Appendix 9

Ardmore Park Quarry – Modification 3

Assessment of the Decline in Flow Rate Phil's Spring – "Inverary Park"

prepared by

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July 2018

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ASSESSMENT OF THE DECLINE IN FLOW RATE PHIL'S SPRING

'Inverary Park'
Lot 2 in DP84966
550 Inverary Road Bungonia

for

Multiquip Quarries

Distribution

Multiquip Quarries (1)

File (1)

Rep.No. 18059-A

13th July 2018

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APPENDICES

1. INTRODUCTION AND BACKGROUND

Larry Cook Consulting Pty Ltd has assessed the declining performance of a 'spring' on 'Inverary Park' known as Phil's Spring in Lot 2 in DP84966 first described in the Groundwater Impact Assessment prepared in support of the EIS for the then proposed quarry on 'Ardmore Park' (Lot 24 in DP1001312).in 2004. The location of Phil's Spring is shown on a lot plan in **Figure 1**. This assessment investigates possible impact/s on the spring's performance from the current quarrying activities and/or extraction from a licensed production bore on 'Ardmore Park'.

'Inverary Park' adjoins the eastern boundary of 'Ardmore Park' (**Figure 1**). Phil's Spring is located approximately 290 m east of the mutual boundary and approximately 980 m south-east of the current quarrying operations in 'Ardmore Park' and 1.56 km south-west of the licensed production bore on 'Ardmore Park'. The approximate coordinates of Phil's Spring are 022596m East and 6132839m North (GDA 94-MGA56).

2. AQUIFER DISCHARGE (SPRINGS)

Phil's spring is one of a series of 'water features' identified in the local area surrounding 'Ardmore Park'. The locations of the closest springs are shown in **Figure 2** and include Phil's Spring, Southern Spring, Western Spring, the Ravensdale spring system and Inverary Spring. An enlarged image showing Phil's Spring, local geology and interpreted direction of groundwater flow is presented in **Figure 3**. An enlarged Google Earth image showing the trace of Phil's Spring is shown in **Figure 4**.

These springs, labelled 'contact springs', are observed to be essentially locally-perched sand-hosted saturated zones overlying a low-permeability layer, where the perched shallow groundwater intersects the topography (land surface). A schematic cross section showing the interpreted geology, spring discharge and profile of the production bore on 'Ardmore Park' is presented in **Figure 5**. The majority of the documented springs in this area are aligned along the eroding fringe of the Tertiary basalt (**Figure 2**). Site inspections revealed that although the springs are in the main associated with the basalt contacts, they are emanating from the base of palaeo-sand layers that are overlain by the basalt flows, and the fringes are eroding back with the more physically resistant basalt. That is, the groundwater is likely discharging from the base of the presently exposed edge of the 'unconfined' sand sequence or at the contact between overlying partly saturated permeable sand and underlying relatively impermeable silty clay. The exception appears to be the Western Spring which appears to be associated with the contact between gravels and underlying alluvium.

The elevations of these spring systems are interpreted to be between 610 and 620 m Australian Height Datum (AHD).

The north-west and south-east contacts of the remnant basalt in the local area shown in **Photo B** in **Figure 2** are coincident with the interpreted linear features annotated on **Photo A** in **Figure 2**. This strongly suggests that this 2 km-wide block of preserved, remnant basalt flows is controlled by bounding faults and that it is possible that the basement rocks to the north and to the south of the basalt may have been 'upthrown' in a relative sense of movement or conversely, the central block has been 'downthrown'.

The discharge volumes from these springs are associated with the storage volume in the sand aquifer and commensurate hydraulic head. The principle that governs how groundwater (fluid) moves in the sand aquifer (sub surface) is called Darcy's Law which states that the discharge rate is proportional to the gradient in hydraulic head and the hydraulic conductivity. That is, the flow will decrease with a decrease in the hydraulic head and vice versa. The flows also fluctuate in direct response to local rainfall events (spikes). The direct correlation between local rainfall recharge and spring flow is revealed in **Figure 6** which charts daily rainfall ('Inverary Park') against spring flow in 'Phil's Spring' for the period January through June 2018. The increase in spring flow following the commencement of a local rain event is almost instantaneous which indicates an immediate response to the recharge of the paleo sand sequence under unconfined hydrogeological conditions. Anecdotal evidence indicates that they are low-volume permanent flows.

3. MONITORING – PHIL'S SPRING

Phil Broadhead provided flow rates for Phil's Spring manually measured by him at different times between 2003 and 2016. The flows were measured using a bucket and stopwatch. The measured flows are charted in Figure 7. Daily rainfall data acquired from the official BOM rain gauge on 'Inverary Park' is also charted. The charts show a demonstrable declining trend in spring flow.

The chart reveals that the flow in Phil's Spring has fluctuated over the monitoring period with a gradual overall decrease noted between 2003 and 2016. Flow rates of approximately 26,000 to 28,000 L/day measured in 2003 have, according to the chart, decreased gradually to approximately 9,000 L/day L/day in 2016. A manually measured flow of between 20,000L and 29,000L per day was recorded in October 2004. This equates to a flow rate of approximately 0.2 to 0.3L/s (160 to 240 gal/hr). A photo of the spring taken in 2004 is shown in **Figure 8**.

The flow in Phil's Spring was estimated by Larry Cook Consulting to be approximately 0.1 L/s on 19th January 2015. This flow was estimated in one small channel emanating from a series of channels constituting the spring system. The flows measured on 28th July 2015 and 23rd September 2015 using the same method were estimated at approximately 0.2 L/s and between 0.1 and 0.2 L/s respectively.

A 'V' notch weir and calibrated automated flow sensor were installed in Phil's Spring in early 2018. A chart showing spring flow and daily rainfall collected between January and June 2018 is presented in **Figure 6**. The 2018 flow data, with the outliers statistically removed, is shown in **Figure 9**. The trend line confirms the gradual decrease in spring flow although the rate of decrease in the flow rate appears to have accelerated in 2018.

4. DISCUSSION

Considered reasons for the decline in spring flow include:

- Potential interception of the shallow water table due to 'hard rock' quarrying activities on 'Ardmore Park';
- Potential interception of the shallow water table due to 'sand extraction' on 'Ardmore Park';
- Induced leakage from the shallow water table due to production bore pumping on 'Ardmore Park';
- Natural decline in spring flow associated with decreased rainfall recharge; and
- Interception of the shallow water table and water extraction due to third party pumping.

These reasons are discussed and assessed in the following sections:

4.1 Potential Interception of the Shallow Water Table Due to 'Hard Rock' Quarrying Activities on 'Ardmore Park'

The active basalt quarry, that commenced operation in 2016, is 'dry'. No water has been observed discharging or seeping from the quarry walls or floor. This is consistent with ongoing quarry observations, discussions with quarry operators and the results of the 2004 groundwater impact assessment that showed that no groundwater was intersected in exploration drill holes within the basalt resource in the quarry precinct.

If groundwater was present, the results of the groundwater impact assessment indicate that the direction of groundwater flow would be to the south and not towards Phil's Spring.

In addition, it is noted that the gradual decline of the spring flow reflected in manual flow measurements between 2003 and 2014 predates the commencement of any quarrying on 'Ardmore Park'.

4.2 Potential Interception of The Shallow Water Table Due to Sand Extraction on 'Ardmore Park'

Sand extraction commenced in the far western part of the Southern Sand Resource (**Figure 2**) on 'Ardmore Park' in early 2018. However, the 'unconfined' aquifer hosted by the sand resource has not been intercepted. It is noted that the gradual decline of the spring flow reflected in manual flow measurements between 2003 and 2014 predates any sand extraction on 'Ardmore Park'.

4.3 Induced Leakage from the Shallow Water Table Due to Production Bore Pumping on 'Ardmore Park'

4.3.1 Introduction

The location of licensed Production Bore APBH6 on 'Ardmore Park' is shown in **Figure 2** and located 1.56 km north-west of Phil's Spring. The details of the bore license and work approval are as follows:

Work Approval	10CA117207
Approval Date	4.10.11
Water Access License	WAL 30111
Reference No.	10AL117206
Water Entitlement	110 units

The geology of the district is shown in **Figure 10** and a hand-drawn cross section (A-B-C) presented in **Figure 11**. The cross section is constructed from near Oallen Ford Road north-east of 'Ardmore Park' through Production Bore APBH6 then through Phil's Spring on 'Inverary Park' terminating south-east of the spring system. The licensed 124 m-deep production bore on 'Ardmore Park' extracts groundwater from a deep 'confined' hardrock aquifer hosted by a regionally-significant regional fault dissecting steeply-dipping and deformed Devonian age metasedimentary rocks. A profile of the bore showing the geophysical signature and geology encountered is shown in **Figure 12**. The aquifers are located approximately 65 m below the contact with the overlying alluvial sequence at 35 m depth.

The rationale behind the selection of the location of the production bore was:

1. Target a regionally significant sub-vertical geological structure with the prospects of producing sustainable, long-term industrial (high volumes) of groundwater;
2. Extract groundwater from a source not intersected by other neighbouring water users (including basic rights bores) thus minimising any potential adverse impacts; and
3. Maximise the distance from other neighbouring water users (including basic rights bores) thus minimising any potential adverse impacts.

4.3.2 Production Bore Operation

A summary of the operation of the production bore is provided in **Table 1**. The time line is annotated in **Figure 7**.

Table 1
Summary Bore Pumping
Production Bore APBH6

Time Line	Activity
24th July 2003	Bore Drilled to 124 m depth
8th April 2004	Pump testing (45 hrs@13 L/s)
July 2004 – early 2007	No pumping
2007	• Limited intermittent pumping for stock watering. • Estimate < 2ML pumped during 2007
2008	• Limited intermittent pumping for stock watering. • Less pumping than 2007. • Estimate < 1ML pumped during 2008
Early 2009 – late 2013	• 'Ardmore Park' rarely visited in this five-year period due to activities on a significant company project near Picton. • Bore rarely pumped during 2009 - 2011 to supplement proximal dam storage for stock watering. • Pump seized in about 2011 due to inactivity. • Attempts in mid-2013 to extract pump failed. Pump stuck. • Pump eventually retrieved in September 2013 and replaced. Bore cleaned in October 2013 and new pump installed.

Nov 2013 – Jan 2014	Bore pumped intermittently to supply water for road works – Bungonia bypass road.
Jan 2014 – late 2015	No pumping
Late 2015 – mid 2016	Bore pumped intermittently to supply water for miscellaneous road works.
Mid 2016 – early 2017	• No pumping. • 'Very much above average' rain in 2016. A total of 834.2 mm was recorded in the BOM Bungonia Station 70012 on 'Inverary Park' which is understood to be highest rainfall recorded in this district since 1974.
Early 2017 - present	• Bore pumped for road works and sand washing. • Approximately 20 ML pumped in this period.

A summary of the bore production monitored by flow metre in 2018 is provided in **Table 2**.

Table 2
Summary Bore Production - 2018
Production Bore APBH6

Parameter	Volume
Total Usage 12.2.18 – 19.6.18	10.95 ML
Minimum Weekly Usage 23.3.18 – 28.3.18	0.183 ML
Maximum Weekly Usage 12.6.18 – 19.6.18	4.387 ML
Average Weekly Usage	0.824 ML

4.3.3 Spring Systems

The 'springs' are water features associated with the shallow 'unconfined' groundwater system hosted by the upper part of the paleo sand sequence, part of a palaeo valley system, is effectively perched atop the older 400 million-year-old metasedimentary basement rock sequence. Detailed hydrogeological investigations carried out in 2004 as part of the EIS revealed that the upper sand sequence is underlain by an approximate 20 to 40 m-thick aerially extensive clay aquitard which in turn overlies sand and gravel. A schematic cross section showing the various geological elements and spring systems is presented in **Figure 5**.

The elevation of the spring systems is interpreted to be between 610 and 620 m AHD whereas the aquifers exploited in the production bore are at an elevation of between 530 and 540 m AHD. The geological mapping shown in **Figure 10** and cross sections illustrated in **Figures 5**

and 11 identifies there to be a significant geological and hydrogeological disconnect between the deeper hardrock aquifers and the relatively shallow 'unconfined' sand aquifer. Although depressurising confined to semi confined hardrock aquifers by pumping can, under certain hydrogeological conditions, induce leakage from an overlying confined to semi-confined aquifer, the sand aquifer is unconfined and separated from the hardrock aquifers by a significant laterally-extensive aquitard.

In addition, the distance between the bore and Phil's Spring is 1.56 km. It is noted that in some groundwater management areas in NSW, required separation distances between hardrock production bores (irrigation, commercial. industrial) is 400 to 1,000 m so that potential interference is avoided. The distance between the production bore and Phil's Spring significantly exceeds this buffer setback.

It is understood that the hardrock aquifer system hosted by the fractured Devonian metasedimentary basement rocks is not directly connected to the shallow palaeo sand-hosted aquifer. Monitoring of the static (non-pumping) water level in this bore indicates that the water level has not significantly changed since drilling and test pumping in 2004. The water level fluctuates between about 57.0 m and 61.1 m below ground level. Water levels monitored in peripheral licensed observation bores ('non-pumping' bores) on 'Ardmore Park' do not reveal any impacts from pumping in the production bore. This is consistent with the results of aquifer testing and distance drawdown analysis in 2004.

It is noted that the water level in Monitoring Bore APBH5 in the north-eastern part of 'Ardmore Park' (**Figure 2**), the only monitoring bore that monitors the deeper paleo alluvial sequence underlying the clay aquitard, has not significantly fluctuated. In fact, the water levels measured since drilling in July 2003 record a rise. The baseline water level was 23.60 m below ground. Water levels measured since 2003 fluctuate between 19.95 and 21.77 m below ground. This suggests that the production bore on 'Ardmore Park' is not depressurising the deeper alluvial aquifer overlying the basement rock sequence and therefore not causing any leakage from the shallow 'unconfined' alluvial aquifer that provides spring flow (groundwater discharge) in the area.

4.3.4 Fluctuations in Spring Flow Associated with Weather and Climate

Spring system flow usually correlates positively with rainfall recharge. The flow in Phil's spring is observed to correlate positively and close to instantaneously with rainfall recharge.

The flow data in **Figure 7** reveals a declining trend in flow volumes since the commencement of measurements in mid-2003. Although there are fluctuations in the data which reflects the short-term recharge and recession characteristics associated with individual rain events, the overall trend is a decline in flow rate exhibiting a constant slope.

The following comments are provided:

- Production Bore APBH6 was drilled in 2003 and an electro-submersible pump installed in early 2004. However, it is understood that the pump was not operated until 2007 with irregular pumping noted in 2007 and less in 2008 through to 2011 for stock watering when the pump failed due to non-use. The pump was removed for repairs in 2013 and the bore cleaned out in October 2013. The bore was pumped intermittently between late 2013 and early 2014 to supply water for road works (Bungonia bypass road). It is understood that no pumping was carried out between early 2014 and late 2015

The bore was then pumped intermittently between late 2015 and mid 2016 to supply water for miscellaneous road works. No pumping between mid 2016 and early 2017 due to ‘very much above average’ rains. Between early 2017 and present, the bore has been operating on a ore regular basis to supply water for dust suppression and sand washing. However, as can be seen in **Figure 7**, the decline in the spring flow rate recorded from the commencement of monitoring in 2003 continued through periods of demonstrated non-pumping, low volume pumping and intermittent (irregular) pumping.

- A review was made of annual decile rainfall charts for Australia prepared by the Bureau of Meteorology (BOM). Charts for the years 2001 through 2017 are reproduced in **Figures 13 and 14.** The charts reveal ‘below average’ to ‘very much below average’ rainfall in south-eastern Australia (including southern NSW) between 2001 and 2009. These conditions could significantly decrease groundwater storage in the shallow aquifers and indeed in hard rock aquifers.
- A review of hydrographs (water levels vs time) recorded in the small number of dedicated state government monitoring bores in the Southern Highlands NSW was undertaken. The closest monitoring bores to ‘Ardmore Park’ and ‘Inverary Park’ are located at Burrado, Burrawang, New Berrima, Sutton Forest and Welby. The bores intersect, and monitor, water level fluctuations in ‘semi-confined’ relatively deep aquifers hosted by the Hawkesbury Sandstone. The hydrographs are presented in **Figures 15, 16, 17, 18 and 19**.

  The hydrographs for Burrado, New Berrima, Welby and Sutton Forest reveal a distinct gradual overall decline in the standing water levels (piezometric levels) between 2001 and 2009 corresponding to ‘average’ to ‘well below average’ rainfall in southern NSW. The hydrograph for Burrawang is less instructive. A rise in water levels is noted between 2010 and early 2012 which corresponds to ‘average’ to ‘well above average’ rainfall. Further decline in the water levels is noted between 2012 and 2014 in the monitoring bores at Burrado and Sutton Forest corresponding to ‘average’ to ‘below average’ rainfall. However, this trend is not observed in the monitoring bores at New Berrima and Welby.

  The decline in the flow rate recorded in Phil’s Spring from commencement of monitoring in 2002 through to at least the end of 2009 is consistent with ‘average’ to ‘very much below average’ rainfall in southern NSW and consistent with the decline in water levels recorded in several of the sandstone-hosted state government monitoring bores north of the area. However, there is no observed increase in spring flow expected during the three-year period 2010 through 2012 when ‘average’ to ‘above average’ rainfall was recorded in the region, especially in 2010.

  It is also noted that ‘average’ to ‘below average’ rain was recorded between 2012 and 2015, ‘very much above average’ rains in 2016 and ‘below average’ to ‘very much below average’ rains in 2017.

- Annual rainfall data acquired from the BOM Bungonia Station 70012 on ‘Inverary Park’ is charted for 2001 through 2017 in **Figure 20**. A review of the data reveals relatively ‘below average’ years in 2002, 2003, 2004 and 2006 with an anomalous ‘above average’ year recorded in 2007 (764.8 mm). However, the total rainfall in 2007 is not reflected in any overall increase in the spring flow for Phil’s Spring but is observed in a rise in water levels in the five state government monitoring bores (Burrado, Burrawang, New Berrima, Sutton Forest and Welby). Equally, the ’above average’ total rainfall recorded on the site in 2010 and 2012 does not result in an overall increase in the flow rate of the spring but is again reflected in a rise in water levels in the same state government monitoring bores in Burrado, Burrawang, New Berrima, Sutton Forest and Welby.

The apparent lack of response to 'above average' rainfall years indicated in the manually-measured flow rates for Phil's Spring may be associated with low storage volume in the sand aquifer (low hydraulic head), a consequence of previous 'below average' rainfall years.

The total rainfall recorded in 2016 (837.2 mm) is the highest total recorded on the site since 1974. This anomalous amount of rain is not reflected in any overall increase in the flow rate of the spring system.

4.4 Impacts on the Shallow Water Table Due to Third Party Pumping

Insufficient data is available to assess any impacts on Phil's Spring from third party pumping interference. An updated review of neighbouring registered bores on the WaterNSW bore database revealed that there are no licensed bores charted in the general area centred on 'Inverary Park' that could impact spring flow. The only licensed bore appearing on the state government charts is GW066105, an 'active' stock & domestic bore located on 'Inverary Park' and drilled in 1991 to a depth of 14 m. The bore on 'Inverary Park', often referred to by Phil Broadhead (56 m water level), does not appear on the charts. This may be a WaterNSW database glitch.

5. CONCLUSIONS AND RECOMMENDATIONS

This assessment of the overall decline in flow rates from Phil's Spring between 2003 and 2018 concludes that the decline is not due to an impact from quarrying activities or any sand extraction on 'Ardmore Park', or from pumping from licensed Production Bore APBH6 on 'Ardmore Park'. A summary of conclusions with recommendations follows:

- The active basalt quarry is 'dry' with no groundwater intercepted;
- Groundwater has not been intercepted to date in the recently-commenced sand extraction operations;
- The flow rates measured in Phil's Spring are observed to decline prior to commissioning the production bore on 'Ardmore Park' in 2004 and throughout periods of demonstrated non-pumping, low-volume pumping and intermittent (irregular) pumping up until early 2017, a period of 13 years.

  These data suggest that the extraction of groundwater from the deep fractured hardrock aquifer system in the production bore on 'Ardmore Park' is not impacting Phil's Spring.
- The trend in the declining flow rate between 2001 and 2009 appears to correlate with 'below average' to 'very much below' average rainfall observed in south-eastern Australia which suggests a decrease in the groundwater storage (decreased hydraulic head) in the shallow sand sequence and commensurate decrease in the discharge rate of the spring system.

  However, annual local rainfall data acquired on 'Inverary Park' shows relatively high rainfall totals in 2007, 2010 and 2012 which would be predicted to provide enhanced recharge to the 'unconfined' sand aquifer, the source of the spring. These rainfall recharge events are not reflected in any rise in the overall flow rates in the spring system. This is in contrast to a demonstrable rise in water levels for these years observed in the hardrock aquifers in five state government monitoring bores north of the area.

- The distance between the production bore on 'Ardmore Park' and Phil's Spring is 1.56 km which significantly exceeds the conservative separation distances that WaterNSW sets for works approval bores (irrigation/commercial/industrial) in some of their Water Sharing Plan areas, particularly for bores exploiting the same alluvial aquifers in irrigation districts that are considered by the state government to be under aquifer stress.
- There appears to be a significant geological and hydrogeological (hydraulic) disconnect between the deeper 'fracture-controlled' hardrock aquifers hosted by the 'old' deformed rock basement sequence and the relatively shallow and younger 'unconfined' alluvial sand aquifer. Further to this, the shallow sand aquifer providing the spring discharges in the local area is separated from the deeper paleo alluvium by a district-significant 20 to 40 m-thick clay aquitard which effectively acts as a hydraulic barrier.

  Induced aquifer leakage is often documented in the literature when the pumping bore extracts groundwater from a semi-confined to confined transmissive alluvial aquifer vertically separated from a shallow unconfined alluvial aquifer by an aquitard. The leakage, if it occurs, is considered to be initially from storage in the overlying clay aquitard then, over time, largely from the shallow alluvial system.
- The water level in Monitoring Bore APBH5 in the north-eastern part of 'Ardmore Park', the only monitoring bore that monitors the deeper paleo alluvial sequence underlying the clay aquitard, has not significantly fluctuated. This indicates that there has not been any significant pump-induced leakage from the lower saturated alluvial sand aquifer, and by inference, no impacts on the shallow sand aquifer, the source of the springs.
- The apparent fluctuations in the water level (piezometric level) in Production Bore APBH6 are not considered unusual for this type of aquifer (deep fractured hardrock aquifer under 'confined' conditions). The change in water level from 57.0 m measured following drilling in July 2003 to recently recorded 61.1 m below ground likely represents fluctuations in aquifer pressure and not necessarily a change in aquifer storage volume. The regional geology and tectonic history suggests that the recharge area for the deep, fracture-controlled hardrock aquifer is extensive and not restricted to the local area.

  The results of the short-term pump testing in April 2004 indicated that the bore has a moderate to high long-term yield and moderate to high transmissivity, not uncommon for fracture-controlled aquifers. Although pump testing provides aquifer parameters characteristic of this groundwater system, it is recognised that it cannot establish the amount of water stored in the aquifer system. That is, the storage of the aquifer system can only be estimated after pumping has occurred over the long term. In this regard, long-term monitoring of the production bore is in place to more accurately determine the long-term safe and sustainable yield.
- Complete the installation of a 'V notch' weir and automated flow monitoring device on the Southern Spring to establish any correlation between production bore pumping/sand extraction, and fluctuations in the flow of the Southern Spring.
- Continue to compile and analyse automated flow data acquired from the "V" notch weir on Phil's Spring.
- As part of the planning process for the proposed quarry extension, a strategically positioned resource drill hole will be sunk in the south-eastern part of the 'Ardmore

Park' with the aim of obtaining valuable additional information and data on the basalt and sand resource. The approximate location of the drill hole is annotated in **Figure 21**. The design of the drill hole will be suitable for conversion to a single, nested or twinned monitoring bore (piezometer) to monitor water level fluctuations, in accordance with state government guidelines. Examples of a suitable construction of a single and twinned monitoring bore are provided in **Appendix A**.

6. CLOSURE

Please do not hesitate to contact Larry Cook on 0428 884645 if you have any questions or require further information.

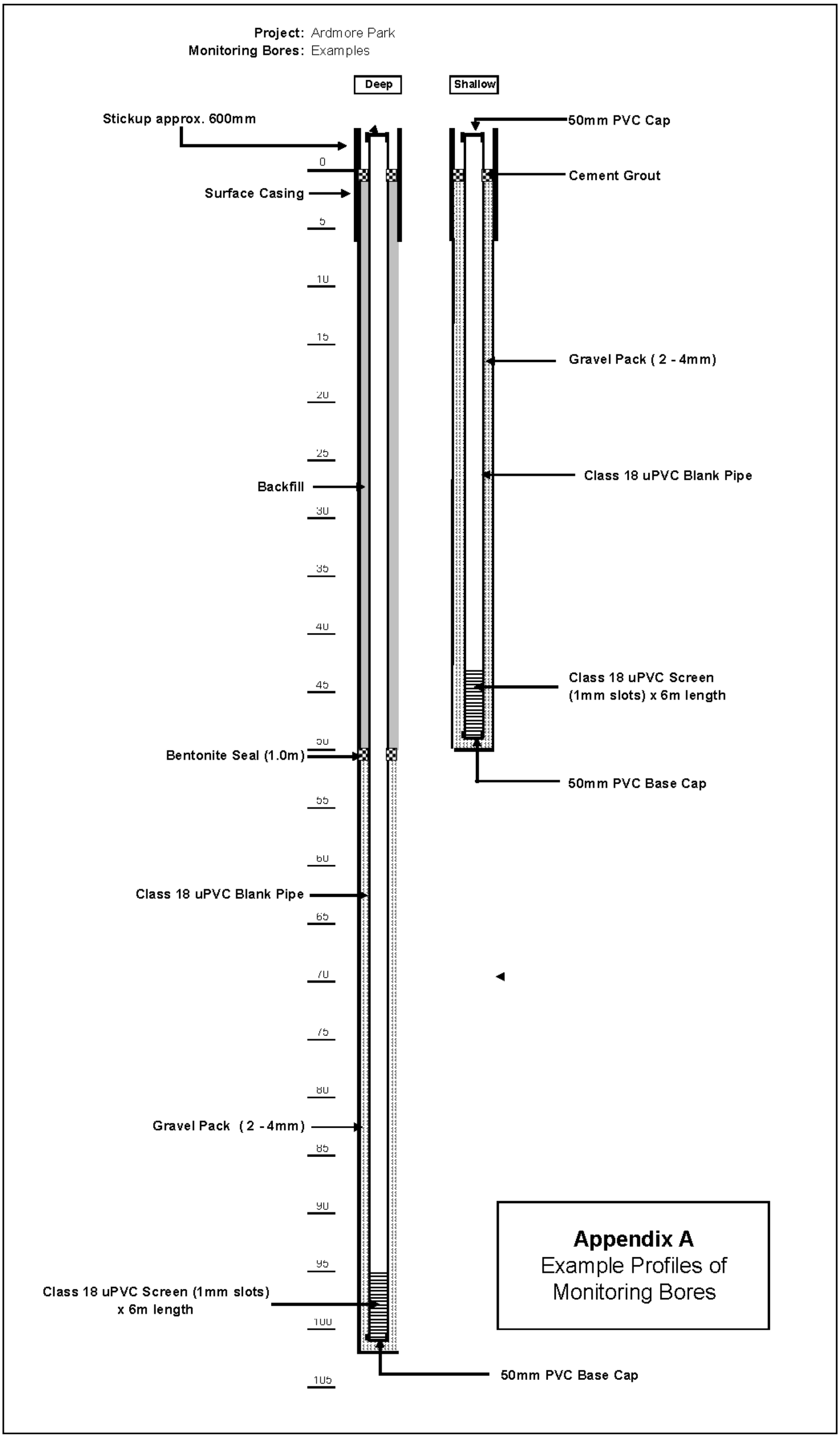
For and on behalf of
Larry Cook Consulting

Larry Cook

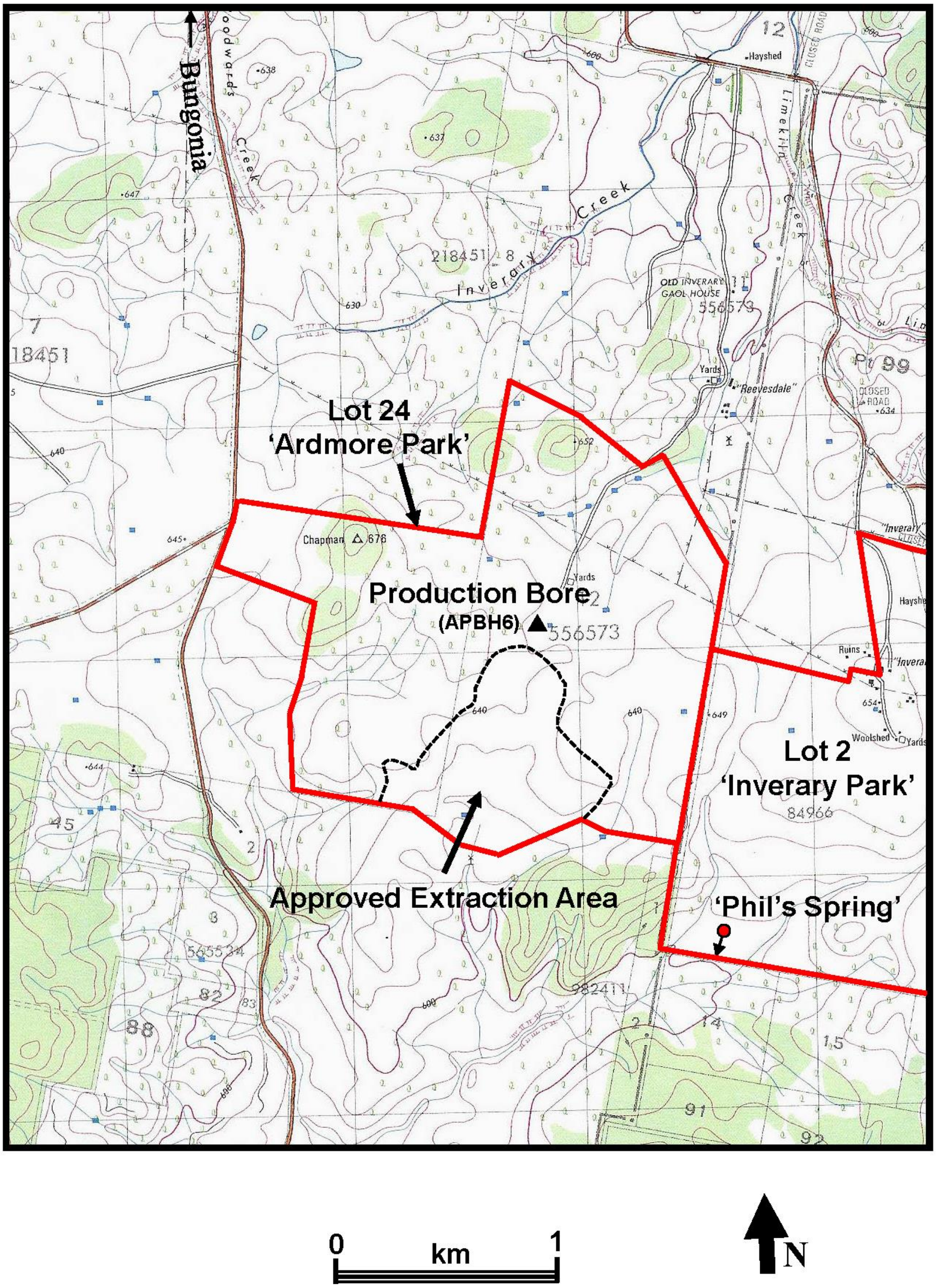
Larry Cook
Hydrogeologist

APPENDIX A

EXAMPLES OF MONITORING BORE CONSTRUCTION


Project: Ardmore Park
Monitoring Bores: Examples
Deep
Shallow
Stickup approx. 600mm
50mm PVC Cap
Cement Grout
Surface Casing
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100
105
Gravel Pack (2 - 4mm)
Class 18 uPVC Blank Pipe
Backfill
Class 18 uPVC Screen (1mm slots) x 6m length
Bentonite Seal (1.0m)
50mm PVC Base Cap
Class 18 uPVC Blank Pipe
Gravel Pack (2 - 4mm)
Class 18 uPVC Screen (1mm slots) x 6m length
50mm PVC Base Cap
Appendix A
Example Profiles of Monitoring Bores

FIGURES



Larry Cook Consulting **PO Box 8146** **Tumbi Umbi NSW 2261** **Ph 02 4340 0193**	**Hydrogeological Assessment**	Scale: As shown
	Lot 24 DP1001312 - 'Ardmore Park' Location of Phil's Spring, Production Bore & Approved Extraction Area	**FIGURE 1**

Photo A

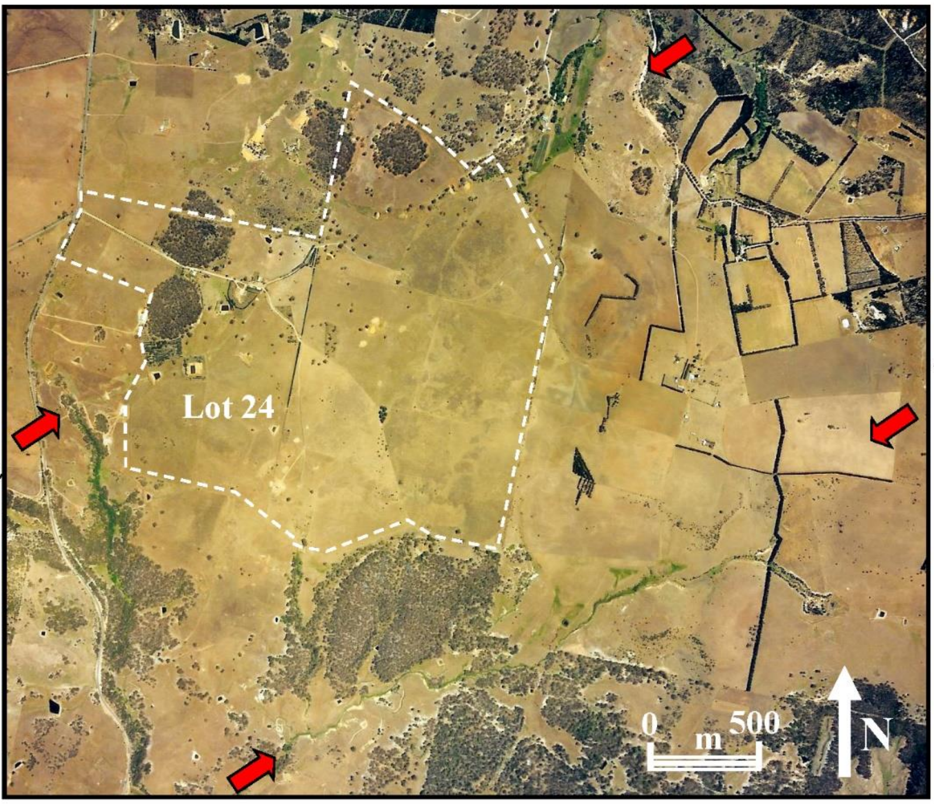
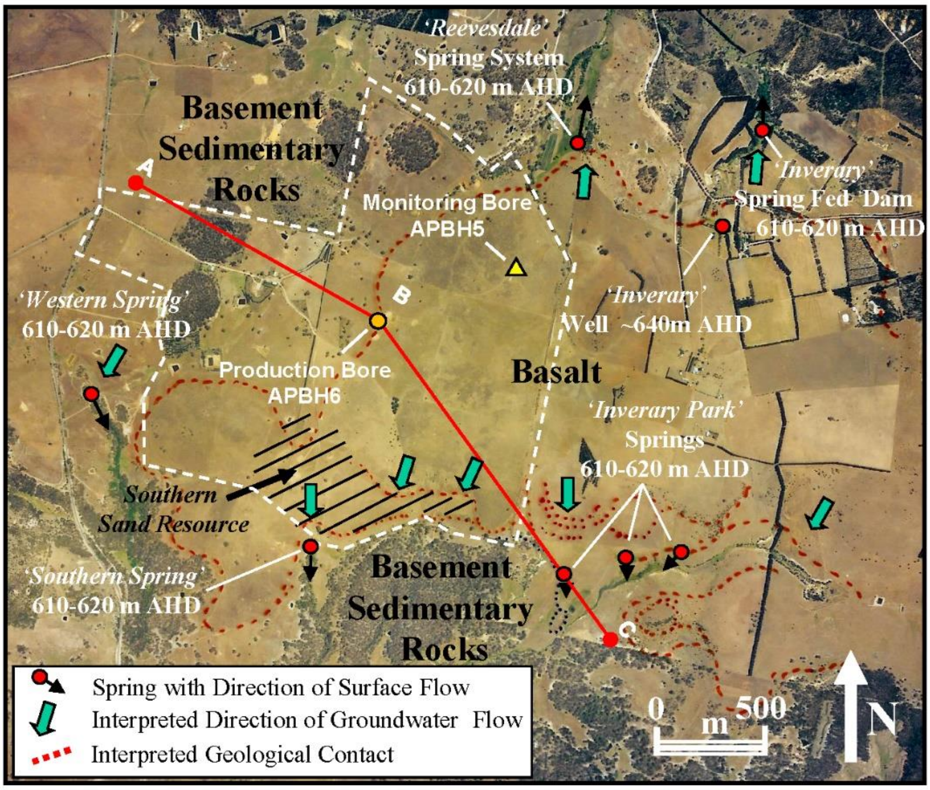
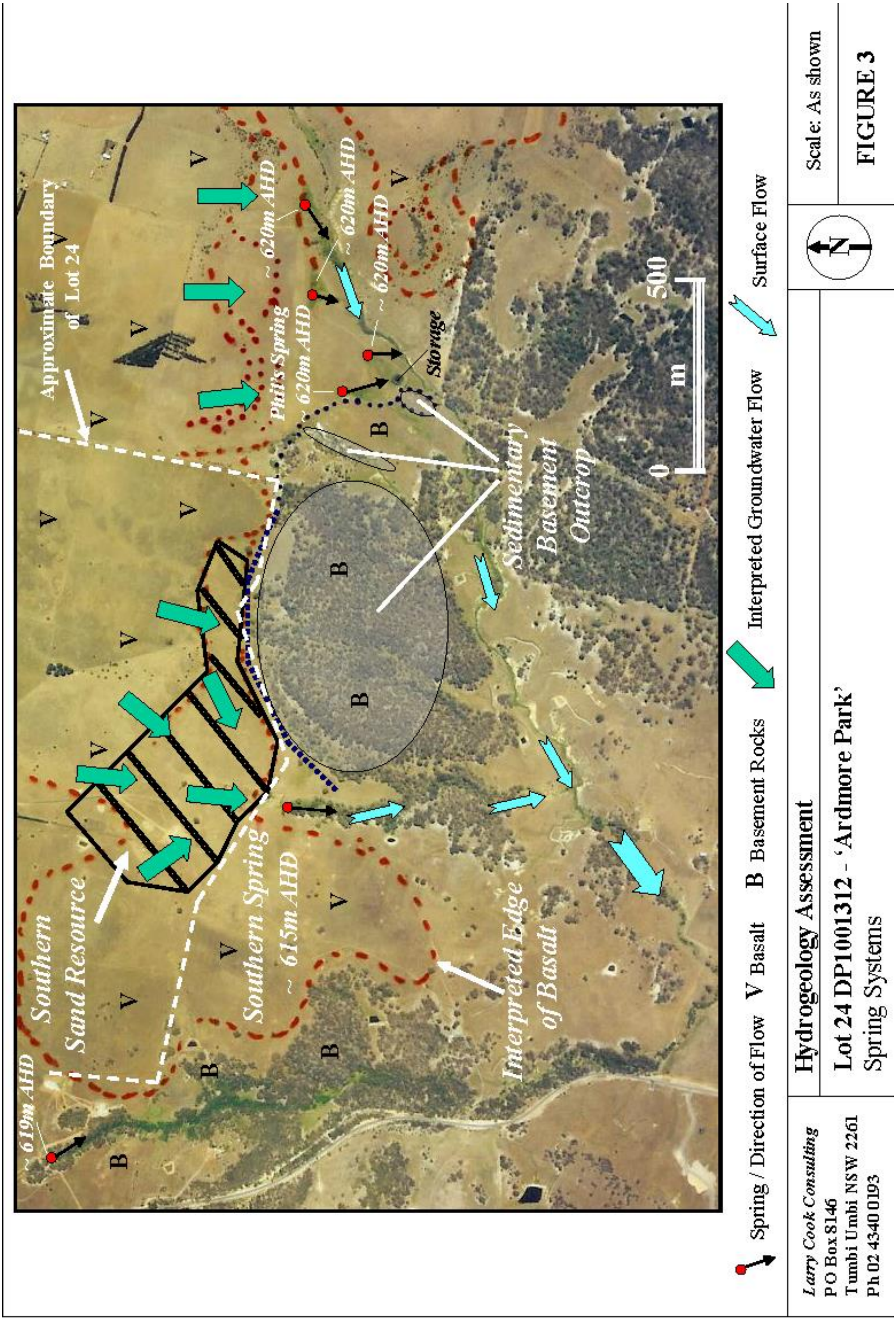


Photo B



Larry Cook Consulting **PO Box 8146** **Tumbi Umbi NSW 2261** **Ph 02 4340 0193**	**Hydrogeological Assessment**	Scale: As shown
	Lot 24 DP1001312 - 'Ardmore Park' Local Geology and Spring Systems	**FIGURE 2**


Approximate Boundary of Lot 24
Phil's Spring
~ 620m AHD
~ 620m AHD
~ 620m AHD
~ 620m AHD
~ 620m AHD
Storage
Sedimentary Basement Outcrop
0
m
500
Southern Sand Resource
Southern Spring
~ 615m AHD
Interpreted Edge of Basalt
~ 619m AHD
V
B
Spring / Direction of Flow
V Basalt
B Basement Rocks
Interpreted Groundwater Flow
Surface Flow
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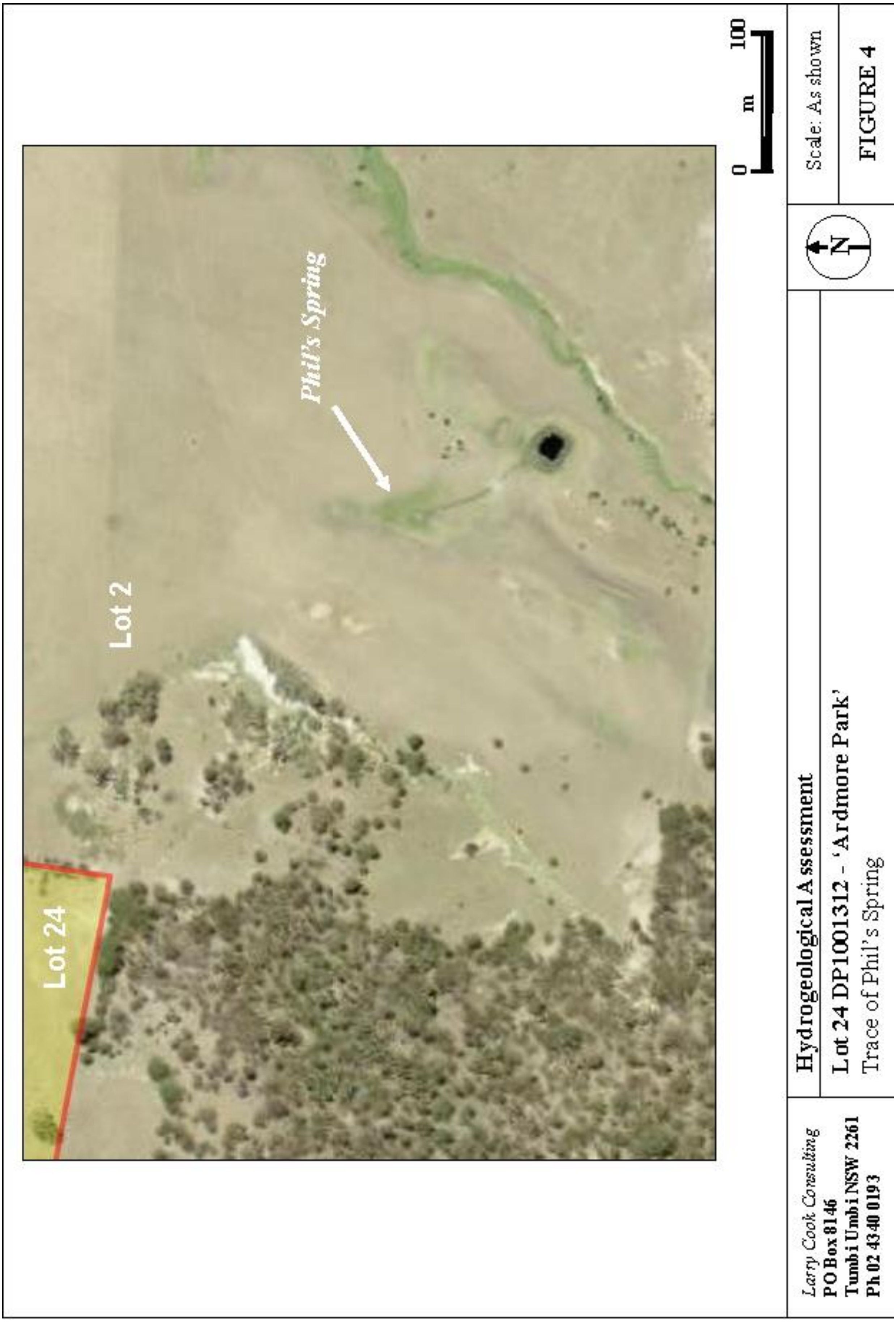
Ph 02 4340 0193
Hydrogeology Assessment
Lot 24 DP1001312 - 'Ardmore Park'
Spring Systems
N
Scale: As shown
FIGURE 3


Phil's Spring
Lot 2
Lot 24
0
m
100
N
Scale: As shown
FIGURE 4
Hydrogeological Assessment
Lot 24 DP1001312 - 'Ardmore Park'
Trace of Phil's Spring
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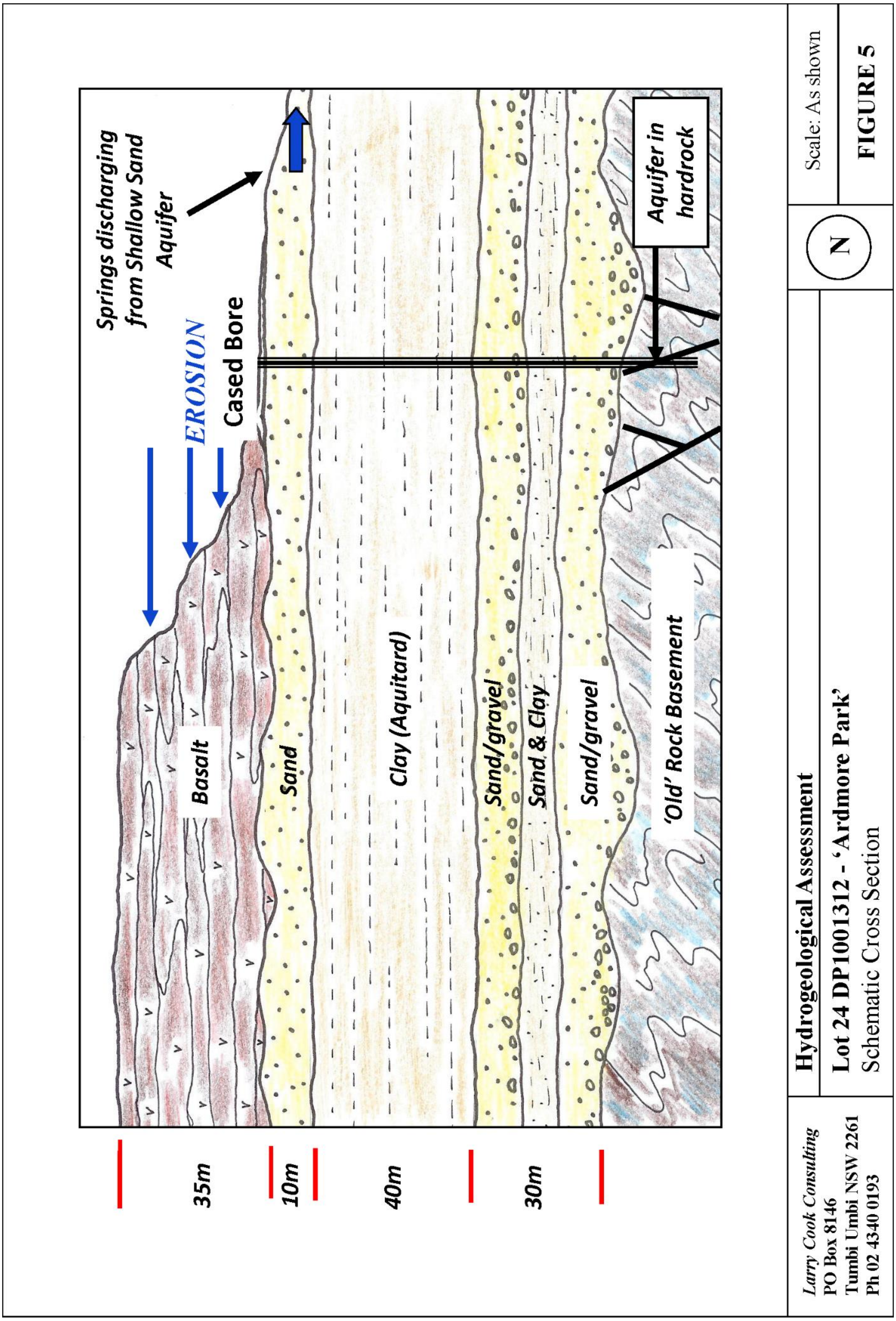
Springs discharging from Shallow Sand Aquifer
EROSION
Cased Bore
Aquifer in hardrock
Basalt
Sand
Clay (Aquitard)
Sand/gravel
Sand & Clay
Sand/gravel
'Old' Rock Basement
35m
10m
40m
30m
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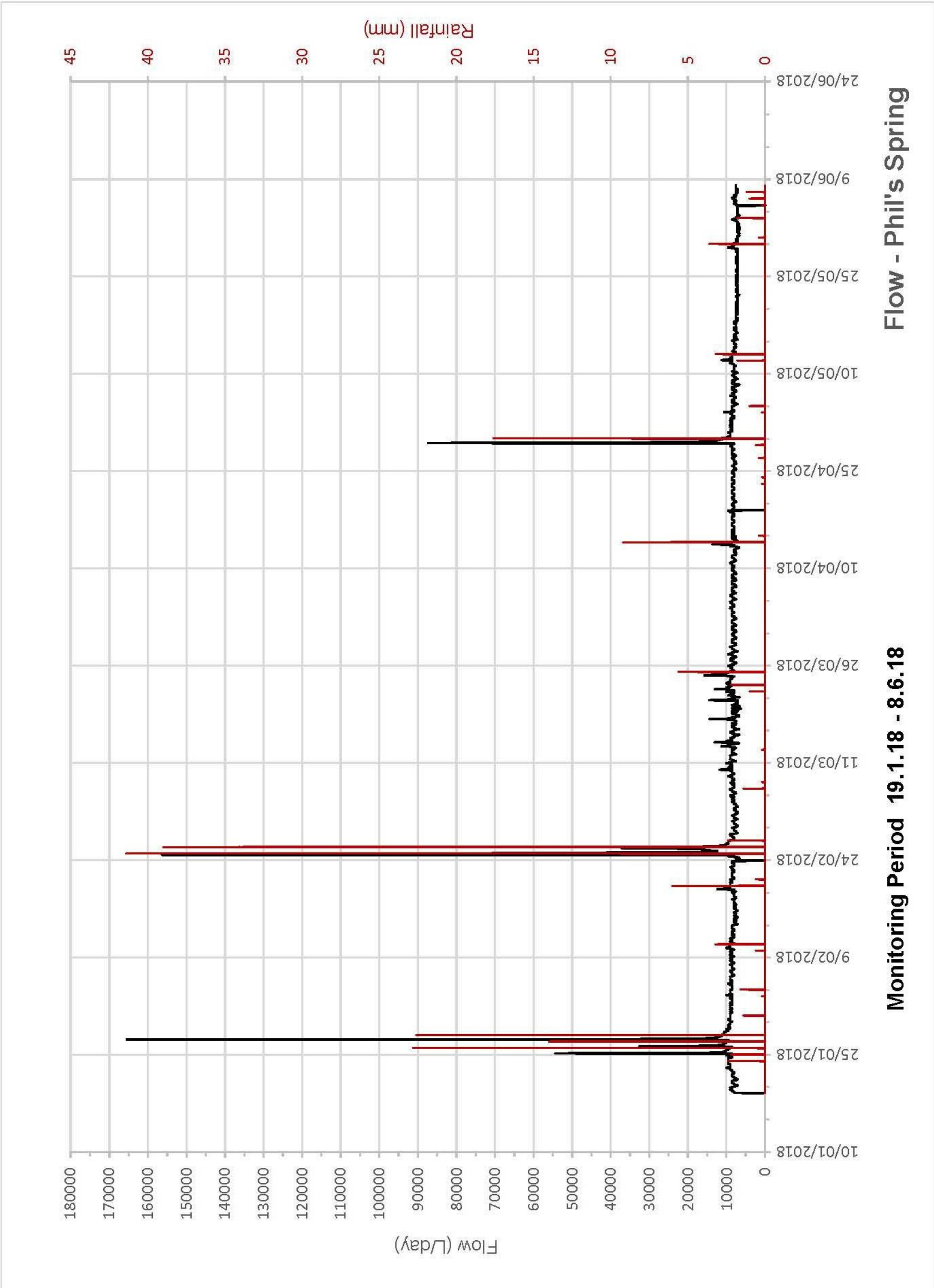
Ph 02 4340 0193
Hydrogeological Assessment
Lot 24 DP1001312 - 'Ardmore Park'
Schematic Cross Section
N
Scale: As shown
FIGURE 5



Scale: As shown

FIGURE 6

N

Hydrogeological Assessment

Lot 24 DP1001312 - 'Ardmore Park'

Flow – Phil's Spring

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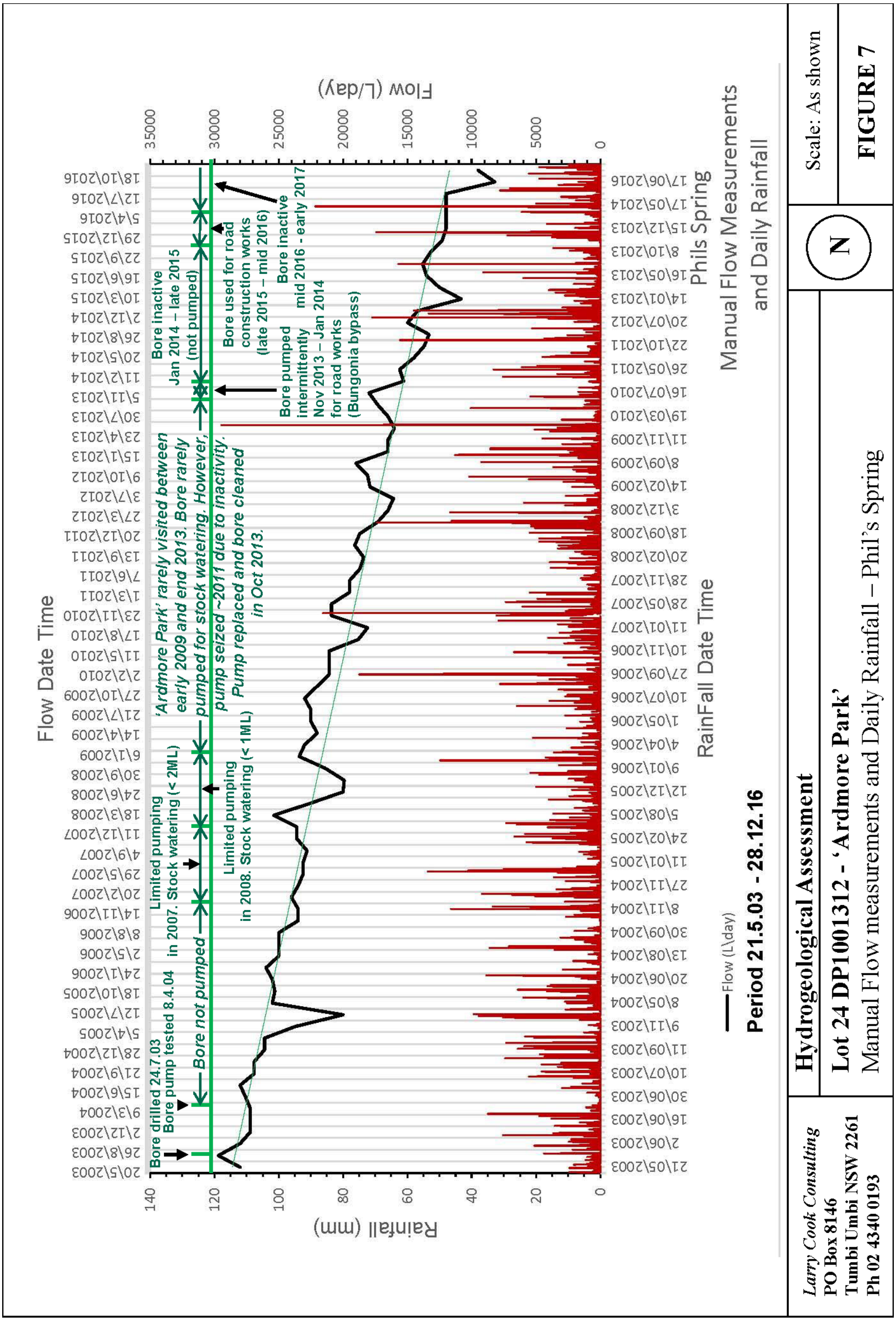
Manual Flow Measurements and Daily Rainfall
Phils Spring
Flow (L/day)
Rainfall (mm)
Flow Date Time
RainFall Date Time
Flow (L\day)
Period 21.5.03 - 28.12.16
Bore drilled 24.7.03
Bore pump tested 8.4.04
Bore not pumped
Limited pumping in 2007. Stock watering (< 2ML)
Limited pumping in 2008. Stock watering (< 1ML)
'Ardmore Park' rarely visited between early 2009 and end 2013. Bore rarely pumped for stock watering. However, pump seized ~2011 due to inactivity. Pump replaced and bore cleaned in Oct 2013.
Bore pumped intermittently Nov 2013 – Jan 2014 for road works (Bungonia bypass)
Bore inactive Jan 2014 – late 2015 (not pumped)
Bore used for road construction works (late 2015 – mid 2016)
Bore inactive mid 2016 - early 2017
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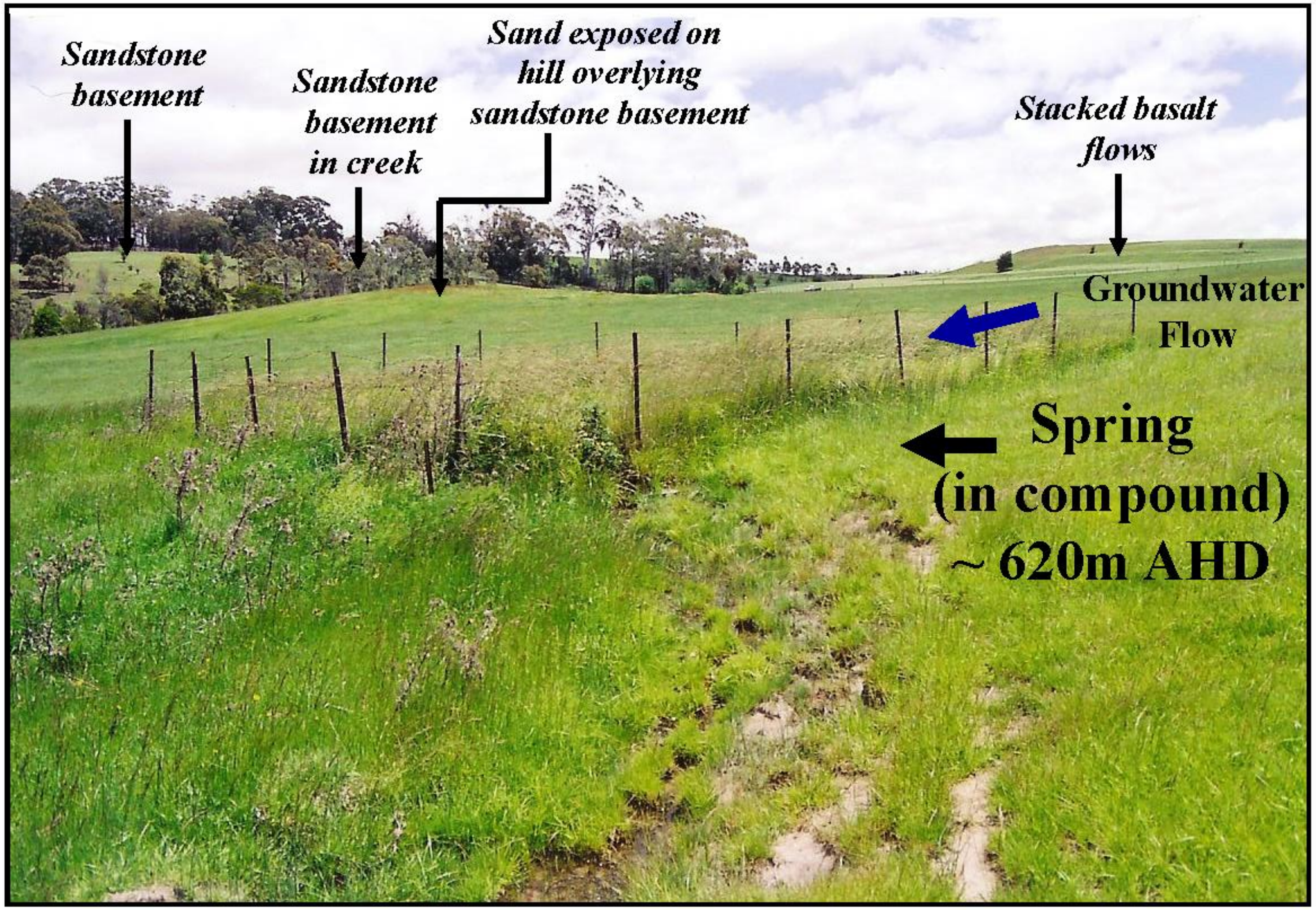
Hydrogeological Assessment
Lot 24 DP1001312 - 'Ardmore Park'
Manual Flow measurements and Daily Rainfall – Phil's Spring
N
Scale: As shown
FIGURE 7



Phil's Spring Flow: Approx. 0.3L/s (240gal/hr) measured manually in 2004.
Historical Daily Flow Range: 20,000L – 29,000L

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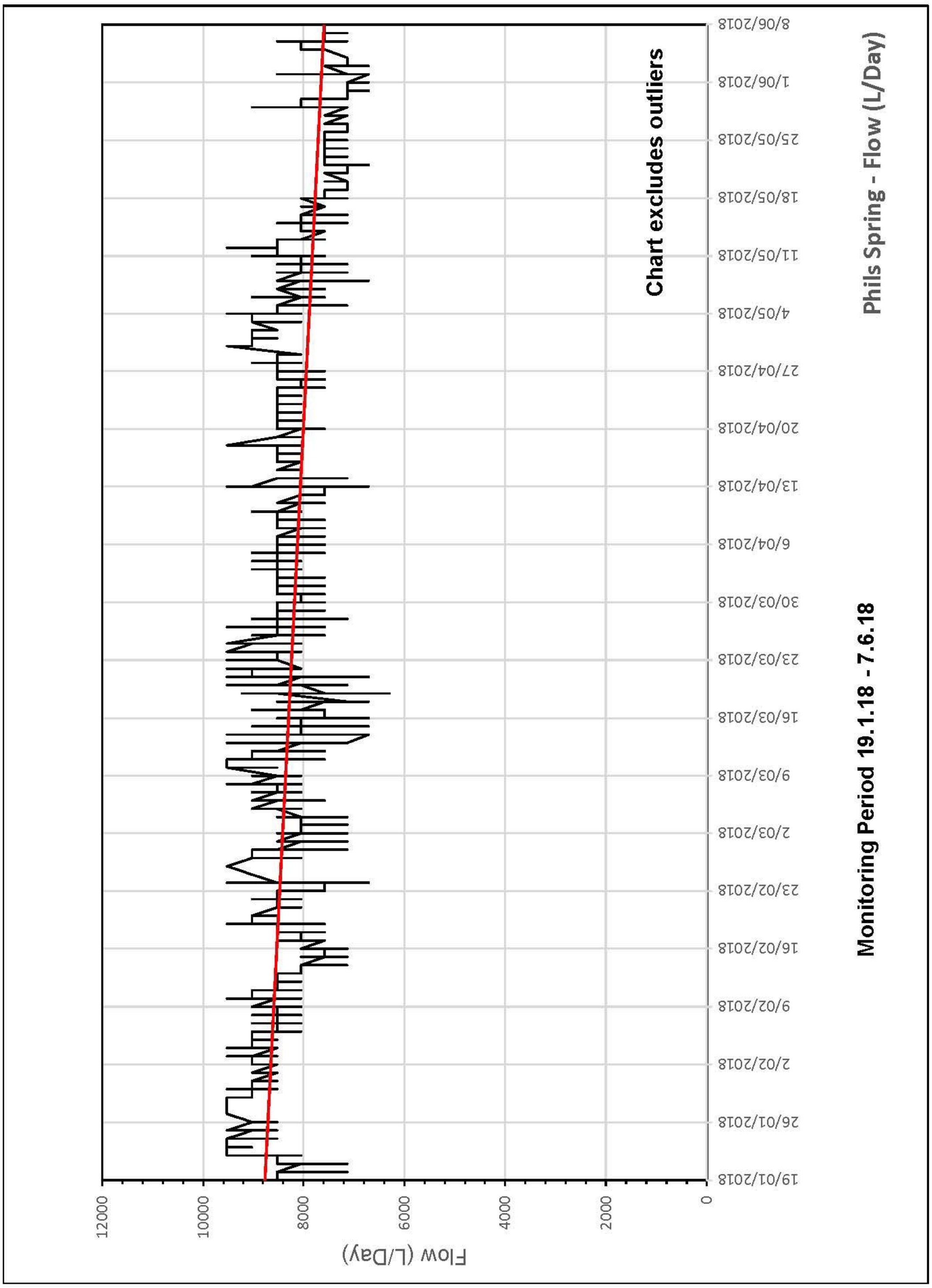

Scale: As shown

FIGURE 9

N

Hydrogeological Assessment

Lot 24 DP1001312 - 'Ardmore Park'

Flow Data Excluding Outliers – Phil's Spring

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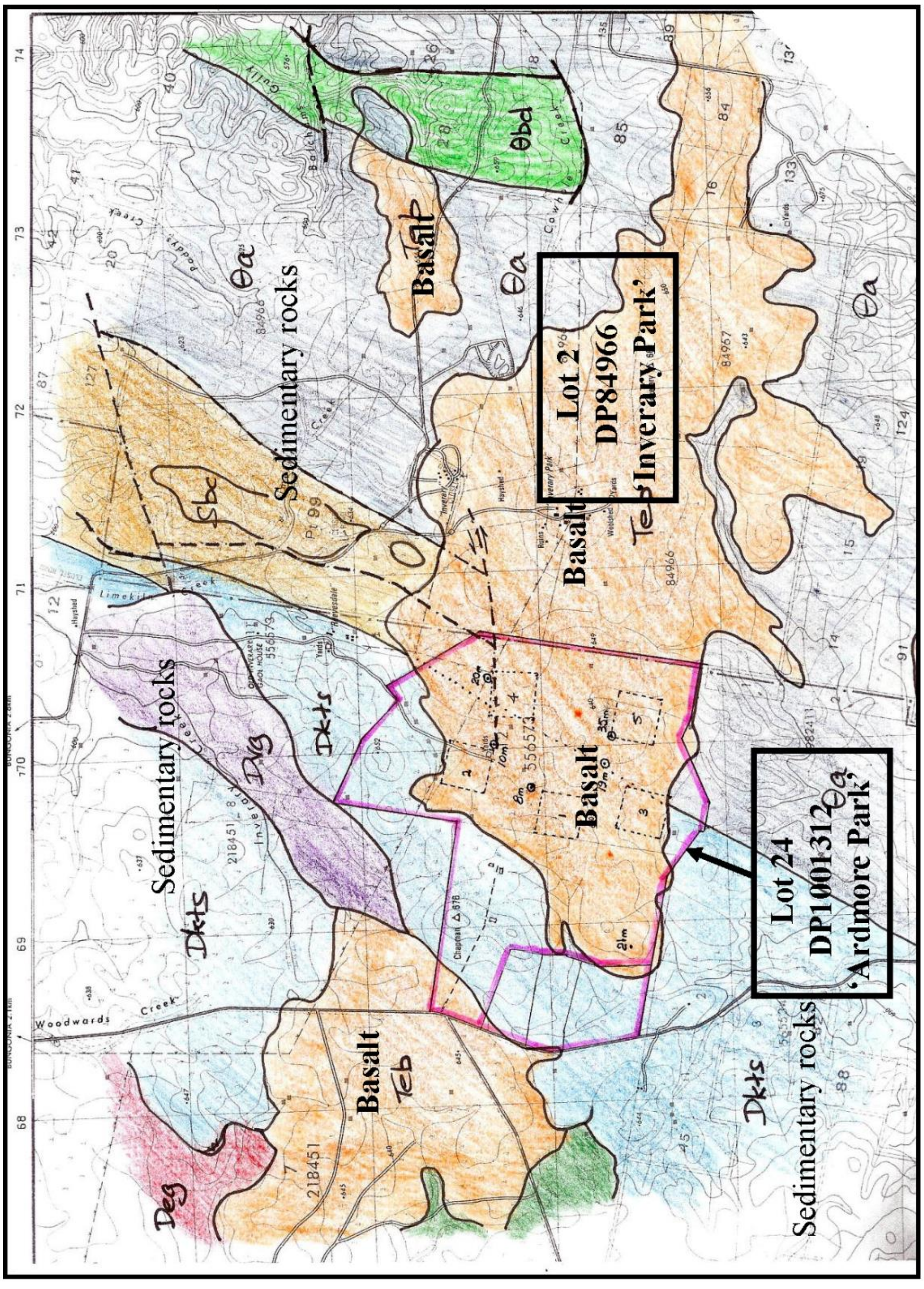

Scale: As shown

FIGURE 10

Hydrogeological Assessment

Lot 24 DP1001312 - 'Ardmore Park'

District Geology

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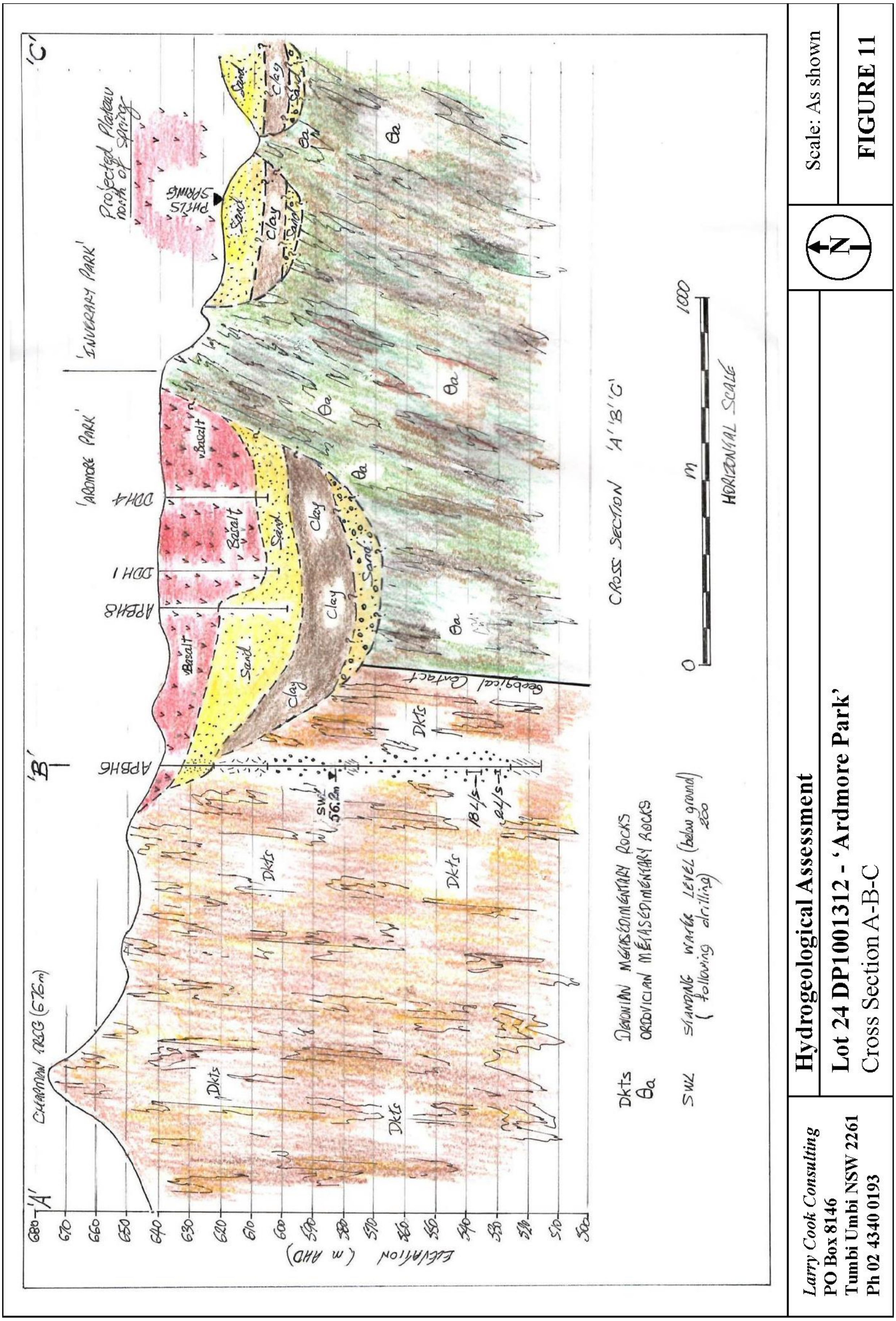

'A'
'B'
'C'
CHAPMAN TRIG (675m)
ARBH6
ARBH8
DDH1
DDH4
'ARDMORE PARK'
'INVERARY PARK'
PHILS SPRING
Projected Plateau north of Spring
Basalt
Sand
Clay
Geological Contact
Dkts
Oa
SWL 56.2m
18 L/s
2 L/s
ELEVATION (m AHD)
680
670
660
650
640
630
620
610
600
590
580
570
560
550
540
530
520
510
500
Dkts DEVONIAN METASEDIMENTARY ROCKS
Oa ORDOVICIAN METASEDIMENTARY ROCKS
SWL STANDING WATER LEVEL (below ground) (following drilling)
CROSS SECTION 'A' 'B' 'C'
0
200
1000
m
HORIZONTAL SCALE
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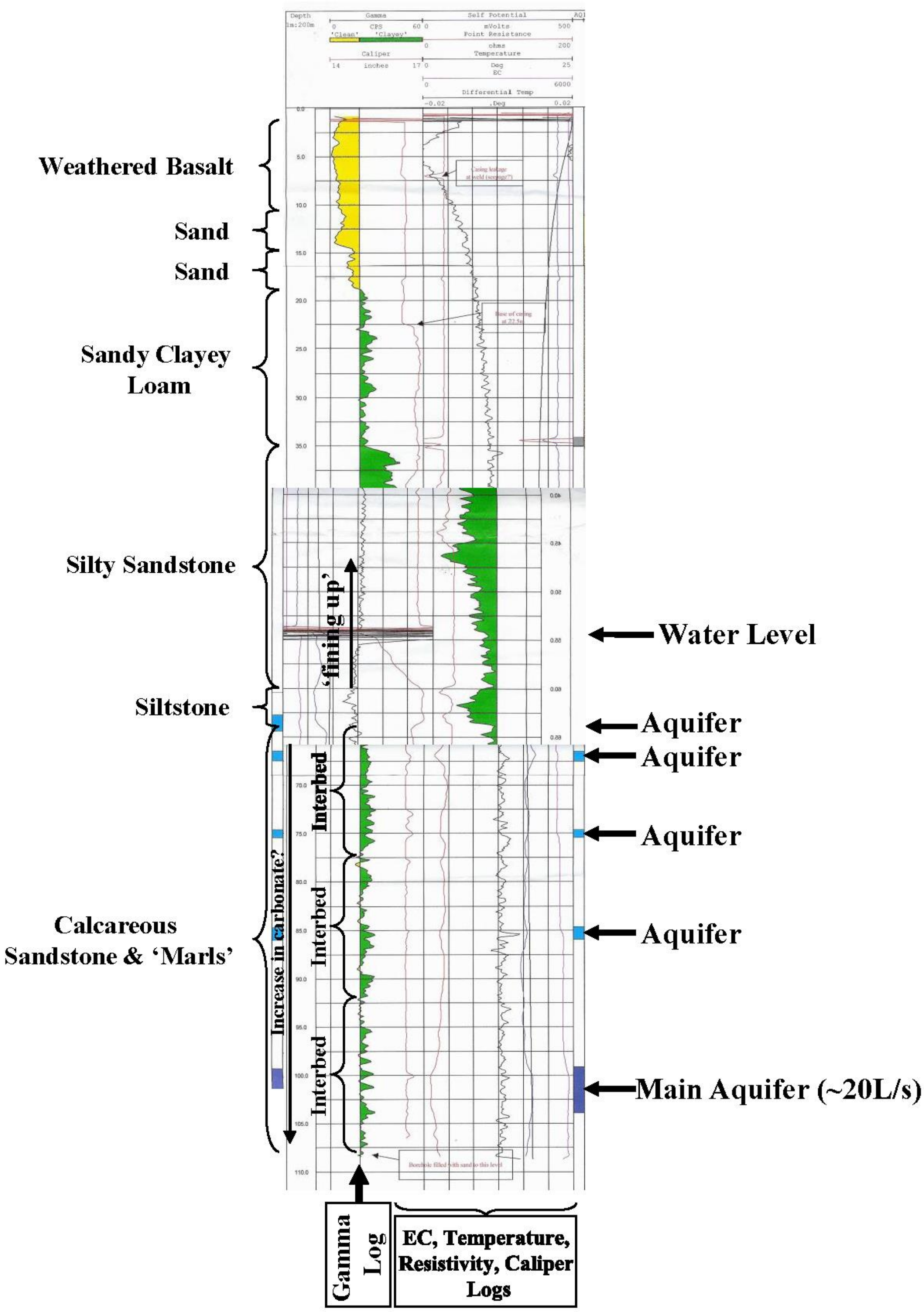
Hydrogeological Assessment
Lot 24 DP1001312 - 'Ardmore Park'
Cross Section A-B-C
Scale: As shown
N
FIGURE 11



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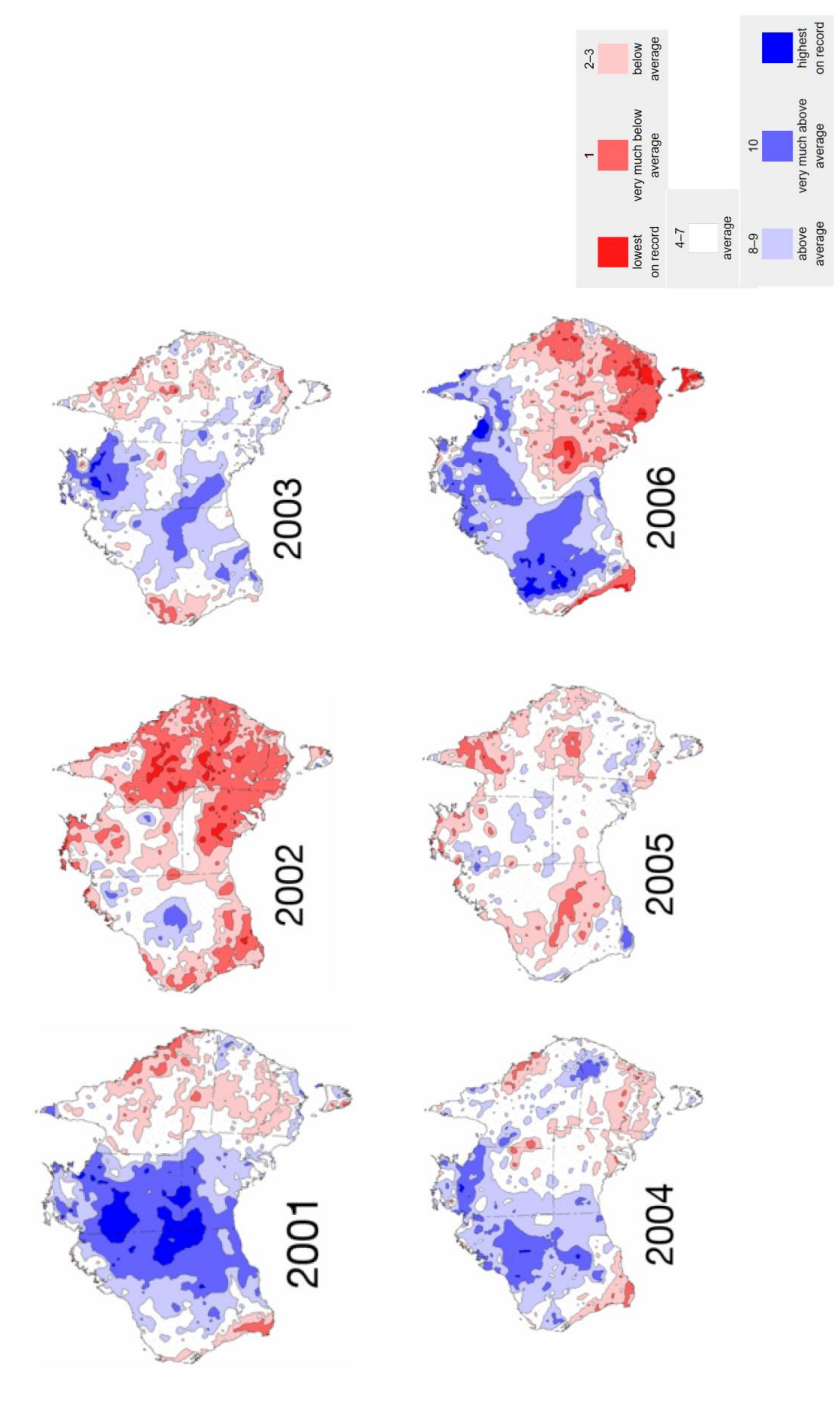
	Lot 24 DP1001312 - 'Ardmore Park' Geophysical Bore Log – BHAP6	**FIGURE 12**



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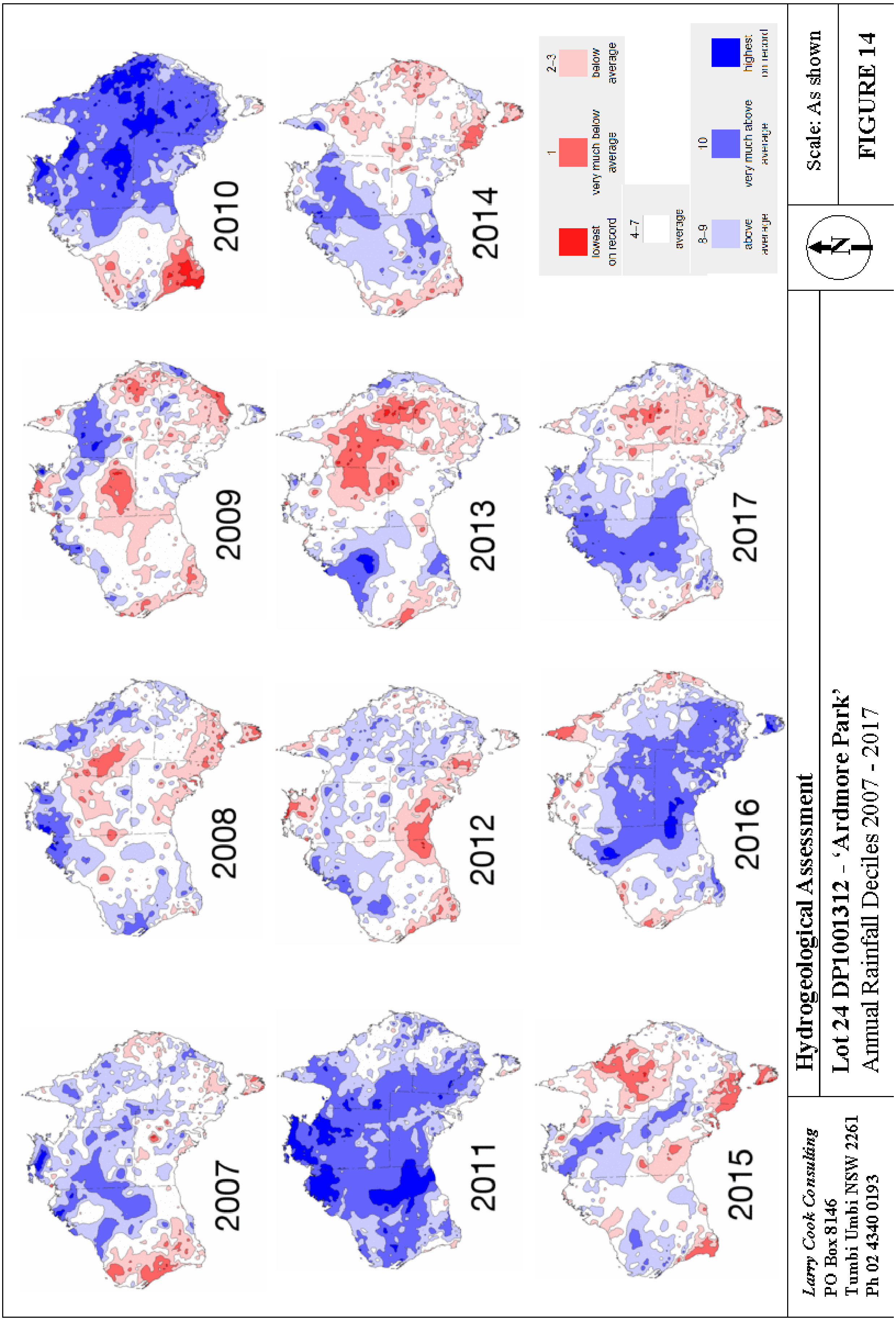
Hydrogeological Assessment
Lot 24 DP1001312 - 'Ardmore Park'
Annual Rainfall Deciles 2001 - 2006

Scale: As shown

FIGURE 13


2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
lowest on record
1 very much below average
2–3 below average
4–7 average
8–9 above average
10 very much above average
highest on record
N
Scale: As shown
FIGURE 14
Hydrogeological Assessment
Lot 24 DP1001312 – 'Ardmore Park'
Annual Rainfall Deciles 2007 - 2017
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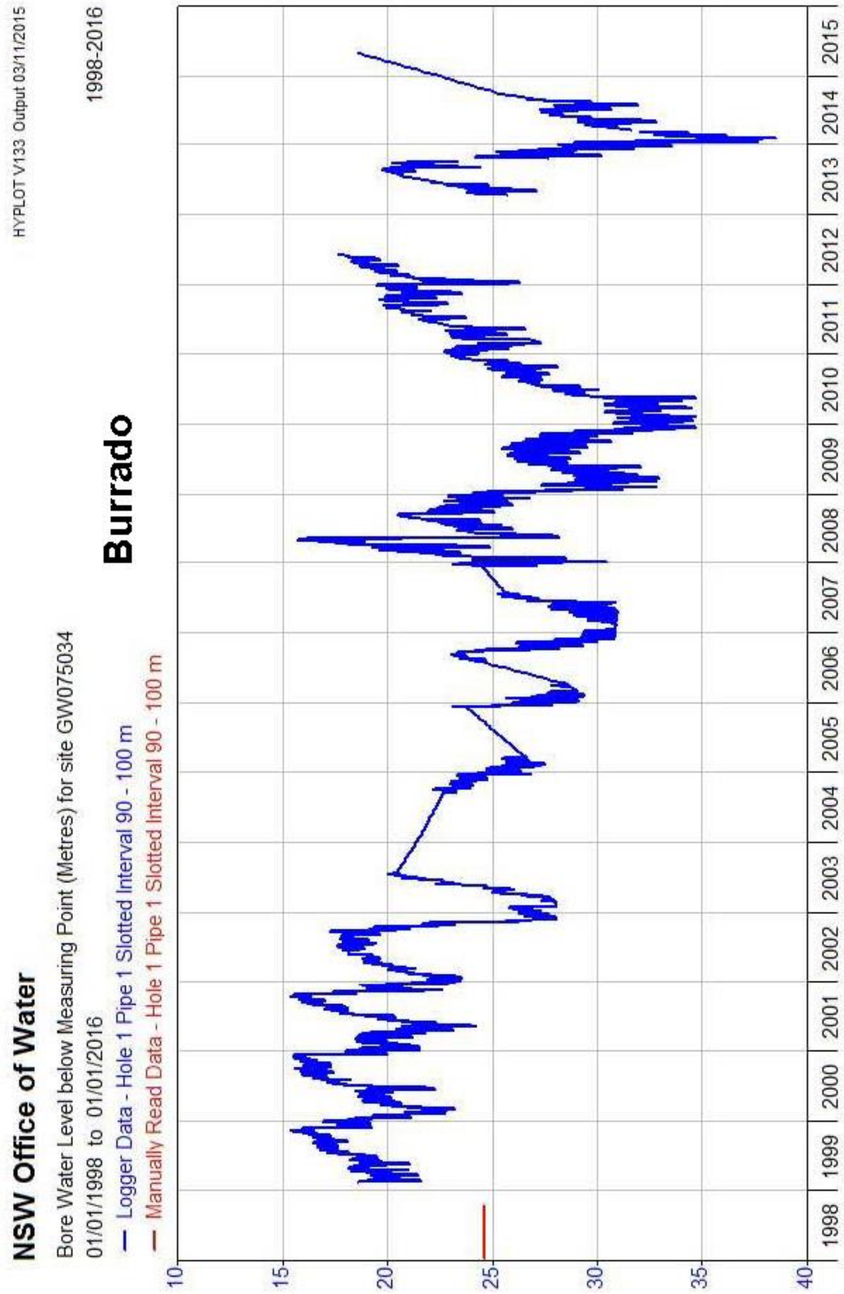

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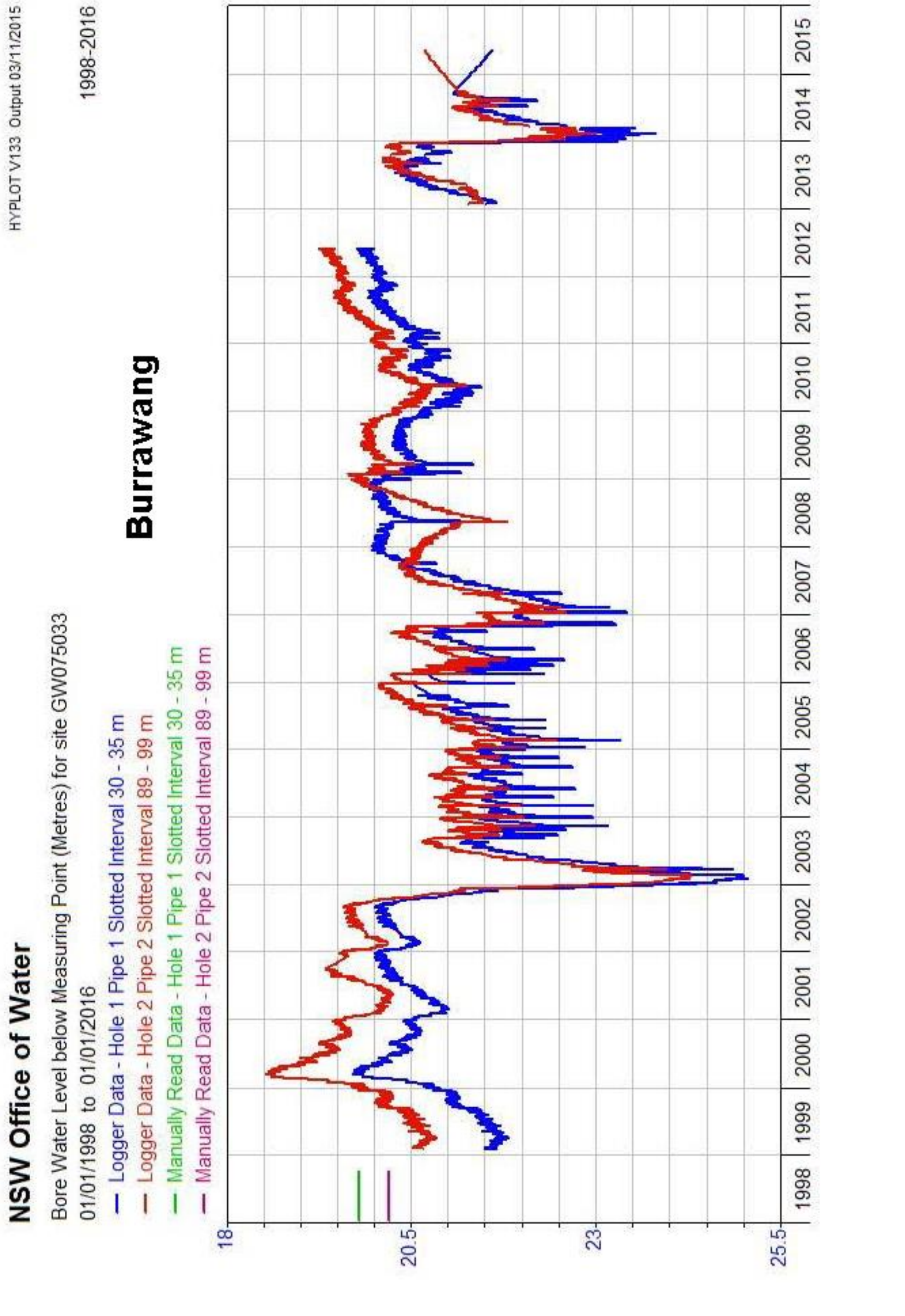
Hydrogeological Assessment
Lot 24 DP1001312 - 'Ardmore Park'
Hydrograph GW075034 - Burrado

Scale: As shown

FIGURE 15



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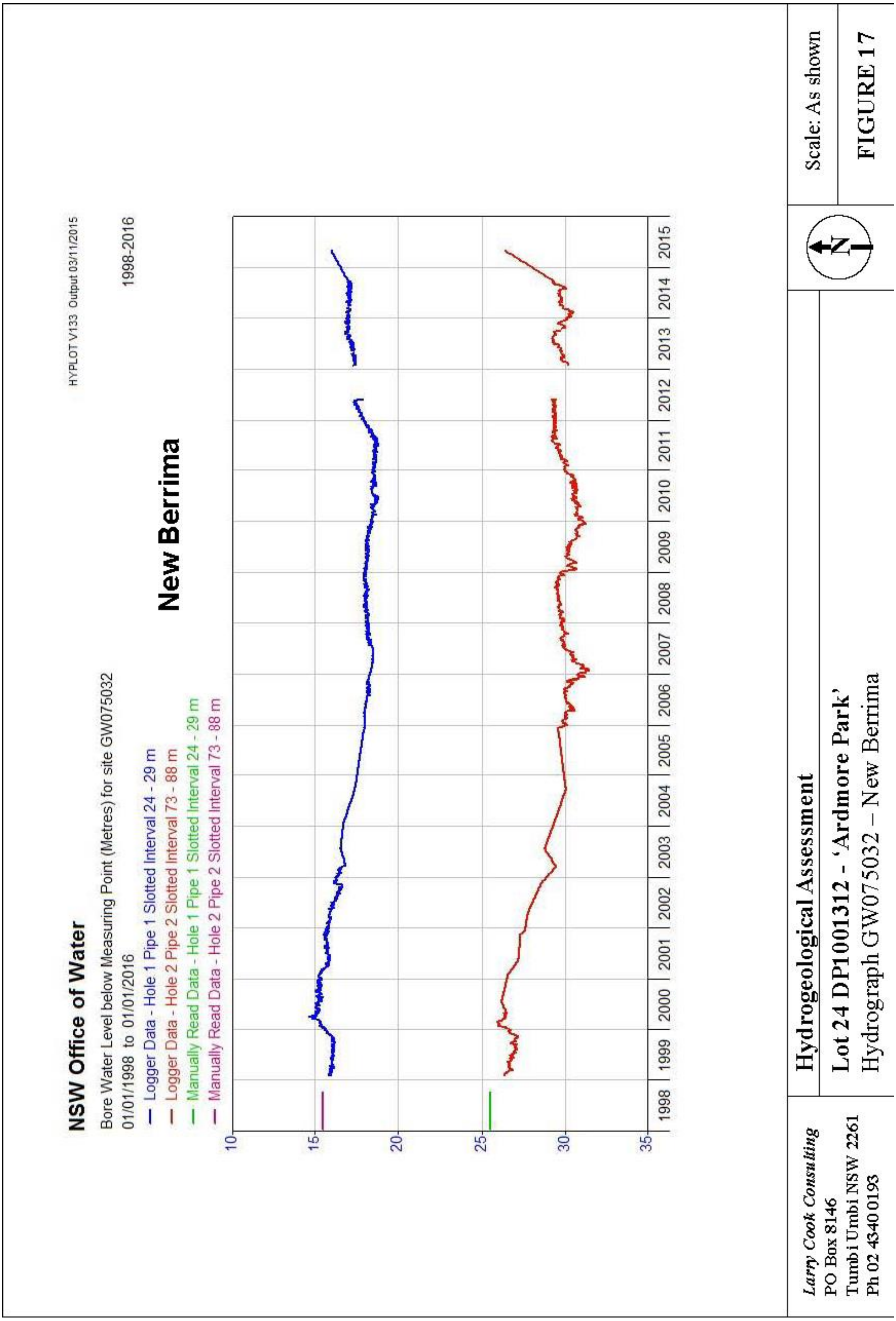
Hydrogeological Assessment

Lot 24 DP1001312 – 'Ardmore Park'

Hydrograph GW075033- Burrawang

Scale: As shown

FIGURE 16



NSW Office of Water
Bore Water Level below Measuring Point (Metres) for site GW075032
01/01/1998 to 01/01/2016
— Logger Data - Hole 1 Pipe 1 Slotted Interval 24 - 29 m
— Logger Data - Hole 2 Pipe 2 Slotted Interval 73 - 88 m
— Manually Read Data - Hole 1 Pipe 1 Slotted Interval 24 - 29 m
— Manually Read Data - Hole 2 Pipe 2 Slotted Interval 73 - 88 m
New Berrima
HYPLOT V133 Output 03/11/2015
1998-2016
10
15
20
25
30
35
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
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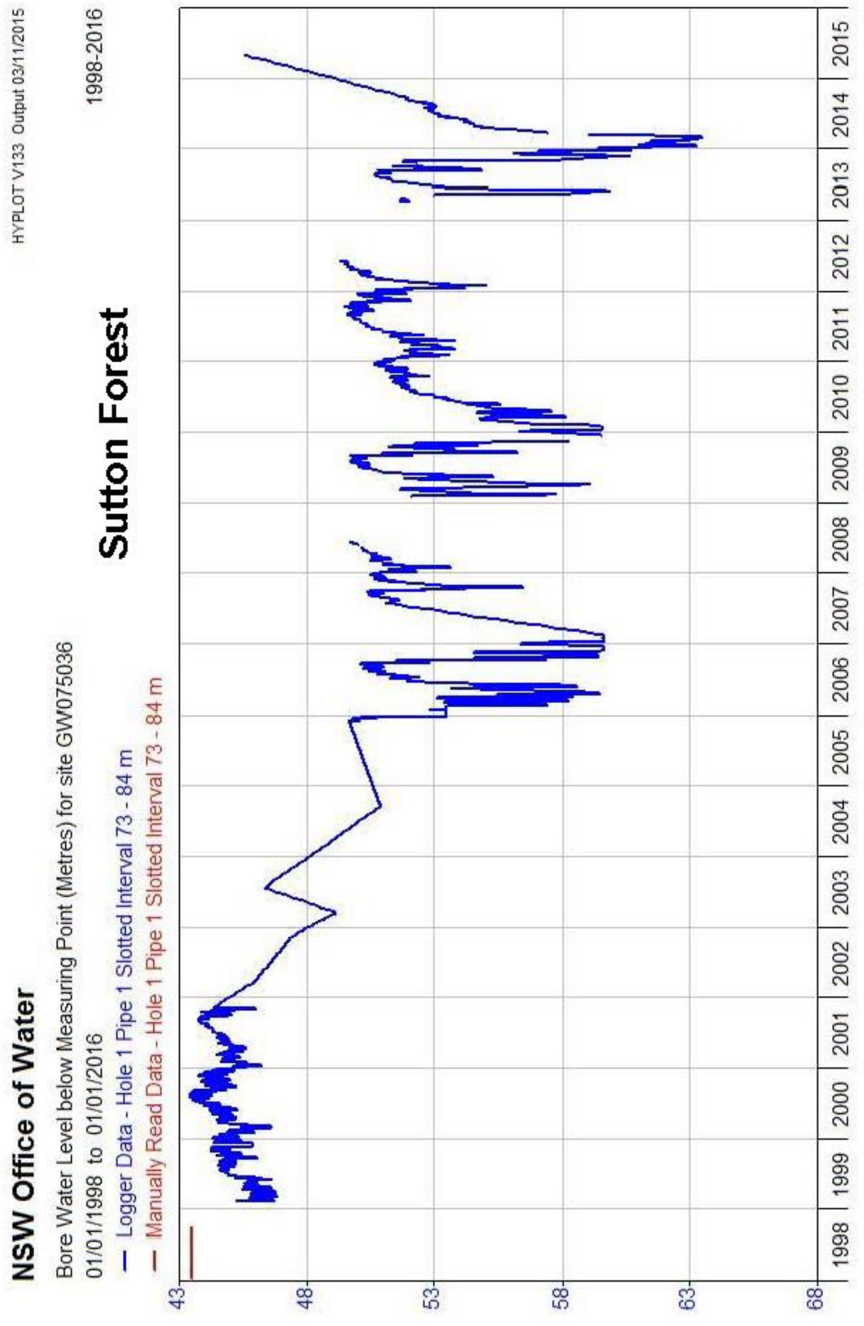
Hydrogeological Assessment
Lot 24 DP1001312 - 'Ardmore Park'
Hydrograph GW075032 – New Berrima
N
Scale: As shown
FIGURE 17



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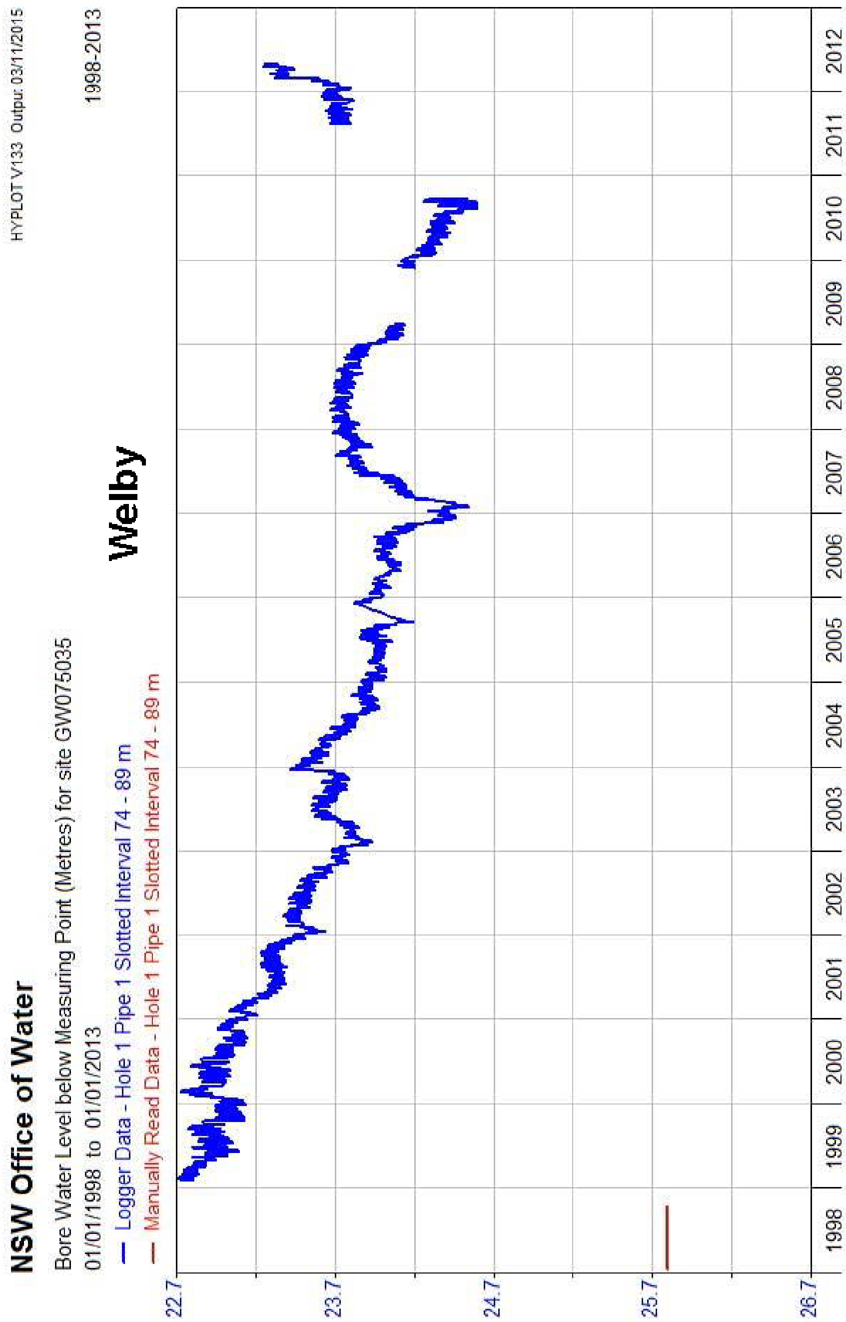
Hydrogeological Assessment
Lot 24 DP1001312 - 'Ardmore Park'
Hydrograph GW075036 – Sutton Forest

N

Scale: As shown

FIGURE 18



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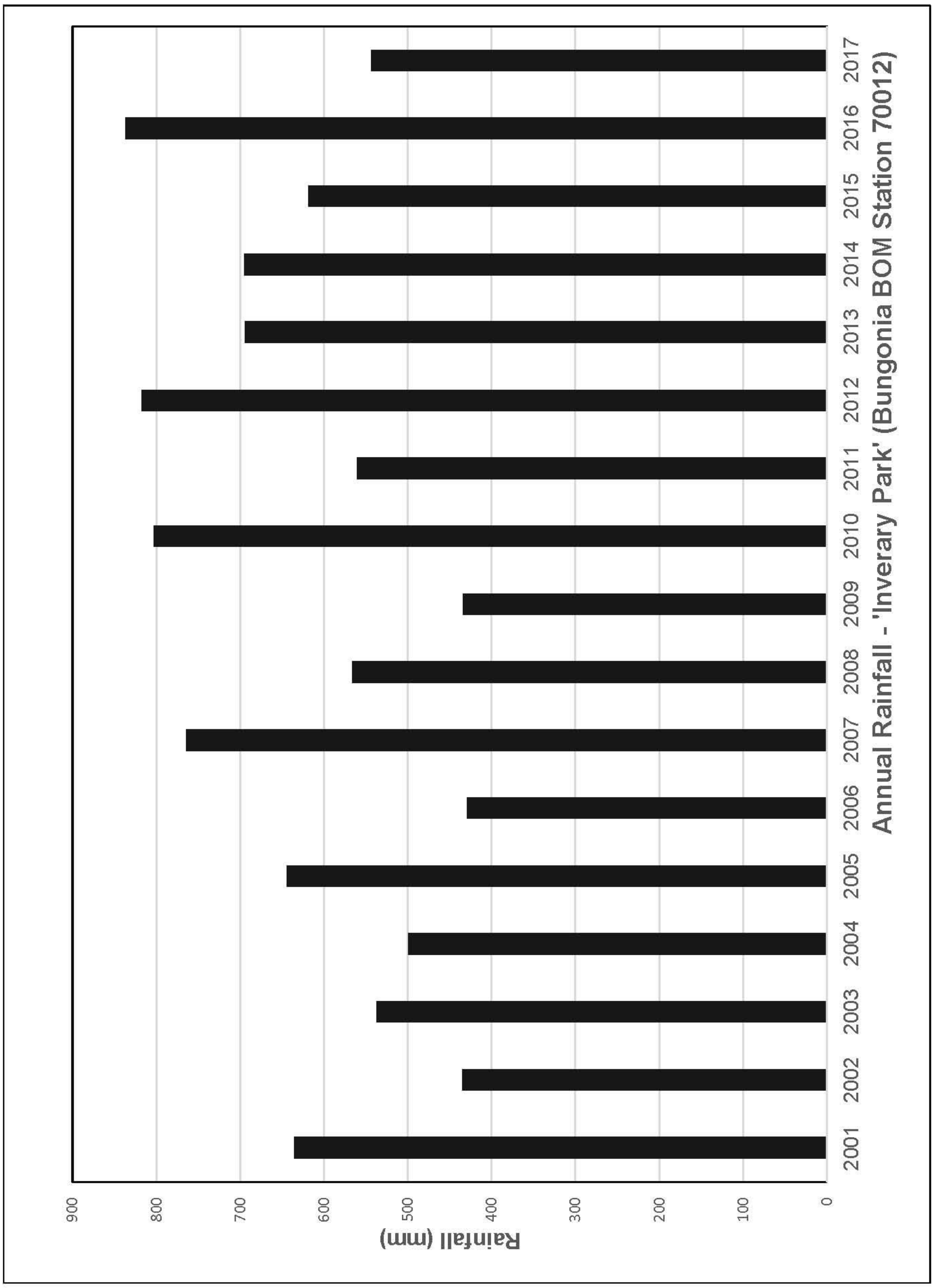
Hydrogeological Assessment
Lot 24 DP1001312 - 'Ardmore Park'
Hydrograph GW075035 - Welby

N

Scale: As shown
FIGURE 19



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Hydrogeological Assessment

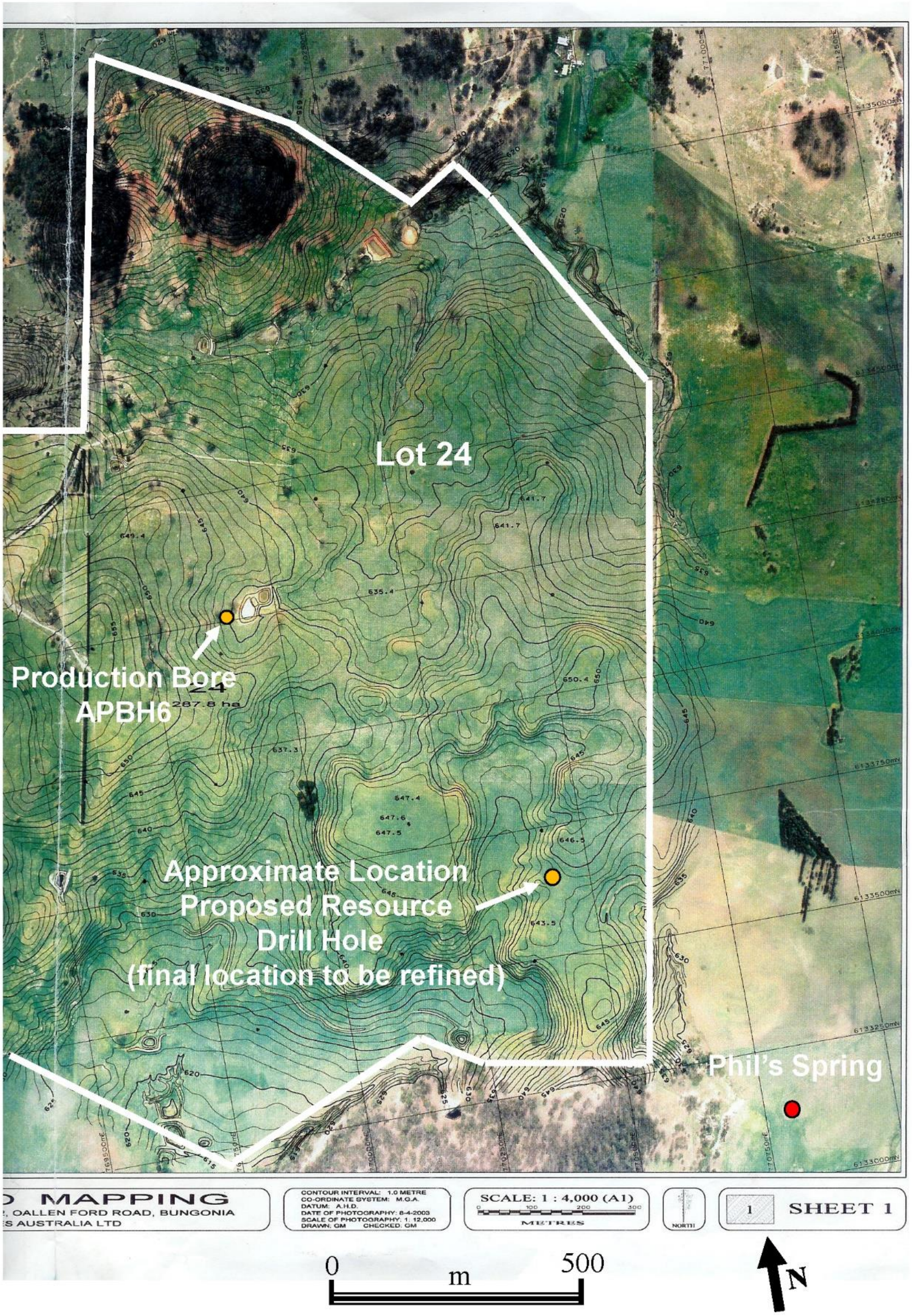
Lot 24 DP1001312 - 'Ardmore Park'

Annual Rainfall – 'Inverary Park' 2001 - 2017

N

Scale: As shown

FIGURE 20



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	Lot 24 DP1001312 - 'Ardmore Park' Proposed Resource Drill Hole	**FIGURE 21**