Barwon Downs Monitoring Program

STAGE 1

Field Investigations and Monitoring Program Scope

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List of Abbreviations and Acronyms

TERM	***DESCRIPTION***
ASS	Acid Sulphate Soils
CMA	Catchment Management Authority
DEPI	Department of Environment and Primary Industries
DO	Dissolved Oxygen
EC	Electrical Conductivity
ET	Evapotranspiration
EVC	Ecological Vegetation Class
GDE	Groundwater Dependent Ecosystem
LTA	Lower Tertiary Aquifer
m bgl	metres below ground level
NDVI	Normalized Difference Vegetation Index
PASS	Potential Acid Sulphate Soils
RWL	Reduced Water Level
SEBAL	Surface Energy Balance Algorithm for Land
SEPP	State Environment Protection Policy
SOBN	State Observation Bore Network
SRW	Southern Rural Water
TAP	Technical Advisory Panel
TDS	Total Dissolved Solids

Glossary of Terms

AQUICLUDE	A formation which, although porous and capable of absorbing water slowly, will not transmit water fast enough to furnish an appreciable supply for a well or spring. Aquicludes are characterised by very low values of "leakage".
AQUIFER	A geologic formation, a group of formations, or a part of a formation that is water bearing. A geological formation or structure that stores or transmits water, or both, such as to wells and springs.
AQUIFER SYSTEM	A body of permeable and relatively impermeable materials that functions regionally as a water-yielding unit. It comprises two or more permeable units separated at least locally by confining units (Aquitards) that impede ground-water movement.
AQUIFER TEST (or Aquifer Pumping Test)	A test to determine hydrologic properties of an aquifer, involving the withdrawal of measured quantities of water from, or the addition of water to, a well and the measurement of resulting changes in head in the aquifer.
AQUIFER, ALLUVIAL	An unconsolidated aquifer that consists of an accumulation of stream-deposited sediments, including sands, silts, clays or gravels
AQUIFER, CONFINED	An aquifer which is bounded above and below by formations of impermeable or relatively impermeable material. An aquifer in which ground water is under pressure significantly greater than atmospheric and its upper limit is the bottom of an aquitard.
AQUIFER, FRACTURED BEDROCK	An aquifer composed of solid rock, but where most water flows through cracks and fractures in the rock instead of through pore spaces. Flow through fractured rock is typically relatively fast.
AQUIFER, LEAKY (Semi-confined)	An aquifer overlaid and/or underlaid by a thin semipervious layer through which flow into or out of the aquifer can take place.
AQUIFER, PERCHED	A groundwater unit, generally of moderate dimensions, that occurs whenever a groundwater body is separated from the main groundwater by an unsaturated zone (and often a relatively impermeable stratum).

AQUIFER, UNCONFINED	An Aquifer made up of loose material, such as sand or gravel, that has not undergone lithification (settling). In an unconfined aquifer the upper boundary is the top of the saturated zone (water table).
AQUITARD	A saturated, but poorly permeable bed that impedes ground-water movement and does not yield water freely to wells, but which may transmit appreciable water to or from adjacent aquifers.
BASEMENT	Rocks below the sedimentary rocks or sedimentary basin of interest; are of metamorphic or igneous origin.
BENEFICIAL USE	A use of the environment or any element of the environment which is conducive to public benefit, welfare, safety, health or aesthetic enjoyment and which requires protection from the effects of waste discharges, emissions or deposits.
BORE, BOREHOLE	A hole advanced into the ground by means of a drilling rig for the purpose of investigating the lithological and groundwater conditions that exist below the surface.
CALIBRATION	In numerical modelling: the model parameters are adjusted until model predictions agree with historical data.
DRAWDOWN	The reduction in piezometric head due to pumping or gravitational drainage.
FLUVIAL	Pertaining to river or stream environments.
GROUNDWATER DISCHARGE	The flow of water from the Saturated Zone, out of a Groundwater System (e.g. to a bore, spring, river, vegetation etc)
GROUNDWATER DIVIDE	A line on a water table on either side of which the water table slopes downward. It is analogous to a drainage divide between two drainage basins on a land surface. It is also the line of highest Hydraulic Head in the water table.
GROUNDWATER RECHARGE	Inflow of water to a ground water reservoir (Unsaturated Zone) from the surface. Infiltration of precipitation and its movement to the water table is one form of natural recharge. Also, the volume of water added by this process.
GROUNDWATER STORAGE	The storage of water in ground water reservoirs.

GROUNDWATER SYSTEM	All the components of subsurface materials that relate to water, including Aquifers (confined and unconfined), Saturated Zone, and Water Tables.
GROUNDWATER,	(1) Water that flows or seeps downward and saturates soil or rock, supplying springs and wells. The upper level of the saturated zone is called the Water Table. (2) Water stored underground in rock crevices and pores.
GROUNDWATER, CONFINED	Ground water under pressure significantly greater than atmospheric, with its upper limit the bottom of a bed with hydraulic conductivity distinctly lower than that of the material in which the confined water occurs.
GROUNDWATER, PERCHED	Ground water that is separated from the main body of ground water by an unsaturated layer.
GROUNDWATER, UNCONFINED	Water in an aquifer that has a water table.
HYDRAULIC GRADIENT	The gradient or slope of a water table or Piezometric Surface in the direction of the greatest slope.
HYDRAULIC HEAD	The height of the free surface of a body of water above a given point beneath the surface.
HYDRAULIC CONDUCTIVITY	A measure to describe the ease of fluid flow through a porous material. It depends on both the fluid properties, such as density and viscosity and on the material properties, such as effective porosity and intrinsic permeability. Can be defined as Kh (horizontal component) or Kv (vertical component of hydraulic conductivity).
HYDROGEOLOGICAL PARAMETERS	Numerical parameters that describe the hydrogeological characteristics of an aquifer such as Porosity, Permeability, and Transmissivity.
HYDROGEOLOGICAL UNIT	Any soil or rock unit or zone that because of its hydraulic properties has a distinct influence on the storage or movement of ground water.
HYDROGEOLOGY	The part of geology concerned with the functions of water in modifying the earth, especially by erosion and deposition; geology of ground water, with particular emphasis on the chemistry and movement of water.

ISOTOPES	Are variants of the same element that have different masses due to a difference in the number of neutrons in the nucleus.
LITHOLOGY	The physical makeup of the sediments or rocks: mineral composition, grain size, texture, packing.
PERMEABILITY	For a rock or an earth material, the ability to transmit fluids; the rate at which liquids pass through soil or other materials in a specified direction.
PERMEABLE	Having pores or openings that permit liquids or gasses to pass through.
PIEZOMETER	A small-diameter observation well used to measure the hydraulic head of groundwater in aquifers
PIEZOMETRIC HEAD	Synonymous with Hydraulic Head, which is now commonly used.
PORE PRESSURE	Pressure exerted by fluid in the void space of soil or rock; the interstitial (pore) movement of water that may take place through a dam, its foundation, or its abutments.
POROSITY	Most generally, porosity is the property of containing openings or interstices. In rock or soil, it is the ratio (usually expressed as a percentage) of the volume of openings in the material to the bulk volume of the material.
POROSITY, EFFECTIVE	The amount of interconnected pore space in a material available for fluid transmission; expressed as a percentage of the total volume occupied by the interconnecting interstices.
POROUS	A condition which allows liquids to pass through.
POTENTIOMETRIC SURFACE	A surface which represents the static head of ground water in tightly cased wells that tap a water-bearing rock unit (i.e., aquifer).
PRESSURE TRANSDUCER	Automatic water level logger often used in boreholes.
PUMPING TEST	A test that is conducted to determine aquifer or well characteristics. More specifically, a test made by pumping a well for a period of time and observing the change in Hydraulic Head in the aquifer.
RECHARGE	The inflow of water from surface to a groundwater system.

SATURATED ZONE	The area in an aquifer, below the watertable, in which relatively all pores and fractures are saturated with water.
SEBAL	Surface Energy Balance Algorithm for Land uses the '"surface"' energy balance to estimate aspects of the hydrological cycle. SEBAL maps evapotranspiration, biomass growth, water deficit and soil moisture
SEMI-CONFINED AQUIFER	An aquifer which is confined by an overlying, low permeability layer that permits water to slowly flow through it. Also known as a leaky confined aquifer.
SLUG TEST	An instantaneous change in hydraulic head is applied to a well and the response is recorded and used to determine hydraulic properties.
STEADY STATE	Numerical simulation where the magnitude and flow of groundwater is constant with time throughout the modelled domain.
SUBSIDENCE	The gradual caving in or sinking of an area of land.
TRANSIENT	Numerical simulation where the magnitude and flow of groundwater is not constant with time.
UNSATURATED ZONE	Zone between the land surface and the top of the watertable i.e. the position at which the groundwater (the water in the soil's pores) is at atmospheric pressure. Water in the unsaturated zone has a pressure head less than atmospheric pressure.
WATERTABLE	The level formed by the upper surface of the groundwater that occurs below the natural ground surface level; above which the profile is unsaturated.
WATERTABLE AQUIFER	An aquifer whose top is exposed to the atmosphere, providing close connection between surface recharge (eg rainfall) and the groundwater within the aquifer. This is the same as an unconfined aquifer.

1. Introduction

1.1. Background to Barwon Downs borefield

Groundwater investigations conducted in Barwon Downs since the early 1960s showed that the area contained an extensive, high quality groundwater resource. In response to the 1967-68 drought, the then Geelong Waterworks and Sewerage Trust began investigating groundwater resources to supplement the surface reservoirs in the Geelong region during times of drought. In 1969, a trial production bore was built close to the Wurdee Boluc inlet channel at Barwon Downs. With knowledge gained from the results, another bore was built at nearby Gerangamete in 1977. Pumping tests on the two bores showed the borefield should be centred on Gerangamete.

There are now six bores in the groundwater borefield, each between 500 metres and 600 metres deep, with four bores constructed in 1982-83, and two additional bores constructed in 2000-01. Pumps located below ground in each bore provide daily flow of up to 12 megalitres (ML) per bore, up from the original design intent of 9.5 ML per day. The water is then treated by an iron removal plant prior to transfer to Barwon Water's surface water system.

Following the extended dry period of 2006-07 and to meet future supply requirements for the region, Barwon Water upgraded the treatment plant and pumping station to enable production of up to 55 ML per day, up from the existing 33 ML per day capacity. The borefield supplemented Geelong’s water supply during drought conditions from 1982-1983, 1997- 1998, and from 2006 to 2011.

The Barwon Downs borefield is operated under licence from Southern Rural Water. This licence was granted in 2004 after an extensive review process involving an expert advisory panel which considered potential impacts and conditions required for the new licence. This licence is due to expire in June, 2019. Barwon Water’s current groundwater extraction licence from Southern Rural Water permits up to 55 ML per day groundwater pumping with a maximum of 20,000 ML in any one year and 80,000 ML in any 10-year period.

Barwon Water undertakes monitoring in the Barwon Downs borefield area in accordance with licence conditions which require monitoring of groundwater water levels and water quality, subsidence, flow in Boundary Creek, as well as the protection of riparian vegetation (floral survey undertaken every five years), protection of stock and domestic use and protection of flows in the Barwon River and tributaries. This data is provided in an annual report to Southern Rural Water (SRW) who administers and regulates groundwater licences on behalf of the Water Minister. Conditions of the licence are intended to prevent any unacceptable impacts.

A review of flora and groundwater levels completed under licence conditions(SKM and EA, 2008-09) recommended that 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 may be contributing to the drying of the catchment.

A review of the existing groundwater monitoring program has also been driven by the community, who are concerned about any potential impacts that groundwater extraction may have caused. To address community interest adequately and be prepared for licence renewal in 2019, Barwon Water commissioned SKM in conjunction with Ecology Australia and Latrobe University to review the existing monitoring program and develop a revised program to:

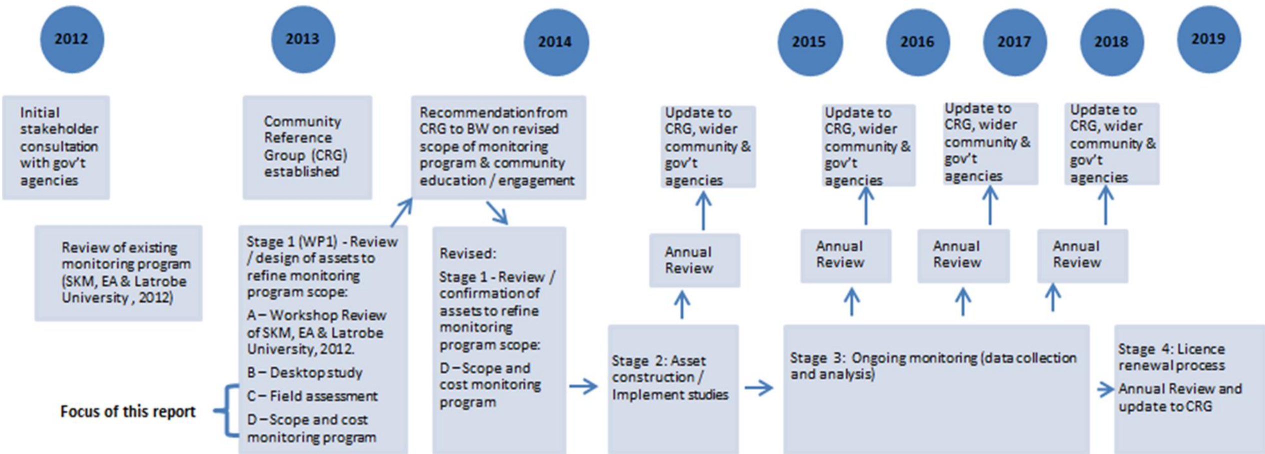
- Better understand the environmental impacts of groundwater extraction;
- Determine the cause and relative contribution of groundwater variability (for example, groundwater extraction, drought and land use changes) in contributing to environmental impacts; and
- Provide additional monitoring data and subsequent analysis required to support the licence renewal process.

That report is documented in SKM / EA / Latrobe University (2012). Following on from that desktop study, Barwon Water commissioned SKM to further refine the monitoring program that was developed in 2012 – that is the focus of this report.

1.2. Context of this investigation

Figure 1 illustrates the major components of the Barwon Downs licence renewal process and how this study fits into that process. This report is the main documentation associated with Stage 1; it is focussed on Task C and D of Stage 1. A summary of Task A and B is provided in Section 1.3 of this report to provide input to Task C and D. (The Task B report is provided in Appendix A). The diagram also shows how the Community Reference Group (CRG) interacts with the scope finalisation of the monitoring program as well as the broader licence renewal process.

Figure 1 Context of this study in the Barwon Downs Licence Renewal Process



1.3. Preliminary activities forming part of this study

This section describes the two key preliminary activities of this study: a workshop (refer Section 1.3.1) and a desktop study (refer Section 1.3.2).

1.3.1. Workshop Outcomes

On 21 February 2013, a workshop was held involving SKM and Barwon Water staff. The purpose of the workshop was to critically assess the recommendations in "Barwon Downs Monitoring Program – Monitoring Review (2012)". Most of the recommendations in that report were endorsed, and this formed the basis for the proposed monitoring program outlined in this report. There were some recommendations that were deemed unnecessary and some additional activities not in the 2012 review that were recommended for inclusion in the scope of works.

The following activities were excluded from the Stage 1 project scope. They were reconsidered at the workshop, but were ultimately excluded from Stage 1 for reasons described below:

- *Subsidence assessment* – the current Barwon Water subsidence monitoring program was reviewed and is considered sufficient. A review of subsidence to date, indicates that subsidence is very minor and is not an issue of concern, which is in general agreement with a subsidence prediction review conducted in the 1980s (RWC, 1986 and RWC, 1987). This review predicted that subsidence related to groundwater pumping (over long timeframes) would be very small.

- *Assessment of streambed conductance* – the need for Stage 1 to scope and cost field assessments to determine streambed conductance was considered in the workshop. The consensus was that sensitivity testing of streambed conductance using the numerical model (i.e. in 2-3 years as part of modelling work related to licence renewal) will adequately address this issue.

- *Land use change* – the assessment agreed with the conclusions of the 2012 review that land use change would not be included in the program because "it is unlikely to have changed significantly since the commencement of pumping in 1986, is unlikely to change significantly in the period leading up to the licence renewal and over the next licence period, and would add significant cost the program for outcomes that may not be definitive''.

- *Unconfined areas south of Bambra Fault* – the need for new bores in this area was discussed and it was agreed that there are already sufficient bores spatially in this area.

The following activities were originally not in the Stage 1 scope, but based on workshop outcomes were added into Stage 1:

- Assessing suitability of newly identified shallow bores in the aquitard. A number of shallow groundwater bores (owned by DEPI, former DPI) were identified on the GMS in the aquitard areas (which had only recently been uploaded onto the GMS). It was recognised that these bores could reduce the number of new observation bores required in the aquitard. A task to check the suitability of these bores (in terms of location, depth, construction and condition) for the purpose of long term monitoring and model calibration was added to the scope.

- The declining EC trend in LTA observation bores is a key piece of data for improving the hydrogeological conceptual understanding of the groundwater system. In particular, identifying whether the declining EC trend is due to leakage of fresher water from the aquitard or through-flow from the recharge areas is important. These activities were scoped as part of Stage 1.

- Investigate the adequacy of the conceptualisation of hydrostratigraphy around the numerical model boundaries. This included reviewing whether the extent of the aquifer around the model boundaries was sufficiently well defined in the following two areas:

    - north and north east of Barongarook High between Colac and Birregurra, and

    - the area around the Barwon and Gellibrand catchment divides.

- PASS and peat assessment in aquitard areas. The original scope of works in Stage 1 only allowed for defining a works program for PASS/peat assessment in the unconfined area. Numerical model sensitivity testing of aquitard vertical hydraulic conductivity (conducted as part of the desktop assessment) indicated that there may be drawdown in the aquitard of sufficient magnitude to dewater PASS, and hence this was added into the scope of Stage 1.

The following list of activities was also discussed at the workshop. They were not included in Stage 1, not necessarily because they were not important, but either because they were not appropriate in Stage 1 and would be addressed later, or because they were not an immediate priority and could be addressed in several years time:

- SKM (2010) highlighted issues with the condition of some of the monitoring bores in the study area. This was not included in Stage 1 but will need to be addressed at a later stage. Further, the need to ensure that the monitoring bores (owned by DEPI) are maintained for the period of the monitoring program was mentioned in the workshop. Both of these issues are being dealt with separately by Barwon Water, the latter in the context of DEPI's SOBN rationalisation program.

- Investigating the significance of ET. Evapotranspiration (ET) from the aquifer and aquitard is a major component of the water balance (excluding lateral flow out of the model). Currently ET is not well defined in the groundwater model. This task would involve developing a program to improve quantification of ET in the model. Sensitivity testing of vertical hydraulic conductivity in the model demonstrated that drawdown in the aquitard areas is likely, indicating the importance of characterising ET, inside and outside of the recharge area. Providing more accurate estimates of ET will be an important part of improving the model in this respect, including helping refine estimates of stream flow depletion and watertable decline. Importantly it will also help differentiate between the impact of drought and pumping impacts on groundwater levels.

A program of works that will enable ET to be more accurately incorporated into the water balance and numerical model would involve two main sub-tasks:

  - Scoping and costing a program to define ET across the model area (e.g. using SEBAL). Importantly this needs to include partitioning of unsaturated zone ET from groundwater ET.
  - Ensuring that the outputs of the ET quantification are suitable for incorporation into the groundwater model

It was decided that these activities were not immediate priorities and could be undertaken closer to licence renewal. Further, it is important to note that significant parts of this work will actually be undertaken as part of the terrestrial vegetation groundwater dependence assessment (and with some additional analysis the ET data could be used an in input to the groundwater model).

- Groundwater recharge studies were not in the Stage 1 scope. The last use of the numerical groundwater model "Climate Change Modelling for the Barwon Downs Aquifers, July 2011" (SKM, 2011) including upgrading the approach to determining recharge in the model. The 1-D model "SWAP" was used for this purpose. However two upgrades to the SWAP model would improve the accuracy of recharge inputs:

  - Currently the recharge model only has one recharge value assigned across the entire aquitard area. Given that recent sensitivity testing has highlighted the importance of the aquitard, it is necessary that recharge across the aquitard is further refined.
  - The SWAP model is currently using a constant rainfall value across the study areas. The model should be improved by allowing for the variable rainfall across the model area.

  It was decided that these improvements to recharge estimation could be undertaken as part of the model re-calibration and did not need to be undertaken as part of Stage 1.

1.3.2. Desktop Assessment

After the workshop, a desktop assessment was undertaken ('Task B') in order to gather and analyse relevant background information regarding each of the discipline areas. This formed the first part of scoping and costing the activities, and was supplemented by the field assessment (Task C). A summary of key outcomes from the desktop assessment is presented in Table 1. The desktop assessment report is presented in Appendix A. It should be noted that this report was only ever developed to draft stage, as it was a 'stepping stone' to Task C and D of Stage 1.

Table 1 Summary of desktop assessment

Discipline	Objective	Key Outcomes
Hydrogeology – Groundwater modelling	Sensitivity testing of aquitard vertical hydraulic conductivity (kv) using the existing numerical model, in order to determine the likelihood that borefield operations could produce a significant response in the aquitard watertable.	The testing showed that drawdown in the aquitard, at least towards the margins where the aquitard is thin, is possible and hence the monitoring program needs to include these areas, as appropriate. The amount of drawdown is controlled by aquitard kv and thickness. The monitoring program (tasks C and D of Stage 1) were extended to include impacts over the aquitard as a result.
Hydrogeology – potential of confined conditions at Barongarook High	Determine if existing bores in the unconfined areas are monitoring the watertable or a potentially confined part of the LTA.	Of 29 bores analysed, there is strong evidence to suggest 3 are screened below a low permeability layer within the LTA. Six bores showed no response and remaining bores showed a subdued response to pumping. This indicates the need for reconsidering the conceptual model in the recharge area, and being mindful of this when constructing watertable surfaces or assessing shallow groundwater processes. Some new shallow bores sites were recommended.
Hydrogeology -Identify bores monitoring the watertable in upper reaches of Boundary Creek	To assess whether there are sufficient numbers of bores to define aquifer water levels and flow direction in the upper reaches of Boundary Creek	The result of this assessment was the recommendation of some potential new bore sites (further assessed in tasks C and D) and possible reinstatement/restoration of some existing bores in the area.
Hydrogeology - Identify baseline monitoring bores in the LTA	To assess adequacy of baseline bore data (i.e. not influenced by pumping) in the unconfined and confined areas of the LTA	No new observation bores in the LTA for baseline monitoring purposes were recommended, as suitable bores were identified. The main action from this task is to ensure identified bores will remain on DEPI's monitoring run.
Hydrogeology - Identify sites for assessing perched groundwater	To assess whether perched groundwater is present across the area of outcropping LTA.	A method for investigating the presence of perched ground-water at the terrestrial vegetation sites was proposed, along with two additional sites.
Hydrogeology - Identify sites for determining aquitard watertable depth and flow direction	To assess adequacy of existing bores to provide information on direction of gw flow and watertable depth in the aquitard. This is required to understand gw contribution to aquitard baseflow.	Six new sites were recommended to ensure sufficient coverage of bores to provide water levels across a range of watertable depths, to assess potential impact of drawdown in the aquitard, to determine vertical gradients between aquifer and aquitard, and to allow 'direct' calculation of baseflow to rivers.
Hydrogeology -	To assess adequacy of baseline	Two suitable nested sites were identified in the aquitard

Discipline	Objective	Key Outcomes
Identify baseline aquitard watertable bore sites	bore data (i.e. not influenced by pumping) in the aquitard.	and hence no new bores were recommended (note however that some of the new bores recommended for the above objective will also serve against this objective).
Hydrogeology - Hydrogeological conceptualisation around numerical model boundaries	To investigate the adequacy of the conceptualisation of model hydro-stratigraphy around the (numerical) model boundaries, focussed on south-west and north east boundaries.	No additional bores were recommended, however a review of logs (including lithological, stratigraphic, and geophysical logs) was recommended to ensure consistent interpretation of aquifer and aquitard thicknesses and depths. For the NE boundary, a search for existing bores that might be suitable for conducting a pumping test to evaluate hydraulic connection across these faults was also recommended
Terrestrial vegetation	To identify terrestrial vegetation monitoring sites suitable for baseline and impact assessment.	14 draft monitoring sites were identified based on criteria of covering unconfined LTA and aquitard areas, covering impact and reference sites, relatively undisturbed forested landscape, representative of identified potential GDE's and ease of access.
Aquatic ecology	To review available information that describes the current distribution and condition of ecological values in the study area. The key input an existing (2005) FLOWS study.	Strengths and weakness in terms of relevance to Stage 1 of the existing environmental FLOWS study were identified. (Lloyd Environmental et al. 2005). A field program for further assessment of the suitability of the FLOWS study was prepared.
Hydrology – rainfall gauge review	A high level review of the adequacy of current rainfall gauging for the Barwon Downs Monitoring Program.	Installation of a new rainfall gauge was not recommended. High correlations between rainfall gauges suggest that long-term rainfall conditions can be reasonably estimated by correlation with nearby long-term gauges. Further, a new gauge is not likely to improve the accuracy of the modelling given other uncertainties in recharge and the model does not appear highly sensitive to changes in recharge.
Hydrology – stream gauge review	The suitability of the current stream gauge network was assessed in terms of suitability for detection of gw pumping impacts on streamflow, understanding nature of gw interaction with streams in the aquitard, estimation of impacts on streamflow and regional gw level behaviour through calibration and simulation of gw and hydrologic models and development of environmental flow recommendations	Five recommendations were made including, reinstating Boundary Creek flow gauges upstream and downstream of MacDonalds Dam, continuous salinity monitoring in Boundary Creek, a new gauge to monitor changes in groundwater discharge from the aquitard, a new gauge at Boundary Creek on bedrock upstream of dam and Source modelling with STEDI plugin.
Potential Acid Sulphate Soils	To identify areas of potential PASS for further (field) assessment.	It was considered that PASS at Boundary Creek Swamp is sufficiently well understood and hence no further subsurface soil / sediment monitoring was recommended here, although an observation bore at the Swamp was recommended. Sites of potential ASS were selected based on intersection of key datasets (inferred Barwon River prior swamp area, predicted groundwater drawdown, geological setting, geomorphical setting, topography and vegetation .

1.4. About this report

The purpose of this report is to document the:

- Monitoring program scope and associated cost estimates.
- Specification, costs and design for new monitoring bores.
- Specification, costs and design for new stream gauges.
- Specification, costs and design for various hydrogeological, ecological and hydrological studies.

The revised monitoring program will strengthen the existing monitoring program by improving the capacity to differentiate between groundwater pumping and climate effects on the groundwater system, predict watertable and stream flow changes where the aquifer is confined and better understand ecological impacts directly related to groundwater extraction.

In preparation for licence renewal in 2018-19, Barwon Water wishes to put in place a robust monitoring program which takes into account both technical and social aspects. This program will assess potential environmental impacts associated with the use of the borefield. The outcomes will then be used to support the licence renewal application and ensure that the appropriate controls are in place to mitigate and/or minimise any environmental impacts.

2. Monitoring program summary

2.1. Scope of monitoring program

The specific monitoring activities addressed in this report are categorised according to discipline and are summarised in Table 2. Note that Stage 1 does not include all activities that will be required up to licence renewal, in particular it does not include the task of re-calibrating and re-building the numerical model, including refinement of the conceptual model based on the outcomes of the investigations scoped in this document). It also does not include review points for interim analysis of collected data or compilation of the licence application technical report.

Table 2 Summary of monitoring activities addressed in Stage 1

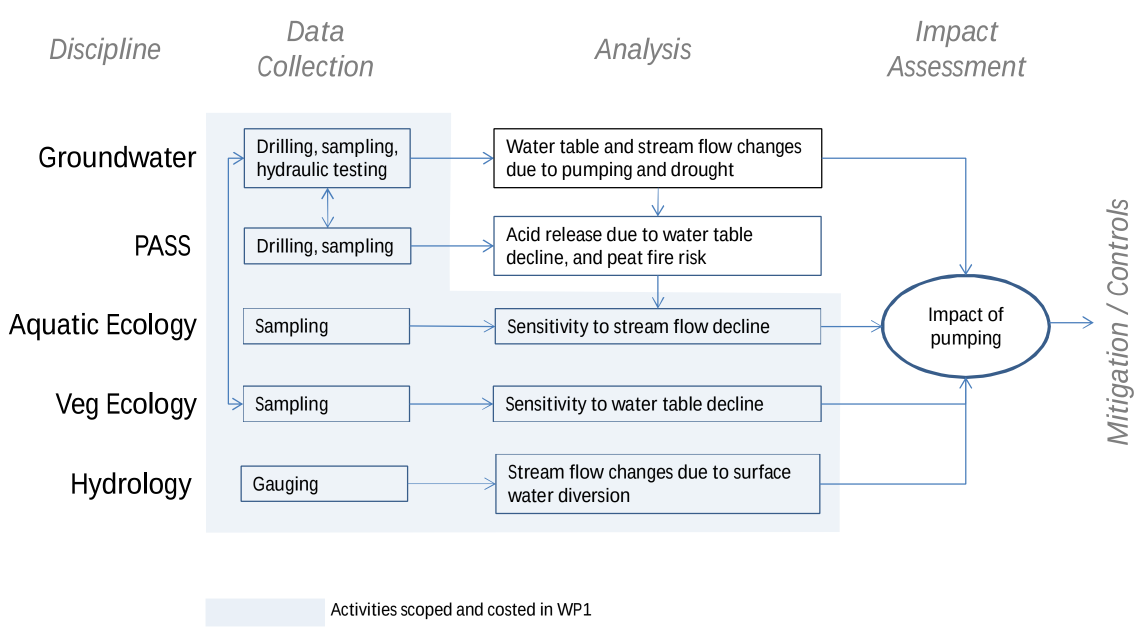
Monitoring Element	Program establishment	On-going monitoring
Groundwater	Installation of 30 new monitoring bores (25 confirmed, and potentially 5 extra depending on outcomes of PASS investigations) Geophysical logging of new bores plus ten existing bores Reinstatement of 6 old monitoring bores Groundwater quality sampling at all bores Hydraulic testing of all new bores and two existing deep aquifer bores Investigation of declining EC trends in production bores	On-going groundwater level monitoring
Terrestrial ecology	Selection of new terrestrial vegetation sites (complete) Terrestrial vegetation groundwater dependence and perched watertable assessment	Monitoring of ecological vegetation classes representing major GDE's Remote sensing analysis (2015-17) depending on outcomes of initial assessment
PASS	Testing for acid sulphate soils at identified sites	For sites where ASS is present, it is recommended that a monitoring bore is installed.*
Aquatic ecology	FLOWS assessment	
Stream flow	Reactivation of two flow gauges in Boundary Creek New flow gauge in Boundary Creek	Continuous salinity and pH monitoring in Boundary Creek Continuous flow monitoring

Note: * The PASS soil investigations are recommended prior to commencing establishment of groundwater monitoring infrastructure to allow the inclusion of these bores in the bore installation contract / drilling program.

It should be noted that all monitoring activities will be subject to an annual review where there may be no change, an increase or decrease in the scope of the monitoring depending on the outcomes and analysis of the monitoring (these reviews include the possibility of recommending the termination of a particular activity). Further, it should not be assumed that just because monitoring occurs up to the licence application stage (i.e. around 2018), that this activity will be necessary beyond that point. Further, it is important to note that ongoing monitoring requirements will be at the discretion of the licensing agency, Southern Rural Water.

Figure 2 depicts the activities scoped in Stage 1 in the context of the overall works that are required for the licence renewal. The activities scoped and costed in Stage 1 are shaded light blue. The figure shows that the task of undertaking the impact assessment and development of mitigation / control measures (if required) are the main activities not included in Stage 1. Also, the major task of determining watertable and stream flow changes due to pumping (conducted via numerical modelling) has not been scoped / costed as part of Stage 1 - that analysis is required to enable the impact assessment for all disciplines. The PASS investigation includes determination of the presence or absence of ASS as well as preliminary calculations of total acid release, but does not include analysis to determine the timing or mechanism of that release to streams, the impact on stream pH or the associated impact on stream ecology.

▪ **Figure 2 Activities scoped in Stage 1**



2.2. Cost estimates summary

Cost estimates for the monitoring activities scoped in Stage 1 are presented in Table 3. They include a contingency of 20%. The method of cost estimation varies from item to item. For some items they are based on quotes (e.g. stream gauges) whereas the drilling costs, for example, are based on past experience and discussions with drillers. Technical consulting costs are based on 'bottom-up' estimates of time to complete the various tasks. The costs can be considered accurate to ± 25%. Details of costs are contained in the relevant sections and Appendices.

Table 3 Summary of cost estimates for monitoring activities addressed in Stage 1

Item	Cost $ (excl GST)	Category
Acid sulphate soil sampling	$36,000	Supporting investigations
Drilling program	$506,000	Infrastructure
Gamma logging	$24,000	Supporting investigations
Reinstatement of groundwater monitoring bores	$17,000	Infrastructure
Groundwater quality sampling	$29,000	Supporting investigations
Aquifer hydraulic testing	$30,000	Supporting investigations
Interpretative report	$30,000	Infrastructure
Automated groundwater monitoring	$81,000	On-going monitoring (over 5 years) (20 year cost: $142,000)
Maintenance of groundwater observation bores	$14,000	On-going maintenance (over 5 years) (20 year cost: $75,000)
Investigation of changes in aquifer salinity	$48,000	Single investigation
Stream flow (and quality) gauges	$106,000	Infrastructure
Stream flow monitoring	$106,000	On-going monitoring 4 years
Stream flow monitoring annual data review plus Source modelling	$96,000	Annual review + single investigation
Terrestrial ecology annual monitoring	$103,000	On-going monitoring 4 years
Terrestrial ecology interp. associated with numerical model review	$30,000	Single investigation (at end of 4 years)
Perched watertable and terrestrial vegetation gw dependence assessment	$227,000	Single investigation
FLOWS assessment (and supporting macro-invertebrate and DO sampling)	$87,000	Supporting investigations
Total Cost (excl GST)	**$1,570,000**	

2.3. Schedules

Two possible schedules for implementation of the capital works program have been prepared, and are presented in Appendix B. The first is the preferred (i.e. planned) schedule, which assumes the infrastructure will be installed in the summer and autumn of 2013/14. The second is a ‘pessimistic’ schedule which allows for substantial delays to the program (e.g. in terms of permits etc for obtaining access to the sites), and assumes the infrastructure will be installed in the summer of 2014/15.

It is important to note that both of these are possible schedules, and are subject to an existing community consultation process. These are activities recommended from a technical perspective which may be re-scoped based on the community consultation process. This may in turn affect the timing of delivery of the program.

2.4. Summary of recommendations

This section outlines important recommendations related to the scope of works outlined in this document.

Effect of Rationalisation of State Observation Bore Network

The Department of Environment and Primary Industries (DEPI) is undergoing a review and rationalisation of the State Observation Bore Network (SOBN). As a region with a relatively high density of SOBN bores, the Barwon Downs area is likely to have a number of bores that DEPI identify as being surplus to their broader regional requirements. This may mean decommissioning of the bores, finding an alternate party to fund the cost of monitoring and maintaining the bores or gifting the bores to an interested third party.

DEPI’s review and rationalisation of the SOBN network is likely to occur in the 2013-14 financial year. It is recommended that when the results of that review are available, Barwon Water should (as a priority) review the report and consider any potential implications for the asset construction and monitoring program described in this document. For example, the most likely implication is that Barwon Water would need to expand its current groundwater monitoring (and maintenance) program to include some of the bores currently monitored by DEPI. It would be logical and cost effective to incorporate these changes into this capital works program (e.g. purchasing and installation of data loggers), provided the timing of the DEPI review is suitable.

Cultural heritage

A review of new works locations against AAV Melbourne’s map of areas of cultural heritage sensitivity has indicated that all stream gauges and 10 new monitoring bores are located within areas of cultural heritage sensitivity (refer locality plan in Appendix H).

As the area of disturbance for each of these activities is less than 25m^2 they will be exempt from the need to prepare a Cultural Heritage Management Plan unless activities will occur on the site of a registered aboriginal place. It is recommended that a desktop search, to identify any registered aboriginal places within the study area be undertaken to confirm that a Cultural Heritage Permit (CHP) is not required.

If the desktop search identifies a registered aboriginal place, relocation of the bore to a distance greater than 50m from the site would avoid the need for the preparation of a CHP (assuming that moving the bore location is feasible and doesn't create any new issues).

Process for permission to install bores in State Forest

The following information regarding permission for installing bores and stream gauges in the State Forest is based on discussions with the Department of Environment and Primary Industries (DEPI), and specifically based on correspondence with the Program Manager, Public Land, Land and Fire, based on Ballarat. If the observation bore sites are on Crown land or Forest land, they will issued a 'miscellaneous licence' giving permission to install the bore. Monitoring bores associated with the Anglesea borefield covered an area of 10 x 10m. (This is not a fenced off or physically delineated area, but simply a GIS boundary defined in the DEPI database). An applicant may apply for a smaller permit area than 10 x 10m. However, the minimum on-going rental payable to DEPI is $104/year per site (i.e. even if permit area is less than 10 x 10m). This describes the land tenure aspect of the permit.

In terms of management aspects of the permit, this will be handled by the Forest management group of DEPI based in Colac. This group will indicate whether there is a requirement to meet with anyone from Barwon Water to assess the sites, and whether any of the sites will need to be re-located or have special conditions imposed associated with the licence. It is considered more likely than not that a site inspection with DEPI will be required. (Any particular conditions required during installation of the bores, e.g. environmental conditions to manage impacts on soil, vegetation etc, would be considered at the time of the inspection).

If the stream gauges are on Crown land or Forest land the process would be the same as described above for the observation bores. If on private land, the CMA should be informed and consulted.

DEPI indicate that the timeframes for obtaining a miscellaneous licence are not expected to be excessive, i.e. in the order of several weeks to a month, not many months. However, it is recommended that ongoing dialogue with DEPI be conducted to ensure that the approvals process does not delay the planed drilling program from occurring in summer 2013-14. It is also recommended that the Colac-Otway Shire Council are involved in the same site inspections as DEPI, to ensure any potential confusion in terms of overlap of decision making and approvals is clarified.

Recommendation regarding borefield operation during monitoring period

For the following two reasons, it is not considered necessary to operate the borefield during the monitoring program (i.e. in the period leading up to licence renewal in 2018-19):

1) The main objective of turning on the borefield would be to enable various monitoring activities (groundwater levels, stream flow, vegetation assessments) to be observed under transient (i.e. changing) groundwater conditions. It is difficult to develop relationships between groundwater condition and other dependent variables if groundwater levels (excluding normal seasonal variation) are relatively constant. However, the regional groundwater system in the vicinity of the borefield is still recovering from prior episodes of pumping and will be for much, if not all, of the monitoring period (up to 2018). Therefore the new infrastructure and monitoring sites will be monitored during a transient period; the fact that it is during recovery rather than decline of water levels is not important. (This is because the emphasis during the monitoring period is on gathering data to calibrate the numerical model, which is in turn used to predict impacts, rather than the monitoring period itself being the means of estimating impacts).
2) For determining relationships between groundwater level and ecological condition, a very long period of borefield operation would be necessary for most monitoring sites. For example, given the relatively slow response times of water levels in the unconfined areas, assessment of vegetation condition versus groundwater level is a relationship that will require many years of data in order to establish scientifically sound conclusions regarding cause and effect. It is not practical for the borefield to be in operation for many years for this purpose (nor permissible under current licence conditions), and hence it is recommended that 'natural' variability in groundwater levels (from recovery from prior pumping, seasonal differences and rainfall induced difference) are instead used as the stressors on the system.

There may be a need for the borefield to operate for very short periods of time (e.g. several days or up to a week) for assessing aquifer hydraulic properties in the confined region of the aquifer, however this would likely only involve use of one production bore.

If drought conditions and storage levels in Barwon Water reservoirs require the borefield to be run during the monitoring period, this would not unduly impact on the monitoring program. To get best value from the bore field being switched on, those responsible for the monitoring program should be advised in advance. However, as described above, turning the borefield on for the primary purpose of stressing the system to observe changes in the monitoring activities is not recommended.

3. Groundwater investigations

3.1. Field investigations

The hydrogeological field assessment was conducted over the period 2nd – 5th April 2013. The main purpose of the work was to identify suitable sites for drilling, building on the desktop hydrogeological assessment of Stage 1 and assessing the condition of old bores for potential inclusion in the monitoring program. Other points of hydrogeological interest were also assessed, such as the quarry on Westwood Road, Big (Yeodene) Swamp and various waterways.

Table 4 summarises the results of field investigation in terms of recommendations for new bores and the re-instatement of existing bores. A map showing the location of these bores is in Appendix C.

Five sites where new bores are recommended were not able to be visited during the hydrogeological field assessment. Four of these sites were identified during the Ecology Australia field assessment, i.e. not during the desk top phase, and one site was identified after the hydrogeological field assessment. These five sites should be visited to assess suitability for drilling rig access - an efficient approach to conduct this could be to visit the sites at the time of final pegging of other bore sites. For the four terrestrial vegetation sites which were not inspected as part of the hydrogeological field survey (TB4, TB6, TB9 and TB10 in Table 4), each of the sites has track access and hence it is assumed that a drilling rig (at least a track mounted rig) will be able to access the site for bore installation. In the event that there is no suitable location along the track close to the site (e.g. a suitable clearing that will minimise disturbance to vegetation), a site in relatively close proximity to the vegetation monitoring survey location will be selected (i.e. as is the case for TB3).

The following bores were not located during the field assessment (it is assumed that they have been decommissioned or destroyed):

- 48002
- 109125
- 109121
- 109115
- 109123
- 109124
- 109125

The following bores were located during the field assessment but were found to be in an unsuitable state for monitoring:

- 109141 – backfilled / decommissioned (photos 103, photo 104)
- 109108 – unlocked, dipped bore but something blocking the bore at 8.5m bgl (photo 113)
- 64243 – found the remains of this bore (vandalised), (photos 84 and 85)

A search for the following bores during the field assessment revealed that they were on private property and, as a result, their status could not be assessed:

- 109136
- 109140
- 109139
- 109144
- 109126
- 109127

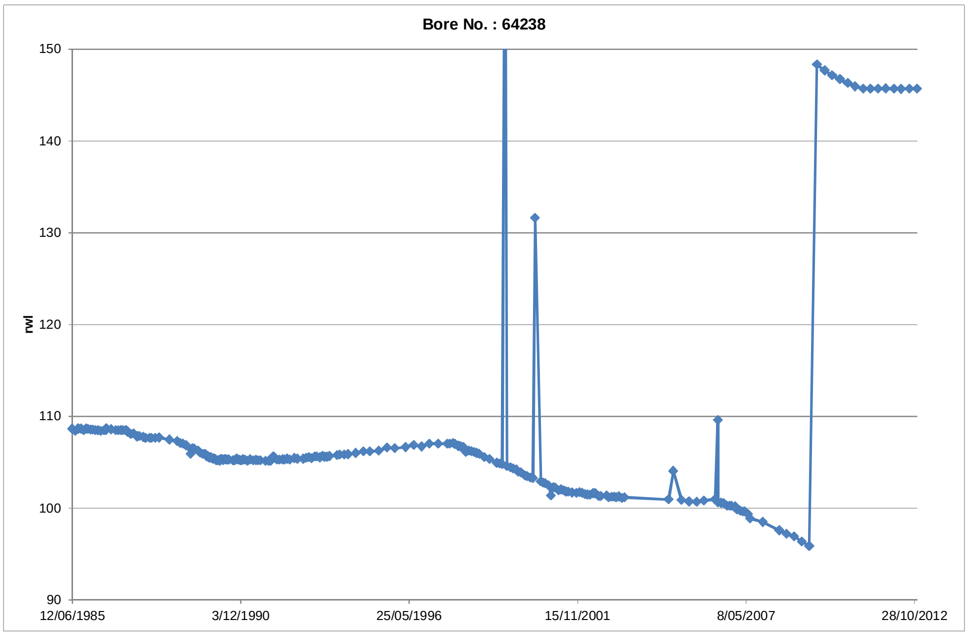
Of these six bores, two are recommended for re-instatement (109136 and 109144, as described in Table 4). This assumes that they can be located in the field; <u>if these bores cannot be found or are found to be in an unsatisfactory condition, then replacement bores will need to be installed</u>. Allowance for drilling of these two bores are covered in the contingency item that has been allowed in the drilling costs, as both bores are expected to be relatively shallow, and therefore relatively inexpensive to install. (Even though bore 109144 has not been monitored since 1989, there is a reasonable prospect that the bore is in a satisfactory condition, given the good condition of bores 109142 and 109143 which were installed at the same time). An attempt to locate these bores and assess their condition is therefore required prior to finalising drilling specifications and tender documents.

The field investigations confirmed the recommendations made from the desktop investigations with the exception of Bore 64239 and Bore 64238. It was noted as part of the field work and associated desk based follow-up that water levels have dropped below the screens in Bore 64239 and Bore 64238. It is recommended that one of these bores should be replaced to enable water levels to be monitored in this area. Bore 64239 is recommended as the preferred site, as it is further west and it is expected that water levels are deeper below the screen at this location (i.e. the groundwater level is more likely to come back into the screen in 64238). Even though both bores have water levels below the screen, it is still recommended that these bores are monitored, as water levels are currently recovering and may rise into the screened section of the bore in the coming months or years. Monitoring of bore 64239 ceased in 2011. It is recommended that Barwon Water discuss with DEPI the re-commencement of water level monitoring for this bore.

Separate to this issue, the cause of the anomalous rise in water level (of approximately 50m) in Bore 64238 since 2008 (refer Figure 3) should be investigated and rectified.

A new shallow bore was recommended at Bore 64238 during the desktop assessment (existing screen is at 70-87m bgl), however this is no longer recommended upon further inspection and consideration of the geological log. The screen is already sited above the (widespread and relatively thick) clay layer (refer Appendix A), and there are no significant clay layers above the screen. (Minor clay layers occur at 23-25m and 38-40m, which are not considered highly likely to create a perched watertable, and certainly not a perched watertable that would be used by terrestrial vegetation).

Figure 3 Bore Hydrographs for Bore 64238 and Bore 64239



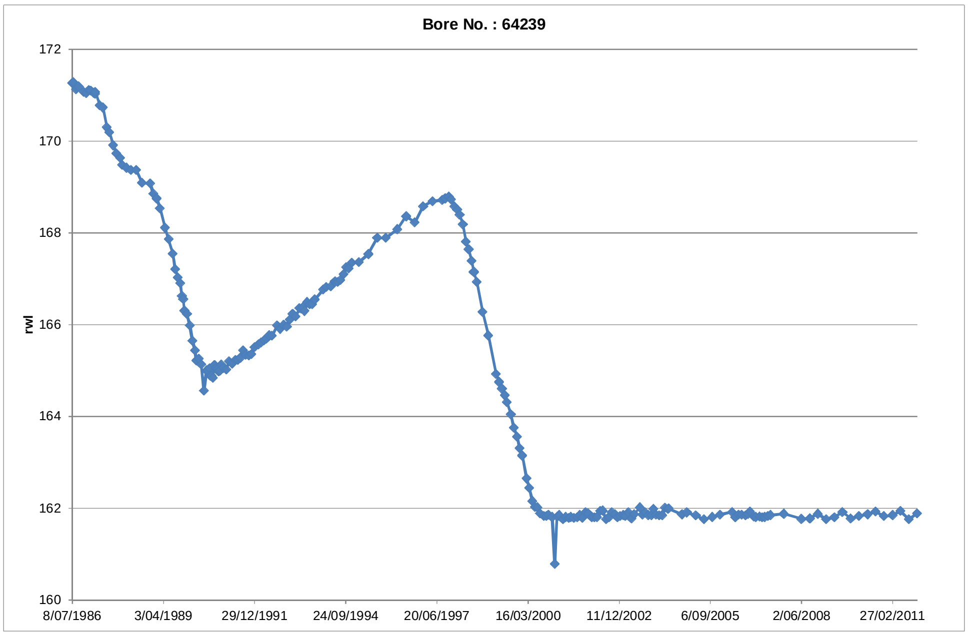


Table 4 Summary of proposed new bores or reinstatement of existing bores

Location Description	Purpose of Bore	New / Existing	Estimated bore depth	Coordinates (Zone 54 MGA)	Photo Reference	Comments
Bores for assessing unconfined areas in the Barongarook High						
109130 ~ 100m downstream of MacDonalds Dam, adjacent Boundary Ck	Currently monitored SOBN bore on the east side of Boundary Creek. (Bore 109142 on other side of Creek).	Existing	17.5m Screen: 8-15.5m SWL: 12.96m bns	210290 E 5745396 N	Photo 110	Bore has been monitored since 1986, however there is only one water level reading since November 2010 (in August 2012). *Recommendation: determine if this bore is still on the DSE monitoring run. If not, it should be restored to the run*.
109142 ~ 100m downstream of MacDonalds Dam, adjacent Boundary Ck	To provide water level adjacent Boundary Creek, immediately downstream of MacDonalds Dam Theoretically, there is no need for both 109130 and this bore, given their close proximity and similar screen interval. However, for three reasons (see comments), it is recommended that 109142 is reinstated.	Existing	20m Screen: 15.5-18.5m	210270 E 5745387 N	Photo 112	Monitoring occurred 1987-1989. However bore still looks in good condition. Bore dipped during field visit: 14.03m bgl (~ 15.35m below TOC). *It is recommended that 109142 is reinstated because*: 1. During their period of overlap there was up to a 1-2m difference in RWL between 109142 and 109130 2. The water level in 109130 could fall below the screen in the next 5-10 years, leaving no bore at this point 3. Anomalous data point in 2010 may potentially be indicative of issues with the bore
109143	To provide water levels downstream of MacDonalds Dam on Boundary Creek, but free from potential impact of leakage/loading effects from the dam, as 109130 and 109142 are potentially.	Existing	24.2m Screen: 11.5-17.5m	210260 E 5745212 N	Photo 111	Monitoring occurred 1987-1989. However bore still looks in good condition (and bore is not dry or silted up). *It is recommended that 109143 is reinstated.*
109136	To provide water levels upstream of MacDonalds Dam, near Boundary Creek.	Existing	37m Screen: 18.5-24.5m	209560 E 5745576 N	n.a.	Bore monitored 1987 – 2001. Could not get access to confirm condition/status of the bore. *Recommendation is to try and locate bore and, if found and in good condition, that the bore is reinstated. If the bore*

Location Description	Purpose of Bore	New / Existing	Estimated bore depth	Coordinates (Zone 54 MGA)	Photo Reference	Comments
						cannot be found (or is found in an unsuitable condition), a replacement bore will be required.
109144	To provide water levels downstream of MacDonalds Dam on Boundary Creek, but free from potential impact of leakage effects from the dam, as 109130, 109142 and 109143 are potentially.	Existing	23.5m Screen: 18.5-24.5m	210360 E 5744727 N	n.a.	Bore monitored 1987 – 1989. Could not get access to confirm condition/status of this bore. There is some prospect that they may be OK, given good condition of 109142 & 109143. *Recommendation is to try and locate bore and if found and is in good condition, that the bore is reinstated. If the bore cannot be found (or is found in an unsuitable condition), a replacement bore will be required.*
109131	To provide a water level away from Boundary Creek (to determine gw flow and flux to / from the creek).	Existing	86.5m Screen: 11-17m	210610E 5744654N	Photo 115	Monitored from 1986 – 2007. Bore unlocked. Looks in good condition. Bore dipped at 16.39m TOC (15.76m bgl). Screen recorded as 11-17m in GMS, however bore depthed in the field at 23.2m bgl, so screen expected to deeper. *Recommend bore is reinstated (subject to camera inspection to confirm screen location – if base of screens at 17m then do not recommend reinstatement).*
RB1 at Bore site 64239	Water level at the existing bore at this site has gone dry. Water level is now in the bedrock. (RB1 = Replacement Bore 1)	New	Screen approx. 90-100m (into bedrock)	208520E 5742279N	Photo 97 (facing S)	Suitable access close to Bore 64239 for the new bore. (Also a very quiet track i.e. no/minimal traffic). *With Bore 64238 to the NE also now dry, it is recommended that at one of these sites, a deeper bore is drilled to fill a spatial gap in watertable depth*. Site of Bore 64239 is recommended.
Bores for monitoring the watertable in the upper (unconfined) reaches of Boundary Creek						
TB5 "Field & Game" track, off Westwood Rd. Front of gun club / T5 (terrestrial veg	Dual purpose: monitor w'table at terrestrial veg. mon. site and determine gw flow direction in upper Boundary Ck	New	10-20m	207250mE 5741800mN	Photo 147	Moderately tight. Assess with DSE if this drainage(?) break is OK to locate a bore. Access easier through gun club front gate (which is locked) than back way

Location Description	Purpose of Bore	New / Existing	Estimated bore depth	Coordinates (Zone 54 MGA)	Photo Reference	Comments
site)						
UBCk1 Former bore site 48002 (Behind "Field and Game"	Determine gw flow direction in upper Boundary Ck	New	15-30m	207350mE 5742450mN	Photo 87 (facing N)	Good access for drilling (to RHS car in photo) Intersection of private & public land. Assess the easier location for permission to drill.
UBCk2 Adjacent Boundary Ck, north of "Field and Game"	Determine gw flow direction in upper Boundary Ck <u>NOTE</u>: The three bores together also form a transect to Boundary Ck.	New	10-15m	207450mE 5743200mN	Photo 90 (facing N)	Good access for drilling. DPI (2009) mapped as private land (no gates from State Forest however)
Sites for assessing the potential of perched groundwater						
No dedicated bore recommended. The original program included bores dedicated to the purpose of assessing perched watertables. The final recommended approach however is that each the bores at the terrestrial vegetation sites (TB1, TB2 etc) be used to assess for perched watertables, as the presence or absence of these has greatest implications for these GDES.						By using a suitable drilling approach and frequent sampling of the profile for moisture content, the presence/absence of a perched watertable in the upper 20m of the profile will be determined.
Bores for determining aquitard watertable depth, groundwater-surface water interaction and flow direction						
A1. Telegraph Rd, ~ 500-700m south of Dewings Rd	To determine depth to watertable in the aquitard at a topographic high point.	New	20-40m	210250mE 5743400mN	Photo 64 (facing S) Photo 65 (facing N)	Very good access at road edge. If this site is difficult for any reason (permission, underground services etc), Dewings Rd ~150m west of intersection with Telegraph Rd is a back-up site.
A2. Colac-Forrest Rd, ~400m south of Boundary Ck (east side of road)	To determine depth to watertable in the aquitard at a topographic high point and, along with Bore A3, determine groundwater gradient to Boundary Creek	New	20-40m	212800mE 5741900mN	Photo 49 (facing N)	Reasonable access (~9m to road edge) but caution required coming on and off Colac-Forrest Rd. No overhead issues, but Telstra cable in vicinity. If site deemed not suitable, need to move to 900m south of Boundary Creek (on Colac-Forrest Rd). Refer photos 47-48.

Location Description	Purpose of Bore	New / Existing	Estimated bore depth	Coordinates (Zone 54 MGA)	Photo Reference	Comments
A3. Colac-Forrest Rd, ~50-60m north of Boundary Ck (east side of road)	To assess the nature of interaction of groundwater in the aquitard with Boundary Creek, and, along with Bore A2, determine the groundwater gradient to Boundary Creek	New	10-20m	212750mE 5742450mN	Photo 46 (facing S)	Bore would be located at far end of the triangular patch of land shown in Photo 46. If site deemed not suitable, could move to nest with SOBN bore on west side of road (refer photo 44). Access tighter however.
A4. MacDonalds Rd, ~ 400m north of Birregurra-Yeodene Rd (west side of rd)	To assess watertable response in an area with potential drawdown in the aquitard	New	30-60m	213950mE 5744350mN	Photo 40 (facing S)	Bore would be located opposite shed shown in Photo 40. If site deemed not suitable, could move several hundred metres further north (refer photo 39) – good access on eastern side of road.
A5a. Dewings Bridge Rd at PB GW2A (nested with Clifton Form Bore: 64234)	To assess aquitard response to pumping in the Clifton Formation at an intermediate point within the aquitard, and provide information on vertical gradients within the aquitard.	New	~ 100m	215300mE 7540050mN	Photo 156 (facing E)	If there is not room within the existing production bore compound for these two new bores, then could potentially drill near bore 64230 ~ 100m north (refer Photo 155)
A5b. As above (nested with Clifton Bore and A5a)	To provide a shallow nested bore with A5a.	New	10-25m	215300mE 7540050mN	Photo 156 (facing E)	If there is not room within the existing production bore compound for these two new bores, then could potentially drill near bore 64230 ~ 100m north (refer Photo 155)
A6a. On Meadowell Rd, ~ 200m east of intersection with Gold Hold Road (nested with Clifton Form. Bore 64235)	To assess aquitard response to pumping in the Clifton Formation at an intermediate point within the aquitard, and provide information on vertical gradients within the aquitard.	New	~ 100m	208750mE 5737350mN	Photo 54 (facing E)	Reasonable access (~5-6m median strip on north side of the road). Quiet road. Telecom table on this side of road would need to be located / avoided.
A6b. as above (nested with Clifton Bore and A6a)	To provide a shallow nested bore with A6a.	New	~ 20-30m	208750mE 5737350mN	Photo 54 (facing E)	Reasonable access (~5-6m median strip on north side of the road). Quiet road. Telecom table on this side of road would need to be located / avoided.

Location Description	Purpose of Bore	New / Existing	Estimated bore depth	Coordinates (Zone 54 MGA)	Photo Reference	Comments
Bores for determining depth to watertable and groundwater trends at terrestrial vegetation monitoring sites						
Unconfined LTA						
TB1. Big Swamp monitoring bore at burnt peat site, bore south of swamp	To assess depth to watertable at vegetation monitoring site – Impact assessment site	New	Preferred site: 5-10m Back-up site: 10-20m	211,531 E 5,742,045 N	Photo 150 (facing N) Photo 151 (facing N)	Location shown in Photo 150 is preferred site, as it at a similar elevation to Big Swamp. Photo 151 shows an satisfactory alternate site (~ 100m south), if there are either permit or access issues with this site.
TB2. Big Swamp, upstream of burnt peat site.	As above	New	5-10m	210,750 E 5,742,067 N	Photo 96 (facing N)	Location shown in Photo 96 is closest site where a reasonable size d rig could be used. To get closer to the vegetation site, a small (e.g. 4-WD Landcruiser mounted style) rig would be required. Former shallow bores in this area could not be located during the field inspection (assumed lost/destroyed)
TB3. 580m north of Westwood Rd, on N-S oriented track (~300m east of gun club access road)	As above	New	20-40m	208,112 E 5,741,587 N	Photo 145 Photo 146	Access for a bore close to the vegetation site is not possible close to the vegetation site and would need to be located near or close to the track off Westwood Road. The two potential sites shown in Photo 145 and 146 are elevated approximately 20m above the swamp .
TB4. Off 'Quarry Tk' off Westwood Rd	As above	New	5-20m	209,078E; 5,742,252N.	No photo (new site not identified by EA prior to field work)	This site was not visited during the hydrogeological field assessment, as it was only identified by Ecology Australia during their field visit. However the site has track access and hence it is assumed that a drilling rig will be able to access the site (at least a track mounted rig) for bore installation.
TB5 "Field & Game" track, off Westwood Rd. Front of gun club / T5	To assess depth to watertable at vegetation monitoring site – Reference site This site has a dual purpose, as it will also assist toward determining gw flow	New	10-20m	207,250 E 5,741,800 N	Photo 147	Access for drilling a bore here is moderately tight. There is a need to assess with DSE if this drainage / grader line break is a permitted location to locate a bore. Access to the site is much easier through the gun club front gate (which is locked) rather than the back tracks

Location Description	Purpose of Bore	New / Existing	Estimated bore depth	Coordinates (Zone 54 MGA)	Photo Reference	Comments
	direction in upper Boundary Ck NOTE: Bore also listed above in table					
TB6. Near end of Langdons Rd	As above	New	10-20m		No photo (new site not identified by EA prior to field work)	This site was not visited during the hydrogeological field assessment, as it was only identified by Ecology Australia during their field visit. However the site has track access and hence it is assumed that a drilling rig will be able to access the site (at least a track mounted rig) for bore installation. Photo 81, Photo 82 are at the original Site 6, but location has changed slightly. Those sites could be used as a back-up if access on Langdon's Rd is poor.
TB7. Upper part of Ten Mile Ck, access is along Old Beechy Rail Trail	As above	New	5-10m	203,875 E 5,740,080 N	Photo 138 (facing W)	There is a currently an active SOBN bore within 200m of the site (47996, with current water level ~ 2.5m) however the bore is screened from 32-46m bgl. The interval from 10 to 30m is predominantly clay and therefore a new shallow bore at the site is recommended to ensure the true watertable is monitored, approximately screening the interval 4.5 - 7.5m (fine sand in log of 47996)
Confined LTA						
TB8. Westwood Track	To assess depth to watertable at vegetation monitoring site – <u>Impact assessment site</u>	New	10-20m	210,582 E 5,739,828 N	Photo 153 (facing SE) Photo 154 (facing NW)	Location at Photo 153 has the advantage of being at a similar elevation to the vegetation site. (Could get a small rig where the 4-WD is parked in the photo, but probably require a half road closure). Photo 154 is an alternate site (only ~ 5m higher elevation) with slightly more room than 153 for a drilling rig, but bore would be sited closer to the road. There are nearby bores, but these are not suitable for monitoring shallow water levels : Bore 64240: Sc 229-235 and Bore 64233: Sc 149-154m
TB9. Headwaters of Porcupine Ck, on	As above	New	10-20m	208623E	No photo (new site not	This site was not visited during the hydrogeological field assessment, as it was only identified by Ecology Australia

Location Description	Purpose of Bore	New / Existing	Estimated bore depth	Coordinates (Zone 54 MGA)	Photo Reference	Comments
Pipeline Rd				5733450N	identified by EA prior to field work)	during their field visit. However the site has track access and hence it is assumed that a drilling rig will be able to access the site (at least a track mounted rig) for bore installation.
TB10. Dividing Ck and Wares Rd	As above	New	10-20m	204,885E 5,737,764N	No photo (new site not identified by EA prior to field work)	This site was not visited during the hydrogeological field assessment, as it was only identified by Ecology Australia during their field visit. However the site has track access and hence it is assumed that a drilling rig will be able to access the site (at least a track mounted rig) for bore installation.
T11. Porcupine Ck on Colac - Olangolah Pipeline Track	To assess depth to watertable at vegetation monitoring site – <u>Reference site</u>	New	10-15m	207,182 E 5,734,799 N	Photo 137 (facing S)	The location shown in Photo 137 has the best access (on east side of track). However the pipeline location and minimum clearance is an issue to investigated. Photo 135 & 136 show alternate locations if this site not suitable, including sites on the west side of the track, depending on the location of the pipeline.
TB12. On tributary of Dividing Ck, on Gold Hole Rd	As above	New	10-20m	207,599 E 5,738,138 N	Photo 133 (facing NW)	Photo 133 is the preferred location, and has ~ 4m road verge for drilling access. This may be sufficient with half road closure, as the road is very quiet. If this site is not possible (due to access, safety or ground conditions) Photo 134 shows an alternate site, ~ 80m SE of above site.
TB13. Pipeline Track	As above	New	10-20m	206,395 E 5,737,118 N	Photo 131 (facing S)	Photo 131 is the preferred location for a bore (subject to pipeline location and minimum clearance issues). This is the northern end of the vegetation monitoring site, however the southern end also has potential sites for a bore to be located. Photo 129 & 130 show alternate locations on Parkes Lodge Road if above sites are not suitable.
Bores for investigating extent of unsaturated LTA material in the Upper Dividing Creek Area						
UDvCk. Corner Link Track and Westwood Track	To assess the extent of unsaturated LTA material in surrounding bores (This has implications for flow paths in the saturated LTA, and associated	New	40-60m	207,100 E 5,739,950 N	No photo (new site identified post-	This site was not visited during the hydrogeological field assessment, as it was only identified during a post-field trip review of the new bores. However access at the site should be good at the

Location Description	Purpose of Bore	New / Existing	Estimated bore depth	Coordinates (Zone 54 MGA)	Photo Reference	Comments
	spread/direction of the drawdown cone)				field work)	intersection of the two tracks.

3.2. Scope and costs of groundwater program

Based on the outcomes of desktop and field investigations the scope of works to establish the groundwater monitoring program includes:

- Installation of 25 new monitoring bores plus potentially 5 bores at the PASS sites (and up to two additional bores to replace existing bores, depending on status of these bores)
- Geophysical logging of 30 new bores plus 12 existing bores
- Reinstatement of 6 old monitoring bores
- Groundwater quality sampling at all new and re-instated bores
- Hydraulic testing of all new bores and two existing deep aquifer bores
- Groundwater level monitoring in the 25 new bores and 6 reinstated monitoring bores plus bores potentially at 5 PASS sites for a period not shorter than five years (i.e. up to licence renewal and associated analysis and review)
- Investigation of changes in aquifer salinity at the production bores

Two possible schedules for the establishment of the groundwater monitoring program can be found in Appendix B (referred to as 'realistic' and 'pessimistic'). The realistic schedule assumes the capital works infrastructure are installed in summer of 2013-14, while the pessimistic schedule assumes a delay until the following summer.

3.2.1. Installation of new monitoring bores

3.2.1.1. New bore design and specification

The design and specification for each of the new bores can be found in Appendix C.3. C.2

3.2.1.2. Costs estimates

Estimated costs for the drilling program are presented in the table below. These estimates have been based on the design and specification found in Appendix C.3. The detailed breakdown of the estimates is found in Appendix C.4.

Table 5 Summary of cost estimates for drilling program

Item	Estimated Cost	Notes
Drilling Contractor	$321,350	Based on estimates from prior drilling programs and discussions with drilling companies (but not actual quotes). Assumes driller contracted by Barwon Water. Assumes no significant environmental conditions at the site. (Costs of surveying bores not included).
Technical Supervision and Project Management	$100,550	Includes ▪ technical supervision (not formal 'Superintendent' role). ▪ factual report on drilling program. ▪ Allowance for landowner / Council / DSE liaison, obtaining permits etc ▪ PASS bores are included ▪ Does not include costs of licence or permit fees (e.g. Bore Construction Licence)
Sub Total	$421,900	
20% contingency	$84,380	
Total (excl GST)	**$506,280**	

The costs presented do allow a nominal amount of time for obtaining bore construction licences, landholder liaison, cultural sensitivity (aboriginal) and drilling permits related to drilling on Crown or Council land. If particular sites prove problematic in terms of permits and access, these costs may need to increase for those bore sites.

3.2.2. Geophysical Logging

3.2.2.1. Scope of works

Table 6 Scope of works for gamma logging program

Item	Description
Purpose	To assist towards refining the hydrostratigraphy of the project area, including providing consistency in estimating lithology between bores and estimating lateral continuity of units.
Locations	▪ All new bores ▪ Existing deep aquitard bores (64234 and 64235) ▪ 10 existing bores across the Barongarook High area (which intercept the LTA aquitard). ▪ The location of these new and existing bores are show in Appendix C.1.
Method / Scope of Activity	Bores should be gamma logged to their full constructed depth. Logging both up and down-hole is recommended.
Risk if not undertaken	Reliance on hand logging of samples to determine lithological changes, with potential for error due to assumed depth of retrieved cuttings and potentially inconsistent interpretation across bores (e.g. between new and existing bores). The ultimate risk is that an incorrect conceptual model is developed which introduces errors to the numerical model and associated predictions.
Frequency	This is a one-off activity.
Data Capture and Recording	The gamma logging should be collected in a digital format and reported in the main drilling report.
Duration	This activity could be completed over approximately 6 days of field work.

3.2.2.2. Costs estimates

The estimated cost for gamma logging is presented in Table 7. The detailed breakdown of the estimates is found in Appendix C.4.

Table 7 Cost estimates for gamma logging program

Item	Cost	Notes
Gamma logging of 42 bores	$11,652	Assumes eight additional bores to new bores (30) plus the two aquitard bores (plus two existing deep aquitard bores 64234 and 64235) (assumes 6 days field time)

Processing data	$1,312	
Analysis and Reporting	$3,400	This is an allowance for a factual report, including importing the gamma logs into bore logs and basic interpretation and comment on the results.
Project Management (inc EHS etc)	$3,273	
Sub Total	$19,637	
20% contingency	$3,927	
Total (excl GST)	**$23,564**	

3.2.3. Reinstatement of old monitoring bores

3.2.3.1. Monitoring bore reinstatement scope of works

- **Table 8 Scope of works for monitoring bore reinstatement**

Item	Description
Purpose	To fill data gaps in the existing groundwater monitoring network using existing but currently un-monitored bores
Locations	The bores recommended for reinstatement are : 109130, 109131, 109136, 109142, 109143, and 109144. Two of these bores were on private land and were not able to be located in the field assessment: 109144 (~650m downstream of MacDonalds Dam) and 109136 (~650m west of MacDonalds Dam). If these bores cannot be found (or are found to be in an unsuitable condition), replacement bores will be required. There are also other bores which could potentially be reinstated (but were unable to be assessed during the field visit as they were on private land), including 109139 and 109140 (immediately upstream of MacDonalds Dam) and 109126 and 109127 (1000m downstream of MacDonalds Dam. For costing purposes it has been assumed that only two of these four bores will be suitable for reinstatement. If these bores cannot be located, drilling of replacement bores is not recommended – while inclusion of these bores is considered to add value to the monitoring network, they are not considered essential. The locations of the bores for reinstatement are shown in Appendix C.1.
Method / Scope of Activity	The bores should be developed via airlifting for 30 to 60 mins, to remove any sediment in the base of the bores, and re-develop the gravel pack around the screen. Ideally development should continue until the water is free (or almost free) of sediment. Care should be taken during development that casing or screens are not ruptured with excessive air pressure.

Item	Description
	Notes should be made of any repairs to surface casing / metal standpipe that may be required.
Risk if not Undertaken	New bores may need to be drilled instead to fill some of these spatial data gaps (involving greater expense, disruption to landowners, etc).
Frequency	This is a one-off activity.
Data Capture and Recording	Water quality (field parameters only) and sediment changes should be recorded during development. Recovery of water levels, to check that recovery to (near) starting levels occurs, should be undertaken (manual dipping, not continuous logging is suitable)
Duration	This activity could be completed over approximately 2 days (potentially 3 days depending on the number of bores added).

3.2.3.2. Costs estimates

Estimated cost for reinstatement of groundwater bores is presented in Table 9. The detailed breakdown of the estimates is found in Appendix C.4.

The cost estimates have been prepared assuming this work will occur as part of the main drilling contract (i.e. drilling of the new bores), and hence cost of mobilisation to the area has not been included.

- **Table 9 Costs estimates for reinstatement of groundwater monitoring bores**

Item	Cost	Notes
Development of 8 bores (drilling contractor costs)	$6,500	Assumes two extra bores would be added to the list of 6 bores already sited in the field and recommended for inclusion. The costs assume the driller used in the bore installation program will be undertaking the work (additional mobilisation costs will otherwise be incurred).
Technical supervision (including post water level recovery monitoring)	$3,790	
Reporting (factual report)	$1,200	
Project Management (inc EHS etc)	$2,298	

Item	Cost	Notes
Sub Total	$13,788	
20% contingency	$2,758	
Total (excl GST)	**$16,456**	

The costs presented above do not allow time for:

- landholder liaison,
- any additional maintenance identified during bore re-development

3.2.4. Groundwater quality sampling

3.2.4.1. Groundwater quality sampling scope of works

Table 10 Scope of works for groundwater sampling

Item	Description	
Purpose	To provide information that contributes to understand the groundwater system (e.g. flow direction and relationship with surface water systems), impacts of groundwater pumping on water levels and provide calibration data for the numerical model.	
Locations	New bores screened in the aquitard: A1, A2, A3, A4, A5a, A5b, A6a & A6b. Plus two existing deep aquitard bores at 64234 and 64235.	All other new bores installed (excluding those listed opposite)
Method / Scope of Activity	Bores to be sampled for major cations, anions, TDS and EC (plus field parameters EC, pH, redox,temp). Bores to be purged of three bore casings prior to sample collection, if feasible (with a minimum of one bore casing)	Bores to be sample for field parameters EC, pH, redox and temp. Bores to be purged of three bore casings prior to final field measurement.
Risk if not Undertaken	An opportunity for use of a relatively inexpensive means of improving understanding of the groundwater system is missed. Obtaining groundwater levels only from a bore provides part of the information that builds the understanding of groundwater movement through the system. In particular there is poor understanding of aquitard chemistry at Barwon Downs.	
Frequency	Once off event.	

Item	Description
Data Capture and Recording	The groundwater chemistry data should be reported in the main drilling report
Duration	Conducted over approximately a 2 week field program

3.2.4.2. Cost estimates

The estimated costs for groundwater sampling are presented in Table 11. The detailed breakdown of the estimates is found in Appendix C.4.

- **Table 11 Costs estimates for groundwater sampling**

Item	Cost	Notes
12 bores (field chemistry and major cations and anions)	$9,000	These bores will take longer to sample (per bore) than remaining bores, as they are either larger diameter (100mm) and/or will take longer to recover
19 bores (field chemistry only)	$8,690	
Reporting	$2,400	
Project Management (inc EHS etc)	$4,018	
Total (excl GST, excl contingency)	$24,108	
20% contingency	$4,822	
Total (excl GST)	**$28,930**	

3.2.5. Aquifer hydraulic testing

3.2.5.1. Aquifer hydraulic testing scope of works

Table 12 Scope of works for aquifer hydraulic testing

Item	Description
Purpose	The purpose of the hydraulic testing is to determine the hydraulic conductivity of the sediments screened (i.e. targeted) by the observation bore. This is a key parameter in determining groundwater flow paths and the rate of water movement through the groundwater system. It is a critical input in the numerical model. In particular, current estimates of the hydraulic conductivity of the aquitard in the numerical model are based on very limited field data, and hydraulic testing will reduce uncertainty in this area. The hydraulic testing of the terrestrial vegetation observation bores will improve the spatial coverage of the data set of hydraulic conductivity in the LTA aquifer – current data is limited to the area around the production bores.
Locations	All new bores plus two existing deep aquitard bores 64234 and 64235.
Method / Scope of Activity	Slug testing is the recommended form of hydraulic testing. This involves rapid addition or removal of a small volume of water from the bore, and measuring the response of groundwater levels after this displacement. Analysis of the rate of recovery of water levels to equilibrium provides an estimate of the hydraulic conductivity of the formation. Conducting pumping tests in an aquitard is generally not possible due to the low yields of bores. Due to the potentially long recovery times in the aquitard bores, field testing will involve multiple tests in parallel to allow as much recovery of levels as possible.
Risk if not Undertaken	A critical input to the numerical model will not be improved compared to previous versions of the model. In particular, aquitard hydraulic conductivity will need to be estimated using other (less certain) means. This is a current weakness of the model in terms of predicting potential impacts of pumping in the aquitard watertable.
Frequency	One off activity
Data Capture and Recording	The data would be captured by the technician / consultant conducting the field work. The results should be reported in the main drilling report.
Duration	Conducted over approximately a 2 week field program

3.2.5.2. Cost estimates

The estimated costs for aquifer hydraulic testing are presented in the table below. The detailed breakdown of the estimates is found in Appendix C.4.

Table 13 Summary of costs for aquifer hydraulic testing

Item	TOTAL
10 aquitard bores	$ 6,600
Remaining (new) 19 bores	$ 8,290
Analysis and Reporting	$ 6,000
PM / EHS	$ 4,178
Sub Total	$ 25,068
20% contingency	$ 5,014
TOTAL (excl GST)	**$ 30,082**

3.2.6. Groundwater level monitoring and bore maintenance

3.2.6.1. Groundwater level monitoring scope of works

Table 14 Scope of works for groundwater level monitoring

Item	Description
Purpose	To understand groundwater behaviour (e.g. flow direction and relationship with surface water systems), impacts of groundwater pumping on water levels and provide calibration data for the numerical model.
Locations	The locations of the new bores are show in Appendix C.1. The bores recommended for reinstatement are : 109130, 109131, 109136, 109142, 109143, and 109144 (potential new bores are described in the text associated with this section) The locations for PASS sites are not yet determined, as this depends on outcomes of the PASS soil testing. Potential sites are shown in Appendix E.1
Method / Scope of Activity	Monitoring using data loggers is recommended. The cost estimate used in this analysis assumes use of the Solinst Levelogger Edge Model 3001. This, or a similar quality data logger should be used. Use of stainless steel cables to suspend the loggers is recommended. Loggers should be set at least 2m below the lowest expected water level decline (either due to seasonal fluctuation or groundwater pumping). Two barologgers should also be installed in two bores (one towards the eastern edge and one towards the western edge of the project area) to compensate for the effect of barometric pressure on water levels.

Item	Description
Risk if not Undertaken	Water levels provide key information on groundwater system behaviour and changes. If the existing network of bores only is used for obtaining levels then the dynamics within aquitards and significant areas of the outcropping LTA will remain poorly characterised. If infrequent manual monitoring of levels (e.g. every 3 months) rather than logging at a sub-daily frequency is adopted, the opportunity to observe system responses to particular stresses will be lost (e.g. barometric response, responses to a particular recharge event, or diurnal fluctuations in water levels due to vegetation).
Frequency	Prior to the first download (i.e. for the first three months) a logging frequency of 15 minutes should be used. This will allow calculation of barometric efficiency for each bore, and allow checking of future logging frequency. A long term logging frequency of around once per 6 hours is likely. Manual dipping of the bores should occur when data loggers are downloaded. It is recommended that this occur four times during the first two years, and then twice per year thereafter.
Data Capture and Recording	The loggers should be downloaded at each site visit (four times during the first two years, and then twice per year thereafter) and then the data checked once per year to confirm logger performance / integrity and data analysis (if required). The data should be stored by Barwon Water, using existing databases for water level data storage. Prior to storage, the logger pressure data should be compensated for barometric pressure (i.e. total pressure read by logger minus barometric pressure) and converted to a RWL
Duration	Some groundwater monitoring will need to occur for as long as the borefield is in operation. However once seasonable patterns are established, loggers may not be necessary in all (or any) of the bores. (The costs show a 5, 15 and 20 year monitoring period). The 5 year figure represents costs that will be incurred up to licence renewal. The 15 year cost represents the likely life of the data loggers, and the 20 year costs represents the time up to the next licence renewal. Given the relatively low logging frequency and relatively good groundwater quality, it is quite possible the loggers could have a 20 year life. The number of bores and frequency of logging should be reviewed as part of the 2018/19 licence renewal process. Up to that point, all new bores should be monitored at the frequency described, above, and existing bores at a frequency not less than current monitoring.

The table outlines the specifications for groundwater level monitoring of the new bores (25 bores), existing bores recommended for re-instatement (6 bores) plus bores potentially required at the PASS sites (assumed to be 5 sites), forming 36 additional bores requiring monitoring.

The recommended method of monitoring these bores is via installation of data loggers. The reasons for this are based on long term costs savings (explained further in the following section) and improved quality of data collection. Use of data loggers will provide a much higher frequency of water level data, helping with conceptualising groundwater processes and improving the quality of calibration data sets.

The exact number of bores to have loggers installed is not known. There are five PASS sites to be tested, and depending on the outcomes of that investigation, some of these sites may not have a bore installed. However, there were some bores which were unable to be assessed during the site visit (109126, 109127, 109136, 109139, 109140, 109144) – the status of these should be investigated and if deemed in good condition, also added to the monitoring program. The costs for loggers and monitoring for these bores has not been included in the cost estimate, however on balance, 36 additional bores to be monitored is a reasonable number for costing and planning purposes, as it is highly likely that some of the PASS bores will be removed after the soil investigation.

Bore Maintenance
The scope of works for bore maintenance includes:

- Clearing native vegetation and ad hoc maintenance (e.g. caused by vandalism) – required annually (At some of the bore sites it is likely that vegetation clearing will be conducted by the land manager, Council or DEPI, and hence this work may not be required at all sites.
- Painting of the steel protective cover – required approximately once per ten years
- Airlifting of the bore to remove any sediment accumulated in the sump – required approximately once per twenty years

3.2.6.2. Costs estimates

Comparison of telemetry and data loggers versus data loggers only
Estimated costs for on-going monitoring are presented in the table below. (Note that this comparison is not a discounted cash flow analysis). The table presents cost comparisons of monitoring using data loggers with manual download versus data loggers with automatic download via a telemetry system. The detailed breakdown of the estimates is found in Appendix C.4.

Table 15 Summary of costs for monitoring of groundwater (includes 20% contingency)

Method	Estimated Cost			Notes and Key Assumptions
	5 year monitoring period (excl GST)	15 year monitoring period (excl GST)	20 year monitoring period (excl GST)	
Data loggers with manual down load	$81,000 ($16,200/yr)	$122,000 ($8,130/yr)	$142,000 ($7,100/yr)	Assumes downloading loggers/dipping bores quarterly per year in the first 2 years, and then twice per year in subsequent years.
Data loggers with automatic down load (telemetry)	$352,000 ($70,300/yr)	$457,000 ($30,500/yr)	$507,000 ($25,350/yr)	Assumes dipping bores once per year.

Assumptions

The cost comparison depends on assumed labour costs for monitoring and the time taken for bores to be visited and water levels to be measured. (Labour and vehicle costs were provided by Barwon Water). These costs assume that the manual download of 36 bores takes 2 days. (The costs for both options exclude data handling costs, i.e. processing and storing the data after download).

An assumption in the 20 year cost estimate is that the loggers will have a 20 year life (i.e. there has been no allowance for replacement of the loggers). The battery life of the loggers, at a one minute sampling interval is 10 years; therefore a 20 year battery life is not an unreasonable assumption given the much lower sampling frequency. Further, the groundwater quality is generally good (i.e. non aggressive) which means that corrosion of the loggers will be reduced. (This will vary between sites however, and at some locations, corrosion may lead to a logger life of less than 20 years).

Discussion

This analysis suggests that telemetry is not a cost effective solution for monitoring the bores. The telemetry option does have the advantage of being able to access data quickly, but the cost of this relatively small benefit does not appear justified. (For key bores where quick access to data might be beneficial, e.g. trigger/criteria bores, telemetry could be installed just at those sites). HydroTerra (the company who provided the quote for the telemetry system) indicated that they may be able to bring these costs down somewhat with a different type of telemetry system. They did not provide this alternate quote in time for inclusion in this project, however it is considered highly unlikely that the cost of the alternate telemetry system would come close to the cost of 'normal' automated logging. (The impression from discussions with HydroTerra is that the cheaper system might reduce costs in the order of 20-30% which would not materially affect the comparison above).

Even if the telemetry system was not monitored at all (i.e. the annual visits to the site were removed from the costs), the cost for the telemetry system would only be reduced by around

$40,000 over a 20 year monitoring period. This is because the bulk of the operating costs for the telemetry system are related to the subscription fees for the telemetry data hosting device.

In summary, even under various scenarios which might reduce the relative cost difference between the two options, remote downloading of logging via telemetry is significantly more expensive than straight use of data loggers with manual downloading. This analysis also excludes the repair costs to possible vandalism to the telemetry system, e.g. aerials, solar panels etc, which is a further disadvantage of telemetry.

Bore Maintenance Costs

Estimated costs for bore maintenance over a five and twenty year period are presented in Table 16. (These do not include whole of life costs, e.g. cost of bore replacement).

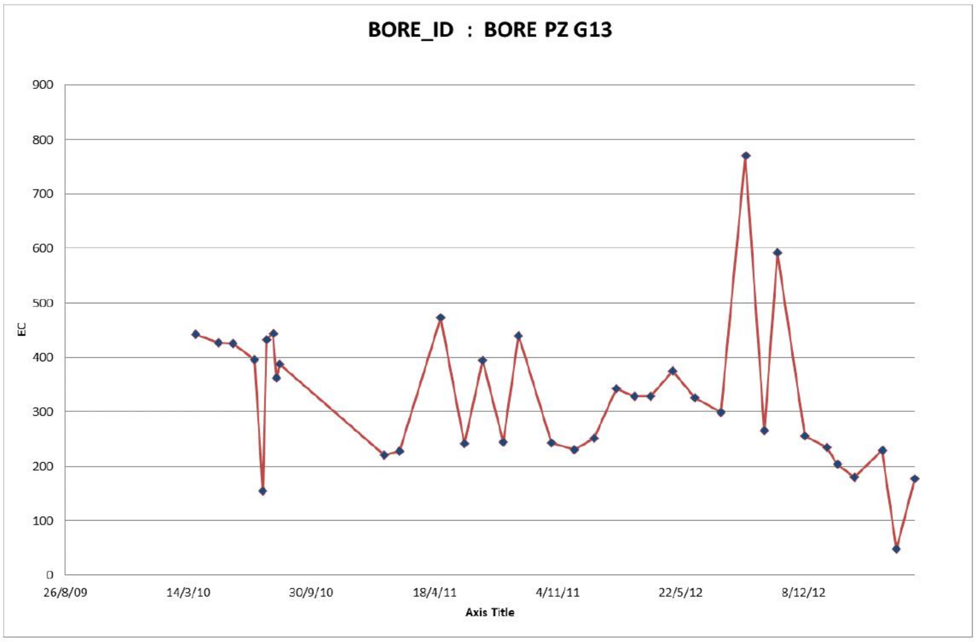
- **Table 16 Summary of cost estimates for observation bore maintenance**

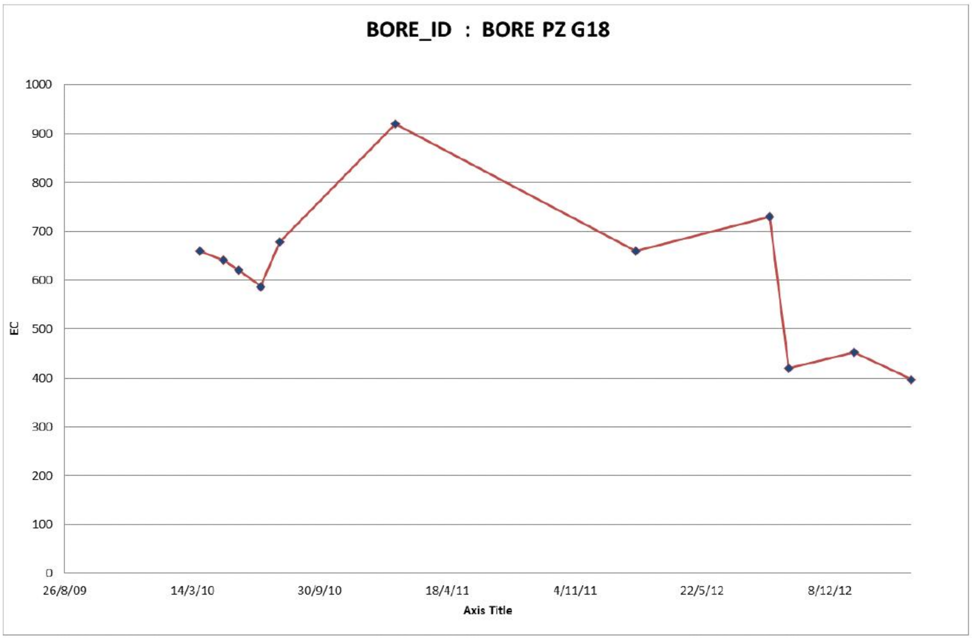
Item	5 years	20 years
Clearing vegetation /ad hoc maintenance (annually)	$ 11,500	$ 46,000
Painting protective steel cover (once per 10 years)	$ -	$ 2,800
Airlifting (once per 20 years)	$ -	$ 13,800
Sub Total	$ 11,500	$ 62,600
20% contingency	$ 2,300	$ 12,520
TOTAL,(excl GST)	**$ 13,800**	**$ 75,120**

3.2.7. Investigating changes in aquifer salinity

Figure 4 shows plots of electrical conductivity for two observation bores near the Barwon Downs borefield. The graphs show a declining EC trend in G13 (64229) from mid-2012 and in G18 (64234) from early 2011. In fact, many of the observation bores across the study area show similar downward trends in EC (across similar timeframes). The magnitude of the changes in EC in these bores (including those shown in Figure 4) is very significant, e.g. a 50% decline in EC in G13 in 12 months. If these changes are real, they represent a significant challenge to the current conceptual understanding of the aquifer system (i.e. how could such a rapid change in salinity occur at this locations in the groundwater flow path?), and as such further investigation of this issue is important. If the changes are not real, and instead indicative of poor sampling technique or well head/casing condition, then the current significant investment in EC monitoring that is being implemented should be reviewed.

- **Figure 4 Salinity (electrical conductivity) trends in two bores near the Barwon Downs borefield (G13 is screened from 515 - 542m and G18 is screened from 247 - 253m).**





3.2.7.1. Scope of works

A three step process to investigate the changes in aquifer salinity across the area is recommended. These are described in detail in Table 17, however some introductory comments are provided below. It is important to note that task two and three may change, depending on the outcomes of task one (including possible termination of the tasks).

- *Task 1 – Review of recently collected salinity data*: As described above, the magnitude of changes observed in the salinity data, as well as the high level of fluctuation in the data, suggests that there may be either an issue with the sampling technique, sampling implementation or wellhead/bore integrity issues. This task will involve reviewing the sampling technique used for EC measurement to see if this might explain the observed data. Tasks 2 and 3 below are based on the assumption that the observed salinity changes are real – if Task 1 demonstrates that the rapidly declining trend may not be real, then the need for, and scope of, tasks 2 and 3 should be adjusted accordingly.
- *Task 2 – Develop salinity contour map*: A salinity contour map was developed for the area using data mainly from the 1980s (in Witebsky et al., 1995). Producing a more recent version of this map would provide a rapid visual assessment of changes in aquifer salinity between then and now.
- *Task 3 – Field investigation to assess changes in chemistry*: The field work program would investigate the change in aquifer chemistry along the flow path from the recharge area to the borefield. One of the objectives of this task would be to address a theory which might be purported based on the salinity data; that the cause of the declining salinity trend is due to water being “sucked” from Boundary Creek and other streams. The program outlined in Table 17 will address this issue in a relatively definitive manner, however there are simpler and lower cost methods which could also address this issue.

  For example, it is relatively easy to demonstrate, using basic groundwater equations, that the cause of the declining salinity in the deep bores near the borefield is very unlikely to be from recent recharge from streams on Barongarook High, based on the long travel time between these areas. (Alternately the numerical model could be used to demonstrate the same thing). This is not to say that the process of losses from streams to groundwater is not occurring, it is just that this would not be yet evident at the borefield.

  However, the program proposed would collect new data that would build conceptual understanding of the groundwater system in a way that the basic analysis does not. In particular it would demonstrate rates of groundwater travel from the recharge areas to the borefield. For the joint purposes of addressing potential questions regarding changing groundwater salinity, as well as improving conceptual understanding of the groundwater system, this activity is considered worthwhile.

Table 17 Scope of works for investigation of changing EC in production bores

Investigation	Groundwater Chemistry
Purpose	There are two main objectives to this task. The first is to assess the veracity of the existing (recently collected) EC observation bore data, and the second is to assess the cause of EC decline in the recent data. Declining salinity in many of the observation bores, including deep observation bores close to the borefield, suggests that pumping is causing an inflow (induced recharge) of a fresher source of water. There are four potential source of fresher water: 1) Isolated zone(s) of low salinity groundwater migrating towards the bore field 2) Seepage of fresh water stored in the aquitard 3) Increased rainfall recharge to the outcropping aquifer 4) Seepage from streams flowing over the aquifer and/or the aquitard Understanding the relative importance of these contributions to the observed change in salinity is an important part of conceptualising the whole groundwater system. While it is likely that all processes may be contributing to the change in salinity, the focus of this investigation is to assess the significance of contributions from streams.
Locations	The locations of the study are outlined in the "Scope of Activity" below. They include bores sites and sampling from streams.
Scope of Activity	***Step 1 – Review of recently collected salinity data*** The rapid rate of change in EC, and the high level of fluctuation in some of the EC data suggests that there may be either an issue with the sampling technique or bore integrity (because normally EC is a parameter which changes slowly). This task will review the sampling technique used for EC measurement, including assessment of equipment used, calibration of equipment etc. This would be conducted by reviewing any documented sampling protocols and discussion of the method with the field staff who conduct the sampling), to see if this might explain the observed data. If there is fresher groundwater in overlying units, then bore integrity issues may cause seepage of fresher water into the deeper aquifer. This task will therefore also involve review of both the potential for this to occur at specific bores (e.g. is there an overlying fresher unit) and the likelihood of this occurring based on bore age, construction, material etc.

Investigation	Groundwater Chemistry
	The task will also involve comparing the recent EC data with early EC data collected for each bore (e.g. available on the GMS and as presented in Witebsky et al., 1995). The key output from this task would be a short report commenting on the integrity/reliability of recently collected groundwater salinity data, (including recommendations for changes in sampling technique and practice if required) and recommendations on the need for, and changes to the scope of Steps 2 and 3. The report will also comment on recommended frequency of groundwater sampling (e.g. the current frequency of groundwater salinity sampling in some bores appears high, and there would be cost savings with a reduced frequency of sampling). ***Step 2 – Develop a recent salinity contour map*** A salinity contour map was developed for the area using data mainly from the 1980s (in Witebsky et al., 1995). Producing a more recent version of this map would provide a rapid visual assessment of changes in aquifer salinity between then and now. A groundwater contour map of salinity in the LTA aquifer would be developed. There are 54 bores which have recent EC and/or TDS data on which this map could be based. ***Step 3 – Field work sample collection and analysis*** This involves sampling groundwater along a bore transect from the recharge area, starting from downstream of MacDonalds Dam where the creek is (likely to be) a losing stream, down to the borefield. The following transect is recommended: ▪ 109130 (Screened 8 – 15m) - downstream of MacDonalds Dam, and immediately adjacent Boundary Creek. ▪ 109110 (Screened 73.5 – 76.5m) and 109111 (Screened 22 – 40m) - These comprise a deep and shallow bore within the LTA aquifer, several hundred metres east of the above bore site. This will provide a contrast to the shallow bore immediately adjacent Boundary Creek (with a likely high surface water signature), as well as providing a deeper chemistry sample. ▪ Bore 109132 (screened 106-109m bgl) - approximately 1000m down-gradient of the above site, within outcropping LTA ▪ 64233 (Screened 150 – 154 m bgl) – approximately 2000m down-gradient of prior bore and within the confined part of the LTA ▪ One of the Barwon Downs production bores – the bore selected for

Investigation	Groundwater Chemistry
	sampling will decided based on a combination of the observed salinity trend in the bore and sampling convenience. The above bores are the key data sets on which the analysis is based. In addition it is recommended that the existing deep aquitard bore (64234) near the borefield (screened in the Clifton Formation) and the new aquitard bore (which will be situated at the same site and screened around 100m bgl) are also sampled. These two bores are already being sampled as part of a separate investigation and hence the additional work only involves collection of additional samples during that program. Two surface water samples should be collected in a period of different flow conditions (one during baseflow and one where runoff is a substantial portion of flow). One sample upstream (e.g. area north of the gun-club) and one downstream of MacDonalds Dam (but before Yeodene Swamp) is recommended. In total eight groundwater samples and four surface water samples (2 locations x 2 at different times of the year) would be collected and analysed. Two of the groundwater samples would be collected as part of a separate investigation. (If this investigation was pursued, then it would be logical to combine the two groundwater sampling programs). **Sample Parameters** The above bores, and two locations within Boundary Creek should be sampled for the following parameters: ▪ Cations and Anions - describes the general chemical type – enables likely <u>non</u> sources to be identified, in that the source of recharge cannot be a higher EC than what is within the aquifer ▪ Stable Oxygen Isotopes – provide insight into the source of recharge, for example, recharge from fresh surface water will have a different isotopic ratio than more diffuse recharge through vegetation into pore water held within the aquitard. Oxygen Isotopes will be useful for identifying if any surface water has moved into the aquifer ▪ Carbon 13 (^{13}C), provides insights into the root zone processes during recharge, recharge through outcropping LTA aquifer will have significant more ^{13}C than recharge through the low permeable marl ▪ Carbon 14 (^{14}C) provides indicative age of groundwater along the flow path – this will be a key piece of information in determining whether current water from the borefield could possibly be related to induced

Investigation	Groundwater Chemistry
	leakage from Boundary Creek. Groundwater age along the transect will demonstrate timeframes of water movement and is expected to eliminate induced stream recharge as the cause of the freshening salinity trend. For example, if surface water was leaking into the aquifer, the very recent (young <10 years) age of the water will show up on the Carbon age of aquifer water in adjacent groundwater bores. (Depending on the alkalinity of the water –up to 4 to 8 litres of sample may be required) It is expected that this analysis will eliminate induced recharge from streams as a cause of currently observed declining trends in EC. In the event that this is not the case, ongoing sampling may be recommended, as this would have significant implications for the conceptual (and numerical) model. All sampling should be in accordance with the Geoscience Australia groundwater sampling guidelines. Care needs to be taken that bores (in particular deep bores), are not drawn down to the point of risking collapse of the casing, due to removal of the water pressure in the bore. **Reporting and outcomes** The implications of the findings need to be documented and described in context with existing physical hydrogeological data. It is important the results of the chemistry are integrated into a physical hydrogeological conceptualisation. Explanation of the change in water quality and a changing recharge source requires use of appropriate groundwater level pressures and gradients. A key outcome will be to identify the likely source of recharge that is causing a shift in the chemistry of the borefield. In addition to address community concerns regarding changing chemistry, this program could be very useful in developing the conceptual model (i.e. what is the main source of the groundwater being pumped).
Risk if not Undertaken	The cause of the declining EC trend in the aquifer over recent years will remain unknown if the activity is not undertaken. In addition to important insights into groundwater recharge and flow processes, there is a risk that incorrect conclusions will be drawn from the data in the absence of a proper review. (If the trend is not real and caused by a change in sampling technique or equipment this also will not be identified if not undertaken).

<table>
<tr><th>Investigation</th><th>Groundwater Chemistry</th></tr>
<tr><td>Timing
(and Duration)</td><td>This would be a once off event for the groundwater sampling (after installation of new monitoring bores), so likely timing would be late summer, early autumn 2014. The sampling of the eight groundwater bores and two surface water samples could be conducted over a one week period in the field.

The surface water sampling would be conducted twice – one during conditions representing significant run-off (e.g. Spring 2013 or late Winter / Spring 2014) and one representing baseflow conditions (e.g. late Summer/early Autumn 2014). The late Summer/early Autumn 2014 would be conducted as part of the one week of bore sampling. The higher flow event sampling could be conducted in one field day.</td></tr>
<tr><td>Data Capture & Recording</td><td>Data capture and recording will include:
Desk based:
Review of recent EC data
development of a groundwater salinity contour map of salinity in the LTA
Field data sheets, including change in groundwater chemistry, chain of custody.
Laboratory analyses records.
Appropriate chemical graphics that display the likely mixing and or separation of different water sources
Result displayed on a conceptual model illustration including flow paths determined from both the chemical tracers and physical hydrogeology</td></tr>
<tr><td>Notes</td><td>Access for sampling SOBN bores will need to be obtained from DSE.
The turn-around time for Carbon 14 sampling is around 6 to 8 weeks</td></tr>
<tr><td>Assumptions</td><td>Assistance from Barwon Water will be required for sampling the production bore.</td></tr>
</table>

3.2.7.2. Cost estimates

Table 18 Cost estimates for investigation of changing EC in production bores

Item	Cost	Notes
Task 1 - Review of recently collected salinity data	$5,600	
Task 2 - Development of EC/TDS contour map	$4,900	
Task 3 - Groundwater Sampling	$10,250	
Task 3 - Surface sampling	$1,770	
Task 3- Lab analysis for chemistry (8 gw samples, 4 sw samples)	$6,480	12 samples. Cat/anion, C13, O Isotopes. Carbon 14
Task 3 - Analysis and Reporting	$6,400	
PM / EHS	$4,338	
Sub Total	$39,738	
Contingency	$7,948	
TOTAL (excl GST)	$47,686	

4. Terrestrial vegetation investigations

This section presents a summary of the terrestrial ecology field investigations and recommended scope and costs of final monitoring program. Further details are contained in the EA (2013) report which is presented in Appendix D.2, as well as information on the desk-top review. The desk-top review includes information on study area delineation, identification of values and potential GDEs and site selection criteria. As described in the EA (2013) report, the preliminary list of sites was selected on the basis of the following criteria:

- located in areas where the watertable depth is generally <10 m (SKM 2013);
- representative of the potential GDEs in the study area namely:
  - ephemeral or permanent stream reaches; or
  - ephemeral or permanent wetlands; or
  - one or more of the following EVCs: Swamp Scrub, Sedgey Riparian Woodland, Wetland Formation and Riparian Forest;
- distributed to represent impact and reference sites for the confined LTA and unconfined LTA;
- part of the remnant vegetation landscape, and to be separate from areas of significant disturbance, e.g. wherever possible, sites should be upstream of roads and tracks;
- ease of access – sites should have access from existing roads or tracks to allow proximate access for small drilling rigs, and to minimise travel and access times during monitoring;
- sites should be on public land.

4.1. Field investigations

The terrestrial vegetation field assessment was conducted over the period 2nd – 5th April and 15th April 2013, by Ecology Australia. The purpose of the work was to identify suitable sites for terrestrial vegetation monitoring, and in particular verify (or exclude) the sites selected during the desktop assessment. A total of 18 sites were surveyed: the preliminary list of 14, plus 4 additional sites considered to better satisfy the selection criteria. At each site data were collected on site location and waypoint, hydrogeology (confined or unconfined LTA), impact or reference site, type of GDE, Ecological Vegetation Class(s), vegetation condition, major plant species, potential habitat for threatened fauna or groundwater dependant assemblages, photographs and access.

Table 19 summarises the results of field investigation in terms of recommendations for new terrestrial vegetation monitoring sites. It includes a description of the location of the site, it's hydrogeological status (overlying aquifer or aquitard material), whether the purpose of the site is for assessing potential impact or for proving information on baseline conditions (i.e. reference site) and the type of vegetation at the site. A map showing the location of these sites is presented in Appendix D.1.

One of the goals of site selection was to obtain three impact and three reference sites in the unconfined LTA (outcropping aquifer) and in the confined (LTA) outcropping aquitard, i.e. comprising 12 sites in total. The reason for three sites in each category was in part to represent a variety of GDE types, but equally importantly to provide enough sites, such that if significant ecological disturbances were to occur at one or more sites (e.g. fire), there would be a reasonable likelihood of retaining at least one undisturbed site in each category. EA consider that three 'replicates' in each of the major hydrogeological categories is minimum or base case requirement.

The exception is that four impact sites are proposed within the unconfined LTA for the following reasons:

- Two sites are on Boundary Creek, one is the peat burn site which should be monitored considering the known hydrological impacts and extent of community interest in this site; the second site is an excellent comparison as it is upstream and in relatively good condition;
- Site 3 is a very unusual and significant wetland and within the drawdown cone – it has also been investigated as part of previous work (Ecology Australia 1994);
- Site 4 is more mainstream in terms of being similar to sites in other hydrogeological categories; and
- The unconfined LTA impact area has been an area with a high level of community interest, therefore a slightly higher level of monitoring in this area is warranted.

It should be noted that these represent the maximum number of sites that will be used for long term vegetation condition monitoring. If groundwater bores installed at the sites or other field based investigations and associated remote sensing (refer Chapter 9) indicate the vegetation is not using groundwater, then on-going monitoring of the site would not be recommended.

It is recommended that the sites in Table 19 supersede the existing vegetation sites currently monitored as part of the groundwater licence. It should be noted that all of the current vegetation survey sites were considered for inclusion in the final list of new sites. However, only two of the former sites have been recommended on the new proposed site list. This is because a more thorough process has been applied to selection of the new sites, including consideration of more up-to-date hydrogeological data, e.g. showing recent extent of drawdown in the LTA and aquitard, enabling more accurate delineation of impact and reference sites. Permission to change monitoring to the new sites when the next round of vegetation monitoring is due is a matter for discussion with Southern Rural Water.

Table 19 Proposed Terrestrial Vegetation Monitoring Sites

Hydrogeology	Reference / Impact	Site no. (previous site no.)	WP	Location	GDE
Unconfined LTA	Impact	1 (1)	007	Boundary Creek	regenerating burnt peat formerly Swamp Scrub
	Impact	2 (2)	002	Boundary Creek	Swamp Scrub
	Impact	3 (3)	005	north of Westwood Track	Sedgy Wetland
	Impact	4 (n.a.)	003	off 'Quarry Tk' off Westwood Rd	Swampy Riparian Woodland
	Reference	5 (n.a.)	006	Field and Game Tk off Westwood Rd	Swamp Scrub
	Reference	6 (n.a.)	023	off Langdons Rd	Swamp Scrub
	Reference	7 (7)	009	Ten Mile Creek – off Old Beechy Rail Trail	Swamp Scrub
Confined LTA	Impact	8 (n.a.)	001	Westwood Track	Swamp Scrub
	Impact	9 (n.a.)	014	Porcupine Creek	Riparian Forest
	Impact	10 (n.a.)	024	Dividing Creek & Wares Rd	Swamp Scrub
	Reference	11 (n.a.)	018, 019, 020, 021	Porcupine Creek on Colac – Olangolah Pipeline Track	Swamp Scrub, Riparian Forest
	Reference	12 (10)	011	Gold Hole Road	Swamp Scrub
	Reference	13 (11)	010	Pipeline Track	Swamp Scrub, Swampy Riparian Woodland

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4.2. Summary of terrestrial flora monitoring program

4.2.1. Scope of works

The terrestrial ecology monitoring site locality plan can be found in Appendix D.1. The scope of works for the terrestrial ecology monitoring is outlined below:

- **Table 20 Monitoring scope for terrestrial ecology - ecological classes representing major GDEs**

Item	Description
Purpose	To assess any changes to the floristics and structure of EVCs by monitoring plant functional groups – as adapted from Casonova (2011) and Doeg et al. (2012)
Location	Sites 1 - 13
Method	Permanent transects of 40 m located across the stream channel; frequency and functional group data would be collected from 20 contiguous 1 x 1 m quadrats positioned along the transect. This methodology will also cover any rare or threatened plant species
Risk if not Undertaken	• Inadequate data to monitor and predict potential long term impacts of groundwater extraction on vegetation • Highly unlikely that licence renewal would be granted without appropriate monitoring of terrestrial vegetation • Continuation of monitoring at current sites would not represent best practice for vegetation monitoring given better data now available for site selection.
Frequency	Annually in spring, during high groundwater conditions (There is also an option for late summer – early autumn survey to capture conditions representative of lower groundwater levels)
Data Capture and Recording	Data recorded onto proforma data sheets or digitally entered in the field. Data in Excel spreadsheet form for analysis
Duration	From commencement of monitoring program until the licence application submission. It is likely that monitoring will continue at a number of these sites after licence renewal – which sites and the frequency of monitoring will be based on results of the monitoring program and upon the discretion of SRW.

In addition to the flora surveying, the EA study (Appendix D) has suggested fauna monitoring of the following:

- Monitoring of threatened vertebrates - Long-nosed Potoroo and Broad Toothed Rat
- Monitoring of threatened invertebrates - Otway Bush Yabby and Hairy Borrowing Crayfish, and,
- Monitoring of frog populations

However for the reasons outlined below, this study has not recommended that this be adopted in the monitoring program leading up to licence renewal. This is not because potential impacts of groundwater extraction on fauna is not of interest or potential importance, but because the conceptual understanding of dependence between groundwater and the identified fauna is very poorly established. This means that it will be extremely difficult to link any changes observed in population back to groundwater condition. Moreover, because the targeted fauna are threatened, surveys are likely to yield relatively few observations and therefore changes in abundance will be very difficult to reliably quantify.

The most likely link between groundwater dependence and the fauna listed in the EA report is that their habitat is (at least in part) maintained by groundwater levels:

- In the case of the Potoroo and Broad-toothed rat, it is assumed that shallow groundwater maintains a water source for lower storey vegetation during periods of low soil moisture stores.
- For the Otway Bush Yabby and the Hairy Burrowing Crayfish, it is assumed that groundwater levels sustain saturated conditions at or slightly below the surface, which are necessary for these invertebrates. Water filled chambers, or at least saturated soils, in the bottom of the burrows are essential to prevent desiccation (Horwitz and Richardson, 1986).

In both of these cases, groundwater dependency is not certain and the degree of dependency not understood. There are two steps to be considered in addressing the question of the potential dependence of these fauna on groundwater:

1. What is the relationship between groundwater levels and the habitat condition?
2. What is the relationship between habitat condition and condition/health of fauna?

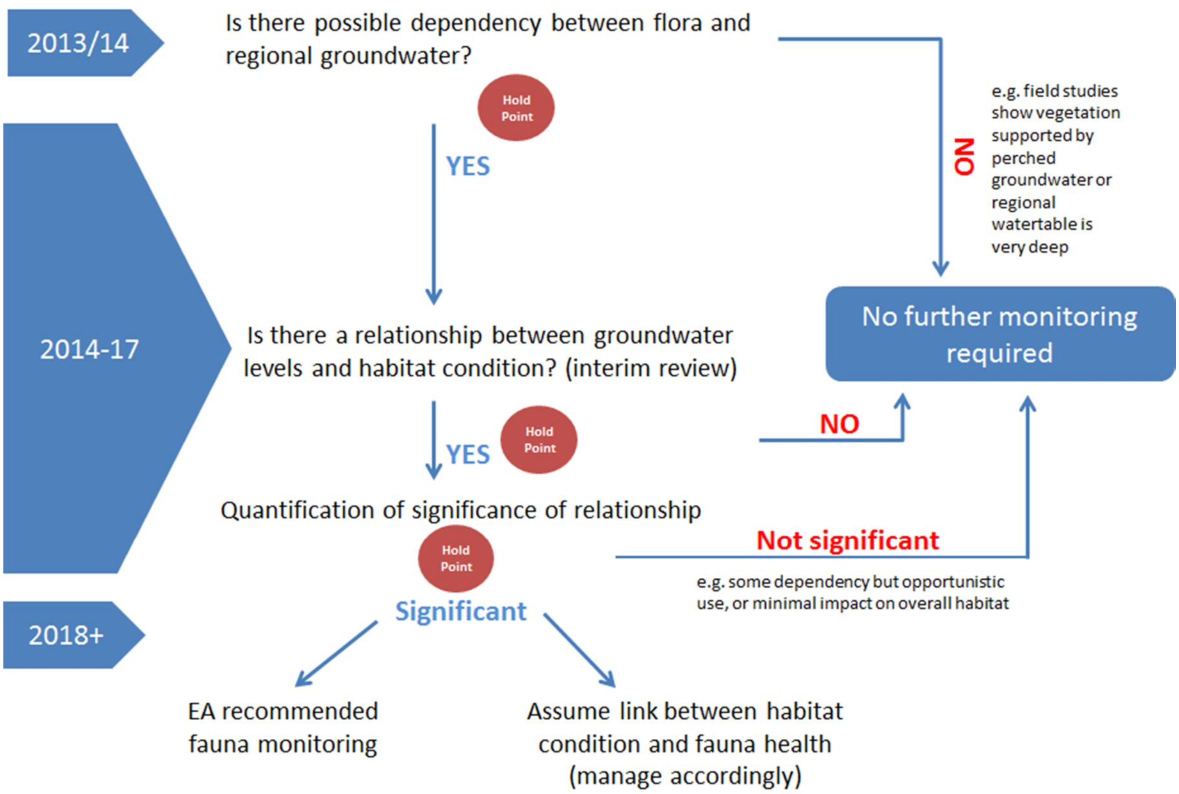
Currently there is insufficient understanding of the first relationship, and it is suggested that until that is better understood, there is limited value in attempting to answer the second question. As described above, there is a very high likelihood the proposed monitoring program would provide an inconclusive result.

Instead it is proposed that a more sound approach is to monitor temporal changes in threatened fauna habitat (lower storey vegetation and shallow groundwater levels) and examine dependence of that habitat on regional groundwater levels. This approach is highlighted in Figure 5 and explained below:

Is there possible dependency between flora and regional groundwater? – This first part of the diagram address the scenario whereby new groundwater bores and new unsaturated zone investigations in the Barongarook High area (described elsewhere in this report) indicate that the flora cannot be dependent on the regional groundwater system, either because it is too deep, or the vegetation is instead supported by a local, perched groundwater system. In this case, no further specific monitoring of flora (which could be a habitat for the above species) is required.

Is there a relationship between (regional) groundwater levels and habitat condition? – Where the new field data suggests there might be a relationship between (regional) groundwater levels and habitat condition, there is period of collecting further data on flora condition. At some point during the 2014 - 2017 monitoring period (e.g. around midpoint), an interim review should be conducted to determine whether there is sufficient data to confirm whether the potential dependency is real or not. If the data is sufficiently 'clear-cut', then potentially the habitat condition monitoring could be terminated (although it should be noted that most of the vegetation surveying will continue in any case, separate to the issue of potential fauna dependency). Otherwise, the monitoring would continue through to approximately the end of 2017.

- **Figure 5 Proposed Approach for Addressing the Potential Groundwater Dependence of Fauna**



Quantification of significance of relationship - If monitoring indicates no significant change in habitat (related to regional groundwater levels), then it may be concluded that the threatened fauna that rely on that habitat will be unaffected. The conclusion that the relationship between groundwater levels and habitat condition is not significant might be based on the fact while there is some groundwater use, the use is opportunistic and not obligatory. Alternately, it might be based on the fact that while there is some relationship (and hence potential for local impact), there is minimal impact on overall habitat health/ condition.

If monitoring does suggest that there is significant relationship between habitat and regional groundwater levels, then it is possible that the fauna that rely on that habitat will also be affected. As shown in the diagram, this could trigger one of the following management options:

i. Assume there is a strong link between habitat condition and fauna health and therefore manage groundwater levels to prevent any deterioration in habitat condition; or,

ii. Quantify the relationship between the habitat condition and condition/health of fauna (e.g. for the Potoroo and Broad-toothed rat). Such an investigation would specifically aim to determine whether fauna are able to tolerate or adapt to changes in the abundance and condition of low-storey vegetation. Given the low abundance of threatened fauna in the landscape, this type of investigation will have to be very targeted and will require a high level of spatial and temporal replication. Depending on the outcome of that study, a more complex management approach could be adopted.

In summary, it is recommended that the proposed monitoring program focus on assessing changes to threatened fauna habitat (i.e. low storey vegetation, shallow groundwater levels and soil saturation) rather than changes in the abundance of threatened fauna in the period leading up to licence renewal. If that monitoring identifies a risk to target habitats then more detailed assessments can be designed and implemented beyond 2018 to determine how threatened fauna may respond to habitat changes and what management actions could be implemented to mitigate any threats.

This conclusion and approach is supported by:

- The TAP review (2013) of the Anglesea Borefield site monitoring program, which concluded that macroinvertebrate results were too variable to establish any relationship with the operation of the borefield (Hart and Merrick 2013).

  This is not to suggest that the Anglesea Borefield monitoring program cannot or will not establish clear links between groundwater pumping and fauna in the future (e.g. as longer/large data sets are gathered), but it does demonstrate the difficulty in doing so.

- Typical national and international approaches to monitoring and managing groundwater dependent ecosystems. Based on the experience of the project team, examples in the national and international literature of monitoring fauna populations and attempting to directly link to groundwater condition are very rare. It is far more common to monitor the groundwater conditions on which the fauna are dependent and manage against those conditions.

The terrestrial ecology monitoring program has been developed on the best available information. As knowledge improves however, the monitoring program needs the capacity to respond to material changes in understanding of the system. Further, there may be some aspects of the terrestrial ecology program that prove to be more efficacious than others, and this also needs to be factored into an adaptive approach. Therefore the monitoring program outlined includes a review period after three years, which may result in changes to the monitoring program. Adaptation of the program may result in no change, increase or decrease in the type or location of monitoring activities.

The scope of works costed in Appendix D.3 includes an option for the additional autumn surveying of the vegetation transects (i.e. additional to spring surveying). At this stage this is not recommended – one vegetation surveying event per year is considered sufficient. However whether this annual surveying occurs in spring or in autumn should be subject to further review prior to commencement of the vegetation surveying - in particular this should include discussions between the consultant undertaking the vegetation transect surveys and the consultant undertaking the scope of works outlined in Section 4.3.

4.2.2. Cost estimates

Cost estimates for the terrestrial ecology monitoring program are presented in Table 21. Further breakdown of the costs is presented in Appendix D.3. (For reasons described above, the fauna monitoring and autumn vegetation surveying have not been carried through to the costs in Table 21).

- **Table 21 Cost estimates for terrestrial vegetation and fauna monitoring program**

Activity	Total Cost	Annual cost [1] (incl. analysis and reporting)
EVC/GDEs transects (vegetation monitoring)	$86,000	$20,000
Contingency	$17,000	$4,000
TOTAL (excl GST)	$103,000	$24,000

1. Plus $6,000 set-up costs in the first year

4.3. Terrestrial vegetation groundwater dependence and perched watertable assessment

4.3.1. Background

The current nationally accepted framework in Australia for assessing groundwater dependent ecosystems is the Australian GDE Toolbox (Richardson et. al 2011a and Richardson et. al 2011b), commissioned by the National Water Commission. The Toolbox advocates a three stage approach to GDE assessment:

- Stage 1: GDE location, classification and basic conceptualisation
- Stage 2: Characterisation of groundwater reliance
- Stage 3: Characterisation of ecological response to change

Figure 6 is an extract from the Toolbox report (Richardson et al, 2011b), and shows links between the GDE toolbox assessment framework, GDE type and tools useful to each assessment stage and GDE type. The ecological monitoring program described in Section 4.2 is primarily a Stage 3 activity (as described in Figure 6). It is difficult to determine impacts of changed groundwater conditions (past or future predictions) when the conceptual understanding of the interaction of terrestrial vegetation and groundwater is poor. In part this is the reason why past attempts at Barwon Downs to correlate vegetation condition survey results to groundwater condition have proved inconclusive. There are key aspects of Stage 1 and Stage 2 assessment that have not been undertaken for potential GDEs in the study area. It is critical that long term monitoring programs are built on the foundations of these assessments. Hence this section scopes a recommended program to address these knowledge gaps.

While the new vegetation sites (i.e. as selected in this study) and the presence of groundwater bores at those sites will improve the ability to imply correlations between groundwater and vegetation condition, there is still a significant likelihood of inconclusive results at the end the monitoring period if vegetation condition monitoring is the only assessment that occurs.

Figure 6 Links between the GDE toolbox assessment framework, GDE type and tools useful to each assessment stage and GDE type (after Richardson et al, 2011b)

Assessment framework	*Aquifer and cave ecosystems (Type 1)*	*Ecosystems dependent on the surface expression of groundwater (Type 2)*	*Ecosystems dependent on the subsurface presence of groundwater (Type 3)*
Stage 1: GDE location, classification and basic conceptualisation 1.1 Where are the ecosystems that use groundwater? 1.2 What is the broad type of GDE and functional grouping?	← T1 Landscape mapping T2 Conceptualisation → (all types)		
Stage 2: Characterisation of groundwater reliance 2.1 Is groundwater part of the ecosystem? 2.2 How reliant is the system on groundwater?	T9 Stygofauna sampling T10 Evaluation of groundwater-surface water interactions T11 Environmental tracers T12 Analysis of introduced tracers	T10 Evaluation of groundwater-surface water interactions T11 Environmental tracers T12 Analysis of introduced tracers	T3 Pre-dawn leaf water potentials T4 Plant water-stable isotopes T5 Plant water use modelling T6 Root depth and morphology T7 Plant groundwater use estimation T8 Water balance – vegetation
Stage 3: Characterisation of ecological response to change 3.1 What are the threats to the groundwater system / ecosystem? 3.2 How might the current ecosystem change if the groundwater system changes? 3.3 What is the predicted long-term ecosystem state due to the change?	← T3–T12 as appropriate (see Stage 2) T13 Long-term observation of system response to change T14 Numerical groundwater modelling → (all types)		

A multiple line of evidence approach is proposed in order to develop a conceptual understanding of the interaction of vegetation, and combined with time series health and ET data, provide a measure of any potential impact groundwater extraction may be having (or has had in the past). In particular, this multiple line of evidence approach will be developed by:

1) Establishing the link between terrestrial vegetation and groundwater through field based measurements. This component provides direct measurement of the water sources for terrestrial vegetation.
2) Establishing baseline and time series measurements of the health / condition of vegetation. This component provides a measure of the health of the system that can be then compared against changes in climatic and groundwater regimes (refer Section 9.1)
3) Collecting time series data of remote sensing ET. This component provides spatial and temporal trends in vegetation activity that can be then compared against changes in climatic and groundwater regimes. This is a key point, because the 13 vegetation sites provide only a small snap shot of the total native vegetation cover – the remote sensing analysis provides the opportunity to examine trends across the whole area, and using the data collected in items 1 and 2 above to "calibrate" the remote sensing analysis. Further, this assessment provides the ability to 'look' back across time and examine for potential changes in vegetation associated with changes in groundwater level.

The combination of these data sets provide a holistic appraisal of vegetation water use and health and can be incorporated into a water balance that aims to identify what component of the change in vegetation activity and water pattern is attributed to groundwater. It is important to note that one of these parameters alone is insufficient information to observe the impact of changing groundwater regimes of vegetation health (with a suitable degree of confidence), therefore all three are recommended.

The tools proposed in the scope for this work (refer Section 4.3.2) are all recommended tools in the GDE Toolbox – specifically they include T1, T4, T5 (in part) and T8 (refer to Figure 6 for tool descriptions). They are based on a review of established methods reported in national and international literature. For each of the tools, the Toolbox report describes the: method, application to components of EWR studies, scale of measurement, principles, how the tool is applied in GDE assessments, analysis approach, limitations, advantages, disadvantages, main data types required, complementary tools and key references and Australian case studies. Information on each of the tools is contained in reports which can be accessed from http://archive.nwc.gov.au/library/waterlines/69-70.

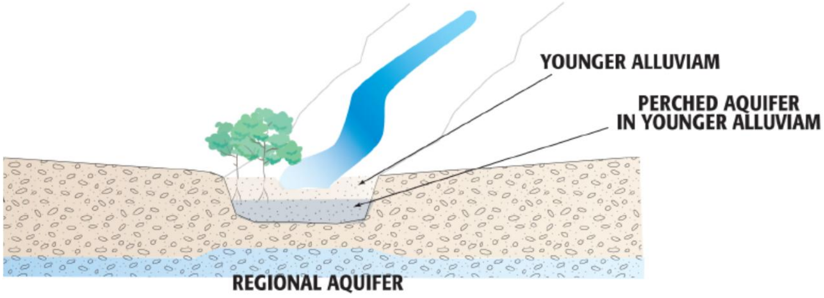
It is expected that for the vast majority of the landscape, away from low lying landscapes, rivers and wetlands, the depth to water table will be 5 metres or greater. Therefore it is likely the vegetation types accessing this water source will be deeper rooted perennial, such as eucalyptus and swamp paper barks. Therefore as an indicator, the deeper rooted trees are more likely to show signs of water stress due to changes in the groundwater regime before smaller, shallower water species. Therefore, using these species as a guide will provide an early warning of the potential impact of changes in groundwater levels.

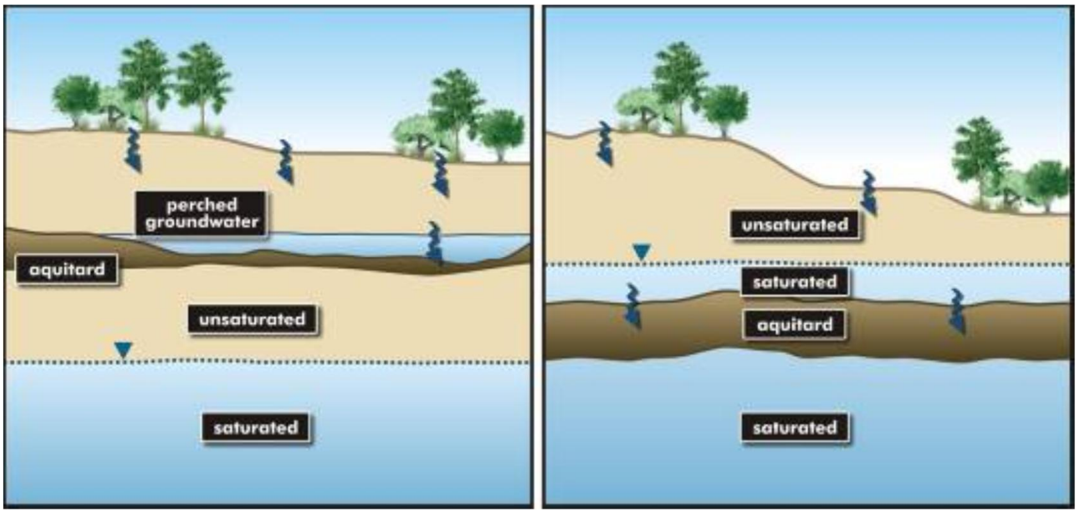
Perched watertable assessment

It is also important to note that the shallow drilling and soil sampling program forming part of this program will assess the issue of perched watertables. The concept of a perched watertable is shown in Figure 7, where a zone of unsaturated soil or aquifer material exists between the two water tables. Ecosystems are sometimes dependent on perched aquifers, which can provide a source of water as a surface or subsurface expression of groundwater. Recognition that a groundwater body is potentially perched is necessary for appropriate groundwater management as groundwater flow pathways in a perched system may differ significantly from those in the underlying flow systems (Carter et al. 2011). The implication of a GDE being potentially dependent on a perched aquifer is that it may be buffered from impacts of groundwater abstraction from underlying aquifers – which would be a very important conclusion for how terrestrial vegetation is conceptualised and managed with respect to the borefield.

The assessment of perched groundwater was in the identified as a data gap in the recent monitoring review (SKM, 2012). Initially it was included in this program as a separate activity, but a more logical approach was seen to combine it with the vegetation assessment, since there was significant overlap between the activities and hence efficiencies in this approach.

- **Figure 7 Concept of a perched aquifer. The upper figure shows a perched aquifer associated with alluvial material and the lower picture a more general example of a perched aquifer – the LHS shows a perched system and the RHS shows a normal two-layered aquifer system. (Upper: Fonesca, 2008 and Lower: Richardson et al., 2011b)**





4.3.2. Scope of works

Investigation	Terrestrial vegetation groundwater dependence
Purpose	There are two primary objectives for this component of the monitoring program: a) To determine whether terrestrial vegetation relies on groundwater and the extent to which it does so. b) To establish the relationship (if any) between the watertable elevation and vegetation functioning. Assuming terrestrial vegetation is found to be using groundwater, monitor changes in tree transpiration via remote sensing, tree condition and changes to groundwater levels. Objective a) will be examined by site investigations that include soil, plant and groundwater sampling and measurement. Objective b) is pursued by on-going monitoring of groundwater levels, rainfall and vegetation functioning. If deemed necessary by the outcomes of the site investigations, the monitoring program may involve the use of remote sensing.
Locations	It is recommended that site investigations and monitoring be undertaken to meet objective A where vegetation condition monitoring is to proceed (i.e. the 13 sites identified by Ecology Australia refer Appendix D.2,).
Scope of Activity	**Baseline terrestrial vegetation activity (NDVI assessment)** The recent dry period and decline in groundwater levels during the decade prior to 2010 enables the change in vegetation activity in wet versus dry periods to be assessed. By using archived Landsat imagery, the change in vegetation activity (NDVI) during this period can be observed spatially and provide a baseline data set of the variability of activity across the terrestrial vegetation This would be achieved by examining climate records to select image acquisition dates of Landsat 30m resolution archive imagery. The criteria of date selection would be based on where climate records indicate seasonally wet and seasonally dry, shallow or deep groundwater levels and where imaging geometry is favourable. To

Investigation	Terrestrial vegetation groundwater dependence
	establish a baseline, it is proposed that 4 wet and dry seasons would be analysed, i.e. 8 seasons in total from 2001 to present (e.g. 2001/2, 2003/4, 2006/7, 2009/10). The output would be maps illustrating the change in activity of vegetation under different climate periods. These maps help provide context to the outcomes of the field based investigations around the potential for groundwater use by terrestrial vegetation and condition. This assessment will cover all of the Boundary Creek area east of the intersection of the Creek and Colac - Lavers Hill Rd, and include all of the 13 terrestrial vegetation condition assessment sites. **Site investigations of tree water use and perched watertable assessment** The initial site investigations will involve an assessment of soil, groundwater and plant water status in order to build the conceptual understanding of where plants access their water, and what role is played by groundwater. The following activities are recommended as part of this assessment: ▪ Soil sampling: soil sampling should occur after the installation of monitoring bores, as this will mean the thickness and lithology of the unsaturated zone is partially characterised prior to the sampling (and enable more exact planning of the sampling intervals). Intact (undisturbed) soil samples would be collected via push tube. Samples should be taken every 30-40 cm in the top 4 m and at 1.5 to 2 m intervals thereafter to a maximum depth of 10m. The samples are to be submitted to a laboratory to measure soil water potential and soil water isotopes (deuterium and Oxygen-18). ▪ Groundwater sampling: groundwater is to be sampled from the regional water table and submitted to a laboratory to measure its isotopic composition (deuterium and Oxygen-18). ▪ Plant assessments: stem samples taken from overstory species are submitted to a laboratory for stem water extraction and determination of isotopic composition (deuterium and Oxygen-18). When the samples are taken, measurements of leaf water potential can be made using a pressure plate apparatus. The site investigations will be used to establish two lines of evidence regarding the likely groundwater dependence of the vegetation. Groundwater levels, soil water potentials and leaf water potentials provide physical measures of groundwater-soil-plant water relationships. This data is used in conjunction with estimates of plant-available soil moisture storage that can be based on soil texture descriptions made during sampling. The second line of evidence is provided by comparing the isotopic composition of groundwater, soil water and stem water which is used to infer where vegetation accesses its water from (groundwater or soil). The outcome of this task is to define the relative sensitivity of the terrestrial vegetation to changes in groundwater levels. This is achieved by developing a conceptual understanding of the tree water use patterns based upon the data collected. *If the analysis and conceptualisation indicates the vegetation is sensitive to changes in groundwater levels, then it is recommended that a monitoring program be developed.*

Investigation	Terrestrial vegetation groundwater dependence
	Monitoring program The monitoring program, if required, would combine field based information around the plant water use and remote sensing derived ET to assess if there is a correlation between groundwater level changes and vegetation activity. Leaf water potentials data would be collected seasonally (in additional to the existing groundwater, climate and vegetation condition data) that would be compared to the existing soil water potential data and remote sensed based ET estimation to provide a spatial context on the changing trend in tree transpiration. The monitoring would occur until 2017 (resulting in three years of data collected over the summer periods of 2015 to 2017), where the results would be analysed to determine if a causal relationship between vegetation transpiration and health and change in groundwater levels exists. The monitoring of leaf water potentials observes the likely source of water for transpiration, and the remote sensing data provides of spatial reference of changes in ET. The component of the program is based upon firstly determining the degree and extent of groundwater interaction with terrestrial vegetation. From these findings the monitoring program can be determined in more detail.
Risk if not Undertaken	• Linking vegetation condition to groundwater condition may prove inconclusive, even after several years of monitoring. (This is because, in terms of best practice as outlined in the GDE Toolbox, undertaking vegetation surveys at the specified sites only is akin to undertaking the later stages of a terrestrial vegetation investigation without a firm conceptual basis of the interaction of vegetation and groundwater). • Pumping impacts resulting from the borefield may be overestimated, if perched groundwater rather than regional groundwater is supporting the terrestrial vegetation (this would not be known however without this investigation) • The spatial distribution of groundwater dependence will remain poorly understood.
Timing (and Duration)	Site investigations would take place after monitoring bores are installed at the terrestrial vegetation monitoring sites (it is proposed that this occur in February/March 2014). Late summer is an optimal time to undertake the investigations as this is considered to be the season when vegetation is most likely to rely on groundwater. The NDVI assessment could occur before or after the field investigations, but reporting and analysis of the field investigation and NDVI work is complementary and should be undertaken together. Hence the NDVI assessment would logically also occur in early 2014. (An allowance of around 8 weeks is sufficient for the NDVI assessment). The “Baseline terrestrial vegetation activity” and “Site investigations of tree water use and perched watertable assessment” are one-off assessments. The “Remote sensing monitoring program” (if deemed necessary based on outcomes of the above two activities) would occur annually over a three year period: 2015-2017.

Investigation	Terrestrial vegetation groundwater dependence
Data Capture & Recording	▪ Field log sheet – soil description and sample locations, depth etc ▪ Remote sensing spatial products ▪ Sample custodian forms ▪ Tabulated results ▪ Documentation of sample testing results and interpretative report outlining extent to which vegetation is dependent on groundwater (if at all) and its sensitivity to changes in groundwater level.

4.3.3. Cost estimates

The estimated costs for the terrestrial vegetation groundwater dependence assessment are outlined in Table 22. The detailed breakdown of the estimates is found in Appendix C.4.

Table 22 Costs for Terrestrial Vegetation Groundwater Dependence Assessment

Item	Cost	Notes
Baseline terrestrial vegetation activity (NDVI assessment)		
Capture and spatial analysis of vegetation activity	$20,000	Enables analysis of 8 periods of vegetation activity (using NDVI from Landsat)
Reporting	$10,000	Report on trend analyses and interpretation of the results in combination with the site investigations. Note – report will be combined with the report on “Site investigations of tree water use and perched watertable assessment”
Sub-total	$30,000	
Site investigations of tree water use and perched watertable assessment		
Soil sampling	$19,300	Assumes 1 test bore per terrestrial vegetation site , 10 m sampling depth and 16 samples per test bore
Field supervision soil sampling	$7,900	
Pressure-bomb equipment hire	$600	
Professional fees for leaf water potential measurement	$5,500	
Leaf water extractions and lab analysis	$4,600	

Item	Cost	Notes
Lab analysis for soil water potential	$5,200	
Lab analysis for soil water isotopic composition	$9,400	
Lab analysis for groundwater isotopic composition	$600	
Analysis and Reporting	$24,000	Report on field investigation results, tree water source assessment, presence/absence of perched watertables. Note – report will be combined with the report on "Site investigations of tree water use and perched watertable assessment"
Sub-total	$77,100	
Remote sensing monitoring program (2015-2017) (This activity would only be undertaken if deemed necessary based on outcomes of the above two activities)		
Leaf water potential measurement and analysis	$18,000	$6,000 for each additional leaf potential sampling round, aligned to the timing of condition monitoring
Remote sensing	$20,000	Remote sensed ET data – enables 3 periods of remote sensed ET data collection and analysis
Analysis and Reporting (at end of three years, in 2017)	$25,000	Will include conclusions on likely impact of changing groundwater levels on tree health and transpiration.
Sub-total	**$63,000**	
Project Management (inc EHS etc)	$19,000	
Sub total	$189,100	
20% contingency	$37,820	
Total (excl GST)	**$226,920**	

5. Potential acid sulphate soil investigations

The *Victorian Best Practice Guidelines for Assessing and Managing Coastal Acid Sulfate Soils* (The State of Victoria Department of Sustainability and Environment 2010) provides the closest guidelines for managing potential acid sulphate soils (PASS). While the guidelines are explicitly for Coastal Acid Sulphate Soils (CASS), most of the principles for identifying and assessing the risk of inland PASS are very similar. Hence the principles in those guidelines have been used in this assessment. 'Stage A preliminary assessment for CASS' in the Guidelines considers questions like 'is CASS present' and 'will it be disturbed', and has been broadly followed in this assessment in the desk-top study and the field investigations. For example, Table 1 in the guidelines ' Landscape, soil and water field indicators for the presence of acid sulfate soil' has been used in the field investigations to assist in identifying PASS sites.

The desktop level assessment for PASS across the study area was initially informed by the review of previous work undertaken in the area and then complimented by consideration of a number of other datasets that can inform likely areas of PASS. Datasets overlain for the study area included the mapped extent of the inferred Barwon River prior swamp area, areas of predicted groundwater drawdown (including in the aquitard), geological setting, geomorphological setting, topography and vegetation (i.e. cleared versus forested areas). Further details on the process used in selecting sites at the desk-top phase is contained in Appendix A.

5.1. Field investigations

The PASS field assessment was conducted over the period 2nd – 3rd April 2013. The main purpose of the work was to further screen the sites identified in the desktop phase, i.e. upon physical inspection of the landscape, vegetation types, observed discharge process soil saturation and geology, to determine whether the sites were still considered a priority for a sampling program.

The plan was to visit the eight PASS sites identified in the desktop review, however two sites were not able to be accessed (Site 6 and 7, as they were entirely contained within private property). A ninth site was identified and inspected during the field assessment. A map of the sites identified during the desktop assessment and referenced in this section are contained in Appendix A.

In assessing the potential of each site to contain ASS, the following were considered:

1. Presence of permanent saturated soil or substrate signs of groundwater discharge
2. Similar vegetation type of Long (Big) Swamp where the occurrence of ASS has been evaluated
3. Likely landscape setting where ASS may form.

Table 23 presents the results of the field assessment. In summary, it is recommended that sites 2, 4, 5, 7 and 9 identified in the desktop assessment are sampled for the presence of ASS. This recommendation is made for site 7, even though it was not able to be assessed in the April 2013 inspection. A groundwater observation bore is recommended at Site 8 (Big Swamp), but not ASS soil sampling.

Site 6 was not able to be visited, however based on re-evaluation of the data gathered in the desk-top phase and inspection of aerial photographs, no further investigation at this site is recommended. It is apparent that the hydrology feature on which (part of) the original selection of this site was based, is a man-made water body, and further, the site is surrounded on all sides by pine plantations. The area is also mapped with relatively deep groundwater levels (> 20m below surface). Therefore the site is of relatively low ecological value and also of low risk of containing conditions for ASS generation.

Table 23 Summary of outcomes and recommendations for Potential Acid Sulphate Soil (PASS) sites based on April 2013 field inspection

Site ID	Location Selection	Accessibility	Priority for sampling on the basis of likelihood of ASS (1 low, 2 medium, 3 high)	Priority to be part of GW monitoring if Acid Sulphate Soils identified (1 low, 2 medium, 3 high)
Site 1 Barwon River at intersection of Colac-Lorne Road	The flood plain of the Barwon River, which is incised around 3 metres deep. During inspection the River was flowing, lined by willow trees. (Photo 15) The floodplain contained several oxbow like features that were dry and heavily cracked, indicating the soil had completely dried out (Photo 14) There exists no vegetation (other than willows) that would indicate shallow water tables and or saturated soils within the first two metres of floodplain soil. Therefore, on a visual inspection this site appears unlikely to contain PASS.	The site has good access and likely road side access for bore if required. (Property: Maguire)	1 This site is not a priority for further investigation	n.a.
Site 2 Den Creek at intersection with Callahans Lane	Broad flat valley with an ephemeral creek meandering through (Photo 16). At the break of slope several discharge zones occur, that are at a higher elevation than the ephemeral creek. Where the land is grazed the discharge zone is exposed (Photo 19), while where less grazed, swamp species, phragmities still persist (Photo 18). The geological and landscape setting is likely to cause groundwater discharge to the surface due to the change in hydraulic conductivities between the Hanson Plains	Access via gates off the road (Callahans Lane) Property: Cunnington to east of Callahans Lane. (West, not yet	3 This site is a priority to determine the presence or absence of ASS Recommend proceeding to	3 (If PASS identified) Installing nested piezometers at this site will help observe the interconnection between the geological units: Hanson Plain Sands, Marl and the aquifer (if ASS identified). (Aquifer bore (i.e. LTA) unlikely to be recommended due to depth however) Conceptually this type of discharge zone may be sourced from localised GW

Site ID	Location Selection	Accessibility	Priority for sampling on the basis of likelihood of ASS (1 low, 2 medium, 3 high)	Priority to be part of GW monitoring if Acid Sulphate Soils identified (1 low, 2 medium, 3 high)
	Sands and the underlying marls. The absence of discharge within the drainage lines suggest the water is not sourced from the underlying geological units, but rather the localised topographic highs of the Hanson Plain Sands. The discharge zones appear to be permanent and are extensive within the valley, however the discharge rates appears low, such as no free flowing water was observed. The absence of vegetation such as melaleuca and red gums present may be due to land use practices, as the discharge appears sufficient to maintain such species It is likely that PASS could exist within the discharge zones, and therefore recommended for sampling	identified)	field testing	systems, separate to the regional aquitard, however it is unlikely that the system (i.e. observed discharge) results from a true perching of the watertable Limited access for bore on road side. Preferred location on private property, adjacent fenceline. (e.g. Photo 19 or 20)
Site 3 Atkins Creek near int'n with Waarncort-Cemetery Rd	Appears to be a series of surface water fed dams in a broad flat valley. Their existence on defined water ways suggests there are dominantly reliant on surface flow. (Photo 37). At the time of the field visit the dams were nearly dry and contained no vegetative evidence of groundwater discharge It appears very unlikely that this site contains ASS	Access via road side gates. Property: Arundel and Knight	1 This site is not a priority for further investigation	n.a.
Site 4 Yan Yan Gurt Creek near int'n	Wetland region located at the intersection of Yan Yan Gurt Creek and Winchelsea – Deans Marsh Rd. The steeply incised creek changes to a broad alluvial setting, with the creek meandering through it (running parallel with	Only access to area appears to be via adjacent	2 This site is less likely than Big (Long) Swamp	3 (If PASS identified) Has suitable location for GW bore, located roadside. (refer Photo 6)

Site ID	Location Selection	Accessibility	Priority for sampling on the basis of likelihood of ASS (1 low, 2 medium, 3 high)	Priority to be part of GW monitoring if Acid Sulphate Soils identified (1 low, 2 medium, 3 high)
with Winchelsea – Deans Marsh Rd and parallel with Fultons Lane	Fultons Lane) Open water was observed in the dissected portion of the creek, lined by Red Gums (Photo 1 and 2) Flood plain alluvial setting dominated by Tall Wheat Grass with reeds lining the permanent water way (Photo 3 and 4) Very likely to have shallow water tables and permanent saturation within the drainage line soils. It is likely however that the presence of the introduced Wheat Grass indicates a much altered landuse, and exposure of soils to oxidation in the past. ASS may be present but most likely confined to the drainage line and likely to have being exposed (if present) in past very dry periods. Ground-water will be sourced from the aquitard and/or the aquifer.	paddocks, no direct access was observed. Property: Stewart	to have ASS, but is recommended for sampling in order to officially discount ASS at this location	
Site 5 Headwaters of Retreat Ck at int'n with Winchelsea – Deans Marsh Rd	The drainage line and flood plain area appears to be the contact between the aquifer/aquitard and the basement material along a proposed fault. In terms of surface groundwater expression, several springs exist that are identified by the presence of melaleuca species and slight mounding and pugging by cows (Photo 11). The discharge zone is very localised, forming discrete landforms that will likely provide the conditions for the formation of ASS. The main discharge zones observed from the road are west of Retreat Creek;	Access via landholder permission required – no gates observed along the road side. Roadside also not suitable for	3 The site contains permanently saturated soil and vegetation that exist within sub soils that may ASS	3 (if ASS identified) The hydrogeological setting makes this site difficult to assess in terms of the source of the water driving the springs. Installing monitoring bores would also assist in understanding regional hydrogeology and assess likely drawdown on ASS if they were identified at the site.

Site ID	Location Selection	Accessibility	Priority for sampling on the basis of likelihood of ASS (1 low, 2 medium, 3 high)	Priority to be part of GW monitoring if Acid Sulphate Soils identified (1 low, 2 medium, 3 high)
	they main appeared to be higher in elevation than the Creek.	bore installation. Property: Dodds and Castle	This site is a high priority for ASS assess-ment Recommend proceeding to field testing	
Site 6	Unable to access or view site 6 during the site assessment. However based on further re-evaluation of the data gathered in the desk-top phase and inspection of aerial photographs, no further investigation at this site is recommended. It is apparent that the hydrology feature on which the original site selection was based is a man-made water body, and further, the site is surrounded on all sides by pine plantations. The area is also mapped with relatively deep groundwater levels (> 20m below surface) and hence is of low risk of ASS generation.	N.a.	1 This site is not a priority for further investigation	-
Site 7 Boundary Creek, between Colac-Forrest Rd and Barwon River	Unable to access or obtain a close up view of site 7, as it is all located on private land. However, geomorphological mapping indicates this area may be an extension of Big Swamp and near the junction with the Barwon River. It lies within the area mapped as former swamp land. Hence a sampling program is recommended, even though the risks of ASS are lower than other sites identified.	No access possible from public roads / public property Property: Shelley	2 This site is less likely than Big (Long) Swamp to have ASS, but is recommended for sampling in	3 (if ASS identified)

Site ID	Location Selection	Accessibility	Priority for sampling on the basis of likelihood of ASS (1 low, 2 medium, 3 high)	Priority to be part of GW monitoring if Acid Sulphate Soils identified (1 low, 2 medium, 3 high)
			order to officially discount ASS at this location	
Site 8 Big Swamp, on Boundary Creek (Long Swamp or Yeodene Swamp)	This site is not recommended for further ASS sampling, as a significant amount of sampling has already occurred.	There is access almost all the way to the swamp on public land, but only part of the swamp is on public land (Owner: Lim and Swan)	1 Sufficient sampling for ASS has already occurred	3 There is no monitoring bore at this site, and hence a shallow bore is recommended. This will complement the ASS sampling and analysis already undertaken at the site. Location at Photo 150 is preferred – may be on private land (Photo 151 is an alternate location – may be on public land)
Site 9 Barwon River East Branch, at intersection with Seven Bridges Road	This site was observed during field trip (i.e. not identified in the desk top study) – it exists within the potential area impacted by drawdown and contains a large swampy wetland (Refer to Photos 21, 22 and 23). This site is the most similar in degree of saturation to Big Swamp. The site appear to be spring fed and permanently saturated; it is located near the intersection of the aquitard and aquifer. The conceptual model is likely to be similar to site 5.	Access is via adjacent paddocks. Appears no suitable roadside location for sampling and or installing bore	3 Likely landscape to contain ASS	3 (If ASS identified)

5.2. Scope and costs of investigation program

Based on the outcomes of the desktop and field investigations six sites have been recommended for investigation to determine the presence of acid sulphate soils. The location of recommended sites for ASS investigations can be found in Appendix E.1.

For sites where acid sulphate soils are present it is recommended that monitoring bores be installed. Therefore these investigations should occur in time to allow the inclusion of any of these bores in the bore installation contract.

5.2.1. PASS investigation scope of works

Item	Description
Purpose	To determine the presence of acid sulphate soils (ASS) at sites within the area potentially impacted by the Barwon Downs borefield.
Locations	After initial field survey five sites were proposed for ASS assessments
Scope of Activity	The scope of works for testing for potential acid sulphate soils include the preparation of tender documents, engagement of a drilling contractor and supervision of the sampling. **Landowner Engagement** All sites are located on private land and early engagement with the landowners is recommended. Steps described below (determining drilling rig routes and pegging drill sites) should be undertaken in conjunction with the landowner. It is assumed that this would be managed by Barwon Water. **Drilling Preliminaries** Prior to tendering and the site work itself, the access route for the drill rig should be confirmed and each site pegged. A visual assessment of soil conditions should be undertaken to ensure minimal damage from drilling equipment prior to sampling. A "Dial Before You Dig" application is required at all sites to ensure that no underground services are damaged during the investigations. This information should be provided to the suppliers. If there are services within the site works boundary, underground service location should be undertaken and services marked prior to drilling. **Technical Specification.** A technical specification should be prepared detailing the scope of works for tendering the drilling contract. It is assumed that Barwon Water standard terms and conditions will be used for the engagement of the contractor and this will be managed by SKM. The soil testing program should be conducted according to Stage B of the *Victorian Best Practice Guidelines for Assessing and Managing Coastal Acid Sulfate Soils* (The State of Victoria Department of Sustainability and Environment 2010), which includes guidance on sampling density, field testing, sample size, sampling equipment, sample handling and storage, soil texture and buffering capacity and laboratory testing and analysis program. **Drilling and Sampling** A suitably qualified / skilled practitioner (hydrogeologist or personnel with ASS sampling experience) should supervise the drilling contractor on site, collect and log

Item	Description
	the samples and supervise any necessary site rehabilitation. Works will include recording of field data and collection of samples for short term storage. At each site, four bores will be drilled to three metres, with (approximately) three samples to be collected per bore. The sampled intervals will be selected based on logging results from the bore. Preparation of samples required for laboratory analyses after field testing for the potential of ASS, based upon visual inspection and field analyses **Laboratory analyses** Selected samples will be sent for laboratory analyses which is to be conducted according to the *Victorian Best Practice Guidelines for Assessing and Managing Coastal Acid Sulfate Soils* (The State of Victoria Department of Sustainability and Environment 2010). (Refer Section 6.2.7 and Appendix B of those Guidelines). The testing will including determining net acidity of ASS in %S. Analytical methods for determining the properties of ASS are described in EPA publication 655.1 and in Australian Standard Methods (AS 4969 series). Particle size distribution, CEC and total metals concentration analyses might also be required. All laboratory testing is to conform with the National Association of Testing Authorities (NATA) accredited standards for acid sulfate soil analysis and to the Australian Standard Methods (AS4969 series). **Reporting** An interpretive report will be produced that provides assessment of the ASS hazard at each site, the likely extent of identified ASS, recommendations for ongoing monitoring of ASS, and recommendations for installing a groundwater monitoring bore at the site. The report is to include net acidity calculations and the sum of existing plus potential acidity for a given volume of ASS. The reporting should be conducted in line with the *Victorian Best Practice Guidelines for Assessing and Managing Coastal Acid Sulfate Soils* (The State of Victoria Department of Sustainability and Environment 2010), as appropriate – refer Section 6.4 'Interpreting and reporting the results' of the Guidelines.
Risk if not undertaken	The presence of PASS sites and the potential magnitude of acid generation at these sites will not be known. If such sites do exist and the borefield causes drawdown in these areas, acidification of these areas (and downstream) may occur.
Timing	Drilling would need to occur when ground conditions are firm (summer, early Autumn), as the sites are located at low points in the landscape. An indicative timeframe is provided below: Landowner engagement (including site assessment, pegging sites) – 4 weeks (could potentially be significantly longer) Prepare tender docs / Dial B4 dig / EHS plan – 2 weeks Tender period – 3 weeks Waiting for drilling availability – 2 to 3 weeks Drilling / sampling – 1 week Waiting for lab results – 2 weeks Reporting – 3 weeks **TOTAL time: 15 weeks** Optimistic – 10 weeks (reduced time associated with landholder engagement and driller availability)

Item	Description
	Pessimistic – 20 weeks (increased time associated with landholder engagement and driller availability)
Duration	The soil sampling and bore installation part of this task is a one-off event. For sites where ASS are confirmed, a monitoring bore will be installed. The monitoring frequency and duration of water level monitoring in these bores will be the same as for other new monitoring bores (refer Section 3.2.6.1). The need for ongoing monitoring of water levels (and frequency of monitoring) would be reviewed as part of the 2018/19 licence renewal process.
Data Capture & Recording	Field log sheet – soil description and sample locations, depth etc Sample custodian forms Tabulated results Documentation of sample testing results and interpretative report recommending sites for bore installations and the likely extent of ASS.
Assumptions	Permission to access from landholders is obtained by Barwon Water for all sites. Conditions are suitable for sampling, and recent weather allows for safe access.

5.2.2. Cost estimates

Cost estimates for the acid sulphate soil (ASS) testing program are presented in Table 24. The detailed breakdown of the estimates is found in Appendix E.2

Table 24 Cost Estimates for Acid Sulphate Soil Sampling

Item	Cost	Notes
Drilling contractor (20 push tubes: five sites x 4 bores x 3m)	$8,700	Assumes 3 days in the field, including mob and de-mob
Field Supervision (including pre-site visit to peg sites)	$8,420	
Laboratory analysis	$5,000	
Reporting (factual report)	$4,900	
Project Management (inc EHS etc)	$2,664	
Sub total	$29,684	
20% contingency	$5,937	
Total (excl GST)	**$35,621**	

6. Aquatic ecology investigations

6.1. Field investigations

The aquatic ecology field assessment was conducted over the period 22nd – 24th April 2013. The main purpose of the work was to assess the variety, quality and condition of stream habitat throughout the study area and to determine whether the assessment sites used in the 2006 environmental flow study are representative of the main habitats that are likely to be affected by groundwater harvesting operations.

Sites visited

A short description of all the sites visited during the field inspection is provided in Table 25 below.

- **Table 25 Sites visited during the aquatic ecology field inspection**

Site	Location	Date	Observation	Private property
Boundary Creek				
Boundary Creek at Barrongarook Rd	Not recorded	22/4/2013	No flow Two similar sized channels join immediately upstream of Barrangarook Road. The riparian zone and channel are in reasonable condition, but are currently dry. The section immediately downstream of Barrangarook Road is more degraded. The riparian zone has been cleared and is dominated by pasture grasses and blackberries.	No
Tributary on Bushby Lane	Not recorded	22/4/2013	This is the site of the pumping station that delivers an environmental flow to Boundary Creek. The outlet appeared to be releasing about 1-2 ML/day and was discharging to a point immediately downstream of a swamp that had dense stands of Typha and a trickle flow. This tributary appears to be providing most of the flow to Boundary Creek at present.	No
Boundary Creek at Langdons Road	54 H 0730274 / 5744788	22/4/2013	This site is in remnant bushland, the channel has retained its natural form. It is the first part of the stream that appeared to have perennial flow. The channel is a series of shallow runs and pools, with substantial branch piles and leaf packs, overhanging vegetation and undercut banks that provide potential habitat for fish and macroinvertebrates. There is some cattle access from a property to the north, but it does not appear to be having much effect. The point we accessed appeared to have a main channel entering from the north that carried most of the flow. A relatively still backwater was present in the other channel upstream of that point, it had a dense stand of submerged vegetation (possibly Valisneria). Some blackberries were present at the site. This site could be a good FLOWS assessment site if one is needed upstream of MacDonalds Dam	No

Site	Location	Date	Observation	Private property
Boundary Creek upstream of MacDonalds Dam	54 H 0733472 / 5745985	22/4/2013	This site appears to have been an old gauge. There are some wooden steps and some rock has been placed in the channel to make a control. The water was stained with iron bacteria and water appeared to be seeping in from a perched swamp on the northern bank. The river flowed through relatively in-tact remnant forest, although there were lots of blackberries close to the stream. The channel was relatively incised with steep banks. The main channel was 1-2 m wide and water depth was up to 50 cm deep. Some good refuge pools were present, but the iron bacteria have smothered most of the in-stream habitats. There are also some overhanging vegetation and undercut banks. This could also be used as a potential FLOWS site, although the iron bacteria may be an issue.	No although had to walk through fenced roadway at end of McCalls Rd
Boundary Creek at MacDonalds Dam spillway	54 H 0734194 / 5745440	22/4/2013	This is the site of the old de-commissioned flow gauge. The bottom of channel is 0.5 – 2.0 m wide, but only 15-30 cm deep and banks are relatively low. The section immediately downstream of the dam has been recently burnt and it then flows through a paddock with cleared riparian zone and stock access to the stream. The substrate is clay and sand, there is some Triglochin present and also some bank slumping where cattle have accessed the stream. There are some branches and leaf packs in the stream, but the cleared riparian zone and dam limit the supply of organic material. The dam was spilling on the day of our visit, but there is also a low flow scour valve.	Private property upstream and downstream of McCalls Road
Boundary Creek upstream of Peat Swamp	54 H 0735025 / 5743840	24/4/2013	This site is in the forest reserve. The stream channel and riparian zone are in excellent condition and are free of weeds. There is a moderate load of LWD and leaf litter in the channel, some undercut banks, overhanging vegetation and submerged vegetation. It has excellent habitat for native fish and macroinvertebrates and had good clean flow on the day of inspection. This would be an excellent FLOWS assessment site because flow disappears once it enters the Peat Swamp.	No
Boundary Creek at Colac Forest Rd	54 H 0736649 / 5743951	22/4/2013	This is the current flow gauging site. There was no flow on the day of inspection. The channel upstream of the road has been re-vegetated, it has a mature Eucalypt overstorey and a good mid storey layer. There was a large leaf litter in the channel, which may create a blackwater event if it fills with water without being fully flushed. Downstream of the road the channel flows through farmland. It has a cleared riparian zone and cattle have access to the stream.	Yes downstream of the road

Site	Location	Date	Observation	Private property
Boundary Creek at Alan and H Shalley's property	54 H 0738752 / 5744015	22/4/2013	This is immediately upstream of the confluence with the Barwon River. The channel here has been recently scraped and has no features. The banks are completely cleared and cattle have access to the channel. There was no flow on the day of survey. Nellie Shalley's property is immediately upstream, the channel through that property is also straightened, but some trees have been planted along the banks.	Yes A&H Shalley
Dividing Creek				
Dividing Creek on Pipeline Track	54 H 0729657 / 5740496	23/4/2013	Small, shallow channel through native forest. Channel and riparian zone are in excellent condition but there was no flow at the day of survey and the channel was completely dry. There appeared to be a scour valve that could be used to make releases from the pipeline.	No
Dividing Creek downstream of Gold Hole Road	54 H 0730621 / 5741085	23/4/2013	Small, shallow channel through native forest. Channel and riparian zone are in excellent condition but there was no flow at the day of survey and the channel was completely dry.	No
Dividing Creek at Colac Forest Road	540H 0734353 / 5740675	23/4/2013	The section upstream of the road is degraded. The channel passes through cleared farmland. Cattle have trampled the area and the channel has lost its definition. However, the section downstream of the road flows through intact native vegetation. The channel is very substantial, it is 3-5 m wide, with well defined banks, overhanging vegetation and fallen logs. There would normally be some good refuge pools in this section, but it was completely dry. Some freshwater mussel shells were found at the site.	Yes
Dividing Creek at Kim Crabbe's property	54 H /	23/4/2013	This is where dividing creek joins the Barwon River. The channel is completely cleared and has been straightened, most flow comes from local springs, but it was dry when we visited. Cattle have access to the stream, although Kim is currently building a fence to keep them out. Kim said that Dividing creek flows well in most years, but is dry because it has been a very dry summer. Very little aquatic value in this section.	Yes

Site	Location	Date	Observation	Private property
Barwon River West Branch				
Barwon River West Branch downstream of West Barwon Reservoir	54 H 0737107 / 5732813	23/4/2013	We walked the section of stream from the Reservoir outlet to the first road crossing (i.e. about 1 km downstream). The river immediately downstream of the reservoir flows through a cleared reserve with mown grass banks and some emergent macrophytes. The substrate has some rock and cobble, but it is not typical of the rest of the reach. Downstream of the Reservoir reserve the river flows through farmland and is choked with willows. There is stock access to the river bank and habitat is generally poor.	No
Barwon West Branch at Forrest	54 H 0737220 / 5734349	23/4/2013	The river through this section is highly degraded. The riparian zone has been completely cleared and stock have access to the channel. The channel is shallow – it appears to have been infilled by sediment and livestock access. It is choked with grasses and weeds and has very shallow flow. It is possible that some of the degradation is due to embankments that were built a long time ago for the railway.	Yes but public access at road and trail bridge
Barwon Rive West Branch upstream of Roadknight Creek	54 H 0735238 / 5733822	23/4/2013	This section of stream differs to the rest of the reach. The floodplain is quite narrow and appears to be constricted by different geology to the rest of the reach. It has a natural riparian zone with mature eucalypt trees and shrub layer. There are some weeds and occasional willows, but they don't appear to have much effect on stream form or condition. The channel is well defined, with stable, steep sided banks. There are some deep pools with submerged wood and vegetation. The channel is 5-8 m wide and there are undercut banks and overhanging vegetation, which will provide good habitat for fish. The Southern Brown Tree Frog was heard calling.	
Barwon River West Branch from vantage point on Colac Forrest Roach		23/4/2013	Meandering channel in wide floodplain. Dominated by willows with no other riparian vegetation and stock access to river channel	Yes
Barwon River West Branch at Boundary Road	54 H 0734243 / 5736136	23/4/2013	Channel has a natural meander pattern in this section, but is completely choked with Willows. They have significantly altered the flow path including lots of isolated backwaters. They also provide a massive input of leaf litter and the roots create an artificial substrate. Some submerged vegetation, pond weed and Triglochin are present. Stock have access to the river. Common Froglet was heard calling	Private land / public roach

Site	Location	Date	Observation	Private property
Barwon River West Branch at 7 Bridges Road	54 H 0734603 / 5738096	23/4/2013	Straightened channel about 3-5 m wide, with deep and shallow runs and pools. There are a few willows and stands of Phragmites present, but the banks are mostly pasture grass. There is some submerged vegetation (possibly Valisneria), which may provide habitat for fish. The substrate appears to be quite silty	No
Barwon River West Branch at confluence with Dividing Creek		23/4/2013	This channel was straightened in about 1885, its natural course was along the western boundary of the floodplain. The channel banks are lined with Willows and they are affecting flow and creating braiding. There are also stands of Phragmites in places, but no other riparian vegetation. Kim said they used to get Blackfish in the river.	Yes
Barwon River at confluence with Boundary Creek	54 H 0739320 / 5744305	22/4/2013	Clay channel with cleared riparian zone and stock access to the stream. The banks are eroded due to stock access. There are some deep pools and stands of Phragmites along the banks. Also some stands of Bulboschoenus and patches of azolla.	Yes A&H Shalley
Barwon River East Branch				
Barwon River East Branch at Kents Road	54 h 0738260 / 5733825	23/4/2013	The channel has a natural meander, but flows through cleared paddocks and stock have access to the channel. It is choked with willows and blackberries. The channel is about 6-8 m wide and includes willow root obstructions, runs and shallow pools. King Creek joins the East Barwon River a short distance downstream from our inspection site.	Yes – but public road access
Barwon River East Branch at end of Kents Road	54 H 0739082 / 5736290	23/4/2013	This part of the floodplain is relatively narrow and flows through some wooded hills that have intact native forest. The floodplain is very swampy and the river channel is relatively small (only 2-5 m wide) with very low banks and is not well defined. Flows would regularly overtop the banks and cross the floodplain. There are some willows and parts of the channel have dense stands of young Typha, which appear to restrict flow.	Yes - we spoke to the landowner. He runs goats on the property during the day.
Barwon River East Branch on 7 Bridges Road	54 H 0739173 / 5737458	23/4/2013	Very broad floodplain with lots of swampy areas and filled wetlands. There is little in the way of a defined river channel. Most large flows would inundate the floodplain.	Yes – but public access road

Site	Location	Date	Observation	Private property
Barwon River East Branch on Dewing Bridge Road	54 H 0739839 / 5742345	23/4/2013	Very degraded channel with stock access and unstable, eroded banks. There is no riparian zone. There are some willows and some patches of Juncus and Triglochin.	Yes – but public access road
Den Creek and Dewing Creek				
Dewing Creek at Callahans Lane	54 H 0740954 / 5739910	24/4/2013	Reasonably well defined channel, but the banks are eroded. The section downstream of the road is choked with Phragmites. Road crossing is a 4 opening round concrete culvert.	Yes
Den Creek on Callahans Lane	54 H 0740852 / 5739537	24/4/2013	Small dry channel, with no riparian vegetation. Box culvert under the road.	Yes
Den Creek off Callahans Road	54 H 0740226 / 5740994	24/4/2013	Well defined, but highly eroded channel through farmland. Stock have access to the channel. No instream values, but could potentially install a flow gauge near the bridge.	Yes
Unnamed tributary North of Boundary Creek				
Unnamed tributary on Colac-Lorne Road	54 H 0740943 / 5748516	24/4/2013	Wide shallow meandering channel that is choked with Phragmites and Typha. There is lots of stock access and they have trampled and eroded the banks.	Yes Barbara Beach. Phoned on 22/4/2013

Boundary Creek

Most of the middle reaches of Boundary Creek flow through native riparian forest. The channel in these reaches has generally retained its natural form and there are diverse instream habitats including small pools with undercut banks and submerged wood, shallow runs and riffles with regular branch piles and leaf packs. Some sections also support stands of native submerged and emergent macrophyte species such as Triglochin.

At the time of our field inspection, most of the flow in the upper reach of Boundary Creek was being provided by a managed release of approximately 2 ML/day (based on visual observation only) into a tributary at Brushby Lane. The main channel of Boundary Creek upstream of that input was dry, but groundwater contributions and inflow from small tributaries appeared to increase flow in the middle reaches (i.e. from the release point down to McDonald's Dam) of the catchment. MacDonalds Dam was spilling at the time of our field inspection and provided a steady flow between the dam and a swamp area approximately 1-2 km upstream of the Colac-Forrest Road. Boundary Creek was completely dry at Colac-Forrest Road and remained dry between that point and the confluence with the Barwon River. Based on these observations it is concluded that most of the flow that enters the swamp is seeping into the bed of the creek and into the aquifer (a smaller proportion may be lost as ET).

Analysis of long-term groundwater level data indicates that sections of Boundary Creek upstream of the peat swamp would have historically received groundwater inflows. Observations of iron bacteria (see Figure 8) and seeping banks approximately 1 km upstream of MacDonalds Dam suggest that parts of the creek still receive some groundwater. An assessment as to whether this is derived from regional groundwater flow, or from a large perched wetland/marsh on top the northern bank of the stream, will be better judged after installation of the new monitoring bores (outlined earlier in this report).

▪ **Figure 8 Photos showing iron bacteria (rust colour) in water in Boundary Creek**

Lloyd Environmental *et al.* (2006) determined environmental flow requirements for Boundary Creek and other reaches and tributaries of the Barwon River to inform the streamflow management plan for the Barwon River. Lloyd *et al.* (2006) used the FLOWS method (DNRE 2002), which is the approved method for determining environmental flow requirements for Victorian rivers and streams. The FLOWS method is sound, however the environmental flow assessment for Boundary Creek was based on observations and a hydraulic model that were developed for the section of stream that runs through Nellie Shalley's property. That site is in a heavily grazed paddock, downstream of the Colac-Forrest Road. The channel at that site is highly modified and is not considered representative of the more natural middle reaches of the stream that are likely to support more significant environmental values. Environmental flow studies rely on hydraulic models that can accurately predict the magnitude of flow required to inundate specific in-stream habitats. Given the assessment site used by Lloyd *et al.* (2006) is not representative of the most important in-stream habitats, we cannot be sure that the recommended flows are adequate to maintain the less disturbed in-stream habitat in the middle reaches of Boundary Creek and the ecological values that rely on them.

We recommend that a new FLOWS study be conducted to determine the minimum flows that are required to maintain aquatic habitat and aquatic biota in Boundary Creek. The results of the new FLOWS study can be used to assess and potentially manage impacts associated with the operation of the Barwon Downs Borefield.

Macroinvertebrate monitoring and water quality monitoring is recommended at selected sites in Boundary Creek to describe the current conditions and inform the FLOWS study. This monitoring is only required for one year. On-going biological and water quality monitoring with an aim of measuring direct impacts associated with the operation of the Barwon Downs borefield is not recommended. Boundary Creek is a naturally highly variable system and therefore macroinvertebrate community composition and condition and water quality are likely to vary considerably over time. That variability will make it very difficult to link any observed changes in macroinvertebrates and water quality to the operation of the Barwon Downs borefield, particularly since the borefield has been operating intermittently for around 30 years. Any major impacts on the Creek associated with land use change / operation of the borefield / drought will have already occurred, and any effect of fluctuations in groundwater level due to recent operations on ecological values will be gradual and probably masked by normal seasonal and yearly variations. The exception to this recommendation regarding long term water quality monitoring is EC and pH monitoring, which will be useful for understanding other processes, such as the contribution of groundwater to streamflow, and potential release of acid water from PASS.

The following sub-sections describe the work that would be required to undertake the new FLOWS study and other biological monitoring.

Recommended FLOWS assessment sites

Current groundwater models suggest that extraction from the Barwon Downs borefield could affect flow in the lower half of Boundary Creek from a point approximately 2 km upstream of MacDonalds Dam to the confluence with the Barwon River. MacDonalds Dam has the potential to control flow in Boundary Creek and during low flow periods, the flow magnitude upstream of the dam may be independent of the flow magnitude downstream of the dam. In order to assess the risk that groundwater extraction poses to the ecological values in Boundary Creek it will be necessary to determine the minimum flows that are required to maintain aquatic values in the section of Boundary Creek where flows may be affected. We recommend that Boundary Creek be divided into two reaches for the purposes of this assessment and that a separate FLOWS assessment site should be selected for each reach. The new assessment sites should represent the best type of stream habitat in each reach. The first reach will be upstream of MacDonalds Dam and we recommend that the FLOWS assessment site should be at the site of the de-commissioned flow gauge that is approximately 1 km upstream of the dam (see Figure 9 for photos of recommended site). The second reach will be downstream of MacDonalds Dam and we recommend the new FLOWS assessment site should be near the forest track immediately upstream of the swamp (see Figure 10 for photos of recommended site). The location of the recommended FLOWS sites are shown in Appendix F.

- **Figure 9 Photos of proposed FLOWS assessment site upstream of MacDonalds Dam**

- **Figure 10 Photos of proposed FLOWS assessment site downstream of MacDonalds Dam**

Other monitoring in Boundary Creek

Fish surveys

Regular fish surveys are not recommended for Boundary Creek for two reasons.

- First, previous surveys and desktop reviews have identified 11 native species that are known or expected to occur in Boundary Creek (Lloyd *et al.* 2005). Very intensive surveys would be needed to be confident that any of those species are no longer present. Moreover, even if new surveys failed to detect certain native species, good fish habitat remains and appropriate flow management may allow native fish to re-colonise Boundary Creek.
- Second, because the native fish that do occur in Boundary Creek are not likely to be very abundant, it will be very difficult to measure quantitative changes in abundance over time and even more difficult to relate any detected changes to groundwater management.

Rather than conduct new fish surveys to try and determine what species are present in Boundary Creek, we recommend that the catchment be managed in a way that aims to provide suitable habitat and flow conditions for the native fish that have previously been recorded or that could potentially occur in the catchment.

The best way to determine whether the Barwon Downs borefield is likely to affect native fish communities will be to measure changes in the abundance and quality of fish habitat and flow.

Macroinvertebrate surveys to inform the FLOWS study

Macroinvertebrates are considered a good indicator of overall river health and condition. Boundary Creek is not expected to support a very abundant macroinvertebrate community, but the sections of stream that flow through forested areas should be diverse and contain many species of mayflies, caddisflies and stoneflies that are only found in healthy waterways.

The 2005 FLOWS study did not present any macroinvertebrate data for Boundary Creek and therefore an initial survey should be undertaken to assess the composition and condition of the macroinvertebrate community at four sites throughout the catchment (see Table 26 and location figure in Appendix F). Macroinvertebrate monitoring should occur in spring 2013 and autumn 2014 and follow the standard AusRivAS protocol of one riffle (kick) and one edge (sweep) sample at each site, followed by timed live picks and laboratory identification (using AusRivAS habitat assessment sheets).

The results of the macroinvertebrate surveys may be compared against the State Environment Protection Policy (SEPP) Waters of Victoria (WoV) guidelines. However, more detailed comparisons of macroinvertebrate community composition between sites will be of most use for this project.

The results of the macroinvertebrate monitoring program may be used as a baseline against which future condition can be compared. Repeat monitoring may be warranted in the future if there is a noticeable change in hydrology either as a result of groundwater harvesting or changes to managed flow releases. Annual macroinvertebrate surveys are not recommended unless flow regimes are expected to fluctuate significantly from one year to another.

The cost to collect and process macroinvertebrate samples from edge and riffle habitats in two seasons at four sites in Boundary Creek will be approximately $7,100 per year (excluding GST) if the samples are identified to family level and $8,700 per year (excluding GST) if samples are identified to genus level.

Table 26 Recommended macroinvertebrate monitoring sites for Boundary Creek

Site		Location	Description
1	Boundary Creek at Langdons Road	206056 / 5742782	This site is in remnant bushland. The channel is a series of shallow runs and pools, with substantial branch piles and leaf packs, overhanging vegetation and undercut banks that provide potential habitat for fish and macroinvertebrates. There is some cattle access from a property to the north, but it does not appear to be having much effect on in-stream or riparian habitat. The point we accessed appeared to have a main channel entering from the north that carried most of the flow. A relatively still backwater was present in the other channel upstream of that point, it had a dense stand of submerged vegetation (possibly Valisneria). Some blackberries were present at the site. This site is upstream of the likely influence of any groundwater harvesting and will act as a potential reference site.

Site		Location	Description
2	Boundary Creek upstream of MacDonalds Dam (FLOWS Site 1)	209460 / 5744009	This site appears to have been an old gauge. There are some wooden steps and some rock has been placed in the channel to make a control. The water was stained with iron bacteria and water appeared to be seeping in from a perched swamp on the northern bank. The riparian zone consists of relatively intact remnant forest, although there are lots of blackberries close to the stream. The channel is relatively incised with steep banks. The low flow path is 1-2 m wide and water depth was up to 50 cm deep at the time of our inspection. Some good refuge pools were present, but the iron bacteria have smothered most of the in-stream habitats. There are also some overhanging vegetation and undercut banks. Flow at this site is likely to be influenced by managed flow releases from the headwaters of the catchment and potential changes in groundwater harvesting.
3	Boundary Creek upstream of swamp (FLOWS Site 2)	211223 / 5742089	This site is in the forest reserve between MacDonalds Dam and the swamp. The stream channel and riparian zone are in excellent condition and are free of weeds. There is a moderate load of large wood (i.e. fallen trees) and leaf litter in the channel, some undercut banks, overhanging vegetation and submerged vegetation. It has excellent habitat for native fish and macroinvertebrates and had good clean flow on the day of inspection. Flow at this site is likely to be influenced by managed flow releases from MacDonalds Dam and potential changes in groundwater harvesting.
4	Boundary Creek at Colac Forest Rd	212837 / 5742306	This is the Yeodene flow gauge site. There was no flow on the day of inspection. The riparian zone upstream of the road crossing was re-vegetated 10-15 years ago. It has a mature Eucalypt overstorey and a good mid storey layer. There was a large load of leaf litter in the channel, which may create a blackwater event if it fills with water without being fully flushed. Downstream of the road the channel flows through farmland and is more degraded. It has a cleared riparian zone and cattle have access to the stream. Flow at this site is influenced by releases from MacDonalds Dam, losses through the swamp and potential changes in groundwater harvesting. The macroinvertebrate community at this site is expected to be more degraded than at the three upstream sites, and will provide a good comparison.

Water quality surveys

Water quality monitoring of surface waters may be used to assess temporal changes in river health due to changes in flow. Improving our understanding of the relationship between flow and water quality will complement and potentially strengthen the FLOWS assessment and may be used to more reliably quantify any impacts associated with the operation of the Barwon Downs bore field.

Water quality can vary over short time scales and therefore very frequent monitoring is required to accurately determine any relationship with flow. Dissolved oxygen and water temperature are the two water quality variables that are likely to have the greatest effect on ecological health in Boundary Creek (fish and other aquatic biota cannot survive if dissolved oxygen levels drop below about 2 mg/L and many will suffer at concentrations less than 4 mg/L.) Monthly water quality monitoring conducted at the Yeodene gauge between 1985 and 2005 indicates that dissolved oxygen levels at the downstream end of Boundary Creek drops below 4 mg/L in some years. Dissolved oxygen levels in forested streams are likely to fall to very low levels when flow ceases and pools become disconnected and also after high flows in summer that carry large amounts of leaf litter into the stream without flushing it out the end of the system.

We recommend that a dissolved oxygen and temperature probe be installed in a pool at the most upstream FLOWS site (FLOWS site 1 in Table 26) to record conditions every 15 minutes. The probe should be connected to loggers on the bank and data should be downloaded and the probe cleaned approximately every 4 weeks. The logger only needs to be in place from mid-November until the end of autumn the following year, in order to capture a period of very low flow and subsequent re-wetting. The collected data will be inspected to identify flow magnitudes that correspond with very low dissolved oxygen levels. The results will be used to inform the flow recommendations for the stream and to assess any potential impacts associated with flow reductions due to groundwater harvesting. If very low dissolved oxygen levels are not recorded then the monitoring may need to be repeated in other years. Until such monitoring occurs the lowest recorded flows will be considered safe for aquatic life.

Dissolved oxygen, electrical conductivity and turbidity were monitored at the Yeodene flow gauge on Boundary Creek every month 1985 to 2005 and total nitrogen and total phosphorus were monitored monthly between 1993 and 2009. This data will be analysed to determine how other water quality parameters vary with flow in Boundary Creek and no extra monitoring of those parameters is recommended at this stage.

The cost of installing and operating dissolved oxygen probes and data loggers at the site on Boundary Creek for six months will be approximately $8,500 (excluding GST). This quote (from Theiss) does not include statistical analysis or interpretation of results.

Dividing Creek

Dividing Creek could potentially be affected by groundwater harvesting, but any change in flow is expected to be relatively small and certainly less than in Boundary Creek. The current data (which is very limited) suggests Dividing Creek is a losing stream, and hence is unlikely to be affected by pumping. Most of Dividing Creek flows through native forest. The channel is in excellent condition and supports a range of habitat types. At the time of our site inspection on 23rd April 2013, the entire creek was dry. Dividing Creek is a naturally ephemeral system, but advice from a landholder during the site visit suggests that it would normally have flow by mid-autumn in most years. Ephemeral streams are unlikely to support significant fish or macroinvertebrate communities and large temporal variation in condition make it difficult to implement a monitoring program to assess the effect of small changes in hydrology. For these reasons we do not recommend any biological or water quality monitoring in Dividing.

The Barwon River and tributaries

Preliminary groundwater modelling suggests that the Barwon Downs Groundwater Harvesting Scheme is not likely to significantly affect surface flow in the East or West Branch of the Barwon River or in other tributaries of those streams not already discussed in this report. Moreover these streams are highly degraded and as a result are unlikely to support significant populations of native fish or other significant aquatic values that may be sensitive to hydrological change.

The East and West Branches of the Barwon River flow through intensively grazed agricultural land. Nearly all of the natural riparian vegetation has been cleared and replaced with either pasture grass or willows. Willows are particularly damaging because their roots form a dense substrate that is unsuitable for macroinvertebrates and other biota. The roots also choke the channel and change the natural flow path of the stream. Cattle have unrestricted access to the stream throughout most of the upper Barwon River catchment. As a result they have trampled in-stream habitat and exacerbated bank erosion. Several kilometres of the West

Barwon River near the confluence with Dividing Creek were artificially straightened in the late 1800s, which further reduced the quality and quantity of habitat for aquatic biota. A 1-2 km section of river upstream of the confluence with Roadknight Creek is the only section of the Barwon River West Branch that retains aspects of its natural form. That section flows through a much narrower floodplain than the rest of the river and has a natural meander pattern, deep pools and a riparian zone dominated by mature *Eucalypt* trees.

Lloyd *et al.* (2006) conducted a FLOWS assessment on the Barwon River immediately upstream of its confluence with Boundary Creek and used the results of that assessment to set environmental flow requirements for all sections of the Barwon River upstream of that point. In contrast to their assessment of Boundary Creek, the flow assessment site on the Barwon River was typical of the East and West Branches of the Barwon River. Therefore the environmental flow recommendations presented in that study are likely to be sound and should continue to be used as the benchmark against which potential changes in hydrology can be assessed. As long as the Barwon Downs borefield does not reduce the capacity to meet the existing environmental flow recommendations for the upper Barwon River it is not likely to have an effect on aquatic values in the reach.

Even if future analysis indicates that the Barwon Downs borefield is likely to reduce flow in the upper reaches of the Barwon River and tributaries such as Den Creek, it is doubtful whether the flow changes would have a significant ecological effect. The combined effect of historical land clearing and current agricultural practices in the catchment are having the greatest impact on the ecology of the upper Barwon River. Those issues would need to be addressed and other measures taken to rehabilitate the stream channel before flow changes will have a noticeable effect. For these reasons we do not recommend any on-going water quality or aquatic ecology monitoring in the upper Barwon River.

Summary of outcome of Field Investigations

- Conduct a new FLOWS assessment on Boundary Creek to determine the minimum flows that are needed to maintain ecological values in the forested sections of the catchment.
- Survey macroinvertebrate communities at four sites in Boundary Creek in spring 2013 and autumn 2014 to help inform the FLOWS study.
- Install water quality probes to monitor dissolved oxygen levels and water temperature in Boundary Creek over the next summer to help inform the FLOWS study.
- The upper reaches of the Barwon River are highly degraded by land clearing and cattle grazing. The 2005 FLOWS study recommendations for those reaches are likely to be adequate and therefore no further assessments or on-going monitoring (biological or water quality) are required.

6.2. Scope and cost of aquatic ecology investigations

Based on the outcomes of the desktop and field investigations it was determined that the aquatic ecology investigations and monitoring program should focus on Boundary Creek because of all the streams that are potentially affected by the Barwon Downs borefield, it has the best physical habitat and is likely to support the most diverse and ecologically sensitive biota.

The recommended monitoring program includes

- FLOWS assessment of Boundary Creek
- Macroinvertebrate survey of Boundary Creek
- Water quality monitoring in Boundary Creek

The Macroinvertabrate survey and water quality sampling monitoring program are intended to inform the FLOWS assessment and therefore need to be conducted in the next financial year. They will not need to continue beyond autumn 2014, unless the coming summer is too wet to allow the effect of low flows on dissolved oxygen concentrations to be quantified.

6.2.1. FLOWS assessment scope of works

Table 27 outlines the scope of works for the FLOWS study and associated macroinvertebrate surveying and water quality logging. A map of these sites is presented in Appendix F.

- **Table 27 Scope of works for FLOWS study and associated macroinvertebrate surveying and water quality logging**

Item	Description
Purpose	To determine the minimum flows that are required to maintain aquatic habitat and aquatic biota in Boundary Creek to be able to assess and potentially manage impacts associated with the operation of the Barwon Downs borefield if it reduces the extent to which the recommended environmental flows are met.
Locations	Current groundwater models suggest that extraction from the Barwon Downs bore field could affect flow in the lower half of Boundary Creek from a point approximately 2 km upstream of MacDonalds Dam to the confluence with the Barwon River. MacDonalds Dam has the potential to control flow in Boundary Creek and during low flow periods, the flow magnitude upstream of the dam may be independent of the flow magnitude downstream of the dam. In order to assess the risk that groundwater extraction poses to the ecological values in Boundary Creek it will be necessary to determine the minimum flows that are required to maintain aquatic values in the section of Boundary Creek where flows may be affected. We recommend that Boundary Creek be divided into two reaches for the purposes of this assessment and that a separate FLOWS assessment site should be selected for each reach. The new assessment sites should represent the best type of stream habitat in each reach. The first reach will be upstream of MacDonalds Dam and we recommend that the FLOWS assessment site should be at the site of the de-commissioned flow gauge that is approximately 1 km upstream of the dam. The second reach will be downstream of MacDonalds Dam and we recommend the new FLOWS assessment site should be near the forest track immediately upstream of the swamp. A map of these sites is presented in Appendix F.
Scope of Activity	An Environmental Flows Technical Panel (EFTP) comprising specialist aquatic ecologists, geomorphologists, and hydrologists will need to inspect each FLOWS site to identify specific habitat features that need to be inundated by particular flows and to select 6-10 cross-sections for detailed survey. A qualified survey team will then survey each of the selected cross-sections and other site features. The survey will record all changes of slope along each cross-section and will focus particularly on the bottom of the channel that would normally be inundated by low or base flows that are most susceptible to changes in groundwater levels. The surveys will need to be conducted when there is some flow

Item	Description
	in the creek, but should not be done during a high flow event for safety reasons. Water levels in the creek will be recorded at the time of the survey and related to known flow at the nearest gauge. Ideally these assessments will be conducted after the new flow gauges have been established in Boundary Creek. However, if those gauges are not installed or are not operational in time, then flow will need to be directly measured at each site. Cross-section surveys only need to be done once, but water level will ideally be measured under two or more different flows to improve the confidence of the flow vs depth relationships. The results of the survey will be used to build a one-dimensional hydraulic model (HEC-RAS), and the relationships between recorded depth and flow will be used to calibrate the model. Once calibrated, the model will be used to estimate the flow magnitude required to inundate specific habitats and in-channel features at each of the FLOWS sites and more broadly throughout Boundary Creek. The EFTP will use the available literature and site observations to determine what values (e.g. native fish species, macroinvertebrates and aquatic and riparian plants) are likely to occur in Boundary Creek and to document their specific flow requirements. They will then use the hydraulic model and historical flow records to determine the magnitude, timing and duration of different flow components that are required to maintain selected values at each site. The FLOWS assessment will focus on the low flow requirements of identified values, as they are the flow components that are most likely to be affected by groundwater harvesting. However, for completeness the assessment will also consider the magnitude and frequency of high flow events that are required to maintain ecological values. The final flow recommendations at each site will describe the minimum flows that are required to maintain the ecological values and ecological health of Boundary Creek. On-going monitoring of surface flow can then be used to determine the extent to which those flow recommendations are achieved. The recommendations will also set the benchmark for the groundwater assessment. Future groundwater harvesting will be considered a threat to the ecological health of Boundary Creek if it reduces the extent to which the environmental flow recommendations are met. Barwon Water may also use the new environmental flow recommendations to determine how much flow needs to be released into tributaries in the headwaters of Boundary Creek to mitigate any in-stream impacts associated with groundwater harvesting.
Risk if not Undertaken	The minimum flows required to maintain aquatic habitat and aquatic biota in Boundary Creek will not be known. Therefore assessment of the risk of groundwater extraction to the ecological values in Boundary Creek will not be known. In turn, management of potential impacts associated with operation of the Barwon Downs borefield will either not be possible, or will be conducted on a non-scientific or semi-scientific basis (with possible end result of an overly conservative or insufficiently conservative management approach).
Timing **(and Duration)**	Summer 2013 (and revised in Autumn 2014 based on results of macro-invertebrate survey and water quality monitoring) Duration – this is one off event
Macro-invertebrate survey	There is little available information on the composition and condition of the macroinvertebrate community in Boundary Creek. Therefore a new survey is recommended to inform the FLOWS assessment. The macroinvertebrate community at four selected sites in Boundary Creek should be assessed in spring 2013 and autumn 2014 using the AusRivAS rapid assessment method. Collected samples should be sorted live in the field and then identified to at least family level, but preferably lower taxonomic level (i.e. genus) in the laboratory. (Refer Table 28 for survey locations). A map of these sites is presented in Appendix F. Monitoring results should be reported as standard AusRivAS metrics and species lists that can be compared against SEPP (WoV) guidelines and can be used to compare differences between sites within Boundary Creek. The assessment will need to be completed in time for the results to inform the FLOWS assessment.
Timing **(and Duration)**	Spring 2013 and Autumn 2014 Duration - this is a one off event
Water quality	Water quality monitoring probes should be installed at the two new FLOWS

Item	Description
monitoring	assessment sites in Boundary Creek to measure dissolved oxygen and water temperature under low flow conditions over the coming summer. The probes should be placed in pool habitats and linked to a data recorder that will collect readings every 15 minutes. The probes should be installed in November 2013 and can be removed when higher flows commence at the end of autumn 2014. The probes will need to be checked and the data downloaded approximately once every four weeks. The collected data will be used to determine critical flow thresholds below which dissolved oxygen levels drop to dangerous levels for aquatic biota. The results of that analysis will be used to inform the FLOWS study. (Refer Table 28 for probe locations). A map of these sites is presented in Appendix F.
Timing **(and Duration)**	November 2013 – April or May 2014. Duration - this is a one off event (no on-going monitoring is recommended)
Data Capture & Recording	Refer to method statements above.

Table 28 FLOWS assessment and monitoring locations

Site	Location	Monitoring	Description
Boundary Creek at Langdons Road (Labelled '1' in Appendix F)	206056 / 5742782	Macro-invertebrates	This site is in remnant bushland. The channel is a series of shallow runs and pools, with substantial branch piles and leaf packs, overhanging vegetation and undercut banks that provide potential habitat for fish and macroinvertebrates. There is some cattle access from a property to the north, but it does not appear to be having much effect on in-stream or riparian habitat. The point we accessed appeared to have a main channel entering from the north that carried most of the flow. A relatively still backwater was present in the other channel upstream of that point, it had a dense stand of submerged vegetation (possibly Valisneria). Some blackberries were present at the site.
Boundary Creek upstream of MacDonalds Dam (FLOWS Site 1) (Labelled '2' in Appendix F)	209460 / 5744009	FLOWS site Macro-invertebrates Water quality	This site appears to have been an old gauge. There are some wooden steps and some rock has been placed in the channel to make a control. The water was stained with iron bacteria and water appeared to be seeping in from a perched swamp on the northern bank. The riparian zone consists of relatively intact remnant forest, although there are lots of blackberries close to the stream. The channel is relatively incised with steep banks. The low flow path is 1-2 m wide and water depth was up to 50 cm deep at the time of our inspection. Some good refuge pools were present, but the iron bacteria have smothered most of the in-stream habitats. There are also some overhanging vegetation and undercut banks.
Boundary Creek upstream of swamp (FLOWS Site 2) (Labelled '3' in Appendix F)	211223 / 5742089	FLOWS site Macro-invertebrates	This site is in the forest reserve between MacDonalds Dam and the swamp. The stream channel and riparian zone are in excellent condition and are free of weeds. There is a moderate load of large wood (i.e. fallen trees) and leaf litter in the channel, some undercut banks, overhanging vegetation and submerged vegetation. It has excellent habitat for native fish and macroinvertebrates and had good clean flow on the day of inspection.

Site	Location	Monitoring	Description
Boundary Creek at Colac Forest Rd (Labelled '4' in Appendix F)	212837 / 5742306	Macro-invertebrates	This is the Yeodene flow gauge site. There was no flow on the day of inspection. The riparian zone upstream of the road crossing was re-vegetated 10-15 years ago. It has a mature Eucalypt overstorey and a good mid storey layer. There was a large load of leaf litter in the channel, which may create a blackwater event if it fills with water without being fully flushed. Downstream of the road the channel flows through farmland and is more degraded. It has a cleared riparian zone and cattle have access to the stream.

A map of these sites is presented in Appendix F.

6.2.2. Cost estimates

- **Table 29 Cost estimates for FLOWS study and associated macroinvertebrate surveying and water quality logging**

Item	Estimated Cost	Notes
FLOWS Study	$55,000	Study is conducted in 2013/14 Financial year. Cost does not include installation of new flows gauging sites
Macroinvertebrate surveying	$8,700	Cost to collect/ process macroinvertebrate samples in two seasons at four sites in Boundary Creek (samples identified to genus level)
Dissolved oxygen probe and data logger at one site	$8,500	Cost of installing and operating dissolved oxygen probe and data logger at one site on Boundary Creek for six months
20% Contingency	$14,440	
Total (excl GST)	**$86,640**	

7. Stream flow monitoring and investigations

7.1. Field investigations

The surface water hydrology field assessment was mostly conducted on 22nd April 2013, with some additional visits on 24th April 2013. The main purpose of the work was to visit each of the sites suggested by the desktop review (refer Appendix A for further details) for new (or renewed) streamflow gauging and conduct a field assessment of their suitability for gauging.

Detailed information on sites visited

A short description of all the sites visited during the field inspection is provided in Table 30. The column of 'observations' in this table is the same as for the aquatic ecology file note (3rd May 2013), since the same set of visits served both purposes. The column 'Comments – surface water hydrology' has been added to explain how each visit assisted in the surface water hydrology assessment. These comments link each site to the initial (pre-fieldwork) recommendations for new or re-instated streamflow gauges.

Following the table are photos of each site visited.

- **Table 30: Sites visited during the surface water hydrology field inspection**

Site	Location	Date	Observation	Private property	Comments - surface water hydrology
Boundary Creek					
Boundary Creek at Barrongarook Rd	Not recorded	22/4/2013	No flow Two similar sized channels join immediately upstream of Barrangarook Road. The riparian zone and channel are in reasonable condition, but are currently dry. The section immediately downstream of Barrangarook Road is more degraded. The riparian zone has been cleared and is dominated by pasture grasses and blackberries.	No	No further comments.
Tributary on Bushby Lane	Not recorded	22/4/2013	This is the site of the pumping station that delivers an environmental flow to Boundary Creek. The outlet appeared to be releasing about 1-2 ML/day and was discharging to a point immediately downstream of a swamp that had dense stands of Typha and a trickle flow. This tributary appears to be providing most of the flow to Boundary Creek at present.	No	No further comments.

Site	Location	Date	Observation	Private property	Comments - surface water hydrology
Boundary Creek at Langdons Road	54 H 0730274 / 5744788	22/4/2013	This site is in remnant bushland, the channel has retained its natural form. It is the first part of the stream that appeared to have perennial flow. The channel is a series of shallow runs and pools, with substantial branch piles and leaf packs, overhanging vegetation and undercut banks that provide potential habitat for fish and macroinvertebrates. There is some cattle access from a property to the north, but it does not appear to be having much effect. The point we accessed appeared to have a main channel entering from the north that carried most of the flow. A relatively still backwater was present in the other channel upstream of that point, it had a dense stand of submerged vegetation (possibly Valisneria). Some blackberries were present at the site. This site could be a good FLOWS assessment site if one is needed upstream of MacDonalds Dam	No	**Photo:** see Figure 11. **Relates to recommendation:** 4 – new gauge at Boundary Creek at upper end of bedrock outcrop. **Notes:** The visit confirmed that the site appears suitable for a gauging station. The banks, while steep in places, are stable and not eroded. It was noted that the stream appeared to flow over sands and silts, and this could be a problem for construction of a gauge. **Action:** Thiess was requested to provide a quote for commissioning of flow and salinity measurement at this site. This quote was subsequently provided on 13/05/2013. **Comments from Thiess:** This site could be difficult and expensive to construct and maintain due to (1) silty / sandy bottom; and (2) difficult access via summer-only track. Therefore, Thiess staff sought out an alternative nearby site upstream. They recommend a site 300m upstream which has several culverts beneath an all access weather track. SKM agrees that this site further upstream is suitable and is happy to proceed on this basis.

Site	Location	Date	Observation	Private property	Comments - surface water hydrology
Boundary Creek upstream of MacDonalds Dam	54 H 0733472 / 5745985	22/4/2013	This site appears to have been an old gauge*. There are some wooden steps and some rock has been placed in the channel to make a control. The water was stained with iron bacteria and water appeared to be seeping in from a perched swamp on the northern bank. The river flowed through relatively in-tact remnant forest, although there were lots of blackberries close to the stream. The channel was relatively incised with steep banks. The main channel was 1-2 m wide and water depth was up to 50 cm deep. Some good refuge pools were present, but the iron bacteria have smothered most of the in-stream habitats. There are also some overhanging vegetation and undercut banks. This could also be used as a potential FLOWS site, although the iron bacteria may be an issue. *note it was later confirmed that, although suitable, this site was not the site of the former gauge. See Comments – surface water hydrology.	No although had to walk through fenced roadway at end of McCalls Rd	**Photo:** see Figure 12. **Relates to recommendation:** 1 – reinstate Boundary Creek flow gauges upstream and downstream of MacDonalds Dam. **Notes:** Difficult to move up and down the reach due to blackberries. Although we could not get confirmation as to where exactly the old gauge was, the site visited was considered suitable for a gauging station. The cross section, while steep, appeared relatively stable, and there was a small cascade over a rocky control, with a pool upstream. **Action:** Thiess was requested to provide a quote for commissioning of flow and salinity measurement at this site. This quote was subsequently provided on 13/05/2013. **Comments from Thiess:** Thiess successfully found the previous gauging site in amongst the blackberries. They propose to repair the existing weir.

Site	Location	Date	Observation	Private property	Comments - surface water hydrology
Boundary Creek at MacDonalds Dam spillway	54 H 0734194 / 5745440	22/4/2013	This is the site of the old de-commissioned flow gauge. The bottom of channel is 0.5 – 2.0 m wide, but only 15-30 cm deep and banks are relatively low. The section immediately downstream of the dam has been recently burnt and it then flows through a paddock with cleared riparian zone and stock access to the stream. The substrate is clay and sand, there is some Triglochin present and also some bank slumping where cattle have accessed the stream. There are some branches and leaf packs in the stream, but the cleared riparian zone and dam limit the supply of organic material. The dam was spilling on the day of our visit, but there is also a low flow scour valve.	Private property upstream and downstream of McCalls Road	**Photo:** see Figure 13. **Relates to recommendation:** 1 – reinstate Boundary Creek flow gauges upstream and downstream of MacDonalds Dam. **Notes:** Some gauging infrastructure is still present at site. The channel itself is relatively eroded, but the channel elevation does not appear to have changed since decommissioning of the gauge (judging by the staff gauge). **Action:** Thiess was requested to provide a quote for commissioning of flow and salinity measurement at this site. This quote was subsequently provided on 13/05/2013. **Comments from Thiess:** Site was confirmed as suitable.

Site	Location	Date	Observation	Private property	Comments - surface water hydrology
Boundary Creek at Colac Forest Rd	54 H 0736649 / 5743951	22/4/2013	This is the current flow gauging site. There was no flow on the day of inspection. The channel upstream of the road has been re-vegetated, it has a mature Eucalypt overstorey and a good mid storey layer. There was a large leaf litter in the channel, which may create a blackwater event if it fills with water without being fully flushed. Downstream of the road the channel flows through farmland. It has a cleared riparian zone and cattle have access to the stream.	Yes downstream of the road	**Photo:** see Figure 14. **Relates to recommendation:** 2 – Continuous salinity monitoring on Boundary Creek **Notes:** Site of the Yeodene gauging station (site 233228). Unusual that this site was dry given that MacDonalds Dam was spilling, which indicates losses from the river between the dam and Yeodene. **Action:** Thiess was requested to provide a quote for salinity monitoring at this site. This quote was subsequently provided on 13/05/2013. **Comments from Thiess:** Site was confirmed as suitable.

Site	Location	Date	Observation	Private property	Comments - surface water hydrology
Boundary Creek at Alan and H Shalley's property (confluence with Barwon River)	54 H 0738752 / 5744015	22/4/2013	This is immediately upstream of the confluence with the Barwon River. The channel here has been recently scraped and has no features. The banks are completely cleared and cattle have access to the channel. There was no flow on the day of survey. Nellie Shallay's property is immediately upstream, the channel through that property is also straightened, but some trees have been planted along the banks.	Yes A&H Shalley	**Photo:** see Figure 15. **Relates to recommendation:** 3 – New gauges to monitor changes in groundwater discharge from the aquitard (Option A) **Notes:** Upon visiting the site, it became clear that the majority of the reach between the Yeodene Gauge and the confluence with Barwon River is on the Barwon River floodplain. Therefore, change in streamflow along this reach, even in low flow periods, could be due to discharge from water stored in the river's alluvial floodplain, rather than discharge from the aquitard. The portion of the reach where this is not the case is so short that groundwater discharging in the channel would be difficult to detect. Also, much of the reach is channelized, with evidence of recent earthworks. This would make it difficult to isolate flow changes due to pumping, from flow changes due to the active alteration of channel form by landowners. Thus, this site is unsuitable to fulfil Recommendation 3. **Action:** None taken
Barwon River West Branch					
Barwon River at confluence with Boundary Creek	54 H 0739320 / 5744305	22/4/2013	Clay channel with cleared riparian zone and stock access to the stream. The banks are eroded due to stock access. There are some deep pools and stands of Phragmites along the banks. Also some stands of Bulboschoenus and patches of azolla.	Yes A&H Shalley	No further comments.
Den Creek and Dewing Creek					

Site	Location	Date	Observation	Private property	Comments - surface water hydrology
Dewing Creek at Callahans Lane	54 H 0740954 / 5739910	24/4/2013	Reasonably well defined channel, but the banks are eroded. The section downstream of the road is choked with Phragmites. Road crossing is a 4 opening round concrete culvert.	Yes	**Photo:** see Figure 16. **Relates to recommendation:** 3 – New gauges to monitor changes in groundwater discharge from the aquitard (Option B) **Notes:** It was decided that this site is unsuitable to fulfil Recommendation 3. The reach between the existing gauge (244257) and the confluence with Den Creek is so short that (as with option A) it would be difficult to detect groundwater flows discharging into the reach. It was originally thought that a gauge could be placed downstream of the confluence with Den Creek, provided the flows in Den Creek could be assumed to be insignificant. However, upon visiting the site (Figure 7) and seeing the size of the channel (and its eroded nature) it was felt that this assumption is not justified. **Action:** None taken
Den Creek on Callahans Lane	54 H 0740852 / 5739537	24/4/2013	Small dry channel, with no riparian vegetation. Box culvert under the road.	Yes	No further comments.
Den Creek off Callahans Road	54 H 0740226 / 5740994	24/4/2013	Well defined, but highly eroded channel through farmland. Stock have access to the channel. No instream values, but could potentially install a flow gauge near the bridge.	Yes	No further comments. See Figure 17.

Site	Location	Date	Observation	Private property	Comments - surface water hydrology
Unnamed tributary North of Boundary Creek					
Unnamed tributary on Colac-Lorne Road	54 H 0740943 / 5748516	24/4/2013	Wide shallow meandering channel that is choked with Phragmites and Typha. There is lots of stock access and they have trampled and eroded the banks.	Yes Barbara Beach. Phoned on 22/4/2013	**Photo:** see Figure 18. **Relates to recommendation:** 3 – New gauges to monitor changes in groundwater discharge from the aquitard (Option C) **Notes:** Relative to the size of this catchment, the channel at this location is very wide (between 10 and 15m wide) and shallow. This means that a large amount of construction would be needed to install a gauge here of suitable low flow accuracy. Furthermore, given the width of the cross section, it would be difficult to ensure that some of the flow did not seep underneath the weir. We searched for a more suitable location upstream and downstream, but none was found. Therefore, we recommend to not proceed with gauging flow on this tributary. **Action:** No further comments

- **Figure 11: Boundary Creek at Langdons Road**

- **Figure 12: Boundary Creek upstream of MacDonalds Dam**

- **Figure 13: Boundary Creek downstream of MacDonalds Dam**

- **Figure 14: Boundary Creek at the Yeodene gauging station (Colac Forrest Road)**

- **Figure 15: Boundary Creek immediately upstream of confluence with Barwon River**

- **Figure 16: Dewing Creek at Callahans Lane**

Figure 17: Den Creek at Callahans Lane

Figure 18: Unnamed tributary downstream of Colac-Lorne Road

Summary of outcomes

The desktop assessment phase made four recommendations concerning on-going monitoring of surface water in the study area. The field investigations examined the feasibility of each of these recommendations. As per Table 31, it was found that one of the recommendations is likely to be unfeasible, but the remaining three were found to be feasible, and cost estimates have subsequently been prepared to provide gauging that is as accurate as possible at low flows. The new monitoring regime will require the re-activation of two gauging sites (Recommendation 1), in addition to a new site (Recommendation 4). All three sites are on private land.

The fifth recommendation is Source modelling[1] with the STEDI plugin to estimate streamflow impacts due to small catchment dams and private diverters. Following the field work, it was clear that a significant degree of flow attenuation (i.e. loss of water from the stream) was occurring between MacDonalds Dam and the Yeodene gauge, since there was no flow at Yeodene on the day of inspection despite MacDonalds Dam discharging via both the spillway and the scour valve. In response to this, we recommend to expand the scope of this task to investigate the following:

[1] Source is an E-Water application that can be used for both catchment and river modelling. Source provides a flexible structure that allows the user to select a level of model complexity appropriate to the project and within constraints imposed by available data and knowledge. A model is constructed by selecting and linking component models from a range of available options. Source is designed to support the construction and operation of river models that mimic river behaviour, and the user to construct and interrogate water and contaminant transport models to assess the impact of future change, on parameters of interest. Source uses a node-link style modelling system for generating, transporting and transforming water and constituents within the major channels in a catchment. Source's capabilities can be extended through the use of plugins, which are data processing tools external to Source.

- The effect of farm dams on streamflow, using the spatially-explicit STEDI plugin to Source;
- The effect of private diverter pumping on stream flows; and
- The degree of flow attenuation that occurs in Boundary Creek in general, and in particular between MacDonalds Dam and the Yeodene gauge.

Having examined these three elements of the hydrology of Boundary Creek, the study should provide analysis and discussion of the relative contribution of Barwon Water discharges, farm dams, private diversions and flow attenuation to catchment hydrology and the implications for assessing trends in groundwater discharge along the creek. We recommend to allocate $50,000 to this task, and to delay the task until at least two years' flow data are available from the new streamflow gauges.

Table 31: Summary of outcomes for surface water hydrology, by recommendation

Recommendation	Technically Feasible?	Comments
1. Reinstate Boundary Creek flow gauges upstream and downstream of MacDonalds Dam	Yes	Field investigations revealed that the former gauging sites can be reactivated, in both cases. Both sites are on private land.
2. Continuous salinity monitoring in Boundary Creek at the existing Yeodene gauge and all new / reactivated gauge sites	Yes	Cost estimates have been prepared for the introduction of salinity monitoring at the Yeodene station (233228). All quotes for new (or reactivated) stations include cost of salinity monitoring.
3. New gauges to monitor changes in groundwater discharge from the aquitard	No	SKM staff visited three potential sites, and found that each site was not suitable, as discussed above.
4. New gauge at Boundary Creek at upper end of bedrock outcrop.	Yes	A new site is recommended at an existing road culvert. This site is on private land.

The field investigation did not identify any suitable sites for siting a stream gauge in the aquitard. This was generally for one or more of four reasons:

1) Instability of stream channel;
2) Very wide width of stream channel (including spreading into multiple minor channels);

3) Undue influence of alluvial sediments overlying the aquitard on flows to the stream (and associated difficulty attributing flows from the aquitard versus alluvial sediments);
4) Short length of sections of streams overlying aquitard, meaning that accuracy of gauges will not be suitable for picking up inflows over such short sections.

It is possible that investment in a significant amount of further field time might enable a site to be identified which overcomes issues 1 and issue 2 (and possibly issue 3), but issue 4 will remain problematic (and particularly as one moves up-catchment to avoid issue 3, this exacerbates issue 4, as the stream section targeted shortens in length).

Further, the preliminary numerical modelling conducted as part of this project suggests that the impact of the pumping on the aquitard is likely to be restricted to sections where the aquitard is relatively thin, and the model output shows this to be narrow band intersecting streams flowing across the aquitard. This means that the impact of drawdown in the aquitard on streams is likely to be, firstly, small in volume, and secondly spatially restricted.

Therefore picking up the impact of stream depletion from changes in aquitard groundwater levels will be very difficult using stream gauges. This, combined with the absence of suitable sites from investigations to date, means that we recommend no further investigation of a suitable gauge site in the aquitard be undertaken. Instead, potential impacts of pumping on aquitard streams flows will need to be derived using secondary methods, including changes in groundwater levels in the aquitards and the numerical model. Once the model is re-calibrated, including with new data on aquitard water levels from new aquitard bores, the model will be better suited for this purpose.

7.2. Scope and cost of stream flow investigations

The desktop assessment phase made four recommendations concerning on-going monitoring of surface water in the study area. The field investigations examined the feasibility of each of these recommendations. It was found that one of the recommendations is likely to be infeasible to carry out, but the remaining three were found to be feasible. The new monitoring regime will require:

- The re-activation of two gauging sites
- Installation of a new gauging site
- Addition of EC and pH monitoring at an existing gauge site
- Source modelling with the STEDI plugin to allow prediction of streamflow impacts due to small catchment dams and private diverters.

All sites are located on private land.

7.3. Steam flow gauge installation scope of works

Table 32 Stream flow gauge installation – scope of works

Item	Description
Purpose	To install stream flow gauges for on-going stream flow monitoring
Locations	The four locations are listed below: 1. Boundary Creek Near Langdons Road 2. Boundary Creek U/S MacDonalds Dam 3. Boundary Creek D/S MacDonalds Dam 4. Boundary Creek Yeodene These locations are mapped in Appendix G.
Scope of Activity	**Boundary Creek Yeodene** Install an electrical conductivity sensor, a sensor mount slide, which is used to retrieve sensor for maintenance and cleaning. A pH probe for on-going monitoring will also be installed. **Boundary Creek D/S MacDonalds Dam** Install a monitoring station at the existing station location. This will include removal of the existing stilling well and shelter from the original station as it damaged and should be removed to eliminate further risks. The proposed new station will utilise the existing culvert as the control feature, which require some work to eliminate leaks under the pipe. It is also proposed to install a band inside the pipe with a small weir to assist with the sensitivity of the control. The instrument housing will be a stainless cabinet with a stainless pole and solar panel mount. The level monitoring instrument will a pumped compressed air sensor The station will also have an electrical conductivity/temperature sensor with slide mount **Boundary Creek U/S MacDonalds Dam** It is proposed to install the monitoring station at the original site which incorporated a stilling well and concrete weir structure. The weir is in good condition however a significant leak beneath the weir will be required to be repaired. The stilling well will not be able to be used The proposed station will use the same instrumentation as identified in the downstream station with repair works required for the existing concrete weir The weir is in excellent condition except for the leak and good quality data will be able to be obtained from the station; some historical data maybe available at the site **Boundary Creek Near Langdons Road** The proposed station will use similar instrumentation and infrastructure to the other proposed stations The stream bed and banks upstream of the culverts will require some minor excavation works and the culverts may require minor works to enable them to be utilised as a control/weir for the project
Risk if not	If the Boundary Creek flow gauges upstream and downstream of MacDonalds Dam

Item	Description
Undertaken	are not reinstated, the ability to reliably use the Boundary Creek streamflow gauge at Yeodene (as an indicator of potential pumping impacts) will remain hindered by uncertainty in the degree of flow attenuation and loss across MacDonalds Dam. If continuous salinity monitoring on Boundary Creek is not undertaken, a semi-independent estimate of changes in baseflow will not be possible. If the new gauge at the upper end of the bedrock outcrop is not installed, the current conceptualisation of the bedrock geology as impervious and providing no baseflow to waterways will be maintained. Reality may be significantly different however and without this new information this potentially incorrect conceptualisation will be kept.
Timing	Installation should occur as early as practicable to allow for collation of low flow data over summer The Source modelling would be commenced approximately two years of installation of the new stream gauges.

7.3.1. Cost estimates

A budget quote was provided by Thiess for the installation of the new stream gauges and refurbishment of existing gauges and is presented in the table below.

- **Table 33 Stream flow gauge installation costs**

Item	Estimated Cost	Notes
Boundary Creek Yeodene Site	$12,225	The cost includes the purchase and installation of an electrical conductivity sensor, a sensor mount slide, which is used to retrieve sensor for maintenance and cleaning The cost also includes the addition of a pH probe for continuous monitoring
Boundary Creek D/S MacDonalds Dam Site	$24,000	Includes, instrumentation, logger box, instrumentation shelter, shelter foundation slide mount for electrical conductivity sensor, mount for level sensor bubbler, staff gauge, battery, solar panel, solar panel mount, band /weir for culvert, culvert repair ,labour and travel to undertake works including decommission existing station and install new station
Boundary Creek U/S MacDonalds Dam Site	$25,900	Includes, instrumentation, logger box, instrumentation shelter, shelter foundation, slide mount for ec sensor, mount for level sensor bubbler, staff gauge, battery, solar panel, solar panel

Item	Estimated Cost	Notes
		mount, weir repairs, some decommission works to stilling well, labour and travel to undertake works
Boundary Creek Near Langdons Road	$26,150	Includes, instrumentation, logger box, instrumentation shelter, shelter foundation, slide mount for ec sensor, mount for level sensor bubbler, staff gauge, battery, solar panel, solar panel mount, excavation of creek and minor modification to culverts, labour and travel to undertake works
Sub Total	$88,275	
20% contingency	$17,655	
Total (excl GST)	**$105,930**	It is assumed that Thiess are engaged directly by Barwon Water for the works.

7.4. Ongoing streamflow monitoring

- **Table 34 Stream flow gauge installation – scope of works**

Item	Description
Purpose	To install stream flow gauge for ongoing stream flow monitoring
Locations	Boundary Creek Yeodene (EC and pH in addition to existing flow monitoring) Boundary Creek D/S MacDonalds Dam (flow and EC) Boundary Creek U/S MacDonalds Dam (flow and EC) Boundary Creek Near Langdons Road (flow and EC)
Scope of Activity	Ongoing maintenance and data collection at each site with periodic data collection
Timing and Duration	Streamflow monitoring would occur from installation until (approximately) licence application submission (e.g. mid-2014 to mid-2018). (Four years of monitoring has been assumed in the costing, in the following section). It is possible that monitoring may continue at some or all of the stream gauge sites after licence renewal – which sites and the frequency of monitoring will be based on results of the monitoring program and upon the discretion of SRW.

7.4.1. Cost estimate

A budget quote was sort from Thiess for the ongoing maintenance and monitoring of each stream gauge. The costs presented below are derived from the existing agreement Thiess has with Barwon Water under the Regional Water Monitoring Partnership.

- **Table 35 Stream flow gauge monitoring costs**

Item	Estimated Cost	Notes
Boundary Creek Yeodene Site	$7,100	Assumed 4 year monitoring period
Boundary Creek D/S MacDonalds Dam Site	$27,200	
Boundary Creek U/S MacDonalds Dam Site	$27,200	
Boundary Creek Near Langdons Road	$27,200	
Sub Total	$88,700	
Contingency	$17,740	
Total (excl GST)	**$106,440**	

7.5. Annual checking and analysis of streamflow data and Source modelling

- **Table 36 Annual checking and analysis of streamflow data and Source modelling – scope of works**

Item	Description
Purpose	The purpose of the annual review and analysis of data is to check the integrity of the collected data at the gauges and make appropriate recommendations if the data quality appears questionable. Its purpose also includes assessment of when sufficient data has been collected to enable the Source modelling to occur. The purpose of the Source modelling is to estimate streamflow impacts due to small catchment dams and private diverters in the Boundary Creek Catchment.
Locations	Four streamflow gauges described above
Scope of Activity	**Annual review and analysis of data** – This will include plotting the data provided by Theiss and checking that the data quality is suitable. The proposed level of analysis is limited but would include checking the data makes sense compared to factors such as: ▪ the conceptual model of the stream (i.e. where it is gaining and losing), ▪ environmental flow releases, and ▪ preceding rainfall conditions

Item	Description
	Source modelling Source modelling with the STEDI plugin will estimate streamflow impacts due to small catchment dams and private diverters. This will involve the following: ▪ The effect of farm dams on streamflow, using the spatially-explicit STEDI plugin to Source; ▪ The effect of private diverter pumping on streamflows; and ▪ The degree of flow attenuation that occurs in Boundary Creek in general, and in particular between MacDonalds Dam and the Yeodene gauge. Having examined these three elements of the hydrology of Boundary Creek, the study will provide analysis and discussion of the relative contribution of Barwon Water discharges, farm dams, private diversions and flow attenuation to catchment hydrology and the implications for assessing trends in groundwater discharge along the creek.
Risk if not Undertaken	Without a periodic review of the data there is a risk of losing significant amounts of stream flow / salinity data (i.e. if errors in the data are not detected until late in the monitoring period). If the Source modelling is not undertaken, the impact of farm dams and private diverters on Boundary Creek streamflow will not be able to be separated from any groundwater extraction impact with any degree of certainty.
Timing	**Annual review and analysis of data** – Annually, starting 12 months from commencement of data collection. **Source modelling -** Source modelling would be informed by the streamflow data collected by the new gauging stations, and for this reason we recommend undertaking this modelling after the new gauges have collected at least two years' worth of data (a judgement would be made based on the annual review of data)
Duration	Streamflow monitoring would occur from installation until (approximately) licence application submission (e.g. mid-2014 to mid-2018). Annual review / data checking therefore is required on three occasions (excluding final reporting)

7.5.1. Cost estimate

Cost estimates for the annual review / analysis of data and the Source modelling are provided in the table below.

Table 37 Cost estimates for annual checking and analysis of streamflow data and Source modelling – scope of works

Item	Estimated Cost	Notes
Annual review and analysis of data	$30,000	$10,000 per year x 3 years
Source modelling	$50,000	'One-off study'
Sub Total	$80,000	
20% contingency	$16,000	
Total (excl GST)	**$96,000**	

8. References

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Appendix A Desktop Assessment Report (Task B)

Barwon Downs Monitoring Program

WORK PACKAGE 1 DESKTOP ASSESSMENT

- Draft 1
- 22 March 2013

Barwon Downs Monitoring Program

BARWON DOWNS MONITORING PROGRAM

- Draft 1
- 22 March 2013

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1. Introduction

The Barwon Downs borefield is a key part of Barwon Water's water supply infrastructure capable of supplying up to (XXML/day). The existing groundwater extraction licence for the Barwon Downs borefield was granted in 2004 and expires in 2019.

Whilst Barwon Water have an existing monitoring program in place, which monitors for environmental impacts associated with the borefield operation, the 2012 review of the current Barwon Downs monitoring program (by SKM, Ecology Australia and Latrobe University) identified gaps in the monitoring program which could place the licence renewal process at risk. The main gaps were related to a need to improve understanding of potential ecological impacts from groundwater extraction, resulting from reduced groundwater levels, reduction in stream flow or water quality impacts caused by acid sulphate soils. In particular, knowledge gaps around the watertable interaction (with surface water, vegetation etc) in the aquitard area were identified.

In preparation for the licence renewal Barwon Water want to put in place, a robust monitoring program to assess potential environmental impacts associated with the use of the borefield. The outcomes of the monitoring program will then be used to support the licence renewal application and ensure that the appropriate controls are in place to mitigate and minimise environmental impacts.

The purpose of this report is to document the outcomes of a detailed desktop assessment (supplemented by a field inspection) to finalise the scope and costs of the new monitoring program.

This report is a working document and the current version (issued March 22 2013) of the document only reports on *Task B – Information Compilation and Analysis.*

2. Review of revised monitoring program

A review of the previous work, Barwon Downs Monitoring Program – Monitoring Review (SKM,2012) was undertaken to confirm the scope of works deemed necessary to support a successful licence renewal. The review included consideration of scope outside of this project (Work Package 1).

3. Information compilation and analysis

3.1. Groundwater modelling – sensitivity testing

Sensitivity testing of aquitard vertical hydraulic conductivity (kv) using the existing groundwater model was conducted to determine the likelihood that borefield operation would produce a significant response in the aquitard watertable. This included revising the groundwater model, by splitting the existing aquitard layers into a number of sub-layers - three divisions were trialled but this resulted in excessively long model run times, and two divisions was ultimately selected. The purpose of splitting the aquitard was to allow the model to more accurately estimate the delays in transmitting responses from deep aquifers through to the watertable.

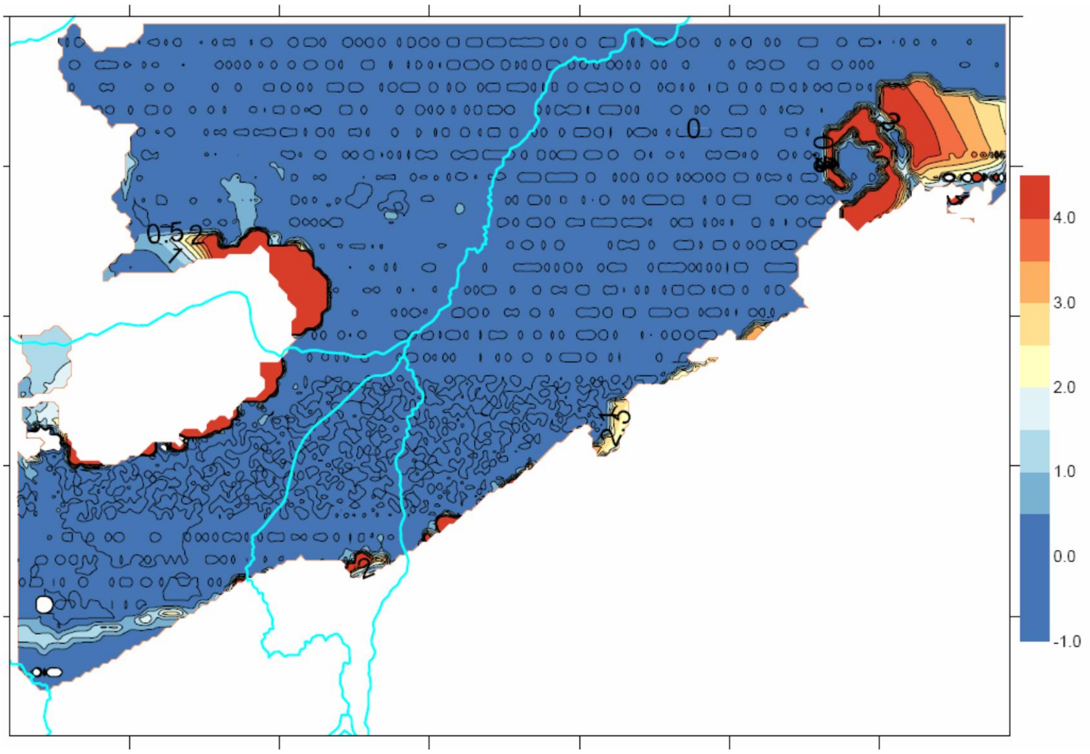
The results of the sensitivity testing (Figure 1 and Figure 2) show that drawdown in the watertable in the aquitard may occur, and the amount of drawdown is controlled by kv, and aquitard thickness. Kv is expected to be between 10^{-5} to 10^{-3} m/day. Analytical analysis of drawdown in the confined aquifer in response to bore field pumping indicates aquitard kv ranges between 10^{-4} to 10^{-2} m/day. The Kv value of 10^{-2} m/day is likely to be too high and may be a result of the production bores extracting water from the upper and lower aquifer (i.e. we have to assume that the Pember Mudstone is not acting as an aquitard between the upper and lower sections of the aquifer).

At the lower bound value of kv drawdown after 13 years of pumping at 9.3 ML/day over most of the aquitard is negligible (Figure 3). Drawdown of up to 4 m occurs on the margins of the aquitard where its thickness is less than 50 m (Figure 3). With a kv of 10^{-4} m/day the area where drawdown is greater than 4 m increases to regions where the aquitard is approximately 150 m thick (Figure 3). Drawdown is negligible where the aquitard thickness is greater than 150 m.

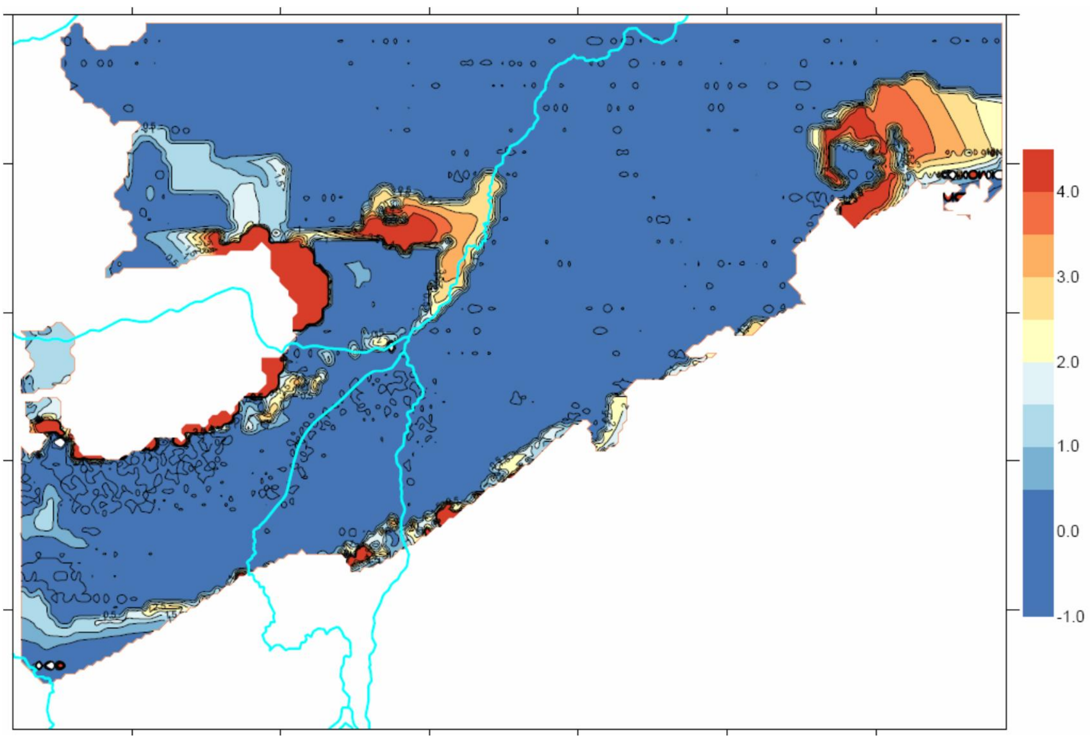
Due to potentially long lag times between the start of pumping and the start of drawdown in the aquitard, drawdown is likely to continue to increase over longer periods of pumping, even though there may be no additional drawdown in the aquifer.

It is recommended that prior to re-calibration of the numerical model (which will occur as part of the licence renewal process), that water levels in the aquitard observation bores are analysed to more reliably define the upper bound kv values using analytical analysis. The hydraulic testing of new aquitard bores (as scoped and recommended in this study) will also help to constrain the aquitard hydraulic conductivity.

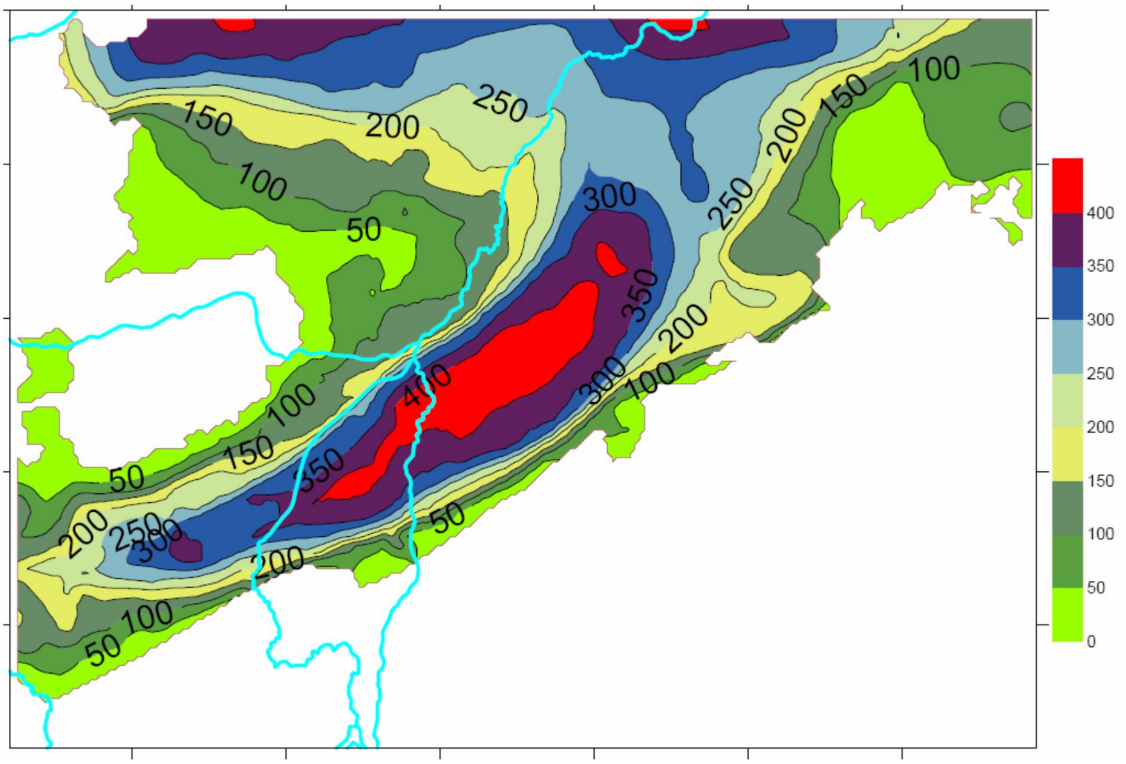
The sensitivity testing has shown that drawdown in the aquitard, at least towards the margins where the aquitard is thin, is possible and hence the monitoring program needs to include these areas, as appropriate.



▪ **Figure 1 Watertable drawdown (m) in aquitard with kv of 10^{-5} m/day**



▪ **Figure 2 Watertable drawdown (m) in aquitard with kv of 10^{-4} m/day**



■ **Figure 3 Aquitard thickness (metres)**

3.2. Preliminary hydrogeological assessment and identification of new monitoring bore sites

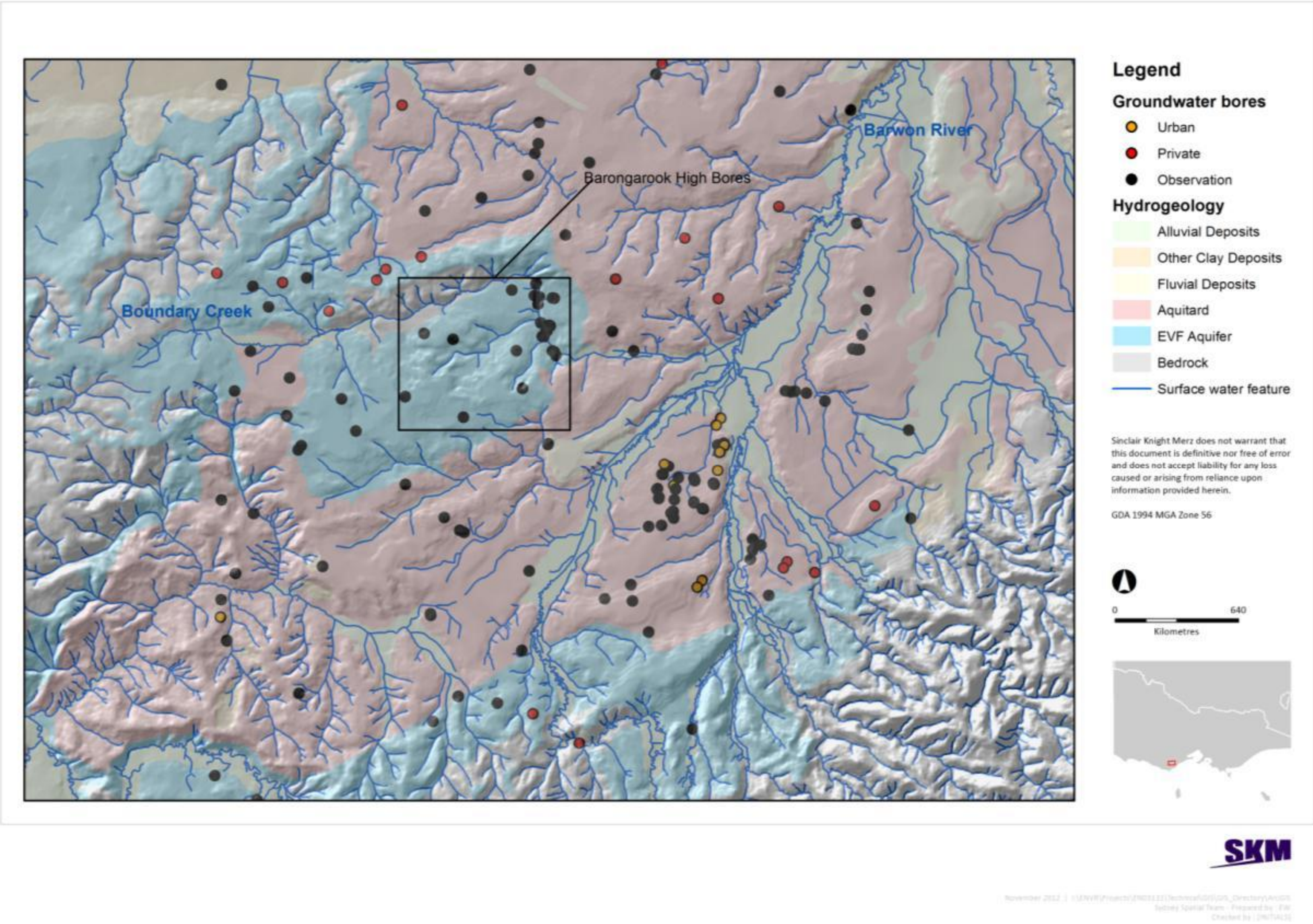
The Victorian Groundwater Management System (GMS) was interrogated to extract all groundwater information available in the study area. This includes private groundwater bores (for example stock and domestic and irrigation bores) and monitoring bores that are maintained by both DPI and the DSE. Figure 4 shows the bores in the study area, classified as either monitoring bores, urban bores or private bores. Bores that did not fall into these classifications were excluded from the assessment. This included 250 bores with use type classifications of; Investigation, Not Groundwater or Not Known and these bores were cross-checked to ensure that there was no time series waterlevel information associated with them.

A summary of the 215 private, urban and observation bores in the study area, including a summary of the time series water level information recorded for each, is provide in Table 1.

Table 1 Summary of groundwater bores in the Barwon Downs area

Bore Type	Bore Use	Count	Number of Waterlevel Readings
Private	Stock & (or) Domestic	16	0
Private	Dairy	1	0
Private	Irrigation	1	0
Commercial	Urban	10	0
State Observation Bore (DSE)	Observation	18	<50
		13	50-100
		20	>100
		34	>200
DPI Observation	Observation	5	<50
		26	50-100
		58	>100
		0	>200
Observation [1]	Observation	5	<50
		5	50-100
		3	>100
Total Bores		**215**	

1. Barwon Water observation bores (tbc)



▪ **Figure 4 Location of private and observation bores in the study area**

3.2.1. Determine if existing bores in the unconfined areas are monitoring the watertable

The importance of this task is explained in SKM (2012) - if existing bores are actually measuring a confined sub-aquifer 'it may mean current (and future) impacts of pumping on streamflow (and aquifer ecology) are less than currently assumed'. This would also have implications for trigger levels in these areas. (Note that this task is primarily concerned with the lower reaches of Boundary Creek, whereas Task B2-2 is concerned with the upper reaches of Boundary Creek).

The bores in the eastern part of Barongarook High (lower reaches of Boundary Creek), where the Lower Tertiary Aquifer (LTA) is the surficial aquifer (and hence is assumed to be a watertable aquifer), are indicated in Figure 4. These bores were targeted for investigation to determine whether they are truly monitoring a watertable aquifer or if there is a low permeability unit within the LTA that is causing semi-confining conditions. This analysis comprised the following steps:

1) Summarise bores in the unconfined area around the Barongarook High in terms of their drilled depth and screen intervals
2) Review the lithological bore logs recorded by the onsite geologist and/or driller for each bore, as recorded by GEDIS
3) Review the hydrographs for these bores
4) Undertake Aqtesolv analysis for those bores behaving as potentially confined to ascertain a storage coefficient
5) Construct a cross section through the unconfined area to provide visual confirmation of the identified low permeability layer.

The result of this assessment is summarised in Table 2. The GEDIS lithological logs for these bores (available for 28 out of the 29 bores analysed) are included in Appendix A.

Of the 29 bores analysed in this area, there is strong evidence to suggest that three of the bores are screened below a low permeability (confining) layer within the LTA. These three bores exhibit waterlevel trends consistent with confined conditions, showing strong/marked drawdown and recovery curves coincident with Barwon Downs pumping events. Time-drawdown analysis (using Aqtesolv) indicates storage coefficients within the range of a typical confined aquifer (i.e. between 5 x 10^{-6} and 5 x 10^{-3}) and the geologist logs indicate a significant coal and clay layer above the screened interval. The hydrographs for these three bores are shown in Figure 5. When compared to two nearby bores that monitor a part of the LTA that is confined by the Gellibrand Marl aquitard, a similar trend is evident (Figure 6). Conversely, Figure 7 shows waterlevels for an observation bore that has lithological information that does not indicate the presence of a low permeability layer, as evidenced by the very subdued response to pumping at the borefield.

A schematic cross-section has been included in Figure 9 that includes the three bores that are considered to be confined (the location of the cross-section is indicated in Figure 8). This cross-section very clearly indicates the presence of a low permeability unit within the LTA, residing above the screens of these three bores. Furthermore, for the additional bores used to develop the cross-section (109111 and 64238) that are believed to be monitoring unconfined LTA, the screened intervals of these bores can be seen to reside above this low permeability layer, which is consistent with their subdued groundwater response to pumping.

The remaining bores fall loosely into two categories:

- very shallow bores which essentially show no discernible/significant response to groundwater pumping (109125, 109144, 109143, 109141, 48002 and 114166) – a key characteristic of these bores is that with one exception) they are screened at shallow depths.
- All remaining bores which show a subdued response to groundwater pumping – these comprise a mix of relatively shallow and deeper bores.

The current state of most of these bores is not known, with most of the monitoring records ceasing in the 1980s or 1990s, as shown by the colour coding of bores in Figure 8. For example, there is only one bore in Table 2 that is less than 20 metres deep and is currently monitoring.

There are three key recommendations from this task:

- A number of the shallow bores, or bores where the water level is in or only slightly above the screen should be re-instated to provide an up-to-date picture of the watertable in the Barongarook High. As a priority this will include the six bores described above (with no water level response to pumping), but will also include other bores in Table 2 which have a very low likelihood of being perched. (*List*). <u>An attempt will be made to identify and assess the (surface) condition of as many of these bores as possible on the field trip</u>. Further work to assess the bores will then be required, e.g. developing the bores and monitoring their response to assess bore condition.
- If a suitable number (and spatial spread) of the above bores cannot be re-instated (i.e. located and restored), then additional shallow bores will be required to be drilled. This would be up to four bores, but less depending on the number of bores which can be reinstated.
- Two shallow bores should be drilled adjacent to 109132 and 64238, to form a deep - shallow nested bore site at each location. This will enable an assessment of whether a shallower watertable (i.e. the real watertable) exists at these locations.

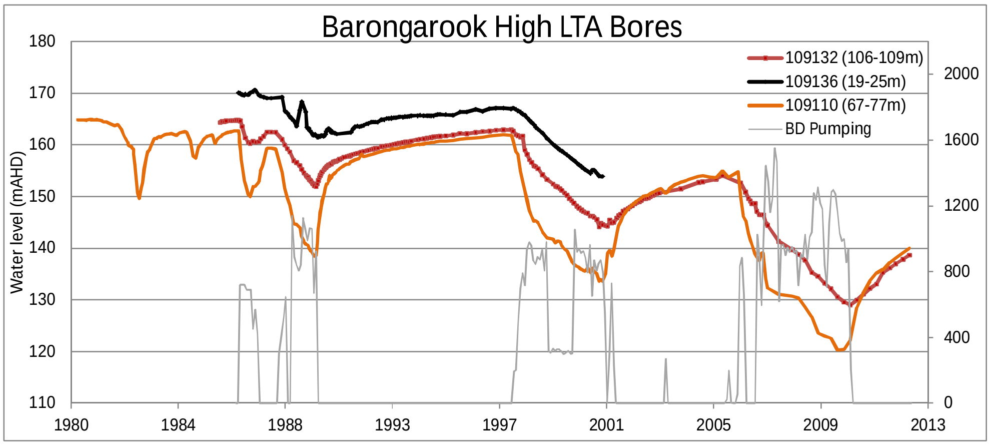
Future recommendation: assess whether the water level elevations in the deep bores are significantly different to water levels in the shallow bores.

Table 2 Barangarook High Bores (Unconfined Analysis)

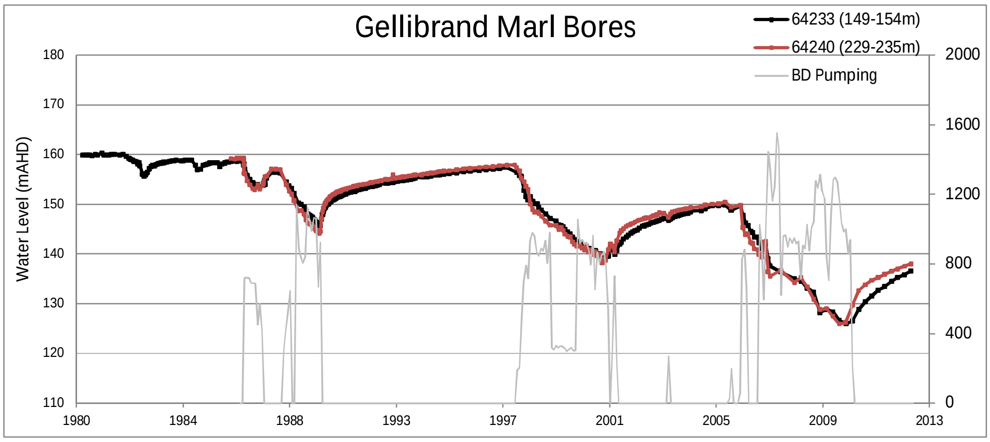
Bore ID	Date	Depth	Screen From (m)	Screen To (m)	No. Waterlevel Readings	First Reading	Last Reading	Indicator 1: Screen Depth	Indicator 2: Hydrograph Analysis	Indicator 3: Portion of clay material above screen	Indicator 4: Aqtesolv S value
109136	23/02/1987	37	19	25	138	1987	2001	<50m	Significant response	6/19m	5×10^{-3}
109110	27/10/1980	99	67	77	324	1981	2012	<100m	Significant response	21/67m clay and coal	2.2×10^{-6}
109132	5/05/1986	123	106	109	216	1986	2012	>100m	Significant response	49/106m clay and coal	4.5×10^{-3}
109125	27/03/1986	24	12	18	32	1986	1987	<20m	No response*	4/12m	
109139	23/03/1987	11	7	10	12	1987	1988	<20m	Subdued response*	All clay	
109140	24/03/1987	11	7	10	13	1987	1988	<20m	Subdued response*	100%	
109144	16/04/1987	24	11	17	13	1987	1989	<20m	No response*	7/11m	
109143	13/04/1987	24	12	18	12	1987	1989	<20m	No response*	4/12m	
109141	31/03/1987	20	15	18	15	1987	1989	<20m	No response*	All clay	
109142	1/04/1987	20	16	19	17	1987	1989	<20m	Subdued response*	9/16m	
109120	8/04/1986	16	0	11	43	1986	1989	<20m	Subdued response*	3/11m	
109121	10/04/1986	16	0	13	43	1986	1989	<20m	Subdued response*	4/13m	
109123	26/03/1986	4	0	4	32	1986	1989	<20m	Subdued response*	No clay above scn	
109124	19/03/1986	6	0	5	4	1988	1989	<20m	Subdued response*	No clay above scn	
47998	4/12/1985	62	23	29	17	1988	1990	<50m	No wl record	2/23m	
109127	1/01/1970	24	13	22	84	1987	1996	<20m	Subdued response	11/13m	
109126	1/01/1970	29	19	27	108	1986	1996	<50m	Subdued response	8/19m	
109115	20/11/1985	124	46	85	81	1985	1996	<100m	Subdued response	No clay above scn	
48002	7/03/1987	23	6	11	66	1987	1997	<20m	No response	6/7m	
109108	24/06/1980	12	6	10	183	1983	2000	<20m	Subdued response	No clay above scn	
64243	13/02/1987	92	30	36	33	1987	2003	<50m	No wl record	All clay	
109131	28/05/1986	87	11	17	162	1986	2007	<20m	Subdued response	4/11m	
109129	1/01/1970	20	12	18	198	1986	2007	<20m	Subdued response	No clay above scn	
109111	13/11/1980	42	22	40	307	1981	2010	<50m	Subdued response	5/22m	
64239	12/06/1986	90	70	73	221	1986	2011	<100m	Subdued response	27/70m	
114166	1/03/1993	61	52	58	89	1993	2012	<100m	No response	NO GEDIS LOG	

Bore ID	Date	Depth	Screen From (m)	Screen To (m)	No. Waterlevel Readings	First Reading	Last Reading	Indicator 1: Screen Depth	Indicator 2: Hydrograph Analysis	Indicator 3: Portion of clay material above screen	Indicator 4: Aqtesolv S value
109130	1/01/1970	18	8	16	232	1986	2012	<20m	Subdued response	4/9m	
109128	1/01/1970	30	20	28	236	1986	2012	<50m	Subdued response	8/20m	
64238	21/05/1985	157	70	87	221	1985	2012	<100m	Subdued response	17/70m	

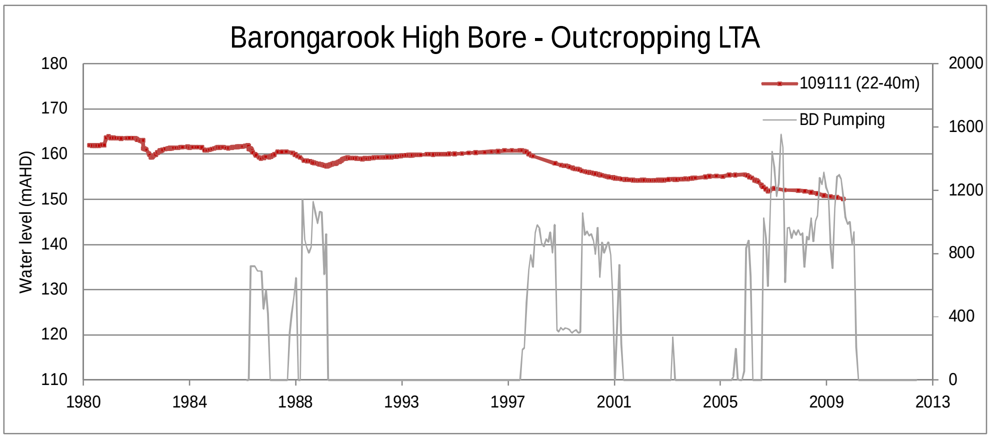
*limited water level record available for analysis



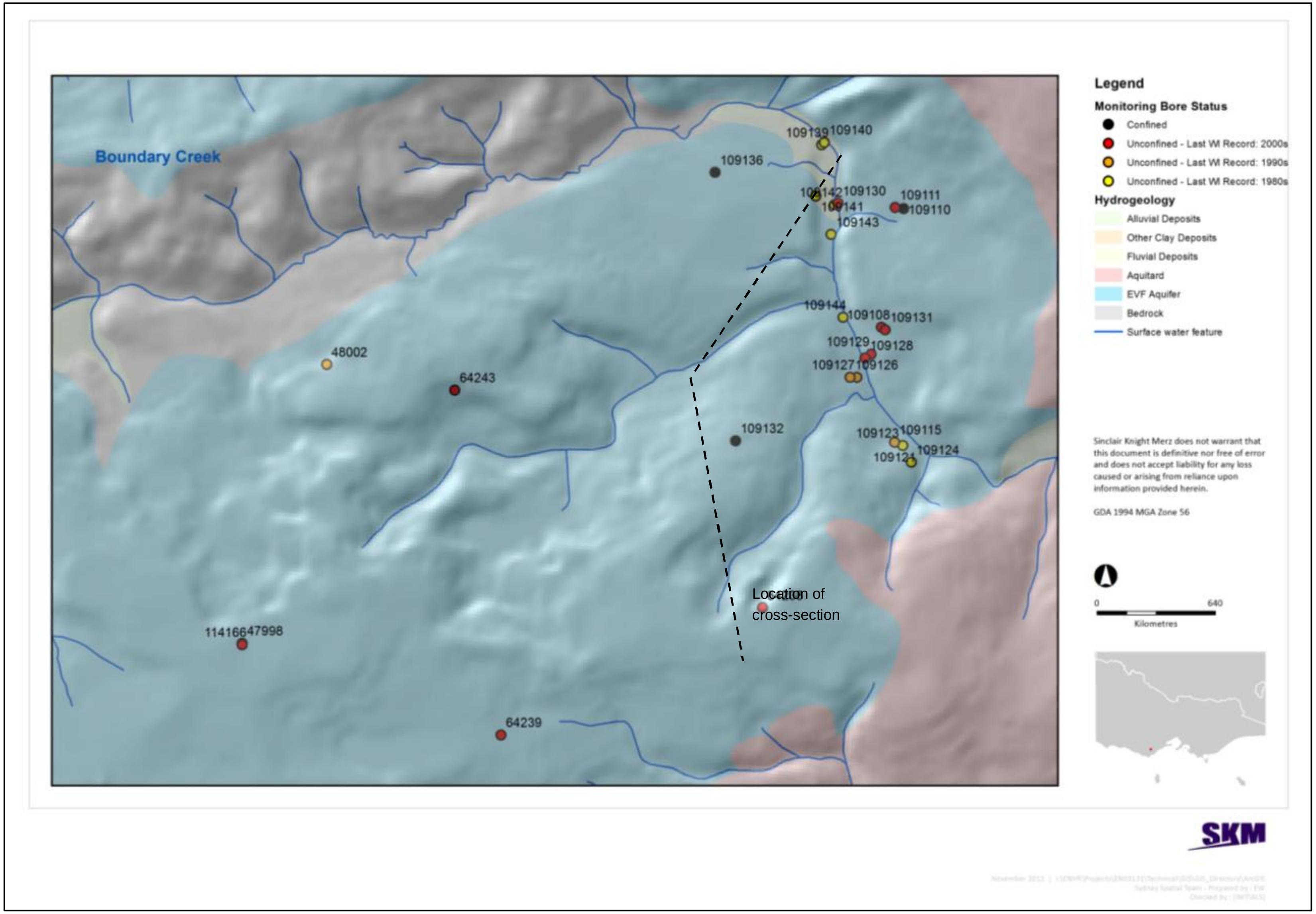
- **Figure 5 Groundwater levels for bores that monitor the unconfined LTA, however demonstrate a semi-confined/confined response to pumping**



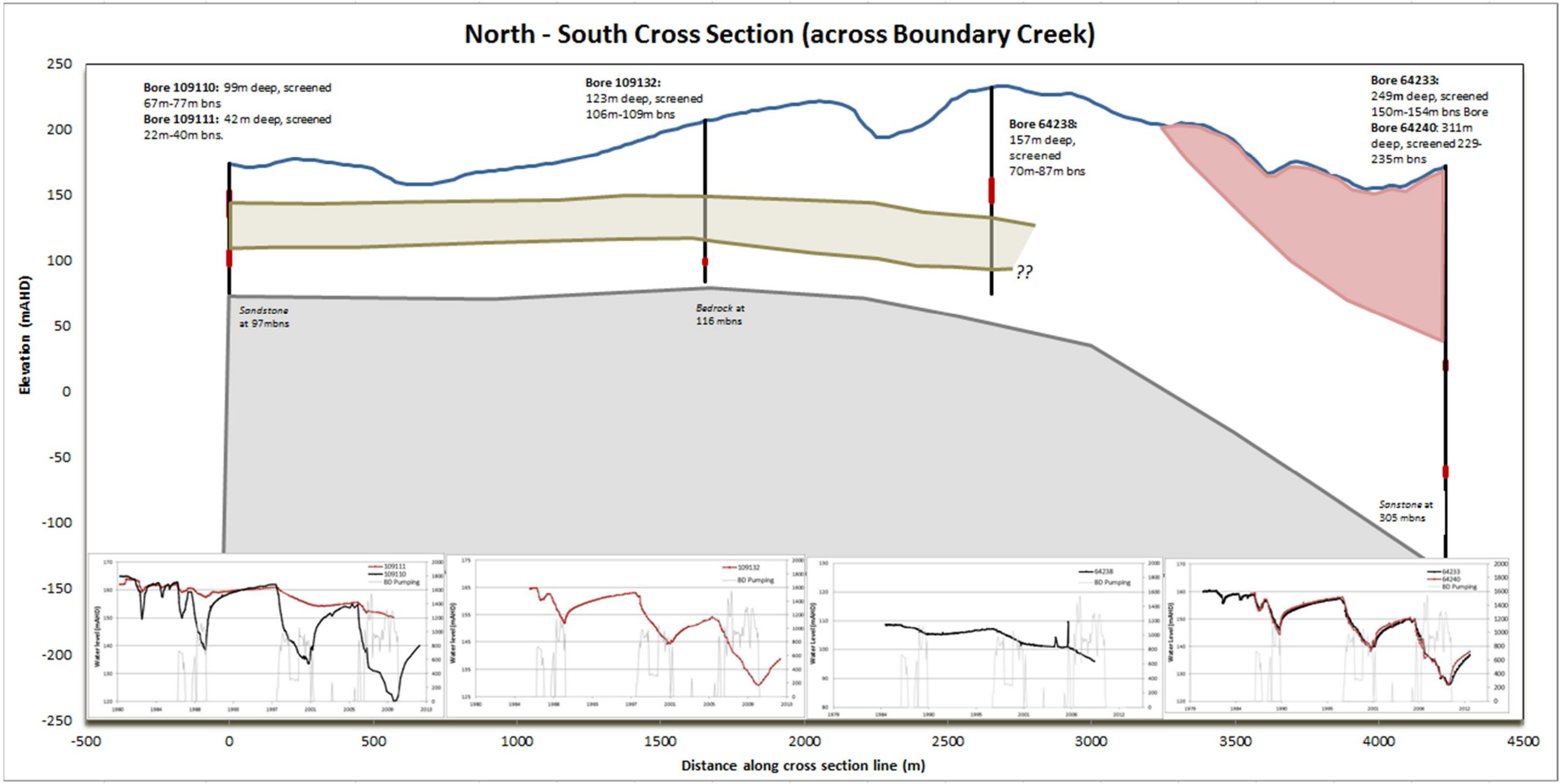
- **Figure 6 Groundwater levels for bores that monitor the LTA where it is confined by Gellibrand Marl**



- **Figure 7 Groundwater levels for bores that monitor the unconfined LTA and demonstrate an unconfined response to pumping**



- **Figure 8 Watertable monitoring bores near the Barongarook High according to current groundwater monitoring status**



- **Figure 9 Schematic cross-section indicating the presence of a low permeability layer in the LTA (cross-section location is indicated in Figure 8).**

3.2.2. Identify bores monitoring the watertable in upper reaches of Boundary Creek

The purpose of this task is to better define changes in aquifer water levels and flow directions in the upper reaches of Boundary Creek, which in turn will allow identification of whether changes are caused by pumping or other factors. There are currently few bores in this area, so the effects of pumping are not well defined.

Groundwater bores with water level readings were reviewed around the upper reaches of Boundary Creek in order to identify potential gaps that may be influencing the conceptualisation of groundwater and surface water interaction in this area. Ten bores with depths ranging from 23 m to 130 m were identified and are summarised in Table 3 and are shown in Figure 11.

Table 3 Observation bores in the upper reaches of Boundary Creek

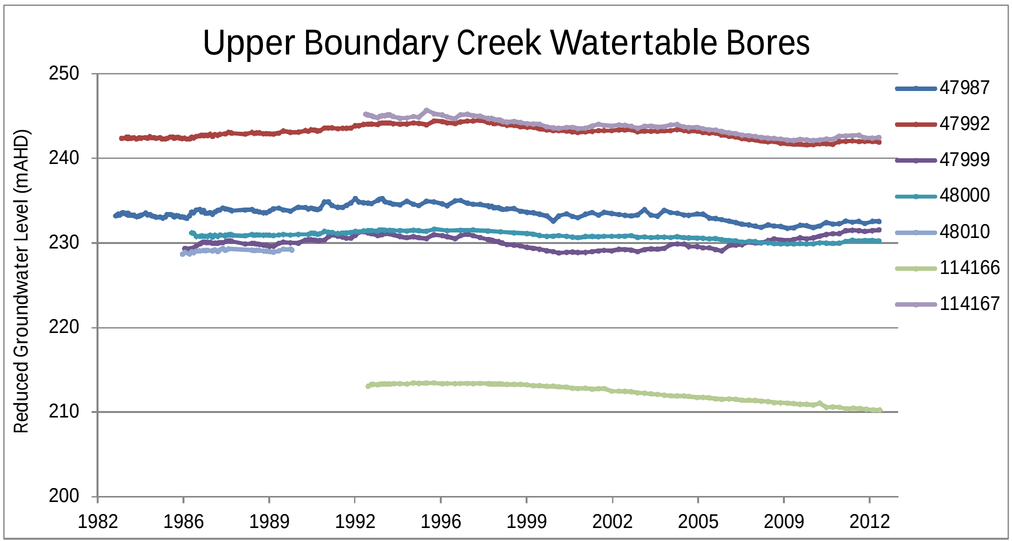
Bore ID	Date	RLNS (mAHD)	Bore Depth (m)	Screen From (m)	Screen To (m)
48010	13.03.1985	251	33	30	33
114167	05.03.1993	265	41	24	29
114166	01.03.1993	256	61	52	58
48000	10.07.1986	259	63	40	46
47992	12.10.1983	250	73	12	45
47987	09.06.1983	241	110	20	39
47999	06.03.1986	232	130	67	73
64243	13.02.1987	231	92	30	36
47998	04.12.1985	256	62	23	29
48002	07.03.1987	223	23	6	11

Three of these bores (64243, 47998 and 48002) have suspect waterlevel data, either showing artesian levels or recording conditions of blocked casing or requiring maintenance. The remaining bores have waterlevels plotted in Figure 10 and indicate that 6 of the 7 remaining bores are currently monitored (114167 has not been monitored since 1990).

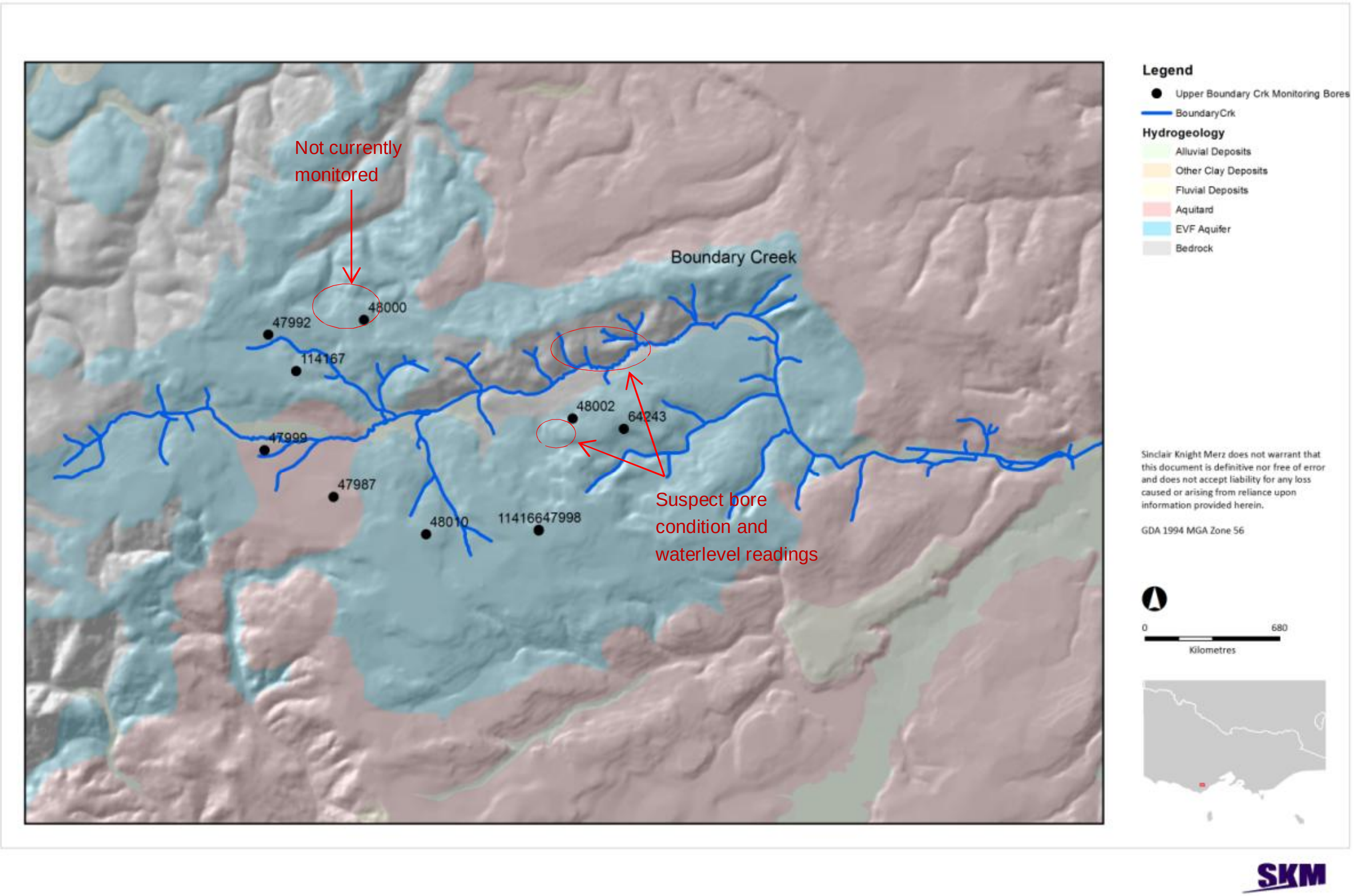
The key conclusions and recommendations for this task are:

- Given that there is concern regarding the integrity of both Bore 48002 and Bore 64243, if these bores cannot be reinstated and their reliability confirmed as suitable, then one new bore is recommended in the vicinity of those two bores. (These two bores will be assessed during the field assessment, assuming they can be located). However, potentially two vegetation sites are proposed in this area (at least one of these will be established), and hence the observation bore/s drilled at the vegetation site will address this recommendation.

- The area identified in Figure 11 south of Boundary Creek and west of Bore 48002 and Bore 64243 would also ideally have an observation bore sited in this area. However there appears to be no access into this area. This will be confirmed during the site assessment and if access is possible, a bore will be recommended.



- **Figure 10 Hydrographs for watertable bores in upper Boundary Creek**



- **Figure 11 Upper Boundary Creek monitoring bores**

3.2.3. Identify baseline Lower Tertiary Aquifer (unconfined and confined) monitoring sites

The purpose of this task is to provide, for the LTA, baseline data that is not influenced by pumping. Appropriate bores for baseline LTA monitoring were selected according to the following prerequisites:

- the bores should be located outside of the modelled drawdown contours associated with the LTA under the groundwater pumping scenario;
- the bores should have a reasonable historical time series water level record and a good condition record (i.e. there are no condition statements to indicate the bore is blocked, damaged, requiring maintenance etc); and
- both the unconfined and confined parts of the LTA should be represented in the baseline data.

Based on these prerequisites 5 bores were identified in the unconfined part of the LTA and 7 bores were identified in the confined part of the LTA, that are considered appropriate for baseline LTA monitoring. These bores are shown in Figure 12, and are located outside of the drawdown cone associated with groundwater extraction from the LTA (as defined by the 5m drawdown contour, so note that there is some potential for a minor impact). Table 4 provides a summary of the bore details, including bore depth, screen interval and use type. All of these bores are managed by the DSE and are part of the State Observation Bore Network.

Figure 13 shows the hydrograph trends for the bores located in the unconfined part of the LTA and although any of these bores could form a baseline network, State Observation Bore 47992 is recommended as the most appropriate, given its extensive monitoring record and its slightly more subdued response to pumping since approximately 1997 (note that the declines in this bore are likely due to rainfall trends, not a pumping influence).

Figure 14 shows the hydrograph trends for the bores located in the confined part of the LTA and from this assessment it is recommended that nested State Observation Bores 114168 and 114169 form baseline sites. The remaining sites may also be appropriate, however further work would be recommended to confirm that the steady decline in groundwater levels since 1997 is due to rainfall trends, as opposed to groundwater pumping.

In summary, no new observation bores are required in the LTA for baseline monitoring purposes, as suitable bores have been identified. The main action arising from this task is to ensure that the identified bores will remain on DSE's monitoring run and maintenance schedule.

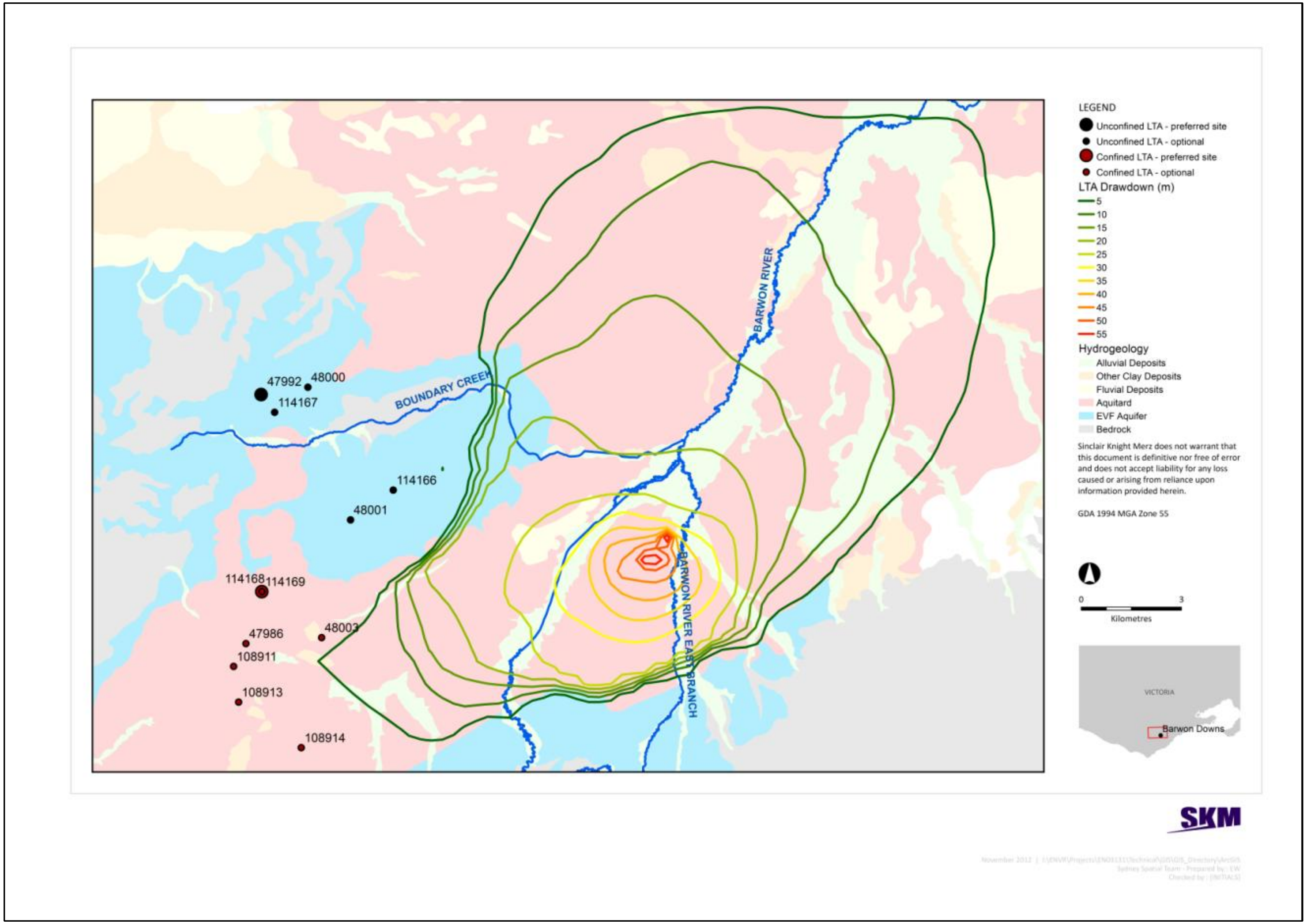
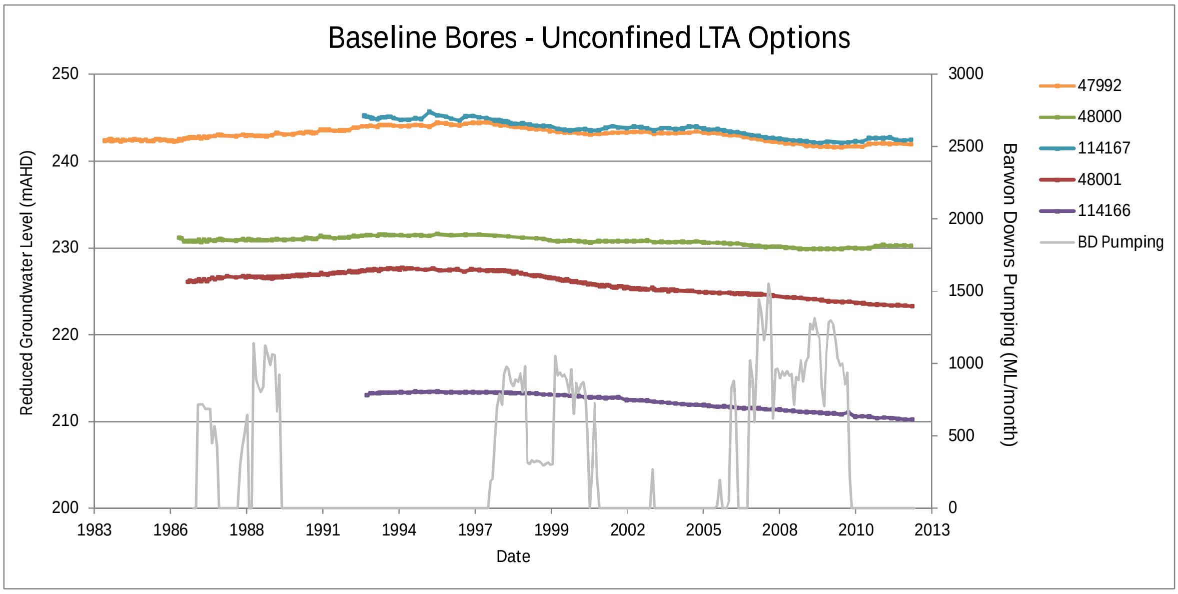


Figure 12 Location of baseline LTA monitoring bores relative to the predicted drawdown under pumping scenario

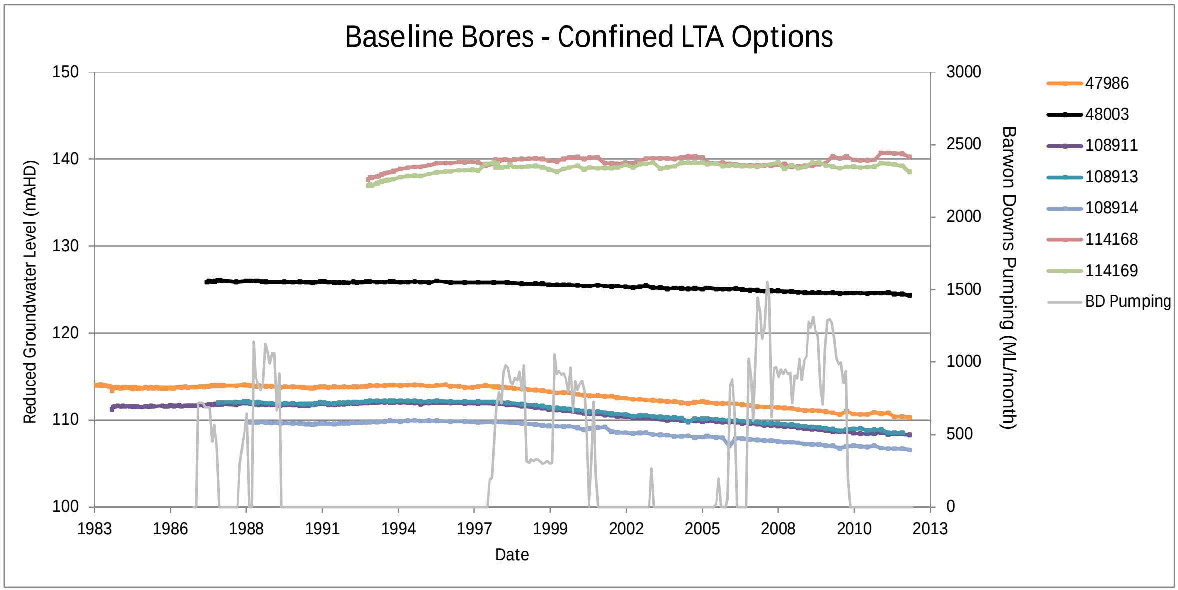
SINCLAIR KNIGHT MERZ
SKM

▪ **Table 4 Summary of bore details for baseline watertable monitoring bores (recommended sites are highlighted grey)**

Bore ID	Depth	Screen From	Screen To	Type
Unconfined LTA area				
47992	73	12	45	SOB
48000	63	40	46	SOB
48001	43	27	33	SOB
114166	61	52	58	SOB
114167	41	24	29	SOB
Confined LTA area				
114168	180	130	133	SOB
114169	82	56	80	SOB
47986	296	182	187	SOB
108911	244	100	203	SOB
108913	152	140	145	SOB
108914	239	207	214	SOB
48003	381	275	278	SOB



▪ **Figure 13 Hydrographs for baseline watertable monitoring bores (unconfined LTA area)**



▪ **Figure 14 Hydrographs for baseline watertable monitoring bores (confined LTA area)**

3.2.4. Identify unconfined vegetation monitoring sites that require bores

A number of potential vegetation monitoring sites in the unconfined LTA have been identified. These are described in Section 3.3 and mapped in Figure 19. Each of these sites will require a new monitoring bore drilled in close proximity to the site.

3.2.5. Identify sites for assessing perched groundwater

Sites selected for vegetation monitoring in the unconfined areas will need to be assessed for the presence of perched groundwater (before final sign off as monitoring sites). This will involve a drilling program of a depth of up to around 20 m or shallower. The drilling method would involve use of hollow augers and without water, so that the depth of water strike can be accurately determined. Bores would be geophysically logged (using a neutron probe or similar) to identify presence/absence of perched watertable. If a perched watertable is identified, then the site should be constructed with a piezometer to monitor the perched watertable. (As part of Task D further description to be included on how one would know if the water intercepted was perched or not. If think the watertable is deep and intersect shallow water, then construct a shallow bore as well as installing a deeper bore?).

Further to the terrestrial vegetation sites, two additional locations for assessing perched groundwater are proposed. These sites are labelled P1 and P2 in Figure 19. The rationale for these additional locations is that most of the terrestrial vegetation sites are located in areas where the watertable is expected to be relatively shallow, and hence perched groundwater is less likely to occur. Sites P1 and P2 are located where the watertable is expected to be relatively deep and hence there is greater potential for the development of perched groundwater.

3.2.6. Identify aquitard vegetation monitoring sites that require bores

A number of potential vegetation monitoring sites in the unconfined LTA have been identified. These are described in Section 3.3 and mapped in Figure 19. Each of these sites will require a new monitoring bore drilled in close proximity to the site.

3.2.7. Identify sites for determining aquitard watertable depth and flow direction

The purpose of these bores is to provide information on direction of groundwater flow and watertable depth in the aquitard (particularly for flow to/from streams and wetlands). This is required to understand how much groundwater is contributing to baseflow in streams and wetlands in the area where the aquitard is present. The direction of groundwater flow and depth to watertable will assist with understanding where streams are losing and gaining (groundwater surface water connectivity) and watertable depth will give an indication of where vegetation is likely to have a high degree of dependence on groundwater. This data, along with other water level data from the aquitard, will significantly improve the reliability of impacts predicted by the groundwater model, as well as improving understanding of areas where GDEs are more likely to be present.

The recommended bore locations are presented in Figure 15. The selection criteria and associated justification for the selected bores sites is outlined below:

1. Ensuring that there is a sufficient coverage of bores to provide water levels across a range of potential watertable depths within the aquitard. Determining the direction of groundwater flow and depth to watertable across the entire aquitard area would require numerous bores. Instead, if a reasonably reliable relationship between surface elevation and depth to watertable can be established across the aquitard area, then a modelled depth to watertable (e.g. as shown in Figure 15) can be produced with more confidence. The shallow DPI bores identified in this study dominantly represent areas with a watertable depth less than 10 metres. Subject to field inspection, these bores are considered sufficient to represent this range of watertable depth (both close to and away from the borefield). A number of the DPI bores may not be representative of typical water levels in the aquitard, as the bores are targeting an agroforestry site, however there are a sufficient number of bores away from the site – the field investigation will identify suitable DPI bores allowing for this issue. Two new sites have been proposed (subject to field verification) to identify watertable depth where the ground elevation is significantly higher than the existing DPI bore sites:

    i. A1 – three potential sites have been identified here (the better site in terms of access and elevation will be selected): A1a - on an elevated area about 1km south of the borefield, A1b – on Dewings Bridge Rd about 500m east of the Barwon River East Branch (both sites can also be used for direct calculations of groundwater flow to Barwon River East Branch) and A1c, near the corner of Telegraph Rd and Callahans Rd.

ii. A2 – on an elevated area about 500m south of Boundary Creek, on Colac Forest Rd. Can also be used for direct calculations of flow to Boundary Creek. A shallow bore, within approximately100m of Boundary Creek, is also recommended in this transect (A3). As well as providing information in terms of gradients to Boundary Creek, this bore will be helpful in terms of indicating the watertable depth in Boundary Creek swamp ("Big Swamp").

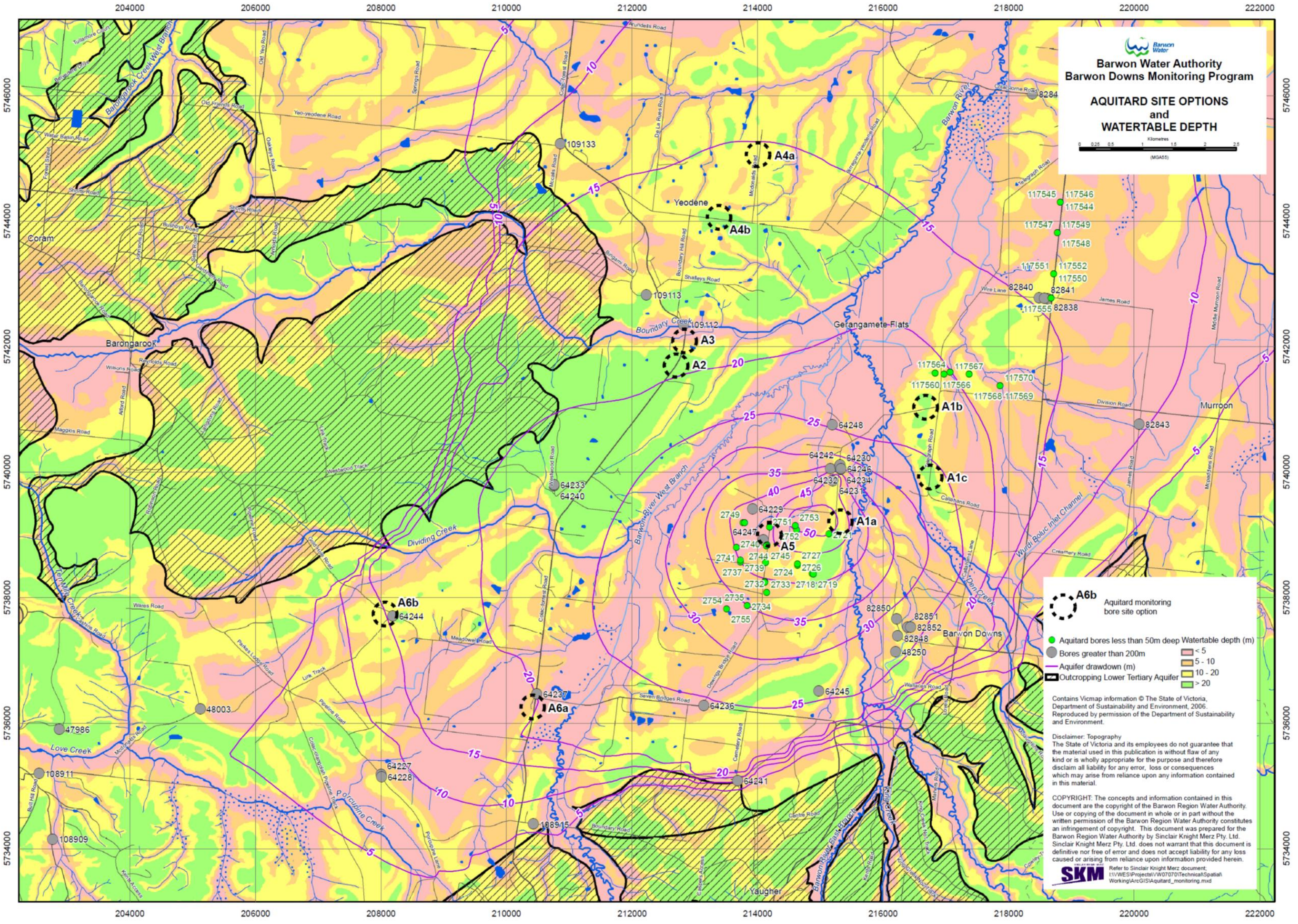
2. To assess potential impact of drawdown in the aquitard – The existing DPI bores are located where the greatest drawdown in the aquifer is likely to occur, but not where the greatest drawdown in the aquitard is expected (as predicted in the modelling conducted as part of this project, e.g. where the aquitard is thin north of Boundary Creek). A bore site in the vicinity of McDonalds Road (A4a or A4b) is proposed. The two potential sites are both targeting higher elevation ground – the site with better access for drilling will be selected.

3. To determine vertical gradients between the aquifer and aquitard, and vertical gradients within the aquitard – Understanding vertical gradients between the aquitard and aquifer and within the aquitard is an important part of the hydrogeological conceptualisation. We propose installing a bore at depth into the aquitard (between 100-200m – depth/target interval to be confirmed in Task D) at Obs bore location 64247 (A5). This will create a nested site with a shallow aquitard water level (from DPI bores 2744 and 2755), a deep aquitard water level (new bore) and an aquifer water level (64247). (Note - check the bores which latest monitoring review from BW indicates monitoring of the Clifton Formation - opportunity to nest with those bores).

   Bore A6 (A6a and A6b) is a provisional bore; it would be another deep aquitard bore nested with 64237 (~ 6km south west of the borefield) or 64244 (~7.5km south west of the borefield). <u>It would only be recommended if bore A5 showed a large difference in the hydraulic gradient within the aquitard. This means bore A5 would need to be drilled first in the drilling program, and a decision on the need for the bore made during the course of the drilling program.</u> (Selection of which bore to use would be subject to space available for drilling and a review of the two hydrographs – both sites will be inspected in the field)

4. To allow 'direct' calculation of baseflow to rivers using groundwater gradient and Darcy's Law (at some locations) – Proposed bore sites A1, A2 and A3 will enable this calculation at two locations. No new bores are proposed.

- **Figure 15 Proposed new aquitard bore sites ~~and proposed new sites for assessing potential existence of a perched watertable~~**



3.2.8. Identify baseline aquitard watertable bore sites

Appropriate bores for baseline aquitard monitoring were selected according to the following prerequisites:

- the bores should be located outside of the drawdown cone (within the aquitard) associated with the sensitivity modelling for vertical hydraulic conductivity (Kv value of 10^{-4});
- the bores should have a reasonable historical time series water level record and a good condition record (i.e. there are no condition statements to indicate the bore is blocked, damaged, requiring maintenance etc); and,
- the bores should reside in the area where aquitard is mapped (either Narrawaturk Marl or the Gellibrand Marl) and should be shallow (a default bore cut off depth of 20 m has been applied here) to ensure the watertable is monitored and not a confined part of the aquitard.

Based on these prerequisites two nested sites have been identified in the aquitard, that are considered appropriate for baseline aquitard monitoring. These bores are shown in Figure 16 and are located outside of the drawdown cone associated with the sensitivity modelling for vertical hydraulic conductivity and occurring in the immediate vicinity of the borefield and north-east of the borefield. Ideally a baseline bore would also be sited to the south-west of the borefield in the aquitard area (refer Figure 16) as it is characterised by higher rainfall and hence different water level response may be observed relative to that in the north-east where the rainfall is lower. However there are no shallow aquitard bores in this area.

Table 5 provides a summary of the bore details, including bore depth, screen interval and use type. The type codes for these bores indicate that they are observation bores managed by the DPI.

Figure 17 shows the hydrograph trends for the bores located in the aquitard in the immediate vicinity of the borefield. This nested site of three bores (with depths of 5m, 10m and 20m) show negligible response to the borefield pumping and hence are considered appropriate for use as baseline bores.

Figure 18 shows the hydrograph trends for the nested site of 3 bores located north-east of the borefield. Interestingly, these bores are also constructed at depths of 20 m, 10 m and 5 m, however the deepest bore has indications of a semi-confined/confined aquifer response to borefield pumping in 1990. For this reason, caution would be required if this deeper bore were to be included as a baseline aquitard watertable monitoring bore. (However, given that this response is not observed in future pumping events, it is more likely that the response in the bore is related to some effect from bore construction/development and subsequent very slow recovery, or some other nearby influence on the bore unrelated to the borefield pumping).

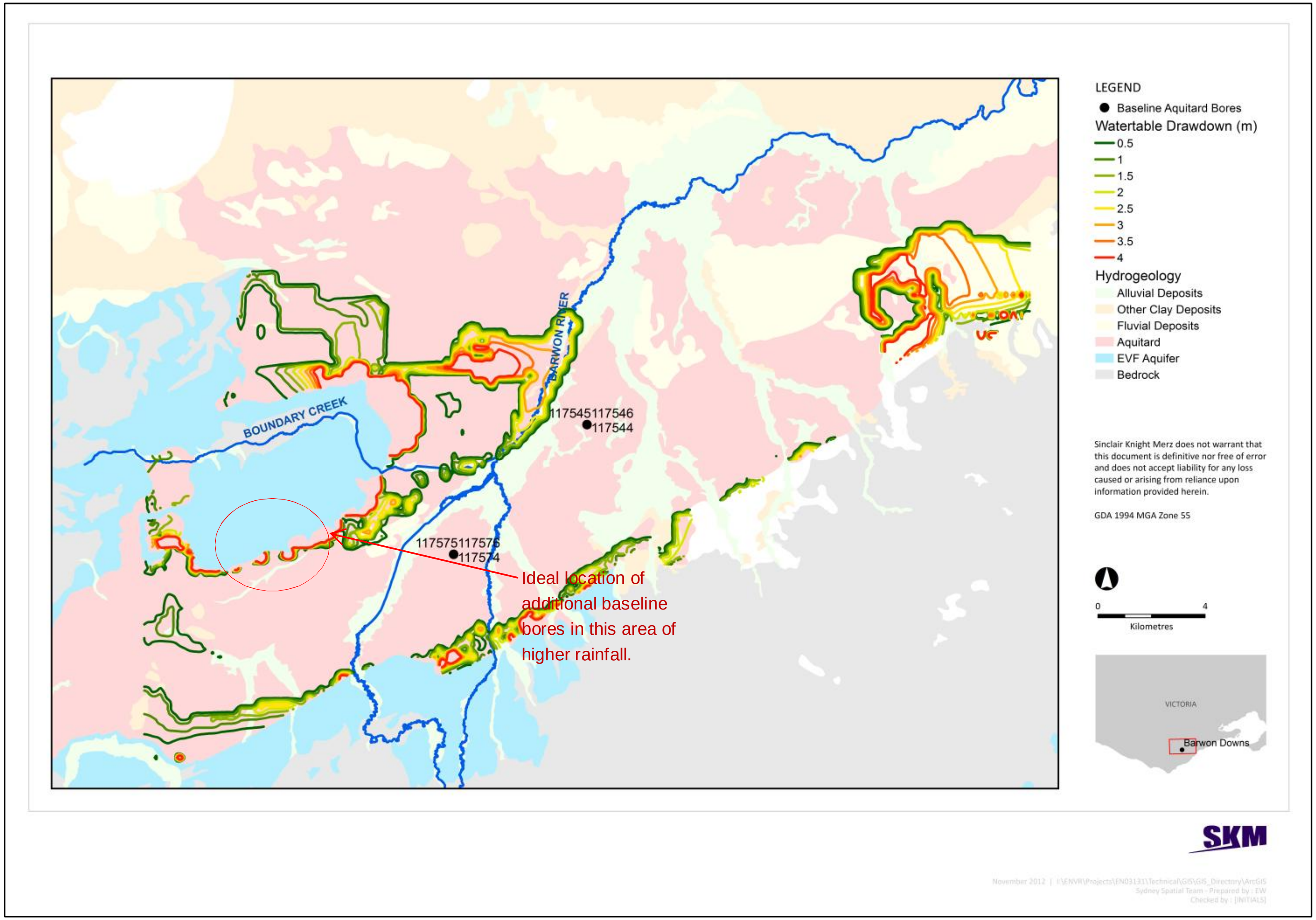
Given the presence of apparently suitable bores, no new bores are recommended. However, as indicated in Figure 16, an aquitard control bore to the south west of the borefield would be useful, in that it is located in an area of slightly higher rainfall – but this bore is not considered essential.

Depending on the results of recommended aquitard bore A5 (refer section 3.2.7) there may be a new aquitard bore drilled here in any case (Bore A6, refer section 3.2.7).

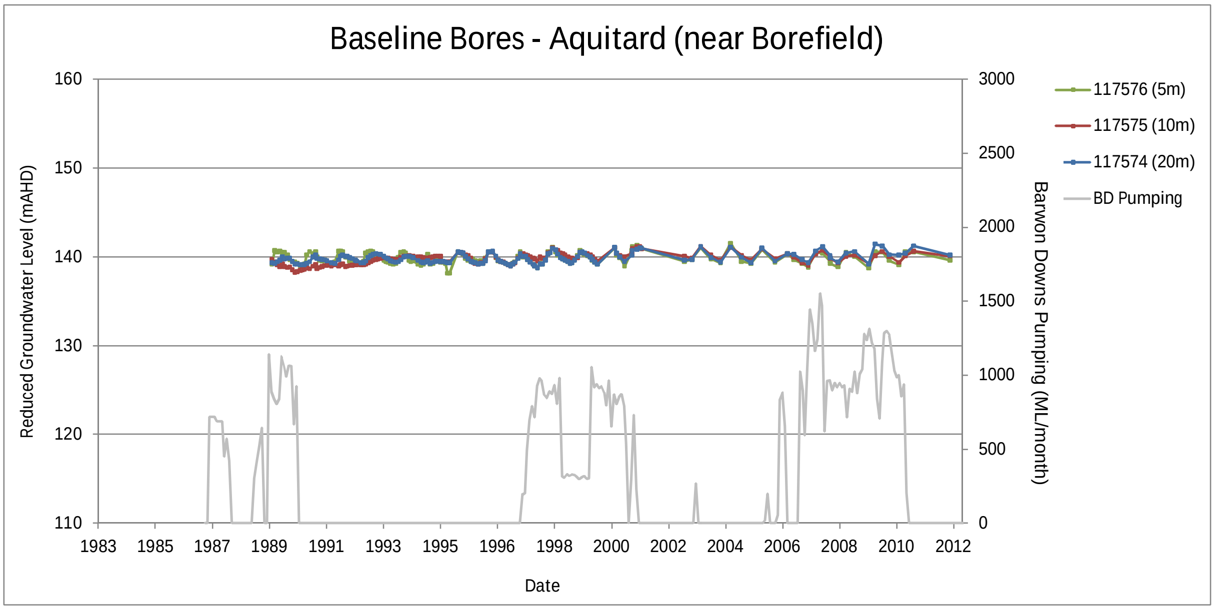
An important part of the field assessment will be to check that the bores recommended as baseline sites are not unduly influenced by nearby land use (e.g. the agroforestry trials that some of the bores are associated with).

- **Table 5 Summary of bore details for baseline watertable aquitard monitoring bores**

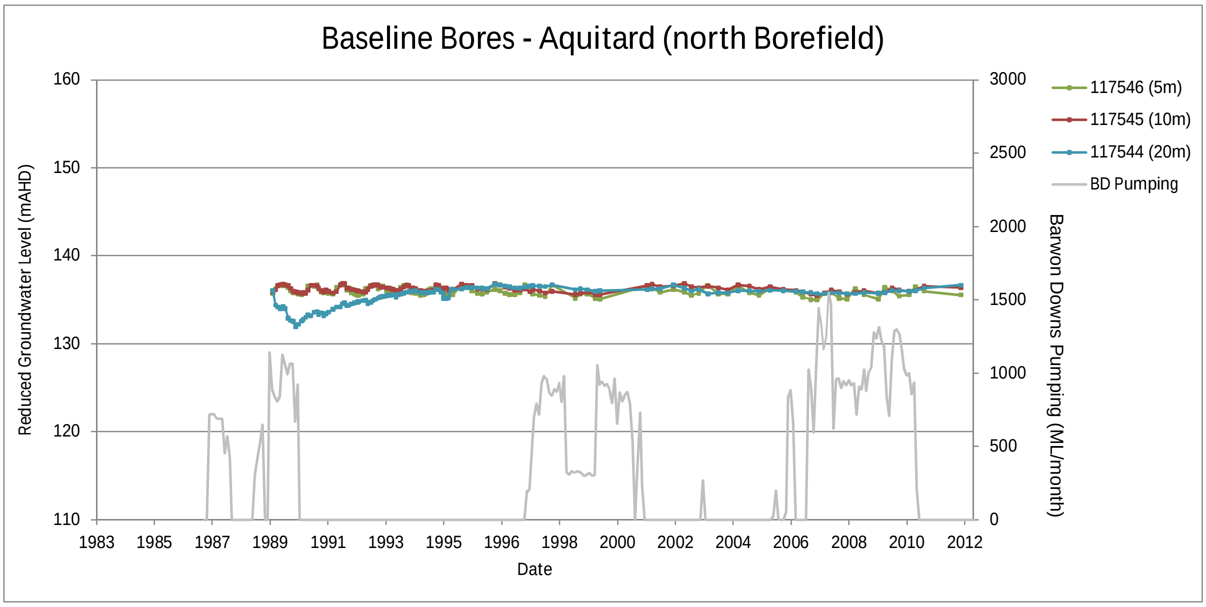
Bore ID	Depth	Screen From	Screen To	Type
Unconfined Aquitard area – near borefield				
117574	20.0	18	20	IV OB DPI
117575	10.0	8	10	IV OB DPI
117576	5.0	3	5	IV OB DPI
Unconfined Aquitard area – north of the borefield				
117544	20	18	20	IV OB DPI
117545	10	8	10	IV OB DPI
117546	5	3	5	IV OB DPI



- **Figure 16 Location of baseline aquitard monitoring bores relative to the predicted drawdown from the Kv sensitivity modelling**



- **Figure 17 Hydrographs for baseline watertable aquitard monitoring bores (near the borefield)**



- **Figure 18 Hydrographs for baseline watertable aquitard monitoring bores (north of the borefield)**

3.3. Terrestrial vegetation desktop review

3.3.1. Target GDE's

The target GDE's are represented by the following major Ecological Vegetation Classes (EVC's):

- EVC 83 Swampy Riparian Woodland (endangered)
- EVC 53 Swamp Scrub (vulnerable)
- EVC 653 Aquatic Herbland (endangered)

These are represented in Figure 19, as potential Groundwater Dependent Ecosystems (GDE's). It should be noted that there is considerable variation within each of these EVCs across the study area. While these EVCs/GDE's are known elsewhere as principally perched systems, the effect of drawdown in the LTA on perched or shallow watertables is not yet known, so these sites can't be discounted at this stage.

Additional information on the site selection process will be included in the final report (Task D), including how the "Potential GDE layer" was developed and which of these locations are the already monitored sites.

3.3.2. Threatened Species

Earlier studies (Ecology Australia 1994, 2001, 2008) suggest that there may be few listed (EPBC, FFG) plant species that are groundwater dependent. While this remains to be confirmed for the new monitoring sites, the distribution of otherwise threatened plant species does little to inform this preliminary layout of potential sites.

Threatened fauna which have some level of groundwater dependency and may be present in the study area include:

- Otway Burrowing Cray (vulnerable)
- Otway Bushy Yabby (endangered)
- Hairy Burrowing Cray (vulnerable)
- SouthernToadlet (vulnerable)

There are a number of threatened vertebrates that are likely to be present but their habitat are not groundwater dependent, these include:

- Southern Brown Bandicoot (EPBC, FFG)
- Long-nosed Potaroo (EPBC, FFG)
- White-footed Dunnart (FFG)

3.3.3. Potential Monitoring Sites

The following criteria have been applied to the location of the potential monitoring sites:

- representative of the unconfined LTA, confined LTA or alluvials
- impact (drawdown ≥ 5 m) or reference (site is located site outside the 5 m drawdown) zone
- located in the relatively undisturbed forested landscape
- representative of the identified potential GDE's
- ease of access

In addition, existing vegetation monitoring sites have been utilised wherever possible.

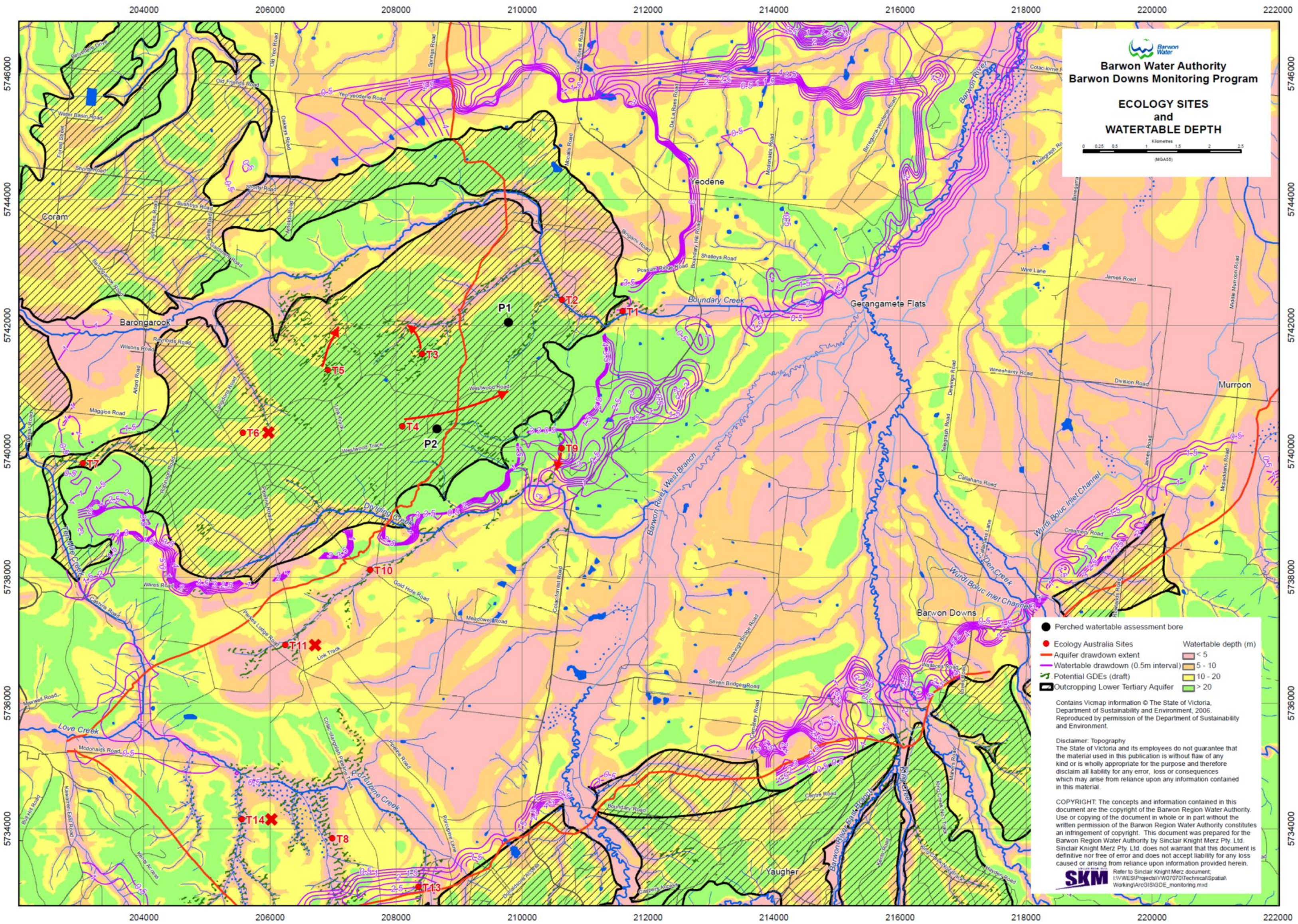
The proposed/potential sites are plotted in Figure 19 and listed in Table 6. Note that these are draft locations only, as recommended by Ecology Australia (EA). Based on the overlay of depth to watertable (and other considerations), SKM have suggested some modifications to the locations of some sites and the potential for removing some sites. Comments on the proposed sites are outlined below: (SKM and EA will further refine these locations prior to the field assessment, although final selection will only occur after the field assessment).

- T1, T2 – Agree to proposed location. Will likely put in an observation bore here related to PASS, so synergies also in these locations.
- T3, T4 & T5 – Need to justify 3 sites in close proximity. (Presumably because of different EVCs?) Estimated depth to watertable map has these 3 sites all greater than 20m depth to watertable – if correct, unlikely for terrestrial vegetation to be groundwater dependent, particularly given high rainfall. (However, these sites may potentially be dependent on perched groundwater). Suggested changes to these locations are shown in Figure 19 so that T3 and T5 are located in areas of shallow watertable. Further, T4 is recommended to move closer to the zone of potential drawdown impact.
- T6 and T7 – suggest that one of these sites is selected as a reference site. Suggest that T6 is removed.
- T9 – Agree to general location, but suggest site is moved approximately 300m to 500m south to increase chance of shallower depth to watertable.
- Impact sites in the aquitard are too far away: T10, T11, suggest that T10 is retained because it is closer to area of potential impact and T11 is removed (as it is in the centre of the aquitard and hence low predicted drawdown).
- Are four reference sites in such close proximity justified? T8, T12, T13, T14 - suggest that keep T8 and T13 are retained and T12 and T14 are removed. Even then, good justification for having two aquitard reference sites in such close proximity will be required.

Table 6 Proposed / potential terrestrial vegetation monitoring sites and associated hydrostratigraphy and EVC type

Site	Location	Geology	Impact/Reference	GDE
1	Boundary Creek	Unconfined LTA	Impact	Swamp Scrub
2	Boundary Creek	Unconfined LTA	Impact	Swamp Scrub
3	Boundary Creek Tributary	Unconfined LTA	Impact	Swamp Scrub/Aquatic Herbfield
4	North of Westwood Track	Unconfined LTA	Impact	not yet known
5	North of Westwood Track	Unconfined LTA	Impact	Swamp Riparian Woodland
6	East of junction of Westwood Road and Westwood Track	Unconfined LTA	Reference (possibly)	Swamp Scrub
7	Off Old Beechy Rail trail	Unconfined LTA	Reference	Swamp Scrub
8	Of Colac- Olangolah Pipeline Track	Confined LTA	Impact	Swamp Scrub
9	West of junction of Westwood Road and Westwood Track	Confined LTA	Impact	Swampy Riparian Woodland
10	Just south of Gold Hold Road	Confined LTA	Impact	Swamp Scrub/ Swampy Riparian Woodland
11	North of junction of Parkes Lodge Road and McDonalds Road	Confined LTA	Impact/Reference?	Swampy Riparian Woodland
12	North of Ridge Road	Confined LTA/Alluvials	Reference	Swamp Scrub
13	East of Colac- Olangolah Pipeline Track	Confined LTA	Reference	Swamp Scrub
14	West of Colac Olangolah Pipeline Track	Confined LTA	Reference	Swamp Scrub/Swampy Riparian Woodland

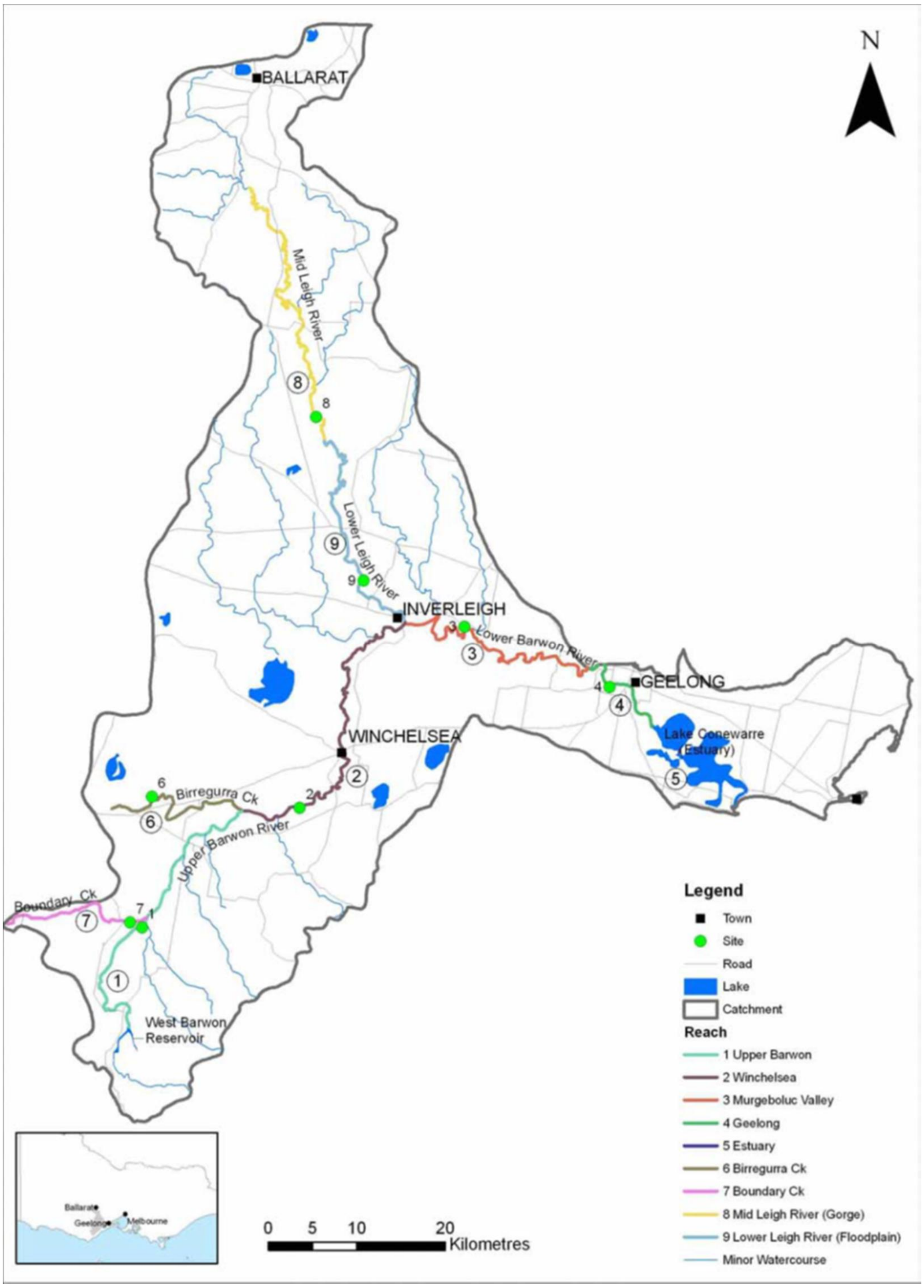
- **Figure 19 Proposed / Potential Terrestrial Vegetation Monitoring Sites**



3.4. Aquatic ecology desktop review

The environmental FLOWS study for the Barwon River system (Lloyd Environmental *et al.* 2005a) divided the catchment into nine reaches (Figure 20). Four of these reaches (1, 2, 6 and 7) are within the study area for the current project. The FLOWS assessment sites in each reach are represented in Figure 20 by green dots.

Reach 1 (the upper Barwon) extends from the West Barwon Reservoir to the Birregurra Creek confluence. Reach 2 (Winchelsea) includes the section from the Birregurra Creek confluence to the Leigh River confluence near Inverleigh. Birregurra Creek (Reach 6) flows east joining the Barwon River upstream of Winchelsea. Boundary Creek (Reach 7) is the most upstream major tributary of the Barwon River.



- **Figure 20 The Barwon River showing reaches as defined in the environmental FLOWS study (taken from Lloyd Environmental *et al.* 2006)**

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SKM

3.4.1. Fish

The fish fauna of the upper Barwon River was reviewed as part of the FLOWS study (Lloyd Environmental *et al.* 2005b). This review was based on a range of information sources, including comprehensive direct surveys (e.g. Zampatti and Koster 2002) and databases (DNRE 2005 fish database). The FLOWS study directly identified which species have been recorded within each reach and which species are expected to occur based on the available habitat at a reach, species in nearby reaches and the position of the reach in the catchment (i.e. the distance from the estuary).

The only significant fish surveys undertaken in the study area since the FLOWS study were in 2006/2007 to investigate the impact of the Millennium Drought on the fish of the Barwon system, predominantly Reach 1 (Environous 2008). This more recent survey agreed with the review of fish species completed for the FLOWS review, however it did confirm the presence of Flat-headed Gudgeon in the upper Barwon.

The current understanding of the presence of fish in the upper Barwon is summarised in Table 7. It is likely that only extensive surveys would increase our understanding of the presence and distribution of fish species in the upper Barwon system.

- **Table 7 Fish species in the upper Barwon system. ✓ = directly recorded at this reach, o = expected to occur at this reach (as reviewed in the FLOWS study; Lloyd Environmental *et al.* 2005b); ✓* = species newly recorded since the FLOWS study (Environous 2008).**

		Reach 1 Upper Barwon	Reach 2 Winchelsea	Reach 6 Birregurra Creek	Reach 7 Boundary Creek
Native species					
Mountain Galaxias	*Galaxias olidus*	✓	✓		✓
River Blackfish	*Gadopsis marmoratus*	✓	✓		✓
Common Galaxias	*Galaxias maculatus*	✓	✓	✓	✓
Spotted Galaxias	*Galaxias truttaceus*	o	✓		o
Climbing Galaxias	*Galaxias brevipinnis*	✓	✓		✓
Dwarf Galaxias	*Galaxiella pusilla*	✓	✓		✓
Flat-headed Gudgeon	*Philypnodon grandiceps*	✓*	✓	✓	✓
Tupong	*Pseudogobius olorum*		✓		
Short-finned Eel	*Anguilla australis*	✓	✓	✓	✓
Pouched Lamprey	*Geotria australis*	✓	✓		
Short-headed Lamprey	*Mordacia mordax*	✓	✓		
Southern Pigmy Perch	*Nannoperca australis*	✓	✓		✓

		Reach 1 Upper Barwon	Reach 2 Winchelsea	Reach 6 Birregurra Creek	Reach 7 Boundary Creek
Yarra Pigmy Perch	*Edelia obscura*	✓	✓		✓
Australian Smelt	*Retropinna semoni*	✓	✓		✓
Australian Grayling	*Prototrocetes maraena*		✓		
Murray Cod	*Maccullochella peelii peelii*		o		
Exotic species					
Eastern Gambusia	*Gambusia holbrooki*	✓	✓	✓	✓
Goldfish	*Carassius auratus*				
Redfin Perch	*Perca fluviatilis*	✓	✓		✓
Brown Trout	*Salmo trutta*	✓	✓		✓
Rainbow Trout	*Onchorhynchus mykiss*	o	o		o
Carp	*Cyprinus carpio*	o	o		o
Roach	*Rutilus rutilus*	o	o		
Tench	*Tinca tinca*		✓		

3.4.2. Macroinvertebrates

Macroinvertebrates are an important part of aquatic ecosystems. They constitute a major source of food for a range of organisms and complete a number of important ecosystem processes such as nutrient cycling and decomposition (Wallace and Webster 1996). The condition of the macroinvertebrates at a stream can also provide an indication of the stream's health (EPA 2003).

The condition of the macroinvertebrate communities of parts of the upper Barwon River have been assessed over a couple of different studies. The environmental FLOWS study (Lloyd Environmental *et al.* 2005b) based its review of macroinvertebrate condition on one study, which assessed condition at three sites in Reach 1 (the upper Barwon) and five sites in Reach 2 (Winchelsea; Canale *et al.* 2001). This study compared sites against objectives set out in the State Environmental Protection Policy (SEPP), which provides objectives for biological measures in each of the bioregions throughout Victoria. All of the surveyed sites failed to meet SEPP guidelines, indicating mild pollution at these sites. This study did not directly investigate the macroinvertebrate communities at Birregurra or Boundary Creeks.

Macroinvertebrate sampling was also completed as part of the statewide *Index of Stream Condition (ISC) Assessment*. The ISC was completed in 2004, but the macroinvertebrate results were not included in the FLOWS assessment (although the overall results of the ISC were included). The condition of the macroinvertebrate communities was directly assessed in Reach 1 (just upstream of the confluence with Birregurra Creek), and in Reach 2. Like the results reported by Canale *et al.* (2001) the ISC assessment found that communities in both

Reach 1 and Reach 2 were moderately degraded compared to the reference state. As with the previous studies, neither Birregurra nor Boundary Creek were examined directly.

Decapod crustaceans have also been recorded from Reach 1 and Reach 2 including the Yarra Spiny Cray (*Euastacus* yarraensis), Freshwater Shrimp (*Paratya australiensis*) (Zampatti and Koster 2002) *and* Burrowing Crayfish (*Engaeus sp.*) (Environous 2008).

3.4.3. Platypus

Platypus (*Ornithorhynchus anatinus*) have been recorded regularly in Reach 1 and Reach 2 of the upper Barwon River and are thought to be relatively abundant (Zampatti and Koster 2002; Environous 2008). No direct surveys have been conducted in Birregurra or Boundary Creeks.

3.4.4. Aquatic vegetation and plant communities

The composition and condition of the aquatic vegetation and plant communities of the upper Barwon system was comprehensively assessed in the field at each reach as part of the FLOWS study (Lloyd Environmental *et al.* 2005b).

The vegetation in Reach 1 is heavily degraded due to the impacts of land clearing and grazing. The riparian vegetation in the upper section of Reach 1 is confined to the banks of the stream due to the steep gradient of the river and the deep, incised banks. In the downstream section of Reach 1, the gradient of the river is much lower, flowing through a cut drain, approximately 4 m wide. The drain is lined by tall emergent vegetation such as the Common Reed (*Phragmites australis*), rushes (e.g. *Juncus sp.*) and sedges (e.g. *Eleocharis spp.*). A complex community of wetland herbs (e.g. sedges like *Carex appressa* and Water Ribbons, *Triglochin procerum*) are found at ground level, and a number of aquatic species (e.g. Duckweed, *Lemna minor*, Water Fern, *Azolla filiculoides* and Watermilfoil, *Myriophyllum spp.*) are located within the channel.

A series of shallow billabongs and depressions are located adjacent to the drain in Reach 1, probably reflecting the meanders of the original stream (before it was channelised). These billabongs are fringed with *Juncus spp.* and sedges and contain a range of aquatic species within the channel.

The high abundance of tall emergent macrophytes and the diverse community of aquatic herbs indicate that the reach is probably permanently waterlogged, with few high velocity flows. Reports from landholders indicate that manual vegetation removal is required regularly to prevent chocking of the channel.

Reach 2 has been mostly cleared of native vegetation, with only scattered stands of River Red Gum (*Eucalyptus camaldulensis*) and Australian Blackwood (*Acacia melanoxylon*) remaining. Flows in Reach 2 are too energetic to allow the establishment of significant in channel vegetation. The only species observed being sparse stands of Phragmites, Triglochin and the introduced Kikuyu Grass (*Pennisetum clandestinum*) which was encroaching from the bank.

Birregurra Creek (Reach 7) intersects a saline water table and also receives saline water diverted from the Lough Culvert Drainage Scheme. Channel vegetation at this reach is dominated by salt tolerant species such as Salt Club-rush (*Bolboschoenus caldwelllii*), and *Triglochin spp.* The surrounding floodplain supports dense stands of Tall Wheat Grass (*Thynopyron ponticum*), *Juncus spp.* and Poa Grass (*Poa labillardieri*).

The vegetation at Birregurra Creek is adapted to prolonged waterlogging by saline groundwater with temporary inundation by fresh (or brackish) surface water. These periods of freshwater inundation provide seasonal growth opportunities for these plants, as they are likely to be dormant during summer and autumn when the soil salinity is high.

Large sections of Boundary Creek have been cleared of native vegetation and now support grazing pasture (Lloyd Environmental *et al.* 2005b). The creek has been channelised and straightened to convey high flows, and the stream bed has limited vegetation. The lower bank of the stream is covered by a mixture of emergent aquatic plants (such as Poa Grass, *Juncus spp.* and sedges). The upper bank supports mostly exotic species.

Lloyd Environmental *et al.* (2005b) suggest that although drying is not a normal characteristic of Boundary Creek, the stream bed vegetation would likely be tolerant to temporary drying. Pools with slow flow also benefit in-channel species such as Water Ribbons. The water requirement in this reach is sustained baseflow in winter and spring and intermittent inundation in summer and autumn.

Upstream of the FLOWS assessment site, in the 'Aquifer Outcrop Area', a higher abundance of native riparian vegetation and wetland plant communities can be found. A review of this area (Carr and Muir 1994) reported:

- *Eucalyptus ovata* (riparian forest)
- *Melaleuca squarros / Leptospermum lanigerum* (swamp forest or scrub)
- *Lepidosperma longitudinale* (sedgeland)
- *Baumea arthrophylla* (sedgeland)
- Wetland herbfields

3.4.5. Dividing Creek and Barwon River East Branch

Dividing Creek flows west and joins the Barwon River West Branch upstream of Boundary Creek near Gerangamete. It only has a small catchment and is only about 10 km in length. The Barwon River East Branch flows north for approximately 25 km and joins the Barwon River West Brach southeast of Yeodene.

Neither Diving Creek nor the Barwon River East Branch were included in the environmental FLOWS study (Lloyd Environmental *et al.* 2005a) and there is limited information about their ecological condition or the environmental values they are likely to support. Given their close proximity to other streams assessed in the FLOWS study, Dividing Creek and the East Branch of the Barwon River are likely to have similar ecological issues as Boundary Creek and the West Branch of the Barwon River. However, this will only be able to be confirmed following the site inspection.

3.4.6. Environmental flow recommendations

The following section presents the environmental flow recommendations for the reaches of interest in the upper Barwon River. The basis for the low flow components is also reviewed in detail.

3.4.6.1. Reach 1 (Upper Barwon)

The flow requirements for Reach 1 are presented in Table 8. The summer Low Flow (5 ML/day) in the upper Barwon River is intended to maintain a depth of 30 - 50 cm in pools, which provides habitat for small fish and macroinvertebrates. This flow will also support the growth of shrubby floodplain vegetation by maintaining a shallow watertable under the floodplain. The summer low flow is also designed to support populations of the federally protected Dwarf Galaxias. The winter baseflow (50 ML/day) will maintain sufficient flow in the channel to inundate wetlands and floodplains, adequate depth to allow fish passage and to support growth of emergent and submerged macrophytes.

- **Table 8 Environmental flow recommendations for Reach 1 (Upper Barwon) from Lloyd *et al.* (2005c)**

Flow				Rationale
Season	**Magnitude**	**Frequency**	**Total event duration**	
Summer	Low Flow 5 ML/day	continuous	-	▪ Perennial riparian shrub growth ▪ Perennial submerged aquatic macrophyte growth ▪ Permanent Dwarf Galaxid population ▪ Habitat for macroinvertebrate communities in summer and autumn
Summer	Low Flow Freshes 215 ML/day	2-3 per year	2 days	▪ Seasonal submerged aquatic macrophyte growth in floodplain pools or wetlands
Winter	Baseflow 50 ML/day	continuous	-	▪ Submerged aquatic macrophyte growth in floodplain pools and wetlands ▪ Seasonal emergent macrophyte growth ▪ Longitudinal connection in channel for *Galaxias olidus* dispersal ▪ Downstream migration of *G. brevipinnis* ▪ Support main growth and reproduction for macroinvertebrates
Winter	Small High Flow Fresh 153 ML/day	2-3 per season	5 days	▪ Create and extend habitat for aquatic macroinvertebrates ▪ Geomorphological features

Flow				Rationale
Winter	Large High Flow Freshes 1600 ML/day	Annual	7-10 days	▪ Riparian shrub community growth ▪ Inundation of floodplain vegetation for Dwarf Galaxid breeding ▪ Geomorphological features ▪ Create and extend habitat for aquatic macroinvertebrates

3.4.6.2. Reach 2 (Winchelsea)

Table 3-9 presents the environmental flow recommendations for Reach 2 (Winchelsea) as determined by Lloyd Environmental *et al.* (2005c). Cease to flow would not naturally occur in Reach 2. Low flows are required to maintain pools at this reach, and the recommendation of 12 ML/day provides a depth of 50 cm in most pools. This flow also maintains some riffle habitat and wets the entire stream bed, promoting the growth of emergent and submerged vegetation.

The winter baseflow recommendation, of 120 ML/day, wets the toe of the bank and will inundate or waterlog sandy benches. This flow will promote seasonal growth of emergent and submerged vegetation, especially on sandy benches, and provide aquatic habitat for macroinvertebrates.

▪ **Table 3-9 Environmental flow recommendations for Reach 2 (Winchelsea) from Lloyd *et al.* (2005c)**

Flow				Rationale
Season	Magnitude	Frequency	Total event duration	
Summer	Low Flow 12 ML/day	continuous	-	▪ River Blackfish require sustained low flows to maintain permanent pools in this reach ▪ Low flows sustain the macroinvertebrate community in summer
Summer	Low Flow Freshes 175 ML/day	2 per year	4 days	▪ Submerge woody debris or hard, clean surfaces for River Blackfish breeding ▪ Flows to connect pools for River Blackfish movement
Winter	Baseflow 120 ML/day	continuous	-	▪ Seasonal growth of emergent macrophytes - Aquatic macroinvertebrates activity
Winter	Elevated Baseflow 240 ML/day	1-2 per year	14 days	▪ Macroinvertebrate growth and reproduction

Flow				Rationale
Winter	Large High Flow Freshes 2400 ML/day	Annual	7 days	▪ Riparian shrub community growth ▪ Upstream migration of *Galaxias olildus* ▪ Downstream migration of *Galaxias brevipinnis* ▪ Inundate sandy benches for Mountain Galaxias habitat ▪ Geomoroplogical features
Winter	Bankfull Flows 12000 ML/day	1 per year	12 days	▪ Geomorphological features
Winter	Overbank flows >12,000 ML/day	One 30,000 ML/day event every 5 years	16 days	▪ Disturb emergent macrophyte beds ▪ Support growth and recruitment of floodplain woody vegetation

3.4.6.3. Reach 6 (Birregurra Creek)

The hydrology and salinity regime of Birregurra Creek has been highly modified from water releases upstream and significant vegetation removal. As a consequence, the environmental flow recommendations do not intend to return the stream to its original state, and rather, the recommendations are designed to protect the salt-tolerant macrophytes that are present at this reach, and the associated fauna. The flow recommendations are summarised in Table 10.

The dominant emergent macrophyte at Birregurra Creek is the salt tolerant Salt Club-rush, which requires seasonal drying. A cease to flow period of 22 days, twice per year is recommended to allow the salinity of the soil and shallow groundwater to increase. Cease-to-flow periods of this frequency and duration is the current regime (Lloyd Environmental *et al.* 2005c). There is no low flow recommendation.

Similarly, no winter baseflow recommendation has been made. Instead, frequent high flow freshes are recommended to maintain water logged soils and temporarily inundate macrophytes to promote seasonal growth. The 24 ML/day recommendation will also provide a depth of 200 mm throughout the reach to allow fish passage at that time (Lloyd *et al.* 2005c).

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- **Table 10 Environmental flow recommendations for Reach 6 (Birregurra Creek) from Lloyd *et al.* (2005c)**

Flow				Rationale
Season	**Magnitude**	**Frequency**	**Total event duration**	
Summer	Cease to flow	2 per year	22 days	▪ Presence of salt indicator plants
Winter	High Flow Freshes 24 ML/day	5-6 events per year (current is 8)	15 days	▪ Seasonal emergent macrophyte growth ▪ Main growth and reproductive season for aquatic macroinvertebrates ▪ *Galaxias olidus* dispersal ▪ Downstream migration of *G. brevipinnis*
Winter	Bankfull flows	1 every 0.8 of a year	9 days	▪ Channel form and key physical habitats ▪ Downstream sediment transport ▪ Extend aquatic macroinvertebrate habitat
Winter	Overbank flows 312 ML/day	1 in 2 years	7 days minimum	▪ Temporary inundation of saline floodplain vegetation

3.4.6.4. Reach 7 (Boundary Creek)

Boundary Creek has been channelised and has steep sides with limited bench habitat. A cease-to-flow period of two weeks, twice per year is recommended to support the growth of reeds and grasses on the stream bed. The summer low flow and winter baseflow of 1 ML/day is recommended to provide habitat for Dwarf Galaxias and macroinvertebrates. It is expected that groundwater discharge would contribute significantly to this flow. Flow of 1 ML/day would wet the width of the channel and support seasonal growth of macrophytes.

- **Table 11 Environmental flow recommendations for Reach 6 (Boundary Creek) from Lloyd *et al.* (2005c)**

Flow				Rationale
Season	**Magnitude**	**Frequency**	**Total event duration**	
Summer	Cease to flow	2 per year	2 weeks	▪ Summer macrophyte and grass colonisation of stream bed
Summer	Low Flow 1 ML/day			▪ Semi-permanent aquatic habitat for Dwarf Galaxid ▪ Macroinvertebrate habitat in summer and autumn
Winter	Baseflow 1 ML/day			▪ Seasonal emergent macrophyte growth ▪ Inundation of vegetation for Dwarf Galaxias breeding ▪ Main growth and reproduction season for aquatic macroinvertebrates
Winter	High Flow Freshes 64 ML/day	4 per season	6 days	▪ Extend aquatic macroinvertebrate habitat
Winter	Overbank Flow 137 ML/day	1 in 2 years	9 days	▪ Perennial riparian shrub growth ▪ Disturb riparian vegetation ▪ Maintain channel form and key habitats ▪ Main downstream sediment transport

3.4.7. Dividing Creek and Barwon River East Branch

Dividing Creek and Barwon River East Branch were not included in the environmental FLOWS study. There are therefore no environmental flow recommendations for these streams.

3.4.8. Conclusion

The environmental FLOWS study (Lloyd Environmental *et al.* 2005) provides a comprehensive review of the environmental values and ecological condition of the Barwon River at upper Barwon and Winchelsea and the Birregurra and Boundary Creeks. It should be noted however, that the review included in the FLOWS study is based on an assessment of one site at each reach. Although the FLOWS assessment site is chosen to be broadly representative of the entire reach, a field inspection is required to determine how accurately these sites represent the whole reach in terms of habitat availability and condition under low flows.

The condition of Reach 2 (Birregurra Creek) and Reach 6 (Barwon River near Winchelsea) has been included in this review for completeness and because aquatic values in one reach are likely to occur in other nearby reaches. However, Birregurra Creek and the section of the Barwon River near Winchelsea are sufficiently distant from the borefield that they are not considered at any material risk from the proposed groundwater extraction. Therefore these reaches will not be inspected during the field visit or considered in any subsequent assessment.

In contrast, Dividing Creek and the Barwon River East Branch may be impacted by water extraction from the borefield. We have little information regarding the environmental values in these two tributaries and therefore we will visit them during the field inspection to determine how similar they are to nearby streams that we have more reliable ecological data.

The results of the planned field inspection will be used to make an informed assessment of the suitability of the existing FLOWS study for Boundary Creek and the West Branch of the Barwon River and to determine if FLOWS studies are also required in Dividing Creek and the Barwon River East Branch. After the field inspection, we will comment on whether the existing flow recommendations provide a suitable benchmark against which to assess any hydrological changes due to groundwater extraction. We will also develop a monitoring and study plan to fill any information gaps that are needed to reliably assess the ecological effect of any changes to low flow as a result of groundwater extraction.

3.5. Hydrology desktop review – rainfall gauge review

This section is a high level review of the adequacy of current rainfall gauging for the Barwon Downs Monitoring Program. The Pennyroyal Creek gauge (090061) has been used in previous groundwater studies and modelling for the Barwon Downs borefield (SKM 2008). However, the Pennyroyal Creek gauge is outside of the main recharge area for the Barwon Downs Aquifer. It is also outside of the surface water catchment of Boundary Creek, which spans the recharge area. This review assesses the suitability of rainfall monitoring for the Barwon Downs borefield, and in particular, whether the rainfall series from the existing Pennyroyal Creek gauge is suitable for use as a representative rainfall series for the Boundary Creek area.

This review compares the availability and quality of rainfall data at sites across the region. It also examines the similarity of rainfall data across the region to determine whether existing gauges can be used to reasonably represent the rainfall in the Boundary Creek recharge area.

There were seven Bureau of Meteorology (BoM) rainfall gauges examined in this review, including the Pennyroyal Creek gauge. All of these gauges are located in the vicinity of the Boundary Creek recharge area for the borefield. The gauges analysed are listed in Table 12. A map showing the gauge locations is shown in Figure 21. It can be seen from this information that:

- Five of the seven rainfall gauges are currently operating, including the Pennyroyal Creek gauge

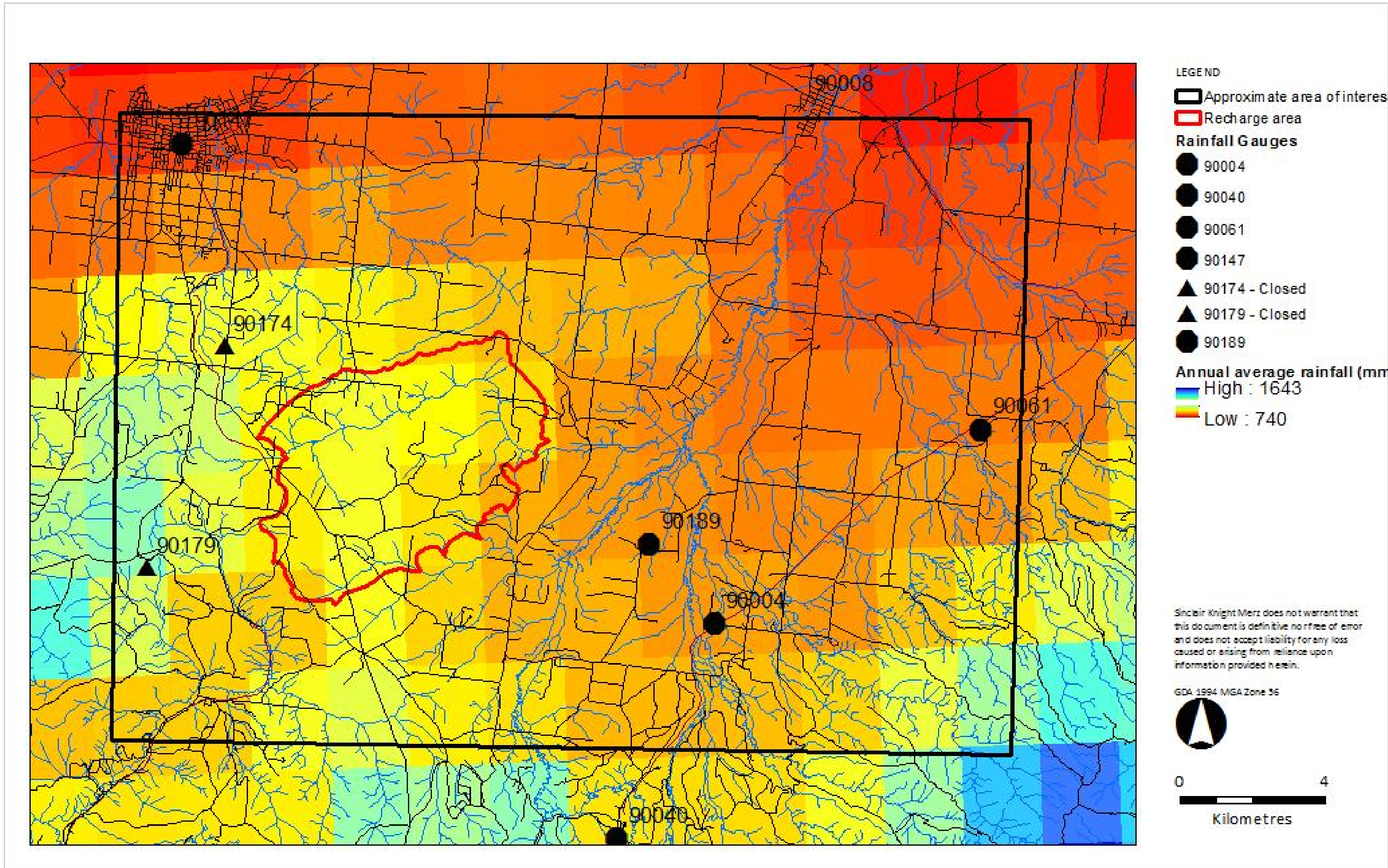
- Three of those gauges are long-term gauges, with data records commencing in the late 1800s and continuing to date. This includes the Pennyroyal Creek gauge
- The two most recently activated, currently operating rainfall gauges are both located at Barwon Downs in the vicinity of the borefield
- None of the available gauges are located within the Boundary Creek recharge area.

Table 12 List of rainfall gauges examined in this review

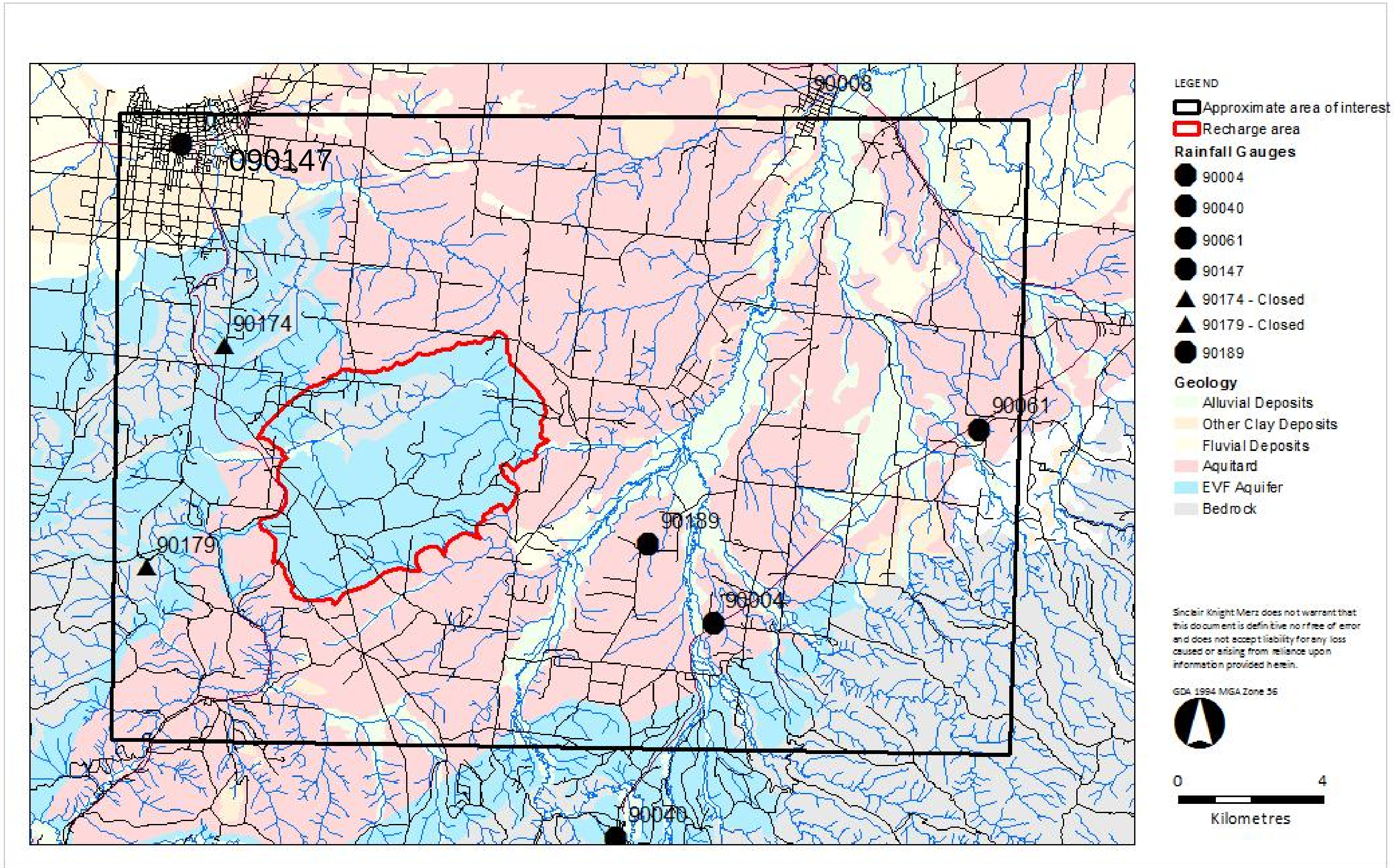
Gauge name	Gauge number	Start date	End date (as per 20/2/2013)	Current status (as per 20/2/2013)
Burtons Lookout	090179	07/05/1990	31/10/2005	Closed
Colac (Elliminyt)	090174	01/05/1983	14/10/1998	Closed
Colac (Shire Office)	090147	15/02/1898	18/2/2013	Open
Forrest State Forest	090040	01/04/1898	04/02/2013	Open
Barwon Downs (Gerangamete)	090189	30/10/2001	30/11/2012	Open
Barwon Downs	090004	01/01/1971	31/12/2012	Open
Pennyroyal Creek	**090061**	**01/12/1885**	**31/01/2013**	**Open**

Figure 21 also shows the average annual rainfall across the region, as estimated by the Bureau of Meteorology's Climate Atlas of Australia for the period 1961-1990 (BoM 2000). This figure illustrates that the average annual rainfall at the discontinued Colac (Elliminyt) is closest in magnitude to the estimated rainfall within the Boundary Creek recharge area, and that the average annual rainfall at Pennyroyal Creek is lower than that in the Boundary Creek recharge area. Rainfall similarity is discussed further in subsequent sections of this review.

Figure 22 shows the location of rainfall gauges relative to the surface geology of the region. It can be seen again that no rainfall gauges are located within the Boundary Creek recharge area. The discontinued Colac (Elliminyt) and Burtons Lookout gauges are located in an area where the Barwon Downs borefield aquifer is at the surface, to the east of the Boundary Creek recharge area. The two Barwon Downs rainfall stations and the Pennyroyal Creek gauge monitor rainfall at locations where the aquitard is at the surface to the east and south of the recharge area.



- **Figure 21 Map of analysed gauges – with average annual rainfall**



- **Figure 22 Figure 23 Map of analysed gauges – with geology**

3.5.1. Data Quality Measures

Data quality for the gauges is presented in Table 13 as the proportion of data missing and/or aggregated in the rainfall series. Aggregated data is where a total rainfall is recorded, but represents the aggregated rainfall over more than one day (e.g. because the gauge was not read every day). It is evident in Table 13 that the rainfall series at Pennyroyal Creek and Colac (Elliminyt) are of very good quality with less than 1% of the record missing or aggregated. The remaining sites are of fair quality, with 5-10% missing data, with the exception of the site at Burtons Lookout, which is missing over most of its available period of record.

- **Table 13 Rainfall gauges quality measures**

Gauge name	Gauge number	% days missing	% days aggregated	% days missing or aggregated
Burtons Lookout	090179	84.6%	3.1%	87.7%
Colac (Elliminyt)	090174	0.0%	0.0%	0.0%
Colac (Shire Office)	090147	3.4%	4.3%	7.6%
Forrest State Forest	090040	7.7%	6.9%	14.6%
Barwon Downs (Gerangamete)	090189	9.6%	0.0%	9.6%
Barwon Downs	090004	5.4%	0.5%	5.9%
Pennyroyal Creek	**090061**	**0.4%**	**0.3%**	**0.7%**

3.5.2. Potential for Errors in Long-Term Rainfall Behaviour

Long-term shifts in rainfall observed at different sites across a region can be identified using a double mass curve. Shifts in a double mass curve have historically been associated with gauging errors (e.g. a tree growing over a rainfall gauge over a period of years), but can also be associated with changes in regional climate. Ideally one of the Bureau of Meteorology's high quality rainfall gauges would be used for this check of long-term rainfall behaviour, as these sites are regularly checked for gauging errors. However the closest high quality site (Lovely Banks Reservoir (087034)) is approximately 74 km away from the area of interest. Given the steep rainfall gradients across the Otways, this high quality site was not used as a reference gauge, because it is likely to be unrepresentative of rainfall patterns in the study area. Instead, double mass curves for each site have been plotted against the Pennyroyal Creek gauge.

The Burtons Lookout and the Barwon Downs (Gerangamete) gauges have been excluded from the analysis due to the poor data availability at those gauges. Reliable double mass curves could not be produced.

Double mass curves for each site are provided in Appendix B. These curves illustrate two small but consistent regional shifts in rainfall relative to the Pennyroyal Creek gauge. For the three long-term gauges, the rainfall observed at both Colac (Shire Office) and Forrest State Forest changed relative to the rainfall at Pennyroyal Creek from the late 1930s and early 1940s onwards. In the post-1940 period, rainfall increased at Forrest and decreased at Colac relative to the Pennyroyal gauge. The magnitude of this change is large, at around 18% of the long-term average rainfall, but has been reasonably consistent since that time.

The second shift observed at more than one site occurs around 1990, when the rainfall at Barwon Downs and Colac (Elliminyt) both increase relative to the Pennyroyal Creek gauge. Again the magnitude of this shift is large at around 14% of the long-term average rainfall, but has been consistent since that time. There is no evidence of this shift at Colac (Shire Office) or Forrest State Forest.

In conclusion, whilst there are minor shifts in cumulative rainfall across the region, there is no large scale systematic bias which would cause the integrity of an individual gauge to be questioned.

3.5.3. Average annual rainfall

Average annual rainfall values from each of the gauges are shown in Table 14. They are obtained by extracting the annual average rainfall from the Bureau of Meteorology's Climate Atlas of Australia (extract shown in Figure 21 for each gauge location. This rainfall map shows average annual rainfall over the concurrent period of 1961 to 1990. The raw data used to derive the maps are interpolated from all available rainfall data, which can include data from outside of the study area.

The Barwon Downs aquifer recharge area, as shown in Figure 21, has average annual rainfall between 988 mm and 1062 mm, with an average of 1030 mm. Based on that, the Colac (Elliminyt) and Forrest State Forest gauges have the most similar average annual rainfall to the recharge area. Pennyroyal Creek gauge is located is an area around 15-20% drier on average than the recharge area.

- **Table 14 Rainfall gauges average annual rainfall**

Gauge name	Gauge number	Average annual rainfall (mm/yr) 1961-1990
Burtons Lookout	090179	1,238
Colac (Elliminyt)	090174	1,061
Colac (Shire Office)	090147	787
Forrest State Forest	090040	1,007
Barwon Downs (Gerangamete)	090189	887
Barwon Downs	090004	904
Pennyroyal Creek	090061	860

3.5.4. Correlation across rainfall gauges

The ability to estimate rainfall at one site from an adjacent site can be measured by comparing the coefficient of determination (R^2) between rainfall at each gauge as shown in Table 15. These figures have been derived over periods of available overlapping data between pairs of sites. It can be seen that correlations are generally high. Importantly, the correlation between the long-term Pennyroyal Creek gauge and the Colac (Elliminyt) gauge near the recharge area is high (monthly R^2=0.82), which indicates that rainfall at one site can be reasonably estimated from the other.

- **Table 15 Coefficient of determination (R^2) of monthly rainfall series**

Gauge	090179	090174	090147	090040	090189	090004	090061
090179		0.88	0.76	0.70	0.68	0.75	0.64
090174			0.89	0.85	-	0.91	0.82
090147				0.79	0.83	0.76	0.76
090040					0.82	0.89	0.82
090189						0.93	0.70
090004							0.83
090061							

3.5.5. Number of rain days

The number of rain days at each gauge is a measure of the homogeneity of daily rainfall patterns across the region. Table 16 shows the number of rain days at one site relative to another site for pairs of gauges. For example, there are 54% more rain days at Colac (Elliminyt) (090174) compared to Pennyroyal Creek (090061). These figures have been derived over periods of available overlapping data between pairs of sites. It can be seen that all other sites in the region have more rain days than the Pennyroyal Creek gauge.

- **Table 16 Relative number of rain days between two gauges in a concurrent period**

		Reference gauge						
		090179	090174	090147	090040	090189	090004	090061
Gauge of interest	090179		0.81	1.29	1.06	1.00	1.27	1.44
	090174	1.23		1.48	1.23	-	1.41	1.54
	090147	0.77	0.68		1.04	0.88	1.14	1.15
	090040	0.94	0.82	0.96		0.94	1.21	1.11
	090189	1.00	-	1.14	1.06		1.09	1.38
	090004	0.79	0.71	0.88	0.83	0.92		1.11
	090061	0.69	0.65	0.87	0.90	0.73	0.90	

Note: Relative number of rain days at gauge of interest is the number of rain days at the gauge of interest divided by number of rain days at gauge reference gauge

3.5.6. Conclusion

Based on the analysis done in this project, there are three long-term rainfall gauges across the region with a mostly continuous rainfall record of greater than 100 years in length. Shorter periods of data are available at several other locations. None of these rainfall gauges is located within the Boundary Creek recharge area for the Barwon Downs borefield. The Colac (Elliminyt) rainfall gauge is considered most representative of the rainfall in the recharge area, however this site is not a long-term gauge (it has 15 years of record) and was discontinued in 2005. Nevertheless, high correlations between rainfall gauges suggest that long-term rainfall conditions at Colac (Elliminyt) can be reasonably estimated by correlation with nearby long-term gauges, provided that differences in the number of rain days are allowed for.

Therefore, an installation of a new rainfall gauge is not recommended. A new gauge is not likely to improve the accuracy of the groundwater modelling given the other uncertainties in recharge and because the Barwon Downs groundwater model does not appear to be sensitive to changes in recharge.

3.6. Streamflow Gauge Review

This section provides a high level review of the adequacy of current streamflow gauging for the Barwon Downs Monitoring Program. The key objectives of streamflow monitoring for the program are:

1. Detection of impacts on streamflow (through measurement) due to groundwater pumping including:
    a. Impact on groundwater interaction with streams intersecting the Barwon Downs pumped aquifer (i.e. LTA);
    b. Impact on groundwater interaction with streams intersecting the aquitard above the Barwon Downs pumped aquifer;
    c. Impact on groundwater interaction with streams intersecting bedrock;
2. Understanding the nature of groundwater interaction with streams intersecting the aquitard
3. Estimation of impacts on streamflow and regional groundwater level behaviour through the calibration and simulation of groundwater and hydrologic models; and
4. Development of environmental flow recommendations and subsequent assessment of compliance against those recommendations.

The suitability of the current streamflow gauge network and the potential benefit of new gauges or other monitoring recommendations were assessed against the objectives above. The review covers the spatial and temporal availability of data, data quality and a series of recommendations to address the monitoring objectives.

3.6.1. Gauge locations and data availability

Streamflow gauging sites within the study area are listed in Table 17 with a map of the location of sites shown in Figure 24. These include currently inactive gauges found in the area.

This information highlights a number of features of the current streamflow gauging network. Within the recharge area for the Barwon Downs aquifer, there are two inactive streamflow gauges, plus an active gauge immediately downstream of the recharge area (at Yeodene). The gauge at Yeodene has operated from 1985 to date.

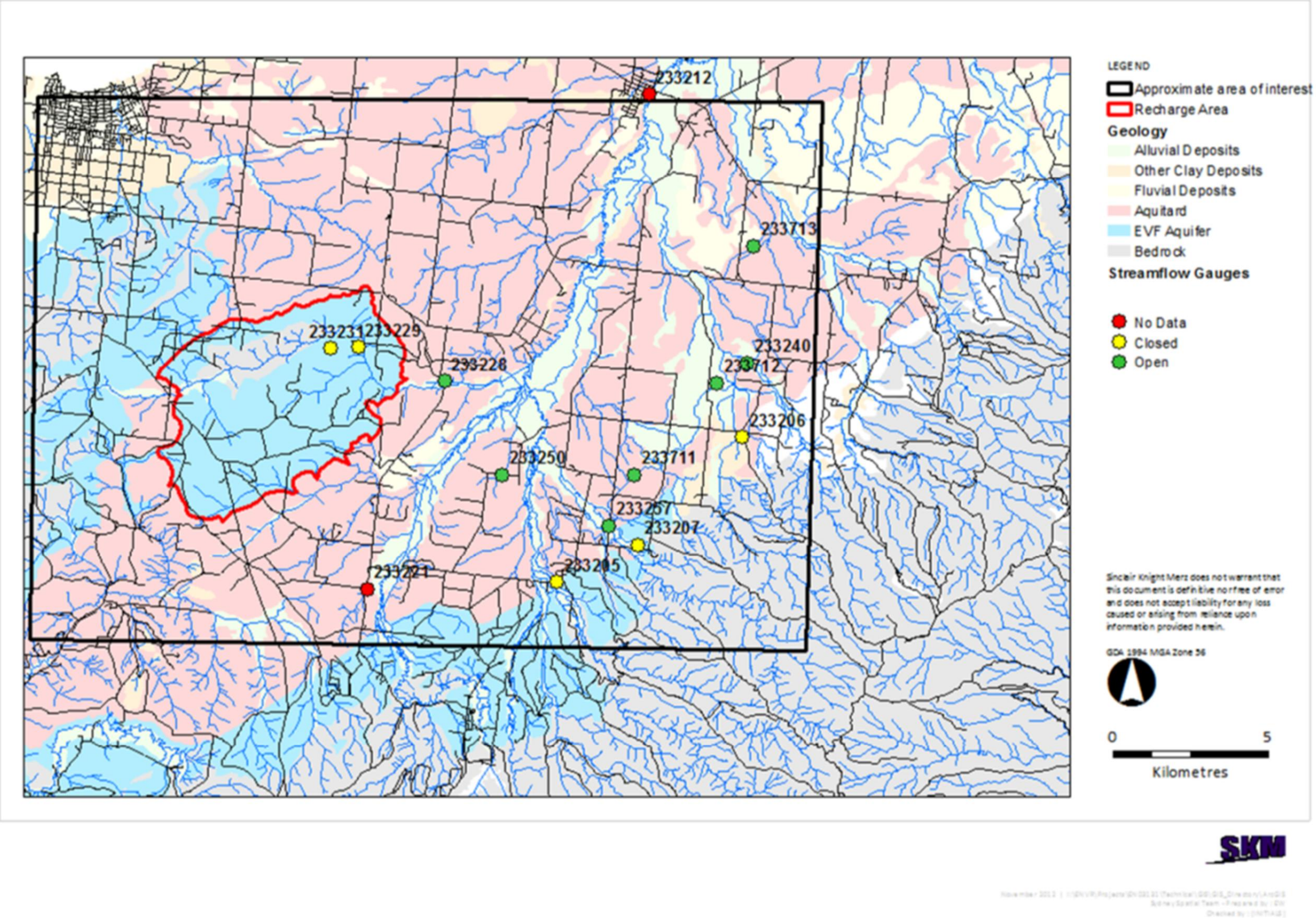
Several sites are located along the Barwon Rive however these sites do not appear to collect any streamflow data. Flows along the Barwon River are regulated from the West Barwon Reservoir and numerous private diverters draw water from the river. (*As part of Task D - need to insert comment here based on data availability from Thiess*).

There are several gauges in the upper reaches of the Barwon River East Branch. These gauges are not considered further as they are south of the Bambra fault, and far from the area of pumping influence.

Table 17 List of streamflow gauges

Gauge Number	Gauge Name	Start Date	End date	Status	Percentage of data missing
233228	BOUNDARY CREEK @ YEODENE	22/03/1985	16/01/2013	Open	0.05%
233231	BOUNDARY CREEK @ U/S OF MACDONALDS DAM	5/12/1989	2/02/1994	Closed	0.39%
233229	BOUNDARY CREEK @ D/S OF MACDONALDS DAM	5/12/1989	2/02/1994	Closed	N/A
233250	AGROFORESTRY SITE @ RACECOURSE PADDOCK GERANGAMETE	29/07/1994	16/01/2013	Open	0.73%
233221	BARWON RIVER WEST BRANCH @ GERANGAMETE	#N/A	#N/A	No Data	N/A
233212	BARWON RIVER @ BIRREGURRA	#N/A	#N/A	No Data	N/A
233205	CALLAHAN CREEK @ BARWON DOWNS	10/10/1929	1/02/1956	Closed	N/A
233207	DEWING CREEK @ BARWON DOWNS	10/10/1929	18/06/1930	Closed	N/A
233257	DEWING CREEK @ BIBIRAGURRA-FORREST ROAD	3/08/2000	10/12/2012	Open	2.34%
233711	WURDIBOLUC CHANNEL @ 8.5 MILE	22/06/2002	7/01/2013	Open	1.61%
233206	GOSLINGS CREEK @ MURROON	10/10/1929	30/06/1930	Closed	N/A
233712	WURDIBOLUC INLET CHANNEL @ 12 MILE	3/08/2000	7/01/2013	Open	6.17%
233240	MATTHEWS CREEK @ SYPHON	3/08/2000	7/01/2013	Open	57.24%
233713	WURDIBOLUC INLET CHANNEL @ 16 MILE	24/05/2002	7/01/2013	Open	61.98%

Gantt charts illustrating data coverage and rating information for active gauges are available in Appendix C



- **Figure 24 Location of streamflow gauges**

3.6.1.1. Boundary Creek gauges

Of particular focus were the gauges in the Boundary Creek catchment. This is because:

- The catchment contains the main groundwater recharge area for the LTA, and is relatively close to the borefield;
- The Boundary Creek at Yeodene gauge has a reasonably long streamflow record;
- The catchment is independent of flow regulation at the Barwon River;

There are three gauges in the Boundary Creek catchment:

- 233228 Boundary Creek at Yeodene;
- 233231 Boundary Creek upstream of Macdonalds Dam; and
- 233229 Boundary Creek downstream of Macdonalds Dam.

Of the three streamflow gauges along Boundary Creek, only the Boundary Creek at Yeodene gauge is currently active.

Macdonalds Dam is an on-stream dam upstream of Yeodene. It was built in 1986 with a capacity at full supply level of 160 ML. There is a surface water licence with winter-fill conditions attached to the dam. The dam can only harvest water between July and October. From November to June, all inflows are to be passed through downstream, which means that if the dam is operated in accordance with its licence conditions, the dam would have no impact on downstream flows during summer/autumn low flow periods. (*The recent Barwon Water monitoring review (2012) implies that this is not occurring*). In practice, this would depend on the operation of the dam. Passing flows at the dam are achieved by monitoring a V-notch weir on Boundary Creek upstream of the dam and matching those flows by opening the gate valve when the supply level is below that of the spillway. The gate valve opening is adjusted to meet the inflows when the dam is not spilling.

3.6.1.2. Suitability for streamflow monitoring objectives

Table 18 provides a measure of how each of the gauges in the current monitoring network can benefit the identified streamflow monitoring objectives listed in Section 3.6.1. In reviewing the existing data, it is evident that:

- Several gauges are either closed or provide no streamflow data;
- Several gauges are measuring flows in the Wurdiboluc Reservoir inlet channel, which is an entirely regulated artificial channel;
- Gauges located in the West Barwon River are not useful to measure pumping impacts on streamflows, or for assessing the nature of groundwater interaction with rives over the aquitard, as it is difficult to isolate the effects of pumping from other larger influences, such as the operation of the West Barwon Reservoir and private diverters;

- Some gauges are either too far from the area of expected impact of drawdown or are in a catchment with significant land use change.

Table 18 Suitability of gauges for streamflow monitoring objectives

Gauge Name	Benefit in meeting monitoring program objectives						Comment
	Assess pumping impacts in Boundary Creek recharge area	Assess pumping impacts on streams in aquitard / understand nature gw-sw interaction in aquitard	Assess pumping impacts on streams in bedrock / understand nature gw-sw interaction in bedrock	Ground-water and surface water model calibration	Environmental flows: Recomm-endations	Environmental flows: Compliance	
BOUNDARY CREEK @ YEODENE	✓	✓	✗	✓	✓	✓	In combination with site d/s of Macdonald's dam
BOUNDARY CREEK @ U/S OF MACDONALDS DAM	✗	✗	✓	✗	✗	✗	Gauge is closed
BOUNDARY CREEK @ D/S OF MACDONALDS DAM	✓	✓	✗	✗	✗	✗	Gauge is closed
AGROFORESTRY SITE @ RACECOURSE PADDOCK GERANGAMETE	✗	✗	✗	✗	✗	✗	Hard to isolate groundwater impact from dominant land use change impact
BARWON RIVER WEST BRANCH @ GERANGAMETE	✗	✗	✗	✗	✗	✗	No data provided
BARWON RIVER @ BIRREGURRA	✗	✗	✗	✗	✗	✗	No data provided
CALLAHAN CREEK @ BARWON DOWNS	✗	✗	✗	✗	✗	✗	Gauge is closed, affected by fault line
DEWING CREEK @ BARWON DOWNS	✗	✗	✗	✗	✗	✗	Gauge is closed, affected by fault line
DEWING CREEK @ BIRREGURRA-FORREST ROAD	✗	✗	✗	✗	✓	✓	Affected by fault line
WURDIBOLUC CHANNEL @ 8.5 MILE	✗	✗	✗	✗	✗	✗	Measures flow in irrigation channel
GOSLINGS CREEK @ MURROON	✗	✗	✗	✗	✗	✗	Affected by fault line
WURDIBOLUC INLET CHANNEL @ 12 MILE	✗	✗	✗	✗	✗	✗	Measures flow in irrigation channel
MATTHEWS CREEK @ SYPHON	✗	✗	✗	✗	✗	✗	Too far from pumping/recharge areas
WURDIBOLUC INLET CHANNEL @ 16 MILE	✗	✗	✗	✗	✗	✗	Measures flow in irrigation channel

3.6.2. Recommendations

The following includes a list of recommendations, associated justification for the recommendation and estimated costs to install and operate the gauge. Note that all recommended gauges are to be installed to provide accurate low flow gauging with a data logger that is uploaded periodically (say every 1-3 months). At some sites, salinity monitoring has also been recommended. The recommendations are provided in decreasing order of importance.

3.6.2.1. Recommendation 1: Reinstate Boundary Creek flow gauges upstream and downstream of Macdonalds Dam

The ability to reliably use the Boundary Creek streamflow gauge at Yeodene is hindered by uncertainty in the degree of flow attenuation and loss across Macdonalds Dam. The re-installation of these two streamflow gauges would serve multiple purposes including the ability to isolate changes in groundwater discharge to Boundary Creek between the dam and Yeodene (intersecting the Barwon Downs pumping aquifer), the creation of a control catchment (intersecting bedrock) upstream of the dam, and provision of the ability to more formally estimate losses across the dam. This last item would improve the ability to develop unimpacted flow regimes for environmental flow studies on Boundary Creek.

Monitoring should be continuous and for at least two low flow (summer/autumn) periods. Ideally, these sites would remain in place for the duration of the operation of the Barwon Downs borefield. Monitoring during winter/spring periods will be of value for environmental flow purposes, but not for estimating changes in baseflow.

In making this recommendation, it is assumed that the current monitoring of outfalls from the Colac pipeline to the upper reaches of Boundary Creek will continue.

Initial cost estimate: *to be completed as part of Task D*

Maintenance cost estimate: *to be completed as part of Task D*

3.6.2.2. Recommendation 2: Continuous salinity monitoring on Boundary Creek

In addition to the above flow monitoring, continuous salinity monitoring at all sites on Boundary Creek would allow changes in baseflow to be estimated using a salt balance. This provides a semi-independent estimate of changes in baseflow in addition to flow monitoring alone. This recommendation would need to be supported with salinity monitoring at groundwater observation bores in the vicinity of the creek.

Monitoring should be continuous and for at least years. Ideally, these sites would remain in place for the duration of the operation of the Barwon Downs borefield, but may be discontinued thereafter if baseflow estimates from streamflow monitoring alone reasonably match those derived from a salt balance. Monitoring during winter/spring periods is also useful (in addition to low flow summer/autumn, as peak flows provide salinity values indicative of zero groundwater contribution, i.e. they provide the opposite end of the continuum compared to the salinity values during low flow periods. Both ends of this spectrum are required to undertaken the salt balance approach to baseflow estimation.

Initial cost estimate: ***to be completed as part of Task D***

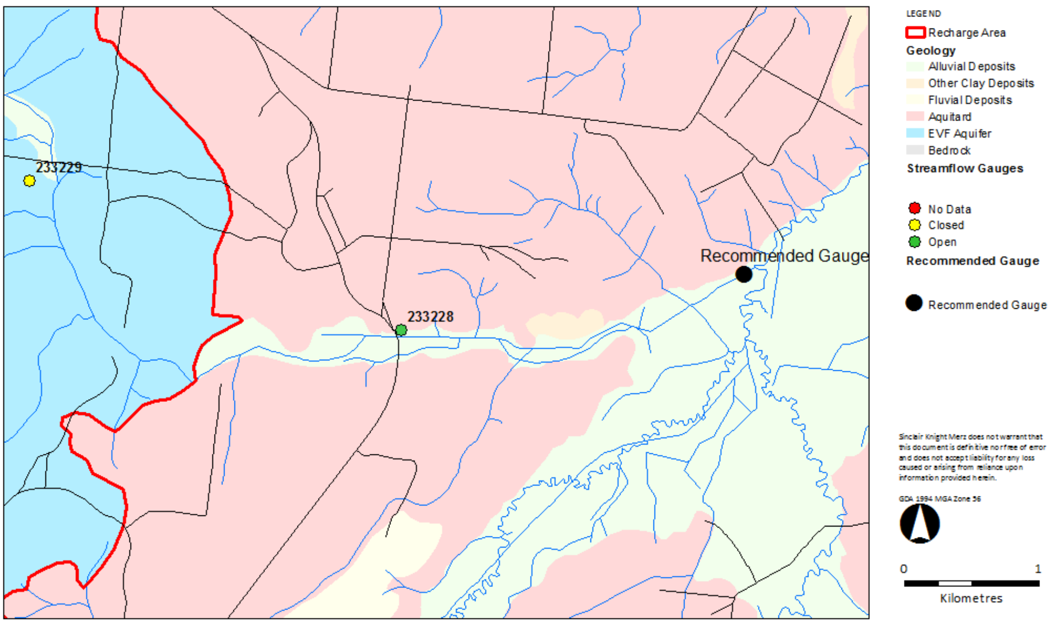
Maintenance cost estimate: ***to be completed as part of Task D***

3.6.2.3. Recommendation 3: New gauges to monitor changes in groundwater discharge from the aquitard

Prior to the field inspection it is unclear which site will be the best for addressing this recommendation. Therefore three options have been presented below for further site inspection. Each site should include continuous flow and salinity monitoring.

Recommendation 3, Option A: New gauge at Boundary Creek immediately upstream of Barwon River confluence

The first option for meeting this recommendation involves installing a new flow and salinity gauge on Boundary Creek, immediately upstream of the Barwon River confluence. A gauge there and the Boundary Creek at Yeodene gauge bounds a reach which predominantly flows over the aquitard. The recommended location is shown in Figure 25. The ability to utilise this site will depend on the hydrographic control section. The reach between Yeodene and the new gauge is quite short, which means that streamflows need to be quite accurate to overcome measurement uncertainty. At times of high flow, there may also be backwater effects from the Barwon River that invalidate streamflow measurements.



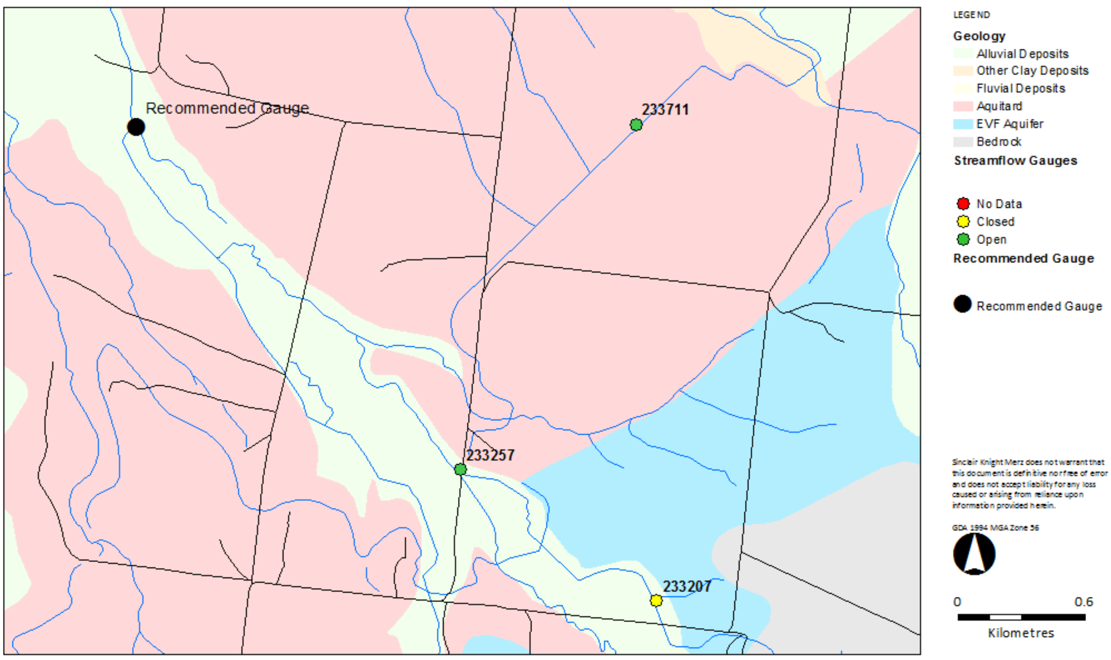
SINCLAIR KNIGHT MERZ SKM

- **Figure 25 Recommended gauge: At Boundary Creek upstream of Barwon River confluence**

Initial cost estimate: ***to be completed as part of Task D***
Maintenance cost estimate: ***to be completed as part of Task D***

3.6.2.4. Recommendation 3, Option B: New gauge at Dewing Creek

If Option A is not feasible, another option is to install a gauge at Dewing Creek downstream of the existing streamflow gauge. The existing gauge is located at Birregurra-Forrest Road. We recommend that a gauge be located downstream of the Birregurra-Forrest Road gauge, and upstream of the Den Creek confluence, as shown in Figure 26. Alternatively, if the flow at Den Creek is found to be insignificant, the gauge can be placed further downstream, upstream of the Barwon River confluence.

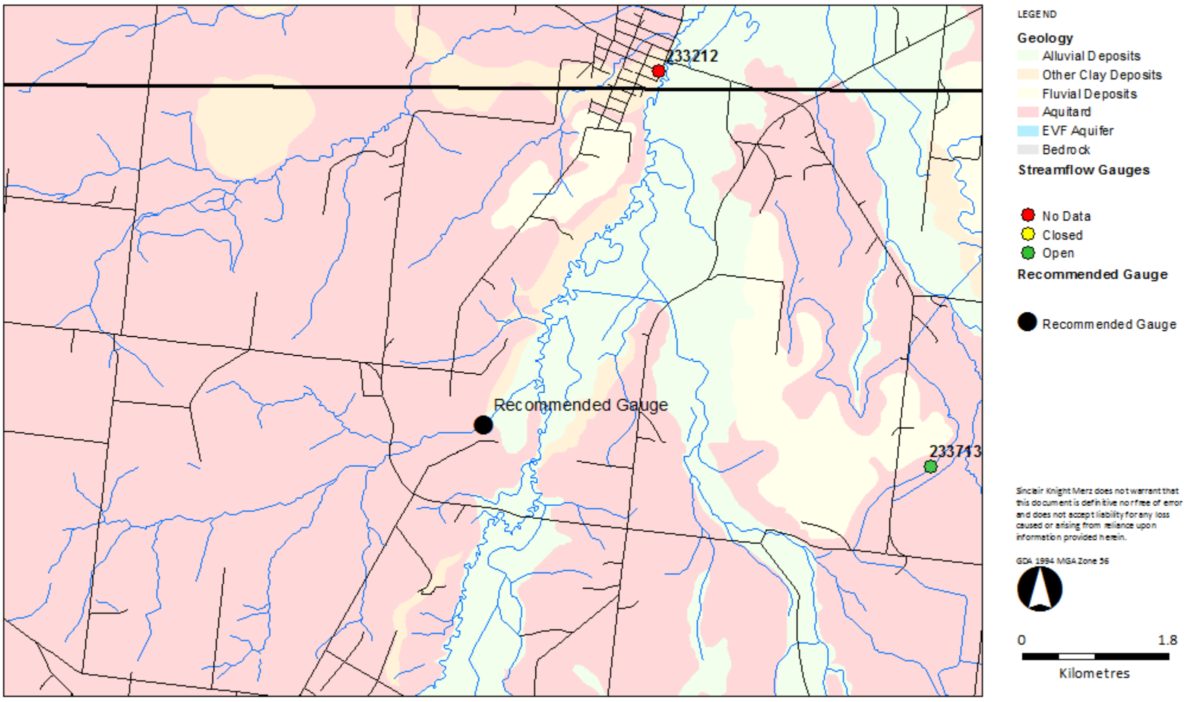


- **Figure 26 Recommended gauge: At Dewing Creek**

Initial cost estimate: ***to be completed as part of Task D***
Maintenance cost estimate: ***to be completed as part of Task D***

3.6.2.5. Recommendation 3, Option C: New gauge in a small catchment fully within the aquitard

If Option B is not feasible, we recommend that the gauge is placed in the unnamed catchment north of Boundary creek as shown in Figure 27. The site is recommended because the underlying geology is predominantly aquitard, the catchment sizes are small, and located close to the pumping areas.



- **Figure 27 Recommended gauge: At unnamed catchment**

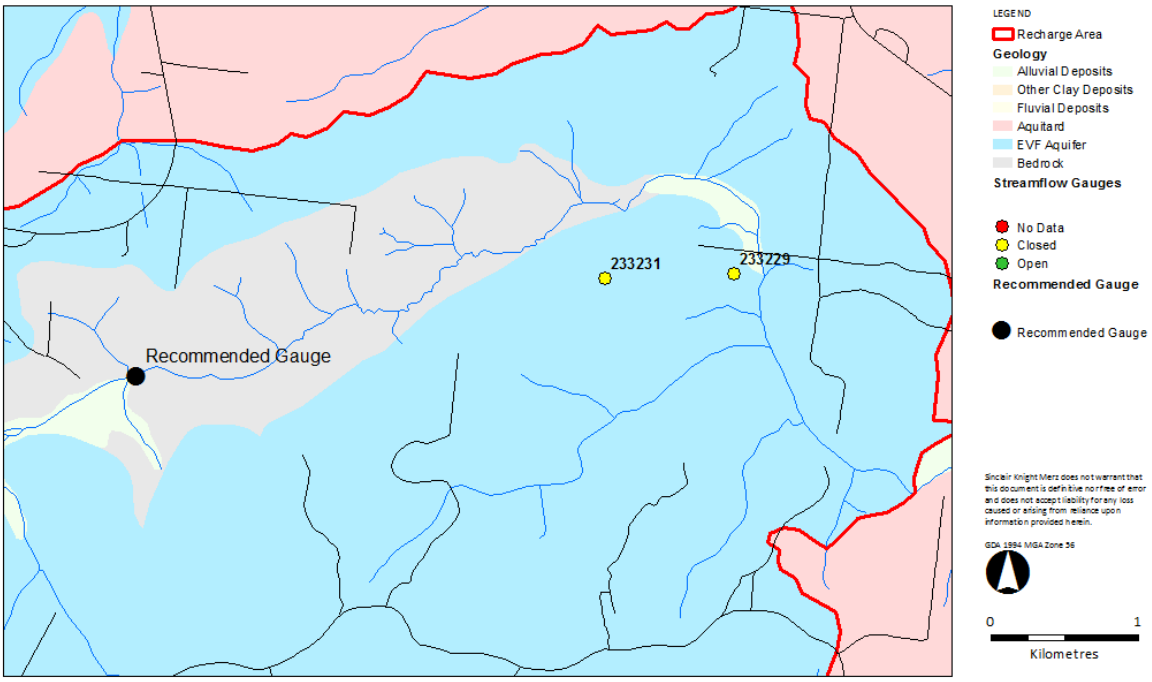
Initial cost estimate: ***to be completed as part of Task D***
Maintenance cost estimate: ***to be completed as part of Task D***

- **Figure 28 Recommended gauge: At Dewing Creek**

3.6.2.6. Recommendation 4: New gauge at Boundary Creek at upper end of bedrock outcrop

Currently the groundwater model assumes that the bedrock geology is impervious and provides no baseflow to waterways. However, if the bedrock is assumed to have some permeability, the model results will change significantly. Therefore, the permeability of the bedrock, and baseflow from river reaches over bedrock should be ascertained. We recommend that this is done by placing a new gauge at Boundary Creek some distance upstream of Macdonalds Dam where the geology transitions from the aquifer to bedrock (as shown in Figure 29).

Comparing flows between this recommended gauge and the reinstated gauge upstream of Macdonalds Dam (refer to Section 3.6.2.1) during low flows will determine if the reach between the two gauges (which is completely over bedrock) is gaining base flow. From this exercise, a more representative estimate of hydraulic conductivity can be obtained for the bedrock in Boundary Creek which can be applied for all bedrock layers in the groundwater model.



- **Figure 29 Recommended gauge: At Boundary Creek on bedrock upstream of Macdonalds Dam**

Initial cost estimate: ***to be completed as part of Task D***
Maintenance cost estimate: ***to be completed as part of Task D***

3.6.2.7. Recommendation 5: Source modelling with STEDI plugin

To predict streamflow impacts due to pumping, impacts of small catchment dams and private diverters in the Boundary Creek catchment and other catchments should be isolated from the streamflow record. This can be done by building a Source model for the catchment of interest incorporating the STEDI plugin. STEDI is a tool used frequently in water resources modelling to determine the impacts of farm dams on a time series of streamflow.

Cost estimate: Significantly dependant on scale and complexity of the modelling required. Typically in the order of low tens of thousands of dollars for small catchments with suitable streamflow and catchment data for model calibration.

3.6.3. Suitability for streamflow monitoring objectives

Table 19 provides a summary of the recommendations specified in Section 3.6.2, in terms of their potential in helping Barwon Water achieve its streamflow monitoring program objectives.

- **Table 19 Suitability of recommendations for streamflow monitoring objectives**

Recommendation	Benefit in meeting monitoring program objectives					
	Assess pumping impacts in Boundary Creek recharge area	Assess pumping impacts on streams intersecting aquitard above pumping aquifer / understand gw-sw interaction in aquitard	Assess pumping impacts on streams intersecting bedrock / understand gw-sw interaction in bedrock	Ground-water and surface water model calibration	Environmental flows	
					Recommend-ations	Compliance
Recommendation 1: Reinstate Boundary Creek flow gauges upstream and downstream of Macdonalds Dam	✓	✗	✓	✓	✓	✓
Recommendation 2: Continuous salinity monitoring along Boundary Creek	✓	✗	✓	✓	✓	✗
Recommendation 3: New gauge to monitor changes in groundwater discharge from aquitard	✗	✓	✗	✓	✓	✓
Recommendation 4: New gauge at Boundary Creek on bedrock upstream of dam	✓	✗	✓	✓	✗	✗
Recommendation 5: Source modelling with STEDI plugin	✓	✗	✗	✓	✓	✗

3.7. Acid Sulphate Soils desktop review

Acid sulphate soils (ASS) contain iron sulphide minerals (particularly pyrite) that oxidise on exposure to the atmosphere, generating sulphuric acid and potentially releasing heavy metals into solution. ASS form in environments with abundant organic matter (e.g. swamps); these have a low oxygen content and bacteria, which are both required for sulphide formation.

ASS are harmless if undisturbed, however oxidation, which may be caused by excavation disturbance or drainage (e.g. for agriculture or lowering of the watertable), can generate acid and this can lead to the mobilisation of metals.

3.7.1. Previous Work

Land and Water Resources Otway Catchment (LAWROC, 2011) conducted an assessment to identify ASS in the Boundary Creek catchment, at locations shown in Figure 30. Subsurface soil sampling was undertaken via borehole excavations and surface sediment samples were also collected. The maximum borehole depth was 2.5m below ground level. Samples were typically collected every half metre. All samples were analysed for Reduced Inorganic Sulfur and Titratable Actual Acidity, some for Acid Volatile Sulfur and some for Retained Acidity Screening.

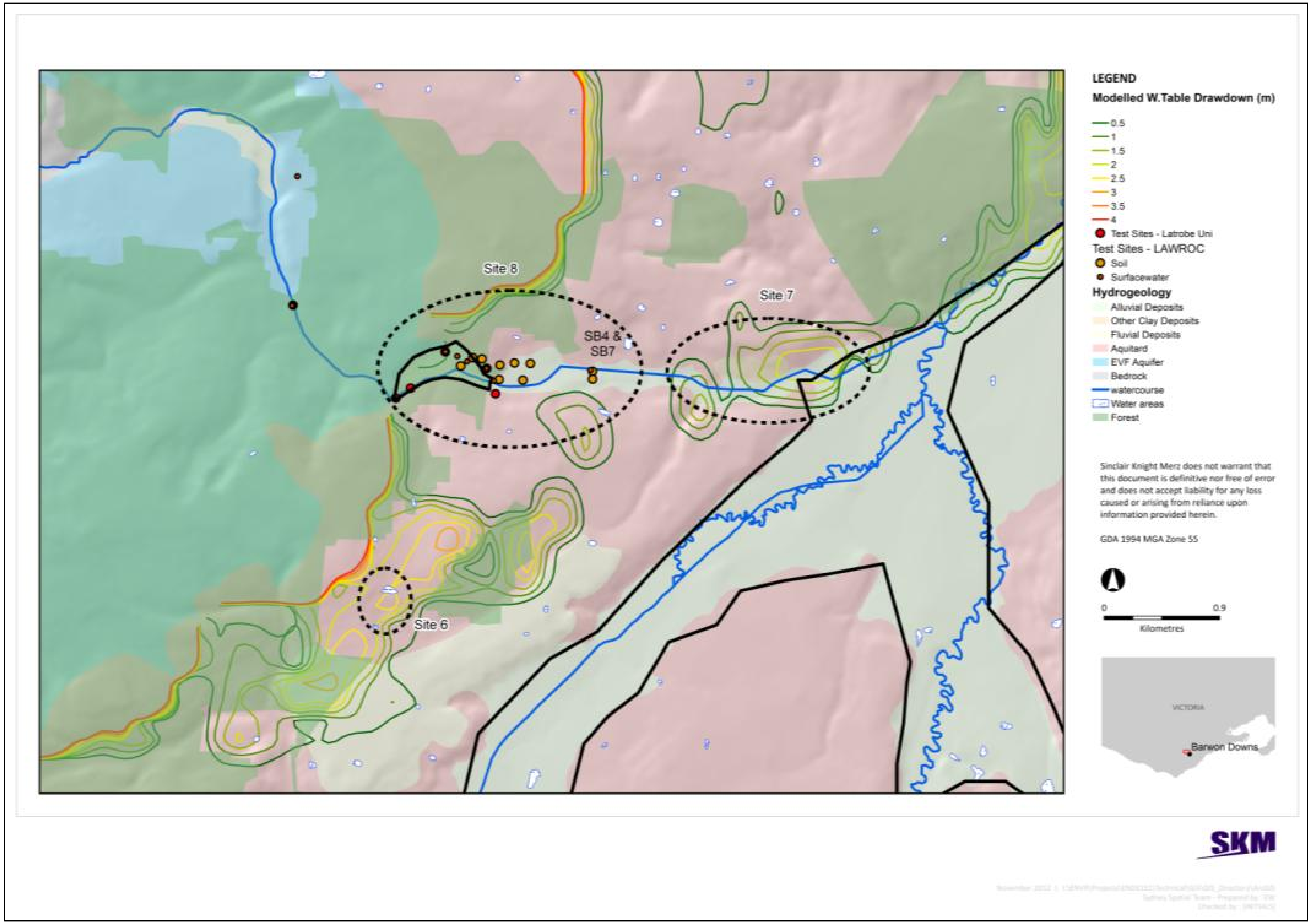
Surface water sampling was also undertaken including both field parameters and samples submitted to a laboratory. A total of 77 soil and sediment samples were collected and an additional 33 soil samples only.

Glover et al. (2011) investigated the peat swamp on Boundary Creek for ASS. Three sites were chosen and samples were taken along the Boundary Creek swamp trench (Figure 30). Samples were taken at half meter intervals to a depth of 2m, along the profile of the site. Two additional cores were also drilled to bedrock. The samples were analysed for:

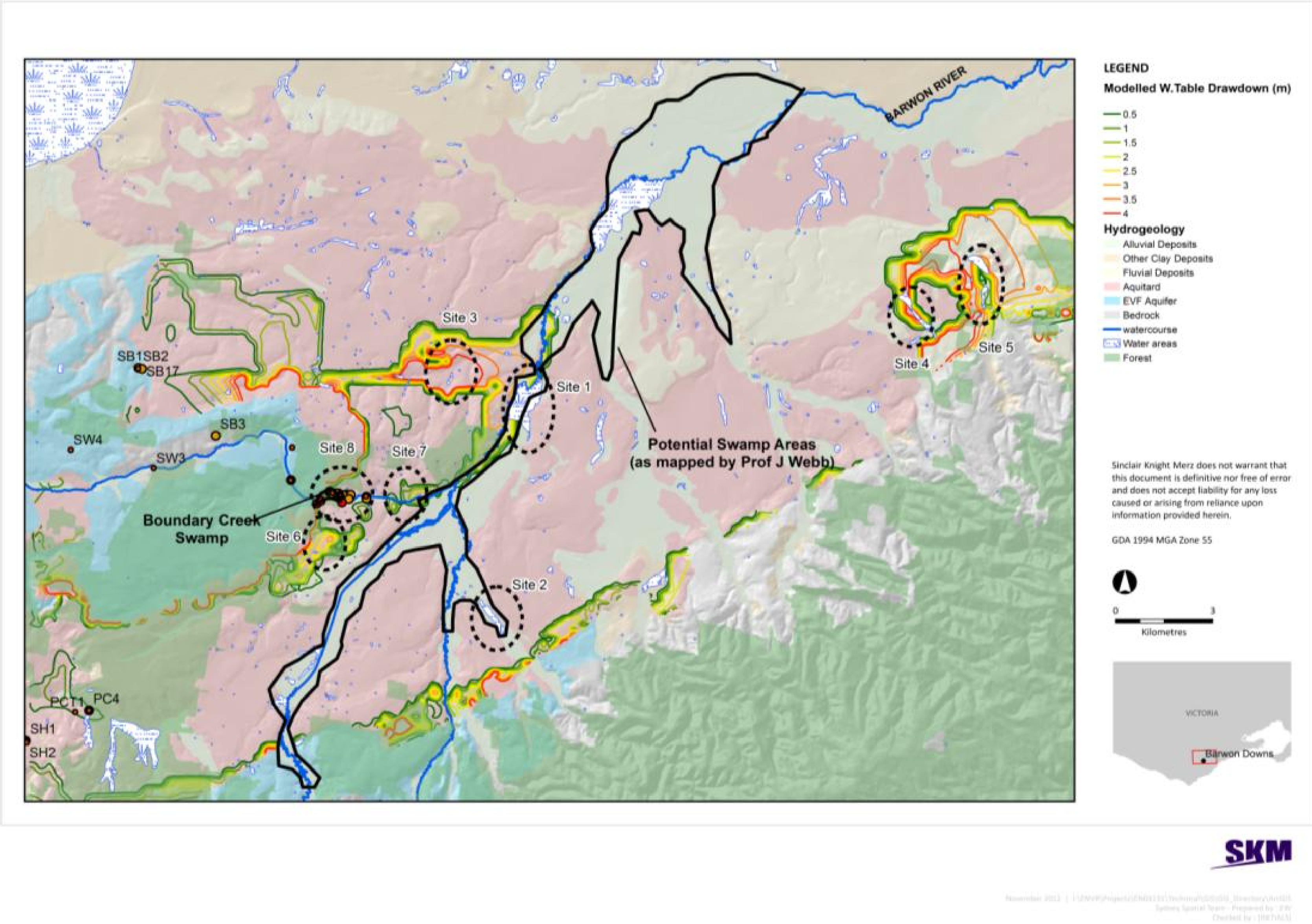
- major minerals and major elements
- loss on ignition percentages (indicative of the volatile components of the sample including organic matter content and water in clay)
- grain size analysis
- field oxidation and pH
- titratable actual acidity (acidity)
- chromium reducible sulphur (acidity)
- acid volatile sulfer (acidity)
- acid neutralising capacity

The Glover et al. (2011) study found actual acid sulfate soil (AASS) within a hypersulfidic horizon of low natural neutralising capacity. This was indicated by the presence of high acidity and iron staining. Chromium reducible sulfur (CRS), acid volatile sulfur (AVS) and titratable sulfidic acidity (TSA) analysis confirmed the presence of a large amount of potential acidity (sulfides yet to oxidise).

Further work undertaken by La Trobe University included mapping of a former extensive swamp region along the Barwon River that was caused by damming of the river by a basalt flow. The extent of the former swamp is shown in Figure 31 and it is considered to have the potential to be underlain by PASS. These PASS are not considered to be causing acid at present, however, it is important to understand whether they have potential to generate acidity if disturbed or dried out.



- **Figure 30 Previous soil and surface water sample points for PASS related to Boundary Creek Swamp**



- **Figure 31 Selected sites for field assessment of PASS**

3.7.2. Areas of PASS and Site Visit Locations

The assessment for potential ASS in the study area was initially informed by the review of previous work undertaken in the area (described above) and was then complimented by consideration of a number of other datasets that can inform likely areas of PASS. The following datasets were overlain for the study area:

- the mapped extent of the inferred Barwon River prior swamp area (as defined by Proj J Webb)
- areas of predicted groundwater drawdown (associated with the modelled scenario that adopts an aquitard Kv of 0.0001 m/day)
- geological setting
- geomorphical setting (from VicMap Hydro) including focus on areas defined as swamps, wetlands or inundated areas
- topography
- vegetation (i.e. cleared versus forested areas)

Table 20 provides a summary of the proposed site visit locations and includes the justification for selection of each and Figure 31 shows the location of each site.

The Boundary Creek Swamp has been well researched in terms of PASS. Previous work undertaken by the Latrobe University (Associate Professor John Webb and PhD student Fiona Glover) indicates the swamp comprises approximately 2.5 m of 'peat' overlying 3.5 m of sands. The peat contains high natural sulphide levels and has become acidic (pH 3.5 to 4.5). The presence of sulphide means there is potential for more acid generation. Furthermore, there is no carbonate minerals present at the Swamp, which means the sediments have no ability to neutralise the acidity generated.

Additional ASS investigations undertaken in the area (LAWROC, 2011) included sample sites downstream of the Boundary Creek Swamp (Figure 30). Samples SB4 and SB7 (the most downstream sample points on Boundary Creek and occurring in the already cleared and drained area) revealed high levels of actual acidity and lower levels of potential acidity. Surface soil samples collected indicated high flow events that deposited dissolved components of the upstream (towards Boundary Creek Swamp) oxidation and / or acidification events. This implies there is potential for acid impacts here, however the acid is not generated at this location.

Based on these results it is considered that PASS at Boundary Creek Swamp is well understood and hence no further subsurface soil or surface sediment monitoring is recommended here. The Swamp will still be visited however (Site 8) to confirm site access should an observation bore be installed in this area. Site 7 has been proposed to confirm the absence of acid generation downstream of the swamp, particularly given the predicted potential groundwater drawdown in this area. The remaining sites of potential ASS (Sites 1-6) were selected based on intersection of the datasets described above (Table 20).

Shallow monitoring bores are not identified at any of these sites (including Boundary Creek Swamp) and hence areas for potential bore construction will also be considered during the site visit. From the previous work done in the Boundary Creek Swamp area, the drill depths ranged from 2.5 m (LAWROC, 2011) to 4.5 m (where the weathered bedrock was reached) (Glover and Webb, 2011). A rotary drill was used to drill the 4.5 m hole.

In summary, the visit to sites listed in Table 20 will be conducted to:

- field validate the site located by providing additional site observations on the likelihood that ASSs exist, or do not exist because of localised conditions (drains etc)
- locate sensible access to the site for a vehicle and locate suitable sample location that is most suitable for identify PASS
- locate sensible access to the site for a rotary drill rig, should the soil sampling exercise indicate a need for groundwater monitoring.

The output of the site visit will include documented observations and photographs of each site. It is unlikely that all sites will be recommended for sampling and hence the field visits will also be used to prioritise sites for further work.

Table 20 Summary of proposed sits for PASS site visits

Site Number	Reason for Site Visit Location
Site 1	▪ Intersects the area of former Barwon River swamp ▪ Intersects an area of potential groundwater drawdown (between 0-3m) ▪ Intersects a mapped water area (potentially a swamp area).
Site 2	▪ Intersects the area of former Barwon River swamp ▪ Intersects a mapped water area (potentially a swamp area).
Site 3	▪ Intersects an area of maximum potential groundwater drawdown (up to 4 m) ▪ Intersects a mapped water area (potentially a swamp area).
Site 4	▪ Intersects an area of maximum potential groundwater drawdown (up to 4 m) ▪ Intersects a mapped water area (potentially a swamp area).
Site 5	▪ Intersects an area of potential groundwater drawdown (up to 3.5 m) ▪ Intersects a mapped water area (potentially a swamp area).
Site 6	▪ Intersects and area of potential groundwater drawdown (between 2 – 2.5 m) ▪ Intersects a mapped water area (potentially a swamp area)
Site 7	▪ Area downstream of the Boundary Creek Swamp ▪ Intersects an area of potential groundwater drawdown (up to 2 m)
Site 8	▪ Access for potential observation bore installation

3.8. Hydrogeological Conceptualisation Around Numerical Model Boundaries

The purpose of this task is to investigate the adequacy of the conceptualisation of model hydro-stratigraphy around the (numerical) model boundaries. In particular the questions to be addressed are whether the extent of the aquifer around the model boundaries is sufficiently well defined in the following two areas:

- South-west boundary
- North east boundary

Aquifer boundaries are well defined around the borefield (due to the large number of bores in the area), however boundaries are potentially poorly defined towards the margins of the model. If the aquifer (extent and thickness) is not well characterised in this area the drawdown (and hence associated impacts) could be over or underestimated.

3.8.1. South-West Boundary (Ten Mile Creek - Porcupine Creek area)

The hydrogeology in this area is complex with the presence of faults, large variations in bedrock depth, and large changes in aquifer thickness. The significance of this area is that it connects the Barwon Downs and Gellibrand groundwater systems, so it is important for identifying effects of pumping on the Gellibrand groundwater system including the Gellibrand River.

Although there are a significant number of existing bores in this region, the complexity of the hydrogeology leads to a number of different possible conceptual models. This is further complicated with many bores having more than one stratigraphic log. Drilling additional bores would assist in clarifying the conceptual model, but this would require at least 4 bores. Drilling less than 4 bores is unlikely to provide any significant improvement of the conceptual model. Given the high cost of drilling (i.e. large depth) it is recommended that no additional bores be drilled, but the bore logs (including lithological, stratigraphic, and geophysical logs) be reviewed to ensure there is a consistent interpretation of aquifer and aquitard thicknesses and depths. Ideally this should be done for all bores in the project area. Obtaining lithological and geophysical logs from mineral exploration (coal) bores and geophysical profiles from mineral exploration is also recommended.

3.8.2. North-East Boundary (Birregurra area)

The hydrogeology of this area is dominated by the near vertical Birregurra Fault which is orientated approximately east-west and is downthrown on the north by approximately 200 to 300m, and the Colac Fault which is parallel to the Birregurra Fault to the west of Birregurra. To the east of Birregurra the Birregurra fault appears to completely truncate the aquifer, but only partially truncate west of Birregurra. The aquifer thins significantly on the north side of the fault, both east and west of Birregurra. The aquifer is postulated to be downthrown by approximately 50 m to the north of the Colac Fault, which is unlikely to fully truncate the aquifer. The Barongarook Fault runs NW from the bore field until it intersects the Colac Fault approximately 4 km east of Colac. This is postulated to offset the aquifer by approximately 50 m which would have minimal effect on groundwater flow near the bore field but may influence groundwater flow in the vicinity of Boundary Ck.

The current model represents the Birregurra fault as a complete barrier or no-flow boundary. This may be too strict an assumption in the area to the west of Birregurra, which may lead to an over-estimate of impacts on the south side of the fault and an under-estimate on the north side. Current modelling indicates that drawdown intersects the fault (and cannot pass the fault due it being a no-flow boundary) although the drawdown is small. There is no representation of the Colac and Barongarook Faults in the current model.

It is recommended that groundwater hydrographs on both sides of the Birregurra Fault and Colac Fault be reviewed to identify if the no-flow boundary is a suitable representation. Hydrographs should also be reviewed on both sides of the Barongarook Fault to identify an influence on groundwater flow. It is also recommended that the bore logs (including lithological, stratigraphic, and geophysical logs) be reviewed to ensure there is a consistent interpretation of aquifer and aquitard thicknesses and depths. A search for bores that are close to the Birregurra and Colac fault that might be suitable for conducting a pumping test to evaluate hydraulic connection across these faults is also recommended.

4. Site Assessment

To be completed following site visits to be undertaken in April

5. Finalising scope and costs of monitoring program

To be completed following the site assessments and workshop with Barwon water

6. Recommendations

To be completed following the site assessments and workshop with Barwon water

7. Conclusions

To be completed following the site assessments and workshop with Barwon water

8. References

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Environous (2008) *Selected fish surveys in the Barwon and Moorabool River catchments following the prolonged low flow period of 2006-2007.* Report by Environous for the Corangamite Catchment Management Authority.

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Appendix A GEDIS Lithological Logs

Bore ID	Type	Lith From (m)	Lith To (m)	Thick (m)	Lithological Description
47998	Geologist	12	19	7	FINE SAND + SILT WHITE YELLOW
47998	Geologist	0	7	7	MEDIUM SAND YELLOW RED + IRONSTONE + CLEAR QUARTZ FRAGMENTS
47998	Geologist	7	12	5	CLAYEY FINE SAND + SILT CALCAREOUS YELLOW WHITE
47998	Geologist	19	21	2	FINE SANDY CLAY
47998	Geologist	54	62	8	MUDSTONE BROWN GREY
47998	Geologist	32	41	9	CLAY + CLAYEY SILT GREY YELLOW
47998	Geologist	21	24	3	SANDY SILTSTONE BROWN
47998	Geologist	45	47	2	CLAYEY SILT WHITE
47998	Geologist	47	54	7	COARSE SAND + GRAVEL GREY WHITE
47998	Geologist	24	32	8	COARSE SAND +GRAVEL YELLOW WHITE GREY QUARTZ MILKY
47998	Geologist	41	45	4	COARSE SAND + GRAVEL WHITE GREY QUARTZ MILKY
47998	Driller	0	3	3	FINE RED SANDS
47998	Driller	3	25	22	FINE SANDY MOTTLED CLAYS
47998	Driller	25	34	9	FINE TO MEDIUM SANDS
47998	Driller	34	41	7	DENSE GREY CLAYS
47998	Driller	41	46	6	SANDY WHITE CLAYS
47998	Driller	54	62	9	SANDSTONE
47998	Driller	47	54	7	LARGE GRAVELS
47998	Driller	46	47	1	LARGE SANDS
48002	Driller	15	23	9	BLUE GREY SANDSTONE (JURASSIC)
48002	Driller	0	0	0	TOPSOIL
48002	Driller	7	9	3	MOTTLED CLAY
48002	Driller	1	7	6	YELLOW SANDY CLAY
48002	Driller	0	1	1	WHITE SANDY LOAM
48002	Driller	9	15	6	BLUEY GREY CLAY
64238	Geologist	0	5	5	SANDY CLAY ORANGE WHITE RED
64238	Geologist	5	11	6	SILTSTONE ORANGE FERRUGINIZED
64238	Geologist	11	17	7	MEDIUM SAND SLIGHTLY CLAYEY YELLOW
64238	Geologist	17	23	6	MEDIUM SAND CLAYEY RED
64238	Geologist	23	25	2	CLAY YELLOW WHITE
64238	Geologist	25	29	4	FINE MEDIUM SAND YELLOW
64238	Geologist	29	35	6	COARSE SAND WHITE
64238	Geologist	35	38	3	FINE MEDIUM SAND ORANGE
64238	Geologist	38	40	2	CLAY YELLOW GREY

Bore ID	Type	Lith From (m)	Lith To (m)	Thick (m)	Lithological Description
64238	Geologist	40	43	3	FINE SANDSTONE SLIGHTLY CLAYEY YELLOW
64238	Geologist	43	46	3	COARSE SAND CLAYEY RED
64238	Geologist	46	50	4	MEDIUM SAND CLAYEY RED
64238	Geologist	50	53	3	FINE SANDY CLAY WHITE YELLOW
64238	Geologist	53	70	17	FINE MEDIUM SAND CLAYEY RED YELLOW
64238	Geologist	70	71	1	CLAY MOTTLED RED GREY ORANGE
64238	Geologist	71	92	21	FINE MEDIUM SAND CLAYEY YELLOW RED
64238	Geologist	92	95	3	FINE SAND CLAYEY BROWN
64238	Geologist	95	98	2	FINE SAND GREY
64238	Geologist	98	99	1	SILTY CLAY
64238	Geologist	99	100	1	COAL
64238	Geologist	100	102	2	SILT + MUDSTONE INTERBEDDED BROWN BLAC
64238	Geologist	102	117	15	FINE TO VERY FINE SAND CLAYEY BROWN GR
64238	Geologist	117	123	6	BROWN COAL
64238	Geologist	123	127	4	SILT + MUDSTONE INTERBEDDED BROWN BLAC
64238	Geologist	127	132	6	SILTY CLAY LIGNEOUS BLACK
64238	Geologist	132	133	1	COAL
64238	Geologist	133	135	2	LIGNEOUS CLAY + COAL
64238	Geologist	135	139	3	MEDIUM SAND CLAYEY BLACK
64238	Geologist	139	143	4	SANDY CLAY DISTURBED GREY
64238	Geologist	143	147	4	MEDIUM SAND CLAYEY BLACK
64238	Geologist	147	148	1	FINE SAND CLAYEY BUFF WHITE
64238	Geologist	148	153	5	MEDIUM SAND CLAYEY BLACK BROWN
64238	Geologist	153	157	4	MEDIUM COARSE SAND BROWN GREY
64238	Driller	0	2	2	BROWN & GREY MOTTLE CLAY
64238	Driller	2	5	3	RED & GREY MOTTLE CLAY
64238	Driller	5	19	15	BROWN CLAYEY SAND
64238	Driller	19	23	4	ORANGE CLAYEY SAND
64238	Driller	23	25	2	ORANGE & GREY SANDY CLAY
64238	Driller	25	29	4	MEDIUM SAND ORANGE
64238	Driller	29	35	6	MEDIUM SAND GREY
64238	Driller	35	38	3	ORANGE CLAYEY SAND
64238	Driller	38	40	2	ORANGE & GREY MOTTLE CLAY
64238	Driller	40	46	6	FINE SAND & GRAVEL GREY
64238	Driller	46	50	4	FINE SAND & GRAVEL ORANGE
64238	Driller	50	53	3	YELLOW & GREY CLAYEY SAND
64238	Driller	53	70	17	BROWN CLAYEY SAND

Bore ID	Type	Lith From (m)	Lith To (m)	Thick (m)	Lithological Description
64238	Driller	70	71	1	ORANGE & GREY MOTTLE CLAY
64238	Driller	71	77	6	FINE GREY SAND
64238	Driller	77	92	15	FINE YELLOW SAND
64238	Driller	92	95	3	FINE BROWN SAND
64238	Driller	95	98	2	FINE GREY SAND
64238	Driller	98	99	1	LIGNEOUS CLAY
64238	Driller	99	100	1	BROWN COAL
64238	Driller	100	102	2	LIGNEOUS CLAY
64238	Driller	102	117	15	FINE GREY CLAYEY SAND
64238	Driller	117	124	7	BROWN COAL
64238	Driller	124	132	9	LIGNEOUS CLAY
64238	Driller	132	133	1	BROWN COAL
64238	Driller	133	135	2	LIGNEOUS CLAY
64238	Driller	135	139	3	GREY CLAYEY SAND
64238	Driller	139	143	4	LIGNEOUS CLAY
64238	Driller	143	147	4	BROWN CLAYEY SAND
64238	Driller	147	148	1	GREY SANDY CLAY
64238	Driller	148	153	5	BROWN CLAYEY SAND
64238	Driller	153	157	4	MEDIUM SAND
64239	Geologist	0	0	0	TOP SOIL
64239	Geologist	0	2	2	BROWISH SANDY CLAY
64239	Geologist	2	4	2	ORANGE GREY FINE SANDY CLAY
64239	Geologist	4	6	2	ORANGE PINK MOTTLED VERY FINE SANDY CL AY
64239	Geologist	6	9	3	YELLOW GREY MOTTLED FINE SANDY CLAY
64239	Geologist	9	19	10	WHITE SAND FINE WELL SORTED ROUNDED M ICACEOUS
64239	Geologist	19	28	9	PALE YELLOW SAND FINE WELL SORTED ROUN DED MICACEOUS
64239	Geologist	28	31	4	PINK FINE SAND WELL SORTED ROUNDED MIC ACEOUS
64239	Geologist	31	36	5	PALE YELLOW FINE SAND AS ABOVE
64239	Geologist	36	39	3	YELLOW CLAYEY SAND FINE
64239	Geologist	39	43	4	PALE YELLOW SILTY CLAY
64239	Geologist	43	46	3	DARK GREY SILTY CLAY
64239	Geologist	46	48	2	LIGHT GREY MEDIUM SANDY CLAY
64239	Geologist	48	50	2	GREY WHITE SAND MEDIUM MODERATELY WELL SORTED SUBANGULAR
64239	Geologist	50	53	3	GREY SILTY CLAY
64239	Geologist	53	56	3	LIGHT GREY CLAY
64239	Geologist	56	57	2	LIGHT BROWN SILTY CLAY

Bore ID	Type	Lith From (m)	Lith To (m)	Thick (m)	Lithological Description
64239	Geologist	57	61	4	LIGHT BROWN CLAYEY SAND
64239	Geologist	61	63	2	WHITE COARSE SAND MODERATELY WELL SORT ED SUBANGULAR
64239	Geologist	63	64	1	GREY LIGNEOUS CLAY
64239	Geologist	64	70	6	GREY COARSE GRAVEL & CLAY
64239	Geologist	70	72	2	GREY COARSE GRAVEL
64239	Geologist	72	73	1	GREY SILTY CLAY
64239	Geologist	73	76	3	GREY MUDSTONE
64239	Geologist	76	90	14	GREEN GREY SILTY CLAY WITH PLANT REMAI NS
64239	Driller	0	0	0	TOPSOIL
64239	Driller	0	2	2	BROWNISH CLAY
64239	Driller	2	4	2	ORANGE & GREY CLAY
64239	Driller	4	6	2	BROWN RED & GREY MOTTLE CLAY
64239	Driller	6	9	3	BROWN & GREY MOTTLE CLAY
64239	Driller	9	17	7	FINE YELLOW SAND
64239	Driller	17	19	3	FINE GREY SAND
64239	Driller	19	28	9	FINE YELLOW SAND
64239	Driller	28	31	4	FINE PINK SAND
64239	Driller	31	36	5	FINE ORANGE SAND
64239	Driller	36	39	3	YELLOW CLAYEY SAND
64239	Driller	39	43	4	ORANGE & GREY SANDY CLAY
64239	Driller	43	46	3	DARK GREY SILTY CLAY
64239	Driller	46	48	2	GREY CLAYEY SAND
64239	Driller	48	50	2	FINE BROWN SAND
64239	Driller	50	56	6	LIGNEOUS CLAY
64239	Driller	56	57	2	LIGHT BROWN SANDY CLAY
64239	Driller	57	61	4	LIGHT BROWN CLAYEY SAND
64239	Driller	61	63	2	COARSE SAND
64239	Driller	63	64	1	LIGNEOUS CLAY
64239	Driller	64	70	6	COARSE GRAVEL & CLAY
64239	Driller	70	72	2	COARSE GRAVEL
64239	Driller	72	73	1	GREY CLAY
64239	Driller	73	76	3	MUDSTONE
64239	Driller	76	90	14	MUDSTONE BEDROCK
64243	Driller	0	1	1	TOPSOIL
64243	Driller	1	1	1	COFFEE ROCK
64243	Driller	1	14	13	YELLOW SANDY CLAY
64243	Driller	14	14	1	MOTTLED CLAY

Bore ID	Type	Lith From (m)	Lith To (m)	Thick (m)	Lithological Description
64243	Driller	14	20	6	LIGHT GREY CLAY
64243	Driller	20	30	11	GRAVELLY LIGHT GREY CLAY
64243	Driller	30	32	2	QUARTZ GRAVELS LARGE
64243	Driller	32	44	13	GREY SANDY CLAY
64243	Driller	44	50	6	GREY CLAY
64243	Driller	50	63	13	LIGENOUS DARKER GREY CLAY
64243	Driller	63	73	10	GREY TO BLUEY SANDY CLAY
64243	Driller	73	73	0	CARBONACEOUS DARK GREY CLAY
64243	Driller	73	77	4	MUDSTONE VERY HARD
64243	Driller	77	77	0	MUDSTONE VERY HARD
64243	Driller	77	79	2	DARK GREY CLAY (MUDSTONE FIRM)
64243	Driller	79	81	2	DARK LIGNEOUS CLAY (CARBONACEOUS)
64243	Driller	81	88	7	LIGHT GREY LIGNEOUS CLAY (FIRM)
64243	Driller	88	89	1	DARK LIGNEOUS CLAY
64243	Driller	89	92	3	LIGHT GREY CLAY (BASEMENT)
109108	Driller	0	0	0	BLACK SANDY LOAM
109108	Driller	0	5	5	SAND AND YELLOW CLAY
109108	Driller	5	7	2	WHITE SANDY CLAY
109108	Driller	7	9	2	SAND FINE WHITE
109108	Driller	9	12	3	YELLOW CLAY
109110	Geologist	0	3	3	SAND FINE MICACEOUS & GRAVEL RED WHITE + IRONSTONE PEBBLES
109110	Geologist	3	6	3	SAND FINE MICACEOUS RED WHITE
109110	Geologist	6	21	15	SAND FINE MICACEOUS WHITE MINOR CLAYS
109110	Geologist	21	27	6	CLAY WHITE ORAGE MINOR FINE SAND
109110	Geologist	27	30	3	SAND MEDIUM FINE + BROWN LIGNEOUS CLAY
109110	Geologist	30	35	5	COAL
109110	Geologist	35	50	15	SAND FINE MICACEOUS WHITE GREY
109110	Geologist	50	55	5	COAL
109110	Geologist	55	62	7	SAND FINE MEDIUM
109110	Geologist	62	67	5	CLAY LIGNEOUS GREY
109110	Geologist	67	69	2	SAND MEDIUM WHITE
109110	Geologist	69	72	3	CLAY LIGNEOUS
109110	Geologist	72	75	3	SAND COARSE GREY
109110	Geologist	75	78	3	SAND FINE + SILTSTONE
109110	Geologist	78	90	12	SAND COARSE + GRAVEL GREY
109110	Geologist	90	97	7	CLAY + GRAVEL GREY

Bore ID	Type	Lith From (m)	Lith To (m)	Thick (m)	Lithological Description
109110	Geologist	97	98	1	SILTY SANDSTONE GREEN GRAY
109110	Driller	0	0	0	SANDY SURFACE SOIL
109110	Driller	0	1	1	SAND WHITE FINE
109110	Driller	1	17	16	LIMESTONE DECOMPOSED
109110	Driller	17	23	7	CLAY YELLOW SANDY
109110	Driller	23	29	6	CLAY LIMEY WHITE
109110	Driller	29	31	2	GREY SANDY CLAY
109110	Driller	31	35	4	BROWN COAL
109110	Driller	35	51	16	GREY CLAY
109110	Driller	51	62	11	BROWN COAL
109110	Driller	62	67	5	COAL & BLACK CLAY
109110	Driller	67	70	3	SAND FINE TO MEDIUM
109110	Driller	70	73	3	GREY CLAY
109110	Driller	73	76	3	SAND MEDIUM
109110	Driller	76	81	5	GREY CLAY
109110	Driller	81	92	11	COARSE SAND
109110	Driller	92	99	7	WHITE CLAY
109111	Driller	0	0	0	SANDY SURFACE SOIL
109111	Driller	0	2	2	WHITE SAND
109111	Driller	2	17	15	DECOMPOSED LIMESTONE
109111	Driller	17	20	3	YELLOW SANDY CLAY
109111	Driller	20	23	3	WHITE LIMEY CLAY
109111	Driller	23	28	5	FINE WHITE SAND
109111	Driller	28	30	3	CLAY BROWN LIGNEOUS & COAL
109111	Driller	30	35	5	CLAY SANDY GREY
109111	Driller	35	42	7	SAND FINE GREY
109115	Geologist	0	3	3	SAND MEDIUM COARSE YELLOW WHITE + IRON STONE PEBBLES
109115	Geologist	3	6	3	SAND MEDIUM COARSE CLAYEY WHITE
109115	Geologist	6	16	10	SAND FINE MICACEOUS WHITE
109115	Geologist	16	19	3	SAND FINE SILTY MICACEOUS GREY + IRONS TONE PEBBLES & QUARTZ GRAVEL
109115	Geologist	19	42	23	SAND FINE MICACEOUS WHITE
109115	Geologist	42	45	3	SAND FINE SILTY MICACEOUS GREY + MINOR CLAY & IRONSTONE
109115	Geologist	45	48	3	SAND FINE MICACEOUS WHITE + MINOR IRON STONE FRAGMENTS
109115	Geologist	48	51	3	SAND FINE SILTY MICACEOUS WHITE
109115	Geologist	51	54	3	SAND FINE MEDIUM SILTY MICACEOUS GREY + LIGNEOUS FRAGMENTS
109115	Geologist	54	56	2	CLAY LIGNEOUS

Bore ID	Type	Lith From (m)	Lith To (m)	Thick (m)	Lithological Description
109115	Geologist	56	69	13	SAND FINE MEDIUM SILTY MICACEOUS
109115	Geologist	69	71	2	CLAY LIGNEOUS
109115	Geologist	71	75	4	COAL
109115	Geologist	75	78	3	SAND FINE SILTY MICACEOUS GREY BLACK + LIGNEOUS FRAGMENTS
109115	Geologist	78	81	3	SAND MEDIUM COARSE WHITE
109115	Geologist	81	87	6	SAND FINE SILTY GREY + WHITE CLAY + LI NEOUS MATTER
109115	Geologist	87	93	6	COAL
109115	Geologist	93	96	3	SAND MEDIUM GREY
109115	Geologist	96	99	3	SAND FINE SILTY GREY
109115	Geologist	99	103	4	SAND COARSE & GRAVEL GREY GRADED
109115	Geologist	103	104	1	CLAY DENSE GREY
109115	Geologist	104	120	17	SAND COARSE & GRAVEL
109115	Geologist	120	123	3	SILTSTONE GREEN GREY
109115	Driller	0	1	1	BLACK SANDS
109115	Driller	1	5	4	RED SANDS
109115	Driller	5	6	1	SANDY MOTTLED CLAYS
109115	Driller	6	20	14	FINE WHITE SANDS
109115	Driller	20	21	1	GREY SANDY CLAYS
109115	Driller	21	45	24	VERY FINE WHITE SANDS
109115	Driller	45	50	5	GREY SANDY CLAYS
109115	Driller	50	51	1	GREY CLAYS
109115	Driller	51	52	1	GREY SANDY CLAYS
109115	Driller	52	57	5	LIGNEOUS STRATA WOOD ETC
109115	Driller	57	58	1	VERY DENSE LIGNEOUS CLAYS
109115	Driller	58	71	13	SANDY GREY CLAYS
109115	Driller	71	73	2	VERY DENSE LIGNEOUS CLAYS
109115	Driller	73	76	4	SANDY LIGNEOUS CLAYS & COAL
109115	Driller	76	88	12	GREY SANDY CLAYS
109115	Driller	88	94	6	LIGNEOUS CLAYS COAL ETC
109115	Driller	94	98	4	FINE SANDS
109115	Driller	98	99	1	GREY CLAYS
109115	Driller	99	103	4	FINE TO MEDIUM SANDS
109115	Driller	103	104	1	DENSE GREY CLAYS
109115	Driller	104	115	12	FINE TO MEDIUM SANDS
109115	Driller	115	118	3	GRAVELS
109115	Driller	118	124	6	SANDSTONE

Bore ID	Type	Lith From (m)	Lith To (m)	Thick (m)	Lithological Description
109120	Geologist	0	1	1	SANDY SOIL BROWN
109120	Geologist	1	2	1	SAND FINE TO MEDIUM CLAYEY BROWN
109120	Geologist	2	3	1	SAND FINE TO MEDIUM CLAYEY RED BROWN
109120	Geologist	3	3	1	SANDY CLAY FINE GREY
109120	Geologist	3	4	1	SAND MEDIUM CLAYEY ORANGE
109120	Geologist	4	6	1	SAND FINE CLAYEY ORANGE
109120	Geologist	6	7	1	SAND FINE CLAYEY ORANGE & WELL ROUNDED QUARTZ & IRONSTONE PEBBLES
109120	Geologist	7	9	2	FINE SANDY CLAY ORANGE BROWN
109120	Geologist	9	16	7	SAND FINE CLAYEY GREY BROWN
109120	Driller	0	1	1	SAND
109120	Driller	1	9	8	SILTY CLAY
109120	Driller	9	16	7	SILT & SAND
109121	Geologist	0	1	1	SANDY SOIL BROWN
109121	Geologist	1	2	1	CLAYEY FINE SAND TO FINE SANDY CLAY BROWN
109121	Geologist	2	3	1	CLAYEY FINE SAND & SANDY CLAY REDBROWN
109121	Geologist	3	4	1	FINE SANDY CLAY GREY
109121	Geologist	4	5	1	SAND FINE CLAYEY RED & IRONSTONE PEBBL ES
109121	Geologist	5	6	1	SAND FINE CLAYEY RED & ROUNDED QUARTZ & IRONSTONE PEBBLES
109121	Geologist	6	7	1	VERY FINE SANDY CLAY WHITE YELLOW
109121	Geologist	7	8	1	FINE SANDY CLAY BROWN
109121	Geologist	8	9	1	FINE SANDY CLAY TO CLAYEY SAND YELLOW BROWN
109121	Geologist	9	15	6	SAND FINE CLAYEY YELLOW BROWN
109121	Driller	0	1	1	SAND
109121	Driller	1	4	3	CLAY
109121	Driller	4	6	2	GRAVEL
109121	Driller	6	8	2	SILTY CLAY
109121	Driller	8	16	8	SANDY CLAY
109123	Geologist	0	1	1	SAND FINE BROWN
109123	Geologist	1	3	2	SAND COARSE & GRAVEL WITH RED FINE SANDY CLAY
109123	Geologist	3	4	1	SAND MEDIUM VERY CLAYEY RED IRONSTONE AT BASE
109123	Driller	0	4	4	GRAVEL & ROCK
109124	Geologist	0	1	1	SAND FINE TO MEDIUM SLIGHTLY CLAYEY BROWN
109124	Geologist	1	3	2	SAND FINE TO MEDIUM & IRONSTONE PEBBLE
109124	Geologist	3	5	3	SAND FINE TO MEDIUM SLIGHTLY CLAYEY
109124	Geologist	5	6	1	RED IRONSTONE AT BASE
109124	Driller	0	3	3	SAND & GRAVEL

Bore ID	Type	Lith From (m)	Lith To (m)	Thick (m)	Lithological Description
109124	Driller	3	3	1	SAND & WATER
109124	Driller	3	6	3	GRAVEL & ROCK
109125	Geologist	0	2	2	FERRUGINIZED SANDSTONE
109125	Geologist	2	3	1	SAND MEDIUM CLAYEY RED
109125	Geologist	3	4	1	SANDY CLAY GREY
109125	Geologist	4	5	1	SAND MEDIUM CLAYEY RED
109125	Geologist	5	15	10	SAND FINE TO MEDIUM CLAYEY RED
109125	Geologist	15	16	1	SAND MEDIUM CLAYEY BROWN
109125	Geologist	16	18	2	SAMPLE MISSING
109125	Geologist	18	19	1	SAND FINE MEDIUM CLAYEY YELLOW
109125	Geologist	19	20	1	SAND FINE CLAYEY YELLOW
109125	Geologist	20	21	1	SAND FINE MEDIUM WHITE
109125	Geologist	21	23	3	SAND FINE WHITE
109125	Driller	0	2	2	FINE SAND
109125	Driller	2	7	5	SILTY SAND
109125	Driller	7	8	1	FINE SAND
109125	Driller	8	16	8	SANDY CLAY
109125	Driller	16	16	1	BLACK CLAY
109125	Driller	16	24	8	SILTY CLAY
109126	Geologist	0	1	1	SAND FINE ORGANIC BLACK GREY
109126	Geologist	1	2	1	SAND FINE BROWN
109126	Geologist	2	10	9	SAND FINE MICACEOUS SLIGHTLY CLAYEY WHITE YELLOW
109126	Geologist	10	11	1	SAND FINE MICACEOUS GREY
109126	Geologist	11	11	1	SILTY CLAY MICACEOUS STIFF BROWN
109126	Geologist	11	12	1	FINE SANDY CLAY MICACEOUS STIFF BROWN
109126	Geologist	12	18	7	SILTY CLAY FINE SANDY CLAY MICACEOUS BROWN
109126	Geologist	18	22	4	SAND FINE CLAYEY MICACEOUS BROWN GREY & ROUNDED QUARTZ PEBBLES
109126	Geologist	22	22	1	FINE SANDY CLAY MICACEOUS BROWN
109126	Geologist	22	27	5	SAND FINE CLAYEY MICACEOUS BROWN GREY
109126	Geologist	27	28	2	FINE SANDY CLAY BROWN GREY
109127	Geologist	0	5	5	CLAY CHARCOAL BLACK STICKY
109127	Geologist	5	5	0	CLAY STIFF BLACK
109127	Geologist	5	5	1	SAND FINE GREY
109127	Geologist	5	6	0	SANDY CLAY BLACK
109127	Geologist	6	6	0	SAND FINE GREY
109127	Geologist	6	6	0	SAND FINE GREY & LARGE ROUND QUARTZ PEBBLES

Bore ID	Type	Lith From (m)	Lith To (m)	Thick (m)	Lithological Description
109127	Geologist	6	6	0	CLAY & CHARCOAL BLACK PEATY Z ROUNDED QUARTZ
109127	Geologist	6	7	1	SILTY CLAY BLACK BROWN ORGANIC
109127	Geologist	7	8	1	SILTY CLAY BLACK BROWN & ROUNDED QTZ
109127	Geologist	8	9	1	SILTY CLAY BLACK BROWN
109127	Geologist	9	10	1	SILTY CLAY BLACK BROWN & ROUNDED QTZ
109127	Geologist	10	10	1	CLAY COAL PEATY BLACK
109127	Geologist	10	12	2	SILTY CLAY LIGNEOUS SOFT TO FIRM
109127	Geologist	12	13	2	SAND FINE CLAYEY GREY BROWN MICACEOUS
109127	Geologist	13	22	9	SAND FINE MEDIUM GREY BROWN FLECKS CARBONACEOUS MATERIAL
109127	Geologist	22	27	5	CLAY DARK BROWN SOFT LIGNEOUS SILTY MICACEOUS
109128	Geologist	0	1	1	SAND FINE SILTY GREY
109128	Geologist	1	9	9	SAND FINE CLAYEY MICACEOUS GREY YELLOW
109128	Geologist	9	12	3	SAND FINE CLAYEY MICACEOUS YELLOW GREY MOTTLED
109128	Geologist	12	20	8	SILTY CLAY MICACEOUS SOFT TO STIFF DARK BROWN
109128	Geologist	20	26	6	SAND FINE SLIGHTLY CLAYEY MICACEOUS BROWN GREY
109128	Geologist	26	28	3	SAND VERY FINE GREY YELLOW
109128	Geologist	28	29	1	CLAY STIFF MICACEOUS DARK BROWN
109128	Geologist	29	30	1	FINE SANDY CLAY MICACEOUS BROWN GREY
109129	Geologist	0	1	1	SAND SILTY BROWN FINE
109129	Geologist	1	2	1	SAND FINE TO VERY FINE BROWN ORANGE
109129	Geologist	2	17	16	SAND FINE TO VERY FINE SLIGHTLY CLAYEY MICACEOUS YELLOW BROWN
109129	Geologist	17	19	2	CLAYEY SAND SANDY CLAY MICACEOUS YELLO W & BLACK MOTTLED
109129	Geologist	19	21	2	CLAY STIFF BLACK BROWN
109129	Geologist	21	21	1	SAND FINE CLAYEY BROWN
109129	Geologist	21	24	3	CLAY FINE SANDY WITH CHARCOAL PIECES
109130	Geologist	0	1	1	SILTY CLAY STIFF DARK BROWN
109130	Geologist	1	4	3	FINE SANDY CLAY SOFT MICACEOUS YELLOW BROWN
109130	Geologist	4	9	6	SAND FINE SLIGHTLY CLAYEY CLAYEY GREY BROWN
109130	Geologist	9	10	1	SAND VERY FINE MICACEOUS GREY BROWN
109130	Geologist	10	10	1	FINE SANDY CLAY DARK BROWN GREY MOTTLE
109130	Geologist	10	15	5	CLAY STIFF BLACK TO FINE SANDY DARK BR OWN GREY
109130	Geologist	15	20	5	SAND FINE MEDIUM CLAYEY BROWN GREY
109130	Geologist	20	21	1	FINE SANDY CLAY DARK BROWN GREY
109130	Geologist	21	24	3	CLAY PEATY STIFF BLACK BROWN
109131	Geologist	0	1	1	FINE SANDY SOIL BLACK + PLANT REMAINS
109131	Geologist	1	3	2	FINE SANDY CLAY BROWN WHITE

Bore ID	Type	Lith From (m)	Lith To (m)	Thick (m)	Lithological Description
109131	Geologist	3	9	6	VERY FINE CLAYEY SAND MICACEOUS YELLOW
109131	Geologist	9	11	2	CLAY YELLOW
109131	Geologist	11	17	6	FINE SAND MICACEOUS WHITE
109131	Geologist	17	22	5	FINE SAND MICACEOUS WHITE + CLAY
109131	Geologist	22	25	4	LIGNEOUS CLAY BROWN
109131	Geologist	25	28	3	BLACK COAL
109131	Geologist	28	33	5	FINE MICACEOUS SAND GREY
109131	Geologist	33	37	4	MEDIUM COARSE SAND GREY ANGULAR
109131	Geologist	37	41	4	BLACK COAL + LIGNEOUS CLAY
109131	Geologist	41	45	4	BLACK COAL
109131	Geologist	45	51	6	DENSE LIGNEOUS CLAY BROWN
109131	Geologist	51	54	3	LIGNEOUS CLAY BLACK COAL + FINE SAND
109131	Geologist	54	58	4	FINE SAND GREY
109131	Geologist	58	60	2	SANDY CLAY
109131	Geologist	60	61	2	FINE MEDIUM SAND
109131	Geologist	61	63	2	SANDY CLAY GREY
109131	Geologist	63	66	4	COARSE SAND ANGULAR GREY
109131	Geologist	66	68	2	DENSE LIGNEOUS CLAY GREY
109131	Geologist	68	70	2	FINE MEDIUM GREY SAND ANGULAR
109131	Geologist	70	77	7	COARSE GRAVEL GREY
109131	Geologist	77	84	7	SILTSTONE BLUE GREY
109131	Driller	0	1	1	BLACK SANDY TOPSOIL
109131	Driller	1	4	3	BROWN & WHITE SANDS
109131	Driller	4	5	1	FINE YELLOW SANDS
109131	Driller	5	6	1	FINE ORANGE SANDS
109131	Driller	6	10	4	FINE YELLOW - ORANGE SANDS
109131	Driller	10	10	0	YELLOW CLAYS
109131	Driller	10	15	5	FINE WHITE SANDS
109131	Driller	15	20	5	FINE WHITE SANDY CLAYS
109131	Driller	20	24	4	LIGNEOUS STRATUM
109131	Driller	24	26	2	LIGNEOUS CLAYS
109131	Driller	26	28	2	COAL
109131	Driller	28	39	11	FINE SANDS
109131	Driller	39	48	9	COAL LIGNEOUS ETC
109131	Driller	48	48	1	FINE SANDS
109131	Driller	48	52	4	DENSE LIGNEOUS CLAYS
109131	Driller	52	54	2	SANDY LIGNEOUS CLAYS

Bore ID	Type	Lith From (m)	Lith To (m)	Thick (m)	Lithological Description
109131	Driller	54	60	6	FINE TO MEDIUM SANDS
109131	Driller	60	60	1	SANDY CLAYS
109131	Driller	60	62	2	FINE TO MEDIUM SANDS
109131	Driller	62	63	1	SANDY GREY CLAYS
109131	Driller	63	67	5	FINE TO MEDIUM SANDS
109131	Driller	67	68	1	DENSE LIGNEOUS CLAYS
109131	Driller	68	78	11	FINE TO MEDIUM SANDS TO MEDIUM TO FINE TO COARSE GRAVELS
109131	Driller	78	87	9	SANDSTONE
109132	Geologist	0	1	1	PALE YELLOW COARSE SANDY CLAY
109132	Geologist	1	2	1	RED BROWN COARSE SANDY CLAY
109132	Geologist	2	5	3	RED FINE SANDY CLAY
109132	Geologist	5	9	4	RED YELLOW WHITE MOTTLED FINE SANDY CL
109132	Geologist	9	12	3	YELLOW COARSE SANDY CLAY
109132	Geologist	12	15	3	RED YELLOW WHITE MOTTLED FINE SANDY CL
109132	Geologist	15	23	8	YELLOW CLAY VERY FINE SAND
109132	Geologist	23	25	2	PALE YELLOW WHITE CLAY
109132	Geologist	25	28	3	YELLOW CLAYEY VERY FINE SAND
109132	Geologist	28	31	3	PALE YELLOW VERY FINE SAND
109132	Geologist	31	34	3	YELLOW VERY FINE SAND
109132	Geologist	34	37	3	PALE YELLOW VERY FINE SAND
109132	Geologist	37	41	4	WHITE VERY FINE SAND
109132	Geologist	41	43	2	YELLOW VERY FINE SAND
109132	Geologist	43	46	3	GREY SILTY MICACEOUS CLAY
109132	Geologist	46	52	6	PINK RED VERY FINE SAND
109132	Geologist	52	56	4	GREY CLAYEY VERY FINE SAND WITH BANDS CLAY
109132	Geologist	56	56	1	BROWN COAL
109132	Geologist	56	58	2	GREY LIGNEOUS CLAY
109132	Geologist	58	61	3	BROWN CLAYEY VERY FINE SAND
109132	Geologist	61	71	10	REDDISH CLAYEY VERY FINE SAND
109132	Geologist	71	77	6	GREY SILTY MICACEOUS CLAY
109132	Geologist	77	79	2	BLACK COAL
109132	Geologist	79	83	4	BLACK MICACEOUS LIGNEOUS CLAY
109132	Geologist	83	90	7	GREY SILTY MICACEOUS CLAY
109132	Geologist	90	93	3	GREY MEDIUM COARSE SAND WELL SORTED SU BANGULAR
109132	Geologist	93	95	2	BROWN MEDIUM SAND + BANDS OF CLAY
109132	Geologist	95	100	5	LIGHT GREY SILTY CLAY

Bore ID	Type	Lith From (m)	Lith To (m)	Thick (m)	Lithological Description
109132	Geologist	100	101	1	GREY MEDIUM COARSE SAND WELL SORTED SU BANGULAR
109132	Geologist	101	103	2	GREY SILTY CLAY
109132	Geologist	103	104	1	GREY MEDIUM SAND WELL SORTED SUBANGULA
109132	Geologist	104	105	1	BROWN GREY SILTY CLAY
109132	Geologist	105	111	6	MEDIUM COARSE SAND GREY MODERATELY WEL SORTED SUBANGULAR
109132	Geologist	111	112	1	GREY CLAY
109132	Geologist	112	114	3	GREY WHITE COARSE GRAVEL + PEBBLES
109132	Geologist	114	123	9	BLUE GREY SILTY CLAY & COAL PIECES
109132	Driller	0	1	1	TOPSOIL
109132	Driller	1	2	1	BROWN CLAY
109132	Driller	2	6	4	ORANGE YELLOW & GREY MOTTLE CLAY
109132	Driller	6	15	9	ORANGE RED & GREY SANDY CLAY
109132	Driller	15	22	7	YELLOW CLAYEY SAND
109132	Driller	22	23	1	YELLOW CLAYEY SAND
109132	Driller	23	25	2	YELLOW & GREY CLAY
109132	Driller	25	37	12	FINE YELLOW SAND
109132	Driller	37	41	4	FINE GREY SAND
109132	Driller	41	43	2	FINE YELLOW SAND
109132	Driller	43	46	3	DARK GREY CLAY
109132	Driller	46	52	6	PINKISH SAND
109132	Driller	52	56	4	GREY SAND & BANDS OF CLAY
109132	Driller	56	56	1	BROWN COAL
109132	Driller	56	58	2	LIGNEOUS CLAY
109132	Driller	58	59	1	BROWN CLAYEY SAND
109132	Driller	59	71	12	FINE GREY CLAYEY SAND
109132	Driller	71	77	6	DARK GREY CLAY
109132	Driller	77	79	2	BROWN COAL
109132	Driller	79	83	4	LIGNEOUS CLAY
109132	Driller	83	84	1	BROWN COAL
109132	Driller	84	90	6	LIGNEOUS CLAY
109132	Driller	90	93	3	MEDIUM SAND
109132	Driller	93	95	2	MEDIUM SAND & BANDS OF CLAY
109132	Driller	95	100	5	LIGHT GREY CLAY
109132	Driller	100	101	2	MEDIUM SAND
109132	Driller	101	103	2	DARK GREY CLAY
109132	Driller	103	104	1	MEDIUM SAND

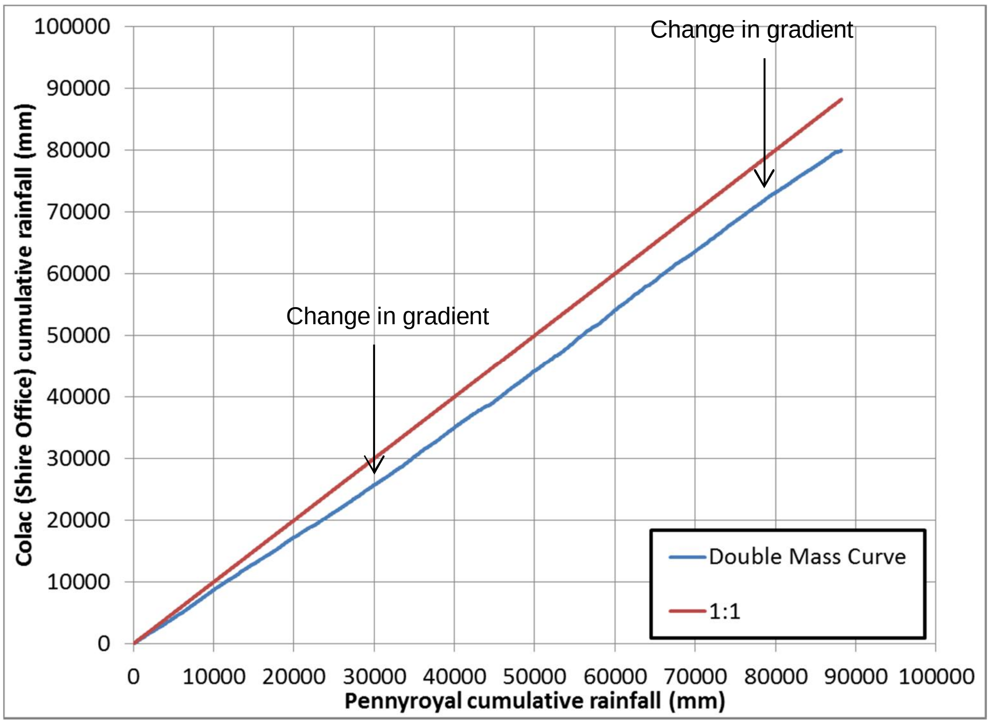
Bore ID	Type	Lith From (m)	Lith To (m)	Thick (m)	Lithological Description
109132	Driller	104	105	1	DARK GREY CLAY
109132	Driller	105	111	6	COARSE SAND
109132	Driller	111	112	1	DARK GREY CLAY
109132	Driller	112	116	5	COARSE GRAVEL & STONES
109132	Driller	116	117	1	BEDROCK
109132	Driller	117	123	7	BEDROCK
109136	Driller	0	1	1	TOPSOIL
109136	Driller	1	4	3	BROWN CLAY
109136	Driller	4	5	1	GREY CLAY
109136	Driller	5	5	0	FINE SAND
109136	Driller	5	5	0	COAL
109136	Driller	5	8	3	QUARTZ SANDS CLAY BOUND
109136	Driller	8	10	2	DARK BROWN CLAY (SOFT)
109136	Driller	10	15	5	QUARTZ SANDS
109136	Driller	15	16	1	WHITE SANDY CLAY
109136	Driller	16	26	11	QUARTZ SAND AND YELLOW BAND CLAY
109136	Driller	26	28	2	GREY CARBONACEOUS CLAY
109136	Driller	28	29	1	DARK CARBONACEOUS CLAY
109136	Driller	29	31	2	LIGHT GREY CLAY
109136	Driller	31	34	4	BLUEY GREY SANDY CLAY
109136	Driller	34	37	3	JURASSIC-CORED 35.30 TO 37.00M BLUEY G REY MUDSTONE
109139	Driller	0	4	4	CLAY
109139	Driller	4	11	7	SANDY CLAY
109140	Driller	0	4	4	CLAY
109140	Driller	4	11	7	SANDY CLAY
109141	Driller	0	5	5	CLAY
109141	Driller	5	15	11	SANDY CLAY
109141	Driller	15	20	5	BLACK SILTY CLAY
109142	Driller	0	4	4	BROWN CLAY
109142	Driller	4	9	5	SILTY CLAY
109142	Driller	9	15	7	SAND
109142	Driller	15	20	5	BLACK CLAY
109143	Driller	0	3	3	CLAY
109143	Driller	3	4	1	SILTY CLAY
109143	Driller	4	18	14	SAND
109143	Driller	18	23	6	BLACK CLAY (COAL)
109143	Driller	23	24	1	HARD BLACK COAL

Bore ID	Type	Lith From (m)	Lith To (m)	Thick (m)	Lithological Description
109144	Driller	0	4	4	CLAY
109144	Driller	4	5	2	SILTY CLAY
109144	Driller	5	7	2	SANDY CLAY
109144	Driller	7	17	10	SAND
109144	Driller	17	20	3	BLACK SILTY CLAY
109144	Driller	20	24	4	BLACK CLAY (COAL)

Appendix B Double Mass Curves

B.1 Colac (Shire Office)

The double mass curve for the Colac (Shire Office) and Pennyroyal Creek gauges is shown in Figure 32. Small changes in gradient are observed at points indicated by an arrow. The points correspond approximately to the years 1935 and 2001 respectively.



▪ **Figure 32 Colac (Shire Office) – Pennyroyal Creek double mass curve**

B.1.1 Forrest State Forest

The double mass curve for the Forrest State Forest and Pennyroyal Creek gauges is shown in Figure 33. A change in gradient is observed at a point indicated by an arrow. This point corresponds approximately to the year 1941.

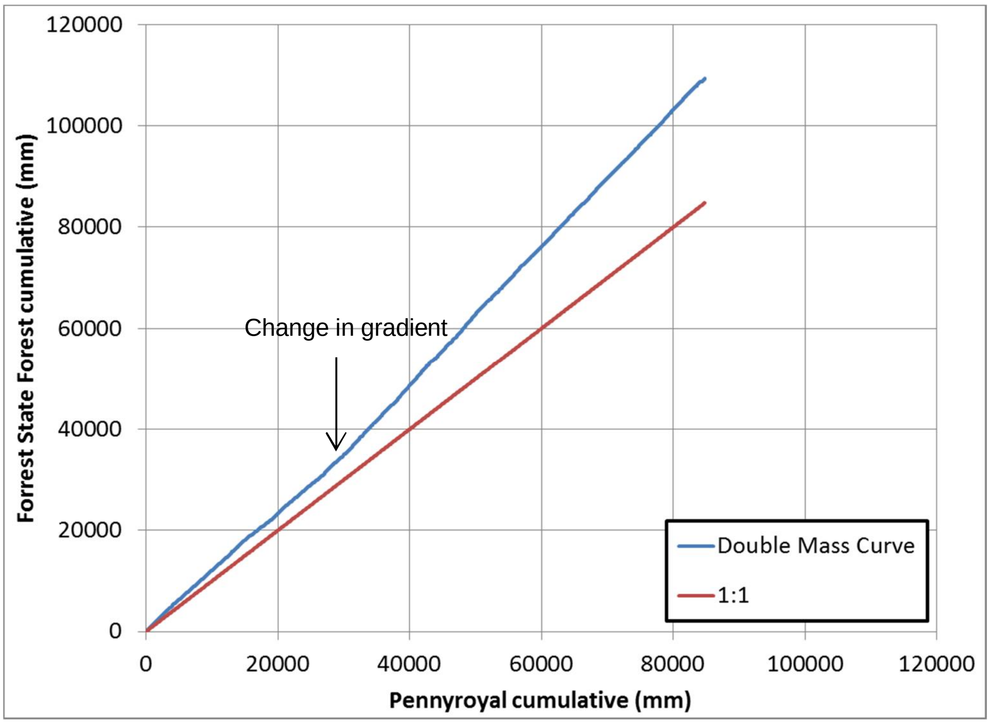
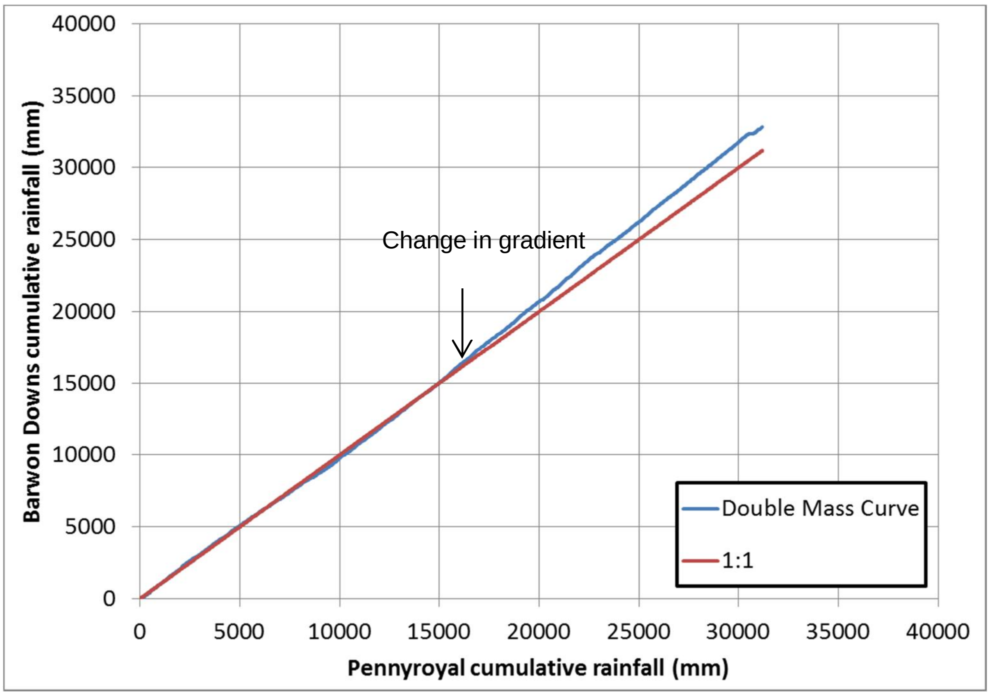


Figure 33 Forrest State Forest – Pennyroyal Creek double mass curve

B.2 Barwon Downs

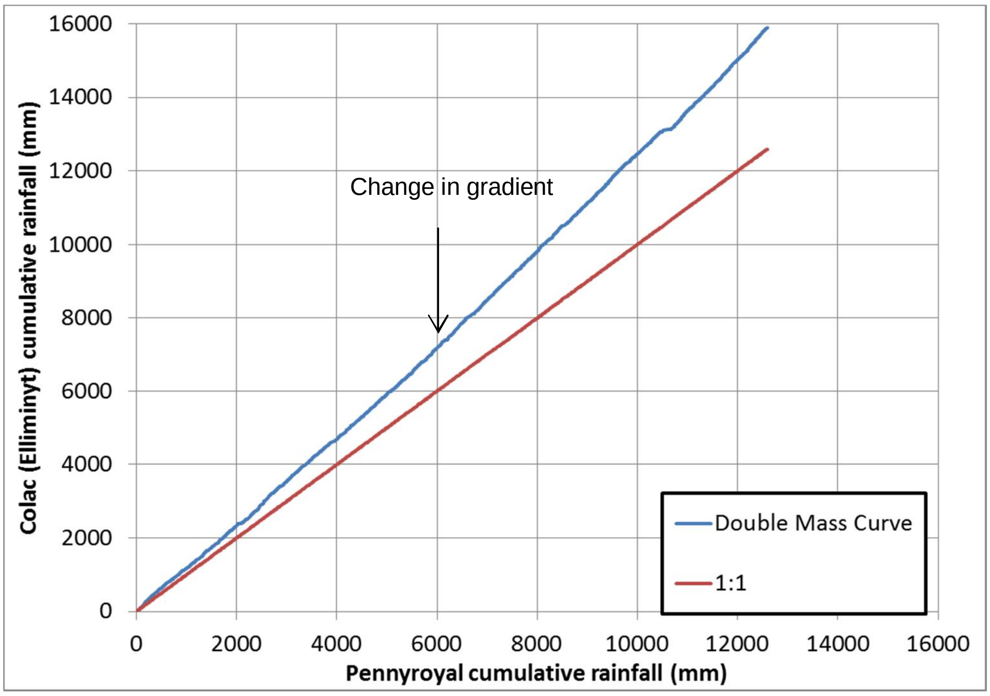
The double mass curve for the Barwon Downs and Pennyroyal Creek gauges is shown in Figure 34. A change in gradient is observed at a point indicated by an arrow. This point corresponds approximately to the year 1989.



- **Figure 34 Barwon Downs – Pennyroyal Creek double mass curve**

B.3 Colac (Elliminyt)

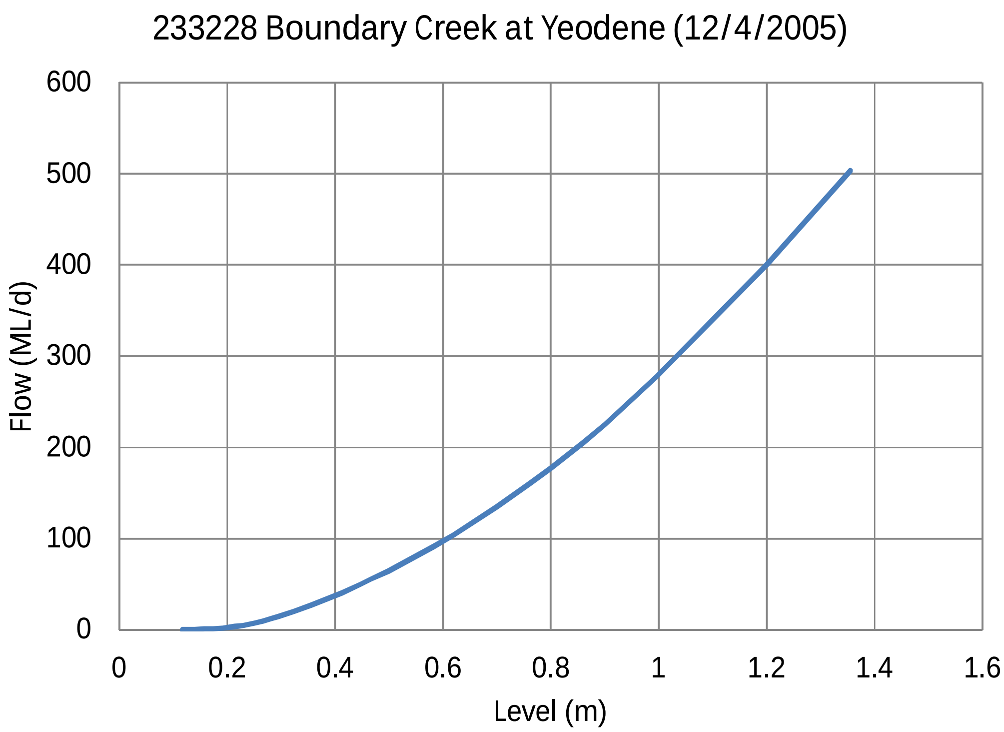
The double mass curve for the Colac (Elliminyt) and Pennyroyal Creek gauges is shown in Figure 35. A very small change in gradient is observed at a point indicated by an arrow. This point corresponds approximately to the year 1991.

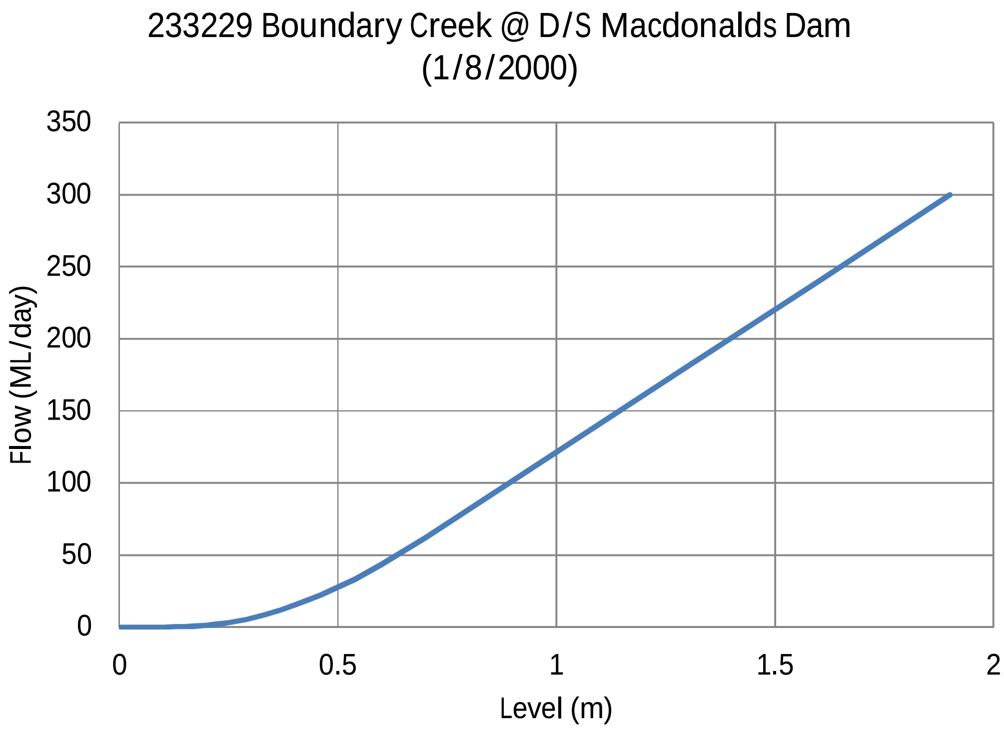


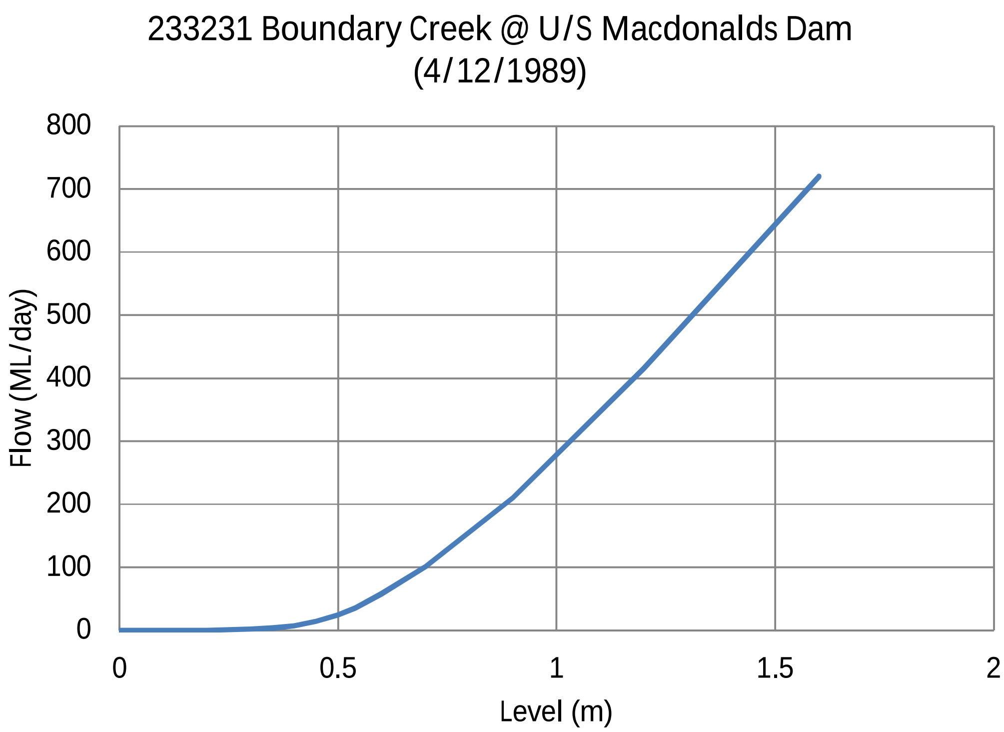
- **Figure 35 Colac (Elliminyt) – Pennyroyal Creek double mass curve**

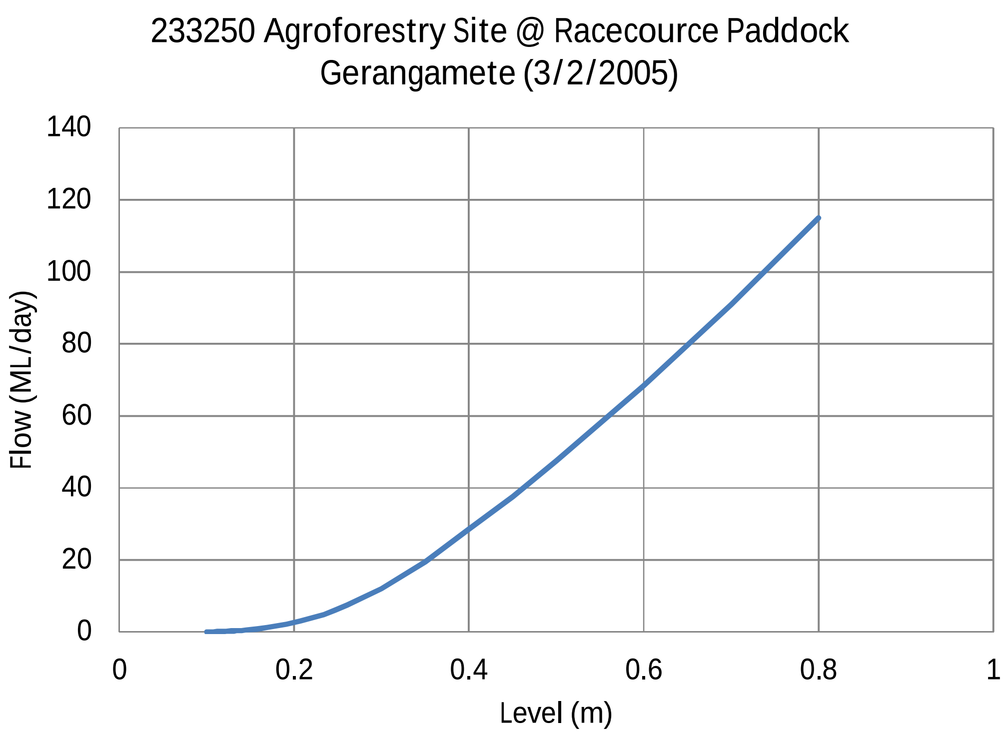
SINCLAIR KNIGHT MERZ
SKM

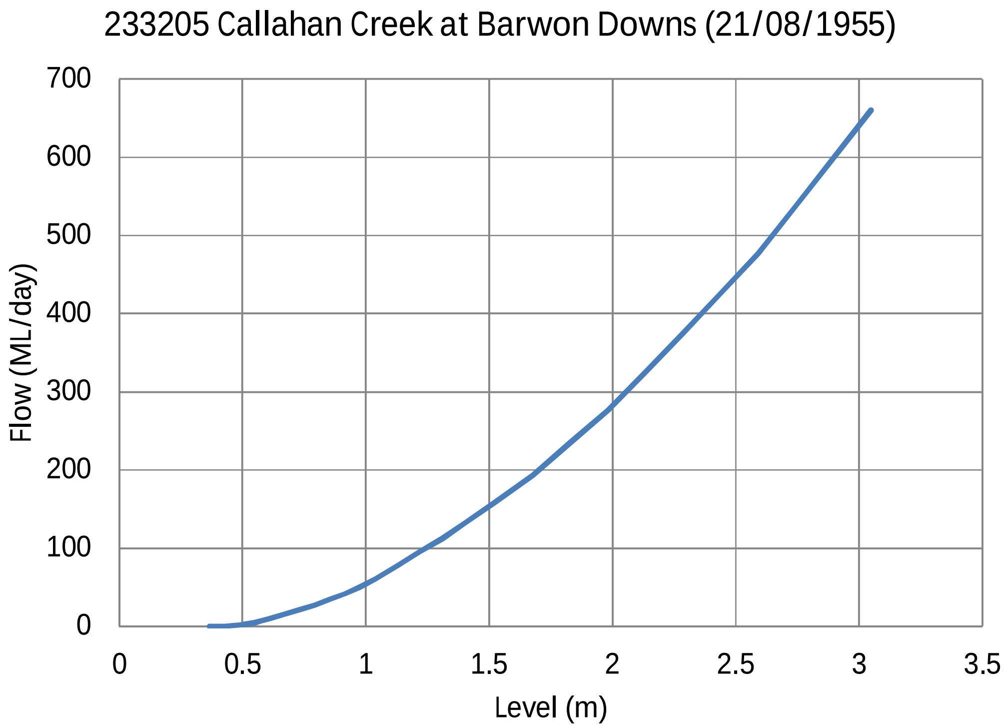
Appendix C Data coverage and ratings information for active gauges

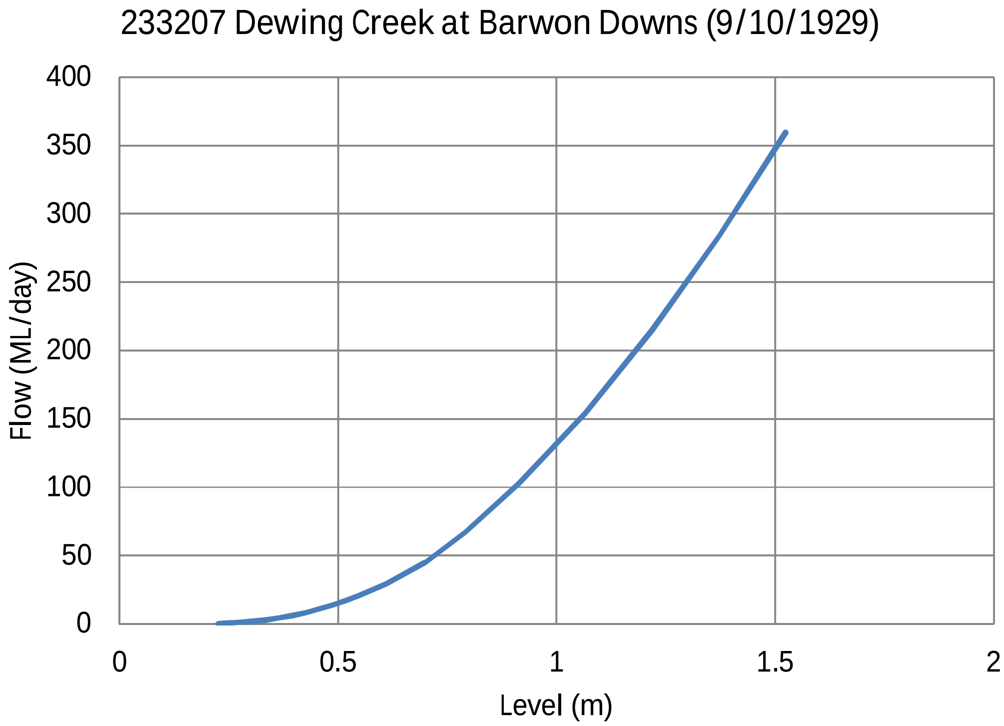

233228 Boundary Creek at Yeodene (12/4/2005)
Flow (ML/d)
600
500
400
300
200
100
0
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
Level (m)

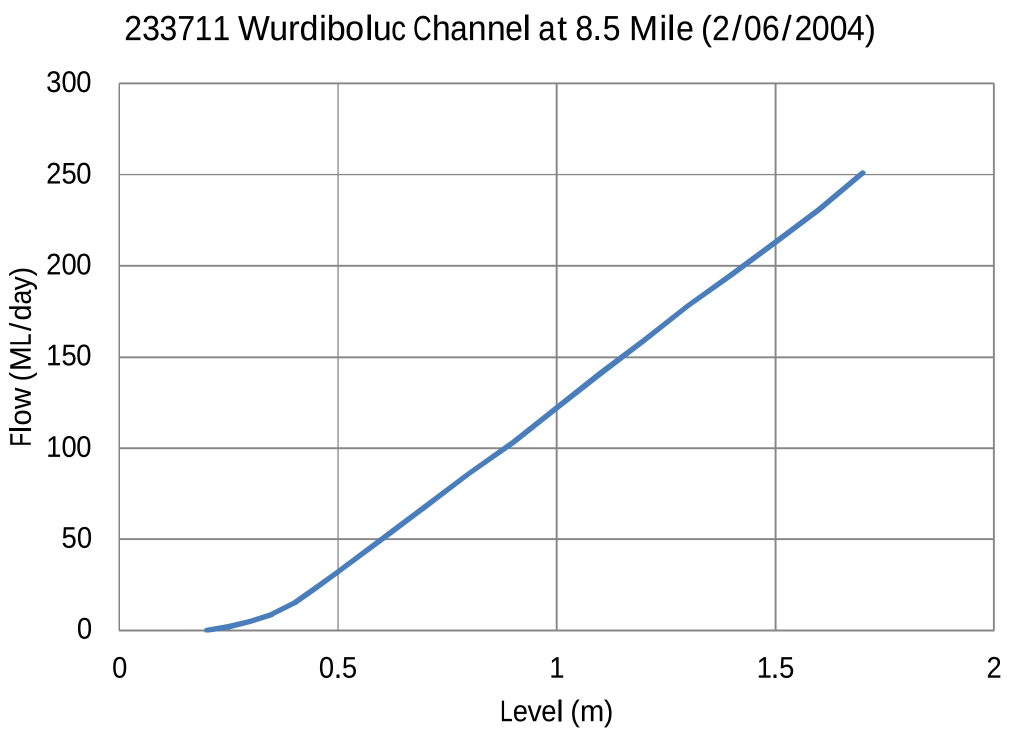

233229 Boundary Creek @ D/S Macdonalds Dam (1/8/2000)
Flow (ML/day)
350
300
250
200
150
100
50
0
0
0.5
1
1.5
2
Level (m)

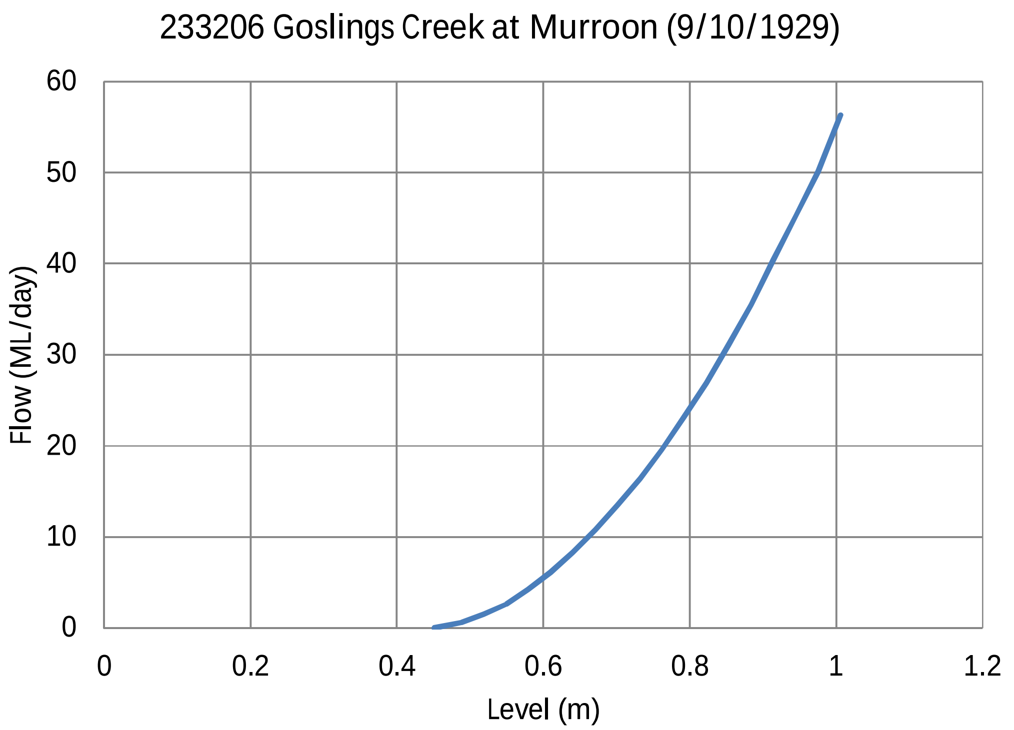

233231 Boundary Creek @ U/S Macdonalds Dam
(4/12/1989)
Flow (ML/day)
0
100
200
300
400
500
600
700
800
0
0.5
1
1.5
2
Level (m)

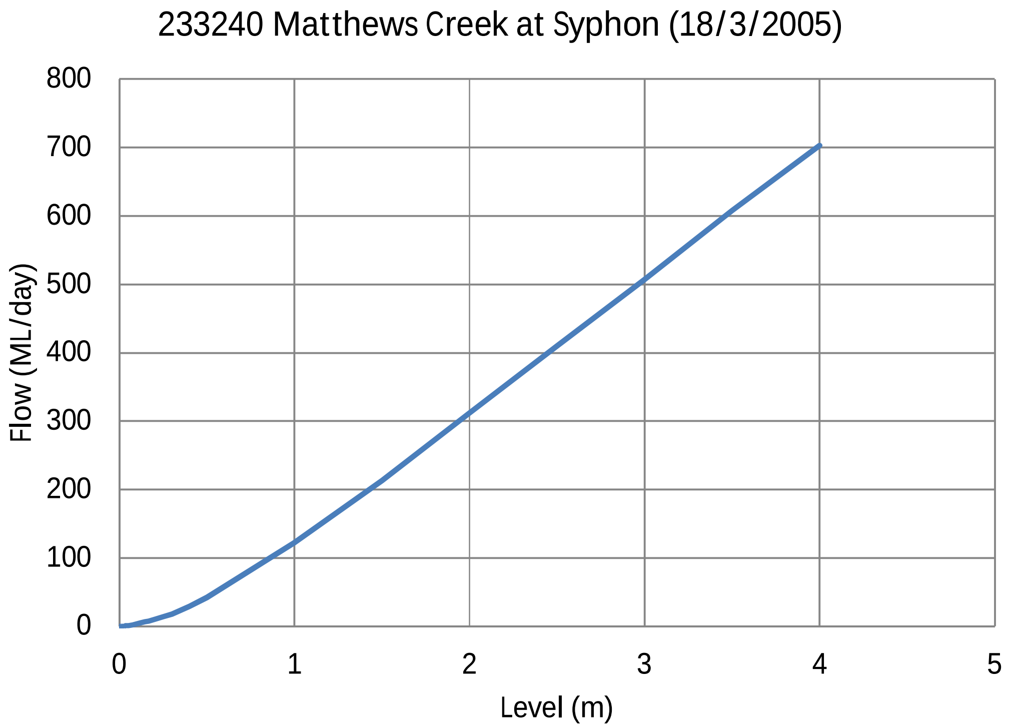

233250 Agroforestry Site @ Racecource Paddock
Gerangamete (3/2/2005)
Flow (ML/day)
0
20
40
60
80
100
120
140
0
0.2
0.4
0.6
0.8
1
Level (m)


233205 Callahan Creek at Barwon Downs (21/08/1955)
Flow (ML/day)
700
600
500
400
300
200
100
0
0
0.5
1
1.5
2
2.5
3
3.5
Level (m)


233207 Dewing Creek at Barwon Downs (9/10/1929)
Flow (ML/day)
400
350
300
250
200
150
100
50
0
0
0.5
1
1.5
2
Level (m)


233711 Wurdiboluc Channel at 8.5 Mile (2/06/2004)
Flow (ML/day)
300
250
200
150
100
50
0
0
0.5
1
1.5
2
Level (m)


233206 Goslings Creek at Murroon (9/10/1929)
Flow (ML/day)
60
50
40
30
20
10
0
0
0.2
0.4
0.6
0.8
1
1.2
Level (m)

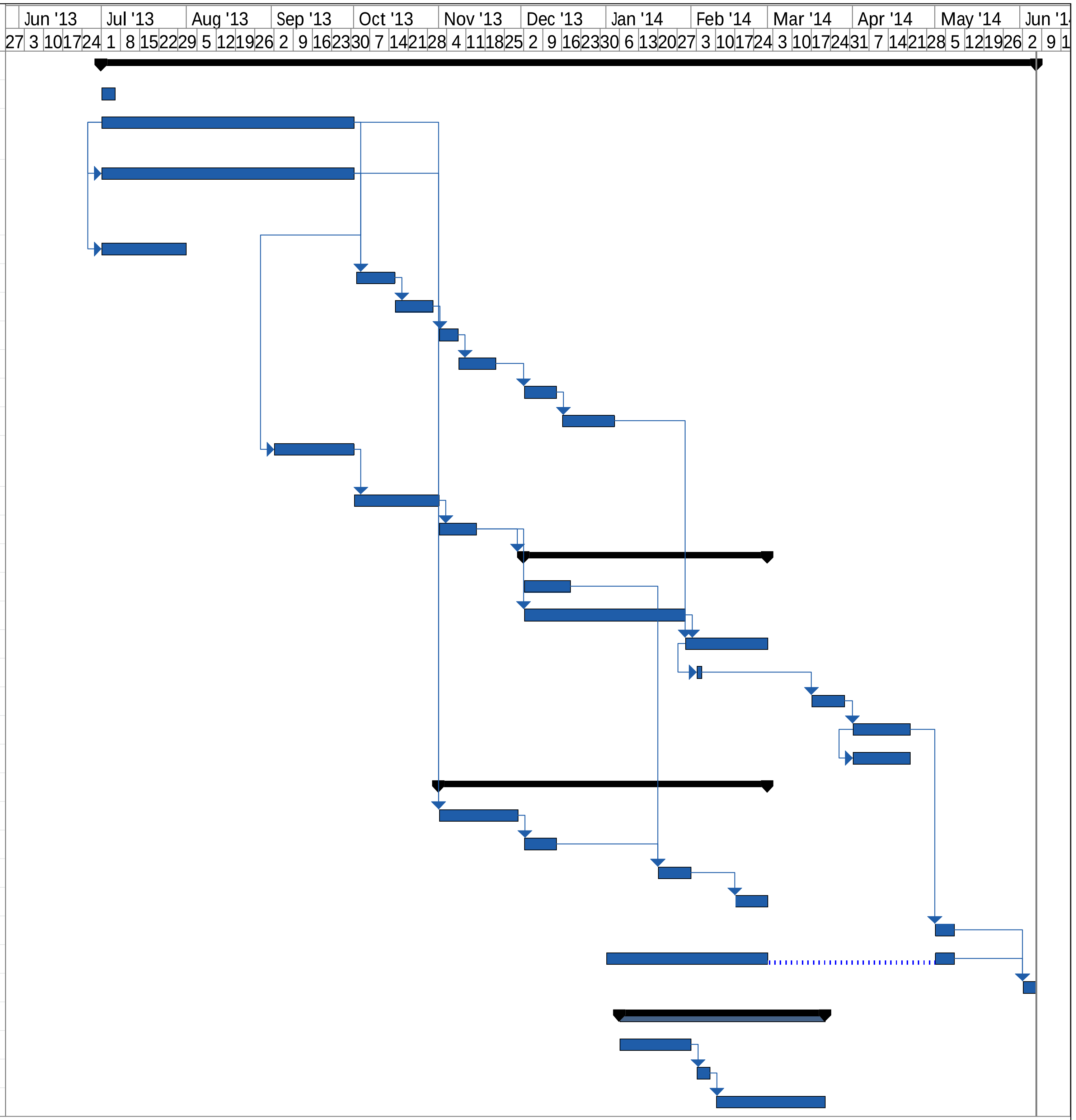

233240 Matthews Creek at Syphon (18/3/2005)
Flow (ML/day)
800
700
600
500
400
300
200
100
0
0
1
2
3
4
5
Level (m)

Appendix B Possible monitoring program schedules

It is important to note that both of these are possible schedules, and are subject to community reference group and community consultation, i.e. these are the activities recommended from a technical perspective but may be altered or added to as a result of the community consultation process, which may in turn affect the timing of delivery of the program.

B.1 Planned schedule

ID	Task Name	Duration	Start	Finish	Resource Names
1	**Groundwater monitoring establishment program**	**245 days?**	**Mon 1/07/13**	**Fri 6/06/14**	
2	Desktop serach for registered aboriginal sites	5 days	Mon 1/07/13	Fri 5/07/13	
3	Landholder consultation; public land (including pegging sites)	66 days	Mon 1/07/13	Mon 30/09/13	
4	Drilling permits / acccess - State Forest (DSE or Parks Victoria?), Road Reserve (Council), including pegging sites, liase DSE for bore reinstatement	66 days	Mon 1/07/13	Mon 30/09/13	
5	Obtain Bore Construction Licence (from SRW)	23 days	Mon 1/07/13	Wed 31/07/13	
6	Tender document preparation - PASS sites	10 days	Wed 2/10/13	Tue 15/10/13	
7	Tendering period - PASS sites	10 days	Wed 16/10/13	Tue 29/10/13	
8	Tender evaluation & awarding tender (PASS Sites)	5 days	Fri 1/11/13	Thu 7/11/13	
9	Drilling (PASS Sites)	10 days	Fri 8/11/13	Thu 21/11/13	
10	PASS Lab soil testing	10 days	Mon 2/12/13	Fri 13/12/13	
11	PASS reporting, incl Reccs for gw observation bores	15 days	Mon 16/12/13	Fri 3/01/14	
12	Tender doc. Prep. - bore installation (including dev existing bores)	21 days	Mon 2/09/13	Mon 30/09/13	
13	Tendering period	23 days	Tue 1/10/13	Thu 31/10/13	
14	Tender evaluation & awarding tender	10 days?	Fri 1/11/13	Thu 14/11/13	
15	**Drilling and Construction of new bores**	**65 days**	**Mon 2/12/13**	**Fri 28/02/14**	
16	Drilling and Construction of new bores Part 1	13 days	Mon 2/12/13	Wed 18/12/13	
17	Drilling and Construction of new bores Part 2	43 days	Mon 2/12/13	Wed 29/01/14	
18	Drilling and Construction of new bores Part 3	22 days	Thu 30/01/14	Fri 28/02/14	
19	Flush out 6 bores to be reinstated	2 days	Mon 3/02/14	Tue 4/02/14	
20	Gamma Logging	10 days	Mon 17/03/14	Fri 28/03/14	
21	Hydraulic testing of bores	15 days	Tue 1/04/14	Mon 21/04/14	
22	Groundwater Sampling	15 days	Tue 1/04/14	Mon 21/04/14	
23	**Unsaturated Zone Characterisation**	**86 days**	**Fri 1/11/13**	**Fri 28/02/14**	
24	Tender Prep	21 days	Fri 1/11/13	Fri 29/11/13	
25	Tendering Period	10 days	Mon 2/12/13	Fri 13/12/13	
26	Tender evaluation & awarding tender	10 days	Mon 20/01/14	Fri 31/01/14	
27	Drilling. Groundwater sampling. Soil sampling	10 days	Mon 17/02/14	Fri 28/02/14	
28	Surveying of bores	5 days	Thu 1/05/14	Wed 7/05/14	
29	Procure loggers / Logger installation	48 days	Wed 1/01/14	Wed 7/05/14	
30	Reporting on drilling program	5 days	Mon 2/06/14	Fri 6/06/14	
31	**Stream Gauge Installation**	**55 days**	**Mon 6/01/14**	**Fri 21/03/14**	
32	Tendering Period	20 days	Mon 6/01/14	Fri 31/01/14	
33	Tender evaluation & award	5 days	Mon 3/02/14	Fri 7/02/14	
34	Gauge re-establishment and installation	30 days	Mon 10/02/14	Fri 21/03/14	

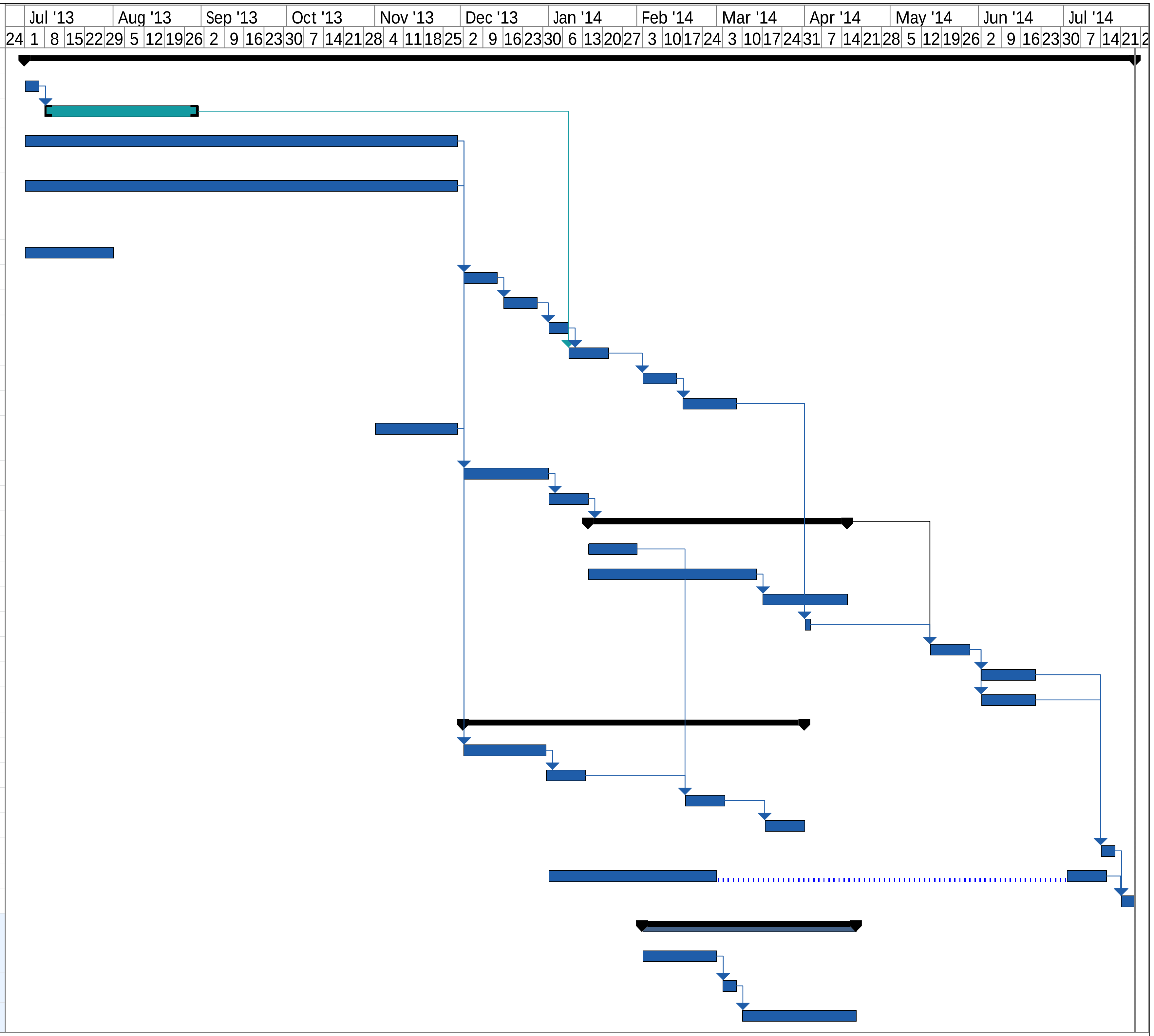


Project: Realistic
Date: Thu 16/05/13

Task	Project Summary	Inactive Milestone	Manual Summary Rollup	Deadline
Split	External Tasks	Inactive Summary	Manual Summary	Progress
Milestone	External Milestone	Manual Task	Start-only	
Summary	Inactive Task	Duration-only	Finish-only	

B.2 Pessimistic schedule

ID	Task Name	Duration	Start	Finish
1	**Groundwater monitoring establishment program**	**280 days**	**Mon 1/07/13**	**Fri 25/07/14**
2	Desktop serach for registered aboriginal sites	5 days	Mon 1/07/13	Fri 5/07/13
3	Preparation and Application for	40 days	Mon 8/07/13	Fri 30/08/13
4	Landholder consultation; public land (including pegging sites)	110 days	Mon 1/07/13	Fri 29/11/13
5	Drilling permits / acccess - State Forest (DSE or Parks Victoria?), Road Reserve (Council), including pegging sites, liase DSE for bore reinstatement	110 days	Mon 1/07/13	Fri 29/11/13
6	Obtain Bore Construction Licence (from SRW)	23 days	Mon 1/07/13	Wed 31/07/13
7	Tender document preparation - PASS sites	10 days	Mon 2/12/13	Fri 13/12/13
8	Tendering period - PASS sites	10 days	Mon 16/12/13	Fri 27/12/13
9	Tender evaluation & awarding tender (PASS Sites)	5 days	Wed 1/01/14	Tue 7/01/14
10	Drilling (PASS Sites)	10 days	Wed 8/01/14	Tue 21/01/14
11	PASS Lab soil testing	10 days	Mon 3/02/14	Fri 14/02/14
12	PASS reporting, incl Reccs for gw observation bores	15 days	Mon 17/02/14	Fri 7/03/14
13	Tender doc. Prep. - bore installation (including dev existing bores)	21 days	Fri 1/11/13	Fri 29/11/13
14	Tendering period	22 days	Mon 2/12/13	Tue 31/12/13
15	Tender evaluation & awarding tender	10 days	Wed 1/01/14	Tue 14/01/14
16	**Drilling and construction of new bores**	**65 days**	**Wed 15/01/14**	**Tue 15/04/14**
17	Drilling and Construction of new bores Part 1	13 days	Wed 15/01/14	Fri 31/01/14
18	Drilling and Construction of new bores Part 2	43 days	Wed 15/01/14	Fri 14/03/14
19	Drilling and Construction of new bores Part 3	22 days	Mon 17/03/14	Tue 15/04/14
20	Flush out 6 bores to be reinstated	2 days	Tue 1/04/14	Wed 2/04/14
21	Geophysical logging	10 days	Thu 15/05/14	Wed 28/05/14
22	Hydraulic testing of bores	15 days	Mon 2/06/14	Fri 20/06/14
23	Groundwater sampling	15 days	Mon 2/06/14	Fri 20/06/14
24	**Unsaturated Zone Characterisation**	**86 days**	**Mon 2/12/13**	**Mon 31/03/14**
25	Tender Prep	21 days	Mon 2/12/13	Mon 30/12/13
26	Tendering Period	10 days	Tue 31/12/13	Mon 13/01/14
27	Tender evaluation & awarding tender	10 days	Tue 18/02/14	Mon 3/03/14
28	Drilling. Groundwater sampling. Soil sampling	10 days	Tue 18/03/14	Mon 31/03/14
29	Surveying of bores	5 days	Mon 14/07/14	Fri 18/07/14
30	Procure loggers / Logger installation	53 days	Wed 1/01/14	Tue 15/07/14
31	Reporting on drilling program	5 days	Mon 21/07/14	Fri 25/07/14
32	Stream Gauge Installation	55 days	Mon 3/02/14	Fri 18/04/14
33	Tendering Period	20 days	Mon 3/02/14	Fri 28/02/14
34	Tender evaluation & award	5 days	Mon 3/03/14	Fri 7/03/14
35	Gauge re-establishment and installation	30 days	Mon 10/03/14	Fri 18/04/14

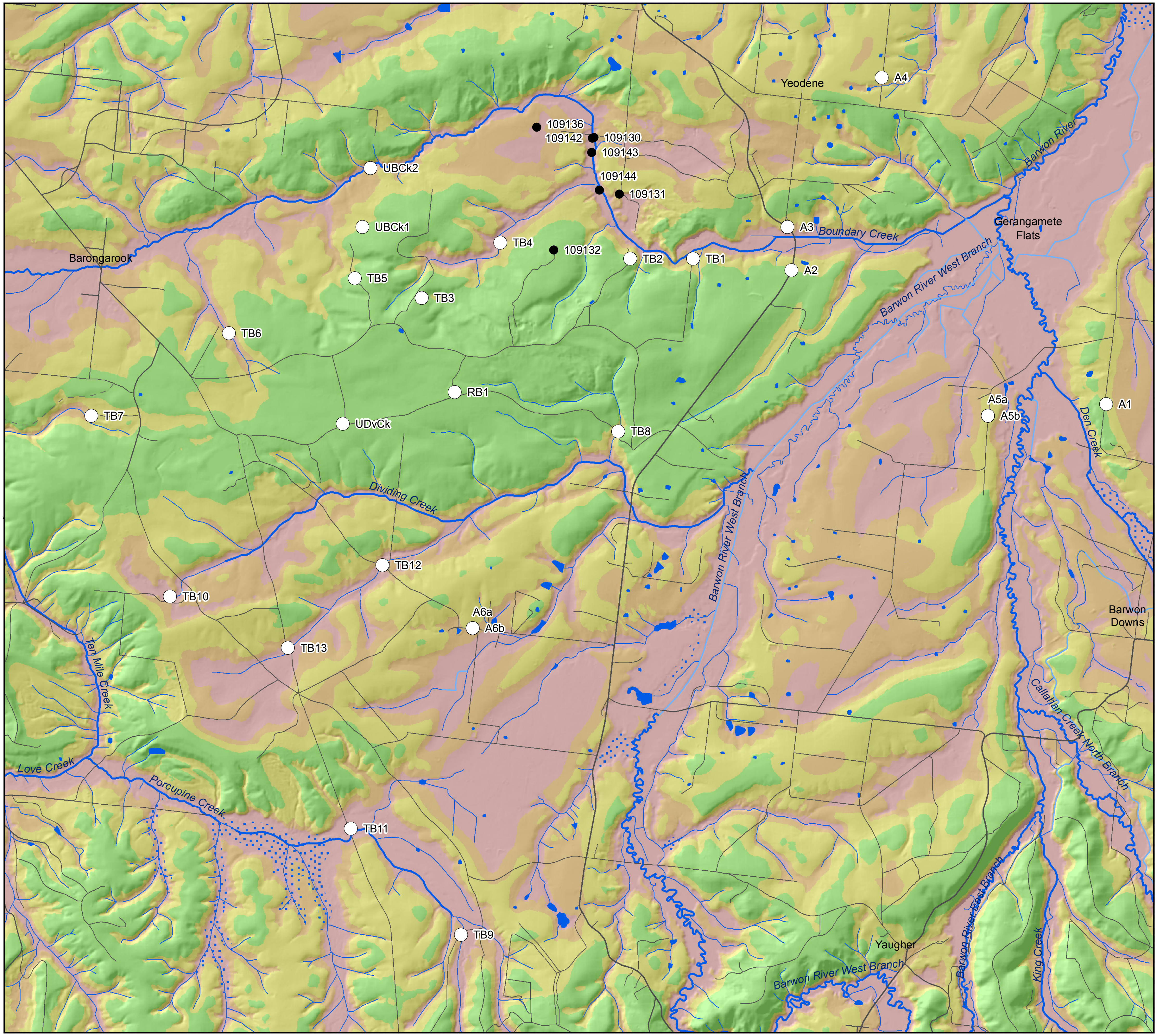


Project: Pessimistic
Date: Thu 16/05/13

Task	Project Summary	Inactive Milestone	Manual Summary Rollup	Deadline
Split	External Tasks	Inactive Summary	Manual Summary	Progress
Milestone	External Milestone	Manual Task	Start-only	
Summary	Inactive Task	Duration-only	Finish-only	

Appendix C Groundwater monitoring

C.1 Groundwater monitoring - New groundwater monitoring bores locality plan



Barwon Water

Barwon Water Authority
Barwon Downs Monitoring Program

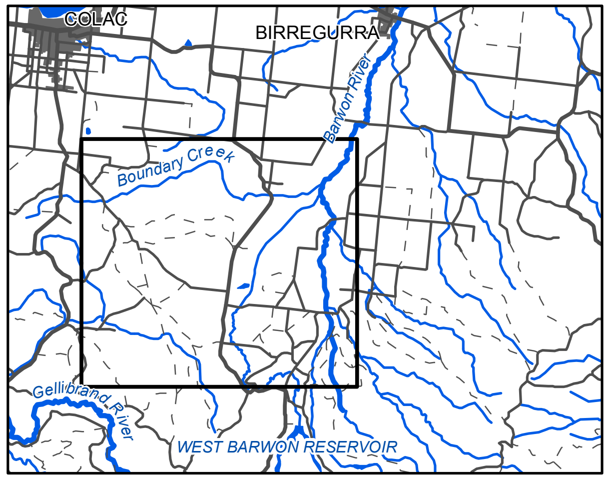
NEW GROUNDWATER MONITORING SITES

Kilometres
0 0.25 0.5 1 1.5 2 2.5
(MGA55)

Bore Site
- New
- Existing

Watertable depth (m)
- < 5
- 5 - 10
- 10 - 20
- > 20

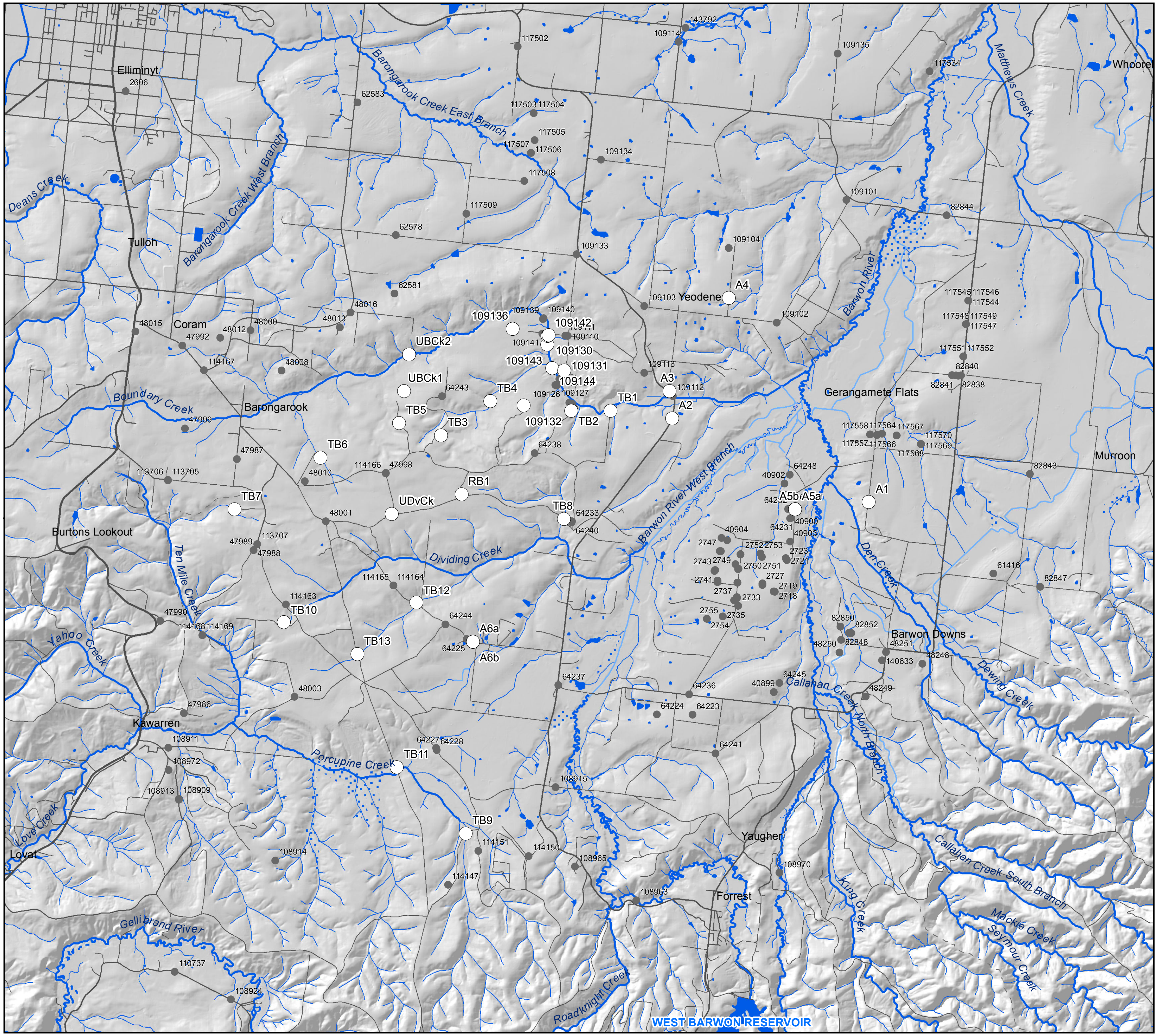
Locality Map



SKM

Refer to Sinclair Knight Merz document;
I:\VWES\Projects\VW07070\Technical\Spatial\Working\ArcGIS\New_bore_sites_A3.mxd

C.2 Groundwater monitoring - All groundwater monitoring bores locality plan (new and existing)



Barwon Water Authority
Barwon Downs Monitoring Program

GROUNDWATER MONITORING SITES and other existing bores.

Kilometres

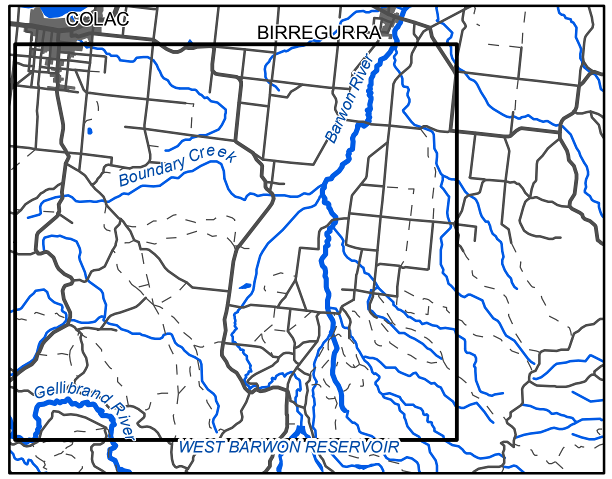
0 0.5 1 2 3 4 5

(MGA55)

Monitoring Bore Site

Existing bore sites

Locality Map



Refer to Sinclair Knight Merz document; I:\VWES\Projects\VW07070\Technical\Spatial\Working\ArcGIS\All_bore_sites_A3.mxd

C.3 Groundwater monitoring - New groundwater monitoring bore specification

Bore: RB1 (at bore site 64239)

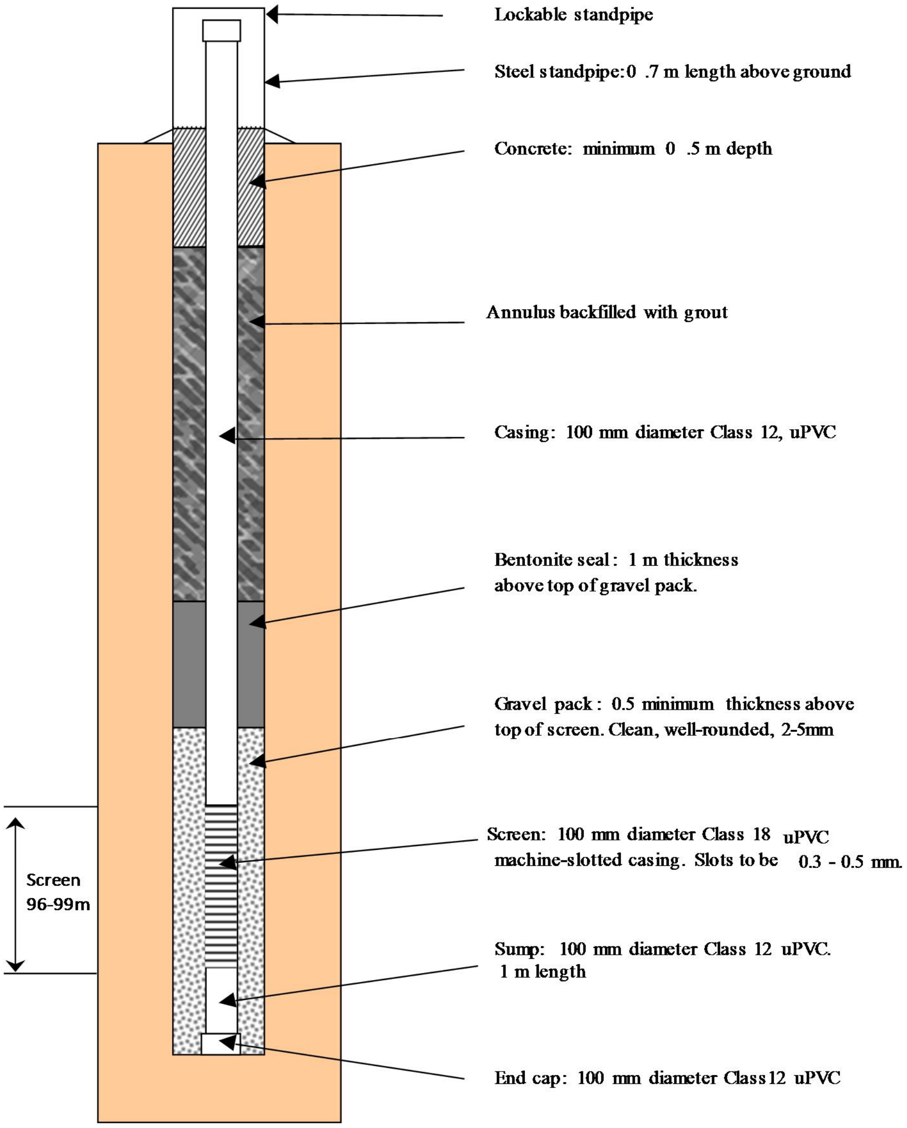
General Information		
Bore ID	64239 nest	Photo (facing south)
Coordinates(approx.), Zone 55	208,520 E 5,742,279 N	
Location Description	At bore 64239	
Purpose of Bore	Water level at the existing bore at this site has gone dry. Water level is now in the bedrock. With Bore 64238 to the NE also now dry, it is recommended that at one of these sites, a deeper bore is drilled to fill a spatial gap in watertable depth.	
GMS No. (future)		
Bore Construction Licence No. (future)		

Access			
Land Owner	DSE / Parks Victoria	*Required Permits*	Use of Crown Land requires consent pursuant to the Crown Land (Reserves) Act 1978 from the land manager (i.e. DSE). Permit required if removing native vegetation.
Access Description	Suitable access close to Bore 64239 for the new bore. (Also a very quiet track i.e. no/minimal traffic).	*Alternate Locations*	N/A
Additional notes			

Construction Information (refer over page for construction diagram)			
Bore Depth (estimated)	Screen approximately 90-100m (into bedrock)	*Screening Target*	The aim is to screen below the lowest expected watertable level.
Nearest Bore, Distance, Expected Lithology (comments)	▪ 64239 ▪ State Observation Bore ▪ GEDIS lithology log. Unknown current condition ▪ At the site	*Nearest bore log(m)*	64239 Log 0.3 2 BROWNISH CLAY 2 4 ORANGE GREY FINE SANDY CLAY 4 9.3 YELLOW GREY FINE SANDY CLAY 9.3 31 FINE YELLOW SAND 31 35.8 FINE ORANGE SAND 35.8 38.8 YELLOW CLAYEY SAND FINE 38.8 43.2 ORANGE & GREY SANDY CLAY 43.2 46 DARK GREY SILTY CLAY 46 48 LIGHT GREY MEDIUM SANDY CLAY 48 49.8 GREY WHITE SAND MEDIUM 49.8 55.5 LIGNEOUS CLAY / LIGHT CLAY 55.5 57 LIGHT BROWN SILTY CLAY 57 60.5 LIGHT BROWN CLAYEY SAND 60.5 62.8 WHITE COARSE SAND 62.8 64 LIGNEOUS CLAY 64 70 GREY COARSE GRAVEL & CLAY 70 71.8 GREY COARSE GRAVEL 71.8 73 GREY SILTY CLAY 73 76 GREY MUDSTONE 76 90 GREEN GREY SILTY CLAY,
Drilling Method	Mud rotary technique will be used for bores greater than 25 m deep.		
Screen Interval / Length	Bottom of hole minus 1 metre / 3m screen *	*Constructed Bore Diameter*	100mm
Casing Material	uPVC Class 12	*Screen Material, Slot Size*	uPVC Class 18, machine slotted, 0.3mm to 0.5mm
Surface Construction	Steel lockable standpipe, ~0.7 to 0.8m high		
Other notes re drilling / construction	Screen depth targeting approximately ~ 15m below watertable is recommended (i.e. top of screen ~ 15m below watertable). Air hammer may be required if bedrock becomes too hard for mud rotary drilling. Depending on drilling method, watertable may not be easy to detect. Conservative estimate of 110m should be used if not able to detect watertable.		

* Final selection of bore depth and screen will be decided based on field logging

Groundwater monitoring bore general construction



Testing Requirements	
Water quality sampling	Sample for field chemistry (EC, pH, ORP, DO) recommended. Conduct at same time as hydraulic testing.
Geophysical testing	Gamma logging recommended (after bore construction)
Hydraulic testing	Slug test recommended

Monitoring Requirements		
Water Level Monitoring Frequency	Manual	Frequency: Quarterly for first 3 years, bi-annual for subsequent years (~ April and Nov.)
	Data logger	Frequency: 6 hourly for first 3 years, daily for subsequent years Annual dipping of bores for cross-checking logger data
Water Level Monitoring Duration	Minimum duration, up to ~ 2018, i.e. point where data is required for analysis contributing to licence renewal. Recommended duration: 10 yrs, with review after 10 yrs data collection.	

Bore Maintenance Requirements	
Assessing need for maintenance	• Annual depthing of the bore and comparison with bore depth and screen interval (combine with a water level monitoring visit). Assess condition of surface steel cover, and concrete seal around top of the bore. • Inspect hydrograph on annual basis for anomalous behaviour
Scheduled maintenance	• Maintain protective steel cover (as required). • Flushing of the bore once every ten years using airlift.

Bore: TB1

General Information

Bore ID	TB1
Coordinates(approx.), Zone 55	211,531 E 5,742,045 N
Location Description	Big Swamp monitoring bore at burnt peat site, bore south of swamp
Purpose of Bore	To assess depth to watertable at vegetation monitoring site – <u>Impact assessment site</u>
GMS No. (future)	
Bore Construction Licence No. (future)	

Photo (facing north)

Access

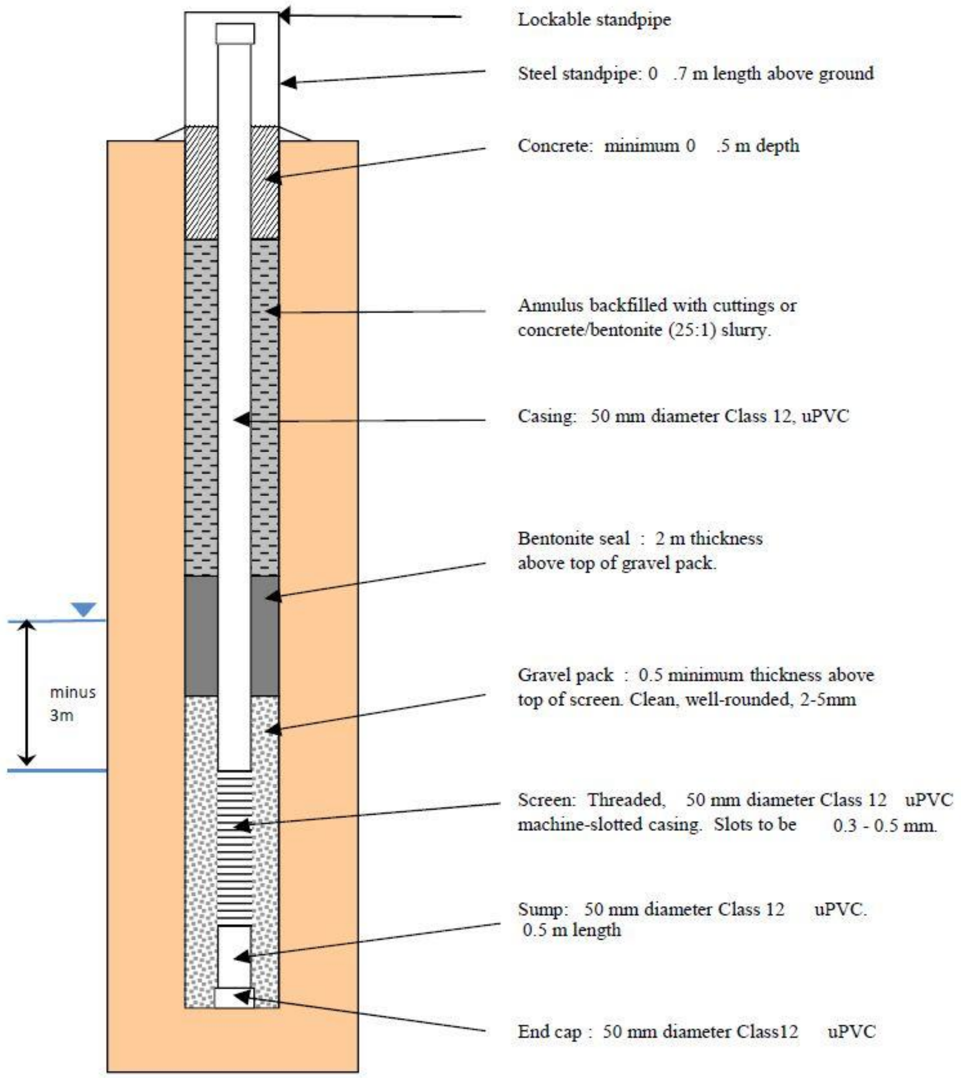
Land Owner	DSE / Parks Victoria	*Required Permits*	Use of Crown Land requires consent pursuant to the Crown Land (Reserves) Act 1978 from the land manager (i.e. DSE). Permit required if removing native vegetation.
Access Description	Preferred site is at a similar elevation to Big Swamp.	*Alternate Locations*	Alternative site (211,531 E; 5,741,993 N) is ~ 100m south and can be used if there are either permit or access issues with the preferred site.
Additional notes	Based on DPI (2009) land tenure, the site is located on an easement of crown land. However, because it appears to be an easement, the landowner of surrounding land will also need to be consulted regarding siting and drilling of the bore (and future monitoring access).		

Construction Information (refer over page for construction diagram)

Bore Depth (estimated)	5 - 10 m (alternate site would be deeper; 10-20m)	*Screening Target*	The aim is to screen slightly below lowest expected watertable level at the site. Expected watertable is around 3-5m below ground level.
Nearest Bore, Distance, Expected Lithology (comments)	▪ 109105 ▪ GEDIS lithology log ▪ Unknown current status ▪ ~ 1,150m east ▪ Alluvial material (sands and clay).	*Nearest bore log(m)*	109105 Log 0 0.3 TOPSOIL 0.3 7.0 YELLOW AND GREY CLAY 7.0 10.4 YELLOW AND CLAYEY SAND --------------------- EOH 98m
Drilling Method	The drilling method should be able to accurately identify the depth to watertable. Hollow auger is therefore the preferred technique. (or “necessary”)		
Screen Interval / Length	Bottom of hole minus 1 metre / 3m screen *	*Constructed Bore Diameter*	50mm
Casing Material	uPVC Class 12	*Screen Material, Slot Size*	uPVC Class 12, machine slotted, 0.3mm to 0.5mm
Surface Construction	Steel lockable standpipe, ~0.7 to 0.8m high		
Other notes re drilling / construction	The drilling method should be able to accurately identify the depth to watertable. Hollow auger is the recommended technique. Bore depth ~ 6m below watertable is recommended (i.e. top of screen ~ 3m below watertable). Large seasonal fluctuation in watertable not expected.		

* Final selection of bore depth and screen will be decided based on field logging

Groundwater monitoring bore general construction



Testing Requirements	
Water quality sampling	Sample for field chemistry (EC, pH, ORP, DO) recommended. Conduct at same time as hydraulic testing.
Geophysical testing	Gamma logging recommended (after bore construction)
Hydraulic testing	Slug test recommended

Monitoring Requirements		
Water Level Monitoring Frequency	Manual	Frequency: Quarterly for first 3 years, bi-annual for subsequent years (~ April and Nov.)
	Data logger	Frequency: 6 hourly for first 3 years, daily for subsequent years Annual dipping of bores for cross-checking logger data
Water Level Monitoring Duration	Minimum duration, up to ~ 2018, i.e. point where data is required for analysis contributing to licence renewal. Recommended duration: 10 yrs, with review after 10 yrs data collection.	

Bore Maintenance Requirements	
Assessing need for maintenance	• Annual depthing of the bore and comparison with bore depth and screen interval (combine with a water level monitoring visit). Assess condition of surface steel cover, and concrete seal around top of the bore. • Inspect hydrograph on annual basis for anomalous behaviour
Scheduled maintenance	• Maintain protective steel cover (as required). • Flushing of the bore once every ten years using airlift.

Bore: TB2

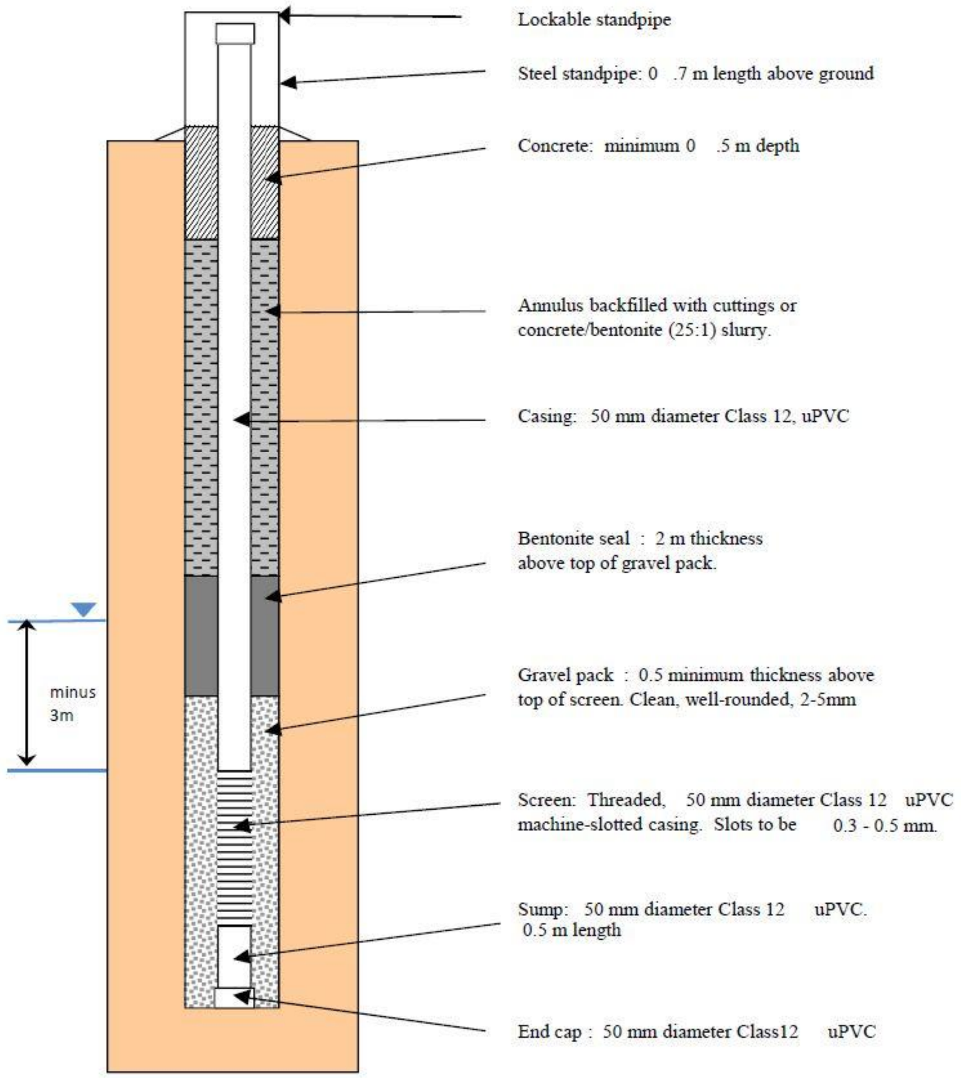
General Information		
Bore ID	TB2	Photo (facing north)
Coordinates(approx.), Zone 55	210,750 E 5,742,067 N	
Location Description	Big Swamp, upstream of burnt peat site.	
Purpose of Bore	To assess depth to watertable at vegetation monitoring site – Impact assessment site	
GMS No. (future)		
Bore Construction Licence No. (future)		

Access			
Land Owner	DSE / Parks Victoria.	*Required Permits*	Use of Crown Land requires consent pursuant to the Crown Land (Reserves) Act 1978 from the land manager (i.e. DSE). Permit required if removing native vegetation.
Access Description	Location shown in the photo is closest site where a reasonable sized rig could be used.	*Alternate Locations*	To get closer to the vegetation site (preferred) option, a track mounted rig would be required. Could be floated to the location shown in above photo, and would then need to move several hundred metres to the site.
Additional notes	Former shallow bores in this area could not be located during the field inspection (assumed lost/destroyed).		

Construction Information (refer over page for construction diagram)			
Bore Depth (estimated)	5 - 10m	*Screening Target*	The aim is to screen slightly below the lowest expected watertable level at the site.
Nearest Bore, Distance, Expected Lithology (comments)	▪ 109125 ▪ State Observation Bore ▪ GEDIS lithology log. Unknown current condition ▪ ~130 m north of site	*Nearest bore log(m)*	109125 Log 0 2.0 FERRUGINISED SANDSTONE 2.0 3.0 SAND MEDIUM CLAYEY RED 3.0 4.0 SANDY CLAY GREY 4.0 5.2 SAND MEDIUM CLAYEY RED 5.2 15.0 SAND FINE TO MEDIUM CLAYEY RED --------------------- EOH 23m
Drilling Method	The drilling method should be able to accurately identify the depth to watertable. Hollow auger is therefore the preferred technique. (or "necessary")		
Screen Interval / Length	Bottom of hole minus 1 metre / 3m screen *	*Constructed Bore Diameter*	50mm
Casing Material	uPVC Class 12	*Screen Material, Slot Size*	uPVC Class 12, machine slotted, 0.3mm to 0.5mm
Surface Construction	Steel lockable standpipe, ~0.7 to 0.8m high		
Other notes re drilling / construction	The drilling method should be able to accurately identify the depth to watertable. Hollow auger is the recommended technique. Bore depth ~ 6m below current watertable is recommended (i.e. top of screen ~ 3m below watertable). Large seasonal fluctuation in watertable not expected. Bore to be gamma logged after construction.		

* Final selection of bore depth and screen will be decided based on field logging

Groundwater monitoring bore general construction



Testing Requirements	
Water quality sampling	Sample for field chemistry (EC, pH, ORP, DO) recommended. Conduct at same time as hydraulic testing.
Geophysical testing	Gamma logging recommended (post-bore construction)
Hydraulic testing	Slug test recommended

Monitoring Requirements		
Water Level Monitoring Frequency	Manual	Frequency: Quarterly for first 3 years, bi-annual for subsequent years (~ April and Nov.)
	Data logger	Frequency: 6 hourly for first 3 years, daily for subsequent years Annual dipping of bores for cross-checking logger data
Water Level Monitoring Duration	Minimum duration, up to ~ 2018, i.e. point where data is required for analysis contributing to licence renewal. Recommended duration: 10 yrs, with review after 10 yrs data collection.	

Bore Maintenance Requirements	
Assessing need for maintenance	• Annual depthing of the bore and comparison with bore depth and screen interval (combine with a water level monitoring visit). Assess condition of surface steel cover, and concrete seal around top of the bore. • Inspect hydrograph on annual basis for anomalous behaviour
Scheduled maintenance	• Maintain protective steel cover (as required). • Flushing of the bore once every ten years using airlift.

Bore: TB3

General Information

Bore ID	TB3	Photo (facing north) (facing north)
Coordinates(approx.), Zone 55	208,112 E 5,741,587 N	 
Location Description	580m north of Westwood Rd, on N-S oriented track (~300m east of gun club access road)	
Purpose of Bore	To assess depth to watertable at vegetation monitoring site – Impact assessment site	
GMS No. (future)		
Bore Construction Licence No. (future)		

Access

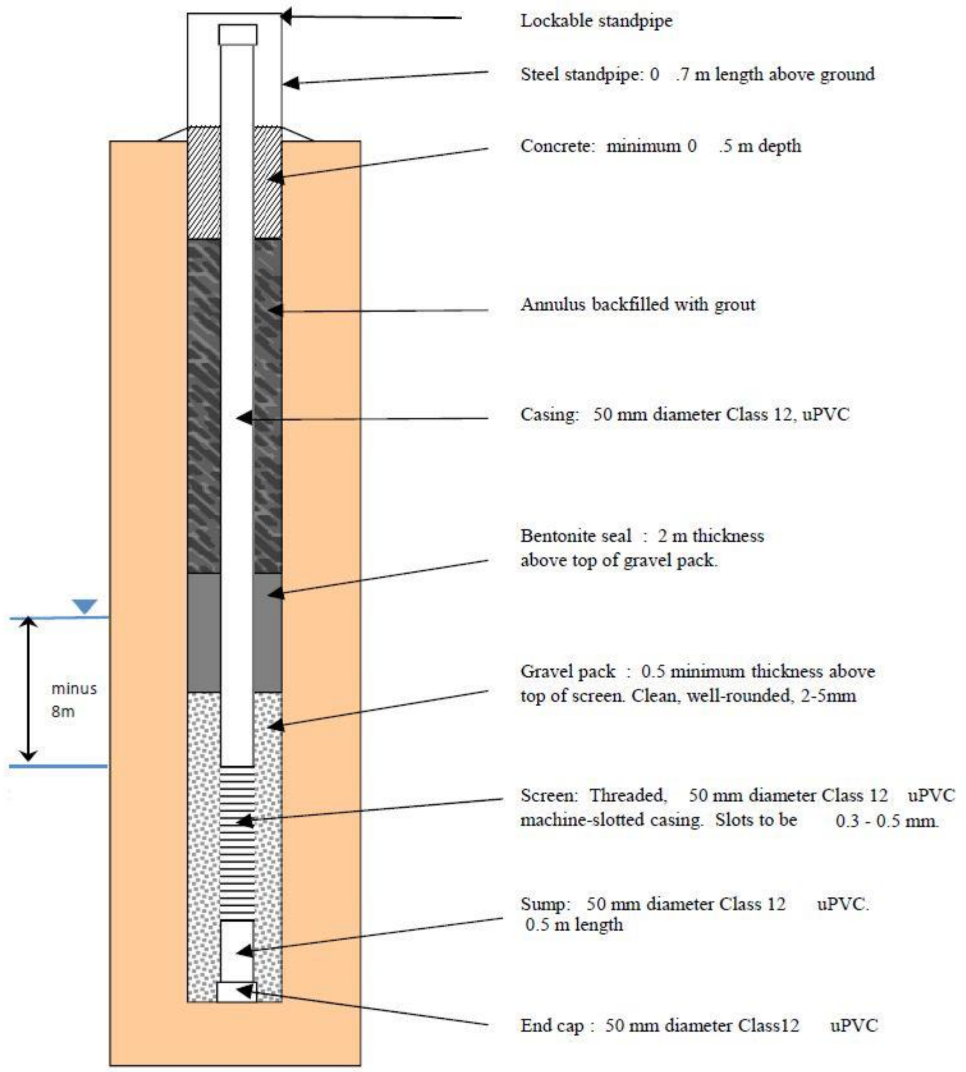
Land Owner	DSE / Parks Victoria	*Required Permits*	Use of Crown Land requires consent pursuant to the Crown Land (Reserves) Act 1978 from the land manager (i.e. DSE). Permit required if removing native vegetation.
Access Description	Access for a bore close to the vegetation site is not possible (due to steep terrain and absence of track) - would need to be located close to the track off Westwood Road. The potential sites are elevated approximately 20m above the swamp.	*Alternate Locations*	There is a site close to Westwood Track (RHS photo) and a site ~ 50-100m down a side track off Westwood Track (LHS photo). Either site would be suitable.
Additional notes			

Construction Information (refer over page for construction diagram)

Bore Depth (estimated)	20 - 40m	*Screening Target*	The aim is to screen below the lowest expected watertable level at the site.
Nearest Bore, Distance, Expected Lithology (comments)	▪ 64243 ▪ State Observation Bore ▪ GEDIS lithology log. ▪ ~ 750 m north of site	*Nearest bore log(m)*	64243 Log 0 0.5 TOPSOIL 0.5 1 COFFEE ROCK 1 13.5 YELLOW SANDY CLAY 13.5 14 MOTTLED CLAY 14 19.5 LIGHT GREY CLAY 19.5 30 GRAVELLY LIGHT GREY CLAY 30 31.5 QUARTZ GRAVELS LARGE 31.5 44 GREY SANDY CLAY ------------------------- EOH 92 m
Drilling Method	Mud rotary technique recommended as bore expected to be greater than 20 m deep.		
Screen Interval / Length	Bottom of hole minus 1 metre / 3m screen *	*Constructed Bore Diameter*	50mm
Casing Material	uPVC Class 12	*Screen Material, Slot Size*	uPVC Class 12, machine slotted, 0.3mm to 0.5mm
Surface Construction	Steel lockable standpipe, ~0.7 to 0.8m high		
Other notes re drilling / construction	Bore depth ~ 10m below watertable is recommended (i.e. top of screen ~ 8m below watertable). This greater depth compared to other terrestrial vegetation sites is due to greater uncertainty due to drilling method and depth to watertable.		

* Final selection of bore depth and screen will be decided based on field logging

Groundwater monitoring bore general construction



Testing Requirements	
Water quality sampling	Sample for field chemistry (EC, pH, ORP, DO) recommended. Conduct at same time as hydraulic testing.
Geophysical testing	Gamma logging recommended (post-construction)
Hydraulic testing	Slug test recommended

Monitoring Requirements		
Water Level Monitoring Frequency	Manual	Frequency: Quarterly for first 3 years, bi-annual for subsequent years (~ April and Nov.)
	Data logger	Frequency: 6 hourly for first 3 years, daily for subsequent years Annual dipping of bores for cross-checking logger data
Water Level Monitoring Duration	Minimum duration, up to ~ 2018, i.e. point where data is required for analysis contributing to licence renewal. Recommended duration: 10 yrs, with review after 10 yrs data collection.	

Bore Maintenance Requirements	
Assessing need for maintenance	• Annual depthing of the bore and comparison with bore depth and screen interval (combine with a water level monitoring visit). Assess condition of surface steel cover, and concrete seal around top of the bore. • Inspect hydrograph on annual basis for anomalous behaviour
Scheduled maintenance	• Maintain protective steel cover (as required). • Flushing of the bore once every ten years using airlift.

Bore: TB4

<table>
<tr><th colspan="3">General Information</th></tr>
<tr><td>Bore ID</td><td>TB4</td><td>Photo – N/A</td></tr>
<tr><td>Coordinates(approx.), Zone 55</td><td>209,078E;
5,742,252N.</td><td rowspan="5"></td></tr>
<tr><td>Location Description</td><td>N/A</td></tr>
<tr><td>Purpose of Bore</td><td>To assess depth to watertable at vegetation monitoring site – Impact assessment site</td></tr>
<tr><td>GMS No. (future)</td><td></td></tr>
<tr><td>Bore Construction Licence No. (future)</td><td></td></tr>
</table>

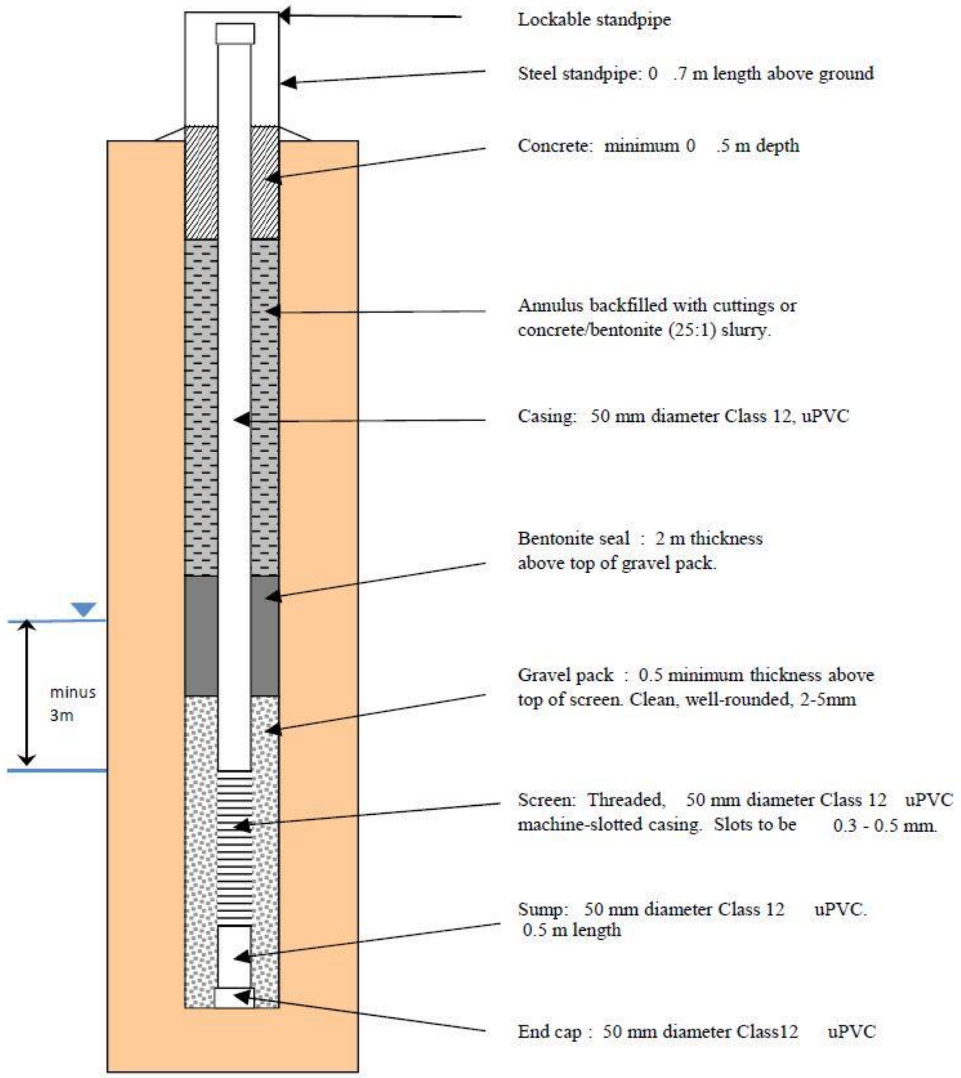
<table>
<tr><th colspan="4">Access</th></tr>
<tr><td>Land Owner</td><td>DSE / Parks Victoria</td><td>Required Permits</td><td>Use of Crown Land requires consent pursuant to the Crown Land (Reserves) Act 1978 from the land manager (i.e. DSE). Permit required if removing native vegetation.</td></tr>
<tr><td>Access Description</td><td>This site was not visited during the hydrogeological field assessment, as it was only identified by Ecology Australia during their field visit.</td><td>Alternate Locations</td><td>-</td></tr>
<tr><td>Additional notes</td><td colspan="3">Site visit required to determine bore position. Very likely that a track mounted rig will be required.</td></tr>
</table>

<table>
<tr><th colspan="5">Construction Information (refer over page for construction diagram)</th></tr>
<tr><td>Bore Depth (estimated)</td><td>5 - 20m</td><td>Screening Target</td><td colspan="2">The aim is to screen below the lowest expected watertable level at the site.</td></tr>
<tr><td>Nearest Bore, Distance, Expected Lithology (comments)</td><td>▪ 109132
▪ ~ 500 m east of site
▪ State Observation Bore
▪ GEDIS lithology log.</td><td>Nearest bore log(m)</td><td colspan="2">109132 Log
0 2 BROWN CLAY
2 5 RED FINE SANDY CLAY
5 9 RED YELLOW WHITE FINE SANDY CLAY
6 15 ORANGE RED & GREY SANDY CLAY
15 22 YELLOW CLAYEY SAND
22 25 PALE YELLOW WHITE CLAY
25 28 YELLOW CLAYEY VERY FINE SAND
28 31 PALE YELLOW VERY FINE SAND
31 41 YELLOW TO WHITE VERY FINE SAND
. .
116 BEDROCK

EOH - 123m</td></tr>
<tr><td>Drilling Method</td><td colspan="4">Hollow auger is recommended technique (as bore depth less than 20m expected)</td></tr>
<tr><td>Screen Interval / Length</td><td>Bottom of hole minus 1 metre / 3m screen *</td><td colspan="2">Constructed Bore Diameter</td><td>50mm</td></tr>
<tr><td>Casing Material</td><td>uPVC Class 12</td><td colspan="2" rowspan="2">Screen Material, Slot Size</td><td rowspan="2">uPVC Class 12, machine slotted, 0.3mm to 0.5mm</td></tr>
<tr><td>Surface Construction</td><td>Steel lockable standpipe, ~0.7 to 0.8m high</td></tr>
<tr><td>Other notes re drilling / construction</td><td colspan="4">The drilling method should be able to accurately identify the depth to watertable. Hollow auger is therefore the preferred technique. Bore depth ~ 6m below watertable is recommended (i.e. top of screen ~ 3m below watertable). Large seasonal fluctuation in watertable is unlikely. Bore to be gamma logged (post- construction)</td></tr>
</table>

* Final selection of bore depth and screen will be decided based on field logging

Groundwater monitoring bore general construction



Testing Requirements	
Water quality sampling	Sample for field chemistry (EC, pH, ORP, DO) recommended. Conduct at same time as hydraulic testing.
Geophysical testing	Gamma logging recommended (post-construction)
Hydraulic testing	Slug test recommended

Monitoring Requirements		
Water Level Monitoring Frequency	Manual	<u>Frequency</u>: Quarterly for first 3 years, bi-annual for subsequent years (~ April and Nov.)
	Data logger	<u>Frequency</u>: 6 hourly for first 3 years, daily for subsequent years Annual dipping of bores for cross-checking logger data
Water Level Monitoring Duration	Minimum duration, up to ~ 2018, i.e. point where data is required for analysis contributing to licence renewal. Recommended duration: 10 yrs, with review after 10 yrs data collection.	

Bore Maintenance Requirements	
Assessing need for maintenance	• Annual depthing of the bore and comparison with bore depth and screen interval (combine with a water level monitoring visit). Assess condition of surface steel cover, and concrete seal around top of the bore. • Inspect hydrograph on annual basis for anomalous behaviour
Scheduled maintenance	• Maintain protective steel cover (as required). • Flushing of the bore once every ten years using airlift.

Bore: TB5

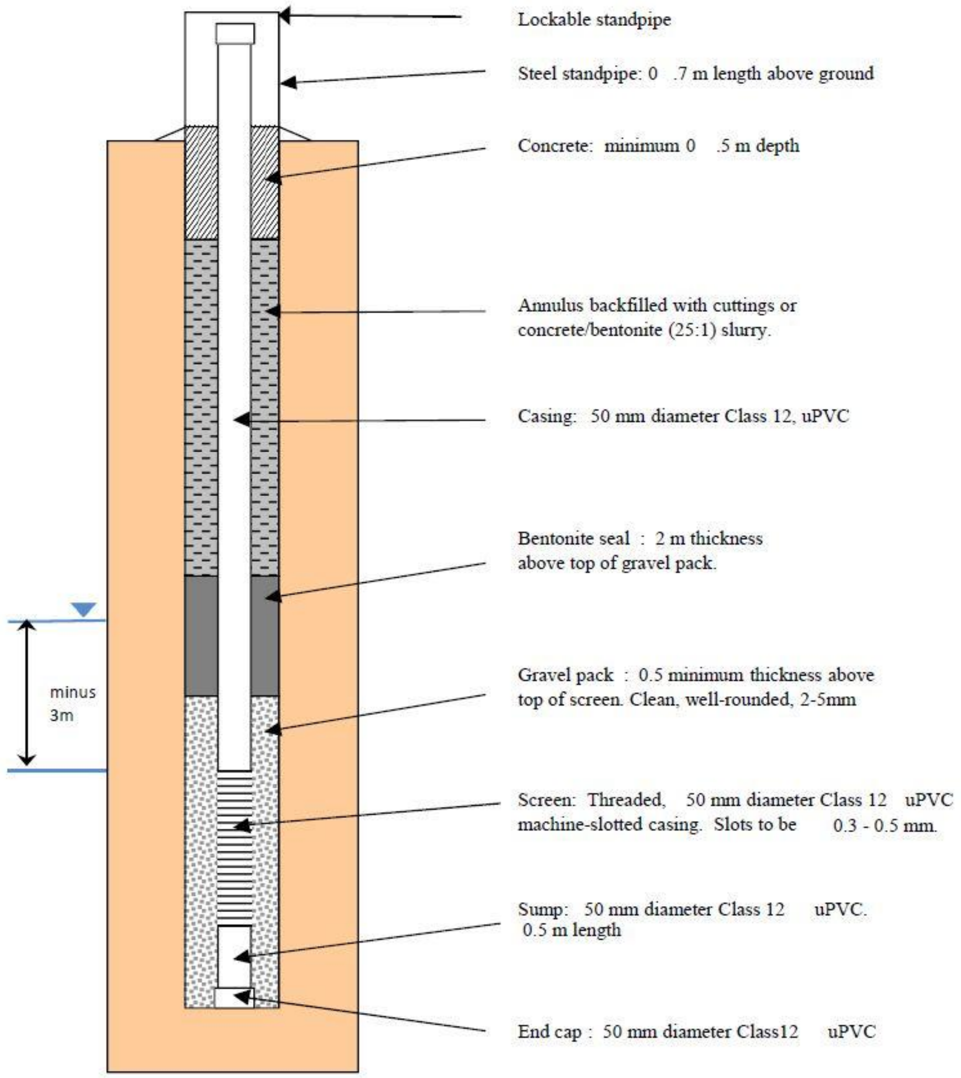
General Information		
Bore ID	TB5	Photo (facing north)
Coordinates(approx.), Zone 55	207,250 E 5,741,800 N	
Location Description	Near front of “Field and Game” (Gun club), ~ 850m along track off Westwood Rd.	
Purpose of Bore	1. Monitoring the watertable at terrestrial vegetation monitoring site (“Reference” Site) 2. Determine gw flow direction in Upper Boundary Creek	
GMS No. (future)		
Bore Construction Licence No. (future)		

Access			
Land Owner	DSE / Parks Victoria	*Required Permits*	Use of Crown Land requires consent pursuant to the Crown Land (Reserves) Act 1978 from the land manager (i.e. DSE). Permit required if removing native vegetation.
Access Description	Near front of “Field and Game” (Gun club), ~ 850m down track off Westwood Rd, on west side of track, in drainage break (as shown in above photo). The site requires access through front gate of gun club track but not through the main gate to the club’s actual grounds.	*Alternate Locations*	There are limited options for siting the bore near the vegetation monitoring site along the track, apart from this location. Inside the gun club (gate can be seen in far distance in photo) may be an option, but would involve more complicated access for monitoring of the bore.
Additional notes	Need to assess whether drilling in this drainage / grader break is permitted.		

Construction Information (refer over page for construction diagram)			
Bore Depth (estimated)	10 - 20m	*Screening Target*	The aim is to screen below the lowest expected watertable level at the site.
Nearest Bore, Distance, Expected Lithology (comments)	▪ 48002 ▪ State Observation bore ▪ GEDIS lithology log ▪ Bore no longer exists ▪ ~ 700m north of site ▪ Alluvial material (sands, silts, clays). Swampy/peaty material & shallow bedrock possible.	*Nearest bore log(m)*	48002 Log 0 0.2 TOPSOIL 0.2 1 WHITE SANDY LOAM 1 6.5 YELLOW SANDY CLAY 6.5 9 MOTTLED CLAY 9 14.5 BLUEY GREY CLAY 14.5 23.3 BLUE GREY SANDSTONE
Drilling Method	Hollow auger is therefore the recommended technique.		
Screen Interval / Length	Bottom of hole minus 1 metre / 3m screen *	*Constructed Bore Diameter*	50mm
Casing Material	uPVC Class 12	*Screen Material, Slot Size*	uPVC Class 12 , machine slotted, 0.3mm to 0.5mm
Surface Construction	Steel lockable standpipe, ~0.7 to 0.8m high		
Other notes re drilling / construction	The drilling method should be able to accurately identify the depth to watertable. Hollow auger is therefore the recommended technique. Bore depth ~ 6m below watertable is recommended (i.e. top of screen ~ 3m below watertable). Large seasonal fluctuation in watertable not expected.		

* Final selection of bore depth and screen will be decided based on field logging

Groundwater monitoring bore general construction



Testing Requirements	
Water quality sampling	Sample for field chemistry (EC, pH, ORP, DO) recommended. Conduct at same time as hydraulic testing.
Geophysical testing	Gamma logging recommended (post-construction)
Hydraulic testing	Slug test recommended

Monitoring Requirements		
Water Level Monitoring Frequency	Manual	<u>Frequency</u>: Quarterly for first 3 years, bi-annual for subsequent years (~ April and Nov.)
	Data logger	<u>Frequency</u>: 6 hourly for first 3 years, daily for subsequent years Annual dipping of bores for cross-checking logger data
Water Level Monitoring Duration	Minimum duration, up to ~ 2018, i.e. point where data is required for analysis contributing to licence renewal. Recommended duration: 10 yrs, with review after 10 yrs data collection.	

Bore Maintenance Requirements	
Assessing need for maintenance	• Annual depthing of the bore and comparison with bore depth and screen interval (combine with a water level monitoring visit). Assess condition of surface steel cover, and concrete seal around top of the bore. • Inspect hydrograph on annual basis for anomalous behaviour
Scheduled maintenance	• Maintain protective steel cover (as required). • Flushing of the bore once every ten years using airlift.

Bore: TB6

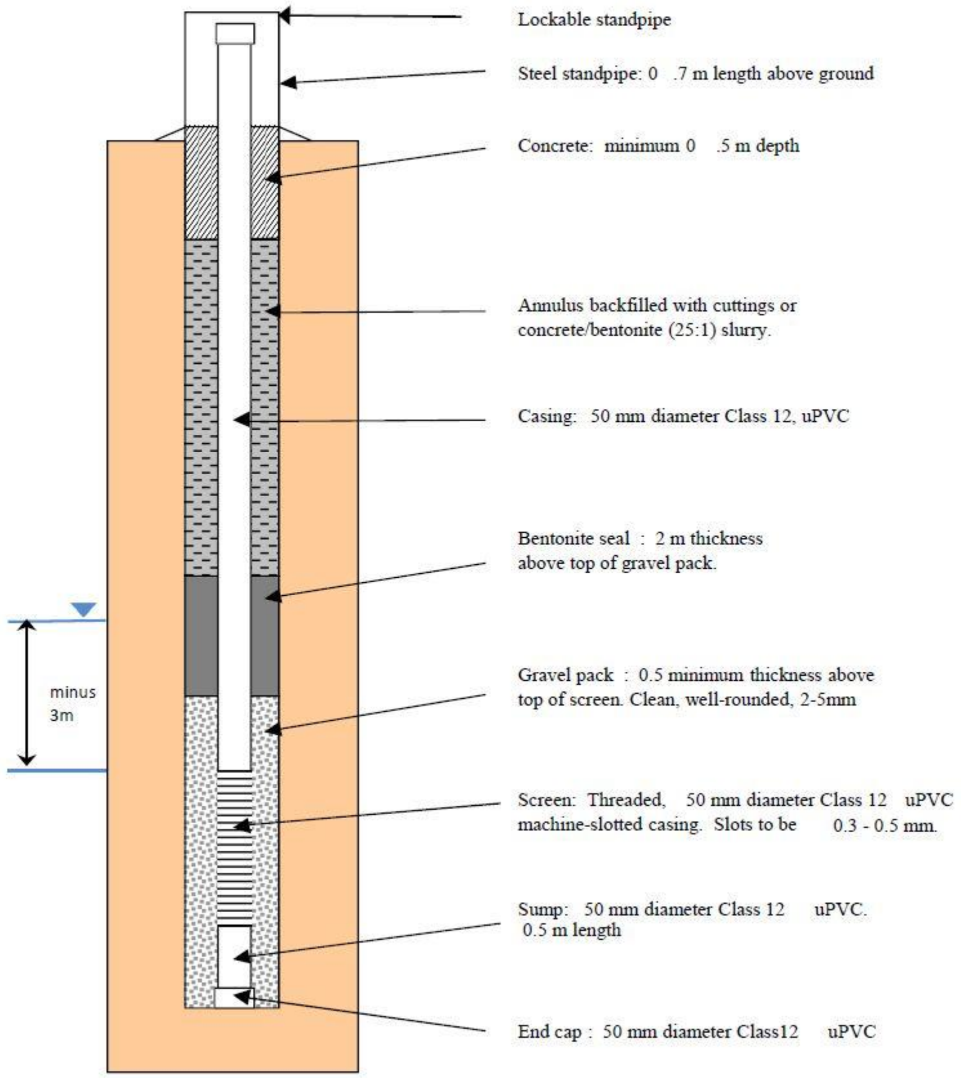
General Information		
Bore ID	TB6	Photo – N/A
Coordinates(approx.), Zone 55	N/A	
Location Description	Near end of Langdons Rd.	
Purpose of Bore	To assess depth to watertable at vegetation monitoring site – Reference site.	
GMS No. (future)		
Bore Construction Licence No. (future)		

Access			
Land Owner	DSE / Parks Victoria	*Required Permits*	Use of Crown Land requires consent pursuant to the Crown Land (Reserves) Act 1978 from the land manager (i.e. DSE). Permit required if removing native vegetation.
Access Description	This site was not visited during the hydrogeological field assessment, as it was only identified by Ecology Australia during their field visit.	*Alternate Locations*	Locations 205,685 E 5,750,542 N and 205,856 5,740,569 N are at the original Site TB6, but location has changed slightly. Those sites could be used as a back-up if access on Langdon's Rd is poor.
Additional notes	Site visit required to determine bore position (and rig type)		

Construction Information (refer over page for construction diagram)			
Bore Depth (estimated)	10 - 20m	*Screening Target*	The aim is to screen below the lowest expected watertable level at the site.
Nearest Bore, Distance, Expected Lithology (comments)	▪ 48010 ▪ State Observation Bore ▪ GEDIS lithology log ▪ Unknown current status ▪ ~ 400m west of site	*Nearest bore log(m)*	48010 Log 0 12 CLAY 12 27 GRAVEL 27 33 SAND -------------------- EOH 33m
Drilling Method	Hollow auger is recommended technique.		
Screen Interval / Length	Bottom of hole minus 1 metre / 3m screen *	*Constructed Bore Diameter*	50mm
Casing Material	uPVC Class 12	*Screen Material, Slot Size*	uPVC Class 12, machine slotted, 0.3mm to 0.5mm
Surface Construction	Steel lockable standpipe, ~0.7 to 0.8m high		
Other notes re drilling / construction	The drilling method should be able to accurately identify the depth to watertable. Hollow auger is therefore the preferred technique. Bore depth ~ 6m below watertable is recommended (i.e. top of screen ~ 3m below watertable). Large seasonal fluctuation in watertable not expected. Large long term decline in watertable level not likely.		

* Final selection of bore depth and screen will be decided based on field logging

Groundwater monitoring bore general construction



Testing Requirements	
Water quality sampling	Sample for field chemistry (EC, pH, ORP, DO) recommended. Conduct at same time as hydraulic testing.
Geophysical testing	Gamma logging recommended (post-construction)
Hydraulic testing	Slug test recommended

Monitoring Requirements		
Water Level Monitoring Frequency	Manual	<u>Frequency</u>: Quarterly for first 3 years, bi-annual for subsequent years (~ April and Nov.)
	Data logger	<u>Frequency</u>: 6 hourly for first 3 years, daily for subsequent years Annual dipping of bores for cross-checking logger data
Water Level Monitoring Duration	Minimum duration, up to ~ 2018, i.e. point where data is required for analysis contributing to licence renewal. Recommended duration: 10 yrs, with review after 10 yrs data collection.	

Bore Maintenance Requirements	
Assessing need for maintenance	• Annual depthing of the bore and comparison with bore depth and screen interval (combine with a water level monitoring visit). Assess condition of surface steel cover, and concrete seal around top of the bore. • Inspect hydrograph on annual basis for anomalous behaviour
Scheduled maintenance	• Maintain protective steel cover (as required). • Flushing of the bore once every ten years using airlift.

Bore: TB7

<table>
<tr><th colspan="3">General Information</th></tr>
<tr><td>Bore ID</td><td>TB7</td><td>Photo (facing west)</td></tr>
<tr><td>Coordinates(approx.), Zone 55</td><td>203,875 E
5,740,080 N</td><td rowspan="6"></td></tr>
<tr><td>Location Description</td><td>Upper part of Ten Mile Ck, access is either along Old Beechy Rail Trail (walking) or on track of Robinson Road (vehicle)</td></tr>
<tr><td>Purpose of Bore</td><td>To assess depth to watertable at veg. monitoring site – Reference site. There is an active SOBN bore nearby (47996), with water level ~ 2.5m however the bore is screened 32-46m bgl. The interval from 10 - 30m is mainly clay & therefore a new shallow bore is recommended to ensure true watertable is monitored, approx. screening 4.5 - 7.5m, (fine sand in log of 47996).</td></tr>
<tr><td>GMS No. (future)</td><td></td></tr>
<tr><td>Bore Construction Licence No. (future)</td><td></td></tr>
</table>

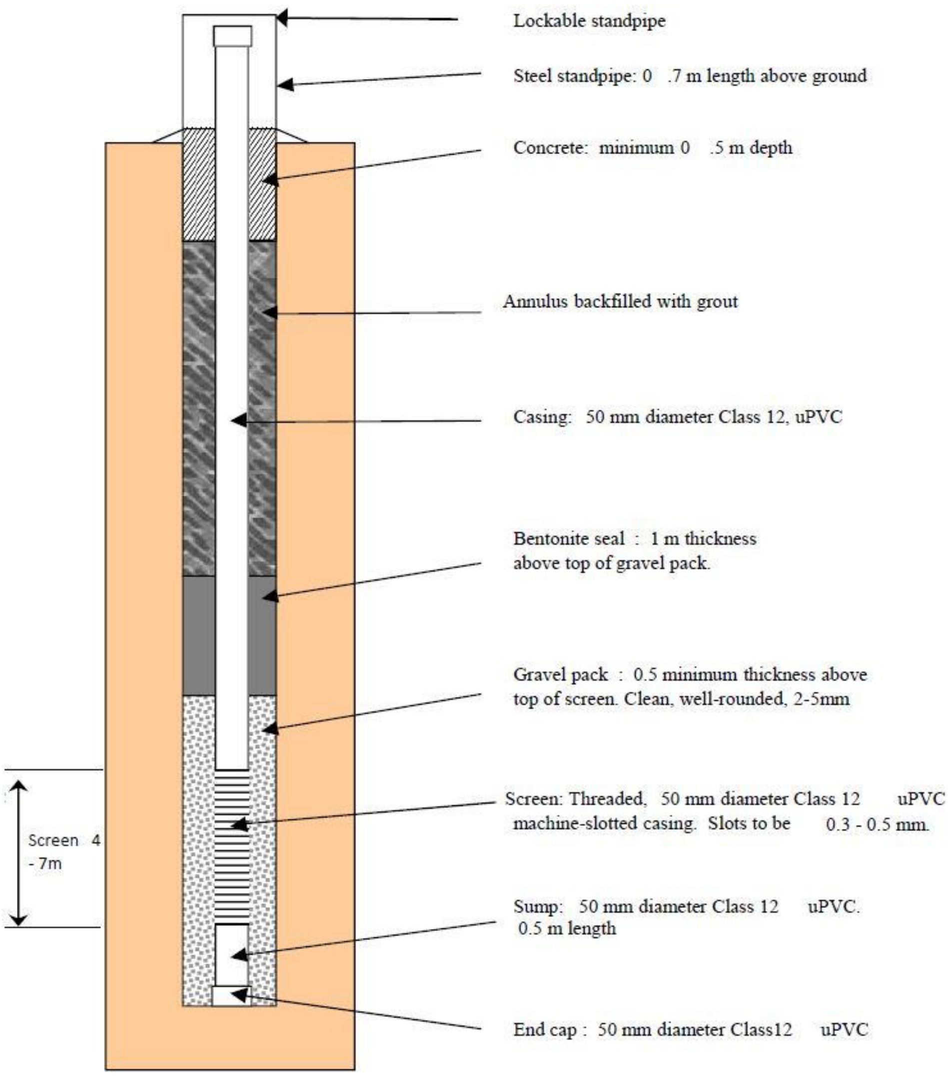
<table>
<tr><th colspan="4">Access</th></tr>
<tr><td>Land Owner</td><td>DSE / Parks Victoria</td><td>Required Permits</td><td>Use of Crown Land requires consent pursuant to the Crown Land (Reserves) Act 1978 from the land manager (i.e. DSE). Permit required if removing native vegetation.</td></tr>
<tr><td>Access Description</td><td>Access for rig is along track off Robinsons Road</td><td>Alternate Locations</td><td>N/A</td></tr>
<tr><td>Additional notes</td><td colspan="3">Track is quite narrow in places and may require track mounted rig - Refer Photo 140 for indication of track width</td></tr>
</table>

<table>
<tr><th colspan="4">Construction Information (refer over page for construction diagram)</th></tr>
<tr><td>Bore Depth (estimated)</td><td>5 - 10m</td><td>Screening Target</td><td>The aim is to screen below the lowest expected watertable level at the site.</td></tr>
<tr><td>Nearest Bore, Distance, Expected Lithology (comments)</td><td>▪ 47996
▪ State Observation Bore
▪ GEDIS lithology log
▪ Currently Monitored
▪ ~ 50 m east</td><td>Nearest bore log(m)</td><td>47996 Log
0 0.3 TOPSOIL
0.3 1.4 BROWN CLAYEY SAND
1.4 4.5 ORANGE CLAY & GRAVEL
4.5 7.5 FINE YELLOW SAND
7.5 10.8 FINE GREY CLAYEY SAND
10.8 13 GREY SILTY CLAY
13 19 FINE SAND & BANDS OF CLAY
19 25 FINE GREY SAND

EOH 94 m</td></tr>
<tr><td>Drilling Method</td><td colspan="3">Hollow auger is recommended technique.</td></tr>
<tr><td>Screen Interval / Length</td><td>Bottom of hole minus 1 metre / 3m screen *</td><td>Constructed Bore Diameter</td><td>50mm</td></tr>
<tr><td>Casing Material</td><td>uPVC Class 12</td><td rowspan="2">Screen Material, Slot Size</td><td rowspan="2">uPVC Class 12, machine slotted, 0.3mm to 0.5mm</td></tr>
<tr><td>Surface Construction</td><td>Steel lockable standpipe, ~0.7 to 0.8m high</td></tr>
<tr><td>Other notes re drilling / construction</td><td colspan="3">The drilling method should be able to accurately identify the depth to watertable. Hollow auger is therefore the preferred technique. Bore depth ~ 6m below watertable is recommended (i.e. top of screen ~ 3m below watertable). Large seasonal fluctuation in watertable not expected. Large long term decline in watertable level not likely at this site.</td></tr>
</table>

* Final selection of bore depth and screen will be decided based on field logging

Groundwater monitoring bore general construction



Testing Requirements	
Water quality sampling	Sample for field chemistry (EC, pH, ORP, DO) recommended. Conduct at same time as hydraulic testing.
Geophysical testing	Gamma logging recommended (post-construction)
Hydraulic testing	Slug test recommended

Monitoring Requirements		
Water Level Monitoring Frequency	Manual	Frequency: Quarterly for first 3 years, bi-annual for subsequent years (~ April and Nov.)
	Data logger	Frequency: 6 hourly for first 3 years, daily for subsequent years Annual dipping of bores for cross-checking logger data
Water Level Monitoring Duration	Minimum duration, up to ~ 2018, i.e. point where data is required for analysis contributing to licence renewal. Recommended duration: 10 yrs, with review after 10 yrs data collection.	

Bore Maintenance Requirements	
Assessing need for maintenance	• Annual depthing of the bore and comparison with bore depth and screen interval (combine with a water level monitoring visit). Assess condition of surface steel cover, and concrete seal around top of the bore. • Inspect hydrograph on annual basis for anomalous behaviour
Scheduled maintenance	• Maintain protective steel cover (as required). • Flushing of the bore once every ten years using airlift.

Bore: UBCk1

General Information

Bore ID	UBCk1	Photo (facing north)
Coordinates(approx.), Zone 55	207,345 E 5,742,450 N	
Location Description	Former bore site 48002 (Behind "Field and Game"	
Purpose of Bore	Determine gw flow direction in upper Boundary Creek	
GMS No. (future)		
Bore Construction Licence No. (future)		

Access

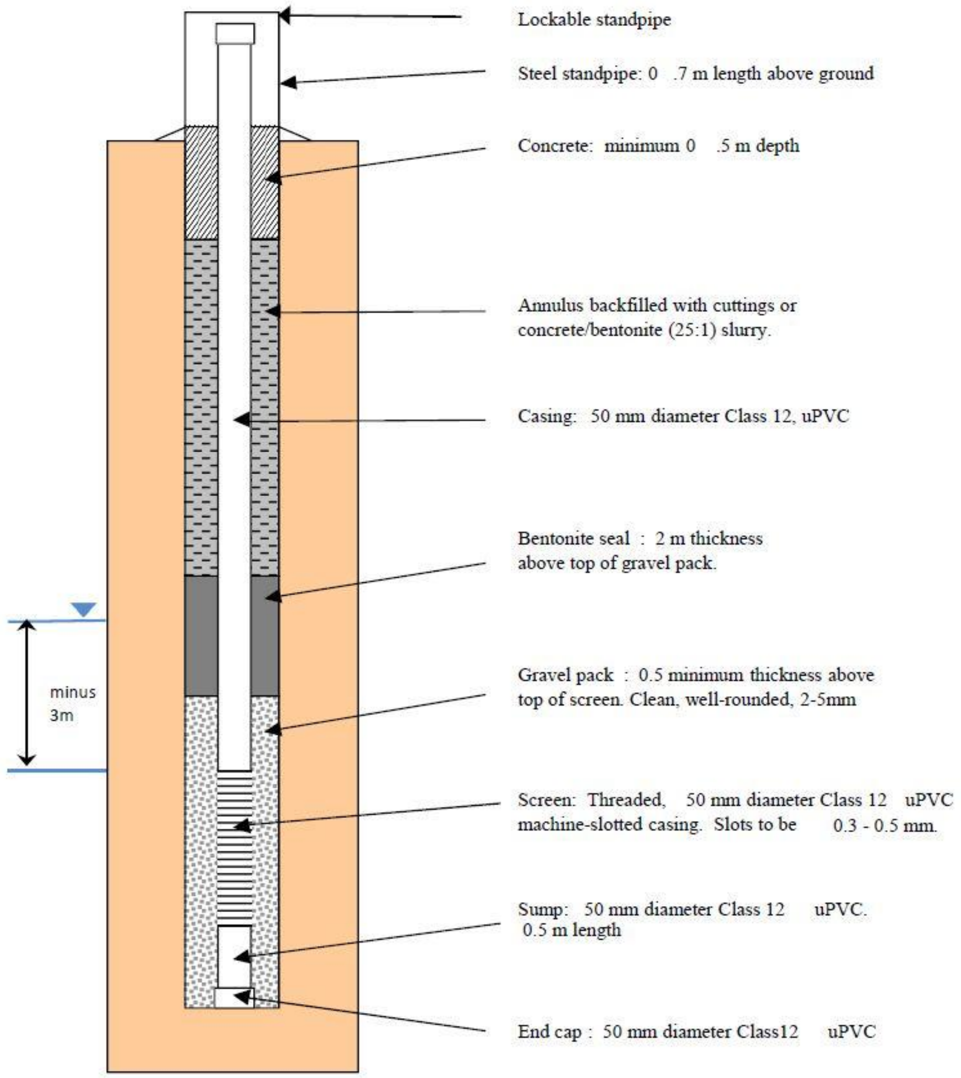
Land Owner	DSE / Parks Victoria	*Required Permits*	Use of Crown Land requires consent pursuant to the Crown Land (Reserves) Act 1978 from the land manager (i.e. DSE). Permit required if removing native vegetation.
Access Description	Good access for drilling (to RHS car in photo).	*Alternate Locations*	There are several sites at the intersection of the two tracks shown in above photo.
Additional notes	Intersection of private and public land. Assess the easier location for permission to drill. Consultation with private landholder and DSE / DSE / Parks Victoria required.		

Construction Information (refer over page for construction diagram)

Bore Depth (estimated)	15-30 m	*Screening Target*	The aim is to screen below the lowest expected watertable level at the site.
Nearest Bore, Distance, Expected Lithology (comments)	▪ 48002 (SOBN bore) ▪ GEDIS lithology log ▪ Bore no longer exists ~ at site ▪ Alluvial material (sands, silts, clays).	*Nearest bore log(m)*	48002 Log 0 0.2 TOPSOIL 0.2 1 WHITE SANDY LOAM 1 6.5 YELLOW SANDY CLAY 6.5 9 MOTTLED CLAY 9 14.5 BLUEY GREY CLAY 14.5 23.3 BLUE GREY SANDSTONE
Drilling Method	Mud rotary technique will be used for bores greater than 25 m deep.		
Screen Interval / Length	Bottom of hole minus 1 metre / 3m screen *	*Constructed Bore Diameter*	50mm
Casing Material	uPVC Class 12	*Screen Material, Slot Size*	uPVC Class 12, machine slotted, 0.3mm to 0.5mm
Surface Construction	Steel lockable standpipe, ~0.7 to 0.8m high		
Other notes re drilling / construction	Bore depth ~ 6m below watertable is recommended (i.e. top of screen ~ 3m below watertable). Large seasonal fluctuation in watertable not expected.		

* Final selection of bore depth and screen will be decided based on field logging

Groundwater monitoring bore general construction



Testing Requirements	
Water quality sampling	Sample for field chemistry (EC, pH, ORP, DO) recommended. Conduct at same time as hydraulic testing.
Geophysical testing	Gamma logging recommended (post-construction)
Hydraulic testing	Slug test recommended

Monitoring Requirements		
Water Level Monitoring Frequency	Manual	Frequency: Quarterly for first 3 years, bi-annual for subsequent years (~ April and Nov.)
	Data logger	Frequency: 6 hourly for first 3 years, daily for subsequent years Annual dipping of bores for cross-checking logger data
Water Level Monitoring Duration	Minimum duration, up to ~ 2018, i.e. point where data is required for analysis contributing to licence renewal. Recommended duration: 10 yrs, with review after 10 yrs data collection.	

Bore Maintenance Requirements	
Assessing need for maintenance	• Annual depthing of the bore and comparison with bore depth and screen interval (combine with a water level monitoring visit). Assess condition of surface steel cover, and concrete seal around top of the bore. • Inspect hydrograph on annual basis for anomalous behaviour
Scheduled maintenance	• Maintain protective steel cover (as required). • Flushing of the bore once every ten years using airlift.

Bore: UBCk2

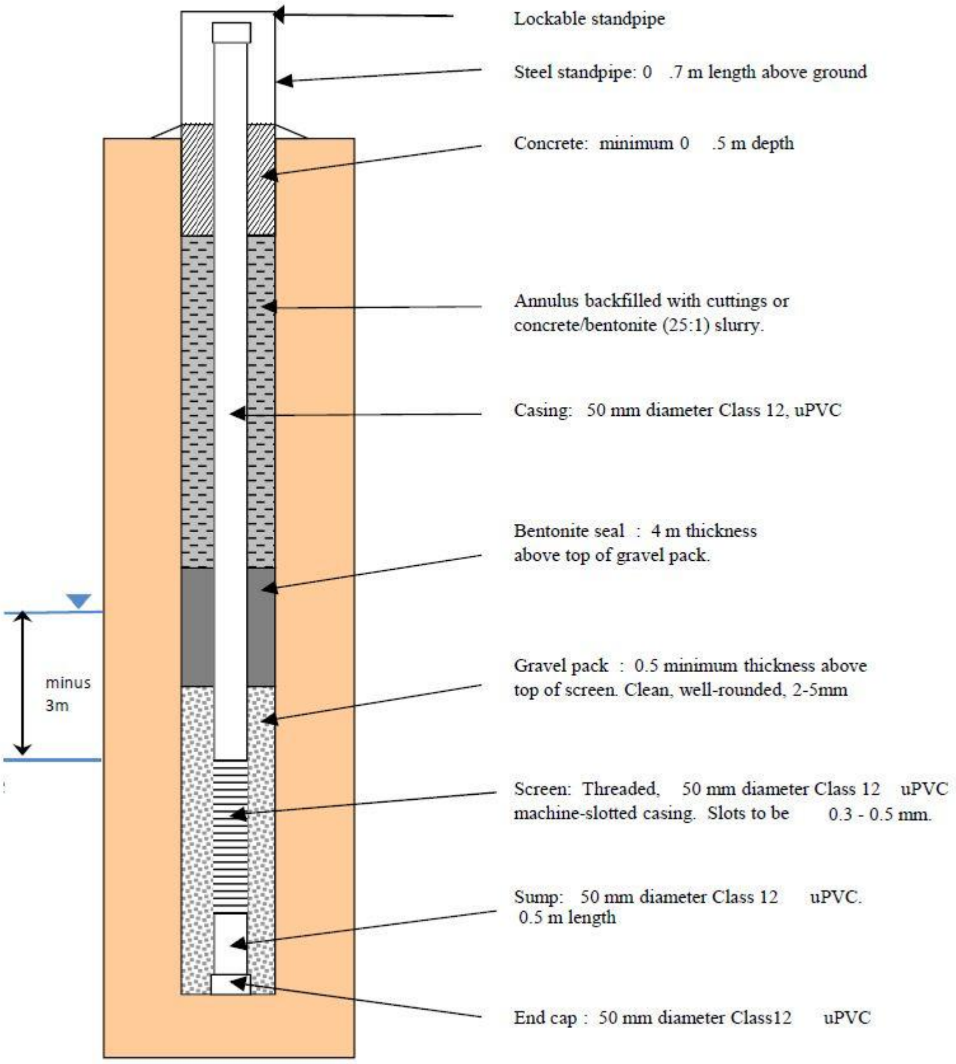
General Information		
Bore ID	UBCk2	Photo (facing north)
Coordinates(approx.), Zone 55	207,437 E 5,743,197 N	
Location Description	Adjacent Boundary Ck, north of "Field and Game"	
Purpose of Bore	Determine gw flow direction in upper Boundary Ck NOTE: The three bores together also form a transect to Boundary Creek	
GMS No. (future)		
Bore Construction Licence No. (future)		

Access			
Land Owner	Private land.	*Required Permits*	If confirmed on private land, no permits should be required
Access Description	Good access for drilling.	*Alternate Locations*	There are alternate locations on the track along Boundary Creek (refer Photo 91, 92 and 93)
Additional notes	DPI (2009) mapped as private land, however no gates from State Forest. Need to confirm land owner.		

Construction Information (refer over page for construction diagram)			
Bore Depth (estimated)	10-15 m	*Screening Target*	The aim is to screen below the lowest expected watertable level at the site.
Nearest Bore, Distance, Expected Lithology (comments)	▪ 48002 (SOBN bore) GEDIS lithology log ▪ ~ 750 m south of site ▪ Alluvial material (sands, silts, clays). Shallow bedrock likely.	*Nearest bore log(m)*	48002 Log 0 0.2 TOPSOIL 0.2 1 WHITE SANDY LOAM 1 6.5 YELLOW SANDY CLAY 6.5 9 MOTTLED CLAY 9 14.5 BLUEY GREY CLAY 14.5 23.3 BLUE GREY SANDSTONE
Drilling Method	The drilling method should be able to accurately identify the depth to watertable. Hollow auger is therefore preferred technique. <u>Air hammer likely to be required, as site is mapped as outcropping bedrock.</u>		
Screen Interval / Length	Bottom of hole minus 1 metre / 3m screen *	*Constructed Bore Diameter*	50mm
Casing Material	uPVC Class 12	*Screen Material, Slot Size*	uPVC Class 12, machine slotted, 0.3mm to 0.5mm
Surface Construction	Steel lockable standpipe, ~0.7 to 0.8m high		
Other notes re drilling / construction	The drilling method should be able to accurately identify the depth to watertable. Hollow auger is therefore the preferred technique, but switch to air hammer likely, as site is mapped as outcropping bedrock. Bore depth ~ 6m below watertable is recommended (i.e. top of screen ~ 3m below watertable).		

* Final selection of bore depth and screen will be decided based on field logging

Groundwater monitoring bore general construction



Testing Requirements	
Water quality sampling	Sample for field chemistry (EC, pH, ORP, DO) recommended. Conduct at same time as hydraulic testing.
Geophysical testing	Gamma logging recommended (post-construction)
Hydraulic testing	Slug test recommended

Monitoring Requirements		
Water Level Monitoring Frequency	Manual	Frequency: Quarterly for first 3 years, bi-annual for subsequent years (~ April and Nov.)
	Data logger	Frequency: 6 hourly for first 3 years, daily for subsequent years Annual dipping of bores for cross-checking logger data
Water Level Monitoring Duration	Minimum duration, up to ~ 2018, i.e. point where data is required for analysis contributing to licence renewal. Recommended duration: 10 yrs, with review after 10 yrs data collection.	

Bore Maintenance Requirements	
Assessing need for maintenance	• Annual depthing of the bore and comparison with bore depth and screen interval (combine with a water level monitoring visit). Assess condition of surface steel cover, and concrete seal around top of the bore. • Inspect hydrograph on annual basis for anomalous behaviour
Scheduled maintenance	• Maintain protective steel cover (as required). • Flushing of the bore once every ten years using airlift.

Bore: A1

General Information

Bore ID	A1	Photo (facing south) (facing north)
Coordinates(approx.), Zone 55	210,250 E 5,743,400 N	 
Location Description	Telegraph Rd, ~ 500-700m south of Dewings Rd	
Purpose of Bore	To determine depth to watertable in the aquitard at a topographic high point.	
GMS No. (future)		
Bore Construction Licence No. (future)		

Access

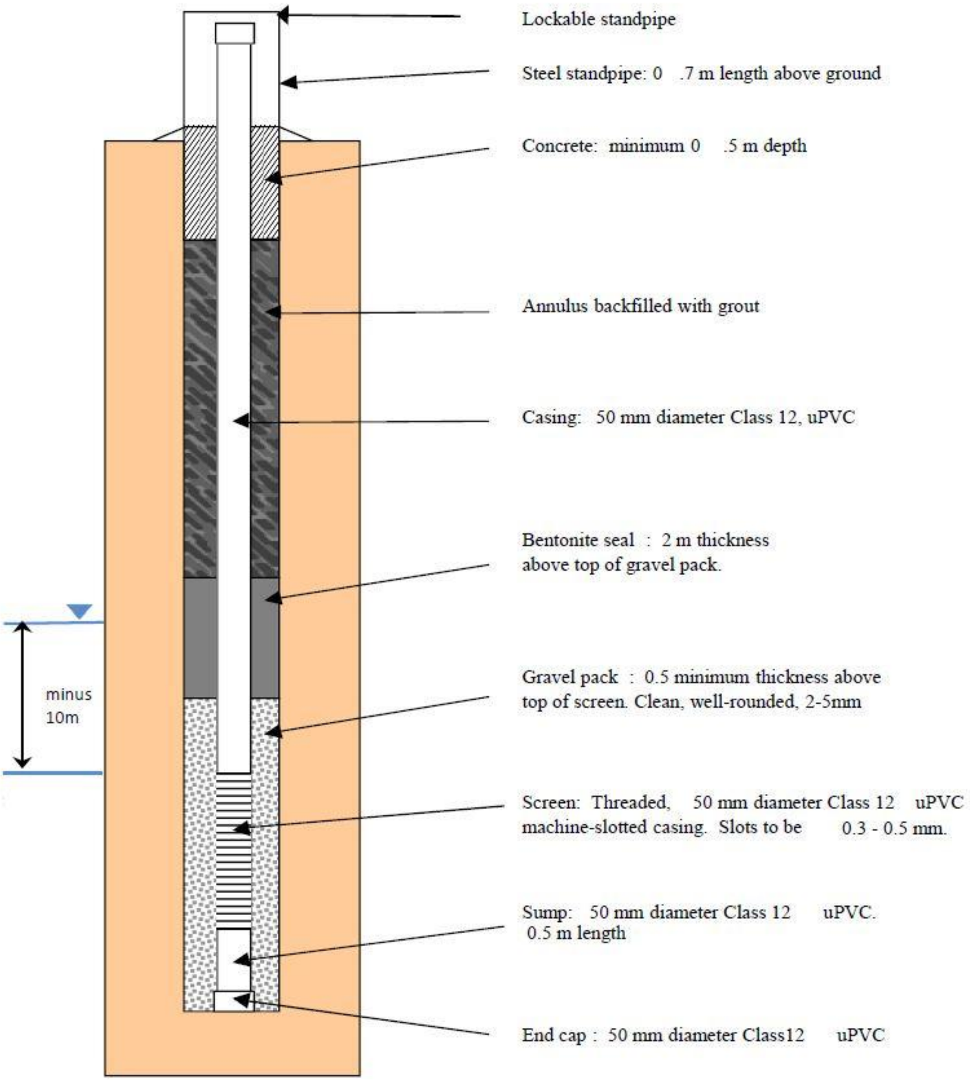
Land Owner	Colac Otway Shire Council	*Required Permits*	Requires consent from Council. Will involve assessment of traffic management requirements, and obtaining road opening permits, if deemed necessary by Council.
Access Description	Very good access at road edge.	*Alternate Locations*	If this site is difficult for any reason (permission, underground services etc) Dewings Rd ~150m west of intersection with Telegraph Rd is an optional alternate location.
Additional notes	Very good access at road edge means there should be no need for road closures. Only basic level of traffic management expected.		

Construction Information (refer over page for construction diagram)

Bore Depth (estimated)	20 – 40 m	*Screening Target*	The aim is to screen below the lowest expected watertable level at the site.
Nearest Bore, Distance, Expected Lithology (comments)	▪ 320891 ▪ GEDIS bore and lithology log ▪ ~ 900 m from site	*Nearest bore log(m)*	320891 Log 0 0.6 TOPSOIL 0.6 2 DARK REDDISH BROWN CLAY 2 4 RED-BROWN SILT AND CLAY 4 5 RED-BROWN GREY SILT & CLAY 5 7 REDDISH BROWN CLAY 7 8 BROWN CLAY 8 10 RED-BROWN GREY SILTY CLAY 10 16 REDDISH BROWN SILTY CLAY 16 19 REDDISH BROWN AND GREY SILT AND CLAY --------------------- EOH 19 m (next closest bore with a lithology log is ~3km away and lithology log indicates that between 19 m and 40 m depth, clay and sand was encountered).
Drilling Method	Mud rotary technique will be used for bores greater than 25 m deep.		
Screen Interval / Length	Bottom of hole minus 1 metre / 3m screen *	*Constructed Bore Diameter*	50mm
Casing Material	uPVC Class 12	*Screen Material, Slot Size*	uPVC Class 12, machine slotted, 0.3mm to 0.5mm
Surface Construction	Steel lockable standpipe, ~0.7 to 0.8m high		
Other notes re drilling / construction	Bore depth ~ 10m below watertable is recommended (i.e. top of screen ~ 6m below watertable). Large long term decline in watertable level not likely. Determining depth to watertable with mud rotary will be difficult. Best estimate of depth to watertable and hence required bore depth should be made based on elevation of site relative to elevation of adjacent Barwon River.		

* Final selection of bore depth and screen will be decided based on field logging

Groundwater monitoring bore general construction



Testing Requirements	
Water quality sampling	To be sampled for major cations, anions, TDS, EC (plus field parameters EC, pH, redox,temp). Conduct at same time as hydraulic testing.
Geophysical testing	Gamma logging recommended (post-construction)
Hydraulic testing	Slug test recommended

Monitoring Requirements		
Water Level Monitoring Frequency	Manual	<u>Frequency</u>: Quarterly for first 3 years, bi-annual for subsequent years (~ April and Nov.)
	Data logger	<u>Frequency</u>: 6 hourly for first 3 years, daily for subsequent years Annual dipping of bores for cross-checking logger data
Water Level Monitoring Duration	Minimum duration, up to ~ 2018, i.e. point where data is required for analysis contributing to licence renewal. Recommended duration: 10 yrs, with review after 10 yrs data collection.	

Bore Maintenance Requirements	
Assessing need for maintenance	• Annual depthing of the bore and comparison with bore depth and screen interval (combine with a water level monitoring visit). Assess condition of surface steel cover, and concrete seal around top of the bore. • Inspect hydrograph on annual basis for anomalous behaviour
Scheduled maintenance	• Maintain protective steel cover (as required). • Flushing of the bore once every ten years using airlift.

Bore: A2

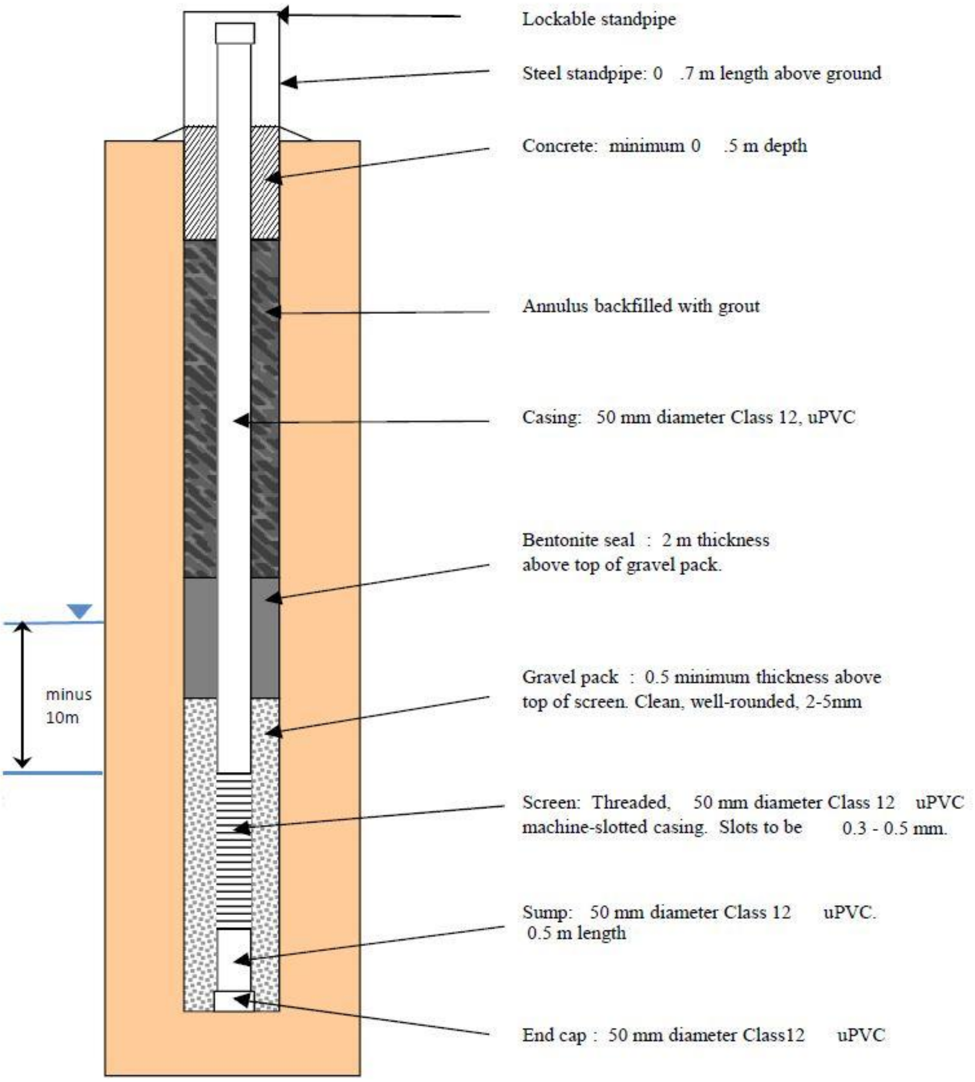
General Information		
Bore ID	A2	Photo (facing north)
Coordinates(approx.), Zone 55	212,800 E 5,741,900 N	
Location Description	Colac-Forrest Rd, ~400m south of Boundary Ck (east side of road)	
Purpose of Bore	To determine depth to watertable in the aquitard at a topographic high point and, along with Bore A3, determine groundwater gradient to Boundary Creek	
GMS No. (future)		
Bore Construction Licence No. (future)		

Access			
Land Owner	Colac Otway Shire Council	*Required Permits*	Requires consent from Council. Will involve assessment of traffic management requirements, and obtaining road opening permits, if deemed necessary by Council.
Access Description	Reasonable access (~9m to road edge) but caution required coming on and off Colac-Forrest Rd. No overhead issues, but Telstra cable in vicinity.	*Alternate Locations*	If site deemed not suitable, alternate location 900m south of Boundary Creek (on Colac-Forrest Rd). Locations (212,525 E; 5,741,487 and 212,543 E; 5,741,471).
Additional notes	Minor clearing of grasses/bracken required. Sufficient space in the road easement, but traffic management may be required for getting on and off the (relatively) busy Colac-Forrest Rd.		

Construction Information (refer over page for construction diagram)			
Bore Depth (estimated)	20 - 40m	*Screening Target*	The aim is to screen below the lowest expected watertable level at the site.
Nearest Bore, Distance, Expected Lithology (comments)	▪ 109105 ▪ GEDIS bore and lithology log ▪ ~400 m north of site	*Nearest bore log(m)*	109105 Log 0 0.3 TOPSOIL 0.3 98 CLAY SAND ---------------------- EOH 98 m
Drilling Method	Mud rotary technique will be used.		
Screen Interval / Length	Bottom of hole minus 1 metre / 3m screen *	*Constructed Bore Diameter*	50mm
Casing Material	uPVC Class 12	*Screen Material, Slot Size*	uPVC Class 12, machine slotted, 0.3mm to 0.5mm
Surface Construction	Steel lockable standpipe, ~0.7 to 0.8m high		
Other notes re drilling / construction	Bore depth ~ 13-15m below watertable is recommended (i.e. top of screen ~ 10m below watertable). Large long term decline in watertable level not likely. Determining depth to watertable with mud rotary will be difficult. It is recommended that Bore A3 be drilled first, as this will determine nearby watertable elevation, and allow depth of this bore to be determined more accurately.		

* Final selection of bore depth and screen will be decided based on field logging

Groundwater monitoring bore general construction



Testing Requirements	
Water quality sampling	To be sampled for major cations, anions, TDS, EC (plus field parameters EC, pH, redox,temp). Conduct at same time as hydraulic testing.
Geophysical testing	Gamma logging recommended (post-construction)
Hydraulic testing	Slug test recommended

Monitoring Requirements		
Water Level Monitoring Frequency	Manual	Frequency: Quarterly for first 3 years, bi-annual for subsequent years (~ April and Nov.)
	Data logger	Frequency: 6 hourly for first 3 years, daily for subsequent years Annual dipping of bores for cross-checking logger data
Water Level Monitoring Duration	Minimum duration, up to ~ 2018, i.e. point where data is required for analysis contributing to licence renewal. Recommended duration: 10 yrs, with review after 10 yrs data collection.	

Bore Maintenance Requirements	
Assessing need for maintenance	• Annual depthing of the bore and comparison with bore depth and screen interval (combine with a water level monitoring visit). Assess condition of surface steel cover, and concrete seal around top of the bore. • Inspect hydrograph on annual basis for anomalous behaviour
Scheduled maintenance	• Maintain protective steel cover (as required). • Flushing of the bore once every ten years using airlift.

Bore: A3

<table>
<tr><th colspan="3">General Information</th></tr>
<tr><td>Bore ID</td><td>A3</td><td>Photo (facing south)</td></tr>
<tr><td>Coordinates(approx.), Zone 55</td><td>212750 E
5,742,450 N</td><td rowspan="5">
</td></tr>
<tr><td>Location Description</td><td>Colac-Forest Rd, ~50-60m north of Boundary Creek (east side of road)</td></tr>
<tr><td>Purpose of Bore</td><td>To assess the nature of interaction of groundwater in the aquitard with Boundary Creek, and, along with Bore A2, determine the groundwater gradient to Boundary Creek</td></tr>
<tr><td>GMS No. (future)</td><td></td></tr>
<tr><td>Bore Construction Licence No. (future)</td><td></td></tr>
</table>

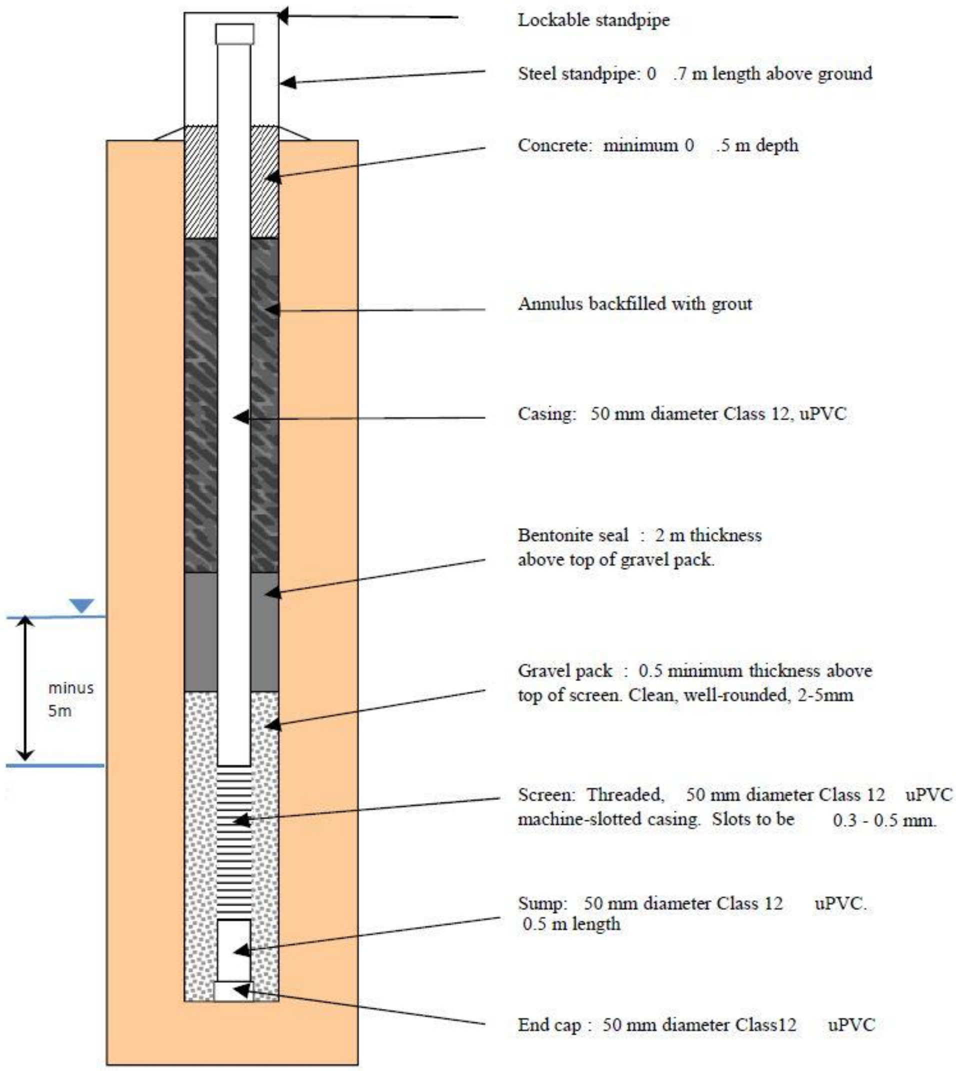
<table>
<tr><th colspan="4">Access</th></tr>
<tr><td>Land Owner</td><td>Colac Otway Shire Council</td><td>Required Permits</td><td>Requires consent from Council. Will involve assessment of traffic management requirements, and obtaining road opening permits, if deemed necessary by Council.</td></tr>
<tr><td>Access Description</td><td>Bore would be located at far end of the triangular patch shown in above photo.</td><td>Alternate Locations</td><td>If site deemed not suitable, could move to nest with SOBN bore on west side of road (refer photo 44). Access tighter however.</td></tr>
<tr><td>Additional notes</td><td colspan="3">Telstra cable runs along fence line on LHS of photo, but should be able to be avoided with required clearances. Excellent access means traffic management unlikely to be required at this site.</td></tr>
</table>

<table>
<tr><th colspan="4">Construction Information (refer over page for construction diagram)</th></tr>
<tr><td>Bore Depth (estimated)</td><td>10 - 20m</td><td>Screening Target</td><td>The aim is to screen below the lowest expected watertable level at the site.</td></tr>
<tr><td>Nearest Bore, Distance, Expected Lithology (comments)</td><td>▪ 109112
▪ State Observation Bore
▪ GEDIS lithology log
▪ Currently monitored
▪ ~60m northeast of site</td><td>Nearest bore log(m)</td><td>109112 Log
0 3 FINE SANDY CLAY BROWN
3 4 DENSE CLAY BROWN
4 9 MOTTLED CLAY & GRAVEL & FERRUGINIZED SANDSTONE
9 24 MARL BLACK & MARLY FINE SAND

EOH 292 m</td></tr>
<tr><td>Drilling Method</td><td colspan="3">The drilling method should be able to accurately identify the depth to watertable. Hollow auger is therefore the recommended technique.</td></tr>
<tr><td>Screen Interval / Length</td><td>Bottom of hole minus 1 metre / 3m screen *</td><td>Constructed Bore Diameter</td><td>50mm</td></tr>
<tr><td>Casing Material</td><td>uPVC Class 12</td><td rowspan="2">Screen Material, Slot Size</td><td rowspan="2">uPVC Class 12 , machine slotted, 0.3mm to 0.5mm</td></tr>
<tr><td>Surface Construction</td><td>Steel lockable standpipe, ~0.7 to 0.8m high</td></tr>
<tr><td>Other notes re drilling / construction</td><td colspan="3">Bore depth ~ 10m below watertable is recommended (i.e. top of screen ~ 5m below watertable).</td></tr>
</table>

* Final selection of bore depth and screen will be decided based on field logging

Groundwater monitoring bore general construction



Testing Requirements	
Water quality sampling	To be sampled for major cations, anions, TDS, EC (plus field parameters EC, pH, redox, temp). Conduct at same time as hydraulic testing.
Geophysical testing	Gamma logging recommended (post construction)
Hydraulic testing	Slug test recommended

Monitoring Requirements		
Water Level Monitoring Frequency	Manual	Frequency: Quarterly for first 3 years, bi-annual for subsequent years (~ April and Nov.)
	Data logger	Frequency: 6 hourly for first 3 years, daily for subsequent years Annual dipping of bores for cross-checking logger data
Water Level Monitoring Duration	Minimum duration, up to ~ 2018, i.e. point where data is required for analysis contributing to licence renewal. Recommended duration: 10 yrs, with review after 10 yrs data collection.	

Bore Maintenance Requirements	
Assessing need for maintenance	• Annual depthing of the bore and comparison with bore depth and screen interval (combine with a water level monitoring visit). Assess condition of surface steel cover, and concrete seal around top of the bore. • Inspect hydrograph on annual basis for anomalous behaviour
Scheduled maintenance	• Maintain protective steel cover (as required). • Flushing of the bore once every ten years using airlift.

Bore: A4

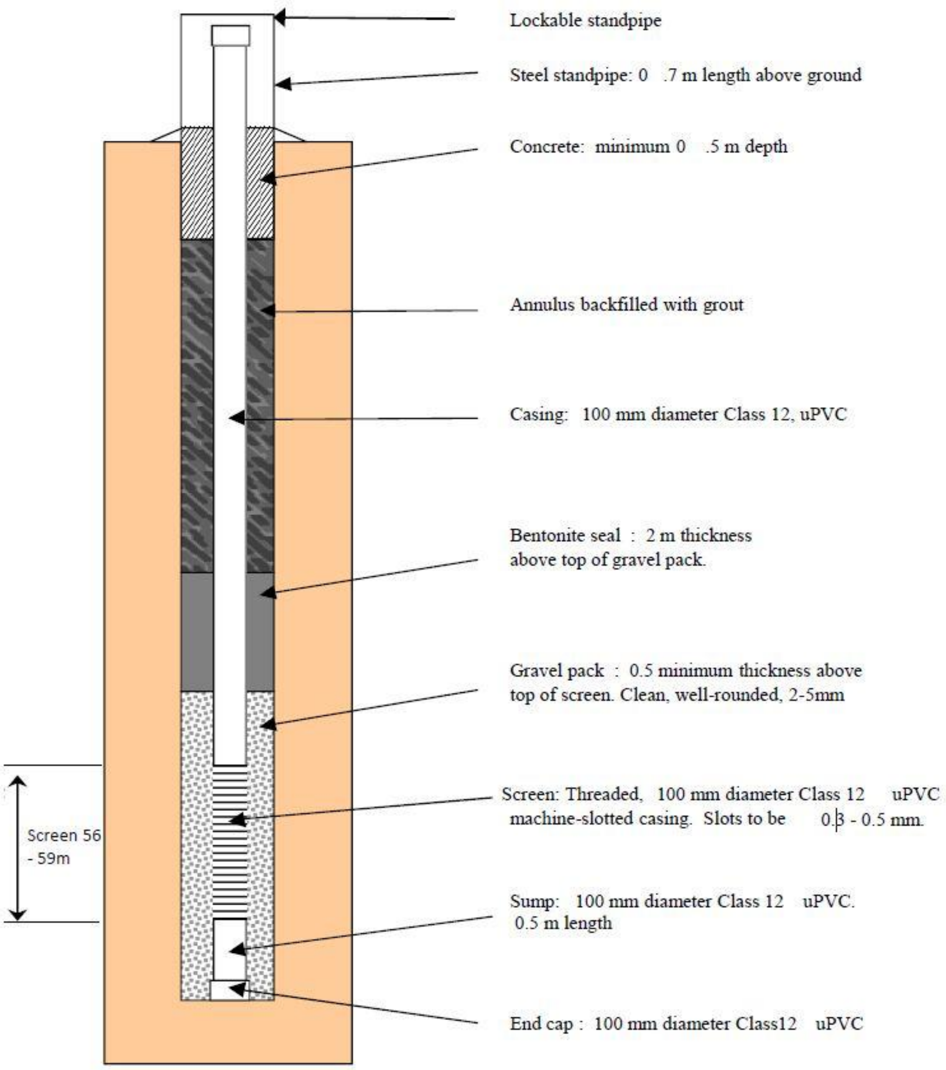
General Information		
Bore ID	A4	Photo (facing south)
Coordinates(approx.), Zone 55	213,950 E 5,744,350 N	
Location Description	McDonalds Rd, ~ 400m north of Birregurra-Yeodene Rd (west side of road)	
Purpose of Bore	To assess watertable response in an area with potential drawdown in the aquitard	
GMS No. (future)		
Bore Construction Licence No. (future)		

Access			
Land Owner	Colac Otway Shire Council	*Required Permits*	Requires consent from Council. Will involve assessment of traffic management requirements, and obtaining road opening permits, if deemed necessary by Council.
Access Description	Bore would be located opposite shed seen in photo above.	*Alternate Locations*	If site deemed not suitable, alternative site located several hundred metres further north (214,027 E; 5,745,015 N). Good access on eastern side of road.
Additional notes	Very quiet road. Minimal traffic management expected (if any). Even though on Council land, consultation with adjoining landowner also recommended.		

Construction Information (refer over page for construction diagram)			
Bore Depth (estimated)	30 -60m	*Screening Target*	The aim is to screen below the lowest expected watertable level at the site.
Nearest Bore, Distance, Expected Lithology (comments)	▪ 109107 ▪ GEDIS bore ▪ ~195 m northwest of site	*Nearest bore log(m)*	109107 Log 0 12 PINK CLAY AND SURFACE CLAY 12 24 YELLOW CLAY 24 59 DARK BROWN CLAY SANDY 59 76 BAND IRONSTONE ------------------------ EOH 303 m
Drilling Method	Mud rotary technique will be used (due to bore depth)		
Screen Interval / Length	Bottom of hole minus 1 metre / 3m screen *	*Constructed Bore Diameter*	100mm
Casing Material	uPVC Class 12	*Screen Material, Slot Size*	uPVC Class 12, machine slotted, 0.3mm to 0.5mm
Surface Construction	Steel lockable standpipe, ~0.7 to 0.8m high		
Other notes re drilling / construction	Bore depth ~ 13-15m below watertable is recommended (i.e. top of screen ~ 10m below watertable). Determining depth to watertable with mud rotary will be difficult. <u>It is recommended that Bore A3 be drilled first. Using WT elevation at that site and based on site elevation relative to floodplain, will allow bore depth to be determined more accurately.</u>		

* Final selection of bore depth and screen will be decided based on field logging

Groundwater monitoring bore general construction



NOTE – Screen interval shown in diagram above indicative only. Top of screen depth 10m below watertable is preferred.

Testing Requirements	
Water quality sampling	To be sampled for major cations, anions, TDS, EC (plus field parameters EC, pH, redox, temp). Conduct at same time as hydraulic testing.
Geophysical testing	Gamma logging recommended (post-construction)
Hydraulic testing	Slug test recommended

Monitoring Requirements		
Water Level Monitoring Frequency	Manual	<u>Frequency</u>: Quarterly for first 3 years, bi-annual for subsequent years (~ April and Nov.)
	Data logger	<u>Frequency</u>: 6 hourly for first 3 years, daily for subsequent years Annual dipping of bores for cross-checking logger data
Water Level Monitoring Duration	Minimum duration, up to ~ 2018, i.e. point where data is required for analysis contributing to licence renewal. Recommended duration: 10 yrs, with review after 10 yrs data collection.	

Bore Maintenance Requirements	
Assessing need for maintenance	• Annual depthing of the bore and comparison with bore depth and screen interval (combine with a water level monitoring visit). Assess condition of surface steel cover, and concrete seal around top of the bore. • Inspect hydrograph on annual basis for anomalous behaviour
Scheduled maintenance	• Maintain protective steel cover (as required). • Flushing of the bore once every ten years using airlift.

Bore: A5a

General Information

Bore ID	A5
Coordinates(approx.), Zone 55	215,300 E 5,740,050 N
Location Description	Dewings Bridge Rd at PB GW2A (nested with Clifton Form Bore: 64234)
Purpose of Bore	To assess aquitard response to pumping at an intermediate point within the aquitard, and provide information on vertical gradients within the aquitard.
GMS No. (future)	
Bore Construction Licence No. (future)	

Photo (facing east)

Access

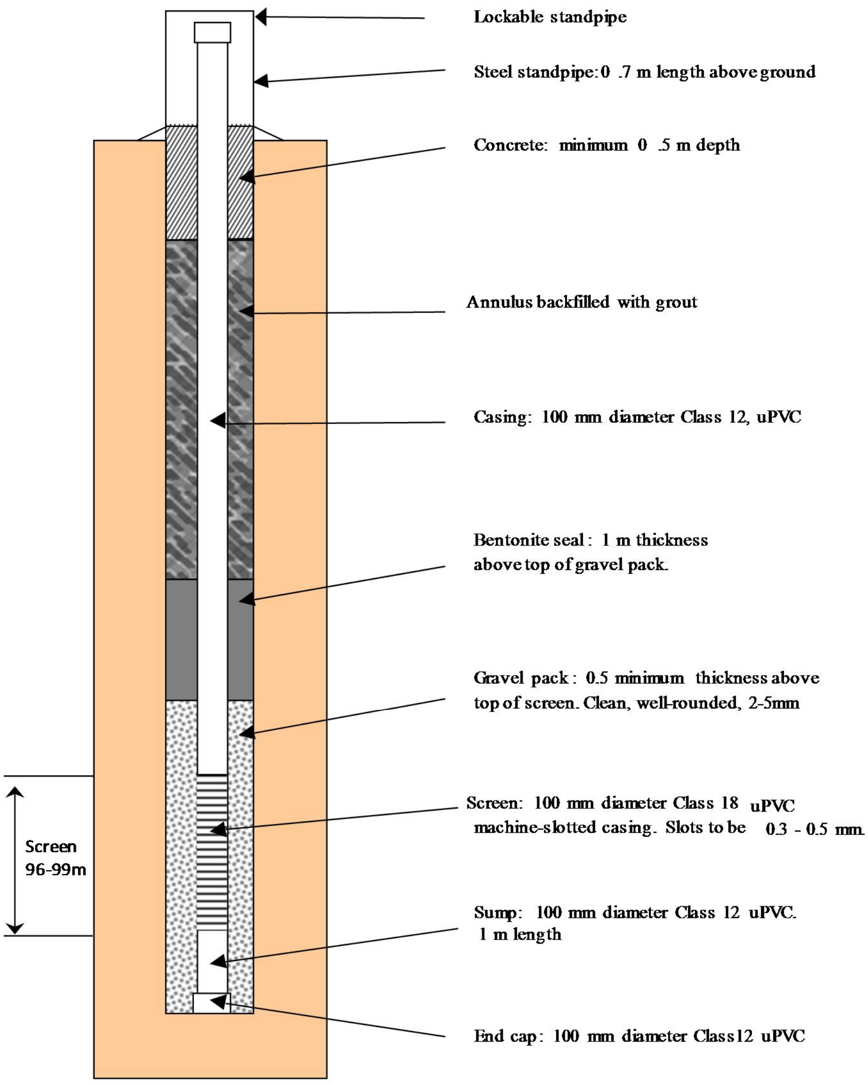
Land Owner	Barwon Water (within bore enclosure)	*Required Permits*	None – on Barwon Water land
Access Description	Located at the Barwon Downs Borefield GW2A.	*Alternate Locations*	If there is not room within the existing production bore compound for these two new bores, then could potentially drill near bore 64230 ~ 100m north.
Additional notes	Need to check if there is room within the enclosure for the bore (given underground services, requirements for access by other vehicles/equipment into the enclosure etc)		

Construction Information (refer over page for construction diagram)

Bore Depth (estimated)	~100 m	*Screening Target*	Screen target is mid-level interval of the aquitard, which has been selected as 100m.
Nearest Bore, Distance, Expected Lithology (comments)	▪ 64242 ▪ GEDIS bore ▪ ~ 10 m southeast from site ▪ Note that bore 64234 does not have a lithology log record	*Nearest bore log(m)*	64242 Log 0 1 TOPSOIL 1 3 RED AND YELLOW CLAY 3 5 MOTTLED CLAYS 5 12 WHITE CLAY 12 18 WHITE YELLOW CLAYS WITH BROWN FRAGMENTS 18 23 GREY WHITE CLAY 23 25 KHAKI 25 123 GREY MARL ------------------------ EOH 404 m
Drilling Method	Mud rotary technique will be used for bores greater than 25 m deep.		
Screen Interval / Length	96 – 99m	*Constructed Bore Diameter*	100mm
Casing Material	uPVC Class 12	*Screen Material, Slot Size*	uPVC Class 18, machine slotted, 0.3mm to 0.5mm
Surface Construction	Steel lockable standpipe, ~0.7 to 0.8m high		
Other notes re drilling / construction			

* Final selection of bore depth and screen will be decided based on field logging

Groundwater monitoring bore general construction



Testing Requirements	
Water quality sampling	To be sampled for major cations, anions, TDS, EC (plus field parameters EC, pH, redox, temp). Conduct at same time as hydraulic testing.
Geophysical testing	Gamma logging recommended (post-construction)
Hydraulic testing	Slug test recommended

Monitoring Requirements		
Water Level Monitoring Frequency	Manual	Frequency: Quarterly for first 3 years, bi-annual for subsequent years (~ April and Nov.)
	Data logger	Frequency: 6 hourly for first 3 years, daily for subsequent years Annual dipping of bores for cross-checking logger data
Water Level Monitoring Duration	Minimum duration, up to ~ 2018, i.e. point where data is required for analysis contributing to licence renewal. Recommended duration: 10 yrs, with review after 10 yrs data collection.	

Bore Maintenance Requirements	
Assessing need for maintenance	• Annual depthing of the bore and comparison with bore depth and screen interval (combine with a water level monitoring visit). Assess condition of surface steel cover, and concrete seal around top of the bore. • Inspect hydrograph on annual basis for anomalous behaviour
Scheduled maintenance	• Maintain protective steel cover (as required). • Flushing of the bore once every ten years using airlift.

Bore: A5b

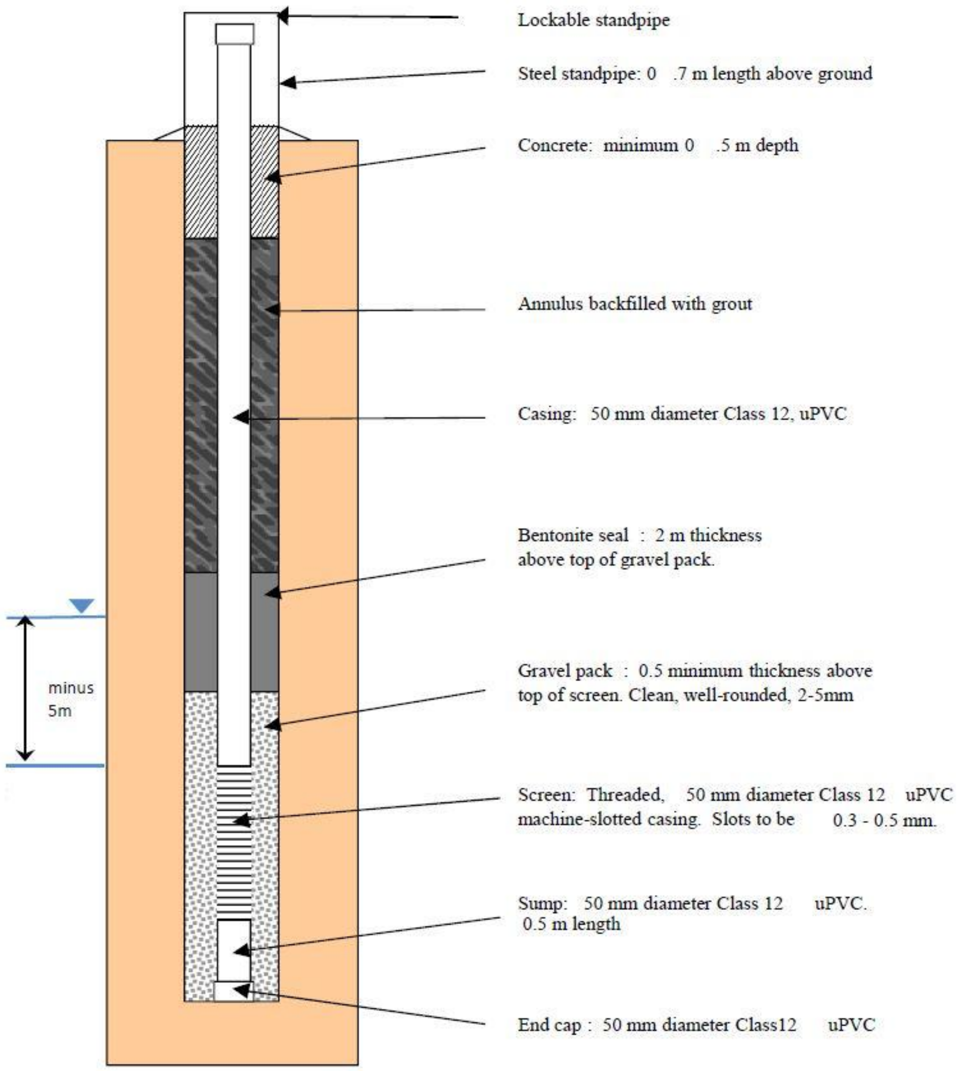
General Information		
Bore ID	A5b	Photo (facing east)
Coordinates(approx.), Zone 55	215,300 E 5,740,050 N	
Location Description	As above (nested with Clifton Bore and A5a)	
Purpose of Bore	To provide a shallow nested bore with A5a. Provide watertable depth in aquitard and vertical gradients info. within aquitard.	
GMS No. (future)		
Bore Construction Licence No. (future)		

Access			
Land Owner	Barwon Water (within bore enclosure)	*Required Permits*	None – on Barwon Water land
Access Description	Located at the Barwon Downs Borefield GW2A.	*Alternate Locations*	If there is not room within the existing production bore compound for these two new bores, then could potentially drill near bore 64230 ~ 100m north.
Additional notes	Need to check if there is room within the enclosure for the bore (given underground services, requirements for access by other vehicles/equipment into the enclosure etc)		

Construction Information (refer over page for construction diagram)			
Bore Depth (estimated)	10 - 25m	*Screening Target*	The aim is to screen below the lowest expected watertable level at the site.
Nearest Bore, Distance, Expected Lithology (comments)	▪ 64242 ▪ GEDIS bore ▪ ~ 10 m southeast from site ▪ Note that bore 64234 does not have a lithology log record	*Nearest bore log(m)*	64242 Log 0 1 TOPSOIL 1 3 RED AND YELLOW CLAY 3 5 MOTTLED CLAYS 5 12 WHITE CLAY 12 18 WHITE YELLOW CLAYS WITH BROWN FRAGMENTS 18 23 GREY WHITE CLAY 23 25 KHAKI 25 123 GREY MARL ------------------------ EOH 404 m
Drilling Method	Hollow auger is the recommended technique.		
Screen Interval / Length	Bottom of hole minus 1 metre / 3m screen *	*Constructed Bore Diameter*	50mm
Casing Material	uPVC Class 12	*Screen Material, Slot Size*	uPVC Class 12 , machine slotted, 0.3mm to 0.5mm
Surface Construction	Steel lockable standpipe, ~0.7 to 0.8m high		
Other notes re drilling / construction	The drilling method should be able to accurately identify the depth to watertable. Hollow auger is therefore the preferred technique. Bore depth ~ 10m below watertable is recommended (i.e. top of screen ~ 5m below watertable).		

* Final selection of bore depth and screen will be decided based on field logging

Groundwater monitoring bore general construction



Testing Requirements	
Water quality sampling	To be sampled for major cations, anions, TDS, EC (plus field parameters EC, pH, redox, temp). Conduct at same time as hydraulic testing.
Geophysical testing	Gamma logging recommended (post-construction)
Hydraulic testing	Slug test recommended

Monitoring Requirements		
Water Level Monitoring Frequency	Manual	Frequency: Quarterly for first 3 years, bi-annual for subsequent years (~ April and Nov.)
	Data logger	Frequency: 6 hourly for first 3 years, daily for subsequent years Annual dipping of bores for cross-checking logger data
Water Level Monitoring Duration	Minimum duration, up to ~ 2018, i.e. point where data is required for analysis contributing to licence renewal. Recommended duration: 10 yrs, with review after 10 yrs data collection.	

Bore Maintenance Requirements	
Assessing need for maintenance	• Annual depthing of the bore and comparison with bore depth and screen interval (combine with a water level monitoring visit). Assess condition of surface steel cover, and concrete seal around top of the bore. • Inspect hydrograph on annual basis for anomalous behaviour
Scheduled maintenance	Flushing of the bore once every ten years using airlift. Maintain protective steel cover.

Bore: A6a

General Information

Bore ID	A6a	Photo (facing east)
Coordinates(approx.), Zone 55	208,750 E 5,737,350 N	
Location Description	On Meadowell Rd, ~ 200m east of intersection with Gold Hold Road (nested with Clifton Form. Bore 64235)	
Purpose of Bore	To assess aquitard response to pumping at an intermediate point within the aquitard, and provide information on vertical gradients within the aquitard.	
GMS No. (future)		
Bore Construction Licence No. (future)		

Access

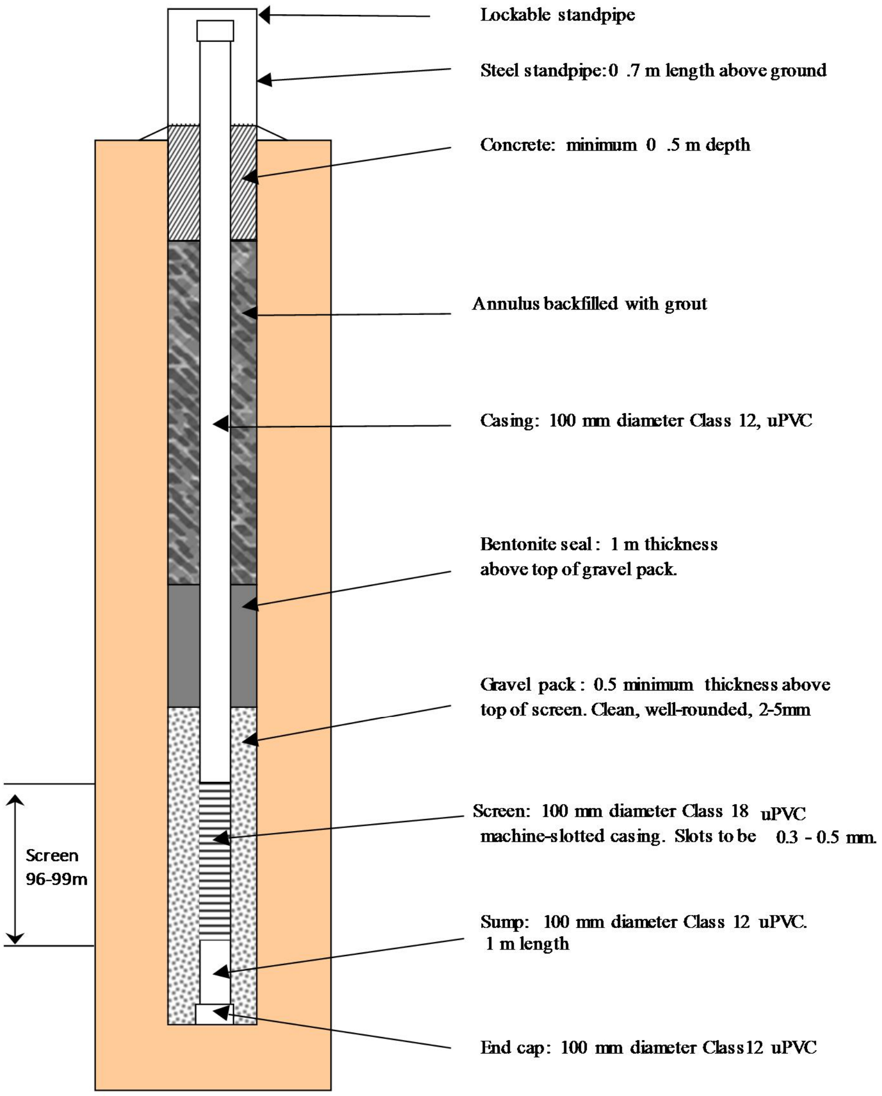
Land Owner	Colac Otway Shire Council	*Required Permits*	Requires consent from Council. Will involve assessment of traffic management requirements, and obtaining road opening permits, if deemed necessary by Council.
Access Description	Reasonable access (~5-6m median strip on north side of the road). Quiet road. Telecom table on this side of road would need to be located / avoided.	*Alternate Locations*	-
Additional notes	Quite road but moderately narrow area for drilling – will require some traffic management and potentially a half road closure.		

Construction Information (refer over page for construction diagram)

Bore Depth (estimated)	~100 m	*Screening Target*	Screen target is mid-level interval of the aquitard, which has been selected as 100m.
Nearest Bore, Distance, Expected Lithology (comments)	▪ 64225 ▪ Observation bore (unknown owner) ▪ Unknown current condition ▪ ~135 m northwest of site	*Nearest bore log(m)*	64225 Log 0 0.3 TOPSOIL 0.3 2 YELLOW CLAY 2 6.4 VARIEGATED CLAY 6.4 8 YELLOW SAND 8 18 VARIEGATED CLAY 18 79.6 GREY SANDY CLAY 79.6 80.2 GREY STONE 80.2 110 GREY SANDY CLAY ------------------------- EOH 180 m
Drilling Method	Mud rotary technique will be used for bores greater than 25 m deep.		
Screen Interval / Length	96-99m	*Constructed Bore Diameter*	100mm
Casing Material	uPVC Class 12	*Screen Material, Slot Size*	uPVC Class 18, machine slotted, 0.3mm to 0.5mm
Surface Construction	Steel lockable standpipe, ~0.7 to 0.8m high		
Other notes re drilling / construction			

* Final selection of bore depth and screen will be decided based on field logging

Groundwater monitoring bore general construction



Testing Requirements	
Water quality sampling	To be sampled for major cations, anions, TDS, EC (plus field parameters EC, pH, redox, temp). Conduct at same time as hydraulic testing.
Geophysical testing	Gamma logging recommended (post-construction)
Hydraulic testing	Slug test recommended

Monitoring Requirements		
Water Level Monitoring Frequency	Manual	Frequency: Quarterly for first 3 years, bi-annual for subsequent years (~ April and Nov.)
	Data logger	Frequency: 6 hourly for first 3 years, daily for subsequent years Annual dipping of bores for cross-checking logger data
Water Level Monitoring Duration	Minimum duration, up to ~ 2018, i.e. point where data is required for analysis contributing to licence renewal. Recommended duration: 10 yrs, with review after 10 yrs data collection.	

Bore Maintenance Requirements	
Assessing need for maintenance	• Annual depthing of the bore and comparison with bore depth and screen interval (combine with a water level monitoring visit). Assess condition of surface steel cover, and concrete seal around top of the bore. • Inspect hydrograph on annual basis for anomalous behaviour
Scheduled maintenance	• Maintain protective steel cover (as required). • Flushing of the bore once every ten years using airlift.

Bore: A6b

<table>
<tr><td colspan="3">General Information</td></tr>
<tr><td>Bore ID</td><td>A6b</td><td>Photo (facing east)</td></tr>
<tr><td>Coordinates(approx.), Zone 55</td><td>208,750 E
5,737,350 N</td><td rowspan="5">
</td></tr>
<tr><td>Location Description</td><td>On Meadowell Rd, ~ 200m east of intersection with Gold Hold Road (nested with Clifton Form. Bore 64235 and bore A6a)</td></tr>
<tr><td>Purpose of Bore</td><td>Provide give information on vertical gradients within the aquitard and depth to watertable within aquitard</td></tr>
<tr><td>GMS No. (future)</td><td></td></tr>
<tr><td>Bore Construction Licence No. (future)</td><td></td></tr>
</table>

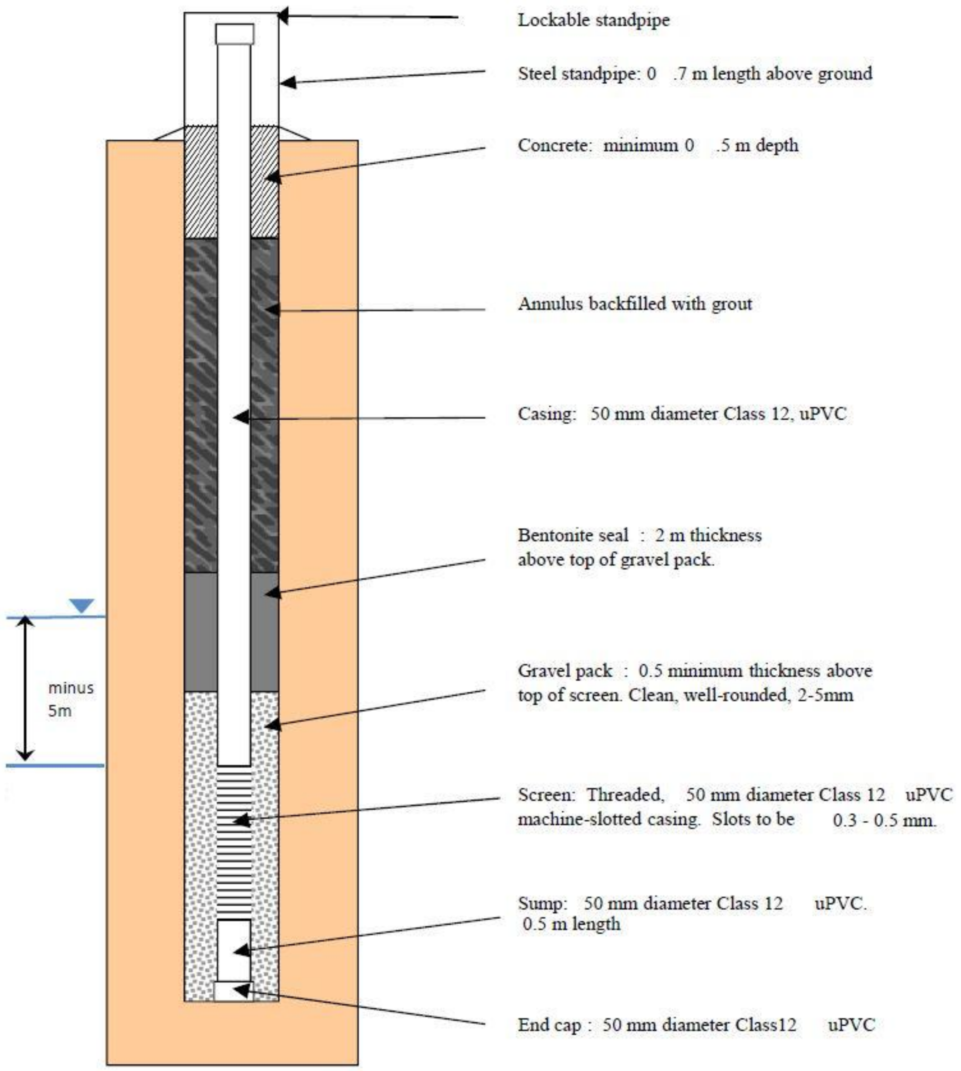
<table>
<tr><td colspan="4">Access</td></tr>
<tr><td>Land Owner</td><td>Colac Otway Shire Council</td><td>Required Permits</td><td>Requires consent from Council. Will involve assessment of traffic management requirements, and obtaining road opening permits, if deemed necessary by Council.</td></tr>
<tr><td>Access Description</td><td>Reasonable access (~5-6m median strip on north side of the road). Quiet road. Telecom table on this side of road would need to be located / avoided.</td><td>Alternate Locations</td><td>-</td></tr>
<tr><td>Additional notes</td><td colspan="3">Quite road but moderately narrow area for drilling – will require some traffic management and potentially a half road closure.</td></tr>
</table>

<table>
<tr><td colspan="4">Construction Information (refer over page for construction diagram)</td></tr>
<tr><td>Bore Depth (estimated)</td><td>~25 m</td><td>Screening Target</td><td>The aim is to screen below the lowest expected watertable level at the site.</td></tr>
<tr><td>Nearest Bore, Distance, Expected Lithology (comments)</td><td>▪ 64225
▪ Observation bore (unknown owner)
▪ Unknown current condition
▪ ~135 m northwest of site</td><td>Nearest bore log(m)</td><td>64225 Log
0 0.3 TOPSOIL
0.3 2 YELLOW CLAY
2 6.4 VARIEGATED CLAY
6.4 8 YELLOW SAND
8 18 VARIEGATED CLAY
18 79.6 GREY SANDY CLAY

EOH 180 m</td></tr>
<tr><td>Drilling Method</td><td colspan="3">Hollow auger is the recommended technique.</td></tr>
<tr><td>Screen Interval / Length</td><td>Bottom of hole minus 1 metre / 3m screen *</td><td>Constructed Bore Diameter</td><td>50mm</td></tr>
<tr><td>Casing Material</td><td>uPVC Class 12</td><td rowspan="2">Screen Material, Slot Size</td><td rowspan="2">uPVC Class 12, machine slotted, 0.3mm to 0.5mm</td></tr>
<tr><td>Surface Construction</td><td>Steel lockable standpipe, ~0.7 to 0.8m high</td></tr>
<tr><td>Other notes re drilling / construction</td><td colspan="3">The drilling method should be able to accurately identify the depth to watertable. Hollow auger is therefore the preferred technique. But may not be able to complete the hole with hollow augers, depending on watertable depth.</td></tr>
</table>

* Final selection of bore depth and screen will be decided based on field logging

Groundwater monitoring bore general construction



Testing Requirements	
Water quality sampling	To be sampled for major cations, anions, TDS, EC (plus field parameters EC, pH, redox, temp). Conduct at same time as hydraulic testing.
Geophysical testing	Gamma logging recommended (post-construction)
Hydraulic testing	Slug test recommended

Monitoring Requirements		
Water Level Monitoring Frequency	Manual	Frequency: Quarterly for first 3 years, bi-annual for subsequent years (~ April and Nov.)
	Data logger	Frequency: 6 hourly for first 3 years, daily for subsequent years Annual dipping of bores for cross-checking logger data
Water Level Monitoring Duration	Minimum duration, up to ~ 2018, i.e. point where data is required for analysis contributing to licence renewal. Recommended duration: 10 yrs, with review after 10 yrs data collection.	

Bore Maintenance Requirements	
Assessing need for maintenance	• Annual depthing of the bore and comparison with bore depth and screen interval (combine with a water level monitoring visit). Assess condition of surface steel cover, and concrete seal around top of the bore. • Inspect hydrograph on annual basis for anomalous behaviour
Scheduled maintenance	• Maintain protective steel cover (as required). • Flushing of the bore once every ten years using airlift.

Bore: TB8

General Information

Bore ID	TB8
Coordinates(approx.), Zone 55	210,582 E 5,739,828 N
Location Description	Westwood Track
Purpose of Bore	To assess depth to watertable at vegetation monitoring site – Impact assessment site
GMS No. (future)	
Bore Construction Licence No. (future)	

Photo (facing southeast)

(facing northwest)

Access

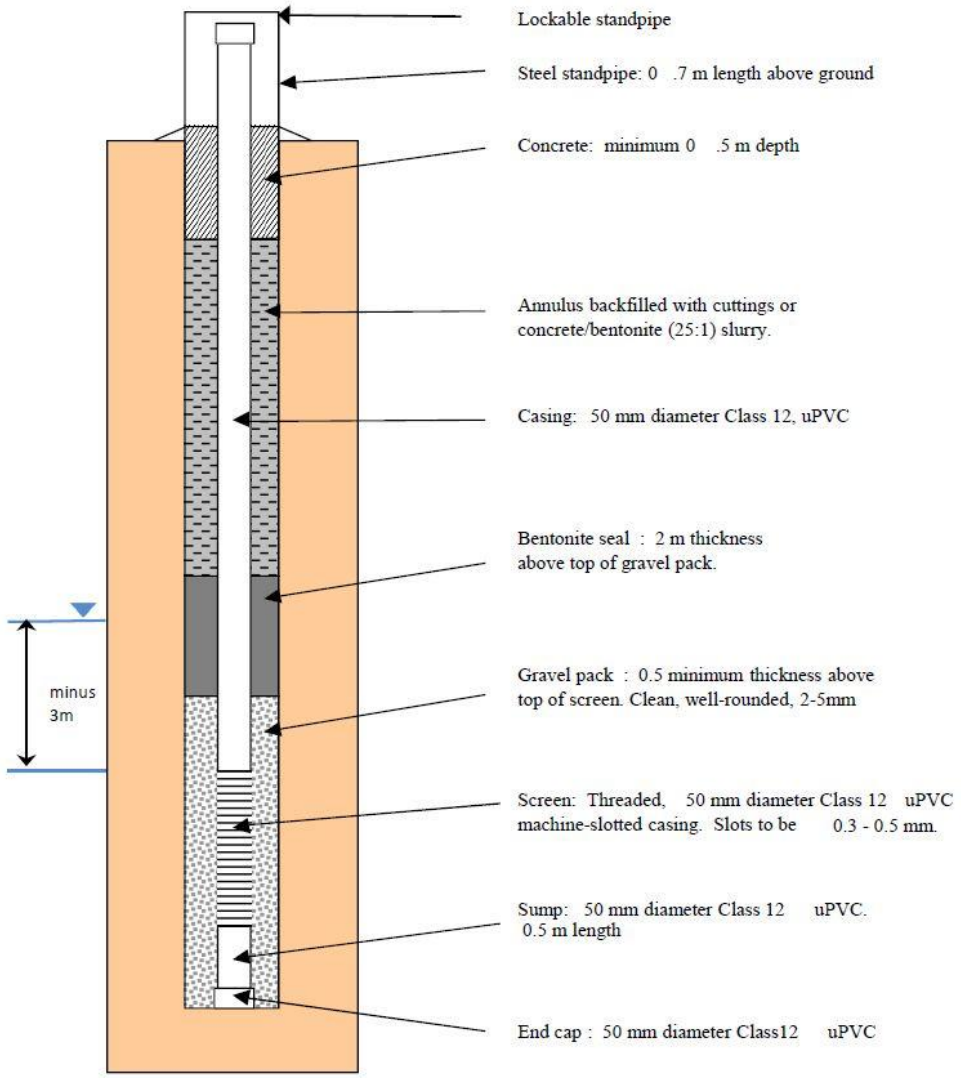
Land Owner	DSE / Parks Victoria	*Required Permits*	Use of Crown Land requires consent pursuant to the Crown Land (Reserves) Act 1978 from the land manager (i.e. DSE). Permit required if removing native vegetation.
Access Description	Location at Photo 153 has the advantage of being at a similar elevation to the vegetation site. (Could get a small rig where the 4-WD is parked in the photo, but probably require a half road closure).	*Alternate Locations*	Photo 154 is an alternate site (only ~ 5m higher elevation) with slightly more room than 153 for a drilling rig, but bore would be sited closer to the road.
Additional notes	Despite the quiet road, either of the above sites will require some traffic management, potentially a half road closure.		

Construction Information (refer over page for construction diagram)

Bore Depth (estimated)	10 - 20m	*Screening Target*	The aim is to screen below the lowest expected watertable level at the site.
Nearest Bore, Distance, Expected Lithology (comments)	▪ 64240 ▪ GEDIS bore ▪ ~ 100 m north of site	*Nearest bore log(m)*	64240 Log 0 9 YELLOW SANDS FINE TO COARSE 9 12 SANDY YELLOW CLAYS 12 26 SANDY GREY CLAYS ------------------------ EOH 311 m
Drilling Method	Hollow auger is the recommended technique.		
Screen Interval / Length	Bottom of hole minus 1 metre / 3m screen *	*Constructed Bore Diameter*	50mm
Casing Material	uPVC Class 12	*Screen Material, Slot Size*	uPVC Class 12 , machine slotted, 0.3mm to 0.5mm
Surface Construction	Steel lockable standpipe, ~0.7 to 0.8m high		
Other notes re drilling / construction	The drilling method should be able to accurately identify the depth to watertable. Hollow auger is therefore the preferred technique. Bore depth ~ 6-7m below watertable is recommended (i.e. top of screen ~ 3m below watertable).		

* Final selection of bore depth and screen will be decided based on field logging

Groundwater monitoring bore general construction



Testing Requirements	
Water quality sampling	To be sampled for major cations, anions, TDS, EC (plus field parameters EC, pH, redox, temp). Conduct at same time as hydraulic testing.
Geophysical testing	Gamma logging recommended (post-construction)
Hydraulic testing	Slug test recommended

Monitoring Requirements		
Water Level Monitoring Frequency	Manual	Frequency: Quarterly for first 3 years, bi-annual for subsequent years (~ April and Nov.)
	Data logger	Frequency: 6 hourly for first 3 years, daily for subsequent years Annual dipping of bores for cross-checking logger data
Water Level Monitoring Duration	Minimum duration, up to ~ 2018, i.e. point where data is required for analysis contributing to licence renewal. Recommended duration: 10 yrs, with review after 10 yrs data collection.	

Bore Maintenance Requirements	
Assessing need for maintenance	• Annual depthing of the bore and comparison with bore depth and screen interval (combine with a water level monitoring visit). Assess condition of surface steel cover, and concrete seal around top of the bore. • Inspect hydrograph on annual basis for anomalous behaviour
Scheduled maintenance	• Maintain protective steel cover (as required). • Flushing of the bore once every ten years using airlift.

Bore: TB9

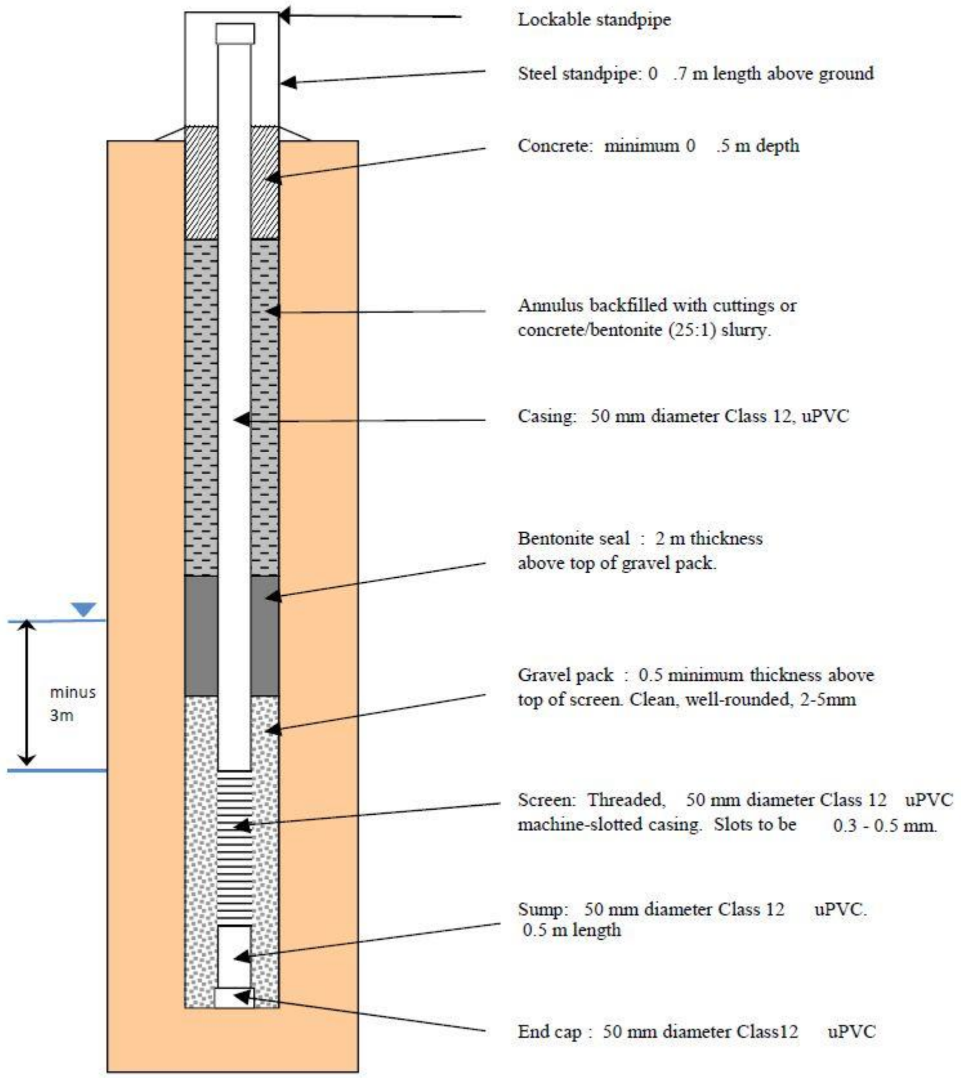
General Information		
Bore ID	TB9	Photo (no photo)
Coordinates(approx.), Zone 55	208623E 5733450N	
Location Description	Headwaters of Porcupine Ck, on Pipeline Rd	
Purpose of Bore	To assess depth to watertable at vegetation monitoring site – Impact assessment site	
GMS No. (future)		
Bore Construction Licence No. (future)		

Access			
Land Owner	DSE / Parks Victoria	*Required Permits*	Use of Crown Land requires consent pursuant to the Crown Land (Reserves) Act 1978 from the land manager (i.e. DSE). Permit required if removing native vegetation.
Access Description	This site was not visited during the hydrogeological field assessment, as it was only identified by Ecology Australia during their field visit.	*Alternate Locations*	
Additional notes	Site visit required to confirm bore location, access etc.		

Construction Information (refer over page for construction diagram)			
Bore Depth (estimated)	10 - 20m	*Screening Target*	The aim is to screen below the lowest expected watertable level at the site.
Nearest Bore, Distance, Expected Lithology (comments)	SOBN Bore: 114151, ~ 2km east	*Nearest bore log(m)*	108965 Log 0 3 TOPSOIL 3 7 CLAY 7 11 SAND-YELLOW 11 14.5 SAND-BLUE 14.5 37 MARL
Drilling Method	Hollow augers are the recommended drilling technique.		
Screen Interval / Length	Bottom of hole minus 1 metre / 3m screen *	*Constructed Bore Diameter*	50mm
Casing Material	uPVC Class 12	*Screen Material, Slot Size*	uPVC Class 12, machine slotted, 0.3mm to 0.5mm
Surface Construction	Steel lockable standpipe, ~0.7 to 0.8m high		
Other notes re drilling / construction	The drilling method should be able to accurately identify the depth to watertable. Hollow auger is therefore the preferred technique. Bore depth ~ 6-7m below watertable is recommended (i.e. top of screen ~ 3m below watertable).		

* Final selection of bore depth and screen will be decided based on field logging

Groundwater monitoring bore general construction



Testing Requirements	
Water quality sampling	Sample for field chemistry (EC, pH, ORP, DO) recommended. Conduct at same time as hydraulic testing.
Geophysical testing	Gamma logging recommended (post-construction)
Hydraulic testing	Slug test recommended

Monitoring Requirements		
Water Level Monitoring Frequency	Manual	<u>Frequency</u>: Quarterly for first 3 years, bi-annual for subsequent years (~ April and Nov.)
	Data logger	<u>Frequency</u>: 6 hourly for first 3 years, daily for subsequent years Annual dipping of bores for cross-checking logger data
Water Level Monitoring Duration	Minimum duration, up to ~ 2018, i.e. point where data is required for analysis contributing to licence renewal. Recommended duration: 10 yrs, with review after 10 yrs data collection.	

Bore Maintenance Requirements	
Assessing need for maintenance	• Annual depthing of the bore and comparison with bore depth and screen interval (combine with a water level monitoring visit). Assess condition of surface steel cover, and concrete seal around top of the bore. • Inspect hydrograph on annual basis for anomalous behaviour
Scheduled maintenance	• Maintain protective steel cover (as required). • Flushing of the bore once every ten years using airlift.

Bore: TB10

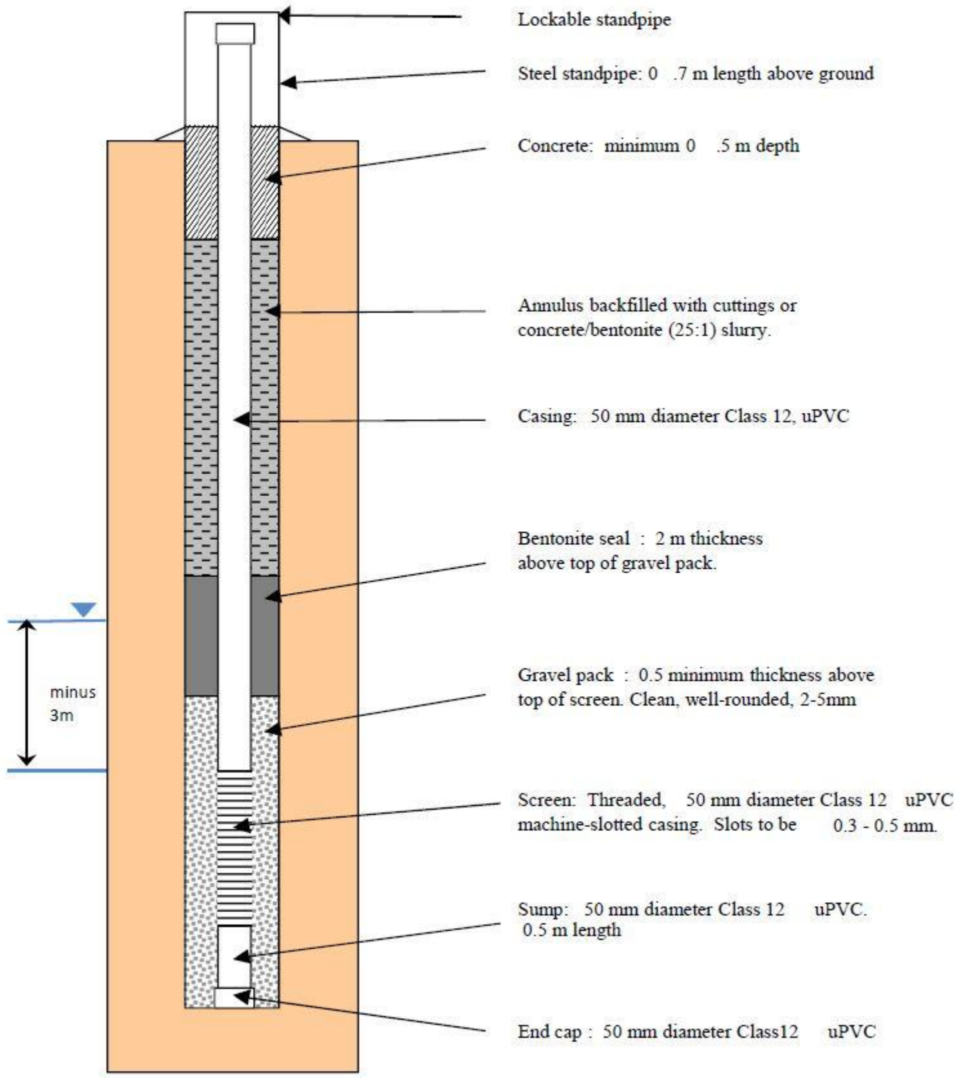
General Information		
Bore ID	TB10	Photo (no photo)
Coordinates(approx.), Zone 55	204,885E 5,737,764N	
Location Description	Dividing Ck and Wares Rd	
Purpose of Bore	To assess depth to watertable at vegetation monitoring site – impact site	
GMS No. (future)		
Bore Construction Licence No. (future)		

Access			
Land Owner	DSE / Parks Victoria	*Required Permits*	Use of Crown Land requires consent pursuant to the Crown Land (Reserves) Act 1978 from the land manager (i.e. DSE). Permit required if removing native vegetation.
Access Description	This site was not visited during the hydrogeological field assessment, as it was only identified by Ecology Australia during their field visit.	*Alternate Locations*	
Additional notes	Site visit required to confirm bore location, access etc.		

Construction Information (refer over page for construction diagram)			
Bore Depth (estimated)	10 - 20m	*Screening Target*	The aim is to screen below the lowest expected watertable level at the site.
Nearest Bore, Distance, Expected Lithology (comments)	SOBN Bore: 48003, ~ 1.25km south	*Nearest bore log(m)*	48003 Log 0 12 MOTTLED CLAY(SANDY) 12 42 LIGNEOUS CLAY(GREY) 42 102 DARK BROWN LIGNEOUS CLAY EOH - 381m
Drilling Method	Hollow auger is the recommended technique.		
Screen Interval / Length	Bottom of hole minus 1 metre / 3m screen *	*Constructed Bore Diameter*	50mm
Casing Material	uPVC Class 12	*Screen Material, Slot Size*	uPVC Class 12, machine slotted, 0.3mm to 0.5mm
Surface Construction	Steel lockable standpipe, ~0.7 to 0.8m high		
Other notes re drilling / construction	The drilling method should be able to accurately identify the depth to watertable. Hollow auger is therefore the preferred technique. Bore depth ~ 6-7m below watertable is recommended (i.e. top of screen ~ 3m below watertable).		

* Final selection of bore depth and screen will be decided based on field logging

Groundwater monitoring bore general construction



Testing Requirements	
Water quality sampling	Sample for field chemistry (EC, pH, ORP, DO) recommended. Conduct at same time as hydraulic testing.
Geophysical testing	Gamma logging recommended (post-construction)
Hydraulic testing	Slug test recommended

Monitoring Requirements		
Water Level Monitoring Frequency	Manual	Frequency: Quarterly for first 3 years, bi-annual for subsequent years (~ April and Nov.)
	Data logger	Frequency: 6 hourly for first 3 years, daily for subsequent years Annual dipping of bores for cross-checking logger data
Water Level Monitoring Duration	Minimum duration, up to ~ 2018, i.e. point where data is required for analysis contributing to licence renewal. Recommended duration: 10 yrs, with review after 10 yrs data collection.	

Bore Maintenance Requirements	
Assessing need for maintenance	• Annual depthing of the bore and comparison with bore depth and screen interval (combine with a water level monitoring visit). Assess condition of surface steel cover, and concrete seal around top of the bore. • Inspect hydrograph on annual basis for anomalous behaviour
Scheduled maintenance	• Maintain protective steel cover (as required). • Flushing of the bore once every ten years using airlift.

Bore: TB11

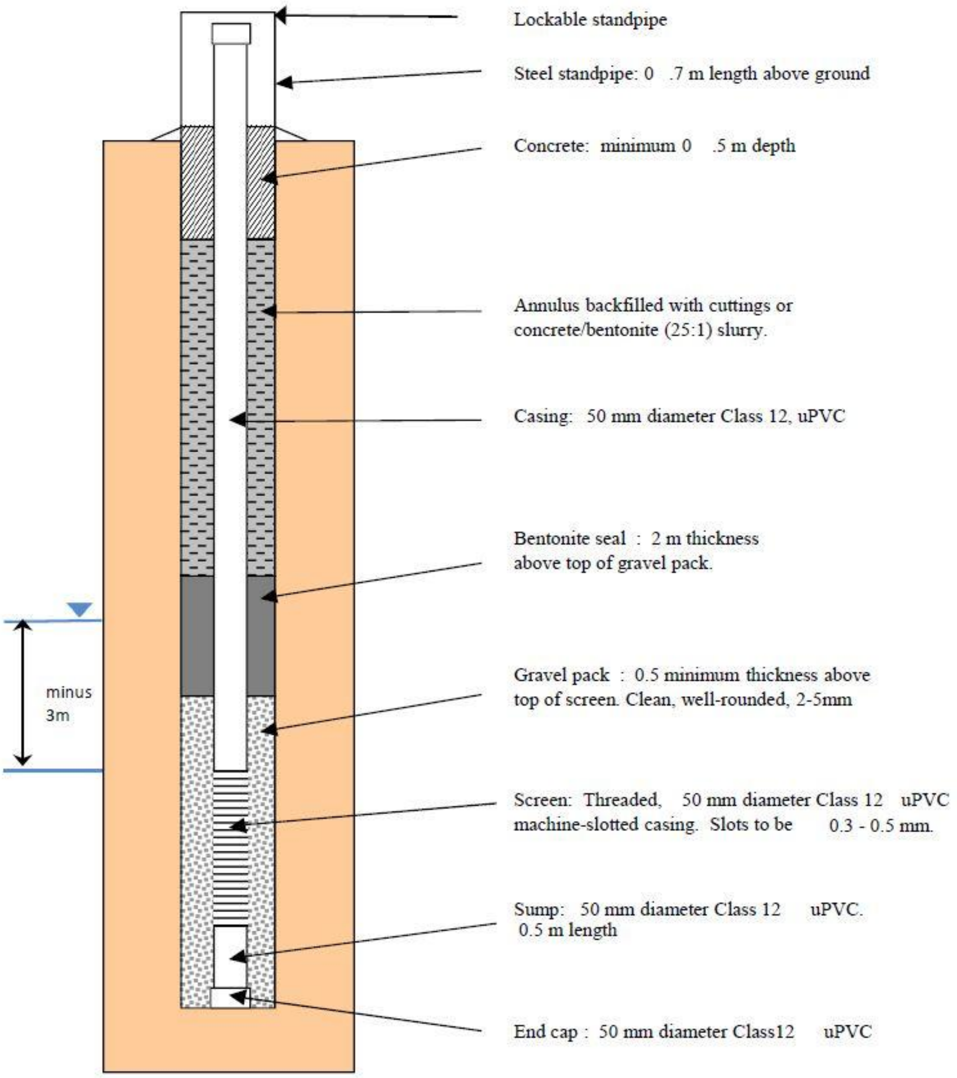
General Information		
Bore ID	T11	Photo (facing south)
Coordinates(approx.), Zone 55	207,182 E 5,734,799 N	
Location Description	Porcupine Ck on Colac - Olangolah Pipeline Track	
Purpose of Bore	To assess depth to watertable at vegetation monitoring site – Reference site	
GMS No. (future)		
Bore Construction Licence No. (future)		

Access			
Land Owner	DSE / Parks Victoria	*Required Permits*	Use of Crown Land requires consent pursuant to the Crown Land (Reserves) Act 1978 from the land manager (i.e. DSE). Permit required if removing native vegetation.
Access Description	The proposed location has the best access (on east side of track). However the pipeline location and minimum clearance is an issue to be investigated.	*Alternate Locations*	Alternate locations (207,265 E; 5,734,582 N and 207,280 E; 5,734,533 N) have been sited if this site is not suitable, including sites on the west side of the track, depending on the location of the pipeline.
Additional notes	Very quiet track. Minimal traffic management, if any, will be required.		

Construction Information (refer over page for construction diagram)			
Bore Depth (estimated)	10 – 15 m	*Screening Target*	The aim is to screen below the lowest expected watertable level at the site.
Nearest Bore, Distance, Expected Lithology (comments)	▪ 64227 (SOBN bore) ▪ Currently monitored ▪ GEDIS lithology log ▪ ~860 m northeast of site	*Nearest bore log(m)*	64227 Log 0 0.2 TOPSOIL 0.2 0.3 BUCK SHOT 0.3 7.6 YELLOW & RED CLAY 7.6 18.3 SANDY RED CLAY ------------------------ EOH 459 m
Drilling Method	Hollow auger is the recommended technique.		
Screen Interval / Length	Bottom of hole minus 1 metre / 3m screen *	*Constructed Bore Diameter*	50mm
Casing Material	uPVC Class 12	*Screen Material, Slot Size*	uPVC Class 12, machine slotted, 0.3mm to 0.5mm
Surface Construction	Steel lockable standpipe, ~0.7 to 0.8m high		
Other notes re drilling / construction	The drilling method should be able to accurately identify the depth to watertable. Hollow auger is therefore the preferred technique. Bore depth ~ 6-7m below watertable is recommended (i.e. top of screen ~ 3m below watertable). Large long term decline in watertable level not likely at this site.		

* Final selection of bore depth and screen will be decided based on field logging

Groundwater monitoring bore general construction



Testing Requirements	
Water quality sampling	Sample for field chemistry (EC, pH, ORP, DO) recommended. Conduct at same time as hydraulic testing.
Geophysical testing	Gamma logging recommended (post-construction)
Hydraulic testing	Slug test recommended

Monitoring Requirements		
Water Level Monitoring Frequency	Manual	<u>Frequency</u>: Quarterly for first 3 years, bi-annual for subsequent years (~ April and Nov.)
	Data logger	<u>Frequency</u>: 6 hourly for first 3 years, daily for subsequent years Annual dipping of bores for cross-checking logger data
Water Level Monitoring Duration	Minimum duration, up to ~ 2018, i.e. point where data is required for analysis contributing to licence renewal. Recommended duration: 10 yrs, with review after 10 yrs data collection.	

Bore Maintenance Requirements	
Assessing need for maintenance	• Annual depthing of the bore and comparison with bore depth and screen interval (combine with a water level monitoring visit). Assess condition of surface steel cover, and concrete seal around top of the bore. • Inspect hydrograph on annual basis for anomalous behaviour
Scheduled maintenance	• Maintain protective steel cover (as required). • Flushing of the bore once every ten years using airlift.

Bore: TB12

General Information

Bore ID	TB12
Coordinates(approx.), Zone 55	207,599 E 5,738,138 N
Location Description	On tributary of Dividing Ck, on Gold Hole Rd
Purpose of Bore	To assess depth to watertable at vegetation monitoring site – Reference site
GMS No. (future)	
Bore Construction Licence No. (future)	

Photo (facing northwest)

Access

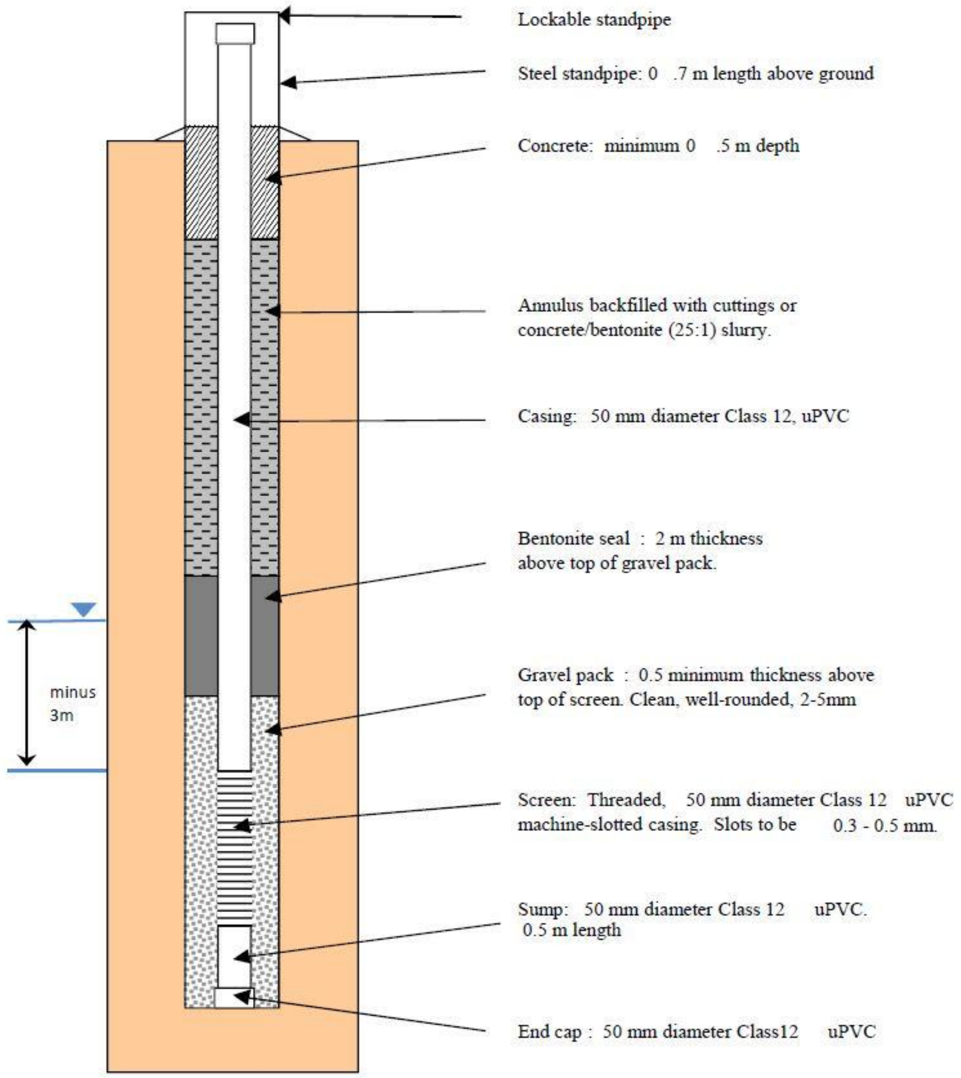
Land Owner	DSE / Parks Victoria	*Required Permits*	Use of Crown Land requires consent pursuant to the Crown Land (Reserves) Act 1978 from the land manager (i.e. DSE). Permit required if removing native vegetation.
Access Description	The preferred location has ~ 4m road verge for drilling access. This may be sufficient with half road closure, as the road is very quiet.	*Alternate Locations*	If the site (shown above) is not possible (due to access, safety or ground conditions) an alternate location (207,679 E; 5,738,079 N) has been sited ~ 80m SE of the above site.
Additional notes	Half road closure may be required due to limited space at road edge.		

Construction Information (refer over page for construction diagram)

Bore Depth (estimated)	10 - 20m	*Screening Target*	The aim is to screen below the lowest expected watertable level at the site.
Nearest Bore, Distance, Expected Lithology (comments)	▪ 64224 (SOBN bore) ▪ Currently Monitored ▪ GEDIS lithology log ▪ ~800 m southeast of site	*Nearest bore log(m)*	64224 Log 0 0.3 TOPSOIL 0.3 1 YELLOW CLAY 1 6 VARIEGATED CLAY 6 12 YELLOW SAND 12 21 WHITE CLAY ------------------------- EOH 115 m
Drilling Method	Hollow auger is the recommended technique.		
Screen Interval / Length	Bottom of hole minus 1 metre / 3m screen *	*Constructed Bore Diameter*	50mm
Casing Material	uPVC Class 12	*Screen Material, Slot Size*	uPVC Class 12, machine slotted, 0.3mm to 0.5mm
Surface Construction	Steel lockable standpipe, ~0.7 to 0.8m high		
Other notes re drilling / construction	The drilling method should be able to accurately identify the depth to watertable. Hollow auger is therefore the preferred technique. Bore depth ~ 6-7m below watertable is recommended (i.e. top of screen ~ 3m below watertable). Large long term decline in watertable level not likely at this site.		

* Final selection of bore depth and screen will be decided based on field logging

Groundwater monitoring bore general construction



Testing Requirements	
Water quality sampling	Sample for field chemistry (EC, pH, ORP, DO) recommended. Conduct at same time as hydraulic testing.
Geophysical testing	Gamma logging recommended (post-construction)
Hydraulic testing	Slug test recommended

Monitoring Requirements		
Water Level Monitoring Frequency	Manual	Frequency: Quarterly for first 3 years, bi-annual for subsequent years (~ April and Nov.)
	Data logger	Frequency: 6 hourly for first 3 years, daily for subsequent years Annual dipping of bores for cross-checking logger data
Water Level Monitoring Duration	Minimum duration, up to ~ 2018, i.e. point where data is required for analysis contributing to licence renewal. Recommended duration: 10 yrs, with review after 10 yrs data collection.	

Bore Maintenance Requirements	
Assessing need for maintenance	• Annual depthing of the bore and comparison with bore depth and screen interval (combine with a water level monitoring visit). Assess condition of surface steel cover, and concrete seal around top of the bore. • Inspect hydrograph on annual basis for anomalous behaviour
Scheduled maintenance	• Maintain protective steel cover (as required). • Flushing of the bore once every ten years using airlift.

Bore: TB13

General Information

Bore ID	TB13	Photo (facing south)
Coordinates(approx.), Zone 55	206,395 E 5,737,118 N	
Location Description	Pipeline Track	
Purpose of Bore	To assess depth to watertable at vegetation monitoring site – Reference site	
GMS No. (future)		
Bore Construction Licence No. (future)		

Access

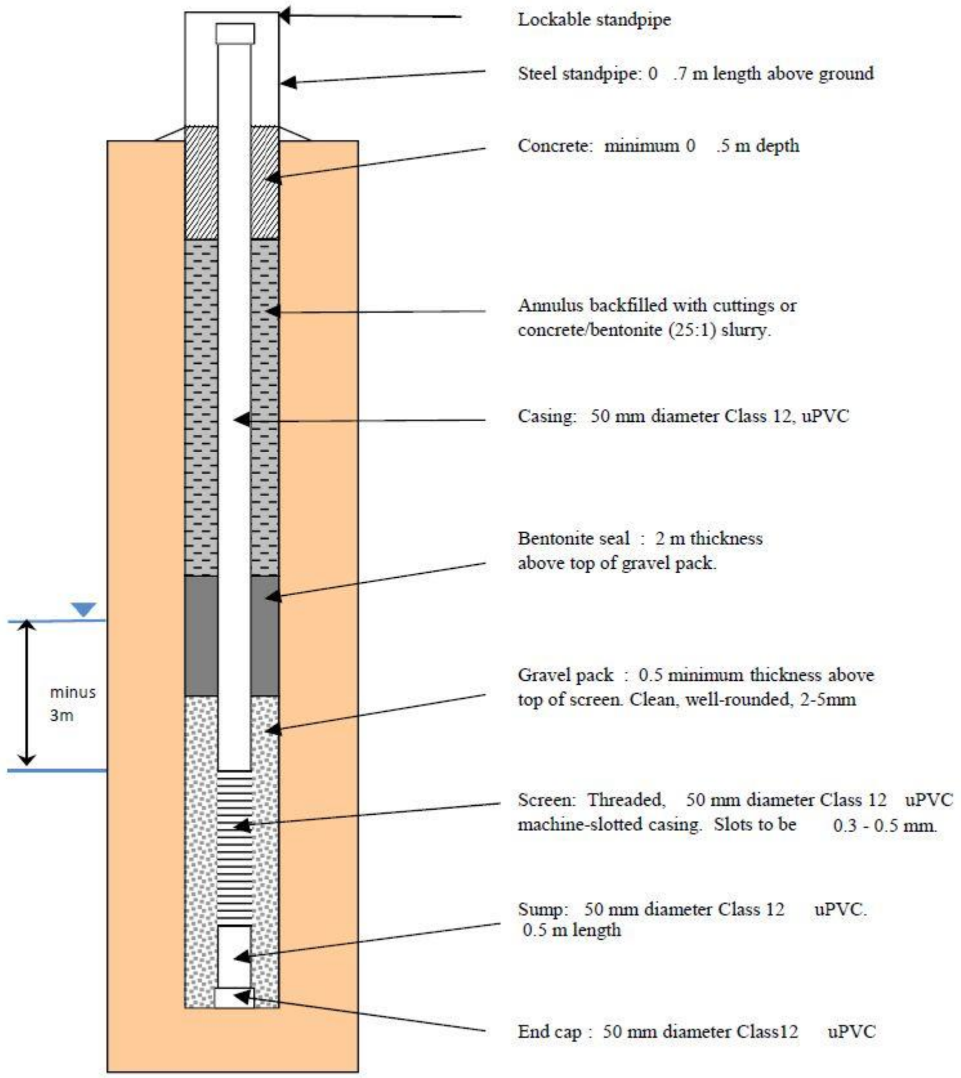
Land Owner	DSE / Parks Victoria	*Required Permits*	Use of Crown Land requires consent pursuant to the Crown Land (Reserves) Act 1978 from the land manager (i.e. DSE). Permit required if removing native vegetation.
Access Description	The preferred location for a bore (subject to pipeline location and minimum clearance issues) is at the northern end of the vegetation monitoring site (show in above photo)	*Alternate Locations*	The southern end of the vegetation monitoring site also has potential sites for a bore to be located. Locations on Parkes Lodge Road (206,052 E; 5,736,900 N or 206,258 E; 5,736,695 N) if above site is not suitable.
Additional notes	Assessment of minimum clearance from pipeline required. Very quiet track. No traffic management / road closure deemed necessary.		

Construction Information (refer over page for construction diagram)

Bore Depth (estimated)	10 - 20m	*Screening Target*	The aim is to screen below the lowest expected watertable level at the site.
Nearest Bore, Distance, Expected Lithology (comments)	▪ 48003 (SOBN bore) ▪ Currently monitored ▪ GEDIS lithology log ▪ ~1500 m southwest from site	*Nearest bore log(m)*	48003 Log 0 0.4 TOPSOIL 0.4 0.6 COFFEE ROCK 0.6 12 MOTTLED CLAY(SANDY) 12 42 LIGNEOUS CLAY(GREY) ------------------------- EOH 381 m
Drilling Method	Hollow auger is the recommended technique.		
Screen Interval / Length	Bottom of hole minus 1 metre / 3m screen *	*Constructed Bore Diameter*	50mm
Casing Material	uPVC Class 12	*Screen Material, Slot Size*	uPVC Class 12, machine slotted, 0.3mm to 0.5mm
Surface Construction	Steel lockable standpipe, ~0.7 to 0.8m high		
Other notes re drilling / construction	The drilling method should be able to accurately identify the depth to watertable. Hollow auger is therefore the preferred technique. Bore depth ~ 6-7m below watertable is recommended (i.e. top of screen ~ 3m below watertable). Large long term decline in watertable level not likely.		

* Final selection of bore depth and screen will be decided based on field logging

Groundwater monitoring bore general construction



Testing Requirements	
Water quality sampling	Sample for field chemistry (EC, pH, ORP, DO) recommended. Conduct at same time as hydraulic testing.
Geophysical testing	Gamma logging recommended (post-construction)
Hydraulic testing	Slug test recommended

Monitoring Requirements		
Water Level Monitoring Frequency	Manual	Frequency: Quarterly for first 3 years, bi-annual for subsequent years (~ April and Nov.)
	Data logger	Frequency: 6 hourly for first 3 years, daily for subsequent years Annual dipping of bores for cross-checking logger data
Water Level Monitoring Duration	Minimum duration, up to ~ 2018, i.e. point where data is required for analysis contributing to licence renewal. Recommended duration: 10 yrs, with review after 10 yrs data collection.	

Bore Maintenance Requirements	
Assessing need for maintenance	• Annual depthing of the bore and comparison with bore depth and screen interval (combine with a water level monitoring visit). Assess condition of surface steel cover, and concrete seal around top of the bore. • Inspect hydrograph on annual basis for anomalous behaviour
Scheduled maintenance	• Maintain protective steel cover (as required). • Flushing of the bore once every ten years using airlift.

Bore: UDvCk

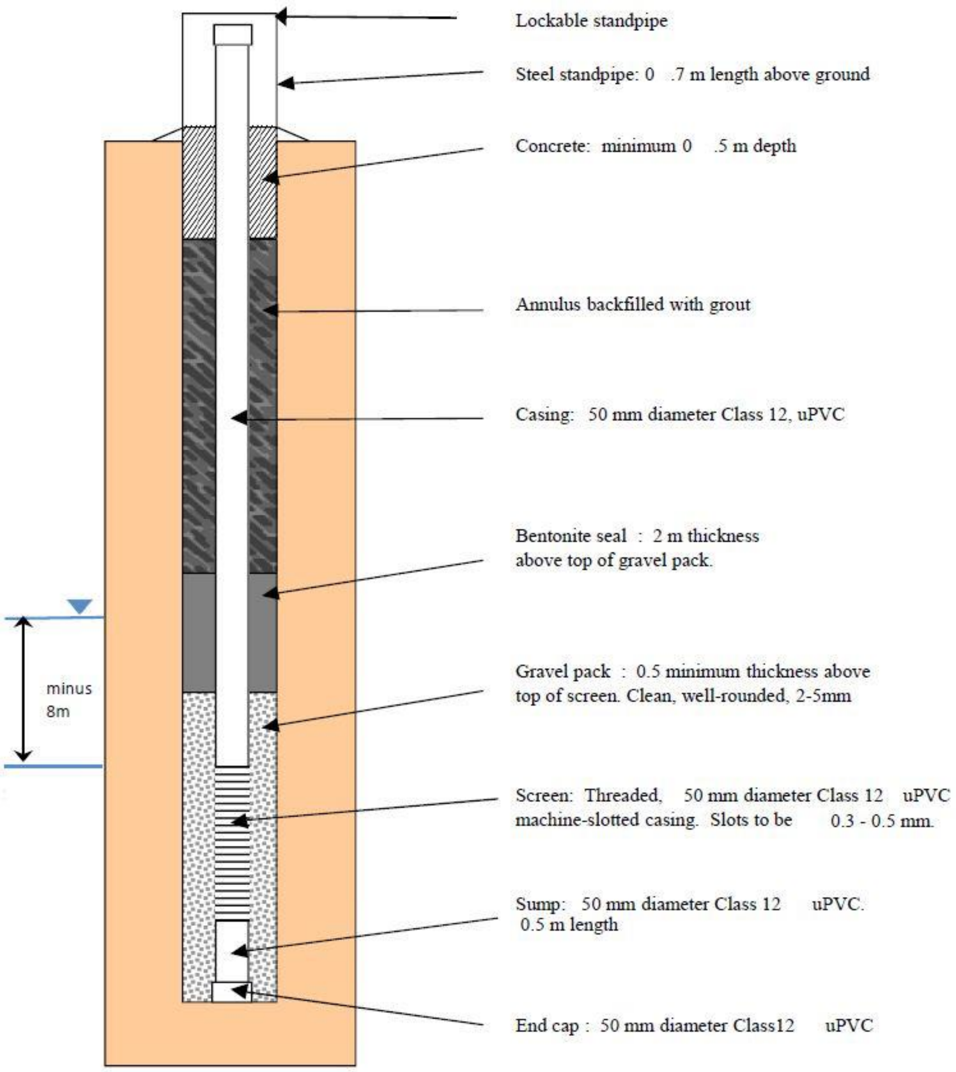
General Information		
Bore ID	UDvCk	Photo (no photo)
Coordinates(approx.), Zone 55	207,100 E 5,739,950 N	
Location Description	Intersection of Westwood Track and Link Track	
Purpose of Bore	To assess the extent of unsaturated LTA material in surrounding bores (has implications for flow paths in saturated LTA)	
GMS No. (future)		
Bore Construction Licence No. (future)		

Access			
Land Owner	DSE / Parks Victoria	*Required Permits*	Use of Crown Land requires consent pursuant to the Crown Land (Reserves) Act 1978 from the land manager (i.e. DSE). Permit required if removing native vegetation.
Access Description	This site was not visited during the hydrogeological field assessment, as it was only identified during a post-field trip review of the assessment.	*Alternate Locations*	-
Additional notes	Site visit required to determine bore position, access etc. Access should be OK at the intersection of the two tracks.		

Construction Information (refer over page for construction diagram)			
Bore Depth (estimated)	40-60m	*Screening Target*	The aim is to screen the lower section of saturated LTA material (if present). Otherwise to screen the watertable in the bedrock.
Nearest Bore, Distance, Expected Lithology (comments)	▪ 47998 (SOBN Bore) ▪ GEDIS lithology log. ▪ ~ 1km m north of site	*Nearest bore log(m)*	47998 Log 0 7 MEDIUM SAND YELLOW RED 7 12 CLAYEY FINE SAND + SILT 12 19 FINE SAND + SILT WHITE, 19 21 FINE SANDY CLAY 21 24 SANDY SILTSTONE BROWN 24 32 COARSE SAND +GRAVEL 25 34 FINE TO MEDIUM SANDS 32 41 CLAY, CLAYEY SILT GREY 34 40.5 DENSE GREY CLAYS 40.5 46 SANDY WHITE CLAYS 41 45 COARSE SAND + GRAVEL 45 47 CLAYEY SILT WHITE 46 47 LARGE SANDS 47 53.5 LARGE GRAVELS 47 54 COARSE SAND + GRAVEL GREY 53.5 62 SANDSTONE 54 62 MUDSTONE BROWN GREY
Drilling Method	Mud rotary technique recommended as bore will be greater than 20 m deep. Air hammer may be required if the watertable is in the bedrock and the bedrock is relatively strong.		
Screen Interval / Length	Bottom of hole minus 1 metre / 3m screen *	*Constructed Bore Diameter*	50mm
Casing Material	uPVC Class 12	*Screen Material, Slot Size*	uPVC Class 12, machine slotted, 0.3mm to 0.5mm
Surface Construction	Steel lockable standpipe, ~0.7 to 0.8m high		
Other notes re drilling / construction	Bore depth ~ 12m below watertable is recommended (i.e. top of screen ~ 10m below watertable).		

* Final selection of bore depth and screen will be decided based on field logging

Groundwater monitoring bore general construction



Testing Requirements	
Water quality sampling	Sample for field chemistry (EC, pH, ORP, DO) recommended. Conduct at same time as hydraulic testing.
Geophysical testing	Gamma logging recommended (post-construction)
Hydraulic testing	Slug test recommended

Monitoring Requirements		
Water Level Monitoring Frequency	Manual	Frequency: Quarterly for first 3 years, bi-annual for subsequent years (~ April and Nov.)
	Data logger	Frequency: 6 hourly for first 3 years, daily for subsequent years Annual dipping of bores for cross-checking logger data
Water Level Monitoring Duration	Minimum duration, up to ~ 2018, i.e. point where data is required for analysis contributing to licence renewal. Recommended duration: 10 yrs, with review after 10 yrs data collection.	

Bore Maintenance Requirements	
Assessing need for maintenance	• Annual depthing of the bore and comparison with bore depth and screen interval (combine with a water level monitoring visit). Assess condition of surface steel cover, and concrete seal around top of the bore. • Inspect hydrograph on annual basis for anomalous behaviour
Scheduled maintenance	• Maintain protective steel cover (as required). • Flushing of the bore once every ten years using airlift.

C.4 Groundwater monitoring - Detailed cost estimates

Cost Estimate for Installing New Groundwater Bores - Contractor Costs

ITEM	Bore ID	Assumed bore depth (m)	50mm or 100mm	Bore Construction Notes	Drilled diameter	drilling method	traffic manage-ment	linear meter drilling costs	drilling fluids	water haulage	pressure cementing	supply casing	supply screens	supply gravel pack	install casing/screen/ gravel pack	Removal drilling waste	un-disturbed sampling	Site Re-instatement	Bore Dev't	Assumed dur'n (days)	Accom.	Mob. / Demob.	Lockable Steel Standpipe	Induction / Reporting	Assumed stand-by (e.g. gamma logging)	TOTAL
								$/m, 175mm+ drilling				$/m, 100mm casing	$/m, 100mm screens		$/deep bore	$/deep bore	$/deep bore	$/deep bore	$/deep bore				$/large standpipe			
								$ 165				$ 25	$ 55		$ 1,500	$ 1,500	$ 1,000	$ 1,500	$ 400				$ 400			
								$/m, 150mm drilling			$/m3 for cementing	$/m, 50mm casing	$/m, 50mm screens		$/shallow bore	$/shallow bore	$/shallow bore	$/shallow bore	$/shallow bore		$/night	mob. Betw'n bores	$/small standpipe		$/hr for standby	
no. of bores								$ 105			$ 1,500	$ 12	$ 25		$ 500	$ 300	$ 400	$ 1,000	$ 200		$ 400	$ 400	$ 200		$ 400	
1	RB1 (64239_nest)	100	100	Sc 96-99m (2m bent. plug, grouted back to surface)	175mm(min)	mud rotary, hammer from 73m	not required	$ 16,500	$ 1,500	$ 1,500	$ 4,239	$ 2,425	$ 165		$ 1,500	$ 1,500	$ 1,000	$ 1,500	$ 400	3	$ 1,200	$ 400	$ 400		$ 600	
2	A4	60	100	Sc. 56-59m, 2m bent plug, grout to surface (check surf. vs riv elvn, minus 10m safety factor)	175mm(min)	mud rotary	not required	$ 9,900	$ 1,000	$ 500	$ 2,355	$ 1,425	$ 165		$ 1,500	$ 1,500	$ 1,000	$ 1,500	$ 400	2	$ 800	$ 400	$ 400		$ 400	
3	A5a	100	100	Sc. 96-99m, 2m bent plug, grout to surface (or 102-105m in limestone.marl)	175mm(min)	mud rotary	not required	$ 16,500	$ 1,000	$ 500	$ 4,239	$ 2,425	$ 165		$ 1,500	$ 1,500	$ 1,000	$ 1,500	$ 400	3	$ 1,200	$ 400	$ 400		$ 600	
4	A6a	100	100	Sc. 96-99m, 2m bent plug, grout to surface	175mm(min)	mud rotary	$ 1,000	$ 16,500	$ 1,000	$ 500	$ 4,239	$ 2,425	$ 165		$ 1,500	$ 1,500	$ 1,000	$ 1,500	$ 400	3	$ 1,200	$ 400	$ 400		$ 600	
5	UBCk1	30	50	Sc top: w'table minus 3m (w'table 11m bgl in 1997), 2m bent plug, natural backfill surface OK	150mm	mud rotary / possibly hammer	not required	$ 3,150	$ 300	$ 250		$ 324	$ 75		$ 500	$ 300	$ 400	$ 1,000	$ 200	1	$ 400	$ 400	$ 200		$ 200	
6	UBCk2	15	50	Sc top: w'table minus 3m, 4m bent plug, natural backfill to surface OK	150mm	hollow auger	not required	$ 1,575	$ 200			$ 144	$ 75		$ 500	$ 300	$ 400	$ 1,000	$ 200	0.5	$ 200	$ 400	$ 200		$ 200	
7	A1	40	50	Sc. Top: W'table minus 10m, 2m bent plug, grout to surface (check surf. vs riv elvn, minus 10m safety factor)	150mm	mud rotary	$ 500	$ 4,200	$ 300	$ 250	$ 1,413	$ 444	$ 75		$ 500	$ 300	$ 400	$ 1,000	$ 200	1	$ 400	$ 400	$ 200		$ 200	
8	A2	40	50	Sc. Top: W'table minus 10m, 2m bent plug, grout to surface (check surf. vs riv elvn, minus 15m safety factor)	150mm	mud rotary	$ 1,500	$ 4,200	$ 300	$ 250	$ 1,413	$ 444	$ 75		$ 500	$ 300	$ 400	$ 1,000	$ 200	1	$ 400	$ 400	$ 200		$ 200	
9	A3	20	50	Sc. Top: W'table minus 5m, 2m bent plug, grout to surface	150mm	hollow auger	not required	$ 2,100	$ 200		$ 471	$ 204	$ 75		$ 500	$ 300	$ 400	$ 1,000	$ 200	1	$ 400	$ 400	$ 200		$ 200	
10	A5b	25	50	Sc. Top: W'table minus 5m, 2m bent plug, grout to surface	150mm	hollow auger	not required	$ 2,625	$ 200		$ 707	$ 264	$ 75		$ 500	$ 300	$ 400	$ 1,000	$ 200	1	$ 400	$ 400	$ 200		$ 200	
11	A6b	25	50	Sc. Top: W'table minus 5m, 2m bent plug, grout to surface	150mm	hollow auger	$ 1,000	$ 2,625	$ 200		$ 707	$ 264	$ 75		$ 500	$ 300	$ 400	$ 1,000	$ 200	1	$ 400	$ 400	$ 200		$ 200	
12	TB1	10	50	Sc. Top: W'table minus 3m, 2m bent plug, natural fill to surface	150mm	hollow auger	not required	$ 1,050	$ 200			$ 84	$ 75		$ 500	$ 300	$ 400	$ 1,000	$ 200	0.5	$ 200	$ 400	$ 200		$ 200	
13	TB2	10	50	Sc. Top: W'table minus 3m, 2m bent plug, natural fill to surface	150mm	hollow auger	not required	$ 1,050	$ 200			$ 84	$ 75		$ 500	$ 300	$ 400	$ 1,000	$ 200	0.5	$ 200	$ 400	$ 200		$ 200	
14	TB3	40	50	Sc. Top: W'table minus 8m, 2m bent plug, grout to surface (check surf. vs SWAMP elvn, minus 10m safety factor)	150mm	mud rotary	not required	$ 4,200	$ 300	$ 250	$ 1,413	$ 444	$ 75		$ 500	$ 300	$ 400	$ 1,000	$ 200	1	$ 400	$ 400	$ 200		$ 200	
15	TB4	20	50	Sc. Top: W'table minus 3m, 2m bent plug, natural fill to surface	150mm	hollow auger	not required	$ 2,100	$ 200			$ 204	$ 75		$ 500	$ 300	$ 400	$ 1,000	$ 200	1	$ 400	$ 400	$ 200		$ 200	
16	TB5	20	50	Sc. Top: W'table minus 3m, 2m bent plug, natural fill to surface	150mm	hollow auger	$ 500	$ 2,100	$ 200			$ 204	$ 75		$ 500	$ 300	$ 400	$ 1,000	$ 200	1	$ 400	$ 400	$ 200		$ 200	
17	TB6	20	50	Sc. Top: W'table minus 3m, 2m bent plug, natural fill to surface	150mm	hollow auger	not required	$ 2,100	$ 200			$ 204	$ 75		$ 500	$ 300	$ 400	$ 1,000	$ 200	0.5	$ 200	$ 400	$ 200		$ 200	
18	TB7	10	50	Sc. approx 4-7m tbc based on field log. bent plug to surface	150mm	hollow auger	not required	$ 1,050	$ 200			$ 84	$ 75		$ 500	$ 300	$ 400	$ 1,000	$ 200	0.5	$ 200	$ 400	$ 200		$ 200	
19	TB8	20	50	Sc. Top: W'table minus 3m, 2m bent plug, natural fill to surface	150mm	hollow auger	$ 1,000	$ 2,100	$ 200			$ 204	$ 75		$ 500	$ 300	$ 400	$ 1,000	$ 200	1	$ 400	$ 400	$ 200		$ 200	
20	TB9	20	50	Sc. Top: W'table minus 3m, 2m bent plug, natural fill to surface	150mm	hollow auger	$ 1,000	$ 2,100	$ 200			$ 204	$ 75		$ 500	$ 300	$ 400	$ 1,000	$ 200	1	$ 400	$ 400	$ 200		$ 200	
21	TB10	20	50	Sc. Top: W'table minus 3m, 2m bent plug, natural fill to surface	150mm	hollow auger	$ 1,000	$ 2,100	$ 200			$ 204	$ 75		$ 500	$ 300	$ 400	$ 1,000	$ 200	1	$ 400	$ 400	$ 200		$ 200	
22	TB11	15	50	Sc. Top: W'table minus 3m, 2m bent plug, natural fill to surface	150mm	hollow auger	$ 500	$ 1,575	$ 200			$ 144	$ 75		$ 500	$ 300	$ 400	$ 1,000	$ 200	0.5	$ 200	$ 400	$ 200		$ 200	
23	TB12	20	50	Sc. Top: W'table minus 3m, 2m bent plug, natural fill to surface	150mm	hollow auger	$ 1,000	$ 2,100	$ 200			$ 204	$ 75		$ 500	$ 300	$ 400	$ 1,000	$ 200	1	$ 400	$ 400	$ 200		$ 200	
24	TB13	20	50	Sc. Top: W'table minus 3m, 2m bent plug, natural fill to surface	150mm	hollow auger	not required	$ 2,100	$ 200			$ 204	$ 75		$ 500	$ 300	$ 400	$ 1,000	$ 200	1	$ 400	$ 400	$ 200		$ 200	
25	UDVCk	50	50	Sc. Top: W'table minus 5m, 2m bent plug, grout to surface	150mm	mud rotary	not required	$ 5,250	$ 200	$ -		$ 564	$ 75		$ 500	$ 300	$ 400	$ 1,000	$ 200	1	$ 200	$ 400	$ 200		$ 200	
26	ASS1	10	50	Sc. Top: W'table minus 1m, 2m bent plug, grout to surface	150mm	hollow auger	$ 1,000	$ 1,050	$ 200			$ 84	$ 75		$ 500	$ 300	$ 1,200	$ 1,000	$ 200	0.5	$ 200	$ 400	$ 200		$ 200	
27	ASS2	10	50	Sc. Top: W'table minus 1m, 2m bent plug, grout to surface	150mm	hollow auger	$ 1,000	$ 1,050	$ 200			$ 84	$ 75		$ 500	$ 300	$ 1,200	$ 1,000	$ 200	0.5	$ 200	$ 400	$ 200		$ 200	
28	ASS3	10	50	Sc. Top: W'table minus 1m, 2m bent plug, grout to surface	150mm	hollow auger	$ 1,000	$ 1,050	$ 200			$ 84	$ 75		$ 500	$ 300	$ 1,200	$ 1,000	$ 200	0.5	$ 200	$ 400	$ 200		$ 200	
29	ASS4	10	50	Sc. Top: W'table minus 1m, 2m bent plug, grout to surface	150mm	hollow auger	$ 1,000	$ 1,050	$ 200			$ 84	$ 75		$ 500	$ 300	$ 1,200	$ 1,000	$ 200	0.5	$ 200	$ 400	$ 200		$ 200	
30	ASS5	10	50	Sc. Top: W'table minus 1m, 2m bent plug, grout to surface	150mm	hollow auger	$ 1,000	$ 1,050	$ 200			$ 84	$ 75		$ 500	$ 300	$ 1,200	$ 1,000	$ 200	0.5	$ 200	$ 400	$ 200		$ 200	
One-off costs														$ 2,500								$ 3,000		$ 5,000		
	TOTAL	**900**					**$ 14,000**	**$ 116,100**	**$ 10,100**	**$ 4,000**	**$ 21,195**	**$ 14,244**	**$ 2,610**	**$ 2,500**	**$ 19,000**	**$ 13,800**	**$ 18,400**	**$ 32,000**	**$ 6,800**		**$ 12,400**	**$ 15,000**	**$ 6,800**	**$ 5,000**	**$ 7,400**	**$ 321,349**
	20% contingency																									$ 64,270
	TOTAL including contingency (excl GST)																									**$ 385,619**

Cost Estimate for Installing New Groundwater Bores - Technical Supervision/Management Costs

ITEM	Bore ID	Assumed bore depth (m)	50mm or 100mm	Drilled diameter	drilling method	Assumed dur'n (days)	Accom., food etc	Time charges (Cat 18)	Time charges (Cat 13)	Car & equipment exp.	Assumed stand-by (e.g. gamma logging)	Permits / PM / EHS / Induction / Reporting / Logs	TOTAL
							$/night	CAT 18	CAT 13	Car, dip meter, EC meter, camera etc	$/hr for standby	CAT 18	
no. of bores							$ 160	$ 150	$ 205	$ 255	$ 150	$ 150	
1	RB1 (109132_nest)	72	100	175mm(min)	mud rotary	2	$ 320		$ 1,640	$ 510			
2	A4	60	100	175mm(min)	mud rotary	2	$ 320		$ 1,640	$ 510			
3	A5a	100	100	175mm(min)	mud rotary	3	$ 480		$ 3,280	$ 765			
4	A6a	100	100	175mm(min)	mud rotary	3	$ 480		$ 3,280	$ 765			
5	UBCk1	30	50	150mm	mud rotary	1	$ 160	$ 1,200		$ 255			
6	UBCk2	15	50	150mm	hollow auger	0.5	$ 80	$ 600		$ 128			
7	A1	40	50	150mm	mud rotary	1	$ 160	$ 1,200		$ 255			
8	A2	40	50	150mm	mud rotary	1	$ 160	$ 1,200		$ 255			
9	A3	20	50	150mm	hollow auger	1	$ 160	$ 1,200		$ 255			
10	A5b	25	50	150mm	hollow auger	1	$ 160	$ 1,200		$ 255			
11	A6b	25	50	150mm	hollow auger	1	$ 160	$ 1,200		$ 255			
12	TB1	10	50	150mm	hollow auger	0.5	$ 80	$ 600		$ 128			
13	TB2	10	50	150mm	hollow auger	0.5	$ 80	$ 600		$ 128			
14	TB3	40	50	150mm	mud rotary	1	$ 160	$ 1,200		$ 255			
15	TB4	20	50	150mm	hollow auger	1	$ 160	$ 1,200		$ 255			
16	TB5	20	50	150mm	hollow auger	1	$ 160	$ 1,200		$ 255			
17	TB6	20	50	150mm	hollow auger	0.5	$ 80	$ 600		$ 128			
18	TB7	10	50	150mm	hollow auger	0.5	$ 80	$ 600		$ 128			
19	TB8	20	50	150mm	hollow auger	1	$ 160	$ 1,200		$ 255			
20	TB9	20	50	150mm	hollow auger	1	$ 160	$ 1,200		$ 255			
21	TB10	20	50	150mm	hollow auger	1	$ 160	$ 1,200		$ 255			
22	TB11	15	50	150mm	hollow auger	0.5	$ 80	$ 600		$ 128			
23	TB12	20	50	150mm	hollow auger	1	$ 160	$ 1,200		$ 255			
24	TB13	20	50	150mm	hollow auger	1	$ 160	$ 1,200		$ 255			
25	UDvCk	50	50	150mm	hollow auger	1	$ 160	$ 1,200		$ 255			
26	ASS1	10	50	150mm	hollow auger	0.5	$ 80	$ 600		$ 128			
27	ASS2	10	50	150mm	hollow auger	0.5	$ 80	$ 600		$ 128			
28	ASS3	10	50	150mm	hollow auger	0.5	$ 80	$ 600		$ 128			
29	ASS4	10	50	150mm	hollow auger	0.5	$ 80	$ 600		$ 128			
30	ASS5	10	50	150mm	hollow auger	0.5	$ 80	$ 600		$ 128			
Produce bore logs in GINT	assumes 1.5hrs per bore											$ 6,750	
Permits (envt, road opening, cultural heritage etc)	assumes 4hrs per bore											$ 18,000	
Report	60hrs Hydrogeologist, 20 hrs Senior Hydrogeologist											$ 13,700	
Project Mngt/ EHS planning (15%)												$ 15,000	
	TOTAL	**872**					**$ 4,880**	**$ 24,600**	**$ 9,840**	**$ 7,778**	**$ -**	**$ 53,450**	**$ 100,548**
	20% contingency												$ 20,110
	TOTAL including contingency (excl GST)												**$ 120,657**

Barwon Downs Monitoring Program: Water quality sampling

Item	**Sampling time** (days) (incl prep, mob-demob)	**labour cost / hr**	**Labour costs**	**Field eqp't**	**Lab costs**	**Accom/ living exp.**	**vehicle costs**	**TOTAL**
10 bores (field chem and major cations/anions)	4	$ 150	$ 4,800	$ 1,700	-	$ 480	$ 700	$ 7,680
19 bores (field chemistry)	5	$ 150	$ 6,000	$ 1,175	$ 1,900	$ 640	$ 875	$ 10,590
Reporting		$ 150	$ 2,400					$ 2,400
PM / EHS								$ 4,134
Total (excl contingency)								$ 24,804
20% contingency								$ 4,961
TOTAL, with contingency (excl GST)								$ 29,765
TOTAL (inc GST)								$ 32,741

Esimated costs for re-instating 6 former SOBN Bores

BORE ID	Develop bore for ~ 1hr via airlift	mob. between sites	driller accom/living exp	consultant supervision (inc recovery monitoring)	expenses (car x 2 day + 1 x accom + dip meter x 2 days + WQ meter x 2 days)	Padlocks	TOTAL
109130	$ 500	$ 200		$ 375		$ 50	
109142	$ 500	$ 200		$ 375		$ 50	
109143	$ 500	$ 200		$ 375		$ 50	
109136	$ 500	$ 200		$ 375		$ 50	
109144	$ 500	$ 200		$ 375		$ 50	
109131	$ 500	$ 200		$ 375		$ 50	
EXTRA BORE	$ 500	$ 200		$ 375		$ 50	
EXTRA BORE	$ 500	$ 200		$ 375		$ 50	
Total	$ 4,000	$ 1,600	$ 500	$ 3,000	$ 790	$ 400	$ 10,290
Reporting							$ 1,200
PM / EHS							$ 2,298
TOTAL (excl. GST & contingency)							$ 13,788
20% contingency							$ 2,758
TOTAL (incl. contingency)							$ 16,546

costs exlcude landholder liason, arranging access to sites etc

costs assume part of main drilling contract - Add ~ $2000 mobilisation if undertaken separately

Barwon Downs Monitoring Program: Hydraulic testing

Item	**Testing time** (days) (incl prep, mob-demob)	**labour cost / hr**	**Labour costs**	**Field eqp't**	**Accom/ living exp.**	**vehicle costs**	**TOTAL**
10 aquitard bores	4	$ 150	$ 4,800	$ 620	$ 480	$ 700	$ 6,600
Remaining (new) 19 bores	5	$ 150	$ 6,000	$ 775	$ 640	$ 875	$ 8,290
Analysis and Reporting		$ 150	$ 6,000				$ 6,000
PM / EHS							$ 4,178
Total (excl contingency)							$ 25,068
20% contingency							$ 5,014
TOTAL, with contingency (excl GST)							$ 30,082
TOTAL (inc GST)							$ 33,090

Barwon Downs Monitoring Program: Comparison of Manual Monitoring vs Automated Logging

Assumed cost comparison period	**15** years

Manual Monitoring

No. of bores	assumed time for monitoring (hours)	labour cost per hour	total per monitoring run	dip meter per monitoring run	vehicle cost per monitoring run	TOTAL per day	TOTAL per year (4 times/yr)	Total: 2014-2023 (10 yrs)	Capital cost	Sub Total	Contigency	TOTAL
39 bores	10	$ 80	$ 800	$ 150	$ 110	$ 1,060	$ 4,240	$ 63,600	$ -	$ 63,600	$ 12,720	$ 76,320
39 bores	15	$ 80	$ 1,200	$ 225	$ 165	$ 1,590	$ 6,360	$ 95,400	$ -	$ 95,400	$ 19,080	$ 114,480
39 bores	20	$ 80	$ 1,600	$ 300	$ 220	$ 2,120	$ 8,480	$ 127,200	$ -	$ 127,200	$ 25,440	$ 152,640

39 bores (27 - current program, 6 at PASS sites, 6 reinstated)

With Data Loggers Installed

No. of bores	assumed time for monitoring (hrs)	labour cost per hour	total per monitoring run	dip meter per monitoring run	vehicle cost per monitoring run	TOTAL per day	TOTAL per year (once/yr)	Total: 2014-2023 (10 yrs)	Capital cost	Sub Total	Allowing for two extra runs in first year and one in the second year	Contigency	TOTAL
39 bores	10	$ 80	$ 800	$ 150	$ 110	$ 1,060	$ 1,060	$ 15,900	$ 38,900	$ 54,800	$ 57,980	$ 11,596	$ 69,576
39 bores	20	$ 80	$ 1,600	$ 300	$ 220	$ 2,120	$ 2,120	$ 31,800	$ 38,900	$ 70,700	$ 77,060	$ 15,412	$ 92,472

39 bores (27 - current program, 6 at PASS sites, 6 reinstated)

Capital Expenditure for Level Loggers (Excl GST)

No. of units	Item	cost/unit	unit	total	
40	loggers	$ 705	per logger	$ 28,200	plus one for barologger, includes 10% discount provided in Hydroterra quote
700	m steel cable	$ 2	per m	$ 1,400	
1	USB cable ($500); fittings ($200)	$ 700	-	$ 700	
5	days installation (incl. 1 day prep)	$ 1,200	per day	$ 6,000	
4	field expenses	$ 300	per day	$ 1,200	
1	procurement costs	$ 1,400	per day	$ 1,400	
			TOTAL	**$ 38,900**	

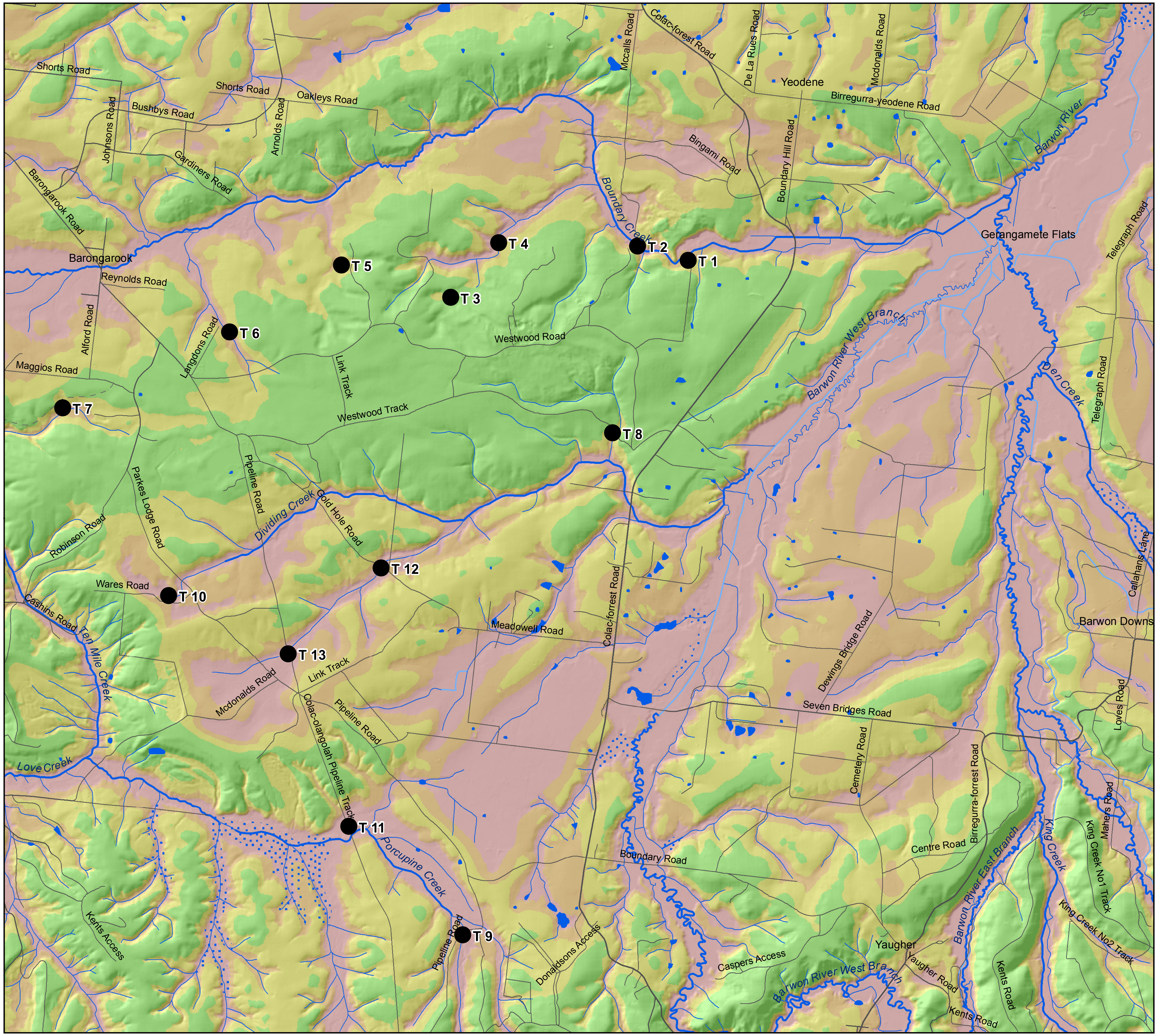
Logger costs based on quote obtained from Hydroterra. Battery life of loggers in 10 yrs at one reading per minute
Recommended reading interval is 4 times per day, hence battery life will be significantly longer than 10 years

Comparison Period

Method	10 years	15 years
Manual monitoring (4 times per year)	$ 76,320	$114,480
Automated monitoring with loggers (downloading once/yr)	$ 69,576	$ 92,472

Appendix D Terrestrial ecology monitoring

D.1 Terrestrial ecology monitoring site locality plan



Barwon Water Authority
Barwon Downs Monitoring Program

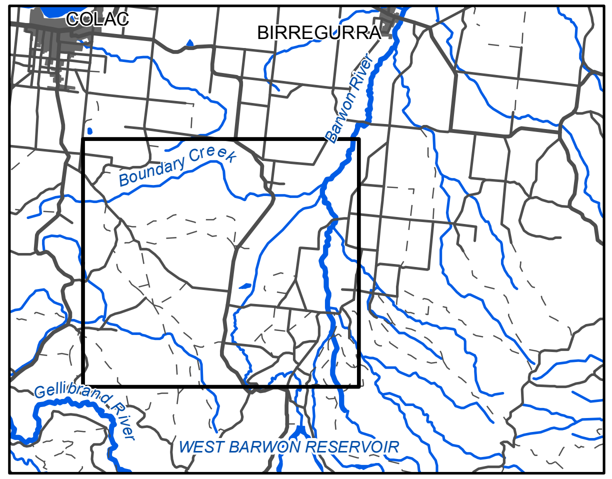
TERRESTRIAL VEGETATION SITES

Kilometres
0 0.25 0.5 1 1.5 2 2.5
(MGA55)

Terrestrial vegetation site

Watertable depth (m)
- < 5
- 5 - 10
- 10 - 20
- > 20

Locality Map



Refer to Sinclair Knight Merz document;
I:\VWES\Projects\VW07070\Technical\Spatial\Working\ArcGIS\EA_sites_A3.mxd

D.2 Terrestrial ecology monitoring scope

Barwon Downs Monitoring Program: Terrestrial Ecology

Project: 13-024

Prepared for:

Sinclair Knight Merz

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Contents

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1 Introduction

This project provides for the basic level of monitoring of Terrestrial Ecology associated with the Barwon Downs Borefield (BDB), located on the northern flanks of the Otway Ranges. It follows previous work on the vegetation of the BDB (Ecology Australia 1994, 2002). The limitations of these studies however produced inconclusive results regarding the key issue of the contribution of groundwater drawdown to observed changes in terrestrial ecology (SKM and Ecology Australia 2008).

The monitoring program is now being reviewed (SKM 2012) with the objectives to:

- better understand the environmental impacts of groundwater extraction;
- determine the role of each groundwater stress (extraction and drought) in contributing to environmental impacts;
- provide monitoring data required to ensure successful licence renewal in 2019.

The scope of the new monitoring program includes:

- hydrogeological and hydrological data to better characterise groundwater and surface water processes;
- terrestrial ecology;
- aquatic ecology;
- potential acid sulphate soils;

This study detailing the terrestrial ecology program has the following components:

- Desk-top review
- Field investigation
- Site selection
- Program outline
- Estimated costs.

2 Desk-top Review

2.1 Study area delineation

The study area was defined by the following parameters:

- drawdown cones associated with the unconfined LTA (outcrops) and confined LTA;
- remnant vegetation – all potential monitoring sites are to be established in vegetated landscapes to minimise the effects of adjoining landuse;
- sites must adequately represent impact (within drawdown cones) and reference areas (outside of drawdown) for both the confined LTA and unconfined LTA.

2.2 Values and potential Groundwater Dependant Ecosystems

The main tasks involved in the identification of values and potential Groundwater Dependent Ecosystems (GDEs), included:

- interrogation of flora and fauna databases, focusing on threatened species (EPBC Act 1999, FFG Act 1988 or Advisory List (DSE 2005, 2013)) potentially susceptible to groundwater drawdown;
- review of previous studies within or in comparable nearby environments;
- review of DSE's Ecological Vegetation Class (EVC) modelling;
- aerial photography interpretation; and
- our previous experience in the study area.

2.3 Site criteria

The preliminary list of sites was selected on the basis of the following criteria:

- located in areas where the watertable depth is generally <10 m (SKM 2013);
- representative of the potential GDEs in the study area namely:
  - ephemeral or permanent stream reaches – some streams potentially have gaining and/or losing sections; or
  - ephemeral or permanent wetlands; or
  - one or more of the following EVCs: Swamp Scrub, Sedgey Riparian Woodland, Wetland Formation and Riparian Forest;
- distributed to represent impact and reference sites for the confined LTA and unconfined LTA;
- part of the remnant vegetation landscape, and to be separate from areas of significant disturbance, e.g. wherever possible, sites should be upstream of roads and tracks;
- ease of access – sites should have access from existing roads or tracks to allow proximate access for small drilling rigs, and to minimise travel and access times during monitoring;
- sites should be on public land.

Output:

- Fourteen locations for potential monitoring sites were identified. Feedback from SKM suggested some changes based on hydrogeology. This information formed the basis of the field investigations
- Key values identified which could be impacted by groundwater drawdown, either directly through reduced water availability or indirectly through loss or modification of habitat include:
    - Threatened EVCs:
      EVC 53 Swamp Scrub (conservation status: vulnerable)
      EVC 198 Sedgey Riparian Woodland (depleted)
      EVC 74 Wetland Formation (endangered)
      EVC 18 Riparian Forest (vulnerable)
    - Threatened vertebrate fauna:
      Southern Toadlet (vulnerable[1])
      Broad-toothed Rat (endangered[1])
      Long-nosed Potoroo (EPBC Act, FFG Act)
    - Threatened invertebrates:
      Otway Bush Yabby (endangered[1])
      Hairy Burrowing Crayfish (vulnerable[1])
    - Threatened plant species:
      Showy Lobelia *Lobelia beaugleholei* (rare)

[1] – Advisory List status (DSE 2009, 2013)

3 Field investigations

Field investigations were carried-out over 5 days: 2 – 5 April and 15 April 2013. A total of 18 sites were surveyed: the preliminary list of 14, plus 4 additional sites considered to better satisfy the selection criteria. At each site the following data were collected:

- site location and waypoint;
- hydrogeology: confined or unconfined LTA;
- impact or reference site;
- type of GDE
- Ecological Vegetation Class(s);
- vegetation condition;
- major plant species;
- potential habitat for threatened fauna or groundwater dependant assemblages, e.g. frogs, burrowing crays;
- photographs;
- access

Output: Thirteen locations identified as suitable monitoring sites (Figure 1):

- 4 unconfined LTA impact
- 3 unconfined LTA reference
- 3 confined LTA impact
- 3 confined LTA reference

4 Site Detail

The proposed monitoring sites must:

- Represent the two major hydrogeological categories (unconfined and confined LTA) with impact and reference sites for each category);
- Represent the variation of GDEs across the forested landscape;
- Provide a level of certainty that the data will address the monitoring objectives;
- Provide for contingencies, e.g. the possibility that sites will be subject to prescribed burns or wildfire over the course of the monitoring program. This would result in post-fire recovery dominating vegetation change over the short term.

To this end we consider three 'replicates' in each of the major hydrogeological categories as a base case requirement. The exception is that we propose four impact sites within the unconfined LTA for the following reasons:

- Two sites are on Boundary Creek, one is the peat burn site which should be monitored considering the known hydrological impacts and extent of community interest in this site; the second site is an excellent comparison as it is upstream and in relatively good condition;
- Site 3 is a very unusual and significant wetland and within the drawdown cone – it has also been investigated as part of previous work (Ecology Australia 1994);
- Site 4 is more mainstream in terms of being similar to sites in other hydrogeological categories; and
- The unconfined LTA impact area has been an area with a high level of community interest, therefore a slightly higher of monitoring in this area is warranted.

Figure 1 Barwon Downs Monitoring Program: Terrestrial Ecology Sites

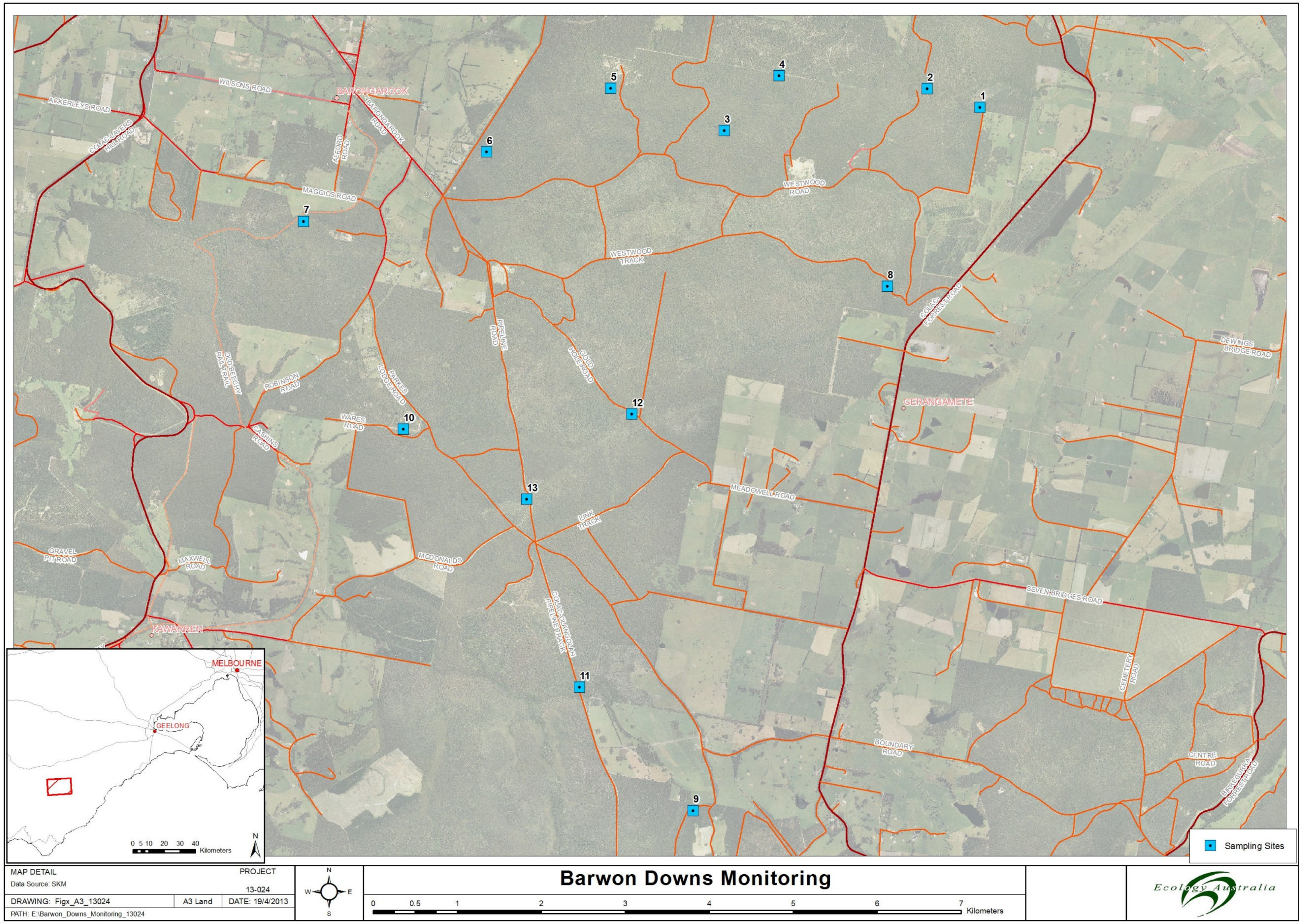

Table 1 Barwon Downs: Potential Monitoring Sites

Geology	Reference Impact	Site No	Photo (appendix 1)	Coordinates East (255)	Coordinates North (255)	Location	GDE	Accessibility	Suitability for inclusion
Unconfined LTA	Impact	1	Plate 1	211489	5742028	Boundary Creek	regenerating burnt peat formerly Swamp Scrub	good, track access	High
	Impact	2	Plate 2	210845	5742211	Boundary Creek	Swamp Scrub	good, track access	High
	Impact	3	Plate 3	208468	5741556	north of Westwood Track	Sedgy Wetland	10 min. walk, c. 330 m off track	High
	Impact	4	Plate 4	209078	5742252	off ‘Quarry Tk’ off Westwood Rd	Swampy Riparian Woodland	good, track access	High
	Reference	5	Plate 5	207083	5741970	Field and Game Tk off Westwood Rd	Swamp Scrub	good, track access	High
	Reference	6	Plate 6	205659	5741116	off Langdons Rd	Swamp Scrub	good, track access	High
	Reference	7	Plate 7	203536	5740152	Ten Mile Creek – off Old Beechy Rail Trail	Swamp Scrub	possible track access off Robinsons Rd, no direct track access	High
Confined LTA	Impact	8	Plate 8	210529	5739834	Westwood Track	Swamp Scrub	good, track access	High
	Impact	9	Plate 9	208623	5733450	Porcupine Creek	Riparian Forest	good, track access	High
	Impact	10	No photo	204885	5737764	Dividing Creek & Wares Rd	Swamp Scrub	good, track access	High
	Reference	11	Plate 10 & 11	207176	5734830	Porcupine Creek on Colac – Olangolah Pipeline Track	Swamp Scrub, Riparian Forest	good, track access	High
	Reference	12	Plate 12	207587	5738116	Gold Hole Road	Swamp Scrub	good, track access	High
	Reference	13	Plate 13 & 14	206405	5737024	Pipeline Track	Swamp Scrub, Swampy Riparian Woodland	good, track access	High

5 Monitoring Program

5.1 Selection criteria

The EVCs, habitats and species considered for monitoring were assessed against the following criteria:

- known or likely to have key functional components dependant on groundwater;
- known or likely to have key life history attributes dependant on groundwater;
- known to be reasonably detectable, i.e. not overly cryptic, i.e. difficult to detect;
- amenable to relatively straightforward and non-destructive monitoring techniques;
- cost effectiveness.

Table 2 summarises the identified key values against the above criteria. The suggested outcomes for the monitoring program are:

- The four Ecological Vegetation Classes representing the major GDEs should be monitored at their respective sites;
- The EPBC and FFG listed Long-nosed Potoroo is likely to be using the above GDEs as habitat, and should be monitored using remote cameras at all sites;
- Broad-tooth Rat (Advisory List – endangered) is also a likely resident of the above GDEs and would simultaneously be monitored with remote cameras;
- Otway Bush Yabby (endangered) and Hairy Borrowing Crayfish (vulnerable) have a high dependence on groundwater and should be monitored, but only at those sites that have observable burrows indicating the potential presence of these species. The number of sites would be limited to four.
- Threatened plant species: any threatened plant would be monitored as part of the transects established for the GDEs;
- Frog assemblages: these should be monitored at sites with surface water in spring – predominantly sites on streams: Boundary Creek, Dividing Creek and Porcupine Creek;
- Southern Toadlet (vulnerable): this species is considered highly cryptic and not particularly groundwater dependant; monitoring is not proposed.

Table 2 Barwon Downs Monitoring Program: Selected Items

Value / Criteria	Functional Component(s)	Life History	Detectability	Technique	Cost Effectiveness	Monitor
EVCs						
Swamp Scrub	✓	✓	H	Transects	H	Yes
Sedgey Riparian Woodland	✓	✓	H	Transects	H	Yes
Aquatic/Amphibious Wetland	✓	✓	H	Transects	H	Yes
Riparian Forest	✓	✓	H	Transects	H	Yes
Threatened Fauna						
Southern Toadlet	–	✓	L	Survey	L	No
Long-nosed Potoroo	✓	–	M	Remote sensing camera	H	Yes
Broad-tooth Rat	✓	✓	M	Remote sensing camera	H	Yes
Otway Bush Yabby	✓	✓	M	Tubular trap	M	Yes – limited sites
Hairy Burrowing Crayfish	✓	✓	M	Tubular trap	M	Yes – limited sites
Threatened Plant Species						
Showy Lobelia	✓	✓	H	Transects (as above)	H	Yes
Other						
Frog assemblages	✓	✓	H	Transects: nocturnal survey	H	Yes – limited sites

5.2 Monitoring Activity Scope

The following tables outline the location, method, frequency and duration of monitoring for each of the selected values.

Activity	Terrestrial Ecology: Ecological Vegetation Classes representing major GDEs
Purpose	To assess any changes to the floristics and structure of EVCs by monitoring plant functional groups – as adapted from Casonova (2011) and Doeg et al. (2012)
Location	Sites 1 – 13
Method	Permanent transects of 40 m located across the stream channel; frequency and functional group data would be collected from 20 contiguous 1 x 1 m quadrats positioned along the transect. This methodology will also cover any rare or threatened plant species
Frequency	Annually in spring, during high groundwater conditions, and in late summer – early autumn during a low groundwater period
Data Capture & Recording	Data recorded onto proforma data sheets or digitally entered in the field. Data in Excel spreadsheet form for analysis
Duration	From commencement of monitoring program until the licence application submission

Activity	Terrestrial Ecology: Threatened vertebrates: Long-nosed Potoroo and Broad-tooth Rat
Purpose	To assess whether any changes to GDEs are likely to impact on habitat for these threatened species
Location	Sites 1 – 13
Method	Remote sensing camera to be placed at a permanent location along the transects established to monitor the GDEs. Camera would be set over a two week period coinciding with, but not disturbed by other monitoring activities
Frequency	Annually in spring
Data Capture & Recording	Camera images analysed and species identifications entered into an Excel spreadsheet
Duration	From commencement of monitoring program until licence application submission

Activity	**Terrestrial Ecology: Threatened invertebrates: Otway Bush Yabby and Hairy Burrowing Crayfish**
Purpose	To assess the status of these species in the study area, and the potential for groundwater drawdown to impact on obligate/dependent yabby and cray species at selected sites
Location	Site 2: Boundary Creek (Unconfined LTA, impact site) Site 7: Ten Mile Creek tributary (Unconfined LTA, reference site) Site 9: Porcupine Creek (Confined LTA, impact site) Site 11: Porcupine Creek (Confined LTA, reference site)
Method	Tubular/modified 'Norrocky' traps: 10 traps at each site over 2 nights
Frequency	Annually in spring
Data Capture & Recording	Data recorded onto proforma data sheets and entered into an Excel spreadsheet for analysis
Duration	From commencement of monitoring program until licence application submission

Activity	**Terrestrial Ecology: Frog population**
Purpose	To assess any observable differences in frog populations between impact and reference sites and to assess whether these are influenced by groundwater drawdown potentially impacting on the availability of surface water
Location	Site 2: Boundary Creek (Unconfined LTA, impact) Site 3: Wetland (Unconfined LTA, impact) Site 7: Ten Mile Creek tributary (Unconfined LTA, reference) Site 9: Porcupine Creek (Confined LTA, impact) Site 11: Porcupine Creek (Confined LTA, reference)
Method	Permanent belt transect, involving set period for calling frogs and spotlighting along transect to record species and number of frogs
Frequency	Annually in spring
Data Capture & Recording	Data recorded onto proforma data sheet and entered into an Excel spreadsheet for analysis
Duration	

6 Costing

Cost estimates apply to the following:

- Annual monitoring with a single spring survey;
- Optional annual summer survey of vegetation;
- Establishment fee, which is a one-off cost to set-up the monitoring program;
- Annual reporting;
- Review of documentation in response to the revised numerical model.

No 20% contingency added to these costs

Charge-out rates are as follows:

Principal Ecologist	$160/hr	$1,280/day
Senior Botanist/Zoologist	$120/hr	$960/day
Botanist/Zoologist	$100/hr	$800/day
GIS technician	$120/hr	$960/day

Expenses include:

- $1.00/km for travel
- $70 / person / day field expenses
- all other expenses are at cost.

1. Annual monitoring

Fees	
• EVC/GDEs: transects	
Principal Ecologist @ 6 days & Botanist @ 6 days	$12,480
• Threatened fauna: remote camera	
Senior Zoologist @ 4 days & Zoologist @ 3 days	$6,240
• Frog assemblages	
Senior Zoologist @ 3 days & Zoologist @ 3 days	$5,280
• Threatened crays	
Senior Zoologist @ 2.5 days & Zoologist @ 2.5 days	$4,400
Expenses	
Accommodation	$2,500
Field expenses	$2,240
Travel: allow 1000 km @ $1.00/km	$1,500
Sub-total field surveys	$34,640
Annual data analysis and reporting	$10,000
Total	**$44,640**

2. Program establishment – fees and expenses

	– applies to first year only	**$5,000**

3. Optional late summer – autumn vegetation survey

Fees		
	Senior Botanist @ 6 days & Botanist @ 6 days	$10,560
Expenses		
	Accommodation	$1,000
	Field expenses	$1,400
	Travel: allow 500 km @ $1.00/km	$500
		$13,460

4. Numerical Model review documentation

	Allow an upper limiting fee	**$25,000**

7 References

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Doeg T, Muller K, Nicol J, VanLaarhoven, J (2012) Environmental water requirements of groundwater dependent ecosystems in the Musgrave and southern basins prescribed wells area on the Eyre Peninsula. Technical Report DFW 2012/16. Government of South Australia Department of Water

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DSE (2009) Advisory list of threatened invertebrate fauna in Victoria – 2009. (Department of Sustainability and Environment : East Melbourne)

DSE (2013) Advisory list of threatened vertebrate fauna in Victoria – 2013. (Department of Sustainability and Environment : East Melbourne)

SKM and Ecology Australia (2008) Barwon Downs Flora Study. Report prepared by Sinclair Knight Merz, Armadale, Victoria

8 Glossary

AVW	Atlas of Victorian Wildlife
Biodiversity	The variety of all life-forms, the different plants, animals and micro-organisms, the genes they contain, and the ecosystems of which they form a part.
Bioregion	Defined regions of Australia with coherent climatic and geophysical characteristics, which contain a set of distinct ecosystems and species.
Bioregional Conservation Status	The level of rarity, depletion and/or degradation of an ecosystem (or EVC) within a bioregion, as compared with its pre-1750 extent and condition.
CaLP Act	Catchment and Land Protection Act 1994
Classification	Creation of classes or categories. Usually involves combining groups of plant species and structural attributes recorded at sites into categories.
Community	Generic term of convenience to describe a unit of any rank, occupying a specific territory and having a characteristic composition and structure. A vegetation community has a characteristic species composition and structure.
Conservation status	Categorisation of biological assets (e.g. species, EVCs or plant communities) which reflects their rarity and likelihood of extinction within a defined region. In Victoria at present, the Department of Sustainability and Environment maintains an Advisory List of Rare and Threatened Plants, and a list recording the Bioregional Conservation Status of EVCs.
DSE	Department of Sustainability and Environment
Ecological Vegetation Class	A type of native vegetation classification described through a combination of its floristics, life form and ecological characteristics, and its association with particular environment attributes. Each EVC includes a collection of floristic communities that occur across a biogeographic range, and have similar habitat and ecological processes operating.
Endemic	Found only in a defined geographic area.
EPBC Act	*Environment Protection and Biodiversity Conservation Act* 1999 (Australian Government).
EVC	Ecological Vegetation Class. One or a number of floristic vegetation communities that appear to be associated with a recognisable and coherent environmental niche.
Exotic Vegetation	Any vegetation that is not native to Australia or its individual States and Territories. This can include non-indigenous vegetation.
FFG	*Flora and Fauna Guarantee Act* 1988 (Victorian State Government).
FIS	Flora Information System - a database of distribution and descriptive data on Victorian plants, managed by the Information Services Section of the Victorian Department of Sustainability and Environment.

GIS	Geographic Information System. A digital platform for creating, analysing and viewing maps and other spatially referenced data.
Ha	Hectares
Habitat hectares	Method for assessing the quality (or condition) of native vegetation. It is a compound index, each component describing different elements of vegetation or habitat structure (presence of large trees, tree canopy health, understorey structure and diversity, lack of weeds, length and size of logs, cover of litter, patch size, patch fragmentation, patch isolation). Habitat hectares is the method of assessment endorsed by Victorian State Government in *Victoria's Native Vegetation Management. A Framework for Action* (Department of Natural Resources and Environment 2002).
High Threat Weed	Introduced species (including non-indigenous 'natives') with the ability to out-compete and substantially reduce one or more indigenous life forms in the longer term assuming on-going current site characteristics and disturbance regime.
Indigenous Vegetation	Includes vegetation that is native to Australia as well as being native to a specific geographic region.
Native Vegetation	Vegetation that grows naturally in Australia, part of the pre-European flora.
Net Gain	Where, over a specified area and period of time, losses of native vegetation and habitat, as measured by a habitat hectares assessment, are reduced, minimised and more than offset by commensurate gains.
VFD	Victorian Fauna Display
VROTS	Victorian Rare or Threatened Species
WONS	Weeds of National Significance

Appendix 1 Photographs of monitoring sites

Plate 1: Site 1 - Regenerating burnt peat formerly Swamp Scrub

Plate 2: Site 2 - Swamp Scrub

Plate 3: Site 3 - Sedgy Wetland

Plate 4: Site 4 - Swampy Riparian Woodland

Plate 5: Site 5 - Swamp Scrub

Plate 6: Site 6 - Swamp Scrub

Plate 7: Site 7 - Swamp Scrub

Plate 8: Site 8 – Swamp Scrub

Plate 9: Site 9 – Riparian Forest

Plate 10: Site 11 – Swamp Scrub

Plate 11: Site 11 – Riparian Forest

Plate 12: Site 12 – Swamp Scrub

Plate 13: Site 13 – Swamp Scrub

Plate 14: Site 13 – Swampy Riparian Woodland

D.3 Terrestrial ecology detailed cost estimates

1. Annual monitoring

Activity	Fees	Expenses (accom, exp, travel)	Analysis and Reporting	Annual TOTAL	TOTAL (4 years) + set-up
• EVC/GDEs: transects Principal Ecologist @ 6 days & Botanist @ 6 days $12,480	$ 12,480	$ 2,742	$ 5,000	$ 20,222	$ 80,888
• Threatened fauna: remote camera Senior Zoologist @ 4 days & Zoologist @ 3 days $6,240	$ 6,240	$ 1,371	$ 2,197	$ 9,808	$ 39,233
• Frog assemblages Senior Zoologist @ 3 days & Zoologist @ 3 days $5,280	$ 5,280	$ 1,160	$ 1,859	$ 8,299	$ 33,197
• Threatened crays Senior Zoologist @ 2.5 days & Zoologist @ 2.5 days $4,400	$ 4,400	$ 967	$ 1,549	$ 6,916	$ 27,664
TOTAL	**$ 28,400**	**$ 6,240**	**$ 10,606**	**$ 45,246**	**$ 185,983**
TOTAL (with 20% contingency)					**$ 223,179**
Terrestrial Vegetation Only				$ 45,246	$ 85,888
Terrestrial Vegetation Only + contingency					$ 103,066.01

NOTES

Expenses

Accommodation $2,500	2500
Field expenses $2,240	2240
Travel: allow 1000 km @ $1.00/km $1,500	1500
Sub-total field surveys $34,640	6240

Annual data analysis and reporting $10,000
Total $44,640
2. Program establishment – fees and expenses – applies to first year only $5,000

2. Optional Summer / Autumn Surveying

Activity	Fees	Expenses (accom, exp, travel)	Annual Data Analysis and Reporting	Annual TOTAL	TOTAL (4 years)
• EVC/GDEs: transects Principal Ecologist @ 6 days & Botanist @ 6 days $12,480	$ 10,560	$ 2,900	$ 5,000	$ 18,460	$ 73,840
TOTAL	**$ 10,560**	**$ 2,900**	**$ 5,000**	**$ 18,460**	**$ 73,840**
TOTAL (with 20% contingency)					**$ 88,608**

Fees
Senior Botanist @ 6 days & Botanist @ 6 days $10,560
Expenses
Accommodation $1,000
Field expenses $1,400
Travel: allow 500 km @ $1.00/km $500
$13,460

3. EA involvement with conceptual / numerical model review

4. Numerical Model review documentation Allow an upper limiting fee $25,000	**$ 25,000**
TOTAL (with 20% contingency)	**$ 30,000**

1687
117
1570

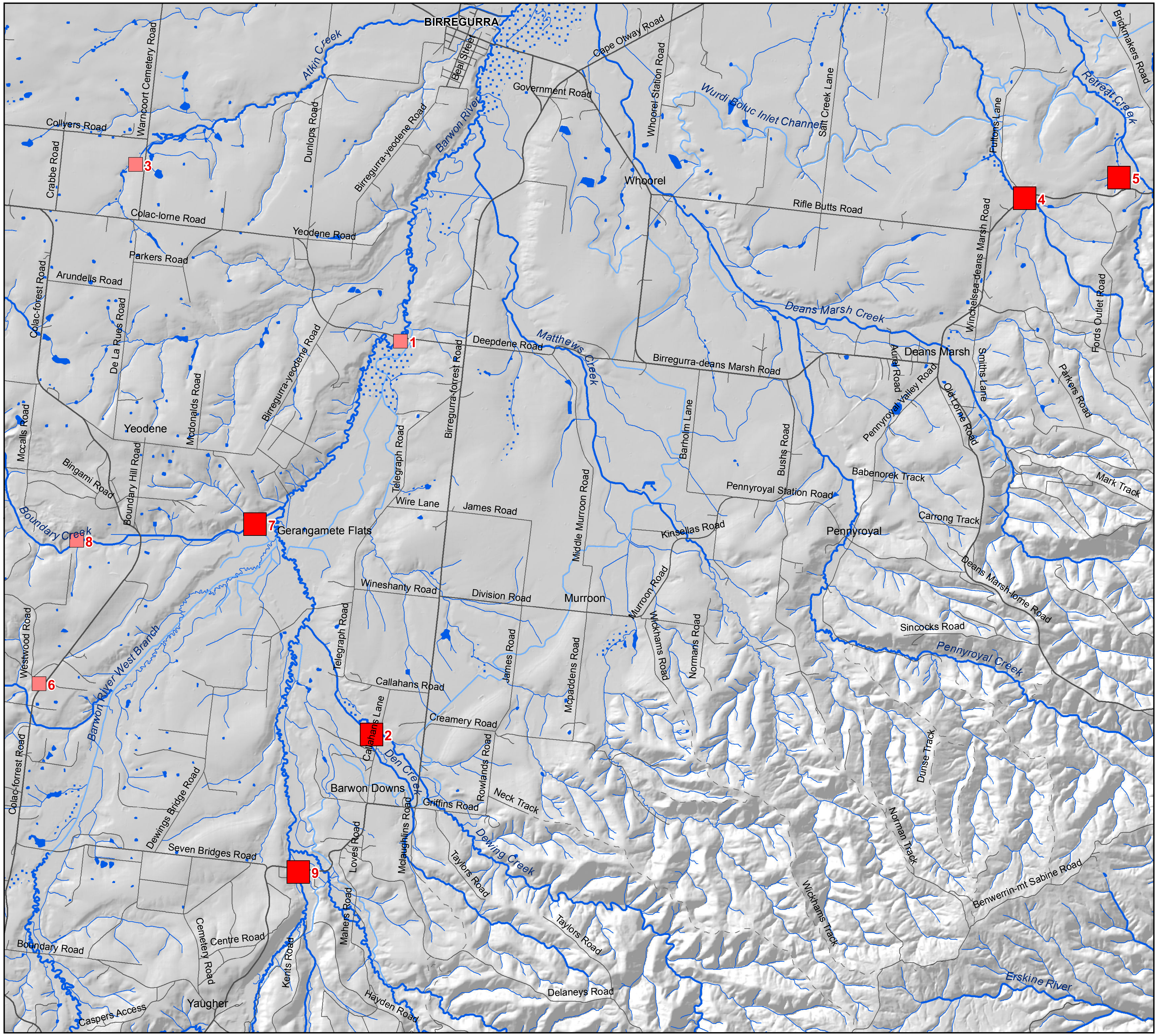
D.4 Terrestrial vegetation groundwater dependence and perched watertable assessment detailed cost estimates

Costing for Terrestrial vegetation groundwater dependence and perched watertable assessment

Item	Cost	Sub-total	Notes
Baseline terrestrial vegetation activity (NDVI assessment)			
Capture and spatial analysis of ET data	$20,000		Enables analysis of 4 periods of assessment of change in veg activity using NDVI (from LandSat)
Reporting	$10,000		Report on trend analyses and interpretation of the results in combination with the site investigations. Note – report will be combined with the report on "Site investigations of tree water use and perched watertable assessment"
Sub-total		$30,000	
Site investigations of tree water use and perched watertable assessment			
Soil sampling	$19,300		Assumes 1 test bore per terrestrial vegetation site , 10 m sampling depth and 16 samples per test bore
Field supervision soil sampling	$7,900		
Pressure-bomb equipment hire	$600		
Professional fees for leaf water potential measurement	$5,500		
Leaf water extractions and lab analysis	$4,600		
Lab analysis for soil water potential	$5,200		
Lab analysis for soil water isotopic composition	$9,400		
Lab analysis for groundwater isotopic composition	$600		
Analysis and Reporting	$24,000		Report on field investigation results, tree water source assessment, presence/absence of perched watertables. Note – report will be combined with the report on "Site investigations of tree water use and perched watertable assessment"
Sub-total		$77,100	
Remote sensing monitoring program (2015-2017) (This activity would only be undertaken if deemed necessary based on outcomes of the above two activities)			
Leaf water potential measurement and analysis	$18,000		$6,000 for each additional leaf potential sampling round, aligned to the timing of condition monitoring
Remote sensing	$20,000		Remote sensed ET data – enables 3 periods of remote sensed ET data collection and analysis
Analysis and Reporting (at end of three years, in 2017)	$25,000		Will include conclusions on likely impact of changing groundwater levels on tree health and transpiration.
Sub-total		**$63,000**	
Project Management (inc EHS etc)		$19,000	
Sub total		$189,100	
20% contingency		$37,820	
Total (excl GST)		$226,920	

Appendix E PASS investigations

E.1 PASS investigation site locality plan



Barwon Water Authority
Barwon Downs Monitoring Program

POTENTIAL ACID SULPHATE SOIL SITES (PASS)

Kilometres

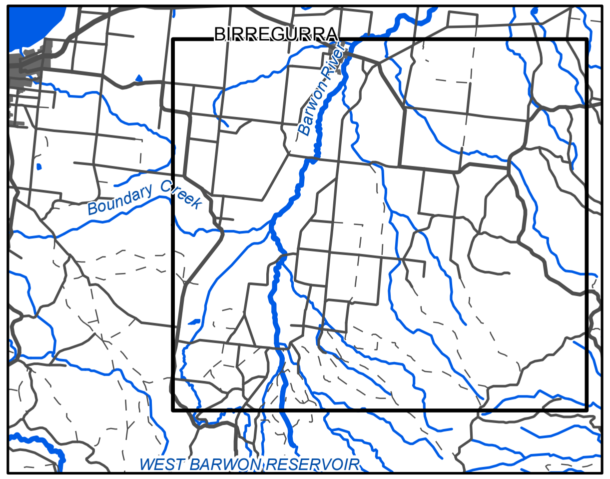
0 0.5 1 2 3 4 5

(MGA55)

PASS sites

- Soil sampling recommended
- Soil sampling not recommended

Locality Map



Refer to Sinclair Knight Merz document;
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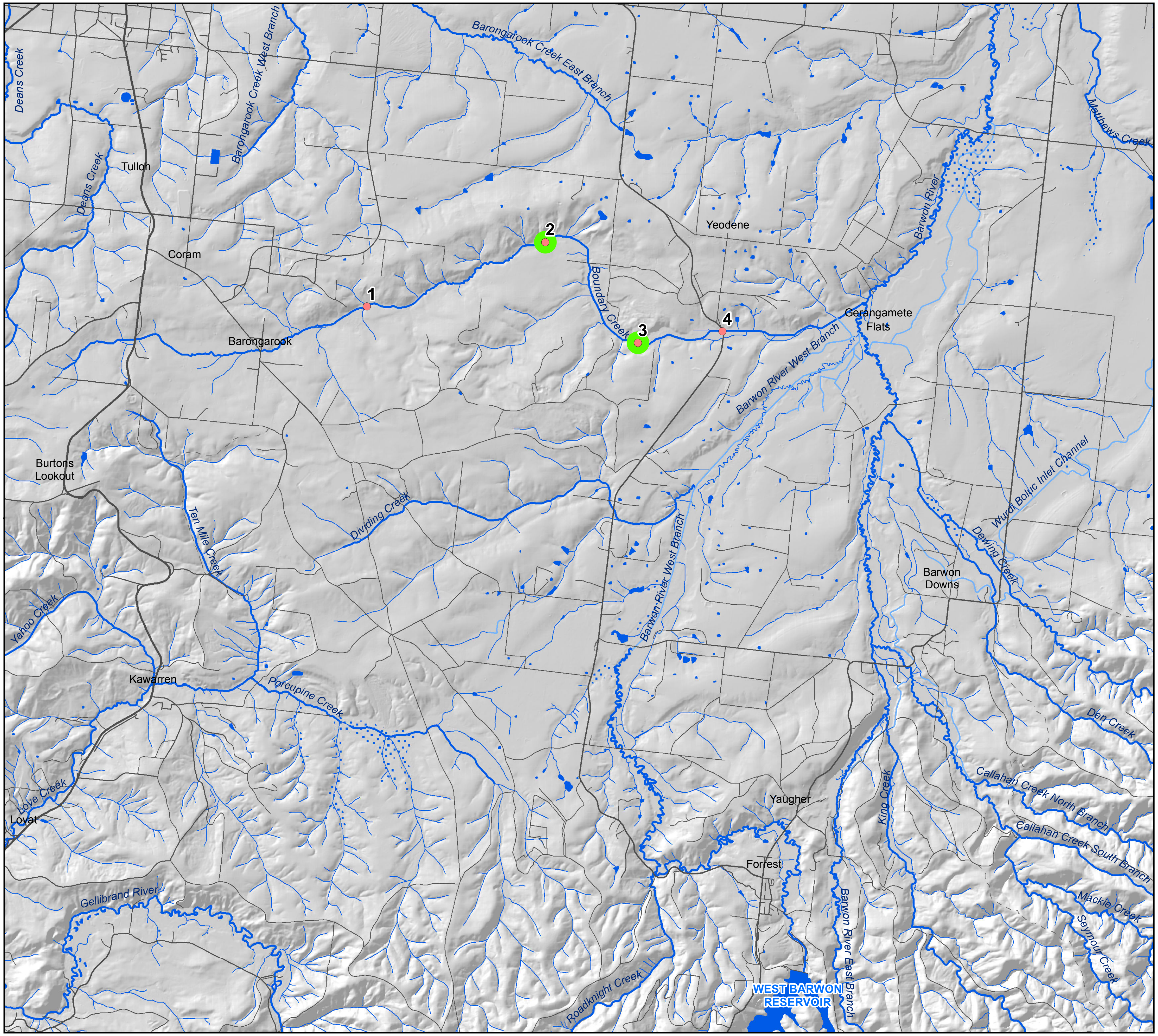
E.2 Detailed potential acid sulphate soils cost estimates

Barwon Downs Monitoring Program: PASS testing

Item	Testing time (days) (incl prep, mob-demob)	labour cost / unit	Labour costs	Expenses	Accom/ living exp.	vehicle costs	TOTAL
Pre-site visit (SKM, landholder, Barwon Water	1	$ 230	$ 1,840	$ 50		$ 155	$ 2,045
Drilling contractor	3	$ 2,500	$ 7,500	$ 700	$ 500		$ 8,700
Field Hydrogeologist	3	$ 230	$ 5,520	$ 50	$ 340	$ 465	$ 6,375
Laboratory Costs				$ 5,000			$ 5,000
Analysis and Factual Report	3.5	$ 175	$ 4,900				$ 4,900
PM / EHS							$ 2,664
Total (excl contingency)							$ 29,684
20% contingency							$ 5,937
TOTAL, with contingency (excl GST)							$ 35,621
TOTAL (inc GST)							$ 39,183

Appendix F Aquatic ecology and FLOWS monitoring sites



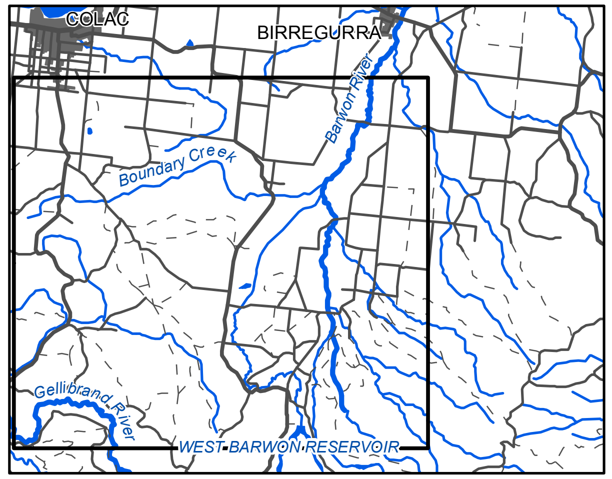
Barwon Water Authority
Barwon Downs Monitoring Program

AQUATIC ECOLOGY MONITORING

Kilometres
0 0.5 1 2 3 4 5
(MGA55)

Macroinvertebrate monitoring site (ID)
FLOWS assessment and water quality monitoring sites

Locality Map



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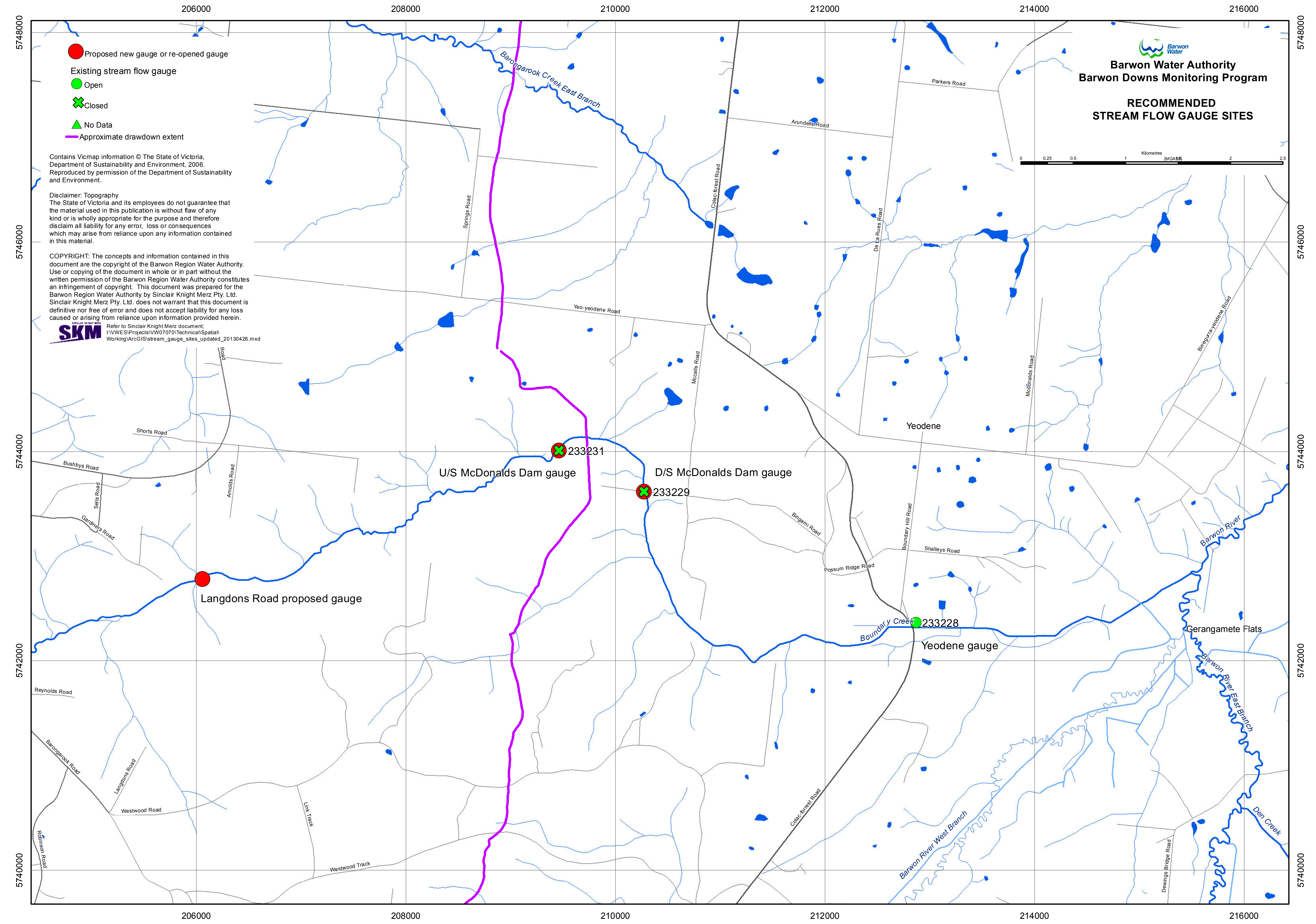
Appendix G Steam flow monitoring sites



Barwon Water
Barwon Water Authority
Barwon Downs Monitoring Program
RECOMMENDED
STREAM FLOW GAUGE SITES
Kilometres
0 0.25 0.5 1 1.5 2 2.5
Proposed new gauge or re-opened gauge
Existing stream flow gauge
Open
Closed
No Data
Approximate drawdown extent
Contains Vicmap information © The State of Victoria, Department of Sustainability and Environment, 2006. Reproduced by permission of the Department of Sustainability and Environment.
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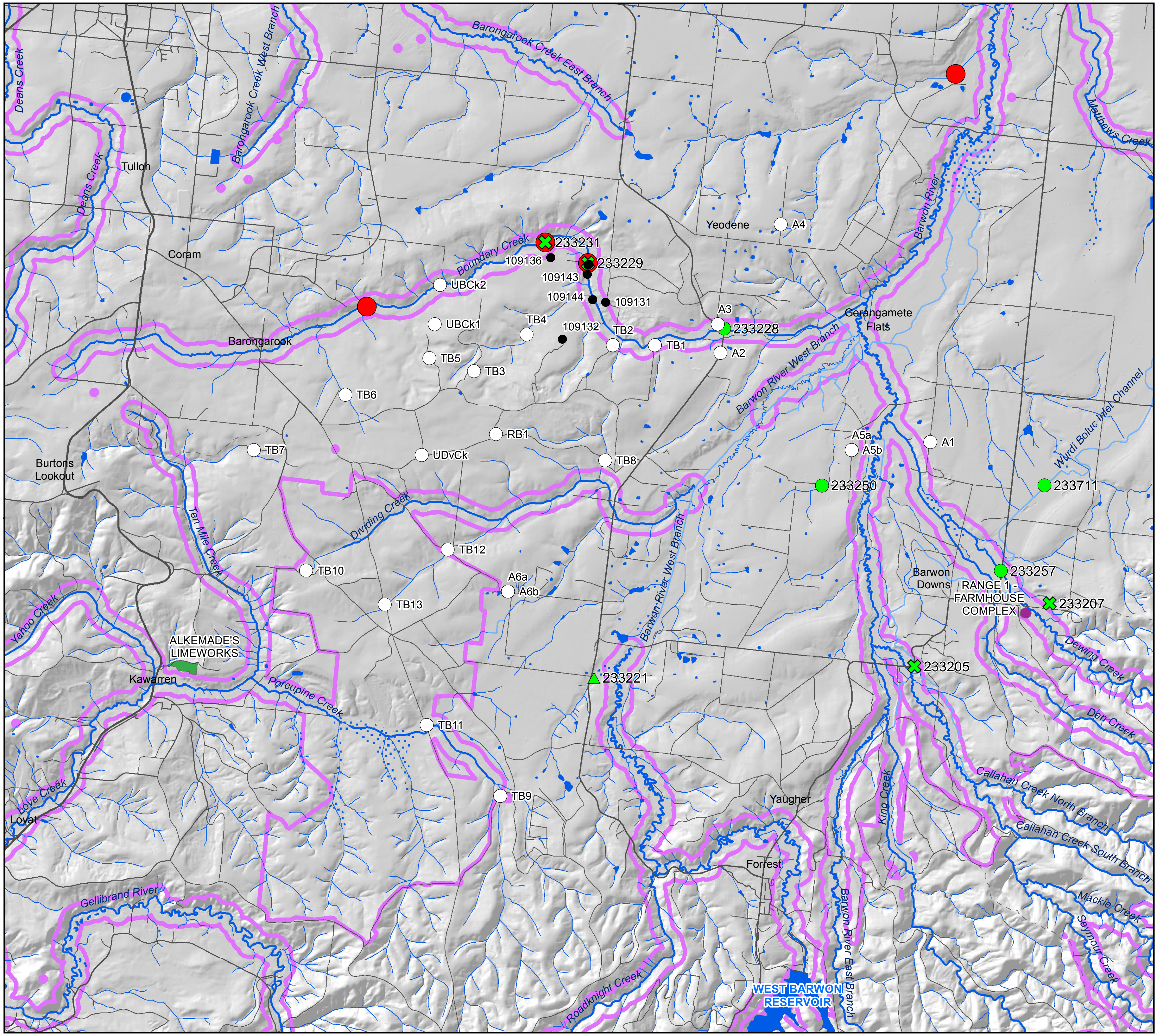
SINCLAIR KNIGHT MERZ
SKM
Refer to Sinclair Knight Merz document; I:\VWES\Projects\VW07070\Technical\Spatial\Working\ArcGIS\stream_gauge_sites_updated_20130426.mxd
206000
208000
210000
212000
214000
216000
5748000
5746000
5744000
5742000
5740000
Barongarook Creek East Branch
Parkers Road
Arundells Road
Colac-forrest Road
De La Rues Road
Springs Road
Yeo-yeodene Road
Bimegurra-yeodene Road
Mccalls Road
Mcdonalds Road
Yeodene
Shorts Road
Bushbys Road
Sells Road
Arnolds Road
Gardiners Road
233231
U/S McDonalds Dam gauge
D/S McDonalds Dam gauge
233229
Bingami Road
Boundary Hill Road
Shalleys Road
Possum Ridge Road
Barwon River
Langdons Road proposed gauge
Boundary Creek
233228
Yeodene gauge
Gerangamete Flats
Barwon River East Branch
Reynolds Road
Barongarook Road
Langdons Road
Westwood Road
Link Track
Robinson Road
Westwood Track
Colac-forrest Road
Barwon River West Branch
Den Creek
Dewings Bridge Road

Appendix H Heritage overlays



Barwon Water

Barwon Water Authority
Barwon Downs Monitoring Program

CULTURAL and HERITAGE OVERLAYS

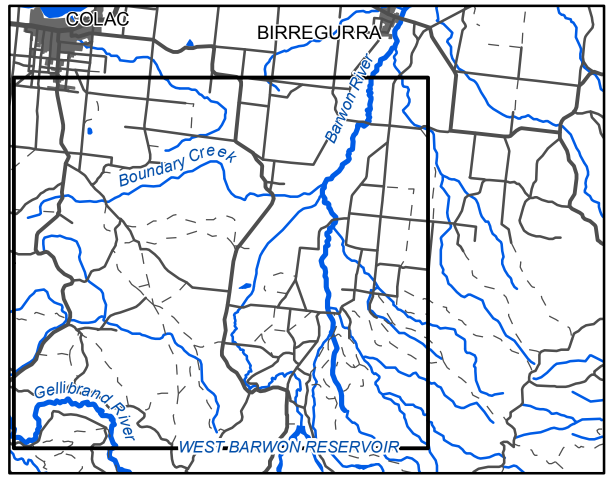
Kilometres
0 0.5 1 2 3 4 5
(MGA55)

Bore Site
- New
- Existing

Existing stream flow gauge
- Open
- Closed
- No Data
- Proposed new gauge or re-opened gauge
- Cultural sensitivity (Aboriginal)

Heritage Inventory
- ALKEMADE'S LIMEWORKS
- RANGE 1 - FARMHOUSE COMPLEX

Locality Map



SKM

Refer to Sinclair Knight Merz document;
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Appendix I Groundwater field visit photos

Photo 1

Photo 2

Photo 3

Photo 4

Photo 5

Photo 6

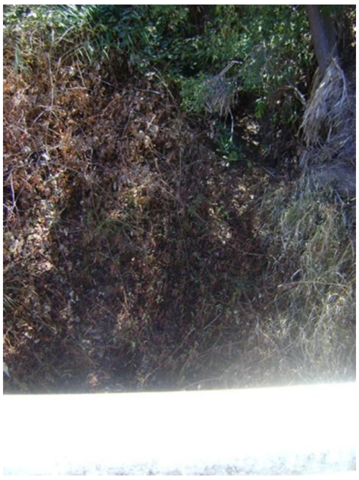
Photo 7

Photo 8

Photo 9

Photo 10

Photo 11



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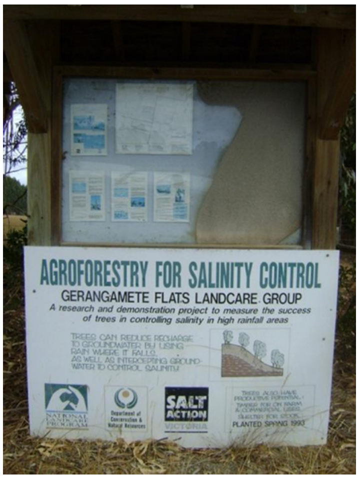

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