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City of Stonnington

Report for Groundwater Supply Potential for Open Space Recreation Areas

Pumping Test Investigations, Victoria Gardens

August 2009

INFRASTRUCTURE | MINING & INDUSTRY | DEFENCE | PROPERTY & BUILDINGS | ENVIRONMENT

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1 Introduction

GHD was engaged by the City of Stonnington (Stonnington) to undertake and analyse the results of a pumping test conducted on a recently constructed bore located in Victoria Gardens (High Street, Prahran). The objective of the pumping test was to enable an estimation of likely sustainable yield of the bore to be formulated.

This report documents the results of the pumping test conducted in June 2009 and includes the following specific, technical information:

- Available information regarding the construction of the production bore;
- Pumping test methodology;
- Pumping test results;
- Conclusions regarding the work completed.

2 Site Characterisation

2.1 Bore Locations

Drilling in Victoria Gardens was conducted late in the 2007 / 2008 financial year. The drilling and construction of the bore was undertaken by Borewell, with hydrogeological support provided by GHD.

The initial test bore was cased to 53.6 m and left open hole below this depth to 96 m. These works were conducted under Bore Construction Licence BCL9032084 issued by Southern Rural Water (SRW). When a test pump was installed to gather information for the desalination plant design, the bore was found to be blocked within the open hole section. Subsequently Borewell were remobilised to the site in June 2009 to remove the blockage and complete the test bore as a fully cased production bore. SRW requested that a new BCL be obtained for this work. BCL 9036868 was subsequently issued for the refurbishment.

The co-ordinates of the bore location are provided in Table 1.

Table 1 Summary of Bore Locations

Bore ID	Location Description	GDA94 AMG Co-ordinates	
		Easting	Northing
BCL9032084 / BCL9036868	Northern end of park, adjacent grounds keeper depot	324,400	5,808,067

Note:

1. Bore locations surveyed with GPS.
2. AMG – Australian Map Grid. GDA94 Geodectic Datum of Australia

2.2 Groundwater Extraction Licence

Groundwater Extraction Licence (GEL) 9035533 has been issued to the City of Stonnington by SRW for 4 bores located in 4 separate parks including Victoria Gardens. The licensed volume and flow rates for the Victoria Gardens bore are summarised in Table 2.

Table 2 Extraction Licence Summary

Site	BCL	Maximum Daily Rate (ML/day)	Maximum Daily Volume (ML)	Maximum annual Volume (ML)
Victoria Gardens	9032084	0.1	0.1	6

2.3 Site Lithology

A summary lithological log for the bore is provided in Table 3. During the drilling of the pilot hole drilling, bore yields were estimated using air-lifting methods at various intervals. The final estimate of the bore yield was 0.5 L/s.

At this site the unconsolidated sediments of the Tertiary age Brighton Group lie directly upon Devonian age granite basement rocks. The granite is highly weathered in its upper sequence with its competency increasing with depth. Considerable difficulty was experienced by the drilling contractor due to the highly weathered nature of the granite with regular collapse of the bore wall experienced during drilling.

Table 3 Simplified Lithological Profile

Depth		Lithology	Interpreted Stratigraphy
From	To		
0	15	SAND – CLAYEY SAND; Mottled light grey, red and brown, trace ironstone gravels in parts, increasing plasticity below 12 m	Brighton Group
15	48	GRANITE; Weathered (blade bit)	Undifferentiated Devonian granite
48	90	GRANITE; Weathered (hammer, rapid penetration, soft and hard bands)	
90	120	GRANITE; Less weathered, occasional softer interval	

2.4 Bore Construction

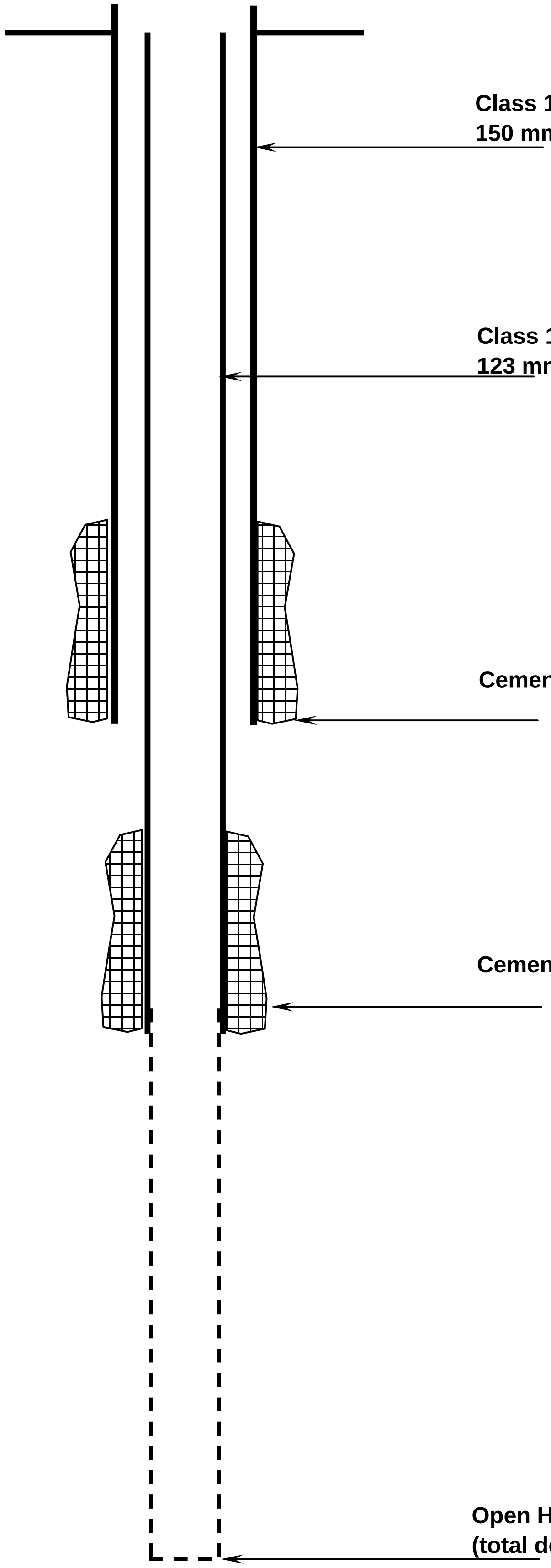
A summary of the bore construction is provided in Table 4. The final bore construction is shown schematically in Figure 1.

The bore was initially constructed only with 150 mm diameter casing to a depth of 53.6 m. Following construction subcontractor of the City of Stonnington was engaged to install a test pump to collect a groundwater sample. The pump could not be lowed to a sufficient depth into the open hole section of the borehole and it was interpreted that the weathered granite had fretted away and partially collapsed in the bore.

Borewell were remobilised to the site to drill out the blockage, and to secure the hole. To achieve this, Borewell installed and cemented a smaller diameter casing inside the existing 150 mm PVC surface casing. This was cemented in to a depth of 89m and the hole left uncased (i.e. open hole) below this depth.

Table 4 Summary Production Bore Construction

Depth		Casing
From	To	
0	53.6	150 mm ID PVC casing, cemented shoe
0	89	123 mm ID PVC casing, tremmie cemented
89	120	Open hole



CLIENTS | PEOPLE | PERFORMANCE

City of Stonnington
Victoria Gardens
Production Bore Construction

job no. 31 / 21490
report no. 167262
Rev no. A

scale: as shown
date: 08 Decembert 2007

Figure 1

3 Pumping Test Program

3.1 Principle of Pumping Test Investigations

A pumping test is a practicable and effective means of obtaining hydraulic characteristics of geological formations. Pumping tests are undertaken to determine one of more of the following (after Hazel, 1975):

- A long term pumping rate for a particular bore;
- To check on the performance of a particular groundwater bore;
- To identify the existence and the location of subsurface boundaries within an aquifer which may affect either beneficially or adversely the long term pumping performance of a particular bore;
- To size a pump of appropriate capacity; and,
- To determine aquifers hydraulic characteristics. These parameters are essential to evaluate the groundwater potential of an aquifer during a broad groundwater investigation. These aquifer characteristics are used to determine the ability of an aquifer to store and transmit water.

In terms of production bores, a pumping test is used to determine the performance of a bore, that is, the relationship between drawdown, laminar flow and turbulent flow. Knowing this relationship, an appropriate pumping rate for a specified drawdown can be determined.

The efficiency of a production bore depends upon its design and aquifer hydraulics. Energy losses, comprising laminar and turbulent flow components are present which effect a production bores' drawdown at a particular flow rate. A step drawdown test is the preferred method for obtaining this information.

In the conduct of a step test, the discharge is varied in controlled stages, with discharge either increasing or decreasing between steps. Laminar losses occur due to the flow of water through the aquifer towards the well. Turbulent losses occur through the screen and gravel pack (if present), inside the casing and from the casing into the pump intake. The following relationship has been suggested regarding the total drawdown:

Drawdown (S) = $BQ + CQ^n$

where Q = pumping well discharge, B = aquifer loss coefficient and C = well loss coefficient. The BQ term represents well losses due to laminar flow and the CQ^n represents turbulent flow losses.

3.2 Objective

The objective of the pumping test at Victoria Gardens was to determine the maximum sustainable flow rate from the test bore. To complete this objective, GHD completed a 3-stage, step drawdown pumping test consistent to AS2369 – 1990.

3.3 Pump Set-up

Agmek mobilised to the Victoria Gardens on the 3rd June 2009 with their pump test trailer and installed a 5 hp electric submersible pump. The pump is capable of yields up to 3 L/s from 80 m depth, which was considered sufficient for this site based on the results obtained from the air lift testing undertaken during drilling.

3.4 Water level Monitoring

Water levels were monitored using an In Situ ™ PSD 250 PSI strain gauge pressure transducer and datalogger. As part of the pump installation, an airline was attached to the rising main of the pump. The airline was manifolded to a regulator, and charged with industrial nitrogen gas. Water level changes within the test bore (i.e. drawdown) could then be recorded by the pressure transducer through measurement of the balancing pressure of nitrogen.

The static water conditions and available drawdown prior to testing has been summarised in Table 5. The test pump was set as deep within the bore as possible to maximise the available drawdown for the pumping test.

Table 5 Pre-pumping conditions

Site	Standing Water Level (m)	Pump Depth (m)	Available Drawdown (m)
Victoria Gardens	12.57	73	60.7

Note:

1. All depths metres (m) below top of bore casing.
2. Available drawdown as recorded by pressure transducer.
3. Airline / transducer depth approximate only.

3.5 Flow Rate Monitoring

The flow rate was measured using an ABB Magflo™ meter. Flow rates were measured periodically throughout the duration of testing and were adjusted during each flow rate step, as required, by either subtle adjustment of a ball valve at the pump's discharge outlet.

Groundwater was discharged over the lawn areas of both parks, and surrounding garden beds at Victoria Gardens. Owing to the duration of the testing, the depth to groundwater and the anticipated surface soil materials, recharge to the aquifer was not anticipated to have occurred during the duration of testing.

3.6 Summary of Testing

A summary of the step drawdown testing at the park is provided in Table 6. Initially during the commencement of the pumping test the bore pump operated too rapidly which resulted in dewatering of the borehole. Adjustments were subsequently made to the sensitivity of the low-flow cut-off switch on the pump to enable pumping to occur at low rates. This resulted in a slight loss in the available drawdown at the commencement of testing as the bore had not fully recovered i.e. initially the available drawdown was 60 m, however at the commencement of the first step it was 49 m. During the third step the flow rate was backed-off, which essentially constituted a fourth step in the testing.

Table 6 Pumping Test Summary

Test	Time		Duration (min)	Flow Rate (L/s)	Drawdown (m)
	Start	Finish			
Step 1	10:05	11:19	74 (74)	0.55	25.9 (25.9)
Step 2	11:19	12:23	64 (138)	0.65	10.4 (36.3)
Step 3	12:23	13:47	84 (222)	0.74	10.5 (46.8)
Step 4	13:47	15:22	95 (317)	0.62	4.5 (42.3)
Recovery	15:22	15:43	21 (338)	0	-34.5 (7.8)

Note:

1. Drawdown in parenthesis represents cumulative drawdown (m).
2. Duration in parenthesis represents cumulative duration (min).
3. Negative drawdown represents recovery.

3.7 Water Quality Monitoring

The discharge water from the Victoria Gardens bore was of high clarity having low turbidity with no obvious evidence of the sediment or discolouration. At the completion of pumping the bore was considered to have been appropriately developed.

A water sampled was collected towards the close of the test by the City of Stonnington's desalination consultant.

4 Pumping Test Results

4.1 Drawdown Response

The aquifer response to pumping is shown in Figure 2 and indicates a step-wise increase in drawdown with each consecutive flow rate increase. At the completion of the test, when the flow rate had been backed off from 0.74 L/s to 0.62 L/s, approximately 8 m of available drawdown remained above the pump intake.

Recovery from the pumping was not instantaneous however approximately 80% of recovery was achieved after 30 mins from the cessation of pumping.

4.2 Pumping Test Analysis

4.2.1 Transmissivity

The aquifer transmissivity was estimated using drawdown data from the pumping bore, and the application of the Cooper-Jacob solution to the non-equilibrium well equation with variable flow rate. The analysis relies on curve-matching and the analysis is shown in Appendix C. The results are summarised in Table 7.

4.2.2 Specific Capacity

The specific capacity of each step was determined and these were plotted to determine a linear relationship based on the Bierschenk method (Kasenow 1997). The production bore specific capacity (Q/s) and production well drawdown can be predicted for any flow rate (Q) using the well performance equation as described in Table 7.

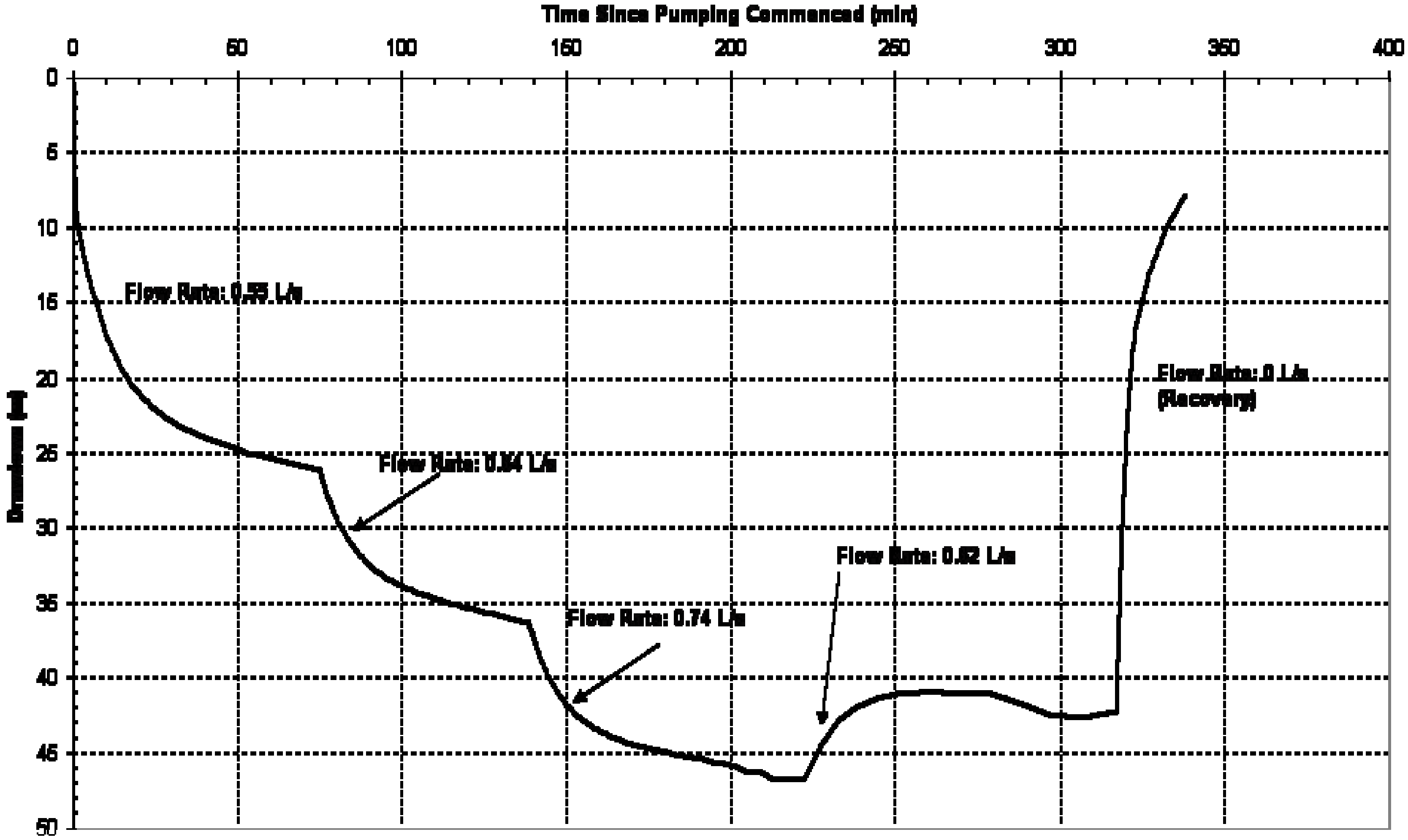
Table 7 Estimate of Transmissivity

Site	Transmissivity (m^2/day)	Specific Capacity Equation
Victoria Gardens	1	$S = 0.0108\ Q^2 + 0.0306\ Q$

Note:

1. Specific Capacity equation: S = drawdown in metres (m) and Q = flow rate in m^3/day.

Figure 2 Aquifer Response to Pumping – Victoria Gardens



4.3 Pump Selection

The final, desired pumping schedule for the site has been assumed to be pumping on a 12 hr basis e.g. overnight filling of water tanks.

The recommended flow rate and pump setting depth has been summarised in Table 8. The testing conducted has revealed that the bore is capable of marginally higher flow rates over shorter pumping durations, however this will necessitate the installation of variable speed drive pump controls. In completing Table 8, data from the 6 hr pumping test period has been extrapolated to longer periods. Testing for extended periods would be required to fully confirm these predictions

Table 8 Pump Selection

Bore	Recommended Pump Intake Depth (m)	Flow Rate at Intake Depth (L/s)	Comment
Victoria Gardens	89	0.5	Above open hole / within cased borehole.

Note:
1. It is recommended that pumps installed adjacent screen intervals be fitted with shrouds.

The pump to be installed at Victoria Gardens does not need a shroud as sufficient water should be drawn upwards past the pump from the second, deeper screen.

Although the step test indicates that higher pump settings than those recommended in Table 8 maybe possible an allowance, or factor of safety in the available drawdown, should be made for the following:

- Aquifer discharge boundaries

  Aquifer discharge boundaries (i.e. thinning of the aquifer, reduction in fracturing etc) can cause rapid increases in drawdown. Whilst discharge boundaries are not likely to be intersected in a 12 hr pumping period, a longer term test is required to confirm such.

- Interference effects from neighbouring groundwater users

  The pumping of neighbouring bores or other on-site bores will create additional water level decline in the aquifer system, which has the potential to rob or interfere with the available drawdown in production bores.

- Full recovery of water level during pumping quiescence.

  If a pumping schedule does not provide for the complete recovery of water levels, a progressive incremental decline in water level will occur over the irrigation season. This may become significant if the bore is heavily or frequently used during the summer season.

- Seasonal variations in water level

  Water levels may fluctuate seasonally, however long term water level monitoring records in the region suggest only a minor declining response caused by the drought. Water levels are expected to be lower than average, however some further decline may occur towards late summer.

Pumping of the bores at higher flow rates may also be possible based on the amount of available drawdown remaining above the pump at the completion of testing, however a number of factors suggest a conservative down-grading of the bores performance, namely due to:

- flow rates in fractured rock aquifers can be highly variable over extended periods; and,
- a bore's performance can change markedly with subtle increases in flow rate (i.e. available drawdown can be consumed rapidly with minor flow rate increases).

It is recommended that any completed production bore at the site should be tested over its intended irrigation pumping period.

4.4 Product Bore Management Plan

A borefield management plan is a means of managing a borefield and ensuring security of supply in terms of water quality and quantity. The key elements of a BMP should include:

- Monitoring objectives;
- Asset Inventory;
- Monitoring requirements;
- Monitoring frequencies;
- Action Triggers and Procedures;
- Maintenance Register;
- Data and System Review.

An outline of a borefield management plan has been presented in Appendix D.

5 Conclusions

A production bore has been installed at Victoria Gardens. The bore extracts groundwater from the weathered granite basement rocks which posed considered issues during the drilling and construction of the bore.

A step performance test was conducted on the bore to provide an estimate of its specific capacity. The bore was shown to be low yielding and could not sustain yields greater than 0.75 L/s for periods longer than 1 hr.

It is however concluded that the bore could be used to supply water to a desalination plant, however pumping at low flow rates is required. To maximise the available drawdown at each site and to mitigate against the variability associated with a fractured rock aquifer system over an extended irrigation season it is concluded that the pump in the bores should be positioned towards the base of the bore casing.

It is further noted that the long term behaviour of the weathered granite is not well understood and therefore the bore water quality requires periodical monitoring. The bore, and its operation may lead to increased weathering and slaking of the granitic materials. If such occurs, which can only be assessed by longer term operation of the bore, a new bore, constructed with a gravel pack will need to be installed.

6 Recommendations

This report makes the following:

On the assumption that pumping periods below 10 hrs are adopted:

- Equip Victoria Gardens bore with a pump set at 89 m depth, capable of flow rates up to 0.5 L/s;

In addition:

- Bores should be equipped with low flow shut-off and motor protection;
- Bore equipping should be consistent with the Southern Rural Water licence conditions e.g. fitting of airlines and flow metering of the headworks.
- Implementation of a borefield management plan.
  - To assess changes in water quality arising from potential degrading of borehole conditions; and,
  - Changes in pumped volume owing to slow recharge rates anticipated in the granitic materials.

7 References

- GHD, 2008: *'Groundwater Supply Potential for Open Space Recreation Areas. Exploratory groundwater investigations at Ardrie Park, Malvern Cricket Ground, Romanis Reserve and Victoria Gardens'*. Report prepared for the City of Stonnington.
- Kasenow, M., 1997: *'Introduction to Aquifer Analysis. 4th Edition'* Water Resource Publications, LLC.

8 Limitations

This hydrogeological investigation report has been prepared to assess the pumping capacity of production bores for the City of Stonnington. The advice provided herein relates only to these purposes and must be reviewed by a competent professional, experienced in hydrogeological investigations, before being used for any other purpose. GHD Pty Ltd (GHD) accepts no responsibility for other use of the advice.

Where borehole construction details, groundwater laboratory analysis, geophysical or pumping tests and similar work have been performed and recorded by others, the data is included and used in the form provided by others. GHD accepts responsibility for satisfying itself that the data is representative of conditions on the site but does not warrant the accuracy of the information.

The advice tendered in this report is based on information obtained from the publicly available groundwater bore information maintained by others and is not warranted in respect to the conditions that may be encountered across the site at other than these locations. It is emphasised that the actual characteristics of the subsurface, surface and groundwaters may vary significantly between adjacent boreholes and at locations other than where observations, explorations and investigations have been made. Sub-surface conditions, including groundwater levels and quality can change over time. This should be borne in mind when assessing the data.

It should be noted that because of the inherent uncertainties in the evaluations of aquifer hydraulic properties, changed or unanticipated hydrogeologic conditions might occur that could affect total project cost and/or execution. GHD does not accept responsibility for the consequences of significant variances in the conditions between test points or with time.

An understanding of the site conditions depends on the integration of many pieces of information, some regional, some site-specific, some structure-specific and some experienced-based. Hence this report should not be altered, amended or abbreviated, issued in part and issued incomplete in any way without prior checking and approval by GHD. GHD accepts no responsibility for any circumstances that arise from the issue of the report that has been modified in any way as outlined above.

Appendix A

BCL Amendment

SOUTHERN
Rural Water

Our Reference: 9035533

12 January 2009

City of Stonnington
C/- GHD
Attn: Tim Anderson
Level 8, 180 Lonsdale Street
MELBOURNE VIC 3000

Dear Mr Anderson

APPLICATION FOR A BORE CONSTRUCTION LICENCE TO ALTER A BORE

Further to your recent application to alter bore no. S9032084/1, please find enclosed your Bore Construction Licence No. 9036868. Please note that the licence is issued on the basis that all the conditions must be adhered to.

When the bore alteration has been satisfactorily completed we will update our records accordingly, to show that bore no. S9032084/1, on Groundwater Licence 9035533 has been deepened.

Please remind your chosen driller that a water sample must be taken from your bore and sent to Australian Laboratory Services as per the condition on your Bore Construction Licence. If the driller is unable to take a water sample at the time your bore is drilled, or does not give you a bottle for you to take a sample once the bore is fully complete, please call Bruce Foley, Licensing Officer on the number noted below and a bottle will be sent to you.

As "Licensee" it is your responsibility to ensure that all conditions of the licence are complied with. You should discuss this matter with your service provider (driller) ensuring that conditions of the licence are understood and adhered to. I am also enclosing the driller's copy of your licence. Could you please pass this onto your chosen driller.

As part of Southern Rural Water's (SRW) bore construction inspection program, there is a need to inspect the bore, preferably during construction. Could you please contact SRW's Rob Dunbar, Drilling Officer 0417 159 928 at least seven days prior to construction commencing on this bore so an inspection can be arranged.

If you have any further enquires regarding this matter then please do not hesitate to contact Alisha Clark, Assessment Officer, on (03) 5139 3137.

Yours sincerely

Vince Lopardi
Manager Administration – Port Phillip & Westernport
Groundwater & Rivers

SOUTHERN RURAL WATER
WATER ACT 1989
Section 67
BORE CONSTRUCTION LICENCE NO. 9036868
(Licence to construct and operate a bore)

Gippsland and Southern Rural Water authorises:

City Of Stonnington
Attn: Peter Murray - Parks Coordinator
Po Box 21
Prahran 3181

To Construct/Alter and operate a bore on the land described below and subject to the conditions stated.

Lot(s)	**2**	Plan of Subdivision No	**140502**
Allotment(s)	**Victoria Gardens**	Section	
Parish	**Prahran**	Township	**Prahran**

for the purpose specified in the application namely:
The Licence is valid until **12 January 2010**

CONDITIONS

1 If the bore cannot be satisfactorily rehabilitated or modified, it must be decommissioned.
2 The bore must be constructed in such a manner as to prevent aquifer contamination caused by vertical flow outside the casing.
3 An airline or piezometer for the measurement of water levels must be installed in the bore. As an alternative, the licensee must be able to advise water levels as requested or as directed by Southern Rural Water. This will be at the licensee's expense.
4 A sample of water proposed to be extracted for use must be taken, after suitable development time, and sent to SGS Environmental Services, PO Box 1956, Traralgon VIC 3844 Tel: (03) 5172 1555, Fax: (03) 5174 9320.
5 The bore shall be constructed to a standard not less than the standard specified in the Minimum Construction Requirements for Water Bores in Australia (2nd Edition Revised September 2003), and to the satisfaction of Southern Rural Water.
6 This bore cannot be used for irrigation purposes until such time as Southern Rural Water acknowledges that a completed and acceptable Bore Completion Report has been received from you or your driller and the groundwater licence has been finalised.
7 This licence has been issued to alter bore number S9032084/1. If the alteration to this bore is not successful, Southern Rural Water must be contacted prior to any further drilling commencing.
8 The maximum depth for this bore is 140.0 metres. Any change to this must be approved by Southern Rural Water prior to drilling beyond this depth.
9 This bore must be constructed by or under the direct supervision of a Class 2 or Class 3 driller with the appropriate drilling endorsement, licensed under the Water Act 1989.
10 Decommissioning of the bore(s) shall be undertaken as set out in section 18, 'Decommissioning of Bores (Abandonment) published within the book titled Minimum Construction Requirements for Water Bores in Australia, 2nd Edition Revised September 2003.'

See over for further conditions and additional information

LICENSEES COPY

Vince Lopardi
Authorising Officer
Issued Date: 12 January 2009

All communication should be addressed to: PO Box 153, MAFFRA VIC 3860

OTHER CONDITIONS

1. The well head of the bore shall be constructed in such a manner as to prevent the introduction of pollutants.

2. The Licensee must ensure that the bore is constructed at the site as indicated on the licence application form.

3. The location of the bore must be indicated on a map which will be sent to the Licensee after the bore has been constructed. The map must be promptly returned to the SRW.

4. The person responsible for the work is required to send a copy of a bore completion report to the SRW and to the Licensee within twenty eight (28) days after the bore is completed.

5. If the bore is to be located close to a septic tank system and is for domestic use the Licensee is advised to contact the local Municipal Authority to meet any requirements of that local Authority.

6. If a bore is unsuccessful, it is necessary to take action to protect the groundwater resource from wastage or pollution. This may be done by decommissioning the bore in accordance with approved methods.

7. If the bore has not been completed prior to the licence expiring the Licensee may apply to renew the licence.

8. This bore cannot be operated until such time as SRW acknowledges that a duly completed and acceptable Bore Completion Report has been received from you or your driller under the Water Act 1989.

9. Water taken under this licence should not be used for human consumption without appropriate treatment.

10. Bore casing wall thickness shall be sufficient to withstand the anticipated formation and hydrostatic pressures imposed on the casing during its installation, bore development and use - as set out in section 9 'Casing' within the Agriculture and Resource Management Council of Australia and New Zealand's Minimum Construction Requirements for Water Bores in Australia.

11. **As part of Southern Rural Water's (SRW) bore construction inspection program, there is a need to inspect the bore, preferably during construction. Could you please contact SRW's Licensing Officer nominated on your covering letter at least seven days prior to construction commencing on this bore so an inspection can be arranged.**

Disclaimer:
Due to varying environmental conditions the quality of water taken under this licence is not guaranteed. It is the responsibility of the licensee to establish the adequacy of the water quality as fit for the licensed purpose.

PLEASE NOTE:
It is an offence to operate a bore unless all conditions are met.

Appendix B

Drillers Completion Report

WATER ACT 1989

BORE COMPLETION REPORT

SOUTHERN Rural Water

GPS CO-ORDS: E N

ZONE: 54 / 55 (delete as applicable) GDA 94/ADG66 (delete as applicable)

BORE CONSTRUCTION LICENCE No. 90368 68

Report on site A ☑ B ☐ C ☐ D ☐

Spear Point System Yes ☐ No ☐

OFFICE USE ONLY

BORE NUMBER

BORE USES

GMA .... ZONE ....

Bore Owner CITY OF STONNINGTON

Site Address VICTORIA GARDENS -

Date Commenced 20/05/09 Date Completed 26/5/09 Total Depth 120 (m)

Was Bore Decommissioned? Y / N N If Yes, State Method

1. DRILLING AND WATER INTERSECTION DETAILS

DRILLING TECHNIQUE				WATER INTERSECTIONS (while drilling, measurements taken from natural surface)									OFFICE USE
Method	From (m)	To (m)	Bit diam (mm)	From (m)	To (m)	Test Method	Static Level (m)	Est. yield l/sec	Draw down (m)	Casing at test (m)	Depth at test (m)	Ec at 25°C (µS/cm)	Lithology
R. MUD	53.6	90	155										
R HAMMER	89	120	120	89	120	AIR	14	•5	TOTAL	O.H	120		

2. CASINGS (CA) SCREENS (SC) SLOTS (SL) OPEN HOLE (OH)

GENERAL			CASING			SCREENS / SLOTS						OFFICE USE
Type CA SC SL OH	From (m)	To (m)	Inner diam (mm)	Outer diam (mm)	Material	Inner diam (mm)	Outer diam (mm)	Material	Aperture (mm)	Filter Y / N	Trade Name	Lithology
CA ☑	0	89	123	140	PVC							
OH ☑	89	120										

WELL HEAD FITTINGS Casing Shoe Y / N ☐ Bullnose / Endcap Y / N ☐

3. CEMENT (C) BENTONITE (B) SEALS (S) PACKERS (P) GRAVEL (G)

Material C B S P G	From (m)	To (m)	Cement (bags)	Water (litres)	Seal / Packer type	Outer diam of seal (mm)	Artificial Gravel Packing Method of placement	Gravel size mesh passing (mm)
C ☑	6.?	89	15	400				

4. FINAL BORE DEVELOPMENT

Method	Yield l/sec	Draw down (m)	Pumping Time (min)	Recovery Time (min)	Final Static Level	Ec at 25°C (µS/cm)

5. DRILLER'S PUMPING TEST

Method	Static Level (m)	Yield l/sec	Pumping Level (m)	Draw down (m)	Pumping Time (min)	Recovery Time (min)	Ec at 25°C (µS/cm)

6. IF NOT A DRILLED BORE

Type	Length (m)	Width (m)	Diam (m)	Lining Material	From (m)	To (m)

7. SAMPLES

Have material samples been taken? Yes ☑ No ☐ If Yes From .... (m)

Have water samples been taken? Yes ☑ No ☐ To .... (m)

Samples taken by: Bore Owner ☐ Driller ☐ Project Geologist ☑

8. DISINFECTION

Was the Bore Disinfected? Yes ☑ No ☐

If yes, state method of disinfection: Chlorine Washed ☑ Steam Cleaned ☐

Other, please specify:

9. DRILLER'S LOG

Material	From (m)	To (m)
THIS LOG IS		
ALTERATION TO		
BORE # 9032084		
WEATHERED GRANITE		
& RUBBLE ZONES	53.6	84
FIRMER GRANITE		
WITH ODD FRACTURE	84	120

Driller's Name ROMANO GRANDE Driller's Licence No. 423

Driller's Signature [signature] Date 25/7/09

Name of Plant Operator ROMANO GRANDE

Appendix C

Photographic Record

Pumping test trailer established over borehole

Monitoring of water levels

Appendix D

Pumping Test Analysis

Figure 3 Curve Match for Ardrie Park Bore

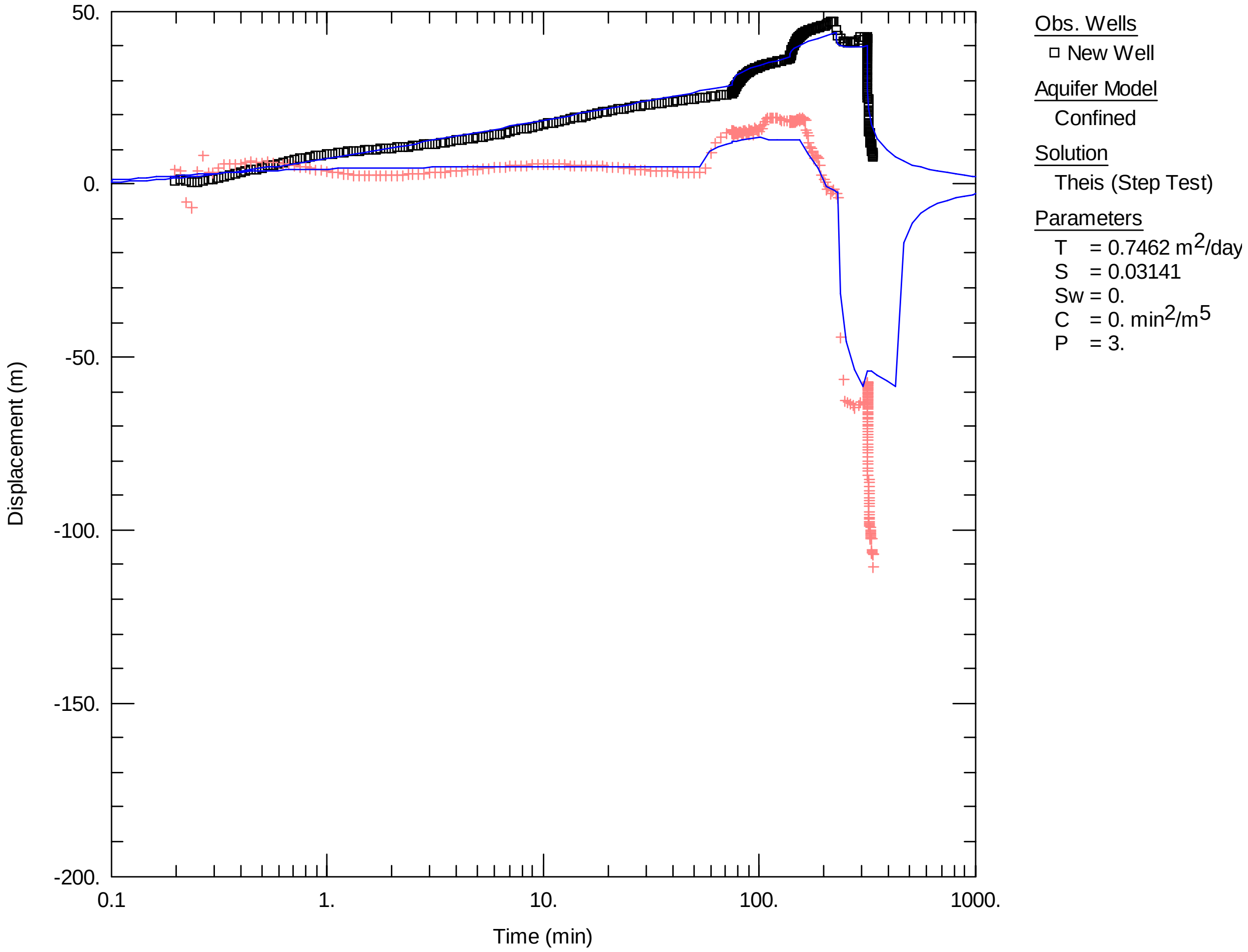


Figure 4 Specific Capacity Analysis – Victoria Gardens

Bierschenck Solution
-for equal time steps

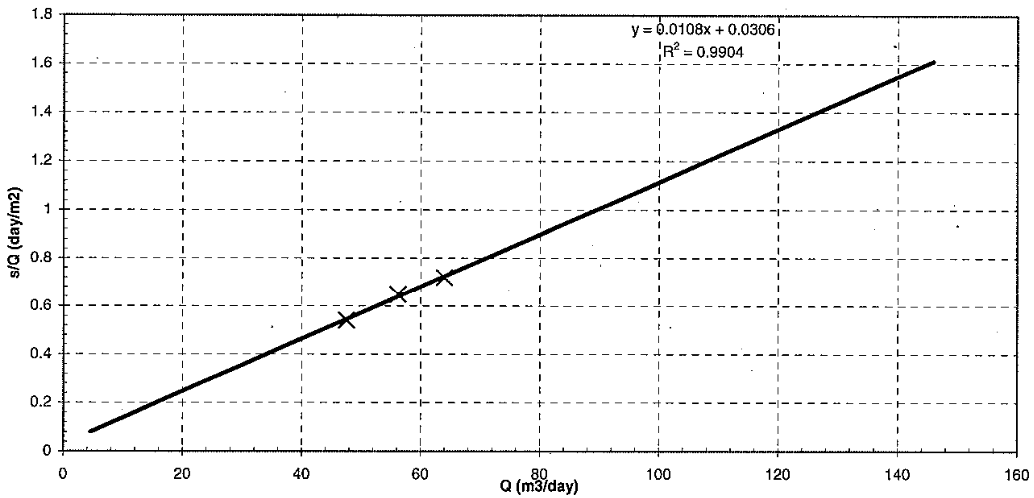
Q L/s	Q m3/day	s (m)	s/Q
0.55	47.52	25.7	0.54082
0.65	56.16	36.47	0.64939
0.74	63.936	45.92	0.71822

s/Q = CQ+ B
where
B = y intercept
C= gradient

From linear regression
B= 0.030572
C= 0.010839

Well Equation:

s = 0.010839 Q^2 + 0.0306 Q



Kasenow Solution

For Bstep1,2	-0.056308
For Bstep2,3	0.152335
Mean B	0.048013
For Cstep1,2	0.012566
For Cstep2,3	0.008851
Mean C	0.010708
Calculated B	0.033569
Calculated C	0.010482

Well Equation:

s = 0.010482 Q^2 + 0.0336 Q

Predicted Drawdown for Flow rate

Enter Q L/s	m3/day	Predicted Drawdown (s) Bierschenck	Predicted Drawdown (s) Kasenow	Predicted Well Loss (m) Bierschenck	Predicted Well Loss (m) Kasenow	Predicted Aquifer Loss (m) Bierschenck	Predicted Aquifer Loss (m) Kasenow	Well Efficiency (%) Bierschenck	Well Efficiency (%) Kasenow
0.45	38.88	17.6	17.2	16.4	15.8	1.2	1.3	7	8
0.5	43.2	21.5	21.0	20.2	19.6	1.3	1.5	6	7
0.55	47.52	25.9	25.3	24.5	23.7	1.5	1.6	6	6
0.6	51.84	30.7	29.9	29.1	28.2	1.6	1.7	5	6
0.65	56.16	35.9	34.9	34.2	33.1	1.7	1.9	5	5

Note: Well efficiency from Williams (1985) and Kawecki (1995) in Kasenow (1997)
Efficiency is time dependent. Increases with time and decreases with flow rate.
Well Loss CQ^2 Aquifer Loss BQ

MANAGEMENT ENGINEERING ENVIRONMENT

Appendix E

Raw Pumping Test Data

Step 1		Step 2		Step 3		Step 4	
ET (min)	**Drawdown (m)**	**ET (min)**	**Drawdown (m)**	**ET (min)**	**Drawdown (m)**	**ET (min)**	**Drawdown (m)**
0.20	1.03	75.25	26.22	138.75	36.35	317.12	42.22
0.21	1.28	75.28	26.24	138.77	36.37	317.12	42.16
0.22	0.88	75.31	26.27	138.80	36.39	317.13	42.15
0.24	0.38	75.35	26.30	138.82	36.42	317.14	42.06
0.25	0.59	75.39	26.34	138.85	36.45	317.15	41.99
0.27	1.10	75.43	26.37	138.88	36.48	317.17	41.86
0.28	1.47	75.48	26.41	138.91	36.51	317.18	41.74
0.30	1.52	75.52	26.44	138.95	36.54	317.19	41.58
0.32	1.75	75.57	26.48	138.98	36.58	317.20	41.44
0.34	2.25	75.63	26.53	139.02	36.62	317.22	41.28
0.36	2.55	75.68	26.57	139.06	36.65	317.23	41.13
0.38	2.79	75.74	26.62	139.10	36.68	317.25	40.96
0.40	3.26	75.80	26.67	139.14	36.71	317.26	40.81
0.42	3.63	75.87	26.71	139.19	36.74	317.28	40.64
0.45	4.06	75.94	26.76	139.24	36.76	317.30	40.46
0.47	4.28	76.01	26.83	139.29	36.79	317.32	40.29
0.50	4.75	76.09	26.90	139.35	36.81	317.34	40.12
0.53	5.22	76.18	26.96	139.41	36.84	317.36	39.95
0.56	5.56	76.26	27.02	139.47	36.87	317.39	39.76
0.60	5.93	76.36	27.09	139.54	36.90	317.41	39.57
0.63	6.29	76.46	27.16	139.61	36.93	317.44	39.36
0.67	6.65	76.56	27.23	139.68	36.97	317.47	39.15
0.71	6.90	76.67	27.31	139.76	37.02	317.50	38.92
0.75	7.26	76.79	27.38	139.85	37.09	317.53	38.68
0.79	7.48	76.92	27.48	139.93	37.15	317.56	38.43
0.84	7.82	77.05	27.56	140.03	37.23	317.60	38.16
0.89	8.08	77.19	27.66	140.13	37.30	317.63	37.87
0.94	8.34	77.34	27.76	140.23	37.38	317.67	37.59
1.00	8.58	77.50	27.86	140.34	37.46	317.72	37.28
1.06	8.80	77.66	27.96	140.46	37.55	317.76	36.97
1.12	8.96	77.84	28.07	140.59	37.64	317.81	36.62
1.19	9.15	78.03	28.17	140.72	37.74	317.86	36.26
1.26	9.31	78.23	28.30	140.86	37.83	317.91	35.88
1.33	9.44	78.44	28.41	141.01	37.93	317.97	35.49
1.41	9.58	78.66	28.55	141.17	38.04	318.03	35.08
1.50	9.72	78.90	28.68	141.33	38.15	318.09	34.67
1.58	9.82	79.15	28.83	141.51	38.26	318.16	34.20
1.68	9.96	79.41	28.96	141.70	38.38	318.23	33.72
1.78	10.11	79.69	29.10	141.90	38.50	318.30	33.26
1.88	10.25	79.99	29.26	142.11	38.63	318.38	32.74
1.99	10.37	80.30	29.40	142.33	38.75	318.47	32.16
2.11	10.53	80.64	29.56	142.57	38.89	318.55	31.67
2.24	10.70	80.99	29.72	142.82	39.03	318.65	31.06
2.37	10.85	81.36	29.88	143.08	39.17	318.75	30.46
2.51	11.01	81.76	30.04	143.36	39.32	318.85	29.87
2.66	11.18	82.18	30.20	143.66	39.47	318.96	29.24
2.82	11.36	82.62	30.37	143.97	39.62	319.08	28.58
2.98	11.53	83.09	30.55	144.31	39.78	319.21	27.88
3.16	11.72	83.59	30.72	144.66	39.93	319.34	27.21
3.35	11.92	84.12	30.90	145.03	40.10	319.48	26.51
3.55	12.13	84.68	31.09	145.43	40.26	319.63	25.80
3.76	12.32	85.28	31.28	145.85	40.43	319.79	25.07
3.98	12.55	85.88	31.44	146.29	40.60	319.95	24.38
4.22	12.77	86.58	31.65	146.76	40.76	320.13	23.64
4.47	13.00	87.28	31.82	147.26	40.93	320.32	22.90
4.73	13.23	87.98	31.99	147.79	41.11	320.52	22.17
5.01	13.47	88.78	32.17	148.35	41.29	320.73	21.46
5.31	13.76	89.68	32.37	148.95	41.47	320.95	20.77
5.62	14.00	90.48	32.54	149.55	41.65	321.19	20.09
5.96	14.27	91.48	32.73	150.25	41.84	321.44	19.45
6.31	14.54	92.48	32.91	150.95	42.01	321.70	18.84
6.68	14.82	93.48	33.08	151.65	42.16	321.98	18.26
7.08	15.14	94.58	33.23	152.45	42.33	322.28	17.72
7.50	15.49	95.78	33.38	153.35	42.52	322.59	17.23
7.94	15.83	97.08	33.55	154.15	42.67	322.93	16.78
8.41	16.17	98.38	33.71	155.15	42.85	323.28	16.35
8.91	16.49	99.78	33.86	156.15	43.00	323.65	15.95
9.44	16.83	101.28	34.03	157.15	43.16	324.05	15.56
10.00	17.14	102.88	34.15	158.25	43.33	324.47	15.16
10.60	17.47	104.48	34.29	159.45	43.50	324.91	14.77
11.20	17.76	106.28	34.43	160.75	43.65	325.38	14.36
11.90	18.11	108.18	34.56	162.05	43.79	325.88	13.95
12.60	18.43	110.18	34.70	163.45	43.93	326.41	13.54
13.30	18.75	112.28	34.85	164.95	44.06	326.97	13.14
14.10	19.07	114.48	34.99	166.55	44.20	327.57	12.73
15.00	19.43	116.88	35.14	168.15	44.32	328.17	12.34
15.80	19.75	119.38	35.28	169.95	44.44	328.87	11.91
16.80	20.08	121.98	35.43	171.85	44.56	329.57	11.49
17.80	20.40	124.78	35.58	173.85	44.67	330.27	11.10
18.80	20.69	127.78	35.75	175.95	44.78	331.07	10.68

Step 1

ET (min)	Drawdown (m)
19.90	20.97
21.10	21.28
22.40	21.57
23.70	21.84
25.10	22.12
26.60	22.37
28.20	22.62
29.80	22.85
31.60	23.08
33.50	23.29
35.50	23.51
37.60	23.72
39.80	23.90
42.20	24.13
44.70	24.32
47.30	24.50
50.10	24.72
53.10	24.96
56.20	25.14
59.60	25.32
63.10	25.51
66.80	25.70
70.80	25.90
74.68	26.11
74.69	26.11
74.69	26.11
74.70	26.11
74.70	26.11
74.70	26.11
74.71	26.11
74.72	26.11
74.72	26.10
74.72	26.10
74.73	26.11
74.73	26.11
74.73	26.11
74.74	26.11
74.74	26.11
74.75	26.12
74.75	26.12
74.75	26.11
74.76	26.11
74.76	26.12
74.77	26.12
74.77	26.11
74.78	26.11
74.78	26.11
74.78	26.11
74.79	26.12
74.80	26.11
74.80	26.12
74.81	26.12
74.82	26.13
74.82	26.12
74.83	26.12
74.84	26.12
74.85	26.12
74.86	26.12
74.87	26.12
74.88	26.13
74.89	26.13
74.91	26.13
74.92	26.12
74.93	26.12
74.95	26.12
74.97	26.12
74.98	26.13
75.00	26.14
75.02	26.13
75.04	26.14
75.06	26.14
75.08	26.13
75.11	26.14
75.13	26.14
75.16	26.18
75.18	26.16
75.21	26.19

Step 2

ET (min)	Drawdown (m)
130.88	35.90
134.28	36.08
138.35	36.28
138.35	36.28
138.36	36.28
138.36	36.28
138.37	36.28
138.37	36.28
138.38	36.27
138.39	36.27
138.39	36.27
138.39	36.28
138.40	36.28
138.40	36.28
138.40	36.28
138.41	36.28
138.41	36.28
138.41	36.27
138.42	36.27
138.42	36.27
138.43	36.28
138.43	36.28
138.43	36.28
138.44	36.28
138.44	36.28
138.45	36.28
138.45	36.28
138.46	36.29
138.46	36.28
138.47	36.28
138.48	36.28
138.48	36.28
138.49	36.28
138.50	36.28
138.51	36.28
138.52	36.29
138.53	36.28
138.54	36.28
138.55	36.29
138.56	36.29
138.57	36.29
138.59	36.29
138.60	36.29
138.62	36.28
138.63	36.30
138.65	36.29
138.67	36.30
138.69	36.30
138.71	36.32
138.73	36.32

Step 3

ET (min)	Drawdown (m)
178.15	44.86
180.55	44.99
183.05	45.11
185.65	45.23
188.45	45.30
191.45	45.43
194.55	45.59
197.95	45.71
201.45	45.92
205.15	46.31
209.15	46.35
213.35	46.82
217.75	46.83
222.45	46.83
227.45	44.55
232.75	42.89
238.35	41.95
244.35	41.39
250.35	41.10
257.35	41.01
264.35	40.99
271.35	41.03
279.35	41.07
288.35	41.74
296.35	42.42
306.35	42.65
316.97	42.26
316.97	42.26
316.98	42.26
316.98	42.26
316.98	42.26
316.99	42.26
317.00	42.26
317.00	42.26
317.01	42.26
317.01	42.26
317.01	42.26
317.02	42.26
317.02	42.26
317.02	42.26
317.03	42.26
317.03	42.25
317.03	42.26
317.04	42.26
317.04	42.25
317.05	42.26
317.05	42.26
317.05	42.26
317.06	42.26
317.06	42.26
317.07	42.26
317.07	42.26
317.08	42.26
317.09	42.26
317.09	42.26
317.10	42.26
317.11	42.26

Step 4

ET (min)	Drawdown (m)
331.97	10.23
332.77	9.85
333.77	9.42
334.77	9.01
335.77	8.63
336.87	8.23
338.07	7.85

Appendix F

Borefield Management Program

D.1 Definition

A borefield management plan (BMP) is a means of managing a borefield and ensuring security of supply in terms of water quality and quantity. The key elements of a BMP should include:

- Monitoring objectives;
- Asset Inventory;
- Monitoring requirements;
- Monitoring frequencies;
- Action Triggers and Procedures;
- Maintenance Register;
- Data and System Review.

The above elements of the BMP are discussed in broad terms in the sections below, and comments are made where applicable, to the new park production bores.

D.2 Objective of Monitoring

D.2.1 Key Objectives

The objective of the BMP are to:

- Identify the risks to the security of the supply;
- Provide early warning mechanisms such that the risks can be alleviated prior to them becoming manifested.

  These early warnings may include issues related to bore condition, water quality, and pump operation which ultimately impacts upon water delivery to the parks. Long term monitoring information can be used to assess broader supply issues associated with the borefield such as possible expansion / augmentation, or deterioration in quality or yield.
- Provide a means of disseminating information regarding the borefield to responsible parties throughout the organisation.

D.2.2 Causes of Adverse Bore Performance

Deterioration of production bore performance (i.e. loss of bore yield) can be caused by a number of factors including:

- Reduction in bore yield
  - Could be caused by chemical or biological precipitation within the pumphouse and transmission casing, or adjacent the bore screen.
  - Excessive interference from neighbouring groundwater users;
  - Regional aquifer behaviour e.g. over pumping, decrease in recharge.
  - Formation plugging

- Structural Bore Collapse
  - Collapse of steel cased bores;
- Sand Pumping
  - A properly designed and developed bore should not pump sand.
  - In fractured rock formations, fretting of lithological materials may cause an increase in fines into the bore.
- Pump Operation
  - Pumps require maintenance to ensure continued performance. Impellor wear and tear may lead to reductions in the pump capacity.
- Water quality changes
  - Some of the factors noted above will effect water quality e.g. regional aquifer behaviour, bore casing integrity, chemical / biological precipitation
  - Landuse activities (on site and surrounding).

D.3 Asset Inventory

An asset inventory is useful in terms of the long term operation of a borefield, particularly when maintenance works or expansion of the borefield is required. The documenting of assets facilitates purchasing, repairs, maintenance histories and performance specification e.g. this report, and the bore completion report (GHD 2008) represent an inventory on the new production bores.

The asset inventory should include as a minimum:

- Production (and monitoring bore) drilling records;
  - Lithological logs and bore construction details;
- Rising main and wellhead specifications;
- Pump database
  - Pump type (make, model, supplier, motor size);
  - Setting depth;
  - Specifications for ordering;
  - Spares for back-up in case of pump failure;
  - Instrumentation (float switching and motor protection).

Included in the asset inventory should be procedures, or preferred suppliers for the removal and maintenance of pumps or other processes / infrastructure involved at the borefield.

D.4 Monitoring Requirements

D.4.1 Parameters to be Monitored

As part of the management of the borefield, monitoring of its operation enables variations to be identified which in turn become early warning signs of risk to security of supply. Monitoring also facilitates forensic enquiries into bore or pump failure. Monitoring should commence prior to commissioning of the borefield (where possible) in order to establish background conditions so that a baseline of information is available for comparison.

Monitoring of the borefield should include:

- Water level
- Groundwater quality
  - Fines content / inspection of filters / tanks / sumps
  - Variations in water quality may reflect bacterial clogging, chemical precipitation and other forms of fouling;
  - Typical analytes: iron (ferrous and ferric), manganese, alkalinity, pH, oxidation – reduction potential, plate count, salinity, turbidity, nitrate.
- Flow rate / pump operation
  - Pump power draw;
  - Pumping water level;
  - Instantaneous and volumetric flow rates;
  - Pressure at bore head.
- Bore Performance
  - Specific capacity / drawdown – flow relationships.

D.4.2 Monitoring Frequencies

The monitoring frequency is a trade off between resources and definition of information trends. It is recommended that monitoring be undertaken at greater frequencies initially to build the knowledge base of the borefield behaviour, however this is less critical in the case of borefields that have been established and operating several years. Verifying borefield performance regularly will ensure that these bores are in the peak condition and regularly maintained so the supply is secure during high demand periods. The frequencies can be reviewed following 1 – 3 years with the objective of the reducing them to optimal levels.

- Water levels
  - The objective of water level monitoring is to build an operational history of groundwater levels (drawdown) in the bores during different stresses on the borefield (e.g. drought, high demand seasons).

  Ideally, automatically recorded water levels on a daily basis are preferred, however this can have high up-front capital costs or be labour intensive. At a minimum, water levels should be recorded prior to, and 1 – 2 months after the completion of the irrigation season e.g. April and November of each year.
- Groundwater Quality
  - Quarterly for the first two years.
- Flow Rate
  - Preferably automatically recorded on a daily basis;
  - Maximum fortnightly frequency for first 18 months;

- Bore Performance Testing
  - Once a baseline has been established for all bores, additional testing should be undertaken every 5 years, or more frequently, if actions are triggered. The testing undertaken as part of the current bore commissioning represents a baseline of information for the bore.
  - If the available drawdown and pumping rates are the same as previous testing, a specific capacity test should provide repeatable specific capacities (assuming that aquifer properties remain constant). Therefore changes in storage capacity (e.g. screen clogging) can be readily identified through performance testing without the need to remove pumps and undertake geophysical inspections.
  - Water level, quality and flow rate monitoring are relatively simple tasks to complete and do not result in loss of supply. Where possible other monitoring works should be completed during programmed maintenance outages (e.g. geophysical downhole camera inspection of casing condition whilst a pump has been removed for repair).
- Pump Performance
  - On a monthly basis initially, which could be extended to quarterly once there is sufficient monitoring data or pump performance and reliability are deemed acceptable. Basic pump performance monitoring includes the pump operating hours, amperage draw and pump starts.
  - Where suspicion is obtained from any of the regular monitoring that a pump is failing either mechanically or electrically, more rigorous testing is required to identified the deterioration in performance. There are several monitoring and testing procedures that enable performance checks on the pump or motor unit both while in operation and other tests with motor leads disconnected. More detailed pump performance monitoring includes:
  - Supply voltage checks by measuring the voltage between phases as large variations in voltage can burn out the motor;
  - Current consumption checks by measuring the amperage on each phase while the pump is operating. The difference in current between the phases should not be more than 5% and the current should always be below that indicated on the information plate attached to the motor. A higher than normal current draw can indicate a number of possible problems with the motor or pump, including burnt motor starter contacts, poor cable connections / joins, variations in voltage, windings failure or mechanical damage within the pump causing additional load.
  - Monitoring the winding resistance between the motor drop cable leads while disconnected from the motor starter cab identify winding or cable problems. The difference between these values should not exceed 5% otherwise the pump would need to be pulled and disconnected from the leads and checked again to find the defect.
  - Isolation resistance of the submersible motors and cables is a means of determining the electrical soundness of the motor and may be useful as an early warning to electrical problems. If the insulation resistance drops to less than 0.5 mOhms the pump should be pulled for motor of cable repair.
  - Pump suppliers normally provide detailed manuals on installation, operation, fault finding and monitoring of their units. This information should be field for future reference as required.

D.5 Action Triggers

Triggers for management response are required during borefield operational periods for:

- Reductions in water quality;
- Changes in groundwater level;
- Loss / reduction in flow rate.

Changes in groundwater quality may be indicative of fouling or impacts associated within the radius of influence of pumping. These changes would prompt trigger actions which may include:

- Re-testing or repeat monitoring as a QA/QC check;
- Hydrogeological review;
- Bore performance testing;
- Geophysical testing (i.e. CCTV, multi-finger calliper, ultra-sonic).

D.6 Maintenance Register

All maintenance and testing works undertaken on the production bores and transfer pumps including headworks modifications, pump removals, bore cleaning etc should be appropriately documented. Files for the production bores should be maintained and an on-going record of events should include the following information:

- Model / make of pump / motor installed, motor capacity (kW), installation date, service dates;
- Record of any pump or motor failure information, results of additional testing and dates;
- Record of outages due to headworks, pipeline or bore maintenance;
- Pump / motor repair or replacement work and relevant dates;
- Installation details of any replacement units.

Pump maintenance is recommended at every 10,000 hrs or 2 years whichever comes first. The maintenance should include removal of the pump, inspection and assessment by appropriate qualified technicians. The maintenance should include a written report on the condition of the pump and motor.

Visual inspection of the motor cooling fluid can identify problems within the motor, whilst lateral and vertical movement of the pump and motor shafts can indicate worn or damaged bearings. If the pump / motor units are proving to be very reliable without any major signs of wear from the assessment, a longer timeframe between overhauls should be considered, alternatively if damage is substantial the timeframe should be reduced. Monitoring and maintenance of pumps is a means of significantly reducing the risk of unexpected and disruptive pump failures. As additional operational and reliability data is collected the performance monitoring and maintenance schedules can be adapted to suit conditions.

Obviously it would be desirable to undertake maintenance on units outside of peak demand periods to ensure that units are in good operating condition leading into the high demand period (e.g. summer).

D.7 Information Management and System Review

GHD recommends that all monitoring information is stored (and backed-up) in a digital format, which facilitates simple information handling and transfer. Microsoft ® Excel ™ or Access ™ databases are useful tools for the management of monitoring data.

It is recommended that a hydrogeological review be completed periodically i.e. biennially. The objective of the review would be to interpret the data to determine:

- Trends
  - Water level, quality and flow behaviour (water usage);
- Forensic review of pump failures (if such have occurred) or supply issues;
- Recommendations regarding improvements or refinements to the monitoring and supply system;
- Review of monitoring procedures, data collection and quality;
- Collation and reporting for management review.

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