and soil moisture.

Strata Engineering (2006) also predict that surface cracks up to 50 to 250 mm in width could occur immediately above goaf areas (ie within the angle of draw extending out from the longwall panel areas). They predict that such cracks could extend to depths of 2 to 5 m, but would not connect with sub-surface cracking extending up from the goaf.

It is possible that surface cracking could impact on any such seepages that may be present above the longwalls, within the area of potential subsidence impact, ie within the area defined by the appropriate angle of draw, as defined by Strata Engineering (2006).

Only one seepage derived from the Triassic aquifer system is expected to be possibly affected by the proposal. Seepage point SP80 on the Westwood property above the Underground 4 area may be impacted by surface cracking, that could lead to a re-routing of current groundwater seepage and emergence at some point further down stream within the gully. SP80 (**Plate 8**) was dry when inspected and is believed to be an ephemeral source, and is not used for water supply purposes.

Plate 8: Ephemeral Spring/Seep (SP80) – Above Underground 4

Other nearby Triassic springs and seeps on adjacent properties (Mullins-Imrie and the Goulburn River National Park), including the Drip and other similar seepages along Goulburn River, will not be impacted by the proposal. Seepages were observed to the east of Underground 4 (SP95 and SP97 on **Figure 2**), but these are well outside the area of potential subsidence impact.

Plate 9: Spring/Seep (SP95) – East of Underground 4 – Outside Zone of Potential Impact

Vegetation along the Goulburn River that supports threatened species is considered to be more reliant on surface water than groundwater. Nevertheless, there is no doubt that surface flow in Goulburn River and its tributary streams is supported by groundwater base flow, so this vegetation would be considered to be partly dependent on groundwater.

As discussed in **Section 3.10**, the water quality of the groundwater component in the Moolarben and Lagoon Creeks is poor and is believed to have a probable adverse impact on any vegetation reliant on stream flow in those tributary catchments. The better quality of the streamflow in Goulburn River compared with that in Moolarben and Lagoon Creeks is probably due to groundwater baseflow contributions from the other tributary catchments, Ryans Creek and Sportsmans Hollow Creek, both of which drain catchments underlain by granitic rocks to the west of the Permian basin margin. Both Ryans Creek and Sportsmans Hollow Creek catchments are beyond the limit of potential impact from the Moolarben coal project.

Within the main Goulburn River in the northern part of EL6288, the main groundwater baseflow influx is believed to derive from the Triassic sandstones, not from the Permian coal measures aquifers. As the Triassic aquifers are predicted to be not significantly impacted by the proposed mine dewatering, there is not predicted to be any consequential significant impact on stream flow or quality in Goulburn River, or its associated ecosystems.

5.15 Final Pit Voids

Small final pit voids proposed for Open Cut 1 and Open Cut 3 will extend below the current water table level of the Permian Coal Measures groundwater. The final void in Open Cut 2 is expected to be above the water table, as the Ulan Seam and overlying coal measures are largely unsaturated in that area.

Two final voids are proposed for Open Cut 1 – one at the northern end about 24ha in area and extending down to a floor elevation of approximately 355 mAHD. It is proposed to use this void for disposal of tailings from the coal preparation plant and rejects from the underground mining operation. It may also be used for ongoing disposal from other future mining operations that may be approved elsewhere on EL6288.

It is also proposed to use this void for the disposal of excess water that will arise in the latter stages of the project life when the groundwater inflow rate to the underground mine will be highest and the demand for water will have reduced following completion of open cut mining. It is proposed to place a low permeability seal around part or all of the Ulan seam outcrop line within the final void below the possible water storage level, to limit the potential for water to recirculate back down-dip to the underground workings, while underground mining is still ongoing.

The groundwater modelling has indicated that groundwater levels are likely to recover to pre-mining levels within 10-20 years after completion of mining, subject to there being no continuing mining at Ulan or other mines in the vicinity. It is likely that groundwater levels could recover to around 400 mAHD post-mining, although the actual final level cannot be predicted with accuracy because the pre-Ulan mining groundwater level is not known.

If this final void remains unfilled, it is likely to represent a local groundwater sink, with evaporation from the water surface leading to a slight local depression in the groundwater surface. The magnitude of the groundwater depression would depend on the water surface area in the pit void, relative to the groundwater inflow and throughflow rate. To avoid evaporation losses and the development of a local groundwater sink at this location would require the backfilling of the void to above the eventual recovery groundwater level.

A second pit void proposed for Open Cut 1 is a box-cut to be preserved on the eastern face of the pit, to serve as a possible portal entry to an underground mine beneath the ridge to the east. The base level of this void will be up to 5 m below the expected ultimate groundwater level.

In Open Cut 3, a small final void is proposed for the southern end of the pit. The base level of this proposed pit void will be up to 5 m below the anticipated recovery water level. This void is expected to constitute a local groundwater sink, due to evaporation from the open water surface in the pit. With a maximum water depth of only 5m, the evaporation effect is likely to prevent a permanent water body from developing in this void. To avoid the evaporation effects and the resultant local groundwater depression, it would be necessary to backfill the void to above the recovery groundwater level.

6 MONITORING AND MANAGEMENT

6.1 Impacts of Groundwater Extraction / Dewatering

It is recommended that the groundwater discharges be monitored closely through the project life. This would include volumes and quality of water discharged from the mine and/or pumped from dewatering and water supply bores, and groundwater levels measured in all pumping bores. It is also recommended that the baseline monitoring program be continued.

Thus the project monitoring program would include the following elements:

- Groundwater extraction volumes – weekly totals from all pumping bores, and weekly totals from each underground pumping station.

- Groundwater discharge quality – weekly measurements on site of the EC and pH of each groundwater extraction, both bores and underground pumping stations.

- Quarterly sampling from all pumping bores and underground pumping stations for comprehensive laboratory analysis, to include:
    - Physical parameters – EC, TDS, TSS and pH
    - Major cations (calcium, magnesium, sodium and potassium) and anions (carbonate, bicarbonate, sulphate and chloride)
    - Dissolved metals (aluminium, arsenic, boron, cobalt, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, silver, selenium, zinc)
    - Nutrients (ammonia, nitrate, phosphorus, reactive phosphorus)
    - Fluoride, cyanide

- Monthly water level measurements from the existing network of monitoring bores, together with additional monitoring bores to be installed within the Triassic sediments above and to the north of Underground 4

- Annual sampling of monitoring bores for laboratory analysis of the above comprehensive suite of analytes.

6.2 Subsidence Impact Monitoring

It is recommended that a monitoring program be implemented above the Underground 4 longwalls to detect the development of both surface and subsurface cracking as a result of subsidence, and to monitor any resultant impacts on groundwater within the Triassic Narrabeen Group sediments and/or the surficial groundwater.

This monitoring network would be based on a combination of multi-level piezometers and extensometers. Multi-level piezometers would initially be installed mid-panel approximately 250 m from each end of Longwall panels 1, 3, 5 and 7, to provide initial data on the subsidence and cracking responses to extraction. The data obtained would be used to verify the predictions of subsurface cracking heights and surface cracking depths, prior to embarking on extraction from the later panels that are planned to approach closest to the Drip are and other seepage zones from the Triassic sediments.

Each multi-level piezometer would comprise a shallow (max 20m deep) standpipe piezometer, and vibrating wire piezometers at nominal 30m intervals between the surface and a point approximately 50 m above the roof of the Ulan Seam extraction. Due to the shallow overburden cover over the southernmost panels, each site would initially comprise 1-3 vibrating wire piezometers. Similar multi-level piezometers to be installed later above the northern panels would comprise up to 5 vibrating wire piezometers.

The multi-level piezometers are intended to develop a piezometric pressure profile above the longwall panels to be monitored before, during and after extraction. Subsurface cracking which provided hydraulic connection to the dewatered goaf zone immediately above the extracted panel would be detected by changes to the hydrostatic pressures recorded by the vibrating wires.

The shallow standpipe piezometer would be intended to monitor for impacts of surface cracking.

After extraction from the first three longwall panels has been completed, a similar monitoring network would be installed above the northern panels, if necessary modified in the light of results obtained from panels 1-3. Based on the monitoring results from the southern panels, the predictions of surface cracking depths and sub-surface cracking heights for the northern panels could be reviewed and modified if necessary.

6.3 Review and Reporting

The above monitoring data should be subjected to an annual review by a competent hydrogeologist to assess the impacts of that the project has had on the groundwater resources and comparison with the groundwater flow model predictions. It is also recommended that two years after commencement of coal production, a modelling post-audit should be carried out, in accordance with industry best-practice (MDBC, 2001), and if necessary the model should be re-calibrated and further forward predictions made at that time. Further post-audits should be carried out five-yearly through the remainder of the project.

Should any review or post-audit indicate a significant variance from the model predictions with respect to either water quality or groundwater levels, then the implications of such variance should be assessed, and appropriate response actions should be implemented in consultation with DNR, DPI and DEC as appropriate.

It is strongly recommended that the monitoring program be closely integrated as much as possible with the ongoing monitoring programs on the adjoining Ulan and Wilpinjong projects.

7 CONTINGENCY RESPONSE PLANS

It is recommended that an emergency response program be adopted for implementation in the event of unforeseen adverse impacts on either groundwater or surface water from the Moolarben project.

Water Levels

In the event that groundwater level drawdowns exceed predicted drawdowns by 20% or more, then the monitoring data should immediately be referred to a competent hydrogeologist for review. The reviewer should assess the data to establish the nature of the exceedence and the reasons for it, and should recommend an appropriate response action plan for implementation in consultation with DNR. The response action may involve one or more of the following:

- Reduction in pumping rate from a particular pumping bore or bores
- Cessation of pumping from a particular pumping bore or bores
- Alteration of the mining plan, if appropriate
- Continuation of pumping and dewatering, with closer monitoring
- No change to the operations.

In the event that an existing water supply is adversely affected by the exceedence in drawdowns, the response action could involve diversion of part of the dewatering discharge as a replacement water supply.

Groundwater Quality

Should the water quality of the mine inflows or dewatering discharge indicate an increase in salinity of more than 50% from the averages listed above in **Table 12**, it is recommended that the nature of the exceedence and all relevant monitoring data be provided to a competent hydrogeologist for review and assessment of the impact of such exceedence on other users or the environment. If remedial action is recommended by the reviewer on the basis of the water quality exceedence, the recommended action will be implemented in consultation with DNR, DEC and DPI as appropriate.

It is envisaged that the remedial action may include one or more of the following:

- Re-location of dewatering pumping location(s)
- Cessation of pumping from one or more bores
- Increase in rate of pumping from one or more bores
- Continuation of pumping and dewatering, with closer monitoring
- No change to the operations.

In the event that an existing water supply is adversely affected by the unforeseen worsening in the groundwater quality, then part of the dewatering extraction may be diverted or an alternative water supply provided from a suitable source, such as a replacement water supply bore.

8 CONCLUSIONS

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

- Groundwater is present in most lithologies in the area, but the principal aquifer is associated with enhanced permeability in the Ulan Coal Seam and immediately overlying Permian coal measures sediments. Lesser permeability is present locally in underlying rocks of the Shoalhaven Group and the basement granite and volcanic rocks.

- The overlying Triassic Narrabeen Group sandstones constitute a moderately permeable aquifer system, that is believed to be hydraulically separate from the Permian aquifer system.

- Minor groundwater is also present in Quaternary alluvium, and in some locations in Tertiary paleochannel sediments.

- Groundwater quality is variable, with salinity ranging from less than 500 to more than 7000 mg/L, and pH in the range 3 to 8. The poor water quality occurs in the southern part of EL6288. Groundwater in the northern part of EL6288 has salinity less than 600 mg/L TDS and pH generally in the range 6.0 to 7.5.

- Groundwater levels in the Permian coal measures generally fall to the north-east, and range from around 500 mAHD at the southern end of the project area to around 380 mAHD at the north-eastern corner of EL6288.

- The dewatering operations at Ulan have caused a significant cone of drawdown in groundwater levels, amounting to between 40 and 50m along the western margin of Moolarben's proposed Underground 4 mine.

- The Ulan mine dewatering appears to have had negligible impact on groundwater levels in the Triassic Narrabeen Group sandstones.

- Dewatering will be required as part of the proposed Moolarben mine developments. Modest groundwater inflows are predicted to Open Cut 1, with minor to negligible inflows to Open Cuts 2 and 3. The Ulan seam and overlying sediments are only partly saturated at Open Cuts 1 and 3, and are virtually dry at Open Cut 2. Groundwater inflows ranging up to 8.9 ML/d have been predicted for the Underground 4 mine, based on the most likely set of assumed hydraulic parameters.

- Sensitivity modelling suggests that the maximum inflow rates could be between about 4.6 and 27 ML/d, however based on the reported inflows experienced at Ulan, it is more likely that inflows to the Moolarben Underground 4 mine will be closer to the low end of the above range.

- Predicted inflows to the Moolarben Underground 4 in Year 1 and Years 4-11 are insufficient to meet the water demands of the project, so additional water will need to be obtained either from surplus production at the adjacent mines if available, or additional pumping from bores around the perimeter of the Underground 4 mine. This pumping will provide some assistance with advance dewatering ahead of mining in subsequent years.

- The makeup water supply is expected to be available from up to 12 dewatering bores, each pumping at 0.3-0.4 ML/d. Three test bores already in place are suitable for use as dewatering bores.

- Initial average water quality of groundwater inflows to Underground 4 is expected to be good, with TDS around 420 mg/L and pH around 7.4. The water is expected to contain moderate levels of dissolved metals. Similar water quality is expected from the water supply bores to be utilised for makeup supply in Years 1 and 4-11.

- Groundwater inflow quality to Open Cut 1 is expected to be similar, with initial TDS of 415 mg/L and pH of 6.5. The groundwater inflows to Open Cuts 2 and 3 however are expected to be of poorer quality – initial TDS 520 mg/L and pH 4.5 to Open Cut 2, and TDS 2050 mg/L and pH 6.5 to Open Cut 3.

- The dewatering associated with the proposed mining at Moolarben is predicted to impact groundwater levels in the Permian Coal Measures up to 20 km from Underground 4. At the completion of mining, the predicted drawdowns 10 km east of the project are 5m in the Ulan Seam and 0.5m in the undisturbed overlying coal measures. Lesser impacts are predicted associated with the three open cuts.

- Small localised drawdowns are predicted to occur in the Triassic Narrabeen Group aquifers, ranging up to 0.5-0.75 m by the completion of the Moolarben project over a small area to the east of Underground 4.

- Recovery simulations indicate that groundwater levels in the Permian coal measures are expected to recover to pre-mining conditions within 10-20 years after completion of mining. Moderate residual drawdowns of up to about 3 m in the Triassic may persist for up to 45 years after completion of mining.

- No adverse impacts are expected on any groundwater dependent ecosystems (GDEs), other than a possible disturbance to the present groundwater flow paths leading to one ephemeral seepage zone above the northern end of Underground 4. No impact on The Drip is expected.

- No adverse impacts on surface water quality are expected.

- Minor reduction in the baseflow component of surface flow in the Moolarben Creek catchment may occur, but negligible impact on flows in the main Goulburn River. Any reduction in the baseflow component of Moolarben Creek would be expected to have a beneficial impact on water quality of the streamflow, both within Moolarben Creek itself and downstream in Goulburn River.

- It is predicted that UCML's potable / fire water supply bore located near the western margin of Underground 4 will be significantly impacted by dewatering of Underground 4. It will be necessary to obtain a replacement water supply from an alternative source.

- A small number of existing springs and groundwater-fed dams or soaks within or close to the footprints of the proposed extraction areas of Open Cuts 2 and 3 are expected to be lost permanently. A number of springs, seeps and soaks in the Murragamba Valley area downdip from the open cuts may be affected temporarily, but are expected to return to their pre-mining condition within at most 10-20 years of project completion as water levels recover.

- Existing groundwater supplies derived from the Quaternary alluvium and the basement granite and volcanics are predicted to be un-affected by the project.

- No existing water supplies from west of the basin margin are expected to be impacted, ie all bores, springs, wells and dams/soaks located west of the subcrop line of the Permian sediments.

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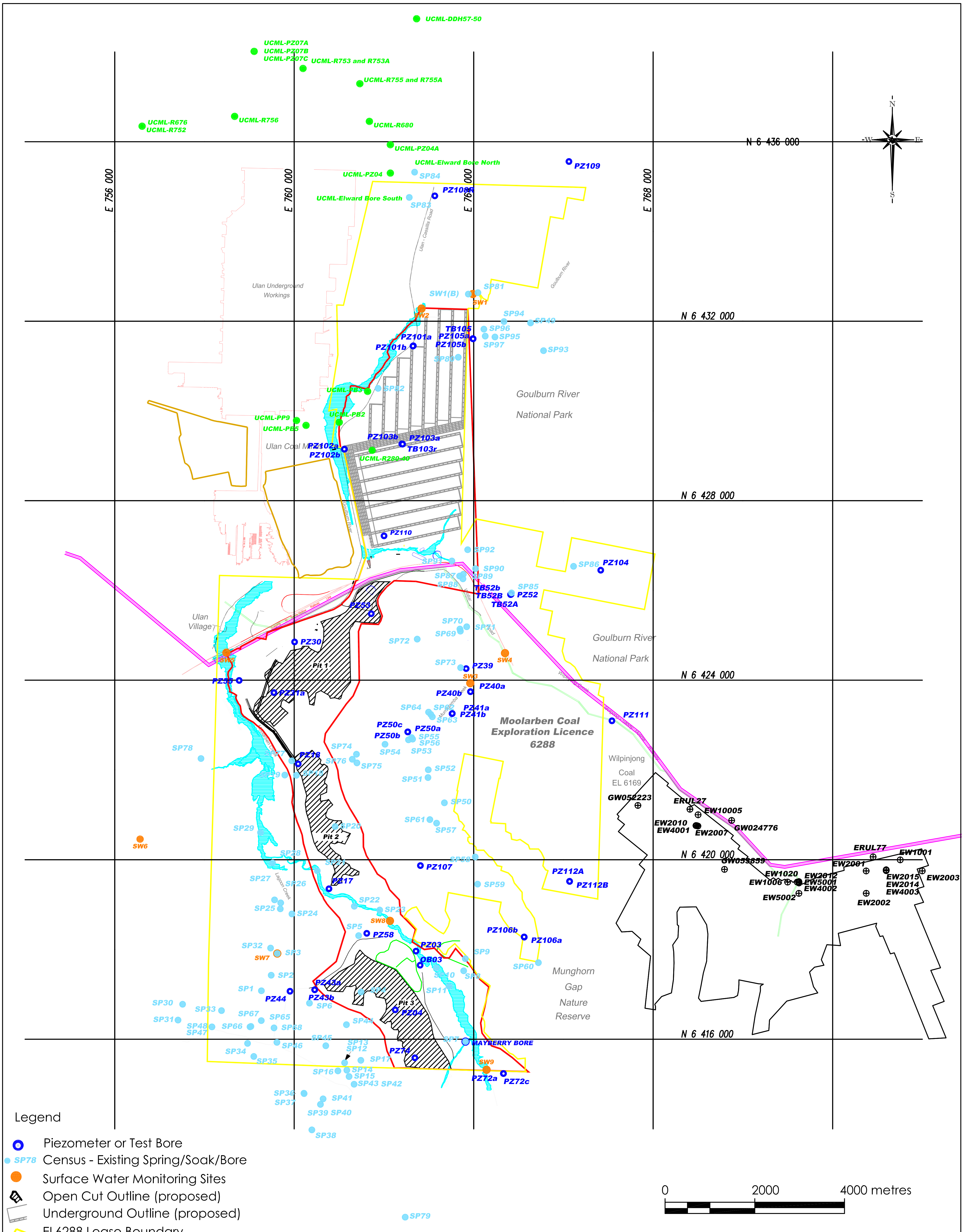
FIGURES

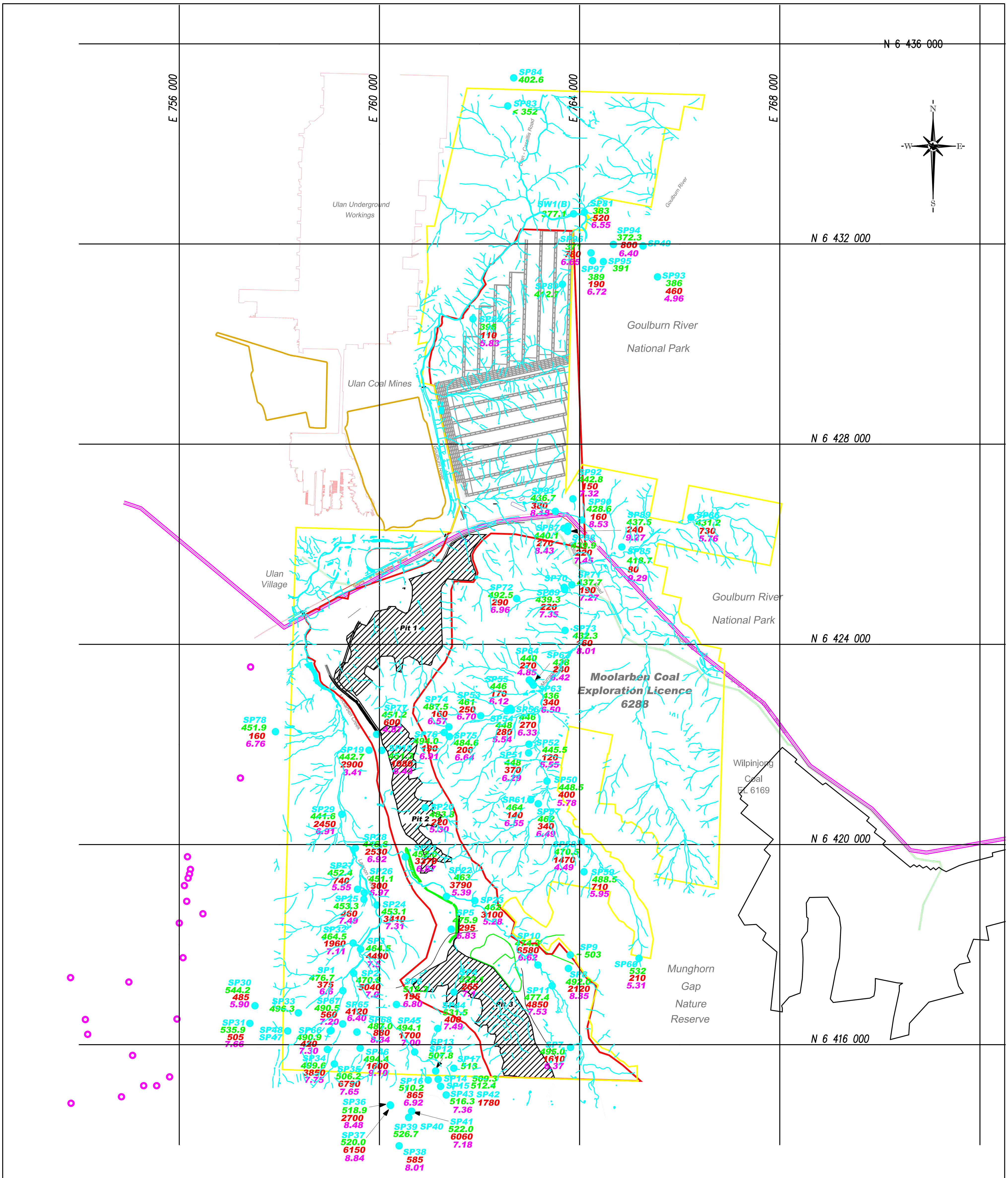


Legend

- Piezometer or Test Bore
- SP78 Census - Existing Spring/Soak/Bore
- Surface Water Monitoring Sites
- Open Cut Outline (proposed)
- Underground Outline (proposed)
- EL6288 Lease Boundary
- Moolarben DA Boundary
- UCML Groundwater Bore
- Wilpinjong Bore
- Wilpinjong Open Cut (under construction)
- Ulan Open Cut Outline
- Ulan Underground Outline (2004 status)

NOTE
MGA Coordinates

Date:	24 August 2006	Scale:	1 : 80 000 (as A3)	**Moolarben Coal Mines Pty Ltd**
Initials:	PJD	Job No:	05-0158	**Moolarben Coal Project Groundwater Investigations Location Plan**
Drawing No:	05-0158-013-D	Rev:	D	
Peter Dundon and Associates Pty Limited				**Figure 1**



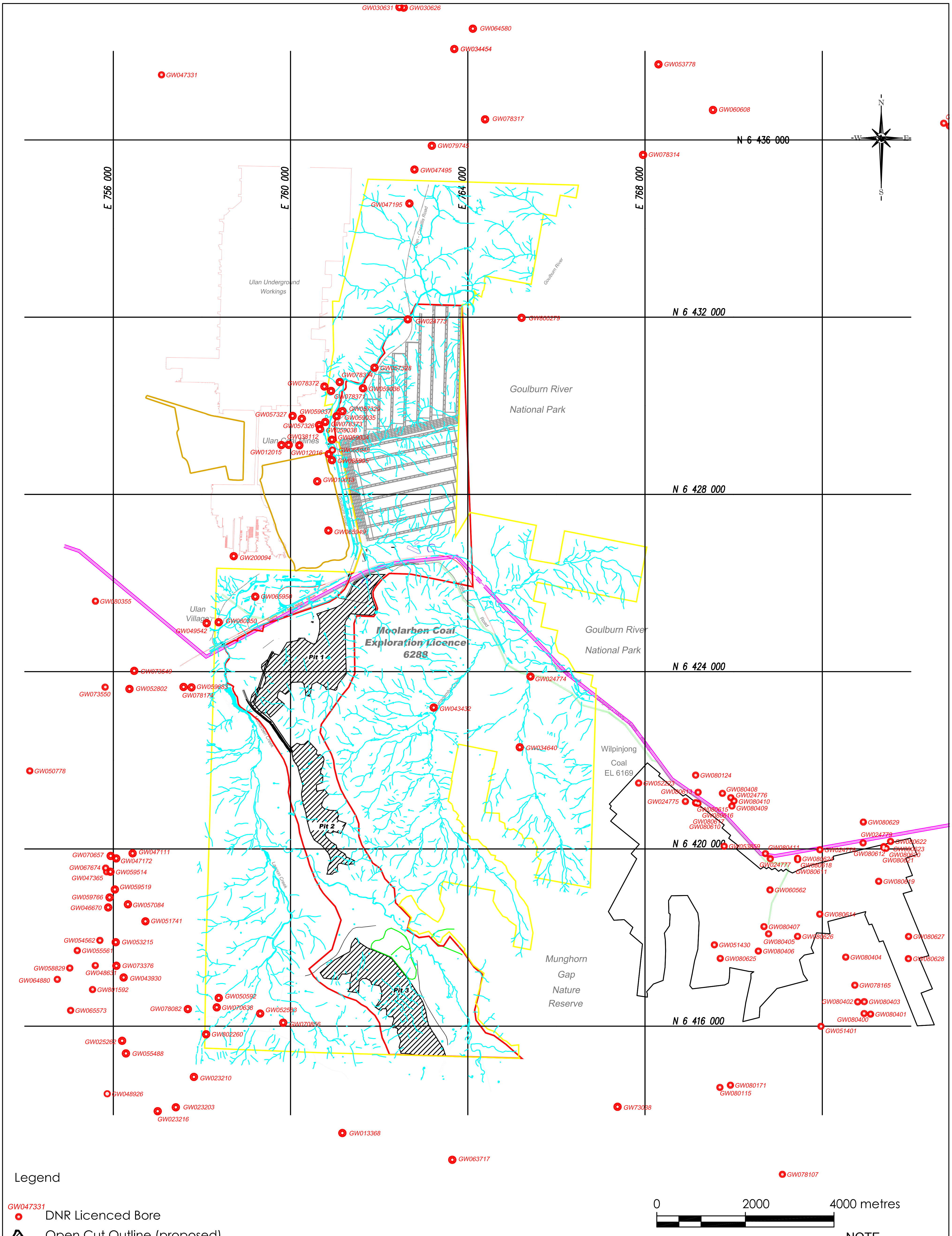
Legend

● SP78	Census - Existing Spring/Soak/Bore/Groundwater-fed Dam
451.9	Groundwater Level (mAHD)
160	EC (uS/cm)
6.76	pH
○	Pump/Windmill
▨	Open Cut Outline (proposed)
▭	Underground Outline (proposed)
/	EL6288 Lease Boundary
—	Moolarben DA Boundary
/	Wilpinjong Open Cut (under construction)
/	Ulan Open Cut Outline
/	Ulan Underground Outline (2004 status)

0 2000 4000 metres

NOTE
MGA Coordinates

Date: 25 August 2006	Scale: 1 : 80 000 (as A3)	**Moolarben Coal Mines Pty Ltd**
Initials: PJD	Job No: 05-0158	**Moolarben Coal Project Census of Existing Groundwater Occurrence / Use**
Drawing No: 05-0158-012-D	Rev: D	
Peter Dundon and Associates Pty Limited		**Figure 2**



Legend

GW047331
● DNR Licenced Bore

Open Cut Outline (proposed)

Underground Outline (proposed)

EL6288 Lease Boundary

Moolarben DA Boundary

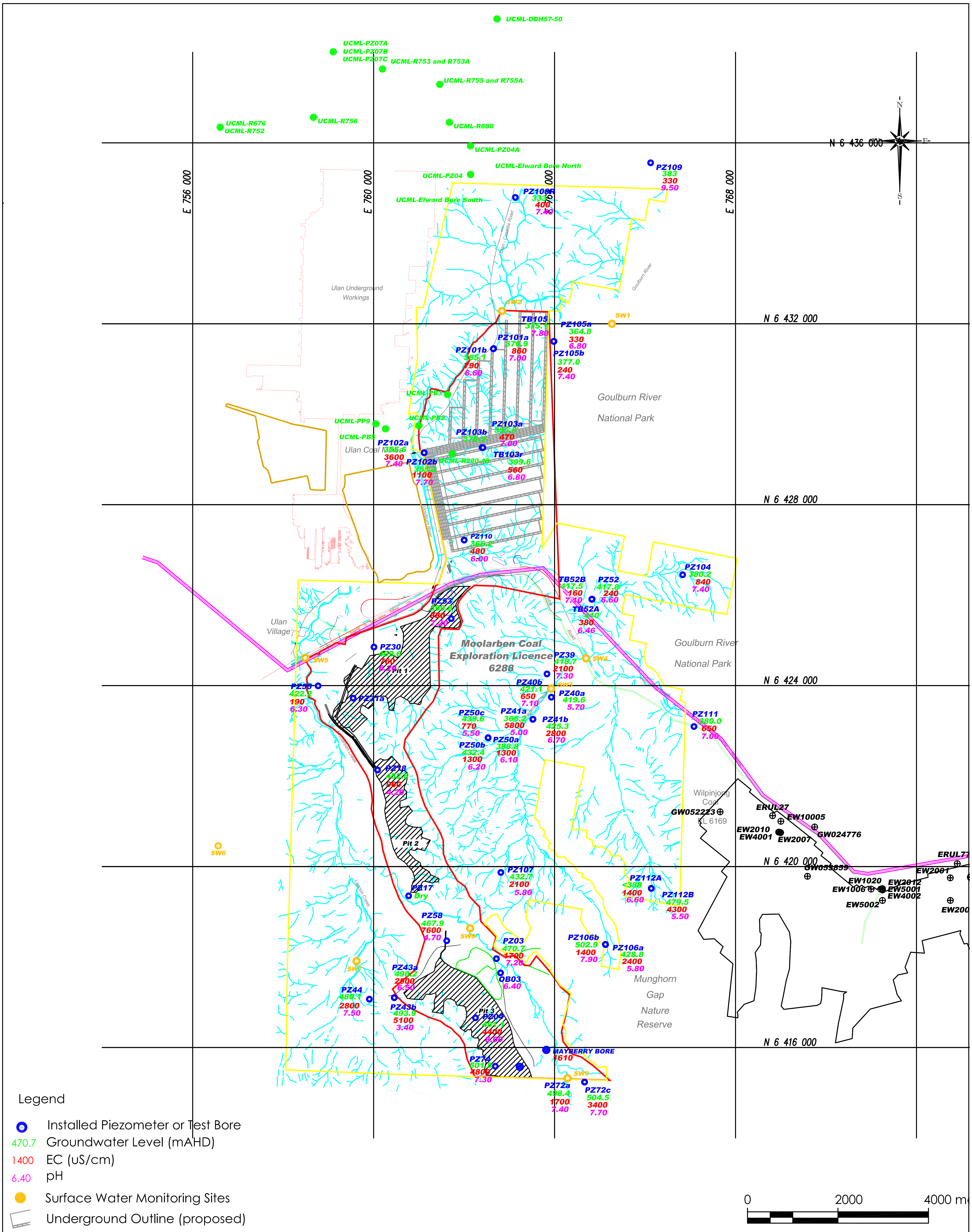
Wilpinjong Open Cut (under construction)

Ulan Open Cut Outline

Ulan Underground Outline (2004 status)

NOTE
MGA Coordinates

Date:	25/08/06	Scale:	1: 80,000 (as A3)	**Moolarben Coal Mines Pty Ltd**
Initials:	PJD	Job No:	05-0158	**Moolarben Coal Project Groundwater Investigation DNR Registered Bores**
Drawing No:	05-0158-020B	Rev:	B	
Peter Dundon and Associates Pty Limited				**Figure 3**



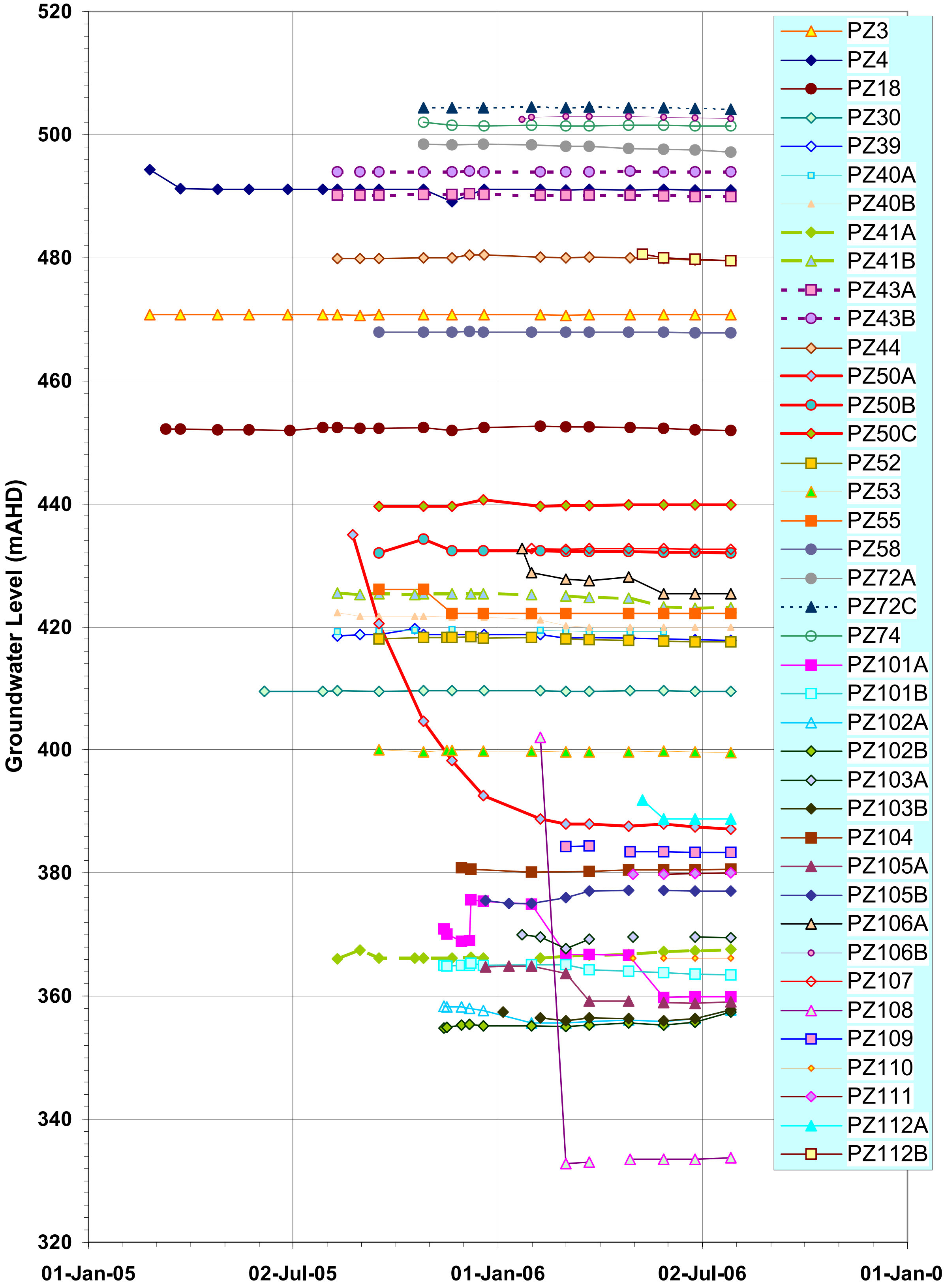
Legend

- ○ Installed Piezometer or Test Bore
- 470.7 Groundwater Level (mAHD)
- 1400 EC (uS/cm)
- 6.40 pH
- ● Surface Water Monitoring Sites
- Underground Outline (proposed)
- EL6288 Lease Boundary
- Moolarben DA Boundary
- Ulan Open Cut Outline
- Ulan Underground Outline (2004 status)
- Wilpinjong Open Cut (under construction)
- ● UCML Groundwater Bore
- ⊕ Wilpinjong Bore

NOTE
MGA Coordinates

Date: 25 August 2006	Scale: 1 : 80 000 (as A3)	**Moolarben Coal Mines Pty Ltd**
Initials: PJD	Job No: 05-0158	**Moolarben Coal Project Groundwater Investigation Piezometer & Test Bores**
Drawing No: 05-0158-011-D	Rev: D	
Peter Dundon and Associates Pty Limited		**Figure 4**

HYDROGRAPH - MOOLARBEN PIEZOMETERS



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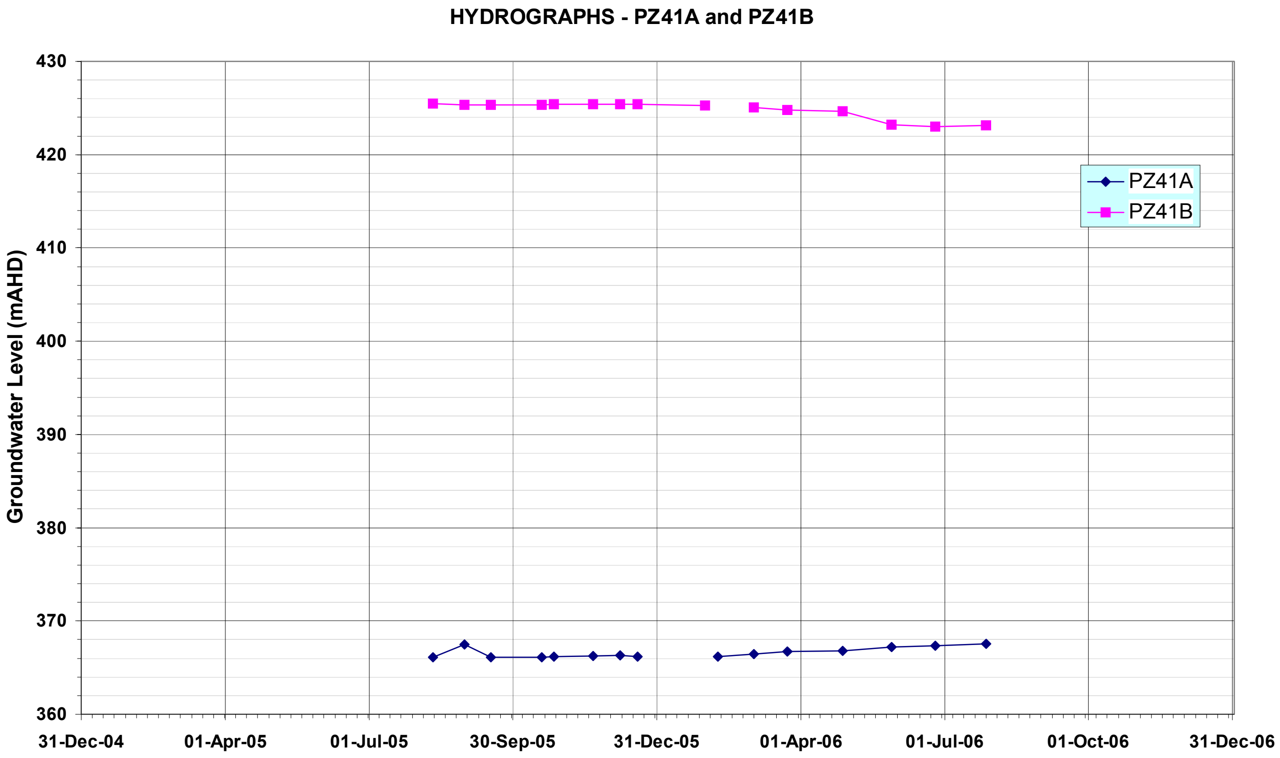
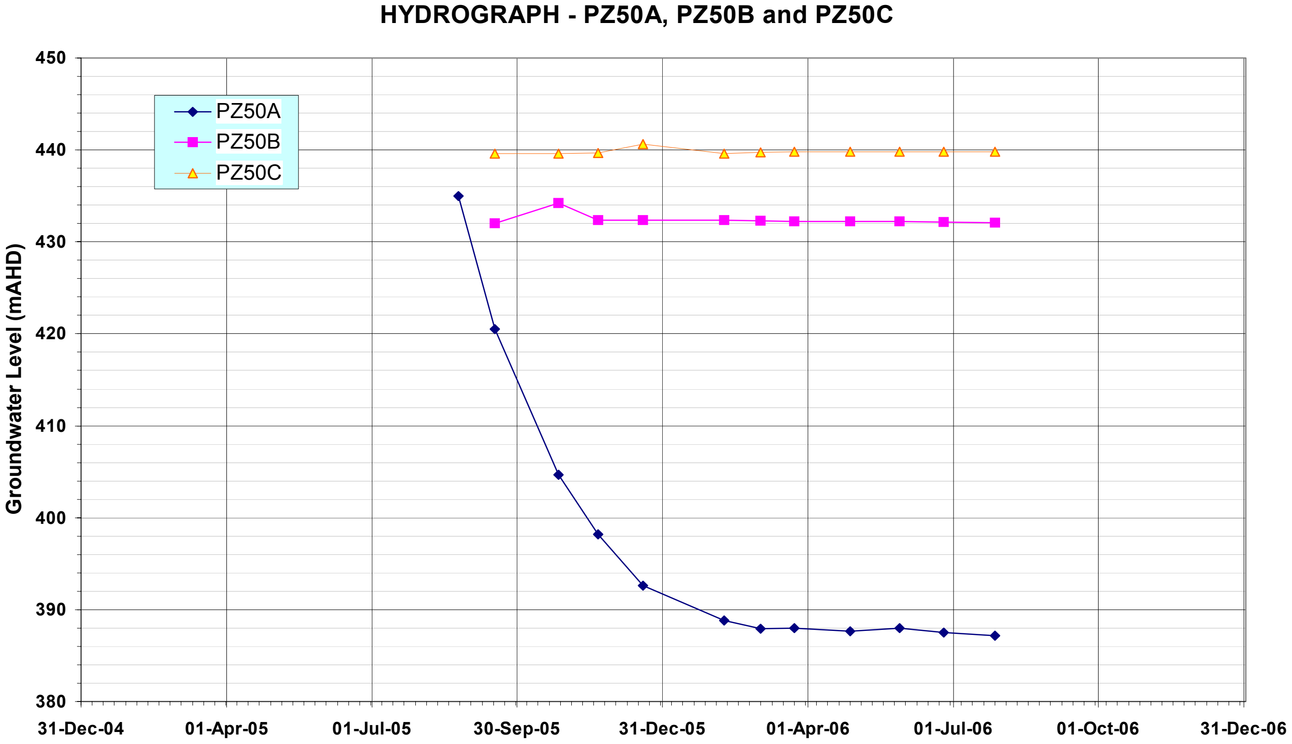
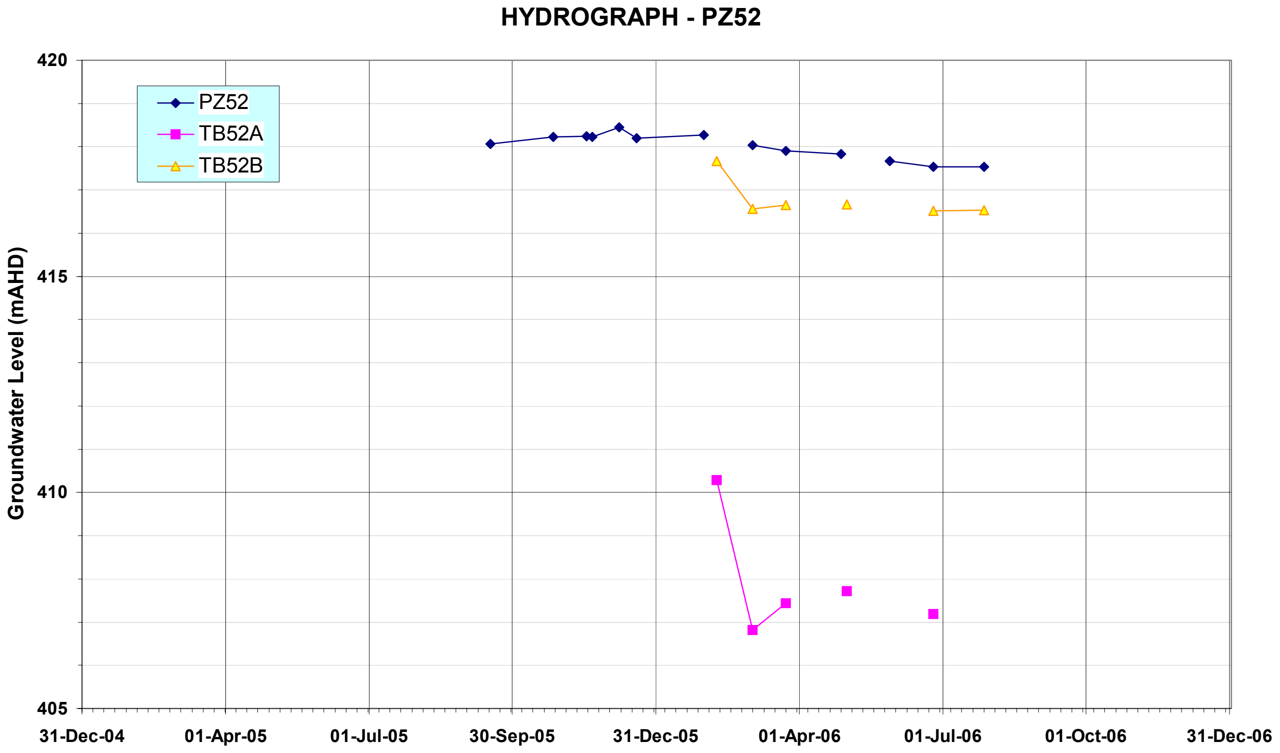
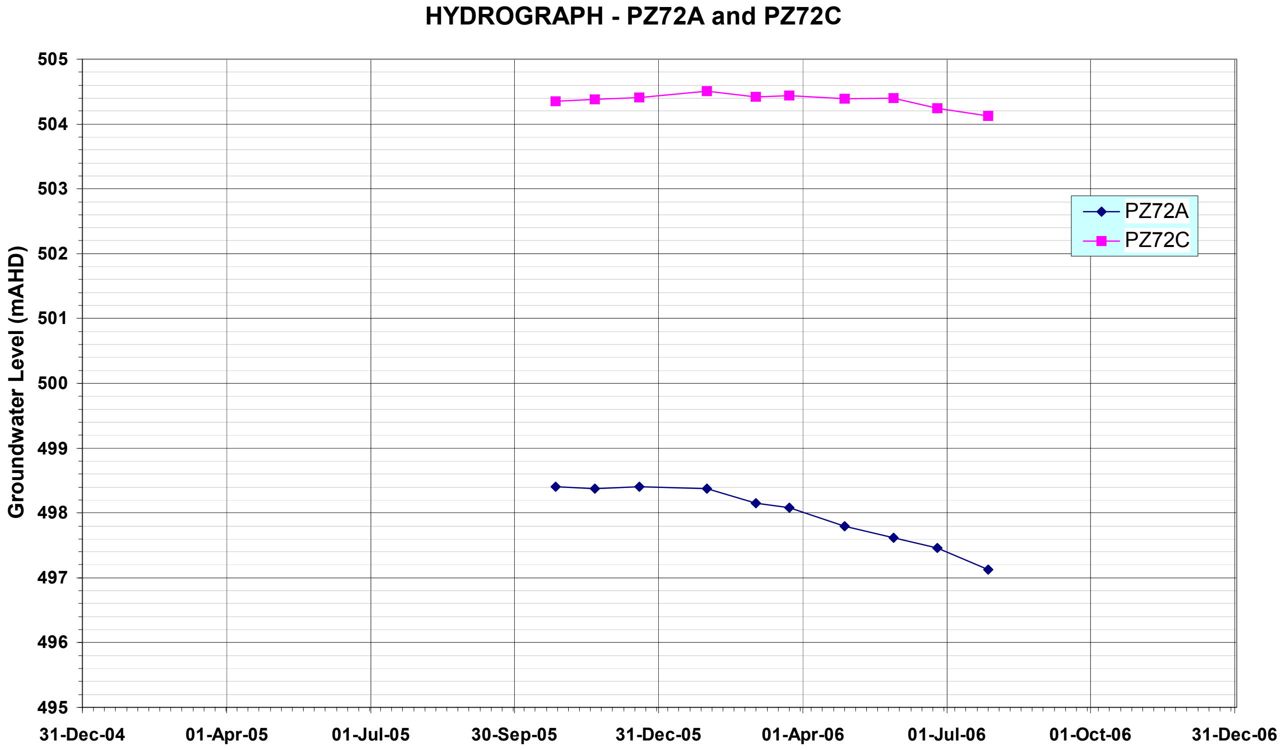
Initials:	PJD	Job No:	05-0158	**MOOLARBEN COAL PROJECT PIEZOMETER HYDROGRAPHS - COMPOSITE**
Drawing No:	05-0158-101-B	Rev:	B	
Peter Dundon and Associates Pty Limited				**Figure 5**





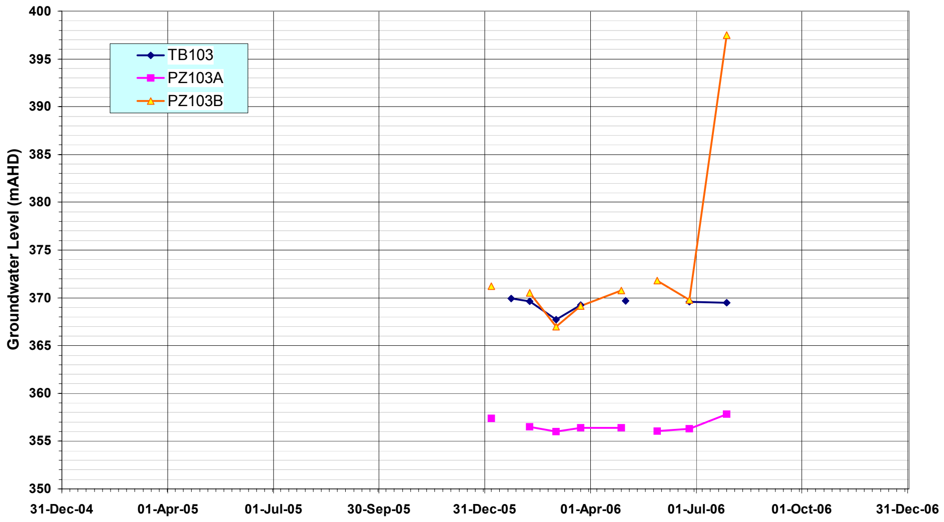
Date:	22 August 2006	Scale:	as indicated	**Moolarben Coal Mines Pty Ltd**
Initials:	PJD	Job No:	05-0158	**MOOLARBEN COAL PROJECT PIEZOMETER HYDROGRAPHS - PZ41A and B; PZ50A to C**
Drawing No:	05-0158-102-B	Rev:	B	
Peter Dundon & Associates Pty Limited				**Figure 6**



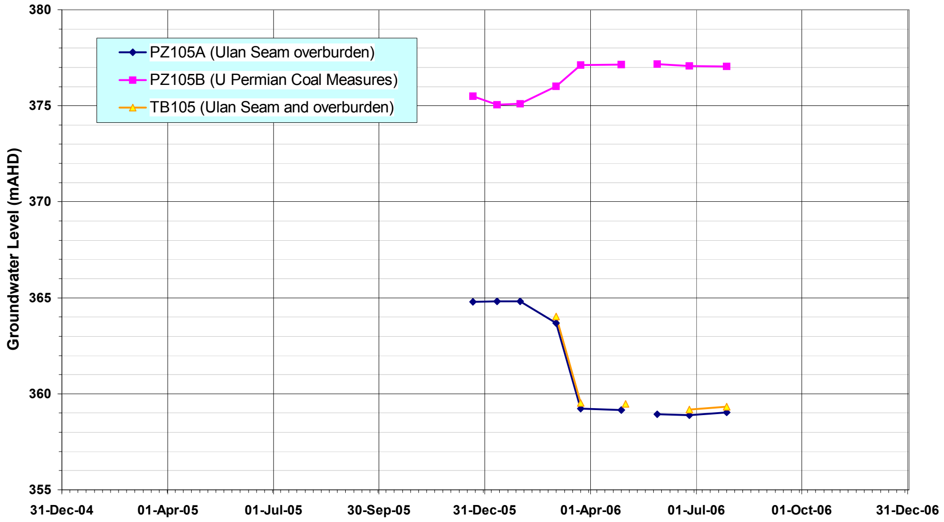


Date: 22 August 2006	Scale: as indicated	**Moolarben Coal Mines Pty Ltd**	
Initials: PJD	Job No: 05-0158	**MOOLARBEN COAL PROJECT PIEZOMETER HYDROGRAPHS - PZ52, TB52A and TB52B; PZ72A to C**	
Drawing No: 05-0158-103-B	Rev: A		
Peter Dundon and Associates Pty Limited			**Figure 7**

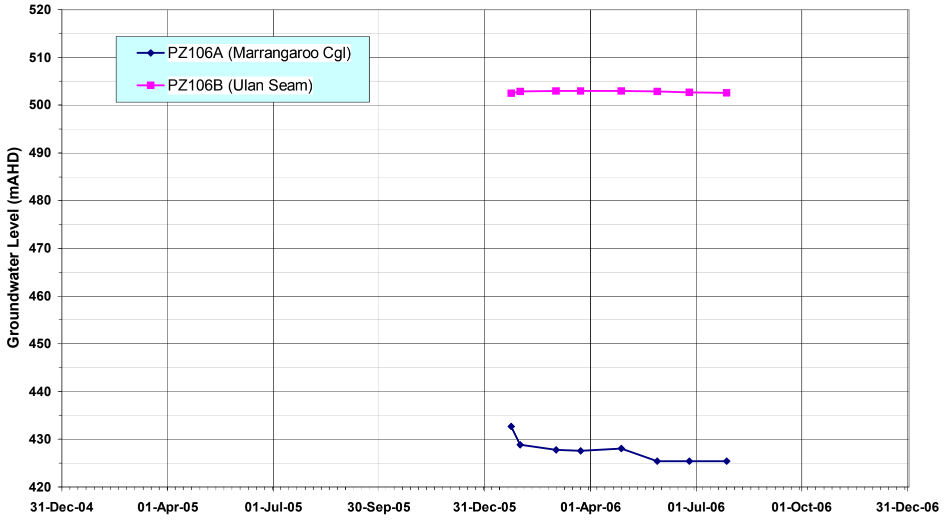
HYDROGRAPH - TB103, PZ103A and PZ103B



HYDROGRAPH - TB105, PZ105A and PZ105B



HYDROGRAPH - PZ106A and PZ106B



Date:	22 August 2006	Scale:	as indicated
Initials:	PJD	Job No:	05-0158
Drawing No:	05-0158-104-B	Rev:	B

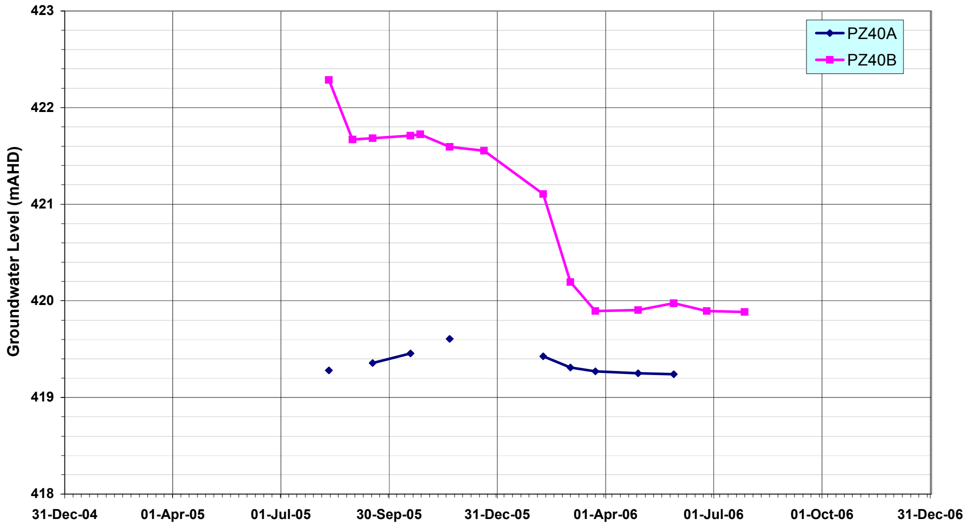
Peter Dundon and Associates Pty Limited

Moolarben Coal Mines Pty Ltd

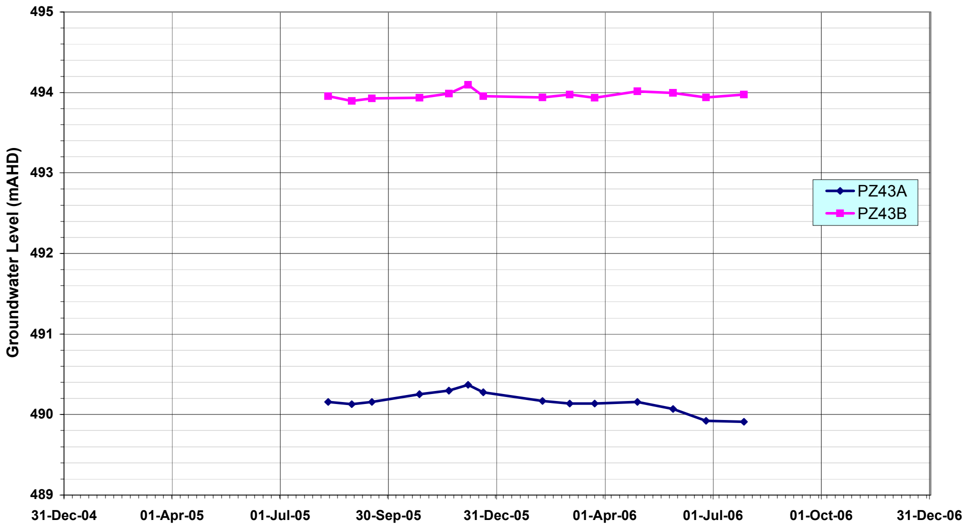
MOOLARBEN COAL PROJECT
PIEZOMETER HYDROGRAPHS -
TB103, PZ103A and B; TB105, PZ105A and B;
PZ106A and B

Figure 8

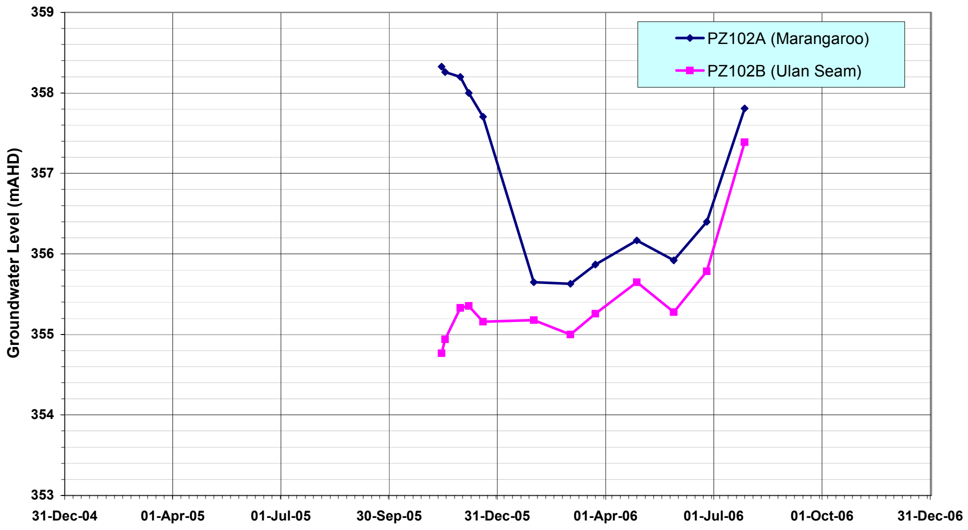
HYDROGRAPH - PZ40A and PZ40B



HYDROGRAPH - PZ43A and PZ43B



HYDROGRAPH - PZ102A and PZ102B



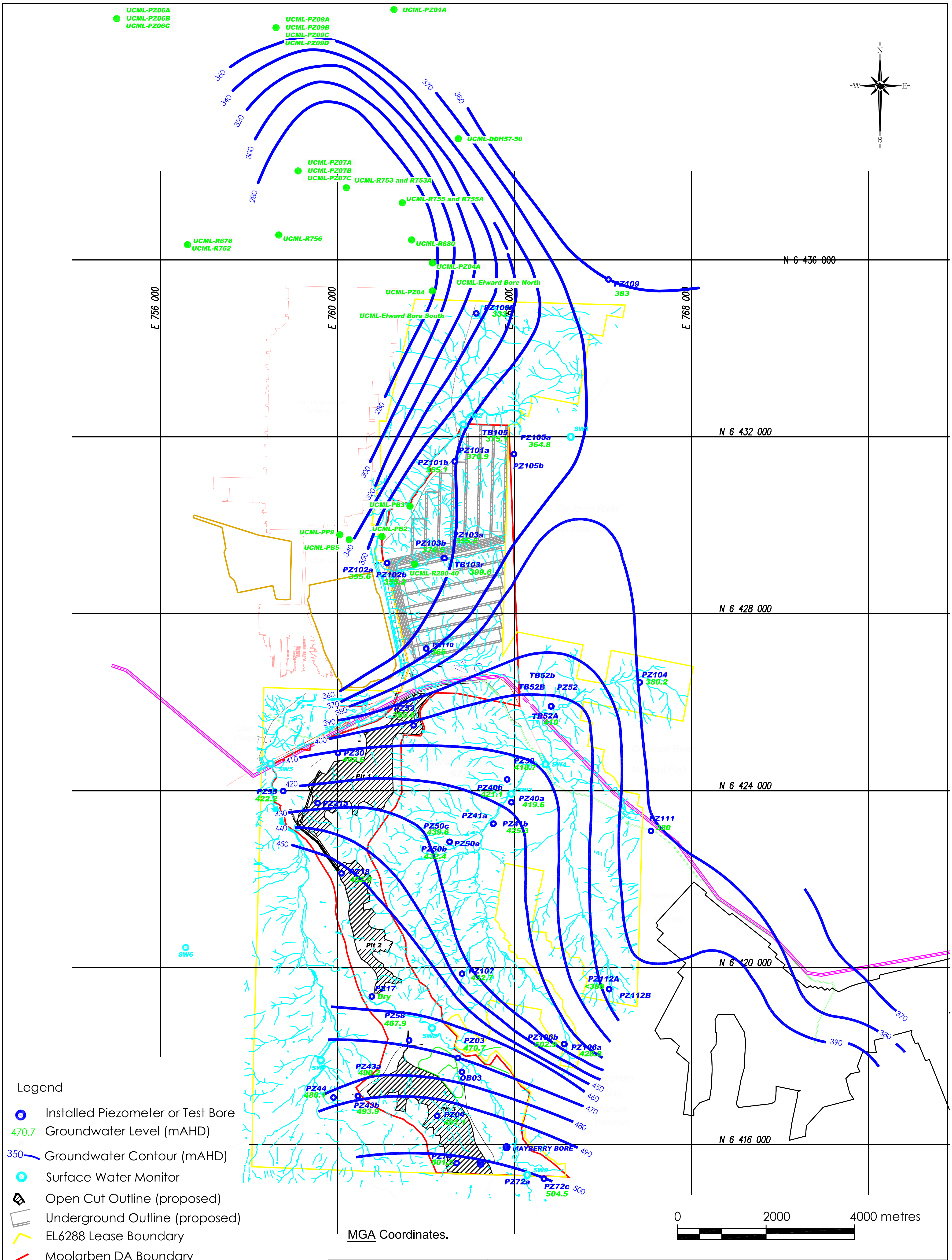
Date:	22 August 2006	Scale:	as indicated
Initials:	PJD	Job No:	05-0158
Drawing No:	05-0158-105-A	Rev:	0

Peter Dundon and Associates Pty Limited

Moolarben Coal Mines Pty Ltd

MOOLARBEN COAL PROJECT
PIEZOMETER HYDROGRAPHS -
PZ40A and B; PZ43A and B;
PZ102A and B

Figure 9

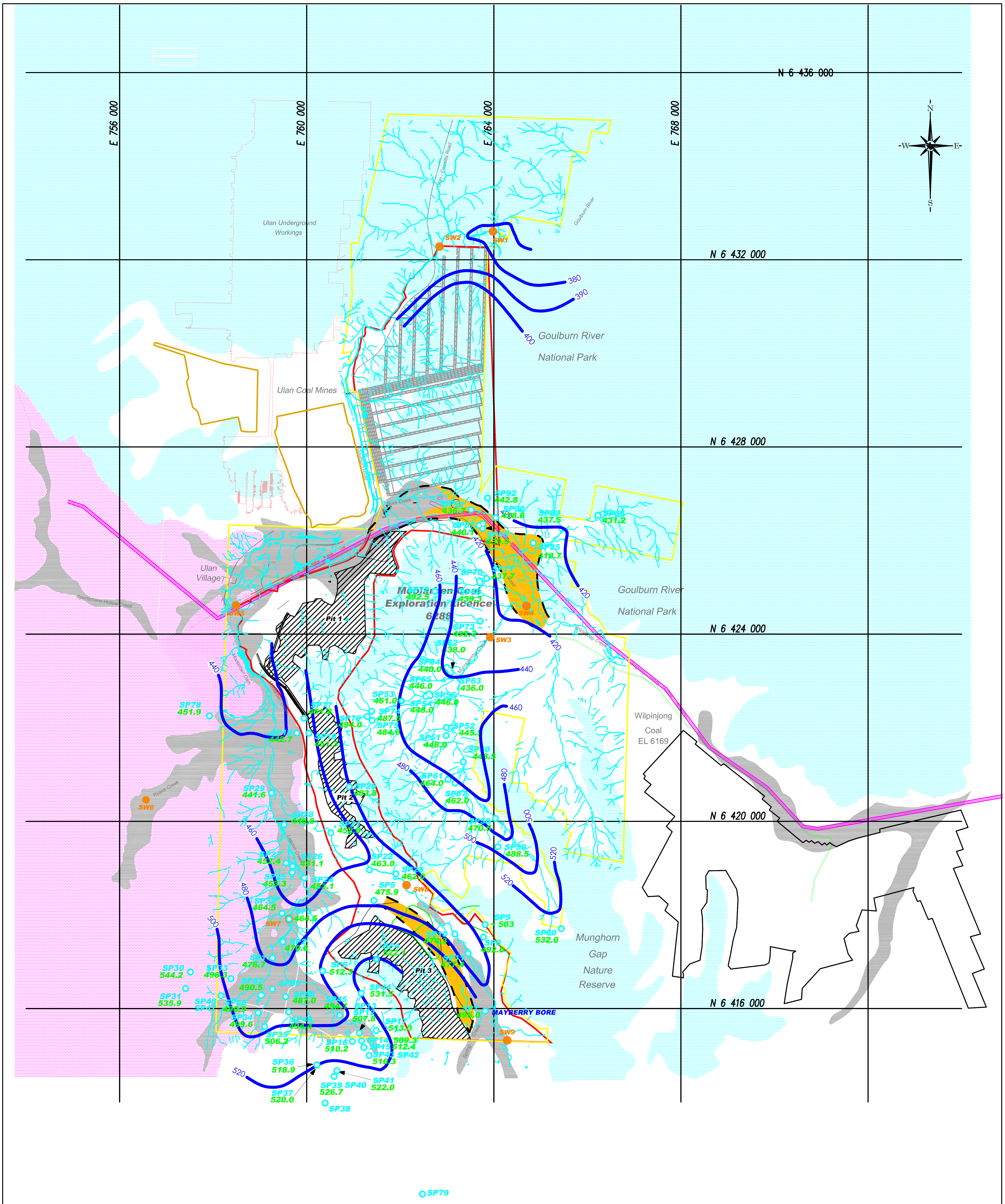


MGA Coordinates.

Legend

- ● Installed Piezometer or Test Bore
- 470.7 Groundwater Level (mAHD)
- 350 Groundwater Contour (mAHD)
- ● Surface Water Monitor
- ▨ Open Cut Outline (proposed)
- ▭ Underground Outline (proposed)
- EL6288 Lease Boundary
- Moolarben DA Boundary
- ● UCML Groundwater Bore
- / Ulan Open Cut Outline
- / Ulan Underground Outline
- / Wilpinjong Open Cut (under construction)

Date:	25 August 2006	Scale: 1 : 80 000 (as A3)	**Moolarben Coal Mines Pty Ltd**
Initials:	PJD	Job No: 05-0158	**Moolarben Coal Project** **Ulan Seam - Permian Coal Measures** **Groundwater Levels**
Drawing No:	05-0158-0010-E	Rev: E	
Peter Dundon and Associates Pty Limited			**Figure 10**



Legend

● SP78 Census - Existing Spring/Soak/Bore
451.9 Groundwater Level (mAHD)

350 Groundwater Contour (mAHD)

▨ Open Cut Outline (proposed)

Underground Outline (proposed)

EL6288 Lease Boundary

Moolarben DA Boundary

Wilpinjong Open Cut (under construction)

Ulan Open Cut Outline

Ulan Underground Outline (2004 Status)

▨ Recent Alluvium

▨ Tertiary Paleochannel Alluvium

▨ Triassic Narrabeen Group

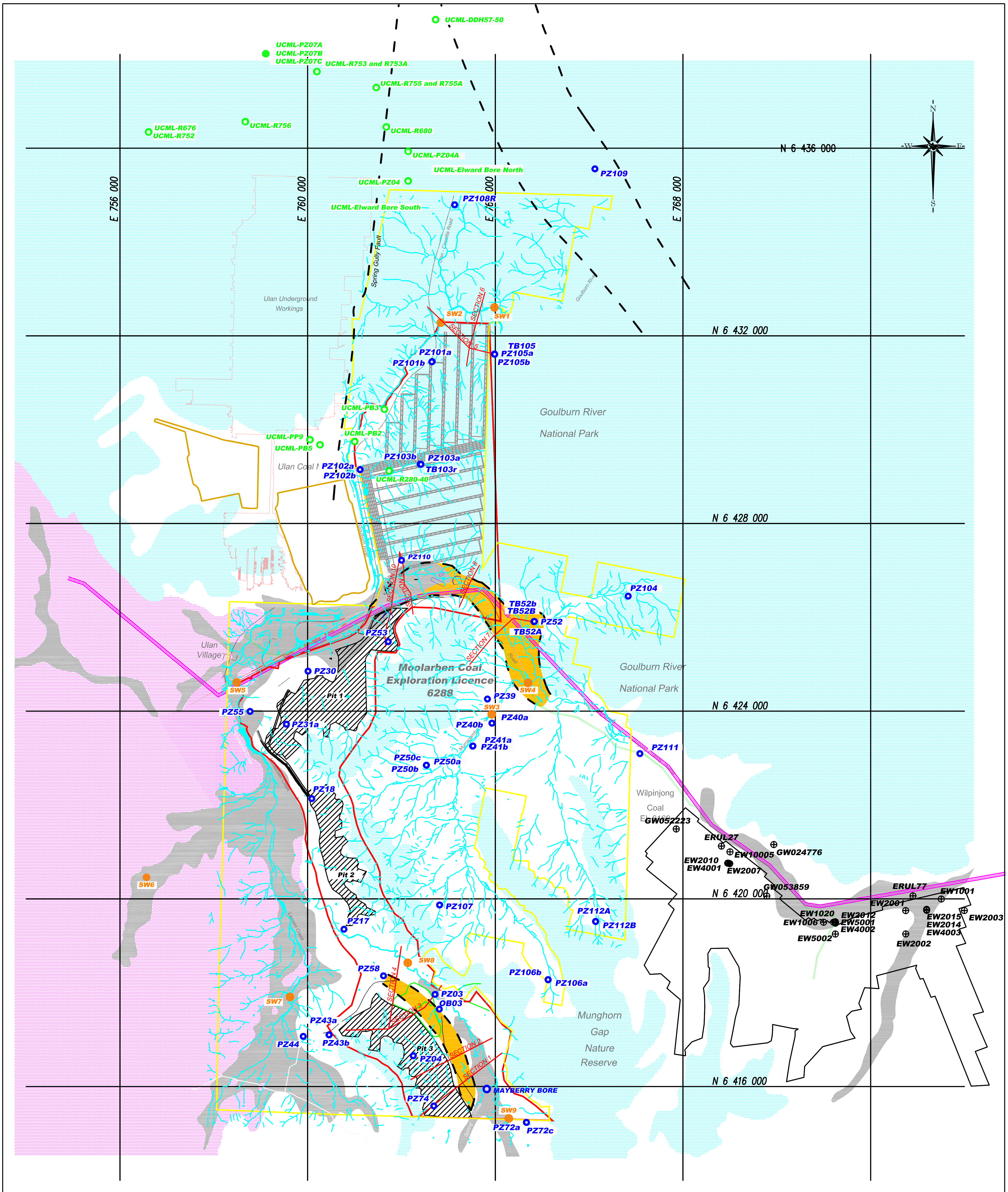
☐ Permian Coal Measures

▨ Granite / Volcanics Basement

0 2000 4000 metres

NOTE
MGA Coordinates

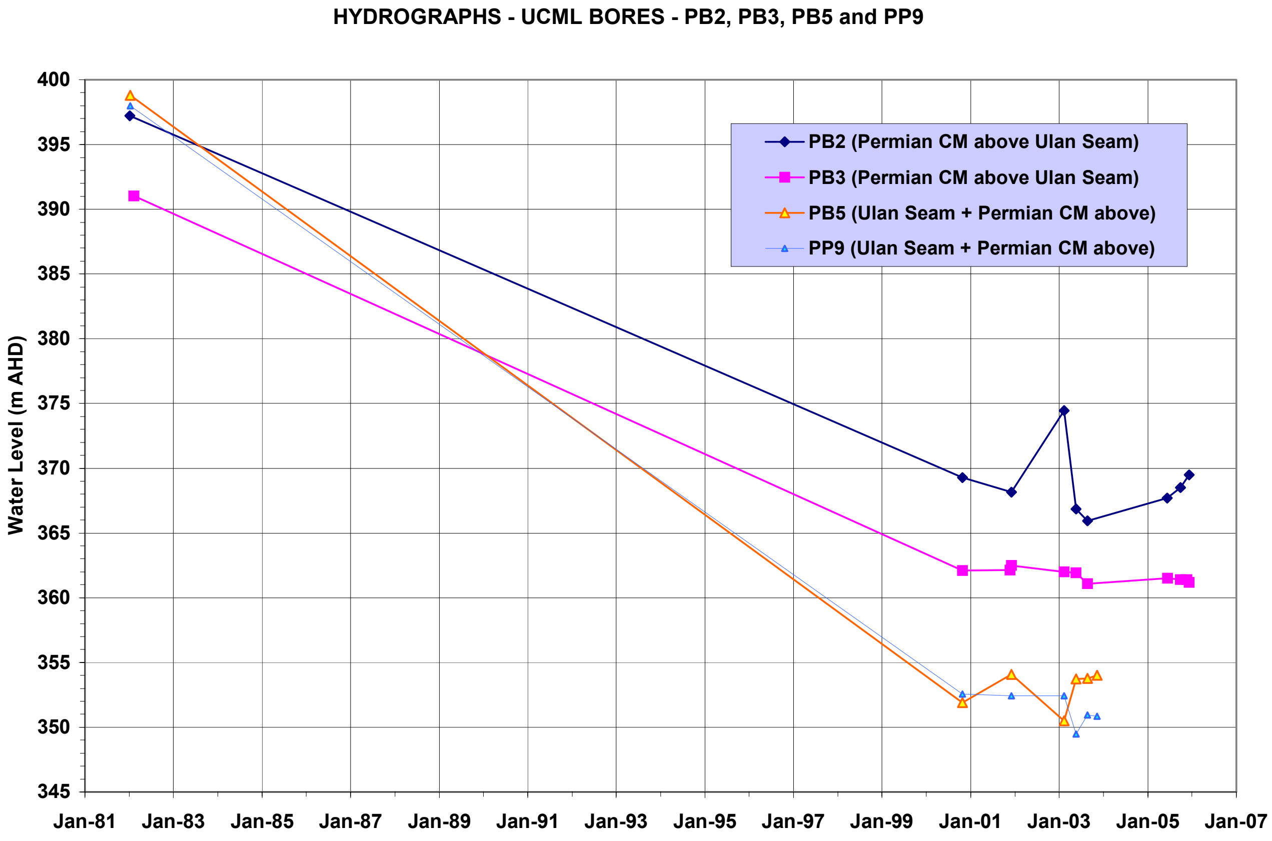
Date:	25 August 2006	Scale:	1: 80,000 as A3	**Moolarben Coal Mines Pty Ltd**
Initials:	PJD	Job No:	05-0158	**Moolarben Coal Project Moolarben Groundwater Investigation Surficial Groundwater Contours**
Drawing No:	05-0158-022-C	Rev:	C	**Figure 11**
Peter Dundon and Associates Pty Limited				

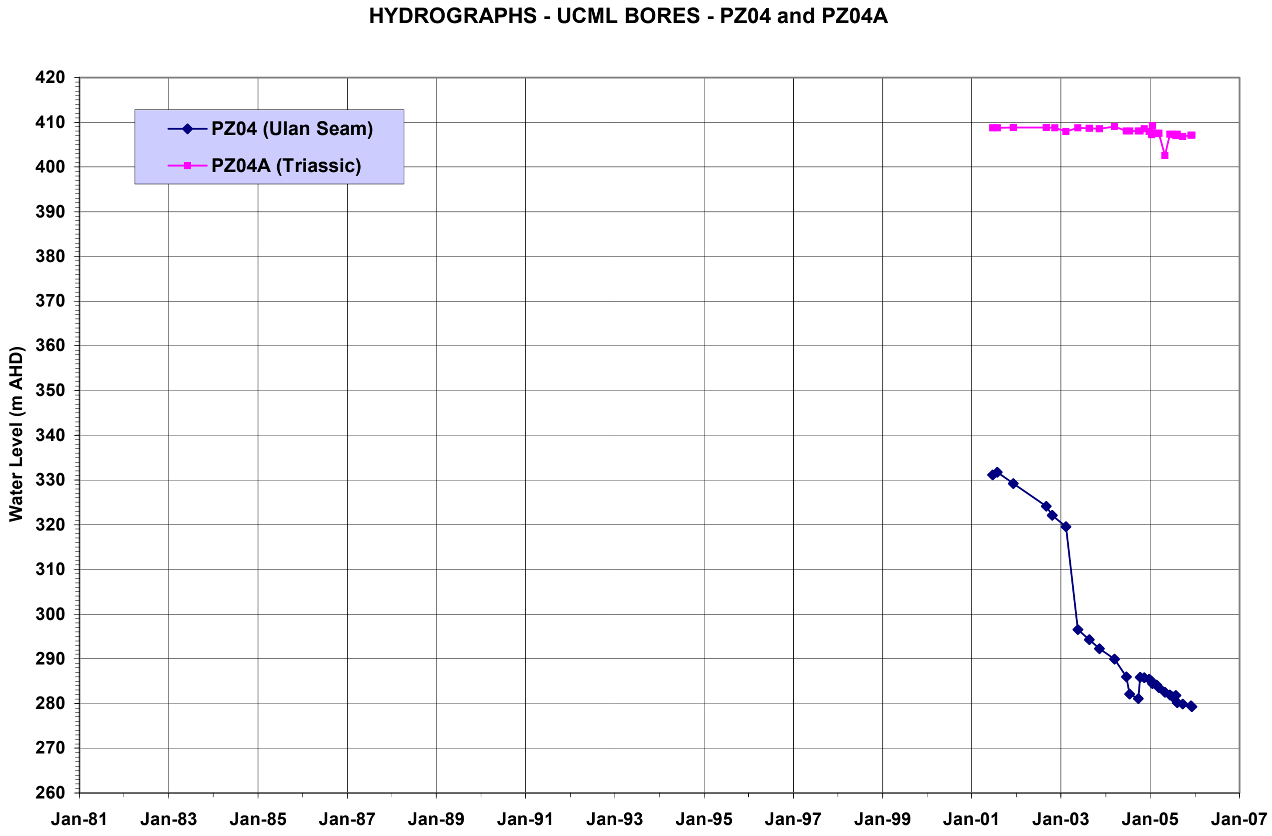


Legend

- ● Piezometer or Test Bore
- ● Surface Water Monitoring Sites
- ▨ Open Cut Outline (proposed)
- ▭ Underground Outline (proposed)
- ╱ EL6288 Lease Boundary
- ╱ Moolarben DA Boundary
- ● UCML Groundwater Bore
- ⊕ Wilpinjong Bore
- ╱ Wilpinjong Open Cut (under construction)
- ╱ Ulan Open Cut Outline
- ╱ Ulan Underground Outline (2004 status)
- ╍ Fault
- ▇ Recent Alluvium
- ▇ Tertiary Paleochannel Alluvium
- ▇ Triassic Narrabeen Group
- ☐ Permian Coal Measures
- ▇ Granite / Volcanics Basement

Date:	25 August 2006	Scale:	1: 80,000 as A3	**Moolarben Coal Mines Pty Ltd**
Initials:	PJD	Job No:	05-0158	**Moolarben Coal Project Hydrogeological Units**
Drawing No:	05-0158-017-E	Rev:	E	
Peter Dundon and Associates Pty Limited				**Figure 12**





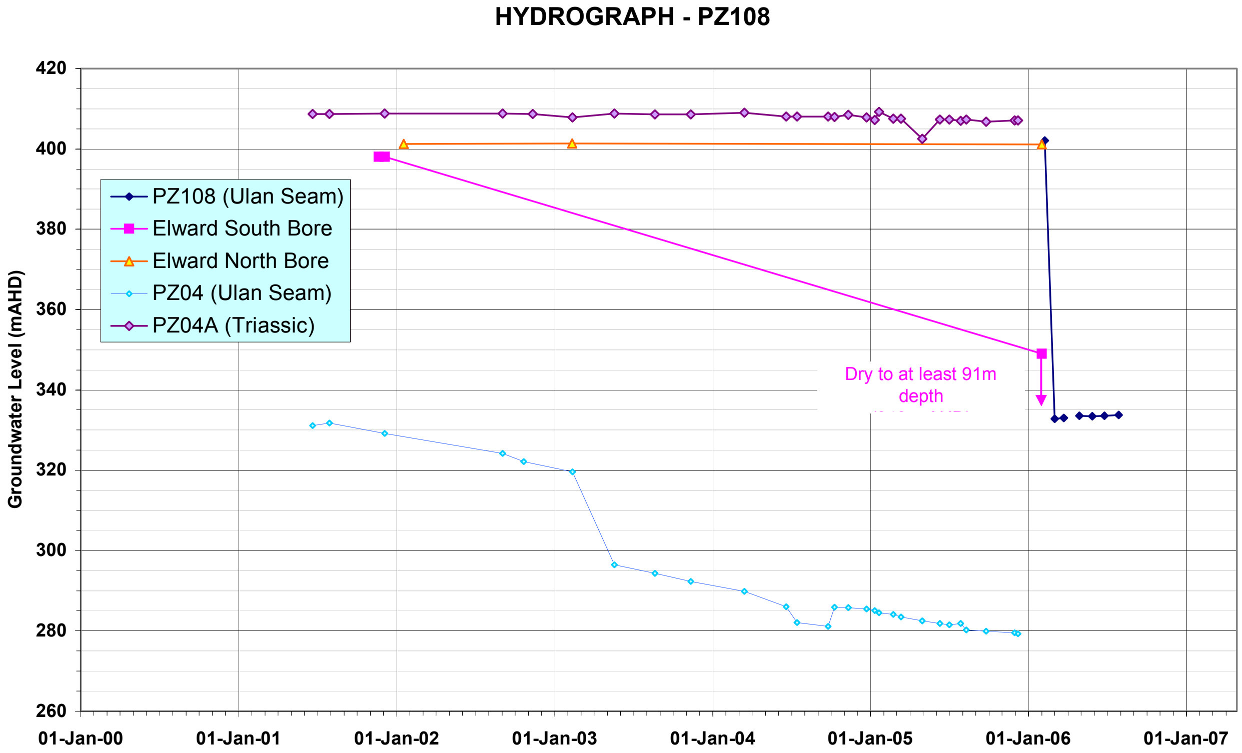
Date:	22 August 2006	Scale:	as indicated
Initials:	PJD	Job No:	05-0158
Drawing No:	05-0158-116-B	Rev:	B

Peter Dundon and Associates Pty Limited

Moolarben Coal Mines Pty Ltd

MOOLARBEN COAL PROJECT
UCML PIEZOMETER HYDROGRAPHS -
PB1, PB2, PB3 and PP9;
PZ04A and B

Figure 13



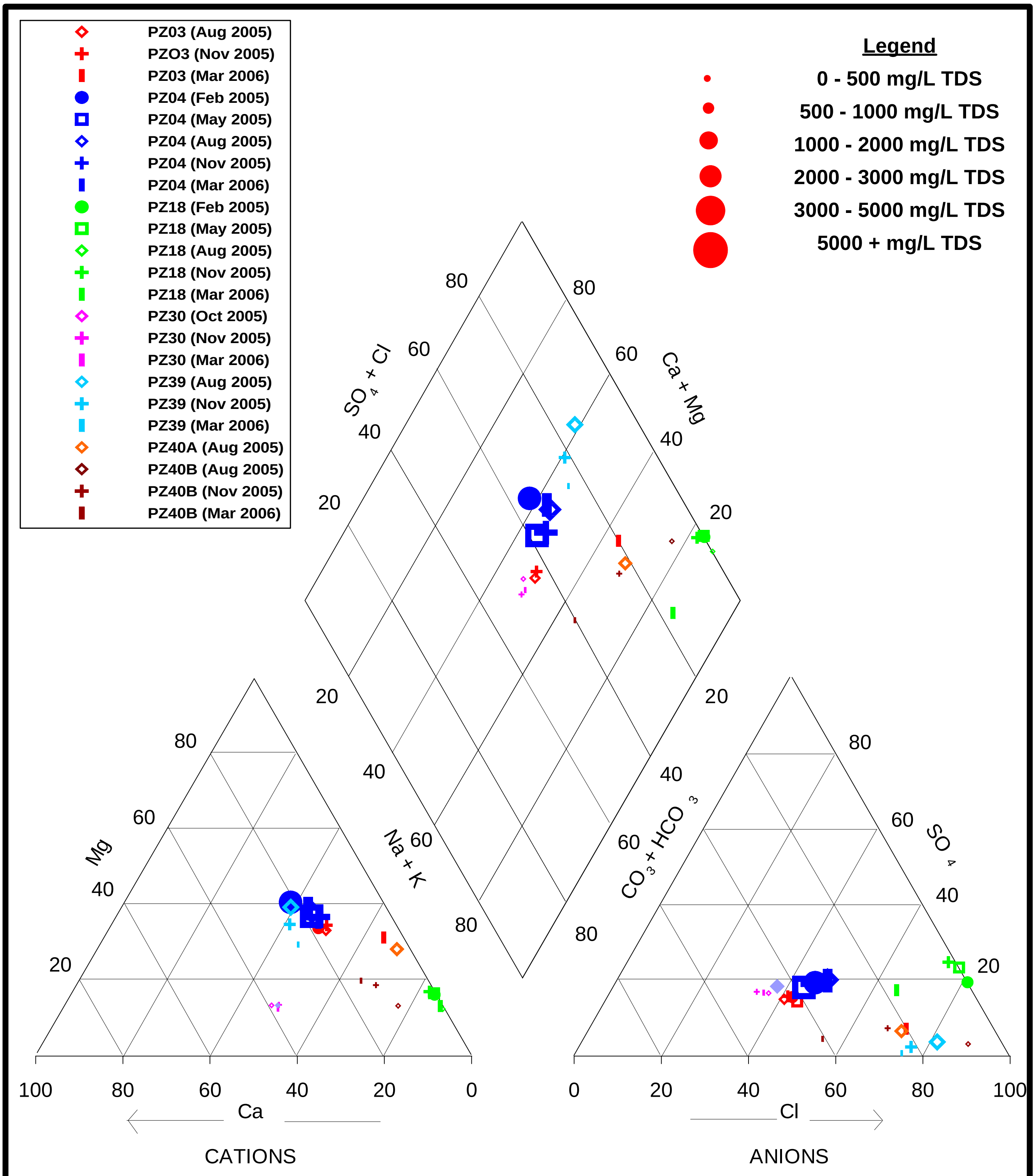
Date: 22 August 2006
Scale: as indicated
Initials: PJD
Job No: 05-0158
Drawing No: 05-0158-117-B
Rev: B

Peter Dundon and Associates Pty Limited

Moolarben Coal Mines Pty Ltd

MOOLARBEN COAL PROJECT
PIEZOMETER HYDROGRAPHS -
PZ108; Elward Bores; UCML PZ04

Figure 14



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fx 61 2 94493193
mb 0418 476 799
pjdundon@ozemail.com.au

CLIENT
Moolarben Coal Mines Pty Ltd

PROJECT
MOOLARBEN COAL PROJECT

DRAWN
PJD

DATE
22 August 2006

TITLE
PIPER TRILINEAR DIAGRAM
PZ03, PZ04, PZ18, PZ31A, PZ39, PZ40A and B

CHECKED

DATE

SCALE
As Shown

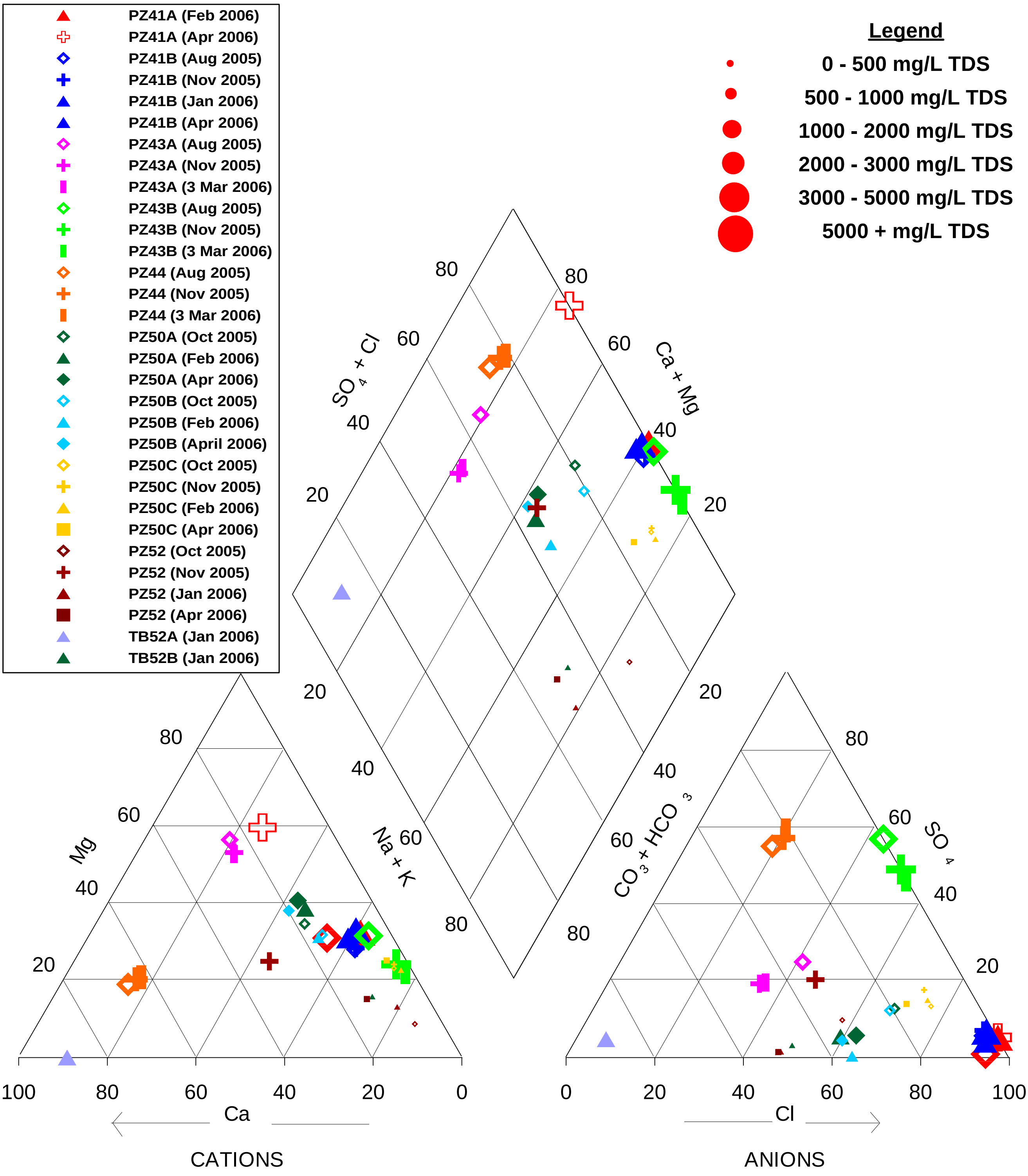
Dwg 05-0158-118

A4

PROJECT No
05-0158

Figure 15

c:\...\05-0158\PZ_A\piper.grt



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CLIENT Moolarben Coal Mines Pty Ltd

DRAWN PJD
DATE 22 August 2006

CHECKED
DATE

SCALE As Shown
Dwg 05-0158-119A
A4

PROJECT **MOOLARBEN COAL PROJECT**

TITLE **PIPER TRILINEAR DIAGRAM**
PZ41A and B, PZ43A and B, PZ44,
PZ50A, B and C, PZ52, TB52A and TB52B

PROJECT No 05-0158

Figure 16

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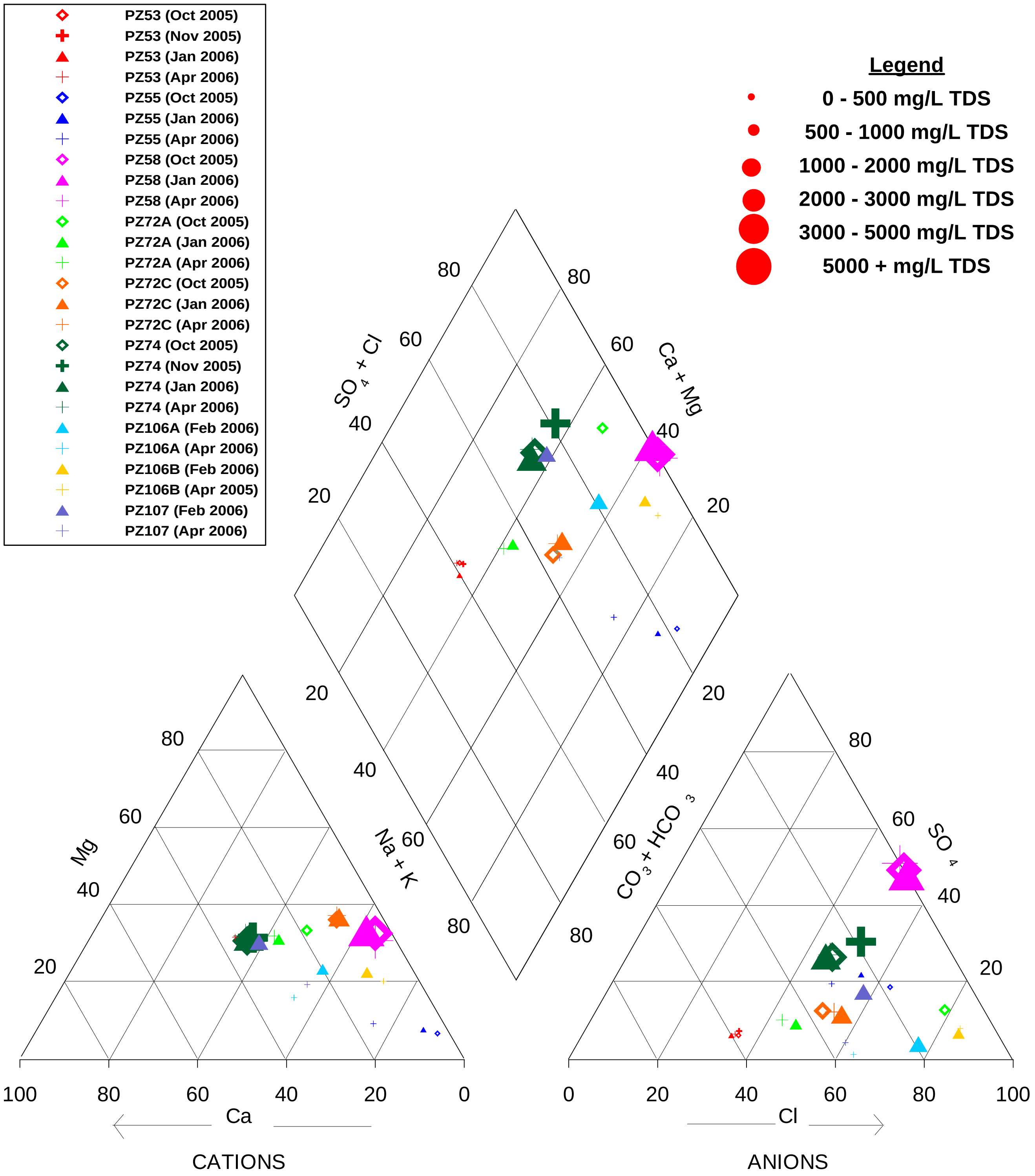

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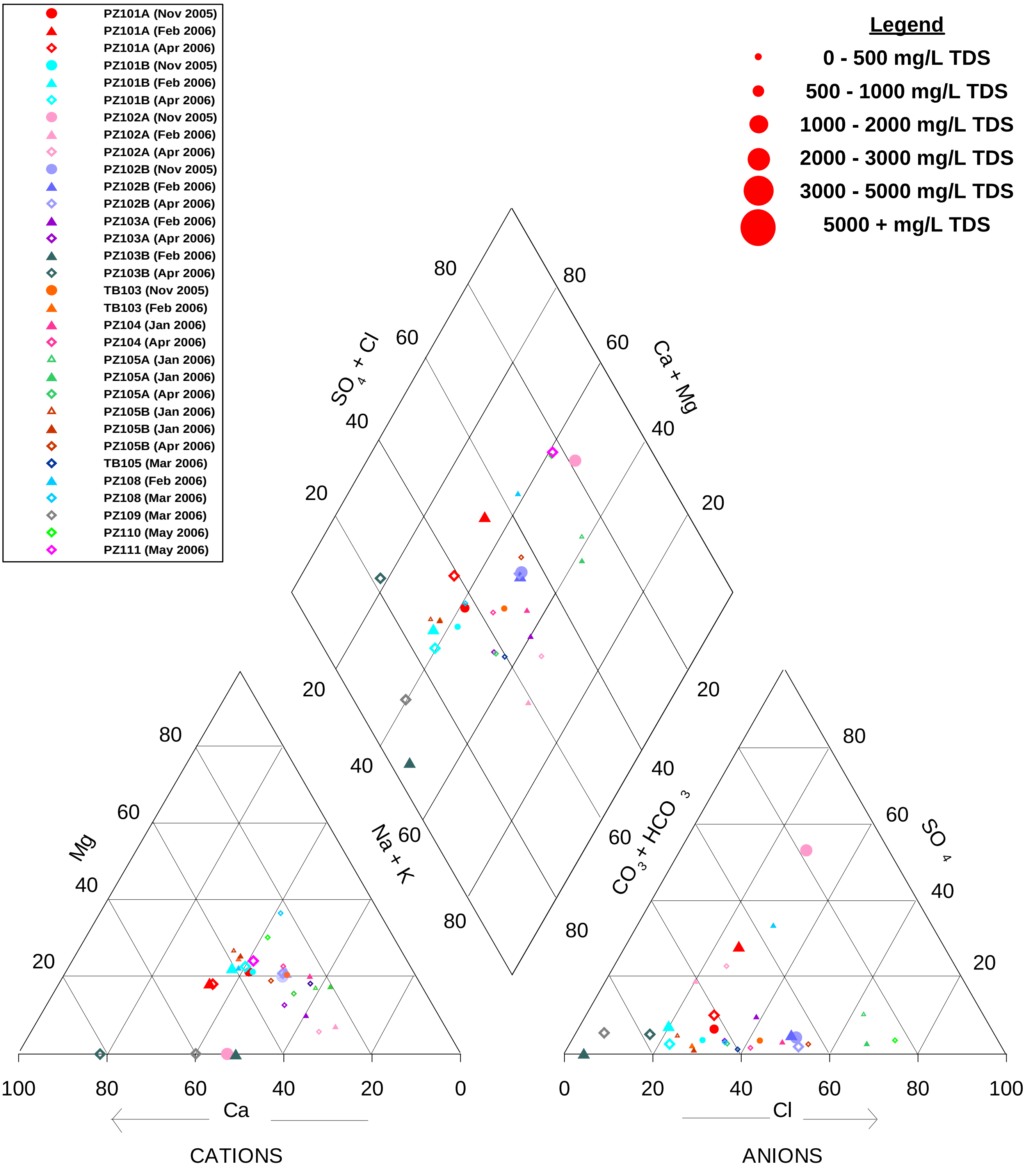
CLIENT Moolarben Coal Mines Pty Ltd		PROJECT	**MOOLARBEN COAL PROJECT**
DRAWN PJD	DATE 22 August 2006	TITLE	**PIPER TRILINEAR DIAGRAM** **PZ53, PZ55, PZ58, PZ72A and B,** **PZ74, PZ106A and B, PZ107**
CHECKED	DATE		
SCALE As Shown	Dwg 05-0158-120A **A4**	PROJECT No 05-0158	**Figure 17**

c:\...\05-0158\PZ_C\piper.grt



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fx 61 2 94493193
mb 0418 476 799
pjdundon@ozemail.com.au

CLIENT Moolarben Coal Mines Pty Ltd

PROJECT **MOOLARBEN COAL PROJECT**

DRAWN PJD

DATE 22 August 2006

TITLE **PIPER TRILINEAR DIAGRAM**
Piezometers from
Underground 4 Area

CHECKED

DATE

SCALE
As Shown

Dwg 05-0158-121A

A4

PROJECT No 05-0158

Figure 18

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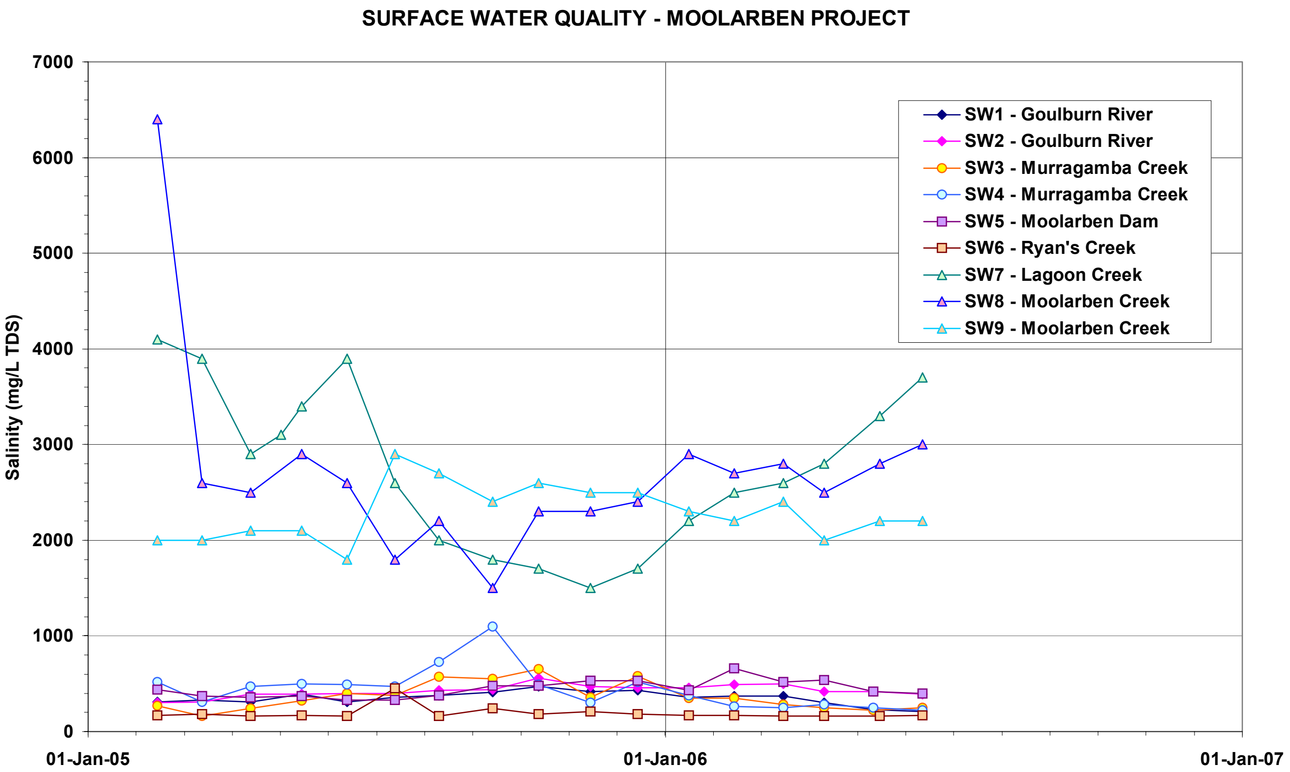
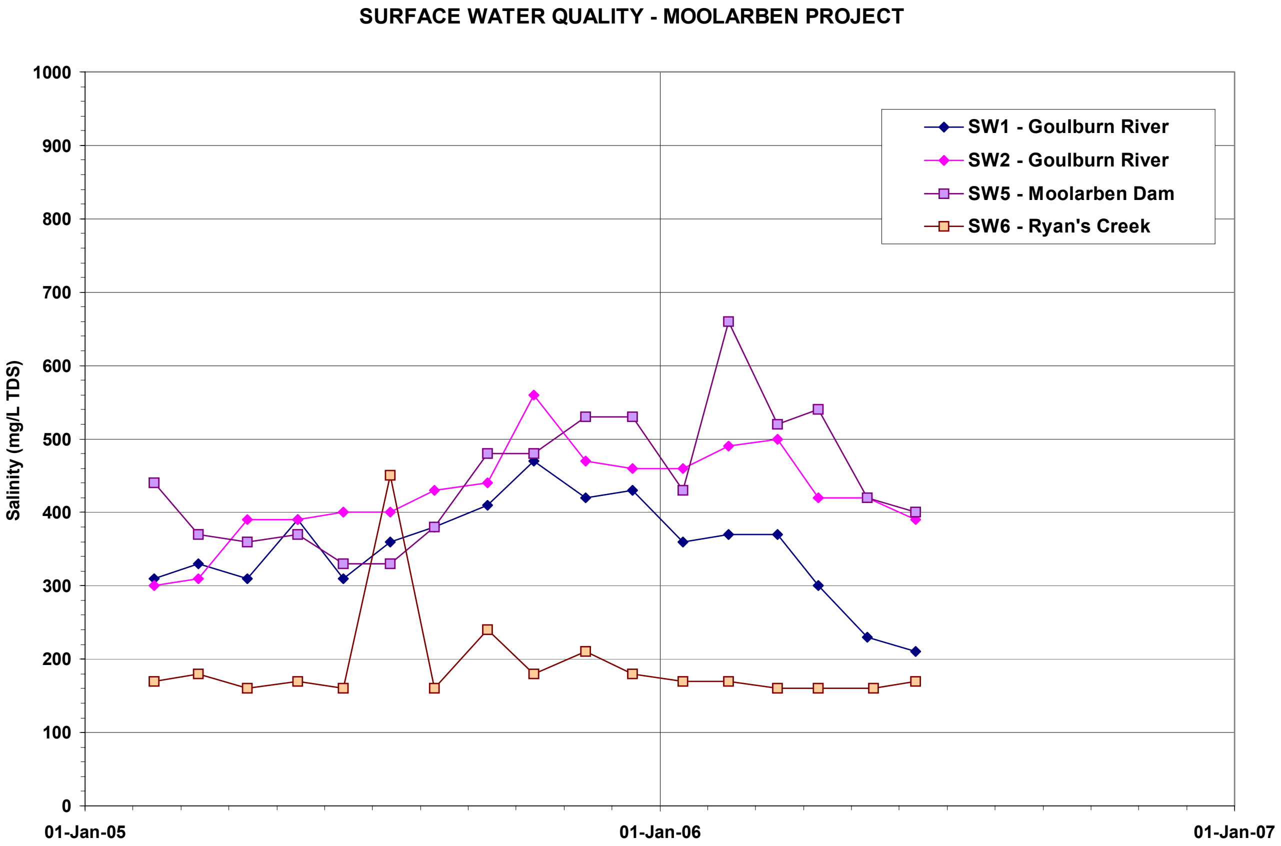




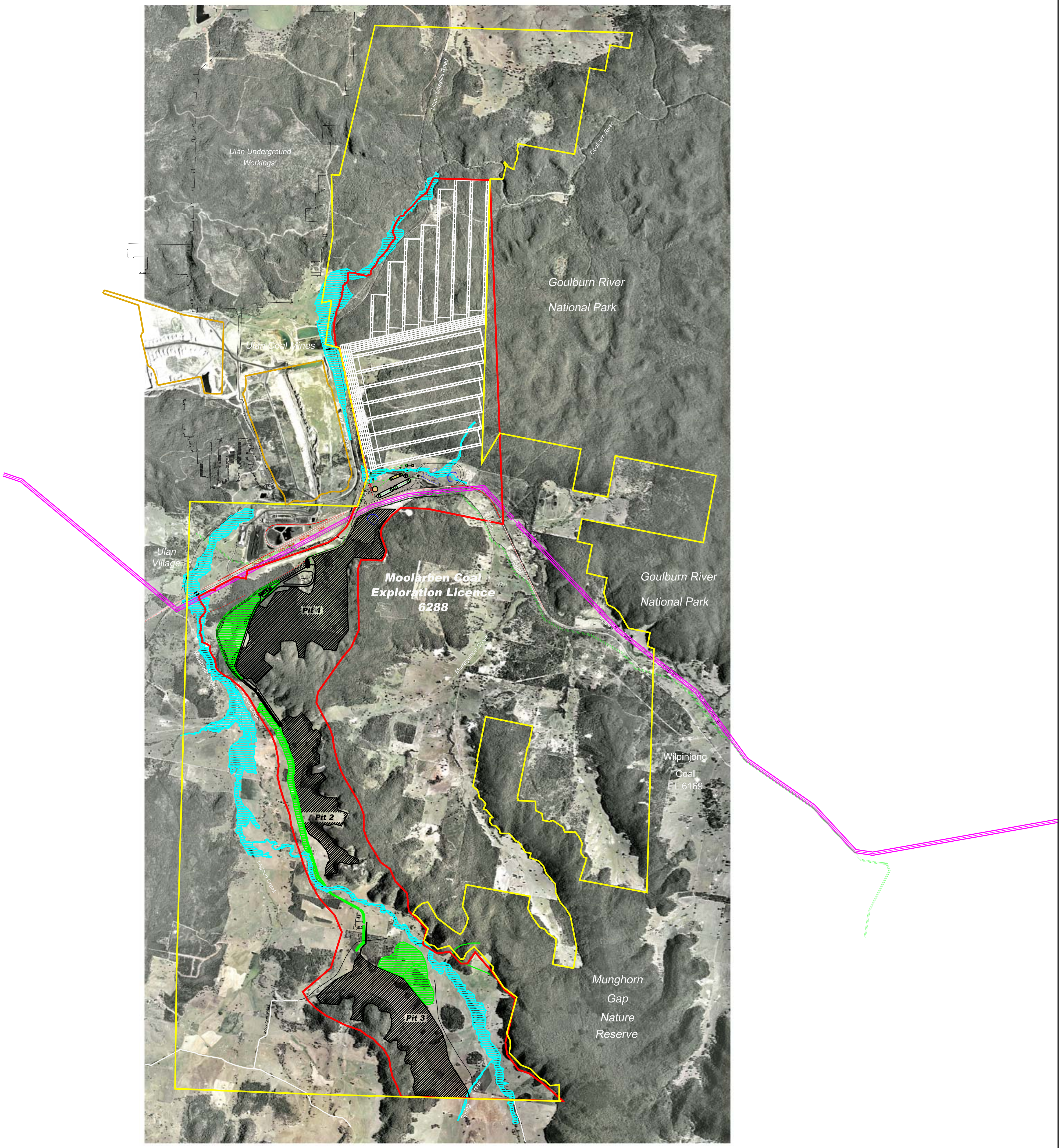
Date:	18 August 2006	Scale:	as indicated
Initials:	PJD	Job No:	05-0158
Drawing No:	05-0158-123	Rev:	0

Peter Dundon and Associates Pty Limited

Moolarben Coal Mines Pty Ltd

MOOLARBEN COAL PROJECT
SURFACE WATER QUALITY -
GOULBURN RIVER AND TRIBUTARIES

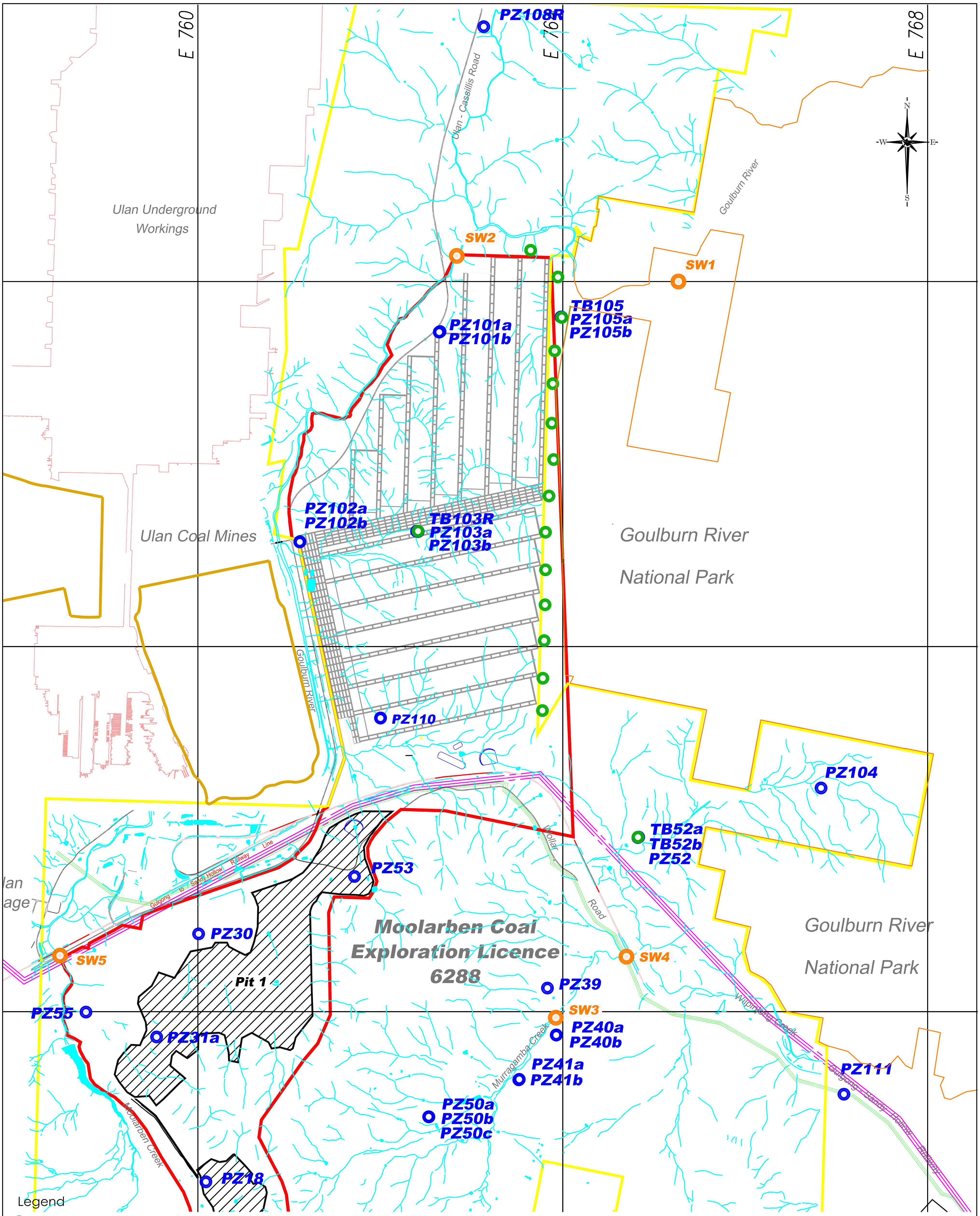
Figure 19



- 🟨 EL 6288 Boundary
- 🟥 DA Boundary
- ▤ 1 in 100 year flood level
- 🟩 Out of Pit Dump
- ▨ Pit

NOTE
MGA Coordinates.

Date:	23 August 2006	Scale:	1 : 75 000	**Moolarben Coal Mines Pty Ltd**
Initials:	PJD	Job No:	05-0158	**Moolarben Coal Project Proposed Mine Layouts**
Drawing No:	05-0158-004-A	Rev:	A	
Peter Dundon and Associates Pty Limited				**Figure 20**



Legend

- ○ Moolarben Dewatering/Water Supply Production Bore Site
- ○ Installed Piezometer or Test Bore
- ● Surface Water Monitoring Sites
- ▨ Open Cut Outline (proposed)
- ▭ Underground Outline (proposed)
- / EL6288 Lease Boundary
- / Moolarben DA Boundary
- / Goulburn River National Park Boundary
- ● UCML Groundwater Bore
- / Ulan Open Cut Outline
- / Ulan Underground Outline

0 1000 2000 metres

NOTE
MGA Coordinates

Date:	25 August 2006	Scale:	1 : 40 000 at A3
Initials:	PJD	Job No:	05-0158
Drawing No:	05-0158-021-C	Rev:	C

Peter Dundon and Associates Pty Limited

Moolarben Coal Mines Pty Ltd

Moolarben Coal Project
Dewatering / Water Supply
Production Bores

Figure 21

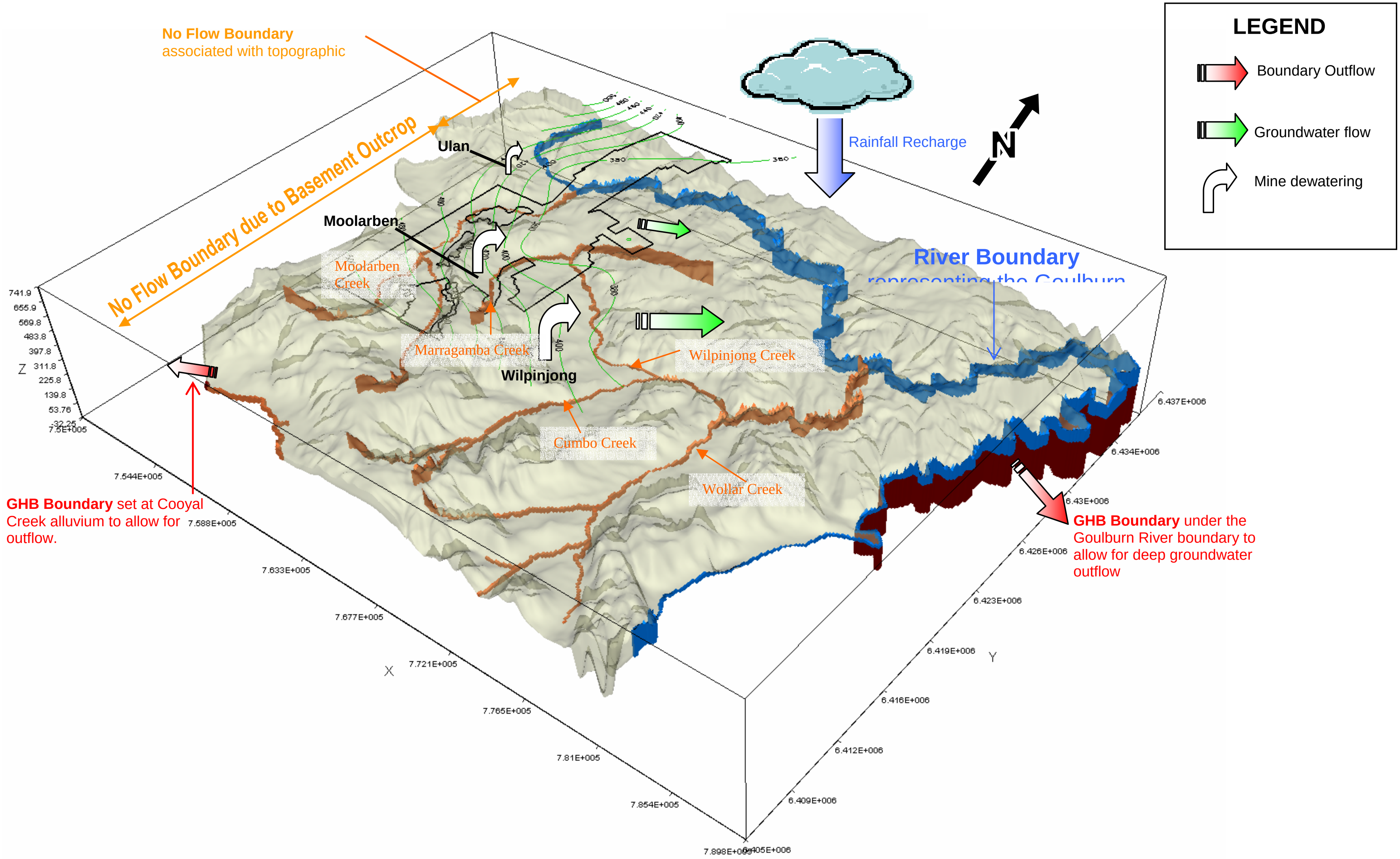
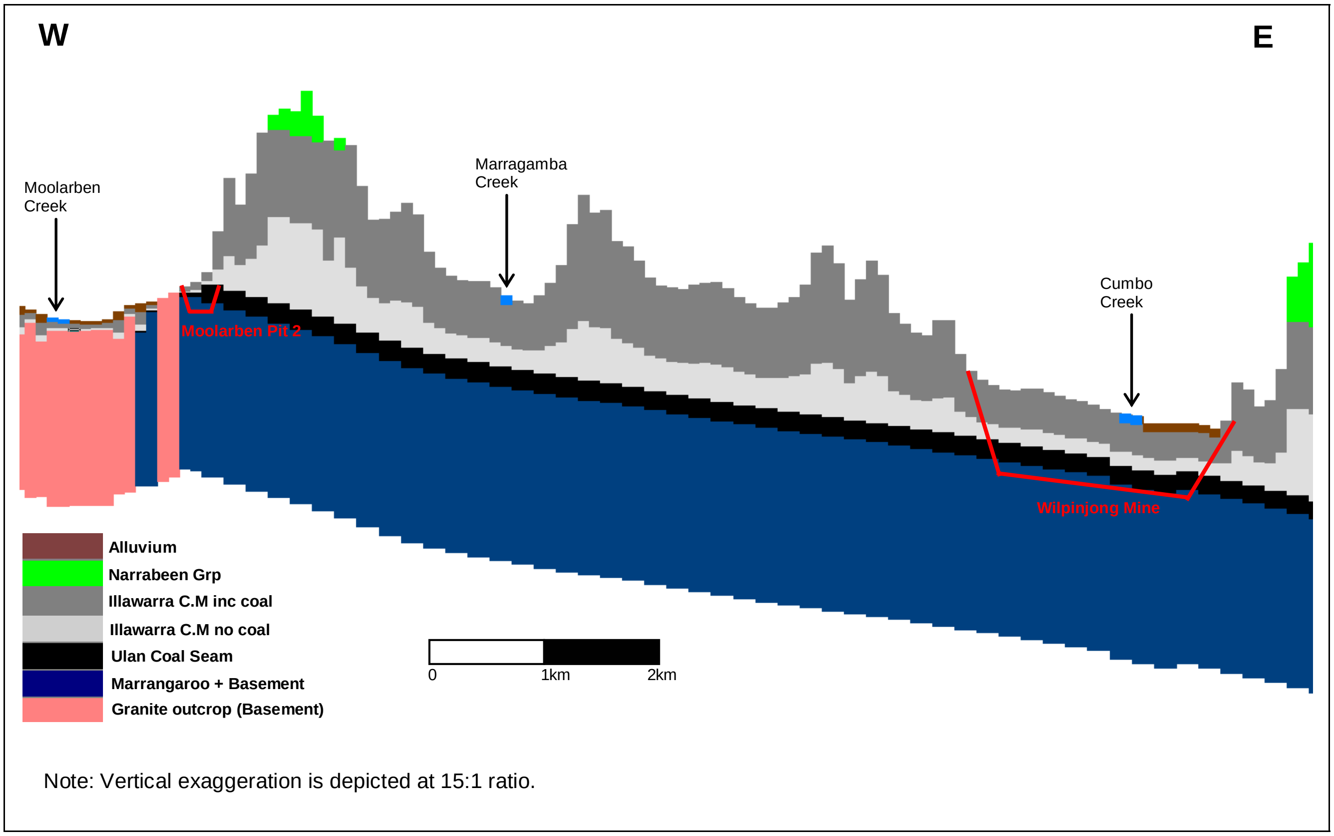


Figure 22: Groundwater Model Domain and Boundary Conditions



Note: Vertical exaggeration is depicted at 15:1 ratio.

Figure 23: Model Cross-Section Through Moolarben and Wilpinjong Mine Areas (Northing 642350)

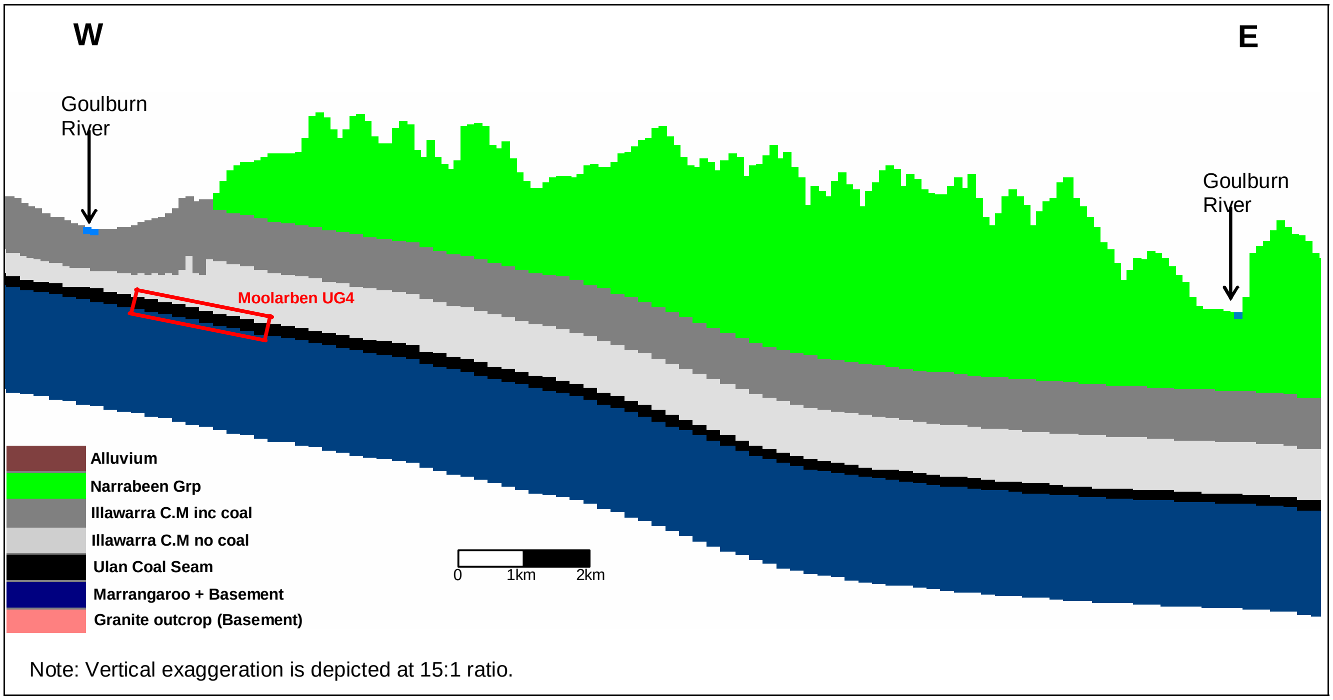
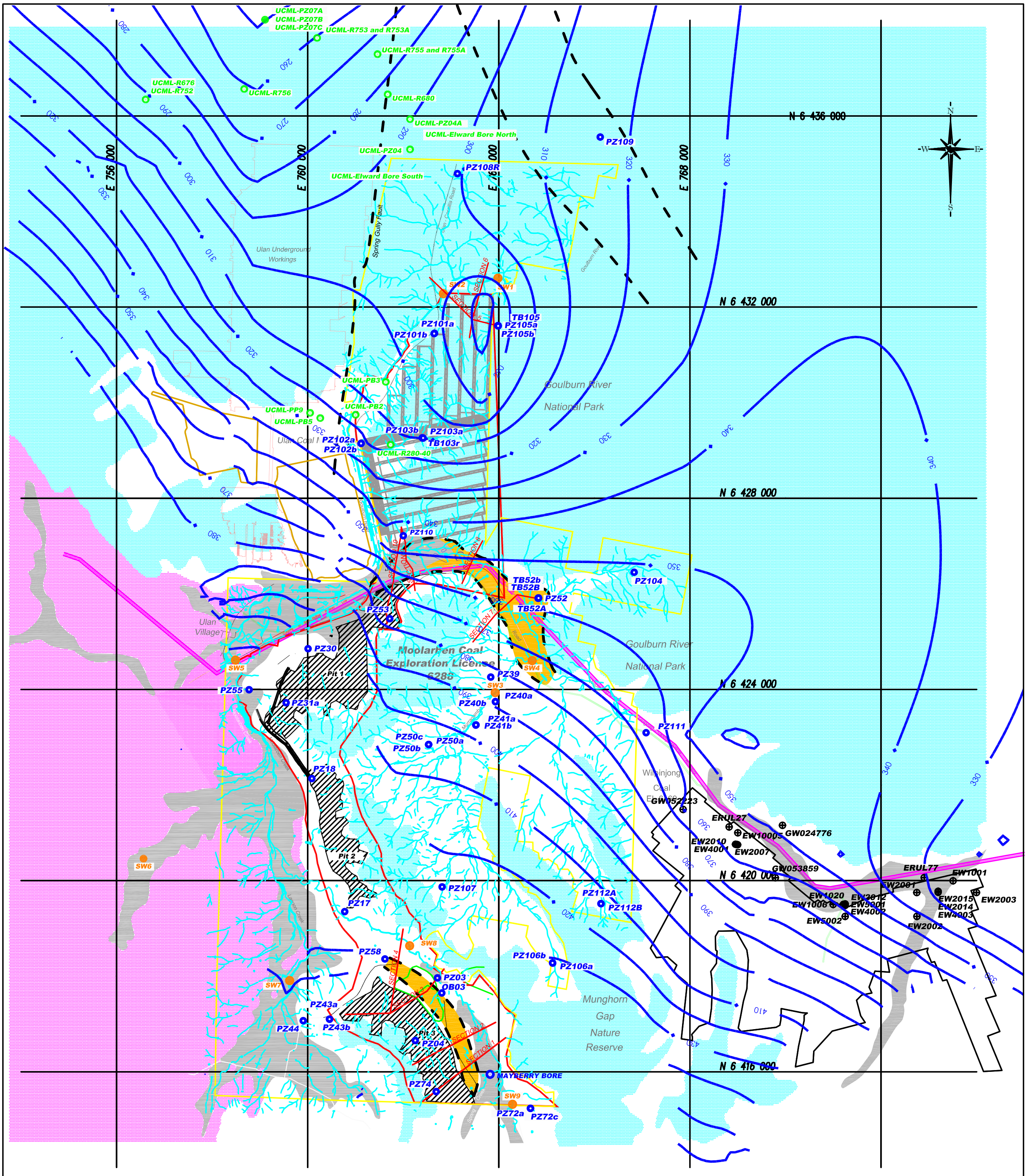


Figure 24: Model Cross-section through Moolarben Underground Mine Area (Northing 6428850)



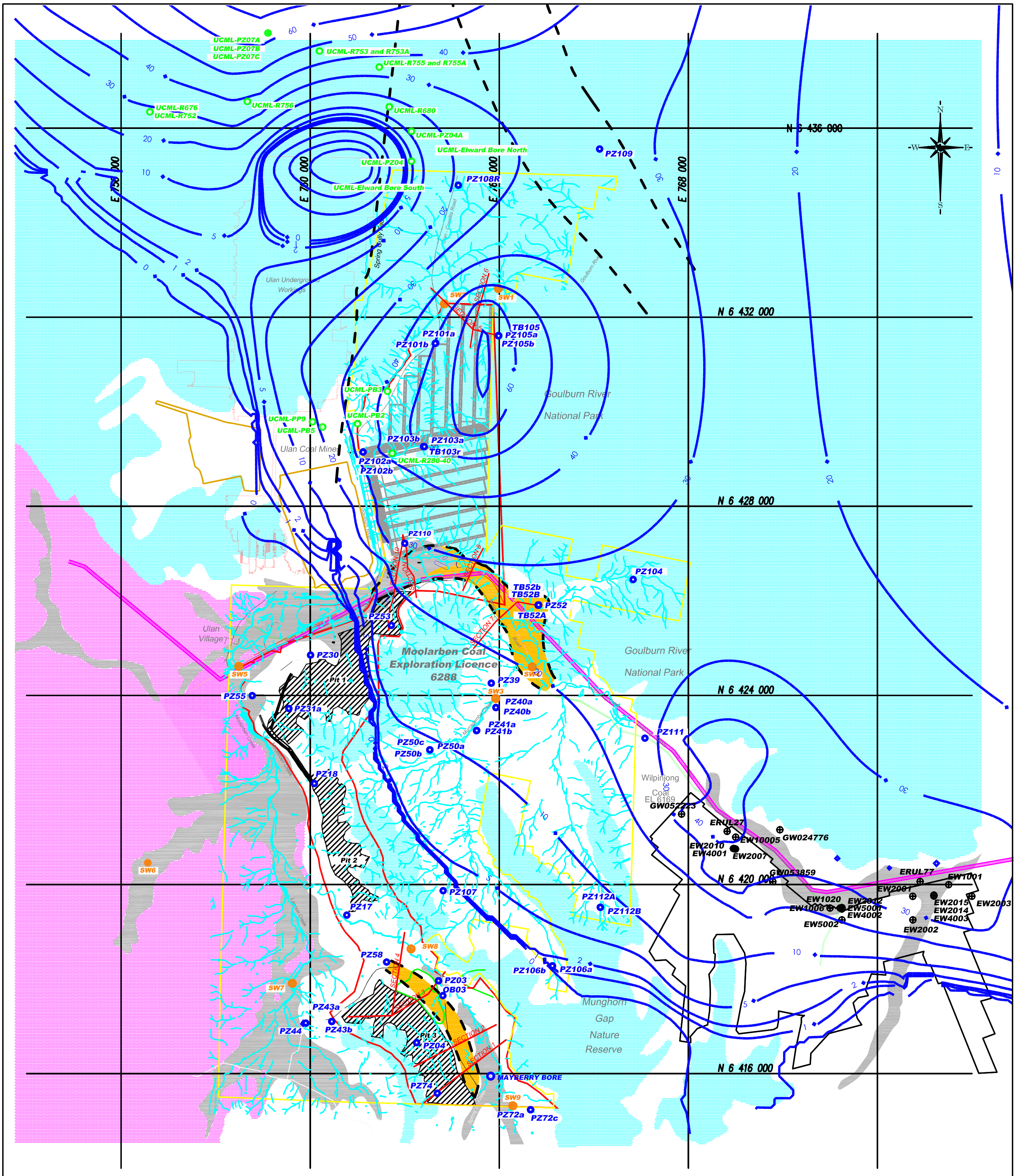
Legend

- ● Piezometer or Test Bore
- ● UCML Groundwater Bore
- ● Surface Water Monitoring Sites
- ⊕ Wilpinjong Bore
- Open Cut Outline (proposed)
- Underground Outline (proposed)
- EL6288 Lease Boundary
- Wilpinjong Open Cut (under construction)
- Ulan Open Cut Outline
- Ulan Underground Outline (2004 Status)
- Moolarben DA Boundary
- 310 Predicted Groundwater Contours(2022-2023)
- Fault Line
- ▨ Recent Alluvium
- ▨ Tertiary Paleochannel Alluvium
- ▨ Triassic Narabeen Group
- ☐ Permian Coal Measures
- ▨ Granite / Volcanics Basement

NOTE
MGA Coordinates

0 2000 4000 metres

Date: 9/09/06	Scale: 1: 80,000 as A3	**Moolarben Coal Mines Pty Ltd**	
Initials: PJD	Job No: 05-0158	**Moolarben Coal Project** **Predicted Water Levels - Ulan Seam at Completion of Mining (2022-23)**	
Drawing No: 05-0158-052-B	Rev: B		**Figure 25**
Peter Dundon and Associates Pty Limited			

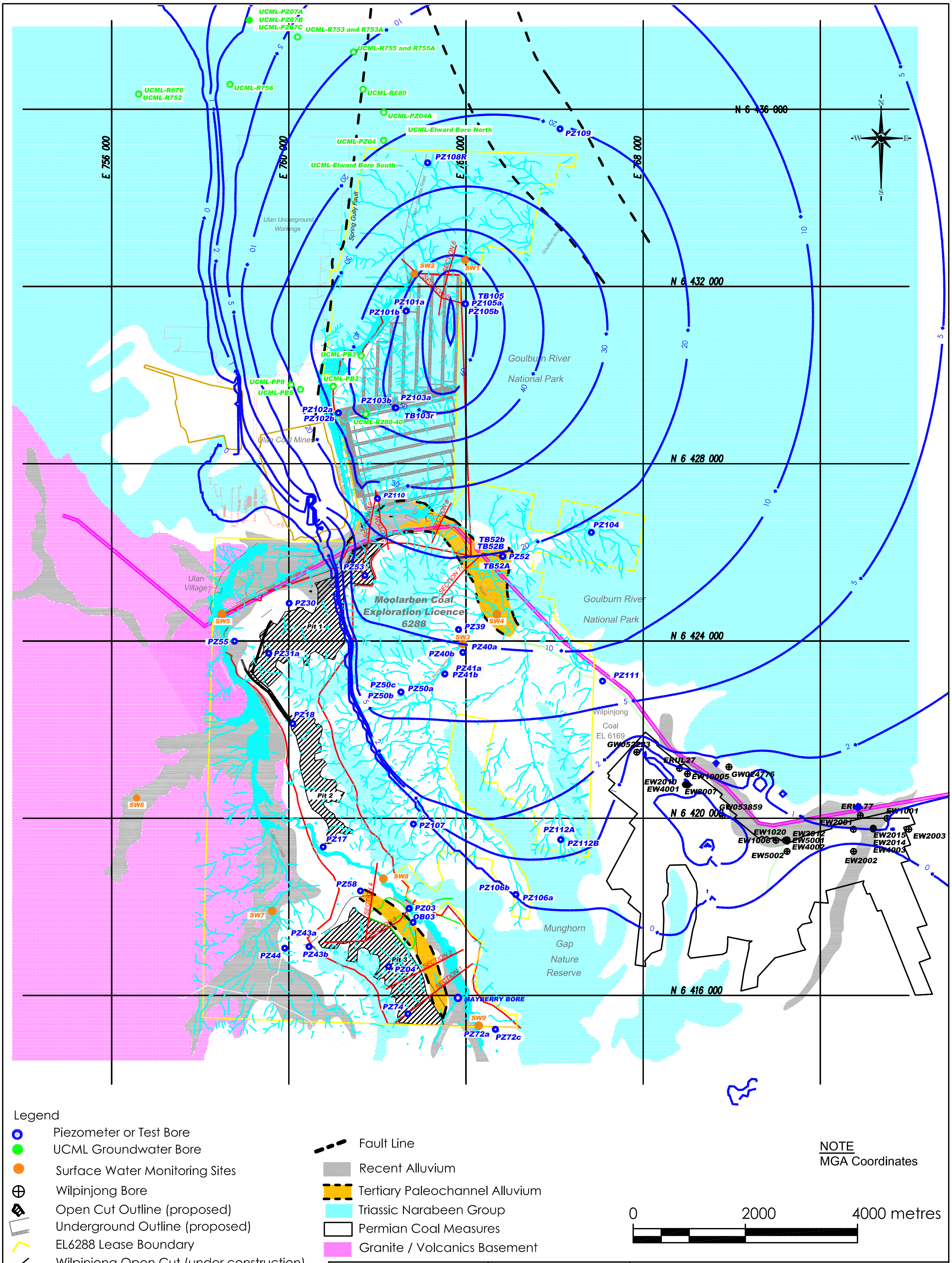


Legend

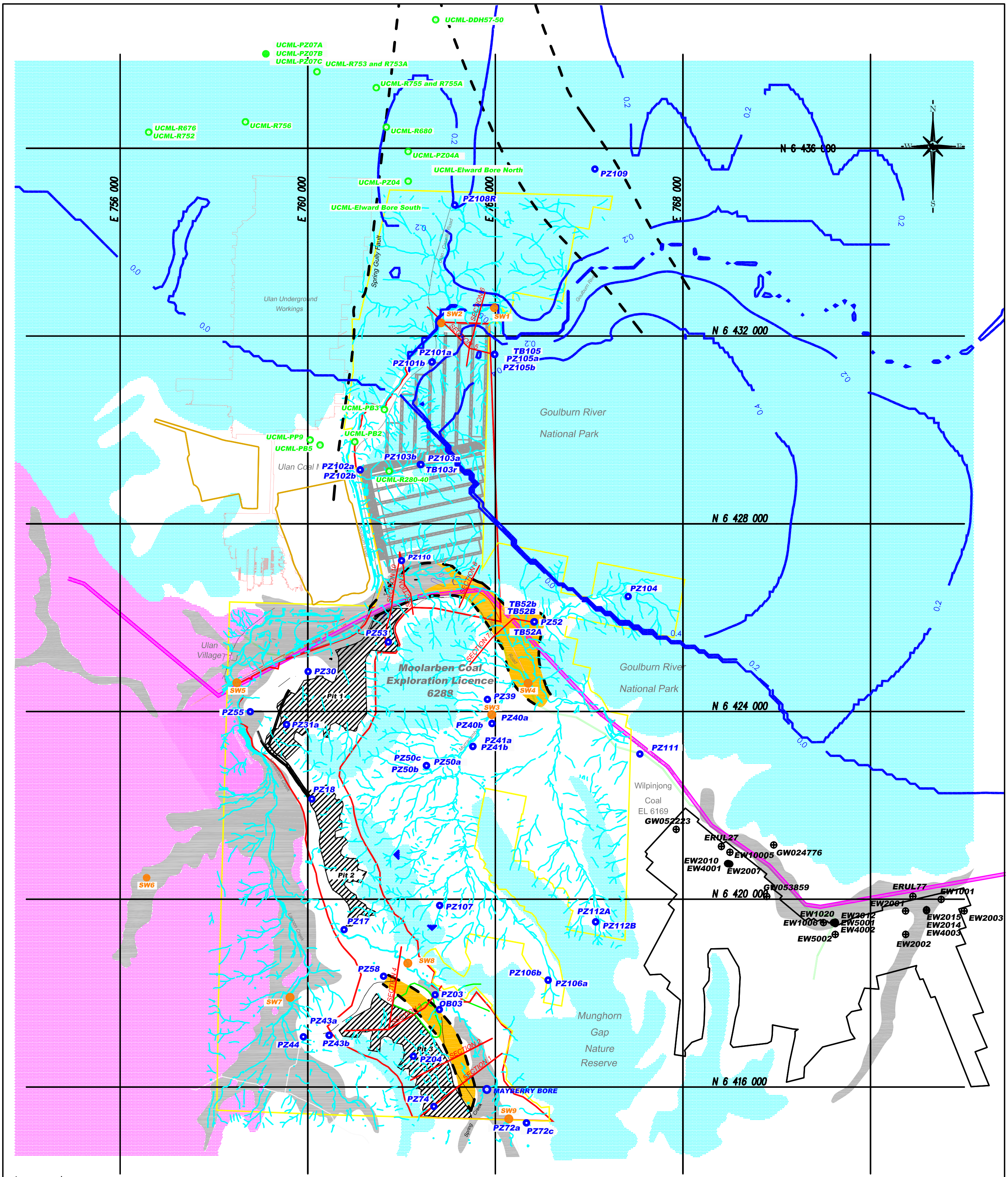
- ● Piezometer or Test Bore
- ● UCML Groundwater Bore
- ● Surface Water Monitoring Sites
- ⊕ Wilpinjong Bore
- Open Cut Outline (proposed)
- Underground Outline (proposed)
- EL6288 Lease Boundary
- Wilpinjong Open Cut (under construction)
- Ulan Open Cut Outline
- Ulan Underground Outline (2004 Status)
- Moolarben DA Boundary
- 310 Predicted Drawdown Contours(2022-2023)
- Fault Line
- Recent Alluvium
- Tertiary Paleochannel Alluvium
- Triassic Narabeen Group
- Permian Coal Measures
- Granite / Volcanics Basement

NOTE
MGA Coordinates

Date:	9/09/06	Scale:	1: 80,000 as A3	**Moolarben Coal Mines Pty Ltd**
Initials:	PJD	Job No:	05-0158	**Predicted Drawdowns - Ulan Seam at Completion of Mining (2022-23) Cumulative Impacts**
Drawing No:	05-0158-050-B	Rev:	B	
Peter Dundon and Associates Pty Limited				**Figure 26**



Date:	9/09/06	Scale:	1: 80,000 as A3	**Moolarben Coal Mines Pty Ltd**
Initials:	PJD	Job No:	05-0158	**Predicted Drawdowns - Ulan Seam at Completion of Mining (2022-23) Moolarben Project Only**
Drawing No:	05-0158-051-B	Rev:	B	
Peter Dundon and Associates Pty Limited				**Figure 27**



Legend

- ◉ Piezometer or Test Bore
- ● UCML Groundwater Bore
- ● Surface Water Monitoring Sites
- ⊕ Wilpinjong Bore
- Open Cut Outline (proposed)
- Underground Outline (proposed)
- EL6288 Lease Boundary
- Wilpinjong Open Cut (under construction)
- Ulan Open Cut Outline
- Ulan Underground Outline (2004 Status)
- Moolarben DA Boundary
- 310 Predicted Drawdown Contours(2022-2023)
- Fault Line
- Recent Alluvium
- Tertiary Paleochannel Alluvium
- Triassic Narabeen Group
- Permian Coal Measures
- Granite / Volcanics Basement

NOTE
MGA Coordinates

0 2000 4000 metres

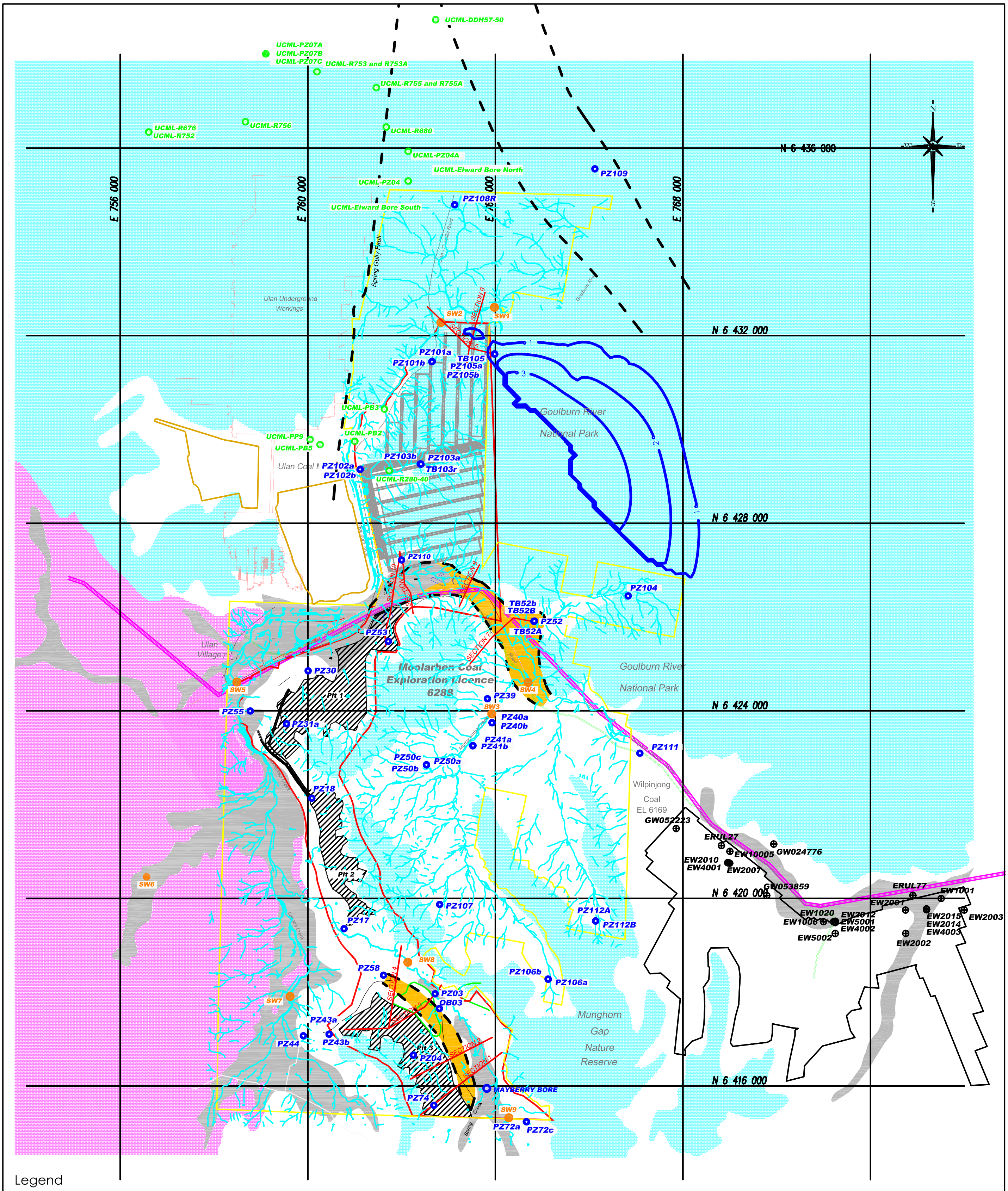
Date:	9/09/06	Scale:	1: 80,000 as A3
Initials:	PJD	Job No:	05-0158
Drawing No:	05-0158-044-B	Rev:	B

Peter Dundon and Associates Pty Limited

Moolarben Coal Mines Pty Ltd

Predicted Drawdowns - Triassic Narrabeen Gp at Completion of Mining (2022-23) Moolarben Project Only

Figure 28



Legend

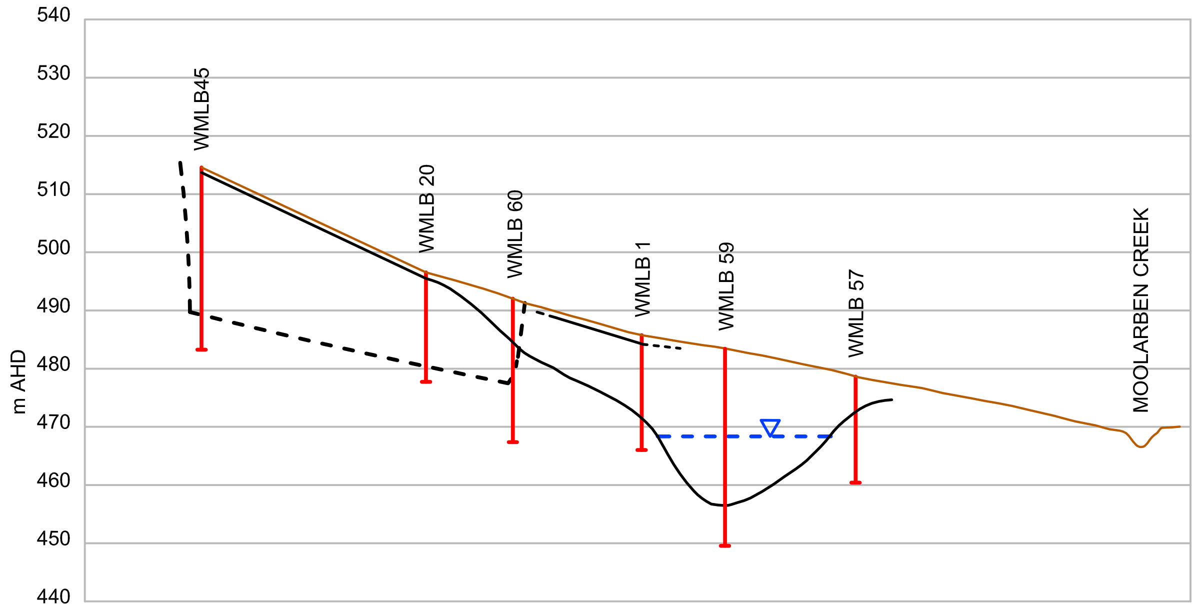
- ⊙ Piezometer or Test Bore
- ● UCML Groundwater Bore
- ● Surface Water Monitoring Sites
- ⊕ Wilpinjong Bore
- ▨ Open Cut Outline (proposed)
- ▭ Underground Outline (proposed)
- ╱ EL6288 Lease Boundary
- ╱ Wilpinjong Open Cut (under construction)
- ╱ Ulan Open Cut Outline
- ╱ Ulan Underground Outline (2004 Status)
- ╱ Moolarben DA Boundary
- 310 Predicted Residual Drawdown Contours (2067)
- ▬ ▬ Fault Line
- ■ Recent Alluvium
- ■ Tertiary Paleochannel Alluvium
- ■ Triassic Narabeen Group
- ☐ Permian Coal Measures
- ■ Granite / Volcanics Basement

NOTE
MGA Coordinates

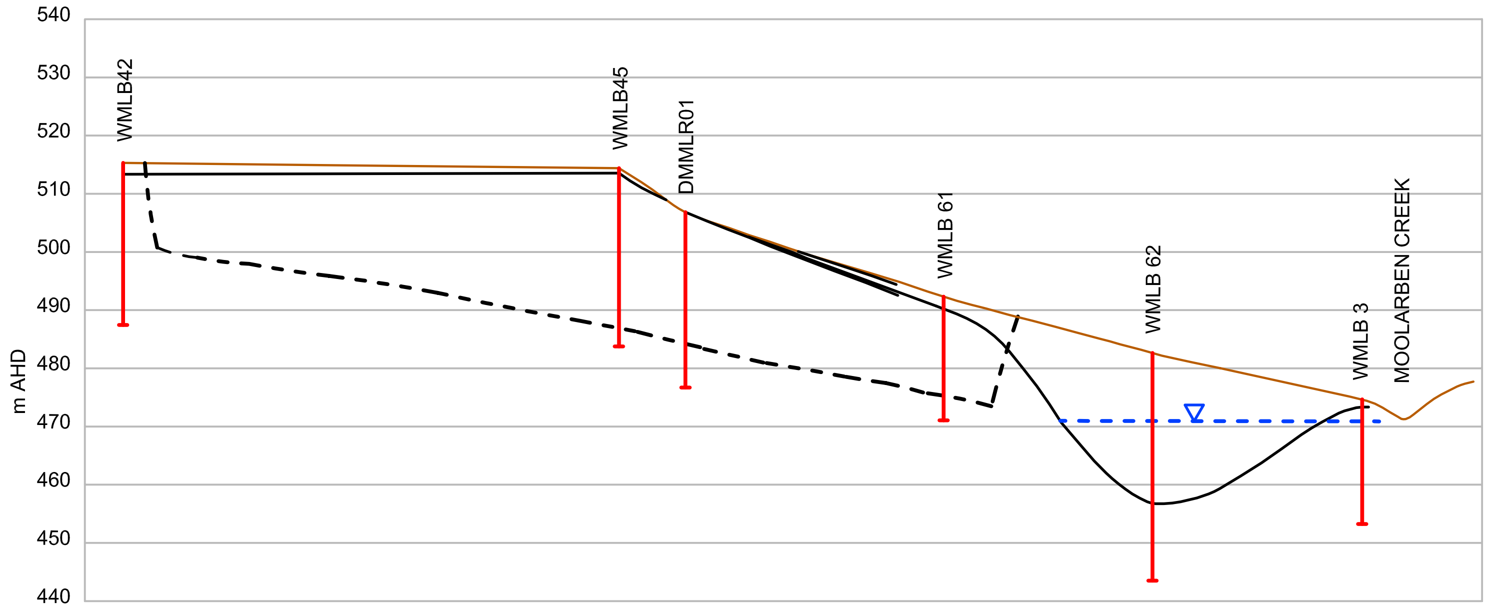
0 2000 4000 metres

Date: 9/09/06	Scale: 1: 80,000 as A3	**Moolarben Coal Mines Pty Ltd**	
Initials: PJD	Job No: 05-0158	**Predicted Residual Drawdowns 45 Years After Completion (2067) Triassic Narrabeen Group Cumulative Impacts**	
Drawing No: 05-0158-041-B	Rev: B		
Peter Dundon & Associates Pty Limited			**Figure 29**

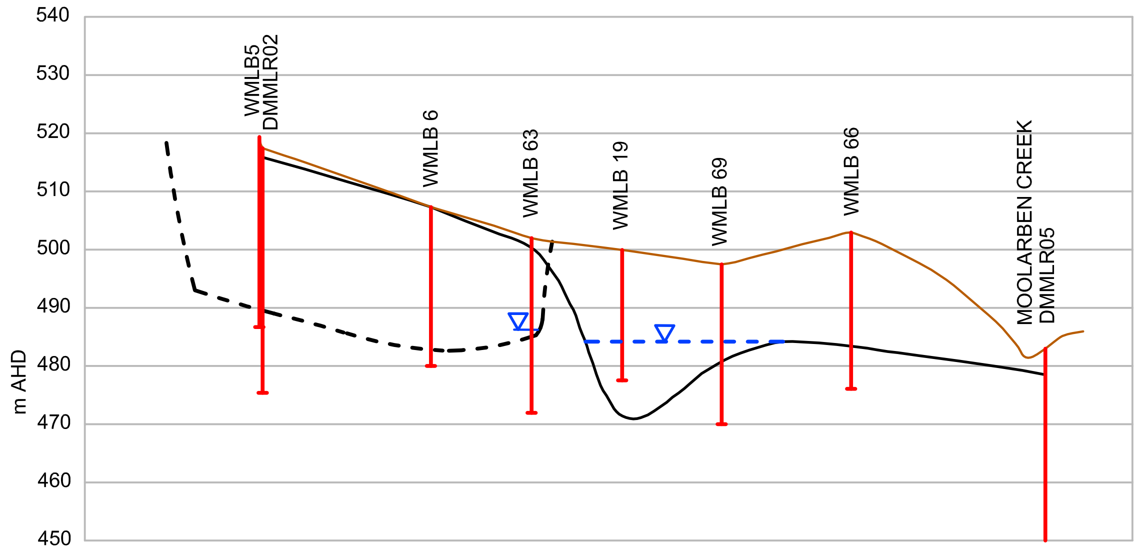
SECTION 4



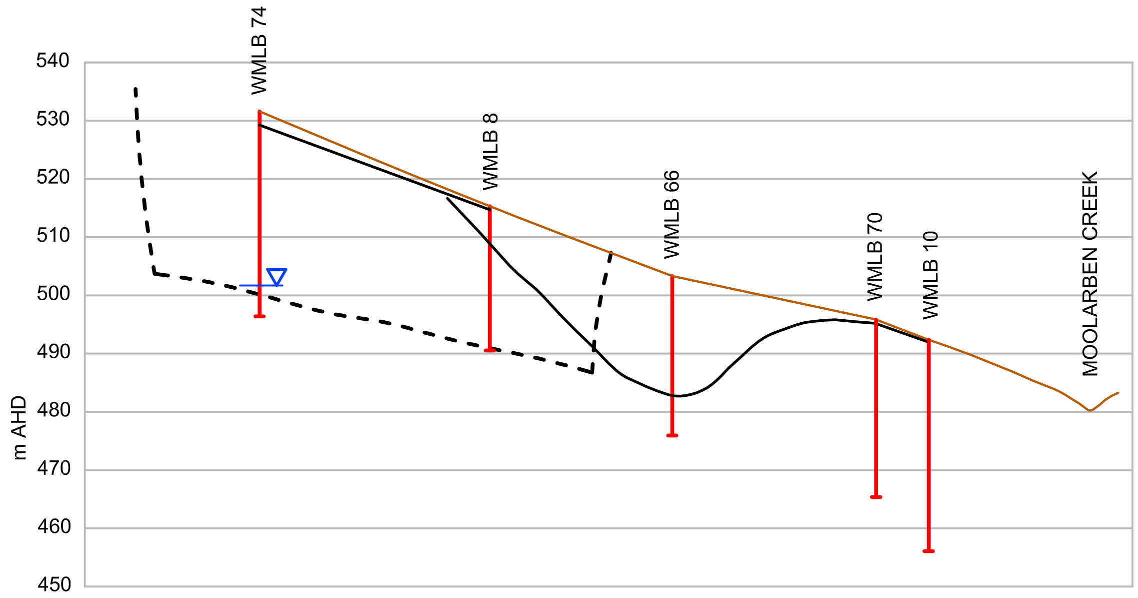
SECTION 3



SECTION 2

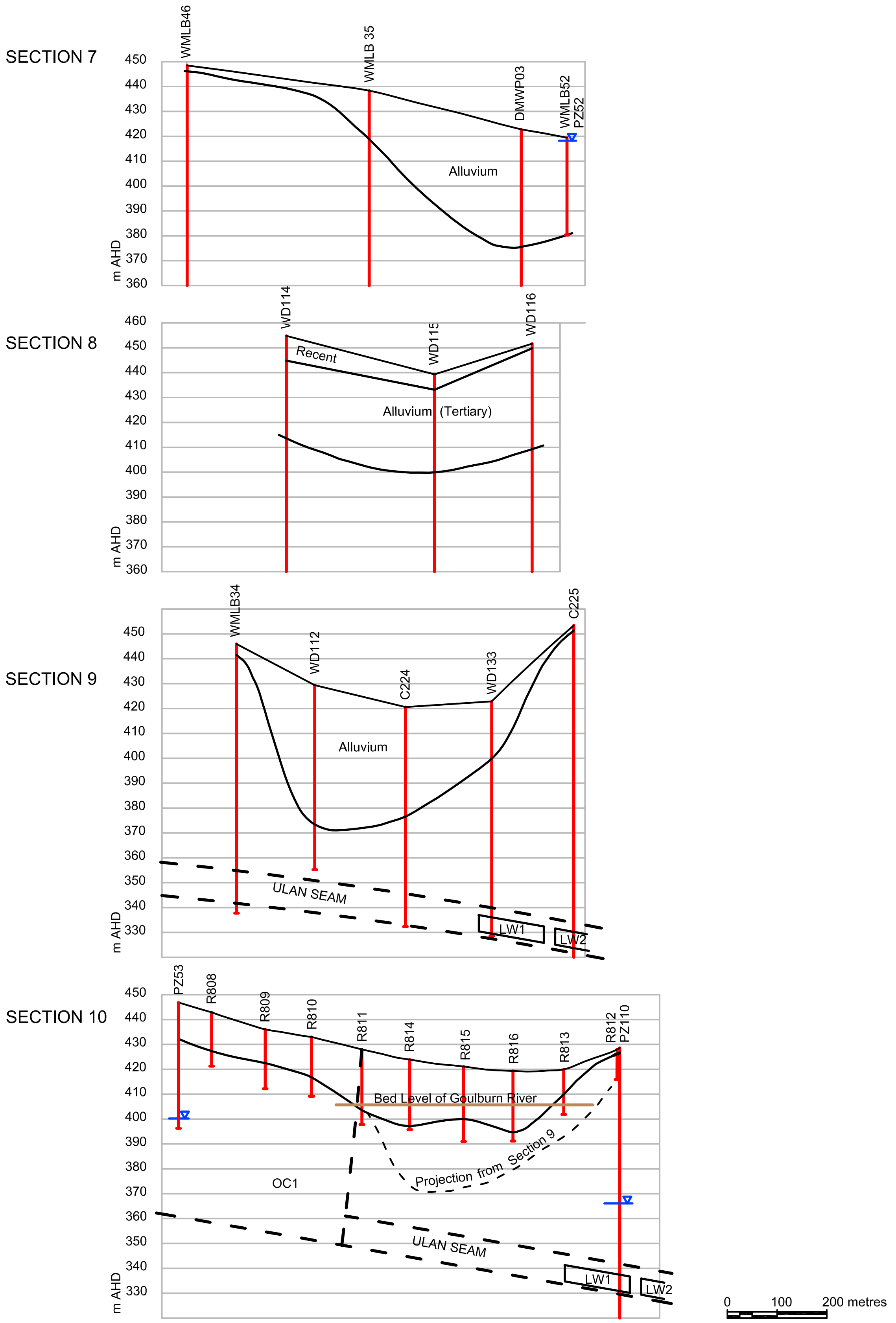


SECTION 1



0 100 200 metres

Date:	25 August 2006	Scale:	as indicated	**Moolarben Coal Mines Pty Ltd**
Initials:	PJD	Job No:	05-0158	**Moolarben Groundwater Investigation** **Moolarben Creek Alluvium** **Near Open Cut 3**
Drawing No:	05-0158-016-A	Rev:	A	
Peter Dundon and Associates Pty Limited				**Figure 30**



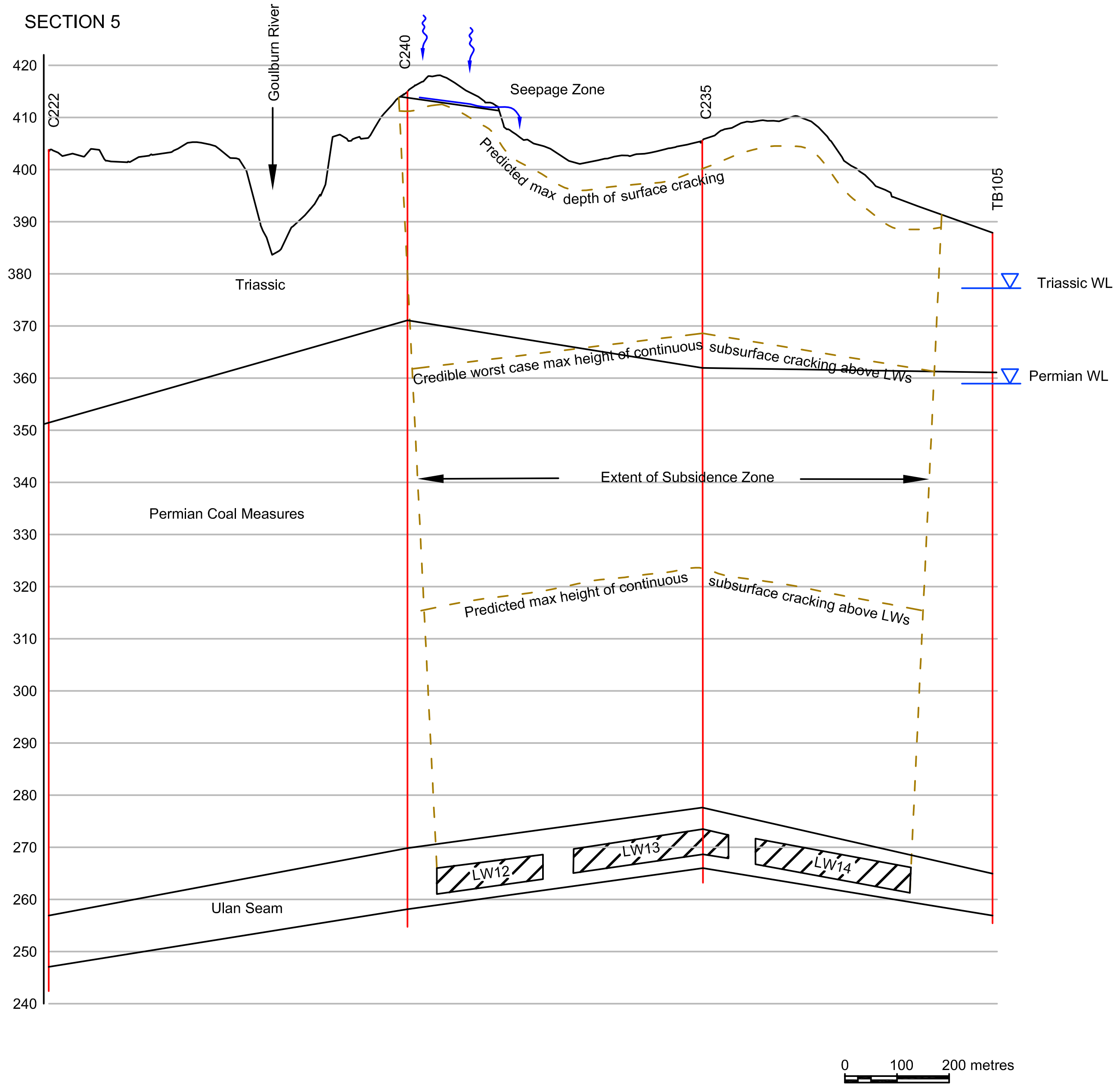
Date: 25 August 2006
Scale: as indicated
Initials: PJD
Job No: 05-0158
Drawing No: 05-0158-015-C
Rev: C

Peter Dundon and Associates Pty Limited

Moolarben Coal Mines Pty Ltd

Paleochannel Cross-Sections Between Underground 4 and Open Cut 1

Figure 31



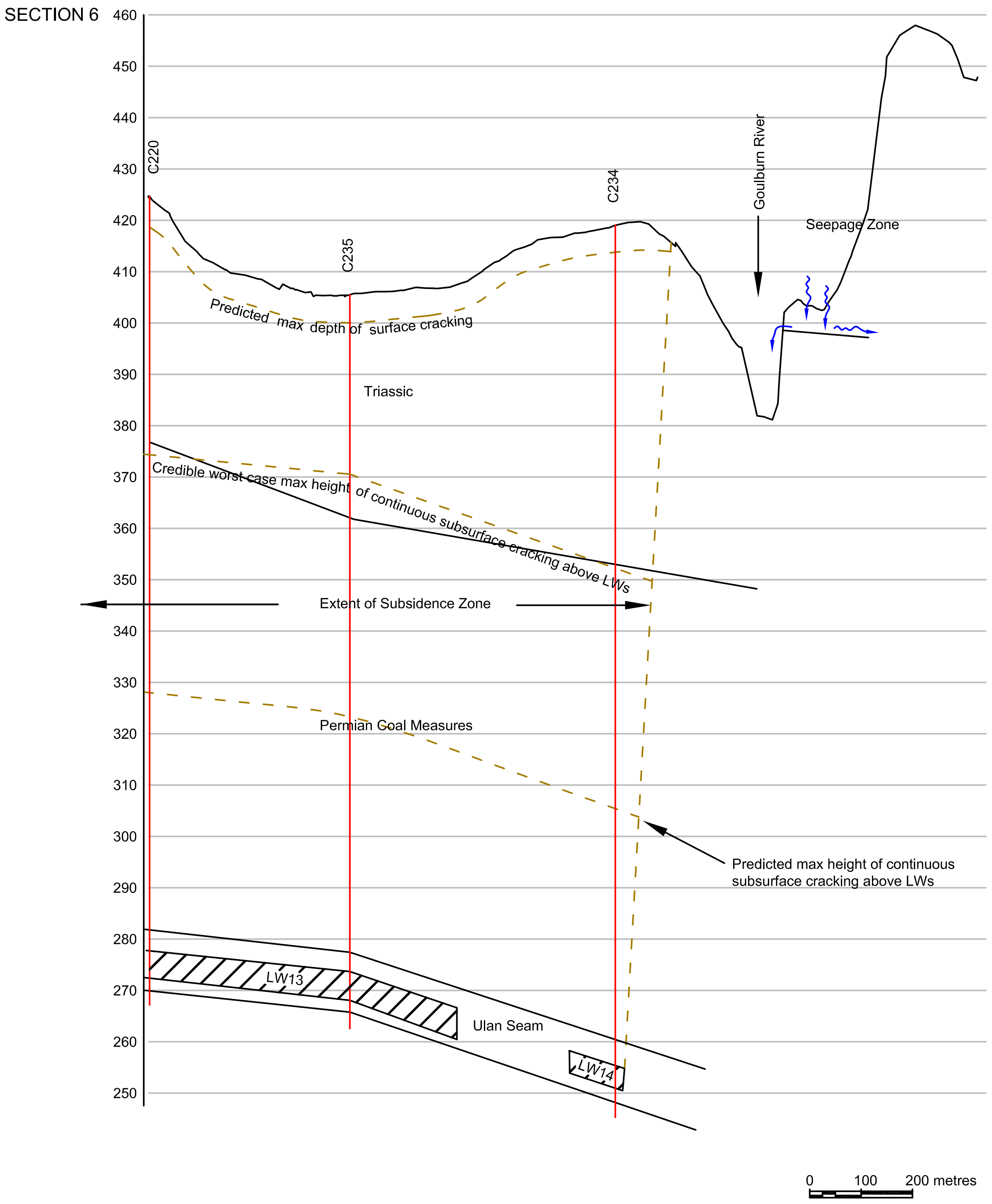
Date:	25 August 2006	Scale:	as indicated
Initials:	PJD	Job No:	05-0158
Drawing No:	05-0158-019-C	Rev:	C

Peter Dundon and Associates Pty Limited

Moolarben Coal Mines Pty Ltd

Moolarben Coal Project
Goulburn River Cross-Section 5

Figure 32



Date:	25 August 2006	Scale:	as indicated	**Moolarben Coal Mines Pty Ltd**
Initials:	PJD	Job No:	05-0158	**Moolarben Coal Project** **Goulburn River Cross-Section 6**
Drawing No:	05-0158-018-C	Rev:	C	
Peter Dundon and Associates Pty Limited				**Figure 33**

APPENDIX A

BORE / SPRING CENSUS

(Peter Dundon and Associates Pty Ltd, 2006)

Appendix A: Summary of Census of Existing Groundwater Occurrence and Use

ID	DP	Lot	Owner	Nature of Groundwater Site	Hydrogeological Unit	Water Level (mAHD)	EC (µS/cm)	pH
SP01	755442	29	J Asztalos	Dam / soak	Quaternary alluvium	477	375	6.28
SP58	1023568	1	B W & H J Best	Soak	Permian coal measures	498	1470	4.49
SP59	1023568	2	B W & H J Best	Seep	Permian coal measures	517	270	5.95
SP50	755454	36	S M Birt & K M Hayes	Soak	Permian coal measures	476	400	5.78
SP51	755454	8	S M Birt & K M Hayes	Dam / soak	Permian coal measures	477	370	6.29
SP52	755454	53	S M Birt & K M Hayes	Dam / soak	Permian coal measures	477	120	6.55
SP53	755454	4	S M Birt & K M Hayes	Dam / soak	Permian coal measures	496	250	6.7
SP54	755454	34	S M Birt & K M Hayes	Dam / soak	Permian coal measures	480	280	5.54
SP55	755454	34	S M Birt & K M Hayes	Dam / soak	Permian coal measures	474	170	6.12
SP56	755454	34	S M Birt & K M Hayes	Dam / soak	Permian coal measures	475	270	6.33
SP57	755454	2	S M Birt & K M Hayes	Dam / soak	Permian coal measures	489	340	6.49
SP61	755454	7	M Carlisle	Dam / soak	Permian coal measures	492	140	6.55
SP65	755442	83	D Chinner	Bore (Chinner House)	Permian coal measures	***487***	4120	6.4
SP66	755442	83	D Chinner	Dam / soak	Quaternary alluvium	491	420	7.3
SP67	755442	83	D Chinner	Dam / soak	Quaternary alluvium	491	560	7.2
SP68	755442	39	D Chinner	Dam / soak	Quaternary alluvium	490	880	8.34
SP46	755442	122	M Cox	Dam / soak	Quaternary alluvium	494	1780	9.1
SP30	582575	191	R Cox	Dam	Granite	544	590	5.9
SP31	582575	191	R Cox	Dam	Granite	536	610	7.66
SP32	755442	111	R Cox	Soak	Quaternary alluvium	464	2230	7.11
SP33	755442	9	R Cox	Bore (Ram Shed)	Granite	496	530	6.5
SP34	755442	83	R Cox	Dam / soak	Quaternary alluvium	500	4400	7.75
SP35	755442	82	R Cox	Dam / soak	Quaternary alluvium	506	7670	7.65
SP36	755442	131	R Cox	Dam / soak	Permian coal measures	519	2850	8.48
SP37	755442	131	R Cox	Dam / soak	Permian coal measures	520	6750	8.84
SP38	755442	72	R Cox	Dam / soak	Permian coal measures	542	710	8.01
SP39-40	755442	135	R Cox	Bore (Hay Shed)	Permian coal measures	***526***	-	-
SP41	755442	131	R Cox	Dam / soak	Permian coal measures	522	6750	7.18
SP42-43	755442	23	R Cox	Bore (Clarke's Gully)	Permian coal measures	***516***	1990	7.36
SP44	755442	124	R Cox	Dam / soak	Permian coal measures	532	460	7.49
SP45	755442	128	R Cox	Dam / soak	Quaternary alluvium	494	1880	7
SP47-48	755442	151	R Cox	Bore (Cox House)	Granite	***500***	840	6.3
SP62	755454	1	C & H Davies	Dam / soak	Permian coal measures	464	240	6.42
SP63	755454	1	C & H Davies	Dam / soak	Permian coal measures	462	340	6.5
SP64	755454	1	C & H Davies	Soak / well	Permian coal measures	465	270	4.85
SP83	704077	84	E H Elward	Bore (Elward South)	Permian coal measures	**Dry**	-	-

Appendix A: Summary of Census of Existing Groundwater Occurrence and Use

ID	DP	Lot	Owner	Nature of Groundwater Site	Hydrogeological Unit	Water Level (mAHD)	EC (µS/cm)	pH
SP84	704077	84	E H Elward	Bore (Elward North)	Triassic Narrabeen Group	403	320	6.4
SP79	755442	154	C Mayberry	Spring / seep	Triassic Narrabeen Group	615	290	6.2
SP07	755442	51	E Mayberry	Bore (Croydon House)	Permian coal measures	***495***	1590	7.9
SP100			E Mayberry	Dam	Permian coal measures ?	?	1590	7.9
SP12-13	755442	132	E Mayberry	Bore (Fernmount House)	Permian coal measures	***508***	1840	6.37
SP14	755442	132	E Mayberry	Dam	Permian coal measures	509	-	-
SP15	755442	132	E Mayberry	Dam	Permian coal measures	512	-	-
SP16	755442	132	E Mayberry	Dam	Permian coal measures	510	950	6.92
SP17	755442	126	E Mayberry	Dam	Permian coal measures	542	1970	7.8
SP98			E Mayberry	Spring	Triassic Narrabeen Group	?	85	4.7
SP99			E Mayberry	Dam	Permian coal measures ?	?	1090	9.2
SP08	755442	205	K & R Mayberry	Dam / soak	Permian coal measures	492	2260	8.35
SP09	755442	205	K & R Mayberry	Soak	Permian coal measures	**Dry**	-	-
SP10	755442	63	K & R Mayberry	Soak	Quaternary alluvium	474	7660	6.62
SP11	755442	107	K & R Mayberry	Soak	Quaternary alluvium	477	5490	7.53
SP49	755439	1	J Mullins & C Imrie	Bore (Mullins House)	Triassic Narrabeen Group	***398***	730	6
SP81	720321	50	J Mullins & C Imrie	Spring / seep (near "The Drip")	Triassic Narrabeen Group	383	520	6.55
SP93	755439	23	J Mullins & C Imrie	Spring	Triassic Narrabeen Group	386	460	4.96
SP95	755439	26	J Mullins & C Imrie	Spring / seep	Triassic Narrabeen Group	391	-	-
SP96	755439	26	J Mullins & C Imrie	Goulburn River	Triassic Narrabeen Group	371	780	6.65
SP02	755442	47	D & Y Rayner	Soak	Quaternary alluvium	471	5040	7
SP03	755442	84	D & Y Rayner	Soak	Quaternary alluvium	465	4490	7.5
SP04	755442	89	D & Y Rayner	Dam	Permian coal measures	522	265	7.1
SP05	755442	238	D & Y Rayner	Dam	Quaternary alluvium	476	295	6.83
SP06	755442	139	D & Y Rayner	Dam	Marrangaroo Conglomerate	512	195	6.8
SP69	878678	5	T R & N C Simpson	Dam	Permian coal measures	439	220	7.35
SP70	878678	5	T R & N C Simpson	Well	Permian coal measures	**Dry**	-	-
SP71	878678	5	T R & N C Simpson	Dam	Permian coal measures	438	190	7.27
SP72	878678	5	T R & N C Simpson	Dam	Triassic Narrabeen Group	492	290	6.96
SP73	878678	5	T R & N C Simpson	Spring / seep	Permian coal measures	432	160	8.01
SP85	755454	87	Splitters Hollow Pty Ltd	Dam / soak	Tertiary alluvium ?	419	730	5.76
SP86	755454	20	Splitters Hollow Pty Ltd	Dam / soak	Triassic Narrabeen Group	431	80	9.29
SP18	755442	60	M & P Swords	Dam	Marrangaroo Conglomerate	451	1080	6.43
SP19	755442	37	M & P Swords	Seep	Quaternary alluvium	443	2900	3.41
SP20	755442	119	M & P Swords	Spring / well	Permian coal measures	488	220	5.3
SP21	755442	44	M & P Swords	Soak	Marrangaroo Conglomerate	452	3370	6.87
SP22	755442	228	M & P Swords	Seep	Permian coal measures	492	3790	5.39
SP23	755442	96	M & P Swords	Seep	Permian coal measures	495	3100	5.28

Appendix A: Summary of Census of Existing Groundwater Occurrence and Use

ID	DP	Lot	Owner	Nature of Groundwater Site	Hydrogeological Unit	Water Level (mAHD)	EC (µS/cm)	pH
SP24	755442	42	M & P Swords	Soak	Quaternary alluvium	453	3410	7.31
SP25	755442	237	M & P Swords	Dam / soak	Quaternary alluvium	453	460	7.49
SP26	755442	237	M & P Swords	Dam / soak	Quaternary alluvium	451	300	6.97
SP27	755442	237	M & P Swords	Seep / well	Quaternary alluvium	452	740	5.55
SP28	755442	6	M & P Swords	Well	Quaternary alluvium	447	2420	7.3
SP29	803204	1	M & P Swords	Soak	Quaternary alluvium	442	2450	6.91
SP87	878678	1	M & J Transport	Dam	Surface water	440	270	8.43
SP88	878678	1	M & J Transport	Dam	Surface water	440	220	7.45
SP89	878678	1	M & J Transport	Dam	Surface water	437	240	9.27
SP90	878678	1	M & J Transport	Dam / soak	Permian coal measures	429	160	8.53
SP91	878678	1	M & J Transport	Dam	Surface water	437	380	8.18
SP92	878678	1	M & J Transport	Dam / soak	Permian coal measures	443	150	7.32
SP77	755442	242	Ulan Coal Mines Ltd	Soak	Permian coal measures	451	600	4.87
SP78	755442	212	Ulan Coal Mines Ltd	Dam / soak	Granite	452	160	6.76
SP74	755454	32	B J & M R Wallis	Dam	Basalt	487	160	6.57
SP75	755454	32	B J & M R Wallis	Dam	Basalt	485	200	6.64
SP76	755454	32	B J & M R Wallis	Dam	Basalt	494	190	6.91
SP80	755439	30	James Westwood	Dry Spring	Triassic Narrabeen Group	**Dry**	-	-
SP82	755439	30	James Westwood	Dam / soak	Permian coal measures	396	110	5.83
SP94	720321	52	Goulburn River National Park	Goulburn River	Triassic Narrabeen Group	372	800	6.4
SP97	-	-	Goulburn River National Park	Spring / seep	Triassic Narrabeen Group	389	190	6.72
SP60	-	-	Munghorn Gap Nature Reserve	Well	Permian coal measures	560	210	5.31

APPENDIX B

PIEZOMETER AND TEST BORE CONSTRUCTION LOGS

Peter Dundon and Assoc.
Logging Sheet

BORE: PZ03

Project No: **05-0158**

Client: **Moolarben Coal Company**
Location: **Moolarben Coal Project**
Drilling Contractor: **Mitchell Drilling**

Elevation (GL): **474.592 mAHD**
Elevation (TOC): **474.918 mAHD**
Stickup: **0.326 m**
Hole Depth: **21.35 m**
Date Started: **23 November 2004**
Date Completed: **24 November 2004**
Supervised By: **M Johnstone**

Description	Depth (metres)	Well Construction Details:

Loam

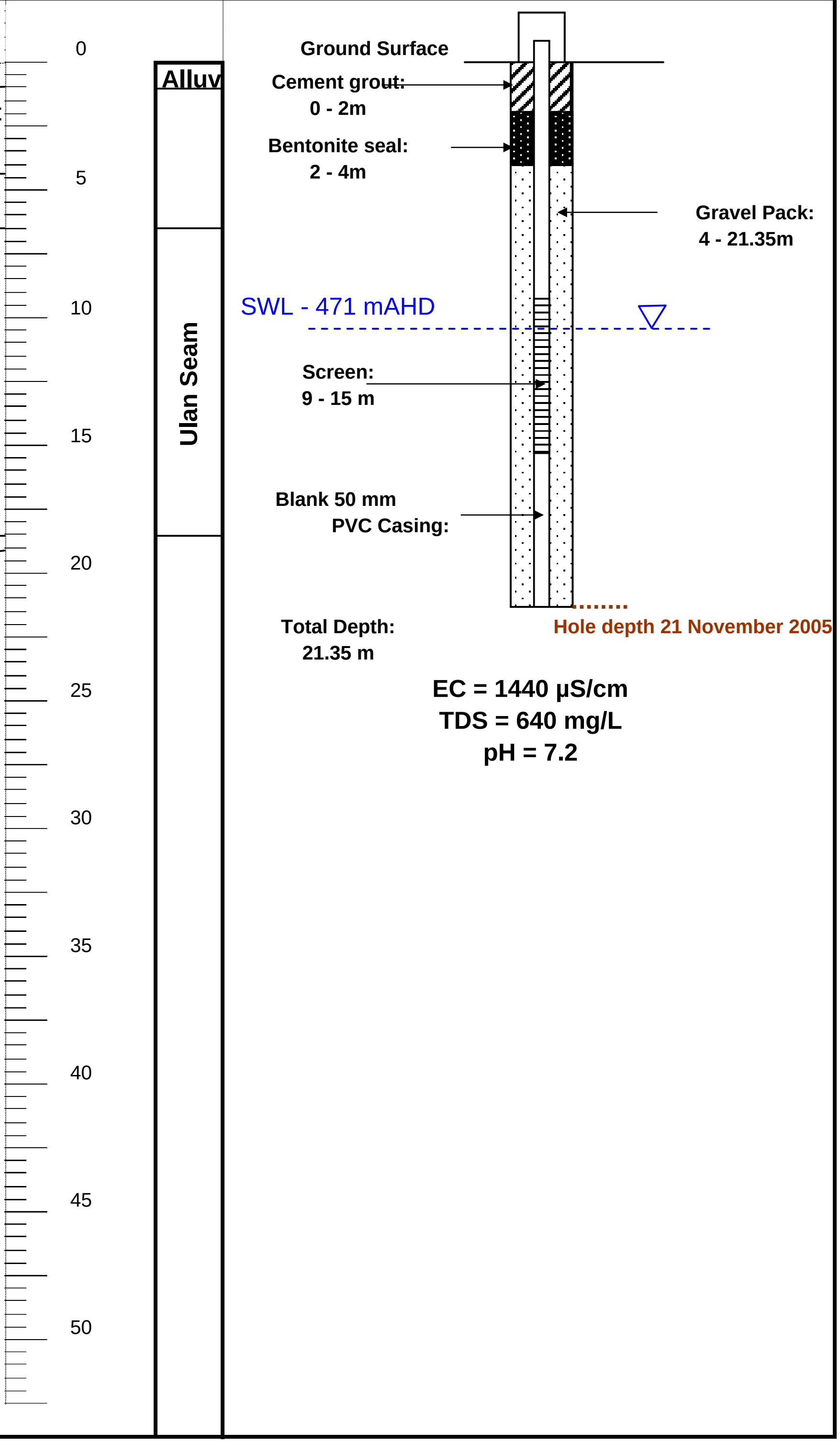
Siltestone laminated with shale, weathered in part

Shale, silty

Coal, minor claystone and mudstone

Siltstone, few coaly traces

Sandstone, f-m, minor silty phases



EC = 1440 µS/cm
TDS = 640 mg/L
pH = 7.2

Figure B1: Bore Log - PZ03

Peter Dundon and Assoc.

Logging Sheet

BORE: PZ04

			Project No:	**05-0158**
Client: **Moolarben Coal Company**	Elevation (GL):	**517.087 mAHD**		
	Elevation (TOC)	**517.398 mAHD**		
Location: **Moolarben Coal Project**	Stickup:	**0.311 m**		
	Hole Depth:	**32.35 m**		
Drilling Contractor: **Mitchell Drilling**	Date Started:	**25 November 2004**	Supervised By: **M Johnstone / M Waide**	
	Date Completed	**26 November 2004**		

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

Loam - brown, sandy

Sandstone, m

Mudstone - laminated with siltstone and sandstone

Altered intrusion

Sandstone - fg, few silty and carbonaceous traces

Claystone / Tuff

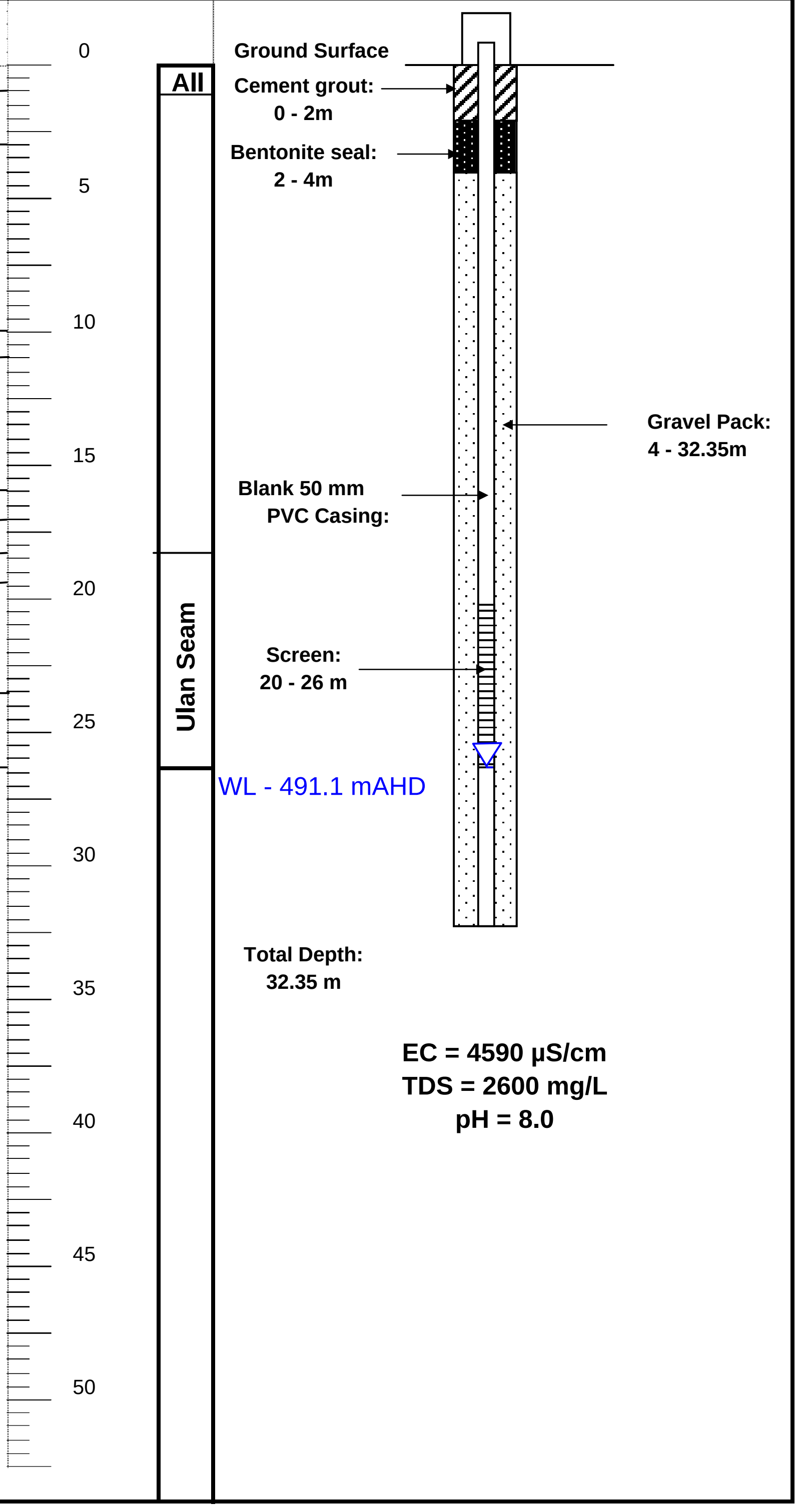
Silt / Shale

Coal

Sandstone - f-m, few silty and carbonaceous laminae

Coal

Sandstone - m-f, few carbonaceous laminae



EC = 4590 µS/cm
TDS = 2600 mg/L
pH = 8.0

Figure B2: Bore Log - PZ04

Peter Dundon and Assoc.

Logging Sheet

BORE: PZ17

		Project No:	**05-0158**
Client: **Moolarben Coal Company**	Elevation (GL): Elevation (TOC	**472.154 mAHD** **... mAHD**	
Location: **Moolarben Coal Project**	Stickup: Hole Depth:	**?** **15.0 m**	
Drilling Contractor:: **Mitchell Drilling**	Date Started: Date Completed	**17 February 2005** **17 February 2005**	Supervised By: **M Johnstone**

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

Loam - sandy clay, reddish brown

Siltstone - grey

Sandstone - coarse-grained, conglomeratic in part
(Blackmans Flat Formation)

Sandstone - fg, laminated with siltstone

Sandstone - fg, tending to massive

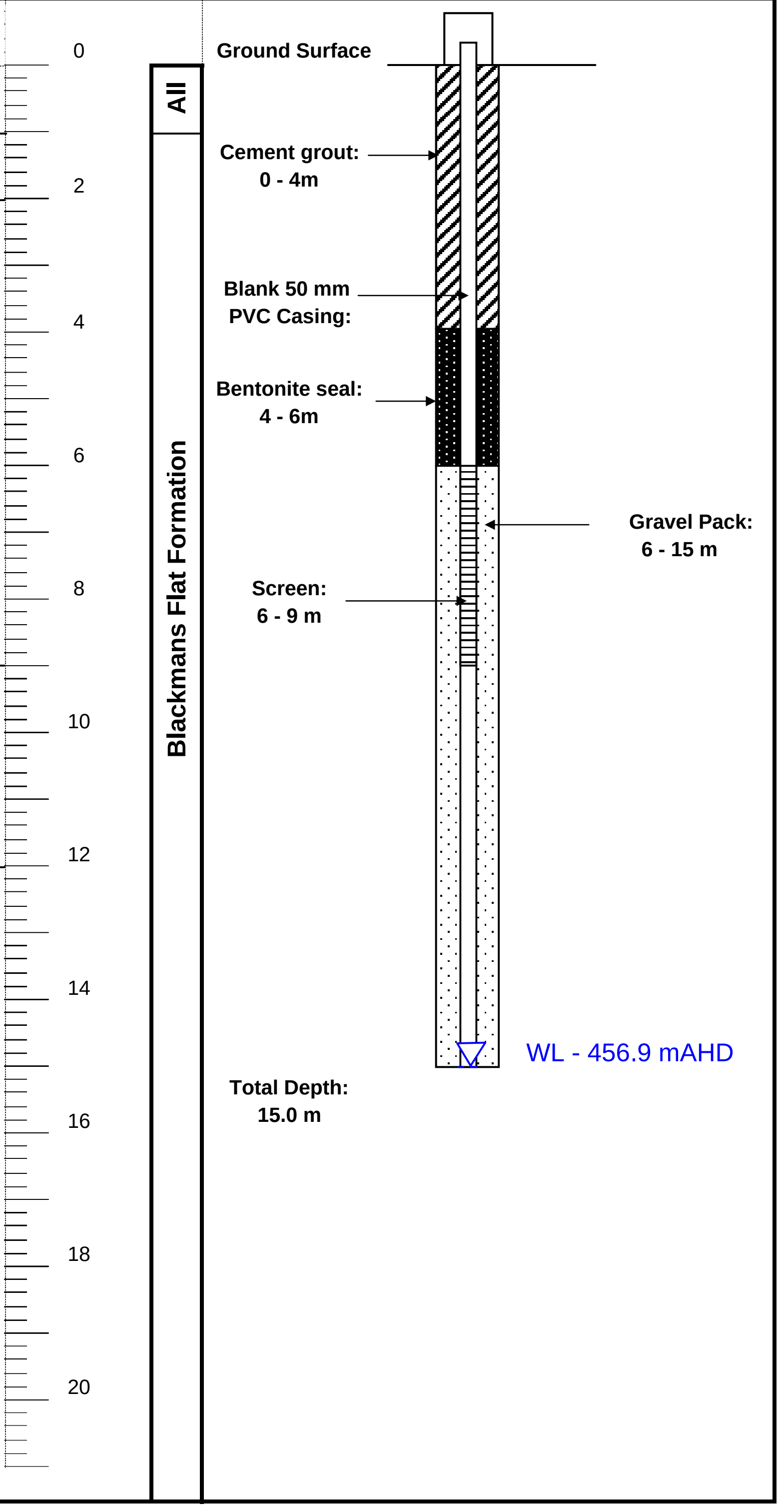


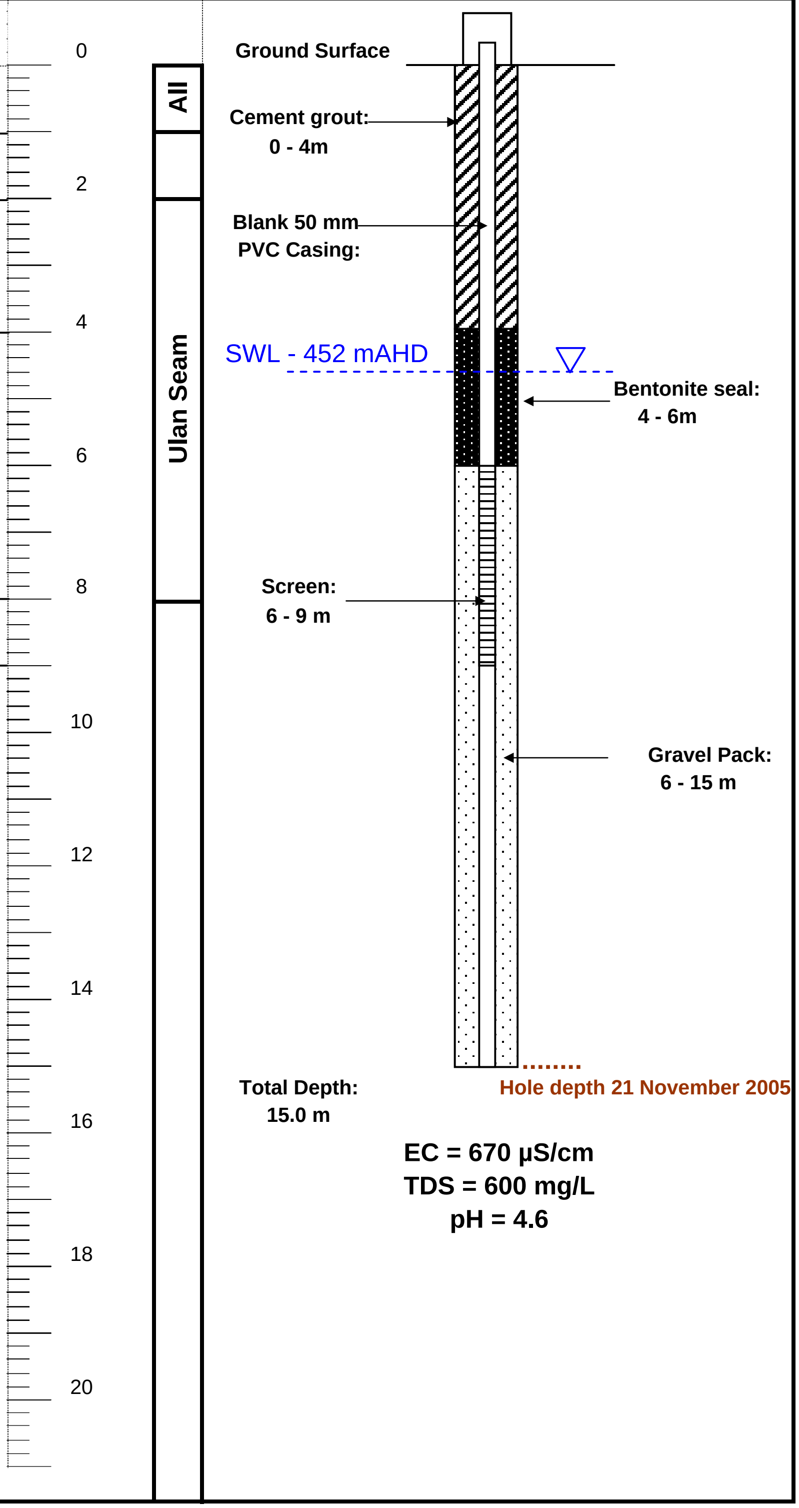
Figure B3: Bore Log - PZ17

Peter Dundon and Assoc.
Logging Sheet

BORE: PZ18

		Project No:	05-0158	
Client: **Moolarben Coal Company**	Elevation (GL):	456.843 mAHD		
	Elevation (TOC	457.143 mAHD		
Location: **Moolarben Coal Project**	Stickup:	0.30 m		
	Hole Depth:	15.0 m		
Drilling Contractor:: **Mitchell Drilling**	Date Started:	18 February 2005	Supervised By: **M Johnstone**	
	Date Complete(	18 February 2005		

Description	Depth (metres)	Well Construction Details:
Loam - brown, sandy		
Mudstone, clay		
Clay - perished coal		
Coal		
Sandstone - fg, few silty phases and laminae		
Sandstone - m-c		



EC = 670 µS/cm
TDS = 600 mg/L
pH = 4.6

Figure B4: Bore Log - PZ18

Peter Dundon and Assoc.

Logging Sheet

BORE: PZ30

		Project No:	**05-0158**
Client: **Moolarben Coal Company**	Elevation (GL): Elevation (TOC	**432.928 mAHD** **433.168 mAHD**	
Location: **Moolarben Coal Project**	Stickup: Hole Depth:	**0.24 m** **30.0 m**	
Drilling Contractor: **Mitchell Drilling**	Date Started: Date Complete(	**1 June 2005** **1 June 2005**	Supervised By: **A Price**

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

Sandy Clay

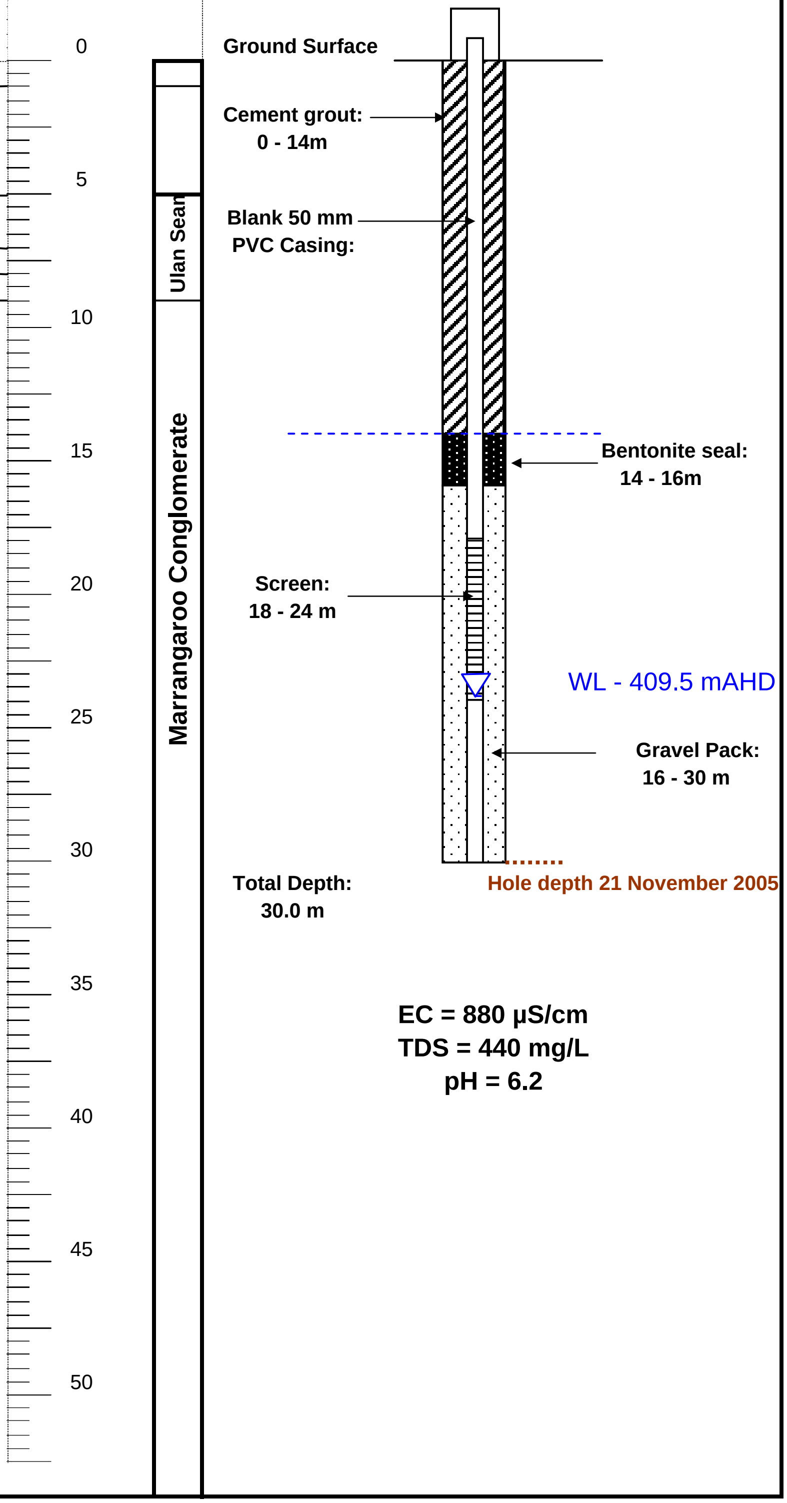
Pebble Conglomerate

Coal - extremely weathered

Sandstone - fg, weathered

Coal - extremely weathered

Pebble Conglomerate



EC = 880 μS/cm
TDS = 440 mg/L
pH = 6.2

Figure B5: Bore Log - PZ30

Peter Dundon and Assoc.
Logging Sheet

BORE: PZ31A

		Project No:		**05-0158**
Client: **Moolarben Coal Company**	Elevation (GL):	**456.794 mAHD**		
	Elevation (TOC	**456.794 mAHD**		
Location: **Moolarben Coal Project**	Stickup:	**0.0 m**		
	Hole Depth:	**30.0 m**		
Drilling Contractor: **Mitchell Drilling**	Date Started:	**2 June 2005**	Supervised By:	
	Date Completec	**2 June 2005**	**A Price**	

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

Pebble conglomerate, with coarse-gr sandstone

Coal - oxidised smut with weathered tuff

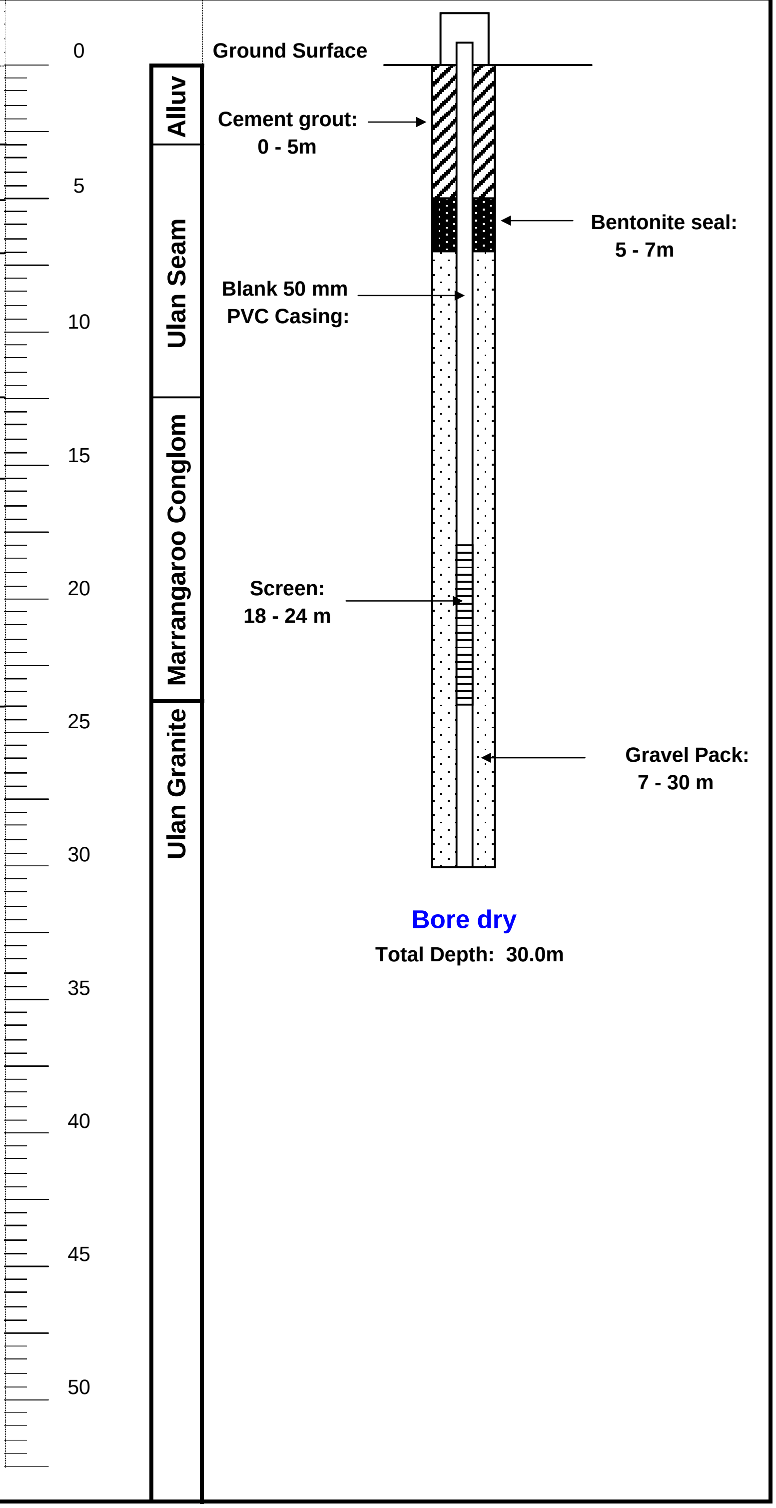
Coal - weathered, few bands of tuffaceous claystone

Coal - moderaately fresh

Sandstone - carbonaceous in part

Sandstone - coarse-gr, with granule conglomerate

Granite - chloritic, greenish in part



Bore dry

Total Depth: 30.0m

Figure B6: Bore Log - PZ31A

Peter Dundon and Assoc.

Logging Sheet

BORE: PZ39

Project No: **05-0158**

Client: **Moolarben Coal Company**

Location: **Moolarben Coal Project**

Drilling Contractor: **Mitchell Drilling**

Elevation (GL): **428.101 mAHD**

Elevation (TOC **428.385 mAHD**

Stickup: **0.284 m**

Hole Depth: **90.35 m**

Date Started: **1 July 2005**

Date Complete **9 July 2005**

Supervised By: **A Price**

Description

Clay / Sandy Clay - red-orange / orange

Sandy Clay / Clayey Sand - orange-white

Gravel - (50%); Sand - yellow-pink, f-vc (50%)

Clay - white-yellow

Sand - red-orange, f-vc (orange clay 16-17m)

Coal, minor carbonaceous mudstone

Conglomerate / Sandstone / Carbonaceous mudstone

Sand - grey, f-c

Clay - light grey white

Coal

Sandstone - grey to black, vf-f; Siltstone - grey to black

Carbonaceous mudstone - black

Coal, minor tuff

Sandstone - dark-light grey, vf

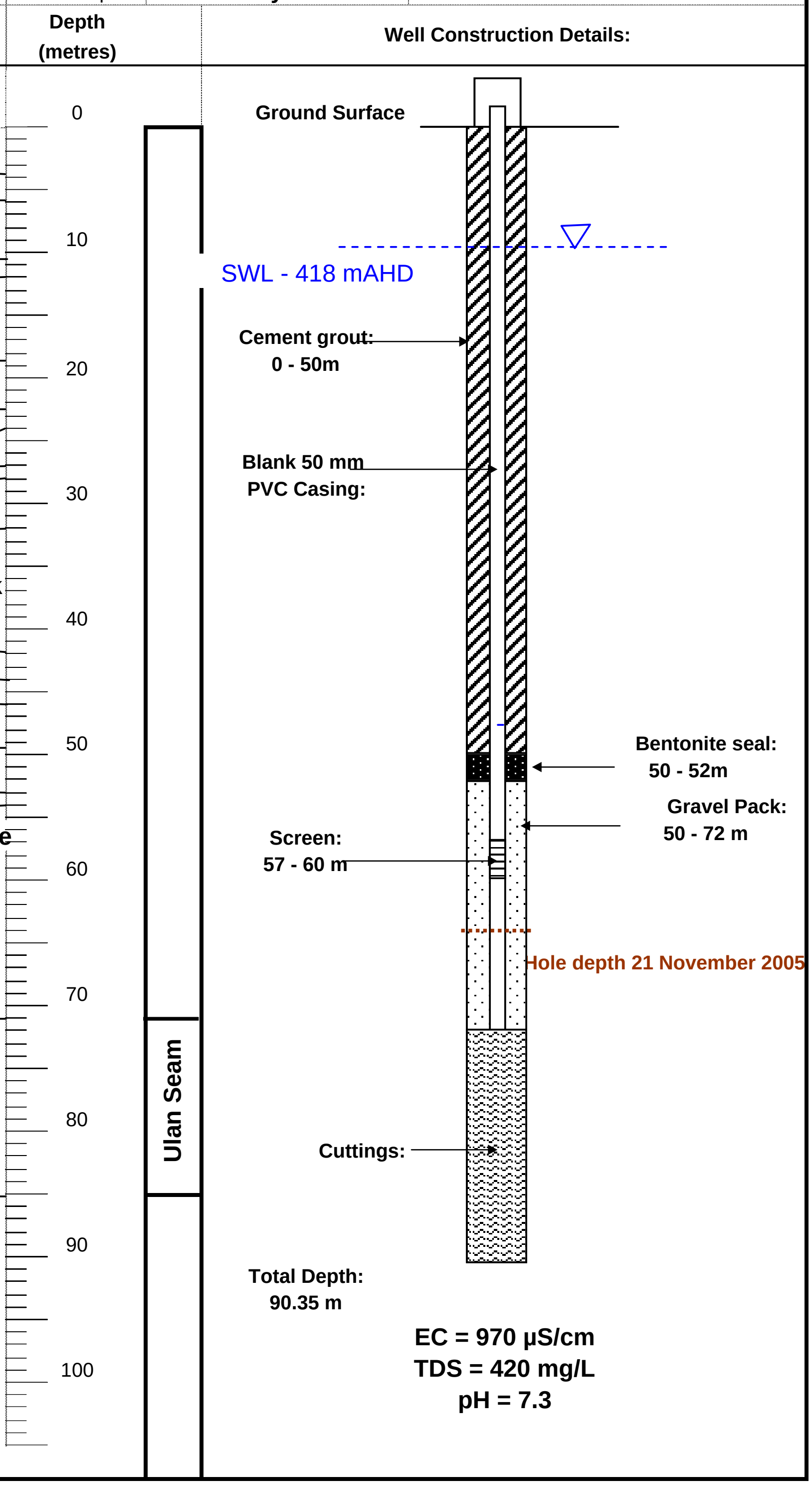
Alt Carb mudstone - black / Sandstone - light grey, vf

Coal

Siltstone / Sandstone / Mudstone / Tuff / Carb Mudstone (minor coal bands)

Coal (minor tuff, sandstone)

Sandstone - grey / light grey, f-m-vc (minor siltstone, conglomerate, mudstone)



EC = 970 µS/cm

TDS = 420 mg/L

pH = 7.3

Figure B7: Bore Log - PZ39

Peter Dundon and Assoc.

Logging Sheet

BORES: PZ40A and PZ40B

Project No: **05-0158**

Client:	Bore:	Elevation (GL):	Elevation (TOC):	Stickup:	Drilling Contractor:	Date Started:	Date Finished:
Moolarben Coal Company	**PZ40A**	**428.270 mAHD**	**428.44 mAHD**	**0.17 m**	**Mitchell Drilling**	**21-Jul-05**	**21-Jul-05**
Location:	**PZ40B**	**428.404 mAHD**	**428.63 mAHD**	**0.23 m**	**Mitchell Drilling**	**21-Jul-05**	**22-Jul-05**
Moolarben Coal Company							
			Hole depths: **As shown**			Supervised By: **A Price**	

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

Sand / Soil

Sandy Clay - orange-white, vf-f

Clay - pink-orange

Sandy Clay - orange, vf-f; Clay - orange-white

Coal - brown-black, extremely weathered

Sandstone - light grey, vf-f, minor siltstone

Coal

Sandstone - grey, vf-f

Siltstone - dark grey to grey-brown, carbonaceous (carbonaceous mudstone 27-28m)

Sandstone - grey-brown, vf

Carbonaceous mudstone - brown to grey, minor siltstone, coal

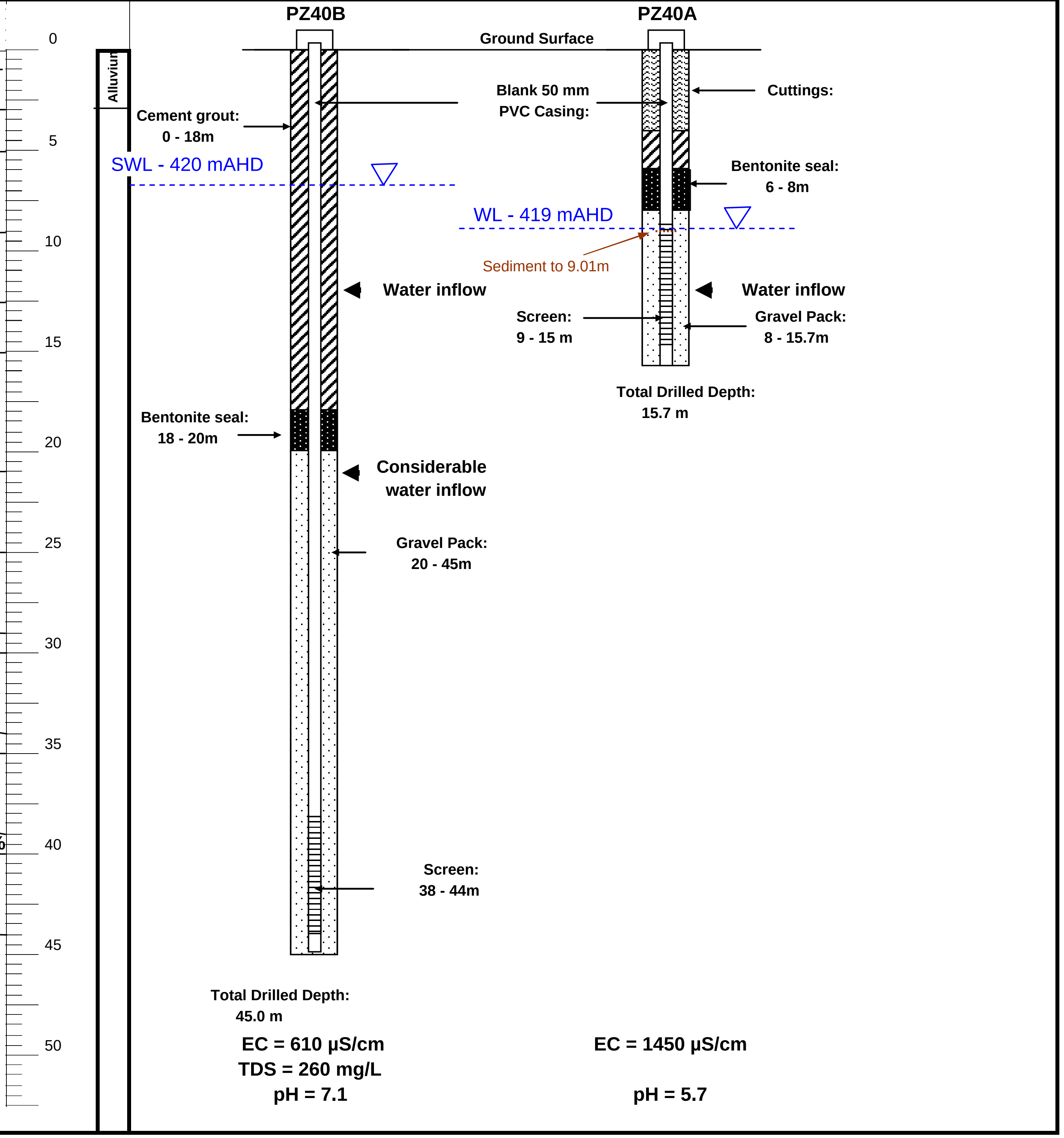
Sandstone - white, vf-f (50%); Mudstone - grey (50%)

Siltstone - black-grey, carbonaceous

Sandstone - grey, m-vc (50%); Siltstone - dk grey (50%

Alternating (Sandstone - brown/grey, f; and (Siltstone - brown/dark grey

Siltstone / Tuff / Coal



EC = 610 µS/cm
TDS = 260 mg/L
pH = 7.1

EC = 1450 µS/cm
pH = 5.7

Figure B8: Bore Logs - PZ40A and PZ40B

Peter Dundon and Assoc.

Logging Sheet

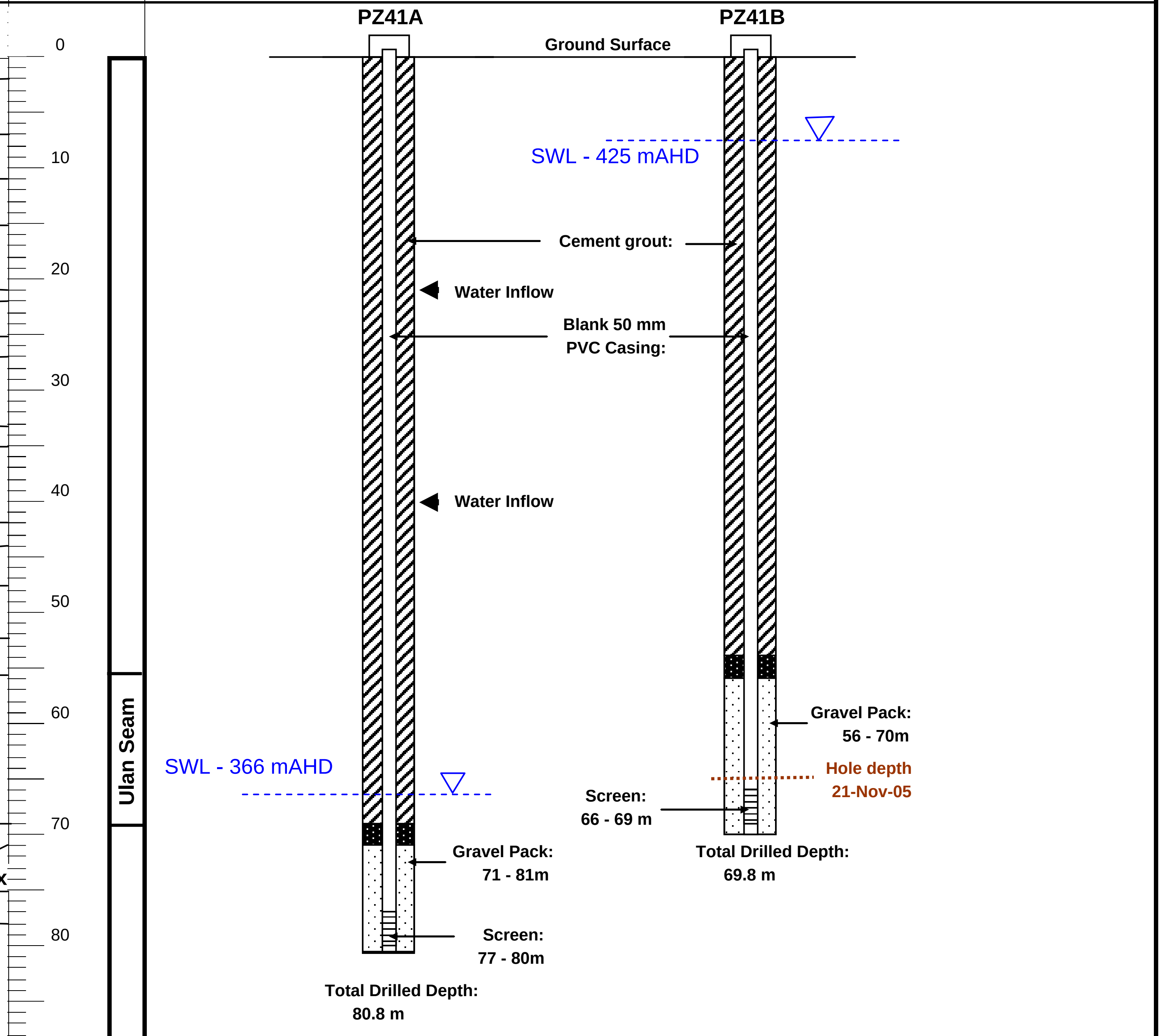
BORES: PZ41A and PZ41B

Project No: **05-0158**

Client:	Bore:	Elevation (GL):	Elevation (TOC):	Stickup:	Drilling Contractor:	Date Started:	Date Finished:
Moolarben Coal Company	**PZ41A**	**432.595 mAHD**	**432.875 mAHD**	**0.28 m**	**Mitchell Drilling**	**22-Jul-05**	**25-Jul-05**
Location:	**PZ41B**	**432.773 mAHD**	**433.103 mAHD**	**0.33 m**	**Mitchell Drilling**	**25-Jul-05**	**26-Jul-05**
Moolarben Coal Company							
			Hole depths: **As shown**			Supervised By: **A Price**	

Description	Depth (metres)	Well Construction Details:

Sand and Clay - orange / orange-white
Sandy Clay - white-orange to yellow, vf-f
Coal, minor tuff
Mudstone - grey, clayey
Siltstone - dark grey to grey-black, carbonaceous, minor coal (19-20m)
Coal (60%), Tuff (40%)
Sandstone (40%), Mudstone (20%), Coal (40%)
Siltstone - dark grey, 30% light grey sandstone
Sandstone - light grey to grey, f-vf
Coal (70%), Tuff (30%)
Siltstone (60%), Sandstone (25%), Tuff (15% - 36-37m)
Mudstone / Carbonaceous Mudstone - grey-black
Siltstone - grey-black; Mudstone - dark grey-black
Mudstone - black to dark grey, minor sandstone
Sandstone / Mudstone / Siltstone / Conglomerate
Coal (minor tuff, mudstone, sandstone, siltstone)
Sandstone - grey, vf-f (40%); Siltstone - d grey (60%)
Granule Conglomerate - light grey, f-c sandstone matrix
Siltstone - dark grey
Sandstone - grey, vf, grading to siltstone



EC = 6470 µS/cm
TDS = 3700 mg/L
pH = 5.0

EC = 6810 µS/cm
TDS = 3300 mg/L
pH = 6.7

Figure B9: Bore Logs - PZ41A and PZ41B

Peter Dundon and Assoc.
Logging Sheet

BORES: PZ43A and PZ43B

Project No: **05-0158**

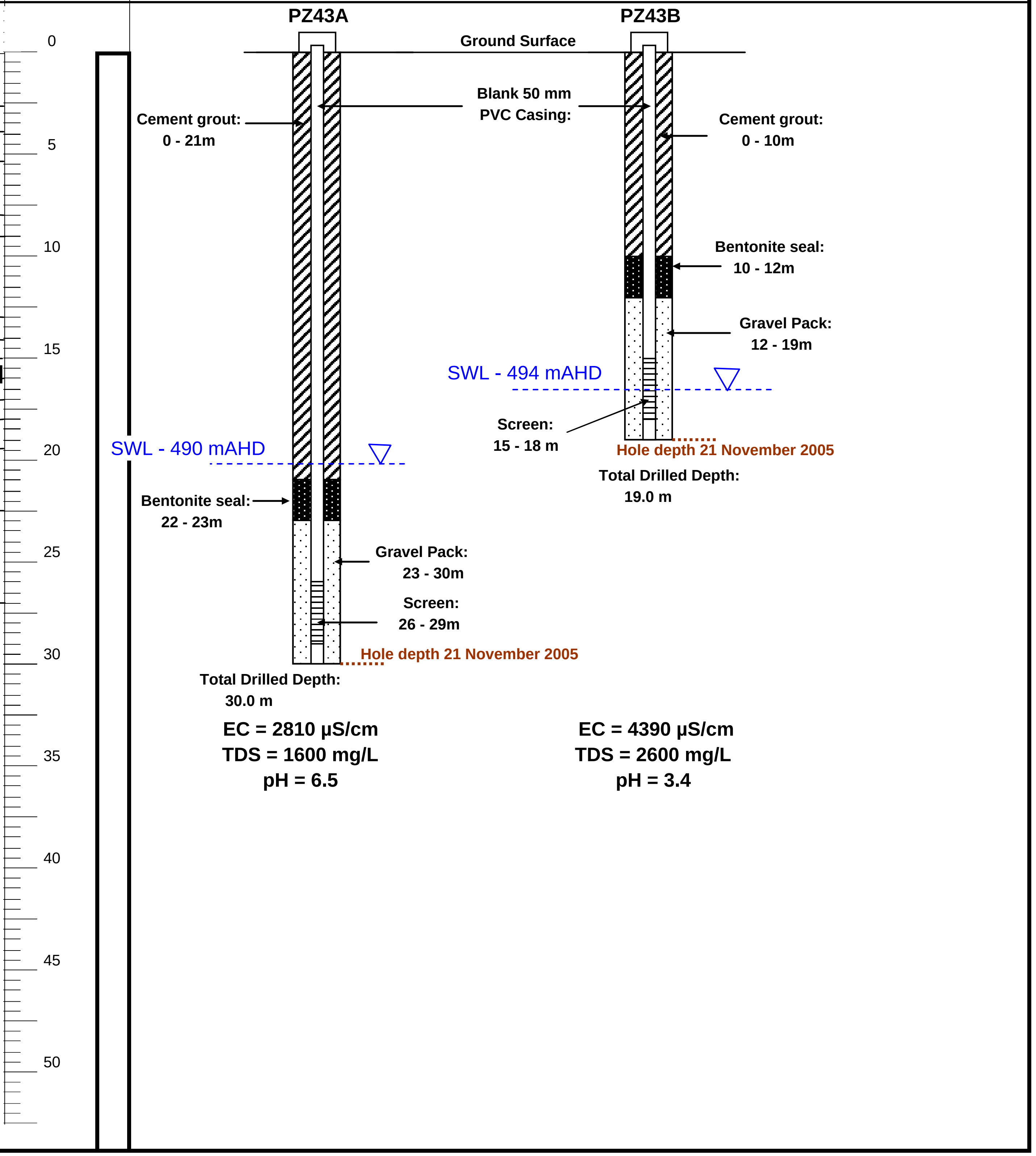
Client: **Moolarben Coal Company**
Location: **Moolarben Coal Company**

Bore:	Elevation (GL):	Elevation (TOC):	Stickup:	Drilling Contractor:	Date Started:	Date Finished:
PZ43A	**510.408 mAHD**	**510.788 mAHD**	**0.38 m**	**Mitchell Drilling**	**28-Jul-05**	**28-Jul-05**
PZ43B	**510.385 mAHD**	**510.715 mAHD**	**0.33 m**	**Mitchell Drilling**	**28-Jul-05**	**28-Jul-05**

Hole depths: **As shown**
Supervised By: **A Price**

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

Soil / Clay / Sandstone
Sandstone - brown, vc
Granule Conglomerate - brown, m-c
Coal
Siltstone - grey black, sandy
Sandstone - light grey, vf-c
Granule Conglomerate - light grey, m-c
Sandstone - light grey, f-vf
Sandstone - lt grey, m-c [20% carbonaceous siltstone]
Granule Conglomerate - lt grey, f-m-c, sandy
Sandstone - grey, f-c
Granule Conglomerate - grey
Sandstone - dark grey, vf
Sandstone - grey yellow brown, vf
Sandstone - dark grey, vf



PZ43A
EC = 2810 µS/cm
TDS = 1600 mg/L
pH = 6.5

PZ43B
EC = 4390 µS/cm
TDS = 2600 mg/L
pH = 3.4

Figure B10: Bore Logs - PZ43A and PZ43B

Peter Dundon and Assoc.
Logging Sheet

BORE: PZ44

		Project No:	**05-0158**
Client: **Moolarben Coal Company**	Elevation (GL): Elevation (TOC	**491.300 mAHD** **491.510 mAHD**	
Location: **Moolarben Coal Project**	Stickup: Hole Depth:	**0.21 m** **24.0 m**	
Drilling Contractor: **Mitchell Drilling**	Date Started: Date Complete(	**28 July 2005** **29 July 2005**	Supervised By: **A Price**

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

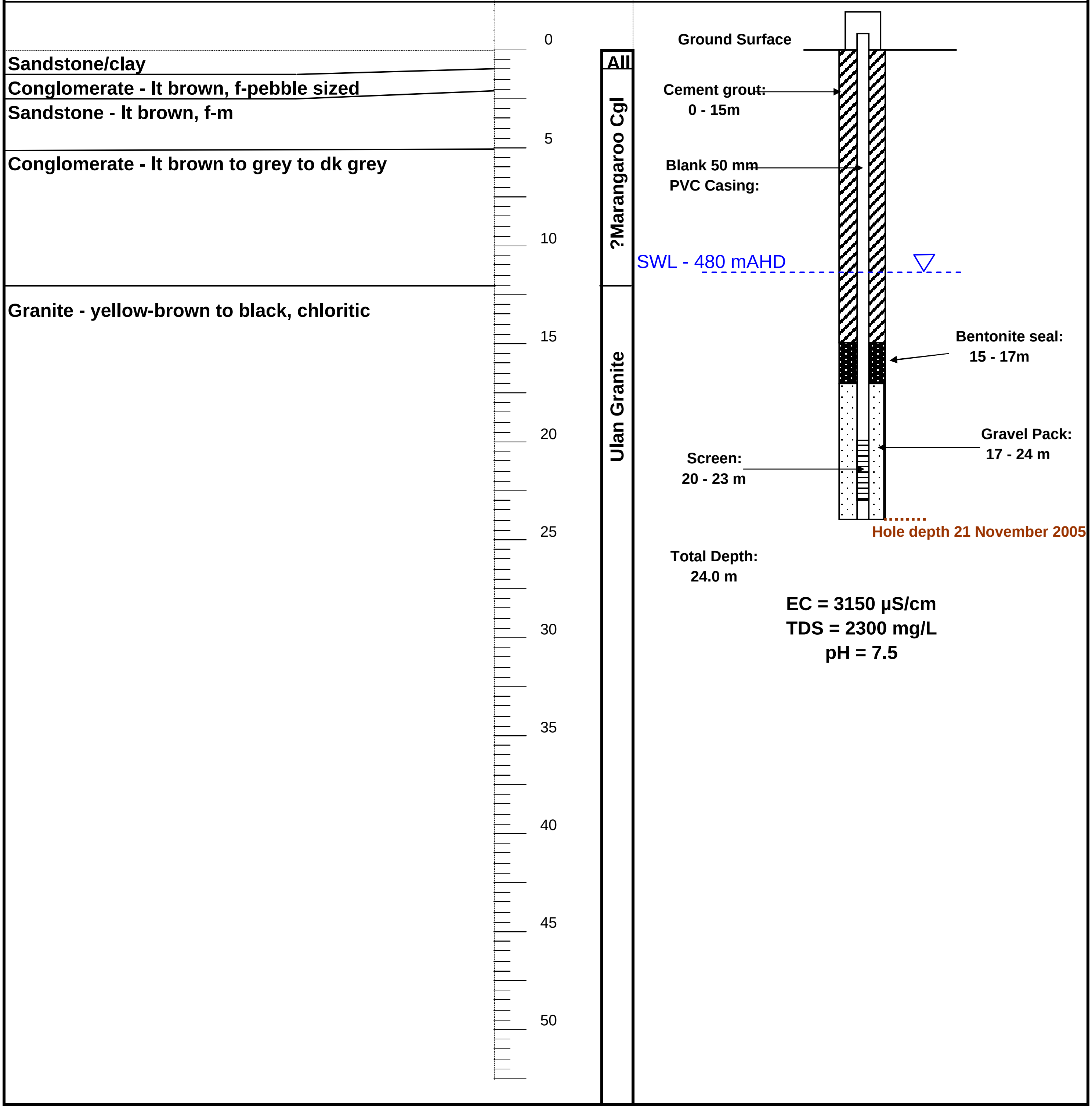


Figure B11: Bore Log - PZ44

Peter Dundon and Assoc.

Logging Sheet

BORES: PZ50A, PZ50B and PZ50C

Project No: **05-0158**

Client:	Bore:	Elevation (GL):	Elevation (TOC):	Stickup:	Drilling Contractor:	Date Started:	Date Finished:
Moolarben Coal Company	**PZ50A**	**449.468 mAHD**	**449.758 mAHD**	**0.290 m**	**Mitchell Drilling**	**25-Aug-05**	**25-Aug-05**
Location:	**PZ50B**	**449.544 mAHD**	**449.871 mAHD**	**0.327 m**	**Mitchell Drilling**	**26-Aug-05**	**26-Aug-05**
Moolarben Coal Company	**PZ50C**	**449.492 mAHD**	**449.632 mAHD**	**0.140 m**	**Mitchell Drilling**	**26-Aug-05**	**26-Aug-05**
			Hole depths: **As shown**			Supervised By: **A Price**	

Description

Gravel (30%); Clay - red / Sand - orange (70%)

Sand - orange, f-c, slightly clayey

Gravel - granule-sized [orange-brown sand at 10-11m]

Claystone - brown to grey, weathered

Sandstone - grey, vf (30%); Siltstone - black (70%)

Coal [tuff at 18.7-19.3m]

Sandstone - grey- black, vf-f, carbonaceous in parts

Conglomerate - granule-sized

Sandstone - dark grey, vf

Siltstone - dark grey

Sandstone - grey to dark grey, f-vf

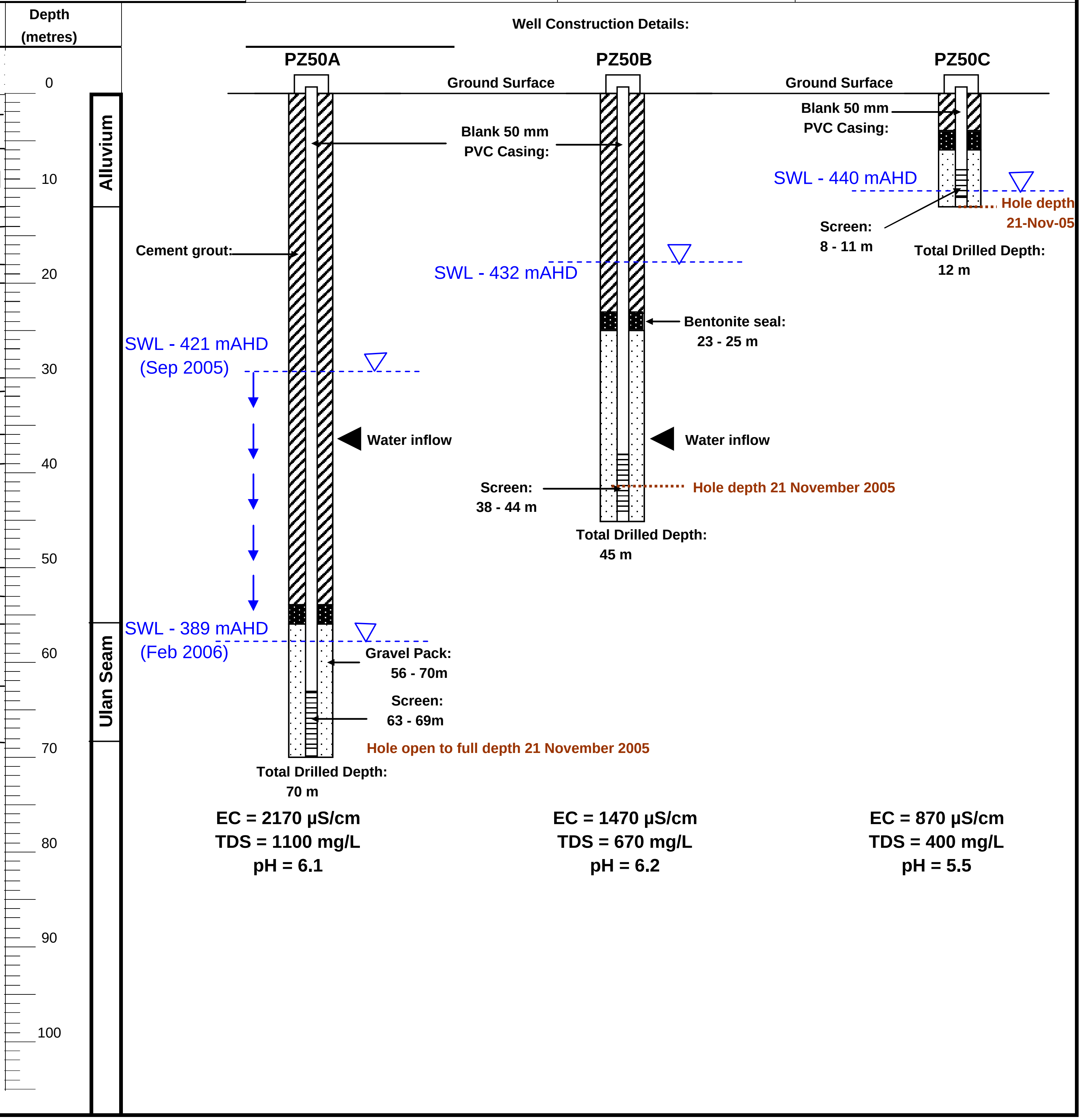
Siltstone - dark grey

Sandstone - grey to dark grey, vf; minor siltstone

Coal, incl 20-40% tuff

Coal

Sandstone - dark grey, vf



EC = 2170 µS/cm	EC = 1470 µS/cm	EC = 870 µS/cm
TDS = 1100 mg/L	TDS = 670 mg/L	TDS = 400 mg/L
pH = 6.1	pH = 6.2	pH = 5.5

Figure B12: Bore Logs - PZ50A, PZ50B and PZ50C

Peter Dundon and Assoc.

Logging Sheet

BORES: PZ52, TB52A and TB52B

Project No: **05-0158**

Client: **Moolarben Coal Company**

Location: **Moolarben Coal Company**

Bore:	Elevation (GL):	Elevation (TOC):	Stickup:	Drilling Contractor:	Date Started:	Date Finished:
PZ52	**419.230 mAHD**	**419.560 mAHD**	**0.330 m**	**Mitchell Drilling**	**31-Aug-05**	**31-Aug-05**
TB52A	**419.088 mAHD**	**419.279 mAHD**	**0.191 m**	**Watermin Drillers**	**19-Jan-06**	**08-Feb-06**
TB52B	**419.148 mAHD**	**419.434 mAHD**	**0.286 m**	**Watermin Drillers**	**18-Jan-06**	**20-Jan-06**

Hole depths:

As shown

Supervised By:

A Price (PZ52)

R McCallum (TB52A and TB52B)

Description

Sandy loam

Clay - white, puggy

Sand - m-gr to gravel

Clay - white, puggy

Silty clay - friable, soft and peaty

Claystone - grey

Sand - m-c grained

Peat - clayey

No sample return

Shale - laminated

Claystone

Shale - laminated, blocky

Conglomerate - sandy

Sandstone/coal - interbedded

Sandstone/shales - laminated

Shale - carbonaceous

Coal - black coal, minor carbonaceous beds

Sandstone/conglomerate

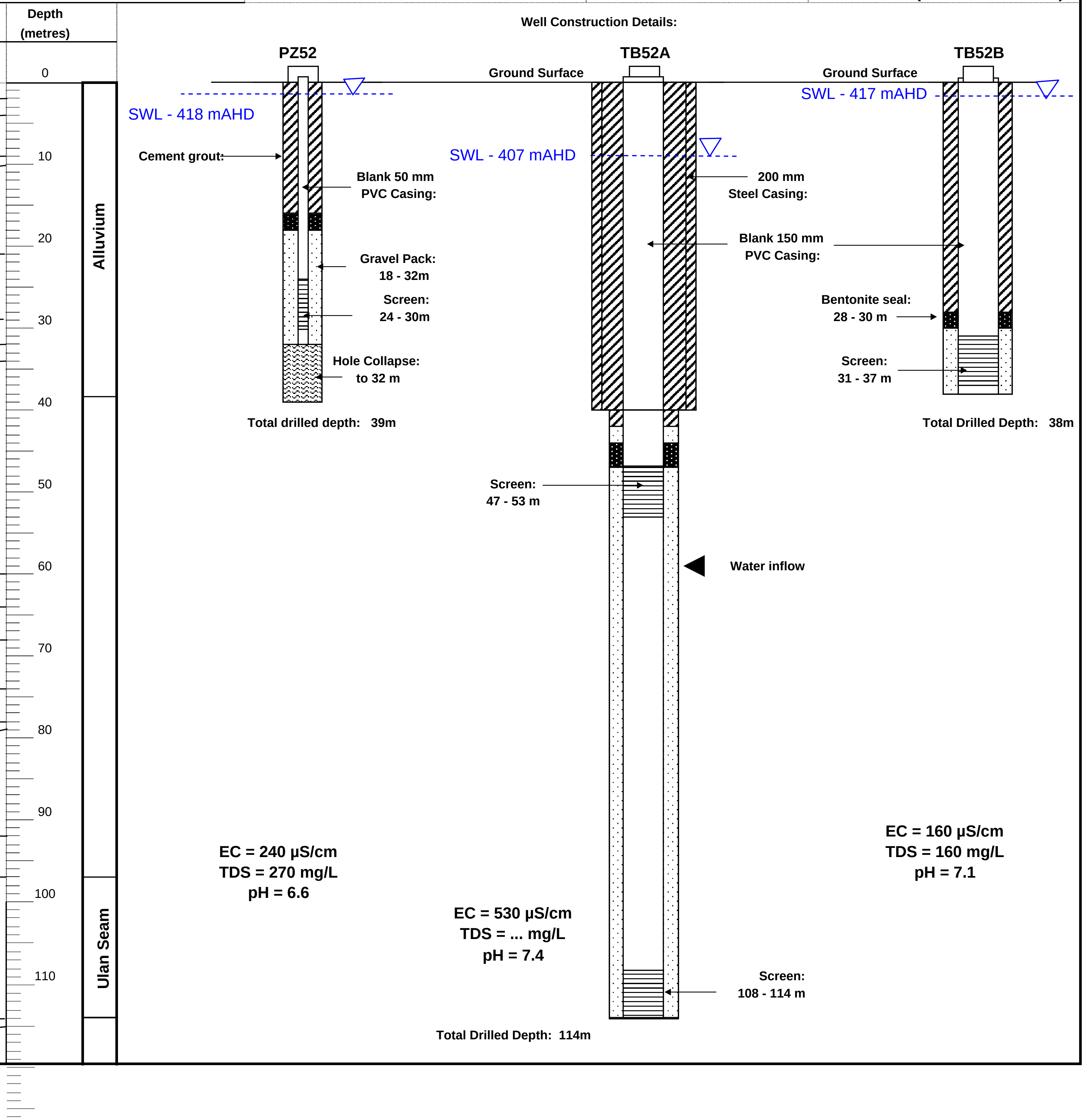


Figure B13: Bore Logs - PZ52, TB52A and TB52B

Peter Dundon and Assoc.

Logging Sheet

BORE: PZ53

Client: **Moolarben Coal Company**	Elevation (GL):	**446.915 mAHD**	
	Elevation (TOC)	**447.015 mAHD**	
Location: **Moolarben Coal Project**	Stickup:	**0.10 m**	
	Hole Depth:	**51.0 m**	
Drilling Contractor: **Mitchell Drilling**	Date Started:	**1 September 2005**	Supervised By:
	Date Completed	**1 September 2005**	**A Price**

Project No: **05-0158**

Description	Depth (metres)	Well Construction Details:

Gravel (70%); Sand (40%)

Clay

Sandy Clay - orange, sl sandy

Clay - orange to white, sl sandy

Sandy Clay - orange, f-grained

Sand - orange, f-c, clayey

Gravel - multicoloured, granule-sized (40%)
Sand - orange, f-c, clayey (60%)

Sandy Clay - grey to brown, f-c

Claystone - grey, slightly sandy

Sandstone - grey, vf, slightly clayey

Coal

Sandstone - grey, f (60%); Siltstone - black (40%)

Sandstone - grey to black, f-vf

Coal

Tuff - buff (40%); Coal (60%)

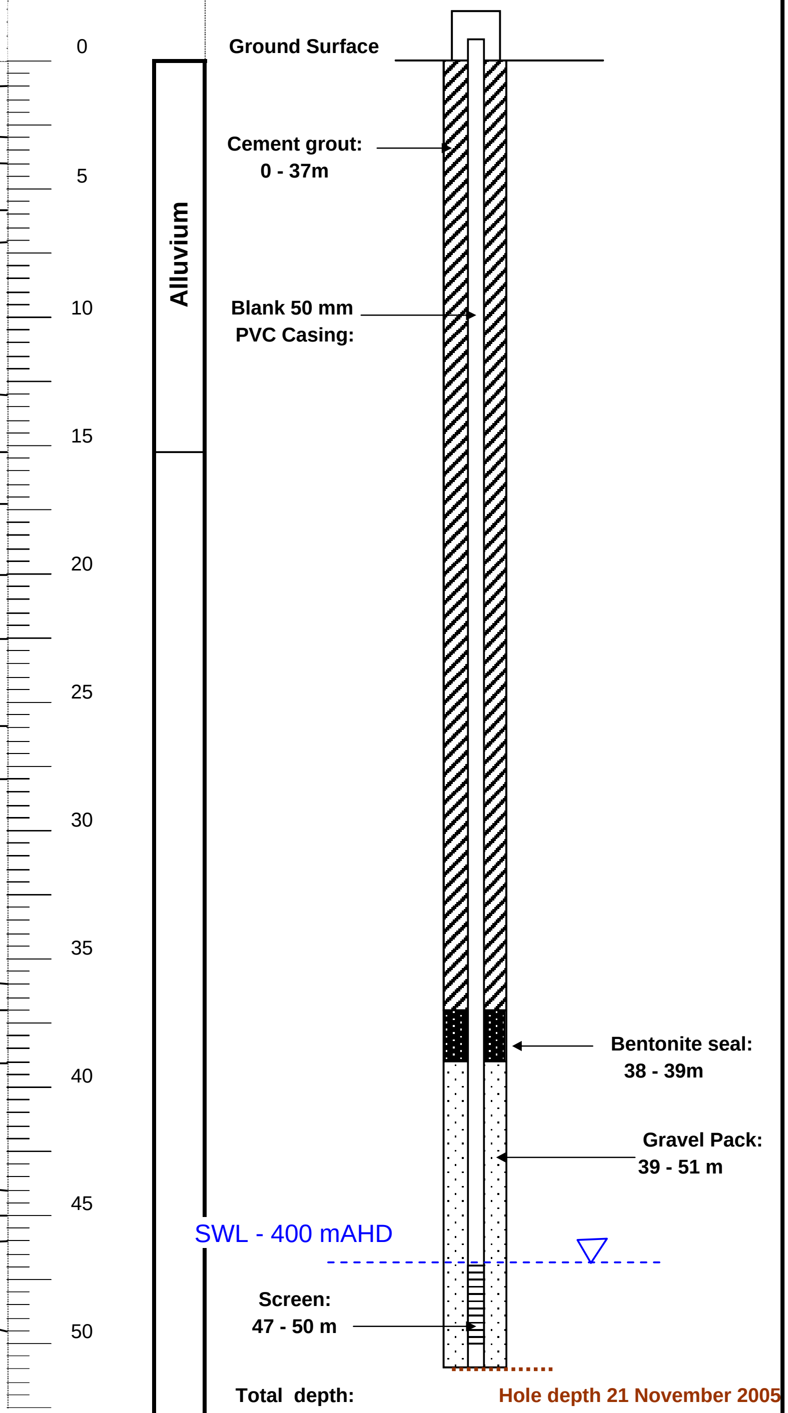
Siltstone - grey to black, slightly carbonaceous

Sandstone - grey, vf-f (40%); Siltstone - sl carb (60%)

Conglomerate - grey to blue, granule-sized

Sandstone - grey to blue, fine to granule-sized

Sandstone - grey, vf (40%); Siltstone - black (60%)
[interlaminated]



Total depth:
51.0 m

Hole depth 21 November 2005

EC = 1050 µS/cm
TDS = 490 mg/L
pH = 7.2

Figure B14: Bore Log - PZ53

Peter Dundon and Assoc.
Logging Sheet

BORE: PZ55

		Project No:	05-0158
Client: **Moolarben Coal Company**	Elevation (GL): Elevation (TOC	429.464 mAHD 429.714 mAHD	
Location: **Moolarben Coal Project**	Stickup: Hole Depth:	0.25 m 15.1 m	
Drilling Contractor: **Mitchell Drilling**	Date Started: Date Complete(	2 September 2005 2 September 2005	Supervised By: **A Price**

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

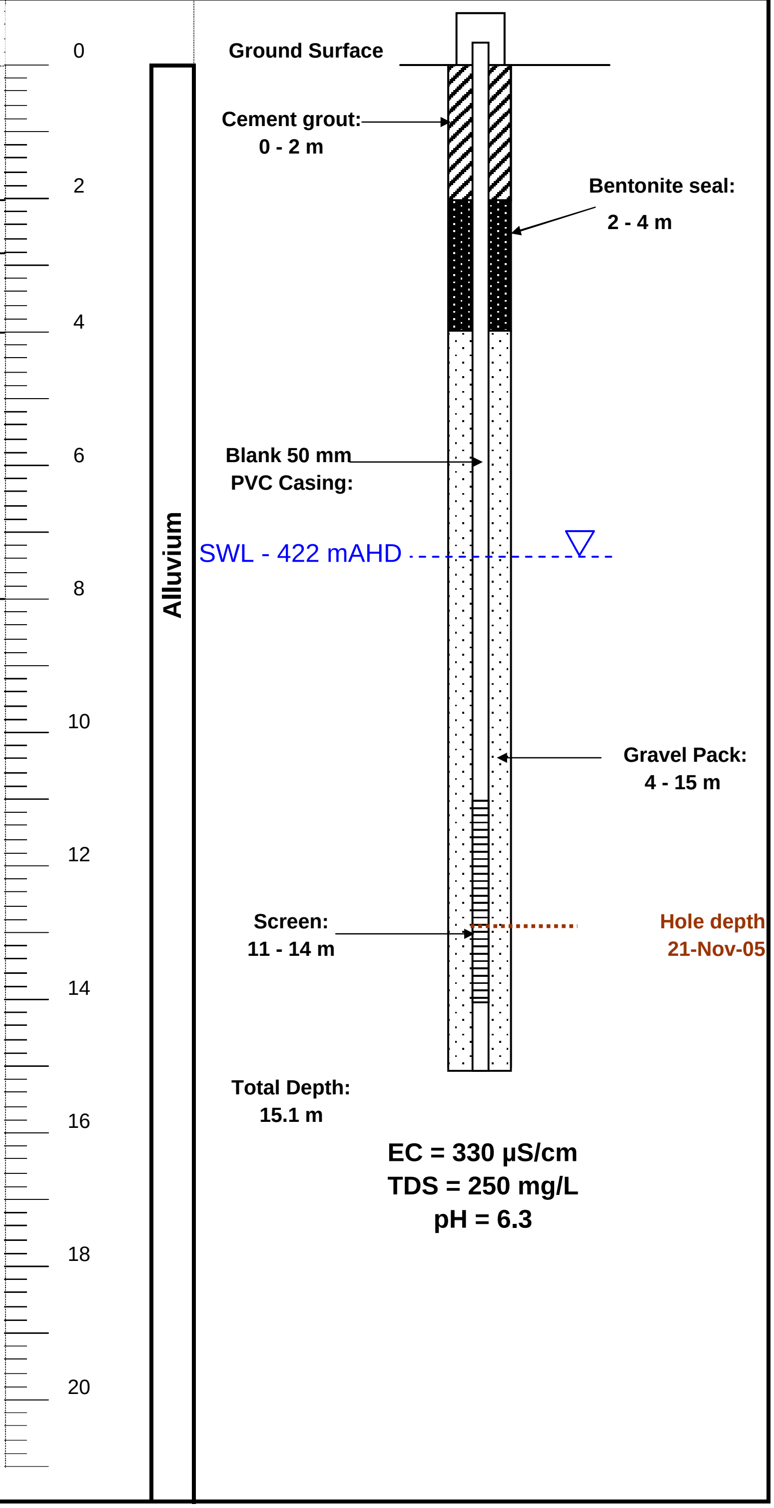
Sandy Clay - brown to grey, f-c

Sand - brown, f-c, clayey

Gravel - multicoloured, pebble-sized (30%)
Sand - grey to brown, c, clayey (70%)

Gravel - multicoloured, granule to pebble-sized (40%)
Sand - red to brown, f-vc, clayey (60%)

Gravel - as above (40%)
Sand - as above, mostly granitic source (60%)



EC = 330 µS/cm
TDS = 250 mg/L
pH = 6.3

Figure B15: Bore Log - PZ55

Peter Dundon and Assoc.
Logging Sheet

BORE: PZ58

		Project No:	**05-0158**
Client: **Moolarben Coal Company**	Elevation (GL):	**477.847 mAHD**	
	Elevation (TOC	**478.083 mAHD**	
Location: **Moolarben Coal Project**	Stickup:	**0.236 m**	
	Hole Depth:	**12.0 m**	
Drilling Contractor: **Mitchell Drilling**	Date Started:	**9 September 2005**	Supervised By:
	Date Complete(	**9 September 2005**	**A Price**

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

Sandy Clay - orange, f-c

Gravel - multicoloured, granule-pebble sized (50%)
Sand - orange-brown, f-vc, slightly clayey (50%)

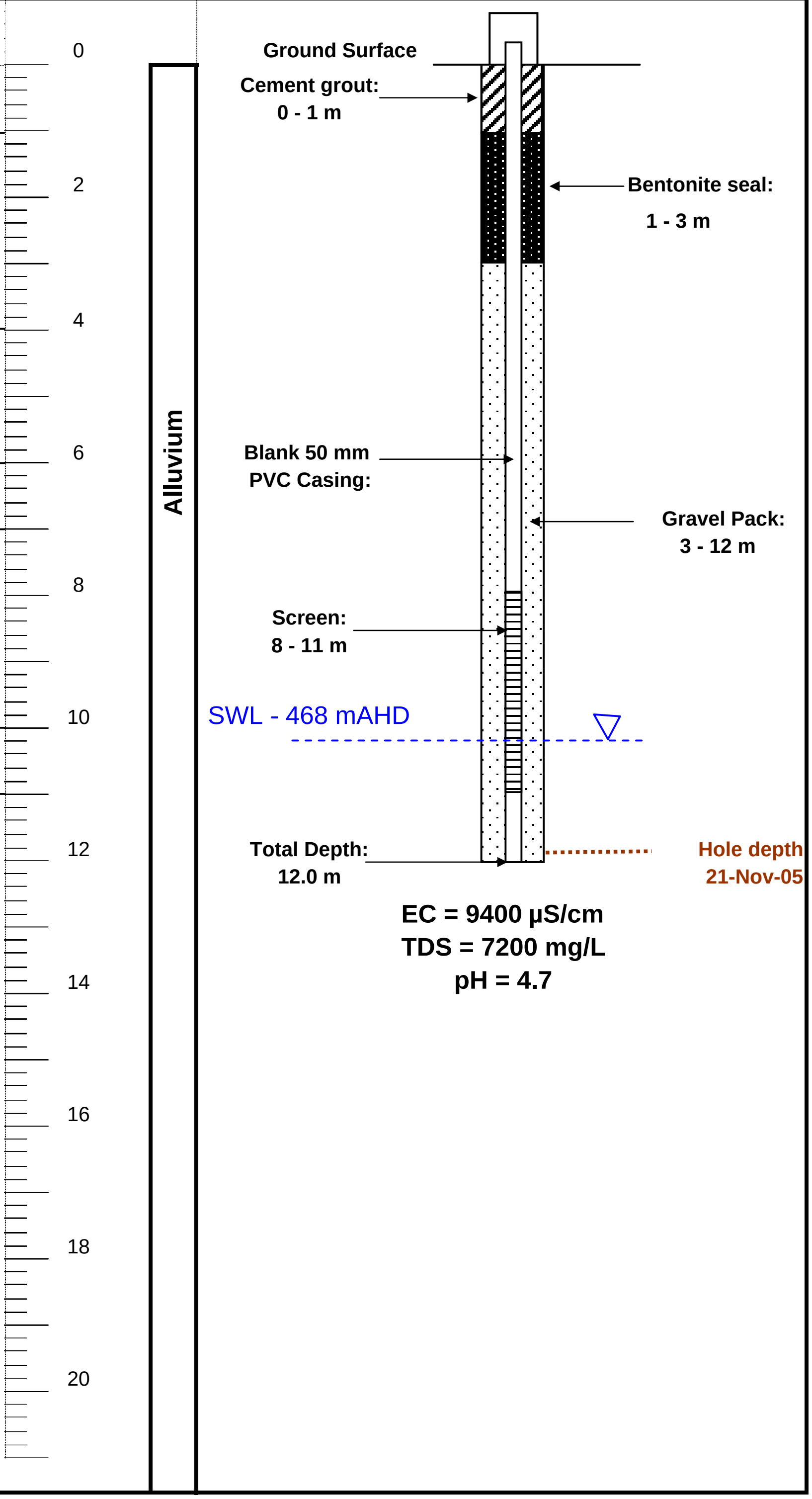
Gravel - as above (70%)
Sand - white to orange, f-vc, slightly clayey (30%)

Gravel - as above (50%)
Sand - pink, f-vc, slightly clayey (50%)

Gravel - as above (50%)
Sand - white, f-vc, slightly clayey (50%)

Gravel - as above (50%)
Sand - pink to orange, f-c, slightly clayey (50%)

Sand - grey and orange, f-c



EC = 9400 µS/cm
TDS = 7200 mg/L
pH = 4.7

Figure B16: Bore Log - PZ58

Peter Dundon and Assoc.

Logging Sheet

BORES: PZ72A and PZ72C

Project No: **05-0158**

Client:	Bore:	Elevation (GL):	Elevation (TOC):	Stickup:	Drilling Contractor:	Date Started:	Date Finished:
Moolarben Coal Company	**PZ72A**	**509.982 mAHD**	**510.142 mAHD**	**0.16 m**	**Mitchell Drilling**	**28-Sep-05**	**28-Sep-05**
Location:	**PZ72C**	**510.108 mAHD**	**510.278 mAHD**	**0.17 m**	**Mitchell Drilling**	**05-Oct-05**	**05-Oct-05**
Moolarben Coal Project							

Hole depths: **As shown**

Supervised By: **A Price**

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

Sand/gravel

Clay, sandy clay - grey to brown

Sand - orange-brown

Gravel, sand - multicoloured

Clay - white

Sandstone

Carb mudstone

Siltstone - dk grey; sandstone - grey, f

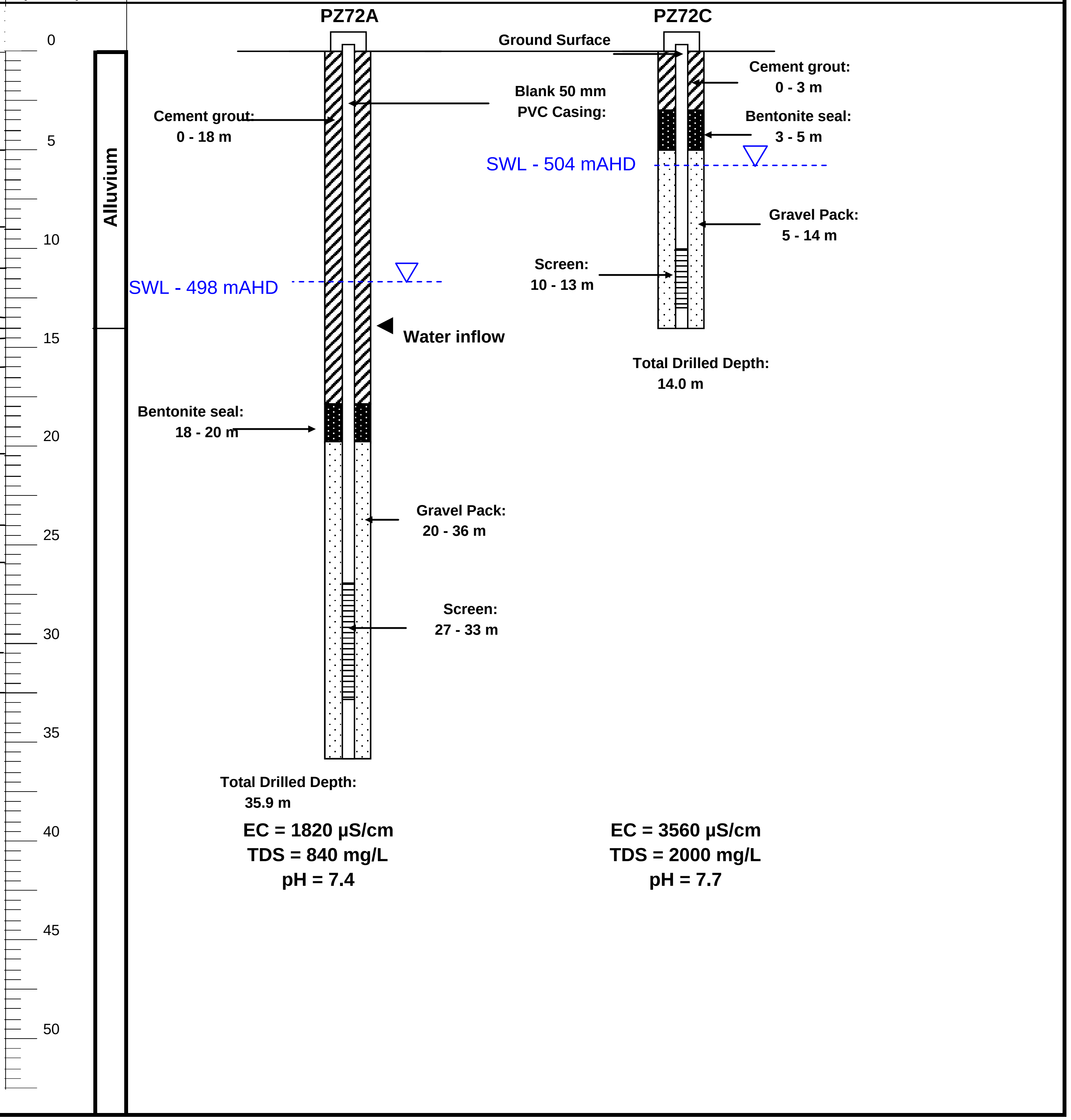
Coal, tuff, carb mudstone

Sandstone, siltstone - brown, grey, dark grey

Coal - stony, minor tuff

Tuff - dark grey-white

Sandstone - dark grey to grey



PZ72A

EC = 1820 µS/cm
TDS = 840 mg/L
pH = 7.4

PZ72C

EC = 3560 µS/cm
TDS = 2000 mg/L
pH = 7.7

Figure B17: Bore Logs - PZ72A and PZ72C

Peter Dundon and Assoc.
Logging Sheet

BORE: PZ74

Project No: **05-0158**

Client:
Moolarben Coal Company

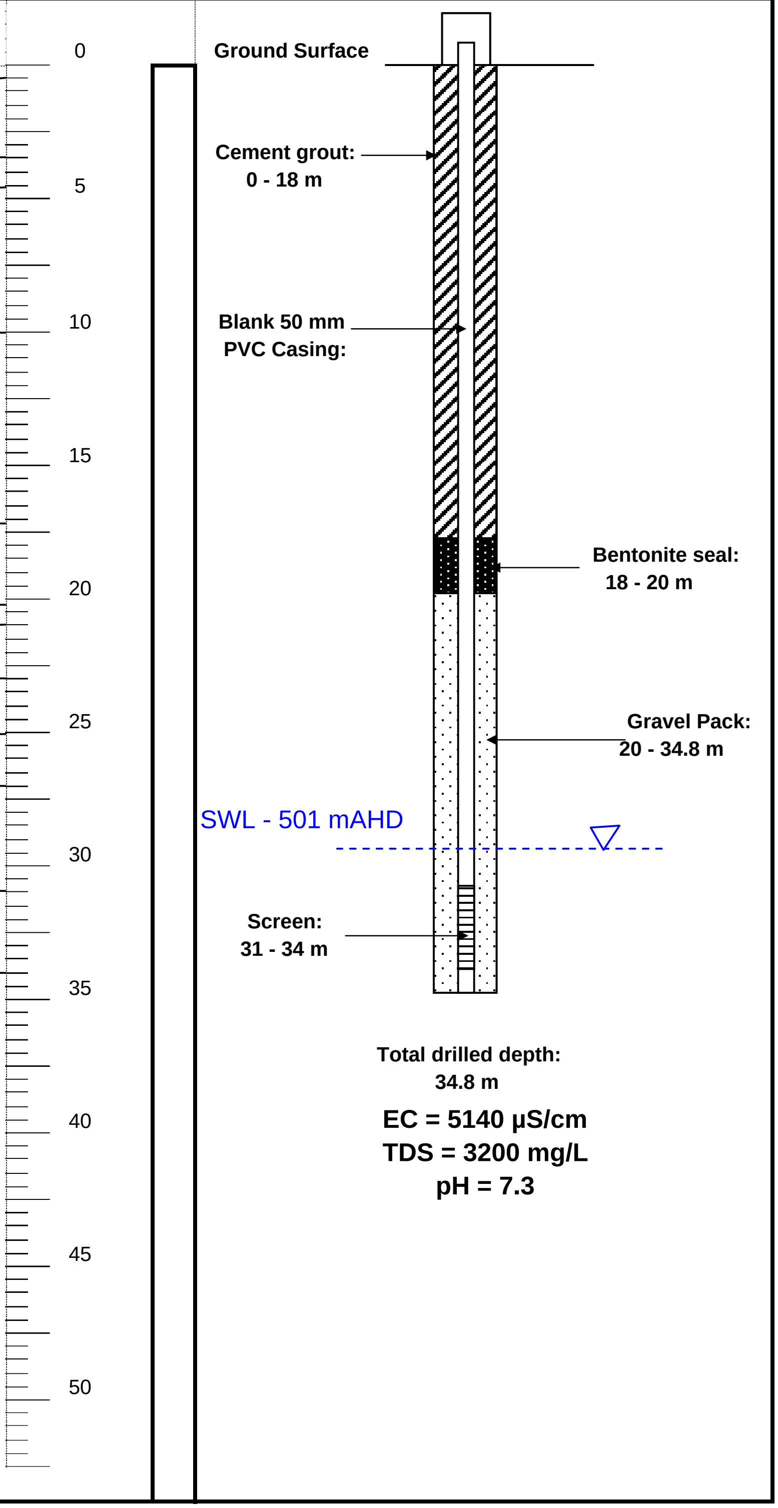
Location:
Moolarben Coal Project

Drilling Contractor:
Mitchell Drilling

Elevation (GL): **531.221 mAHD**
Elevation (TOC **531.621 mAHD**
Stickup: **0.4 m**
Hole Depth: **34.8 m**
Date Started: **6 October 2005**
Date Completed **6 October 2005**

Supervised By: **A Price**

Description	Depth (metres)	Well Construction Details:
Soil	0 - 1	
Clay/claystone - white-orange-brown	1 - 3.5	
Siderite	3.5 - 5	
Siltstone, claystone, mudstone, sandstone, carb mudstone	5 - 10	
Sandstone - dark grey to grey, vf-m	10 - 17	
Carbonbaceous mudstone	17 - 20	
Sandstone - lt grey, f	20 - 21	
Mudstone	21 - 23	
Siltstone- black, tuff - white/brown	23 - 25	
Carb mudstone, minor tuff	25 - 27	
Mudstone, tuff, sandstone, coal	27 - 31	
Siltstone - dark grey	31 - 34	
Sandstone - lt grey, f-vc	34 - 34.8	



EC = 5140 µS/cm
TDS = 3200 mg/L
pH = 7.3

Figure B18: Bore Log - PZ74

Peter Dundon and Assoc.

Logging Sheet

BORES: PZ101A and PZ101B

Project No: **05-0158**

Client:	Bore:	Elevation (GL):	Elevation (TOC):	Stickup:	Drilling Contractor:	Date Started:	Date Finished:
Moolarben Coal Company	**PZ101A**	**402.418 mAHD**	**403.465 mAHD**	**1.047 m**	**Watermin Drillers**	**01-Nov-05**	**08-Nov-05**
Location: **Moolarben Coal Project**	**PZ101B**	**402.591 mAHD**	**403.284 mAHD**	**0.693 m**	**Watermin Drillers**	**08-Nov-05**	**09-Nov-05**

Hole depths: **As shown**

Supervised By: **R McCallum**

Description	Depth (metres)	Well Construction Details:

Sandstone - f-m, yellow-brown-grey

Conglomerate - rounded cobbles, white clay matrix

Mudstone - black, grey laminated

Claystone - grey, alternating with d grey mudstone

Conglomerate - white clay matrix (water at 30m)

Carbonaceous mudstone, contaminated from above

Sandstone - f-m, lt grey, interbedded black shale

Siltstone - grey, interbedded black shale

Carbonaceous shale/mudstone

Sandstone - f-grained, lt grey
(Minor coal 86-87m)

Laminated siltstone - dk grey, minor carb mudst, coal

Alternating black siltstone/ly grey sandstone

Coal - Ulan Seam

Siltstone - dk grey (60%); sandstone - f, lt grey (40%)

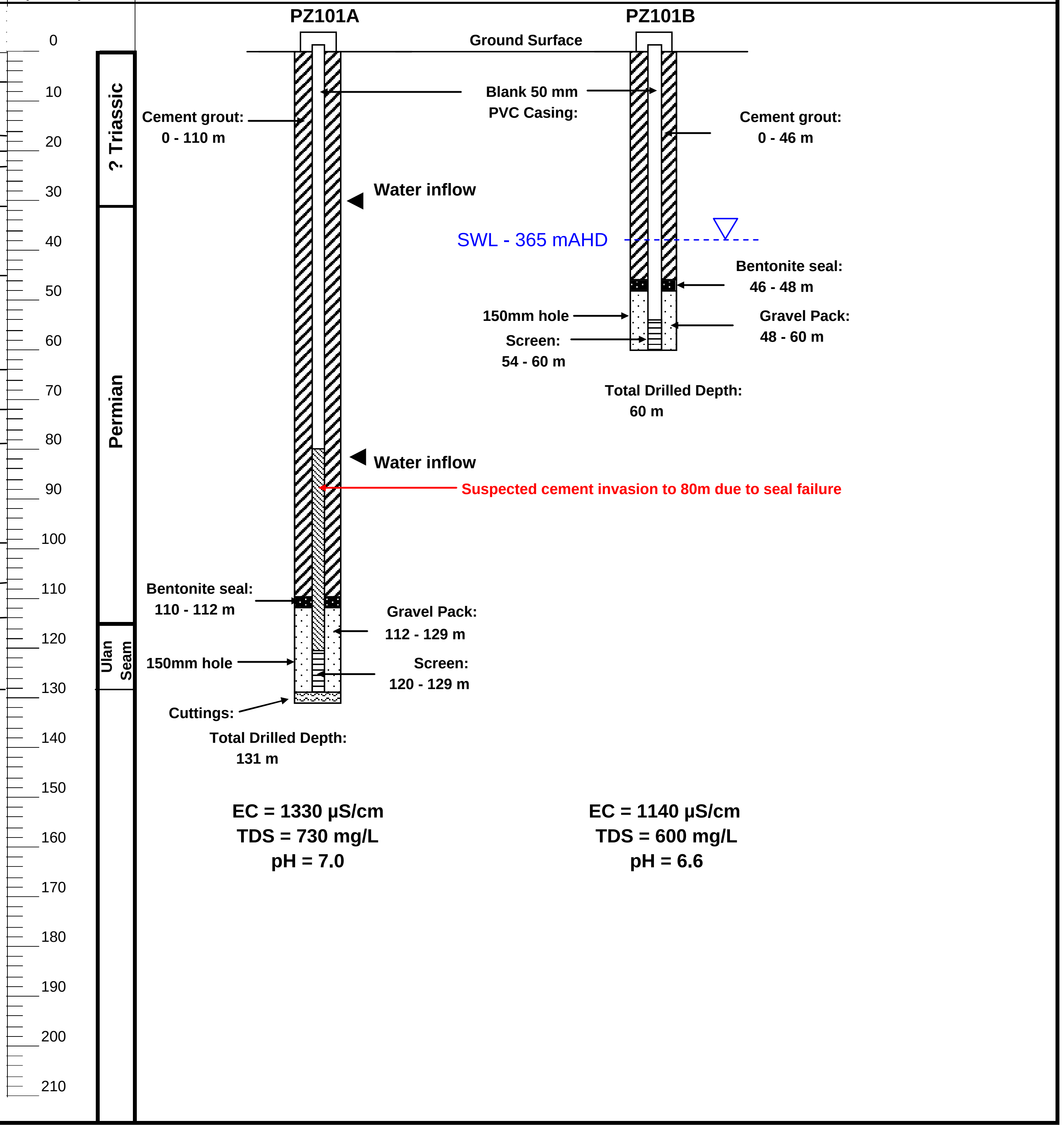


Figure B19: Bore Logs - PZ101A and PZ101B

Peter Dundon and Assoc.

Logging Sheet

BORES: PZ102A and PZ102B

Project No: **05-0158**

Client: **Moolarben Coal Company**

Location: **Moolarben Coal Project**

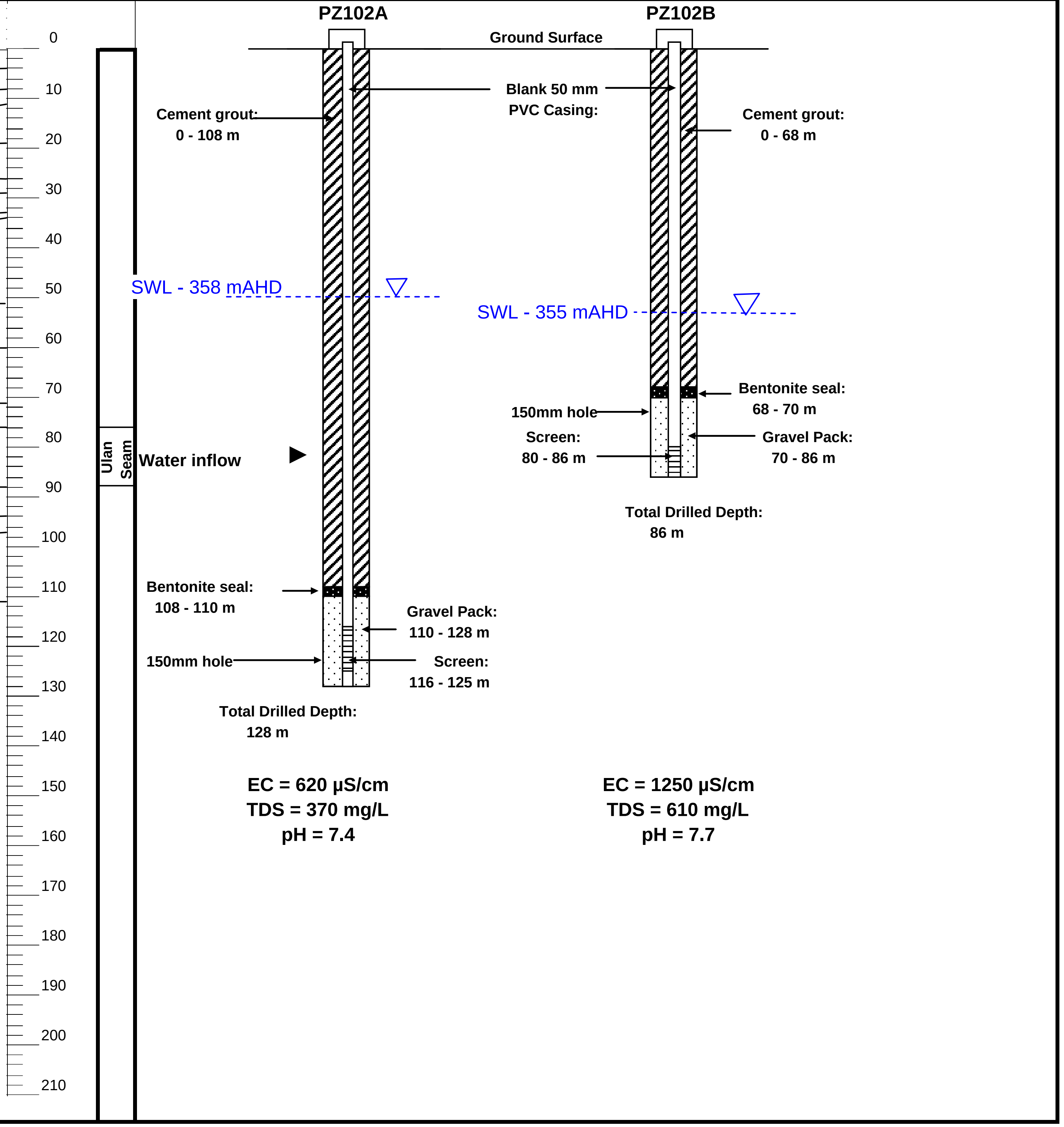
Bore:	Elevation (GL):	Elevation (TOC):	Stickup:	Drilling Contractor:	Date Started:	Date Finished:
PZ102A	**408.027 mAHD**	**408.537 mAHD**	**0.510 m**	**Watermin Drillers**	**09-Nov-05**	**11-Nov-05**
PZ102B	**407.767 mAHD**	**408.229 mAHD**	**0.462 m**	**Watermin Drillers**	**10-Nov-05**	**11-Nov-05**

Hole depths: **As shown**

Supervised By: **R McCallum**

Description	Depth (metres)	Well Construction Details:

Soil/clay
Siltstone - grey/lt grey
Sandstone - mottled orange/grey/dk grey
Clay/mudstone
Carbonaceous shale
Sandstone - light grey, silty
Carbonaceous shale
Sandstone - grey-black
Clay/silty clay - mottled grey/dark grey/brown
Carbonaceous shale
Sandstone - f-grained, light grey
Carbonaceous shale - dark grey
Coal - Ulan Seam
Sandstone - mottled grey-brown
Shale - dark grey, minor sandstone
Sandstone - dark grey, f-grained
Sandstone - grey-white, m-grained



EC = 620 µS/cm
TDS = 370 mg/L
pH = 7.4

EC = 1250 µS/cm
TDS = 610 mg/L
pH = 7.7

Figure B20: Bore Logs - PZ102A and PZ102B

Peter Dundon and Assoc.

Logging Sheet

BORES: TB103, PZ103A and P103B

						Project No:	**05-0158**
Client:	Bore:	Elevation (GL):	Elevation (TOC):	Stickup:	Drilling Contractor:	Date Started:	Date Finished:
Moolarben Coal Company	**TB103**	**424.925m AHD**	**425.195 mAHD**	**0.25 m**	**Watermin Drillers**	**05-Jan-06**	**16-Jan-06**
Location:	**PZ103A**	**425.115m AHD**	**425.205 mAHD**	**0.09 m**	**Watermin Drillers**	**17-Dec-05**	**19-Dec-05**
Moolarben Coal Project	**PZ103B**	**424.850m AHD**	**425.000 mAHD**	**0.15 m**	**Watermin Drillers**	**28-Nov-05**	**20-Dec-05**
			Hole depths: **As shown**			Supervised By: **R McCallum**	

Description

Topsoil

Clay - silty, sandy, mottled yellow, orange, white

Sandstone - c-grained, clayey

Clay/shale - light brown, to sandstone at base

Interbedded grey sandstone and carbonaceous shale

Sandstone - dark grey, f-grained

Carbonaceous shale

Sandstone - grey

Carbonaceous shale

Sandstone - grey, f-grained, silty

Sandstone - grey, f-grained

Interbedded grey sandstone and carb shale

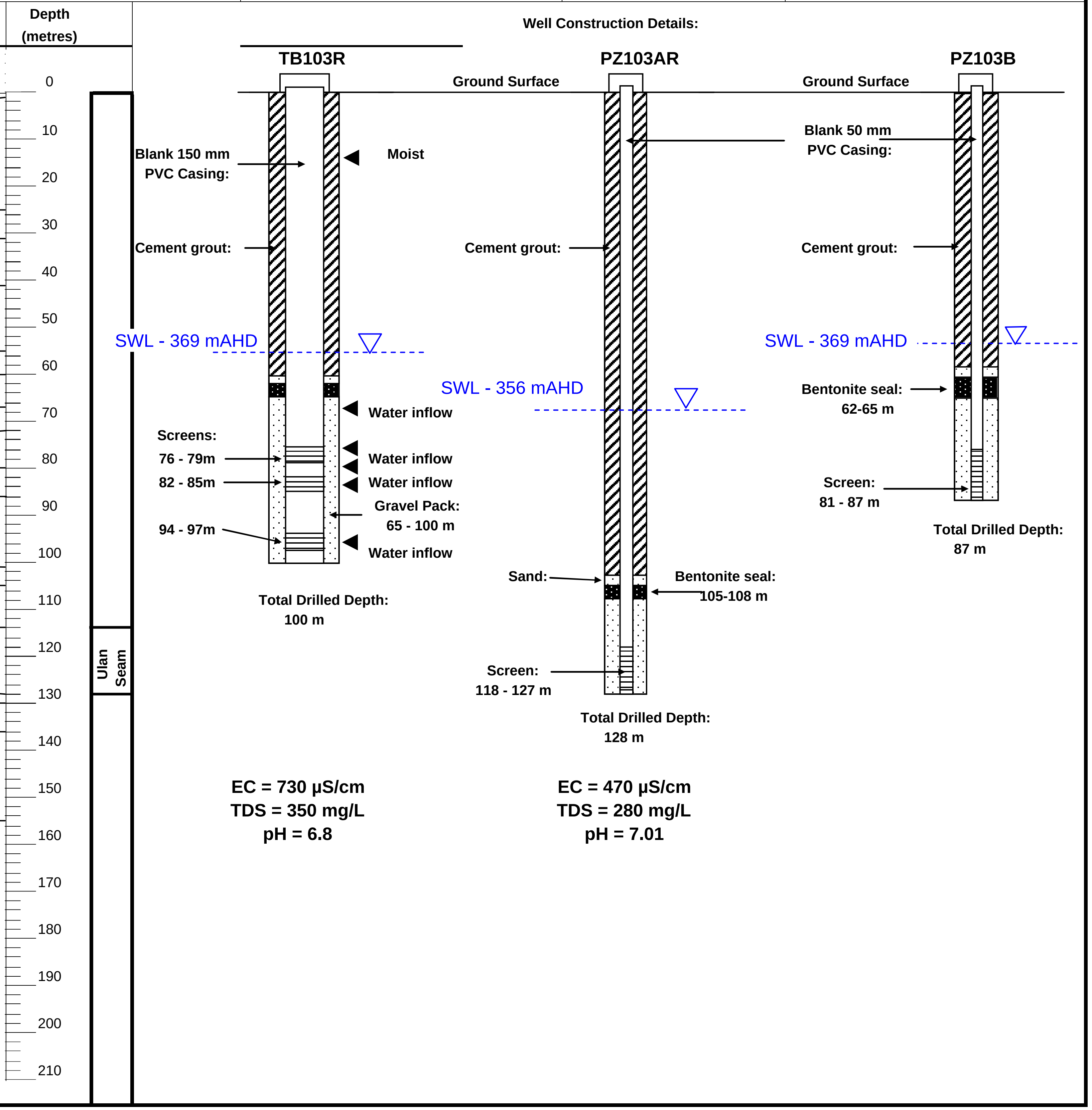
Carbonaceous shale

Coal - Ulan Seam

Carbonaceous shale

Sandstone - grey, silty

Sandstone - dark grey, interbedded shale



EC = 730 µS/cm
TDS = 350 mg/L
pH = 6.8

EC = 470 µS/cm
TDS = 280 mg/L
pH = 7.01

Figure B21: Bore Logs - TB103, PZ103A and PZ103B

Peter Dundon and Assoc.

Logging Sheet

BORE: PZ104

Project No: **05-0158**

Client:
Moolarben Coal Company

Location:
Moolarben Coal Company

Drilling Contractor:
Watermin Drillers

Elevation (GL): **438.500 mAHD**

Elevation (TOC **438.926 mAHD**

Stickup: **0.426 m**

Hole Depth: **160.0 m**

Date Started:

Date Complete **23 November 2004**

Supervised By: **R McCallum**

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

Sand - f-m, mottled yellow/orange/red

Sand - m-c-granular, off-white

Gravel - granular, off-white

Basic intrusion - grey, fresh, massive, hard

Claystone and coal

Sandstone, siltstone - grey, coaly wisps

Coal and claystone

Sandstone - grey, f-m, siltstone interbeds

Basic intrusion

Siltstone, interbedded sandstone, minor claystone

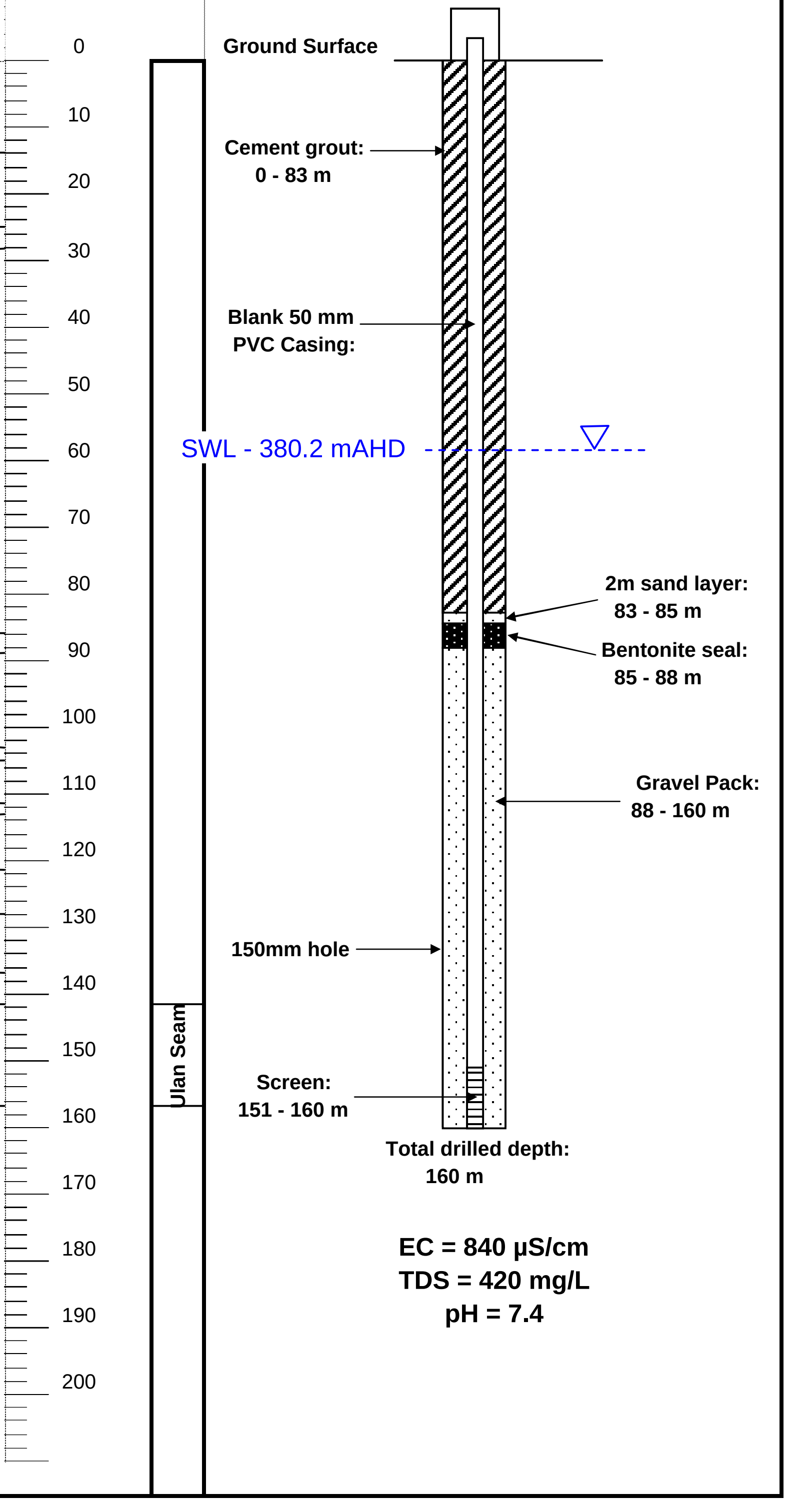
Interbedded siltstone/sandstone and igneous rock

Siltstone, minor interbedded sandstone

Sandstone - lt grey, f-m

Coal - Ulan Seam

Sandstone-conglomerate



EC = 840 µS/cm
TDS = 420 mg/L
pH = 7.4

Figure B22: Bore Log - PZ104

Peter Dundon and Assoc.
Logging Sheet

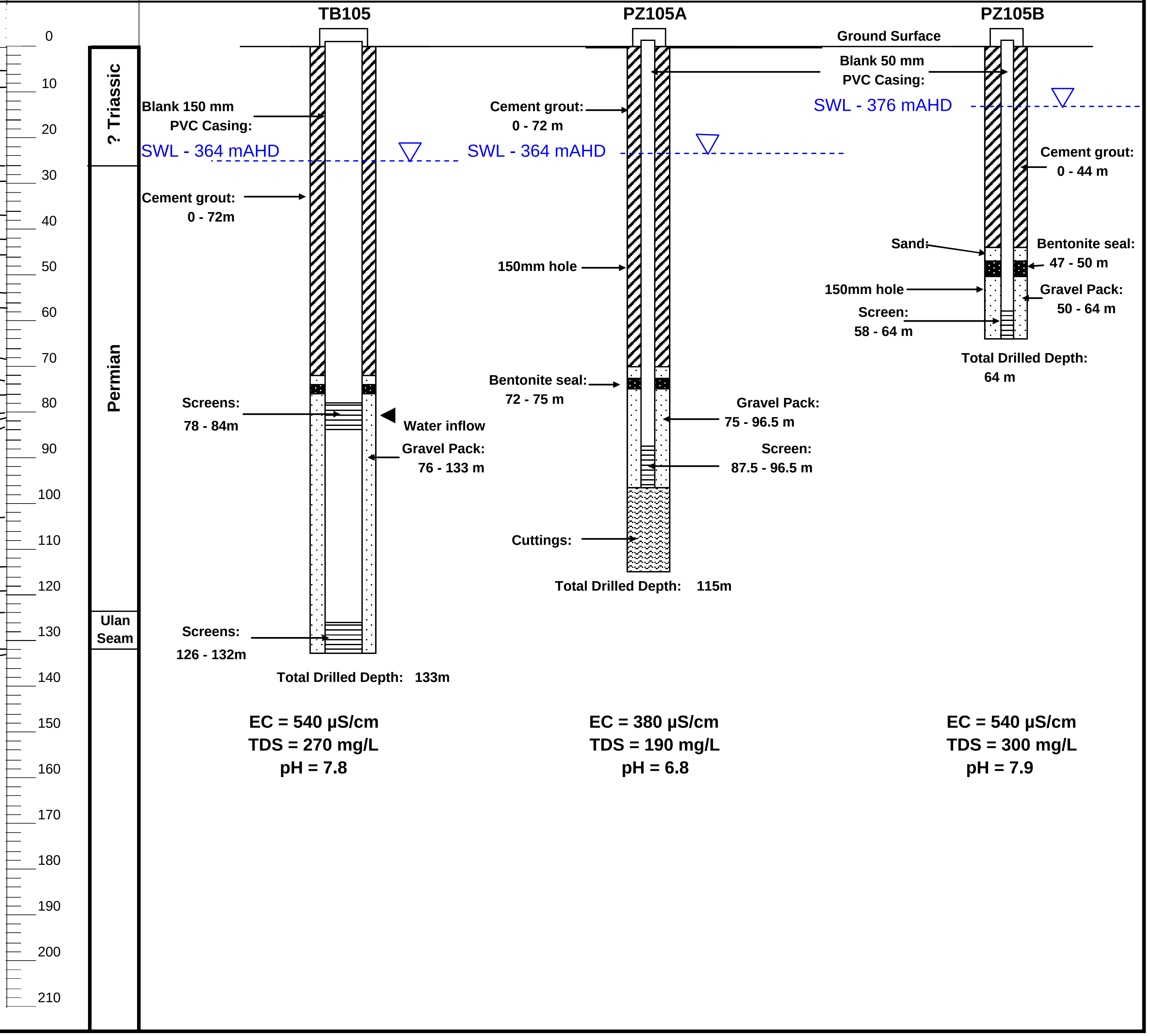
BORES: TB105, PZ105A and PZ105B

Project No: **05-0158**

Client:	Bore:	Elevation (Concrete):	Elevation (TOC):	Stickup:	Drilling Contractor:	Date Started:	Date Finished:
Moolarben Coal Company	**TB105**	**388.600 mAHD**	**388.780 mAHD**	**0.180 m**	**Watermin Drillers**	**05-Jan-06**	**16-Jan-06**
Location:	**PZ105A**	**388.184 mAHD**	**388.605 mAHD**	**0.421 m**	**Watermin Drillers**	**15-Dec-05**	**20-Dec-05**
Moolarben Coal Project	**PZ105B**	**388.736 mAHD**	**389.052 mAHD**	**0.316 m**	**Watermin Drillers**	**19-Dec-05**	**20-Dec-05**
			Hole depths: **As shown**			Supervised By: **R McCallum**	

Description	Depth (metres)	Well Construction Details:

Gravel conglomerate, yellow-white clay matrix
Sandstone - pink/white; shale/clay at base
Sandstone - grey-white, m-c, and gravel
Black carbonaceous shale / coal
Sandstone - lt grey/lt brown, minor siltstone
Shale - lt brown and grey
Sandstone - lt grey, with brown shale
Sandstone - fn grain
Claystone - dark grey / black carb shale
Shale/siltstone - thinly interbedded
Shale
Shale/siltstone - interbedded
Sandstone - vfg
Coal - coal and carbonaceous shale
Sandstone/coal - interbedded
Siltstone/sandstone - FeO stained at 83 to 84m
Claystone
Siltstone/shale - interbedded
Shale - carbonaceous
Coal - Ulan Seam, siderite layer at 126m
Siltstone



TB105	PZ105A	PZ105B
EC = 540 µS/cm	EC = 380 µS/cm	EC = 540 µS/cm
TDS = 270 mg/L	TDS = 190 mg/L	TDS = 300 mg/L
pH = 7.8	pH = 6.8	pH = 7.9

Figure B23: Bore Logs - PZ105A and PZ105B

Peter Dundon and Assoc.

Logging Sheet

BORES: PZ106A and PZ106B

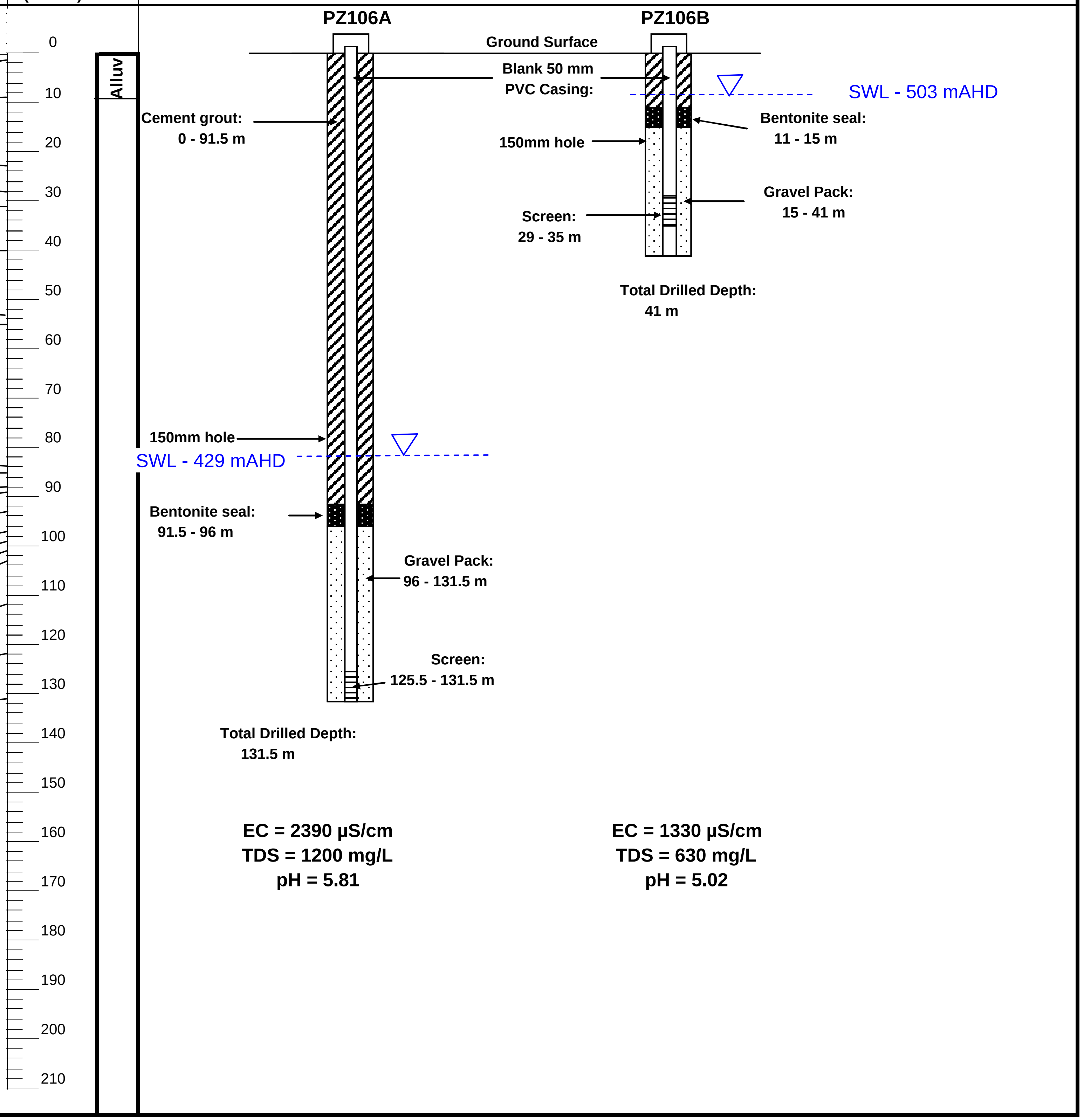
Project No:	**05-0158**

Client:	Bore:	Elevation (Concrete):	Elevation (TOC):	Stickup:	Drilling Contractor:	Date Started:	Date Finished:
Moolarben Coal Company	**PZ106A**	**510.492 mAHD**	**510.687 mAHD**	**0.195 m**	**Watermin Drillers**	**4-Jan-06**	**18-Jan-06**
Location:	**PZ106B**	**510.718 mAHD**	**510.907 mAHD**	**0.189 m**	**Watermin Drillers**	**17-Jan-06**	**18-Jan-06**
Moolarben Coal Project							

Hole depths:		Supervised By:
As shown		**R McCallum**

Description	Depth (metres)	Well Construction Details:

Sand/Gravel - f-m, mottled yellow/orange/red
Sand - f-m, poorly sorted
Claystone - oxidized
Sandstone - fine grained
Coal
Siltstone - interlaminae of shale
Siltstone/shale - interbedded
Sand - m gr to pebble size
Sandstone/shale and siltstone
- interbedded sequence of f sandstone, carbonaceous shales and laminated siltstone
Coal
Carbonaceous Shale
Coal
Carbonaceous Shale
Sandstone - f grained
Coal
Shale
Mudstone
Sandstone-fn grain
Siltstone, laminated
Shale



PZ106A	PZ106B
EC = 2390 µS/cm	**EC = 1330 µS/cm**
TDS = 1200 mg/L	**TDS = 630 mg/L**
pH = 5.81	**pH = 5.02**

Figure B24: Bore Logs - PZ106A and PZ106B

Peter Dundon and Assoc.

Logging Sheet

BORE: PZ107

		Project No:	05-0158
Client: **Moolarben Coal Company**	Elevation (Concr) Elevation (TOC):	**498.998 mAHD** **499.361 mAHD**	
Location: **Moolarben Coal Company**	Stickup: Hole Depth:	**0.363 m** **125 m**	
Drilling Contractor: **Watermin Drillers**	Date Started: Date Completed:	 **23 November 2004**	Supervised By: **R McCallum**

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

Sandy clay top soil

Shale - slightly carbonaceous

Sandstone - fine grained

Laminated f sandstone / carbonaceous shale

Sand - m-c, minor clay

Sandstone - f grained

Claystone/siltstone

Carbonaceous shale, grading to coal 27 to 28m

Sandstone - f gr, minor siltstone beds

Shale

Siltstone

Shale/siltstone - interbedded

Coal - Ulan Seam, minor carbonaceous shale

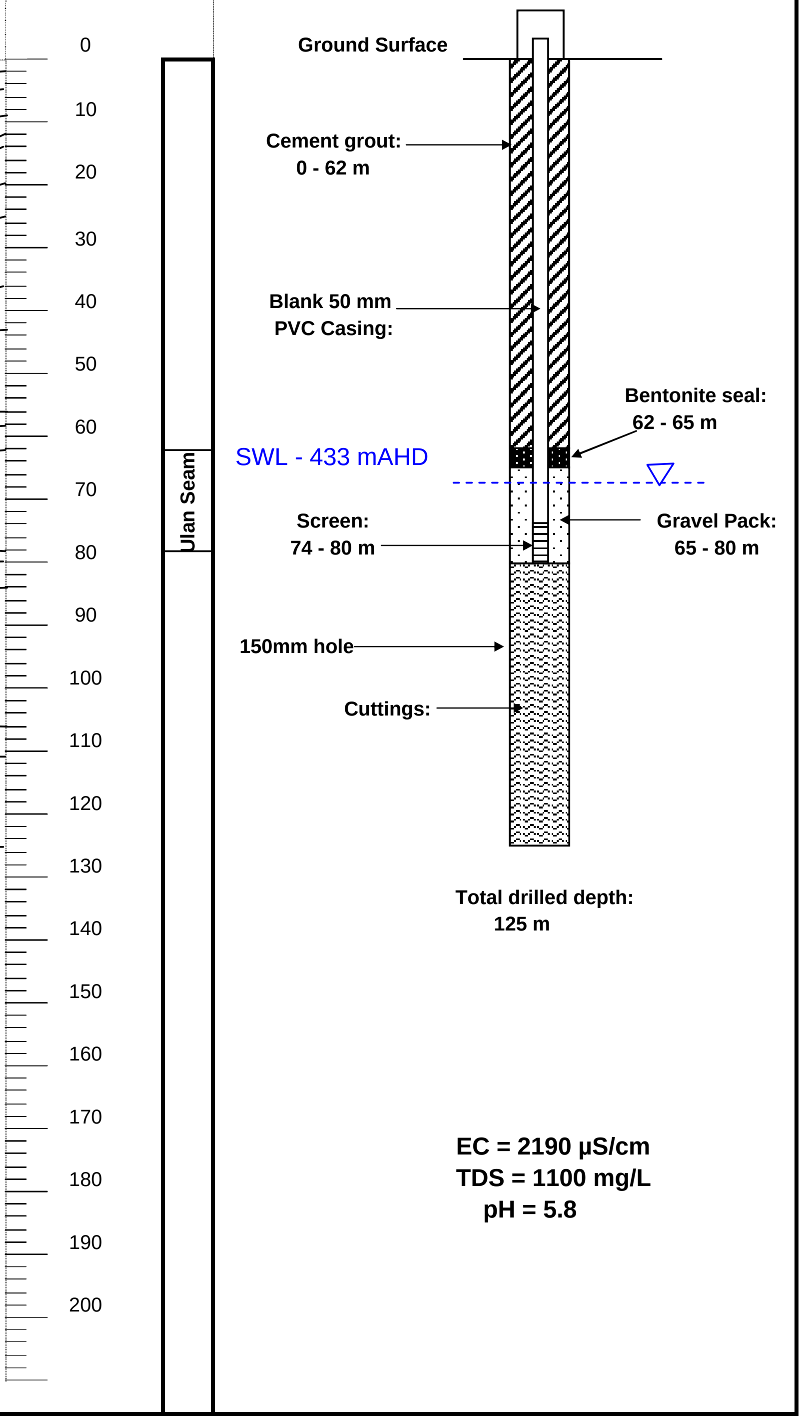
Shale - carbonaceous

Sandstone - f grained

Claystone - minor carbonaceous beds
and mudstone with lithic fragments

Conglomerate - qtz pebbles set in clay matrix

Claystone - very siliceous
(possible contact metamorphism)



EC = 2190 µS/cm
TDS = 1100 mg/L
pH = 5.8

Figure B25: Bore Log - PZ107

Peter Dundon and Assoc.

BORE: PZ108R

Logging Sheet

Project No: **05-0158**

Client: **Moolarben Coal Company**

Location: **Moolarben Coal Company**

Drilling Contractor: **Watermin Drillers**

Elevation (Concr): **419.366 mAHD**

Elevation (TOC): **419.463 mAHD**

Stickup: **0.10 m**

Hole Depth: **227.0 m**

Date Started:

Date Completed: **23 November 2004**

Supervised By: **R McCallum**

Description

Topsoil

Sandstone - FeO cemented

Sand - m-c grained

Sand - f grained, weakly cemented;
minor bands kaolin clay

Sands - m-c grained, gravelly.
Cemented and f grained at 47 to 51m

Sandstone - purple FeO stained

Sands - m grained

Sandstone, conglomerate - chert,qtz pebbles in
f grained sandstone matrix

Coal

Shale/conglomerate/sandstone - transition

Sandstone/shale - laminated

Coal

Sandstone/shale - interbedded

Shale - carbonaceous with minor beds sandstone

Sandstone/shale-interbedded

Sandstone - f grained

Shale/siltstone - interbedded

Shale-carbonaceous

Coal - thin beds in carbonaceous shale

Shale - carbonaceous

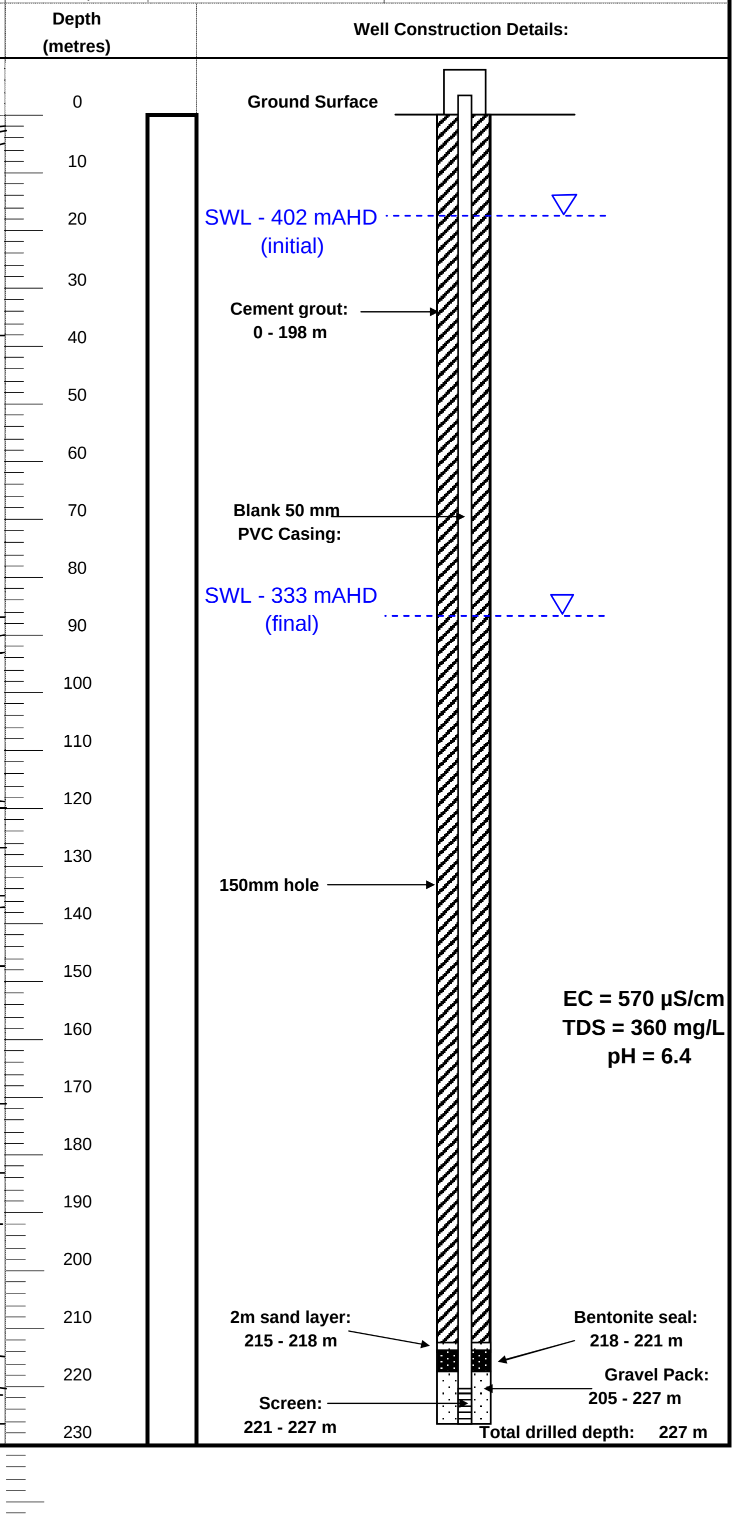


Figure B26: Bore Log - PZ108

Peter Dundon and Assoc.
Logging Sheet

BORE: PZ109

Project No: **05-0158**

Client: **Moolarben Coal Company**
Location: **Moolarben Coal Company**
Drilling Contractor: **Watermin Drillers**

Elevation (Concr): **436.644 mAHD**
Elevation (TOC): **437.115 mAHD**
Stickup: **0.47 m**
Hole Depth: **254.0 m**
Date Started:
Date Completed: **23 November 2004**
Supervised By: **R McCallum**

Description

Topsoil
Silty clay
Sandstone/shale-interbedded
Sand - m-c grained
Claystone - with occasional siltstone laminae
Claystone - FeO stained, some vughs 57m
Shale/siltstone - interbedded FeO stained and cemented
Quartz conglomerate - conglomerate with weakly cemented fgr quartz sandstone
Claystone - FeO stained
Sandstone conglomerate - chert,qtz pebbles in f-gr sandstone matrix
Claystone - FeO stained
Sandstone - fine grained
Sandstone conglomerate - chert, qtz pebbles in f grained sandstone matrix
Claystone - FeO stained
Sandstone conglomerate - chert, qtz pebbles in f grained sandstone matrix
Carbonaceous shale, trace coal
Sandstone conglomerate - chert,qtz pebbles in f grained sandstone matrix
Coal
Sandstone - f grained
Sandstone/shale-interbedded
Shale
Very carbonaceous shale
Shale - carbonaceous
Coal/shale - very carbonaceous shale
Siltstone/shale

Depth (metres)

Well Construction Details:

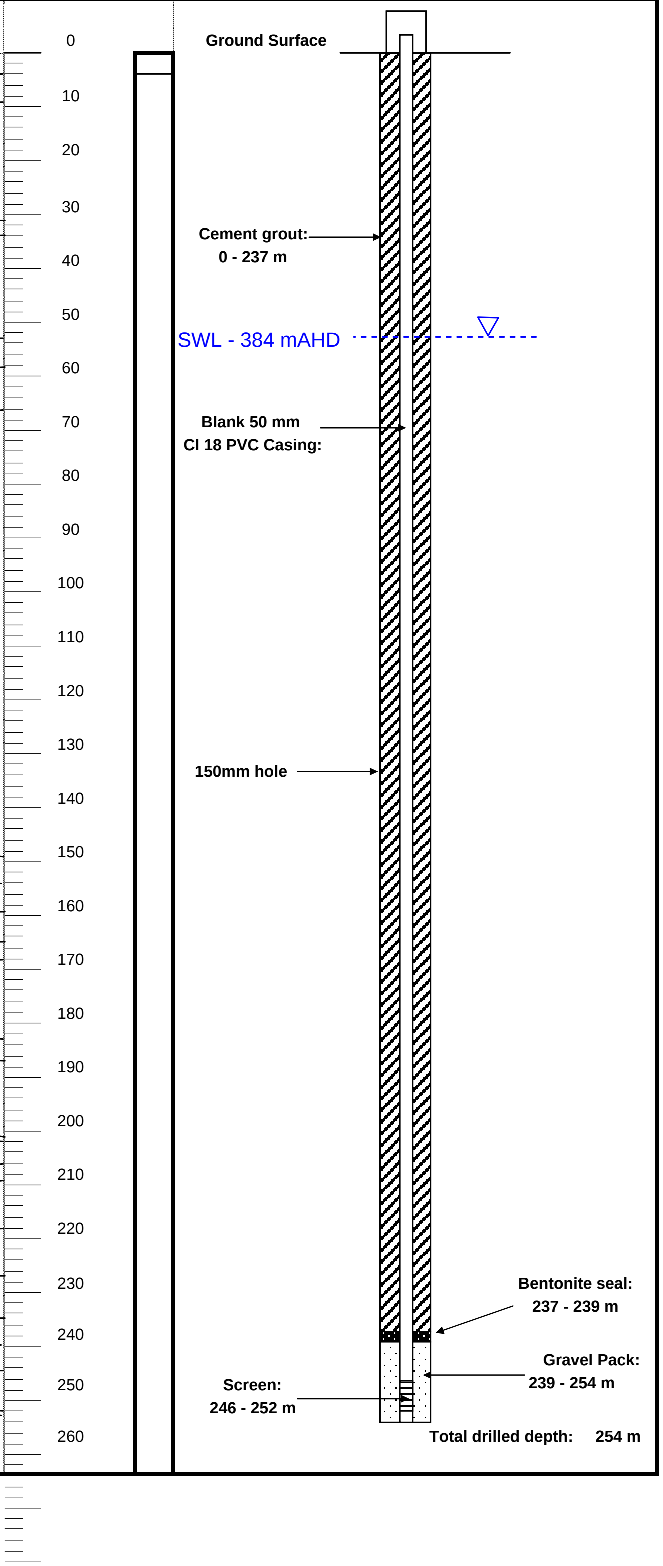


Figure B27: Bore Log - PZ109

Peter Dundon and Assoc.

Logging Sheet

BORE: PZ110

		Project No:	**05-0158**
Client: **Moolarben Coal Company**	Elevation (Concr) Elevation (TOC):	**428.387 mAHD** **428.717 mAHD**	
Location: **Moolarben Coal Company**	Stickup: Hole Depth:	**0.33 m** **134.5 m**	
Drilling Contractor: **Watermin Drillers**	Date Started: Date Completed:	**21 April 2006** **1 May 2006**	Supervised By: **R McCallum**

Description	Depth (metres)	Well Construction Details:

Sand - red

Clay - white, iron-stained; minor siltstone, mudstone

Siltstone - grey - pale grey, minor clay

Carbonaceous shale

Sandstone - pale grey; Siltstone - medium grey

Coal - carbonaceous shale

Sandstone - pale grey; Siltstone - med grey

Siltstone - med to dark grey

Carbonaceous shale

Siltstone - dark and medium grey

Clay - grey, some med grey siltstone

Carbonaceous shale and pale grey fine sandstone

Sandstone - pale grey, fine; some carb shale

Coal

Carbonaceous shale

Coal

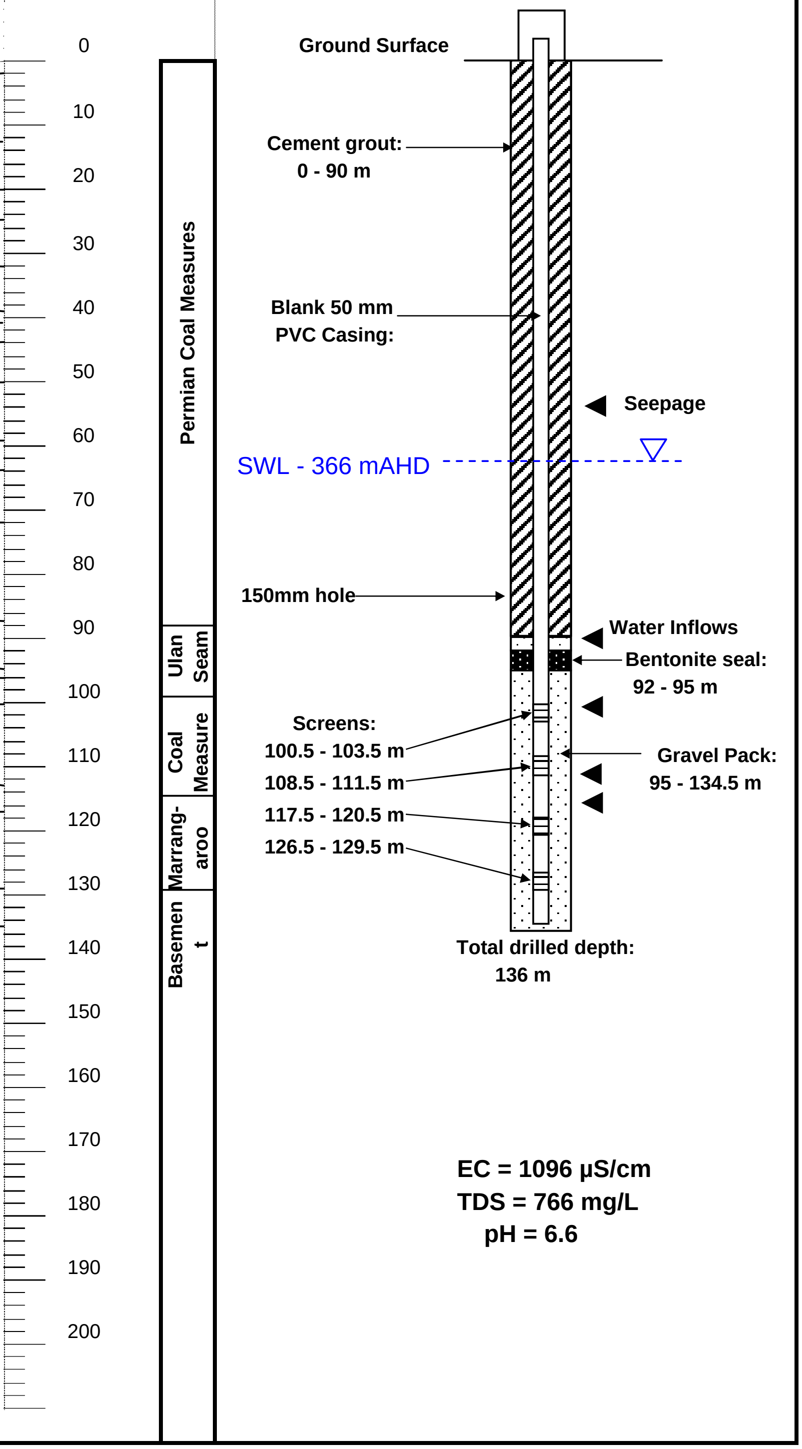
Siltstone - dark-med grey; sandstone, pale grey, fine

Mudstone - pale grey; sandstone - pale grey, fine

Siltstone - med to dark grey

Volcanic sediment?

Shale



EC = 1096 µS/cm
TDS = 766 mg/L
pH = 6.6

Figure B28: Bore Log - PZ110

Peter Dundon and Assoc.

Logging Sheet

BORE: PZ111

		Project No:	**05-0158**
Client: **Moolarben Coal Company**	Elevation (GL):	**404.553 mAHD**	
	Elevation (TOC	**404.783 mAHD**	
Location: **Moolarben Coal Project**	Stickup:	**0.23 m**	
	Hole Depth:	**83 m**	
Drilling Contractor: **Watermin Drillers**	Date Started:	**21 April 2006**	Supervised By:
	Date Complete	**24 April 2006**	**R McCallum**

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

Clay - grey, some Fe staining; some sand at base

Clay - yellow-khaki

Carbonaceous shale, with coal lenses

Siltstone - grey

Siltstone - grey, with carbonaceous lenses

Carbonaceous shale; minor siltstone

Siltstone - light grey

Sandstone - pale grey to white; minor carb shale

Carbonaceous shale

Siltstone - dark grey to light grey

Shale/mudstone - dark grey

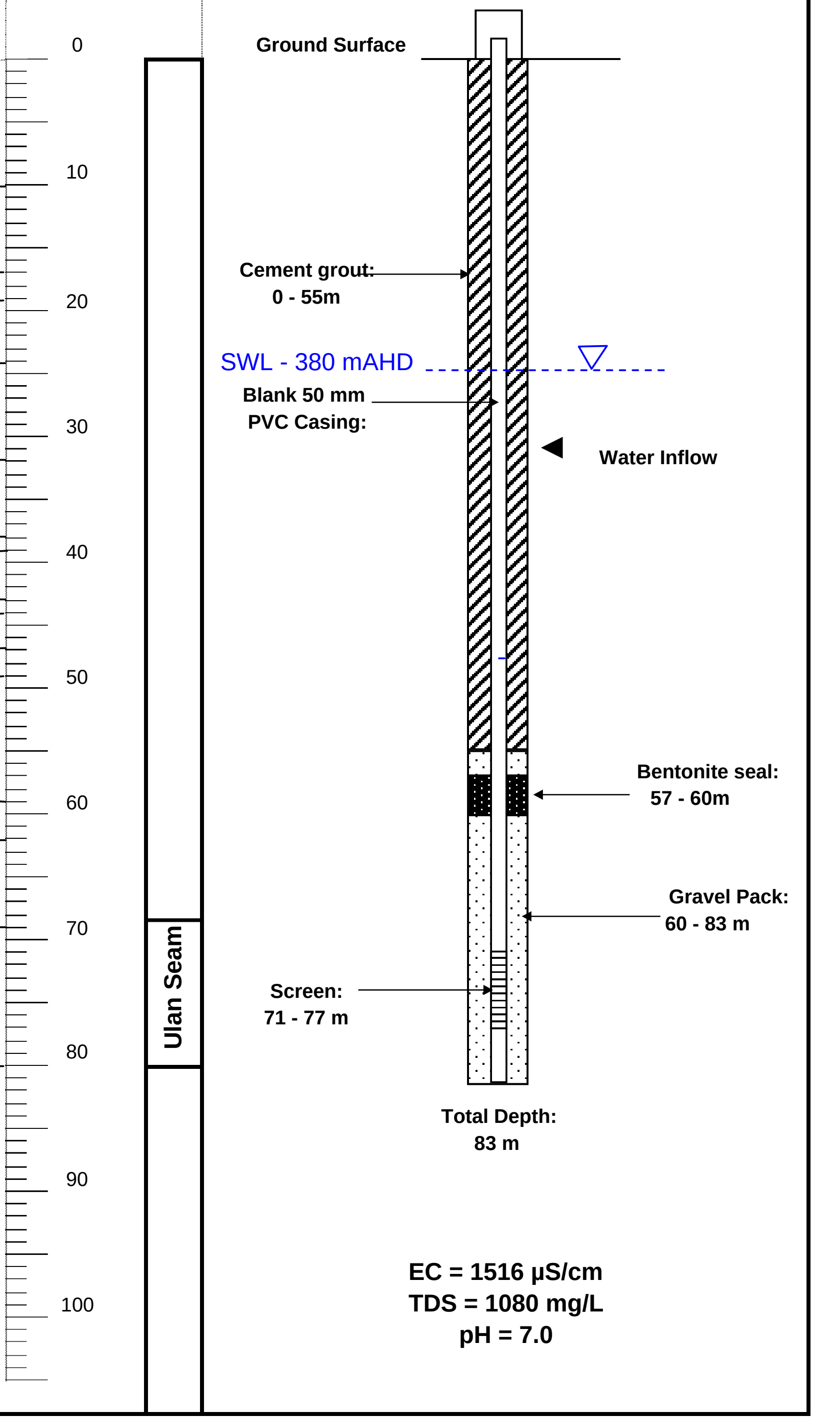
Carbonaceous shale, some dark grey siltstone lenses

Siltstone - med grey; some mudstone

Carbonaceous shale

Coal with some carbonaceous shale

Siltstone to fine sandstone - pale grey



EC = 1516 µS/cm

TDS = 1080 mg/L

pH = 7.0

Figure B29: Bore Log - PZ111

Peter Dundon and Assoc.

Logging Sheet

BORES: PZ112A and PZ112B

Project No: **05-0158**

Client:	Bore:	Elevation (GL):	Elevation (TOC):	Stickup:	Drilling Contractor:	Date Started:	Date Finished:
Moolarben Coal Company	**PZ112A**	**485.403 mAHD**	**485.643 mAHD**	**0.24 m**	**Watermin Drillers**	**26-Apr-06**	**28-Apr-06**
Location:	**PZ112B**	**485.294 mAHD**	**485.674 mAHD**	**0.38 m**	**Watermin Drillers**	**28-Apr-06**	**28-Apr-06**
Moolarben Coal Company							
			Hole depths: **As shown**			Supervised By: **R McCallum**	

Description

Fine gravel to pebbles

Sandstone - Fe stained; and Clay

Clay - pale grey, Fe-staining

Siltstone - grey; with some clay and Fe staining

Carbonaceous shale

Siltstone - dark grey

Sandstone - pale grey

Coal

Siltstone - pale grey

Siltstone/shale - med gray

Siltstone - dark grey / carbonaceous shale

Sandstone - fine, pale grey

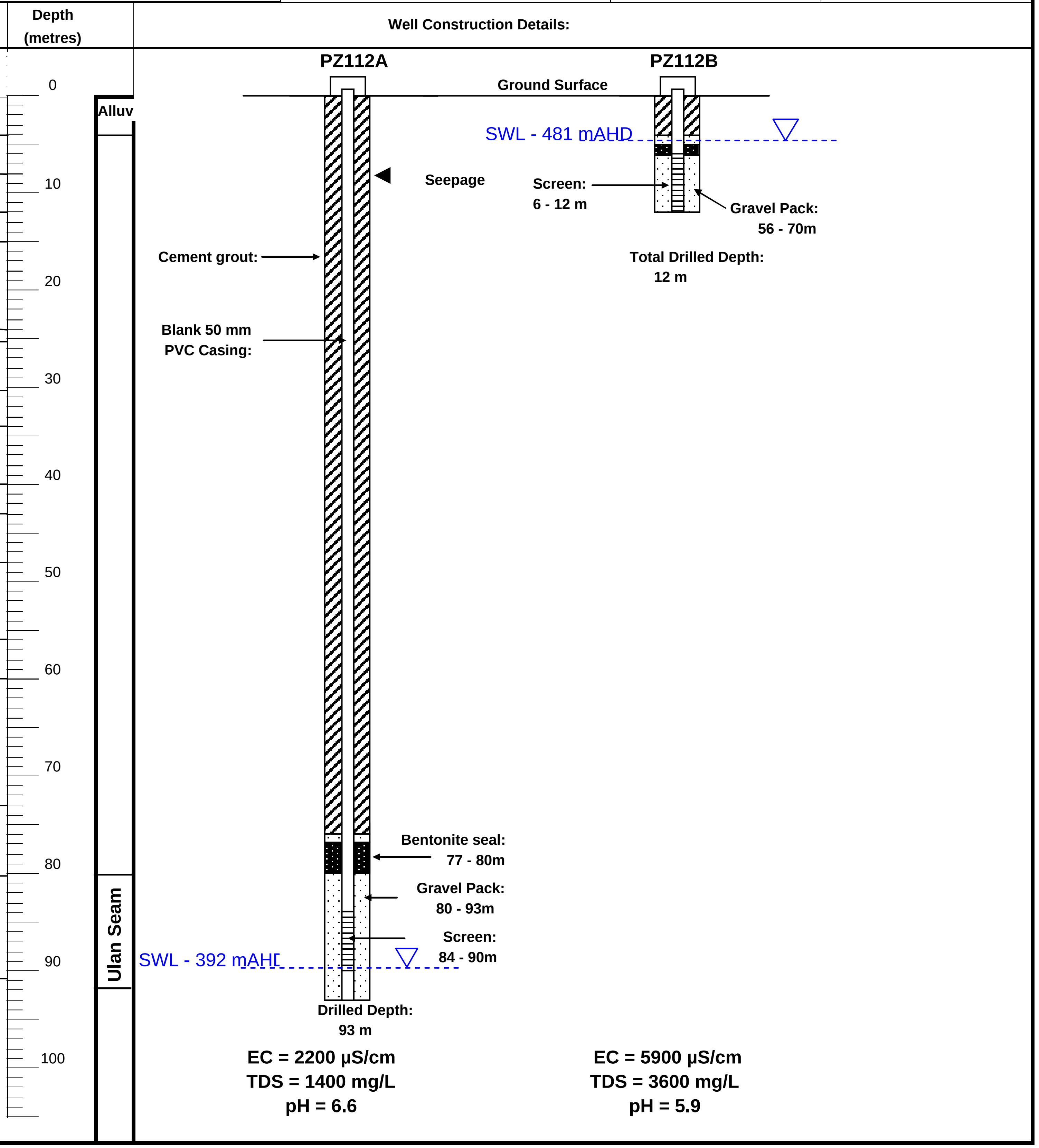
Siltstone - dark grey

Carbonaceous shale; lenses of dark grey siltstone

Carbonaceous shale

Coal, some carb shale

Siltstone/sandstone - grey



EC = 2200 µS/cm
TDS = 1400 mg/L
pH = 6.6

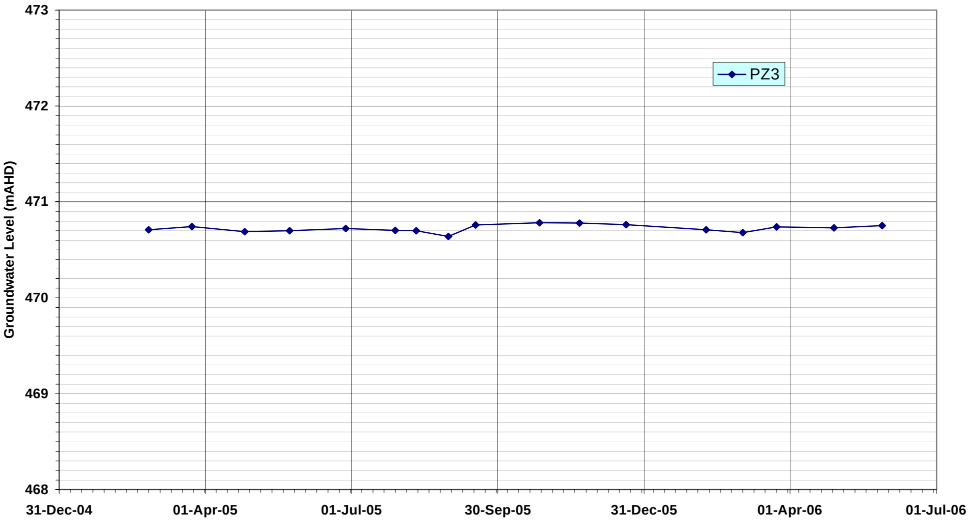
EC = 5900 µS/cm
TDS = 3600 mg/L
pH = 5.9

Figure B30: Bore Logs - PZ112A and PZ112B

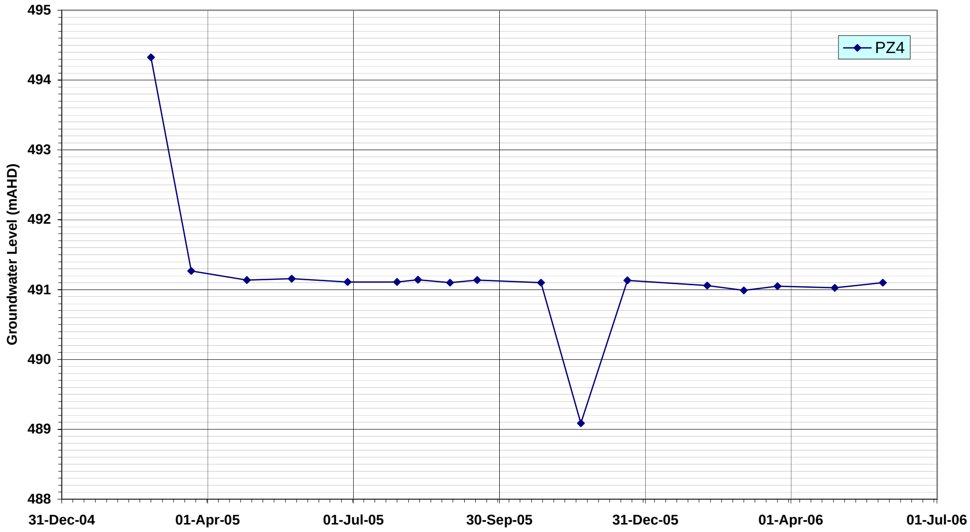
APPENDIX C

GROUNDWATER LEVEL HYDROGRAPHS

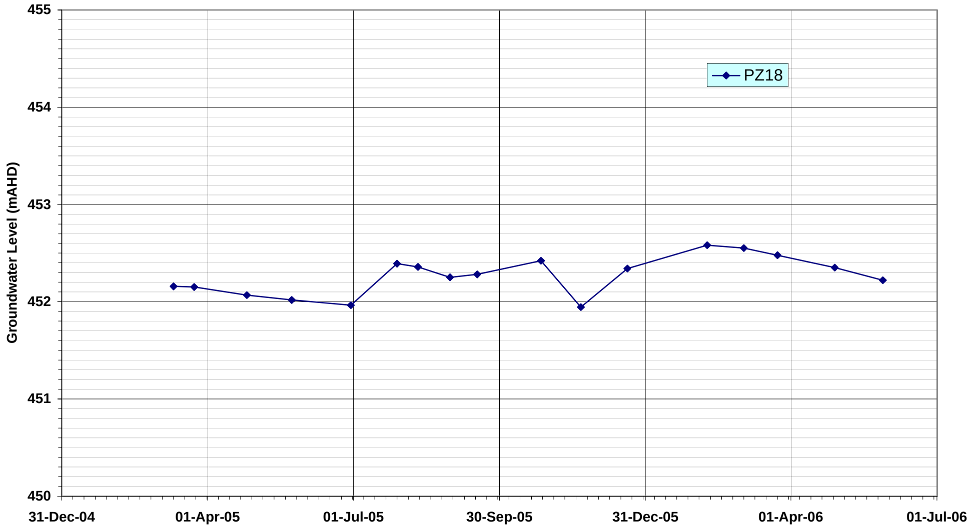
HYDROGRAPH - PZ3



HYDROGRAPH - PZ4

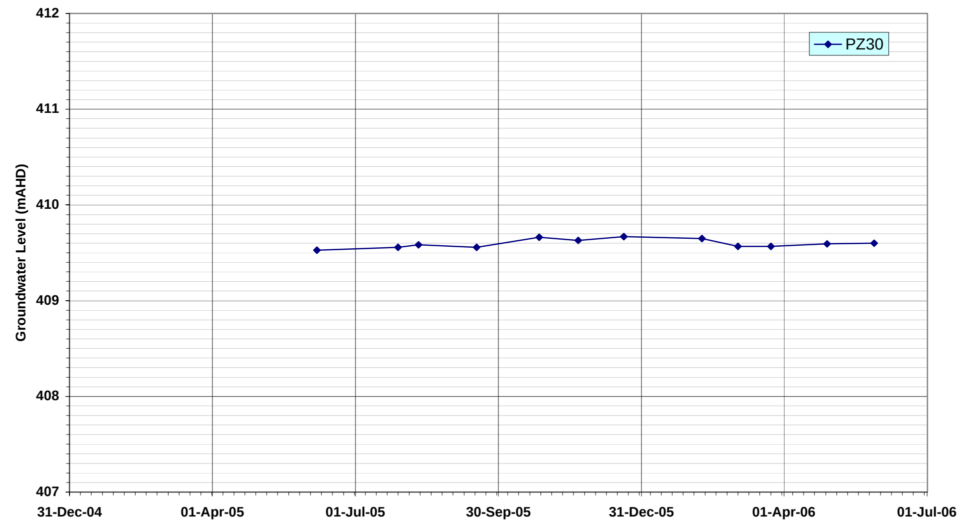


HYDROGRAPH - PZ18

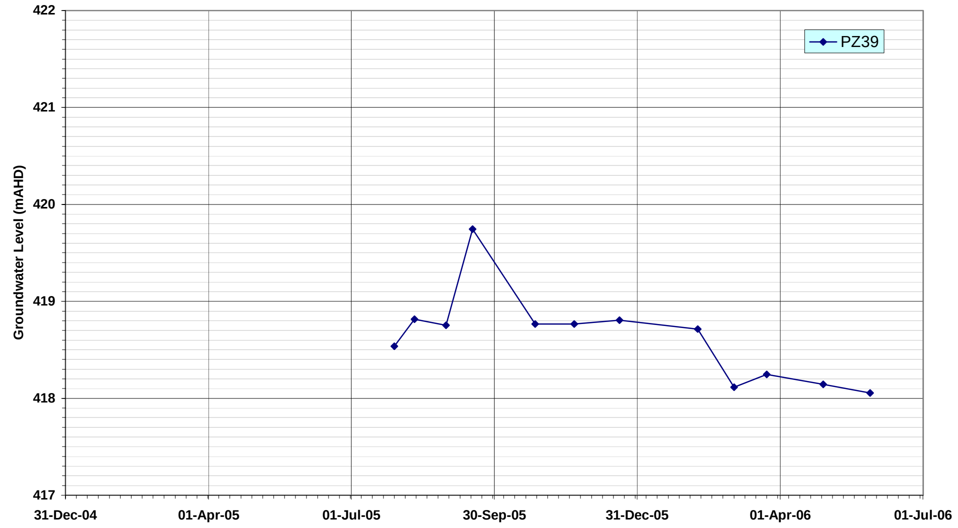


Date: 12 June 2006	Scale: as indicated	**Moolarben Coal Mines Pty Ltd**	
Initials: PJD	Job No: 05-0158	**MOOLARBEN COAL PROJECT PIEZOMETER HYDROGRAPHS - PZ03, PZ04, PZ18**	
Drawing No: 05-0158-106	Rev: 0		
Peter Dundon & Associates Pty Limited			**Figure C1**

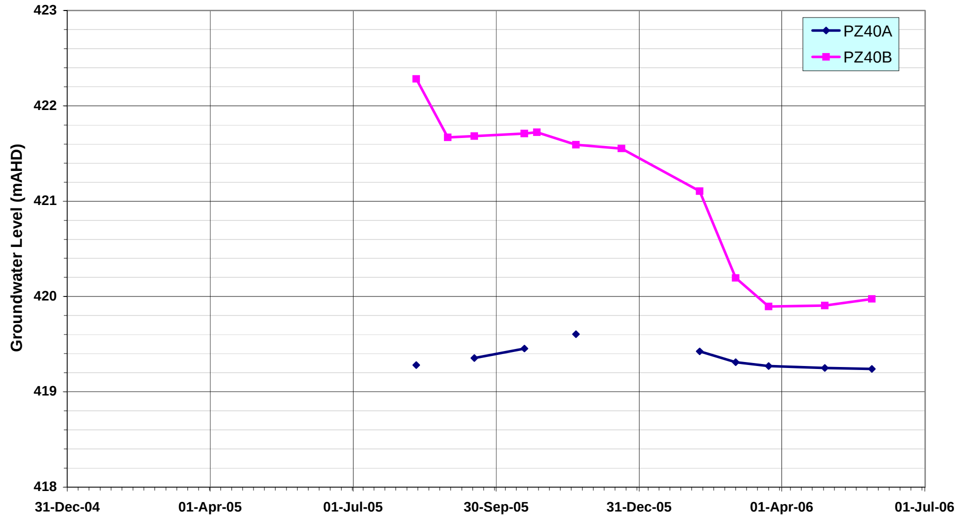
HYDROGRAPH - PZ30



HYDROGRAPH - PZ39



HYDROGRAPH - PZ40A and PZ40B



Date:	12 June 2006	Scale:	as indicated
Initials:	PJD	Job No:	05-0158
Drawing No:	05-0158-107	Rev:	0

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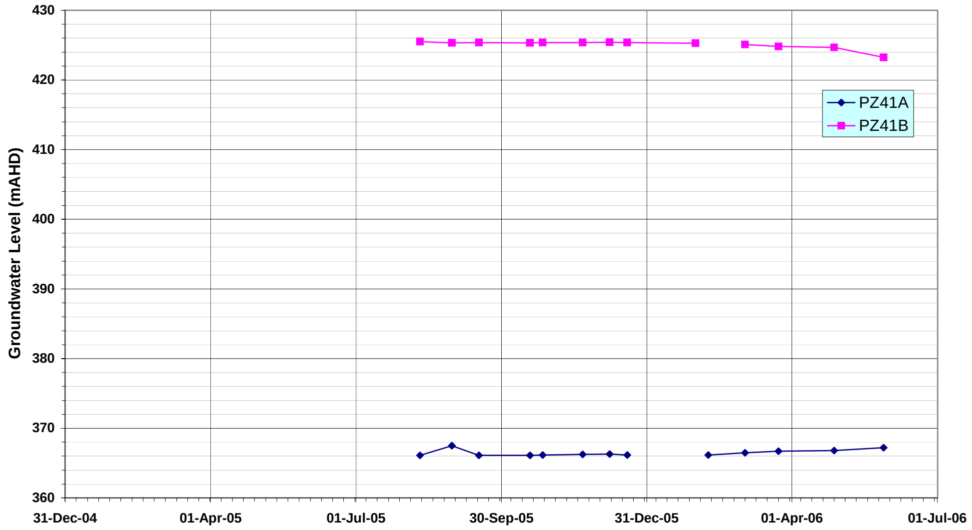
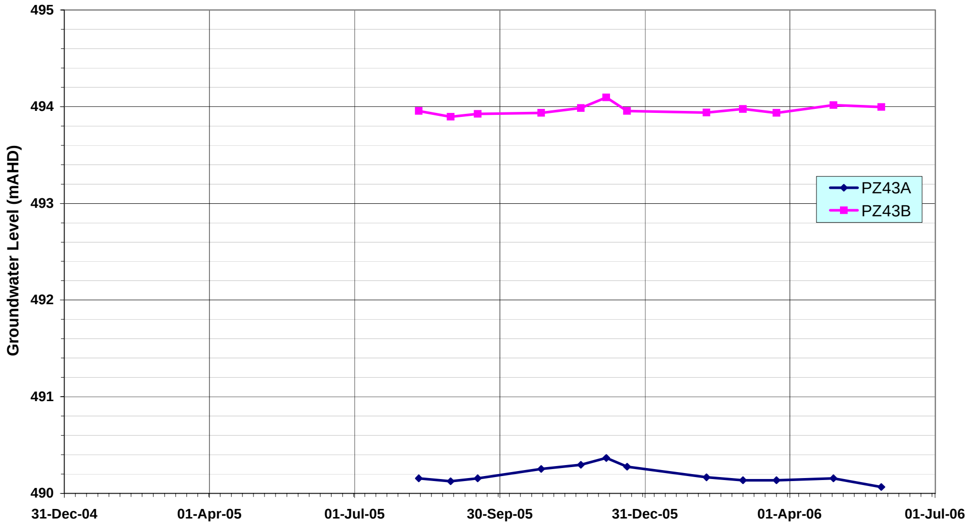
MOOLARBEN COAL PROJECT
PIEZOMETER HYDROGRAPHS -
PZ30, PZ39, PZ40A and B

Figure C2

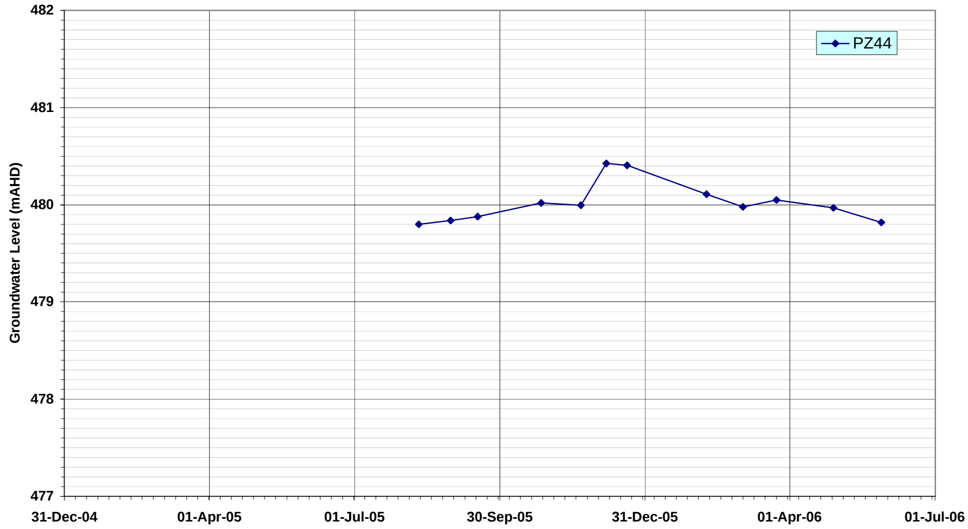
HYDROGRAPHS - PZ41A and PZ41B



HYDROGRAPH - PZ43A and PZ43B



HYDROGRAPH - PZ44



Date:	12 June 2006	Scale:	as indicated
Initials:	PJD	Job No:	05-0158
Drawing No:	05-0158-108	Rev:	0

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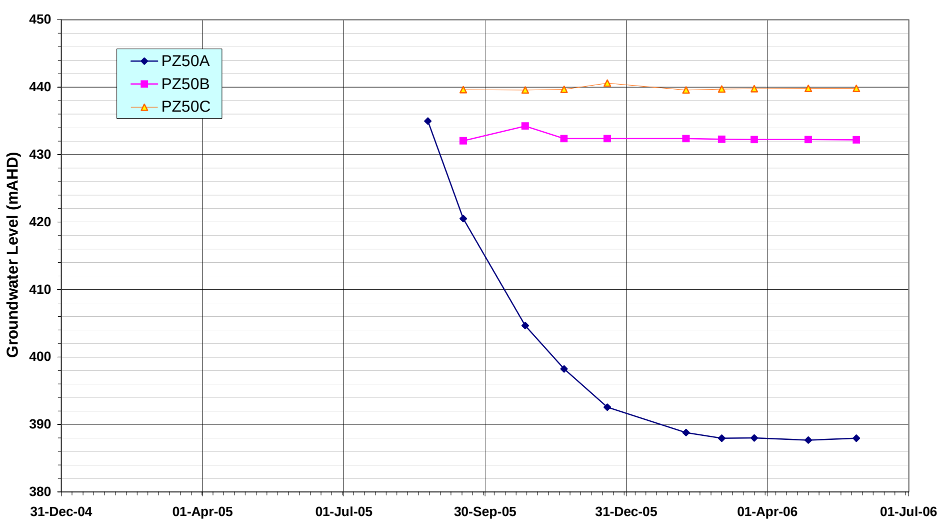
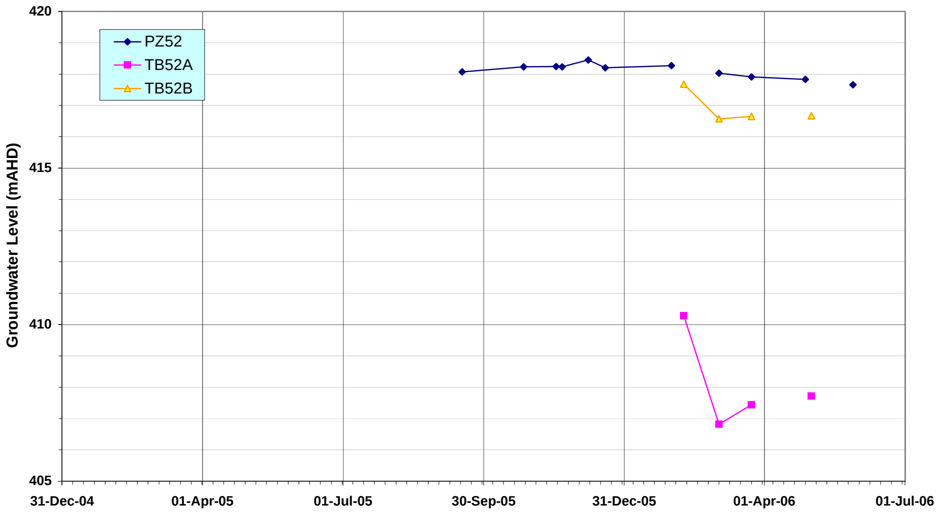
MOOLARBEN COAL PROJECT
PIEZOMETER HYDROGRAPHS -
PZ41A and B, PZ43A and B, PZ44

Figure C3

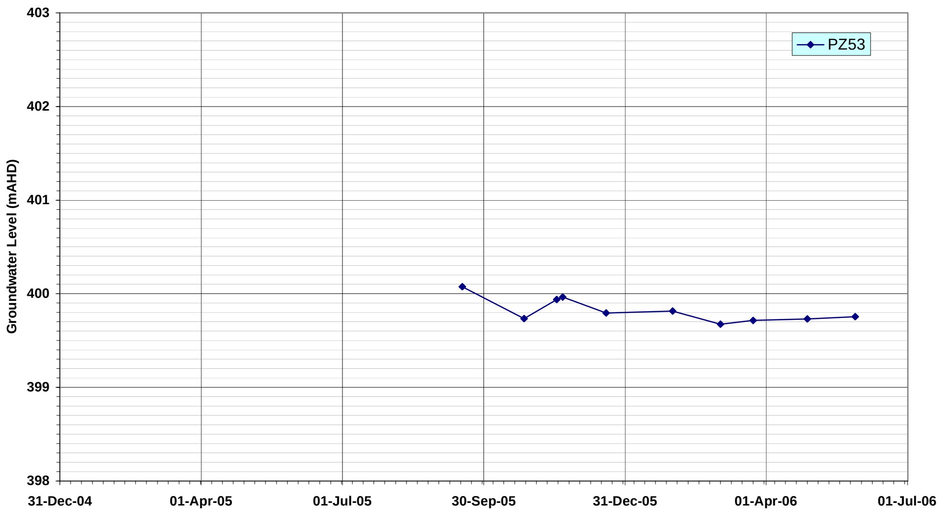
HYDROGRAPH - PZ50A, PZ50B and PZ50C



HYDROGRAPH - PZ52



HYDROGRAPH - PZ53



Date:	12 June 2006	Scale:	as indicated
Initials:	PJD	Job No:	05-0158
Drawing No:	05-0158-109	Rev:	0

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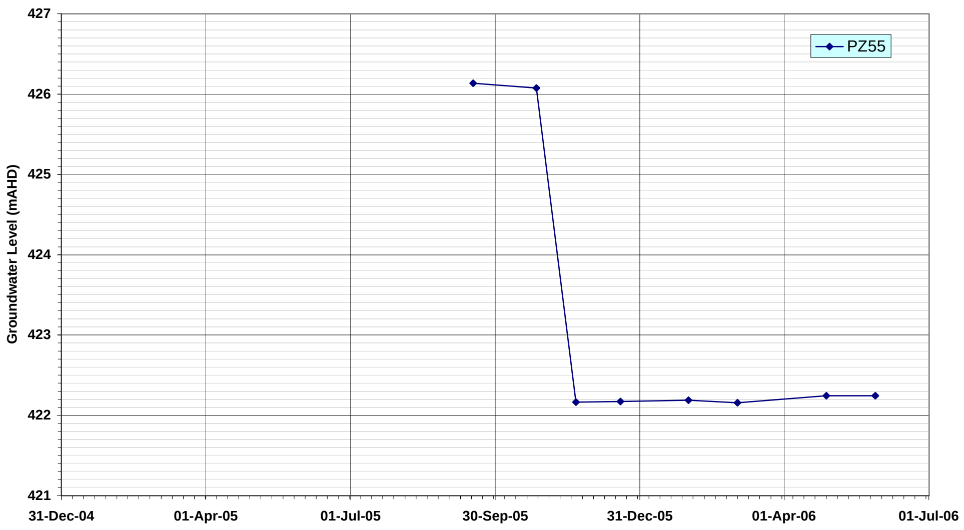
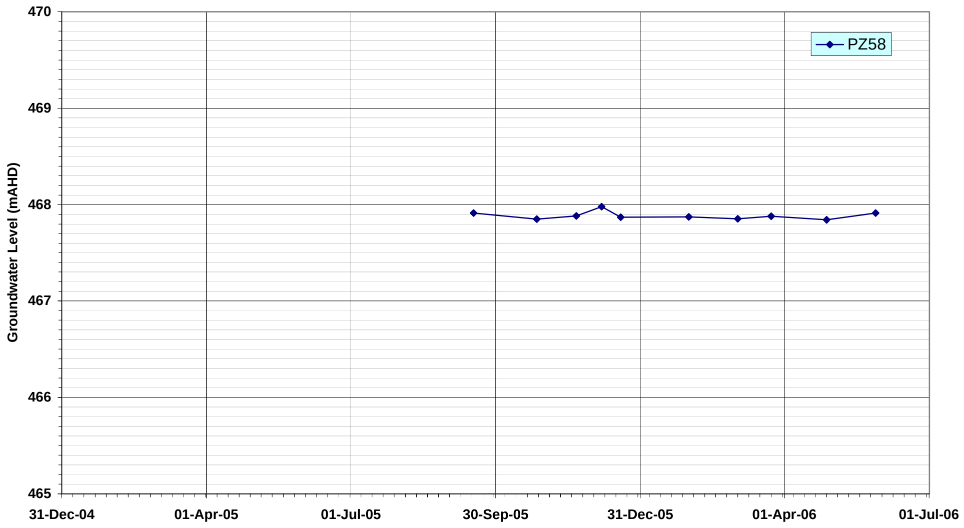
MOOLARBEN COAL PROJECT
PIEZOMETER HYDROGRAPHS -
PZ50A to C, PZ52, TB52A and B,
PZ53

Figure C4

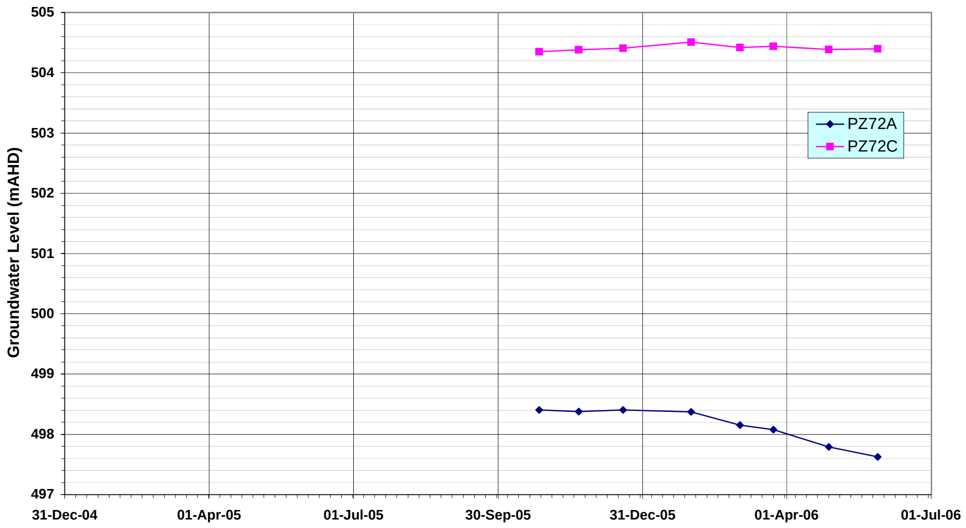
HYDROGRAPH - PZ55



HYDROGRAPH - PZ58



HYDROGRAPH - PZ72A and PZ72C



Date:	12 June 2006	Scale:	as indicated
Initials:	PJD	Job No:	05-0158
Drawing No:	05-0158-110	Rev:	0

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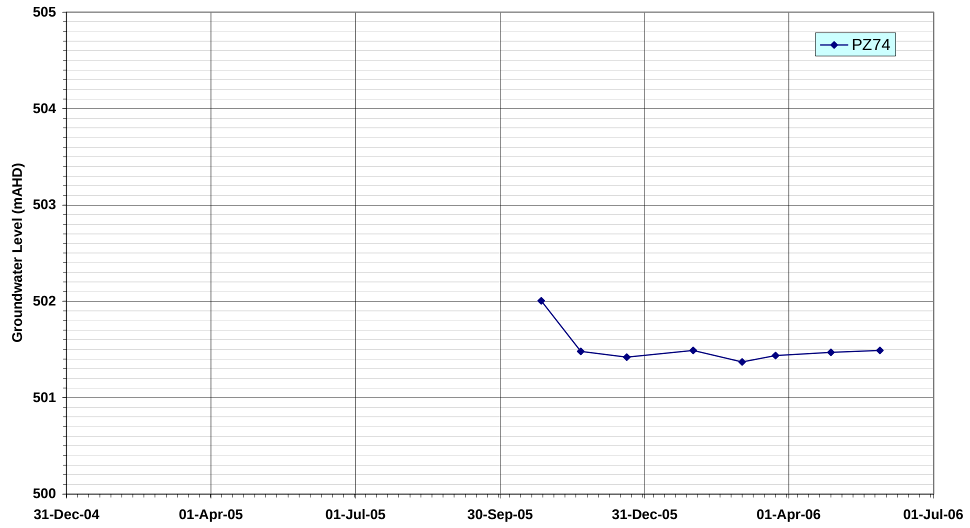
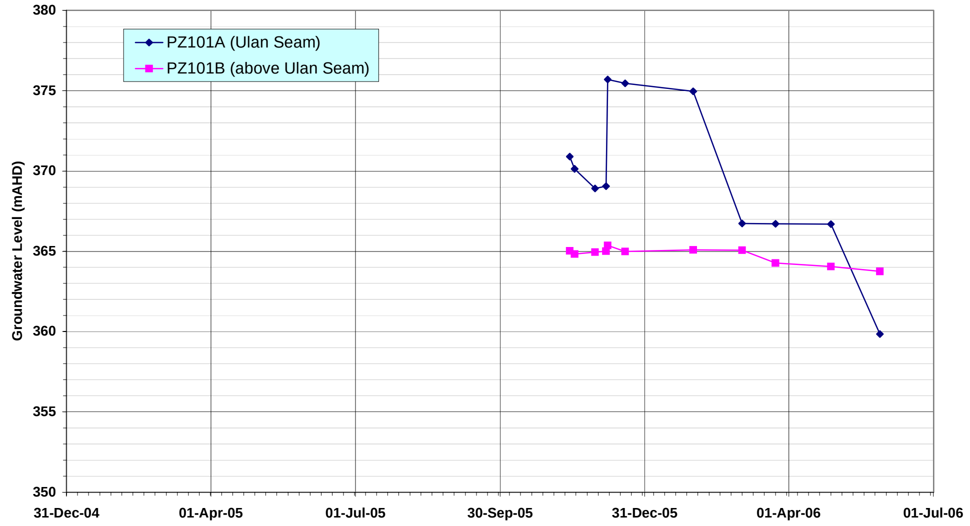
MOOLARBEN COAL PROJECT
PIEZOMETER HYDROGRAPHS -
PZ55, PZ58, PZ72A and C

Figure C5

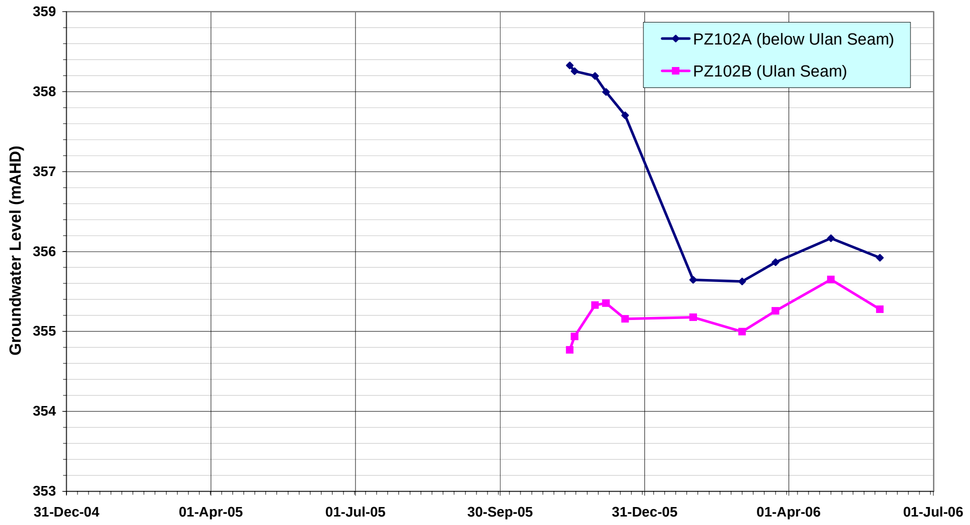
HYDROGRAPH - PZ74



HYDROGRAPH - PZ101A and PZ101B



HYDROGRAPH - PZ102A and PZ102B



Date:	12 June 2006	Scale:	as indicated
Initials:	PJD	Job No:	05-0158
Drawing No:	05-0158-111	Rev:	0

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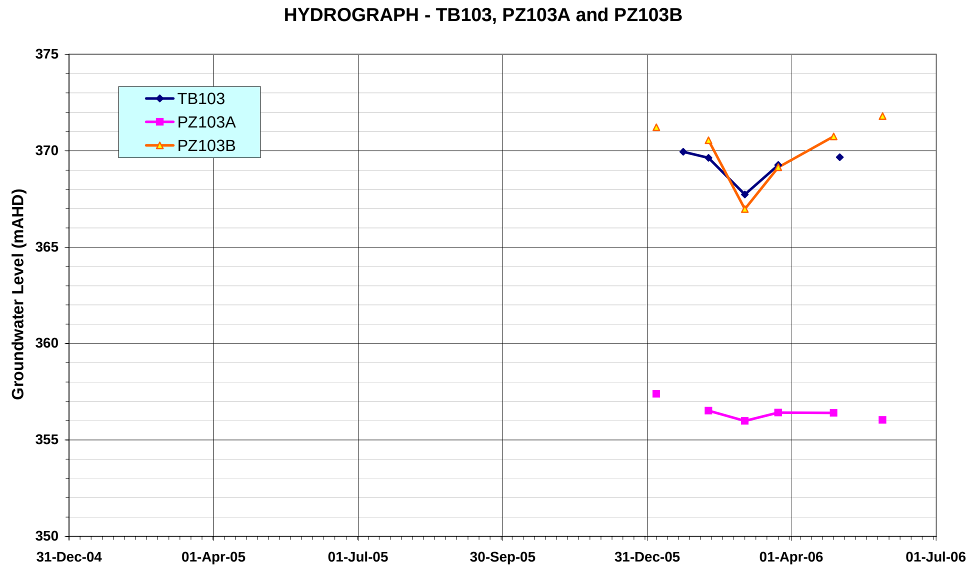
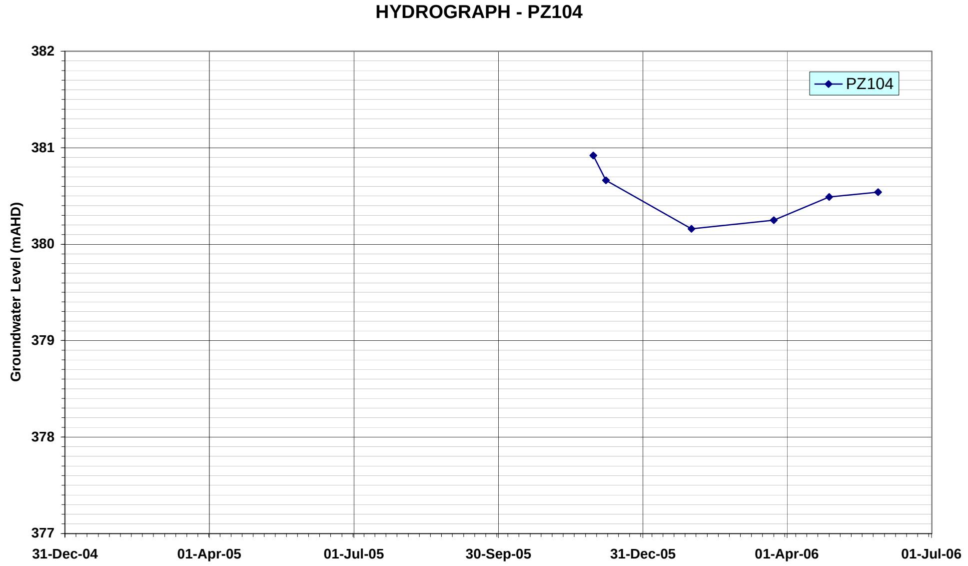
Moolarben Coal Mines Pty Ltd

MOOLARBEN COAL PROJECT
PIEZOMETER HYDROGRAPHS -
PZ74, PZ101A and B, PZ102A and B

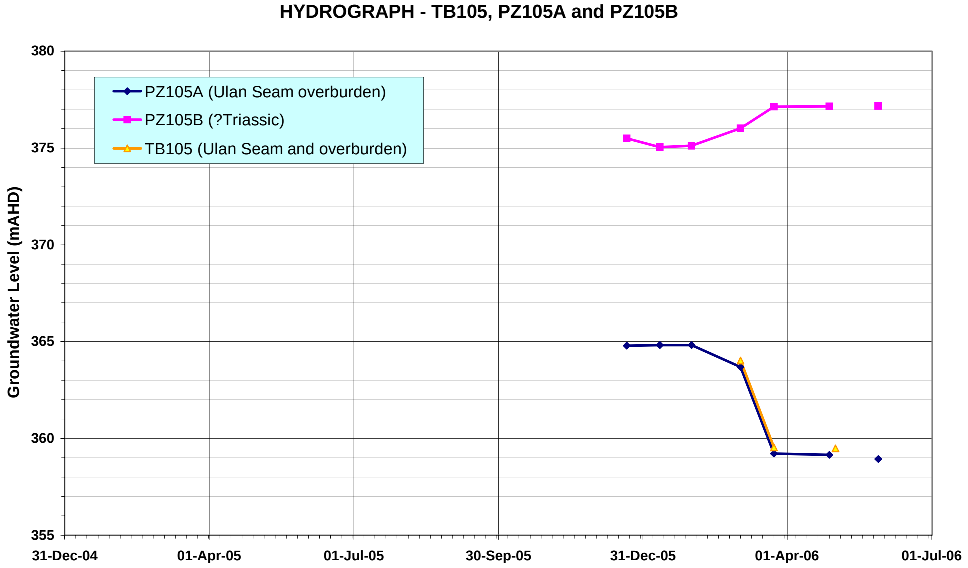
Figure C6



HYDROGRAPH - TB103, PZ103A and PZ103B



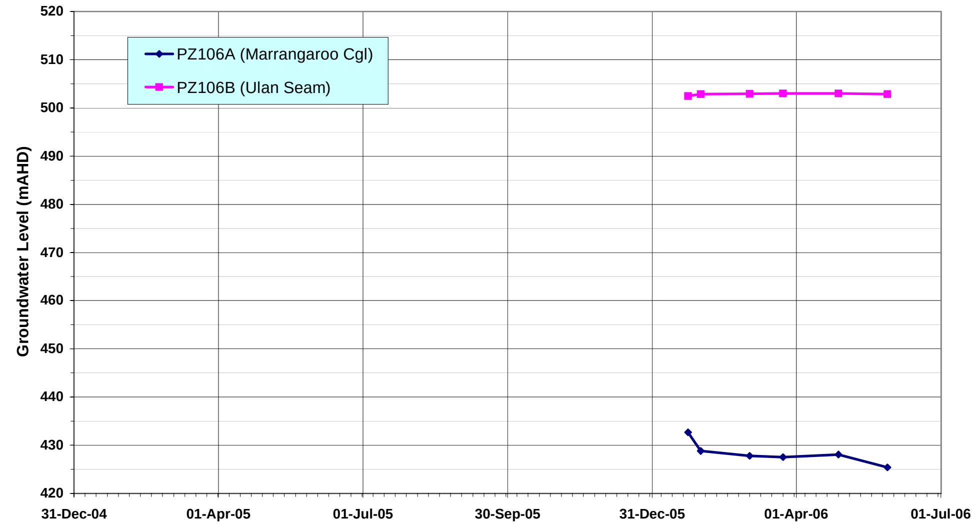
HYDROGRAPH - PZ104



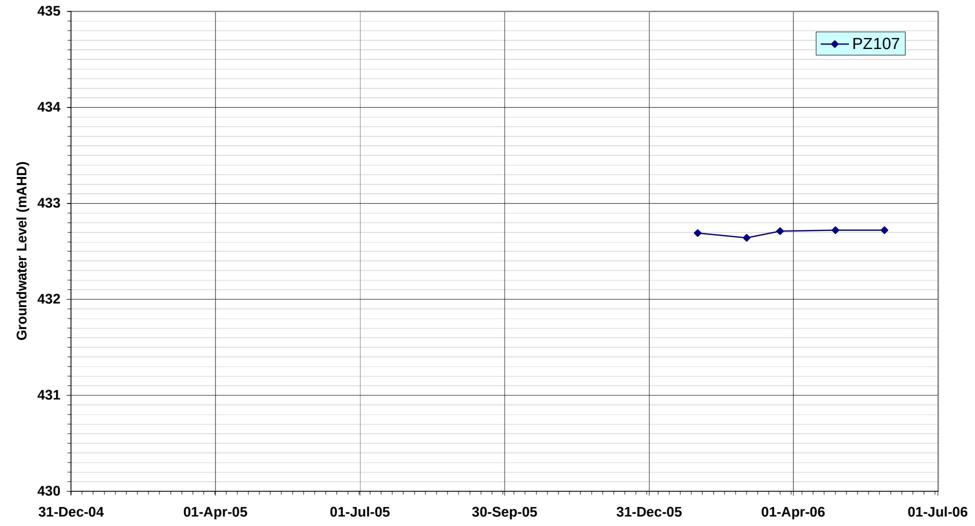
HYDROGRAPH - TB105, PZ105A and PZ105B

Date: 12 June 2006	Scale: as indicated	**Moolarben Coal Mines Pty Ltd**
Initials: PJD	Job No: 05-0158	**MOOLARBEN COAL PROJECT PIEZOMETER HYDROGRAPHS - PZ103A and B, TB103, PZ104, PZ105A and B, TB105**
Drawing No: 05-0158-112	Rev: 0	
Peter Dundon & Associates Pty Limited		**Figure C7**

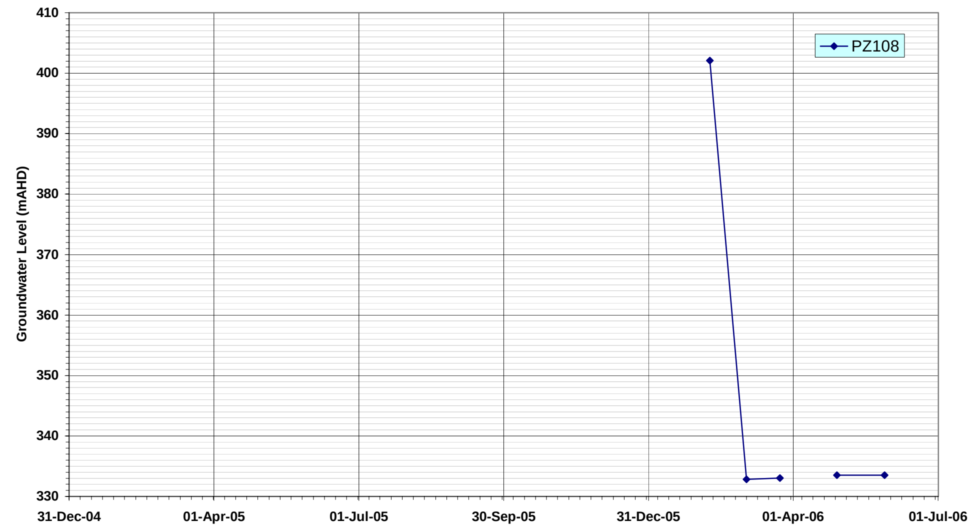
HYDROGRAPH - PZ106A and PZ106B



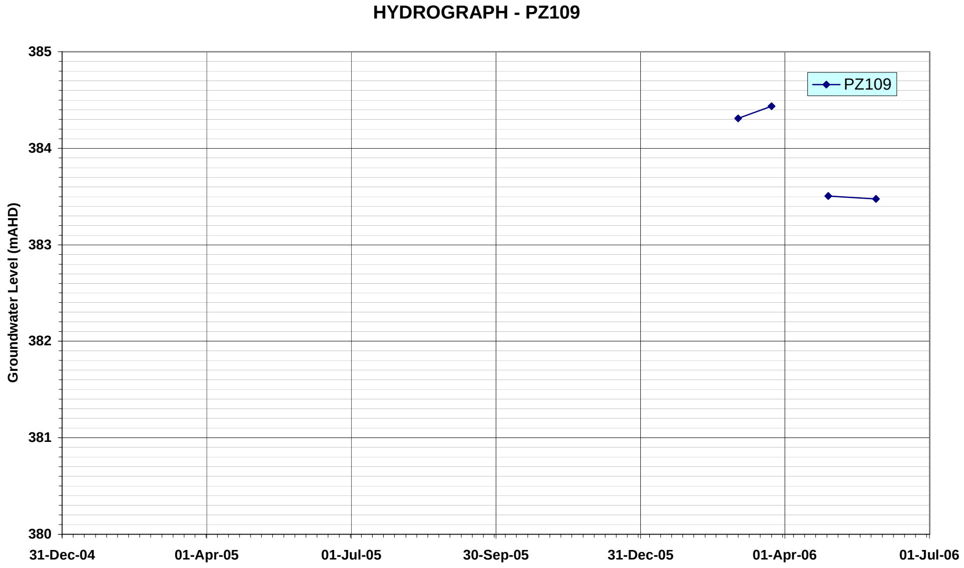
HYDROGRAPH - PZ107

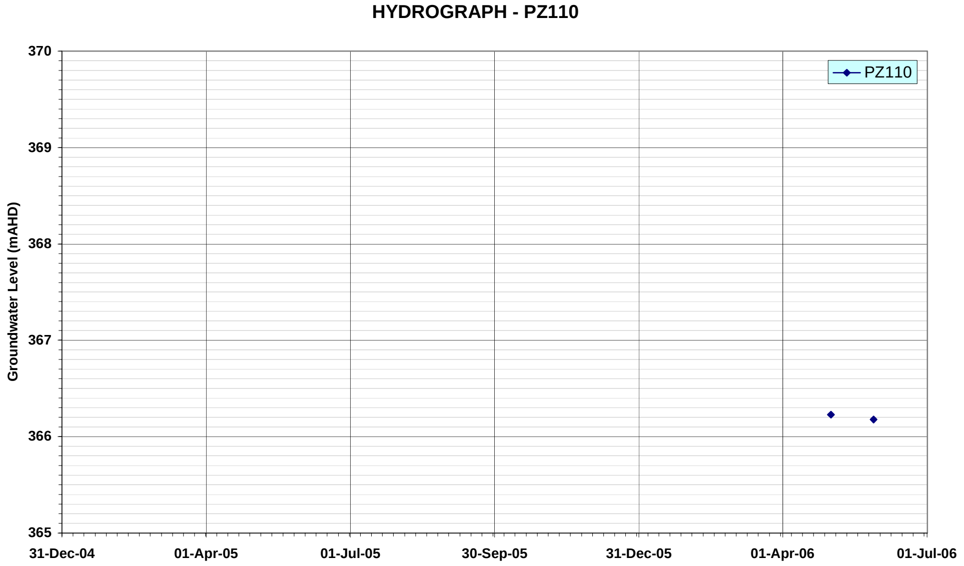


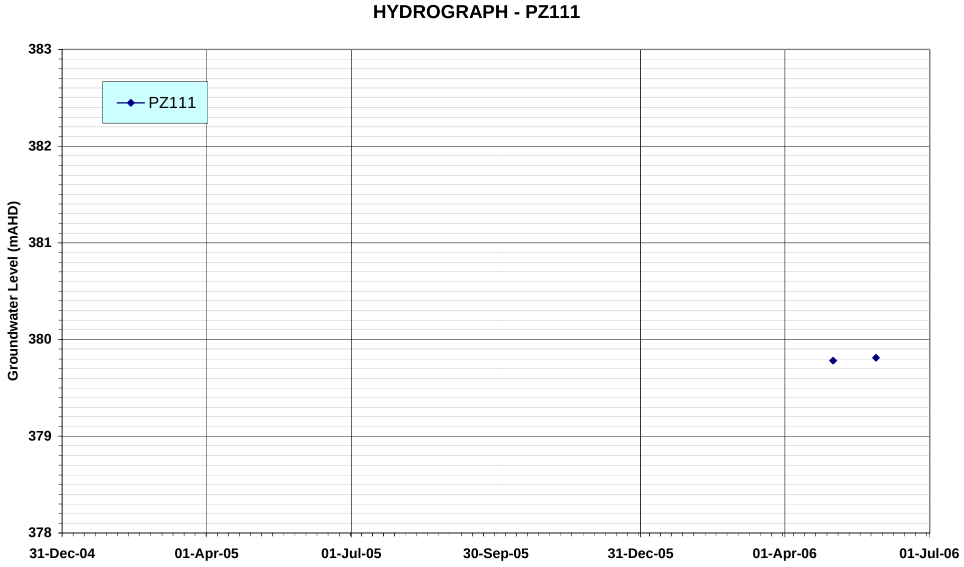
HYDROGRAPH - PZ108



Date: 12 June 2006	Scale: as indicated	**Moolarben Coal Mines Pty Ltd**
Initials: PJD	Job No: 05-0158	**MOOLARBEN COAL PROJECT PIEZOMETER HYDROGRAPHS - PZ106A and B, PZ107, PZ108**
Drawing No: 05-0158-113	Rev: 0	
Peter Dundon & Associates Pty Limited		**Figure C8**







Date:	12 June 2006	Scale:	as indicated
Initials:	PJD	Job No:	05-0158
Drawing No:	05-0158-114	Rev:	0

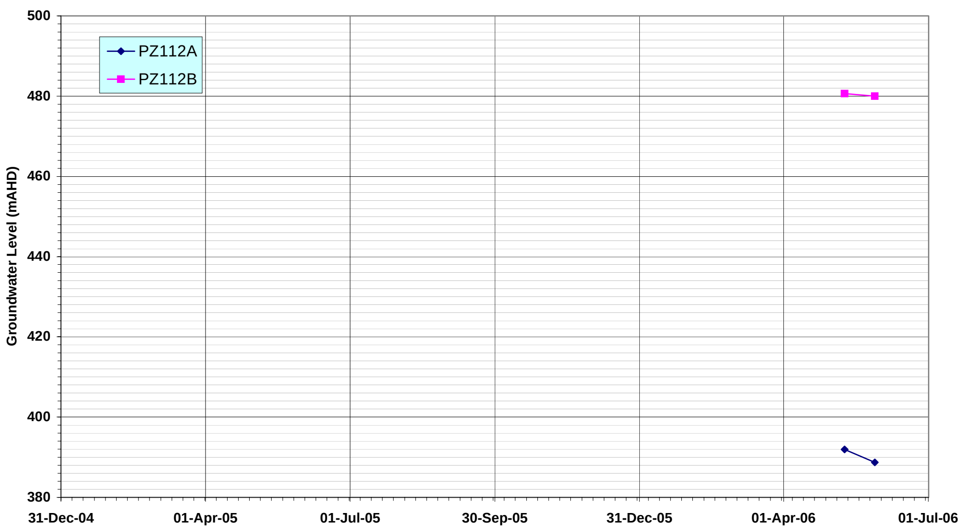
Peter Dundon & Associates Pty Limited

Moolarben Coal Mines Pty Ltd

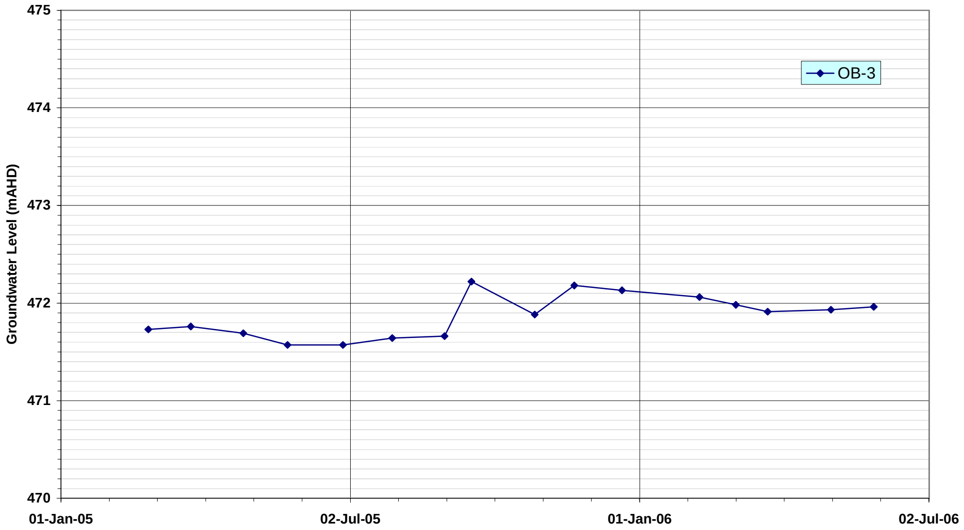
MOOLARBEN COAL PROJECT
PIEZOMETER HYDROGRAPHS -
PZ109, PZ110, PZ111

Figure C9

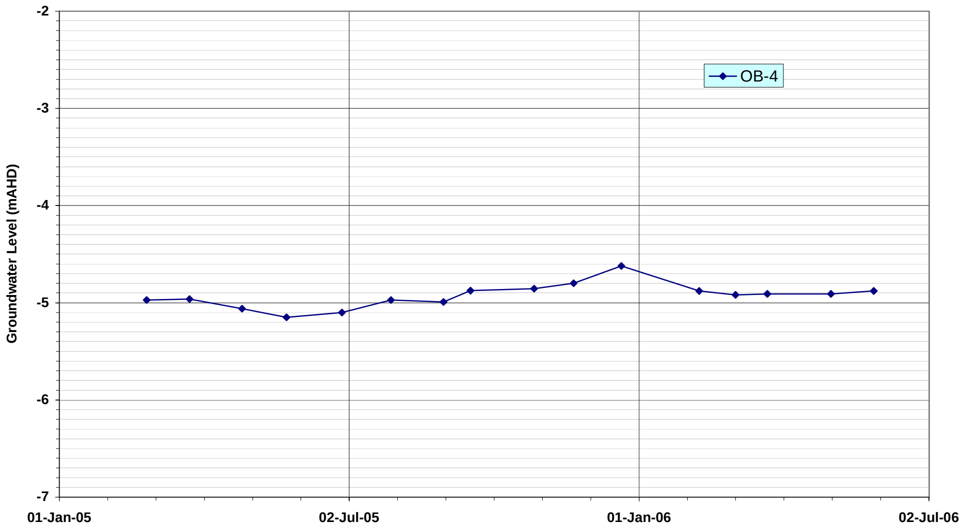
HYDROGRAPH - PZ112A



HYDROGRAPH - OB-3



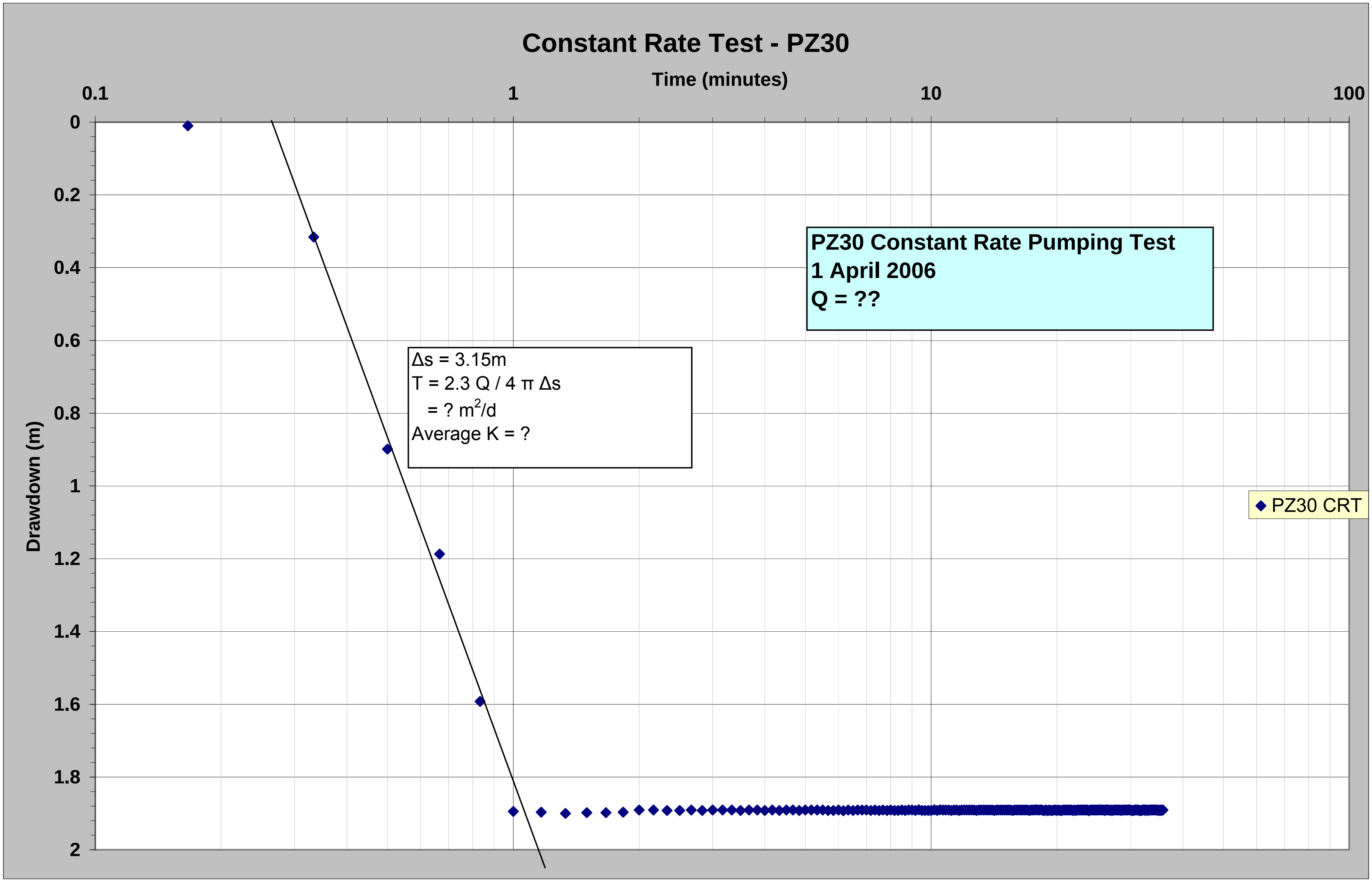
HYDROGRAPH - OB-4

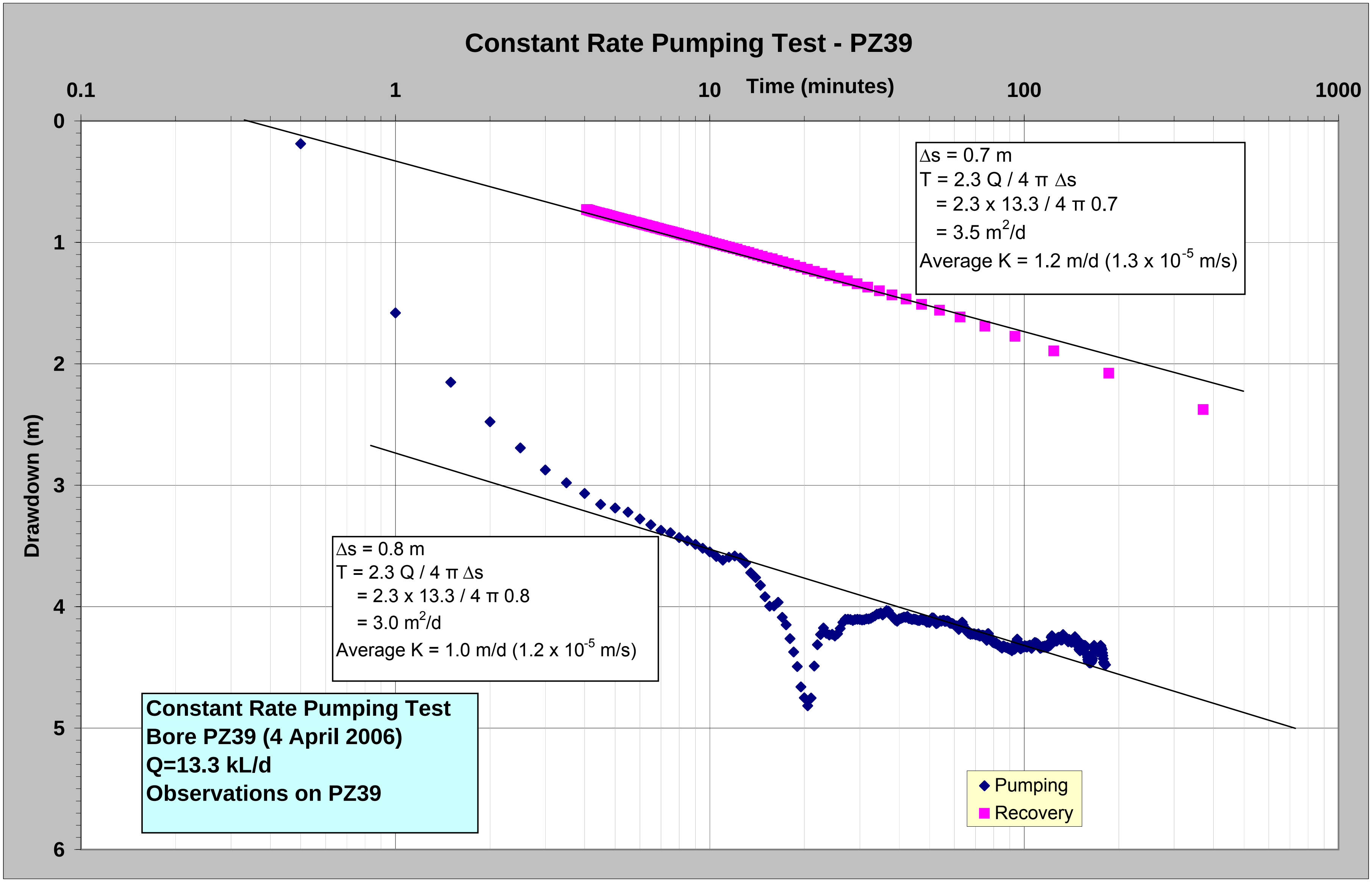


Date:	12 June 2006	Scale:	as indicated	**Moolarben Coal Mines Pty Ltd**
Initials:	PJD	Job No:	05-0158	**MOOLARBEN COAL PROJECT PIEZOMETER HYDROGRAPHS - PZ112A and B, OB3, OB4**
Drawing No:	05-0158-115	Rev:	0	
Peter Dundon & Associates Pty Limited				**Figure C10**

APPENDIX D

HYDRAULIC TESTING RESULTS


Constant Rate Test - PZ30
Time (minutes)
0.1
1
10
100
Drawdown (m)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
PZ30 Constant Rate Pumping Test
1 April 2006
Q = ??
Δs = 3.15m
T = 2.3 Q / 4 π Δs
= ? m²/d
Average K = ?
◆ PZ30 CRT

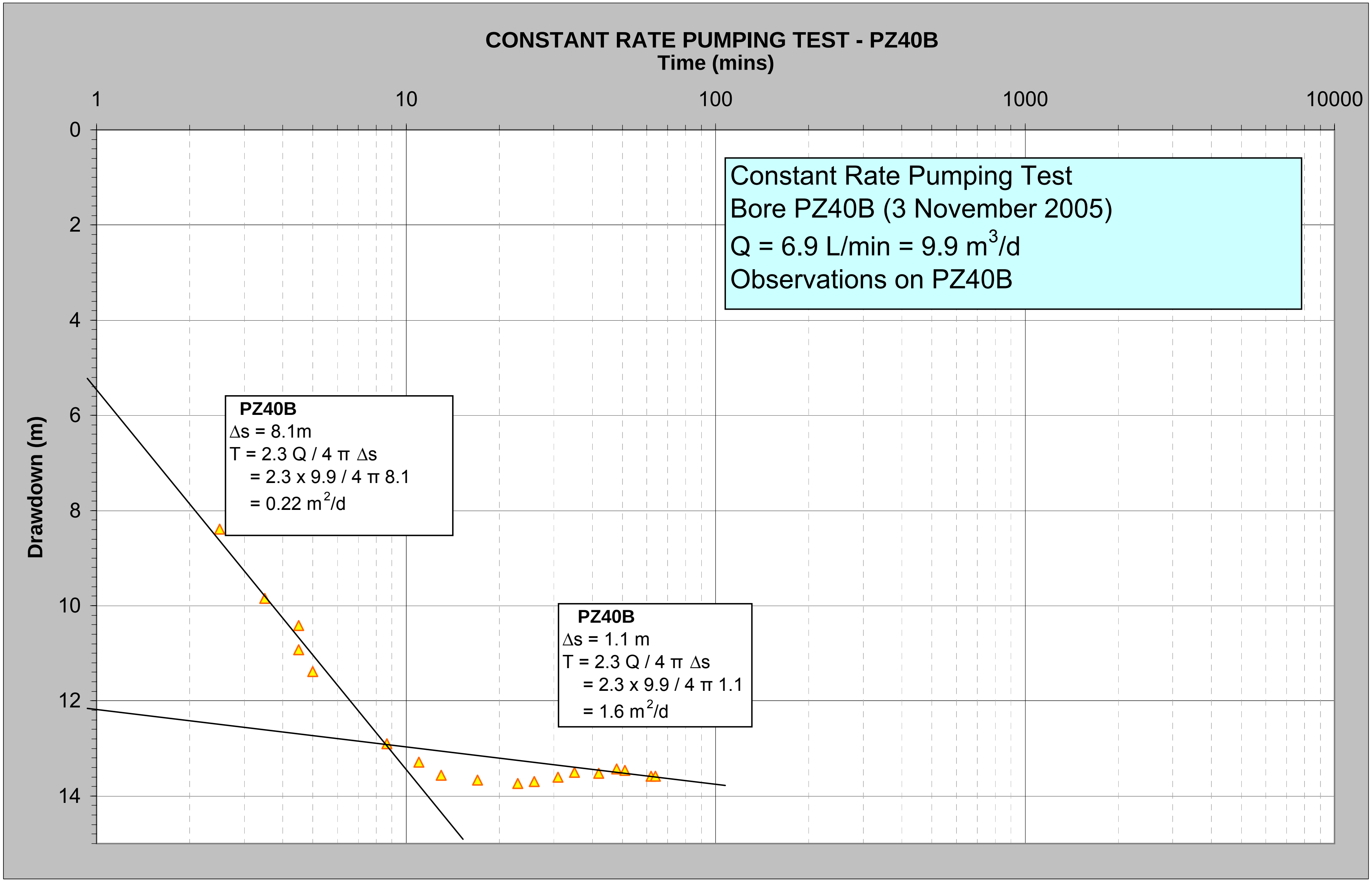


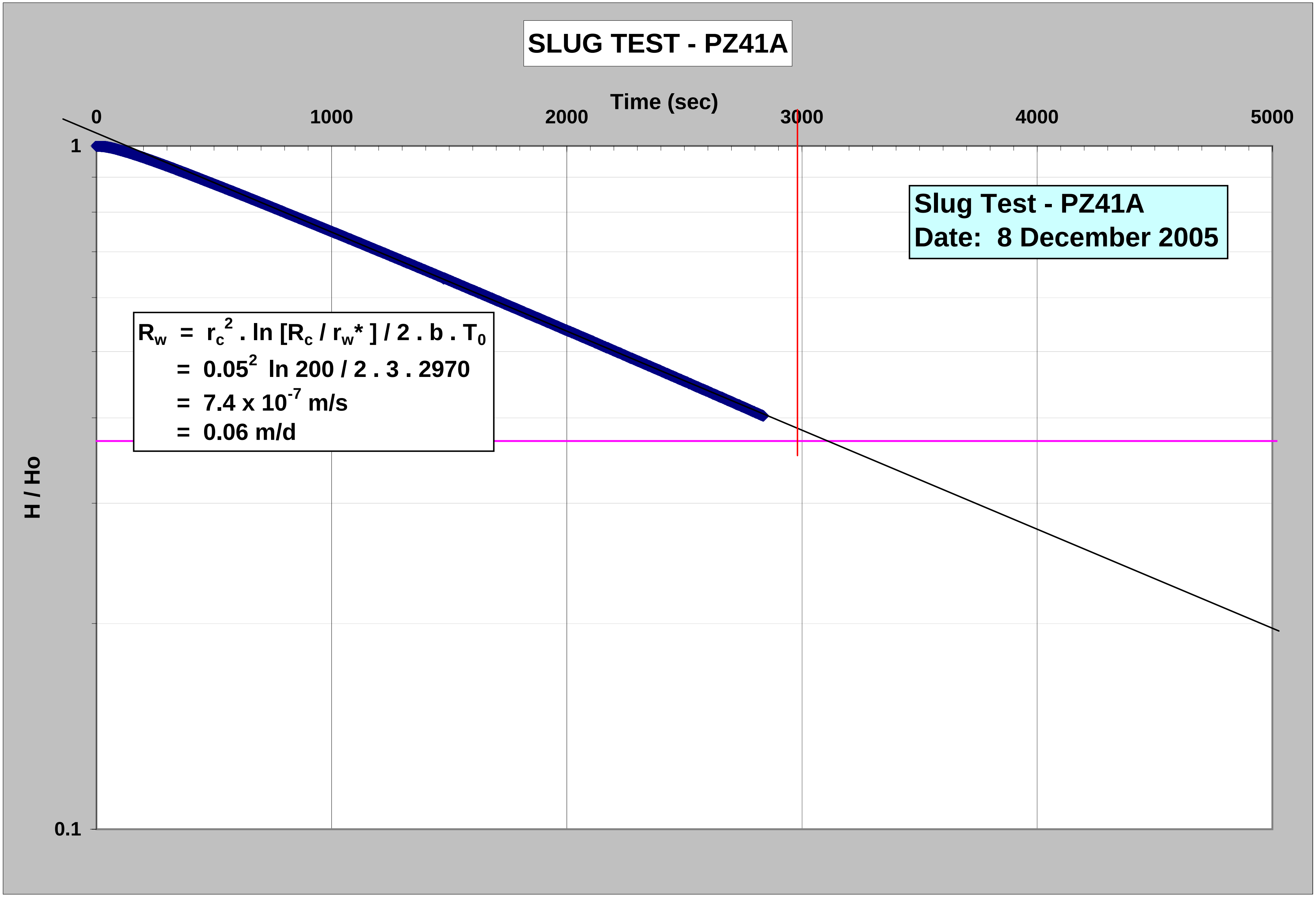
Constant Rate Pumping Test - PZ39

$\Delta s = 0.7$ m
$T = 2.3\ Q / 4\ \pi\ \Delta s$
$= 2.3 \times 13.3 / 4\ \pi\ 0.7$
$= 3.5\ m^2/d$
Average K = 1.2 m/d (1.3×10^{-5} m/s)

$\Delta s = 0.8$ m
$T = 2.3\ Q / 4\ \pi\ \Delta s$
$= 2.3 \times 13.3 / 4\ \pi\ 0.8$
$= 3.0\ m^2/d$
Average K = 1.0 m/d (1.2×10^{-5} m/s)

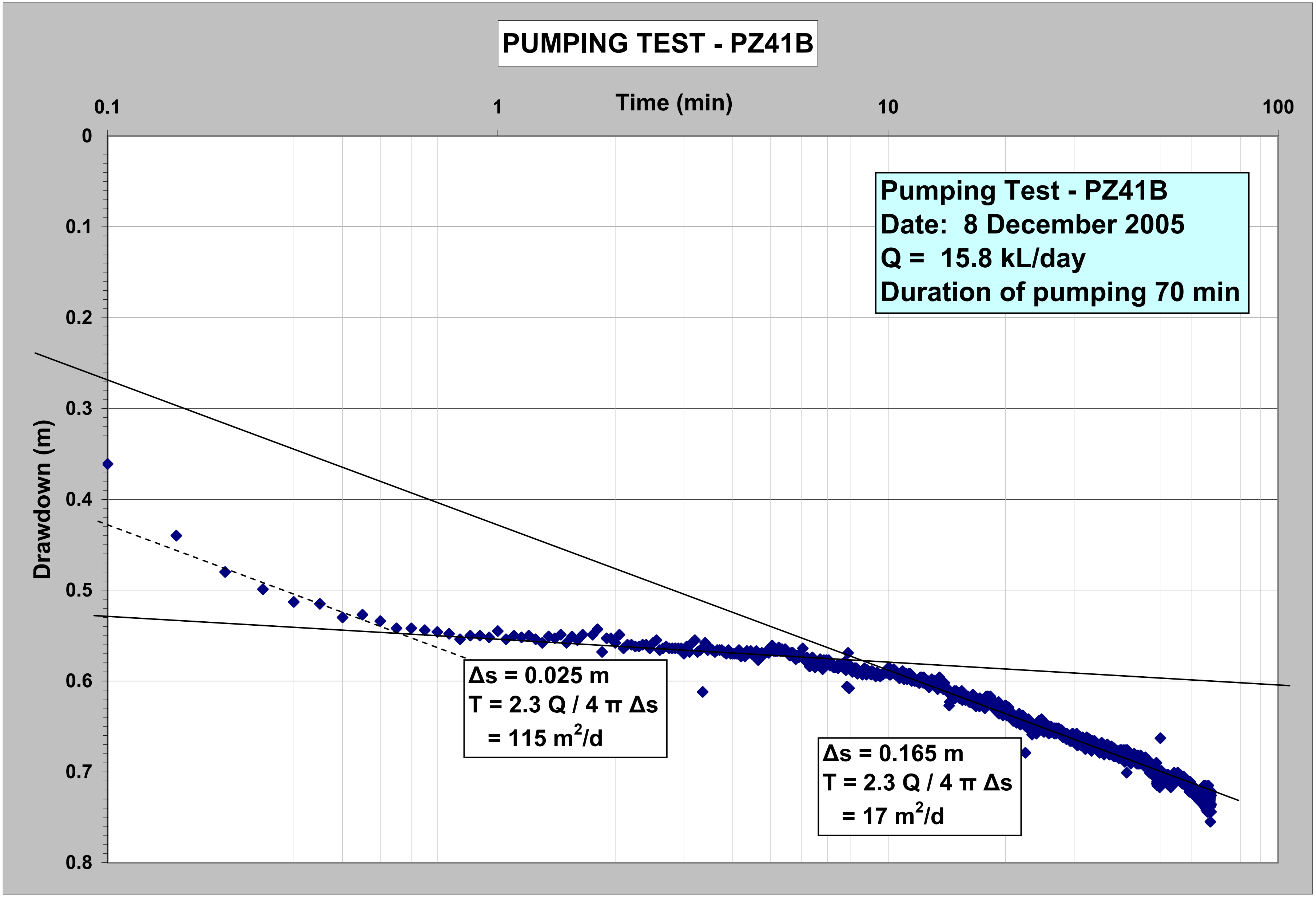
Constant Rate Pumping Test
Bore PZ39 (4 April 2006)
Q=13.3 kL/d
Observations on PZ39


CONSTANT RATE PUMPING TEST - PZ40B
Time (mins)
1
10
100
1000
10000
Drawdown (m)
0
2
4
6
8
10
12
14
Constant Rate Pumping Test
Bore PZ40B (3 November 2005)
Q = 6.9 L/min = 9.9 m³/d
Observations on PZ40B
PZ40B
Δs = 8.1m
T = 2.3 Q / 4 π Δs
= 2.3 x 9.9 / 4 π 8.1
= 0.22 m²/d
PZ40B
Δs = 1.1 m
T = 2.3 Q / 4 π Δs
= 2.3 x 9.9 / 4 π 1.1
= 1.6 m²/d


SLUG TEST - PZ41A

Slug Test - PZ41A
Date: 8 December 2005

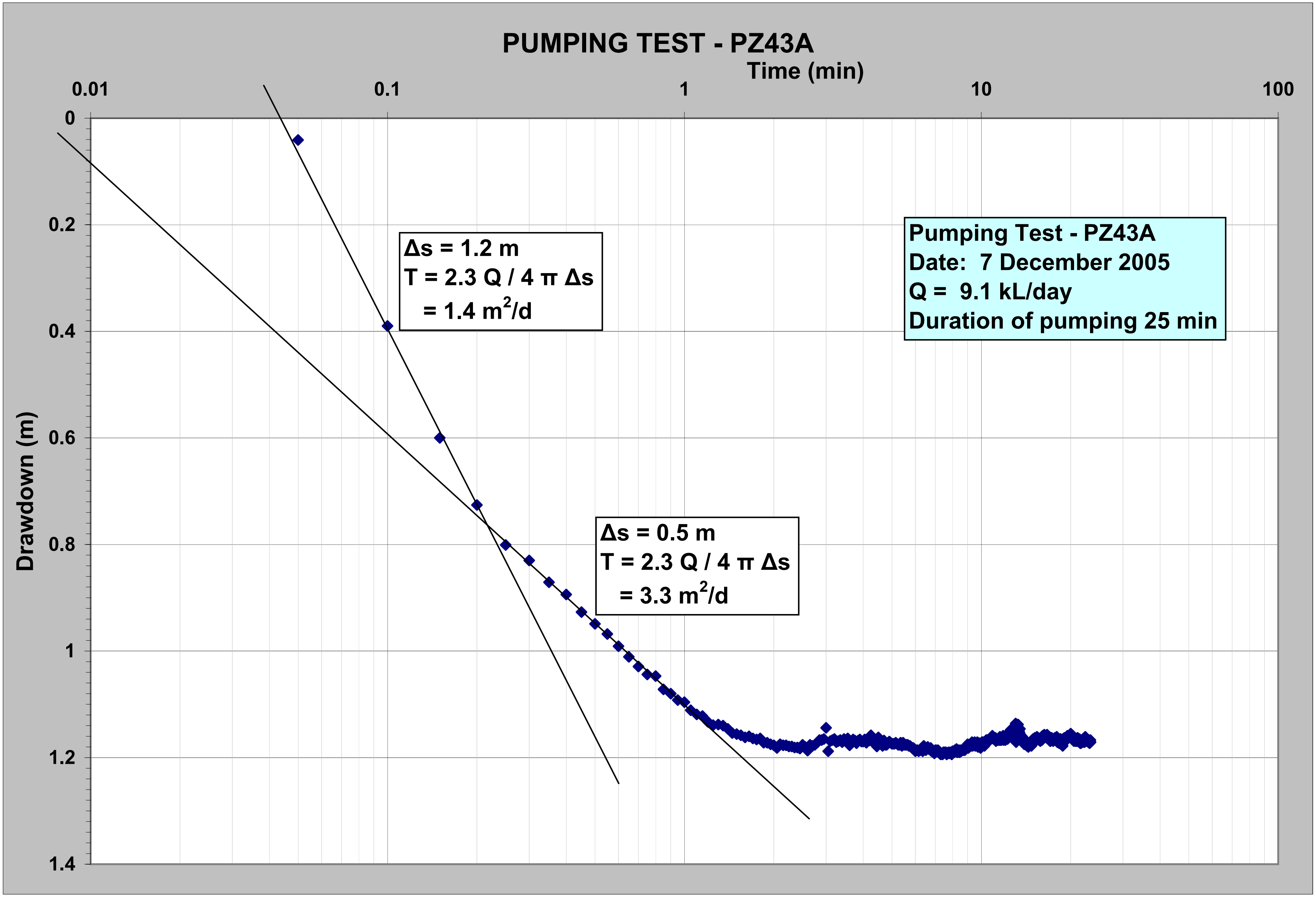
R_w = $r_c^2 . \ln [R_c / r_w^*] / 2 . b . T_0$
= 0.05^2 ln 200 / 2 . 3 . 2970
= 7.4 x 10^{-7} m/s
= 0.06 m/d

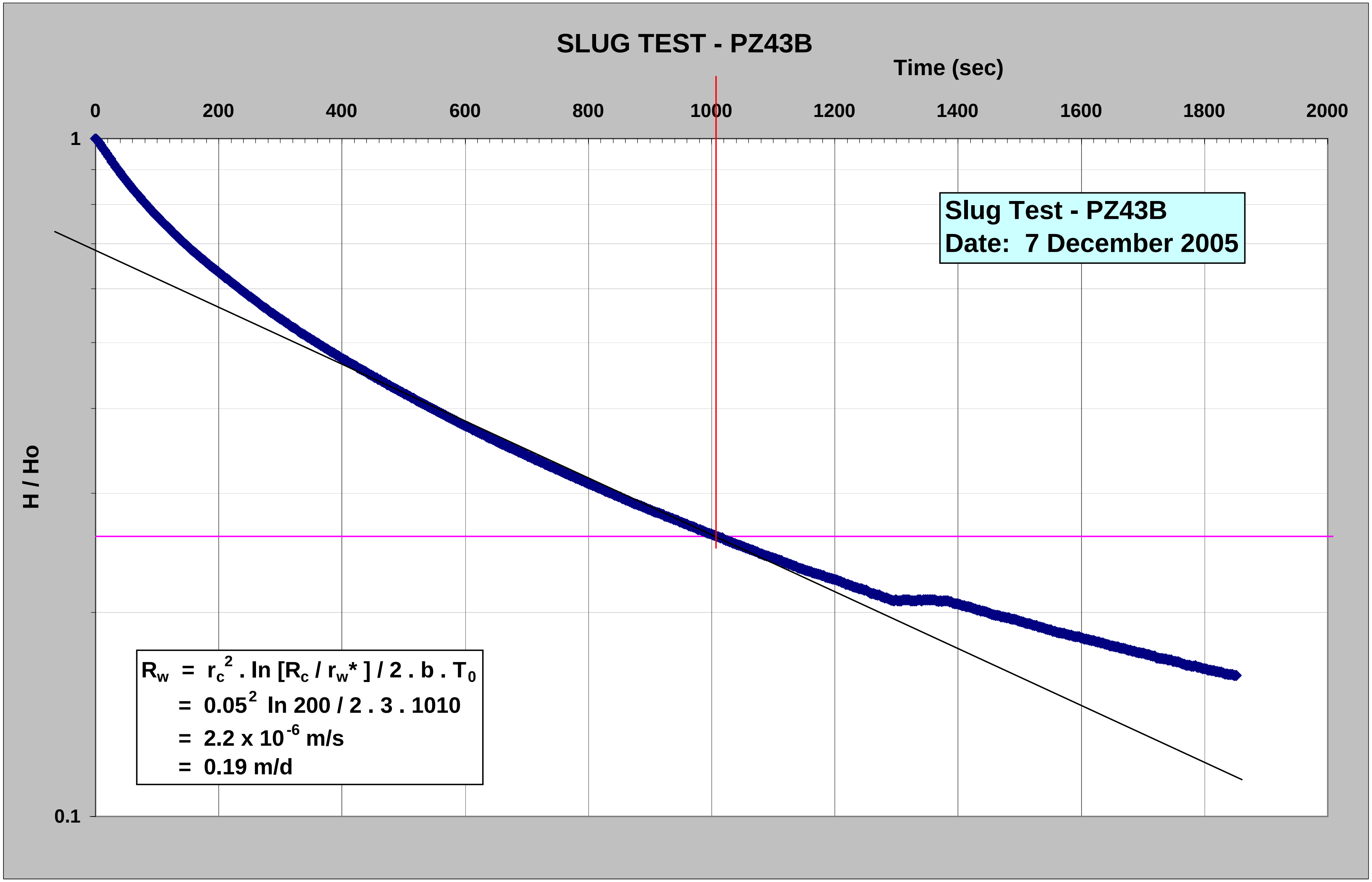


Pumping Test - PZ41B
Date: 8 December 2005
Q = 15.8 kL/day
Duration of pumping 70 min

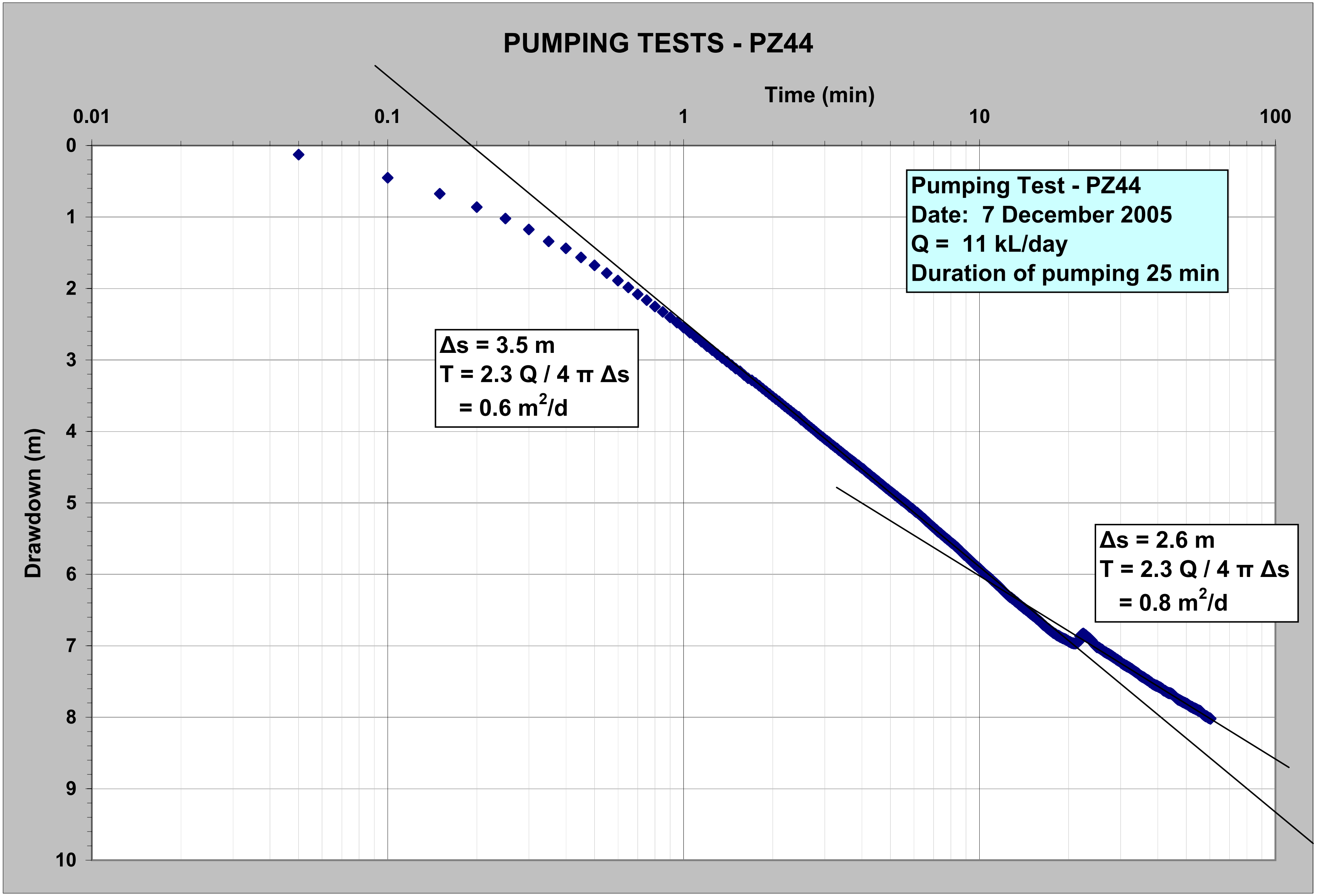
Δs = 0.025 m
T = 2.3 Q / 4 π Δs
= 115 m^2/d

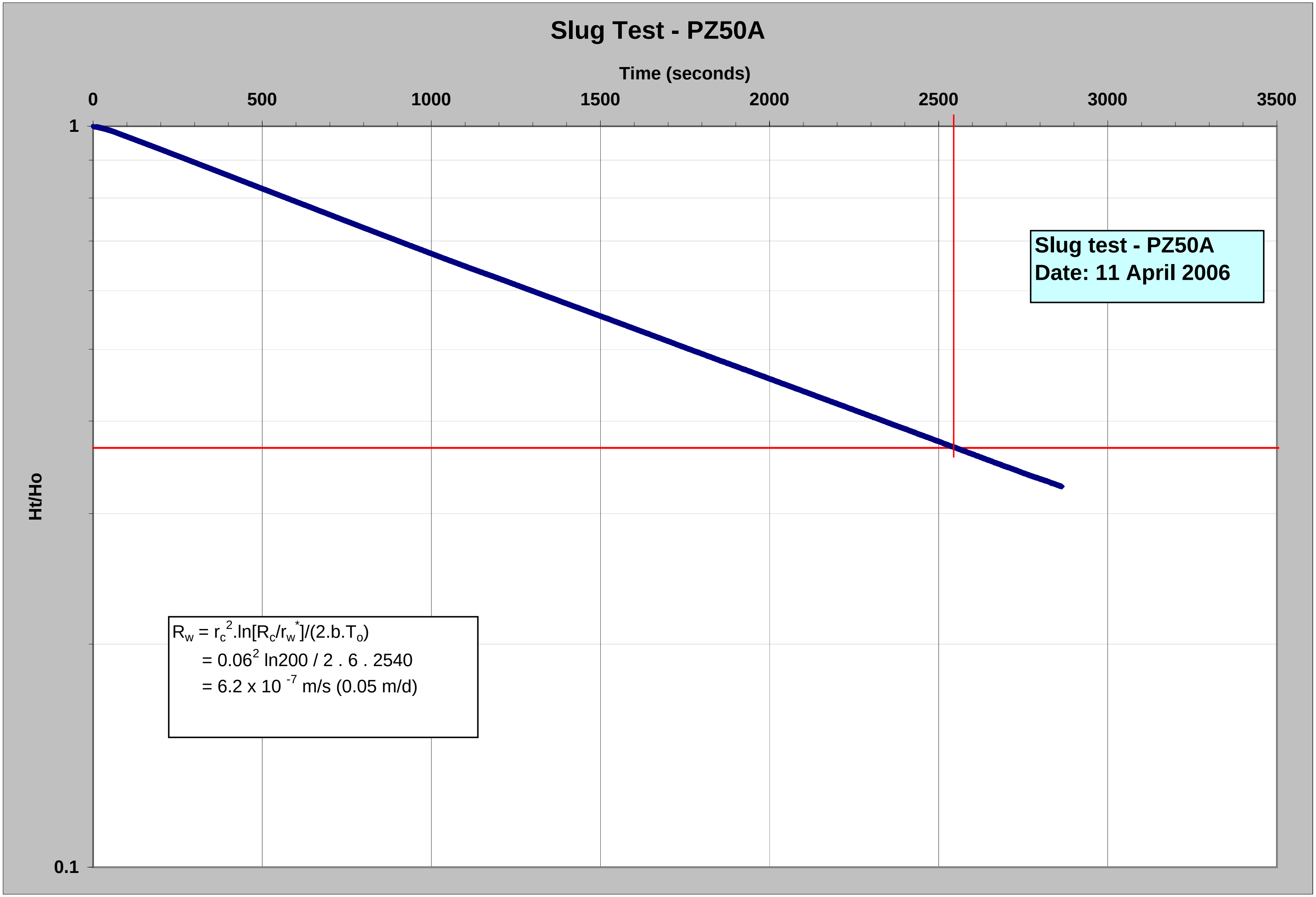
Δs = 0.165 m
T = 2.3 Q / 4 π Δs
= 17 m^2/d


PUMPING TEST - PZ43A
Time (min)
0.01
0.1
1
10
100
Drawdown (m)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
Δs = 1.2 m
T = 2.3 Q / 4 π Δs
= 1.4 m²/d
Δs = 0.5 m
T = 2.3 Q / 4 π Δs
= 3.3 m²/d
Pumping Test - PZ43A
Date: 7 December 2005
Q = 9.1 kL/day
Duration of pumping 25 min



R_w = r_c^2 . ln [R_c / r_w*] / 2 . b . T_0
= 0.05^2 ln 200 / 2 . 3 . 1010
= 2.2 x 10^{-6} m/s
= 0.19 m/d

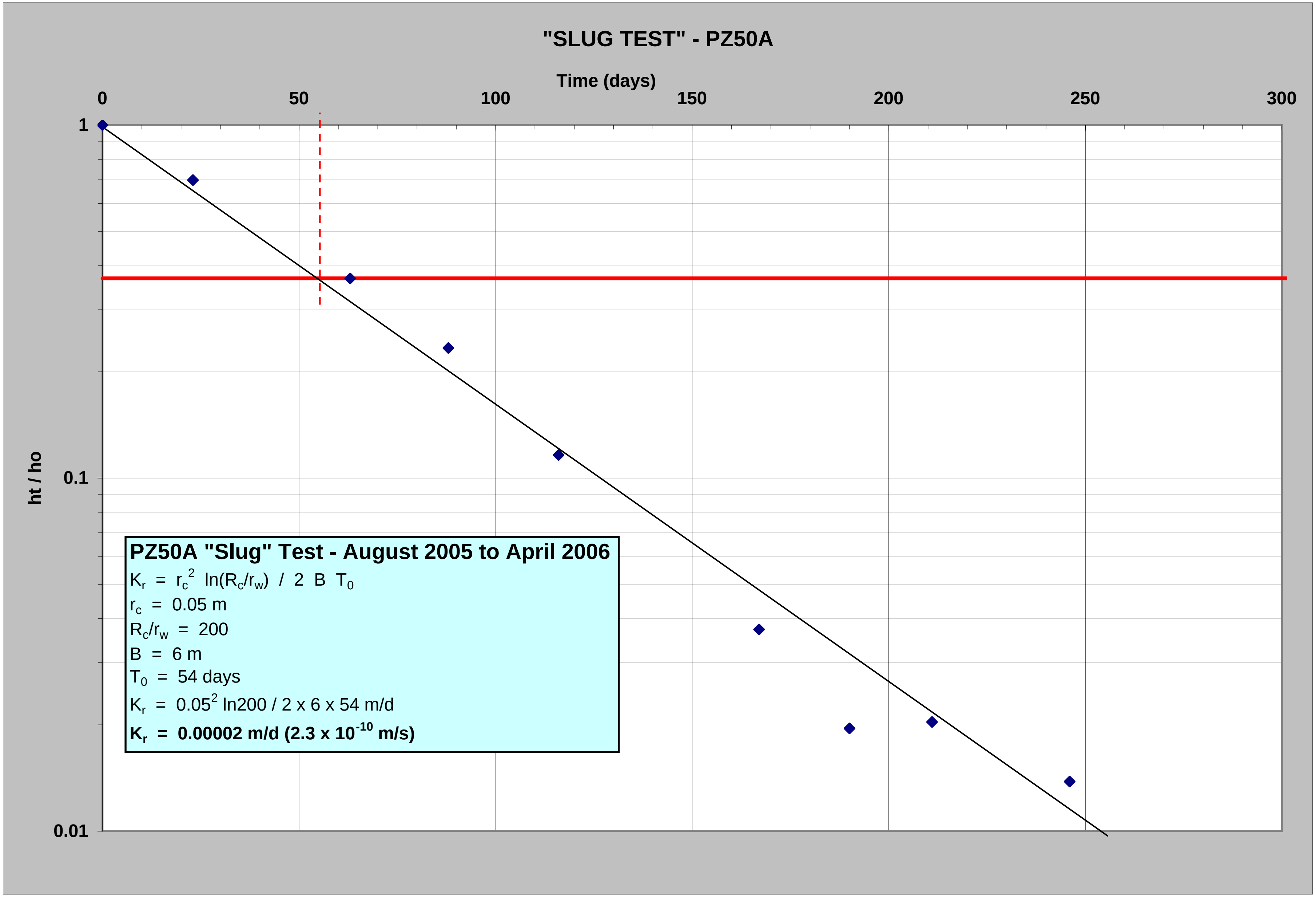

PUMPING TESTS - PZ44
Time (min)
0.01
0.1
1
10
100
Drawdown (m)
0
1
2
3
4
5
6
7
8
9
10
Pumping Test - PZ44
Date: 7 December 2005
Q = 11 kL/day
Duration of pumping 25 min
Δs = 3.5 m
T = 2.3 Q / 4 π Δs
= 0.6 m²/d
Δs = 2.6 m
T = 2.3 Q / 4 π Δs
= 0.8 m²/d



$R_w = r_c^2.\ln[R_c/r_w^*]/(2.b.T_o)$

$= 0.06^2 \ln200 / 2 . 6 . 2540$

$= 6.2 \times 10^{-7}$ m/s (0.05 m/d)



PZ50A "Slug" Test - August 2005 to April 2006

$K_r = r_c^2 \ln(R_c/r_w) / 2 B T_0$

$r_c = 0.05$ m

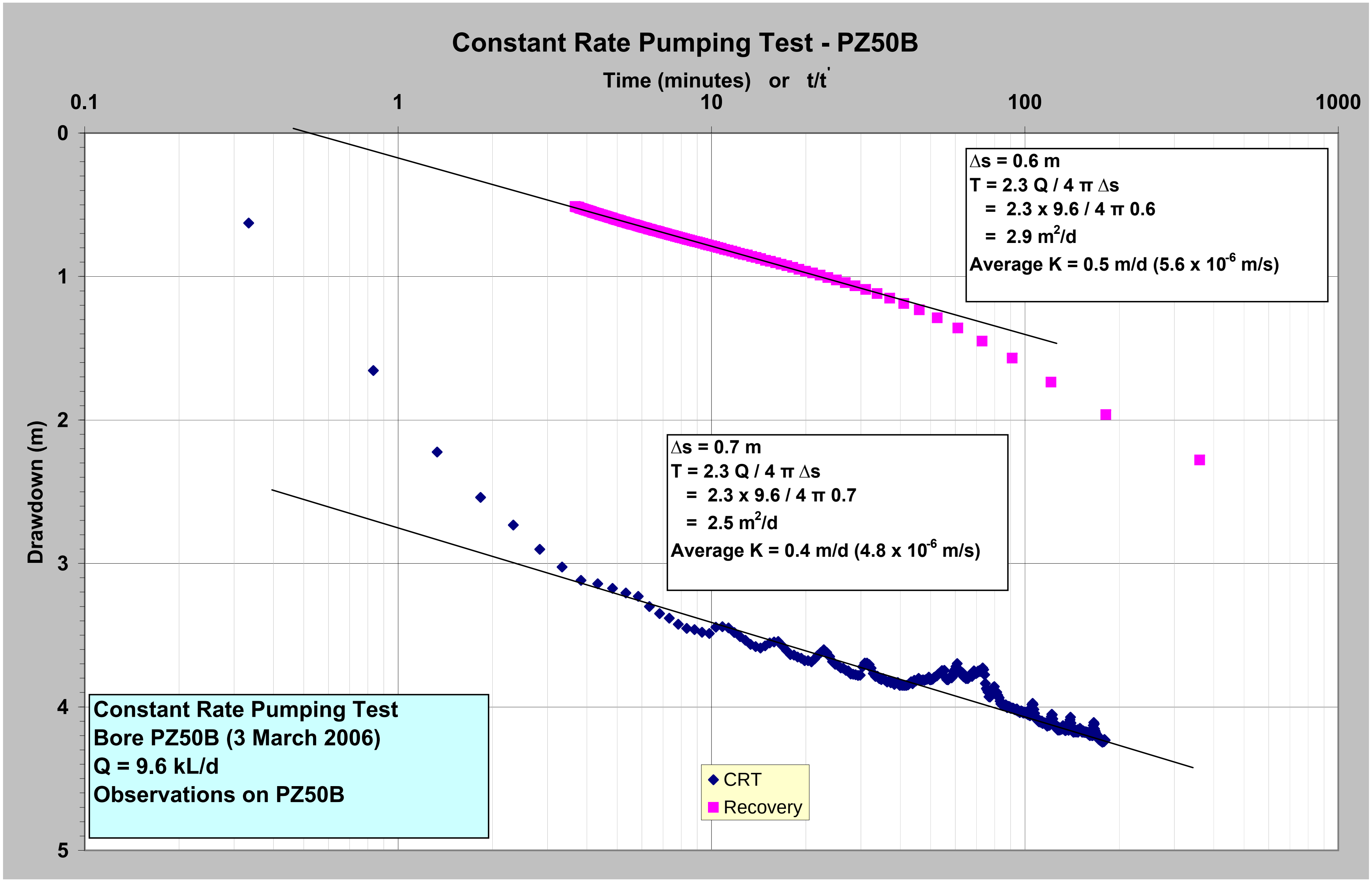
$R_c/r_w = 200$

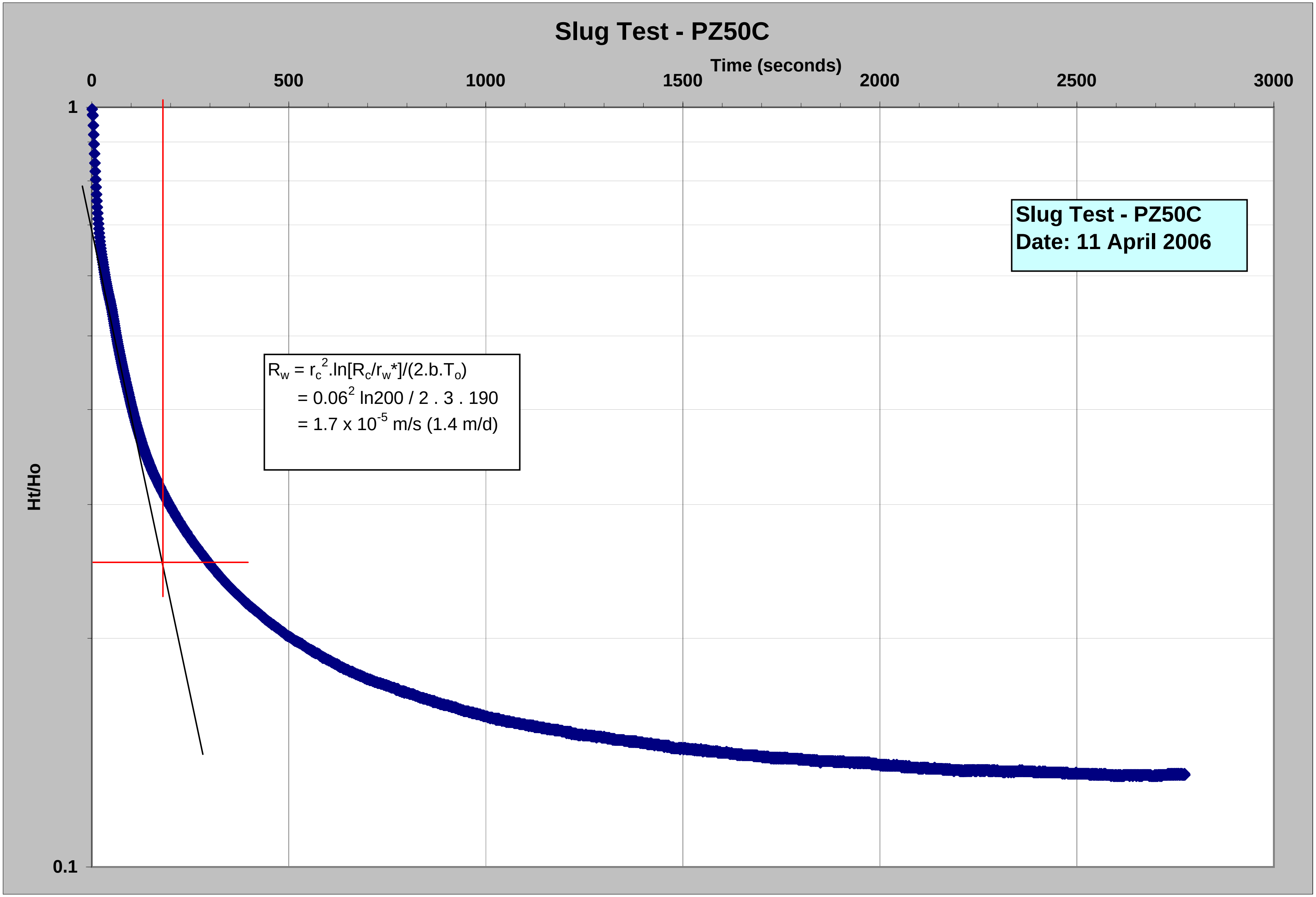
$B = 6$ m

$T_0 = 54$ days

$K_r = 0.05^2 \ln 200 / 2 \times 6 \times 54$ m/d

$K_r = 0.00002$ m/d (2.3×10^{-10} m/s)


Constant Rate Pumping Test - PZ50B
Time (minutes) or t/t'
0.1
1
10
100
1000
Drawdown (m)
0
1
2
3
4
5
Δs = 0.6 m
T = 2.3 Q / 4 π Δs
= 2.3 x 9.6 / 4 π 0.6
= 2.9 m²/d
Average K = 0.5 m/d (5.6 x 10⁻⁶ m/s)
Δs = 0.7 m
T = 2.3 Q / 4 π Δs
= 2.3 x 9.6 / 4 π 0.7
= 2.5 m²/d
Average K = 0.4 m/d (4.8 x 10⁻⁶ m/s)
Constant Rate Pumping Test
Bore PZ50B (3 March 2006)
Q = 9.6 kL/d
Observations on PZ50B
◆ CRT
■ Recovery

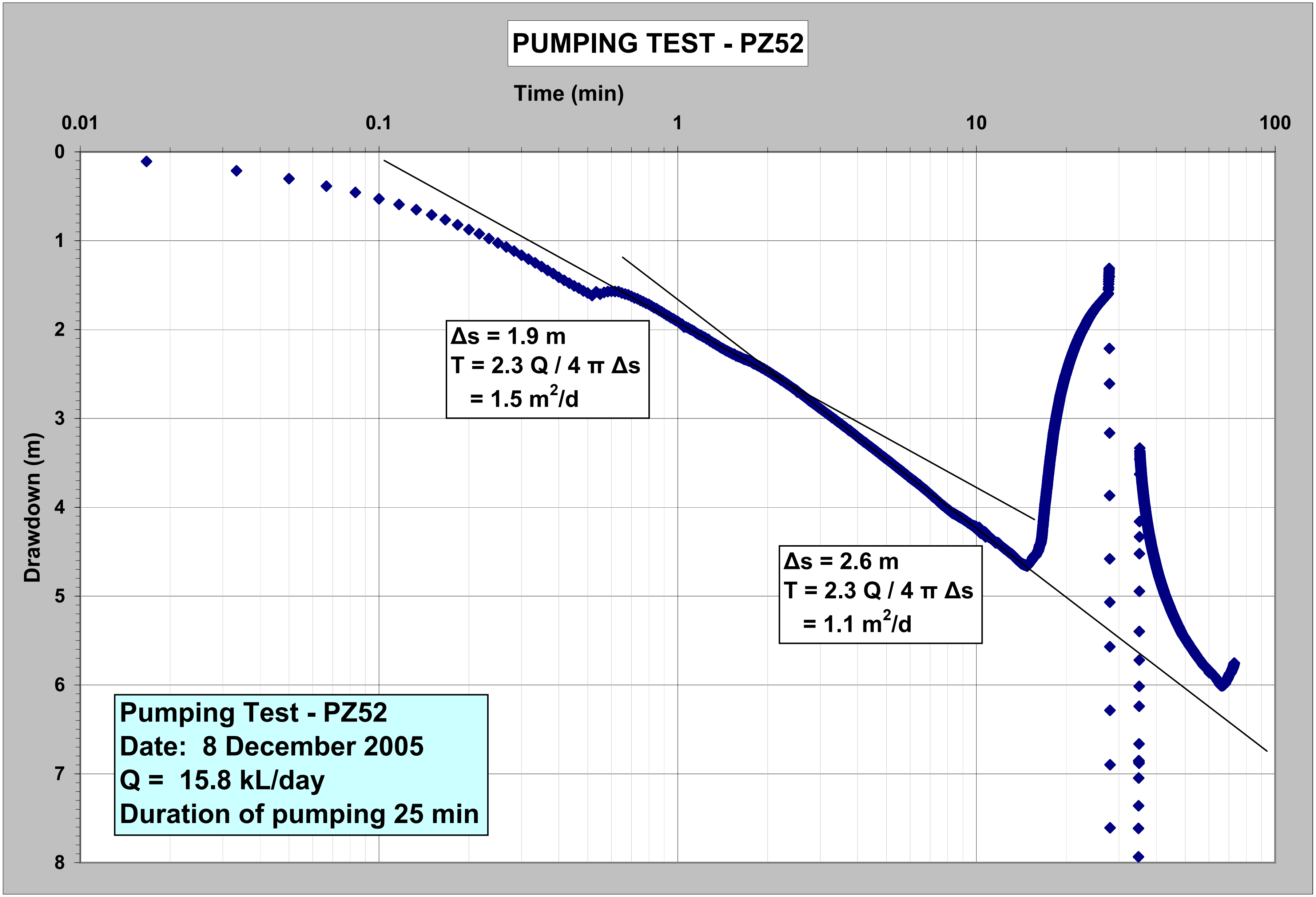


Slug Test - PZ50C
Date: 11 April 2006

$R_w = r_c^2.\ln[R_c/r_w*]/(2.b.T_o)$

$= 0.06^2 \ln 200 / 2 . 3 . 190$

$= 1.7 \times 10^{-5}$ m/s (1.4 m/d)

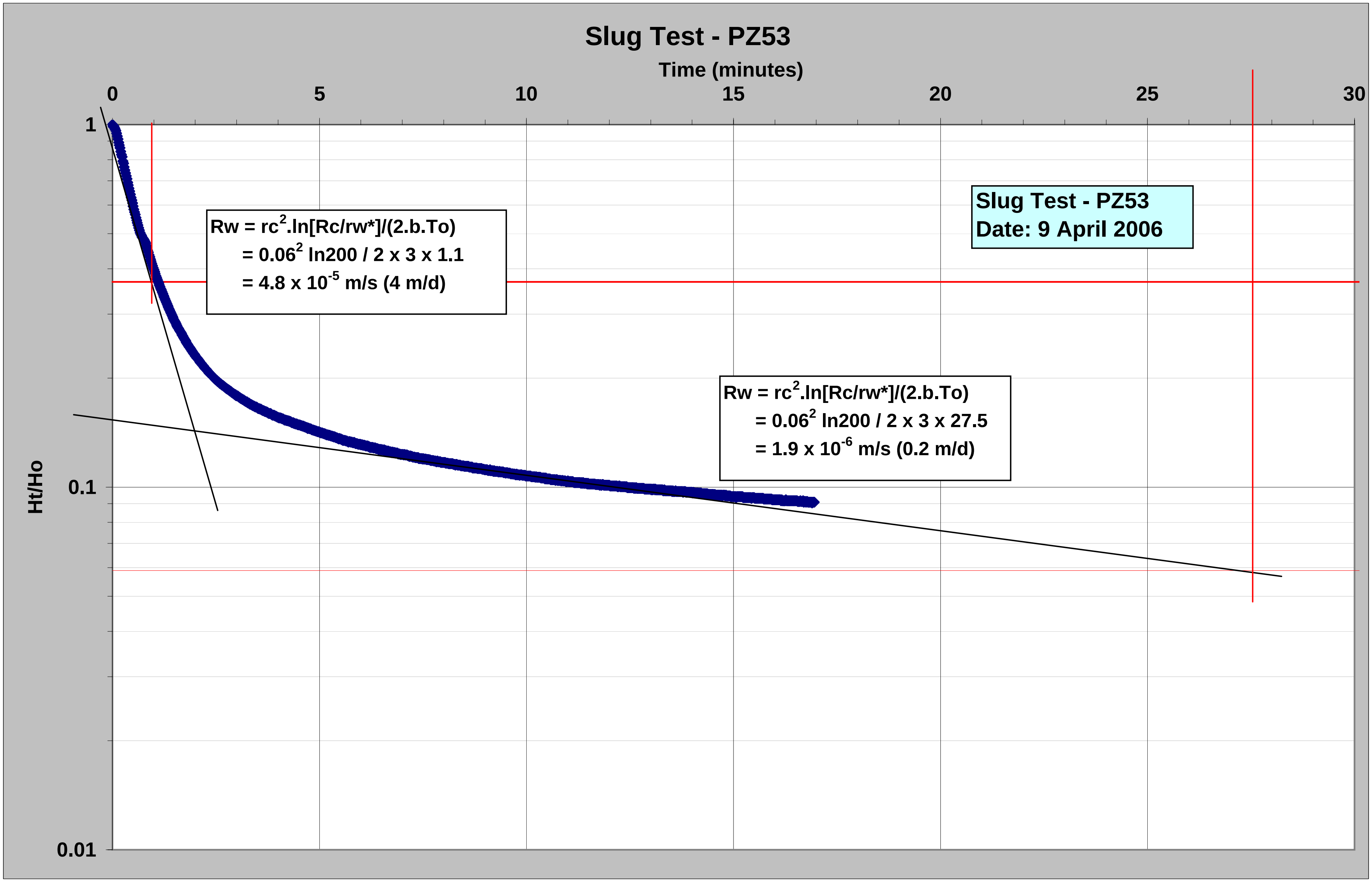


PUMPING TEST - PZ52

Δs = 1.9 m
T = 2.3 Q / 4 π Δs
= 1.5 m^2/d

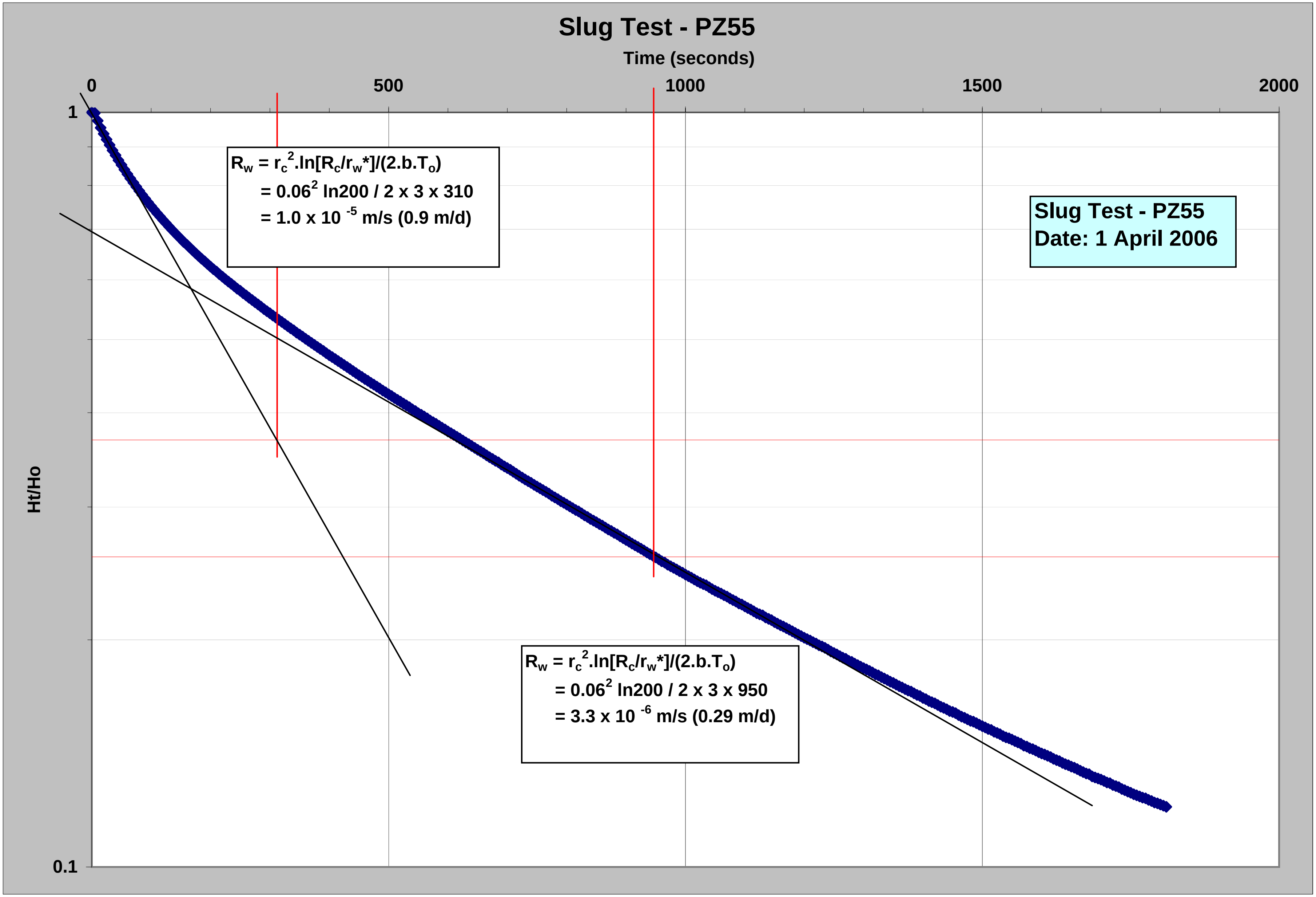
Δs = 2.6 m
T = 2.3 Q / 4 π Δs
= 1.1 m^2/d

Pumping Test - PZ52
Date: 8 December 2005
Q = 15.8 kL/day
Duration of pumping 25 min



Rw = rc^2.ln[Rc/rw*]/(2.b.To)
= 0.06^2 ln200 / 2 x 3 x 1.1
= 4.8 x 10^{-5} m/s (4 m/d)

Rw = rc^2.ln[Rc/rw*]/(2.b.To)
= 0.06^2 ln200 / 2 x 3 x 27.5
= 1.9 x 10^{-6} m/s (0.2 m/d)



$R_w = r_c^2.\text{ln}[R_c/r_w*]/(2.b.T_o)$

$= 0.06^2$ ln200 / 2 x 3 x 310

$= 1.0 \text{ x } 10^{-5}$ m/s (0.9 m/d)

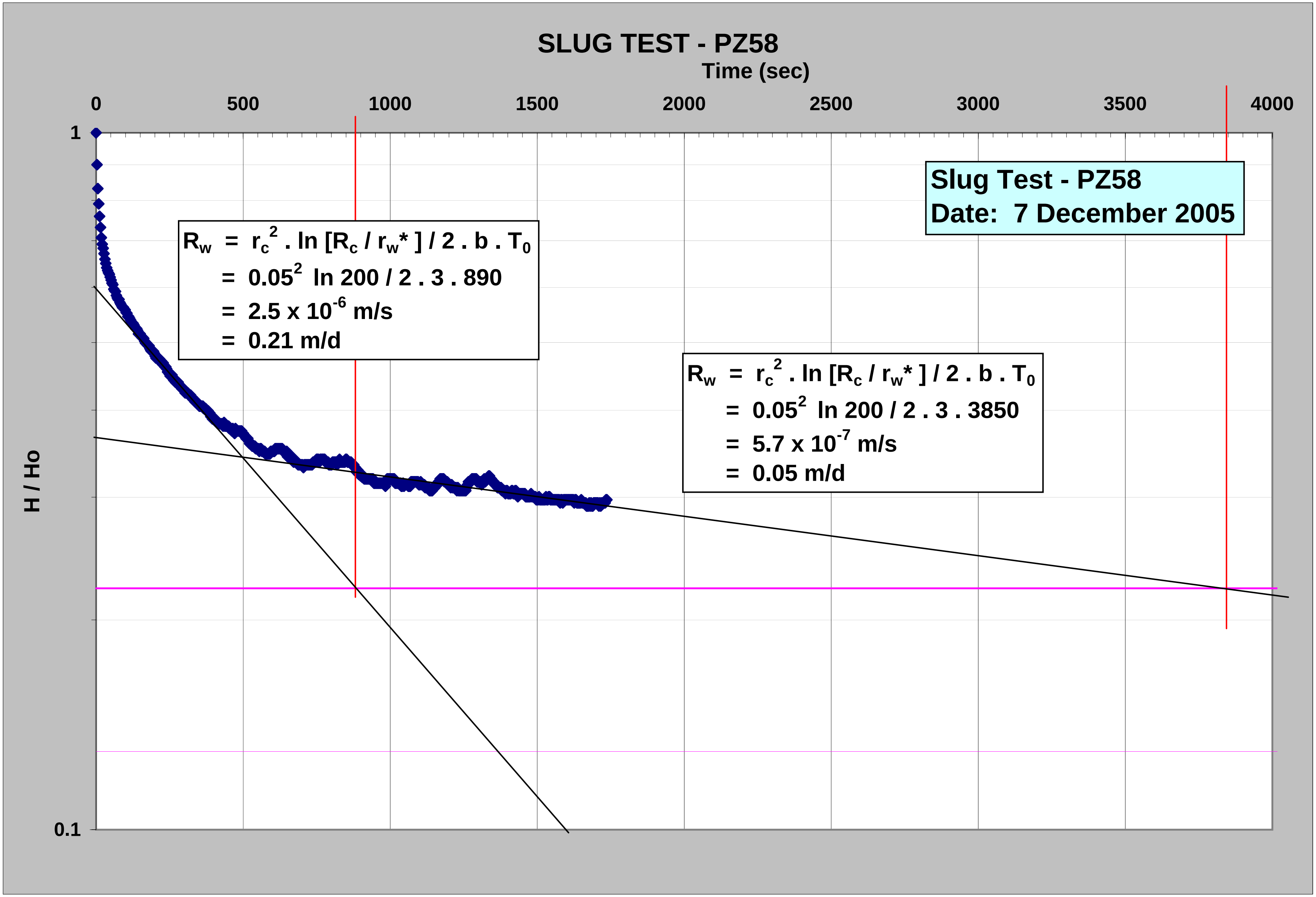
Slug Test - PZ55

Date: 1 April 2006

$R_w = r_c^2.\text{ln}[R_c/r_w*]/(2.b.T_o)$

$= 0.06^2$ ln200 / 2 x 3 x 950

$= 3.3 \text{ x } 10^{-6}$ m/s (0.29 m/d)

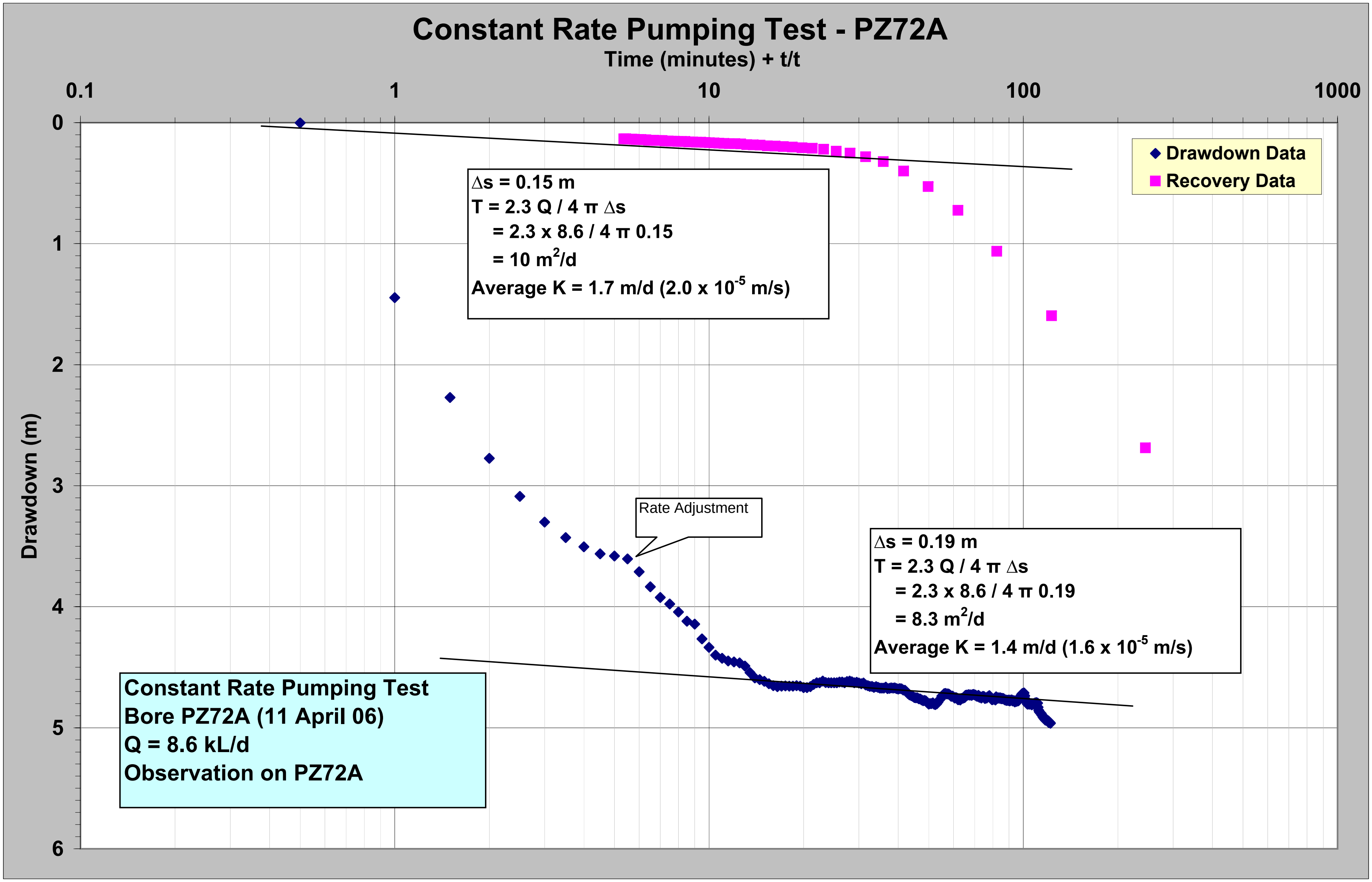


SLUG TEST - PZ58

Slug Test - PZ58
Date: 7 December 2005

$R_w = r_c^2 . \ln [R_c / r_w^*] / 2 . b . T_0$
$= 0.05^2 \ \ln 200 / 2 . 3 . 890$
$= 2.5 \times 10^{-6}$ m/s
= 0.21 m/d

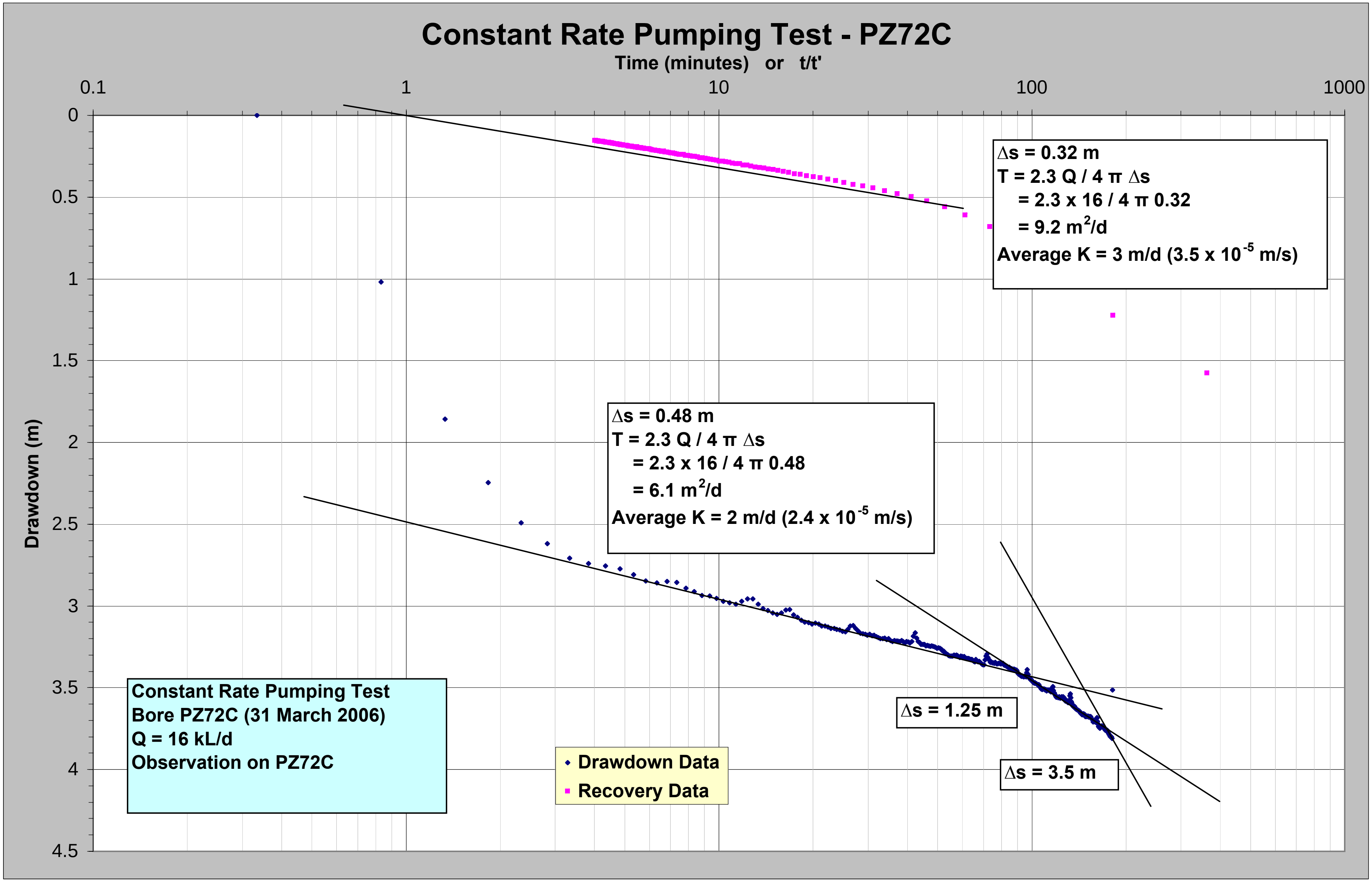
$R_w = r_c^2 . \ln [R_c / r_w^*] / 2 . b . T_0$
$= 0.05^2 \ \ln 200 / 2 . 3 . 3850$
$= 5.7 \times 10^{-7}$ m/s
= 0.05 m/d



$\Delta s = 0.15$ m
$T = 2.3\ Q / 4\ \pi\ \Delta s$
$= 2.3 \times 8.6 / 4\ \pi\ 0.15$
$= 10\ m^2/d$
Average K = 1.7 m/d (2.0×10^{-5} m/s)

$\Delta s = 0.19$ m
$T = 2.3\ Q / 4\ \pi\ \Delta s$
$= 2.3 \times 8.6 / 4\ \pi\ 0.19$
$= 8.3\ m^2/d$
Average K = 1.4 m/d (1.6×10^{-5} m/s)

Constant Rate Pumping Test
Bore PZ72A (11 April 06)
Q = 8.6 kL/d
Observation on PZ72A



Constant Rate Pumping Test - PZ72C

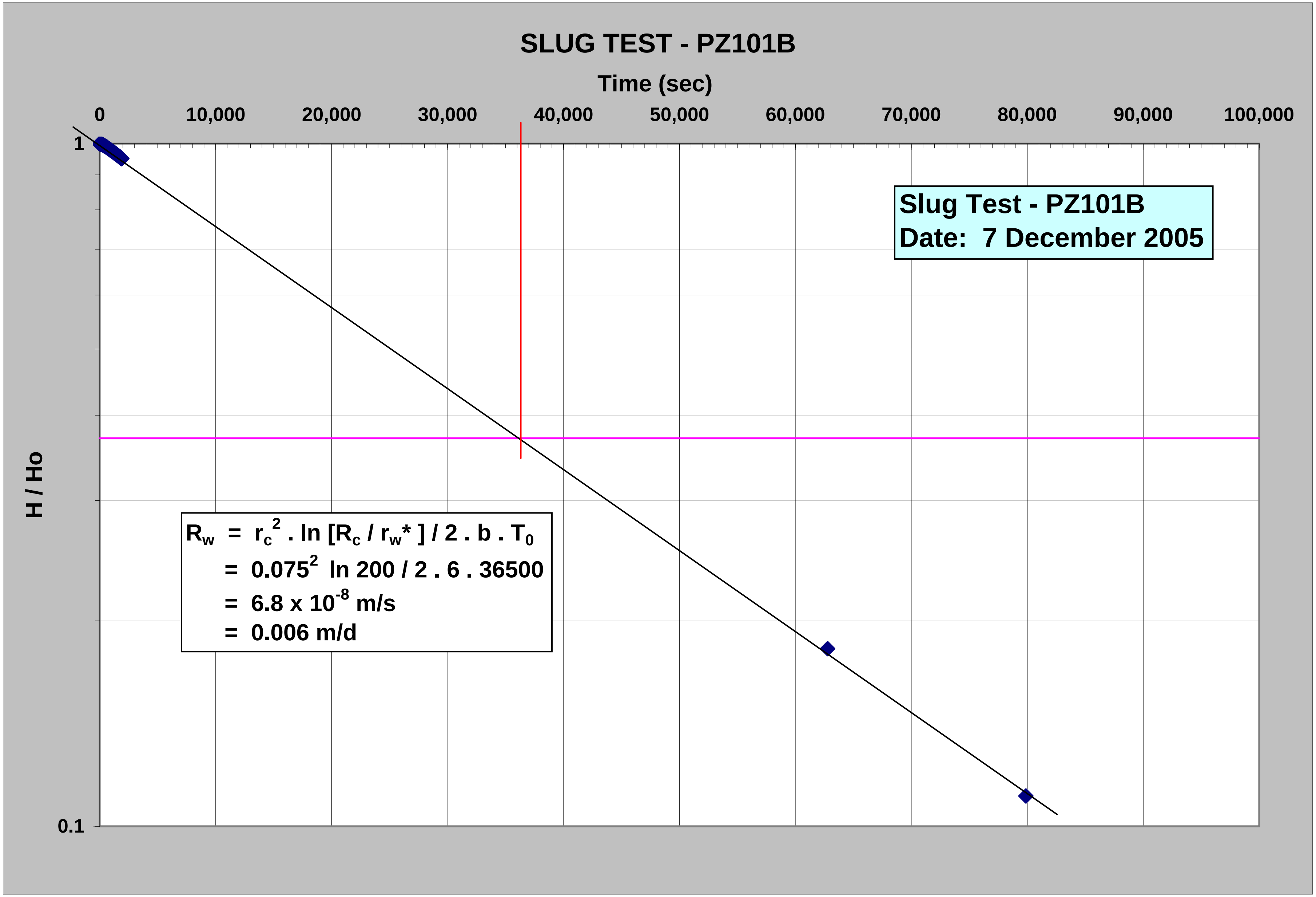
Δs = 0.32 m
T = 2.3 Q / 4 π Δs
= 2.3 x 16 / 4 π 0.32
= 9.2 m^2/d
Average K = 3 m/d (3.5 x 10^{-5} m/s)

Δs = 0.48 m
T = 2.3 Q / 4 π Δs
= 2.3 x 16 / 4 π 0.48
= 6.1 m^2/d
Average K = 2 m/d (2.4 x 10^{-5} m/s)

Δs = 1.25 m

Δs = 3.5 m

Constant Rate Pumping Test
Bore PZ72C (31 March 2006)
Q = 16 kL/d
Observation on PZ72C

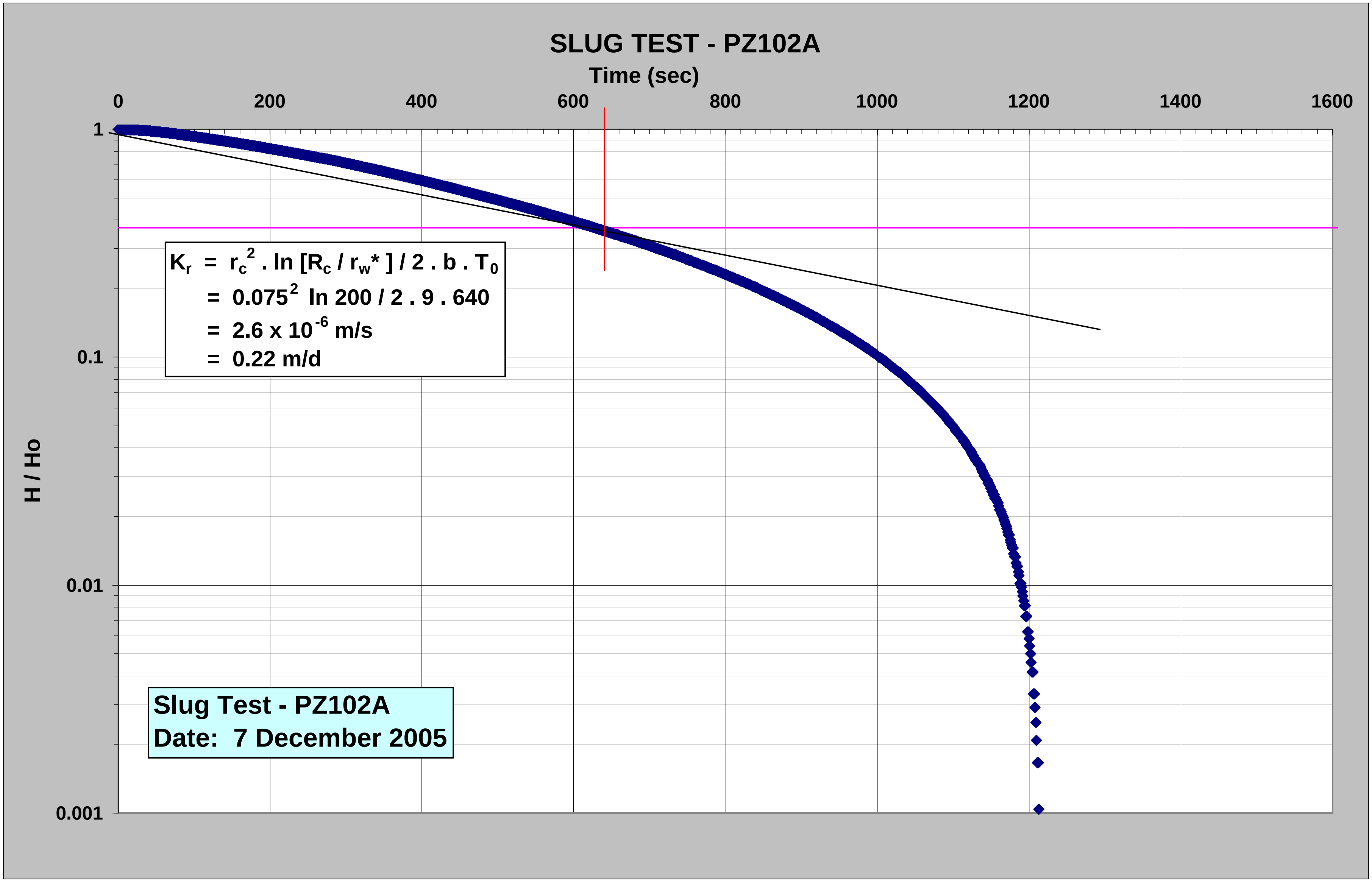


$R_w = r_c^2 . \ln [R_c / r_w^*] / 2 . b . T_0$

$= 0.075^2 \ \ln 200 / 2 . 6 . 36500$

$= 6.8 \times 10^{-8}$ m/s

$= 0.006$ m/d



SLUG TEST - PZ102A

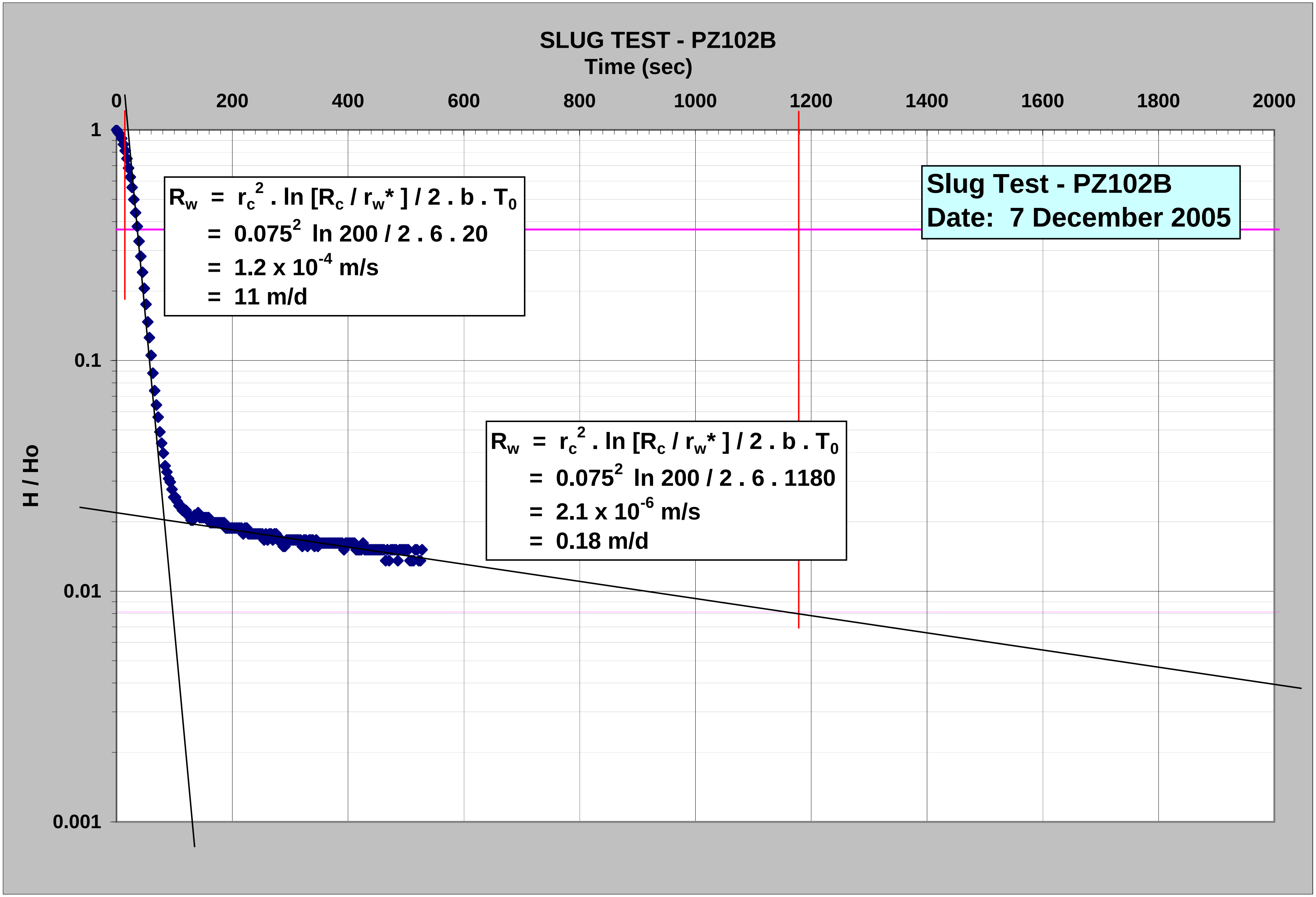
$$K_r = r_c^2 \,.\, \ln [R_c / r_w^*] / 2 \,.\, b \,.\, T_0$$

$$= 0.075^2 \ \ln 200 / 2 \,.\, 9 \,.\, 640$$

$$= 2.6 \times 10^{-6} \text{ m/s}$$

$$= 0.22 \text{ m/d}$$

Slug Test - PZ102A
Date: 7 December 2005



$R_w = r_c^2 \, . \ln [R_c / r_w^*] / 2 \, . \, b \, . \, T_0$

$= 0.075^2 \ \ln 200 / 2 \, . \, 6 \, . \, 20$

$= 1.2 \times 10^{-4}$ m/s

$=$ 11 m/d

Slug Test - PZ102B

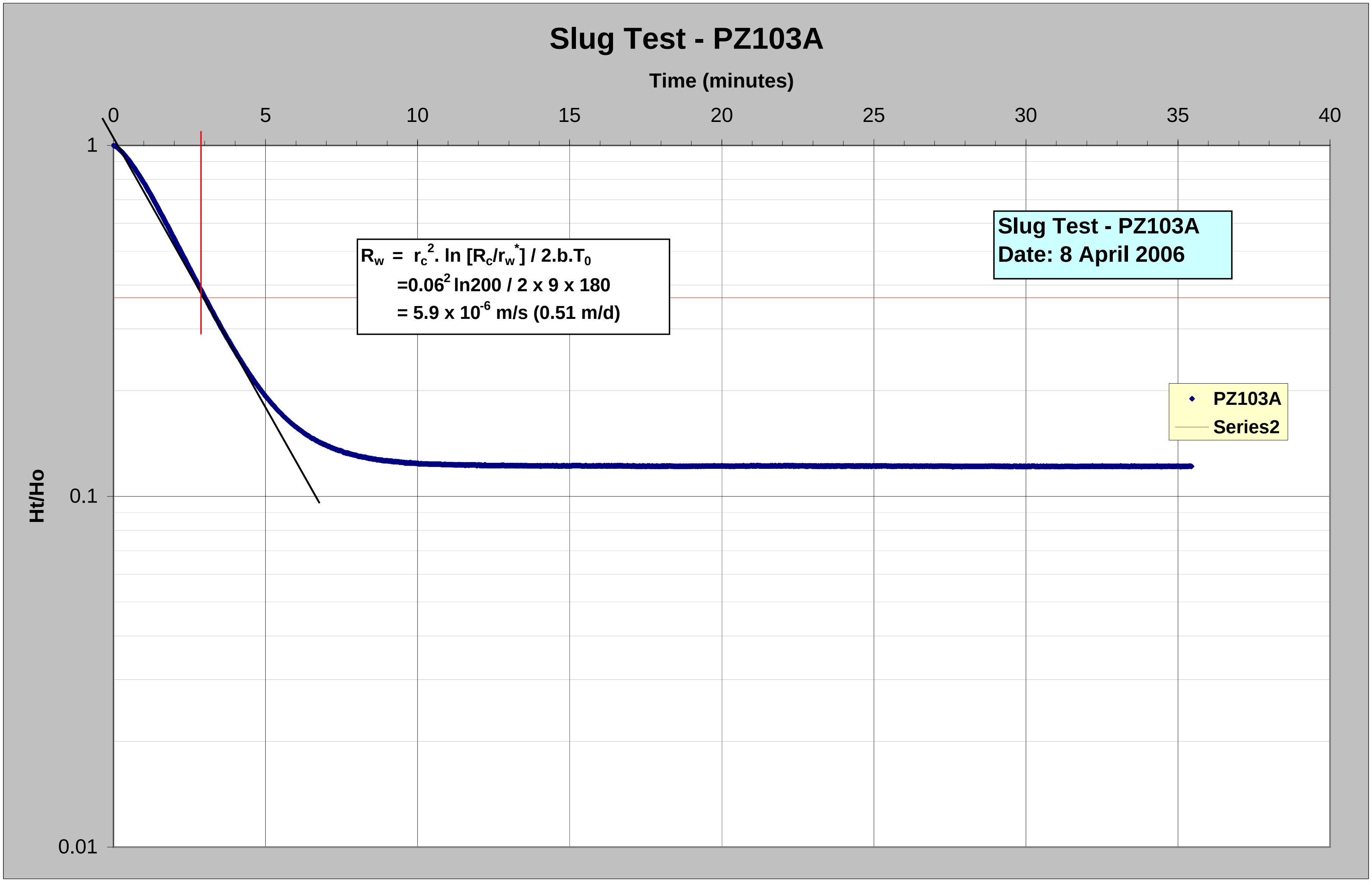
Date: 7 December 2005

$R_w = r_c^2 \, . \ln [R_c / r_w^*] / 2 \, . \, b \, . \, T_0$

$= 0.075^2 \ \ln 200 / 2 \, . \, 6 \, . \, 1180$

$= 2.1 \times 10^{-6}$ m/s

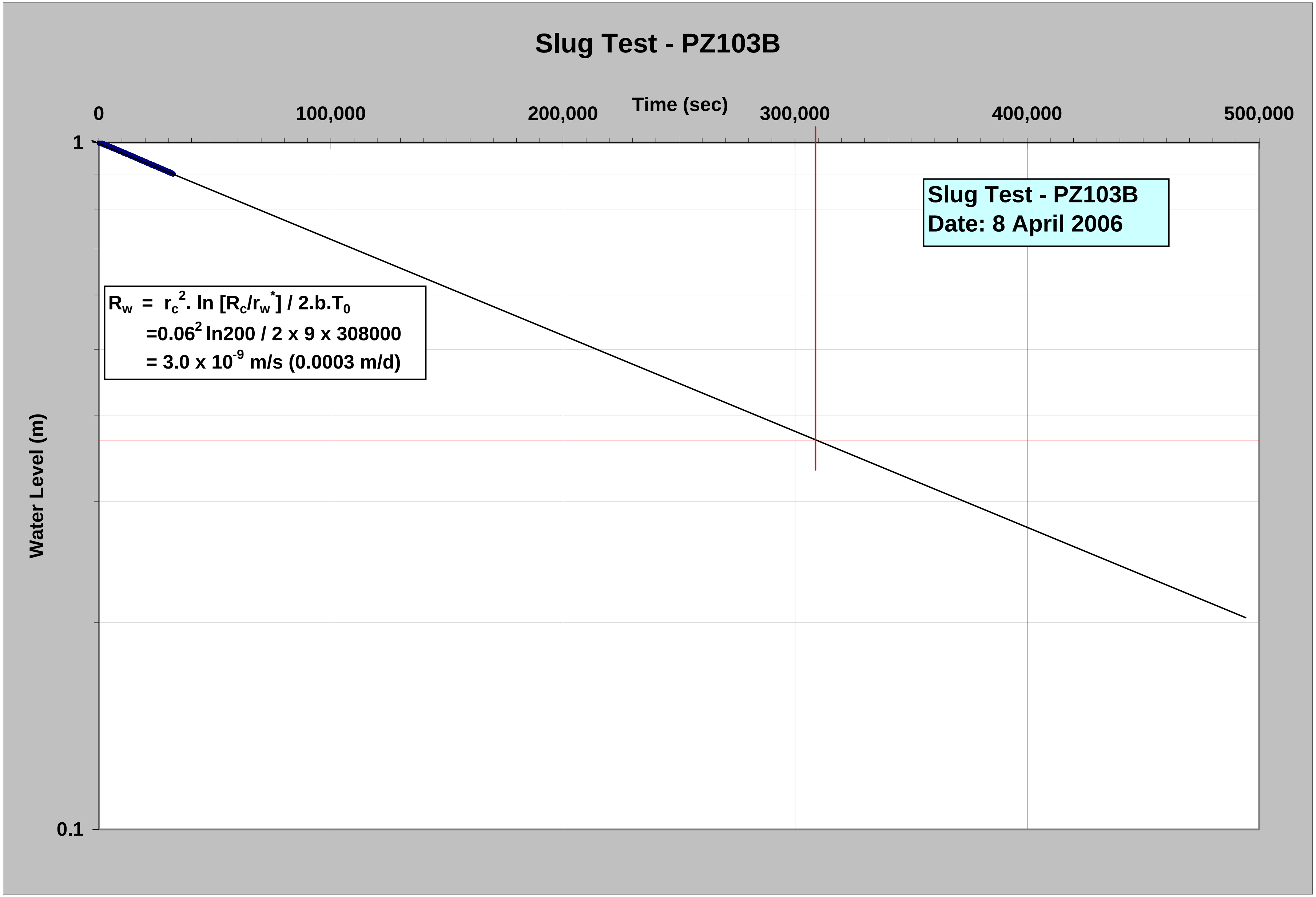
$=$ 0.18 m/d



$$R_w = r_c^2 . \ln [R_c / r_w^*] / 2.b.T_0$$

$$=0.06^2 \ln 200 / 2 \times 9 \times 180$$

$$= 5.9 \times 10^{-6} \text{ m/s } (0.51 \text{ m/d})$$

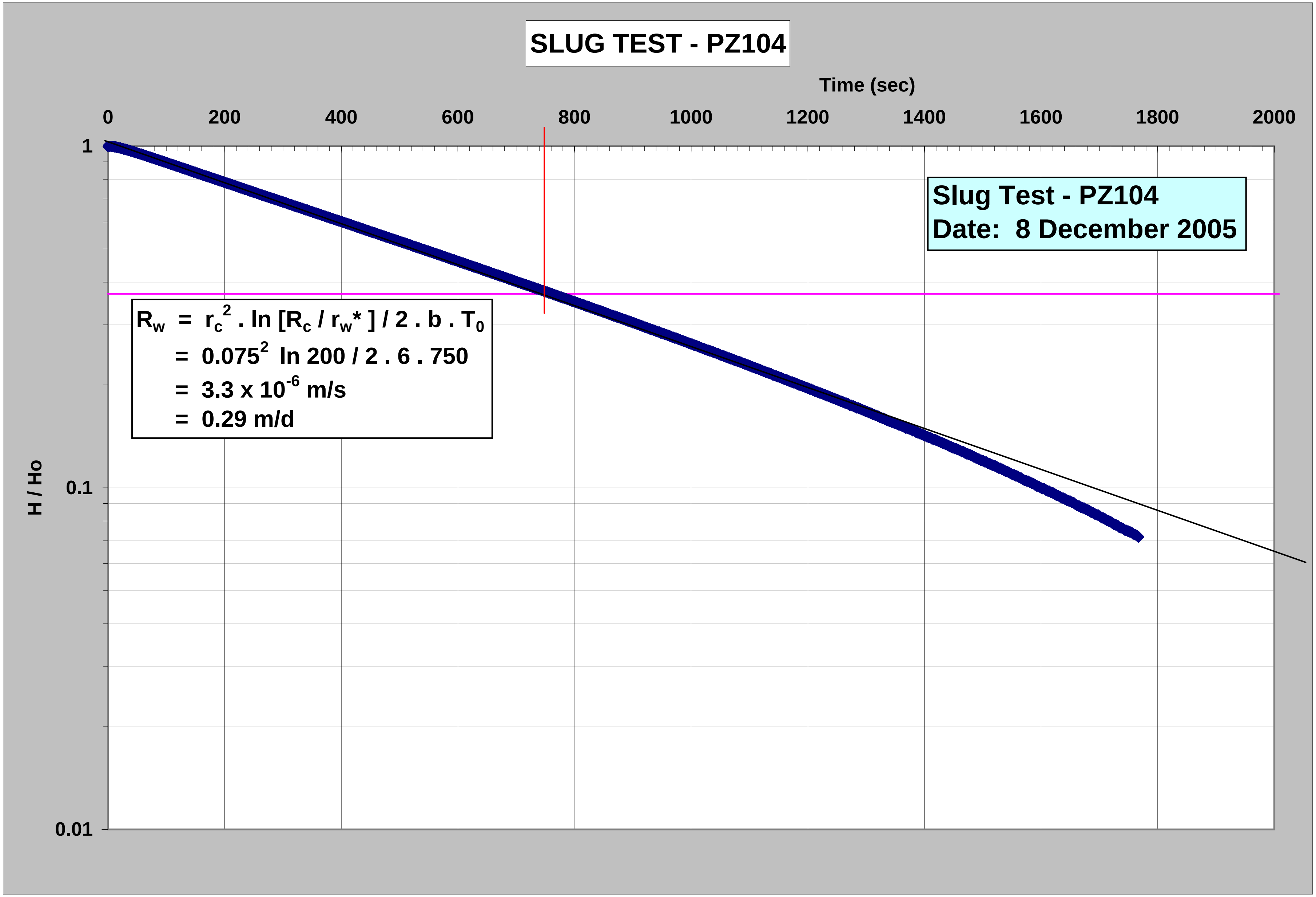


R_w = r_c^2. ln [R_c/r_w^*] / 2.b.T_0

=0.06^2 ln200 / 2 x 9 x 308000

= 3.0 x 10^{-9} m/s (0.0003 m/d)

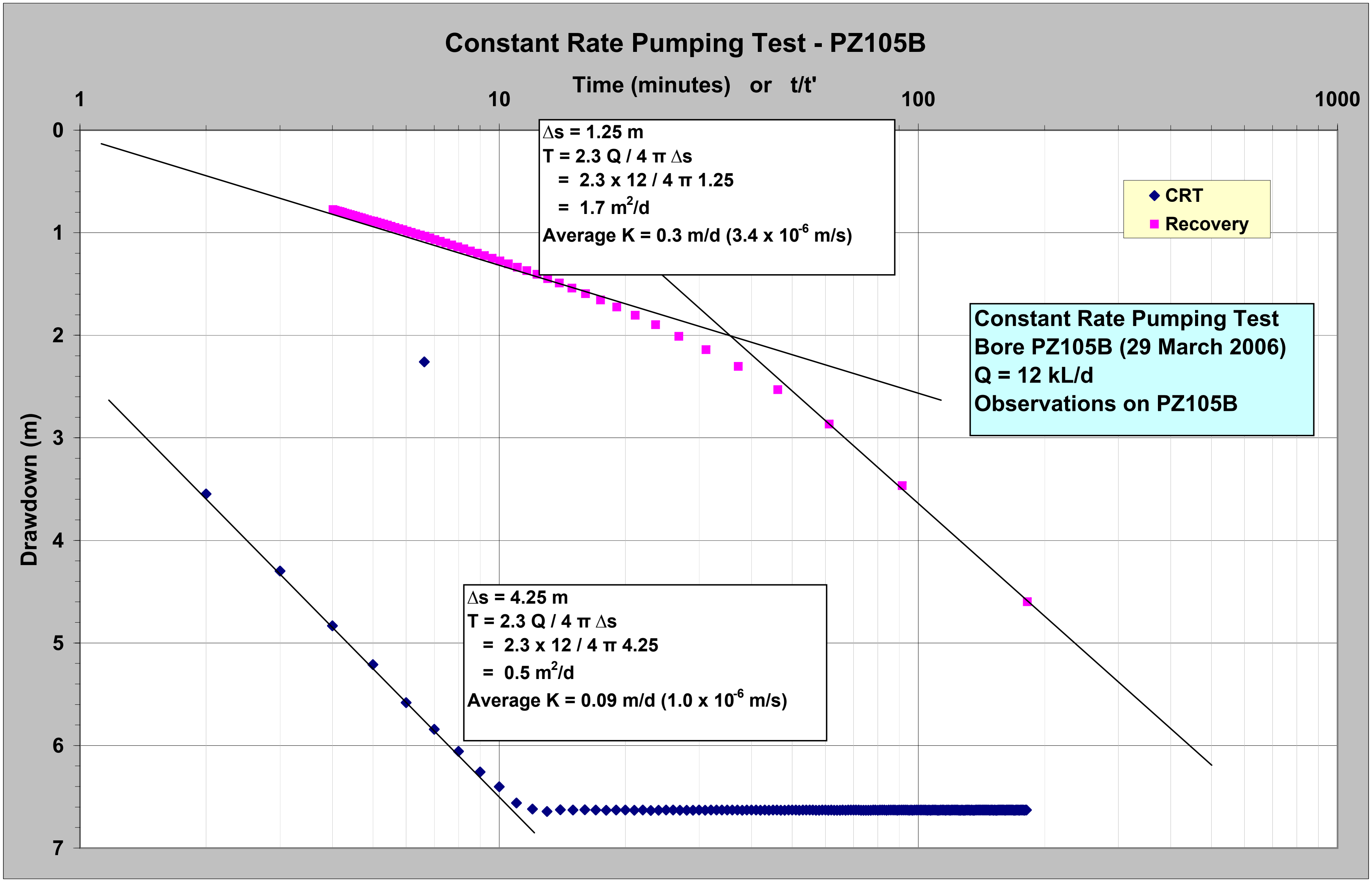
Slug Test - PZ103B
Date: 8 April 2006



SLUG TEST - PZ104

Slug Test - PZ104
Date: 8 December 2005

$R_w = r_c^2 . \ln [R_c / r_w^*] / 2 . b . T_0$
$= 0.075^2 \ \ln 200 / 2 . 6 . 750$
$= 3.3 \times 10^{-6}$ m/s
$= 0.29$ m/d

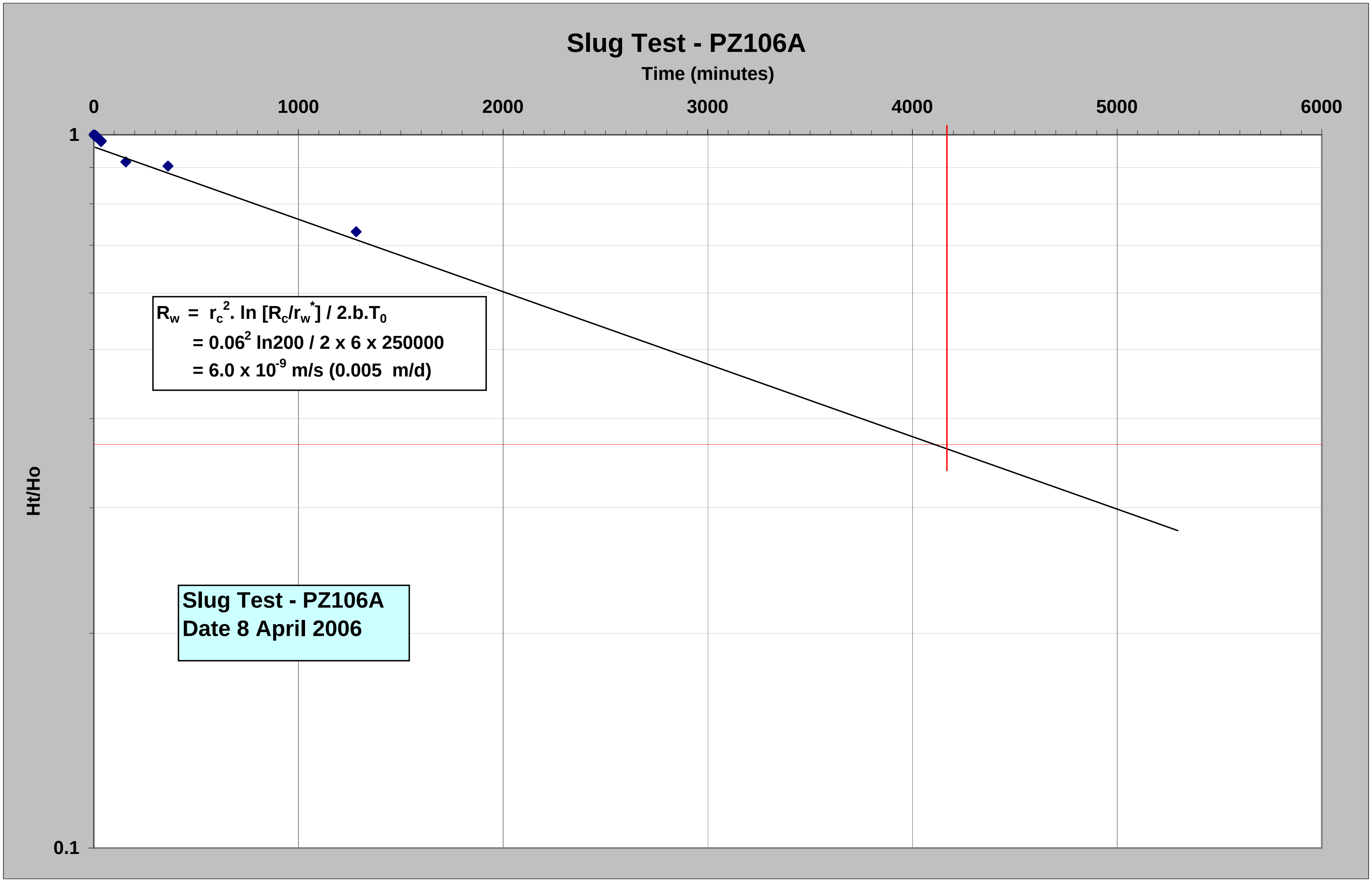


Constant Rate Pumping Test - PZ105B

Δs = 1.25 m
T = 2.3 Q / 4 π Δs
= 2.3 x 12 / 4 π 1.25
= 1.7 m^2/d
Average K = 0.3 m/d (3.4 x 10^{-6} m/s)

Constant Rate Pumping Test
Bore PZ105B (29 March 2006)
Q = 12 kL/d
Observations on PZ105B

Δs = 4.25 m
T = 2.3 Q / 4 π Δs
= 2.3 x 12 / 4 π 4.25
= 0.5 m^2/d
Average K = 0.09 m/d (1.0 x 10^{-6} m/s)



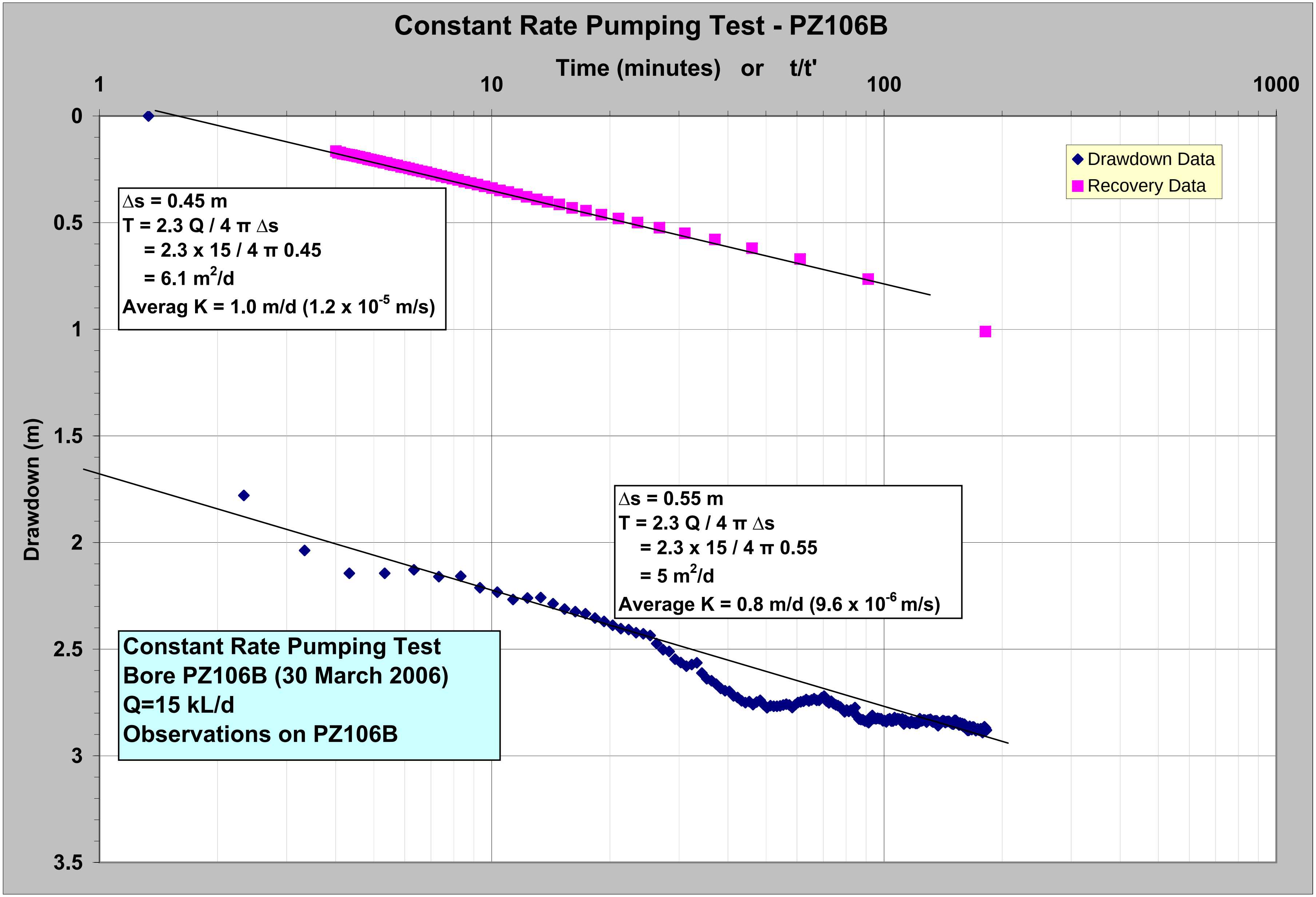
Slug Test - PZ106A

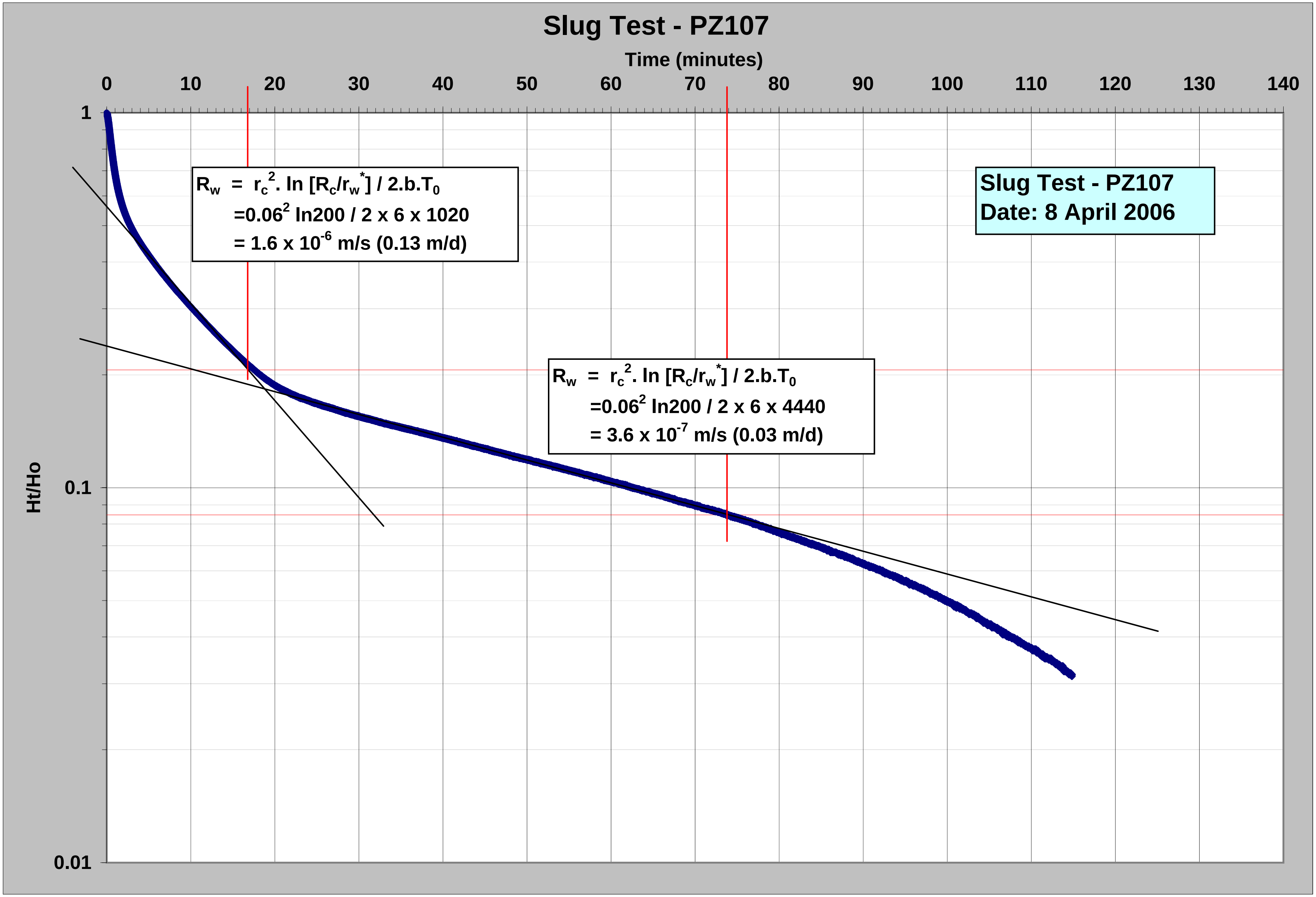
$R_w = r_c^2 . \ln [R_c/r_w^*] / 2.b.T_0$

$= 0.06^2 \ln 200 / 2 \times 6 \times 250000$

$= 6.0 \times 10^{-9}$ m/s (0.005 m/d)

Slug Test - PZ106A
Date 8 April 2006


Constant Rate Pumping Test - PZ106B
Time (minutes) or t/t'
1
10
100
1000
Drawdown (m)
0
0.5
1
1.5
2
2.5
3
3.5
◆ Drawdown Data
■ Recovery Data
Δs = 0.45 m
T = 2.3 Q / 4 π Δs
= 2.3 x 15 / 4 π 0.45
= 6.1 m²/d
Averag K = 1.0 m/d (1.2 x 10⁻⁵ m/s)
Δs = 0.55 m
T = 2.3 Q / 4 π Δs
= 2.3 x 15 / 4 π 0.55
= 5 m²/d
Average K = 0.8 m/d (9.6 x 10⁻⁶ m/s)
Constant Rate Pumping Test
Bore PZ106B (30 March 2006)
Q=15 kL/d
Observations on PZ106B



$R_w = r_c^2 . \text{In} [R_c/r_w^*] / 2.b.T_0$

$= 0.06^2 \text{ In}200 / 2 \times 6 \times 1020$

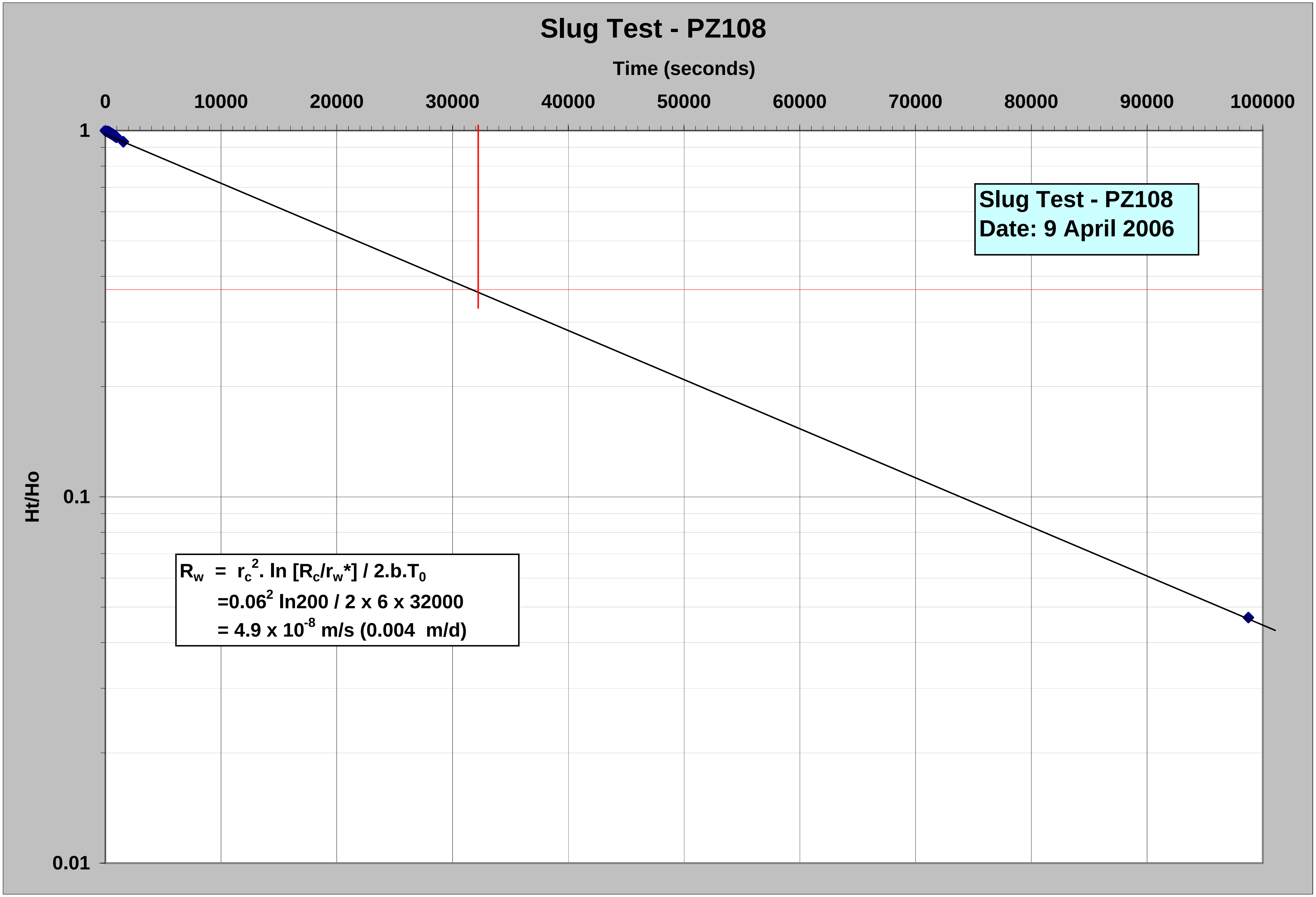
$= 1.6 \times 10^{-6}$ m/s (0.13 m/d)

$R_w = r_c^2 . \text{In} [R_c/r_w^*] / 2.b.T_0$

$= 0.06^2 \text{ In}200 / 2 \times 6 \times 4440$

$= 3.6 \times 10^{-7}$ m/s (0.03 m/d)

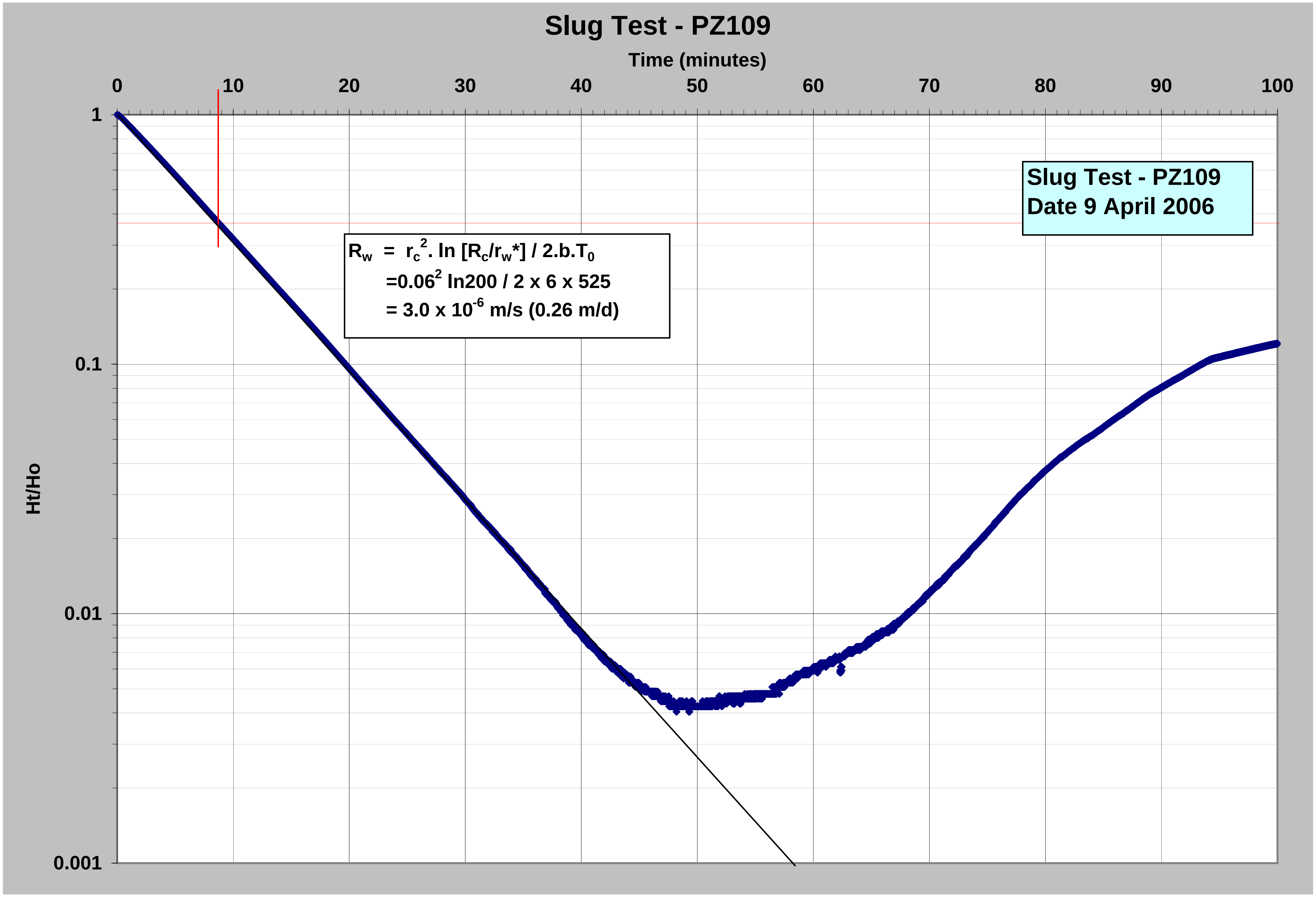
Slug Test - PZ107
Date: 8 April 2006



$R_w = r_c^2 . \ln [R_c/r_w*] / 2.b.T_0$

$=0.06^2 \ln 200 / 2 \times 6 \times 32000$

$= 4.9 \times 10^{-8}$ m/s (0.004 m/d)



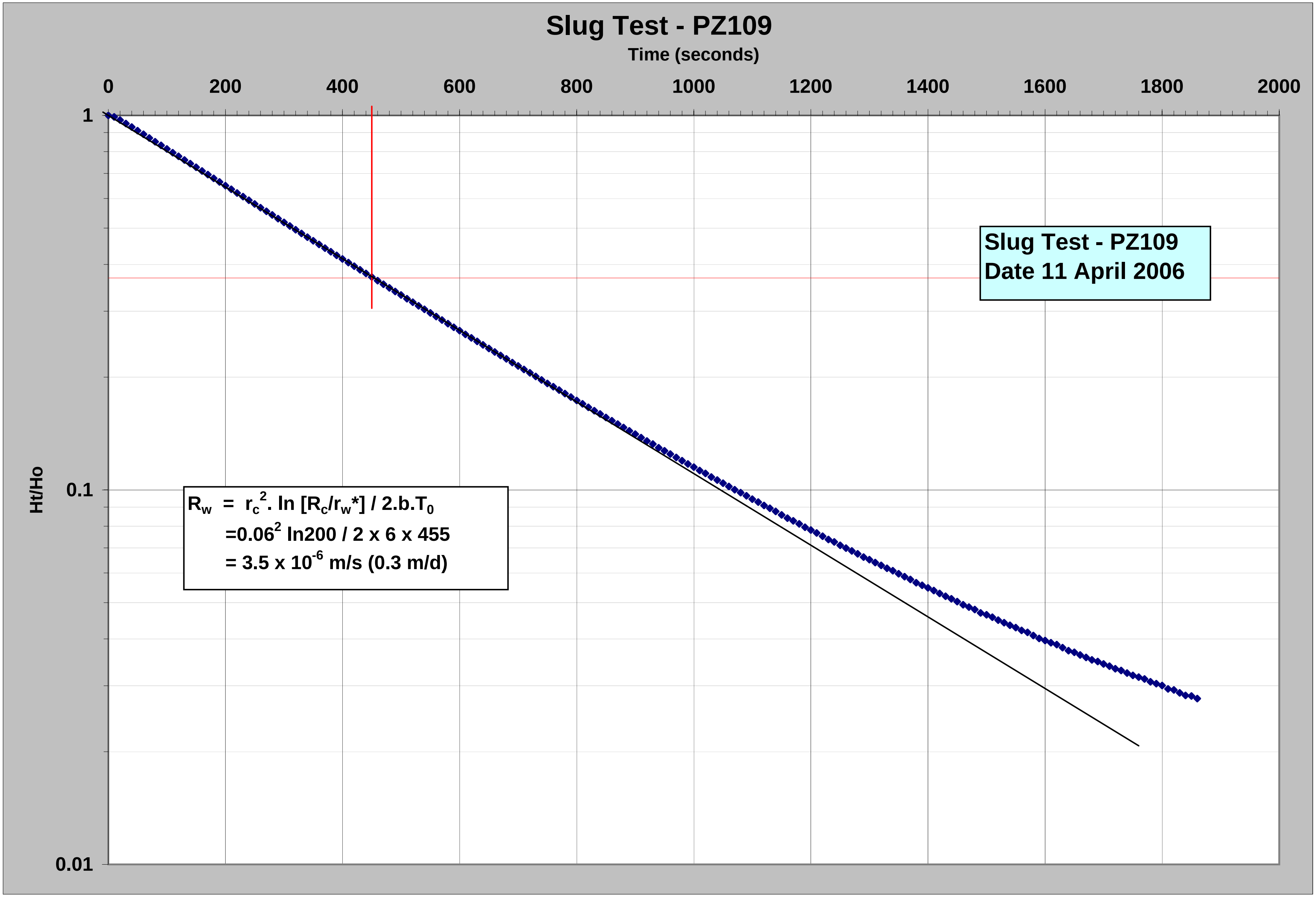
Slug Test - PZ109

$R_w = r_c^2. \ln [R_c/r_w^*] / 2.b.T_0$

$=0.06^2 \ln 200 / 2 \times 6 \times 525$

$= 3.0 \times 10^{-6}$ m/s (0.26 m/d)

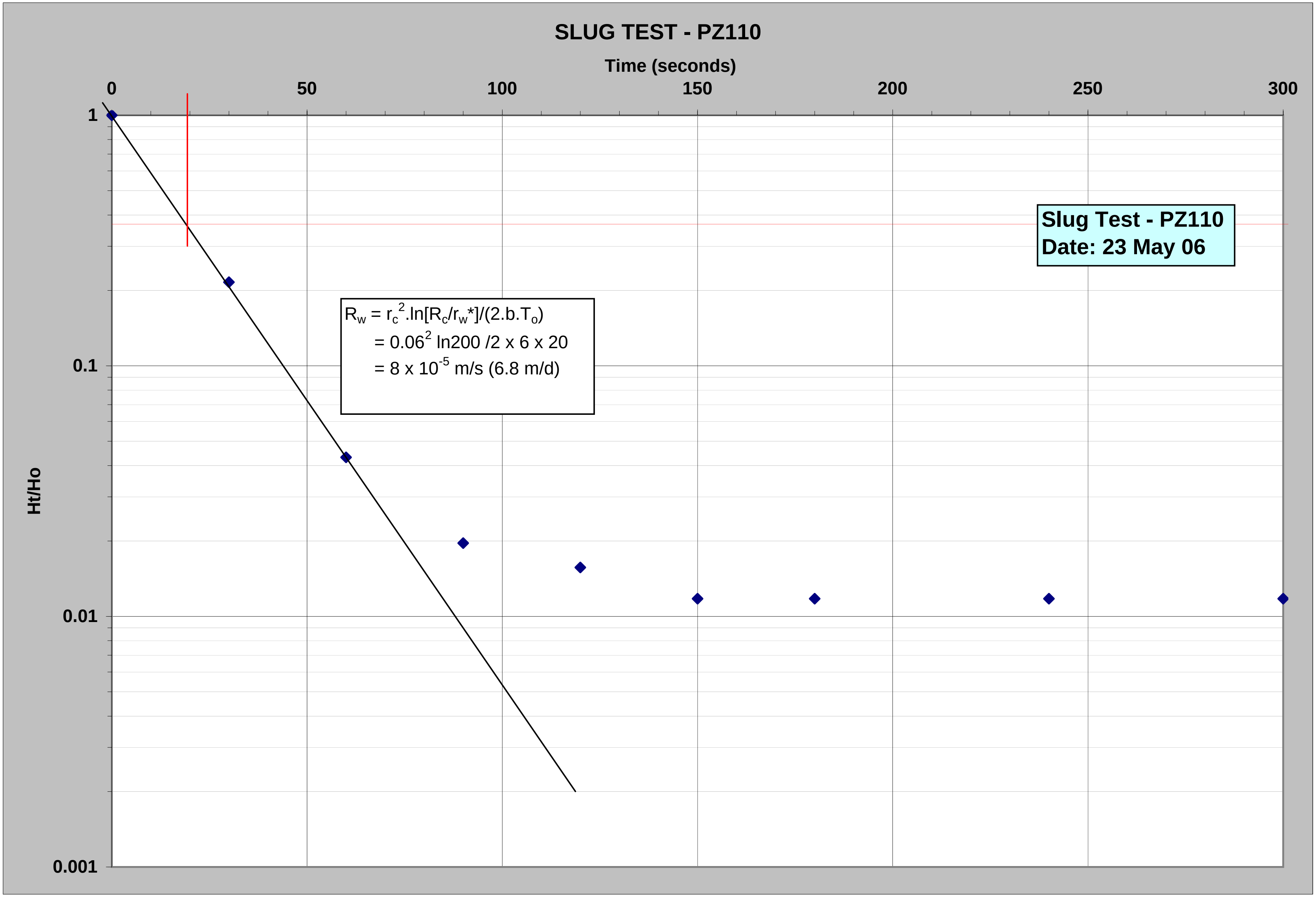
Slug Test - PZ109
Date 9 April 2006



$R_w = r_c^2. \ln [R_c/r_w*] / 2.b.T_0$

$=0.06^2 \ln 200 / 2 \times 6 \times 455$

$= 3.5 \times 10^{-6}$ m/s (0.3 m/d)



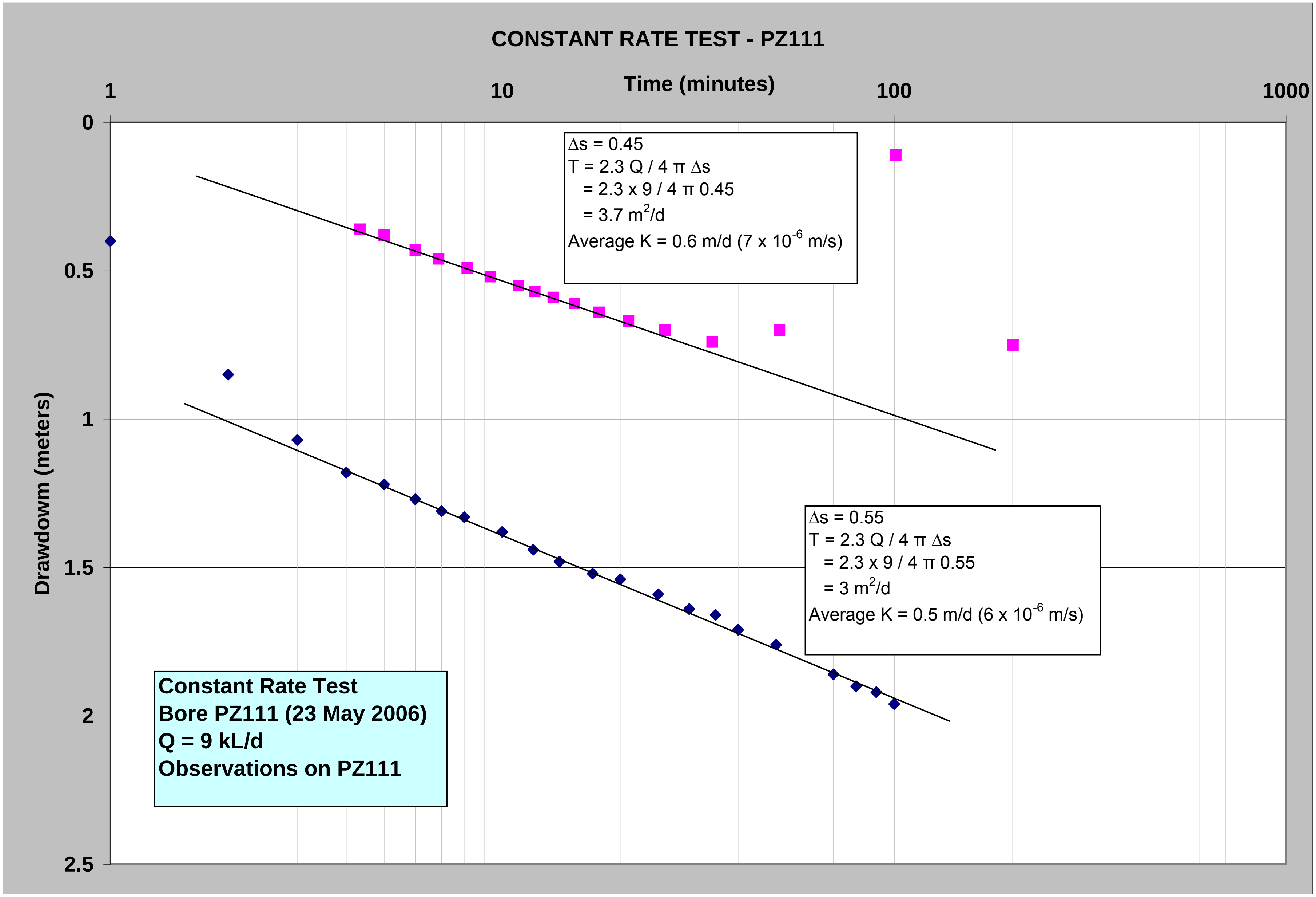
SLUG TEST - PZ110

$R_w = r_c^{2}.\text{ln}[R_c/r_w*]/(2.b.T_o)$

$= 0.06^{2}$ ln200 /2 x 6 x 20

$= 8 \times 10^{-5}$ m/s (6.8 m/d)

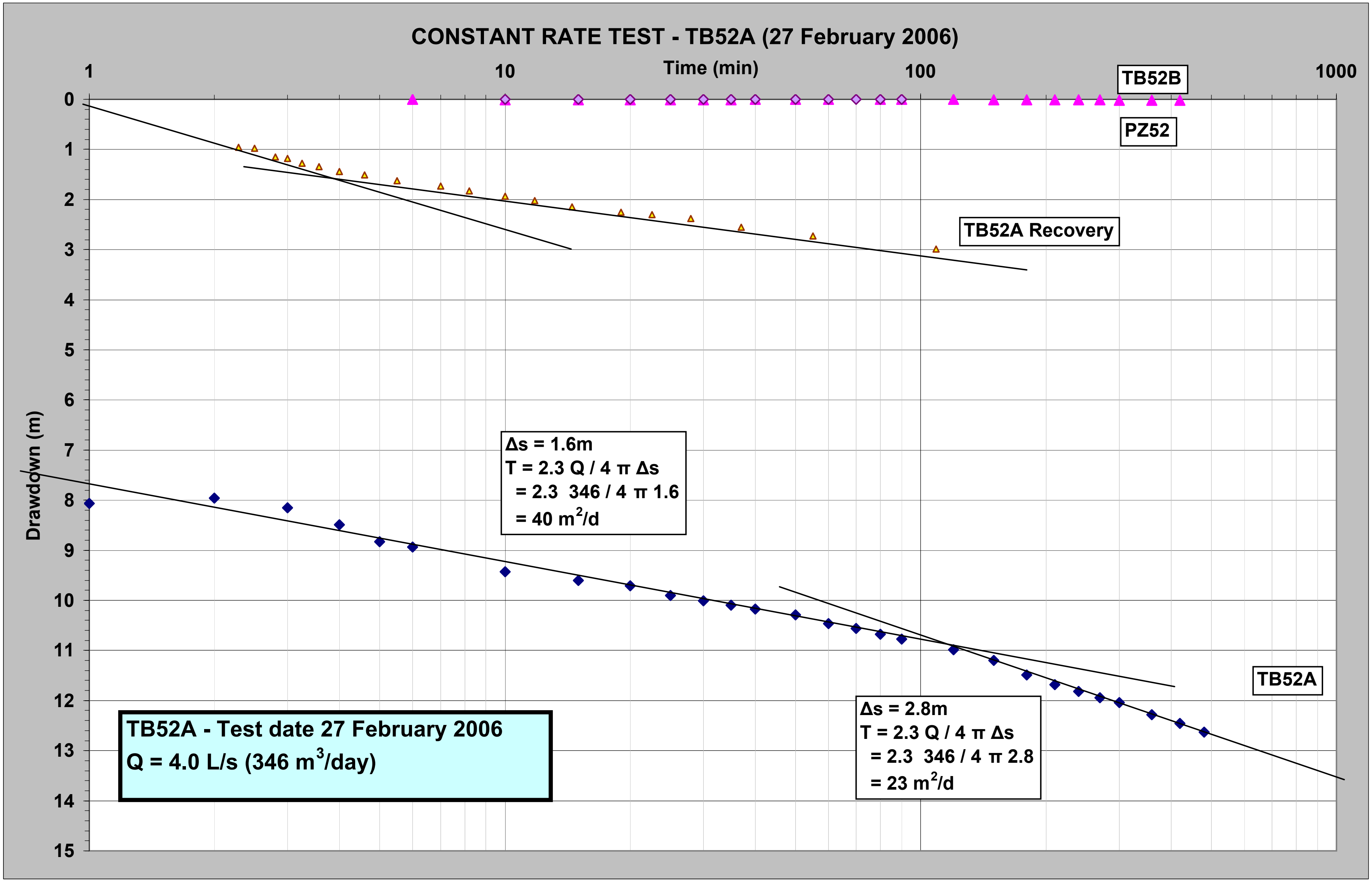
Slug Test - PZ110
Date: 23 May 06

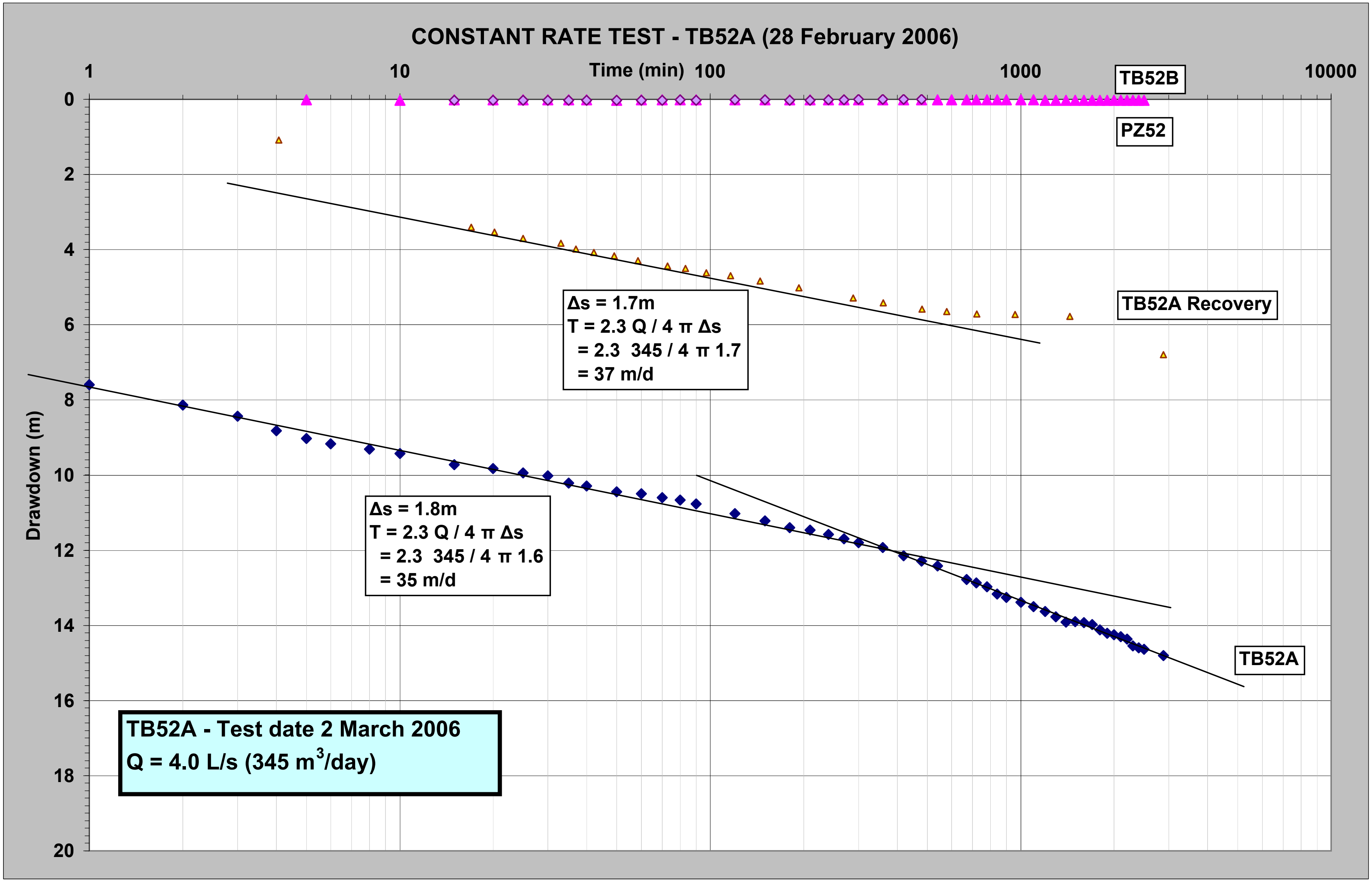


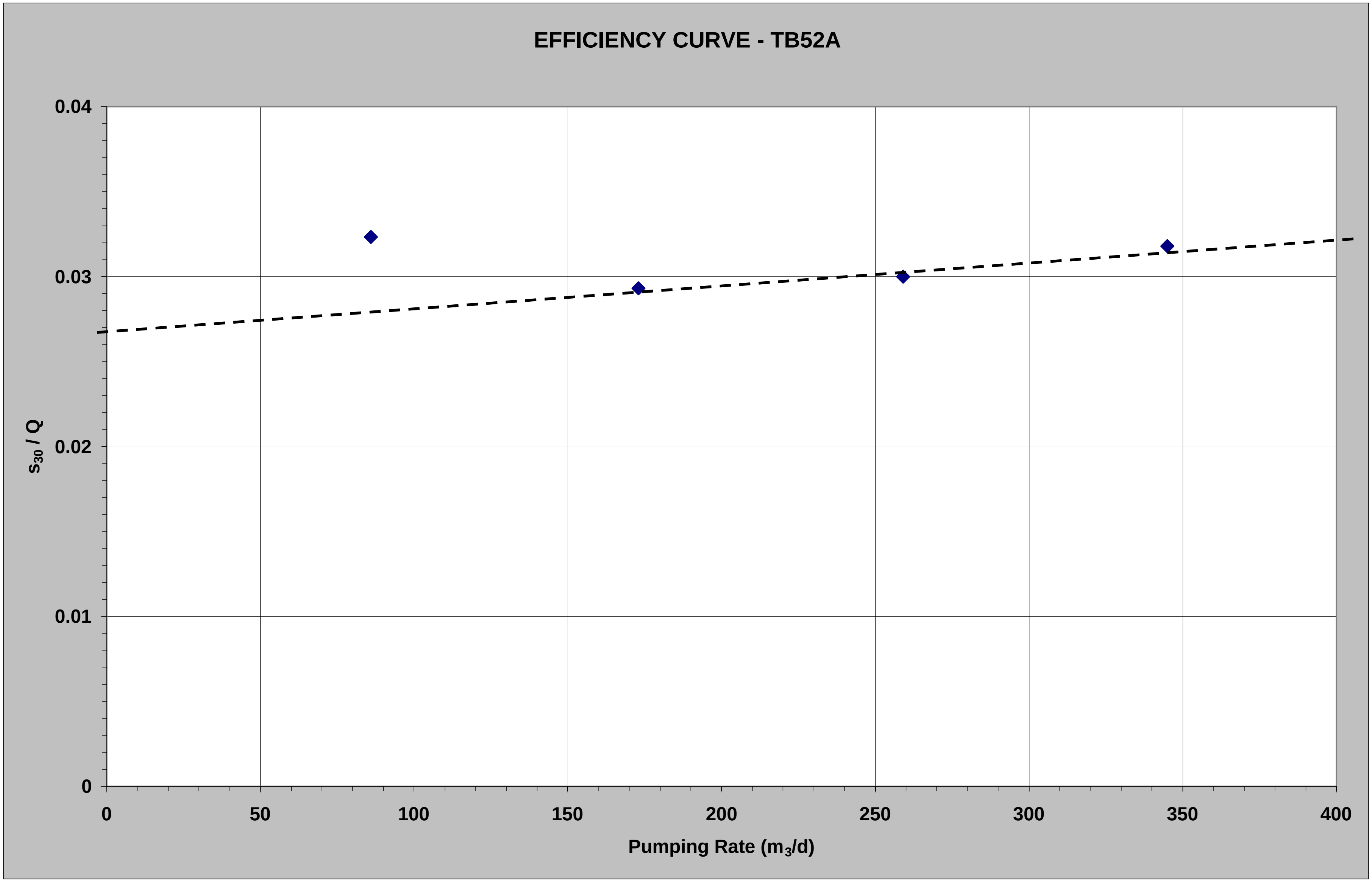
$\Delta s = 0.45$
$T = 2.3\ Q / 4\ \pi\ \Delta s$
$= 2.3 \times 9 / 4\ \pi\ 0.45$
$= 3.7\ m^2/d$
Average K = 0.6 m/d (7 x 10^{-6} m/s)

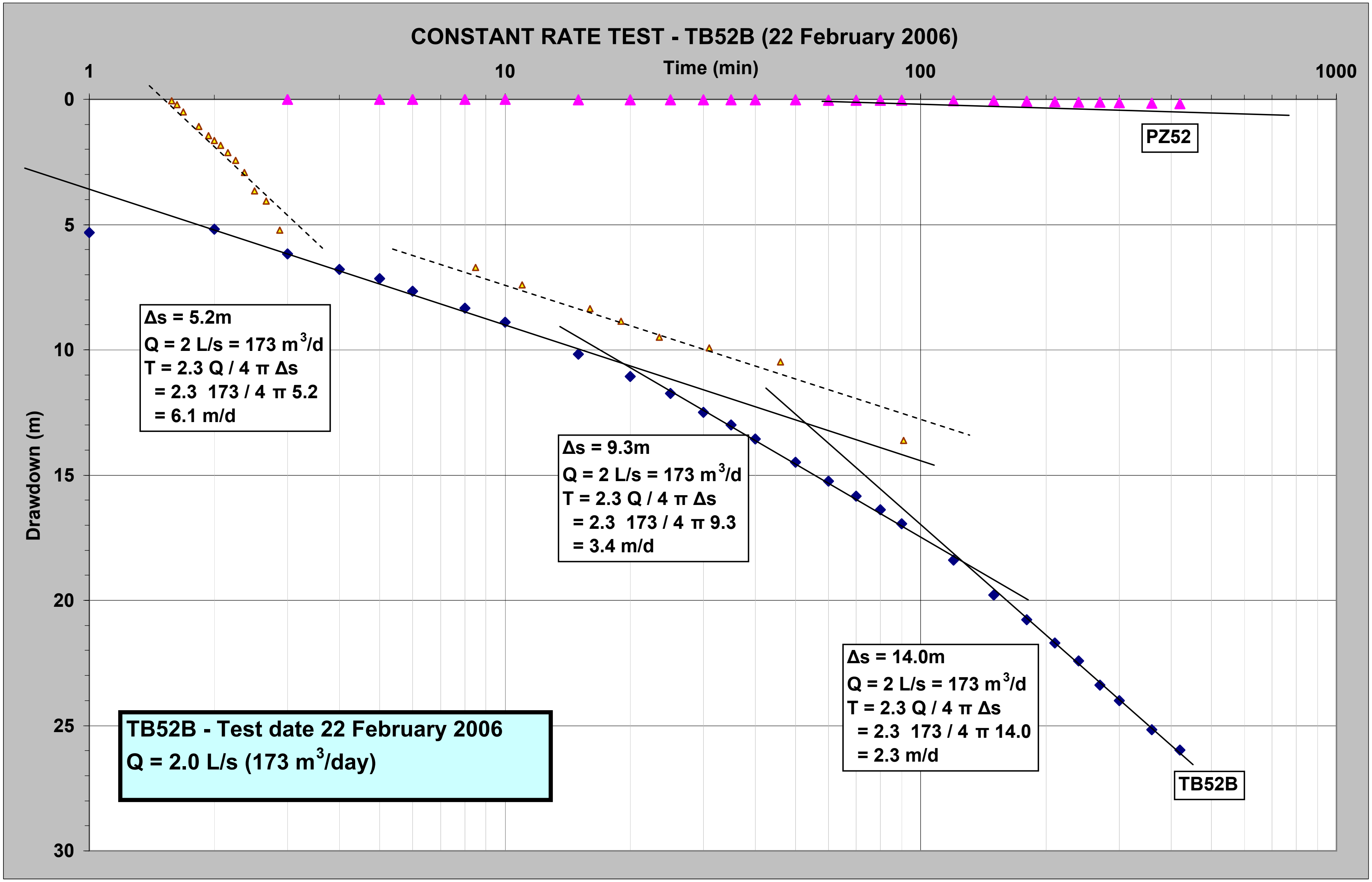
$\Delta s = 0.55$
$T = 2.3\ Q / 4\ \pi\ \Delta s$
$= 2.3 \times 9 / 4\ \pi\ 0.55$
$= 3\ m^2/d$
Average K = 0.5 m/d (6 x 10^{-6} m/s)

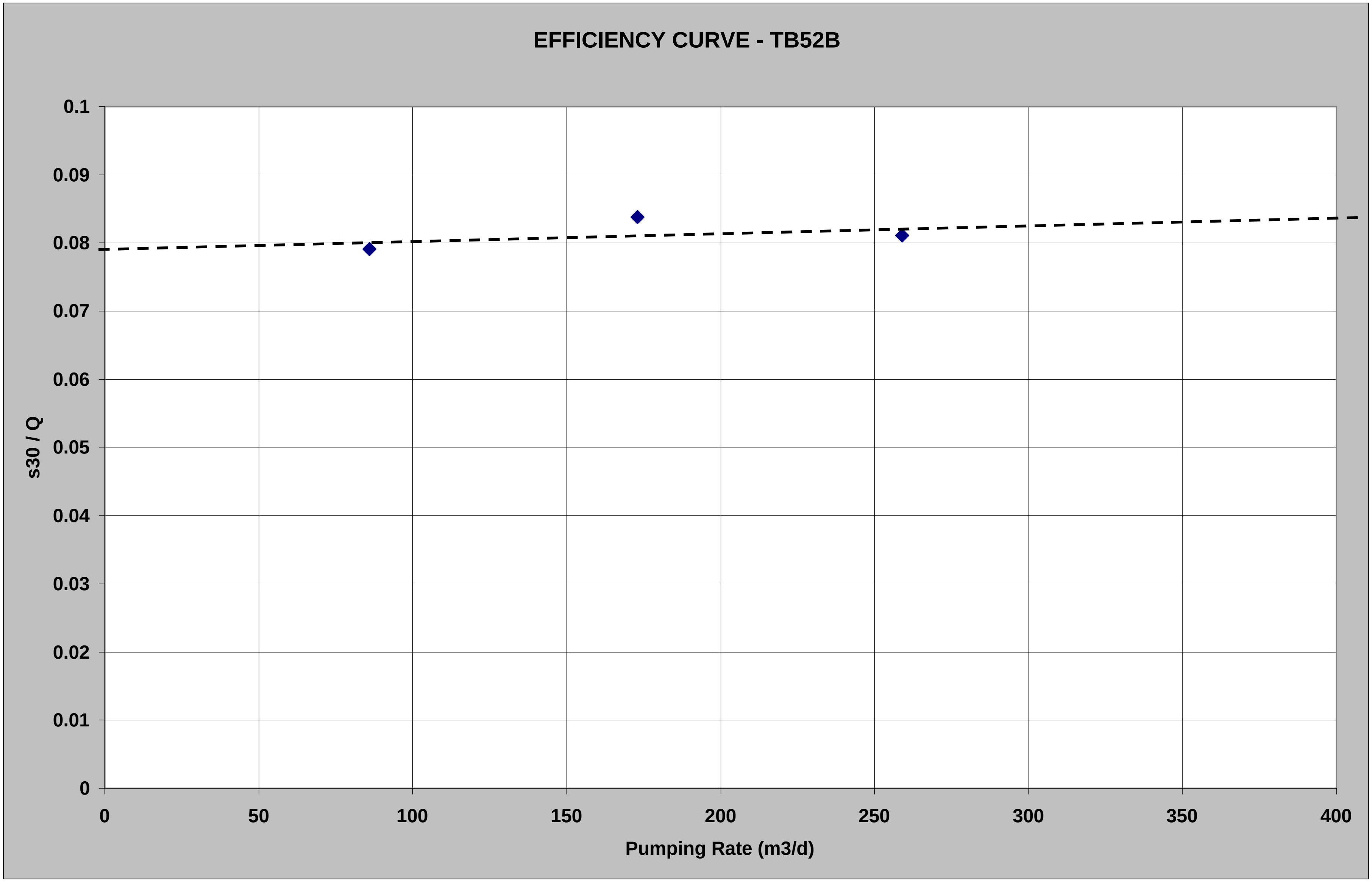
Constant Rate Test
Bore PZ111 (23 May 2006)
Q = 9 kL/d
Observations on PZ111

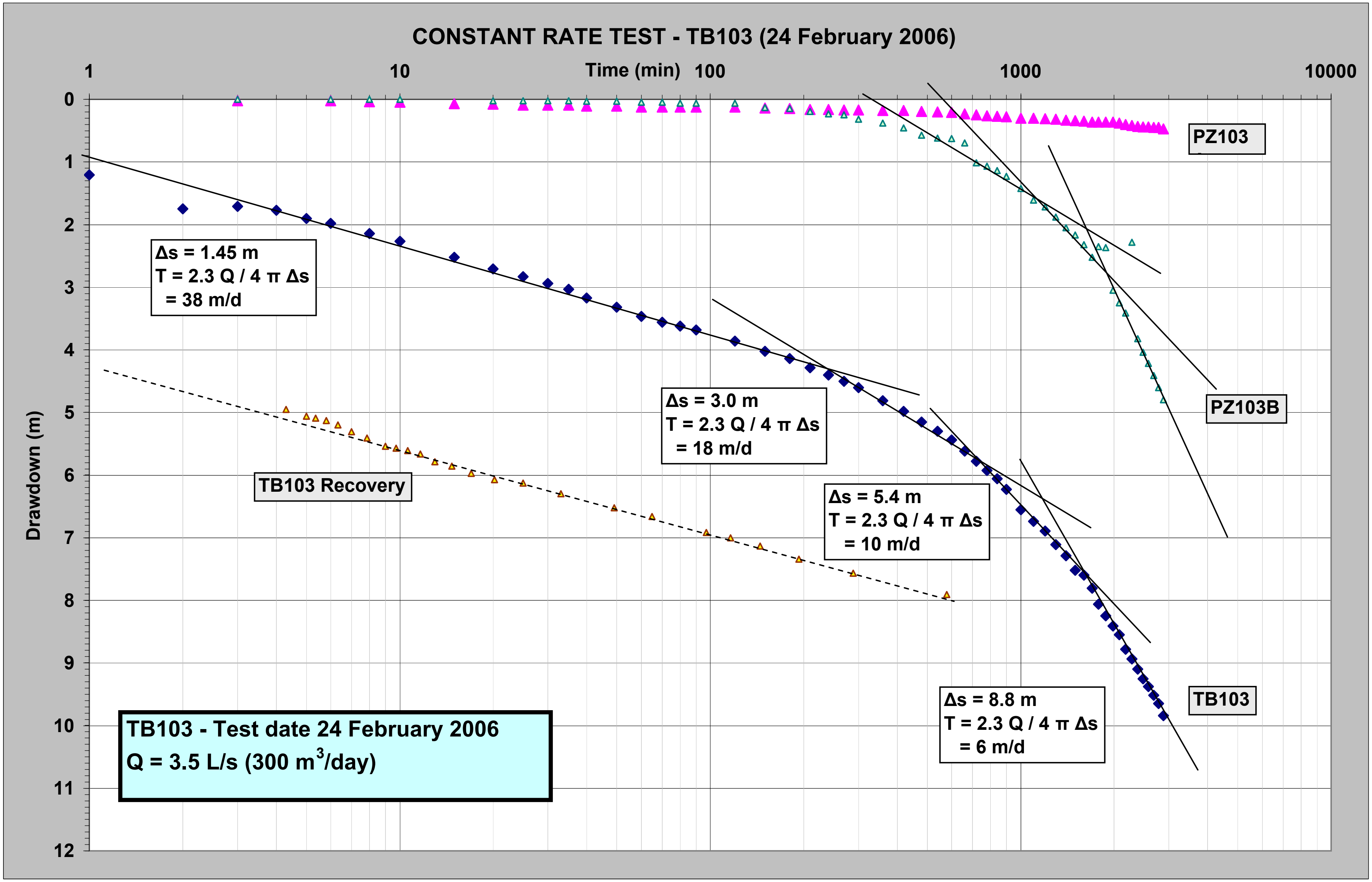

CONSTANT RATE TEST - TB52A (27 February 2006)
Time (min)
1
10
100
1000
Drawdown (m)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
TB52B
PZ52
TB52A Recovery
TB52A
Δs = 1.6m
T = 2.3 Q / 4 π Δs
= 2.3 346 / 4 π 1.6
= 40 m^2/d
Δs = 2.8m
T = 2.3 Q / 4 π Δs
= 2.3 346 / 4 π 2.8
= 23 m^2/d
TB52A - Test date 27 February 2006
Q = 4.0 L/s (346 m^3/day)

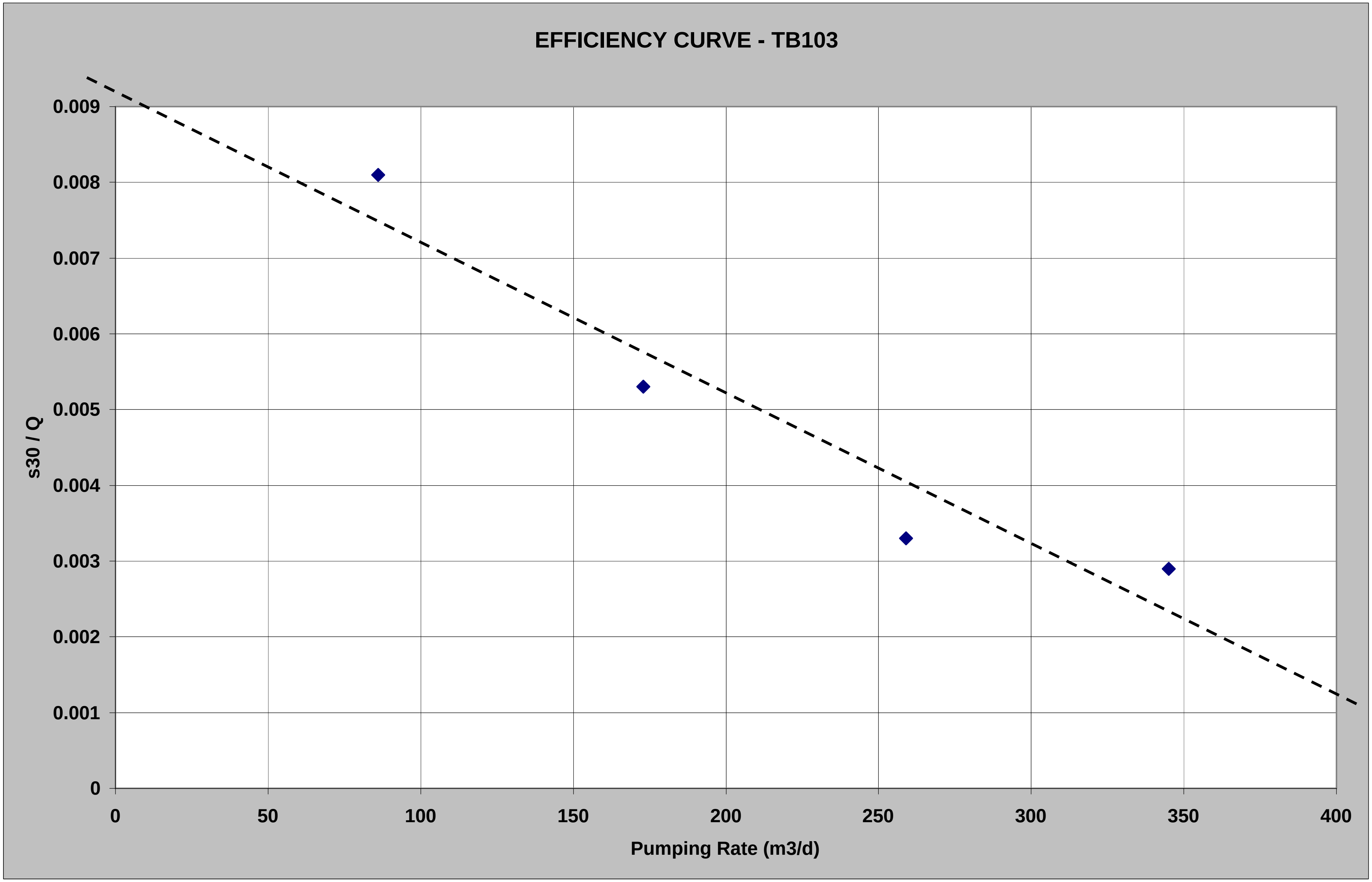

CONSTANT RATE TEST - TB52A (28 February 2006)
Time (min)
1
10
100
1000
10000
Drawdown (m)
0
2
4
6
8
10
12
14
16
18
20
TB52B
PZ52
TB52A Recovery
TB52A
Δs = 1.7m
T = 2.3 Q / 4 π Δs
= 2.3 345 / 4 π 1.7
= 37 m/d
Δs = 1.8m
T = 2.3 Q / 4 π Δs
= 2.3 345 / 4 π 1.6
= 35 m/d
TB52A - Test date 2 March 2006
Q = 4.0 L/s (345 m^3/day)

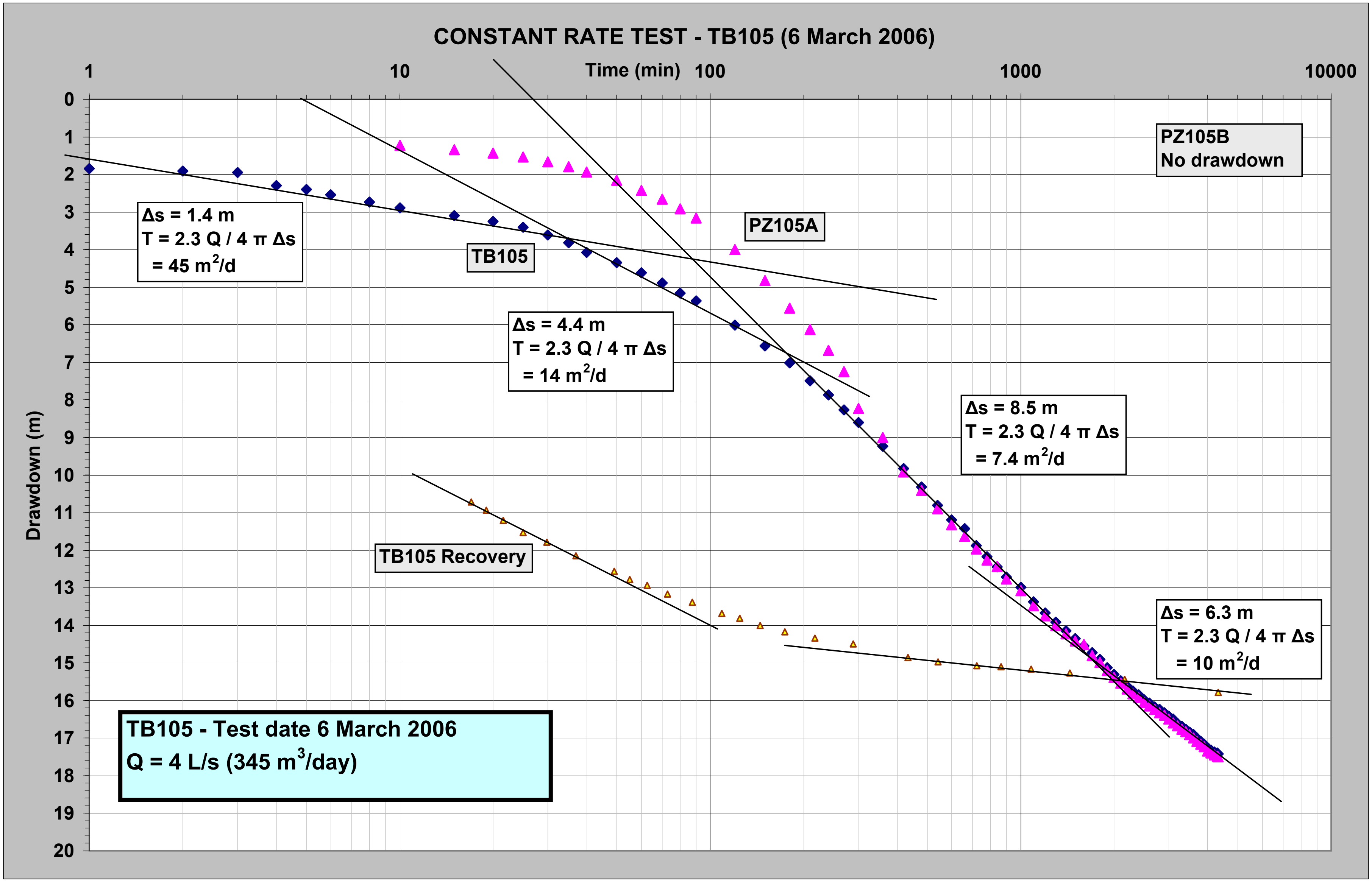

EFFICIENCY CURVE - TB52A
0.04
0.03
0.02
0.01
0
s_{30} / Q
0
50
100
150
200
250
300
350
400
Pumping Rate (m_3/d)

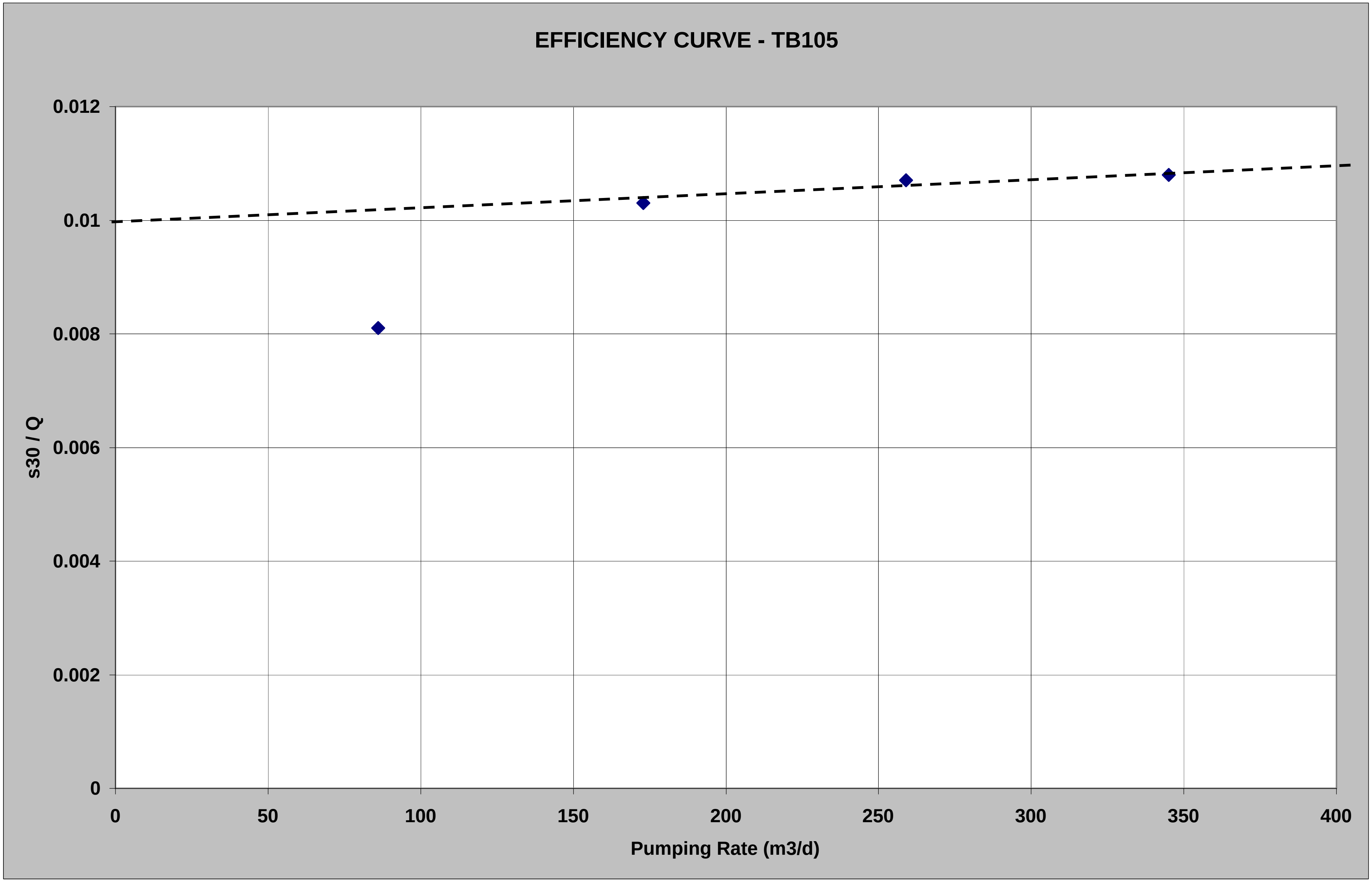

CONSTANT RATE TEST - TB52B (22 February 2006)
Time (min)
1
10
100
1000
Drawdown (m)
0
5
10
15
20
25
30
PZ52
TB52B
Δs = 5.2m
Q = 2 L/s = 173 m3/d
T = 2.3 Q / 4 π Δs
= 2.3 173 / 4 π 5.2
= 6.1 m/d
Δs = 9.3m
Q = 2 L/s = 173 m3/d
T = 2.3 Q / 4 π Δs
= 2.3 173 / 4 π 9.3
= 3.4 m/d
Δs = 14.0m
Q = 2 L/s = 173 m3/d
T = 2.3 Q / 4 π Δs
= 2.3 173 / 4 π 14.0
= 2.3 m/d
TB52B - Test date 22 February 2006
Q = 2.0 L/s (173 m3/day)


EFFICIENCY CURVE - TB52B
s30 / Q
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
0
50
100
150
200
250
300
350
400
Pumping Rate (m3/d)


CONSTANT RATE TEST - TB103 (24 February 2006)
Time (min)
1
10
100
1000
10000
Drawdown (m)
0
1
2
3
4
5
6
7
8
9
10
11
12
Δs = 1.45 m
T = 2.3 Q / 4 π Δs
= 38 m/d
Δs = 3.0 m
T = 2.3 Q / 4 π Δs
= 18 m/d
Δs = 5.4 m
T = 2.3 Q / 4 π Δs
= 10 m/d
Δs = 8.8 m
T = 2.3 Q / 4 π Δs
= 6 m/d
PZ103
PZ103B
TB103
TB103 Recovery
TB103 - Test date 24 February 2006
Q = 3.5 L/s (300 m3/day)


EFFICIENCY CURVE - TB103
s30 / Q
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0
0
50
100
150
200
250
300
350
400
Pumping Rate (m3/d)


CONSTANT RATE TEST - TB105 (6 March 2006)
Time (min)
1
10
100
1000
10000
Drawdown (m)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
PZ105B
No drawdown
PZ105A
TB105
TB105 Recovery
Δs = 1.4 m
T = 2.3 Q / 4 π Δs
= 45 m²/d
Δs = 4.4 m
T = 2.3 Q / 4 π Δs
= 14 m²/d
Δs = 8.5 m
T = 2.3 Q / 4 π Δs
= 7.4 m²/d
Δs = 6.3 m
T = 2.3 Q / 4 π Δs
= 10 m²/d
TB105 - Test date 6 March 2006
Q = 4 L/s (345 m³/day)


EFFICIENCY CURVE - TB105
s30 / Q
0.012
0.01
0.008
0.006
0.004
0.002
0
0
50
100
150
200
250
300
350
400
Pumping Rate (m3/d)

APPENDIX E

DNR REGISTERED BORES

Appendix E: DNR Database Search - Registered Bores / Wells

Page 1 of 3

Reg No	Licence	Type	Owner	Completed	Depth	Drilled depth	County	Parish	SWL	Salinity	Comment	Yield	Comment	AMG Easting	AMG Northing	MGA Easting	MGA Northing
GW012015		Bore	Other Govt	1/10/1956	0.0	76.2	BLIGH	ULAN			(Unknown)			759688	6428924	759793	6429114
GW012016		Bore	Other Govt	1/10/1956	76.2	76.2	BLIGH	ULAN			(Unknown)			760093	6429108	760198	6429108
GW013368	20BL005420	Bore	Private	1/03/1954	18.8	18.9	PHILLIP	MOOLARBEN			(Unknown)			761064	6413399	761169	6413589
GW023203	20BL015692	Well	Private		7.6	7.6	PHILLIP	MOOLARBEN			(Unknown)			757305	6413980	757410	6414170
GW023210	20BL015691	Well	Private		7.6	7.6	PHILLIP	MOOLARBEN			(Unknown)			757713	6414665	757818	6414855
GW023216	20BL015693	Well	Private		10.6	10.7	PHILLIP	MOOLARBEN			(Unknown)			756896	6413891	757001	6414081
GW024773		Bore	J.C.B.	1/03/1975	126.0	126.0	PHILLIP	LENNOX			(Unknown)			762540	6431760	762645	6431950
GW024774		Bore	Private	1/12/1979	91.1	91.1	PHILLIP	WILPINJONG			0-500 ppm			765310	6423700	765415	6423890
GW024775		Bore	Private	1/01/1980	45.1	45.1	PHILLIP	CUMBO			501-1000 ppm			768725	6420790	768830	6420980
GW024776		Bore	Private	1/10/1980	48.8	48.8	PHILLIP	CUMBO			1001-3000 ppm			769750	6420875	769855	6421065
GW024777		Bore	Private	1/10/1980	26.1	26.1	PHILLIP	CUMBO			1001-3000 ppm			770640	6419500	770745	6419690
GW024778		Bore	Private	1/10/1980	31.8	31.8	PHILLIP	CUMBO			1001-3000 ppm			771760	6419700	771865	6419890
GW024779		Bore	Private	1/10/1980	41.3	41.3	PHILLIP	CUMBO			1001-3000 ppm			772725	6419860	772839	6420045
GW025262	20BL022473	Bore open thru rock	Private	1/09/1968	0.0	126.5	PHILLIP	MOOLARBEN			501-1000 ppm			756084	6415485	756198	6415670
GW030626		Bore	Private	1/05/1972	0.0	0.0	BLIGH	BOBADEEN			(Unknown)			762440	6438801	762554	6438985
GW030631	20BL027210	Bore	Private	1/06/1972	121.9	121.9	BLIGH	BOBADEEN			(Unknown)			762344	6438812	762458	6438996
GW034454	20BL027654	(Unknown)	Private	1/01/1920	61.0	0.0	BLIGH	BOBADEEN			(Unknown)			763581	6437867	763695	6438051
GW034640	20BL027911	Bore open thru rock	Private	1/11/1971	70.1	70.1	PHILLIP	WILPINJONG			S.Brackish			765059	6422109	765173	6422294
GW038112	20BL102747	Bore open thru rock	Private		80.7	0.0	BLIGH	ULAN			(Unknown)			759844	6428933	759958	6429118
GW043432	20BL102183	Well	Private	1/01/1956	0.0	0.0	PHILLIP	WILPINJONG			(Unknown)			763117	6423005	763231	6423190
GW043930	20BL102022	Bore	Private	1/06/1975	35.0	35.1	PHILLIP	MOOLARBEN			Good			756118	6416915	756232	6417099
GW046670	20BL105865	Bore	Private	1/03/1977	19.0	19.0	PHILLIP	MOOLARBEN			Good			755770	6418492	755884	6418679
GW047111	20BL107324	Bore	Private	1/05/1978	11.9	11.9	PHILLIP	MOOLARBEN			Fresh			756321	6419715	756435	6419900
GW047172	20BL107323	Bore	Private	1/05/1978	15.2	15.2	PHILLIP	MOOLARBEN			Fresh			755951	6419601	756065	6419786
GW047195	20BL107487	Bore open thru rock	Private	1/04/1979	107.3	107.3	BLIGH	BOBADEEN			0-500 ppm			762568	6434380	762682	6434565
GW047331	20BL108052	Bore	Private	1/05/1979	61.0	61.0	BLIGH	BLIGH			(Unknown)			756892	6437193	757006	6437377
GW047365	20BL108644	Bore open thru rock	Private	1/07/1979	53.3	53.3	PHILLIP	MOOLARBEN			Good			755653	6419208	755767	6419393
GW047495	20BL107537	Bore open thru rock	Private	1/04/1979	149.4	149.4	BLIGH	BOBADEEN			0-500 ppm			762682	6435146	762796	6435331
GW048631	20BL107137	Bore	Private	1/09/1978	22.9	22.9	PHILLIP	MOOLARBEN			Fresh			755396	6417092	755510	6417276
GW048926	20BL107973	Bore	Private	1/02/1978	9.1	0.0	PHILLIP	MOOLARBEN			(Unknown)			755667	6414198	755781	6414383
GW049542	20BL110252	Bore open thru rock	Private	1/06/1979	31.1	31.1	BLIGH	ULAN			Good			757992	6424907	758106	6425092
GW050592	20BL113124	Bore open thru rock	Private	1/06/1980	39.0	39.0	PHILLIP	MOOLARBEN			Fresh			758265	6416453	758379	6416638
GW051401	20BL117710	Well	Private		12.0	0.0	PHILLIP	CUMBO			(Unknown)			771775	6415720	771889	6415905
GW051430	20BL115862	Bore	Private	1/07/1980	46.1	46.1	PHILLIP	CUMBO			Brackish			769370	6417560	769484	6417745
GW051741	20BL113001	Bore open thru rock	Private	1/07/1980	26.7	26.7	PHILLIP	MOOLARBEN			Fresh			756610	6418181	756724	6418366
GW052223	20BL115642	Bore open thru rock	Private	1/09/1980	54.2	54.2	PHILLIP	WILPINJONG			Good			767660	6421210	767774	6421395
GW052583	20BL113120	Bore open thru rock	Private	1/06/1980	32.9	36.0	PHILLIP	MOOLARBEN			3001-7000 ppm			759200	6416100	759314	6416285
GW052802	20BL113133	Bore open thru rock	Private	1/07/1980	45.7	45.7	PHILLIP	MOOLARBEN			Good			756250	6423425	756364	6423610
GW053215	20BL118263	Bore	Private	1/03/1981	22.8	22.9	PHILLIP	MOOLARBEN			Fresh			755940	6417710	756054	6417895
GW053778	20BL117431	Bore	Private	1/06/1981	93.0	93.0	BLIGH	DURRIDGERE			(Unknown)			768190	6437520	768304	6437705
GW053859	20BL122237	Bore open thru rock	Private	1/07/1980	30.5	30.5	PHILLIP	CUMBO			Good			769590	6419785	769704	6419970
GW054562	20BL116458	Bore	Private	1/03/1981	21.9	22.0	PHILLIP	MOOLARBEN			(Unknown)			755500	6417660	755614	6417845
GW055488	20BL113009	Bore	Private	1/02/1983	11.0	0.0	PHILLIP	MOOLARBEN			(Unknown)			756170	6415200	756284	6415385
GW057084	20BL124673	Bore	Private	1/03/1983	42.1	42.1	PHILLIP	MOOLARBEN			0-500 ppm			756215	6418565	756329	6418750
GW057326	20BL124955	Bore	Private	1/12/1981	72.5	72.5	BLIGH	ULAN			invalid code			760530	6429380	760644	6429565
GW057327	20BL124956	Bore	Private	1/01/1982	61.7	61.7	BLIGH	ULAN			invalid code			759932	6429586	760046	6429771
GW057328	20BL124957	Bore	Private	1/12/1981	115.0	115.0	PHILLIP	LENNOX			invalid code			761780	6430675	761894	6430860
GW057329	20BL124958	Bore	Private	1/11/1981	93.0	93.0	PHILLIP	LENNOX			invalid code			761057	6429693	761171	6429878
GW059034	20BL121127	Bore	Private	1/01/1982	72.0	89.0	PHILLIP	LENNOX			501-1000 ppm			760820	6429050	760934	6429235
GW059035	20BL121128	Bore	Private	1/02/1982	79.8	79.0	PHILLIP	LENNOX			501-1000 ppm			760925	6429580	761039	6429765
GW059036	20BL121130	Bore	Private	1/01/1982	109.0	109.0	PHILLIP	LENNOX			501-1000 ppm			761520	6430210	761634	6430395

Appendix E: DNR Database Search - Registered Bores / Wells

Page 2 of 3

Reg No	Licence	Type	Owner	Completed	Depth	Drilled depth	County	Parish	SWL	Salinity	Comment	Yield	Comment	AMG Easting	AMG Northing	MGA Easting	MGA Northing
GW059037	20BL121131	Bore	Private	1/02/1982	69.5	69.5	BLIGH	ULAN			0-500 ppm			760140	6429525	760254	9429710
GW059038	20BL121129	Bore	Private	1/11/1981	73.0	73.0	BLIGH	ULAN			0-500 ppm			760550	6429290	760664	6429475
GW059124	20BL114686	Bore	Private	1/11/1983	32.0	32.0	BLIGH	CURRYALL			(Unknown)			762900	6439600	763014	6439784
GW059514	20BL131263	Bore	Private	1/08/1984	19.4	19.6	PHILLIP	MOOLARBEN			Fresh			755820	6419300	755934	6419485
GW059519	20BL125780	Bore	Private	1/04/1983	24.4	24.4	PHILLIP	MOOLARBEN			0-500 ppm			755920	6418900	756034	6419085
GW059683	20BL122034	Bore open thru rock	Private	1/08/1984	61.5	61.5	PHILLIP	MOOLARBEN			Fresh			757650	6423460	757764	6423645
GW059766	20BL130632	Bore	Private	1/08/1984	30.5	30.5	PHILLIP	MOOLARBEN			Good			755800	6418720	755914	6418905
GW060562	20BL131827	Bore open thru rock	Private	1/12/1984	41.1	41.2	PHILLIP	CUMBO			(Unknown)			770625	6418800	770739	6418985
GW060608	20BL131820	Bore	Private	1/12/1984	62.5	62.5	BLIGH	DURRIDGERE			0-500 ppm			769420	6436490	769534	6436675
GW063717	20BL135331	Well	Private		3.4	0.0	PHILLIP	MOOLARBEN			0-500 ppm			763540	6412800	763650	6412985
GW064580	20BL137225	Bore	Private	1/01/1988	70.1	70.1	BLIGH	BOBADEEN			Good			764000	6438325	764114	6438510
GW065948		Bore	Private	15/11/1988	94.5	0.0	PHILLIP	LENNOX			Good			760750	6428725	760864	6428910
GW065949		Bore	Private	18/11/1988	57.0	0.0	PHILLIP	LENNOX			Good			760740	6427000	760854	6427185
GW065950		Bore open thru rock	Private	22/11/1988	81.0	0.0	PHILLIP	LENNOX			Good			759090	6425508	759204	6425693
GW065995		Bore	Private	1/01/1990	105.0	0.0	BLIGH	ULAN						760820	6428588	760934	6428773
GW067674	20BL139359	Bore	Private	10/03/1989	30.4	30.4	PHILLIP	MOOLARBEN						755631	6419291	755745	6419476
GW070638							PHILLIP	MOOLARBEN						758220	6416240	758334	6416425
GW070657	80BL152122	Bore		26/04/1993	32.0	32.0	PHILLIP	MOOLARBEN	3.0		Good	0.18		755826	6418657	755940	6419842
GW070856	20BL150485	Bore open thru rock	Private	1/08/1992	55.5	0.0	PHILLIP	MOOLARBEN						759720	6415893	759834	6416078
GW073038	20BL166333	Bore		8/05/1995	42.0	42.0	PHILLIP	CUMBO						767266	6413996	767380	6414181
GW073376		Bore	Private	16/05/1994	36.0	36.0	PHILLIP	MOOLARBEN						755955	6417178	756069	6417363
GW073549	20BL166215	Bore open thru rock	Private	24/11/1994	53.3	53.3	PHILLIP	MOOLARBEN			Potable			756357	6423833	756471	6424018
GW073550	20BL166216	Bore open thru rock	Private	24/11/1994	53.3	53.3	PHILLIP	MOOLARBEN			Good			755618	6423374	755732	6423559
GW078082	20BL166624	Bore		9/03/1981	23.0	23.0	PHILLIP	MOOLARBEN	16.9		Fresh	0.31		757566	6416200	757681	6416385
GW078107		Well	Private		3.0		PHILLIP	CUMBO						770905	6412382	771019	6413566
GW078165		Well	Private				PHILLIP	CUMBO						772539	6416649	772653	6416834
GW078174	20BL152584	Bore		25/06/1993	83.8	83.8	PHILLIP	MOOLARBEN			Good	0.19	Airlift	757471	6423470	757585	6423655
GW078314	20BL166146	Bore		14/10/1994	99.0	99.0	BLIGH	DURRIDGERE						767842	6435477	767956	6435662
GW078317		Bore	Private				BLIGH	BOBADEEN						764276	6436278	764390	6436463
GW078371	20BL167677	Bore		14/05/1999	3.0	6.0	BLIGH	ULAN		1.1				760800	6430150	760914	6430335
GW078372	20BL167677	Bore		14/05/1999	2.0	3.5	BLIGH	ULAN						760650	6430250	760764	6430435
GW078373	20BL167677	Bore		14/05/1999	4.8	5.0	BLIGH	ULAN	3.6	1.6				760668	6429449	760782	6429634
GW078374	20BL167677	Bore		14/05/1999	2.2	5.5	BLIGH	ULAN	3.2	1.5				760995	6430350	761109	6430535
GW079745		Bore	Private		34.3		BLIGH	BOBADEEN						763075	6435684	763189	6435869
GW080092		Bore	Private				PHILLIP	MOOLARBEN						755440	6419431	775554	6419616
GW080111		Bore		1/02/1993	4.0		BLIGH	DURRIDGERE	2.8	966				774675	6436034	774789	6436219
GW080112		Bore		1/02/1963	6.3		BLIGH	DURRIDGERE	5.0	346				774546	6436100	774660	6436285
GW080115		Bore	Private	27/07/1996	70.1	70.1	PHILLIP	CUMBO	4.6	2800	Brackish	0.06		769494	6414341	769608	6414526
GW080124		Bore	Private				PHILLIP	WILPINJONG						768947	6421389	769061	6421574
GW080171	20BL168184	Bore		27/07/1996	5.0		PHILLIP	CUMBO						769732	6414392	769846	6414577
GW080350	20BL168215	Bore		28/11/2002			BLIGH	ULAN						758264	6424931	758378	6425115
GW080355	20BL168261	Bore		29/11/2002			BLIGH	ULAN						755400	6425314	755514	6425499
GW080400		Bore	Landcare Group	7/01/2003	9.0	9.0	PHILLIP	CUMBO						772750	6416009	772864	6416194
GW080401		Bore	Landcare Group	7/01/2003	5.0	5.0	PHILLIP	CUMBO	2.6	3700				772895	6415995	773009	6416180
GW080402		Bore	Landcare Group	7/01/2002	4.0	4.0	PHILLIP	CUMBO						772604	6416272	772718	6416457
GW080403		Bore	Landcare Group	7/01/2003	5.0	5.0	PHILLIP	CUMBO	1.4	3600				772752	6416278	772866	6416463
GW080404		Bore	Landcare Group	7/01/2003	3.5	3.5	PHILLIP	CUMBO	1.6	2100				772334	6417282	772448	6417467
GW080405		Bore	Landcare Group	7/01/2003	3.5	3.5	PHILLIP	CUMBO	2.5	4200				770593	6417807	770707	6417992
GW080406		Bore	Landcare Group	8/01/2003	3.5	3.5	PHILLIP	CUMBO						770362	6417419	770476	6417604
GW080407		Bore	Landcare Group	8/01/2003	3.0	3.0	PHILLIP	CUMBO						770489	6417970	770603	9418155
GW080408		Bore	Landcare Group	8/01/2003	4.5	4.5	PHILLIP	CUMBO	1.8	2600				769551	6420978	769665	6421163

Appendix E: DNR Database Search - Registered Bores / Wells

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Reg No	Licence	Type	Owner	Completed	Depth	Drilled depth	County	Parish	SWL	Salinity	Comment	Yield	Comment	AMG Easting	AMG Northing	MGA Easting	MGA Northing
GW080409		Bore	Landcare Group	8/01/2003	2.0	2.0	PHILLIP	CUMBO						769766	6420693	769880	6420878
GW080410		Bore	Landcare Group	8/01/2003	5.0	5.0	PHILLIP	CUMBO	2.6	1000				769811	6420808	769925	6420993
GW080411		Bore	Landcare Group	9/01/2003	5.0	5.0	PHILLIP	CUMBO	2.6	3400				770522	6419618	770636	9419803
GW080610	20BL169261	Bore		30/06/2004	48.1	48.1	PHILLIP	CUMBO	7.5			3		768975	6420759	769089	6420944
GW080611	20BL169262	Bore		30/06/2004	27.6	27.6	PHILLIP	CUMBO	0.6			2		771249	6419482	771363	6419667
GW080612	20BL169263	Bore		30/06/2004	36.0	36.0	PHILLIP	CUMBO	1.0			2		773194	6419756	773308	6419941
GW080613	20BL169264	Bore		30/06/2004	48.9	48.9	PHILLIP	CUMBO	1.0			1		769002	6421002	769116	6421187
GW080614	20BL169264	Bore		30/06/2004	8.0	8.0	PHILLIP	CUMBO	7.5			1		771748	6418251	771862	9418436
GW080615	20BL169264	Bore		30/06/2004	51.5	50.0	PHILLIP	CUMBO	3.7			3		768998	6420751	769112	6420936
GW080616	20BL169264	Bore		30/06/2004	41.0	41.0	PHILLIP	CUMBO	4.3			2		768954	6420761	769068	6420946
GW080617	20BL169264	Bore		30/06/2004	12.0	12.0	PHILLIP	CUMBO	3.4			0.5		768945	6420766	769059	6420951
GW080618	20BL169264	Bore		30/06/2004	22.0	22.0	PHILLIP	CUMBO	16.0			2		771248	6419512	771362	6419697
GW080619	20BL169264	Bore		30/06/2004	15.3	15.3	PHILLIP	CUMBO	5.0			0.5		773078	6418993	773192	6419178
GW080620	20BL169264	Bore		30/06/2004	36.3	36.3	PHILLIP	CUMBO	0.7			2		773194	6419766	773308	6419951
GW080621	20BL169264	Bore		30/06/2004	44.0	44.0	PHILLIP	CUMBO	0.3			3		773194	6419776	773308	6419961
GW080622	20BL169264	Bore		30/06/2004	1.8	2.0	PHILLIP	CUMBO	0.0			0.5		773346	6419892	773460	6420077
GW080623	20BL169264	Bore		30/06/2004	1.4	1.3	PHILLIP	CUMBO	0.8			0.5		773244	6419738	773358	6419923
GW080624	20BL169264	Bore		30/06/2004	33.5	33.5	PHILLIP	CUMBO	0.2			3		771248	6419502	771362	6419687
GW080625	20BL169264	Bore		30/06/2004	20.0	20.0	PHILLIP	CUMBO	10.5			3		769502	6417252	769616	6417437
GW080626	20BL169264	Bore		30/06/2004	17.0	17.0	PHILLIP	CUMBO	8.3			1		771247	6417750	771361	6417935
GW080627	20BL169264	Bore		30/06/2004	16.0	16.0	PHILLIP	CUMBO	6.2			2		773752	6417748	773866	6417933
GW080628	20BL169264	Bore		30/06/2004	14.0	14.0	PHILLIP	CUMBO	7.3			3		773748	6417248	773862	6417433
GW080629	20BL169264	Bore		30/06/2004	4.2	4.2	PHILLIP	CUMBO	3.4			1		772732	6420329	772846	6420514
GW200094	20BL167677	Bore		13/12/1999			BLIGH	ULAN						758603	6426421	758717	6426606
GW800279	80BL236762	Bore	Private	27/11/1995	24.4	24.4	PHILLIP	LENNOX						765100	6431800	765214	6431985
GW801592	80BL154963	Bore	Private	9/07/1994	91.4	91.4	PHILLIP	MOOLARBEN	18.3		Good	0.25		755335	6416550	755449	6146735
GW802260	80BL242378	Bore	Private	27/08/2004	42.0	42.0	PHILLIP	MOOLARBEN	13.0		(Unknown)	0.5	Cumulative	757980	6415632	758094	6415817

APPENDIX F

GROUNDWATER FLOW MODELLING

PETER DUNDON AND ASSOCIATES

MOOLARBEN COAL GROUNDWATER MODEL
('MC1 MODEL')

SEPTEMBER 2006

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8 September 2006

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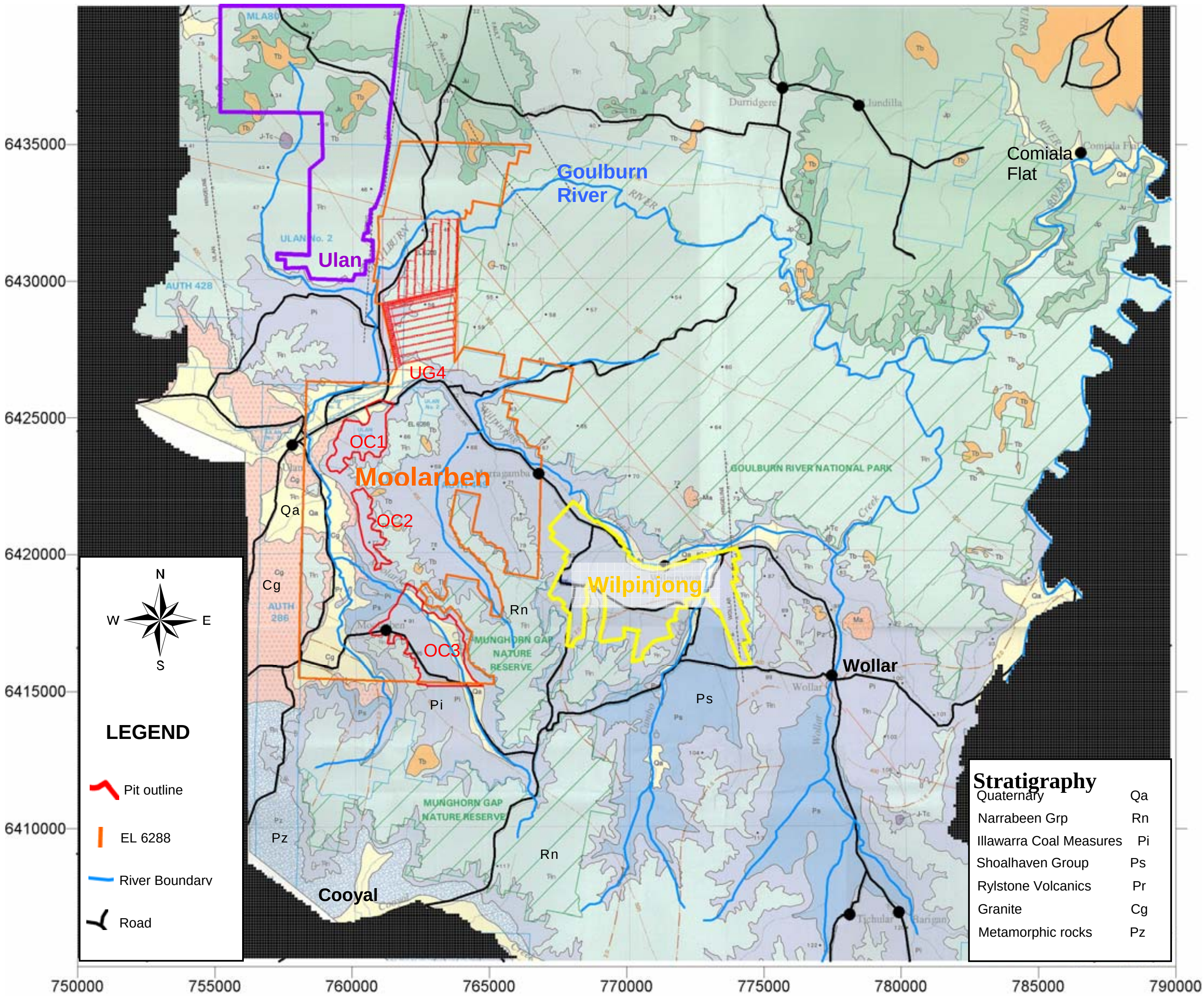
1.1 SCOPE OF WORK

The Moolarben Coal Mine Project (EL6288) is located approximately 30 km north of Mudgee, at the western end of the upper Hunter Valley of NSW (Figure 1.1). Moolarben mining operations are planned to comprise of three open cut pits and one underground mine, accessing the Ulan Coal Seam. Moolarben is located between the existing Ulan Coal Mine to the west, and the proposed Wilpinjong Coal Mine to the east.

The Moolarben Coal Company has engaged Peter Dundon and Associates to undertake hydrogeological investigations to support the preparation of an Environmental Assessment report, through preparation of a Water Resource Assessment and draft life-of-mine Water Management Plan, including water management relating to mine closure and post-mining. As part of these investigations, Peter Dundon has engaged Aquaterra to develop a regional numerical groundwater flow model of the area, with independent review by Dr Noel Merrick (University of Technology, Sydney).

Figure 1.1
Moolarben Coal Mine Model Extent and Generalised Geology (from 1:100,000 Geology Map)
Note: model extends 5km further north to 6445000 (not shown)



The hydrogeological and groundwater modelling investigations consider:

- potential impacts on the groundwater system due to groundwater abstractions for water supply and mine dewatering and other water management activities at Moolarben,
- interactions with the Goulburn River, Moolarben and Wilpinjong Creeks and other local creeks,
- cumulative impacts due to abstractions for the Ulan and Wilpinjong coal mines and,
- potential impacts downstream or down-gradient from the study area that may arise due to the mining and closure operations.

This report provides details of the groundwater modelling approach and results.

1.2 OBJECTIVES

The **main objectives** of this version 1 of the Moolarben Coal Groundwater Model (referred to as the “MC1” model) are to:

- assist in the overall hydrogeological assessment, and the design of the water supply and dewatering wellfields to support the mining operation on the Ulan Coal Seam; and,
- predict the cumulative potential impacts of Moolarben, Ulan and Wilpinjong mine sites, including impact of abstractions and post-mining water management plans.

The **specific aims** of the MC1 model are to:

- evaluate groundwater responses to mine dewatering and associated aquifer depressurisation, with due consideration of interactions between the Goulburn River and other creeks, and associated alluvial deposits and other aquifers in the vicinity of the proposed mine(s);
- provide information for others to examine the means of minimising the generation of mine wastewater, maximising use or re-use of mine wastewater, and options for the mine to achieve a “nil discharge” status;
- evaluate potential final void configurations and predict groundwater inflows post mining, and assess post-mining management options and outcomes for any residual water resources impacts.

1.3 METHODOLOGY

Best practice groundwater modelling (MDBC, 2001) calls for a staged approach, beginning with a review of the available data to devise a conceptual hydrogeological model, which is then used to derive a conceptual model as the basis to design a numerical groundwater flow model. The MC1 groundwater flow model development methodology involved the following tasks and outcomes:

- define and implement the hydrogeological conceptualisation of the aquifer system and surface-groundwater interaction processes (natural and developed) in a numerical groundwater flow model; in this case, a model design report was prepared as an initial step, and independently reviewed by Dr Noel Merrick;

- calibrate the model such that it reproduces measured aquifer water levels at a range of monitoring sites, ideally (eventually) over a period when there is a significant range in hydrological/climatic conditions and/or water management stresses; in this case, initial model calibration will be in steady state ("long term average") mode for this project, to establish initial water table conditions for a transient calibration over the 20-year period 1987 to 2006, when there is some information available on dewatering operations at the adjacent Ulan Coal Mine, as documented in this report;

- achieve performance criteria for calibration/validation in terms of quantitative (statistical) measures and qualitative (pattern-matching) measures, based on best practice groundwater modelling guidelines (MDBC, 2001); in this case, the model design report proposed a scaled RMS criterion of 5% to 10%, which is consistent with the guidelines for a first generation version of a model;

- undertake scenario modelling with the calibrated model to predict the behaviour of the aquifer system and to help assess/optimise water management and planning strategies;

- use the model to help identify where data deficiencies critically constrain the use of the model as a management tool, and make recommendations on how the deficiencies can be addressed; and,

- use the model to guide decision-making by demonstrating uncertainties through sensitivity analyses.

The following sections provide details on the:

- key features of the conceptual hydrogeological model and appropriate level of model complexity

- modelling package(s) used

- design of the numerical model consistent with the hydrogeological conceptual model, including details on the model extent, grid, layers and boundary conditions

- calibration period and model performance

- prediction scenarios, including post-mining period

- sensitivity model runs.

SECTION 2 - CONCEPTUAL HYDROGEOLOGY

2.1 HYDROLOGY AND HYDROGEOLOGY

A conceptual model is a simple version of the real system, identifying the main geological units and hydrogeological processes, while acknowledging that the real system is hydrologically and geologically much more complex. The conceptual model forms the basis for the computational groundwater flow model. The key conceptual model features are described below, and are graphically presented in Figure 2.1.

Background geological and hydrogeological information can be found in reports by Peter Dundon and Associates, which were used to design the conceptual hydrogeological model for the area. Some summary hydrogeological information is provided below, with more detail provided later in relation to the conceptual model and its implementation in the numerical model.

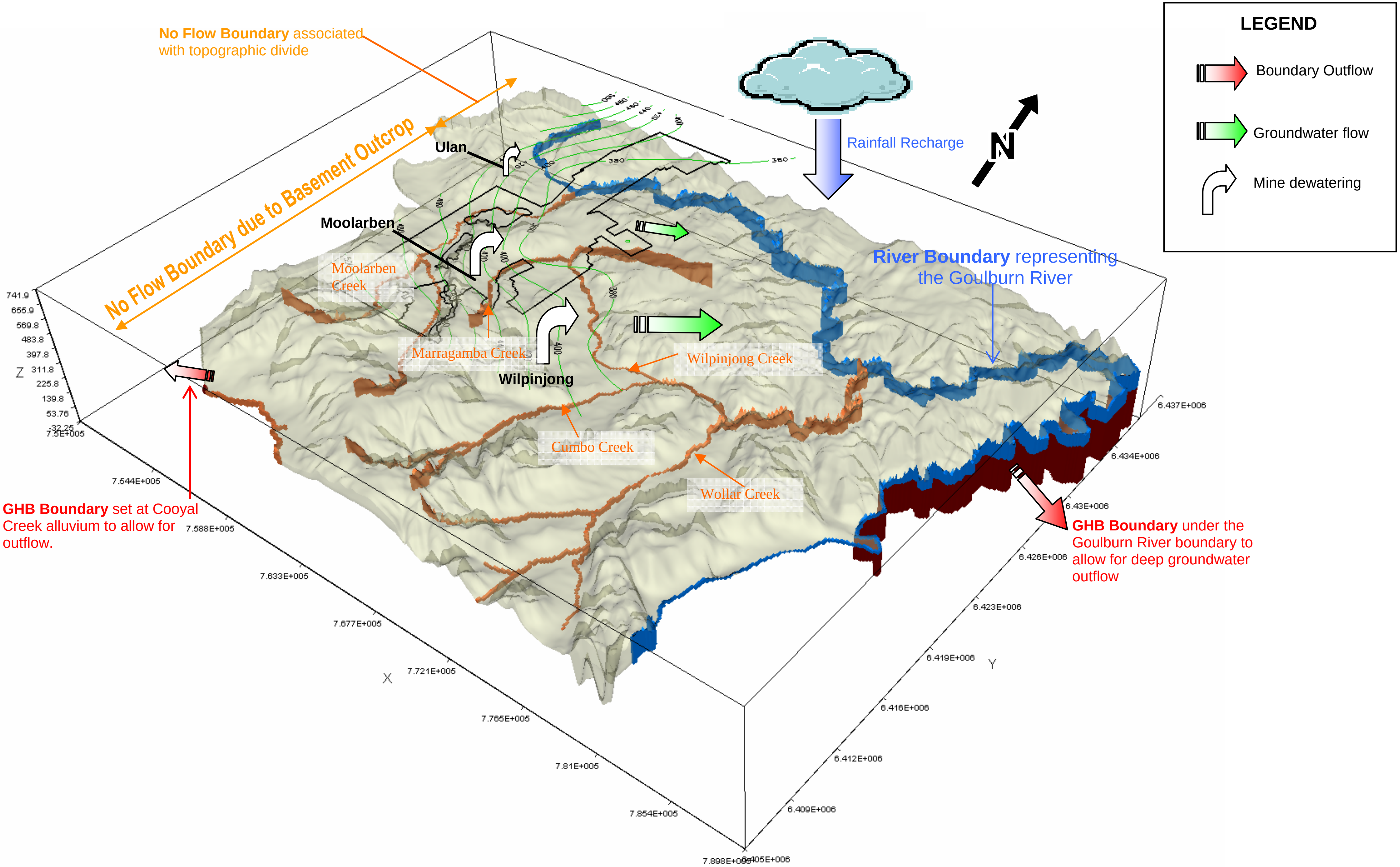
Surface drainage in the Moolarben area drains to both the north (Goulburn River) and east (Wilpinjong Creek). Drainage to the north occurs via Moolarben Creek, a tributary to the headwaters of the Goulburn River, which lies to the north and northeast of the project area. Drainage to the east occurs via Murragamba Creek, a tributary to the headwaters of Wilpinjong Creek, which itself flows east past Wilpinjong and eventually joins Wollar Creek and then the Goulburn River on the eastern edge of the study area. The Goulburn River flows west to east across the northern edge of the study area and eventually joins the Hunter River near Denman. Current monitoring data shows that groundwater levels are generally higher than river levels, but dewatering may result in lower groundwater levels near the streams, and the model needs to be able to predict the quantum of any induced recharge from the streams.

Baseflow contributions to river and stream features represents the primary natural groundwater discharge process. Baseflow is groundwater that discharges into a stream, with contribution rates increasing during the recession of runoff after a rainfall event that has recharged the aquifer. The creeks in the area are considered to be generally “gaining” in the sense that baseflow drains from the aquifer after rainfall recharge events. Ephemeral creek character is apparent where the baseflow is insufficient to maintain permanent creek flow, and these creeks would not represent a major source of groundwater recharge (eg. Wilpinjong Creek). It is possible for larger river/creek systems to provide some recharge to the aquifer at least at some times, and the MC1 model is designed to allow this process to occur.

The **general flow pattern** (for groundwater and rivers) is from the west to the east (the indicative flow pattern is shown by green contours in Figure 2.1, from measured levels in early 2006), with the top of the Great Dividing Range in this area forming the western catchment divide for the study area. Groundwater flow is expected to generally follow the regional topography, with the highest groundwater levels in elevated terrain and the lowest in the valleys and the floodplains. There is believed to be a component of lateral groundwater flow out of the model area over the northern, southern and eastern boundaries.

The **Illawarra Coal Measures** (symbol Pi, refer to Figure 2.1) hosts the Ulan coal seam which is the target coal resource at Moolarben, (Figure 1). The Illawarra C.M. are made up by a series of well-bedded sandstone, claystone, mudstone and coal sequences of Permian age. The Ulan coal seam dips gently north-northeast at 1 to 2 degrees, continuing north-northeast beyond the economic depth of open pit mining. The Illawarra C.M. are generally overlain by alluvium (Qa) in selected creek areas and elsewhere by the Narrabeen Group (Rn), and are underlain by basement.

Figure 2.1 Moolarben Coal ("MC1") Conceptual Model and Boundary Conditions



The typical lithology of the **Narrabeen Group** overlying the Illawarra C.M. includes pebbly to medium-grained quartz sandstone, red-brown and green mudstone and lenses of quartz conglomerate (Wilpinjong Coal, 2005). The **basement** underlying the Illawarra C.M. comprises the Shoalhaven Group and Nile Sub-Group (Ps), Rylstone Volcanics (Pr), Undifferentiated Granite (Cg) and Metamorphosed Palaeozoic Rocks (Pz), as shown on Figure 2.1. The Carboniferous aged Granite (Cg) is the most significant basement unit in the Moolarben area with extensive outcropping occurring directly west of the proposed Moolarben mine pits and extending further in a north-northwest direction. The Nile Sub-Group was shown to be quite impermeable, and of almost no influence on the flow processes at Wilpinjong (Wilpinjong Coal, 2005), and so will not be represented specifically in the Moolarben model.

In terms of **aquifer units**, the coal measures and the interburden units in the study area (generally sandstone, siltstone and mudstone) are all poorly permeable and have low storage characteristics, but permeability is generally highest in the coal seams and areas of significant fracturing or faulting. The interbedded sandstone and siltstones are of lower permeability (by at least one order of magnitude) and offer very limited intergranular porosity and little secondary permeability and storage in joints. Neither the Illawarra C.M. nor the sandstones of the Narrabeen Group are considered significant aquifers, and the Marrangaroo Sandstone which underlies the Ulan Seam is also believed to have poor aquifer properties, while the underlying Nile Sub-Group is relatively impermeable. Groundwater also occurs in the high permeability alluvial overburden, which is generally aligned with present day streams and rivers. There is believed to be limited hydraulic connectivity between the alluvium and the coal measures.

A summary of representative aquifer properties of the hydrogeological units in the study area is given in Table 2.1. These are based on investigations by Peter Dundon and Associates in the area and information from the Wilpinjong EIS (2005), plus experience in other parts of the Hunter Valley coalfields. Investigations that are being carried out at present will bring additional data on aquifer parameters and might result in some revision of the parameters in Table 2.1. Vertical hydraulic conductivities are assumed to be at least 1/10th of the horizontal hydraulic conductivity.

Table 2.1

Typical parameter values for hydrogeological units – Moolarben area

Units	Horizontal Hydraulic Conductivity “Kh” (m/d)	Confined Storativity	Unconfined Specific Yield
Coal Seams	0.1 to 1.0	1e-5 to 1e-4	0.05
Interburden (undisturbed)	0.01 to 0.1	1e-5 to 1e-4	0.05
Interburden (disturbed through mining)	0.1 to 10 (also Kh = Kv)	0.10	0.10
Alluvium	1 to 5	1e-4	0.2

There is ongoing investigation and monitoring work within and adjacent to the Moolarben mining lease area, and a summary of data available up to date is provided later (in the section on Model Calibration). The data includes water level records for the area around the Ulan mining lease just to the west of the Moolarben mining area, which shows the influence of dewatering in the Ulan Mine area with a cone of depression located to the north-west of Moolarben (used as a target for model calibration).

Substantial **groundwater abstraction** has been associated with the Ulan Coal Mine operations, possibly from as early as 1957. Development at Ulan increased in the 1980s with a direct rail link to Newcastle, and development of underground mines 1 to 3, which involved mine dewatering operations that began in 1986 and continue to the present, involving discharge of excess water to the Goulburn River, and to irrigated crops.

2.2 RAINFALL RECHARGE

Average monthly rainfall data are available for the station at Wollar (Table 2.2), based on more than 100 years of daily rainfall data since 1901. The maximum annual rainfall recorded was 1,205 mm (1950) and the minimum was 129 mm (1922).

Table 2.2
Mean monthly rainfall at Wollar (BoM 62032)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Mean (mm)	68.2	63.0	51.7	39.7	39.0	43.1	41.3	42.4	39.5	54.2	52.2	56.6	590.7

Rainfall recharge is the primary recharge process and is a function of rainfall intensity, evaporation, vegetation coverage and density, topography and soil properties of the surficial aquifer material (Wilpinjong Coal, 2005). The coal seams, where covered by overburden, are recharged through downward percolation of rainfall through the overlying sediments. After reaching the water table, flow is predominantly down-gradient along the more permeable horizons, but also with a component of continuing downward flow to recharge underlying coal seam aquifers.

A site inspection, conducted for Wilpinjong Coal by Dr Noel Merrick (University of Technology, Sydney) and Mr Lindsay Gilbert (Gilbert and Associates) in March 2005, identified that substantial recharge could be associated with the topographically high Narrabeen Group, and alluvials associated with the numerous creeks and rivers (WCPL, 2005). The layering of mudstones and siltstones within the Illawarra C.M. would tend to restrict the vertical movement of water and this formation is considered to have a low recharge associated with it, with the exception of areas of Ulan Seam outcrop where recharge may be enhanced.

Appropriate recharge rates for the Moolarben study would be broadly consistent with the recently reviewed model study at Wilpinjong, which assumed an average annual rainfall rate of 591 mm/yr. The percentage of annual rainfall recharging the water table varies depending on the type of surficial outcrop and topography. To be consistent with the Wilpinjong model and keeping in mind the recommendations of Dr Noel Merrick and Mr Lindsay Gilbert for the Wilpinjong area (Wilpinjong Coal, 2005), larger recharge rates should be specified on outcrop parts of the Narrabeen Group, alluvials and Ulan Seam outcrop areas. Reduced recharge rates should be applied to the Illawarra Coal Measures and basement outcrop. For the steady-state (“long term average”) MC1 model, rainfall recharge will be modelled by applying a spatially-variable assumed effective recharge rate for different formations, and this will be carried forward to the transient (time-varying) model as an average annual daily rate. The calibrated MC1 model recharge rates are detailed in Appendix A.

2.3 GROUNDWATER DISCHARGE

Groundwater discharge occurs through evaporation, seepage and spring flow where the water table intersects the land surface and through baseflow contributions to creeks and rivers, including discharge to the alluvium where it occurs. There is almost no existing groundwater abstraction in the study area other than for coal mine dewatering (notably at Ulan, at about 10 ML/day in 2004 (Ulan Coal Mines, 2005)).

Streams essentially act as drains under natural conditions (i.e. discharge features), based on current monitoring data that shows that groundwater levels are generally higher than river levels. However, dewatering may result in lower groundwater levels near the streams, and the MC1 model is designed with stream-aquifer interaction features to predict the quantum of any reduced baseflow to streams and/or induced leakage from any major streams (notably the Goulburn River and Moolarben Creek) that are supported by flow contributions from upstream catchments.

Evapotranspiration features should also be incorporated along stream alignments, where vegetation mapping suggests that such features would be appropriate. Average A Class pan evaporation data for the Moolarben project area (Table 2.3) indicates that evaporation exceeds mean monthly rainfall throughout the year.

Table 2.3
Mean monthly evaporation data for the project area (BoM, 2001)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Evap'n (mm)	220	175	170	120	85	65	70	100	120	168	200	235	1,728

For the steady-state numerical model, evaporation will be included using the Evapotranspiration (EVT) package of MODFLOW in areas of low topography along surface water courses such as the Goulburn River and Wilpinjong Creek and tributaries. The EVT parameter values adopted will be a constant rate of 250 mm/yr and an extinction depth of 5 m.

2.4 SURFACE DRAINAGE

The land surface within the Moolarben mining lease area is located within the upper headwaters of the Goulburn River and Wilpinjong Creek catchments and consists of sandstone plateaus, scree slopes and broad valley floors. The tributary creeks are generally ephemeral, but the Goulburn River is believed to be virtually permanent, while Wilpinjong Creek is believed to not flow permanently. The western headwaters of the Wilpinjong Creek overly a significant palaeochannel that may represent an ancient course of the Goulburn River. The palaeochannel is infilled with at least 5 m of alluvium, and in some isolated areas up to 40 m of alluvium, which is generally fine-grained, comprising sands, silts and clays.

The numerical model design incorporates river/aquifer interaction features to enable quantification of the impacts of groundwater pumping on surface water features. Monitoring is currently being undertaken to obtain data on the relationship of aquifer water levels and stream levels over time, in order to deduce the extent to which rivers gain water from or lose water to the underlying aquifers. This is of particular importance as mining may lower water levels and reduce baseflow to permanent streams. However, it should be noted that the streams in the study are mainly ephemeral because baseflow support is relatively short, and extensive periods of no flow occur naturally.

SECTION 3 - IMPLEMENTATION OF CONCEPTUALISATION IN THE MODEL

3.1 MODEL SELECTION AND COMPLEXITY

The MODFLOW numerical groundwater flow modelling package is applied to this study, operating under the Processing Modflow Pro software package (IES).

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

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

The hydrogeological investigations (including modelling) will also be undertaken with reference to the ‘Guidelines for Management of Stream/Aquifer Systems in Coal Mining Developments – Hunter Region’ (DNR, April 2005), and with the MC1 model developed in accordance with the best practice guidelines on groundwater flow modelling (MDBC, 2001). Although there is ongoing discussion of the validity of some issues raised in the Dept of Planning report on *Coal Mining Potential in the Upper Hunter Valley - Strategic Assessment* (October 2005), that report will also influence the methodologies applied to these investigations.

3.2 MC1 MODEL EXTENT, BOUNDARIES, LAYERS AND GRID

The 40x40 km extent and boundaries of the MC1 model are presented in Figures 1.1 and 2.1. The **finite difference grid** uses a uniform cell size of 100 x 100 m, but further grid refinement to perhaps 20 x 20 m is possible in future. Relatively fine grid cell sizes are usually required in areas around the proposed wellfields and the mine, where steep curvature in the water table and/or steep hydraulic gradients are likely to occur. However, at this stage of development of a medium complexity model, a 100 m uniform grid size is adequate.

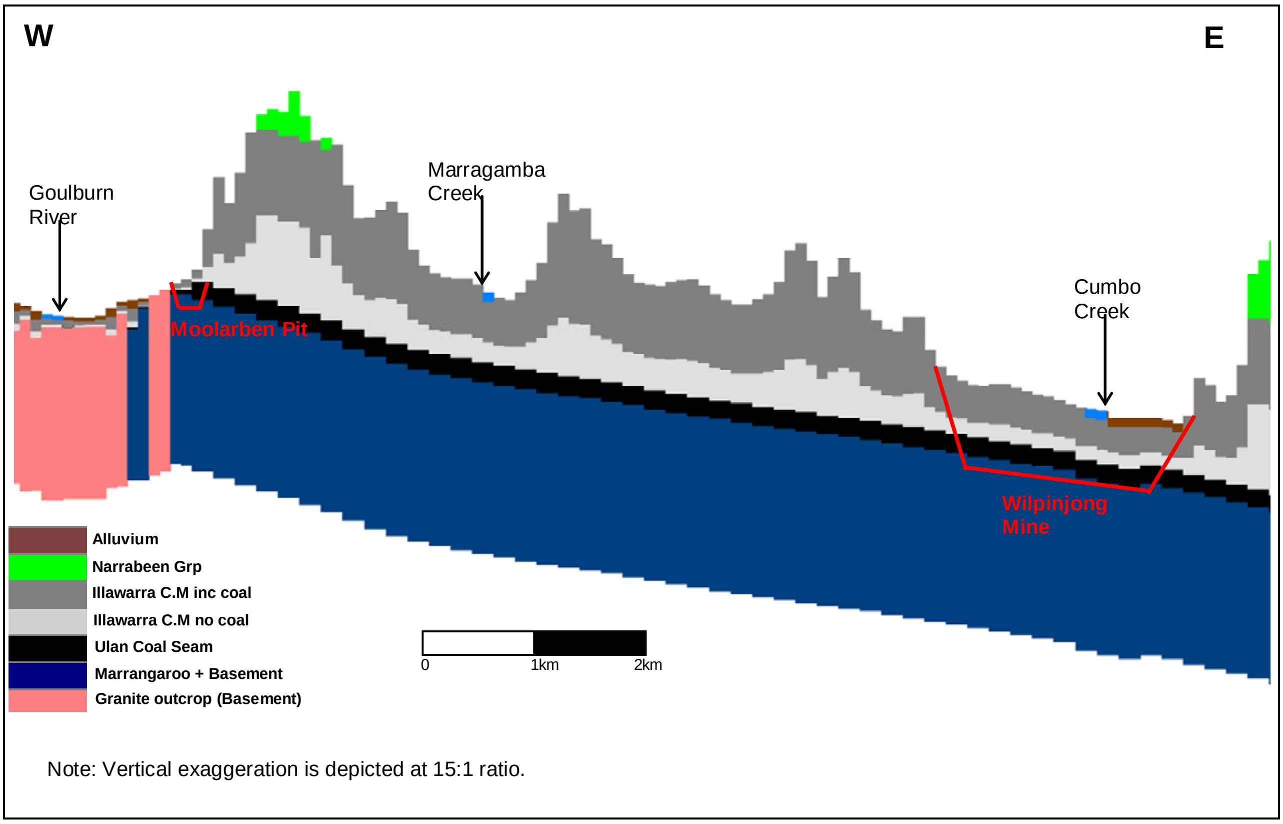
The hydrogeological model can be represented numerically with a 5 layer model (Figures 3.1 and 3.2), where coal seams and interburden are represented independently. Alluvial deposits are not represented as a specific layer but are included in layers 1 to 4 according to their location and surface elevation. The MC1 model **layers** comprise:

1. Alluvial deposits and Narrabeen Group mainly, but this layer also represents Illawarra Coal Measures and Basement outcrop where they occur
2. Illawarra Coal Measures (mainly) containing interbedded coal, siltstone and mudstones, but also alluvium and Basement material in areas of outcrop
3. Illawarra Coal Measures (mainly) not containing interbedded coal, but also alluvium and Basement material in areas of outcrop
4. Ulan Coal Seam, plus Basement and some alluviual material in areas of outcrop on the west
5. Marrangaroo Sandstone and Basement outcrop.

Layer elevation surfaces were defined as follows. The top elevation of Layer 1 was specified from the surface topography DEM. The Ulan Coal Seam (layer 4) top and base elevations were interpolated from project specific borelogs locally to Moolarben, extended regionally using information from the Wilpinjong groundwater model (using data kindly provided by Wilpinjong Coal Mines). The regional structure of the Ulan Coal Seam was also based on spot level and general dip information provided by the 1:100,000 geological map. The basement (layer 5) has an assumed nominal thickness of 100 m, and is represented in the MC1 model using a constant transmissivity. Layer surface elevation data is presented in Appendix A.

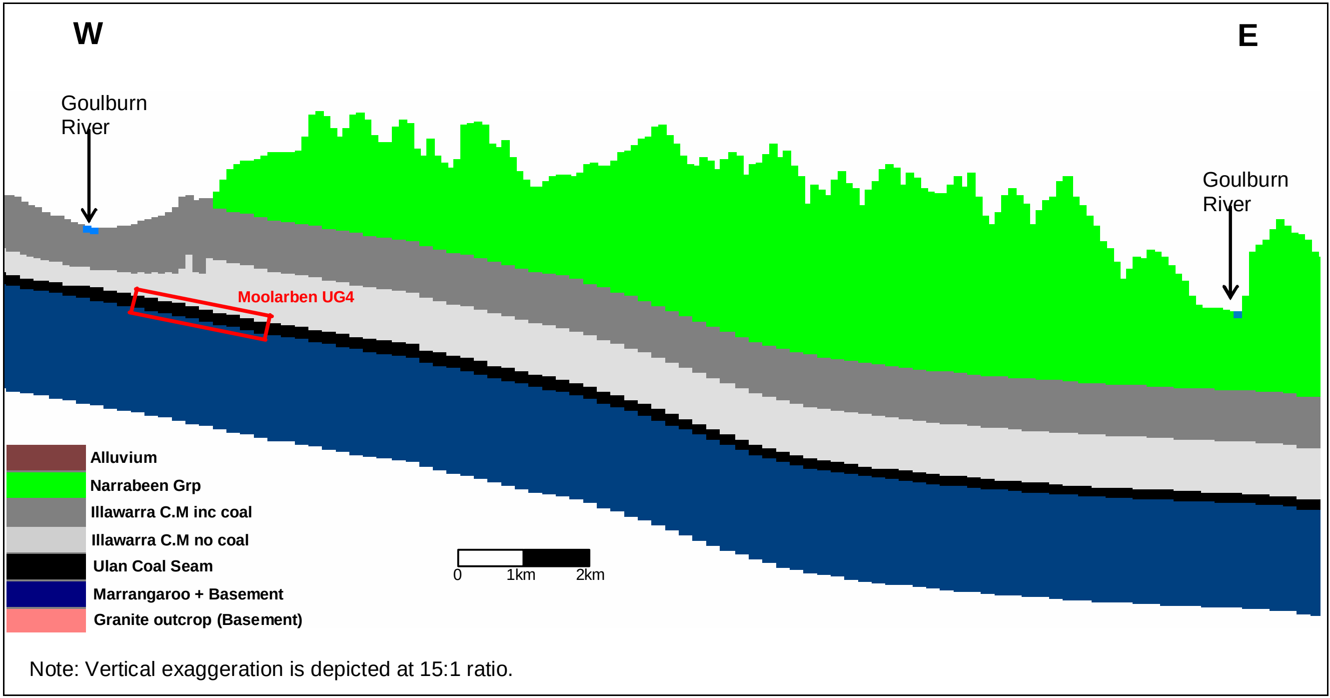
The Illawarra C.M. (layers 2 and 3) were assumed to have a maximum combined thickness of 100 metres, extending upwards from the top of the Ulan Coal Seam (layer 4). The topography data was used to identify cut-throughs in low-lying areas of each of these layers. Layers 2 and 3 were assigned equal thickness to allow for a "**goaf"** unit in layer 3 (in the lower Illawarra C.M. above the Ulan Coal Seam), and an undisturbed unit above the goaf. The goaf zone of about 50 m thickness above the coal seams represents interburden where subsidence during and after underground mining may result in increased hydraulic conductivity.

Figures 3.1 and 3.2 are **cross-sections** from the MC1 model after applying the above layering methodology. Figure 3.1 shows the cross section through the proposed open cuts at Moolarben and Wilpinjong, while Figure 3.2 shows the layer arrangement near the proposed Moolarben underground operation. The model transects show the Ulan Coal Seam dipping to the east, with the seam about 30–40 m below the surface at Wilpinjong and 0–10 m at Moolarben Pit 2. In the MC1 model, the Ulan seam is about 70–180 m below the surface at the Moolarben underground mine, with a goaf unit of about 50 m thickness at the western end, where the overburden is thin.



Note: Vertical exaggeration is depicted at 15:1 ratio.

Figure 3.1 Model Cross-section through Moolarben and Wilpinjong mine areas (Northing 6421350)



Note: Vertical exaggeration is depicted at 15:1 ratio.

Figure 3.2 Model Cross-section through Moolarben underground mine area (Northing 6428850)

The MC1 model domain covers an area of about 40 km square, with the southwestern corner defined by Cooyal Creek and the northeastern corner bounded by the Goulburn River near Comiala Flat. The northern boundary has been set beyond the Goulburn River to reduce potential boundary effects, and aligns approximately with a topographic divide north of the Ulan mine boundary; it is set as a no-flow condition, as it broadly parallels the groundwater flow lines in this area. The Goulburn River forms the eastern boundary condition for the shallow system (represented using the River package for leakage to or from the groundwater system), with deeper layers using head-dependent flow boundaries to represent deep groundwater outflow down-gradient. The southern boundary is aligned roughly with a topographic divide, except for the south-western corner, which is aligned with Cooyal Creek and set as drain (outflow) feature, with underlying head-dependent flow boundaries to represent deep groundwater outflow down-gradient. The main part of the western boundary is set as no flow as it is aligned with areas of basement outcrop, and the northern end is aligned with a topographic divide that runs approximately parallel with Ulan Creek.

Rainfall recharge will be the main inflow boundary condition to the model, with rates varying spatially depending on topography and surficial material as explained in Section 2. The main outflow features will be the creeks and rivers, notably the Goulburn River and Wilpinjong Creek, with associated tributaries such as Moolarben and Marragamba Creeks, and Cumbo and Wollar Creeks, plus deep groundwater outflow.

The rivers, creeks and tributaries will be represented using the River or Drain packages of Modflow. The Goulburn River will be simulated using the River package with the river stage elevations set to topography and river bed depth set to 0.2m below the stage. The Drain package will be used to represent the minor creeks and tributaries in the area including Moolarben, Marragamba, Cumbo, Wilpinjong and Wollar Creeks. These creeks are believed to be mainly ephemeral in nature, draining the shallow groundwater system, and thus the creek features in the model should not represent a potential source of groundwater recharge. Drain elevations of the creeks have been set consistent with surface topography, with conductance parameters set to a high value (1000 m^2/day).

3.3 SIMULATION OF MINING OPERATIONS

The historical and projected future Ulan Coal Mine dewatering operations are represented in the MC1 model so that the cumulative effects of mining can be assessed. Similarly, the proposed groundwater pumping operations at the adjacent Wilpinjong coal mine are also represented in the prediction period for the Moolarben study. Although there is little readily available detailed information on the Ulan dewatering operations, information on the proposed Wilpinjong operation is available from the EIS for that project (WCPL, 2005), and the MC1 model was designed with features and performance consistent with that study.

Groundwater pumping began at the Ulan Coal Mine as early as 1924, but it is believed that regular and substantial pumping did not commence until 1957. The readily available data on Ulan dewatering comes from the 2004 Annual Environmental Management Report (Ulan Coal Mines, 2005), which indicated a pumping rate at Ulan of about 10ML/day in 2004, and a projected increase of up to about 18ML/day by the end of mining in 2024. At this stage of model development, rather than try to incorporate specific pumping points in the model for Ulan dewatering, it is more appropriate to include a broad dewatering representation as a drainage feature in the MC1 model, and to check that the model can reproduce the reported historical pumping rate, as well as provide a reasonable match to the groundwater levels in the area. For this purpose, a Modflow drain feature is suitable, as this allows the calibrated (“history match”) model parameters and the drain feature configuration for Ulan to be applied to the Moolarben area for predictive scenario modelling of the effects of Moolarben dewatering.

In principle, underground mining and dewatering activity will be represented in the MC1 model using drain cells within the mined coal seams, with modelled drain elevations set to the coal seam base (base of layer 4), and assuming a relatively low conductance value. These drain cells will be emplaced where workings occur and will progress in accordance to the mine plan (generally down-dip) through a transient model set-up on an annual basis. The basic setup involves de-activating the drain cells after mining specific underground panels, but maintaining drain cells along the main drives throughout the underground dewatering simulation. A sensitivity run will be undertaken to allow for all the drain cells to remain active throughout the dewatering simulation, to help assess potential goaf effects during mining, and to provide an indication of the upper limit of dewatering volumes and drawdown effects.

Open cut mining and dewatering operations will be represented similarly, but by specifying drain cell levels at 1m above the base of the layer for the period of mining and backfilling, and then de-activating the drain cell thereafter. It is understood that all Moolarben and Ulan open cut areas will be backfilled above the water table. The drain cell conductance parameter for open cut mining will be set higher than for underground mine operations.

The drain conductance should reflect the resistance to flow between the interburden material and the mined-out seam. This is a critical model parameter which determines the simulated seepage inflow into the workings and selection of appropriate permeability values will be based on achieving an adequate history match to Ulan dewatering operations. Sensitivity runs will be undertaken to assess uncertainties in model predictions of mine inflow rates and other indicators.

For the post-mining recovery model run, aquifer properties of the coal seam (layer 4) and the interburden above the mine workings (Layer 3) at Moolarben will be increased to reflect the increased permeability of goaf zones (eg. increasing the horizontal and vertical hydraulic conductivity by two orders of magnitude, and setting the aquifer storage to 10% for these units). Two residual open cut voids will remain at Wilpinjong (WCPL, 2005), and these will be represented in the post-mining recovery run as cells with very high permeability (Kh=Kv=10^3m/day), and 100% aquifer storage, plus allowing evaporation from any mine void lake that develops as the water table recovers, at 50% of the potential evaporation rate (ie. 2.37mm/day, based on the average annual evaporation of 1728 mm from Table 2.3). A small residual pit void will also be specified at Ulan using the same approach (ie. assuming incomplete backfill of the open pit adjacent to the southern extent of the underground workings).

The aquifer parameters will change with time only for the separate post-mining recovery run, which is a re-start from the end of mining run. Changing parameters with time is not possible with the benchmarked Modflow code, without stop-restart model runs. The parameters need to change for the post-mining recovery runs, to represent the goaf effects post-mining, but trying to do this throughout the dewatering simulation would involve a very large number of model runs, which is not appropriate at this stage of model development, which involves a large number of sensitivity runs as well. Future modelling programmes should seek to refine this approach, perhaps using Modflow-Surfact to represent the underground dewatering conditions with more detail than is possible with the standard Modflow code.

The additional groundwater abstraction that is required in some years for the proposed Wilpinjong operation (ie. years 1 to 14 of that project), and also for certain years of the Moolarben project will be represented in the MC1 model with specified well pumping rates. For Moolarben, additional pumping will be required for any year when the predicted dewatering alone does not meet water demands, such as the pre-mining year (“year 0”) while the decline is being constructed, the post-mining decommissioning year (“year 16”) when dewatering will be inactive, and slightly more than half the other mining years. The locations of the modelled Wilpinjong wells are based on information from the EIS (WCPL, 2005), and the pumping rate matches the reported schedule. Where additional wells are required for the Moolarben project, they will be specified in the MC1 model at existing wells constructed during the investigation programme, plus additional wells on the eastern and southern edges of the underground mine workings, pumping at maximum rates of up to 330 kL/day from the Ulan coal seam, and also from the immediate overburden at some times. Discharge of excess water is not modelled specifically in the MC1 model, other than through the specification of river stage levels in the Goulburn River (for the Ulan project).

Table 3.1 outlines the MC1 model stress period setup for the history match calibration run, which is followed by the prediction simulation, and then the post-mining recovery run. A stress period is the timeframe in the model when all hydrological stresses (eg. recharge, mine dewatering) remain constant. Table 3.1 shows a “year of mining”, which refers to the prediction simulation going forward from the present, and assuming a project start for Wilpinjong in the 2006-2007 period, along with construction at Moolarben (“year 0”), and mining at Moolarben starting in year 1 (2007-2008).

Table 3.1

MC1 model stress period setup

	Stress Period	From	To	Days	**Timing of Operations**				**Mining Year**
CALIBRATION	**1**	1/07/1987	30/06/1990	1096			**Ulan Underground**		
	2	1/07/1990	29/06/1992	730					
	3	30/06/1992	30/06/1994	731					
	4	1/07/1994	29/06/1996	730					
	5	30/06/1996	30/06/1998	731					
	6	1/07/1998	29/06/2000	730					
	7	30/06/2000	30/06/2002	731					
	8	1/07/2002	29/06/2004	730					
	9	30/06/2004	30/06/2006	731					
PREDICTION	**10**	1/07/2006	30/06/2007	365	**Moolarben Open Cuts (1, 2 & 3)**	**decline**		**Wilpinjong Open Cuts**	**0**
	11	1/07/2007	30/06/2008	366					**1**
	12	1/07/2008	30/06/2009	365		**Moolarben Underground UG4**			**2**
	13	1/07/2009	30/06/2010	365					**3**
	14	1/07/2010	30/06/2011	365					**4**
	15	1/07/2011	30/06/2012	366					**5**
	16	1/07/2012	30/06/2013	365					**6**
	17	1/07/2013	30/06/2014	365					**7**
	18	1/07/2014	30/06/2015	365					**8**
	19	1/07/2015	30/06/2016	366					**9**
	20	1/07/2016	30/06/2017	365					**10**
	21	1/07/2017	30/06/2018	365					**11**
	22	1/07/2018	30/06/2019	365					**12**
	23	1/07/2019	30/06/2020	366					**13**
	24	1/07/2020	30/06/2021	365					**14**
	25	1/07/2021	30/06/2022	365					**15**
	26	1/07/2022	30/06/2023	365					**16**
	27	1/07/2023	30/06/2024	366					**17**
	28	1/07/2024	30/06/2025	365					**18**
	29	1/07/2025	30/06/2026	365					**19**
	30	1/07/2026	30/06/2027	365					**20**
	31	1/07/2027	30/06/2067	14610	**Post-mining Recovery**				

SECTION 4 - MC1 MODEL CALIBRATION, PREDICTION AND SENSITIVITY

4.1 CALIBRATION AND PREDICTION

Calibration is the process by which the independent variables (parameters and boundary conditions) of a model are adjusted, within realistic limits, to produce the best match between simulated and measured data. The realistic limits on parameter values are constrained by the range of measured values from pumping tests and other hydrogeological investigations (refer to Table 2.1).

Rather than present separate calibration and prediction tables and plots, this report provides a **joint presentation and discussion of the calibration and prediction results.** However, note that the "**Base case**" prediction refers to the prediction results with the calibrated model parameters, which relates to version MC1.3 of the Moolarben Coal model.

The MC1 groundwater model was set up and run initially in steady state mode, to represent long term average aquifer conditions, including historical open cut and underground mine dewatering at Ulan. The objective was not to derive a comprehensive simulation of pre-development steady-state conditions, but to derive a set of modelled aquifer heads that represented the effects of historical mining, for use as initial conditions in the transient model calibration run from 1987 to the present. The aim of the transient calibration was to try to achieve a history match to the effects of mining at Ulan in terms of dewatering volumes and piezometric levels. While there are some long term transient water level records for the Ulan area, there is poor information on the exact bore construction (especially relating to the integrity of the screened intervals), and there is poor information available on a time series of dewatering volumes from Ulan. Therefore, the targets for the transient history match comprise a snapshot of the piezometric water level data between 2004 and 2006 (generally the latter at Moolarben, but sometimes earlier dates in other areas), and the reported 2004 dewatering rate of 10 ML/day at Ulan (Ulan Coal Mines, 2005). In addition, there is data available from the DNR database, and from reported Wilpinjong bore data (WCPL, 2005).

Data from observation boreholes which fall within the MC1 model area range across different depths within the geological profile. The 2004 Ulan Annual Environmental Management Report (Ulan Coal Mines, 2005) identifies some issues around the integrity of some of the monitoring bores, and those bores have been excluded from the nominal data set, along with some other bores that showed similar inconsistencies. Also, vertical hydraulic gradients within one geological unit, as seen from some of the piezometer readings, cannot be represented in the MC1 model in some cases due to the vertical discretisation being restricted to one to two model layers per geological unit.

Table 4.1 summarises the 63 bores used for transient model **calibration**, and the model performance. Figure 4.1 shows a scatter plot of the modelled heads at 2006 and the measured calibration targets (for all model layers). The bore locations are shown as spot heights , along with the modelled contour levels at 2004 for the Ulan coal seam only (see Figure 4.3 later). Note that the measured data are sparse in space and time, and the measured targets use available data taken generally between 2004 and 2006, with some data from DNR bores taken from when the bore was drilled.

Table 4.1 Transient Calibration Data Set for MC1.3 model.

(Dates generally 2004 to 2006, except some DNR bores, which are usually when drilled.)

Bore	Area	Observed head (mAHD)	Modelled head at 2006 (mAHD)	Head Difference (m)	Difference Squared (m^2)	Aquifer Unit
ERUL27	**Wilpinjong** (levels from DEM, which has accuracy of +/-10m)	389.5	393.3598	3.9	14.90	Ulan Seam
ERUL77		365.9	367.7041	1.8	3.25	Ulan Seam
EW10005		389.6	392.6262	3.0	9.16	Ulan Seam
EW1001		365.3	363.2517	-2.0	4.20	Ulan Seam
EW1006		373.3	383.6921	10.4	108.00	Ulan Seam
EW1020		372.8	382.033	9.2	85.25	Ulan Seam
EW2001		366.9	369.4189	2.5	6.34	Ulan Seam
EW2002		367.2	370.3596	3.2	9.98	Ulan Seam
EW2003		367.1	359.8276	-7.3	52.89	Ulan Seam
EW2007		389.6	385.7945	-3.8	14.48	Marrangaroo
EW2010		389.4	393.9329	4.5	20.55	Ulan Seam
EW2012		373.5	381.6962	8.2	67.18	Ulan Seam
EW2014		366.9	365.9383	-1.0	0.92	Ulan Seam
EW2015		366.9	360.4988	-6.4	40.98	Marrangaroo
EW4001		386.4	385.8744	-0.5	0.28	Marrangaroo
EW4002		372.9	381.8101	8.9	79.39	Ulan Seam + Marrangaroo
EW4003		366.9	365.9526	-0.9	0.90	Ulan Seam
EW5001		373.7	378.3147	4.6	21.30	Marrangaroo
EW5002		374.8	382.8353	8.0	64.57	Ulan Seam
GW024776	**DNR Regional Bores** (mostly Wilpinjong area; usually record of water level at time of drilling and many not surveyed)	380.8	388.0128	7.2	52.02	Ulan Seam
GW052223		398.5	400.7644	2.3	5.13	Ulan Seam
GW053859		388.4	393.438	5.0	25.38	Ulan Seam
GW078082		504.1	500.3182	-3.8	14.30	
GW078105		413.3	427.2625	14.0	196.35	Ulan Seam
GW078373		394.45	398.4211	4.0	15.77	
GW078374		393.9	398.0718	4.2	17.82	Illawarra (Ulan overburden)
GW080401		397.4	389.8654	-7.5	56.32	basement outcrop
GW080403		396.7	392.3892	-4.3	18.15	basement outcrop
GW080408		378.2	378.1149	-0.1	0.00	Illawarra (Ulan overburden)
GW080410		377.4	376.885	-0.5	0.27	Illawarra (Ulan overburden)
GW080411		372.4	373.929	1.5	2.40	Illawarra (Ulan overburden)
GW080413		354.4	348.2157	-6.2	38.25	Illawarra (Ulan overburden)
GW802260		500	521.2811	21.3	452.89	
PZ01A	**Moolarben bores** (levels from DEM, which has accuracy of +/-10m)	417	447.0044	30.0	900.26	Triassic
PZ04A		408.5	431.1123	22.6	511.32	Triassic
PZ101A		366.7	342.0142	-24.7	609.39	Ulan Seam
PZ101B		365.0	380.5011	15.5	241.53	Narrabeen
PZ102A		356.2	384.5244	28.3	802.27	Illawarra (Ulan overburden)
PZ102B		355.1	355.3901	0.3	0.07	Ulan Seam
PZ103A		356.6	358.8265	2.2	5.05	Ulan Seam
PZ103B		369.5	384.1898	14.7	216.67	Illawarra (Ulan overburden)
PZ104		380.5	379.0068	-1.5	2.23	Ulan Seam
PZ105B		377.1	383.7093	6.6	43.68	Illawarra (Ulan overburden)
PZ106A		429.2	422.1646	-7.0	49.64	Illawarra (Ulan overburden)
PZ108		333.5	376.0322	42.5	1808.99	Illawarra (Ulan overburden)
PZ109		384.4	401.3867	17.0	289.57	Ulan Seam
PZ17		456.9	423.9662	-32.9	1085.29	Blackman's Flat
PZ30		409.6	389.8192	-19.8	391.28	Marrangaroo
PZ39		418.7	407.3243	-11.4	130.09	Marrangaroo
PZ40A		419.4	409.7641	-9.6	92.66	Narrabeen
PZ41B		425.3	408.5797	-16.7	279.23	Ulan Seam
PZ44		480.1	478.5237	-1.5	2.33	Basement
PZ50B		432.6	424.0997	-8.5	71.41	Illawarra (Ulan overburden)
PZ52		418.2	412.1798	-6.0	36.00	Alluvium
PZ53		399.8	408.4205	8.6	73.62	Illawarra (Ulan overburden)
TB103		369.1	387.0121	17.9	319.41	Illawarra (Ulan overburden)
TB105		359.5	348.7159	-10.8	116.30	Illawarra (Ulan overburden) + Seam
TB52A		407.7	383.6822	-24.0	576.85	Illawarra (Ulan overburden) + Seam
R280-40	**Ulan bores** (affected by mine dewatering)	368.0	359.3412	-8.7	74.97	Ulan Seam
R680		409.0	436.2761	27.3	743.99	Ulan Seam
R755		398.0	439.6548	41.7	1735.12	Ulan Seam
R756		414.0	454.0058	40.0	1600.46	Ulan Seam
	Min (m)	333.5		Sum Squares	14309.25	
	Max (m)	504.1		Mean (Sum Squares)	230.79	
	Range (m)	170.6		SQRT(Mean SSq)	15.19	
	Count	62		**Scaled RMS (%)**	**8.90**	

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Model calibration performance is demonstrated in quantitative and qualitative terms, by:

- scatter plots of modelled versus measured head, and the scaled root mean square (RMS) target of 5% to 10% (Scaled RMS of 8.9% was achieved; refer to Table 4.1 and Figure 4.1);
- the range of calibrated aquifer parameters are shown in Table 4.2 (see also Appendix A);
- water balance components (Tables 4.3 and 4.4, and Figure 4.2; presented later);
- contour plans of modelled head (Figure 4.3; presented later).

The scaled RMS value is the RMS error term divided by the range of heads across the site and it forms the main quantitative performance indicator. Given uncertainties in the overall water balance volumes (eg. it is difficult to directly measure evaporation and baseflow into the creeks directly, and there is little accurate data available on dewatering volumes at Ulan), the 10% scaled RMS value is an appropriate target for this project, with an ideal target for long term model refinement suggested as 5% or lower. This approach is consistent with the Australian best practice groundwater modelling guideline (MDBC, 2001). Table 4.1 and Figure 4.1 show these performance indicators, and Table 4.2 summarises the calibrated aquifer parameters.

Figure 4.1

MC1.3 model scatter plot (transient calibration result at 2006)

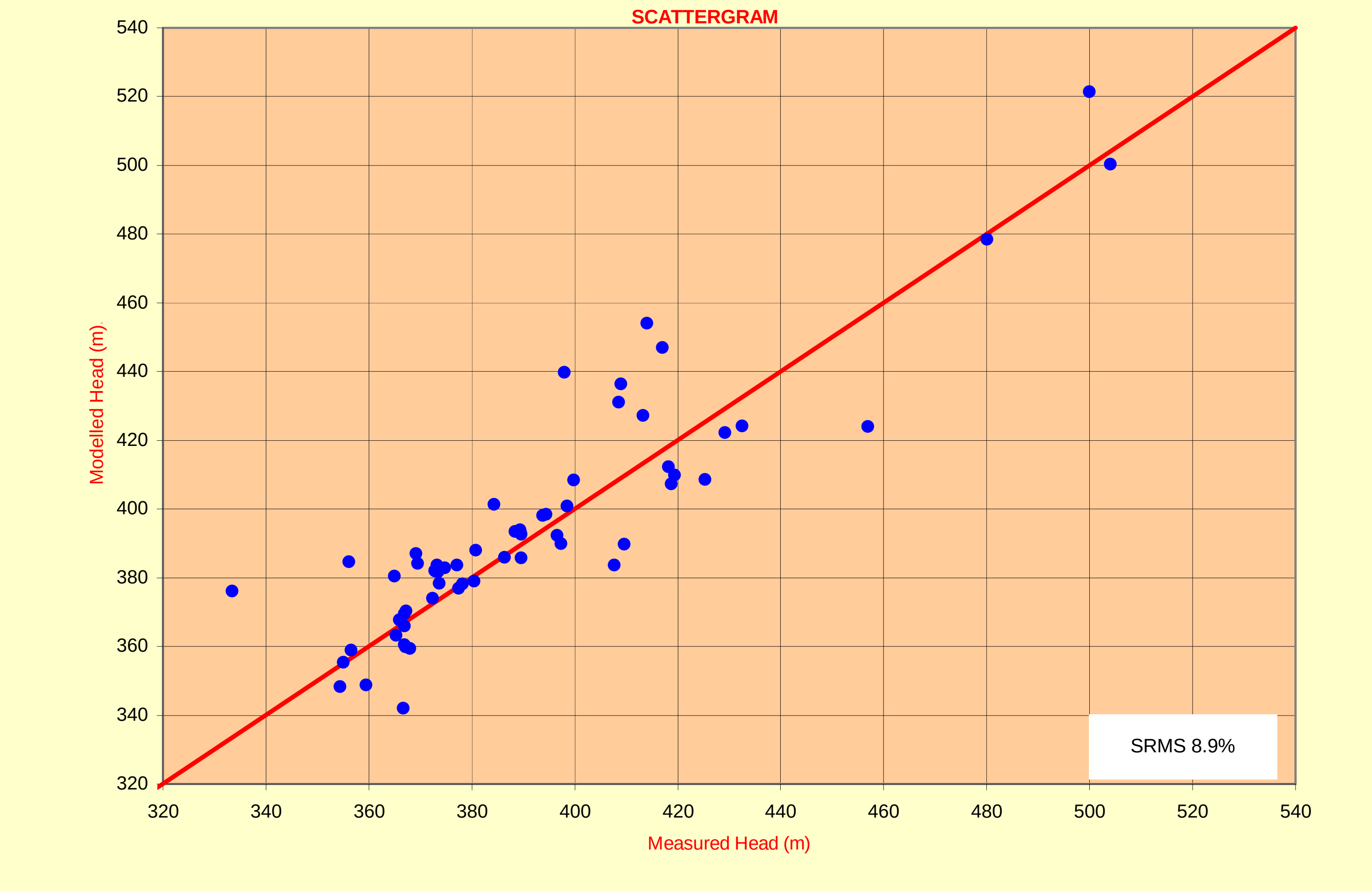


Table 4.2
Calibrated MC1.3 model aquifer parameters (spatial distributions shown in Appendix A)

Main Layer	Aquifer/Aquitard	T (m^2/d)	K_h (m/d)	K_v (m/d)	Unconfined S_y (-)	Confined S (-)
1 & 2	Alluvial deposits	-	0.7-1.5	0.005-0.15	0.20	n/a
1	Narrabeen Group	-	0.1	0.001-0.001	0.05	5e-05
2	Illawarra Coal Measures (coal seams present; undisturbed)	-	0.06-0.8	0.0007	0.05	5e-05
3	Illawarra Coal Measures (coal seams absent; undisturbed)	-	0.01-0.8	0.00001-0.0004	0.05	5e-05
4	Ulan Coal Seam (undisturbed)	-	1.7-3.0	0.00015-0.025	0.05	5e-05
5	Marrangaroo Sandstone	1-5		0.0000025-0.1	0.05	5e-05
4 & 5	Basement (T in layer 5 only)	0.1	0.001	0.00001	0.05	5e-05

The adopted calibration is actually version MC1.3 of the Moolarben Coal model. The initial version MC1.1 involved higher Kv values than MC1.3 (by a factor of about 3), and resulted in a lower RMS than MC1.3 (about 8.3% compared to 8.9%). However, MC1.1 also resulted in a higher predicted inflow to Ulan at 2004 of about 13 ML/day, compared to the reported 10 ML/day inflow (Ulan Coal Mines, 2005), which is matched better by the MC1.3 prediction of 8.7 ML/day, hence the adoption of MC1.3 as the calibrated model version. Future modelling programmes should aim to further improve the calibration performance in terms of head and flow performance.

The calibrated MC1.3 model was applied to **predictions** of the hydrological impact of progressive mining at Ulan, Moolarben and Wilpinjong, and then post-mining recovery. The focus for the prediction evaluations is on the effects of mining at Moolarben and on the cumulative impacts of all mines, with the other operations represented as accurately as possible, although there will inevitably be less accurate representation of Ulan and Wilpinjong due to the lack of detailed information available at this time. Particular interest is placed on the regional change in groundwater levels during mining and after mine closure, on changes in baseflow contributions to surface water courses, and on the predicted water ingress into the mine workings through vertical leakage during the life of the mines. Mine dewatering operations were simulated as described in Section 3.3, with the range of parameter values for sensitivity testing outlined later in Section 4.2.

4.2 DISCUSSION OF CALIBRATION HISTORY MATCH AND MINING EFFECTS

Table 4.3 lists the annual changes in predicted dewatering rates for Ulan, Moolarben and Wilpinjong, which extends from the history match period out through the prediction period, with the Ulan underground in operation throughout, and the Moolarben and Wilpinjong operations varying with time as indicated in Table 3.1. During finalisation of this report, it became apparent that the water demand volumes applied to the model for certain years of Moolarben may differ slightly from the latest mine plan. Reporting deadlines precluded re-running of the models at this time, but the results from the range of sensitivity runs completed indicate that the effects of the additional water supply pumping would not materially affect the impact predictions presented herein. Figure 4.2 presents a hydrograph of the modelled mine dewatering rates.

Table 4.3 (see also Figure 4.2)

Predicted mine dewatering rates in relation to water demand (MC1.3 base case)

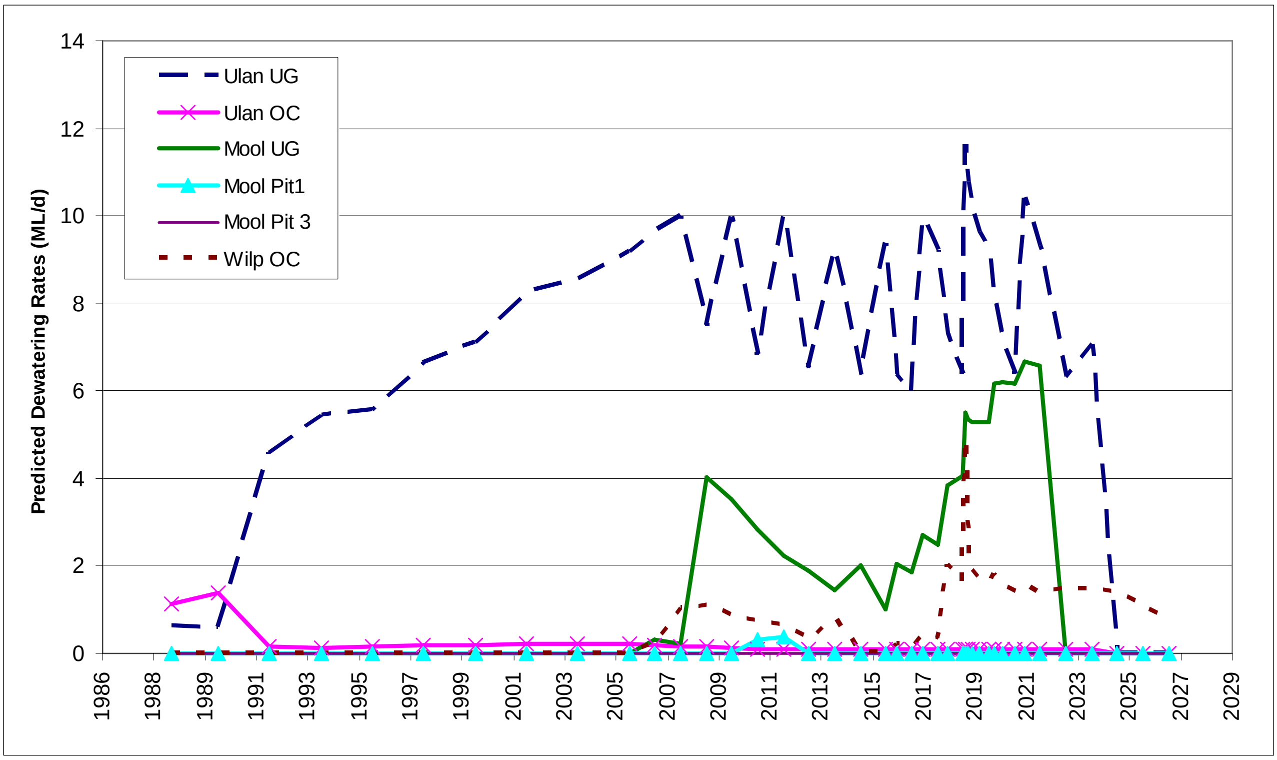
Mine Year	Stress Period	Year	Moolarben Mine Water Inflows (ML/a)				Water Demand	Surplus	Moolarben wells	Other Mine Water Inflows (ML/a)		
			UG 4	OC 1	OC 3	Total Inflow	ML/a	ML/a	ML/a	Ulan OC	Ulan UG	Wilpinjong OC
	1	1987-90								509	217	
	2	1990-92								53	1,680	
	3	1992-94								44	1,982	
	4	1994-96								53	2,034	
	5	1996-98								63	2,426	
	6	1998-00								72	2,597	
	7	2000-02								75	3,003	
	8	2002-04								79	3,119	
	9	2004-06								75	3,358	
0	10	2006-07	113	-	-	113	208	25	120	71	3,520	88
1	11	2007-08	83	-	-	83	1,000	47	964	60	3,648	379
2	12	2008-09	1,472	-	-	1,472	1,458	14	-	53	2,731	404
3	13	2009-10	1,282	4	-	1,285	1,510	16	241	46	3,646	317
4	14	2010-11	1,035	116	-	1,151	2,291	56	1,196	39	2,490	266
5	15	2011-12	821	139	-	960	2,500	94	1,633	35	3,661	242
6	16	2012-13	693	-	-	693	2,500	0	1,807	32	2,382	128
7	17	2013-14	527	-	-	527	2,500	46	2,019	31	3,372	304
8	18	2014-15	733	-	-	733	2,500	80	1,846	30	2,321	7
9	19	2015-16	371	-	-	371	2,500	39	2,168	30	3,418	13
10	20	2016-17	679	-	-	679	2,500	14	1,835	30	2,176	61
11	21	2017-18	902	-	-	902	2,500	153	1,751	30	3,370	121
12	22	2018-19	1,479	-	-	1,479	937	542	-	30	2,328	605
13	23	2019-20	1,925	-	-	1,925	833	1,092	-	30	3,378	582
14	24	2020-21	2,255	-	-	2,255	833	1,422	-	30	2,328	522
15	25	2021-22	2,402	-	-	2,402	833	1,569	-	30	3,402	509
16	26	2022-23	-	-	-	-	52	3	55	30	2,308	534
17	27	2023-24	-	-	-	-	-	-	-	30	2,579	538
18	28	2024-25	-	-	-	-	-	-	-	-	-	506
19	29	2025-26	-	-	-	-	-	-	-	-	-	399
20	30	2026-27	-	-	-	-	-	-	-	-	-	262

F:\adelaide\jobs\A37_Moolarben\B1\370_Pred\MC1.3\[MC1.3_Mool Pred_dewatering.xls]Pred Dewater (Table 4.3)

The predicted Ulan open cut and underground dewatering around 1987 (Table 4.3 and Figure 4.2) is broadly consistent with the anecdotal indications of 3 ML/day (or 1095 ML/annum) pumping rates at Ulan. The 2004 Environmental Management report for Ulan indicated that the dewatering in 2004 amounted to around 10 ML/day (Ulan Coal Mines, 2005), or 3650 ML/annum. That report also suggests that the projected dewatering at Ulan may reach around 18 ML/day (or 6570 ML/annum) by the mid-2020's. Table 4.3 and Figure 4.2 show that the early time modelled dewatering rates are well-matched to the reported values, although the late time projections are lower than the Ulan predictions, with the MC1.3 basecase prediction indicating Ulan dewatering rates varying between 6 and 12 ML/day going forward.

Figure 4.2

Predicted mine dewatering rates (MC1.3 base case)



The **saw-tooth pattern** of predicted underground dewatering rates at Ulan (Figure 4.2) is due to the assumption that panels are mined on alternative sides of the main drive that bisects the workings. Thus, the higher dewatering rates are due to mining panels on down-dip side (the right-side), and the lower rates are due to mining panels on the up-dip side. Similar effects occur in relation to the predicted Moolarben underground dewatering. Note also that Moolarben Open Cut No. 2 is predicted to be virtually dry, with just nuisance dewatering needs.

The predicted peak of inflows to **Wilpinjong** open cuts occurs around its mine year 14, which is when the most northerly (or deepest down-dip) panels are mined. The additional water supply make-up bores for Wilpinjong are de-activated after that as dewatering is predicted to meet demands.

The figures presented under the Figure 4.3 main heading present contour plans of the modelled water levels in the various aquifers at 2006, and the spot heights of the measured water levels (ie. the data presented at Table 4.1). The figures presented under the Figure 4.4 main heading present contour plans of the modelled water levels in the various aquifers at 2022, and also the drawdown due to the effects of mine dewatering between 2006 and 2022. The cumulative drawdowns at 2022 are presented (ie. due to all mining), and the effects due to Moolarben only are separated out by subtracting the predicted water levels at 2022 for the basecase (ie. all mines active) from the predicted water levels for the “no Moolarben mining” case.

Figure 4.3.1

MC1.3 contour plan for Triassic aquifers (Layer 1) at 2006 (cumulative impacts)

(piezometric water level contours in mAHD of cumulative impacts, with measured spot heights)

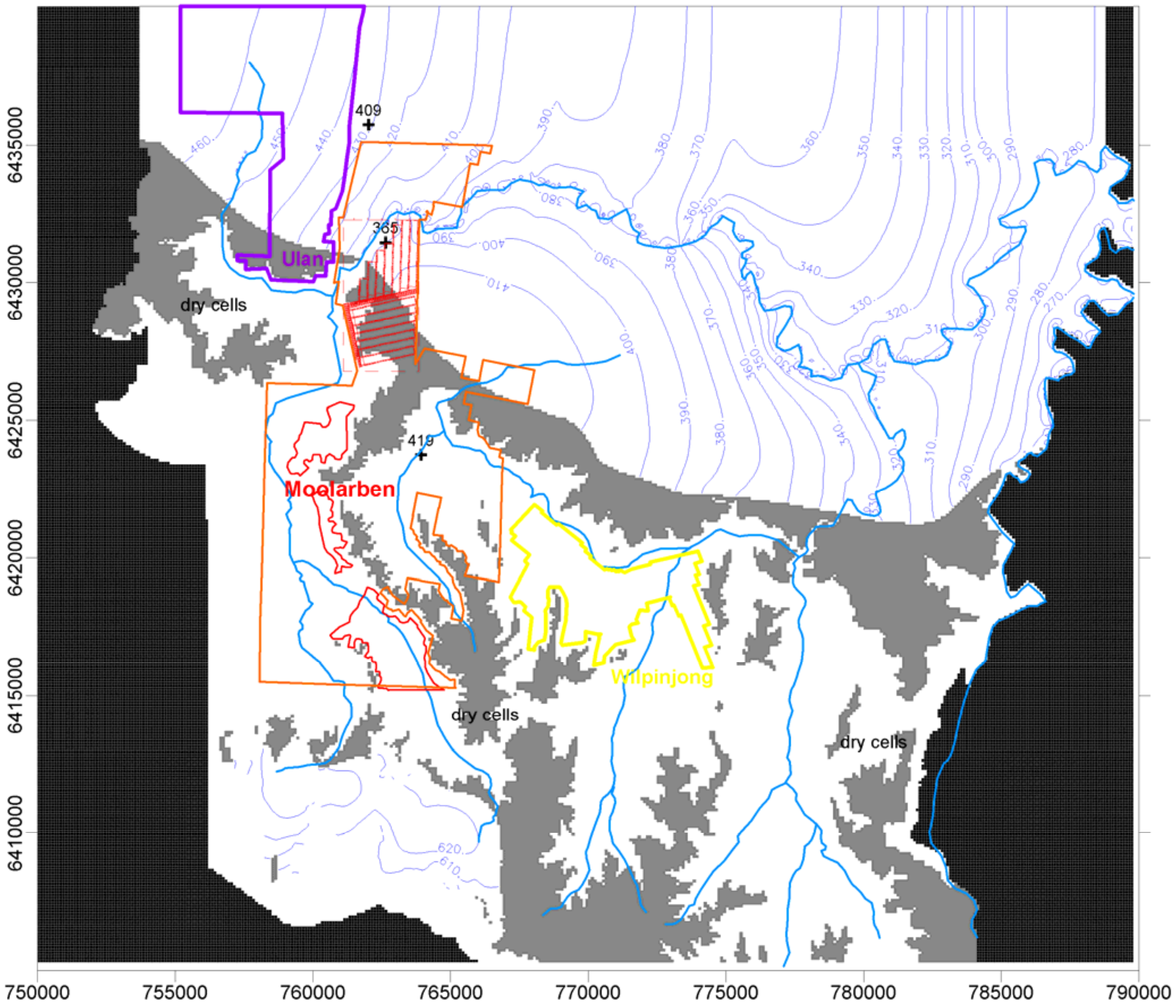


Figure 4.3.2

MC1.3 contour plan for Permian aquifers (Layer 2) at 2006 (cumulative impacts)

(piezometric water level contours in mAHD of cumulative impacts, with measured spot heights)

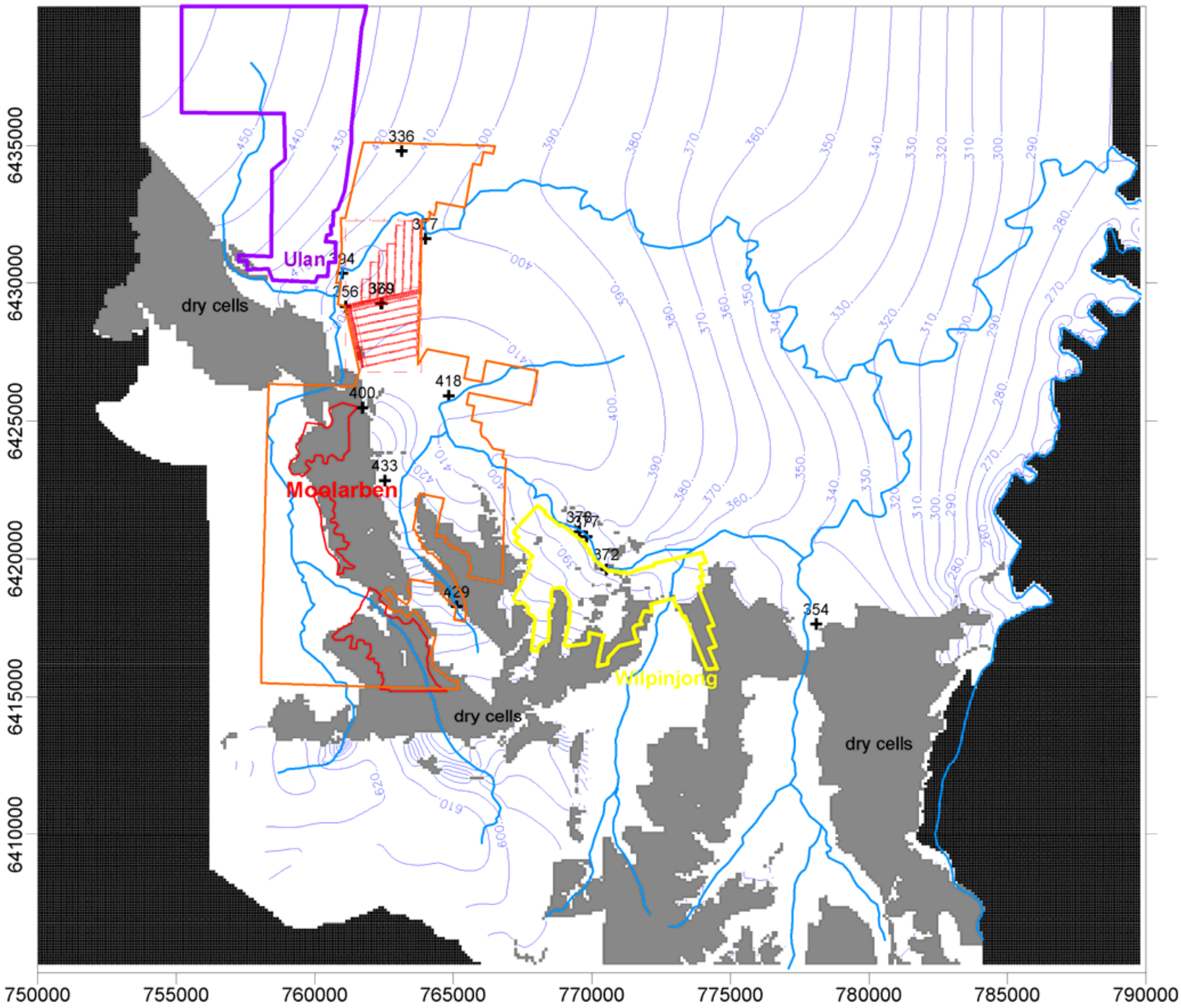


Figure 4.3.3

MC1.3 contour plan for Ulan seam (Layer 4) at 2006 (cumulative impacts)

(piezometric water level contours in mAHD of cumulative impacts, with measured spot heights)

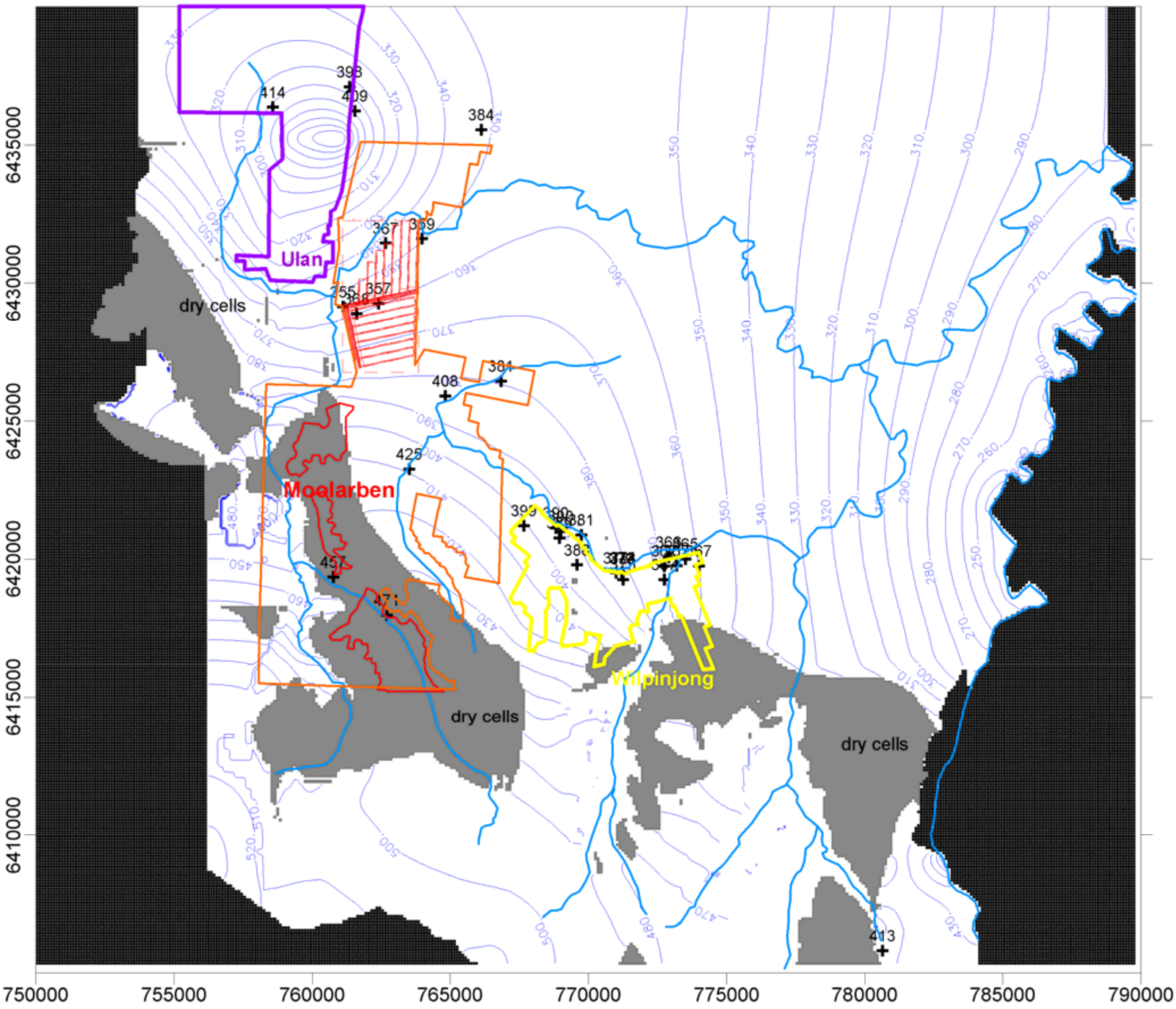


Figure 4.4.1

MC1.3 piezometric contour plan for Triassic aquifers (Layer 1) at 2022 (cumulative impacts)

(piezometric water level contours in mAHD of cumulative impacts)

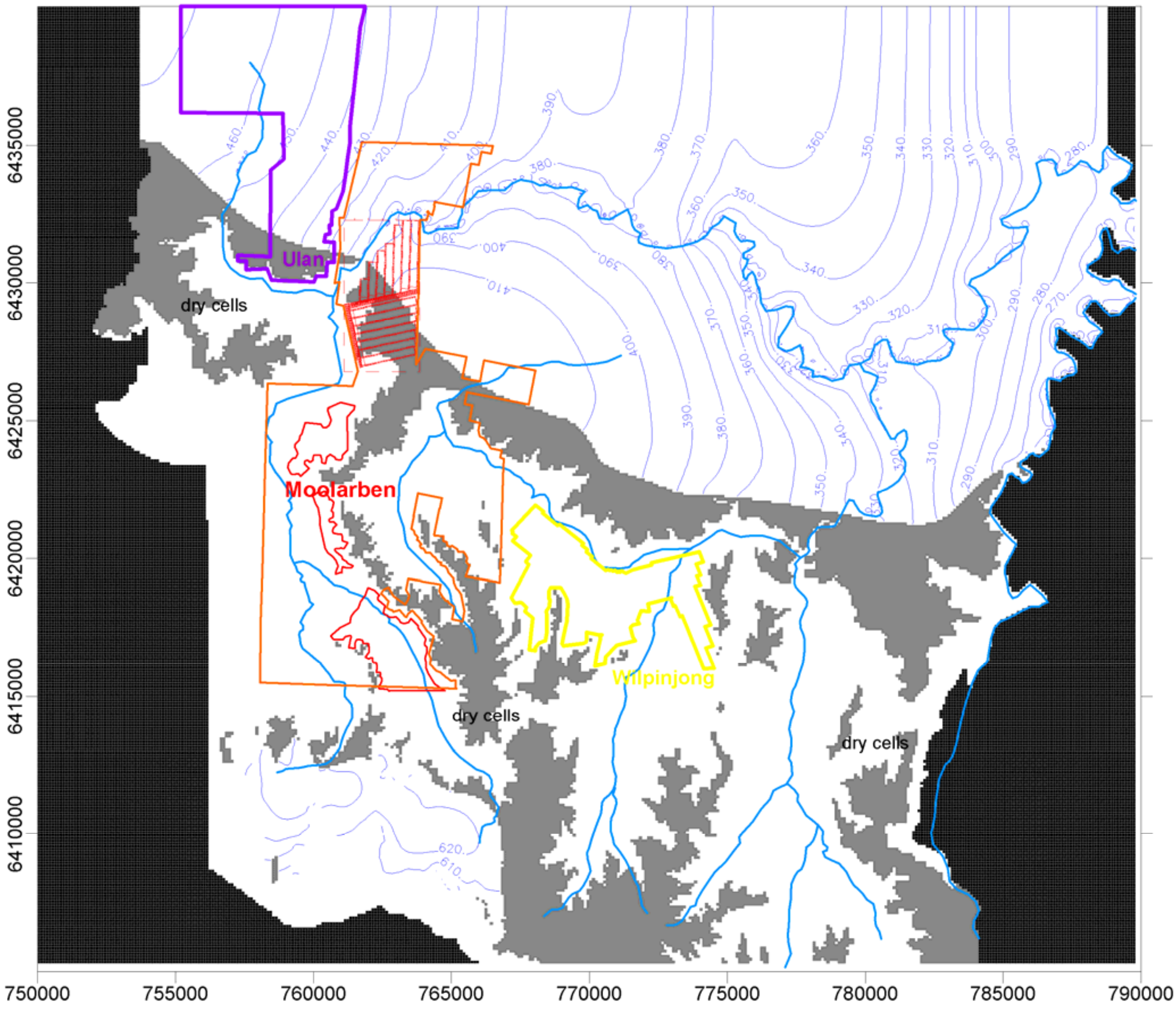


Figure 4.4.2

MC1.3 piezometric contour plan for Permian aquifers (Layer 2) at 2022 (cumulative impacts)

(piezometric water level contours in mAHD of cumulative impacts)

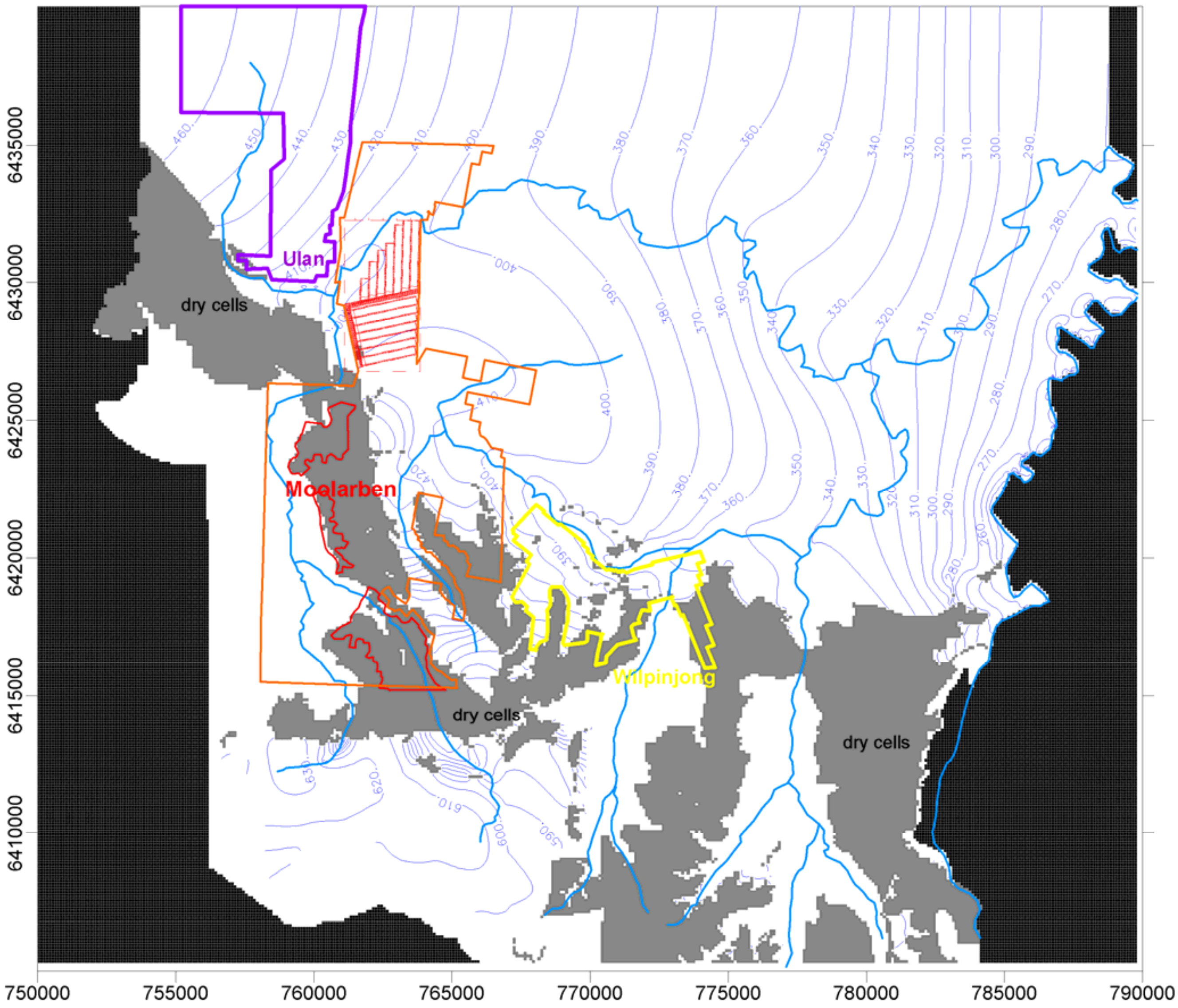


Figure 4.4.3

MC1.3 piezometric contour plan for Ulan seam (Layer 4) at 2022 (cumulative impacts)

(piezometric water level contours in mAHD of cumulative impacts)

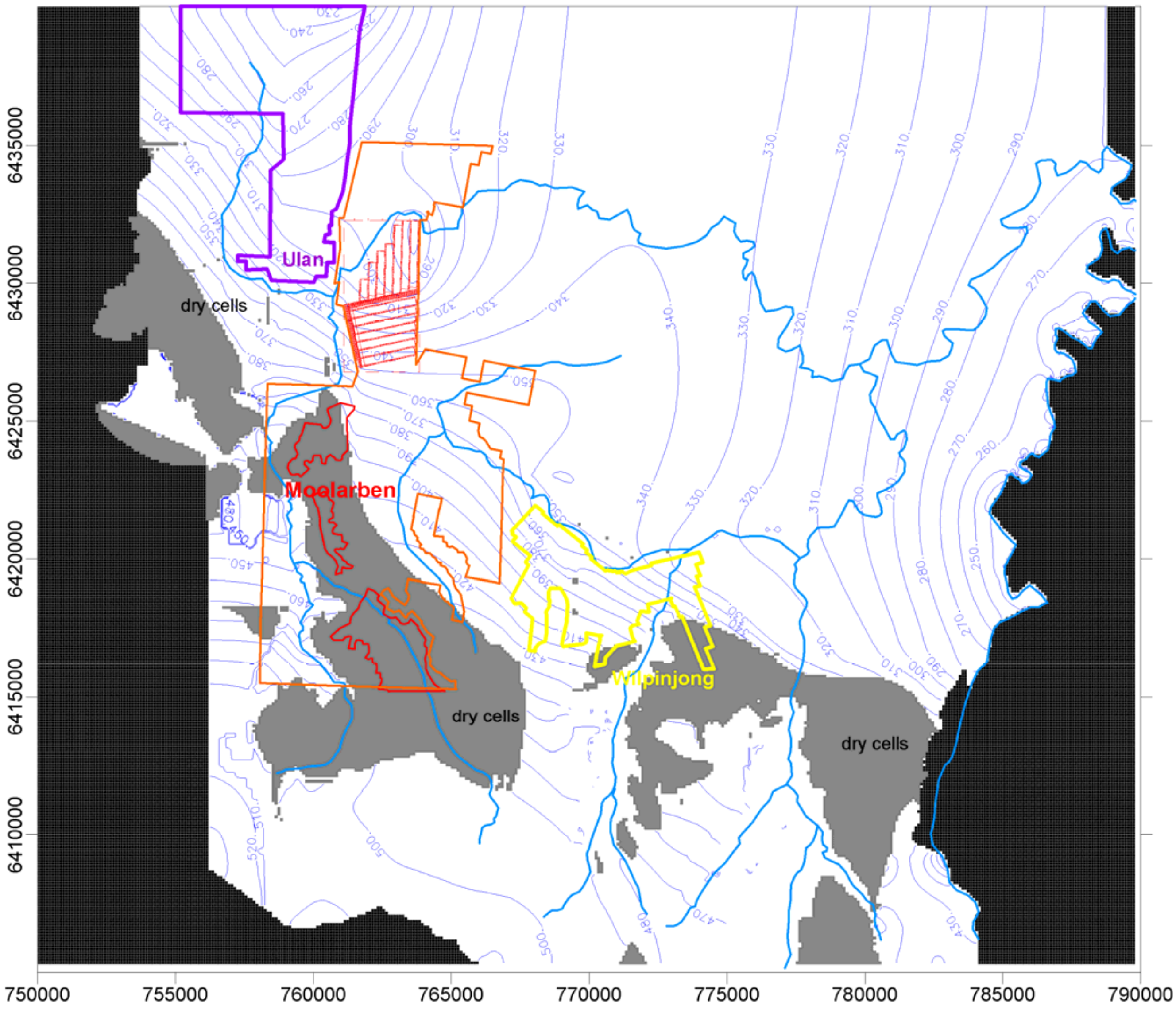


Figure 4.4.4

MC1.3 Moolarben-only drawdown contour plan for Triassic aquifers (Layer 1) 2022 - 2006

Drawdown due to Moolarben only mining (separate effect calculated by subtracting predicted water levels at 2022 for basecase (ie. all mines active) from predicted water levels for the “no Moolarben mining” case)

(drawdown in metres due to dewatering from 2006 to 2022)

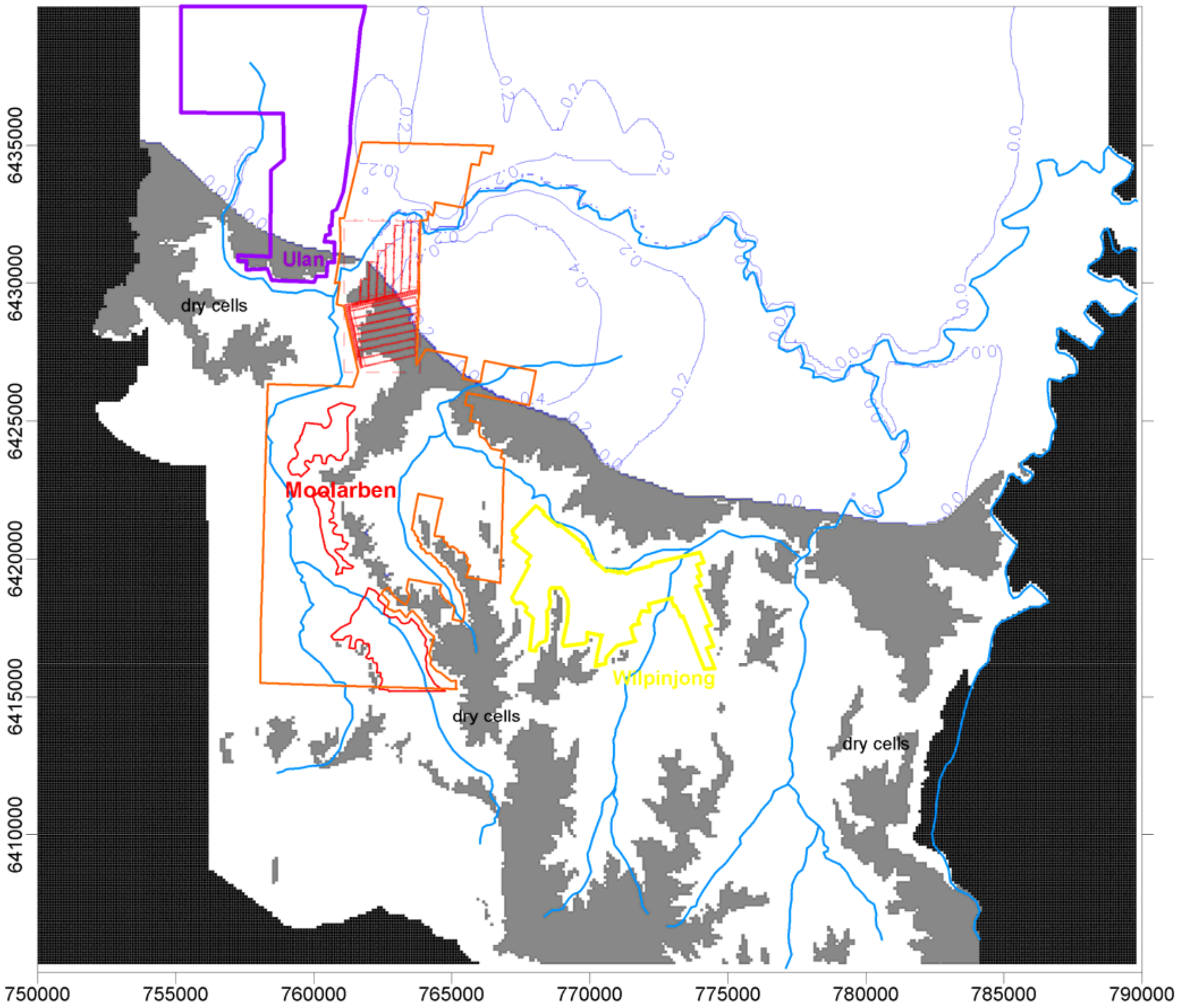


Figure 4.4.5

MC1.3 Moolarben-only drawdown contour plan for Permian aquifers (Layer 2) 2022 – 2006

Drawdown due to Moolarben only mining (separate effect calculated by subtracting predicted water levels at 2022 for basecase (ie. all mines active) from predicted water levels for the "no Moolarben mining" case)

(drawdown in metres due to dewatering from 2006 to 2022)

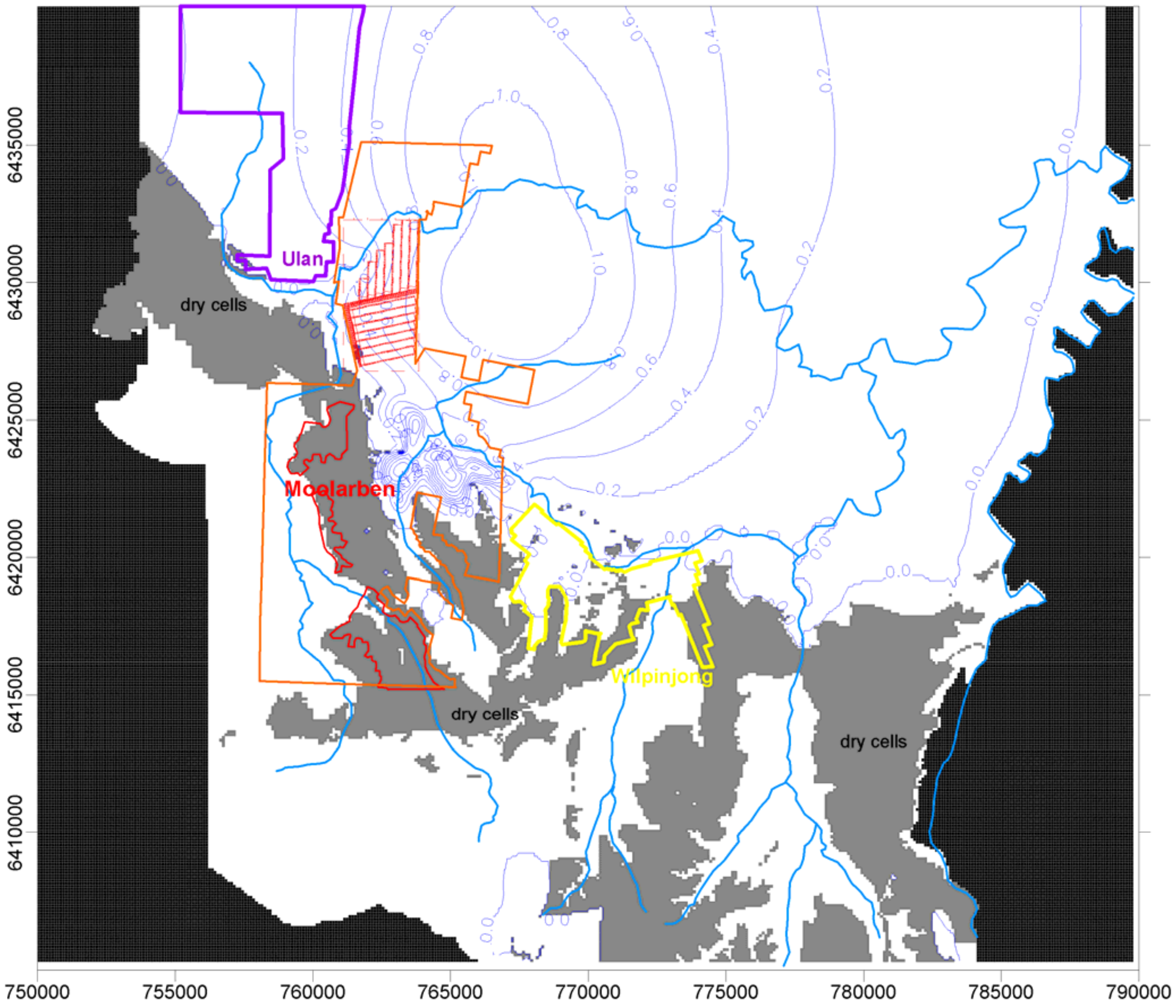


Figure 4.4.6

MC1.3 Moolarben-only drawdown contour plan for Ulan seam (Layer 4) 2022 - 2006

Drawdown due to Moolarben only mining (separate effect calculated by subtracting predicted water levels at 2022 for basecase (ie. all mines active) from predicted water levels for the “no Moolarben mining” case)

(drawdown in metres due to dewatering from 2006 to 2022)

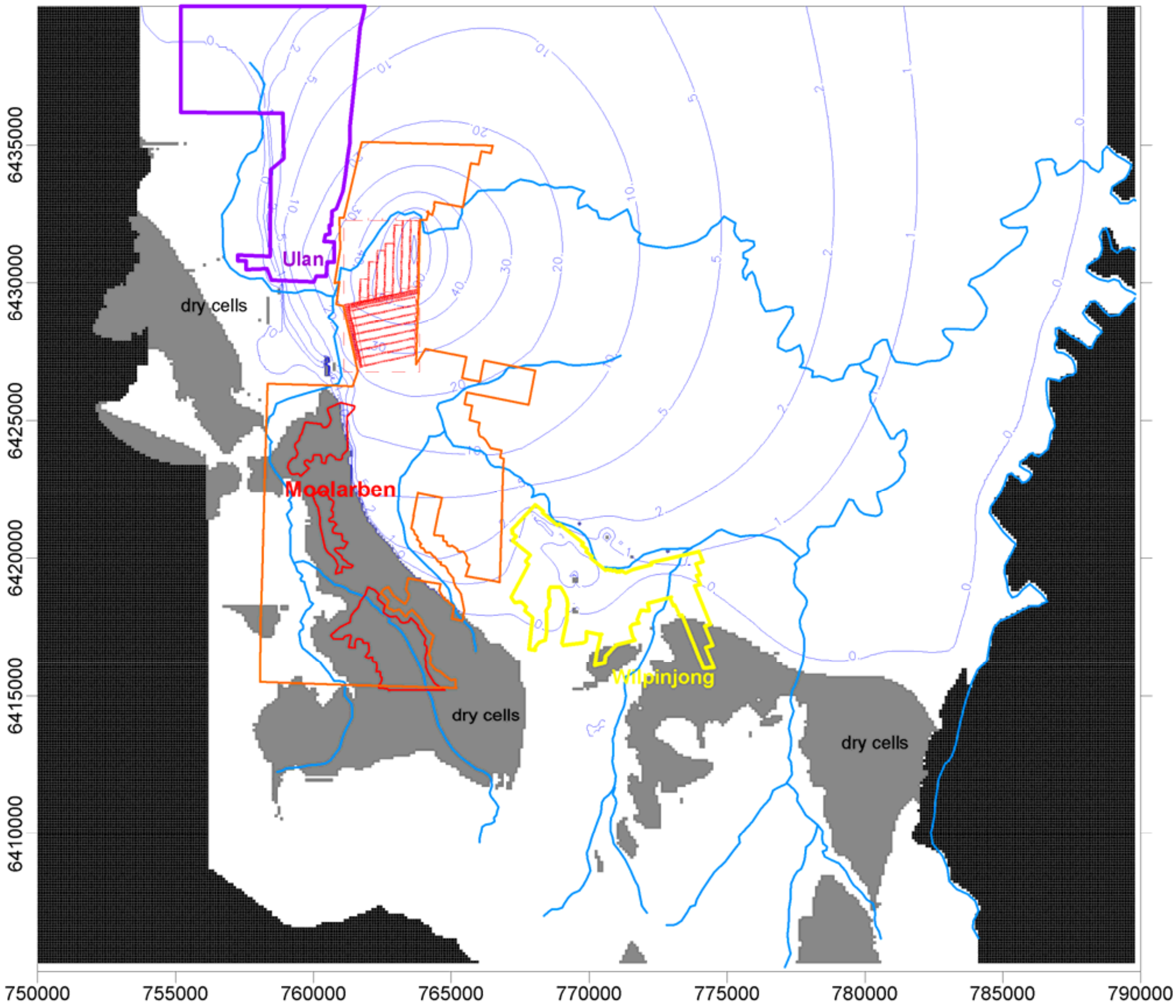


Figure 4.4.7

MC1.3 cumulative impacts drawdown contour plan for Triassic aquifers (Layer 1) 2022 - 2006

Drawdown due to cumulative impacts of mining (Ulan + Wilpinjong + Moolarben)

(drawdown in metres due to dewatering from 2006 to 2022)

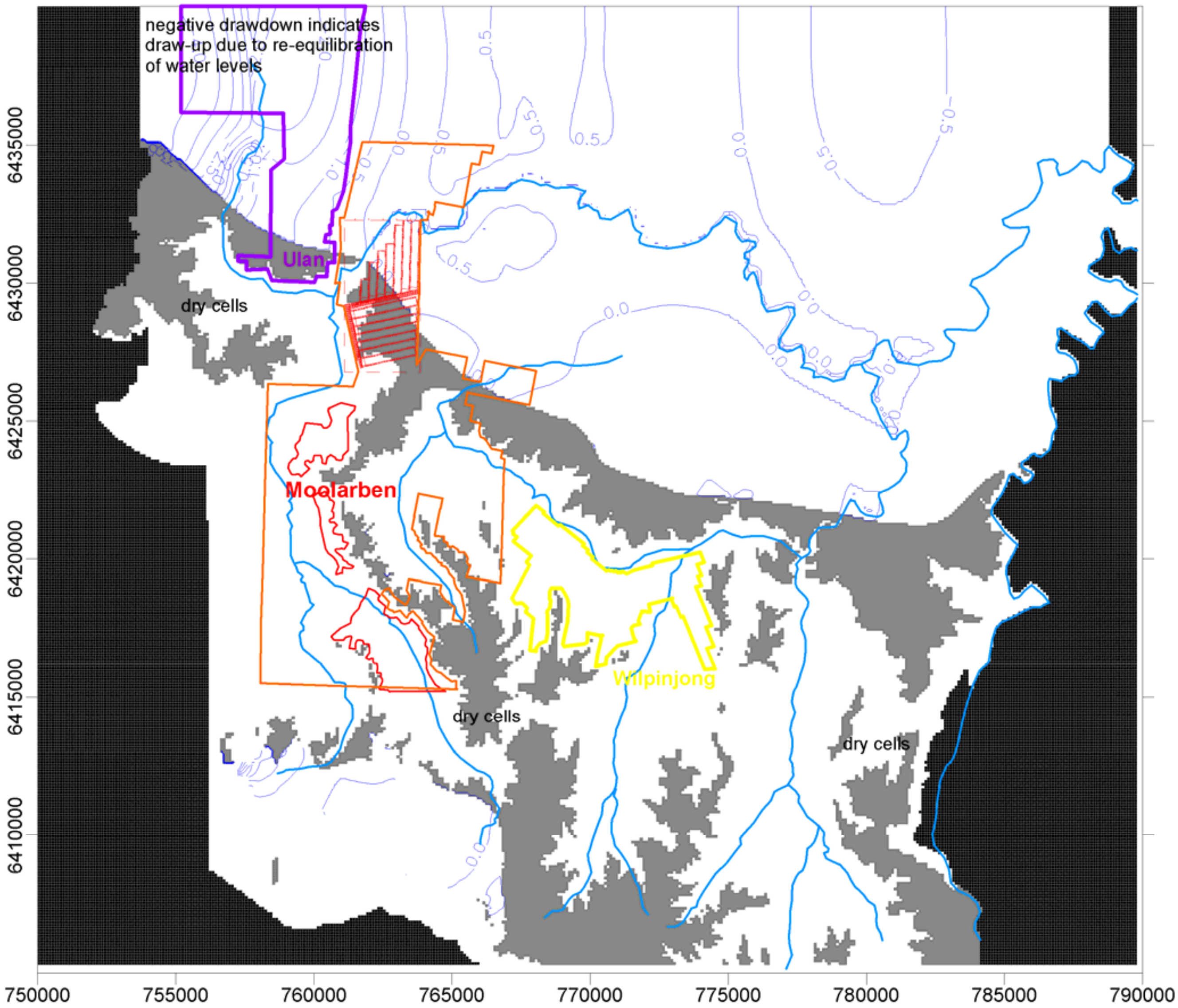


Figure 4.4.8

MC1.3 cumulative impacts drawdown contour plan for Permian aquifers (Layer 2) 2022 - 2006

Drawdown due to cumulative impacts of mining (Ulan + Wilpinjong + Moolarben)

(drawdown in metres due to dewatering from 2006 to 2022)

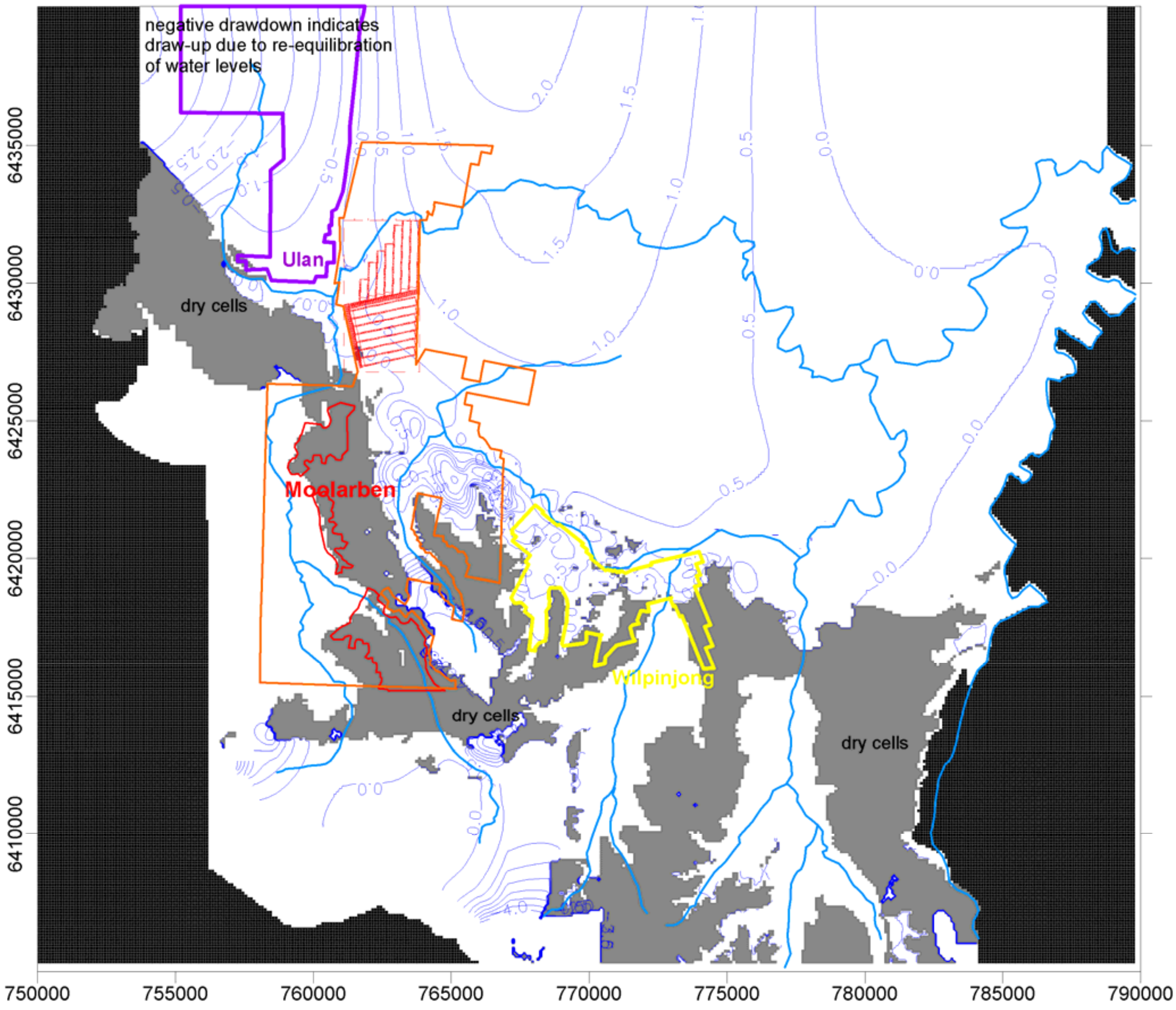
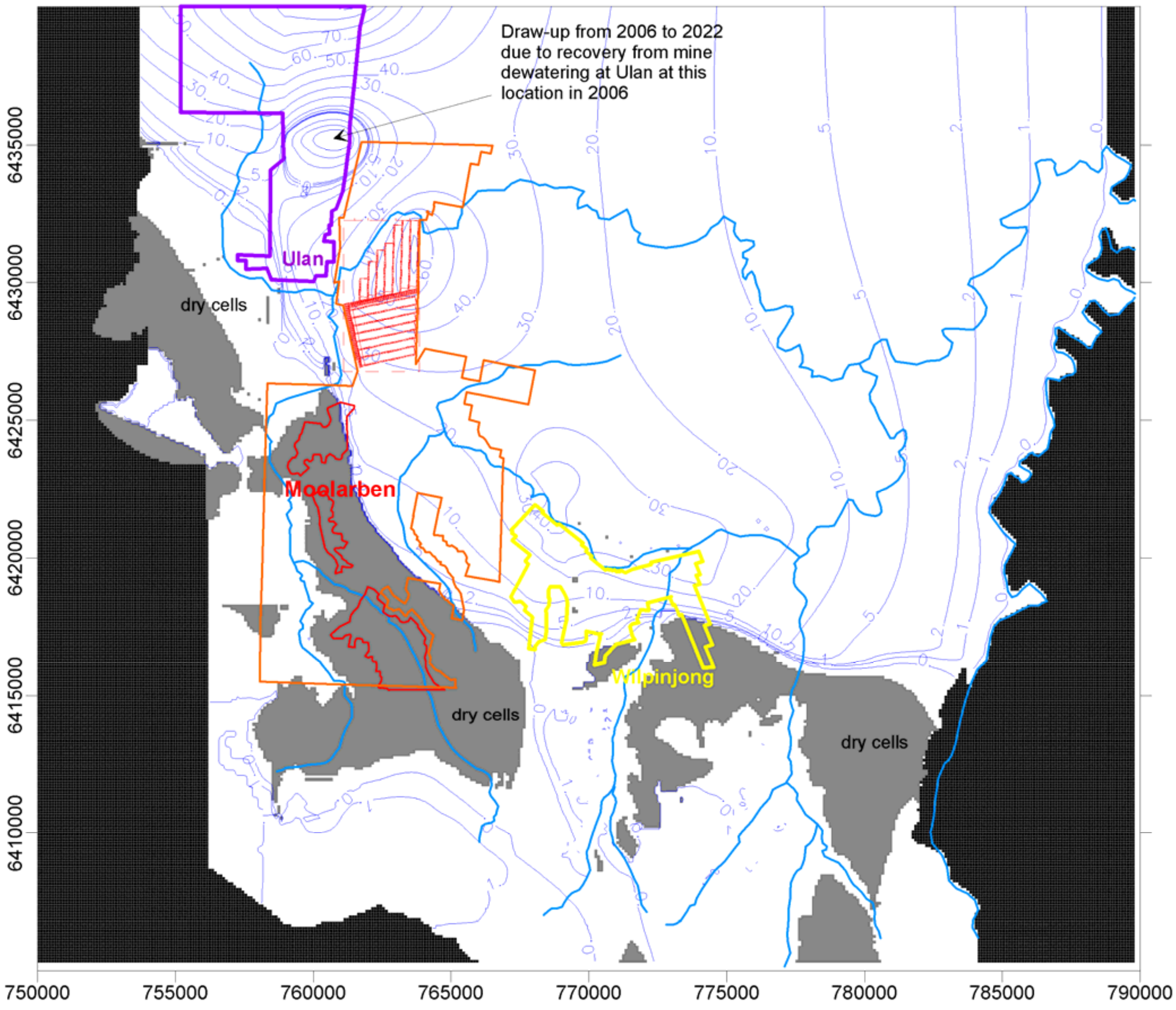


Figure 4.4.9

MC1.3 cumulative impacts drawdown contour plan for Ulan seam aquifer (Layer 4) 2022 - 2006

Drawdown due to cumulative impacts of mining (Ulan + Wilpinjong + Moolarben)

(drawdown in metres due to dewatering from 2006 to 2022)



The calibration performance is acceptable (ie. achievement of <10% RMS error, and a good match to reported Ulan inflows), but not ideal (ie. RMS >5%). It was very difficult to determine the suitable balance between the main calibration parameter values, while achieving a reasonable match to both the reported dewatering volumes and the distribution of aquifer heads spatially, as well as the head differences between layers. The best summary of the head matches is the scatter plot (Figure 4.1), and the associated scaled RMS calibration performance (Table 4.1). The scaled RMS value is used in the later sensitivity analysis as it provides a simple but valid indication of overall model performance. The main calibration parameters are the hydraulic conductivity for the Ulan seam, the overburden and the underlying layers, and the drain cell conductance parameters (representing impedance to underground mine inflows). As will be discussed in the sensitivity section, the model results are very sensitive to the vertical hydraulic conductivity (Kv) value, but also to the horizontal (Kh) value. To address the underlying uncertainties, a range of sensitivity runs were undertaken, with the results presented in the next section (and summarised in Table 4.5).

It should be noted that this is a predictive modelling exercise. Due to lack of long term observation data in the Moolarben area (many of the available monitoring bores were drilled during the recent investigation phase), there is considerable uncertainty about the behaviour of the aquifer under stress induced through mining. Results are based on the best available data at present, however, they cannot be robustly verified at this stage (other than by reference to information from Ulan that is itself not certain), and hence predicted seepage rates and drawdowns should be used with caution at this time. When observation data becomes available (e.g. on the decline of water levels at the start of the underground mining), model results should be compared to observed data and, if necessary, adjusted accordingly.

Given the uncertainties, it is recommended that appropriate contingencies be incorporated into mine water management plans, to cater for potentially higher mine inflow rates than the predicted base case. This is because the adopted model calibration is affected by “low value parameter saturation” in relation to one of the main (sensitive) parameters, the vertical hydraulic conductivity (Kv), as will be discussed in the next section. For example, increases or decreases in the adopted Kv values by factors of 3-4 result in changes of up to around 30% in the predicted mine inflow rates. In other words, there is low risk of substantial under-estimation of mine inflow rates. However, an increase in the Kv value by a factor of 10 or more (which is plausible) would result in much greater increases in predicted mine inflows. It cannot be determined at this time whether there is a low or high **risk** of much higher Kv values being encountered, but there could be significant potential **consequences** in terms of possibly much greater mine inflows, and appropriate planning is warranted.

4.3 WATER BALANCE SUMMARY

Table 4.4 provides information on the MC1.3 model water balance elements at various times through the prediction, with the following points summarising the conclusions:

- the major input to the system is rainfall recharge, with evaporation output (representing groundwater dependent ecosystems along the valley floors) forming around 50% of the rainfall recharge inputs;

- the other major inputs of head-dependent inflows and Goulburn River leakage (into model components in Table 4.4) form about 90% of the head-dependent outflows and Goulburn River baseflow (out of model components in Table 4.4);

Table 4.4

MC1.3 model water balances (base case)

MC1.3 Model Water Balance Component volumes (kL/d)	Rainfall Recharge	Head-dependent Flow	Goulburn River	Minor Creeks	Evap'n	Wells	Mine dewatering	Storage replenishment	Storage depletion	Total
2006 (Ulan o/c & u/g active; stress period 9)										
Into model	98,960	263,140	42,510	-	-	-	-	-	6,150	410,760
Out of model	-	280,000	62,090	5,930	48,540	-	9,410	6,080	-	412,050
2022 (End Moolarben mining; stress period 25)										
Into model	98,960	263,750	42,540	-	-	-	-	-	13,330	418,580
Out of model	-	278,380	61,920	5,740	47,580	5,860	17,380	3,630	-	420,490
2024 (End Ulan mining; stress period 27)										
Into model	98,960	263,600	42,500	-	-	-	-	-	7,200	412,260
Out of model	-	278,790	61,990	4,770	47,640	-	9,620	8,650	-	411,460
2027 (End Wilpinjong mining; stress period 30)										
Into model	98,960	263,550	42,470	-	-	-	-	-	4,410	409,390
Out of model	-	279,030	62,080	5,700	47,870	-	720	13,330	-	408,730
2067 (End Recovery Run; stress period 31)										
Into model	98,960	267,080	42,290	-	-	-	-	-	1,675	410,005
Out of model	-	281,700	62,420	6,140	51,740	-	-	8,040	-	410,040

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- the MC1.3 model indicates that the baseflow contribution to the minor creeks is about 10% of the volume reporting to the Goulburn River, even though these model features are setup similarly;

- the Goulburn River flow components are affected in a very minor way by the cumulative impacts of mining (Ulan, Wilpinjong and Moolarben), with a much less than 1% reduction in baseflow contributions and a insignificant percentage change in modelled leakage to the aquifer, (amounting to about 0.2 ML/d);

- the minor creeks (represented by drains in the MC1.3 model, to allow for baseflow processes) are affected by decreases of up to 20% in baseflow contributions during the mining period (due to the cumulative effects of all mines) from 2007 to 2024 (end of Ulan mining); this amounts to a volume of up to 1.2 ML/d, which is expected to result in minor extensions to the cease-to-flow periods of these ephemeral creeks; minor drawdown impacts to the water table in the alluvium are predicted to occur, but the model does not show any dewatering of the alluvium (contour plans are presented later, along with further discussion);

- evaporation discharge reduces by about 15% (about 1 ML/d) due to the cumulative effects of mining since 2006, indicating potentially reduced water availability to groundwater dependent ecosystems (GDEs); evaporation increases throughout the recovery period, due to the cessation of all mining activities, until it is about 0.2 ML/day larger than the 2006 volume (ie. this suggests that Ulan alone has a current effect of about 0.2 ML/day on GDEs);

- the head-dependent flow boundary terms are almost unchanged for all runs (maximum changes of around 1 ML/day), which indicates that the impacts are restricted to local areas around the mines, and do not extend to the regional boundaries; boundary outflows increase throughout the recovery period, due to the cessation of all mining activities, until they are about 6 ML/day (or 1%) larger than the 2006 volume (ie. this suggests that Ulan alone has a current effect of about 6 ML/day on boundary flows);

- the sum total of the predicted impacts on the water balance at 2022 (end of Moolarben mining) is about 3 ML/d (in terms of reductions in baseflows, evaporation and boundary outflows) due to the cumulative effects of all mining, which is very small (less than 1%) of the throughput in the system (about 400 ML/d);
- the recovery run shows that the modelled water balance components of minor creek baseflow and evaporation (Table 4.4) are around 5% higher than for 2006 values (while Goulburn River flows are little changed); this is not surprising, as hydrological system is recovering from the effects of all mine dewatering operations (Moolarben, Wilpinjong and Ulan); note that the steady state run that was used to derive the initial conditions for the history match run (1987-2006) assumed that dewatering operations applied to the Ulan open pit, whereas the recovery run involves decommissioning of all mine dewatering; hence there should be ongoing recovery of the hydrological system.

4.4 SENSITIVITY SCENARIO MODELLING

4.4.1 Results Summary

Table 4.5 sets out the range of prediction scenarios undertaken, and the results in terms of changes to the scaled RMS error at 2006 (an indicator of the goodness of fit to measured data), and in terms of the predicted dewatering rates for the various mine dewatering operations. The results of the sensitivity runs are also presented in Figures 4.5 to 4.8, with discussion below.

As outlined in Section 4.2, it is very difficult to achieve the desired combination of a good match to the reported Ulan dewatering rates, and a good match to water levels (as indicated by a low RMS). Table 4.5 shows that the combination of one of the lowest RMS values with the best match to the Ulan dewatering information is the adopted base case, closely followed by the goaf run, the lower Kv case and the high drain conductance case (a higher drain conductance value indicates lower impedance to underground inflows). This suggests that the model results are not sensitive to invoking goaf parameters on the underground footprint (goaf parameters involved a higher Kh and Kv by two orders of magnitude, and a confined aquifer storage of 1e-1 for layers 3 and 4). While the run with a lower seam permeability (Kh) gives lower Ulan dewatering rates over the last 5-10 years (ie. 3.9 ML/d at 2004), the RMS error is about 10.5%, indicating that the head matches are poor.

The high Kv and the high Kh cases have high predicted inflows to Ulan at 2004, and probably represent an upper limit of predicted impacts. Note that the high Kh and Kv runs involve parameter changes to zones with a much greater regional spread than just the underground footprint used for the goaf parameter changes; hence the much smaller effect on results for the goaf run. More effort on parameter adjustment is be required to achieve an acceptable head calibration with lower Ulan inflow rates.

The sensitivity analysis shows that the adopted MC1.3 model calibration is affected by “low value parameter saturation” in relation to one of the main parameters, the vertical hydraulic conductivity (Kv). For example, increases or decreases in the adopted Kv values by factors of 3-4 result in changes of up to 30% in the predicted mine inflow rates. In other words, there is low risk of substantial under-estimation of mine inflow rates. However, an increase in the Kv value by a factor of 10 or more (which is plausible) is predicted to result in much greater increases in predicted mine inflows.

Table 4.5 - MC1.3 model range of sensitivity predictions in terms of scaled RMS and predicted inflow

SENSITIVITY ANALYSIS: Horizontal Hydraulic Conductivity of the Ulan Seam (layer 4)								
Layer @ Location	Basecase Kh (m/d)		High Kh (m/d)			Low Kh (m/d)		
L4 @ Ulan	3		10			1		
L4 @ Moolarben	1.7		5.5			0.5		
SRMS% at 2006	8.9		9.4			10.5		
Mine Inflow Rates (ML/d) for Basecase Kh			Mine Inflow Rates (ML/d) for High Kh			Mine Inflow Rates (ML/d) for Low Kh		
Ulan Mine at 2004	Moolarben UG at 2009	Moolarben UG at 2022	Ulan Mine at 2004	Moolarben UG at 2009	Moolarben UG at 2022	Ulan Mine at 2004	Moolarben UG at 2009	Moolarben UG at 2022
8.5	4.0	6.6	18.9	6.9	14.6	3.9	2.7	4.9

SENSITIVITY ANALYSIS: Vertical Hydraulic Conductivity of Goaf layer, Ulan Seam and Marrangaroo Cong. (layers 3, 4 & 5)								
Layer @ Location	Basecase Kv (m/d)	High Kv (m/d)	Medium Kv (m/d)			Low Kv (m/d)		
L3 @ Ulan	2.5e-6	1e-3	1e-5			1e-6		
L3 @ Moolarben	2.5e-5 & 1e-4	1e-2 & 4e-2	1e-4 & 4e-4			1e-5 & 4e-5		
L4 @ Ulan	1.5e-4	6e-2	6e-4			6e-5		
L4 @ Moolarben	2.5e-2 & 2e-4	1e0 & 8e-2	1e-1 & 8e-4			1e-2 & 8e-5		
L5 @ Ulan	2.5e-6	1e-3	1e-5			1e-6		
L5 @ Moolarben	2.5e-6	1e-3	1e-5			1e-6		
SRMS% at 2006	8.9	8.5	9.3			9.3		
Mine Inflow Rates (ML/d) for High Kv			Mine Inflow Rates (ML/d) for Medium Kv			Mine Inflow Rates (ML/d) for Low Kv		
Ulan Mine at 2004	Moolarben UG at 2009	Moolarben UG at 2022	Ulan Mine at 2004	Moolarben UG at 2009	Moolarben UG at 2022	Ulan Mine at 2004	Moolarben UG at 2009	Moolarben UG at 2022
31.1	12.1	27.2	13.3	7.1	16.4	6.9	2.7	5.9

SENSITIVITY ANALYSIS: Drain Conductance (m^2/d) for the Ulan and Moolarben Mines								
Location	Basecase Conductance (m^2/day)		High Conductance (m^2/day)			Low Conductance (m^2/day)		
Underground	4		10			1		
Opencut	1000		10000			100		
SRMS% at 2006	8.9		9.3			9.8		
			Mine Inflow rates (ML/d) for High Drain Conductance			Mine Inflow rates (ML/d) for Low Drain Conductance		
			Ulan Mine at 2004	Moolarben UG at 2009	Moolarben UG at 2022	Ulan Mine at 2004	Moolarben UG at 2009	Moolarben UG at 2022
			9.9	5.8	9.7	7.3	2.9	6.3

SENSITIVITY ANALYSIS: Drain Setup for the Ulan and Moolarben UG Mine					
Basecase SRMS% at 2006	Goaf run SRMS% at 2006	Basecase: Drains active only for main drive and current panel			
8.9	9.3	Goaf Run: Drains remain active after panel is mined.			
Mine Inflow rates (ML/d) for Basecase			Mine Inflow rates (ML/d) for Goaf Run		
Ulan Mine at 2004	Moolarben UG at 2009	Moolarben UG at 2022	Ulan Mine at 2004	Moolarben UG at 2009	Moolarben UG at 2022
8.5	4.0	6.6	11.2	4.5	9.6

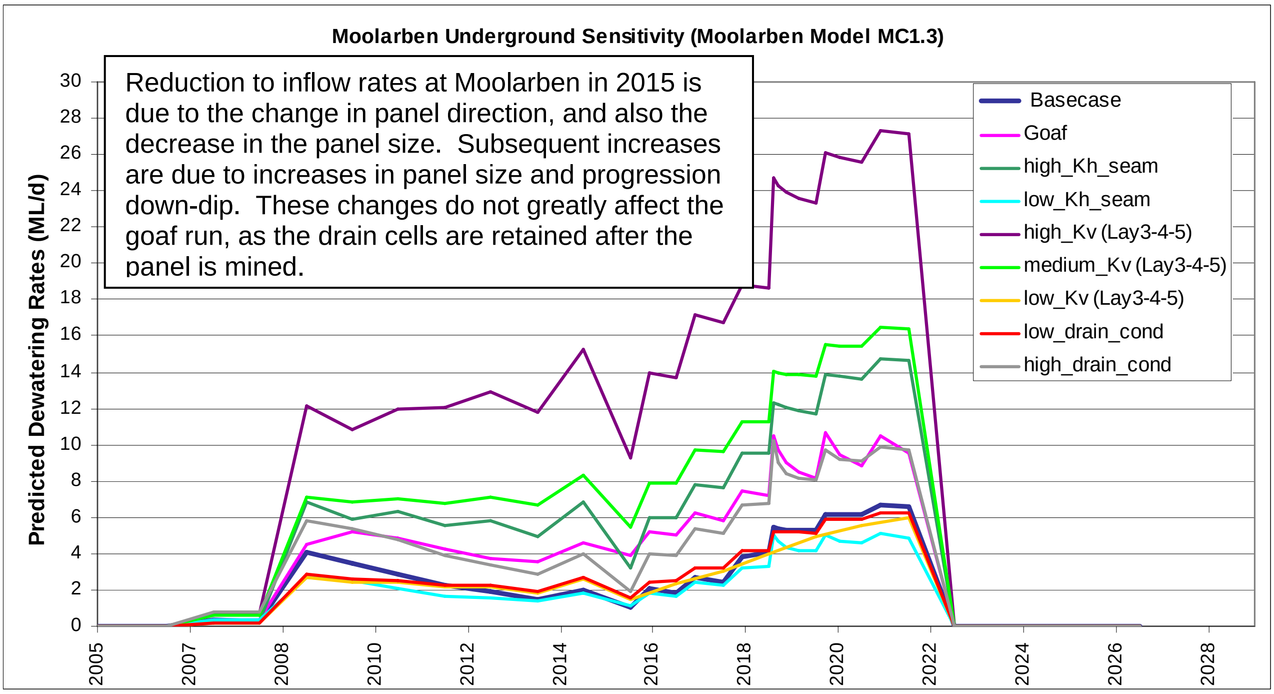
F:\adelaide\jobs\A37_Moolarben\B1\370_Pred\MC1.3\[MC1.3_Mool Pred_dewatering.xls]Sensitivity (Table 4.5)

It cannot be determined at this time whether there is a low or high **risk** of much higher Kv values being encountered, but there are significant potential **consequences** in terms of the predicted greater mine inflows, and appropriate planning is warranted.

Given the uncertainties, it is recommended that appropriate contingencies be incorporated into mine water management plans, to cater for potentially higher mine inflow rates than the MC1.3 base case.

Figure 4.5

MC1.3 model sensitivity: predicted Moolarben dewatering rates – underground



Reduction to inflow rates at Moolarben in 2015 is due to the change in panel direction, and also the decrease in the panel size. Subsequent increases are due to increases in panel size and progression down-dip. These changes do not greatly affect the goaf run, as the drain cells are retained after the panel is mined.

Figure 4.6

MC1.3 model sensitivity: predicted Moolarben dewatering rates – open cut 1

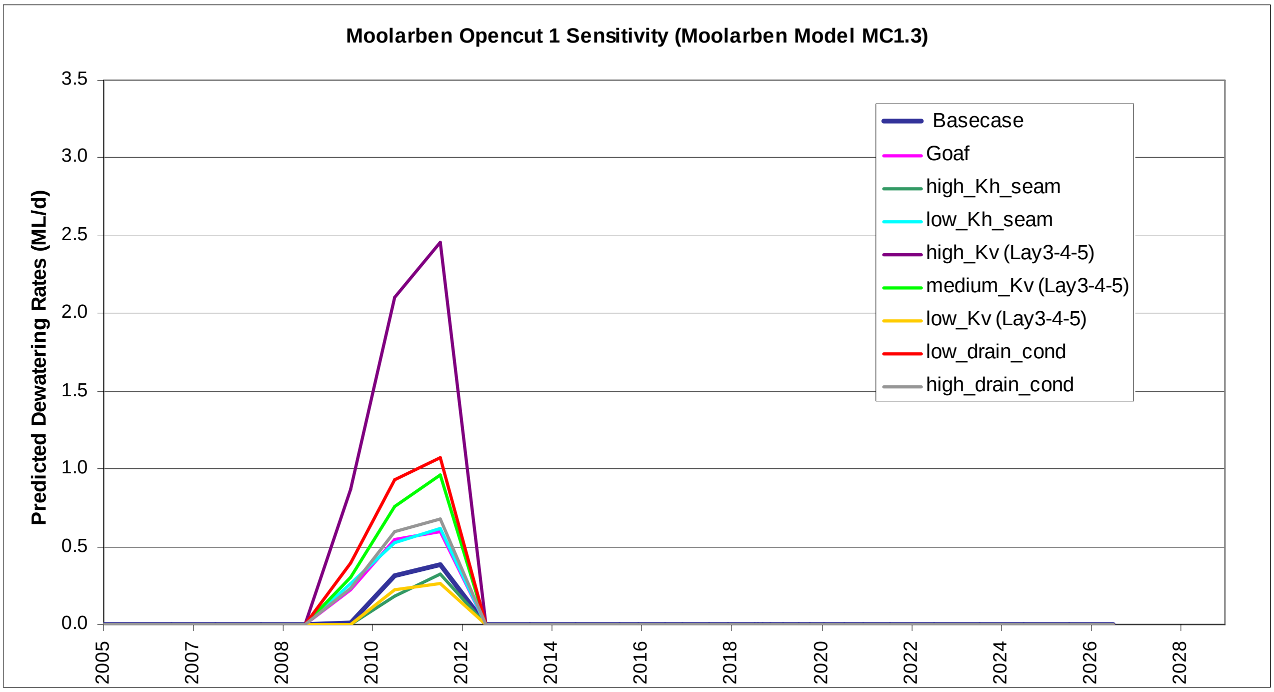


Figure 4.7

MC1.3 model sensitivity: predicted Moolarben dewatering rates – open cut 3

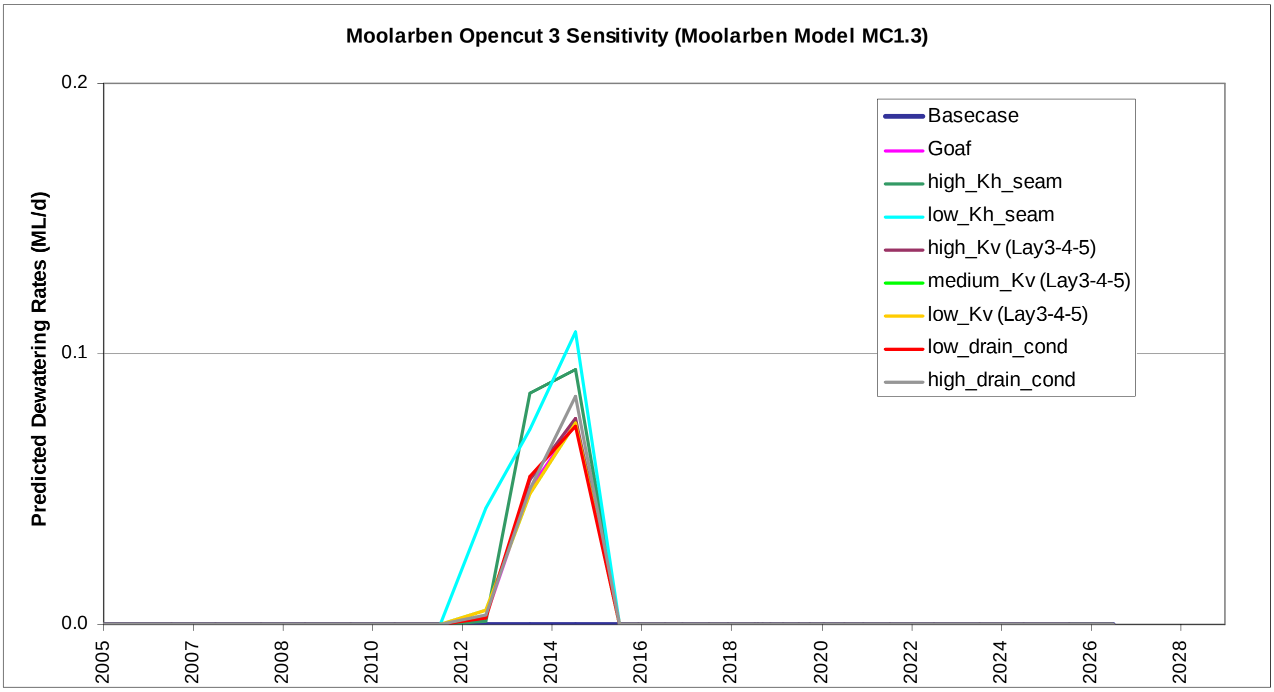
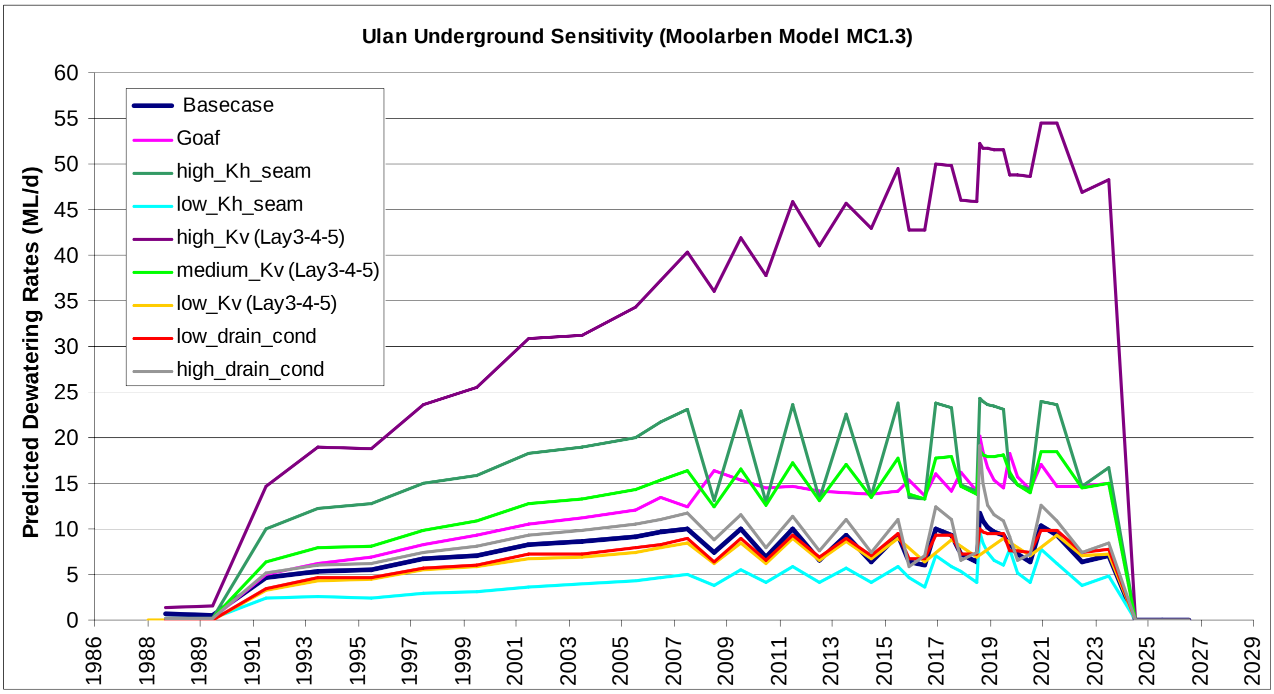


Figure 4.8

MC12. model sensitivity: predicted Ulan dewatering rates



4.3.2 Goaf Run

Considering that the MC1.3 model was calibrated without applying goaf parameters to the Ulan area, and also by assuming that the drain cells for underground workings should be de-activated after the panel is mined, it would not be appropriate to run base case simulations with goaf parameters (as outlined in Section 3.3), although a sensitivity assessment is warranted of the effect of invoking goaf parameters. The “goaf run” involved increased Kh and Kv by two orders of magnitude and increased storage parameters for the Ulan seam and overlying layer to a value of 1e-1. The goaf run is predicted to result in increased peak underground inflows at Moolarben by about 2 to 4 ML/day over the base case (Figure 4.5), and by about 5 to 7 ML/day at Ulan over the base case (Figure 4.8). This is a smaller increase than that due to increasing the horizontal hydraulic conductivity (Kh) of the Ulan Coal Seam, but gives a similar result to increasing the drain conductance value (a higher drain conductance value indicates lower impedance to underground inflows). In summary, the model results are not sensitive to goaf parameter changes.

4.3.3 Summary of Sensitivity to Kh, Kv and Drain Conductance

Separate to the goaf run, sensitivity was also tested to variations in the vertical hydraulic conductivity (Kv) of the Ulan Coal seam (Layer 4), and also the overburden (Layer 3) and underburden (Layer 5). As expected, the predicted mine inflow rates at Moolarben and Ulan are reduced, but only slightly (compared to the base case) due to lower values for the Kv of the Ulan Coal Seam (due to the parameter saturation effect discussed above), and also for a lower drain conductance (a lower drain conductance value indicates higher impedance to underground inflows). Increasing the value of Kv by a factor of 3 to 4 (the “medium Kv” case) can increase the predicted base case inflow rates by around double (depending on the time and the site considered), with a further increase in Kv by two orders of magnitude predicted to result in inflows of up to five times higher than the base case. This “high Kv” case is considered unlikely, but not impossible, given the current hydrogeological understanding.

4.3.4 Sensitivity in Wilpinjong Area

The MC1.3 model predicted **Wilpinjong** dewatering rates to be around 1 to 2 ML/d (with one peak of up to about 5 ML/d; refer to Figure 4.2 and Table 4.3), which is consistent with the predicted rates reported in the EIS (WCPL, 2005) of around 2 to 4 ML./d.

Sensitivity testing showed that these rates are not sensitive to changing the Wilpinjong mine dewatering drain conductance parameter between values of 1000 and 50 m^2/d. This probably indicates that the combination of Kh and Kv values of the overburden layer is the constraining factor on predicted inflows (i.e. the selected drain conductances generally equate to higher permeability of the drain compared to the overlying material through which the inflow leakage needs to occur; in other words, sensitivity analysis shows that mine influx is not sensitive to the range of drain conductance values tested, but could reduce if lower drain conductances were applied).

The testing undertaken during model calibration did show, however, that the Wilpinjong inflow rates increased by a factor of about 3 when the vertical permeability (Kv) of the underlying Marrangaroo Sandstone was increased from 1e-5 m/d (the calibrated or base case value) to 1e-1 m/d (ie. higher Kv results in much greater mine inflows from formations underlying the Ulan seam). The MC1.3 model also does not incorporate the variation of Kv with depth, as was invoked for the Wilpinjong model (WCPL, 2005), and this may also affect the differences between the two predictions. For the purpose of adequately representing the cumulative impacts of mining, the MC1.3 simulation of the effect of Wilpinjong is considered to be adequate.

4.5 RECOVERY SIMULATION

Using the results at the end of the Moolarben mine dewatering prediction base case as an initial condition (ie. 2022, or stress period 25), a set of post-mining recovery runs were undertaken over a 45-year period, with aquifer parameters in the Moolarben and Ulan underground goaf units increased from the base case values (refer to Section 3.3). Parameters were also changed to represent residual pit voids at Ulan and Wilpinjong, and it was assumed that there would be no residual pit voids at Moolarben (late changes to the mine plan do now involve small residual pit voids). Recovery of water levels does occur due to cessation of mine dewatering stresses on the system, but the recovery is affected by the goaf parameters (higher permeability by two orders of magnitude, and higher aquifer storage), and also by the residual pit void lakes at Wilpinjong and Ulan. The Moolarben open pits are mostly backfilled above the water table, such that there are no residual pit voids, except for small areas at the northern end of OC1 and the southern end of OC3 (see Figure 1); which would minimise long term post-mining hydrological impacts at Moolarben.

For the recovery run, some simplifying assumptions were invoked:

- small residual pit void lakes were invoked at the northern end of Moolarben Open Cut 1;
- residual pit void lakes were invoked at Wilpinjong at 2022 (Pit 3) and 2028 (Pit 6), as outlined in the Wilpinjong mine plan (WCPL, 2005);
- pit void parameters were also applied to a small area at the Ulan open cut at 2022 (even though Ulan mining is expected to continue to 2024), with the de-activation of Ulan mining at this time for the duration of the recovery run.

The residual open pit voids are represented with high permeability (Kh=Kv=1e3 m/d) and high aquifer storage (confined=unconfined=0.99), plus the activation of pit lake evaporation at rates equivalent to 50% of the net pan rate (Table 2.3 gives annual evaporation of 1728mm; at 50% pan factor gives 864mm/yr, or 0.00237m/d). Dry (or dewatered) cell re-wetting was activated for this run, to properly represent the rebound of water tables post-mining.

Figure 4.9 shows the (minor) residual drawdown in the shallow (layer 1, Triassic) aquifer at 40 years after mining. Figure 4.10 shows predicted hydrographs of recovering water levels at the Ulan and Wilpinjong residual pit voids, and also at the northern end of Moolarben Open Cut 1 (assumed to be backfilled in the model configuration), which is adjacent to the underground UG4. These plots show that water levels at Moolarben, Wilpinjong and Ulan recover to close to the pre-1987 levels within about 10 to 20 years after mining ceases. While the recovery at Wilpinjong does not quite achieve the pre-mining levels, it should be remembered that there are residual pit lakes at Wilpinjong, which result in a slight drawdown effect due to evaporation, and the same minor effects would be expected near Moolarben OC1 and OC2.

Figure 4.9

MC1.3 cumulative impacts residual drawdown contour plan for Triassic aquifers (Layer 1) at 2067

Drawdown due to cumulative impacts of mining (Ulan + Wilpinjong + Moolarben)

(drawdown contours in metres)

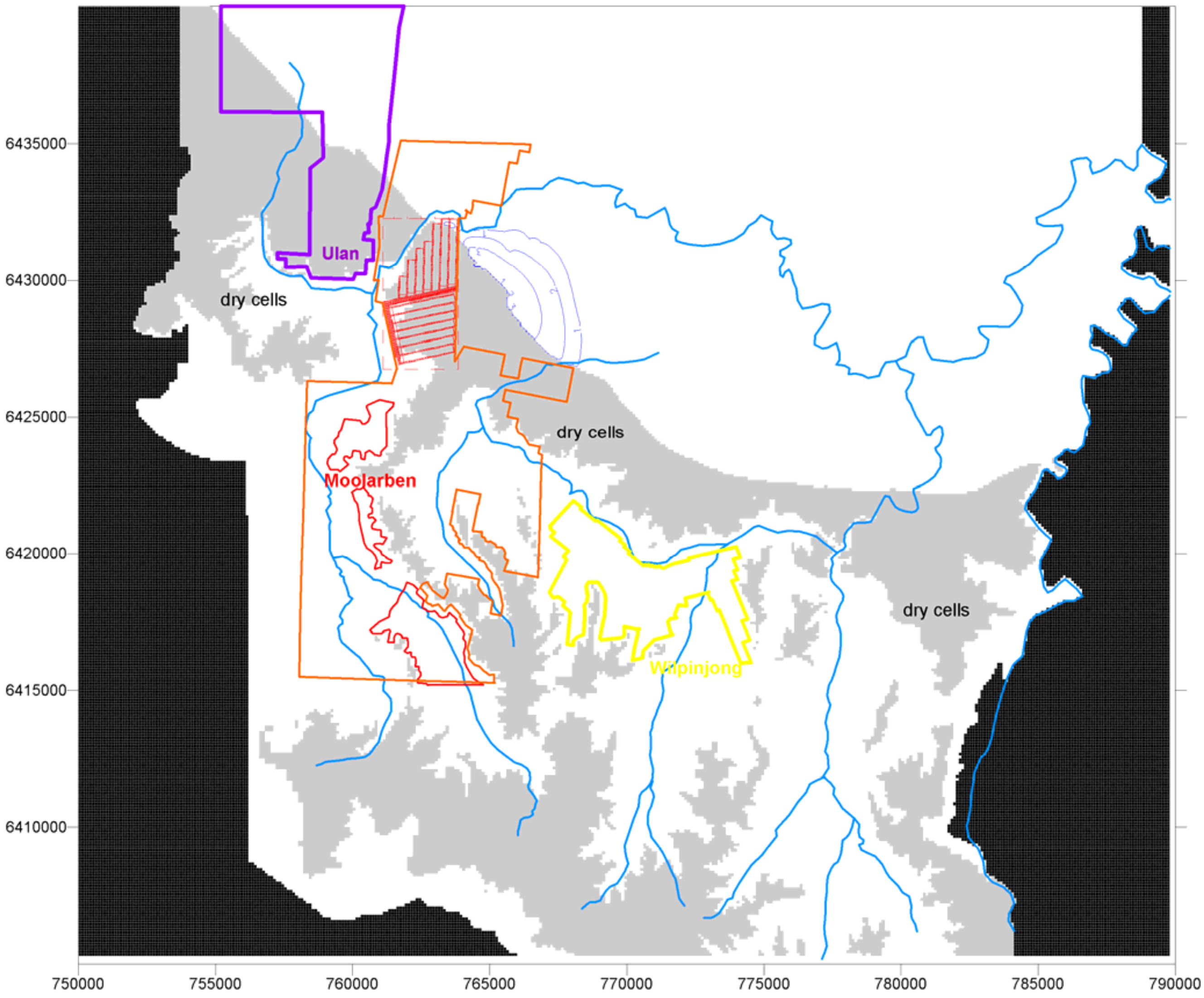
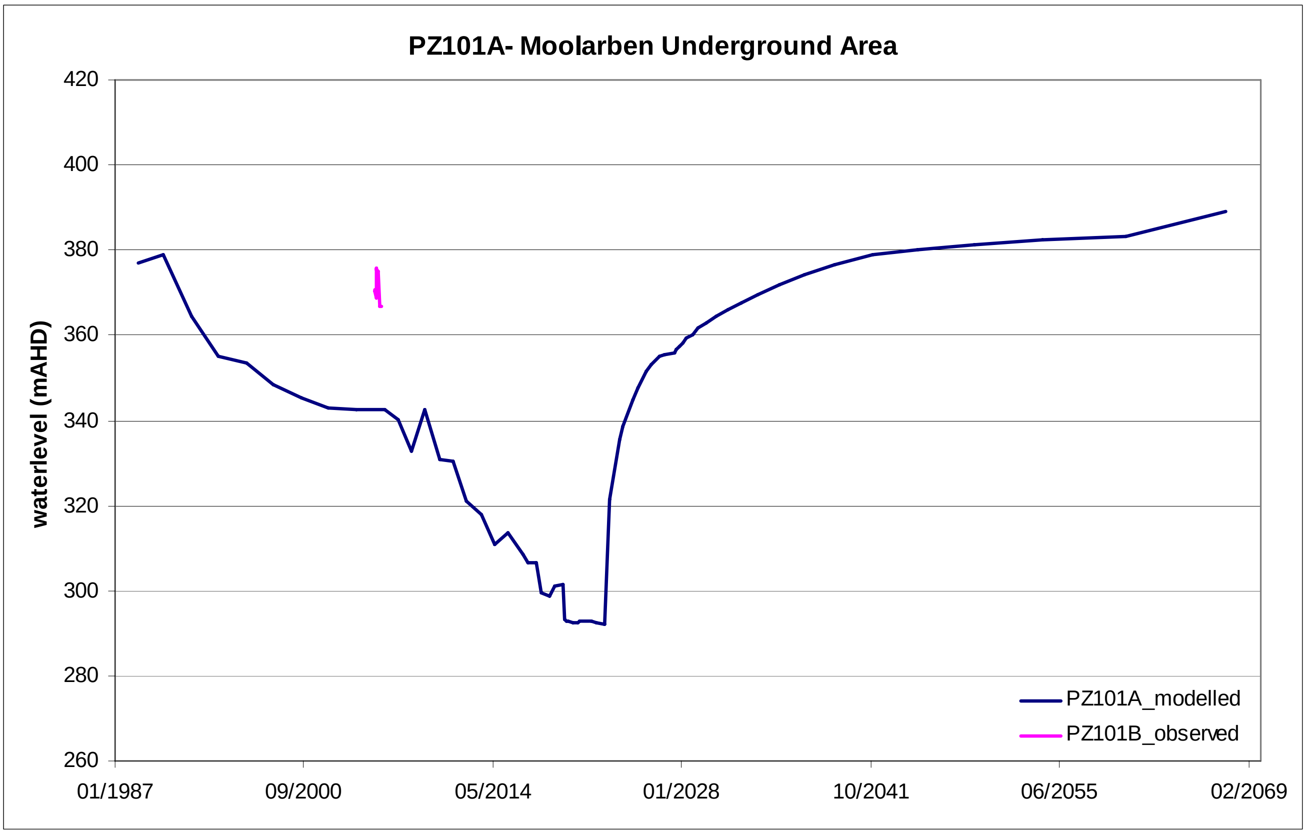


Figure 4.10.1

MC1.3 model: predicted hydrographs of water level recovery post-mining (Moolarben and Ulan areas)



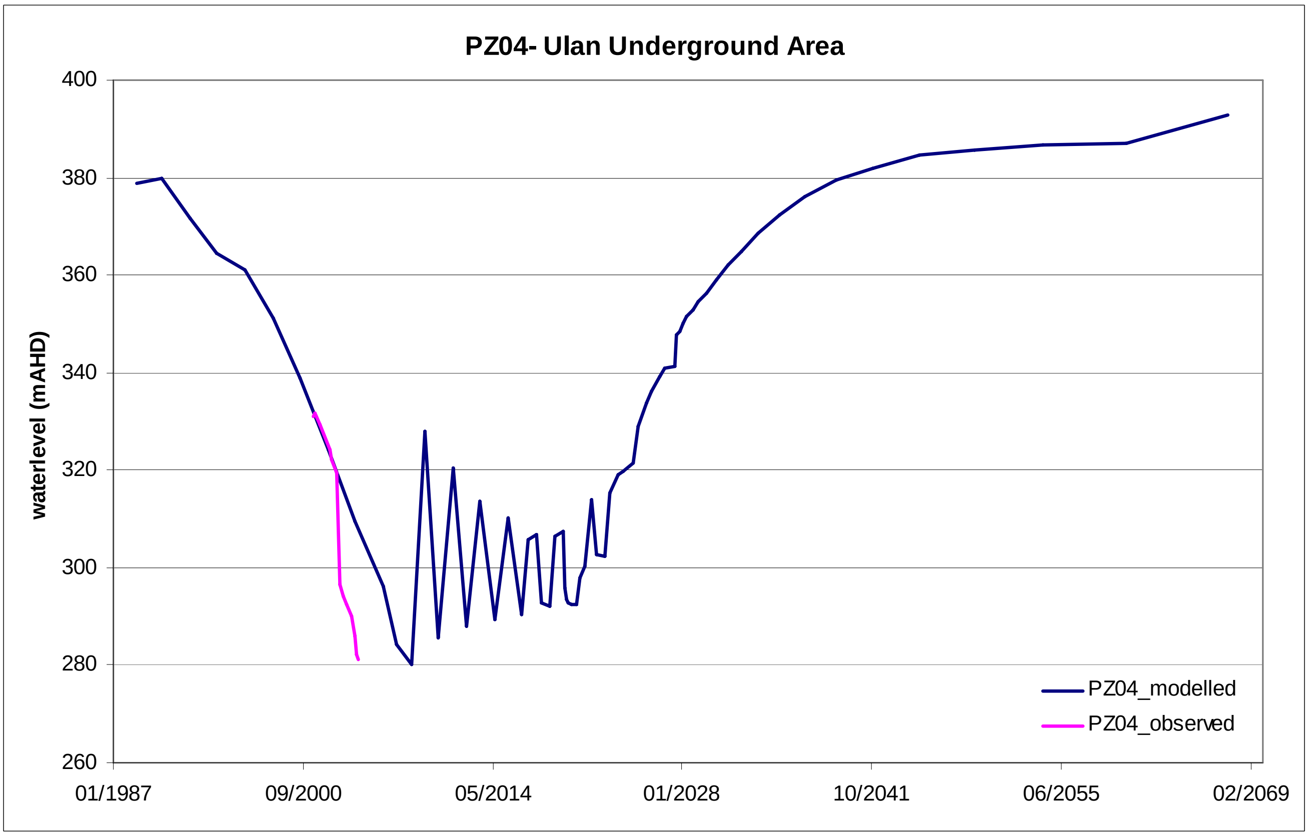
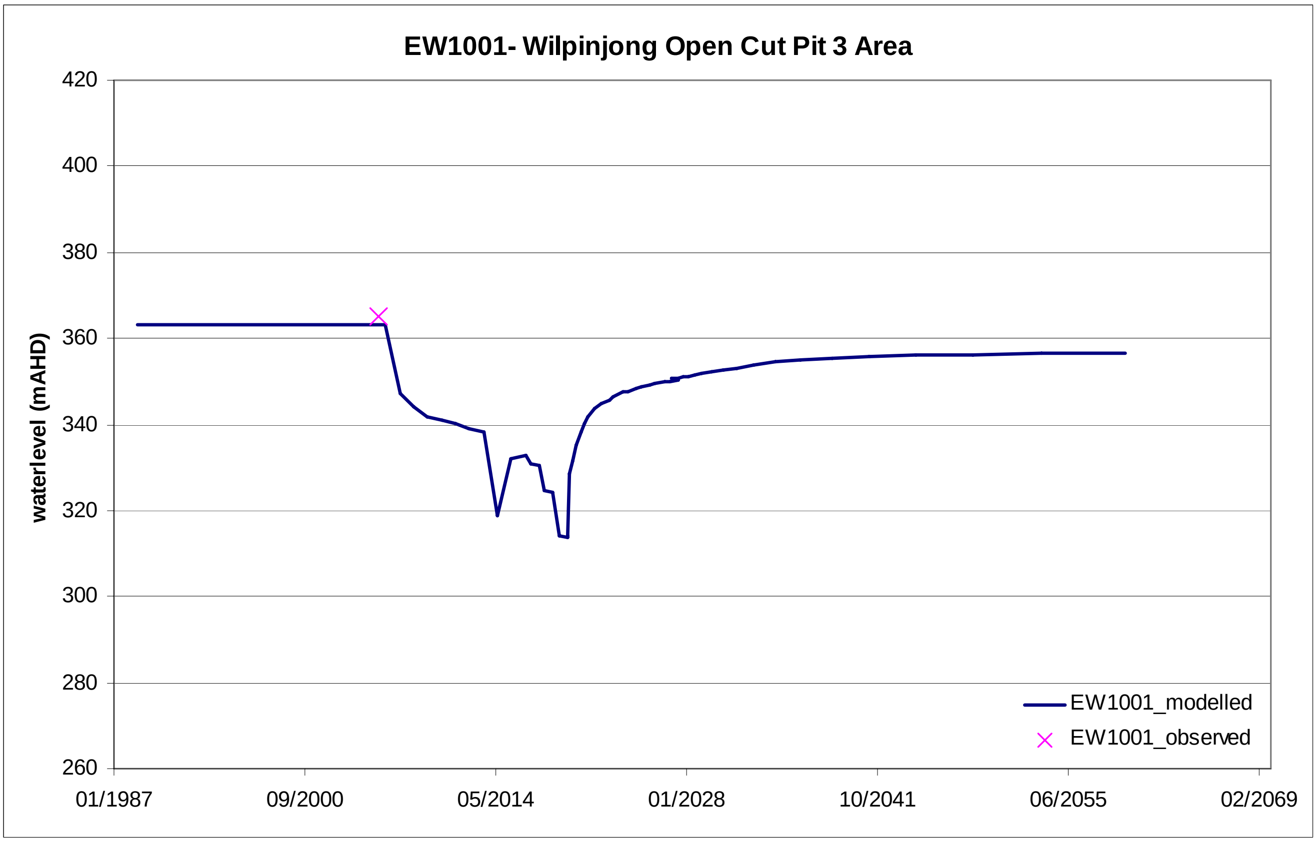


Figure 4.10.2

MC1.3 model: predicted hydrographs of water level recovery post-mining (Wilpinjong area)



SECTION 5 - MC1 MODEL LIMITATIONS

It should be noted that this is a predictive modelling exercise. Due to lack of long term observation data in the Moolarben area (many bores were drilled during the recent investigation phase), there is considerable uncertainty about the behaviour of the aquifer under stress induced through mining. Results are based on the best available data at present, however, they cannot be robustly verified at this stage (other than by reference to poorly documented information from Ulan), and hence predicted seepage rates and drawdowns should be used with caution at this time. When observation data becomes available (e.g. on the decline of water levels at the start of the underground mining), model results should be compared to observed data and, if necessary, adjusted accordingly.

As indicated in Section 4, given the sensitivities/uncertainties in relation to the vertical hydraulic conductivity parameter, it is recommended that appropriate contingencies be incorporated into mine water management plans, to cater for potentially higher mine inflow rates than the MC1.3 base case.

Due to uncertainties in model input parameters, certain limitations of the MC1.3 numerical model apply, which need to be taken into consideration. These are summarised below:

- Recharge and evapotranspiration are included in the model, at constant mean yearly rates, and climatic variability is not included in the model. If required, this feature could be added to the model in future. There is uncertainty about actual recharge rates to the interburden material and coal, where at outcrop and to the alluvial deposits in the study area. Recharge values have been changed within a plausible range to obtain a calibrated model, but values cannot be verified. The maximum possible rate of evaporation in the MC1.3 model is 250mm/yr, acting in areas of shallow (<5m) water levels, to represent possible groundwater dependent ecosystems. This is a best estimate, but could be improved with some site-specific data on vegetation type and/or water use characteristics.
- There is a high level of uncertainty with respect to the distribution of hydraulic conductivity in the subsurface in the vertical as well as horizontal direction. If more data becomes available in future through pump test analysis and/or water level measurements, the model should be adjusted if necessary.
- Five model layers allow the simulation of vertical head gradients in the MC1.3 model area. Heads are averaged over any one model layer, and the resolution of heads with depth cannot be as detailed as observed in the field using the current MC1.3 model configuration. Further model refinement is possible in future, including layer refinement, which should be based on improvements in hydrogeological understanding and ongoing monitoring and assessment.
- There is limited detailed data on historical pumping volumes and locations at the Ulan Coal mining operation. The Ulan dewatering has been included in the MC1.3 model in a somewhat simplistic way (using drain features), and a reasonable history match (if possibly high predicted dewatering rates) was achieved for this stage of model development. The same features were applied to represent the Moolarben underground, which could result in a conservatively high estimate of dewatering volumes for Moolarben.
- Uncertainties exist on the “resistance to flow” between the interburden and the underground mining shaft, simulated in the MC1.3 model using a drain conductance. The uncertainty has been addressed

by running sensitivity model runs, varying the conductance to establish the effect on model results. It is expected that the conductance increases with mining as the rock mass gets disturbed, however the increase in permeability is a best-guess at this stage, based on experience elsewhere.

In conclusion, the MC1.3 groundwater model is based on a reasonable but relatively sparse data set which invariably results in model uncertainties. The model results can be regarded as a best estimate based on the currently available data. The base case predicted seepage rates and drawdowns should be regarded as rough estimates, possibly a conservatively low estimate (ie. there is a low risk of lower inflows than predicted being encountered), and the range of sensitivity run results may provide a realistic estimate of the potential volumes of higher inflows, on which to base appropriate contingency planning.

SECTION 6 - REFERENCES

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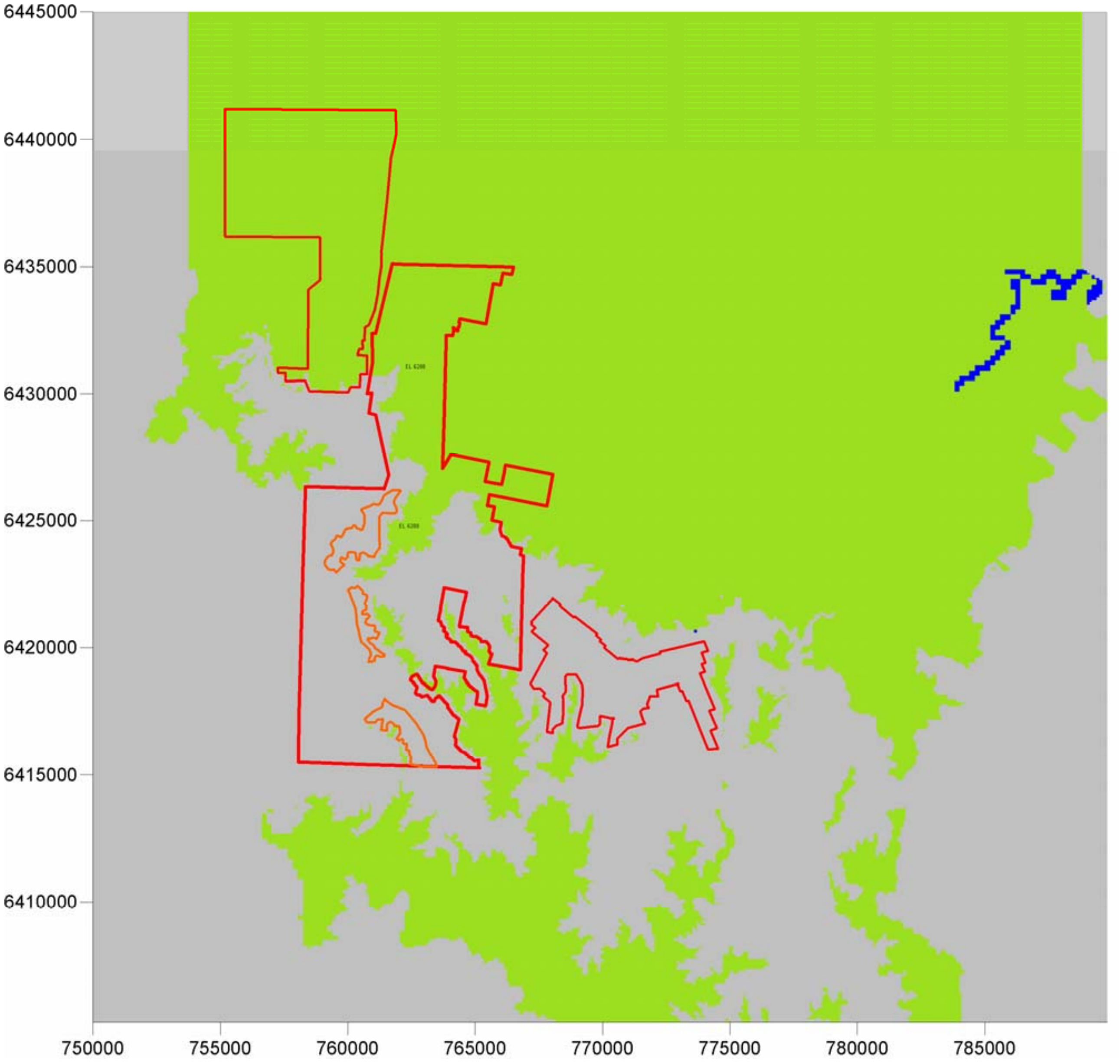
APPENDIX A

MC1 MODEL INPUT DATA

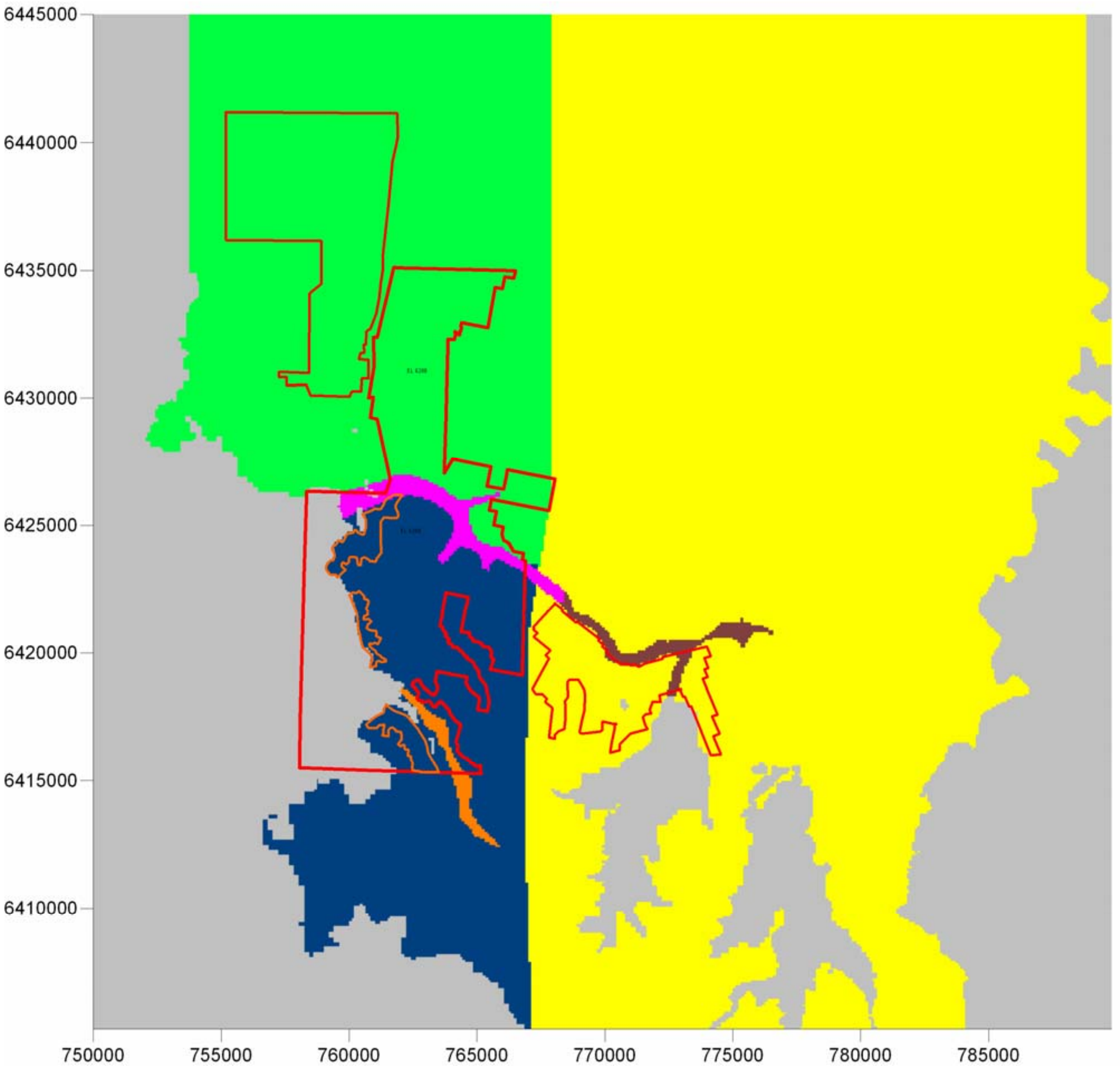
- Horizontal Hydraulic Conductivity: Layer 1 to Layer 5
- Vertical Hydraulic Conductivity: Layer 1 to Layer 5
- Recharge Rates
- Layer Elevations:
    - Topography
    - Base of Layer 1 to Layer 5 (top of underlying layer is base of overlying layer)

HORIZONTAL HYDRAULIC CONDUCTIVITY – L1



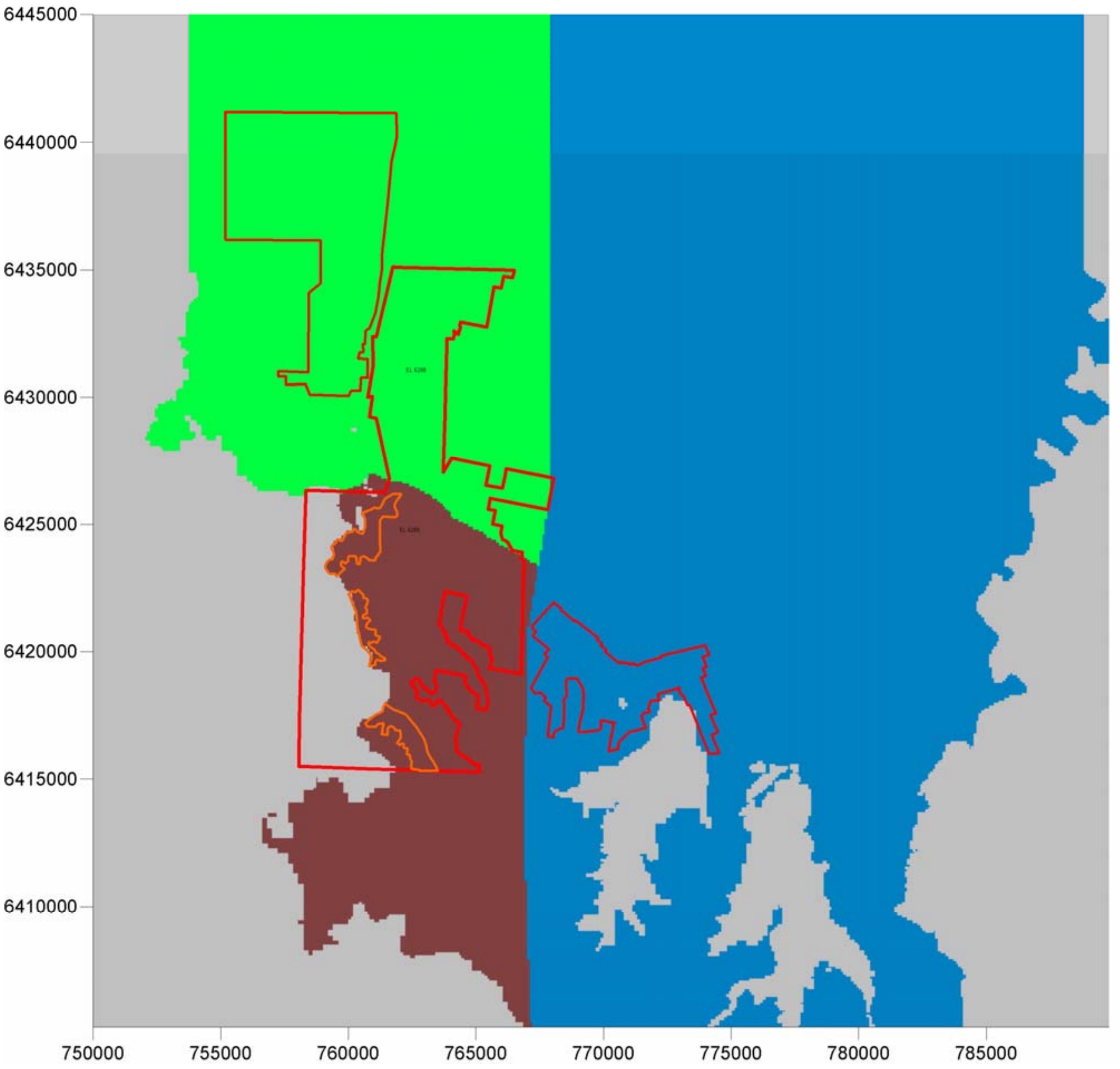
LEGEND	Kh (m/d)	PROPERTY
🟩	0.1	Narrabeen Group
🟦	1	Alluvium
▒	Inactive cells	

HORIZONTAL HYDRAULIC CONDUCTIVITY – L2



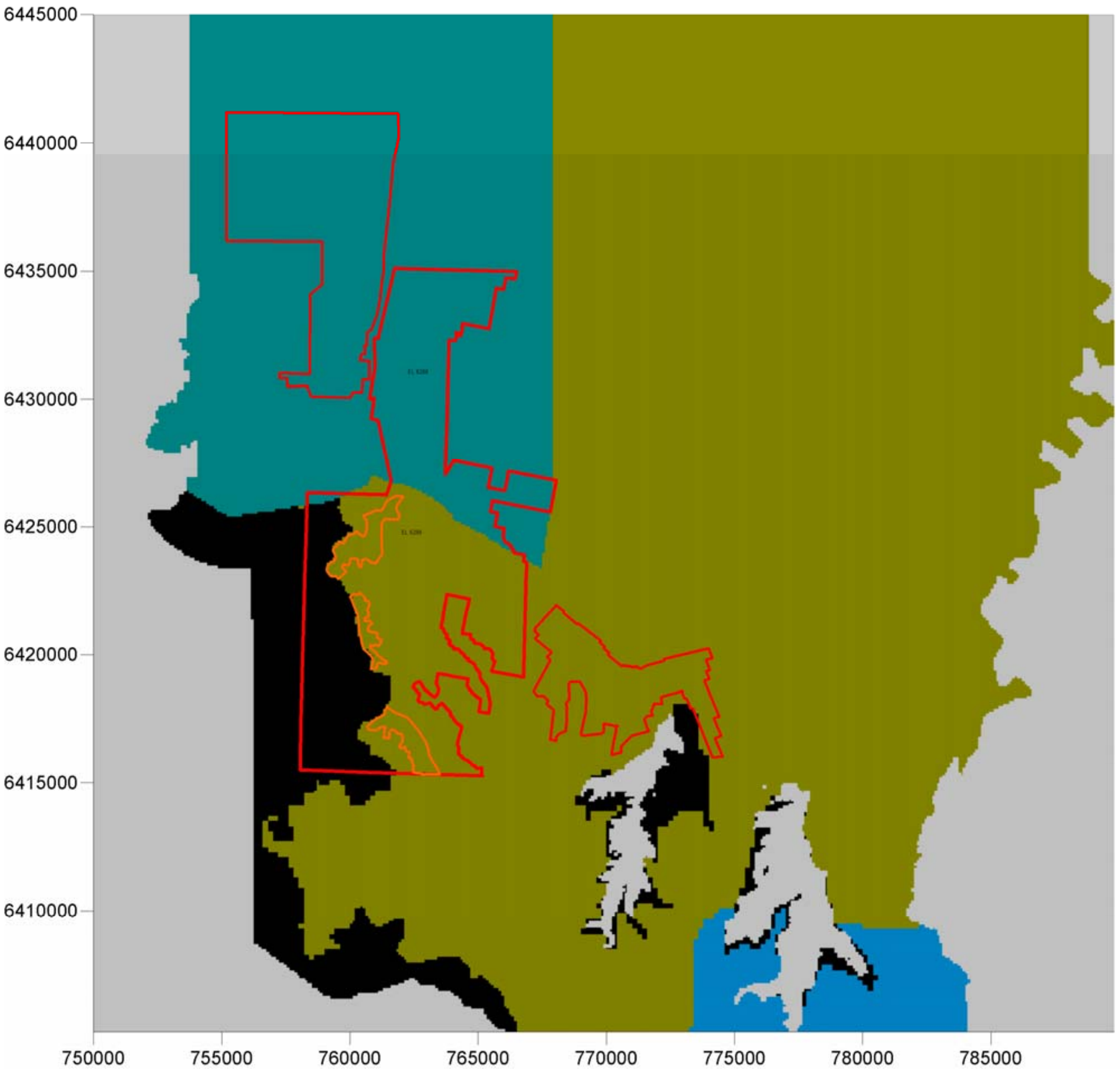
LEGEND	Kh (m/d)	PROPERTY
🟩	0.8	Overburden (inc interbedded Coal)
🟦	0.06	Overburden (inc interbedded Coal)
🟨	0.5	Overburden (inc interbedded Coal)
🟧	0.7	Alluvium
🟫	1.5	Alluvium
🟪	1	Alluvium
⬜	Inactive cells	

HYDRAULIC CONDUCTIVITY – L3



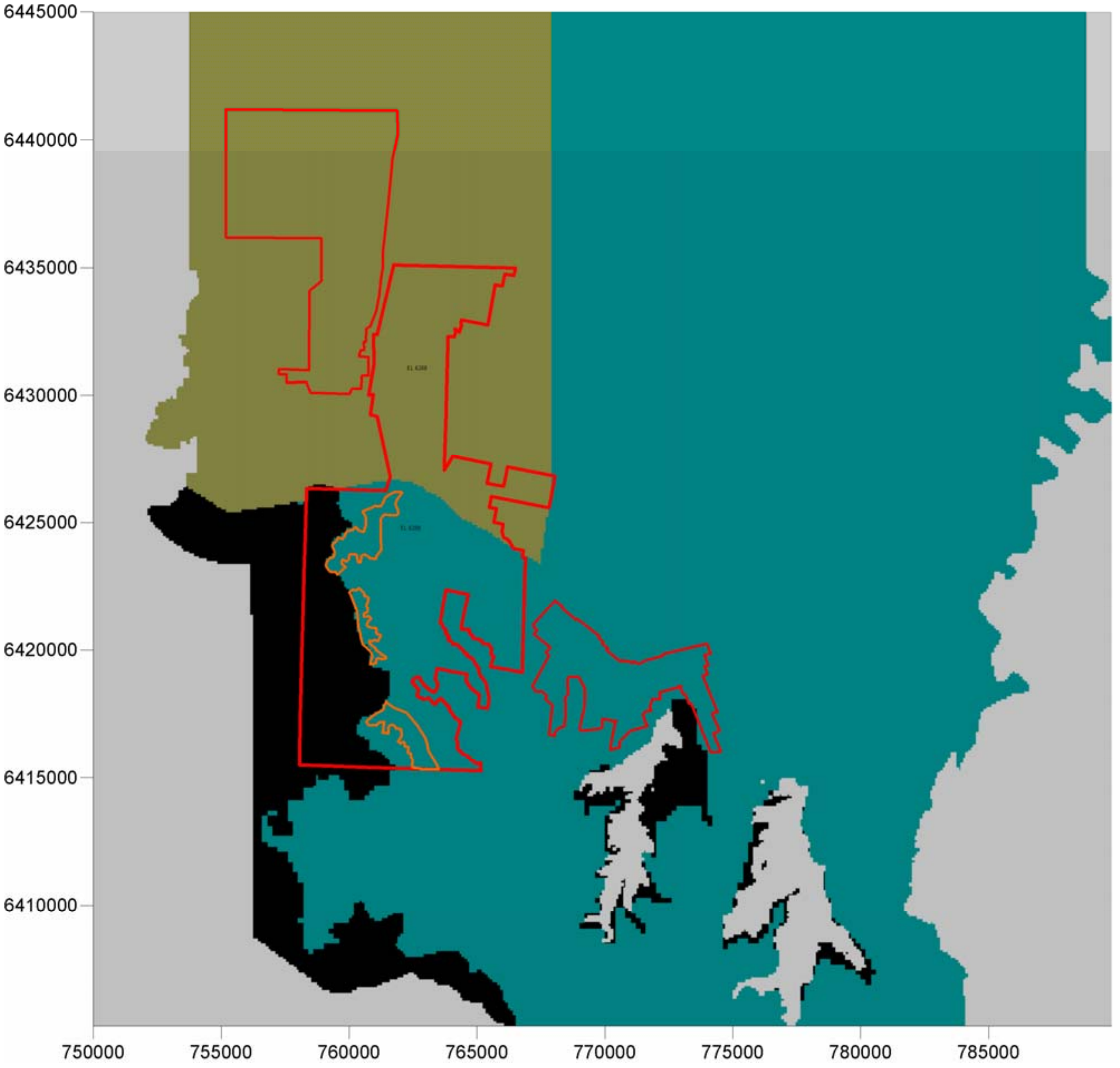
LEGEND	Kh (m/d)	PROPERTY
🟩	0.8	Overburden (no interbedded Coal)
🟫	0.01	Overburden (no interbedded Coal)
🟦	0.05	Overburden (no interbedded Coal)
⬜	Inactive cells	

HORIZONTAL HYDRAULIC CONDUCTIVITY – L4



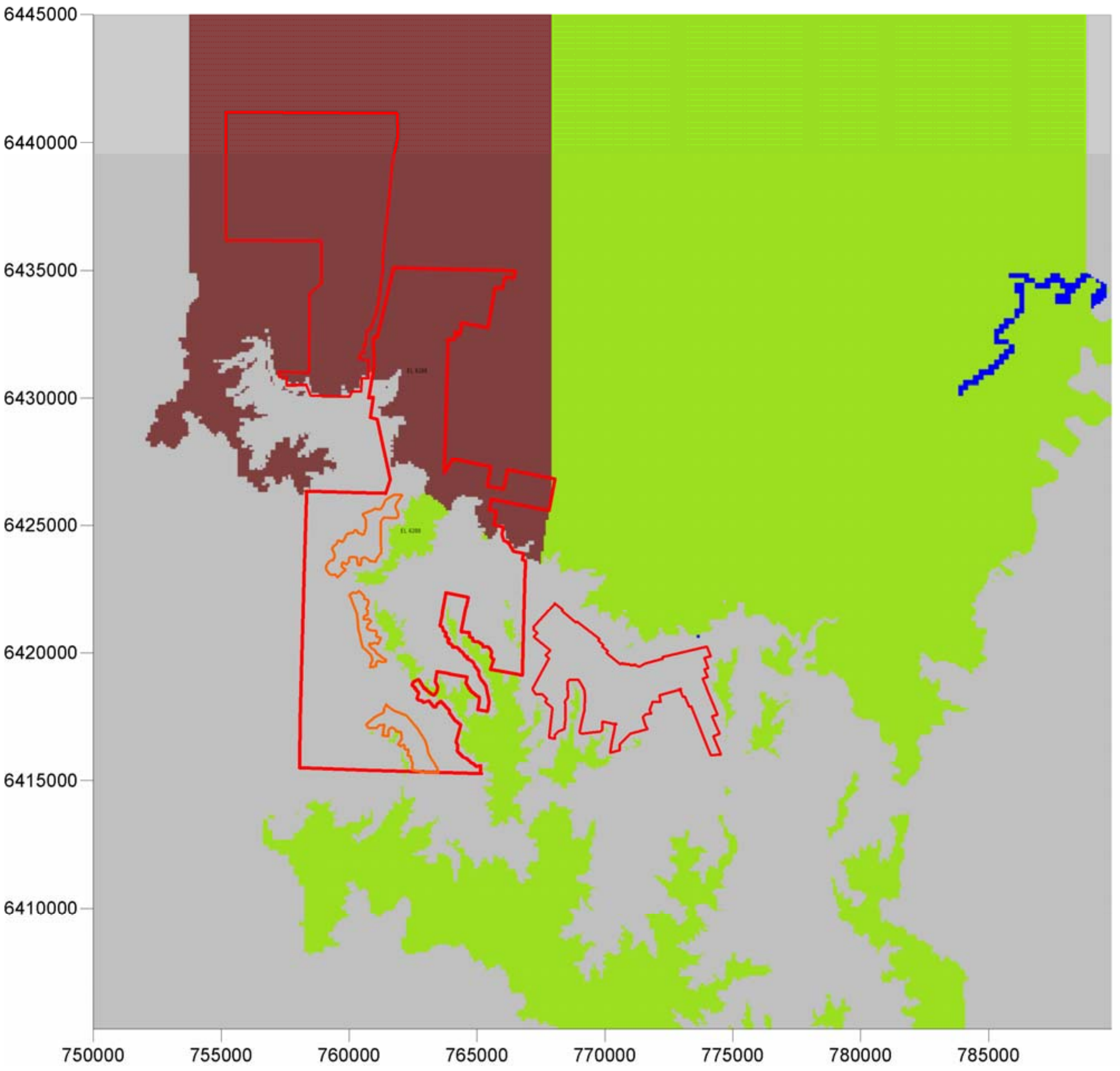
LEGEND	Kh (m/d)	PROPERTY
🟩	3	Ulan Seam
🟫	1.7	Ulan Seam
🟦	0.05	Over-burden
⬛	0.0001	Basement
⬜	Inactive cells	

TRANSMISSIVITY – L5



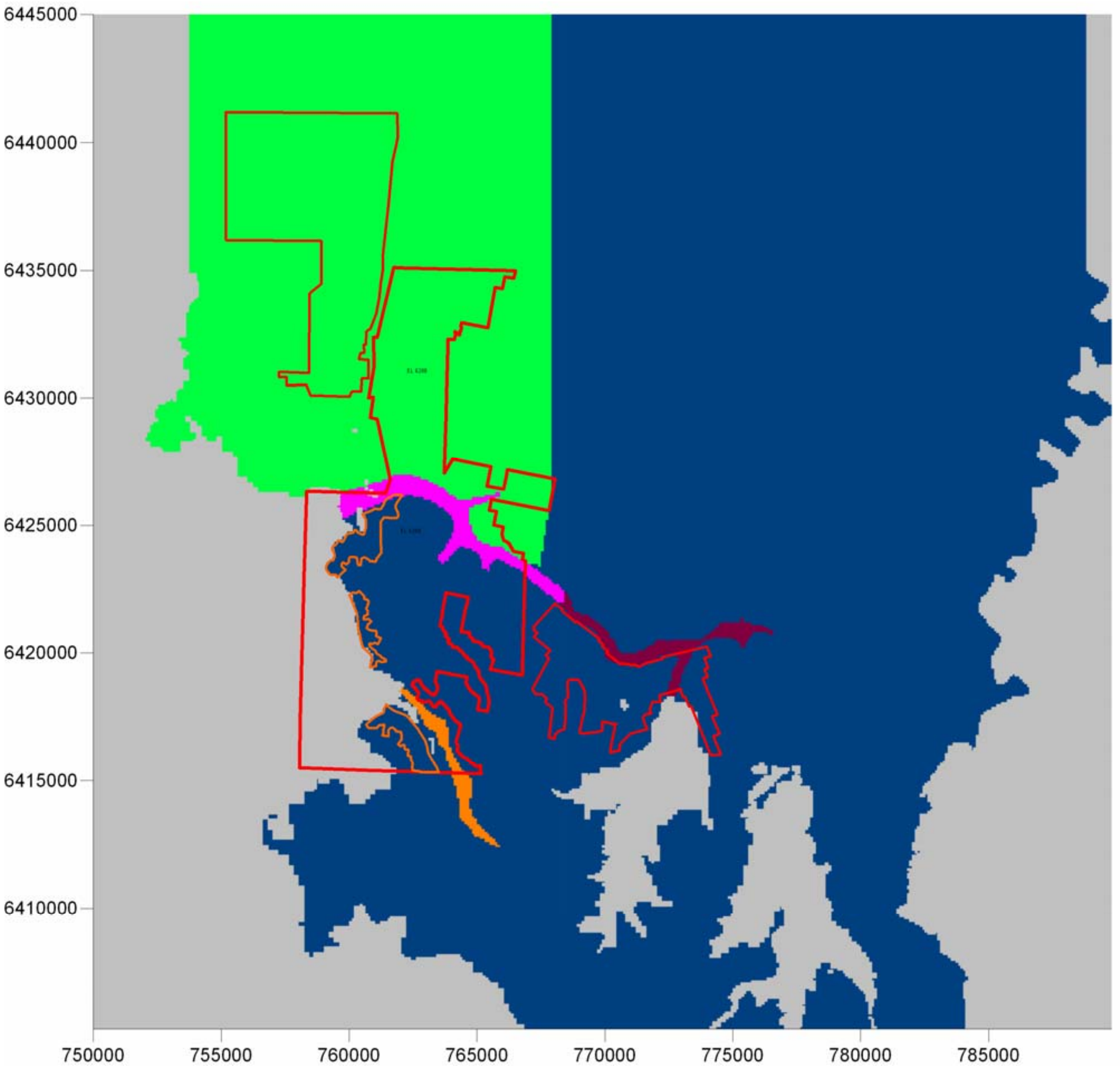
LEGEND	T (m^2/d)	PROPERTY
🟦	5	Marrangaroo Conglomerate
🟫	1	Marrangaroo Conglomerate
⬛	0.1	Basement
⬜	Inactive cells	

VERTICAL HYDRAULIC CONDUCTIVITY – L1



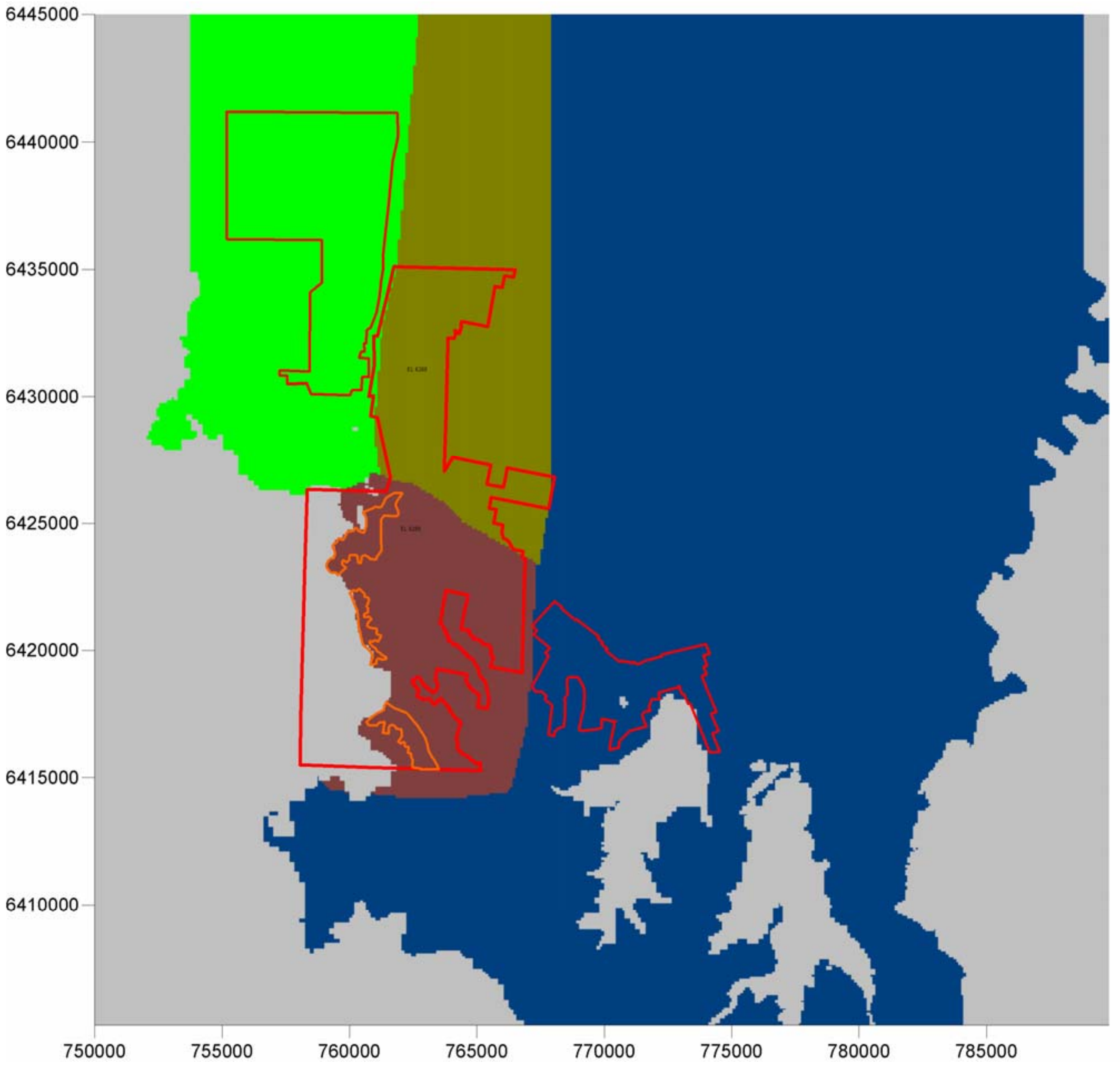
LEGEND	Kv (m/d)	PROPERTY
🟩	0.001	Narrabeen Group
🟫	0.001	Narrabeen Group
🟦	0.1	Alluvium
⬜	Inactive cells	

VERTICAL HYDRAULIC CONDUCTIVITY – L2



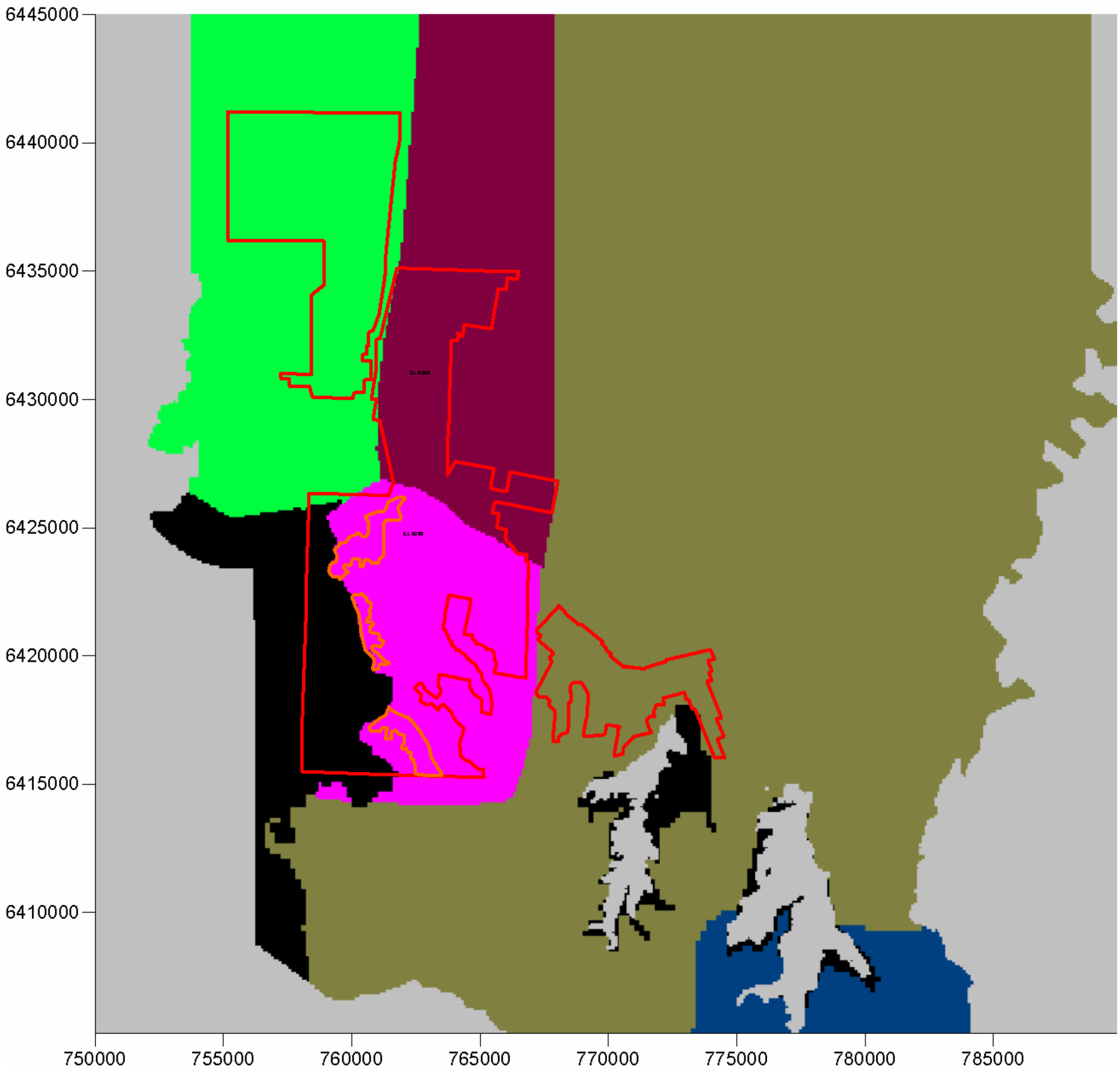
LEGEND	Kv (m/d)	PROPERTY
🟩	0.0007	Overburden (inc interbedded Coal)
🟦	0.0007	Overburden (inc interbedded Coal)
🟧	0.07	Alluvium
🟥	0.15	Alluvium
🟪	0.005	Alluvium
⬜	Inactive cells	

VERTICAL HYDRAULIC CONDUCTIVITY – L3



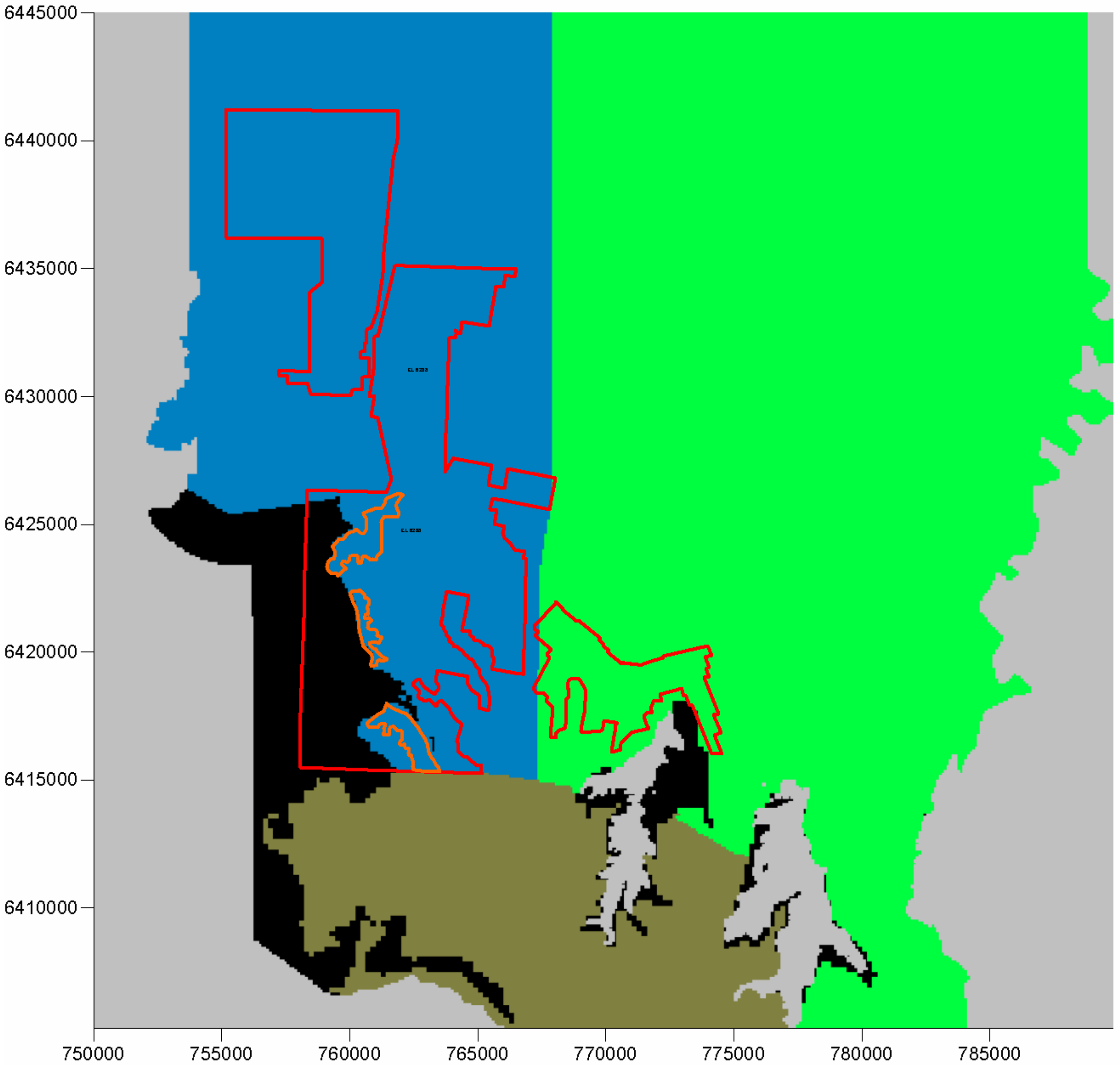
LEGEND	Kv (m/d)	PROPERTY
🟩	0.00001	Overburden (no interbedded Coal)
🟦	0.0004	Overburden (no interbedded Coal)
🟫	0.0004	Overburden (no interbedded Coal)
🟥	0.0001	Overburden (no interbedded Coal)
⬜	Inactive cells	

VERTICAL HYDRAULIC CONDUCTIVITY – L4



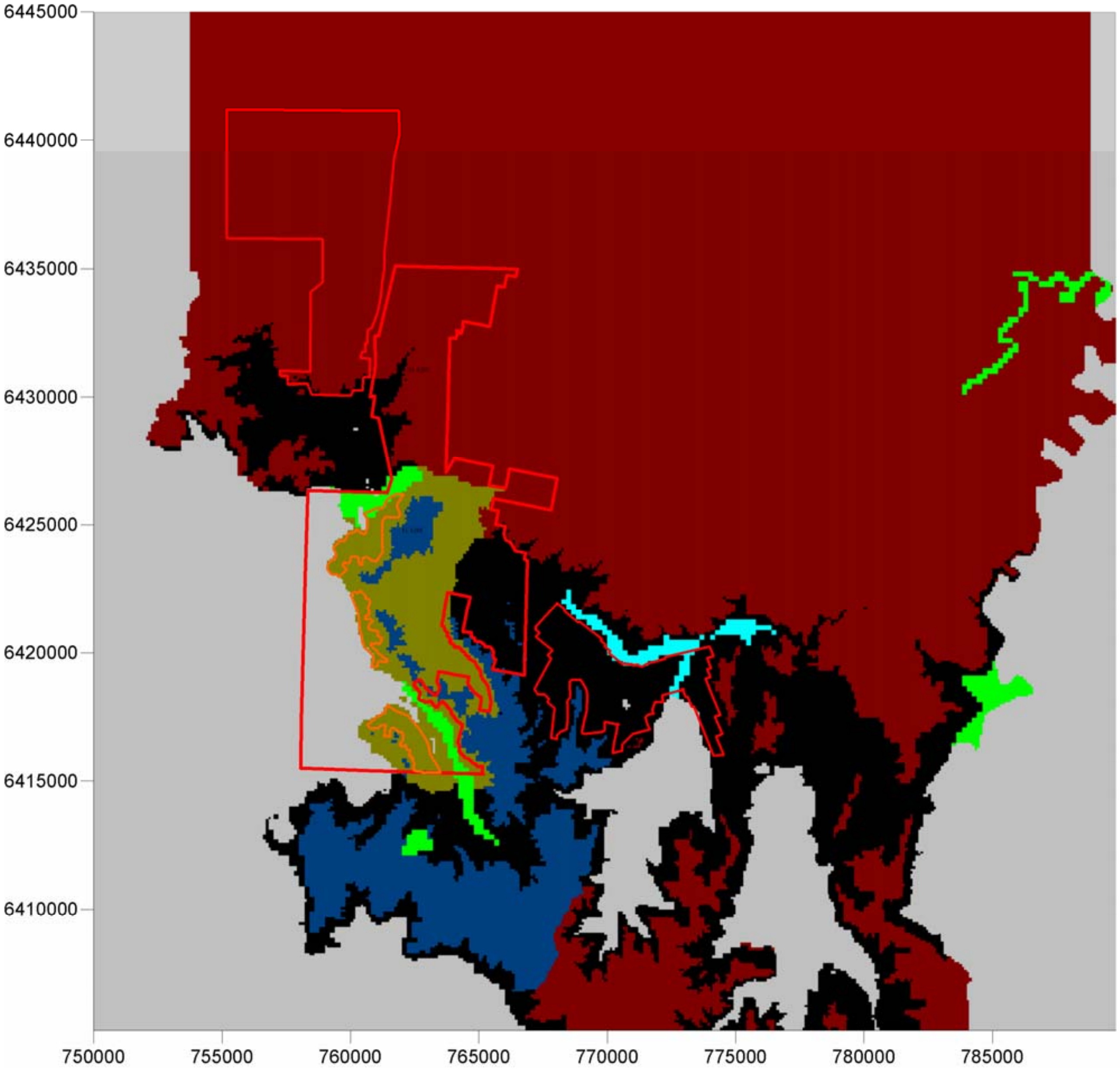
LEGEND	Kv (m/d)	PROPERTY
🟩	0.00015	Ulan Coal Seam
🟦	0.006	Overburden (Coal Seam Absent)
🟫	0.0002	Ulan Coal Seam
🟥	0.0002	Ulan Coal Seam
🟪	0.025	Ulan Coal Seam
⬛	0.00001	Basement
⬜	Inactive cells	

VERTICAL HYDRAULIC CONDUCTIVITY – L5



LEGEND	Kv (m/d)	PROPERTY
🟩	0.00001	Marrangaroo Conglomerate + Basement
🟫	0.1	Marrangaroo Conglomerate
🟦	0.0000025	Marrangaroo Conglomerate + Basement
⬛	0.00001	Basement
⬜	Inactive cells	

RECHARGE DISTRIBUTION- (TO HIGHEST ACTIVE CELL)



LEGEND	Recharge (m/d)
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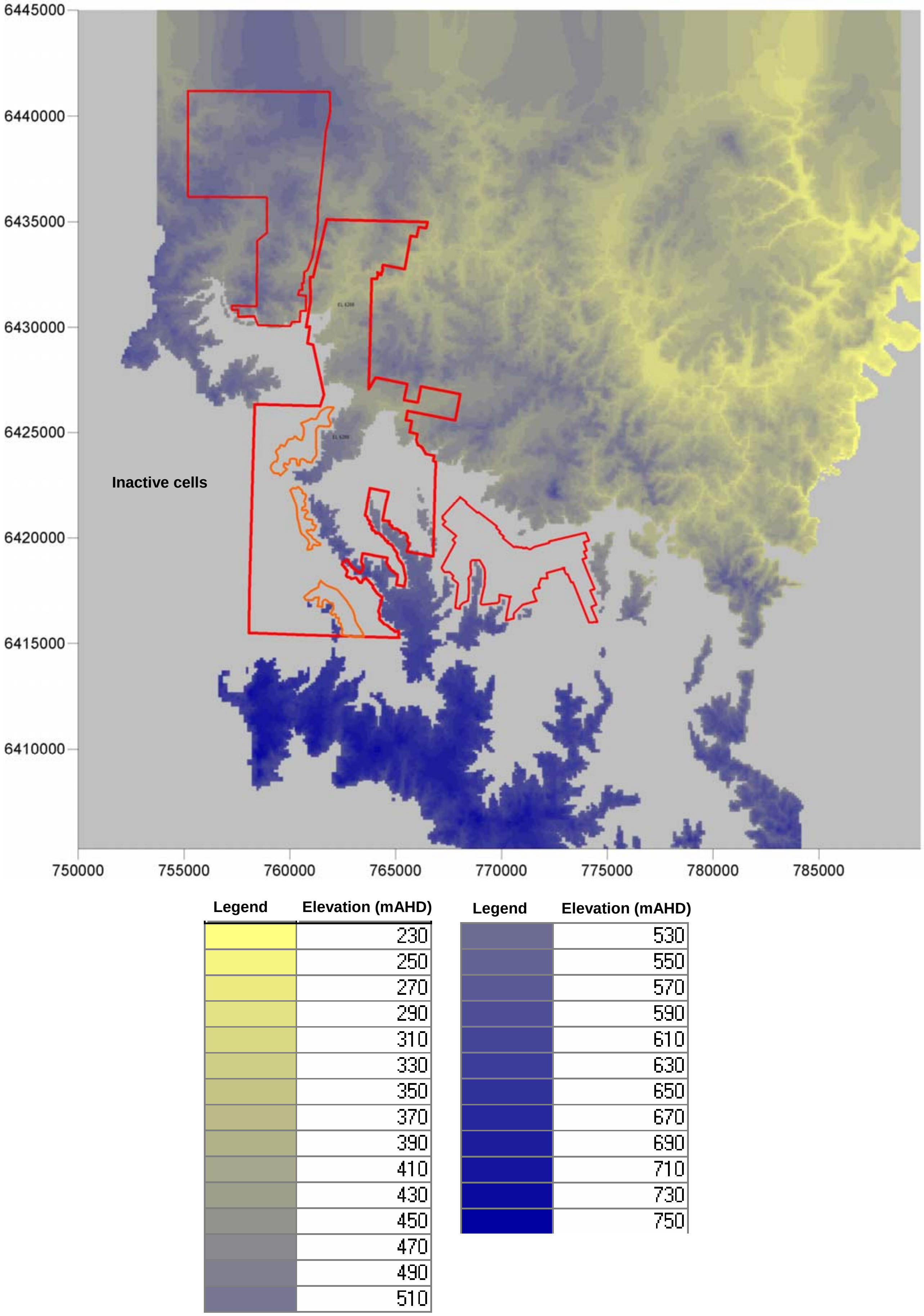
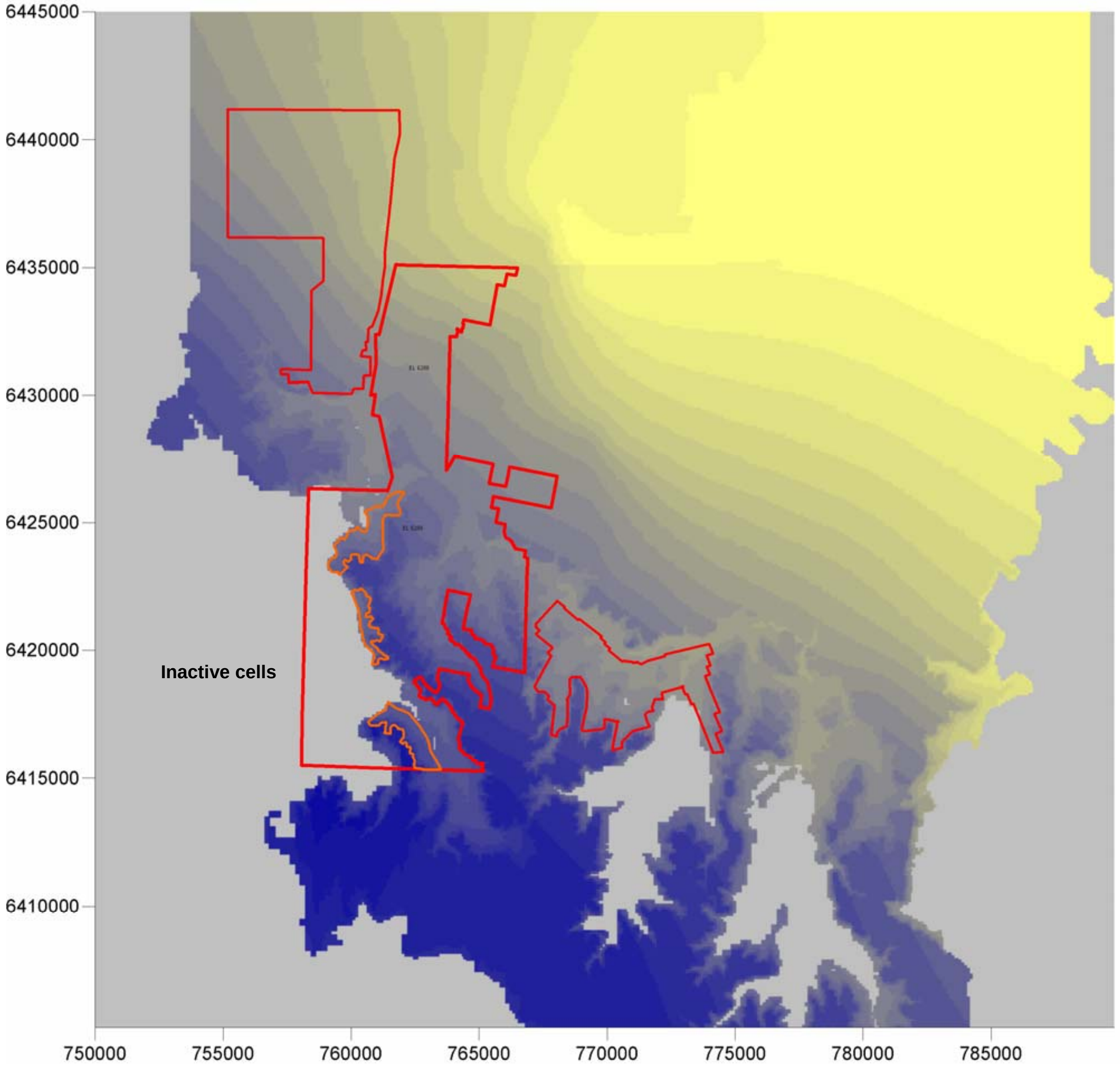
🟪	0.0002
🟫	0.00008
🟥	0.0001
⬛	0.00003
🟦	0.00011
⬜	0

TOPOGRAPHY (TOP OF LAYER 1)



TOP OF LAYER 2



Legend	Elevation (mAHD)
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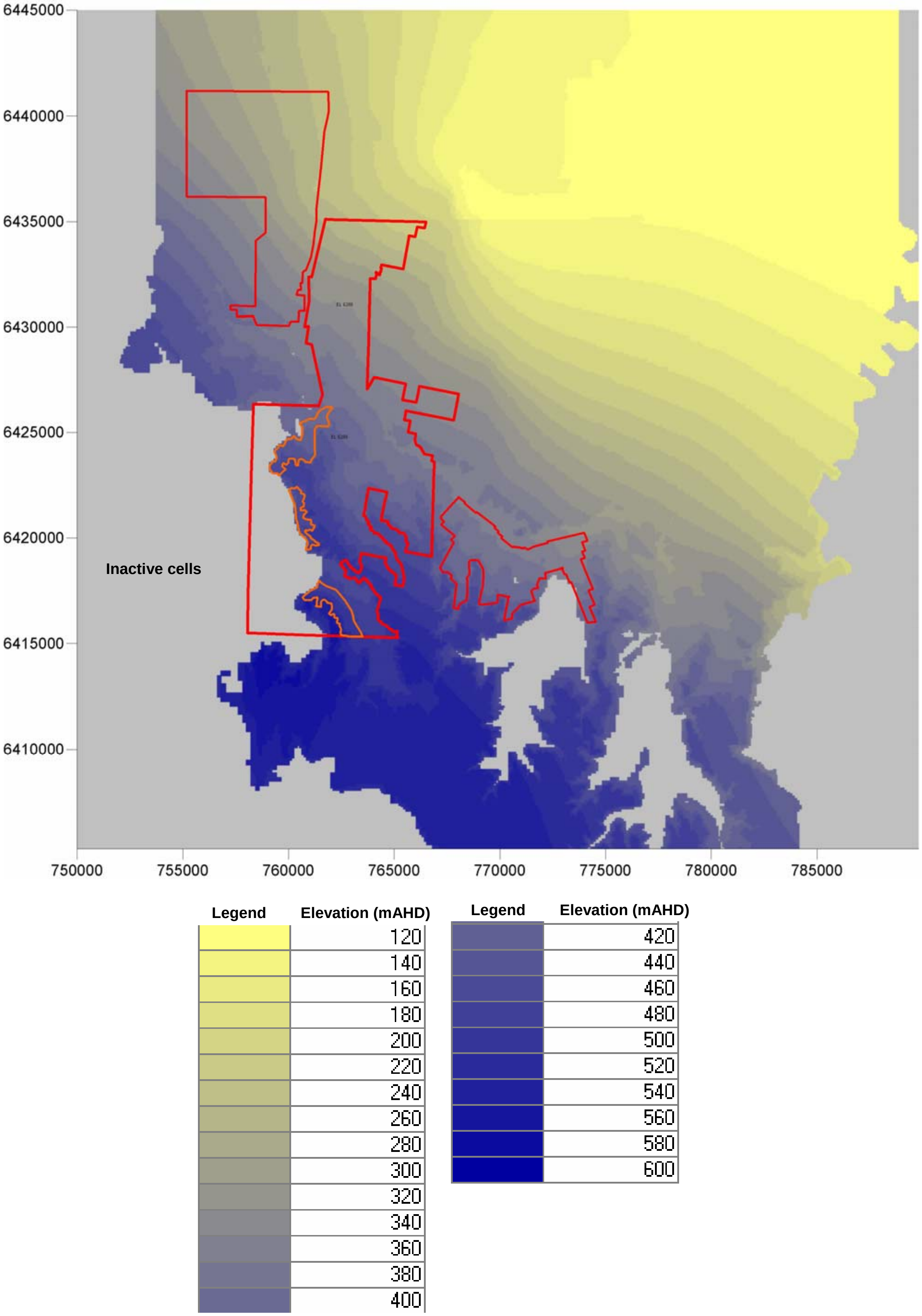
🟨	190
🟨	210
🟨	230
🟨	250
🟨	270
🟨	290
🟨	310
▨	330
▨	350
▨	370
▨	390
▨	410
▨	430
▨	450

Legend	Elevation (mAHD)
🟦	470
🟦	490
🟦	510
🟦	530
🟦	550
🟦	570
🟦	590
🟦	610
🟦	630
🟦	650

TOP OF LAYER 3



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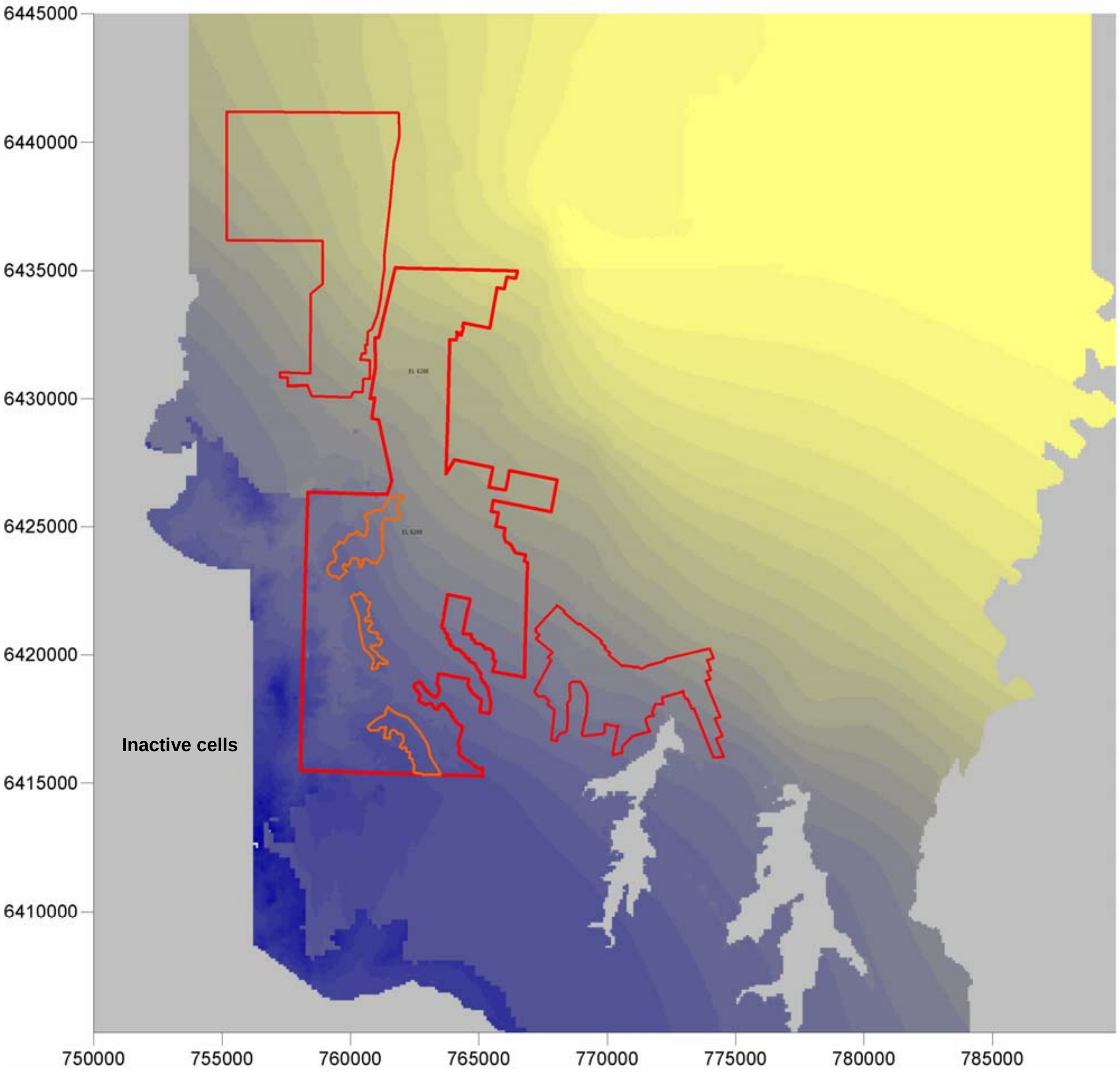

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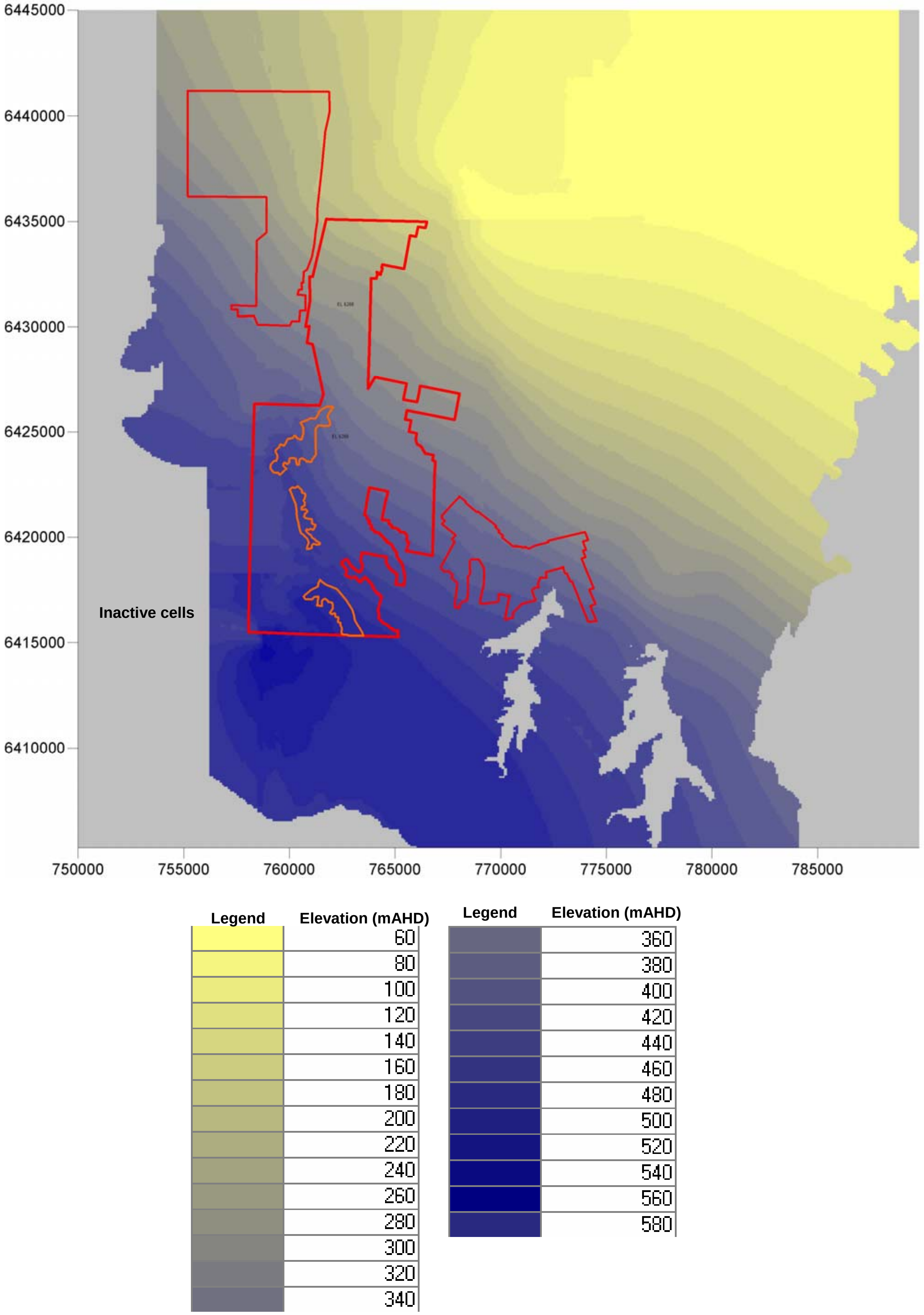
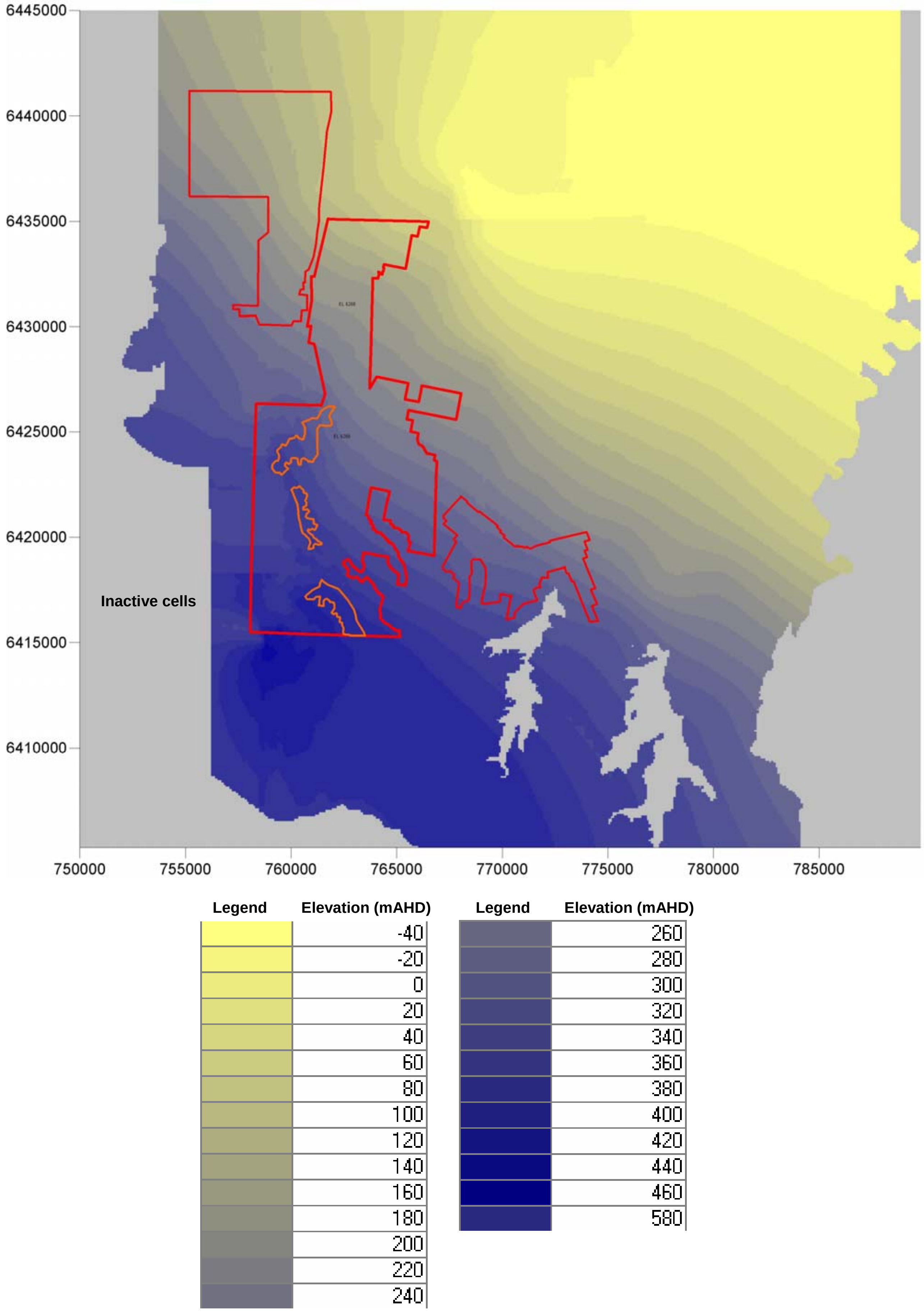
🟨	110
🟨	130
🟨	150
🟨	170
🟨	190
🟨	210
🟨	230
🟨	250
⬜	270
⬜	290
⬜	310
⬜	330
⬜	350

Legend	Elevation (mAHD)
⬜	370
⬜	390
🟦	410
🟦	430
🟦	450
🟦	470
🟦	490
🟦	510
🟦	530
🟦	550
🟦	570
🟦	590
🟦	610
🟦	630
🟦	650
🟦	670
🟦	690

TOP OF LAYER 5



BASE OF LAYER 5



APPENDIX G

CHECKLIST AGAINST DIRECTOR-GENERAL'S REQUIREMENTS

Specific Issues Identified in the Director-General's Requirements

1. Existing Environment

Key Issues	**Objective**	**Addressed**	**Comments**
Hydrogeological setting	Description of groundwater flow regime and 'conceptual' groundwater model	Section 3 Section 5	Salinity distribution, sewage points, current saline areas, mining water discharge
Groundwater quality	Distribution map showing water quality and pollution	Figures 2, 4	
Groundwater interaction with rivers, creeks and surface water bodies	Identify, quantify and map any surface water/ groundwater interaction.	Section 3.10, 5.10, 5.13	
Groundwater dependant ecosystems	Identify groundwater dependant flora / fauna systems	Section 5.10	Includes the 'Drip'
Current groundwater users	Identify current groundwater users and impact and/or dependence on groundwater	Sections 2.2, 2.3 and 3.6, Section 5.13, Appendix A and E	

2. Potential Impacts

Key Issues	**Objective**	**Addressed**	**Comment**
Mine dewatering	Predictions of cone of depression and impact on other aquifers and users. Estimate of cumulative impact from each mine - open cut and underground. Include predictions of mine water inflows (discharge rates) both during operations then after mine closure.	Section 5	Cumulative impacts of Moolarben, Ulan and Wilpinjong projects assessed as base case. Impacts of Moolarben project alone assessed separately.
Mine water discharge	Prediction of impact on groundwater systems from mine discharge points	Not applicable	No release of mine water is proposed.

Key Issues	Objective	Addressed	Comment
Removal of Moolarben Creek alluvium	Assessment of removal of aquifers associated with the Moolarben Creek alluvium	Not applicable	No encroachment by pits into Moolarben Creek alluvium
Cumulative impact	Assessment of total impact on the groundwater system from the project and other groundwater users (Wilpinjong and Ulan Coal)	Section 5	Moolarben impacts and cumulative impacts are both assessed.

3. Groundwater Monitoring and Management Plan

Key Issues	Objectives	Addressed	Comments
Environmental Risk Analysis	Examine potential impacts of mining activities on groundwater system and risk to environment	Section 5	
Monitoring programme	Detail monitoring programme and map of monitoring points	Section 6	
Mitigation and Contingency Response Plan	Include details on monitoring review and proposed strategies and measures that would be implemented to minimise impact of mining activities on groundwater dependant users and ecosystems	Section 7	

4. Additional Groundwater Issues Arising from DNR Adequacy Review

Key Issues	Objectives	Addressed	Comments
Protection of Connected Groundwater	Meet relevant State policies; identify linkages between surface and groundwater systems; remedial measures for GDEs	Sections 5.10and 5.11	Goulburn River and Moolarben Creek alluvium

Key Issues	Objectives	Addressed	Comments
Protection of Groundwater Dependent Ecosystems	As above	Section 5.14	
Monitoring, Mitigation and Remediation	Water budget, segregation of different quality waters, water management	Sections 6 and 7	Integrate with surface water program
Subsidence Impacts on Groundwater	Link subsidence assessment with groundwater impact	Section 5.12	
Salinity Budget, Groundwater Impacts	Salinity buffering potential of Moolarben Creek	Section 5.9	Integrated with surface water management
Impacts on Other Water Users	Connectivity between Moolarben Creek and perched groundwater	Section 5.13, Section 7, Appendices A and E	Specific impact predicted for each identified existing water user
Production Borefield	Extent of depressurisation, impacts on other users, GDEs	Sections 4.5 and 5.5, Figure 21	Water supply impact integrated with underground dewatering impacts
Identify Risks to, and Improve Management of Riparian Buffer Areas	Criteria to limit extent of mine pits, protective criteria of Moolarben Creek, its tributaries and connected groundwaters	Sections 5.9, 5.10, 5.13 and 5.14 Section 5.15	

5. Additional Issues Arising from Independent Groundwater Review

Key Issues	Objectives	Addressed	Comments
Shallow Regolith Groundwater (upper 30m)	Piezometric surface and groundwater flow directions. Local drainages and associated alluvium, paleochannels.	Section 3.7, Figure 11	
Final Pit Voids	Long-term water table impacts	Section 5.15	
Long term Water Level Recovery	Re-saturation impacts	Section 5.15	
Hydrogeological Structures	Identify structures that may influence groundwater flow or provide connectivity to drainages	Sections 3.2, 3.3 and 3.4 Figure 12	

Key Issues	**Objectives**	**Addressed**	**Comments**
Subsidence Impacts on Hydraulic Conductivity	Assess impacts of increased hydraulic conductivity during mining phase, as well as post-mining	Sections 5.4 and 5.7	Effect of altered K addressed in sensitivity modelling
Groundwater Dependent Ecosystems	Identify	Section 5.14	Identified descriptively, rather than on a map.
Drawdown Impacts	Present drawdown impacts, as well as piezometric surfaces	Sections5.6 and 5.8 Figures 25-29	