Review of Groundwater Permissible Consumptive Volume (PCV) in Gippsland Region

DELWP

Preliminary Assessment of PCV in Gippsland

CS/03/3588 | Final

4 July 2019

Contract 340446

Review of Groundwater Permissible Consumptive Volume (PCV) in Gippsland Region

Project No: IS282900
Document Title: Preliminary Assessment of PCV in Gippsland
Document No.: CS/03/3588
Revision: Final
Date: 4 July 2019
Client Name: DELWP
Client No: Contract 340446
Project Manager: Louise Lennon
Author: Louise Lennon / Ana Rastorgueva
File Name: C:\Users\llennon\Desktop\PCVGipps FINAL.docx

Jacobs Group (Australia) Pty Limited
ABN 37 001 024 095
Floor 11, 452 Flinders Street
Melbourne VIC 3000
PO Box 312, Flinders Lane
Melbourne VIC 8009 Australia
T +61 3 8668 3000
F +61 3 8668 3001
www.jacobs.com

Document history and status

Revision	Date	Description	By	Review	Approved
Final Draft	27/6/19	Final draft issued for client review	LL/AR	GH	LL
Final	5/7/19	Final report	LL/AR	LL	LL

Contents

Executive Summary

As part of preparatory work to assist a potential review of PCV's Jacobs has prepared a baseline assessment of the information available to inform a review of the sustainable yield for each Groundwater Management Area (GMA).

The original sustainable yield assessment was undertaken in the 1997 PAV assessment which formed the basis of the current PCVs. The PAV assessments has number of deficiencies including those identified by Reid's review in 2004. Major deficiencies include considering that 100% of recharge is the sustainable yield, and no consideration of climate change impact, long term trends in groundwater levels and use, and the uncertainties in hydrogeological parameters.

Considering these deficiencies and the passage of time, a review of the sustainable yield is considered to be appropriate. This report collates and summarises the key studies with hydrogeological data and analysis that would be used to revise the sustainable yield for Gippsland GMAs. This report does not present a review of the PCV's, rather it presents a preliminary assessment of the groundwater conditions and available data that will inform a (separate) decision about whether a review of the sustainable yield will be conducted.

For each of the 12 GMA areas in the Gippsland region of Victoria, data has been collated and an overview of the following is presented:

- The basis of the original PAV estimate
- Review findings from the Reid (2004) for some GMA's
- A compendium of recent studies and reports that provide new and additional information that is relevant to setting a sustainable yield estimate and then leading to PCV declaration
- An overview of recent entitlement and usage data for each GMA
- Presentation of regional groundwater trends for each GMA (from other studies).

For each GMA we have drawn together this information and formed a preliminary assessment of the issues and potential priority for future PCV review. In reaching these conclusions, we have taken into account the value of the resource, potential threats from climate change and the overall resilience of the aquifer system. The preliminary priority assessment and comments are provided in Table ES1.

Table ES1: Summary of findings and possible priority for GMA areas.

GMA	Level of priority	Commentary on priority
Unconfined aquifers		
Denison	Medium	• PAV was estimated used four methods • Shallow aquifer influenced by high rainfall and vertical recharge, 10% of rainfall and irrigation infiltration, significant river recharge. • Current PCV is at 50% higher than PAV assessment • A conjunctive management approach may be appropriate in consideration of irrigation return recharge in light of climate change and infrastructure modernization.
Moe	Medium	• PAV was estimated using the rainfall recharge method. • Primary recharge mechanism is infiltration from rainfall, assumed to be 5% of rainfall. • PCV has not been updated since the PAV estimate. • GMA is not fully allocated, yet declining groundwater levels indicate unsustainable extraction is some areas. Key risks are around impacts of climate change and likely future demand.

GMA	Level of priority	Commentary on priority
Wa De lock	Medium	• PAV was determined using rainfall recharge, with recharge rates ranging between 7% and 10% of rainfall. • The PAV was changed to 30,084 ML/year in 2006 based on recommendations from Reid. The current PCV is 30,795 ML/year. • Although GMA is almost fully allocated, groundwater use is low. • Little new information but likely to be vulnerable to climate effects and is close to other important confined resources
Leongatha	Low	• PAV assessment used throughflow method and rainfall recharge method • Current PCV is as recommended by Reid (2004) based on technical assessment to account for rainfall recharge and discharge to rivers. • GMA is priority GMA for town water supply however allocations are well under the PCV. • Key risks associated with climate change, however groundwater use is modest and there is no evidence of imminent issues
Tarwin	Low	• PAV estimate was based on rainfall recharge and considered effects of sea water intrusion. • PCV was reduced to 1,300 ML/year in 2006 based on recommendations by Reid. • Licensed entitlements are well within PCV. • Groundwater trends are reasonably stable but key risks around water quality due to proximity of septic tanks and climate change.
Wy Yung	Low	• PAV estimate was calculated using recharge from rainfall and discharge to rivers. • PCV was decreased to 7,463 ML/year in 2011, to match licensed entitlements. • Recent unpublished work held by DEWLP suggests that the conceptual model for this area may require significant revision to consider strong river connection.
Confined aquifers		
Rosedale	High	• PAV assessment based on aquifer throughflow method • The PCV was increased to 22,313 ML/year in 2007, to align with entitlement volumes and amended again in 2013 to 22,372 ML/year. • Current PCV is well in excess of the recommended PAV. • Likely to be ongoing demand from the same aquifer upgradient of the GMA associated with the operation and rehabilitation of the coal mines. • Declining groundwater levels indicate that aquifer is yet to reach a new equilibrium.
Sale	High	• PAV assessment based on aquifer throughflow method • The PCV was increased to 21,212 ML/year in 2007 to align with entitlement volumes and was amended again in 2013 to 21,238 ML/year.

GMA	Level of priority	Commentary on priority
		• Current PCV is well in excess of the recommended PAV, although groundwater use is around 12,000 ML/year which is similar to the PAV estimate. • Groundwater levels are declining and have the potential cause saline intrusion from Lake Wellington. • Groundwater pumping in the long term for operation and rehabilitation of the Latrobe Valley coal mines is likely to continue to affect the GMA.
Stratford	High	• PAV for the Latrobe Group aquifer was estimated using the aquifer throughflow method for the old Seacombe GMA which covers Stratford and Yarram. • PCV was declared in 2006 to be 27,643 ML/year and subsequently amended in 2011 and 2018, and is now 27,686 ML/year. • The current entitlement is 37,043 ML/year with metered use of 22,076 ML (DELWP, pers. comm, 2019). • Groundwater levels are expected to continue to decline as a result of ongoing mine dewatering and other related pumping, as well as offshore extraction and groundwater trends indicate that the aquifer is yet to reach an equilibrium level. • Important to understand the sustainable yield of the aquifer in the context of the close and rehabilitation of coal mines.
Yarram	High	• PAV for the Latrobe Group aquifer was estimated using the aquifer throughflow method for the old Seacombe GMA which covers Stratford and Yarram. • PCV was declared in 2008 to be 25,317 ML/yr, and amended to 25,690 ML/yr in PCV Order 2013 to match licence entitlements. • Groundwater levels are expected to continue to decline as a result of ongoing mine dewatering and other related pumping, as well as offshore extraction and groundwater trends indicate that the aquifer is yet to reach an equilibrium level. • Important to understand the sustainable yield of the aquifer in the context of the close and rehabilitation of coal mines.

Giffard	Low	• PAV assessment used aquifer throughflow method
		• GMA has two zones:
		    • Zone 1 has difference recharge regime than Zone 2 and warrants management separately and has implication for Sale GMA management
		    • Zone 1 PAV was recommended for PCV with moratorium on Zone 2
		• Current PCV is 60% higher than recommended PAV
		• Key risk is saline intrusion due to declining water level, however groundwater use is modest and water level trends are steady.

Orbost	Low	• PAV assessment used throughflow method and took into account the volume of water required to protect groundwater quality. • Current PCV was increased marginally from the PAV assessment of 1,200 to 1,217 ML/day

GMA	Level of priority	Commentary on priority
		• Licensed entitlements are similar to the PCV and groundwater use is low. • Key risks associated with declining groundwater levels and deteriorating groundwater quality, however groundwater trends are currently rising.

1. Introduction

DEWLP is considering reviewing the current declaration of Permissible Consumptive Volumes (PCVs) across south eastern Victoria. As part of preparatory work to assist a potential review of PCV's Jacobs has prepared a baseline assessment of the information available to inform a review of the sustainable yield for each Groundwater Management Area (GMA). Estimates of sustainable yield are an input to PCV determination.

In 1997, DELWP commissioned SKM to conduct a technical assessment of key aquifer areas to define the Permissible Annual Volume of aquifers (and part of aquifers) across the state. The purpose of the assessment was to make the first steps in setting a Permissible Annual Volume or PAV for these areas. The initial focus was on areas of high value water with concentrated use. PAV is no longer used for groundwater management and is now referred to as PCV. These assessments were completed using the limited data available at the time of the studies. They were intended to be a first estimate. With the benefit of hindsight, the main deficiencies with the original PAV assessments are:

- The consideration of 100% of recharge as the sustainable yield;
- No consideration of the potential for climate change impact in the assessment;
- Little formal inclusion of analysis of uncertainties in the parameters used in the assessment;
- No consideration of long-term groundwater use records in the assessment (as these were generally not available; and
- Limited consideration of long-term trends in ground water levels in the assessment.

Considering these deficiencies and the passage of time, a review of the PCV would appear appropriate. An approach is needed to prioritise the areas in Gippsland for possible review. This report supports a prioritisation task.

This report collates and summarises the key studies with hydrogeological data and analysis for Gippsland GMAs. This report does not present a review of the PCV's, rather it develops a preliminary assessment of the groundwater conditions and available data that will inform a (separate) decision about whether a review of the sustainable yield will be conducted.

A consolidation of reviewed information is compiled in the associated EXCEL spreadsheet titled 'Consolidated Table of Gippsland PCV Review' which providing information on current and historical PCVs, the principle on which it was set, groundwater level trends, values, aquifer parameters, recharge rates and groundwater surface water interaction.

The following GMAs have been considered in the report:

- Denison GMA – Chapter 2
- Giffard GMA – Chapter 3
- Leongatha GMA – Chapter 4
- Moe GMA – Chapter 5
- Orbost GMA – Chapter 6
- Rosedale GMA – Chapter 7
- Sale GMA – Chapter 8

- Stratford GMA – Chapter 9
- Tarwin GMA – Chapter 10
- Wa De Lock GMA – Chapter 11
- Wy Yung GMA – Chapter 12
- Yarrum WSPA – Chapter 13

2. Denison WSPA

The Denison WSPA boundary is based on the areal extent of the Nambrok-Denison sub-region of the Macalister Irrigation Area (see Appendix A). This sub-region is bounded by the Thomson River in the north and Princess Highway in the south. The eastern and western boundaries are not based on specific geological features but are considered as hydraulic barriers, represented by areas of intense irrigation. The groundwater systems covered by the GMA consist of the shallow unconfined aquifers in the Haunted Hill Gravels and recent Alluvials.

The Denison area experienced salinity problems in the past which resulted in the construction of a significant dewatering scheme. At the time of the study the licensed volume of extraction was 8,902 ML/year. In addition to that, SRW groundwater control bores were extracting 4,500 ML/year and another 500 ML/year was being extracted by free-flowing groundwater control bores (SKM, 1998a).

2.1 Original PAV estimate method

The original PAV assessment for the Denison WSPA was conducted by SKM (1998a). Four methods were used to estimate the annual groundwater available including rainfall infiltration, hydrograph fluctuation, river recharge and aquifer throughflow. Considerations were also made regarding regional drawdown and well interference volumes.

The original PAV assessment assumed rainfall and irrigation infiltration occurred at 10% infiltration rate. The annual rainfall of 917 mm/year over an area of 196 km^2. The total recharge volume was calculated as 17,973 ML/year.

The hydrograph fluctuation method used the median annual fluctuation of 3 bores, with an aquifer area of 195 km^2 and an adopted specific yield of 0.1. The median annual recharge was determined to be 12,025 ML/year which was calculated by summing the values of 3 bores (see Table 2-1). The bore IDs were not provided in the report.

Table 2-1: Bores used in the hydrograph fluctuation method

Bore	Median Annual Fluctuation (m)	Median Recharge Estimates (ML/year)
1	0.4	2,275
2	0.7	4,550
3	0.8	5,200
Total		**12,025**

River recharge was considered to be significant along a 10 km reach of Rainbow Creek and a 20 km reach of the Thomson River. Darcy's Law was used to calculate the volume of recharge using the following parameters:

- Hydraulic gradient of 0.001 for both Rainbow Creek and Thompson River
- Conductivity of the river bed sediments was 20 m/d for both rivers

The total recharge from rivers was calculated as 1,752 ML/year which was considered as a minor component of the total recharge to the aquifer compared to the rainfall recharge estimate. Discharge to rivers was not considered as a significant discharge mechanism and was therefore not estimated.

Like river recharge, the through flow method indicated relatively small through flow into the aquifer with a value of 243 ML/year. The following vales were used to calculate aquifer through flow:

- A cross-sectional area of 80 km^2

- Hydraulic conductivity of 5 m/day
- A horizontal gradient of 0.00167

The following factors strongly influenced the setting of the PAV:

- A high annual rainfall and high vertical recharge rate of 17,973 ML/year
- Relatively low aquifer storage of 78,000 ML/year and a small horizontal through flow of 243 ML/year
- Salinity issues are known to emerge when usage is below 7,000 ML/year

Based on these factors a PAV of 12,000 ML/year was recommended for the Denison WSPA. PCV Order 2006 declared the PCV for Denison as 17,743 ML/year. The VWA 2011-2012 reported that entitlement in Denison was 18,502 ML thus exceeding the existing PCV. Therefore, the PCV Order 2013 amended the PCV for Denison from 17,743ML to 18,502 M – there was not technical basis for this increase.

2.2 Subsequent New or Local Studies

2.2.1 List of Studies and Reports

Reports	Purpose of study
RMCG (2008) Groundwater Economics. For Department of Sustainability and Environment (DSE) 29 August 2008	This study was completed for the Department of Sustainability and Environment (now DELWP) with the objective of developing an updated approach and revised analysis to improve the understanding of the economic value of groundwater to support future policy and management practices. The study quantified the overall economic value in terms of support irrigation, urban water supply, commerce and industry, stock and domestic and sleeper and unallocated entitlements.
West Gippsland CMA (2008) Macalister Land and Water Management Plan	This plan covers land and water management in the Macalister Irrigation District and the surrounding dryland areas. The driver behind its development was the need to review the MID nutrient reduction plan (SKM, 1998). The nutrient export from the region is s significant threat to the health of the downstream Gippsland Lakes. The land and water management plan built on existing management plans with the aim of addressing knowledge gaps, integrating common actions in separate plans and renewing the MID Nutrient Reduction Plan. The plan covers many natural and artificial assets including rivers, Lake Wellington, Ramsar listed wetlands, remnant native vegetation and groundwater.
GHD (2010a) West Gippsland CMA Groundwater Model. Interim steady-state model development report. Report prepared by GHD for the Department of Sustainability and Environment (DSE), Victoria.	The groundwater model was developed by GHD on behalf of DSE (now DELWP) as part of the ecoMarkets project. The intention of ecoMarkets projects were to use a groundwater model as a tool to assess the relative merits of improving native vegetation management and revegetation initiatives. The model's primary objective was to provide a tool for assessing the impacts of land use change on depth to water.

Reports	Purpose of study
	Calibrated aquifer parameters are available for each of the formations in the model.
SKM (2012) Baseflow Separation Analysis for Unregulated Rivers (1889 to 2012)	The study completed a baseflow separation analysis for 180 stream gauges on unregulated rivers in Victoria Reference. Originally published on-line through the WMIS database, the dataset is now available through data.vic. The report is cited in Jacobs (2014). A copy of the original report appears to be no longer available.
Beverly et al. (2015) The Gippsland groundwater Model, Onshore natural gas water science studies, DEDJTR.	The report describes the conceptualization, development, calibration and application of the Gippsland groundwater model. The model was designed to assess impacts to groundwater resources from potential coal seam gas development. Calibrated regional aquifer parameters are available for each formation in the Gippsland Basin.
DELWP (2017) Victorian Water Accounts 2016 – 2017.	The report presents annual information about the resources of the state of Victoria, reporting on volumes of surface water, groundwater and recycled water systems used and water available during the year.
CDMSmith (2017) Groundwater Data Inventory, Stocktake and Enhancement options	CDMSmith was commissioned by DEWLP to collate available data relating to four themes of groundwater recharge, aquifer/aquitard properties, groundwater use and aquifer/aquitard thickness into a database. The quality of the data was assessed through a data stocktake process. Enhancement methods were also considered for each data theme. A total of 65 studies were collated and the information was summarized into a spatial database.
CDMSmith (2018) Data Mapping – Aquifer properties and Recharge	CDMSmith was commission by DELWP to create visual products of recharge and aquifer properties for Victoria. Two products were developed – a high level communication tool to quickly inform a range of audiences of the variability in historical estimates and a finer resolution product for technical specialists to assess in future assessments of groundwater management.
GHD (2018) Groundwater Condition Reporting – Stage 4, September.	GHD developed a method to determine the Groundwater Resource Condition Assessment for DELWP. They key components of the approach was to adopt a representative Suite for reporting on groundwater resource condition and predict groundwater level as a means to compare against observation to qualitatively assess groundwater resource condition.

2.2.2 Key findings relevant to sustainable yield

RMCG (2008) Groundwater Economics

RMCG assessed the economic value of the Denison GMA and it was not classified as high value in terms of irrigation, urban supply, commerce/industry or power generation. The GMA was classified a high value in terms of unallocated entitlement, which was valued at $500,000 at the time of the study.

West Gippsland CMA (2008) Macalister Land and Water Management Plan

The Macalister Land and Water Management Plan was developed to manage nutrient loads entering Lake Wellington from several catchments including the Macalister catchment. Several groundwater management actions were identified including:

- It was recognised that a formal Groundwater Management Plan may not be the best tool for managing groundwater resources. Recommended that the Denison WSPA be un-declared and develop management arrangement that allow flexible management of the resource (e.g. triggers, local management rules).
- Align the northern boundary of the Denison WSPA with the southern boundary of the Wa De Lock GMA.
- Improve the understanding of groundwater surface water interactions for all rivers including the Macalister River to enable conjunctive water management of both resources.

Woodwater (2017) conducted a review after eight years of implementation of the Macalister Land and Water Management Plan. Progress against these recommendations is summarized below:

- Denison WSPA continues to exist.
- Mid Term Review reports indicate that the boundaries between the Denison and Wa De Lock GMAs have been aligned with the river catchments
- Baseflow analysis has been completed for the Lower Macalister River.

GHD (2010a) West Gippsland CMA Groundwater Model - Interim steady-state model development report

GHDs 2010 groundwater model has been created for the West Gippsland CMA. The primary objective of the model is to provide a tool for assessing the impacts of land use change on depth to water. Calibrated model aquifer parameters for aquifers in the Gippsland region were listed for the Denison GMA.

The Haunted Hills formation and recent Quaternary sediments were reported in layer 1, followed by Boisdale formation in layer 2, Balook formation in layers 3 and 4, and the Seaspray Sands in layer 5.

The hydraulic conductivity values for the Quaternary aquifers determined using the calibrated model are provided in Table 7-1.

Table 2-2: Calibrated Hydraulic Conductivity Values

Model Layer	Hydrostratigraphic Unit	Kh (m/d)	Kv (m/d)
1	Haunted Hills Formation and Quaternary Sediments	2.01	4.21 (2.01E-3 around the LV mines)

* LV = Latrobe Valley; LVD = Latrobe valley Depression; SD = Seaspray Depression; Kh = horizontal hydraulic conductivity; Kv = vertical hydraulic conductivity.

Beverly et al., (2015) The Gippsland groundwater Model - Onshore natural gas water science studies

The Gippsland Groundwater Model was developed to assess the potential impact of coal seam gas development on groundwater resources.

Calibrated model aquifer parameters for aquifers in the Gippsland region were listed for the Denison GMA. The recent alluvial deposits were reported as part of the Quaternary aquifer, followed by the Haunted Hill Formation and Boisdale Formation. The Balook Formation was reported as part of the Lower M2 Interseam and Seaspray sands aquifer was reported as the M2c aquifer/Seaspray Sands. A summary of the aquifer parameters used in the model are provided in Table 7-2.

Table 2-3: Calibrated model aquifer parameterisation.

Zone	Aquifer	Kxy (m/d)	Kz (m/d)	Specific yeild	Specific storage (m^{-1})	Kzz/Kxy
2	Quaternary	6.507	9.761×10^{-1}	0.1	1×10^{-5}	0.150
3	Haunted Hill Formation	3.203	4.804×10^{-1}	0.1	1×10^{-5}	0.150
36	Quaternary	1.501×10^{-1}	2.009×10^{-2}	0.07	1×10^{-5}	0.134

DELWP (2017) Victorian Water Accounts 2016 – 2017

The Victorian Water Accounts report provides information on the usage and annual trends associated with water resources in the state of Victoria. To provide a consistent picture of water use across all GMA areas considered in this report we have reported the water usage figures from the most recent annual statement. Trends over two years do not necessarily represent the longer-term trends but are nevertheless considered instructive. Future assessment of the PCV should consider the full record of groundwater usage trends. The total licensed use volumes for the period of 2015 - 2017 are provided in the table below.

The groundwater level trends in Denison WSPA were not established due to insufficient state observation bores to adequately define the groundwater resource or changes to the resource over time.

The latest published licensed groundwater volumes and use for the Denison WSPA are provided in Table 2-4.

Table 2-4: Licensed groundwater volumes and use.

GMA	GMA aquifer depth limits (m)	Licensed entitlement (ML/year)	Total licensed groundwater use (ML) 2016-17	Total licensed groundwater use (ML) 2015-16
Denison GMA	<=25	18,499	6,882	8,741

GHD (2018) Groundwater Condition Reporting – Stage 4

GHD developed a range of aquifer classification codes, which were used to represent groundwater level responses. Details of suite description, classification and suite hydrograph development and representative suite hydrograph for resource condition reporting can be found in (GHD 2014; GHD 2017; GHD 2018). The suites are grouped based on the aquifer monitored (upper, middle, lower or basement), suite code which is an alphabetic naming convention and fluctuation code which is a numerical identifier that indicates bores with similar magnitude in seasonal fluctuations (GHD, 2018). The suites to be reported for a particular GMU were selected based on the following:

- Suite representativeness (the proportion of the suite that occurs within the GMU must be spatially significant)

- Relevance of the aquifer layer (the unit the GMU is intended to manage)
- Spatial coverage of groundwater monitoring bores across a Suite or GMU
- Spatial coverage of groundwater extraction bores across the GMU
- Conceptualization considerations (improving the understanding of recharge processes, inter aquifer connectivity or aquifer leakage)

GHD determined that the Denison GMA is best represented by suite U_AB_1 which covers the upper aquifer. The area covered by the suite is shown in Figure 2-1Figure 5-1. The representative hydrograph for the aquifer classification is shown in Figure 2-2. The hydrograph shows that groundwater levels in U_AB_1 have been declining since 1988.

Figure 2-1: Location of suite U_AB_1 (GHD, 2018)

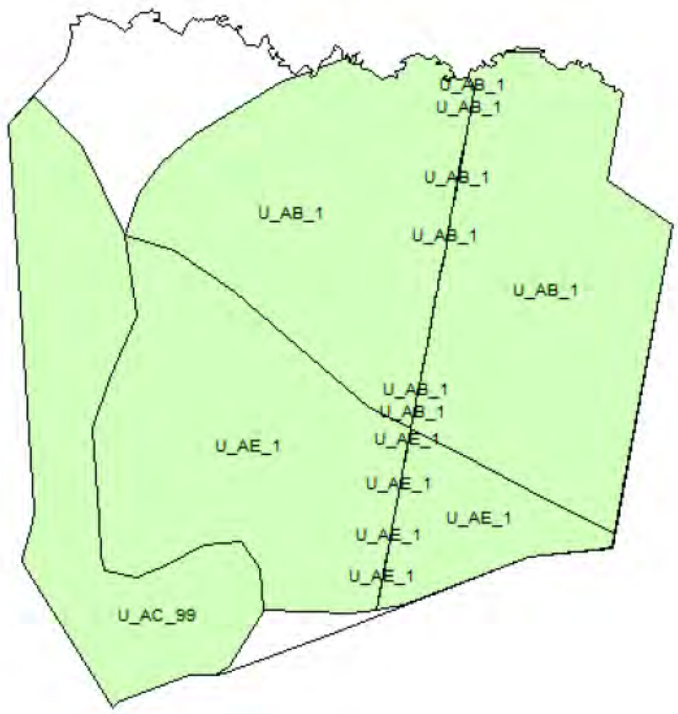
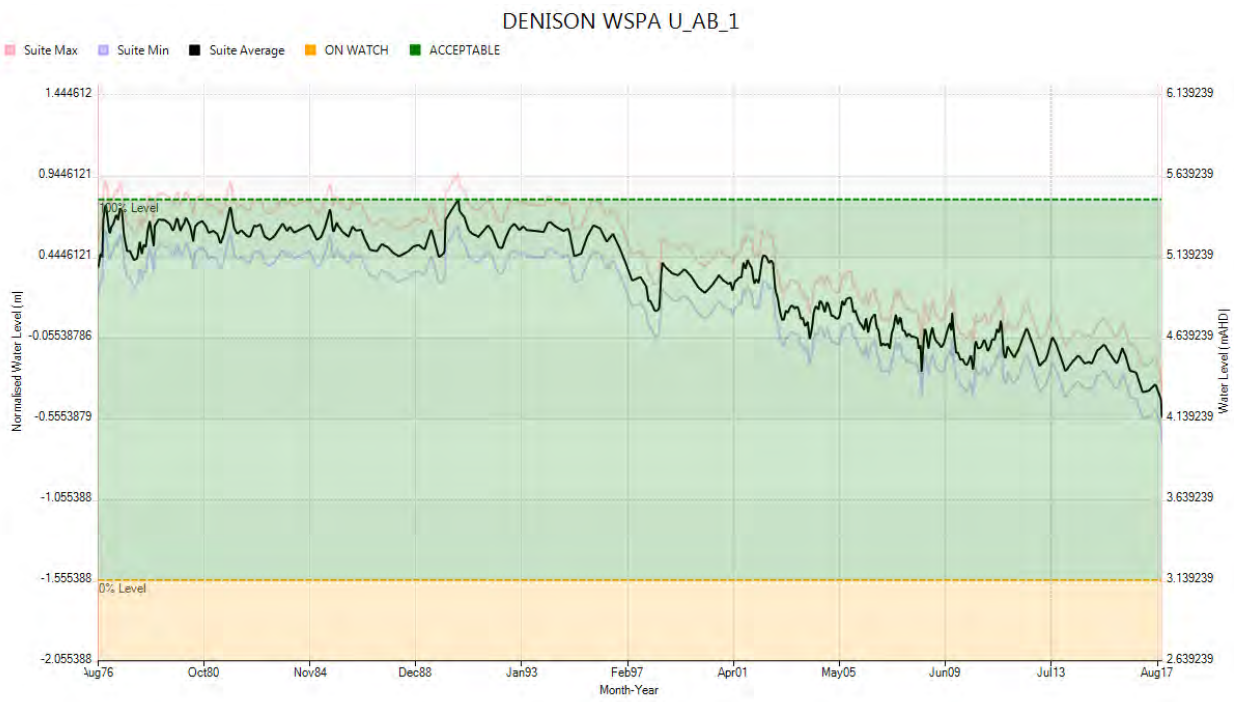


Figure 2-2: Denison WSPA Suite Chart for U_AB_1



2.3 Relevant matters for consideration

- Original PAV based on the following factors:
  - A high annual rainfall and high vertical recharge rate of 17,973 ML/year
  - Relatively low aquifer storage of 78,000 ML/year and a small horizontal through flow of 243 ML/year
  - Salinity issues are known to emerge when groundwater usage is below 7,000 ML/year
  - Taking into account the above factors, a PAV of 12,000 ML/year was recommended for the Denison GMA.
- As this GMA is a shallow aquifer and is driven by rainfall recharge it is likely to be vulnerable to the lower rainfall that has occurred over recent times and future climate change.
- This area was essentially declared to assist with management of salinity and excess recharge from irrigation. These issues may not as relevant as they once were, so a review of the need for the GMA would appear appropriate. For example:
  - Allocation and use have increased substantially over time, indicating that there is strong demand.
  - Ongoing reconfiguration of the irrigation system and modernization is likely to lead to reduced losses from the irrigation system, which in turn is likely to lead to less recharge to the shallow aquifer system. This may represent a fundamental change in the water balance for the area that warrants review.
  - The potential for groundwater take and use to affect rivers and streams should be taken into account.
- The Macalister Land and Water Management Plan highlighted that a GMA or WSPA may not be the best approach to managing these groundwater resources and indicated that conjunctive management of groundwater and surface water be considered.
- A review of the sustainable yield is warranted and is considered a moderate priority

3. Giffard GMA

The Giffard GMA is located within the Gippsland Basin and extends from the region east of Yarram to Loch Sport. The northern boundary of the GMA is the southern limit of the Baragwanath Anticline, and the coast forms the southern boundary of the GMA (see Appendix A).

The GMA covers the Boisdale Formation with the depth range of the GMA between 50 and 200 m. The GMA overlies the Yarram WSPA, which covers the deeper Balook and Latrobe Group aquifers.

3.1 Original PAV estimate method

The original PAV assessment for the Giffard GMA was conducted by SKM (1999a). The GMA was divided into two zones, where Zone 1 covers the area west of Dutson Downs, and Zone 2 covers the area east of Dutson Downs. This division of the GMA has not been formally acknowledged in the declaration. The Boisdale Formation in Zone 1 is isolated from the Boisdale Formation in the Latrobe Valley and has its own recharge area in the north. Whereas Zone 2 is connected to the Boisdale Formation in the Sale GMA and is recharged by throughflow from the Sale GMA.

The Boisdale aquifer is confined and groundwater flow direction is considered to be to the south-east, towards the coast. There are three State Observation Bores (104537, 105484, 104534) and the water level at bore 104534 at Woodside beach was recorded to be just above sea level, which was interpreted as the Boisdale aquifer being hydraulically connected with the sea.

Aquifer throughflow to Zone 1 was calculate using Darcy's Law with the following assumptions:

- Average hydraulic conductivity is 2.5 m/d,
- Hydraulic gradient of the potentiometric surface is the slope between the water level in the bore at Woodside (104537) and the bore at Woodside Beach (104534) which was calculated as 0.0005, and
- Cross sectional area of the aquifer in Zone 1 = 100 × 67,500 m^2

The PAV for Zone 1 calculates as follows:

Hydraulic conductivity × potentiometric gradient × cross sectional area = PAV

Where PAV = 3,080 ML/year = 3,000 ML/year

In Zone 2, the Boisdale Formation thins towards the east and also becomes shallower. The water quality also deteriorates to the east where the salinity is around 1,000 mg/L TDS, which suggests that the Boisdale Formation is hydraulically connected with the Gippsland Lakes.

Aquifer throughflow to Zone 2 was calculated using Darcy's Law using the below values:

- Average hydraulic conductivity is 2.5 m/d,
- Hydraulic gradient of the potentiometric surface is 0.0005, and
- Cross sectional area of the aquifer in Zone 1 = 75 × 20,000 m^2

The PAV for Zone 2 calculates as follows:

Hydraulic conductivity × potentiometric gradient × cross sectional area = PAV

Where PAV = 684 ML/year = 700 ML/year

The recommended PAV was 3,000 ML/year for the Giffard GMA.

Only the PAV for Zone 1 was used due to the recharge in Zone 2 being derived from throughflow from the Sale GMA, which is fully allocated. Therefore, it was determined no further allocation should be allowed for Zone 2. Additionally, it was noted that excessive pumping increases the risk of saline intrusion.

.

The PAV for Giffard GMA was increased to 5,665 ML/year in 2008 and subsequently amended to 5,670 ML/year in 2011 (DELWP pers. comm, 2019). In 2013, the PAV was increased further to 5,689 ML/year to match the licensed entitlements at the time.

3.2 Subsequent New or Local Studies

3.2.1 List of Studies and Reports

Reports	Purpose of study
SKM (2001) Giffard Groundwater Management Plan, Monitoring Bore Assessment.	SKM were engaged by Southern Rural Water to examine the monitoring needs of the Giffard Groundwater Management Area and determine whether the current monitoring network was sufficient.
Reid (2004) Audit of Permissible Annual Volumes for 35 Victorian Groundwater Management Areas. May 2004. Department of Primary Industries	Reid conducted an internal audit of 35 reports that estimated the Permissible Annual Volume (PAV) of groundwater that could be extracted from GMAs. Reid was commissioned by the former Department of Natural Resources and Environment (now DELWP).
RMCG (2008) Groundwater Economics. For Department of Sustainability and Environment (DSE) 29 August 2008	This study was completed for the Department of Sustainability and Environment (now DELWP) with the objective of developing an updated approach and revised analysis to improve the understanding of the economic value of groundwater to support future policy and management practices. The study quantified the overall economic value in terms of support irrigation, urban water supply, commerce and industry, stock and domestic and sleeper and unallocated entitlements.
GHD (2010a) West Gippsland CMA Groundwater Model. Interim steady-state model development report. Report prepared by GHD for the Department of Sustainability and Environment (DSE), Victoria.	The groundwater model was developed by GHD on behalf of DSE (now DELWP) as part of the ecoMarkets project. The intention of ecoMarkets projects were to using a groundwater model as a tool to assess the relative merits of improving native vegetation management and revegetation initiatives. The model's primary objective was to provide a tool for assessing the impacts of land use change on depth to water. Calibrated aquifer parameters are available for each of the formations in the model.
Beverly et al. (2015) The Gippsland groundwater Model, Onshore natural gas water science studies, DEDJTR.	The report describes the conceptualization, development, calibration and application of the Gippsland groundwater model. The model was designed to assess impacts to groundwater resources from potential coal seam gas development. Calibrated regional aquifer parameters are available for each formation in the Gippsland Basin.
DELWP (2017) Victorian Water Accounts 2016 – 2017.	The report presents annual information about the resources of the state of Victoria, reporting on volumes of surface water,

Reports	Purpose of study
	groundwater and recycled water systems used and water available during the year.
CDMSmith (2017) Groundwater Data Inventory, Stocktake and Enhancement options	CDMSmith was commissioned by DEWLP to collate available data relating to four themes of groundwater recharge, aquifer/aquitard properties, groundwater use and aquifer/aquitard thickness into a database. The quality of the data was assessed through a data stocktake process. Enhancement methods were also considered for each data theme. A total of 65 studies were collated and the information was summarized into a spatial database.
CDMSmith (2018) Data Mapping – Aquifer properties and Recharge	CDMSmith was commission by DELWP to create visual products of recharge and aquifer properties for Victoria. Two products were developed – a high level communication tool to quickly inform a range of audiences of the variability in historical estimates and a finer resolution product for technical specialists to assess in future assessments of groundwater management.
GHD (2018) Groundwater Condition Reporting – Stage 4, September.	GHD developed a method to determine the Groundwater Resource Condition Assessment for DELWP. They key components of the approach was to adopt a representative Suite for reporting on groundwater resource condition and predict groundwater level as a means to compare against observation to qualitatively assess groundwater resource condition.

3.2.2 Key findings relevant to sustainable yield

SKM (2001) Giffard Groundwater Management Plan, Monitoring Bore Assessment

SKM (2001) were engaged to determine appropriate groundwater monitoring objectives for the Giffard GMA. SKM identified several groundwater resource issues in the Giffard GMA, with respect to the impact of groundwater extraction on resource availability and quality, as well as possible saline intrusion. In order to increase the level of understanding of the hydrogeology and recharge mechanisms to the aquifer, two new bores were recommended to be installed - one bore to monitor the combined effect of cluster irrigation and one bore located between the coast and area of development to monitor sea water intrusion.

Additionally, bores were also recommended to be installed at the following locations:

- A bore located between the coast and the cluster of irrigation bores in the Woodside and Seaspray area, to monitor sea water intrusion and the combined effects of pumping.
- One bore in Golden Beach area to monitor the effects of the irrigation bore or any further development, and to provide monitoring data for the north-eastern end of the GMA.
- One bore in the Giffard area to monitor the combined effects from a cluster of irrigation bores.
- One bore located north of Woodside to monitor the effects the effects of irrigation bores near the western boundary of the GMA.

Reid (2004) Audit of Permissible Annual Volumes for 35 Victorian Groundwater Management Areas

Reid (2004) conducted an internal audit of reports that estimated the PAVs in the Gippsland region, highlighting some limitations associated with the PAV assessment. Reid's comments regarding the methods used to calculate the PAV are summarised below:

- Lack of geology and hydrogeological data on the GMA aquifer
- Inaccurate throughflow analysis due to lack of data and understanding of the groundwater trends, hydrostratigraphy and hydraulic interaction between the Boisdale Formation and overlying beds
- Lack of quantitative analysis for intrusion of sea or coastal wetlands
- Lack of consideration for stream recharge/discharge

RMCG (2008) Groundwater Economics

RMCG assessed the economic value of the Giffard GMA. The GMA was not considered to be a priority GMA in terms of value for irrigation, commercial/industrial or water supply. Groundwater is extracted predominantly for dairying, beef grazing and irrigation and the total value of groundwater use was estimated to be around $630,000.

GHD (2010a) West Gippsland CMA Groundwater Model - Interim steady-state model development report

GHDs 2010 groundwater model has been created for the West Gippsland CMA. The primary objective of the model is to provide a tool for assessing the impacts of land use change on depth to water. Calibrated model aquifer parameters for aquifers in the Gippsland region were listed for the Boisdale Formation. The hydraulic conductivity values determined using the calibrated model are provided in Table 7-1.

Table 3-1: Calibrated Hydraulic Conductivity Values

Model Layer	Hydrostratigraphic Unit	Kh (m/d)	Kv (m/d)
2	Boisdale Fm (Wurruk Sand)	12.38	3.60E-2

* Kh = horizontal hydraulic conductivity; Kv = vertical hydraulic conductivity.

Beverly et al., (2015) The Gippsland groundwater Model - Onshore natural gas water science studies

The Gippsland Groundwater Model was developed to assess the potential impact of coal seam gas development on groundwater resources.

Calibrated model aquifer parameters for aquifers in the Gippsland region were listed for the Boisdale Formation. A summary of the aquifer parameters used in the model are provided in Table 7-2. It is recognized that there is significant difference in the hydraulic conductivity values between the PAV determination and the models. The implications are that there is possibly more water available than originally estimated. This needs specific consideration in any review.

Table 3-2: Calibrated model aquifer parameterisation.

Zone	Aquifer	Kxy (m/d)	Kz (m/d)	Specific yeild	Specific storage (m^{-1})	Kzz/Kxy
5	Boisdale Formation	29.86	4.479	0.1	1 X 10^{-5}	0.150

DELWP (2017) Victorian Water Accounts 2016 – 2017

The Victorian Water Accounts report provides information on the usage and annual trends associated with water resources in the state of Victoria. To provide a consistent picture of water use across all GMA areas considered in this report we have reported the water usage figures from the most recent annual statement. Trends over two years do not necessarily represent the longer term trends, but are nevertheless considered instructive. Future assessment of the PCV should consider the full record of groundwater usage trends. The total licensed use volumes for the period of 2015 - 2017 are provided in the table below.

The groundwater level trends in the Giffard GMA were declining in June 2016 and have been stable between September 2016 and June 2017.The latest published licensed groundwater volumes and use for the Giffard GMA are described in Table 3-3.

Metered groundwater use has increased to 3,784 ML in 2017 – 2018 (Unpublished data, provided by DELWP).

Table 3-3: Licensed groundwater volumes and use.

GMA	GMA aquifer depth limits (m)	Licensed entitlement (ML/year)	Total licensed groundwater use (ML) 2016-17	Total licensed groundwater use (ML) 2015-16
Giffard GMA	50 – 200	5,689	1,856	2,312

GHD (2018) Groundwater Condition Reporting – Stage 4

GHD developed a range of aquifer classification codes, which were used to represent groundwater level responses. Details of suite description, classification and suite hydrograph development and representative suite hydrograph for resource condition reporting can be found in (GHD 2014; GHD 2017; GHD 2018). The suites are grouped based on the aquifer monitored (upper, middle, lower or basement), suite code which is an alphabetic naming convention and fluctuation code which is a numerical identifier that indicates bores with similar magnitude in seasonal fluctuations (GHD, 2018). The suites to be reported for a particular GMU were selected based on the following:

- Suite representativeness (the proportion of the suite that occurs within the GMU must be spatially significant)
- Relevance of the aquifer layer (the unit the GMU is intended to manage)
- Spatial coverage of groundwater monitoring bores across a Suite or GMU
- Spatial coverage of groundwater extraction bores across the GMU
- Conceptualization considerations (improving the understanding of recharge processes, inter aquifer connectivity or aquifer leakage)

GHD determined that the Giffard GMA is best represented by suite U_AG_1 which covers the upper aquifer. The area covered by the suite is shown in Figure 3-1Figure 5-1. The representative hydrograph for the aquifer classification is shown in

Figure 3-2. The hydrograph shows that groundwater levels in U_AG_1 have been declining since 2003 and continued to decline at a lesser rate between 2008 and 2017.

Figure 3-1: Location of suite U_AG_1 (GHD, 2018)

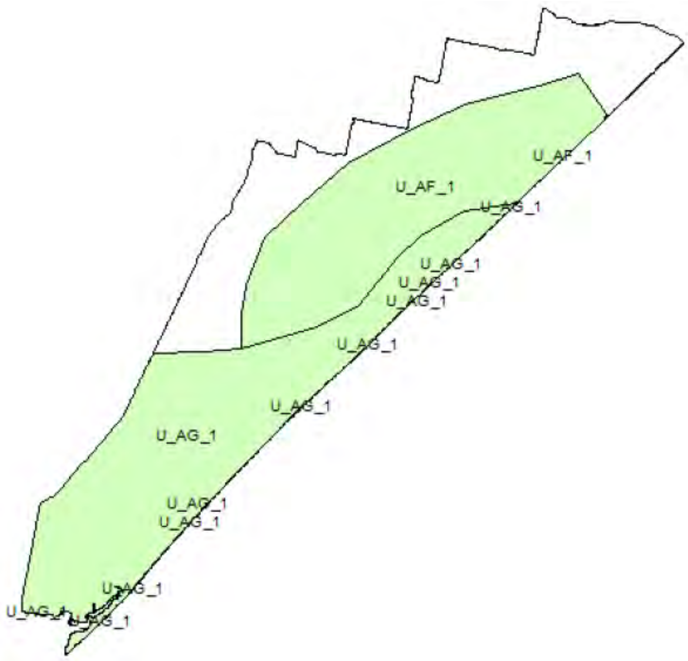
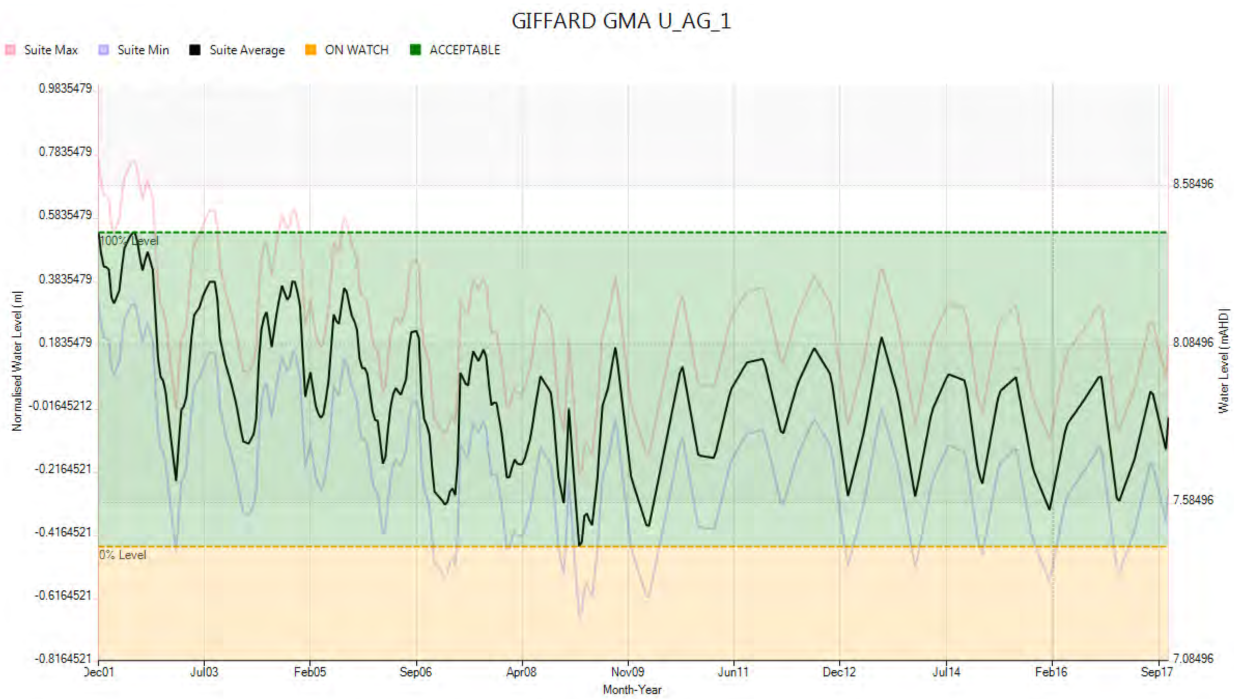


Figure 3-2: Giffard Suite Chart for U_AG_1



3.3 Relevant matters for consideration

- The PAV increased from 3,000 ML/year to 5,689 ML/year for the whole of Giffard GMA without technical reassessment being conducted.
- The current GMA is not divided into two zones and it is unknown whether further allocation was restricted in Zone 2 when the PAV was raised.
- Current licensed entitlement (approximately 3,700 ML/year) is less than the current PCV of 5,689 ML/year,but higher than the original throughflow recharge estimate of 3,000 ML/year.
- Consistent with trends in regional aquifers, groundwater levels have been declining until recently. Recent groundwater trends are flat to slightly rising, which suggests that a new equilibrium level has been reached.
- Relatively small resource and metered groundwater use is less than the current PCV of 5,689 ML.
- Key risks associated with declining groundwater levels causing saline intrusion and deteriorating groundwater quality.
- Groundwater use has been relatively low, but very recent indications are for a significant increase in use.
- There is little evidence of sustainability issues, but the recent increase in use warrants watching.
- At the current time, this GMA is considered a low priority for review.

4. Leongatha GMA

The location of the Leongatha GMA is shown in Appendix A. The Leongatha GMA incorporates the major part of the Woorayl Graben. The Woorayl Graben consists of a basin structure filled with a sequence of Cainozoic aged sand and clay and basaltic volcanics. The Cainozoic sequence has a maximum thickness of around 200 m.

The main aquifers in the Leongatha GMA are found in the fresh basalt in the Older Volcanics and in gravel and sand in the Childers Formation. A thin veneer of Quaternary alluvial deposits (Haunted Hills Formation) covers the volcanics in the southern part of the zone, whilst the volcanics outcrop in the northern part. The Older Volcanics outcrop extensively in the northern and central parts of the GMA and vary between being confined and unconfined.

The Childers Formation outcrops to a limited extent around the edges of the graben to the north of Leongatha. Elsewhere, the formation occurs at depths below the Older Volcanics, where it is generally confined. There is a degree of hydraulic connection between the Childers Formation and the Older Volcanics, so the two aquifers are managed as one aquifer system.

4.1 Original PAV estimate method

The original PAV assessment for the Leongatha GMA was conducted by SKM (1998b). The PAV of the area was determined using the following methods: aquifer throughflow, hydrograph fluctuation, and rainfall infiltration. River recharge was not estimated for this area, as discharge to the Tarwin River and the Powlett River is considered the dominant process. Considerations were also made with regard to volumes of discharge to streams, limited regional drawdown, and volume for well interference.

Using the aquifer throughflow method the recharge to the GMA was calculated to be 7,300 ML/year. Darcy's Law was used to estimate the aquifer throughflow, using the following parameters:

- Average hydraulic conductivity of 2 m/d
- Hydraulic gradient of 0.01
- Upstream cross-sectional area = 20,000 × 50 m^2

Two bores used for the hydrograph fluctuation method were Bores 75399 and 75403. The recharge estimate derived using the hydrograph fluctuation method was very small (67 ML/year). This was considered to be due to the fact that there is limited groundwater extraction occurring in the aquifer and limited drawdown. SKM (1998) concluded that the hydrographs in this area were not suitable to provide an estimate of the potential recharge to the system and are therefore not applicable from the point of view of estimating the PAV.

Recharge from rainfall was estimated by dividing the GMA into two zones and using the following assumptions:

- The area of each zone is assumed to be 95 km^2
- The annual rainfall volume in each zone is 968 mm/year
- Recharge rate for the Older Volcanics was estimated to be 7% of rainfall and the recharge rate for the Haunted Hills gravels was estimated to be 5% of rainfall

The volume of recharge to the Older Volcanics was found to be 6,437 ML/year, while the Haunter Hills gravels received 4,598 ML/year. The total volume of recharge via rainfall is 11,035 ML/year which was determined to be the PAV for the Leongatha GMA. The rainfall infiltration method was considered to be the most accurate due because it allows for recharge to the unconfined and the confined parts of the aquifer system to be taken into account.

Total aquifer storage, discharge to streams, limited regional drawdown and well interference were estimated and were not a limiting factor for the estimated PAV volume. The discharge to streams, in this case to the Tarwin River, was estimated as 3,500 ML/yr.

The PAV was amended to 6,500 ML/year in 2006, based recommendations by Reid (2004).

4.2 Subsequent New or Local Studies

4.2.1 List of Studies and Reports

Reports	Purpose of study
Reid (2004) Audit of Permissible Annual Volumes for 35 Victorian Groundwater Management Areas. May 2004. Department of Primary Industries	Reid conducted an internal audit of 35 reports that estimated the Permissible Annual Volume (PAV) of groundwater that could be extracted from GMAs. Reid was commissioned by the former Department of Natural Resources and Environment (now DELWP).
RMCG (2008) Groundwater Economics. For Department of Sustainability and Environment (DSE) 29 August 2008	This study was completed for the Department of Sustainability and Environment (now DELWP) with the objective of developing an updated approach and revised analysis to improve the understanding of the economic value of groundwater to support future policy and management practices. The study quantified the overall economic value in terms of support irrigation, urban water supply, commerce and industry, stock and domestic and sleeper and unallocated entitlements.
GHD (2010a) West Gippsland CMA Groundwater Model. Interim steady-state model development report. Report prepared by GHD for the Department of Sustainability and Environment (DSE), Victoria.	The groundwater model was developed by GHD on behalf of DSE (now DELWP) as part of the ecoMarkets project. The intention of ecoMarkets projects were to using a groundwater model as a tool to assess the relative merits of improving native vegetation management and revegetation initiatives. The model's primary objective was to provide a tool for assessing the impacts of land use change on depth to water. Calibrated aquifer parameters are available for each of the formations in the model.
Beverly et al. (2015) The Gippsland groundwater Model, Onshore natural gas water science studies, DEDJTR.	The report describes the conceptualization, development, calibration and application of the Gippsland groundwater model. The model was designed to assess impacts to groundwater resources from potential coal seam gas development. Calibrated regional aquifer parameters are available for each formation in the Gippsland Basin.
DELWP (2017) Victorian Water Accounts 2016 – 2017.	The report presents annual information about the resources of the state of Victoria, reporting on volumes of surface water, groundwater and recycled water systems used and water available during the year.

Reports	Purpose of study
CDMSmith (2017) Groundwater Data Inventory, Stocktake and Enhancement options	CDMSmith was commissioned by DEWLP to collate available data relating to four themes of groundwater recharge, aquifer/aquitard properties, groundwater use and aquifer/aquitard thickness into a database. The quality of the data was assessed through a data stocktake process. Enhancement methods were also considered for each data theme. A total of 65 studies were collated and the information was summarized into a spatial database.
CDMSmith (2018) Data Mapping – Aquifer properties and Recharge	CDMSmith was commission by DELWP to create visual products of recharge and aquifer properties for Victoria. Two products were developed – a high level communication tool to quickly inform a range of audiences of the variability in historical estimates and a finer resolution product for technical specialists to assess in future assessments of groundwater management.
GHD (2018) Groundwater Condition Reporting – Stage 4, September.	GHD developed a method to determine the Groundwater Resource Condition Assessment for DELWP. They key components of the approach was to adopt a representative Suite for reporting on groundwater resource condition and predict groundwater level as a means to compare against observation to qualitatively assess groundwater resource condition.

4.2.2 Key findings relevant to sustainable yield

Reid (2004) Audit of Permissible Annual Volumes for 35 Victorian Groundwater Management Areas

Reid (2004) conducted an internal audit of reports that estimated the PAVs in the Gippsland region, highlighting some limitations associated with the PAV assessment. Reid's comments regarding the methods used to calculate the PAV are summarised below:

- Rainfall recharge calculations were determined to be subjective with the recharge area delineation to be inadequate. Reid noted the GMA could extend to the northern faulted margin of the basin to include additional recharge from rainfall and rivers.
- Lack of geological and hydrogeological data and analysis, such as groundwater trends, quality and behaviour across the GMA
- Subjective and incomplete calculation of discharge to streams and lack of consideration for stream recharge
- Hydrograph fluctuation analysis was determined to be invalid due to the selected bores not monitoring unconfined conditions

Reid recommended that the PAV be reduced to 6,500 ML/year to account for discharge to rivers.

RMCG (2008) Groundwater Economics

RMCG assessed the economic value of the Leongatha GMA and determined that Leongatha GMA is a priority GMA for urban supply, with a value close to $3,000,000. The GMA also had $600,000 valued in unallocated entitlements.

GHD (2010a) West Gippsland CMA Groundwater Model - Interim steady-state model development report

GHDs 2010 groundwater model has been created for the West Gippsland CMA. The primary objective of the model is to provide a tool for assessing the impacts of land use change on depth to water. Calibrated model aquifer parameters for aquifers in the Gippsland region were listed for the aquifers covered by the Leongatha GMA.

The Haunted Hills gravels and Quaternary sediments were reported in model layer 1, the Older Volcanics aquifer was reported in model layer 1, and the Childers Formation was reported in model layer 5. The hydraulic conductivity values determined using the calibrated model are provided in Table 7-1.

Table 4-1: Calibrated Hydraulic Conductivity Values

Model Layer	Hydrostratigraphic Unit	Kh (m/d)	Kv (m/d)
1	Haunted Hills Formation and Quaternary Sediments	2.01	4.21 (0.002 around the LV mines)
4	Older (Thorpdale) Volcanics	0.51	0.69
5	Childers Fm	0.76	0.03

- * SD = Seaspray Depression; Kh = horizontal hydraulic conductivity; Kv = vertical hydraulic conductivity.

Beverly et al., (2015) The Gippsland groundwater Model - Onshore natural gas water science studies

The Gippsland Groundwater Model was developed to assess the potential impact of coal seam gas development on groundwater resources.

Calibrated model aquifer parameters for aquifers in the Gippsland region were listed for the aquifers in the Leongatha GMA. The Older Volcanics was reported as part of the Thorpdale Volcanics and the Childers Formation was reported as the Upper Latrobe Group. A summary of the aquifer parameters used in the model are provided in Table 7-2.

Table 4-2: Calibrated model aquifer parameterisation.

Zone	Aquifer	Kxy (m/d)	Kz (m/d)	Specific yeild	Specific storage (m^{-1})	Kzz/Kxy
2	Quaternary	6.507	9.761×10^{-1}	0.1	1×10^{-5}	0.150
36	Quaternary	1.501×10^{-1}	2.009×10^{-2}	0.07	1×10^{-5}	0.134
3	Haunted Hill Formation	3.203	4.804×10^{-1}	0.1	1×10^{-5}	0.150
17	Thorpdale Volcanics	6.522×10^{-1}	1.820×10^{-2}	0.1	1×10^{-5}	0.028
18	Upper Latrobe Group	2.350	3.524 X 10-1	0.1	1×10^{-5}	0.150

DELWP (2017) Victorian Water Accounts 2016 – 2017

The Victorian Water Accounts report provides information on the usage and annual trends associated with water resources in the state of Victoria. To provide a consistent picture of water use across all GMA areas considered in this report we have reported the water usage figures from the most recent annual statement. Trends over two years do not necessarily represent the longer term trends but are nevertheless considered instructive. Future assessment of the PCV should consider the full record of groundwater usage trends. The total licensed use volumes for the period of 2015 - 2017 are provided in the table below.

The groundwater level trends in the Leongatha GMA were reported as stable during the winter months and declining in the spring and autumn periods.

The latest published licensed groundwater volumes and use for the Leongatha GMA are described in Table 4-3.

Table 4-3: Licensed groundwater volumes and use

GMA	GMA aquifer depth limits (m)	Licensed entitlement (ML/year)	Total licensed groundwater use (ML) 2016-17	Total licensed groundwater use (ML) 2015-16
Leongatha GMA	All depths	1,803	115	206

GHD (2018) Groundwater Condition Reporting – Stage 4

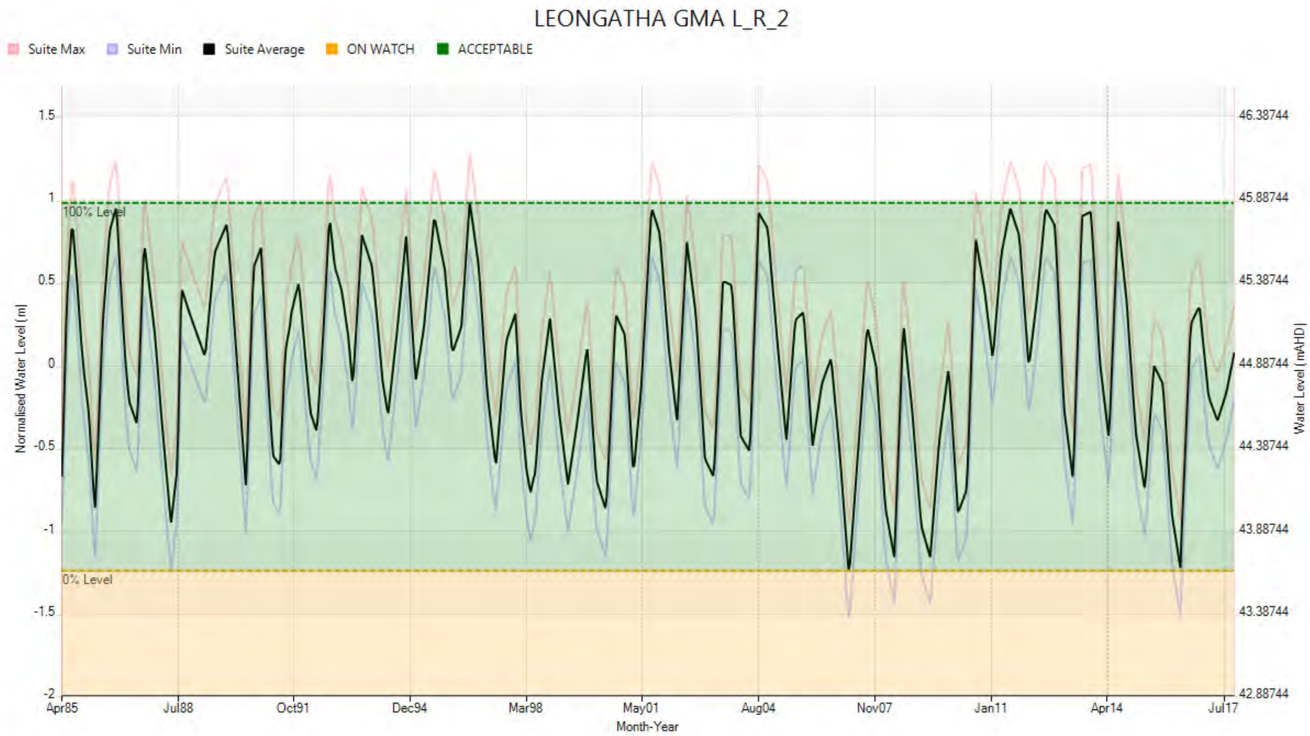
GHD developed a range of aquifer classification codes, which were used to represent groundwater level responses. Details of suite description, classification and suite hydrograph development and representative suite hydrograph for resource condition reporting can be found in (GHD 2014; GHD 2017; GHD 2018). The suites are grouped based on the aquifer monitored (upper, middle, lower or basement), suite code which is an alphabetic naming convention and fluctuation code which is a numerical identifier that indicates bores with similar magnitude in seasonal fluctuations (GHD, 2018). The suites to be reported for a particular GMU were selected based on the following:

- Suite representativeness (the proportion of the suite that occurs within the GMU must be spatially significant)
- Relevance of the aquifer layer (the unit the GMU is intended to manage)
- Spatial coverage of groundwater monitoring bores across a Suite or GMU
- Spatial coverage of groundwater extraction bores across the GMU
- Conceptualization considerations (improving the understanding of recharge processes, inter aquifer connectivity or aquifer leakage)

GHD determined that the Leongatha GMA is best represented by suite L_R_2 which covers the lower aquifer. The area covered by the suite is shown in Figure 5-1. The representative hydrograph for the aquifer classification is shown in. The hydrograph shows that groundwater levels in L_R_2 have been stable since 1985.

Figure 4-1: Location of suite L_R_2 (GHD, 2018)

Figure 4-2: Leongatha GMA Suite Chart for L_R_2



4.3 Relevant matters for consideration

- Original PAV was based on recharge from rainfall. Reid (2004) highlighted that while discharge to rivers was acknowledged by SKM (1998), it was not included in the PAV assessment. The PCV was reduced to 6,500 ML/year in 2006, to account for discharge to rivers.
- This GMA is vulnerable to changes in rainfall recharge and this parameter is not well described or quantified. The sustainable yield is therefore considered vulnerable to lower rainfall and climate change.
- In terms of groundwater use, Leongatha is a priority GMA for urban water supply however licensed allocations are well under the PCV.
- River discharge is in low areas in the landscape and may not be major constraint on take and use.
- Additional work could be undertaken to improve the recharge estimates including assesses additional recharge areas identified by Reid (2004), however given the groundwater use and trends, a review of the sustainable yield is considered to be a low priority.

5. Moe GMA

The Moe Groundwater Management Area covers the Moe Swamp Basin, located in the north western corner of the Gippsland Basin (see Appendix A). The topography declines from the peak of the alpine areas in the north, through to the lowland region near the Moe River and rises again at the Strzelecki Ranges in the south (Jacobs, 2014). To the east a narrow valley leads to the broader Gippsland Basin region.

Landuse in the area is native vegetation in the highland and agriculture in the valley, comprising predominantly dryland grazing/perennial pasture with some irrigation of pasture and crops to support the dairy industry (Jacobs, 2014).

The Moe Swamp Basin consists of Tertiary sediments and volcanics 200-300 m thick, of the Haunted Hill Gravels, Yarragon formation, Thorpdale Volcanics and Childers Formation resting on Pre- Tertiary basement (SKM, 1998).

5.1 Original PAV estimate method

The original Permissible Annual Volume (PAV) assessment for the Moe GMA was conducted by SKM (1998c). The principal of the PAV was 100% of annual recharge minus discharge to rivers.

Four methods were used to estimate the annual groundwater available including rainfall infiltration, annual hydrograph fluctuation, river recharge and aquifer throughflow. Of these, the rainfall and recharge to streams methods were used to calculate the PAV.

Recharge occurs via infiltration of rainfall. The original PAV assessment assumed there were two recharge areas (Areas 1 and 2) and different rainfall was assumed for each area. The annual rainfall for Area 1 was 729 mm/year and 939 mm/year for Area 2. The total recharge area for both areas was assumed to be 161 km^2, although the recharge areas were not shown in the figures in the report. The recharge rate was assumed to be 5%, which equated to 6,456 ML/year of recharge.

Recharge and discharge from rivers was also calculated. Recharge from rivers was assumed to occur from an 8 km reach of the Latrobe River and a 3 km reach of the Narracan Creek. Darcy's Law was used to calculate the volume of recharge using the following parameters:

- Hydraulic gradient of 0.04 for Latrobe River and 0.5 for Narracan Creek
- Conductivity of the river bed sediments was 2 m/d for La Trobe River and 1 m/d for Narracan Creek

The total recharge to rivers was estimated to be 2,263 ML/year.

Discharge to rivers was calculated using the same method for a 6 km reach of the Latrobe River. The following parameters were used:

- Hydraulic gradient of 0.04
- Conductivity of the river bed sediments of 1 m/day.

The total discharge to rivers was estimated to be 526 ML/day.

The overall PAV was calculated as follows:

Rainfall recharge + River recharge – River discharge = PAV

6,456 + 2,263 – 526 = 8,193 ML/year

A PAV value of 8,200 ML/year was recommended for the Moe GMA. There have been no changes to the PCV since the original technical assessment.

5.2 New or Local Studies Published after the PAV estimate

5.2.1 List of Studies and Reports

Reports	Purpose of study
Reid (2004) Audit of Permissible Annual Volumes for 35 Victorian Groundwater Management Areas. May 2004. Department of Primary Industries	Reid conducted an internal audit of 35 reports that estimated the Permissible Annual Volume (PAV) of groundwater that could be extracted from GMAs. Reid was commissioned by the former Department of Natural Resources and Environment (now DELWP).
EarthTech (2007) Assessment of Environmental Flow Requirements for the Latrobe River Revision D.6 March 2007	Described environmental flow objectives for different reaches of the Latrobe River, of which two are relevant to the Moe Groundwater Catchment – Upper Latrobe River and Willow Grove to Lake Narracan.
RMCG (2008) Groundwater Economics. For Department of Sustainability and Environment (DSE) 29 August 2008	This study was completed for the Department of Sustainability and Environment (now DELWP) with the objective of developing an updated approach and revised analysis to improve the understanding of the economic value of groundwater to support future policy and management practices. The study quantified the overall economic value in terms of support for irrigation, urban water supply, commerce and industry, stock and domestic and sleeper and unallocated entitlements.
GHD (2010a) West Gippsland CMA Groundwater Model. Interim steady-state model development report. Report prepared by GHD for the Department of Sustainability and Environment (DSE), Victoria.	The groundwater model was developed by GHD on behalf of DSE (now DELWP) as part of the ecoMarkets project. The intention of ecoMarkets projects were to use a groundwater model as a tool to assess the relative merits of improving native vegetation management and revegetation initiatives. The model's primary objective was to provide a tool for assessing the impacts of land use change on depth to water. Calibrated aquifer parameters are available for each of the formations in the model.
SKM (2012) Baseflow Separation Analysis for Unregulated Rivers (1889 to 2012)	The study completed a baseflow separation analysis for 180 stream gauges on unregulated rivers in Victoria Reference. Originally published on-line through the WMIS database, the dataset is now available through data.vic. The report is cited in Jacobs (2014). A copy of the original report is unavailable.

Reports	Purpose of study
Hofmann, H. and Cartwright, I. (2013) Using hydrogeochemistry to understand inter-aquifer mixing in the on-shore part of the Gippsland Basin, southeast Australia, Applied Geochemistry, 33, 84-103	Reference cited in Jacobs (2014) for aquifer parameters for Haunted Hills and Thorpdale Volcanics.
GHD (2013) Groundwater assessment – Baseflow dependent rivers, characterising groundwater contribution to baseflow, November 2013	Baseflow Index (BFI) estimates for the lower reaches of the Latrobe River were calculated using a numerical baseflow filter (Eckhart, 2005) that was calibrated against electrical conductivity (EC) data. Reference cited in Jacobs (2014).
Jacobs (2014) Moe Groundwater Catchment Resource Appraisal. For the Department of Environment and Primary Industries (Victoria). June 2014	Jacobs was engaged by the former Department of Environment and Primary Industries (now DELWP) to complete a resource appraisal for the Moe Groundwater Catchment using an approach outlined in DEPI (2013) Draft Water Sharing Guidance Document. The intent for the resource appraisal was to use a logical, transparent and repeatable process that focuses on optimizing groundwater values and minimizing impacts.
DELWP (2017) Victorian Water Accounts 2016 – 2017.	The report presents annual information about the resources of the state of Victoria, reporting on volumes of surface water, groundwater and recycled water systems used and water available during the year.
CDMSmith (2017) Groundwater Data Inventory, Stocktake and Enhancement options	CDMSmith was commissioned by DEWLP to collate available data relating to four themes of groundwater recharge, aquifer/aquitard properties, groundwater use and aquifer/aquitard thickness into a database. The quality of the data was assessed through a data stocktake process. Enhancement methods were also considered for each data theme. A total of 65 studies were collated and the information was summarized into a spatial database.
CDMSmith (2018) Data Mapping – Aquifer properties and Recharge	CDMSmith was commission by DELWP to create visual products of recharge and aquifer properties for Victoria. Two products were developed – a high level communication tool to quickly inform a range of audiences of the variability in historical estimates and a finer resolution product for technical

Reports	Purpose of study
	specialists to assess in future assessments of groundwater management.
GHD (2018) Groundwater Condition Reporting – Stage 4, September.	GHD developed a method to determine the Groundwater Resource Condition Assessment for DELWP. They key components of the approach was to adopt: • a representative Suite for reporting on groundwater resource condition and • predicted groundwater level as a means to compare against observation to qualitatively assess groundwater resource condition.

5.2.2 Key Findings relevant to sustainable yield

Reid (2004) Audit of Permissible Annual Volumes for 35 Victorian Groundwater Management Areas

Reid (2004) completed a critical review of the PAV assessment and highlighted some limitations associated with the PAV assessment. An overview of Reid's comments specific to the methods used to calculate the PAV are summarized below:

- GMA boundary excludes possible recharge areas
- Lack of references provided to justify rainfall recharge rate of 5% of rainfall
- Lack of justification of areas used to calculate the recharge rates (Area 1 and 2)
- Stream recharge and discharge estimates could have included recharge from a number of other rivers.
- Lack of transparency around the assumptions used to calculate the stream recharge and discharge (eg hydraulic gradients, hydraulic conductivity, length of river reach).

EarthTech (2007) Assessment of Environmental Flow Requirements for the Latrobe River Revision D.6

This study was cited in Jacobs (2014) and described the environmental flow objectives and recommendations for different reaches of the Latrobe River, of which two were relevant to the Moe region:

- Reach 1 – Upper Latrobe River (upstream of Willow Grove)
- Reach 2 – Willow Grove to Lake Narracan.

The flow recommendations in the Latrobe River defined by EarthTech (2007), were summarized in Jacobs (2014) and are outlined in Table 5-1.

Table 5-1: Environmental flow recommendations in the Latrobe River, documents in Jacobs (2014) and determined by Earth Tech (2007)

River Reach	Flow Magnitude	Duration
1. Upper Latrobe	Low flow	Continuous December to May
	Low flow freshes*	3 days
	High flow	Continuous June to November

River Reach	Flow Magnitude	Duration
	High flow freshes	2 days
	Overbank flow	2 days
2. Willow Grove to Lake Narracan	Low flow	Continuous December to May
	Low flow freshes	11 days
	High flow	Continuous June to November
	High flow freshes	<4 days
	Overbank flow	2 days

* Freshes are short-duration flow events that submerge the lower parts of the river channel. They are important for plants that grow on the banks and provide opportunities for fish and other animals to move more easily along the river.

RMCG (2008) Groundwater Economics. For Department of Sustainability and Environment (DSE)

RMCG assessed the economic value of the Moe GMA and determined that Moe GMA was not classified as high value in terms of irrigation, urban water supply, commerce/industry or power generation. The GMA was classified a high value in terms of unallocated entitlement, which was valued at $500,000 at the time of the study.

SKM (2012) Baseflow Separation Analysis for Unregulated Rivers (1889 to 2012)

Cited in Jacobs (2014), the study completed a baseflow separation analysis for 180 stream gauges on unregulated rivers in Victoria. This included 178 gauges assessed in previous DEPI and MDBA assessment. The baseflow separation analysis was undertaken on historical river flow records up to 2012 and utilized a filter parameter of 0.98.

estimated Baseflow Index (BFI) using the more traditional Lyne and Hollick (1972) numerical baseflow filter and determined the following BFIs for reaches of the Latrobe River:

- Latrobe River at Willow Grove 0.80
- Latrobe River at Hawthorn 0.78
- Lock River and Tooronga River 0.79
- Tanjil River and tributaries has BFIs ranging between 0.72 and 0.75, indicating slightly lower groundwater contribution to the Tanjil River compared to the Latrobe River.

Gauging stations for these rivers are limited in the lower catchment where Quaternary units dominate, so baseflow indices for these sections were not calculated by SKM (2012).

GHD (2013) Groundwater assessment – Baseflow dependent rivers, characterising groundwater contribution to baseflow

Cited in Jacobs (2014), the Baseflow Index (BFI) estimates from GHD (2013) ranged between 0.08 and 0.24 for the lower sections of the Latrobe River (between Thomms Bridge and Rosedale).

Jacobs (2014) Moe Groundwater Catchment Resource Appraisal. For the Department of Environment and Primary Industries (Victoria).

Jacobs (2014) applied the risk assessment framework outlined in the Resource Sharing Guidance to identify values and risks of groundwater development to the identified values. The following environmental features were identified:

- Key waterways include Latrobe River, Narracan Creek, Moe River/Drain, downstream Lake Narrcan.

- Aquifers including all major aquifers as well as, Shady Creek aquifer region, alluvial aquifer in Moe, Thorpdale near Cloverlea, all aquifers near urban area, coal seam gas and geothermal
- Wetlands
- Springs
- Terrestrial vegetation (Alpine bogs)

In discussion with key stakeholders, the highest priority features were identified to be the flow regime in the Latrobe River and the major aquifers in the basin, specifically the current and future consumptive groundwater use (all potential uses).

Jacobs (2014) also considered the risks of groundwater extraction to the Latrobe River. The consequence of different groundwater development options was classified according to the DEPI Resource Sharing Guidance (draft v3) as insignificant. Likelihood of impact to the Latrobe River was classified as low or rare (depending on the timing of the impact), which gave an overall risk ranking of low.

For the aquifer, the consequence was defined as insignificant based on the average groundwater use in shallow basins. The likelihood was also defined as rare and unlikely so the overall risk was low.

Impact of drawdown on existing infrastructure and springs were not included in the assessment.

The resource appraisal concluded that there is low or very low risk of adverse consequence to the catchment values that would result from the allocation and use of groundwater as described in the development scenarios.

DELWP (2017) Victorian Water Accounts 2016 – 2017

The Victorian Water Accounts report provides information on the usage and annual trends associated with water resources in the state of Victoria. To provide a consistent picture of water use across all GMA areas considered in this report we have reported the water usage figures from the most recent annual statement. Trends over two years do not necessarily represent the longer term trends, but are nevertheless considered instructive. Future assessment of the PCV should consider the full record of groundwater usage trends. The total licensed use volumes for the period of 2015 - 2017 are provided in the table below.

Groundwater level trends in the Moe GMA were reported as declining for the period of June 2016 and June 2017.The latest published licensed groundwater volumes and use for the Moe GMA are described in Table 5-2.

Table 5-2: Licensed groundwater volumes and use.

GMA	GMA aquifer depth limits (m)	Licensed entitlement (ML/year)	Total licensed groundwater use (ML) 2016-17	Total licensed groundwater use (ML) 2015-16
Moe GMA	>25 m	3,856	903	1,211

GHD (2018) Groundwater Condition Reporting – Stage 4

GHD developed a range of aquifer classification codes, which were used to represent groundwater level responses (GHD 2014; GHD 2017; GHD 2018). The suites are grouped based on the aquifer monitored (upper, middle, lower or basement), suite code which is an alphabetic naming convention and fluctuation code which is a numerical identifier that indicates bores with similar magnitude in seasonal fluctuations (GHD, 2018). The suites to be reported for a particular GMU were selected based on the following:

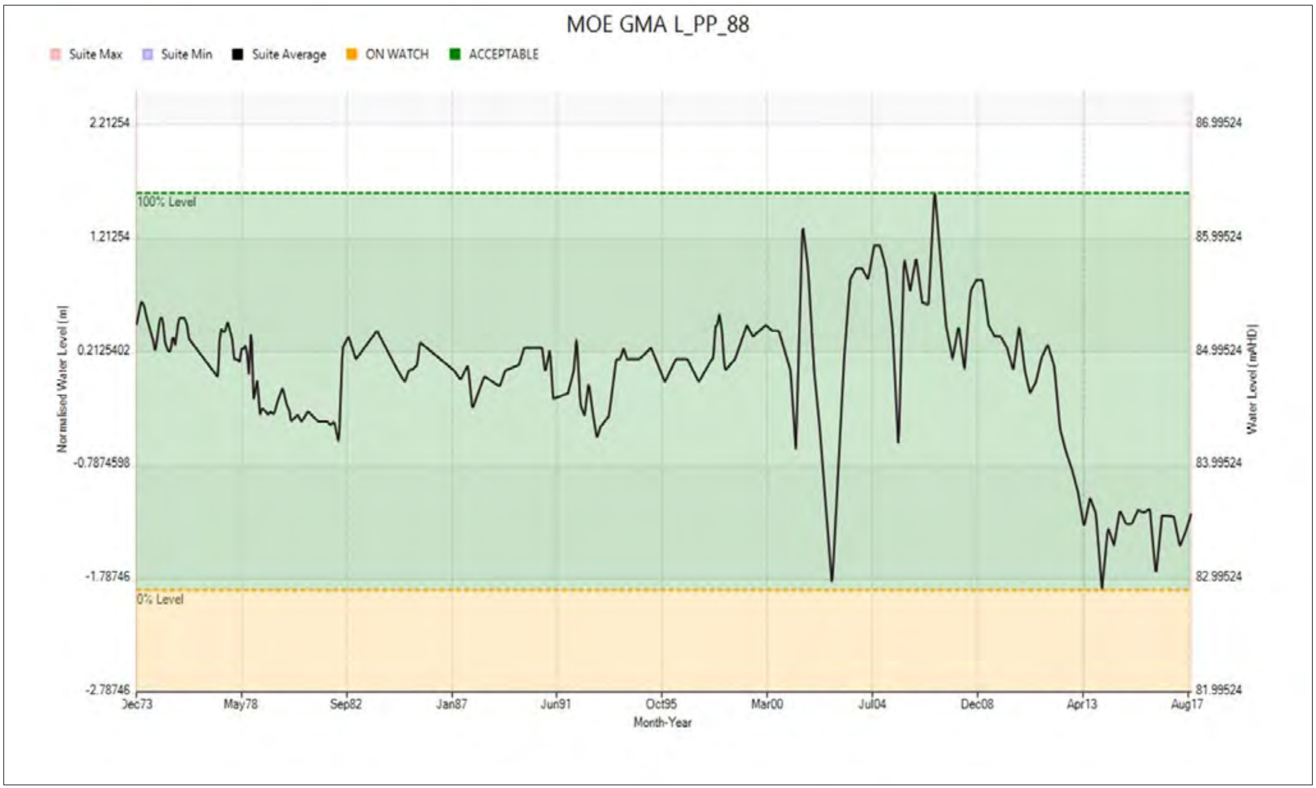
- Suite representativeness (the proportion of the suite that occurs within the GMU must be spatially significant)
- Relevance of the aquifer layer (the unit the GMU is intended to manage)

- Spatial coverage of groundwater monitoring bores across a Suite or GMU
- Spatial coverage of groundwater extraction bores across the GMU
- Conceptualization considerations (improving the understanding of recharge processes, inter aquifer connectivity or aquifer leakage)

GHD determined that the Moe GMA is best represented by suite L_PP_88 which covers the lower aquifer. The area covered by the suite is shown in Figure 5-1. The representative hydrograph for the aquifer classification is shown in Figure 5-2. The hydrograph shows that groundwater levels in L_PP_88 have been declining since 2005.

Figure 5-1: Location of suite L_PP_88 (GHD, 2018)

Figure 5-2: Moe Suite Chart for L_PP_88



5.3 Relevant matters for consideration

- Original PAV based on recharge from rainfall and rivers and had a low level of certainty. There appears not have been any substantive investigation or analysis of these parameters that would significantly lower this uncertainty. As Moe GMA is essentially a rainfall fed system uncertainty in recharge will provide considerable uncertainty in the available volume for allocation.
- Reid questioned the use of 5% rainfall (among other minor concerns). No alternate figure was offered, and this matter remains unresolved.
- Jacobs (2014) estimated recharge using 5% of rainfall and an alternate approach using Ensym. The Ensym approach was found to significantly over estimate recharge compared with other estimates.
- Moe GMA is not considered to be a high value groundwater resource, because of the uses and level of use. Unclear if this may change over time.
- GMA is not fully allocated, yet declining groundwater levels indicate that the recent low rainfall period has had a significant effect on the resource.
- There is large uncertainty about the recharge and inflows to the aquifer system which in turn must lead to large uncertainty about the PCV.
- Analysis of recharge, ideally using natural tracers, such as chloride or tritium, would be needed to resolve the recharge rates
- There is essentially no additional information on baseflow discharge. It is likely that low flow events in the rivers are supported by groundwater. This is modified by the contribution of storages (Blue Rock) to flow in the lower sections.

- Whilst allocation is a large percentage of the PCV, the security of this is unclear. A review of the sustainable yield is warranted and is considered a medium priority

6. Orbost GMA

The boundaries of the Orbost GMA are set within the physical limits of the Curlip Gravel aquifer and the location of the GMA is shown in Appendix A. The boundary is roughly defined by the extent of the Snowy River flood plain and the groundwater quality. Good quality groundwater exists in the Curlip Gravel aquifer west of the Princess Highway Bridge and to the east, the groundwater quality deteriorates. The Curlip Gravel is a series of Quaternary sediments consisting of coarse-grained fossiliferous gravels.

6.1 Original PAV estimate method

The original PAV assessment for the Orbost GMA was conducted by SKM (2000a). The PAV was determined using aquifer throughflow minus volume of water required to protect groundwater quality.

The GMA has two aquifers present, the Curlip Gravel aquifer, estimated to be between 20 – 45 m thick, and the Jarrahmond Formation that has little potential for water supply. Therefore, only the Curlip Gravel aquifer was considered when determining the PAV for the area.

The Curlip Gravel aquifer is assumed to be confined or semi-confined, therefore the throughflow method was used in recharge calculations. The recharge in the aquifer is assumed to be via inter formational leakage near the beginning of the flood plain.

The following assumptions were made when calculating the annual recharge volume:

- Average hydraulic conductivity is 100 m/d
- A down valley hydraulic gradient of 0.002
- Cross sectional area of the aquifer is 2.5×10^4 m^2

The throughflow recharge for the zone calculates as follows:

Hydraulic conductivity × potentiometric gradient × cross sectional area = throughflow volume

Where throughflow volume = 1,820 ML/year with an estimated uncertainty of $\pm$ 560 ML.

The risks to the aquifer from changes in salinity were also considered. The increment in salinity of the groundwater in the Curlip Gravel aquifer from west to east of the bridge by around 2,000 mg/L, was suggested by SKM to be a result of around 10% of the water in the aquifer being derived from the sea water. The volume required to protect the groundwater quality was calculated as 620 ML.

The overall calculations for PAV are as follows:

Throughflow volume – Volume to protect groundwater quality = PAV

1,820 ML/year – 620 ML = 1,200 ML/year

A PAV value of 1,200 ML/year was recommended for the Orbost GMA. PCV changed to 1,217 ML/year with the PCV Order 2011.

6.2 Subsequent New or Local Studies

6.2.1 List of Studies and Reports

Reports	Purpose of study
Reid (2004) Audit of Permissible Annual Volumes for 35 Victorian Groundwater Management Areas. May 2004. Department of Primary Industries	Reid conducted an internal audit of 35 reports that estimated the Permissible Annual Volume (PAV) of groundwater that could be extracted from GMAs. Reid was commissioned by the former Department of Natural Resources and Environment (now DELWP).
RMCG (2008) Groundwater Economics. For Department of Sustainability and Environment (DSE) 29 August 2008	This study was completed for the Department of Sustainability and Environment (now DELWP) with the objective of developing an updated approach and revised analysis to improve the understanding of the economic value of groundwater to support future policy and management practices. The study quantified the overall economic value in terms of support irrigation, urban water supply, commerce and industry, stock and domestic and sleeper and unallocated entitlements.
GHD (2010b) East Gippsland CMA Groundwater Model. Interim steady-state model development report. Report prepared by GHD for the Department of Sustainability and Environment (DSE), Victoria.	The groundwater model was developed by GHD on behalf of DSE (now DELWP) as part of the ecoMarkets project. The intention of ecoMarkets projects were to use a groundwater model as a tool to assess the relative merits of improving native vegetation management and revegetation initiatives. The model's primary objective was to provide a tool for assessing the impacts of land use change on depth to water. Calibrated aquifer parameters are available for each of the formations in the model.
Beverly et al. (2015) The Gippsland groundwater Model, Onshore natural gas water science studies, DEDJTR.	The report describes the conceptualization, development, calibration and application of the Gippsland groundwater model. The model was designed to assess impacts to groundwater resources from potential coal seam gas development. Calibrated regional aquifer parameters are available for each formation in the Gippsland Basin.
DELWP (2017) Victorian Water Accounts 2016 – 2017.	The report presents annual information about the resources of the state of Victoria, reporting on volumes of surface water, groundwater and recycled water systems used and water available during the year.
CDMSmith (2017) Groundwater Data Inventory, Stocktake and Enhancement options	CDMSmith was commissioned by DEWLP to collate available data relating to four themes of groundwater recharge, aquifer/aquitard properties, groundwater use and aquifer/aquitard thickness into a database. The quality of the data was assessed through a data stocktake process.

Reports	Purpose of study
	Enhancement methods were also considered for each data theme. A total of 65 studies were collated and the information was summarized into a spatial database.
CDMSmith (2018) Data Mapping – Aquifer properties and Recharge	CDMSmith was commission by DELWP to create visual products of recharge and aquifer properties for Victoria. Two products were developed – a high level communication tool to quickly inform a range of audiences of the variability in historical estimates and a finer resolution product for technical specialists to assess in future assessments of groundwater management.
GHD (2018) Groundwater Condition Reporting – Stage 4, September.	GHD developed a method to determine the Groundwater Resource Condition Assessment for DELWP. They key components of the approach was to adopt a representative Suite for reporting on groundwater resource condition and predict groundwater level as a means to compare against observation to qualitatively assess groundwater resource condition.

6.2.2 Key findings relevant to sustainable yield

Reid (2004) Audit of Permissible Annual Volumes for 35 Victorian Groundwater Management Areas

Reid (2004) conducted an internal audit of reports that estimated the PAVs in the Gippsland region, highlighting some limitations associated with the PAV assessment. Reid's comments regarding the methods used to calculate the PAV are summarised below:

- Lack of geological and hydrogeological data, and the disregard of the Jarrahmond Formation aquifer and the hydraulic interaction of the two aquifers
- Lack of consideration for the recharge/discharge processes and distribution
- Inaccurate throughflow analysis and allowance for seawater intrusion, and lack of consideration for the aquifer storage
- Insufficient assessment of the nature and severity of the water quality risks

RMCG (2008) Groundwater Economics

RMCG assessed the economic value of the Orbost GMA and determined that Orbost GMA was not classified as high value in terms of irrigation, urban water supply, commerce/industry or power generation. The total licensed use of groundwater was valued at $99,000, which was mainly allocated to irrigation.

GHD (2010b) East Gippsland CMA Groundwater Model - Interim steady-state model development report

GHDs 2010 groundwater model has been created for the East Gippsland CMA. The primary objective of the model is to provide a tool for assessing the impacts of land use change on depth to water. Calibrated model aquifer parameters for aquifers in the Gippsland region were listed for the Curlip Gravels aquifer.

The Orbost GMA was covered in conceptual layers 1 and 2, which contains the Quaternary sediments and Curlip Gravels, respectively. The hydraulic conductivity, storativity and specific yield values were determined using the calibrated model are provided in Table 7-1.

Table 6-1: Calibrated Hydraulic Conductivity Values

Conceptual Layer	Zone	Dominant Unit	Kh (m/d)	Kv (m/d)	Storativity (confined)	Sy
1	(1) west of Orbost	Quaternary/ Upper Tert Sediments	0.1	0.005	0.02	0.08
2	(8) Orbost	Curlip Gravels	10	0.1	0.005	0.04

* Kh = horizontal hydraulic conductivity; Kv = vertical hydraulic conductivity.

Beverly et al., (2015) The Gippsland groundwater Model - Onshore natural gas water science studies

The Gippsland Groundwater Model was developed to assess the potential impact of coal seam gas development on groundwater resources.

Calibrated model aquifer parameters for aquifers in the Gippsland region were listed for the Orbost GMA. The Jarrahmond Formation and Curlip Gravels were reported as part of the Haunted Hill Formation and Zone 36 Quaternary deposits. A summary of the aquifer parameters used in the model are provided in Table 7-2.

Table 6-2: Calibrated model aquifer parameterisation.

Zone	Aquifer	Kxy (m/d)	Kz (m/d)	Specific yeild	Specific storage (m^{-1})	Kzz/Kxy
3	Haunted Hill Formation	3.203	4.804×10^{-1}	0.1	1×10^{-5}	0.150
36	Quaternary	1.501×10^{-1}	2.009×10^{-2}	0.07	1×10^{-5}	0.134

DELWP (2017) Victorian Water Accounts 2016 – 2017

The Victorian Water Accounts report provides information on the usage and annual trends associated with water resources in the state of Victoria. To provide a consistent picture of water use across all GMA areas considered in this report we have reported the water usage figures from the most recent annual statement. Trends over two years do not necessarily represent the longer term trends, but are nevertheless considered instructive. Future assessment of the PCV should consider the full record of groundwater usage trends. The total licensed use volumes for the period of 2015 - 2017 are provided in the table below.

The groundwater level trends in the Orbost GMA were reported as stable during the winter months and declining in the spring and autumn periods.

The latest published licensed groundwater volumes and use for the Orbost GMA are described in Table 6-3.

Table 6-3: Licensed groundwater volumes and use.

GMA	GMA aquifer depth limits (m)	Licensed entitlement (ML/year)	Total licensed groundwater use (ML) 2016-17	Total licensed groundwater use (ML) 2015-16
Orbost GMA	20 – 45	1,217	104	154

GHD (2018) Groundwater Condition Reporting – Stage 4

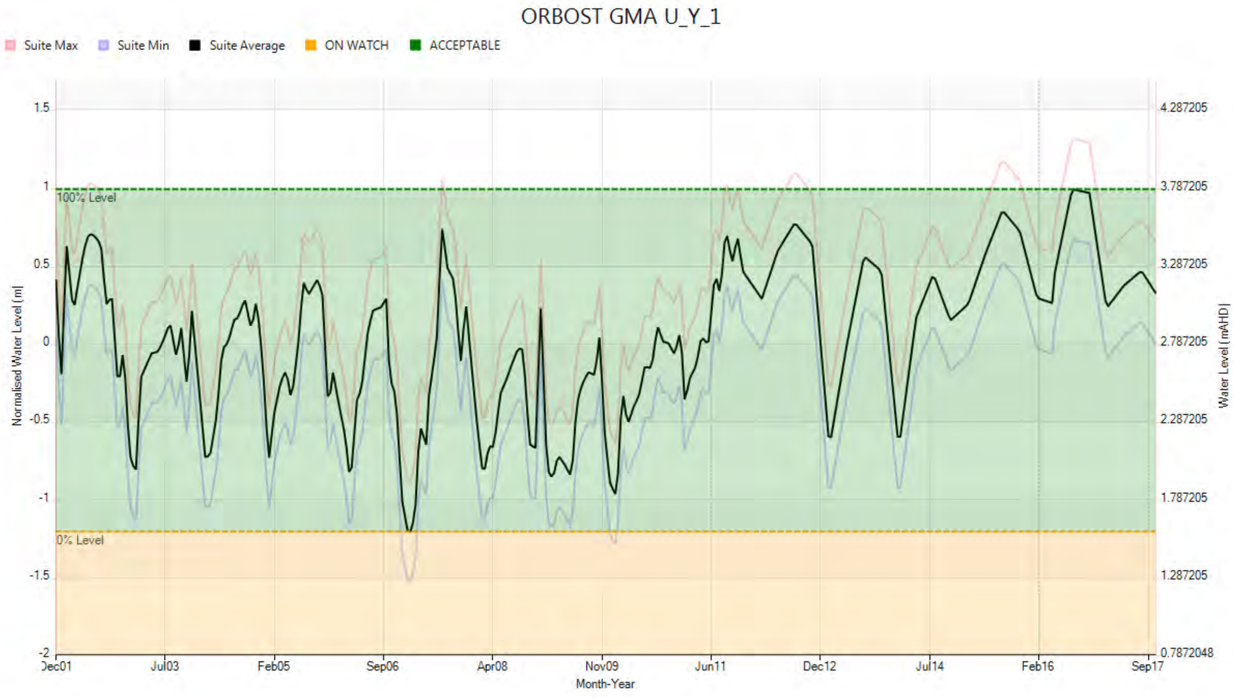
GHD developed a range of aquifer classification codes, which were used to represent groundwater level responses. Details of suite description, classification and suite hydrograph development and representative suite hydrograph for resource condition reporting can be found in (GHD 2014; GHD 2017; GHD 2018). The suites are grouped based on the aquifer monitored (upper, middle, lower or basement), suite code which is an alphabetic naming convention and fluctuation code which is a numerical identifier that indicates bores with similar magnitude in seasonal fluctuations (GHD, 2018). The suites to be reported for a particular GMU were selected based on the following:

- Suite representativeness (the proportion of the suite that occurs within the GMU must be spatially significant)
- Relevance of the aquifer layer (the unit the GMU is intended to manage)
- Spatial coverage of groundwater monitoring bores across a Suite or GMU
- Spatial coverage of groundwater extraction bores across the GMU
- Conceptualization considerations (improving the understanding of recharge processes, inter aquifer connectivity or aquifer leakage)

GHD determined that the Orbost GMA is best represented by suite U_Y_1 which covers the upper aquifer. The area covered by the suite is shown in Figure 6-1. The representative hydrograph for the aquifer classification is shown in Figure 6-2. The hydrograph shows that groundwater levels in U_Y_1 have been rising since 2009.

Figure 6-1: Location of suite U_Y_1 (GHD, 2018)

Figure 6-2: Orbost GMA Suite Chart for U_Y_1



6.3 Relevant matters for consideration

- Relatively small resource and licensed entitlements are similar to the PCV
- Key risks associated with declining groundwater levels and deteriorating groundwater quality.
- Given rising groundwater trends and low rates of groundwater use, a review of the sustainable yield is considered to have a low priority for further assessment at this time.

7. Rosedale GMA

The Rosedale GMA is located in central Gippsland and lies beneath the Denison, Sale and Wa De Lock GMA (see Appendix A).

7.1 Original PAV estimate method

The original PAV assessment for the Rosedale GMA was conducted by SKM (1999b). The GMA was divided into two zones, and a PAV volume for each zone was calculated using the through flow method. The Rosedale GMA is separated by the Baragwanath Anticline into a zone to the north of the anticline (Zone 1) and a zone to the south of the Anticline (Zone 2).

The PAV for Zone 1 was calculated using data collected for the open cut mines in the area, which provides reasonable amount of information for the Latrobe Group Aquifer, however limited data existed for the Balook Formation. The aquifers are confined and the recharge area in Zone 1 was considered to be west of the Latrobe Valley and around the northern margin of the Gippsland basin.

Aquifer throughflow to the Latrobe Group and Balook aquifers was calculated using Darcy's Law across two cross-sectional areas (locations not provided) with the following estimates:

- Average hydraulic conductivity is 1.5 m/d
- Hydraulic gradient of 0.001 (assumed to be similar to underlying Latrobe Group)
- Cross sectional area 1 = 1.25×10^6 m^2; Cross-sectional area 2 = 1.50×10^7 m^2

The PAV for Zone 1 was calculated as follows:

Recharge of cross-sectional area 1 + Recharge of cross-sectional area 2 = PAV

684 + 8,212 = 8,897 ML/year = 9,000 ML/year

Similar to Zone 1, Zone 2 is a confined aquifer and the throughflow method was used to estimate the PAV. In the Yarram area, the Latrobe Group is considered to be recharged from rainfall infiltration around the western margin of the Gippsland Basin, which flows towards the east into the Balook Formation. The following assumptions were made:

- Average hydraulic conductivity is 2.0 m/d
- Hydraulic gradient of 0.001 (assuming it is same as Zone 1)
- Cross sectional area 1 = 6.0×10^6 m^2; Cross-sectional area 2 = 7.5×10^5 m^2

The overall PAV calculates as follows:

Recharge of cross-sectional area 1 + Recharge of cross-sectional area 2 = PAV

4,380 + 548 = 4,928 ML/year = 5,000 ML/year

The figures representing where the cross-sections for each of the zones are located are not included in available copy of SKM (1999b). The available copy of SKM (1999b) is incomplete and figures and conclusions are not provided.

The recommended PAV was 9,000 ML/year, and the rationale for adopting the recharge from Zone 1 only, was not provided.

The PAV for Rosedale GMA was increased to 22,313 ML/year in 2007 (DELWP, 2017). Victorian Water Account (VWA) commenced publication in 2004. VWA reported Rosedale PCV as 9,000 ML/year PCV until 2006. The licensed entitlement fluctuated between 13,000 and 21,000 ML/ year during that period. The PCV was amended in 2006 by defining 3 zones and collective PCV of 22,313ML/year. This was most likely done to align the PCV to the entitlement volumes existing at that time and not based on technical assessment. Subsequently further amendment was undertaken in 2013 to amend the PCV to 22,372 ML/year.

7.2 Subsequent New or Local Studies

7.2.1 List of Studies and Reports

Reports	Purpose of study
SKM (2001a) Rosedale Groundwater Management Plan, Monitoring Bore Assessment.	SKM were engaged by Southern Rural Water to examine the monitoring needs of the Rosedale Groundwater Management Area and determine whether the current monitoring network is sufficient.
RMCG (2008) Groundwater Economics. For Department of Sustainability and Environment (DSE) 29 August 2008	This study was completed for the Department of Sustainability and Environment (now DELWP) with the objective of developing an updated approach and revised analysis to improve the understanding of the economic value of groundwater to support future policy and management practices. The study quantified the overall economic value in terms of support irrigation, urban water supply, commerce and industry, stock and domestic and sleeper and unallocated entitlements.
GHD (2010a) West Gippsland CMA Groundwater Model. Interim steady-state model development report. Report prepared by GHD for the Department of Sustainability and Environment (DSE), Victoria.	The groundwater model was developed by GHD on behalf of DSE (now DELWP) as part of the ecoMarkets project. The intention of ecoMarkets projects were to using a groundwater model as a tool to assess the relative merits of improving native vegetation management and revegetation initiatives. The model's primary objective was to provide a tool for assessing the impacts of land use change on depth to water. Calibrated aquifer parameters are available for each of the formations in the model.
Beverly et al. (2015) The Gippsland groundwater Model, Onshore natural gas water science studies, DEDJTR.	The report describes the conceptualization, development, calibration and application of the Gippsland groundwater model. The model was designed to assess impacts to groundwater resources from potential coal seam gas development. Calibrated regional aquifer parameters are available for each formation in the Gippsland Basin.
GHD (various dates) Regional Monitoring Committee Annual Report.	Annual reports submitted to SRW against groundwater license conditions to report on groundwater use, water level, land subsidence at annual basis. This report may not be in the public domain and may not be available for general review.
GHD (2016) Latrobe Valley Groundwater and Land Level Monitoring 5 Year Review.	The report provides a 5-year review of groundwater use, groundwater levels and land subsidence trends and compares with projected trends. This report may not be in the public domain and may not be available for general review

Reports	Purpose of study
GHD (2016) Regional Groundwater Model Review 2015 Update.	The report provides detailed model information and results about prediction of mine aquifer depressurization on regional groundwater levels and land subsidence. This report may not be in the public domain and may not be available for general review
DELWP (2017) Victorian Water Accounts 2016 – 2017.	The report presents annual information about the resources of the state of Victoria, reporting on volumes of surface water, groundwater and recycled water systems used and water available during the year.
CDMSmith (2017) Groundwater Data Inventory, Stocktake and Enhancement options	CDMSmith was commissioned by DEWLP to collate available data relating to four themes of groundwater recharge, aquifer/aquitard properties, groundwater use and aquifer/aquitard thickness into a database. The quality of the data was assessed through a data stocktake process. Enhancement methods were also considered for each data theme. A total of 65 studies were collated and the information was summarized into a spatial database.
CDMSmith (2018) Data Mapping – Aquifer properties and Recharge	CDMSmith was commission by DELWP to create visual products of recharge and aquifer properties for Victoria. Two products were developed – a high level communication tool to quickly inform a range of audiences of the variability in historical estimates and a finer resolution product for technical specialists to assess in future assessments of groundwater management.
GHD (2018) Groundwater Condition Reporting – Stage 4, September.	GHD developed a method to determine the Groundwater Resource Condition Assessment for DELWP. They key components of the approach was to adopt a representative Suite for reporting on groundwater resource condition and predict groundwater level as a means to compare against observation to qualitatively assess groundwater resource condition.

7.2.2 Key findings relevant to sustainable yield

SKM (2001) Rosedale Groundwater Management Plan, Monitoring Bore Assessment

SKM (2001) were engaged to determine appropriate groundwater monitoring objectives for the Rosedale GMA. SKM suggested that this information would be used to review the original PAV estimate for the Rosedale GMA and mitigate the current overallocation with respect to Zone 1 and 2 PAVs.

Reid (2004) Audit of Permissible Annual Volumes for 35 Victorian Groundwater Management Areas

Reid (2004) conducted an internal audit of reports that estimated the PAVs in the Gippsland region, highlighting some limitations associated with the PAV assessment. Reid's comments regarding the methods used to calculate the PAV are summarised below:

- The locations of the cross-sectional areas used to calculate the PAV do not account for all inflows and outflows and have no apparent consideration of relevant potentiometric surface data
- Lack of confidence in the adopted hydraulic conductivity value of 1.5 m/day
- Lack of consideration of recharge sources and impacts of mine dewatering in the PAV determination.

RMCG (2008) Groundwater Economics

RMCG assessed the economic value of the Rosedale GMA and determined that Rosedale GMA was third most valued aquifer for industrial/commercial water supply for power generation valued at $30,000,000. Comparatively, urban and stock and domestic uses we determined to be of low economic value in the area as the aquifers are deep and expensive to access.

GHD (2010a) West Gippsland CMA Groundwater Model - Interim steady-state model development report

GHDs 2010 groundwater model has been created for the West Gippsland CMA. The primary objective of the model is to provide a tool for assessing the impacts of land use change on depth to water. Calibrated model aquifer parameters for aquifers in the Gippsland region were listed for the Balook Formation and the Latrobe Group Aquifer.

The Balook Formation was reported in model layers 3 and 4, the Upper Latrobe Valley Group aquifer was reported in model layer 5 as M2c aquifer/Seaspray Sands. The hydraulic conductivity values determined using the calibrated model are provided in Table 7-1.

Table 7-1: Calibrated Hydraulic Conductivity Values

Model Layer	Hydrostratigraphic Unit	Kh (m/d)	Kv (m/d)
3	Balook Fm	3.53	6.58E-2
4	Balook Fm	7.50	0.14
5	M2C Aquifer / Seaspray Sand	1.63	0.30

- * LV = Latrobe Valley; LVD = Latrobe valley Depression; SD = Seaspray Depression; Kh = horizontal hydraulic conductivity; Kv = vertical hydraulic conductivity.

Beverly et al., (2015) The Gippsland groundwater Model - Onshore natural gas water science studies

The Gippsland Groundwater Model was developed to assess the potential impact of coal seam gas development on groundwater resources. The conceptualization was based on previous studies and there limited new information relevant to groundwater management as the study focused on understanding impacts from coal seam gas development. Flow between aquifers was not presented and the study noted that the deeper aquifers have limited interaction with the rivers and creeks.

Calibrated model aquifer parameters for aquifers in the Gippsland region were listed for the Balook Formations and the Latrobe Group Aquifer. The Balook Formation was reported as part of the Lower M2 Interseam and the Upper Latrobe Valley Group was reported as the M2c aquifer/Seaspray Sands and the Lower Latrobe Valley Group was reported as the T2 Interseam. A summary of the aquifer parameters used in the model are provided in Table 7-2.

Table 7-2: Calibrated model aquifer parameterisation.

Zone	Aquifer	Kxy (m/d)	Kz (m/d)	Specific yeild	Specific storage (m^{-1})	Kzz/Kxy
9	Lower M2 Interseam	1.605 X 10^{1}	1.202	0.1	1 X 10^{-5}	0.075
16	M2c aquifer/Seaspray sands	6.119	3.902 X 10^{-1}	0.1	1 X 10^{-5}	0.064
22	T2 interseam	8.862 X 10^{-1}	9.566 X 10^{-2}	0.1	1 X 10^{-5}	0.108
32	Lower M2 interseam	6.077	6.273 X 10^{-1}	0.1	1 X 10^{-5}	0.103
33	Upper Latrobe Group	2.665	3.997 X 10^{-1}	0.1	1 X 10^{-5}	0.150
34	Upper Latrobe Group	2.930	3.163 X 10^{-1}	0.12	1 X 10^{-5}	0.108

GHD (2016), Regional Groundwater Management Committee, Regional Groundwater Model Review, 2015, Update

The Latrobe Valley Regional Groundwater Model (LVRGM) was developed, as a requirement of coal mine groundwater license, for the prediction of regional groundwater decline due to mine depressurization. The model is update every 5 years, and the report provides comprehensive documentation of model configuration, calibration and prediction using improved knowledge on conceptualization, aquifer properties, and monitoring data. The model is owned by the three coal mines and the report is not a public document. However, relevant information can be sourced from this report for improved sustainable yield assessment.

DELWP (2017) Victorian Water Accounts 2016 – 2017

The Victorian Water Accounts report provides information on the usage and annual trends associated with water resources in the state of Victoria. To provide a consistent picture of water use across all GMA areas considered in this report we have reported the water usage figures from the most recent annual statement. Trends over two years do not necessarily represent the longer term trends, but are nevertheless considered instructive. Future assessment of the PCV should consider the full record of groundwater usage trends. The total licensed use volumes for the period of 2015 - 2017 are provided in the table below.

The groundwater level trends in the Rosedale GMA were rising in June 2016 and began declining from September 2016 to June 2017. There are about 70 groundwater licenses with approximately 9,000 ML entitlements for the coal mines and 13,000 ML for irrigation and dairy.

The latest published licensed groundwater volumes and use for the Rosedale GMA in 2016 – 2017 are described in Table 7-3.

Table 7-3: Licensed groundwater volumes and use (2016-2017)

GMA	GMA aquifer depth limits (m)	Licensed entitlement (ML/year)	Total licensed groundwater use (ML) 2016-17	Total licensed groundwater use (ML) 2015-16
Rosedale GMA	Zone 1: 50-150 Zone 2: 25 – 350 Zone 3: 200 - 300	22,322	7,573	11,401

GHD (2018) Groundwater Condition Reporting – Stage 4

GHD developed a range of aquifer classification codes, which were used to represent groundwater level responses (GHD 2014; GHD 2017; GHD 2018). The suites are grouped based on the aquifer monitored (upper, middle, lower or basement), suite code which is an alphabetic naming convention and fluctuation code which is a numerical identifier that indicates bores with similar magnitude in seasonal fluctuations (GHD, 2018). The suites to be reported for a particular GMU were selected based on the following:

- Suite representativeness (the proportion of the suite that occurs within the GMU must be spatially significant)
- Relevance of the aquifer layer (the unit the GMU is intended to manage)
- Spatial coverage of groundwater monitoring bores across a Suite or GMU
- Spatial coverage of groundwater extraction bores across the GMU
- Conceptualization considerations (improving the understanding of recharge processes, inter aquifer connectivity or aquifer leakage)

GHD determined that the Rosedale GMA is best represented by suite M_O_2 which covers the middle aquifer. The area covered by the suite is shown in Figure 7-1. The representative hydrograph for the aquifer classification is shown in Figure 7-3. The hydrograph shows that groundwater levels in M_O_2 have been declining since 1982.

The lower aquifer suite L_O_1 does not represent Rosedale GMA, the hydrograph has been retained to demonstrate groundwater trends in this aquifer.

The area covered by the suite is shown in Figure 7-2. The representative hydrograph for the aquifer classification is shown in Figure 7-4. The hydrograph shows that groundwater levels in L_O_1 have been declining since 1983.

Figure 7-1: Location of suite M_O_2 (GHD, 2018)

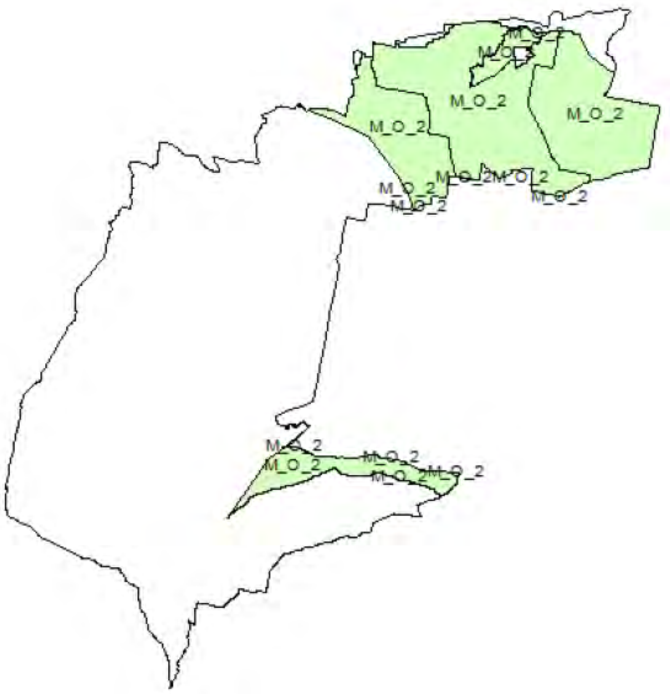


Figure 7-2: Location of suite L_O_1 (GHD, 2018)

Figure 7-3: Rosedale Suite Chart for M_O_2

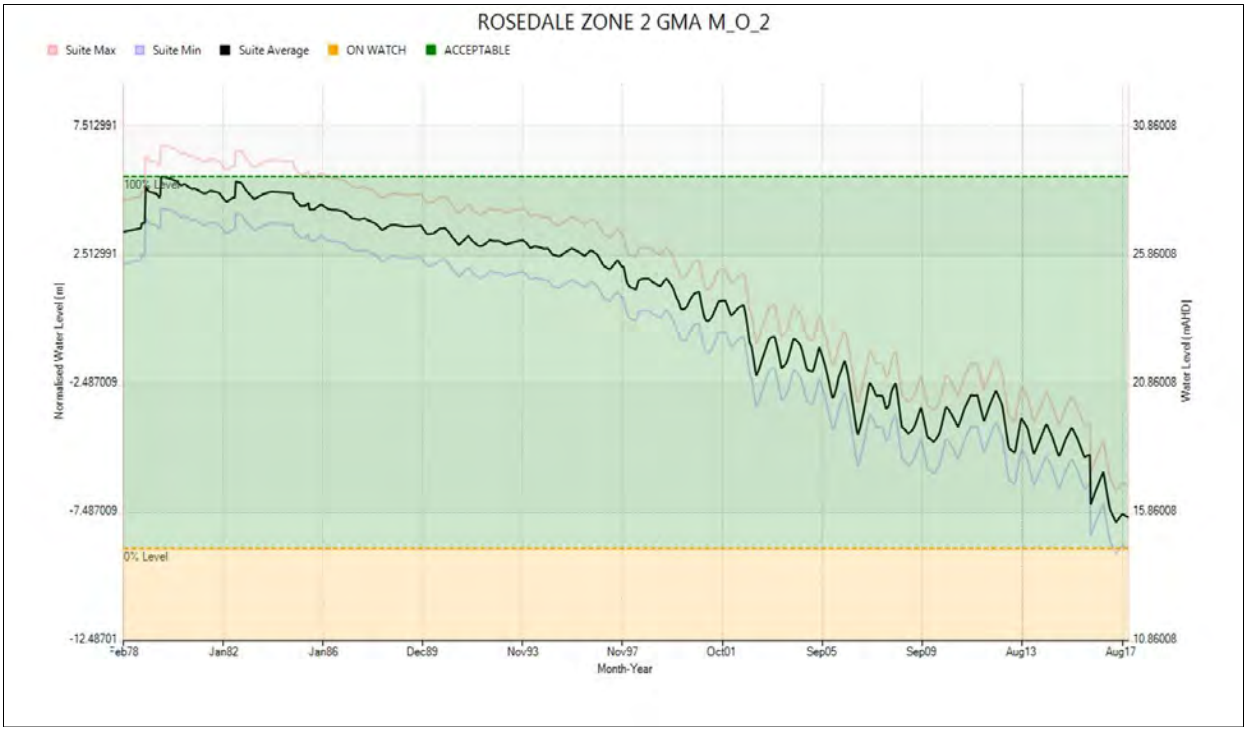
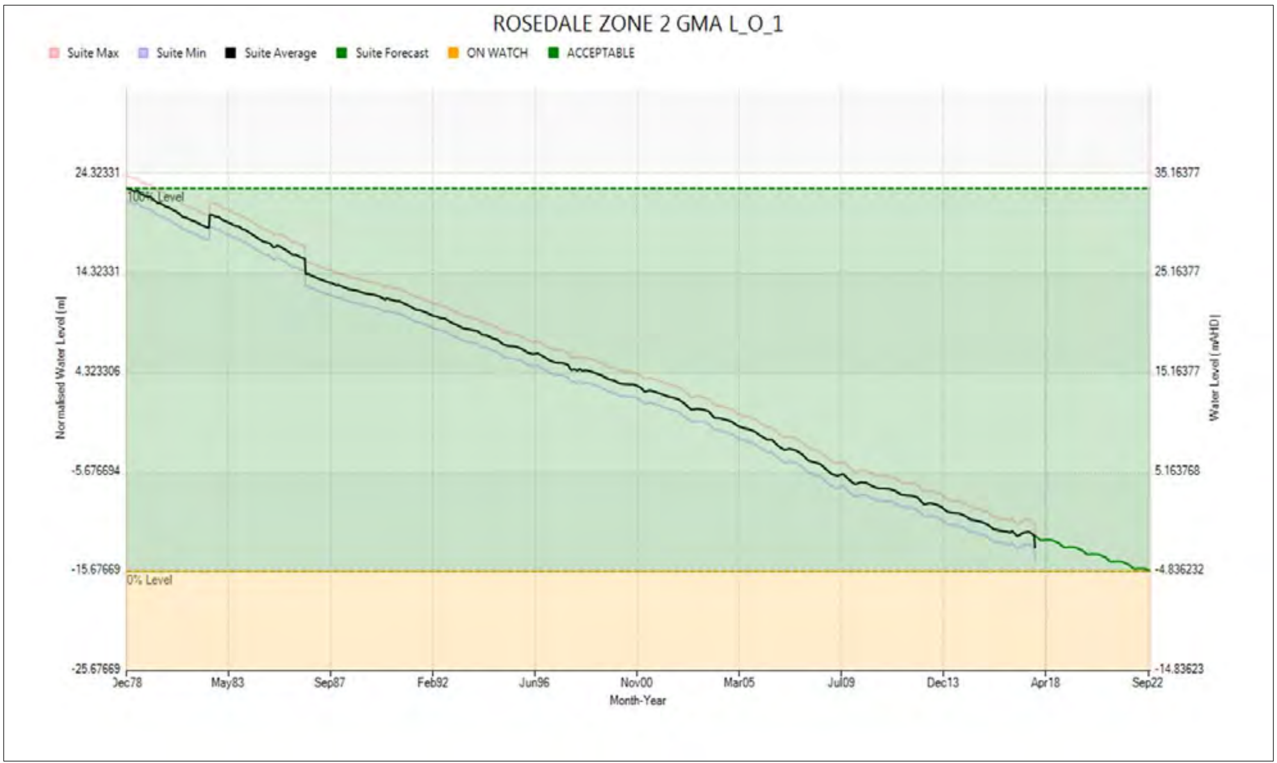


Figure 7-4: Rosedale Suite Chart for L_O_1



7.3 Relevant matters for consideration

- The most important aspect of the Rosedale GMA is that the current PCV is well in excess of the original estimates and there does not appear to have been a review to determine whether the current allocation can be considered sustainable. On this issue alone, the Rosedale GMA is a priority candidate for PCV review.
- There is limited recharge within the GMA area to provide for the resource and so the allocation must rely on drawing in water from other areas or from local storage.
- There is likely to be ongoing demand for water from the same aquifer upgradient of Rosedale for the ongoing operation and rehabilitation of the coal mines. This is expected to be required over the long term (many decades).
- Groundwater levels are expected to continue to decline as a result of offshore extraction downgradient of the GMA. Groundwater trends indicate that the aquifer is yet to reach an equilibrium level
- Accurate estimates of aquifer throughflow are required to improve the sustainable yield. Original PAV estimate was calculated by estimating aquifer throughflow, using a K of 1.5 m/day. Reid highlighted a lack of confidence in the adopted K value and suggested a value of 3 m/day. Existing models have adopted values ranging between 1.6 and 7.5 m/d depending on the aquifer. This suggests that the aquifer parameters used in the original PAV estimate are conservative compared to regional data.
- Given the high value of the resource this is considered a high priority for additional work to review the sustainable yield.

8. Sale GMA

The Sale GMA covers the high yielding Boisdale Formation where there is significant groundwater use for urban supply and irrigation. The Boisdale aquifer is confined and the GMA vertical limits correspond with depths of 25 to 200 m.

The Sale GMA extends beneath the Wa De Lock and Denison GMAs which both cover the overlying Quaternary aquifers (see Appendix A). It also overlies the Yarram Water Supply Protection Area (WSPA).

8.1 Original PAV estimate method

The original PAV assessment for the Sale GMA was conducted by SKM (1998d). SKM (1998d) note that a simple groundwater model was developed for the Boisdale Formation aquifer by Hydrotechnology (1994). The model assumed recharge from the overlying aquifers and was used to understand impacts of pumping on the water supply. The modelling results indicated the sustainable yield of the aquifer ranged between 6,500 and 15,000 ML/year, with the key risk of over-extraction associated with saline intrusion from Lake Wellington.

SKM (1998d) used two methods to assess the PAV for the Sale GMA:

- Hydrograph fluctuation
- Aquifer throughflow

Two bores used for the hydrograph fluctuation method were Bores 86464 and 77947. The recharge estimate derived using the hydrograph fluctuation method was very small (1,956 ML/year), as it did not take into account throughflow into the aquifer system. It was therefore not considered to be a reliable estimate compared to the aquifer throughflow estimate.

The aquifer throughflow method was calculated using Darcy's Law and two cross sectional areas, one for upstream and one for downstream. For the upstream cross section, the total length was 80 km, with a thickness of ranging between 75 and 100 m thickness. The hydraulic conductivity was assumed to be 5 m/d and the gradient was assumed to 0.001. The total inflow to the aquifer was calculated to be 13,003 ML/day.

The PAV for the Sale GMA was therefore recommended to be 13,000 ML/yr, using the aquifer throughflow method. PCV Order 2006 records Sale PCV as 21,212 ML/year, with PVC Order 2013 amending the Sale PCV to 21,238 ML/year. It should be noted that Reid (2004) did not review the PAV for the Sale GMA.

8.2 Subsequent New or Local Studies

8.2.1 List of Studies and Reports

Reports	Purpose of study
HydroTechnology (1994). Boisdale aquifer groundwater resource - Regional hydrogeological assessment. Report for the Department of Conservation and Natural Resources. Unpublished.	Hydrotechnology developed a simple model for the Boisdale Formations aquifer for the Department of Conservation and Natural Resources. This report is unpublished, and a copy of the original report is unavailable.
Nolan-ITU (1999) Groundwater System Status Report. For Department of Natural Resources and Environment	Nolan-ITC reviewed the status of the Sale GMA for the Department of Natural Resources and Environment (now DELWP). The study reviewed historical water level and quality trends, existing and potential impacts on the resource and

Reports	Purpose of study
	provided advice on optimizing development using the existing groundwater model.
RMCG (2008) Groundwater Economics. For Department of Sustainability and Environment (DSE) 29 August 2008	This study was completed for the Department of Sustainability and Environment (now DELWP) with the objective of developing an updated approach and revised analysis to improve the understanding of the economic value of groundwater to support future policy and management practices. The study quantified the overall economic value in terms of support irrigation, urban water supply, commerce and industry, stock and domestic and sleeper and unallocated entitlements.
SKM (2008a) Sale Groundwater Management Area – Groundwater Resource Appraisal. Southern Rural Water.	The objective of this study was to improve the conceptual understanding of the aquifer's behaviours and threats to sustainability using the available new information. The key objectives of the study were to: • Critically review available data and identify gaps • Use recently information to fill the data gaps • Develop and numerical groundwater model and predict the impacts associated with development scenarios • Revise the conceptual model based on outcomes from the numerical model.
GHD (2010a) West Gippsland CMA Groundwater Model. Interim steady-state model development report. Report prepared by GHD for the Department of Sustainability and Environment (DSE), Victoria.	The groundwater model was developed by GHD on behalf of DSE (now DELWP) as part of the ecoMarkets project. The intention of ecoMarkets projects were to use a groundwater model as a tool to assess the relative merits of improving native vegetation management and revegetation initiatives. The model's primary objective was to provide a tool for assessing the impacts of land use change on depth to water. Calibrated aquifer parameters are available for each of the formations in the model.
Beverly et al. (2015) The Gippsland groundwater Model, Onshore natural gas water science studies, DEDJTR.	The report describes the conceptualization, development, calibration and application of the Gippsland groundwater model. The model was designed to assess impacts to groundwater resources from potential coal seam gas development. Calibrated regional aquifer parameters are available for each formation in the Gippsland Basin.
DELWP (2017) Victorian Water Accounts 2016 – 2017.	The report presents annual information about the resources of the state of Victoria, reporting on volumes of surface water,

Reports	Purpose of study
	groundwater and recycled water systems used and water available during the year.
CDMSmith (2017) Groundwater Data Inventory, Stocktake and Enhancement options	CDMSmith was commissioned by DEWLP to collate available data relating to four themes of groundwater recharge, aquifer/aquitard properties, groundwater use and aquifer/aquitard thickness into a database. The quality of the data was assessed through a data stocktake process. Enhancement methods were also considered for each data theme. A total of 65 studies were collated and the information was summarized into a spatial database.
CDMSmith (2018) Data Mapping – Aquifer properties and Recharge	CDMSmith was commission by DELWP to create visual products of recharge and aquifer properties for Victoria. Two products were developed – a high level communication tool to quickly inform a range of audiences of the variability in historical estimates and a finer resolution product for technical specalists to assess in future assessments of groundwater management.
GHD (2018) Groundwater Condition Reporting – Stage 4, September.	GHD developed a method to determine the Groundwater Resource Condition Assessment for DELWP. They key components of the approach was to adopt: • a representative Suite for reporting on groundwater resource condition and • predicted groundwater level as a means to compare against observation to qualitatively assess groundwater resource condition.

8.2.2 Key Findings relevant to sustainable yield

Nolan-ITU (1999) Groundwater System Status Report

The study reviewed historical water level and quality trends to determine appropriate groundwater management arrangements for the GMA. Nolan-ITU used the existing groundwater model to assess impacts of three groundwater development scenarios:

- Scenario 1 – Average groundwater use (9,826 ML/yr)
- Scenario 2 – Groundwater use corresponding to the licensed allocation (14,149 ML/yr)
- Scenario 3 – Groundwater use corresponding to the PAV (13,000 ML/yr)

Nolan-ITU concluded that:

- The GMA boundary was adequate to encompass all recharge and discharge areas
- There was no evidence of long term decline under all the modelled scenarios

- Significant drawdown was predicted which has the potential to induce seasonal saline intrusion
- Establishing sub-zones within the GMA was not warranted as a broad resource management measure, although could be considered as a means to manage areas with bore interference.

RMCG (2008) Groundwater Economics. For Department of Sustainability and Environment (DSE)

RMCG assessed the economic value of the Sale GMA and the GMA was classified as the third most valuable groundwater resource for urban supply, with a value of $10.9 million. The GMA was also identified as a priority GMA for stock and domestic use, with a value of $2.1 million.

SKM (2008a) Sale Groundwater Management Area – Groundwater Resource Appraisal.

The Sale Water Supply Protection Area (WSPA) was established the PCV Order 2006 (SKM, 2008a). At the time of the study, the total licence allocation was 21,335 ML, compared to the PAV of 13,000 ML. In 2016/17, the metered use was 11,982 ML/year, up slightly from 10,172 in 2014/16. This suggests that groundwater use is similar to the original PAV estimate of 13,000 ML/year (VWA, 2017).

The potential for pumping to induce saline intrusion into the aquifer was assessed and there was no evidence that pumping would induce saline intrusion in the near the future. The pattern of increasing salinity towards the Gippsland Lakes was considered to be a natural process, as there was no evidence that groundwater levels had declined below the lake level.

The study also considered different aquifer behaviours on the eastern and western regions of the WSPA and potential management responses. New boundaries were proposed that extend the northern and eastern boundaries to include recharge areas and areas of known potential groundwater resources in the Forge Creek area. It is not known if the boundary has been updated since this time.

GHD (2010a) West Gippsland CMA Groundwater Model. Interim steady-state model development report

The groundwater model was created for the West Gippsland CMA with the primary objective to provide a tool for assessing the impacts of land use change on depth to water. Calibrated model aquifer parameters for aquifers in the Gippsland region were listed for all aquifers including the Boisdale Formation.

The Boisdale Formation was reported in model layer 2 and the hydraulic conductivity values determined using the calibrated model are provided in **Error! Reference source not found.**.

Table 8-1: Calibrated Hydraulic Conductivity Values

Model Layer	Hydrostratigraphic Unit	Kh (m/d)	Kv (m/d)
2	Boisdale Formation (Wurruk Sand)	12.38	3.60E-2

Beverly et al., (2015) The Gippsland groundwater Model - Onshore natural gas water science studies

The Gippsland Groundwater Model was developed to assess the potential impact of coal seam gas development on groundwater resources. Calibrated model aquifer parameters for aquifers in the Gippsland region were listed for the Boisdale aquifer and a summary of the aquifer parameters used in the model are provided in Table 7-2.

Table 8-2: Calibrated model aquifer parameterisation

Zone	Aquifer	Kxy (m/d)	Kz (m/d)	Specific yeild	Specific storage (m^{-1})	Kzz/Kxy
5	Boisdale Formation	29.86	4.479	0.1	1 X 10^{-5}	0.15

DELWP (2017) Victorian Water Accounts 2016 – 2017

The Victorian Water Accounts report provides information on the usage and annual trends associated with water resources in the state of Victoria. To provide a consistent picture of water use across all GMA areas considered in this report we have reported the water usage figures from the most recent annual statement. Trends over two years do not necessarily represent the longer term trends, but are nevertheless considered instructive. Future assessment of the PCV should consider the full record of groundwater usage trends. The total licensed use volumes for the period of 2015 - 2017 are provided in the table below.

Groundwater level trends in the Sale GMA were reported as declining in late 2016 and stable in the first half of 2017. The latest published licensed groundwater volumes and use are provided in Table 8-3.

Table 8-3: Summary of groundwater licences and use in the Sale GMA (DELWP, 2017)

GMA	GMA aquifer depth limits (m)	Licensed entitlement (ML/year)	Total licensed groundwater use (ML) 2016-17	Total licensed groundwater use (ML) 2015-16
Sale GMA	25 - 200	21,218	11,982	10,172

GHD (2018) Groundwater Condition Reporting – Stage 4

GHD developed a range of aquifer classification codes, which were used to represent groundwater level responses. Details of suite description, classification and suite hydrograph development and representative suite hydrograph for resource condition reporting can be found in (GHD 2014; GHD 2017; GHD 2018). The suites are grouped based on the aquifer monitored (upper, middle, lower or basement), suite code which is an alphabetic naming convention and fluctuation code which is a numerical identifier that indicates bores with similar magnitude in seasonal fluctuations (GHD, 2018). The suites to be reported for a particular GMU were selected based on the following:

- Suite representativeness (the proportion of the suite that occurs within the GMU must be spatially significant)
- Relevance of the aquifer layer (the unit the GMU is intended to manage)
- Spatial coverage of groundwater monitoring bores across a Suite or GMU
- Spatial coverage of groundwater extraction bores across the GMU
- Conceptualization considerations (improving the understanding of recharge processes, inter aquifer connectivity or aquifer leakage)

GHD determined that the Sale GMA is best represented by suite M_O_1 which covers the middle aquifer. The area covered by the suite is shown in Figure 8-1Figure 5-1. The representative hydrograph for the aquifer classification is shown in Figure 8-2. The hydrograph shows that groundwater levels in M_O_1 have been declining since 1997.

Figure 8-1: Location of suite M_O_1 (GHD, 2018)

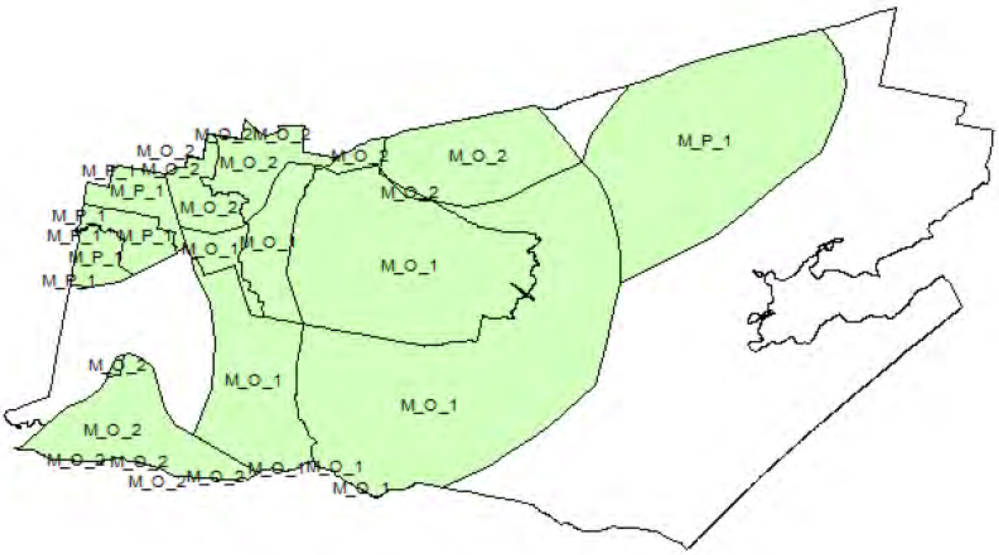
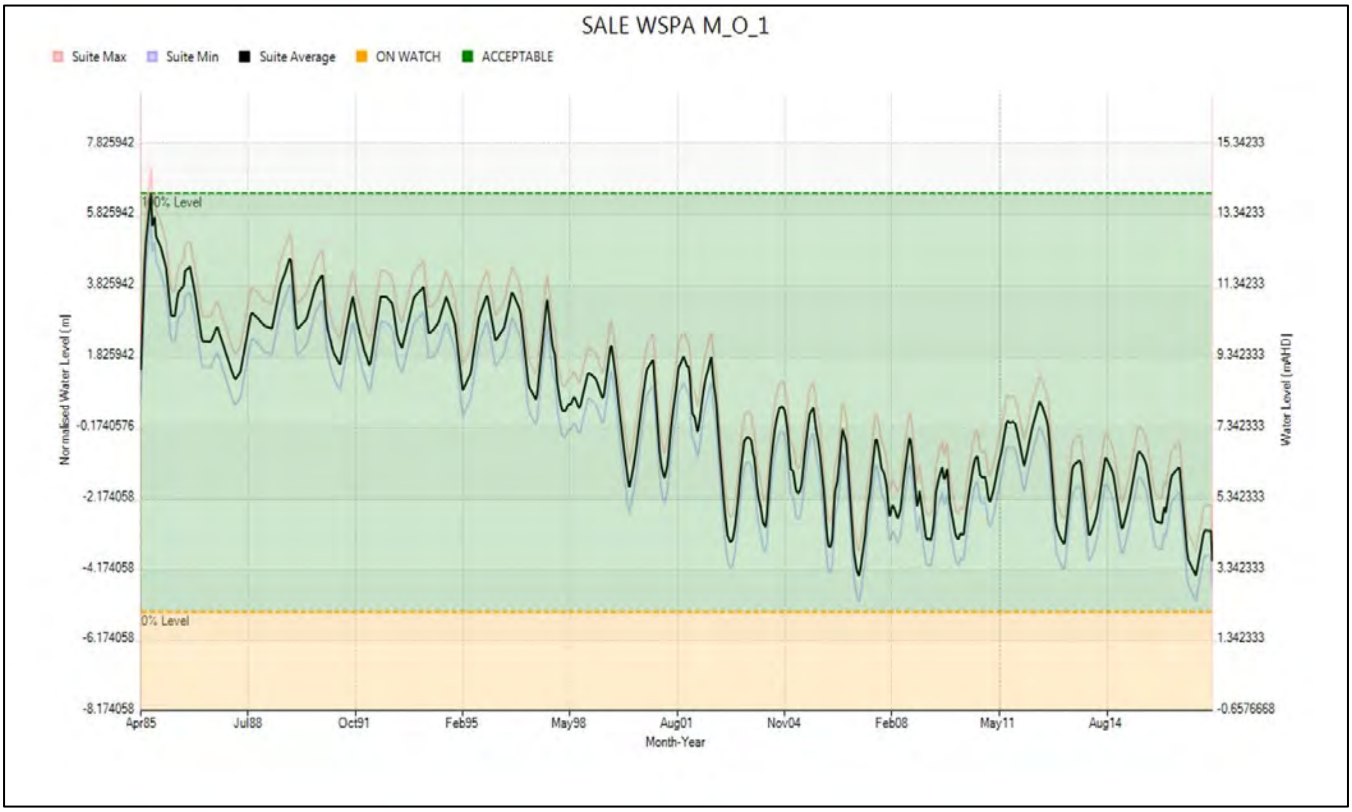


Figure 8-2: Sale WSPA Suite Chart for M_O_1



8.3 Relevant matters for consideration

- Original PAV based on an existing groundwater model PAV was recommended to be 13,000 ML/year, using the aquifer throughflow method. PCV Order 2006 increased PCV to 21,212 ML/year to match the licensed entitlements.
- The GMA is a priority GMA for urban water supply and stock and domestic uses.
- Current metered (licensed) use is just under 12,000 ML/year, and stock and domestic use is in addition to this. Given the current use is likely to be similar (or even exceed) the original PCV estimate, and the licensed entitlements is 60% more than the original PCV estimate.
- Groundwater levels are declining and have the potential cause saline intrusion from Lake Wellington.
- Groundwater pumped from the GMA is sourced only from adjacent areas, over and underlying aquifers or storage. It is considered likely there could be less inflow into the aquifer in the future.
- Groundwater pumping in the long term for operation and rehabilitation of the Latrobe Valley coal mines is likely to continue to affect the GMA
- There remains considerable uncertainty in the volume of available water, despite many models covering the area. It is possible that uncertainty cannot be reduced in the short term by additional modelling and PCV determination needs to consider this risk.
- Given the value of the resource, groundwater trends and extant risks, this GMA is a high priority for review of sustainable yield. The GMA boundary should be reviewed to confirm all recharge areas are included.

9. Stratford

9.1 Original PAV estimate method

The current Stratford GMA falls within the boundary of the old Seacombe GMA. The old Seacombe GMA applied to the Latrobe Group aquifer system which is currently managed as the Yarram WSPA and Stratford GMA. The Yarram WPSA covers the southern half of the old Seacombe GMA and the Stratford GMA covers the northern half. The Stratford GMA lies beneath the Sale, Denison and Wa De Lock GMAs which apply to the overlying Quaternary and Tertiary aquifers in central Gippsland (see Appendix A).

SKM (1998) completed an assessment of the PAV for the Latrobe aquifer of the Seacombe GMA. This assessment is described in the context of the whole Latrobe Group aquifer and is not specific to Yarram only, due to the Yarram GMA being established later. The PAV for the Latrobe Group aquifer was determined using the aquifer throughflow method. A value of 100,000 ML/year was calculated by Walker and Mollica (1990) however the details of the study were not available at the time of this work. SKM (1998) noted that 80,000 ML/year of the 100,000 ML/year of recharge occurred south of the Baragwanath Anticline and the areas west of Yarram. SKM (1998) suggested that this PAV calculation is an overestimate and that the groundwater extraction volume from the Latrobe Group exceeded the recharge rate.

9.1.1 Stratford GMA

The Stratford GMA covers the Latrobe Group aquifer. The GMA is divided into two zones:

- Zone 1 - All formations below 150 m from the surface
- Zone 2 - All formations below 350 m from the surface

The PCV Order 2006 declared PCV of 27,643 ML/year, which was subsequently amended in PCV order 2011 to 27,645 ML/year. Further amendments were made in PCV Order 2018 to 27,686 ML. The current entitlement for the Stratford GMA is 37,043 ML/year with metered use of 22,076 ML (DELWP, pers. comm, 2019). The GMA contains a number of regularly monitored State Observation Bores plus another network of observation bores owned and managed collectively by three coal mining companies in the region (WGCMA, 2008; WGCMA, 2017).

The PCV for Stratford GMA is 27,643 ML/year, with a total allocation of 27,645 ML/year (WGCMA, 2008; WGCMA, 2017).

9.2 Subsequent New or Local Studies

9.2.1 List of Studies and Reports

Reports	Purpose of study
WGCMA (2008) Macalister Land and Water Management Plan, Part A and Part B.	The plan provides strategic direction for the management of land and water for the area covering the Macalister Irrigation District and surrounding dryland areas for the sustainability of the local area and the down-catchment Gippsland Lakes. The plan integrates overlapping land and water management issues to improve the health of the high value assets in the area. Part B of the document provides supporting information for the Macalister Land and Water Management Plan (2008).

Reports	Purpose of study
RMCG (2008) Groundwater Economics. For Department of Sustainability and Environment (DSE) 29 August 2008	This study was completed for the Department of Sustainability and Environment (now DELWP) with the objective of developing an updated approach and revised analysis to improve the understanding of the economic value of groundwater to support future policy and management practices. The study quantified the overall economic value in terms of support irrigation, urban water supply, commerce and industry, stock and domestic and sleeper and unallocated entitlements.
GHD (2010a) West Gippsland CMA Groundwater Model. Interim steady-state model development report. Report prepared by GHD for the Department of Sustainability and Environment (DSE), Victoria.	The groundwater model was developed by GHD on behalf of DSE (now DELWP) as part of the ecoMarkets project. The intention of ecoMarkets projects were to use a groundwater model as a tool to assess the relative merits of improving native vegetation management and revegetation initiatives. The model's primary objective was to provide a tool for assessing the impacts of land use change on depth to water. Calibrated aquifer parameters are available for each of the formations in the model.
Beverly et al. (2015) The Gippsland groundwater Model, Onshore natural gas water science studies, DEDJTR.	The report describes the conceptualization, development, calibration and application of the Gippsland groundwater model. The model was designed to assess impacts to groundwater resources from potential coal seam gas development. Calibrated regional aquifer parameters are available for each formation in the Gippsland Basin.
GHD (various dates) Regional Monitoring Committee Annual Report.	Annual reports submitted to SRW against groundwater license conditions to report on groundwater use, water level, land subsidence at annual basis. This report may not be in the public domain and may not be available for general review
GHD (2016) Latrobe Valley Groundwater and Land Level Monitoring 5 Year Review.	The report provides a 5-year review of groundwater use, groundwater levels and land subsidence trends and compares with projected trends. This report may not be in the public domain and may not be available for general review
GHD (2016) Regional Groundwater Model Review 2015 Update.	The report provides detailed model information and results about prediction of mine aquifer depressurization on regional groundwater levels and land subsidence. This report may not be in the public domain and may not be available for general review
DELWP (2017) Victorian Water Accounts 2016 – 2017.	The report presents annual information about the resources of the state of Victoria, reporting on volumes of surface water,

Reports	Purpose of study
	groundwater and recycled water systems used and water available during the year.
CDMSmith (2017) Groundwater Data Inventory, Stocktake and Enhancement options	CDMSmith was commissioned by DEWLP to collate available data relating to four themes of groundwater recharge, aquifer/aquitard properties, groundwater use and aquifer/aquitard thickness into a database. The quality of the data was assessed through a data stocktake process. Enhancement methods were also considered for each data theme. A total of 65 studies were collated and the information was summarized into a spatial database.
WGCMA (2017) Macalister Land and Water Management Plan Review.	This report describes the review of eight years of Macalister Land and Water Management Plan (MLWMP) implementation, from 2008 to 2016.
CDMSmith (2018) Data Mapping – Aquifer properties and Recharge	CDMSmith was commission by DELWP to create visual products of recharge and aquifer properties for Victoria. Two products were developed – a high level communication tool to quickly inform a range of audiences of the variability in historical estimates and a finer resolution product for technical specialists to assess in future assessments of groundwater management.
GHD (2018) Groundwater Condition Reporting – Stage 4, September.	GHD developed a method to determine the Groundwater Resource Condition Assessment for DELWP. They key components of the approach was to adopt: • a representative Suite for reporting on groundwater resource condition and predicted groundwater level as a means to compare against observation to qualitatively assess groundwater resource condition.

9.2.2 Key findings relevant to sustainable yield

WGCMA (2008) Macalister Land and Water Management Plan Part A and Part B

The plan provides strategic direction for the management of land and water for the area covering the Macalister Irrigation District and surrounding dryland areas for the sustainability of the local area and the down-catchment Gippsland Lakes.

The Stratford GMA at the time of the report contained a number of regularly monitored SOBs and a network of observation bores owned and managed collectively by the three coal mining companies in the region. The Macalister Land and Water Management Plan proposed to review the existing monitoring network and identify gaps in the monitoring network. The plan also recommends ongoing investigations into the effect of declining groundwater levels on land subsidence including land survey monitoring.

The key issues in Stratford GMA are:

- Declining water levels (approximately 1 m/year) from a combination of offshore gas and oil extraction, dewatering of coal mines and a small contribution from irrigation bores in the Yarram area.

- Potential for land subsidence caused by the consolidation of clays above the aquifer.

Several management actions were implemented to understand and mitigate the issues associated with unsustainable extraction in the GMA:

- Theoretical studies were being undertaken into potential subsidence rates as well as studies into measurement of subsidence

- Metering of bores was done to determine usage

- New licenses were not being allocated

- As part of their license, coal mining companies undertake regular land subsidence monitoring and modelling.

Part B of the document provides supporting information for the Macalister Land and Water Management Plan (2008). The plan outlines all the assets located in the study area, with groundwater assets being divided into shallow groundwater defined as the water table aquifer and deep groundwater defined as all aquifers beneath the water table aquifer.

The Stratford GMA covers the deep aquifer systems with the following asset services being identified for deep groundwater:

- Environmental asset services include provision of habitat for groundwater bacteria and prevention of land subsidence;
- Economic asset services were identified as water supply
- No social asset services were identified for the deep aquifers

The total area affected by salinity due to irrigation with saline water or shallow groundwater was mapped for the Stratford GMA. Salinity affected land covered 403 ha, with 195 ha being classified as severe salinity.

Woodwater (2017) conducted a review of the eight years of implementation of the Macalister Land and Water Management Plan. Progress against these recommendations is summarized below:

- Stratford GMA continues to exist,

- The study into land subsidence in the region has been completed and periodic monitoring has been implemented.

RMCG (2008) Groundwater Economics

RMCG assessed the economic value of the Stratford GMA and determined it is the highest priority GMA in terms of economic value ($78.7M). The Latrobe Valley Mining Operations are the biggest user of the groundwater in the GMA ($77.8M) with minor volumes used for irrigation of grazing pastures ($916,832). The value associated with sleeper licences was $1.6M.

GHD (2010a) West Gippsland CMA Groundwater Model - Interim steady-state model development report

GHDs 2010 groundwater model has been created for the West Gippsland CMA. The primary objective of the model is to provide a tool for assessing the impacts of land use change on depth to water. Calibrated model aquifer parameters for aquifers in the Gippsland region were listed for the Latrobe Group Aquifer.

The Lower Latrobe Group aquifer was reported in model layer 3 as M1B Aquifer. The hydraulic conductivity values determined using the calibrated model are provided in Table 7-1.

Table 9-1: Calibrated Hydraulic Conductivity Values

Model Layer	Hydrostratigraphic Unit	Kh (m/d)	Kv (m/d)
3	M1B Aquifer (Latrobe Valley)	0.97	0.13

* Kh = horizontal hydraulic conductivity; Kv = vertical hydraulic conductivity.

Beverly et al., (2015) The Gippsland groundwater Model - Onshore natural gas water science studies

The Gippsland Groundwater Model was developed to assess the potential impact of coal seam gas development on groundwater resources.

Calibrated model aquifer parameters for aquifers in the Gippsland region were listed for the Latrobe Group Aquifer. The Lower Latrobe Group was reported as the T2 Interseam. A summary of the aquifer parameters used in the model are provided in Table 7-2.

Table 9-2: Calibrated model aquifer parameterisation.

Zone	Aquifer	Kxy (m/d)	Kz (m/d)	Specific yeild	Specific storage (m^{-1})	Kzz/Kxy
22	T2 interseam	8.862×10^{-1}	9.566×10^{-2}	0.1	1×10^{-5}	0.108

DELWP (2017) Victorian Water Accounts 2016 – 2017

The Victorian Water Accounts report provides information on the usage and annual trends associated with water resources in the state of Victoria. To provide a consistent picture of water use across all GMA areas considered in this report we have reported the water usage figures from the most recent annual statement. Trends over two years do not necessarily represent the longer term trends, but are nevertheless considered instructive. Future assessment of the PCV should consider the full record of groundwater usage trends. The total licensed use volumes for the period of 2015 - 2017 are provided in the table below.

The groundwater level trends in the Stratford GMA were stable in June 2016 and were declining between September 2016 to June 2017. The combined groundwater level trends in the Stratford GMA in Central Gippsland and Seaspray Groundwater Catchments are described in Table 9-3.

Metered groundwater use is 22,076 ML in 2017 – 2018 (Unpublished data, provided by DELWP).

Table 9-3: Licensed groundwater volumes and use

GMA	GMA aquifer depth limits (m)	Licensed entitlement (ML/year)	Total licensed groundwater use (ML) 2016-17	Total licensed groundwater use (ML) 2015-16
Stratford GMA	Zone 1: >150 Zone 2: >350	36,953	25,103	21,824

GHD (2018) Groundwater Condition Reporting – Stage 4

GHD developed a range of aquifer classification codes, which were used to represent groundwater level responses. Details of suite description, classification and suite hydrograph development and representative suite hydrograph for resource condition reporting can be found in (GHD 2014; GHD 2017; GHD 2018). The suites are grouped based on the aquifer monitored (upper, middle, lower or basement), suite code which is an alphabetic naming convention and fluctuation code which is a numerical identifier that indicates bores with similar magnitude in seasonal fluctuations (GHD, 2018). The suites to be reported for a particular GMU were selected based on the following:

- Suite representativeness (the proportion of the suite that occurs within the GMU must be spatially significant)
- Relevance of the aquifer layer (the unit the GMU is intended to manage)
- Spatial coverage of groundwater monitoring bores across a Suite or GMU
- Spatial coverage of groundwater extraction bores across the GMU
- Conceptualization considerations (improving the understanding of recharge processes, inter aquifer connectivity or aquifer leakage)

GHD determined that the Stratford GMA is best represented by suite L_O_1 which covers the lower aquifer. The area covered by the suite is shown in Figure 9-1. The representative hydrograph for the aquifer classification is shown in Figure 9-2. The hydrograph shows that groundwater levels in L_O_1 have been declining since 1978.

Figure 9-1: Location of suite L_O_1 (GHD, 2018)

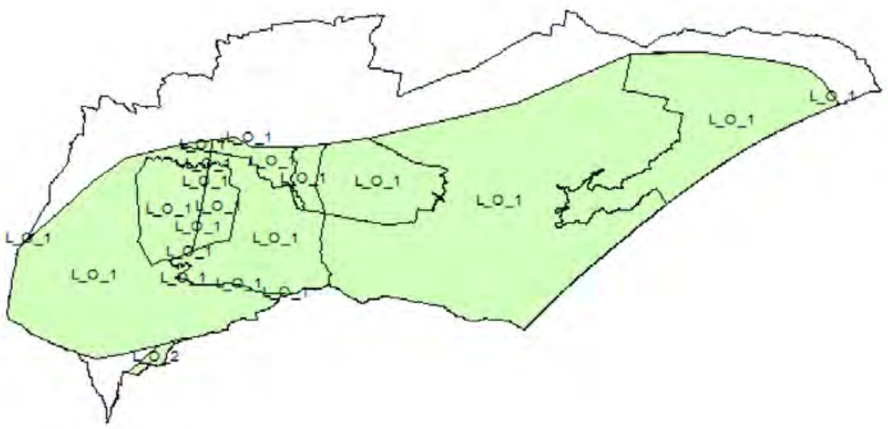
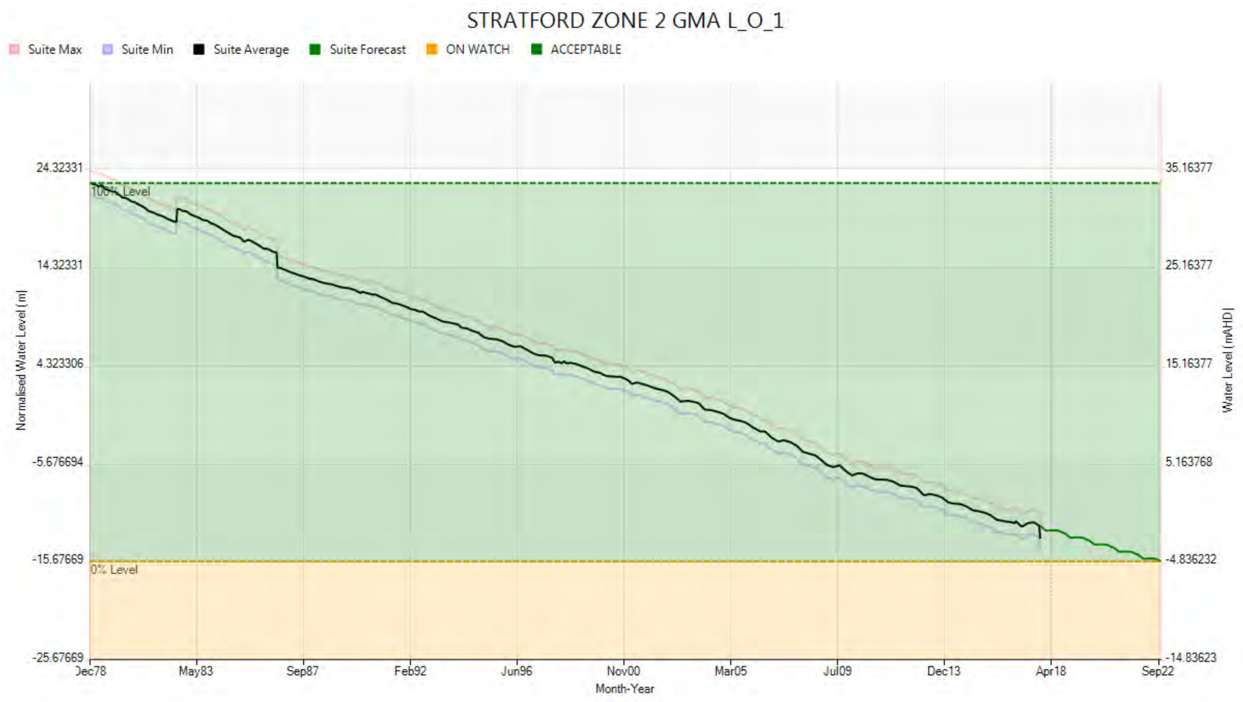


Figure 9-2: Stratford Zone 2 Suite Chart for L_O_1



9.3 Relevant matters for consideration

- The major use of groundwater in this GMA is for electricity generation and associated activities around the open cut coal mines. This area is the subject of a significant whole of government initiative to deal with closure and rehabilitation of the coal mines. Given that other uses are modest in comparison to the mining activity, it is suggested that this area is a low priority for PCV assessment on its own and that any further evaluation should be included in the studies for the regional rehabilitation strategy,
- There is likely to be ongoing demand for water and this is expected to be required over the long term (many decades).
- Groundwater levels are expected to continue to decline as a result of ongoing mine dewatering and other related pumping, as well as offshore extraction and groundwater trends indicate that the aquifer is yet to reach an equilibrium level
- Accurate estimates of aquifer throughflow are required to improve the sustainable yield.
- The Stratford GMA is defined by depth; however coal mine entitlements are defined by aquifer name. Considering that the major entitlement holders are coal mining companies, there is a potential issue regarding water accounting in the GMA.
- There is a need to review and update the estimate of sustainable yield for this system as the current conditions are significantly different from what was assumed during the initial work. However, there is a risk of overlapping studies with the effort being expended on the coal mine rehabilitation. It is recommended that a revised estimate of the sustainable yield be developed as a matter of high priority, but that it not proceed to a formal PCV review until the rehabilitation process is more progressed.

10. Tarwin GMA

The Tarwin GMA boundary is defined by the coastline of the spit forming Anderson Inlet in the north, south and west (see Appendix A). The eastern boundary coincides with the Tarwin Meadows Road and the Walkerville Road to its intersection with Evergreen Road.

The upper geological sequence is composed of aeolian dune deposit of Quaternary age carbonaceous sand, which extends to 25 m depth and overlies Tertiary age limestone and marls. The sand dune ridges are elevated toward the ocean side, reaching to over 30 m above sea-levels. The water table is generally less than two meters above sea-level and is typically around one meter above sea level through most of the area.

There are significant differences between groundwater bore density in the urbanised areas of Venus Bay relative to the remaining areas of the zone.

10.1 Original PAV estimate method

The original PAV assessment for the Tarwin GMA was conducted by SKM (1998f). The main aquifer considered was the unconfined Quaternary age sand dune deposits.

The likely annual recharge to the groundwater system was estimated using rainfall infiltration and annual hydrograph fluctuation methods. Factors limiting the utilization of annual recharge volumes were considered, such as limited regional drawdown, well interference and saline intrusion. There are no rivers in the Tarwin GMA, therefore the influence of river recharge was not taken into account.

The rainfall infiltration method is suitable in estimating the recharge as the aquifer is unconfined. Two areas of recharge were identified, where Area 1 was the area of GMA excluding a low-lying area, and Area 2 was the low-lying area. The overall rainfall recharge to the Tarwin GMA was calculated as 4,499 ML/year. The following parameters were used to calculate rainfall infiltration:

- Area 1 was considered to be 22 km^2 with an infiltration rate of 18% of rainfall,
- Area 2 had the area of 5 km^2 with an infiltration rate of 10% of rainfall,
- Annual rainfall to the area of the GMA was determined as 962 mm/year.

The hydrograph fluctuation method used the median annual fluctuation of 2 bores. The median annual recharge was determined to be 4,197 ML/year which was calculated by summing the values of 2 bores (see Table 10-1).

Table 10-1: Bores used in the hydrograph fluctuation method for the Tarwin PAV

ID	Median Annual Fluctuation (m)	Area (m^2)	Adopted Storage	Median Recharge Estimates (ML/year)
Bore 1 - 94802	0.8	17,109,000	0.23	3,148
Bore 2 - 94814	0.4	11,406,000	0.23	1,049
Total				4,197

It was considered that the rainfall infiltration method provides the most reliable estimate for recharge, however, there was only a small difference between the two methods and this provided some degree of confidence in the adopted figure.

An upper limit of extraction of 3,350 ML/year was calculated for sea water intrusion. This was calculated using the following values:

- A hydraulic conductivity of 20 m/day for the entire aquifer
- Minimum depth to fresh water is 80% of the aquifer thickness
- The minimum required outflow was determining to be 1,149 ML/year

The PAV for the Tarwin GMA is determined by:

Rainfall Infiltration – Volume of throughflow for sea water intrusion control = PAV

4,499 ML/year – 1,149 ML/year = 3,350 ML/year

The Tarwin GMA was allocated a PAV of 3,350 ML/year. Sea water intrusion was considered the main limiting factor in determining the PAV. The PAV for Tarwin GMA was decreased to 1,300 ML/year in 2006 (DELWP, 2017).

10.2 Subsequent New or Local Studies

10.2.1 List of Studies and Reports

Reports	Purpose of study
Reid (2004) Audit of Permissible Annual Volumes for 35 Victorian Groundwater Management Areas. May 2004. Department of Primary Industries	Reid conducted an internal audit of 35 reports that estimated the Permissible Annual Volume (PAV) of groundwater that could be extracted from GMAs. Reid was commissioned by the former Department of Natural Resources and Environment (now DELWP).
RMCG (2008) Groundwater Economics. For Department of Sustainability and Environment (DSE) 29 August 2008	This study was completed for the Department of Sustainability and Environment (now DELWP) with the objective of developing an updated approach and revised analysis to improve the understanding of the economic value of groundwater to support future policy and management practices. The study quantified the overall economic value in terms of support irrigation, urban water supply, commerce and industry, stock and domestic and sleeper and unallocated entitlements.
GHD (2010a) West Gippsland CMA Groundwater Model. Interim steady-state model development report. Report prepared by GHD for the Department of Sustainability and Environment (DSE), Victoria.	The groundwater model was developed by GHD on behalf of DSE (now DELWP) as part of the ecoMarkets project. The intention of ecoMarkets projects were to using a groundwater model as a tool to assess the relative merits of improving native vegetation management and revegetation initiatives. The model's primary objective was to provide a tool for assessing the impacts of land use change on depth to water. Calibrated aquifer parameters are available for each of the formations in the model.

Reports	Purpose of study
SKM (2012) Baseflow Separation Analysis for Unregulated Rivers (1889 to 2012)	The study completed a baseflow separation analysis for 180 stream gauges on unregulated rivers in Victoria Reference. Originally published on-line through the WMIS database, the dataset is now available through data.vic. The report is cited in Jacobs (2014). A copy of the original report is not believed to be available.
Beverly et al. (2015) The Gippsland groundwater Model, Onshore natural gas water science studies, DEDJTR.	The report describes the conceptualization, development, calibration and application of the Gippsland groundwater model. The model was designed to assess impacts to groundwater resources from potential coal seam gas development. Calibrated regional aquifer parameters are available for each formation in the Gippsland Basin.
DELWP (2017) Victorian Water Accounts 2016 – 2017.	The report presents annual information about the resources of the state of Victoria, reporting on volumes of surface water, groundwater and recycled water systems used and water available during the year.
CDMSmith (2017) Groundwater Data Inventory, Stocktake and Enhancement options	CDMSmith was commissioned by DEWLP to collate available data relating to four themes of groundwater recharge, aquifer/aquitard properties, groundwater use and aquifer/aquitard thickness into a database. The quality of the data was assessed through a data stocktake process. Enhancement methods were also considered for each data theme. A total of 65 studies were collated and the information was summarized into a spatial database.
CDMSmith (2018) Data Mapping – Aquifer properties and Recharge	CDMSmith was commission by DELWP to create visual products of recharge and aquifer properties for Victoria. Two products were developed – a high level communication tool to quickly inform a range of audiences of the variability in historical estimates and a finer resolution product for technical specialists to assess in future assessments of groundwater management.
GHD (2018) Groundwater Condition Reporting – Stage 4, September.	GHD developed a method to determine the Groundwater Resource Condition Assessment for DELWP. They key components of the approach was to adopt a representative Suite for reporting on groundwater resource condition and predict groundwater level as a means to compare against observation to qualitatively assess groundwater resource condition.

10.2.2 Key findings relevant to sustainable yield

Reid (2004) Audit of Permissible Annual Volumes for 35 Victorian Groundwater Management Areas

Reid (2004) conducted an internal audit of reports that estimated the PAVs in the Gippsland region, highlighting some limitations associated with the PAV assessment. Reid's comments regarding the methods used to calculate the PAV are summarised below:

- Subjective rainfall recharge calculations potentially due to the lack of data
- Inaccurate sea water control throughflow calculation due to uncertainty in aquifer thickness, hydraulic conductivity, sweater interface location, and what constitutes an appropriate distance and depth limit for seawater interface management
- Lack of geological and hydrogeological data such as thicknesses and extents of the aquifers, as well as data regarding hydrostratigraphy, the interaction of the sand dunes and alluvium aquifers, recharge and discharge processes and their distribution in the area
- Uncertainty regarding the reliability of the hydrograph recharge calculation due to the use of only two bores and uncertainty about the recharge interpretations, and inadequate recharge area delineation
- Lack of consideration for the aquifer potentiometry and throughflow analysis, groundwater levels, trends and quality, and aquifer storage

RMCG (2008) Groundwater Economics

The Tarwin GMA is a priority GMA for stock and domestic users. RMCG assessed the economic value of the Tarwin GMA and valued stock and domestic use at around $1,800,000. Given the predominant groundwater use is stock and domestic, the total licensed use is not known.

GHD (2010a) West Gippsland CMA Groundwater Model - Interim steady-state model development report

GHDs 2010 groundwater model has been created for the West Gippsland CMA. The primary objective of the model is to provide a tool for assessing the impacts of land use change on depth to water. Calibrated model aquifer parameters for aquifers in the Gippsland region were listed for the Quaternary age sand dune deposits.

The Quaternary sediments aquifer was reported in model layer 1. The hydraulic conductivity values determined using the calibrated model are provided in Table 7-1.

Table 10-2: Calibrated Hydraulic Conductivity Values

Model Layer	Hydrostratigraphic Unit	Kh (m/d)	Kv (m/d)
1	Haunted Hills Formation and Quaternary Sediments	2.01	4.21 (2.01E-3 around the LV mines)

* Kh = horizontal hydraulic conductivity; Kv = vertical hydraulic conductivity.

Beverly et al., (2015) The Gippsland groundwater Model - Onshore natural gas water science studies

The Gippsland Groundwater Model was developed to assess the potential impact of coal seam gas development on groundwater resources.

Calibrated model aquifer parameters for aquifers in the Gippsland region were listed for the Quaternary sand dune sediments, which were reported in Zone 2 of the calibrated model. A summary of the aquifer parameters used in the model are provided in Table 7-2.

Table 10-3: Calibrated model aquifer parameterisation.

Zone	Aquifer	Kxy (m/d)	Kz (m/d)	Specific yeild	Specific storage (m^{-1})	Kzz/Kxy
2	Quaternary	6.507	9.761×10^{-1}	0.1	1×10^{-5}	0.150

DELWP (2017) Victorian Water Accounts 2016 – 2017

The Victorian Water Accounts report provides information on the usage and annual trends associated with water resources in the state of Victoria. To provide a consistent picture of water use across all GMA areas considered in this report we have reported the water usage figures from the most recent annual statement. Trends over two years do not necessarily represent the longer term trends, but are nevertheless considered instructive. Future assessment of the PCV should consider the full record of groundwater usage trends. The total licensed use volumes for the period of 2015 - 2017 are provided in the table below.

The groundwater level trends in the Tarwin GMA were overall stable between June 2016 and June 2017, with declining levels reported in March 2017.

The latest published licensed groundwater volumes and use for the Tarwin GMA are described in Table 10-4. In addition to the licences listed here, there are almost 500 stock and domestic users with an estimated use of 740 ML/year.

Table 10-4: Licensed groundwater volumes and use

GMA	GMA aquifer depth limits (m)	Licensed entitlement (ML/year)	Total licensed groundwater use (ML) 2016-17	Total licensed groundwater use (ML) 2015-16
Tarwin GMA	<=25	38	5	7

GHD (2018) Groundwater Condition Reporting – Stage 4

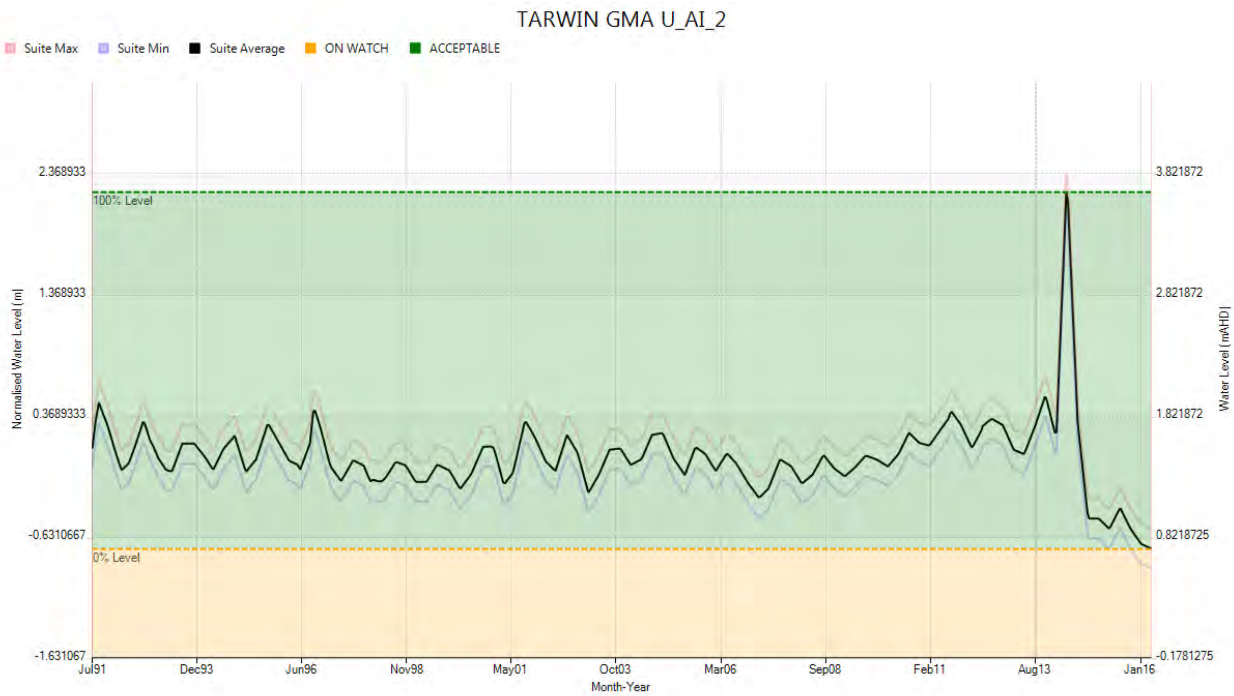
GHD developed a range of aquifer classification codes, which were used to represent groundwater level responses. Details of suite description, classification and suite hydrograph development and representative suite hydrograph for resource condition reporting can be found in (GHD 2014; GHD 2017; GHD 2018). The suites are grouped based on the aquifer monitored (upper, middle, lower or basement), suite code which is an alphabetic naming convention and fluctuation code which is a numerical identifier that indicates bores with similar magnitude in seasonal fluctuations (GHD, 2018). The suites to be reported for a particular GMU were selected based on the following:

- Suite representativeness (the proportion of the suite that occurs within the GMU must be spatially significant)
- Relevance of the aquifer layer (the unit the GMU is intended to manage)
- Spatial coverage of groundwater monitoring bores across a Suite or GMU
- Spatial coverage of groundwater extraction bores across the GMU
- Conceptualization considerations (improving the understanding of recharge processes, inter aquifer connectivity or aquifer leakage)

GHD determined that the Tarwin GMA is best represented by suite U_AI_2 which covers the upper aquifer. The area covered by the suite is shown in Figure 10-1. The representative hydrograph for the aquifer classification is shown in Figure 10-2. The hydrograph shows that groundwater levels in U_AI_2 have been stable between 1991 to 2013, and have been declining since 2014.

Figure 10-1: Location of suite U_AI_2 (GHD, 2018)

Figure 10-2: Tarwin GMA Suite Chart for U_AI_2



10.3 Relevant matters for consideration

- Original PAV was based on recharge from rainfall and volume required to control saline intrusion
- Saline intrusion risk needs to be re-visited considering sea level rise
- Rainfall recharge is vulnerable to changes in rainfall trends
- Highly settled areas generally contaminated with septic tank effluent, which may constrain use
- Reid (2004) highlighted the absence of many critical data sets to undertake a complete analysis and these do not appear to have changes substantively since then.
- Groundwater levels show strong seasonality, and reasonably stable trends, although declining groundwater levels have been noted in recent years.
- In terms of groundwater use, Tarwin is a priority GMA for stock and domestic use but is not considered a priority GMA given the level of groundwater use and value of the aquifer.
- Low priority for further assessment

11. Wa De Lock GMA

The Wa De Lock GMA is located in the northern margin of the Gippsland Basin (see Appendix A). The vertical limit of the GMA is 25 meters deep which covers the maximum depth of the Quaternary aquifers. The Wa De Lock GMA is located over the Sale GMA which covers the underlying Boisdale Formation groundwater resource, and the Stratford GMA which covers the deep Latrobe group groundwater resource.

11.1 Original PAV estimate method

The PAV for Wa De Lock was initially assessed in 1998 (SKM, 1998g). The Wa De Lock GMA was split into three zones that are effectively hydraulically separated from one another by geological controls. Zone 1 covers the Macalister River flood plain deposits, Zone 2 covers the Avon River flood plain deposits and Zone 3 covers a small area of flood plain deposits associated with Freestone Creek.

Two methods were used to estimate the recharge (rainfall recharge and hydrograph fluctuation).

The hydrograph fluctuation was calculated using three bores, one in each area. The total recharge estimate using this method was 31,024 ML/year. The parameters used for each zone are summarised in Table 11-1.

Table 11-1: Summary of parameters used in calculating recharge using the hydrograph fluctuation method in the Wa De Lock PAV assessment

Zone	Bore	Annual Median Fluctuations (m)	Adopted Storage	Median Recharge Estimate (ML/year)
Zone 1	Bore 76892	0.8	0.05	8,536
Zone 2	Bore 98121	0.6	0.05	11,829
Zone 3	Bore 110167	2.6	0.2	10,660
Total				31,025

Rainfall recharge method was chosen to estimate the PAV. The respective PAVs for Zones, 1, 2 and 3 were 12,783, 17,775 and 1,443 ML/year, with a total of 32,000 ML/year. The areas, rainfall and recharge rates used to estimate the rainfall recharge are summarized in Table 11-2.

The recharge rate of 10% for Zone 1 has been used because of the substantial areas of irrigation. In Zone 2 a smaller infiltration rate was used because of the semi-confined to confined nature of the aquifer in the southern part of the zone. The recharge rate of 10% for Zone 3 has been set due to the porous nature of the unconfined aquifer.

Table 11-2 Summary of parameters used to estimate rainfall recharge in the Wa De Lock PAV assessment

Zone	Area (km^2)	Annual rainfall (mm)	Recharge rate	Volume available
Zone 1	213.4	599	10%	12,782
Zone 2	394.3	644	7%	17,775
Zone 3	20.5	704	10%	1,443
Total				32,001

The PAV for Wa De Lock GMA was determined as 32,001 ML/year using rainfall recharge. The PAV was changed to 30,084 ML/year in 2006, to 30,172 ML/year in 2011, and to 30,795 ML/year in 2015 – 2016.

11.2 Subsequent New or Local Studies

11.2.1 List of Studies and Reports

Reports	Purpose of study
Reid (2004) Audit of Permissible Annual Volumes for 35 Victorian Groundwater Management Areas. May 2004. Department of Primary Industries	Reid conducted an internal audit of 35 reports that estimated the Permissible Annual Volume (PAV) of groundwater that could be extracted from GMAs. Reid was commissioned by the former Department of Natural Resources and Environment (now DELWP).
RMCG (2008) Groundwater Economics. For Department of Sustainability and Environment (DSE) 29 August 2008	This study was completed for the Department of Sustainability and Environment (now DELWP) with the objective of developing an updated approach and revised analysis to improve the understanding of the economic value of groundwater to support future policy and management practices. The study quantified the overall economic value in terms of support irrigation, urban water supply, commerce and industry, stock and domestic and sleeper and unallocated entitlements.
SKM (2009) Investigation of groundwater/surface water interaction in the Avon River catchment.	This is a study of the groundwater/surface water interaction in the lower Avon River catchment, which provided input to the management of the surface water and groundwater resources in the area. SKM prepared this report for the West Gippsland Catchment Management Authority and A Steering Committee of stakeholders.
GHD (2010a) West Gippsland CMA Groundwater Model. Interim steady-state model development report. Report prepared by GHD for the Department of Sustainability and Environment (DSE), Victoria.	The groundwater model was developed by GHD on behalf of DSE (now DELWP) as part of the ecoMarkets project. The intention of ecoMarkets projects were to use a groundwater model as a tool to assess the relative merits of improving native vegetation management and revegetation initiatives. The model's primary objective was to provide a tool for assessing the impacts of land use change on depth to water. Calibrated aquifer parameters are available for each of the formations in the model.
SKM (2012) Baseflow Separation Analysis for Unregulated Rivers (1889 to 2012)	The study completed a baseflow separation analysis for 180 stream gauges on unregulated rivers in Victoria Reference. Originally published on-line through the WMIS database, the dataset is now available through data.vic. The report is cited in Jacobs (2014). A copy of the original report is unavailable.
Beverly et al. (2015) The Gippsland groundwater Model, Onshore natural gas water science studies, DEDJTR.	The report describes the conceptualization, development, calibration and application of the Gippsland groundwater model.

Reports	Purpose of study
	The model was designed to assess impacts to groundwater resources from potential coal seam gas development. Calibrated regional aquifer parameters are available for each formation in the Gippsland Basin.
DELWP (2017) Victorian Water Accounts 2016 – 2017	The report presents annual information about the resources of the state of Victoria, reporting on volumes of surface water, groundwater and recycled water systems used and water available during the year.
CDMSmith (2017) Groundwater Data Inventory, Stocktake and Enhancement options	CDMSmith was commissioned by DEWLP to collate available data relating to four themes of groundwater recharge, aquifer/aquitard properties, groundwater use and aquifer/aquitard thickness into a database. The quality of the data was assessed through a data stocktake process. Enhancement methods were also considered for each data theme. A total of 65 studies were collated and the information was summarized into a spatial database.
CDMSmith (2018) Data Mapping – Aquifer properties and Recharge	CDMSmith was commission by DELWP to create visual products of recharge and aquifer properties for Victoria. Two products were developed – a high level communication tool to quickly inform a range of audiences of the variability in historical estimates and a finer resolution product for technical specialists to assess in future assessments of groundwater management.
GHD (2018) Groundwater Condition Reporting – Stage 4, September.	GHD developed a method to determine the Groundwater Resource Condition Assessment for DELWP. They key components of the approach was to adopt: • a representative Suite for reporting on groundwater resource condition and • predicted groundwater level as a means to compare against observation to qualitatively assess groundwater resource condition.

11.2.2 Key findings relevant to sustainable yield

Reid (2004) Audit of Permissible Annual Volumes for 35 Victorian Groundwater Management Areas

Reid (2004) conducted an internal audit of reports that estimated the PAVs in the Gippsland region, highlighting some limitations associated with the PAV assessment. Reid's comments regarding the methods used to calculate the PAV for the Wa De Lock GMA are summarised below:

- The rainfall recharge rates are subjective as reasoning was not provided.
- Lack of consideration of interaction with rivers, including recharge during high flow and reliance of rivers on baseflow during low flows.

- Calculations made using the hydrograph method were considered to be statistically weak due to only one bore being allocated per zone
- Overall lack of data regarding the geology of the GMA, aquifer potentiometry, and major recharge and discharge areas
- Lack of consideration for the aquifer storage, groundwater level trends, groundwater quality or risks.

RMCG (2008) Groundwater Economics

RMCG assessed the economic value of the Wa De Lock GMA and although groundwater is used for irrigation, the aquifer is not in the top 10 valuable aquifer for irrigation. RMCG determined that the GMA has a sleeper entitlement value of $2 million and $1.1 million value of stock and domestic purposes. Urban and commercial uses were determined to be of low economic value.

SKM (2009) Investigation of groundwater/surface water interaction in the Avon River catchment

SKM conducted a study of the groundwater/surface water interaction in the lower Avon River catchment, which lies within the eastern half of Wa De Lock GMA. The study focused on the lower alluvial plains where the rivers and creeks are typically gaining.

Baseflow separation was used to estimate the contribution of groundwater to rivers. During periods of average rainfall, baseflow to streams was estimated to be 24-36% of average annual flow in the Avon River and 17-25% of average annual flow in Freestone Creek.

The impact of groundwater extraction was also assessed and the results indicated a 1:1 relationship between volumes of groundwater pumped and reduction in streamflow. At the time of the study, the groundwater use was 3.6 GL/year, which reduced streamflow by 3.4 GL/year. This is equivalent to 4% of annual streamflow.

GHD (2010a) West Gippsland CMA Groundwater Model. Interim steady-state model development report.

GHDs 2010 groundwater model has been created for the West Gippsland CMA. The primary objective of the model is to provide a tool to assess the impacts of land use change on depth to water. Calibrated model aquifer parameters for aquifers in the Gippsland region were provided. The Wa De Lock GMA consists of shallow alluvium deposits in river flood plains, which are reported in model layer 3 as Quaternary sediments.

The hydraulic conductivity values determined using the calibrated model are provided in Table 7-1.

Table 11-3: Calibrated Hydraulic Conductivity Values

Model Layer	Hydrostratigraphic Unit	Kh (m/d)	Kv (m/d)
1	Haunted Hills Formation and Quaternary Sediments	2.01	4.21

* Kh = horizontal hydraulic conductivity; Kv = vertical hydraulic conductivity.

Beverly et al. (2015) The Gippsland groundwater Model, Onshore natural gas water science studies

The Gippsland Groundwater Model was developed to assess the potential impact of coal seam gas development on groundwater resources.

Calibrated model aquifer parameters for aquifers in the Gippsland region were listed for Quaternary deposits which const of coarse sand and gravel along the river valleys and flood plains of major rivers, such as Avon and Macalister rivers. A summary of the aquifer parameters used in the model are provided in Table 7-2.

Table 11-4: Calibrated model aquifer parameterisation.

Zone	Aquifer	Kxy (m/d)	Kz (m/d)	Specific yeild	Specific storage (m^{-1})	Kzz/Kxy
2	Quaternary	6.507	9.761×10^{-1}	0.1	1×10^{-5}	0.150
36	Quaternary	1.501×10^{-1}	2.009×10^{-2}	0.07	1×10^{-5}	0.134

DELWP (2017) Victorian Water Accounts 2016 – 2017

The Victorian Water Accounts report provides information on the usage and annual trends associated with water resources in the state of Victoria. To provide a consistent picture of water use across all GMA areas considered in this report we have reported the water usage figures from the most recent annual statement. Trends over two years do not necessarily represent the longer term trends, but are nevertheless considered instructive. Future assessment of the PCV should consider the full record of groundwater usage trends. The total licensed use volumes for the period of 2015 - 2017 are provided in the table below.

The groundwater level trends in the Wa De Lock GMA have been reported as stable between June 2016 and June 2017.

The latest published licensed groundwater volumes and use for the Wa De Lock GMA are described in Table 11-5.

Table 11-5: Licensed groundwater volumes and use

GMA	GMA aquifer depth limits (m)	Licensed entitlement (ML/year)	Total licensed groundwater use (ML) 2016-17	Total licensed groundwater use (ML) 2015-16
Wa De Lock GMA	<=25	29,140	6,984	7,201

GHD (2018) Groundwater Condition Reporting – Stage 4, September

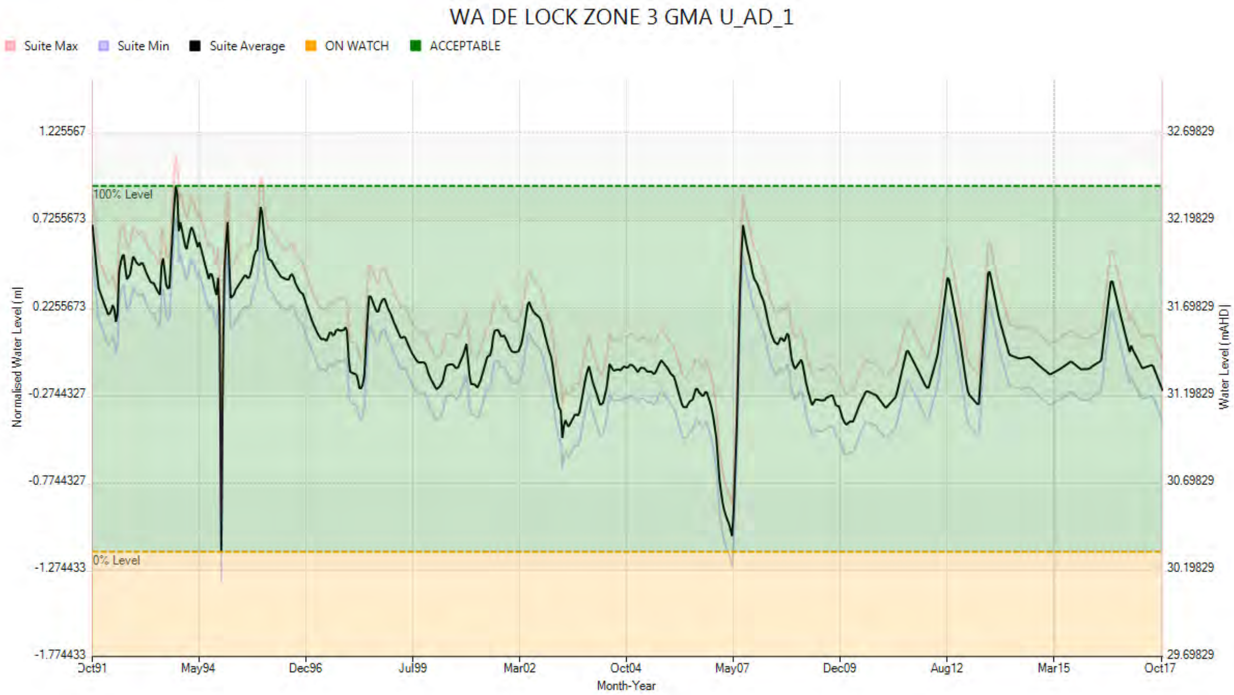
GHD developed a range of aquifer classification codes, which were used to represent groundwater level responses. Details of suite description, classification and suite hydrograph development and representative suite hydrograph for resource condition reporting can be found in (GHD 2014; GHD 2017; GHD 2018). The suites are grouped based on the aquifer monitored (upper, middle, lower or basement), suite code which is an alphabetic naming convention and fluctuation code which is a numerical identifier that indicates bores with similar magnitude in seasonal fluctuations (GHD, 2018). The suites to be reported for a particular GMU were selected based on the following:

- Suite representativeness (the proportion of the suite that occurs within the GMU must be spatially significant)
- Relevance of the aquifer layer (the unit the GMU is intended to manage)
- Spatial coverage of groundwater monitoring bores across a Suite or GMU
- Spatial coverage of groundwater extraction bores across the GMU
- Conceptualization considerations (improving the understanding of recharge processes, inter aquifer connectivity or aquifer leakage)

GHD determined that the Wa De Lock GMA is best represented by suite U_AD_1 which covers the upper aquifer. The area covered by the suite is shown in Figure 11-1Figure 5-1. The representative hydrograph for the aquifer classification is shown in Figure 11-2. The hydrograph shows that groundwater levels in U_AD_1 have been stable since 1998.

Figure 11-1: Location of suite U_AD_1 (GHD, 2018)

Figure 11-2: Wa De Lock Suite Chart for U_AD_1



11.3 Relevant matters for consideration

- Original PAV based on recharge from rainfall and had a low level of certainty. Recharge from rivers and discharge to rivers was not included and while Reid noted this, there was no attempt to estimate volumes. SKM (2009) indicated there is a 1:1 relationship between groundwater pumping and streamflow reduction, however the timing of when this impact occurs was not confirmed.

- No new information or analysis is available that improves the fundamental uncertainty associated with recharge.

- Use of groundwater from the GMA is likely to have a direct effect on stream flow, although no substantive work has been done to characterize this beyond the initial work in 2009. The areas of uncertainty highlighted by Reid remain essentially unresolved. Stream flows in this area are sensitive to changes and if impacts from groundwater are to be avoided this will provide a significant constraint on take and use from this system.

- This sustainable yield of the GMA is regarded as highly uncertain and vulnerable in the long term because of the likely changes in rainfall over time. Given the moderate value of the resource this is considered a medium priority for additional work.

- Additional work must focus on defining recharge areas, mechanisms and likely future trends, and characterizing the interaction with surface water.

12. Wy Yung GMA

The GMA includes the shallow alluvial aquifer system in the Mitchell River valley as far east as Bairnsdale (see Appendix A). The boundary of the GMA extends from Bairnsdale about 26 km to the west. The southern boundary is formed by Dargo Rd and Princes Highway as far as Bairnsdale East. The eastern boundary extends along the Omeo Highway from Bairnsdale East to just north of Lucknow and the northern boundary is located north of Lucknow. The GMA is divided into three zones (Figure 12-1: Wy Yung GMA Zone Distribution.).

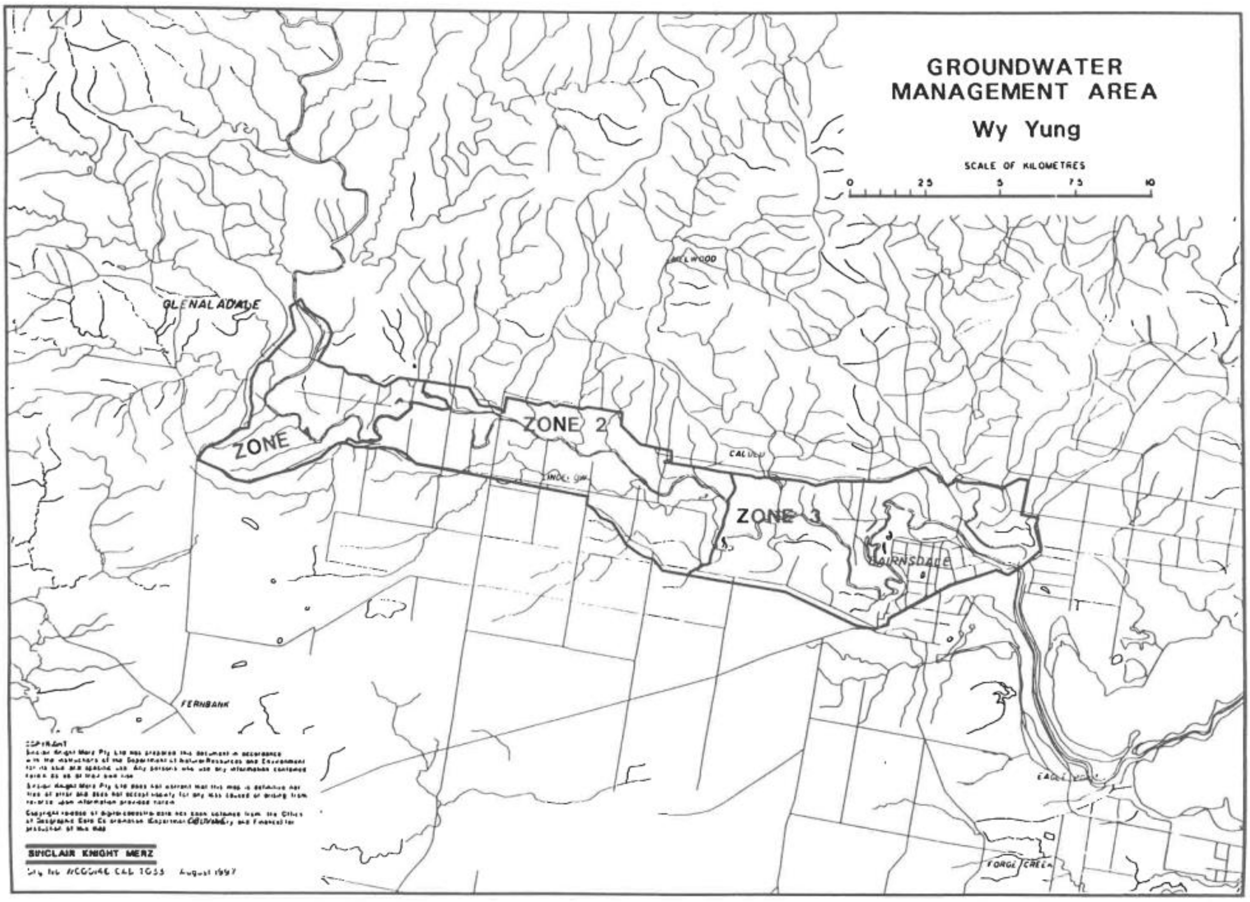


Figure 12-1: Wy Yung GMA Zone Distribution.

12.1 Original PAV estimate method

The original PAV assessment for the Wy Yung GMA was conducted by SKM (1998h). The PAV was calculated for the whole GMA after which a PAV for each zone was appointed on a pro rata areal basis.

The rainfall recharge method used an area of 92 km^2, with an annual rainfall volume of 725 mm/year and 15% aquifer infiltration rate. The volume of rainfall recharge was determined to be 10,038 ML/year. The relatively high percentage of 15% has been used to incorporate an additional 10% of irrigation which infiltrated to the aquifer.

Zone 2 of the Wy Yung GMA has an extensive network of observation bores in the shallow aquifer system, with limited number of bores available in Zone 1 and no observation bores in Zone 3. The hydrograph fluctuation method used two bores (80761 and 80762). The recharge rate was calculated to be 19,845 ML/year. Other parameters used are summarised in Table 12-1. The calculations refer to Bore 1 and 2, although the Bore IDs are not specified.

Table 12-1: Summary of parameters used to estimate aquifer recharge through hydrograph fluctuation

Location	Median Annual Fluctuation (m)	Area (km^2)	Adopted Storage	Median Annual Recharge (ML/year)
Bore 1	2.5	46	0.1	11,538
Bore 2	1.8	46	0.1	8,307
Total				19,845

Recharge and discharge from rivers were also calculated. Recharge from rivers was assumed to occur from a 37 km reach (assuming Mitchell River was used, however not stated in calculations). Darcy's Law was used to calculate the volume of recharge using the following parameters:

- Vertical hydraulic gradient of 0.0014
- Conductivity of near river sediments was 30 m/day

The total recharge from rivers was estimated to be 5,788 ML/year.

Discharge to rivers was calculated using the same method for a 6 km reach. The following parameters were used:

- Vertical hydraulic gradient of -0.0017 (negative is a loss from the aquifer)
- Conductivity of near river sediments was 30 m/day

The total discharge to rivers was estimated to be 939 ML/day.

The overall PAV was determined as follows:

Rainfall recharge – discharge to rivers = PAV

10,038 – 939 = 9,099 ML/year

The PAV appointed to each zone is:

- Zone 1 – 1,873 ML/year
- Zone 2 – 3,214 ML/year
- Zone 3 – 4,012 ML/year

The PAV for Wy Yung was calculated as 9,099 ML/year. The PAV was decreased to 7,463 ML/year in 2011, to match licensed entitlements.

Recent unpublished work held by DEWLP suggests that the conceptual model for this area may require significant revision.

12.2 Subsequent New or Local Studies

12.2.1 List of Studies and Reports

Reports	Purpose of study
GHD (2008) East Gippsland Water, Hydrogeological Assessment to Support License Application (BCL 9030173), July 2008.	GHD was engaged by the holder of the BCL 9030173 license to undertake a hydrogeological assessment to support a Groundwater License Application for critical urban supply during periods of low flows in the Mitchell River. The report characterises the site, its geological and hydrogeological setting and identifies the current level of groundwater usage in the area.
RMCG (2008) Groundwater Economics. For Department of Sustainability and Environment (DSE) 29 August 2008	This study was completed for the Department of Sustainability and Environment (now DELWP) with the objective of developing an updated approach and revised analysis to improve the understanding of the economic value of groundwater to support future policy and management practices. The study quantified the overall economic value in terms of support irrigation, urban water supply, commerce and industry, stock and domestic and sleeper and unallocated entitlements.
SKM (2009) Investigation of groundwater/surface water interaction in the Avon River catchment.	This is a study of the groundwater/surface water interaction in the lower Avon River catchment, which provided input to the management of the surface water and groundwater resources in the area. SKM prepared this report for the West Gippsland Catchment Management Authority and A Steering Committee of stakeholders.
GHD (2010a) West Gippsland CMA Groundwater Model. Interim steady-state model development report. Report prepared by GHD for the Department of Sustainability and Environment (DSE), Victoria.	The groundwater model was developed by GHD on behalf of DSE (now DELWP) as part of the ecoMarkets project. The intention of ecoMarkets projects were to use a groundwater model as a tool to assess the relative merits of improving native vegetation management and revegetation initiatives. The model’s primary objective was to provide a tool for assessing the impacts of land use change on depth to water. Calibrated aquifer parameters are available for each of the formations in the model.
SKM (2012) Baseflow Separation Analysis for Unregulated Rivers (1889 to 2012)	The study completed a baseflow separation analysis for 180 stream gauges on unregulated rivers in Victoria Reference. Originally published on-line through the WMIS database, the dataset is now available through data.vic. The report is cited in Jacobs (2014). A copy of the original report is unavailable.

Reports	Purpose of study
Beverly et al. (2015) The Gippsland groundwater Model, Onshore natural gas water science studies, DEDJTR.	The report describes the conceptualization, development, calibration and application of the Gippsland groundwater model. The model was designed to assess impacts to groundwater resources from potential coal seam gas development. Calibrated regional aquifer parameters are available for each formation in the Gippsland Basin.
DELWP (2017) Victorian Water Accounts 2016 – 2017	The report presents annual information about the resources of the state of Victoria, reporting on volumes of surface water, groundwater and recycled water systems used and water available during the year.
CDMSmith (2017) Groundwater Data Inventory, Stocktake and Enhancement options	CDMSmith was commissioned by DEWLP to collate available data relating to four themes of groundwater recharge, aquifer/aquitard properties, groundwater use and aquifer/aquitard thickness into a database. The quality of the data was assessed through a data stocktake process. Enhancement methods were also considered for each data theme. A total of 65 studies were collated and the information was summarized into a spatial database.
CDMSmith (2018) Data Mapping – Aquifer properties and Recharge	CDMSmith was commission by DELWP to create visual products of recharge and aquifer properties for Victoria. Two products were developed – a high level communication tool to quickly inform a range of audiences of the variability in historical estimates and a finer resolution product for technical specialists to assess in future assessments of groundwater management.
GHD (2018) Groundwater Condition Reporting – Stage 4, September.	GHD developed a method to determine the Groundwater Resource Condition Assessment for DELWP. They key components of the approach was to adopt a representative Suite for reporting on groundwater resource condition and predict groundwater level as a means to compare against observation to qualitatively assess groundwater resource condition.

12.2.2 Key findings relevant to sustainable yield

GHD (2008) East Gippsland Water, Hydrogeological Assessment to Support License Application (BCL 9030173)

GHD was engaged by the holder of the BCL 9030173 license to undertake a hydrogeological assessment to support a Groundwater License Application for critical urban supply during periods of low flows in the Mitchell River. The bores intersected the Latrobe Valley Group aquifer, which underlies the shallow Quaternary aquifers in the Wy Yung GMA.

The following characteristics were obtained for the Quaternary sediments:

- Hydraulic conductivity of 0.1 to 50 m/day
- Specific yield of 0.05
- Aquifer thickness is assumed to be the upper 25 m, which extends to 30 m at Woodglen
- Groundwater levels respond seasonally to river stage height ad may range from 5 to 10 m below ground level
- A significant number of private bores are screened in the aquifer and use groundwater for irrigation, stock and domestic supply
- Rainfall recharge is estimated as 667 ML/year at 8% aquifer infiltration rate.

The study focused on the Latrobe Valley Group aquifer which is outside the Wy Yung GMA boundary. Rainfall recharge to the Latrobe Valley Group aquifer may occur where the aquifer subcrops against basement along the western and northern margin of river flats. The rate of rainfall recharge has been calculated as 420 ML/year to 620 ML/year. The total surface water seepage from the Mitchell River and tributaries in the Wooden – Glenaladale area to the Latrobe Valley Group aquifer has been estimated as 100 to 200 ML/year. This constitutes of 0.5 to 1% of annual surface water flows. The calculated through flow volume for the aquifer is 876 ML/year.

RMCG (2008) Groundwater Economics

RMCG assessed the economic value of the Wy Yung GMA and determined that the Wy Yung GMA was not classified as high in terms of irrigation, urban water supply commerce/industry or power generation. The total use of the GMA was valued at approximately $1,200,000.

GHD (2010a) West Gippsland CMA Groundwater Model. Interim steady-state model development report.

GHDs 2010 groundwater model has been created for the West Gippsland CMA. The primary objective of the model is to provide a tool to assess the impacts of land use change on depth to water. Calibrated model aquifer parameters for aquifers in the Gippsland region were provided. The Wy Yung GMA consists of shallow alluvium deposits in river flood plains, which are reported in model layer 1 as Quaternary sediments.

The hydraulic conductivity values determined using the calibrated model are provided in Table 7-1.

Table 12-2: Calibrated Hydraulic Conductivity Values

Model Layer	Hydrostratigraphic Unit	Kh (m/d)	Kv (m/d)
1	Haunted Hills Formation and Quaternary Sediments	2.01	4.21

* Kh = horizontal hydraulic conductivity; Kv = vertical hydraulic conductivity.

Beverly et al. (2015) The Gippsland groundwater Model, Onshore natural gas water science studies

The Gippsland Groundwater Model was developed to assess the potential impact of coal seam gas development on groundwater resources.

Calibrated model aquifer parameters for aquifers in the Gippsland region were listed for Quaternary deposits which const of coarse sand and gravel along the river valleys and flood plains of major rivers, such as Avon and Macalister rivers. A summary of the aquifer parameters used in the model are provided in Table 7-2.

Table 12-3: Calibrated model aquifer parameterisation.

Zone	Aquifer	Kxy (m/d)	Kz (m/d)	Specific yeild	Specific storage (m^{-1})	Kzz/Kxy
2	Quaternary	6.507	9.761×10^{-1}	0.1	1×10^{-5}	0.150

DELWP (2017) Victorian Water Accounts 2016 – 2017

The Victorian Water Accounts report provides information on the usage and annual trends associated with water resources in the state of Victoria. To provide a consistent picture of water use across all GMA areas considered in this report we have reported the water usage figures from the most recent annual statement. Trends over two years do not necessarily represent the longer term trends, but are nevertheless considered instructive. Future assessment of the PCV should consider the full record of groundwater usage trends. The total licensed use volumes for the period of 2015 - 2017 are provided in the table below

The groundwater level trends in the Wy Yung GMA have been reported as stable between June 2016 and June 2017. The latest published licensed groundwater volumes and use for the Wy Yung GMA are described in Table 12-4.

Table 12-4: Licensed groundwater volumes and use

GMA	GMA aquifer depth limits (m)	Licensed entitlement (ML/year)	Total licensed groundwater use (ML) 2016-17	Total licensed groundwater use (ML) 2015-16
Wa De Lock GMA	<=25	7,462	560	414

GHD (2018) Groundwater Condition Reporting – Stage 4, September

GHD developed a range of aquifer classification codes, which were used to represent groundwater level responses. Details of suite description, classification and suite hydrograph development and representative suite hydrograph for resource condition reporting can be found in (GHD 2014; GHD 2017; GHD 2018). The suites are grouped based on the aquifer monitored (upper, middle, lower or basement), suite code which is an alphabetic naming convention and fluctuation code which is a numerical identifier that indicates bores with similar magnitude in seasonal fluctuations (GHD, 2018). The suites to be reported for a particular GMU were selected based on the following:

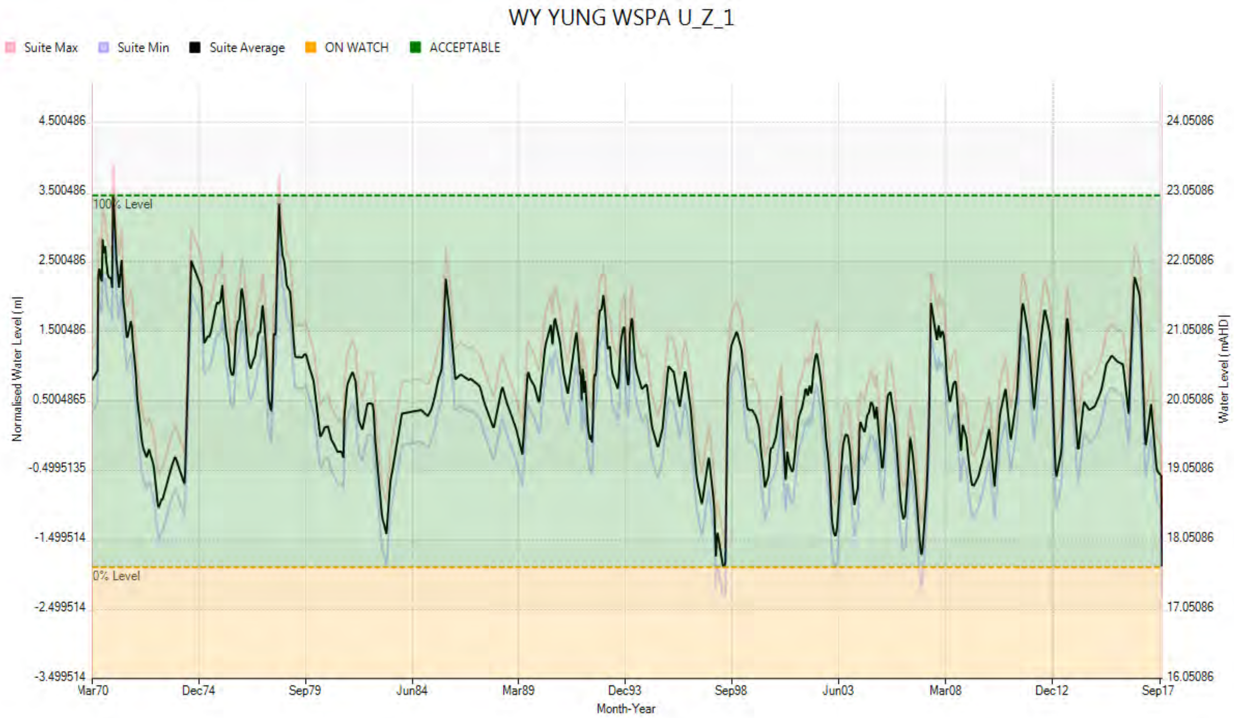
- Suite representativeness (the proportion of the suite that occurs within the GMU must be spatially significant)
- Relevance of the aquifer layer (the unit the GMU is intended to manage)
- Spatial coverage of groundwater monitoring bores across a Suite or GMU
- Spatial coverage of groundwater extraction bores across the GMU
- Conceptualization considerations (improving the understanding of recharge processes, inter aquifer connectivity or aquifer leakage)

GHD determined that the Wy Yung WSPA is best represented by suite U_Z_1 which covers the upper aquifer. The area covered by the suite is shown in Figure 12-2Figure 5-1. The representative hydrograph for the aquifer classification is shown in

Figure 12-3. The hydrograph shows that groundwater levels in U_Z_1 have been stable since 1974.

Figure 12-2: Location of suite U_Z_1 (GHD, 2018)

Figure 12-3: Wy Yung Suite Chart for U_Z_1



12.3 Relevant matters for consideration

- This aquifer is dependent on rainfall recharge and is highly linked to stream flows.
- The risks to groundwater use are large, given the basis of assumptions on recharge rates.
- The current conceptual model has been questioned and requires formal review
- A systematic study of recharge would be needed to define resource.
- Is a relatively small resource.
- Low priority for further assessment at this time and likely that the sustainable yield would be lowered upon review.

13. Yarram

13.1 Original PAV estimate method

The current Yarram Water Supply Protection Area (WSPA) falls within the boundary of the old Seacombe GMA. The old Seacombe GMA applies to the Latrobe Group aquifer system which is currently managed as the Yarram WSPA and Stratford GMA. The Yarram WPSA covers the southern half and the Stratford GMA the northern half. The Yarram GMA lies beneath the Giffard GMA which applies to the overlying Quaternary and Tertiary aquifers (see Appendix A).

SKM (1998) completed an assessment of the PAV for the Latrobe aquifer of the Seacombe GMA. This assessment is described in the context of the whole Latrobe Group aquifer and is not specific to Yarram only, due to the Yarram GMA being established later. The PAV for the Latrobe Group aquifer was determined using the aquifer throughflow method. A value of 100,000 ML/year was calculated by Walker and Mollica (1990) however the details of study were not available at the time of this study. SKM (1998) noted that 80,000 ML/year of the 100,000 ML/year of recharge occurred south of the Baragwanath Anticline and the areas west of Yarram. SKM (1998) suggested that this PAV calculation is an overestimate and that the groundwater extraction volume from the Latrobe Group exceeded the recharge rate.

13.1.1 Yarram Water Supply Protection Area

The Yarram Water Supply Protection Area (YWSPA) was declared in 2002 (Victorian Government Gazette G50, 12 Dec 2002). The YWSPA extends from Port Welshpool in the south-west to Golden Beach in the north-east. It is declared to manage groundwater extractions from the Latrobe Group aquifer and the Balook Formation, however also includes aquifers belonging to the Latrobe Valley Coal Measures, and the Boisdale Formation where the Boisdale Formation is outside of the Giffard GMA (SKM, 2004a).

Recharge to the aquifer occurs through vertical leakage, from the Balook Formation to the Latrobe Group and through direct infiltration where the Latrobe Group outcrops or is closely connected to the surficial units (SKM, 2004a). The total allocations in the WSPA were equal to 26,234 ML/year. At the time of the SKM (2004a) study the total allocations in the WSPA were equal to 26,234 ML/year. However, PAV 26,625 ML/yr was reported in the State Water Report 2003-2004. A 25,317 ML/yr PCV was declared in the PCV Order 2008, combined PCV for zone 1 (all formations below 200mbns) and zone 2 (all formations below natural surface). PCV amended to 25,690 ML/yr in PCV Order 2013, with total entitlement of 25,689ML reported in VWA 2016-17.

The Yarram WSPA has had long term continuous decline in groundwater water levels. This is due to a combination of groundwater extraction for offshore oil production and onshore irrigation. In 2005, SKM recommended that no further licenses be issued and that the PCV should be set at the volume of licensed entitlements, which at the time was 25,317 ML/year (SRW, 2008b).

13.2 Subsequent New or Local Studies

13.2.1 List of Studies and Reports

Reports	Purpose of study
SKM (2000b) Assessment of Survey Options for Recommencement of Monitoring	SKM was commissioned by the Department of Natural Resources and Environment (DNRE, now DELWP) to review the requirements for survey monitoring of land surface elevations in the Gippsland Basin to monitor land subsidence. The aim was to review previously undertaken survey monitoring in 1990 to 1996 and to make recommendations on recommencing the program.

Reports	Purpose of study
SKM (2001b) Risk Analysis for Possible Subsidence Along the Gippsland Coast. Department of Natural Resources and Environment, Final Report, Revised May 2001.	This study was commissioned by DNRE to prepare a risk analysis evaluating three scenarios with regards to subsidence in the Gippsland Coast. The three cases analysed included a no intervention case, a wait and see case, and a proactive investigations case. COMPAC modeling was used to perform the analysis.
SKM (2001c) Gippsland Subsidence Modelling – Yarram. Department of Natural Resources and Environment. September 2001.	SKM prepared a report for the DNRE calculating subsidence in the Gippsland region, particularly Yarram. The Alberton East 3 bore was chosen for the study from a number of bores for which borelogs were available.
SKM (2001d) Gippsland Declining Levels: Impacts on Yarram Irrigators, October 2001. For Department of Natural Resources and Environment. October 2001.	SKM were engaged to undertake an assessment of the impact of declining groundwater levels on irrigators in the Yarram region of south east Gippsland. The objective of the study was to provide information to make management decisions regarding the impact of declining groundwater levels on irrigators.
SKM (2004a) Yarram Water Supply Protection Area – Background Technical Information for the Yarram Water Supply Protection Areas. For Department of Sustainability and Environment (DSE) March 2004.	This study was completed for the Department of Sustainability and Environment (now DELWP). The report provides background technical information to understand the relevant management issues that need to be considered in the development of a management plan for the Yarram Water Supply Protection Area.
SKM (2004b) Yarram Artificial Recharge Study, Feasibility Assessment. Southern Rural Water. May 2004	SKM were engaged by Southern Rural water on behalf of Water for Growth Committee to undertake an assessment of the feasibility of artificial recharge as a means for mitigating the decline in groundwater levels in the Yarram WSPA.
SKM (2004c) Paper No. 1: The Yarram WSPA Boundary.	SKM prepared the paper to refine the existing Yarram WSPA boundary, determine new depth boundaries and inform a management recommendation for the WSPA.
SKM (2004d) Paper No. 2: Seawater Intrusion in the Yarram WSPA.	SKM prepared the paper to determine the likelihood of seawater intrusion in the Yarram WSPA, develop options to address and manage the problem and to establish a monitoring program to further investigate the matter.
SKM (2004e) Paper No. 3: Groundwater and Stream flow Interaction in the Yarram WSPA.	This study provides a summary of the relevant issues on groundwater and stream flow interaction in the Yarram WSPA, including background and technical information, options to address the issues and recommendations on further investigations.
SKM (2004f) Paper No.4: Artificial recharge in the Yarram WSPA.	This study provides an overview of existing information on artificial recharge in the Yarram WSPA and provides a

Reports	Purpose of study
	summary of the relevant issues, background and technical information and recommendations for further investigation. The impacts associated with declining water levels are summarised as loss of artesian conditions, increased pumping costs, lowering of pumps and decommissioning of bores once groundwater levels drops below their maximum depth.
SKM (2004g) Paper No. 5: Land Subsidence in the Yarram Region.	This paper summarises the issues related to land subsidence in the Yarram WSPA region, including background and technical information, options to address the issues and recommendations on further investigations.
SKM (2004h) Paper No. 6: Local Bore interference in the Yarram Region.	This paper examines the issue of local bore interference in the Yarram region by defining local bore interference in relation to other types of interference in the region, and by examining bore density, usage, allocation and construction details.
SKM (2004i) Paper No. 7: Policy options for groundwater allocation and trading in the Yarram WSPA.	This paper critically reviews the interim arrangement for the Yarram WSPA and determines whether new allocations can be justified.
SKM (2005) Assessment of Potential Groundwater Decline Induced Changes in Tarra River Baseflow.	The WGCMA engaged SKM to prepare an assessment of the depletion of stream flow of the Tara River and its tributary stream due to falling groundwater levels, including potential future impacts.
SKM (2006a) Tara River REALM Development Estimation of Daily Flows, July 2006.	SKM developed a Resource Allocation Model for the Tarra River and prepared historic, current, unimpacted an fully impacted daily stream flow series.
SKM (2006b) Tara River Environmental Flows Assessment, September 2006.	SKM conducted an environmental flows assessment to determine the environmental flow requirements for the Tara River and its tributaries.
RMCG (2008) Groundwater Economics. For Department of Sustainability and Environment (DSE) 29 August 2008	This study was completed for the Department of Sustainability and Environment (now DELWP) with the objective of developing an updated approach and revised analysis to improve the understanding of the economic value of groundwater to support future policy and management practices. The study quantified the overall economic value in terms of support irrigation, urban water supply, commerce and industry, stock and domestic and sleeper and unallocated entitlements.
GHD (2010a) West Gippsland CMA Groundwater Model. Interim steady-state model development report. Report	The groundwater model was developed by GHD on behalf of DSE (now DELWP) as part of the ecoMarkets project. The intention of ecoMarkets projects were to use a groundwater

Reports	Purpose of study
prepared by GHD for the Department of Sustainability and Environment (DSE), Victoria.	model as a tool to assess the relative merits of improving native vegetation management and revegetation initiatives. The model's primary objective was to provide a tool for to assessing the impacts of land use change on depth to water. Calibrated aquifer parameters are available for each of the formations in the model.
Southern Rural Water (2010) Groundwater Management Plan, Yarram Water Supply Protection Area.	The management plan has been prepared under the Water Act 1998 for the Yarram Water Supply Protection Area. The objective of the management plan is to ensure that resources of the Yarram area are managed in a sustainable manner.
SKM (2012) Baseflow Separation Analysis for Unregulated Rivers (1889 to 2012)	The study completed a baseflow separation analysis for 180 stream gauges on unregulated rivers in Victoria Reference. Originally published on-line through the WMIS database, the dataset is now available through data.vic. The report is cited in Jacobs (2014). A copy of the original report is unavailable.
Southern Rural Water (2014) Seaspray Groundwater Catchment Statement, January 2014.	Groundwater Catchments were introduced in Victoria to capture the full extent of connected groundwater resources. Catchment Statements were prepared for all groundwater catchments as a first step towards developing a complete picture of the current groundwater management. This document captures all the plans affecting the licensed use of groundwater in the Seaspray Groundwater Catchment, including Water Supply Protection Area and Groundwater Management Areas exist within the catchment. The objective of the report is to begin to simply management of groundwater throughout the catchment and enable users to get access to water for future development. The Catchment Statement provides a high-level understanding of the regional hydrogeology and local groundwater management plans for each GMA and WSPA.
Beverly et al. (2015) The Gippsland groundwater Model, Onshore natural gas water science studies, DEDJTR.	The report describes the conceptualization, development, calibration and application of the Gippsland groundwater model. The model was designed to assess impacts to groundwater resources from potential coal seam gas development. Calibrated regional aquifer parameters are available for each formation in the Gippsland Basin.
DELWP (2017) Victorian Water Accounts 2016 – 2017.	The report presents annual information about the resources of the state of Victoria, reporting on volumes of surface water, groundwater and recycled water systems used and water available during the year.
CDMSmith (2017) Groundwater Data Inventory, Stocktake and Enhancement options	CDMSmith was commissioned by DEWLP to collate available data relating to four themes of groundwater recharge,

Reports	Purpose of study
	aquifer/aquitard properties, groundwater use and aquifer/aquitard thickness into a database. The quality of the data was assessed through a data stocktake process. Enhancement methods were also considered for each data theme. A total of 65 studies were collated and the information was summarized into a spatial database.
CDMSmith (2018) Data Mapping – Aquifer properties and Recharge	CDMSmith was commission by DELWP to create visual products of recharge and aquifer properties for Victoria. Two products were developed – a high level communication tool to quickly inform a range of audiences of the variability in historical estimates and a finer resolution product for technical specialists to assess in future assessments of groundwater management.
GHD (2018) Groundwater Condition Reporting – Stage 4, September.	GHD developed a method to determine the Groundwater Resource Condition Assessment for DELWP. They key components of the approach was to adopt a representative Suite for reporting on groundwater resource condition and predict groundwater level as a means to compare against observation to qualitatively assess groundwater resource condition.

13.2.2 Key findings relevant to sustainable yield

SKM (2000b) Assessment of Survey Options for Recommencement of Monitoring

SKM was commissioned by DNRE to review the requirements for survey monitoring of land surface elevations in the Gippsland Basin to monitor land subsidence. The aim was to review previously undertaken survey monitoring in 1990 to 1996 and to make recommendations on recommencing the program.

The monitoring program was developed to monitor land subsidence over a 5-year timeframe, whilst also being cost effective, have suitable accuracy and be reliable and flexible. Given this, the following criteria were set for the monitoring network:

- Subsidence rates of 5 mm/year were considered negligible and not required to be detected within the 5-year observation period
- The program must recognise the potential for the subsidence rate to dramatically increase should reconsolidation stresses on the basin sediments be exceeded
- The design life of the network is at least 20 years and subsidence detection is required at the 90th percentile confidence level

Subsidence is a potential constraint on use in this area and needs to be considered in any PCV assessment.

SKM (2001b) Risk Analysis for Possible Subsidence Along the Gippsland Coast. Department of Natural Resources and Environment, Final Report, Revised May 2001.

DNRE requested that SKM prepare a risk analysis evaluating three scenarios with regards to subsidence in the Gippsland Coast. The three cases analysed included a No Intervention case, a Wait and See case, and a Proactive Investigations case. The No Invention case involves continued monitoring. The Wait and See case and the Proactive Investigations case, considered remedial actions (ie artificial recharge into the aquifer) that could be implemented to offset potential subsidence. For the Wait and See case remedial actions were assumed to be introduced when subsidence exceeded 0.1 m and for the Proactive Investigations case, remedial actions were implemented immediately.

The predicted band of subsidence from this study was predicted to be of “no concern” (i.e. subsidence has been eliminated as an issue), or of “great concern” (ie serious planning of mitigation options should begin). To understand the risks, a risk management investigation program was recommended.

SKM (2001c) Gippsland Subsidence Modelling – Yarram. Department of Natural Resources and Environment. September, 2001.

SKM prepared a report for DNRE calculating subsidence in the Gippsland region, particularly Yarram, using the Alberton East 3 bore. The results indicated that there is a 10% chance that subsidence will exceed 800 mm by the time offshore oil and gas production will cease operation by 2023. There is a 90% chance that subsidence will not exceed 1 m at the locations of the Alberton East No.3 bore. The study also suggested that there is a greater risk of subsidence along the margins of the basin where the Latrobe Group sediments are shallower and thinner. It is noted that parameters used to develop the subsidence simulation model are poorly constrained so there is significant uncertainty in the predicted results. Significant lowering of ground surface may have implications for land use. As this effect is from off-shore extraction which is not controlled by the water regulations, the ongoing take from the aquifer must be allowed for in any PCV determination.

SKM (2001d) Gippsland Declining Levels: Impacts on Yarram Irrigators, October 2001.

SKM were engaged to undertake an assessment of the impact of declining groundwater levels on irrigators in the Yarram region of south east Gippsland. The objective of the study was to provide information to make management decisions regarding the impact of declining groundwater levels on irrigators.

The rate of decline across the Latrobe Group aquifer, Balook Formation and Boisdale Formations was 1.1 m/year, 0.55 m/year and 0 m/year, respectively. An analysis was undertaken to determine the impacts of declining groundwater levels on irrigators. The analysis showed that most bores are expected to require their pumps to be lowered and be replaced sometime in the next 30 years since the completion of the study. The analysis did not include 14 bores which were located in the Boisdale Formation since the water levels in the formation were considered to be stable. The total cost of declining water levels was calculated as $5.9M ($3.8M PV at time of study), with an upper bound of $6.9M ($4.7M PV) and a lower band of $5.7M ($3.2M PV), for transmissivities of 600, 325 and 1125 m^2/day. A readjustment package was approved for this area to allow for the declines. This should be considered when setting any revised yield.

SKM (2004b) Yarram Artificial Recharge Study, Feasibility Assessment. Southern Rural Water. May 2004

SKM was engaged by Southern Rural water on behalf of Water for Growth Committee to undertake an assessment of the feasibility of artificial recharge as a means for mitigating the decline in groundwater levels in the Yarram WSPA.

The findings of the feasibility assessment highlighted that artificial recharge of 4,000 ML/year and 10,000 ML/year using injection wells would be required to stabilise the declining levels over a 5 km radius for 8 years and 20 years, respectively. Artificial recharge using spreading basins was considered inefficient for the Latrobe Group aquifer given the limited areas of outcrop.

The key constraint to artificial recharge was considered to be the lack of surface water availability, with only 1,122 ML/year being determined as the Sustainable Diversion Limit. Another constraint was the costs associated with artificial recharge. Artificial injection of 4,000 ML/year and 10,000 ML/year was estimated as $27M and $51M for winter only operation and $37M and $71M for continuous operation. This option may warrant further assessment looking for alternate water sources, which would influence any PCV review.

Several benefits of artificial recharge were identified including:

- Prevention of sea water intrusion into the Latrobe Group Aquifer
- Reduction in the potential loss of baseflow in approximately 46 km of rivers and streams that cross the Latrobe Group recharge area between the Tara River and Binginwarri
- Reduction in the sea water intrusion along the main rivers of the region during the summer months

The following parameters for the Latrobe aquifer were used in the feasibility assessment:

- Average transmissivity adopted was 600 m^2/day
- Recharge from Tara River was estimated as 1,400 ML/year using a gradient of 0.004, hydraulic conductivity of river bed of 0.5 m/day and an aquifer thickness of 130 m
- The potential seepage from dams is estimated to be between 0.2 ML/day – 10 ML/day
- The cost of artificial recharge was found to be between $5,000/ML and $9,000/ML, with continuous injection being 30% more costly than winter only injection due to high storage costs.

SKM (2004a) Yarram Water Supply Protection Area - Background Technical Information for the Yarram Water Supply Protection Areas.

The report provides background technical information for the Yarram Water Supply Protection Area. It covers the geology and hydrogeology of the area, groundwater license and use, and groundwater resource management issues. The following findings are presented:

- There has been significant aquifer depressurization in the Latrobe Group aquifer as a result of groundwater extraction for irrigation around Yarram, groundwater extraction for industrial purposes at Esso and offshore gas extraction.
- Historically there was an upward gradient from the Latrobe Group aquifer to the overlying Balook aquifer, however aquifer depressurization has reversed this gradient, so there is now a downward gradient from the Balook aquifer to Latrobe Group aquifer.
- Observed groundwater levels demonstrate that the average declining trend for the Latrobe Group is of 1.1 m/year, and 0.55 m/year for the Balook Formation aquifers.
- Potential impacts of aquifer depressurization and declining groundwater levels were highlighted to include changes to existing bore and pump infrastructure, sea water intrusion, subsidence, loss of water supply for irrigators and other domestic and stock users, bore interference and groundwater dependent ecosystems.
- Costs associated with upgrading existing infrastructure were estimated to be between $6 and $8 million.
- Recharge volumes were calculated based on recharge rates ranging between 2 and 10% of rainfall (assumed to be 800 mm/year) depending on the land use. Recharge volumes were estimated to be around 39,000 ML/year under steady-state conditions (assuming no onshore or offshore extraction) and this increased to around 68,000 ML/year. The areas used were not presented in the report.
- Artificial recharge was considered to be technically feasible, but not economically feasible
- Subsidence has been estimated theoretically by SKM in the early 2000s (SKM, 2000b, 2001b, 2001c), however a lack of field-based subsidence investigations was noted so many assumptions

were untested. The existing land surface monitoring was recommended to be upgraded in 2000, and it is not known if this was undertaken.

- Environmental impacts including a loss of baseflow to 46 km of rivers and streams that flow over the Latrobe Group recharge areas at the base of the Strzelecki ranges (SKM, 2004b).
- Further work was recommended to meter licensed bores, continue monitoring private bores, numerical modelling to enable the assessment of groundwater management options, refurbish and replace state observation bores, undertake long term land level monitoring and assess sea water intrusion north east of Welshpool.

SKM (2004c) Paper No. 1: The Yarram WSPA Boundary.

This paper refined the existing Yarram WSPA boundary, depth boundaries and confirm which licensed bores will be in the revised Yarram WSPA.

The lateral boundaries were revised to exclude the area where the Cretaceous Strzelecki Group outcrops, as they do not represent a viable groundwater resource; include the islands off the south coast to protect the groundwater resources in the region in the future and align the lateral extent of the WSPA along the property (cadastral) boundaries in the region.

The depth boundaries were revised to include all depths in the areas along the western boundary to protect recharge areas where the Latrobe Group outcrops and depths greater than 200 m in areas underlying the Giffard GMA.

The revised depth boundary did not result in the removal of any irrigation bores screened in the Latrobe Group or Balook Formation.

SKM (2004d) Paper No. 2: Seawater Intrusion in the Yarram WSPA.

This paper determined the likelihood of seawater intrusion in the Yarram WSPA, develop options to address and manage the problem and establish a monitoring program to further investigate the matter.

The study found that the declining groundwater levels across the Yarram region impose an increased risk to sweater intrusion. To monitor long term trends in salinity and groundwater levels in the Latrobe Group aquifer, it was recommended to install additional monitoring bores between Port Albert and Port Welshpool screened in the Latrobe Group.

SKM highlighted the need to address short-term management issues prior to implementing long-term management changes. To address short-term management issues it was necessary to identify the area at risk, impose limitations on further allocation and trading, increase the seawater intrusion monitoring network and assess the need to limit groundwater extraction.

SKM (2004e) Paper No. 3: Groundwater and Stream flow Interaction in the Yarram WSPA.

This paper provides a summary of the relevant issues on groundwater and stream flow interaction in the Yarram WSPA, including background technical information, options to address the issues and recommendations on further investigations.

The study summarises the recharge mechanisms for the Latrobe Group aquifer. Vertical recharge occurs via leakage from the Balook Formation to the Latrobe Group, and other recharge areas are where the Latrobe Group outcrops, such as the margins of the Gippsland Basin, edges of the Strzelecki ranges and the high country between Traralgon and Seaspray.

Information regarding the surface water features in the WSPA details the demand for water from the Tara River ranging from 2.5 ML to 10 ML/day at certain monitoring sites. The study suggests that although the

Latrobe Group is a confined aquifer and the system does not interact with surface water, the regional declining groundwater levels may in time lead to a decrease in water levels in shallow aquifers.

The recommendations for management options were as follows:

- Installation of additional observation bores in the recharge zone across the Latrobe Group aquifer adjacent to streams, to collect and analyse groundwater and stream flow monitoring data. At the time of the paper, there were no observation bores installed in the Latrobe Group aquifer in the mapped recharge areas.

- Undertake trend analyses on base flows in rivers and streams in the Yarram WSPA to provide quantitative information regarding the influence of declining groundwater levels on base flow.

- Considerations to be made regarding modeling of the groundwater and stream interaction within the region.

SKM (2004f) Paper No.4: Artificial recharge in the Yarram WSPA.

SKM prepared the paper to review studies regarding artificial recharge in the Yarram WSPA to provide a summary of the relevant issues, background and technical information and recommendations for further investigation. The impacts associated with declining water levels are summarised as loss of artesian conditions, increased pumping costs, lowering of pumps and decommissioning of bores once groundwater levels drops below their maximum depth.

The findings of the SKM (2004) artificial recharge feasibility study were assessed and summarised. The SKM paper determined that the costs related to agriculture due to declining groundwater levels are too low to justify the cost required for artificial recharge in the Yarram WSPA.

SKM (2004g) Paper No. 5: Land Subsidence in the Yarram Region.

The paper summarized the issues related to land subsidence in the Yarram WSPA region, including background and technical information, options to address the issues and recommendations on further investigations.

The findings presented in the report regarding subsidence in the Yaram region overall suggest that there is a potential for significant land subsidence. The subsidence rates were difficult to estimate due to the lack of data required, such as the degree of consolidation of aquitards, the thickness of compressible materials and the extent of pressure declines. The summary of findings of two reports by SKM (2001b; 2001c) presented predicted subsidence rates of 300 mm would occur by 2023 and subsidence of 800 mm would occur by 2023. Both studies concluded that more information is required.

The following recommendation were presented in the paper:

- Ensure the subsidence-monitoring network is of sufficient accuracy and duration to determine whether any subsidence is occurring

- Gain additional information about the physical properties of the basin sequence likely to be subject to compaction

- Undertake regular monitoring of observation and private bores, prior and post irrigation season, as well as bore maintenance or decommissioning of bores

- Investigate the possibility of artificial recharge

SKM (2004h) Paper No. 6: Local Bore interference in the Yarram Region.

This paper examines the issue of local bore interference in the Yarram region by defining local bore interference in relation to other types of interference in the region, and by examining bore density, usage, allocation and construction details.

The key findings of a SKM (2004a) drawdown study were summarised. The study used 24 bores to confirm that there is likely to be a localized area of drawdown during the irrigation season in an area south of Alberton. Few bores are found in the area which indicates it is sensitive to bore interference. The nature of the drawdown was determined to vary temporally, and water levels were expected to recover post-irrigation season. The remaining bores were considered to have minor impact on drawdown as they are scattered west and south of the Yarram township.

The following recommendations are detailed in the briefing paper:

- The relationship between pumping rates, extraction volumes and observed drawdown needs to be determined through monthly monitoring of all existing bores, collection of measured drawdown data, pumping rates and pumped volumes. This would enable establishing seasonal interferences and long- term trends.

- After collecting the above data, mapping of localized depressions in the aquifer should be undertaken for bore density and groundwater allocation information. This would be used to determine and manage high risk zones within the Yarram WSPA.

SKM (2004i) Paper No. 7: Policy options for groundwater allocation and trading in the Yarram WSPA.

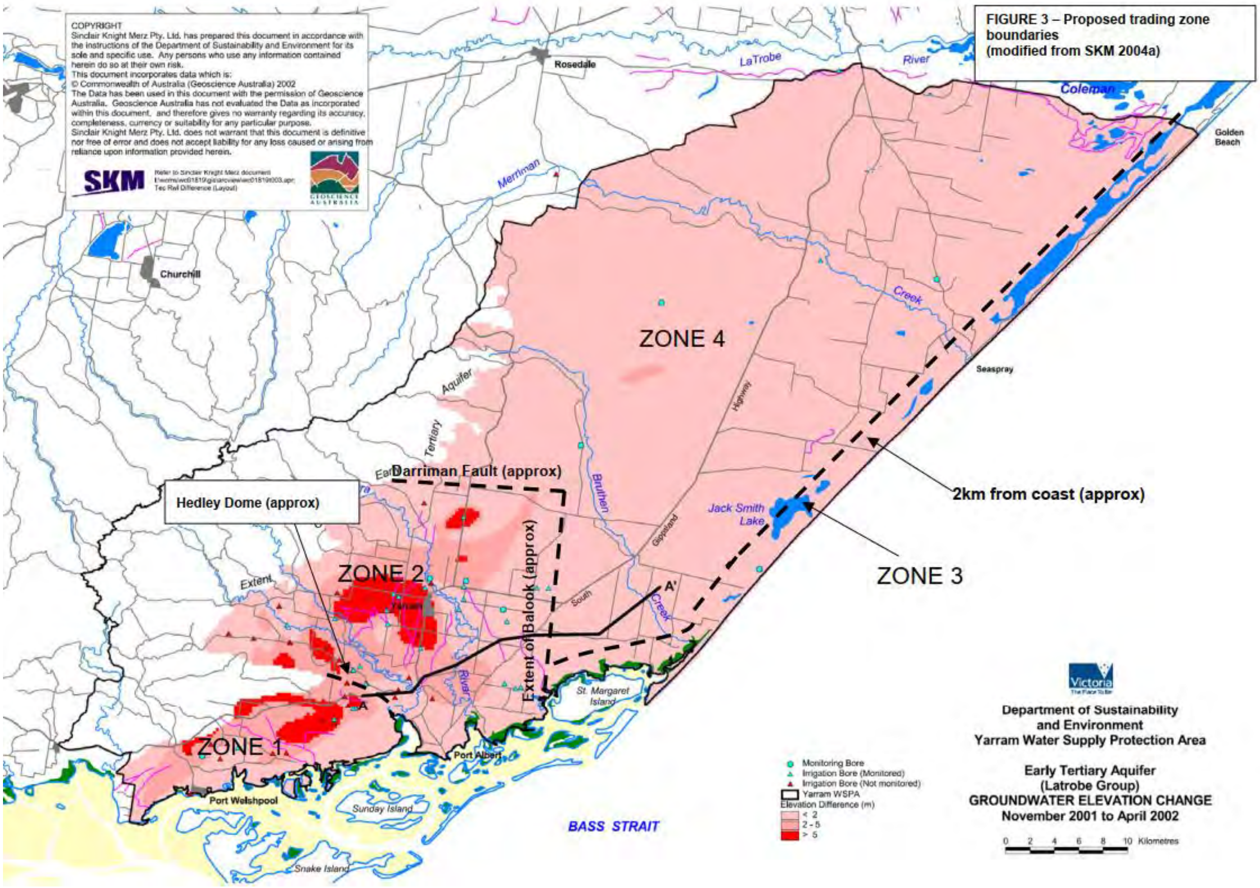
SKM prepared this paper as a critical review of the interim arrangement for the Yarram WSPA and determines whether new allocations can be justified. The PAV for the Yarram WSPA was set at the allocation volume at the time and no new allocations were allowed.

The paper suggests that allowing increased irrigation usage in areas in the east where the aquifer is strongly confined may have minor impact on long term storage volumes. However, the outskirts of the WSPA where the Balook Formation or the Latrobe Group aquifer is unconfined have significant cones of depression and further allocation usage in these areas would exacerbate the issue. The restriction on usage allocation in such areas also protects the baseflow in surface water bodies in the WSPA.

The area between Port Albert and Port Welshpool has been previously identified as at risk for sea water intrusion. The SKM paper suggests that although sea water intrusion has not been recorded in the area due to lack of data, further allocation is advised against as a precaution measure. Additionally, if groundwater declines continue, the risk of downwards flow increases which can result in saline water flowing to the Balook Formation or the Latrobe Group aquifer. Installation of new observation bores in the area is recommended for further groundwater data collection.

The paper suggests that the Yarram WSPA Committee consider the option of using internal trading zone boundaries to reduce the risk of local bore interference, stream interference and sea water intrusion. The Yarram WSPA was divided into four zones, as seen in Figure 13-1. No trading was recommended into Zone 1, 2 or 3, instead trading into Zone 4 from Zone 1 or 2 and trading within Zone 1 and 2 was suggested.

Figure 13-1: Proposed trading zone boundaries (SKM, 2004).



SKM (2005) Assessment of Potential Groundwater Decline Induced Changes in Tarra River Baseflow.

The WGCMA has engaged SKM to prepare an assessment of the depletion of stream flow of the Tara River and its tributary stream due to falling groundwater levels.

A Generalised Additive Model (GAM) was used to model the trend in baseflow recorded at three stream gauges within the Tarra River and its tributaries. It was found that baseflow in the main Tara River gauge has declined by 75% since 1950. The gauge located adjacent to the recharge areas indicates that baseflow had declined by 50% between 1960 and 1998, while at the gauge located 5 km upgradient of the recharge areas, baseflow had declined by 40% between late 1960 and 2005.

The potential stream flow losses were also calculated using the Darcy equation and Theis analysis. The losses due to decline in watertable ranged from 1.5 – 25 ML/day using Darcy's equation and 2 ML/day to 38 ML/day using Theis equation.

The following recommendations were made in the report to improve the accuracy of pressure decline induced changes in baseflow:

- Two transects of nested bores at different recharge locations and one transect of nested bores 1 km upstream of the recharge areas.
- Two gauges upstream and downstream of the stream targeted by the bores
- Monthly monitoring of the gauge and bore network

- Hydraulic testing to be conducted to determine aquifer parameters and analysis of all the data collected

- Installation and monthly data collection of metering of all water users upstream of the stream flow gauge at Yarram

SKM (2006a) Tara River REALM Development Estimation of Daily Flows, July 2006.

The Tara Rive has been identified as a priority river due to its range of consumptive uses and important environmental values. SKM developed a Resource Allocation Model for the Tarra River and prepared historic, current, unimpacted an fully impacted daily stream flow series. This data was to be used in the assessment of environmental flows for the Tarra River.

The current, fully impacted, unimpacted and historic flows were compared at each environmental flow site. Overall, the most flow occurred under the unimpacted scenario followed by historical, current and fully impacted, which was expected.

SKM (2006b) Tara River Environmental Flows Assessment, September 2006.

SKM conducted an environmental flows assessment to determine the environmental flow requirements for the Tara River and its tributaries. The objectives of the study were to:

- Identify the water dependent environmental and social values, gauge the health of the identified environmental values and assess current and future threats to those values.

- Recommend environmental flow objectives and an environmental flow regime to meet the flow objectives.

- Analyse the current flow regime and undertake a risk assessment to the environmental values if the recommended flow regime is not met.

The surface-groundwater interaction considered the findings from SKM (2005 and 2006a), which investigated the link between groundwater and surface water in the Tarra River and tributaries. Based on the findings of those studies, it is concluded that there has been a decline in baseflow in the Tarra River over the last 50 years. This decline was attributed to reduction in rainfall, with circumstantial evidence suggesting that the decline in baseflow may also be contributed to a smaller extent by declines in groundwater levels resulting from off-shore gas and oil extraction and local extraction for irrigation.

The study identifies functions and processes supported by flow components such as low flow, high flow, bank flow and overbank flow. Environmental assets of the reaches of the Tara River were categorized based on the flow they require. These findings were used to carry out hydraulic modelling to relate channel morphology to stream flow.

RMCG (2008) Groundwater Economics

RMCG assessed the economic value of the Yarram WSPA and determined the WSPA has significant value in terms of irrigation and commercial use. The WSPA was classified as a priority GMAs in terms of value for irrigation, commercial/industrial, domestic and stock and sleeper licences. The industrial/commercial value of the Yarram WSPA was valued at $4M, and the irrigation value of the YWSPA was valued at $3.5M. The value associated with domestic and stock and sleeper licences was considerably less ($2.1M and $1.2M respectively).

GHD (2010a) West Gippsland CMA Groundwater Model - Interim steady-state model development report

GHDs 2010 groundwater model has been created for the West Gippsland CMA. The primary objective of the model is to provide a tool for assessing the impacts of land use change on depth to water. Calibrated model aquifer parameters for aquifers in the Gippsland region were listed for the Boisdale Formation, the Balook Formation and the Latrobe Group Aquifer.

The Balook Formation was reported in model layers 3 and 4, and the Lower Latrobe Group aquifer was reported in model layer 3 as M1B Aquifer. The hydraulic conductivity values determined using the calibrated model are provided in Table 7-1.

Table 13-1: Calibrated Hydraulic Conductivity Values

Model Layer	Hydrostratigraphic Unit	Kh (m/d)	Kv (m/d)
3	Balook Fm	3.53	6.58E-2
4	Balook Fm	7.50	0.14
3	M1B Aquifer (Latrobe Valley)	0.97	0.13

* Kh = horizontal hydraulic conductivity; Kv = vertical hydraulic conductivity.

SRW (2010) Groundwater Management Plan, Yarram Water Supply Protection Area

The objective of the management plan is to make sure that resources of the Yarram area are managed in an equitable and sustainable manner. The following information on the Yarram WSPA is presented:

- The WSPA includes 83 groundwater licences with a total allocation of 25,317 ML/year. The majority of groundwater is used for irrigation, with other uses being for dairies and other commercial and industrial use.
- Metered groundwater use has ranged between 6,682 and 11,778 since 2001 to 2010. The actual groundwater use is higher than the metered volume, as groundwater extractions occur from non-metered domestic and stock bores.
- The water levels in the WSPA have been in decline since 1983. The Balook Formation shows a decline of up to 0.5 m/yr, and the Latrobe Group aquifers show a steady water level decline of 1.1 m/yr.
- Significant and consistent contribution to the declining groundwater levels in the WSPA have been made by the offshore extraction of oil, water and gas.

Some of the prescriptions stated in the Plan to mitigate the identified potential impacts can be summarised:

- Southern Rural Water Cooperation (SRWC) must not approve an application for the permanent or temporary transfer of a license into the Coastal Zone and the corporation must also not approve permanent license transfers into the Central Zone.
- New licences may be issued to overcome an administrative oversight or other anomaly or through a transfer of entitlement provided the PVC is not exceeded.
- No new licences are permitted in the Haunted Hills Formation, which applied to any applications to transfer into or within the haunter Hills Formation.
- DSE must ensure that monitoring bores are properly maintained and replaced in necessary.
- DSE and SRWC must ensure that appropriate monitoring and investigations are carried out to assess potential issues such as saline water intrusion, pumping impacts on water level trends, drawdown, as well as examine the relationship between groundwater, surface water and GDEs and provide information for future assessments.

SRW (2014) Seaspray Groundwater Catchment Statement

The Seaspray Groundwater Catchment is located in the Gippsland Basin in eastern Victoria. Local Management plans have been developed for sub-areas of the catchment to form the basis for groundwater management. The Local Management plan area covers the Giffard GMA, the Yarram WSPA and the areas remaining. A Local Management Plan has been developed for each area, which documents and explains management objectives for each system, including any limits, trading zones and rules.

The Yarram Local Management Plan does not define any specific rules for the Yarram WSPA stated in the Groundwater Management Plan (SRW, 2010).

Beverly et al., (2015) The Gippsland groundwater Model - Onshore natural gas water science studies

The Gippsland Groundwater Model was developed to assess the potential impact of coal seam gas development on groundwater resources.

Calibrated model aquifer parameters for aquifers in the Gippsland region were listed for the Balook Formation and the Latrobe Group Aquifer. The Balook Formation was reported as part of the Lower M2 Interseam and the Lower Latrobe Valley Group was reported as the T2 Interseam. A summary of the aquifer parameters used in the model are provided in Table 7-2.

Table 13-2: Calibrated model aquifer parameterisation.

Zone	Aquifer	Kxy (m/d)	Kz (m/d)	Specific yield	Specific storage (m^{-1})	Kzz/Kxy
9	Lower M2 Interseam	1.605×10^{1}	1.202	0.1	1×10^{-5}	0.075
22	T2 interseam	8.862×10^{-1}	9.566×10^{-2}	0.1	1×10^{-5}	0.108

DELWP (2017) Victorian Water Accounts 2016 – 2017

The Victorian Water Accounts report provides information on the usage and annual trends associated with water resources in the state of Victoria. To provide a consistent picture of water use across all GMA areas considered in this report we have reported the water usage figures from the most recent annual statement. Trends over two years do not necessarily represent the longer term trends, but are nevertheless considered instructive. Future assessment of the PCV should consider the full record of groundwater usage trends. The total licensed use volumes for the period of 2015 - 2017 are provided in the table below.

The groundwater level trends in Yarram WSPA were reported as declining between June 2016 and June 2017, due to the continued influence by off-shore oil and gas production. The latest published combined licensed groundwater volumes and use for the Yarram WSPA in Central Gippsland and Seaspray Catchments are described in Table 13-3.

Table 13-3: Licensed groundwater volumes and use

GMA	GMA aquifer depth limits (m)	Licensed entitlement (ML/year)	Total licensed groundwater use (ML) 2016-17	Total licensed groundwater use (ML) 2015-16
Yarram WSPA	Zone 1: >200 Zone 2: All depths	25,689	12,246	14,941

GHD (2018) Groundwater Condition Reporting – Stage 4

GHD developed a range of aquifer classification codes, which were used to represent groundwater level responses. Details of suite description, classification and suite hydrograph development and representative suite hydrograph for resource condition reporting can be found in (GHD 2014; GHD 2017; GHD 2018). The suites are grouped based on the aquifer monitored (upper, middle, lower or basement), suite code which is an alphabetic naming convention and fluctuation code which is a numerical identifier that indicates bores with similar magnitude in seasonal fluctuations (GHD, 2018). The suites to be reported for a particular GMU were selected based on the following:

- Suite representativeness (the proportion of the suite that occurs within the GMU must be spatially significant)
- Relevance of the aquifer layer (the unit the GMU is intended to manage)
- Spatial coverage of groundwater monitoring bores across a Suite or GMU
- Spatial coverage of groundwater extraction bores across the GMU
- Conceptualization considerations (improving the understanding of recharge processes, inter aquifer connectivity or aquifer leakage)

GHD determined that the Yarram WSPA is best represented by suite L_O_1 and L_O_2 which cover the lower aquifer. Yarram WSPA Zone 2 is covered by suite L_O_1 and Yarram WSPA Zone 1 is covered by suite L_O_2. The area covered by the L_O_1 suite is shown in Figure 13-2Figure 5-1. The figure showing the area covered by suite L_O_2 has not been provided (GHD, 2018). The representative hydrograph for the aquifer classifications L_O_1 and L_O_2 is shown in Figure 13-3 and Figure 13-4 respectively

Figure 12-3. The hydrographs shows that groundwater levels in L_O_1 have been declining since 1983, and water levels in L_O_2 have been declining since 1985.

Figure 13-2: Location of suite L_O_1 (GHD, 2018)

Figure 13-3: Yarram WSPA Zone 2 Suite Chart for L_O_1

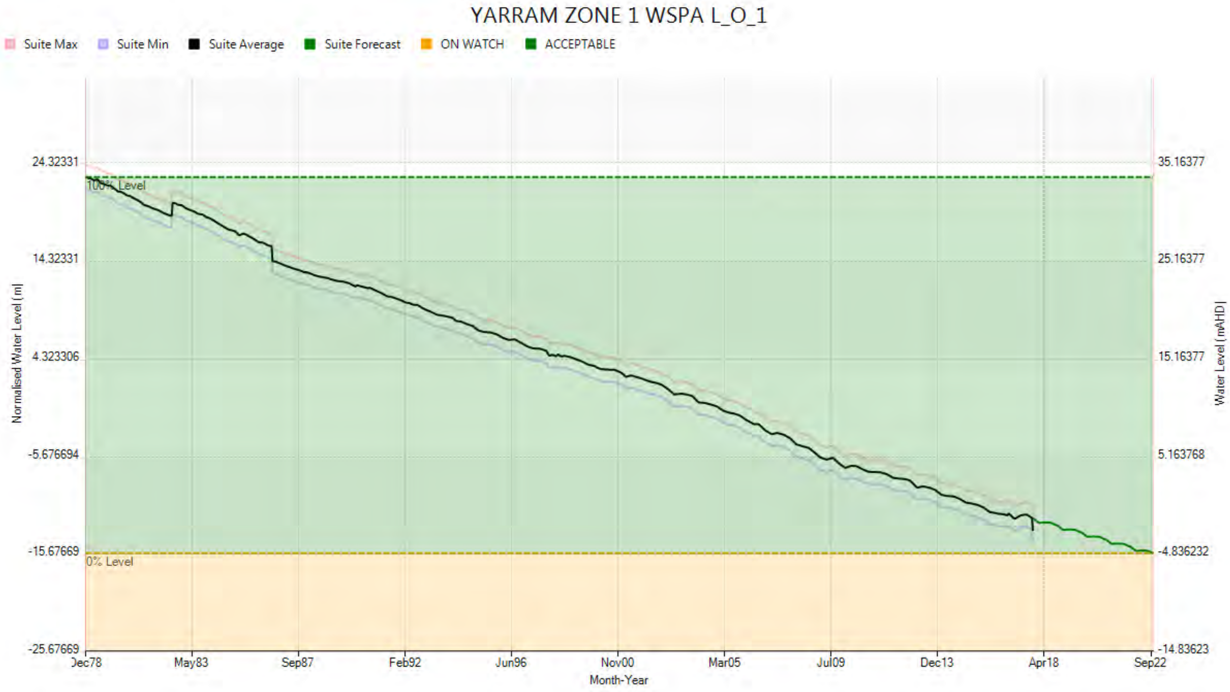
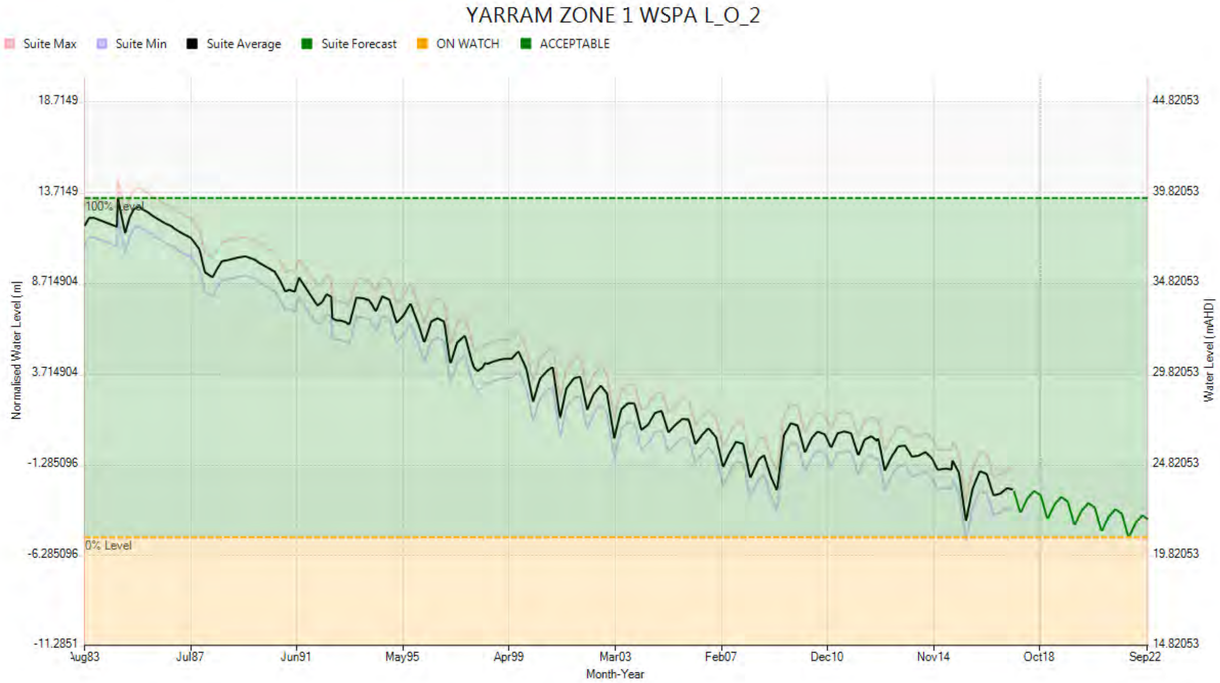


Figure 13-4: Yarram WSPA Zone 1 Suite Chart for L_O_2



13.3 Relevant matters for consideration

- The Yarram WSPA covers an important and valuable groundwater resource that supports a high volume of supply and has broad usage. This warrants the area being a high priority for review.
- The impact of off-shore oil and gas extraction is a significant complication to assessing a PCV for this area and despite that fact that there has been significant work done in the area, more is needed to develop the technical basis of a PCV that can be resilient and robust in the face of ongoing significant declining levels.
- Assessment of likely future trends for levels and the implication for groundwater availability is considered to be a high priority. This includes the issue of sea water intrusion, although this is likely to be restricted to the near coastal area.
- Given the sustainable yield of the aquifer has not been determined by a technical assessment and the groundwater levels are declining, the Yarram GMA is a priority candidate for PCV review.
- There is likely to be ongoing demand for water and this is expected to be required over the long term (many decades).
- Groundwater levels are expected to continue to decline as a result of offshore extraction and groundwater trends indicate that the aquifer is yet to reach an equilibrium level
- Accurate estimates of aquifer throughflow are required to improve the sustainable yield. Coupled with generally weak estimates of aquifer parameters and key inputs (including stream interaction) there is a requirement for a significant effort to fully review this area.
- Given the high value of the resource and risks of land subsidence this is considered a high priority for additional work to review the sustainable yield.

14. Summary

For each of the 12 GMA areas in the Gippsland region of Victoria, we have presented an overview of:

- The basis of the original PAV estimate
- Review findings from the Reid (2004) for some GMA's
- A compendium of recent studies and reports that provide new and additional information that is relevant to setting a sustainable yield estimate and then leading to PCV declaration
- An overview of recent entitlement and usage data for each GMA
- Presentation of regional groundwater trends for each GMA (from other studies).

For each GMA we have drawn together this information and formed a preliminary assessment of the issues and potential priority for future PCV review. In reaching these conclusions we have taken into account the value of the resource, potential threats from climate change and the overall resilience of the aquifer system. The preliminary priority assessment and comments are provided in Table 14-1.

Table 14 1: Summary of findings and possible priority for GMA areas.

GMA	Level of priority	Commentary on priority
Unconfined aquifers		
Denison	Medium	• PAV was estimated used four methods • Shallow aquifer influenced by high rainfall and vertical recharge, 10% of rainfall and irrigation infiltration, significant river recharge. • Current PCV is at 50% higher than PAV assessment • A conjunctive management approach may be appropriate in consideration of irrigation return recharge in light of climate change and infrastructure modernization.
Moe	Medium	• PAV was estimated using the rainfall recharge method. • Primary recharge mechanism is infiltration from rainfall, assumed to be 5% of rainfall. • PCV has not been updated since the PAV estimate. • GMA is not fully allocated, yet declining groundwater levels indicate unsustainable extraction is some areas. Key risks are around impacts of climate change and likely future demand.
Wa De lock	Medium	• PAV was determined using rainfall recharge, with recharge rates ranging between 7% and 10% of rainfall. • The PAV was changed to 30,084 ML/year in 2006 based on recommendations from Reid. The current PCV is 30,795 ML/year. • Although GMA is almost fully allocated, groundwater use is low. • Little new information but likely to be vulnerable to climate effects and is close to other important confined resources
Leongatha	Low	• PAV assessment used throughflow method and rainfall recharge method • Current PCV is as recommended by Reid (2004) based on technical assessment to account for rainfall recharge and discharge to rivers. • GMA is priority GMA for town water supply however allocations are well under the PCV.

GMA	Level of priority	Commentary on priority
		• Key risks associated with climate change, however groundwater use is modest and there is no evidence of imminent issues
Tarwin	Low	• PAV estimate was based on rainfall recharge and considered effects of sea water intrusion. • PCV was reduced to 1,300 ML/year in 2006 based on recommendations by Reid. • Licensed entitlements are well within PCV. • Groundwater trends are reasonably stable but key risks around water quality due to proximity of septic tanks and climate change.
Wy Yung	Low	• PAV estimate was calculated using recharge from rainfall and discharge to rivers. • PCV was decreased to 7,463 ML/year in 2011, to match licensed entitlements. • Recent unpublished work held by DEWLP suggests that the conceptual model for this area may require significant revision to consider strong river connection.
Confined aquifers		
Rosedale	High	• PAV assessment based on aquifer throughflow method • The PCV was increased to 22,313 ML/year in 2007, to align with entitlement volumes and amended again in 2013 to 22,372 ML/year. • Current PCV is well in excess of the recommended PAV. • Likely to be ongoing demand from the same aquifer upgradient of the GMA associated with the operation and rehabilitation of the coal mines. • Declining groundwater levels indicate that aquifer is yet to reach a new equilibrium.
Sale	High	• PAV assessment based on aquifer throughflow method • The PCV was increased to 21,212 ML/year in 2007 to align with entitlement volumes and was amended again in 2013 to 21,238 ML/year. • Current PCV is well in excess of the recommended PAV, although groundwater use is around 12,000 ML/year which is similar to the PAV estimate. • Groundwater levels are declining and have the potential cause saline intrusion from Lake Wellington. • Groundwater pumping in the long term for operation and rehabilitation of the Latrobe Valley coal mines is likely to continue to affect the GMA.
Stratford	High	• PAV for the Latrobe Group aquifer was estimated using the aquifer throughflow method for the old Seacombe GMA which covers Stratford and Yarram. • PCV was declared in 2006 to be 27,643 ML/year and subsequently amended in 2011 and 2018, and is now 27,686 ML/year. • The current entitlement is 37,043 ML/year with metered use of 22,076 ML (DELWP, pers. comm, 2019).

GMA	Level of priority	Commentary on priority
		• Groundwater levels are expected to continue to decline as a result of ongoing mine dewatering and other related pumping, as well as offshore extraction and groundwater trends indicate that the aquifer is yet to reach an equilibrium level. • Important to understand the sustainable yield of the aquifer in the context of the close and rehabilitation of coal mines.
Yarram	High	• PAV for the Latrobe Group aquifer was estimated using the aquifer throughflow method for the old Seacombe GMA which covers Stratford and Yarram. • PCV was declared in 2008 to be 25,317 ML/yr, and amended to 25,690 ML/yr in PCV Order 2013 to match licence entitlements. • Groundwater levels are expected to continue to decline as a result of ongoing mine dewatering and other related pumping, as well as offshore extraction and groundwater trends indicate that the aquifer is yet to reach an equilibrium level. • Important to understand the sustainable yield of the aquifer in the context of the close and rehabilitation of coal mines.

Giffard	Low	• PAV assessment used aquifer throughflow method
		• GMA has two zones:
		  • Zone 1 has difference recharge regime than Zone 2 and warrants management separately and has implication for Sale GMA management
		  • Zone 1 PAV was recommended for PCV with moratorium on Zone 2
		• Current PCV is 60% higher than recommended PAV
		• Key risk is saline intrusion due to declining water level, however groundwater use is modest and water level trends are steady.

Orbost	Low	• PAV assessment used throughflow method and took into account the volume of water required to protect groundwater quality. • Current PCV was increased marginally from the PAV assessment of 1,200 to 1,217 ML/day • Licensed entitlements are similar to the PCV and groundwater use is low. • Key risks associated with declining groundwater levels and deteriorating groundwater quality, however groundwater trends are currently rising.

15. References

Beverly et al. (2015) The Gippsland groundwater Model, Onshore natural gas water science studies, DEDJTR.

Birch W.D. (2003) Geology of Victoria, 3rd Edition, Geological Society of Australia, Victorian Division.

CDMSmith (2017) Groundwater Data Inventory, Stocktake and Enhancement options.

CDMSmith (2018) Data Mapping – Aquifer properties and Recharge.

DELWP (2017) Victorian Water Accounts 2016 – 2017.

EarthTech (2007) Assessment of Environmental Flow Requirements for the Latrobe River Revision D.6 March 2007.

Eckhart, K. (2005) How to construct digital recursive filters for baseflow separation, Hydrological Processes, 19, 507-515.

GHD (2008) East Gippsland Water, Hydrogeological Assessment to Support License Application (BCL 9030173), July 2008.

GHD (2010a) West Gippsland CMA Groundwater Model. Interim steady-state model development report. Report prepared by GHD for the Department of Sustainability and Environment (DSE), Victoria.

GHD (2010b) East Gippsland CMA Groundwater Model. Interim steady-state model development report. Report prepared by GHD for the Department of Sustainability and Environment (DSE), Victoria.

GHD (2013) Groundwater assessment – Baseflow dependent rivers, characterising groundwater contribution to baseflow, November 2013.

GHD (various dates) Regional Monitoring Committee Annual Report.

GHD (2016) Latrobe Valley Groundwater and Land Level Monitoring 5 Year Review.

GHD (2016) Regional Groundwater Model Review 2015 Update.

GHD (2018) Groundwater Condition Reporting – Stage 4, September.

Hofmann, H. and Cartwright, I. (2013) Using hydrogeochemistry to understand inter-aquifer mixing in the on-shore part of the Gippsland Basin, southeast Australia, Applied Geochemistry, 33, 84-103.

HydroTechnology (1994). Boisdale aquifer groundwater resource- regional hydrogeological assessment. Report for the Department of Conservation and Natural Resources. Unpublished.

Jacobs (2014) Moe Groundwater Catchment Resource Appraisal. For the Department of Environment and Primary Industries (Victoria). June 2014.

Lyne, V.D. and Hollick, M. (1972) Stochastic time-variable rainfall runoff modelling, Hydrology and Water Resources Symposium, Institution of Engineers Australia, Perth, 89-92.

Nolan-ITU (1999) Groundwater System Status Report. For Department of Natural Resources and Environment.

Reid (2004) Audit of Permissible Annual Volumes for 35 Victorian Groundwater Management Areas. May 2004. Department of Primary Industries.

RMCG (2008) Groundwater Economics. For Department of Sustainability and Environment (DSE) 29 August 2008.

Sinclair Knight Merz (1996) Permissible Annual Volume Project – Methodology Report, Department of Natural Resources and Environment, Victoria, 1996.

Sinclair Knight Merz (1998a) The Permissible Annual Volume Project – The Denison GMA, Department of Natural Resources and Environment, Victoria, 1998.

Sinclair Knight Merz (1998b) The Permissible Annual Volume Project – Leongatha GMA, Department of Natural Resources and Environment, Victoria, 1998.

Sinclair Knight Merz (1998c) The Permissible Annual Volume Project – The Moe GMA, Department of Natural Resources and Environment, Victoria, January 1998.

Sinclair Knight Merz (1998d) The Permissible Annual Volume Project – The Sale GMA, Department of Natural Resources and Environment, Victoria, 1998.

Sinclair Knight Merz (1998e) The Permissible Annual Volume Project – The Seacombe GMA, Department of Natural Resources and Environment, Victoria, 1998.

Sinclair Knight Merz (1998f) The Permissible Annual Volume Project – Tarwin GMA, Department of Natural Resources and Environment, Victoria, 1998.

Sinclair Knight Merz (1998g) The Permissible Annual Volume Project – Wa De Lock GMA, Department of Natural Resources and Environment, Victoria, 1998.

Sinclair Knight Merz (1998h) The Permissible Annual Volume Project – Wy Yung GMA, Department of Natural Resources and Environment, Victoria, 1998.

Sinclair Knight Merz (1999a) The Permissible Annual Volume Project – The Giffard GMA, Department of Natural Resources and Environment, Victoria, 1999.

Sinclair Knight Merz (1999b) The Permissible Annual Volume Project – The Rosedale GMA, Department of Natural Resources and Environment, Victoria, 1999.

Sinclair Knight Merz (2000a) The Permissible Annual Volume Project – The Orbost GMA, Department of Natural Resources and Environment, Victoria, 2000.

Sinclair Knight Merz (2000b) Assessment of Survey Options for Recommencement of Monitoring.

Sinclair Knight Merz (2001a) Rosedale Groundwater Management Plan, Monitoring Bore Assessment.

SKM (2001b) Risk Analysis for Possible Subsidence Along the Gippsland Coast. Department of Natural Resources and Environment, Final Report, Revised May 2001.

SKM (2001c) Gippsland Subsidence Modelling – Yarram. Department of Natural Resources and Environment. September 2001.

SKM (2001d) Gippsland Declining Levels: Impacts on Yarram Irrigators, October 2001.

Sinclair Knight Merz (2004a) Yarram Water Supply Protection Area – Background Technical Information for the Yarram Water Supply Protection Areas. For Department of Sustainability and Environment (DSE) March 2004.

Sinclair Knight Merz (2004b) Yarram Artificial Recharge Study, Feasibility Assessment. Southern Rural Water. May 2004.

Sinclair Knight Merz (2004c) Paper No. 1: The Yarram WSPA Boundary.

Sinclair Knight Merz (2004d) Paper No. 2: Seawater Intrusion in the Yarram WSPA.

Sinclair Knight Merz (2004e) Paper No. 3: Groundwater and Stream flow Interaction in the Yarram WSPA.

Sinclair Knight Merz (2004f) Paper No.4: Artificial recharge in the Yarram WSPA.

Sinclair Knight Merz (2004g) Paper No. 5: Land Subsidence in the Yarram Region.

Sinclair Knight Merz (2004h) Paper No. 6: Local Bore interference in the Yarram Region.

Sinclair Knight Merz (2004i) Paper No. 7: Policy options for groundwater allocation and trading in the Yarram WSPA.

Sinclair Knight Merz (2005) Assessment of Potential Groundwater Decline Induced Changes in Tarra River Baseflow.

Sinclair Knight Merz (2006a) Tara River REALM Development Estimation of Daily Flows, July 2006.

Sinclair Knight Merz (2006b) Tara River Environmental Flows Assessment, September 2006.

Sinclair Knight Merz (2008a) Sale Groundwater Management Area – Groundwater Resource Appraisal. Southern Rural Water.

Southern Rural Water (2008b) Technical Issues Paper 8: Aquifer Sustainability in the Yarram WSPA, February 2008.

WGCMA (2008) Macalister Land and Water Management Plan, Part A and Part B.

Sinclair Knight Merz (2009) Investigation of groundwater/surface water interaction in the Avon River catchment, January 2009.

Southern Rural Water (2010) Groundwater Management Plan, Yarram Water Supply Protection Area.

Sinclair Knight Merz (2012) Baseflow Separation Analysis for Unregulated Rivers (1889 to 2012).

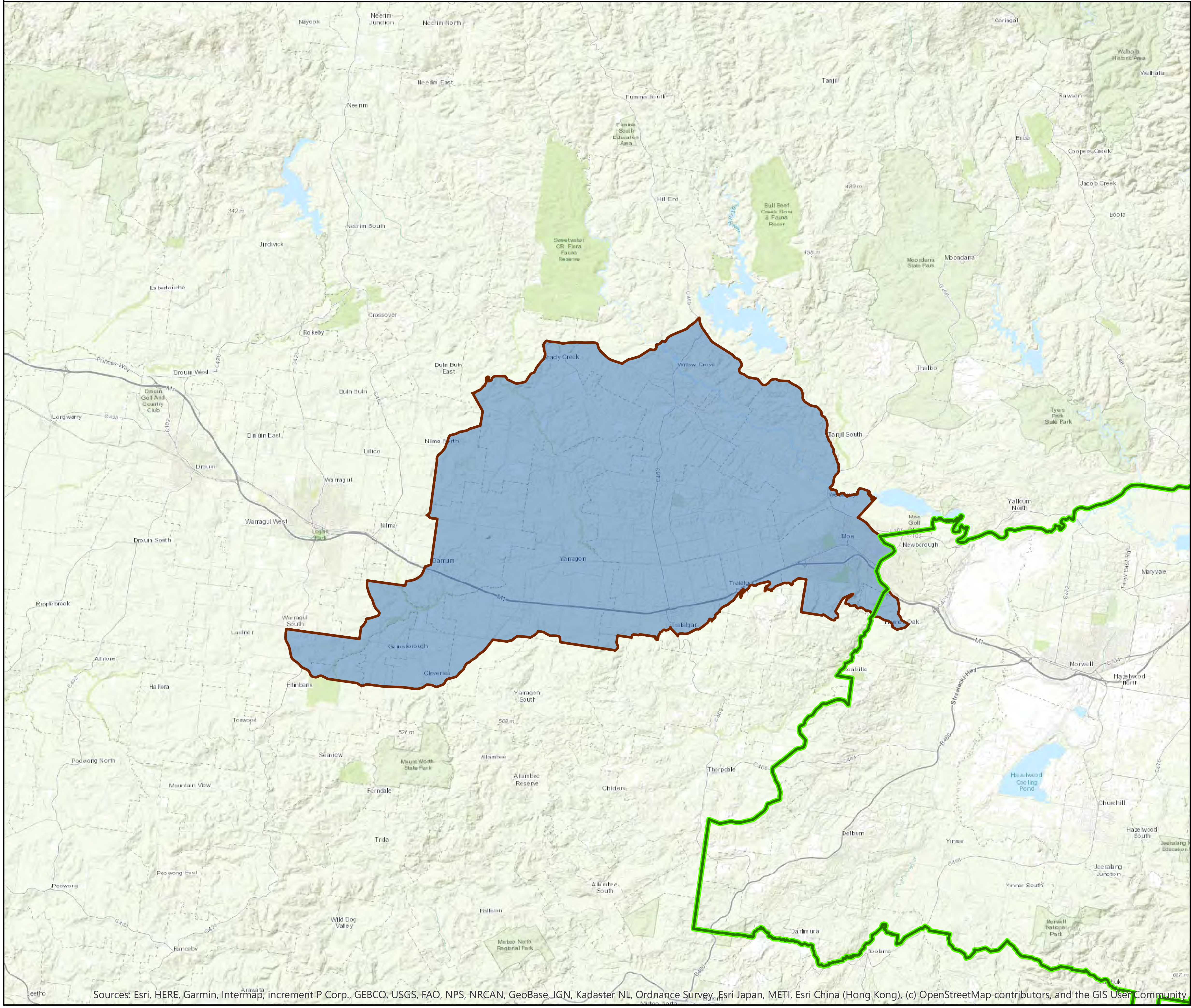
Southern Rural Water (2014) Seaspray Groundwater Catchment Statement, January 2014.

WGCMA (2017) Macalister Land and Water Management Plan Review.

Appendix A. Maps

Gippsland GMA's

MOE GROUNDWATER MANAGEMENT AREA



MOE GROUNDWATER MANAGEMENT AREA

GMA's in the area

MOE GROUNDWATER MANAGEMENT AREA

ROSEDALE GROUNDWATER MANAGEMENT AREA

STRATFORD GROUNDWATER MANAGEMENT AREA

N

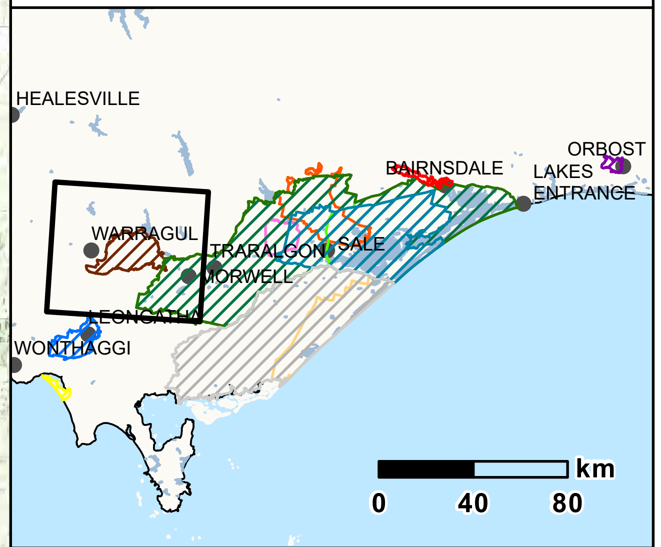
IS2600AQ

Name: GDA 1994 MGA Zone 54

0 2.5 5

Kilometres

DATA SOURCES
© Commonwealth of Australia (Geoscience Australia) 2006 Geodata Topo 250k Series 3; Vicmap Data © State of Victoria 2019; Jacobs 2019.
ESRI Basemap 2019



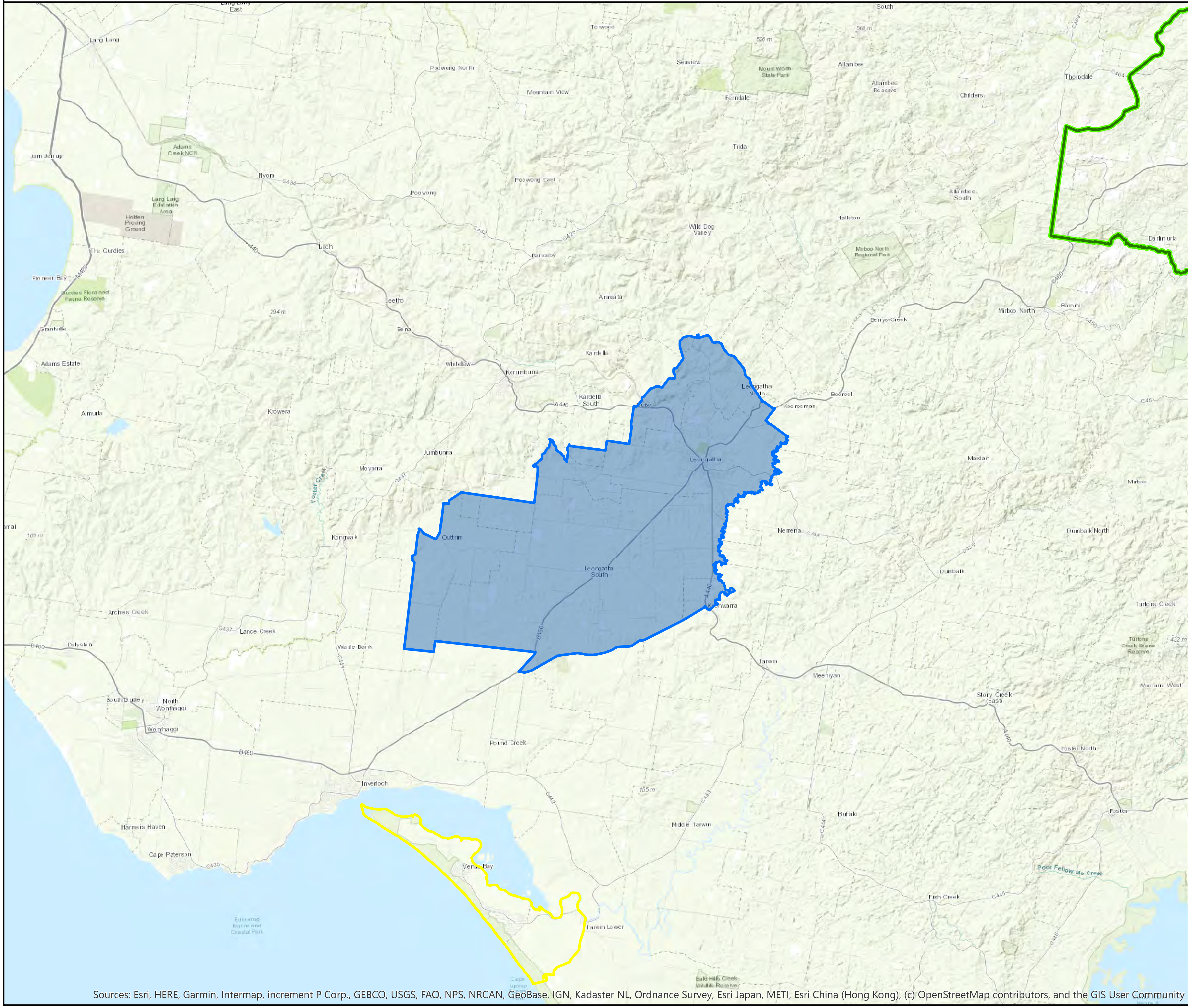
JACOBS

Path: J:\IE\Projects\03_Southern\IS282900\Spatial\ArcPro\IS282900\IS282900_GMA_AB.aprx

Date Exported: 27/06/2019

Gippsland GMA's

LEONGATHA GROUNDWATER MANAGEMENT AREA



LEONGATHA GROUNDWATER MANAGEMENT AREA

GMA's in the area

LEONGATHA GROUNDWATER MANAGEMENT AREA

ROSEDALE GROUNDWATER MANAGEMENT AREA

STRATFORD GROUNDWATER MANAGEMENT AREA

TARWIN GROUNDWATER MANAGEMENT AREA

N

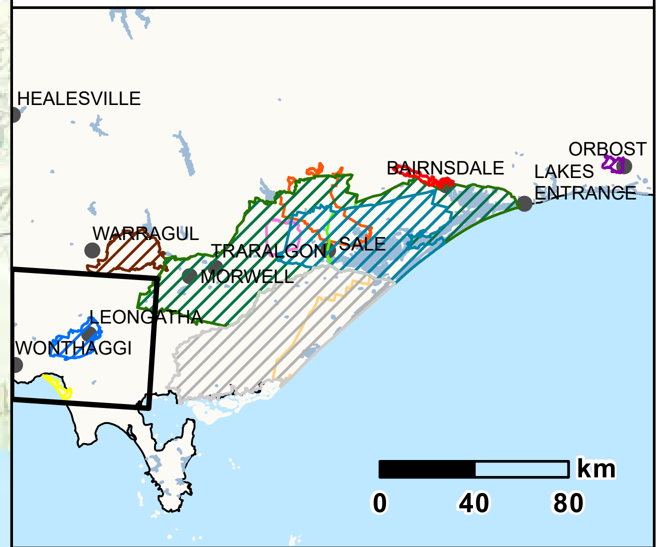
IS2600AQ

Name: GDA 1994 MGA Zone 54

0 2.5 5

Kilometres

DATA SOURCES
© Commonwealth of Australia (Geoscience Australia) 2006 Geodata Topo 250k Series 3; Vicmap Data © State of Victoria 2019; Jacobs 2019.
ESRI Basemap 2019



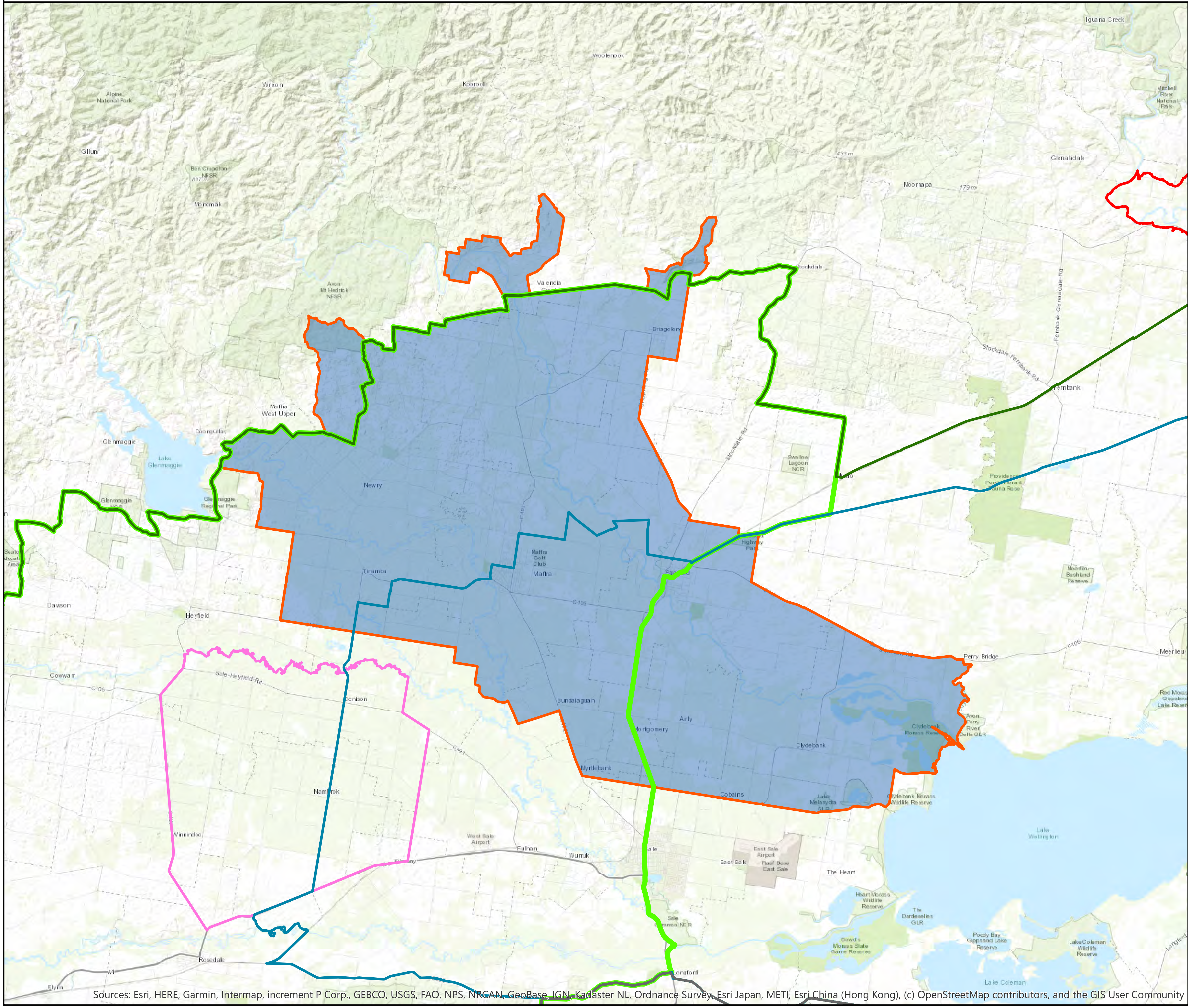
JACOBS

Path: J:\IE\Projects\03_Southern\IS282900\Spatial\ArcPro\IS282900\IS282900_GMA_AB.aprx

Date Exported: 27/06/2019

Gippsland GMA's

WA DE LOCK GROUNDWATER MANAGEMENT AREA



WA DE LOCK GROUNDWATER MANAGEMENT AREA

GMA's in the area

- DENISON GROUNDWATER MANAGEMENT AREA
- ROSEDALE GROUNDWATER MANAGEMENT AREA
- SALE WATER SUPPLY PROTECTION AREA
- STRATFORD GROUNDWATER MANAGEMENT AREA
- WA DE LOCK GROUNDWATER MANAGEMENT AREA
- WY YUNG GROUNDWATER MANAGEMENT AREA
- YARRAM WATER SUPPLY PROTECTION AREA

N

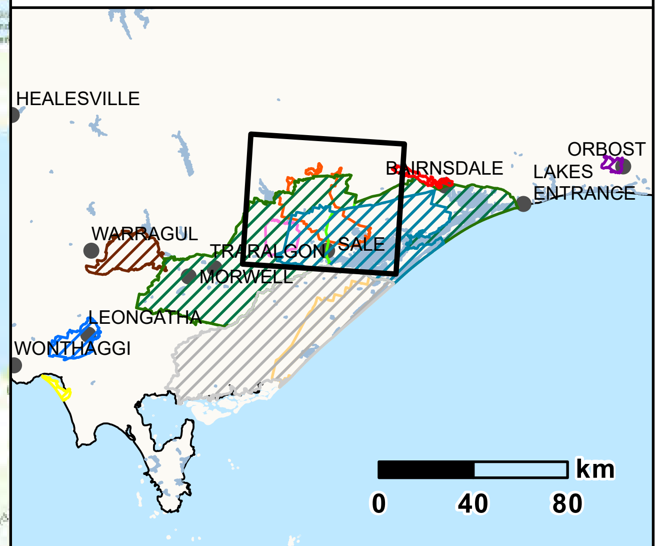
IS2600AQ

Name: GDA 1994 MGA Zone 54

0 2.5 5

Kilometres

DATA SOURCES
© Commonwealth of Australia (Geoscience Australia) 2006 Geodata Topo 250k Series 3; Vicmap Data © State of Victoria 2019; Jacobs 2019.
ESRI Basemap 2019



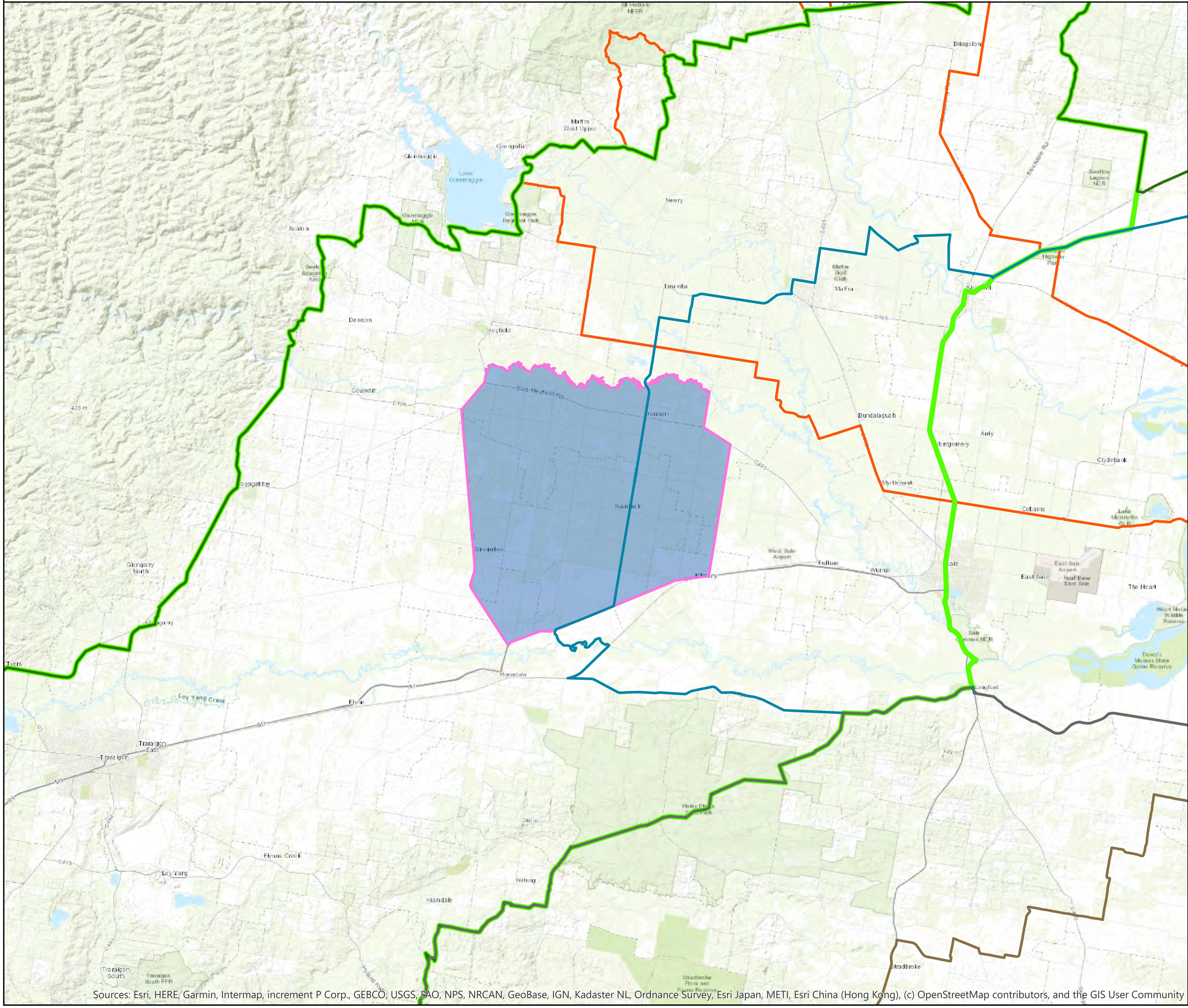
JACOBS

Path: J:\IE\Projects\03_Southern\IS282900\Spatial\ArcPro\IS282900\IS282900_GMA_AB.aprx

Date Exported: 27/06/2019

Gippsland GMA's

DENISON GROUNDWATER MANAGEMENT AREA



DENISON GROUNDWATER MANAGEMENT AREA

GMA's in the area

- DENISON GROUNDWATER MANAGEMENT AREA
- GIFFARD GROUNDWATER MANAGEMENT AREA
- ROSEDALE GROUNDWATER MANAGEMENT AREA
- SALE WATER SUPPLY PROTECTION AREA
- STRATFORD GROUNDWATER MANAGEMENT AREA
- WA DE LOCK GROUNDWATER MANAGEMENT AREA
- YARRAM WATER SUPPLY PROTECTION AREA

N

IS2600AQ

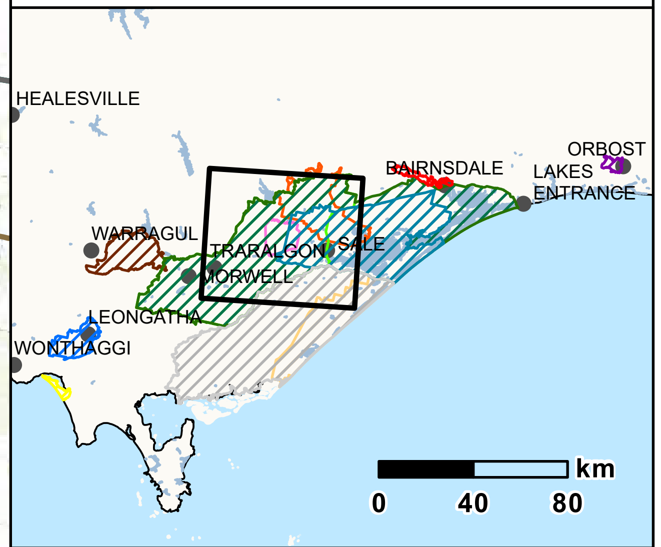
Name: GDA 1994 MGA Zone 54

0 2.5 5

Kilometres

DATA SOURCES

© Commonwealth of Australia (Geoscience Australia) 2006 Geodata Topo 250k Series 3; Vicmap Data © State of Victoria 2019; Jacobs 2019.
ESRI Basemap 2019



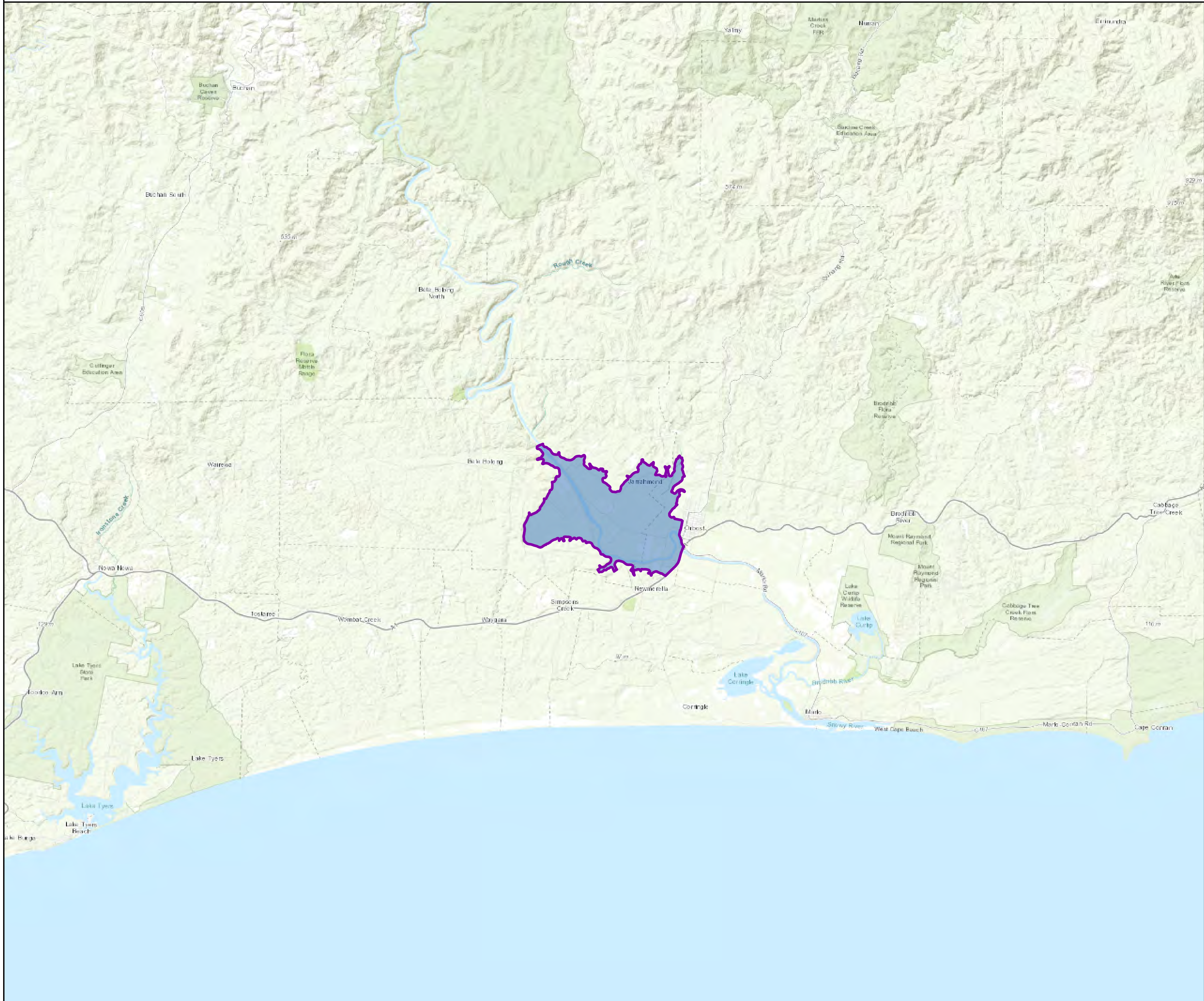
JACOBS

Path: J:\IE\Projects\03_Southern\IS282900\Spatial\ArcPro\IS282900\IS282900_GMA_AB.aprx

Date Exported: 27/06/2019

Gippsland GMA's

ORBOST GROUNDWATER MANAGEMENT AREA



Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community

ORBOST GROUNDWATER MANAGEMENT AREA

GMA's in the area

ORBOST GROUNDWATER MANAGEMENT AREA

N

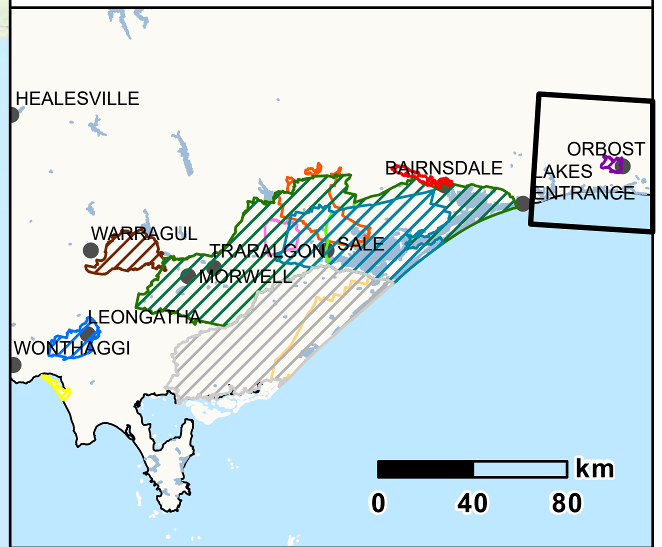
IS2600AQ

Name: GDA 1994 MGA Zone 54

0 2.5 5

Kilometres

DATA SOURCES
© Commonwealth of Australia (Geoscience Australia) 2006 Geodata Topo 250k Series 3; Vicmap Data © State of Victoria 2019; Jacobs 2019. ESRI Basemap 2019



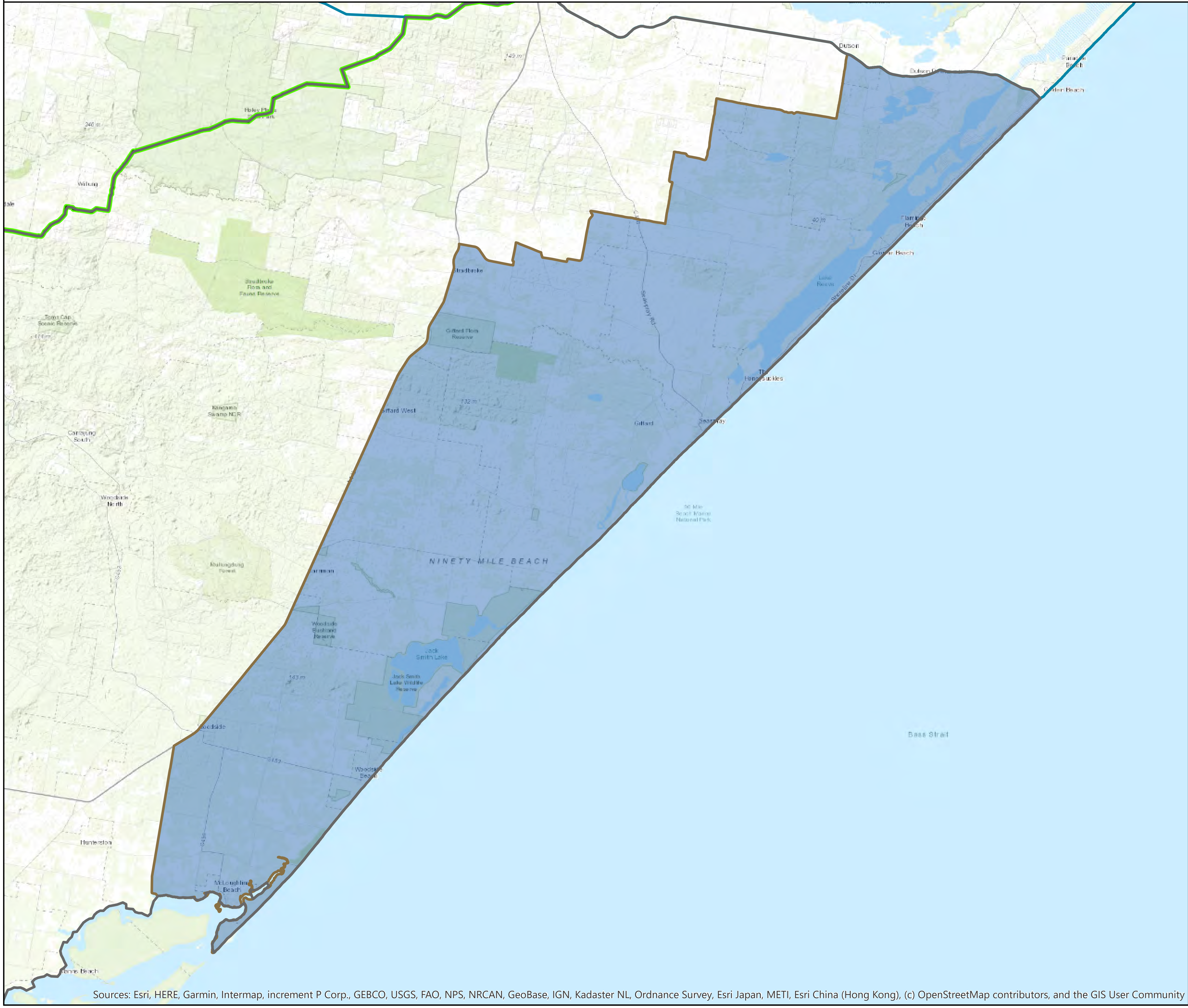
JACOBS

Path: J:\IE\Projects\03_Southern\IS282900\Spatial\ArcPro\IS282900\IS282900_GMA_AB.aprx

Date Exported: 27/06/2019

Gippsland GMA's

GIFFARD GROUNDWATER MANAGEMENT AREA



GIFFARD GROUNDWATER MANAGEMENT AREA

GMA's in the area

- GIFFARD GROUNDWATER MANAGEMENT AREA
- ROSEDALE GROUNDWATER MANAGEMENT AREA
- SALE WATER SUPPLY PROTECTION AREA
- STRATFORD GROUNDWATER MANAGEMENT AREA
- YARRAM WATER SUPPLY PROTECTION AREA

N

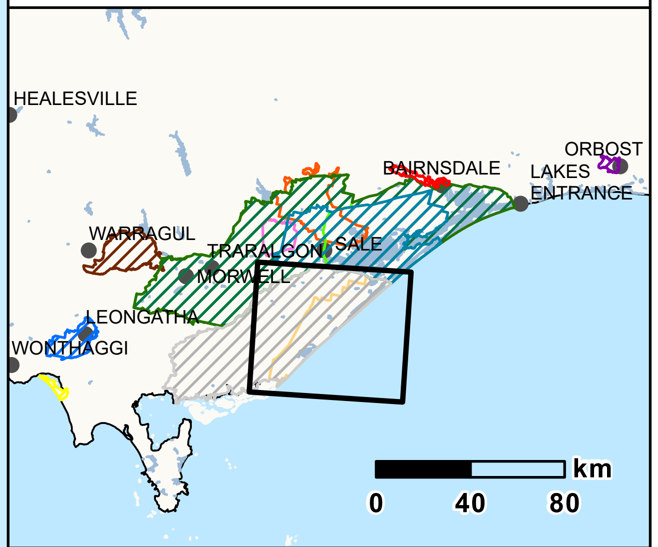
IS2600AQ

Name: GDA 1994 MGA Zone 54

0 2.5 5

Kilometres

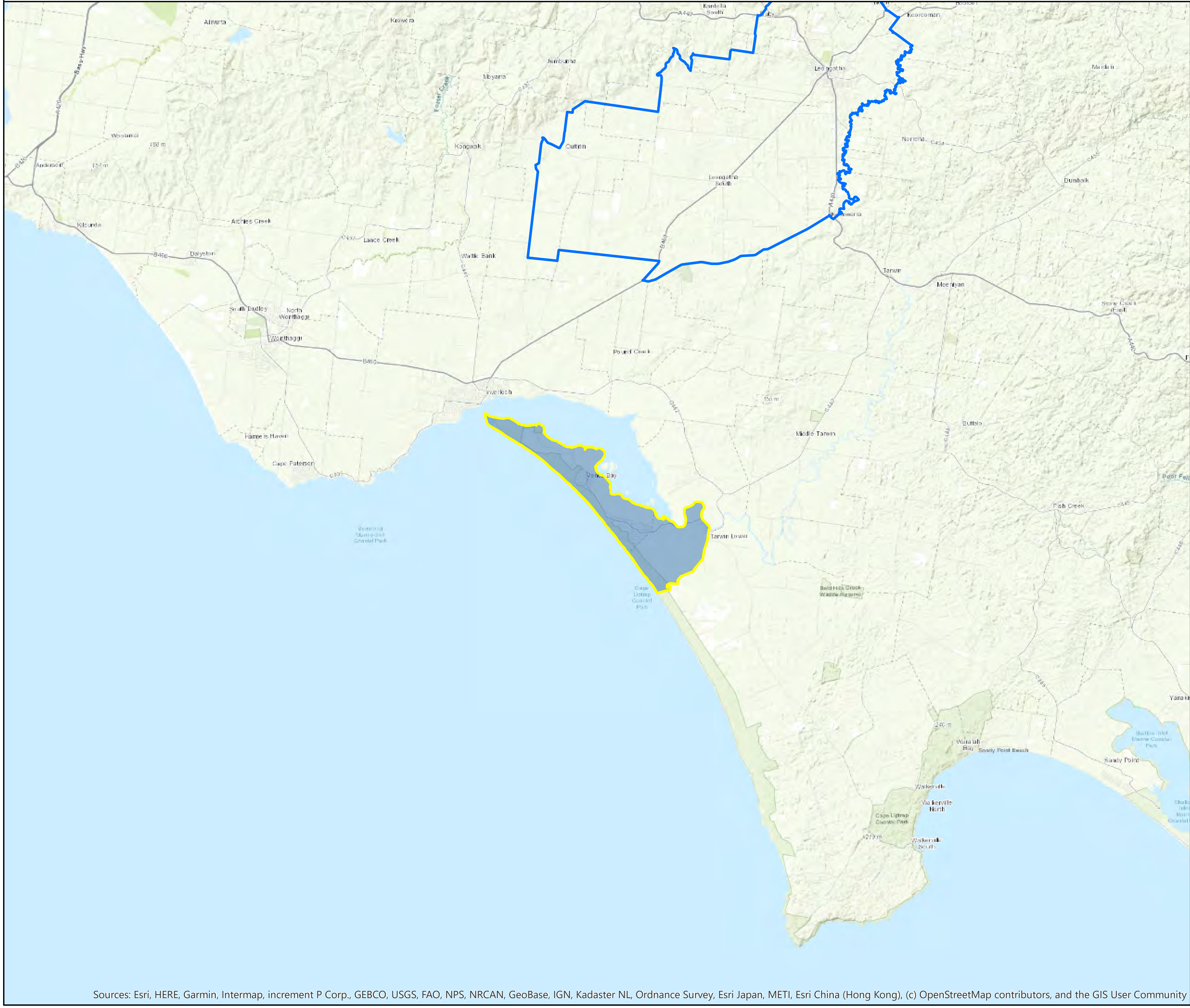
DATA SOURCES
© Commonwealth of Australia (Geoscience Australia) 2006 Geodata Topo 250k Series 3; Vicmap Data © State of Victoria 2019; Jacobs 2019. ESRI Basemap 2019



JACOBS

Gippsland GMA's

TARWIN GROUNDWATER MANAGEMENT AREA



TARWIN GROUNDWATER MANAGEMENT AREA

GMA's in the area

LEONGATHA GROUNDWATER MANAGEMENT AREA

TARWIN GROUNDWATER MANAGEMENT AREA

N

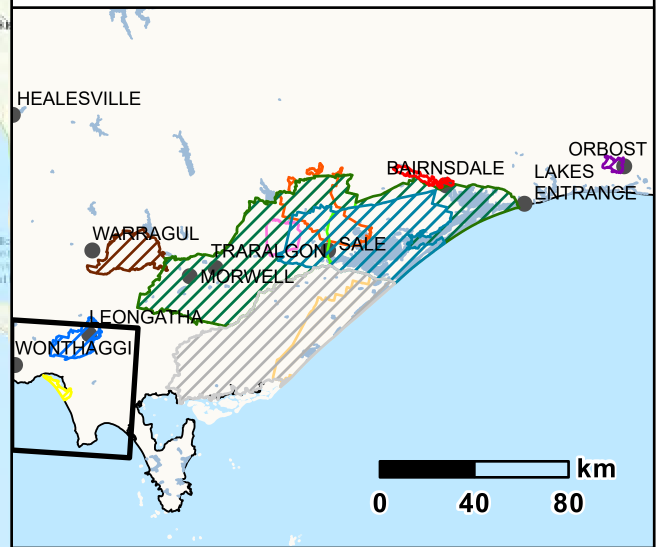
IS2600AQ

Name: GDA 1994 MGA Zone 54

0 2.5 5

Kilometres

DATA SOURCES
© Commonwealth of Australia (Geoscience Australia) 2006 Geodata Topo 250k Series 3; Vicmap Data © State of Victoria 2019; Jacobs 2019.
ESRI Basemap 2019



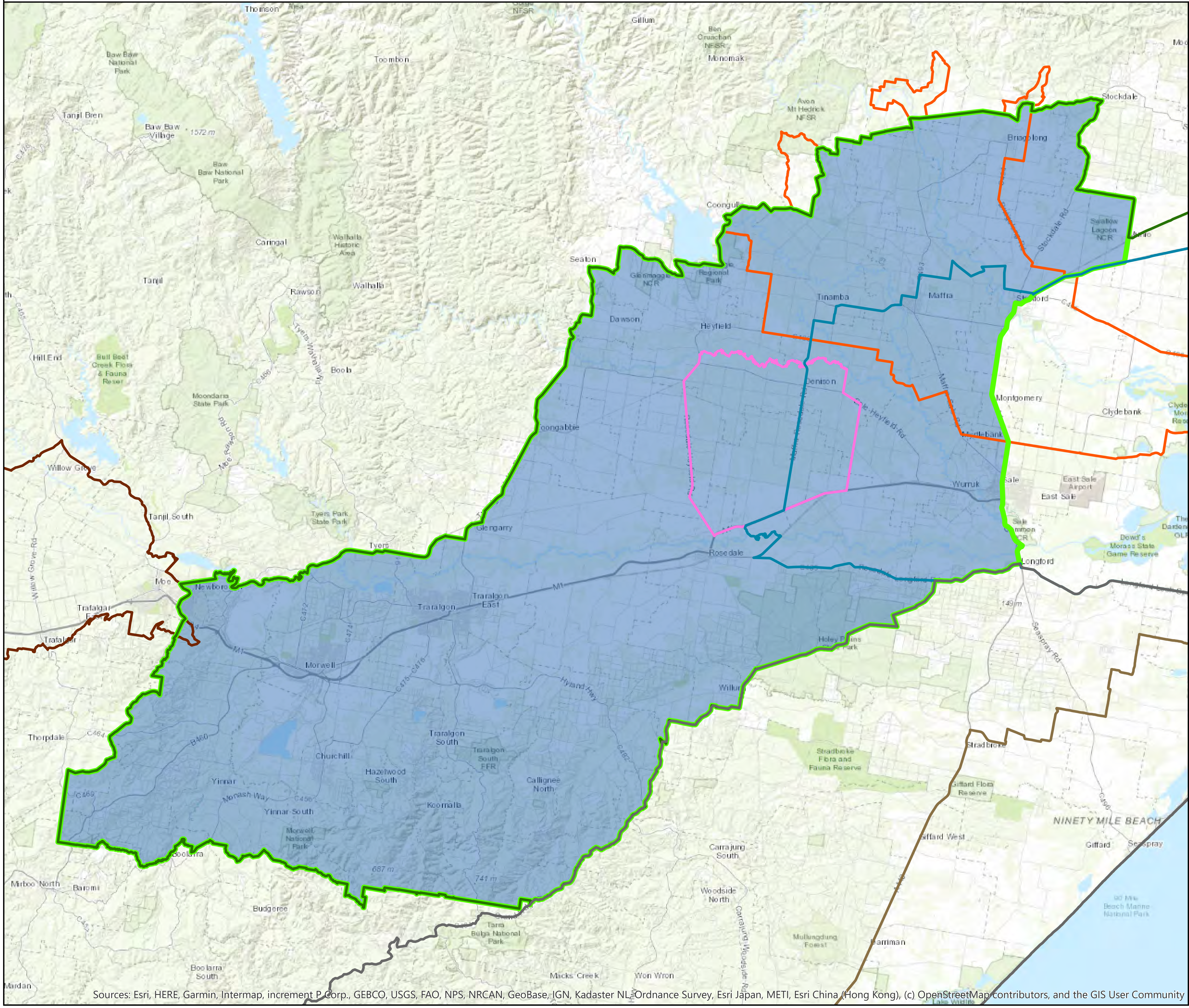
JACOBS

Path: J:\IE\Projects\03_Southern\IS282900\Spatial\ArcPro\IS282900\IS282900_GMA_AB.aprx

Date Exported: 27/06/2019

Gippsland GMA's

ROSEDALE GROUNDWATER MANAGEMENT AREA - Zone 3



■ ROSEDALE GROUNDWATER MANAGEMENT AREA

GMA's in the area

- DENISON GROUNDWATER MANAGEMENT AREA
- GIFFARD GROUNDWATER MANAGEMENT AREA
- MOE GROUNDWATER MANAGEMENT AREA
- ROSEDALE GROUNDWATER MANAGEMENT AREA
- SALE WATER SUPPLY PROTECTION AREA
- STRATFORD GROUNDWATER MANAGEMENT AREA
- WA DE LOCK GROUNDWATER MANAGEMENT AREA
- YARRAM WATER SUPPLY PROTECTION AREA

N

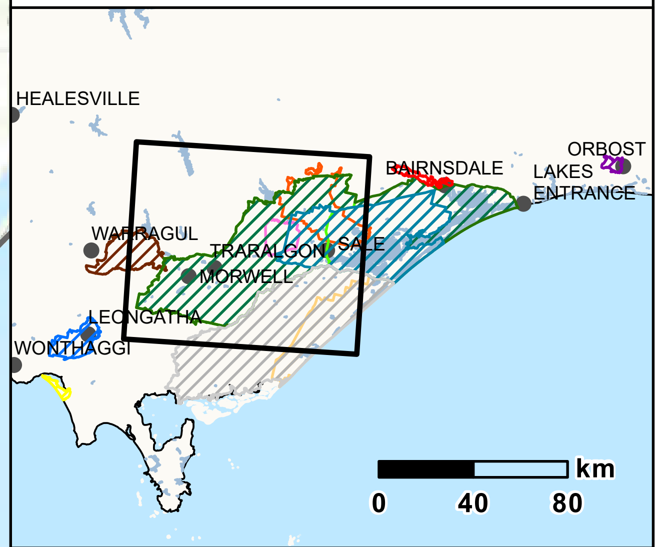
IS2600AQ

Name: GDA 1994 MGA Zone 54

0 2.5 5

Kilometres

DATA SOURCES
© Commonwealth of Australia (Geoscience Australia) 2006 Geodata Topo 250k Series 3; Vicmap Data © State of Victoria 2019; Jacobs 2019.
ESRI Basemap 2019



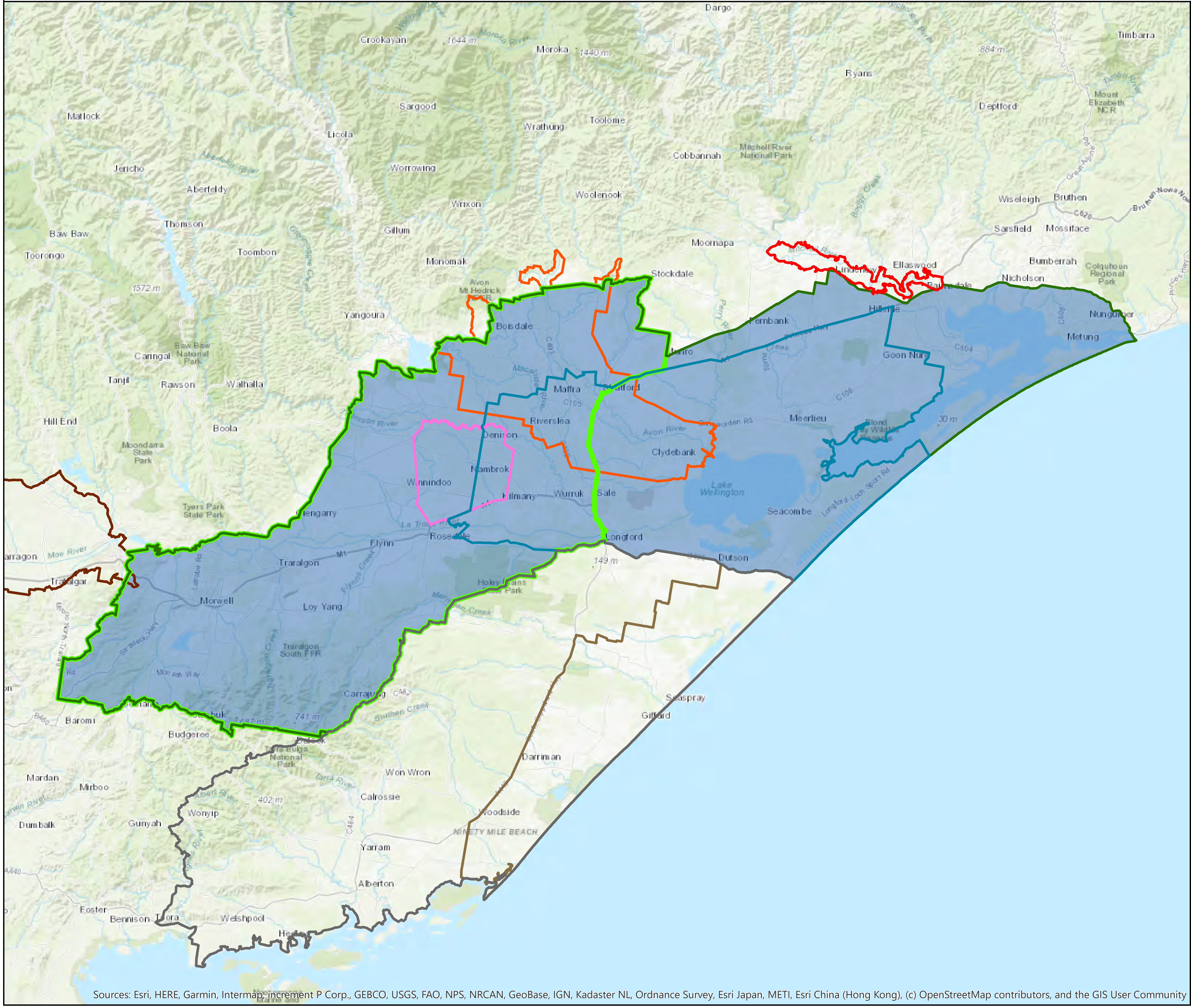
JACOBS

Path: J:\IE\Projects\03_Southern\IS282900\Spatial\ArcPro\IS282900\IS282900_GMA_AB.aprx

Date Exported: 27/06/2019

Gippsland GMA's

STRATFORD GROUNDWATER MANAGEMENT AREA - Zone 1



STRATFORD GROUNDWATER MANAGEMENT AREA

GMA's in the area

- DENISON GROUNDWATER MANAGEMENT AREA
- GIFFARD GROUNDWATER MANAGEMENT AREA
- MOE GROUNDWATER MANAGEMENT AREA
- ROSEDALE GROUNDWATER MANAGEMENT AREA
- SALE WATER SUPPLY PROTECTION AREA
- STRATFORD GROUNDWATER MANAGEMENT AREA
- WA DE LOCK GROUNDWATER MANAGEMENT AREA
- WY YUNG GROUNDWATER MANAGEMENT AREA
- YARRAM WATER SUPPLY PROTECTION AREA

N

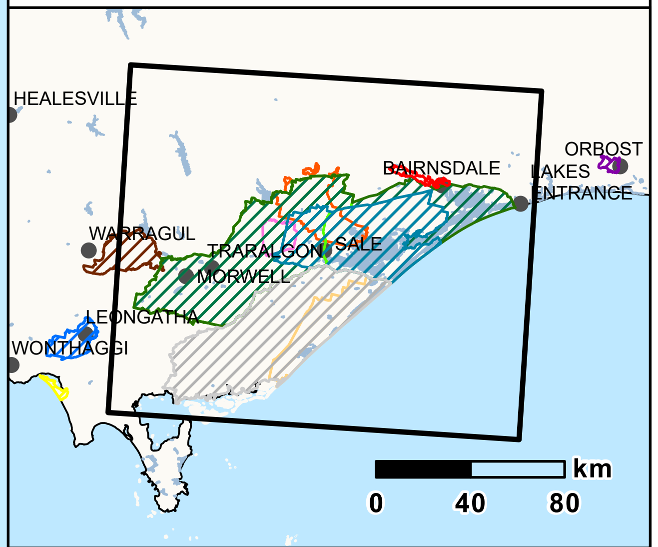
IS2600AQ

Name: GDA 1994 MGA Zone 54

0 2.5 5

Kilometres

DATA SOURCES
© Commonwealth of Australia (Geoscience Australia) 2006 Geodata Topo 250k Series 3; Vicmap Data © State of Victoria 2019; Jacobs 2019.
ESRI Basemap 2019



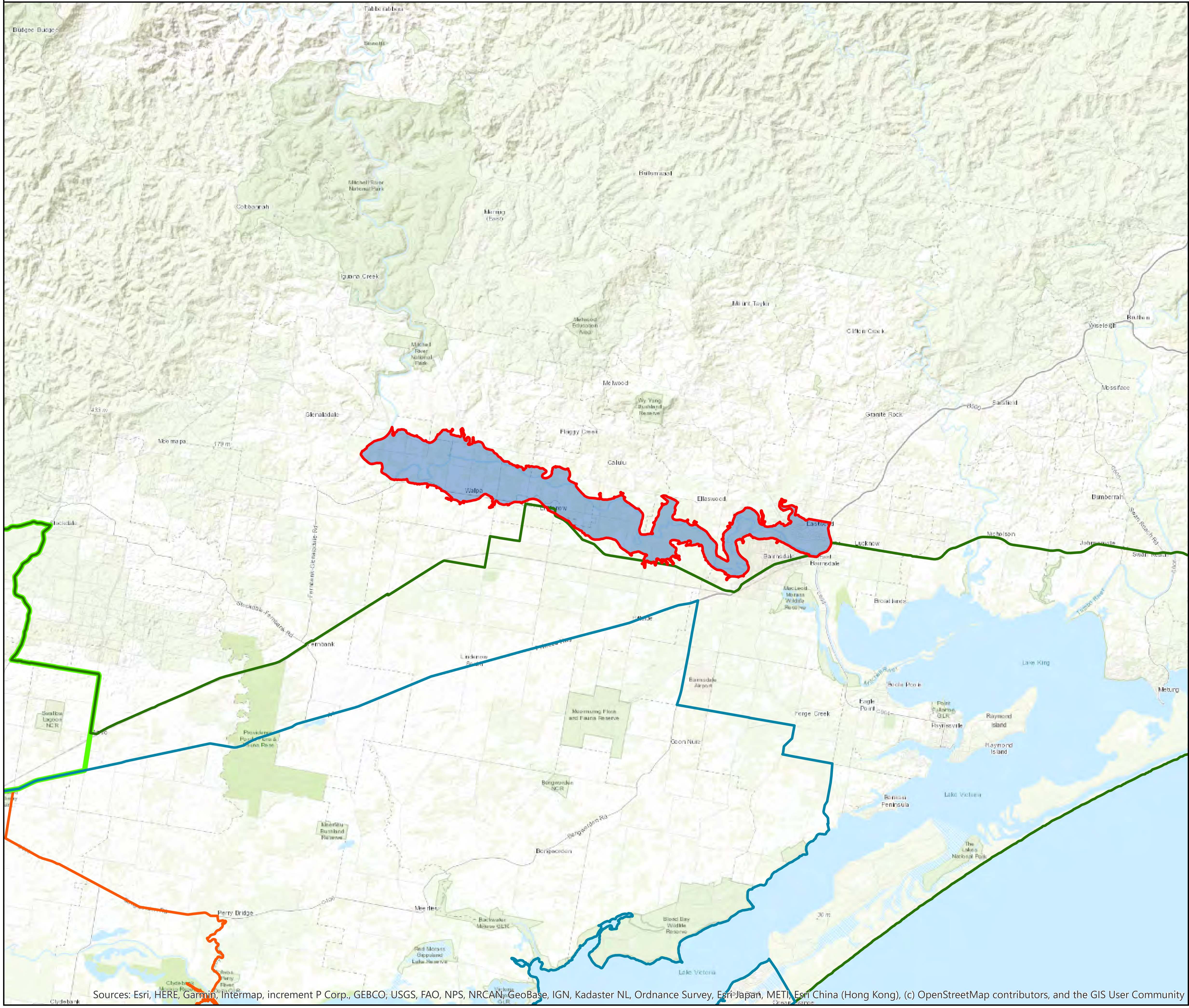
JACOBS

Path: J:\IE\Projects\03_Southern\IS282900\Spatial\ArcPro\IS282900\IS282900_GMA_AB.aprx

Date Exported: 27/06/2019

Gippsland GMA's

WY YUNG GROUNDWATER MANAGEMENT AREA



WY YUNG GROUNDWATER MANAGEMENT AREA

GMA's in the area

- ROSEDALE GROUNDWATER MANAGEMENT AREA
- SALE WATER SUPPLY PROTECTION AREA
- STRATFORD GROUNDWATER MANAGEMENT AREA
- WA DE LOCK GROUNDWATER MANAGEMENT AREA
- WY YUNG GROUNDWATER MANAGEMENT AREA

N

IS2600AQ

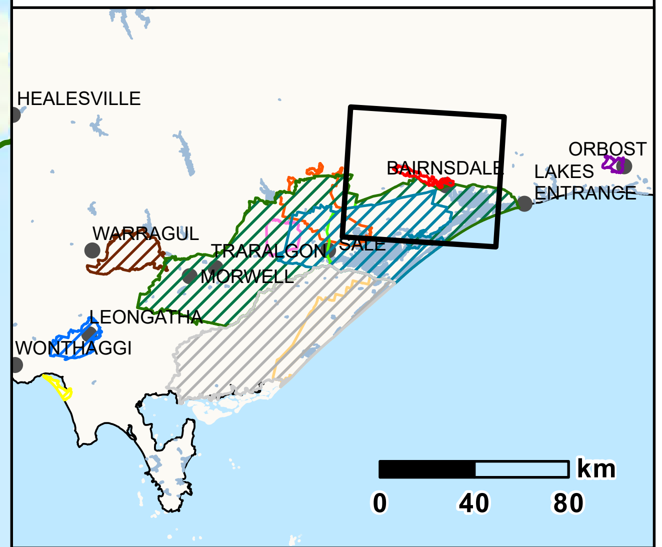
Name: GDA 1994 MGA Zone 54

0 2.5 5

Kilometres

DATA SOURCES

© Commonwealth of Australia (Geoscience Australia) 2006 Geodata Topo 250k Series 3; Vicmap Data © State of Victoria 2019; Jacobs 2019. ESRI Basemap 2019



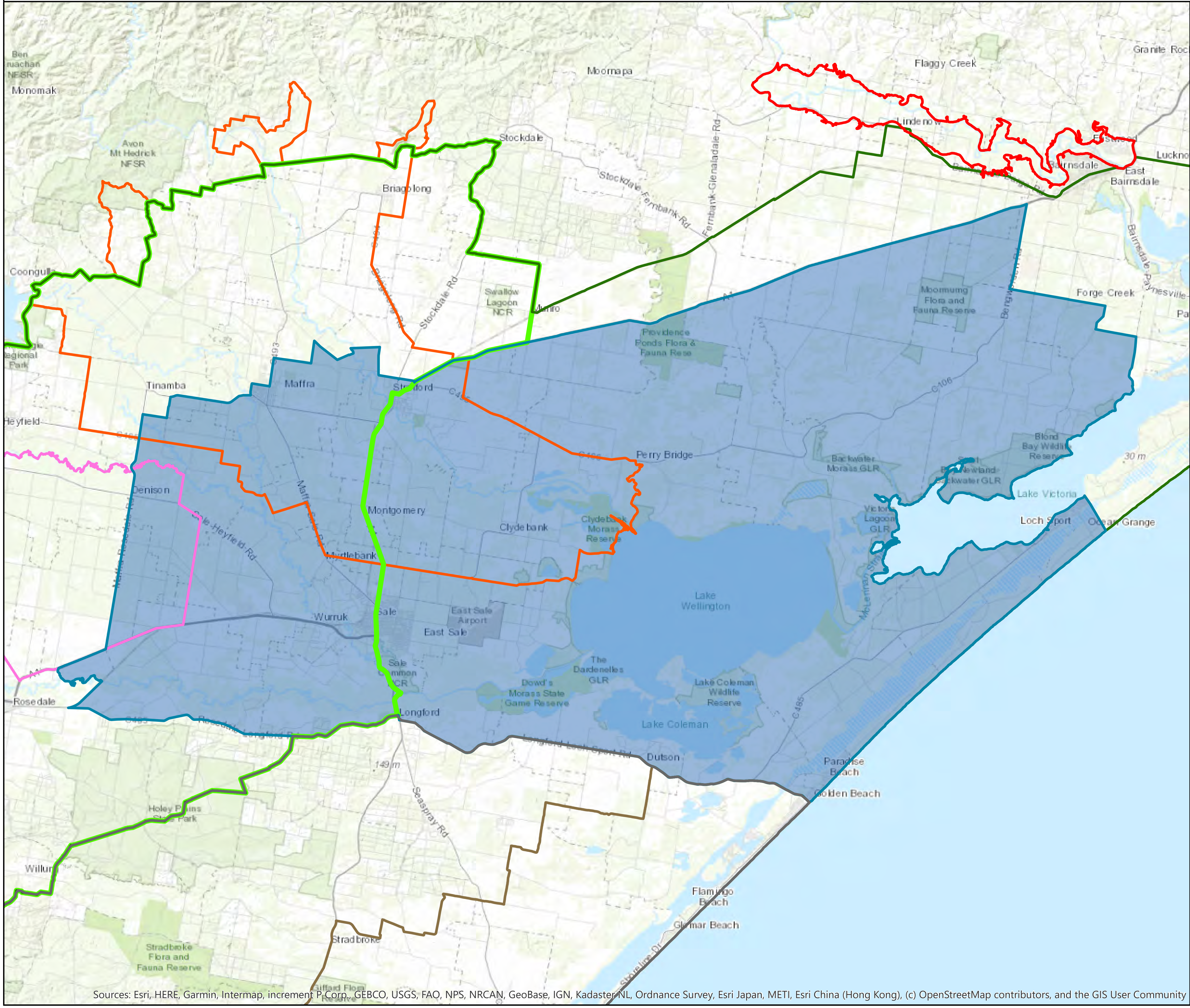
JACOBS

Path: J:\IE\Projects\03_Southern\IS282900\Spatial\ArcPro\IS282900\IS282900_GMA_AB.aprx

Date Exported: 27/06/2019

Gippsland GMA's

SALE WATER SUPPLY PROTECTION AREA



SALE WATER SUPPLY PROTECTION AREA

GMA's in the area

- DENISON GROUNDWATER MANAGEMENT AREA
- GIFFARD GROUNDWATER MANAGEMENT AREA
- ROSEDALE GROUNDWATER MANAGEMENT AREA
- SALE WATER SUPPLY PROTECTION AREA
- STRATFORD GROUNDWATER MANAGEMENT AREA
- WA DE LOCK GROUNDWATER MANAGEMENT AREA
- WY YUNG GROUNDWATER MANAGEMENT AREA
- YARRAM WATER SUPPLY PROTECTION AREA

N

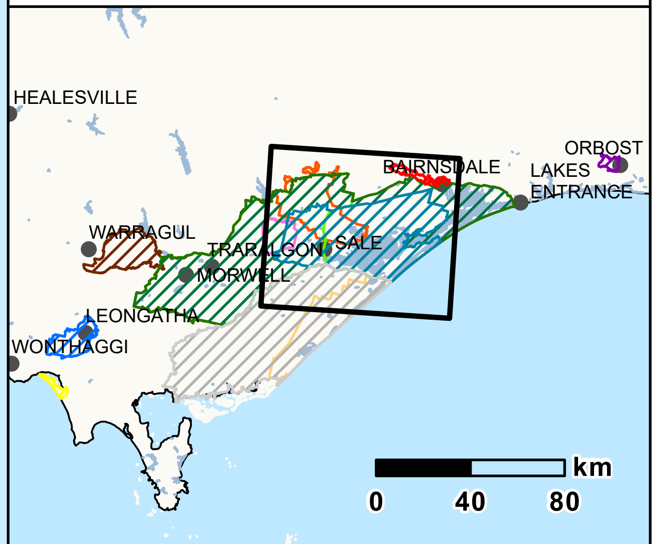
IS2600AQ

Name: GDA 1994 MGA Zone 54

0 2.5 5

Kilometres

DATA SOURCES
© Commonwealth of Australia (Geoscience Australia) 2006 Geodata Topo 250k Series 3; Vicmap Data © State of Victoria 2019; Jacobs 2019. ESRI Basemap 2019



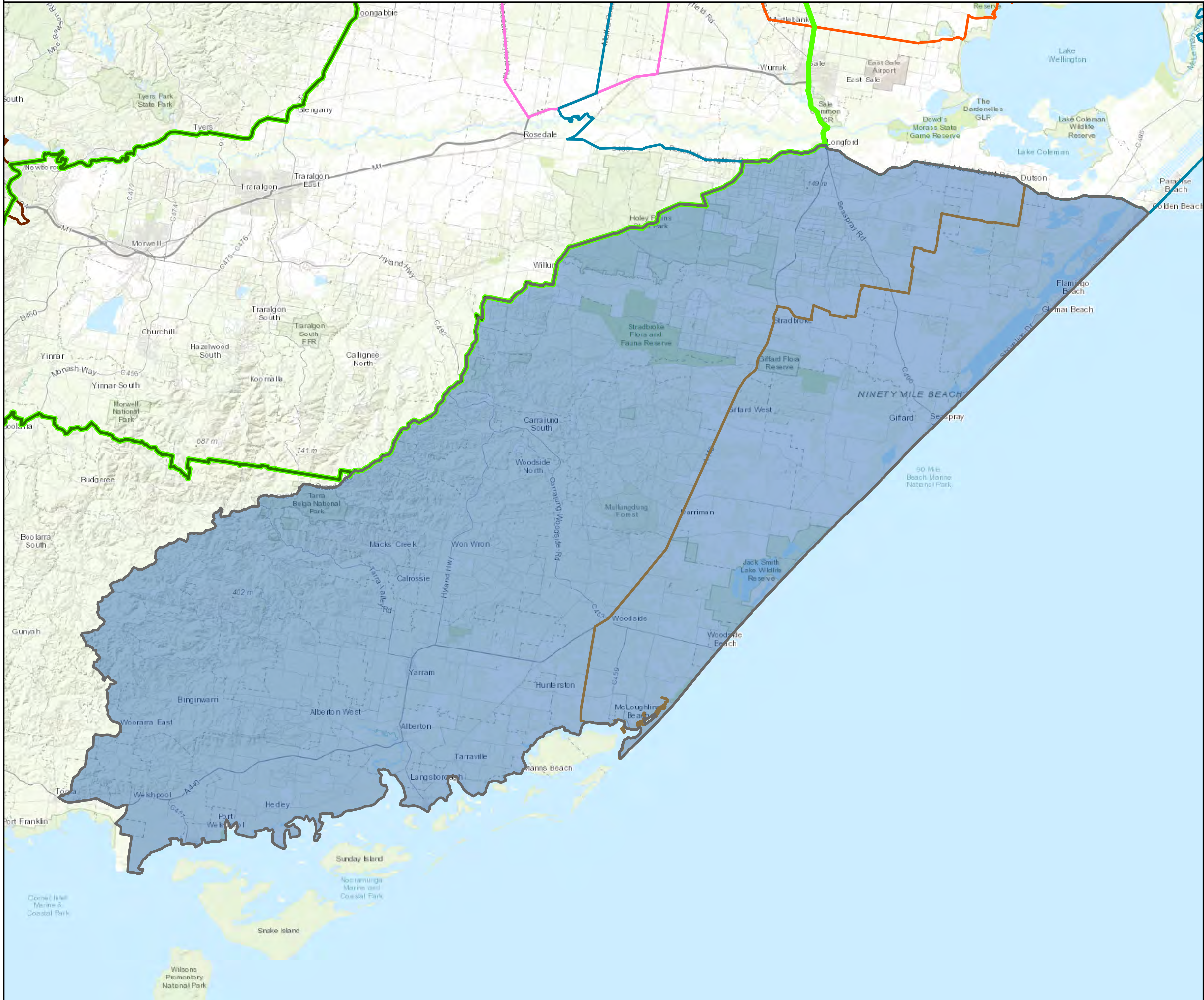
JACOBS

Path: J:\IE\Projects\03_Southern\IS282900\Spatial\ArcPro\IS282900\IS282900_GMA_AB.aprx

Date Exported: 27/06/2019

Gippsland GMA's

YARRAM WATER SUPPLY PROTECTION AREA - Zone 1



Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community

YARRAM WATER SUPPLY PROTECTION AREA

GMA's in the area

- DENISON GROUNDWATER MANAGEMENT AREA
- GIFFARD GROUNDWATER MANAGEMENT AREA
- MOE GROUNDWATER MANAGEMENT AREA
- ROSEDALE GROUNDWATER MANAGEMENT AREA
- SALE WATER SUPPLY PROTECTION AREA
- STRATFORD GROUNDWATER MANAGEMENT AREA
- WA DE LOCK GROUNDWATER MANAGEMENT AREA
- YARRAM WATER SUPPLY PROTECTION AREA

N

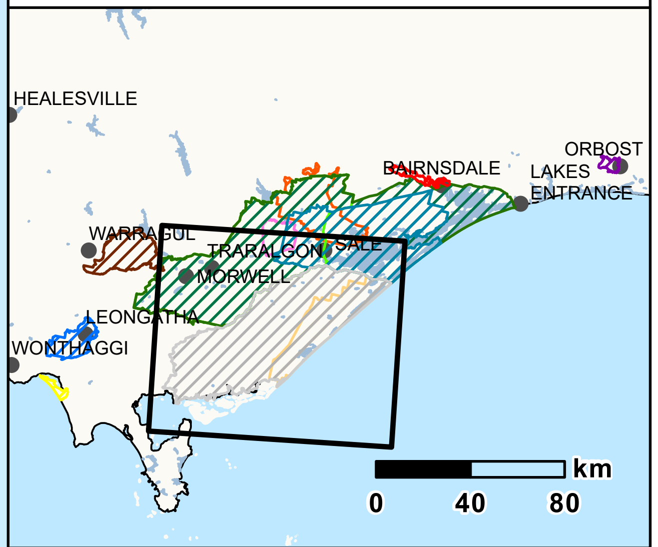
IS2600AQ

Name: GDA 1994 MGA Zone 54

0 2.5 5

Kilometres

DATA SOURCES
© Commonwealth of Australia (Geoscience Australia) 2006 Geodata Topo 250k Series 3; Vicmap Data © State of Victoria 2019; Jacobs 2019.
ESRI Basemap 2019



JACOBS

Path: J:\IE\Projects\03_Southern\IS282900\Spatial\ArcPro\IS282900\IS282900_GMA_AB.aprx

Date Exported: 27/06/2019

Abstract

Kalbar and their consultants have systematically downplayed the significance of the locality as it is today. In doing such, they have devalued and debased the Natural assets to a point where, through technical sleight of hand they have portrayed the Project as an essential element to the landscape and the community.

Undertaking simplistic, scientific analysis skews the science to reveal biased outcomes; cost and value estimates are inaccurate, unfavourable data has been omitted; favourable data has been cherry-picked to create a rosy feeling among the people of the district and surrounds.

All aspects of the EES contain clear flaws that render the Project higher risk than is stated. Despite the EES's content's intent to demonstrate viability and many benefits, in reality, the direct, and the hidden indirect costs will result in a great loss to the taxpayer, environment, local community, and future generations who have been denied opportunity to have their voice. The consequences being too many future options being foreclosed.

There are many reasons to save the environment, there is only one reason to destroy it – short-term economics. As the Project is driven for the benefit of a select few, Kalbar's values are at odds with what constitutes a sustainable society:

- Morally and ethically, written into every religious scripture
- Legislatively, written into many State and Commonwealth Acts, ie. the Victorian Sustainability Act 2005 (Sec 4a)
- Strategically, written into too many strategic direction and policy documents, and
- Operationally, the proposed project is based on antiquated mining and land management prescriptions

We must not let short-term economic decisions isolate our ways of thinking or the evidence that without resource extraction we won't have sustainable industries. If we trash and liquidate these natural assets and the repair jobs fail – as they have over much of the world, the industry in question will be the bath water thrown out with the baby.

Introduction

I am writing from the position of local resident and father, down-stream and down-wind horticulturalist, environmental restoration practitioner. With my 30+ years of experience in the environmental / ecological agricultural business, the assertions that annoy me the most are 'it is safe, the impacts are negligible or acceptable' These are illogical assertions. The only answer that makes sense is 'It depends – on the alternatives available and on the benefits to be gained by making a certain decision'. This includes not liquidating natural resources, not destroying the environment, and forgoing some values to the benefit of others.

We are all part of the land, and as adults, we are only trustees holding this asset (the land at the Project site and beyond, to our whole planet) in trust for the next generation. As adults / trustees it is any parent's duty to leave more options, a good name, and the tools for the next generation to carry on their lives so they can reach their optimum and genetic potential. Kalbar and their consultants formulation of the EES for the proposed resource extraction project is the antithesis of prudent trustee.

Behind the façade of 'sustainable / socially required' proclamations, the underlying utilitarian-economic focus dominates. Linear thinking and linear scientific modelling and analysis undertaken by Kalbar and their consultants only touch on singular elements in a narrow time frame. It is mathematically impossible to model out past 5 years. The grossly incomplete knowledge combined with an unquestioning faith in the 'science' fails to address ecological realities in the foreseeable future. This is risky business.

Despite the vacuous rhetoric and a variety of rationales to support their claims from Kalbar and their consultants of espousing the essential needs to society for what they want to extract, the cornerstones of a healthy environment – soil, water, air, sunlight, and biodiversity will be the first casualties to fall. Such environmentally damaging actions are but a mirror reflection of the mentality with which we treat the region, ourselves, and one another. Kalbar wish to do this all in the frantic drive for short-term profits.

When examined holistically, the proposal has the potential for a range of significant environmental effects on key environmental assets, such as, the RAMSAR Listed Gippsland Lakes, local fisheries, native vegetation, threatened species, water environments, and a major fresh food growing area. It makes neither ecological or economic sense to destroy a landscape at put at risk eastern Victoria's environmental assets for the lowest value end-use.

When decisions are motivated and based on a short-term economic and political basis, they are never optimal for society. And as we have seen in the community, hidden political agendas have come to the fore, with decisions biased towards the select few who would 'win' at the expense of those that will lose. The bitter irony is that this behaviour has gone on through the history of the region and has contributed to the social problems we face today. Such environmentally damaging actions are but a mirror reflection of the mentality with which we treat the region, ourselves, and one another.

- **The potential extent and magnitude of some effects are unclear, due to the uncertainty associated with key aspects of the project scope, the limited knowledge of the existing environment, the biased, inaccurate and skewed technical data.**
- **As Australians, mining to send raw materials overseas which we then purchase back from corporations who offshore their tax liabilities isn't in our best geopolitical interests.**

An EES process should enable an integrated assessment of a range of potentially significant and uncertain adverse effects, including consideration of some complex and inter-related terrestrial, aquatic and geotechnical aspects of the proposal. This hasn't occurred. A simple, traditional, linear assessment favoured by 'scientists / experts' of the major facets of the project have been addressed. At best, only tangible benefits have been measured. The intangible, interconnected externalities that are too difficult to measure are ignored and omitted. No amount of modelling can predict or put certainty into any assertions made in the EES. This demonstrates the EES is biased and flawed.

- **The general public have never been privy to the technical documents until this EES public review process. The only information publicly disseminated was carefully scripted propaganda in the form of 'information fliers'.**

- **Kalbar, their consultants, and the project disregards and forecloses many future options.**

Sadly, decisions based on precedent regarding resource extraction practices are now affecting all other land uses: air, water, carbon storage, climate modification, public amenity and recreation, tourism, fish, wildlife and the non-renewable resources in-situ themselves. With ever increasing energy and input prices, social pressures, variable ore grades, and now Sovereign risk and COVID-19, a mine of the future has to be vastly different to the 'mine of the past' described in the EES.

An examination of the Ecological and Economic fallacies

Ecological fallacy #1

- The project will have minimal impact to aquifers, local water catchments
- The project will create improved habitat for all creatures great and small
- The project will not be intrusive to the surrounds
- The project will provide prosperity, in perpetuity

Ecological reality #1

- The project does not contribute to the water cycle, it despoils it
- The project does not provide habitat, it destroys it
- The project does not add to the aesthetic of the area, it devaluates it
- The project does not facilitate social wellbeing – it depresses it

---

Biodiversity

This project will cause irreparable damage to the environmental integrity of the Site and its surrounds. We can't see much of this damage as it is too small to see, and too subtle to see. Also many negative effects don't get seen for many years. These biological legacies can take decades to repair, foreclosing options for future generations, when the resource extraction industry and people are long gone. The cost burden of the repair is then unfairly placed on future generations that have no say in things (as shown in community consultation – children and their views have been excluded).

- **This fallacious, vacuous rhetoric is simply a box-ticking exercise based on antiquated models. Claims of utilising 'best-practice' techniques, is simply a euphemism for 'industry minimum standard'.**

Simplifying diversity – flora, fauna, landscape, chemical, social; reducing it to the lowest common denominator.

- **What little remnant vegetation is left will be simplified and add to the homogeneity of the area.**
- **Open-cut mining is the most efficient, and in the short-term, the most cost-effective method of extracting desired mineral elements. It is also the most ecologically damaging, as is currently demonstrated in rare earth and mineral sand mines around the world.**

Ecological fallacy #2 The ecological effects of the project will be confined to the Site / mine footprint

Ecological reality #2 The Site / mine footprint is part of an interconnected whole

- **What little remnant vegetation is left will be simplified and add to the homogeneity of the area.**

Water

Water quality is highly affected as the entire resource extraction operation changes the way water moves through the landscape. For example, there is no vegetation to intercept and redirect precipitation, roads concentrate overland flow, changes in biochemical interactions with rainfall and the new, exposed soil horizons, concentrations of water the erode their way to freedom further into the catchments.

Conclusions based on analysis of water use and extraction by the consultants are sub-optimal on merit alone. Here are some salient points:

- Demand estimates are way out and do not allow for increased demand vs less supply in times of drought, nor extra demand from irrigators given assurances to access 'winter-flows'
- The studies completely contradict and ignore DEWLP's Gippsland Groundwater assessment report which states that every aquifer in the region is in serious decline of both quality and quantity
- 'Direct' impacts will have negligible effects to anything….but 'Indirect' effects do not rate a mention and pose more critical importance the functioning environment
- There has been no studies on the impacts of the sheer volume of freshwater removed from the system and how it will change aquatic conditions all the way into the ocean continually for the next 20 years, nor how it will effect fish lifecycles, and by extension local benthic and pelagic fisheries and the local $200million / annum fishing industry?
- Grossly inaccurate flood history data – serious flooding occurred in 2016. Flood debris from as far as Dargo ended up in the Gippsland Lakes
- There has been no study of the effects on stygofauna and its influence on ecosystem health

Once this water is used in the mining operation, it is contaminated. It can't be used again for anything productive. Kalbar wants to take a valuable resource – water (which is part of the global commons, fresh, clean water is everyone's birthright), contaminate it, and keep adding it to the ground within the site, thereby further concentrating any pollutants. This is the lowest value use for the water. It is a poor moral and ethical choice, it's legal standing is arbitrary and capricious, it is strategically unsound, and operationally unsustainable.

When different chemical elements are exposed to each other (such as deep soil horizon elements and the air / rainfall/ overland water flow / deep soil seepage – air – soil chemical elements) a chemical reaction occurs. This produces different chemical compounds. This basic scientific tenet has been ignored in the EES. This omission is serious, because:

- These new compounds are unknown
- Their behaviour in the existing and surrounding ecosystems is unknown
- These chemicals behaviour in an interconnected ecosystem that flows into the RAMSAR Listed Gippsland Lakes and ocean is unknown
- The effect on the reproductive health of flora and fauna, beneficial insects for agriculture, humans – the elderly, immune compromised, children, the unborn foetus is unknown

Such negligence on behalf of Kalbar and their consultant is capricious and demonstrates that the EES is biased and flawed.

- **It forecloses the water's potential option value for 20 years / in perpetuity, in the face of serious climate change.**
- **Over-pumping groundwater not only depletes the resource but also tends to draw chemical contamination towards bores / aquifers**
- **The EES fails to acknowledge that the Mitchell and Perry Rivers' and their tributaries, are a sinuous, continuum of habitats that transport water and all its ingredients, both good and bad, downstream while recognizing neither human boundaries nor human measures for its containment—as every major toxic substance spill has abundantly demonstrated.**
- **Clean, fresh water is part of the global commons. Access to clean, fresh water is everyone's birthright**

Air

The preponderance of evidence says that if you're adding heavy metals, dioxins and the like that will recombine with synthetic fertilisers and other agricultural biocides, then have these distributed around the landscape, you're playing Russian roulette with food supply and food security. In addition to what these re-combinations, introductions, releases, and additives are doing to the water passing through the soils to which they were exposed.

What if the project fails, breaches any pollution mitigation measures, or runs amok, as they so often have around the world? Kalbar has frequently stated that they will responsible for rectifying any damages, this rarely happens – as also demonstrated around the world (Exxon Valdez, Deepwater Horizon, Brazil, Ok Tedi, this list goes on). A prudent operator would demonstrate this basic risk management from the beginning.

- **Air is part of the global commons. Clean air is everyone's birthright.**
- **It does not make sense to introduce and release toxic materials, at whatever level of toxicity, to the atmosphere, water and land that is producing our food and fibre**
- **There is no evidence of insurance disclosure in any risk management statements**

Noise pollution

Kalbar and their consultants make an admission that there will be noise, but no different to the surrounding agricultural area. The stated effects to wildlife is that they will most likely avoid the area and move away – to where? What about the wildlife already there? There has been no studies of the impacts of noise to insects. There is much literature on the benefits of insects to agriculture. What Kalbar and their consults perceive is that such lifeforms have no value. A practitioner of ecological and/or holistic agriculture would state otherwise. Such perturbations have a high potential of disrupting agriculture outside the project footprint.

Disappointingly, additional noise from the shift work of all of the full time staff from their points of departure to the site, the extra freight trains all the way to their destination (Melbourne) every second day for the next 20 years have not been evaluated.

Ecological fallacy #3 Kalbar and the consultants stated view that any fauna affected by noise will simply move elsewhere, and any EPBC Listed species will frequent the area to use habitat resources.

Ecological reality #3 On a still night a person with attuned hearing can detect a pobblebonk frog over 3 km away. How is it that 1000s of horsepower of heavy plant and equipment won't make any detectable audible noise from outside the mine footprint?

With all of the 'science', this simple experiment will let anyone know if there will be any 'noticeable' noise pollution

Experiment: before, during and after mining. NOTE: you can apply this to any form of disruptive activity.

- Go to a Site (Nature), away from human created noise and listen to Nature. Is there any human noise to punctuate the quiet (on a continuum of human noises and natural noises). Then go into the city / town centre and listen to humanity. Is there any sound of Nature punctuating it? Then go to where human created sounds and Nature blend. What punctuates what? Or does it blur together in such a way that little stands out as unique without intense concentration on each of our behalf.
- What makes you feel more at ease?

Transport

The rail option – The envisaged scenario is comprehensive enough and addresses the activity. However, it fails to analyse the gross weight of the trains and carriages and the load bearing capacity of the track gauge. Strong anecdotal evidence sourced from industry insiders regarding the same strategy for freighting ore from the Benambra mine indicated the cost of track upgrades to the tax payer was in excess of $60 million, and that was only to Pakenham. the train still has to go through Melbourne. This omission is a major oversight.

The road option

The envisaged scenario is comprehensive enough and addresses the activity. However, there has been no consultation with those residents and inhabitants that reside along the route. For example, nobody asked the local school of what they think about all of the truck movements past the school. This demonstrates that Kalbar will impose its views, values and needs over everyone else. The fact that it hasn't been properly recognised by the consultants indicates the EES is incomplete, biased and flawed.

No cycle routes have been considered, nor has cyclist or pedestrian safety

- **There is no analysis undertaken that considers any impacts from the transport of the mined material through all of the locales from the project site to its destination.**

Environmental valuations / Offsets

The Offset requirements stated in the EES are flawed in every aspect. These are some salient points:

- The initial requirement has been underestimated due to more destruction than has been modelled to actually occur
- The initial offset assessment is suspiciously low both in quantity and quality required. Studies undertaken by the consultants were curiously undertaken when any biological values would be low.
- The consultants in question have since been removed from DELWPs preferred supplier list for talking jobs down to get development approvals
- The price estimates for the offsets are outdated and seriously undervalued
- Some available offsets do not qualify for the sites geographical position
- Market valuation metric suffers from perverse distortions that keep the offset values unsustainably low – which leads to non-compliance and undermines the system

Ecological fallacy #4 Any native vegetation that will be destroyed can easily and readily be countered by first and third party offsets

Ecological reality #4 We did not design the environment that will be liquidated, so we don't have a 'blueprint' or a 'parts catalogue and maintenance manual' with which to understand and repair it. Nor is there a service department in which the necessary repairs can be made. Therefore, we cannot afford to liquidate the Natural assets that are the blueprint, parts catalogue, maintenance manual and service department.

Non-visual characteristics and their values throughout the EES are absent.

- Soundscape: birds, wind, trees, insects, water
- Touchscape: textures of bark, feel of bushes and foliage, the coolness of flowing water
- Smellscape: the perfumes of plants in the spring, the tang of ozone after rain

This is important with the myriad of intimate interactions between people and Nature where a sense of place and wellbeing evolves.

Outdated and sub-standard environmental studies undertaken by low-tier consultants fail to recognise current changes to environmental laws. There are over 700 plant and animal species that have been allocated Critically Endangered Listing under the FFG Act based on globally accepted assessment standards.

The ecological communities at risk will further suffer cumulative damage until they collapse – certainly at a local level, and will contribute to the same at a regional / State level. This is flawed morally, ethically, legally, strategically, and operationally.

- **Due to the downplaying, discounting and biased nature of data in the EES, environmental valuations are reduced to the lowest common denominator, effectively justifying the wholesale liquidation of any Natural Capital that exists**

The visual amenity

Its' all based on modelling – optimum growth rates of trees and vegetation.....doesn't reflect the reality – in fact, most revegetation projects in the region are a failure. Ironically, the revegetation prescription is no different to what has failed and been failing for the last 3 decades.

There is a great desire to reduce / hide the visual impact....out of sight, out of mind, no one will see what really goes on.

You just can't replace big, old trees

There is no consideration of other viewing areas, ie. a local farmer with their favorite spot in the paddock. Kalbar's level of community sensitivity is related to their and their consultants view of the primary function of the land – which is deriving an existence from grazing.

No tourists have been considered on the beautiful views

- **The indigenous community, farmers and many other people have deeper connections to the land**

Agriculture and horticulture

Soils
Considering it may take 100 years to form 1mm topsoil, aeolian forces can remove this in a matter of minutes. The loss of 1mm of topsoil is estimated at 14t/hectare. Winds of only 5kmh is enough to get fine soil and dust particles airborne. This is quite substantial over the exposed area of the mine footprint.

Ecological fallacy #5 Post mining agricultural restoration will bring the pastures back to a productive capacity at, or better levels than pre mining.

Ecological reality #5 Soils cannot be repaired or 'rehabilitated by any means, no matter how much money is spent

How much dust could potentially blow off the exposed soils of the site? per day? How many tonnes could potentially head downwind and how far could it blow? Has this been researched? If not, why has no research been done? If so, what are the results?

Ecological fallacy #6 The site's only future use is low-productivity grazing that can have a definitive economic value ascribed to it

Ecological reality #6 The site is able to support many high-value agricultural enterprises depending on the desire and ambitions of the landholder at any given time

Narrow crop residue analysis, limited to a few leafy vegetables. It ignores the down-stream and down-wind agriculturalists. There has been no effort to research the effects on other crops such as, pecans, apples, pears, apricots, peaches, nectarines, cherries, avocados, lemons and limes.

- **There has been no effort to research the effects on down-stream and down-wind agricultural enterprises that will suffer the effects of the project.**

Cultural heritage

The tangible and intangible Cultural Heritage values in the project area have been totally disregarded. This typifies the Australia-wide attitude at present. These values of cultural, archaeological, and historic significance are important to not only those with indigenous heritage, but also are a significant cultural, archaeological, and historic asset to all Australians. It would be a great travesty to knowingly and willingly destroy such artefacts.

- **The insensitivities demonstrated towards the Cultural Heritage of the area are morally inconsistent to all people who have a great attachment to this land.**

Socio-economic

Resource extraction jobs are based on environmental destruction. To be economically viable, productivity of each worker / mechanisation unit needs optimal material to extract. Therefore the only focus will always be on obtaining the resource in the lowest cost-of-production attainable.

A frequent argument proponents of resource extraction use to justify their position is jobs; and jobs fuel the local economy. Interestingly, in the continual corporate drive for profits, industries are always on the lookout to replace high-cost workers with lower-cost technology wherever possible. The unwelcome result is fewer jobs than promised.

- **Widening of the prosperity gap corelates with increased crime and policing costs**

Ecological fallacy #7 Resource extraction provides sustainable, expanding employment

Ecological reality #7 'Rape and run' resource extraction mentality does not provide dignified, meaningful work

Ecological fallacy #8 Resource extraction is necessary to compete in the global economy

Ecological reality #8 Corporate resource extraction interests impose their short-term economic objectives on local communities which result in degraded environments, and degraded local communities.

With the 'promise' of the economic benefits from local jobs, there will be those governmental and agency individuals that will ensure 'cheap' resources that can be taken in massive amounts by the least-cost means, transported for processing to any place that has ready workers and benevolent terms.

Kalbar and their consultants promote the spin-off benefits to perpetual increasing property prices, and good rental increases which is 'good' for the greater community. There has been no analysis done on the effect of these increases on those who are of a low economic demographic, of which this region has a high proportion.

There has been ample socio-economic studies compiled about this region dating as far back as the 1960s. All show decline. The depletion and degradation caused by the failure of Nature to provide fundamental services has caused it. This is nothing new in the history of humanity. The 3 pillars of society since settlement – mining, logging and farming have facilitated the impoverishment of the quality of life for local residents, the people of Victoria, Australia, the planet, and so on

Any good parent's duty is to leave more options to the next generation. Kalbar and their consultants mining Project will foreclose options.

- **When communities are stripped of their resources, they inevitably collapse**

Economics

With the 'promise' of the economic benefits from local jobs, there will be those governmental and agency individuals that will ensure 'cheap' resources that can be taken in massive amounts by the least-cost means, transported for processing to any place that has ready workers and benevolent terms.

There is no doubting the 'back of the envelope' figures to support the income potential of the project are very attractive. However, as external costs and liabilities have been omitted from any analysis, the whole-of-cost liability soon takes the shine off the project, unless you are a direct beneficiary of the after tax (if any) profits. Many of these beneficiaries have no connection with the community

Powerful new extractive technologies whose correspondingly extensive damage to ecosystems is seldom given a monetary value. After richer ores are exhausted, skilled mining companies can now level and grind up whole mountains of poor quality ores to extract the materials desired. But while technology keeps ahead of depletion providing what appear to be ever cheaper materials only appear cheap because the stripped landscape and mountain of toxic tailings spilling into rivers, impoverished communities and their eroded indigenous cultures with all the consequences they leave in their wake, are not factored into the cost of production. (**externalities**)

Such a waste is currently rewarded by deliberate distortions in the marketplace in the form of subsidies to industries that extract raw materials from the earth and damage the biosphere. As long as that damage goes unaccounted for, as long as virgin resource royalties and prices are maintained at artificially low levels, it makes sense to continue to use virgin materials rather than reuse resources discarded from previous products.

Ecological fallacy #9 Mining projects bring great wealth to local communities, providing many tripple-bottom line benefits

Ecological reality #9 Any inputs to the operation benefit distant businesses and economies. When this occurs, local communities are manipulated for someone else's benefit. This is rogue economics.

Royalties paid to the government for a one-off opportunity – because mining is a non-renewable activity, are arbitrary and can be manipulated in a way so as to minimise the value of resource extracted. This is a common practice in the industry. Back-of-the-envelope figures supported by quotations from the CEO at a community engagement meeting suggest that taxes and royalties may be less than 1% of gross income. It would be highly likely that the governments cost to administer this project wouldn't be covered, thus the State is operating at a loss; a loss that can never be regained or recovered.

Ecological fallacy #10 Open cut mining is the most efficient way of extracting a resource

Ecological reality #10 This form of resource extraction only considers short-term resource use economics, not long-term socio-environmental economics

- **By ignoring externalities, economic arguments are flawed**
- **Approval of the Project creates the short-term, myopic situation of stealing the future, selling it in the now, unfairly placing the repair costs and burdens on the future generations and calling that good socio-economics.**
- **The misapplication of technologies and skewed data leads to ludicrous claims and goals of perpetual economic benefit and growth from a finite resource. This is biophysically impossible.**
- **There are many reasons to protect the environment – there is only one reason for liquidating it….short-term economics**

Human health

A simplistic, linear analysis of the recalcitrant elements and their effects on a narrow sample of lifeforms discounts the actual synergistic impacts and effects that would manifest. There are some incredibly basic uncertainties that haven't been addressed. Some are:

- The biodegradability of toxic outputs
- The toxicity of these outputs on THE local ecosystems, not some random study from the other side of the world
- The toxicological effects of the likely recombination's of the mines outputs and the chemicals present down-stream and down-wind of the mine, if they could become more toxic
- How these toxic outputs and combination's enter and move through the food-chain
- How biodegradable are these recombination's
- The biophysical effects of exposure to the local lifeforms

- **Simplistic desktop analysis and rudimentary tests on lettuce and broccoli do not factor in the infinite number of 'real' variables and actualities. This is too hard, therefore gets ignored**

Rehabilitation and closure

Maintaining and enhancing (opposed to destroying and diminishing) biodiversity is a central concept in modern conservation. The imperative of Site protection ensures that landscape and environmental processes are resilient as possible. Resiliency / stability equates to adaptability which allows biological communities the greatest opportunity to adapt to new and changing environmental conditions.

Ecological fallacy #11 Environmental repair after open-cut mining provides healthy future environments that enable reintroduction of Listed species, increases in quality and extent of habitat, and reconstructs complex habitat. Any infrastructure can be safely decommissioned and there will be no ongoing environmental issues.

Ecological reality #11 We can plant trees and provide 'nest boxes', but we can't piece back together 50m of soil horizons that fulfil original ecosystem processes. We can't replace 450 + year old trees. The catastrophic impacts and disruptions on the environment are permanent. There is no example on how the landscape will function after it has been turn upside down, or had the desired minerals extracted from it. An analogy would be 'if you removed 5 elements from your blood and manipulated your body to exclude them forever, how would the rest of your body react?'

- **Anyone can identify destructive land management practices. You don't have to be a landscape ecologist to recognise bad landscape management anymore than you need to be a doctor to recognise ill health. If mining looks bad, it is bad.**

All any environmental repair actions do is help heal inappropriate human modifications. The ecological integrity of the site will be altered and/or destroyed forever. What is also an ongoing challenge is that any repair efforts take place in biological systems we do not fully understand on top of the influences of climate change.

We did not design the environment that will be liquidated, so we don't have a 'blueprint' or a 'parts catalogue and maintenance manual' with which to understand and repair it. Nor is there a service department in which the necessary repairs can be made. Therefore, we cannot afford to liquidate the Natural assets that are the blueprint, parts catalogue, maintenance manual and service department.

- **This is blatant economically motivation extinction. What little remnant vegetation is left will be simplified and add to the homogeneity of the area despite what fanciful claims have been stated.**

MORALS AND ETHICS

As parents / adults, we have a moral and ethical obligation to leave to our children / future generations, more options for them to navigate through their lives. To foreclose options, which the Kalbar project will do is nothing short of a remote form of tyranny. Stealing from the future and selling it in the now while unfairly imposing the cost burden of repair on future generations.

Kalbar's myopic, corporate paradigm of the need and benefit of constant economic growth, - which is a biophysical impossibility in an interconnected universe of ever-novel cyclical processes, completely ignores Nature's inviolable ecological realities. As such, has presented a neo-classical blueprint of resource extraction in a sensitive environment. The proposed project is a relic from the past and will never be a resource project of the future.

Low-tier consultants who have more in common with the world's oldest profession than scientific analysis have been employed to 'scientifically prove' – under the auspice of 'world's best-practice', which is just a euphemism for minimum standard – that no matter what, the project and its operations and outcomes will be benign, and arrogantly, beneficial to the environment and all those who inhabit the surrounding area. With incomplete knowledge and short-sighted, unquestioning faith in that knowledge, technical information provided in the EES and to the community has been biased, statistics have been used selectively, and arguments left out if they counter a preferred position. This isn't science, this isn't risk management.

Ensuring a healthy environment is the foundation of a sustainable society. This is clearly written and communicated in many religious texts

Christianity / Bible

- Revelation 11:18 – *'God will see destroyed those who destroy the earth'.*
- Isaiah 24 – shows the relationship between man and earth
- Leviticus 25:23 – the land is God's and the people are tenants....*what does a good tenant do? Preserve the foundation/s of life – food, water, shelter....and love*

Hebrew / Torah

- Genesis – *'Be careful not to destroy my world, for if you do, there will be nobody after you to repair it'*
- Psalm 24 *'the earth is the Lord's and the fullness thereof'* – meaning, any act that damages our Earth is an offence of God's ownership of the land.

Hinduism / Rig Veda

- Communicates the divine nature of air, water, vegetation, soil
- Throughout the Hymns there is a clear message that the environment belongs to all living beings, so it needs protection by all, for the welfare of all.
- 'The oceans are treasure of wealth, protect them' (Yajurveda 38.22); 'Do not poison/pollute water and do not harm or cut the trees' (Yajurveda 6.33); Do not disturb the sky and do not poison/pollute the atmosphere' (Yajurveda 5.43).

Buddhism

- Espouses the benefits of an undefiled environment – clean air, water, and soil, shade
- Includes the protection of the various defenceless creatures that have no say in having to either live or die from our actions

Islam / Qur'an *paraphrased*

- *'And do not commit abuse on the earth, spreading corruption.'* (Qur'an, 2.60); *And do not desire corruption on the land. Indeed, God does not like corruptors.'* (Qur'an 28.77)

Shintoism

- Nature is divine
- Every aspect in the landscape are viewed as dwellings for the divine

Daoism

- The Principles of: Harmony with Nature, affluence in biodiversity
- Restrained in the over-exploitation of resources

Despite careful legislative analysis by Kalbar's legal team, legal interpretations undertaken to communicate that Kalbar is a law abiding entity, sadly contradicts the Purposes and Objectives of many Sate and Commonwealth Acts and fails to acknowledge realities of the Project's operational outcomes.

THE LAW

Kalbar's undertaking the EES is no more than a box ticking exercise that 'tells what is needed – yet surrenders no further information'. Project strategies adopted to appear legislatively compliant are arbitrary and capricious.

Acts that I have come to understand haven't been researched or referenced

- Nuclear non-proliferation (safeguards) Act 1987
- Export Control Act 2020

EPBC Act 1999

Definition - ***"ecologically sustainable use"*** of natural resources means use of the natural resources within their capacity to sustain natural processes while maintaining the life-support systems of nature and ensuring that the benefit of the use to the present generation does not diminish the potential to meet the needs and aspirations of future generations.
Kalbar want all the resources, at the cheapest cost, extracted as fast as possible. The project's outcomes contradict ecologically sustainability.

Sec 3
(f) includes provisions to enhance the protection, conservation and presentation of world heritage properties and the conservation and wise use of Ramsar wetlands of international importance; and

(fa) includes provisions to identify places for inclusion in the National Heritage List and Commonwealth Heritage List and to enhance the protection, conservation and presentation of those places; and

'enhance' and 'protect' means no net-loss. Kalbar's project can not deliver this requirement.

ENVIRONMENT PROTECTION AND BIODIVERSITY CONSERVATION ACT 1999 - SECT 3A
Principles of ecologically sustainable development

Principles of ecologically sustainable development
The following principles are ***principles of ecologically sustainable development***:

(a) decision-making processes should effectively integrate both long-term and short-term economic, environmental, social and equitable considerations;

(b) if there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation;

(c) the principle of inter-generational equity–that the present generation should ensure that the health, diversity and productivity of the environment is maintained or enhanced for the benefit of future generations;

(d) the conservation of biological diversity and ecological integrity should be a fundamental consideration in decision-making;

(e) improved valuation, pricing and incentive mechanisms should be promoted.

PLANNING AND ENVIRONMENT ACT 1987

SECT 1 Purpose
The purpose of this Act is to establish a framework for planning the use, development and protection of land in Victoria in the present and long-term interests of all Victorians.

SECT 4 Objectives

Objectives
(1) The objectives of planning in Victoria are—

(a) to provide for the fair, orderly, economic and sustainable use, and development of land;

(b) to provide for the protection of natural and man-made resources and the maintenance of ecological processes and genetic diversity;

(c) to secure a pleasant, efficient and safe working, living and recreational environment for all Victorians and visitors to Victoria;

(d) to conserve and enhance those buildings, areas or other places which are of scientific, aesthetic, architectural or historical interest, or otherwise of special cultural value;

(e) to protect public utilities and other assets and enable the orderly provision and co-ordination of public utilities and other facilities for the benefit of the community;

Kalbar's project isn't sustainable (it has a 20 year plan....a finite amount of resource). It does not preserve, protect, enhance or secure environmental and ecological Capital for anyone, ever.

SUSTAINABILITY VICTORIA ACT 2005

SECT 4 Principles
It is the intention of Parliament that in the administration of this Act the following are to be considered as guiding principles—

(a) that decision making processes should effectively integrate both long-term and short-term economic, environmental, social and equity considerations; short-term profit take-all

(b) if there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation; violates every benchmark

(c) the need to consider the global dimension of environmental impacts of actions and policies; extinction debt, threat to global commons – oceans, air, RAMSAR Listed Gippsland Lakes, Providence Ponds

(d) the need to develop a strong, growing and diversified economy which can enhance the capacity for environment protection; commodity extraction is profit based, so disappointingly doesn't deliver on promised outcomes – jobs. It promotes homogeneity opposed to diversity

(e) the need to maintain and enhance international competitiveness in an environmentally sound manner; the project is not environmentally sound

(f) the need to adopt cost effective and flexible policy instruments such as improved valuation, pricing and incentive mechanisms; valuation metrics are outdated

(g) the need to facilitate community involvement in decisions and actions on issues that affect the community. Has been inadequate, condescending

---

WATER ACT 1989

SECT 1 Purposes
This Act has the following purposes—

(a) to re-state, with amendments, the law relating to water in Victoria;

(b) to provide for the integrated management of all elements of the terrestrial phase of the water cycle;

(c) to promote the orderly, equitable and efficient use of water resources;

(d) to make sure that water resources are conserved and properly managed for sustainable use for the benefit of present and future Victorians;

(e) to maximise community involvement in the making and implementation of arrangements relating to the use, conservation or management of water resources;

Again, catch words – 'sustainable use', 'present and future Victorians', 'conservation', 'equitable', 'orderly' and so on.

STRATEGIES

To work within the boundaries of the law, all sorts of legal gymnastics have occurred….and that is the skill and art of the legal teams.

Down-playing the value of existing social, economic and environmental assets

Ostracising the children of those who oppose the Project by the proponents

Undertaking only the bare minimum of monitoring outside of the Project's footprint – ie. water quality, air pollution, noise, traffic

Selecting favourable information to disseminate to the public – with the online response survey recently, all of the community groups that a $10 donation was made for each survey, MFG didn't get mentioned….pretty childish

Basing scientific evidence that rests on the theoretical formulation of an idealistic model. Once created, this ideal model is implemented in the real world. Kalbar and its consultants argue that as long as a concept can be formulated intellectually, it exists in the real world and, therefore, can be implemented.

But here is the reality....
It is mathematically impossible to maximize more than one variable at a time in an interlinked system. Modelling encounters serious problems in situations that cannot be fully comprehended rationally or logically. This happens when mathematical patterns cannot be formulated. Therefore, modelling is pointless because it requires ideal circumstances that have nothing to do with reality. This is the domain of chaos.

....this is risky business

Environmental damage done by the Project is irreversible and can't be hidden, therefore, Kalbar's project and the EES is biased and flawed

Despite assertions made by Kalbar and their consultants

OPERATIONS

I haven't seen anything regarding insurance and who would be underwriting such a project

Kalbar wishes to run down the local ecosystem by discounting / ignoring knowing its real worth– Kalbar is testing these theories, strategies and actions by conducting a large-scale experiment, entirely unplanned, with irreversible results and unknown outcome – with the main impact of Kalbar's experiment's repercussions left to fall on future unborn generations. Such Projects that are based on short-term estimations of material return that discount future long-term negative environmental impacts needs to be viewed not only as bad economics but also as morally inconsistent with our sense of community membership and stewardship.

1. The local remnant vegetation and ecosystems are ever-changing continuums of living and non-living things and processes—embedded in time.

Kalbar assumes it can design remnant vegetation and ecosystems as rigid monocultures—suspended from time.

2. Local remnant vegetation, ecosystems and deep soil horizons are part of complex landscapes whose patterns reflect crucial underlying structure and process.

Kalbar would design remnant vegetation, ecosystems and deep soil horizons which largely ignore these structures and processes and their imperatives for pattern.

3. Remnant vegetation, ecosystems and deep soil horizons are mixtures of living and non-living things and processes which are:

Self-organized.
Self-repairing.
Self-sustaining.
Dynamic yet relatively stable.

Kalbar would design remnant vegetation, ecosystems and deep soil horizons requiring frequently destructive, ultimately impossible subsidies of energy, fertilizer, pesticides, and even water.

4. Diversity is a fundamental property of remnant vegetation, ecosystems and deep soil horizons, and emerges for many "reasons" at many system levels—from chemical compounds through species and communities, to galaxies.

Kalbar would design remnant vegetation, ecosystems and deep soil horizons with simplistic uniformity for only one "reason": Efficient Commodity Production.

5. Remnant vegetation, ecosystems and deep soil horizons reflect various laws of impossibility—of physics and thermodynamics—not trends.

Kalbar would design remnant vegetation, ecosystems and deep soil horizons that vainly ignore these laws for short-term, and increasingly trivial cravings.

6. Remnant vegetation, ecosystems and deep soil horizons are co-evolving, and interrelated systems of things and processes meet many 'ends' and functions. Energy and materials which 'fuel' these processes do not merely pass through but remain as wastes with subsequent effects on processes. (One creatures waste is another's food)

Kalbar would design remnant vegetation, ecosystems and deep soil horizons imagining that they can give up huge portions of their matter and energy for only human ends, to be consumed elsewhere, largely ignoring the effects of waste on subsequent processes. (the helicopter analogy)

7. Remnant vegetation, ecosystems and deep soil horizons are inherently value-neutral, and we are largely ignorant of their functional and dynamic interrelations.

Kalbar would presume to judge which components and processes are good or bad—which is to say, which ones suit THEIR current human values and moral vision.

8. The direction of the remnant vegetation, ecosystems and deep soil horizons are largely unpredictable and their moral implications ambiguous—but it works! What is more, it so far still includes us.

Kalbar would design machine-like remnant vegetation, ecosystems and deep soil horizons, forever altering the possibilities of a robust creation.

Social

Many submissions have mentioned that Kalbar have no social licence….if they claim they have / do, then there should be no problem in answering the following questions: NOTE – I put you (the public and IAC), that the younger generation haven't been consulted.

Kalbar and those who seek economic gain despite probable, negative, social-environment outcomes—must be accountable for answering relevant questions concerning the potential consequences of their actions. Because such accountability is to be taken seriously, I posed the following questions before the IAC:

1. With long distance-transport of air pollutants and their ability to alter habitats, Kalbar's project is also altering the long-term habitat for people. Does Kalbar have the people's permission—adults and children—to add pollution to the air that alters the health of the plant communities that constitute the quality of the habitat in which wildlife and people must live, considering that they would be adding to the potential irreversibility of the negative, cumulative effects that present and future generations must endure? Is a good quality of habitat in which to live the inherent birthright of every human being—or is it not?

2. Does Kalbar have the people's permission—adults and children—to add pollution to the air everyone must breathe, considering they would be irreversibly adding to the very long-term negative, cumulative effects that all plants and animals, including humans, must live with? After all, clean air is a global commons and therefore everyone's birthright.

3. Does Kalbar have the people's permission—adults and children—to add pollution to the air that can exacerbate global warming and alter the local pattern of precipitation, considering that they would be adding to the negative, cumulative effects that all generations must live with? After all, clean air, which protects Nature's regime of local precipitation, is part of the commons and so everyone's birthright.

4. Does Kalbar have the people's permission—adults and children—to add pollution to the air, which then pollutes the soil that grows their food and affects the water everyone must drink (water needed for life itself, water for which there is no substitute) and thereby add to the negative, cumulative effects that all generations must live with? As with air, healthy soil and clean water are part of the global commons through successive generations of children and so everyone's birthright.

5. Does Kalbar have the people's permission—adults and children—to add pollution to the Rivers, RAMSAR Listed Gippsland Lakes or Bass Straight, considering that they would be irreversibly adding to the negative, cumulative effects that all generations must progressively live with because our oceans, of which it is a part, have no outlet and so concentrate not only the amount of toxic chemicals but also their increasing toxicity? I ask this because both the Gippsland Lakes and the ocean are part of the marine-commons and their biophysical health is everyone's birthright.

Ignoring questions….lack of transparency in all forms of conduct….not telling the full story…. social ostricisation of those with opposing views….this is childish behaviour…. Kalbar is in a societal state of arrested adolescence. Everyone knows that children make more messes than they clean up. Kalbar's present societal concepts of organization, governance and business, will make more mess than they can clean up.

The only part of toxic chemical products that is tested for toxicity is the active ingredient/constituent that, by themselves, usually form a tiny portion of the solution. This means the larger, untested portion of most toxic chemical products, containing other, so-called 'inert' chemicals can be more toxic than the active ingredients.

Water

"Whiskey is for drinking and water is for fighting over" – Mark Twain

The combination of pollutants – Kalbar's Project outputs, wastes, fugitive emissions, along with other non-point-source pollution coming from intensive agriculture, including intensive forestry, which laces the soil with toxic pesticides, herbicides, and synthetic fertilizers, not only kills fish and other aquatic life but also damages EPBC Listed saltmarshes in our coastal areas.

In every rainfall event, this 'toxic cocktail' in tons of soil supplied from the mine footprint—and its myriad synthetic chemicals—will erode with each inch of rain. As the soil moves, it carries the poisonous compounds into ditches, streams and aquifers in the catchment. In addition, the pollutants leach through the soil into the groundwater, and from there into the same ditches, streams and aquifers in the catchment.

Once in the waterways, the chemicals can cause bone deformities aquatic and amphibious fauna, damage their reproductive systems, destroy their food supply, and block their adaptation to the differing water qualities downstream to the ocean. These contaminants can also prevent migrating adult aquatic fauna (such as eels) from finding their home waters in which to spawn.

There has been no studies or research done into how these probabilities affect the local water and its chemistry.

….the Project is a massive assault on the regional water cycle and the pollution of these water sources….once water is polluted, particularly groundwater, it is difficult, if not impossible to clean up.

….the amount and quality of water for human use is largely the result of climate, topography, and the ecological integrity of the water catchments. The availability of clean water throughout the year determines the fundamental quality of life of a community….this is being interfered with from the headwaters of the Mitchell Catchment (clear-fell logging) (also severely bushfire affected)– all the way to the ocean. Some of these impacts have occurred since the Kalbar's studies have been submitted and aren't factored into their model

In addition….
The local farming lobby secured $10m from the government to be match dollar for dollar for off-stream water infrastructure do draw extra winter-flows from the Mitchell river; that equates to $20m available for dam building. From experience a quality dam may cost app. $3000 per megalitre – enough to extract another 6500-7000 megalitres from the system, or 6-7 giga litres….that on top of Kalbar's requirements…. this hasn't been factored in by Kalbar in relation to above and below ground water impacts, and very concerning that the administrative agencies make no mention of this.

Vegetation

Fragile ecosystems can go awry in more ways and can break down more suddenly, with less warning, than is likely in robust ecosystems, because fragile systems have a larger number of components with narrow tolerances than do robust ones. As such, the failure of any component can disrupt the system. Therefore, when an ecosystem is altered for human benefit, it is made more fragile, which means that it will require more planning and maintenance to approach the stability of the original system.

In addition, while incremental changes in an ecosystem may seem insignificant to us humans and their effects for a time to be invisible, ecosystems operate on thresholds with unknown margins of safety. But once a threshold is crossed, it is crossed. There is no going back to the original condition. It is thus necessary to understand something about the relative fragility of simplified ecosystems as opposed to the robustness of complex ones.

It is becoming more apparent that Kalbar's *modus operande* of discounting ecological assets to incrementally liquidate these assets. Kalbar's low-tier consultants are complicit in this behaviour, structuring their advice to 'get-the-project-through'. This is a common practice among developers. This bastardisation of the environment needs to be nipped in the bud. The outcomes are a degraded environment with no accountability….with the cost burden of repair unfairly placed on future generations.

Other points of discussion will be ‘piggybacked’ from my previous submissions

Scott Dizais
Submission 712
Supplementary submission – Centrifuges

The complexity of industrial engineering

Summary
The 'last-minute' inclusion of the centrifuge extraction method raises further questions, if the potential, biophysical effects of this action are to be ascertained. The purpose of the questions is to assess both the possibility and the probability of whether or not certain, negative, environmental consequences will result from of a proposed, economically motivated action. I feel these questions are necessary because an apparently good, short-term, economic proposition may prove to harbor potential, long-term, detrimental, environmental effects of which legacy cost of this high-risk, open-ended experiment with the burden of failure unfairly imposed on future generations, is inconsistent morally and ethically, legally, strategically, and operationally to society. By this, I mean a good, short-term, economic decision may, in fact, turn out to be a bad, long-term, ecological decision, which therefore is a bad, long-term economic decision—to which delayed, social-environmental costs are always attached, costs the present generation is passing forward to those of the future.

For the addition of the centrifuge process, it would be only just that Kalbar are required to go back to 'square one', review and redesign the entire mine project and resubmit a new EES. This may seem labour and time intensive, however considering the spruiked economic benefits to all and sundry, the 'extremely' high value of the resources that could be obtained over a long period of time (20 years), the 'dedication' to the local community by the new owners, then a redesigned and resubmitted EES shouldn't be too much of a bother.

Some salient points

Ramifications of failure

- Insurance
  One would expect some difficulty in obtaining adequate insurance in such a unique proposal, considering the additional ad-hoc impact and effects documents so rapidly provided with the new changes and additions. This is high risk and not conducive to long-term, sustainable resource extraction and processing operations. On risk management alone, it is a bad investment – as mining accidents around the world attest.

- Breakdown
  The more complex and complicated any industrial process is, the more chance of engineering failures and the unknown outcomes that ensue – human and environmental exposure to unprocessed concentrates and contaminants. As I farm downwind and downstream, it will directly affect my agricultural operation.

  Specialist processes, complex engineering are not separate to the whole resource extraction process. If one small part of the system fails, it effects the whole system. I haven't read in any of Kalbar's studies, the identification of associated risks, events and effects when this occurs.

- Contamination
  As far as I have read there are no risk and effect analyses of any new waste substances that will enter the environment and their behaviour once added to the environment in the mine footprint and downstream into the ocean. Nor how these contaminants behave and enter the food chain when recombined with toxicants already present. As I farm downwind and downstream, it will directly affect my agricultural operation.

- Water re-use and its changed chemistry
  Claims of a small water saving is admirable, but nonetheless not that significant considering the total demands of the entire system for the next 20 years. There is no evidence of a risk and effects analyses of how the changed water chemistry will impact the environment and everything that relies on a healthy environment, clean air and water – which are part of the global commons and everyone's birthright. As I farm downwind and downstream, it will directly affect my agricultural operation.

Inputs

- Energy / electricity
  I see no analysis of the new energy demands of the centrifuge dewatering system and associated processes. Can the grid cope? Who pays for the upgrades? Is the taxpayer potentially going to subsidise this?

- Additives
  With any new process, new recipes, prescriptions of use and waste are used. This has an impact in every step of the process. This hasn't been adequately researched; just added / modelled / extrapolated / or compared to some other mine on the other side of the world.

- Cost of production
  As with any resource extraction industry, the drive to lower costs of production will always be the aim. Ironically, with new and complex industrial engineering systems, they require a higher degree of maintenance and oversight. One could argue more jobs, however, this is offset by more downtime and higher labour costs as the need for specialisation inevitably occurs. Downtime affects every other part of the operation. For example, so the earthmoving equipment can keep operating, more stockpile area is needed; containment measures haven't factored in bigger volumes; natural climate events accentuate disasters and so on. This equals system failure. Worst case scenarios haven't been included in any study.

- Parts, oils, lubricants, consumables
  There is no risk and effects analyses of what, how much, toxicity etc of what it takes to have a centrifuge operational. This adds to the toxicological load that humans and the environment will be exposed to, 24 / 7, for the next 20 years. As I farm downwind and downstream, it will directly affect my agricultural operation.

  What is the operating life of a centrifuge using water from our environment, and the actual soils extracted from the Fingerboards Site?

Outputs

- Operating wastes
  There is no documentation how and where these contaminants will be disposed. It's doubtful the Shire's local landfill could accommodate industrial waste. This could breach EPA regulations and / or add significantly to operating costs.

- Sludges and the chemical composition
  The cumulative effects of changed chemical composition and their behaviour in the environment haven't been demonstrated, nor how far they will impact before their undetectable point. This has the potential to directly affect my agricultural operation.

- Noise 24/7
  To state that 3 centrifuges running 24/7 and a changed extraction and haulage plan will not adversely contribute to current noise levels is farcical.

- Pollution and its recombination with upwind contaminants such as the proposed battery recycling facility in the LaTrobe Valley
  There is no study of the effects of any recombination of pollutants coming from outside the mine footprint, nor the new facility required for the centrifuges. As I farm downwind and downstream, it will directly affect my agricultural operation.

Footprint of the new facility

- Changed access and egress routes
  This has to inevitably alter the mine design and extraction methodology, which then will have other knock-on effects. What changes have been proposed are based on past surveys and a desktop analysis and don't reflect realities at the site. This will affect noise, visual amenity, rehabilitation, energy use, water and rainfall impacts, machinery requirements, timing of delivery of extracted material to the centrifuge and many other factors.

- Permanency of structures (changed soil compaction and long term contamination conditions)
  This will adversely affect any decommissioning, and rehabilitation aspirations and outcomes – current rehabilitation strategies will fail and rehabilitation costs will significantly blowout. This demonstrates that rehabilitation budgets are nowhere near enough, and the government environmental bond is too low. We already have the taxpayer funded Benambra Mine rehab project that went over budget by 2+ million dollars and the tailings dam leaks more than before the rehab project started - in our region, along with other disused, abandoned, and unrehabilitated quarry and mine sites.

These points raise many questions that continue to go unanswered

These following questions are important with respect to Kalbar's proposed centrifuge extraction facility at the Fingerboards and the Mitchell River because the area is part of a sinuous, continuum of habitats that transports water and all its ingredients, both good and bad, downstream while recognizing neither human boundaries nor human measures for its containment—as every major mine failure and oil spill has abundantly demonstrated:

1. How can the "affected area" of the Fingerboards and the Mitchell River be limited to the footprint of Kalbar's centrifuge facility, when that footprint is an integral part of a continuous, interactive ecosystem that will, through cumulative impacts, affect all aquatic and terrestrial life that lives within it, drinks its water, and/or uses its vegetation as food—especially during periods of drought?
2. How will the 24/7 exposure of noise, air, soil, water toxic pollutants from Kalbar's centrifuge facility affect the physical configuration and stability of the Fingerboards and Mitchell River ecosystem, which has evolved to cope with periods of high water and low water? Has this been researched? If not, why has no research been done? If so, what are the results?
3. Will the environment become destabilized by a 24/7 exposure of noise, air, soil, water toxic pollutants? Will the critical habitats formed by terrestrial inputs be affected? Has this been researched? If not, why has no research been done? If so, what are the results?
4. What will be the cumulative effects of the chemicals and toxicants that will be added to the Fingerboards and Mitchell River ecosystem from 24/7 for 20 years of operations especially during drought when everything in the water of the Fingerboards area and Mitchell River concentrates into a small per-unit area, and wildlife come to drink the water? Has this been researched? If not, why has no research been done? If so, what are the results?

5. Where will the changed chemical compounds and chemical pollutants concentrate in a drought-stricken Fingerboards and Mitchell River ecosystem?

- in the vegetation that uses the water for survival?
- in the aquatic and terrestrial animals, including livestock, that use the vegetation and/or water for survival?

Has this been researched? If not, why has no research been done? If so, what are the results?

6. What is the biophysical fate of the various chemical compounds discharged from Kalbar's centrifuge facility once they enter the Fingerboards environment then the aquatic ecosystem of the Mitchell River?

- How toxic to the ecosystem are the chemicals? Has this been researched? If not, why has no research been done? If so, what are the results?
- How biodegradable, in fact, are the chemicals in the discharge from Kalbar's facility? Has this been researched? If not, why has no research been done? If so, what are the results?
- Have the "active" ingredients of the chemical compounds discharged from Kalbar's facility been tested for their toxicity to the Fingerboards and Mitchell River ecosystem and its food chain? If not, why has no research been done? If so, what are the results?
- What recombination can and might the "active" ingredients make with the chemical compounds already in the Fingerboards and Mitchell River ecosystem? Could they become more toxic than the chemical compounds discharged in the centrifuge process? Has this possibility been tested? If not, why has no research been done? If so, what are the results?
- Have "inert" ingredients in the chemical compounds in the discharge from Kalbar's facility been tested for their toxicity to the Fingerboards and Mitchell River ecosystem and its food chain? If not, why has no research been done (after all, *there's no such thing as an inert substance in any interactive system*)? If so, what are the results?
- What recombination can and might the "inert" ingredients make with chemical compounds already in the Fingerboards and Mitchell River ecosystem? Could a recombination become more toxic than the chemical compounds discharged in the centrifuge process? Has this possibility been tested? If not, why has no research been done? If so, what are the results?
- How biodegradable, in fact, is a potential recombination? Has this been researched? If not, why has no research been done? If so, what are the results?
- Where in the ecosystem do the discharged chemicals from Kalbar's facility accumulate—especially during a drought? Has this been researched? If not, why has no research been done? If so, what are the results?
- What are the synergistic, biophysical effects (positive and negative) of the chemicals' concentration? Has this been researched? If not, why has no research been done? If so, what are the results?

7. During floods, how far from the Mine footprint does the water go? Does it collect in low areas? How long does it stand? Do the plants in these flooded areas take up more chemical pollutants than they would otherwise do? Has this been researched? If not, why has no research been done? If so, what are the results?
8. Assuming the plants of flooded areas absorb greater amounts of chemical pollutants from the discharged waste-water, how does the consumption of the contaminated vegetation affect livestock and wildlife? Has this been researched? If not, why has no research been done? If so, what are the results?
9. How far will the discharged chemical compounds from Kalbar's centrifuge facility be transported downstream through the Fingerboards and Mitchell River ecosystem? At what

distance in kilometres will they cease to have a negative effect? Has this been researched? If not, why has no research been done? If so, what are the results?

10. At their farthest detectable point:

- What other chemical compounds will those discharged from Kalbar's centrifuge facility recombine with (those discharged by communities in the Fingerboards area and along the Mitchell River) on their journey downstream from the point of discharge? Has this been researched? If not, why has no research been done? If so, what are the results?
- How toxic will a potential recombination be? Has this been researched? If not, why has no research been done? If so, what are the results?
- How will a potential recombination affect the micro-plants and animals that form the basis of the food chain that feeds the aquatic invertebrates that feed the fish and frogs, that, in turn, feed the snakes, herons, eagles, and so on—especially during droughts when the water is already low and will concentrate wildlife and all pollutants into a small unit of area? Has this been researched? If not, why has no research been done? If so, what are the results?