2016 - 2017 Technical Works Program

Barwon Water

Yeodene Swamp Study

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Important note about your report

The sole purpose of this report is to present the findings of a desktop and field investigation carried out by Jacobs for Barwon Water ('the Client') in connection with the Yeodene Swamp ("the site"). This report was produced in accordance with and is limited to the scope of services set out in the contract between Jacobs and the Client.

The scope of work was limited to two sampling events conducted in autumn and winter. This report is based on assumptions that the site conditions as revealed through these sampling events are indicative of conditions throughout the site. The findings are the result of standard assessment techniques used in accordance with normal practices and standards, and (to the best of Jacobs' knowledge) they represent a reasonable interpretation of the current conditions on the site.

Sampling techniques, by definition, cannot determine the conditions between the sample points and so this report cannot be taken to be a full representation of the hydrological and hydrogeological conditions. This report only provides an indication of the likely hydrological and hydrogeological conditions.

Conditions encountered when site work commences may be different from those inferred in this report, for the reasons explained in this limitation statement. If site conditions encountered during site works are different from those encountered during Jacobs' site investigation, Jacobs reserves the right to revise any of the findings, observations and conclusions expressed in this report.

The passage of time, manifestation of latent conditions or impacts of future events may require further examination of the project and subsequent data analysis, and re-evaluation of the data, findings, observations and conclusions expressed in this report.

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Executive Summary

KEY FINDINGS

- This study has characterised the chemical and physical processes occurring in and around Yeodene (Big) Swamp to improve the understanding of the swamp's behaviour and how that affects the volume and quality of water being released downstream.

- Building on previous technical studies, the following is known:
    - The monitoring program has shown that groundwater levels in the regional aquifer have declined. This has caused an adverse impact in lower reaches of Boundary Creek, through the mechanism of reduced flow in Boundary Creek.
    - The regional aquifer is present at the surface (outcrops) in the middle reach of Boundary Creek which is also known as Reach 2. Historically Reach 2 was a gaining reach (i.e. groundwater flows into the creek), however it is now a losing reach, where the creek loses flow to groundwater, through seepage.
    - The use of the borefield over the past 30 years has been responsible for most (two thirds) of the reduction in groundwater flow to Boundary Creek. The dry climate experienced during the same period accounts for the remaining part of the reduction (about one third). As the borefield was anticipated to impact stream flows in this part of the catchment, a supplementary flow of 2 ML/day has been released by Barwon Water into the upper reaches of Boundary Creek since 2002 to offset the reduction in groundwater flow to the creek.
- A review of existing information undertaken for this study highlighted:
    - Although "McDonalds Dam" is required by licence conditions to pass all inflows to the Dam (including the supplementary flow) between October and June, the flow measured downstream of the dam was significant less than upstream of the dam during the summer low flow months. Barwon Water discharges the supplementary flow in accordance with the conditions of the groundwater licence. Since monitoring commenced in 2014, flows immediately downstream of McDonalds Dam during the warmer months (November to April) were significantly less than 2 ML/day, confirming that all the supplementary flow is not passed through the dam during critical low flow periods.
    - Since 1999, significant declines in pH of water have occurred in Reach 3 of Boundary Creek and are related to the drying of acid sulfate soils in Yeodene Swamp. Drying acid sulfate soils allows acid water and heavy metals to discharge to Boundary Creek.

- The field program conducted during this study determined:
    - Surface water flow in Boundary Creek often increases between McDonalds Dam and Damplands and this is likely to be the result of surface runoff from the catchment and potentially inflow to the creek from the local alluvial aquifer that is very close to the creek.
    - Surface water flow losses between the Damplands and Yeodene Swamp are as a result of groundwater recharge to the alluvial aquifer and evapotranspiration (water use by vegetation near the stream). The losses through this part of the catchment will fluctuate throughout the year depending on the seasonal climate. The surface water losses ranged between 2.9 and 9.9 ML/day in May and August respectively, and are representative of the Damplands and Swamp wetting up after a period of no flow. The losses will be higher during the wet months due to the high flows in the creek and are less significant because there is more water available at this time of year.
    - The most significant changes in water quality in Boundary Creek occur through Yeodene Swamp and are consistent with the effects of acid sulfate soils. These effects include reduced pH, increased salinity, and increased concentrations of sulfate and dissolved metals.
    - Winter high flow conditions of greater than 15 ML/day in 2017 did not dilute acidic inputs or the concentration of dissolved metals significantly, which indicates that significantly more water is required for dilution to be used as a mechanism to improve water quality.

- Analysis of the data and field program concluded that:
    - The decline in pH (acidic water) appears to be correlated to reduced flow and in particular, periods when Boundary Creek has recorded cease to flow (no flow) at the Yeodene stream gauge.
    - It can be asserted that the processes contributing to flow reductions in Boundary Creek during 1990-1992 and since 1999 are the key factors driving pH change at those times. Those factors are known to be primarily groundwater extraction and contribution from a drier climate.
    - Cease to flow events have caused:
        - The swamp to dry and switch from a reducing to an oxidising environment,
        - Potential Acid Sulfate Soils turning into Actual Acid Sulfate Soils, and
        - Release of acidic water with high concentrations of dissolved metals downstream of the swamp.
    - The drying of the swamp and subsequent acidic water being released has been further exacerbated due to the 2 ML/day supplementary flow not reaching the swamp because the flows have not been passed at McDonalds Dam over the summer months.

- A review of possible management options to remediate the swamp indicated that:
    - Of the six options considered, inundating the swamp is recommended as the most technically feasible option. As evidenced in other case studies, improvements in water quality (increasing pH levels) are expected to be achieved within six months. Key features of this management option are:
        - Increasing the supplementary flow initially from 2 ML/day to 3 ML/day as recorded downstream of McDonalds Dam to account for the losses in this reach and meet the recommended low flow requirement of 0.5 ML/day at Yeodene. It is possible that additional supplementary flows could be required during extreme dry weather events to prevent cease to flow periods at the Yeodene stream gauge (downstream of the swamp). Ongoing monitoring will help to assess the requirement for the supplementary flow.
        - Hydraulic barrier to close off the fire trenches and agricultural drains at the eastern end the swamp to minimise water flow out of the swamp, therefore helping to keep areas saturated.

- Ongoing adaptive management would likely include:
    - Ongoing soil, surface water and groundwater monitoring, and
    - Regular site visits during summer months to complete spot flow gauging and surface water quality monitoring.

BACKGROUND

The Yeodene (Big) Swamp is a peat swamp that contains acid sulfate soils that have dried out, resulting in the release of acidic water to the lower reach of Boundary Creek and ultimately, the Barwon River.

The current state of the swamp reflects the culmination of numerous events throughout the catchment’s history. This includes:

- The initial deposition of acid sulfate soils in the swamp,
- The construction of nearby agricultural drains and farming in the area over 100 years ago,
- Step changes in climate (including the Millennium Drought),
- The construction of an on-stream dam upstream of the swamp,
- Groundwater extraction by Barwon Water and the release of supplementary flows to Boundary Creek, and
- Peat fires in the swamp and the excavation of trenches by CFA to control these fires.

Before the study that is documented in this report there has been limited assessment of the swamp to understand the relative contributions of each of these factors and the hydraulic controls of the swamp.

In addition to Yeodene swamp itself, there have been limited scientific studies that have focussed on characterising the lower reaches of Boundary Creek. While monitoring downstream of Yeodene Swamp (Yeodene gauge at Colac-Forrest Rd) has been conducted since 1979, subsequent changes in the flow and quality of the water as it moves past this gauge and into the Barwon River have not been undertaken.

OBJECTIVES

The objectives of the Yeodene Swamp study were to:

- Improve the conceptual understanding of the processes that affect the volume and quality of water between McDonalds Dam and the Barwon River
- Recommend future management options for Yeodene Swamp to improve the condition and water quality downstream of the swamp (i.e. Reach 3 of Boundary Creek).

APPROACH

This study involved three stages of work:

1. Review available data on groundwater levels, surface water flows and water quality changes over time.
2. An in-field program involving:
    a. The installation of six shallow bores (< 3m) in Yeodene Swamp to improve understanding of groundwater level fluctuations.
    b. Surface water flow and water quality monitoring upstream and downstream of Yeodene Swamp to understand changes and potential causes.
3. To determine the feasibility of possible remediation options to neutralise the acid sulfate soils in Yeodene Swamp.

SUMMARY OF FINDINGS

Improved conceptual understanding

The review of existing data, together with the new information collected during the field program, has significantly improved the conceptual understanding of the lower reaches (Reach 2 and 3) of Boundary Creek.

A conceptual diagram focussed on Reach 2 is shown below in Figure 0-1-1. For the purpose of describing the conceptual understanding, Boundary Creek is divided into three reaches that are hydraulically and hydrogeologically distinct:

- **Reach 1** (upstream of McDonalds Dam): the creek flows over basement and receives minor groundwater inflows. This section is considered to be gaining water from surrounding aquifers.
- **Reach 2** (downstream of McDonalds Dam to Yeodene Swamp): the creek flows over the regional aquifer (Lower Tertiary Aquifer). This reach used to receive groundwater inflow, however groundwater extraction and a drier climate have lowered the groundwater level in the aquifer and the creek now mostly loses water in Reach 2 via seepage. Yeodene Swamp is located at the downstream end of the Reach 2 and is situated on the boundary of the regional aquifer and the regional aquitard. This section is considered to be losing water to the surrounding alluvial aquifer.
- **Reach 3:** The creek flows over aquitard and receives minor groundwater inflow. This section is considered to be gaining water (albeit to a very minor degree).

The key features of the conceptual model are summarised in Table 0-1-1.

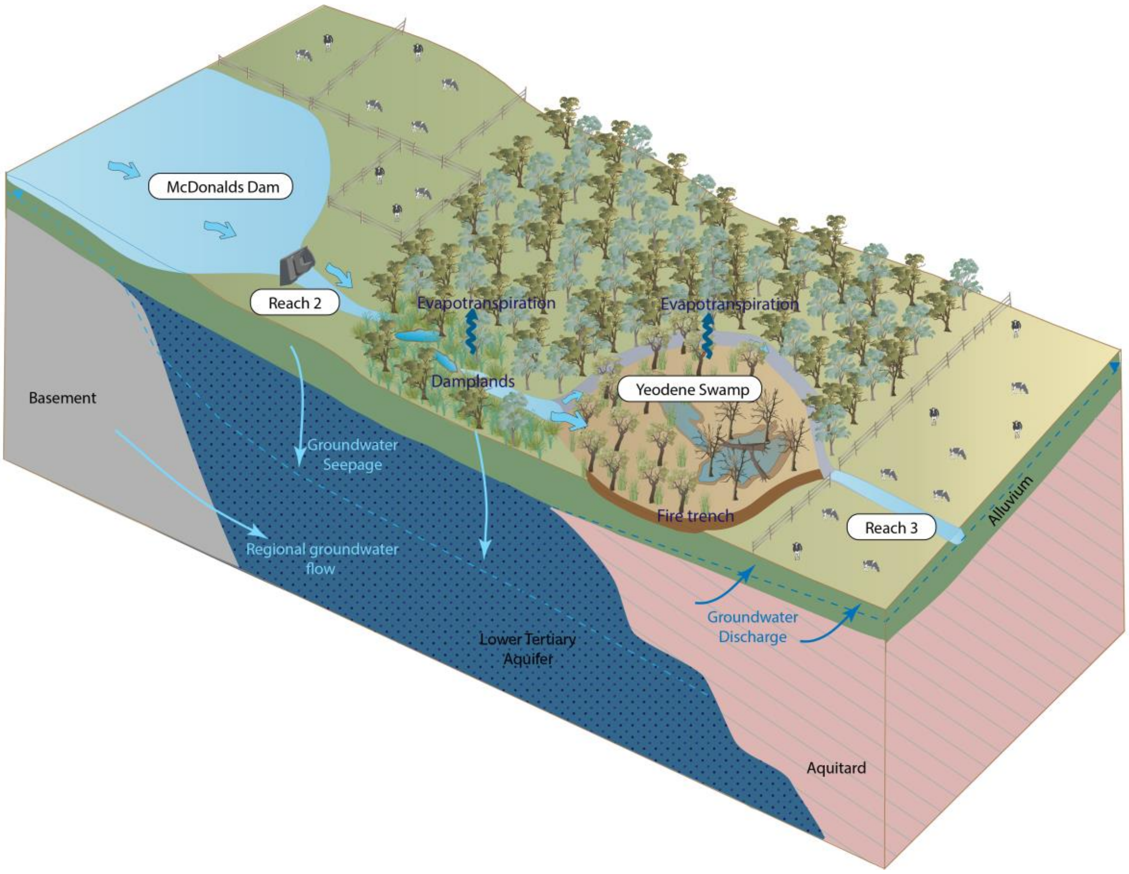

Figure 0-1-1 Conceptual diagram of Reach 2 in Boundary Creek

Table 0-1-1 Key features of the conceptual model of the lower reaches of Boundary Creek

Feature	Key findings
Catchment history	The major changes to the Boundary Creek catchment include: • Land clearing and channelisation of sections of Boundary Creek through the 1900s for agriculture and farming, • Installation of an on-stream dam (McDonalds Dam) subject to licence conditions of 160 ML capacity in 1979, • Major groundwater extraction by Barwon Water between 1985-1990, 1997-2001 and 2005-2010. • Peat fires at Yeodene Swamp in 1997, 1998 and 2006. • Excavation of fire trenches in 2010 by the CFA for fire control.
Hydrogeology	• Saturated alluvial sediments are likely to be present upstream of Yeodene Swamp as a localised perched aquifer (that is, separated to a large extent from the regional aquifer). • Depth to watertable in the regional aquifer is 10-15 m below ground level upstream of Yeodene Swamp. • Saturated peat sediments in Yeodene Swamp are hydraulically separated from the underlying regional aquifer (LTA) by the aquitard. • The eastern end of swamp comprises saturated alluvial deposits overlying aquitard. • The aquitard thins to the west and is absent upstream of the swamp, however the exact location where aquitard is absent is not known.
Groundwater quality	• Groundwater in the centre of the swamp is most affected by acid sulfate soils and less so downstream of the swamp (A3 and TB1a).

Feature	Key findings
	• Groundwater upstream of the swamp and in Reach 3 (downstream of the Yeodene stream gauge) is relatively unaffected by acid sulfate soils.
Surface water flow	• Review of existing data showed that since monitoring commenced in 2014, flows downstream of "McDonalds Dam" during the warmer months (November to April) were less than 2 ML/day. • Surface water flows increase between "McDonalds Dam" and the top of the Damplands, which is likely to be result of surface runoff from the catchment and potential inflow from the local (perched) alluvial aquifer. • Two spot flow measurement showed that surface water flow declines through the Damplands and Yeodene Swamp which is interpreted to be a result of groundwater recharge and evapotranspiration. The losses will vary seasonally, and were 2.9 ML/day in May 2017 and 9.9 ML/day in August 2017 which represents the swamp re-wetting after a period of no flow. • Surface water flows are variable gaining and losing in Reach 3.
Surface water quality	• Review of existing data showed that since 1999, significant declines in pH have occurred in Reach 3 of Boundary Creek and are related to the drying of acid sulfate soils in Yeodene Swamp. • The most significant changes in water quality occur through Yeodene Swamp. These changes are consistent with the effects of acid sulfate soils including reduced pH, increased salinity, and increased concentrations of sulfate and dissolved metals.
Groundwater – surface water interaction	• Immediately downstream of "McDonalds Dam" to the Damplands the spot flow measurements indicate the creek could be gaining water. Inflows to the creek are likely to be result of surface runoff from the wider catchment and potential inflow from the local (perched) alluvial aquifer. This is new information and improves the conceptualisation of the Reach 2. • The Damplands and Yeodene Swamp were observed to be losing water to groundwater, which is consistent with the existing conceptualisation. • Reach 3 of Boundary Creek is variable gaining/losing to groundwater, consistent with the existing conceptualisation.
Water balance	• The greatest losses of surface water occur through the Damplands and Yeodene Swamp. This is estimated to range between 2.9 ML/day in May and 9.9 ML/day in August 2017. • These volumes of water are representative of the swamp re-wetting after a period of no flow, noting that losses will be higher during the wet months due to the high flows in the creek. These losses are less significant as there is increased availability of water at this time of year. • It is estimated that the majority of the loss is recharge to groundwater with evapotranspiration making up less than 1 ML/day during these months. • Evaporation losses will be higher during the summer months and could be up to 2.5 ML/day.
Vegetation	• This part of Yeodene Swamp was not a permanent swamp historically (i.e. greater than 50 years ago) as the tree ferns and trees would not have established unless there was periodic drying. This could be the result of the construction of agricultural drains in the area. • The trees and tree ferns are likely to have died as a result of root death caused by permanent inundation. • Inundated area is un-vegetated as a result of the acidic water which is toxic to most plant species.

Remediation options for Yeodene Swamp

Potential management strategies to improve the quality and volume of water flowing in Reach 3 of Boundary Creek were considered. Six options were reviewed:

1. Do nothing
2. Direct treatment of soils with neutralising agents in Yeodene Swamp
3. In-drain water treatment with limestone in Reach 3 of Boundary Creek (downstream of swamp)
4. Diluting acidic discharge in Reach 3 of Boundary Creek.
5. Revising flow release location to Reach 3 of Boundary Creek and isolating the swamp from the creek.
6. Inundating Yeodene Swamp

A summary of the feasibility of each option is provided below in Table 0-1-2.

Table 0-1-2 Summary of the key findings of the potential management options

Option	Feasibility for Yeodene Swamp	Rationale
Do nothing	Unacceptable	• Yeodene Swamp will continue to release acidic water in Reach 3. This is considered unacceptable because acid releases will continue for several hundred years. • Groundwater levels upstream of Yeodene Swamp will take at least 25-30 years to recover to pre-pumping levels. In addition to this, the swamp is highly unlikely to recover naturally with the fire trenches and drains at the eastern end of the swamp and predicted climate change. This means that the swamp cannot be rehabilitated without intervention.
Treatment of soils	Low-Moderate	• Significant works would be required to access the entire swamp to distribute neutralising agents, which will be very disruptive to existing flora and fauna. • Significant costs associated with first application and subsequent applications are likely to be required.
Installation of a lime drain in Reach 3	Low	• A limestone drain has the potential to improve water quality during low flow periods, however there would be limited benefit during high flow events. • Significant capital costs would be required which would result in major modifications to Reach 3 and ongoing maintenance would also be necessary. Furthermore, water quality in Yeodene Swamp would not improve.
Diluting acidic discharge	Not feasible	• Volumes of water required for dilution cannot be sourced in this region and would increase flooding and adversely impact Reach 3: ○ 250 ML/day during low flows ○ 60 ML/day during high flows
Revising flow release location	Low	• Require the hydraulic isolation of Yeodene Swamp from Boundary Creek. • Improve water quality in Reach 3 under summer low flow conditions, however likely to cause adverse impacts on water quality under high flow conditions when the swamp floods as pent up acid would be flushed out in high flows. • This would increase drying in the swamp, which would exacerbate the acid sulfate soils in the swamp.
Inundating Yeodene Swamp	Moderate - High	• Key indicator for low pH events is “cease to flow” conditions at the Yeodene Swamp. This objective of inundating the swamp is to prevent cease to flow events at Yeodene. • Technically feasible and cost effective option to inundate swamp by increasing supplementary flows and infilling fire trenches and agricultural drain at eastern end. Approach to complete this would involve: ○ Infill the fire trenches and block the agricultural drain, ideally before a summer period to allow the swamp to retain more water over the winter months. ○ Minimum flow required initially is 3 ML/day as measured below McDonald’s Dam. • Low flow requirement of 3 ML/day is a best estimate based on a detailed assessment of the historical data. It is possible that more water could be required for short time periods during very dry conditions. Equally it’s also possible that this volume could be reduced to 2 ML/day within 2-3 years as the swamp remains saturated. • Ongoing adaptive management is required that involves regular monitoring and site visits are recommended to ensure the minimum flow requirement is meeting the objective.

CONCLUSIONS

This Yeodene Swamp study has improved the conceptual understanding of water related processes in the lower reaches of Boundary Creek. The improved understanding was used to assess potential remediation options to improve the condition of the Yeodene Swamp and subsequent water quality issues in Reach 3 of Boundary Creek.

Inundating Yeodene Swamp to reduce the availability of oxygen to create reducing conditions, could ultimately reinstate the acid generation profile of the Swamp to pre 1999 conditions and is considered to be both technically feasible and is likely to be cost effective. A review of the historical data and an estimate of the losses through the Damplands and the swamp, suggest that approximately 3 ML/day is likely to be required (as measured at “McDonalds Dam”) to ensure the swamp remains saturated and the low flow recommendation is met at the Yeodene stream gauge.

In addition to the increased supplementary flow, the fire trenches and agricultural drain at the eastern end the swamp would also need to be closed off using a hydraulic barrier to minimise water losses from the swamp by drainage.

RECOMMENDATIONS

It is recommended that in order to improve the volume and quality of water draining the Yeodene Swamp, and to rehabilitate the swamp itself, permanent inundation should be further investigated as a remediation strategy.

Monitoring data suggests that an initial increase of flow of approximately 3 ML/day measured downstream of “McDonalds Dam” is likely to be sufficient to achieve this outcome.

Recommendations to implement this remediation strategy are:

- Undertake a soil sampling and analysis program to confirm properties of the peat soils and their capacity to re-wet.
- Confirm design to block fire trenches and agricultural drain.
- Undertake capital works to infill trenches and agricultural drain as soon as practicable.
- Automate flow release from “McDonalds Dam” to ensure minimum 3 ML/day is released between November and June as soon as practicable.
- Continue groundwater and surface water monitoring.
- Install data loggers in bores YS01, YS02 and YS05.
- Decommission bores YS03, YS04, YS06.
- Regular site visits (e.g. monthly) between November and May to complete spot flow gauging and surface water quality monitoring.

1. Introduction

1.1 Barwon Downs region

The Barwon Downs bore field is located approximately 70 km south west of Geelong and 30 km south east of Colac (refer to Figure 1-1). The surrounding land is a mixture of agriculture and state forest. A substantial proportion of the study area has been farmed for over a century which has resulted in some parts of the landscape being highly modified compared to the surrounding natural environment.

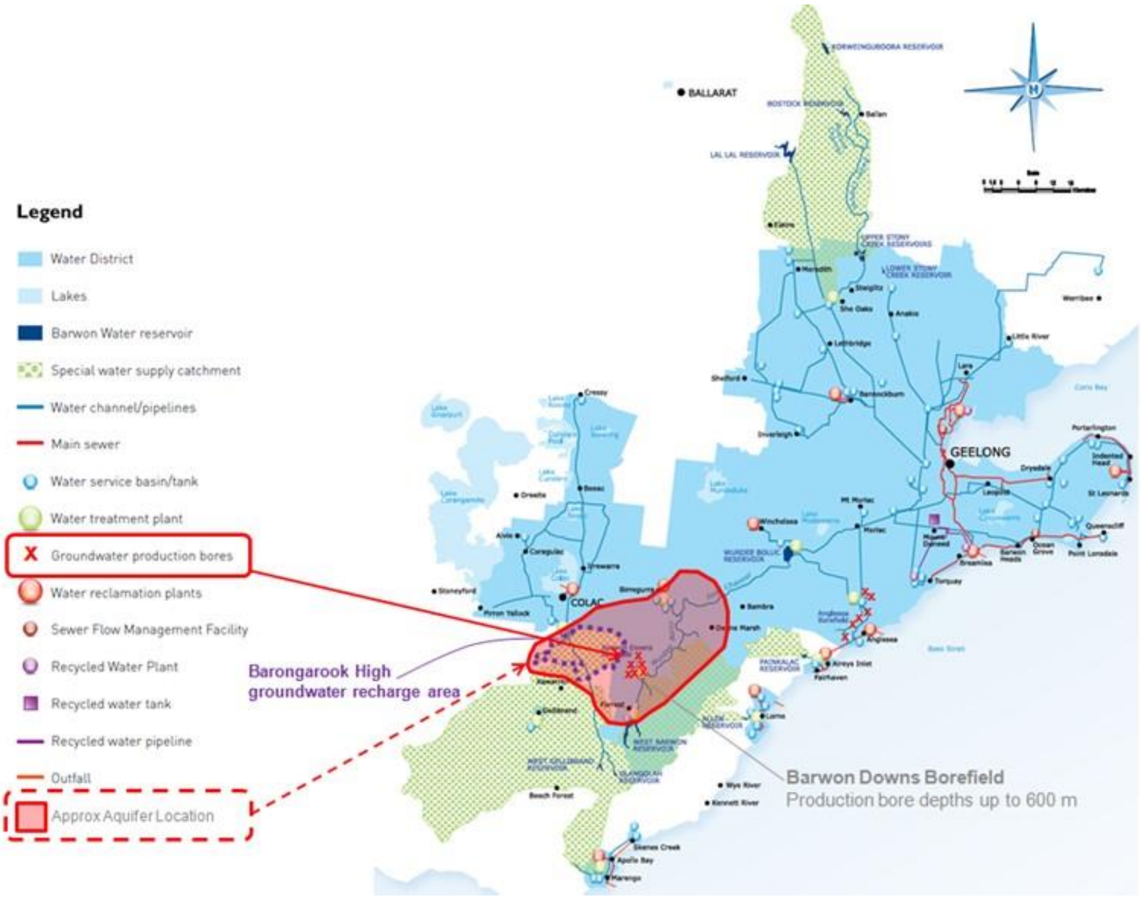

Figure 1-1 Map of the Barwon Downs region including the aquifer extent and the primary groundwater recharge area.

The regional groundwater system extends beneath two surface water catchments, the Barwon River catchment and the Otways Coast catchment.

The Barwon River and its tributaries rise in the Otway Ranges and flow north through Forrest and Birregurra. The Barwon River West Branch and East Branch drain the southern half of the catchment and come together just upstream of the confluence with Boundary Creek. Boundary Creek flows east across the Barongarook High and joins the Barwon River around Yeodene.

The Otways Coast catchment is a large catchment with many rivers that flow towards the coast. The Gellibrand River is in the Otways Coast catchment and rises near Upper Gellibrand and flows in a westerly direction towards Gellibrand. The Gellibrand River discharges to the ocean at Princetown.

The borefield taps into an underground source of water, known as the Lower Tertiary Aquifer, with depths of up to 600 metres at the borefield (see Figure 1-2). The aquifer covers an area of approximately 500 km2 below the surface and is connected to the surface in both the Barwon River catchment (Barongarook High) and the Otways Coast catchment near Gellibrand. Barongarook High is the main recharge area of the aquifer because of its unconfined nature.

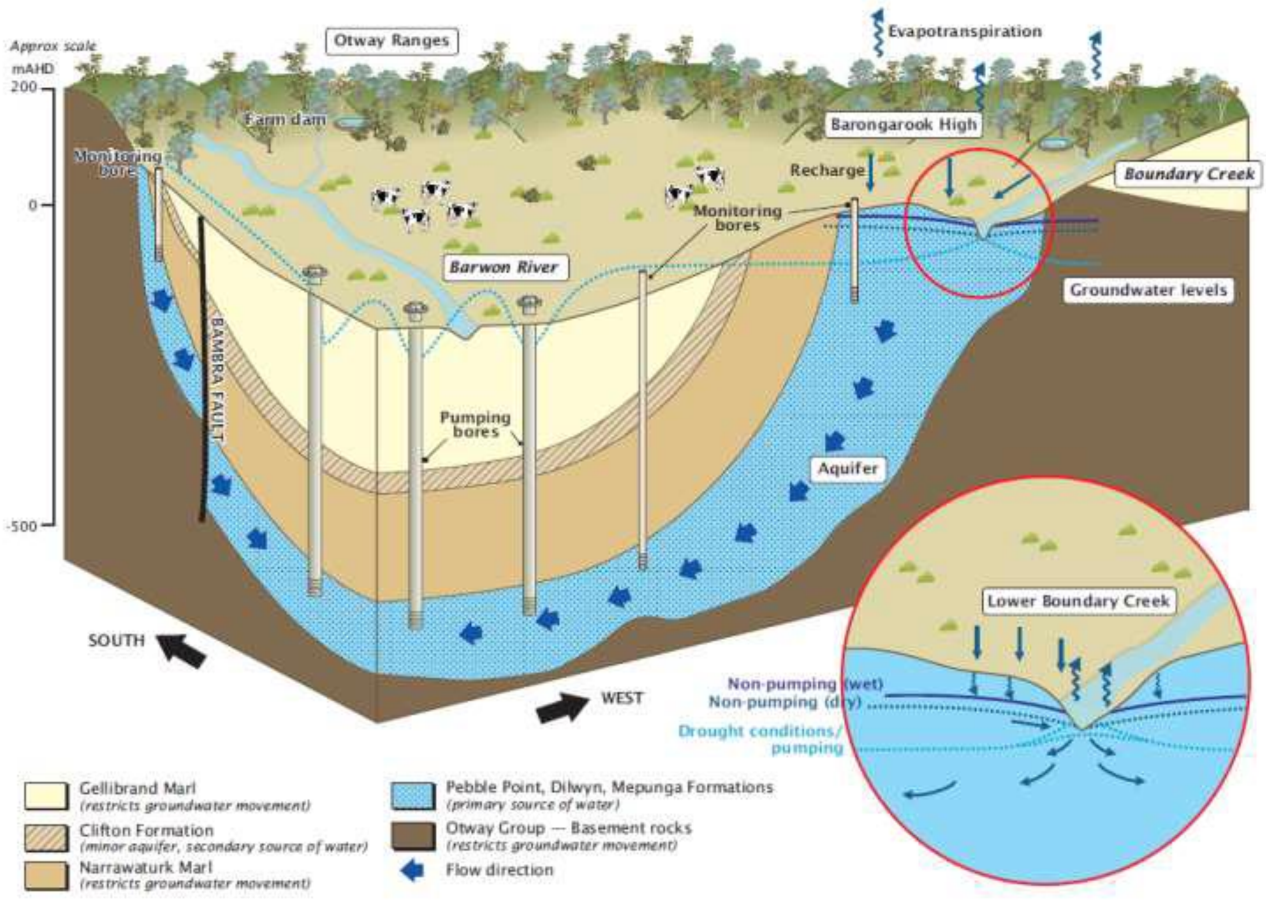

Figure 1-2 Schematic of the Lower Tertiary Aquifer and where it outcrops at the surface.

1.2 History of the Barwon Downs borefield

1.2.1 Borefield history

In response to the 1967-68 drought, when water supplies reached critical levels, the Geelong Waterworks and Sewerage Trust (now Barwon Water) began investigating groundwater resources as a means of supplementing surface water supplies used for the Geelong region. Investigations conducted in the Barwon Downs region revealed a significant groundwater resource with potential to meet this need.

In 1969 a trial production bore was built and tested close to the Wurdee Boluc inlet channel at Barwon Downs. With knowledge gained from these results another bore was built at nearby Gerangamete in 1977. A long term pump testing programme from 1987-1990 confirmed that the borefield should be centred on Gerangamete.

There are now six production bores in the borefield each between 500 and 600 metres deep. Pumps in each bore are capable of providing daily flows of up to 12 megalitres (ML) per day per bore. The pumped water is treated by an iron removal plant prior to transfer to Wurdee Buloc Reservoir. Total borefield production capacity is 55 ML per day.

1.2.2 Groundwater extraction

Barwon Water operates the borefield in times of extended dry periods. This has occurred only five times in the last 30 years. The borefield is a critical back up source for Barwon Water because it is buffered from climate variability due to the depth and large storage capacity of the aquifer, whereas surface water catchments are susceptible to seasonal fill patterns mostly driven by rainfall.

Although extraction occurs infrequently, large amounts of groundwater are drawn when needed to supplement surface water storages during drought. This is completed in compliance with the groundwater licence (refer to Section 1.3). This operational philosophy of intermittent pumping has been an effective way to provide customers with security of supply, especially in times of prolonged dry conditions.

To date, Barwon Water has extracted the following volumes from the aquifer:

- 3,652 ML from February to April in 1983 due to drought,
- 19,074 ML during a long term pump test in the late 1980s,
- 36,817 ML during the 1997 - 2001 drought,
- 52,684 ML during the 2006 – 2010 millennium drought, and
- 3,449 ML in 2016 to boost storages after a record dry summer.

Groundwater extraction has supplemented surface water supply by a total of 115,676 ML equating to approximately 30 per cent of the maximum volume of water that may be taken in any period of 100 years according to the current licence conditions (400,000ML).

1.2.3 Licence history

The first licence was issued in 1975 but did not come into effect until 1982, as the bores were not brought into operation until the 1982-83 drought. This was the first time the borefield was used to supply water to Geelong. The licence issued by the State Rivers and Water Supply Commission (now Southern Rural Water) was to allow Barwon Water to operate four production bores based on the following conditions:

- Extraction for the purpose of urban water supply;
- Maximum daily extraction rate of 42.5 ML;
- Maximum annual extraction rate of 12,600 ML;
- Maximum ten-year extraction rate of 80,000 ML; and
- Periods of licence renewal of 15 years (1975 – 1990).

The licence was subsequently renewed for two periods of five years up to 2000. From 2000, the licence was temporarily extended three times for a total of four years to allow the licence renewal to take place through to 31 August 2004.

In 2002[1], Barwon Region Water Authority (now Barwon Water) applied to renew the Barwon Downs borefield licence for extraction of groundwater to meet urban water supply needs. The application proposed the following:

- Maximum daily extraction rate of 55 ML;
- Maximum annual extraction rate of 20,000 ML;
- Maximum ten-year extraction rate of 80,000 ML;

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[1] *Note: Bulk Entitlement was considered in 2002 so that the Upper Barwon System could be managed conjunctively. This was put aside as the view at the time was that the rights to groundwater should continue to be contained in a licence and subject to regular review.*

- Long term (100-year period) average extraction rate of 4,000 ML/year; and
- Licence renewal period of 15 years.

From 2004 to 2006, the licence was temporarily extended to allow for the licence renewal to take place. Licence conditions were drafted by the panel taking into consideration the findings of the technical groups and the submissions received. This licence is valid to 30 June 2019.

A timeline of events relating to the Barwon Downs borefield is shown in Figure 1-3.

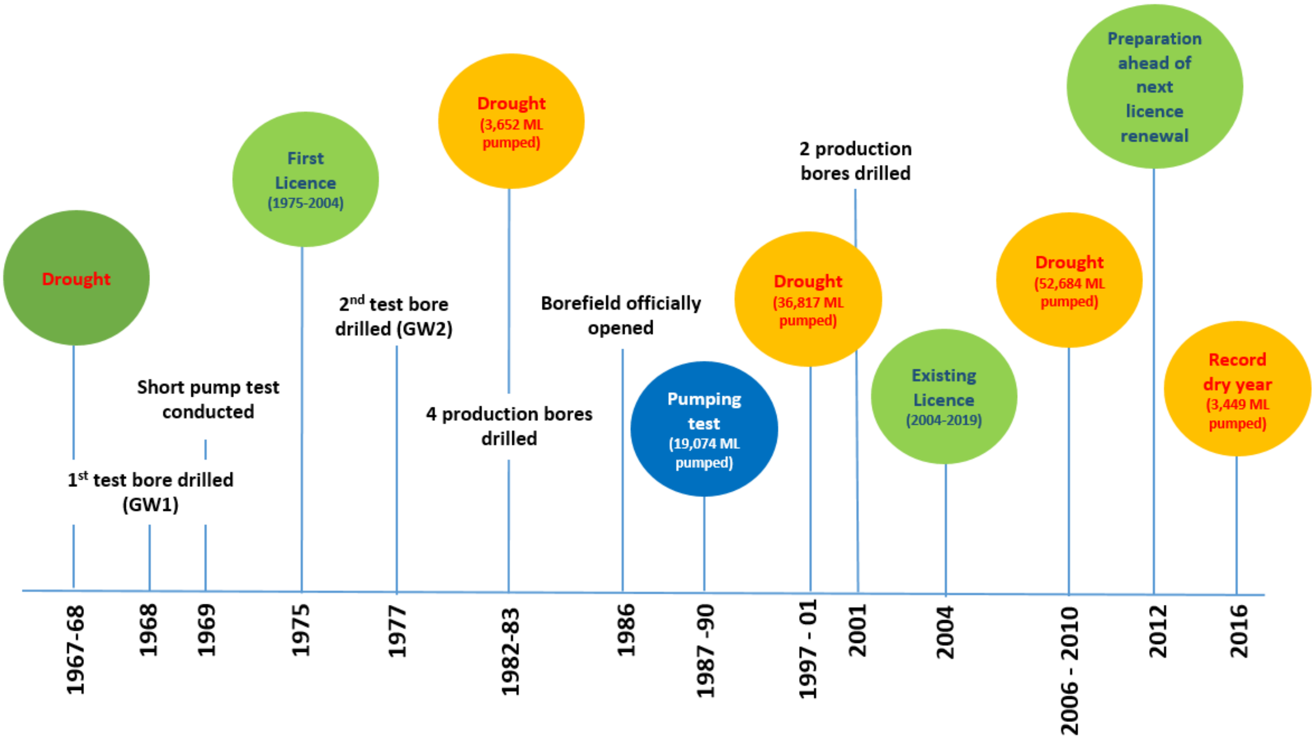

Figure 1-3 Timeline of events that surround the development and use of the Borefield.

1.3 Current groundwater licence

The Barwon Downs borefield is operated under licence from Southern Rural Water. This licence was granted in 2004 and is due for renewal by June, 2019.

This licence makes provision for extraction limits on a volumetric basis over a range of time scales. As part of the licence conditions, Barwon Water monitor groundwater levels and quality, subsidence, flow in Boundary Creek and Barwon River, as well as the protection of riparian vegetation, protection of stock and domestic use and the protection of flows in the Barwon River tributaries.

Reporting against these licence conditions is provided in an annual report to Southern Rural Water who administers and regulates groundwater licences on behalf of the Water Minister.

1.4 Strategic drivers for the Barwon Downs technical works monitoring program

Ahead of the upcoming 2019 licence renewal process, Barwon Water instigated a technical works monitoring program to improve the comprehensiveness of the current monitoring program to ensure the submission of a technically sound licence application.

Driving the need for this monitoring program is the reliance on the borefield to provide water security for Barwon Water customers, to address outstanding community issues particularly where the relationship between cause and effect is not yet fully understood, and to close out any known technical knowledge gaps.

1.4.1 Water security

The Barwon Downs borefield provides water for the regional communities of Geelong, the Surf Coast, the Bellarine Peninsula and part of the Golden Plains Shire.

A prolonged period of unprecedented drought (known as the Millennium drought) saw a sustained dry climate average from 1997 to 2011. In 1997, many of the region’s water storages were close to capacity, however by January 1998, after high consumption and low catchment inflows, water restrictions were necessary to balance supply and demand in the Geelong area. This clearly highlighted that even by having large storages the region was susceptible to rapid changes.

In 2001, strong catchment inflows from healthy rainfall refilled storages, ending water restrictions in Geelong. Five years later, after a very dry year, strict water restrictions were again required with climate extremes exceeding the historical record. At the height of the Millennium drought, Geelong’s water storages dropped to 14 per cent when catchment inflows were severely reduced. To meet demand during this time 52,684 ML was extracted from the borefield providing up to 70 per cent of Geelong's drinking water.

In 2010, improved rainfall restored storages and restrictions were again slowly lifted in the Geelong area. This allowed the Barwon Downs borefield to be switched off and to begin recharging. Without the use of the borefield during this time, residents and industry in Geelong, Bellarine Peninsula, Surf Coast and southern parts of the Golden Plains Shire would have run out of water.

The township of Colac will soon be connected to the Geelong system through construction of a pipeline between Colac and Geelong. This interconnection will also allow the borefield to supply Colac residents and will provide additional water security for the water supply system which is currently susceptible to seasonal fill patterns.

1.4.2 Community issues

Although Barwon Water is compliant with the monitoring program associated with the 2004 licence, it is accepted that this program is not comprehensive enough to address community interest about specific issues centred on potential environmental impacts in the local catchment.

Areas of community interest recently have included the:

- extent of stream flow reduction and any ecological impacts at various points along Boundary Creek, which flows across the key recharge area for Lower Tertiary Aquifer and has the potential to be impacted by drawdown in the aquifer
- potential to increase existing acid sulphate soil risks in the Yeodene peat swamp, and impacts on Boundary Creek and the Barwon River downstream of the swamp from decreased pH,
- potential to increase the existing fire risk at the Yeodene peat swamp if the swamp dries, and
- extraction limits and the current operational regime of the borefield, and whether they are sustainable under climate change projections.

A Community Reference Group was established in 2013 to provide community feedback and input into the technical works monitoring program.

1.4.3 Informing the licence renewal

To address community interest adequately and inform the licence renewal in 2019, Barwon Water commissioned a review of the existing monitoring program associated with the 2004 licence. This technical review recommended that a revised technical works monitoring program be developed with the following objectives:

- Better understand the environmental impacts throughout the study area of groundwater extraction;
- Estimate, and quantify where possible, the causes and relative contributions of groundwater variability (for example, groundwater extraction and drought) in contributing to environmental impacts; and
- Provide additional monitoring data and subsequent analysis required to support the licence renewal process.

1.5 Overview of the technical works monitoring program

1.5.1 Monitoring program development

The development of the technical works monitoring program is shown in Figure 1-4 and can be broken down into the following stages.

Stage 1: Review of the existing monitoring program

In 2012, Barwon Water initiated a review of the Barwon Downs monitoring program. The technical works monitoring program was developed in response to the:

- desire to address key community issues (see section 1.4.2), and
- 2008-09 flora study which recommended a long term vegetation and hydrogeological monitoring program be designed and implemented to better understand a range of factors such as groundwater extraction, drought and land use changes that were contributing to the drying of the catchment.

This review took into account both the social and technical issues that needed to be addressed to inform the licence renewal process in 2019 and was initiated early to allow sufficient time to establish a comprehensive monitoring program. A risk based approach was used to rank these issues, and control measures were developed to downgrade the residual risk ranking, which included activities such as additional monitoring and technical studies.

Stage 2: Technical works monitoring program scope refinement

In 2013, the scope of the technical works monitoring program was developed based on the recommendations of Stage 1. The Technical Works Monitoring Program was designed to improve the capacity of the monitoring to differentiate between groundwater extraction and climate effects on the groundwater system, predict water table and stream flow changes, and increase understanding of potential ecological impacts. Key improvement areas include:

- differentiating between groundwater extraction and climate effects on the regional groundwater system,
- understanding the potential risks of acid sulphate soils and whether that could change future extraction practices,
- assessing whether vegetation in areas dependent on groundwater will be at risk from water table decline, which could change future extraction practices,
- assessing flow requirements in Boundary Creek to determine if the current supplementary flow is effective,
- characterising groundwater dynamics in the aquitard to improve hydrogeological understanding of groundwater flow and quantity, and
- better understanding of groundwater and surface water interaction, particularly along Boundary Creek where groundwater contributes to base flow.

In the same year, the Barwon Downs Groundwater Community Reference Group was also formed by Barwon Water to ensure where possible, the monitoring program was adjusted and the scope refined, to take into consideration community issues and views. This was a critical contribution towards the broader licence renewal strategy as it raised confidence that the right monitoring data would be captured to specifically target key areas of community concern.

Stage 3: Construction of additional monitoring assets

During 2014-15, the following construction works were completed:

- 33 new groundwater monitoring bores drilled, including the replacement of one existing bore,
- 3 existing bores refurbished,
- 4 new potential acid sulphate soils monitoring bores were installed,
- 32 data loggers and two barometric loggers installed in new and existing bores,
- 1 new stream flow gauges installed, and
- 2 existing stream flow gauges replaced refurbished and reinstated.

Stage 4: Ongoing monitoring

The technical works monitoring program is now in a phase of data collection and preliminary analysis. The intention of this stage is to update the conceptual understanding of the hydrogeology in the Barwon Downs region. This will be based on data collected from additional and existing monitoring assets and the outcomes of a range of investigative technical studies, all of which will be used to update and calibrate the groundwater model.

Preparation will also begin at this stage to form a comprehensive licence application.

Stage 5: Preparation for licence renewal submission

Prior to 2019, Barwon Water will need to formally submit a licence renewal application to Southern Rural Water. This will initiate a groundwater resource assessment process as set out under the Water Act.

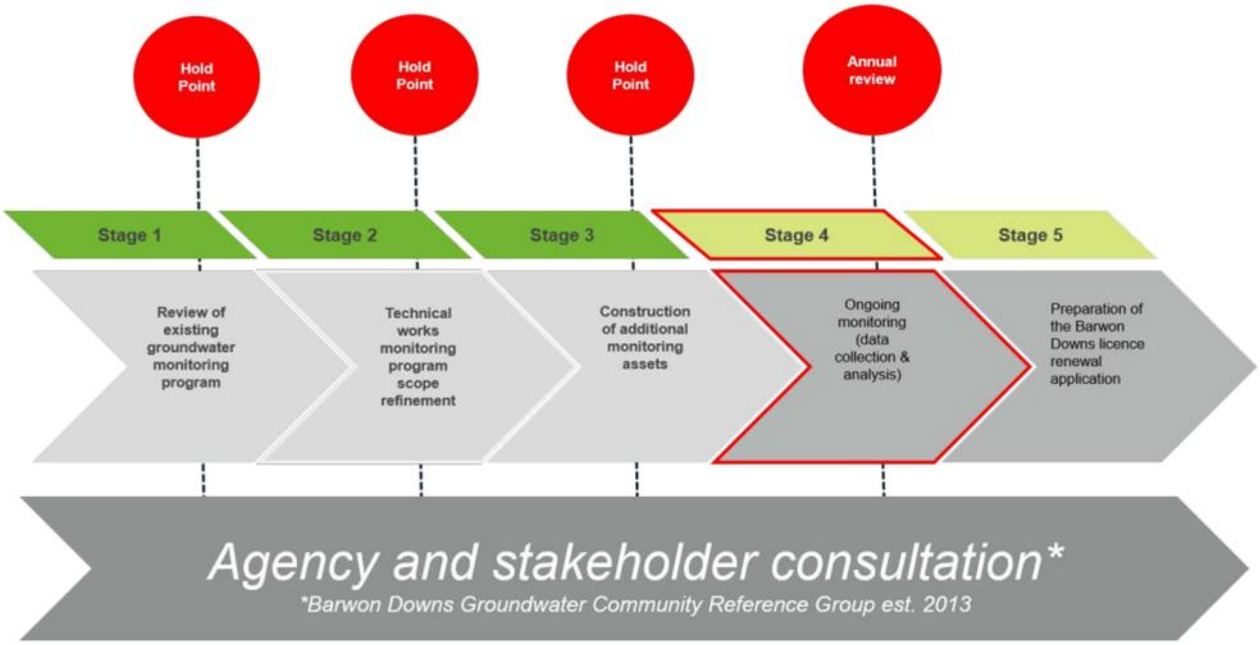

Figure 1-4 Development of the technical works monitoring program.

1.5.2 The inter-relationships of the technical works monitoring program

The technical works monitoring program is a complex, multi-disciplinary project due to the overlapping nature of the various components of the program as shown in Figure 1-5.

Changes in climate, land use practices and groundwater pumping will alter water availability throughout the catchment, including stream flow and groundwater levels. Many receptors are sensitive to changes in groundwater levels and stream flows, particularly those that are dependent on groundwater. Ultimately this can lead to the loss of ecological values (refer to Figure 1-5).

For example, a decline in groundwater level beneath a stream can cause a reduction in stream flow, which in turn can impact the habitat of aquatic ecology in the stream. Declining groundwater levels or reduced stream flow also has the potential to impact riparian vegetation and potential groundwater dependent activities.

The technical works monitoring program is designed to address knowledge gaps to better understand potential impacts from the borefield. The program is underpinned by scientific rigor using multiple lines of evidence-based techniques to establish the relationship between cause and effect for potential impacts caused by groundwater extraction.

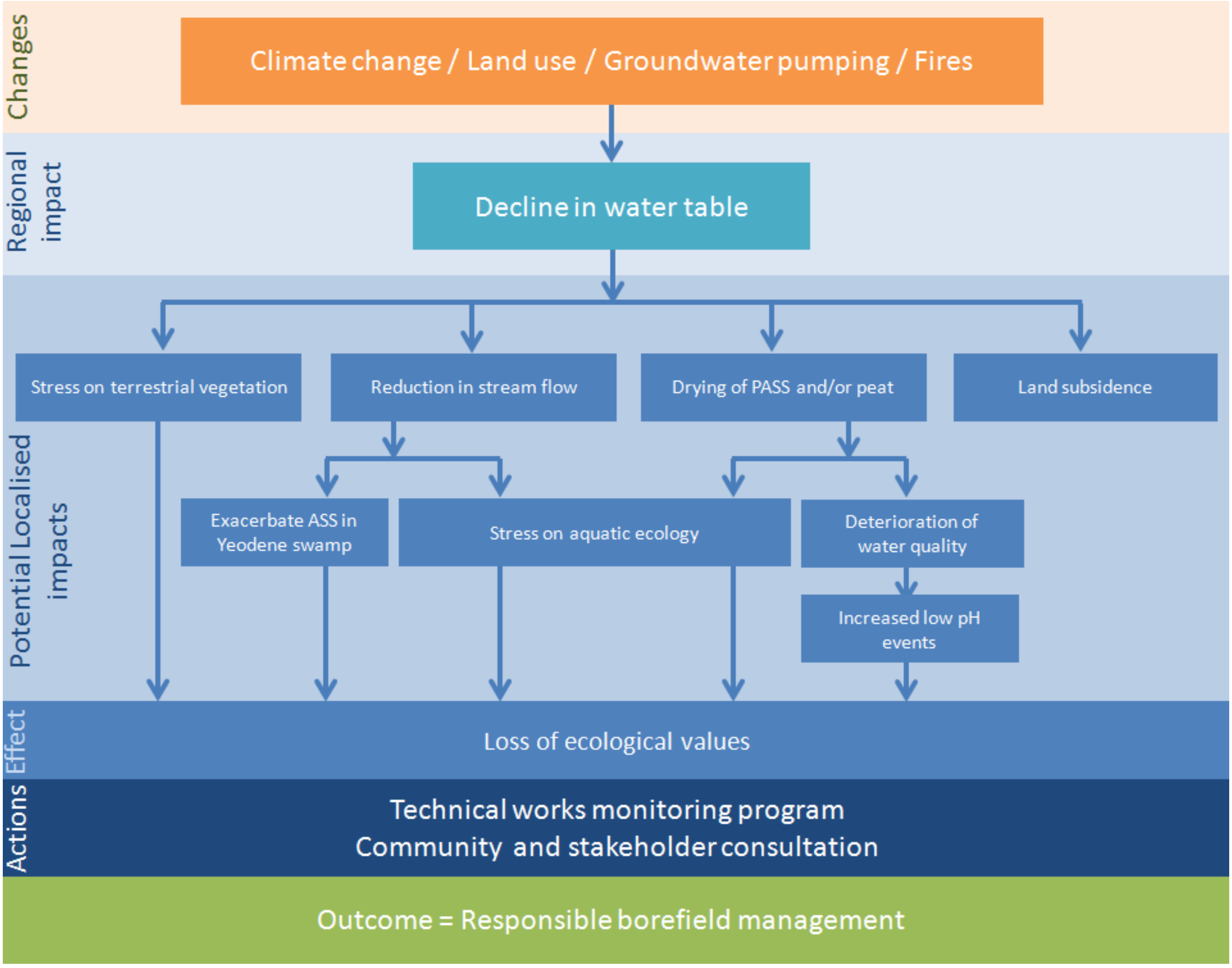

Figure 1-5 Potential impacts in the catchment from changes in the catchment.

1.6 This report

This report documents the findings of the Yeodene Swamp. The purpose of this study is to characterise the chemical and physical processes affecting the volume and quality of water which will be used to inform potential strategies to help manage current water quality issues in the lower reaches of Boundary Creek.

1.6.1 Scope of work

Understanding the processes that affect the volume and quality of water as it moves through the Boundary Creek Catchment requires an understanding of both the processes that have led to the current state of the catchment, and of how the catchment operates currently.

The first section of this study provides a summarised history of the Boundary Creek catchment. This includes a timeline of major events that have occurred in the Boundary Creek catchment historically, and the potential impact that these may have had on water flow and quality. Additionally, existing monitoring data and information provided by past studies will be reviewed within the context of this report.

The second section of the study details a field program aimed at characterising the current state of the Boundary Creek system. The field program includes the installation of piezometers, lithological analysis, soils analysis, surface water flow gauging, and both surface and groundwater quality monitoring. A detailed soil sampling program was not undertaken. The results of the field program are then used to estimate the movement of water through Yeodene Swamp and Boundary Creek, and the major processes affecting water quality as it moves through the system.

The final section of this study builds on the understanding developed during the first two sections, to assess potential strategies for the management of Yeodene Swamp and Boundary Creek, including a review of the potential positive and negative impacts of different strategies.

2. Boundary Creek Catchment

2.1 Chapter overview

The purpose of this chapter is to describe the changes over time in the Boundary Creek catchment and how these have influenced the volume and quality of water moving through Boundary Creek.

This chapter also describes the conceptual understanding of the local hydrology and hydrogeology of the lower reaches of the creek, including Yeodene (Big) Swamp.

The key findings are summarised in Table 2-1.

Table 2-1 Key findings of the conceptual understanding of the lower reaches of Boundary Creek

Feature	Key findings
Catchment history	The major changes to the Boundary Creek catchment include: • Land clearing and channelisation of sections of Boundary Creek through the 1900s for agriculture and farming, • Installation of an on-stream water storage (“McDonalds Dam”) of 160 ML capacity in 1979, • Major groundwater extraction by Barwon Water between 1985-1990, 1997-2001 and 2005-2010. • Peat fires at Yeodene Swamp in 1997, 1998 and 2006. • Excavation of fire trenches in 2006 by the CFA for fire control.
Groundwater surface water interactions	For the purpose of describing the conceptual understanding, Boundary Creek is divided into three reaches that are hydrogeologically distinct: • Reach 1 flows over basement and receives minor groundwater inflows. • Reach 2 flows over the regional aquifer. This reach used to receive groundwater inflows, however groundwater extraction and changes in climate have lowered the groundwater level in the aquifer, and the creek now loses water in Reach 2 via seepage. Yeodene Swamp is located at the downstream end of Reach 2 on the boundary between the aquifer and aquitard. • Reach 3 flows over aquitard and receives minor groundwater inflows.
Surface water flows	• Since monitoring commenced in 2014, flows downstream of “McDonalds Dam” during the warmer months (November to April) was significantly less than 2 ML/day. • Since 1999, significant declines in pH have occurred in Reach 3 of Boundary Creek and are related to the drying of acid sulfate soils in Yeodene Swamp.

2.2 Catchment history

Agriculture and farming

The Boundary Creek catchment has undergone significant modification over the last century. In 1886 the Gerangamete drain was completed, followed by a series of adjacent drains inn 1888 (Jennings, 2008). These drains claimed low lying land for agricultural production, and resulted in the removal of large sections of lowland forest and grassy woodland, as evidenced by Ecological Vegetation Class mapping (Figure 2-1). The drainage of these areas is likely to have lowered the groundwater level near the drains and increased runoff, while reduced forest coverage may have increased groundwater recharge in these areas.

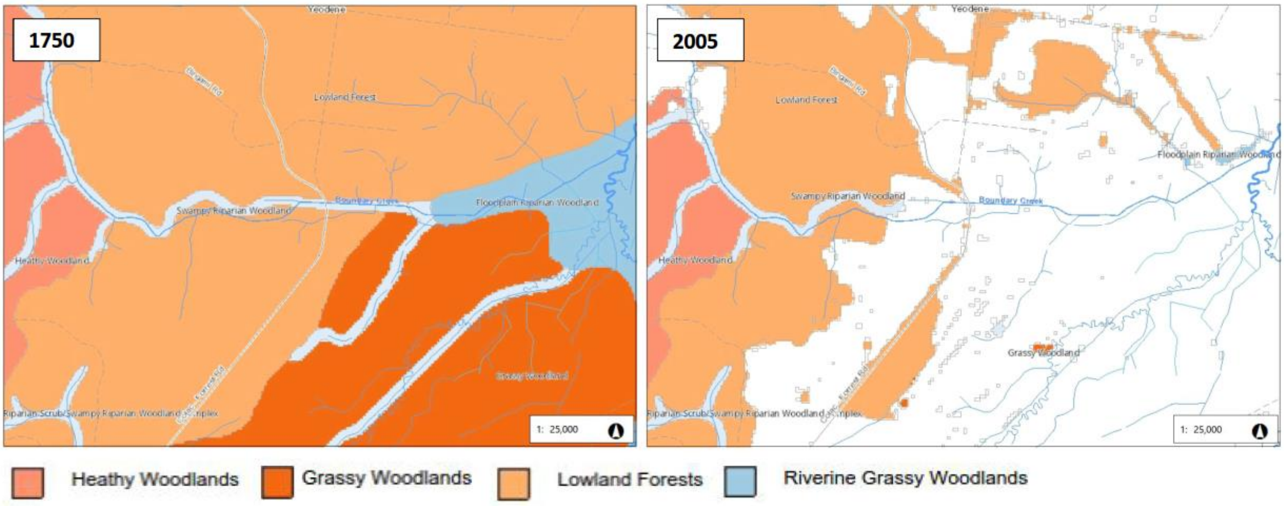

Figure 2-1 Ecological Vegetation Class mapping of Boundary Creek catchment in 1750 and 2005

McDonalds Dam

In 1979, an on stream water storage (referred to as "McDonalds Dam") was constructed in the central reach of the creek. The dam has a storage capacity of 160 ML, is between 8 and 9 hectares in surface area and is a source of evaporation and flow retardation in the catchment. The dam operates under the following conditions:

- **Passing flows:** *The licence holder must, at all times that there is natural inflow into the on-waterway storage, maintain a flow in the waterway downstream of the storage, to the satisfaction of the Authority.*
- **Take period:** *Unless otherwise directed by the Authority, water may only be harvested into the on-waterway dam during the period from 1 July to 31 October inclusive; at all other times, the entire stream flow must be passed downstream of the dam.*

Groundwater extraction

In August 1982, the first period of groundwater extraction from the Barwon Downs borefield commenced. This continued until June 1983, resulting in the extraction of approximately 3,650 ML of water (Figure 2-2). This represented an initial test phase, and was followed by further extraction tests between 1985 and 1990, resulting in the extraction of over 22,000 ML. Subsequently, borefield operation between 1997 and 2001 resulted in the extraction of ~36,500 ML which was taken under the previously held licence. Since the current licence was issued in 2004, periods of extraction have occurred during 2005-2010 and in 2016, resulting in extractions totalling ~55,000 ML over these periods.

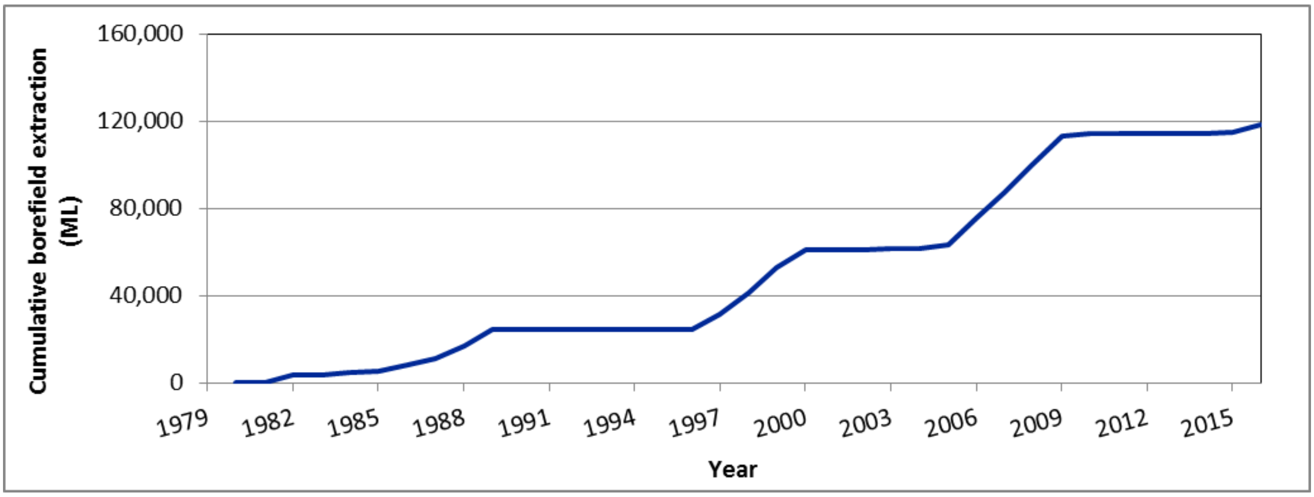

Figure 2-2 Cumulative volume of borefield extraction

Climate variability

In addition to borefield operation, there have been significant shifts in the long term climatic conditions across Victoria and the Boundary Creek catchment. Figure 2-3 shows the rainfall plotted as cumulative departure from the mean. This figure shows rising trends when the rainfall is above average and declining trends when the rainfall is below average. The rainfall during this time includes an extended period of reduced rainfall in between 1900 and 1955, and has been followed by a period of increased rainfall between 1955 and 1997. More recently, climatic variability has included a period of drought between 1982 to 1983, a period of above average rainfall between 1983 and 1995, the millennium drought between 1995 and 2010, and below average rainfall between 2014 and today.

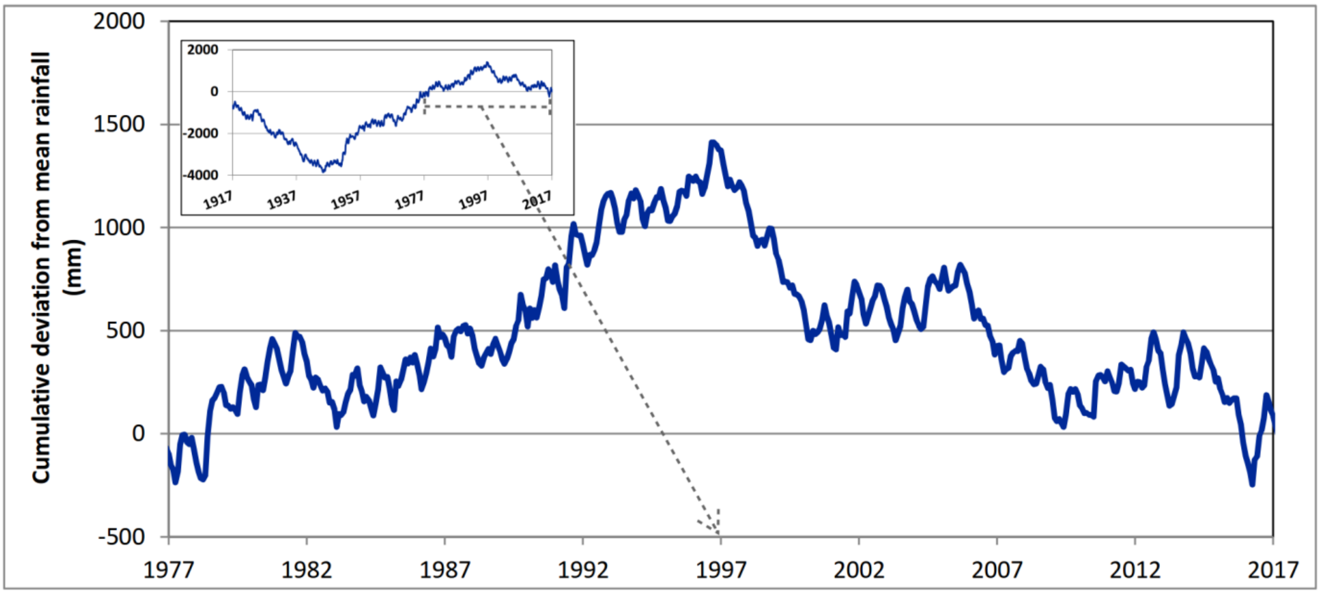

Figure 2-3 Cumulative deviation from mean annual rainfall at Forest State gauge (BOM gauge 090040)

Fires in Yeodene Swamp

At the start of the millennium drought, in the summer of 1997, a bushfire through the state forest in Yeodene resulted in the ignition of peat in the Yeodene Swamp (Glover, 2014). Infra-red scans by the CFA in 1998 suggested that the fire had been put out, however anecdotal records of smoke in the swamp, and subsequent re-ignition of the fire in 2010 suggest that peat may have been smouldering in the subsurface of the swamp between 1998 and 2010 (Himmelreich, 2010).

In response to the 2010 re-ignition, a fire trench up to 3 m deep and 1 km long was excavated by the local CFA along the southern and eastern boundaries of the swamp (see Figure 2-4) to contain the peat fire in early 2010 (Glover, 2004). The construction of these fire trenches is likely to have intersected some runoff to the swamp from the southern uphill slopes. Further, the trenches are likely to have intersected the water table, resulting in the drainage of groundwater and the lowering of the water table.

Studies have shown that the structure and chemistry of peat can be altered as a result of fire (Hirst et al., 2012; Tsibart et al., 2015). While this may be the case here, a full assessment of this is beyond the scope of this study and such changes in the peat at Yeodene Swamp have not been considered here. Further work may be required to assess this (see Section 6.2).

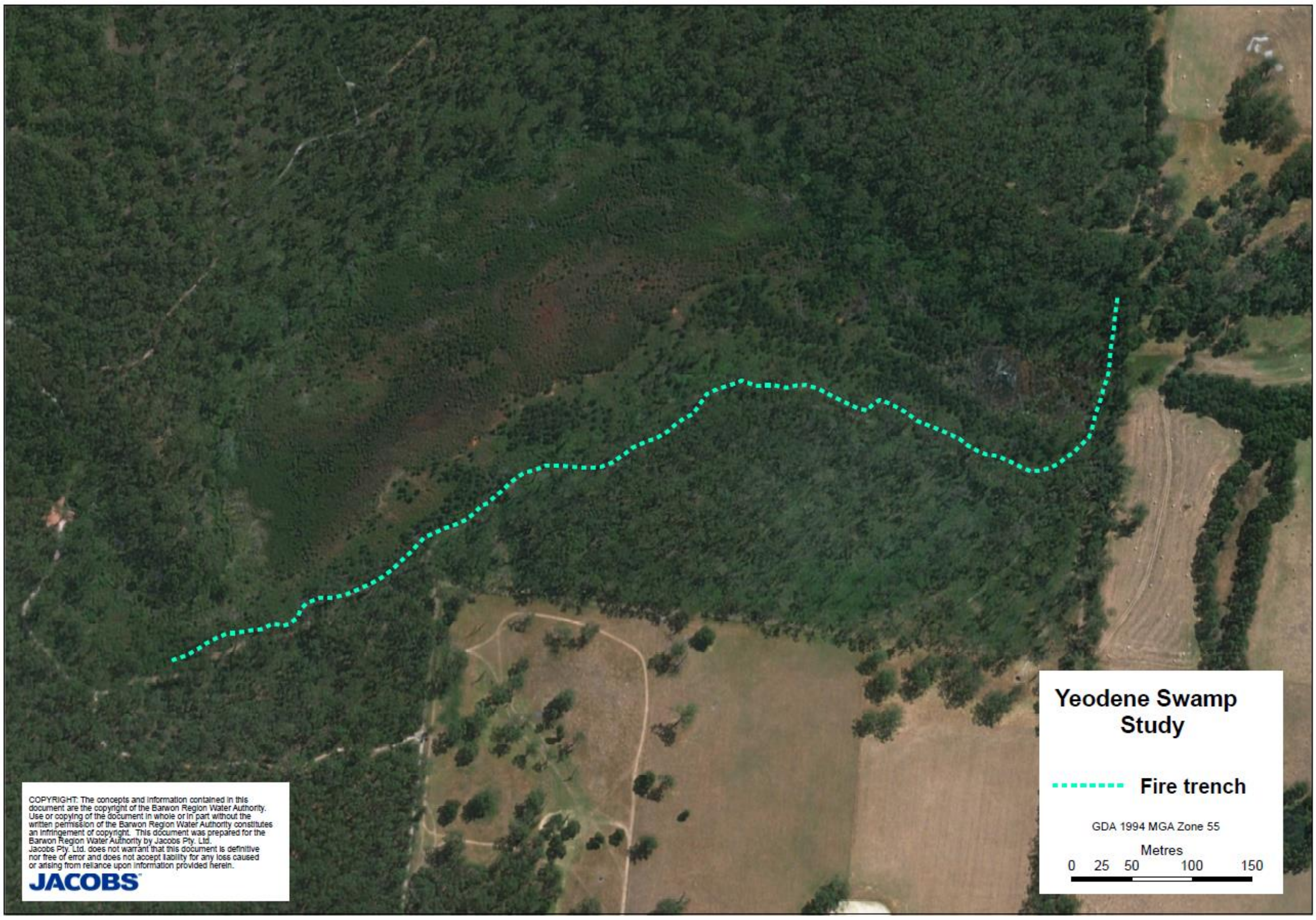

Figure 2-4 Approximate location of the fire trench excavated by the CFA in 2010

2.3 Hydrogeology

Boundary Creek flows through three distinct hydrogeological settings. These have been classified as Reaches 1, 2 and 3 (Jacobs, 2017a) and are illustrated in Figure 2-5 below.

- The upper reach (Reach 1) flows predominantly over outcropping bedrock which is characterised by impermeable Palaeozoic sandstone, siltstone and mudstone.

- The central reach of the creek (Reach 2) flows over the outcropping regional aquifer (the Lower Tertiary Aquifer or LTA), which is characterised by permeable sands of the Mepunga, Dilwyn and Pebble point formations. The Yeodene Swamp is located at the downstream end of Reach 2 on boundary between the regional aquifer and the aquitard.

- The lower reach of Boundary Creek (Reach 3) flows over an aquitard (the Mid-Tertiary Aquitard or MTD) and is characterised by silty clays of the Gellibrand Marl.
- Shallow Quaternary alluvium occurs locally along the flow path and overlies most of these regional formations. This includes swamp deposits and acid sulfate soils that occur throughout the Yeodene Swamp.

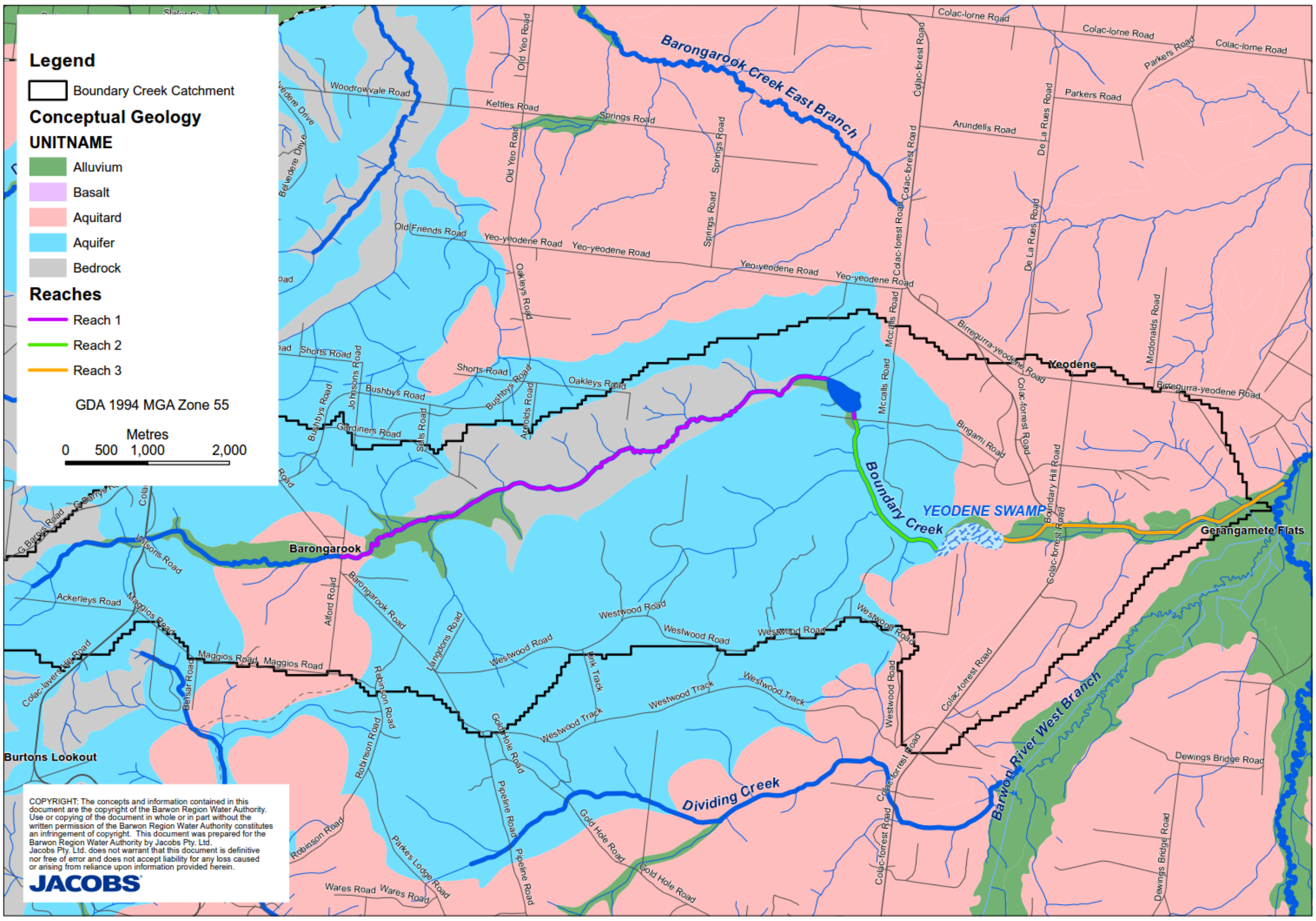

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Figure 2-5 Simplified geology of the Boundary Creek Catchment

2.3.1 Groundwater levels and groundwater surface water interaction

Groundwater levels adjacent to the river in this part of the catchment are monitored by several groundwater bores as listed in Table 2-2 and shown in Figure 2-6.

Table 2-2 Summary of existing bores monitoring groundwater levels adjacent to the river

Bore	Depth (m)	Screened interval (m)	Unit monitored	Water level record	Water quality available
109108	12	6 - 10	Regional aquifer (LTA)	1983-2010	Yes
109110	99	67 - 77	Regional aquifer (LTA)	1981-2017	Yes
109111	42	22 - 40	Regional aquifer (LTA)	1980-2015	Yes
109112	59	24 - 59	Regional aquifer (LTA)	1984-2017	Yes

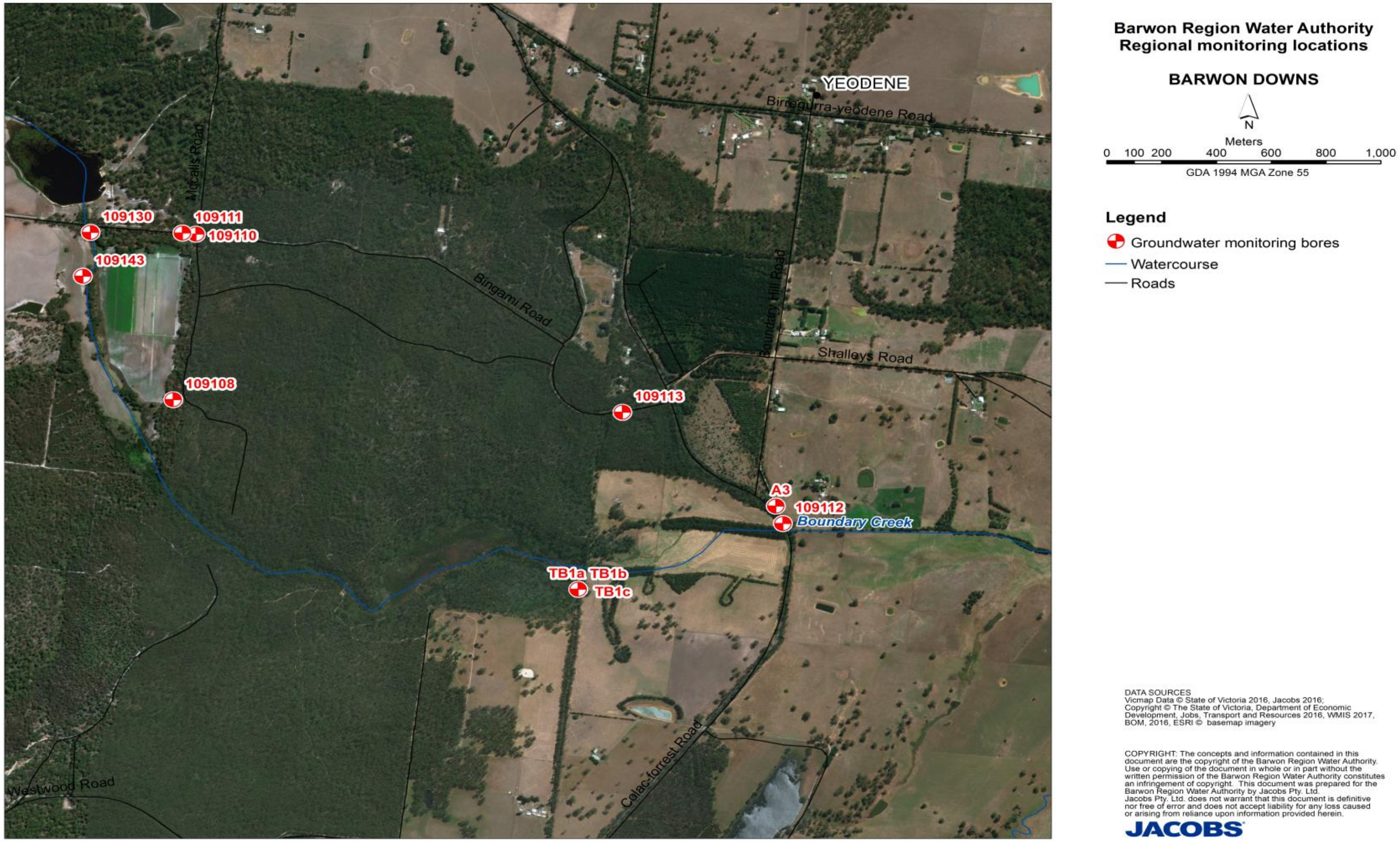
Bore	Depth (m)	Screened interval (m)	Unit monitored	Water level record	Water quality available
109113	271	198 - 231	Regional aquifer (LTA)	1984-2017	Yes
109130	18	8 - 16	Regional aquifer (LTA)	1986-2017	Yes
109143	24	12 - 18	Regional aquifer (LTA)	1987-1989	No
TB1a	13	9 - 12	Alluvial aquifer	2014-2017	Field only
TB1b	19	17 - 19	Aquitard (MTD)	2015-2017	Field only
TB1c	37	33 - 37	Regional aquifer (LTA)	2015-2017	Field only
TB2b	7	4 - 7	Alluvial aquifer	2014-2015	Field only
TB2c	3	2 - 3	Alluvial aquifer	N/A	Field only
A3	14	10 to 13	Aquitard (MTD)	2014-2017	Yes
PASS1	10	4 to 9	Aquitard (MTD)	2015-2017	Yes

Groundwater levels in the Boundary catchment vary in each of the four hydrogeological units outlined above.

Recently installed monitoring bores in the basement (bedrock) indicate that Boundary Creek receives groundwater discharge from the basement in Reach 1. However, due to the low permeability of the basement, inflows volumes to Boundary Creek in Reach 1 are small. Seasonal groundwater fluctuations in the basement aquifer are around 1 to 2 m (Jacobs, 2016a).

In the Lower Tertiary Aquifer, historical monitoring indicates a significant decline in regional groundwater levels in this part of the Boundary Creek catchment. This is predominantly attributed to borefield operation and changes in climate over this time. This decline has resulted in groundwater levels falling below the streambed elevation in Reach 2 (Figure 2-7), and a transition from a system that receives groundwater, to one that loses water via seepage.

Monitoring bores in the aquitard indicate groundwater level fluctuations of around 1 to 2 m between 2014 and 2017 (Jacobs, 2016a). Fluctuations are consistent with seasonal trends in rainfall. This indicates that the upper layers of the aquitard are more influenced by rainfall recharge than the operation of the borefield. Where Boundary Creek intersects the aquitard in Reach 3, groundwater levels are above the streambed, indicating that Boundary Creek receives groundwater through this reach. However, groundwater discharge volumes are limited by the low permeability of the aquitard, resulting in periods of no flow in Reach 3.



DATA SOURCES
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Figure 2-6 Location of regional groundwater monitoring bores

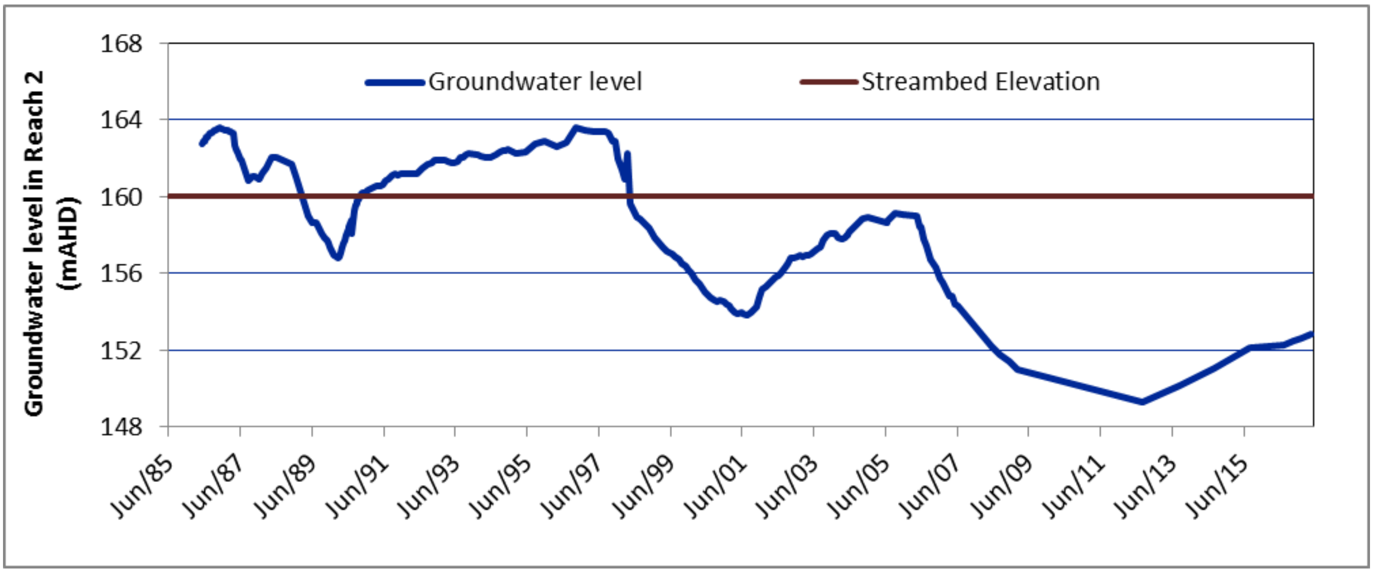


Figure 2-7 Historical monitoring of regional aquifer in Reach 2 (bore 109130)

2.3.2 Groundwater quality

Historical groundwater quality information is not typically available for the basement and aquitard units in the Boundary Creek catchment. However monitoring bores installed by Jacobs in 2014 indicate that groundwater in the basement in Reach 1 has an EC between 4,000 and 6,000 µS/cm and is slightly acidic, with a pH of between 5.5 and 7.0 (Jacobs, 2016b). It is not uncommon for groundwater to be slightly acidic, so this is not interpreted to be linked to the acid events in the swamp.

Water quality data is available for bores installed in the regional aquifer in Reach 2 following their construction and development. The data has been summarised in Table 2-3 below and show that groundwater in the regional aquifer around Boundary Creek is typically fresh (TDS < 500 mg/L) and slightly acidic, with pH generally ranging between 5.5 and 7.0. The dissolved major ions are dominated by Cl and Na, consistent with rainfall recharge. Given this, it would be expected that water in Boundary Creek would also be slightly acidity when groundwater discharge from Reach 2 is the dominant source of flows to the creek.

Groundwater monitoring in the aquitard in Reach 3 by Jacobs (2016b) indicates that groundwater ranges in EC between 1,300 and 2,500 µS/cm and ranges between slightly acidic and slightly basic (pH between 5.45 and 7.56).

Table 2-3 Summary groundwater quality data for the aquifer in the Boundary Creek Catchment

Bore	Date sampled	EC (µS/cm)	pH (units)	TDS	Na	K	Ca	Mg	Cl	HCO_3	SO_4	Fe
109108	13/09/1983	220	7.5	118.4	28	0.4	2.8	6.4	46	34.2	9.0	24.0
109110	24/11/1980	910	5.9	470.0	148	2.0	2.0	12.0	255	23.0	15.0	n/a
	25/11/1980	880	5.7	458.0	143	2.0	8.0	11.0	248	21.0	16.0	n/a
	25/11/1980	880	5.8	460.0	143	2.0	8.0	12.0	248	23.0	15.0	n/a
	28/01/1987	860	6.4	427.0	140	2.1	7.1	9.3	260	8.5	0.3	9.6
109111	28/01/1987	370	5.5	176.9	55	0.9	3.1	5.9	99	9.8	6.6	0.0
	24/02/1987	910	4.3	416.8	140	0.8	8.1	16.0	260	1.2	14.0	0.0
109112	29/01/1987	770	9.2	403.5	94	5.5	19.0	17.0	210	n/a	0.3	0.2
	23/02/1987	890	5.8	402.7	100	5.6	42.0	20.0	210	24.4	76.0	0.0
109113	29/01/1987	610	7.3	322.3	98	2.8	4.2	7.6	170	39.0	0.3	7.0

2.4 Surface water

2.4.1 Surface water flows

Flow has been monitored continuously in Boundary Creek at Yeodene since 1979. Additional gauges were installed both upstream and downstream of “McDonalds Dam” in 1989, but fell into disrepair by 1994. These were repaired in 2014 and since then, automated monitoring of flow has occurred at all three gauges. The flow gauges in the catchment and a summary of the flows are listed in Table 2-4.

Table 2-4 Flow gauges in the Boundary Creek catchment

Gauge Number	Gauge Name	Period of record	Average annual flow (ML/year)	Average daily flow (ML/day)	Average low flow December - March (ML/day)
233273	Barongarook	July 2014 - current	2,210	6.1	2.6
233231	Upstream McDonald Dam	Dec 1989 – Feb 1994	4,039	11.1	1.7
		June 2014 to current	2,276	6.2	2.3
233230	McDonald Dam	Dec 1989 – Feb 1994	Level only		
		June 2014 to current			
233229	Downstream McDonald Dam	Dec 1989 – Feb 1994	4,451	12.2	1.9
		June 2014 to current	3,145	8.6	7.3
233228	Yeodene	Mar 1985 - current	2,874	7.9	1.1

Historical flows in Boundary Creek at the Yeodene stream gauge have been illustrated in Figure 2-8 below. The figure illustrates a clear step change in flow in the lower reach of Boundary Creek. The creek rarely stopped flowing at any time of year prior to 1999. However since then, the creek has generally ceased to flow during summer months.

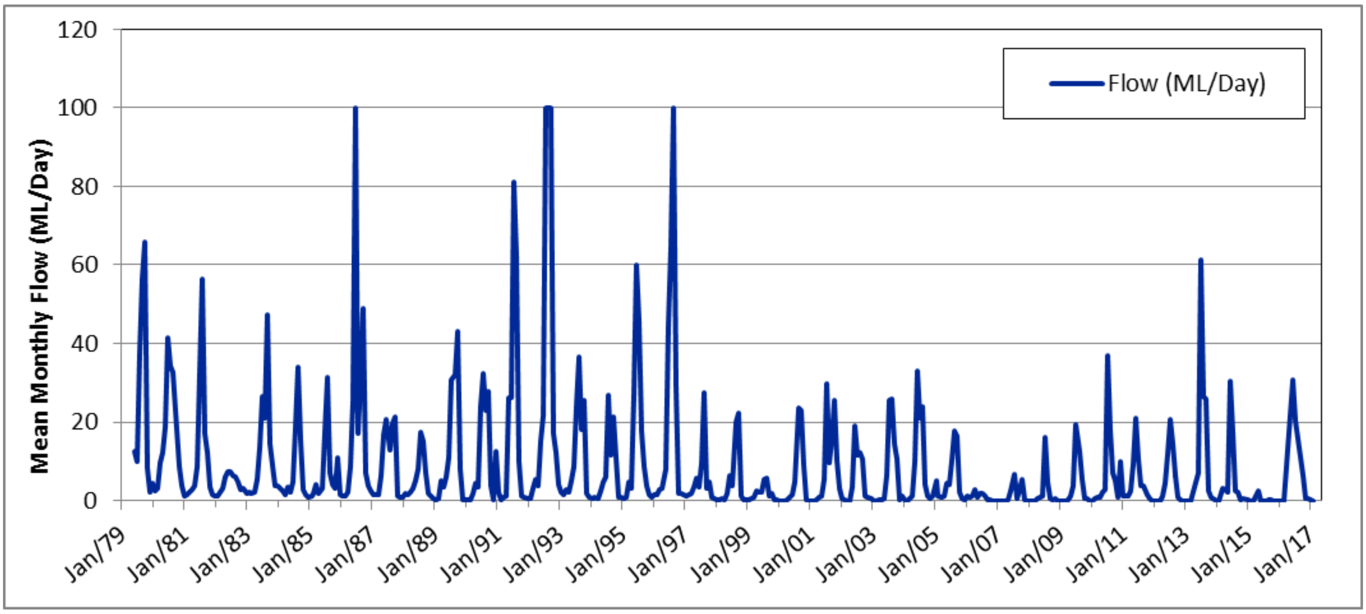


Figure 2-8 Average monthly flow in Boundary Creek at Yeodene

Reduced streamflow in Boundary Creek can be attributed to the reduction of groundwater discharge into the creek through Reach 2. In response to this, Barwon Water has released a supplementary flow of 2 ML/day into the upstream reach of Boundary Creek (when triggered by licence conditions) since 2002 (Jacobs 2017b, Jacobs 2016a, SKM 2011, and SKM 2001).

Stream gauging data shows that not all of the inflow is always passed through “McDonalds Dam”. The table below shows the flows upstream of “McDonalds Dam”, downstream of “McDonalds Dam”, the difference between the inflows and outflows and how this volume relates to the volume released by Barwon Water. Table 2-5 supports Figure 2-9 to Figure 2-11 below, which shows periods of time where there is a significant difference in the flow upstream and downstream of the Dam as recorded by the stream gauges. This has reduced the total volume of water delivered to the lower reaches of Boundary Creek.

The failure of flows to pass through “McDonalds Dam” is in conflict with the operational conditions stipulated in section 2.2, and is believed to be the result of a dysfunctional release valve at the lower end of the dam.

Table 2-5 Difference in flows into and out of “McDonalds Dam”

Period		Barwon Water Flow Release (ML)	Flow “McDonalds Dam” upstream (ML)	Flow “McDonalds Dam” downstream (ML)	Difference: U/S vs D/S (ML)	Average daily difference (ML/Day)
1 Nov 2014	10 Dec 2014	85	121	77	44	1.1
16 Jan 2015	16 Feb 2015	67	73	34	39	1.2
1 Nov 2015	1 Apr 2016	329	315	159	156	1.0
14 Jan 2017	10 Apr 2017	175	188	66	122	1.4

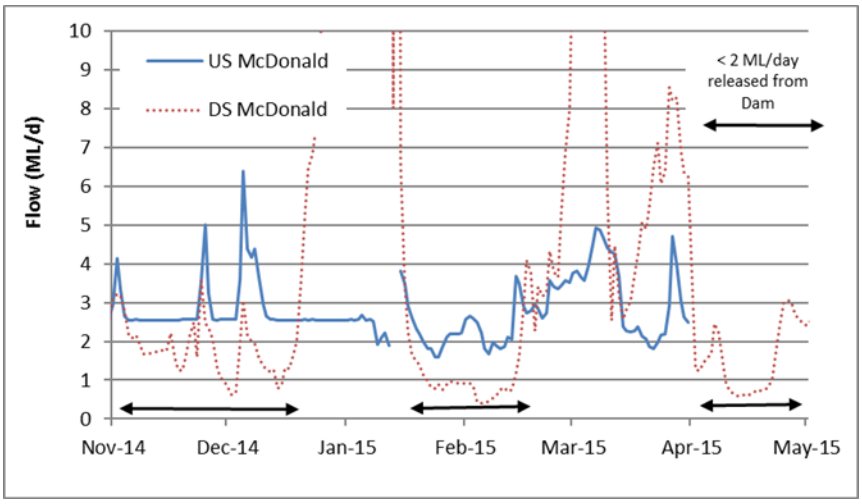


Figure 2-9 Surface water flows upstream and downstream of “McDonalds Dam” (2014/15)

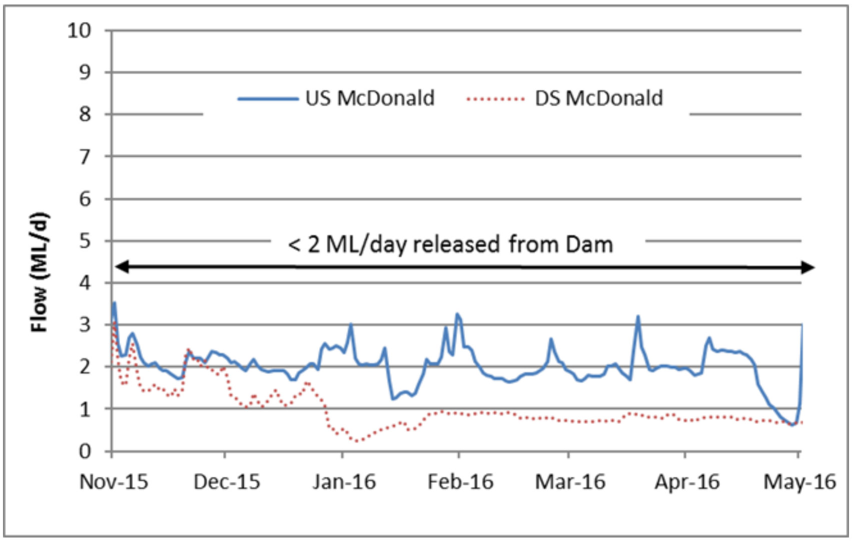


Figure 2-10 Surface water flows upstream and downstream of “McDonalds Dam” (2015/16)

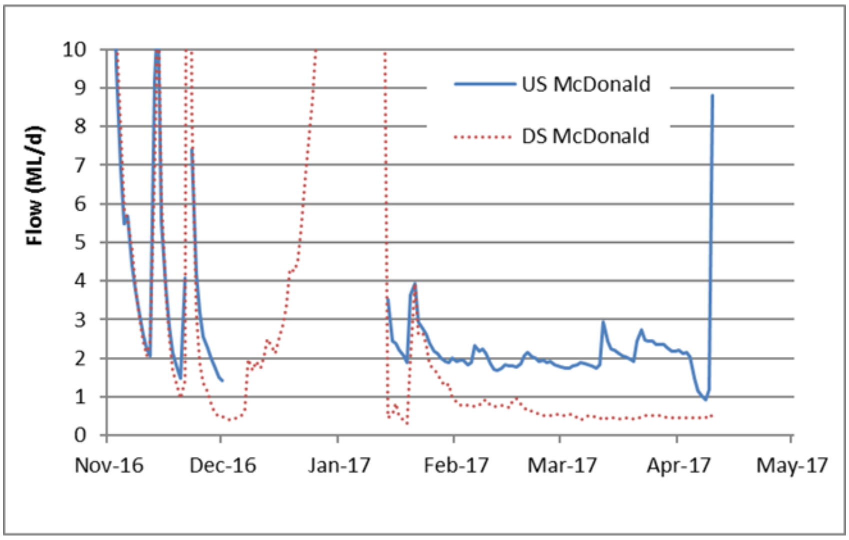


Figure 2-11 Surface water flows upstream and downstream of “McDonalds Dam” (206/17)

2.4.2 Surface water quality

Electrical conductivity (EC) and pH have been monitored at monthly intervals at the Yeodene stream gauge since 1985. The median pH of water in Boundary Creek at the Yeodene gauge prior to 1990 was 6.5, and readings around 5.0 were recorded under some summer and autumn conditions when flows in the creek were reduced (see Figure 2-12).

A brief overview of the historical pH readings since 1990 at Yeodene Gauge is below:

- Between 1990 and 1992, monthly pH readings fell to a median pH of 5.1, and readings below 4 were recorded in the summer and autumn periods when flows in the creek were reduced.
- Between 1992 and 1999, the median pH increased to 5.9, with only two readings below 4.0.
- Since 1999, the median pH at the Yeodene stream gauge has fallen to 3.8 and has rarely been above 5.

The median pH of water at "McDonalds Dam" between 2014 and 2017 is ~7.0, indicating that the decline in pH occurs between "McDonalds Dam" and the Yeodene stream gauge as a result of acid releases from Yeodene Swamp.

The decline in pH in Boundary Creek appears to be related to a reduction in flow and in particular, periods when Boundary Creek has ceased to flow at the Yeodene stream gauge. This is illustrated in Figure 2-12 below which shows trends in surface water pH and the number of days each year when Boundary Creek ceases to flow as recorded at the Yeodene stream gauge.

This shows that after 38 days of no flow in Boundary Creek in 1990, there was a significant decline in pH for approximately 2 years. Additionally, cease to flow events have occurred annually since 1999 after a step change of reduced flow in the creek. Over this time, pH has fallen and has not recovered.

This suggests that there is a correlation between cease to flow events and a progressive lowering in pH values.

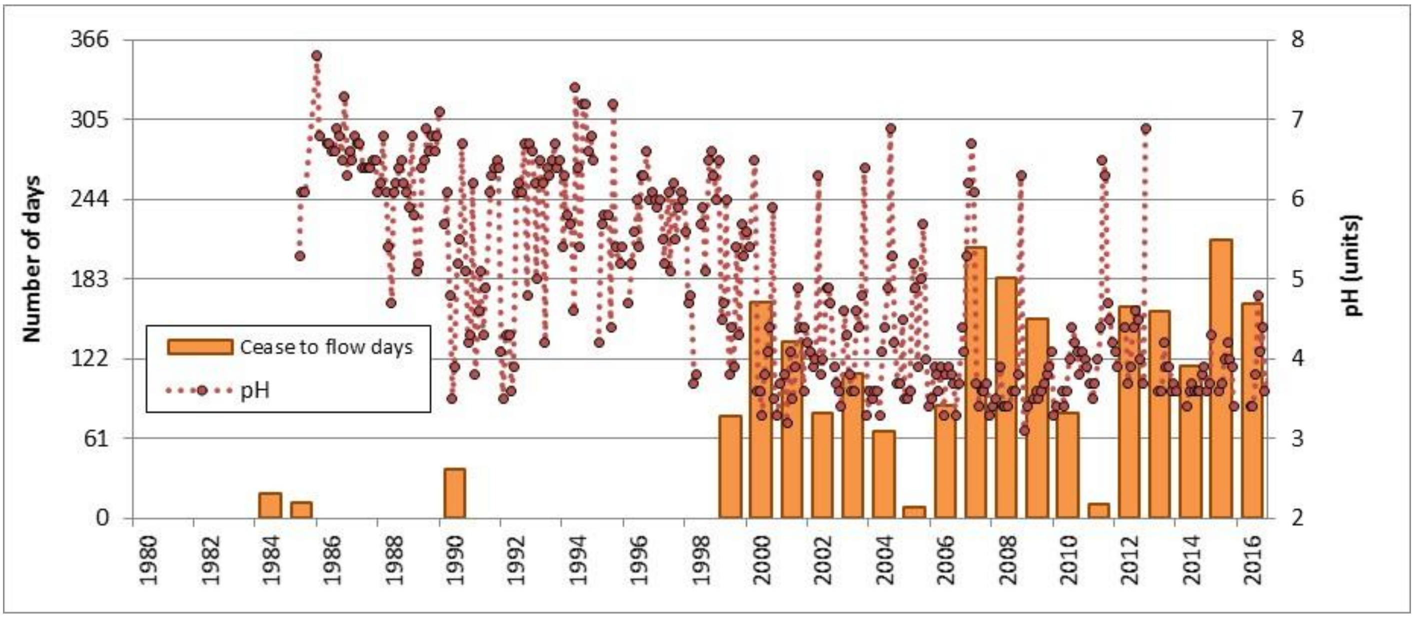


Figure 2-12 Number of cease to flow days in Boundary Creek at Yeodene vs monthly pH at Yeodene

2.5 Causes of changes in water quality

The above data indicates that when Boundary Creek ceases to flow at Yeodene, drying and oxidation of acid sulfate soils in the Yeodene Swamp occurs, resulting in the release of acid and pH values of less than 4 at Yeodene. **It can therefore be asserted that the processes contributing to flow reductions in Boundary Creek in 1990 and since 1999 are key factors driving pH change at those times**.

The installation of agricultural drains occurred in the early 1900’s and while this may have yielded acidification following installation, there are no records available to assess this. Further, it is unlikely that their construction in the early 1900’s are responsible for the clear and sudden shift in pH since 1990.

Similarly, while the installation of “McDonalds Dam” and failure to pass all flows between November and June (as stipulated in its operational conditions) may have reduced flow into the middle and lower reaches of Boundary Creek, the dams presence through the late 1980’s (when pH values were typically above 5) suggests that during relatively wet conditions, sufficient water was being held in Yeodene Swamp to limit acidification of acid sulfate soils.

While both the peat fire in 1997-2010 and the excavation of fire trenches in Yeodene Swamp in 2010 are likely to have altered the current drainage regime in the swamp, they are unlikely to be the direct cause of drying, as low pH events (pH <4) have occurred since 1990.

Although all these factors will have contributed to the changing landscape in the Boundary Creek catchment, the two variables that appear to have had the greatest influence on flows in Boundary Creek (and the resulting water moving through Yeodene Swamp) are climate and borefield operation.

The period between 1990 and 1992 represents a period when groundwater extraction had lowered groundwater levels in the regional aquifer. Over this time, Boundary Creek ceased to flow during summer periods, resulting in the acidification in Yeodene Swamp and Boundary Creek.

This suggests that borefield operation was the major factor controlling acidification in Yeodene Swamp by lowering the groundwater levels, leading to a loss of groundwater base flow into the creek. This is further supported by numerical modelling results which indicate that approximately two thirds of flow reduction in Boundary Creek was borefield driven (Jacobs 2017b). The groundwater model was used to determine the historical impact of borefield operations on flow in Boundary Creek, as illustrated in Figure 2-13. This shows that there was groundwater flow into the creek until the mid-1980s (indicated by positive values) and since then the flow has reversed and surface water flows to the groundwater (indicated by negative values). With no pumping, the groundwater would have continued to discharge to the river until the late 90’s as demonstrated by the orange line.

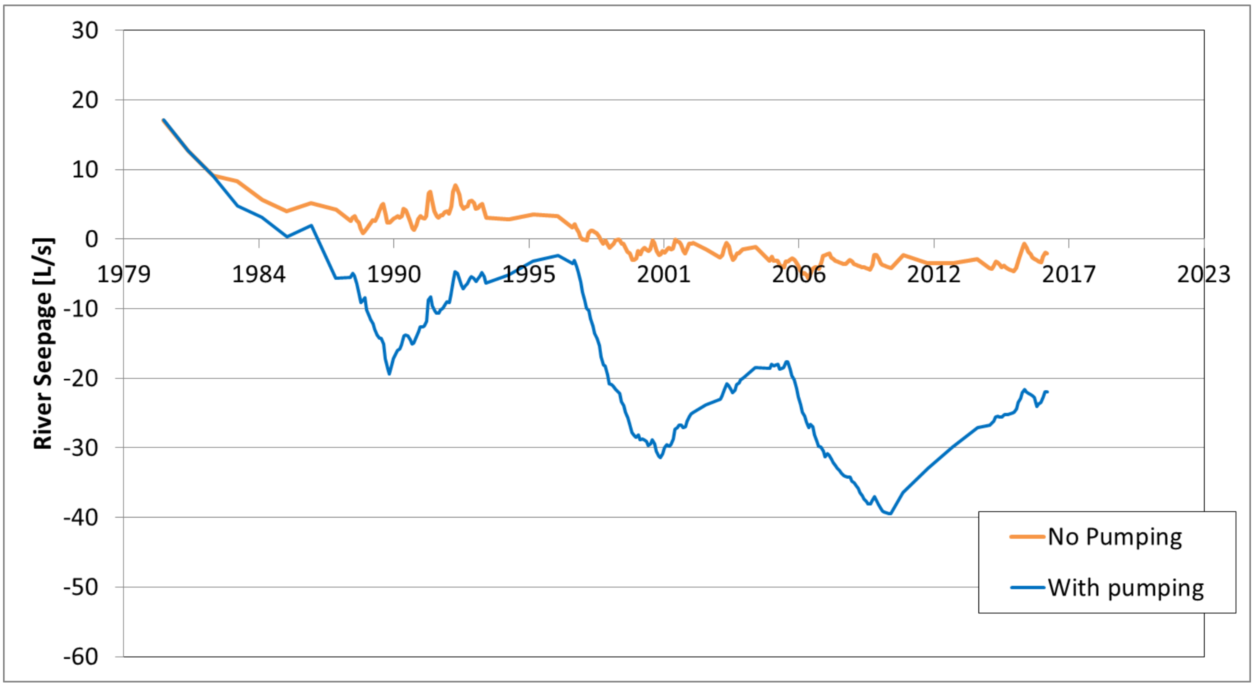


Figure 2-13 Numerical model results – changes in seepage to Boundary Creek from borefield operation

3. Field program

3.1 Chapter overview

This chapter provides an overview of the field works undertaken as part of this study. It summarises the methods used during monitoring and sampling so that the results can be assessed with rigor and within the context of the program. All soil and water sampling was undertaken in accordance with relevant guidelines.

The program was designed to better characterise the physical and chemical processes occurring within the Boundary Creek catchment, with particular emphasis on assessing groundwater - surface water interaction and changes in flow, so as to inform potential remediation strategies focussed on managing water quality in Boundary Creek. The field program included the installation of piezometers (shallow bores <3 m deep), lithological analysis, chemical soils analysis, surface water flow gauging, and both surface and groundwater quality monitoring. As a number of previous studies have undertaken sampling and characterisation of soils within the Yeodene Swamp (Davison and Lancaster, 2011; Hirst et. Al., 2012; Glover, 2014) a full soil mapping program was not undertaken as part of this study.

Groundwater and surface water monitoring was conducted twice during 2017 to understand how the water quality changes through the wetter months after a period of cease to flow. The location of the monitoring locations is shown in Figure 3-1. The first monitoring period occurred on the 4th and 5th of May. This represented the first period of flow in Boundary Creek following the 2016-2017 summer. The second monitoring period occurred between the 22nd and 23rd of August and represented high flows following winter rainfalls.

More detail on the field program is provided in the sections below and key findings from the field program are discussed in Chapter 4.

3.2 Piezometer installation

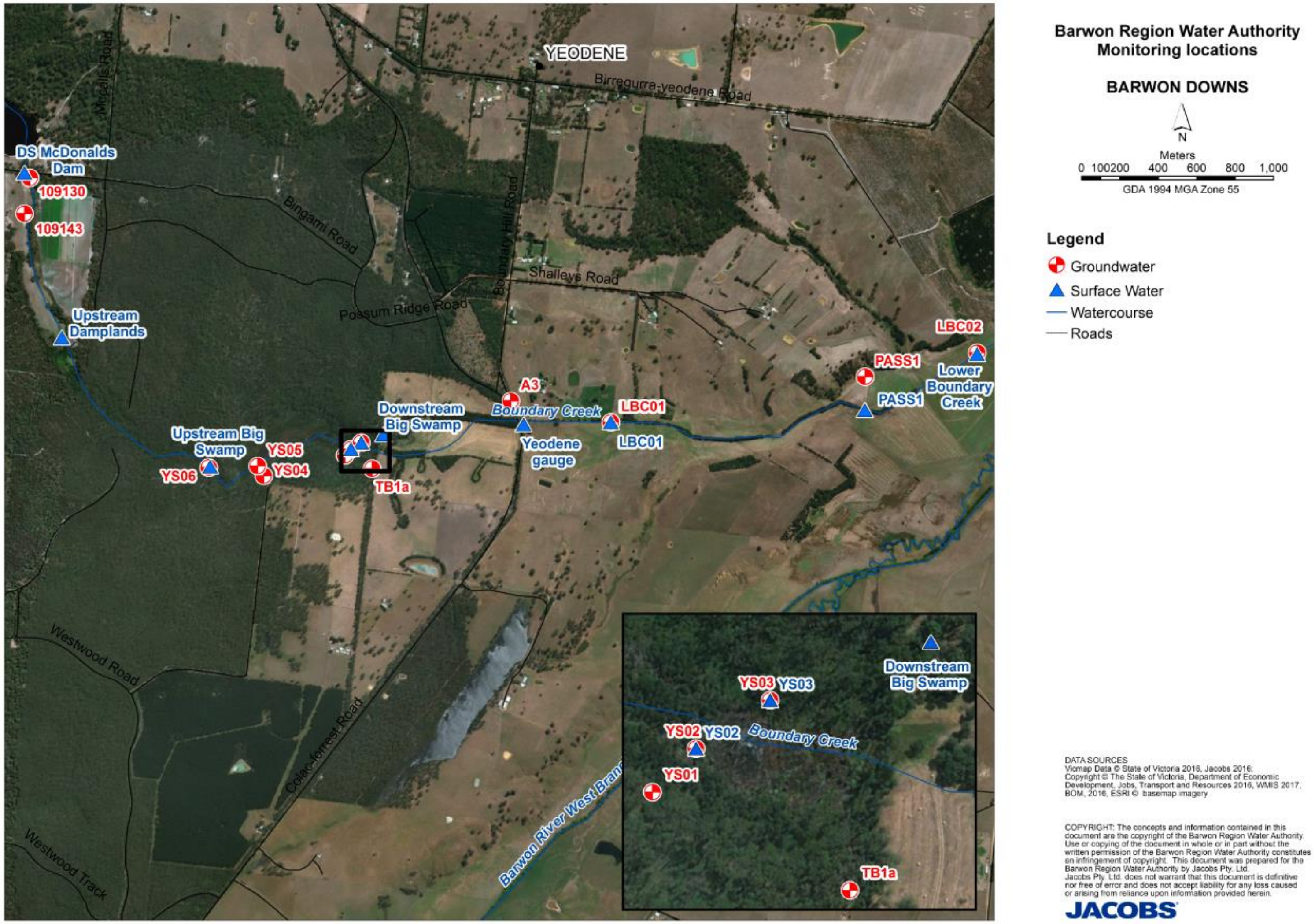
Six piezometers were installed in Yeodene Swamp and two bores were installed along the lower reach of Boundary Creek in order to assess groundwater-surface water interaction in those areas. The construction details of these bores, their method of construction and lithological analysis has been detailed in Appendix A.

3.3 Groundwater monitoring

Groundwater monitoring was conducted at previously established monitoring bores in the Boundary Creek catchment, as well as those constructed as part of these investigations. A complete list of the groundwater monitoring locations and the data collected at each site is provided in Table 3-1 below and illustrated in Figure 3-1.

At each of the monitoring locations listed in Table 3-1, the groundwater level was recorded using an electronic water level tape and groundwater samples were collected for analysis. Bores and piezometers were purged prior to sample collected using a hand bailer (in accordance with publication 669 EPA, 2000) and field water quality parameters were recorded using an YSI pro plus water quality meter. Samples were collected in bottles containing requisite preservatives according to Eurofins sampling guidelines. Samples were field filtered (where necessary) and stored on ice in the field before being refrigerated on return from field.

Groundwater level loggers in A3, PASS1 and TB1 were downloaded during investigations (see Figure 2-6 for locations).



DATA SOURCES
Vicmap Data © State of Victoria 2016, Jacobs 2016;
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Figure 3-1 Location of groundwater and surface water monitoring locations

Table 3-1 Groundwater monitoring locations for Yeodene Swamp study

ID	Zone	Easting	Northing	Manual water level monitoring	Water quality monitoring	Water level monitoring with logger
A3	55	212792	5742428	x	x	x
LBC01	55	213312	5742317	x	x	
LBC02	55	215218	5742679	x	x	
PASS1	55	214635	5742553	x	x	x
TB1a, b, c	55	212070	5742075	x	x	x
YS01	55	211929	5742145	x	x	
YS02	55	211960	5742176	x	x	
YS03	55	212013	5742211	x	x	
YS04	55	211506	5742039	x	x	
YS05	55	211475	5742090	x	x	
YS06	55	211220	5742081	x	x	

3.4 Surface water monitoring

Surface water monitoring was conducted at 9 locations. These have been listed in Table 3-2 below. The monitoring included a combination of water level measurement to assess groundwater and surface water interaction, spot flow measurement to assess change in flow along the creek under different conditions and sampling for water quality analysis.

Spot flow gauging was conducted downstream of “McDonalds Dam”, upstream of the Damplands, upstream and downstream of Yeodene Swamp, at the existing Yeodene stream gauge and at the lower end of Boundary Creek before its discharge point at the Barwon River. Flow velocity was recorded at 0.3 m intervals using a propeller driven flow meter to allow calculation of volume moving through the cross section in accordance with Olsen and Morris (2007).

Surface water levels along Boundary Creek were recorded relative to surveyed monitoring bores (see Table 3-1) and streambed cross sections. Spot flow gauging results were calibrated using permanent flow gauging information collected at downstream of “McDonalds Dam” and the Yeodene streamflow gauges.

Field surface water quality parameters were recorded using a YSI pro plus water quality meter and samples were collected in polyethylene containers in the field. Subsequently, samples were field filtered (where necessary) and transferred to bottles containing requisite preservatives according to Eurofins sampling guidelines. These were stored on ice in the field before being refrigerated on return from field.

Table 3-2 Surface water monitoring locations for Yeodene Swamp study

ID	Zone	Easting	Northing	Water level	Water quality	Spot gauge	Constant gauge
Downstream “McDonalds Dam”	55	210261	5743613	x	x	x	x
Upstream Damplands	55	210455	5742757	x			
Upstream Yeodene Swamp	55	211227	5742086	x	x	x	
YS02	55	211960	5742176	x	x		
Downstream Yeodene Swamp	55	212127	5742252	x	x	x	
Yeodene gauge	55	212858	5742305	x	x	x	x
LBC01	55	213312	5742317	x	x		

ID	Zone	Easting	Northing	Water level	Water quality	Spot gauge	Constant gauge
PASS1	55	214633	5742380	x	x		
Lower Boundary Creek	55	215218	5742671	x	x	x	

3.5 Soil analysis

During bore and piezometer installation, soil samples were collected at ~1 m intervals. Subsequent to lithological characterisation (as detailed in Appendix A), soil samples were placed in plastic re-sealable bags and stored on ice in the field according to EPA publication 655.1 (EPP, 2009). These were frozen on the night of collection and sent to Eurofins Laboratories for acid sulfate soil analysis (via screen tests and chromium reducible sulfur suite). The results of the analysis have been summarised in Appendix B and detailed in full in Appendix C.

3.6 Hydraulic testing

Hydraulic testing was conducted between the 26th and 27th of April, 2017. Hydraulic testing was conducted via the introduction and removal of a weighted PVC slug to displace approximately 1 m of water. Changes in water level during the tests were recorded at 1 second intervals using a solinst water level logger and cross checked at regular intervals using an electronic water level tape. The hydraulic conductivity (k) value given by the tests were determined using the Bouwer-Rice (1976) analytical method in the aquifer testing software program Aqtesolv. The results of hydraulic testing have been detailed in Appendix D.

3.7 Vegetation survey

A survey of the abundance and type of vegetation in Yeodene Swamp was conducted on 6 June 2017 along a transect extended from YS01 to YS03 (Figure 2-6). The transect was ~110m in length and included eight 5 x 5 m quadrats at 15 m intervals on alternating sides of the transect line in a method adapted from previous vegetation surveys throughout the Otway Forest in groundwater dependant ecosystems. All flora species within the plot were identified and cover estimated to the nearest 5%.

4. Results of field program

4.1 Chapter overview

This chapter summarises the results of the field program and the significance of the results within the context of this project. The chapter presents the results of geological logging, acid sulfate soils analysis, flow in Boundary Creek, surface water quality and groundwater quality analysis, a water balance for Boundary Creek and a vegetation survey of Yeodene Swamp.

The key results presented in each section are summarised in Table 4-1.

Table 4-1 Summary of results and findings of field program

Feature	Key findings
Hydrogeology	• Saturated alluvial sediments are likely to be present upstream of Yeodene Swamp as a localised perched aquifer. • Depth to watertable in the regional aquifer is 10-15 m below ground level upstream of Yeodene Swamp. • Saturated peat sediments in Yeodene Swamp are hydraulically separated from the underlying regional aquifer (LTA) by the aquitard. • The eastern end of swamp comprises saturated alluvial deposits overlying aquitard. • The aquitard thins to the west and is absent upstream of the swamp, however the exact location where aquitard is absent is not known. Shallow bores indicate that at the western end of the swamp the alluvial deposits overlie the regional aquifer.
Acid sulfate soils	• The highest concentration of net and potential acidity were found in the central and lower lying areas of Yeodene Swamp.
Surface water flow	• Surface water flows increase between “McDonalds Dam” and the top of the Damplands, which is likely to be result of surface runoff from the catchment and potential inflow from the local alluvial aquifer. • Two spot flow measurement showed that surface water flow declines through the Damplands and Yeodene Swamp as a result of groundwater recharge and evapotranspiration. The losses varied seasonally, and were 2.9 ML/day in May 2017 and 9.9 ML/day in August 2017. • The greater losses in August are likely to be associated with storage and are not necessary to maintain flows through the swamp. • Surface water flows are variably gaining and losing in Reach 3.
Surface water quality	• The most significant changes in water quality occur through Yeodene Swamp. • Changes in water quality through the swamp are consistent with the effects of acid sulfate soils including reduced pH, increased salinity, and increased concentrations of sulfate and dissolved metals. • Winter high flow conditions of greater than 15 ML/day did not dilute acidic inputs or the concentration of dissolved metals significantly.
Groundwater quality	• Groundwater quality affected by acid sulfate soils typically has low pH values a relatively high proportion of sulfate and dissolved metals. Accordingly: ○ Groundwater in the centre of the swamp was the most affected by acid sulfate soils. ○ Groundwater downstream of the swamp (A3 and TB1a) was somewhat affected by acid sulfate soils. ○ Groundwater upstream of the swamp and in Reach 3 (downstream of Yeodene gauge) is relatively unaffected by acid sulfate soils.
Groundwater – surface water interaction	• Immediately downstream of “McDonalds Dam” to the Damplands the spot flow measurements indicate the creek could be gaining. Inflows to the creek are likely to be result of surface runoff from the catchment and potential inflow from the local alluvial aquifer. This is new information and improves the conceptualisation of the Reach 2. • The Damplands and Yeodene Swamp are losing to groundwater, which is consistent with the existing conceptualisation. • Reach 3 of Boundary Creek is variably gaining/losing, and consistent with the existing conceptualisation.

Feature	Key findings
Water balance	• The greatest losses of surface water occur through the Damplands and Yeodene Swamp – ranging between 2.9 ML/day in May and 9.9 ML/day in August 2017. These volumes of water are representative of the swamp re-wetting after a period of no flow. It is estimated that the majority of the loss is recharge to groundwater with evapotranspiration making up less than 1 ML/day during these months. • Evaporation losses will be higher during the summer months and could be up to 2.5 ML/day.
Vegetation	• This part of Yeodene Swamp was not a permanent swamp historically (i.e. greater than 50 years ago) as the tree ferns and trees would not have established unless there was periodic drying. This could be the result of the construction of agricultural drains in the area. • The trees and tree ferns are likely to have died as a result of root death cause by permanent inundation. • Inundated area are un-vegetated as a result of the acidic water which is toxic to most plant species.

4.2 Geology

The location of monitoring bores is shown in Figure 4-1.

Lithological logs from YS01, YS02 and YS03 indicate the presence of silty and sandy clays to a depth of ~4 m. This is consistent with regional mapping and previous drilling at TB1 which indicated the alluvial deposits overlie aquitard deposits towards the eastern end of the swamp (Jacobs, 2016b). A schematic cross section extending between YS01 to YS03 has been illustrated in Figure 4-2.

Lithological logs indicate coarse sands at YS04. While regional mapping suggests the occurrence of outcropping aquitard material in this area (Figure 4-1), it is possible that drilling has penetrated through thin alluvial deposits and into the regional aquifer. Lithological logs at YS05 are consistent with alluvial deposits, while sandy and silty clay deposits at YS06 could be consistent with either shallow alluvial deposits or regional aquifer deposits. Based on these results, it remains unclear as to the exact boundary between outcropping aquifer deposits in the west, and aquitard deposits in the east.

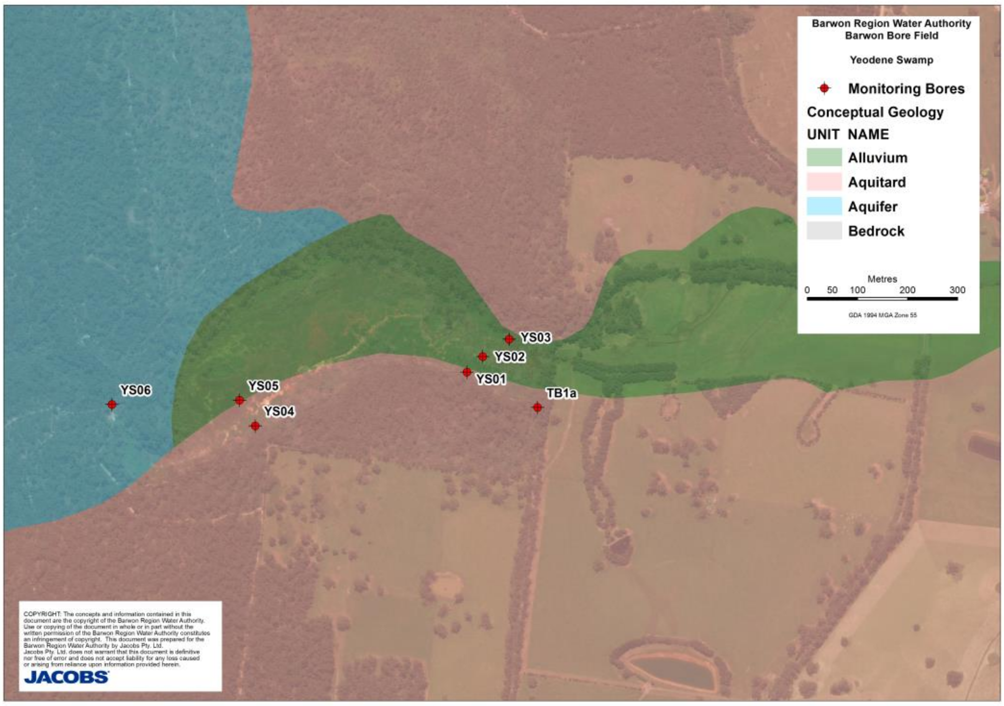

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Figure 4-1 Surface geology and monitoring locations (points of lithological analysis)

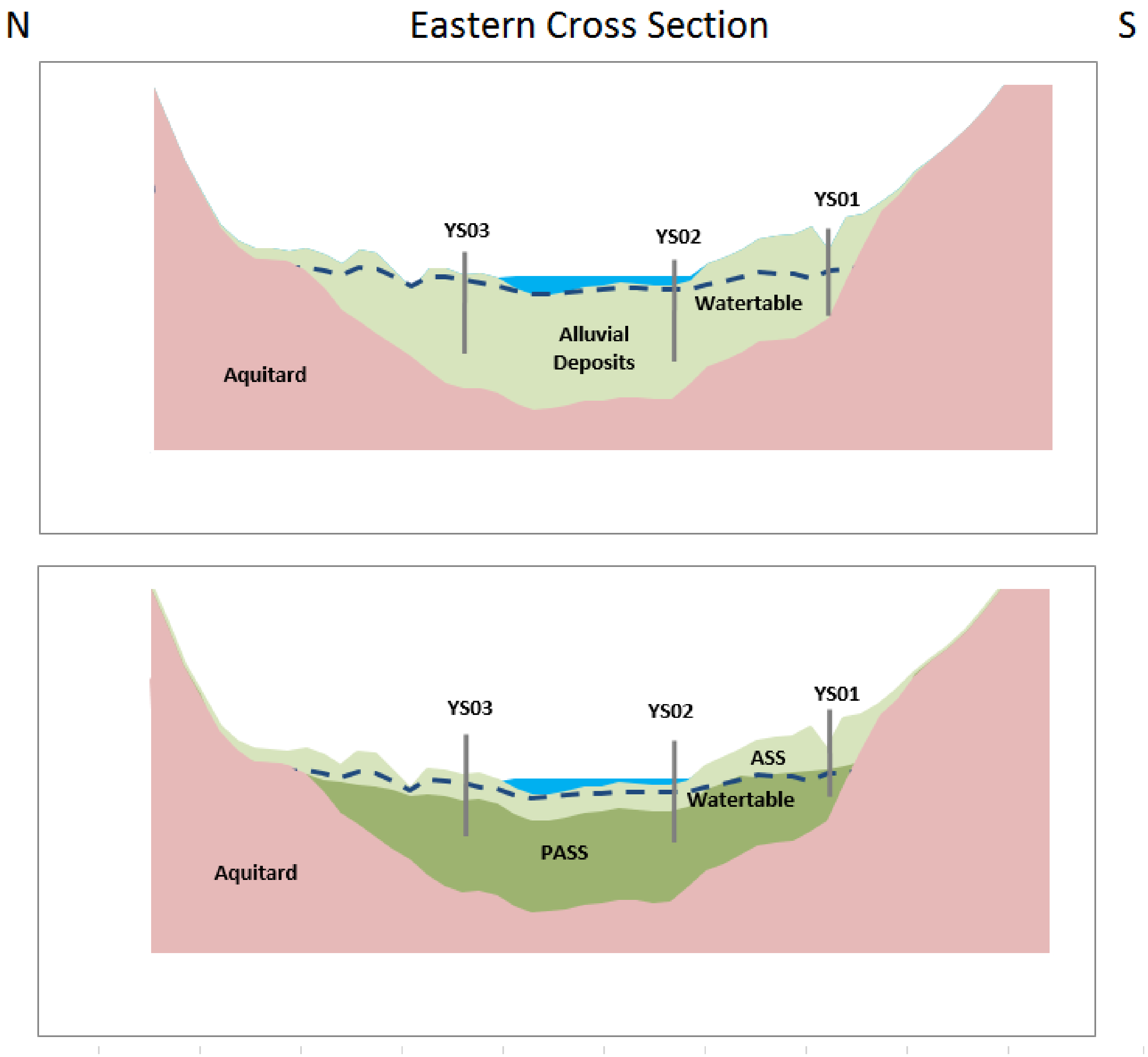


Figure 4-2 Conceptual cross sections of eastern end of Yeodene Swamp based on coring

4.3 Soils

Soil samples were collected at one metre intervals in the six shallow bores installed across Yeodene Swamp. The soils were analysed to inform the extent of actual and potential aid sulfate soils. This information is assits in assessing how much acid is in the swamp and the viability of different remediation options.

The results of acid sulfate soils analysis are provided in Appendix D and complete laboratory reports in Appendix E. This includes screen tests and chromium reducible sulfur analysis. A summary of these results can be found below.

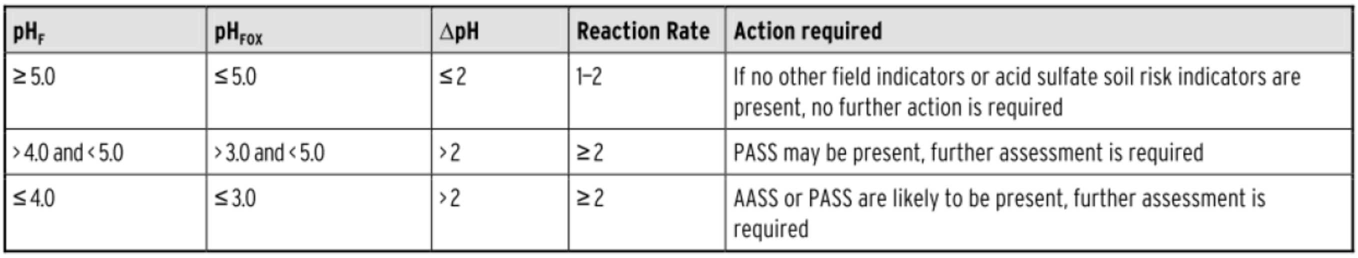
4.3.1 Screen tests

The results of the acid sulfate soil screen tests provide four preliminary indicators of acid sulfate soils:

- The soil pH (pH_F) which provides an indication of the current pH of the soils.
- The pH after addition of peroxide (pH_{FOX}), which provides an indication of the potential soil pH after oxidation.
- The change between the two pH values (ΔpH) and
- The reaction rate (RR) observed, which provides an indication of the rate at which oxidation occurs (a rate of 1 is unreactive indicating a slow rate of oxidation, while a rate of 4 is highly reactive and indicates rapid oxidation).

A total of 30 screen tests were collected at approximately 1 m intervals in each bores to understand the variability in soil pH spatially and with depth in the swamp. Analysis was conducted at Eurofins with results summarised in Table 7-1 of Appendix B. These have been compared against the guidelines provided in publication 655.1 (EPA, 2009) as illustrated in Table 4-2 below.

Table 4-2 Guideline criteria for acid sulfate soil screen tests



pH_F	pH_{FOX}	ΔpH	Reaction Rate	Action required
≥ 5.0	≤ 5.0	≤ 2	1–2	If no other field indicators or acid sulfate soil risk indicators are present, no further action is required
> 4.0 and < 5.0	> 3.0 and < 5.0	> 2	≥ 2	PASS may be present, further assessment is required
≤ 4.0	≤ 3.0	> 2	≥ 2	AASS or PASS are likely to be present, further assessment is required

The results of the screen tests can be summarised as follows:

- Soil pH (pH_F) results ranged between 2.8 and 6.3.
  - 6 of 30 samples had a pH_F below 4, indicating the presence of actual acid sulfate soils in these samples.
  - these occurred in the upper 1 m of the profile at YS01, YS02, YS03 and YS05 and correlate with parts of the swamp that are lower in elevation.
- Soil pH after addition of peroxide (pH_{FOX}) ranged from 1.5 to 4.0.
  - 17 of 30 samples had a pH_{FOX} below 3.0, indicating the presence of acid sulfate soils in Bores YS02 and YS05 and intervals in other bores (except LBC02)
  - 13 of 30 samples had a pH_{FOX} between 3 and 5, indicating the possible occurrence of acid sulfate soils. These results were found in intervals in all bores except YS02 and YS05 where pH_{FOX} values were lower.

- Soil ΔpH was >2 in 10 of 30 samples, indicating the presence of potential acidity. This was more common below 1 m depth soil profiles where reducing conditions persist and occurred at LBC01, LBC02, YS02, YS03 and YS06.

- Reaction rates were ≥2 in 29 of the 30 samples, suggesting the potential for rapid pyrite oxidation and acidification during drying and exposure to oxygen.

4.3.2 Acid sulfate soil testing

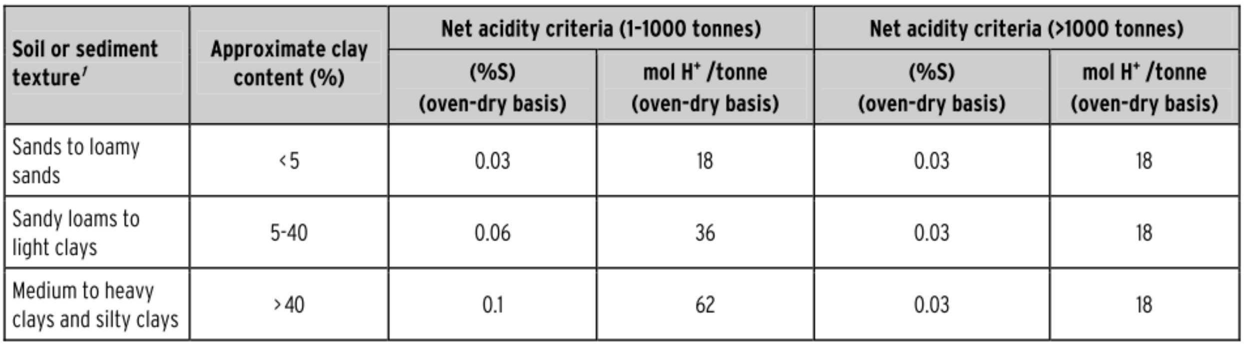
Chromium suite analysis was conducted on 30 samples. The chromium suite identifies different stores of acidity in the soil samples in order to estimate their acid generating potential, this includes:

- titratable actual acidity (which estimates the **actual acidity**)
- HCl and KCl extractable sulfur (which combined estimate the **retained acidity**)
- chromium reducible sulfur (which estimates the **potential acidity**)
- the **acid neutralising capacity** (which estimates the capacity of the soils to neutralise any acidity present)

Together, these results are used to estimate the **net acidity** present in the soils by subtracting the neutralising capacity from the combined actual, residual and potential acidities. This provides an estimation of the total (potential and actual) acid that could to be released from the swamp.

The results of the chromium suite have been summarised in Table 7-2 of Appendix B. The results have been compared against the texture based criteria for classification of acid sulfate soils, as illustrated in Table 4-3 below.

Table 4-3 texture based criteria for classification of acid sulfate soils (EPA, 2009)



Soil or sediment texture[1]	Approximate clay content (%)	Net acidity criteria (1-1000 tonnes)		Net acidity criteria (>1000 tonnes)	
		(%S) (oven-dry basis)	mol H^+ /tonne (oven-dry basis)	(%S) (oven-dry basis)	mol H^+ /tonne (oven-dry basis)
Sands to loamy sands	<5	0.03	18	0.03	18
Sandy loams to light clays	5-40	0.06	36	0.03	18
Medium to heavy clays and silty clays	>40	0.1	62	0.03	18

The concentration of **actual acidity** ranged from 3.7 to 910 moles of acid (H+/tonne). The highest concentrations were recorded in samples from YS02 and YS05 located through the centre of the swamp. These areas are most susceptible to inundation, pyrite formation and any resulting acidification. Additionally, acidic leachate is more likely to pool and concentrate in these lower areas of the swamp.

Concentrations of actual acidity were >18 moles of acid (H+/tonne) in all but 4 samples, indicating the widespread occurrence of actual acid sulfate soils. Actual acid sulfate soils were absent below 1 m depth at YS04 and YS06. These locations are higher in elevation than other areas of Yeodene Swamp and as such, are less susceptible to inundation, pyrite formation and any resulting acidification. In addition, there is evidence to suggest that aquitard deposits at YS04 and YS06 are limited. This could also increase drainage of these areas, reducing their susceptibility of inundation.

Retained acidity generally contributed little to the net acidity of samples. Concentrations were below detection (10 moles of acid (H+/tonne)) in 25 of the 30 samples. Concentrations only exceeded 18 moles of acid (H+/tonne) in two samples, including one sample from YS03 and one from YS05.

Concentrations of **potential acidity** ranged from below detection (3 moles of acid (H+/tonne)) to 9,000 moles of acid (H+/tonne), and were greater than 18 moles of acid (H+/tonne) in 12 of 30 samples. This indicates the presence of **significant additional stores of acidity which may be released in the event of ongoing drying and oxidation in the swamp**. Concentrations were highest below 1 m depth at YS02, YS03 and YS05. It is likely that these areas are often below the water table where pyrite oxidation is limited, resulting in greater stores of potential acidity.

As the mass of material affected in Yeodene Swamp is greater than 1,000 tonnes, the results have been compared against the guideline level of 18 moles of acid (H^+) per tonne (EPA, 2009). As the pH of all samples under addition of KCl solution was acidic (<6.5), samples were determined to be void of **acid neutralising capacity**.

The resulting **net acidities** based on the above analysis confirms the widespread distribution of acid sulfate soils throughout Yeodene Swamp. Concentrations of net acidity ranged from <10 to 9,600 mole of acid (H^+/tonne) and were greater than the criteria level of 18 mole of acid (H^+/tonne) in 26 of 30 samples.

The net acidity was used to estimate how much acid was in the swamp. Assuming that acidity in the upper 1 m of the soil profile could be mobilised, there is estimated to be 134 million moles of acid in the swamp. The creek flows for approximately 6 months of the year and the annual flux leaving the Yeodene Swamp is estimated to be around 55,000 moles of acid per year (assuming a flow of 2 ML/day for 6 months a year). Based on this, it is estimated that conditions similar to those observed currently could persist for decades to hundreds of years.

4.4 Surface water flow

Flow measurements in Boundary Creek were recorded in May and August 2017. Flows were initially measured via spot flow gauging at multiple locations between “McDonalds Dam” and Yeodene stream flow gauges. These results were then calibrated to the constant gauging data recorded at both “McDonalds Dam” and Yeodene stream gauges.

Rainfall in the week leading up to flow gauging on May 4th was minimal and flow records from both the “McDonalds Dam” and Yeodene stream gauges indicate that flow in Boundary Creek was at a relatively steady state (Figure 4-3). Given this, no allowance has been made for any lag in flow peaks moving through the creek.

Significant rainfall was recorded in the week preceding flow gauging on August 22nd, however gauging records indicate that the flood peak had passed through the system on the day of gauging. As such, allowance for flood peak lag was unnecessary during August flow gauging.

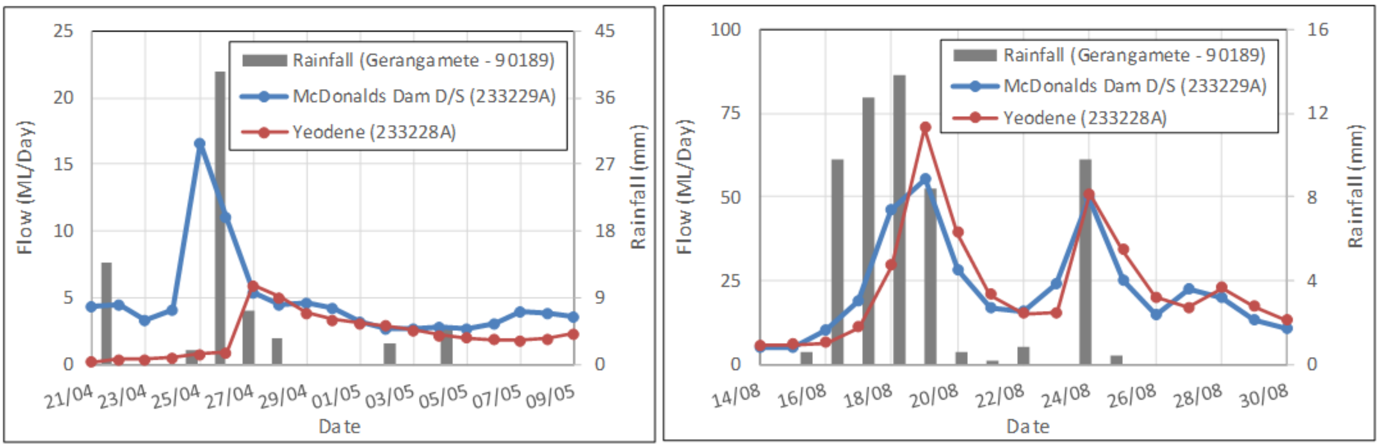


Figure 4-3 Streamflow in Boundary Creek at “McDonalds Dam” D/S flow gauge (233229A) and Yeodene (233228A) in response to rainfall recorded at Barwon Downs (Gerangamete gauge - 90189)

Typical of spot gauging, the spot gauging results overestimated the flow compared to the metered flow gauging data by an average of 19% in May and an average of 16% in August. As such, spot flow measurements have been reduced by 19% in May and 16% in August in order to calibrate the results to constant flow data. The results of the spot flow gauging and the calibrated flow measurements have been listed in Table 4-4 below.

The results highlighted that surface water flow increased between “McDonalds Dam” and the top of the Damplands in both sampling events. This is likely to be result of surface runoff from the catchment and potential inflow from the local alluvial aquifer. Streamflow declined through the Damplands and Yeodene Swamp in both sampling events with losses of 2.9 ML/day recorded in May and 9.9 ML/day in August. These losses are attributed to a combination of evapotranspiration (ET) and recharge to the shallow groundwater. Given the time of year, recharge to the shallow groundwater is considered to be the dominating process, with ET making up less than 1 ML/day.

Between the swamp and the Yeodene gauge, flow decreased marginally in May and increased marginally in August. Surface water flow was lost to the shallow aquifer in May as this was after a period of cease to flow where groundwater levels would have declined. The shallow aquifer would have been recharged between May and August which meant groundwater levels rose sufficiently by August, allowing groundwater to discharge to the creek.

Downstream of the Yeodene gauge, surface water flows increased in May and August as a result of runoff in this part of the catchment and groundwater discharge.

Table 4-4 Summary of stream flow along Boundary Creek

Condition	Location	Spot gauging	Constant gauging	Calibrated flow	Losses/Gains
		ML/Day	ML/Day	ML/Day	
First flow 4/05/2017	**Downstream of McDonald's Dam**	3.9	3.0	3.2	
	Upstream Damplands	6.6		5.3	Gain 2.1 ML/day
	Upstream of Big Swamp	4.7		3.8	Loss 1.5 ML/day
	Downstream of Big Swamp	3.0		2.4	Loss 1.4 ML/day
	Yeodene Gauge	2.6	2.2	2.1	Loss 0.3 ML/day
	Lower Boundary Creek	4.6		3.7	Gain 1.6 ML/day
Winter high flow 22/08/2017	**Downstream of McDonald's Dam**	19.5	15.6	16.3	
	Upstream Damplands	28.0		23.4	Gain 7.1 ML/day
	Upstream of Big Swamp	23.0		19.2	Loss 4.2 ML/day
	Downstream of Big Swamp	16.1		13.5	Loss 5.7 ML/day
	Yeodene Gauge	17.2	15.0	14.4	Gain 0.9 ML/day
	Lower Boundary Creek	20.2		16.9	Gain 2.5 ML/day

4.5 Water quality

4.5.1 Surface water

Water quality samples were collected at the same time as the spot gauging. The results of field and laboratory analysis of surface water from Boundary Creek has been summarised in Appendix B and detailed in full in Appendix C. The key findings of these analysis are summarised below.

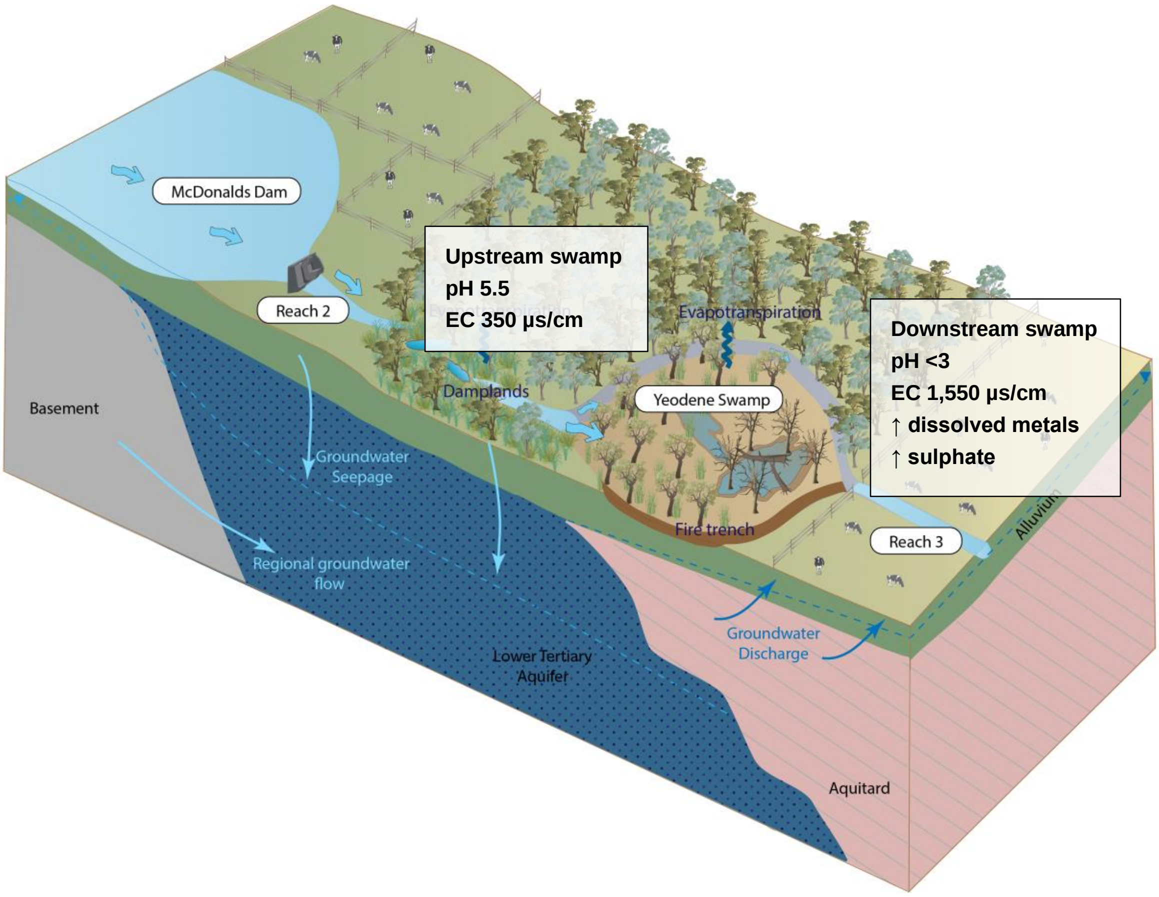


Figure 4-4 Conceptual model showing changes in water quality

In May 2017, water upstream of the Damplands was slightly acidic ranging in pH between 5.5 and 5.76, and fresh ranging in EC between 337 and 392 µS/cm (see Figure 4-5). Water pH fell significantly through Yeodene Swamp, resulting in a pH of 2.95 downstream of the swamp. This is symptomatic of acidic inputs from acid sulfate soils and is further evidenced by an increase in sulfate concentrations from ~6 mg/L to 700 mg/L (see Figure 4-5). Surface water downstream of the swamp also increased in EC (to 1,553 µS/cm) along with the concentrations of various dissolved metals such as Aluminium (which increased from <0.05 mg/L to 75 mg/L), indicating the acidic mobilisation of metals.

Between Yeodene Swamp and Yeodene Gauge, pH increased slightly (to 3.21) while EC and the concentration various dissolved metal species fell (see Figure 4-5). The increase in pH may be related to minor inputs of surface water runoff, as well as any buffering from streambed sediment or oxidation. Runoff may have also contributed to the dilution of various metal species and the reduction in EC, however this may also be related to the sorption of dissolved metal species on streambed sediments or their precipitation at slightly higher pH levels. Between the Yeodene stream flow gauge, and the Lower Boundary Creek site, the pH increased with concentrations of sulfate and various metals and pH falling while EC increased. This is likely to be related to inputs of water that is saltier and higher in pH than Boundary Creek, such as groundwater or tributary inflows.

In August 2017, surface water in the upper reaches of Boundary Creek was circum-neutral, ranging in pH between 7.54 and 7.28, and fresh, with an EC of ~450 µS/cm. Water pH again declined through Yeodene Swamp, resulting in a pH of 3.60 downstream of the swamp (see Figure 4-5). Similar trends in EC, sulfate and dissolved metals were also observed, with EC increasing to 645 µS/cm, sulfate increasing from 16 to 68 mg/L and dissolved metals such as aluminium increasing from 0.23 mg/L to 8.0 mg/L. These results were again consistent with the input of acidic leachate from acid sulfate soils.

Less variation was observed in the chemistry of water downstream of Yeodene Swamp in August compared to May. Changes in pH were minor, increasing from 3.60 downstream of Yeodene Swamp site to 3.74 at the Lower Boundary Creek site (see Figure 4-5). Concentrations of sulfate increased through this section, from 68 mg/L to 110 mg/L, along with aluminium from 0.23 to 8.0 mg/L and EC from 645 to 901 µS/cm. Reduced surface water variability through this reach during August may be related to the higher volume of water that was moving through the creek at this time, and a reduced capacity for things like groundwater inflow, streambed and atmospheric interactions which affect water chemistry.

It is also noted that the concentration of many dissolved metals, including Aluminium, Cadmium, Nickel and Zinc were below or near the analytical detection limit upstream of Yeodene Swamp. These increased by several orders of magnitude downstream of the swamp, and were above the ANZECC guideline for the protection of 80% of freshwater species (ANZECC, 2000). Similar trends were observed in August for Aluminium, Nickel and Zinc.

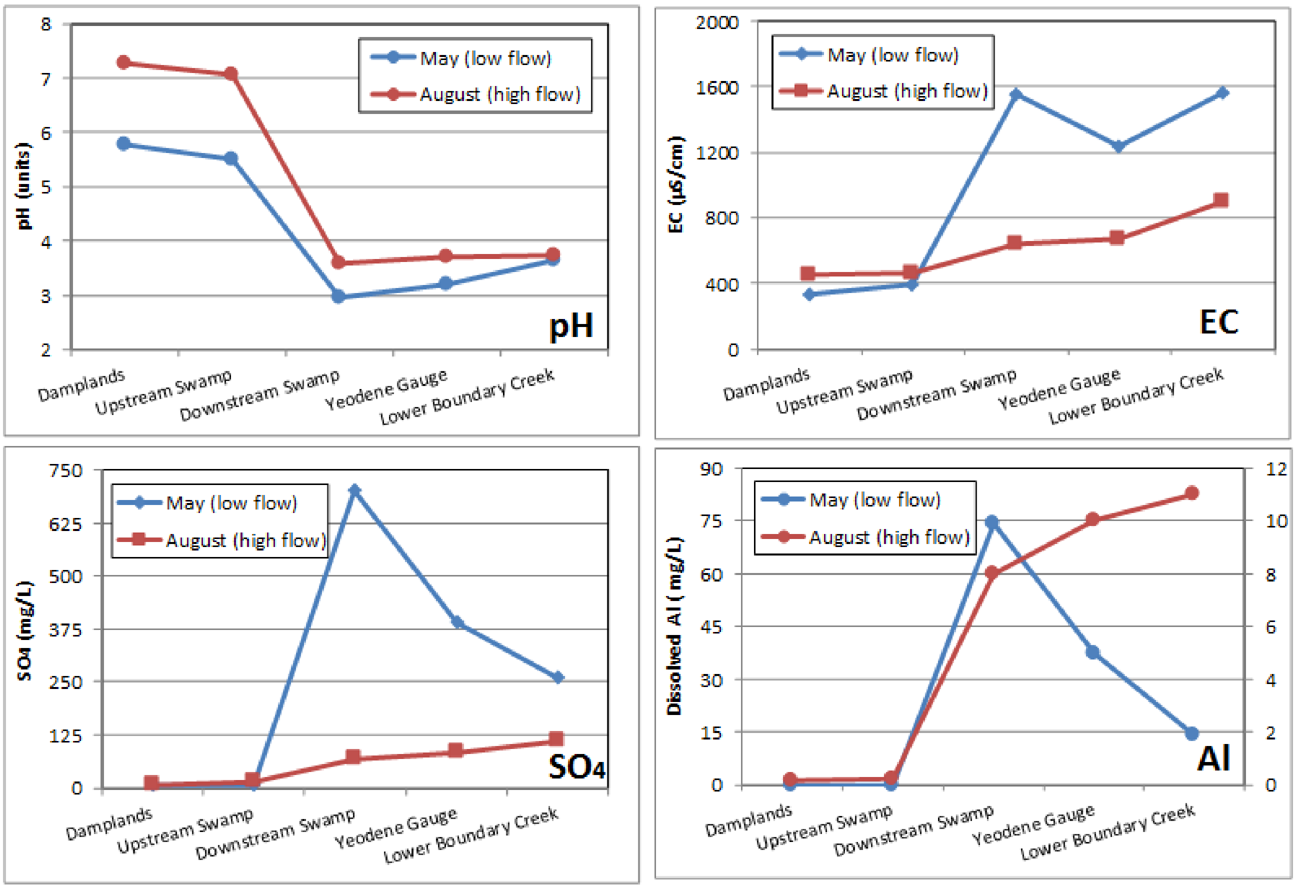


Figure 4-5 Change in pH, EC, sulfate and Al concentrations in Boundary Creek during May and August

4.5.2 Groundwater

Groundwater pH in the shallow alluvial aquifer was the lowest in YS01, YS03 and YS05, ranging between 1.58 and 2.72 in May and between 2.59 and 3.80 in August, 2017. Groundwater downstream of Yeodene Swamp (in bores A3 and TB1a) was also acidic, ranging in pH between 4.03 and 4.19 in May and 4.56 and 5.0 in August. Groundwater in the remaining bores (YS02, YS06, LBC01, LBC02 and PASS1) was circum-neutral to mildly acidic, ranging between 5.33 and 6.28 in May and between 5.71 and 6.64 in August.

The results suggest that the shallow alluvial aquifer is affected by acid sulfate soils. Groundwater at YS01, YS03 and YS05 are the most affected by acid sulfate soils, followed by A3 and TB1a. Further, groundwater upstream of the swamp and downstream of Yeodene streamflow gauge does not appear to be affected by the local occurrence of acid sulfate soils, and is consistent with regional groundwater pH throughout the catchment.

This is also demonstrated by the concentration of sulfate and chloride in groundwater supports this assertion, with a higher proportion of sulfate relative to chloride in groundwater with lower pH values (Figure 4-6). This is expected in groundwater affected by acid sulfate soils, as sulfate is released during the oxidation of acid sulfate soils, but not chloride.

Similar trends are also observed between metal concentrations and pH, with elevated concentrations of dissolved metals observed in groundwater affected by acid sulfate soils. This correlation is related to the acidic leaching of metals from soils and is well documented in scientific literature. The trends have been illustrated in Figure 4-7 below which shows a logarithmic correlation between aluminium and zinc concentrations and pH. These have been presented relative to the concentration of chloride in order to account for any increase in metal or sulfate associated with increased salinity.

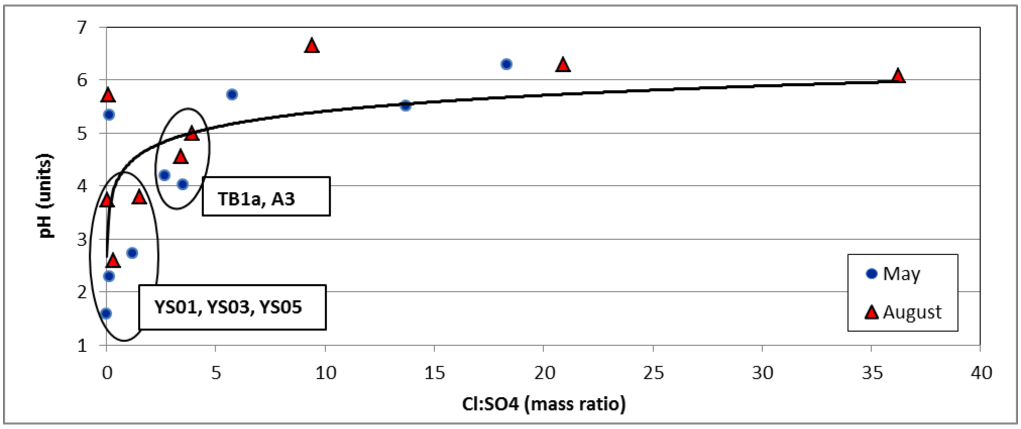


Figure 4-6 Covariance between groundwater pH and ratio of Cl:SO_4

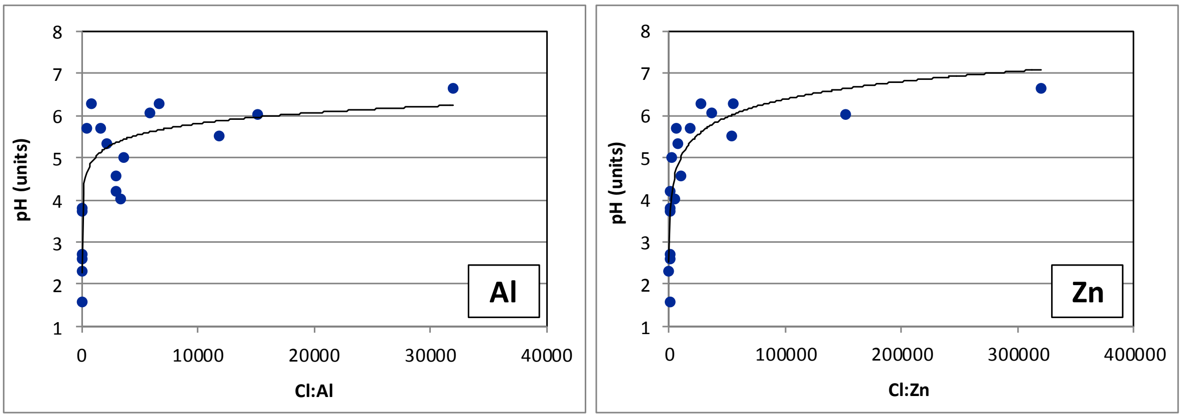


Figure 4-7 Covariance between groundwater pH and ratio of Cl:Al and Cl:Zn

4.6 Groundwater and surface water interaction

Groundwater and surface water levels were measured at 8 locations along Boundary Creek and Yeodene Swamp. These were collected during May, after the creek had resumed flowing from summer flow cessation, and during August, after 3 months of continuous flow in the creek. The levels have been listed in Table 4-5 and the gaining or losing status of each site has been listed.

Downstream of the dam surface water flow increase and this could be the result of runoff in the catchment or discharge from a local alluvial aquifer. There are no shallow existing bores in this part of the catchment to confirm the presence of a local alluvial aquifer. Existing bores are around 10 m deep and groundwater levels in these bores are below the stream bed elevation confirming that creek is losing to the regional aquifer system. However it is possible that there is a local alluvial aquifer system perched that provides some flow to creek. Equally it is also possible that there are small drainage lines that direct runoff to the creek, or potentially there could be some leakage from the dam.

The results indicate that the Damplands and Yeodene Swamp were losing during May 2017, however the hydraulic gradient between groundwater and surface water was much lower through the swamp than in Damplands. The lower reaches of Boundary Creek were gaining in May, with groundwater levels higher than surface water levels between the Yeodene gauge (at bore A3) and the lower Boundary Creek site (at bore LBC02).

The Damplands was again losing during August, as were the upper parts of Yeodene Swamp at YS06 and YS05. However, through some lower parts of Yeodene Swamp, groundwater recharge over winter had increased the groundwater levels such that they were equal to surface water levels. This indicates that at this point in time, groundwater and surface water levels were hydraulically neutral, resulting in a zero net water exchange at this location (YS02). The lower reaches of Boundary Creek between the Yeodene Gauge and the Lower Boundary Creek site were again gaining.

Table 4-5 Summary of gaining and losing conditions along Boundary Creek

Condition	Location	Surface Water	Groundwater	Status
		mAHD	mAHD	
First flow	**109130**	159.40	152.64	Losing
	109143	156.70	151.05	Losing
	YS06	149.38	149.17	Losing
	YS05	148.16	148.02	Losing
	YS02	141.51	141.37	Losing
	A3	132.90	138.28	Gaining
	LBC01	130.38	130.56	Gaining
	LBC02	118.68	118.72	Gaining
Winter high flow	**109130**	159.83	153.14	Losing
	109143	157.06	151.57	Losing
	YS06	149.68	149.57	Losing
	YS05	148.40	147.95	Losing
	YS02	141.55	141.55	Neutral
	A3	133.57	139.21	Gaining
	LBC01	129.40	130.92	Gaining
	LBC02	119.00	119.23	Gaining

4.7 Vegetation

The area assessed at the eastern extent of Yeodene Swamp (as detailed in Section 3.7) showed signs of change in the relatively recent past. The transect began and ended in terrestrial environments that showed no sign of regular inundation, however the majority of the area was a seemingly permanent swamp of between 10 cm and 1 m depth. The permanence of the swamp is assumed due to the lack of any emergent vegetation on the fringes that commonly develops if a swamp is ephemeral such as annual grasses, sedges or small seedlings of surrounding shrubs and trees. The area was clearly not a permanent swamp in the recent past due to the presence of remnant tree fern stumps and fallen eucalypt trees within the permanent swamp. The size of the trees would suggest that they were more than 50 years old.

Whilst both tree ferns and the eucalypts, most likely Swamp Gum based on surrounding vegetation at the fringes of the swamp, rely on damp conditions and can tolerate periodic inundation, these species cannot survive constant inundation, particularly in slow moving water with little dissolved oxygen. The conditions of constant inundation would likely have resulted in root death. It is therefore most likely that both the trees and the tree ferns died due to an increase in the duration of inundation at the location due to changes in the local hydrology. Whilst this may have been exacerbated by the acidic conditions and increases in toxic metallic ions (e.g. zinc, cadmium and aluminium) as described in section 4.5.1, the primary cause of the change in vegetation noted is the change in hydrology resulting in increased inundation. The timing of the change cannot be pinpointed based on the observations made at the site but is estimated to have been within the last 10-30 years based on the decay in the logs observed and the fact the tree ferns are still standing.

The current vegetation present at the fringes of the swamp is typical of the vegetation along Boundary Creek and within Yeodene Swamp upstream of the assessed area. A cover of Scented Paperbark and Prickly Tea-tree shrubs over sedges and rushes (Po’ongort and Tall Rush) was recorded in areas not subject to constant inundation on the edges of the inundated swamp with Swamp Gums present where the topography was slightly higher.

Further up the banks at the ends of the transect, obligate terrestrial species such as Hazel Pomaderris, Forest Wire-grass and Hemp Bush were dominant due to being slightly elevated again, although all measurements within the transect were within only ~1.5 m elevation. Within the water of the swamp only Nodding Club-rush was noted and then only at the fringes. Largely, the only vegetation noted other than Nodding Club-rush within the water was large amounts of filamentous green algae attached to the fallen logs submerged in the swamp. It would be expected that other obligate aquatic species known to occur upstream such as Southern Water-ribbons, Twig-Sedges and even Tall Rush would be present within the inundated sections of the swamp and are conspicuous in their absence. This is most likely due to the relatively high acidity as a pH<4 is considered to be generally toxic to the majority of plant species. Coupled with the potential presence of potentially toxic concentrations of metallic ions, it is likely that the inundated portion of the swamp will remain largely un-vegetated without a change in water quality.

In summary, the vegetation at this location indicates:

- This part of Yeodene Swamp was not a permanent swamp historically (i.e. greater than 50 years ago) as the tree ferns and trees would not have established unless there was periodic drying. This could be the result of the construction of agricultural drains in the area.
- The trees and tree ferns are likely to have died as a result of root death cause by permanent inundation.
- Inundated area is un-vegetated as a result of the acidic water which is toxic to most plant species.

Figure 4-8 : 180 degree photo from centre of transect in Yeodene Swamp.

4.8 Conclusions and flow recommendations

The review of historical data, together with the new information collected during the field program, highlights the importance of maintaining flow all year round at the Yeodene gauge to prevent drying at Yeodene Swamp, thereby improving the existing water quality issues downstream of the swamp.

The first cease to flow event where there is both surface water flow and quality data available was in 1990. The creek was dry for one month which allowed the swamp to dry and for acid sulfate soils to oxidise. The groundwater quality at Yeodene gauge had a pH < 5 for approximately 3 months. Low pH events were also recorded in the following two summers (1991 and 1992) as a result of low summer flows. The low pH events extended for a period of 4-5 months and the pH levels improved during the winter months.

It is difficult to determine the actual flow required to improve and maintain the water quality downstream of the swamp as for significant periods of time during the warmer months, less than 2 ML/day has been recorded downstream of “McDonalds Dam”. Consequently it is certain that more than 1.5 ML/day is required.

It could be that 2 ML/day is sufficient, but there is no scientific evidence to support this. However, flow records at Yeodene gauge start declining when the flow drops below 3 ML/day downstream of “McDonalds Dam”. The streamflow gauging also estimated that approximately 3 ML/day was being lost through the Damplands and the Yeodene Swamp.

Therefore it is recommended that the environmental flow requirement of Reach 2 is increased initially from 2ML/day to 3 ML/day as recorded downstream of “McDonalds Dam”. It is possible that additional supplementary flows could be required during dry weather events during the short term (likely to be weeks or months) to prevent cease to flow events at the Yeodene stream gauge (downstream of the swamp). It is also likely that this volume would be reduced to 2 ML/day once the swamp is permanently inundated.

Ongoing groundwater and surface water monitoring in the context of adaptive management is recommended to confirm that the flow recommendation is meeting the desired outcome.

5. Management strategies

5.1 Chapter overview

This section considers a range of management strategies with the aim of neutralising acidity in the Yeodene Swamp and improving the quality and volume of water flowing in Reach 3 of Boundary Creek. More specifically, this means maintaining a minimum flow of 0.5 ML/day through Reach 3 that doesn't result in future fish death events, either within the reach or the Barwon River.

Each potential remediation strategy is discussed in terms of whether it would reach this objective, how it may be implemented conceptually, the potential outcomes of the strategy and the estimated costs (if feasible). The strategies that have been considered in this report include:

1. Do nothing
2. Direct treatment of soils with neutralising agents
3. In drain water treatment with limestone
4. Diluting acidic discharge
5. Revising flow release location
6. Inundating Yeodene Swamp

It should be noted that each of these options has been assessed in isolation from each other. While this approach is valid and useful in highlighting the strengths and weaknesses of each method, it does not preclude the combination of strategies in their whole, or part, as part of an overall management plan.

The outcomes of the assessment have been summarised in Table 5-1 below. More detail on each option is provided in the following sections.

Table 5-1 Summary of management options

Option	Feasibility	Rationale
Do nothing	Unacceptable	• Will not reach management objective for decades. • Yeodene Swamp will continue to release acidic water in Reach 3. This is considered unacceptable because acid releases will continue for several hundred years. • Groundwater levels upstream of Yeodene Swamp will take at least 25-30 years to recover to pre-pumping levels. In addition to this, the swamp is highly unlikely to recover naturally with the fire trenches and drains at the eastern end of the swamp and predicted climate change. This means that the swamp cannot be rehabilitated without intervention.
Treatment of soils	Low - Moderate	• Could reach objective in short term, but likely to cause additional environmental impacts. • Significant works would be required to access the entire swamp to distribute neutralising agents, which will be very disruptive to existing flora and fauna. • Significant costs associated with first application and subsequent applications are likely to be required.
Installation of a lime drain in Reach 3	Low	• Could reach water quality objective in reach 3 the short term. • A limestone drain has the potential to improve water quality during low flow periods, however likely to be limited benefit during high flow events. • Significant capital costs would be required which would result in major modifications to Reach 3 and ongoing maintenance would also be necessary. Furthermore, water quality in Yeodene Swamp would not improve. • This option focusses on fixing the symptom rather than the problem.
Diluting acidic discharge	Not feasible	• Insufficient volumes available to reach objective. • Volumes of water required for dilution cannot be sourced in this region and would increase flooding and adversely impact Reach 3:

Option	Feasibility	Rationale
		○ 250 ML/day during low flows ○ 60 ML/day during high flows
Revising flow release location	Low	• Will not reach management objective as acidic flush events would continue. • Require the hydraulic isolation of Yeodene Swamp from Boundary Creek. • Improve water quality in Reach 3 under summer low flow conditions, however likely to cause adverse impacts on water quality under high flow conditions when the swamp floods as pent up acid would be flushed out in high flows. • This would increase drying in the swamp, which would exacerbate the acid sulfate soils in the swamp.
Inundating Yeodene Swamp	Moderate - High	• Has potential to achieve management objective in swamp and reach 3 in the medium to long term. • Key indicator for low pH events is "cease to flow" conditions at the Yeodene Swamp. This objective of inundating the swamp is to prevent cease to flow events at Yeodene. • Likely to be technically feasible and cost effective option to inundate swamp by increasing supplementary flows and infilling fire trenches and agricultural drain at eastern end. Approach to complete this could involve: ○ Infill the fire trenches and block the agriculture drain to allow the swamp to retain more water over the winter months. ○ Minimum flow required initially is 3 ML/day as measured below McDonald's Dam. • Low flow requirement of 3 ML/day is a best estimate based on a detailed assessment of the historical data. It is possible that more water could be required for short time periods during very dry conditions. Equally it's also possible that this volume could be reduced to 2 ML/day within 2-3 years as the swamp remains saturated. • Ongoing adaptive management is required that involves regular monitoring and site visits are recommended to ensure the minimum flow requirement is meeting the objective.

5.2 Management objective

The objective of the management strategy is to maintain a flow of 0.5 ML/day, with a median pH of 5 in Reach 3 of Boundary Creek, to ensure there are no fish death events in either Boundary Creek or downstream Barwon River. Given the altered nature of the Yeodene Swamp over time, a median pH of 5 is considered to be an reasonable management objective.

The State Environment and Protection Policy (SEPP) guidelines recommends that the pH for waterways should be between 6.4 and 7.7, with minimum acceptable pH of 6.4 for 75 percent of the time to support ecological values of a creek. At pH less than 6 and greater than 9, harmful effects to aquatic species may occur (e.g. stress, disease susceptibility), and at pH less than 5 or greater than 10, harmful effects are almost certain (NSW DPI 2011; Waterwatch Victoria undated). When the pH is less than 4, there is a significant risk of fish deaths (NSW DPI 2011).

The median pH of water in Reach 3 since 1999 has been 3.8, which poses a significant risk of fish deaths in this reach and further downstream in the Barwon River. The risk is particularly high during autumn rainfall events when there are low flows in the Barwon River that do not sufficiently dilute low pH water from Boundary Creek. A pH of 3.8 is also less than the median pH between 1990 and 1999 (5.9) and significantly less than the pre 1990 median pH of 6.5. Given the altered nature of the Yeodene Swamp as a result of reduced flows and fires, a reasonable objective of the remediation is to increase the median pH of the water measured at the Yeodene flow gauge to 5, which is expected to significantly reduce the risk of fish kills death events in Boundary Creek and the Barwon River due to low pH water from Yeodene Swamp.

Although a median pH of 5 exiting the swamp will improve the current water quality and is expected to significantly reduce the risk of a subsequent fish death event, a pH of 5 will still pose a moderate risk to aquatic species in Reach 3 of Boundary Creek as it does not return the creek to its historical state (pH greater than 6). It also does not bring the water quality to be within the State Environment and Protection Policy (SEPP) guidelines. Furthermore, as the objective is a median value, there could be short term low pH events that may require a management response. Given the altered nature of the Yeodene Swamp over time, a median pH of 5 is considered to be a reasonable management objective.

5.3 Do nothing

5.3.1 Objective

This option considers the likely environmental outcomes if active management strategies for Boundary Creek and Yeodene Swamp are not implemented. As such, consideration of this option provides a baseline against which subsequent options can be assessed.

5.3.2 Concept

In the event that no remedial or management actions are undertaken in Yeodene Swamp or the Boundary Creek catchment, then it is expected that the creek system would operate in a similar way to those observed currently. Periods of flow cessation would be expected to continue in Boundary Creek, along with periods of drying in Yeodene Swamp, acid generation, and the input of acidic and metalliferous leachate into the lower reaches of Boundary Creek.

5.3.3 Potential outcomes

Regardless of whether the Barwon Downs borefield operates in the future, the groundwater levels upstream of Yeodene Swamp will take 25-30 years to recover to pre-pumping levels. In addition to this, the swamp is highly unlikely to recover naturally with the fire trenches and drains at the eastern end of the swamp and predicted climate change. This means that the swamp cannot be rehabilitated without intervention.

The absence of remediation would result in continued acid generation in Yeodene Swamp, and the input of acidic and metalliferous leachate into the lower reaches of Boundary Creek. It would be expected that the lower reach of Boundary Creek would cease to flow during summer/autumn periods. Winter and spring flows would be acidic (pH <4) and contain toxic concentrations of dissolved metals (including Al, Cd, Ni and Zn) as currently observed.

Under current conditions (assuming a concentration of acid of around 530 mg$CaCO_3$/L and a flow of 2 ML/day for 6 months of the year), the annual flux of acid leaving Yeodene Swamp has been estimated to be around 230 tonnes of acid per year ($CaCO_3$ equiv). The mass of acid currently stored in the swamp (according to net acidities measured during this study and the assumption only acidity in the upper 1 m of the soil profile will be mobilised) is estimated to be 11,000 tonnes of acid ($CaCO_3$).

Based on this, it is estimated that conditions similar to those observed currently could persist for decades to hundreds of years.

Given the “do nothing” option will not achieve the management objectives, and acidic metalliferous conditions would persist, it is considered to be an unacceptable option and therefore cost estimates have not been provided.

5.4 Direct treatment of soils with neutralising agents

5.4.1 Objective

This option aims to neutralise the acidity present in soils in Yeodene Swamp, and to enhance the quality of water in the lower reaches of Boundary Creek.

5.4.2 Concept

The addition of chemical agents to neutralise acidity is a well-established management practice in the treatment of acid sulfate soils. The agents are compounds with a high acid neutralising capacity such as calcium carbonate (often in the form of agricultural lime), calcium oxide, calcium hydroxide and others. These are either added to water flowing through the affected system, or are directly incorporated into sediments.

A variety of application methods are also available pending the nature of the site and access limitations. These include the direct application of lime (CaOH) powder, the application of agricultural lime ($CaCO_3$) slurries via pressure hose, or dusting large areas with agricultural lime from an aircraft (see Figure 5-1).

Figure 5-1 Application of slurry to Lower Murray Lakes (left) and aerial application of lime to Currency Creek (right) (EPHC & NRMMC, 2011).

One of the main disadvantages of using neutralising agents is the difficulty of ensuring its effective application. For example, the agent may be eroded and mobilised from a system before it has had sufficient time to neutralise the acid present. Additionally, the agent may not fully dissolve in the aquatic system, further reducing its efficacy. The neutralising capacity of the agent can also be further reduced if it becomes coated with iron oxides or gypsum.

In addition to the above factors, if the agent is to be incorporated into the soil profile (to improve its effectiveness), sediment disruption can impact species and habitats. Finally, neutralisation of a water column will cause the precipitation of any heavy metals dissolved during acidification, leading to sediment surfaces being coated with a sludge that is enriched by heavy metals. This can be subsequently released if acidic conditions return, resulting in highly metalliferous “slugs” of water.

Examples of direct application over acid sulfate soils in the Lower Murray River region has been shown to have immediate effects on soil and water quality, increasing pH by around 2 units (Mosley et al., 2014). However, multiple applications may need to be undertaken over time if the efficacy of the agent is reduced.

5.4.3 Potential outcomes

It is likely that given sufficient treatment, the acidity present in Yeodene Swamp could be neutralised. This would have the effect of increasing soil and water pH, and reducing the export of acidic and metalliferous leachate to the lower reaches of Boundary Creek.

However, the effective application of agents throughout the swamp presents significant logistical difficulties. For example, the mobilisation of equipment to deliver slurries through the swamp would require the clearing of access tracks. Further, in order to deliver such slurries into the soil profile, existing vegetation or trees occupying that soil would either need to be cleared or would at least, become highly disturbed. In addition, the treatment material and precipitated metals will be incorporated into the food chain by bottom-feeding and filter-feeding organisms.

5.4.4 Option summary

The direct treatment of soils in Yeodene Swamp with neutralising agents is likely to be highly disruptive to the existing flora and fauna, and logistically difficult to execute. Given the issues associated with applying the lime treatment and the ongoing application requirements, this option is considered to be a low to moderately feasibly management option.

5.5 In drain treatment with limestone

5.5.1 Objective

The objective of installing a lime drain is to neutralise the acidic water discharging from Yeodene Swamp, and thereby improving water quality in the lower reach of Boundary Creek.

5.5.2 Concept

A range of drain designs exist for the treatment of acidic discharge from water bodies. These include systems aimed at directly treating acidic discharge with neutralising agents, and others aimed at removing acidity from a water column via the precipitation of compounds under reducing conditions. This section considers an open limestone drain, as is illustrated in Figure 5-2 below.

The advantage of this kind of system is that it can be modified or managed (i.e. agents can be added to the drain in varying quantities) to suite a desired outcome. Further, and unlike direct in swamp treatment (section 5.4), if sludge’s are enriched in heavy metals during neutralisation, these can be dredged and removed from the drains.

However there are several disadvantages of this option related to the initial capital works, ongoing maintenance and that it only benefits Reach 3, not Yeodene Swamp. The main disadvantages are:

- Initial design and construction costs to ensure the water quality objectives are achieved.
- Modification of Reach 3 would be required.
- Ongoing maintenance costs - materials added to the drain can become buried, coated with by-products of chemical reactions, eroded or transported from the channel over time, and will be consumed during neutralisation. Regular dredging could be required to remove this material and/or further limestone could be required to ensure their ongoing efficacy.
- Limestone drains would only affect the quality of water flowing out of Yeodene Swamp and not the swamp itself.

Such systems have been employed in a range of settings with varying levels of success. For example, after the addition of lime sand to an acidic drainage channel in Becon, WA, the effectiveness of the drain became negligible after only 3 weeks (Degnes, 2009). In contrast, a 230 m long lime drain on Lasilva Stream in Spain was shown to increase water pH from <3.0 to up to 4.5 for over a year, with no apparent reduction in efficiency (Santofimia and Lopez-Pamo, 2016).

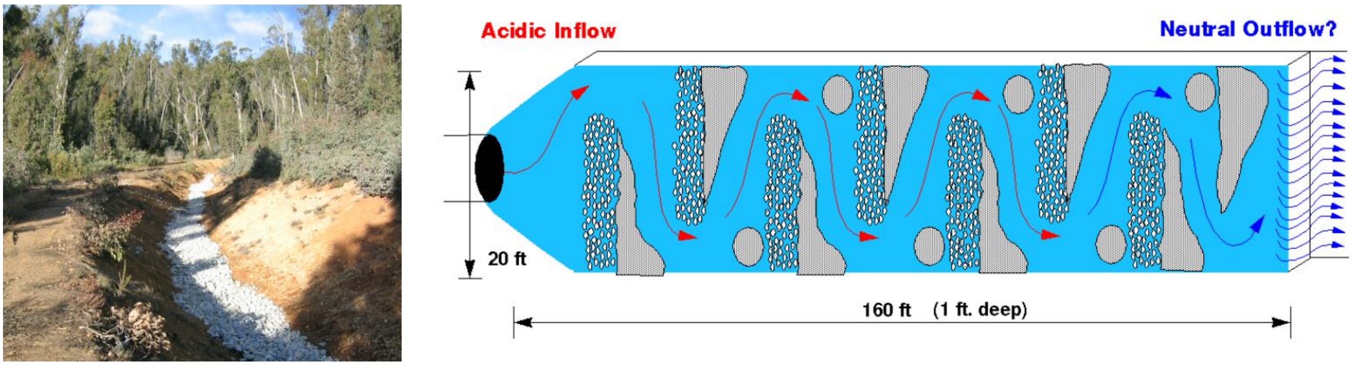


Figure 5-2 Example of open limestone drain - images from Taylor et al., 2005 (left) and Cravotta 2010 (right)

5.5.3 Potential outcomes

The installation of a limestone drain is likely to result in improved water quality in the lower reaches in Boundary Creek in the short term. A review of case studies suggest that limestone drains are likely to increase water pH by anywhere between 0.2 and 2.0 units, and that concentrations of dissolved metals in the outflow water will be reduced (Ziemkiewicz et al., 2003).

However, the effect of the limestone drain on water quality will depend on the design of the drain, the velocity and residence time of water in the drain, the volume of water moving through the drain, and the initial quality of water entering the drain. Under high flow conditions such as those observed in August 2017 (~15 ML/day), reduced residence times and high flow volumes are likely to render a limestone drain ineffective.

However, under low flow conditions such as those observed in May 2017 (~2.5 ML/day), a well-designed drain may be effective. Work by Santomartino and Webb (2007) has estimated the decline in efficiency of such drains over time in response to metal coating, based on the amount of limestone used, the mass of metals fluxing through the system and their retention rate. While this work was specifically related to dissolved Fe^{2+} under reduced conditions, it is likely to provide a first order estimate as to the timing of drain failure.

Based on conditions observed during May (total dissolved Al and Fe = 102 mg/L) and assuming Al and Fe behave similarly, with 20% retention in the drain, the estimated lifespan of a drain containing 5,000 tonnes of limestone is ~7 years.

5.5.4 Option summary

A limestone drain along Reach 3 has the potential to improve the water quality during low flow periods, however there would be limited benefit during high flow events. There are also several disadvantages related to the initial capital costs, ongoing maintenance and significant modifications required to Reach 3. Further, this option will not improve the water quality in Yeodene Swamp. Therefore, the feasibility of this option to achieve the objectives outlined in Section 5.1 is considered to be low.

5.6 Dilution of acidic discharge

5.6.1 Objective

Increasing surface water flows in Boundary Creek aims to directly buffer or dilute the acidity moving through the system, in order to improve the quality of water moving through Boundary Creek.

5.6.2 Concept

The effect of increasing the release volume has been assessed using the hydro-chemical modelling package PHREEQC. The package has been used to simulate the quality of water likely to result from different mixtures of release water and leachate from the swamp. The outputs are highly conservative with respect to the estimated release volumes required to increase pH and reduce metal concentrations. This is because the model considers the effects of mixing, and does not account for in catchment processes including flow loss in Reach 2 (which would reduce any dilution or buffering) or any increased mobilisation of acid and metals through Yeodene Swamp as a result of greater flow rates.

The chemistry of the release water has been assumed to be the same or similar as water sampled downstream of “McDonalds Dam” during low flow conditions in May 2017. This assumption is reasonable as the upper reaches of Boundary Creek where the water is released predominantly flows over outcropping bedrock. As such, groundwater inflows to the release water are minor and unlikely to result in appreciable changes in flow and water quality.

The chemistry of swamp leachate has been characterised by that measured flowing out of the swamp under both low flow (~2.5 ML/day) and high flow (~15 ML/day) conditions. The chemical nature of these waters is detailed in Appendix C.

5.6.3 Potential outcomes

The effect of flow release on water quality has been illustrated in Figure 5-3 and Figure 5-4. These figures show the expected change in pH and aluminium concentrations associated with the mixing of release water with swamp leachate.

The figures illustrate that to achieve a pH of >4.5, release water would need to reflect ~99% of the water exiting the swamp under low flow conditions (~250 ML/day) and ~80% under high flow conditions (60 ML/day). This is because release water has a very limited buffering capacity and as such, only begins to effect pH at exceptionally high input volumes. Given this, changes in metal concentrations such as Al are only likely to be affected by dilution and not precipitation that would occur under higher pH conditions.

The release of such volumes of water would also significantly change the current environmental setting of Boundary Creek and Yeodene Swamp and negatively impact the existing flora and fauna. Further, such flow releases would also almost certainly result in flooding in the catchment.

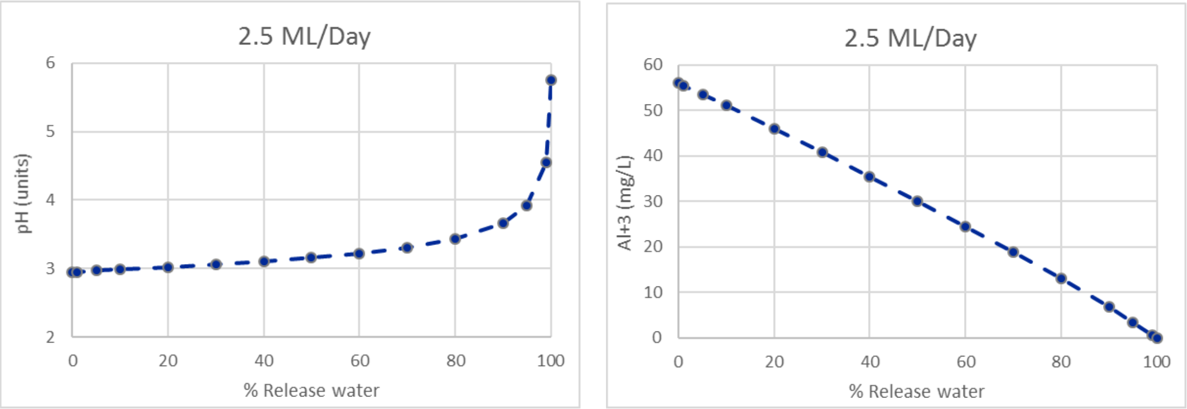


Figure 5-3 Change in pH and Al^{+3} concentration under addition of release water to swamp water at 2.5ML/day

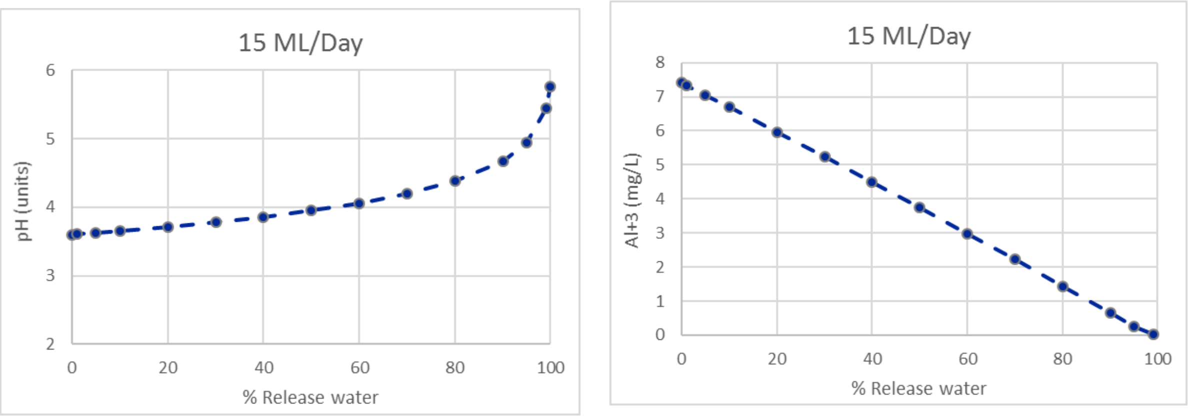


Figure 5-4 Change in pH and Al^{+3} concentration under addition of release water to swamp water at 15ML/day

5.6.4 Option summary

The above results indicate that the release volumes necessary to have a manifest influence on water quality in Boundary Creek are impractical, would increase flooding and negatively impact the existing flora and fauna. As such, this management option is not feasible in the Boundary Creek catchment and therefore not costed.

5.7 Revising flow release location / swamp isolation

5.7.1 Objective

The objective of this option is to improve the volume and quality of water flowing through the lower reach (Reach 3) of Boundary Creek by delivering supplementary flows directly into Reach 3. Given the findings from the previous management option discussed in Section 5.5, the volume of water required for dilution is impractical to improve the water quality in Reach 3. Therefore this option also requires Yeodene Swamp to be isolated from Boundary Creek to prevent acidic water discharging into Reach 3.

5.7.2 Concept

Currently, Boundary Creek flows predominantly through incised channels. However, observations during this field program indicate that the flow path is less defined at Yeodene Swamp, where multiple minor flow paths braid out. This allows for the interaction between the inflowing water and acid sulfate soils in the swamp, resulting in the outflow of acidic and metalliferous water. This option considers channelizing the existing northern drainage line around Yeodene Swamp in order to limit the interaction between the flowing water and the acid sulfate soils. Simultaneously, the option considers the potential water quality effects of flow release downstream of the swamp.

5.7.3 Potential outcomes

This option has several potential outcomes:

- The Damplands upstream of the swamp are likely to be adversely impacted by reduced surface water flows.
- Isolating Yeodene Swamp from Boundary Creek will likely cause the swamp to dry out further and therefore increasing acidification and evapo-concentration from increased drying. It will also be difficult to completely isolate the swamp during high flow events, and is likely to result in the periodic discharge of acidic into Reach 3.
- During low flow conditions, the water quality in Reach 3 is likely to improve due to the absence of acid discharge from the swamp and a permanent flow of good quality water.
- Given the difficulty in isolating the swamp during high flow conditions, it is likely that the water quality would be influenced by acidic flushes of water released into Reach 3.

However, as asserted in section 5.5, increasing the release of water to Boundary Creek is unlikely to have any significant effect on the quality of water draining from the swamp via either dilution or buffering. This is because release water has very little buffering capacity. As such, the volume of water required to effectively buffer acidity, or dilute the concentration of metals in water draining the swamp, far exceed any practical release volume.

Given this, it is likely that under high flow conditions, flooding through the swamp will result in overbanking and the discharge of acidic and metalliferous water into Boundary Creek. Further, the quality of this water is likely to be worse than currently recorded in the swamp, as a result of increasing acidification and evapo-concentration from increased drying.

In addition, the segregation of Yeodene Swamp from Boundary Creek would reduce the inflow of water onto the swamp. This would reduce the water available for the existing vegetation and fauna in the swamp.

5.7.4 Option summary

The segregation of Yeodene Swamp from Boundary Creek and introduction of flow release into Reach 3 is only likely to improve water quality in Reach 3 under summer low flow conditions, and may deteriorate water quality under high flow conditions. Further, it would increase drying in the swamp, which would have a deleterious effect on the existing flora and fauna. Accordingly, the feasibility of this option achieving the management objective is considered to be low and has therefore not been considered further.

5.8 Inundating Yeodene Swamp

5.8.1 Objective

The objective of inundating Yeodene Swamp is to induce reducing conditions that would neutralise in situ acidity in Yeodene Swamp and reduce the acidity and concentration of dissolved metals in water draining from Yeodene Swamp.

5.8.2 Concept

Inundating the Swamp and inducing reducing conditions could potentially reinstate the environmental setting that formed acid sulfate soils in the swamp initially. The process that produces acid sulfate soils under reducing conditions also produces alkalinity, which can neutralise acidity in the system. That is, the chemical reaction is reversible.

The chemical reaction is shown below. This reaction is reversible, which means that as oxygen is used up and reducing conditions are created, pyrite will re-form.

$$\mathbf{FeS_2 + 15/4\ O_2 + 7/2\ H_2O = Fe(OH)_3 + 2SO_4^{2-} + 4H^+}$$

pyrite oxygen iron hydroxide acidity

This management strategy has been shown to be effective in a number of freshwater acid sulfate soil wetlands in Australia and Victoria. This includes Partridge Creek and Darawakh Wetland (Johnson et al., 2008), the Lower Murray Lakes (Baker, 2014), Lake Mealup (Jenkinson and Appleyard 2014) and in Bottle Bend Lagoon.

Reducing conditions are formed in carbon rich environments that are kept permanently inundated and oxygen poor, such as those that have historically existed within Yeodene Swamp. Given this, this option considers the flow and drainage requirements necessary to induce such conditions in Yeodene Swamp.

It should be noted that some studies have highlighted that the structure and composition of the peat can change after fire which alters the chemistry (Hirst et al., 2012; Tsibart et al., 2015). This has not been considered in this study and a site specific soil sampling and analysis program would need to be undertaken to confirm the influence of fire on the peat. Three aspects are required to keep the swamp inundated and create reducing conditions:

1. Minimum low flow requirement released from “McDonalds Dam”, and
2. Infilling the fire trench and agricultural drain at the eastern end of Yeodene Swamp.
3. Hydraulic barrier.

Minimum low flow requirement

Historical pH and flow monitoring at Yeodene suggests that reducing conditions persisted through significant portions of Yeodene Swamp prior to 1990 and between 1990 and 1999, as evidenced by pH values typically >5 during these periods (Figure 2-12). Flow in Boundary Creek at Yeodene was typically perennial during these periods, indicating that flow cessation and swamp drying was the major driver of acid release.

This is further supported by low pH values in 1992, the only period of flow cessation in Boundary Creek between 1990 and 1999 (Figure 2-12). Given that groundwater levels in the catchment had largely recovered in 1992 and that Reach 2 was gaining (Figure 2-7), it can be asserted that acid release during this time was controlled by reduced surface water flows and not groundwater processes. It is therefore concluded that a drainage regime similar to pre-1999 conditions could induce reducing conditions in areas of Yeodene Swamp, and increase the pH of water draining form the swamp to >4.5.

Limited gauging data is available for both the downstream “McDonalds Dam” and Yeodene stream flow gauging stations over the same time series. However, data collected during the summers of 2014-15, 2015-16 and 2016-17 suggest that an outflow of at least 3 ML/day at downstream of “McDonalds Dam” gauge is necessary to yield flows at the Yeodene gauge under summer low flow conditions (Figure 5-5).

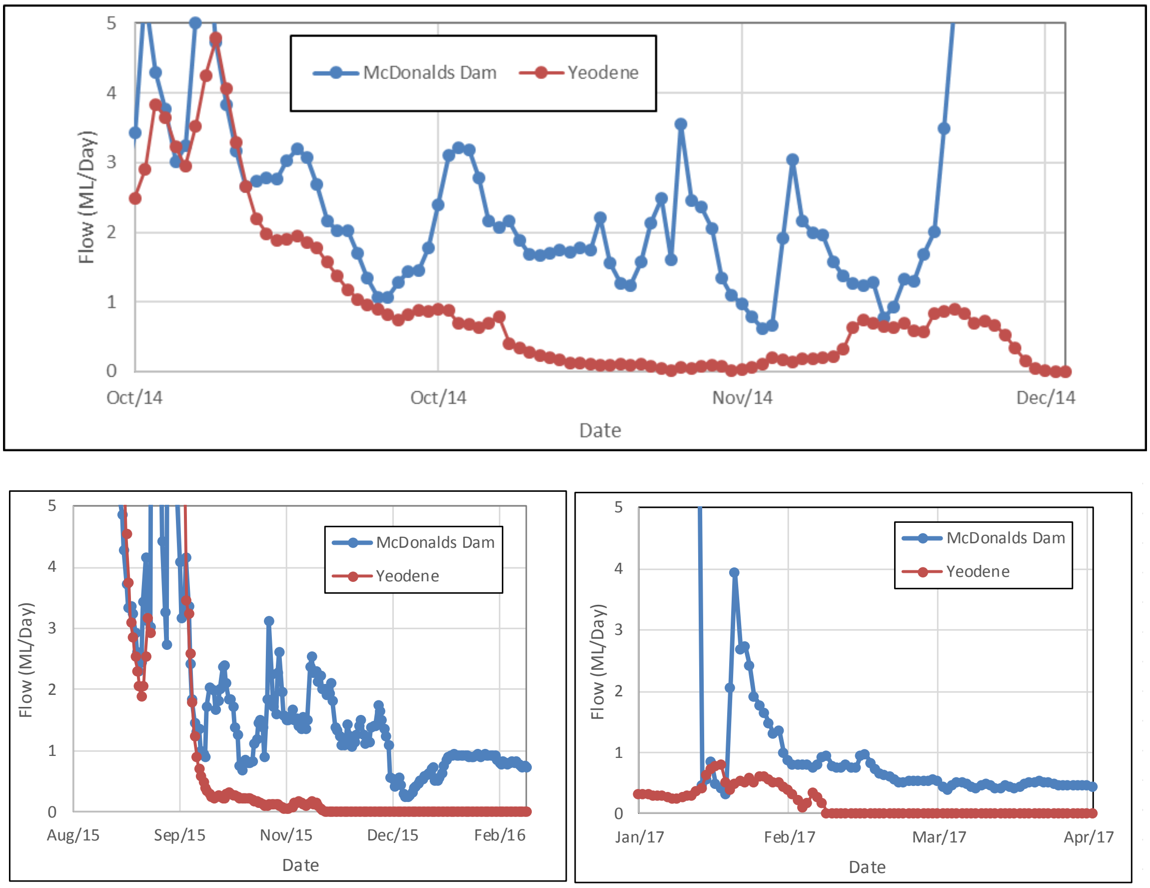


Figure 5-5 Flow measurements at D/S “McDonalds Dam” and Yeodene gauges

Infill fire trench and agricultural drain

The construction of fire trenches in Yeodene Swamp has altered the swamps drainage regime. Currently, significant volumes of water are drained from the swamp via these trenches and their connection with existing drainage lines. The introduction of hydraulic barriers at inflection points in this drainage network, to levels consistent with pre-trench elevations, would increase the surface water elevation required to drive outflows from the swamp.

This could (along with increased inflows) increase the depth and extent of inundation in the swamp, promote reducing conditions, and neutralise the acidity present within Yeodene Swamp. A schematic design for a potential barrier has been illustrated in Figure 5-6 where the fire trench crosses the major drainage line from Yeodene Swamp.

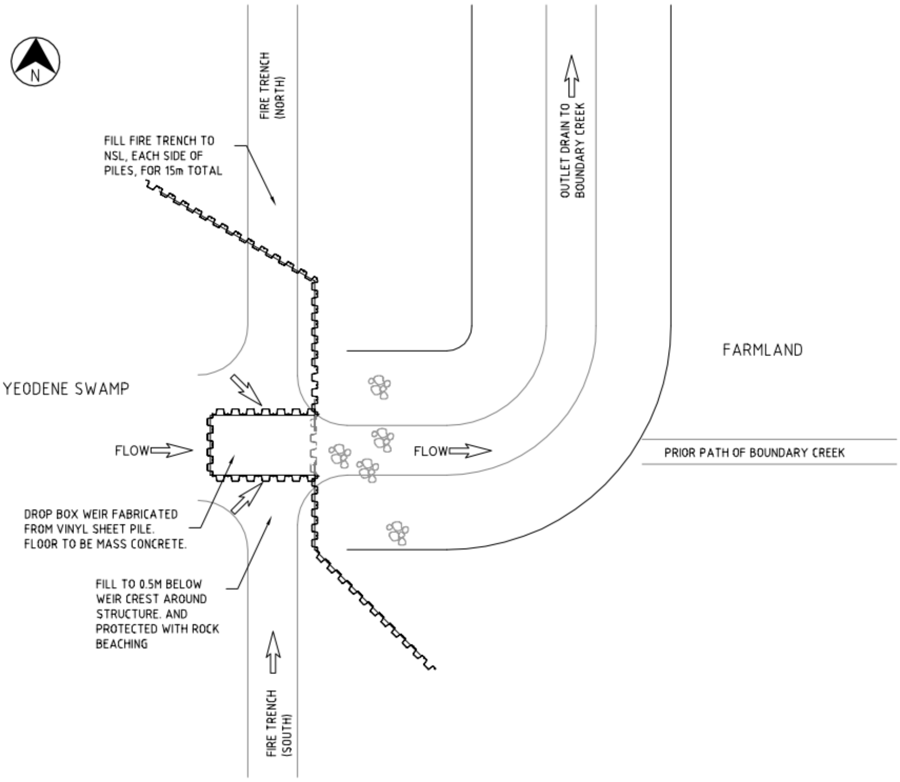


Figure 5-6 Schematic drainage paths from Yeodene Swamp

5.8.3 Potential outcomes

The return of large portions of Yeodene Swamp to reducing conditions, similar to those between 1992 and 1999 is likely to increase the pH of the water both in the swamp and in reach 3. Historical monitoring suggests that if such conditions are sustained, the median pH of water draining from the swamp could increase to 5 and may increase to around 6. Given the altered nature of the Yeodene Swamp since this time, a median pH of 5 is considered to be achievable, consistent with the management objectives set out in Section 5.1.

It should be noted that by creating reducing conditions, precipitation of dissolved metals in Yeodene Swamp could occur. While this would reduce the outflow of dissolved heavy metals downstream of the swamp and improve water quality, it could also lead to a build-up of heavy metals on sediments. While this would in effect return the dissolved metals back into the soil profile from which they came, it is important to note that once achieved, reducing conditions would need to be maintained to prevent subsequent drying and acidic, metalliferous flushes.

It is also noted that the vegetation in the swamp could change if the area of permanent inundation increases. The vegetation will shift to species that can tolerate inundation. As the water quality improves aquatic vegetation will also return to the area.

An assessment of the risk to the Barwon River involving the passing flow and dilution potential of water from Boundary Creek is beyond the scope of the current project.

Ongoing monitoring and adjustment of the environmental flow release as needed – in line with a careful and adaptive approach - is recommended.

5.8.4 Cost estimate

A cost estimate to install an automated flow release from “McDonalds Dam” to ensure that supplementary flows are being passed is based on the requirements below:

- Upgrade the existing stream gauges immediately upstream and downstream of the dam to allow for telemetry.
- Installation of a manual control valve.
- Installation of a flow meter with solar and battery backup.
- Construction and site works.

Accordingly the cost estimated for the installation of an automated flow release would be upwards of $130,000.

A cost estimate of the hydraulic barrier as described in 5.8.2 is based on the arrangement described below:

- It consists of a drop box type structure fabricated primarily from vinyl sheet pile. The piles extend across the fire trench (north side) which would be blocked to natural surface level. This leaves the original outlet drain as the only swamp outlet.
- The floor of the drop box would be mass concrete (corrosion resistance) placed over gravel which would act to prop the piles in the box.
- Earth fill would be placed in the fire trench (north) and for part height on the upstream side of the box.
- Rock beaching placed over geotextile would be provided on the outlet channel until the downstream side of the bend to prevent erosion toward the prior creek line.
- Sheet piles would be placed by an excavator with a vibrating attachment. It is assumed the peat would need to be removed and the piles vibrated into place in the underlying sands. Piles would terminate at the underlying rock.
- Seepage resistance would be achieved by a combination of the pile length and fill material.

Accordingly the cost estimated for the construction of a once-off hydraulic barrier would be upwards of $500,000. See Appendix E for detailed cost estimates.

It should be noted that this is one option for a potential hydraulic barrier that has been used to provide an indicative cost estimate. The hydraulic barrier could be designed differently and constructed using different materials. Alternative designs and materials could be assessed during detailed design phase.

5.8.5 Option summary

It is likely that returning Yeodene Swamp to similar conditions as those prior to 1999 could increase the pH and decrease the concentration of dissolved metals both in the swamp, and draining from the swamp into Boundary Creek.

A review of flows downstream of “McDonalds Dam” and Yeodene suggests that a discharge of 3 ML/day at “McDonalds Dam” may be sufficient to perennially inundate enough of Yeodene Swamp to have such an outcome. This effect could be further enhanced by blocking drainage lines formed during the excavation of fire trenches.

This option is likely to be a technically feasible and cost effective option which could improve both the Yeodene Swamp and Reach 3. Potential changes to the peat as a result of fire and the capacity of reducing conditions to return and neutralise the soils would need to be confirmed with a site specific study. This option aims to re-instate conditions similar to those that existed through the 1990’s and that currently exist for large periods of the year. As such, if the area of permanent inundation increases significantly, the vegetation in this area is likely to change to species that can tolerate permanent inundation.

The timeframes to implement this option are also an important consideration. The first step is to infill the fire trenches and block the agriculture drain. Preferably this should be completed before the onset of a summer period, pending approvals. This would allow the swamp to retain more water over the winter months. Once the trenches and agricultural drain have been blocked, the minimum flow requirement of 3 ML/day is required to be released from McDonald’s Dam, and meet the 0.5 ML/day low flow recommendation at the Yeodene gauge as noted in Jacobs (2018).

It is important to highlight that the low flow requirement of 3 ML/day is a best estimate based on a detailed assessment of the historical data. An ongoing adaptive management approach that involves regular monitoring and site visits is recommended to ensure the low flow requirement is meeting the objective as documented in Jacobs (2018).

Based on a review of historical data and similar case studies, it is expected that the pH of water draining from the swamp could increase to 5 and may increase to around 6. Improvements in water quality are likely to take a minimum of 6 months to see change. Previous studies suggest that a return to such conditions could significantly improve water quality in Yeodene Swamp over a period of several months.

The total cost is estimated to be upwards of $500,000 associated with the capital works and ongoing maintenance would be minimal.

6. Conclusions and recommendations

6.1 Conclusions

This report documents the findings of a study focussed on Yeodene Swamp. The purpose of this study was to characterise the chemical and physical processes affecting the volume and quality of water which will be used to inform potential strategies to help manage acidic water in the lower reaches of Boundary Creek. This study did not involve a detailed assessment of the soils across the swamp.

The Boundary Creek catchment has experienced significant change including land clearing, construction of a dam, groundwater extraction, climate changes, and peat fires at Yeodene Swamp and the subsequent excavation of trenches to control the fire. These changes have contributed to the drying of acid sulfate soils in Yeodene Swamp which has resulted in poor water quality (low pH, metalliferous water) as a result of borefield operation combined with reduced rainfall in the catchment.

This study involved a field program to better characterise the physical and chemical processes occurring within the Boundary Creek catchment and to inform potential strategies focussed on managing water quality in Boundary Creek. The field program includes the installation of piezometers (shallow bores <3 m deep), lithological analysis, chemical soils analysis, surface water flow gauging, and both surface and groundwater quality monitoring.

The field program described in this report characterised a range of physical and chemical processes occurring within the Boundary Creek catchment. The major findings of the program included:

- Aquitard deposits occur towards the east of the swamp, and aquifer deposits towards the west of the swamp.
- The most severe acid sulfate soils (highest acidity) occurred in the central and lower lying areas of the swamp.
- Surface flows increase between “McDonalds Dam” and the Damplands.
- Boundary Creek losses surface water via groundwater seepage through the Damplands and Yeodene Swamp. Reductions in streamflow was 2.9 ML/day between the Damplands and Yeodene Swamp in May 2017.
- Changes in water quality through the swamp were consistent with the influence of acid sulfate soils, and the export of acid and dissolved metals were effectively estimated.
- Groundwater monitoring characterised the areas most affected by acid sulfate soils as those immediately down hydraulic gradient of the acidic soils.

As a result of the improved conceptual understanding, and chemical characterisation of both Boundary Creek and Yeodene Swamp, the effectiveness of different management options was assessed. Six options were considered:

1. Do nothing,
2. Direct treatment of soils with neutralising agents,
3. Treatment of outflows through a limestone drain,
4. Dilution with more surface water flows,
5. Relocating the flow release and isolating the swamp, and
6. Inundating Yeodene Swamp.

Options 1 to 5 were considered to be unacceptable, not feasible or of low feasibility.

The permanent inundation of acid sulfate soil wetlands has been shown to be an effective management strategy in a number of case studies in Australia. This option could be a technically feasible and cost effective option to improve both the Yeodene Swamp and Reach 3.

It aims to re-instate conditions similar to those that existed through the 1990's and that currently exist for large periods of the year. Flow and water quality monitoring in Boundary Creek indicates that permanent inundation of the swamp could effectively neutralised acidic outflows historically, after periods of acidification.

6.2 Recommendations

It is recommended that in order to improve the volume and quality of water draining Yeodene Swamp, and to rehabilitate the swamp itself, permanent inundation be further investigated as a remediation strategy. Monitoring data suggests that a flow of initially 3 ML/day immediately downstream of "McDonalds Dam" could be sufficient to achieve this outcome.

It is important to highlight that the low flow requirement of 3 ML/day is a best estimate to meet the low flow recommendation at Yeodene gauge, based on a detailed assessment of the historical data. An ongoing adaptive management approach that involves regular monitoring and site visits is recommended to ensure the low flow requirement is meeting the objective (i.e. constant flow at the Yeodene stream flow gauge).

Given this, it is recommended that Barwon Water adaptively manage flow release volumes and monitor the surface water level in Yeodene Swamp in order to keep it inundated. **It is noted that even brief periods (<1 week) of drying and flow cessation in Boundary Creek are likely to result in significant acidification historically, and as such, should be avoided.**

Ongoing monitoring at bores YS03, YS04 and YS06 is unlikely to be necessary and could be decommissioned. Bores YS01, YS02 and YS05 provide the most hydraulic and chemical information in Yeodene Swamp and as such, it is recommended that these continue to be monitored.

Recommendations to implement this remediation strategy are:

- Undertake a soil sampling and analysis program to confirm properties of the peat soils and their capacity to re-wet and neutralise.
- Confirm design to block fire trenches and agricultural drain.
- Undertake capital works to infill trenches and agricultural drain as soon as practicable.
- Automate flow release from "McDonalds Dam" to ensure minimum 3 ML/day is released between November and June as soon as practicable.
- Continue groundwater and surface water monitoring.
- Install data loggers in bores YS01, YS02 and YS05.
- Decommission bores YS03, YS04, YS06.
- Regular site visits (e.g. monthly) between November and May to complete spot flow gauging and surface water quality monitoring.

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Appendix A. Installation of additional monitoring assets

Installation of additional monitoring assets

Barwon Water

Bore completion report

IS195000-RP-001 | Draft A

11 April 2017

Installation of additional monitoring assets

Project No:	IS195000
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Document No.:	IS195000-RP-001
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Date:	11 April 2017
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Project Manager:	Nicolaas Unland
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1. Introduction

1.1 Background

The Barwon Downs borefield provides potable water for Geelong during periods of low rainfall. It is a critical asset in Barwon Water’s water supply network and has the capacity to supply the majority of Geelong’s water supply. Water is pumped from the borefield subject to conditions of a licence issued by Southern Rural Water, which is due for renewal in 2019. To support the licence renewal, Barwon Water has invested in a program of technical works to address knowledge gaps and community concerns that surround the use of the borefield.

One of the priorities of the Barwon Downs hydrogeological study in 2016/17 is to improve the understanding of Yeodene (Big) Swamp and the lower reaches of Boundary Creek, in which there is an absence of shallow monitoring bores.

Another of the knowledge gaps identified by Barwon Water is related to the status of an existing monitoring bore YEO 20 (GMS number 109111). A down-hole camera inspection of this bore has confirmed a blockage caused by tree root ingress, resulting in erroneous water level readings in the bore. YEO 20 is unique in that it is nested with a deeper bore screened in the same aquifer. These monitor the difference in the water level within the shallow and deeper parts of the aquifer. This is a feature important in conceptualising the Barwon Downs aquifer system.

1.2 Scope of works

In order to address these knowledge gaps, Jacobs were engaged by Barwon Water to design and supervise the installation of six shallow piezometers in Yeodene (Big) Swamp, two shallow monitoring bores along the lower reaches of Boundary Creek, and a replacement for the damaged YEO 20 bore.

This report summarises the outcomes of the drilling and installation of these monitoring bores including:

- A description of the drilling program as it was undertaken
- The lithological units encountered during drilling
- Specifications of the bores installed
- Initial groundwater levels and water quality data collected during bore development

2. Bore installation

2.1 Program overview

The bore drilling program included the installation of 6 piezometers and 3 new bores between the 21st and the 30th of March.

- **YS01, YS02, YS03, YS04, YS05 and YS06** were installed using hand auger in Yeodene (Big) Swamp between the 21st and 24th of March. They have been installed to monitoring groundwater and surface water interaction in Yeodene Swamp. These bores will also be used to help estimate the volumetric flux of water between the swamp and groundwater system and the influence that such processes may have on water quality in the swamp.

- **LBC01 and LBC02** were drilled, constructed and developed on the 28th and 29th of March, 2017. These are new bores located along the lower reaches of Boundary Creek. They have been installed to monitoring groundwater and surface water interaction in this section of Boundary Creek. More specifically, these bores will be used to help estimate the volumetric flux of water between the creek and groundwater system and the influence that such processes may have on water quality in the creek.

- **YEO20** was drilled, constructed and developed between the 29th and 31st of March, 2017. This is a replacement for the existing (damaged) Bore 109111 (YEO20). In conjunction with Bore 109110, this bore will be used to help monitor water levels at different depths in the Lower Tertiary Aquifer system.

Table 1 below provides a summary of the bores drilled as part of the program. YS01 through YS06 denote piezometers installed in Yeodene Swamp, LBC01 and LBC02 denote bores drilled along the “Lower Boundary Creek” reaches and YEO20 denotes the replacement of Bore 109111 (YEO20).

Piezometers were installed by Jacobs staff by hand auger. Holes were originally augured to a depth of 3 m, however due to the unconsolidated nature of the lithological material, the PVC casing slumped a further ~0.5 m during installation in some cases.

Bores LBC01, LBC02 and YEO20 were all drilled by Matrix Drilling Pty Ltd. The head driller on site was Liam Blake, supervised by Jacobs staff. All bores were constructed in accordance with the minimum construction requirements for water bores in Australia (NUDLC, 2012).

A Comacchio GEO405 drilling rig was used to drill the three bores. This was equipped with a 150 mm diameter solid flight auger stem during the construction of LBC01 and LBC02, and a 165 mm diameter drill head for mud rotary drilling of YEO20.

Representative lithological samples were collected during drilling process. These were combined with interpretive notes from the driller and drilling supervisor to create lithological logs for each borehole. These are presented in section 3.

Table 1 Summary of borehole drilling notes

Bore ID	Drilling Start	Drilling End	Drilling method	Hole Diameter (mm)[1]	Total depth (m)	Depth top backfill (m)	Backfill type
YS01	21/03/2017	21/03/2017	Hand auger	100/65	3.0	4.08	Slumping
YS02	22/03/2017	22/03/2017	Hand auger	100/65	3.0	3.43	Slumping
YS03	22/03/2017	22/03/2017	Hand auger	100/65	3.0	3.70	Slumping
YS04	23/03/2017	23/03/2017	Hand auger	100/65	3.0	3.55	Slumping
YS05	23/03/2017	23/03/2017	Hand auger	100/65	3.0	3.00	Slumping
YS06	23/03/2017	23/03/2017	Hand auger	100/65	3.0	3.12	Slumping
LBC01	29/04/2017	29/04/2017	Solid auger	150	8.5	7.7	Fall in
LBC02	28/04/2017	28/04/2017	Solid auger	150	8.1	8.1	Nil
YEO20	29/04/2017	30/04/2017	Mud rotary	165	41	40.8	Fall in

[1] Two numbers indicate the use of a wider diameter at the surface to prevent collapse/fall in

2.2 Construction

Table 2 below provides a summary of the locations and construction details of both bores and piezometers. The locations of these bores are illustrated in Section 3.

Monitoring bores and piezometers were constructed by sequentially joining threaded casing and screen lengths and lowering them down the drilled hole. The Yeodene Swamp piezometers were constructed with 50 mm PVC using approximately 3.0 m of casing and 1.5 m of screen. LBC01 and LBC02 were also constructed with 50 mm PVC, using ~6 m of casing 3 m of screen. YEO20 was constructed with 100 mm PVC with two screened sections (from approximately 20-26 m and 32-41 m) separated by 6 m of screen. This was done to case off ligneous clay and provide cross aquifer connectivity while limiting silt ingress.

Gravel pack (8/16 Sibelco gravel) was free poured into the annulus between the casing and drilled hole to provide a filter pack around the screened section. Bentonite (Pel plug pellets or bentonite chips) was free poured on top of the gravel pack to prevent grout seeping into the gravel pack. This was only poured on the uppermost gravel pack on YEO20.

A grout mixture consisting of approximately 25:1 cement to hydrated bentonite powder was free poured down the annulus on top pf the bentonite plug. Constructed bores were finished approximately 0.60 m above ground level and encased in steel standpipes that were finished approximately 0.75 m above ground level. Piezometers have been left exposed without lockable standpipes until a determination has been made regarding the permanency of the piezometers.

During construction of the steel standpipes, surficial material surrounding the bore was removed to allow the base of the standpipe to be concreted at a depth of approximately 0.30 m below ground surface.

Table 2 Summary of borehole construction details

Bore ID	MZ (MGA94)	Easting	Northing	Surface Elevation (mAHD)	Stickup (m)	Total depth (mbgl)	Screen from (m)	Screen to (m)	Diameter (mm)
YS01	54	735733	5743850	142.87	0.87	4.08	3.08	4.08	50
YS02	54	735766	5743879	141.31	0.90	3.43	1.43	3.43	50
YS03[1]	54	735821	5743910	142.26	0.76	3.67	2.17	3.67	50
YS04	54	735304	5743771	149.99	0.88	3.55	2.05	3.55	50
YS05	54	735276	5743824	148.72	1.04	3.00	1.50	3.00	50
YS06	54	735021	5743832	149.80	0.97	3.12	1.62	3.12	50
LBC01	54	737124	5743931	131.44	0.87	7.61	4.60	7.60	50
LBC02	54	739049	5744168	119.64	0.66	8.10	5.10	8.10	50
YEO20	54	734518	5745357	173.38	0.76	40.80	19.80 31.80	25.80 40.80	100

[1] Survey location approximate, GPS unable to locate under tree cover and relay station not possible as swamp was flooded

2.3 Bore development

Bore were developed in order to remove introduced products, improve near well permeability, reduce entry loss, reduce entry of suspended solids and increase well efficiency. Accordingly, all bores and piezometers were developed according to the minimum construction requirements for water bores in Australia (NUDLC, 2012).

All assets were developed by removing standing water from the casing via air lift purging and/or bailing. During air lifting, polyethylene tubing was gradually lowered down-hole with a continuous flow of air supplied by a compressor. Standing water in the bore was displaced by air and brought to the surface. Water was then allowed to flow through high pressure polyethylene piping secured to the top of the bore, and was collected in a vessel to monitor water quality. The tubing was continuously lowered down the bore until the bottom was reached and the bore was purged of water.

If yields from the bore were adequate, the tubing was left in the bore to provide a continuous flow of water from the aquifer to the surface for periods of time ranging from 0.5 to 5 hours. If yields were low, the bore was allowed to recover for a period of time before being purged again using a hand bailer. Development of piezometers was not undertaken via air lifting as mobilisation of a compressor into Yeodene Swamp was not feasible.

The duration of development, the volume of water extracted and sediment suspended in the extracted water was recorded and have been summarised in Table 3. Field water quality parameters were also measured and recorded. Changes in electrical conductivity (EC) during development can indicate a change between remnant drilling fluids in the aquifer and natural groundwater. Drilling fluids are typically fresh (depending on the source water used to make the drilling fluids) compared to natural groundwater and an increase in EC during development can indicate when natural groundwater is being drawn into the bore.

This is illustrated in the development of YEO20 which exhibited an initial EC of 737 µS/cm that increased to 2,302 µS/cm during development. As drilling fluids were not used in the construction of LBC01, LBC02 or Yeodene Swamp piezometers, water from these bores did not exhibit a significant change in EC during development.

Table 3 Bore development details

Bore ID	Duration (hrs)	Volume Extracted (L)	EC (µS/cm)[1]	pH (units)[1]	DO (mg/L)[1]	Sediment removed
YS01	1:00	5.5	2,011	3.8	2.53	Milky brown
YS02	1:00	8.0	1,201	6	1.71	Dark brown to black
YS03	1:00	8.0	435	3.66	1.47	Dark brown to black
YS04	1:00	Dry	n/a	n/a	n/a	n/a
YS05	1:00	4.5	3,940	2.86	1.31	Dark brown to black
YS06	1:00	8.0	1,033	5.68	3.58	Orange brown silt
LBC01	1:30	20	2,880 - 1,671	6.38 - 6.59	4.44 - 0.24	Dark brown silt
LBC02	1:30	20	5120 - 5,120	6.64 - 6.64	7.65 - 7.65	Dark brown silt
YEO20	1:00	2,100	737 - 2,302	6.07 - 5.95	9.16 - 7.01	Dark brown silt

[1] Two numbers separated by a dash (-) indicate initial and final water quality parameters during development

3. Bore locations

The locations of the piezometers installed around Yeodene Swamp are illustrated in Figure 1. Access to YS01, YS02 and YS03 can be gained from a track to the north of Colac-Forest Rd. Access to YS04, YS05 and YS06 can be gained from tracks to the north of Westwood Rd.

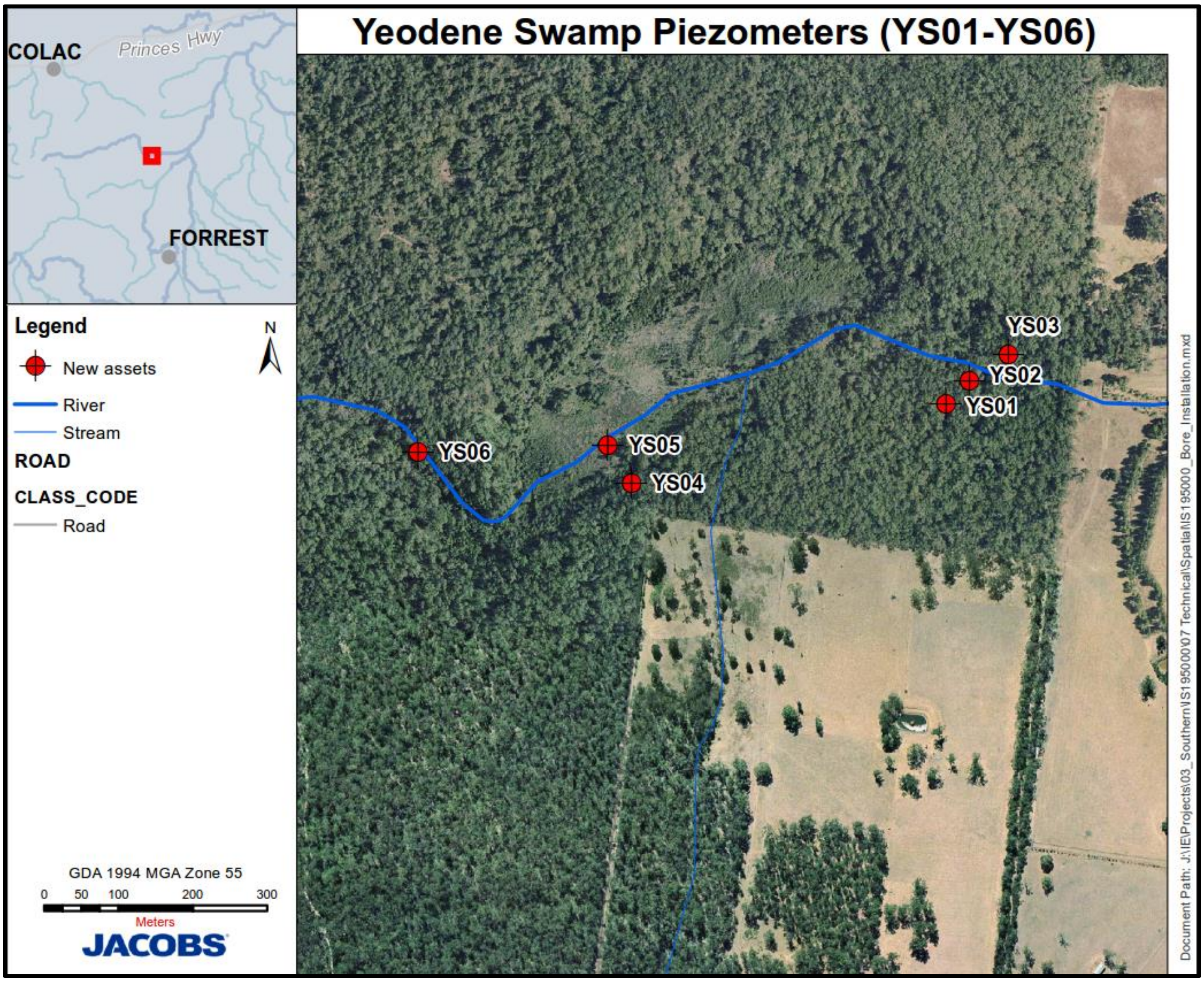


Figure 1 Location of Yeodene Swamp piezometers

The YEO20/109111 replacement bore is located to the south-west of the Bingami Rd and McCalls Rd intersection (Figure 2). Access to the bore can be gained through an unlocked gate to McDonald's property on the west side of the intersection.

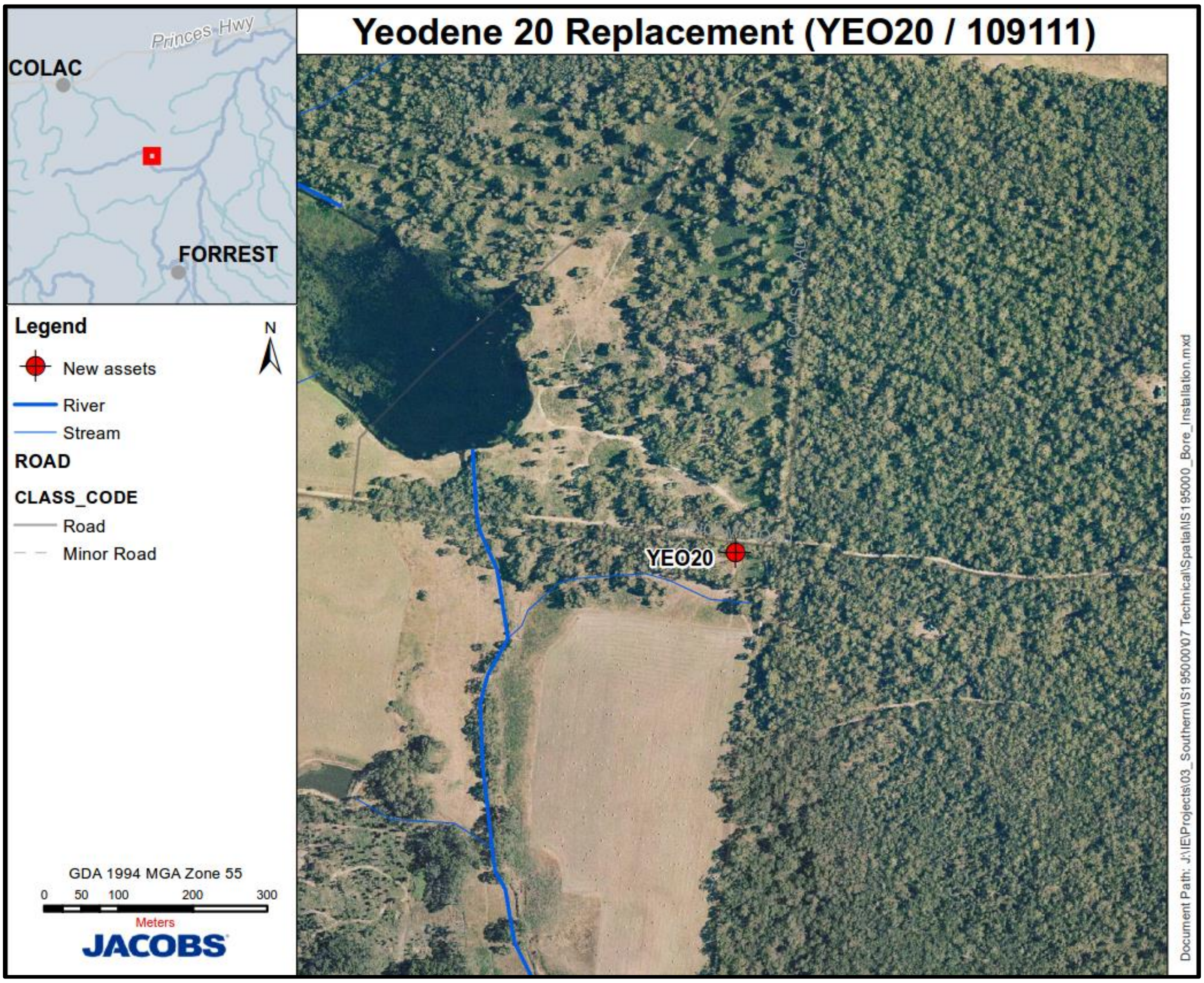


Figure 2 Location of Yeodene 20 / 109111 replacement bore

The Lower Boundary Creek 01 bore is located on the Southern side of Boundary Creek (Figure 3). It can be accessed through a gate on the Southern side of the Yeodene Bridge. The gate provides access to John Day's property and is on the eastern side of Colac-Forest Rd. Once entered, follow the creek bank to the east unit the LBC01 bore is reached (note – there is an additional paddock rope that needs to be pulled down between the first paddock and that of the LBC01 bore).

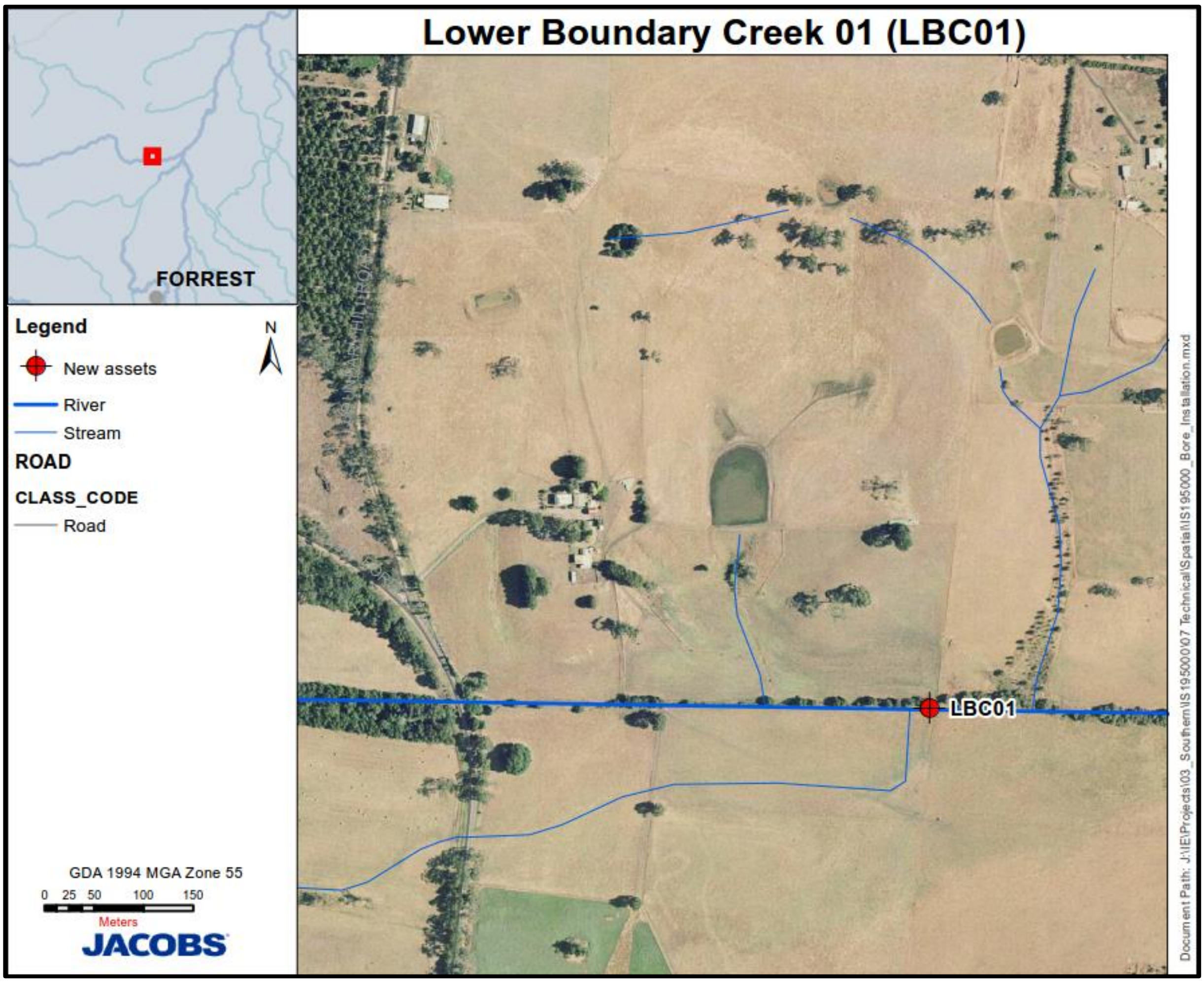


Figure 3 Location of Lower Boundary Creek bore 01 (LBC01)

The Lower Boundary Creek 02 bore is located on the Northern side of Boundary Creek (Figure 4). Access to this bore can be gained via a track to the south of Birregurra-Yeodene Rd (east of Allen Shalleys residence at 250 Birregurra-Yeodene Rd). The track can be followed south-east before veering to the west along a narrow track that circles around a tree-line, before turning south and reaching the paddock in which the bore resides.

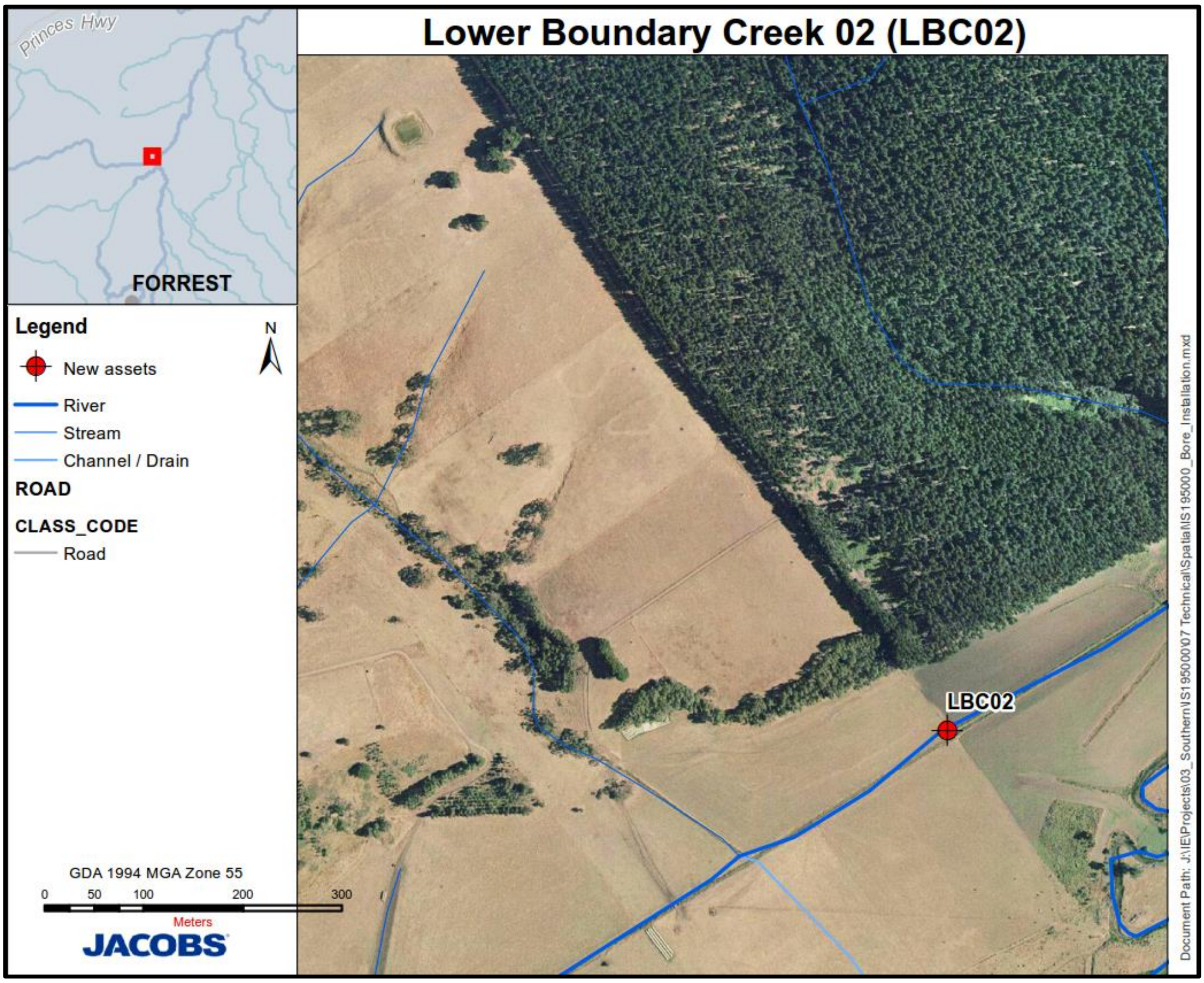


Figure 4 Location of Lower Boundary Creek bore 02 (LBC02)

4. Conclusions and Recommendations

4.1 Conclusions

This report documents the capital works associated with the installation six piezometers at Yeodene (Big) Swamp, two bores along the lower reaches of Boundary Creek, and a replacement for the YEO20/109111 bore where the Lower Tertiary Aquifer (Dilwyn Formation) outcrops at ground surface.

These assets will supplement the current bore network used to monitor groundwater surrounding the Barwon Downs borefield. The assets were drilled, constructed and developed in accordance with minimum construction requirements for water bores in Australia (NUDLC, 2012).

The six piezometers at Yeodene Swamp were installed to a depth of ~3 m below ground level and are likely to reflect the water levels in quaternary alluvium and swamp deposits.

The two bores along Boundary Creek were installed at a depth of approximately 8 m below ground level and are likely to reflect water levels in quaternary alluvial deposits and the underlying Gellibrand Marl aquitard.

The replacement bore for YEO20 was drilled to a depth of approximately 41 m below ground level and is likely to reflect groundwater levels in the upper Dilwyn Formation.

4.2 Recommendations

The six piezometers in Yeodene Swamp are currently being monitored by Jacobs as part of the 2016-2017 technical works program. At the conclusion of the program, Jacobs will provide a recommendations as to which of these bores shall be retained for ongoing monitoring, as well recommendations as to the frequency and type of monitoring be undertaken.

The two monitoring bores along Boundary Creek have both been constructed with lockable standpipes. It is recommended these bores be fit with Barwon Water padlocks to ensure the security of the bores. These can be fit during the next round of monitoring by Jacobs if supplied by Barwon Water. Similar to the Yeodene Swamp piezometers, these bores are currently being monitored by Jacobs as part of the 2016-2017 technical works program. Recommendations as to the frequency and type of ongoing monitoring to be undertaken in these bores will be provided by Jacobs at the conclusion of the program.

The YEO20 replacement bore has been constructed with a lockable standpipe and it is recommended this be fit with a padlock to ensure its security. It is recommended that groundwater level monitoring in this bore be undertaken at a quarterly frequency, as is consistent with Barwon Waters ongoing water level monitoring in the area. This will also allow ongoing evaluation of groundwater level trends as established by quarterly monitoring in the original YEO20 (109111) bore.

5. References

National Uniform Drillers Licensing Committee – NUDLC (2012) Minimum construction requirements for water bores in Australia: Third Edition. February 2012.

Appendix A. Bore logs

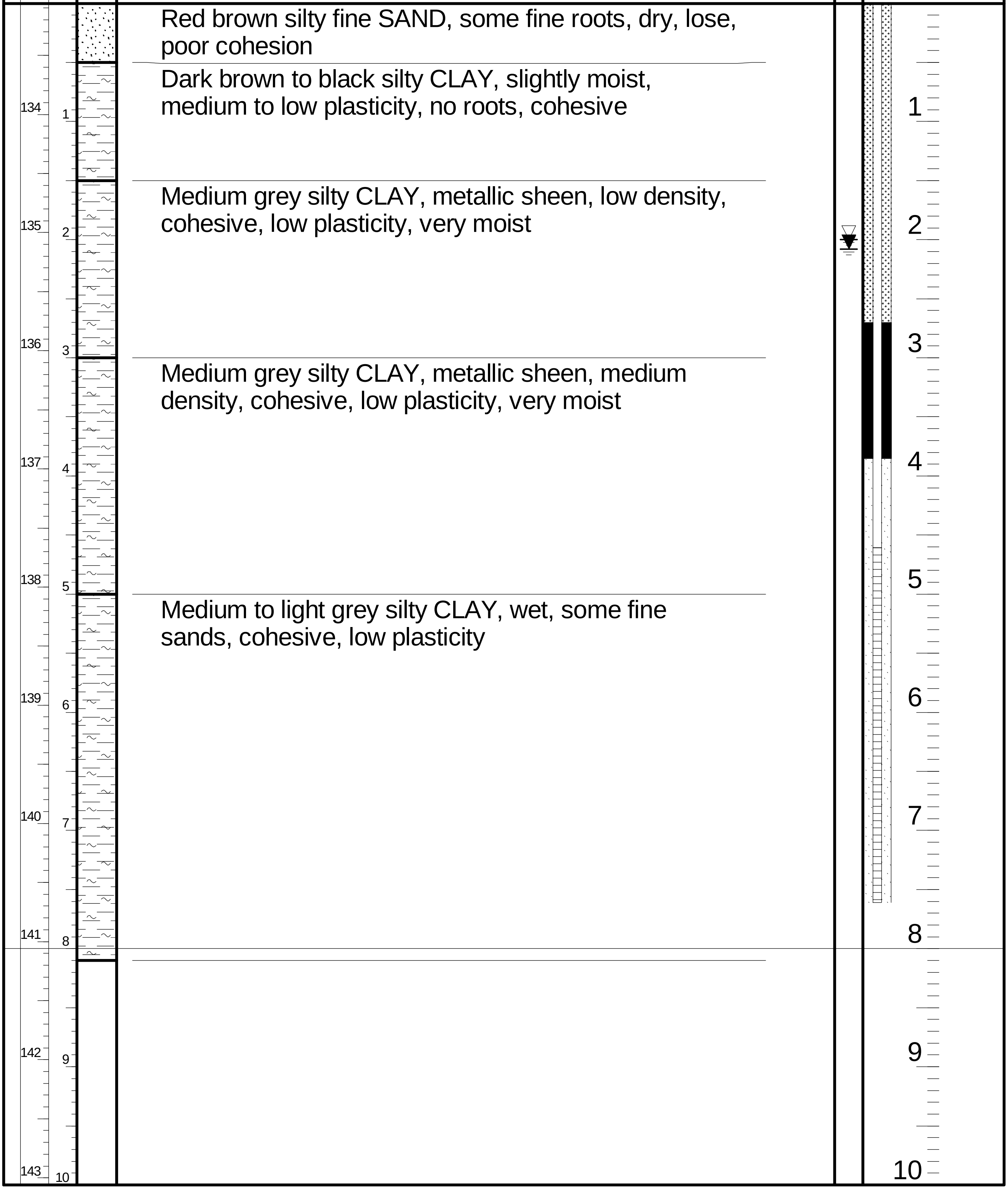
JACOBS

BOREHOLE No. LBC01

Sheet 1 of 1

Project: Additional monitoring assets
Job No: IS195000
Client: Barwon Water
Completion Date: - 29/03/2017
Bore dia: 150
Driller: Liam Blake
Rig: Comacchio
Creek bank
Northings: 5742314.5mN
Eastings: 213313.2mE
RLNS: 133.1
Logged: Unland

FIELD DATA	SOIL DESCRIPTION	COMMENTS
sample type · elevation (m) · depth (m) · graphic log	soil type, unified classification, colour, structure, particle characteristics, minor components	ground water · drilling method, well construction, water and additional observations



Red brown silty fine SAND, some fine roots, dry, lose, poor cohesion

Dark brown to black silty CLAY, slightly moist, medium to low plasticity, no roots, cohesive

Medium grey silty CLAY, metallic sheen, low density, cohesive, low plasticity, very moist

Medium grey silty CLAY, metallic sheen, medium density, cohesive, low plasticity, very moist

Medium to light grey silty CLAY, wet, some fine sands, cohesive, low plasticity

GROUNDWATER SYMBOLS

▼ = Water level (static) ▽ = Water level (during drilling) ◄ ► = Outflow / Inflow

FIELD DATA SYMBOLS

▯ = Bulk Sample ● = Disturbed Sample ■ = Undisturbed Tube Sample

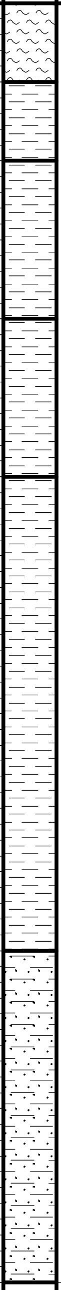
JACOBS

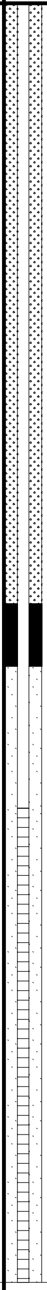
BOREHOLE No. LBC02

Sheet 1 of 1

Project:	Additional monitoring assets	Client: Barwon Water		Driller: Liam Blake	Northings:	5742678.9mN	
Job No:	IS195000	Completion Date:	- 28/03/2017	Rig: Comacchio	Eastings:	215219.7mE	Logged: Unland
		Bore dia: 150		Creek bank	RLNS:	120.5	

FIELD DATA			SOIL DESCRIPTION			COMMENTS	
sample type	elevation (m)	depth (m)	graphic log	soil type, unified classification, colour, structure, particle characteristics, minor components	ground water	drilling method, well construction, water and additional observations	
	121			Red to orange brown clayey SILT, slightly moist, rich in root materials and organic matter			
		1		Dark brown to black CLAY, moist, medium density, high plasticity, some fine roots with ferric staining			1
	122			Black brown CLAY, metallic sheen, wet, moderate to high plasticity, buttery texture			
		2			▽		2
	123			Black brown CLAY, metallic sheen, wet, moderate to high plasticity, soft buttery texture, some fine sands	▼		
		3					3
	124			Black brown CLAY, metallic sheen, moist, moderate to high plasticity, soft buttery texture, some fine sands			
		4					4
	125						
		5					5
	126						
		6					6
	127			Black brown sandy CLAY, metallic sheen, moist, moderate to high plasticity, soft buttery texture			
		7					7
	128						
		8					8
	129						
		9					9
	130						
		10					10





GROUNDWATER SYMBOLS

▼ = Water level (static) ▽ = Water level (during drilling) ◀ ▶ = Outflow / Inflow

FIELD DATA SYMBOLS

▯ = Bulk Sample ● = Disturbed Sample ■ = Undisturbed Tube Sample

JACOBS

BOREHOLE No. YEO20

Sheet 1 of 4

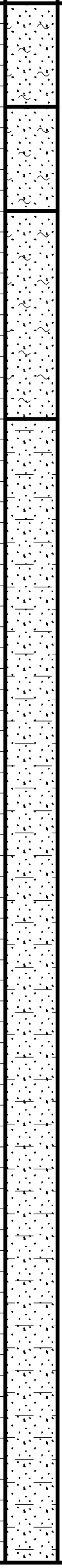
Project: Additional monitoring assets	Client: Barwon Water	Driller: Liam Blake		Northings: 5743568.0mN		
Job No: IS195000	Completion Date: - 31/03/2017	Rig: Comacchio		Eastings: 210618.6mE	Logged: Unland	
	Bore dia: 150		Hill slope	RLNS: 178.9		

FIELD DATA | SOIL DESCRIPTION | COMMENTS

sample type | elevation (m) | depth (m) | graphic log | soil type, unified classification, colour, structure, particle characteristics, minor components | ground water | drilling method, well construction, water and additional observations

Elevation (m): 179, 180, 181, 182, 183, 184, 185, 186, 187, 188, 189, 190, 191, 192, 193

Depth (m): 2, 4, 6, 8, 10, 12, 14

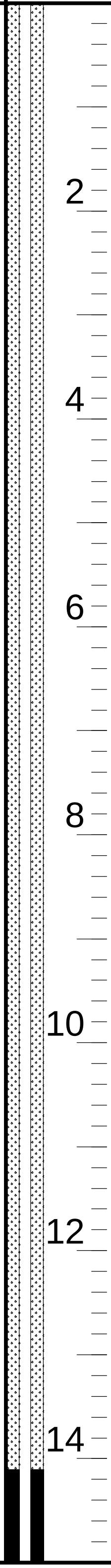


Light orange-brown medium grained SAND, silty, trace rounded feldspathic gravels (~4 mm diameter)

Light orange-brown medium grained SAND, diffuse dark grey mottles, silty, trace rounded feldspathic gravels (~4 mm diameter)

Dark red-brown medium to coarse grained silty SAND, dark grey mottles

Light orange to yellow brown clayey fine SAND with white mottles



GROUNDWATER SYMBOLS

▼ = Water level (static) ▽ = Water level (during drilling) —◀ ▶— = Outflow / Inflow

FIELD DATA SYMBOLS

▯ = Bulk Sample ● = Disturbed Sample ■ = Undisturbed Tube Sample

JACOBS

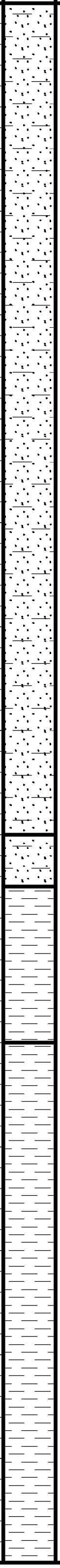
BOREHOLE No. YEO20

Sheet 2 of 4

Project: Additional monitoring assets
Job No: IS195000
Client: Barwon Water
Completion Date: - 31/03/2017
Bore dia: 150
Driller: Liam Blake
Rig: Comacchio
Hill slope
Northings: 5743568.0mN
Eastings: 210618.6mE
RLNS: 178.9
Logged: Unland

FIELD DATA			SOIL DESCRIPTION		COMMENTS
sample type	elevation (m)	depth (m)	graphic log	soil type, unified classification, colour, structure, particle characteristics, minor components	ground water	drilling method, well construction, water and additional observations

elevation (m)	depth (m)
194	
195	16
196	
197	18
198	
199	20
200	
201	22
202	
203	24
204	
205	26
206	
207	28
208	
	30

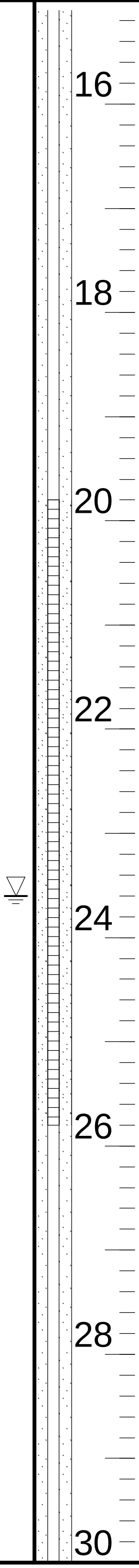


Light orange to yellow brown clayey fine SAND with white mottles *(continued)*

Medium orange-brown clayey fine to medium grained SAND with red and white mottles

Indurated dark brown to black brown ligneous CLAY, light density, soft, low plasticity

Dark brown to black brown stiff ligneous CLAY, medium to high density, firm, moderate plasticity



GROUNDWATER SYMBOLS

▼ = Water level (static) ▽ = Water level (during drilling) ◄ ► = Outflow / Inflow

FIELD DATA SYMBOLS

▯ = Bulk Sample ● = Disturbed Sample ■ = Undisturbed Tube Sample

JACOBS

BOREHOLE No. YEO20

Sheet 3 of 4

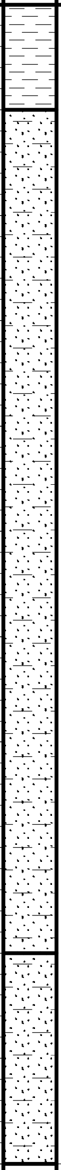
Project: Additional monitoring assets
Job No: IS195000
Client: Barwon Water
Completion Date: - 31/03/2017
Bore dia: 150
Driller: Liam Blake
Rig: Comacchio
Hill slope
Northings: 5743568.0mN
Eastings: 210618.6mE
RLNS: 178.9
Logged: Unland

FIELD DATA | SOIL DESCRIPTION | COMMENTS

sample type | elevation (m) | depth (m) | graphic log | soil type, unified classification, colour, structure, particle characteristics, minor components | ground water | drilling method, well construction, water and additional observations

elevation (m): 209, 210, 211, 212, 213, 214, 215, 216, 217, 218, 219, 220, 221, 222, 223

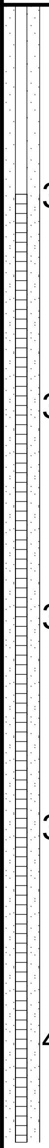
depth (m): 32, 34, 36, 38, 40, 42, 44



Dark brown to black brown stiff ligneous CLAY, medium to high density, firm, moderate plasticity *(continued)*

Medium grey clayey fine grained SAND, clays soft with low plasticity

Medium grey clayey fine grained SAND, clays firm with moderate plasticity



32

34

36

38

40

42

44

GROUNDWATER SYMBOLS

▼ = Water level (static) ▽ = Water level (during drilling) ◀ ▶ = Outflow / Inflow

FIELD DATA SYMBOLS

▯ = Bulk Sample ● = Disturbed Sample ■ = Undisturbed Tube Sample

JACOBS

BOREHOLE No. YS01

Sheet 1 of 1

Project: Additional monitoring assets
Job No: IS195000
Client: Barwon Water
Completion Date: - 21/03/2014
Bore dia: 100/65mm
Driller: Unland
Rig: Hand auger
Fire trench
Northings: mN
Eastings: mE
RLNS:
Logged: Unland

FIELD DATA			SOIL DESCRIPTION			COMMENTS
sample type	elevation (m)	depth (m)	graphic log	soil type, unified classification, colour, structure, particle characteristics, minor components	ground water	drilling method, well construction, water and additional observations

Dark brown TOPSOIL, some orange iron hydroxide mottles, abundant decaying organic material, some 1-5 mm roots

Medium brown to grey SILT with some fine sands, minor clay, poor cohesion.

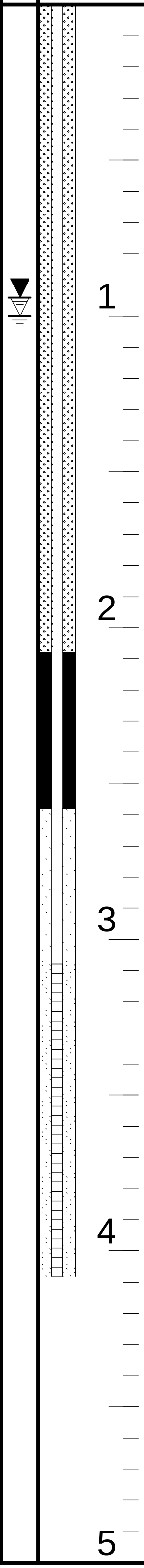
Yellow to grey very sandy CLAY. Soft to firm, moderate plasticity and moderate cohesion. Some moisture.

Light grey CLAY with orange mottles, moderate to high plasticity, soft to firm, moist.

Light grey CLAY, firm to stiff, high plasticity, moist.

Light grey medium grained silty SAND, very moist, poor cohesion.

depth (m): 1, 2, 3, 4, 5



GROUNDWATER SYMBOLS

▼ = Water level (static) ▽ = Water level (during drilling) ◄ ► = Outflow / Inflow

FIELD DATA SYMBOLS

▯ = Bulk Sample ● = Disturbed Sample ■ = Undisturbed Tube Sample

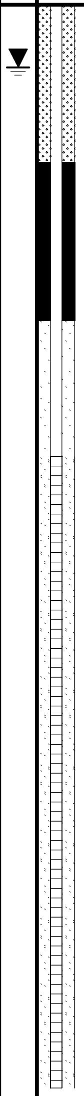
JACOBS

BOREHOLE No. YS02

Sheet 1 of 1

Project: Additional monitoring assets
Job No: IS195000
Client: Barwon Water
Completion Date: - 22/03/2017
Bore dia: 100/65mm
Driller: Unland
Rig: Hand auger
Swamp
Northings: mN
Eastings: mE
RLNS:
Logged: Unland

FIELD DATA			SOIL DESCRIPTION		COMMENTS	
sample type	elevation (m)	depth (m)	graphic log	soil type, unified classification, colour, structure, particle characteristics, minor components	ground water	drilling method, well construction, water and additional observations
				No recovery	▼	
		1		Dark brown silty CLAY with some bright red mottles, soft, poor cohesion.		1
		2		Dark brown silty CLAY with some bright red mottles, soft, poor cohesion, very moist		2
				Dark brown silty CLAY with some bright red mottles, soft, buttery texture, poor cohesion, wet.		
		3		Dark brown to grey silty CLAY with some bright red mottles, soft, buttery texture, poor cohesion, wet.		3
		4				4
		5				5



GROUNDWATER SYMBOLS

▼ = Water level (static) ▽ = Water level (during drilling) ◄ ► = Outflow / Inflow

FIELD DATA SYMBOLS

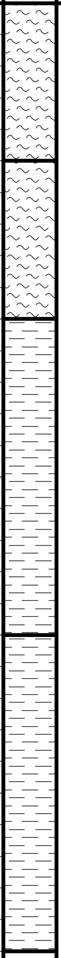
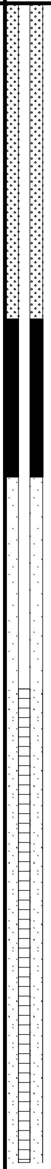
▯ = Bulk Sample ● = Disturbed Sample █ = Undisturbed Tube Sample

JACOBS

BOREHOLE No. YS03

Sheet 1 of 1

Project: Additional monitoring assets
Job No: IS195000
Client: Barwon Water
Completion Date: - 22/03/2017
Bore dia: 100/65mm
Driller: Unland
Rig: Hand auger
Northings: mN
Eastings: mE
Creek Bank RLNS:
Logged: Unland

FIELD DATA			SOIL DESCRIPTION		COMMENTS	
sample type	elevation (m)	depth (m)	graphic log	soil type, unified classification, colour, structure, particle characteristics, minor components	ground water	drilling method, well construction, water and additional observations
				Red brown very sandy SILT with iron hydroxide staining, rich in decaying organic material, fine roots abundant.	▼	
		1		Black grey clayey SILT with bright red mottles, moderate plasticity and cohesion, slightly moist.		1
		2		Dark brown to black silty CLAY, a few fine roots, soft buttery texture.		2
		3		Dark brown to black silty CLAY with metallic lustre, a few fine roots, soft buttery texture.		3
		4				4
		5				5

GROUNDWATER SYMBOLS

▼ = Water level (static) ▽ = Water level (during drilling) ◄ ► = Outflow / Inflow

FIELD DATA SYMBOLS

▯ = Bulk Sample ● = Disturbed Sample █ = Undisturbed Tube Sample

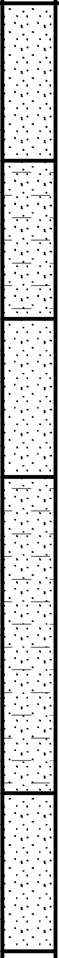
JACOBS

BOREHOLE No. YS04

Sheet 1 of 1

Project: Additional monitoring assets	Client: Barwon Water	Driller: Unland		Northings: mN	
Job No: IS195000	Completion Date: - 23/03/2017	Rig: Hand auger		Eastings: mE	Logged: Unland
	Bore dia: 100/65mm		Fire trench	RLNS:	

FIELD DATA			SOIL DESCRIPTION		COMMENTS	
sample type	elevation (m)	depth (m)	graphic log	soil type, unified classification, colour, structure, particle characteristics, minor components	ground water	drilling method, well construction, water and additional observations



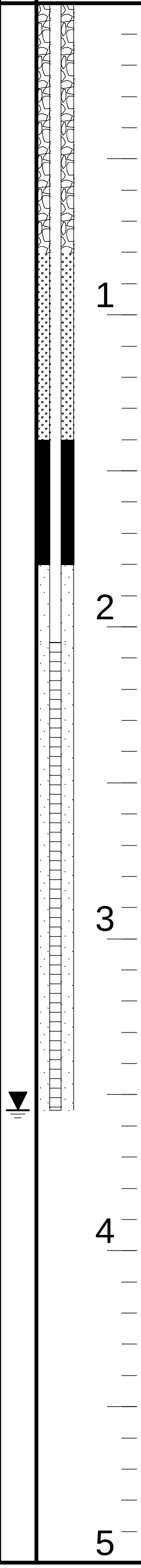
Light grey brown very silty medium to fine grained SAND, firm, dry, poor cohesion.

Light grey silty, clayey SAND, hard, dry, some sub rounded silicic lithic fragments.

Medium to light grey coarse SAND, firm, moist.

Medium to light grey clayey coarse SAND, firm, moist.

Orange coarse SAND with minor clay, very moist, firm to hard.



GROUNDWATER SYMBOLS

▼ = Water level (static) ▽ = Water level (during drilling) ◄ ► = Outflow / Inflow

FIELD DATA SYMBOLS

▯ = Bulk Sample ● = Disturbed Sample █ = Undisturbed Tube Sample

JACOBS

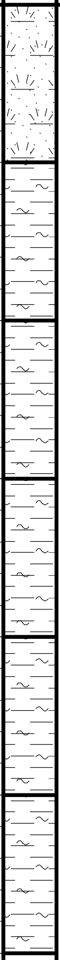
BOREHOLE No. YS05

Sheet 1 of 1

Project: Additional monitoring assets	Client: Barwon Water	Driller: Unland	Northings: mN
Job No: IS195000	Completion Date: - 23/03/2017	Rig: Hand auger	Eastings: mE
	Bore dia: 100/65mm	Swamp	RLNS:

Logged: Unland

FIELD DATA			SOIL DESCRIPTION		COMMENTS
sample type	elevation (m)	depth (m)	graphic log	soil type, unified classification, colour, structure, particle characteristics, minor components	ground water	drilling method, well construction, water and additional observations



Black and red TOPSOIL, lose, dry, poor cohesion, ligneous.

Dark brown to black silty CLAY with bright red mottles, moist, soft, moderate plasticity.

Dark brown to black silty CLAY, moist, soft, moderate plasticity.

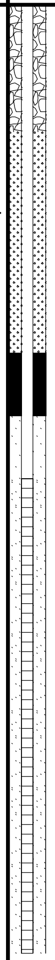
Dark grey to yellow brown silty CLAY, moderate to low plasticity, wet, soft to firm.

Medium grey silty CLAY with some fine sand, moderate plasticity, soft to frim, wet.

Medium grey silty CLAY with abundant fine sand, moderate plasticity, soft to frim, wet.

Depth (m): 1, 2, 3, 4, 5

▼



GROUNDWATER SYMBOLS

▼ = Water level (static) ▽ = Water level (during drilling) ◀ ▶ = Outflow / Inflow

FIELD DATA SYMBOLS

▯ = Bulk Sample ● = Disturbed Sample ■ = Undisturbed Tube Sample

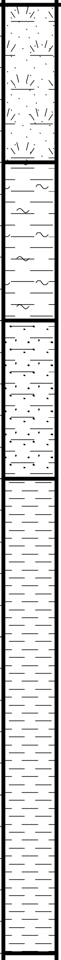
JACOBS

BOREHOLE No. YS06

Sheet 1 of 1

Project: Additional monitoring assets
Job No: IS195000
Client: Barwon Water
Completion Date: - 23/03/2017
Bore dia: 100/65mm
Driller: Unland
Rig: Hand auger
Northings: mN
Eastings: mE
Creek Bank RLNS:
Logged: Unland

FIELD DATA			SOIL DESCRIPTION		COMMENTS	
sample type	elevation (m)	depth (m)	graphic log	soil type, unified classification, colour, structure, particle characteristics, minor components	ground water	drilling method, well construction, water and additional observations

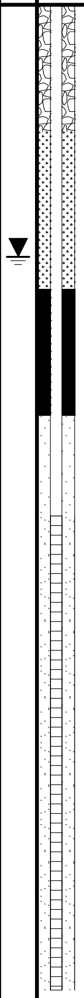


Red brown sandy TOPSOIL, lose, dry, fine roots abundant.

Dark brown to black silty CLAY, very firm, slightly moist.

Dark brown very sandy CLAY, soft, poor cohesion, slightly moist.

Yellow brown to grey CLAY, soft, wet.



Depth (m): 1, 2, 3, 4, 5

GROUNDWATER SYMBOLS

▼ = Water level (static) ▽ = Water level (during drilling) ◄ ► = Outflow / Inflow

FIELD DATA SYMBOLS

▯ = Bulk Sample ● = Disturbed Sample ■ = Undisturbed Tube Sample

GROUNDWATER NO GAMMA IS195000.GPJ SKM_GAMMA.GDT 10/5/17

Appendix B. Bore completion photos

Lower Boundary Creek 01 (LBC01)

Lower Boundary Creek 02 (LBC02)

Yeodene 20 (YEO02)

Yeodene Swamp 01 (YS01)

Yeodene Swamp 02 (YS02)

Yeodene Swamp 03 (YS03)

Yeodene Swamp 04 (YS04)

Yeodene Swamp 05 (YS05)

Yeodene Swamp 06 (YS06)

Appendix B. Summary Field and Laboratory Results

Table 7-1 Summary of acid sulfate soil screen tests

Site	Depth	pH_F	pH_{FOX}	ΔpH	Reaction
	(m)	units	units	units	Rate (1-4)
LBC01	0.5	4.7	3.4	1.3	4
LBC01	1.5	4.6	2.4	2.2	4
LBC01	3.0	6	2.8	3.2	4
LBC02	0.5	5.1	4	1.1	4
LBC02	1.0	4.5	3	1.5	4
LBC02	3.0	6.3	3.6	2.7	4
YS01	0.5	4.6	2.9	1.7	4
YS01	1.0	3.9	3.1	0.8	4
YS01	1.5	3.9	2.6	1.3	2
YS01	3.0	4.1	3.1	1	2
YS02	1.0	3.4	1.6	1.8	3
YS02	2.0	4.5	1.5	3	4
YS02	3.0	5.9	1.8	4.1	4
YS03	0.5	4.8	3.6	1.2	4
YS03	1.0	3.9	2.7	1.2	4
YS03	2.0	5.9	1.9	4	4
YS03	3.0	5.9	2.2	3.7	4
YS04	0.5	4.3	2.6	1.7	3
YS04	1.0	4.3	3.4	0.9	1
YS04	2.0	4.3	3.6	0.7	1
YS04	3.0	4.2	3.4	0.8	1
YS05	0.5	3.6	1.6	2	4
YS05	1.0	2.8	1.6	1.2	4
YS05	2.0	4.1	2.3	1.8	4
YS05	3.0	4.2	2.3	1.9	4
YS06	0.5	5.6	2.1	3.5	3
YS06	1.0	5.8	3.2	2.6	4
YS06	1.5	5	2	3	3
YS06	2.5	5.3	3.5	1.8	1
YS06	3.0	5.2	3.8	1.4	2

Table 7-2 Summary of chromium reducible sulfur tests

Site	Depth	Actual acidity	Potential acidity	Retained acidity	Net Acidity
	(m)	Mole H+/t	Mole H+/t	Mole H+/t	Mole H+/t
LBC01	0.5	250	8	< 10	270
LBC01	1.5	260	14	< 10	280
LBC01	3.0	120	190	12	320
LBC02	0.5	150	4	13	170
LBC02	1.0	200	6	< 10	210
LBC02	3.0	28	5	n/a	33
YS01	0.5	270	5	< 10	280
YS01	1.0	39	< 3	n/a	39
YS01	1.5	89	< 3	< 10	89
YS01	3.0	28	< 3	n/a	28
YS02	1.0	910	550	< 10	1500
YS02	2.0	470	2900	< 10	3400
YS02	3.0	81	1200	n/a	1200
YS03	0.5	110	3	16	130
YS03	1.0	240	23	43	310
YS03	2.0	72	230	n/a	300
YS03	3.0	78	150	n/a	230
YS04	0.5	49	4	< 10	54
YS04	1.0	59	< 3	< 10	68
YS04	2.0	13	< 3	n/a	13
YS04	3.0	7.3	< 3	n/a	< 10
YS05	0.5	570	31	37	640
YS05	1.0	580	9000	< 10	9600
YS05	2.0	110	120	< 10	230
YS05	3.0	48	44	< 10	93
YS06	0.5	21	4	n/a	25
YS06	1.0	81	10	< 10	91
YS06	1.5	44	22	< 10	65
YS06	2.5	3.7	< 3	n/a	< 10
YS06	3.0	5.5	< 3	n/a	< 10

Appendix C. Laboratory Reports

				Inorganics																						
			Nitrogen (Organic)	Alkalinity (Bicarbonate as CaCO3)	Nitrite + Nitrate as N	Sulphite as S	Thiosulphate(S)	Alkalinity (Hydroxide) as CaCO3	Alkalinity (total) as CaCO3	Ammonia as N	BOD	Carbonate	Chloride	COD	Dissolved Organic Carbon	Ferrous Iron	Fluoride	Kjeldahl Nitrogen Total	Nitrate (as N)	Nitrite (as N)	Nitrogen (Total)	Phosphate total (P)	Sodium	Sulphate	Sulphate as S	Sulphide
			mg/L	mg/L	mg/L	mg/L	mg/L	µg/L	mg/L	µg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	µg/L	mg/L	mg/L	mg/L	mg/L	mg/L
EQL			0.2	20	0.05	0.5	1	10000	20	10	5	10	1	25	5	0.05	0.5	0.2	0.02	0.02	200	0.05	0.5	5	5	0.05
ANZECC 2000 FW 90%																										
Field_ID	Sampled_Date-	SampleCode																								
Lower Boundary Creek	4/05/2017	M17-My09643	0.4	<20	0.08	<1	<2	<10,000	<20	20	<5	<10	330	<25	7.3	0.24	<0.5	0.4	0.07	<0.02	500	0.1	140	260	88	<0.05
Lower Boundary Creek	22/08/2017	M17-Au28091	-	<20	-	<1	<2	<10,000	<20	<10	-	<10	220	-	-	0.25	<0.5	-	0.32	-	-	<0.05	84	110	35	<0.05
Damplands	4/05/2017	M17-My09642	0.5	30	1.3	<1	<2	<10,000	30	320	<5	<10	97	<25	7.9	0.25	<0.5	0.8	1.3	<0.02	2100	0.05	46	6.2	<5	<0.05
Damplands	22/08/2017	M17-Au28087	-	<20	-	<1	<2	<10,000	<20	90	-	<10	140	-	-	0.51	<0.5	-	0.15	-	-	0.07	57	7.8	<5	<0.05
Upstream Swamp	4/05/2017	M17-My09640	0.3	31	0.06	<1	<2	<10,000	31	20	<5	<10	96	25	8.2	0.3	<0.5	0.3	0.06	<0.02	400	0.05	46	5.8	<5	<0.05
Upstream Swamp	22/08/2017	M17-Au28088	-	72	-	<1	<2	<10,000	72	180	-	<10	160	-	-	3.2	<0.5	-	<0.02	-	-	0.08	66	16	5.4	<0.05
Downstream Swamp	4/05/2017	M17-My09644	0.4	<20	<0.05	<1	<2	<10,000	<20	510	<5	<10	99	<25	10	0.44	<0.5	0.9	<0.02	<0.02	900	0.14	63	700	230	<0.05
Downstream Swamp	22/08/2017	M17-Au28089	-	<20	-	<1	<2	<10,000	<20	<10	-	<10	150	-	-	0.44	<0.5	-	0.07	-	-	<0.05	60	68	23	<0.05
Yeodene Gauge	4/05/2017	M17-My09639	0.4	<20	<0.05	<1	<2	<10,000	<20	310	<5	<10	140	<25	9.1	5.7	<0.5	0.7	<0.02	<0.02	700	0.14	76	390	130	<0.05
Yeodene Gauge	22/08/2017	M17-Au28090	-	<20	-	<1	<2	<10,000	<20	20	-	<10	160	-	-	0.69	<0.5	-	0.2	-	-	<0.05	60	84	28	<0.05
McDonalds Dam D/S	22/08/2017	M17-Au28086	-	<20	-	<1	<2	<10,000	<20	120	-	<10	120	-	-	0.57	<0.5	-	0.16	-	-	0.07	59	7.2	<5	<0.05
YS02-SW	23/08/2017	M17-Au28101	-	<20	-	<1	<2	<10,000	<20	30	-	<10	150	-	-	0.25	<0.5	-	<0.02	-	-	0.11	54	140	46	<0.05
YS05-SW	23/08/2017	M17-Au28102	-	<20	-	<1	<2	<10,000	<20	20	-	<10	150	-	-	3	<0.5	-	0.11	-	-	0.05	62	13	<5	<0.05
A3	4/05/2017	M17-My09638	<0.2	<20	0.17	<1	<2	<10,000	<20	<10	<5	<10	600	<25	<5	<0.05	<0.5	<0.2	0.17	<0.02	<200	0.08	310	170	55	<0.05
A3	22/08/2017	M17-Au28092	-	<20	-	<1	<2	<10,000	<20	60	-	<10	580	-	-	0.18	<0.5	-	0.17	-	-	0.07	370	170	55	<0.05
LBC01	5/05/2017	M17-My09650	<0.2	140	<0.05	<1	<2	<10,000	140	12,000	6.1	<10	590	30	5.2	80	<0.5	12	<0.02	<0.02	12,000	<0.05	160	43	14	<0.05
LBC01	23/08/2017	M17-Au28094	-	130	-	<1	<2	<10,000	130	15,000	-	<10	760	-	-	100	<0.5	-	<0.02	-	-	0.63	160	<5	<5	<0.05
LBC02	5/05/2017	M17-My09652	0.2	140	<0.05	<1	<2	<10,000	140	90	<5	<10	330	30	8.1	18	<0.5	0.3	<0.02	<0.02	300	0.12	130	18	6.1	<0.05
LBC02	22/08/2017	M17-Au28093	-	190	-	<1	<2	<10,000	190	<10	-	<10	290	-	-	23	<0.5	-	<0.02	-	-	0.39	140	8	<5	<0.05
PASS1	5/05/2017	M17-My09651	<0.2	230	0.3	<1	<2	<10,000	230	800	6.5	<10	1400	<25	<5	6.9	<0.5	0.8	0.27	0.03	1100	0.21	510	160	53	<0.05
PASS1	23/08/2017	M17-Au28095	-	270	-	<1	<2	<10,000	270	1000	-	<10	1600	-	-	28	<0.5	-	0.21	-	-	2.3	520	170	56	<0.05
TB1	22/08/2017	M17-Au28103	-	<20	-	<1	<2	<10,000	<20	30	-	<10	180	-	-	1.5	<0.5	-	0.26	-	-	0.08	58	46	15	<0.05
TB1	5/05/2017	M17-My09649	<0.2	<20	0.31	<1	<2	<10,000	<20	<10	<5	<10	150	<25	<5	<0.05	<0.5	<0.2	0.31	<0.02	300	<0.05	63	56	19	<0.05
YS01	5/05/2017	M17-My09648	0.2	<20	0.31	<1	<2	<10,000	<20	200	<5	<10	570	35	9.9	30	<0.5	0.4	0.3	<0.02	700	<0.05	110	470	160	<0.05
YS01	23/08/2017	M17-Au28096	-	<20	-	<1	<2	<10,000	<20	220	-	<10	920	-	-	91	<0.5	-	<0.02	-	-	0.08	290	600	200	<0.05
YS02	5/05/2017	M17-My09647	0.4	<20	<0.05	<1	<2	<10,000	<20	2600	<5	<10	110	72	6.1	56	<0.5	3	<0.02	<0.02	3000	0.17	71	840	280	<0.05
YS02	23/08/2017	M17-Au28097	-	<20	-	<1	<2	<10,000	<20	3400	-	<10	110	-	-	210	<0.5	-	<0.1	-	-	0.25	84	1400	460	<0.05
YS03	5/05/2017	M17-My09646	0.4	<20	<0.05	<1	<2	<10,000	<20	5100	58	<10	100	230	19	350	<0.5	5.5	<0.02	<0.02	5500	0.38	89	860	290	<0.05
YS03	23/08/2017	M17-Au28098	-	<20	-	<1	<2	<10,000	<20	8500	-	<10	97	-	-	1000	<0.5	-	<0.1	-	-	0.36	190	3600	1200	<0.05
YS05	5/05/2017	M17-My09645	0.7	<20	<0.05	<1	<2	<10,000	<20	4400	38	<10	72	180	41	150	<0.5	5.1	<0.02	<0.02	5100	0.57	69	4000	1300	<0.05
YS05	23/08/2017	M17-Au28099	-	<20	-	<1	<2	<10,000	<20	1200	-	<10	140	-	-	120	<0.5	-	<0.02	-	-	0.12	50	450	150	<0.05
YS06	4/05/2017	M17-My09641	0.4	50	<0.05	<1	<2	<10,000	50	60	<5	<10	110	45	13	1.7	<0.5	0.5	<0.02	<0.02	500	<0.05	53	19	6.5	<0.05
YS06	22/08/2017	M17-Au28100	-	<20	-	<1	<2	<10,000	<20	30	-	<10	140	-	-	0.41	<0.5	-	0.14	-	-	0.09	54	6.7	<5	<0.05

					Lead		Metals																
			Sulphur as S	TOC	Lead	Lead (Filtered)	Aluminium	Aluminium (Filtered)	Arsenic	Arsenic (Filtered)	Cadmium	Cadmium (Filtered)	Calcium	Chromium (III+VI)	Chromium (III+VI) (Filtered)	Copper	Copper (Filtered)	Ferric Iron	Iron	Iron (Filtered)	Magnesium	Manganese	Manganese (Filtered)
			mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
EQL			5	5	0.001	0.001	0.05	0.05	0.001	0.001	0.0002	0.0002	0.5	0.001	0.001	0.001	0.001	0.05	0.05	0.05	0.5	0.005	0.005
ANZECC 2000 FW 90%					0.0056	0.0056	0.08	0.08			0.0004	0.0004				0.0018	0.0018					2.5	2.5
Field_ID	Sampled_Date-	SampleCode																					
Lower Boundary Creek	4/05/2017	M17-My09643	88	7.6	<0.001	<0.001	15	14	<0.001	<0.001	0.0003	0.0003	38	0.001	0.001	<0.001	<0.001	0.44	0.68	0.64	31	0.26	0.26
Lower Boundary Creek	22/08/2017	M17-Au28091	35	-	<0.001	<0.001	11	11	<0.001	<0.001	<0.0002	<0.0002	16	<0.001	<0.001	<0.001	<0.001	0.46	0.77	0.71	14	0.081	0.081
Damplands	4/05/2017	M17-My09642	<5	8.9	<0.001	<0.001	<0.05	<0.05	<0.001	<0.001	<0.0002	<0.0002	5.3	<0.001	<0.001	<0.001	<0.001	0.48	0.73	0.5	8.1	0.038	0.026
Damplands	22/08/2017	M17-Au28087	<5	-	<0.001	<0.001	0.18	0.16	<0.001	<0.001	<0.0002	<0.0002	5.8	0.007	<0.001	0.001	<0.001	0.41	1.4	0.91	7.7	0.076	0.065
Upstream Swamp	4/05/2017	M17-My09640	<5	9.8	<0.001	<0.001	<0.05	<0.05	<0.001	<0.001	<0.0002	<0.0002	5.2	0.001	<0.001	<0.001	<0.001	0.17	0.47	0.37	8.3	0.016	0.015
Upstream Swamp	22/08/2017	M17-Au28088	5.4	-	0.01	<0.001	8.5	0.23	0.003	0.002	<0.0002	<0.0002	27	0.013	<0.001	0.004	<0.001	0.2	6.2	3.4	17	0.097	0.098
Downstream Swamp	4/05/2017	M17-My09644	230	10	<0.001	<0.001	75	74	0.002	0.002	0.0012	0.0013	20	0.003	0.003	<0.001	<0.001	28	28	27	25	0.15	0.15
Downstream Swamp	22/08/2017	M17-Au28089	23	-	<0.001	<0.001	8.4	8	<0.001	<0.001	<0.0002	<0.0002	5.2	0.001	<0.001	<0.001	<0.001	0.56	1.2	1	8.1	0.023	0.023
Yeodene Gauge	4/05/2017	M17-My09639	130	9.5	0.001	0.001	36	37	0.002	0.002	0.0007	0.0006	23	0.002	0.002	<0.001	<0.001	6	12	12	24	0.17	0.17
Yeodene Gauge	22/08/2017	M17-Au28090	28	-	<0.001	<0.001	10	10	<0.001	<0.001	<0.0002	<0.0002	6.8	0.001	<0.001	<0.001	<0.001	0.51	1.4	1.2	8.9	0.035	0.035
McDonalds Dam D/S	22/08/2017	M17-Au28086	<5	-	<0.001	<0.001	0.18	0.17	<0.001	<0.001	<0.0002	<0.0002	5.9	0.002	<0.001	<0.001	<0.001	0.35	1.4	0.92	7.7	0.062	0.05
YS02-SW	23/08/2017	M17-Au28101	46	-	<0.001	<0.001	25	23	0.001	0.001	0.0004	0.0004	5.1	0.002	0.001	<0.001	<0.001	0.48	1.3	0.73	8.1	0.037	0.036
YS05-SW	23/08/2017	M17-Au28102	<5	-	<0.001	<0.001	0.16	0.16	0.003	0.003	<0.0002	<0.0002	4.7	<0.001	<0.001	<0.001	<0.001	0.4	3.6	3.4	7.5	0.009	0.008
A3	4/05/2017	M17-My09638	55	<5	<0.001	<0.001	0.18	0.18	<0.001	<0.001	<0.0002	<0.0002	37	0.002	0.001	0.01	0.009	0.06	0.06	<0.05	24	0.06	0.06
A3	22/08/2017	M17-Au28092	55	-	<0.001	<0.001	0.29	0.2	<0.001	<0.001	<0.0002	<0.0002	54	0.004	<0.001	0.006	0.005	<0.05	1.2	0.19	30	0.045	0.045
LBC01	5/05/2017	M17-My09650	14	6	<0.001	<0.001	<0.05	<0.05	<0.001	<0.001	<0.0002	<0.0002	99	<0.001	<0.001	<0.001	<0.001	12	92	24	68	0.082	0.088
LBC01	23/08/2017	M17-Au28094	<5	-	0.012	<0.001	9.1	<0.05	0.031	0.021	0.0002	<0.0002	120	0.019	<0.001	0.004	<0.001	<0.05	120	100	73	0.1	0.1
LBC02	5/05/2017	M17-My09652	6.1	7.5	<0.001	<0.001	<0.05	<0.05	0.011	<0.001	<0.0002	<0.0002	59	<0.001	<0.001	<0.001	<0.001	<0.05	17	2.9	28	0.28	0.26
LBC02	22/08/2017	M17-Au28093	<5	-	0.004	<0.001	1.7	<0.05	0.036	0.031	<0.0002	<0.0002	82	0.003	<0.001	0.002	<0.001	<0.05	28	23	33	0.23	0.21
PASS1	5/05/2017	M17-My09651	53	<5	<0.001	<0.001	0.17	<0.05	0.006	<0.001	<0.0002	<0.0002	240	0.001	<0.001	0.001	<0.001	4	11	<0.05	91	0.032	0.044
PASS1	23/08/2017	M17-Au28095	56	-	0.01	<0.001	3.3	<0.05	0.028	0.009	<0.0002	<0.0002	290	0.007	<0.001	0.006	<0.001	<0.05	45	28	94	0.065	0.049
TB1	22/08/2017	M17-Au28103	15	-	<0.001	<0.001	<0.05	<0.05	<0.001	<0.001	<0.0002	<0.0002	24	<0.001	<0.001	0.002	0.002	<0.05	5.7	1.5	10	0.14	0.14
TB1	5/05/2017	M17-My09649	19	<5	<0.001	<0.001	<0.05	<0.05	<0.001	<0.001	<0.0002	<0.0002	21	<0.001	<0.001	<0.001	<0.001	<0.05	<0.05	<0.05	11	0.13	0.13
YS01	5/05/2017	M17-My09648	160	9.7	0.004	0.004	54	40	0.003	0.002	0.0016	0.001	27	0.004	0.004	<0.001	<0.001	<0.05	30	15	37	0.63	0.43
YS01	23/08/2017	M17-Au28096	200	-	0.006	<0.005	83	73	0.007	0.006	0.0024	0.0024	59	0.008	0.005	<0.005	<0.005	<0.05	92	91	77	0.89	0.89
YS02	5/05/2017	M17-My09647	280	5.2	<0.001	<0.001	0.63	<0.05	0.001	<0.001	<0.0002	<0.0002	170	0.001	<0.001	0.001	<0.001	11	67	75	48	0.77	0.77
YS02	23/08/2017	M17-Au28097	460	-	0.002	<0.001	6	0.07	0.004	0.003	<0.0002	<0.0002	280	0.005	<0.001	0.001	<0.001	10	230	220	67	1.3	1.3
YS03	5/05/2017	M17-My09646	290	26	0.012	0.009	130	130	0.022	0.014	0.0003	0.0003	150	0.023	0.02	0.006	0.005	540	890	900	73	0.96	0.94
YS03	23/08/2017	M17-Au28098	1200	-	<0.01	<0.01	52	51	0.013	<0.01	<0.002	<0.002	370	<0.01	<0.01	<0.01	<0.01	100	1400	1100	180	2.5	2.5
YS05	5/05/2017	M17-My09645	1300	42	0.01	0.01	33	34	0.32	0.37	0.0005	0.0006	13	0.017	0.023	0.004	0.005	570	720	720	13	0.14	0.15
YS05	23/08/2017	M17-Au28099	150	-	<0.001	<0.001	22	22	0.017	0.013	<0.0002	<0.0002	3.3	0.005	0.004	<0.001	<0.001	20	140	140	5.8	0.055	0.055
YS06	4/05/2017	M17-My09641	6.5	14	<0.001	<0.001	0.4	0.29	0.002	0.001	<0.0002	<0.0002	13	0.001	<0.001	<0.001	<0.001	<0.05	1.4	0.63	12	0.066	0.062
YS06	22/08/2017	M17-Au28100	<5	-	<0.001	<0.001	0.17	0.17	<0.001	<0.001	<0.0002	<0.0002	5.8	<0.001	<0.001	<0.001	<0.001	0.51	1	0.92	8	0.029	0.025

										Other
			Mercury	Mercury (Filtered)	Nickel	Nickel (Filtered)	Potassium	Zinc	Zinc (Filtered)	Acidity (as CaCO3)
			mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
EQL			0.0001	0.0001	0.001	0.001	0.5	0.005	0.005	10
ANZECC 2000 FW 90%			0.0019	0.0019	0.013	0.013		0.015	0.015	
Field_ID	Sampled_Date-	SampleCode								
Lower Boundary Creek	4/05/2017	M17-My09643	<0.0001	<0.0001	0.091	0.091	5.8	0.33	0.35	-
Lower Boundary Creek	22/08/2017	M17-Au28091	<0.0001	<0.0001	0.046	0.046	4	0.25	0.25	95
Damplands	4/05/2017	M17-My09642	<0.0001	<0.0001	<0.001	<0.001	3.5	0.016	0.01	-
Damplands	22/08/2017	M17-Au28087	<0.0001	<0.0001	0.003	<0.001	4.1	<0.005	0.008	<10
Upstream Swamp	4/05/2017	M17-My09640	<0.0001	<0.0001	0.001	<0.001	3.4	0.005	0.005	-
Upstream Swamp	22/08/2017	M17-Au28088	0.0001	<0.0001	0.011	0.007	3.4	0.031	0.008	53
Downstream Swamp	4/05/2017	M17-My09644	<0.0001	<0.0001	0.2	0.22	3.5	1.3	1.5	-
Downstream Swamp	22/08/2017	M17-Au28089	<0.0001	<0.0001	0.025	0.025	3.4	0.17	0.17	90
Yeodene Gauge	4/05/2017	M17-My09639	<0.0001	<0.0001	0.16	0.16	4.9	0.84	0.84	-
Yeodene Gauge	22/08/2017	M17-Au28090	<0.0001	<0.0001	0.037	0.037	3.4	0.23	0.23	100
McDonalds Dam D/S	22/08/2017	M17-Au28086	<0.0001	<0.0001	0.004	<0.001	4.1	<0.005	0.005	<10
YS02-SW	23/08/2017	M17-Au28101	<0.0001	<0.0001	0.058	0.058	2.9	0.45	0.45	160
YS05-SW	23/08/2017	M17-Au28102	<0.0001	<0.0001	0.002	0.002	3.8	0.014	0.014	35
A3	4/05/2017	M17-My09638	<0.0001	<0.0001	0.063	0.061	5.8	0.11	0.11	-
A3	22/08/2017	M17-Au28092	<0.0001	<0.0001	0.036	0.036	6.3	0.059	0.059	45
LBC01	5/05/2017	M17-My09650	<0.0001	<0.0001	0.001	0.001	5.3	0.008	0.011	-
LBC01	23/08/2017	M17-Au28094	<0.0001	<0.0001	0.013	0.002	5.9	0.15	0.005	180
LBC02	5/05/2017	M17-My09652	<0.0001	<0.0001	0.002	0.002	5.4	0.006	0.006	-
LBC02	22/08/2017	M17-Au28093	<0.0001	<0.0001	0.004	<0.001	5.9	0.02	0.008	52
PASS1	5/05/2017	M17-My09651	<0.0001	<0.0001	0.002	<0.001	11	<0.005	<0.005	-
PASS1	23/08/2017	M17-Au28095	<0.0001	<0.0001	0.006	<0.001	10	0.021	<0.005	44
TB1	22/08/2017	M17-Au28103	<0.0001	<0.0001	0.008	0.008	4	0.065	0.065	34
TB1	5/05/2017	M17-My09649	<0.0001	<0.0001	0.009	0.009	4.1	0.1	0.1	-
YS01	5/05/2017	M17-My09648	<0.0001	<0.0001	0.49	0.37	5	0.86	0.81	-
YS01	23/08/2017	M17-Au28096	<0.0005	<0.0005	0.86	0.86	6.8	1.4	1.4	670
YS02	5/05/2017	M17-My09647	<0.0001	<0.0001	0.005	0.003	8.4	0.024	0.016	-
YS02	23/08/2017	M17-Au28097	<0.0001	<0.0001	0.01	0.002	9.1	0.012	0.006	390
YS03	5/05/2017	M17-My09646	<0.0001	<0.0001	0.47	0.43	10	0.69	0.61	-
YS03	23/08/2017	M17-Au28098	<0.001	<0.001	0.18	0.18	13	0.37	0.37	1900
YS05	5/05/2017	M17-My09645	<0.0001	<0.0001	0.17	0.2	5.1	0.35	0.36	-
YS05	23/08/2017	M17-Au28099	<0.0001	<0.0001	0.031	0.031	3.6	0.11	0.11	560
YS06	4/05/2017	M17-My09641	<0.0001	<0.0001	0.004	0.004	3.8	0.018	0.02	-
YS06	22/08/2017	M17-Au28100	<0.0001	<0.0001	0.001	<0.001	4	<0.005	<0.005	<10

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CHAIN OF CUSTODY & ANALYSIS REQUEST

LAB: Eurofins
ADDRESS: 3 Kingston Town Close, Oakleigh, VIC, 3166
PHONE: +61 3 9564 7055
FAX:

Page 1 **of** 2

PROJECT # IS191000
PROJECT NAME Barwon Water Task 5
SAMPLE COLLECTOR'S NAME Nicolaas Unland
LAB JOB #

PRELIM. RESULTS BY: Email ☑ VERBAL ☐ FAX ☑ EMAIL
FINAL REPORT B Email **SEND TO EMAIL ADDRESS(ES):** Nicolaas.unland@jacobs.com
LAB QUOTE REF
Jacobs ORDER No:

SAMPLE ID	DEPTH (metres)	LAB #	MATRIX				PRESERVATION METHOD				SAMPLING DATE	No. OF CONTAINERS	METHOD CODE & ANALYSIS REQUIRED						COMMENTS	(see below)		
			WATER	SOIL	AIR	SLUDGE	ICE	ACID	OTHER	NONE			Chromium reducible sulfur suite	ASS screen tests						(1)	(2)	(3)
LBC01-0.5	0.5			X			X					1							Please hold samples	☐	☐	☐
LBC01-1.5	1.5			X			X					1							until notified	☐	☐	☐
LBC01-2.0	2.0			X			X					1							↓	☐	☐	☐
LBC01-S1	0.5			X			X					1								☐	☐	☐
LBC01-S2	1.0			X			X					1								☐	☐	☐
LBC02-0.5	0.5			X			X					1								☐	☐	☐
LBC02-1.0	1.0			X			X					1								☐	☐	☐
LBC02-2.0	2.0			X			X					1								☐	☐	☐
LBC01-3.0	3.0			X			X					1								☐	☐	☐
LCB02-3.0	3.0			X			X					1								☐	☐	☐
YS01-1.0	1.0			X			X					1								☐	☐	☐
YS04-0.5	0.5			X			X					1								☐	☐	☐
YS04-1.5	1.5			X			X					1								☐	☐	☐
YS04-2.0	2.0			X			X					1								☐	☐	☐
YS04-2.5	2.5			X			X					1								☐	☐	☐
YS04-3.0	3.0			X			X					1								☐	☐	☐
YS05-0.5	0.5			X			X					1								☐	☐	☐
YS05-1.5	1.5			X			X					1								☐	☐	☐
YS05-2.0	2.0			X			X					1								☐	☐	☐
YS05-2.5	2.5			X			X					1								☐	☐	☐
YS05-3.0	3.0			X			X					1								☐	☐	☐
YS06-1.0	1.0			X			X					1								☐	☐	☐
YS06-1.5	1.5			X			X					1								☐	☐	☐
YS06-2.0	2.0			X			X					1								☐	☐	☐
YS06-2.5	2.5			X			X					1								☐	☐	☐
TOTALS												25										

Relinquished by (SIGN/PRINT): Nicolaas Unland of Jacobs
Date 05-Apr-17 **Time**
Received by (SIGN/PRINT): of
Date 6/4/17 **Time**
Custody Seals Intact? Yes / No

Relinquished by (SIGN/PRINT): of
Date **Time**
Received by (SIGN/PRINT): of
Date **Time**
Sample Receipt Temp. °C

Additional Comments/Instructions:
All final lab reports to be provided electronically as .pdf and datafile to both emails above.

Re $\frac{7.4}{9.1}$

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CHAIN OF CUSTODY & ANALYSIS REQUEST

LAB: Eurofins
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PHONE: +61 3 9564 7055
FAX:

Page of

PROJECT #: IS191000
PROJECT NAME: Barwon Water Task 5
SAMPLE COLLECTOR'S NAME: Nicolaas Unland
LAB JOB #:

PRELIM. RESULTS BY: ☑ VERBAL
Email ☐ FAX
☑ EMAIL

FINAL REPORT E Email
SEND TO EMAIL ADDRESS(ES): Nicolaas.unland@jacobs.com

LAB QUOTE REF
Jacobs ORDER No:

SAMPLE ID	DEPTH (metres)	LAB #	MATRIX				PRESERVATION METHOD				SAMPLING DATE	No. OF CONTAINERS	METHOD CODE & ANALYSIS REQUIRED						COMMENTS	(see below)		
			WATER	SOIL	AIR	SLUDGE	ICE	ACID	OTHER	NONE			Chromium reducible sulfur suite	ASS screen tests						(1)	(2)	(3)
YS01-0.5				X			X					1							Please hold samples until notified	☐	☐	☐
YS01-1.0				X			X					1								☐	☐	☐
YS01-1.5				X			X					1								☐	☐	☐
YS01-2.0				X			X					1								☐	☐	☐
YS01-2.5				X			X					1								☐	☐	☐
YS01-3.0				X			X					1								☐	☐	☐
YS02-1.0				X			X					1								☐	☐	☐
YS02-1.5				X			X					1								☐	☐	☐
YS02-2.0				X			X					1								☐	☐	☐
YS02-2.5				X			X					1								☐	☐	☐
YS02-3.0				X			X					1								☐	☐	☐
YS03-0.5				X			X					1								☐	☐	☐
YS03-1.0				X			X					1								☐	☐	☐
YS03-1.5				X			X					1								☐	☐	☐
YS03-2.0				X			X					1								☐	☐	☐
YS03-2.5				X			X					1								☐	☐	☐
YS03-3.0				X			X					1								☐	☐	☐
YS05-1.0				X			X					1								☐	☐	☐
YS06-0.5				X			X					1								☐	☐	☐
YS06-3.0				X			X					1								☐	☐	☐
																				☐	☐	☐
																				☐	☐	☐
																				☐	☐	☐
																				☐	☐	☐
																				☐	☐	☐
TOTALS												20										

Relinquished by (SIGN/PRINT): Nicolaas Unland of Jacobs
Date 05-Apr-17 Time
Received by (SIGN/PRINT): of
Date 6/4/17 Time 0906
Custody Seals Intact? Yes / No

Relinquished by (SIGN/PRINT): of
Date Time
Received by (SIGN/PRINT): of
Date Time
Sample Receipt Temp. °C

Additional Comments/Instructions:
All final lab reports to be provided electronically as .pdf and datafile to both emails above.

COC

9 am
GT 4/7

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5.6

6.8

From: Unland, Nicolaas <Nicolaas.Unland@jacobs.com>
Sent: Monday, 10 April 2017 9:22 AM
To: Onur Mehmet
Subject: soil samples collected from the Melbourne office

Hi Onur,

I had 3 eskies of soil samples collected from the Melbourne office on Wednesday last week and asked to have them placed on hold. I am yet to receive a SRN yet.

Could you please follow up for me.

Kind regards,
Nic

Dr Nicolaas Unland | Jacobs

Hydrogeologist – ANZ Infrastructure and Environment
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CHAIN OF CUSTODY & ANALYSIS REQUEST

LAB: Eurofins
ADDRESS: 3 Kingston Town Close, Oakleigh, VIC, 3166
PHONE: +61 3 9564 7055
FAX:

Page 1 **of** 2

PROJECT # IS191000

PROJECT NAME Barwon Water Task 5

SAMPLE COLLECTOR'S NAME Nicolaas Unland

LAB JOB #

PRELIM. RESULTS BY: ☑ VERBAL
Email ☐ FAX
☑ EMAIL

FINAL REPORT B Email

SEND TO EMAIL ADDRESS(ES): Nicolaas.unland@jacobs.com

LAB QUOTE REF **Jacobs ORDER No:**

SAMPLE ID	DEPTH (metres)	LAB #	MATRIX				PRESERVATION METHOD				SAMPLING DATE	No. OF CONTAINERS	METHOD CODE & ANALYSIS REQUIRED						COMMENTS	(see below)		
			WATER	SOIL	AIR	SLUDGE	ICE	ACID	OTHER	NONE			Chromium reducible sulfur suite	ASS screen tests	EC/TDS					(1)	(2)	(3)
LBC01-0.5	0.5			X			X					1	x	x						☐	☐	☐
LBC01-1.5	1.5			X			X					1	x	x						☐	☐	☐
LBC01-2.0	2.0			X			X					1								☐	☐	☐
LBC01-S1	0.5			X			X					1			x					☐	☐	☐
LBC01-S2	1.0			X			X					1			x					☐	☐	☐
LBC02-0.5	0.5			X			X					1	x	x						☐	☐	☐
LBC02-1.0	1.0			X			X					1	x	x						☐	☐	☐
LBC02-2.0	2.0			X			X					1								☐	☐	☐
LBC01-3.0	3.0			X			X					1	x	x						☐	☐	☐
LCB02-3.0	3.0			X			X					1	x	x						☐	☐	☐
YS04-0.5	0.5			X			X					1	x	x						☐	☐	☐
YS04-1.0	1.0			X			X					1	x	x						☐	☐	☐
YS04-1.5	1.5			X			X					1								☐	☐	☐
YS04-2.0	2.0			X			X					1	x	x						☐	☐	☐
YS04-2.5	2.5			X			X					1								☐	☐	☐
YS04-3.0	3.0			X			X					1	x	x						☐	☐	☐
YS05-0.5	0.5			X			X					1	x	x						☐	☐	☐
YS05-1.5	1.5			X			X					1								☐	☐	☐
YS05-2.0	2.0			X			X					1	x	x						☐	☐	☐
YS05-2.5	2.5			X			X					1								☐	☐	☐
YS05-3.0	3.0			X			X					1	x	x						☐	☐	☐
YS06-1.0	1.0			X			X					1	x	x						☐	☐	☐
YS06-1.5	1.5			X			X					1	x	x						☐	☐	☐
YS06-2.0	2.0			X			X					1								☐	☐	☐
YS06-2.5	2.5			X			X					1	x	x						☐	☐	☐
TOTALS												25	16	16	2							

Relinquished by (SIGN/PRINT):	Date	Time	Received by (SIGN/PRINT):	Date	Time			Additional Comments/Instructions:
Nicolaas Unland of Jacobs	05-Apr-17		of			Custody Seals Intact?	Yes / No	All final lab reports to be provided electronically as .pdf and datafile to both emails above.
Relinquished by (SIGN/PRINT): of	**Date**	**Time**	**Received by (SIGN/PRINT):** of	**Date**	**Time**	Sample Receipt Temp.	°C	

JACOBS

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CHAIN OF CUSTODY & ANALYSIS REQUEST

LAB: Eurofins
ADDRESS: 3 Kingston Town Close, Oakleigh, VIC, 3166
PHONE: +61 3 9564 7055
FAX:

Page of

PROJECT #: IS191000
PROJECT NAME: Barwon Water Task 5
SAMPLE COLLECTOR'S NAME: Nicolaas Unland
LAB JOB #:

PRELIM. RESULTS BY: ☑ VERBAL
Email ☐ FAX
☑ EMAIL

FINAL REPORT B
Email
SEND TO EMAIL ADDRESS(ES): Nicolaas.unland@jacobs.com

LAB QUOTE REF
Jacobs ORDER No:

SAMPLE ID	DEPTH (metres)	LAB #	MATRIX				PRESERVATION METHOD				SAMPLING DATE	No. OF CONTAINERS	METHOD CODE & ANALYSIS REQUIRED						COMMENTS	(see below) (1) (2) (3)
			WATER	SOIL	AIR	SLUDGE	ICE	ACID	OTHER	NONE			Chromium reducible sulfur suite	ASS screen tests						
YS01-0.5				X			X					1	x	x						☐ ☐ ☐
YS01-1.0				X			X					1	x	x						☐ ☐ ☐
YS01-1.5				X			X					1	x	x						☐ ☐ ☐
YS01-2.0				X			X					1								☐ ☐ ☐
YS01-2.5				X			X					1								☐ ☐ ☐
YS01-3.0				X			X					1	x	x						☐ ☐ ☐
YS02-1.0				X			X					1	x	x						☐ ☐ ☐
YS02-1.5				X			X					1								☐ ☐ ☐
YS02-2.0				X			X					1	x	x						☐ ☐ ☐
YS02-2.5				X			X					1								☐ ☐ ☐
YS02-3.0				X			X					1	x	x						☐ ☐ ☐
YS03-0.5				X			X					1	x	x						☐ ☐ ☐
YS03-1.0				X			X					1	x	x						☐ ☐ ☐
YS03-1.5				X			X					1								☐ ☐ ☐
YS03-2.0				X			X					1	x	x						☐ ☐ ☐
YS03-2.5				X			X					1								☐ ☐ ☐
YS03-3.0				X			X					1	x	x						☐ ☐ ☐
YS05-1.0				X			X					1	x	x						☐ ☐ ☐
YS06-0.5				X			X					1	x	x						☐ ☐ ☐
YS06-3.0				X			X					1	x	x						☐ ☐ ☐
																				☐ ☐ ☐
																				☐ ☐ ☐
																				☐ ☐ ☐
																				☐ ☐ ☐
																				☐ ☐ ☐
TOTALS												20	14	14						

Relinquished by (SIGN/PRINT): Nicolaas Unland of Jacobs
Date: 05-Apr-17 Time:

Received by (SIGN/PRINT): of
Date: Time:

Relinquished by (SIGN/PRINT): of
Date: Time:

Received by (SIGN/PRINT): of
Date: Time:

Custody Seals Intact? Yes / No

Sample Receipt Temp. °C

Additional Comments/Instructions:
All final lab reports to be provided electronically as .pdf and datafile to both emails above.

COC (2)

Certificate of Analysis

NATA Accredited
Accreditation Number 1261
Site Number 20794

Accredited for compliance with ISO/IEC 17025 – Testing
The results of the tests, calibrations and/or measurements included in this document are traceable to Australian/national standards.

Jacobs Group (Australia) P/L VIC
PO Box 312 Flinders Lane
Melbourne
VIC 8009

Attention: **Nicolaas Unland**

Report **541765-S**
Project name BARWON WATER TASK 5
Project ID IS191000
Received Date Apr 10, 2017

Client Sample ID **Sample Matrix** **Eurofins | mgt Sample No.** **Date Sampled** Test/Reference	LOR	Unit	**LBC01_0.5** **Soil** **B17-Ap07250** **Not Provided**	**LBC01_1.5** **Soil** **B17-Ap07251** **Not Provided**	**LBC01_S1** **Soil** **B17-Ap07253** **Not Provided**	**LBC01_S2** **Soil** **B17-Ap07254** **Not Provided**
Conductivity (1:5 aqueous extract at 25°C)	10	uS/cm	-	-	110	600
% Moisture	1	%	28	61	28	32
Acid Sulfate Soils Field pH Test						
pH-F (Field pH test)*	0.1	pH Units	4.7	4.6	-	-
pH-FOX (Field pH Peroxide test)*	0.1	pH Units	3.4	2.4	-	-
Reaction Ratings*[S05]		comment	4.0	4.0	-	-
Chromium Suite						
pH-KCL	0.1	pH Units	4.1	4.1	-	-
Acid trail - Titratable Actual Acidity	2	mol H+/t	250	260	-	-
sulfidic - TAA equiv. S% pyrite	0.02	% pyrite S	0.40	0.42	-	-
Chromium Reducible Sulfur[S04]	0.005	% S	0.013	0.023	-	-
Chromium Reducible Sulfur -acidity units	3	mol H+/t	8.0	14	-	-
Sulfur - KCl Extractable	0.02	% S	0.03	0.02	-	-
HCl Extractable Sulfur	0.02	% S	0.05	0.04	-	-
Net Acid soluble sulfur	0.02	% S	0.02	0.02	-	-
Net Acid soluble sulfur - acidity units	10	mol H+/t	< 10	< 10	-	-
Net Acid soluble sulfur - equivalent S% pyrite[S02]	0.02	% S	< 0.02	< 0.02	-	-
Acid Neutralising Capacity (ANCbt)	0.01	%CaCO3	n/a	n/a	-	-
Acid Neutralising Capacity - acidity (ANCbt)	2	mol H+/t	n/a	n/a	-	-
Acid Neutralising Capacity - equivalent S% pyrite (s-ANCbt)[S03]	0.02	% S	n/a	n/a	-	-
ANC Fineness Factor		factor	1.5	1.5	-	-
Net Acidity (Sulfur Units)	0.02	% S	0.43	0.46	-	-
Net Acidity (Acidity Units)	10	mol H+/t	270	280	-	-
Liming Rate[S01]	1	kg CaCO3/t	20	21	-	-
Extraneous Material						
<2mm Fraction	0.005	g	45	52	-	-
>2mm Fraction	0.005	g	0.30	0.93	-	-
Analysed Material	0.1	%	99	98	-	-
Extraneous Material	0.1	%	0.7	1.8	-	-

Client Sample ID			**LBC02_0.5**	**LBC02_1.0**	**LBC01_3.0**	**LBC02_3.0**
Sample Matrix			**Soil**	**Soil**	**Soil**	**Soil**
Eurofins | mgt Sample No.			**B17-Ap07255**	**B17-Ap07256**	**B17-Ap07258**	**B17-Ap07259**
Date Sampled			**Not Provided**	**Not Provided**	**Not Provided**	**Not Provided**
Test/Reference	LOR	Unit				
% Moisture	1	%	28	44	63	25
Acid Sulfate Soils Field pH Test						
pH-F (Field pH test)*	0.1	pH Units	5.1	4.5	6.0	6.3
pH-FOX (Field pH Peroxide test)*	0.1	pH Units	4.0	3.0	2.8	3.6
Reaction Ratings*^{S05}		comment	4.0	4.0	4.0	4.0
Chromium Suite						
pH-KCL	0.1	pH Units	4.4	4.0	4.4	4.7
Acid trail - Titratable Actual Acidity	2	mol H+/t	150	200	120	28
sulfidic - TAA equiv. S% pyrite	0.02	% pyrite S	0.24	0.33	0.19	0.04
Chromium Reducible Sulfur^{S04}	0.005	% S	0.006	0.009	0.30	0.008
Chromium Reducible Sulfur -acidity units	3	mol H+/t	4.0	6.0	190	5.0
Sulfur - KCl Extractable	0.02	% S	< 0.02	0.03	< 0.02	n/a
HCl Extractable Sulfur	0.02	% S	0.03	0.04	0.02	n/a
Net Acid soluble sulfur	0.02	% S	0.03	< 0.02	0.02	n/a
Net Acid soluble sulfur - acidity units	10	mol H+/t	13	< 10	12	n/a
Net Acid soluble sulfur - equivalent S% pyrite^{S02}	0.02	% S	0.02	< 0.02	0.02	n/a
Acid Neutralising Capacity (ANCbt)	0.01	%CaCO3	n/a	n/a	n/a	n/a
Acid Neutralising Capacity - acidity (ANCbt)	2	mol H+/t	n/a	n/a	n/a	n/a
Acid Neutralising Capacity - equivalent S% pyrite (s-ANCbt)^{S03}	0.02	% S	n/a	n/a	n/a	n/a
ANC Fineness Factor		factor	1.5	1.5	1.5	1.5
Net Acidity (Sulfur Units)	0.02	% S	0.27	0.34	0.51	0.05
Net Acidity (Acidity Units)	10	mol H+/t	170	210	320	33
Liming Rate^{S01}	1	kg CaCO3/t	13	16	24	2.5
Extraneous Material						
<2mm Fraction	0.005	g	110	70	64	180
>2mm Fraction	0.005	g	< 0.005	< 0.005	< 0.005	< 0.005
Analysed Material	0.1	%	100	100	100	100
Extraneous Material	0.1	%	< 0.1	< 0.1	< 0.1	< 0.1

Client Sample ID			**YS01_1.0**	**YS04_0.5**	**YS04_2.0**	**YS04_3.0**
Sample Matrix			**Soil**	**Soil**	**Soil**	**Soil**
Eurofins | mgt Sample No.			**B17-Ap07260**	**B17-Ap07261**	**B17-Ap07263**	**B17-Ap07265**
Date Sampled			**Not Provided**	**Not Provided**	**Not Provided**	**Not Provided**
Test/Reference	LOR	Unit				
% Moisture	1	%	11	9.6	4.8	7.6
Acid Sulfate Soils Field pH Test						
pH-F (Field pH test)*	0.1	pH Units	3.9	4.3	4.3	4.2
pH-FOX (Field pH Peroxide test)*	0.1	pH Units	3.1	2.6	3.6	3.4
Reaction Ratings*^{S05}		comment	4.0	3.0	1.0	1.0
Chromium Suite						
pH-KCL	0.1	pH Units	4.5	4.4	4.8	5.1
Acid trail - Titratable Actual Acidity	2	mol H+/t	39	49	13	7.3
sulfidic - TAA equiv. S% pyrite	0.02	% pyrite S	0.06	0.08	0.02	< 0.02
Chromium Reducible Sulfur^{S04}	0.005	% S	< 0.005	0.007	< 0.005	< 0.005
Chromium Reducible Sulfur -acidity units	3	mol H+/t	< 3	4.0	< 3	< 3
Sulfur - KCl Extractable	0.02	% S	n/a	< 0.02	n/a	n/a

Client Sample ID			YS01_1.0	YS04_0.5	YS04_2.0	YS04_3.0
Sample Matrix			**Soil**	**Soil**	**Soil**	**Soil**
Eurofins | mgt Sample No.			**B17-Ap07260**	**B17-Ap07261**	**B17-Ap07263**	**B17-Ap07265**
Date Sampled			**Not Provided**	**Not Provided**	**Not Provided**	**Not Provided**
Test/Reference	LOR	Unit				
Chromium Suite						
HCl Extractable Sulfur	0.02	% S	n/a	< 0.02	n/a	n/a
Net Acid soluble sulfur	0.02	% S	n/a	< 0.02	n/a	n/a
Net Acid soluble sulfur - acidity units	10	mol H+/t	n/a	< 10	n/a	n/a
Net Acid soluble sulfur - equivalent S% pyrite[S02]	0.02	% S	n/a	< 0.02	n/a	n/a
Acid Neutralising Capacity (ANCbt)	0.01	%CaCO3	n/a	n/a	n/a	n/a
Acid Neutralising Capacity - acidity (ANCbt)	2	mol H+/t	n/a	n/a	n/a	n/a
Acid Neutralising Capacity - equivalent S% pyrite (s-ANCbt)[S03]	0.02	% S	n/a	n/a	n/a	n/a
ANC Fineness Factor		factor	1.5	1.5	1.5	1.5
Net Acidity (Sulfur Units)	0.02	% S	0.06	0.09	0.02	< 0.02
Net Acidity (Acidity Units)	10	mol H+/t	39	54	13	< 10
Liming Rate[S01]	1	kg CaCO3/t	2.9	4.0	< 1	< 1
Extraneous Material						
<2mm Fraction	0.005	g	110	25	140	100
>2mm Fraction	0.005	g	0.39	130	0.76	2.9
Analysed Material	0.1	%	100	17	99	97
Extraneous Material	0.1	%	0.4	83	0.5	2.7

Client Sample ID			YS05_0.5	YS05_2.0	YS05_3.0	YS06_1.0
Sample Matrix			**Soil**	**Soil**	**Soil**	**Soil**
Eurofins | mgt Sample No.			**B17-Ap07266**	**B17-Ap07268**	**B17-Ap07270**	**B17-Ap07271**
Date Sampled			**Not Provided**	**Not Provided**	**Not Provided**	**Not Provided**
Test/Reference	LOR	Unit				
% Moisture	1	%	27	31	18	25
Acid Sulfate Soils Field pH Test						
pH-F (Field pH test)*	0.1	pH Units	3.6	4.1	4.2	5.8
pH-FOX (Field pH Peroxide test)*	0.1	pH Units	1.6	2.3	2.3	3.2
Reaction Ratings*[S05]		comment	4.0	4.0	4.0	4.0
Chromium Suite						
pH-KCL	0.1	pH Units	2.7	4.0	4.4	4.4
Acid trail - Titratable Actual Acidity	2	mol H+/t	570	110	48	81
sulfidic - TAA equiv. S% pyrite	0.02	% pyrite S	0.92	0.18	0.08	0.13
Chromium Reducible Sulfur[S04]	0.005	% S	0.050	0.19	0.071	0.016
Chromium Reducible Sulfur -acidity units	3	mol H+/t	31	120	44	10
Sulfur - KCl Extractable	0.02	% S	0.05	0.13	0.06	< 0.02
HCl Extractable Sulfur	0.02	% S	0.13	0.12	0.06	< 0.02
Net Acid soluble sulfur	0.02	% S	0.08	< 0.02	< 0.02	< 0.02
Net Acid soluble sulfur - acidity units	10	mol H+/t	37	< 10	< 10	< 10
Net Acid soluble sulfur - equivalent S% pyrite[S02]	0.02	% S	0.06	< 0.02	< 0.02	< 0.02
Acid Neutralising Capacity (ANCbt)	0.01	%CaCO3	n/a	n/a	n/a	n/a
Acid Neutralising Capacity - acidity (ANCbt)	2	mol H+/t	n/a	n/a	n/a	n/a
Acid Neutralising Capacity - equivalent S% pyrite (s-ANCbt)[S03]	0.02	% S	n/a	n/a	n/a	n/a
ANC Fineness Factor		factor	1.5	1.5	1.5	1.5
Net Acidity (Sulfur Units)	0.02	% S	1.0	0.36	0.15	0.15
Net Acidity (Acidity Units)	10	mol H+/t	640	230	93	91
Liming Rate[S01]	1	kg CaCO3/t	48	17	7.0	6.8

Client Sample ID			**YS05_0.5**	**YS05_2.0**	**YS05_3.0**	**YS06_1.0**
Sample Matrix			**Soil**	**Soil**	**Soil**	**Soil**
Eurofins | mgt Sample No.			**B17-Ap07266**	**B17-Ap07268**	**B17-Ap07270**	**B17-Ap07271**
Date Sampled			**Not Provided**	**Not Provided**	**Not Provided**	**Not Provided**
Test/Reference	LOR	Unit				
Extraneous Material						
<2mm Fraction	0.005	g	46	130	97	80
>2mm Fraction	0.005	g	< 0.005	0.60	0.60	< 0.005
Analysed Material	0.1	%	100	100	99	100
Extraneous Material	0.1	%	< 0.1	0.5	0.6	< 0.1

Client Sample ID			**YS06_1.5**	**YS06_2.5**	**YS01_0.5**	**YS01_1.5**
Sample Matrix			**Soil**	**Soil**	**Soil**	**Soil**
Eurofins | mgt Sample No.			**B17-Ap07272**	**B17-Ap07274**	**B17-Ap07275**	**B17-Ap07276**
Date Sampled			**Not Provided**	**Not Provided**	**Not Provided**	**Not Provided**
Test/Reference	LOR	Unit				
% Moisture	1	%	13	13	25	17
Acid Sulfate Soils Field pH Test						
pH-F (Field pH test)*	0.1	pH Units	5.0	5.3	4.6	3.9
pH-FOX (Field pH Peroxide test)*	0.1	pH Units	2.0	3.5	2.9	2.6
Reaction Ratings*^{S05}		comment	3.0	1.0	4.0	2.0
Chromium Suite						
pH-KCL	0.1	pH Units	4.4	5.3	4.0	4.2
Acid trail - Titratable Actual Acidity	2	mol H+/t	44	3.7	270	89
sulfidic - TAA equiv. S% pyrite	0.02	% pyrite S	0.07	< 0.02	0.43	0.14
Chromium Reducible Sulfur^{S04}	0.005	% S	0.035	< 0.005	0.008	< 0.005
Chromium Reducible Sulfur -acidity units	3	mol H+/t	22	< 3	5.0	< 3
Sulfur - KCl Extractable	0.02	% S	< 0.02	n/a	0.03	0.06
HCl Extractable Sulfur	0.02	% S	< 0.02	n/a	0.04	0.05
Net Acid soluble sulfur	0.02	% S	< 0.02	n/a	< 0.02	< 0.02
Net Acid soluble sulfur - acidity units	10	mol H+/t	< 10	n/a	< 10	< 10
Net Acid soluble sulfur - equivalent S% pyrite^{S02}	0.02	% S	< 0.02	n/a	< 0.02	< 0.02
Acid Neutralising Capacity (ANCbt)	0.01	%CaCO3	n/a	n/a	n/a	n/a
Acid Neutralising Capacity - acidity (ANCbt)	2	mol H+/t	n/a	n/a	n/a	n/a
Acid Neutralising Capacity - equivalent S% pyrite (s-ANCbt)^{S03}	0.02	% S	n/a	n/a	n/a	n/a
ANC Fineness Factor		factor	1.5	1.5	1.5	1.5
Net Acidity (Sulfur Units)	0.02	% S	0.10	< 0.02	0.45	0.14
Net Acidity (Acidity Units)	10	mol H+/t	65	< 10	280	89
Liming Rate^{S01}	1	kg CaCO3/t	4.9	< 1	21	6.7
Extraneous Material						
<2mm Fraction	0.005	g	110	120	76	97
>2mm Fraction	0.005	g	0.99	7.2	< 0.005	1.8
Analysed Material	0.1	%	99	94	100	98
Extraneous Material	0.1	%	0.9	5.9	< 0.1	1.8

Client Sample ID			**YS01_3.0**	**YS02_1.0**	**YS02_2.0**	**YS02_3.0**
Sample Matrix			**Soil**	**Soil**	**Soil**	**Soil**
Eurofins | mgt Sample No.			**B17-Ap07279**	**B17-Ap07280**	**B17-Ap07282**	**B17-Ap07284**
Date Sampled			**Not Provided**	**Not Provided**	**Not Provided**	**Not Provided**
Test/Reference	LOR	Unit				
% Moisture	1	%	17	79	78	64
Acid Sulfate Soils Field pH Test						
pH-F (Field pH test)*	0.1	pH Units	4.1	3.4	4.5	5.9
pH-FOX (Field pH Peroxide test)*	0.1	pH Units	3.1	1.6	1.5	1.8
Reaction Ratings*[S05]		comment	2.0	3.0	4.0	4.0
Chromium Suite						
pH-KCL	0.1	pH Units	4.6	3.3	4.2	5.1
Acid trail - Titratable Actual Acidity	2	mol H+/t	28	910	470	81
sulfidic - TAA equiv. S% pyrite	0.02	% pyrite S	0.05	1.5	0.76	0.13
Chromium Reducible Sulfur[S04]	0.005	% S	< 0.005	0.88	4.7	1.9
Chromium Reducible Sulfur -acidity units	3	mol H+/t	< 3	550	2900	1200
Sulfur - KCl Extractable	0.02	% S	n/a	0.29	0.65	n/a
HCl Extractable Sulfur	0.02	% S	n/a	0.30	0.60	n/a
Net Acid soluble sulfur	0.02	% S	n/a	< 0.02	< 0.02	n/a
Net Acid soluble sulfur - acidity units	10	mol H+/t	n/a	< 10	< 10	n/a
Net Acid soluble sulfur - equivalent S% pyrite[S02]	0.02	% S	n/a	< 0.02	< 0.02	n/a
Acid Neutralising Capacity (ANCbt)	0.01	%CaCO3	n/a	n/a	n/a	n/a
Acid Neutralising Capacity - acidity (ANCbt)	2	mol H+/t	n/a	n/a	n/a	n/a
Acid Neutralising Capacity - equivalent S% pyrite (s-ANCbt)[S03]	0.02	% S	n/a	n/a	n/a	n/a
ANC Fineness Factor		factor	1.5	1.5	1.5	1.5
Net Acidity (Sulfur Units)	0.02	% S	0.05	2.4	5.4	2.0
Net Acidity (Acidity Units)	10	mol H+/t	28	1500	3400	1200
Liming Rate[S01]	1	kg CaCO3/t	2.1	110	250	93
Extraneous Material						
<2mm Fraction	0.005	g	120	18	14	54
>2mm Fraction	0.005	g	< 0.005	< 0.005	< 0.005	< 0.005
Analysed Material	0.1	%	100	100	100	100
Extraneous Material	0.1	%	< 0.1	< 0.1	< 0.1	< 0.1

Client Sample ID			**YS03_0.5**	**YS03_1.0**	**YS03_2.0**	**YS03_3.0**
Sample Matrix			**Soil**	**Soil**	**Soil**	**Soil**
Eurofins | mgt Sample No.			**B17-Ap07285**	**B17-Ap07286**	**B17-Ap07288**	**B17-Ap07290**
Date Sampled			**Not Provided**	**Not Provided**	**Not Provided**	**Not Provided**
Test/Reference	LOR	Unit				
% Moisture	1	%	20	44	73	72
Acid Sulfate Soils Field pH Test						
pH-F (Field pH test)*	0.1	pH Units	4.8	3.9	5.9	5.9
pH-FOX (Field pH Peroxide test)*	0.1	pH Units	3.6	2.7	1.9	2.2
Reaction Ratings*[S05]		comment	4.0	4.0	4.0	4.0
Chromium Suite						
pH-KCL	0.1	pH Units	4.4	3.7	4.8	4.7
Acid trail - Titratable Actual Acidity	2	mol H+/t	110	240	72	78
sulfidic - TAA equiv. S% pyrite	0.02	% pyrite S	0.17	0.39	0.12	0.13
Chromium Reducible Sulfur[S04]	0.005	% S	0.005	0.036	0.37	0.24
Chromium Reducible Sulfur -acidity units	3	mol H+/t	3.0	23	230	150
Sulfur - KCl Extractable	0.02	% S	0.02	0.05	n/a	n/a

Client Sample ID			YS03_0.5	YS03_1.0	YS03_2.0	YS03_3.0
Sample Matrix			**Soil**	**Soil**	**Soil**	**Soil**
Eurofins | mgt Sample No.			**B17-Ap07285**	**B17-Ap07286**	**B17-Ap07288**	**B17-Ap07290**
Date Sampled			**Not Provided**	**Not Provided**	**Not Provided**	**Not Provided**
Test/Reference	LOR	Unit				
Chromium Suite						
HCl Extractable Sulfur	0.02	% S	0.06	0.14	n/a	n/a
Net Acid soluble sulfur	0.02	% S	0.03	0.09	n/a	n/a
Net Acid soluble sulfur - acidity units	10	mol H+/t	16	43	n/a	n/a
Net Acid soluble sulfur - equivalent S% pyrite[S02]	0.02	% S	0.03	0.07	n/a	n/a
Acid Neutralising Capacity (ANCbt)	0.01	%CaCO3	n/a	n/a	n/a	n/a
Acid Neutralising Capacity - acidity (ANCbt)	2	mol H+/t	n/a	n/a	n/a	n/a
Acid Neutralising Capacity - equivalent S% pyrite (s-ANCbt)[S03]	0.02	% S	n/a	n/a	n/a	n/a
ANC Fineness Factor		factor	1.5	1.5	1.5	1.5
Net Acidity (Sulfur Units)	0.02	% S	0.20	0.49	0.49	0.36
Net Acidity (Acidity Units)	10	mol H+/t	130	310	300	230
Liming Rate[S01]	1	kg CaCO3/t	9.4	23	23	17
Extraneous Material						
<2mm Fraction	0.005	g	65	32	80	93
>2mm Fraction	0.005	g	< 0.005	< 0.005	< 0.005	< 0.005
Analysed Material	0.1	%	100	100	100	100
Extraneous Material	0.1	%	< 0.1	< 0.1	< 0.1	< 0.1

Client Sample ID			YS05_1.0	YS06_0.5	YS06_3.0	YS04_1.0
Sample Matrix			**Soil**	**Soil**	**Soil**	**Soil**
Eurofins | mgt Sample No.			**B17-Ap07291**	**B17-Ap07292**	**B17-Ap07293**	**B17-Ap07392**
Date Sampled			**Not Provided**	**Not Provided**	**Not Provided**	**Not Provided**
Test/Reference	LOR	Unit				
% Moisture	1	%	64	7.6	17	10
Acid Sulfate Soils Field pH Test						
pH-F (Field pH test)*	0.1	pH Units	2.8	5.6	5.2	4.3
pH-FOX (Field pH Peroxide test)*	0.1	pH Units	1.6	2.1	3.8	3.4
Reaction Ratings*[S05]		comment	4.0	3.0	2.0	1.0
Chromium Suite						
pH-KCL	0.1	pH Units	3.0	4.7	5.3	4.3
Acid trail - Titratable Actual Acidity	2	mol H+/t	580	21	5.5	59
sulfidic - TAA equiv. S% pyrite	0.02	% pyrite S	0.93	0.03	< 0.02	0.09
Chromium Reducible Sulfur[S04]	0.005	% S	14	0.007	< 0.005	< 0.005
Chromium Reducible Sulfur -acidity units	3	mol H+/t	9000	4.0	< 3	< 3
Sulfur - KCl Extractable	0.02	% S	0.47	n/a	n/a	< 0.02
HCl Extractable Sulfur	0.02	% S	0.47	n/a	n/a	0.02
Net Acid soluble sulfur	0.02	% S	< 0.02	n/a	n/a	0.02
Net Acid soluble sulfur - acidity units	10	mol H+/t	< 10	n/a	n/a	< 10
Net Acid soluble sulfur - equivalent S% pyrite[S02]	0.02	% S	< 0.02	n/a	n/a	0.02
Acid Neutralising Capacity (ANCbt)	0.01	%CaCO3	n/a	n/a	n/a	n/a
Acid Neutralising Capacity - acidity (ANCbt)	2	mol H+/t	n/a	n/a	n/a	n/a
Acid Neutralising Capacity - equivalent S% pyrite (s-ANCbt)[S03]	0.02	% S	n/a	n/a	n/a	n/a
ANC Fineness Factor		factor	1.5	1.5	1.5	1.5
Net Acidity (Sulfur Units)	0.02	% S	15	0.04	< 0.02	0.11
Net Acidity (Acidity Units)	10	mol H+/t	9600	25	< 10	68
Liming Rate[S01]	1	kg CaCO3/t	720	1.9	< 1	5.1

Client Sample ID **Sample Matrix** **Eurofins | mgt Sample No.** **Date Sampled** Test/Reference	LOR	Unit	**YS05_1.0** **Soil** **B17-Ap07291** **Not Provided**	**YS06_0.5** **Soil** **B17-Ap07292** **Not Provided**	**YS06_3.0** **Soil** **B17-Ap07293** **Not Provided**	**YS04_1.0** **Soil** **B17-Ap07392** **Not Provided**
Extraneous Material						
<2mm Fraction	0.005	g	47	87	140	110
>2mm Fraction	0.005	g	< 0.005	5.2	2.2	5.4
Analysed Material	0.1	%	100	94	98	95
Extraneous Material	0.1	%	< 0.1	5.6	1.5	4.6

Sample History

Where samples are submitted/analysed over several days, the last date of extraction and analysis is reported.
A recent review of our LIMS has resulted in the correction or clarification of some method identifications. Due to this, some of the method reference information on reports has changed. However, no substantive change has been made to our laboratory methods, and as such there is no change in the validity of current or previous results (regarding both quality and NATA accreditation).

If the date and time of sampling are not provided, the Laboratory will not be responsible for compromised results should testing be performed outside the recommended holding time.

Description	**Testing Site**	**Extracted**	**Holding Time**
Conductivity (1:5 aqueous extract at 25°C)	Melbourne	Apr 12, 2017	7 Day
- Method: LTM-INO-4030			
Acid Sulfate Soils Field pH Test	Brisbane	Apr 11, 2017	7 Days
- Method: LTM-GEN-7060 Determination of field pH (pHF) and field pH peroxide (pHFOX) tests			
% Moisture	Brisbane	Apr 11, 2017	14 Day
- Method: LTM-GEN-7080 Moisture			
Chromium Suite			
Chromium Suite	Brisbane	Apr 11, 2017	6 Week
- Method: LTM-GEN-7070			
Extraneous Material	Brisbane	Apr 11, 2017	6 Week
- Method: LTM-GEN-7050/7070			

Company Name: Jacobs Group (Australia) P/L VIC
Address: PO Box 312 Flinders Lane
Melbourne
VIC 8009

Project Name: BARWON WATER TASK 5
Project ID: IS191000

Order No.:
Report #: 541765
Phone: 03 8668 3000
Fax: 03 8668 3001

Received: Apr 10, 2017 9:00 AM
Due: Apr 19, 2017
Priority: 5 Day
Contact Name: Nicolaas Unland

Eurofins | mgt Analytical Services Manager : Onur Mehmet

Sample Detail						Conductivity (1:5 aqueous extract at 25°C)	HOLD	Acid Sulfate Soils Field pH Test	Chromium Suite	Moisture Set	Moisture Set
Melbourne Laboratory - NATA Site # 1254 & 14271						X				X	X
Sydney Laboratory - NATA Site # 18217											
Brisbane Laboratory - NATA Site # 20794							X	X	X	X	X
Perth Laboratory - NATA Site # 18217											
External Laboratory											
No	**Sample ID**	**Sample Date**	**Sampling Time**	**Matrix**	**LAB ID**						
1	LBC01_0.5	Not Provided		Soil	B17-Ap07250			X	X		X
2	LBC01_1.5	Not Provided		Soil	B17-Ap07251			X	X		X
3	LBC01_2.0	Not Provided		Soil	B17-Ap07252		X				
4	LBC01_S1	Not Provided		Soil	B17-Ap07253	X				X	
5	LBC01_S2	Not Provided		Soil	B17-Ap07254	X				X	
6	LBC02_0.5	Not Provided		Soil	B17-Ap07255			X	X		X
7	LBC02_1.0	Not Provided		Soil	B17-Ap07256			X	X		X
8	LBC02_2.0	Not Provided		Soil	B17-Ap07257		X				
9	LBC01_3.0	Not Provided		Soil	B17-Ap07258			X	X		X

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Melbourne Laboratory - NATA Site # 1254 & 14271						X				X	X
Sydney Laboratory - NATA Site # 18217											
Brisbane Laboratory - NATA Site # 20794							X	X	X	X	X
Perth Laboratory - NATA Site # 18217											
10	LBC02_3.0	Not Provided		Soil	B17-Ap07259			X	X		X
11	YS01_1.0	Not Provided		Soil	B17-Ap07260			X	X		X
12	YS04_0.5	Not Provided		Soil	B17-Ap07261			X	X		X
13	YS04_1.5	Not Provided		Soil	B17-Ap07262		X				
14	YS04_2.0	Not Provided		Soil	B17-Ap07263			X	X		X
15	YS04_2.5	Not Provided		Soil	B17-Ap07264		X				
16	YS04_3.0	Not Provided		Soil	B17-Ap07265			X	X		X
17	YS05_0.5	Not Provided		Soil	B17-Ap07266			X	X		X
18	YS05_1.5	Not Provided		Soil	B17-Ap07267		X				
19	YS05_2.0	Not Provided		Soil	B17-Ap07268			X	X		X
20	YS05_2.5	Not Provided		Soil	B17-Ap07269		X				
21	YS05_3.0	Not Provided		Soil	B17-Ap07270			X	X		X

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Melbourne Laboratory - NATA Site # 1254 & 14271						X				X	X
Sydney Laboratory - NATA Site # 18217											
Brisbane Laboratory - NATA Site # 20794							X	X	X	X	X
Perth Laboratory - NATA Site # 18217											
22	YS06_1.0	Not Provided		Soil	B17-Ap07271			X	X		X
23	YS06_1.5	Not Provided		Soil	B17-Ap07272			X	X		X
24	YS06_2.0	Not Provided		Soil	B17-Ap07273		X				
25	YS06_2.5	Not Provided		Soil	B17-Ap07274			X	X		X
26	YS01_0.5	Not Provided		Soil	B17-Ap07275			X	X		X
27	YS01_1.5	Not Provided		Soil	B17-Ap07276			X	X		X
28	YS01_2.0	Not Provided		Soil	B17-Ap07277		X				
29	YS01_2.5	Not Provided		Soil	B17-Ap07278		X				
30	YS01_3.0	Not Provided		Soil	B17-Ap07279			X	X		X
31	YS02_1.0	Not Provided		Soil	B17-Ap07280			X	X		X
32	YS02_1.5	Not Provided		Soil	B17-Ap07281		X				
33	YS02_2.0	Not Provided		Soil	B17-Ap07282			X	X		X

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Sample Detail						Conductivity (1:5 aqueous extract at 25°C)	HOLD	Acid Sulfate Soils Field pH Test	Chromium Suite	Moisture Set	Moisture Set
Melbourne Laboratory - NATA Site # 1254 & 14271						X				X	X
Sydney Laboratory - NATA Site # 18217											
Brisbane Laboratory - NATA Site # 20794							X	X	X	X	X
Perth Laboratory - NATA Site # 18217											
34	YS02_2.5	Not Provided		Soil	B17-Ap07283		X				
35	YS02_3.0	Not Provided		Soil	B17-Ap07284			X	X		X
36	YS03_0.5	Not Provided		Soil	B17-Ap07285			X	X		X
37	YS03_1.0	Not Provided		Soil	B17-Ap07286			X	X		X
38	YS03_1.5	Not Provided		Soil	B17-Ap07287		X				
39	YS03_2.0	Not Provided		Soil	B17-Ap07288			X	X		X
40	YS03_2.5	Not Provided		Soil	B17-Ap07289		X				
41	YS03_3.0	Not Provided		Soil	B17-Ap07290			X	X		X
42	YS05_1.0	Not Provided		Soil	B17-Ap07291			X	X		X
43	YS06_0.5	Not Provided		Soil	B17-Ap07292			X	X		X
44	YS06_3.0	Not Provided		Soil	B17-Ap07293			X	X		X
45	YS04_1.0	Not Provided		Soil	B17-Ap07392			X	X		X

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Sample Detail	Conductivity (1:5 aqueous extract at 25°C)	HOLD	Acid Sulfate Soils Field pH Test	Chromium Suite	Moisture Set	Moisture Set
Melbourne Laboratory - NATA Site # 1254 & 14271	X				X	X
Sydney Laboratory - NATA Site # 18217						
Brisbane Laboratory - NATA Site # 20794		X	X	X	X	X
Perth Laboratory - NATA Site # 18217						
Test Counts	2	13	30	30	32	32

Internal Quality Control Review and Glossary

General

1. Laboratory QC results for Method Blanks, Duplicates, Matrix Spikes, and Laboratory Control Samples are included in this QC report where applicable. Additional QC data may be available on request.
2. All soil results are reported on a dry basis, unless otherwise stated.
3. Actual LORs are matrix dependant. Quoted LORs may be raised where sample extracts are diluted due to interferences.
4. Results are uncorrected for matrix spikes or surrogate recoveries.
5. SVOC analysis on waters are performed on homogenised, unfiltered samples, unless noted otherwise.
6. Samples were analysed on an 'as received' basis. 7. This report replaces any interim results previously issued.

Holding Times

Please refer to 'Sample Preservation and Container Guide' for holding times (QS3001).

For samples received on the last day of holding time, notification of testing requirements should have been received at least 6 hours prior to sample receipt deadlines as stated on the Sample Receipt Advice.

If the Laboratory did not receive the information in the required timeframe, and regardless of any other integrity issues, suitably qualified results may still be reported.

Holding times apply from the date of sampling, therefore compliance to these may be outside the laboratory's control.

****NOTE:** pH duplicates are reported as a range NOT as RPD

Units

mg/kg: milligrams per Kilogram
ug/l: micrograms per litre
ppb: Parts per billion
org/100ml: Organisms per 100 millilitres
MPN/100mL: Most Probable Number of organisms per 100 millilitres
mg/l: milligrams per litre
ppm: Parts per million
%: Percentage
NTU: Nephelometric Turbidity Units

Terms

Dry	Where a moisture has been determined on a solid sample the result is expressed on a dry basis.
LOR	Limit of Reporting.
SPIKE	Addition of the analyte to the sample and reported as percentage recovery.
RPD	Relative Percent Difference between two Duplicate pieces of analysis.
LCS	Laboratory Control Sample - reported as percent recovery
CRM	Certified Reference Material - reported as percent recovery
Method Blank	In the case of solid samples these are performed on laboratory certified clean sands. In the case of water samples these are performed on de-ionised water.
Surr - Surrogate	The addition of a like compound to the analyte target and reported as percentage recovery.
Duplicate	A second piece of analysis from the same sample and reported in the same units as the result to show comparison.
Batch Duplicate	A second piece of analysis from a sample outside of the clients batch of samples but run within the laboratory batch of analysis.
Batch SPIKE	Spike recovery reported on a sample from outside of the clients batch of samples but run within the laboratory batch of analysis.
USEPA	United States Environmental Protection Agency
APHA	American Public Health Association
TCLP	Toxicity Characteristic Leaching Procedure
COC	Chain of Custody
SRA	Sample Receipt Advice
CP	Client Parent - QC was performed on samples pertaining to this report
NCP	Non-Client Parent - QC performed on samples not pertaining to this report, QC is representative of the sequence or batch that client samples were analysed within
TEQ	Toxic Equivalency Quotient

QC - Acceptance Criteria

RPD Duplicates: Global RPD Duplicates Acceptance Criteria is 30% however the following acceptance guidelines are equally applicable:

Results <10 times the LOR : No Limit

Results between 10-20 times the LOR : RPD must lie between 0-50%

Results >20 times the LOR : RPD must lie between 0-30%

Surrogate Recoveries: Recoveries must lie between 50-150%-Phenols & PFASs 20-130%

QC Data General Comments

1. Where a result is reported as a less than (<), higher than the nominated LOR, this is due to either matrix interference, extract dilution required due to interferences or contaminant levels within the sample, high moisture content or insufficient sample provided.
2. Duplicate data shown within this report that states the word "BATCH" is a Batch Duplicate from outside of your sample batch, but within the laboratory sample batch at a 1:10 ratio. The Parent and Duplicate data shown is not data from your samples.
3. Organochlorine Pesticide analysis - where reporting LCS data, Toxaphene & Chlordane are not added to the LCS.
4. Organochlorine Pesticide analysis - where reporting Spike data, Toxaphene is not added to the Spike.
5. Total Recoverable Hydrocarbons - where reporting Spike & LCS data, a single spike of commercial Hydrocarbon products in the range of C12-C30 is added and it's Total Recovery is reported in the C10-C14 cell of the Report.
6. pH and Free Chlorine analysed in the laboratory - Analysis on this test must begin within 30 minutes of sampling.Therefore laboratory analysis is unlikely to be completed within holding time. Analysis will begin as soon as possible after sample receipt.
7. Recovery Data (Spikes & Surrogates) - where chromatographic interference does not allow the determination of Recovery the term "INT" appears against that analyte.
8. Polychlorinated Biphenyls are spiked only using Aroclor 1260 in Matrix Spikes and LCS.
9. For Matrix Spikes and LCS results a dash " -" in the report means that the specific analyte was not added to the QC sample.
10. Duplicate RPDs are calculated from raw analytical data thus it is possible to have two sets of data.

Quality Control Results

Test			Units	Result 1			Acceptance Limits	Pass Limits	Qualifying Code
LCS - % Recovery									
Chromium Suite									
Chromium Reducible Sulfur			%	95			70-130	Pass	
Acid Neutralising Capacity (ANCbt)			%	94			70-130	Pass	
Test	**Lab Sample ID**	**QA Source**	**Units**	**Result 1**			**Acceptance Limits**	**Pass Limits**	**Qualifying Code**
Duplicate									
Acid Sulfate Soils Field pH Test				Result 1	Result 2	RPD			
pH-F (Field pH test)*	B17-Ap07250	CP	pH Units	4.7	4.7	pass	30%	Pass	
Reaction Ratings*	B17-Ap07250	CP	comment	4.0	4.0	pass	30%	Pass	
Duplicate									
Chromium Suite				Result 1	Result 2	RPD			
pH-KCL	B17-Ap07260	CP	pH Units	4.5	4.5	<1	30%	Pass	
Acid trail - Titratable Actual Acidity	B17-Ap07260	CP	mol H+/t	39	38	2.0	30%	Pass	
sulfidic - TAA equiv. S% pyrite	B17-Ap07260	CP	% pyrite S	0.06	0.06	2.0	30%	Pass	
Chromium Reducible Sulfur	B17-Ap07260	CP	% S	< 0.005	< 0.005	<1	30%	Pass	
Chromium Reducible Sulfur -acidity units	B17-Ap07260	CP	mol H+/t	< 3	< 3	<1	30%	Pass	
Sulfur - KCl Extractable	B17-Ap07260	CP	% S	n/a	n/a	n/a	30%	Pass	
HCl Extractable Sulfur	B17-Ap07260	CP	% S	n/a	n/a	n/a	30%	Pass	
Net Acid soluble sulfur	B17-Ap07260	CP	% S	n/a	n/a	n/a	30%	Pass	
Net Acid soluble sulfur - acidity units	B17-Ap07260	CP	mol H+/t	n/a	n/a	n/a	30%	Pass	
Net Acid soluble sulfur - equivalent S% pyrite	B17-Ap07260	CP	% S	n/a	n/a	n/a	30%	Pass	
Acid Neutralising Capacity (ANCbt)	B17-Ap07260	CP	%CaCO3	n/a	n/a	n/a	30%	Pass	
Acid Neutralising Capacity - equivalent S% pyrite (s-ANCbt)	B17-Ap07260	CP	% S	n/a	n/a	n/a	30%	Pass	
ANC Fineness Factor	B17-Ap07260	CP	factor	1.5	1.5	<1	30%	Pass	
Net Acidity (Sulfur Units)	B17-Ap07260	CP	% S	0.06	0.06	n/a	30%	Pass	
Net Acidity (Acidity Units)	B17-Ap07260	CP	mol H+/t	39	38	n/a	30%	Pass	
Liming Rate	B17-Ap07260	CP	kg CaCO3/t	2.9	2.9	2.0	30%	Pass	
Duplicate									
				Result 1	Result 2	RPD			
% Moisture	B17-Ap07263	CP	%	4.8	5.2	8.0	30%	Pass	
Duplicate									
Acid Sulfate Soils Field pH Test				Result 1	Result 2	RPD			
pH-F (Field pH test)*	B17-Ap07266	CP	pH Units	3.6	3.5	pass	30%	Pass	
Reaction Ratings*	B17-Ap07266	CP	comment	4.0	4.0	pass	30%	Pass	
Duplicate									
Chromium Suite				Result 1	Result 2	RPD			
pH-KCL	B17-Ap07275	CP	pH Units	4.0	4.0	<1	30%	Pass	
Acid trail - Titratable Actual Acidity	B17-Ap07275	CP	mol H+/t	270	270	<1	30%	Pass	
sulfidic - TAA equiv. S% pyrite	B17-Ap07275	CP	% pyrite S	0.43	0.44	1.0	30%	Pass	
Chromium Reducible Sulfur	B17-Ap07275	CP	% S	0.008	0.006	17	30%	Pass	
Chromium Reducible Sulfur -acidity units	B17-Ap07275	CP	mol H+/t	5.0	4.0	17	30%	Pass	
Sulfur - KCl Extractable	B17-Ap07275	CP	% S	0.03	0.03	15	30%	Pass	
HCl Extractable Sulfur	B17-Ap07275	CP	% S	0.04	0.04	1.0	30%	Pass	
Net Acid soluble sulfur	B17-Ap07275	CP	% S	< 0.02	< 0.02	<1	30%	Pass	
Net Acid soluble sulfur - acidity units	B17-Ap07275	CP	mol H+/t	< 10	< 10	<1	30%	Pass	
Net Acid soluble sulfur - equivalent S% pyrite	B17-Ap07275	CP	% S	< 0.02	< 0.02	<1	30%	Pass	

Duplicate									
Chromium Suite				Result 1	Result 2	RPD			
Acid Neutralising Capacity (ANCbt)	B17-Ap07275	CP	%CaCO3	n/a	n/a	n/a	30%	Pass	
Acid Neutralising Capacity - equivalent S% pyrite (s-ANCbt)	B17-Ap07275	CP	% S	n/a	n/a	n/a	30%	Pass	
ANC Fineness Factor	B17-Ap07275	CP	factor	1.5	1.5	<1	30%	Pass	
Net Acidity (Sulfur Units)	B17-Ap07275	CP	% S	0.45	0.45	n/a	30%	Pass	
Net Acidity (Acidity Units)	B17-Ap07275	CP	mol H+/t	280	280	n/a	30%	Pass	
Liming Rate	B17-Ap07275	CP	kg CaCO3/t	21	21	<1	30%	Pass	
Duplicate									
				Result 1	Result 2	RPD			
% Moisture	B17-Ap07279	CP	%	17	19	8.0	30%	Pass	
Duplicate									
Acid Sulfate Soils Field pH Test				Result 1	Result 2	RPD			
pH-F (Field pH test)*	B17-Ap07282	CP	pH Units	4.5	4.3	pass	30%	Pass	
Reaction Ratings*	B17-Ap07282	CP	comment	4.0	4.0	pass	30%	Pass	
Duplicate									
Chromium Suite				Result 1	Result 2	RPD			
pH-KCL	B17-Ap07291	CP	pH Units	3.0	3.0	<1	30%	Pass	
Acid trail - Titratable Actual Acidity	B17-Ap07291	CP	mol H+/t	580	550	4.6	30%	Pass	
sulfidic - TAA equiv. S% pyrite	B17-Ap07291	CP	% pyrite S	0.93	0.89	5.0	30%	Pass	
Chromium Reducible Sulfur	B17-Ap07291	CP	% S	14	14	5.0	30%	Pass	
Chromium Reducible Sulfur -acidity units	B17-Ap07291	CP	mol H+/t	9000	8600	5.0	30%	Pass	
Sulfur - KCl Extractable	B17-Ap07291	CP	% S	0.47	0.46	3.0	30%	Pass	
HCl Extractable Sulfur	B17-Ap07291	CP	% S	0.47	0.42	12	30%	Pass	
Net Acid soluble sulfur	B17-Ap07291	CP	% S	< 0.02	< 0.02	<1	30%	Pass	
Net Acid soluble sulfur - acidity units	B17-Ap07291	CP	mol H+/t	< 10	< 10	<1	30%	Pass	
Net Acid soluble sulfur - equivalent S% pyrite	B17-Ap07291	CP	% S	< 0.02	< 0.02	<1	30%	Pass	
Acid Neutralising Capacity (ANCbt)	B17-Ap07291	CP	%CaCO3	n/a	n/a	n/a	30%	Pass	
Acid Neutralising Capacity - equivalent S% pyrite (s-ANCbt)	B17-Ap07291	CP	% S	n/a	n/a	n/a	30%	Pass	
ANC Fineness Factor	B17-Ap07291	CP	factor	1.5	1.5	<1	30%	Pass	
Net Acidity (Sulfur Units)	B17-Ap07291	CP	% S	15	15	n/a	30%	Pass	
Net Acidity (Acidity Units)	B17-Ap07291	CP	mol H+/t	9600	9100	n/a	30%	Pass	
Liming Rate	B17-Ap07291	CP	kg CaCO3/t	720	680	5.0	30%	Pass	
Duplicate									
				Result 1	Result 2	RPD			
% Moisture	B17-Ap07293	CP	%	17	16	8.0	30%	Pass	

Comments

Sample Integrity

Custody Seals Intact (if used)	N/A
Attempt to Chill was evident	Yes
Sample correctly preserved	Yes
Appropriate sample containers have been used	Yes
Sample containers for volatile analysis received with minimal headspace	Yes
Samples received within HoldingTime	Yes
Some samples have been subcontracted	No

Qualifier Codes/Comments

Code	Description
S01	Liming rate is calculated and reported on a dry weight basis assuming use of fine agricultural lime (CaCO3) and using a safety factor of 1.5 to allow for non-homogeneous mixing and poor reactivity of lime. For conversion of Liming Rate from 'kg/t dry weight' to 'kg/m3 in-situ soil' multiply 'reported results' x 'wet bulk density of soil in t/m3'
S02	Retained Acidity is Reported when the pHKCl is less than pH 4.5
S03	Acid Neutralising Capacity is only required if the pHKCl if greater than or equal to pH 6.5
S04	Acid Sulfate Soil Samples have a 24 hour holding time unless frozen or dried within that period
S05	Field Screen uses the following fizz rating to classify the rate the samples reacted to the peroxide: 1.0; No reaction to slight. 2.0; Moderate reaction. 3.0; Strong reaction with persistent froth. 4.0; Extreme reaction.

Authorised By

Onur Mehmet	Analytical Services Manager
Alex Petridis	Senior Analyst-Metal (VIC)
Bryan Wilson	Senior Analyst-Metal (QLD)
Huong Le	Senior Analyst-Inorganic (VIC)
Jonathon Angell	Senior Analyst-Inorganic (QLD)

Glenn Jackson

National Operations Manager

Final report - this Report replaces any previously issued Report

- Indicates Not Requested

* Indicates NATA accreditation does not cover the performance of this service

Measurement uncertainty of test data is available on request or please click here.

CHAIN OF CUSTODY RECORD

ABN 50 005 085 521

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Company: JACOBS

Address: LEVEL 11, 452 FLINDERS ST MELBOURNE VIC

Contact Name: ANDREW NELSON

Contact Phone №: 0477306803

Special Direction:

Relinquished by (Signature)

(Time / Date) __:__ 8/5/17

Purchase Order: B191000

Eurofins | mgt Quote №: 170501JAC

Project Manager:

Project №:

Project Name: BARWON DOWNS HYDROGEOLOGICAL ASSESSMENT

Electronic Results Format: .XLS .PDF

Email for Results: ANDREW.NELSON2@JACOBS.COM NICOLAAS.UNLAND@JACOBS.COM

Turn Around Requirements: ☐ 1 DAY* ☐ 2 DAY* ☐ 3 DAY* ☑ 5 DAY (Std.) ☐ Other ( )

* Surcharges apply

Method of Shipment: ☑ Courier ( ) ☐ Hand Delivered ☐ Postal

Analysis [Note: Where metals are requested, please specify "Total" or "Filtered"]: ANALYSIS AS PER QUOTE #170501JAC

№	Client Sample ID	Date	Matrix	ANALYSIS AS PER QUOTE #170501JAC	1L Plastic	250mL Plastic	125mL Plastic	200mL Amber Glass	40mL vial	125mL Amber Glass	Jar	Sample Comments / DG Hazard Warning
1	A3	4/5/17	W	↓								
2	YGS	↓	↓	↓								
3	SUS	↓	↓	↓								
4	YS06	↓	↓	↓								
5	CS1	↓	↓	↓								
6	LBC	↓	↓	↓								
7	SDS	↓	↓	↓								
8	YS05	5/5/17	↓	↓								
9	YS03	↓	↓	↓								
10	YS02	↓	↓	↓								
11	YS01	↓	↓	↓								
12	TB1A	↓	↓	↓								

Laboratory Use Only

Received By: AMY EUROFINS | MGT — SYD | BNE | [✓ MEL] | PER | ADL | NEW | DAR — Date: 10/5/17 — Time: 9.31am — Signature: — Temperature: 16·2

Received By: — SYD | BNE | MEL | PER | ADL | NEW | DAR — Date: __/__/__ — Time: ____ — Signature: — Report №: 545553

QS3 004_R0 Modified by P. Ranjan Approved by T. Lakeland Approved on 16 Jan 2015

Submission of samples to the laboratory will be deemed as acceptance of Eurofins | mgt Standard Terms and Conditions unless agreed otherwise. A copy of Eurofins | mgt Standard Terms and Conditions is available on request.

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CHAIN OF CUSTODY RECORD

ABN 50 005 085 521

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Company: JACOBS

Address: LEVEL 11
452 FLINDERS ST
MELBOURNE VIC

Contact Name: ANDREW HELSON

Contact Phone №: 0477 306 803

Special Direction:

Purchase Order: IS191000

Eurofins | mgt Quote №: 170501JAC

Project Manager:

Project №:

Project Name:

Electronic Results Format:

Email for Results:

Turn Around Requirements: ☐ 1DAY* ☐ 2DAY* ☐ 3DAY* ☑ 5DAY (Std.) ☐ Other ( )
* Surcharges apply

Method of Shipment: ☑ Courier ( ) ☐ Hand Delivered ☐ Postal

Relinquished by (Signature)

(Time / Date) __:__ 8/5/17

№	Client Sample ID	Date	Matrix	Analysis [Note: Where metals are requested, please specify "Total" or "Filtered"] ANALYSIS AS PER QUOTE #170501JAC	1L Plastic	250mL Plastic	125mL Plastic	200mL Amber Glass	40mL vial	125mL Amber Glass	Jar	Sample Comments / DG Hazard Warning
1	LBC01	5/5/17	W									
2	PASS1	↓	↓									
3	LBC02	↓	↓									
4												
5												
6												
7												
8												
9												
10												
11												
12												

Laboratory Use Only	Received By		SYD | BNE | MEL | PER | ADL | NEW | DAR	Date	__/__/__	Time	__:__	Signature	Temperature	
	Received By		SYD | BNE | MEL | PER | ADL | NEW | DAR	Date	__/__/__	Time	__:__	Signature	Report №	

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Pg 2/2

Certificate of Analysis

NATA Accredited
Accreditation Number 1261
Site Number 1254

Accredited for compliance with ISO/IEC 17025 – Testing
The results of the tests, calibrations and/or measurements included in this document are traceable to Australian/national standards.

Jacobs Group (Australia) P/L VIC
PO Box 312 Flinders Lane
Melbourne
VIC 8009

Attention:	**Andrew Nelson**
Report	**545553-W**
Project name	BARWON DOWNS HYDROGEN LOGICAL ASSESSMENT
Received Date	May 10, 2017

Client Sample ID **Sample Matrix** **Eurofins | mgt Sample No.** **Date Sampled** Test/Reference	LOR	Unit	**A3** **Water** **M17-My09638** **May 04, 2017**	**YGS** **Water** **M17-My09639** **May 04, 2017**	**SUS** **Water** **M17-My09640** **May 04, 2017**	**YS06** **Water** **M17-My09641** **May 04, 2017**
Ammonia (as N)	0.01	mg/L	< 0.01	0.31	0.02	0.06
Biochemical Oxygen Demand (BOD-5 Day)	5	mg/L	< 5	< 5	< 5	< 5
Chemical Oxygen Demand (COD)	25	mg/L	< 25	< 25	25	45
Chloride	1	mg/L	600	140	96	110
Dissolved Organic Carbon	5	mg/L	< 5	9.1	8.2	13
Ferric Iron - Fe3+	0.05	mg/L	0.06	6	0.17	< 0.05
Ferrous Iron - Fe2+	0.05	mg/L	< 0.05	5.7	0.30	[Q18]1.7
Fluoride	0.5	mg/L	< 0.5	< 0.5	< 0.5	< 0.5
Nitrate & Nitrite (as N)	0.05	mg/L	0.17	< 0.05	0.06	< 0.05
Nitrate (as N)	0.02	mg/L	0.17	< 0.02	0.06	< 0.02
Nitrite (as N)	0.02	mg/L	< 0.02	< 0.02	< 0.02	< 0.02
Organic Nitrogen (as N)	0.2	mg/L	< 0.2	0.4	0.3	0.4
Phosphate total (as P)	0.05	mg/L	0.08	0.14	0.05	< 0.05
Sulphate (as S)	5	mg/L	55	130	< 5	6.5
Sulphate (as SO4)	5	mg/L	170	390	5.8	19
Sulphide (as S)	0.05	mg/L	< 0.05	< 0.05	< 0.05	< 0.05
Sulphite (as S)	0.5	mg/L	< 1	< 1	< 1	< 1
Thiosulphate (as S)	1	mg/L	< 2	< 2	< 2	< 2
Total Kjeldahl Nitrogen (as N)	0.2	mg/L	< 0.2	0.7	0.3	0.5
Total Nitrogen (as N)	0.2	mg/L	< 0.2	0.7	0.4	0.5
Total Organic Carbon	5	mg/L	< 5	9.5	9.8	14
Total Sulphur (as S)	5	mg/L	55	130	< 5	6.5
Alkalinity (speciated)						
Bicarbonate Alkalinity (as CaCO3)	20	mg/L	< 20	< 20	31	50
Carbonate Alkalinity (as CaCO3)	10	mg/L	< 10	< 10	< 10	< 10
Hydroxide Alkalinity (as CaCO3)	10	mg/L	< 10	< 10	< 10	< 10
Total Alkalinity (as CaCO3)	20	mg/L	< 20	< 20	31	50
Heavy Metals						
Aluminium	0.05	mg/L	0.18	[R05]36	< 0.05	0.40
Aluminium (filtered)	0.05	mg/L	0.18	37	< 0.05	0.29
Arsenic	0.001	mg/L	< 0.001	0.002	< 0.001	0.002
Arsenic (filtered)	0.001	mg/L	< 0.001	0.002	< 0.001	0.001
Cadmium	0.0002	mg/L	< 0.0002	0.0007	< 0.0002	< 0.0002
Cadmium (filtered)	0.0002	mg/L	< 0.0002	0.0006	< 0.0002	< 0.0002
Chromium	0.001	mg/L	0.002	0.002	0.001	0.001
Chromium (filtered)	0.001	mg/L	0.001	0.002	< 0.001	< 0.001

Client Sample ID			**A3**	**YGS**	**SUS**	**YS06**
Sample Matrix			**Water**	**Water**	**Water**	**Water**
Eurofins | mgt Sample No.			**M17-My09638**	**M17-My09639**	**M17-My09640**	**M17-My09641**
Date Sampled			**May 04, 2017**	**May 04, 2017**	**May 04, 2017**	**May 04, 2017**
Test/Reference	LOR	Unit				
Heavy Metals						
Copper	0.001	mg/L	0.010	< 0.001	< 0.001	< 0.001
Copper (filtered)	0.001	mg/L	0.009	< 0.001	< 0.001	< 0.001
Iron	0.05	mg/L	0.06	12	0.47	^{Q18}1.4
Iron (filtered)	0.05	mg/L	< 0.05	12	0.37	0.63
Lead	0.001	mg/L	< 0.001	0.001	< 0.001	< 0.001
Lead (filtered)	0.001	mg/L	< 0.001	0.001	< 0.001	< 0.001
Manganese	0.005	mg/L	0.060	0.17	0.016	0.066
Manganese (filtered)	0.005	mg/L	0.060	0.17	0.015	0.062
Mercury	0.0001	mg/L	< 0.0001	< 0.0001	< 0.0001	< 0.0001
Mercury (filtered)	0.0001	mg/L	< 0.0001	< 0.0001	< 0.0001	< 0.0001
Nickel	0.001	mg/L	0.063	0.16	0.001	0.004
Nickel (filtered)	0.001	mg/L	0.061	0.16	< 0.001	0.004
Zinc	0.005	mg/L	0.11	0.84	0.005	^{R05}0.018
Zinc (filtered)	0.005	mg/L	0.11	0.84	0.005	0.020
Alkali Metals						
Calcium	0.5	mg/L	37	23	5.2	13
Magnesium	0.5	mg/L	24	24	8.3	12
Potassium	0.5	mg/L	5.8	4.9	3.4	3.8
Sodium	0.5	mg/L	310	76	46	53

Client Sample ID			**CS1**	**LBC**	**SDS**	**YS05**
Sample Matrix			**Water**	**Water**	**Water**	**Water**
Eurofins | mgt Sample No.			**M17-My09642**	**M17-My09643**	**M17-My09644**	**M17-My09645**
Date Sampled			**May 04, 2017**	**May 04, 2017**	**May 04, 2017**	**May 05, 2017**
Test/Reference	LOR	Unit				
Ammonia (as N)	0.01	mg/L	0.32	0.02	0.51	4.4
Biochemical Oxygen Demand (BOD-5 Day)	5	mg/L	< 5	< 5	< 5	38
Chemical Oxygen Demand (COD)	25	mg/L	< 25	< 25	< 25	180
Chloride	1	mg/L	97	330	99	72
Dissolved Organic Carbon	5	mg/L	7.9	7.3	10	41
Ferric Iron - Fe3+	0.05	mg/L	0.48	0.44	28	570
Ferrous Iron - Fe2+	0.05	mg/L	0.25	0.24	0.44	150
Fluoride	0.5	mg/L	< 0.5	< 0.5	< 0.5	< 0.5
Nitrate & Nitrite (as N)	0.05	mg/L	1.3	0.08	< 0.05	< 0.05
Nitrate (as N)	0.02	mg/L	1.3	0.07	< 0.02	< 0.02
Nitrite (as N)	0.02	mg/L	< 0.02	< 0.02	< 0.02	< 0.02
Organic Nitrogen (as N)	0.2	mg/L	0.5	0.4	0.4	0.7
Phosphate total (as P)	0.05	mg/L	0.05	0.10	0.14	0.57
Sulphate (as S)	5	mg/L	< 5	88	230	1300
Sulphate (as SO4)	5	mg/L	6.2	260	700	4000
Sulphide (as S)	0.05	mg/L	< 0.05	< 0.05	< 0.05	< 0.05
Sulphite (as S)	0.5	mg/L	< 1	< 1	< 1	< 1
Thiosulphate (as S)	1	mg/L	< 2	< 2	< 2	< 2
Total Kjeldahl Nitrogen (as N)	0.2	mg/L	0.8	0.4	0.9	5.1
Total Nitrogen (as N)	0.2	mg/L	2.1	0.5	0.9	5.1
Total Organic Carbon	5	mg/L	8.9	7.6	10	42
Total Sulphur (as S)	5	mg/L	< 5	88	230	1300

Client Sample ID **Sample Matrix** **Eurofins | mgt Sample No.** **Date Sampled** Test/Reference	LOR	Unit	**CS1** **Water** **M17-My09642** **May 04, 2017**	**LBC** **Water** **M17-My09643** **May 04, 2017**	**SDS** **Water** **M17-My09644** **May 04, 2017**	**YS05** **Water** **M17-My09645** **May 05, 2017**
Alkalinity (speciated)						
Bicarbonate Alkalinity (as CaCO3)	20	mg/L	30	< 20	< 20	< 20
Carbonate Alkalinity (as CaCO3)	10	mg/L	< 10	< 10	< 10	< 10
Hydroxide Alkalinity (as CaCO3)	10	mg/L	< 10	< 10	< 10	< 10
Total Alkalinity (as CaCO3)	20	mg/L	30	< 20	< 20	< 20
Heavy Metals						
Aluminium	0.05	mg/L	< 0.05	15	75	[R05]33
Aluminium (filtered)	0.05	mg/L	< 0.05	14	74	34
Arsenic	0.001	mg/L	< 0.001	< 0.001	0.002	[R05]0.32
Arsenic (filtered)	0.001	mg/L	< 0.001	< 0.001	0.002	0.37
Cadmium	0.0002	mg/L	< 0.0002	0.0003	0.0012	[R05]0.0005
Cadmium (filtered)	0.0002	mg/L	< 0.0002	0.0003	0.0013	0.0006
Chromium	0.001	mg/L	< 0.001	0.001	0.003	[R05]0.017
Chromium (filtered)	0.001	mg/L	< 0.001	0.001	0.003	0.023
Copper	0.001	mg/L	< 0.001	< 0.001	< 0.001	[R05]0.004
Copper (filtered)	0.001	mg/L	< 0.001	< 0.001	< 0.001	0.005
Iron	0.05	mg/L	0.73	0.68	28	720
Iron (filtered)	0.05	mg/L	0.50	0.64	27	720
Lead	0.001	mg/L	< 0.001	< 0.001	< 0.001	0.010
Lead (filtered)	0.001	mg/L	< 0.001	< 0.001	< 0.001	0.010
Manganese	0.005	mg/L	0.038	0.26	0.15	[R05]0.14
Manganese (filtered)	0.005	mg/L	0.026	0.26	0.15	0.15
Mercury	0.0001	mg/L	< 0.0001	< 0.0001	< 0.0001	< 0.0001
Mercury (filtered)	0.0001	mg/L	< 0.0001	< 0.0001	< 0.0001	< 0.0001
Nickel	0.001	mg/L	< 0.001	0.091	[R05]0.20	[R05]0.17
Nickel (filtered)	0.001	mg/L	< 0.001	0.091	0.22	0.20
Zinc	0.005	mg/L	0.016	[R05]0.33	[R05]1.3	[R05]0.35
Zinc (filtered)	0.005	mg/L	0.010	0.35	1.5	0.36
Alkali Metals						
Calcium	0.5	mg/L	5.3	38	20	13
Magnesium	0.5	mg/L	8.1	31	25	13
Potassium	0.5	mg/L	3.5	5.8	3.5	5.1
Sodium	0.5	mg/L	46	140	63	69

Client Sample ID **Sample Matrix** **Eurofins | mgt Sample No.** **Date Sampled** Test/Reference	LOR	Unit	**YS03** **Water** **M17-My09646** **May 05, 2017**	**YS02** **Water** **M17-My09647** **May 05, 2017**	**YS01** **Water** **M17-My09648** **May 05, 2017**	**TB1A** **Water** **M17-My09649** **May 05, 2017**
Ammonia (as N)	0.01	mg/L	5.1	2.6	0.20	< 0.01
Biochemical Oxygen Demand (BOD-5 Day)	5	mg/L	58	< 5	< 5	< 5
Chemical Oxygen Demand (COD)	25	mg/L	230	72	35	< 25
Chloride	1	mg/L	100	110	570	150
Dissolved Organic Carbon	5	mg/L	19	6.1	9.9	< 5
Ferric Iron - Fe3+	0.05	mg/L	540	11	< 0.05	< 0.05
Ferrous Iron - Fe2+	0.05	mg/L	350	56	30	< 0.05
Fluoride	0.5	mg/L	< 0.5	< 0.5	< 0.5	< 0.5
Nitrate & Nitrite (as N)	0.05	mg/L	< 0.05	< 0.05	0.31	0.31

Client Sample ID			**YS03**	**YS02**	**YS01**	**TB1A**
Sample Matrix			**Water**	**Water**	**Water**	**Water**
Eurofins | mgt Sample No.			**M17-My09646**	**M17-My09647**	**M17-My09648**	**M17-My09649**
Date Sampled			**May 05, 2017**	**May 05, 2017**	**May 05, 2017**	**May 05, 2017**
Test/Reference	LOR	Unit				
Nitrate (as N)	0.02	mg/L	< 0.02	< 0.02	0.30	0.31
Nitrite (as N)	0.02	mg/L	< 0.02	< 0.02	< 0.02	< 0.02
Organic Nitrogen (as N)	0.2	mg/L	0.4	0.4	0.2	< 0.2
Phosphate total (as P)	0.05	mg/L	0.38	0.17	< 0.05	< 0.05
Sulphate (as S)	5	mg/L	290	280	160	19
Sulphate (as SO4)	5	mg/L	860	840	470	56
Sulphide (as S)	0.05	mg/L	< 0.05	< 0.05	< 0.05	< 0.05
Sulphite (as S)	0.5	mg/L	< 1	< 1	< 1	< 1
Thiosulphate (as S)	1	mg/L	< 2	< 2	< 2	< 2
Total Kjeldahl Nitrogen (as N)	0.2	mg/L	5.5	3.0	0.4	< 0.2
Total Nitrogen (as N)	0.2	mg/L	5.5	3.0	0.7	0.3
Total Organic Carbon	5	mg/L	26	5.2	9.7	< 5
Total Sulphur (as S)	5	mg/L	290	280	160	19
Alkalinity (speciated)						
Bicarbonate Alkalinity (as CaCO3)	20	mg/L	< 20	< 20	< 20	< 20
Carbonate Alkalinity (as CaCO3)	10	mg/L	< 10	< 10	< 10	< 10
Hydroxide Alkalinity (as CaCO3)	10	mg/L	< 10	< 10	< 10	< 10
Total Alkalinity (as CaCO3)	20	mg/L	< 20	< 20	< 20	< 20
Heavy Metals						
Aluminium	0.05	mg/L	130	0.63	54	< 0.05
Aluminium (filtered)	0.05	mg/L	130	< 0.05	40	< 0.05
Arsenic	0.001	mg/L	0.022	0.001	0.003	< 0.001
Arsenic (filtered)	0.001	mg/L	0.014	< 0.001	0.002	< 0.001
Cadmium	0.0002	mg/L	0.0003	< 0.0002	0.0016	< 0.0002
Cadmium (filtered)	0.0002	mg/L	0.0003	< 0.0002	0.0010	< 0.0002
Chromium	0.001	mg/L	0.023	0.001	0.004	< 0.001
Chromium (filtered)	0.001	mg/L	0.020	< 0.001	0.004	< 0.001
Copper	0.001	mg/L	0.006	0.001	< 0.001	< 0.001
Copper (filtered)	0.001	mg/L	0.005	< 0.001	< 0.001	< 0.001
Iron	0.05	mg/L	^{R05}890	^{R05}67	30	< 0.05
Iron (filtered)	0.05	mg/L	900	75	15	< 0.05
Lead	0.001	mg/L	0.012	< 0.001	0.004	< 0.001
Lead (filtered)	0.001	mg/L	0.009	< 0.001	0.004	< 0.001
Manganese	0.005	mg/L	0.96	0.77	0.63	0.13
Manganese (filtered)	0.005	mg/L	0.94	0.77	0.43	0.13
Mercury	0.0001	mg/L	< 0.0001	< 0.0001	< 0.0001	< 0.0001
Mercury (filtered)	0.0001	mg/L	< 0.0001	< 0.0001	< 0.0001	< 0.0001
Nickel	0.001	mg/L	0.47	0.005	0.49	0.009
Nickel (filtered)	0.001	mg/L	0.43	0.003	0.37	0.009
Zinc	0.005	mg/L	0.69	0.024	0.86	0.10
Zinc (filtered)	0.005	mg/L	0.61	0.016	0.81	0.10
Alkali Metals						
Calcium	0.5	mg/L	150	170	27	21
Magnesium	0.5	mg/L	73	48	37	11
Potassium	0.5	mg/L	10	8.4	5.0	4.1
Sodium	0.5	mg/L	89	71	110	63

Client Sample ID			**LBC01**	**PASS1**	**LBC02**
Sample Matrix			**Water**	**Water**	**Water**
Eurofins | mgt Sample No.			**M17-My09650**	**M17-My09651**	**M17-My09652**
Date Sampled			**May 05, 2017**	**May 05, 2017**	**May 05, 2017**
Test/Reference	LOR	Unit			
Ammonia (as N)	0.01	mg/L	12	0.80	0.09
Biochemical Oxygen Demand (BOD-5 Day)	5	mg/L	6.1	6.5	< 5
Chemical Oxygen Demand (COD)	25	mg/L	30	< 25	30
Chloride	1	mg/L	590	1400	330
Dissolved Organic Carbon	5	mg/L	5.2	< 5	8.1
Ferric Iron - Fe3+	0.05	mg/L	12	4	< 0.05
Ferrous Iron - Fe2+	0.05	mg/L	80	6.9	^{Q18}18
Fluoride	0.5	mg/L	< 0.5	< 0.5	< 0.5
Nitrate & Nitrite (as N)	0.05	mg/L	< 0.05	0.30	< 0.05
Nitrate (as N)	0.02	mg/L	< 0.02	0.27	< 0.02
Nitrite (as N)	0.02	mg/L	< 0.02	0.03	< 0.02
Organic Nitrogen (as N)	0.2	mg/L	< 0.2	< 0.2	0.2
Phosphate total (as P)	0.05	mg/L	< 0.05	0.21	0.12
Sulphate (as S)	5	mg/L	14	53	6.1
Sulphate (as SO4)	5	mg/L	43	160	18
Sulphide (as S)	0.05	mg/L	< 0.05	< 0.05	< 0.05
Sulphite (as S)	0.5	mg/L	< 1	< 1	< 1
Thiosulphate (as S)	1	mg/L	< 2	< 2	< 2
Total Kjeldahl Nitrogen (as N)	0.2	mg/L	12	0.8	0.3
Total Nitrogen (as N)	0.2	mg/L	12	1.1	0.3
Total Organic Carbon	5	mg/L	6.0	< 5	7.5
Total Sulphur (as S)	5	mg/L	14	53	6.1
Alkalinity (speciated)					
Bicarbonate Alkalinity (as CaCO3)	20	mg/L	140	230	140
Carbonate Alkalinity (as CaCO3)	10	mg/L	< 10	< 10	< 10
Hydroxide Alkalinity (as CaCO3)	10	mg/L	< 10	< 10	< 10
Total Alkalinity (as CaCO3)	20	mg/L	140	230	140
Heavy Metals					
Aluminium	0.05	mg/L	< 0.05	0.17	< 0.05
Aluminium (filtered)	0.05	mg/L	< 0.05	< 0.05	< 0.05
Arsenic	0.001	mg/L	< 0.001	0.006	0.011
Arsenic (filtered)	0.001	mg/L	< 0.001	< 0.001	< 0.001
Cadmium	0.0002	mg/L	< 0.0002	< 0.0002	< 0.0002
Cadmium (filtered)	0.0002	mg/L	< 0.0002	< 0.0002	< 0.0002
Chromium	0.001	mg/L	< 0.001	0.001	< 0.001
Chromium (filtered)	0.001	mg/L	< 0.001	< 0.001	< 0.001
Copper	0.001	mg/L	< 0.001	0.001	< 0.001
Copper (filtered)	0.001	mg/L	< 0.001	< 0.001	< 0.001
Iron	0.05	mg/L	92	11	^{Q18}17
Iron (filtered)	0.05	mg/L	24	< 0.05	2.9
Lead	0.001	mg/L	< 0.001	< 0.001	< 0.001
Lead (filtered)	0.001	mg/L	< 0.001	< 0.001	< 0.001
Manganese	0.005	mg/L	^{R05}0.082	^{R05}0.032	0.28
Manganese (filtered)	0.005	mg/L	0.088	0.044	0.26
Mercury	0.0001	mg/L	< 0.0001	< 0.0001	< 0.0001
Mercury (filtered)	0.0001	mg/L	< 0.0001	< 0.0001	< 0.0001
Nickel	0.001	mg/L	0.001	0.002	0.002
Nickel (filtered)	0.001	mg/L	0.001	< 0.001	0.002
Zinc	0.005	mg/L	^{R05}0.008	< 0.005	0.006
Zinc (filtered)	0.005	mg/L	0.011	< 0.005	0.006

Client Sample ID			**LBC01**	**PASS1**	**LBC02**
Sample Matrix			**Water**	**Water**	**Water**
Eurofins | mgt Sample No.			**M17-My09650**	**M17-My09651**	**M17-My09652**
Date Sampled			**May 05, 2017**	**May 05, 2017**	**May 05, 2017**
Test/Reference	LOR	Unit			
Alkali Metals					
Calcium	0.5	mg/L	99	240	59
Magnesium	0.5	mg/L	68	91	28
Potassium	0.5	mg/L	5.3	11	5.4
Sodium	0.5	mg/L	160	510	130

Sample History

Where samples are submitted/analysed over several days, the last date of extraction and analysis is reported.
A recent review of our LIMS has resulted in the correction or clarification of some method identifications. Due to this, some of the method reference information on reports has changed. However, no substantive change has been made to our laboratory methods, and as such there is no change in the validity of current or previous results (regarding both quality and NATA accreditation).

If the date and time of sampling are not provided, the Laboratory will not be responsible for compromised results should testing be performed outside the recommended holding time.

Description	Testing Site	Extracted	Holding Time
Nitrogens (speciated)			
Ammonia (as N)	Melbourne	May 12, 2017	28 Day
- Method: APHA 4500-NH3 Ammonia Nitrogen by FIA			
Nitrate & Nitrite (as N)	Melbourne	May 12, 2017	28 Day
- Method: APHA 4500-NO3/NO2 Nitrate-Nitrite Nitrogen by FIA			
Nitrate (as N)	Melbourne	May 12, 2017	7 Day
- Method: APHA 4500-NO3 Nitrate Nitrogen by FIA			
Nitrite (as N)	Melbourne	May 12, 2017	2 Day
- Method: APHA 4500-NO2 Nitrite Nitrogen by FIA			
Organic Nitrogen (as N)	Melbourne	May 10, 2017	7 Day
- Method: APHA 4500 Organic Nitrogen (N)			
Total Kjeldahl Nitrogen (as N)	Melbourne	May 12, 2017	7 Day
- Method: APHA 4500 TKN			
Biochemical Oxygen Demand (BOD-5 Day)	Melbourne	May 12, 2017	2 Day
- Method: LTM-INO-4010			
Chemical Oxygen Demand (COD)	Melbourne	May 12, 2017	28 Days
- Method: LTM-INO-4220 Determination of COD in Water			
Dissolved Organic Carbon	Melbourne	May 12, 2017	28 Day
- Method: APHA 5310B Dissolved Organic Carbon			
Phosphate total (as P)	Melbourne	May 12, 2017	28 Day
- Method: APHA 4500-P E. Phosphorous			
Total Organic Carbon	Melbourne	May 12, 2017	28 Day
- Method: APHA 5310B Total Organic Carbon			
Heavy Metals	Melbourne	May 12, 2017	180 Day
- Method: LTM-MET-3040 Metals in Waters by ICP-MS			
Heavy Metals (filtered)	Melbourne	May 12, 2017	180 Day
- Method: LTM-MET-3040 Metals in Waters by ICP-MS			
Mercury (filtered)	Melbourne	May 12, 2017	28 Day
- Method: USEPA 7470/1 Mercury			
Alkali Metals	Melbourne	May 12, 2017	180 Day
- Method: USEPA 6010 Alkali Metals			
Eurofins | mgt Suite B11F: Cl, SO4, Alkalinity (CO3, HCO3, OH-, Total Alkalinity), Total F			
Chloride	Melbourne	May 12, 2017	28 Day
- Method: LTM-INO-4090 Chloride by Discrete Analyser			
Fluoride	Melbourne	May 15, 2017	28 Day
- Method: LM-LTM-INO-4300 (Fluoride by Ion Chromatography)			
Sulphate (as SO4)	Melbourne	May 12, 2017	28 Day
- Method: LTM-INO-4110 Sulfate by Discrete Analyser			
Alkalinity (speciated)	Melbourne	May 12, 2017	14 Day
- Method: APHA 2320 Alkalinity by Titration			
Iron (speciated)			
Ferrous Iron - Fe2+	Melbourne	May 12, 2017	7 Days
- Method: LTM-INO-4190 Ferrous Iron in Water by Discrete Analyser			
Total Sulphur Set (as S)			
Sulphate (as S)	Melbourne	May 12, 2017	28 Day
- Method: LTM-INO-4110 Sulfate by Discrete Analyser			
Sulphide (as S)	Melbourne	May 12, 2017	7 Day
- Method: APHA 4500-S C & D - Sulphide			
Sulphite (as S)	Melbourne	May 12, 2017	2 Day
- Method: LTM-INO-4240 Sulfite & Thiosulfate in Water			

Description	Testing Site	Extracted	Holding Time
Thiosulphate (as S) - Method: LTM-INO-4240 Sulfite & Thiosulfate in Water	Melbourne	May 12, 2017	2 Day
Total Sulphur (as S) - Method: Sum of Constituent Analytes	Melbourne	May 12, 2017	7 Day

Company Name:	Jacobs Group (Australia) P/L VIC	**Order No.:**	b191000	**Received:**	May 10, 2017 9:31 AM
Address:	PO Box 312 Flinders Lane Melbourne VIC 8009	**Report #:**	545553	**Due:**	May 17, 2017
		Phone:	03 8668 3000	**Priority:**	5 Day
		Fax:	03 8668 3001	**Contact Name:**	Andrew Nelson
Project Name:	BARWON DOWNS HYDROGEN LOGICAL ASSESSMENT				

Eurofins | mgt Analytical Services Manager : Onur Mehmet

Sample Detail						Aluminium	Aluminium	Aluminium (filtered)	Aluminium (filtered)	Arsenic	Arsenic	Arsenic (filtered)	Arsenic (filtered)	Biochemical Oxygen Demand (BOD-5 Day)	Cadmium	Cadmium	Cadmium (filtered)	Cadmium (filtered)	Calcium	Chemical Oxygen Demand (COD)	Chromium	Chromium	Chromium (filtered)	Chromium (filtered)	Copper	Copper	Copper (filtered)	Copper (filtered)	Dissolved Organic Carbon	Iron (filtered)	Iron (filtered)	Lead	Lead	Lead (filtered)	Lead (filtered)	Magnesium	Manganese	Manganese	Manganese (filtered)	Manganese (filtered)	Mercury	Mercury	Mercury (filtered)	Mercury (filtered)	Nickel	Nickel	Nickel (filtered)	Nickel (filtered)	Phosphate total (as P)	Potassium	Sodium	Total Organic Carbon	Zinc	Zinc	Zinc (filtered)	Zinc (filtered)	Iron (speciated)	Total Sulphur Set (as S)	Nitrogens (speciated)	Eurofins | mgt Suite B11F: Cl, SO4, Alkalinity
Melbourne Laboratory - NATA Site # 1254 & 14271						X		X		X		X		X	X		X		X	X	X		X		X		X		X	X		X		X		X	X		X		X		X		X		X		X	X	X	X	X		X		X	X	X	X
Sydney Laboratory - NATA Site # 18217							X		X		X		X			X		X				X		X		X		X			X		X		X			X		X		X		X		X		X						X		X	X			
Brisbane Laboratory - NATA Site # 20794																																																												
Perth Laboratory - NATA Site # 18217																																																												
External Laboratory																																																												
No	**Sample ID**	**Sample Date**	**Sampling Time**	**Matrix**	**LAB ID**																																																							
1	A3	May 04, 2017		Water	M17-My09638	X		X		X		X		X	X		X		X	X	X		X		X		X		X	X		X		X		X	X		X		X		X		X		X		X	X	X	X	X		X		X	X	X	X
2	YGS	May 04, 2017		Water	M17-My09639	X		X		X		X		X	X		X		X	X	X		X		X		X		X	X		X		X		X	X		X		X		X		X		X		X	X	X	X	X		X		X	X	X	X
3	SUS	May 04, 2017		Water	M17-My09640	X		X		X		X		X	X		X		X	X	X		X		X		X		X	X		X		X		X	X		X		X		X		X		X		X	X	X	X	X		X		X	X	X	X
4	YS06	May 04, 2017		Water	M17-My09641		X		X		X		X	X		X		X	X	X		X		X		X		X	X		X		X		X	X		X		X		X		X		X		X	X	X	X	X		X		X	X	X	X	X
5	CS1	May 04, 2017		Water	M17-My09642	X		X		X		X		X	X		X		X	X	X		X		X		X		X	X		X		X		X	X		X		X		X		X		X		X	X	X	X		X		X	X	X	X	X
6	LBC	May 04, 2017		Water	M17-My09643	X		X		X		X		X	X		X		X	X	X		X		X		X		X	X		X		X		X	X		X		X		X		X		X		X	X	X	X		X		X	X	X	X	X
7	SDS	May 04, 2017		Water	M17-My09644	X		X			X		X	X		X		X	X	X		X		X		X		X	X	X			X		X	X		X		X		X		X		X		X	X	X	X	X		X		X	X	X	X	X
8	YS05	May 05, 2017		Water	M17-My09645		X		X		X		X	X		X		X	X	X		X		X		X		X	X		X		X		X	X		X		X		X		X		X		X	X	X	X	X		X		X	X	X	X	X
9	YS03	May 05, 2017		Water	M17-My09646		X		X		X		X	X		X		X	X	X		X		X		X		X	X		X		X		X	X		X		X		X		X		X		X	X	X	X	X		X		X	X	X	X	X
10	YS02	May 05, 2017		Water	M17-My09647	X		X		X		X		X	X		X		X	X	X		X		X		X		X	X		X		X		X	X		X		X		X		X		X		X	X	X	X		X		X	X	X	X	X

Company Name:	Jacobs Group (Australia) P/L VIC	**Order No.:**	b191000	**Received:**	May 10, 2017 9:31 AM
Address:	PO Box 312 Flinders Lane Melbourne VIC 8009	**Report #:**	545553	**Due:**	May 17, 2017
		Phone:	03 8668 3000	**Priority:**	5 Day
		Fax:	03 8668 3001	**Contact Name:**	Andrew Nelson
Project Name:	BARWON DOWNS HYDROGEN LOGICAL ASSESSMENT				

Eurofins | mgt Analytical Services Manager : Onur Mehmet

Sample Detail						Aluminium	Aluminium	Aluminium (filtered)	Aluminium (filtered)	Arsenic	Arsenic	Arsenic (filtered)	Arsenic (filtered)	Biochemical Oxygen Demand (BOD-5 Day)	Cadmium	Cadmium	Cadmium (filtered)	Cadmium (filtered)	Calcium	Chemical Oxygen Demand (COD)	Chromium	Chromium	Chromium (filtered)	Chromium (filtered)	Copper	Copper	Copper (filtered)	Copper (filtered)	Dissolved Organic Carbon	Iron (filtered)	Iron (filtered)	Lead	Lead	Lead (filtered)	Lead (filtered)	Magnesium	Manganese	Manganese	Manganese (filtered)	Manganese (filtered)	Mercury	Mercury	Mercury (filtered)	Mercury (filtered)	Nickel	Nickel	Nickel (filtered)	Nickel (filtered)	Phosphate total (as P)	Potassium	Sodium	Total Organic Carbon	Zinc	Zinc	Zinc (filtered)	Zinc (filtered)	Iron (speciated)	Total Sulphur Set (as S)	Nitrogens (speciated)	Eurofins | mgt Suite B11F: Cl, SO4, Alkalinity
Melbourne Laboratory - NATA Site # 1254 & 14271						X		X		X		X		X	X		X		X	X	X		X		X		X		X	X		X		X		X	X		X		X		X		X		X		X	X	X	X	X		X		X	X	X	X
Sydney Laboratory - NATA Site # 18217							X		X		X		X			X		X				X		X		X		X			X		X		X			X		X		X		X		X		X						X		X	X			
Brisbane Laboratory - NATA Site # 20794																																																												
Perth Laboratory - NATA Site # 18217																																																												
11	YS01	May 05, 2017		Water	M17-My09648	X		X			X		X	X		X		X	X	X		X		X		X		X	X	X			X		X	X		X		X		X		X		X		X	X	X	X	X		X		X	X	X	X	X
12	TB1A	May 05, 2017		Water	M17-My09649	X		X		X		X		X	X		X		X	X	X		X		X		X		X	X		X		X		X	X		X		X		X		X		X		X	X	X	X	X		X		X	X	X	X
13	LBC01	May 05, 2017		Water	M17-My09650		X		X		X		X	X		X		X	X	X		X		X		X		X	X		X		X		X	X		X		X		X		X		X		X	X	X	X	X		X		X	X	X	X	X
14	PASS1	May 05, 2017		Water	M17-My09651	X		X		X		X		X	X		X		X	X	X		X		X		X		X	X		X		X		X	X		X		X		X		X		X		X	X	X	X	X		X		X	X	X	X
15	LBC02	May 05, 2017		Water	M17-My09652	X		X		X		X		X	X		X		X	X	X		X		X		X		X	X		X		X		X	X		X		X		X		X		X		X	X	X	X	X		X		X	X	X	X
Test Counts						15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15

Internal Quality Control Review and Glossary

General

1. Laboratory QC results for Method Blanks, Duplicates, Matrix Spikes, and Laboratory Control Samples are included in this QC report where applicable. Additional QC data may be available on request.
2. All soil results are reported on a dry basis, unless otherwise stated.
3. All biota results are reported on a wet weight basis on the edible portion, unless otherwise stated.
4. Actual LORs are matrix dependant. Quoted LORs may be raised where sample extracts are diluted due to interferences.
5. Results are uncorrected for matrix spikes or surrogate recoveries.
6. SVOC analysis on waters are performed on homogenised, unfiltered samples, unless noted otherwise.
7. Samples were analysed on an 'as received' basis.
8. This report replaces any interim results previously issued.

Holding Times

Please refer to 'Sample Preservation and Container Guide' for holding times (QS3001).

For samples received on the last day of holding time, notification of testing requirements should have been received at least 6 hours prior to sample receipt deadlines as stated on the Sample Receipt Advice.

If the Laboratory did not receive the information in the required timeframe, and regardless of any other integrity issues, suitably qualified results may still be reported.

Holding times apply from the date of sampling, therefore compliance to these may be outside the laboratory's control.

****NOTE:** pH duplicates are reported as a range NOT as RPD

Units

mg/kg: milligrams per kilogram

ug/L: micrograms per litre

ppb: Parts per billion

org/100mL: Organisms per 100 millilitres

MPN/100mL: Most Probable Number of organisms per 100 millilitres

mg/L: milligrams per litre

ppm: Parts per million

%: Percentage

NTU: Nephelometric Turbidity Units

Terms

Dry	Where a moisture has been determined on a solid sample the result is expressed on a dry basis.
LOR	Limit of Reporting.
SPIKE	Addition of the analyte to the sample and reported as percentage recovery.
RPD	Relative Percent Difference between two Duplicate pieces of analysis.
LCS	Laboratory Control Sample - reported as percent recovery.
CRM	Certified Reference Material - reported as percent recovery.
Method Blank	In the case of solid samples these are performed on laboratory certified clean sands. In the case of water samples these are performed on de-ionised water.
Surr - Surrogate	The addition of a like compound to the analyte target and reported as percentage recovery.
Duplicate	A second piece of analysis from the same sample and reported in the same units as the result to show comparison.
Batch Duplicate	A second piece of analysis from a sample outside of the clients batch of samples but run within the laboratory batch of analysis.
Batch SPIKE	Spike recovery reported on a sample from outside of the clients batch of samples but run within the laboratory batch of analysis.
USEPA	United States Environmental Protection Agency
APHA	American Public Health Association
TCLP	Toxicity Characteristic Leaching Procedure
COC	Chain of Custody
SRA	Sample Receipt Advice
CP	Client Parent - QC was performed on samples pertaining to this report
NCP	Non-Client Parent - QC performed on samples not pertaining to this report, QC is representative of the sequence or batch that client samples were analysed within.
TEQ	Toxic Equivalency Quotient

QC - Acceptance Criteria

RPD Duplicates: Global RPD Duplicates Acceptance Criteria is 30% however the following acceptance guidelines are equally applicable:

Results <10 times the LOR : No Limit

Results between 10-20 times the LOR : RPD must lie between 0-50%

Results >20 times the LOR : RPD must lie between 0-30%

Surrogate Recoveries: Recoveries must lie between 50-150%-Phenols & PFASs 20-130%

QC Data General Comments

1. Where a result is reported as a less than (<), higher than the nominated LOR, this is due to either matrix interference, extract dilution required due to interferences or contaminant levels within the sample, high moisture content or insufficient sample provided.
2. Duplicate data shown within this report that states the word "BATCH" is a Batch Duplicate from outside of your sample batch, but within the laboratory sample batch at a 1:10 ratio. The Parent and Duplicate data shown is not data from your samples.
3. Organochlorine Pesticide analysis - where reporting LCS data, Toxaphene & Chlordane are not added to the LCS.
4. Organochlorine Pesticide analysis - where reporting Spike data, Toxaphene is not added to the Spike.
5. Total Recoverable Hydrocarbons - where reporting Spike & LCS data, a single spike of commercial Hydrocarbon products in the range of C12-C30 is added and it's Total Recovery is reported in the C10-C14 cell of the Report.
6. pH and Free Chlorine analysed in the laboratory - Analysis on this test must begin within 30 minutes of sampling.Therefore laboratory analysis is unlikely to be completed within holding time. Analysis will begin as soon as possible after sample receipt.
7. Recovery Data (Spikes & Surrogates) - where chromatographic interference does not allow the determination of Recovery the term "INT" appears against that analyte.
8. Polychlorinated Biphenyls are spiked only using Aroclor 1260 in Matrix Spikes and LCS.
9. For Matrix Spikes and LCS results a dash " -" in the report means that the specific analyte was not added to the QC sample.
10. Duplicate RPDs are calculated from raw analytical data thus it is possible to have two sets of data.

Quality Control Results

Test	Units	Result 1			Acceptance Limits	Pass Limits	Qualifying Code
Method Blank							
Ammonia (as N)	mg/L	< 0.01			0.01	Pass	
Biochemical Oxygen Demand (BOD-5 Day)	mg/L	< 5			5	Pass	
Chemical Oxygen Demand (COD)	mg/L	< 25			25	Pass	
Chloride	mg/L	< 1			1	Pass	
Ferrous Iron - Fe2+	mg/L	< 0.05			0.05	Pass	
Fluoride	mg/L	< 0.5			0.5	Pass	
Nitrate & Nitrite (as N)	mg/L	< 0.05			0.05	Pass	
Nitrate (as N)	mg/L	< 0.02			0.02	Pass	
Nitrite (as N)	mg/L	< 0.02			0.02	Pass	
Phosphate total (as P)	mg/L	< 0.05			0.05	Pass	
Sulphate (as S)	mg/L	< 5			5	Pass	
Sulphate (as SO4)	mg/L	< 5			5	Pass	
Sulphide (as S)	mg/L	< 0.05			0.05	Pass	
Sulphite (as S)	mg/L	< 0.5			0.5	Pass	
Thiosulphate (as S)	mg/L	< 1			1	Pass	
Total Kjeldahl Nitrogen (as N)	mg/L	< 0.2			0.2	Pass	
Total Organic Carbon	mg/L	< 5			5	Pass	
Method Blank							
Alkalinity (speciated)							
Bicarbonate Alkalinity (as CaCO3)	mg/L	< 20			20	Pass	
Carbonate Alkalinity (as CaCO3)	mg/L	< 10			10	Pass	
Hydroxide Alkalinity (as CaCO3)	mg/L	< 10			10	Pass	
Total Alkalinity (as CaCO3)	mg/L	< 20			20	Pass	
Method Blank							
Heavy Metals							
Aluminium	mg/L	< 0.05			0.05	Pass	
Aluminium (filtered)	mg/L	< 0.05			0.05	Pass	
Arsenic	mg/L	< 0.001			0.001	Pass	
Arsenic (filtered)	mg/L	< 0.001			0.001	Pass	
Cadmium	mg/L	< 0.0002			0.0002	Pass	
Cadmium (filtered)	mg/L	< 0.0002			0.0002	Pass	
Chromium	mg/L	< 0.001			0.001	Pass	
Chromium (filtered)	mg/L	< 0.001			0.001	Pass	
Copper	mg/L	< 0.001			0.001	Pass	
Copper (filtered)	mg/L	< 0.001			0.001	Pass	
Iron	mg/L	< 0.05			0.05	Pass	
Iron (filtered)	mg/L	< 0.05			0.05	Pass	
Lead	mg/L	< 0.001			0.001	Pass	
Lead (filtered)	mg/L	< 0.001			0.001	Pass	
Manganese	mg/L	< 0.005			0.005	Pass	
Manganese (filtered)	mg/L	< 0.005			0.005	Pass	
Mercury	mg/L	< 0.0001			0.0001	Pass	
Mercury (filtered)	mg/L	< 0.0001			0.0001	Pass	
Nickel	mg/L	< 0.001			0.001	Pass	
Nickel (filtered)	mg/L	< 0.001			0.001	Pass	
Zinc	mg/L	< 0.005			0.005	Pass	
Zinc (filtered)	mg/L	< 0.005			0.005	Pass	
Method Blank							
Alkali Metals							
Calcium	mg/L	< 0.5			0.5	Pass	
Magnesium	mg/L	< 0.5			0.5	Pass	

Test	Units	Result 1			Acceptance Limits	Pass Limits	Qualifying Code
Potassium	mg/L	< 0.5			0.5	Pass	
Sodium	mg/L	< 0.5			0.5	Pass	
LCS - % Recovery							
Ammonia (as N)	%	89			70-130	Pass	
Chemical Oxygen Demand (COD)	%	96			70-130	Pass	
Chloride	%	97			70-130	Pass	
Ferrous Iron - Fe2+	%	101			70-130	Pass	
Fluoride	%	93			70-130	Pass	
Nitrate & Nitrite (as N)	%	90			70-130	Pass	
Nitrate (as N)	%	90			70-130	Pass	
Nitrite (as N)	%	105			70-130	Pass	
Phosphate total (as P)	%	94			70-130	Pass	
Sulphate (as S)	%	100			70-130	Pass	
Sulphate (as SO4)	%	100			70-130	Pass	
Sulphide (as S)	%	100			70-130	Pass	
Thiosulphate (as S)	%	100			70-130	Pass	
Total Kjeldahl Nitrogen (as N)	%	111			70-130	Pass	
Total Organic Carbon	%	107			70-130	Pass	
LCS - % Recovery							
Alkalinity (speciated)							
Carbonate Alkalinity (as CaCO3)	%	89			70-130	Pass	
Total Alkalinity (as CaCO3)	%	89			70-130	Pass	
LCS - % Recovery							
Heavy Metals							
Aluminium	%	94			80-120	Pass	
Aluminium (filtered)	%	94			80-120	Pass	
Arsenic	%	104			80-120	Pass	
Arsenic (filtered)	%	104			80-120	Pass	
Cadmium	%	109			80-120	Pass	
Cadmium (filtered)	%	109			80-120	Pass	
Chromium	%	100			80-120	Pass	
Chromium (filtered)	%	100			80-120	Pass	
Copper	%	104			80-120	Pass	
Copper (filtered)	%	104			80-120	Pass	
Iron	%	120			80-120	Pass	
Iron (filtered)	%	120			80-120	Pass	
Lead	%	102			80-120	Pass	
Lead (filtered)	%	102			80-120	Pass	
Manganese	%	101			80-120	Pass	
Manganese (filtered)	%	101			80-120	Pass	
Mercury	%	96			75-125	Pass	
Mercury (filtered)	%	96			70-130	Pass	
Nickel	%	103			80-120	Pass	
Nickel (filtered)	%	103			80-120	Pass	
Zinc	%	108			80-120	Pass	
Zinc (filtered)	%	108			80-120	Pass	
LCS - % Recovery							
Alkali Metals							
Calcium	%	95			70-130	Pass	
Magnesium	%	103			70-130	Pass	
Potassium	%	92			70-130	Pass	
Sodium	%	91			70-130	Pass	

Test	Lab Sample ID	QA Source	Units	Result 1			Acceptance Limits	Pass Limits	Qualifying Code
Spike - % Recovery									
				Result 1					
Ferrous Iron - Fe2+	M17-My12093	NCP	%	88			70-130	Pass	
Nitrate & Nitrite (as N)	M17-My10516	NCP	%	83			70-130	Pass	
Nitrate (as N)	M17-My10516	NCP	%	83			70-130	Pass	
Nitrite (as N)	M17-My10516	NCP	%	92			70-130	Pass	
Phosphate total (as P)	P17-My11673	NCP	%	97			70-130	Pass	
Spike - % Recovery									
Heavy Metals				Result 1					
Iron (filtered)	M17-My07820	NCP	%	87			70-130	Pass	
Spike - % Recovery									
Alkali Metals				Result 1					
Calcium	M17-My09638	CP	%	92			70-130	Pass	
Magnesium	M17-My09638	CP	%	94			70-130	Pass	
Potassium	M17-My09638	CP	%	85			70-130	Pass	
Sodium	M17-My09638	CP	%	104			70-130	Pass	
Spike - % Recovery									
Heavy Metals				Result 1					
Aluminium	M17-My09640	CP	%	88			75-125	Pass	
Arsenic	M17-My09640	CP	%	109			75-125	Pass	
Cadmium	M17-My09640	CP	%	108			75-125	Pass	
Chromium	M17-My09640	CP	%	98			75-125	Pass	
Copper	M17-My09640	CP	%	104			75-125	Pass	
Iron	M17-My09640	CP	%	49			75-125	Fail	Q08
Lead	M17-My09640	CP	%	103			75-125	Pass	
Manganese	M17-My09640	CP	%	103			75-125	Pass	
Mercury	M17-My09640	CP	%	97			70-130	Pass	
Nickel	M17-My09640	CP	%	104			75-125	Pass	
Zinc	M17-My09640	CP	%	107			75-125	Pass	
Spike - % Recovery									
				Result 1					
Chloride	M17-My09643	CP	%	109			70-130	Pass	
Sulphate (as S)	M17-My09643	CP	%	103			70-130	Pass	
Sulphate (as SO4)	M17-My09643	CP	%	103			70-130	Pass	
Spike - % Recovery									
				Result 1					
Fluoride	M17-My09644	CP	%	69			70-130	Fail	Q08
Spike - % Recovery									
				Result 1					
Ammonia (as N)	M17-My09645	CP	%	81			70-130	Pass	
Spike - % Recovery									
				Result 1					
Total Kjeldahl Nitrogen (as N)	M17-My09646	CP	%	99			70-130	Pass	
Spike - % Recovery									
Heavy Metals				Result 1					
Aluminium (filtered)	M17-My09647	CP	%	91			75-125	Pass	
Arsenic (filtered)	M17-My09647	CP	%	108			70-130	Pass	
Cadmium (filtered)	M17-My09647	CP	%	101			70-130	Pass	
Chromium (filtered)	M17-My09647	CP	%	101			70-130	Pass	
Copper (filtered)	M17-My09647	CP	%	103			70-130	Pass	
Lead (filtered)	M17-My09647	CP	%	104			70-130	Pass	
Manganese (filtered)	M17-My09647	CP	%	21			70-130	Fail	Q08
Mercury (filtered)	M17-My09647	CP	%	99			70-130	Pass	
Nickel (filtered)	M17-My09647	CP	%	103			70-130	Pass	

Test	Lab Sample ID	QA Source	Units	Result 1			Acceptance Limits	Pass Limits	Qualifying Code
Zinc (filtered)	M17-My09647	CP	%	104			70-130	Pass	
Spike - % Recovery									
Alkali Metals				Result 1					
Calcium	M17-My09648	CP	%	101			70-130	Pass	
Magnesium	M17-My09648	CP	%	106			70-130	Pass	
Potassium	M17-My09648	CP	%	95			70-130	Pass	
Sodium	M17-My09648	CP	%	107			70-130	Pass	
Spike - % Recovery									
				Result 1					
Chemical Oxygen Demand (COD)	M17-My09649	CP	%	123			70-130	Pass	
Spike - % Recovery									
Heavy Metals				Result 1					
Aluminium	M17-My09650	CP	%	78			70-130	Pass	
Arsenic	M17-My09650	CP	%	82			70-130	Pass	
Cadmium	M17-My09650	CP	%	76			70-130	Pass	
Chromium	M17-My09650	CP	%	75			70-130	Pass	
Copper	M17-My09650	CP	%	71			70-130	Pass	
Lead	M17-My09650	CP	%	80			70-130	Pass	
Zinc	M17-My09650	CP	%	71			70-130	Pass	
Test	**Lab Sample ID**	**QA Source**	**Units**	**Result 1**			**Acceptance Limits**	**Pass Limits**	**Qualifying Code**
Duplicate									
				Result 1	Result 2	RPD			
Biochemical Oxygen Demand (BOD-5 Day)	M17-My09638	CP	mg/L	< 5	< 5	<1	30%	Pass	
Dissolved Organic Carbon	M17-My13467	NCP	mg/L	8.5	7.5	12	30%	Pass	
Phosphate total (as P)	P17-My11672	NCP	mg/L	0.07	0.05	33	30%	Fail	Q15
Sulphite (as S)	M17-My22083	NCP	mg/L	< 5	< 5	<1	30%	Pass	
Thiosulphate (as S)	M17-My22083	NCP	mg/L	< 10	< 10	<1	30%	Pass	
Total Kjeldahl Nitrogen (as N)	P17-My11672	NCP	mg/L	1.2	1.2	2.0	30%	Pass	
Total Organic Carbon	M17-My13321	NCP	mg/L	< 5	< 5	<1	30%	Pass	
Duplicate									
Heavy Metals				Result 1	Result 2	RPD			
Iron (filtered)	M17-My07820	NCP	mg/L	0.33	0.33	1.0	30%	Pass	
Zinc (filtered)	M17-My07820	NCP	mg/L	< 0.005	< 0.005	<1	30%	Pass	
Duplicate									
Alkali Metals				Result 1	Result 2	RPD			
Calcium	M17-My09638	CP	mg/L	37	38	2.0	30%	Pass	
Magnesium	M17-My09638	CP	mg/L	24	25	3.0	30%	Pass	
Potassium	M17-My09638	CP	mg/L	5.8	6.3	7.0	30%	Pass	
Sodium	M17-My09638	CP	mg/L	310	320	2.0	30%	Pass	
Duplicate									
Heavy Metals				Result 1	Result 2	RPD			
Aluminium	M17-My09640	CP	mg/L	< 0.05	< 0.05	<1	30%	Pass	
Arsenic	M17-My09640	CP	mg/L	< 0.001	< 0.001	<1	30%	Pass	
Cadmium	M17-My09640	CP	mg/L	< 0.0002	< 0.0002	<1	30%	Pass	
Chromium	M17-My09640	CP	mg/L	0.001	0.001	8.0	30%	Pass	
Copper	M17-My09640	CP	mg/L	< 0.001	< 0.001	<1	30%	Pass	
Iron	M17-My09640	CP	mg/L	0.47	0.45	3.0	30%	Pass	
Lead	M17-My09640	CP	mg/L	< 0.001	< 0.001	<1	30%	Pass	
Manganese	M17-My09640	CP	mg/L	0.016	0.016	1.0	30%	Pass	
Mercury	M17-My09640	CP	mg/L	< 0.0001	< 0.0001	<1	30%	Pass	
Nickel	M17-My09640	CP	mg/L	0.001	< 0.001	13	30%	Pass	
Zinc	M17-My09640	CP	mg/L	0.005	0.005	<1	30%	Pass	

Duplicate									
				Result 1	Result 2	RPD			
Biochemical Oxygen Demand (BOD-5 Day)	M17-My09641	CP	mg/L	< 5	< 5	<1	30%	Pass	
Duplicate									
				Result 1	Result 2	RPD			
Chloride	M17-My09643	CP	mg/L	330	330	1.7	30%	Pass	
Fluoride	M17-My09643	CP	mg/L	< 0.5	< 0.5	<1	30%	Pass	
Sulphate (as S)	M17-My09643	CP	mg/L	88	92	4.1	30%	Pass	
Sulphate (as SO4)	M17-My09643	CP	mg/L	260	280	4.1	30%	Pass	
Duplicate									
				Result 1	Result 2	RPD			
Sulphide (as S)	M17-My09644	CP	mg/L	< 0.05	< 0.05	<1	30%	Pass	
Duplicate									
				Result 1	Result 2	RPD			
Ammonia (as N)	M17-My09645	CP	mg/L	4.4	4.5	1.0	30%	Pass	
Nitrate & Nitrite (as N)	M17-My09645	CP	mg/L	< 0.05	< 0.05	<1	30%	Pass	
Nitrate (as N)	M17-My09645	CP	mg/L	< 0.02	< 0.02	<1	30%	Pass	
Nitrite (as N)	M17-My09645	CP	mg/L	< 0.02	< 0.02	<1	30%	Pass	
Duplicate									
Alkalinity (speciated)				Result 1	Result 2	RPD			
Bicarbonate Alkalinity (as CaCO3)	M17-My09645	CP	mg/L	< 20	< 20	<1	30%	Pass	
Carbonate Alkalinity (as CaCO3)	M17-My09645	CP	mg/L	< 10	< 10	<1	30%	Pass	
Hydroxide Alkalinity (as CaCO3)	M17-My09645	CP	mg/L	< 10	< 10	<1	30%	Pass	
Total Alkalinity (as CaCO3)	M17-My09645	CP	mg/L	< 20	< 20	<1	30%	Pass	
Duplicate									
Heavy Metals				Result 1	Result 2	RPD			
Aluminium (filtered)	M17-My09647	CP	mg/L	< 0.05	< 0.05	<1	30%	Pass	
Arsenic (filtered)	M17-My09647	CP	mg/L	< 0.001	< 0.001	<1	30%	Pass	
Cadmium (filtered)	M17-My09647	CP	mg/L	< 0.0002	< 0.0002	<1	30%	Pass	
Chromium (filtered)	M17-My09647	CP	mg/L	< 0.001	< 0.001	<1	30%	Pass	
Copper (filtered)	M17-My09647	CP	mg/L	< 0.001	< 0.001	<1	30%	Pass	
Lead (filtered)	M17-My09647	CP	mg/L	< 0.001	< 0.001	<1	30%	Pass	
Manganese (filtered)	M17-My09647	CP	mg/L	0.77	0.75	2.0	30%	Pass	
Mercury (filtered)	M17-My09647	CP	mg/L	< 0.0001	< 0.0001	<1	30%	Pass	
Nickel (filtered)	M17-My09647	CP	mg/L	0.003	0.003	<1	30%	Pass	
Duplicate									
				Result 1	Result 2	RPD			
Chemical Oxygen Demand (COD)	M17-My09648	CP	mg/L	35	< 25	79	30%	Fail	Q15
Duplicate									
Alkali Metals				Result 1	Result 2	RPD			
Calcium	M17-My09648	CP	mg/L	27	29	7.0	30%	Pass	
Magnesium	M17-My09648	CP	mg/L	37	40	7.0	30%	Pass	
Potassium	M17-My09648	CP	mg/L	5.0	4.9	1.0	30%	Pass	
Sodium	M17-My09648	CP	mg/L	110	110	8.0	30%	Pass	
Duplicate									
				Result 1	Result 2	RPD			
Ferrous Iron - Fe2+	M17-My09650	CP	mg/L	80	75	6.8	30%	Pass	
Duplicate									
Heavy Metals				Result 1	Result 2	RPD			
Cadmium	M17-My09650	CP	mg/L	< 0.0002	< 0.0002	<1	30%	Pass	
Copper	M17-My09650	CP	mg/L	< 0.001	< 0.001	<1	30%	Pass	
Manganese	M17-My09650	CP	mg/L	0.082	0.086	4.0	30%	Pass	
Nickel	M17-My09650	CP	mg/L	0.001	0.001	2.0	30%	Pass	

Comments

Sample Integrity

Custody Seals Intact (if used)	N/A
Attempt to Chill was evident	Yes
Sample correctly preserved	Yes
Appropriate sample containers have been used	Yes
Sample containers for volatile analysis received with minimal headspace	Yes
Samples received within HoldingTime	Yes
Some samples have been subcontracted	No

Qualifier Codes/Comments

Code	Description
Q08	The matrix spike recovery is outside of the recommended acceptance criteria. An acceptable recovery was obtained for the laboratory control sample indicating a sample matrix interference
Q15	The RPD reported passes Eurofins | mgt's QC - Acceptance Criteria as defined in the Internal Quality Control Review and Glossary page of this report.
Q18	Ferrous Iron results are present at higher levels than total/soluble Iron results. This is due to experimental uncertainties associated with the different analytical techniques used in analysing Iron (total/soluble) and Ferrous Iron.
R05	Theoretically the total result should be greater or equal to the dissolved concentration. However the difference reported is within the uncertainty of the individual tests

Authorised By

Onur Mehmet	Analytical Services Manager
Alex Petridis	Senior Analyst-Metal (VIC)
Huong Le	Senior Analyst-Inorganic (VIC)
Ryan Hamilton	Senior Analyst-Metal (NSW)

Glenn Jackson

National Operations Manager

Final report - this Report replaces any previously issued Report

- Indicates Not Requested

* Indicates NATA accreditation does not cover the performance of this service

Measurement uncertainty of test data is available on request or please click here.

JACOBS

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CHAIN OF CUSTODY & ANALYSIS REQUEST

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FAX:

Page 1 **of** 1

PROJECT # IS191000
PROJECT NAME Barwon Water Task 5
SAMPLE COLLECTOR'S NAME Nicolaas Unland
LAB JOB #

PRELIM. RESULTS BY: ☑ VERBAL
Email ☐ FAX
☑ EMAIL

FINAL REPORT BY Email
SEND TO EMAIL ADDRESS(ES): Nicolaas.unland@jacobs.com

LAB QUOTE REF
Jacobs ORDER No:

METHOD CODE & ANALYSIS REQUIRED

SAMPLE ID	**DEPTH (metres)**	**LAB #**	**MATRIX**				**PRESERVATION METHOD**				**SAMPLING DATE**	**No. OF CONTAINERS**	Analysis as per quote #170501JAC (see attached e-mail)						**COMMENTS**	(see below)	
			WATER	SOIL	AIR	SLUDGE	ICE	ACID	OTHER	NONE										(1)	(2)	(3)
McDonalds			x				x	x	x		22-Aug-17	7							Please include acidity analysis	☐	☐	☐
Damplands			x				x	x	x		22-Aug-17	7								☐	☐	☐
Yeodene Swamp U/S			x				x	x	x		22-Aug-17	7								☐	☐	☐
Yeodene Swamp D/S			x				x	x	x		22-Aug-17	7								☐	☐	☐
YG			x				x	x	x		22-Aug-17	7								☐	☐	☐
Lower BC			x				x	x	x		22-Aug-17	7								☐	☐	☐
A3			x				x	x	x		22-Aug-17	7								☐	☐	☐
LBC02			x				x	x	x		22-Aug-17	7								☐	☐	☐
LBC01			x				x	x	x		23-Aug-17	7								☐	☐	☐
PASS1			x				x	x	x		23-Aug-17	7								☐	☐	☐
YS01			x				x	x	x		23-Aug-17	7								☐	☐	☐
YS02			x				x	x	x		23-Aug-17	7								☐	☐	☐
YS03			x				x	x	x		23-Aug-17	7								☐	☐	☐
YS05			x				x	x	x		23-Aug-17	7								☐	☐	☐
YS06			x				x	x	x		22-Aug-17	7								☐	☐	☐
YS02-SW			x				x	x	x		23-Aug-17	7								☐	☐	☐
YS05-SW			x				x	x	x		23-Aug-17	7								☐	☐	☐
TB1			x				x	x	x		22-Aug-17	7								☐	☐	☐
																				☐	☐	☐
																				☐	☐	☐
																				☐	☐	☐
																				☐	☐	☐
																				☐	☐	☐
																				☐	☐	☐
																				☐	☐	☐
TOTALS												126										

Relinquished by (SIGN/PRINT): Nicolaas Unland of Jacobs	Date 23/8/17 ~~########~~	Time 1600	**Received by (SIGN/PRINT):** PMANE of Eurofins	Date 23/8	Time 1750
Relinquished by (SIGN/PRINT): of	Date	Time	**Received by (SIGN/PRINT):** of	Date	Time

Custody Seals Intact? Yes / No

Sample Receipt Temp. 8.5 °C

Additional Comments/Instructions:
All final lab reports to be provided electronically as .pdf and datafile to both emails above.

#559957

ANALYTICAL RATES

The following analysis prices are on a per sample basis, excluding GST and any associated fees that may apply. Prices apply for the scope of laboratory testing requested and do not apply to secondary/QC samples unless agreed otherwise.

— WATER—

Analysis	*Sample Number*	*Cost per Sample*	*Total Cost*
Eurofins mgt Suite: B11C*1 Cation Suite : Na, K, Ca, Mg	18	$11.70	$210.60
Eurofins mgt Suite: B11F*1 Anion Suite : Cl, SO4, Alkalinity (CO3, HCO3, OH-, Total Alkalinity), Fluoride.	18	$23.40	$421.20
Acidity	18	$8.30	$149.40
Total Metals (Al,As,Cd,Cr,Cu,Fe,Hg,Mn,Ni, Pb,Zn)	18	$24.00	$432.00
Dissolved Metals (Al,As,Cd,Cr,Cu,Fe,Hg,Mn,Ni, Pb,Zn)	18	$24.00	$432.00
Ferrous/Ferric Iron Speciation	18	$18.80	$338.40
NH3 as N	18	$12.00	$216.00
NO3 as N	18	$8.30	$149.40
Phosphate (Total)	18	$8.30	$149.40
Sulfur (SO4, SO3, S2O3, S2-, Total)	18	$30.00	$540.00
Total Cost excluding GST			**$3038.40**

Please use suite codes on all COC's to obtain the quoted price

— ASSOCIATED FEES —

Associated Fees	*Price*
Project fee	$30.00 per batch

Please refer to "PRICING NOTES" on the following pages for Pricing and Payment conditions.

#557957
PMAN(1)
23/8
1750

Certificate of Analysis

NATA Accredited
Accreditation Number 1261
Site Number 1254

Accredited for compliance with ISO/IEC 17025 – Testing
The results of the tests, calibrations and/or measurements included in this document are traceable to Australian/national standards.

Jacobs Group (Australia) P/L VIC
PO Box 312 Flinders Lane
Melbourne
VIC 8009

Attention: **Nicolaas Unland**

Report **559951-W**
Project name BARWON WATER TASK 5
Project ID IS191000
Received Date Aug 23, 2017

Client Sample ID			**MCDONALDS**	**DAMPLANDS**	**YEODENE SWAMP U/S**	**YEODENE SWAMP D/S**
Sample Matrix			**Water**	**Water**	**Water**	**Water**
Eurofins | mgt Sample No.			**M17-Au28086**	**M17-Au28087**	**M17-Au28088**	**M17-Au28089**
Date Sampled			**Aug 22, 2017**	**Aug 22, 2017**	**Aug 22, 2017**	**Aug 22, 2017**
Test/Reference	LOR	Unit				
Acidity (as CaCO3)	10	mg/L	< 10	< 10	53	90
Ammonia (as N)	0.01	mg/L	0.12	0.09	0.18	< 0.01
Chloride	1	mg/L	120	140	160	150
Ferric Iron - Fe3+	0.05	mg/L	0.35	0.41	0.2	0.56
Ferrous Iron - Fe2+	0.05	mg/L	0.57	0.51	3.2	0.44
Fluoride	0.5	mg/L	< 0.5	< 0.5	< 0.5	< 0.5
Nitrate (as N)	0.02	mg/L	0.16	0.15	< 0.02	0.07
Phosphate total (as P)	0.05	mg/L	0.07	0.07	0.08	< 0.05
Sulphate (as S)	5	mg/L	< 5	< 5	5.4	23
Sulphate (as SO4)	5	mg/L	7.2	7.8	16	68
Sulphide (as S)	0.05	mg/L	< 0.05	< 0.05	< 0.05	< 0.05
Sulphite (as S)	0.5	mg/L	< 1	< 1	< 1	< 1
Thiosulphate (as S)	1	mg/L	< 2	< 2	< 2	< 2
Total Sulphur (as S)	5	mg/L	< 5	< 5	5.4	23
Alkalinity (speciated)						
Bicarbonate Alkalinity (as CaCO3)	20	mg/L	< 20	< 20	72	< 20
Carbonate Alkalinity (as CaCO3)	10	mg/L	< 10	< 10	< 10	< 10
Hydroxide Alkalinity (as CaCO3)	10	mg/L	< 10	< 10	< 10	< 10
Total Alkalinity (as CaCO3)	20	mg/L	< 20	< 20	72	< 20
Heavy Metals						
Aluminium	0.05	mg/L	0.18	0.18	8.5	8.4
Aluminium (filtered)	0.05	mg/L	0.17	0.16	0.23	8.0
Arsenic	0.001	mg/L	< 0.001	< 0.001	0.003	< 0.001
Arsenic (filtered)	0.001	mg/L	< 0.001	< 0.001	0.002	< 0.001
Cadmium	0.0002	mg/L	< 0.0002	< 0.0002	< 0.0002	< 0.0002
Cadmium (filtered)	0.0002	mg/L	< 0.0002	< 0.0002	< 0.0002	< 0.0002
Chromium	0.001	mg/L	0.002	0.007	0.013	0.001
Chromium (filtered)	0.001	mg/L	< 0.001	< 0.001	< 0.001	< 0.001
Copper	0.001	mg/L	< 0.001	0.001	0.004	< 0.001
Copper (filtered)	0.001	mg/L	< 0.001	< 0.001	< 0.001	< 0.001
Iron	0.05	mg/L	1.4	1.4	6.2	1.2
Iron (filtered)	0.05	mg/L	0.92	0.91	3.4	1.0
Lead	0.001	mg/L	< 0.001	< 0.001	0.010	< 0.001
Lead (filtered)	0.001	mg/L	< 0.001	< 0.001	< 0.001	< 0.001
Manganese	0.005	mg/L	0.062	0.076	0.097	0.023

Client Sample ID			**MCDONALDS**	**DAMPLANDS**	**YEODENE SWAMP U/S**	**YEODENE SWAMP D/S**
Sample Matrix			**Water**	**Water**	**Water**	**Water**
Eurofins | mgt Sample No.			**M17-Au28086**	**M17-Au28087**	**M17-Au28088**	**M17-Au28089**
Date Sampled			**Aug 22, 2017**	**Aug 22, 2017**	**Aug 22, 2017**	**Aug 22, 2017**
Test/Reference	LOR	Unit				
Heavy Metals						
Manganese (filtered)	0.005	mg/L	0.050	0.065	0.098	0.023
Mercury	0.0001	mg/L	< 0.0001	< 0.0001	0.0001	< 0.0001
Mercury (filtered)	0.0001	mg/L	< 0.0001	< 0.0001	< 0.0001	< 0.0001
Nickel	0.001	mg/L	0.004	0.003	0.011	0.025
Nickel (filtered)	0.001	mg/L	< 0.001	< 0.001	0.007	0.025
Zinc	0.005	mg/L	< 0.005	< 0.005	0.031	0.17
Zinc (filtered)	0.005	mg/L	0.005	0.008	0.008	0.17
Alkali Metals						
Calcium	0.5	mg/L	5.9	5.8	27	5.2
Magnesium	0.5	mg/L	7.7	7.7	17	8.1
Potassium	0.5	mg/L	4.1	4.1	3.4	3.4
Sodium	0.5	mg/L	59	57	66	60

Client Sample ID			**YG**	**LOWER BC**	**A3**	**LBC02**
Sample Matrix			**Water**	**Water**	**Water**	**Water**
Eurofins | mgt Sample No.			**M17-Au28090**	**M17-Au28091**	**M17-Au28092**	**M17-Au28093**
Date Sampled			**Aug 22, 2017**	**Aug 22, 2017**	**Aug 22, 2017**	**Aug 22, 2017**
Test/Reference	LOR	Unit				
Acidity (as CaCO3)	10	mg/L	100	95	45	52
Ammonia (as N)	0.01	mg/L	0.02	< 0.01	0.06	< 0.01
Chloride	1	mg/L	160	220	580	290
Ferric Iron - Fe3+	0.05	mg/L	0.51	0.46	< 0.05	< 0.05
Ferrous Iron - Fe2+	0.05	mg/L	0.69	0.25	0.18	23
Fluoride	0.5	mg/L	< 0.5	< 0.5	< 0.5	< 0.5
Nitrate (as N)	0.02	mg/L	0.20	0.32	0.17	< 0.02
Phosphate total (as P)	0.05	mg/L	< 0.05	< 0.05	0.07	0.39
Sulphate (as S)	5	mg/L	28	35	55	< 5
Sulphate (as SO4)	5	mg/L	84	110	170	8.0
Sulphide (as S)	0.05	mg/L	< 0.05	< 0.05	< 0.05	< 0.05
Sulphite (as S)	0.5	mg/L	< 1	< 1	< 1	< 1
Thiosulphate (as S)	1	mg/L	< 2	< 2	< 2	< 2
Total Sulphur (as S)	5	mg/L	28	35	55	< 5
Alkalinity (speciated)						
Bicarbonate Alkalinity (as CaCO3)	20	mg/L	< 20	< 20	< 20	190
Carbonate Alkalinity (as CaCO3)	10	mg/L	< 10	< 10	< 10	< 10
Hydroxide Alkalinity (as CaCO3)	10	mg/L	< 10	< 10	< 10	< 10
Total Alkalinity (as CaCO3)	20	mg/L	< 20	< 20	< 20	190
Heavy Metals						
Aluminium	0.05	mg/L	10	11	0.29	1.7
Aluminium (filtered)	0.05	mg/L	10	11	0.20	< 0.05
Arsenic	0.001	mg/L	< 0.001	< 0.001	< 0.001	0.036
Arsenic (filtered)	0.001	mg/L	< 0.001	< 0.001	< 0.001	0.031
Cadmium	0.0002	mg/L	< 0.0002	< 0.0002	< 0.0002	< 0.0002
Cadmium (filtered)	0.0002	mg/L	< 0.0002	< 0.0002	< 0.0002	< 0.0002
Chromium	0.001	mg/L	0.001	< 0.001	0.004	0.003
Chromium (filtered)	0.001	mg/L	< 0.001	< 0.001	< 0.001	< 0.001

Client Sample ID			**YG**	**LOWER BC**	**A3**	**LBC02**
Sample Matrix			**Water**	**Water**	**Water**	**Water**
Eurofins | mgt Sample No.			**M17-Au28090**	**M17-Au28091**	**M17-Au28092**	**M17-Au28093**
Date Sampled			**Aug 22, 2017**	**Aug 22, 2017**	**Aug 22, 2017**	**Aug 22, 2017**
Test/Reference	LOR	Unit				
Heavy Metals						
Copper	0.001	mg/L	< 0.001	< 0.001	0.006	0.002
Copper (filtered)	0.001	mg/L	< 0.001	< 0.001	0.005	< 0.001
Iron	0.05	mg/L	1.4	0.77	1.2	28
Iron (filtered)	0.05	mg/L	1.2	0.71	0.19	23
Lead	0.001	mg/L	< 0.001	< 0.001	< 0.001	0.004
Lead (filtered)	0.001	mg/L	< 0.001	< 0.001	< 0.001	< 0.001
Manganese	0.005	mg/L	0.035	0.081	0.045	0.23
Manganese (filtered)	0.005	mg/L	0.035	0.081	0.045	0.21
Mercury	0.0001	mg/L	< 0.0001	< 0.0001	< 0.0001	< 0.0001
Mercury (filtered)	0.0001	mg/L	< 0.0001	< 0.0001	< 0.0001	< 0.0001
Nickel	0.001	mg/L	0.037	0.046	0.036	0.004
Nickel (filtered)	0.001	mg/L	0.037	0.046	0.036	< 0.001
Zinc	0.005	mg/L	0.23	0.25	0.059	0.020
Zinc (filtered)	0.005	mg/L	0.23	0.25	0.059	0.008
Alkali Metals						
Calcium	0.5	mg/L	6.8	16	54	82
Magnesium	0.5	mg/L	8.9	14	30	33
Potassium	0.5	mg/L	3.4	4.0	6.3	5.9
Sodium	0.5	mg/L	60	84	370	140

Client Sample ID			**LBC01**	**PASS1**	**YS01**	**YS02**
Sample Matrix			**Water**	**Water**	**Water**	**Water**
Eurofins | mgt Sample No.			**M17-Au28094**	**M17-Au28095**	**M17-Au28096**	**M17-Au28097**
Date Sampled			**Aug 23, 2017**	**Aug 23, 2017**	**Aug 23, 2017**	**Aug 23, 2017**
Test/Reference	LOR	Unit				
Acidity (as CaCO3)	10	mg/L	180	44	670	390
Ammonia (as N)	0.01	mg/L	15	1.0	0.22	3.4
Chloride	1	mg/L	760	1600	920	110
Ferric Iron - Fe3+	0.05	mg/L	< 0.05	< 0.05	< 0.05	10
Ferrous Iron - Fe2+	0.05	mg/L	100	28	91	210
Fluoride	0.5	mg/L	< 0.5	< 0.5	< 0.5	< 0.5
Nitrate (as N)	0.02	mg/L	< 0.02	0.21	< 0.02	< 0.1
Phosphate total (as P)	0.05	mg/L	0.63	2.3	0.08	0.25
Sulphate (as S)	5	mg/L	< 5	56	200	460
Sulphate (as SO4)	5	mg/L	< 5	170	600	1400
Sulphide (as S)	0.05	mg/L	< 0.05	< 0.05	< 0.05	< 0.05
Sulphite (as S)	0.5	mg/L	< 1	< 1	< 1	< 1
Thiosulphate (as S)	1	mg/L	< 2	< 2	< 2	< 2
Total Sulphur (as S)	5	mg/L	< 5	56	200	460
Alkalinity (speciated)						
Bicarbonate Alkalinity (as CaCO3)	20	mg/L	130	270	< 20	< 20
Carbonate Alkalinity (as CaCO3)	10	mg/L	< 10	< 10	< 10	< 10
Hydroxide Alkalinity (as CaCO3)	10	mg/L	< 10	< 10	< 10	< 10
Total Alkalinity (as CaCO3)	20	mg/L	130	270	< 20	< 20

Client Sample ID			**LBC01**	**PASS1**	**YS01**	**YS02**
Sample Matrix			**Water**	**Water**	**Water**	**Water**
Eurofins | mgt Sample No.			**M17-Au28094**	**M17-Au28095**	**M17-Au28096**	**M17-Au28097**
Date Sampled			**Aug 23, 2017**	**Aug 23, 2017**	**Aug 23, 2017**	**Aug 23, 2017**
Test/Reference	LOR	Unit				
Heavy Metals						
Aluminium	0.05	mg/L	9.1	3.3	83	6.0
Aluminium (filtered)	0.05	mg/L	< 0.05	< 0.05	73	0.07
Arsenic	0.001	mg/L	0.031	0.028	0.007	0.004
Arsenic (filtered)	0.001	mg/L	0.021	0.009	0.006	0.003
Cadmium	0.0002	mg/L	0.0002	< 0.0002	0.0024	< 0.0002
Cadmium (filtered)	0.0002	mg/L	< 0.0002	< 0.0002	0.0024	< 0.0002
Chromium	0.001	mg/L	0.019	0.007	0.008	0.005
Chromium (filtered)	0.001	mg/L	< 0.001	< 0.001	0.005	< 0.001
Copper	0.001	mg/L	0.004	0.006	< 0.005	0.001
Copper (filtered)	0.001	mg/L	< 0.001	< 0.001	< 0.005	< 0.001
Iron	0.05	mg/L	120	45	92	230
Iron (filtered)	0.05	mg/L	100	28	91	220
Lead	0.001	mg/L	0.012	0.010	0.006	0.002
Lead (filtered)	0.001	mg/L	< 0.001	< 0.001	< 0.005	< 0.001
Manganese	0.005	mg/L	0.10	0.065	0.89	1.3
Manganese (filtered)	0.005	mg/L	0.10	0.049	0.89	1.3
Mercury	0.0001	mg/L	< 0.0001	< 0.0001	< 0.0005	< 0.0001
Mercury (filtered)	0.0001	mg/L	< 0.0001	< 0.0001	< 0.0005	< 0.0001
Nickel	0.001	mg/L	0.013	0.006	0.86	0.010
Nickel (filtered)	0.001	mg/L	0.002	< 0.001	0.86	0.002
Zinc	0.005	mg/L	0.15	0.021	1.4	0.012
Zinc (filtered)	0.005	mg/L	0.005	< 0.005	1.4	0.006
Alkali Metals						
Calcium	0.5	mg/L	120	290	59	280
Magnesium	0.5	mg/L	73	94	77	67
Potassium	0.5	mg/L	5.9	10.0	6.8	9.1
Sodium	0.5	mg/L	160	520	290	84

Client Sample ID			**YS03**	**YS05**	**YS06**	**YS02-SW**
Sample Matrix			**Water**	**Water**	**Water**	**Water**
Eurofins | mgt Sample No.			**M17-Au28098**	**M17-Au28099**	**M17-Au28100**	**M17-Au28101**
Date Sampled			**Aug 23, 2017**	**Aug 23, 2017**	**Aug 22, 2017**	**Aug 23, 2017**
Test/Reference	LOR	Unit				
Acidity (as CaCO3)	10	mg/L	1900	560	< 10	160
Ammonia (as N)	0.01	mg/L	8.5	1.2	0.03	0.03
Chloride	1	mg/L	97	140	140	150
Ferric Iron - Fe3+	0.05	mg/L	100	20	0.51	0.48
Ferrous Iron - Fe2+	0.05	mg/L	1000	120	0.41	0.25
Fluoride	0.5	mg/L	< 0.5	< 0.5	< 0.5	< 0.5
Nitrate (as N)	0.02	mg/L	< 0.1	< 0.02	0.14	< 0.02
Phosphate total (as P)	0.05	mg/L	0.36	0.12	0.09	0.11
Sulphate (as S)	5	mg/L	1200	150	< 5	46
Sulphate (as SO4)	5	mg/L	3600	450	6.7	140
Sulphide (as S)	0.05	mg/L	< 0.05	< 0.05	< 0.05	< 0.05
Sulphite (as S)	0.5	mg/L	< 1	< 1	< 1	< 1
Thiosulphate (as S)	1	mg/L	< 2	< 2	< 2	< 2
Total Sulphur (as S)	5	mg/L	1200	150	< 5	46

Client Sample ID			**YS03**	**YS05**	**YS06**	**YS02-SW**
Sample Matrix			**Water**	**Water**	**Water**	**Water**
Eurofins | mgt Sample No.			**M17-Au28098**	**M17-Au28099**	**M17-Au28100**	**M17-Au28101**
Date Sampled			**Aug 23, 2017**	**Aug 23, 2017**	**Aug 22, 2017**	**Aug 23, 2017**
Test/Reference	LOR	Unit				
Alkalinity (speciated)						
Bicarbonate Alkalinity (as CaCO3)	20	mg/L	< 20	< 20	< 20	< 20
Carbonate Alkalinity (as CaCO3)	10	mg/L	< 10	< 10	< 10	< 10
Hydroxide Alkalinity (as CaCO3)	10	mg/L	< 10	< 10	< 10	< 10
Total Alkalinity (as CaCO3)	20	mg/L	< 20	< 20	< 20	< 20
Heavy Metals						
Aluminium	0.05	mg/L	52	22	0.17	25
Aluminium (filtered)	0.05	mg/L	51	22	0.17	23
Arsenic	0.001	mg/L	0.013	0.017	< 0.001	0.001
Arsenic (filtered)	0.001	mg/L	< 0.01	0.013	< 0.001	0.001
Cadmium	0.0002	mg/L	< 0.002	< 0.0002	< 0.0002	0.0004
Cadmium (filtered)	0.0002	mg/L	< 0.002	< 0.0002	< 0.0002	0.0004
Chromium	0.001	mg/L	< 0.01	0.005	< 0.001	0.002
Chromium (filtered)	0.001	mg/L	< 0.01	0.004	< 0.001	0.001
Copper	0.001	mg/L	< 0.01	< 0.001	< 0.001	< 0.001
Copper (filtered)	0.001	mg/L	< 0.01	< 0.001	< 0.001	< 0.001
Iron	0.05	mg/L	1400	140	1.0	1.3
Iron (filtered)	0.05	mg/L	1100	140	0.92	0.73
Lead	0.001	mg/L	< 0.01	< 0.001	< 0.001	< 0.001
Lead (filtered)	0.001	mg/L	< 0.01	< 0.001	< 0.001	< 0.001
Manganese	0.005	mg/L	2.5	0.055	0.029	0.037
Manganese (filtered)	0.005	mg/L	2.5	0.055	0.025	0.036
Mercury	0.0001	mg/L	< 0.001	< 0.0001	< 0.0001	< 0.0001
Mercury (filtered)	0.0001	mg/L	< 0.001	< 0.0001	< 0.0001	< 0.0001
Nickel	0.001	mg/L	0.18	0.031	0.001	0.058
Nickel (filtered)	0.001	mg/L	0.18	0.031	< 0.001	0.058
Zinc	0.005	mg/L	0.37	0.11	< 0.005	0.45
Zinc (filtered)	0.005	mg/L	0.37	0.11	< 0.005	0.45
Alkali Metals						
Calcium	0.5	mg/L	370	3.3	5.8	5.1
Magnesium	0.5	mg/L	180	5.8	8.0	8.1
Potassium	0.5	mg/L	13	3.6	4.0	2.9
Sodium	0.5	mg/L	190	50	54	54

Client Sample ID			**YS05-SW**	**TB1**
Sample Matrix			**Water**	**Water**
Eurofins | mgt Sample No.			**M17-Au28102**	**M17-Au28103**
Date Sampled			**Aug 23, 2017**	**Aug 22, 2017**
Test/Reference	LOR	Unit		
Acidity (as CaCO3)	10	mg/L	35	34
Ammonia (as N)	0.01	mg/L	0.02	0.03
Chloride	1	mg/L	150	180
Ferric Iron - Fe3+	0.05	mg/L	0.4	< 0.05
Ferrous Iron - Fe2+	0.05	mg/L	3.0	1.5
Fluoride	0.5	mg/L	< 0.5	< 0.5
Nitrate (as N)	0.02	mg/L	0.11	0.26
Phosphate total (as P)	0.05	mg/L	0.05	0.08
Sulphate (as S)	5	mg/L	< 5	15

Client Sample ID **Sample Matrix** **Eurofins | mgt Sample No.** **Date Sampled** Test/Reference	LOR	Unit	**YS05-SW** **Water** **M17-Au28102** **Aug 23, 2017**	**TB1** **Water** **M17-Au28103** **Aug 22, 2017**
Sulphate (as SO4)	5	mg/L	13	46
Sulphide (as S)	0.05	mg/L	< 0.05	< 0.05
Sulphite (as S)	0.5	mg/L	< 1	< 1
Thiosulphate (as S)	1	mg/L	< 2	< 2
Total Sulphur (as S)	5	mg/L	< 5	15
Alkalinity (speciated)				
Bicarbonate Alkalinity (as CaCO3)	20	mg/L	< 20	< 20
Carbonate Alkalinity (as CaCO3)	10	mg/L	< 10	< 10
Hydroxide Alkalinity (as CaCO3)	10	mg/L	< 10	< 10
Total Alkalinity (as CaCO3)	20	mg/L	< 20	< 20
Heavy Metals				
Aluminium	0.05	mg/L	0.16	< 0.05
Aluminium (filtered)	0.05	mg/L	0.16	< 0.05
Arsenic	0.001	mg/L	0.003	< 0.001
Arsenic (filtered)	0.001	mg/L	0.003	< 0.001
Cadmium	0.0002	mg/L	< 0.0002	< 0.0002
Cadmium (filtered)	0.0002	mg/L	< 0.0002	< 0.0002
Chromium	0.001	mg/L	< 0.001	< 0.001
Chromium (filtered)	0.001	mg/L	< 0.001	< 0.001
Copper	0.001	mg/L	< 0.001	0.002
Copper (filtered)	0.001	mg/L	< 0.001	0.002
Iron	0.05	mg/L	3.6	5.7
Iron (filtered)	0.05	mg/L	3.4	1.5
Lead	0.001	mg/L	< 0.001	< 0.001
Lead (filtered)	0.001	mg/L	< 0.001	< 0.001
Manganese	0.005	mg/L	0.009	0.14
Manganese (filtered)	0.005	mg/L	0.008	0.14
Mercury	0.0001	mg/L	< 0.0001	< 0.0001
Mercury (filtered)	0.0001	mg/L	< 0.0001	< 0.0001
Nickel	0.001	mg/L	0.002	0.008
Nickel (filtered)	0.001	mg/L	0.002	0.008
Zinc	0.005	mg/L	0.014	0.065
Zinc (filtered)	0.005	mg/L	0.014	0.065
Alkali Metals				
Calcium	0.5	mg/L	4.7	24
Magnesium	0.5	mg/L	7.5	10
Potassium	0.5	mg/L	3.8	4.0
Sodium	0.5	mg/L	62	58

Sample History

Where samples are submitted/analysed over several days, the last date of extraction and analysis is reported.
A recent review of our LIMS has resulted in the correction or clarification of some method identifications. Due to this, some of the method reference information on reports has changed. However, no substantive change has been made to our laboratory methods, and as such there is no change in the validity of current or previous results (regarding both quality and NATA accreditation).

If the date and time of sampling are not provided, the Laboratory will not be responsible for compromised results should testing be performed outside the recommended holding time.

Description	Testing Site	Extracted	Holding Time
Acidity (as CaCO3)	Melbourne	Aug 28, 2017	14 Day
- Method: LTM-INO-4210 Acidity			
Ammonia (as N)	Melbourne	Aug 28, 2017	28 Day
- Method: APHA 4500-NH3 Ammonia Nitrogen by FIA			
Nitrate (as N)	Melbourne	Aug 31, 2017	7 Day
- Method: APHA 4500-NO3 Nitrate Nitrogen by FIA			
Phosphate total (as P)	Melbourne	Aug 28, 2017	28 Day
- Method: APHA 4500-P E. Phosphorous			
Heavy Metals	Melbourne	Aug 28, 2017	180 Day
- Method: LTM-MET-3040 Metals in Waters by ICP-MS			
Heavy Metals (filtered)	Melbourne	Aug 28, 2017	180 Day
- Method: LTM-MET-3040 Metals in Waters by ICP-MS			
Mercury (filtered)	Melbourne	Aug 28, 2017	28 Day
- Method: USEPA 7470/1 Mercury			
Alkali Metals	Melbourne	Aug 28, 2017	180 Day
- Method: USEPA 6010 Alkali Metals			
Eurofins | mgt Suite B11F: Cl, SO4, Alkalinity (CO3, HCO3, OH-, Total Alkalinity), Total F			
Chloride	Melbourne	Aug 28, 2017	28 Day
- Method: LTM-INO-4090 Chloride by Discrete Analyser			
Fluoride	Melbourne	Aug 28, 2017	28 Day
- Method: APHA-F-C			
Sulphate (as SO4)	Melbourne	Aug 28, 2017	28 Day
- Method: LTM-INO-4110 Sulfate by Discrete Analyser			
Alkalinity (speciated)	Melbourne	Aug 28, 2017	14 Day
- Method: APHA 2320 Alkalinity by Titration			
Iron (speciated)			
Ferrous Iron - Fe2+	Melbourne	Aug 28, 2017	7 Days
- Method: LTM-INO-4190 Ferrous Iron in Water by Discrete Analyser			
Total Sulphur Set (as S)			
Sulphate (as S)	Melbourne	Aug 28, 2017	28 Day
- Method: LTM-INO-4110 Sulfate by Discrete Analyser			
Sulphide (as S)	Melbourne	Aug 28, 2017	7 Day
- Method: APHA 4500-S C & D - Sulphide			
Sulphite (as S)	Melbourne	Aug 28, 2017	2 Day
- Method: LTM-INO-4240 Sulfite & Thiosulfate in Water			
Thiosulphate (as S)	Melbourne	Aug 28, 2017	2 Day
- Method: LTM-INO-4240 Sulfite & Thiosulfate in Water			
Total Sulphur (as S)	Melbourne	Aug 28, 2017	7 Day
- Method: Sum of Constituent Analytes			

Company Name: Jacobs Group (Australia) P/L VIC
Address: PO Box 312 Flinders Lane
Melbourne
VIC 8009

Project Name: BARWON WATER TASK 5
Project ID: IS191000

Order No.:
Report #: 559951
Phone: 03 8668 3000
Fax: 03 8668 3001

Received: Aug 23, 2017 5:50 PM
Due: Aug 31, 2017
Priority: 5 Day
Contact Name: Nicolaas Unland

Eurofins | mgt Analytical Services Manager : Mary Makarios

Sample Detail						Acidity (as CaCO3)	Aluminium	Aluminium (filtered)	Ammonia (as N)	Arsenic	Arsenic (filtered)	Cadmium	Cadmium (filtered)	Chromium	Chromium (filtered)	Copper	Copper (filtered)	Iron (filtered)	Lead	Lead (filtered)	Manganese	Manganese (filtered)	Mercury	Mercury (filtered)	Nickel	Nickel (filtered)	Nitrate (as N)	Phosphate total (as P)	Zinc	Zinc (filtered)	Alkali Metals	Iron (speciated)	Total Sulphur Set (as S)	Eurofins | mgt Suite B11F: Cl, SO4, Alkalinity (CO3, HCO3, OH-, Total Alkalinity), Total F
Melbourne Laboratory - NATA Site # 1254 & 14271						X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Sydney Laboratory - NATA Site # 18217																																		
Brisbane Laboratory - NATA Site # 20794																																		
Perth Laboratory - NATA Site # 23736																																		
External Laboratory																																		
No	**Sample ID**	**Sample Date**	**Sampling Time**	**Matrix**	**LAB ID**																													
1	MCDONALDS	Aug 22, 2017		Water	M17-Au28086	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
2	DAMPLANDS	Aug 22, 2017		Water	M17-Au28087	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
3	YEODENE SWAMP U/S	Aug 22, 2017		Water	M17-Au28088	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
4	YEODENE SWAMP D/S	Aug 22, 2017		Water	M17-Au28089	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
5	YG	Aug 22, 2017		Water	M17-Au28090	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
6	LOWER BC	Aug 22, 2017		Water	M17-Au28091	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
7	A3	Aug 22, 2017		Water	M17-Au28092	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
8	LBC02	Aug 22, 2017		Water	M17-Au28093	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

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Sample Detail						Acidity (as CaCO3)	Aluminium	Aluminium (filtered)	Ammonia (as N)	Arsenic	Arsenic (filtered)	Cadmium	Cadmium (filtered)	Chromium	Chromium (filtered)	Copper	Copper (filtered)	Iron (filtered)	Lead	Lead (filtered)	Manganese	Manganese (filtered)	Mercury	Mercury (filtered)	Nickel	Nickel (filtered)	Nitrate (as N)	Phosphate total (as P)	Zinc	Zinc (filtered)	Alkali Metals	Iron (speciated)	Total Sulphur Set (as S)	Eurofins | mgt Suite B11F: Cl, SO4, Alkalinity (CO3, HCO3, OH-, Total Alkalinity), Total F
Melbourne Laboratory - NATA Site # 1254 & 14271						X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Sydney Laboratory - NATA Site # 18217																																		
Brisbane Laboratory - NATA Site # 20794																																		
Perth Laboratory - NATA Site # 23736																																		
9	LBC01	Aug 23, 2017		Water	M17-Au28094	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
10	PASS1	Aug 23, 2017		Water	M17-Au28095	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
11	YS01	Aug 23, 2017		Water	M17-Au28096	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
12	YS02	Aug 23, 2017		Water	M17-Au28097	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
13	YS03	Aug 23, 2017		Water	M17-Au28098	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
14	YS05	Aug 23, 2017		Water	M17-Au28099	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
15	YS06	Aug 22, 2017		Water	M17-Au28100	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
16	YS02-SW	Aug 23, 2017		Water	M17-Au28101	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
17	YS05-SW	Aug 23, 2017		Water	M17-Au28102	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
18	TB1	Aug 22, 2017		Water	M17-Au28103	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Test Counts						18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18

Internal Quality Control Review and Glossary

General

1. Laboratory QC results for Method Blanks, Duplicates, Matrix Spikes, and Laboratory Control Samples are included in this QC report where applicable. Additional QC data may be available on request.
2. All soil results are reported on a dry basis, unless otherwise stated.
3. All biota results are reported on a wet weight basis on the edible portion, unless otherwise stated.
4. Actual LORs are matrix dependant. Quoted LORs may be raised where sample extracts are diluted due to interferences.
5. Results are uncorrected for matrix spikes or surrogate recoveries except for PFAS compounds.
6. SVOC analysis on waters are performed on homogenised, unfiltered samples, unless noted otherwise.
7. Samples were analysed on an 'as received' basis.
8. This report replaces any interim results previously issued.

Holding Times

Please refer to 'Sample Preservation and Container Guide' for holding times (QS3001).

For samples received on the last day of holding time, notification of testing requirements should have been received at least 6 hours prior to sample receipt deadlines as stated on the Sample Receipt Advice.

If the Laboratory did not receive the information in the required timeframe, and regardless of any other integrity issues, suitably qualified results may still be reported.

Holding times apply from the date of sampling, therefore compliance to these may be outside the laboratory's control.

****NOTE:** pH duplicates are reported as a range NOT as RPD

Units

mg/kg: milligrams per kilogram	**mg/L:** milligrams per litre
ug/L: micrograms per litre	**ppm:** Parts per million
ppb: Parts per billion	**%:** Percentage
org/100mL: Organisms per 100 millilitres	**NTU:** Nephelometric Turbidity Units
MPN/100mL: Most Probable Number of organisms per 100 millilitres	

Terms

Dry	Where a moisture has been determined on a solid sample the result is expressed on a dry basis.
LOR	Limit of Reporting.
SPIKE	Addition of the analyte to the sample and reported as percentage recovery.
RPD	Relative Percent Difference between two Duplicate pieces of analysis.
LCS	Laboratory Control Sample - reported as percent recovery.
CRM	Certified Reference Material - reported as percent recovery.
Method Blank	In the case of solid samples these are performed on laboratory certified clean sands and in the case of water samples these are performed on de-ionised water.
Surr - Surrogate	The addition of a like compound to the analyte target and reported as percentage recovery.
Duplicate	A second piece of analysis from the same sample and reported in the same units as the result to show comparison.
USEPA	United States Environmental Protection Agency
APHA	American Public Health Association
TCLP	Toxicity Characteristic Leaching Procedure
COC	Chain of Custody
SRA	Sample Receipt Advice
QSM	Quality Systems Manual ver 5.1 US Department of Defense
CP	Client Parent - QC was performed on samples pertaining to this report
NCP	Non-Client Parent - QC performed on samples not pertaining to this report, QC is representative of the sequence or batch that client samples were analysed within.
TEQ	Toxic Equivalency Quotient

QC - Acceptance Criteria

RPD Duplicates: Global RPD Duplicates Acceptance Criteria is 30% however the following acceptance guidelines are equally applicable:

Results <10 times the LOR : No Limit

Results between 10-20 times the LOR : RPD must lie between 0-50%

Results >20 times the LOR : RPD must lie between 0-30%

Surrogate Recoveries: Recoveries must lie between 50-150%-Phenols & PFASs

PFAS field samples that contain surrogate recoveries in excess of the QC limit designated in QSM 5.1 where no positive PFAS results have been reported have been reviewed and no data was affected.

QC Data General Comments

1. Where a result is reported as a less than (<), higher than the nominated LOR, this is due to either matrix interference, extract dilution required due to interferences or contaminant levels within the sample, high moisture content or insufficient sample provided.
2. Duplicate data shown within this report that states the word "BATCH" is a Batch Duplicate from outside of your sample batch, but within the laboratory sample batch at a 1:10 ratio. The Parent and Duplicate data shown is not data from your samples.
3. Organochlorine Pesticide analysis - where reporting LCS data, Toxaphene & Chlordane are not added to the LCS.
4. Organochlorine Pesticide analysis - where reporting Spike data, Toxaphene is not added to the Spike.
5. Total Recoverable Hydrocarbons - where reporting Spike & LCS data, a single spike of commercial Hydrocarbon products in the range of C12-C30 is added and it's Total Recovery is reported in the C10-C14 cell of the Report.
6. pH and Free Chlorine analysed in the laboratory - Analysis on this test must begin within 30 minutes of sampling.Therefore laboratory analysis is unlikely to be completed within holding time. Analysis will begin as soon as possible after sample receipt.
7. Recovery Data (Spikes & Surrogates) - where chromatographic interference does not allow the determination of Recovery the term "INT" appears against that analyte.
8. Polychlorinated Biphenyls are spiked only using Aroclor 1260 in Matrix Spikes and LCS.
9. For Matrix Spikes and LCS results a dash " -" in the report means that the specific analyte was not added to the QC sample.
10. Duplicate RPDs are calculated from raw analytical data thus it is possible to have two sets of data.

Quality Control Results

Test	Units	Result 1			Acceptance Limits	Pass Limits	Qualifying Code
Method Blank							
Acidity (as CaCO3)	mg/L	< 10			10	Pass	
Ammonia (as N)	mg/L	< 0.01			0.01	Pass	
Chloride	mg/L	< 1			1	Pass	
Ferrous Iron - Fe2+	mg/L	< 0.05			0.05	Pass	
Fluoride	mg/L	< 0.5			0.5	Pass	
Nitrate (as N)	mg/L	< 0.02			0.02	Pass	
Phosphate total (as P)	mg/L	< 0.05			0.05	Pass	
Sulphate (as S)	mg/L	< 5			5	Pass	
Sulphate (as SO4)	mg/L	< 5			5	Pass	
Sulphide (as S)	mg/L	< 0.05			0.05	Pass	
Sulphite (as S)	mg/L	< 0.5			0.5	Pass	
Thiosulphate (as S)	mg/L	< 1			1	Pass	
Method Blank							
Alkalinity (speciated)							
Bicarbonate Alkalinity (as CaCO3)	mg/L	< 20			20	Pass	
Carbonate Alkalinity (as CaCO3)	mg/L	< 10			10	Pass	
Hydroxide Alkalinity (as CaCO3)	mg/L	< 10			10	Pass	
Total Alkalinity (as CaCO3)	mg/L	< 20			20	Pass	
Method Blank							
Heavy Metals							
Aluminium	mg/L	< 0.05			0.05	Pass	
Aluminium (filtered)	mg/L	< 0.05			0.05	Pass	
Arsenic	mg/L	< 0.001			0.001	Pass	
Arsenic (filtered)	mg/L	< 0.001			0.001	Pass	
Cadmium	mg/L	< 0.0002			0.0002	Pass	
Cadmium (filtered)	mg/L	< 0.0002			0.0002	Pass	
Chromium	mg/L	< 0.001			0.001	Pass	
Chromium (filtered)	mg/L	< 0.001			0.001	Pass	
Copper	mg/L	< 0.001			0.001	Pass	
Copper (filtered)	mg/L	< 0.001			0.001	Pass	
Iron	mg/L	< 0.05			0.05	Pass	
Iron (filtered)	mg/L	< 0.05			0.05	Pass	
Lead	mg/L	< 0.001			0.001	Pass	
Lead (filtered)	mg/L	< 0.001			0.001	Pass	
Manganese	mg/L	< 0.005			0.005	Pass	
Manganese (filtered)	mg/L	< 0.005			0.005	Pass	
Mercury	mg/L	< 0.0001			0.0001	Pass	
Mercury (filtered)	mg/L	< 0.0001			0.0001	Pass	
Nickel	mg/L	< 0.001			0.001	Pass	
Nickel (filtered)	mg/L	< 0.001			0.001	Pass	
Zinc	mg/L	< 0.005			0.005	Pass	
Zinc (filtered)	mg/L	< 0.005			0.005	Pass	
Method Blank							
Alkali Metals							
Calcium	mg/L	< 0.5			0.5	Pass	
Magnesium	mg/L	< 0.5			0.5	Pass	
Potassium	mg/L	< 0.5			0.5	Pass	
Sodium	mg/L	< 0.5			0.5	Pass	
LCS - % Recovery							
Acidity (as CaCO3)	%	104			70-130	Pass	
Ammonia (as N)	%	100			70-130	Pass	

Test	Units	Result 1			Acceptance Limits	Pass Limits	Qualifying Code
Chloride	%	114			70-130	Pass	
Ferrous Iron - Fe2+	%	101			70-130	Pass	
Fluoride	%	90			70-130	Pass	
Nitrate (as N)	%	96			70-130	Pass	
Phosphate total (as P)	%	95			70-130	Pass	
Sulphate (as S)	%	114			70-130	Pass	
Sulphate (as SO4)	%	114			70-130	Pass	
Sulphide (as S)	%	102			70-130	Pass	
Thiosulphate (as S)	%	100			70-130	Pass	
LCS - % Recovery							
Alkalinity (speciated)							
Bicarbonate Alkalinity (as CaCO3)	%	83			70-130	Pass	
Carbonate Alkalinity (as CaCO3)	%	97			70-130	Pass	
Total Alkalinity (as CaCO3)	%	99			70-130	Pass	
LCS - % Recovery							
Heavy Metals							
Aluminium	%	120			80-120	Pass	
Aluminium (filtered)	%	120			80-120	Pass	
Arsenic	%	104			80-120	Pass	
Arsenic (filtered)	%	104			80-120	Pass	
Cadmium	%	105			80-120	Pass	
Cadmium (filtered)	%	105			80-120	Pass	
Chromium	%	104			80-120	Pass	
Chromium (filtered)	%	104			80-120	Pass	
Copper	%	105			80-120	Pass	
Copper (filtered)	%	105			80-120	Pass	
Iron	%	105			80-120	Pass	
Iron (filtered)	%	105			80-120	Pass	
Lead	%	104			80-120	Pass	
Lead (filtered)	%	104			80-120	Pass	
Manganese	%	105			80-120	Pass	
Manganese (filtered)	%	105			80-120	Pass	
Mercury	%	92			75-125	Pass	
Mercury (filtered)	%	92			70-130	Pass	
Nickel	%	105			80-120	Pass	
Nickel (filtered)	%	105			80-120	Pass	
Zinc	%	106			80-120	Pass	
Zinc (filtered)	%	106			80-120	Pass	
LCS - % Recovery							
Alkali Metals							
Calcium	%	99			70-130	Pass	
Magnesium	%	112			70-130	Pass	
Potassium	%	93			70-130	Pass	
Sodium	%	91			70-130	Pass	

Test	Lab Sample ID	QA Source	Units	Result 1			Acceptance Limits	Pass Limits	Qualifying Code
Spike - % Recovery									
				Result 1					
Sulphate (as S)	M17-Au28188	NCP	%	105			70-130	Pass	
Sulphate (as SO4)	M17-Au28188	NCP	%	105			70-130	Pass	
Spike - % Recovery									
Alkalinity (speciated)				Result 1					
Carbonate Alkalinity (as CaCO3)	M17-Au27506	NCP	%	85			70-130	Pass	
Total Alkalinity (as CaCO3)	M17-Au27506	NCP	%	113			70-130	Pass	
Spike - % Recovery									

Test	Lab Sample ID	QA Source	Units	Result 1			Acceptance Limits	Pass Limits	Qualifying Code
Heavy Metals				Result 1					
Aluminium	S17-Au29598	NCP	%	114			75-125	Pass	
Aluminium (filtered)	M17-Au28086	CP	%	108			75-125	Pass	
Arsenic (filtered)	M17-Au28086	CP	%	95			70-130	Pass	
Cadmium (filtered)	M17-Au28086	CP	%	94			70-130	Pass	
Chromium (filtered)	M17-Au28086	CP	%	92			70-130	Pass	
Copper (filtered)	M17-Au28086	CP	%	93			70-130	Pass	
Lead (filtered)	M17-Au28086	CP	%	94			70-130	Pass	
Manganese (filtered)	M17-Au28086	CP	%	88			70-130	Pass	
Mercury (filtered)	M17-Au28086	CP	%	87			70-130	Pass	
Nickel (filtered)	M17-Au28086	CP	%	92			70-130	Pass	
Zinc (filtered)	M17-Au28086	CP	%	99			70-130	Pass	
Spike - % Recovery									
Alkali Metals				Result 1					
Calcium	M17-Au31093	NCP	%	101			70-130	Pass	
Magnesium	M17-Au31093	NCP	%	92			70-130	Pass	
Potassium	M17-Au28001	NCP	%	100			70-130	Pass	
Spike - % Recovery									
				Result 1					
Chloride	M17-Au28087	CP	%	105			70-130	Pass	
Spike - % Recovery									
				Result 1					
Chloride	M17-Au28091	CP	%	103			70-130	Pass	
Spike - % Recovery									
Alkalinity (speciated)				Result 1					
Bicarbonate Alkalinity (as CaCO3)	P17-Au30755	NCP	%	78			70-130	Pass	
Spike - % Recovery									
				Result 1					
Ammonia (as N)	M17-Au28096	CP	%	98			70-130	Pass	
Nitrate (as N)	M17-Au28096	CP	%	75			70-130	Pass	
Spike - % Recovery									
Heavy Metals				Result 1					
Arsenic (filtered)	M17-Au28096	CP	%	109			70-130	Pass	
Cadmium (filtered)	M17-Au28096	CP	%	100			70-130	Pass	
Chromium (filtered)	M17-Au28096	CP	%	104			70-130	Pass	
Copper (filtered)	M17-Au28096	CP	%	99			70-130	Pass	
Lead (filtered)	M17-Au28096	CP	%	103			70-130	Pass	
Manganese (filtered)	M17-Au28096	CP	%	38			70-130	Fail	Q08
Mercury (filtered)	M17-Au28096	CP	%	98			70-130	Pass	
Nickel (filtered)	M17-Au28096	CP	%	36			70-130	Fail	Q08
Spike - % Recovery									
				Result 1					
Phosphate total (as P)	M17-Au28098	CP	%	94			70-130	Pass	
Spike - % Recovery									
Alkali Metals				Result 1					
Sodium	M17-Au28099	CP	%	104			70-130	Pass	
Spike - % Recovery									
				Result 1					
Ferrous Iron - Fe2+	M17-Au28101	CP	%	94			70-130	Pass	
Spike - % Recovery									
Heavy Metals				Result 1					
Arsenic	M17-Au28101	CP	%	97			75-125	Pass	
Cadmium	M17-Au28101	CP	%	94			75-125	Pass	
Chromium	M17-Au28101	CP	%	92			75-125	Pass	

Test	Lab Sample ID	QA Source	Units	Result 1			Acceptance Limits	Pass Limits	Qualifying Code
Copper	M17-Au28101	CP	%	93			75-125	Pass	
Lead	M17-Au28101	CP	%	94			75-125	Pass	
Manganese	M17-Au28101	CP	%	92			75-125	Pass	
Mercury	M17-Au28101	CP	%	90			70-130	Pass	
Nickel	M17-Au28101	CP	%	86			75-125	Pass	
Test	**Lab Sample ID**	**QA Source**	**Units**	**Result 1**			**Acceptance Limits**	**Pass Limits**	**Qualifying Code**
Duplicate									
				Result 1	Result 2	RPD			
Acidity (as CaCO3)	M17-Au28086	CP	mg/L	< 10	< 10	<1	30%	Pass	
Sulphite (as S)	M17-Au35272	NCP	mg/L	< 5	< 5	<1	30%	Pass	
Thiosulphate (as S)	M17-Au35272	NCP	mg/L	< 10	< 10	<1	30%	Pass	
Duplicate									
Alkalinity (speciated)				Result 1	Result 2	RPD			
Bicarbonate Alkalinity (as CaCO3)	M17-Au28086	CP	mg/L	< 20	< 20	<1	30%	Pass	
Carbonate Alkalinity (as CaCO3)	M17-Au28086	CP	mg/L	< 10	< 10	<1	30%	Pass	
Hydroxide Alkalinity (as CaCO3)	M17-Au28086	CP	mg/L	< 10	< 10	<1	30%	Pass	
Total Alkalinity (as CaCO3)	M17-Au28086	CP	mg/L	< 20	< 20	<1	30%	Pass	
Duplicate									
Heavy Metals				Result 1	Result 2	RPD			
Aluminium (filtered)	M17-Au28086	CP	mg/L	0.17	0.18	5.0	30%	Pass	
Arsenic (filtered)	M17-Au28086	CP	mg/L	< 0.001	< 0.001	<1	30%	Pass	
Cadmium (filtered)	M17-Au28086	CP	mg/L	< 0.0002	< 0.0002	<1	30%	Pass	
Chromium (filtered)	M17-Au28086	CP	mg/L	< 0.001	< 0.001	<1	30%	Pass	
Copper (filtered)	M17-Au28086	CP	mg/L	< 0.001	< 0.001	<1	30%	Pass	
Iron (filtered)	M17-Au28086	CP	mg/L	0.92	0.94	2.0	30%	Pass	
Lead (filtered)	M17-Au28086	CP	mg/L	< 0.001	< 0.001	<1	30%	Pass	
Manganese (filtered)	M17-Au28086	CP	mg/L	0.050	0.049	1.0	30%	Pass	
Mercury (filtered)	M17-Au28086	CP	mg/L	< 0.0001	< 0.0001	<1	30%	Pass	
Nickel (filtered)	M17-Au28086	CP	mg/L	< 0.001	< 0.001	<1	30%	Pass	
Zinc (filtered)	M17-Au28086	CP	mg/L	0.005	0.006	4.0	30%	Pass	
Duplicate									
				Result 1	Result 2	RPD			
Chloride	M17-Au28087	CP	mg/L	140	130	3.7	30%	Pass	
Sulphate (as S)	M17-Au28087	CP	mg/L	< 5	< 5	<1	30%	Pass	
Sulphate (as SO4)	M17-Au28087	CP	mg/L	7.8	7.4	5.7	30%	Pass	
Duplicate									
				Result 1	Result 2	RPD			
Phosphate total (as P)	M17-Au28088	CP	mg/L	0.08	0.08	2.0	30%	Pass	
Duplicate									
				Result 1	Result 2	RPD			
Chloride	M17-Au28091	CP	mg/L	220	220	<1	30%	Pass	
Sulphate (as S)	M17-Au28091	CP	mg/L	35	35	<1	30%	Pass	
Sulphate (as SO4)	M17-Au28091	CP	mg/L	110	110	<1	30%	Pass	
Duplicate									
				Result 1	Result 2	RPD			
Ferrous Iron - Fe2+	M17-Au28094	CP	mg/L	100	100	1.4	30%	Pass	
Duplicate									
				Result 1	Result 2	RPD			
Ammonia (as N)	M17-Au28096	CP	mg/L	0.22	0.23	4.0	30%	Pass	
Fluoride	M17-Au28096	CP	mg/L	< 0.5	< 0.5	<1	30%	Pass	
Nitrate (as N)	M17-Au28096	CP	mg/L	< 0.02	< 0.02	<1	30%	Pass	

Duplicate									
Alkalinity (speciated)				Result 1	Result 2	RPD			
Bicarbonate Alkalinity (as CaCO3)	M17-Au28096	CP	mg/L	< 20	< 20	<1	30%	Pass	
Carbonate Alkalinity (as CaCO3)	M17-Au28096	CP	mg/L	< 10	< 10	<1	30%	Pass	
Hydroxide Alkalinity (as CaCO3)	M17-Au28096	CP	mg/L	< 10	< 10	<1	30%	Pass	
Total Alkalinity (as CaCO3)	M17-Au28096	CP	mg/L	< 20	< 20	<1	30%	Pass	
Duplicate									
Heavy Metals				Result 1	Result 2	RPD			
Aluminium (filtered)	M17-Au28096	CP	mg/L	73	78	7.0	30%	Pass	
Arsenic (filtered)	M17-Au28096	CP	mg/L	0.006	0.006	2.0	30%	Pass	
Cadmium (filtered)	M17-Au28096	CP	mg/L	0.0024	0.0024	<1	30%	Pass	
Chromium (filtered)	M17-Au28096	CP	mg/L	0.005	0.006	2.0	30%	Pass	
Copper (filtered)	M17-Au28096	CP	mg/L	< 0.005	< 0.005	<1	30%	Pass	
Iron (filtered)	M17-Au28096	CP	mg/L	91	88	8.0	30%	Pass	
Lead (filtered)	M17-Au28096	CP	mg/L	< 0.005	< 0.005	<1	30%	Pass	
Manganese (filtered)	M17-Au28096	CP	mg/L	0.89	0.88	1.0	30%	Pass	
Mercury (filtered)	M17-Au28096	CP	mg/L	< 0.0005	< 0.0005	<1	30%	Pass	
Nickel (filtered)	M17-Au28096	CP	mg/L	0.86	0.85	1.0	30%	Pass	
Zinc (filtered)	M17-Au28096	CP	mg/L	1.4	1.3	1.0	30%	Pass	
Duplicate									
				Result 1	Result 2	RPD			
Acidity (as CaCO3)	M17-Au28098	CP	mg/L	1900	1900	1.0	30%	Pass	
Sulphide (as S)	M17-Au28098	CP	mg/L	< 0.05	< 0.05	<1	30%	Pass	
Duplicate									
Alkali Metals				Result 1	Result 2	RPD			
Calcium	M17-Au28099	CP	mg/L	3.3	3.3	<1	30%	Pass	
Magnesium	M17-Au28099	CP	mg/L	5.8	5.8	1.0	30%	Pass	
Potassium	M17-Au28099	CP	mg/L	3.6	3.7	3.0	30%	Pass	
Sodium	M17-Au28099	CP	mg/L	50	50	<1	30%	Pass	
Duplicate									
				Result 1	Result 2	RPD			
Ferrous Iron - Fe2+	M17-Au28100	CP	mg/L	0.41	0.40	1.9	30%	Pass	
Duplicate									
Heavy Metals				Result 1	Result 2	RPD			
Aluminium	M17-Au28101	CP	mg/L	25	25	2.0	30%	Pass	
Arsenic	M17-Au28101	CP	mg/L	0.001	0.001	3.0	30%	Pass	
Cadmium	M17-Au28101	CP	mg/L	0.0004	0.0004	3.0	30%	Pass	
Chromium	M17-Au28101	CP	mg/L	0.002	0.003	6.0	30%	Pass	
Copper	M17-Au28101	CP	mg/L	< 0.001	< 0.001	<1	30%	Pass	
Iron	M17-Au28101	CP	mg/L	1.3	1.4	9.0	30%	Pass	
Lead	M17-Au28101	CP	mg/L	< 0.001	< 0.001	<1	30%	Pass	
Manganese	M17-Au28101	CP	mg/L	0.037	0.037	<1	30%	Pass	
Mercury	M17-Au28101	CP	mg/L	< 0.0001	< 0.0001	<1	30%	Pass	
Nickel	M17-Au28101	CP	mg/L	0.058	0.059	2.0	30%	Pass	
Zinc	M17-Au28101	CP	mg/L	0.45	0.45	<1	30%	Pass	
Duplicate									
				Result 1	Result 2	RPD			
Sulphide (as S)	M17-Au28103	CP	mg/L	< 0.05	< 0.05	<1	30%	Pass	

Comments

Sample Integrity

Custody Seals Intact (if used)	N/A
Attempt to Chill was evident	Yes
Sample correctly preserved	Yes
Appropriate sample containers have been used	Yes
Sample containers for volatile analysis received with minimal headspace	Yes
Samples received within HoldingTime	Yes
Some samples have been subcontracted	No

Qualifier Codes/Comments

Code	Description
Q08	The matrix spike recovery is outside of the recommended acceptance criteria. An acceptable recovery was obtained for the laboratory control sample indicating a sample matrix interference

Authorised By

Mary Makarios	Analytical Services Manager
Alex Petridis	Senior Analyst-Metal (VIC)
Huong Le	Senior Analyst-Inorganic (VIC)

Glenn Jackson

National Operations Manager

Final report - this Report replaces any previously issued Report

- Indicates Not Requested

* Indicates NATA accreditation does not cover the performance of this service

Measurement uncertainty of test data is available on request or please click here.

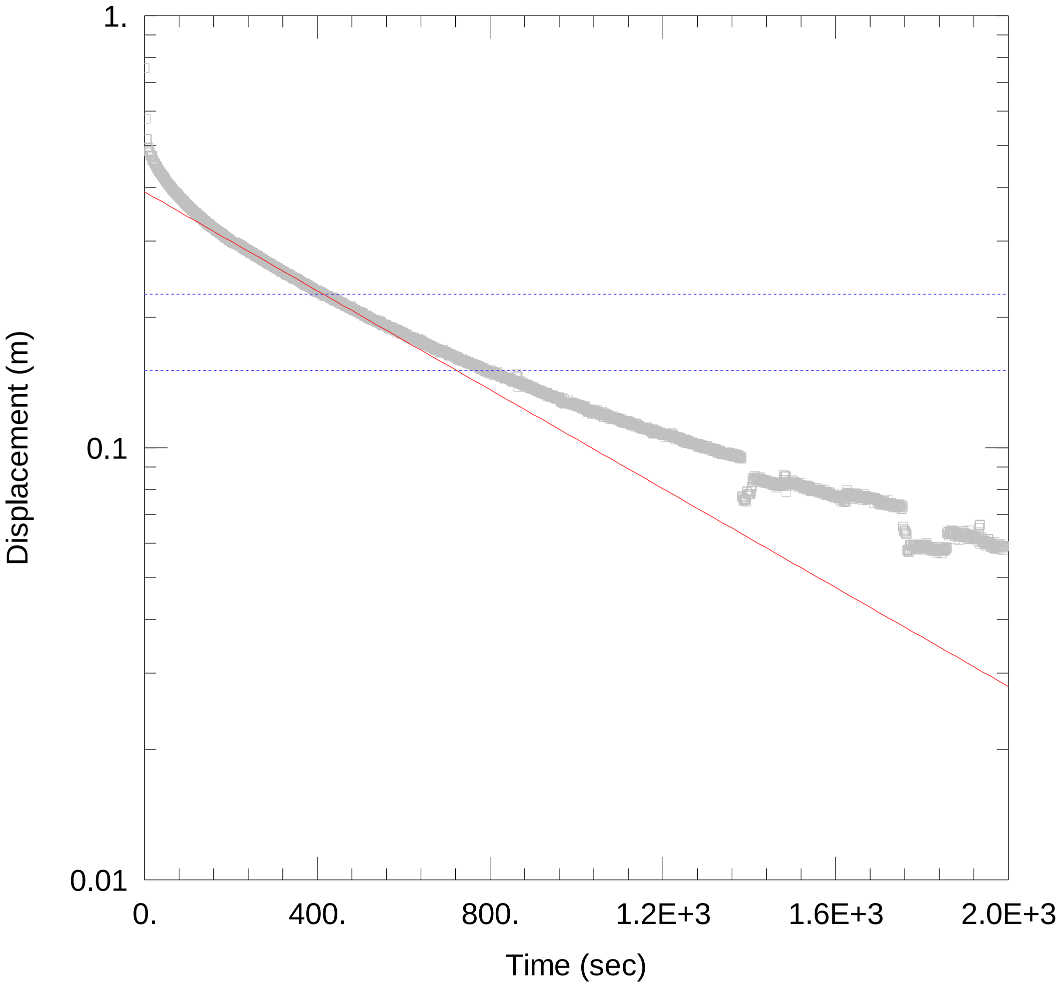
Appendix D. Hydraulic testing

The results of hydraulic testing have been summarised in Table 7-3 below. The results indicate that the hydraulic conductivity of the sediments in Yeodene Swamp and Reach 3 of Boundary typically ranged between 0.02 and 0.2 m/day. This falls within the range of hydraulic conductivities given for silty material similar, to that encountered during these investigations (Domenico and Schwartz, 1990). The exception to this range was YS05 which recorded a hydraulic conductivity of 1.5 m/day. This is at the upper bound of what is expected for unconsolidated silty material (Domenico and Schwartz, 1990) and may reflect a higher sand content at this site.

The results suggest that the hydraulic conductivity of sediments in Yeodene Swamp and Reach 3 of Boundary Creek are in relative terms, moderate to low. However, areas of higher hydraulic conductivity may exist where sands become more abundant. Such areas could facilitate greater groundwater and surface water exchange.

Table 7-3 Summary of hydraulic test analysis

Bore Identification	Test type	Test hydraulic conductivity	Representative hydraulic conductivity
		m/day	m/day
YS01	Falling	0.30	0.20
YS01	Rising	0.11	
YS02	Falling	0.021	0.036
YS02	Rising	0.052	
YS03	Falling	0.052	0.048
YS03	Rising	0.044	
YS05	Falling	1.3	1.5
YS05	Rising	2.0	
YS05	Falling	0.7	
YS05	Rising	1.8	
YS06	Falling	0.28	0.19
YS06	Rising	0.11	
LBC01	Falling	0.041	0.038
LBC01	Rising	0.036	
LBC02	Falling	0.022	0.017
LBC02	Rising	0.013	



WELL TEST ANALYSIS

Data Set: \...\LBC01 - Falling.aqt
Date: 10/10/17
Time: 10:35:29

PROJECT INFORMATION

Company: Jacobs
Client: Barwon Water
Project: IS191000
Location: Yeodene Swamp
Test Well: YS01
Test Date: 26/04/17

AQUIFER DATA

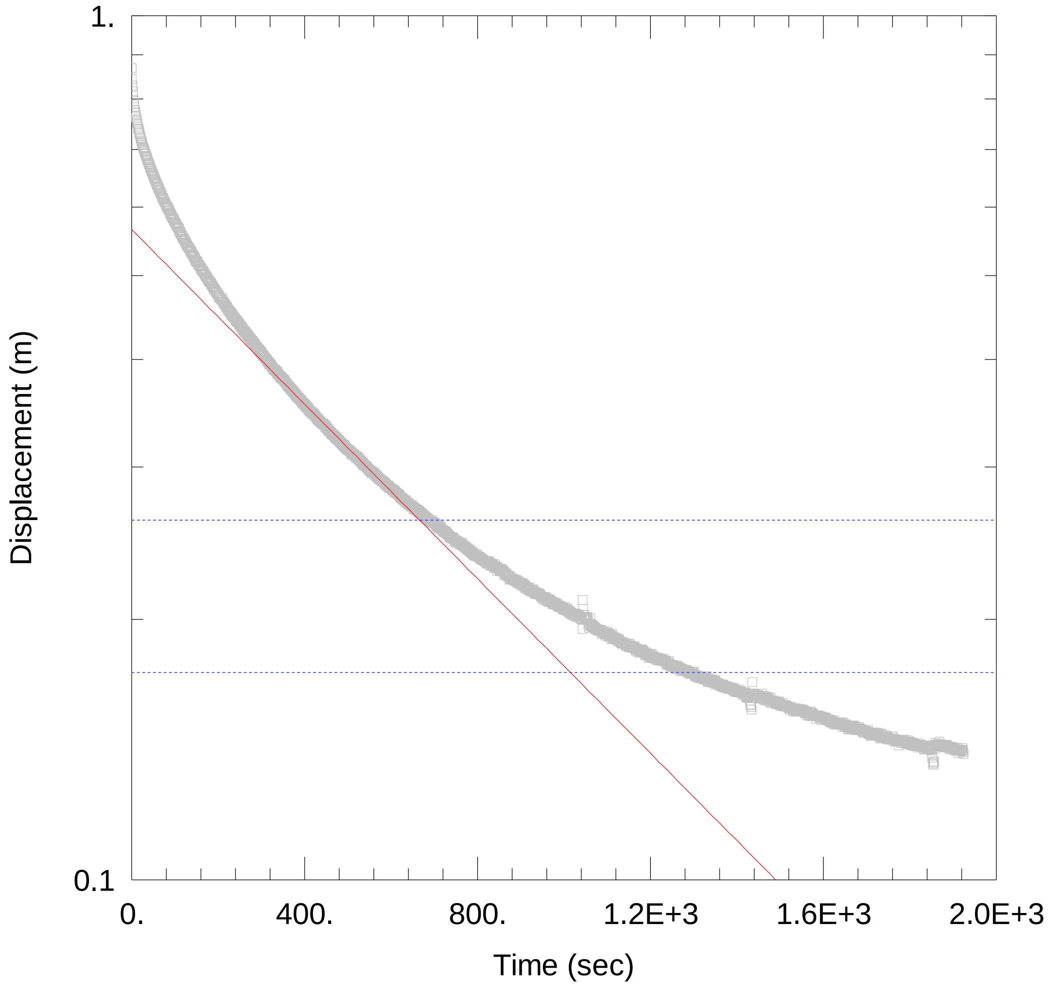
Saturated Thickness: 10. m
Anisotropy Ratio (Kz/Kr): 0.25

WELL DATA (LBC01)

Initial Displacement: 0.7541 m
Static Water Column Height: 6.63 m
Total Well Penetration Depth: 7.6 m
Screen Length: 3. m
Casing Radius: 0.025 m
Well Radius: 0.075 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
K = 0.04105 m/day
y0 = 0.3907 m



WELL TEST ANALYSIS

Data Set: \...\LBC01 - Rising.aqt
Date: 10/10/17 Time: 10:35:49

PROJECT INFORMATION

Company: Jacobs
Client: Barwon Water
Project: IS191000
Location: Yeodene Swamp
Test Well: YS01
Test Date: 26/04/17

AQUIFER DATA

Saturated Thickness: 10. m
Anisotropy Ratio (Kz/Kr): 0.25

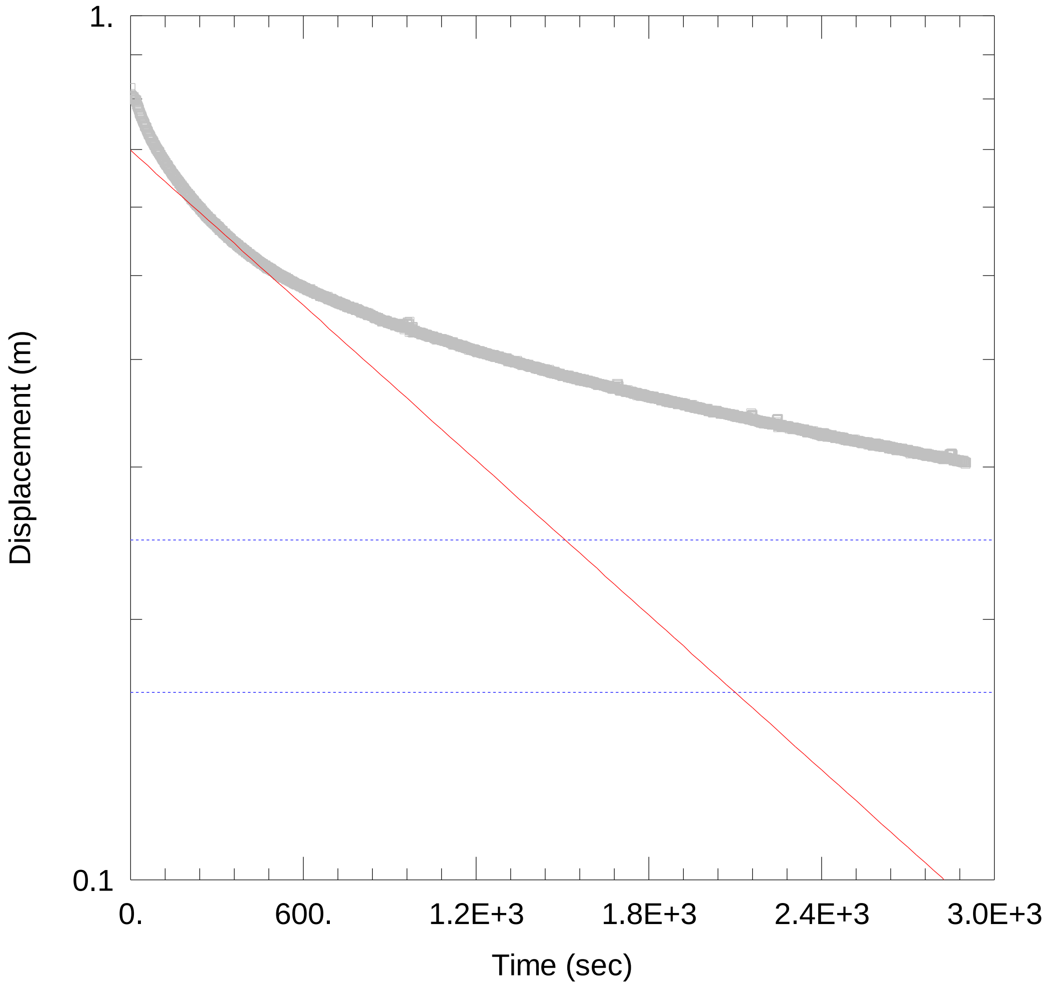
WELL DATA (LBC01)

Initial Displacement: 0.8688 m
Static Water Column Height: 6.63 m
Total Well Penetration Depth: 7.06 m
Screen Length: 3. m
Casing Radius: 0.025 m
Well Radius: 0.075 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

K = 0.03567 m/day
y0 = 0.5654 m



WELL TEST ANALYSIS

Data Set: \...\LBC02 - Falling.aqt
Date: 10/10/17 Time: 10:36:02

PROJECT INFORMATION

Company: Jacobs
Client: Barwon Water
Project: IS191000
Location: Yeodene Swamp
Test Well: YS01
Test Date: 26/04/17

AQUIFER DATA

Saturated Thickness: 10. m
Anisotropy Ratio (Kz/Kr): 0.25

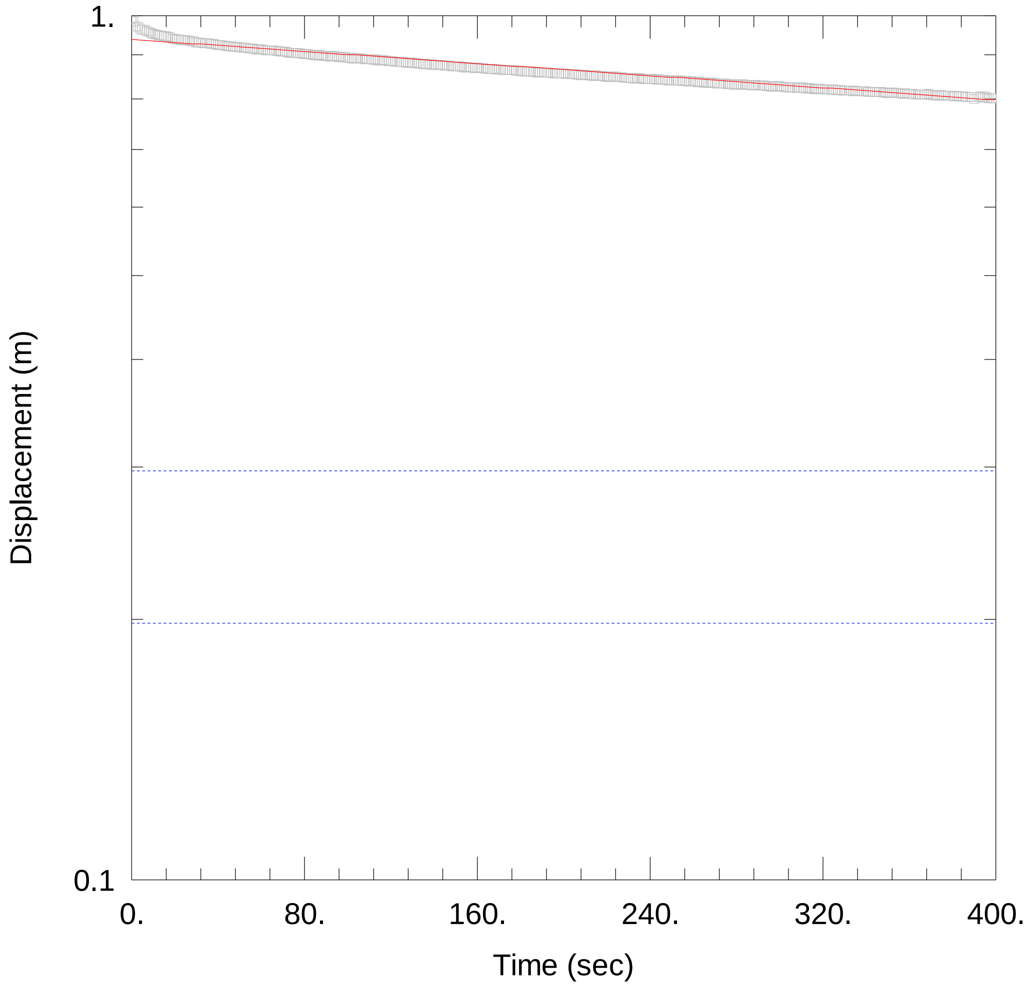
WELL DATA (LBC02)

Initial Displacement: 0.8236 m
Static Water Column Height: 7.31 m
Total Well Penetration Depth: 8.1 m
Screen Length: 3. m
Casing Radius: 0.025 m
Well Radius: 0.075 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

K = 0.02174 m/day
y0 = 0.698 m



WELL TEST ANALYSIS

Data Set: \...\LBC02 - Rising.aqt
Date: 10/10/17 Time: 10:36:15

PROJECT INFORMATION

Company: Jacobs
Client: Barwon Water
Project: IS191000
Location: Yeodene Swamp
Test Well: YS01
Test Date: 26/04/17

AQUIFER DATA

Saturated Thickness: 10. m
Anisotropy Ratio (Kz/Kr): 0.25

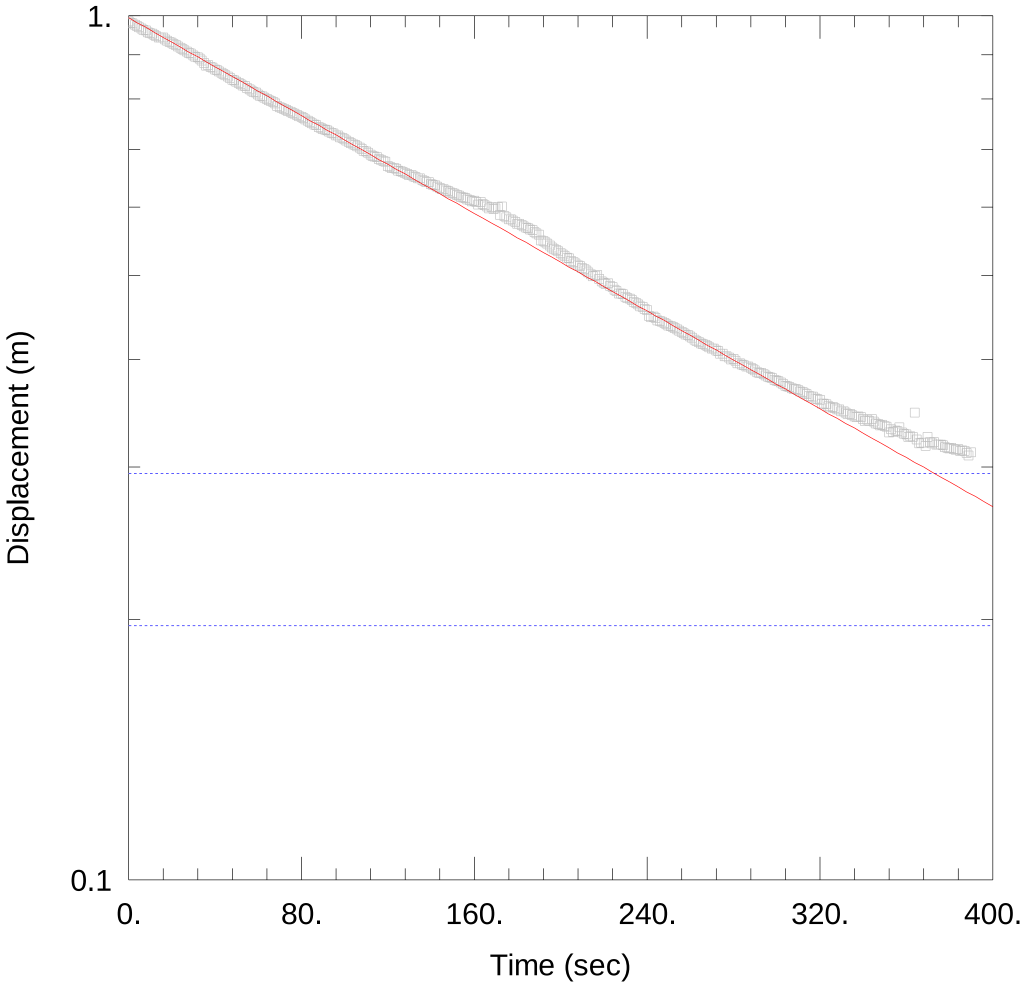
WELL DATA (LBC02)

Initial Displacement: 0.9902 m
Static Water Column Height: 7.31 m
Total Well Penetration Depth: 8.1 m
Screen Length: 3. m
Casing Radius: 0.025 m
Well Radius: 0.075 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

K = 0.01275 m/day
y0 = 0.9382 m



WELL TEST ANALYSIS

Data Set: \...\YS01 - Falling.aqt
Date: 10/10/17 Time: 10:36:34

PROJECT INFORMATION

Company: Jacobs
Client: Barwon Water
Project: IS191000
Location: Yeodene Swamp
Test Well: YS01
Test Date: 26/04/17

AQUIFER DATA

Saturated Thickness: 5. m
Anisotropy Ratio (Kz/Kr): 0.25

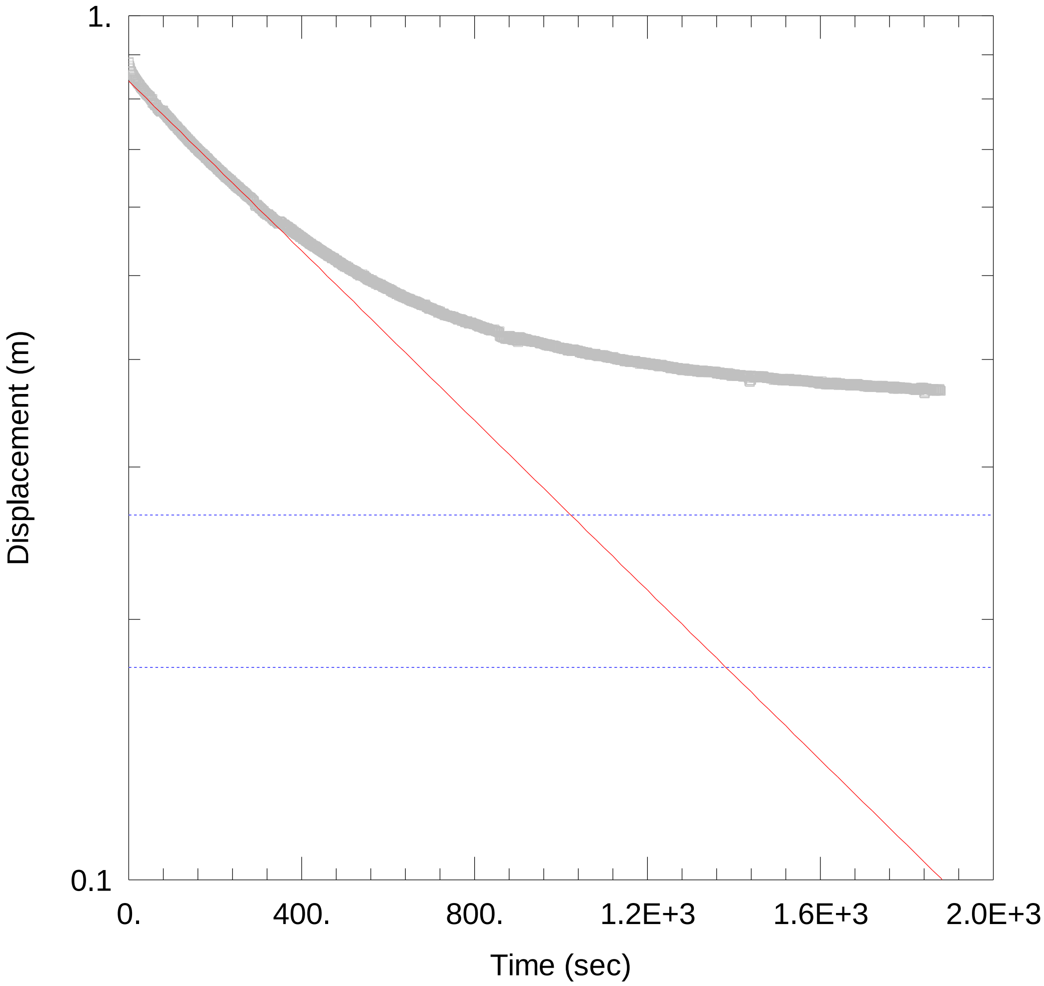
WELL DATA (YS01)

Initial Displacement: 0.984 m
Total Well Penetration Depth: 4.08 m
Casing Radius: 0.025 m
Static Water Column Height: 3.14 m
Screen Length: 1. m
Well Radius: 0.0325 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

K = 0.3025 m/day
y0 = 0.9937 m



WELL TEST ANALYSIS

Data Set: \...\YS01 - Rising.aqt
Date: 10/10/17
Time: 10:37:03

PROJECT INFORMATION

Company: Jacobs
Client: Barwon Water
Project: IS191000
Location: Yeodene Swamp
Test Well: YS01
Test Date: 26/04/17

AQUIFER DATA

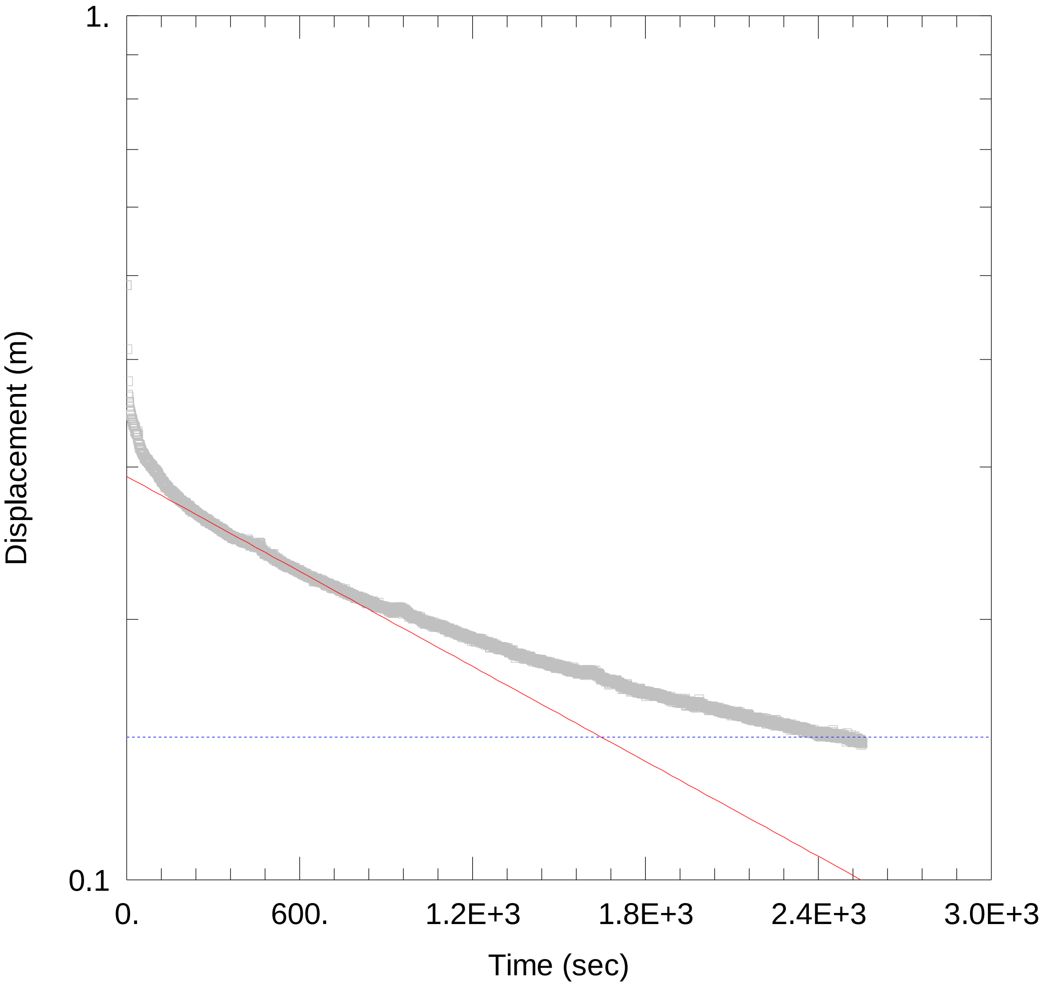
Saturated Thickness: 5. m
Anisotropy Ratio (Kz/Kr): 0.25

WELL DATA (YS01)

Initial Displacement: 0.8803 m
Total Well Penetration Depth: 4.08 m
Casing Radius: 0.025 m
Static Water Column Height: 3.14 m
Screen Length: 1. m
Well Radius: 0.0325 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
K = 0.1051 m/day
y0 = 0.84 m



WELL TEST ANALYSIS

Data Set: \...\YS02 - Falling.aqt
Date: 10/10/17 Time: 10:37:19

PROJECT INFORMATION

Company: Jacobs
Client: Barwon Water
Project: IS191000
Location: Yeodene Swamp
Test Well: YS01
Test Date: 26/04/17

AQUIFER DATA

Saturated Thickness: 5. m
Anisotropy Ratio (Kz/Kr): 0.25

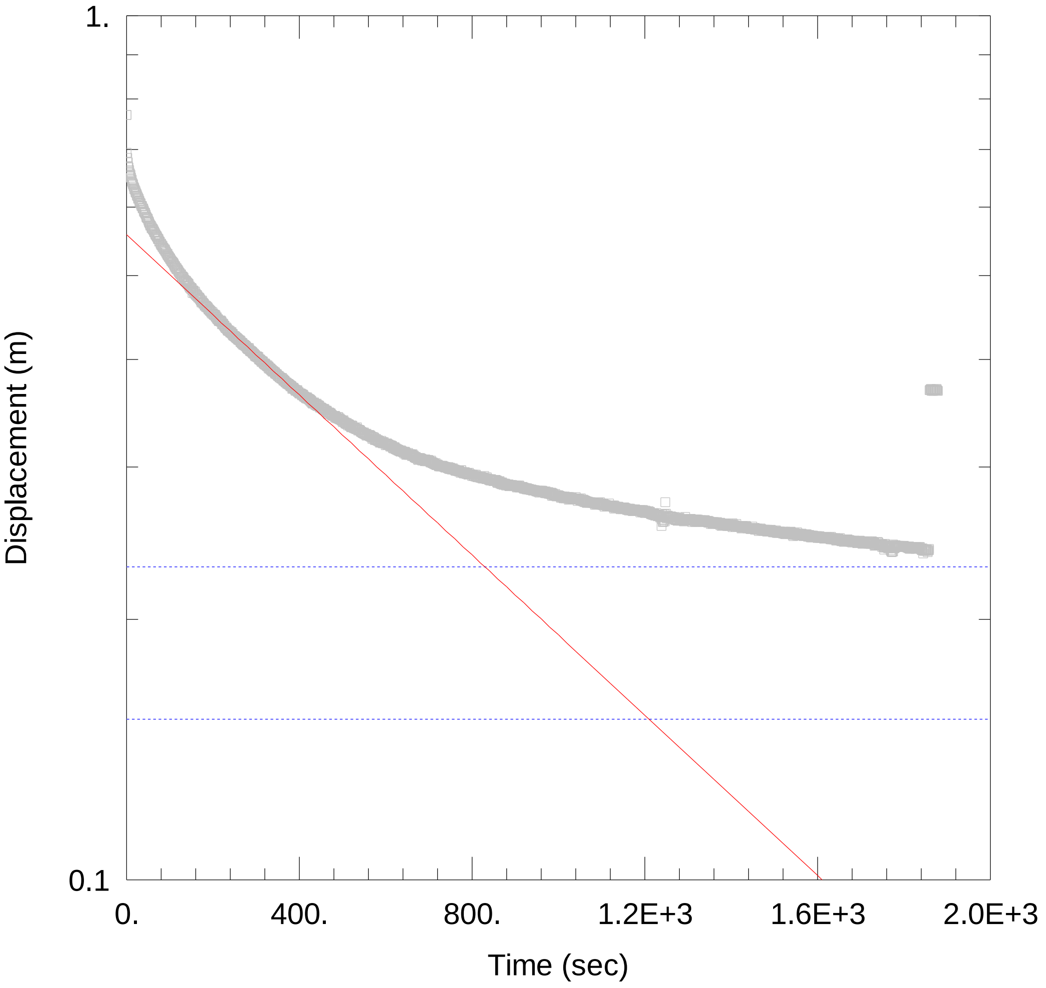
WELL DATA (YS02)

Initial Displacement: 0.487 m
Static Water Column Height: 3.23 m
Total Well Penetration Depth: 3.43 m
Screen Length: 2. m
Casing Radius: 0.025 m
Well Radius: 0.0325 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

K = 0.02063 m/day
y0 = 0.2928 m



WELL TEST ANALYSIS

Data Set: \...\YS02 - Rising.aqt
Date: 10/10/17 Time: 10:37:33

PROJECT INFORMATION

Company: Jacobs
Client: Barwon Water
Project: IS191000
Location: Yeodene Swamp
Test Well: YS01
Test Date: 26/04/17

AQUIFER DATA

Saturated Thickness: 5. m
Anisotropy Ratio (Kz/Kr): 0.25

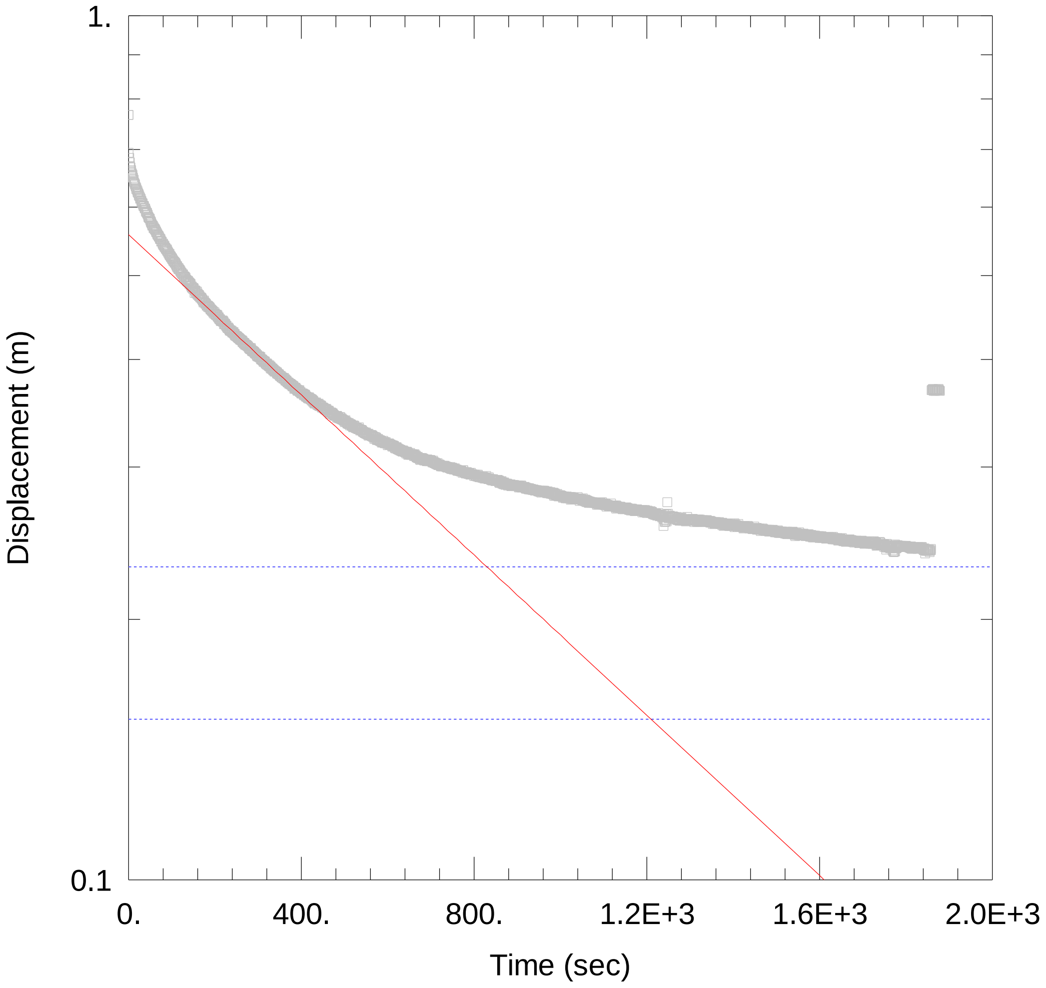
WELL DATA (YS02)

Initial Displacement: 0.7665 m
Static Water Column Height: 3.23 m
Total Well Penetration Depth: 3.43 m
Screen Length: 2. m
Casing Radius: 0.025 m
Well Radius: 0.0325 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

K = 0.0522 m/day
y0 = 0.5577 m



WELL TEST ANALYSIS

Data Set: \...\YS03 - Falling.aqt
Date: 10/10/17 Time: 10:37:50

PROJECT INFORMATION

Company: Jacobs
Client: Barwon Water
Project: IS191000
Location: Yeodene Swamp
Test Well: YS01
Test Date: 26/04/17

AQUIFER DATA

Saturated Thickness: 5. m
Anisotropy Ratio (Kz/Kr): 0.25

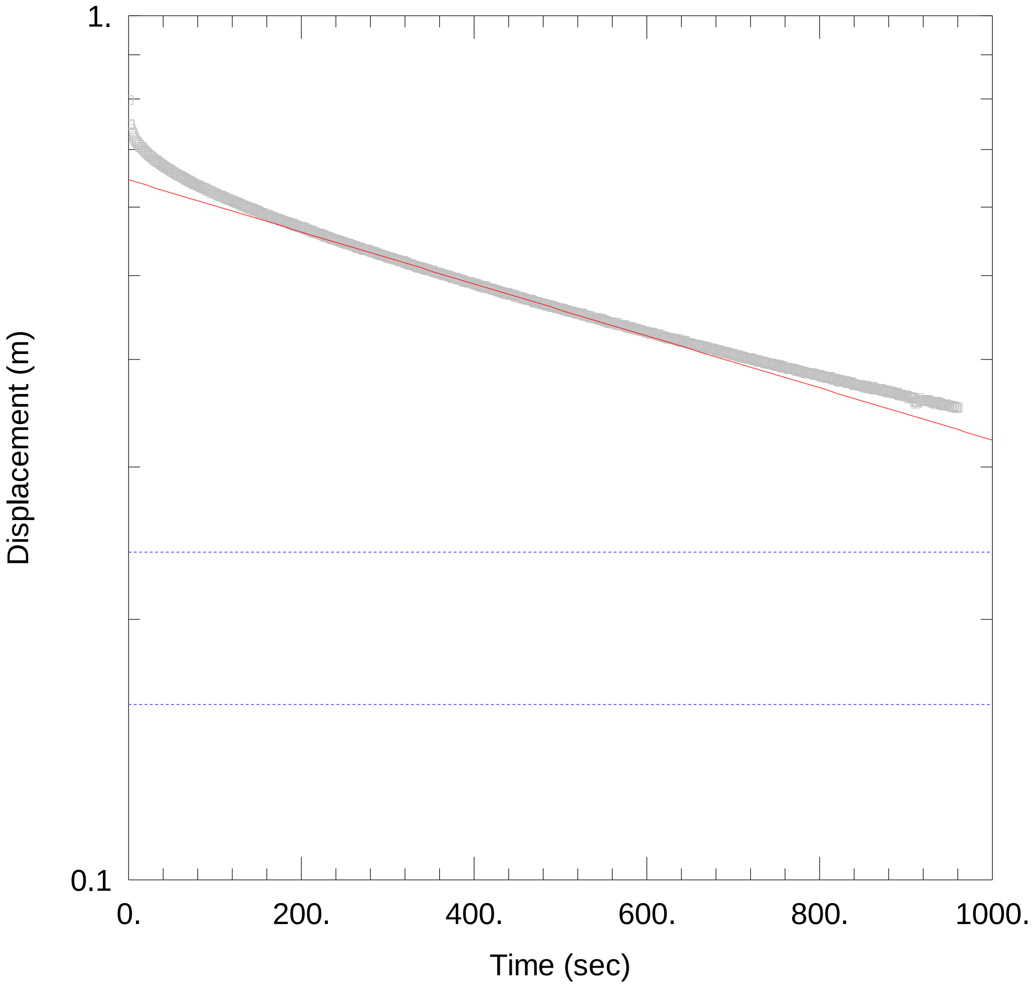
WELL DATA (YS02)

Initial Displacement: 0.7665 m
Static Water Column Height: 3.23 m
Total Well Penetration Depth: 3.43 m
Screen Length: 2. m
Casing Radius: 0.025 m
Well Radius: 0.0325 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

K = 0.0522 m/day
y0 = 0.5577 m



WELL TEST ANALYSIS

Data Set: \...\YS03 - Rising.aqt
Date: 10/10/17 Time: 10:38:05

PROJECT INFORMATION

Company: Jacobs
Client: Barwon Water
Project: IS191000
Location: Yeodene Swamp
Test Well: YS01
Test Date: 26/04/17

AQUIFER DATA

Saturated Thickness: 5. m Anisotropy Ratio (Kz/Kr): 0.25

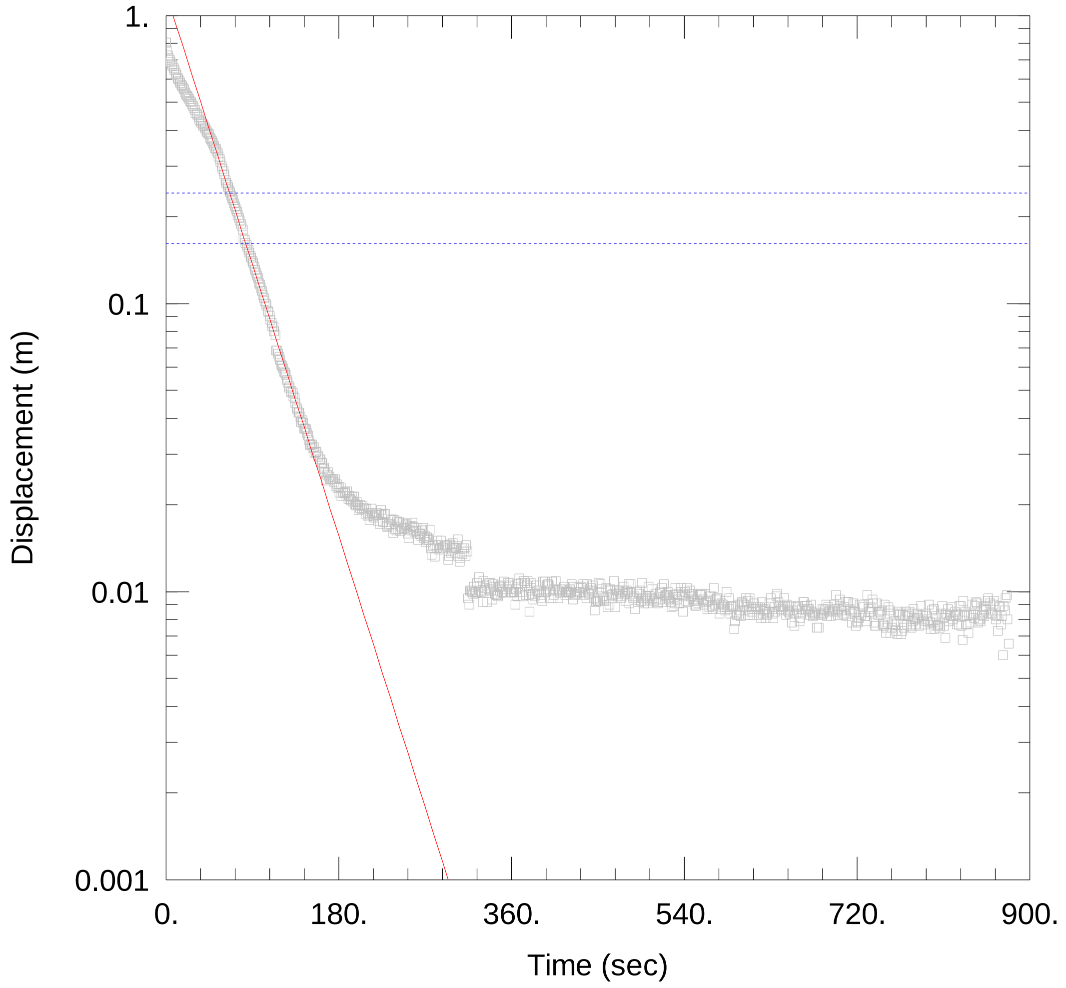
WELL DATA (YS03)

Initial Displacement: 0.7977 m
Total Well Penetration Depth: 3.67 m
Casing Radius: 0.025 m
Static Water Column Height: 3.41 m
Screen Length: 1.5 m
Well Radius: 0.0325 m

SOLUTION

Aquifer Model: Unconfined Solution Method: Bouwer-Rice

K = 0.04431 m/day y0 = 0.6453 m



WELL TEST ANALYSIS

Data Set: \...\YS05 - Falling.aqt
Date: 10/10/17 Time: 10:38:20

PROJECT INFORMATION

Company: Jacobs
Client: Barwon Water
Project: IS191000
Location: Yeodene Swamp
Test Well: YS01
Test Date: 26/04/17

AQUIFER DATA

Saturated Thickness: 5. m Anisotropy Ratio (Kz/Kr): 0.25

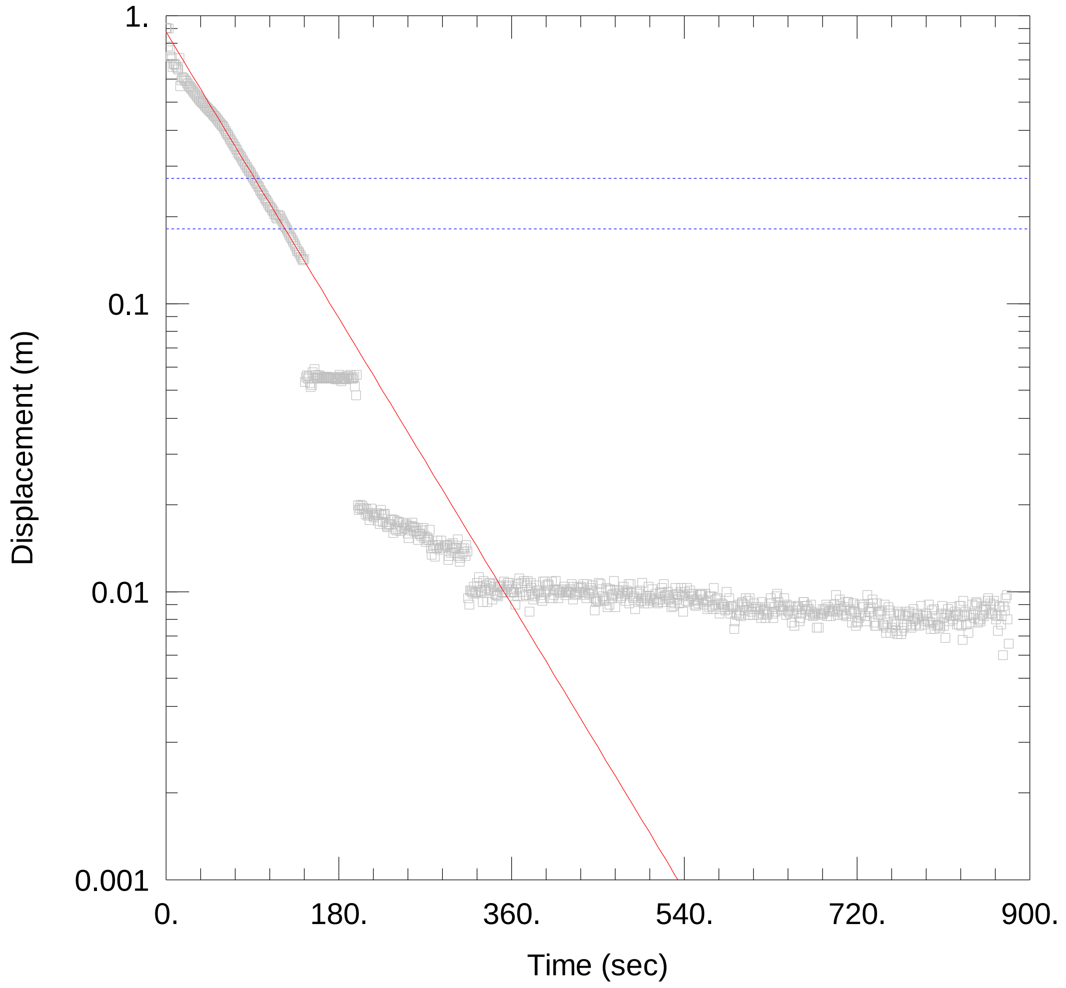
WELL DATA (YS05)

Initial Displacement: 0.8061 m Static Water Column Height: 2.34 m
Total Well Penetration Depth: 3. m Screen Length: 1.5 m
Casing Radius: 0.025 m Well Radius: 0.05 m

SOLUTION

Aquifer Model: Unconfined Solution Method: Bouwer-Rice

K = 1.333 m/day y0 = 1.198 m



WELL TEST ANALYSIS

Data Set: \...\YS05 - Falling_2.aqt
Date: 10/10/17 Time: 10:38:48

PROJECT INFORMATION

Company: Jacobs
Client: Barwon Water
Project: IS191000
Location: Yeodene Swamp
Test Well: YS01
Test Date: 26/04/17

AQUIFER DATA

Saturated Thickness: 5. m
Anisotropy Ratio (Kz/Kr): 0.25

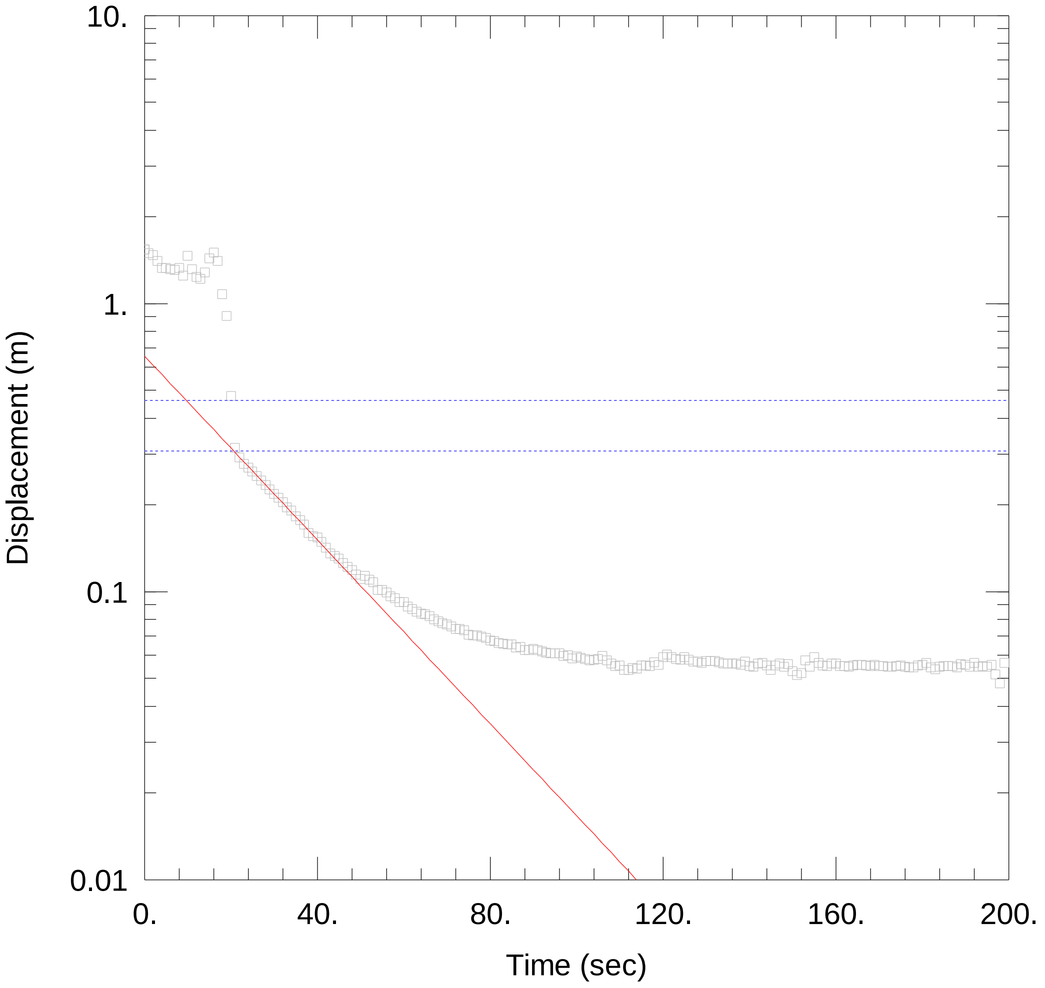
WELL DATA (YS05)

Initial Displacement: 0.9071 m
Static Water Column Height: 2.34 m
Total Well Penetration Depth: 3. m
Screen Length: 1.5 m
Casing Radius: 0.025 m
Well Radius: 0.05 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

K = 0.7028 m/day
y0 = 0.878 m



WELL TEST ANALYSIS

Data Set: \...\YS05 - Rising.aqt
Date: 10/10/17 Time: 11:33:22

PROJECT INFORMATION

Company: Jacobs
Client: Barwon Water
Project: IS191000
Location: Yeodene Swamp
Test Well: YS01
Test Date: 26/04/17

AQUIFER DATA

Saturated Thickness: 5. m Anisotropy Ratio (Kz/Kr): 0.25

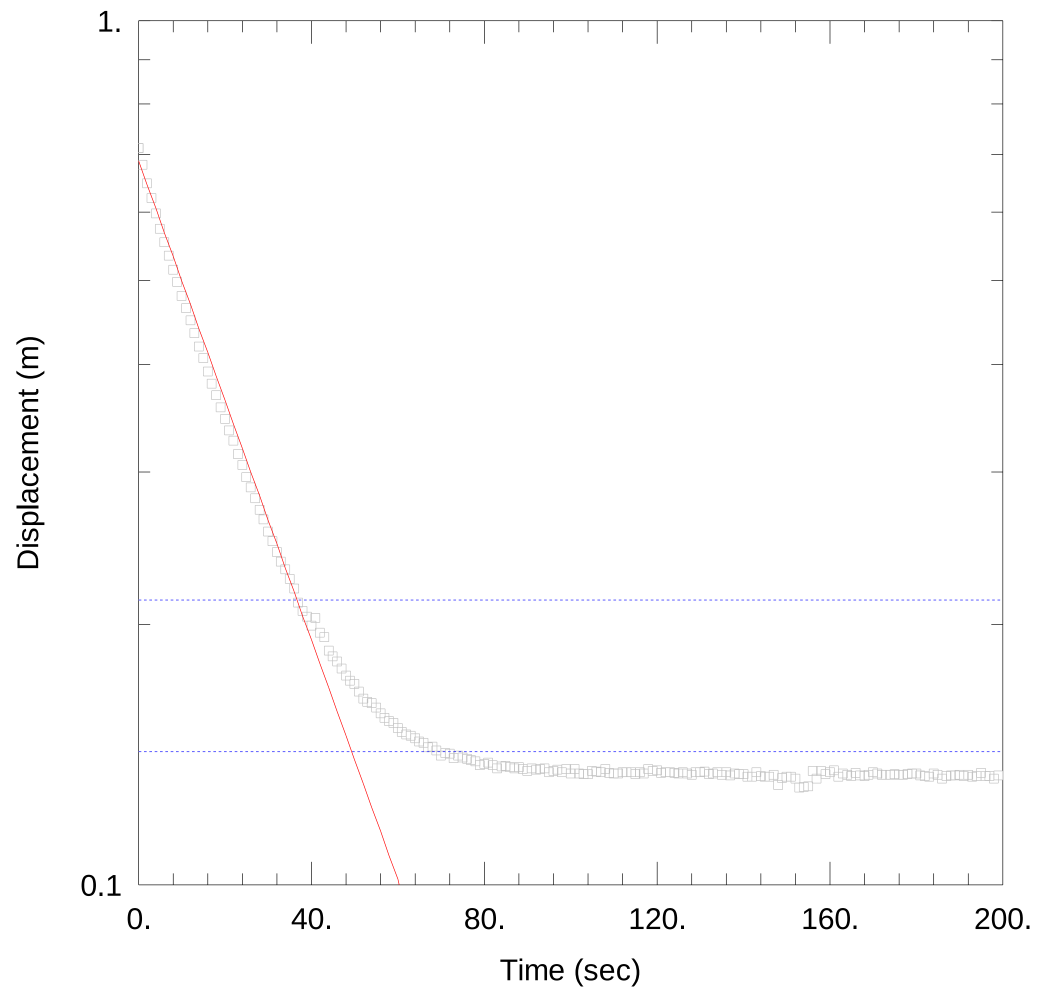
WELL DATA (YS05)

Initial Displacement: 1.539 m
Total Well Penetration Depth: 3. m
Casing Radius: 0.025 m
Static Water Column Height: 2.34 m
Screen Length: 1.5 m
Well Radius: 0.05 m

SOLUTION

Aquifer Model: Unconfined Solution Method: Bouwer-Rice

K = 2.033 m/day y0 = 0.6572 m



WELL TEST ANALYSIS

Data Set: \...\YS05 - Rising_2.aqt
Date: 10/10/17
Time: 11:33:35

PROJECT INFORMATION

Company: Jacobs
Client: Barwon Water
Project: IS191000
Location: Yeodene Swamp
Test Well: YS01
Test Date: 26/04/17

AQUIFER DATA

Saturated Thickness: 5. m
Anisotropy Ratio (Kz/Kr): 0.25

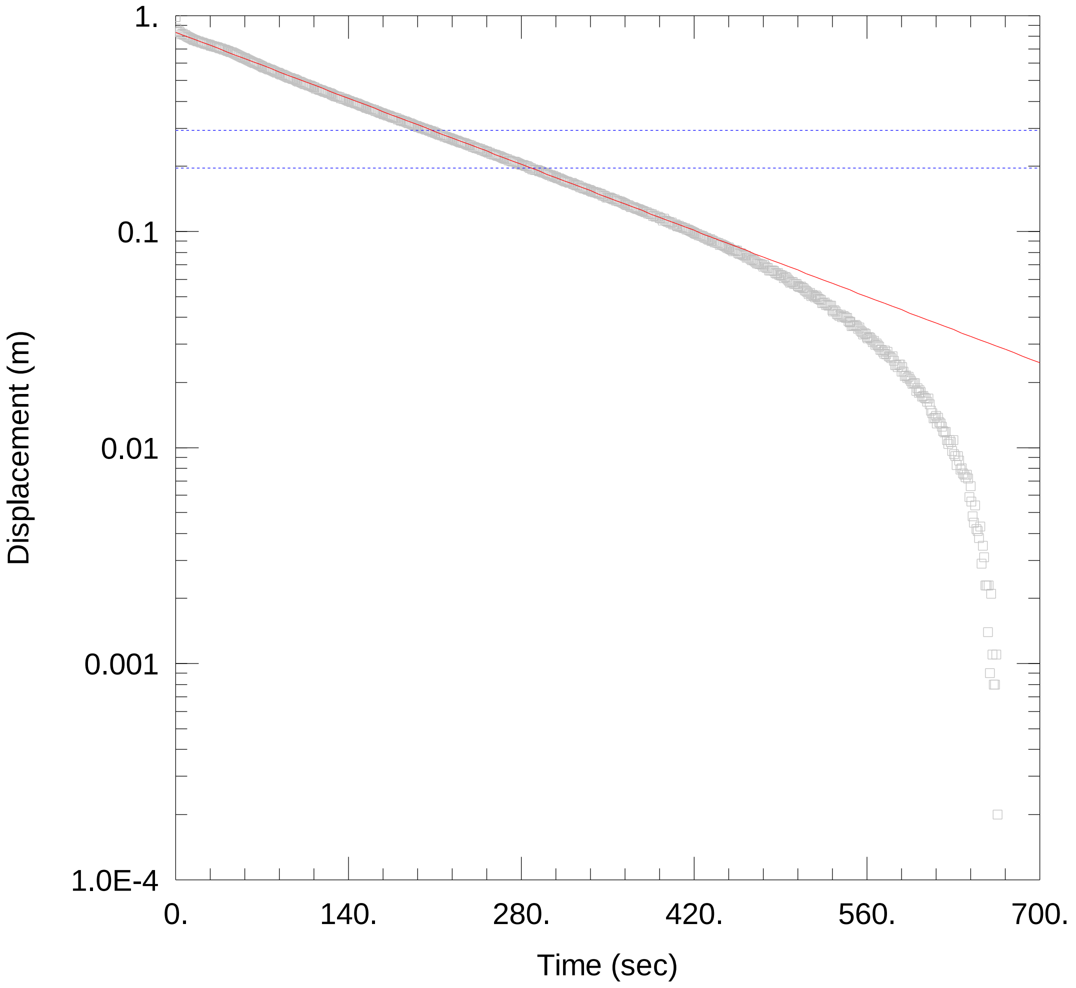
WELL DATA (YS05)

Initial Displacement: 0.7118 m
Static Water Column Height: 2.34 m
Total Well Penetration Depth: 3. m
Screen Length: 1.5 m
Casing Radius: 0.025 m
Well Radius: 0.05 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

K = 1.765 m/day
y0 = 0.6882 m



WELL TEST ANALYSIS

Data Set: \...\YS06 - Falling.aqt

Date: 10/10/17 Time: 11:33:48

PROJECT INFORMATION

Company: Jacobs
Client: Barwon Water
Project: IS191000
Location: Yeodene Swamp
Test Well: YS01
Test Date: 26/04/17

AQUIFER DATA

Saturated Thickness: 5. m
Anisotropy Ratio (Kz/Kr): 0.25

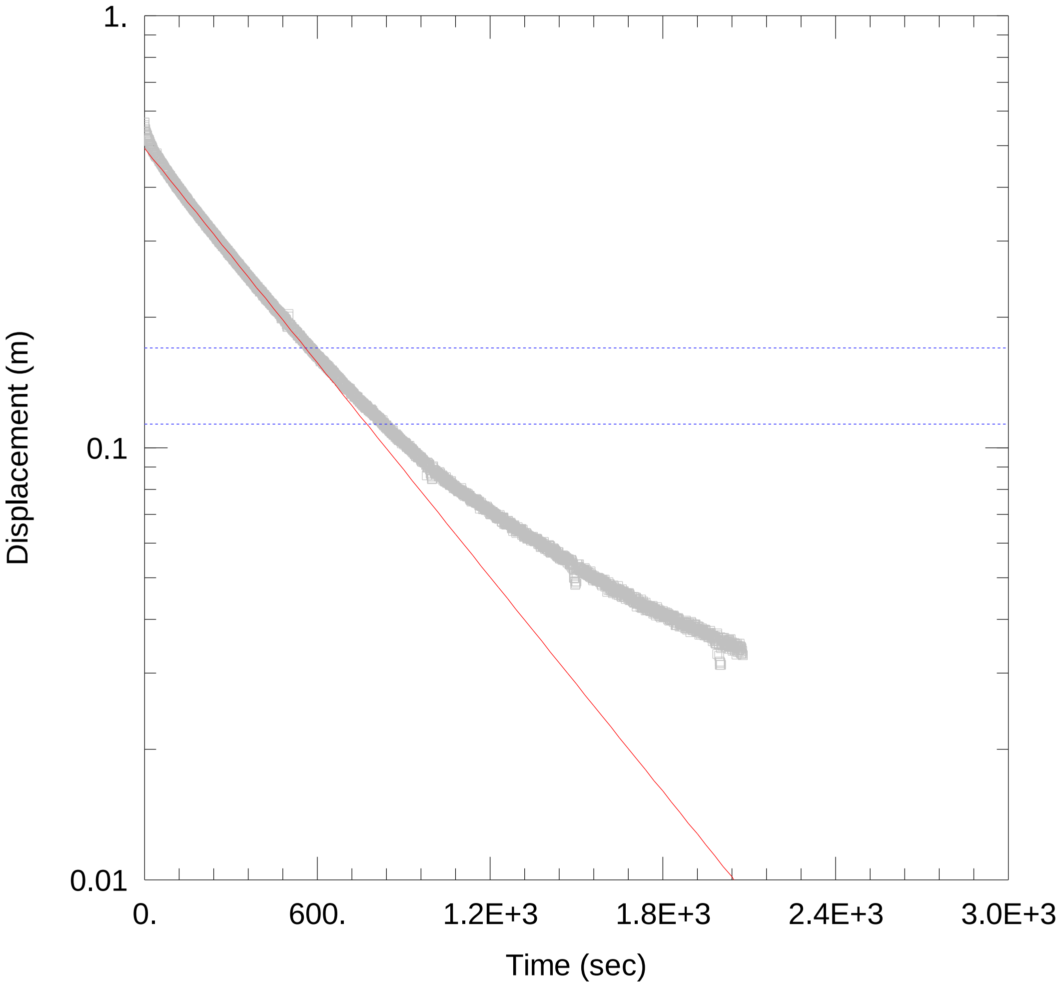
WELL DATA (YS06)

Initial Displacement: 0.9811 m
Static Water Column Height: 2.32 m
Total Well Penetration Depth: 3.12 m
Screen Length: 1.5 m
Casing Radius: 0.025 m
Well Radius: 0.05 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

K = 0.2805 m/day
y0 = 0.837 m



WELL TEST ANALYSIS

Data Set: \...\YS06 - Rising.aqt
Date: 10/10/17 Time: 11:34:03

PROJECT INFORMATION

Company: Jacobs
Client: Barwon Water
Project: IS191000
Location: Yeodene Swamp
Test Well: YS01
Test Date: 26/04/17

AQUIFER DATA

Saturated Thickness: 5. m
Anisotropy Ratio (Kz/Kr): 0.25

WELL DATA (YS06)

Initial Displacement: 0.5657 m
Static Water Column Height: 2.32 m
Total Well Penetration Depth: 3.12 m
Screen Length: 1.5 m
Casing Radius: 0.025 m
Well Radius: 0.05 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

K = 0.1061 m/day
y0 = 0.4927 m

Appendix E. Cost Estimate for Inundating Yeodene Swamp

Item	Description of work	Qty	Unit	Rate	Amount ($)	Subtotal ($)
1	**Design and Planning**					
	Survey	1	Item	$ 13,000	$ 13,000	
	Geotechnical	1	Item	$ 10,000	$ 10,000	
	Environmental Management	1	Item	$ 7,000	$ 7,000	
	Detailed Design	1	Item	$ 25,000	$ 30,000	
	Tendering	1	Item	$ 10,000	$ 10,000	
	Environmental Offset (net gain) for vegetation removal	1	Item	$ 30,000	$ 30,000	
						$ 100,000
2	**Project Management**					
	Manage Design and Planning	1	Item	$ 10,000	$ 10,000	
	Tendering	1	Item	$ 12,000	$ 12,000	
	Construction Management	1	Item	$ 12,000	$ 12,000	
						$ 34,000
3	**Construction Preliminaries**					
	Contract work insurance	1	Item	$ 450	$ 450	
	Public Liability Insurance	1	Item	$ 600	$ 600	
	Facilities (toilet, lunchroom, storage)	4	week	$ 125	$ 500	
	Facilities - delivery	1	Item	$ 500	$ 500	
	Construction Set out	1	Item	$ 5,000	$ 5,000	
						$ 7,050
4	**Move in / Move Out**					
	Prime Mover and Float	8	hrs	$ 200	$ 1,600	
	Excavator - 30 T with operator	4	hrs	$ 180	$ 720	
	Compactor	4	hrs	$ 90	$ 360	
	Staff	18	hrs	$ 90	$ 1,620	
						$ 4,300
5	**Create Access - including tree clearing and gravel access - mix of private and public land**					
	Excavator - 30 T with operator	32	hrs	$ 180	$ 5,760	
	Grader	24	hrs	$ 175	$ 4,200	
	Material - class 3 gravel - 100mm thick, 3m wide	351	tonne	$ 32	$ 11,232	
	Fencing - Reinstate and install gate	1	Item	$ 3,000	$ 3,000	
	Staff - crew of 2 + vehicle	1	days	$ 2,000	$ 2,000	
						$ 26,192
6	**Clear Vegetation - and move off site short distance**					
	Excavator - 30 T with operator	16	hrs	$ 180	$ 2,880	
	Truck	16	hrs	$ 90	$ 1,440	
	Staff - crew of 2 + vehicle	2	days	$ 2,000	$ 4,000	
						$ 8,320
7	**Site Retention - Create coffer dam and pump out**					
	Excavator - 30 T with operator	8	hrs	$ 180	$ 1,440	
	Pump Hire 100mm diesel	16	days	$ 200	$ 3,200	
	Pump Fuel	1	Item	$ 2,000	$ 2,000	
	Staff - crew of 2 + vehicle	2	days	$ 2,000	$ 4,000	
						$ 10,640
8	**Sheet Pile Weir Construction - including excavation, sheet pile, concrete**					
	Assuming 3 weeks for weir construction					
8.1	LABOUR					
	Labourer - Class 1 x 2	260	hrs	$ 84	$ 21,840	
	Foreman	260	hrs	$ 100	$ 26,000	
						$ 47,840
8.2	PLANT					
	Excavator - 30 T with operator	120	hrs	$ 180	$ 21,600	
	Compactor- up to 5 t or vibrating plate	24	hrs	$ 90	$ 2,160	
	Vibrating head-for sheet pile placement	60	hrs	$ 80	$ 4,800	
	Jig for sheet pile	1	Item	$ 5,000	$ 5,000	
	Crew vehicle	15	days	$ 250	$ 3,750	
						$ 37,310
8.3	MATERIALS					
	Sheet pile - Vinyl CL 9000 or heavier	219	sqm	$ 140	$ 30,660	
	Imported fill	516	Tonne	$ 25	$ 12,900	
	Rock Beaching	161	Tonne	$ 25	$ 4,025	
	Transport Crushed rock and rock beaching	677	Tonne	$ 9	$ 6,093	
	Geotextile Bidum A44	538	sqm	$ 5	$ 2,690	
	Mass Concrete in apron	6	cum	$ 300	$ 1,800	
	Filter rock under apron (included in other rock)					

Item	Description of work	Qty	Unit	Rate	Amount ($)	Subtotal ($)
	Misc. materials	1	Item	$ 5,000	$ 5,000	$ 63,168
	Exclusions Any additional levee works to separate the swamp from private land					
					DIRECT COST (DC)	$ 338,820
			Contingencies	0.5		$ 169,410
					Total Construction Cost	$ 508,230