Weaber Plain aquifer test results

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June 2011
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Cover photo: Step test of production bore 10WP35PB (Photo: Grant Stainer)

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Acknowledgments

The Weaber Plain hydrogeology assessment was initiated in April 2010, funded in May by LandCorp, commenced in June, and completed in September 2010. Up to October 2010, more than 150 days of field work had been undertaken. The hydrogeology and aquifer testing program could not have happened without the support of many people:

- site access was provided by Peter Cottle and team (Northern Development Company)
- survey of bores and access roads was undertaken by Nathan Allister (Survey North)
- drilling was undertaken by Andrew McWaters and team (Direct Drilling)
- the test pumping program, lead by team leader Dennis Low (Northern Territory Department of Natural Resources, Environment, The Arts and Sports).

All teams’ work was of a high, professional standard.

Thanks also to Russell Speed and Grant Stainer for their technical review of the document and to Angela Massenbauer for final report editing.
Summary

In 2008, the Ord Irrigation Expansion Project was approved by the Western Australian Government. The project aimed to develop the Weaber Plain, which is located north-east of the existing, 14,000 ha Ord River Irrigation Area, 30 km from Kununurra. Construction of a new irrigation water supply channel connecting the Weaber Plain to the existing Ord River Irrigation Area (ORIA) irrigation infrastructure, and the final period of irrigation design, environmental management and related approval processes, commenced in 2010.

As a part of the environmental planning and approvals process, the state government was required to prepare Groundwater Management and Hydrodynamic Plans. These plans are to address potential issues of salinity and water quality that could result from the development of irrigated agriculture on the Weaber Plain. The Weaber Plain groundwater modelling report (KBR 2010a) identified several options to manage watertables and salinity, which was previously identified as a hazard by SkyTEM airborne electromagnetics (Lawrie et al. 2010). Both studies identified that the existing groundwater data was inadequate for the purpose of substantiating options to manage shallow watertables and salinity. Soil and subsoil data was also limited, and downstream impacts required further evaluation.

As a result, the Department of Agriculture and Food (DAFWA) was requested to lead a program of investigation to support a second phase of modelling. The program was divided into five phases: two addressing deficiencies related to groundwater, two relating to soils/subsoils, and one addressing surface and groundwater quality aspects. Of the issues relating to groundwater, uncertainty existed over the location, hydraulic properties and yield of the palaeochannel aquifer, and permeability in areas to the north where the aquifer was forecast to be absent (Lawrie et al. 2010). This report summarises the results of aquifer testing aimed explicitly at providing information on the hydraulic properties of the palaeochannel and aquifers to the north, and the yields that could be expected from pumping from these aquifers.

Production bores 10WP35PB and 10WP36PB were drilled in the palaeochannel on sites selected from the interpretation of airborne geophysics. Production bore 10WP35PB was drilled into 23 m of mainly coarse sand and 10WP36PB was drilled into 18 m of coarse sand and gravel.

Production bore 10WP36PB has the screens set against 6 m of the upper section of gravel. The gravel in the section below the screen was coarse and could not be lifted from the borehole with the mud rotary system used. It is probable that the lower gravel aquifer will have a higher transmissivity, hydraulic conductivity and potential yield. The 16 m of screen in production bore 10WP35PB is optimally set against coarse sands and gravels.

The calculated transmissivity for production bore 10WP35PB was in the range of 3480 to 6240 m²/d and the resultant hydraulic conductivity ranged from 150 to 270 m/d. The calculated transmissivity for production bore 10WP36PB was in the range 4340 to 8790 m²/d and the resultant hydraulic conductivity ranged from 240 to 390 m/d.

The transmissivity values calculated for production bores 10WP36PB and 10WP35PB are similar to values obtained from previously tested production bores in the Ord River Irrigation Area that intersect the thickest sand and gravel sections of the Ord palaeochannel and are more reliable estimates of the palaeochannel conductivity than the value obtained from a series of slug tests performed at bore 10WP31. Observation of water levels during pumping from production bores 10WP36PB and 10WP35PB at 25 L/s indicated impacts up to one kilometre away from the bores.
Hydraulic conductivity values for aquifer materials on the northern portion of the Weaber Plain were derived from slug tests. These values are at least an order of magnitude less than those determined for the palaeochannel.
1. Introduction

In 2008, the Ord Irrigation Expansion Project was approved by the Western Australian Government. The project aimed to develop the Weaber Plain, which is located north-east of the existing, 14 000 ha Ord River Irrigation Area, 30 km from Kununurra (Figure 1). Construction of a new irrigation water supply channel connecting the Weaber Plain to the existing Ord River Irrigation Area (ORIA) irrigation infrastructure, and the final period of irrigation design, environmental management and related approval processes, commenced in 2010.

As a part of the environmental planning and approvals process, the state government was required to prepare Groundwater Management and Hydrodynamic Plans. These plans were to address potential issues of salinity and water quality that could result from the development of irrigated agriculture on the Weaber Plain. The Weaber Plain groundwater modelling report (KBR 2010a) identified several options to manage watertables and salinity, which was previously identified as a hazard by interpretation of SkyTEM airborne electromagnetics data (Lawrie et al. 2010). Both studies identified that the existing groundwater data was inadequate for the purpose of substantiating options to manage shallow watertables and salinity. Soil and subsoil data was also limited, and downstream impacts required further evaluation.

The Department of Agriculture and Food (DAFWA) supervised the drilling and completion of two high yield production bores and 14 monitoring bores on the Weaber Plain in June and July 2010 as part of the environmental approvals process for the proposed expansion (Figure 2). This drilling program was in support of a broader effort to characterise the hydrogeology of the Weaber Plain to ensure that irrigated agriculture can be developed there without adverse environmental consequences.

The aims of this drilling program were to determine:

(i) the location and aquifer characteristics of a palaeochannel
(ii) the location and characteristics of sediments in the Border Creek area
(iii) the location and characteristics of sediments in the southern Weaber Plain, adjacent to the Pincombe Range
(iv) aquifer properties and potential bore yields, and
(v) aquifer chemistry.

The bore sites were selected from a geophysical interpretation of the airborne electromagnetics (AEM) data acquired in August 2008 by Geoscience Australia. The data was acquired using the SkyTEM time domain AEM system and was flown over existing and proposed irrigation areas. The AEM data provided a greater clarity on the 3-dimensional distribution of the palaeochannel gravels under the Weaber Plain (Lawrie et al. 2010).

This report details the results of:

(i) step tests and constant rate pumping tests on the two high yield production bores
(ii) a short duration pumping test performed on one of the low yield monitoring bores that displayed higher than anticipated yield during drilling
(iii) a series of slug tests performed on several of the bores installed during the 2010 drilling program, as well as four bores previously completed by the Geological Survey of Western Australia in 1996 (Nixon 1997a).
These tests were performed to determine the aquifer properties, in particular the estimation of long-term pumping yields and the likely extent of the cone of depression from long-term pumping. The principal motivation for determining the hydraulic properties of the different aquifer materials encountered on the Weaber Plain was to obtain better estimates of hydraulic parameters for a numerical groundwater model. The model was used to predict the likely groundwater impacts of clearing and irrigation and to determine the feasibility of maintaining groundwater levels at appropriate depths using pumping and drainage options (KBR 2010b).

This report was previously presented as Appendix H2 of the KBR (2010b) report, which is part of Appendix 4 of the Environmental Impact Statement submitted by the Western Australian Government (Strategen 2010).
Weaber Plain aquifer test results

Figure 1: Study area locality map
Figure 2 Location of proposed farms, palaeochannel, existing bores and monitoring and production bores drilled in 2010
2. Previous hydrogeological investigations

O’Boy et al. (2001) summarised the hydrogeological studies of the ORIA between 1969 and 1996. Drilling investigations on the Weaber Plain were carried out in 1983 by the Geological Survey of Western Australia (Laws 1983) and in 1996 by the Water and Rivers Commission (Nixon 1997a) to refine the hydrogeological understanding of the plain. Nixon (1997a) drilled 21 investigation bores and one production bore, WP6PB; all these bores are identified with the prefix WP (Weaber Plain).

In 2009, Lawrie et al. (2010) augmented the bores drilled throughout the designated Ord Expansion areas with one additional piezometer (KS1) on the Weaber Plain to assist their interpretation of the regolith and salinity hazard derived from SkyTEM (AEM) data. They determined that the extent and permeability of the palaeochannel sediments was much less than forecast by O’Boy et al. (2001). Together, the AEM data, the low permeability implied from the aquifer tests of Nixon (1997a), and prior drilling, cast doubt on the extent and permeability of the palaeochannel within the Weaber Plain. Drilling was carried out in 2010 to address this uncertainty (George et al. 2011).

2.1 Previous test pumping

Production bores on the Weaber, Ivanhoe, Packsaddle, Knox Creek and Keep River Plains have been test pumped in the past. A summary of aquifer parameters from the test pumping programs are shown in Table 1 and production bore locations are shown in Figure 1.

2.1.1 Weaber Plain

A test production bore, WP6PB, was drilled next to investigation bore WP6 and test pumped in 1996. The bore was constructed with 100 mm PVC and screened with 6 m of 100 mm stainless steel screen (Nixon 1997a). From the bore log of WP6PB, the screen is set from 24 to 30 m below ground level (m BGL). The geological log shows the top of the weathered basement at 26 m. The test determined that the bore could be continuously pumped at 1 L/s (86 m³/d). The analysis of the test pumping results produced a low transmissivity (T) value for a bore screened in gravels. It was concluded that the screen was incorrectly set and was only partially intersecting the gravels of the palaeochannel.

2.1.2 Ivanhoe Plain

Two major gravel units have been identified under the Ivanhoe Plain and both are present over a considerable area of the plain (McGowan 1983). Three production bores were drilled and test pumped in 1983 (McGowan 1983). Production bore PB1 had a thick, continuous sand and gravel sequence. In this area, there is complete hydraulic connection between the two gravel units with coarse sands and gravels from 5.3 m to at least 27.7 m BGL; the watertable was at 9.2 m in 1983. In production bore PB2, only the lower gravel unit was present; a 2.1 m thick layer was penetrated. Production bore PB3 is on the margin of the gravel deposits, with both gravel units present in a clayey sequence.

Production bore PB4 was drilled and tested in 1996 and only the lower gravel unit was intersected (O’Boy 1997). A short-term pumping test was undertaken followed by a long-term pumping test starting on 27 October 1997, lasting for 115 days, and finishing on 19 February 1998.
Production bores 10/00 and 11/00 are located on the northern Ivanhoe Plain, adjacent to the S5 and S5C supply channels. Both bores are screened within the high-transmissivity palaeochannel aquifer system (Smith et al. 2005). Production bore 10/00 was installed east of Dumas Lookout with 5 m of screen from 26 to 31 m BGL. Production bore 11/00 was installed north-east of Dumas Lookout, about 2 km from production bore 10/00. The bore screen is 11 m long, set from 23 to 34 m BGL, and is located in at least 8 m of palaeochannel gravels. Drilling did not penetrate the full thickness of valley sediments, therefore basement depth is unknown at this location.

The groundwater pumping trial was conducted between July 2003 and April 2005 to determine the effectiveness of groundwater pumping as an option to control rising groundwater levels beneath the Stage 1 ORIA. Recommended long-term pumping rates based on testing by Water Corporation (2000) were 4558 m$^3$/d for bore 10/00 and 7684 m$^3$/d for bore 11/00. Pumping rates achieved from bores 10/00 and 11/00 during the trial in 2005 were 4,492 m$^3$/d and 4372 m$^3$/d, respectively, with about 1.5 m drawdown at both production bores. The radius of influence around each bore was about one kilometre (Smith et al. 2005).

2.1.3 Packsaddle Plain

In 1996, a test production bore, PB1, and monitoring bores were installed on the Packsaddle Plain (O’Boy 1998). The Packsaddle site had two gravel aquifer units and the production bore was constructed with wire wound stainless steel screens set against both gravel aquifers. As for PB4 on the Ivanhoe Plain in 1996, a short-term pumping test was undertaken followed by a long-term (115 day) pumping test starting on 27 October 1997 and finishing on 19 February 1998. The drawdown had reached steady state after a few days of pumping, probably because the cone of depression had reached Lake Kununurra 1500 m to the east, which then acted as constant head recharge boundary (O’Boy 1998).

2.1.4 Keep River Plain

Production bore RN29659 was drilled and constructed in 1994 to test the performance of bores in the palaeochannel aquifer and obtain an indication of the aquifer’s transmissivity. An extended step test was carried out with the final step of 15 L/s being carried out for 1140 minutes. The final drawdown was 5 m (Humphreys et al. 1995).

2.1.5 Knox Creek Plain

A test production bore, KC3PB, was drilled next to investigation bore KC3 in 1996. The bore was constructed with 100 mm PVC and screened with 6 m of 100 mm stainless steel screens from 26 to 32 m BGL (Nixon 1997b). The bore was test pumped in 1996 at 4 L/s for 8 hours. The analysis of the test pumping results showed some leakage from overlying materials.
Table 1 Previous Ord River Irrigation Area test pumping results

<table>
<thead>
<tr>
<th>Bore</th>
<th>Location</th>
<th>Test type</th>
<th>Aquifer</th>
<th>Aquifer transmissivity (m²/d)</th>
<th>Aquifer hydraulic conductivity (m/d)</th>
<th>Aquitard vertical hydraulic cond. (m/d)</th>
<th>Storativity</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>PB1</td>
<td>Ivanhoe</td>
<td>Constant rate: 72 h @ 750 KL/d</td>
<td>Palaeochannel</td>
<td>6000–7000</td>
<td></td>
<td></td>
<td></td>
<td>McGowan (1983)</td>
</tr>
<tr>
<td>PB2</td>
<td>Ivanhoe</td>
<td>Constant rate: 72 h @ 705 KL/d</td>
<td>Palaeochannel</td>
<td>1700</td>
<td>110</td>
<td></td>
<td></td>
<td>McGowan (1983)</td>
</tr>
<tr>
<td>PB3</td>
<td>Ivanhoe</td>
<td>Constant rate: 72 h @ 750 KL/d</td>
<td>Palaeochannel</td>
<td>360</td>
<td>14</td>
<td>0.22</td>
<td></td>
<td>McGowan (1983)</td>
</tr>
<tr>
<td>PB4</td>
<td>Ivanhoe</td>
<td>Constant rate: 7.5 h @ 1302 KL/d</td>
<td>Palaeochannel</td>
<td>1342–3355 mean: 2400</td>
<td>223–559 mean: 400</td>
<td>0.004–0.06 approx. 0.01</td>
<td>1.8 × 10⁻⁵–1.4 × 10⁻² mean: 5.0 × 10⁻⁵</td>
<td>O'Boy (1997)</td>
</tr>
<tr>
<td>PB4</td>
<td>Ivanhoe</td>
<td>Long-term: 115 days @ 1220 KL/d</td>
<td>Palaeochannel</td>
<td>1460–2800</td>
<td>245–440</td>
<td>0.1</td>
<td>1.8 × 10⁻⁴–2.0 × 10⁻² mean: 4.0 × 10⁻⁴</td>
<td>O'Boy (1998)</td>
</tr>
<tr>
<td>10/00</td>
<td>Ivanhoe</td>
<td>Constant rate: 24 h @ 3000 KL/d</td>
<td>Palaeochannel</td>
<td>408</td>
<td>68</td>
<td></td>
<td></td>
<td>Water Corporation (2000)</td>
</tr>
<tr>
<td>11/00</td>
<td>Ivanhoe</td>
<td>Constant rate: 24 h @ 3000 KL/d</td>
<td>Palaeochannel</td>
<td>1100</td>
<td>105</td>
<td></td>
<td></td>
<td>Water Corporation (2000)</td>
</tr>
<tr>
<td>PSPB1</td>
<td>Packsaddle</td>
<td>Constant rate: 8.5 h @ 1613 KL/d</td>
<td>Palaeochannel (deep gravel)</td>
<td>1158–5179 mean: 2000</td>
<td>270–586 mean: 330</td>
<td>0.06–0.18 approx. 0.1</td>
<td>1.95 × 10⁻⁴–2.0 × 10⁻² mean: 2.0 × 10⁻²</td>
<td>O'Boy (1997)</td>
</tr>
<tr>
<td>PSPB1</td>
<td>Packsaddle</td>
<td>Constant rate: 8.5 h @ 1613 KL/d</td>
<td>Palaeochannel (shallow gravel)</td>
<td>mean: 1000</td>
<td>mean: 330</td>
<td></td>
<td></td>
<td>O'Boy (1997)</td>
</tr>
<tr>
<td>10/00</td>
<td>Ivanhoe</td>
<td>Long-term: 548 days @ 4492 KL/d</td>
<td>Palaeochannel</td>
<td>as above</td>
<td></td>
<td></td>
<td></td>
<td>Smith et al. (2005)</td>
</tr>
<tr>
<td>11/00</td>
<td>Ivanhoe</td>
<td>Long-term: 309 days @ 4372 KL/d</td>
<td>Palaeochannel</td>
<td>as above</td>
<td></td>
<td></td>
<td></td>
<td>Smith et al. (2005)</td>
</tr>
<tr>
<td>RN029659</td>
<td>Keep River</td>
<td>Extended step test 19 h @ 1296 KL/d</td>
<td>Palaeochannel</td>
<td>&gt; 3000</td>
<td></td>
<td></td>
<td></td>
<td>Humphreys et al. (1995)</td>
</tr>
<tr>
<td>WP6PB</td>
<td>Weaber</td>
<td>Constant rate: 3 h @ 129 KL/d – 14 h @ 86 KL/d</td>
<td>Palaeochannel</td>
<td>37 for 1ˢᵗ slope 5 for 2ⁿᵈ slope</td>
<td></td>
<td>0.012</td>
<td></td>
<td></td>
</tr>
<tr>
<td>KC3PB</td>
<td>Knox Creek</td>
<td>Constant rate: 8 h @ 346 KL/d</td>
<td>Palaeochannel</td>
<td>290</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table modified from Smith et al. (2005)
3. Methods

3.1 Bore construction

The drilling and construction of production bores 10WP35PB and 10WP36PB are described in George et al (2011); information relevant to the interpretation of the test pumping is presented here for clarity.

Production bores 10WP35PB and 10WP36PB were constructed with 200 mm internal diameter (ID) wire wound stainless steel screens set against the aquifer. Production bore 10WP35PB was constructed with 18 m of screen. The aquifer thickness (b) at production bore 10WP35PB is 23 m, from 6 to 29 m BGL.

Production bore 10WP36PB was constructed with 6 m of screen set from 14.4 to 20.4 m BGL. The main aquifer is 18 m thick at this point, from 11.2 to 29.0 m BGL, so there is only partial penetration of the screens into the aquifer. The coarser gravels at the bottom of the aquifer were not screened because the mud pump capacity was insufficient to lift them from the base of the hole.

Bore 10WP39 was completed with 100 mm, class 12, PVC casing and screen. However, because of collapse of the unconsolidated formation, the hole could only be cased to 18 m BGL. The 12 m screen therefore sits adjacent to 6 m of clay, sand and fine gravels that produced little water during drilling, and 6 m of calcarenite and clay bands which constitute the main aquifer at the site. The calcarenite bands extend to 19 m BGL, and a second moderately permeable unit of banded sands and clays was encountered between 22 and 30 m BGL.

The geological logs and bore construction diagrams of the production bores are presented in Appendix A and bore completion details relevant to the interpretation of the test pumping results are summarised in Table 2. The locations of production bores 10WP35PB and 10WP36PB, monitored observation bores and bore 10WP39 are shown in Figure 2

<table>
<thead>
<tr>
<th>Table 2 Observation and production bore construction summary</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bore</strong></td>
</tr>
<tr>
<td>----------</td>
</tr>
<tr>
<td>10WP36N</td>
</tr>
<tr>
<td>10WP36PB*</td>
</tr>
<tr>
<td>10WP36S</td>
</tr>
<tr>
<td>10WP37</td>
</tr>
<tr>
<td>10WP35N</td>
</tr>
<tr>
<td>10WP35PB</td>
</tr>
<tr>
<td>10WP35S</td>
</tr>
<tr>
<td>WP1</td>
</tr>
<tr>
<td>WP2</td>
</tr>
<tr>
<td>WP3</td>
</tr>
<tr>
<td>WP6PB</td>
</tr>
<tr>
<td>WP16</td>
</tr>
<tr>
<td>10WP33</td>
</tr>
<tr>
<td>10WP39</td>
</tr>
</tbody>
</table>

* Bores in bold are production bores
3.2 Test pumping program

Production bores 10WP35PB and 10WP36PB were test pumped by the Northern Territory Department of Natural Resources, Environment, the Arts and Sports (NRETAS) between 25 July 2010 and 31 July 2010 under the supervision of DAFWA personnel and 10WP39 was test pumped by DAFWA personnel.

During the test pumping of 10WP35PB and 10WP36PB the flow rate was monitored using a circular orifice weir and piezometer tube. The pumped water was discharged into a 1000 L tank with a 200 mm outlet pipe. Plastic lay-flat with a nominal diameter of 300 mm was connected to the discharge pipe and directed the discharge water to an area about 300 m to the west. The groundwater levels in the nearest observation bores were measured using an electric water level probe. The configurations for each pumping test are shown in Table 3.

Two test pumping methodologies were applied at 10WP35PB and 10WP36PB: a step test and a constant rate test (CRT). A step test, comprising a series of controlled step increases in the discharge rate was conducted on each production bore to evaluate bore efficiency, to assess the effectiveness of development, and to predict short-term drawdown response under various pumping rates. The Hantush-Bierschenk data analysis method was used to determine the linear and non-linear well loss coefficients, to predict drawdown in the bore, and calculate bore efficiency (Bierschenk 1963).

The step test was followed by a CRT to provide an estimate of aquifer hydraulic properties and to evaluate potential long-term bore yield. Discharge rates for the CRT were selected on the basis of the step test results. Aquifer recovery was measured after the test pumping to provide a second estimate of aquifer hydraulic parameters.

Only a four-hour, short-term constant was conducted at 10WP39; a small submersible pump supplied by the drilling contractor was used. Two hours of groundwater level recovery data was also collected from the bore at the completion of the pumping test, using an electronic water level sensor.

Table 3 Weaber Plain pumping test configurations

<table>
<thead>
<tr>
<th>Bore</th>
<th>Test pump operator:</th>
<th>Test start date</th>
<th>Static water level (m BGL)</th>
<th>Pump inlet setting (m BGL)</th>
<th>Available drawdown (m)</th>
<th>Pump type</th>
<th>PVC casing diameter</th>
<th>Screen type and size</th>
<th>Main aquifer (m BGL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10WP35PB</td>
<td>NRETAS*</td>
<td>30 July 2010</td>
<td>4.44 (22 July 2010)</td>
<td>17.1</td>
<td>5</td>
<td>19-stage turbine with 100 mm column</td>
<td>200 mm Class 12</td>
<td>200 mm wire wound stainless steel, 1 mm slots</td>
<td>9.5–27.5</td>
</tr>
<tr>
<td>10WP36PB</td>
<td>NRETAS</td>
<td>25 July 2010</td>
<td>4.16 (22 July 2010)</td>
<td>17.1 24 July 2010 (Mono); 16.4 26 July 2010 (Turbine)</td>
<td>5</td>
<td>Mono 820 with 80 mm column; 19-stage turbine with 100 mm column</td>
<td>200 mm Class 12</td>
<td>200 mm wire wound stainless steel, 1 mm slots</td>
<td>14.4–20.4</td>
</tr>
<tr>
<td>10WP39</td>
<td>DAFWA</td>
<td>17 July 2010</td>
<td>6.18 (17 July 2010)</td>
<td>15.0</td>
<td>8.8</td>
<td>submersible</td>
<td>100 mm Class 12</td>
<td>100 mm PVC, 1.0 mm slots</td>
<td>6.07–18.07</td>
</tr>
</tbody>
</table>

* Northern Territory Department of Natural Resources, Environment, the Arts and Sports
The data analysis software AQTESOLV (Duffield 2007) was used to analyse the CRT data from the production and observation bores. The analysis methods applied were the Theis and Theis recovery (Theis 1935), and the Cooper-Jacob (Cooper & Jacob 1946).

3.2.1 10WP36PB test pumping summary

The test pumping program for 10WP36PB consisted of a four-part step test with 100-minute steps and a 48-hour CRT starting two days after the step test. After the pump was turned off at the end of the CRT, the recovery of the groundwater level was measured in the production bore and the two nearest observation bores for two hours. A test pumping summary for 10WP36PB is shown in Table 4.

Table 4 Production bore 10WP36PB test pumping program 2010 summary

<table>
<thead>
<tr>
<th>Discharge rate</th>
<th>Step test*</th>
<th>CRT*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q (m$^3$/d)</td>
<td>604.8</td>
<td>864.0</td>
</tr>
<tr>
<td>Q (L/s)</td>
<td>7.0</td>
<td>10.0</td>
</tr>
</tbody>
</table>

* Step test with 100-minute steps started on 25 July 2008 at 07:30
+ CRT started 27 July 2010 at 08:00 and concluded on 29 July 2010 at 08:00

3.2.2 10WP35PB test pumping summary

The test pumping program for 10WP35PB consisted of a four-part step test with 100-minute steps with the last step extended into a 24-hour CRT. After the pump was turned off at the end of the CRT, the recovery of the groundwater level was measured in the production bore and observation bores for two hours. A test pumping summary for 10WP35PB is shown in Table 5.

Table 5 10WP35PB test pumping program 2010 summary

<table>
<thead>
<tr>
<th>Discharge rate</th>
<th>Step test*</th>
<th>CRT*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q (m$^3$/d)</td>
<td>864.0</td>
<td>1209.6</td>
</tr>
<tr>
<td>Q (L/s)</td>
<td>10.0</td>
<td>14.0</td>
</tr>
</tbody>
</table>

* Step test with 100-minute steps started on 30 July 2008 at 08:00
+ 4th step started 30 July 2010 at 13:00 and became an extended 24 hour CRT that concluded on 31 July 2010 at 13:00

3.3 Water level observations

The following observation bores were monitored using dataloggers during the CRTs of 10WP36PB and 10WP35PB: 10WP36N, 10WP36S, 10WP37, 10WP35N, 10WP35S, WP1, WP2, WP3, WP6PB, WP16 and 10WP33. The locations of these bores are shown in Figure 2. The observed production and observation bore water levels were corrected for variations in barometric pressure and the effects of earth tides.
3.4 Slug tests

Slug addition and slug withdrawal tests (Bouwer & Rice 1976) were performed on seven bores on the Weaber Plain. Slug displacement rods were constructed using 25 mm (33.4 mm outside diameter (OD)) or 32 mm (42.1 mm OD), class 12 PVC. The rods were filled with concrete to ensure that they were heavy enough to sink quickly when introduced into the bores. The 25 mm rods were 2.2 m long and the 32 mm rods were 2.5 m long. The different diameter rods were used to allow sufficient space for the vented cable of electronic water level sensors that were installed in the bores before the slug tests were performed. The water level sensors were set to record water level at either 1.0 or 0.5 second time intervals; 0.5 seconds is the highest logging frequency of which the sensors are capable. Several slug addition and slug withdrawal tests were performed on each bore depending on the time taken for the groundwater level to reach equilibrium and the noise observed in the data (see Figure 19).

For slug tests in bores 10WP39 and WP6PB, which are completed with 100 mm casing, multiple displacement rods were taped together and introduced simultaneously. The diameters of single cylindrical rods of equivalent displacement were calculated for use in the analysis of the data.

The slug test data was analysed to calculate the hydraulic conductivity of the aquifer intersected by each bore using an automated spreadsheet application developed by the United States Geological Survey (Halford & Kuniansky 2002), which implements the method of Bouwer and Rice (1976).
4. Results

The dataloggers in 10WP36N and 10WP36S malfunctioned and the data was unavailable for analysis. Observation bores WP2, WP3, WP16 and 10WP33, all of which are over 2 km from the production bores, showed no response to the test pumping of 10WP36PB and 10WP35PB. The plots for the available logger data in Figure 3 show a diurnal variation in groundwater levels of up to 0.07 m in a day. This variation has been attributed to barometric pressure changes and earth tides. The drawdowns in the observation bores were small and the barometric pressure and earth tide variations during the CRT were of a similar magnitude, complicating the interpretation of drawdown levels (Figure 4).

Figure 3 Datalogger groundwater levels during test pumping of 10WP36PB and 10WP35PB
4.1 Production bore 10WP36PB test pumping

A four-part step test with 100-minute steps was carried out on 25 July 2010 and a 48-hour constant rate test (CRT) commenced on 27 July 2010, two days after the step test.

4.1.1 Step test

The static water level (SWL) in the bore at the start of test pumping was 4.10 m BGL. The total drawdown at the end of the step test was 0.58 m. The step test data is presented as a plot of drawdown versus time for the four steps in (Figure 5). An analysis of the bore efficiency was made using all four steps and the CRT data, which gave a calculated drawdown equation at 100 minutes pumping of:

\[ s = 2.8204 \times 10^{-4} Q + 6.6278 \times 10^{-8} Q^2 \]

where \( s \) = drawdown (m)
\( Q \) = discharge rate (m³/d)

The first term on the right hand side of the equation is the drawdown because of laminar flow (aquifer loss) and the second is the drawdown because of turbulent flow (well loss). The calculated nominal bore efficiency is 66 per cent at a discharge rate of 25 L/s after 100 minutes pumping (Table 6).
Table 6 10WP36PB bore efficiencies from step test

<table>
<thead>
<tr>
<th>Discharge rate (L/s)</th>
<th>Discharge rate (m³/d)</th>
<th>s (100 min)</th>
<th>Laminar flow drawdown (m)</th>
<th>Turbulent flow drawdown (m)</th>
<th>Calculated drawdown (m)</th>
<th>Bore efficiency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>605</td>
<td>0.202</td>
<td>0.171</td>
<td>0.024</td>
<td>0.195</td>
<td>88</td>
</tr>
<tr>
<td>10</td>
<td>864</td>
<td>0.281</td>
<td>0.244</td>
<td>0.049</td>
<td>0.293</td>
<td>83</td>
</tr>
<tr>
<td>14</td>
<td>1210</td>
<td>0.430</td>
<td>0.341</td>
<td>0.097</td>
<td>0.438</td>
<td>78</td>
</tr>
<tr>
<td>18</td>
<td>1555</td>
<td>0.610</td>
<td>0.439</td>
<td>0.160</td>
<td>0.599</td>
<td>73</td>
</tr>
<tr>
<td>25</td>
<td>2160</td>
<td>0.920</td>
<td>0.609</td>
<td>0.309</td>
<td>0.918</td>
<td>66</td>
</tr>
</tbody>
</table>

4.1.2 Constant rate test

Based on drawdowns obtained during the step tests, the discharge rate for the CRT of production bore 10WP36PB was set at 25 L/s. Starting from a water level of 4.10 m BGL, the drawdown at 2880 minutes (two days) was 1.07 m (5.17 m BGL).

The distance of observation bores from production bore 10WP36PB are shown in Table 7. The groundwater level data from the observation bores during the CRT is presented in Figure 6. The calculated values of transmissivity (T), storativity (S) and vertical anisotropy ratio (Kz/Kr) resulting from the Cooper-Jacob, Theis and Theis recovery analyses are shown in Tables 8 and 9 and the analysis plots are shown in Figures 8, 9 and 10, respectively.

Table 7 Locations of observation bores and distances from production bore 10WP36PB

<table>
<thead>
<tr>
<th>Bore</th>
<th>Easting (MGA)</th>
<th>Northing (MGA)</th>
<th>Distance from 10WP36PB (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10WP36N</td>
<td>481 885</td>
<td>8 289 635</td>
<td>40</td>
</tr>
<tr>
<td>10WP36PB</td>
<td>481 885</td>
<td>8 289 596</td>
<td>0.1</td>
</tr>
<tr>
<td>10WP36S</td>
<td>481 885</td>
<td>8 289 516</td>
<td>80</td>
</tr>
<tr>
<td>10WP37</td>
<td>481 886</td>
<td>8 289 026</td>
<td>570</td>
</tr>
<tr>
<td>10WP35N</td>
<td>481 887</td>
<td>8 288 653</td>
<td>943</td>
</tr>
<tr>
<td>10WP35PB</td>
<td>481 887</td>
<td>8 288 567</td>
<td>1028</td>
</tr>
<tr>
<td>10WP35S</td>
<td>481 886</td>
<td>8 288 526</td>
<td>1070</td>
</tr>
<tr>
<td>WP1</td>
<td>481 602</td>
<td>8 287 791</td>
<td>1827</td>
</tr>
<tr>
<td>WP6PB</td>
<td>482 518</td>
<td>8 290 413</td>
<td>1033</td>
</tr>
<tr>
<td>WP16</td>
<td>483 251</td>
<td>8 291 605</td>
<td>2429</td>
</tr>
<tr>
<td>WP2</td>
<td>481 630</td>
<td>8 286 159</td>
<td>3447</td>
</tr>
<tr>
<td>WP3</td>
<td>480 637</td>
<td>8 286 206</td>
<td>3613</td>
</tr>
<tr>
<td>WP4</td>
<td>479 667</td>
<td>8 286 274</td>
<td>3995</td>
</tr>
<tr>
<td>10WP33</td>
<td>486 514</td>
<td>8 290 136</td>
<td>4660</td>
</tr>
</tbody>
</table>
Table 8 *Aquifer parameters of production bore 10WP36PB assuming a confined aquifer*

<table>
<thead>
<tr>
<th>Bore</th>
<th>Lateral distance from pump (m)</th>
<th>Final drawdown (m)</th>
<th>Cooper-Jacob T (m²/d)</th>
<th>S</th>
<th>Theis T (m²/d)</th>
<th>Kz/Kr</th>
<th>S</th>
<th>Theis recovery T (m²/d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10WP36PB</td>
<td>0.1</td>
<td>1.07</td>
<td>434</td>
<td>NA*</td>
<td>7990</td>
<td>0.0071</td>
<td>NA</td>
<td>8790</td>
</tr>
<tr>
<td>10WP36N</td>
<td>40</td>
<td>0.24</td>
<td>598</td>
<td>0.0043</td>
<td>5650</td>
<td>0.0098</td>
<td>0.009</td>
<td>7070</td>
</tr>
<tr>
<td>10WP36S</td>
<td>80</td>
<td>0.12</td>
<td>608</td>
<td>0.0041</td>
<td>6440</td>
<td>0.0041</td>
<td>0.006</td>
<td>7070</td>
</tr>
<tr>
<td>10WP37</td>
<td>570</td>
<td>0.05</td>
<td>1030</td>
<td>0.0090</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>10WP35N</td>
<td>943</td>
<td>0.04</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>10WP35S</td>
<td>1070</td>
<td>0.04</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>WP1</td>
<td>1828</td>
<td>0.03</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
</tbody>
</table>

* analysis not relevant

Table 9 *Aquifer parameters of production bore 10WP36PB assuming an unconfined aquifer*

<table>
<thead>
<tr>
<th>Bore</th>
<th>Lateral distance from pump (m)</th>
<th>Final drawdown (m)</th>
<th>Cooper-Jacob T (m²/d)</th>
<th>S</th>
<th>Theis T (m²/d)</th>
<th>Kz/Kr</th>
<th>S</th>
</tr>
</thead>
<tbody>
<tr>
<td>10WP36PB</td>
<td>0.1</td>
<td>1.07</td>
<td>450</td>
<td>NA*</td>
<td>8040</td>
<td>0.086</td>
<td>NA</td>
</tr>
<tr>
<td>10WP36N</td>
<td>40</td>
<td>0.24</td>
<td>602</td>
<td>0.0043</td>
<td>5670</td>
<td>0.023</td>
<td>0.000</td>
</tr>
<tr>
<td>10WP36S</td>
<td>80</td>
<td>0.12</td>
<td>611</td>
<td>0.0040</td>
<td>6430</td>
<td>0.0041</td>
<td>0.004</td>
</tr>
<tr>
<td>10WP37</td>
<td>570</td>
<td>0.05</td>
<td>1036</td>
<td>0.0090</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>10WP35N</td>
<td>943</td>
<td>0.04</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>10WP35S</td>
<td>1070</td>
<td>0.04</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>WP1</td>
<td>1828</td>
<td>0.03</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
</tbody>
</table>

* analysis not relevant

Figure 10 is a distance-drawdown plot at the end of the 2880-minute CRT of production bore 10WP36PB and the nearest observation bores. The plot shows that the drawdown at the end of the CRT extends more than 1.1 km from the production bore. The calculated transmissivity and storativity values agree well with the values calculated from the curve fitting methods.
Weaber Plain aquifer test results

Figure 5 Step test analysis for production bore 10WP36PB

Figure 6 Datalogger data during test pumping of production bore 10WP36PB
Weaber Plain aquifer test results

1. Adjusted Time (min)
2. Drawdown (m)

Obs. Wells
- 10WP36PB
- 10WP36N
- 10WP36S
- 10WP37

Aquifer Model
Confined

Solution
Cooper-Jacob

Parameters
T = 5978.9 m²/day
S = 0.004302

Figure 7 Cooper-Jacob plot for production bore 10WP36PB test pumping

Obs. Wells
- 10WP36PB
- 10WP36N
- 10WP36S
- 10WP37

Aquifer Model
Confined

Solution
Theis

Parameters
T = 5647.2 m²/day
S = 0.009033
Kz/Kr = 0.004145
b = 18. m

Figure 8 Theis plot for production bore 10WP36PB test pumping
Figure 9 Recovery plot for production bore 10WP36PB test pumping

Figure 10 Distance–drawdown plot for production bore 10WP36PB test pumping
4.2 Production bore 10WP35PB test pumping

A step test was carried out on 30 July 2010 and the fourth step test was extended for 24 hours.

4.2.1 Step test

The static water level in the bore at the start of test pumping was 4.4 m BGL. The total drawdown at the end of the step test was 1.34 m. The fourth step was extended to 24 hours pumping at 25 L/s. The groundwater level data from the observation bores during the step and extended constant rate test is presented in Figure 11. An analysis of the bore efficiency was made using the first three steps which gave a calculated drawdown equation at 100 minutes pumping of:

\[ s = 5.674 \times 10^{-4} Q + 4.382 \times 10^{-8} Q^2 \]

where \( s \) = drawdown (m)  
\( Q \) = discharge rate (m³/d)

The first term on the right hand side of the equation is the drawdown due to laminar flow (aquifer loss) and the second is the drawdown due to turbulent flow (well loss). The calculated nominal bore efficiency is 85 per cent at a discharge rate of 25 L/s after 100 minutes pumping (Table 10).

The groundwater levels in the last step at 25 L/s showed groundwater levels rising for the first 3 minutes. This is attributed to the bore still developing because the calculated drawdown and the measured corrected drawdown for the fourth step show a difference of almost 10 per cent while the first three steps show similar values for the measured and calculated drawdowns.

Table 10 10WP35PB bore efficiencies from step test

<table>
<thead>
<tr>
<th>Q (L/s)</th>
<th>Q (m³/d)</th>
<th>S (100 min)</th>
<th>Laminar flow drawdown (m)</th>
<th>Turbulent flow drawdown (m)</th>
<th>Calculated drawdown (m)</th>
<th>Bore efficiency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>864</td>
<td>0.52</td>
<td>0.490</td>
<td>0.033</td>
<td>0.523</td>
<td>93.7</td>
</tr>
<tr>
<td>14</td>
<td>1210</td>
<td>0.76</td>
<td>0.687</td>
<td>0.064</td>
<td>0.750</td>
<td>91.5</td>
</tr>
<tr>
<td>18</td>
<td>1555</td>
<td>0.98</td>
<td>0.882</td>
<td>0.106</td>
<td>0.988</td>
<td>89.3</td>
</tr>
<tr>
<td>25</td>
<td>2160</td>
<td>1.30</td>
<td>1.226</td>
<td>0.204</td>
<td>1.430</td>
<td>85.7</td>
</tr>
</tbody>
</table>

4.2.2 Constant rate test

Based on drawdowns obtained from the CRT of 10WP36PB, the discharge rate for the extended step test of bore 10WP35PB was set at 25 L/s. Starting from a water level of 4.40 m BGL, the drawdown at the end of the test was 1.51 m. The distances of observation bores from 10WP36PB are shown in Table 11. The groundwater level data from the observation bores during the CRT is presented in Figure 12. The calculated aquifer parameters are in Tables 12 and 13. The plots of the Cooper-Jacob, Theis and Theis recovery are shown in Figures 14, 15 and 16, respectively.

Figure 16 is a distance-drawdown plot at the end of the 1440-minute CRT of 10WP35PB and the nearest observation bores. The plot shows that the drawdown at the end of the CRT is extending almost one kilometre from the production bore. The calculated transmissivity are within the range calculated from the curve fitting methods.
### Table 11  Observation bore distances from 10WP35PB

<table>
<thead>
<tr>
<th>Bore</th>
<th>Easting (MGA)</th>
<th>Northing (MGA)</th>
<th>Distance from 10WP35PB (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10WP36N</td>
<td>481 885</td>
<td>8 289 635</td>
<td>1068</td>
</tr>
<tr>
<td>10WP36PB</td>
<td>481 885</td>
<td>8 289 596</td>
<td>1028</td>
</tr>
<tr>
<td>10WP36S</td>
<td>481 885</td>
<td>8 289 516</td>
<td>949</td>
</tr>
<tr>
<td>10WP37</td>
<td>481 886</td>
<td>8 289 026</td>
<td>459</td>
</tr>
<tr>
<td>10WP35N</td>
<td>481 887</td>
<td>8 288 653</td>
<td>85</td>
</tr>
<tr>
<td>10WP35PB</td>
<td>481 887</td>
<td>8 288 567</td>
<td>0.1</td>
</tr>
<tr>
<td>10WP35S</td>
<td>481 886</td>
<td>8 288 526</td>
<td>41</td>
</tr>
<tr>
<td>WP1</td>
<td>481 602</td>
<td>8 287 791</td>
<td>828</td>
</tr>
<tr>
<td>WP6PB</td>
<td>482 518</td>
<td>8 290 413</td>
<td>1950</td>
</tr>
<tr>
<td>WP2</td>
<td>481 630</td>
<td>8 286 159</td>
<td>2423</td>
</tr>
<tr>
<td>WP3</td>
<td>480 637</td>
<td>8 286 206</td>
<td>2673</td>
</tr>
<tr>
<td>WP4</td>
<td>479 667</td>
<td>8 286 274</td>
<td>3193</td>
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<tr>
<td>WP16</td>
<td>483 251</td>
<td>8 291 605</td>
<td>3329</td>
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<tr>
<td>10WP33</td>
<td>486 514</td>
<td>8 290 136</td>
<td>4886</td>
</tr>
</tbody>
</table>

### Table 12  10WP35PB aquifer parameters assuming a confined aquifer

<table>
<thead>
<tr>
<th>Bore</th>
<th>Lateral distance from pump (m)</th>
<th>Final drawdown (m)</th>
<th>Cooper-Jacob</th>
<th>Theis</th>
<th>Theis recovery</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>T (m²/d)</td>
<td>S</td>
<td>T (m²/d)</td>
<td>S</td>
<td>T (m²/d)</td>
</tr>
<tr>
<td>10WP35PB</td>
<td>0.1</td>
<td>1.51</td>
<td>3480</td>
<td>NA*</td>
<td>3670</td>
</tr>
<tr>
<td>10WP35S</td>
<td>41</td>
<td>0.23</td>
<td>4460</td>
<td>0.015</td>
<td>4790</td>
</tr>
<tr>
<td>10WP35N</td>
<td>85</td>
<td>0.15</td>
<td>5140</td>
<td>0.017</td>
<td>5450</td>
</tr>
<tr>
<td>10WP37</td>
<td>459</td>
<td>0.03</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>WP1</td>
<td>828</td>
<td>0.02</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
</tbody>
</table>

* analysis not relevant

### Table 13  10WP35PB aquifer parameters assuming an unconfined aquifer

<table>
<thead>
<tr>
<th>Bore</th>
<th>Lateral distance from pump (m)</th>
<th>Final drawdown (m)</th>
<th>Cooper-Jacob</th>
<th>Theis</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>T (m²/d)</td>
<td>S</td>
<td>T (m²/d)</td>
<td>S</td>
</tr>
<tr>
<td>10WP35PB</td>
<td>0.1</td>
<td>1.51</td>
<td>3990</td>
<td>NA*</td>
</tr>
<tr>
<td>10WP35S</td>
<td>41</td>
<td>0.23</td>
<td>4500</td>
<td>0.015</td>
</tr>
<tr>
<td>10WP35N</td>
<td>85</td>
<td>0.15</td>
<td>5170</td>
<td>0.017</td>
</tr>
<tr>
<td>10WP37</td>
<td>459</td>
<td>0.03</td>
<td>9760</td>
<td>0.014</td>
</tr>
<tr>
<td>WP1</td>
<td>828</td>
<td>0.02</td>
<td>NA</td>
<td>NA</td>
</tr>
</tbody>
</table>

* analysis not relevant
Figure 11 **Step test analysis for production bore 10WP35PB**

Figure 12 **Datalogger data during test pumping of production bore 10WP35PB**
Figure 13 Cooper-Jacob plot for production bore 10WP35PB test pumping

Figure 14 Theis plot for production bore 10WP35PB test pumping
Weaber Plain aquifer test results

Observation Wells
- 10WP35PB
- 10WP35SD
- 10WP35N
- 10WP37I

Aquifer Model
- Confined

Solution
- Theis (Recovery)

Parameters
- $T = 5214.4 \, \text{m}^2/\text{day}$
- $S/S' = 0.9226$

Figure 15: Recovery plot for production bore 10WP35PB test pumping

Observation Wells
- 10WP35PB
- 10WP35S
- 10WP35N
- 10WP37I

Aquifer Model
- Unconfined

Solution
- Theis

Parameters
- $T = 3850.4 \, \text{m}^2/\text{day}$
- $S = 0.03834$
- $Kz/Kr = 0.1$
- $b = 23. \, \text{m}$

Figure 16: Distance–drawdown plot for production bore 10WP35PB test pumping
4.3 Bore 10WP39 constant rate and recovery tests

Bore 10WP39 yielded an estimated 3 L/s during airlifting immediately following its construction. The submersible pump used for the test was capable of discharging 2 L/s against the 6.2 m of head at the start of the test. The maximum drawdown observed after 4 hours pumping was 2.82 m (SWL 9.05 m BGL).

Figure 17 shows the Cooper-Jacob analysis of the drawdown data during the constant rate test of bore 10WP39. The bore was pumped for about 4 hours at 2 L/s. The figure shows the response to the discharge line being crimped at about 220 minutes and subsequent rapid return to the pre-existing drawdown curve when the crimp was rectified. The Cooper-Jacob analysis of the recovery data is shown in Figure 18. The transmissivity values calculated from the pumping and recovery data were 63.8 and 76.1 m²/d, respectively. These translate to hydraulic conductivity values of 3.5 and 4.2 m/d, respectively. These values are compared to the values determined from slug tests on 10WP39 in Table 14.
Despite the fact that the dataloggers used during the slug tests were not capable of recording data at less than 0.5 second intervals, the data collected showed signs of the disturbance of water levels due to the introduction and removal of the displacement rods. Figure 19 shows the data collected during a slug addition test at bore 10WP38; the figure shows the initial disturbance and other characteristics common to the data retrieved during most of the slug tests:

(i) the observed maximum displacement was not instantaneous
(ii) the observed maximum displacement of water did not equal the expected maximum displacement
(iii) there is considerable noise in the early time water level response data.

Removal of the noise in the early time water level data was necessary before it was analysed because the analysis requires fitting a straight line to the plotted water level displacement, normalised against the maximum displacement. Figure 19 also shows the data selected for analysis for bore 10WP38; this type of data selection was required for all slug addition and slug withdrawal data sets.

The results of all the slug test analyses are summarised in Table 14.
Figure 19 Slug withdrawal data observed at bore 10WP38, showing all raw data and the data selected for calculation of hydraulic conductivity, the depth to water is shown in m below the top of the casing (m BToC)
Table 14 Calculated values of hydraulic conductivity (K) from multiple slug and pumping tests at selected bores on the Weaber Plain, and inferred values, considered to be the most representative for each bore

<table>
<thead>
<tr>
<th>Bore</th>
<th>Aquifer materials</th>
<th>Test</th>
<th>K (m/d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10WP31</td>
<td>sands, gravels &amp; minor clay</td>
<td>slug addition</td>
<td>&gt; 2.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>slug withdrawal</td>
<td>&gt; 4.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>slug addition</td>
<td>&gt; 4.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>slug withdrawal</td>
<td>&gt; 3.2</td>
</tr>
<tr>
<td>inferred</td>
<td>value</td>
<td></td>
<td>5.0</td>
</tr>
<tr>
<td>10WP38</td>
<td>weathered shale</td>
<td>slug addition</td>
<td>&lt; 0.11</td>
</tr>
<tr>
<td></td>
<td></td>
<td>slug withdrawal</td>
<td>&lt; 0.13</td>
</tr>
<tr>
<td></td>
<td></td>
<td>slug withdrawal</td>
<td>&lt; 0.16</td>
</tr>
<tr>
<td>inferred</td>
<td>value</td>
<td></td>
<td>0.1</td>
</tr>
<tr>
<td>10WP39</td>
<td>calcarenite, sands &amp; clays</td>
<td>pump test at 2 L/s</td>
<td>3.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>recovery from pumping at 2 L/s</td>
<td>4.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>slug addition</td>
<td>&gt; 3.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>slug addition</td>
<td>&gt; 2.8</td>
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<tr>
<td></td>
<td></td>
<td>slug addition</td>
<td>&gt; 1.4</td>
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<td></td>
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<td>slug addition</td>
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<tr>
<td>10WP40</td>
<td>clay; weathered quartzite</td>
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<td></td>
<td>0.05</td>
</tr>
<tr>
<td>WP6</td>
<td>sands &amp; gravels</td>
<td>slug addition</td>
<td>&lt; 9.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>slug withdrawal</td>
<td>&gt; 10.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>slug addition</td>
<td>&gt; 10.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>slug withdrawal</td>
<td>&gt; 6.9</td>
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<tr>
<td>inferred</td>
<td>value</td>
<td></td>
<td>10.0</td>
</tr>
<tr>
<td>WP6PB</td>
<td>weathered sandstone, sands &amp; gravels</td>
<td>slug addition</td>
<td>&lt; 6.9</td>
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<td>slug withdrawal</td>
<td>18.0</td>
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<td></td>
<td>slug addition</td>
<td>&lt; 15.0</td>
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<td></td>
<td></td>
<td>slug withdrawal</td>
<td>15.0</td>
</tr>
<tr>
<td>inferred</td>
<td>value</td>
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<td>15.0</td>
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<td>WP16</td>
<td>limestone</td>
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<td>&lt; 0.5</td>
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<td>slug withdrawal</td>
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</tr>
<tr>
<td>inferred</td>
<td>value</td>
<td></td>
<td>0.5</td>
</tr>
</tbody>
</table>
5. Discussion

The transmissivity values calculated from the 2010 Weaber Plain test pumping program are similar to values obtained from previously tested production bores in the Ord River Irrigation Area that are sited on the thickest sand and gravel section of the Ord palaeochannel.

A summary of the transmissivities calculated from the test pumping of production bores 10WP35PB and 10WP36PB are shown in Tables 15 and 16. The hydraulic conductivities, $K$, have been calculated from the aquifer thickness, $b$, and $T$ values, that is $K = T/b$. For production bore 10WP35PB, there is 23 m of aquifer material and for production bore 10WP36PB, there is 18 m of aquifer material. Because production bore 10WP36PB is only screened in the upper section of the aquifer, and the lower section has coarser gravels, it is probable that the hydraulic conductivity for this bore is higher than calculated. The low vertical anisotropy ratios calculated for production bore 10WP36PB indicate that the horizontal hydraulic conductivity of the Ord palaeochannel is far greater than its vertical hydraulic conductivity (Tables 8 and 9).

<table>
<thead>
<tr>
<th>Table 15 Calculated T and K values for production bore 10WP35PB</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bore</strong></td>
</tr>
<tr>
<td>----------</td>
</tr>
<tr>
<td>10WP35PB</td>
</tr>
<tr>
<td>10WP35S</td>
</tr>
<tr>
<td>10WP35N</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 16 Calculated T and K values for production bore 10WP36PB</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bore</strong></td>
</tr>
<tr>
<td>----------</td>
</tr>
<tr>
<td>10WP36PB</td>
</tr>
<tr>
<td>10WP36N</td>
</tr>
<tr>
<td>10WP36S</td>
</tr>
</tbody>
</table>

Projecting the data from production bore 10WP35PB indicates that the bore would have a drawdown of 1.7 m after 20 years pumping at 25 L/s, as long as no boundary or recharge effects were encountered. The production bore could be pumped at rates closer to 75 L/s before the entrance velocity in the screens would be nearing the recommended maximum entrance velocity of 0.03 m/sec (Sterrett 2007). This would give a drawdown of about 5 m after 20 years pumping, as long as no boundary or recharge effects were encountered. The distance-drawdown figure for 10WP35PB shows that pumping will have a drawdown effect at least one kilometre away.

Projecting the data from production bore 10WP36PB indicates that the bore would have a drawdown of 1.5 m after 20 years pumping at 25 L/s, as long as no boundary or recharge effects were encountered. Theoretically, production bore 10WP36PB could not be pumped at much more than 25 L/s because the entrance velocity in the screens would be nearing the recommended maximum of 0.03 m/s (Sterrett 2007). However, Johnson Screen staff (pers. comm.) state that the screen should be capable of pumping up to 50 L/s. The efficiency of production bore 10WP36PB would decrease with increased pumping rates. The distance-drawdown figure for this bore shows that pumping will have a drawdown effect over one kilometre away.
The hydraulic conductivity values reported for mixed sedimentary aquifers in Table 14 are at least an order of magnitude less than those determined for the palaeochannel. This difference is due to the inherently higher permeability of the gravelly palaeochannel sediments.

The screens in several of the bores on which slug tests were performed were installed in less than ideal locations and these are discussed below. The hydraulic conductivity values reported in Table 14 for those bores therefore represent the effective values for the multiple aquifer materials screened rather than the hydraulic conductivity values of the most permeable sections of the profiles.

Bore 10WP31 was drilled to 23.2 m BGL. However, it was drilled with air-core equipment and the coarse gravels encountered from 20 m BGL could not be lifted from the hole. Sands and clays from higher in the profile collapsed into the hole to a depth of 22.8 m BGL before the casing could be installed. The well screen is therefore exposed to 3.2 m of fine sands and clay and 2.8 m of sands and gravels. The hydraulic conductivity calculated from the slug tests is therefore reflective of this mix of aquifer materials rather than the coarse gravels which constitute the main palaeochannel aquifer (George et al. 2011). Furthermore, slug tests have been shown to be sensitive to near-well conditions (Butler & Healey 1998), and therefore there is the possibility that the fine sands and clay that collapsed into the hole prior to the installation of the casing could have a negative influence on the calculated hydraulic conductivity.

Bores WP6 and WP6PB are similarly screened across multiple aquifer materials. Bore WP6 is screened in 5 m of sand and gravel and 1 m of weathered sandstone of Proterozoic age. Bore WP6PB is screened in similar materials (1 m of sand and gravel and 5 m of weathered sandstone).

Bore 10WP39 is partially screened in 6 m of banded sands, gravels and clays and 6 m of calcarenite and clays. Table 14 shows that pumping and slug tests performed at this bore produced very similar results, which is contrary to the common experience of slug test results being significantly less than pumping test results at the same bore. Butler and Healey (1998) show that poor well development and vertical anisotropy are the most likely causes of such a result. Achieving close agreement between slug and pumping test analyses indicates that the bore was well developed following construction and that the reported hydraulic conductivity is representative of the depth-averaged value for the relatively recent (Cainozoic) sediments found under the northern portion of the Weaber Plain immediately south of Border Creek.

Bore WP16 is screened in indurated limestone of Devonian age, and therefore the reported hydraulic conductivity relates to the Ningbing Group limestone basement.
6. Conclusions

The drilling program described by George et al (2011) confirmed the existence and nature of the Ord palaeochannel under the Weaber Plain. The aquifer testing reported here provides quantitative estimates of its aquifer properties for use in a numerical groundwater model to assess options to manage watertables and salinity under the Weaber Plain following development for irrigated agriculture (KBR 2010b). This work also provides reliable estimates of the yields that can be expected from production bores sited in the Ord palaeochannel.

The production bores 10WP35PB and 10WP36PB were drilled in the Ord palaeochannel on sites selected from the interpretation of airborne geophysics. Production bore 10WP35PB was drilled into 23 m of mainly coarse sand and production bore 10WP36PB was drilled into 18 m of coarse sand and gravel.

The calculated transmissivity for production bore 10WP35PB was in the range of 3480 to 6240 m²/d and the resultant hydraulic conductivity ranged from 150 to 270 m/d. The calculated transmissivity for production bore 10WP36PB was in the range of 4340 to 8790 m²/d and the resultant hydraulic conductivity ranged from 240 to 390 m/d.

Production bore 10WP36PB has the screens set against 6 m of the upper section of gravel. The gravel in the section below the screen was coarser and could not be lifted from the borehole even when drilling with mud so it is probable that the lower gravel will have a higher hydraulic conductivity. The hydraulic conductivity calculated for bore 10WP31 is significantly lower than those calculated for production bores 10WP35PB and 10WP36PB and this difference may be due to the near-well impacts of fine sands and clay collapsing into the hole prior to the installation of the casing.

Pumping from production bores 10WP35PB and 10WP36PB at 25 L/s will have an effect on groundwater levels about one kilometre away from the bores.

The transmissivity values calculated for production bores 10WP35PB and 10WP36PB are similar to values obtained from previously tested production bores in the Ord River Irrigation Area that are sited on the thickest sand and gravel section of the Ord palaeochannel.

The hydraulic conductivities derived from slug tests represent values for multi-layered aquifers encountered on the Weaber Plain. These values are at least an order of magnitude less than those determined for the palaeochannel. To provide maximum information for input into the groundwater model used to predict the likely groundwater impacts of clearing and irrigation aquifer properties for each of the main aquifer materials would have been preferred. However, the results of the aquifer tests reported here provide useful information for some aquifer units directly applicable to the modelling.
7. References


Theis, CV 1935, ‘The relation between the lowering of the piezometric surface and the rate and duration of discharge of a well using groundwater storage’, *American Geophysical Union Transactions*, vol. 16, pp. 519–524.

Appendix A Bore drill logs and bore completion diagrams
**Weaber Plain aquifer test results**

**Org:** KIM  
**Bore name:** 10WP35PB  
**Project:** Ord  
**Supervisor/s:** J. Simons & R. George

**Date:** 05 July 2010  
**Catchment:** Keep River  
**Sub-catchment:** Weaber Plain – Border Creek

**Location:** Weaber Plain, on boundary of proposed Lots 2 and 3

**Datum:** GDA94  
**Zone:** 52  
**Location QC:** DGPS  
**AHD (m):** 26.71  
**E (m):** 481887.62  
**N (m):** 8288568.84

**Landholder:** Carlton Station / Crown Land (Lot 711 on Plan 220360 & Lot 393 on Plan 58305)

**Land use:** Pastoral grazing  
**Year cleared:** Uncleared

**Landform / Soil description:** Lowland flat / Cununurra clay black soil adjacent to the D8 Swamp

<table>
<thead>
<tr>
<th>Depth (m)</th>
<th>Sample description and drilling comments</th>
<th>Geology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface</td>
<td>Very dark grey (10YR 3/1) cracking light–medium clay</td>
<td>Topsoil—clay</td>
</tr>
<tr>
<td>0–1.75</td>
<td>Dark grey (10YR 4/1) cracking clay</td>
<td>Subsoil—clay</td>
</tr>
<tr>
<td>1.75</td>
<td>Brown (7.5YR 4/3) very fine sandy silt and clay</td>
<td>Palaeochannel aquifer (top of sands)</td>
</tr>
<tr>
<td>4.75</td>
<td>Brown (7.5YR 4/3) coarse sandy clay with fine sands and calccrete nodules. Very few sub-rounded gravels 5–10 mm</td>
<td></td>
</tr>
<tr>
<td>6.0</td>
<td>Coarse sands</td>
<td></td>
</tr>
<tr>
<td>12.0</td>
<td>Very coarse sands with many sub-rounded fine (2–6 mm) gravels</td>
<td></td>
</tr>
<tr>
<td>17.0</td>
<td>Fine sands becoming coarser at depth</td>
<td></td>
</tr>
<tr>
<td>20.0</td>
<td>Coarse sands</td>
<td></td>
</tr>
<tr>
<td>21.0</td>
<td>Very coarse sands with many sub-rounded fine (2–6 mm) gravels, few gypsum plates (10 mm) and very few 'broken' sub-rounded gravels up to 10 mm</td>
<td></td>
</tr>
<tr>
<td>23.0</td>
<td>Very coarse sands with many sub-rounded gravels (up to 10 mm)</td>
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</tr>
<tr>
<td>25.0</td>
<td>Lens of brown (7.5YR 4/4) sandy clay</td>
<td></td>
</tr>
<tr>
<td>25.0</td>
<td>Coarse sands with many sub-rounded ‘broken’ gravels up to 10 mm</td>
<td></td>
</tr>
<tr>
<td>29.0</td>
<td>Very dusty red (10YR 2.5/2) sandy clay with many sub-angular 2–10 mm conchoidal fractured, oxidised and fresh siliceous fine siltstone fragments</td>
<td></td>
</tr>
<tr>
<td>31.5</td>
<td>Many dusty red (10YR 2.5 3/2) ‘purplish’ sub-angular very fine siltstone fragments</td>
<td></td>
</tr>
<tr>
<td>35.0</td>
<td>EOH</td>
<td></td>
</tr>
</tbody>
</table>

**Driller:** Direct Drilling  
**Drill method:** Mud rotary  
**Drill bit diam. (mm):** 317 mm

**Depth drilled (m):** 35  
**Casing total length (m):** 27.83  
**Casing above ground (m):** 0.47

**Casing diam. (mm):** 200  
**Casing type:** Stainless / PN12 PVC  
**Casing installation:** Good

**Screen length (m):** 18  
**Screen from and to (m):** 9.36–27.36  
**Screen type:** Wire wound stainless steel, 1 mm slots

**Annulus seal:** Bentonite pellets  
**Screen gravel:** Graded sand 2–4 mm  
**Yield (L/s):** 20

**SWL (m BGL):** -4.60  
**EC (mS/m):** 180  
**pH:** 7.0

**SWL date:** 07 July 10  
**Method of fixing:** Stainless steel screens welded together, screwed to PVC and PVC casing glued.  
**Construction type:** Production bore

**Notes:** Airlift made 20 L/s (2.5 h development) with very little drawdown—fully recovered in 15 minutes. Very little sediment.
## Weaber Plain aquifer test results

### BORE CONSTRUCTION DETAILS

<table>
<thead>
<tr>
<th>Depth (m)</th>
<th>Description of strata</th>
<th>Section</th>
<th>Casing</th>
<th>Fixing</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
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<td></td>
<td>TOC 0.47 m</td>
<td>Steel headworks</td>
</tr>
<tr>
<td>1</td>
<td>CLAY</td>
<td></td>
<td></td>
<td>Cement +0.05–6.2 m</td>
</tr>
<tr>
<td>2</td>
<td>1.75</td>
<td>PLAIN PVC 200 mm PN12 (+0.47–9.36)</td>
<td>Bentonite pellets (12.5 kg) 6.2–6.9 m</td>
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</tr>
<tr>
<td>3</td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>4</td>
<td>CLAY &amp; SILT</td>
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<td></td>
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<tr>
<td>5</td>
<td>4.75</td>
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<tr>
<td>6</td>
<td>SANDY CLAY</td>
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<tr>
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<td>9</td>
<td>FINE &amp; COARSE SANDS</td>
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<td>20</td>
<td>COARSE SANDS WITH 20–50%</td>
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<td>Graded sand 2–4 mm (3250 kg) 6.9–27.5 m</td>
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<td>SUB-ROUNDED</td>
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<td>22</td>
<td>GRAVELS (2–10 mm)</td>
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</tbody>
</table>

### NOTES:

- **Airlifting information**
  - Duration: 2.5 h
  - Flow rate: 20 L/s

- **Water level**
  - Date: 6/07/2010
  - SWL: 4.6 m BGL

- **Water quality**
  - EC: 180 mS/m
  - pH: 7.0
  - SWL: 4.6 m BGL

- **Pump test**
  - Ks: 151–209 m/d
  - T: 3480–4800 m²/d
### Weaber Plain aquifer test results

<table>
<thead>
<tr>
<th>Org: KIM</th>
<th>Bore name: 10WP36PB</th>
<th>Project: Ord</th>
<th>Supervisor: R. George</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date: 08 July 2010</td>
<td>Catchment: Keep River</td>
<td>Sub-catchment: Weaber Plain – Border Creek</td>
<td></td>
</tr>
<tr>
<td>Location: Weaber Plain proposed farmlands – West side Lot 3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Datum: GDA94</td>
<td>Zone: 52</td>
<td>Location QC: DGPS</td>
<td>AHD (m): 26.06</td>
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<tr>
<td>Landholder: Carlton Station / Crown Land (Lot 711 on Plan 220360 &amp; Lot 393 on Plan 58305)</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Land use: Pastoral grazing</td>
<td>Year cleared: Uncleared</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Landform / Soil description:** Flat / Aquitaine clay; adjacent to the D8 Swamp

<table>
<thead>
<tr>
<th>Depth (m)</th>
<th>Sample description and drilling comments</th>
<th>Geology</th>
</tr>
</thead>
<tbody>
<tr>
<td>0–1.5</td>
<td>Black soil, cracking (10YR 3/1), fine to medium clay</td>
<td>Topsoil—black</td>
</tr>
<tr>
<td></td>
<td>Red-brown (10YR 4/1) fine silty to medium clay, little or no sand-sized grains</td>
<td>Subsoil—clay</td>
</tr>
<tr>
<td>1.5</td>
<td>Red-brown silty clay (7.5YR 4/2), fine sand grains 1–2 mm, (&lt; 5% sand)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Iron cemented thin band of sand (in fine silty clay)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Increased sand % (10–15%), grains 1–3 mm, sub-rounded (sandy clay)</td>
<td></td>
</tr>
<tr>
<td>3.2</td>
<td>Coarse sand, rounded 1–5 mm, occasional small gravels (5 mm), moderately to well sorted lenses. Drill bit breaking larger stones; conchoidal fracture.</td>
<td>Palaeochannel aquifer (top of sands)</td>
</tr>
<tr>
<td>7.2</td>
<td>As above, rounded pebbles 4–8 mm, estimates 10–20% sub-1 mm</td>
<td></td>
</tr>
<tr>
<td>10.5</td>
<td>As above, finer zones, rig crunching through larger rocks/lenses</td>
<td></td>
</tr>
<tr>
<td>11.2</td>
<td>Coarser, 1–5 mm, moderately to poorly sorted sandstone, fine quartzite, siliceous siltstones</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>As above, less well-rounded, estimated 30% sub-1 mm grain size, some larger sample</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>As above, rounded pebbles 4–8 mm, estimates 10–20% sub-1 mm</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>As above, finer zones, rig crunching through larger rocks/lenses</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>Coarser, 1–5 mm, moderately to poorly sorted sandstone, fine quartzite, siliceous siltstones</td>
<td></td>
</tr>
<tr>
<td>21–23</td>
<td>Gravels/stones, mean size 5–15 mm rocks, broken by bit</td>
<td>Aquifer (to gravel)</td>
</tr>
<tr>
<td>26</td>
<td>Gravels, quartzite, siltstone, fine sandstone, conchoidal fracture, poorly to moderately sorted, decreased rounding by 29 m</td>
<td>Aquifer (base?)</td>
</tr>
<tr>
<td>29</td>
<td>As above, moderately well sorted lenses, fine-grained sections, minor sandy clays, larger stones accumulating in annulus?, potential transition to weathered basement?</td>
<td></td>
</tr>
</tbody>
</table>

**Driller:** Direct Drilling  
**Drill method:** Mud rotary  
**Drill bit diam. (mm):** 317 mm

<table>
<thead>
<tr>
<th>Depth drilled (m): 29</th>
<th>Casing total length (m): 20.80</th>
<th>Casing above ground (m): 0.44</th>
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</thead>
<tbody>
<tr>
<td>Casing diam. (mm): 200</td>
<td>Casing type: Stainless / PN12 PVC</td>
<td>Casing installation: Good</td>
</tr>
<tr>
<td>Screen length (m): 6</td>
<td>Screen to and from (m): 14.36–20.36</td>
<td>Screen type: Wire wound stainless steel, 1 mm slots</td>
</tr>
<tr>
<td>Annulus seal: Bentonite pellets</td>
<td>Screen gravel: Graded sand 2–4 mm</td>
<td>Yield (L/s): &gt; 25</td>
</tr>
<tr>
<td>SWL (m BGL): -4.70</td>
<td>EC (mS/m): 115</td>
<td>pH: 7.4</td>
</tr>
<tr>
<td>SWL date: 08 July 10</td>
<td>Method of fixing: Stainless steel screens screwed to PVC and PVC casing glued.</td>
<td>Construction type: Production bore</td>
</tr>
</tbody>
</table>

**Notes:** Mud viscosity 50 s (8 x 25 kg AugGel; 25 kg Pak R, 8 kg Pak L). Hole blockages at 21 m and 17 m; redrilled, extra muds added. Hole stable and pumped to clear water in 135 minutes. Hole developed by jetting and airlifting at compressor capacity (2.25 h) to free of silt (< 2 g/L); WELLCLEAN® also used. Nil drawdown. Minor sediment.
### BORE CONSTRUCTION DETAILS

<table>
<thead>
<tr>
<th>Depth (m)</th>
<th>Description of strata</th>
<th>Section</th>
<th>Casing</th>
<th>Fixing</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>TOC 0.44 m</td>
<td></td>
<td>Steel headworks</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>CLAY</td>
<td>0.0</td>
<td>Cement +0.05–7.4 m</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>1.5</td>
<td>Bentonite pellets</td>
<td>(12.5 kg)</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td>7.4–7.7 m</td>
</tr>
<tr>
<td>4</td>
<td>SILTY CLAY</td>
<td></td>
<td>Graded sand</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td>BASE PLATE STAINLESS</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
<td>21.0</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td></td>
<td></td>
<td>SCREEN STAINLESS</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td></td>
<td></td>
<td>ID 200 mm</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td></td>
<td></td>
<td>WOUND 1 mm</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td></td>
<td></td>
<td>(14.36–20.36)</td>
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<td>11</td>
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<td>28</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>29</td>
<td>GRAVELS (fine grained at base)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>29</td>
<td>END OF HOLE</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**NOTES:**
- **Airlifting information**
  - Duration: 2.25 h
  - Flow rate: 25 L/s
- **Water level**
  - Date: 8/07/2010
  - SWL: 4.70 m BGL
- **Water quality**
  - EC: 115 mS/m
  - pH: 7.4
- **Pump test**
  - Ks: 241–488 m/d
  - T: 4340–8790 m²/d
Weaber Plain aquifer test results

<table>
<thead>
<tr>
<th>Org: KIM</th>
<th>Bore name: 10WP39</th>
<th>Project: Ord</th>
<th>Supervisor/s: P. Raper</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date: 15 July 2010</td>
<td>Catchment: Keep River</td>
<td>Sub-catchment: Weaber Plain – Border Creek</td>
<td></td>
</tr>
<tr>
<td>Location: Weaber Plain proposed farmlands, north of Brown Ridge, on Lot 9B</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Datum: GDA94</td>
<td>Zone: 52</td>
<td>Location QC: DGPS</td>
<td>AHD (m): 23.26</td>
</tr>
<tr>
<td>Landholder: Carlton Hills Station / Crown Land (Lot 394 on Plan 058305)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Land use: Pastoral grazing</td>
<td>Year cleared: Uncleared</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Landform / Soil description:** Flat / Aquitaine clay

<table>
<thead>
<tr>
<th>Depth (m)</th>
<th>Sample description and drilling comments</th>
<th>Geology</th>
</tr>
</thead>
<tbody>
<tr>
<td>0–1</td>
<td>Dark reddish grey (2.5YR 4/2) cracking clay</td>
<td>Topsoil—grey Sub-soil</td>
</tr>
<tr>
<td>2.0</td>
<td>Brown (7.5YR 4/3) silty clay. Red-brown silty clay and minor very fine sand, minor CaCO₃ nodules, strongly banded (&lt; 0.1 m thick).</td>
<td>Calcarenite</td>
</tr>
<tr>
<td>4.0</td>
<td>Yellow-orange to grey clay and fine sand, sub-rounded, minor CaCO₃. Driller noted variable resistance from 4 m on, banding.</td>
<td></td>
</tr>
<tr>
<td>5.0</td>
<td>Yellow clay, sand and fine to medium gravels, strongly banded, some CaCO₃. Occasional grey clay.</td>
<td></td>
</tr>
<tr>
<td>12.0</td>
<td>Strongly cemented calcarenite with pale yellowish orange marling, very little clay.</td>
<td>Poorly weathered basement, Milligan formation</td>
</tr>
<tr>
<td>14.0</td>
<td>Calcarenite and off-white to yellow clay, banded. Some calcarenite fragments are roughly cylindrical, infilled root channels.</td>
<td>Calcarenite</td>
</tr>
<tr>
<td>15.0</td>
<td>Calcarenite and cream to yellow clay in bands.</td>
<td></td>
</tr>
<tr>
<td>18.0</td>
<td>Calcarenite and clay as above, possible signs of calcarenite having been formed in open cavity.</td>
<td></td>
</tr>
<tr>
<td>19.0</td>
<td>Fine to coarse sand and pale yellow clay, poorly cemented in places.</td>
<td></td>
</tr>
<tr>
<td>22.0</td>
<td>Banded sands and pale yellow clays.</td>
<td></td>
</tr>
<tr>
<td>30.0</td>
<td>Dark grey shale, soft. Sand and clay returned in sample is from above. Fossilised tooth returned in 30–31 m sample, assumed to have originated from calcarenite 12 to 19 m.</td>
<td></td>
</tr>
<tr>
<td>33.0</td>
<td>EOH</td>
<td></td>
</tr>
</tbody>
</table>

**Driller:** Direct Drilling  
**Drill method:** Rotary air blast  
**Drill bit diam. (mm):** 178

<table>
<thead>
<tr>
<th>Depth drilled (m): 33</th>
<th>Casing method: Rotary air blast</th>
<th>Casing bit diam. (mm): 178</th>
</tr>
</thead>
<tbody>
<tr>
<td>Casing diam. (mm): 100</td>
<td>Casing type: PN12 PVC</td>
<td>Casing installation: Formation collapsed, cased only to 18 m</td>
</tr>
<tr>
<td>Screen length (m): 12</td>
<td>Screen to and from (m): 6.07–18.07</td>
<td>Screen type: PVC 1 mm slots</td>
</tr>
<tr>
<td>Annulus Seal: Bentonite pellets</td>
<td>Screen gravel: Graded sand 2–4 mm</td>
<td>Yield (L/s): &gt; 3</td>
</tr>
<tr>
<td>SWL (mBGL): -6.10</td>
<td>EC (mS/m): 120</td>
<td>pH: 7.1</td>
</tr>
<tr>
<td>SWL date: 19 July 10</td>
<td>Method of fixing: Threaded PVC casing installed using centralisers</td>
<td>Construction type: Monitoring bore</td>
</tr>
</tbody>
</table>

**Notes:** Foam injected at 23 m BGL but not again. Large cavity generated, 13 to about 16 m BGL during drilling. 2700 kg gravel pack required to fill cavity.
## Weaber Plain aquifer test results

### bore construction details

<table>
<thead>
<tr>
<th>Depth (m)</th>
<th>Description of strata</th>
<th>Section</th>
<th>Casing</th>
<th>Fixing</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0</td>
<td>TOC</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.59</td>
<td>Steel headworks</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.00</td>
<td>Clay</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.0</td>
<td>SILTY CLAY</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.0</td>
<td>CLAY / SAND / FINE GRAVELS</td>
<td></td>
<td>PLAIN PVC</td>
<td></td>
</tr>
<tr>
<td>100 mm PN12 (+0.59–6.07)</td>
<td>Cement</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12.0</td>
<td>CLAY / SAND / FINE GRAVELS</td>
<td></td>
<td>SCREEN PVC</td>
<td></td>
</tr>
<tr>
<td>100 mm PN12 (6.07–18.07)</td>
<td>Bentonite pellets</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.3–2.6 m</td>
<td>Graded sand</td>
<td>2–4 mm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.6–18.0 m</td>
<td>(2700 kg)</td>
<td>2.6–18.0 m</td>
<td></td>
<td></td>
</tr>
<tr>
<td>19.0</td>
<td>END CAP PVC</td>
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<td></td>
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</tr>
<tr>
<td>18.07</td>
<td>END OF HOLE</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30.0</td>
<td>SHALE (WEATHERED BASEMENT)</td>
<td></td>
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</tr>
<tr>
<td>33.0</td>
<td>END OF HOLE</td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

### NOTES:

**Airlifting information**
- Duration: 1.5 h
- Flow rate: > 3 L/s
- Slug Test: Ks: 3.0 m/d

**Water level**
- Date: 24/07/2010
- SWL: 6.05 m BGL

**Water quality**
- EC: 120 mS/m
- pH: 7.1