Barwon Downs Borefield

Requirements for reports as outlined in the existing licence (BEE032496)

2018

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1. Introduction

Barwon Water's compliance with the Groundwater Extraction Licence No. BEE032496 (formerly #893889) (licence) was provided in annual reports throughout the duration of the licence period.

The licence contains several conditions which must be met upon applying for renewal of the licence. These are documented below:

- First schedule, clause 7
  When BW applies for renewal of this licence, it must submit a report demonstrating how the Barwon Downs wellfield has been operated in accordance with the intent of the REALM model

- Second schedule, clause 5.5b
  When it applies for the renewal of this licence, a report by an appropriately qualified geotechnical consultant that reviews the subsidence monitoring program and includes:
  i. A comparison of actual and predicted subsidence;
  ii. An assessment of the accuracy and reliability of the subsidence measurements undertaken; and
  iii. Recommendations regarding amendments to the program to improve the adequacy, reliability or accuracy of monitoring

- Second schedule, clause 7.2b
  When it applies for the renewal of this licence, a report assessing the degree of dependence of riparian vegetation at the sites specified in sub-clause 7.1 on the regional groundwater system, and that includes recommendations for any further work necessary to ensure their protection.

- Second schedule, clause 9.4b
  When it applies for the renewal of this licence, a report containing an assessment of the loss of flow in the East Barwon River between the stream gauge referred to in sub-clause 9.1 and the aqueduct crossing on the East Barwon River east of Yaugher due to pumping under this licence.

Reports relating to each of these conditions are detailed in the sections below.

2. First Schedule, Clause 7 – Water Resource Modelling

2.1. Licence Condition

Clause 7 of the First Schedule of the licence states that:

"... When Barwon Water applies for renewal of this Licence, it must submit a report demonstrating how the Barwon Downs wellfield has been operated in accordance with the intent of the REALM model."

The licence goes on to state:

"Barwon Water's Greater Geelong water supply system conjunctively uses surface water from the Barwon and Moorabool catchments together with groundwater from the Gerangamete Groundwater Management Area. The most efficient use of the resources dictates that Barwon Water only extracts groundwater during dry periods when surface water supplies are falling. This principle has been incorporated into Barwon Water's REALM model to determine periods when the Barwon Downs wellfield should be operated."

Barwon Water has since updated our water resource modelling software to a program called SOURCE. The intent of the modelling program remains the same as REALM.
The detail around the REALM model triggers is presented below.

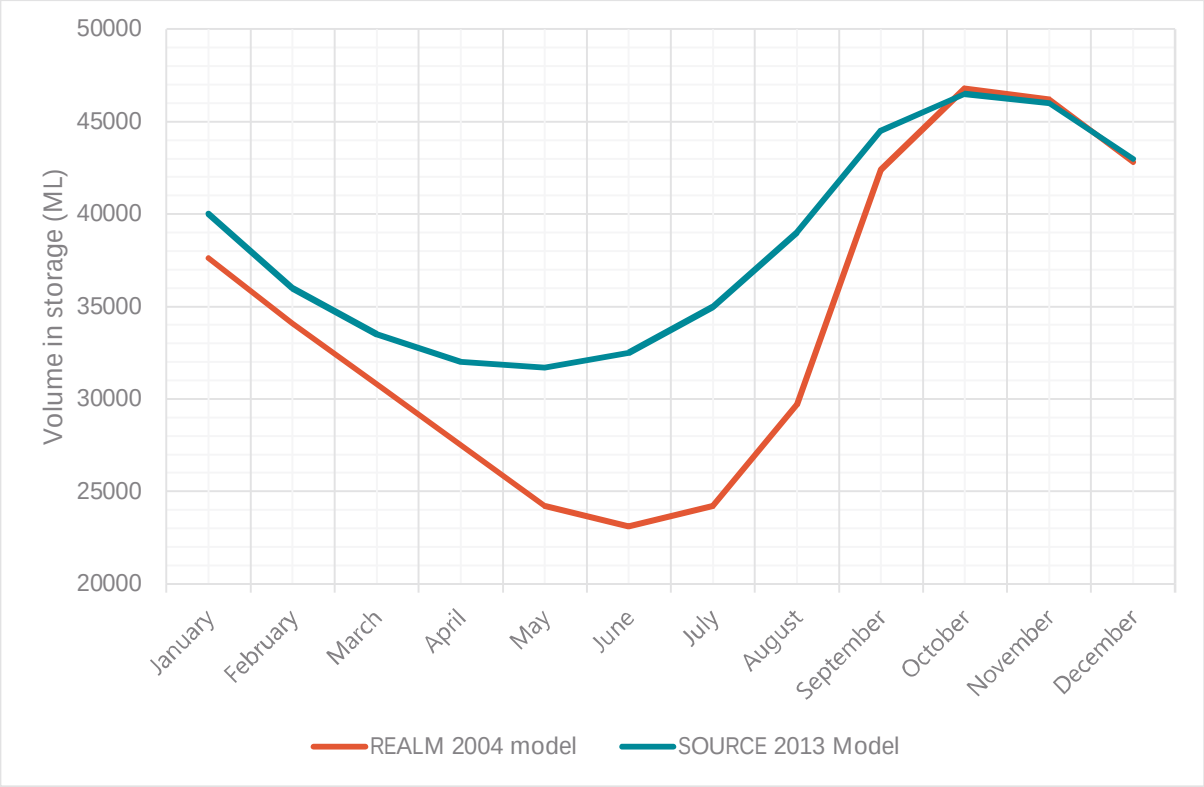
2.2. REALM

The REsource ALlocation Model (REALM), is a computer program that can simulate the operation of both urban and rural water supply systems during droughts as well as during periods of normal and high stream flows. Barwon Water utilised REALM models to prepare for the 2004 Barwon Downs licence submission.

At the time of issue of the licence, the Barwon Downs borefield was to be used as a drought relief tool in times of declining water storages. At that time Barwon Water's only standby source was the borefield. In the model, the use of the borefield was linked to the trigger levels for Stage 1 water restrictions. The trigger to "turn on" the borefield in the REALM model, and subsequent SOURCE model, is shown in the figure and table below.

Barwon Water progressively updated our REALM model over the following 15 years. Updates to the model triggers were made due to population growth as well as the introduction of new standby sources – the Anglesea Borefield in 2009 and the Melbourne Geelong Pipeline in 2012. In 2013, Barwon Water switched to a new product, SOURCE, for our water resource modelling needs.

The triggers set in the model provided direction to Barwon Water management and operators around the need for standby sources and the risks to existing water supplies. The decision to either turn on, or off, extraction from the borefield was not solely driven by the model trigger but also included operational issues, customer feedback and government direction.



Month	Model trigger (ML in storage) 2004 REALM Model	Model trigger (ML in storage) 2013 SOURCE Model
January	37,600	40,000
February	34,100	36,000
March	30,800	33,500
April	27,500	32,000
May	24,200	31,700
June	23,100	32,500
July	24,200	35,000
August	29,700	39,000
September	42,400	44,500
October	46,800	46,500
November	46,200	46,000
December	42,800	43,000

Table 1: Model Trigger Levels

2.3. Compliance with REALM

Barwon Water has operated the borefield in general compliance with the licence, with the exception of minor exceedances of the daily maximum extraction rates in some individual bores. However, there have been no instances during the current licencing period where Barwon Water has exceeded the total daily volumetric limit of 72 ML, total annual extraction volumetric limit of 20,000 ML or 10-year extraction volumetric limit of 80,000 ML.

Table 2 attached, details the months Barwon Water have extracted water from the borefield and the corresponding actual water storage levels to demonstrate operation in accordance with the intent of the REALM model.

Generally, BW has operated in accordance with the intent of the REALM model, that is, "only extracts groundwater during dry periods when surface water supplies are falling".

More specific comments are provided below.

2006-2010 – Millennium Drought

During this period, water storages fell to as low as 14%. The Geelong region was placed on Stage 4 water restrictions to curb demand and had sustained low inflows leading to precariously declining storages levels.

During this period the Barwon Downs Borefield was the only standby source available to supplement the Geelong region water supply and with no other alternative sources to bring online the borefield was heavily relied upon to maintain supply of water and at times it supplied above 70% of Geelong's daily water requirements. Without the use of the borefield Geelong would have almost certainly run out of drinking water. During this period 52,684 ML of groundwater was extracted.

Exceptions to the model triggers are described as follows:

- By January 2006, storage levels had fallen below the model trigger line. Barwon Water made a decision to activate the Barwon Downs Borefield. The process of activating the borefield took several months and involved re-commissioning the bores and treatment plant. The borefield was activated in April 2006. In May and June 2006, the storages had risen slightly back over the model trigger, however given the investment and time to commission the borefield it continued operation. By the end of June 2006, storages fell back below the model triggers.
- Between May and July 2008, the borefield continued to be used despite storage levels above the model triggers. Barwon Water had been in prolonged drought and had not yet recovered, therefore the decision was made to continue operation. By August 2008, storages fell back below the model triggers.

- Between April and August 2010, the borefield continued to be used despite storage levels being above the model triggers. Barwon Water had endured five years of drought and as storages recovered sufficiently, further water was not extracted from the borefield.

2016 – Record dry summer

Barwon Water extracted water from the borefield in 2016. Our decision to activate the borefield was due to record low summer rainfall and storage levels in April 2016 which were below the model trigger in the updated SOURCE model for use of standby sources.

It is noted that we continued to extract between August and December 2016 when storages were above the model trigger range. A comparatively small volume (2150 ML) was extracted during this period, the vast majority of which was extracted in August. The decision was made for operational efficiency reasons.

A total of 3,449ML was extracted during this period.

2.4. Conclusion

This report demonstrates how the Barwon Downs wellfield has been operated in accordance with the intent of the REALM model developed for the licence. Barwon Water only extracted groundwater over the 15 years during dry periods when surface water supplies were falling.

Despite some instances of storage levels being above the model triggers during the millennium drought, and again in 2016, the borefield was a critical water supply source for Barwon Water during that period.

Barwon Water has operated the borefield in general compliance with its groundwater licence and in accordance with the intent of the REALM model.

Table 2: Volume in storages and groundwater extraction when above or below the model trigger

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
January	38,363*	19,291	32,696	24,122	32,008	68,597	75,866	78,956	80,122	65,268	41,593	70,889	60,327
February	34,083*	18,051	30,239	21,062	30,454	73,136	73,322	74,514	74,784	61,687	37,567	66,598	55,481
March	29,175*	15,729	27,646	19,556	28,988	70,285	69,906	69,586	71,250	57,676	33,827	62,595	50,942
April	26,373	14,096	25,742	18,358	28,157	69,514	69,041	66,168	68,618	55,028	30,699	61,268	47,578
May	25,633	13,859	24,662	17,695	28,027	68,684	68,133	63,785	66,944	54,493	30,540	59,157	46,418
June	24,228	13,986	24,243	17,694	28,536	68,605	68,983	63,279	66,152	53,945	30,561	57,628	45,620
July	24,196	15,693	24,470	17,781	29,961	72,455	80,296	64,701	69,210	54,035	32,229	57,327	48,430
August	28,332	23,766	25,970	20,664	32,406	85,387	86,496	66,043	77,235	55,919	46,994	59,038	52,545
September	27,941	28,010	30,174	27,762	55,854	86,313	91,263	79,192	79,374	58,693	56,425	64,979	62,270
October	26,976	29,202	28,428	33,725	68,578	85,423	92,066	83,328	76,543	55,538	72,131	73,984	
November	24,702	30,284	26,453	34,895	69,143	83,744	88,776	86,681	72,972	51,806	80,400	70,206	
December	21,494	35,911	25,394	34,926	69,848	80,576	84,889	85,564	67,846	46,606	75,935	66,150	

Groundwater Extraction when below model trigger

Groundwater Extraction when above model trigger

*No extraction, however below model trigger

3. Second Schedule, Clause 5.5b – Subsidence

3.1. Licence Condition

Second schedule, clause 5.5b states:

> "When it applies for the renewal of this licence, a report by an appropriately qualified geotechnical consultant that reviews the subsidence monitoring program and includes:
>
> i. A comparison of actual and predicted subsidence;
>
> ii. An assessment of the accuracy and reliability of the subsidence measurements undertaken; and
>
> iii. Recommendations regarding amendments to the program to improve the adequacy, reliability or accuracy of monitoring."

This section (Section 3) outlines the results of land subsidence monitoring undertaken for the Barwon Downs Borefield over the past 15 years and provides a comparison with predicted subsidence and the existing licence triggers. It also provides commentary regarding the accuracy and reliability of the data and makes recommendations regarding amendments (if any) to the program to improve the data.

In accordance with the requirement for an appropriately qualified geotechnical consultant to review the subsidence program, Barwon Water engaged Jacobs to provide a specific report. That report is provided as Attachment 1.

3.2. Existing Licence Triggers

Clause 5.1 of the Second Schedule in the licence states the following:

"Barwon Water must not extract groundwater to the extent that it causes subsidence to exceed 200mm measured at any station in the subsidence monitoring network specified in the fourth schedule".

As can be seen in the data in table 3 below, monitoring of ground levels at the 15 measuring stations listed in the Fourth Schedule of the licence has shown subsidence to be well within the maximum allowable limit of 200mm stipulated in the licence. Further, the maximum subsidence recorded at any of the 15 measuring stations since 2003 was 89mm in 2018.

3.3. Comparison of actual and predicted subsidence

In 2002, consultants SKM (now Jacobs) conducted land subsidence modelling to estimate ground movements under varied groundwater extraction scenarios. This modelling indicated that under the 100 year pumping scenario at 4 GL/year, the net land subsidence would be in the order of 77mm at observation bore G13, 46mm at observation bore W7, and 64mm at observation bore YEO22.

Bore G13 is located in close proximity to survey mark 26470032 which has experienced net land subsidence of 40mm of since 2003, with a maximum of 63mm of subsidence recorded in 2009 and 2010.

Bore W7 is located in close proximity to survey mark 38090025 which has experienced net land subsidence of 34mm since 2003 and a maximum of 48mm of subsidence recorded in 2012.

Bore YEO22 has no survey marks within close proximity, however measuring stations 39870025 and 26470036 are both approximately 1,500 metres away and have recorded a net subsidence of 21mm and 24mm respectively during the 2018 monitoring. A maximum subsidence level of 37mm was recorded in 2011 for measuring station 39870025 while a maximum of 63mm was recorded at station 26470036 in 2010.

Under an increased pumping scenario with extraction of 8 GL/year, the maximum subsidence predicted by the modelling undertaken by SKM was 125mm[1]. As outlined above, since 2003 the maximum subsidence recorded has been 89mm at measuring station 38090024 in 2018.

These results indicate that the observed land subsidence has remained below the maximum predicted values, and well within the maximum of 200mm as stipulated in the licence.

3.4. Assessment of the accuracy and reliability of the subsidence measurements undertaken

Currently, ellipsoidal heights are resected using GPS net observation from 4 base stations (Bambra, Dewings, Forrest, Yeodene) which are located outside the zone of influence from groundwater drawdown. This method is considered more accurate (±20mm) compared to the traditional GPS AHD heighting method which has an accuracy of 30-50mm. The rigour of GPS results has also been improved through provision of access to a second satellite system in 2009.

Each base station is levelled from the 2 adjacent deep seated marks located at that the base station. All measuring stations are measured twice from base stations, then a third time from another monitoring station to compare results. This methodology has also subsequently been adopted to monitor the land subsidence in accordance with the Bulk Entitlement (Anglesea Groundwater) Order 2009.

Despite this, in our efforts for continual improvement, Barwon Water is investigating installation of solar panel and battery infrastructure at the Deans Marsh Base Station to enable continuous level monitoring. Barwon Water is also investigating installation of fixed monuments/pillars at the 3 remaining base stations to allow seating of survey equipment directly to the station which will improve accuracy through removing the need for additional measurement of height between measuring station and survey equipment.

[1] Barwon Downs Borefield Groundwater and Subsidence Modelling Project – Barwon Water Subsidence Modelling, Sinclair Knight Merz, May 2001

3.5. Recommendations regarding amendments to the program to improve the adequacy, reliability or accuracy of monitoring

As outlined above, monitoring for net and maximum subsidence associated with groundwater pumping from the Barwon Downs Borefield indicates subsidence remains well within the maximum limits set in the licence and as predicted in the SKM (now Jacobs) land subsidence modelling undertaken in 2002. The extent and frequency of monitoring is also considered sufficient for identification of any significant ground movement resulting from groundwater extraction under the licence. As such it is not proposed to expand the survey network or increase the frequency of monitoring.

Table 3: Subsidence Monitoring – Ellipsoidal height differences

Ellipsoid Height Differences as compared to 2003 data (mm)																
Primary Control Station ID	June 2004	May 2005	May 2006	June 2007	Dec 2007	June 2008	July 2009	May 2010	July 2011	June 2012	June 2013	June 2014	June 2015	June 2016	June 2017	June 2018
20790040	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20880024	-8	-2	-8	-18	-16	-8	-21	-25	-25	-12	-23	-20	-21	-11	-19	-19
20590052	-6	0	+6	-3	-12	+7	+8	+8	+15	+8	+14	+1	+3	+13	+27	+11
39780106	-1	0	+3	-27	-9	-15	-16	-30	-14	-16	-30	-24	-25	-11	-19	-15
Monitoring Station ID																
32390045	-6	+1	-11	-42	-42	-36	-66	-75	-47	-42	-54	-42	-42	-47	-35	-39
32390046	+3	+1	-8	-20	-19	-20	-47	-50	-32	-25	-46	-32	-28	-37	-25	-27
26470027	-6	+2	-2	+6	-11	-22	-37	-45	-36	-39	-43	-42	-35	-32	-37	-36
26470032	-5	+5	-1	-43	-30	-36	-63	-63	-35	-40	-45	-42	-37	-42	-39	-40
26470033	-8	+3	-13	-40	-35	-36	-65	-76	-38	-39	-44	-38	-35	-46	-39	-36
26470036	+5	+10	+1	-32	-23	-30	-48	-63	-42	-38	-39	-33	-23	-33	-33	-24
39870025	-1	-4	-5	-15	-11	-17	-23	-34	-37	-31	-25	-29	-33	-27	-27	-21
39870026	-3	0	+2	-9	-6	-15	-22	-38	-37	-33	-31	-31	-35	-21	-28	-23
38090024	-4	-3	+12	+8	NA	0	-26	-25	-18	-30	-15	-36	-36	-81	-74	-89
38090025	-5	-5	+9	-12	NA	-5	-30	-33	-28	-48	-23	-33	-35	-27	-27	-34
38090026	-5	0	+6	-15	NA	-6	-33	-31	-30	-41	-30	-33	-28	-31	-31	-33

4. Second Schedule, Clause 7.2b – Vegetation

4.1. Licence Condition

Second schedule, clause 7.2b states:

"When it applies for the renewal of this licence, a report assessing the degree of dependence of riparian vegetation at the sites specified in sub-clause 7.1 on the regional groundwater system, and that includes recommendations for any further work necessary to ensure their protection."

4.2. Response

During the development of Barwon Waters technical works program, as outlined our submissions accompanying this application for renewal (section 3) Barwon Water sought to better understand knowledge gaps in the current application and address items such as dependent riparian vegetation.

Vegetation condition across the catchment has been monitored regularly since the mid-1990s, although early surveys were inconclusive due to difficulties in separating the influences of surface water, groundwater, land use change and the provision of environmental flows. Based on a review completed by SKM (2008), Barwon Water revised the vegetation monitoring network to ensure the monitoring locations are located in areas where vegetation is likely to groundwater dependent. Shallow groundwater bores have also been installed at each location and are monitored with data loggers.

Over the last 15 years, vegetation surveys have been undertaken by SKM and Ecology Australia in 2008; Jacobs in 2014/2015 and again in 2016. An additional study was also undertaken to determine the groundwater dependency of deeper rooted vegetation (e.g. trees) in 2015.

As a result, assessing the degree of dependence of riparian vegetation on the regional groundwater system, was incorporated into the technical works program. That assessment is set out in the following technical reports:

- Barwon Downs vegetation monitoring – vegetation monitoring report (Jacobs, 2015)
- Barwon Downs groundwater dependent terrestrial vegetation investigations – understanding tree water use (Jacobs, 2016)
- Barwon Downs vegetation survey report (Jacobs, 2017)

The recommendations regarding the protection of riparian vegetation are detailed in these reports and summarised in the report below:

- Barwon Downs Borefield Groundwater Assessment Report (Jacobs, 2018)

5. Second Schedule, Clause 9.4b – Stream flow

5.1. Licence Condition

Second schedule, clause 9.4b states:

"When it applies for the renewal of this licence, a report containing an assessment of the loss of flow in the East Barwon River between the stream gauge referred to in sub-clause 9.1 and the aqueduct crossing on the East Barwon River east of Yaugher due to pumping under this licence."

5.2. Response

During the development of Barwon Waters technical works program, as outlined in submissions accompanying this application for licence renewal (section 3). Barwon Water sought to better understand knowledge gaps in the current application and address items such as loss of flow in the East Barwon River.

A numerical groundwater model has been used to assess both the historical impacts of the borefield and the predicted future impacts. The groundwater model includes the East Barwon River and the change in river flux has been quantified. Further site specific work has been recommended to confirm the model predictions.

As a result, the above requirement was incorporated into the technical work and is set out in the following technical reports:

- Predicted impacts from future operation of the Barwon Downs borefield (Jacobs, 2018)

The recommendations regarding the assessment of the loss of flow in the East Barwon River are detailed in that report and the proposed outcomes are summarised in the report below:

- Barwon Downs Borefield Groundwater Assessment Report (Jacobs, 2018)

6. Conclusion

This report has been prepared to respond to the requirements of the existing licence which require the provision of the information set out above upon application for renewal of the licence.

Attachment 1 – Geotechnical review of subsidence monitoring for Barwon Downs Groundwater Extraction Licence (Jacobs, 2018)

Barwon Downs Hydrogeological Studies 2016-2017

Barwon Water

Geotechnical review of subsidence monitoring for Barwon Downs Groundwater Extraction Licence

GT.0001 | 1

26 November 2018

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Barwon Downs Hydrogeological Studies 2016-2017

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Executive Summary

Jacobs has undertaken an assessment of the current subsidence monitoring program being implemented at the Barwon Downs Borefield based on information provided by Barwon Region Water Authority. The subsidence monitoring network specified in the Fourth Schedule of the Groundwater Extraction Licence No. BEE032496 (formerly # 893889) has been monitored on a yearly basis since 2003 until 2018.

Assessment of the monitoring data indicates that subsidence measured at the monitoring stations are well within the trigger limit of 200 mm stipulated in the Licence and has remained below the maximum subsidence predicted by the modelling undertaken by SKM in 2002.

Barwon Water has adopted a new method for measuring the ellipsoidal heights of the monitoring stations. This method with an accuracy of ±20 mm, is considered more accurate compared to the traditional GPS AHD heightening method. Besides that, in its efforts for continual improvement, Barwon Water is also investigating the following improvements to the method of measurement.

i) Installation of solar panel and battery infrastructure at the Deans Marsh Base Station to enable continuous level monitoring; and

ii) Installation of fixed monuments/pillars at the 3 remaining base stations to allow seating of survey equipment directly to the station, which will improve accuracy.

The extent and frequency of current monitoring scheme are considered sufficient for identification of any significant ground subsidence resulting from groundwater extraction under the Licence. As such, it is not required to expand the monitoring network or increase the frequency of monitoring.

Important note about your report

The sole purpose of this report is to present the outcomes of a review undertaken by Jacobs for Barwon Region Water Authority, of the current subsidence monitoring program in connection with the Barwon Downs Borefield.

In preparing this report, Jacobs has relied upon, and presumed accurate, any information (or confirmation of the absence thereof) provided by the client and from other sources. Except as otherwise stated in the report, Jacobs has not attempted to verify the accuracies or completeness of any such information. If the information is subsequently assessed to be false, inaccurate, or incomplete, then it is possible that our observations and conclusions as expressed in this report may change.

Jacobs has prepared this report in accordance with the usual care and thoroughness of the consulting profession, for the sole purpose described above and by reference to applicable standards, guidelines, procedures, and practices at the date of issue of this report. For the reasons outlined above, however, no other warranty or guarantee, whether expressed or implied, is made as to the data, observations, and findings expressed in this report, to the extent permitted by law. Opinions and judgements expressed in the report are based on Jacobs' understanding and interpretation of current regulatory standards and should not be construed as legal opinions.

This report should be read in full and no excerpts are to be taken as representative of the findings. No responsibility is accepted by Jacobs for use of any part of this report in any other context. This report has been prepared on behalf of, and for the exclusive use of, Barwon Region Water Authority, and is subject to and issued in accordance with, the provisions of the contract between Jacobs and the Barwon Region Water Authority. Jacobs accepts no liability or responsibility whatsoever for, or in respect of, any use of, or reliance upon, this report by any third party.

1. Introduction

Jacobs was commissioned by Barwon Region Water Authority to undertake a review of the current subsidence monitoring program as part of the requirements for renewal of their Groundwater Extraction Licence No. BEE032496 (formerly # 893889). The license to extract groundwater from the Gerangamete Groundwater Management Area was authorised by Southern Rural Water and is valid until 30 June 2019.

Clause 5.5 of the Second Schedule of the Groundwater Extraction License requires Barwon Water, when they apply for renewal of the Licence, to submit a report by an appropriately-qualified geotechnical consultant that reviews the subsidence monitoring program and includes:

i) a comparison of actual and predicted subsidence;

ii) an assessment of the accuracy and reliability of the subsidence measurements undertaken, and

iii) recommendations regarding amendments to the program to improve the adequacy, reliability or accuracy of monitoring.

The current subsidence monitoring network consists of four deep seated bench marks control clusters (high stability marks), and eleven monitoring stations as presented in Table 1. Measurements of levels were undertaken using GPS.

Table 1: Subsidence monitoring network

	Station ID	Easting (z54)	Northing (z54)
Control Clusters			
Yeo	20790040	730262	5745488
Forrest	39780106	734047	5731948
Dewings	20880024	742309	5736919
Bambra	20590052	752872	5741632
Monitoring Stations			
	32390045	740327	5738869
	32390046	742196	5743862
	26470027	734015	5737951
	26470032	737430	5741001
	26470033	738685	5740722
	36470036	735959	5743011
	39870025	745547	5751969
	39870026	733833	5745378
	38090024	749124	5753920
	38090025	745547	5751969
	38090026	746148	5746544

The following documents were provided by Barwon Water for undertaking the review.

i) Subsidence monitoring data of the measuring stations listed in Table 1 for the period from May 2003 to June 2018; and

ii) SKM Report, “Barwon Downs Borefield Groundwater and Subsidence Modelling” dated 2002.

Geotechnical review of subsidence monitoring for Barwon Downs Groundwater Extraction Licence

JACOBS

This geotechnical report presents the results of subsidence monitoring undertaken for the Barwon Downs Borefield over the past 15 years (from 2003 until 2018) and provides comparisons with the trigger value stipulated in the Licence and the estimated subsidence predicted by SKM's groundwater and subsidence modelling in 2002. It also provides commentary on the accuracy and reliability of the data and makes recommendations for improving the current subsidence monitoring program, if any.

2. Assessment of Subsidence Monitoring Results

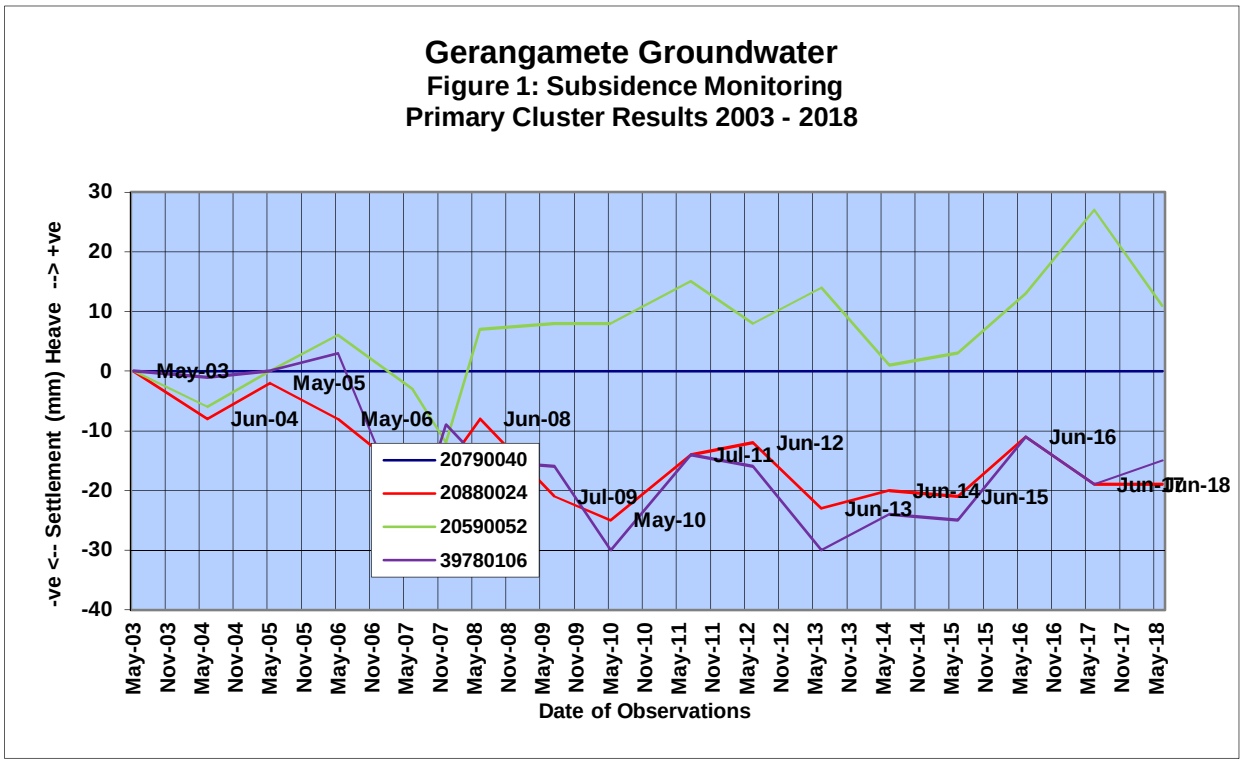
2.1 Subsidence Monitoring Results

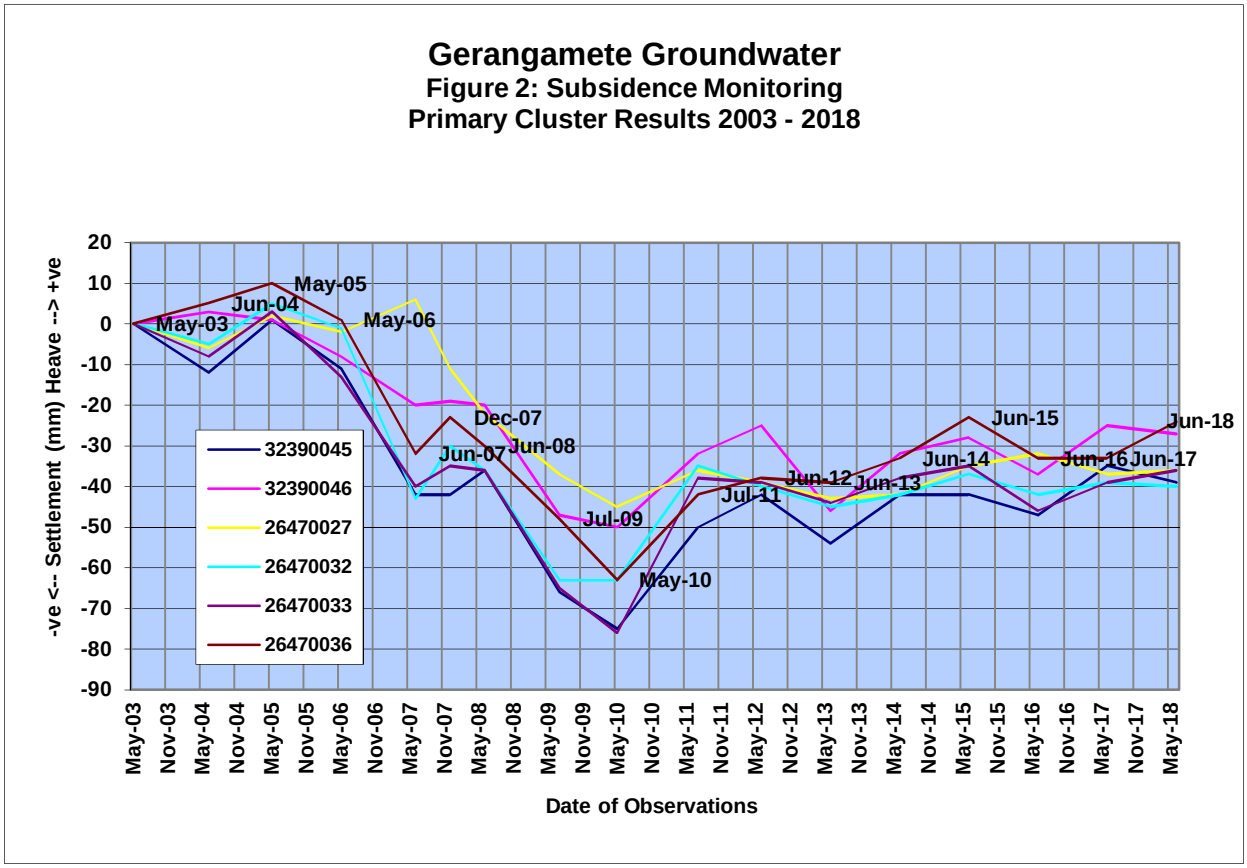
The subsidence monitoring results for the period from May 2003 until June 2018 are summarised in Table 2 and plotted in Figures 1, 2 and 3. Figure 1 presents the settlements of the four primary control stations while Figure 2 shows settlements of monitoring stations 32390045, 32390046, 26470027, 26470032, 26470033 and 26470036 and Figure 3, monitoring stations 39870025, 39870026, 38090024, 38090025 and 38090026.

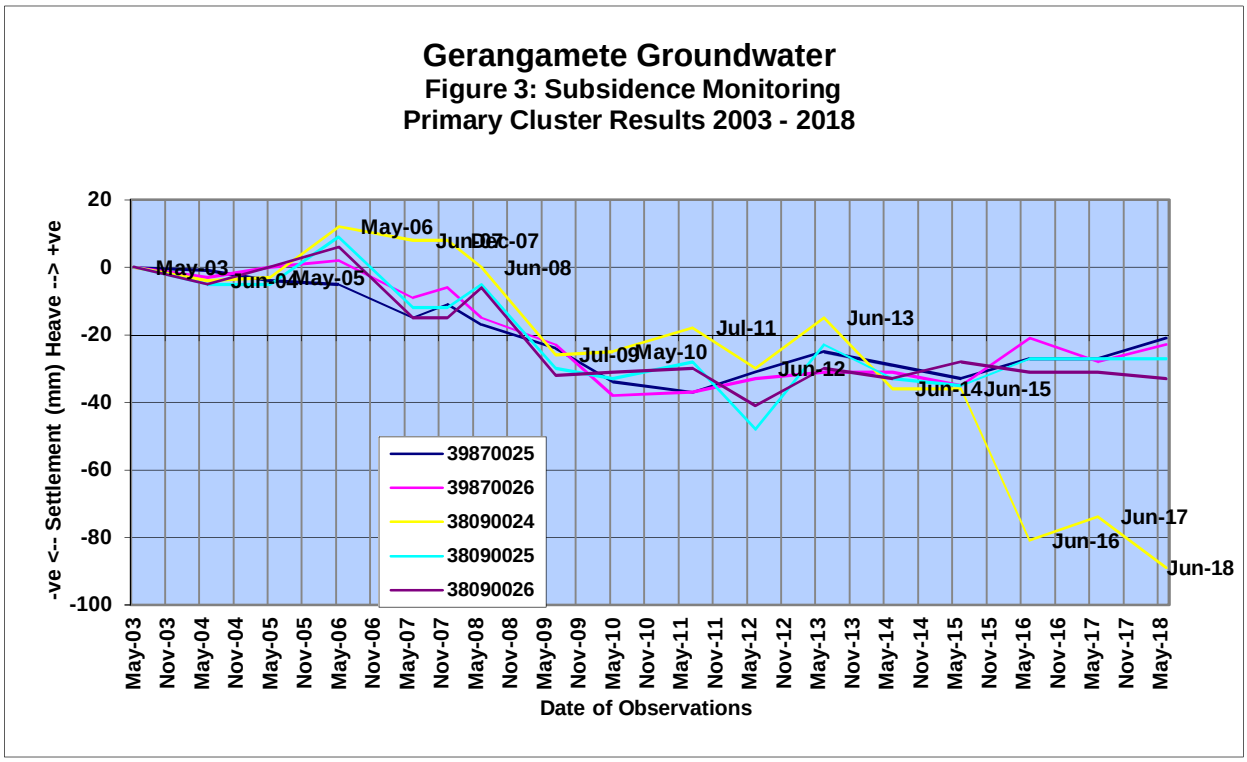
Table 2: Subsidence Monitoring – Ellipsoidal height differences

Ellipsoid Height Differences as compared to 2003 data (mm)																
Primary Control Station ID	June 2004	May 2005	May 2006	June 2007	Dec 2007	June 2008	July 2009	May 2010	July 2011	June 2012	June 2013	June 2014	June 2015	June 2016	June 2017	June 2018
20790040	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20880024	-8	-2	-8	-18	-16	-8	-21	-25	-25	-12	-23	-20	-21	-11	-19	-19
20590052	-6	0	+6	-3	-12	+7	+8	+8	+15	+8	+14	+1	+3	+13	+27	+11
39780106	-1	0	+3	-27	-9	-15	-16	-30	-14	-16	-30	-24	-25	-11	-19	-15
Monitoring Station ID																
32390045	-6	+1	-11	-42	-42	-36	-66	-75	-47	-42	-54	-42	-42	-47	-35	-39
32390046	+3	+1	-8	-20	-19	-20	-47	-50	-32	-25	-46	-32	-28	-37	-25	-27
26470027	-6	+2	-2	+6	-11	-22	-37	-45	-36	-39	-43	-42	-35	-32	-37	-36
26470032	-5	+5	-1	-43	-30	-36	-63	-63	-35	-40	-45	-42	-37	-42	-39	-40
26470033	-8	+3	-13	-40	-35	-36	-65	-76	-38	-39	-44	-38	-35	-46	-39	-36
26470036	+5	+10	+1	-32	-23	-30	-50	-63	-42	-38	-39	-33	-23	-23	-33	-24
39870025	-1	-4	-5	-15	-11	-17	-24	-34	-37	-31	-25	-29	-33	-27	-27	-21
39870026	-3	0	+2	-9	-6	-15	-23	-38	-37	-33	-31	-31	-35	-21	-28	-23
38090024	-4	-3	+12	+8	NA	0	-26	-25	-18	-30	-15	-36	-36	-81	-74	-89
38090025	-5	-5	+9	-12	NA	-5	-30	-33	-28	-48	-23	-33	-35	-27	-27	-27
38090026	-5	0	+6	-15	NA	-6	-32	-31	-30	-41	-30	-33	-28	-31	-31	-33

Notes: i) Monitoring station 38090024 was damaged and repaired in 2015. The subsidence from year 2016 does not include subsidence that might have occurred between the 2014 and 2015 readings.
ii) A new monitoring station was installed at 38090025 in June 2017.


Gerangamete Groundwater
Figure 1: Subsidence Monitoring
Primary Cluster Results 2003 - 2018
-ve <-- Settlement (mm) Heave --> +ve
Date of Observations
20790040
20880024
20590052
39780106
May-03
May-05
Jun-04
May-06
Jun-08
Jul-09
May-10
Jul-11
Jun-12
Jun-13
Jun-14
Jun-15
Jun-16
Jun-18


Gerangamete Groundwater
Figure 2: Subsidence Monitoring
Primary Cluster Results 2003 - 2018
-ve <-- Settlement (mm) Heave --> +ve
Date of Observations
32390045
32390046
26470027
26470032
26470033
26470036
May-03
Jun-04
May-05
May-06
Jun-07
Dec-07
Jun-08
Jul-09
May-10
Jul-11
Jun-12
Jun-13
Jun-14
Jun-15
Jun-16
Jun-17
Jun-18



2.2 Existing Licence Triggers

Clause 5.1 of the Second Schedule of the Groundwater licence stipulates that Barwon Water must not extract groundwater to the extent that it causes subsidence to exceed 200 mm, as measured at any measuring station in the subsidence monitoring network specified in the Fourth Schedule of the Licence.

As presented in Table 2 and Figures 1, 2 and 3, the monitoring data obtained from the four (4) primary control stations and the eleven (11) monitoring stations listed in the Fourth Schedule of the Groundwater Licence indicate that the subsidence are well within the maximum allowable limit of 200 mm. Except for the monitoring station 38090024, the rest of the measuring stations recorded highest subsidence in either year 2009 or 2010. This was following intensive operation of Barwon Downs Borefield during the peak of the millennium drought to maintain water security for Geelong and the surrounding areas. Monitoring undertaken in 2018 indicates some recovery of the subsidence with the maximum subsidence of 40 mm measured at monitoring station 26470032.

Two of the measuring stations experienced unusual ground movements i.e. primary control station, 20590052 and monitoring station, 38090024. Control station 20590052 recorded a maximum heave of 27 mm in June 2017 and a heave of 11 mm in June 2018. Monitoring station 38090024 experienced a sudden subsidence of 45 mm in June 2016 and has since stabilised as it recorded a subsidence of 89 mm in June 2018. The cause of the sudden increase in subsidence in 2016 should be investigated and if found necessary, the station may need to be replaced.

The maximum recorded subsidence at any of the fifteen (15) measuring stations since 2004 was 89 mm, which was measured at monitoring station 38090024 in 2018.

2.3 Comparison between Actual and Predicted subsidence

In 2002, SKM (now Jacobs) was commissioned by Barwon Water to develop both groundwater and subsidence models. SKM used the Compac Model to estimate subsidence at three designated subsidence sites for 100 years Pumping and No Pumping scenarios. A summary of the estimated net subsidence at each of the modelled subsidence assessment sites is presented in Table 3.

Table 3: Net modelled subsidence at G13, W7 and YEO22

Estimated Net Subsidence (m) due to 100 years of Pumping			
Pumping Scenario	**G13**	**W7**	**YEO22**
1 (8,000 ML/a)	0.125	0.084	0.090
2 (900 ML/a)	0.035	0.015	0.042
3 (4,000 ML/a)	0.077	0.046	0.064

The results of the modelling completed by SKM indicated that under the 100 years pumping scenario at 4 GL/year, the net ground subsidence would be in the order of 77 mm at observation bore G13, 46 mm at observation bore W7 and 64 mm at observation bore YEO22.

Bore G13 is located in close proximity to monitoring station 26470032 which has experienced a maximum net land subsidence of 63 mm in 2009 and 2010 and a net land subsidence of approximately 40 mm since 2012.

Bore W7 is located in close proximity to monitoring station 38090025 which has experienced a net land subsidence of less than 50 mm since 2003.

Bore YEO22 has no monitoring stations within close proximity, the nearest monitoring stations 39870025 and 26470036 are both approximately 1,500 metres away and have recorded a net subsidence of 21 mm and 24 mm respectively during the 2018 monitoring. A maximum net subsidence of 37 mm was recorded in 2011 at monitoring station 39870025 while a maximum of 63 mm was recorded at station 26470036 in 2010.

Under an increased pumping scenario with extraction of 8 GL/year, the maximum net subsidence predicted by the modelling completed by SKM was 125 mm at Bore G13. As shown in Table 2, the maximum recorded subsidence since 2003 is 89 mm measured at monitoring station 38090024 in 2018.

The subsidence monitoring results over the past 15 years has remained less than the maximum net subsidence predicted by previous modelling, and well within the trigger limit of 200 mm stipulated in the Licence.

3. Accuracy and Reliability of Subsidence Monitoring Program

The method adopted by Barwon Water for subsidence measurement includes resetting the ellipsoidal heights using GPS net observation from 4 base stations (Bambra, Dewings, Forrest and Yeodene) which are located outside the zone of influence from groundwater drawdown. This method is considered more accurate (±20 mm) compared to the traditional GPS AHD heighting method which has an accuracy of 30-50 mm. The rigour of GPS results has also been improved through provision of access to a second satellite system in 2009.

Since 2009, in accordance with the Bulk Entitlement (Anglesea Groundwater) Order 2009, each base station is levelled from the two adjacent deep seated marks located at that base station. All measuring stations are measured twice from base stations, then a third time from another monitoring station to compare results.

Despite the above, Barwon Water in their efforts for continual improvement, is also investigating the following improvements.

i) Installation of solar panel and battery infrastructure at the Deans Marsh Base Station to enable continuous level monitoring; and

ii) Installation of fixed monuments/pillars at the 3 remaining base stations to allow seating of survey equipment directly to the station which will improve accuracy through removing the need for additional measurement of height between measuring station and survey equipment.

As outlined above, monitoring for net and maximum subsidence associated with groundwater pumping from the Barwon Downs Borefield indicates subsidence remains well within the maximum limits stipulated in the Licence and the prediction in SKM (now Jacobs) land subsidence modelling undertaken in 2002. The extent and frequency of monitoring are considered sufficient for identification of any significant ground movement resulting from groundwater extraction under the Licence. As such it is not required to expand the survey network or increase the frequency of monitoring.