APPENDIX H. GROUNDWATER MONITORING SUMMARY

Pardoo Beef Corporation Pty Ltd

Groundwater Monitoring Summary 2016
Irrigation Project
Pastoral Lease 3114/46 - Pardoo Station
Shire of East Pilbara, Western Australia

FINAL

GCS Project Number: PBC005
DoW Reference: RF13415
Report Date: May 2017

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1. INTRODUCTION

Pardoo Beef Corporation Pty Ltd uses the artesian groundwater resources of the Wallal aquifer for an irrigated fodder project at Pardoo Station which is located 100km east of Port Hedland on the Great Northern Highway in the Shire of East Pilbara *(Figure 1, Appendix A)*. Pardoo Beef Corporation purchased the lease for Pardoo Station in March 2015.

The use of groundwater from the Wallal aquifer was authorised under the terms and conditions of Groundwater Well Licence 158616(11) (*Table 1.1)* which was issued to Pardoo Beef Corporation on 20 March 2015 and subsequent licences listed in *Table 1.1*. A condition of each Groundwater Well Licence is that a groundwater monitoring summary is provided to the Department of Water each year. This report is a groundwater monitoring summary for the 2016 water year from 1 January 2016 to 1 January 2017. Groundwater Consulting Services has prepared annual groundwater monitoring reports for the project on behalf of Pardoo Beef Corporation and the previous leaseholder since 2012.

1.1 STAGE 1A DEVELOPMENT

The previous leaseholder completed Stage 1a of the irrigated fodder project *(Figure 2a, Appendix A)*. Two irrigation bores, Pardoo PB1 and Pardoo PB2, were installed in the Wallal aquifer and each bore supplies a 43 ha (Pivot 1) or 40 ha (Pivot 2) centre-pivot irrigator *(Figure 2b, Appendix A).* Irrigation of the Stage 1a pivot areas commenced in August 2012. The last crops planted by the previous leaseholder were harvested by Pardoo Beef Corporation in April/May 2015. In late 2015, Pardoo Beef Corporation planted their first fodder crops since taking over the lease and the pivot areas have been in full production since that time.

The fodder on Pivots 1 and 2 is cut and baled for use on Pardoo Station.

1.2 STAGE 1B DEVELOPMENT

The Stage 1b development was completed in the 2016 water year. Four additional 40-ha pivot areas (Pivots 3 to 6) were developed adjacent to the two existing Stage 1a pivot areas *(Figure 2b, Appendix A)*. A total of 243 ha is under irrigation in the Stage 1 development.

Austral Drilling Services installed two Wallal aquifer irrigation bores (Pardoo PB3 and Pardoo PB4) between October and December 2015. Irrigation bore Pardoo PB3 supplies the centre-pivot irrigators on Pivot 3 and Pivot 6. Irrigation bore Pardoo PB4 supplies the centre-pivot irrigators on Pivot 4 and Pivot 5.

Planting on Pivots 3, 4 and 6 commenced in July 2016 and on Pivot 5 in August 2016 (*Table 1.3).*

Table 1.1 Summary of Groundwater Well Licences

Item	Licence in-force at start of 2016 water year Groundwater Well Licence 158616(11)	Interim Stage 2 Licence Groundwater Well Licence 158616(14)	Current In-force Licence Groundwater Well Licence 158717(16)
Licensee	Pardoo Beef Corporation Pty Ltd	Pardoo Beef Corporation Pty Ltd	Pardoo Beef Corporation Pty Ltd
Department of Water Reference	RF13415	RF13415	RF13415
Groundwater Management Area	Canning-Kimberley	Canning-Kimberley	Canning-Kimberley
Groundwater Management Subarea	West Canning	West Canning	West Canning
Aquifer	Wallal aquifer	Wallal aquifer	Wallal aquifer
Location of Water Source	Pastoral Lease 3114/446 - Pardoo Station	Pastoral Lease 3114/446 - Pardoo Station	Pastoral Lease 3114/446 - Pardoo Station
Licence Allocation	**7,740,000 kL/annum**	**10,000,000 kL/annum**	**14,822,250 kL/annum**
Purpose	Caravan park purposes Commercial purposes Domestic use Irrigation of up to 243 ha of pasture Irrigation of up to 5 ha of lawns and gardens Stock watering.	Caravan park purposes Commercial purposes Domestic use Irrigation of up to 593 ha of pasture Irrigation of up to 5 ha of lawns and gardens Stock watering.	Caravan park purposes Commercial purposes Domestic use Irrigation of up to 893 ha of pasture Irrigation of up to 5 ha of lawns and gardens Stock watering.
Licence Duration	20 March 2015 to 31 December 2017	27 June 2016 to 31 December 2018	25 January 2017 to 24 January 2027
Summary of Key Conditions	• The licensee shall comply with the commitments or requirements of the **operating strategy approved by the Department of Water on 30 November 2009** including any modifications to the commitments as approved during the term of the licence. • The licensee shall comply with the Pardoo Station staged development program as approved by the Department of Water on 30 May 2011 and any subsequent approved modifications. • Every 1 year(s) the licensee shall provide to the Department of Water a groundwater monitoring summary for the preceding year. The first report is due 31 March 2015. • Every 3 year(s) the licensee shall provide to the Department of Water a groundwater monitoring review. The first report is due 31 March 2017. • The licensee is to provide the approved diversification permit to the Department of Water prior to undertaking any abstraction for Stage 1b of the Pardoo irrigation project.	• Every 1 year(s) the licensee shall provide to the Department of Water a groundwater monitoring summary for the preceding water year. The first report is due **31 March 2017**. • The licensee shall provide an updated operating strategy to the Department of Water for approval by **30 September 2016.** The strategy shall be prepared in accordance with Department of Water's Operational Policy 5.08 'Use of Operating Strategies in the water licensing process'. *Draft operating strategy submitted to the Department of Water in August 2016 (Groundwater Consulting Services, 2016b).* • The licensee is to provide the approved diversification permit to the Department of Water prior to undertaking any abstraction for Stage 1b of the Pardoo irrigation project. • If the Department is satisfied that the licensee has not complied with their schedule of water use, it shall notify the licensee in writing of this fact within 2 months after the licensee has presented its compliance report to the Department, and any other evidence requested by the Department, and the Department may specify an alternative maximum annual volume of water use for the coming year.	• Every 1 year(s) the licensee shall provide to the Department of Water a groundwater monitoring summary for the preceding water year. The first report is due **31 March 2017**. • The licensee shall provide an updated operating strategy to the Department of Water for approval by **31 May 2017**. The strategy shall be prepared in accordance with Department of Water's Operational Policy 5.08 'Use of Operating Strategies in the water licensing process'.

Table 1.2 Groundwater development schedule

<table>
<tr><td colspan="6">DEVELOPMENT SCHEDULE
Development of Stage 2 is contingent on:
- Permit to clear native vegetation, Diversification Permit.</td></tr>
<tr><td colspan="3">STAGE</td><td>Current and on-going</td><td>2015-2016</td><td>2017</td><td>2018</td></tr>
<tr><td rowspan="3">Current development area - north of WCB17</td><td rowspan="3">STAGE 1</td><td>1A (Completed)</td><td colspan="4">Existing Pivots 1 and 2 (total 83ha)</td></tr>
<tr><td rowspan="2">1B (Completed)</td><td></td><td colspan="3">Pivots 3 and 4 (additional 80ha, total 163ha)</td></tr>
<tr><td colspan="2"></td><td colspan="2">Pivots 5 and 6 (additional 80ha, total 243ha)</td></tr>
<tr><td>East of Stage 1 area.</td><td colspan="2">STAGE 2 (IN PROGRESS)</td><td colspan="2"></td><td colspan="2">Additional 6 x 50 ha pivot areas (additional 300 ha, total 543ha).</td></tr>
<tr><td>West of Stage 1 area.</td><td colspan="2">STAGE 3</td><td colspan="3"></td><td>An additional 4 x 50 ha and 3 x 40 ha pivot areas (additional 320 ha). Total project area is 863 ha.</td></tr>
<tr><td colspan="7">GROUNDWATER REQUIREMENT (kL/annum)
Based on 17,000 kL/ha/annum irrigation application rate.</td></tr>
<tr><td colspan="3">STAGE</td><td>Current and on-going</td><td>2015-2016</td><td>2017</td><td>2018</td></tr>
<tr><td rowspan="4">Irrigation Water Requirement</td><td rowspan="2">STAGE 1</td><td>1A (Completed)</td><td>2,241,000*</td><td>2,241,000*</td><td>1,411,000</td><td>1,411,000</td></tr>
<tr><td>1B (Completed)</td><td></td><td>4,320,000*</td><td>2,720,000</td><td>2,720,000</td></tr>
<tr><td colspan="3">STAGE 2 (IN PROGRESS)</td><td colspan="2"></td><td>5,100,000</td><td>5,100,000</td></tr>
<tr><td colspan="3">STAGE 3</td><td colspan="3"></td><td>5,440,000</td></tr>
<tr><td colspan="3">Additional stock / garden / accommodation allowance</td><td>161,250</td><td>161,250</td><td>151,250</td><td>151,250</td></tr>
<tr><td colspan="3">TOTAL (kL/annum):</td><td>2,402,250*</td><td>6,772,250*</td><td>9,382,250</td><td>14,822,250</td></tr>
<tr><td colspan="3">STATUS:</td><td colspan="2">Superseded Licence GWL 158616(11)
7,740,000 kL/annum
* Based on application rate of 27,000 kL/ha/annum for intensive hay production by previous site operator.</td><td colspan="2">Licence Issued
GWL 158616(16) 14,822,250 kL/annum
Based on irrigation application rate of 17,000 kL/ha/annum which may not be achievable in dry years. The number of active pivot areas or pivot size for the Stage 3 development may be reduced based on the outcomes of the Stage 2 development.</td></tr>
</table>

Table 1.3 Crop status

Date of Site Visit	Status of crop production					
	Pivot 1 (43 ha)	**Pivot 2 (40 ha)**	**Pivot 3 (40 ha)**	**Pivot 4 (40 ha)**	**Pivot 5 (40 ha)**	**Pivot 6 (40 ha)**
24 to 29 January 2016	Young sorghum crop.	Harvesting and baling of sorghum crop.	-	-	-	-
3 to 7 April 2017	Young sorghum crop.	Sorghum residue	-	-	-	-
12 to 14 July 2016	Cultivating	Cultivating	Pivot 3 planted.	Pivot 4 young crop.	Pivot 5 not yet commissioned.	Pivot 6 planted.
14 and 15 October 2016	Dry oats 50% harvested	Cultivated ready to plant	Cell grazing active.	Cell grazing active.	Cell grazing active.	Cell grazing active.
10 to 14 February 2017	Sorghum	Sorghum	Cell grazing active.	Cell grazing active.	Cell grazing active.	Cell grazing active.

The Stage 1b pivot areas (Pivot 3 to Pivot 6) are used as a stand-and-graze operation, with cattle grazing directly on the pivot area. The cattle graze in a discrete cell within the pivot area and are then rotated to the next cell which has regrown since it was last grazed. The number of cattle and rotation cycle must be balanced to optimise cattle production. Rhodes grass is the predominant crop grown on the stand-and-graze pivots with lesser quantities of panic and Lucerne. Excess fodder is baled.

1.3 STAGE 2 DEVELOPMENT

In the 2016 water year, Pardoo Beef Corporation commenced the approvals process for the Stage 2 development and is waiting for the Department of Environment Regulation to issue a Permit to Clear Native Vegetation before clearing of the pivot areas can commence. A Diversification Permit, to be issued by the Department of Lands, has been approved in principle but cannot be issued until the Permit to Clear Native Vegetation has been issued.

Pardoo Beef Corporation is working through an administrative process to convert the wider area encompassing the irrigation project to freehold.

The Stage 2 development involves the installation of six 50 ha pivot areas (Pivots 7 to 12) at a distance of 3.1 km east of the Stage 1 development area *(Figure 2b, Appendix A).* The full groundwater allocation (14,822,250 kL/annum) required for the Stage 2 expansion was released by the Department of Water in January 2017 (*Table 1.2).*

Three Wallal aquifer irrigation bores (Pardoo PB5, PB6 and PB7) were installed in 2016 to service the centre-pivot irrigators for the Stage 2 development. Each irrigation bore will supply two 50 ha pivot areas.

Pardoo PB5 was installed by Austral Drilling Services in January 2016 to serve as a dedicated Wallal aquifer monitoring bore for the first year of the completed Stage 1 irrigation project. Pardoo PB6 was completed in April 2016 and Pardoo PB7 was completed in

December 2016. Drilling was authorised by Licence to Construct or Alter Well 180719(1) (copy in *Appendix B*).

The Department of Water issued an interim Groundwater Well Licence issued for the Stage 2 expansion in June 2016 (*Table 1.1*) for 10,000,000 kL/annum. A condition of the interim licence (copy in *Appendix B*) was that a revised operating strategy outlining groundwater monitoring commitments and management protocols is submitted to the Department of Water for review. A draft operating strategy was submitted to the Department of Water in August 2016 (Groundwater Consulting Services, 2016b). The Department of Water requested that Pardoo Beef Corporation install additional Broome aquifer monitoring bores to assess the potential impacts of the irrigation project on groundwater quality within the unconfined Broome aquifer system. Three Broome aquifer monitoring bores were installed for the Stage 1a development in 2013. An additional five Broome aquifer monitoring bores, including baseline control bores, were installed at the Stage 1b, Stage 2 and Stage 3 development areas in April 2017 (*Section 4.1).*

1.4 STAGE 3 DEVELOPMENT

The location of the Stage 3 development area is approximately 2.2 km west of existing Pivot 3 (*Figure 2a, Appendix A).* Stage 3 involves the installation of an additional 4 x 50 ha and 3 x 40 ha pivot areas (additional 320 ha). The Stage 3 expansion, with a total of 863 ha under irrigation, can be accommodated within the current licensed allocation of 14,822,250 kL/annum, using an average application rate of 17,000 kL/ha/annum *(Table 1.2).*

Pardoo Beef Corporation intends to install the first Wallal aquifer irrigation bore at the Stage 3 development area after Austral Drilling Services has completed the current drilling programme at the neighbouring Wallal Downs Station. The drilling of the Stage 3 bores is authorised under Licence to Construct or Alter Well 183436(1) which expires on 6 October 2018 (copy in *Appendix B*). A dedicated Wallal aquifer monitoring bore will be installed on the boundary of Pardoo Station and Wallal Downs Station after the first Stage 3 irrigation bore is completed as the narrow drilling rods required to drill/install the monitoring bore are not currently available.

Pardoo Beef Corporation commenced the approvals process for the Stage 3 development with the Department of Environment Regulation in July 2016.

2. CLIMATE

The local climate is tropical with hot, humid, wet summers and warm, dry winters. Rainfall occurs predominantly between December and March, the wet season, and is associated with thunderstorms, tropical lows and cyclones.

Rainfall occurrence and intensity is highly variable during the wet season depending on the movement of tropical low pressure systems and cyclones. Rainfall records for Pardoo Station supplied by the Bureau of Meteorology for the last ten years are provided in *Table 2.1.*

Table 2.1 Rainfall

Year	BoM Station 004028 Pardoo Station Rainfall (mm)												
	Jan.	Feb.	Mar.	Apr	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
2007	30.5	8.6	630.2	0	0	0.6	3.9	0	0	0	0	15.8	690
2008	16.6	98.8	5.3	4.4	0	47.4	0	0	0.6	1.1	8	19.2	201
2009	45.2	92.1	141.5	1.0	9.4	11.7	0	0	0	0	7.2	100.1	408
2010	50.0	19.0	0.5	2.0	7.2	0	37.5	0.1	23.3	0	0.2	36.4	176
2011	137.6	222.4	104.3	0.2	20.7	1	15.6	0	0	0	3.0	0	505
2012	290.9	28.3	142.7	4.8	0	17.7	0	0	0	10.0	0	13.2	508
2013	219.5	578.9	7.4	6.0	49.7	94.6	0	0	6	1.4	0	110.9	1074
2014	216.9	122.9	18.5	0	10.0	0	37.2	0	0	0	1.2	1.0	408
2015	19.3	76.9	5.9	119.0	26.1	0.8	0	0	0	0.1	0	0.1	263
2016	84.7	11.4	0	4.5	11.0	46.2	0.6	11.8	1.9	14.6	0	29.4	216
2017	15.4	119.3	117.6										>252

Note: Data supplied by Bureau of Meteorology. Accessed online (www.bom.gov.au).
March to December 2015 - incomplete data on Bureau of Meteorology website, interim value from SILO (http://www.longpaddock.qld.gov.au/silo/)

The last significant rainfall event was associated with Tropical Cyclone Rusty in February 2013. In 2015, the total rainfall recorded at Pardoo Station was 263 mm and in 2016 the total rainfall was 215 mm. There were several heavy rainfall periods in February and March 2017.

3. REGIONAL HYDROGEOLOGY

3.1 GEOMORPHOLOGY

There are three main geomorphologic units within the vicinity of the irrigation project which are clearly seen on the aerial photograph shown on *Figure 2a, Appendix A:*

- Coastal dunes. A mostly continuous belt of aeolian sand dunes, parallel to the coast and above the high water mark, typically 5-10m high and 100-200m wide, stabilised in areas by grassy vegetation.
- Tidal flats deposit. Forms a continuous coastal plain fringe which is locally up to about 3 km wide. Thickly grassed supratidal flats support halophytic vegetation and form swales and embayments behind the beach and sand ridges. The surface geology of the coastal plain is predominantly clay, silt and sand.
- Aeolian sandplain and dunes. "Pindan" country inland of the coastal plain. The pindan sandplain forms extensive undulating plains with little or no surface drainage. The pindan soil is described by Hesp and Curry (2004) as a light, clayey, fine-grained non-water-repellent sand, and has a characteristic deep red colouration due to iron-oxide staining of the quartz grains. The sandplain covers most of Pardoo Station and is part of the Great Sandy Desert.

The development areas on Pardoo Station are located on a peninsula of pindan sandplain (Stages 1 and 3) or the edge of the pindan sandplain (Stage 2) which are bounded by the lower-lying coastal plain.

3.2 GEOLOGY

The Canning Basin is the largest sedimentary basin in Western Australia, covering about 550,000km^2, of which about one third is offshore (Middleton, 1990).

Sediments within the west Canning Basin locally comprise the basal Wallal Sandstone, Alexander Formation, Jarlemai Siltstone and Broome Sandstone. The Callawa Formation appears on the published geological map shown on *Figure 2a, Appendix A* (Hickman *et al* 2012) and is the same unit as the Broome Sandstone (Middleton, 1990).

The structure of the Canning Basin at Wallal Downs Station is shown on *Figure 3, Appendix A* and a cross-section showing available gamma logs and interpreted stratigraphy for bores along the coast is provided on *Figure 4, Appendix A*. The geophysical log for Pardoo PB5 in the Stage 2 development area is included on the cross-section. The unit intercepts are consistent with the cross-section, given that Pardoo PB5 is two kilometres north of the section line and unit intercepts are deeper.

Pardoo Station is located on the Lambert Shelf, on which the Wallal Sandstone overlies shallow Archaean basement. The aquifers thicken in the Wallal Embayment which lies to the east of Pardoo Station.

Leech (1979a,b) describes the Wallal Sandstone as a poorly consolidated coarse- to fine-grained, fawn to light grey sandstone with rare siltstone and conglomerate interbeds. The Wallal Sandstone intersected in the irrigation bores Pardoo PB1 and Pardoo PB2 contained very coarse sand to fine granules *(Appendix E)*.

The greatest thickness of the Wallal Sandstone intersected on Pardoo Station is in Pardoo PB1 (>112m) and the combined thickness of Alexander Formation and Wallal Sandstone is >148m. At WCB17A, the combined Wallal Sandstone and Alexander Formation is 133m thick and these units thin to the west and the south. At Pardoo Homestead the combined thickness of the units is around 50m.

The Alexander Formation is identified in oil wells drilled on the Wallal Embayment and Wallal Platform (Chirup 1 and BMR04A described in WAPET, 1969 and Bastian, 1962). Aquaterra (2010) suggested that Leech (1979a,b) included the Alexander Formation within the Wallal Sandstone unit. The Department of Water does not recognise the Alexander Formation in the *West Canning Basin groundwater allocation limit report* (Department of Water, 2012b) and also presumably includes it within the Wallal Sandstone, however a layer for the Alexander Formation is included in the Department's groundwater model.

The Alexander Formation is a fine to medium grained sandstone and interbedded mudstone and is considered a transitional unit between Wallal Sandstone and Jarlemai Siltstone. There are differing interpretations between the bores drilled for groundwater investigation and bores drilled for oil exploration. It is hoped that hydrogeologists in the Department of Water will be able to resolve these differing interpretations by reviewing the lithological samples taken during drilling on the Lambert Shelf with the lithological samples taken from drilling on the Wallal Embayment and Wallal Platform in the Sandfire groundwater investigation programme.

The Alexander Formation is recognised as a transitional zone and is poorly defined. Groundwater Consulting Services has defined in the Alexander Formation in the following manner:

- Top of Alexander Formation: first occurrence of sandy zones that may transmit pressure to the drilling fluid at flow rates sufficient to dilute the drilling fluid and underbalance the hole. Assessed from natural gamma log.

- Base of Alexander Formation: last occurrence of silty, fine to medium grained strata (from natural gamma log) or base of transition to resistive portion of the long normal resistivity log.

The Jarlemai Siltstone conformably overlies the Alexander Formation, and is continuous across Pardoo Station. The Jarlemai Siltstone pinches out near the margins of the basin and

the Wallal Sandstone outcrops or subcrops the Broome Sandstone. The Jarlemai Siltstone is a light-grey to black, puggy, silty, clay (Leech 1979b).

The Broome Sandstone unconformably overlies the Jarlemai Siltstone where present. The Broome Sandstone overlies the Wallal Sandstone near the edge of the basin and overlaps the Wallal Sandstone and lies directly on the Archaean basement (Leech, 1979b). The formation comprises cross-bedded sandstone, siltstone and conglomerate. The maximum recorded thickness of Broome Sandstone beneath Pardoo Station is 80m in WCB17A.

Tertiary and Quaternary deposits including laterite, kankar, Bossut Formation (coastal limestone), tidal-flat deposits, alluvial and residual sand and related deposits occur on Pardoo Station.

3.3 HYDROGEOLOGY

3.3.1 Broome Aquifer

The Broome aquifer is unconfined over most of Pardoo Station but may be in hydraulic connection with a thin localised surficial aquifer on the coastal plain (Leech, 1979a,b).

Groundwater levels in the Broome aquifer reflect the general topography, with a gradient showing flow towards the coast. The aquifer is recharged by direct infiltration of rainfall, and discharges over a saline wedge near the coastline.

At Pardoo Station, the salinity in the Broome aquifer is marginal and variable, areas of lower salinity water occur in the eastern part of Pardoo and south of the highway.

3.3.2 Wallal Aquifer

The Wallal aquifer is a mostly confined aquifer consisting of the Alexander Formation and Wallal Sandstone. At Pardoo Station, the direction of groundwater flow in the Wallal aquifer is broadly westerly.

The Jarlemai Siltstone forms the confining layer for the Wallal aquifer, and hydraulically separates the Wallal aquifer from the overlying Broome aquifer across most of Pardoo Station *(Figure 4, Appendix A)*. The Wallal aquifer is artesian at the coast and up to 30km inland from the coast. The Jarlemai aquitard is not present along the margins of the basin and was not intersected at site WCB12 on Pardoo Station. The Wallal aquifer subcrops the Broome aquifer or outcrops along the margins of the west Canning Basin and is recharged by rainfall infiltration directly or through the Broome aquifer. The Wallal aquifer is bounded below by Archaean bedrock.

Groundwater salinity in the Wallal aquifer beneath Pardoo Station ranges from 200 to 1,700 mg/L total dissolved solids concentration, with a regional increase in salinity from south-east to north-west, in the direction of groundwater flow.

Single-well testing was undertaken by Leech (1979a,b) at low flow rates. Aquifer parameters derived by Leech (1979b) were based on short screen intervals that screen relatively shallow parts of the aquifer. There was one Wallal aquifer test conducted by Leech during which drawdown at an observation bore was measured for an estimate of aquifer storativity. Aquifer testing by Leech (1979) indicates an average transmissivity for the Wallal aquifer of 340 m^2/day (hydraulic conductivity of 18.5m/day) and a storativity of 2 x 10^{-4}.

More recent tests of the Wallal aquifer with suitable observation bores include those conducted by Atlas Iron (near WCB10A), the Water Corporation on Pardoo Station and Wallal Downs Station, and Fortescue Metals Group on Wallal Downs Station. These tests were 24 to 48 hours duration and conducted at moderate flow rates (30 - 70L/s), constrained by bore construction and pumping equipment. A number of hydraulic conductivity estimates for the Wallal aquifer were obtained from testing and model calibration (Aquaterra 2009, Aquaterra 2010 and Worley Parsons 2012). The adopted hydraulic parameters in the numerical models for the Wallal aquifer are hydraulic conductivity within the range from 20 m/day to 100 m/day and storativity of around 10^{-5} (Worley Parsons, 2012, part report provided by the Water Corporation).

A test conducted by Futura Asset on irrigation bore Wallal PB1 on Wallal Downs Station was run for six days at about 210 L/s with a measured drawdown response in Wallal aquifer monitoring bore WCB25Y which is 4 km distant from the irrigation bore (Groundwater Consulting Services, 2012).

Analysis of responses in observation bores during short-term flow tests conducted on Pardoo PB1 at Pardoo Station were affected by stock water use in the observation bores and a drawdown response could not be reliably discerned.

The Department of Water conducted an aquifer test at WCS06P, discharging at flow rates of around 121L/s in 2015. Data from the nearby observation bores WCS06A and WCS06C provided useable aquifer responses. The derived transmissivity was 7,655m^2/day, equating to a hydraulic conductivity of 30m/day based on a 250m aquifer thickness and the Storativity was 0.001.

CyMod Systems (reported in Groundwater Consulting Services, 2014b) completed a lumped parameter analysis of the potential drawdown impacts of the Stage 1b development by constructing a MODFLOW model of the Wallal aquifer, based on aquifer parameters from the Department of Water West Canning Basin model (Aquaterra, 2011). CyMod Systems has recently developed a sub-regional groundwater flow model which is calibrated to groundwater abstraction and monitoring data collected for the Pardoo Station and Wallal Downs Station irrigation projects over the last five years. The sub-regional model uses a calibration-derived hydraulic conductivity of 44 m/day for the Wallal aquifer in the vicinity of the Stage 1a development (CyMod Systems, 2016).

3.3.3 Groundwater Investigation Programmes

The Water Corporation engaged Worley Parsons to co-ordinate a drilling investigation which included four investigation bore sites on Pardoo Station and one investigation bore site on Wallal Downs Station. Basic bore data only are available from the Department of Water.

The survey and construction details for these bores were released by the Department of Water via the online Water Information Reporting database in 2016. Lithological records or unit picks are not provided. The database shows additional Water Corporation investigation bores – WC 06A/12, WC 07A/12, WC 07B/12 at three locations on Pardoo Station (*Figure 2a, Appendix A*). Groundwater Consulting Services measured groundwater levels in WC 06A/12 and WC 07A/12 in October 2016. The Department of Water provided a groundwater level measurement for WC 07C/12 which is located to the south of Pardoo Station taken in August 2016. These bores are believed to screen the Wallal aquifer and are non-artesian.

Fortescue Metals Group has also undertaken investigation drilling at two sites on Wallal Downs Station and, in a subsequent programme, at four sites extending inland from the southern boundary of Wallal Downs Station.

The Department of Water has currently undertaking the West Canning Basin Groundwater Investigation Programme which is due for completion in July 2017. The department has completed the following:

- Drilling of replacement bores from the original Leech investigation to maintain the availability of monitoring infrastructure for measurement of water levels and quality. Bores at sites WCB05, WCB15, WCB18, WCB21, WCB24 and WCB25 were replaced in 2011/2012 and replacement bores were installed at sites WCB19, WCB23 and WCB24 in 2013.

- Exploration of the West Canning Basin in the central and eastern portions of Wallal Downs Station extending inland from the south-eastern corner of Wallal Downs Station in the Sandfire drilling programme. Bores screening the Broome aquifer and Wallal aquifer systems have been installed at thirteen sites with the prefix WCS- denoting the bore sites. The department conducted aquifer testing of Wallal aquifer at the site of WCS06.

- Re-interpreting the hydrogeology of the West Canning Basin after completion of the Sandfire drilling and testing programme to incorporate the results of the groundwater investigation programmes carried out by Pardoo Station, Wallal Downs Station, Atlas Iron, the Water Corporation and Fortescue Metals Group.

- Development of a numerical groundwater model of the West Canning Basin.

3.3.4 Regional Groundwater Monitoring

There has been limited historical groundwater monitoring of the Leech investigation bores in the West Canning Basin. High frequency water level monitoring was carried out between

1978 and 1984. Less frequent monitoring of groundwater levels in Broome aquifer monitoring bore WCB24C and Wallal aquifer monitoring bore WCB20C, which is non-artesian, recommenced in 1989 and ceased in 2004. Groundwater hydrographs for these bores are provided on *Figure 5, Appendix A.*

The Department of Water commenced intensive groundwater monitoring in bores in the West Canning Basin in 2014, using pressure dataloggers installed in selected bores across the West Canning basin, with periodic field visits for manual measurements. These data has been used to support the numerical modelling project that the Department of Water. The water level/pressure data are supported by additional water quality sampling, age determination and downhole nuclear magnetic resonance logging. The Department of Water has provided the raw logger data files to Groundwater Consulting Services for incorporation in the numerical model of the West Canning Basin developed by CyMod Systems to support the application for the release of the allocation for the Stage 2 expansion (CyMod Systems, 2016 and 2017).

3.4 GROUNDWATER USE

Small quantities of groundwater from the Broome and Wallal aquifers have been used for stock watering across the West Canning Basin for many years.

The Department of Water stopped up to 3.7 GL/annum of previously uncontrolled flow from the Wallal aquifer in 2004/2005 (SNRMO, 2008) by cementing eleven of the artesian investigation bores installed by the Geological Survey of Western Australia.

Prior to 2012, regional commercial development of the Wallal aquifer was limited to small-scale use (understood to be about 1 GL/annum) by BHP at the Shay Gap borefield.

There has been increased level of interest in the groundwater resources of the Wallal aquifer in the West Canning Basin as evident in the resource allocation reports for the Wallal aquifer within the West Canning subarea over the last three years (*Table 3.2).* The Department of Water will use the numerical model of the West Canning Basin to refine the groundwater allocation limits for the Broome and Wallal aquifer systems.

The irrigated fodder project at Pardoo Station is the first large-scale project that uses groundwater from the Wallal aquifer in the Canning-Wallal subarea. A similarly-sized irrigation project to the Pardoo Station irrigated fodder project is being developed on Wallal Downs Station, located to the east of Pardoo Station. The irrigation projects at Wallal Downs Station and Pardoo Station are comparable in scale and the projects hold allocations of 14,625,000 kL/annum and 14,822,250 kL/annum (*Table 3.3)*.

Table 3.1 Resource allocation – Wallal Aquifer

Item	Resource Allocation		
Report Date	16/02/2015	17/02/2016	1/03/2017
Management Area	Canning-Kimberley	Canning-Kimberley	Canning-Kimberley
Management Sub Area	West Canning	West Canning	West Canning
Resource	Canning - Wallal.	Canning - Wallal.	Canning - Wallal.
Component	General	General	General
Component Status	G2	G2	G4
Allocation Limit (kL/annum)	40,000,000	40,000,000	40,000,000
Allocated Volume (kL/annum)	12,423,000	12,458,270	44,707,520
Committed Volume (kL/annum)	11,542,000	6,302,000	13,125,000
Remaining Volume (kL/annum)	16,035,000	21,239,730	-17,832,520
% Allocated and committed	60%	47%	145%
Additional Requested Volume (kL/annum)	39,340,260	16,707,250	0
Data provided by the Department of Water with the following proviso: *"The Department of Water is committed to quality service to its customers and makes every attempt to ensure accuracy, currency and reliability of the data contained in this document. However changes in circumstances after time of publication may impact the quality of this information."*			

Pilbara Water and Power were issued with an allocation of 14,000,000 kL/annum on 22 September 2016. No Wallal aquifer production bores have been installed for the project to date – the works are limited to investigation and monitoring bores.

The *Pilbara groundwater allocation plan* (Department of Water, 2013a) acknowledges the irrigation projects at Wallal Downs Station and Pardoo Station, the reliance of the projects on available artesian pressure and the sensitivity of the projects to drawdown impacts.

Table 3.2 Licences – Wallal aquifer

Groundwater Area	Groundwater Subarea	Aquifer	Licence Number	Issue Date	Expiry Date	Licence Allocation (kL/annum)	Licensee/Project	Licence Address
Canning-Kimberley	West Canning	Canning - Wallal.	150360	25/01/2017	24/01/2027	14,625,000	Grenleigh Pty. Ltd	Wallal Downs Pastoral Lease (Lot 44 on Plan 238511 & Lot 3 on Plan 144039)
Canning-Kimberley	West Canning	Canning - Wallal.	107451	26/07/2010	26/07/2019	1,200,000	BHP Billiton Iron Ore Pty. Ltd.	E45/1072 - Yarrie Camp, E45/1072
Canning-Kimberley	West Canning	Canning - Wallal.	109428	25/08/2009	25/08/2019	25,000	Badger, Robb	Lot 18 On Plan 215404 - Volume/Folio 1839/820 - Lot 18 Pardoo Lot 18 On Plan 215404 - Volume/Folio 1839/820 - Lot 18 Pardoo - Pardoo Roadhouse
Canning-Kimberley	West Canning	Canning - Wallal.	158616	25/01/2017	24/01/2027	14,822,250	Pardoo Beef Corporation Pty Ltd	Pastoral Lease 3114/446 - Pardoo Station
Canning-Kimberley	West Canning	Canning - Wallal.	175700	22/09/2016	5/01/2020	14,000,000	Pilbara Water and Power Pty Ltd	L45/272, E45/3606, E45/3442, E45/3443, E45/3611
Canning-Kimberley	West Canning	Canning - Wallal.	181345	4/08/2015	3/08/2025	35,000	Shire of East Pilbara	Cape Keraudren reserve - Lot 19 on plan216173 - Volume/folio Lr3024/453
Canning-Kimberley	West Canning	Canning - Wallal.	180180	1/05/2015	30/04/2025	270	Areva Resources Australia Pty Ltd	Wallal Downs Pastoral Lease - CL1974/155

3.5 GROUNDWATER DEPENDENT ECOSYSTEMS

The Department of Water states the current understanding of groundwater dependent ecosystems on the West Canning Basin in the *Monitoring program to support the Pilbara groundwater allocation plan* (Department of Water, 2013b):

- *Due to the large depths to groundwater of the Wallal aquifer across the basin, groundwater-dependent ecosystems are relatively limited. Several springs occur on the coastal plain which may be sourced from minor upward leakage from the Wallal or by the Broome sandstone, however they have been heavily impacted by grazing and weed invasion and are likely to be of low ecological value.*
- *A series of Ramsar-listed wetlands occur along the coast as part of the Eighty Mile Beach system. Their dependence on groundwater is unknown but discharge from the Broome sandstone aquifer may also provide some hydrological support to these systems*.

Inspections of the pindan and coastal plain transition on Pardoo Station in March 2011 by Groundwater Consulting Services, the Department of Water and the Department of Environment and Conservation did not locate any areas of groundwater seepage nor obvious groundwater dependence. Groves of melaleuca (paperbarks) were observed in thickets in areas of the coastal plain and may be restricted to areas of shallow groundwater in the Broome or surficial aquifer. Groundwater Consulting Services met with a water-resource officer of the Kimberley Land Council in June 2011 in relation to projects east of Sandfire Roadhouse. Although details could not be provided, the officer displayed a map linking the major indigenous water-based sites with the boundary between the pindan and the coastal plain. Ad hoc aerial inspections of the boundary between the pindan and the coastal plain between Broome and Port Hedland (between 2011 and 2014) reveal that the water features such as Injudinah Swamp, in the La Grange area, occur where the edge of the coastal plain is deeply embayed into the pindan. The concentration of rainfall runoff or groundwater discharge into areas of deep embayments (from three sides) may result in a greater accumulation of water.

Mandora Marsh is located about 130km east of the development areas at Pardoo Station. Mandora Marsh was identified as being possibly supported by artesian pressures in the Wallal Sandstone (pers. comm., Milton, 2016). An aerial inspection conducted by Groundwater Consulting Services in late April 2017 indicated no apparent structural spatial relationships between the springs. If structurally controlled, then some alignment of springs would be expected. They appear to occur all in low-lying ground and probably represent discharge of Broome sandstone or palaeochannel water through localised weaknesses in the clayey strata that form the base of the March system. There are no springs on the north-eastern side of the system, apart from one claypan. The support mechanism is likely to be similar to those wetlands that occur on the pindan/coastal plain margin in the La Grange region where artesian conditions are generated in the Broome Sandstone aquifer, and a component of contribution from the inferred palaeochannel aquifer is also likely.

The Department of Water met with the Department of Parks and Wildlife and the Office of the Environmental Protection Authority met in April 2017 to discuss the concerns of those agencies regarding the potential impacts on ecosystems.

4. BOREFIELD DESCRIPTION

4.1 IRRIGATION BOREFIELD

Seven Wallal aquifer irrigation bores have been installed at the Stage 1 and Stage 2 development areas. Construction details for the bores are summarised in *Table 4.1* and bore completion diagrams for Pardoo PB5, Pardoo PB6 and Pardoo PB7 which were drilled in the 2016 water year are provided in *Appendix D.*

All irrigation bores have cumulative flowmeters installed on the headworks and photographs of the flowmeters are provided in *Appendix C.*

Pulse flow loggers are installed in the Stage 1 irrigation bores and will be installed in the Stage 2 irrigation bores prior to commissioning.

Pressure data loggers are also installed in each of the irrigation bores.

The artesian pressure provides an open flow rate of between 125 L/s (Pardoo PB2) and 240 L/s (Pardoo PB7) (*Table 4.1*). The centre-pivot irrigators were configured to operate on an instantaneous flow rate of around 70 L/s and there is sufficient residual operating pressure within the borefield to ensure uniform distribution of irrigation water.

Three groundwater monitoring bores that screen the Broome aquifer *(Table 4.2)* were installed by the previous leaseholder of Pardoo Station in 2013. Monitoring bores Pardoo BMB2 and Pardoo BMB3 are adjacent to Pivot 1 and Pivot 2 and Pardoo BMB1 is located at the site of WCB17 *(Figure 2b, Appendix A).*

In October 2016, five additional Broome aquifer monitoring bores were installed by Kimberley Water on Pardoo Station (*Figure 2b, Appendix A*):

- Two bores, Pardoo BMB6 and Pardoo BMB7 are downgradient of proposed pivot areas.
- One bore, Pardoo BMB4, is a monitoring and proposed domestic bore which is located up-gradient of and between the Stage 1 and 2 development areas.
- Two bores, Pardoo BMB5 and Pardoo BMB8, are remote from the development areas and will serve provide a baseline for groundwater levels and quality in the Broome aquifer.

The Department of Water reviewed and agreed the proposed location of the monitoring bores prior to installation.

Table 4.1 Wallal aquifer irrigation bores

Stage	Bore ID	Status Feb. 2017	Date Drilled	Drilling Company	Z50S GPS Easting (m)	Z50S GPS Northing (m)	Coord. Source	Ground Elevation (mAHD)	Elevation Source	Screened Aquifer	Drilled Depth (mBGL)	Screen Interval (mBGL)	Casing Material	Screen Material	Yield (L/s)
1a	Pardoo PB1	Operational – supplies Pivot 1	Sept. 2010 to 18/10/2010	Western Drilling	810299.6	7787686.6	DoW Survey	8.535	Land Surveys	Wallal	271	136.3-262	0 to 126m: 254mm ID schedule 40 mild steel butt welded 6m joints centralised and pressure cemented SG1.65. 124 to 136.3m: 204mm ID schedule 40 grade 304 stainless steel pipe butt welded 6m joints, no annular fill.	136.3 to 166.3m: 204mm ID grade 304 stainless steel screens 0.5mm aperture. 166.3 to 262m: 155mm ID grade 304 stainless steel screens 0.6mm aperture.	180 L/s open flow measured through flowmeter.
	Pardoo PB2	Operational – supplies Pivot 2	6/12/2012 to 21/1/2013	Western Drilling	809425.3	7788290.8	DoW Survey	9.892	Land Surveys	Wallal	252	162-252	0-151m: 227mmOD 214mm ID FRP casing. 150-162m: 158mm ID Blank s/s screen.	162-210m: 158mm ID wire-wound s/s 0.4mm aperture. 210-252m: 158mm ID wire-wound s/s 0.76mm aperture.	125 L/s open flow measured through flowmeter.
1b	Pardoo PB3	Operational – supplies Pivots 3 & 6	23/10/2015 to 19/11/2015	Austral Drilling Services	809441.94	7787547.46	Land Surveys	11.97	Land Surveys	Wallal	245	158.8-242.8	0-151m: 250mm NB FRP casing with stainless steel extensions. 146.2-158.8m: 200mm NB plain stainless steel pipe with rubber K packer.	158.8-242.8m: 200mm NB wire-wound stainless steel 1.0mm aperture screen.	200 L/s open flow measured through testing headworks.
	Pardoo PB4	Operational – supplies Pivots 4 & 5	18/11/2015 to 10/12/2015	Austral Drilling Services	809209.54	7786827.11	Land Surveys	12.30	Land Surveys	Wallal	251	159.45-249.6	0-143.8m: 250mm NB FRP casing with stainless steel extensions. 134.91-159.45m: 200mm NB plain stainless steel pipe with rubber K packer.	159.45-171.47m: 200mm NB wire-wound stainless steel 0.75mm aperture screen. 171.47-249.6m: 200mm NB wire-wound stainless steel 1.0mm aperture screen.	210 L/s open flow measured through testing headworks.
2	Pardoo PB5	Not commissioned April 2017. Will supply Pivots 7 & 8	16/01/2016 to 9/03/2016	Austral Drilling Services	813897.1	7787806.5	Land Surveys	10.43	Land Surveys	Wallal	272	169.5-271.5	0-156.5m: 250mm NB FRP casing with stainless steel extensions. 139.5-169.5m: 200mm NB plain stainless steel pipe with rubber K packer.	169.5-187.5m: 200mm NB wire-wound stainless steel 0.75mm aperture screen. 187.5-271.5m: 200mm NB wire-wound stainless steel 1.0mm aperture screen.	220 L/s open flow measured through testing headworks.
	Pardoo PB6	Not commissioned April 2017. Will supply Pivots 9 & 10	21/03/2016 to 29/04/2016	Austral Drilling Services	815305	7788647.5	GPS	11.66	Estimate from DEM	Wallal	286.5	177.1-286.1	0-146.6m: 250mm NB FRP casing with stainless steel extensions. 140.4-177.1m: 200mm NB plain stainless steel pipe with rubber K packer.	177.1-207.1m: 200mm NB wire-wound stainless steel 0.75mm aperture screen. 207.1-286.1m: 200mm NB wire-wound stainless steel 1.0mm aperture screen.	190 L/s open flow measured through testing headworks.
	Pardoo PB7	Not commissioned April 2017. Will supply Pivots 11 & 12	15/11/2016 to 13/12/2016	Austral Drilling Services	816860	7789042	GPS	8.98	Estimate from DEM	Wallal	263	166.6-251.4	142.26-166.62m: 200mm NB plain stainless steel pipe with rubber K packer.	166.62-178.78m: 200mm NB wire-wound stainless steel 0.5mm aperture screen. 178.78-196.92m: 200mm NB wire-wound stainless steel 0.75mm aperture screen. 196.92-251.4m: 200mm NB wire-wound stainless steel 1.0mm aperture screen.	240 L/s open flow measured through testing headworks.

Notes: Department of Water survey data for Pardoo PB1 and Pardoo PB2 have been converted from Zone 51 to Zone 50.
Stage 2 irrigation bores have not been commissioned for irrigation use and are currently operating as monitoring bores for the Stage 1 development.

Table 4.2 Broome aquifer monitoring bores

Bore ID	Purpose	Date Completed	Drilling Company	Z50S GPS Easting (m)	Z50S GPS Northing (m)	Coord. Source	Ground Elevation (mAHD)	Elevation Source	Screened Aquifer	Drilled Depth (mBGL)	Screen Interval (mBGL)	Casing Material	Screen Material	Depth to Water (mBGL)	Electrical conductivity (uS/cm @ 25deg C)
Pardoo BMB1 (near WCB17C)	Up-gradient Stage 1 bore	9/7/2013	Delta Drilling	809091	7784882	GCS GPS	18.6	Estimate based on WCB17B	Broome	19.8	13.3-19.3	100mm Cl. 12 PVC	100mm Cl.12 slotted 0.5mm aperture PVC	14.94 (9/4/17)	1,221 (9/4/17)
Pardoo BMB2 (adjacent Pivot 1)	Down-gradient Stage 1 pivot area	7/6/2013	Delta Drilling	810688	7787794	GCS GPS	8.09	Estimate from DEM	Broome	7.95	1.51-7.95	100mm Cl. 12 PVC	100mm Cl.12 slotted 0.5mm aperture PVC	3.01 (9/4/17)	2,210 (9/4/17)
Pardoo BMB3 (adjacent Pivot 2)	Edge Stage 1 pivot area	7/6/2013	Delta Drilling	809482	7788678	GCS GPS	7.68	Estimate from DEM	Broome	7.3	1.3-7.3	100mm Cl. 12 PVC	100mm Cl.12 slotted 0.5mm aperture PVC	4.60 (9/4/17)	2,650 (9/4/17)
Pardoo BMB4 (east of WCB17C)	Domestic bore for new homestead	11/4/2017	Kimberley Water	810528	7785258	GCS GPS	25.15	Estimate from DEM	Broome	43.2	31- 43	155mm Cl. 12 PVC	155mm Cl.12 slotted 0.5mm aperture PVC	19.60 (12/4/17)	1,365 (12/4/17)
Pardoo BMB5 (eastern station boundary)	Remote baseline	9/4/2017	Kimberley Water	820096	7790474	GCS GPS	6.02	Estimate from DEM	Broome	23.2	17.2 - 23.2	100mm Cl. 12 PVC	100mm Cl.12 slotted 0.5mm aperture PVC	3.67 (9/4/17)	3,400 (9/4/17)
Pardoo BMB6 (adjacent Pivot 9)	Down-gradient Stage 2 pivot area	9/4/2017	Kimberley Water	814471	7789024	GCS GPS	5.81	Estimate from DEM	Broome	11	5.0 - 11.0	100mm Cl. 12 PVC	100mm Cl.12 slotted 0.5mm aperture PVC	3.37 (9/4/17)	4,600 (9/4/17)
Pardoo BMB7 (adjacent Pivot 2)	Down-gradient Stage 3 pivot area	11/4/2017	Kimberley Water	804633	7788024	GCS GPS	8.00	Estimate from DEM	Broome	11	5.0 - 11.0	100mm Cl. 12 PVC	100mm Cl.12 slotted 0.5mm aperture PVC	3.53 (10/4/17)	1,940 (10/4/17)
Pardoo BMB8 (adjacent Chower bore)	Remote baseline	12/4/2017	Kimberley Water	797595	7780616	GCS GPS	17.13	Estimate based on Chower bore	Broome	24	18.15-24.15	100mm Cl. 12 PVC	100mm Cl.12 slotted 0.5mm aperture PVC	Measurement next site visit	

4.2 STOCK AND OTHER BORES

The Department of Water's regional monitoring bore sites WCB04 to WCB12 and WCB14 to WCB17 are located on Pardoo Station *(Figure 2a, Appendix A, Table 4.4).* Several bores are used for stock water supply. The closest Wallal aquifer investigation bore to Wallal aquifer to the irrigated fodder project is WCB17A which is located 3 km to the south of Pardoo PB1 (*Figure 2a, Appendix A).* Currently, WCB17C is used for stock water supply. The adjacent bore, WCB17A, was cemented by the Department of Water in mid-2016.

A list of stock, domestic, investigation and other-purpose bores and wells that have been visited by Groundwater Consulting Services at Pardoo Station is also provided in *Table 4.4.* The list of stock bores is a work in progress. Groundwater Consulting Services has not assessed every bore and well at Pardoo Station, but has focused on capturing all Wallal aquifer bores to the east of Pardoo Homestead.

An artesian bore was installed in September 2014 to supply water for domestic purposes to the ranger's residence at Cape Keraudren. Currently the Cape Keraudren bore is not used and the water supply for the ranger's residence is drawn from WCB09E from a dedicated pipeline. The Cape Keraudren bore will be commissioned after a small reverse-osmosis plant is installed, and the water may be provided to campers using the coastal campground as well as the ranger's residence.

Key Broome aquifer bores are also included in *Table 4.4,* but most Broome aquifer bores and shallow wells on Pardoo Station have not been assessed by Groundwater Consulting Services.

There are very few details regarding the depths of the private bores and how the bores were constructed. Photographs of the bores are provided in *Appendix C.*

The Water Corporation installed investigation bores in the Wallal aquifer and Broome aquifer at four sites on Pardoo Station. The closest bores to the irrigation borefield are WC 02A/12 and WC 02B/12. Both bores are artesian and are located 9km south of Pardoo PB1 *(Figure 2a, Appendix A).*

Table 4.3 Pardoo Station stock water and monitoring networks

Bore	Asset Owner	Date Completed	Z50S Easting (m)	Z50S Northing (m)	Co-ordinate Source	Ground Elevation (mAHD)	Elevation Source	Aquifer	Current Use	Artesian or Non-artesian	Pumping Infrastructure	Screen Interval (m)	Included in operating strategy monitoring programme *(Section 5)*
Atlas MB1	Pardoo Beef Corp. (*)		781878.72	7771815.79	DoW Survey	23.183	DoW Survey	Broome	Monitoring	Leaky	None	17-28	
Atlas MB2	Pardoo Beef Corp. (*)		781900.63	7771839.63	DoW Survey	23.122	DoW Survey	Wallal	Monitoring	Artesian	None	41-102	
Atlas MB3	Pardoo Beef Corp. (*)		783006.60	7773625.80	DoW Survey	18.763	DoW Survey	Wallal	Stock / Monitoring	Artesian	None	52-115	Yes
Atlas PB1	Pardoo Beef Corp. (*)		781891.15	7771825.48	DoW Survey	23.061	DoW Survey	Wallal	Stock / Monitoring	Artesian	None	43-101	Yes
Brumby bore	Pardoo Beef Corp. by default		783990	7775576	GCS GPS	18	Google Earth	Wallal	Stock / Monitoring	Artesian	None	Unknown	
Chower bore	Pardoo Beef Corp.	Nov. 2011	797604.86	7780629.16	DoW Survey	17.126	DoW Survey	Wallal	Stock / Domestic / Monitoring	Artesian	None	133-151.65	Yes
CRA bore	Pardoo Beef Corp. by default		785667	7763975	GCS GPS	48	Google Earth	Unknown	Stock / Monitoring	Non-Artesian	Solar Pump	Unknown	
Deep well	Pardoo Beef Corp.		770233	7764550	GCS GPS	43	Google Earth	Broome	Stock / Monitoring	Non-Artesian	Solar Pump	Unknown	
Homestead bore	Pardoo Beef Corp.		769864	7774646	GCS GPS	11	Google Earth	Wallal	Lawn, Gardens, Caravan Park	Artesian	None	54.86-56.69	Yes
Noba bore	Pardoo Beef Corp.		789057	7779984	GCS GPS	11	Google Earth	Wallal	Stock / Monitoring	Artesian	None	Unknown	
Pardoo well	Pardoo Beef Corp.		769586	7774369	Google Earth	8	Google Earth	Surficial?	Disused	Non-Artesian	None	Unknown	
Pawnia well	Pardoo Beef Corp.		770349	7769965	Google Earth	23	Google Earth	Broome	Disused	Non-Artesian	Old Windmill	Unknown	
Stockyard bore	Pardoo Beef Corp.		769783	7774396	GCS GPS	9	Google Earth	Wallal	Stock / Monitoring	Artesian	None	Unknown	
Telegram bore	Pardoo Beef Corp.		777687	7776192	GCS GPS	11	Google Earth	Wallal	Stock / Monitoring	Artesian	None	Unknown	
WCB04B	Department of Water	6/07/2005	763800	7775361	Driller GPS	12.7	Estimate	Wallal	Stock / Monitoring	Artesian	None	79-85	Yes
WCB05Y	Department of Water	25/09/2011	790473	7756590	DoW Survey	63.4	DoW Survey	Wallal	Monitoring	Non-Artesian	None	33.3-39.3	
WCB06A	Department of Water	1973	791074	7763717	GCS GPS	48.269	Leech	Wallal	Stock / Monitoring	Non-Artesian	Solar Pump	50.7-74.7	
WCB07A	Department of Water	1973	791140	7769724	GCS GPS	34.229	Leech	Wallal	Stock / Monitoring	Non-Artesian	Solar Pump	91.7-115.7	
WCB08C	Department of Water	29/07/2005	791263	7777362	GCS GPS	15	Estimate	Wallal	Stock / Monitoring	Artesian	None	81-90	Yes
WCB09E	Department of Water	24/09/2005	791486	7784722	GCS GPS	7	Estimate	Wallal	Stock / Domestic / Monitoring	Artesian	None	130-142	Yes
WCB10B	Department of Water	15/07/2005	780816	7771956	GCS GPS	21	Estimate	Wallal	Stock / Monitoring	Artesian	Diesel Pump	65-80	
WCB11A	Department of Water	1974	772094	7772189	GCS GPS	19.732	Leech	Wallal	Cemented 2013	Artesian	None	61-85	
WCB11Y	Department of Water	2013	772106	7772186	DoW Survey	19.64	DoW Survey	Wallal	Stock / Monitoring	Artesian	None	Unknown	Yes
WCB12A	Department of Water	1974	767281	7764827	Dow WIR	32.168	Leech	Broome	Unknown	Non-Artesian	Unknown	31-43	
WCB13A	Department of Water	1974	756724	7761795	Dow WIR	46.1	Leech	Broome	Unknown	Non-Artesian	Unknown	42-54	
WCB14A	Department of Water	1974	779850	7764161	GCS GPS	53.704	Leech	Wallal	Stock / Monitoring	Non-Artesian	Solar Pump	57.7-70.1	
WCB15Y	Department of Water	25/10/2011	808696	7762490	DoW Survey	84.23	Survey	Wallal	Monitoring	Non-Artesian	None	103-115	
WCB16A	Department of Water	1974	808615.46	7774410.07	DoW Survey	41.407	Survey	Wallal	Stock / Monitoring	Artesian	Solar Pump	138-153	Yes
WCB16B	Department of Water	1974	808629.78	7774324.95	DoW Survey	42	Survey	Broome	Monitoring	Non-Artesian	None	37-43	
WCB16C	Department of Water	1974	808615.46	7774410.07	DoW Survey	41.815	Survey	Wallal	Monitoring	Artesian	None	135.2-153.4	Yes
WCB17A	Department of Water	1974	809038.58	7784926.98	DoW Survey	18.687	Survey	Wallal	Cemented 2016	Artesian	None	220-244	
WCB17B	Department of Water	1974	809002	7784925	GCS GPS	18.558	Leech	Broome	Disused	Non-Artesian	None	64-70	
WCB17C	Department of Water	30/10/2005	809083.27	7784888.64	DoW Survey	18.62	DoW Survey	Wallal	Stock / Monitoring	Artesian	None	130.8-148.8	Yes
Cape Keraudren	Shire of East Pilbara	2/9/2014	791958	7787071	GCS GPS	9	Google Earth	Wallal	Monitoring	Artesian	None	166.6-208.9	Yes

Note: Shaded bores are screened in the Broome or surficial aquifers.
(*) Access to Atlas bores as per access agreement. Atlas MB1 has a tagged depth of 29m, but is weeping at surface. Suspect pilot hole was drilled to greater depth and ineffectively cemented.
Department of Water has reinstalled screens in WCB05Y at a deeper setting in June 2016. Original setting was 25-31m.

Table 4.3 Pardoo Station stock water and monitoring networks cont..

Bore	Asset Owner	Z50S Easting (m)	Z50S Northing (m)	Co-ordinate Source	Date Completed	Top of Casing Elevation (mAHD)	Elevation Source	Aquifer	Current Use	Artesian or Non-artesian	Pumping Infrastructure	Screen Interval (m)
WC 01A/12	Water Corporation	796834	7773886	Survey (WIR)	29/10/2012	30.38	Survey (WIR)	Wallal	Stock / Monitoring	artesian	none	63.2 - 153.5
WC 01B/12	Water Corporation	796821	7773897	Survey (WIR)	7/11/2012	30.26	Survey (WIR)	Wallal	Monitoring	artesian	none	57.3 - 151.4
WC 02A/12	Water Corporation	808830	7778565	Survey (WIR)	4/10/2012	32.31	Survey (WIR)	Wallal	Monitoring	artesian	none	88.6 - 153.5
WC 02B/12	Water Corporation	808814	7778557	Survey (WIR)	20/10/2012	32.19	Survey (WIR)	Wallal	Stock / Monitoring	artesian	none	93.6 - 218
WC 03A/12	Water Corporation	808642	7767363	Survey (WIR)	25/08/2012	67.53	Survey (WIR)	Wallal	Monitoring	non-artesian	none	79.6 - 153.5
WC 03B/12	Water Corporation	808650	7767374	Survey (WIR)	1/09/2012	67.42	Survey (WIR)	Wallal	Monitoring	non-artesian	none	78.5 - 144.9
WC 03C/12	Water Corporation	808637	7767368	Survey (WIR)	7/09/2012	67.44	Survey (WIR)	Broome	Monitoring	non-artesian	none	11 - 35
WC 04A/12	Water Corporation	781638	7767881	Survey (WIR)	16/11/2012	36.36	Survey (WIR)	Wallal	Monitoring	non-artesian	none	34.2 - 100.2
WC 04B/12	Water Corporation	781640	7767865	Survey (WIR)	24/11/2012	36.31	Survey (WIR)	Wallal	Monitoring	non-artesian	none	35.1 - 95.7
WC 06A/12	Water Corporation	770597	7760860	Survey (WIR)	3/12/2012	49.37	Survey (WIR)	Wallal*	Monitoring	non-artesian*	none	35.6 - 53.6
WC 07A/12	Water Corporation	802605	7757249	Survey (WIR)	28/11/2012	100.30	Survey (WIR)	Wallal*	Monitoring	non-artesian*	none	68.7 - 85.7
WC 07B/12	Water Corporation	811213	7752147	Survey (WIR)	30/11/2012	144.16	Survey (WIR)	Wallal*	Monitoring	non-artesian*	none	83.25 - 101.25
WC 07C/12	Water Corporation	823999	7746228	Survey (WIR)	15/09/2012	155.42	Survey (WIR)	Wallal*	Monitoring	non-artesian*	none	74.5 - 92.5

Note: Data from Department of Water's online WIR database.
** No aquifer data in WIR, requires confirmation.*
Ground elevation not provided in WIR database.
Shaded bores are screened in the Broome or surficial aquifers.
WC 05A/12 and WC 05B/12 are located on Wallal Downs Station.

5. GROUNDWATER USE

5.1 IRRIGATION

Flowmeter readings for the active irrigation bores at Pardoo Station for the 2016 water year are provided in *Table 6.1* and calculated abstraction volumes are provided in *Table 6.2.*

In 2016, a total of 3,297,418 kL was abstracted from the Wallal aquifer for irrigation purposes, taken from 1 January 2016 (pulse logger estimate) to 31 December 2016 (manual flowmeter reading).

Groundwater abstraction increased in the second-half of 2016 as planting commenced on Pivots 3, 4 and 6 in July 2016 and on Pivot 5 in August 2016.

5.2 STOCK AND COMMERCIAL WATER

Quarterly flowmeter readings for stock bores, recorded by Groundwater Consulting Services, are listed in *Table 5.3.* Calculated abstraction volumes are provided in *Table 5.4.*

Groundwater from Chower bore was used for commercial purposes (water carting).

The total measured volume of groundwater from the Wallal aquifer used for stock watering and commercial purposed between 24 January 2016 and 14 February 2017 was 44,484 kL.

Irrigation bore Pardoo PB5 was used to supply water for dust suppression, road construction and drilling purposes in 2016, prior to a flowmeter being installed on the headworks of the bore. The periods when the bore was used to fill a water cart is evident in the pressure logger trace for the bore (*Figure 6a, Figure 9a, Appendix A).* It is estimated that around 30,000 kL was abstracted from Pardoo PB5 in the 2016 water year.

Table 5.1 Irrigation bore flowmeter readings and pulse logger estimates 2016

Irrigation Bore:	PB1		PB2		PB3				PB4				
Supplies:	Pivot 1		Pivot 2		Pivot 3		Pivot 6		Pivot 4		Pivot 5		
Meter Type	Flowmeter	Pulse Logger	Flowmeter	Pulse Logger	Flowmeter	Pulse Logger	Flowmeter	Pulse Logger	Flowmeter	Pulse Logger	Flowmeter	Pulse Logger	
Brand	**Arad**	**-**	**BIL**	**-**	**Seametrics**	**-**	**Seametrics**	**-**	**Seametrics**	**-**	**Seametrics**	**-**	
Serial Number	**IRT8"1003002**	**-**	**120821020**	**-**	**22016000579**	**-**	**22016000578**	**-**	**102015001508**	**-**	**102015001507**	**-**	
Meter Unit	**x 10 m³**	**m³**	**x 10 m³**	**m³**	**x 1000 m³**	**m³**	**x 1000 m³**	**m³**	**x 1000 m³**	**m³**	**x 1000 m³**	**m³**	**Flowmeter Read By**
1/01/2016		5007414		3317758									
9/01/2016	**500790**	5007465	**335755**	3357582									Pardoo Beef Corporation
25/01/2016	**503620**	5035744	**344844**	3448033									Groundwater Consulting Services
1/02/2016		5048655		3449811									
1/03/2016		5167005		3544196									
1/04/2016		5276743		3677381									
3/04/2016	**527776**	5278534	**368018**	3677381									Groundwater Consulting Services
1/05/2016		5392951		3776329									
1/06/2016		5406657		3826108		0		2		461.3		0	
7/06/2016	**540900**	5410807	**383002**	3829827									Pardoo Beef Corporation
1/07/2016		5419639		3838808		61.8		18494		29919			
12/07/2016	**543458**	5432290	**384796**	3845154	**19.15**	18758	**32.65**	32869	**47.25**	47250	**1.2**	1210	Groundwater Consulting Services
14/07/2016	**-**	-	**-**	-	**24.15**	23780	**36.91**	37133	**49.36**	49359	**1.23**	1210	Groundwater Consulting Services
1/08/2016		5472238		3880561		65711		65948		80739		5850	
3/08/2016	**547972**	5477751	**388964**	3886841	**71.1**	71100	**70.01**	70010	**85.4**	85420	**11.3**	11300	Pardoo Beef Corporation
29/08/2016	**555409**	5551789	**395519**	3952373	**125.54**	124973	**136.39**	116954	**116.92**	136436	**44.69**	44707	Pardoo Beef Corporation
1/09/2016		5556375		3955634		128752		120077		140070		47252	
1/10/2016		5659483		4022501		202224		197396		216573		96172	
14/10/2016	**566178**	5659488	**403067**	4027866	**242.37**	241749	**231.52**	231489	**226.93**	226954	**122.55**	122584	Groundwater Consulting Services
1/11/2016		5661729		4067512		314578		300592		246156		168315	
1/12/2016		5748412		4168577		412735		385345		293782		245283	
6/12/2016	**576545**	5763163	**418355**	4180752	**425.39**	424822	**396.62**	396658	**304.7**	304789	**250.3**	250286	Pardoo Beef Corporation
31/12/2016	**583873**	5837310	**424909**	4247115	**463.22**	463237	**438.34**	438373	**344.8**	344726	**278.2**	279627	Pardoo Beef Corporation

Note: Flowmeters installed on discharge pipeline to Pivots 3 to 6 installed prior to irrigation commencing.
Pulse loggers installed at Pivots 3 and 6 functioning from 14 July 2016. Abstraction from PB3 commenced 23 June 2016.
Pulse loggers installed at Pivots 4 and 5 functioning from 31 July 2016. Abstraction from PB4 commenced 12 June 2016 (minor commissioning abstraction in May 2016)
Pumping cycles determined from pressure head responses were used to estimate pulse logger cumulative flow in the period prior to loggers being installed.
Pulse logger cumulative flow reset to flowmeter readings measured on 3 August 2016 for Pivots 3 to 6.

Table 5.2 Calculated abstraction volumes 2016 - Irrigation

Development Stage			Stage 1a		Stage 1b		Total Irrigation Abstraction (kL)
Irrigation Bore:			PB1	PB2	PB3	PB4	
Supplies:			Pivot 1	Pivot 2	Pivots 3 and 6	Pivots 4 and 5	
From	To	Month	Abstraction (kL)				
October 2010 to end 2011:			1,616,363	0	-	-	1,616,363
2012:			491,412	0	-	-	491,412
2013:			1,016,880	999,800	-	-	2,016,680
2014:			1,159,035	1,362,370	-	-	2,521,405
2015:			665,089	991,231	-	-	1,656,320
1/01/2016	*1/02/2016*	*January 2016*	*41,240*	*132,053*	*0*	*0*	*173,293*
1/02/2016	*1/03/2016*	*February 2016*	*118,350*	*94,385*	*0*	*0*	*212,735*
1/03/2016	*1/04/2016*	*March 2016*	*109,738*	*133,185*	*0*	*0*	*242,923*
1/04/2016	*1/05/2016*	*April 2016*	*116,207*	*98,948*	*0*	*0*	*215,155*
1/05/2016	*1/06/2016*	*May 2016*	*13,706*	*49,779*	*2*	*461*	*63,948*
1/06/2016	*1/07/2016*	*June 2016*	*12,982*	*12,700*	*18,554*	*29,457*	*73,693*
1/07/2016	*1/08/2016*	*July 2016*	*52,599*	*41,753*	*113,103*	*56,670*	*264,125*
1/08/2016	*1/09/2016*	*August 2016*	*84,137*	*75,073*	*117,170*	*100,733*	*377,113*
1/09/2016	*1/10/2016*	*September 2016*	*103,108*	*66,867*	*150,791*	*125,423*	*446,189*
1/10/2016	*1/11/2016*	*October 2016*	*2,246*	*45,010*	*215,550*	*101,726*	*364,532*
1/11/2016	*1/12/2016*	*November 2016*	*86,683*	*101,065*	*182,910*	*124,594*	*495,252*
1/12/2016	*31/12/2016*	*December 2016*	*90,319*	*83,926*	*106,465*	*87,750*	*368,460*
Total 2016 Abstraction (kL):			831,315	934,744	904,545	626,814	3,297,418

Table 5.3 Stock bore flowmeter readings

Bore	Atlas PB1	Chower bore	WCB04B	WCB08C	WCB11Y	WCB14A	WCB17C
Brand	Dorot	Arad	Dorot	Dorot	Dorot	Dorot	Dorot
Flowmeter Serial Number	0710 207285	WSTp1-3"-10-04180	211067	010600-SN	SN 207283	1003 010587	1003 010593
Flowmeter Unit	m^3	m^3	m^3	m^3	m^3	m^3	m^3
Aquifer	Wallal	Wallal	Wallal	Wallal	Wallal	Wallal	Wallal
DATE	**FLOWMETER READING**						
24/01/2016	29525	82000		16467			
25/01/2016			23000				
27/01/2016					29412	2377	50704
3/04/2016		82006					
4/04/2016	29543			16539		2377	62852
5/04/2016					30179		
7/04/2016			23000				
13/07/2016	29613	82066		16592	31762	2377	74856
14/07/2016			23008				
14/10/2016					33410		79689
15/10/2016	29914	82230	23000	16594		2377	
10/02/2017		82236					
11/02/2017	29934				33853		87443
14/02/2017				17124		2377	
13/03/2017			25002				
Comments 2016 water year	Minor stock use.	Minor water carting	Could not visit during February 2017, Pardoo Creek in flood.	Minor stock use.	Minor stock use.	No cattle at this bore. Tank is dry, bore is shut off. Pump is faulty.	Minor stock use.

Notes: All measurements recorded by Groundwater Consulting Services.

Table 5.4 Calculated abstraction volumes 2016 - Stock

Period	Year	Wallal Aquifer Stock Water Abstraction (kL)							
		Atlas PB1	**Chower bore**	**WCB04B**	**WCB08C**	**Pardoo 11 WCB11A WCB11Y**	**WCB14A**	**WCB17C**	**Total**
Mar 2011 to Feb 2012	2011	280	not drilled	unknown	203	3,343	unknown	22,321	**>26,147**
Feb 2012 to Jan 2013	2012	661	751	unknown	310	3,797	unknown	7,129	**>12,648**
Jan 2013 to Jan 2014	2013	14,921	29,301	unknown	15,682	2,793	813	meter seized	**>63,510**
Jan 2014 to Jan/Feb 2015	2014	12,908	50,503	3,198	338	3,148	441	20,684	**91,220**
Jan/Feb 2015 to Jan 2016	2015	108	1,445	996	219	5,937	173	27,393	**36,271**
Jan 2016 to Feb 2017 (Mar 17 WCB04B)	2016	409	236	2,002	657	4,441	0	36,739	**44,484**

5.3 ACCOMMODATION FACILITIES

The Homestead bore provides groundwater from the Wallal aquifer for domestic use at the caravan park and Pardoo Homestead, as well as water for irrigating gardens and lawns.

After problems with the meter in 2015 and with the meter again seizing in 2016, the meter was removed and a new ultrasonic meter was installed on the bore in December 2016 *(Table 5.5)*.

Based on the average daily use between 11/12/2016 and 10/4/2017, the estimated annual groundwater abstraction from Homestead bore is around 120,000 kL.

Table 5.5 Homestead bore flowmeter readings

Date	Bore	Brand	Flowmeter Serial Number	Flowmeter Reading (m^3)	Groundwater Consulting Services Comment
25/01/2016	Pardoo Homestead bore	Dorot	SN 010596	86805	
6/04/2016	Pardoo Homestead bore	Dorot	SN 010596	101888	
14/07/2016	Pardoo Homestead bore	Dorot	SN 010596	*105864*	Meter seized.
14/10/2016	Pardoo Homestead bore	Dorot	SN 010596	*104759*	Meter seized and running backwards.
11/12/2016	Pardoo Homestead bore	Octave	627030529	73.54	Meter replaced.
12/02/2017	Pardoo Homestead bore	Octave	627030529	20643	
10/4/2017	Pardoo Homestead bore	Octave	627030529	39320	

6. MONITORING RESULTS

Overview charts of all groundwater monitoring data collected since the project commenced are provided on *Figure 6a,b, Appendix A* for Wallal aquifer bores and *Figure 7, Appendix A* for Broome aquifer bores.

6.1 GROUNDWATER LEVELS AND PRESSURE

Groundwater Consulting Services records groundwater pressure *(Table 6.1)* or depth to water *(Table 6.2)* in selected Wallal aquifer and Broome aquifer bores on a quarterly basis.

Groundwater Consulting Services has been using a digital pressure gauge to supplement fixed pressure gauge readings since January 2013. The digital gauge is more accurate and provides pressure readings that are closer to the pressure readings recorded by the pressure dataloggers installed in selected bores. Both the digital and fixed pressure gauge readings are shown on the charts of logger data with data prior to 2013 *(Figures 6a, 8 and 9, Appendix A).* Only digital gauge readings are listed in *Table 6.1.*

Groundwater Consulting Services has installed unvented pressure loggers in each of the seven irrigation bores (Pardoo PB1 to Pardoo PB7) as well as Pardoo BMB1, Pardoo BMB2, Chower bore, Atlas MB3, WCB09E, WCB16C and WCB17C. In addition, the Department of Water has installed unvented pressure loggers in Wallal aquifer bores WC04B, WCB11Y, WCB15Y, WC 01A/12, WC 02A/12, WC 03A/12, WC 04A/12 and WC 07A/12 across Pardoo Station. The department provided these data to Groundwater Consulting Services to be used in the numerical model developed for the project (CyMod Systems, 2017).

All of the pressure loggers used on Pardoo Station are unvented and barometric pressure needs to be subtracted from the logger pressure data. The Department of Water has installed a barometric logger at each bore location so that the local station pressure is recorded and a more accurate water pressure can be calculated.

Groundwater Consulting Services installed a barometer at WCB25Z on Wallal Downs Station on 30 April 2012. These data are used to reduce the unvented logger data from the bores on Pardoo Station. A correction is made to the barometric pressure based on the difference in elevation between the Pardoo Station bore and WCB25Z as detailed in the previous groundwater monitoring summary (Groundwater Consulting Services, 2016a).

Groundwater Consulting Services installed a barometer at Pardoo BMB2 in January 2016 and barometric data at this site has been used to correct the unvented logger pressure since that time. Groundwater Consulting Services also installed a logger at Pardoo PB5 in November 2016 which will be used to correct unvented logger pressure from the Stage 2 development area bores in 2017.

Table 6.1 Groundwater pressure monitoring

Bore	Wallal Aquifer Pressure (mH_2O above ground level) using digital pressure gauge																
	January 2016				**April 2016**				**July 2016**			**October 2016**		**February 2017**			**March 2017**
	24/01/16	25/01/16	26/01/16	27/01/16	3/04/16	4/04/16	5/04/16	7/04/16	12/07/16	13/07/16	14/07/16	14/10/16	15/10/16	10/02/17	11/02/17	14/02/17	13/03/17
Atlas MB2						4.68				4.48			4.49		4.51		
Atlas MB3		10.04				9.82				9.60			9.63		9.64		
Atlas PB1	4.76					4.62				4.58			4.38		4.34		
Brumby bore				15.35			14.76			14.70		14.67			14.68		
Cape Keraudren				25.44			25.34			25.45		25.12		25.27			
Chower bore	20.15				19.89					19.90			19.73	19.82			
Pardoo PB1		*23.64*			32.33				31.98			31.51				32.07	
Pardoo PB2		30.46	30.80	*21.33*	30.84				30.48			29.99				30.36	
Pardoo PB3					28.83				*23.45*			*16.25*				28.45	
Pardoo PB4					28.33				*23.65*			*23.93*				28.06	
Pardoo PB5					31.10				31.07			30.93		31.34			
Pardoo PB6									30.54		30.53	30.70		30.82			
Pardoo PB7														28.30			
Telegram bore				11.73			16.07			17.40		11.53			17.38		
WC 01A/12				5.13		4.95					4.56		4.37			4.44	
WC 01B/12				3.93		4.74					4.67		4.50			4.41	
WC 02A/12		8.10			8.02					7.98			7.73		7.77		
WCB04B		6.05						5.70			6.01		5.98				6.13
WCB08C	18.62					18.63				18.65			18.54			18.40	
WCB09E				27.89			27.72			27.75		27.66		27.64			
WCB10B				6.16			5.82			6.29		6.01			5.95		
WCB11Y				2.09			2.10			1.87		1.54					
WCB17A		21.47				21.54											
WCB17C		21.81				21.85				21.79		21.44			21.71		

Notes: Bold, italic values indicate bore operating at time of measurement.
All measurements recorded by Groundwater Consulting Services.

Table 6.2 Groundwater level monitoring

Aquifer:		BROOME							WALLAL													Measured By
Bore:		Deep well	Pardoo BMB1	Pardoo BMB2	Pardoo BMB3	WCB 16B	WCB 17B	WC 03C/12	WCB 05Y	WCB 05YR	WCB 07A	WCB 15Y	WCB 16A	WCB 16C	WC 03A/12	WC 03B/12	WC 04A/12	WC 04B/12	WC 06A/12	WC 07A/12	WC 07C/12	
Water Year	Date	Depth to Water (mBGL)																				
2016	25/01/16	16.50	14.62	3.51	5.00	7.26		28.21				43.84	2.22	2.04	27.86	27.76	8.42	8.35				Groundwater Consulting Services
	27/01/16								31.12													Groundwater Consulting Services
	3/04/16				5.01	7.41		28.25				43.86	2.28	2.12	27.92	27.80						Groundwater Consulting Services
	4/04/16		14.63	3.39													8.52	8.46				Groundwater Consulting Services
	7/04/16	16.53																				Groundwater Consulting Services
	18/06/16						14.40															Department of Water
	13/07/16		14.78	3.62	5.21	7.63		28.29		31.05		43.90	2.30	2.11	27.95	27.85						Groundwater Consulting Services
	14/07/16	17.30															8.71	8.69				Groundwater Consulting Services
	11/08/16		14.78			7.76	14.42	28.26		31.03	2.89	43.90	2.65	2.20	27.98							Department of Water
	12/08/16																8.74			61.88	90.12	Department of Water
	14/10/16		14.84	3.53	5.24																	Groundwater Consulting Services
	15/10/16	16.87				7.63		28.28		31.07		43.86	2.53	2.35	28.03	27.92	8.80	8.73	24.77	61.86		Groundwater Consulting Services
2017	10/02/17																8.90	8.84				Groundwater Consulting Services
	11/02/17					7.88	14.54	27.59				43.92	2.53	2.33	28.07	27.96						Groundwater Consulting Services
	12/02/17							**obstructed**											24.79			Groundwater Consulting Services
	14/02/17	17.02		3.01	4.66					31.10	2.89									61.92		Groundwater Consulting Services
	15/02/17		14.94																			Groundwater Consulting Services

6.2 GROUNDWATER QUALITY

During quarterly site visits, Groundwater Consulting Services measures electrical conductivity (*Table 6.4*) in samples collected from selected:

- non-artesian Wallal aquifer bores fitted with a pump;
- artesian Wallal aquifer bores with a functioning valve; and
- Broome aquifer monitoring bores installed for the irrigation project, with samples collected using using a 12v or 240V sampling pump.

Field electrical conductivity measurements are presented as charts on *Figure 6b, Appendix A* (Wallal aquifer bores) and *Figure 7, Appendix A* (Broome aquifer bores).

Annual groundwater sampling is undertaken for laboratory analysis of major ions and nutrients. Samples are submitted to Agrifood Technology for analysis. Results are presented in *Table 6.5* and laboratory results since the project commenced are collated in *Appendix E.* A copy of the laboratory certificate for October 2016 sampling round is provided in *Appendix F.*

Table 6.3 Field electrical conductivity

Bore	Aquifer	FIELD ELECTRICAL CONDUCTIVITY (uS/cm @ 25degC)																	
		January 2016			April 2016				July 2016			October 2016		February 17					March 17
		24/1/16	25/1/16	27/1/16	3/4/16	4/4/16	5/4/16	7/4/16	12/7/16	13/7/16	14/7/16	14/10/16	15/10/16	10/2/17	11/2/17	12/2/17	14/2/17	15/2/17	13/3/17
Deep well	Broome							3,560			3,680		3,540			3,050			
Pardoo BMB1	Broome		1,210			1,251				1,270		1,255						1,233	
Pardoo BMB2	Broome		1,822			1,889				1,979		2,230					2,230		
Pardoo BMB3	Broome		2,700		2,620					2,600		2,590					2,590		
CRA bore	Unknown			2,180		2,180													
Atlas MB2	Wallal		2,030			2,070				2,080			2,030		2,060				
Atlas MB3	Wallal		2,000			2,020				2,050			2,030		2,030				
Atlas PB1	Wallal	2,030				2,060				2,070			2,060		2,060				
Brumby bore	Wallal			2,010			1,971			2,000		2,000			1,860				
Cape Keraudren	Wallal			1,860			1,890			1,871		1,882		1,820					
Chower bore	Wallal	1,088			1,098					1,133			1,095	1,076					
Noba bore	Wallal			1,880			1,860			1,866		1871			1,795				
Pardoo Homestead bore	Wallal		2,780			2,850					2,830	2,690				2,760			
Pardoo PB1	Wallal		960		962				962			981					988		
Pardoo PB2	Wallal		1,240		1,217				1,227			1,232					1,215		
Pardoo PB3	Wallal				925			930	959			974					980		
Pardoo PB4	Wallal				951				958			950					954		
Pardoo PB5	Wallal				805			810	824			808					825		
Pardoo PB6	Wallal										960	990		960					
Pardoo PB7	Wallal													780					
Stockyard bore	Wallal		2,440				2,490				2,830	2,490				2,410			
Telegram bore	Wallal			2,040			2,040			2,030		2,020			1,992				
WC 01A/12	Wallal			744		728					724		725				726		
WC 01B/12	Wallal					723											712		
WC 02A/12	Wallal		605		624					627			623		602				
WC 02B/12	Wallal		615		660					645			601		611				
WCB04B	Wallal		3,020					3,080			3,080		3,080						2,950
WCB06A	Wallal			860		852											800		
WCB07A	Wallal			591		574				566							553		
WCB08C	Wallal	1,692				1,730				1,723			1,725				1,685		
WCB09E	Wallal			1,690			1,698			1,706		1,702		1652					
WCB10B	Wallal			2,070			2,060			2,060		2,060			2,050				
WCB11Y	Wallal			2,090			2,090			2,090		2,090			2,040				
WCB14A	Wallal																		
WCB16A	Wallal																		
WCB17A	Wallal		740			732													
WCB17C	Wallal		892			908				907		908			893				

Table 6.4 Laboratory analyses

Aquifer	WALLAL AQUIFER												BROOME AQUIFER		
Bore	**Pardoo PB1**	**Pardoo PB2**	**Pardoo PB3**	**Pardoo PB4**	**Pardoo PB5**	**Pardoo PB6**	**Pardoo Homestead bore**	**Atlas PB1**	**Cape Keraudren**	**Chower bore**	**WCB04B**	**WCB17C**	**Pardoo BMB1**	**Pardoo BMB2**	**Pardoo BMB3**
Screen Interval (mBGL)	136.3 to 262	162 to 252	158.8 to 242.8	159.45 to 249.6	175 to 193	177.1 to 286.1	54.86 to 56.69	43 to 101	166.55 to 208.85	133 to 151.65	79 to 85	130.75 to 148.75	13.3 to 19.3	1.51 to 7.95	1.3 to 7.3
Sample Date	14/10/16	14/10/16	14/10/16	14/10/16	14/10/16	14/10/16	14/10/16	15/10/16	14/10/16	15/10/16	15/10/16	14/10/16	14/10/16	14/10/16	14/10/16
Laboratory	Agrifood	Agrifood	Agrifood	Agrifood	Agrifood	Agrifood	Agrifood	Agrifood	Agrifood	Agrifood	Agrifood	Agrifood	Agrifood	Agrifood	Agrifood
Appearance	Colourless	Colourless	Colourless	Colourless	Colourless	Sand	Colourless	Colourless	Colourless	Colourless	Colourless	Colourless	Sand	Colourless	Iron
Odour	Odourless	Odourless	Odourless	Odourless	Odourless	Odourless	Odourless	Odourless	Odourless	Odourless	Odourless	Odourless	Odourless	Odourless	Odourless
pH	7.0	7.1	7.2	7.1	7.6	7.1	6.9	6.9	7.2	7.1	6.7	7.3	7.3	7.8	7.8
Electrical Conductivity (mS/cm)	1.07	1.27	0.98	0.96	0.82	0.99	2.80	2.02	1.87	1.11	3.07	0.91	1.25	2.04	2.55
Total Dissolved Salts (calc.)	550	680	550	540	470	550	1470	1120	960	620	1670	510	820	1300	1600
Sodium	140	160	140	140	120	140	370	260	220	150	450	130	130	440	560
Potassium	11	13	12	11	11	11	19	15	14	12	25	9.7	3.9	7.5	26
Calcium	24	34	23	21	16	22	69	55	54	27	61	19	80	16	11
Magnesium	13	19	13	12	8.8	12	42	32	32	15	38	11	16	5.3	6.0
Bicarbonate	175	145	170	175	175	165	70	90	70	165	75	195	245	595	715
Chloride	160	240	160	160	130	170	790	510	490	200	780	140	170	270	380
Sulphate, SO_4	89	120	90	87	71	91	120	170	95	110	260	79	61	180	180
Nitrate, NO_3	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	1.5	<0.5	<0.5	<0.5	<0.5	<0.5	130	12	1.4
Nitrate, N	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.3	<0.1	<0.1	<0.1	<0.1	<0.1	29.4	2.7	0.3
Total Nitrogen, N	<0.1	<0.1	<0.1	0.3	0.2	0.1	0.4	0.2	0.1	<0.1	0.1	<0.1	30	2.9	0.4
Phosphate, P	<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
Total Phosphorus, P	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	0.01	0.03
Boron	0.28	0.25	0.26	0.27	0.28	0.28	0.2	0.21	0.17	0.27	0.24	0.34	0.31	1.8	2.0
Iron	0.0044	0.0058	0.012	0.0066	0.068	0.092	0.0024	0.0019	0.03	0.0042	0.0072	0.015	<0.0010	<0.0010	0.052
Fluoride	0.43	0.32	0.42	0.4	0.39	0.34	0.17	0.19	0.21	0.3	0.15	0.49	0.21	3.74	6.24
Manganese	0.011	0.0091	0.0046	0.0063	0.01	0.017	0.00081	<0.00050	0.006	0.0085	0.048	0.0045	0.0017	0.00051	0.0075
Hardness (as $CaCO_3$)	115	165	110	100	75	105	345	270	265	130	310	95	265	60	50
Alkalinity (as $CaCO_3$)	140	120	140	145	140	135	60	75	60	135	65	160	200	485	585
Ammonium, NH_4	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Silica, SiO_2	25	25	26	28	28	28	23	29	19	23	19	29	110	82	78
Dissolved Carbon Dioxide	28	18	17	22	7	21	14	18	7	21	24	16	19	15	18
Cations (me/L)	8.6	10.6	8.6	8.4	7.0	8.5	23.5	17.1	15.3	9.4	26.4	7.8			
Anions (me/L)	9.2	11.6	9.2	9.2	8.0	9.4	25.9	19.4	16.9	10.6	28.6	8.7			

Notes: All units mg/L unless stated.
Historical groundwater quality results provided in Appendix E .

6.3 COMPLIANCE

The groundwater monitoring programme that was in-force at the start of the 2016 water year was the revised monitoring programme provided to the Department of Water in the 2013 groundwater monitoring summary (Groundwater Consulting Services, 2014a) which is reproduced in *Table 6.4.*

The Department of Water requested an updated operating strategy when the interim Stage 2 licence for 10,000,000 kL/annum was issued in June 2016. A draft revised operating strategy (Groundwater Consulting Services, 2016b) was provided to the Department of Water in August 2016 and the proposed groundwater monitoring programme for the Stage 2 expansion provided in the draft operating strategy is also provided in *Table 6.4.* Additional groundwater monitoring has been carried out by Groundwater Consulting Services on behalf of Pardoo Beef Corporation that is not prescribed in the groundwater monitoring programme but which is appropriate for the groundwater allocation required for the Stage 2 development and most of the proposed monitoring commitments for the Stage 2 expansion were met in the 2016 water year.

A final version of the Stage 2 operating strategy is being developed in consultation with the Department of Water.

Table 6.5 Compliance with monitoring programme

CATEGORY	PARAMETERS	MONITORING PROGRAMME (Groundwater Consulting Services, 2014a)	MONITORING PROGRAMME IN DRAFT OPERATING STRATEGY AUGUST 2016	FREQUENCY	COMPLIANCE 2016
Rainfall	Rainfall	Pardoo Homestead	Pardoo Homestead	Daily	**Compliant** – BoM
Water Use	Manual flowmeter reading	Irrigation bores Pardoo PB1 and Pardoo PB2	Irrigation bores Pardoo PB1, Pardoo PB2, Pardoo PB3, Pardoo PB4 Pardoo PB5, Pardoo PB6 (when commissioned)	Quarterly 2014 programme Monthly 2016 programme	**Compliant** with 2014 monitoring programme.
	Automated flow volume counter	Irrigation bores Pardoo PB1 and Pardoo PB2	Irrigation bores Pardoo PB1, Pardoo PB2, Pardoo PB3, Pardoo PB4 Pardoo PB5, Pardoo PB6 (when commissioned)	Minimum hourly. Download logger on a quarterly basis.	**Compliant** for commissioned irrigation bores Pardoo PB1 to PB4. Flow loggers will be installed in PB5 to PB7 prior to commissioning.
	Manual flowmeter reading	All stock and domestic bores fitted with a flowmeter.	Key stock and other use bores Atlas PB1, Chower bore, Homestead bore WCB04B, WCB08C, WCB11Y, WCB14A, WCB17C	Quarterly	**Compliant** with 2016 programme operating strategy includes a programme to fit other stock bores with flowmeters.
Barometric Pressure	Pressure (logger data)	Logger installed in headworks of WCB25Z on Wallal Downs Station.	Barometric logger installed at Pardoo BMB2.	Minimum hourly. Download logger on a quarterly basis.	**Compliant** Barometers at WCB25Z, BMB2
Groundwater Pressure	Pressure (logger data)	Wallal aquifer: Pardoo PB1, Pardoo PB2, Chower, WCB17A, Atlas MB3 Broome aquifer: Pardoo BMB2	Wallal aquifer: Pardoo PB1 to Pardoo PB6 Atlas MB3, Chower bore, WCB09E, WCB16C, WCB17C Broome aquifer: Pardoo BMB2	Minimum hourly. Download logger on a quarterly basis.	**Compliant** with 2016 programme Loggers installed in Pardoo PB1 to PB7 on bore completion.
	Pressure (pressure gauge reading)	Wallal aquifer: Pardoo PB1, Pardoo PB2, Chower, WCB17A, Atlas MB3 WCB08C, WCB09E, WCB11Y,	Wallal aquifer: Pardoo PB1 to Pardoo PB6 Atlas MB3, Cape Keraudren bore, Chower bore, WCB04B, WCB08C, WCB09E, WCB11Y, WCB17C	Quarterly	**Compliant** with 2016 programme including Pardoo PB7
Groundwater Levels	Depth to water	Wallal aquifer: WCB16C Broome aquifer: Pardoo BMB1, Pardoo BMB2, Pardoo BMB3	Wallal aquifer: WCB15Y, WCB16C Broome aquifer: Pardoo BMB1, Pardoo BMB2, Pardoo BMB3	Quarterly	**Compliant** with 2016 programme including BMB5 to BMB8 following completion.
Groundwater Salinity	Electrical conductivity (field)	Wallal aquifer: Pardoo PB1, Pardoo PB2, Chower, WCB17A, Atlas MB3 WCB08C, WCB09E, WCB11Y, Homestead bore.	Wallal aquifer: Pardoo PB1 to Pardoo PB6, Atlas PB1, Cape Keraudren bore, Chower bore, Homestead bore WCB04B, WCB08C, WCB09E, WCB11Y, WCB16A*, WCB17C Broome aquifer: Pardoo BMB2, Pardoo BMB3	Quarterly	**Compliant** with 2016 programme. WCB16A is non-artesian and a representative groundwater sample is only available if the bore is in use for stock watering.
Groundwater Quality	Laboratory analysis of major ions, physico-chemical parameters and nutrients.	Wallal aquifer: Pardoo PB1, Pardoo PB2, Atlas PB1, Chower bore, Pardoo Homestead bore, WCB17C Broome aquifer: Pardoo BMB2, Pardoo BMB3	Wallal aquifer: Pardoo PB1 to Pardoo PB6, Atlas PB1, Cape Keraudren bore, Chower bore, Homestead bore, WCB04B, WCB17C Broome aquifer: Pardoo BMB2, Pardoo BMB3	Annual	**Compliant** with 2016 programme. Sampling carried out on 14 and 15 October 2016.
Note:		Any additional irrigation bores installed on Pardoo Station will be monitored in the same manner as the existing irrigation bores Pardoo PB1 and Pardoo PB2 as listed above.	**The monitoring programme listed in the draft operating strategy is being finalised in conjunction with the Department of Water. The above programme was nominated in August 2016. Since that time, irrigation bore Pardoo PB7 and five additional Broome aquifer monitoring bores have been installed and will be incorporated in the final version of the operating strategy.**		

Table 6.6 Status of recommendations

Recommendation in groundwater monitoring review (Groundwater Consulting Services, 2016)	**Responsible Party**	**Status**
Pardoo Beef Corporation record flowmeter readings for the irrigation bores on a monthly basis and submit readings to Groundwater Consulting Services.	Pardoo Beef Corporation	Not compliant End of year readings provided.
If site personnel are at a stock bore that fitted with a flowmeter, the date and flowmeter reading should be recorded and the information should be forwarded to Groundwater Consulting Services.	Pardoo Beef Corporation	Not done
Pardoo Beef Corporation should focus on water use and nutrient efficiency now that planting of crops on the Stage 1a pivot areas has commenced after a period of transition following the purchasing of Pardoo Station in March 2015.	Pardoo Beef Corporation	In progress Refer to *Section 6.4*
Pardoo PB5 should not be used for stock watering as an undisturbed pressure response is important to understand the drawdown impacts that develop in response to commencement of irrigation at the additional crop area at Stage 1.	Pardoo Beef Corporation	Pardoo PB5 was not used for stock water but was used for dust suppression, road construction and drilling water supply purposes.

6.4 WATER AND NUTRIENT USE EFFICIENCY

In the 2016 water year, Pardoo Beef Corporation continued to grow fodder crops for cattle feed on Pivots 1 and 2. Oats were grown during cooler dry season and sorghum during the wet season. The fodder on Pivots 1 and 2 is cut and baled for use on Pardoo Station.

Pivots 3 to 6 were installed and commissioned in mid-2016 and were put into production for cell grazing of cattle directly on the pivot areas. Hay and silage produced from Pivots 1 and 2 were provided to the cattle as an alternative to the green feed. The cell grazing production system appears to convert the available water resources into beef more efficiently than feeding cattle with hay or silage products, and Pardoo Beef Corporation will convert Pivots 1 and 2 over to cell grazing production methods in 2017.

Pardoo Beef Corporation is using the agronomy services provided by Landmark (Landmark Operations Ltd). Opportunities to use water and nutrients more efficiently and more effectively to maximise cattle production were identified. Pardoo Beef Corporation is preparing to source soil moisture monitoring equipment on Landmark's recommendation. Soil moisture is monitored several times per week using a steel rod inserted into the ground to obtain indicative soil moisture profile information.

Irrigation and nutrient applications are modified on a periodic basis in response to changes in crop growth stage, climatic conditions and grazing pressure. Soil nutrient and leaf tissue tests have been undertaken sporadically and will be undertaken more regularly under Landmark's guidance. Potassium and phosphorus based fertilisers are applied in granular form using a tractor mounted spreader. Nitrogen based fertilisers are injected in liquid form into the irrigation water supply.

Pardoo Beef Corporation has engaged a dedicated innovation and technical manager with the assistance of the Meat Livestock Australia to optimise the production system by conducting trials and reviews of the production system. A key outcome of the role is maximising the value of the beef end product that can be produced for each unit of water.

7. ASSESSMENT OF IMPACTS

7.1 IMPACT OF ABSTRACTION FROM WALLAL AQUIFER

7.1.1 DRAWDOWN

The following context is provided for assessing the drawdown impacts of the irrigation project on the regional Wallal aquifer system:

- Potentiometric heads in the Wallal aquifer are higher, in some bores by several metres, than the heads recorded by Leech in the late 1970s (Leech 1979a,b, *Figure 5, Appendix A*)
- Regionally, potentiometric heads in bores in the western portion of Pardoo Station are receding following Cyclone Rusty in 2013 (*Figure 6a, Appendix A*).
- Most Wallal aquifer bores on Pardoo Station are also used for stock watering or commercial purposes and it is difficult to separate drawdown for this purpose from drawdown impacts caused by the irrigation project *(Figure 9a,b, Appendix A).*

For the initial stage of the project, groundwater abstraction was in the order of 1,656,320 kL in 2015 and the highest annual abstraction was 2,521,405 kL in 2014. Drawdown within the highly transmissive Wallal aquifer was small and difficult to discern in the regional hydrographs.

Since Pardoo Beef Corporation purchased the lease for Pardoo Station in March 2015, there are two significant periods:

- Period of no abstraction in July and August 2015 during which time groundwater levels in Pardoo PB1, Pardoo PB2 and WCB17A show a recovery response (*Figures 8a and 9b, Appendix A*).
- Commissioning of the additional four centre-pivot irrigator for the Stage 1b development in July and August 2016 (*Figure 9a,b, Appendix A*). Abstraction from the Wallal aquifer has increased to around 4,875,000 kL/annum (based on doubling the measured abstraction over six months from October 2016 to March 2017).

These two periods were used as markers to calculate drawdown for the closest Wallal aquifer bores to the irrigation project shown on *Figure 9b, Appendix A*:

- Drawdown in WCB17A/C between August 2015 and April 2017 is around 1.3m, of which 0.8 to 0.9 m occurred when the Stage 1b bores were operating between August 2016 and April 2017. WCB17A/C is the closest bore to the irrigation borefield and is 3.0 km from Pardoo PB1.
- Additional drawdown in Pardoo PB5 when the Stage 1b bores were commissioned in is around 0.7 to 0.8m. Pardoo PB5 is around 3.6km from Pardoo PB1.

- Drawdown in Chower bore, which is located 14.5 km west of Pardoo PB1, between August 2015 and April 2017 is around 0.6 m.

The broad drawdown estimates are based on the assumption that potentiometric heads have fully recovered when irrigation was curtailed during the lease transfer period and that all declines in potentiometric heads over the periods listed are due to the irrigation project on Pardoo Station. The estimates exclude consideration of declining seasonal trends, abstraction for stock water or commercial purposes from each bore and the impacts of groundwater abstraction by other users.

When the Stage 2 development borefield is commissioned, the further increase in abstraction from the Wallal aquifer will provide a less ambiguous understanding of the regional drawdown response within the Wallal aquifer and an improvement in the understanding of the initial drawdown impact of the Stage 1 irrigation project.

The irrigation borefield at Wallal Downs Station is around 30 km east of the Stage 1 development area and around 23 km east of the Stage 2 development area on Pardoo Station. The irrigation projects at both stations are at similar stages of development and have each imposed small drawdown impact on the other at each borefield (less than 0.5m).

Pardoo Beef Corporation will install a dedicated Wallal aquifer monitoring bore on the boundary of Pardoo Station and Wallal Downs Station prior to the commissioning of the Stage 2 borefield.

7.1.2 GROUNDWATER QUALITY

Groundwater salinity in Wallal aquifer bores within the irrigation borefield has remained consistent since monitoring commenced in 2011 *(Figure 6b, Appendix A).*

The irrigation project has had no impact on groundwater quality within the Wallal aquifer system.

7.2 IMPACT OF IRRIGATION ACTIVITIES ON BROOME AQUIFER

Over-irrigation and over-fertigation of the fodder crops can potentially result in the mobilisation of salts as the water table rises and increased nutrient concentrations in the down-gradient portion of the aquifer system. Groundwater salinity in samples from BMB2 which is located to the east of Pivot 3 increased over the 2016 water year from 1822 to 2230 uS/cm while groundwater levels in the bore were declining. The increase in salinity observed in BMB2 was not apparent in the results for BMB3 which is located to the north of Pivot 2 *(Figure 7, Appendix A).* Nutrient concentrations in samples from both bores are low with total nitrogen concentration less than 3 mg/L and total phosphorus <0.03 mg/L.

Groundwater levels in both BMB1 and BMB2, which both screen the water table, were declining over most of 2016 and rose in February 2017 in response to rainfall.

8. CONCLUSIONS

In the 2016 water year, Pardoo Beef Corporation completed Stage 1b of the irrigated fodder project. An additional four 40-ha pivot areas (Pivots 3 to 6) were commissioned between July and August 2016. There is a total of 243 ha under centre-pivot irrigation for the Stage 1 project.

The total groundwater abstraction from the Wallal aquifer for irrigation purposes was 3,297,418 kL in 2016. In addition, around 200,000 kL was abstracted from the Wallal aquifer from six WCB- stock bores, Homestead bore, Chower bore and Pardoo PB5 for stock watering, domestic, accommodation purposes, water carting and drilling water supply.

Pardoo Beef Corporation is near completion of the approvals process for the Stage 2 development area. The Stage 2 development involves the installation of six 50-ha pivot areas (Pivots 7 to 12) at a distance of 3.1 km east of the Stage 1 development area *(Figure 2b, Appendix A).* Pardoo Beef Corporation has also recently submitted applications for the required permits for the Stage 3 development area which is around 2.2 km west of the Stage 1 development area (*Figure 2a, Appendix A*).

Three Wallal aquifer irrigation bores (Pardoo PB5 to PB7) were installed for the Stage 2 development in the 2016 water year. Each bore will supply centre-pivot irrigators on two 50-ha pivot areas. In April 2017, flowmeters were installed on each discharge line to the six centre-pivot irrigators which are currently being erected. A pressure head logger has been installed in each irrigation bore and a pulse flow logger will be installed prior to commissioning the bores.

In January 2017, the full groundwater allocation required for the Stage 2 expansion was released by the Department of Water and Pardoo Beef Corporation is authorised to abstract up to 14,822,250 kL/annum from the Wallal aquifer. If Pardoo Beef Corporation is able to improve water use efficiency and decrease the irrigation application rate to around 17,000 kL/ha/annum, then the Stage 3 expansion can be accommodated within the current licensed allocation of 14,822,250 kL/annum. Pardoo Beef Corporation has engaged an agronomy services provided and employed a dedicated innovation and technical manager to improve water use efficiency.

Monitoring of groundwater pressure in the Wallal aquifer has been on-going since 2011. The low level of groundwater abstraction from the highly-transmissive Wallal aquifer system, combined with local use of regional Wallal aquifer bores, has meant that drawdown due to abstraction for the initial stage of the irrigation project has been difficult to discern from seasonal and local use responses. In July and August 2016, the four Stage 1b centre-pivot irrigators were commissioned and groundwater abstraction increased from around 1,600,000 kL/annum to the equivalent of 4,875,000 kL/annum with a measurable drawdown impact response in hydrographs for the Wallal aquifer bores closes to the irrigation borefield.

Drawdown of up to 1.3 m is estimated at WCB17A/C (3km from the irrigation borefield) since Pardoo Beef Corporation commenced irrigation in August 2015, of which around of which 0.8

to 0.9 m occurred when the Stage 1b bores were operating between August 2016 and April 2017. The estimated drawdown in April 2017 at Chower bore which is 14.1km west of the irrigation borefield is around 0.6m. Drawdown in more remote bores is difficult to separate from fluctuations in potentiometric head resulting from the use of the bore for stock watering and from seasonal trends.

The irrigation borefield at Wallal Downs Station is around 30 km east of the Stage 1 development area and around 23 km east of the Stage 2 development area. The irrigation projects at both stations are at similar stages of development and have each imposed small drawdown impacts on the other (less than 0.5m).

Pardoo Beef Corporation will install a dedicated Wallal aquifer monitoring bore on the boundary of Pardoo Station and Wallal Downs Station prior to the commissioning of the Stage 2 borefield.

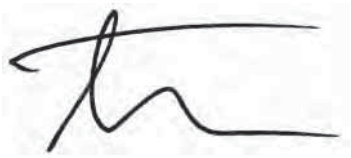
Groundwater quality in the Wallal aquifer and Broome aquifer systems has not been adversely affected by the irrigation project. The Broome aquifer monitoring network has been expanded from three to eight bores as part of the Stage 2 expansion.

8.1 RECOMMENDATIONS

- Pardoo Beef Corporation record flowmeter readings for the irrigation bores on a monthly basis and submit readings to Groundwater Consulting Services.
- If site personnel are at a stock bore that fitted with a flowmeter, the date and flowmeter reading should be recorded and the information should be forwarded to Groundwater Consulting Services.
- Pardoo Beef Corporation should implement the monitoring and management protocols in the Stage 2 operating strategy which is being finalised in conjunction with the Department of Water.
- Pardoo Beef Corporation will install a dedicated Wallal aquifer monitoring bore on the boundary of Pardoo Station and Wallal Downs Station prior to the commissioning of the Stage 2 borefield.

* * *

On behalf of Groundwater Consulting Services Pty Ltd,



Sam Burton
Director.

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10. LIMITATIONS

Groundwater Consulting Services Pty Ltd has prepared this report for Pardoo Beef Corporation Pty Ltd in accordance with generally accepted consulting practice. The specific conditions of the contract and subsequent communications have had a bearing on the depth and breadth of the project and on the confidence in the findings. When client constraints, whether express or implied, have limited the scope of work, a lower than normal confidence may occur.

The confidence in the ability of a groundwater resource to support a nominated withdrawal of groundwater is subject to spatial and temporal variations in the aquifers, climate and landuse that may not be known or predictable. Conservative assumptions will have been used where-ever possible, however, estimates of bore yield or predicted impacts of pumping can be incorrect, especially where conditions on which predictions were made have been changed. Groundwater Consulting Services Pty Ltd's predictions are made on the basis that Groundwater Consulting Services Pty Ltd will be contracted to undertake regular reviews of operational data that may lead to groundwater availability or quality predictions being re-estimated.

Groundwater Consulting Services Pty Ltd does not provide advice on crop water requirements, irrigation schedules, irrigation system design and other non-groundwater related areas. Groundwater Consulting Services Pty Ltd's advice on bore placement and operation must be considered by the proponent with reference to expert advice from other disciplines.

The project for which Groundwater Consulting Services Pty Ltd was contracted was undertaken for the client and its consulting advisers, and for review by regulatory agencies. The report should not be used by other parties without the consent of Groundwater Consulting Services Pty Ltd due to the potential for misunderstandings to occur.

11. APPENDICES

Appendix A – Figures

Appendix B – Licences

Appendix C – Plates

Appendix D – Bore Completion Logs

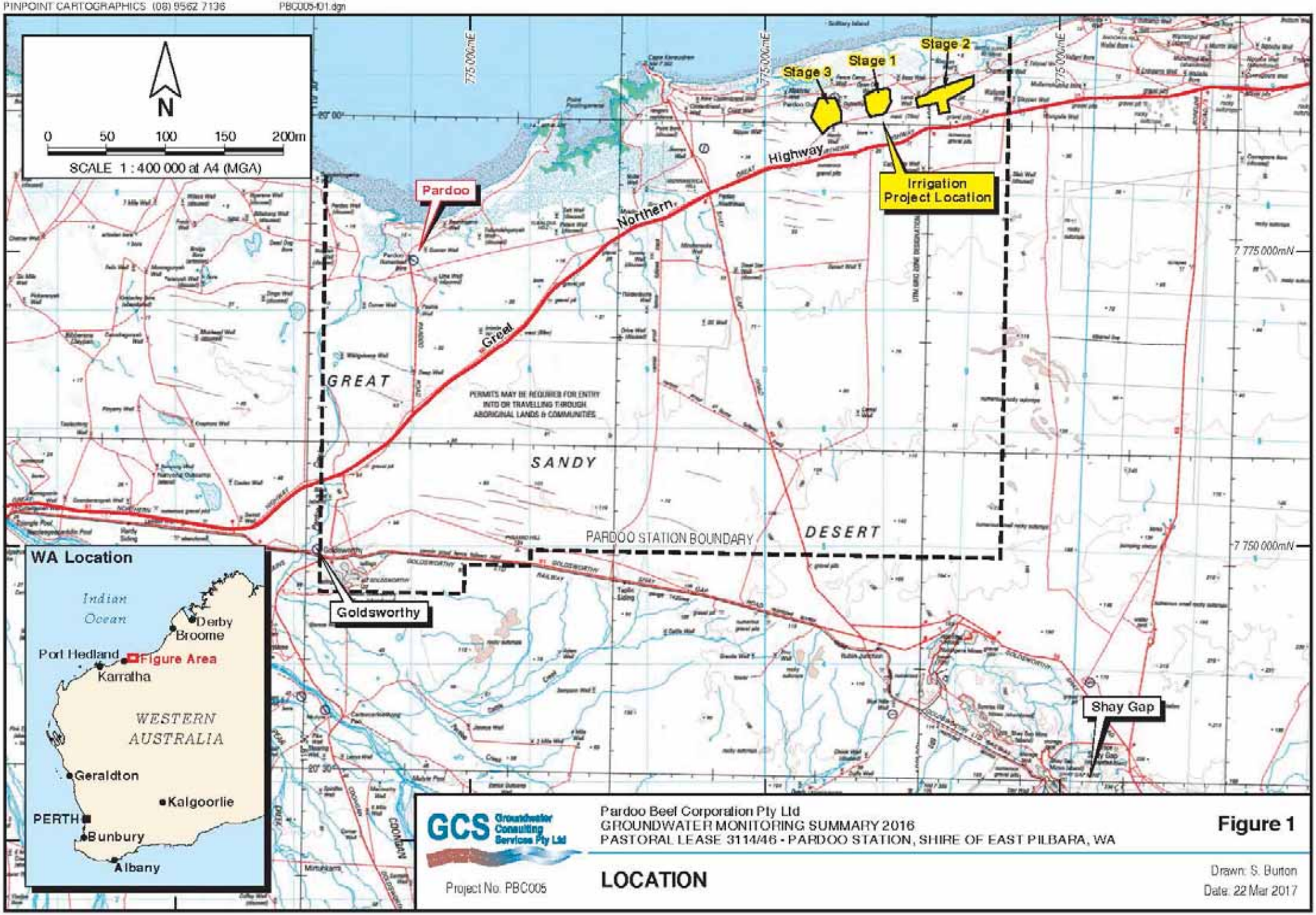
Appendix E – Historical Groundwater Quality

Appendix F – Laboratory Certificate

Appendix A

Figures

PINPOINT CARTOGRAPHICS (08) 9562 7136 PBC005-f01.dgn



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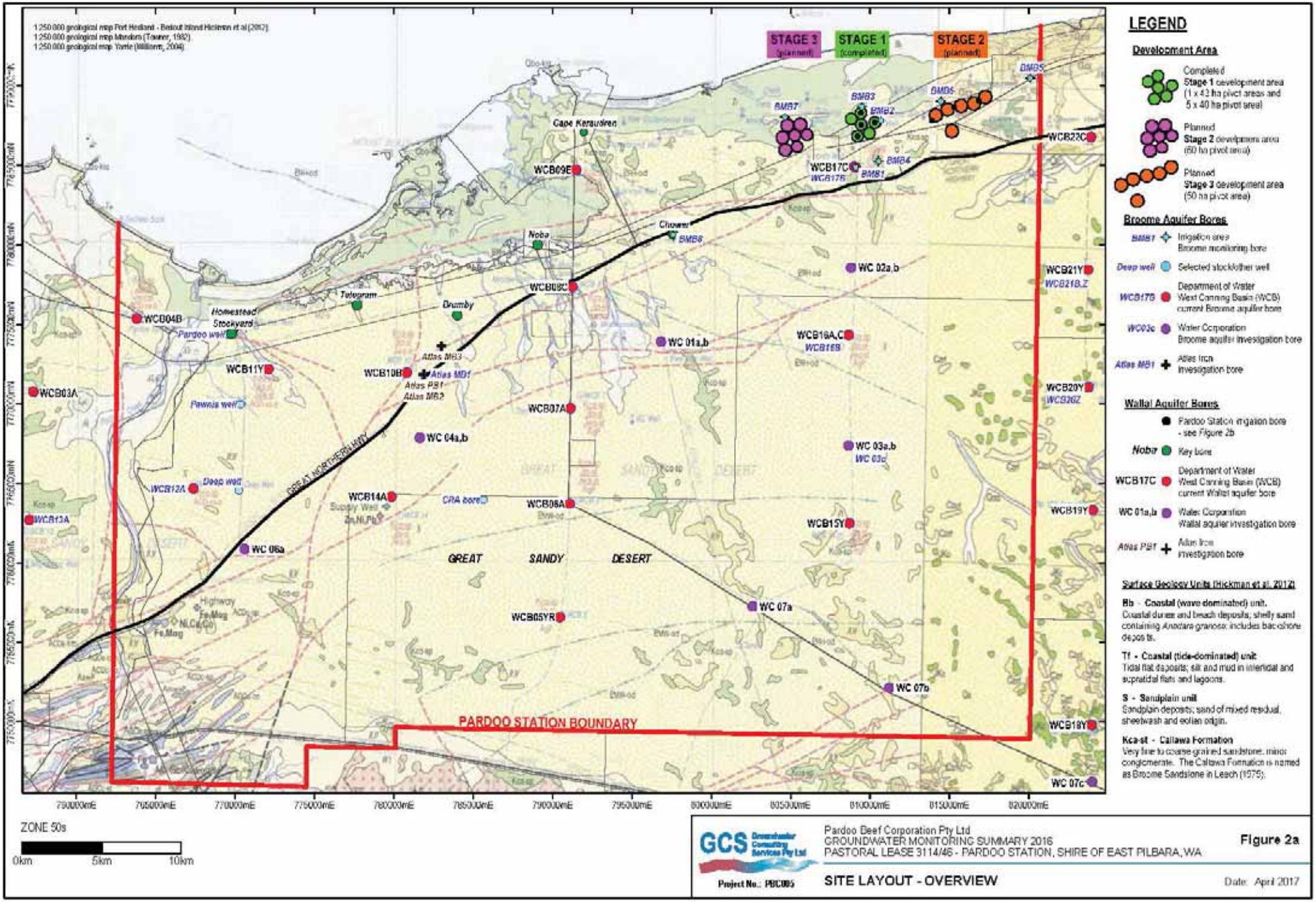
Project No. PBC005

Pardoo Beef Corporation Pty Ltd
GROUNDWATER MONITORING SUMMARY 2016
PASTORAL LEASE 3114/46 - PARDOO STATION, SHIRE OF EAST PILBARA, WA

Figure 1

LOCATION

Drawn: S. Burton
Date: 22 Mar 2017



LEGEND

Development Area

- Completed **Stage 1** development area (1 x 42 ha pivot areas and 5 x 40 ha pivot areal)
- Planned **Stage 2** development area (60 ha pivot areal)
- Planned **Stage 3** development area (50 ha pivot areal)

Broome Aquifer Bores

- BMB1 — Irrigation area Broome monitoring bore
- Deep well — Selected stock/other well
- WCB17S — Department of Water West Canning Basin (WCB) current Broome aquifer bore
- WC03c — Water Corporation Broome aquifer investigation bore
- Atlas MB1 — Atlas Iron investigation bore

Wallal Aquifer Bores

- Pardoo Station irrigation bore - see Figure 2b
- Noba — Key bore
- WCB17C — Department of Water West Canning Basin (WCB) current Wallal aquifer bore
- WC 01a,b — Water Corporation Wallal aquifer investigation bore
- Atlas PB1 — Atlas Iron investigation bore

Surface Geology Units (Hickman et al, 2012)

Bb - Coastal (wave-dominated) unit.
Coastal dunes and beach deposits; shelly sand containing *Anadara granosa*; includes backshore deposits.

Tf - Coastal (tide-dominated) unit
Tidal flat deposits; silt and mud in intertidal and supratidal flats and lagoons.

S - Sandplain unit
Sandplain deposits; sand of mixed residual, sheetwash and eolian origin.

Kca-st - Callawa Formation
Very fine to coarse grained sandstone, minor conglomerate. The Callawa Formation is named as Broome Sandstone in Leech (1975).

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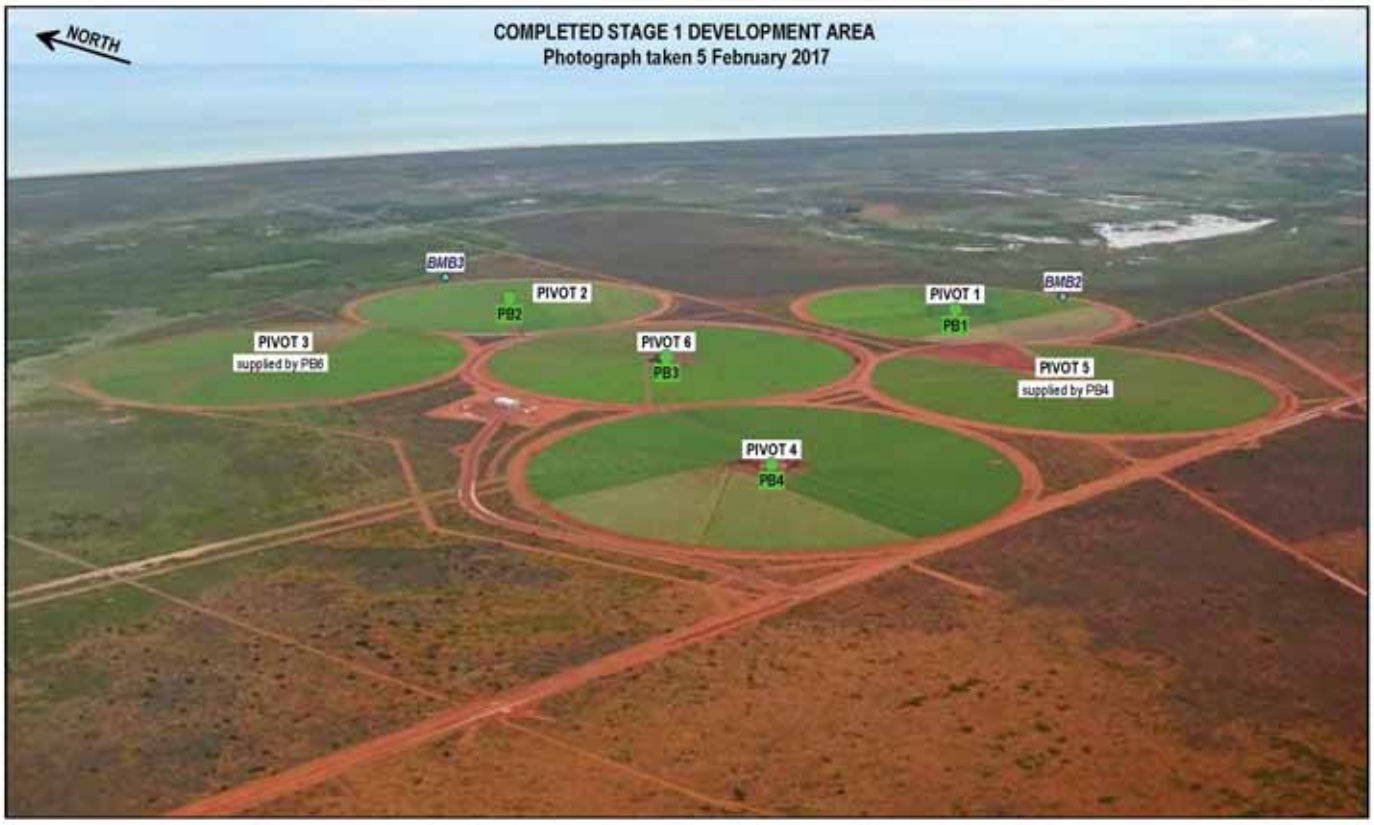
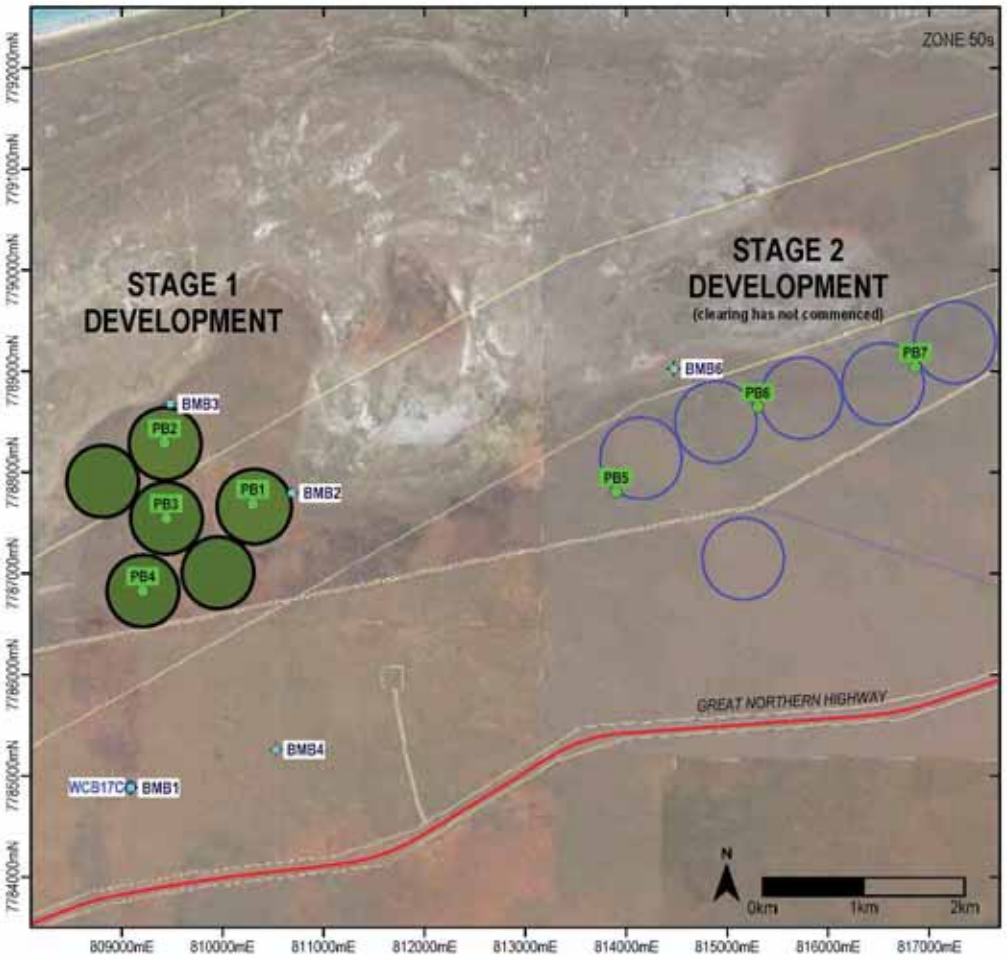
Pardoo Beef Corporation Pty Ltd
GROUNDWATER MONITORING SUMMARY 2016
PASTORAL LEASE 3114/46 - PARDOO STATION, SHIRE OF EAST PILBARA, WA

Figure 2a

SITE LAYOUT - OVERVIEW

Date: April 2017





PIVOT AREAS

Active pivot area

Planned pivot area

WALLAL AQUIFER BORES

PB1 Irrigation Bore
(Stage 2 bores not commissioned)

WCB17C Department of Water
monitoring bore also used for stock

BROOME AQUIFER BORES

BMB1 Monitoring bore

Notes:
All Stage 1 pivot areas shown are 40ha, except Pivot 1 which is 43ha in area. Stage 2 & 3 pivot areas are 50ha.

Top aerial photograph taken by Groundwater Consulting Services on 5 February 2017. Bottom aerial photograph is a mosaic with cadastre provided by Landgate and georeferenced by Groundwater Consulting Services. Image captured in 2012.

Aerial photograph of Stage 2 drilling pads and bores provided in Appendix C-3.

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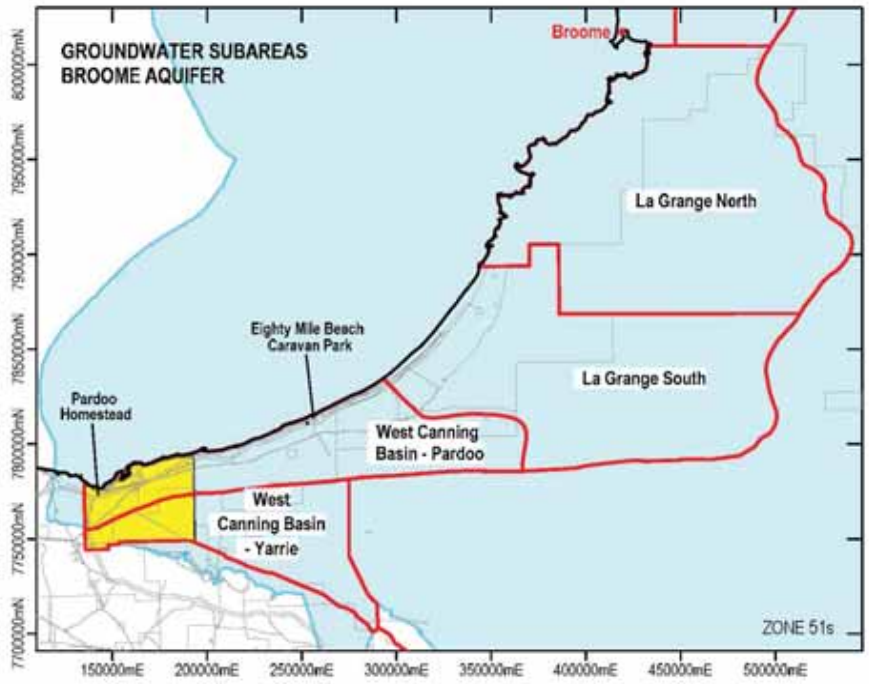
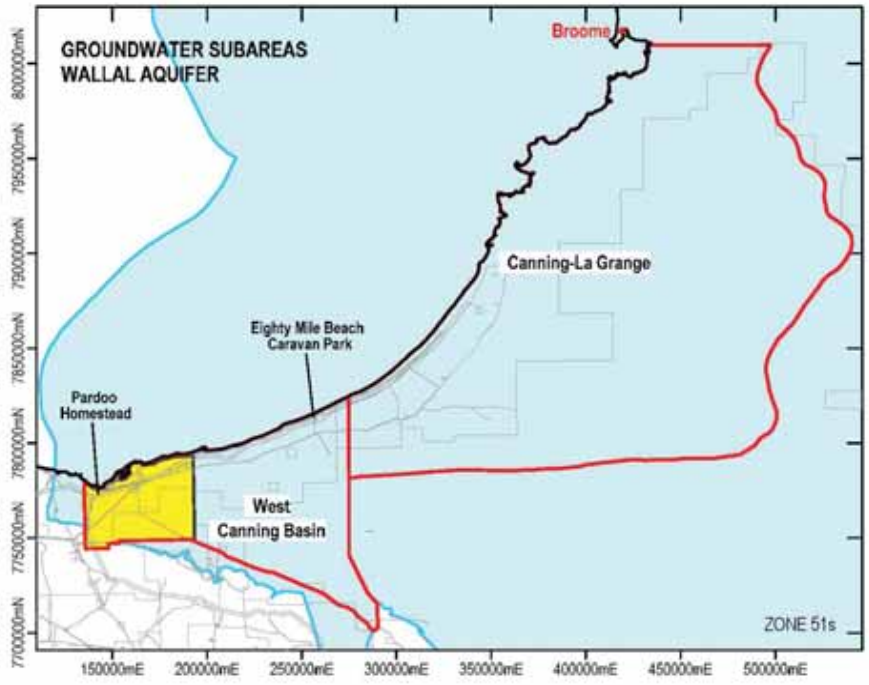
GROUNDWATER MONITORING SUMMARY 2016
PASTORAL LEASE 3114/46 - PARDOO STATION, SHIRE OF EAST PILBARA, WA

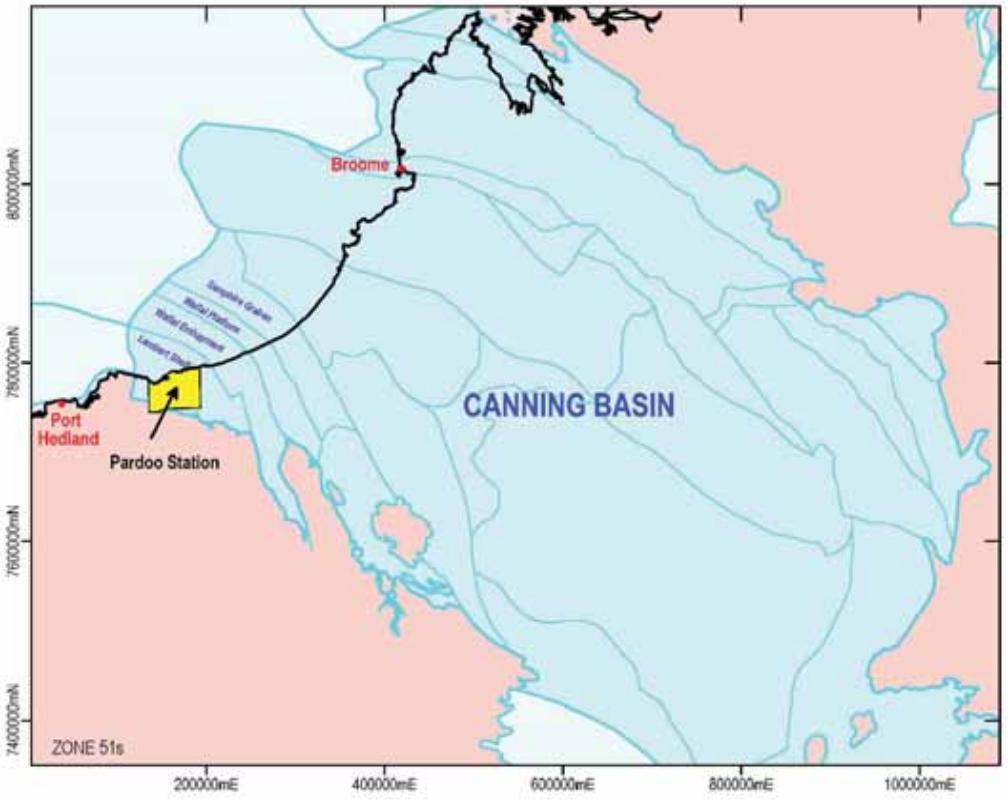
Figure 2b

SITE LAYOUT
- STAGE 1 AND STAGE 2 DEVELOPMENT AREAS

Date: April 2017







LEGEND

Pardoo Station

Extent of Canning Basin

Sub-basin

Cadastre

Groundwater subarea boundary

Canning Basin basemap from Mory (2010).
Groundwater subareas provided by Department of Water.

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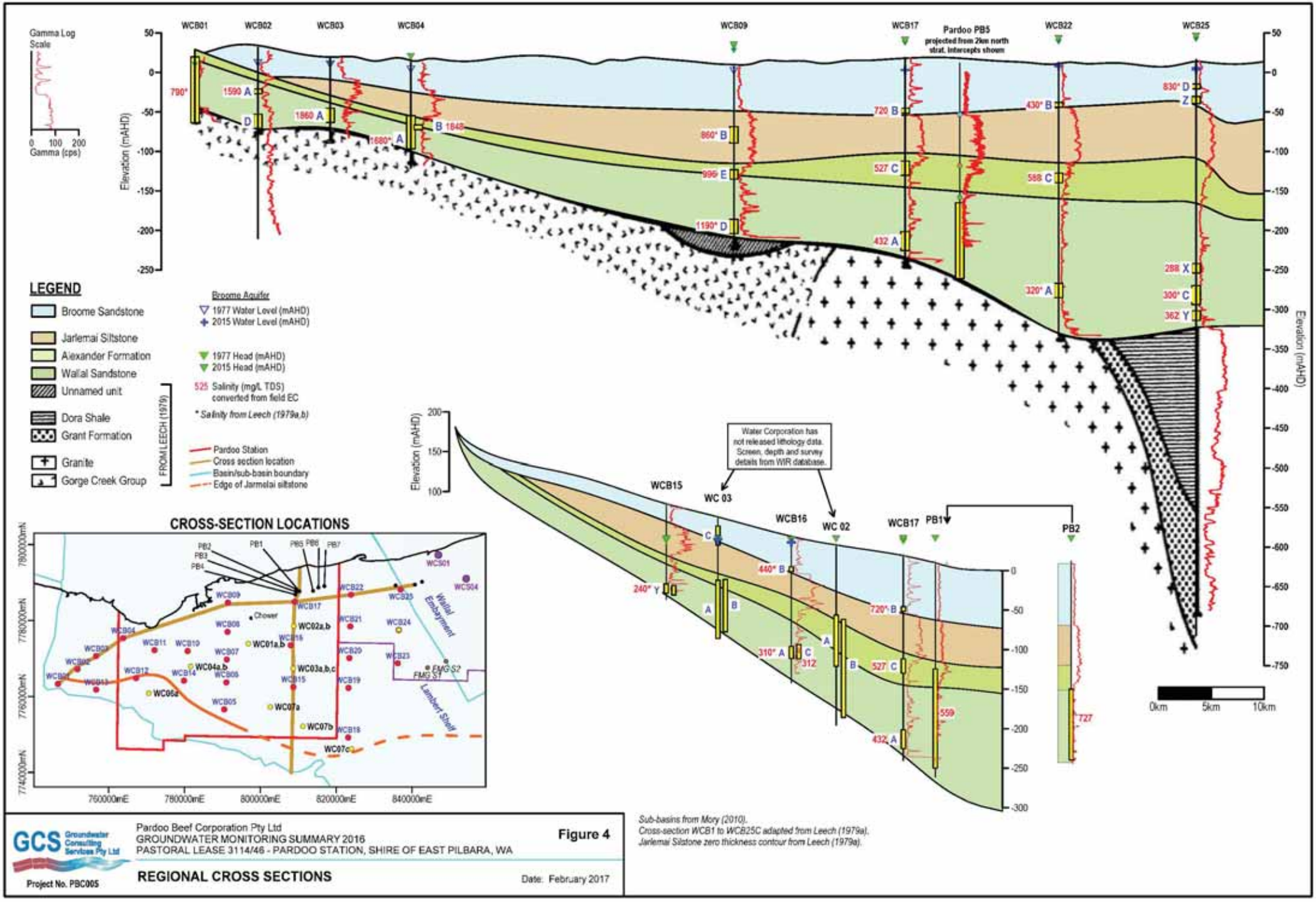
Project No.: PBC085

Pardoo Beef Corporation Pty Ltd
GROUNDWATER MONITORING SUMMARY 2016
PASTORAL LEASE 3114/46 - PARDOO STATION, SHIRE OF EAST PILBARA, WA

Figure 3

GROUNDWATER MANAGEMENT CONTEXT

Date: April 2017



Sub-basins from Mory (2010).
Cross-section WCB1 to WCB25C adapted from Leech (1979a).
Jarlemai Silstone zero thickness contour from Leech (1979a).

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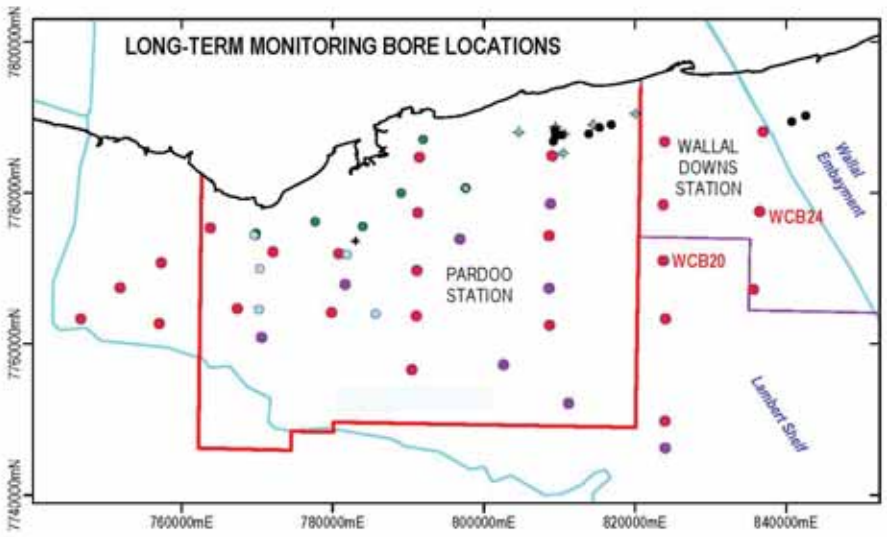
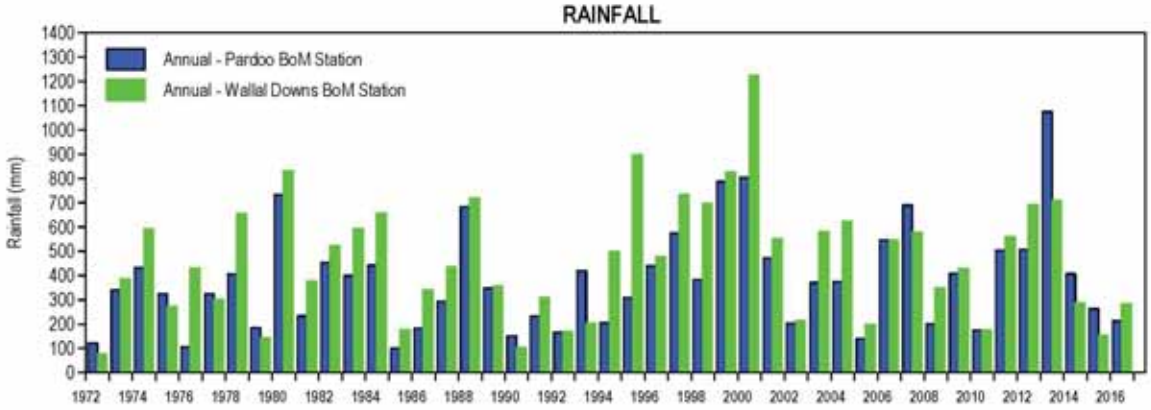
GROUNDWATER MONITORING SUMMARY 2016
PASTORAL LEASE 3114/46 - PARDOO STATION, SHIRE OF EAST PILBARA, WA

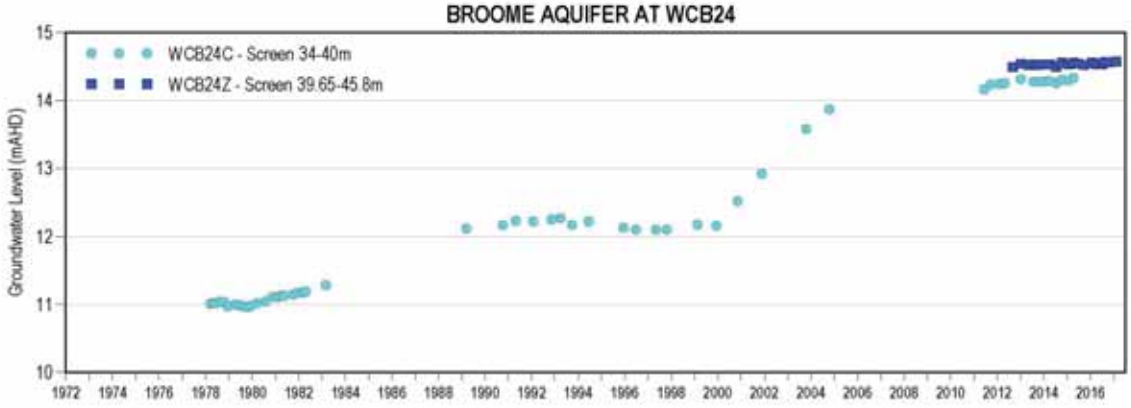
Figure 4

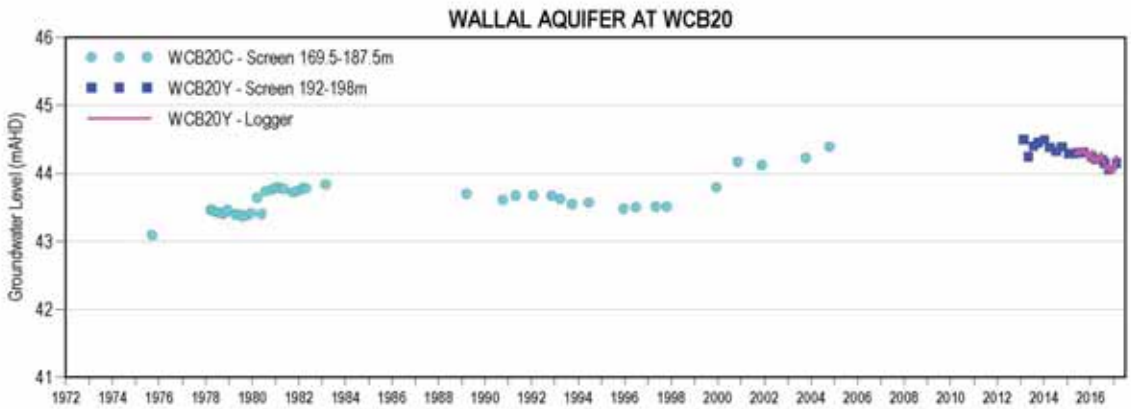
REGIONAL CROSS SECTIONS

Date: February 2017









Note:
Original bores were not re-surveyed by Department of Water in 2015.

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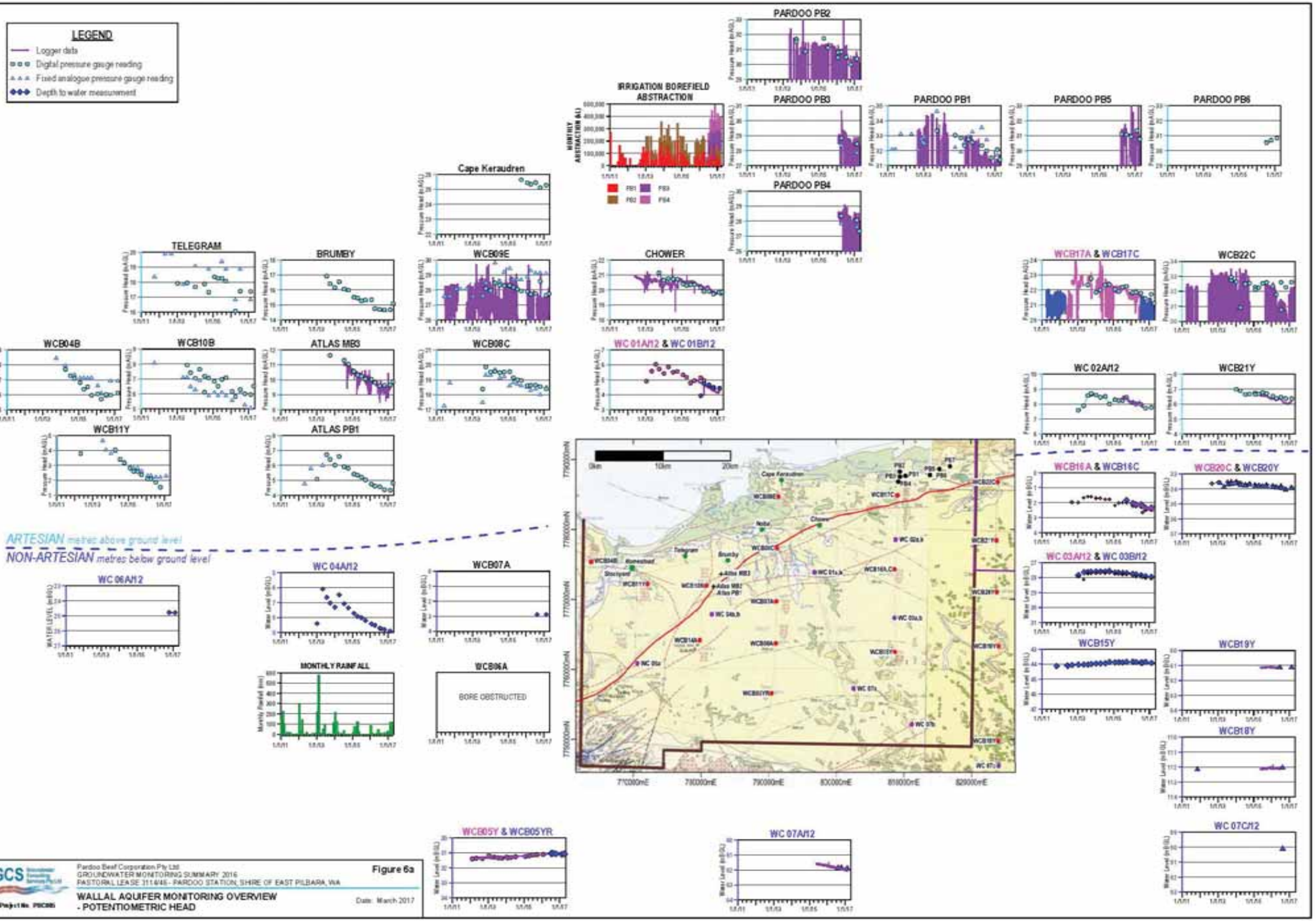
GROUNDWATER MONITORING SUMMARY 2016
PASTORAL LEASE 3114/46 - PARDOO STATION, SHIRE OF EAST PILBARA, WA

Figure 5

LONG-TERM HYDROGRAPHS

Date: February 2017



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GROUNDWATER MONITORING SUMMARY 2016
PASTORAL LEASE 3114/48 - PARDOO STATION, SHIRE OF EAST PILBARA, WA

WALLAL AQUIFER MONITORING OVERVIEW - POTENTIOMETRIC HEAD

Figure 6a

Date: March 2017

NOTE CHANGE OF SCALE

WCB04B

STOCKYARD & HOMESTEAD

TELEGRAM

BRUMBY

PARDOO 11 & WCB11Y

WCB10B

ATLAS PB1

CAPE KERAUDREN

WCB09E

NOBA

WCB09C

WCB07A

WCB14A

WCB06A

MONTHLY RAINFALL

IRRIGATION BOREFIELD ABSTRACTION

PARDOO PB1 & PARDOO PB2

PARDOO PB5 & PARDOO PB6

WCB17A & WC17C

WCB22C

CHOWER

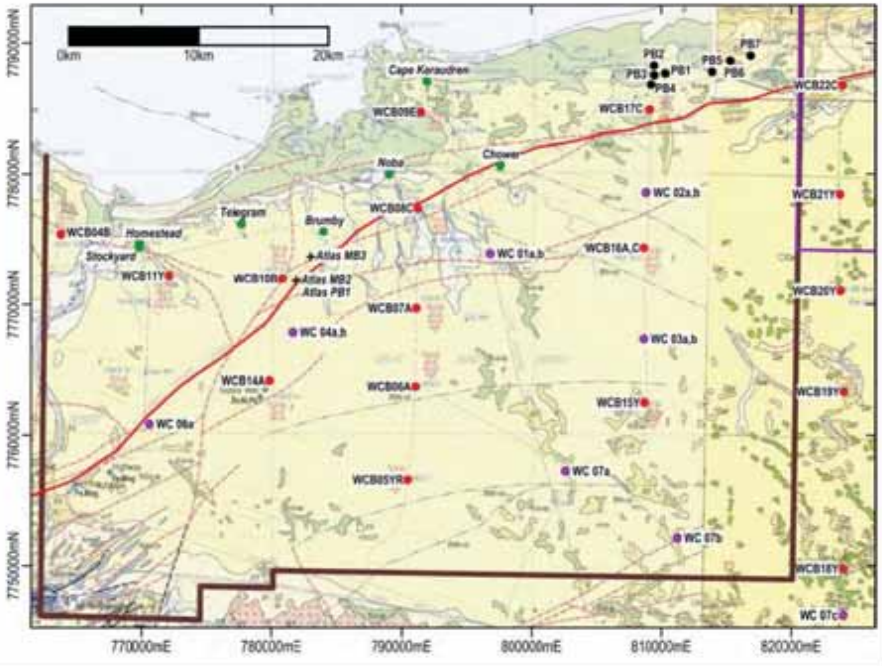
WC 02A/12 & WC02B/12

WCB21Y

WC 01A/12 & WC 01B/12

WCB16A

Not in use in 2016.



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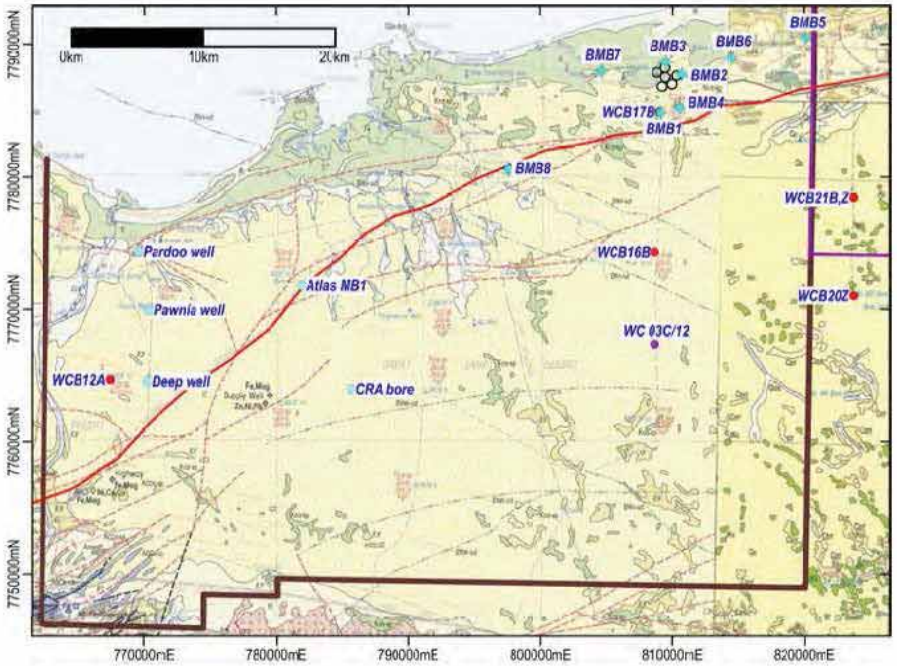
Project No. PSC005

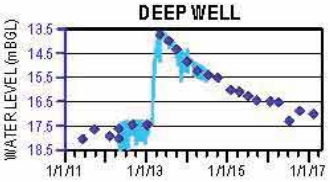
Pardoo Beef Corporation Pty Ltd
GROUNDWATER MONITORING SUMMARY 2016
PASTORAL LEASE 3114/46 - PARDOO STATION, SHIRE OF EAST PILBARA, WA

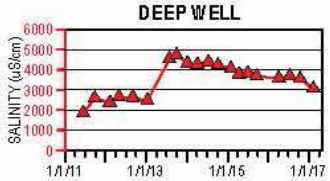
Figure 6b

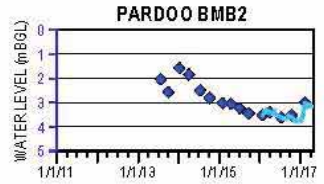
WALLAL AQUIFER MONITORING OVERVIEW
- SALINITY MONITORING

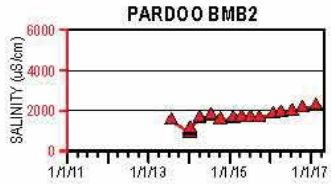
Date: March 2017

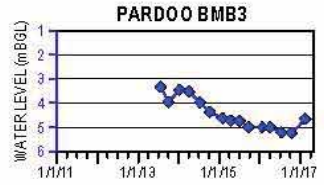


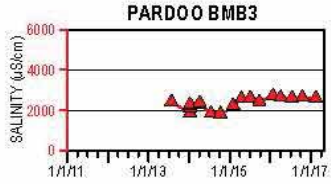


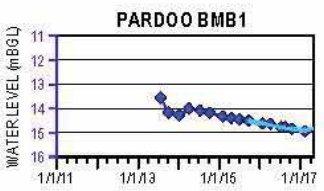


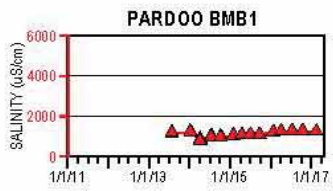


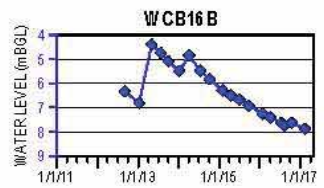


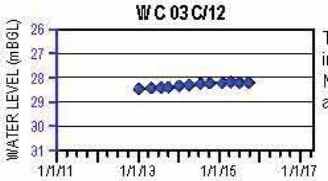




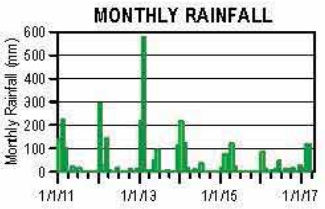


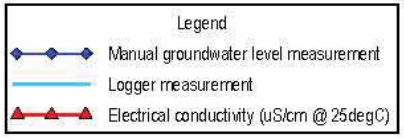






Tree roots have invaded bore. No water level access.





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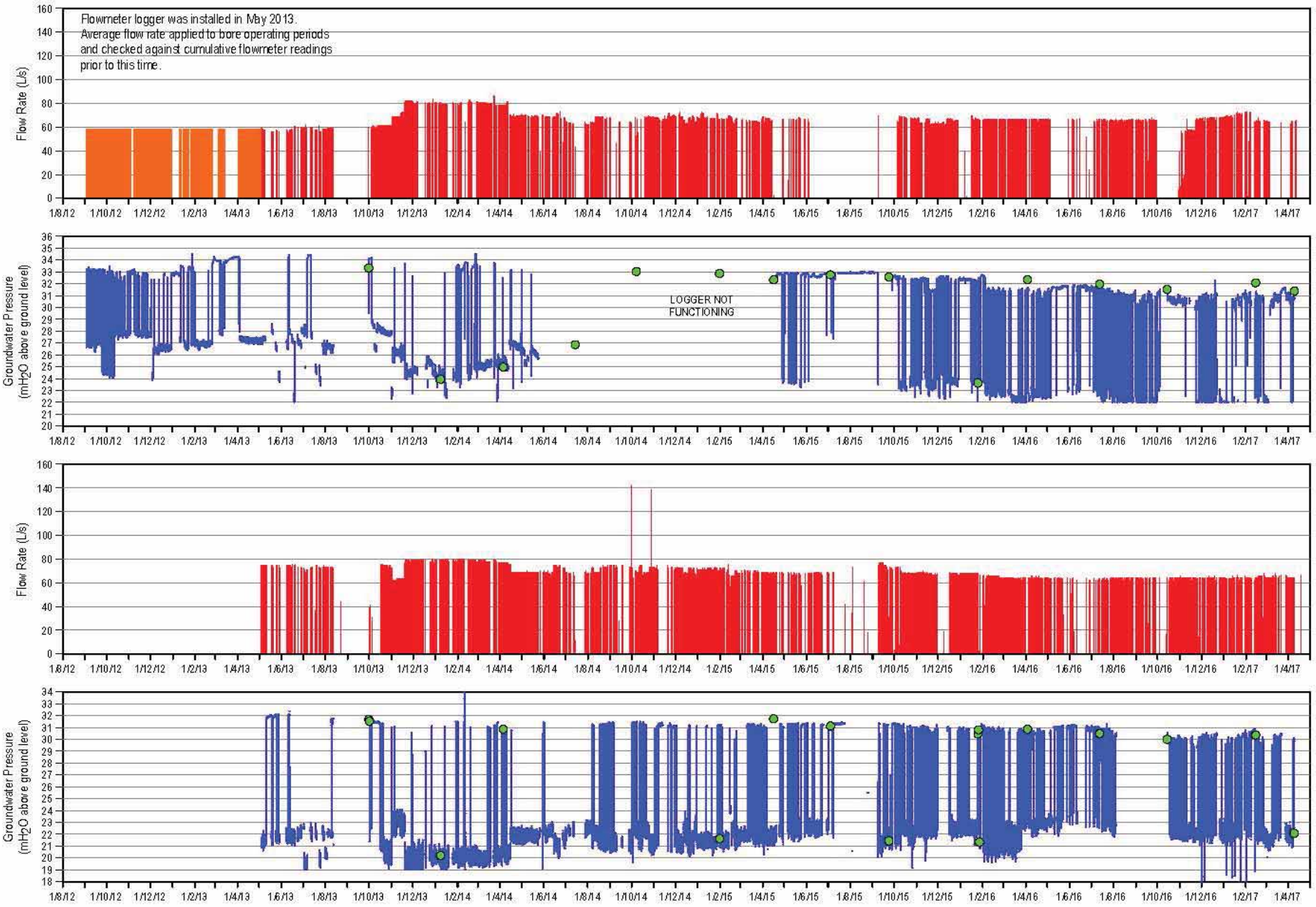
Pardoo Beef Corporation Pty Ltd
GROUNDWATER MONITORING SUMMARY 2016
PASTORAL LEASE 3114/46 - PARDOO STATION, SHIRE OF EAST PILBARA, WA

Figure 7

MONITORING OVERVIEW - BROOME AQUIFER

Date: March 2017



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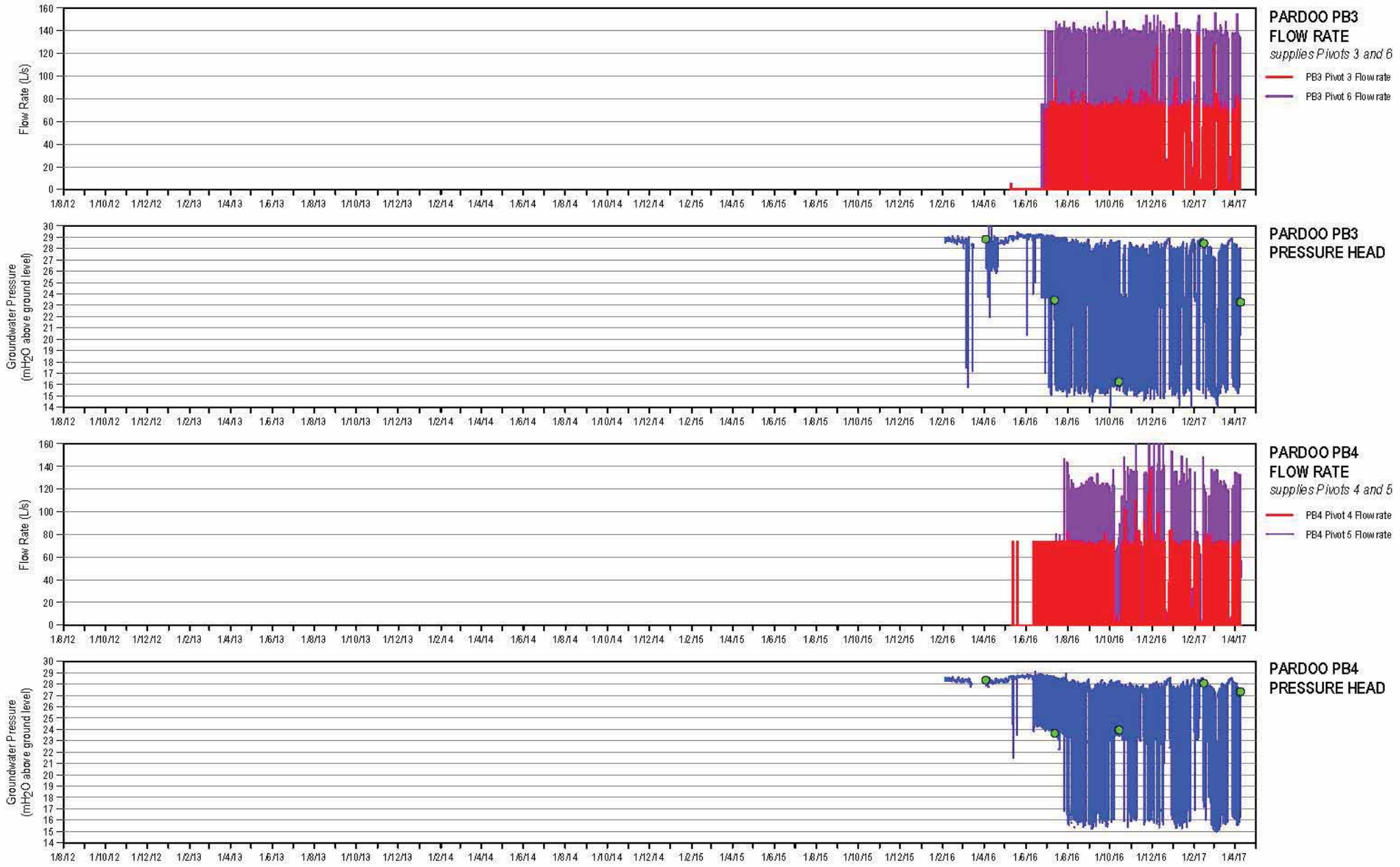
Pardoo Beef Corporation Pty Ltd
GROUNDWATER MONITORING SUMMARY 2016
PASTORAL LEASE 3114/46 - PARDOO STATION, SHIRE OF EAST PILBARA, WA

Figure 8a

PARDOO PB1 AND PB2 LOGGER DATA

Date: March 2017



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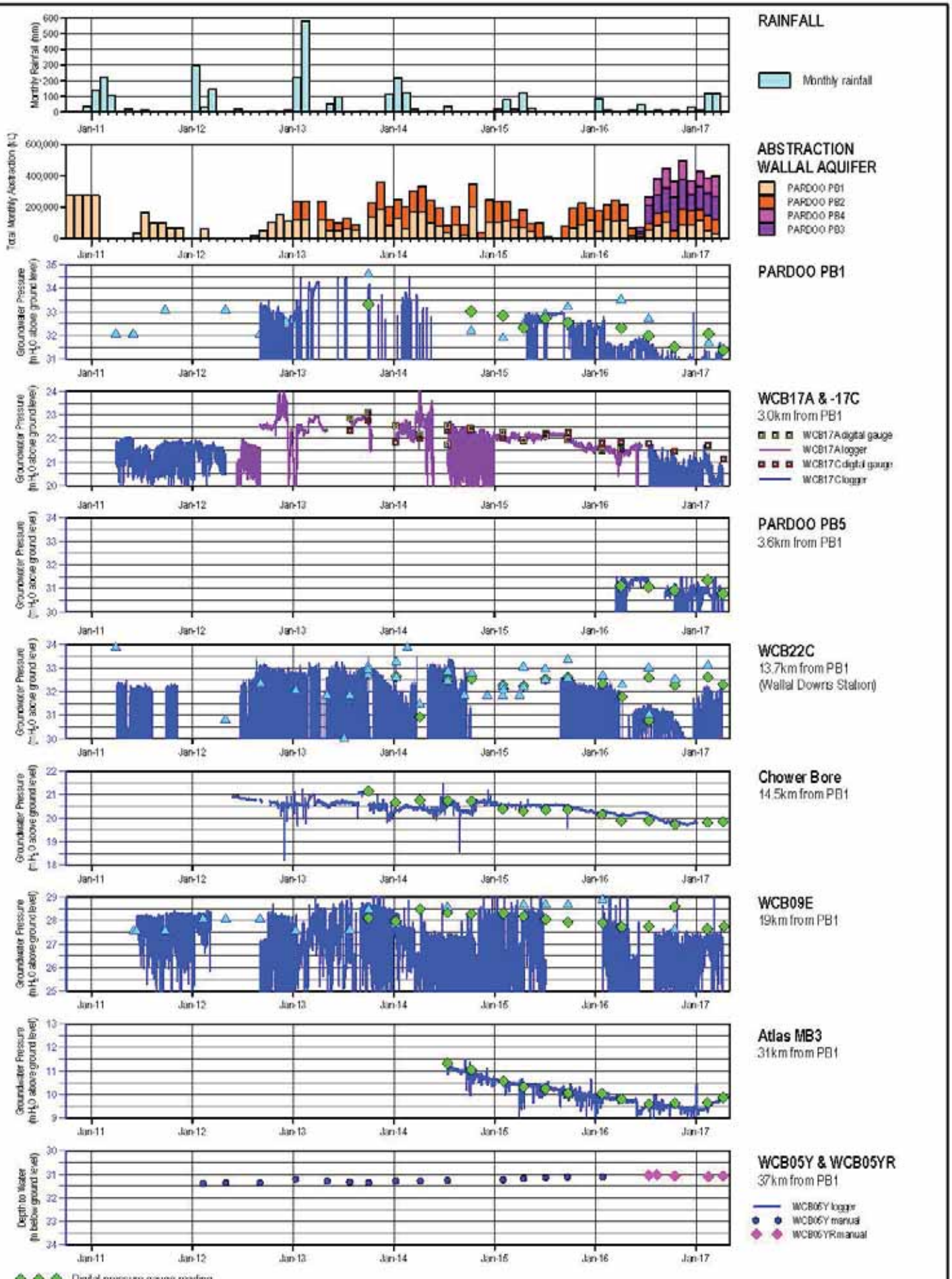
Pardoo Beef Corporation Pty Ltd
GROUNDWATER MONITORING SUMMARY 2016
PASTORAL LEASE 3114/46 - PARDOO STATION, SHIRE OF EAST PILBARA, WA

Figure 8b

PARDOO PB3 AND PB4 LOGGER DATA

Date: April 2017



Note: Recorded pressure for stock bores is affected many factors including pipeline leaks, drinking habits of cattle, changes in stock numbers, availability of surface water sources among others. Barometric pressure recorded at WCB25Z (Wallal Downs Station). Rainfall recorded at Pardoo Homestead.

GCS Groundwater Consulting Services Pty Ltd

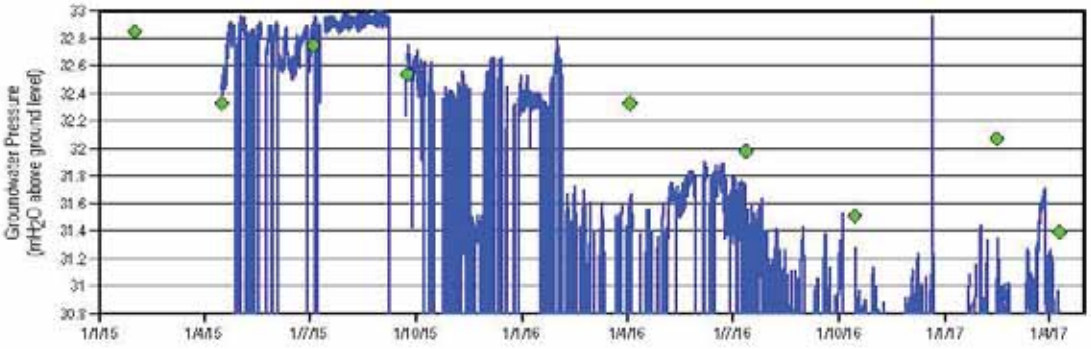
Project No PBC006

Pardoo Beef Company Pty Ltd
GROUNDWATER MONITORING SUMMARY 2016
PARDOO STATION, 43 GREAT NORTHERN HIGHWAY, PARDOO, WA

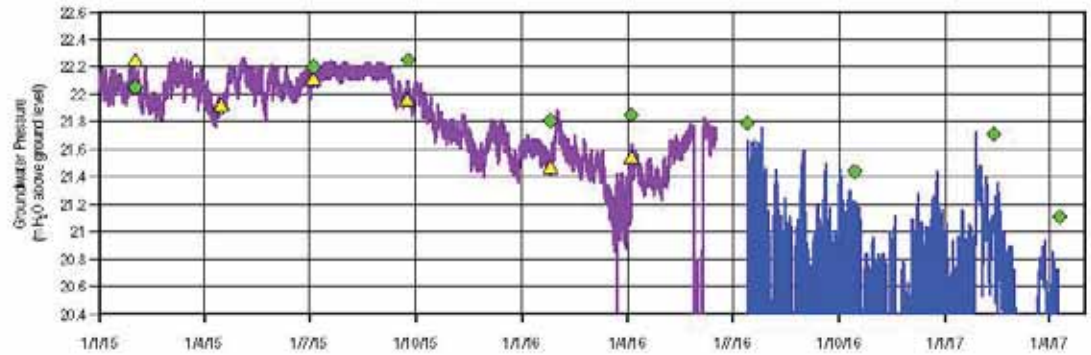
MONITORING SUMMARY - KEY BORES 2011 on

Figure 9a

Date: March 2017

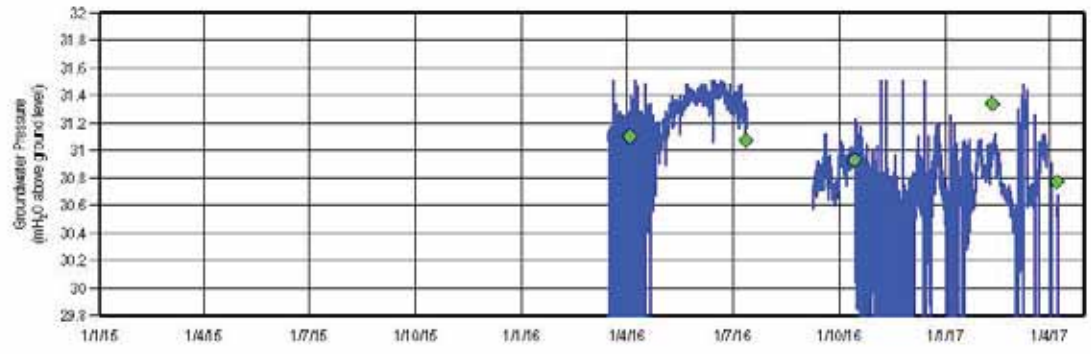


PARDOO PB1
PRESSURE HEAD

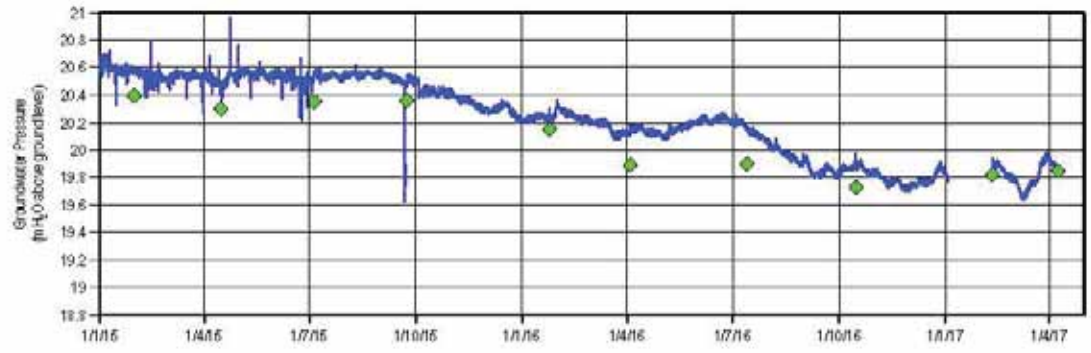


WCB17A & -17C
3.0km from PB1

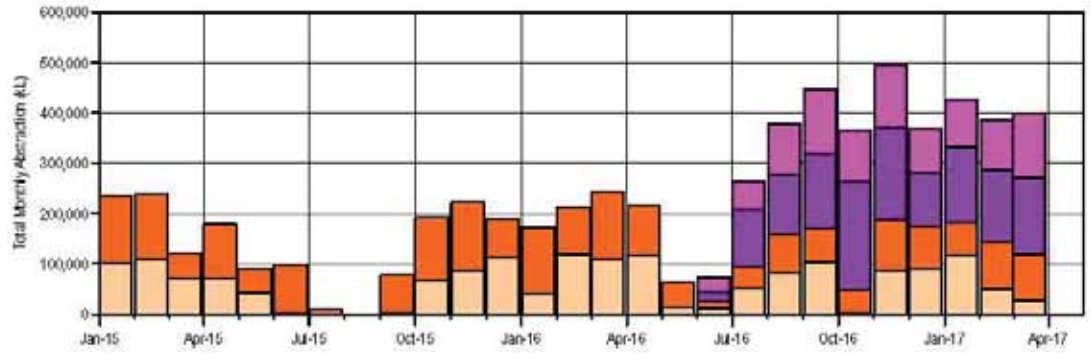
△△△ WCB17A digital gauge
WCB17A logger
◆◆◆ WCB17C digital gauge
WCB17C logger



PARDOO PB5
3.6km from PB1



Chower Bore
14.5km from PB1



ABSTRACTION
WALLAL AQUIFER

PARDOO PB1
PARDOO PB2
PARDOO PB4
PARDOO PB3

GCS Groundwater Consulting Services Pty Ltd

Project No. PBC006

Pardoo Beef Company Pty Ltd
GROUNDWATER MONITORING SUMMARY 2016
PARDOO STATION, 43 GREAT NORTHERN HIGHWAY, PARDOO, WA

Figure 9b

MONITORING SUMMARY - KEY BORES 2015 on

Date: April 2017

Appendix B

Licences

Groundwater Well Licence 158616(11)
Groundwater Well Licence 158616(14)
Groundwater Well Licence 158616(16)
Licence to Construct or Alter Well 180719(1)
Licence to Construct or Alter Well 183416(1)

LICENCE TO TAKE WATER

Granted by the Minister under section 5C of the Rights in Water and Irrigation Act 1914

Licensee(s)	Pardoo Beef Corporation Pty Ltd		
Description of Water Resource	Canning-Kimberley Canning - Wallal.	**Annual Water Entitlement**	7740000 kL
Location of Water Source	Pastoral Lease 3114/446 - Pardoo Station		

Authorised Activities	**Taking of water for**	**Location of Activity**
	Caravan park purposes Commercial purposes Domestic use Irrigation of up to 243 ha of pasture Irrigation of up to 5 ha of lawns and gardens Stock watering	Pastoral Lease 3114/446 - Pardoo Station

Duration of Licence	From 20 March 2015 to 31 December 2017

This Licence is subject to the following terms, conditions and restrictions:

1 The licensee must install an approved meter to each water draw-point through which water is taken under this licence.

2 The meter(s) must be installed in accordance with the provisions of the document entitled "Guidelines for Water Meter Installation 2009" before any water is taken under tbis licence.

3 The licensee shall comply with the commitments of the operating strategy "Operating and Monitoring Strategy Stage 1a/b, Wallal Sandstone Aquifer, Cattle Feed Irrigation, Pardoo Station" dated November 2009, as prepared by GE & JA Rogers and approved by the Department of Water on 30th November 2009 including any modifications to the commitments as approved during the term of the licence.

4 The licensee shall comply with the commitments of Pardoo Station Staged Development program as prepared by licensee and approved by the Department of Water on 30 May 2011, including any modifications to the commitments as approved during the term of the licence.

5 Every 1 year(s) the licensee shall provide to the Department of Water a Groundwater Monitoring Summary for the preceding water year. The first report is due 31/03/2015.

6 Every 3 year(s) the licensee shall provide to the Department of Water a Groundwater Monitoring Review. The first report is due 31/03/2017. A Groundwater Monitoring Summary need not be submitted in a year in which a Groundwater Monitoriug Review is due.

LICENCE TO TAKE WATER

Granted by the Minister under section 5C of the Rights in Water and Irrigation Act 1914

This Licence is subject to the following terms, conditions and restrictions:

7 If the Department is satisfied that the licensee has not complied with their schedule of water use, it shall notify the licensee in writing of this fact within 2 months after the licensee has presented its compliance report to the Department, and any other evidence requested by the Department, and the Department may specify an alternative maximum annual volume of water use for the coming year.

8 The licensee is to provide the approved diversification permit to the Department of Water prior to undertaking any abstraction for stage 1b of the Pardoo irrigation project.

End of terms, conditions and restrictions

Government of **Western Australia**
Department of **Water**

Instrument No. GWL158616(16)

LICENCE TO TAKE WATER

Granted by the Minister under section 5C of the Rights in Water and Irrigation Act 1914

Licensee(s)	Pardoo Beef Corporation Pty Ltd		
Description of Water Resource	Canning-Kimberley Canning - Wallal.	**Annual Water Entitlement**	14822250 kL
Location of Water Source	Pastoral Lease 3114/446 - Pardoo Station		

Authorised Activities	**Taking of water for**	**Location of Activity**
	Caravan park purposes Commercial purposes Domestic use Irrigation of up to 5 ha of lawns and gardens Irrigation of up to 893 ha of pasture Stock watering	Pastoral Lease 3114/446 - Pardoo Station

Duration of Licence	From 25 January 2017 to 24 January 2027

This Licence is subject to the following terms, conditions and restrictions:

1 The licensee must install an approved meter to each water draw-point through which water is taken under this licence.

2 The meter(s) must be installed in accordance with the provisions of the document entitled "Guidelines for Water Meter Installation 2009" before any water is taken under this licence.

3 Every 1 year(s) the licensee shall provide to the Department of Water a Groundwater Monitoring Summary for the preceding water year. The first report is due 31/03/2017.

4 The licensee shall provide a updated operating strategy to the Department of Water for approval by 31/5/2017. The strategy shall be prepared in accordance with the Department of Water's Operational Policy 5.08 'Use of Operating Strategies in the water licensing process'.

End of terms, conditions and restrictions

File No: RF13415

Government of Western Australia
Department of Water

Instrument No. CAW183436(1)

LICENCE TO CONSTRUCT OR ALTER WELL

Granted by the Minister under section 26D of the Rights in Water and Irrigation Act 1914

Licensee(s)	Pardoo Beef Corporation Pty Ltd	
Description of Water Resource	Canning-Kimberley Canning - Wallal.	
Location of Well(s)	Lot 1556 On Plan 70856 - Volume/Folio Lr3165/320 - Lot 1556	
Authorised Activities	**Activity**	**Location of Activity**
	Construct 6 artesian well(s).	Lot 1556 On Plan 70856 - Volume/Folio Lr3165/320 - Lot 1556
Duration of Licence	From 7 October 2016 to 6 October 2018	

This Licence is subject to the following terms, limitations and conditions:

1 The well must be constructed by a driller having a current class 3 water well drillers certificate issued by the Western Australian branch of the Australian Drilling Industry Association or equivalent certification recognised nationally by the Australian Drilling Industry Association.

2 Any flowing well shall be fitted with a tapping (including a bayonet fitting) in the wellhead construction to enable the measurement of the aquifer's hydraulic pressure (potentiometric head pressure).

3 The clearance (annulus) between the casing and the side of the borehole shall be cement grouted from the top of the sand/gravel pack adjacent to the screen to a point below ground level (BGL) or below top of casing (bTOC), as specified in the application for this licence dated 14 September 2016.

4 The well shall be constructed with a clearance (annulus) of at least 30mm between the casing and the sides of the borehole.

5 The casing(s) shall be equipped with centralisers not less than one per six metres of casing length to ensure that the casing remains central to the borehole.

6 The well must be adequately capped to prevent surface entry of contaminants. Flowing wells must be equipped with a *valve to control the flow.*

7 The depth of the well(s) and the screened interval shall be limited to the Wallal aquifer.

8 The licensee must install an approved meter to each well, and provide evidence of the installation to the Department of Water within 30 days of completion of the well.

9 The licensee is to comply with the bore design submitted with the application dated 14 September 2016 and any amendments made by or with the approval of the Department.

End of terms, limitations and conditions

This Licence is granted subject to the Rights in Water and Irrigation Regulations 2000.

Appendix C

Plates

Pivot 1 (5 March 2017)

Pivot 2 (9 April 2017)

Pivot 3 (13 July 2016)

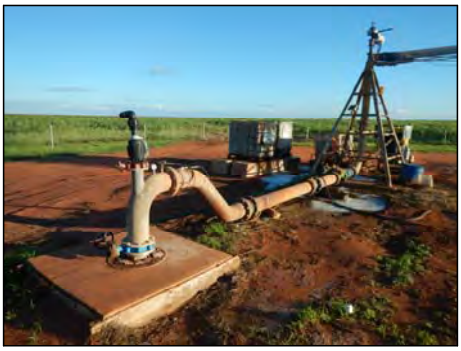
Pivot 4 (11 April 2017)

Pivot 5 (5 March 2017)

Pivot 6 (14 February 2017)

Silage Pivot 2 (14 February 2017)

On-pivot grazing (5 March 2017)



Pardoo PB1 (11 February 2017)

Pardoo PB1 (5 March 2017)

Pardoo PB1 meter (11 February 2017)

Pardoo PB2 new gauge (11 February 2017)

Pardoo PB2 (11 February 2017)

Pardoo PB2 meter (11 February 2017)

Pardoo PB3 (14 February 2017)

Pardoo PB3 Pivot 3 meter (14 February 2017)

Pardoo PB3 Pivot 6 meter (14 February 2017)

Pardoo PB4 (14 February 2017)

Pardoo PB4 Pivot 4 meter (14 February 2017)

Pardoo PB4 Pivot 5 meter (14 February 2017)

Pardoo PB5 (7 April 2017)

Pardoo PB5 meter 1 (7 April 2017)

Pardoo PB5 meter 2 (7 April 2017)

Pardoo PB6 (10 April 2017)

Pardoo PB6 meter for Pivot 9 (10 April 2017)

Pardoo PB6 meter for Pivot 10 (10 April 2017)

Pardoo PB7 (8 April 2017)

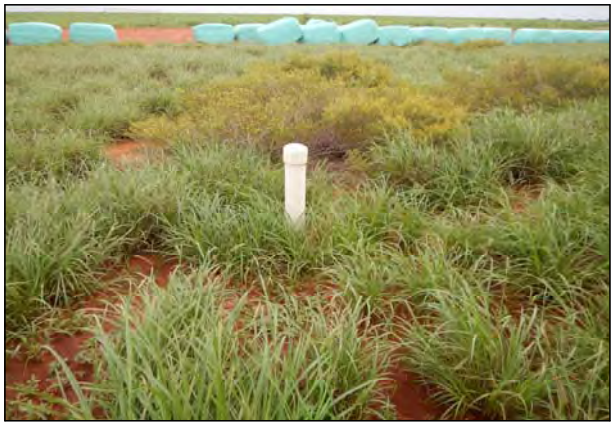
Pardoo PB7 meter for Pivot 11 (8 April 2017))

Pardoo PB7 meter for Pivot 12 (8 April 2017)

Stage 2 Development Area (5 February 2017)

BMB1 (15 February 2017)

BMB2 (14 February 2017)

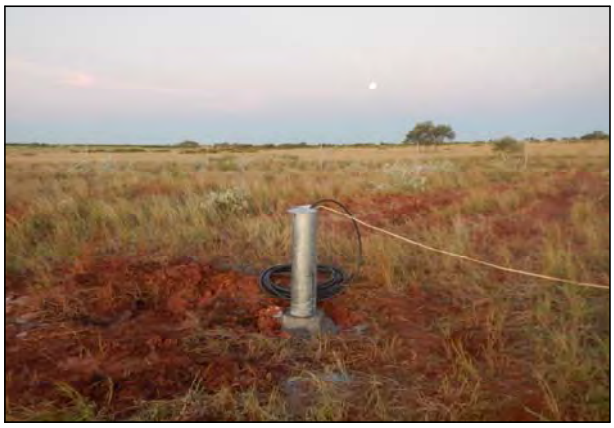


BMB3 (14 February 2017)

BMB4 (12 April 2017)

BMB5 (9 April 2017)

BMB6 (9 April 2017)



BMB7 (10 April 2017)

Note: BMB8 is in progress.

Atlas PB1 (13 July 2016)

Atlas PB1 meter (13 July 2016)

Chower bore (13 July 2016)

Chower bore meter (13 July 2016)

Noba bore flowing (27 January 2016)

Noba bore leaking (5 April 2016)

Pardoo Homestead bore (4 April 2016)

Pardoo Homestead bore meter (6 April 2016)

Stockyard bore and cattle (25 January 2016)

Stockyard bore (14 July 2016)

Telegram bore and tank (5 April 2016)

Telegram bore (13 July 2016)

GCS Groundwater Consulting Services Pty Ltd

Project No.: PBC004

Pardoo Beef Corporation Pty Ltd
GROUNDWATER MONITORING SUMMARY 2016
PASTORAL LEASE 3114/46 - PARDOO STATION, SHIRE OF EAST PILBARA, WA

Appendix C-4

PLATES - KEY STOCK BORES

Date: April 2017

WCB04B (14 July 2016)

WCB04B meter (14 July 2016)

WCB08C (13 July 2016)

WCB08C meter (13 July 2016)

WCB09E (13 July 2016)

WCB10B (13 July 2016)

WCB11Y (13 July 2016)

WCB11Y meter (13 July 2016)

WCB14A (14 July 2016)

WCB14A meter (14 July 2016)

WCB17C (13 July 2016)

WCB17C meter (13 July 2016)

GCS Groundwater Consulting Services Pty Ltd

Project No.: PBC004

Pardoo Beef Corporation Pty Ltd
GROUNDWATER MONITORING SUMMARY 2016
PASTORAL LEASE 3114/46 - PARDOO STATION, SHIRE OF EAST PILBARA, WA

Appendix C-6

PLATES - KEY STOCK BORES CONT.

Date: September 2016

Atlas MB3 (13 July 2016)

Brumby bore (13 July 2016)

CRA bore (14 July 2016)

WC 01A/12 (14 July 2016)

WC02B/12 (3 April 2016)

WCB06A (14 July 2016)

WCB06A trough (14 July 2016)

WCB07A (14 July 2016)

WCB07A trough (14 July 2016)

WCB16A (13 July 2016)

GCS Groundwater Consulting Services Pty Ltd

Project No.: PBC005

Pardoo Beef Corporation Pty Ltd
GROUNDWATER MONITORING SUMMARY 2016
PASTORAL LEASE 3114/46 - PARDOO STATION, SHIRE OF EAST PILBARA, WA

Appendix C-7

PLATES - MINOR USE STOCK BORES

Date: September 2016

Appendix D

Bore Completion Diagrams

Drilling Company:	Austral Drilling	**Grid/Zone:**	z50S MGA GDA94	**Water Level:** mBGL	30.96mAGL
Driller:	Glenn Van Hees	**Easting:**	813897.1	**Date Measured:**	15 Mar 2016
Rig/Method:	Mud Rotary	**Northing:**	7787806.5	**Salinity:** TDS Lab.	550 mg/L TDS
Date:	16/01/2016 to 9/03/2016	**Measured:**	Survey	**Test Details:**	225L/s open flow
Licence No:	CAW 180719(1)	**Elevation:**	Ground 10.43mAHD (Survey)	**Project Stage:**	2

COMMENTS: Geophysical logs by Westlog in 315mm hole
Hole terminated 272m on intersection of sufficient aquifer material.

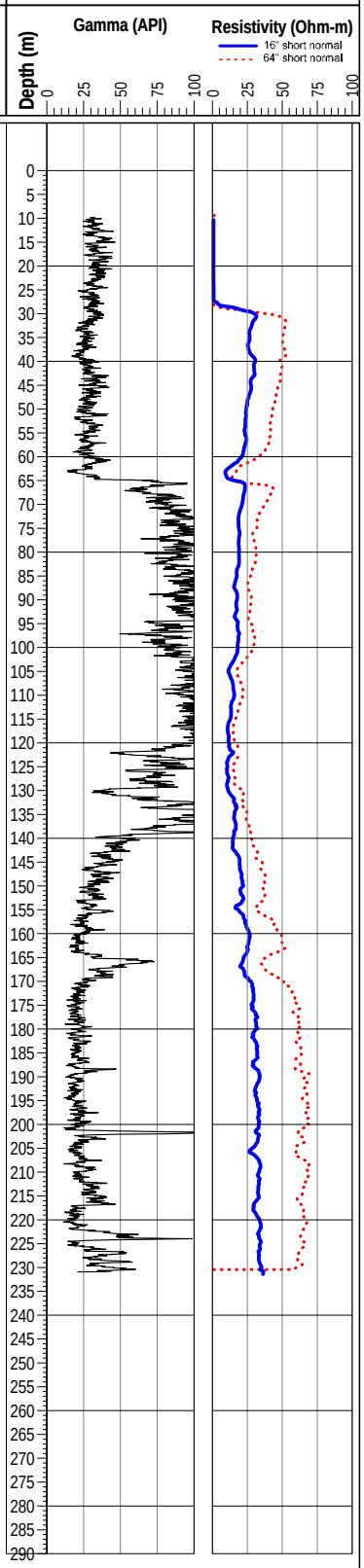
COMPLETION DIAGRAM
Production Bore

PARDOO PB5

Depth (m)	Stratigraphy	Lithology	Lithology Description
0–5		Pindan	SAND, silty, red/brown, fine to medium sand, subangular (pindan)
5–10	Broome Sandstone		SANDSTONE, pale red/brown, medium to coarse, weakly indurated, quartz
10–30			SANDSTONE, pale orange/brown, very fine to medium, weakly indurated, quartz with medium to coarse grained subangular quartz san
30–45			SANDSTONE, red/brown, very fine to medium, weakly indurated, quartz with medium to coarse grained subangular quartz san
45–50			SAND, red/brown, medium to very coarse sand, subrounded to subangular quartz
50–65			SAND, pale grey, coarse sand to fine granules, subrounded to subangular quartz
65–70	Jarlemai Siltstone		FERRICRETE, red/brown, well indurated sandstone
70–75			SILTSTONE, pale grey/brown
75–100			SILTSTONE, dark grey to black, slightly sandy
100–130			SILTSTONE, dark grey to black, slightly sandy, with fine brown laminations
130–135	Alex Fm		SAND, inferred from geophysical log, not sighted in strata samples.
135–145			SILTSTONE, dark grey to black, slightly sandy, with fine brown laminations
145–165			SAND, dark grey, silty and fine to to very coarse sand, suangular quartz and minor lithics
165–170			SAND, grey, coarse to very coarse, subangular, quartz
170–175			SILTSTONE, grey
175–185	Wallal Sandstone		SAND, grey, coarse to very coarse, subangular, quartz
185–190			SAND, grey, very coarse sand to fine granules, subangular, quartz and lithics
190–200			SILTSTONE, interpreted from geophyscial log, not visible in strata samples
200–205			SAND, grey, very coarse sand to fine granules, subangular, quartz
205–225			SAND, GRAVELLY, grey, very coarse sand to fine granules, subangular quartz, with 5-10% rounded quartz and lithic pebbles.
225–230			SAND, mineral sands gamma spike on geophysical log, not observed in strata samples
230–245			SAND, GRAVELLY, pale grey, very coarse sand to fine granules, suangular quartz, with 5-10% rounded quartz and lithic pebbles, m
245–260			SAND, GRAVELLY, pale grey, coarse sand to fine granules, subangular quartz, with 5% coal, shaley layers, gravelly layers
260–270			SAND, GRAVELLY, pale grey, coarse sand to fine granules to 10mm, rounded quartz and lithics
270–280			SAND, GRAVELLY, pale grey, coarse sand to fine granules, subangular quartz, with 5% coal, shaley layers, gravelly layers
280–290			SAND, GRAVELLY, pale grey, coarse sand to fine granules, subangular quartz, with 20% coal, gravelly layers.

Bore Construction Diagram

- Flowing borehead assembly installed.
- 0-30m: 404mmOD Steel surface casing, pressure cemented.
- 0-156.5m: Cement slurry
- 0-156.5m: 250mm NB FRP casing with stainless steel extensions.
- 139.5-169.5m: 200mm NB plain stainless steel pipe with rubber K packer.
- 169.5-193.5m: 200mm NB wire-wound stainless steel 0.75mm aperture screen.
- 193.5-271.5m: 200mm NB wire-wound stainless steel 1.0mm aperture screen.
- Naturally developed, no gravel pack.



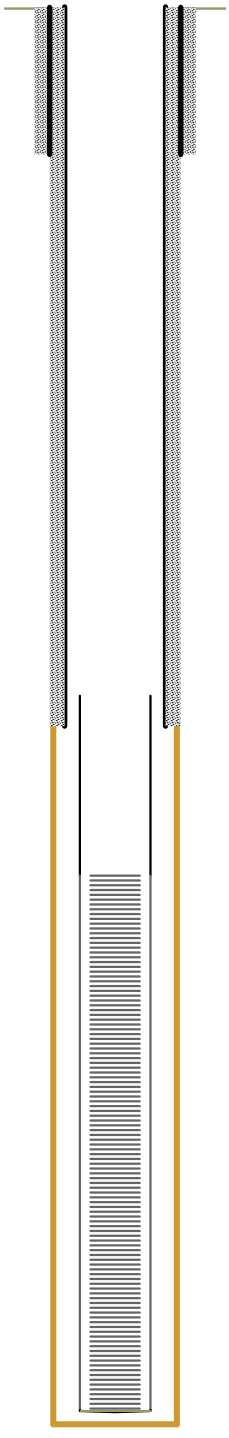
Drilling Company:	Austral Drilling	**Grid/Zone:**	z51S MGA GDA94	**Water Level:** mBGL	30.82mAGL
Driller:	Glen van Hees	**Easting:**	187343	**Date Measured:**	10 Feb 2017
Rig/Method:	Mud Rotary	**Northing:**	7788697	**Salinity:** TDS Lab.	650mg/L TDS
Date:	21/03/2016 to 29/04/2016	**Measured:**	GPS	**Test Details:**	190L/s open
Licence No:	CAW180719	**Elevation:**	Ground 11.7mAHD (DEM)	**Project Stage:**	2

COMMENTS: Geophysical logs by Westlog in 315mm hole
Hole terminated on intersection of sufficient aquifer material.

COMPLETION DIAGRAM
Production Bore

PARDOO PB6

Depth (m)	Stratigraphy	Lithology	Lithology Description
0–5		Pindan	SAND, silty, red/brown, fine to medium sand, subangular (pindan)
5–65	Broome Sandstone		SANDSTONE, pale red/brown, fine to coarse, subangular quartz, moderately indurated, with sand to granules
			SANDSTONE, orange/brown, coarse sand to fine granules, subangular to subrounded quartz
			SAND, gravelly, pale orange/brown to off-white, very coarse sand to fine granules, subroundd quartz, minor clayey layers
			SAND, off-white, coarse to very coarse, subrounded, quartz
65–140	Jarlemai Siltstone		SILTSTONE, pale yellow/brown grading grey, firm, sandy zones.
			SILTSTONE, dark grey, soft, glauconitic
			SILTSTONE, dark grey/green, soft, glauconitic
140–165	Alex Fm		SAND, recognised from geophysical log
			SILTSTONE, grey, with fine sand, becoming sandier with depth.
			SAND, dark grey, fine to coarse, shaley, subangular quartz
			SILTSTONE, dark grey, soft
165–290	Wallal Sandstone		SAND, pale grey, coarse to very coarse, subangular, quartz with trace chert, jasper and BIF
			GRAVEL, pale grey, fine to medium granules, rounded quartz
			SILTSTONE, dark grey, silty, intercalated with sand, coarse to very corase, subangular quartz
			SAND, grey, coarse to very coarse, subangular, quartz with minor siltstone
			GRAVEL, pale grey, fine to medium granules, rounded quartz and lithics, sandy
			SAND, pale grey, coarse to very coarse, subangular to subrounded, quartz with minor lithics, coal
			GRAVEL, pale grey, fine to medium granules, subangular to subrounded quartz and lithics, minor coal
			242-286.5m: Not logged



Flowing borehead assembly installed.

0-30m: 404mmOD Steel surface casing, pressure cemented.

0-146.6m: Cement slurry

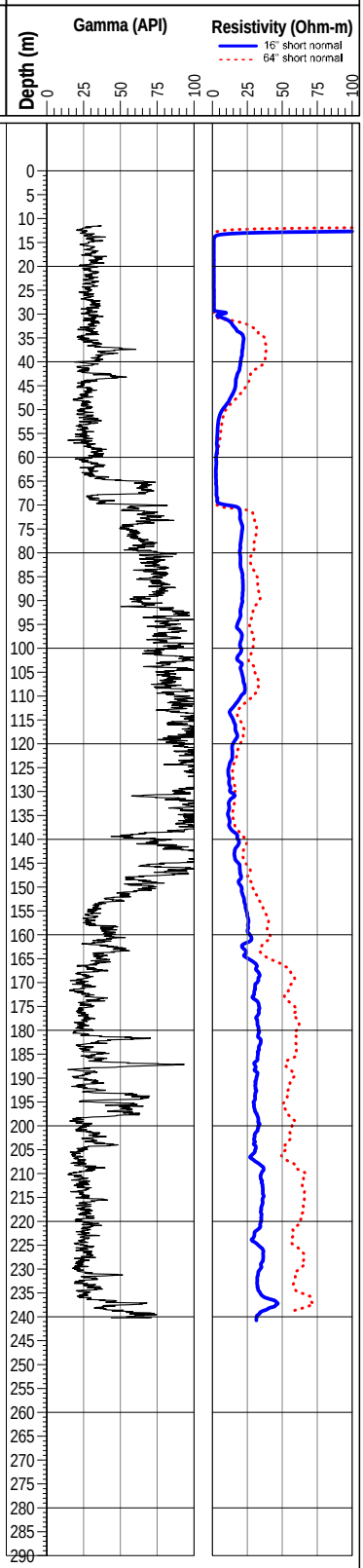
0-146.6m: 250mm NB FRP casing with stainless steel extensions.

140.4-177.1m: 200mm NB plain stainless steel pipe with rubber K packer.

177.1-207.1m: 200mm NB wire-wound stainless steel 0.75mm aperture screen.

207.1-286.1m: 200mm NB wire-wound stainless steel 1.0mm aperture screen.

Naturally developed, no gravel pack.



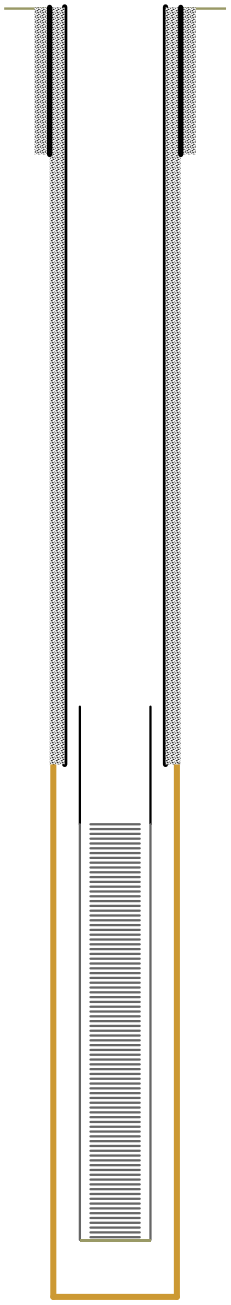
Drilling Company:	Austral Drilling	**Grid/Zone:**	z51S MGA GDA94	**Water Level:** mBGL	29.3mAGL
Driller:	John Grant	**Easting:**	188886	**Date Measured:**	10 Feb 2017
Rig/Method:	Mud Rotary	**Northing:**	7789145	**Salinity:** TDS Lab.	500mg/L TDS
Date:	15/11/2016 to 13/12/2016	**Measured:**	GPS	**Test Details:**	240L/s open
Licence No:	CAW183436	**Elevation:**	Ground 9.0mAHD (DEM)	**Project Stage:**	2

COMMENTS: Geophysical logs by Westlog in 315mm hole
Hole terminated on loss of 311mm bottom hole assembly, remains in the hole.

COMPLETION DIAGRAM
Production Bore

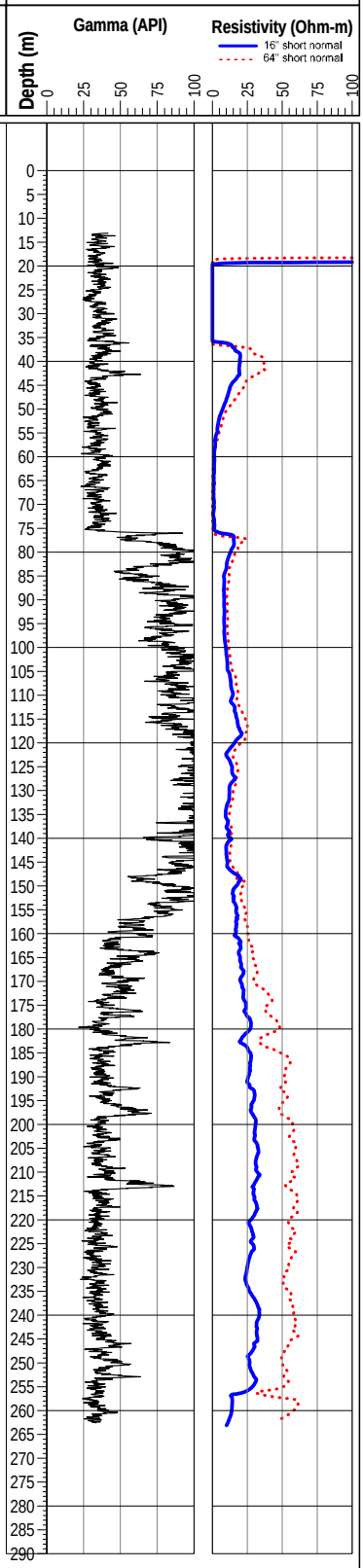
PARDOO PB7

Depth (m)	Stratigraphy	Lithology	Lithology Description
0–5	Pindan		SAND, silty, red/brown, fine to medium sand, subangular (pindan)
5–25	Broome Sandstone		SANDSTONE, red/brown fine to medium, well indurated, with medium to very coarse sand and gravel layers
25–65	Broome Sandstone		GRAVEL, off-white, 2-8mm grainsize, rounded to subrounded, quartz and banded iron formation lithics.
65–75	Broome Sandstone		SAND, off-white, very coarse sand to fine granules, subangular quartz and trace lithics
75–120	Jarlemai Siltstone		SHALE, dark grey, massive, slightly micaceous
120–150	Jarlemai Siltstone		SHALE, dark grey, with orange/brown and yellow/green mottles
150–160	Alex Fm		SHALE, sandy, dark grey, coarse sand to fine granules, subrounded quartz
160–185	Alex Fm		SAND, shaley, dark grey to black, fine to medium, quartz.
185–210	Wallal Sandstone		SAND, grey, coarse sand to fine granules, subangular quartz and trace ltihics.
210–225	Wallal Sandstone		SAND/GRAVEL, grey, coarse sand to fine granules, 10% gravel 2-6mm, subangular quartz and banded iron formation lithics and volcanics.
225–245	Wallal Sandstone		SAND, grey, coarse sand to fine granules, subangular quartz and trace ltihics.
245–260	Wallal Sandstone		SAND/GRAVEL, pale grey, coarse sand to fine granules, 10% gravel 2-4mm, subangular quartz and lithics



Bore Construction Diagram

- Flowing borehead assembly installed.
- 0-30m: 404mmOD Steel surface casing, pressure cemented.
- 0-154.4m: Cement slurry
- 0-154.4m: 250mm NB FRP casing with stainless steel extensions.
- 142.26-166.62m: 200mm NB plain stainless steel pipe with rubber K packer.
- 166.62-178.78m: 200mm NB wire-wound stainless steel 0.5mm aperture screen.
- 178.78-196.92m: 200mm NB wire-wound stainless steel 0.75mm aperture screen.
- 196.92-251.4m: 200mm NB wire-wound stainless steel 1.0mm aperture screen.
- Naturally developed, no gravel pack.



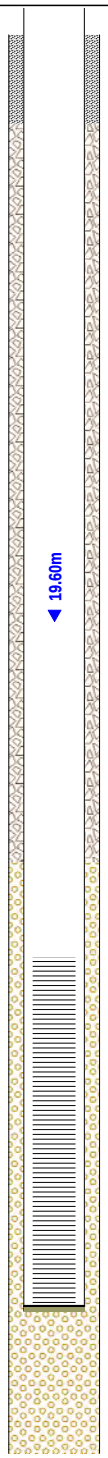
Drilling Company:	Kimberley Water	**Grid/Zone:**	z50S MGA GDA94	**Water Level:** mBGL	19.60
Driller:	Karl Bennett	**Easting:**	810528	**Date Measured:**	12/4/2017
Rig/Method:	Mud Rotary	**Northing:**	7785258	**Conductivity:** µS/cm	1365
Date:	11/4/2017	**Measured:**	GPS	**Airlift Yield:**	5L/s
Licence No:	Not required	**Elevation:**	~25.2 (DEM)		

COMMENTS: Water level and salinity measured by GCS

COMPLETION DIAGRAM
Monitoring

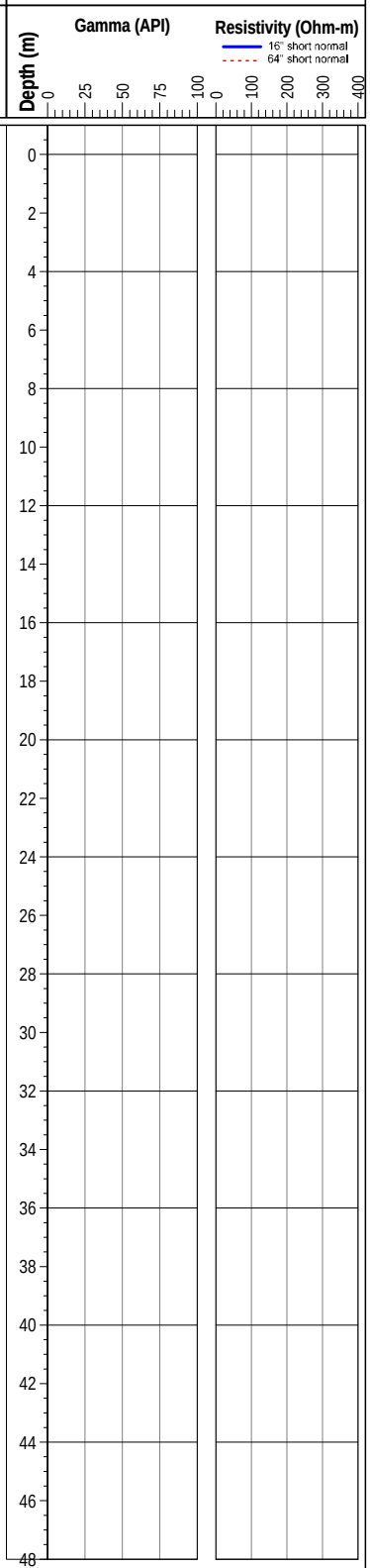
Pardoo BMB4

Depth (m)	Stratigraphy	Lithology	Lithology Description
0 – 2	Pindan		SAND, redy brown pindan, silty
2 – 4	Broome Sandstone		SANDSTONE
4 – 10			SANDY GRAVEL, off-white
10 – 12			GRAVEL, 2-10mm
12 – 20			SAND, gravely and silty
20 – 22			SAND, coarse to very coarse
22 – 32			CLAY, silty, sandy and gravelly zones, off-white
32 – 44			SAND, very coarse and gravelly
44 – 48			SAND, medium pale brown



Bore Construction Diagram

- 0 to 3m: cement
- -0.5 to 31.2m: 155mm CL9 PVC casing
- 3 to 28m: backfill cuttings
- 31.2 to 43.2m: 155mm CL9 slotted PVC 0.5mm aperture screen
- 28 to 48m: 1.6-3.2mm graded gravel pack
- 43.2m: end cap



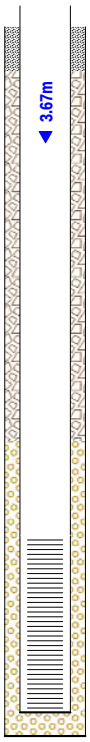
Drilling Company:	Kimberley Water	**Grid/Zone:**	z51S MGA GDA94	**Water Level:** mBGL	3.67
Driller:	Karl Bennett	**Easting:**	192068	**Date Measured:**	9/4/2017
Rig/Method:	Mud Rotary	**Northing:**	7790692	**Conductivity:** µS/cm	3400
Date:	9/4/2017	**Measured:**	GPS	**Airlift Yield:**	5L/s
Licence No:	Not required	**Elevation:**	~6.0 (DEM)		

COMMENTS: Water level and salinity measured by GCS

COMPLETION DIAGRAM
Monitoring

Pardoo BMB5

Depth (m)	Stratigraphy	Lithology	Lithology Description
0	P		SAND, pindan silty
2	Broome Sandstone		LATERITE, iron oxide cemented sandstone ,red/brown/black
4			SANDSTONE, pale brown/black, fine to medium, well indurated
6			SANDSTONE, pale orange/brown to off-white, fine to coarse, quartz with laminae of fine grained sandstone and rare lithics
8			
10			
12			
14			SANDSTONE, with sandy layers
16			
18			
20			
22			
24			
26			
28			
30			
32			
34			
36			
38			
40			
42			
44			
46			
48			



Bore Construction Diagram

0 to 1.5m: cement

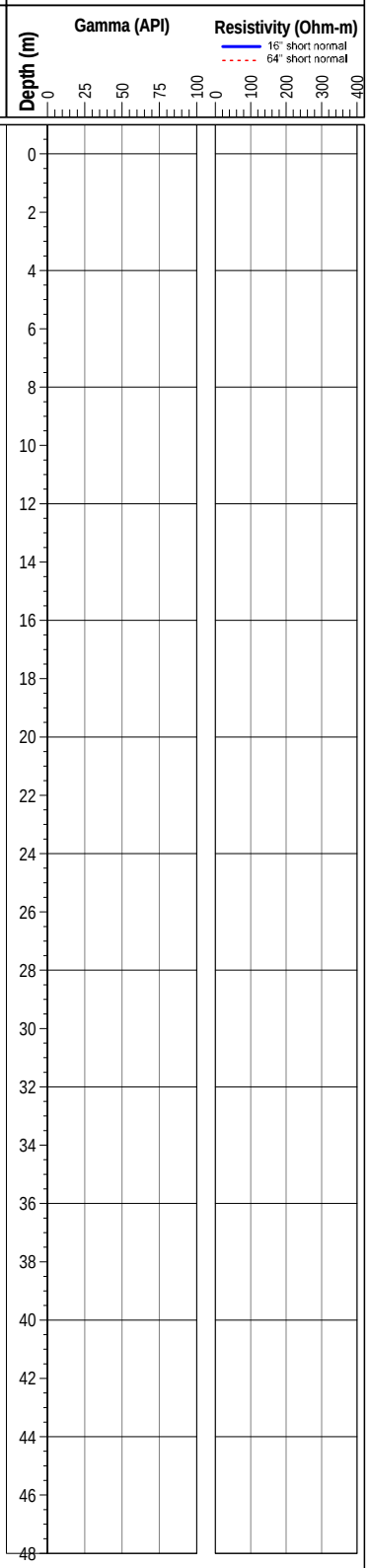
-0.71 to 17.2m: 100m CL12 PVC casing

1.5 to 14m: backfill cuttings

14 to 23.2m: 1.6-3.2mm graded gravel pack

17.2 to 23.2m: 100mm CLI2 slotted PVC 0.5mm aperture screen

23.2m: end cap



Drilling Company: Kimberley Water	**Grid/Zone:** z51S MGA GDA94	**Water Level:** 3.37 mBGL
Driller: Karl Bennett	**Easting:** 186499	**Date Measured:** 9/4/2017
Rig/Method: Mud Rotary	**Northing:** 7789041	**Conductivity:** µS/cm 4600
Date: 9/4/2017	**Measured:** GPS	**Airlift Yield:** 0.5L/s
Licence No: Not required	**Elevation:** ~5.8 (DEM)	

COMMENTS: Water level and salinity measured by GCS

COMPLETION DIAGRAM
Monitoring

Pardoo BMB6

Depth (m)	Stratigraphy	Lithology	Lithology Description
0	P		SILTY SAND, pale grey/brown pindan
2	Broome Sandstone		SANDSTONE, red/brown
4			
6			SAND, coarse sand to very fine gravel
8			
10			SANDSTONE, siltstone with sand and gravel offwhite
12			

Bore Construction Diagram

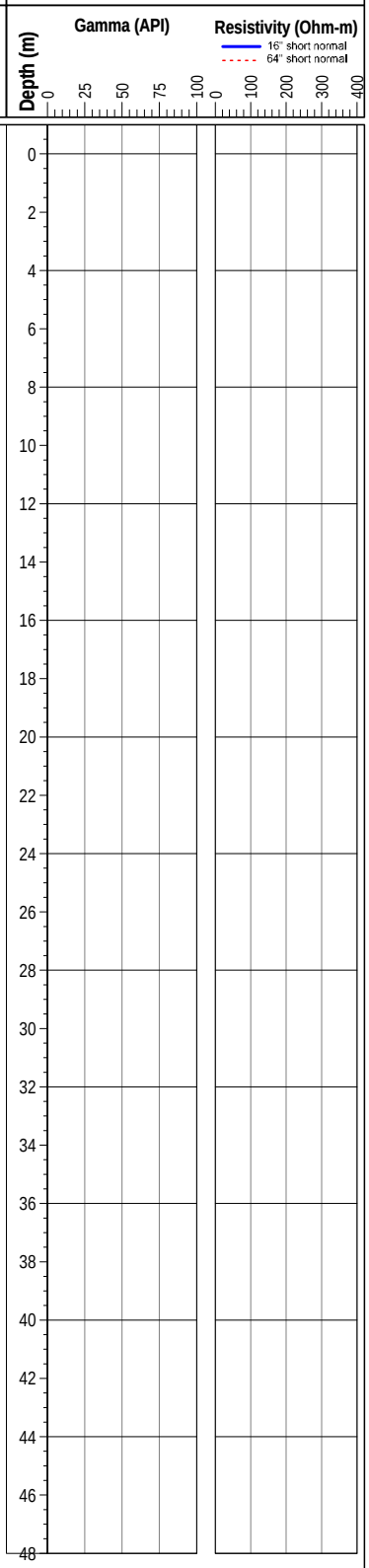
0 to 1.5m: cement

-0.68 to 5.1m: 100m CL12 PVC casing

1.5 to 11.1m: 1.6-3.2mm graded gravel pack

5.1 to 11.1m: 100mm CLI2 slotted PVC 0.5mm aperture screen

11.1m: end cap



Drilling Company:	Kimberley Water	**Grid/Zone:**	z50S MGA GDA94	**Water Level:** mBGL	3.53
Driller:	Karl Bennett	**Easting:**	804635	**Date Measured:**	10/4/2017
Rig/Method:	Mud Rotary	**Northing:**	7788024	**Conductivity:** µS/cm	1940
Date:	10/4/2017	**Measured:**	GPS	**Airlift Yield:**	0.5L/s
Licence No:	Not required	**Elevation:**	~8.0 (DEM)		

COMMENTS: Water level and salinity measured by GCS

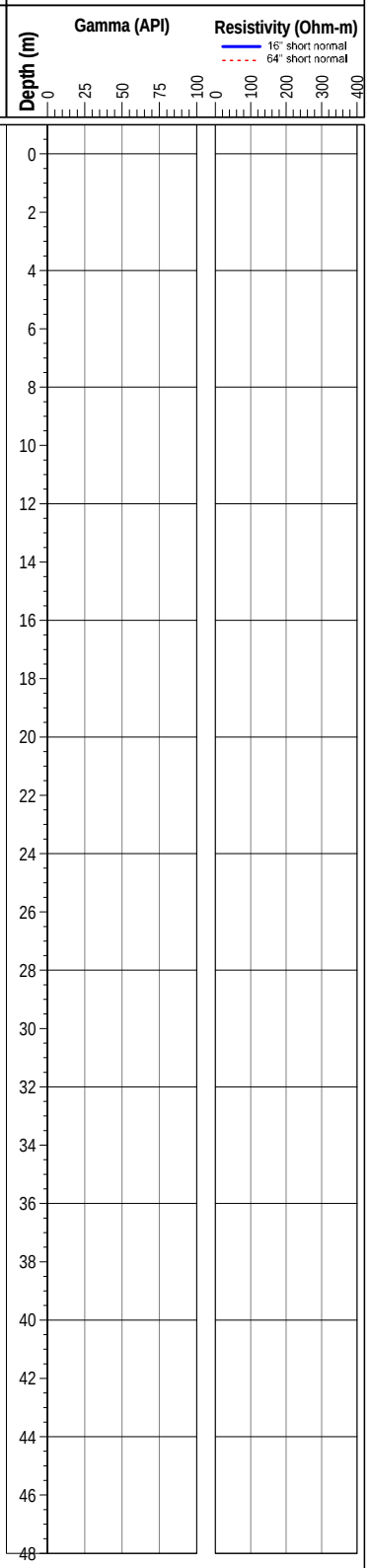
COMPLETION DIAGRAM
Monitoring

Pardoo BMB7

Depth (m)	Stratigraphy	Lithology	Lithology Description
0 – 2	Pindan		SAND, red/black pindan very coarse
2 – 6	Broome Sandstone		SANDY GRAVEL
6 – 12	Broome Sandstone		SANDSTONE, red/black fine to coarse

Bore Construction Diagram

- 0 to 1.5m: cement
- 1.5 to 4m: backfill cuttings
- -0.59 to 5.65m: 100m CL12 PVC casing
- 5.65 to 11.65m: 100mm CL12 slotted PVC 0.5mm aperture screen
- 4 to 12m: 1.6-3.2mm graded gravel pack
- 11.65m: end cap

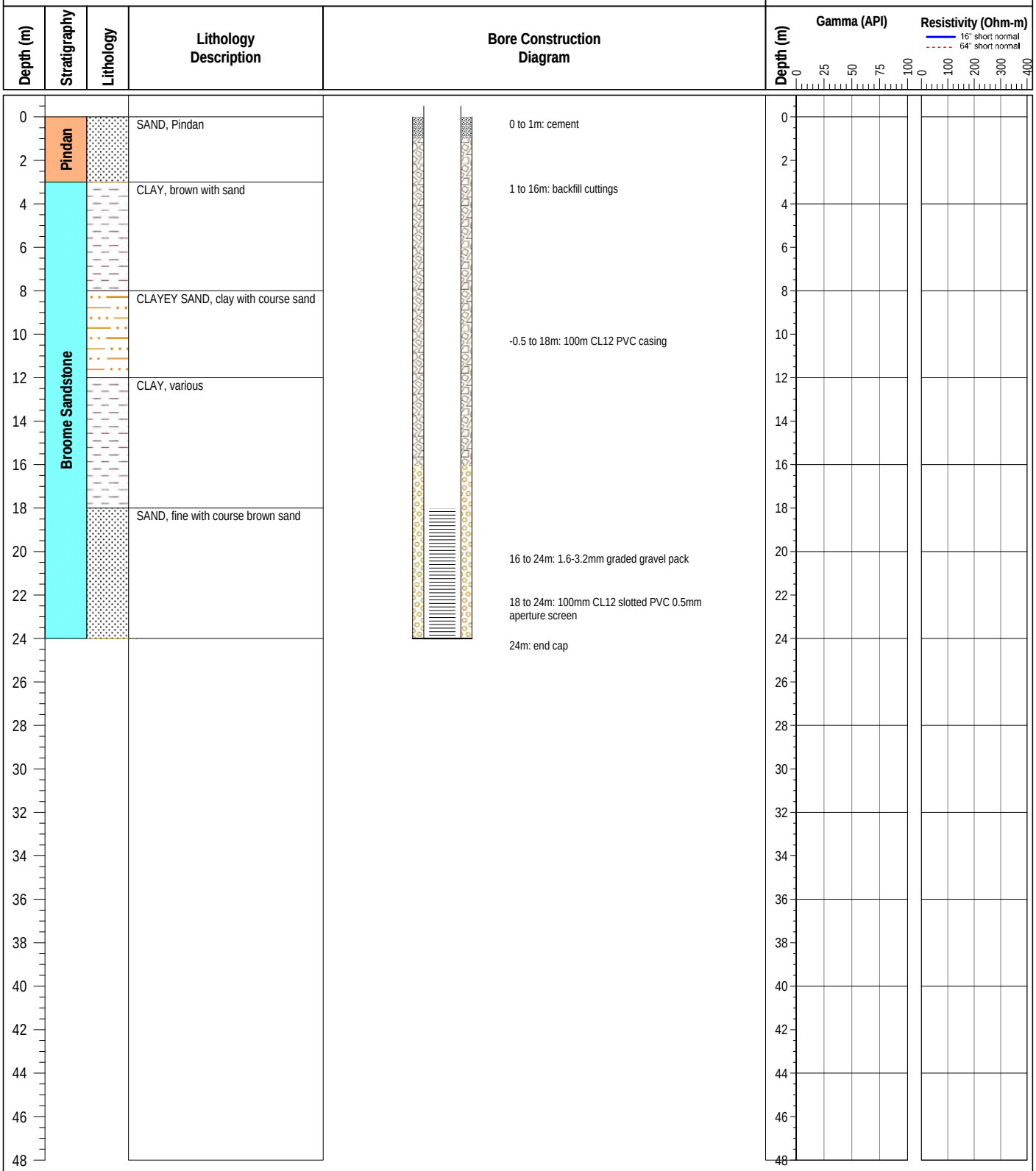


Drilling Company: Kimberley Water	**Grid/Zone:** z50S MGA GDA94	**Water Level:** mBGL
Driller: Karl Bennett	**Easting:** 797595	**Date Measured:**
Rig/Method: Mud Rotary	**Northing:** 7780616	**Conductivity:** µS/cm
Date: 12/4/2017	**Measured:** GPS	**Airlift Yield:**
Licence No: Not required	**Elevation:** ~17.1 (estimate)	

COMMENTS: Water level and salinity to be measured by GCS May 2017.

COMPLETION DIAGRAM
Monitoring

Pardoo BMB8



Appendix E

Historical Groundwater Quality

Selected Bores

Appendix E-1 Historical Groundwater Quality Selected Bores

Aquifer	**WALLAL AQUIFER**														
Bore	**Pardoo PB1**							**Pardoo PB2**				**Pardoo PB3**	**Pardoo PB4**	**Pardoo PB5**	**Pardoo PB6**
Sample Date	3/6/11	2/12/11	2/9/12	30/9/13	7/10/14	23/9/15	**14/10/16**	30/9/13	7/10/14	23/9/15	**14/10/16**	**14/10/16**	**14/10/16**	**14/10/16**	**14/10/16**
Laboratory	ARL	ARL	Agrifood	Agrifood	Agrifood	Agrifood	**Agrifood**	Agrifood	Agrifood	Agrifood	**Agrifood**	**Agrifood**	**Agrifood**	**Agrifood**	**Agrifood**
pH	7	7.5	7.2	7.2	7.1	7.1	**7.0**	7	7	6.9	**7.1**	**7.2**	**7.1**	**7.6**	**7.1**
Electrical Cond. (mS/cm)	0.97	1.1	0.93	0.96	0.97	1.14	**1.07**	1.19	1.23	1.22	**1.27**	**0.98**	**0.96**	**0.82**	**0.99**
Total Dissolved Salts (calc.)	550	530	530	520	530	650	**550**	660	670	680	**680**	**550**	**540**	**470**	**550**
Sodium	140	160	150	140	140	170	**140**	160	170	180	**160**	**140**	**140**	**120**	**140**
Potassium	7.2	7.8	11	11	10	12	**11**	10	12	12	**13**	**12**	**11**	**11**	**11**
Calcium	21	23	19	24	22	36	**24**	34	34	37	**34**	**23**	**21**	**16**	**22**
Magnesium	12	112	11	13	11	17	**13**	23	17	18	**19**	**13**	**12**	**8.8**	**12**
Carbonate	<3 c	<3 c	<5	<5	<5	-	**-**	<5	<5	-	**-**	**-**	**-**	**-**	**-**
Bicarbonate	84 c	23 c	170	150	175	190	**175**	145	150	145	**145**	**170**	**175**	**175**	**165**
Chloride	180	170	155	156	160	210	**160**	221	230	230	**240**	**160**	**160**	**130**	**170**
Sulphate, SO_4	89	89	87	90	83	100	**89**	122	120	120	**120**	**90**	**87**	**71**	**91**
Nitrate, NO_3	<0.05	0.09	<0.5	<0.5	<0.5	<0.5	**<0.5**	<0.5	<0.5	<0.5	**<0.5**	**<0.5**	**<0.5**	**<0.5**	**<0.5**
Nitrate, N	<0.01	0.02	<0.1	<0.1	<0.1	<0.1	**<0.1**	<0.1	<0.1	<0.1	**<0.1**	**<0.1**	**<0.1**	**<0.1**	**<0.1**
Total Nitrogen, N	-	-	<0.1	0.1	<0.1	<0.1	**<0.1**	0.5	0.1	<0.1	**<0.1**	**<0.1**	**0.3**	**0.2**	**0.1**
Phosphate, P	-	-	0.02	<0.01	<0.01	<0.01	**<0.01**	<0.01	<0.01	<0.01	**<0.01**	**<0.01**	**<0.01**	**<0.01**	**<0.01**
Total Phosphorus, P	0.18	<0.01	0.02	<0.01	0.01	0.01	**<0.01**	<0.01	<0.01	0.01	**<0.01**	**<0.01**	**<0.01**	**<0.01**	**<0.01**
Boron	-	-	0.27	0.25	0.24	0.26	**0.28**	0.22	0.21	0.26	**0.25**	**0.26**	**0.27**	**0.28**	**0.28**
Iron	-	-	0.16	0.025	1.7	0.06	**0.0044**	0.022	0.01	<0.0010	**0.0058**	**0.012**	**0.0066**	**0.068**	**0.092**
Manganese	-	-	0.0075	0.0082	0.062	0.021	**0.011**	0.014	0.0089	0.0081	**0.0091**	**0.0046**	**0.0063**	**0.01**	**0.017**
Hardness (as $CaCO_3$)	-	-	95	115	100	160	**115**	180	155	170	**165**	**110**	**100**	**75**	**105**
Alkalinity (as $CaCO_3$)	69	32	140	125	145	155	**140**	120	125	120	**120**	**140**	**145**	**140**	**135**
Ammonium, NH_4	-	-	<0.1	0.1	<0.1	<0.1	**<0.1**	<0.1	<0.1	<0.1	**<0.1**	**<0.1**	**<0.1**	**<0.1**	**<0.1**
Total Kjeldahl Nitrogen, N	-	-	<0.1	0.1	<0.1	-	**-**	0.5	0.1	-	**-**	**-**	**-**	**-**	**-**
Silica, SiO_2	-	-	16	15	16	16	**25**	15	16	16	**25**	**26**	**28**	**28**	**28**
Dissolved Carbon Dioxide	-	-	17	15	22	24	**28**	23	24	29	**18**	**17**	**22**	**7**	**21**
Cations (me/L)	-	-	8.7	8.6	8.4	10.89	**8.6**	10.8	10.8	11.46	**10.6**	**8.6**	**8.4**	**7.0**	**8.5**
Anions (me/L)	-	-	9	8.7	9.1	11.12	**9.2**	11.2	11.4	11.36	**11.6**	**9.2**	**9.2**	**8.0**	**9.4**

Note – All units mg/L unless stated.

***c** indicates that the result has been calculated from other parameter species*

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Appendix E-1 Historical Groundwater Quality Selected Bores (cont.)

Aquifer	**WALLAL AQUIFER**													
Bore	**Atlas PB1**						**Cape Keraudren**	**Chower bore**						
Sample Date	3/6/11	2/9/12	30/9/13	8/10/14	24/9/15	**15/10/16**	**14/10/16**	9/2/12	2/9/12	30/9/13	8/10/14	23/9/15	**15/10/16**
Laboratory	ARL	Agrifood	Agrifood	Agrifood	Agrifood	**Agrifood**	**Agrifood**	ARL	Agrifood	Agrifood	Agrifood	Agrifood	**Agrifood**
pH	6.6	6.7	6.9	6.9	6.9	**6.9**	**7.2**	8.3	7	6.8	7	7	**7.1**
Electrical Cond. (mS/cm)	2	1.4	2.09	0.77	2.07	**2.02**	**1.87**	1.2	1.1	1.13	1.13	1.11	**1.11**
Total Dissolved Salts (calc.)	1,200	810	1,130	400	1,100	**1120**	**960**	630	610	630	610	620	**620**
Sodium	270	200	270	96	290	**260**	**220**	140	160	150	160	170	**150**
Potassium	10	9.6	12	6	14	**15**	**14**	12	12	12	11	11	**12**
Calcium	61	48	68	21	67	**55**	**54**	27	25	34	27	30	**27**
Magnesium	32	28	40	10	31	**32**	**32**	15	14	22	13	15	**15**
Carbonate	<3 c	<5	<5	<5	-	**-**	**-**	4.8 c	<5	<5	<5	-	**-**
Bicarbonate	81 c	60	85	35	90	**90**	**70**	159 c	150	165	165	165	**165**
Chloride	560	367	508	180	500	**510**	**490**	230	198	197	200	190	**200**
Sulphate, SO_4	160	114	169	56	160	**170**	**95**	100	107	110	100	100	**110**
Nitrate, NO_3	<0.05	<0.5	<0.5	<0.5	<0.5	**<0.5**	**<0.5**	<0.05	<0.5	<0.5	<0.5	<0.5	**<0.5**
Nitrate, N	<0.01	<0.1	<0.1	<0.1	<0.1	**<0.1**	**<0.1**	<0.01	<0.1	<0.1	<0.1	<0.1	**<0.1**
Total Nitrogen, N	-	-	<0.1	<0.1	<0.1	**0.2**	**0.1**	-	<0.1	0.5	0.1	<0.1	**<0.1**
Phosphate, P	-	<0.01	<0.01	<0.01	<0.01	**<0.01**	**<0.01**	-	<0.01	<0.01	<0.01	<0.01	**<0.01**
Total Phosphorus, P	0.27	-	<0.01	<0.01	<0.01	**<0.01**	**<0.01**	0.08	0.01	<0.01	<0.01	0.02	**<0.01**
Boron	-	0.1	0.18	0.1	0.23	**0.21**	**0.17**	-	0.26	0.25	0.24	0.29	**0.27**
Iron	-	0.004	<0.001	0.0013	<0.001	**0.0019**	**0.03**	-	0.11	0.02	0.0086	<0.001	**0.0042**
Manganese	-	0.0007	<0.0005	<0.0005	<0.0005	**<0.00050**	**0.006**	-	0.06	0.014	0.0024	0.0024	**0.0085**
Hardness (as $CaCO_3$)	-	235	335	95	295	**270**	**265**	-	120	175	120	135	**130**
Alkalinity (as $CaCO_3$)	66	50	70	30	75	**75**	**60**	-	125	135	135	135	**135**
Ammonium, NH_4	-	<0.1	0.1	<0.1	<0.1	**<0.1**	**<0.1**	-	<0.1	<0.1	<0.1	<0.1	**<0.1**
Total Kjeldahl Nitrogen, N	-	-	<0.1	<0.1	-	**-**	**-**	-	<0.1	0.5	0.1	-	**-**
Silica, SiO_2	-	12	24	12	25	**29**	**19**	-	20	19	21	20	**23**
Dissolved Carbon Dioxide	-	19	17	7	18	**18**	**7**	-	24	42	26	26	**21**
Cations (me/L)	-	13.6	18.7	6.2	18.86	**17.1**	**15.3**	-	9.7	10.3	9.7	10.4	**9.4**
Anions (me/L)	-	13.7	19.2	6.8	18.91	**19.4**	**16.9**	-	10.3	10.6	10.4	10.15	**10.6**

Note – All units mg/L unless stated.

***c** indicates that the result has been calculated from other parameter species*

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Appendix E-1 Historical Groundwater Quality Selected Bores (cont.)

Aquifer	**WALLAL AQUIFER**												
Bore	**Homestead bore**					**WCB17C**							
Sample Date	2/9/12	1/10/13	8/10/14	24/9/15	**14/10/16**	3/12/08	14/10/09	3/6/11	2/9/12	30/9/13	8/10/14	23/9/15	**14/10/16**
Laboratory	Agrifood	Agrifood	Agrifood	Agrifood	**Agrifood**	ANSTO	ANSTO	ARL	Agrifood	Agrifood	Agrifood	Agrifood	**Agrifood**
pH	6.8	7.1	7	6.9	**6.9**	6.52	6.84	7	7	-	7.2	7.2	**7.3**
Electrical Cond. (mS/cm)	1.13	2.88	2.84	2.84	**2.80**	1	1	0.94	0.93	0.93	0.93	0.92	**0.91**
Total Dissolved Salts (calc.)	630	1,520	1,500	1,500	**1470**	680	589	550	540	520	500	520	**510**
Sodium	160	390	400	390	**370**	150	140	150	150	-	140	150	**130**
Potassium	8.3	17	18	20	**19**	6	7	6.6	9.2	-	9	10	**9.7**
Calcium	38	90	74	85	**69**	20	21	18	20	-	18	21	**19**
Magnesium	21	52	33	30	**42**	11	11	11	13	-	8.9	9.6	**11**
Carbonate	<5	<5	<5	-	**-**	0.06	N/A	<3 c	<5	-	<5	-	**-**
Bicarbonate	30	65	75	65	**70**	245	173.4	195 c	200 c	-	195	200	**195**
Chloride	336	796	790	780	**790**	140	150	160	147	-	140	140	**140**
Sulphate, SO_4	48	123	120	110	**120**	73	79	83	504	-	73	76	**79**
Nitrate, NO_3	<0.5	<0.5	<0.5	<0.5	**1.5**	<0.01	<0.01	<0.05	<0.5	-	<0.5	<0.5	**<0.5**
Nitrate, N	<0.1	<0.1	<0.1	<0.1	**0.3**	<0.002	<0.002	0.01	<0.1	-	<0.1	<0.1	**<0.1**
Total Nitrogen, N	-	0.1	0.2	<0.1	**0.4**	-	-	-	-	-	0.2	<0.1	**<0.1**
Phosphate, P	<0.01	0.01	<0.01	<0.01	**<0.01**	<0.005	0.006	-	<0.01	-	0.01	<0.01	**<0.01**
Total Phosphorus, P	-	<0.01	<0.01	<0.01	**<0.01**	-	-	0.2	-	-	0.01	0.01	**<0.01**
Boron	0.064	0.18	0.18	0.17	**0.2**	0.24	0.35	-	0.27	-	0.29	0.37	**0.34**
Iron	0.05	0.0029	<0.001	0.011	**0.0024**	0.15	0.033	-	0.005	-	0.0061	0.013	**0.015**
Manganese	<0.0005	<0.0005	<0.0005	0.004	**0.00081**	0.006	0.005	-	0.0037	-	0.0045	0.0044	**0.0045**
Hardness (as $CaCO_3$)	180	440	320	340	**345**	-	-	-	105	-	80	90	**95**
Alkalinity (as $CaCO_3$)	25	55	60	55	**60**	203	144	160	165	-	160	165	**160**
Ammonium, NH_4	<0.1	0.1	<0.1	<0.1	**<0.1**	-	-	-	<0.1	-	<0.1	<0.1	**<0.1**
Total Kjeldahl Nitrogen, N	-	0.1	0.2	-	**-**	-	-	-	-	-	0.2	-	**-**
Silica, SiO_2	4.6	15	16	15	**23**	16	17	-	14	-	18	17	**29**
Dissolved Carbon Dioxide	8	8	12	13	**14**	-	-	-	32	-	20	20	**16**
Cations (me/L)	10.8	26.2	24.3	24.18	**23.5**	-	-	-	8.8	-	8	8.56	**7.8**
Anions (me/L)	11	26.1	26	25.36	**25.9**	-	-	-	9.2	-	8.7	8.81	**8.7**

Notes – All units mg/L unless stated.
***c** indicates that the result has been calculated from other parameter species.*
WCB17C ANSTO results from Meredith (2009) and Meredith (2010).

Appendix E-1 Historical Groundwater Quality Selected Bores (cont.)

Aquifer	**BROOME AQUIFER**										
Bore	**Pardoo BMB1**			**Pardoo BMB2**				**Pardoo BMB3**			
Sample Date	25/7/13	7/10/14	**14/10/16**	25/7/13	7/10/14	23/9/15	**14/10/16**	25/7/13	7/10/14	23/9/15	**14/10/16**
Laboratory	Agrifood	Agrifood	**Agrifood**	Agrifood	Agrifood	Agrifood	**Agrifood**	Agrifood	Agrifood	Agrifood	**Agrifood**
pH	7.2	7.4	**7.3**	7.6	8.0	7.7	**7.8**	7.9	8.1	7.8	**7.8**
Electrical Cond. (mS/cm)	1.22	0.88	**1.25**	1.56	1.60	1.68	**2.04**	2.48	0.90*	2.56	**2.55**
Total Dissolved Salts (calc.)	820	540	**820**	1,020	1,000	1,100	**1300**	1,530	520*	1,600	**1600**
Sodium	160	110	**130**	350	350	380	**440**	570	180	570	**560**
Potassium	11	2	**3.9**	15	5	5.3	**7.5**	45	8	24	**26**
Calcium	73	52	**80**	25	10	13	**16**	8.7	4.8	12	**11**
Magnesium	13	9.4	**16**	9.4	3.3	3.7	**5.3**	5.2	1.5	6.2	**6.0**
Carbonate	<5	<5	**-**	<5	<5	-	**-**	<5	<5	-	**-**
Bicarbonate	255	190	**245**	610	520	490	**595**	560	285	710	**715**
Chloride	161	100	**170**	157	170	200	**270**	438	110	380	**380**
Sulphate, SO_4	74	50	**61**	87	120	140	**180**	114	26	160	**180**
Nitrate, NO_3	106	71	**130**	7.4	22	13	**12**	15	0.9	2.5	**1.4**
Nitrate, N	23.9	15.9	**29.4**	1.7	4.9	2.9	**2.7**	3.4	0.2	0.6	**0.3**
Total Nitrogen, N	24.2	16.1	**30**	2	5.3	3	**2.9**	3.7	0.6	0.6	**0.4**
Phosphate, P	<0.01	0.01	**<0.01**	<0.01	<0.01	0.01	**<0.01**	<0.01	<0.01	0.09	**0.01**
Total Phosphorus, P	0.01	0.01	**0.02**	0.01	0.02	0.01	**0.01**	0.01	0.08	0.13	**0.03**
Boron	0.35	0.22	**0.31**	2.4	2.2	2.3	**1.8**	1.5	0.85	2.3	**2.0**
Iron	0.068	0.0025	**<0.0010**	0.37	0.1	<0.0010	**<0.0010**	0.42	0.13	2.2	**0.052**
Manganese	0.2	0.03	**0.0017**	0.045	0.0067	0.0014	**0.00051**	0.02	0.07	0.16	**0.0075**
Hardness (as $CaCO_3$)	235	170	**265**	100	40	50	**60**	45	20	55	**50**
Alkalinity (as $CaCO_3$)	210	155	**200**	500	425	400	**485**	460	235	580	**585**
Ammonium, NH_4	0.2	<0.1	**<0.1**	0.2	<0.1	0.1	**<0.1**	0.1	<0.1	<0.1	**<0.1**
Total Kjeldahl Nitrogen, N	0.3	0.2	**-**	0.3	0.4	-	**-**	0.3	0.4	-	**-**
Silica, SiO_2	94	49	**110**	69	61	71	**82**	59	51	64	**78**
Dissolved Carbon Dioxide	26	12	**19**	24	8	15	**15**	11	4	18	**18**
Cations (me/L)	12	8.2	**11.1**	17.6	16.2	17.61	**20.6**	26.8	8.4	26.51	**26.1**
Anions (me/L)	12	8.1	**12.2**	16.4	16.2	16.8	**21.3**	24.2	8.3	25.73	**26.2**

Notes – All units mg/L unless stated.
***c** indicates that the result has been calculated from other parameter species.*
** Inconsistent with field electrical conductivity readings*

Appendix F

Laboratory Certificate

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Certificate of Analysis

Project ID: PBC005
Lab No. B1610-0174
Client: Groundwater Consulting Services
Client Address: P O Box 8323, South Perth WA 6151

Date Received: 31 October 2016

Water analysis
Test Method: The analysis was performed in accordance with APHA – Standard Test Methods for the Examination of Water and Wastewater – 21 Edition 2005.

Analysis	*Units*	PARDOO PB1 14/10/16	PARDOO PB2 14/10/16	PARDOO PB3 14/10/16	PARDOO PB4 14/10/16
Appearance		Colourless	Colourless	Colourless	Colourless
Odour		Odourless	Odourless	Odourless	Odourless
pH		7.0	7.1	7.2	7.1
Electrical Conductivity	mS/cm	1.07	1.27	0.98	0.96
Total Dissolved Salts	mg/L	550	680	550	540
Boron	mg/L	0.28	0.25	0.26	0.27
Calcium	mg/L	24	34	23	21
Iron	mg/L	0.0044	0.0058	0.012	0.0066
Potassium	mg/L	11	13	12	11
Magnesium	mg/L	13	19	13	12
Manganese	mg/L	0.011	0.0091	0.0046	0.0063
Sodium	mg/L	140	160	140	140
Silicon	mg/L	12	12	12	13
SiO2	mg/L	25	25	26	28
Alkalinity (to pH 4.5@25degC)	mg CaCO3/L	140	120	140	145
Bicarbonate	mg/L	175	145	170	175
Chloride	mg/L	160	240	160	160
Sulphate SO4	mg/L	89	120	90	87
Nitrate - as NO3	mg/L	<0.5	<0.5	<0.5	<0.5
Ammonium (NH4)	mg/L	<0.1	<0.1	<0.1	<0.1
PO4 - P	mg/L	<0.01	<0.01	<0.01	<0.01
Fluoride	mg/L	0.43	0.32	0.42	0.4
Hardness	mg CaCO3/L	115	165	110	100
Dissolved Carbon Dioxide	mg/L	28	18	17	22
Cations	meq/L	8.6	10.6	8.6	8.4
Anions	meq/L	9.2	11.6	9.2	9.2
Balance	%	93	91	93	91
Total Nitrogen	mg/L	<0.1	<0.1	<0.1	0.3
Total Phosphorus	mg/L	<0.01	<0.01	<0.01	<0.01

** Concentrations reported as ppm (mg/L) unless otherwise stated.*

Checked: M. Horvat Approved Signatory:.....

Date 12.1.2017

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Certificate of Analysis

Project ID: PBC005
Lab No. B1610-0174
Client: Groundwater Consulting Services
Client Address: P O Box 8323, South Perth WA 6151

Date Received: 31 October 2016

Water analysis
Test Method: The analysis was performed in accordance with APHA – Standard Test Methods for the Examination of Water and Wastewater – 21 Edition 2005.

Analysis	*Units*	PARDOO PB5 14/10/16	PARDOO PB6 14/10/16	PARDOO BMB1 14/10/16	PARDOO BMB2 14/10/16
Appearance		Colourless	Sand	Sand	Colourless
Odour		Odourless	Odourless	Odourless	Odourless
pH		7.6	7.1	7.3	7.8
Electrical Conductivity	mS/cm	0.82	0.99	1.25	2.04
Total Dissolved Salts	mg/L	470	550	820	1300
Boron	mg/L	0.28	0.28	0.31	1.8
Calcium	mg/L	16	22	80	16
Iron	mg/L	0.068	0.092	<0.0010	<0.0010
Potassium	mg/L	11	11	3.9	7.5
Magnesium	mg/L	8.8	12	16	5.3
Manganese	mg/L	0.01	0.017	0.0017	0.00051
Sodium	mg/L	120	140	130	440
Silicon	mg/L	13	13	52	38
SiO2	mg/L	28	28	110	82
Alkalinity (to pH 4.5@25degC)	mg CaCO3/L	140	135	200	485
Bicarbonate	mg/L	175	165	245	595
Chloride	mg/L	130	170	170	270
Sulphate SO4	mg/L	71	91	61	180
Nitrate - as NO3	mg/L	<0.5	<0.5	130	12
Ammonium (NH4)	mg/L	<0.1	<0.1	<0.1	<0.1
PO4 - P	mg/L	<0.01	<0.01	<0.01	<0.01
Fluoride	mg/L	0.39	0.34	0.21	3.74
Hardness	mg CaCO3/L	75	105	265	60
Dissolved Carbon Dioxide	mg/L	7	21	19	15
Cations	meq/L	7.0	8.5	11.1	20.6
Anions	meq/L	8.0	9.4	12.2	21.3
Balance	%	88	90	91	97
Total Nitrogen	mg/L	0.2	0.1	30	2.9
Total Phosphorus	mg/L	<0.01	<0.01	0.02	0.01

* *Concentrations reported as ppm (mg/L) unless otherwise stated.*

Checked: M. Horvat Approved Signatory: .....

Date 12.1.2017

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Certificate of Analysis

Project ID: PBC005
Lab No. B1610-0174
Client: Groundwater Consulting Services
Client Address: P O Box 8323, South Perth WA 6151

Date Received: 31 October 2016

Water analysis
Test Method: The analysis was performed in accordance with APHA – Standard Test Methods for the Examination of Water and Wastewater – 21 Edition 2005.

Analysis	*Units*	PARDOO BMB3 14/10/16	WCB04B 15/10/16	Homestead 14/10/16	Atlas PB1 15/10/16
Appearance		Iron	Colourless	Colourless	Colourless
Odour		Odourless	Odourless	Odourless	Odourless
pH		7.8	6.7	6.9	6.9
Electrical Conductivity	mS/cm	2.55	3.07	2.80	2.02
Total Dissolved Salts	mg/L	1600	1670	1470	1120
Boron	mg/L	2.0	0.24	0.2	0.21
Calcium	mg/L	11	61	69	55
Iron	mg/L	0.052	0.0072	0.0024	0.0019
Potassium	mg/L	26	25	19	15
Magnesium	mg/L	6.0	38	42	32
Manganese	mg/L	0.0075	0.048	0.00081	<0.00050
Sodium	mg/L	560	450	370	260
Silicon	mg/L	36	9.1	11	14
SiO2	mg/L	78	19	23	29
Alkalinity (to pH 4.5@25degC)	mg CaCO3/L	585	65	60	75
Bicarbonate	mg/L	715	75	70	90
Chloride	mg/L	380	780	790	510
Sulphate SO4	mg/L	180	260	120	170
Nitrate - as NO3	mg/L	1.4	<0.5	1.5	<0.5
Ammonium (NH4)	mg/L	<0.1	<0.1	<0.1	<0.1
PO4 - P	mg/L	0.01	<0.01	<0.01	<0.01
Fluoride	mg/L	6.24	0.15	0.17	0.19
Hardness	mg CaCO3/L	50	310	345	270
Dissolved Carbon Dioxide	mg/L	18	24	14	18
Cations	meq/L	26.1	26.4	23.5	17.1
Anions	meq/L	26.2	28.6	25.9	19.4
Balance	%	100	92	91	88
Total Nitrogen	mg/L	0.4	0.1	0.4	0.2
Total Phosphorus	mg/L	0.03	<0.01	<0.01	<0.01

** Concentrations reported as ppm (mg/L) unless otherwise stated.*

Checked: M. Horvat Approved Signatory:.....

Date 12.1.2017

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Certificate of Analysis

Project ID: PBC005
Lab No. B1610-0174
Client: Groundwater Consulting Services
Client Address: P O Box 8323, South Perth WA 6151

Date Received: 31 October 2016

Water analysis
Test Method: The analysis was performed in accordance with APHA – Standard Test Methods for the Examination of Water and Wastewater – 21 Edition 2005.

Analysis	*Units*	Cape Keraudren 14/10/16	Chower 15/10/16	WCB17C 14/10/16
Appearance		Colourless	Colourless	Colourless
Odour		Odourless	Odourless	Odourless
pH		7.2	7.1	7.3
Electrical Conductivity	mS/cm	1.87	1.11	0.91
Total Dissolved Salts	mg/L	960	620	510
Boron	mg/L	0.17	0.27	0.34
Calcium	mg/L	54	27	19
Iron	mg/L	0.03	0.0042	0.015
Potassium	mg/L	14	12	9.7
Magnesium	mg/L	32	15	11
Manganese	mg/L	0.006	0.0085	0.0045
Sodium	mg/L	220	150	130
Silicon	mg/L	9.0	11	13
SiO2	mg/L	19	23	29
Alkalinity (to pH 4.5@25degC)	mg CaCO3/L	60	135	160
Bicarbonate	mg/L	70	165	195
Chloride	mg/L	490	200	140
Sulphate SO4	mg/L	95	110	79
Nitrate - as NO3	mg/L	<0.5	<0.5	<0.5
Ammonium (NH4)	mg/L	<0.1	<0.1	<0.1
PO4 - P	mg/L	<0.01	<0.01	<0.01
Fluoride	mg/L	0.21	0.3	0.49
Hardness	mg CaCO3/L	265	130	95
Dissolved Carbon Dioxide	mg/L	7	21	16
Cations	meq/L	15.3	9.4	7.8
Anions	meq/L	16.9	10.6	8.7
Balance	%	91	89	90
Total Nitrogen	mg/L	0.1	<0.1	<0.1
Total Phosphorus	mg/L	<0.01	<0.01	<0.01

* *Concentrations reported as ppm (mg/L) unless otherwise stated.*

Checked: M. Horvat Approved Signatory:.....

Date 12.1.2017

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Project ID: PBC005
Lab No. B1610-0174
Client: Groundwater Consulting Services
Client Address: P O Box 8323, South Perth WA 6151

Date Received: 31 October 2016

Comments:

The pH data indicates the waters range from neutral to slightly alkaline in reaction.

Electrical conductivity and total soluble salts data show the salinity of the waters is within the moderate range.

Nitrate is high in sample PARDOO BMB1, above the maximum recommended health guideline for potable water of 50 mg/L (Australian Drinking Water Guidelines 2011). Ammonia is within the normal range. Reactive and total phosphorus is within the normal range.

The main mineral components are sodium and chloride. Chloride to sulphate ratio is slightly low in most of these samples.

Yours sincerely,

M. Horvat
Agrifood WA
12.01.2017

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APPENDIX I. STYGOFAUNA HABITAT ASSESSMENT

13 November 2017

Pardoo Beef Corporation Pty Ltd
PMB 1
Port Hedland, WA 6721

Attention: Mr Brett Blanchett, Chief Executive Officer

Stage 3 Environmental Assessment Pardoo Station: Stygofauna

Pardoo Beef Corporation asked Bennelongia to consider whether development and operation of the Stage 3 irrigation project (the Project) on Pardoo Station may negatively impact stygofauna.

The following sections describing the Project and hydrogeological setting are based on information supplied by EnviroWorks Consulting and Groundwater Consulting Services.

Project Description

Pardoo Station lies at the southern end of Eighty-Mile Beach about 60 km east of the lower part and mouth of the De Grey River (Figure 1). The Project is situated in a flat flood-out area (in a geological sense) about 4 km inland from the coast. The existing Stages 1 and 2 of this project contain 595 ha of pivots and the existing water licence is for approximately 14.82 GL of groundwater per annum from the Wallal aquifer (EnviroWorks Consulting 2017).

The proposed Stage 3 irrigation project will comprise:

- Three 50 ha pivots and two 38 ha pivots (total of 266 ha);
- 14 ha for support infrastructure (fencing, pipelines, bores and roads);
- Abstraction of up to 4.123 gigalitres (GL) per annum; and
- Fertiliser application per annum of up to: 186 tonnes of Nitrogen, 5.3 tonnes of Phosphorus and 53 tonnes of Potassium.

Depth to the water table in the pivot area is 3-10 m (Groundwater Consulting Services 2017). The Project will be operated in a way that ensures no irrigation water moves through to the water table. Liquid nitrogen will be applied by direct injection into irrigation water and other fertilisers will be applied in granular form using a spreader. No pesticides will be used (EnviroWorks Consulting 2017).

Hydrogeology

The oldest and deepest unit in the Project area is the Wallal Sandstone which is permeable and contains the Wallal aquifer (Groundwater Consulting Services 2017). The Wallal Sandstone grades upwards conformably through a transitional unit, the Alexander Formation, into the Jarlemai Siltstone. The Jarlemai Siltstone represents an aquitard which holds the pressurised water in the Wallal aquifer. The Jarlemai Siltstone is overlain unconformably by the Broome Sandstone, which contains the Broome aquifer. This is a major regional, mostly unconfined, aquifer with water levels controlled principally by

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Rainfall recharge. Deeper parts of the aquifer are saline, reflecting proximity to the coastline and the incursion of seawater.

Wallal Aquifer

Groundwater in the Wallal aquifer is recharged by rainfall east of the Jarlemai Siltstone (Groundwater Consulting Services 2017). The groundwater flows in a westerly to north-westerly direction and discharges to the ocean well off-shore. Some water leaks vertically into the Jarlemai Siltstone under the artesian pressure. The groundwater salinity in the Wallal aquifer in the Project area is between 500 and 680 mg/L total dissolved solids (TDS).

Groundwater Resource Changes

Abstraction of irrigation water is expected to induce a reduction in piezometric pressure in the Wallal aquifer of about 5 m (CyMod Systems 2016). The small reduction in pressure will reduce upwards leakage into the Jarlemai siltstone but groundwater levels in the Broome aquifer will continue to be dominated by rainfall recharge. Monitoring data do not indicate any changes in conditions within the Broome aquifer as a result of the operation of Stage 1 of the Project, where irrigation commenced in 2011 and has been operated on a continuous basis since.

Along the southern boundary of the Wallal aquifer, where it is unconfined (approximately 20 km from the Project), there may be groundwater drawdown in the order of 0.5-1m that will develop slowly over a period of about 4-5 years.

Stygofauna near the Project

There is a small amount of information available about the stygofauna community in the immediate vicinity of the Project. Seven bores or wells on Pardoo in the Broome aquifer were sampled between 2003 and 2005 as part of the Pilbara Biodiversity Survey. These sites yielded at least 13 species of stygofauna, including copepods, amphipods, ostracods and worms (Table 1; Halse et al. 2014).

Jimmy's Well (GNHSLK1746), is only slightly west of the Project and is the most analogous site in terms of distance from the coast (Figure 2). It yielded three copepod species. Paunia Well (PS2) which has a comparable landscape position, but is further west, yielded at least seven species, including melitid and paramelitid amphipods, worms, copepods, and ostracods.

Table 1. Stygofauna species collected at Pardoo during Pilbara Biodiversity Survey.

Group	Species	No.	Bore/well code
Aphaneura	Aeolosoma sp. 1 (PSS)	3	PS1, PS2
Oligochaeta	Monopylephorus sp. nov. WA29 (ex Pristina WA3) (PSS)	8	PS2
	Phreodrilidae AP DVC spp.	1	PS1
	Stygoridgewayia trispinosa	4	GNHSLK1746, PS1
Copepoda	Diacyclops humphreysi humphreysi	1	GNHSLK1708
	Halicyclops calm	3	PS2
	Mesocyclops brooksi	20	GNHSLK1708, GNHSLK1746
	Metacyclops sp.	30	PS1
	Megastygonitocrella trispinosa	50	GNHSLK1746, PS2
Ostracoda	Limnocythere stationis	4	PS1
	Cyprinotus kimberleyensis	100	PS1
	Ostracoda sp. (one of above species?)	99	CK1, PS1, PS2
Amphipoda	Paramelitidae cf. sp. 2 (PSS)	2	PS2
	Nedsia sp.	1	PS2

While full characterisation of the stygofauna community of the Broome aquifer in the Project area requires additional sampling, there appears to be a relatively rich community present.

There is no information available about the stygofauna community of the Wallal aquifer in the vicinity of the Project. However, the occurrence of subterranean fauna depends on the presence of suitable habitat. This has two elements: the existence of a network of voids and spaces suitable for microscopic animals and the occurrence of moderately strong hydraulic connectivity with the surface.

The Wallal Sandstone Aquifer has very poor hydraulic connectivity with the surface until approximately 20 km south of the Project. While a network of suitable voids and spaces is likely to be present (because the aquifer is transmissive), the lack of hydraulic connectivity with the surface means it is unlikely there will be an energy source that is adequate to sustain stygofauna in this aquifer. Groundwater Consulting Services (2017) also suggest dissolved oxygen concentrations will be low (although stygofauna are tolerant of low oxygen levels).

It is concluded that stygofauna are unlikely to occur in the Wallal aquifer within the Project area because there is a distance of 20 km or more to the nearest part of the aquifer where the confining layer is absent. This confining layer would stop colonisation of the aquifer from above and would prevent energy input from the surface to sustain stygofauna.

Threats to Stygofauna from the Project

Agricultural and irrigation projects are often considered likely to have deleterious effects on stygofauna communities (Korbel and Hose 2013; Di Lorenzo et al. 2017). However, if the information supplied by EnviroWorks Consulting and Groundwater Consulting Services is correct, the Project is unlikely to impact the stygofauna species present in the Broome aquifer.

Abstraction of groundwater from the Wallal aquifer will be managed to ensure there is no associated drawdown of the Broome aquifer in the Project area. This means there will be no reduction of stygofauna habitat as a result of Project development.

Irrigation and application of fertilisers will be managed in a way that will maintain water quality in the Project area and no pesticides will be used. Nitrate, which is more mobile than phosphate, is often regarded as the major contaminant in irrigation areas. However, calculations by Water Technology (2017) suggest that the increase in nitrate concentration in the overall Wallal aquifer as a result of the Project will be negligible.

On the basis that the Project will be managed and monitored to ensure that groundwater level and groundwater quality remain within natural parameters, it is unlikely that Project development will threaten any stygofauna species occurring in the Project area.

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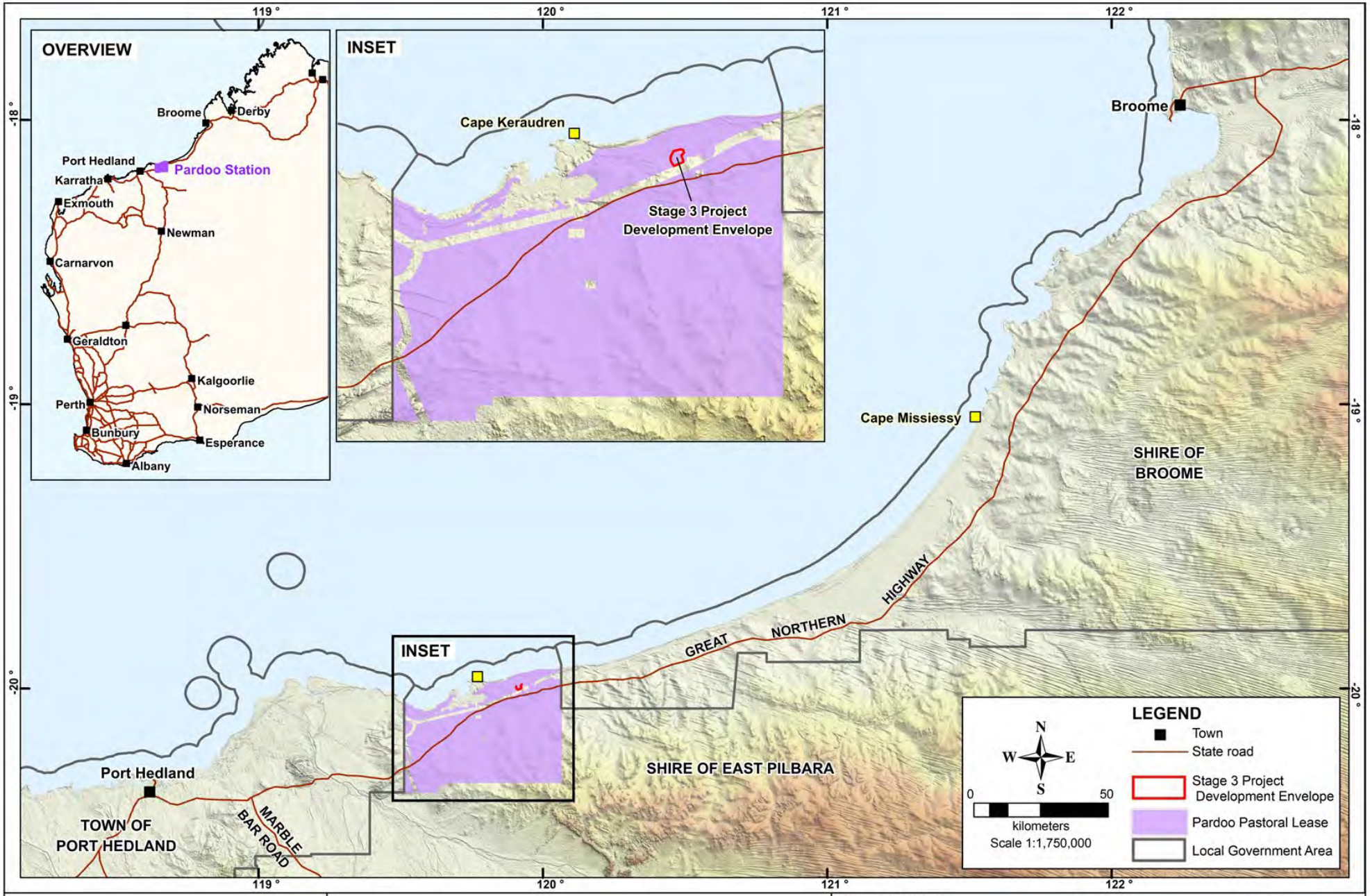
Prepared by Michael Curran and Stuart Halse, Bennelongia Environmental Consultants



EnviroWorks CONSULTING

Figure 1. Pardoo Stage 3 Irrigation Project Location

Date: 18/10/2017 Paper: A4 L GDA94
Data Source: 4A, 4E, 6A, 8A, 9A, 17A
File Info:P07_J06_Location_20171004

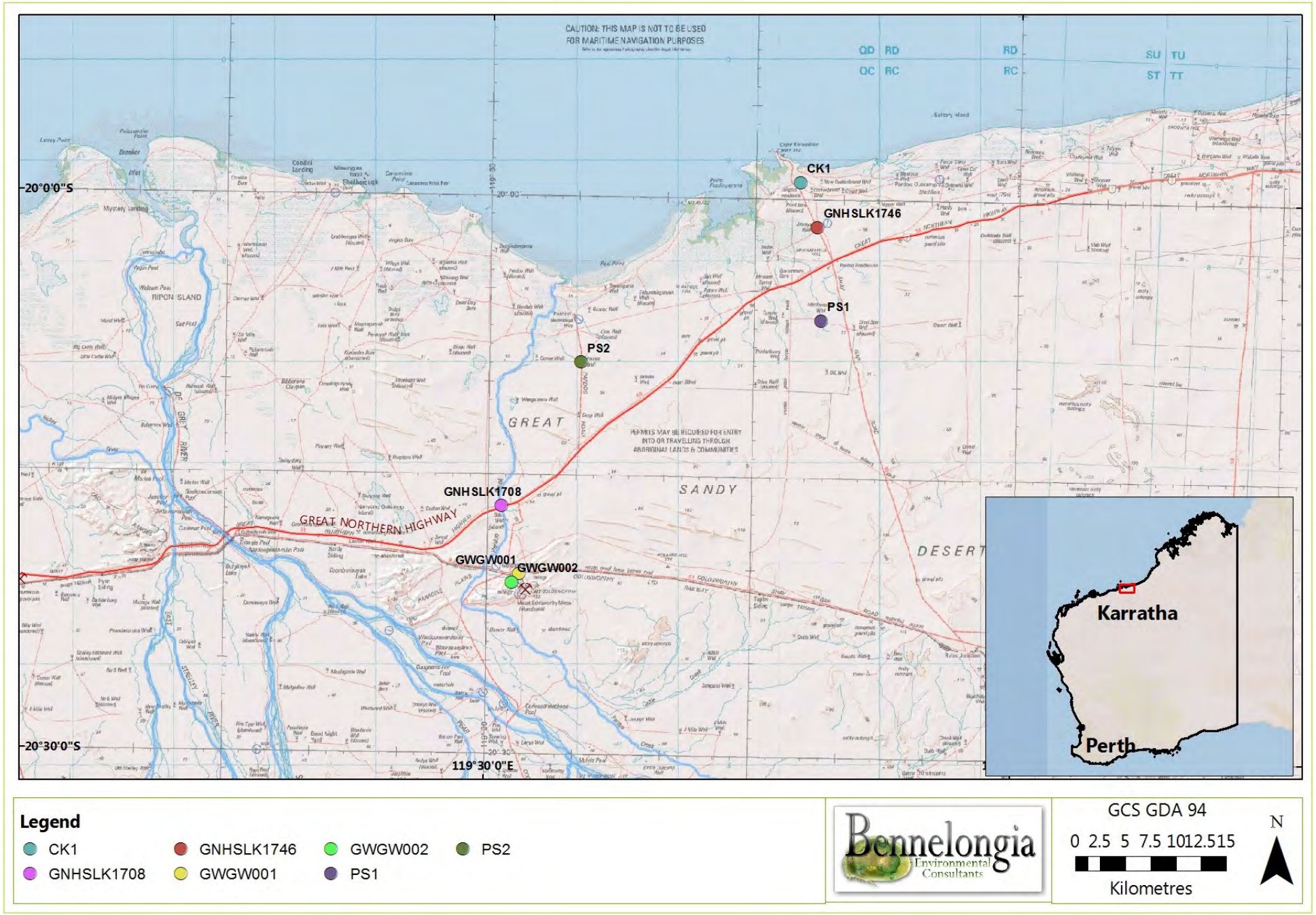


Figure 2. Bores and wells sampled for stygofauna at Pardoo.