

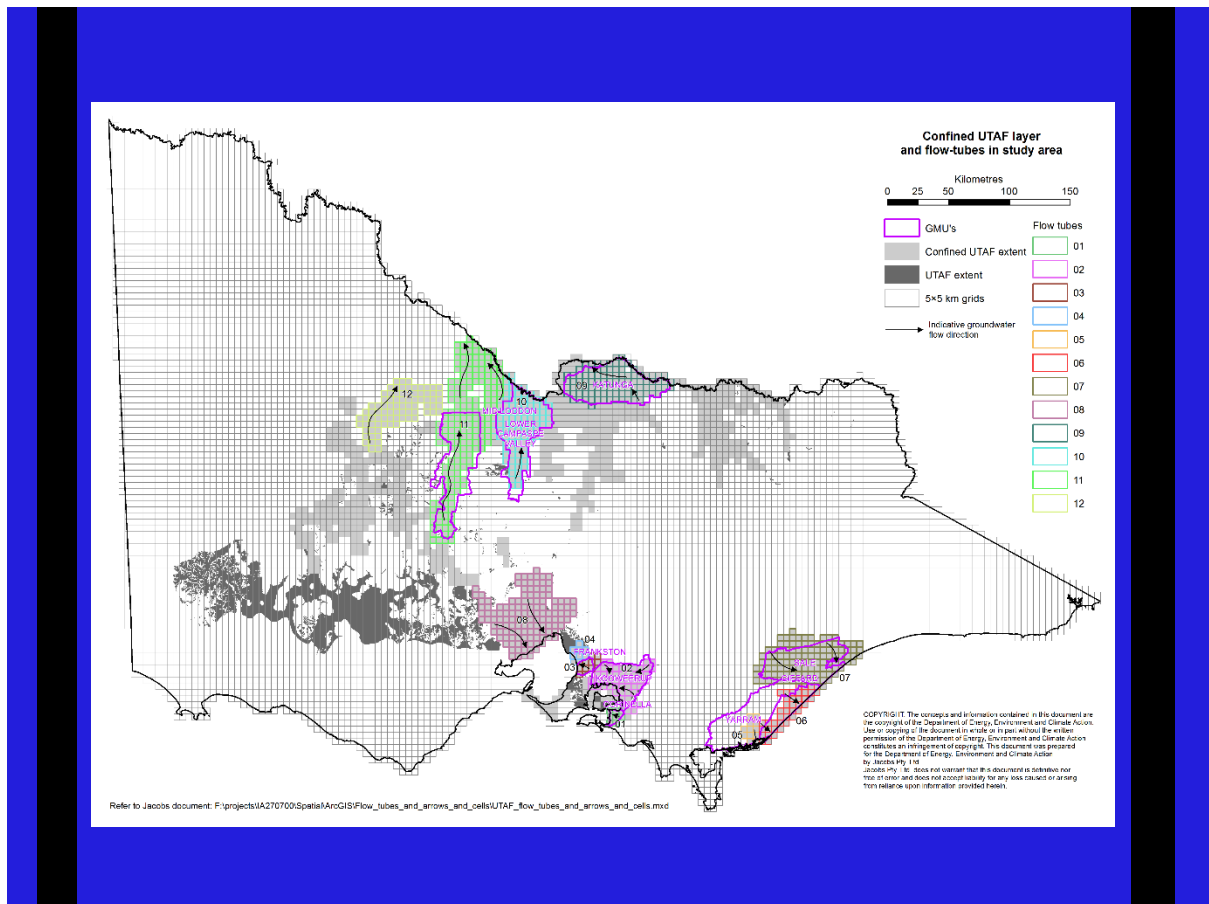
Confined Aquifer Throughflow Assessment – Updated Method and Phase B State-wide Rollout

Document no: R02_IA270700

Revision no: Final

Department of Department of Energy, Environment and Climate Action
CMS104180

Confined Aquifer Throughflow Assessment - Updated Method and Phase B
State-wide Rollout
13 May 2024



Confined Aquifer Throughflow Assessment – Updated Method and Phase B State-wide Rollout

Confined Aquifer Throughflow Assessment – Updated Method and Phase B State-wide Rollout

Client name: Department of Department of Energy, Environment and Climate Action
Project name: Confined Aquifer Throughflow Assessment - Updated Method and Phase B State-wide Rollout
Client reference: CMS104180 **Project no:** IA270700
Document no: R02_IA270700 **Project manager:** Deb Green
Revision no: Final **Prepared by:** Deb Green
Date: 13 May 2024 **File name:** R02_IA270700_Final
Doc status: Final

Document history and status

Revision	Date	Description	Author	Checked	Reviewed	Approved
Draft V6	21/07/2023	Draft for technical review	D Green		G Hoxley	G Hoxley
Draft V9	19/10/2023	Second draft for technical review	D Green		G Hoxley	G Hoxley
Draft V10	06/02/2024	Update to previous draft to include UTAM layer	D Green		G Hoxley	G Hoxley
Final	13/05/2024	Final	D Green		G Hoxley	G Hoxley

Distribution of copies

Revision	Issue approved	Date issued	Issued to	Comments
Draft V3	Draft (not for comment)	27/06/2023	DEECA	Draft to demonstrate reporting progress
Draft V7	First draft	25/07/2023	DEECA	First draft for DEECA review and comment
Draft V9	Second draft	20/10/2023	DEECA	Second draft for DEECA review and comment
Draft V10	Update to second draft	07/02/2024	DEECA	Update to second draft for DEECA review and comment
Final	Final	13/05/2024	DEECA	Final for issue.

Executive summary

Project context

In order to provide for the secure allocation of water in Victoria, the Department of Energy, Environment and Climate Action (DEECA) requires a defensible estimate of the amount of water available now and in the future, and the factors that may affect that availability. In regard to groundwater resources, sustainable yields have not been reviewed at a State-wide scale since caps (Permissible Consumptive Volumes, PCVs) for Groundwater Management Units (GMUs) were implemented in the late 1990s. DEECA considers a review of groundwater sustainable yields warranted, in part, as there is an improved understanding of groundwater systems from data collected and technical studies undertaken since this time to inform revised estimates. Inclusion of uncertainty and risks to environmental values in the derivation of sustainable yields is also considered to be an important part of this revision.

In addition to this review, DEECA seeks an approach that will enable the implementation of the national definition of sustainable yields: *"the groundwater extraction regime, measured over a specified planning timeframe, that allows acceptable levels of stress and protects dependent economic, social and environmental values"* (NGC, 2004). This national definition is a principle, and it does not provide the acceptable levels of stress that will protect economic, social, and environmental values. To apply this national definition, DEECA is developing metrics to protect the values of the groundwater resource including access to consumptive users, protection of the environment dependent on groundwater and Traditional Owners. The metrics will provide a measure of the level of potential adverse impacts to be avoided and are to be used as a means for validating the quantification of sustainable yield volumes.

The review of sustainable groundwater yields in Victoria will be conducted using multiple lines of evidence developed through the following three separate but coordinated projects:

- Sustainable yield assessment of unconfined aquifers in Victoria (CDM Smith).
- Sustainable yield assessment (use-drawdown method) of confined aquifers in Victoria (GHD).
- Throughflow calculations of confined aquifers in Victoria (Jacobs, this project).

Project scope

The overarching aim of this project was to develop and implement a relatively simple (analytical) semi-automated GIS-based method (tool) for estimating predevelopment throughflow rates for Victoria's confined aquifers. The output of this project will ultimately assist DEECA in reviewing sustainable yields for these confined systems. The project has been undertaken in two parts; Phase A Pilot program (complete) and Phase B State-wide rollout (the subject of this report).

The purpose of Phase A was to develop and test a method (tool) for calculating predevelopment throughflow rates of confined aquifers in five Pilot study areas. Following enhancements of the method (tool) in Phase B, the approach has been rolled-out to the confined aquifers systems in the study area across Victoria.

Study area

For data synthesising and reporting purposes the Phase B State-wide study area was divided into Victoria's five Groundwater Management Basins (GMB): Wimmera-Mallee GMB, Goulburn-Murray GMB, Otway-Torquay GMB, Central GMB and Gippsland GMB. A further sub-division was made with the representation of groundwater catchments within each GMB.¹

The study area subject to the State-wide rollout includes the following confined aquifers (as described in the Victorian Aquifer Framework (VAF), GHD, 2012), within the 17 GMAs and 7 WSPAs listed in the table below:

- Upper Tertiary Aquifer (marine) (UTAM).
- Upper Tertiary Aquifer (fluvial) (UTAF).
- Upper-Mid Tertiary Aquifer (UMTA).

¹ While DEECA no longer use the GMB and groundwater catchment approach for reporting and managing Victoria's groundwater resources, it provides a logical framework for synthesising data and reporting outputs in this state-wide study.

Confined Aquifer Throughflow Assessment – Updated Method and Phase B State-wide Rollout

- Lower-Mid Tertiary Aquifer (LMTA).
- Lower Tertiary Basalts Aquifer (LTB).
- Lower Tertiary Aquifer (LTA).

GMB	GMU	GMB	GMU	
Wimmera-Mallee	West Wimmera GMA	Central	Cut Paw Paw GMA	
	Murrayville GMA		Moorabbin GMA	
Goulburn-Murray	Mid-Loddon GMA		Frankston GMA	
	Lower Campaspe Valley WSPA		Koo-Wee-Rup WSPA	
	Katunga WSPA		Corinella GMA	
Otway-Torquay	Glenelg WSPA (abolished) ⁽¹⁾		Gippsland	Moe GMA
	Portland GMA			Sale WSPA
	Condah WSPA			Rosedale GMA
	Paaratte GMA	Stratford GMA		
	Newlingbrook GMA	Giffard GMA		
	Gellibrand GMA	Yarram WSPA		
	Gerangamete GMA	-		
	Jan Jac GMA	-		

Notes:

The GMUs listed in shaded cells were subject to assessment in the Phase A Pilot study. Additionally, the LTA below the Murrayville GMA formed a pilot area to test the approach in an Unincorporated Area (UA).

(1) Glenelg WSPA was abolished in September 2022. The management area remains to be used by DEECA for reporting purposes, however, and therefore forms part of the study area for this project.

Areas of confined VAF layers not occupied by a GMU (i.e., within Unincorporated Areas (UAs)), are also included in the study area.

Outcomes of Phase A

The key outcome of the Phase A project (Jacobs, 2022) was the development of a GIS semi-automated tool for calculating (at a gridded 5×5 km scale) predevelopment throughflows of confined VAF layers, based on Darcy's equation. At the GMU (or UA) scale, throughflows were estimated by summing gridded throughflows along cross-sections perpendicular to groundwater flow. Uncertainty in throughflow rates was quantified at both the gridded and GMU (or UA) scale. The approach was trialled and demonstrated in the five Pilot study areas indicated in the table above.

Methodology

The Phase B methodology was generally consistent with that developed, trialled and refined in the Phase A Pilot study, and included the following steps:

- Collation of VAF layer based GIS data including top and bottom elevations and modelled predevelopment confined aquifer potentiometric surfaces. The data informed the aquifer thickness (b) and hydraulic gradient (H_L/L) components of the throughflow calculation using Darcy's equation.
- Collation of hydrogeological information of GMUs to enable the interrogation and contextualisation of predevelopment throughflow outputs.
- Collation and interrogation of hydraulic conductivity (K) data for each VAF layer at the GMB scale to inform this component of the Darcy throughflow calculation.
- Calculation of best estimate 50th percentile K (P50 K) predevelopment throughflows across the State-wide study area at the following scales:
 - Gridded (5×5 km): using the ArcGIS tool developed in Phase A.

- Flow-tube²: based on the development of an ArcGIS Pro tool (hosted on the Jacobs server) with the additional capability of automating cross-sectional throughflow calculations at this scale.
- **Assessment of uncertainty** in the best estimate (P50 K) predevelopment throughflow outputs, at the flow-tube scale, according to the following calculations:
 - Lower range best estimate (P50 K) throughflow: minimum calculated cross-sectional throughflow rate adopting the P50 K.
 - Upper range best estimate (P50 K) throughflow: maximum calculated cross-sectional throughflow rate adopting the P50 K.
 - Lower range minimum 20th percentile K (P20 K) throughflow: minimum calculated cross-sectional throughflow rate adopting the P20 K.
- Interrogation of predevelopment throughflow outputs at the flow-tube scale, and GMU scale, in the context of management arrangements and licensed usage.
- Assignment of overall ranking of GMUs based on the criteria of *relative reliability* and *uncertainty* of the throughflow outputs, and according to the licensed usage, the *relative potential for adverse impact on aquifer value(s)*. The overall rankings can be used by DEECA for decision making purposes in their review of sustainable yields for these confined systems across the State.

Study outputs

The following outputs were generated in Phase B and are documented in this report:

- Predevelopment (or early development depending on the available potentiometric surface data) throughflow outputs and uncertainty (i.e., average, lower and upper range P50 K and lower range minimum P20 K throughflows) at the flow-tube scale, and in the context of the GMU's PCV and average, minimum and maximum licensed usage. The concept of P50 K and P20 K refers to assessed horizontal hydraulic conductivity for each flow tube and is explained in detail in the report.
- For GMUs, observations concerning the calculated (predevelopment) throughflows in the context of management arrangements and licensed usage, their spatial variability and considerations for assigning a sustainable yield. Noting that for some areas, true "predevelopment" H_L/L conditions were not available.
- For GMUs, rankings of the *relative reliability* and *uncertainty* of the throughflow outputs, and *relative potential for adverse impact on aquifer value(s)*, including an *overall ranking*.

These outputs should be considered in the context of the study's assumptions, approximations, limitations and exclusions that are listed in this report.

Additionally, the following digital outputs were generated in Phase B and provided to DEECA:

- Spatial datasets (as shapefiles):
 - Modelled predevelopment confined aquifer (VAF layer) potentiometric surfaces.
 - Gridded cells that represented the flow-tubes and cross-sections assigned in each VAF layer.
- ArcGIS Pro throughflow calculation tool which allows the project team (in the Jacobs IT environment) to:
 - Inspect individual cells for input and output data of the throughflow calculation including average reduced water level (RWL), H_L/L and b, total dissolved solids (TDS), default and adopted K and gridded predevelopment throughflows.
 - Create flow-tubes, assign K data and calculate gridded and flow-tube scale predevelopment throughflows.
- Excel files consisting of predevelopment throughflow outputs (and raw data generated in the ArcGIS Pro tool) at the flow-tube and GMU scale, including uncertainty, and in the context of the GMU's PCV and minimum, average and maximum licensed usage values.

The Phase B throughflow outputs are summarised for GMUs in the study area in the table below, in the context of their *overall ranking*. This information can be used by DEECA for decision making purposes in their

² A flow-tube is a three-dimensional (3D) conceptualisation of groundwater flow (i.e., an inferred flow-path from areas of recharge to discharge). The term is used in this study to represent a regional scale 3D conceptualisation of groundwater flow in a confined VAF layer. Flow-tubes have been defined at the GMU or UA scale (or sub-scale) and delineated, in plan view, perpendicular to modelled (predevelopment) potentiometric surfaces (available from other modelling studies).

Confined Aquifer Throughflow Assessment – Updated Method and Phase B State-wide Rollout

review of sustainable yields for these confined systems across the State. As indicated in this report, a practical approach would be to first reduce uncertainty in the throughflow outputs using desktop approaches. Following any updates to the throughflow estimates, and corresponding impact assessment, investment in additional monitoring and assessment can be considered.

		Ranking of the relative potential for adverse impact on aquifer value(s) (based on average licenced usage)			
		Low	Medium	High	Very High
Ranking of relative uncertainty of throughflow estimates	Low	Katunga WSPA Glenelg WSPA ⁽¹⁾ Paaratte GMA Gerangamete GMA Cut Paw Paw GMA Frankston GMA Moe GMA	Sale WSPA Koo-Wee-Rup WSPA*	Mid-Loddon GMA	Lower Campaspe Valley WSPA
	Medium	Portland GMA Corinella GMA Yarram WSPA Condah WSPA*	-	Stratford GMA Murrayville GMA*	West Wimmera GMA
	High	Newlingrook GMA Gellibrand GMA Jan Juc GMA Giffard GMA	Rosedale GMA	Moorabbin GMA	-

Notes:

GMUs identified with * are inferred to have a comparatively higher reliability (i.e., medium reliability ranking) than the GMUs in the same cells (i.e., low reliability ranking).

(1) The Glenelg WSPA was abolished in September 2022.

Important note about your report

The sole purpose of this “Technical Assessment of State-Wide Groundwater Sustainable Yields – Confined Aquifers (Throughflow method), Phase B State-wide Rollout” report is to present the method developed and outputs of its application in the State-wide (Phase B) study area. This report was produced in accordance with and is limited to the scope of services set out in the contract between Jacobs and the Department of Energy, Environment and Climate Action (DEECA) (‘the Client’).

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

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

Jacobs has prepared this report in accordance with the usual care and thoroughness of the consulting profession, for the sole purpose described above and by reference to applicable standards, guidelines, procedures and practices at the date of issue of this report. For the reasons outlined above, however, no other warranty or guarantee, whether expressed or implied, is made as to the data, observations and findings expressed in this report, to the extent permitted by law.

This report should be read in full, and no excerpts are to be taken as representative of the findings. No responsibility is accepted by Jacobs for use of any part of this report in any other context.

This report has been prepared on behalf of, and for the exclusive use of, the Client, and is subject to, and issued in accordance with, the provisions of the contract between Jacobs and the Client. Jacobs accepts no liability or responsibility whatsoever for, or in respect of, any use of, or reliance upon, this report by any third party.

Contents

Executive summary	ii
Project context	ii
Project scope.....	ii
Study area.....	ii
Outcomes of Phase A.....	iii
Methodology.....	iii
Study outputs.....	iv
Important note about your report	vi
Acronyms, abbreviations and definitions	xv
Assumptions, approximations, limitations and exclusions	xviii
1. Introduction.....	1
1.1 Project context	1
1.2 Scope of works	2
1.3 Study area	2
1.4 Report structure.....	7
2. Technical concepts and terms	8
3. Outcomes of Phase A	10
4. Methodology.....	12
4.1 Step 1 – Collate GIS data.....	12
4.2 Step 2 – Collate hydrogeological information.....	13
4.3 Step 3 – Collate and interrogate K data	13
4.4 Step 4 – Develop GIS throughflow tools.....	14
4.5 Step 5 – Interrogate throughflow outputs and assess uncertainty	15
4.6 Step 6 – Assign GMU rankings	17
4.7 Assumptions, approximations, limitations and exclusions.....	20
5. Flow-tube classification.....	24
6. Wimmera-Mallee GMB.....	34
6.1 Hydrogeological characterisation.....	34
6.2 Aquifer property data	38
6.3 Outputs.....	40
7. Goulburn-Murray GMB.....	50
7.1 Hydrogeological characterisation.....	50
7.2 Aquifer property data	55
7.3 Outputs.....	60
8. Otway-Torquay GMB	73
8.1 Hydrogeological characterisation.....	74
8.2 Aquifer property data	85
8.3 Outputs.....	88
9. Central GMB – Port Phillip Bay groundwater catchments.....	109
9.1 Hydrogeological characterisation.....	109

9.2	Aquifer property data	113
9.3	Outputs.....	115
10.	Central GMB – Westernport groundwater catchment	126
10.1	Hydrogeological characterisation.....	126
10.2	Aquifer property data	129
10.3	Outputs.....	132
11.	Gippsland GMB – Moe groundwater catchment & GMA	141
11.1	Hydrogeological characterisation.....	141
11.2	Aquifer property data	143
11.3	Outputs.....	144
12.	Gippsland GMB – Central groundwater catchment	148
12.1	Hydrogeological characterisation.....	148
12.2	Aquifer property data	155
12.3	Outputs.....	156
13.	Gippsland GMB – Seaspray groundwater catchment	165
13.1	Hydrogeological characterisation.....	165
13.2	Aquifer property data	170
13.3	Outputs.....	171
14.	Summary of throughflow outputs.....	177
15.	Conclusions.....	182
16.	References	184

Appendices

Appendix A.	User guide - ArcGIS Pro throughflow tool.....	188
Appendix B.	Relative rankings and prioritisation of GMUs.....	189
B.1	Relative reliability of throughflow estimates	190
B.2	Relative uncertainty of throughflow estimates	191
B.3	Relative potential for adverse impacts on aquifer value(s)	193

Tables

Table 1-1	GMUs with confined aquifers subject to the Phase B state-wide rollout.....	3
Table 3-1	Key recommendations from Phase A and outcomes for Phase B study.....	10
Table 4-1	Hydrogeological information collected for each GMU.....	13
Table 4-2	Expression of flow-tube scale predevelopment throughflows and corresponding management strategy options	16
Table 4-3	Score of areal density of K data	17
Table 4-4	Score of number of cross-sections within flow-tube.....	18
Table 4-5	Relative reliability ranking of throughflow estimates (flow-tube scale)	18
Table 4-6	Score of CV of cross-section throughflow estimates for flow-tube.....	18
Table 4-7	Score of factor difference between adopted P50 K and P20 K for flow-tube.....	18
Table 4-8	Relative uncertainty ranking of throughflow estimates (flow-tube scale)	19
Table 4-9	Relative potential for adverse impacts on aquifer value(s)	19
Table 4-10	Overall GMU rankings	20

Table 4-11 List of assumptions, approximations, limitations and exclusions for the study	20
Table 5-1 Flow-tube classification	24
Table 6-1 Wimmera-Mallee GMB – assigned flow-tubes.....	34
Table 6-2 Hydrostratigraphic profile in and around the West Wimmera GMA	34
Table 6-3 West Wimmera GMA – Key hydrogeological attributes	35
Table 6-4 Hydrostratigraphic profile in and around the Murrayville GMA	36
Table 6-5 Murrayville GMA - Key hydrogeological attributes.....	37
Table 6-6 Wimmera-Mallee GMB – UTAM properties.....	38
Table 6-7 Wimmera-Mallee GMB – UMTA properties.....	38
Table 6-8 Wimmera-Mallee GMB – LTA properties.....	39
Table 6-9 Wimmera-Mallee GMB – UMTA and LTA K_h statistics.....	40
Table 6-10 Predevelopment throughflow estimates for flow-tubes – UTAM ft01, UMTA ft07, UMTA ft08, LTA ft21 and LTA ft22.....	40
Table 6-11 Summary of predevelopment throughflows in context of West Wimmera GMA	43
Table 6-12 Predevelopment throughflow estimates for flow-tube – UMTA ft07	44
Table 6-13 Summary of predevelopment throughflows in context of Murrayville GMA	45
Table 6-14 Predevelopment throughflow estimates for flow-tube – UTAM ft02	46
Table 6-15 Predevelopment throughflow estimates for flow-tube – LTA ft23	47
Table 6-16 Predevelopment throughflow estimates for flow-tube – LTA ft24	48
Table 7-1 Goulburn-Murray GMB – assigned flow-tubes.....	50
Table 7-2 Hydrostratigraphic profile in and around the Mid Loddon GMA.....	50
Table 7-3 Mid Loddon GMA – Key hydrogeological attributes.....	51
Table 7-4 Hydrostratigraphic profile in and around the Lower Campaspe Valley WSPA	52
Table 7-5 Lower Campaspe Valley WSPA – Key hydrogeological attributes	52
Table 7-6 Hydrostratigraphic profile in and around the Katunga WSPA	54
Table 7-7 Katunga WSPA – Key hydrogeological attributes.....	54
Table 7-8 Goulburn-Murray GMB – UTAF properties	55
Table 7-9 Goulburn-Murray GMB – LTA properties	58
Table 7-10 Goulburn-Murray GMB – UTAF and LTA K_h statistics	60
Table 7-11 Predevelopment throughflow estimates for flow-tubes – UTAF ft11 and LTA ft26	60
Table 7-12 Summary of predevelopment throughflows in context of Mid-Loddon GMA	62
Table 7-13 Predevelopment throughflow estimates for flow-tube – UTAF ft12	63
Table 7-14 Predevelopment throughflow estimates for flow-tube – LTA ft25	64
Table 7-15 Predevelopment throughflow estimates for flow-tubes – UTAF ft10 and LTA ft28	65
Table 7-16 Summary of predevelopment throughflows in context of Lower Campaspe Valley WSPA.....	67
Table 7-17 Predevelopment throughflow estimates for flow-tubes – LTA ft27	68
Table 7-18 Predevelopment throughflow estimates for flow-tubes – UTAF ft09 and LTA ft29	69
Table 7-19 Summary of predevelopment throughflows in context of Katunga WSPA	71
Table 8-1 Otway-Torquay GMB – assigned flow-tubes.....	73
Table 8-2 Hydrostratigraphic profile in and around the Glenelg WSPA (abolished).....	74
Table 8-3 Glenelg WSPA (abolished) – Key hydrogeological attributes.....	74
Table 8-4 Hydrostratigraphic profile in and around the Portland GMA.....	75
Table 8-5 Portland GMA – Key hydrogeological attributes.....	76
Table 8-6 Hydrostratigraphic profile in and around the Condah WSPA	77
Table 8-7 Condah WSPA – Key hydrogeological attributes	77
Table 8-8 Hydrostratigraphic profile in and around the Paaratte GMA	78
Table 8-9 Paaratte GMA – Key hydrogeological attributes	79
Table 8-10 Hydrostratigraphic profile in and around the Newlingrook GMA.....	79
Table 8-11 Newlingrook GMA – Key hydrogeological attributes.....	80
Table 8-12 Hydrostratigraphic profile in and around the Gellibrand GMA	81
Table 8-13 Gellibrand GMA – Key hydrogeological attributes	81
Table 8-14 Hydrostratigraphic profile in and around the Gerangamete GMA.....	82
Table 8-15 Gerangamete GMA – Key hydrogeological attributes.....	83
Table 8-16 Hydrostratigraphic profile in and around the Jan Jac GMA	84
Table 8-17 Jan Juc GMA – Key hydrogeological attributes	84
Table 8-18 Otway-Torquay GMB - LMTA properties	85
Table 8-19 Otway-Torquay GMB - LTA properties	86
Table 8-20 Otway-Torquay GMB – LMTA and LTA K_h statistics.....	87
Table 8-21 Predevelopment throughflow estimates for flow-tubes - LMTA ft03 and LTA ft11	88
Table 8-22 Summary of predevelopment throughflows in context of Glenelg WSPA (abolished)	90

Table 8-23 Predevelopment throughflow estimates for flow-tube LTA ft12.....	90
Table 8-24 Summary of predevelopment throughflows in context of Portland GMA.....	92
Table 8-25 Predevelopment throughflow estimates for flow-tube LMTA ft04.....	92
Table 8-26 Summary of predevelopment throughflows in context of Condah WSPA.....	93
Table 8-27 Predevelopment throughflow estimates for flow-tube LTA ft14.....	94
Table 8-28 Summary of predevelopment throughflows in context of Paaratte GMA.....	95
Table 8-29 Predevelopment throughflow estimates for flow-tube - LTA ft15.....	96
Table 8-30 Summary of predevelopment throughflows in context of Newlingbrook GMA.....	97
Table 8-31 Predevelopment throughflow estimates for flow-tube - LTA ft16.....	98
Table 8-32 Summary of predevelopment throughflows in context of Gellibrand GMA.....	99
Table 8-33 Predevelopment throughflow estimates for flow-tube - LTA ft31.....	100
Table 8-34 Summary of predevelopment throughflows in context of Gerangamete GMA.....	101
Table 8-35 Predevelopment throughflow estimates for flow-tube – LMTA ft05.....	102
Table 8-36 Predevelopment throughflow estimates for flow-tube – LTA ft32.....	103
Table 8-37 Predevelopment throughflow estimates for flow-tube - LTA ft13.....	104
Table 8-38 Predevelopment throughflow estimates for flow-tube - LTA ft30.....	105
Table 8-39 Predevelopment throughflow estimates for flow-tube - LTA ft17.....	107
Table 8-40 Summary of predevelopment throughflows in context of Jan Juc GMA.....	108
Table 9-1 Port Phillip Bay groundwater catchments – assigned flow-tubes.....	109
Table 9-2 Hydrostratigraphic profile in and around the Cut Paw Paw GMA.....	109
Table 9-3 Cut Paw Paw GMA – Key hydrogeological attributes.....	110
Table 9-4 Hydrostratigraphic profile in and around the Moorabbin GMA.....	111
Table 9-5 Moorabbin GMA – Key hydrogeological attributes.....	111
Table 9-6 Hydrostratigraphic profile in and around the Frankston GMA.....	112
Table 9-7 Frankston GMA – Key hydrogeological attributes.....	113
Table 9-8 Port Phillip Bay groundwater catchments - UTAF properties.....	114
Table 9-9 Port Phillip Bay groundwater catchments - LTA properties.....	114
Table 9-10 Port Phillip Bay groundwater catchments - LTBa properties.....	114
Table 9-11 Port Phillip Bay groundwater catchments K_h statistics.....	114
Table 9-12 Predevelopment throughflow estimates for flow-tube - LTA ft05.....	115
Table 9-13 Summary of predevelopment throughflows in context of Cut Paw Paw GMA.....	116
Table 9-14 Predevelopment throughflow estimates for flow-tube - LTA ft04.....	117
Table 9-15 Summary of predevelopment throughflows in context of Moorabbin GMA.....	118
Table 9-16 Predevelopment throughflow estimates for flow-tube – UTAF ft08.....	119
Table 9-17 Predevelopment throughflow estimates for flow-tube – LTA ft06.....	120
Table 9-18 Predevelopment throughflow estimates for flow-tube - LTA ft18.....	121
Table 9-19 Predevelopment throughflow estimates for flow-tubes - UTAF ft03, LTA ft03 and LTBa ft04....	123
Table 9-20 Summary of predevelopment throughflows in context of Frankston GMA.....	124
Table 10-1 Westernport groundwater catchment – assigned flow-tubes.....	126
Table 10-2 Hydrostratigraphic profile in and around the Koo-Wee-Rup WSPA.....	126
Table 10-3 Koo-Wee-Rup WSPA – Key hydrogeological attributes.....	127
Table 10-4 Hydrostratigraphic profile in and around the Corinella GMA.....	128
Table 10-5 Corinella GMA – Key hydrogeological attributes.....	128
Table 10-6 Westernport groundwater catchment - UTAF properties.....	129
Table 10-7 Westernport groundwater catchment - UMTA properties.....	130
Table 10-8 Westernport groundwater catchment - LTBa properties.....	130
Table 10-9 Westernport groundwater catchment - LTA properties.....	131
Table 10-10 Westernport groundwater catchment K_h statistics.....	131
Table 10-11 Predevelopment throughflow estimates for flow tubes - UTAF ft02, UMTA ft02, LTBa ft02, LTBa ft03 and LTA ft02.....	132
Table 10-12 Summary of predevelopment throughflows in context of Koo-Wee-Rup WSPA.....	134
Table 10-13 Predevelopment throughflow estimates for flow tubes - UTAF ft01, UMTA ft01 and LTA ft01.....	136
Table 10-14 Summary of predevelopment throughflows in context of Corinella GMA.....	137
Table 10-15 Predevelopment throughflow estimates for flow tubes – UTAF ft04.....	138
Table 10-16 Predevelopment throughflow estimates for flow tubes – UMTA ft03.....	139
Table 11-1 Moe groundwater catchment – assigned flow-tubes.....	141
Table 11-2 Hydrostratigraphic profile in and around the Moe GMA.....	141
Table 11-3 Moe GMA – Key hydrogeological attributes.....	142
Table 11-4 Moe groundwater catchment – UMTA properties.....	143
Table 11-5 Moe groundwater catchment – LTBa properties.....	143

Table 11-6 Moe groundwater catchment – LTA properties	143
Table 11-7 Moe groundwater catchment K_h statistics	144
Table 11-8 Predevelopment throughflow estimates for flow tubes – UMTA ft05, LTBa ft05 and LTA ft10...	144
Table 11-9 Summary of predevelopment throughflows in context of Moe GMA	146
Table 12-1 Central groundwater catchments – assigned flow-tubes	148
Table 12-2 Hydrostratigraphic profile in and around the Sale WSPA	148
Table 12-3 Sale WSPA – Key hydrogeological attributes	149
Table 12-4 Hydrostratigraphic profile in and around the Rosedale GMA	151
Table 12-5 Rosedale GMA – Key hydrogeological attributes	152
Table 12-6 Hydrostratigraphic profile in and around the Stratford GMA	153
Table 12-7 Stratford GMA – Key hydrogeological attributes	154
Table 12-8 Central Gippsland groundwater catchment – UTAF properties	155
Table 12-9 Central Gippsland groundwater catchment – UMTA properties	155
Table 12-10 Central Gippsland groundwater catchment – LMTA properties	155
Table 12-11 Central Gippsland groundwater catchment – LTA properties (aquifer units only) ⁽¹⁾	156
Table 12-12 Central Gippsland groundwater catchment – K_h statistics	156
Table 12-13 Predevelopment throughflow estimates for flow-tubes – UTAF ft07	156
Table 12-14 Summary of predevelopment throughflows in context of Sale WSPA	158
Table 12-15 Predevelopment throughflow estimates for flow-tube – UMTA ft06	159
Table 12-16 Summary of predevelopment throughflows in context of Rosedale GMA	160
Table 12-17 Predevelopment throughflow estimates for flow-tubes – LMTA ft06 and LTA ft08	160
Table 12-18 Summary of predevelopment throughflows in context of Stratford GMA	162
Table 12-19 Predevelopment throughflow estimates for flow-tube - LTA ft09	163
Table 13-1 Seaspray groundwater catchment - assigned flow-tubes	165
Table 13-2 Hydrostratigraphic profile in and around the Giffard GMA	165
Table 13-3 Giffard GMA – Key hydrogeological attributes	166
Table 13-4 Hydrostratigraphic profile in and around the Yarram WSPA	168
Table 13-5 Yarram WSPA – Key hydrogeological attributes	169
Table 13-6 Seaspray groundwater catchment - UTAF properties	170
Table 13-7 Seaspray groundwater catchment - UMTA properties	170
Table 13-8 Seaspray groundwater catchment - LMTA properties	170
Table 13-9 Seaspray groundwater catchment - LTA properties (aquifer units only) ⁽¹⁾	171
Table 13-10 Seaspray groundwater catchment K_h statistics	171
Table 13-11 Predevelopment throughflow estimates for flow-tube - UTAF ft06	172
Table 13-12 Summary of predevelopment throughflows in context of Giffard GMA	173
Table 13-13 Predevelopment throughflow estimates for flow-tubes - UTAF ft05, UMTA ft04, LMTA ft01 and LTA ft07	173
Table 13-14 Summary of predevelopment throughflows in context of Yarram WSPA	175
Table 14-1 Summary of flow-tube scale throughflow outputs	178
Table 15-1 Overall GMU rankings	183

Figures

Figure 1-1 GMBs and groundwater catchments in Victoria	5
Figure 1-2 GMUs within Phase B study area	6
Figure 2-1 Schematic diagram of hypothetical flow-tubes (plan view)	9
Figure 5-1 Confined UTAM VAF layer and flow-tubes in study area	28
Figure 5-2 Confined UTAF VAF layer and flow-tubes in study area	29
Figure 5-3 Confined UMTA VAF layer and flow-tubes in study area	30
Figure 5-4 Confined LMTA VAF layer and flow-tubes in study area	31
Figure 5-5 Confined LTB VAF layer and flow-tubes in study area	32
Figure 5-6 Confined LTA VAF layer and flow-tubes in study area	33
Figure 6-1 West Wimmera GMA – PCV and licensed usage relative to predevelopment throughflow estimates of combined flow-tubes UTAM ft01, UMTA ft07, UMTA ft08, LTA ft21 and LTA ft22	43
Figure 6-2 Murrayville GMA – PCV and licensed usage relative to predevelopment throughflow estimates of flow-tube UMTA ft07	45
Figure 6-3 Predevelopment throughflow estimates of flow-tube UTAM ft02 near Salt Lake	47
Figure 6-4 Predevelopment throughflow estimates of flow-tube LTA ft23 east and north of Horsham	48
Figure 6-5 Predevelopment throughflow estimates of flow-tube LTA ft24 between Donald and Robinvale ...	49

Figure 7-1 Mid Loddon GMA – PCV and licensed usage relative to predevelopment throughflow estimates of combined flow-tubes UTAF ft11 and LTA ft26	62
Figure 7-2 Predevelopment throughflow estimates of flow-tube UTAF ft12 east of Wycheproof	64
Figure 7-3 Predevelopment throughflow estimates of flow-tube LTA ft25 near Kerang	65
Figure 7-4 Lower Campaspe Valley WSPA – PCV and licensed usage relative to relative to predevelopment throughflow estimates of combined flow-tubes UTAF ft10 and LTA ft28	67
Figure 7-5 Predevelopment throughflow estimates of flow-tube LTA ft27 near Cohuna	69
Figure 7-6 Katunga WSPA – PCV and licensed usage relative to relative to predevelopment throughflow estimates of combined flow-tubes UTAF ft09 and LTA ft29	71
Figure 8-1 Glenelg WSPA (abolished) - PCV and licensed usage relative to relative to predevelopment throughflow estimates of combined flow-tubes LMTA ft03 and LTA ft11	89
Figure 8-2 Portland GMA - PCV and licensed usage relative to predevelopment throughflow estimate of flow-tube LTA ft12	91
Figure 8-3 Condah WSPA - PCV and licensed usage relative to predevelopment throughflow estimate of flow-tube LMTA ft04	93
Figure 8-4 Paaratte GMA - PCV and licensed usage relative to predevelopment throughflow estimate of flow-tube LTA ft14	95
Figure 8-5 Newlingrook GMA - PCV and licensed usage relative to predevelopment throughflow estimate of flow-tube LTA ft15.....	97
Figure 8-6 Gellibrand GMA - predevelopment throughflow estimate of flow-tube LTA ft16	99
Figure 8-7 Gerangamete GMA - PCV and licensed usage relative to predevelopment throughflow estimate of flow-tube LTA ft31.....	101
Figure 8-8 Predevelopment throughflow estimates of flow-tube LMTA ft05 near Warrnambool.....	103
Figure 8-9 Predevelopment throughflow estimates of flow-tube LTA ft32 north of Colac.....	104
Figure 8-10 Predevelopment throughflow estimates of flow-tube LTA ft13 near Warrnambool.....	105
Figure 8-11 Predevelopment throughflow estimates of flow-tube LTA ft30 near Skipton	106
Figure 8-12 Jan Juc GMA - PCV and licensed usage relative to predevelopment throughflow estimate of flow-tube LTA ft17	107
Figure 9-1 Cut Paw Paw GMA - PCV and licensed usage relative to predevelopment throughflow estimate of flow-tube LTA ft05.....	116
Figure 9-2 Moorabbin GMA - PCV and licensed usage relative to predevelopment throughflow estimate of flow-tube LTA ft04.....	118
Figure 9-3 Predevelopment throughflow estimates of flow-tube UTAF ft08 between Melbourne and Geelong	120
Figure 9-4 Predevelopment throughflow estimates of flow-tube LTA ft06 LTA near Werribee	121
Figure 9-5 Predevelopment throughflow estimates of flow-tube LTA ft18 LTA southeast of Geelong	122
Figure 9-6 Frankston GMA - PCV and licensed usage relative to predevelopment throughflow estimates of combined flow-tubes UTAF ft03, LTA ft03 and LTBa ft04	124
Figure 10-1 Koo-Wee-Rup WSPA - PCV and licensed usage relative to predevelopment throughflow estimates of combined flow-tubes UTAF ft02, UMTA ft02, LTBa ft02, LTBa ft03 and LTA ft02	134
Figure 10-2 Corinella GMA - PCV and licensed usage relative to predevelopment throughflow estimates of combined flow-tubes UTAF ft01, UMTA ft01 and LTA ft01.....	137
Figure 10-3 Predevelopment throughflow estimates of flow-tube UTAF ft04 north of Bonbeach.....	139
Figure 10-4 Predevelopment throughflow estimates of flow-tube UMTA ft03 near Hastings	140
Figure 11-1 Moe GMA – PCV and licensed usage relative to predevelopment throughflow estimates of combined flow-tubes UMTA ft05, LTBa ft05 and LTA ft10.....	146
Figure 12-1 Sale WSPA – PCV and licensed usage relative to predevelopment throughflow estimate of flow-tube UTAF ft07	157
Figure 12-2 Rosedale GMA – PCV and licensed usage relative to predevelopment throughflow estimate of flow-tube UMTA ft06	159
Figure 12-3 Stratford GMA – PCV and licensed usage relative to relative to predevelopment throughflow estimates of combined flow-tubes LMTA ft06 and LTA ft08	162
Figure 12-4 UA west of Marlo - PCV and licensed usage relative to predevelopment throughflow estimates of flow-tube LTA ft09.....	164
Figure 13-1 Giffard GMA - PCV and licensed usage relative to predevelopment throughflow estimate of flow-tube UTAF ft06	172
Figure 13-2 Yarram WSPA - PCV and licensed usage relative to predevelopment throughflow estimates of combined flow-tubes UTAF ft05, UMTA ft04, LMTA ft01 and LTA ft07	175

Acronyms, abbreviations and definitions

3D	Three-dimension
b	Aquifer thickness
BSE	Mesozoic and Palaeozoic Bedrock
CHM	Conceptual hydrogeological model
CMA	Catchment Management Area
CPS	Cretaceous and Permian Sediments
CV	Coefficient of variability
DEECA	Department of Energy, Environment and Climate Action
DELWP	Department of Environment, Land, Water and Planning
Flow-tube	A 3D conceptualisation of regional scale groundwater flow, within a VAF layer, defined in plan view, according to modelled pre-development potentiometric surfaces (i.e., flow is perpendicular to the potentiometric surface). The delineation of flow-tubes permitted the calculation of cross-sectional groundwater throughflow.
ft	Flow-tube (number)
GDE	Groundwater dependent ecosystem
GMA	Groundwater Management Area. An area that groundwater has been intensively developed or has the potential to be developed further.
GMB	Groundwater Management Basin
GMU	Groundwater Management Unit
GU	Geological Unit
HGU	Hydrogeological Unit
H _L /L	Hydraulic gradient
K	Hydraulic conductivity (in this project, K refers to horizontal hydraulic conductivity)
K _h	Horizontal hydraulic conductivity
K _v	Vertical hydraulic conductivity
KWR	Koo Wee Rup
LCV	Lower Campaspe Valley
LMTA	Lower Mid-Tertiary Aquifer
LMTD	Lower Mid-Tertiary Aquitard
LTA	Lower Tertiary Aquifer
LTB	Lower Tertiary Basalt Aquifer. In the VAF, the LTB is designated into two age groups, the younger LTBa – Phase 2 Basalts (Otway), Mornington Volcanics (Central), Thorpdale Volcanics (Gippsland) and the older LTBB – Phase 1 Volcanics (Murray).
LTWRA	Long-Term Water Resource Assessment

m/d	metres per day
mg/L	milligrams per litre
MGL	Murray Group Limestone
N/a	Not applicable or Not available
NGC	National Groundwater Committee
no.	Number
P	Percentile
PAV	Permissible Annual Volume
PCV	Permissible Consumptive Volume
PD	Predevelopment
P20 K	20 th percentile of the hydraulic conductivity data
P50 K	50 th percentile of the hydraulic conductivity data
P80 K	80 th percentile of the hydraulic conductivity data
QA	Quaternary Aquifer
RWL	Reduced water level
SD	Standard deviation
SOBN	State Observation Bore Network
SRW	Southern Rural Water
Suite	<p>For the GHD (2018) “Groundwater Condition Reporting” project, monitoring bores that indicated similar water level responses were classified into groups, or suites. Each suite was defined by VAF layer (Upper (U), Middle (M), Lower (L) or Basement (B)), suite code (letter) and fluctuation (numerical) code. The VAF layers were grouped as follows:</p> <p>Upper VAF layers: QA, UTB, UTQA, UTQD and UTAM.</p> <p>Middle VAF layers: UTAF, UTD, UMTA and UMTD.</p> <p>Lower VAF layers: LMTA, LMTD, LTA and LTB.</p> <p>Basement VAF layers: CPS and BSE.</p>
SWL	South West Limestone
TCSA	Tertiary Confined Sand Aquifer
TDS	Total dissolved solids
TLA	Tertiary Limestone Aquifer
TRP	Technical Review Panel
UA	Unincorporated area where no WSPA or GMA is currently defined due to low levels of groundwater use.
UMTA	Upper Mid-Tertiary Aquifer
UMTD	Upper Mid-Tertiary Aquitard

Confined Aquifer Throughflow Assessment – Updated Method and Phase B State-wide Rollout

UTAF	Upper Tertiary Aquifer (fluvial)
UTAM	Upper Tertiary Aquifer (marine)
UTB	Upper Tertiary/Quaternary Basalt
UTD	Upper Tertiary Aquitard
UTQA	Upper Tertiary/Quaternary Aquifer
UTQD	Upper Tertiary/Quaternary Aquitard
VAF	Victorian Aquifer Framework
WSPA	Water Supply Protection Area. An area that requires intensive management and monitoring due to risks associated with groundwater extraction.

Assumptions, approximations, limitations and exclusions

Type	Element of methodology	Description
Assumptions	Definition of confined aquifer boundary	<ul style="list-style-type: none"> The unconfined-confined aquifer boundary is defined as where the (predevelopment) modelled potentiometric surface is equivalent to the top of the confined VAF layer. Where these aquifer units' outcrop (and so are unconfined), it has been assumed that these areas will form part of the CDM Smith unconfined aquifer sustainable yield project. Where a GMU extends to depth and incorporates confined aquifer system(s) that are not intended to be represented by the current PCV, professional judgement is applied to include those confined aquifer systems that represent a reasonable groundwater resource potential, with regards to aquifer extent and yield (but not salinity).
	GIS data	<ul style="list-style-type: none"> The VAF layers and predevelopment modelled potentiometric surfaces provide reasonable regional scale representations of the b and H_L/L parameters, respectively. The term "predevelopment" is used in this study to broadly represent conditions prior to significant and regional scale groundwater development. In some cases, predevelopment modelled potentiometric surfaces adopted may rely on gauged levels influenced by low levels of early groundwater development.
	Hydrogeological information	<ul style="list-style-type: none"> The documented hydrogeological characterisations of the GMUs are sufficient to make observations concerning the throughflow outputs.
	K data	<ul style="list-style-type: none"> The adopted P20 K, P50 K and P80 K values are representative of regional scale conditions and the entire thickness of the confined VAF layer.
	Throughflow calculations	<ul style="list-style-type: none"> The throughflow calculations have been undertaken according to the definition of the confined aquifer boundaries adopted for the study (as above). The throughflow calculations use Darcy's law and its assumptions will apply including that the confined aquifer is porous and saturated and laminar flow is valid.
	Interrogation of throughflow outputs	<ul style="list-style-type: none"> The groundwater licensed usage data (supplied by DEECA, 2023) provide a reasonable regional scale representation of licensed groundwater use.
Approximations	Definition of confined aquifer boundary	<ul style="list-style-type: none"> Where a GMA/WSPA vertical and/or lateral boundary does not correspond to VAF geometry, the VAF geometry overrides the GMU boundary.
	GIS data	-
	Hydrogeological information	-
	K data	<ul style="list-style-type: none"> The P20 K, P50 K and P80 K were calculated based on a minimum of 5 K data points within a GMB. In the absence of sufficient K point data (i.e., < 5 per VAF layer within a GMB), the typical K ranges from pumping tests informed (but did not directly determine) the selection of representative values of P20 K, P50 K and P80 K.
	Throughflow calculations	-
Interrogation of throughflow outputs	<ul style="list-style-type: none"> For some GMUs (indicated in the following sections), the management boundaries do not occupy the <i>entire width</i> of the flow-tube such that the flow-tube contains a number of unincorporated area flow cells perpendicular to flow. In these instances, the entire extent of the flow-tube, that includes the additional unincorporated area flow cells, should be acknowledged and accounted for when adopting the throughflow outputs for a GMU, including in the determination of a sustainable yield. For some GMUs (indicated in the following sections), the management boundaries do not occupy the <i>entire length</i> of the flow-tube such that the 	

Confined Aquifer Throughflow Assessment – Updated Method and Phase B State-wide Rollout

Type	Element of methodology	Description
		<p>flow-tube contains unincorporated area flow cells, parallel to flow, upgradient or downgradient of the GMU. In these instances, throughflow rates have been calculated for both the:</p> <ul style="list-style-type: none"> - Entire flow-tube. - Length of the GMU. <p>If a GMU receives flow from an unincorporated area, or contributes flow to an unincorporated area, the entire length of the flow path (i.e., the entire flow-tube) should be acknowledged and accounted for when adopting the throughflow outputs for a GMU, including in the determination of a sustainable yield. The same principle applies if flow occurs between GMUs, as is the case for the UMTA layer that is indicated to flow from the West Wimmera GMA to the Murrayville GMA.</p>
Limitations	Definition of confined aquifer boundary	-
	GIS data	-
	Hydrogeological information	<ul style="list-style-type: none"> ▪ The hydrogeological characterisation of GMUs are not comprehensive or exhaustive. The hydrogeological processes described broadly represent regional scale, post-development processes. ▪ The hydrogeological characterisation of GMUs are used to contextualise the throughflow rates, in particular, throughflow variability along inferred flow paths and possible hydrogeological factors contributing to this variability.
	K data	<ul style="list-style-type: none"> ▪ The K data was sourced from the PCV review projects (Jacobs, 2019 and GHD, 2020), aquifer property mapping project (CDM Smith, 2018) and other readily available literature sources. ▪ The K data sources were not interrogated to exclude any numerical model derived data.
	Throughflow calculations	<ul style="list-style-type: none"> ▪ The throughflow rates are based on predevelopment H_i/L. Any changes in throughflows due to drawdown or inter-aquifer leakage from groundwater development will not be reflected in these rates. ▪ The predevelopment throughflow rates are not intended to be representative of potential aquifer yields either at a local or regional scale as there may be other constraints or values that need to be protected which would reduce the safe yield below throughflow.
	Interrogation of throughflow outputs	<ul style="list-style-type: none"> ▪ The throughflow outputs derived have not been cross-checked or validated. ▪ The impacts to predevelopment throughflow rates from historic or current groundwater development (and implications for receptors) has not been assessed in this project.
Exclusions	Definition of confined aquifer boundary	<ul style="list-style-type: none"> ▪ Where the VAF layer is indicated to outcrop based on the predevelopment potentiometric surface (and so is unconfined), it has been excluded from the study area. ▪ In cases where an aquifer is confined by an overlying aquitard but the aquifer itself is not fully saturated (e.g., West Wimmera GMA), it is excluded from the study area based on the definition of the confined aquifer boundary (above). ▪ Basement units, due to their comparatively limited yield and potential access constraints, are not subject to the throughflow analysis.
	GIS data	<ul style="list-style-type: none"> ▪ Updated geological mapping is not included where the VAF layering does not incorporate it. ▪ The predevelopment potentiometric surfaces are mismatched at most CMA model boundaries and have not been manipulated for consistency across the whole state. ▪ Sand layers within aquitard layers that are considered a groundwater resource (e.g., Fyansford Formation (UMTD) in the Cut Paw Paw GMA) cannot be accommodated in this VAF based throughflow analysis and have been excluded.

Confined Aquifer Throughflow Assessment – Updated Method and Phase B State-wide Rollout

Type	Element of methodology	Description
	Hydrogeological information	<ul style="list-style-type: none"> ▪ Some elements of the CHM reported on (i.e., groundwater-surface water interaction, groundwater discharge and groundwater quality variability along flow path) in Phase A have not been excluded in Phase B as they were considered of limited value to the study. ▪ Rigorous testing of alternate CHMs has not been undertaken. ▪ Hydrogeological characterisations were not reported on for the UAs due to the limited availability of information in these areas.
	K data	-
	Throughflow calculations	<ul style="list-style-type: none"> ▪ Confined areas of UTAM VAF layer that are non-continuous and/or are mapped with no overlying VAF designated aquitard are excluded from the throughflow analysis. The non-continuous and semi-confined nature of the UTAM in these areas is such that it is not suited to assessment using the throughflow approach. ▪ Cells indicated to be confined, but limited and non-continuous in extent, are not considered suited to throughflow assessment and have been excluded from the analysis, figures and ArcGIS Pro tool. These cells typically occurred in UAs. ▪ In some areas the modelled predevelopment potentiometric surfaces may be affected by early groundwater development and/or oil and gas production. As the throughflow calculations are based on predevelopment conditions, areas where there is clear groundwater level drawdown have been excluded from the cross-sectional throughflow analysis. ▪ Cross-sectional throughflow analysis has been excluded in areas where the predevelopment potentiometric surfaces are indicated to be affected by model boundary conditions (e.g., adjacent to the South Australian-Victorian border). ▪ The sensitivity analysis of H_L/L and b input parameters (termed “alternative (P50 K) estimate” in the Pilot study) has not been repeated in Phase B. The sensitivity analyses were demonstrated to contribute minimal uncertainty at both the gridded and GMU scale throughflow rates and there was considered limited value in rolling out the analysis state-wide.
	Interrogation of throughflow outputs	<ul style="list-style-type: none"> ▪ A factor contributing to throughflow rate variability along inferred flow paths may be misrepresentation of the physical aquifer property inputs (i.e., K, H_L/L, b) in the calculation. This factor may be common to all GMUs (and UAs) and to avoid repetition is not listed in the discussion of observations for each GMU or UA. ▪ Groundwater usage includes licensed usage only. Stock and domestic usage, due to inherent uncertainty in the dataset, was not included in the analysis. ▪ There is no spatial or temporal component to the assessment of the relative potential for adverse impacts to aquifer value(s) which is based on average licensed usage as a proportion of the average (P50 K) throughflow rate. Nor is there a consideration of GMU specific risks of groundwater extraction (i.e., depletion of surface water flow).

1. Introduction

1.1 Project context

In order to allocate water securely in Victoria, the Department of Energy, Environment and Climate Action (DEECA) requires a defensible estimate of the amount of water available now and in the future, and the factors that may affect that availability. Water availability is determined through a range of mechanisms including monitoring of surface water flow, groundwater levels and water quality, and water resource modelling, and in consideration of patterns of use, the needs of the environment, recreational users and Traditional Owners. The effects of climate change on the security of water resources, and the potential for population and economic growth to drive increasing demands on water, add additional complexities to water resource assessments (DELWP, 2022a).

In Victoria, the sustainable yields of groundwater resources have not been reviewed at a State-wide scale since caps (Permissible Consumptive Volumes, PCVs) for Groundwater Management Units (GMUs) were implemented in the late 1990s. DEECA (DELWP, 2022a) considers a review of groundwater sustainable yields warranted as:

- Additional GMUs have been declared, while other GMUs have merged.
- Original sustainable yield estimates were often based on limited data sets. There is now an opportunity to use the large volumes of groundwater monitoring data collected over the last 20 years through the implementation of government initiatives, and the improved understanding of groundwater systems from technical studies, to inform revised sustainable yield estimates.
- Single sustainable yield volumes were typically estimated without consideration of uncertainty and risks to environmental values.
- The Millennium Drought (1996 to 2010) increased reliance and awareness of groundwater resources, as well as the importance of understanding groundwater connectivity with surface water resources.
- Greater interest in developing groundwater, and increasing flexibility of access through trading, meaning more pressure on the resource and heightened community value seen in groundwater. As groundwater use is approximately 34 % of the amount that is available for consumption by licence holders, the potential exists for increased groundwater usage.
- Impacts of climate change on groundwater availability were not considered in the original sustainable yield estimates. Climate change projections and more specifically, predictions on the impact of possible climate scenarios for Victoria on its water resources (DELWP, 2020a), foreshadows less available water resources.
- There is a need to consider Traditional Owner values in water resource management.

In addition to reviewing sustainable yields, DEECA seeks an approach that will enable the implementation of the national definition of sustainable yields: *"the groundwater extraction regime, measured over a specified planning timeframe, that allows acceptable levels of stress and protects dependent economic, social and environmental values"* (NGC, 2004).

This national definition is a principle, and it does not provide the acceptable levels of stress that will protect economic, social, and environmental values. To apply this national definition, DEECA is developing metrics to protect the values of the groundwater resource including access to consumptive users, protection of the environment dependent on groundwater and Traditional Owners (DELWP, 2022a). The metrics will provide a measure of the level of potential adverse impact to be avoided and are to be used as a means for validating the quantification of sustainable yield volumes. The intention of the metrics is to allow an application of the national definition of sustainable yields and to meet the requirement of the Water Act 1989 for sustainable management.

1.2 Scope of works

The overarching aim of this project is to develop and rollout a relatively simple (analytical) semi-automated GIS-based method (tool) for estimating predevelopment throughflow rates for Victoria's *confined aquifers*. The output of this project will assist DEECA in reviewing sustainable yields for these *confined systems* across the State. The project is being undertaken in two parts; Phase A Pilot program (complete) and Phase B state-wide rollout (the subject of this report).

The purpose of Phase A (Jacobs, 2022) was to develop and test a tool for calculating predevelopment throughflow rates of *confined aquifers* in five Pilot study areas. Following enhancements of the tool in Phase B (Section 4), the approach has been rolled-out to the *confined aquifers systems* in the study area across Victoria.

The following scope of works was undertaken in Phase B for the *confined aquifer systems* in the study area:

- Enhance the semi-automated GIS-based throughflow tool.
- Collate relevant spatial data and information relating to the confined aquifers.
- Collate key hydrogeological data and information for each GMU.
- Using the tool, conduct predevelopment throughflow analyses and quantify uncertainty.
- Interrogate the throughflow outputs in the context of management arrangements and licensed groundwater usage in each GMU.
- For GMUs, define in relative terms, the reliability and uncertainty of the throughflow outputs and potential for adverse impact to aquifer values. This exercise, while outside the agreed scope of works, will provide DEECA with an approach to compare and prioritise monitoring and assessment options for GMUs.

For the benefit of the reader, this project is being undertaken in parallel with two other related DEECA projects:

- Sustainable yield assessment of unconfined aquifers in Victoria (CDM Smith).
- Sustainable yield assessment (use-drawdown method) of confined aquifers in Victoria (GHD).

1.3 Study area

For data synthesising and reporting purposes the Phase B state-wide study area is divided into Victoria's five Groundwater Management Basins (GMB) (Figure 1-1):

- Wimmera-Mallee GMB.
- Goulburn-Murray GMB.
- Otway-Torquay GMB.
- Central GMB.
- Gippsland GMB.

GMBs were defined by DEECA based on an understanding of groundwater geological basins, whilst also being aligned with the administrative boundaries of water corporations. A further sub-division was made with the representation of groundwater catchments within each GMB (Figure 1-1). A groundwater catchment approximates the surface water basin, with adjustments based on knowledge and assumptions concerning groundwater flow divides (DELWP, 2021).³

Groundwater Management Areas (GMAs) and Water Supply Protection Areas (WSPAs), collectively termed GMUs, are smaller management units within groundwater catchments. While a groundwater catchment can

³ While DEECA no longer use the GMB and groundwater catchment approach for reporting and managing Victoria's groundwater resources, it provides a logical framework for synthesising data and reporting outputs in this state-wide study.

Confined Aquifer Throughflow Assessment – Updated Method and Phase B State-wide Rollout

include several GMUs, the geographical boundaries of a GMU are generally contained within and/or aligned with the groundwater catchment boundaries.

The study area subject to the state-wide rollout includes the following confined aquifers (as described in the Victorian Aquifer Framework (VAF), GHD, 2012)⁴:

- Upper Tertiary Aquifer (marine) (UTAM).
- Upper Tertiary Aquifer (fluvial) (UTAF).
- Upper-Mid Tertiary Aquifer (UMTA).
- Lower-Mid Tertiary Aquifer (LMTA).
- Lower Tertiary Basalts Aquifer (LTB).
- Lower Tertiary Aquifer (LTA).

The extents of each of the six confined VAF layers are presented in Section 5 (Figure 5-1 to Figure 5-6). Overlaid on the figures are the boundaries of the GMUs designated by DEECA as being part of the study area. As indicated in Table 1-1 and Figure 1-2, a total of 17 GMAs and 7 WSPAs are included in the Phase B study area. Figure 1-2 also shows the GMUs not included in the study area. These GMUs generally consist of unconfined aquifer systems and are the subject of the CDM Smith sustainable yield assessment.

Areas of confined VAF layers not occupied by a GMU are classified as Unincorporated Areas (UAs) which also form part of the study area.

Table 1-1 GMUs with confined aquifers subject to the Phase B state-wide rollout

Groundwater management basin (GMB)	Groundwater management unit (GMU)
Wimmera-Mallee	West Wimmera GMA
	Murrayville GMA
Goulburn-Murray	Mid-Loddon GMA
	Lower Campaspe Valley WSPA
	Katunga WSPA
Otway-Torquay	Glenelg WSPA (abolished) ⁽¹⁾
	Portland GMA
	Condah WSPA
	Paaratte GMA
	Newlingrook GMA
	Gellibrand GMA
	Gerangamete GMA
	Jan Jac GMA
Central	Cut Paw Paw GMA
	Moorabbin GMA
	Frankston GMA
	Koo-Wee-Rup WSPA
	Corinella GMA
Gippsland ⁽²⁾	Moe GMA
	Sale WSPA
	Rosedale GMA
	Stratford GMA
	Giffard GMA
	Yarram WSPA

⁴ The VAF takes a hierarchical approach to setting out the stratigraphy of Victoria, with a particular focus on groundwater. The VAF starts with the smallest units, Geological Units (GUs) and then groups these GHs by age, and then their general lithological characteristics or aquifer potential, into Hydrogeological Units (HGUs). These HGUs are subsequently grouped into VAF “aquifers” and “aquitards”. These are the layers that are mapped in the VAF. The VAF confined “aquifers” are the subject of the current study.

Confined Aquifer Throughflow Assessment – Updated Method and Phase B State-wide Rollout

Notes:

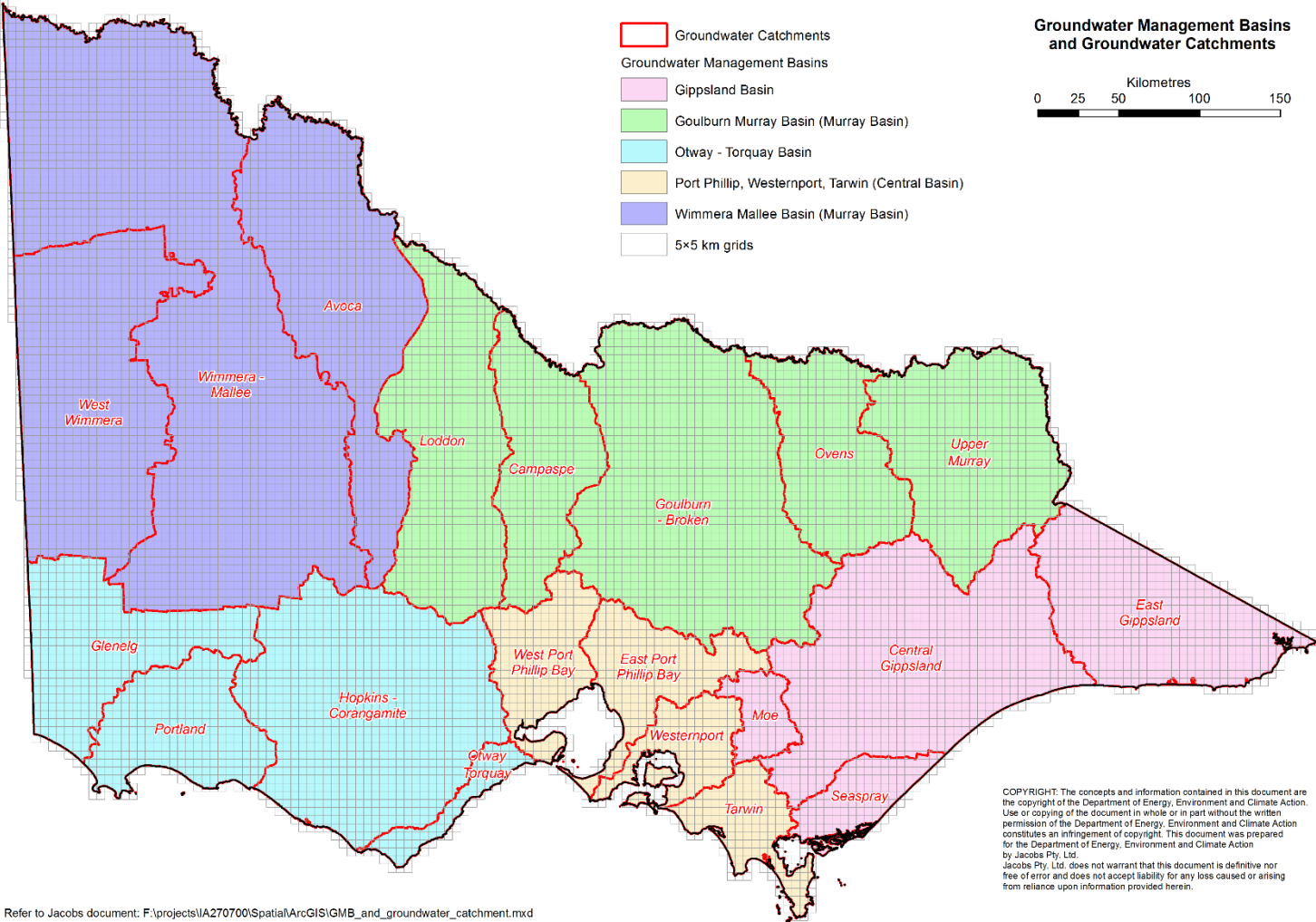
The GMUs listed in shaded cells were subject to assessment in the Phase A Pilot study. Additionally, the LTA below the Murrayville GMA formed a pilot area to test the approach in an UA.

(1) Glenelg WSPA was abolished in September 2022. The management area remains to be used by DEECA for reporting purposes, however, and therefore forms part of the study area for this project.

(2) The Orbost GMA was originally intended to be part of the Phase B study area. Due to the small occurrence of confined aquifer within the GMA, the throughflow methodology was not considered appropriate and has been excluded.

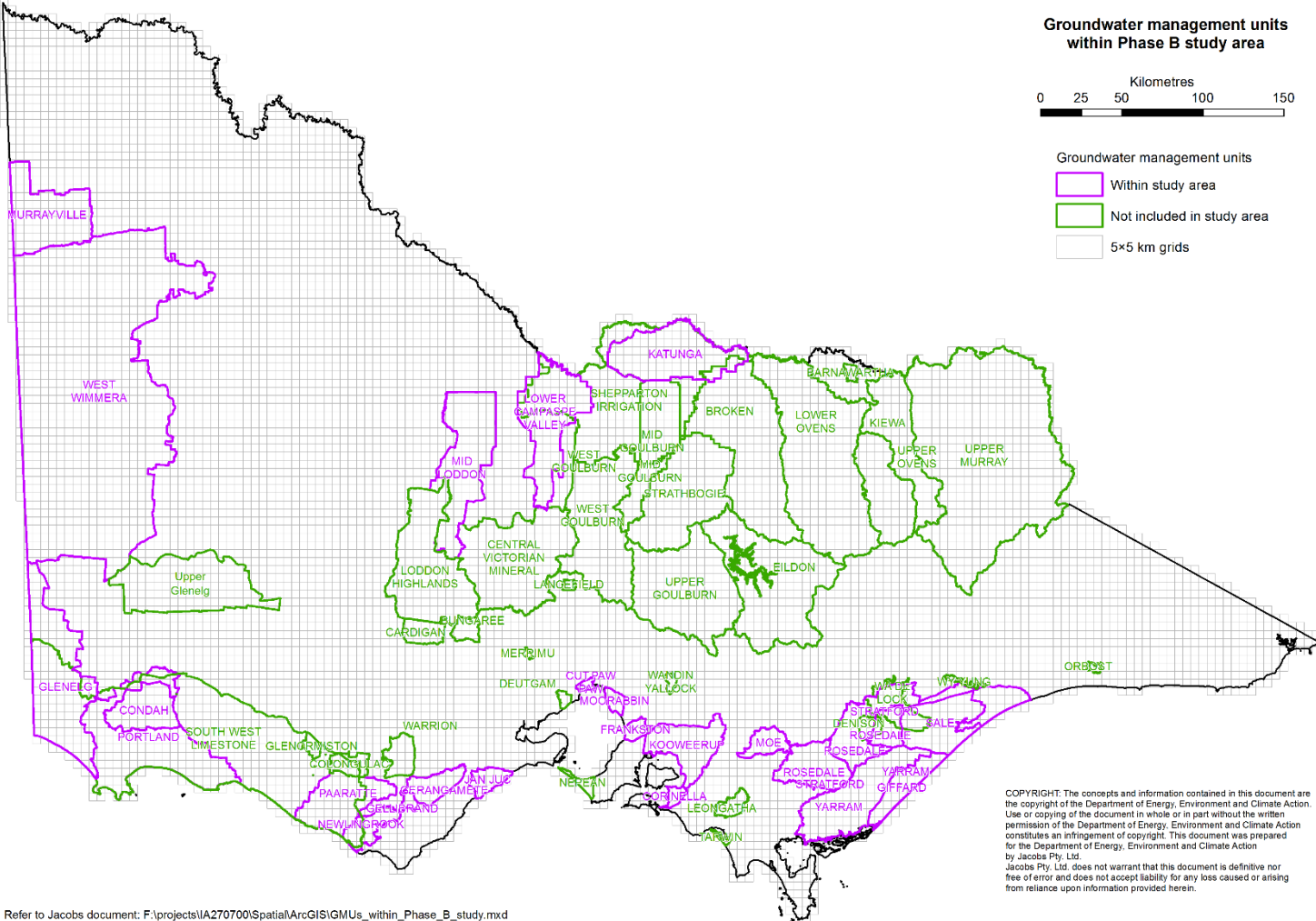
Confined Aquifer Throughflow Assessment – Updated Method and Phase B State-wide Rollout

Figure 1-1 GMBs and groundwater catchments in Victoria



Confined Aquifer Throughflow Assessment – Updated Method and Phase B State-wide Rollout

Figure 1-2 GMUs within Phase B study area



Refer to Jacobs document: F:\projects\IA270700\Spatial\ArcGIS\GMUs_within_Phase_B_study.mxd

1.4 Report structure

The Phase B report contains the following sections (noting that the study outputs are documented according to GMBs):

- Section 1: Project context, scope of works and study area definition.
- Section 2: Technical concepts and terms relating to groundwater throughflow and its calculation.
- Section 3: Summary of outcomes of the Phase A study.
- Section 4: Description of analytical throughflow approach and tool development.
- Section 5: Classification of flow-tubes in the study area.
- Section 6: Throughflow results for GMUs and UAs in the Wimmera-Mallee GMB.
- Section 7: Throughflow results for GMUs and UAs in the Goulburn-Murray GMB.
- Section 8: Throughflow results for GMUs and UAs in the Otway-Torquay GMB.
- Section 9: Throughflow results for GMUs and UAs in the Port Phillip Bay groundwater catchments of the Central GMB.
- Section 10: Throughflow results for GMUs and UAs in the Westernport groundwater catchment of the Central GMB.
- Section 11: Throughflow results for the Moe GMA in the Moe groundwater catchment of the Gippsland GMB.
- Section 12: Throughflow results for GMUs in the Central groundwater catchment of the Gippsland GMB.
- Section 13: Throughflow results for the GMUs and UA in the Seaspray groundwater catchment of the Gippsland GMB.
- Section 14: Summary of key throughflow outputs.
- Section 15: Project conclusions.
- Section 16: References.

The study outputs presented in Sections 6 and 13 are intended to be read as standalone sections, and hence, are repetitive in content.

2. Technical concepts and terms

Assessing sustainable yields based on groundwater throughflow rates is often used as a surrogate for estimating recharge, particularly for *confined systems* where quantifying recharge to an aquifer using standard recharge techniques is not practical or even possible.

The method can be used for *unconfined aquifers* where there is limited discharge points that have the potential to affect throughflow volumes (i.e., loss), and where vertical recharge (i.e., gain) can be accounted for at multiple points along the flow path. This may also be the case for confined systems where inter-aquifer vertical leakage represents a significant loss or gain in an aquifer's water balance (SKM, 2010). Developing a conceptual hydrogeological model (CHM) of the aquifer system assists in contextualising and understanding calculated throughflow rates and any variability along flow paths.

Analytical estimates of throughflow adopt Darcy's equation:

$$\text{Throughflow rate} = \text{Hydraulic conductivity } (K_h) \times \text{Hydraulic gradient } \left(\frac{HL}{L}\right) \times \text{Cross sectional area}$$

Where:

- Throughflow rate: m³/day
- Hydraulic conductivity (horizontal) (K_h): m/day
- Hydraulic gradient (H_L/L): $\frac{\Delta \text{Head}}{\Delta \text{Length}}$
- Cross-sectional area of aquifer: m²

In Phase B, the calculation of throughflow rate in a GMU or UA scale required a three-dimensional (3D) conceptualisation of groundwater flow (i.e., an inferred flow-path from areas of recharge to discharge) and its delineation in plan view. The term "**flow-tube**" is used in this report to represent this regional scale 3D conceptualisation of groundwater flow in a confined VAF layer. Flow-tubes have been defined at the GMU or UA scale (or sub-scale) and delineated, in plan view, perpendicular to modelled predevelopment potentiometric surfaces, and separated by inferred groundwater divides. A plan view schematic depicting three hypothetical flow-tubes (A, B and C (partial flow-tube)), overlaying the 5×5 km gridded cells adopted in the methodology, is presented in Figure 2-1.

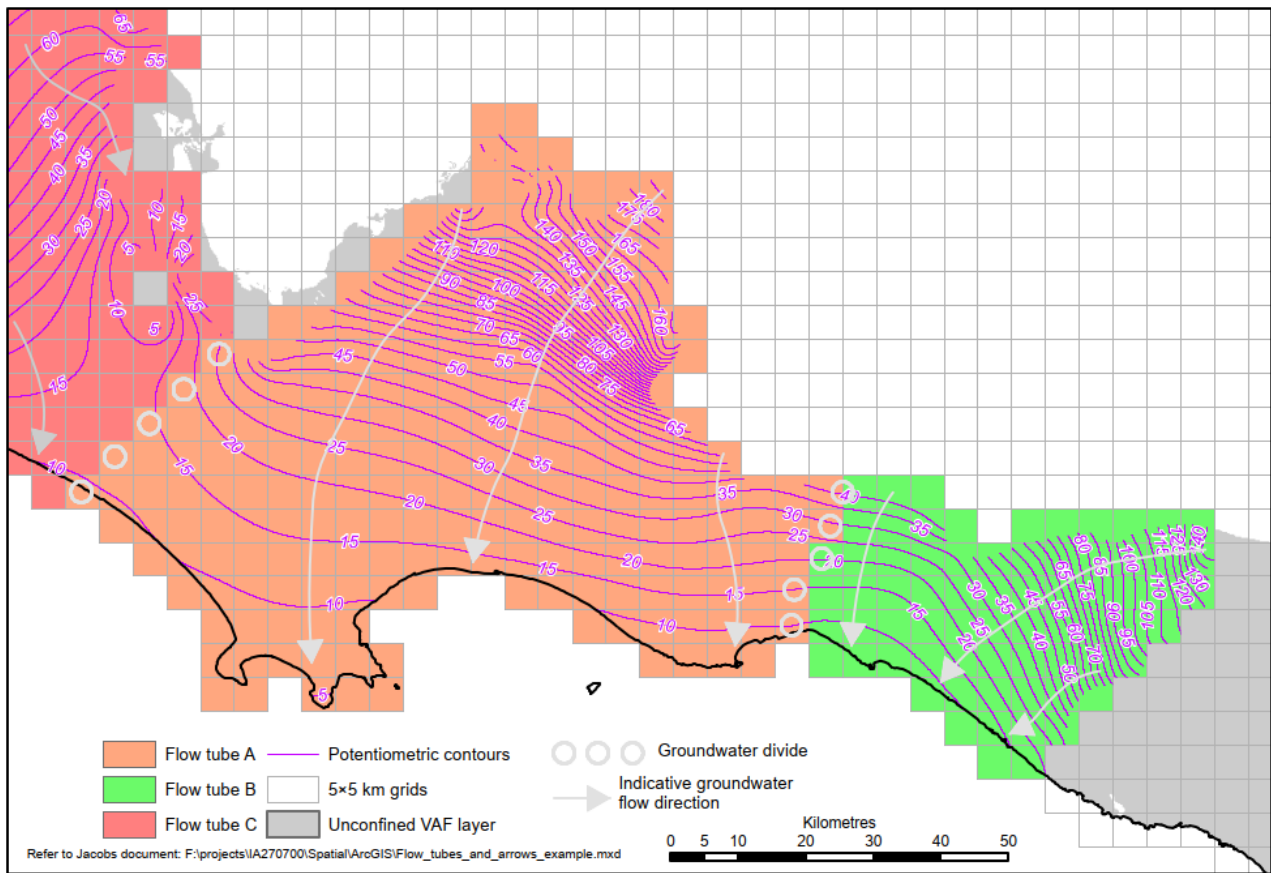
For the input parameters to the Darcy equation, K_h can be estimated from pump test data and/or lithological information, while the H_L/L along the flow path is usually determined from groundwater levels of observation wells screened in the aquifer of interest. For this study, H_L/L was determined from modelled predevelopment groundwater elevation surfaces derived from state-wide Catchment Management Area (CMA) numerical groundwater models.⁵ The cross sectional area of the aquifer can be estimated from borehole lithology and/or geology maps. The derivation and source of the input parameters adopted in the throughflow assessment are described in Section 4.

Typically the greatest uncertainty in the throughflow calculation is associated with the K parameter and its extrapolation from point source data (such as pumping tests). Reliance on throughflow rates for water resource management decision making can be enhanced with a corresponding assessment of uncertainty (SKM, 2010).

Being based on historical recharge, the throughflow method is not a predictive tool for assessing future scenarios (e.g., climate change). For large scale systems (e.g., basin margins and basin systems) this is less of a limitation. However, in the case of the small scale systems (e.g., upland valleys) where the response time between change in recharge and throughflow is relatively short, future climate dependent variability may impact the throughflow rates within a shorter time frame.

⁵ The term "predevelopment" is used in this study to broadly represent conditions prior to significant and regional scale groundwater development. In some cases, the predevelopment modelled potentiometric surfaces adopted in the study may rely on gauged levels influenced by low levels of early groundwater development.

Figure 2-1 Schematic diagram of hypothetical flow-tubes (plan view)



3. Outcomes of Phase A

The key outcome of the Phase A project (Jacobs, 2022) was the development of a GIS semi-automated tool for calculating (at a gridded 5x5 km scale) predevelopment throughflows of confined VAF layers, based on Darcy's equation (Section 2). At the larger GMU (or UA) scale, throughflows were estimated by summing gridded throughflows along cross-sections perpendicular to groundwater flow. Uncertainty in throughflow rates was quantified at both the gridded and GMU (or UA) scale.

The following outputs were generated for each VAF layer in the Phase A Pilot study areas:

- Gridded (5x5 km) throughflow rates for:
 - **Best estimate** - 50th percentile K (P50 K) and average b and H_L/L of the individual gridded cell.
 - **Lower bound** – 20th percentile K (P20 K) and average b and H_L/L of the individual gridded cell.
 - **Upper bound** – 80th percentile K (P80 K) and average b and H_L/L of the individual gridded cell.
 - **“Alternative” estimate** - P50 K and mean H_L/L and b values of the grid cell of interest, plus its eight neighbouring cells (nine grid cells in total).
- GMU (or UA) scale throughflow rates for:
 - Average, lower (-1 standard deviation (SD)) and upper (+1SD) range **best estimate** (P50 K) of the cross-sectional throughflows.
 - Average, lower (-1SD) and upper (+1SD) range **“alternative” estimate** (P50 K) of the cross-sectional throughflows.
 - Average, lower (-1SD) and upper (+1SD) range **minimum estimate** (P20 K) of the cross-sectional throughflows.

To assist with contextualising the outputs, the **average, lower and upper range best estimate** (P50 K) and **lower range minimum estimate** (P20 K) GMU scale throughflow rates were compared with current groundwater management arrangements (i.e., PCV) and usage data (i.e., average, minimum and maximum licensed usage).

The approach, having been trialled and demonstrated in five Pilot study areas (i.e., Sale WSPA, Koo-Wee-Rup WSPA, Lower Campaspe Valley WSPA, Murrayville GMA and the UA under the Murrayville GMA consisting of the LTA, Figure 1-2), was generally considered by DEECA and the Technical Review Panel (TRP) to be suitable for the state-wide rollout in Phase B. The methodology, and any significant modifications and enhancements made in Phase B, is described in Section 4. 2.

Based on the Phase A Pilot trial (Jacobs, 2022), three recommendations were made for consideration by DEECA in the Phase B state-wide rollout. The recommendations are summarised in Table 3-1, including the corresponding decision or outcome for the Phase B.

Table 3-1 Key recommendations from Phase A and outcomes for Phase B study

Recommendation from Phase A Pilot study	Outcome for Phase B State-wide rollout
Exclude the sensitivity analysis of H _L /L and b input parameters (represented by the “alternative” estimate). The Phase A Pilot study demonstrated that uncertainty in the H _L /L and b input parameters contributed minimal uncertainty (i.e., <±20%) to the best estimate (P50 K) throughflow rates.	It was agreed with DEECA that investment in the “alternative” estimate was not warranted for the Phase B study.
Invest in collating additional K point data, that may not have been captured in the PCV review projects (Jacobs, 2019 and GHD, 2020) and aquifer property mapping project (CDM Smith, 2018). This recommendation was made on the basis that the K parameter was demonstrated to contribute to the greatest uncertainty in throughflow rates.	This additional task has not been undertaken in Phase B. While additional K point data may reduce uncertainty in throughflow rates, it is unlikely to significantly change the best estimate (P50 K) of throughflow.
Trial the following approach to cross-check the predevelopment GMU throughflow calculations: <ul style="list-style-type: none"> ▪ Prepare or access an already generated recent potentiometric surface, and using the GIS semi- 	While the value of this cross-checking task was agreed with DEECA in principle, it has not been undertaken in Phase B due to resource constraints at DECCA. This is a standalone task and can be undertaken outside the course of the Phase B study.

Confined Aquifer Throughflow Assessment – Updated Method and Phase B State-wide Rollout

Recommendation from Phase A Pilot study	Outcome for Phase B State-wide rollout
<p>automated tool, calculate the current gridded and GMU scale throughflow rates.</p> <ul style="list-style-type: none">▪ Calculate the change in GMU scale throughflow (i.e., difference between predevelopment and current throughflow).▪ Compare the change in GMU scale throughflow with estimated (average) usage. <p>This exercise would provide a valuable cross-check of the predevelopment throughflow calculation and an indication of whether any significant stress-induced leakage is occurring from groundwater development.</p> <p>A spatial interrogation of current gridded throughflow rates would also provide an indication of the local and regional scale changes to hydraulic gradients and throughflows as a consequence of groundwater development. Ultimately, the outcomes of this additional work could support the development of a risk based approach to assessing sustainable yields that adopts a change in predevelopment throughflow metric.</p>	

4. Methodology

The groundwater throughflow project outputs in Phase B have been generated *sequentially* according to the following steps (1 to 6) described herein:



The methodology is generally consistent with that developed, trialled and refined in the Phase A Pilot Study. Modifications and enhancements made in the Phase B state-wide rollout, where significant, are indicated in the following sections (Section 4.1 to 4.6).

The range of assumptions, approximations, limitations and exclusions that that apply to each component of the methodology are described in Section 4.7.

4.1 Step 1 – Collate GIS data

To directly inform the calculation of throughflow (using Darcy's equation, Section 2), the following spatial datasets were collated for the Phase B study area:

- Groundwater management boundaries, including GMBs, groundwater catchments and GMUs.
- VAF layer top and bottom elevations (GHD, 2012) for the following confined VAF layers:
 - UTAF.
 - UMTA.
 - LMTA.
 - LTB.
 - LTA.

This spatial data has been used to calculate the aquifer thickness (b) component of the throughflow calculation.

- Predevelopment confined aquifer potentiometric surfaces for the confined VAF layers. The surfaces were derived from the following sources:
 - Wimmera-Mallee GMB: Murray Basin Hydrogeological Map Series and Wimmera CMA "EcoMarkets" model (Hocking et al., 2010b).
 - Goulburn-Murray GMB: North Central "EcoMarkets" CMA model (Hocking et al., 2010a) and Goulburn Broken CMA "Ecomarkets" model (Hocking et al., 2010c).
 - Otway-Torquay GMB: Glenelg Hopkins "EcoMarkets" CMA model (SKM, 2009b) and Southern Rural Water (SRW) hydrographical mapping project (SKM & GHD, 2009).
 - Central GMB: Port Phillip "EcoMarkets" CMA model (GHD, 2010a).
 - Gippsland GMB: West Gippsland "EcoMarkets" CMA model (GHD, 2010b) and SRW hydrographical mapping project (SKM & GHD, 2009).

This spatial data has been used to determine the predevelopment hydraulic gradient (H_L/L) component of the throughflow calculation. Where groundwater model surfaces have been used, the calibrated initial conditions were adopted to represent largely predevelopment or undisturbed hydraulic gradients. In some GMUs, it is acknowledged that the calibrated potentiometric surfaces do not represent true predevelopment conditions (e.g., Latrobe Valley and close to Portland).

4.2 Step 2 – Collate hydrogeological information

In Step 2, hydrogeological information for the GMUs in the study area was collated to enable the interrogation and contextualisation of throughflow outputs, including uncertainty. The source of the hydrogeological information included:

- PCV review projects (Jacobs, 2019 and GHD, 2020).
- Readily available literature sources.

The hydrogeological information collated included the attributes listed in Table 4-1.

Table 4-1 Hydrogeological information collected for each GMU

Attribute	Parameter
Hydrostratigraphic profile	Geological formation. VAF code. Geological period. Lithology.
GMU groundwater management	GMU size. PCV Order depth. Overlying and underlying GMUs. Confined aquifers (and VAF code) constituting the GMU. PCV and derivation.
Groundwater usage	Licensed volume. Licensed usage and target VAF layer(s).
Hydrogeological conceptualisation	Recharge area(s). Groundwater flow and aquifer/aquitard characteristics. Cross-border flows.
Groundwater monitoring	Groundwater suite hydrographic classification.

4.3 Step 3 – Collate and interrogate K data

In Step 3, a database was developed of the horizontal hydraulic conductivity point source data (K_h , herein referred to as K) to inform this component of the Darcy throughflow calculation (Section 2). The K data was collated for VAF layers within the study area from the following references:

- PCV review projects (Jacobs, 2019 and GHD, 2020).
- Aquifer property mapping project (CDM Smith, 2018).
- Readily available literature sources.

The K database was enhanced by collating the following additional data from the above sources:

- Ranges in K from pump tests.
- Vertical hydraulic conductivity (K_v), transmissivity and storativity.

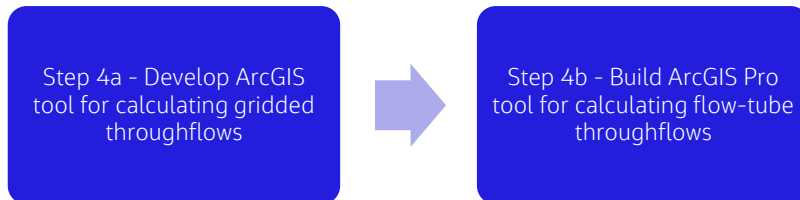
At the GMB scale (Figure 1-1), the K dataset for each VAF layer was interrogated according to the following statistical analyses:

- Number of K data points.
- Minimum, average and maximum K.
- P20 K, P50 K, P80 K and SD if ≥ 5 K point data within the GMB.

The P20 K, P50 K and P80 K were selected to represent a lower bound, best estimate and upper bound in K's at the gridded scale (Section 3). In the absence of sufficient K point data (i.e., < 5 per VAF layer in a GMB), the typical K ranges from pumping tests informed (but did not directly determine) the selection of representative values of P20 K, P50 K and P80 K for adoption in the throughflow assessment.

4.4 Step 4 – Develop GIS throughflow tools

The approach to developing the GIS tools for the calculation of gridded (Step 4a) and flow-tube (Step 4b) predevelopment throughflow rates is described below according to the following *sequential* steps:



4.4.1 Step 4a – Develop ArcGIS tool (gridded throughflows)

A GIS tool was built in ArcGIS software for calculating gridded throughflow rates as follows:

- The following spatial datasets (collated in Step 1, Section 4.1) were imported for each VAF layer in the study area and compiled at 100 m (node) resolution rasters:
 - VAF layer top and bottom elevations.
 - Predevelopment confined aquifer potentiometric surfaces.
- The State was divided into a 5×5 km polygon (cell) array, configured such that the edge of each polygon corresponded to the edge of associated cells within the input data. Each gridded cell was assigned a unique column and row number.
- The three components of the Darcy throughflow calculation (b , H_L/L and K , Section 2) were derived at the gridded (5×5 km cell) scale as follows:
 - Average b : computed based on the difference between the VAF top and bottom elevations, and in turn the average volume of confined aquifer within each cell. This approach ensured that those cells only partially occupied by an aquifer did not overstate the potential throughflow from the whole cell area. The cross-sectional area of the cells was defined by the average aquifer thickness multiplied by the 5 km cell profile length.
 - Average H_L/L : computed from the 2,500 raster values of predevelopment potentiometric surface within each cell.
 - Default K : a uniform default K of 10 m/d was adopted for each VAF layer, across the entire study area. In Step 4b (Section 4.4.1), the ArcGIS Pro tool was developed with the added functionality of allowing the user to specify the relevant P50 K to be adopted in the throughflow analysis. This feature will enable the user to update the throughflow analyses in the event that additional K data is derived and a different K value is adopted.
- The tool was coded to enable gridded throughflow rates (adopting a default K of 10 m/d) to be calculated based on Darcy's equation (Section 2).

4.4.1 Step 4b – Develop ArcGIS Pro tool (flow-tube throughflows)

In the Phase A Pilot study, GMU scale cross-sectional predevelopment throughflows were manually calculated based on visual inspection of the gridded throughflows derived from the ArcGIS tool (Step 4a). As an enhancement to the State-wide rollout in Phase B, an ArcGIS Pro tool (hosted on the Jacobs server) was built based on the ArcGIS gridded outputs (derived from Step 4a), that had the additional capability of automating the cross-sectional throughflow calculations.

This additional tool was built for the purposes of:

- Eliminating transcription errors.
- Assisting to conceptualise groundwater flow paths (i.e., flow-tubes) from recharge to discharge areas and their consistency (or otherwise) with groundwater management boundaries.
- Enhancing efficiencies (i.e., reducing time investment) in deriving the State-wide GMU scale throughflow outputs.
- Maintaining a digital record of cells selected for cross-sectional throughflow calculations.

The cross-sectional throughflow calculation is undertaken by the user as follows:

- *Select and assign gridded cells to “flow-tubes” within a VAF layer:*
 - Flow-tubes were conceptualised at regional (GMU or UA) scale based on modelled predevelopment potentiometric surfaces (i.e., flow is perpendicular to the potentiometric surface). The delineation of flow-tubes permits the user to select relevant cells within the flow-tube for the calculation of cross-sectional groundwater throughflow (see below). In most cases, the designated flow-tube boundary is consistent with the GMU boundary.
 - As part of the flow-tube designation, the K field is updated from the default K (10 m/d) to the selected P50 K (derived in Step 3), and the gridded throughflows are re-calculated.
 - Flow-tubes are assigned an identification that includes the relevant VAF layer number and code, and a flow-tube (ft) number (e.g., 105UTAF_ft01).
 - Any cell within a designated flow-tube can be inspected by the user (within Jacobs environment) to derive the following information:
 - Cell, row and column identification.
 - VAF code.
 - Average reduced water level (RWL) (m AHD) and H_L/L.
 - Average b (m).
 - Total dissolved solids (TDS) (mg/L) (CDM Smith, 2022). This attribute was outside the agreed scope of works for Phase B but was included in the event that DEECA choose to exclude areas based on groundwater salinity.
 - Default and adopted K (m/d).
 - Gridded predevelopment throughflow (m³/d) based on the default K and adopted K.
- *Select and export gridded cells (within a flow-tube) to represent throughflow cross-sections:*
 - Cells are selected parallel to modelled predevelopment potentiometric surfaces (perpendicular to groundwater flow) to represent throughflow cross-sections.
 - Cross-sections are assigned an identification that includes the relevant VAF layer number and code, flow-tube number, cross-section number and date of export (e.g., 105_UTAF_ft01_cs01_20230524.xlsx).
 - The relevant data of each selected cell (as above) constituting a cross-section is exported to an Excel file for further user analysis (Section 4.5.2). Where possible, flow-tubes are assigned multiple cross-sections for throughflow analysis.

The ArcGIS Pro tool has been provided to DEECA (as an output of this study) and for reference the tool's user guide is provided in Appendix A. Spatial datasets, including the selected cells constituting both flow-tubes and cross-sections in each VAF layer have also been provided to DEECA as an outputs of this study. At the time of writing this report it was unclear whether the DECCA GIS environment would allow use of the tool.

4.5 Step 5 – Interrogate throughflow outputs and assess uncertainty

4.5.1 Gridded scale outputs and uncertainty

The 5×5 km scale, VAF layer based, **best estimate** gridded predevelopment throughflows rely on the following input data:

- K: P50 K of the GMB.
- b: average b of the individual gridded cell.
- H_L/L: average b of the individual gridded cell.

At the gridded scale, uncertainty in the K component of the throughflow equation was assessed in Phase A by way of a sensitivity analysis whereby:

- **Lower bound** gridded predevelopment throughflows was expressed by the P20 K.
- **Upper bound** gridded predevelopment throughflows was expressed by the P80 K.

The Phase A study demonstrated that uncertainty in the H_L/L and b components of the Darcy equation contributed comparatively minimal uncertainty to the **best estimate** (P50 K) predevelopment throughflow estimates. Accordingly, a sensitivity analysis of these parameters has not been undertaken in Phase B (Section 3).

The gridded scale predevelopment throughflow outputs have not been documented in the Phase B report. Based on the objectives of this study and the approach adopted, there is considered limited value in inspecting individual cell throughflow rates. Should DEECA wish to view the throughflows at this scale, the gridded **best estimate** (P50 K) throughflows can be inspected in the GIS dataset or ArcGIS Pro tool (Section 4.4.1) by selecting any cell within an assigned flow-tube. Within the tool, the user can change the K parameter of the flow-tube to any value (i.e., lower bound P20 K or upper bound P80 K) to assess the corresponding implications for gridded throughflows.

4.5.2 Flow-tube scale outputs and uncertainty

The flow-tube scale, VAF layer based, **best estimate** (P50 K) predevelopment throughflow is calculated based on the sum of the gridded throughflow cells along a selected cross-section perpendicular to groundwater flow (output of Step 4b, Section 4.4.1). Where possible, multiple cross-sections within a flow-tube were selected for analysis, and the **average best estimate** (P50 K) predevelopment throughflow was derived.

Where a GMU occupied only a portion of the flow-tube, an additional **average best estimate** (P50 K) **GMU specific** calculation was undertaken and reported on for those cross-section(s) that occurred within the area of the GMU.

At the flow-tube scale, uncertainty in the **average best estimate** (P50 K) predevelopment throughflow estimates was represented by its potential spatial variability. Such variability may be attributed to:

- Significant errors in the adopted input parameters (i.e., K, H_L/L and b).
- Inter-aquifer vertical leakage contributing to increases or decreases in groundwater throughflow along flow paths.

The potential for spatial variability between multiple cross-sections in a flow-tube was expressed by:

- **Lower range best estimate** (P50 K) throughflow: minimum calculated cross-sectional throughflow rate.
- **Upper range best estimate** (P50 K) throughflow: maximum calculated cross-sectional throughflow rate.

In Phase A, the **lower** and **upper ranges** were expressed by – 1SD and +1SD, respectively (Section 3). In Phase B, due to the generally small number of cross-sections comprising the flow-tube throughflow analysis, the derivation of minimum and maximum values was considered a more appropriate representation of the potential range.

As for Phase A, an additional component of the uncertainty analysis has been undertaken in acknowledgment of pumping test data tending to preferentially bias higher conductivity formations (i.e., pumping tests are usually only conducted on reasonably high yielding bores), such that the P50 K may be an over-estimate of the K on a regional scale. The **P20 K (lower bound)**, Section 4.5.1) throughflow rate is therefore a key output, particularly in the context of understanding the risk of different extraction levels.

As indicated in Table 4-2, these approaches to expressing the flow-tube scale predevelopment throughflow are intended to be broadly aligned to the different management strategy options described in DEECA's groundwater assessment framework (Jacobs, 2020, Section 2.1), that combines a level of uncertainty and level of risk of adverse impact.

Table 4-2 Expression of flow-tube scale predevelopment throughflows and corresponding management strategy options

Expression of flow-tube scale predevelopment throughflow	Description	Alignment with management strategies
Average, lower and upper range P50 K predevelopment throughflow	Average, lower (minimum) and upper (maximum) range best estimate of cross-sectional predevelopment throughflows in a flow-tube, adopting the P50 K and average H _L /L and b values of the individual grid cell.	Adaptive management strategy Informed by representative (likely) conditions in association with high uncertainty but low to moderate risk of adverse impact as management arrangements can be easily adapted in the future with minimal impact, as more information becomes available.

Expression of flow-tube scale predevelopment throughflow	Description	Alignment with management strategies
Lower range minimum P20 K predevelopment throughflow	Lower range (minimum) of cross-sectional predevelopment throughflows in a flow-tube, adopting the P20 K and average H _L /L and b values of the individual grid cell.	Least regret strategy A risk averse strategy in consideration of high levels of uncertainty and risk of potential adverse impact. Future changes to the strategy are still possible if impacts are identified (e.g., through monitoring) in a timely manner.

While each of these management strategies accommodate different levels of risk of adverse impacts, they both reflect high levels of uncertainty in the derivation of the flow-tube scale throughflow results. The inference of high uncertainty is made in consideration of the simplified method adopted in the assessment and the range of assumptions, approximations, limitations and exclusions that apply to the method, including the generally sparse nature of the available K (and hence transmissivity) data on which the throughflow calculations largely depend (Section 4.7).

4.6 Step 6 – Assign GMU rankings

For the purposes of summarising and contextualising the results of the study in relative terms, the throughflow outputs were ranked for each GMU according to the following criteria:

- Relative reliability (Step 6a, Section 4.6.1).
- Relative uncertainty (Step 6b, Section 4.6.2).
- Relative potential for adverse impact on aquifer value(s) (Step 6c, Section 4.6.3).

The relative reliability and uncertainty criteria are accompanied by monitoring and/or assessment options that will assist to increase the reliability, and reduce uncertainty, in the assigned rankings. For the relative potential for adverse impact on aquifer value(s) criteria, progressive monitoring and assessment options are described that are compatible with the assessed level of potential impact for each ranking.

In Step 6d (4.6.4), these ranked criteria were combined to determine an overall ranking for each GMU that can be used by DEECA for decision making purposes in their State-wide review of confined aquifer sustainable yields (Section 1.2).

4.6.1 Step 6a – Relative reliability of throughflow estimates

The *relative reliability* of the throughflow estimates has been assessed for each flow-tube overlapping with a GMU according to the following parameters:

- Areal density of K data (i.e., number of K data points/1,000 km² in GMB) (Table 4-3).
- Number of cross-sections within the flow-tube (Table 4-4).

Table 4-3 Score of areal density of K data

Parameter	Score		
	1	2	3
Areal density of K data (number of K data points/1,000 km ² in GMB)	<10	10-20	>20

Notes:

Where ranges in K values were available in the database (Step 3, Section 4.3), they were included in the summation of the number of K data points.

Where multiple VAF layers occurred within a flow-tube, each VAF layer was scored separately, and an average was derived for the flow-tube.

Table 4-4 Score of number of cross-sections within flow-tube

Parameter	Score		
	1	2	3
Number of cross-sections within flow-tube	1-2	3-5	>5

Note:

Where multiple VAF layers occurred within a flow-tube, each VAF layer was scored separately, and an average was derived for the flow-tube.

By combining the scores from these two parameters, the overall *relative reliability* of the throughflow estimates, at the flow-tube scale, was identified with a low, medium or high relative ranking (Table 4-5). An assessment option to increase the reliability of the throughflow calculations is also indicated in the table.

Table 4-5 Relative reliability ranking of throughflow estimates (flow-tube scale)

Parameter	Overall ranking of relative reliability of throughflow estimates for flow-tube		
	Low	Medium	High
Combined scores for areal density of K data points and number of cross-sections in flow-tube	2-3	4	5-6
Assessment option to increase reliability	<ul style="list-style-type: none"> Access additional sources of K data. Note: This may assist in reducing the potential range in calculated throughflow rates, however, it is unlikely to significantly change the average P50 K throughflow estimate. 		

4.6.2 Step 6b – Relative uncertainty of throughflow estimates

The *relative uncertainty* of the throughflow estimates has been assessed for each flow-tube overlapping with a GMU according to the following parameters:

- Coefficient of Variability (CV%) of the cross-section throughflow estimates for a flow-tube (Table 4-6).
- Factor difference between the adopted P50 K and P20 K for a flow-tube (Table 4-7).

Table 4-6 Score of CV of cross-section throughflow estimates for flow-tube

Parameter	Score		
	1	2	3
CV (%) of cross-section throughflow estimates for a flow-tube	<50	50-100	>100

Note:

In cases where a flow-tube relied on one throughflow cross-section (per VAF layer), and therefore no CV value was available, a score of “3” was adopted.

Table 4-7 Score of factor difference between adopted P50 K and P20 K for flow-tube

Parameter	Score		
	1	2	3
Factor difference between adopted P50 K and P20 K for a flow-tube	<2	2-5	>5

Note:

Where multiple VAF layers occurred within a flow-tube, each VAF layer was scored separately, and an average was derived for the flow-tube.

By combining the scores from these two parameters, the overall *relative uncertainty* of the throughflow estimates, at the flow-tube scale, was identified with a low, medium or high relative ranking (Table 4-8). Assessment options to reduce the uncertainty of the throughflow calculations is also indicated in the table.

Table 4-8 Relative uncertainty ranking of throughflow estimates (flow-tube scale)

Parameter	Overall ranking of relative uncertainty of throughflow estimates for flow-tube		
	Low	Medium	High
Combined scores for CV and factor difference between P50 K and P20 K	2-3	4	5-6
Assessment options to reduce uncertainty	<ul style="list-style-type: none"> ▪ Access additional sources of K data. Note: This may assist in reducing the potential range in calculated throughflow rates, however, it is unlikely to significantly change the average P50 K throughflow estimate. ▪ Cross-check the throughflow estimates (Section 3). ▪ Build on CHM to determine whether the range in potential throughflow rates is supported by hydrogeological processes (i.e., potential for inter-aquifer leakage, groundwater-surface water interaction). ▪ Verify modelled predevelopment potentiometric surface(s) (H_L/L) and/or VAF layer elevations (b) with data records and revise these parameters if necessary. ▪ Apply K data (if supported by CHM) based on sub-areas within a flow-tube. 		

4.6.3 Step 6c – Relative potential for adverse impact on aquifer value(s)

The *relative potential for adverse impact on aquifer value(s)* in a GMU was calculated as a percentage (%) according to:

$$\left(\frac{\text{Average licensed usage for the GMU (ML per year)}}{\text{Average P50 K throughflow rate in flow – tube (ML per year)}} \right) \times 100$$

Based on the calculated percentage, the ranking of the relative potential for adverse impact was assigned from low, medium, high to very high (Table 4-9). Importantly, this assessment does not include a spatial or temporal component (e.g., short, medium, long-term potential of impacts), nor is there a consideration of GMU specific risks of groundwater extraction (i.e., depletion of surface water flow).

Progressive monitoring and assessment options are also described in the table that are compatible with the assessed level of potential impact for each ranking. While outside the current scope of works, this exercise can also be applied to UAs based on licensed usage in these areas.

Table 4-9 Relative potential for adverse impacts on aquifer value(s)

Parameter	Ranking of the relative potential for adverse impact on aquifer value(s)			
	Low	Medium	High	Very High
Average licensed usage as a proportion of average P50 K throughflow rate (%)	0-30	30-60	60-100	>100
Progressive monitoring and assessment options	<ul style="list-style-type: none"> ▪ Monitor growth of consumptive use. 	<ul style="list-style-type: none"> ▪ Evaluate concentration and distribution of groundwater usage, and if concentrated, consider elevating ranking. ▪ Enhance groundwater 	<ul style="list-style-type: none"> ▪ Conduct more detailed projections of aquifer behaviour and potential to impact aquifer value(s). ▪ Monitor aquifer value(s) to be 	<ul style="list-style-type: none"> ▪ Enhance monitoring of aquifer value(s). ▪ Validate detailed projections of aquifer behaviour, impacts to aquifer value(s) and suitability of trigger levels.

Parameter	Ranking of the relative potential for adverse impact on aquifer value(s)			
	Low	Medium	High	Very High
		monitoring network and programs. <ul style="list-style-type: none"> Identify key aquifer value(s) to be protected. Baseline aquifer value(s) and set trigger levels. Conduct projections of aquifer behaviour and value(s) to be protected. 	protected against trigger levels.	

4.6.4 Step 6d – Overall GMU ranking

The rankings of the *relative uncertainty* and *potential for adverse impact on aquifer value(s)* criteria have been combined to determine an *overall ranking* for each GMU (Table 4-10) that can be used by DEECA in their review of sustainable yields for these confined systems across the State (Section 1.2). Where GMUs are categorised with the same overall ranking, the *relative reliability* ranking (Table 4-5) has been used to order these GMUs from lower to higher relative reliability.

A practical approach would be to first attempt to reduce uncertainty using the progressive desktop assessment approaches listed in Table 4-8 (Step 6b). Following any updates to the throughflow estimates and corresponding impact assessment (Step 6c), investment in the monitoring and assessment options described in Table 4-9 can be considered.

Table 4-10 Overall GMU rankings

		Ranking of the relative potential for adverse impact on aquifer value(s)			
		Low	Medium	High	Very High
Ranking of relative uncertainty of throughflow estimates for flow-tube	Low	L-L	L-M	L-H	L-VH
	Medium	M-L	M-M	M-H	M-VH
	High	H-L	H-M	H-H	H-VH

4.7 Assumptions, approximations, limitations and exclusions

The assumptions, approximations, limitations and exclusions that apply to the study's outputs are listed in Table 4-11 according to each element of the methodology.

Table 4-11 List of assumptions, approximations, limitations and exclusions for the study

Type	Element of methodology	Description
Assumptions	Definition of confined aquifer boundary	<ul style="list-style-type: none"> The unconfined-confined aquifer boundary is defined as where the (predevelopment) modelled potentiometric surface is equivalent to the top of the confined VAF layer. Where these aquifer units' outcrop (and so are unconfined), it has been assumed that these areas will form part of the CDM Smith unconfined aquifer sustainable yield project. Where a GMU extends to depth and incorporates confined aquifer system(s) that are not intended to be represented by the current PCV, professional judgement is applied to include those confined aquifer systems

Confined Aquifer Throughflow Assessment – Updated Method and Phase B State-wide Rollout

Type	Element of methodology	Description
		that represent a reasonable groundwater resource potential, with regards to aquifer extent and yield (but not salinity).
	GIS data	<ul style="list-style-type: none"> The VAF layers and predevelopment modelled potentiometric surfaces provide reasonable regional scale representations of the b and H_L/L parameters, respectively. The term “predevelopment” is used in this study to broadly represent conditions prior to significant and regional scale groundwater development. In some cases, predevelopment modelled potentiometric surfaces adopted may rely on gauged levels influenced by low levels of early groundwater development.
	Hydrogeological information	<ul style="list-style-type: none"> The documented hydrogeological characterisations of the GMUs are sufficient to make observations concerning the throughflow outputs.
	K data	<ul style="list-style-type: none"> The adopted P20 K, P50 K and P80 K values are representative of regional scale conditions and the entire thickness of the confined VAF layer.
	Throughflow calculations	<ul style="list-style-type: none"> The throughflow calculations have been undertaken according to the definition of the confined aquifer boundaries adopted for the study (as above). The throughflow calculations use Darcy’s law and its assumptions will apply including that the confined aquifer is porous and saturated and laminar flow is valid.
	Interrogation of throughflow outputs	<ul style="list-style-type: none"> The groundwater licensed usage data (supplied by DEECA, 2023) provide a reasonable regional scale representation of licensed groundwater use.
Approximations	Definition of confined aquifer boundary	<ul style="list-style-type: none"> Where a GMA/WSPA vertical and/or lateral boundary does not correspond to VAF geometry, the VAF geometry overrides the GMU boundary.
	GIS data	-
	Hydrogeological information	-
	K data	<ul style="list-style-type: none"> The P20 K, P50 K and P80 K were calculated based on a minimum of 5 K data points within a GMB. In the absence of sufficient K point data (i.e., < 5 per VAF layer within a GMB), the typical K ranges from pumping tests informed (but did not directly determine) the selection of representative values of P20 K, P50 K and P80 K.
	Throughflow calculations	-
	Interrogation of throughflow outputs	<ul style="list-style-type: none"> For some GMUs (indicated in the following sections), the management boundaries do not occupy the <i>entire width</i> of the flow-tube such that the flow-tube contains a number of unincorporated area flow cells perpendicular to flow. In these instances, the entire extent of the flow-tube, that includes the additional unincorporated area flow cells, should be acknowledged and accounted for when adopting the throughflow outputs for a GMU, including in the determination of a sustainable yield. For some GMUs (indicated in the following sections), the management boundaries do not occupy the <i>entire length</i> of the flow-tube such that the flow-tube contains unincorporated area flow cells, parallel to flow, upgradient or downgradient of the GMU. In these instances, throughflow rates have been calculated for both the: <ul style="list-style-type: none"> Entire flow-tube. Length of the GMU. <p>If a GMU receives flow from an unincorporated area, or contributes flow to an unincorporated area, the entire length of the flow path (i.e., the entire flow-tube) should be acknowledged and accounted for when adopting the throughflow outputs for a GMU, including in the determination of a sustainable yield. The same principle applies if flow occurs between GMUs,</p>

Confined Aquifer Throughflow Assessment – Updated Method and Phase B State-wide Rollout

Type	Element of methodology	Description
		as is the case for the UMTA layer that is indicated to flow from the West Wimmera GMA to the Murrayville GMA.
Limitations	Definition of confined aquifer boundary	-
	GIS data	-
	Hydrogeological information	<ul style="list-style-type: none"> The hydrogeological characterisation of GMUs are not comprehensive or exhaustive. The hydrogeological processes described broadly represent regional scale, post-development processes. The hydrogeological characterisation of GMUs are used to contextualise the throughflow rates, in particular, throughflow variability along inferred flow paths and possible hydrogeological factors contributing to this variability.
	K data	<ul style="list-style-type: none"> The K data was sourced from the PCV review projects (Jacobs, 2019 and GHD, 2020), aquifer property mapping project (CDM Smith, 2018) and other readily available literature sources. The K data sources were not interrogated to exclude any numerical model derived data.
	Throughflow calculations	<ul style="list-style-type: none"> The throughflow rates are based on predevelopment H_L/L. Any changes in throughflows due to drawdown or inter-aquifer leakage from groundwater development will not be reflected in these rates. The predevelopment throughflow rates are not intended to be representative of potential aquifer yields either at a local or regional scale as there may be other constraints or values that need to be protected which would reduce the safe yield below throughflow.
	Interrogation of throughflow outputs	<ul style="list-style-type: none"> The throughflow outputs derived have not been cross-checked or validated. The impacts to predevelopment throughflow rates from historic or current groundwater development (and implications for receptors) has not been assessed in this project.
Exclusions	Definition of confined aquifer boundary	<ul style="list-style-type: none"> Where the VAF layer is indicated to outcrop based on the predevelopment potentiometric surface (and so is unconfined), it has been excluded from the study area. In cases where an aquifer is confined by an overlying aquitard but the aquifer itself is not fully saturated (e.g., West Wimmera GMA), it is excluded from the study area based on the definition of the confined aquifer boundary (above). Basement units, due to their comparatively limited yield and potential access constraints, are not subject to the throughflow analysis.
	GIS data	<ul style="list-style-type: none"> Updated geological mapping is not included where the VAF layering does not incorporate it. The predevelopment potentiometric surfaces are mismatched at most CMA model boundaries and have not been manipulated for consistency across the whole state. Sand layers within aquitard layers that are considered a groundwater resource (e.g., Fyansford Formation (UMTD) in the Cut Paw Paw GMA) cannot be accommodated in this VAF based throughflow analysis and have been excluded.
	Hydrogeological information	<ul style="list-style-type: none"> Some elements of the CHM reported on (i.e., groundwater-surface water interaction, groundwater discharge and groundwater quality variability along flow path) in Phase A have not been excluded in Phase B as they were considered of limited value to the study. Rigorous testing of alternate CHMs has not been undertaken. Hydrogeological characterisations were not reported on for the UAs due to the limited availability of information in these areas.
	K data	-

Confined Aquifer Throughflow Assessment – Updated Method and Phase B State-wide Rollout

Type	Element of methodology	Description
	Throughflow calculations	<ul style="list-style-type: none"> ▪ Confined areas of UTAM VAF layer that are non-continuous and/or are mapped with no overlying VAF designated aquitard are excluded from the throughflow analysis. The non-continuous and semi-confined nature of the UTAM in these areas is such that it is not suited to assessment using the throughflow approach. ▪ Cells indicated to be confined, but limited and non-continuous in extent, are not considered suited to throughflow assessment and have been excluded from the analysis, figures and ArcGIS Pro tool. These cells typically occurred in UAs. ▪ In some areas the modelled predevelopment potentiometric surfaces may be affected by early groundwater development and/or oil and gas production. As the throughflow calculations are based on predevelopment conditions, areas where there is clear groundwater level drawdown have been excluded from the cross-sectional throughflow analysis. ▪ Cross-sectional throughflow analysis has been excluded in areas where the predevelopment potentiometric surfaces are indicated to be affected by model boundary conditions (e.g., adjacent to the South Australian-Victorian border). ▪ The sensitivity analysis of H_L/L and b input parameters (termed "alternative (P50 K) estimate" in the Pilot study) has not been repeated in Phase B. The sensitivity analyses were demonstrated to contribute minimal uncertainty at both the gridded and GMU scale throughflow rates and there was considered limited value in rolling out the analysis state-wide.
	Interrogation of throughflow outputs	<ul style="list-style-type: none"> ▪ A factor contributing to throughflow rate variability along inferred flow paths may be misrepresentation of the physical aquifer property inputs (i.e., K, H_L/L, b) in the calculation. This factor may be common to all GMUs (and UAs) and to avoid repetition is not listed in the discussion of observations for each GMU or UA. ▪ Groundwater usage includes licensed usage only. Stock and domestic usage, due to inherent uncertainty in the dataset, was not included in the analysis. ▪ There is no spatial or temporal component to the assessment of the relative potential for adverse impacts to aquifer value(s) which is based on average licensed usage as a proportion of the average (P50 K) throughflow rate. Nor is there a consideration of GMU specific risks of groundwater extraction (i.e., depletion of surface water flow).

5. Flow-tube classification

The throughflow results are reported for each confined VAF layer at the flow-tube scale. The classification of each flow-tube is documented in Table 5-1 according to:

- GMB and groundwater catchment (Figure 1-1) the flow-tube is situated in.
- GMU (i.e., GMA or WSPA) or UA that the flow-tube relates to.
- The reporting section where the throughflow outputs are documented.
- For GMUs, the depth range that the management area relates to.
- Confined VAF layer code (and flow-tube number).
- Name of the confined aquifer layer.

Table 5-1 Flow-tube classification

GMB	Groundwater catchment	GMU or UA	Reporting section	PCV Order depth	Confined VAF layer and flow-tube no.	Aquifer name
Wimmera-Mallee	West Wimmera	West Wimmera GMA	6.3.1	Not depth defined ⁽³⁾	UTAM ft01	Parilla Sand
					UMTA ft07,08	Murray Group Limestone (MGL)/Tertiary Limestone Aquifer (TLA) (Duddo Limestone)
					LTA ft21,22	Renmark Group/Tertiary Confined Sand Aquifer (TCSA)
	Wimmera-Mallee	Murrayville GMA	6.3.2	All formations from 70 to 200 m below surface	UMTA ft07	Murray Group/TLA (Duddo Limestone)
	Wimmera-Mallee	UA near Salt Lake	6.3.3	N/a	UTAM ft02	Parilla Sand
		UA east and north of Horsham	6.3.4	N/a	LTA ft23	N/a
	Avoca	UA between Donald and Robinvale	6.3.5	N/a	LTA ft24	N/a
Goulburn-Murray	Loddon	Mid Loddon GMA	7.3.1	All formations below surface	UTAF ft11	Calivil Formation
					LTA ft26	Renmark Group
		UA east of Wycheproof	7.3.2	N/a	UTAF ft12	N/a
		UA near Kerang	7.3.3	N/a	LTA ft25	N/a
	Campaspe	Lower Campaspe Valley WSPA	7.3.4	All formations below surface with an exception ⁽¹⁾	UTAF ft10	Calivil Formation
					LTA ft28	Renmark Group
		UA near Cohuna	7.3.5	N/a	LTA ft27	N/a
Goulburn-Broken	Katunga WSPA	7.3.6	All formations below 25 m from surface	UTAF ft09	Calivil Formation	
				LTA ft29	Renmark Group	
	Glenelg		8.3.1		LMTA ft03	Clifton Formation

Confined Aquifer Throughflow Assessment – Updated Method and Phase B State-wide Rollout

GMB	Groundwater catchment	GMU or UA	Reporting section	PCV Order depth	Confined VAF layer and flow-tube no.	Aquifer name
Otway-Torquay		Glenelg WSPA (abolished)		All formations below surface	LTA ft11	Dilwyn Formation
	Portland	Portland GMA	8.3.2	All formations below 200 m from surface	LTA ft12	Dilwyn Formation
		Condah WSPA	8.3.3	All formations from 70 m to 200 m below surface	LMTA ft04	Clifton Formation
	Hopkins-Corangamite	Paaratte GMA	8.3.4	Not depth defined ⁽⁴⁾	LTA ft14	Dilwyn Formation
		Newlingbrook GMA	8.3.5	All formations below surface	LTA ft15	Mepunga & Dilwyn formations
		Gellibrand GMA	8.3.6	All formations below surface	LTA ft16	Dilwyn Formation
		Gerangamete GMA	8.3.7	All formations below surface	LTA ft31	Dilwyn, Pebble Point and Mepunga formations (Eastern View Formation)
		UA near Warrnambool	8.3.8	N/a	LMTA ft05	N/a
		UA north of Colac	8.3.9	N/a	LTA ft32	N/a
		UA near Warrnambool	8.3.10	N/a	LTA ft13	N/a
		UA near Skipton	8.3.11	N/a	LTA ft30	N/a
	Otway-Torquay	Jan Juc GMA	8.3.12	Not depth defined ⁽⁵⁾	LTA ft17	Eastern View Formation
	Central	West Port Phillip Bay	Cut Paw Paw GMA	9.1.1	All formations below 50 m	LTA ft05
Moorabbin GMA			9.3.2	All formations below surface	LTA ft04	Werribee Formation
UA between Melbourne and Geelong			9.3.3	N/a	UTAF ft08	N/a
UA near Werribee			9.3.4	N/a	LTA ft06	N/a
UA southeast of Geelong			9.3.5	N/a	LTA ft18	N/a
East Port Phillip Bay		Frankston GMA	9.3.6	All formations below surface	UTAF ft03	Brighton Group/Baxter Sandstone
					LTA ft03	Werribee Formation
					LTBa ⁽⁶⁾ ft04	Mornington Volcanics
Westernport		Koo-Wee-Rup WSPA	10.3.1	All formations below surface	UTAF ft02	Baxter Sandstone
					UMTA ft02	Sherwood Formation/Yallock Formation

Confined Aquifer Throughflow Assessment – Updated Method and Phase B State-wide Rollout

GMB	Groundwater catchment	GMU or UA	Reporting section	PCV Order depth	Confined VAF layer and flow-tube no.	Aquifer name		
			10.3.2	All formations below surface	LTBa ⁽⁶⁾ ft02, ft03	Mornington Volcanics		
					LTA ft02	Childers Formation		
					UTAF ft01	Brighton Group/Baxter Sandstone		
				Corinella GMA	10.3.2	All formations below surface	UMTA ft01	Batesford Limestone
				LTA ft01			Childers Formation	
				UA north of Bonbeach	10.3.3	N/a	UTAF ft04	N/a
				UA near Hastings	10.3.4	N/a	UMTA ft03	N/a
Gippsland	Moe	Moe GMA	11.3	All formations below 25 m from surface	UMTA ft05	Yarragon Formation		
					LTBa ⁽⁶⁾ ft05	Thorpdale Volcanics		
					LTA ft10	Childers Formation		
	Central Gippsland		Sale WSPA	12.3.1	All formations from 25 to 200 m	UTAF ft07	Boisdale Formation (Wurruk Sand)	
			Rosedale GMA	12.3.2	Zone 1 - all formations from 50 to 150 m below surface Zone 2 - all formations from 25 to 350 m below surface Zone 3 - all formations from 200 to 300 m below surface	UMTA ft06	Balook Formation	
								Stratford GMA ⁽²⁾
			LTA ft08	Latrobe Group				
			UA west of Marlo	12.3.4	N/a	LTA ft09	N/a	
	Seaspray		Giffard GMA	13.3.1	All formations from 50 to 200 m below surface	UTAF ft06	Boisdale Formation (Wurruk Sand)	
			Yarram WSPA	13.3.2		UTAF (Zone 2 only) ft05	Boisdale Formation (Wurruk Sand)	

Confined Aquifer Throughflow Assessment – Updated Method and Phase B State-wide Rollout

GMB	Groundwater catchment	GMU or UA	Reporting section	PCV Order depth	Confined VAF layer and flow-tube no.	Aquifer name
				Zone 1 – all formations below 200 m	UMTA (Zone 2 only) ft04	Balook Formation
				Zone 2 – all formations below surface	LMTA ft01	M2C aquifer and Seaspray Sand
					LTA ft07	Latrobe Group

Notes:

(1) The WSPA incorporates all depths below the surface with the exception of all formations from the surface to 25 metres below the surface north of the Waranga West Channel.

(2) Based on the GMU depth criteria ranges, the confined LMTA is allocated to the Stratford GMA.

(3) The West Wimmera GMA PCV Order 2013 is defined by stratigraphic units and includes the Pliocene Sands Aquifer, Tertiary Limestone Aquifer, and Tertiary Confined Sand Aquifer.

(4) The Paaratte GMA PCV Order 2018 is defined by the upper and lower contour surfaces of the geological formation as described by Plan No. LEGL./18-090, lodged in the Central Plan Office of DEECA.

(5) The Jan Jac GMA is defined by stratigraphic units and includes the Upper Eastern View Formation Aquifer and the Lower Eastern View Formation Aquifer. Zone 1 includes all formations below the surface. Zone 2 is managed by formation and includes (i) all formations below the surface other than the Lower and Upper Eastern View Formation, (ii) Upper Eastern View Formation and (iii) Lower Eastern View Formation.

(6) In the VAF, the LTB is designated into two age groups, the younger LTBa – Phase 2 Basalts (Otway), Mornington Volcanics (Central), Thorpdale Volcanics (Gippsland) and the older LTBB – Phase 1 Volcanics (Murray).

Shaded cells indicate the flow-tube is assigned to a GMU but includes multiple cells of UA either upgradient or downgradient of the GMU.

The lateral extent of the VAF layers, distinguishing where the aquifer is confined and unconfined according to the assumptions adopted in this study (Table 4-11), are presented in Figure 5-1 (UTAM), Figure 5-2 (UTAF), Figure 5-3 (UMTA), Figure 5-4 (LMTA), Figure 5-5 (LTB) and Figure 5-6 (LTA). Colour shaded cells indicate where flow-tubes have been assigned, and their flow-tube (ft) numbers are marked accordingly. The GMU boundaries, if relevant to the VAF layer, are also indicated in the figures, as are indicative predevelopment groundwater flow directions.

Figure 5-1 Confined UTAM VAF layer and flow-tubes in study area

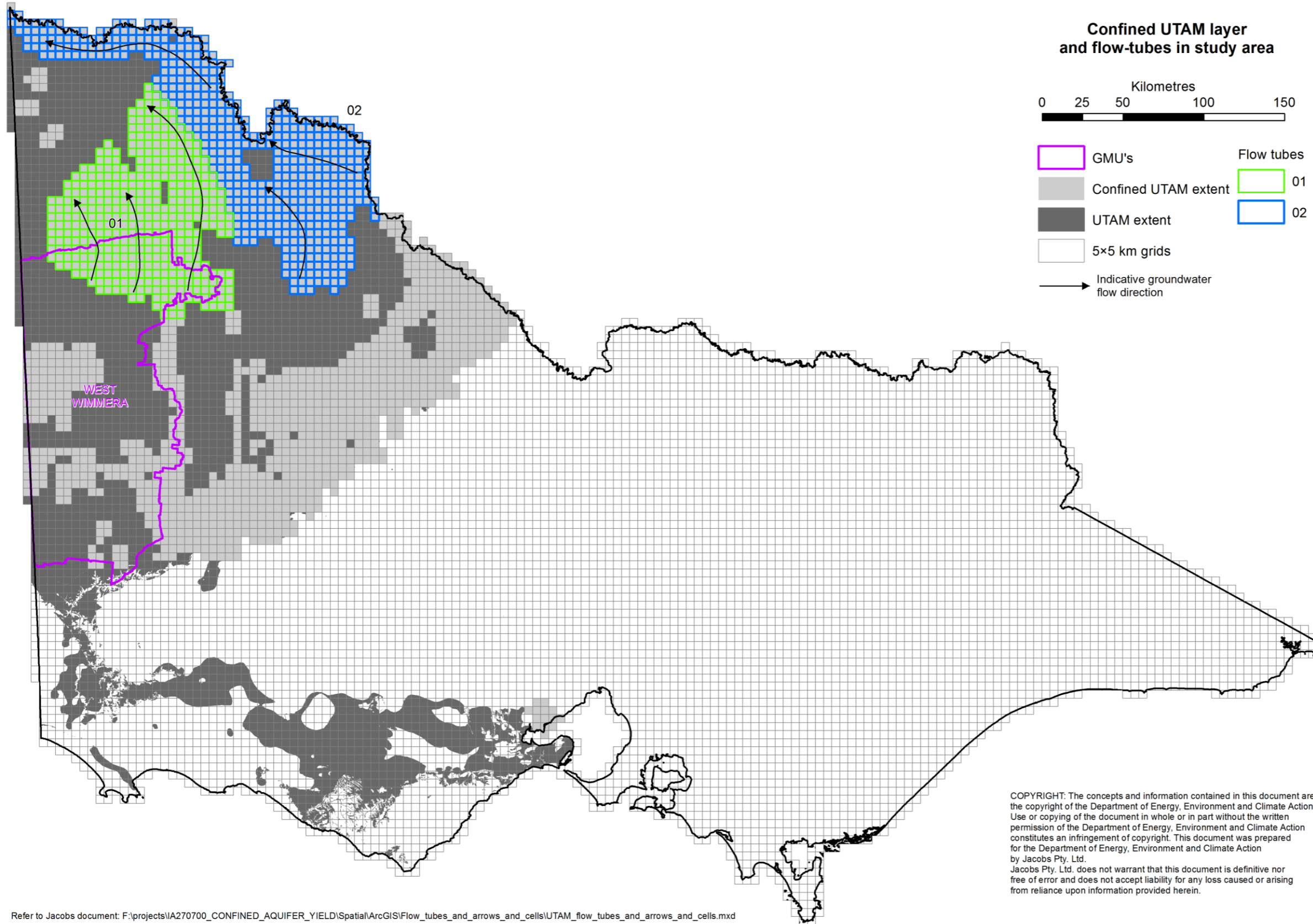


Figure 5-2 Confined UTAF VAF layer and flow-tubes in study area

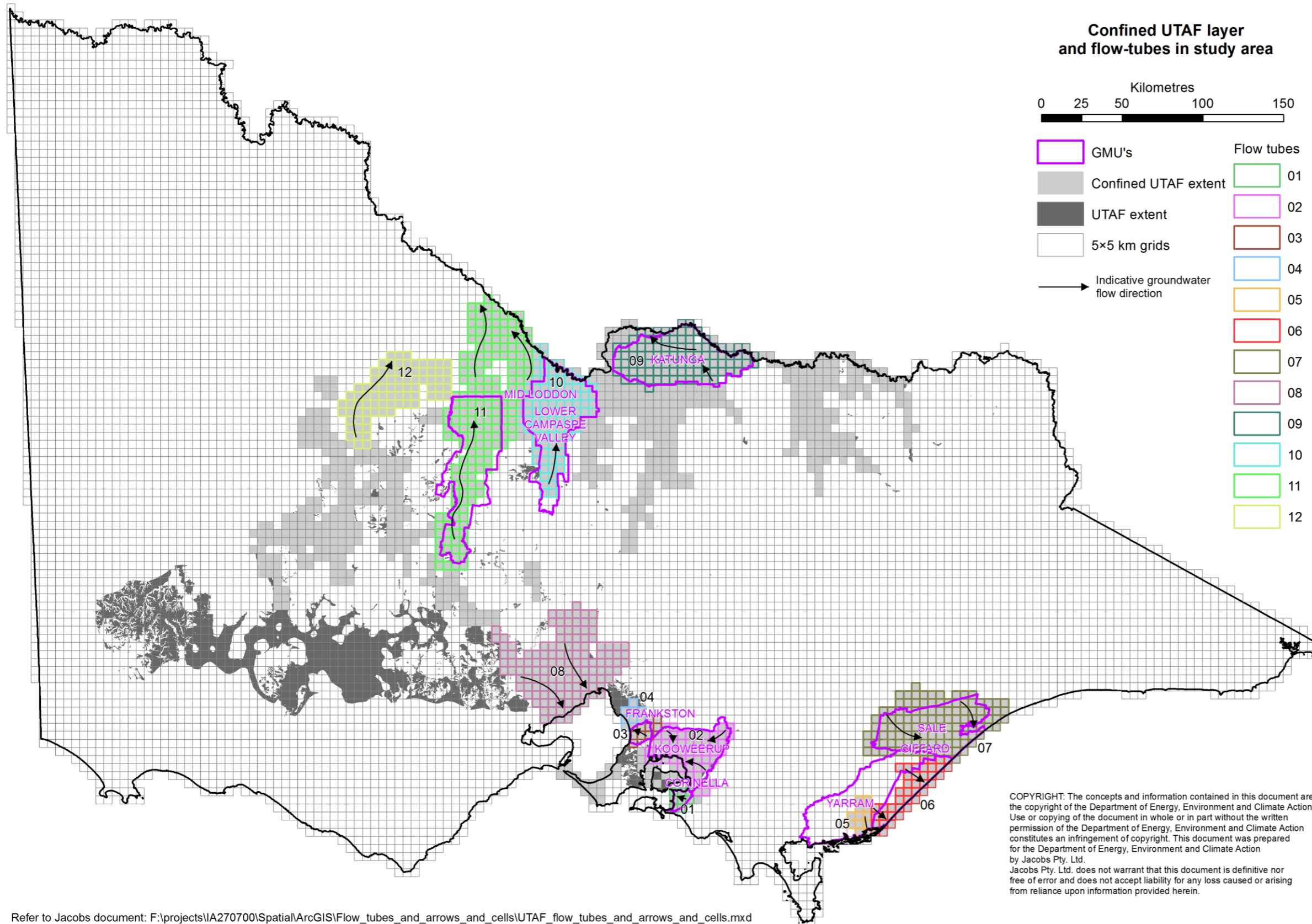
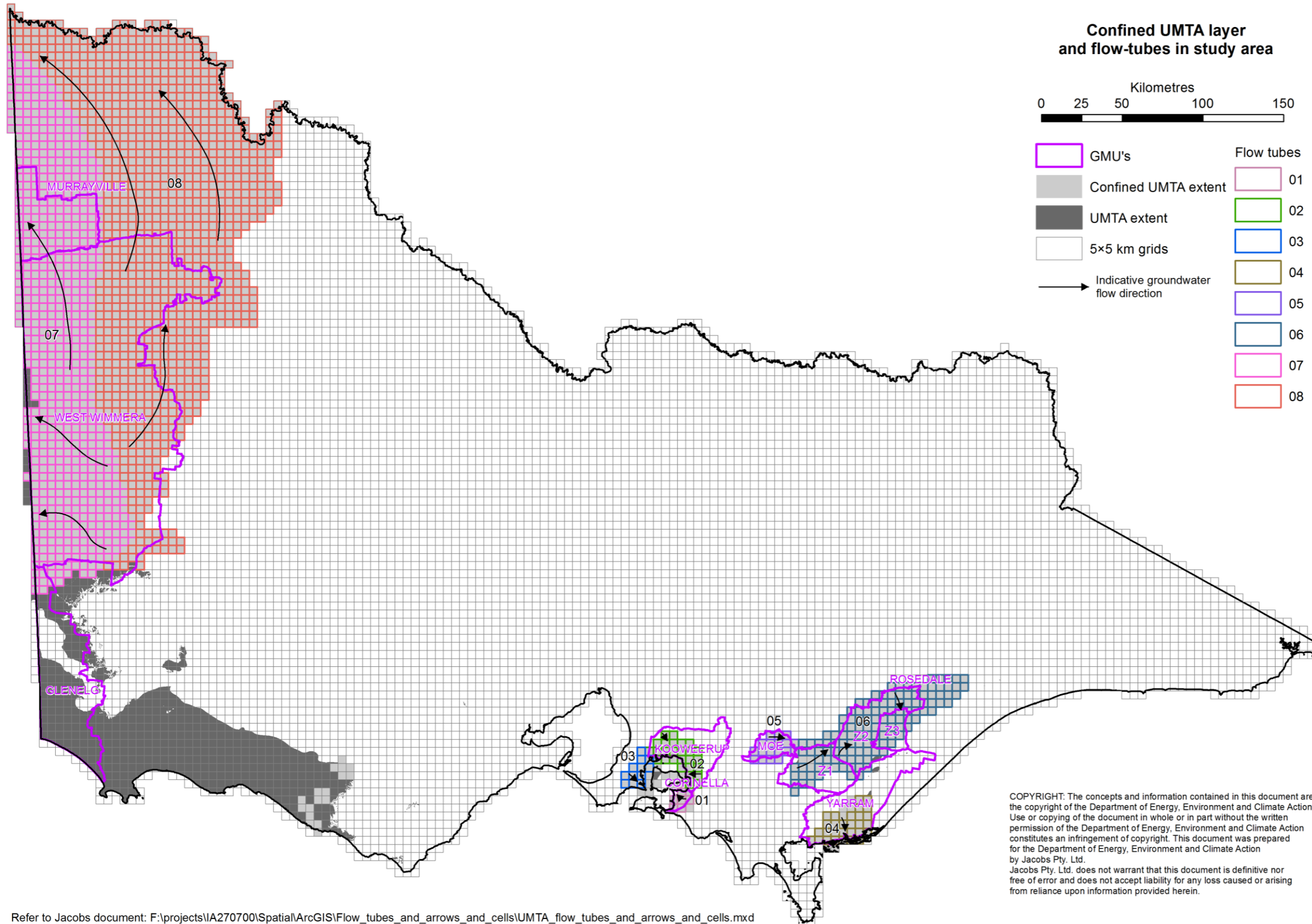
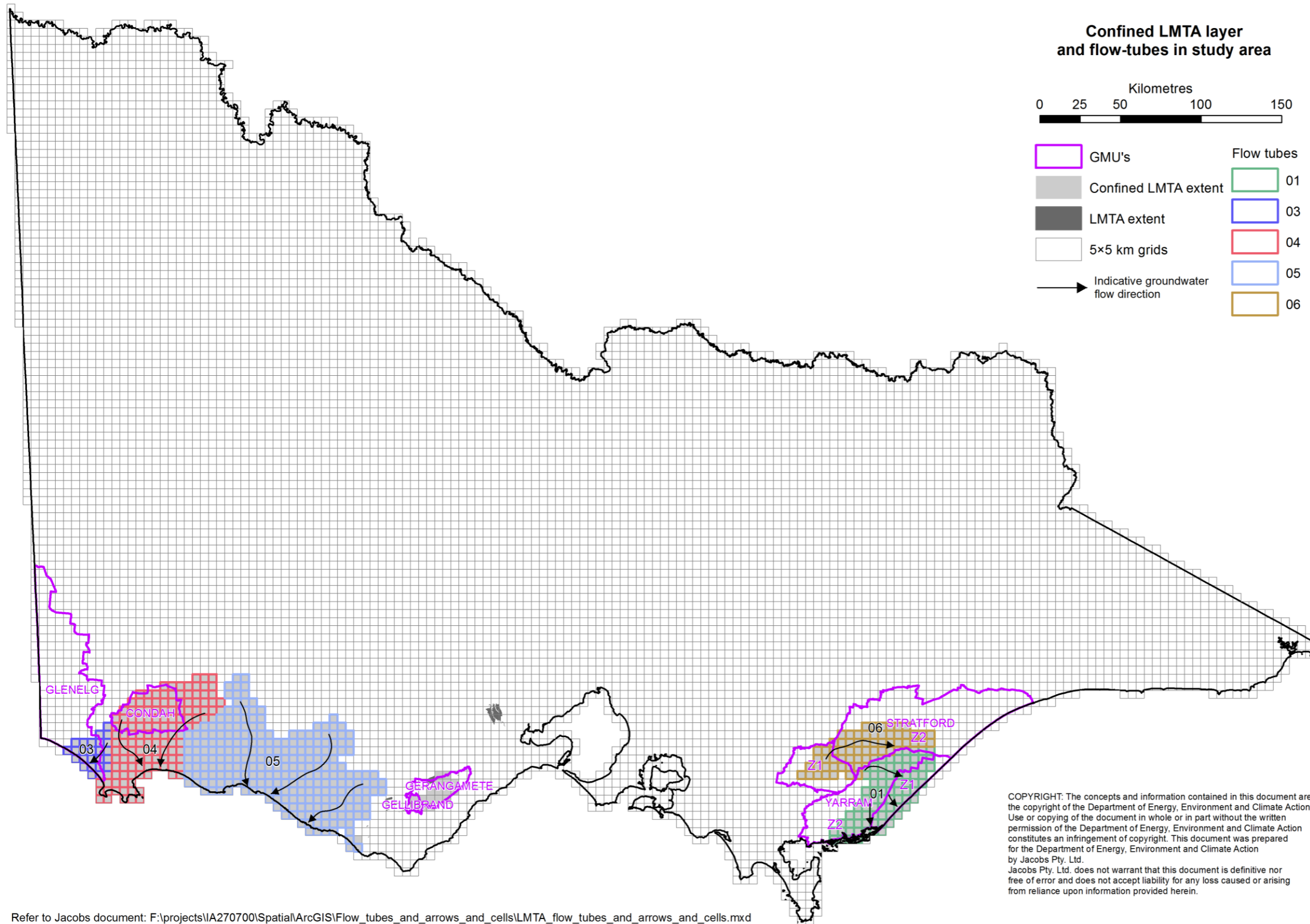


Figure 5-3 Confined UMTA VAF layer and flow-tubes in study area



Refer to Jacobs document: F:\projects\IA270700\Spatial\ArcGIS\Flow_tubes_and_arrows_and_cells\UMTA_flow_tubes_and_arrows_and_cells.mxd

Figure 5-4 Confined LMTA VAF layer and flow-tubes in study area



Refer to Jacobs document: F:\projects\IA270700\Spatial\ArcGIS\Flow_tubes_and_arrows_and_cells\LMTA_flow_tubes_and_arrows_and_cells.mxd

Figure 5-5 Confined LTB VAF layer and flow-tubes in study area

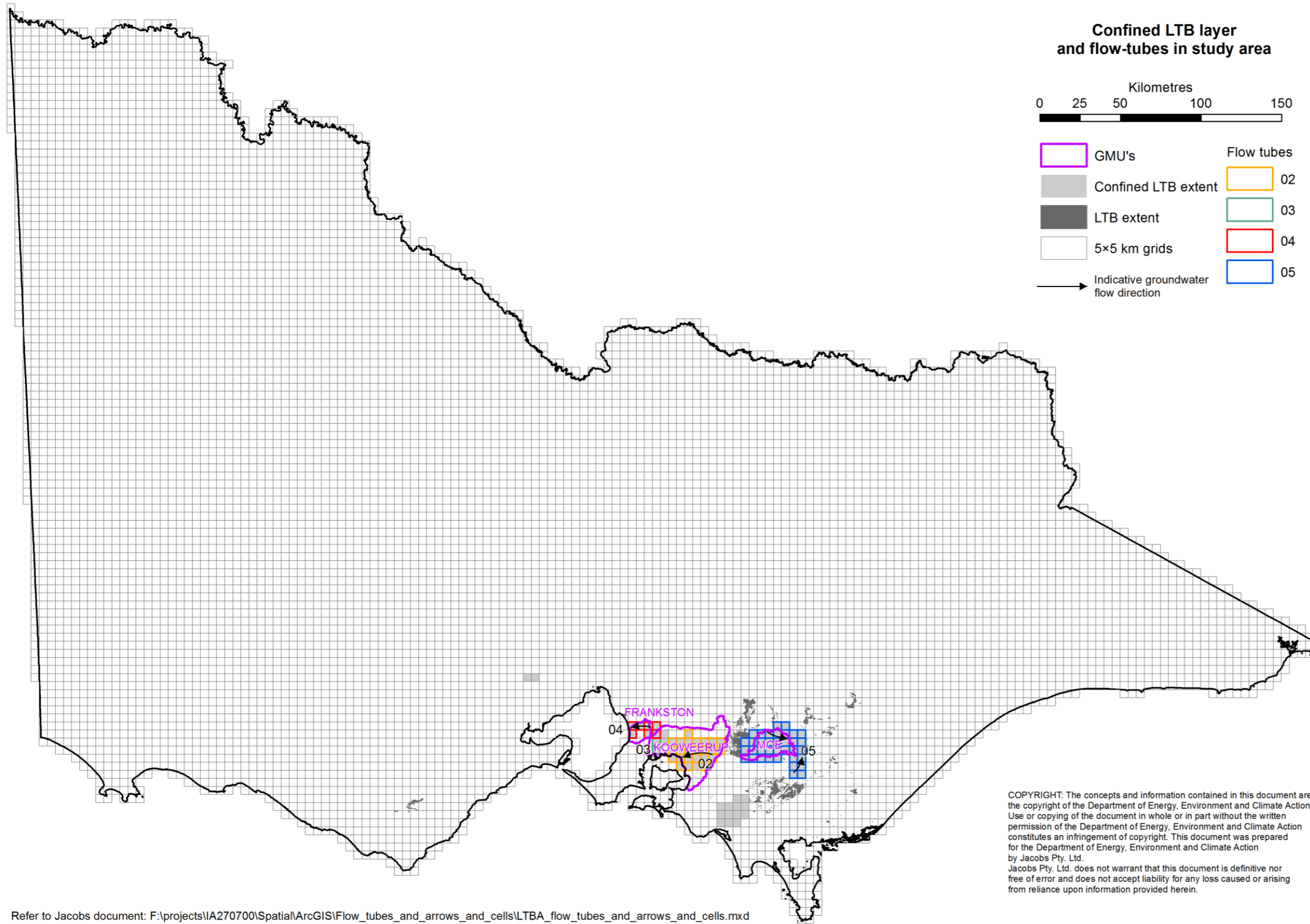
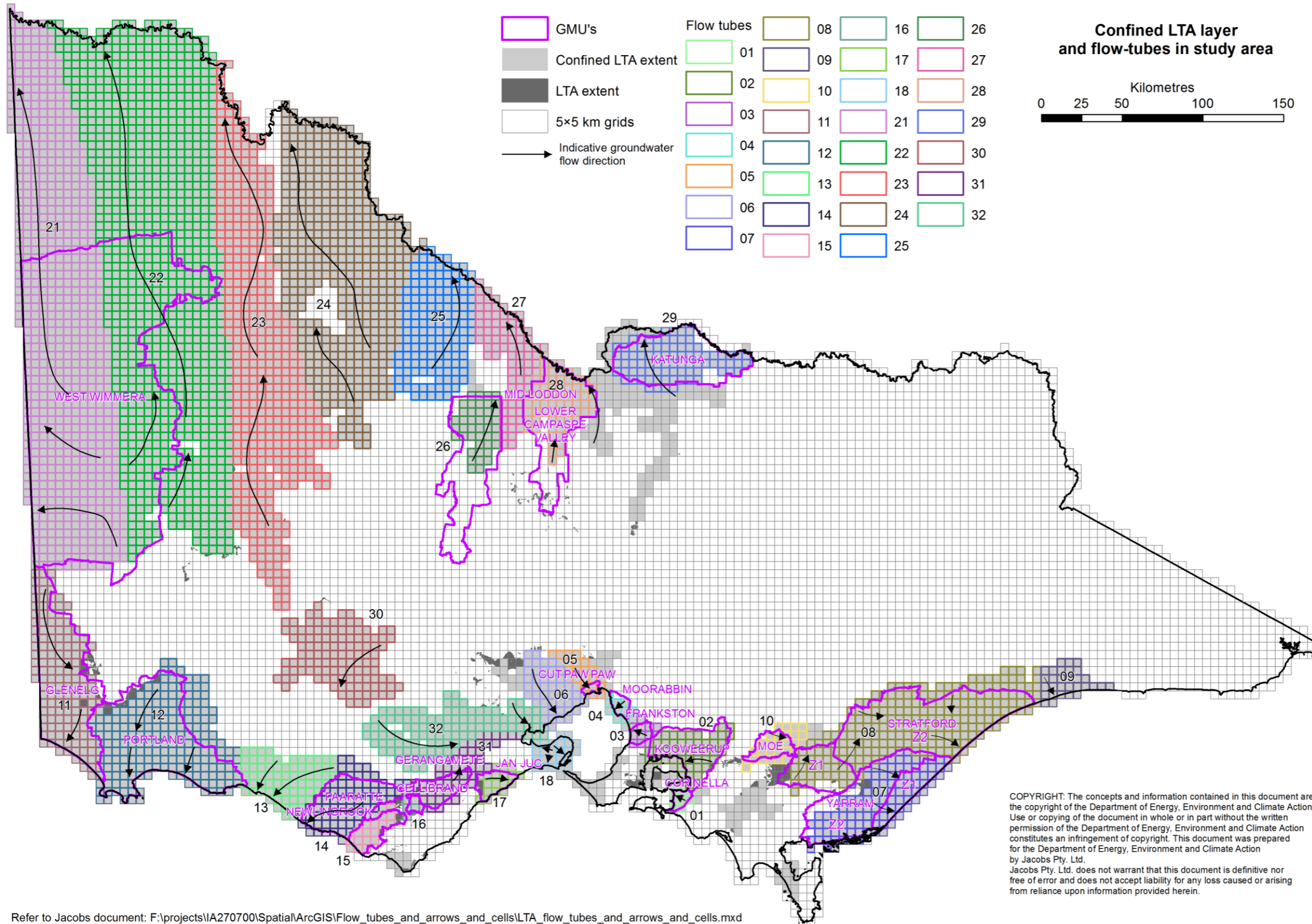


Figure 5-6 Confined LTA VAF layer and flow-tubes in study area



COPYRIGHT: The concepts and information contained in this document are the copyright of the Department of Energy, Environment and Climate Action. Use or copying of the document in whole or in part without the written permission of the Department of Energy, Environment and Climate Action constitutes an infringement of copyright. This document was prepared for the Department of Energy, Environment and Climate Action by Jacobs Pty. Ltd. Jacobs Pty. Ltd. does not warrant that this document is definitive nor free of error and does not accept liability for any loss caused or arising from reliance upon information provided herein.

Refer to Jacobs document: F:\projects\IA270700\Spatial\ArcGIS\Flow_tubes_and_arrows_and_cells\LTA_flow_tubes_and_arrows_and_cells.mxd

6. Wimmera-Mallee GMB

The Wimmera–Mallee GMB is located in northwest Victoria and includes the Wimmera–Mallee, West Wimmera and Avoca groundwater catchments.

The confined aquifers within this GMB include:

- Parilla Sand (UTAM) (Figure 5-1).
- MGL/TLA (UMTA) (Figure 5-3).
- Renmark Group/TCSA (LTA) (Figure 5-6).

The Wimmera-Mallee GMB contains two GMUs that incorporate confined aquifers. Outside of these GMUs, the UTAM, UMTA and LTA are managed as unincorporated areas (Figure 5-1, Figure 5-3 and Figure 5-6). The flow-tubes assigned in the GMB are listed in Table 6-1.

Table 6-1 Wimmera-Mallee GMB – assigned flow-tubes

Groundwater catchment	GMU or non-GMU	PCV Order depth	Confined VAF layer and flow-tube no.	Aquifer name
West Wimmera	West Wimmera GMA	Not depth defined ⁽¹⁾	UTAM ft01	Parilla Sand
			UMTA ft07, 08	MGL/TLA (Duddo Limestone)
			LTA ft21, 22	Renmark Group/TCSA
Wimmera Mallee	Murrayville GMA	All formations from 70 to 200 m below surface	UMTA ft07	MGL/TLA (Duddo Limestone)
	UA near Salt Lake	N/a	UTAM ft02	Parilla Sand
	UA east and north of Horsham	N/a	LTA ft23	N/a
Avoca	UA between Donald and Robinvale	N/a	LTA ft24	N/a

Notes:

(1) The West Wimmera GMA PCV Order 2013 is defined by stratigraphic units and includes the Pliocene Sands Aquifer, Tertiary Limestone Aquifer, and Tertiary Confined Sand Aquifer.

Shaded cells indicate the flow-tube is assigned to a GMU but includes a significant UA (of multiple cells) either upgradient or downgradient of the GMU.

6.1 Hydrogeological characterisation

6.1.1 West Wimmera GMA

The West Wimmera GMA is situated in western Victoria, bordered in the north by the Mallee Highway, the east by the Mallee River, Apsley and Edenhope in the south and the South Australian border in the west. The management area was intended to primarily manage the groundwater resources of the shallow Pliocene Sands aquifer (UTAM), unconfined to confined MGL/TLA (UMTA) and deeper confined Renmark Group/TCSA (LTA). The PCV therefore relates to both unconfined and confined aquifers.

The regional scale hydrostratigraphic profile in and around the West Wimmera GMA is listed in Table 6-2 and key hydrogeological attributes are described in Table 6-3.

Table 6-2 Hydrostratigraphic profile in and around the West Wimmera GMA

Geological formation	VAF code	Geological period	Lithology
Woorinen Formation	QA	Pleistocene	Sand, gravels, clay, silts.
Shepparton Formation	UTQA	Pleistocene to Pliocene	Layered clay, sands and silt

Confined Aquifer Throughflow Assessment – Updated Method and Phase B State-wide Rollout

Geological formation	VAF code	Geological period	Lithology
Loxton-Parilla Sand (unconfined aquifer)	UTAM	Upper Tertiary	Sand.
Bookpurnong Beds	UTD	Upper Tertiary	Clay, silt, coal.
MGL/TLA (Duddo Limestone)	UMTA	Upper-Middle Tertiary	Limestone (fractured rock), sand, gravel, clay, minor coal.
Ettrick Marl	LMTD	Lower-Middle Tertiary	Clay, silt, siltstone, marl (fractured rock), minor sand.
Renmark Group/TCSA	LTA	Lower Tertiary	Sand, gravel, clay and silt, minor coal.
Basement rocks	BSE	Mesozoic and Palaeozoic	Sedimentary (fractured rock): sandstone, siltstone, mudstone, shale. Igneous (fractured rock): includes volcanics, granites, granodiorites.

Source: (GHD, 2020b).

Note: The shaded grey cells indicate the confined aquifer VAF layers subject to the Phase B study.

Table 6-3 West Wimmera GMA – Key hydrogeological attributes

Attribute	Parameter	Description
Groundwater management	GMU size ⁽¹⁾	17,251 km ²
	PCV Order depth	Defined by stratigraphic units and includes the Pliocene Sands Aquifer (UTAM), MGL/TLA (UMTA) and Renmark Group/TCSA (LTA) (PCV Order 2013).
	Overlying GMUs	None.
	Underlying GMUs	None.
	Confined aquifers (and VAF code, number) ⁽¹⁾	Parilla Sand (UTAM, 104), MGL/TLA (UMTA, 107) and Renmark Group/TCSA (LTA, 111).
	PCV and derivation ⁽¹⁾	57,409 ML/year (PCV Order 2013). Derivation: Combination of throughflow, rainfall infiltration, hydrograph fluctuation, water balance and aquifer storage, in addition to restrictions on groundwater extraction.
Groundwater usage	Licensed volume ⁽³⁾	53,358 ML/year (June 2021).
	Licensed use ⁽³⁾ and target VAF layer(s)	Average: 22,033 ML/year (2011-2021). Minimum: 15,601 ML/year (2011-2012). Maximum: 27,310 ML/year (2017-2018). The MGL/TLA (UMTA) is the primary source for groundwater extraction due to the relatively high bore yields and the low salinity groundwater located at shallow depths.
Hydrogeological conceptualisation	Recharge areas ⁽²⁾	Diffuse rainfall recharge to the MGL/TLA (UMTA) is considered to be low (i.e., few millimetres per year) across most of the GMA, varying recently (i.e. the last 200 years) due to land use changes and climate variability. The majority of recharge occurred over 20,000 years ago, and hence, the groundwater resource of the MGL/TLA (UMTA) is considered predominately an ancient water resource. In the western portion of the GMA (where the MGL/TLA (UMTA) is considered to be unconfined), diffuse and point source recharge

Confined Aquifer Throughflow Assessment – Updated Method and Phase B State-wide Rollout

Attribute	Parameter	Description
		occurs directly via sinkhole and karst features. Across the remainder of the GMA, recharge occurs via leakage from the overlying Pliocene Sands aquifer and underlying Bookpurnong bed aquitard.
	Groundwater flow and aquifer/aquitard characteristics ⁽²⁾	The MGL/TLA (UMTA) is considered to be unconfined in the western portion of the GMA, and partially confined by the overlying Bookpurnong Beds in the north and east. Groundwater flow in the MGL/TLA (UMTA) is generally north westerly. The vertical hydraulic gradient throughout most of the GMA is downwards from the Pliocene Sands aquifer to the MGL/TLA (UMTA) and into the Renmark Group/TCSA (LTA). The exception is in the northwest corner of the GMA where an upward gradient is indicated. Where the Bookpurnong Beds are absent, and the Parilla Sand aquifer is present, there is more potential for connection with the MGL/TLA (UMTA).
	Cross border flows ⁽¹⁾	Groundwater in the GMU is subject to the Border Groundwaters Agreement. A key uncertainty in the sustainable yield estimate is allowing sufficient throughflow for downgradient users in South Australia.
Groundwater monitoring	Groundwater suite hydrographic classification ⁽¹⁾	The Middle (UMTA) and Lower (LTA) aquifers are generally indicated to have stable water level trends, best represented by Suites M_E_8 and L_D_1, respectively.

References: (1) GHD. (2020b), (2) GWM Water. (2019), (3) DEECA. (2023).

6.1.2 Murrayville GMA

The Murrayville GMA, located in the Wimmera region of north western Victoria, adjacent to the South Australian border, incorporates the confined MGL/TLA (UMTA). The GMA has vertical depth limits for the confined aquifer of between 70 and 200 m. The GMA incorporates the bulk of extraction bores in the Murrayville–Underbool area.

The regional scale hydrostratigraphic profile in and around the Murrayville GMA is listed in Table 6-4 and key hydrogeological attributes are described in Table 6-5.

Table 6-4 Hydrostratigraphic profile in and around the Murrayville GMA

Geological formation	VAF code	Geological period	Lithology
Loxton-Parilla Sand (unconfined aquifer)	UTAM	Upper Tertiary	Sand.
Bookpurnong Beds	UTD	Upper Tertiary	Clay, silt, coal.
MGL/TLA (Duddo Limestone)	UMTA	Upper-Middle Tertiary	Limestone (fractured rock), sand, gravel, clay, minor coal (occurs at depth 70-200 m).
Ettrick Marl	LMTD	Lower-Middle Tertiary	Clay, silt, siltstone, marl (fractured rock), minor sand (15 m thickness).
Renmark Group/TCSA	LTA	Lower Tertiary	Sand, gravel, clay and silt, minor coal (150 m thickness).
Basement rocks	BSE	Mesozoic and Palaeozoic	Sedimentary (fractured rock): sandstone, siltstone, mudstone, shale. Igneous (fractured rock): includes volcanics, granites, granodiorites.

Source: (GHD, 2020b).

Note: The shaded grey cell indicates the confined aquifer VAF layer subject to the Phase B study.

Confined Aquifer Throughflow Assessment – Updated Method and Phase B State-wide Rollout

Table 6-5 Murrayville GMA - Key hydrogeological attributes

Attribute	Parameter	Description
Groundwater management	GMU size ⁽¹⁾	1,916 km ²
	PCV Order depth	70–200 m.
	Overlying GMUs	None.
	Underlying GMUs	None.
	Confined aquifers (and VAF code, number) ⁽¹⁾	MGL/TLA (UMTA,107).
	PCV and derivation ⁽¹⁾	11,005 ML/year (PCV Order 2017). Derivation: The GMA consists of the former Murrayville WSPA and former Berrook GMA. For the Murrayville WSPA a 10,883 ML/year Permissible Annual Volume (PAV) was calculated based on utilisation percentage of the stored water in the aquifer at a rate of 5 cm/year under equivalent unconfined aquifer conditions (excluding the area in the northeast of the WSPA which has a salinity greater than 3,000 mg/L TDS). For the Berrook GMA, a PAV of 1,109 ML/year was calculated based on annual aquifer throughflow. The PCV Order 2017 of 11,005 ML/year was determined to be the previous PAV (10,883 ML) plus the licensed entitlement (121.3 ML) that existed in the previous unincorporated area.
Groundwater usage	Licensed volume ⁽³⁾	9,755 ML/year (June 2021).
	Licensed use ⁽³⁾ and target VAF layer(s)	Average (2004–2021): 5,408 ML/year. Minimum (2005–2006): 2,866 ML/year. Maximum (2017–2018): 8,331 ML/year. The MGL/TLA (UMTA) is the primary source for groundwater extraction due to the relatively high bore yields and the low salinity groundwater located at shallow depths.
Hydrogeological conceptualisation	Recharge areas ⁽²⁾	The MGL/TLA (UMTA) is confined in the Murrayville area and is distant from the recharge areas of south western Victoria where rainfall is much higher.
	Groundwater flow and aquifer/aquitard characteristics ⁽²⁾	While the MGL/TLA (UMTA) is assumed to be largely confined by the Bookpurnong Beds and Ettrick Marl, there is a potential for groundwater flow vertically upwards from the Renmark Group/TCSA (LTA) across the Ettrick Formation. Within the MGL/TLA (UMTA), predevelopment groundwater gradients are low (0.0001 m/m) and in a north westerly direction. Due to the confined nature of the MGL/TLA (UMTA), sizable rates of short term seasonal drawdown (of up to 14 m) occur with moderate rates of extraction for irrigation. As the total volume of water in storage is significant (noting the aquifer is up to 100 m in thickness) the MGL/TLA (UMTA) is being managed as a non-renewable (fossil) resource and some amount of residual drawdown, utilising a small proportion of groundwater storage, is permitted.
	Groundwater quality variability along flow paths and between aquifers ⁽²⁾	Within the MGL/TLA (UMTA), salinity is generally 600 to 1,500 mg/L TDS, decreasing in quality from the west to the north east.
	Cross border flows ⁽¹⁾	Groundwater in the GMU is subject to the Border Groundwaters Agreement. A key uncertainty in the estimate of sustainable yield is allowing sufficient throughflow for down-gradient users in South Australia.

Confined Aquifer Throughflow Assessment – Updated Method and Phase B State-wide Rollout

Attribute	Parameter	Description
	Groundwater-surface water interaction ^(1,2)	No potential for groundwater-surface water interaction. The depth of the MGL/TLA (UMTA) and are such that the aquifer does not support any terrestrial vegetation or wetlands.
	Saline intrusion ⁽²⁾	A long-term threat to the Murrayville area is the naturally occurring lateral movement of more saline water from the east, which may be exacerbated by groundwater extraction (for irrigation). This risk is managed by ongoing monitoring.
	Points of groundwater discharge ⁽²⁾	Murray River, South Australia.
Groundwater monitoring	Groundwater suite hydrographic classification ⁽¹⁾	Within the MGL/TLA (UMTA), generally a declining long-term trend with significant influence of seasonal groundwater pumping (M_AC_2). In the east of the GMA, where groundwater extraction is comparatively sparse, water level trends are generally represented by Suite M_E_99.

References: (1) GHD (2020b), (2) GWM Water (2017), (3) DEECA (2023).

6.2 Aquifer property data

Aquifer property data collected for the Parilla Sand (UTAM), MGL/TLA (UMTA) and Renmark Group/TCSA (LTA) in the Wimmera-Mallee GMB is presented in Table 6-6, Table 6-7 and Table 6-8, respectively. The statistical analysis of the K (K_h) point data for each of the VAF layers is presented in Table 6-9, including the P20 K, P50 K and P80 K values adopted for the throughflow calculations.

Table 6-6 Wimmera-Mallee GMB – UTAM properties

Area	Aquifer	K _h (m/d)	K _v (m/d)	T (m ² /d)	S	Reference
Murrayville GMA	Parilla Sand	0.1-10.0	N/a	N/a	N/a	Macumber (1978).
South Australia (border with Victoria)	Parilla Sand	1-5.0	N/a	N/a	N/a	EAS (2010).
West Wimmera GMA	Parilla Sand	0.5-5.0	N/a	N/a	N/a	SKM (2005).

Table 6-7 Wimmera-Mallee GMB – UMTA properties

Area	Aquifer	K _h (m/d)	K _v (m/d)	T (m ² /d)	S	Reference
Murrayville GMA	MGL/TLA	7	N/a	750	0.1	SKM (1998g).
Murrayville GMA	MGL/TLA	3.3	N/a	455	4x10 ⁻⁴ to 1.4 1.4x10 ⁻²	DWLBC (2006).
Murrayville GMA	MGL/TLA	2.2	N/a	235		DWLBC (2006).
Murrayville GMA	MGL/TLA	7.2	N/a	900		DWLBC (2006).
Murrayville GMA	MGL/TLA	7.3	N/a	550		DWLBC (2006).
Murrayville GMA	MGL/TLA	0.7	N/a	50		DWLBC (2006).
Murrayville GMA	MGL/TLA	3.7	N/a	500		DWLBC (2006).
Murrayville GMA	MGL/TLA	2.2	N/a	220		DWLBC (2006).
Murrayville GMA	MGL/TLA	7.0	N/a	980		N/a
West Wimmera GMA	MGL/TLA	2.0	N/a	N/a	N/a	GHD (2020).
West Wimmera GMA	MGL/TLA	9.0	N/a	N/a	N/a	GHD (2020).
West Wimmera GMA	MGL/TLA	10.8	N/a	N/a	N/a	GHD (2020).
West Wimmera GMA	MGL/TLA	16	N/a	N/a	N/a	GHD (2020).

Confined Aquifer Throughflow Assessment – Updated Method and Phase B State-wide Rollout

Area	Aquifer	K_h (m/d)	K_v (m/d)	T (m ² /d)	S	Reference
West Wimmera GMA	MGL/TLA	3.8	N/a	N/a	N/a	GHD (2020).
West Wimmera GMA	MGL/TLA	19.15	N/a	N/a	N/a	GHD (2020).
West Wimmera GMA	MGL/TLA	17.44	N/a	N/a	N/a	GHD (2020).
West Wimmera GMA	MGL/TLA	10	N/a	N/a	N/a	GHD (2020).
West Wimmera GMA	MGL/TLA	1.9	N/a	N/a	N/a	GHD (2020).
West Wimmera GMA	MGL/TLA	0.87	N/a	N/a	N/a	GHD (2020).
West Wimmera	MGL/TLA	3.0	N/a	N/a	N/a	Palmer & Hocking (2003)
Murrayville GMA	MGL/TLA	0.1-30.0, median 10	N/a	N/a	0.0001-0.001, median 0.0005	DEPI (2014).
Kaniva	MGL/TLA	21-103	N/a	N/a	N/a	Palmer & Hocking (2003).
Neuarpar	MGL/TLA	20-40	N/a	N/a	N/a	Palmer & Hocking (2003).
Balrootan	MGL/TLA	0.5-1.0	N/a	N/a	N/a	Palmer & Hocking (2003).
Apsley	MGL/TLA	0.5-3.0	N/a	N/a	N/a	Palmer & Hocking (2003).
Telopa Downs	MGL/TLA	6.0-19.0	N/a	N/a	N/a	Palmer & Hocking (2003).
West Wimmera GMA	MGL/TLA	5-8	N/a	N/a	N/a	GHD (2020).
West Wimmera GMA	MGL/TLA	10-48	N/a	N/a	N/a	GHD (2020).

Table 6-8 Wimmera-Mallee GMB – LTA properties

Area	Aquifer	K_h (m/d)	K_v (m/d)	T (m ² /d)	S	Reference
West Wimmera GMA	Renmark Group/TCSA	8.0	0.00001	N/a	N/a	GHD (2020).
West Wimmera GMA	Renmark Group/TCSA	1.9	N/a	38	0.0001	GHD (2020).
Southern Wimmera	Renmark Group/TCSA	2.5	N/a	N/a	N/a	Palmer & Hocking (2003).
West Wimmera GMA	Renmark Group/TCSA	2.0-10.0, median 5	N/a	100-500	N/a	GHD (2020).
Murrayville GMA	Renmark Group/TCSA	0.5-10, median 1	N/a	N/a	0.0001-0.001, median 0.0002	DEPI (2014).
Sothorn Wimmera	Renmark Group/TCSA	1-5	N/a	N/a	N/a	Palmer & Hocking (2003).
Murrayville CMA	Renmark Group/TCSA	mean 2, upper end 100	N/a	N/a	N/a	Aquaterra (2010).

Table 6-9 Wimmera-Mallee GMB – UMTA and LTA K_h statistics

K_h statistical parameter	Value		
	UTAM	UMTA	LTA
Number of data points	0	20	3
Minimum	0.1 m/d	0.7 m/d	1.9 m/d
P20	N/a (0.5 m/d)	2.2 m/d	N/a (1 m/d)
P50	N/a (2.0 m/d)	5.4 m/d	N/a (2 m/d)
Average	N/a	6.7 m/d	4.1 m/d
P80	N/a (8.0 m/d)	10.2 m/d	N/a (7 m/d)
Maximum	10 m/d	19.2 m/d	8.0 m/d
Standard deviation	N/a	5.57	3.4

Notes:

The shaded cells indicate the P20 K, P50 K and P80 K values adopted in the gridded throughflow rate analysis.

The inputted K values were rounded to the nearest 0.5 for the throughflow analysis.

N/a: Insufficient K_h point data to inform statistical analysis. In the absence of sufficient K point data, the typical K ranges from pumping tests informed the selection of representative values of P20, P50 and P80 K for adoption in the throughflow assessment. These adopted values are indicated in brackets.

6.3 Outputs

6.3.1 West Wimmera GMA

The West Wimmera GMA is designated flow-tubes UTAM ft01, UMTA ft07, UMTA ft08, LTA ft21 and LTA ft22 (Table 6-1). The predevelopment throughflows for these flow-tubes rely on throughflow outputs from the following cross-sections perpendicular to groundwater flow:

- UTAM ft01: 40 m, 50 m and 60 m modelled RWL contours.
- UMTA ft07: 30 m, 40 m, 50 m, 60 m, 70 m, 100 m, 120 m, 140 m and 150 m modelled RWL contours.
- UMTA ft08: 30 m, 40 m, 50 m, 60 m, 70 m, 100 m, 120 m and 140 m modelled RWL contours.
- LTA ft21: 35 m, 40 m, 45 m, 50 m, 55 m, 60 m, 70 m, 110 m and 140 m modelled RWL contours.
- LTA ft22: 35 m, 40 m, 45 m, 50 m, 55 m, 60 m, 70 m, 110 m and 140 m modelled RWL contours.

The (P50 K) predevelopment throughflow estimate of each cross-section in the West Wimmera GMA is reported in Table 6-10. The corresponding average, lower and upper range (P50 K), and lower range minimum (P20 K) predevelopment throughflow estimates for the flow-tubes, and a combined estimate, are also reported. The spatial variability of the calculated throughflow rate within the flow-tubes, and combined, is represented by the SD and CV in Table 6-10.

Table 6-10 Predevelopment throughflow estimates for flow-tubes – UTAM ft01, UMTA ft07, UMTA ft08, LTA ft21 and LTA ft22

Parameter	Value
UTAM ft01	
P50 K PD throughflow, Cross-section 1 (40 m RWL) (ML/y)	1,332
P50 K PD throughflow, Cross-section 2 (50 m RWL) (ML/y)	577
P50 K PD throughflow, Cross-section 3 (60 m RWL) (ML/y) ⁽¹⁾	568
Average (P50 K) PD throughflow (ML/y)	826
Lower range (P50 K) PD throughflow (ML/y)	568
Upper range (P50 K) PD throughflow (ML/y)	1,332
Lower range minimum (P20 K) PD throughflow (ML/y)	142
SD (ML/y)	438
CV (%)	53

Confined Aquifer Throughflow Assessment – Updated Method and Phase B State-wide Rollout

Parameter	Value
Approximate length of flow-tube (km) ⁽⁴⁾	110
UMTA ft07 ⁽²⁾	
P50 K PD throughflow, Cross-section 1 (30 m RWL) (ML/y)	3,610
P50 K PD throughflow, Cross-section 2 (40 m RWL) (ML/y)	8,379
P50 K PD throughflow, Cross-section 3 (50 m RWL) (ML/y)	13,345
P50 K PD throughflow, Cross-section 4 (60 m RWL) (ML/y)	4,986
P50 K PD throughflow, Cross-section 5 (70 m RWL) (ML/y) ⁽¹⁾	4,288
P50 K PD throughflow, Cross-section 9 (150 m RWL) (ML/y) ⁽¹⁾	5,269
Average (P50 K) PD throughflow (ML/y)	6,646
Lower range (P50 K) PD throughflow (ML/y)	3,610
Upper range (P50 K) PD throughflow (ML/y)	13,345
Lower range minimum (P20 K) PD throughflow (ML/y)	1,313
SD (ML/y)	3,669
CV (%)	55
Approximate length of flow-tube (km)	315
UMTA ft08	
P50 K PD throughflow, Cross-section 1 (30 m RWL) (ML/y)	2,050
P50 K PD throughflow, Cross-section 2 (40 m RWL) (ML/y)	4,062
P50 K PD throughflow, Cross-section 3 (50 m RWL) (ML/y)	7,848
P50 K PD throughflow, Cross-section 4 (60 m RWL) (ML/y) ⁽¹⁾	5,890
P50 K PD throughflow, Cross-section 5 (70 m RWL) (ML/y) ⁽¹⁾	7,768
P50 K PD throughflow, Cross-section 6 (100 m RWL) (ML/y) ⁽¹⁾	13,718
P50 K PD throughflow, Cross-section 7 (120 m RWL) (ML/y) ⁽¹⁾	6,494
P50 K PD throughflow, Cross-section 8 (140 m RWL) (ML/y) ⁽¹⁾	2,199
Average (P50 K) PD throughflow (ML/y)	6,254
Lower range (P50 K) PD throughflow (ML/y)	2,050
Upper range (P50 K) PD throughflow (ML/y)	13,718
Lower range minimum (P20 K) PD throughflow (ML/y)	745
SD (ML/y)	3,773
CV (%)	60
Approximate length of flow-tube (km)	360
LTA ft21 ⁽³⁾	
P50 K PD throughflow, Cross-section 1 (35 m RWL) (ML/y)	1,211
P50 K PD throughflow, Cross-section 2 (40 m RWL) (ML/y)	1,288
P50 K PD throughflow, Cross-section 3 (45 m RWL) (ML/y)	958
P50 K PD throughflow, Cross-section 4 (50 m RWL) (ML/y)	1,696
P50 K PD throughflow, Cross-section 5 (55 m RWL) (ML/y)	1,782
P50 K PD throughflow, Cross-section 6 (60 m RWL) (ML/y)	1,567
Average (P50 K) PD throughflow (ML/y)	1,417
Lower range (P50 K) PD throughflow (ML/y)	958
Upper range (P50 K) PD throughflow (ML/y)	1,782
Lower range minimum (P20 K) PD throughflow (ML/y)	479
SD (ML/y)	317

Confined Aquifer Throughflow Assessment – Updated Method and Phase B State-wide Rollout

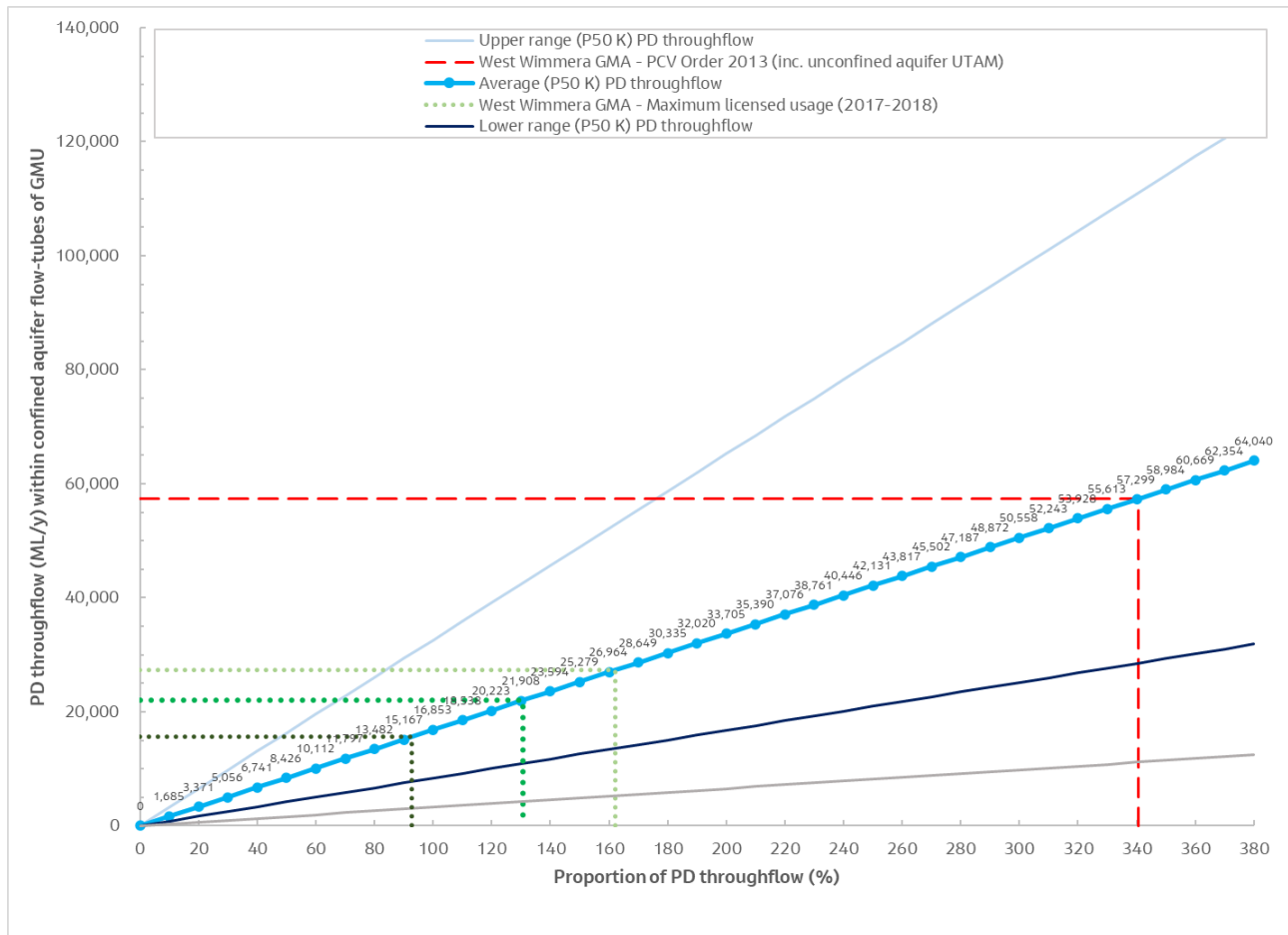
Parameter	Value
CV (%)	22
Approximate length of flow-tube (km)	330
LTA ft22	
P50 K PD throughflow, Cross-section 1 (35 m RWL) (ML/y)	1,459
P50 K PD throughflow, Cross-section 2 (40 m RWL) (ML/y)	1,200
P50 K PD throughflow, Cross-section 3 (45 m RWL) (ML/y)	1,232
P50 K PD throughflow, Cross-section 4 (50 m RWL) (ML/y) ⁽¹⁾	1,696
P50 K PD throughflow, Cross-section 5 (55 m RWL) (ML/y) ⁽¹⁾	1,453
P50 K PD throughflow, Cross-section 6 (60 m RWL) (ML/y) ⁽¹⁾	1,541
P50 K PD throughflow, Cross-section 7 (70 m RWL) (ML/y) ⁽¹⁾	2,229
P50 K PD throughflow, Cross-section 8 (110 m RWL) (ML/y) ⁽¹⁾	2,434
P50 K PD throughflow, Cross-section 9 (140 m RWL) (ML/y) ⁽¹⁾	2,147
Average (P50 K) PD throughflow (ML/y)	1,710
Lower range (P50 K) PD throughflow (ML/y)	1,200
Upper range (P50 K) PD throughflow (ML/y)	2,434
Lower range minimum (P20 K) PD throughflow (ML/y)	600
SD (ML/y)	452
CV (%)	26
Approximate length of flow-tube (km)	335
Combined UTAM ft01, UMTA ft07, UMTA ft08, LTA ft21 and LTA ft22	
Average (P50 K) PD throughflow (ML/y)	16,853
Lower range (P50 K) PD throughflow (ML/y)	8,385
Upper range (P50 K) PD throughflow (ML/y)	32,611
Lower range minimum (P20 K) PD throughflow (ML/y)	3,279
SD (ML/y)	8,649
CV (%)	51

Notes:

- (1) The cross-sections identified occur within the boundary of the West Wimmera GMA.
- (2) For UMTA ft07, cross-sections 06 (100 m), 07 (120 m), 08 (140 m) were excluded as these potentiometric surface contours are potentially affected by model boundary conditions adjacent to the South Australian-Victorian border.
- (3) For LTA ft21, cross-sections 07 (70 m), 08 (110 m), 09 (140 m) were excluded as these potentiometric surface contours are potentially affected by model boundary conditions adjacent to the South Australian-Victorian border.
- (4) The length of the UTAM ft01 flow-tube reported in this table considers only the that part of flow that is confined.

To assist with contextualising the throughflow outputs, the average, lower and upper range (P50 K) and lower range minimum (P20 K) predevelopment throughflow estimates for combined flow-tubes UTAM ft01, UMTA ft07, UMTA ft08, LTA ft21 and LTA ft22 are presented in Figure 6-1. For comparison, the West Wimmera GMA PCV and minimum, average and maximum licensed usage values are overlaid on the figure.

Figure 6-1 West Wimmera GMA – PCV and licensed usage relative to relative to predevelopment throughflow estimates of combined flow-tubes UTAM ft01, UMTA ft07, UMTA ft08, LTA ft21 and LTA ft22



The throughflow results of the flow-tubes, and their spatial variability, are summarised in Table 6-11 in the context of management arrangements and licensed usage in the West Wimmera GMA, including any considerations for assigning a sustainable yield.

Table 6-11 Summary of predevelopment throughflows in context of West Wimmera GMA

Flow-tube parameter	Result
Confined VAF layers	UTAM, UMTA and LTA.
Comparison with GMA boundary	For UTAM ft01, UMTA ft07 and LTA ft21, the GMA occupies the close to the whole width of the flow-tubes. For UMTA ft08 and LTA ft 22, the eastern boundary of the GMA generally does not occupy the whole width of flow-tubes and cells in this area are within an UA. The GMA represents between approximately 40-85 % of the flow-tube lengths.
Flow from, or to, GMUs or UAs	Groundwater within the UTAM flow-tube is indicated to flow from the West Wimmera GMA to a downgradient UA. Notably, the flow-tube considers only that portion of the VAF layer that is confined. Upgradient and downgradient of the UTAM flow-tube, the aquifer is unconfined. Groundwater within the UMTA and LTA flow-tubes is indicated to flow from the West Wimmera GMA to the Murrayville GMA and thereafter, to a downgradient UA. Cross-border flows may also occur in both the UMTA and LTA.
GMU PD throughflow estimate	The average (P50 K) predevelopment throughflow of the cross-sections within the West Wimmera GMA is 15,978 ML/y , compared with the estimate of the flow-tubes of 16,853 ML/y .

Confined Aquifer Throughflow Assessment – Updated Method and Phase B State-wide Rollout

Flow-tube parameter	Result
Confined aquifer(s) contributing majority of PD throughflow	MGL/TLA (UMTA) (76%).
CV (%) and potential factors contributing to spatial variability	CV: 51 %. A range of spatially variable processes may be responsible including recharge to the MGL/TLA via sinkhole and karst features (western area of GMA), leakage from the overlying Pliocene Sands aquifer and underlying Bookpurnong bed aquitard and leakage to the Pliocene Sands (north-west corner of GMA).
PCV relative to PD throughflow	The PCV (57,409 ML/y) represents 341% of the average (P50 K) predevelopment throughflow (16,853 ML/y) but allowing for spatial variability may be between 176 % and 685 %. The PCV represents 1,751 % of the lower range minimum (P20 K) predevelopment throughflow.
Average licensed usage relative to PD throughflow	The average licensed usage (22,033 ML/y) represents 131 % of the average (P50 K) predevelopment throughflow (16,853 ML/y) but allowing for spatial variability may be between 68 % and 263 %. The average licensed usage represents 672 % of the lower range minimum (P20 K) predevelopment throughflow.
Relative rankings (Appendix B)	Relative reliability ranking: Medium; Relative uncertainty ranking: Medium; Relative potential for adverse impact on aquifer value(s): Very High; Overall GMU ranking: Medium-Very High.
Considerations for assigning sustainable yield	The throughflow results should be considered in the context of the whole flow system in the UTAM ft01, UMTA ft07, UMTA ft08, LTA ft21 and LTA ft22. This will have implications for equitable sharing of the groundwater resources between the West Wimmera and Murrayville GMAs, unincorporated areas, and in the case of cross-border flows, South Australia.

6.3.2 Murrayville GMA

The Murrayville GMA is designated flow-tube UMTA ft07 (Table 6-1). The predevelopment throughflows for UMTA ft07 rely on throughflow outputs from six cross-sections perpendicular to groundwater flow (at 30 m, 40 m, 50 m, 60 m, 70 m and 150 m modelled RWL contours).

The (P50 K) predevelopment throughflow estimate of each cross-section in the UMTA ft07 is reported in Table 6-12. The corresponding average, lower and upper range (P50 K), and lower range minimum (P20 K), predevelopment throughflow estimates for the flow-tube are also reported. The spatial variability of the calculated throughflow rate within the flow-tube is represented by the SD and CV in Table 6-12.

Table 6-12 Predevelopment throughflow estimates for flow-tube – UMTA ft07

Parameter	Value
P50 K PD throughflow, Cross-section 1 (30 m RWL) (ML/y)	3,610
P50 K PD throughflow, Cross-section 2 (40 m RWL) (ML/y) ⁽¹⁾	8,379
P50 K PD throughflow, Cross-section 3 (50 m RWL) (ML/y) ⁽¹⁾	13,345
P50 K PD throughflow, Cross-section 4 (60 m RWL) (ML/y)	4,986
P50 K PD throughflow, Cross-section 5 (70 m RWL) (ML/y)	4,288
P50 K PD throughflow, Cross-section 9 (150 m RWL) (ML/y)	5,269
Average (P50 K) PD throughflow (ML/y)	6,646
Lower range (P50 K) PD throughflow (ML/y)	3,610
Upper range (P50 K) PD throughflow (ML/y)	13,345
Lower range minimum (P20 K) PD throughflow (ML/y)	1,313
SD (ML/y)	3,669
CV (%)	55
Approximate length of flow-tube (km)	315

Notes:

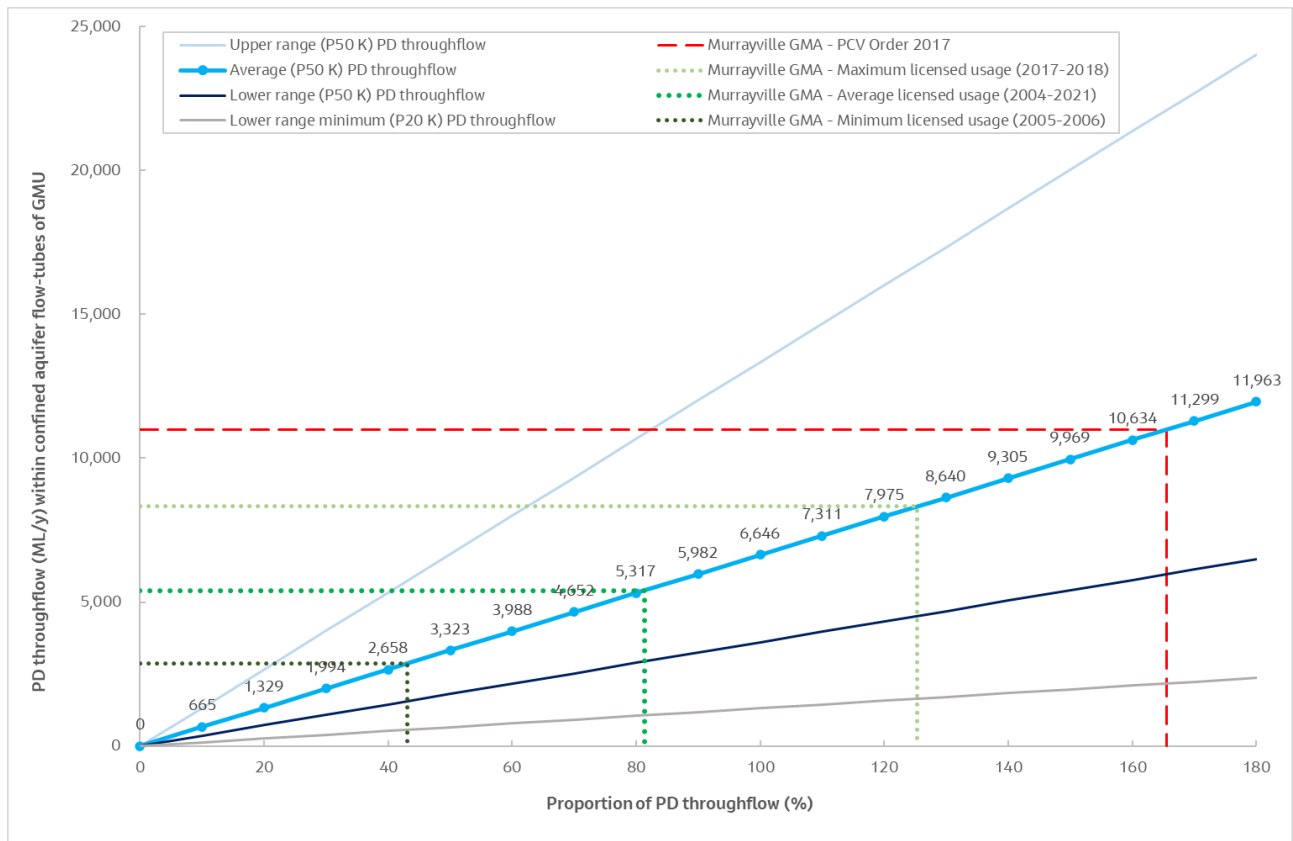
Cross-sections 6 (100 m), 7 (120 m), 8 (140 m) were excluded as these potentiometric surface contours are potentially affected by the model boundary conditions adjacent to the South Australian-Victorian border.

Confined Aquifer Throughflow Assessment – Updated Method and Phase B State-wide Rollout

(1) The cross-sections identified occur within the boundary of the Murrayville GMA. The throughflow estimates do not accommodate narrowing of the GMA in the north.

To assist with contextualising the throughflow outputs, the average, lower and upper range (P50 K) and lower range minimum (P20 K) predevelopment throughflow estimates for flow-tube UMTA ft07 are presented in Figure 6-2. For comparison, the Murrayville GMA PCV and minimum, average and maximum licensed usage values are overlaid on the figure.

Figure 6-2 Murrayville GMA – PCV and licensed usage relative to predevelopment throughflow estimates of flow-tube UMTA ft07



The throughflow results of the flow-tube, and its spatial variability, are summarised in Table 6-13 in the context of management arrangements and licensed usage in the Murrayville GMA, including any considerations for assigning a sustainable yield.

Table 6-13 Summary of predevelopment throughflows in context of Murrayville GMA

Flow-tube parameter	Result
Confined VAF layer	UMTA.
Comparison with GMA boundary	Narrowing of the GMA boundary in the north is such that the GMA occupies a proportion of the width of the flow-tube in this area. The GMA represents approximately 17% of the flow-tube length.
Flow from, or to, GMUs or UAs	Groundwater within the flow-tube is indicated to flow from the West Wimmera GMA to the Murrayville GMA and thereafter, to a downgradient UA. Cross-border flows may also occur.
GMU PD throughflow estimate	The average (P50 K) predevelopment throughflow of the cross-sections within the Murrayville GMA , is 10,862 ML/y , compared with the estimate for the flow-tube of 6,646 ML/y .

Flow-tube parameter	Result
CV (%) and potential factors contributing to spatial variability	CV: 55 %. A range of spatial variable processes may be responsible including the potential for groundwater flow vertically upwards from the Renmark Group/TCSA (LTA) to the MGL/TLA (UMTA).
PCV relative to PD throughflow	The PCV (11,005 ML/y) represents 166 % of the average (P50 K) predevelopment throughflow (6,646 ML/y) but allowing for spatial variability may be between 82 % and 305 %. The PCV represents 838 % of the lower range minimum (P20 K) predevelopment throughflow.
Average licensed usage relative to PD throughflow	The average licensed usage (5,408 ML/y) represents 81 % of the average (P50 K) predevelopment throughflow (6,646 ML/y) but allowing for spatial variability may be between 41 % and 150 %. The average licensed usage represents 412 % of the lower range minimum (P20 K) predevelopment throughflow.
Relative rankings (Appendix B)	Relative reliability ranking: Medium; Relative uncertainty ranking: Medium; Relative potential for adverse impact on aquifer value(s): High; Overall GMU ranking: Medium-High.
Considerations for assigning sustainable yield	While the MGL/TLA is currently managed as fossil resource, the throughflow results should be considered in the context of the whole of flow system in the UMTA, represented by flow-tube UTMA ft-07. This will have implications for equitable sharing of the groundwater resource between the West Wimmera and Murrayville GMAs, and in case of cross-border flows, South Australia.

6.3.3 UA UTAM near Salt Lake

The UA UTAM near Salt Lake (Figure 5-1) is designated flow-tube UTAM ft02 (Table 6-1). The predevelopment throughflows for UTAM ft02 rely on throughflow outputs from three cross-sections perpendicular to groundwater flow (at 35, 40 and 50 m modelled RWL contours).

The (P50 K) predevelopment throughflow estimate of each cross-section in UTAM ft02 is reported in Table 6-14. The corresponding average, lower and upper range (P50 K), and lower range minimum (P20 K), predevelopment throughflow estimates for the flow-tube are also reported. The spatial variability of the calculated throughflow rate within the flow-tube is represented by the SD and CV in Table 6-14.

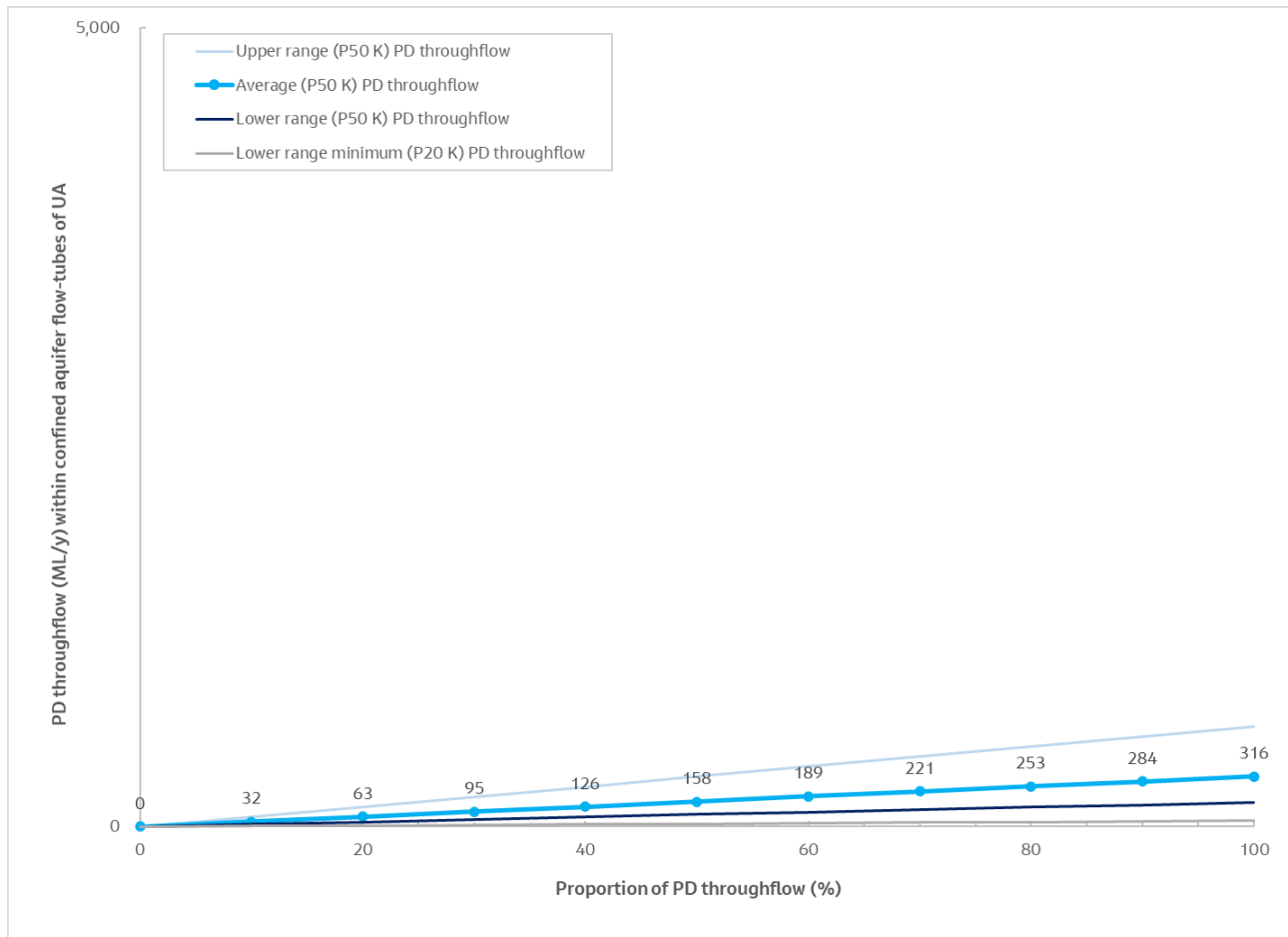
Table 6-14 Predevelopment throughflow estimates for flow-tube – UTAM ft02

Parameter	Value
P50 K PD throughflow, Cross-section 1 (35 m RWL) (ML/y)	166
P50 K PD throughflow, Cross-section 2 (40 m RWL) (ML/y)	153
P50 K PD throughflow, Cross-section 3 (50 m RWL) (ML/y)	627
Average (P50 K) PD throughflow (ML/y)	316
Lower range (P50 K) PD throughflow (ML/y)	153
Upper range (P50 K) PD throughflow (ML/y)	627
Lower range minimum (P20 K) PD throughflow (ML/y)	38
SD (ML/y)	270
CV (%)	86
Approximate length of flow-tube (km) ⁽¹⁾	190

(1) The length of the UTAM ft02 flow-tube reported in this table considers only the that part of flow that is confined.

To assist with contextualising the throughflow outputs, the average, lower and upper range (P50 K) and lower range minimum (P20 K) predevelopment throughflow estimates for flow-tube UTAM ft02 are presented in Figure 6-3.

Figure 6-3 Predevelopment throughflow estimates of flow-tube UTAM ft02 near Salt Lake



6.3.4 UA LTA east and north of Horsham

The UA LTA east and north of Horsham (Figure 5-6) is designated flow-tube LTA ft23 (Table 6-1). The predevelopment throughflows for LTA ft23 rely on throughflow outputs from three cross-sections perpendicular to groundwater flow (at 50 m, 70 m and 90 m modelled RWL contours).

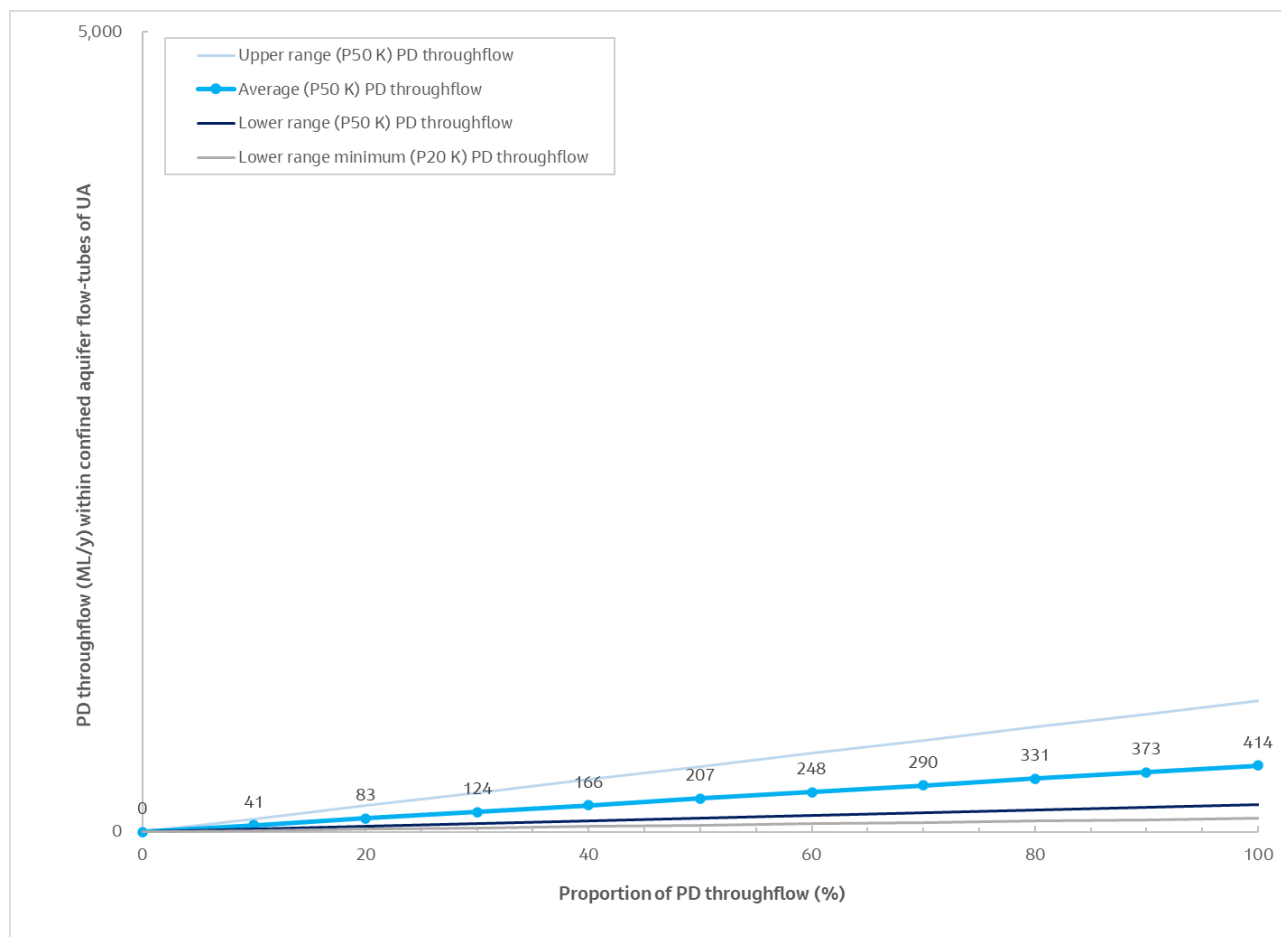
The (P50 K) predevelopment throughflow estimate of each cross-section in LTA ft23 is reported in Table 6-15. The corresponding average, lower and upper range (P50 K), and lower range minimum (P20 K), predevelopment throughflow estimates for the flow-tube are also reported. The spatial variability of the calculated throughflow rate within the flow-tube is represented by the SD and CV in Table 6-15.

Table 6-15 Predevelopment throughflow estimates for flow-tube – LTA ft23

Parameter	Value
P50 K PD throughflow, Cross-section 1 (50 m RWL) (ML/y)	256
P50 K PD throughflow, Cross-section 2 (70 m RWL) (ML/y)	169
P50 K PD throughflow, Cross-section 3 (90 m RWL) (ML/y)	817
Average (P50 K) PD throughflow (ML/y)	414
Lower range (P50 K) PD throughflow (ML/y)	169
Upper range (P50 K) PD throughflow (ML/y)	817
Lower range minimum (P20 K) PD throughflow (ML/y)	85
SD (ML/y)	351
CV (%)	85
Approximate length of flow-tube (km)	315

To assist with contextualising the throughflow outputs, the average, lower and upper range (P50 K) and lower range minimum (P20 K) predevelopment throughflow estimates for flow-tube LTA ft23 are presented in Figure 6-4.

Figure 6-4 Predevelopment throughflow estimates of flow-tube LTA ft23 east and north of Horsham



6.3.5 UA LTA between Donald and Robinvale

The UA LTA between Donald and Robinvale (Figure 5-6) is designated flow-tube LTA ft24 (Table 6-1). The predevelopment throughflows for LTA ft24 rely on throughflow outputs from three cross-sections perpendicular to groundwater flow (at 50 m, 55 m and 80 m modelled RWL contours).

The (P50 K) predevelopment throughflow estimate of each cross-section in LTA ft24 is reported in Table 6-16. The corresponding average, lower and upper range (P50 K), and lower range minimum (P20 K), predevelopment throughflow estimates for the flow-tube are also reported. The spatial variability of the calculated throughflow rate within the flow-tube is represented by the SD and CV in Table 6-16.

Table 6-16 Predevelopment throughflow estimates for flow-tube – LTA ft24

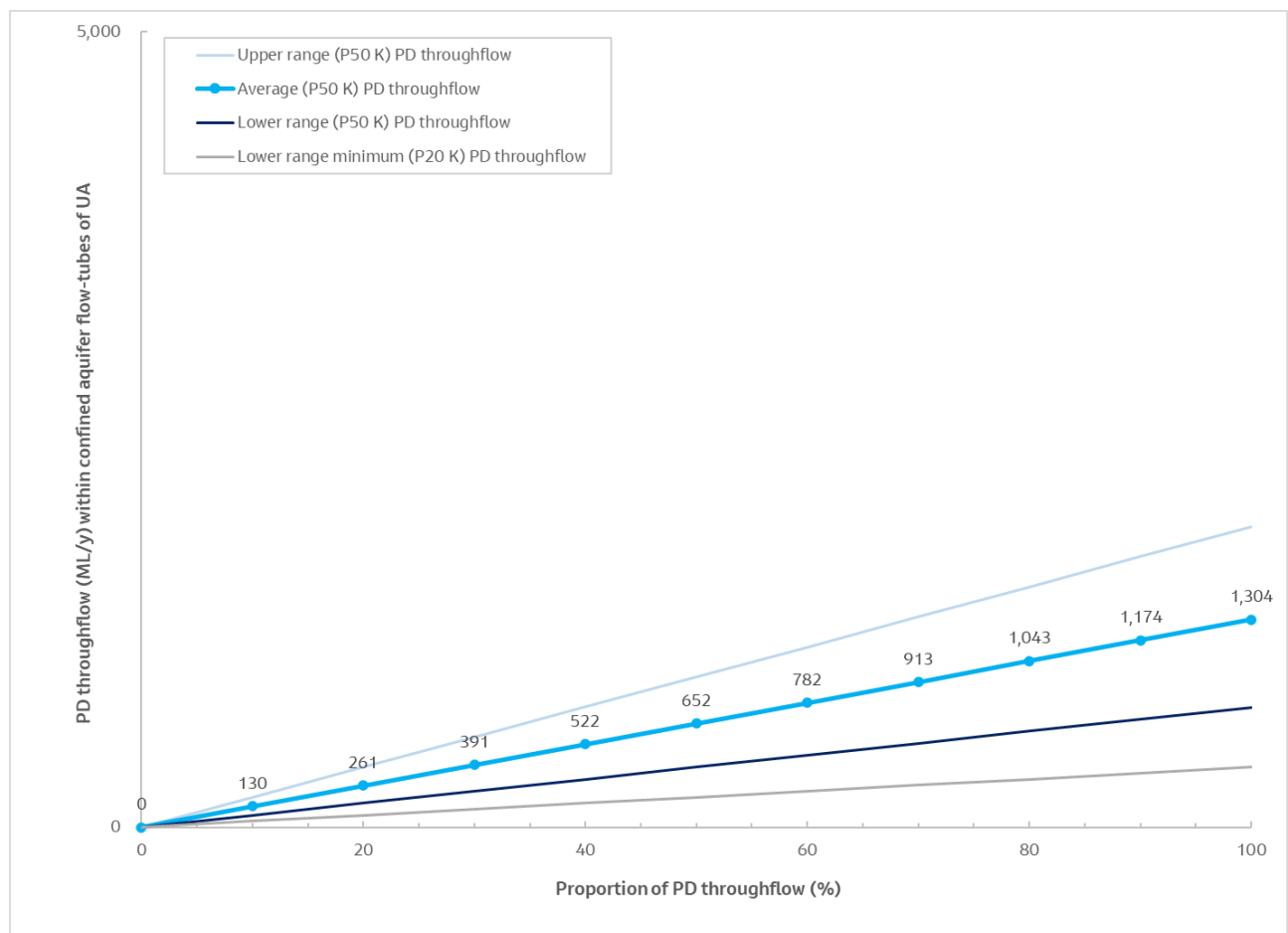
Parameter	Value
P50 K PD throughflow, Cross-section 1 (50 m RWL) (ML/y)	754
P50 K PD throughflow, Cross-section 2 (55 m RWL) (ML/y)	1,270
P50 K PD throughflow, Cross-section 3 (80 m RWL) (ML/y)	1,888
Average (P50 K) PD throughflow (ML/y)	1,304
Lower range (P50 K) PD throughflow (ML/y)	754
Upper range (P50 K) PD throughflow (ML/y)	1,888
Lower range minimum (P20 K) PD throughflow (ML/y)	377

Confined Aquifer Throughflow Assessment – Updated Method and Phase B State-wide Rollout

Parameter	Value
SD (ML/y)	568
CV (%)	44
Approximate length of flow-tube (km)	225

To assist with contextualising the throughflow outputs, the average, lower and upper range (P50 K) and lower range minimum (P20 K) predevelopment throughflow estimates for flow-tube LTA ft24 are presented in Figure 6-5.

Figure 6-5 Predevelopment throughflow estimates of flow-tube LTA ft24 between Donald and Robinvale



7. Goulburn–Murray GMB

The Goulburn–Murray GMB is located in northern and north-eastern Victoria and includes the Loddon, Campaspe, Goulburn–Broken, Ovens and Upper Murray groundwater catchments.

The confined aquifers within this GMB include:

- Calivil Formation (UTAF) (Figure 5-2).
- Renmark Group (LTA) (Figure 5-6).

The Goulburn–Murray GMB contains three GMUs that incorporate confined aquifers. Outside of these GMUs, the UTAF and LTA are managed as unincorporated areas (Figure 5-2 and Figure 5-6). The flow-tubes assigned in the GMB are listed in Table 7-1.

Table 7-1 Goulburn–Murray GMB – assigned flow-tubes

Groundwater catchment	GMU or non-GMU	PCV Order depth	Confined VAF layer and flow-tube no.	Aquifer name
Loddon	Mid Loddon GMA	All formations below surface	UTAF ft11	Calivil Formation
			LTA ft26	Renmark Group
	UA east of Wycheproof	N/a	UTAF ft12	N/a
	UA near Kerang	N/a	LTA ft25	N/a
Campaspe	Lower Campaspe Valley WSPA	All formations below surface with an exception ⁽¹⁾	UTAF ft10	Calivil Formation
			LTA ft28	Renmark Group
	UA near Cohuna	N/a	LTA ft27	N/a
Goulburn–Broken	Katunga WSPA	All formations below 25 m from surface	UTAF ft09	Calivil Formation
			LTA ft29	Renmark Group

Notes:

(1) The WSPA incorporates all depths below the surface with the exception of all formations from the surface to 25 metres below the surface north of the Waranga West Channel.

Shaded cell indicates the flow-tube is assigned to a GMU but includes a significant (multiple cells) UA either upgradient or downgradient of the GMU.

7.1 Hydrogeological characterisation

7.1.1 Mid Loddon GMA

The Mid Loddon GMA, located in northern Victoria within the Loddon River Catchment, extends from the foothills of the Great Dividing Range near Moolort in the south to Mitiamo in the north. The management unit includes all formations below the surface but was intended to primarily manage the groundwater resource of the confined Calivil Formation (UTAF).

The regional scale hydrostratigraphic profile in and around the Mid Loddon GMA is listed in Table 7-2 and key hydrogeological attributes are described in Table 7-3.

Table 7-2 Hydrostratigraphic profile in and around the Mid Loddon GMA

Geological formation	VAF code	Geological period	Lithology
Coonambidgal Formation	QA	Quaternary	Sand, gravels, clay, silts.
Newer Volcanics	UTB	Quaternary- Upper Tertiary	Basalt (fractured rock).
Shepparton Formation	UTQA	Quaternary- Upper Tertiary	Layered clay, sands and silt.

Confined Aquifer Throughflow Assessment – Updated Method and Phase B State-wide Rollout

Geological formation	VAF code	Geological period	Lithology
Calivil Formation	UTAF	Upper Tertiary	Sand, gravel and clay.
Renmark Group	LTA	Lower Tertiary	Sand, gravel, clay and silt, minor coal.
Cretaceous and Permian Sediments	CPS	Cretaceous and Permian	Sandstone, mudstone, siltstone (fractured), sand and minor coal.
Basement rocks	BSE	Mesozoic and Palaeozoic	Sedimentary (fractured rock): sandstone, siltstone, mudstone, shale. Igneous (fractured rock): includes volcanics, granites, granodiorites.

Source: (GHD, 2020c).

Note: The shaded grey cells indicate the confined aquifer VAF layers subject to the Phase B study.

Table 7-3 Mid Loddon GMA – Key hydrogeological attributes

Attribute	Parameter	Description
Groundwater management	GMU size ⁽¹⁾	2,324 km ²
	PCV Order depth	All formations below surface.
	Overlying GMUs	None.
	Underlying GMUs	None.
	Confined aquifers (and VAF code, number) ⁽¹⁾	Calivil Formation (UTAF, 105) and Renmark Group (LTA, 111). Intended to primarily manage groundwater resources of the UTAF (105).
	PCV and derivation ⁽¹⁾	34,037 ML/year (PCV Order 2013). Derivation: water balance.
Groundwater usage	Licensed volume ⁽³⁾	33,927 ML/year (June 2021).
	Licensed use ⁽³⁾	Average (2004–2021): 17,689 ML/year. Minimum (2010–2011): 2,738 ML/year. Maximum (2018–2019): 30,310 ML/year.
Hydrogeological conceptualisation	Recharge areas ⁽²⁾	Recharge areas are located within the highlands and on the southern plains.
	Groundwater flow and aquifer/aquitard characteristics ⁽²⁾	Groundwater flows northwards from the recharge areas to a regional groundwater discharge area further down basin commencing in the northern areas of the management unit. The Calivil Formation (UTAF), Shepparton Formation (UTQA) and the Newer Volcanic basalt (UTB) behave as a single strongly interconnected aquifer. Groundwater salinity exhibits a west to east gradient across the valley suggesting that groundwater flow passing northwards from the southern boundary of the GMA is added to along its length by more saline water entering via tributaries from the west (the Chalkes, Bet Valley and Bul-a-Bul Deep Leads). Groundwater discharge to the surface both now and in the past has led to a rapid increase in groundwater salinity in the northernmost parts of the GMA.
	Cross border flows	Potential for cross-border flows to NSW.

Confined Aquifer Throughflow Assessment – Updated Method and Phase B State-wide Rollout

Attribute	Parameter	Description
Groundwater monitoring	Groundwater suite hydrographic classification ⁽¹⁾	The Middle aquifer (UTAF) is generally indicated to have a variable long-term trend that fluctuates with long term climatic and seasonal use trends, best represented by Suite M_F_2.

References: (1) GHD (2020c), (2) Macumber. (2007), (3) DEECA (2023).

7.1.2 Lower Campaspe Valley WSPA

The Lower Campaspe Valley WSPA, located in northern Victoria within the Campaspe River catchment, is bound in the north by the Murray River and in the south by Lake Eppalock. The WSPA applies to all depths below the surface, with the exception of all formations from the surface to 25 m below the surface north of the Waranga West Channel. The GMU is intended to primarily manage the groundwater resources of the Calivil Formation (UTAF) and the Renmark Group (LTA), both of which comprise the Deep Leads. The PCV therefore primarily relates to confined aquifers.

The regional scale hydrostratigraphic profile in and around the Lower Campaspe Valley WSPA is listed in Table 7-4 and key hydrogeological attributes are described in Table 7-5.

Table 7-4 Hydrostratigraphic profile in and around the Lower Campaspe Valley WSPA

Geological formation	VAF code	Geological period	Lithology
Coonambidgal Formation	QA	Quaternary	Sand, gravels, clay, silts.
Shepparton Formation	UTQA	Quaternary- Upper Tertiary	Layered clay, sands and silt.
Calivil Formation	UTAF	Upper Tertiary	Sand, gravel and clay.
Renmark Group	LTA	Lower Tertiary	Sand, gravel, clay and silt, minor coal.
Cretaceous and Permian Sediments	CPS	Cretaceous and Permian	Sandstone, mudstone, siltstone (fractured), sand and minor coal.
Basement rocks	BSE	Mesozoic and Palaeozoic	Sedimentary (fractured rock): sandstone, siltstone, mudstone, shale. Igneous (fractured rock): includes volcanics, granites, granodiorites.

Source: (GHD, 2020c).

Note: The shaded grey cells indicate the confined aquifer VAF layers subject to the Phase B study.

Table 7-5 Lower Campaspe Valley WSPA – Key hydrogeological attributes

Attribute	Parameter	Description
Groundwater management	GMU size ⁽¹⁾	2,153 km ²
	PCV Order depth	All formations below the surface with the exception of all formations from the surface to 25 m below the surface north of the Waranga West Channel.
	Overlying GMUs	Shepparton Irrigation WSPA.
	Underlying GMUs	None.
	Confined aquifers (and VAF code, number) ⁽¹⁾	Intended to primarily manage groundwater resources of the Calivil Formation (UTAF105) and the Renmark Group (LTA, 111), both of which comprise the Deep Leads.
	PCV and derivation ⁽¹⁾	55,875 ML/year (PCV Order 2013). Derivation: Inferred to align to volume of licensed use.

Confined Aquifer Throughflow Assessment – Updated Method and Phase B State-wide Rollout

Attribute	Parameter	Description
Groundwater usage	Licensed volume ⁽³⁾	55,860 ML/year (June 2021).
	Licensed use ⁽³⁾	Average (2004-2021): 29,689 ML/year. Minimum (2010-2011): 8,523 ML/year. Maximum (2018-2019): 50,259 ML/year. Restrictions when triggered are imposed to limit groundwater extractions and manage groundwater levels. Trigger levels have been set using information from the State Observation Bore Network (SOBN) to protect existing groundwater users and the environment.
Hydrogeological conceptualisation	Recharge areas ⁽²⁾	Recharge occurs from rainfall, irrigation and leakage from the Campaspe River to Deep Leads.
	Groundwater flow and aquifer/aquitard characteristics ⁽²⁾	The Deep Lead broadens and thickens to the north. Hydraulic connection exists between the Shepparton Formation and Deep Leads. The Deep Lead is more confined in the Bamawm and Echuca Zone (due to higher clay content in the Shepparton Formation), north of the Waranga Western Channel.
	Groundwater quality variability along flow paths and between aquifers ⁽²⁾	Groundwater salinity varies across the WSPA from east to west, with lower salinity along the north-south axis, increasing towards the west and east north of the Waranga Western Channel.
	Cross border flows ⁽¹⁾	To the Lower Murray alluvium (NSW).
	Groundwater-surface water interaction ⁽²⁾	Campaspe River is well connected to the Coonambidgal Formation and slowly leaks to the regional groundwater system. The clays in the underlying Shepparton Formation control the rate of leakage. Downstream of the Campaspe Weir, where groundwater levels are elevated due to irrigation, groundwater discharges to the Campaspe River.
	Saline intrusion ⁽²⁾	There is potential for saline groundwater to be drawn into the area in response to groundwater pumping. This risk is managed by restricting extractions from the Deep Lead.
Groundwater monitoring	Points of groundwater discharge ⁽²⁾	Groundwater flows northward through the aquifer under the Murray River.
Groundwater monitoring	Groundwater suite hydrographic classification ⁽¹⁾	Groundwater levels exhibit marginally declining long-term trends that fluctuate with long term climatic and seasonal use trends. Classifications include M_H_1 and M_H_2 (Middle, UTAF) and U_N_4 (Upper, QA and UTQA). Approximately 32% of the WSPA occurs within Suite M_H_1 and M_H_2 collectively, and approximately 40% occurs in Suite U_N_4.

References: (1) GHD (2020c), (2) DSE (2012), (3) DEECA (2023).

7.1.3 Katunga WSPA

The Katunga WSPA, located in northern Victoria within the floodplains of the Murray and Goulburn Rivers follows an area of intensive groundwater use south of the Murray River along the Victoria – NSW border. The management unit applies to all formations below 25 m from the surface but was intended to primarily manage the groundwater resource of the Calivil Formation (UTAF). The PCV therefore primarily relates to confined aquifers.

The regional scale hydrostratigraphic profile in and around the Katunga WSPA is listed in Table 7-4 and key hydrogeological attributes are described in Table 7-5.

Confined Aquifer Throughflow Assessment – Updated Method and Phase B State-wide Rollout

Table 7-6 Hydrostratigraphic profile in and around the Katunga WSPA

Geological formation	VAF code	Geological period	Lithology
Coonambidgal Formation	QA	Quaternary	Dune, channel, lake swamp and flood plain deposits.
Shepparton Formation	UTQA	Quaternary- Upper Tertiary	Sand, silt and clay.
Calivil Formation	UTAF	Upper Tertiary	Sand, gravel and clay.
Renmark Group	LTA	Lower Tertiary	Sand, gravel, clay and silt, minor coal.
Cretaceous and Permian Sediments	CPS	Cretaceous and Permian	Sandstone, mudstone, siltstone (fractured), sand and minor coal.
Basement rocks	BSE	Mesozoic and Palaeozoic	Sedimentary (fractured rock): sandstone, siltstone, mudstone, shale. Igneous (fractured rock): includes volcanics, granites, granodiorites.

Source: (GHD, 2020c).

Note: The shaded grey cells indicate the confined aquifer VAF layers subject to the Phase B study.

Table 7-7 Katunga WSPA – Key hydrogeological attributes

Attribute	Parameter	Description
Groundwater management	GMU size ⁽¹⁾	2,116 km ²
	PCV Order depth	All formations below 25 m from surface.
	Overlying GMUs	Shepparton Irrigation GMA.
	Underlying GMUs	None.
	Confined aquifers (and VAF code, number) ⁽¹⁾	Calivil Formation (UTAF, 105) and Renmark Group (LTA, 111). Intended to primarily manage groundwater resources of the UTAF (105).
	PCV and derivation ⁽¹⁾	60,577 ML/year (PCV Order 2008). Derivation: Inferred to align to volume of licensed use.
Groundwater usage	Licensed volume ⁽³⁾	60,203 ML/year (June 2021).
	Licensed use ⁽³⁾	Average (2004-2021): 27,785 ML/year. Minimum (2010-2011): 11,654 ML/year. Maximum (2018-2019): 41,104 ML/year.
Hydrogeological conceptualisation	Recharge areas ⁽²⁾	Vertical leakage from the overlying Shepparton Formation.
	Groundwater flow and aquifer/aquitard characteristics ⁽²⁾	The Deep Lead incorporates the unconsolidated Calivil Formation (UTAF) and the Renmark Group (LTA), occurring at depths ranging from approximately 75 to 175 m. Groundwater salinity within the Deep Lead generally increases from east to west and northwest of the Katunga WSPA. In addition to vertical leakage from the overlying Shepparton Formation, a small proportion of groundwater moves into the Deep Lead aquifer from the underlying bedrock. Pressure from the weight of water in the overlying Shepparton Formation can impact the potentiometric surface in the Deep Lead.

Confined Aquifer Throughflow Assessment – Updated Method and Phase B State-wide Rollout

Attribute	Parameter	Description
	Cross border flows ⁽²⁾	The Deep Lead extends and flows into NSW and cross-border pumping can impact groundwater levels in the WSPA (and vice-versa).
Groundwater monitoring	Groundwater suite hydrographic classification ⁽¹⁾	The Upper (UTQA) and Middle (UTAF) aquifers are generally indicated to have a variable long-term trend that fluctuates with long term climatic and seasonal use trends, best represented by Suites U_Q_2 and U_QQ_1 (Upper aquifer) and M_I_1 and M_I_2 (Middle aquifer).

References: (1) GHD (2020c), (2) GMW Water. (2017), (3) DEECA (2023).

7.2 Aquifer property data

Aquifer property data collected for the Calivil Formation (UTAF) and Renmark Group (LTA) in the Goulburn-Murray GMB is presented in Table 7-8 and Table 7-9, respectively. The statistical analysis of the K (K_h) point data for each of the VAF layers is presented in Table 7-10, including the P20 K, P50 K and P80 K values adopted for the throughflow calculations.

Table 7-8 Goulburn-Murray GMB – UTAF properties

Area	Aquifer	K_h (m/d)	K_v (m/d)	T (m ² /d)	S	Reference
LCV WSPA	Calivil Formation	0.3	N/a	N/a	N/a	DELWP (2016), as cited in GHD (2020).
LCV WSPA	Calivil Formation	86.7	N/a	3,821	N/a	DELWP (2016), as cited in GHD (2020).
LCV WSPA	Calivil Formation	49	N/a	740	N/a	DELWP (2016), as cited in GHD (2020).
LCV WSPA	Calivil Formation	N/a	N/a	1,500	N/a	DELWP (2016), as cited in GHD (2020).
LCV WSPA	Calivil Formation	174	N/a	6,451	4.7×10^{-5}	DELWP (2016), as cited in GHD (2020).
LCV WSPA	Calivil Formation	188	N/a	6,942	N/a	DELWP (2016), as cited in GHD (2020).
LCV WSPA	Calivil Formation	26	N/a	746	N/a	DELWP (2016), as cited in GHD (2020).
LCV WSPA	Calivil Formation	138	N/a	2,066	N/a	DELWP (2016), as cited in GHD (2020).
LCV WSPA	Calivil Formation	276	N/a	9,381	N/a	DELWP (2016), as cited in GHD (2020).
LCV WSPA	Calivil Formation	133	N/a	2,142	N/a	DELWP (2016), as cited in GHD (2020).
LCV WSPA	Calivil Formation	83	N/a	2,066	N/a	DELWP (2016), as cited in GHD (2020).
Victorian portion of Riverine Plain	Calivil Formation/Renmark Group	42	N/a	697	3.9×10^{-4}	Tickell & Humphrys (1986).
Victorian portion of Riverine Plain	Calivil Formation/Renmark Group	41	N/a	672	N/a	Tickell & Humphrys (1986).
Victorian portion of Riverine Plain	Calivil Formation/Renmark Group	230	N/a	6,200	7.2×10^{-4}	Tickell & Humphrys (1986).

Confined Aquifer Throughflow Assessment – Updated Method and Phase B State-wide Rollout

Area	Aquifer	K_h (m/d)	K_v (m/d)	T (m ² /d)	S	Reference
Victorian portion of Riverine Plain	Calivil Formation/Renmark Group	24	N/a	648	9.4×10^{-4}	Tickell & Humphrys (1986).
Victorian portion of Riverine Plain	Calivil Formation/Renmark Group	81	N/a	1,953	4.3×10^{-3}	Tickell & Humphrys (1986).
Victorian portion of Riverine Plain	Calivil Formation/Renmark Group	57	N/a	1,168	3.7×10^{-4}	Tickell & Humphrys (1986).
Victorian portion of Riverine Plain	Calivil Formation/Renmark Group	182	N/a	6,718	3.5×10^{-5}	Tickell & Humphrys (1986).
Victorian portion of Riverine Plain	Calivil Formation/Renmark Group	178	N/a	1,420	1.9×10^{-3}	Tickell & Humphrys (1986).
Victorian portion of Riverine Plain	Calivil Formation/Renmark Group	61	N/a	1,565	2.7×10^{-4}	Tickell & Humphrys (1986).
Victorian portion of Riverine Plain	Calivil Formation/Renmark Group	13	N/a	290	4.9×10^{-4}	Tickell & Humphrys (1986).
Victorian portion of Riverine Plain	Calivil Formation/Renmark Group	11	N/a	608	3.8×10^{-2}	Tickell & Humphrys (1986).
Victorian portion of Riverine Plain	Calivil Formation/Renmark Group	85	N/a	5,200	8.5×10^{-4}	Tickell & Humphrys (1986).
Victorian portion of Riverine Plain	Calivil Formation/Renmark Group	36	N/a	2,424	5.8×10^{-4}	Tickell & Humphrys (1986).
Victorian portion of Riverine Plain	Calivil Formation/Renmark Group	59	N/a	890	1.7×10^{-3}	Tickell & Humphrys (1986).
Victorian portion of Riverine Plain	Calivil Formation/Renmark Group	182	N/a	4,320	2.0×10^{-4}	Tickell & Humphrys (1986).
Victorian portion of Riverine Plain	Calivil Formation/Renmark Group	94	N/a	4,122	5.1×10^{-5}	Tickell & Humphrys (1986).
LCV WSPA	Calivil Formation	25-260, typically 40-140	N/a	740-16,000, typically 2,000-6,000	N/a	Aquade (2011), as cited in GHD, 2020.

Confined Aquifer Throughflow Assessment – Updated Method and Phase B State-wide Rollout

Area	Aquifer	K_h (m/d)	K_v (m/d)	T (m ² /d)	S	Reference
LCV WSPA	Calivil Formation	10-200, typically 100	N/a	500-10,000	5×10^{-4} - 5×10^{-3}	Nolan-ITU (2003), as cited in GHD (2020).
LCV WSPA	Calivil Formation	N/a	N/a	500-4000, typically 900-1,300	5×10^{-4} - 5×10^{-3}	Nolan-ITU (2003), as cited in GHD (2020).
Northern Victoria	Calivil Formation	2.0-15.0, median 12	N/a	N/a	0.0001-0.001, median 0.0002	DEPI (2014), as cited in GHD (2020).
LCV WSPA	Calivil Formation	10-30	N/a	N/a	N/a	Tickell & Humphrys (1986), as cited in GHD (2020).
LCV WSPA, Mid Loddon GMA and Katunga GMA	Calivil Formation	50-75	0.05-0.5	N/a	5×10^{-6}	SKM (2010c), as cited in GHD (2020).
LCV WSPA	Calivil Formation	7.4-18.6	N/a	N/a	N/a	Cartwright & Weaver (2005), as cited in GHD (2020).
North Central CMA	Calivil Formation	30-120, mean 60	N/a	N/a	N/a	Hocking et al. (2010a).
LCV WSPA	Calivil Formation/Renmark Group	25-200 m/d, typically ~ 100 m/d in the south, grading to lower values in the north. However, K values increase markedly to the extreme north where Ks of 185 m/d have been recorded in sediments associated with the Murray Trench.	N/a	500-10,000	10^{-4} - 10^{-2}	Nolan-ITU (2001), also cited in GHD (2020)
Mid Loddon GMA	Calivil Formation	132	N/a	562	N/a	DELWP (2016), as cited in GHD (2020).
Mid Loddon GMA	Calivil Formation	50	N/a	220	N/a	DELWP (2016), as cited in GHD (2020).
Katunga WSPA	Calivil Formation	197	N/a	6,200	0.0714	DELWP (2016), as cited in GHD (2020).
Victorian portion of Riverine Plain	Calivil Formation	10-130	N/a	N/a	N/a	Tickell & Humphrys (1986).
Mid Loddon GMA	Loddon Deep Lead (Calivil Formation)	50-180, mean 120	N/a	N/a	8.5×10^{-4} - 2×10^{-3}	GHD (2020).
Mid Loddon GMA	Calivil Formation	N/a	N/a	860	N/a	DELWP (2016), as cited in GHD (2020).

Confined Aquifer Throughflow Assessment – Updated Method and Phase B State-wide Rollout

Area	Aquifer	K_h (m/d)	K_v (m/d)	T (m ² /d)	S	Reference
Mid Loddon GMA	Calivil Formation	N/a	N/a	4,100	N/a	DELWP (2016), as cited in GHD (2020).
Mid Loddon GMA	Calivil Formation	N/a	N/a	60.6	N/a	DELWP (2016), as cited in GHD (2020).
Katunga WSPA	Calivil Formation	N/a	N/a	696	N/a	DELWP (2016), as cited in GHD (2020).
Katunga WSPA	Calivil Formation	0.1-10	N/a	N/a	0.005	GHD (2020).

Table 7-9 Goulburn-Murray GMB – LTA properties

Area	Aquifer	K_h (m/d)	K_v (m/d)	T (m ² /d)	S	Reference
Victorian portion of Riverine Plain	Calivil Formation/Renmark Group	42	N/a	697	3.9×10^{-4}	Tickell & Humphrys (1986).
Victorian portion of Riverine Plain	Calivil Formation/Renmark Group	41	N/a	672	N/a	Tickell & Humphrys (1986).
Victorian portion of Riverine Plain	Calivil Formation/Renmark Group	230	N/a	6,200	7.2×10^{-4}	Tickell & Humphrys (1986).
Victorian portion of Riverine Plain	Calivil Formation/Renmark Group	24	N/a	648	9.4×10^{-4}	Tickell & Humphrys (1986).
Victorian portion of Riverine Plain	Calivil Formation/Renmark Group	81	N/a	1,953	4.3×10^{-3}	Tickell & Humphrys (1986).
Victorian portion of Riverine Plain	Calivil Formation/Renmark Group	57	N/a	1,168	3.7×10^{-4}	Tickell & Humphrys (1986).
Victorian portion of Riverine Plain	Calivil Formation/Renmark Group	182	N/a	6,718	3.5×10^{-5}	Tickell & Humphrys (1986).
Victorian portion of Riverine Plain	Calivil Formation/Renmark Group	178	N/a	1,420	1.9×10^{-3}	Tickell & Humphrys (1986).
Victorian portion of Riverine Plain	Calivil Formation/Renmark Group	61	N/a	1,565	2.7×10^{-4}	Tickell & Humphrys (1986).
Victorian portion of Riverine Plain	Calivil Formation/Renmark Group	13	N/a	290	4.9×10^{-4}	Tickell & Humphrys (1986).
Victorian portion of Riverine Plain	Calivil Formation/Renmark Group	11	N/a	608	3.8×10^{-2}	Tickell & Humphrys (1986).
Victorian portion of Riverine Plain	Calivil Formation/Renmark Group	85	N/a	5,200	8.5×10^{-4}	Tickell & Humphrys (1986).
Victorian portion of Riverine Plain	Calivil Formation/Renmark Group	36	N/a	2,424	5.8×10^{-4}	Tickell & Humphrys (1986).

Confined Aquifer Throughflow Assessment – Updated Method and Phase B State-wide Rollout

Area	Aquifer	K_h (m/d)	K_v (m/d)	T (m ² /d)	S	Reference
Victorian portion of Riverine Plain	Calivil Formation/Renmark Group	59	N/a	890	1.7×10^{-3}	Tickell & Humphrys (1986).
Victorian portion of Riverine Plain	Calivil Formation/Renmark Group	182	N/a	4,320	2.0×10^{-4}	Tickell & Humphrys (1986).
Victorian portion of Riverine Plain	Calivil Formation/Renmark Group	94	N/a	4,122	5.1×10^{-5}	Tickell & Humphrys (1986).
LCV WSPA	Renmark Group	133	N/a	2,592	N/a	DELWP (2016), as cited in GHD (2020).
LCV WSPA	Renmark Group	N/a	N/a	900	N/a	DELWP (2016), as cited in GHD (2020).
LCV WSPA	Renmark Group	N/a	N/a	1,500	N/a	DELWP (2016), as cited in GHD (2020).
LCV WSPA	Renmark Group	35	N/a	1,100	N/a	DELWP (2016), as cited in GHD (2020).
LCV WSPA	Renmark Group	N/a	N/a	1,100	N/a	DELWP (2016), as cited in GHD (2020).
LCV WSPA	Renmark Group	35	N/a	1,100	N/a	DELWP (2016), as cited in GHD (2020).
LCV WSPA	Renmark Group	138	N/a	2,066	N/a	DELWP (2016), as cited in GHD (2020).
LCV WSPA	Renmark Group	10	N/a	212	N/a	DELWP (2016), as cited in GHD (2020).
LCV WSPA	Renmark Group	53	N/a	1,327	N/a	DELWP (2016), as cited in GHD (2020).
Mallee CMA	Renmark Group	0.5-10.0, median 2	N/a	N/a	0.0001-0.001, median 0.0002	DEPI (2014), as cited in GHD (2020).
LCV WSPA	Renmark Group	50-100	2.5-10	N/a	5×10^{-6}	SKM (2010c), as cited in GHD (2020).
Coleambally Irrigation Area (CIA), southern NSW	Renmark Group	10-30, as high as 100	N/a	N/a	N/a	Prathapar (1997).
North Central CMA	Renmark Group	3-10, mean 5	N/a	N/a	N/a	Hocking et al. (2010a).
Katunga WSPA	Renmark Group	N/a	N/a	185	N/a	DELWP (2016), as cited in GHD (2020).
Mid Loddon	Renmark Group	N/a	N/a	807	N/a	DELWP (2016), as cited in GHD (2020).

Table 7-10 Goulburn-Murray GMB – UTAF and LTA K_h statistics

K_h statistical parameter	Value	
	UTAF	LTA
Number of data points	29	22
Minimum	0.3 m/d	10.0 m/d
P20	39.0 m/d	35.0 m/d
P50	83.0 m/d	58.0 m/d
Average	100.3 m/d	80.9 m/d
P80	179.6 m/d	137.0 m/d
Maximum	276.0 m/d	230.0 m/d
Standard deviation	73.78	64.58

Notes:

The shaded cells indicate the P20 K, P50 K and P80 K values adopted in the gridded throughflow rate analysis.

The inputted K values were rounded to the nearest 0.5 for the throughflow analysis.

7.3 Outputs

7.3.1 Mid Loddon GMA

The Mid Loddon GMA is designated flow-tubes UTAF ft11 and LTA ft26 (Table 7-1). The predevelopment throughflows for these flow-tubes rely on throughflow outputs from the following cross-sections perpendicular to groundwater flow:

- UTAF ft11: 80 m, 90 m, 100 m, 110 m and 130 m modelled RWL contours.
- LTA ft26: 105 m and 115 m modelled RWL contours.

The (P50 K) predevelopment throughflow estimate of each cross-section in the UTAF ft11 and LTA ft26 is reported in Table 7-11. The corresponding average, lower and upper range (P50 K), and lower range minimum (P20 K) predevelopment throughflow estimates for the flow-tubes, and a combined estimate, are also reported. The spatial variability of the calculated throughflow rate within the flow-tubes, and combined, is represented by the SD and CV in Table 7-11.

Table 7-11 Predevelopment throughflow estimates for flow-tubes – UTAF ft11 and LTA ft26

Parameter	Value
UTAF ft11	
P50 K PD throughflow, Cross-section 1 (80 m RWL) (ML/y)	5,961
P50 K PD throughflow, Cross-section 2 (90 m RWL) (ML/y)	5,467
P50 K PD throughflow, Cross-section 3 (100 m RWL) (ML/y)	7,361
P50 K PD throughflow, Cross-section 4 (110 m RWL) (ML/y)	10,175
P50 K PD throughflow, Cross-section 5 (130 m RWL) (ML/y)	34,697
Average (P50 K) PD throughflow (ML/y)	12,732
Lower range (P50 K) PD throughflow (ML/y)	5,467
Upper range (P50 K) PD throughflow (ML/y)	34,697
Lower range minimum (P20 K) PD throughflow (ML/y)	2,569
SD (ML/y)	12,415
CV (%)	98
Approximate length of flow-tube (km)	170
LTA ft26	
P50 K PD throughflow, Cross-section 1 (105 m RWL) (ML/y)	6,575

Confined Aquifer Throughflow Assessment – Updated Method and Phase B State-wide Rollout

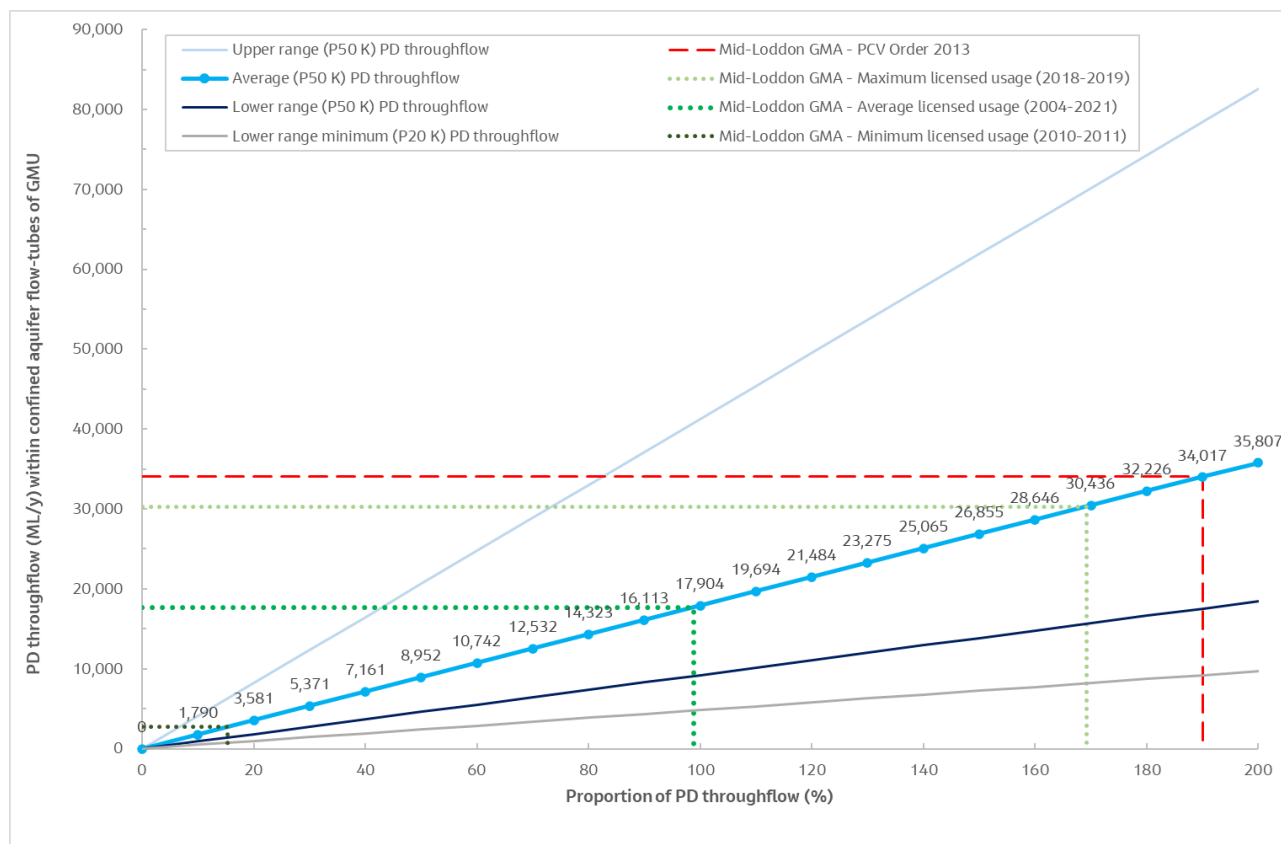
Parameter	Value
P50 K PD throughflow, Cross-section 2 (115 m RWL) (ML/y)	3,768
Average (P50 K) PD throughflow (ML/y)	5,171
Lower range (P50 K) PD throughflow (ML/y)	3,768
Upper range (P50 K) PD throughflow (ML/y)	6,575
Lower range minimum (P20 K) PD throughflow (ML/y)	2,274
SD (ML/y)	1,985
CV (%)	38
Approximate length of flow-tube (km)	45
Combined UTAF ft11 and LTA ft26	
Average (P50 K) PD throughflow (ML/y)	17,904
Lower range (P50 K) PD throughflow (ML/y)	9,235
Upper range (P50 K) PD throughflow (ML/y)	41,272
Lower range minimum (P20 K) PD throughflow (ML/y)	4,843
SD (ML/y)	14,399
CV (%)	80

Note:

All of the cross-sections occur within the GMU boundary.

To assist with contextualising the throughflow outputs, the average, lower and upper range (P50 K) and lower range minimum (P20 K) predevelopment throughflow estimates for the combined flow-tubes UTAF ft11 and LTA ft26 are presented in Figure 7-1. For comparison, the Mid-Loddon GMA PCV and minimum, average and maximum licensed usage values are overlaid on the figure.

Figure 7-1 Mid Loddon GMA – PCV and licensed usage relative to predevelopment throughflow estimates of combined flow-tubes UTAF ft11 and LTA ft26



The throughflow results of the flow-tubes, and their spatial variability, are summarised in Table 7-12 in the context of management arrangements and licensed usage in the Mid-Loddon GMA, including considerations for assigning a sustainable yield.

Table 7-12 Summary of predevelopment throughflows in context of Mid-Loddon GMA

Flow-tube parameter	Result
Confined VAF layers	UTAF and LTA.
Comparison with GMA boundary	The GMA boundary generally occupies the entire width of the flow-tubes, with the exception of a number of UA cells in UTAF ft11, located to the west and east of the GMU. The GMA represents approximately 60 % of the UTAF flow-tube length and the entire LTA flow-tube length.
Flow from, or to, GMUs or UAs	From the Mid-Loddon GMA, the UTAF flows to an UA.
GMU PD throughflow estimate	The average (P50 K) predevelopment throughflow of the cross-sections within the Mid-Loddon GMA is 22,582 ML/y , compared with the estimate of the flow-tubes of 17,904 ML/y .
Confined aquifer(s) contributing majority of PD throughflow	Calivil Formation (UTAF) (70%).
CV (%) and potential factors contributing to spatial variability	CV: 80 %. A range of spatially variable processes may be responsible including hydraulic connection between the Deep Leads and Shepparton Formation.
PCV relative to PD throughflow	The PCV (34,037 ML/y) represents 190 % of the average (P50 K) predevelopment throughflow (17,904 ML/y) but allowing for spatial variability may be between 82 % and 369 %. The PCV represents 703 % of the lower range minimum (P20 K) predevelopment throughflow.

Flow-tube parameter	Result
Average licensed usage relative to PD throughflow	The average licensed usage (17,689 ML/y) represents 99 % of the average (P50 K) predevelopment throughflow (17,904 ML/y) but allowing for spatial variability may be between 43 % and 192 %. The average licensed usage represents 365 % of the lower range minimum (P20 K) predevelopment throughflow.
Relative rankings (Appendix B)	Relative reliability ranking: Low; Relative uncertainty ranking: Low; Relative potential for adverse impact on aquifer value(s): High; Overall GMU ranking: Low-High.
Considerations for assigning sustainable yield	<ul style="list-style-type: none"> ▪ The unconfined Shepparton Formation aquifer forms part of the Mid-Loddon GMA and is subject to the CDM Smith unconfined aquifer sustainable yield study. The assessment of the overall sustainable yield for the Mid-Loddon GMA will therefore need to consider contributions from this unconfined aquifer. ▪ Potential for inter-aquifer leakage and stress induced yield augmentation. ▪ Groundwater resources may need to be managed on an aquifer by aquifer basis due to: <ul style="list-style-type: none"> - Variability in throughflow contributions. - Differing hydrogeological processes between aquifers (e.g., for the UTAF, effects of inter-aquifer connectivity with the overlying Shepparton Formation and Newer Volcanics). ▪ Equitable sharing of the Deep Lead groundwater resource across the border with NSW.

7.3.2 UA UTAF east of Wycheproof

The UA UTAF east of Wycheproof (Figure 5-2) is designated flow-tube UTAF ft12 (Table 7-1). The predevelopment throughflows for UTAF ft12 rely on throughflow outputs from two cross-sections perpendicular to groundwater flow (at 110 m and 130 m modelled RWL contours).

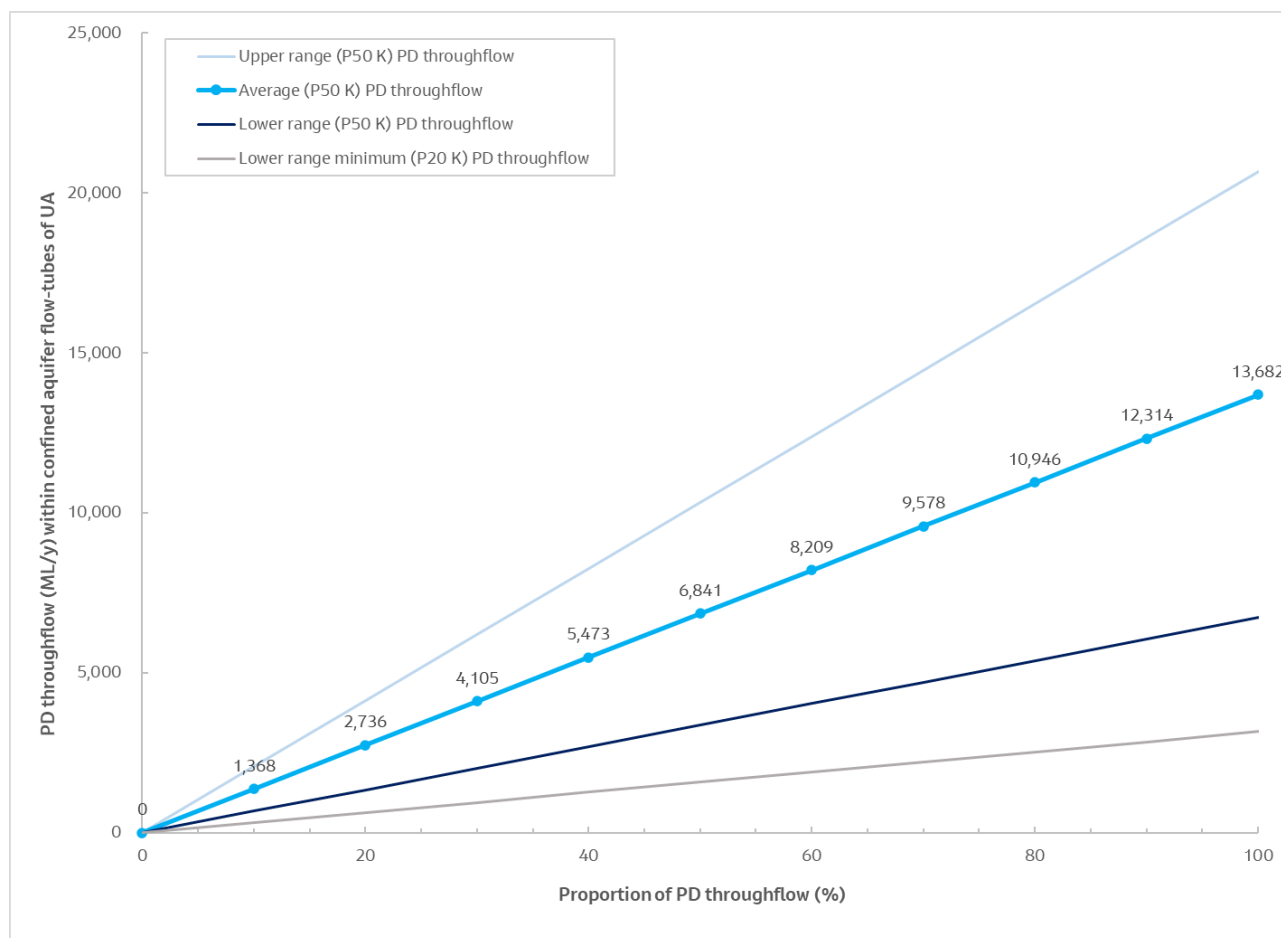
The (P50 K) predevelopment throughflow estimate of each cross-section in the UTAF ft12 is reported in Table 7-13. The corresponding average, lower and upper range (P50 K), and lower range minimum (P20 K), predevelopment throughflow estimates for the flow-tube are also reported. The spatial variability of the calculated throughflow rate within the flow-tube is represented by the SD and CV in Table 7-13.

Table 7-13 Predevelopment throughflow estimates for flow-tube – UTAF ft12

Parameter	Value
P50 K PD throughflow, Cross-section 1 (110 m RWL) (ML/y)	6,714
P50 K PD throughflow, Cross-section 2 (130 m RWL) (ML/y)	20,650
Average (P50 K) PD throughflow (ML/y)	13,682
Lower range (P50 K) PD throughflow (ML/y)	6,714
Upper range (P50 K) PD throughflow (ML/y)	20,650
Lower range minimum (P20 K) PD throughflow (ML/y)	3,155
SD (ML/y)	9,854
CV (%)	72
Approximate length of flow-tube (km)	80

To assist with contextualising the throughflow outputs, the average, lower and upper range (P50 K) and lower range minimum (P20 K) predevelopment throughflow estimates for flow-tube UTAF ft12 are presented in Figure 7-2.

Figure 7-2 Predevelopment throughflow estimates of flow-tube UTAF ft12 east of Wycheproof



7.3.3 UA LTA near Kerang

The UA LTA near Kerang (Figure 5-6) is designated flow-tube LTA ft25 (Table 7-1). The predevelopment throughflows for LTA ft25 rely on throughflow outputs from three cross-sections perpendicular to groundwater flow (at 75 m, 85 m and 95 m modelled RWL contours).

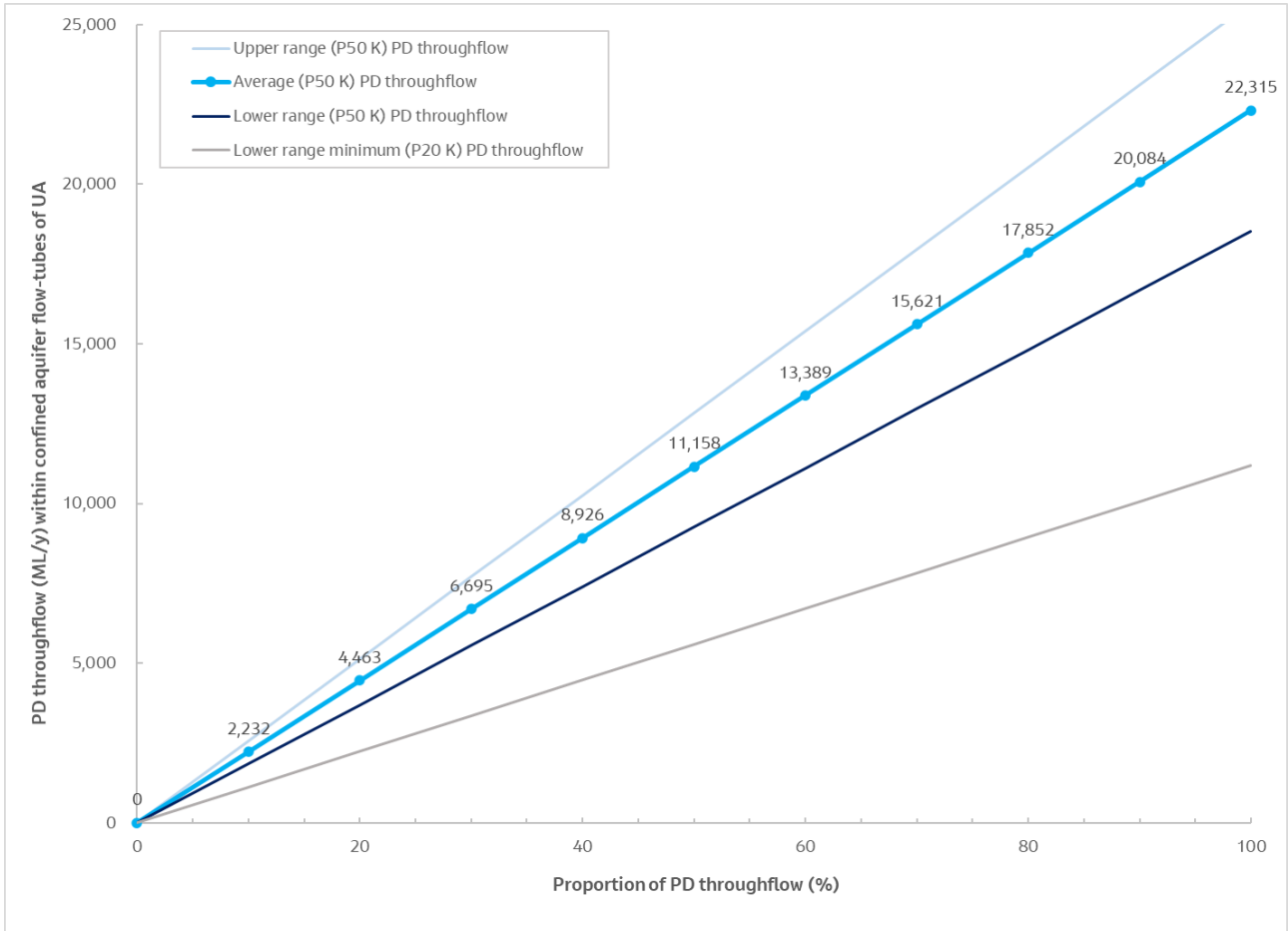
The (P50 K) predevelopment throughflow estimate of each cross-section in the LTA ft25 is reported in Table 7-14. The corresponding average, lower and upper range (P50 K), and lower range minimum (P20 K), predevelopment throughflow estimates for the flow-tube are also reported. The spatial variability of the calculated throughflow rate within the flow-tube is represented by the SD and CV in Table 7-14.

Table 7-14 Predevelopment throughflow estimates for flow-tube – LTA ft25

Parameter	Value
P50 K PD throughflow, Cross-section 1 (75 m RWL) (ML/y)	25,666
P50 K PD throughflow, Cross-section 2 (85 m RWL) (ML/y)	22,746
P50 K PD throughflow, Cross-section 3 (95 m RWL) (ML/y)	18,533
Average (P50 K) PD throughflow (ML/y)	22,315
Lower range (P50 K) PD throughflow (ML/y)	18,533
Upper range (P50 K) PD throughflow (ML/y)	25,666
Lower range minimum (P20 K) PD throughflow (ML/y)	11,184
SD (ML/y)	3,586
CV (%)	16
Approximate length of flow-tube (km)	95

To assist with contextualising the throughflow outputs, the average, lower and upper range (P50 K) and lower range minimum (P20 K) predevelopment throughflow estimates for flow-tube LTA ft25 are presented in Figure 7-3.

Figure 7-3 Predevelopment throughflow estimates of flow-tube LTA ft25 near Kerang



7.3.4 Lower Campaspe Valley WSPA

The Lower Campaspe WSPA is designated flow-tubes UTAF ft10 and LTA ft28 (Table 7-1). The predevelopment throughflows for these flow-tubes rely on throughflow outputs from the following cross-sections perpendicular to groundwater flow:

- UTAF ft10: 90 m and 100 m modelled RWL contours.
- LTA ft28: 90 m, 95 m and 105 m modelled RWL contours.

The (P50 K) predevelopment throughflow estimate of each cross-section in the UTAF ft10 and LTA ft28 is reported in Table 7-15. The corresponding average, lower and upper range (P50 K), and lower range minimum (P20 K) predevelopment throughflow estimates for the flow-tubes, and a combined estimate, are also reported. The spatial variability of the calculated throughflow rate within the flow-tubes, and combined, is represented by the SD and CV in Table 7-15.

Table 7-15 Predevelopment throughflow estimates for flow-tubes – UTAF ft10 and LTA ft28

Parameter	Value
UTAF ft10 ⁽¹⁾	
P50 K PD throughflow, Cross-section 1 (90 m RWL) (ML/y)	17,500
P50 K PD throughflow, Cross-section 2 (100 m RWL) (ML/y)	11,018
Average (P50 K) PD throughflow (ML/y)	14,259

Confined Aquifer Throughflow Assessment – Updated Method and Phase B State-wide Rollout

Parameter	Value
Lower range (P50 K) PD throughflow (ML/y)	11,018
Upper range (P50 K) PD throughflow (ML/y)	17,500
Lower range minimum (P20 K) PD throughflow (ML/y)	5,177
SD (ML/y)	4,584
CV (%)	32
Approximate length of flow-tube (km)	80
LTA ft28	
P50 K PD throughflow, Cross-section 1 (90 m RWL) (ML/y)	10,825
P50 K PD throughflow, Cross-section 2 (95 m RWL) (ML/y)	10,556
P50 K PD throughflow, Cross-section 3 (105 m RWL) (ML/y)	7,792
Average (P50 K) PD throughflow (ML/y)	9,724
Lower range (P50 K) PD throughflow (ML/y)	7,792
Upper range (P50 K) PD throughflow (ML/y)	10,825
Lower range minimum (P20 K) PD throughflow (ML/y)	4,702
SD (ML/y)	1,679
CV (%)	17
Approximate length of flow-tube (km)	60
Combined UTAF ft10 and LTA ft28	
Average (P50 K) PD throughflow (ML/y)	23,983
Lower range (P50 K) PD throughflow (ML/y)	18,810
Upper range (P50 K) PD throughflow (ML/y)	28,325
Lower range minimum (P20 K) PD throughflow (ML/y)	9,879
SD (ML/y)	6,263
CV (%)	26

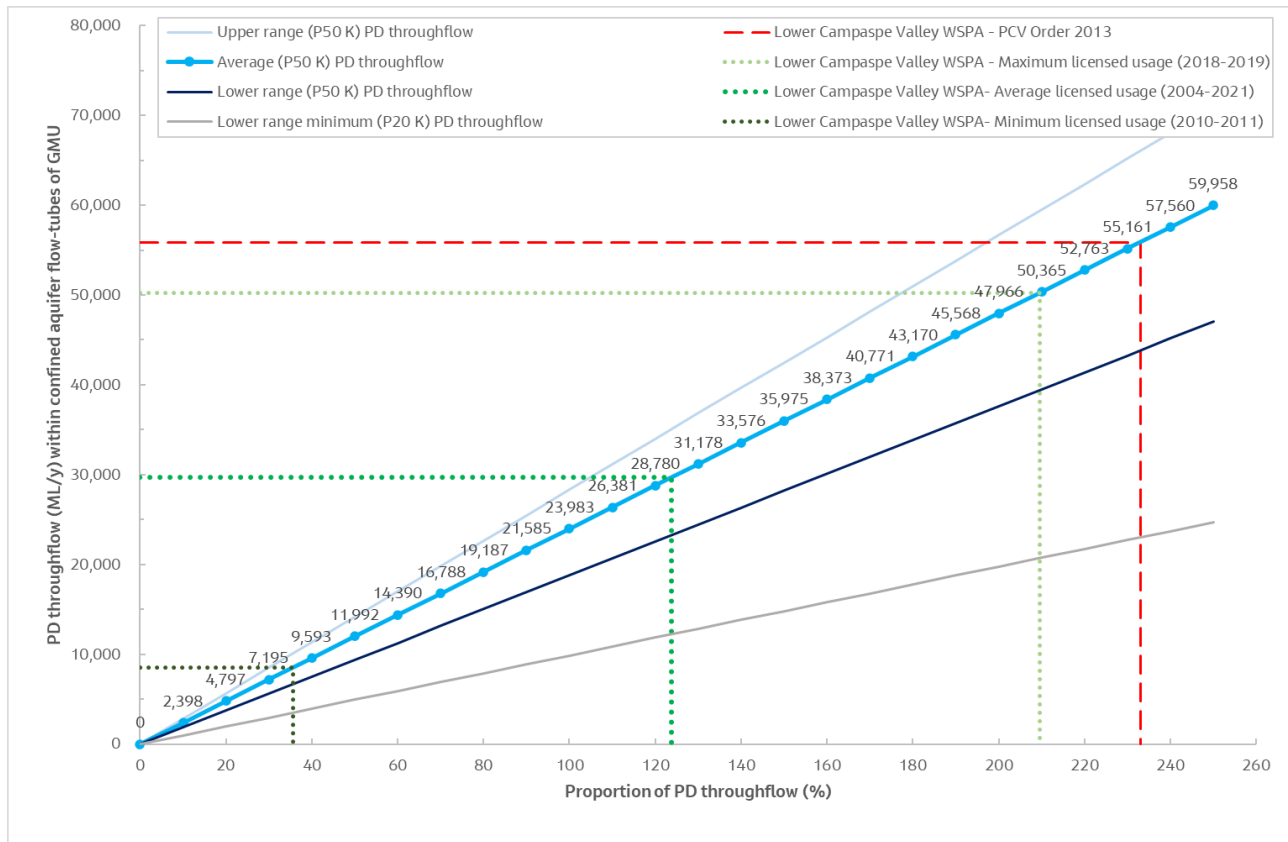
Notes:

All of the cross-sections occur within the GMU boundary.

(1) For UTAF ft10, in the northeast section of the GMU (Bamawm Zone), pre-development modelled RWL contours (e.g., 85 m, 80 m) appear significantly influenced by groundwater development. The inferred cone of depression contributes to steepening hydraulic gradients and the potential to redirect groundwater flow from the northeast. Both factors significantly increase the calculated throughflow rates in this area of the GMU. The modelled potentiometric surface used in the throughflow analysis (Hocking et al., 2010a) is reported to be based on 1995 water levels, post-dating groundwater development which commenced in the late 1970s. As the elevated throughflow rates in the UTAF within this northeast section of the GMU are unlikely to be representative of predevelopment conditions, they have been excluded from the GMU scale throughflow estimate.

To assist with contextualising the throughflow outputs, the average, lower and upper range (P50 K) and lower range minimum (P20 K) predevelopment throughflow estimates for combined flow-tubes UTAF ft10 and LTA ft28 are presented in Figure 7-4. For comparison, the Lower Campaspe Valley WSPA PCV and minimum, average and maximum licensed usage values are overlaid on the figure.

Figure 7-4 Lower Campaspe Valley WSPA – PCV and licensed usage relative to relative to predevelopment throughflow estimates of combined flow-tubes UTAF ft10 and LTA ft28



The throughflow results of the flow-tubes, and their spatial variability, are summarised in Table 7-16 in the context of management arrangements and licensed usage in the Lower Campaspe Valley WSPA, including considerations for assigning a sustainable yield.

Table 7-16 Summary of predevelopment throughflows in context of Lower Campaspe Valley WSPA

Flow-tube parameter	Result
Confined VAF layers	UTAF and LTA.
Comparison with WSPA boundary	The WSPA boundary generally occupies the entire width and length of the flow-tubes.
Flow from, or to, GMUs or UAs	A number of cells occur to the east of the flow-tubes, within the West Goulburn GMA (outside of the study area), that may be contributing to flow in the downgradient area of the WSPA.
GMU PD throughflow estimate	All of the flow-tube cross-sections occur within the boundary of the WSPA. The average (P50 K) predevelopment throughflow of the WSPA is therefore estimated to be 23,983 ML/y .
Confined aquifer(s) contributing majority of PD throughflow	Calivil Formation (UTAF) (60%).
CV (%) and potential factors contributing to spatial variability	CV: 26 %. A range of spatially variable processes may be responsible including hydraulic connection between the Deep Leads and Shepparton Formation.
PCV relative to PD throughflow	The PCV (55,875 ML/y) represents 233 % of the average (P50 K) predevelopment throughflow (23,983 ML/y) but allowing for spatial variability may be between 197 % and 297 %. The PCV represents 566 % of the lower range minimum (P20 K) predevelopment throughflow.

Flow-tube parameter	Result
Average licensed usage relative to PD throughflow	The average licensed usage (29,689 ML/y) represents 124 % of the average (P50 K) predevelopment throughflow (23,983 ML/y) but allowing for spatial variability may be between 105 % and 158 %. The average licensed usage represents 301 % of the lower range minimum (P20 K) predevelopment throughflow.
Relative rankings (Appendix B)	Relative reliability ranking: Low; Relative uncertainty ranking: Low; Relative potential for adverse impact on aquifer value(s): Very High; Overall GMU ranking: Low-Very High.
Considerations for assigning sustainable yield	<ul style="list-style-type: none"> ▪ The unconfined aquifer (Shepparton Formation) south of the Waranga Western Channel forms part of the Lower Campaspe Valley WSPA and is subject to the CDM Smith unconfined aquifer sustainable yield study. The assessment of the overall sustainable yield for the Lower Campaspe Valley WSPA will therefore need to consider contributions from this unconfined aquifer. ▪ Based on the adopted modelled potentiometric surface, groundwater pumping in the Bamawm Zone (central to northeast corner of the GMU) appears to be contributing to steeping hydraulic gradients in the Calivil Formation, creating a cone of depression, and redirecting groundwater flow from the northwest, into the GMU. Both factors significantly increase the calculated gridded throughflow rates in this area of the GMU. As the elevated throughflow rates in the UTAF within this northeast section of the GMU are unlikely to be representative of predevelopment conditions, they have been excluded from the GMU scale throughflow estimate. This is an example of stress induced yield augmentation and consideration will be required of how this process may influence the assessment of a sustainable yield. ▪ Groundwater resources may need to be managed on an aquifer by aquifer basis due to both variability in throughflow contributions and differing hydrogeological processes between aquifers. For example, the UTAF is subject to the effects of vertical leakage from the overlying Shepparton Formation, in addition to groundwater pumping in the Bamawm Zone. These hydrogeological processes within the UTAF also have spatial variability meaning that a zonal approach to groundwater management (e.g., setting trigger levels) may be warranted for this aquifer unit. ▪ Equitable sharing of the Deep Lead groundwater resource across the border with NSW.

7.3.5 UA LTA near Cohuna

The UA LTA near Cohuna (Figure 5-6) is designated flow-tube LTA ft27 (Table 7-1). The predevelopment throughflows for LTA ft27 rely on throughflow outputs from three cross-sections perpendicular to groundwater flow (at 80 m, 85 m and 105 m modelled RWL contours).

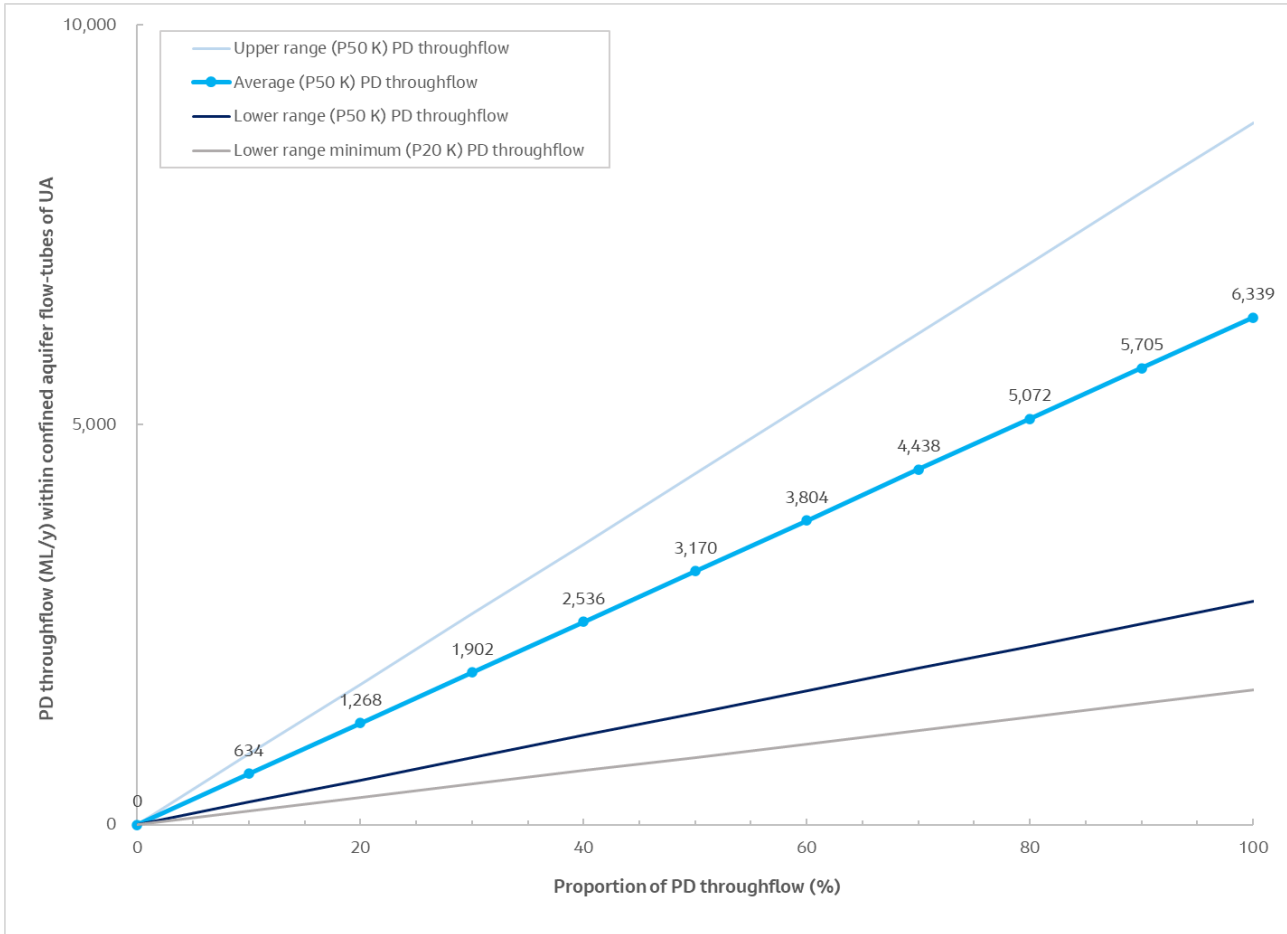
The (P50 K) predevelopment throughflow estimate of each cross-section in the LTA ft27 is reported in Table 7-17. The corresponding average, lower and upper range (P50 K), and lower range minimum (P20 K), predevelopment throughflow estimates for the flow-tube are also reported. The spatial variability of the calculated throughflow rate within the flow-tube is represented by the SD and CV in Table 7-17.

Table 7-17 Predevelopment throughflow estimates for flow-tubes – LTA ft27

Parameter	Value
P50 K PD throughflow, Cross-section 1 (80 m RWL) (ML/y)	8,774
P50 K PD throughflow, Cross-section 2 (85 m RWL) (ML/y)	2,790
P50 K PD throughflow, Cross-section 3 (105 m RWL) (ML/y)	7,454
Average (P50 K) PD throughflow (ML/y)	6,339
Lower range (P50 K) PD throughflow (ML/y)	2,790
Upper range (P50 K) PD throughflow (ML/y)	8,774
Lower range minimum (P20 K) PD throughflow (ML/y)	1,684
SD (ML/y)	3,144
CV (%)	50
Approximate length of flow-tube (km)	100

To assist with contextualising the throughflow outputs, the average, lower and upper range (P50 K) and lower range minimum (P20 K) predevelopment throughflow estimates for flow-tube LTA ft27 are presented in Figure 7-5.

Figure 7-5 Predevelopment throughflow estimates of flow-tube LTA ft27 near Cohuna



7.3.6 Katunga WSPA

The Katunga WSPA is designated flow-tubes UTAF ft09 and LTA ft29 (Table 7-1). The predevelopment throughflows for these flow-tubes rely on throughflow outputs from the following cross-sections perpendicular to groundwater flow:

- UTAF ft09: 90 m and 105 m modelled RWL contours.
- LTA ft29: 90 m, 95 m and 105 m and 115 m modelled RWL contours.

The (P50 K) predevelopment throughflow estimate of each cross-section in the UTAF ft09 and LTA ft29 is reported in Table 7-18. The corresponding average, lower and upper range (P50 K), and lower range minimum (P20 K) predevelopment throughflow estimates for the flow-tubes, and a combined estimate, are also reported. The spatial variability of the calculated throughflow rate within the flow-tubes, and combined, is represented by the SD and CV in Table 7-18.

Table 7-18 Predevelopment throughflow estimates for flow-tubes – UTAF ft09 and LTA ft29

Parameter	Value
UTAF ft09	
P50 K PD throughflow, Cross-section 1 (90 m RWL) (ML/y)	39,055
P50 K PD throughflow, Cross-section 2 (105 m RWL) (ML/y)	92,364
Average (P50 K) PD throughflow (ML/y)	65,710

Confined Aquifer Throughflow Assessment – Updated Method and Phase B State-wide Rollout

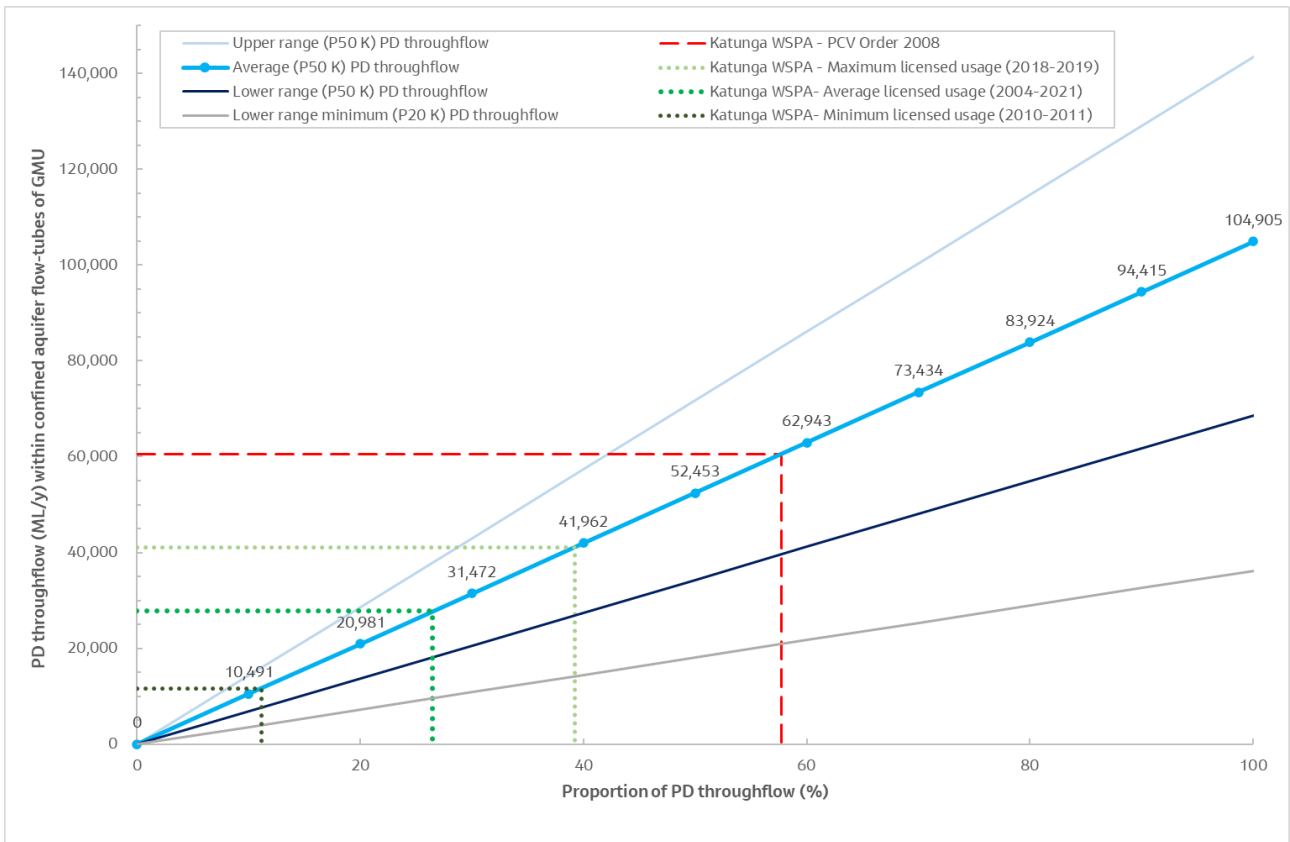
Parameter	Value
Lower range (P50 K) PD throughflow (ML/y)	39,055
Upper range (P50 K) PD throughflow (ML/y)	92,364
Lower range minimum (P20 K) PD throughflow (ML/y)	18,351
SD (ML/y)	37,695
CV (%)	57
Approximate length of flow-tube (km)	40
LTA ft29	
P50 K PD throughflow, Cross-section 1 (90 m RWL) (ML/y)	37,019
P50 K PD throughflow, Cross-section 2 (95 m RWL) (ML/y)	51,027
P50 K PD throughflow, Cross-section 3 (105 m RWL) (ML/y)	29,540
Average (P50 K) PD throughflow (ML/y)	39,196
Lower range (P50 K) PD throughflow (ML/y)	29,540
Upper range (P50 K) PD throughflow (ML/y)	51,027
Lower range minimum (P20 K) PD throughflow (ML/y)	17,826
SD (ML/y)	10,908
CV (%)	28
Approximate length of flow-tube (km)	40
Combined UTAF ft09 and LTA ft29	
Average (P50 K) PD throughflow (ML/y)	104,905
Lower range (P50 K) PD throughflow (ML/y)	68,595
Upper range (P50 K) PD throughflow (ML/y)	143,392
Lower range minimum (P20 K) PD throughflow (ML/y)	36,177
SD (ML/y)	48,603
CV (%)	46

Note:

All of the cross-sections occur within the GMU boundary.

To assist with contextualising the throughflow outputs, the average, lower and upper range (P50 K) and lower range minimum (P20 K) predevelopment throughflow estimates for combined flow-tubes UTAF ft09 and LTA ft29 are presented in Figure 7-6. For comparison, the Katunga WSPA PCV and minimum, average and maximum licensed usage values are overlaid on the figure.

Figure 7-6 Katunga WSPA – PCV and licensed usage relative to relative to predevelopment throughflow estimates of combined flow-tubes UTAF ft09 and LTA ft29



The throughflow results of the flow-tubes, and their spatial variability, are summarised in Table 7-19 the context of management arrangements and licensed usage in the Katunga WSPA, including considerations for assigning a sustainable yield.

Table 7-19 Summary of predevelopment throughflows in context of Katunga WSPA

Flow-tube parameter	Result
Confined VAF layers	UTAF and LTA.
Comparison with WSPA boundary	The WSPA boundary generally occupies the entire width and length of the flow-tubes.
Flow from, or to, GMUs or UAs	For both the UTAF and LTA, groundwater flows from the Mid-Goulburn GMA and Broken GMA to the Katunga WSPA. These GMAs are outside the study area.
GMU PD throughflow estimate	All of the flow-tube cross-sections occur within the boundary of the WSPA. The average (P50 K) predevelopment throughflow of the WSPA is therefore estimated to be 104,905 ML/y .
Confined aquifer(s) contributing majority of PD throughflow	Calivil Formation (UTAF) (60%).
CV (%) and potential factors contributing to spatial variability	CV: 46 %. A range of spatially variable processes may be responsible including hydraulic connection between the Deep Leads and Shepparton Formation and upwards vertical leakage from the underlying bedrock.
PCV relative to PD throughflow	The PCV (60,577 ML/y) represents 58 % of the average (P50 K) predevelopment throughflow (104,905 ML/y) but allowing for spatial variability may be between 42 % and 88 %. The PCV represents 167 % of the lower range minimum (P20 K) predevelopment throughflow.

Confined Aquifer Throughflow Assessment – Updated Method and Phase B State-wide Rollout

Flow-tube parameter	Result
Average licensed usage relative to PD throughflow	The average licensed usage (27,785 ML/y) represents 26 % of the average (P50 K) predevelopment throughflow (104,905 ML/y) but allowing for spatial variability may be between 19 % and 41 %. The average licensed usage represents 77 % of the lower range minimum (P20 K) predevelopment throughflow.
Relative rankings (Appendix B)	Relative reliability ranking: Low; Relative uncertainty ranking: Low; Relative potential for adverse impact on aquifer value(s): Low; Overall GMU ranking: Low-Low.
Considerations for assigning sustainable yield	<ul style="list-style-type: none"> ▪ Potential for inter-aquifer leakage and stress induced yield augmentation. ▪ Groundwater resources may need to be managed on an aquifer by aquifer basis due to: <ul style="list-style-type: none"> - Variability in throughflow contributions. - Differing hydrogeological processes between aquifers (e.g., for the UTAF, effects of inter-aquifer connectivity with the overlying Shepparton Formation). ▪ Equitable sharing of the Deep Lead groundwater resource across the border with NSW.

8. Otway-Torquay GMB

The Otway-Torquay GMB is located in southwestern Victoria and includes the Glenelg, Portland, Hopkins–Corangamite and Otway–Torquay groundwater catchments.

The confined aquifers within this GMB include:

- Clifton Formation (LMTA) (Figure 5-4).
- Dilwyn, Pebble Point and Mepunga formations (Eastern View Formation) (LTA) (Figure 5-6).

The Otway-Torquay GMB contains eight GMUs that incorporate confined aquifers. Outside of these GMUs the LMTA and LTA are managed as unincorporated areas (Figure 5-4 and Figure 5-6). The flow-tubes assigned in the GMB are listed in Table 8-1.

Table 8-1 Otway-Torquay GMB – assigned flow-tubes

Groundwater catchment	GMU or non-GMU	PCV Order depth	Confined VAF layer and flow-tube no.	Aquifer name
Glenelg	Glenelg WSPA (abolished) ⁽¹⁾	All formations below surface	LMTA ft03	Clifton Formation
			LTA ft11	Dilwyn Formation
Portland	Portland GMA	All formations below 200 m from surface	LTA ft12	Dilwyn Formation
	Condah WSPA	All formations from 70 to 200 m below surface	LMTA ft04	Clifton Formation
Hopkins–Corangamite	Paaratte GMA	Not depth defined ⁽²⁾	LTA ft14	Dilwyn Formation
	Newlingrook GMA	All formations below surface	LTA ft15	Mepunga & Dilwyn formations
	Gellibrand GMA	All formations below surface	LTA ft16	Dilwyn Formation
	Gerangamete GMA	All formations below surface	LTA ft31	Dilwyn, Pebble Point and Mepunga formations (Eastern View Formation)
	UA near Warrnambool	N/a	LMTA ft05	N/a
	UA north of Colac	N/a	LTA ft32	N/a
	UA near Warrnambool	N/a	LTA ft13	N/a
	UA near Skipton	N/a	LTA ft30	N/a
Otway-Torquay	Jan Juc GMA	Not depth defined ⁽³⁾	LTA ft17	Eastern View Formation

Note:

Shaded cells indicate the flow-tube is assigned to a GMU but includes a significant (multiple cells) UA either upgradient or downgradient of the GMU.

(1) Glenelg WSPA was abolished in September 2022. The management area remains to be used by DEECA for reporting purposes, however, and therefore forms part of the study area for this project.

(2) The Paaratte GMA PCV Order 2018 is defined by the upper and lower contour surfaces of the geological formation as described by Plan No. LEGL./18-090, lodged in the Central Plan Office of DEECA.

(3) The Jan Jac GMA is defined by stratigraphic units and includes the Upper Eastern View Formation Aquifer and the Lower Eastern View Formation Aquifer. Zone 1 includes all formations below the surface. Zone 2 is managed by formation and includes (i) all formations below the surface other than the Lower and Upper Eastern View Formation, (ii) Upper Eastern View Formation and (iii) Lower Eastern View Formation.

8.1 Hydrogeological characterisation

8.1.1 Glenelg WSPA (abolished)

The Glenelg WSPA was abolished in September 2022. The management area remains to be used by DEECA for reporting purposes, however, and therefore forms part of the study area for this project.

The now abolished Glenelg WSPA, situated in southwest Victoria, is bordered in the south by the Discovery Bay coastline, the west by the South Australian border and the east by a line extending from Cape Bridgewater to the south-western corner of the West Wimmera GMA.

The management area comprises flat plains and undulating terrain and incorporates all formations below the surface. It was intended to primarily manage the groundwater resource of the Bridgewater Formation (QA) and the Port Campbell Limestone (UMTA). The PCV therefore related primarily to unconfined aquifers. The UMTA in southwestern Victoria is now managed under the South West Limestone (SWL) GMA.

Areas of the now abolished WSPA were located within the Border Designated Zone (Zones 1B, 2B, 3B (partial) and 4B (partial)) under the joint management arrangements of the South Australian/Victorian Border Zone Agreement.

A regional scale hydrostratigraphic profile in and around the Glenelg WSPA is listed in Table 8-2 and key hydrogeological attributes are described in Table 8-3.

Table 8-2 Hydrostratigraphic profile in and around the Glenelg WSPA (abolished)

Geological formation	VAF code	Geological period	Lithology
Bridgewater Formation	QA	Quaternary	Sand, gravels, clay, silts.
Newer Volcanics	UTB	Upper Tertiary	Basalt (fractured rock).
Hanson Plain Sand	UTAM	Upper Tertiary	Sand.
Port Campbell Limestone ⁽¹⁾	UMTA	Upper-Mid Tertiary	Limestone (fractured rock), sand, gravel, clay, minor coal.
Gellibrand Marl	UMTD	Upper Middle to Lower-Middle Tertiary	Clay, silt, siltstone (fractured rock), marl (fractured rock), minor sand.
Clifton Formation	LMTA	Lower-Middle Tertiary	Sand, gravel, limestone (fractured rock), minor clay, occasional coal.
Narrawaturk Marl	LMTD	Lower-Middle to Lower Tertiary	Clay, silt, siltstone (fractured rock), marl (fractured rock), minor sand.
Dilwyn Formation	LTA	Lower Tertiary	Sand, gravel, clay, silt, minor coal.
Cretaceous and Permian Sediments	CPS	Cretaceous and Permian	Sandstone, mudstone siltstone (fractured), sand and minor coal.
Basement Rocks	BSE	Mesozoic and Palaeozoic	Sedimentary (fractured rock): sandstone, siltstone, mudstone, shale. Igneous: includes volcanics, granites, granodiorites.

Source: (GHD, 2020d).

Notes:

The shaded grey cells indicate the confined aquifer VAF layers subject to the Phase B study.

(1) The small area of confined UMTA in the Glenelg WSPA (abolished) flows in a northerly direction into the West Wimmera GMA and is considered as part of UMTA ft07.

Table 8-3 Glenelg WSPA (abolished) – Key hydrogeological attributes

Attribute	Parameter	Description
	GMU size ⁽¹⁾	3,008 km ²

Confined Aquifer Throughflow Assessment – Updated Method and Phase B State-wide Rollout

Attribute	Parameter	Description
Groundwater management	PCV Order depth	All formations below surface.
	Overlying GMUs	None.
	Underlying GMUs	None.
	Confined aquifers (and VAF code, number) ⁽¹⁾	Clifton Formation (LMTA, 109) and Dilwyn Formation (LTA, 111). Intended to primarily manage the groundwater resource of the Bridgewater Formation (QA, 100) and the Port Campbell Limestone (UMTA, 107). The PCV therefore related primarily to unconfined aquifers.
	PCV and derivation ⁽¹⁾	33,262 ML/year (PVC Order 2013). Derivation: Unknown.
Groundwater usage	Licensed volume ⁽²⁾	16,092 ML/year (June 2021).
	Licensed use ⁽²⁾	Average (2004-2021): 7,383 ML/year. Minimum (2020-2021): 2,413 ML/year. Maximum (2004-2005): 19,952 ML/year.
Hydrogeological conceptualisation	Recharge areas	N/a.
	Groundwater flow and aquifer/aquitard characteristics	N/a.
	Cross border flows	Areas of the now abolished WSPA were located within the Border Designated Zone (Zones 1B, 2B, 3B (partial) and 4B (partial)) under the joint management arrangements of the South Australian/Victorian Border Zone Agreement.
Groundwater monitoring	Groundwater suite hydrographic classification ⁽¹⁾	For the Upper aquifer (QA), a variable trend is indicated (Suite U_D_8). For the Middle aquifer (UMTA), a declining long-term trend that fluctuates over the short term due to climatic and seasonal use trends is indicated (Suite M_AF_1). For the Lower aquifer (LMTA, LTA), a variable trend is indicated (Suite L_AF_1 and L_C_1).

References: (1) GHD (2020d), (2) DEECA. (2023).

8.1.2 Portland GMA

The Portland GMA, situated in western Victoria has a western boundary along the north-south flow line in the Dilwyn Formation from the nose of the Merino high to the coast. The margin of the Merino Block represents the northern boundary. The GMA's eastern boundary extends to cover Port Fairy and the coastline bounds the south.

The GMA comprises relatively flat plains that slope downhill to the southeast. The management area incorporates all formations below 200 m from surface but was intended to primarily manage the groundwater resource of the Mepunga/Dilwyn Formation (LTA). The PCV therefore relates to confined aquifers.

A regional scale hydrostratigraphic profile in and around the Portland GMA is listed in Table 8-4 and key hydrogeological attributes are described in Table 8-5.

Table 8-4 Hydrostratigraphic profile in and around the Portland GMA

Geological formation	VAF code	Geological period	Lithology
Hanson Plain Sand	UTAM	Upper Tertiary	Sand.
Port Campbell Limestone	UMTA	Upper-Middle Tertiary	Limestone (fractured rock), sand, gravel, clay, minor coal.

Confined Aquifer Throughflow Assessment – Updated Method and Phase B State-wide Rollout

Geological formation	VAF code	Geological period	Lithology
Gellibrand Marl	UMTD	Upper-Middle to Lower-Middle Tertiary	Clay, silt, siltstone (fractured rock), marl (fractured rock), minor sand.
Clifton Formation	LMTA	Lower-Middle Tertiary	Sand, gravel, limestone (fractured rock), minor clay, occasional coal.
Narrawaturk Marl	LMTD	Lower-Middle to Lower Tertiary	Clay, silt, siltstone (fractured rock), marl (fractured rock), minor sand.
Dilwyn Formation	LTA	Lower Tertiary	Sand, gravel, clay, silt, minor coal.
Cretaceous and Permian Sediments	CPS	Cretaceous and Permian	Sandstone, mudstone siltstone (fractured), sand and minor coal.
Basement Rocks	BSE	Mesozoic and Palaeozoic	Sedimentary (fractured rock): sandstone, siltstone, mudstone, shale. Igneous: includes volcanics, granites, granodiorites.

Source: (GHD, 2020d).

Note:

The shaded grey cell indicates the confined aquifer VAF layer subject to the Phase B study.

Table 8-5 Portland GMA – Key hydrogeological attributes

Attribute	Parameter	Description
Groundwater management	GMU size ⁽¹⁾	4,000 km ²
	PCV Order depth	All formations below 200 m from surface.
	Overlying GMUs	Condah WSPA.
	Underlying GMUs	None.
	Confined aquifers (and VAF code, number) ⁽¹⁾	Mepunga/Dilwyn Formation (LTA, 111). The PCV relates to confined aquifers.
	PCV and derivation ⁽¹⁾	7,795 ML/year (PVC Order 2011). Derivation: Volume of licence entitlement (inferred).
Groundwater usage	Licensed volume ⁽²⁾	7,794 ML/year (June 2021).
	Licensed use ⁽²⁾	Average (2006-2021): 2,607 ML/year. Minimum (2008-2009): 2,121 ML/year. Maximum (2006-2007): 3,244 ML/year.
Hydrogeological conceptualisation	Recharge areas ⁽¹⁾	Direct recharge occurs to the Dilwyn Formation (LTA) along the margins of the Merino Block where there is limited outcrop on the flanks of the structure, and in the valley of the Crawford River. The area of outcrop is small and not necessarily representative of the total recharge to the Dilwyn Formation (LTA) which is thought to occur through overlying sediments.
	Groundwater flow and aquifer/aquitard characteristics ⁽¹⁾	There is potential for groundwater-surface water interaction in outcropping areas of the aquifer.
	Cross border flows	Not applicable.
Groundwater monitoring	Groundwater suite hydrographic classification ⁽¹⁾	For the Lower aquifer (LTA), a variable long-term trend that fluctuates with long term climatic and use trends (Suite L_C_1).

References: (1) GHD (2020d), (2) DEECA. (2023).

8.1.3 Condah WSPA

The Condah WSPA, situated in western Victoria north of Portland and Heywood has northern and western boundaries that coincide with Clifton Formation outcrops along the Crawford River and an associated elevation high. The eastern boundary occurs near the Port Fairy-Hamilton and Branxholme-Brisbane Hill Roads and Miakite Creek. The southern boundary correlates with a point where aquifer depth is greater than 200 m, corresponding with the nearby Princes Highway and Carters, Loftus, Anya Creek and Mt Eccles roads.

The WSPA comprises relatively flat plains that generally sloping downhill to the south and west. The management area incorporates all formations between 70-200 m but was intended to manage the groundwater resource of the Clifton Formation (LMTA). The PCV primarily relates to confined aquifers.

A regional scale hydrostratigraphic profile in and around the Condah WSPA is listed in Table 8-6 and key hydrogeological attributes are described in Table 8-7.

Table 8-6 Hydrostratigraphic profile in and around the Condah WSPA

Geological formation	VAF code	Geological period	Lithology
Hanson Plain Sand	UTAM	Upper Tertiary	Sand.
Port Campbell Limestone	UMTA	Upper-Middle Tertiary	Limestone (fractured rock), sand, gravel, clay, minor coal.
Gellibrand Marl	UMTD	Upper-Middle to Lower-Middle Tertiary	Clay, silt, siltstone (fractured rock), marl (fractured rock), minor sand.
Clifton Formation	LMTA	Lower-Middle Tertiary	Sand, gravel, limestone (fractured rock), minor clay, occasional coal.
Narrawaturk Marl	LMTD	Lower-Middle to Lower Tertiary	Clay, silt, siltstone (fractured rock), marl (fractured rock), minor sand.
Dilwyn Formation	LTA	Lower Tertiary	Sand, gravel, clay, silt, minor coal.
Cretaceous and Permian Sediments	CPS	Cretaceous and Permian	Sandstone, mudstone siltstone (fractured), sand and minor coal.
Basement Rocks	BSE	Mesozoic and Palaeozoic	Sedimentary (fractured rock): sandstone, siltstone, mudstone, shale. Igneous: includes volcanics, granites, granodiorites.

Source: (GHD, 2020d).

Note:

The shaded grey cell indicates the confined aquifer VAF layer subject to the Phase B study.

Table 8-7 Condah WSPA – Key hydrogeological attributes

Attribute	Parameter	Description
Groundwater management	GMU size ⁽¹⁾	975 km ²
	PCV Order depth	All formations from 70 m to 200 m below surface.
	Overlying GMUs	None.
	Underlying GMUs	Portland GMA.
	Confined aquifers (and VAF code, number) ⁽¹⁾	Clifton Formation (LMTA, 109). The PCV primarily relates to confined aquifers.
	PCV and derivation ⁽¹⁾	7,475 ML/year (PVC Order 2013). Derivation: Volume of licence entitlement (inferred).
	Licensed volume ⁽²⁾	7,470 ML/year (June 2021).

Confined Aquifer Throughflow Assessment – Updated Method and Phase B State-wide Rollout

Attribute	Parameter	Description
Groundwater usage	Licensed use ⁽²⁾	Average (2005-2021): 2,782 ML/year. Minimum (2010-2011): 1,115 ML/year. Maximum (2006-2007): 3,912 ML/year.
Hydrogeological conceptualisation	Recharge areas ⁽¹⁾	The main recharge area is the Crawford River.
	Groundwater flow and aquifer/aquitard characteristics ⁽¹⁾	Groundwater movement is away from the recharge zone of the Crawford River, towards the southeast.
	Cross border flows	Not applicable.
Groundwater monitoring	Groundwater suite hydrographic classification ⁽¹⁾	Hydrographs of two suites at the epicentre of groundwater extraction in the Lower aquifer (LMTA) exhibit a decreasing long-term trend since 1995 that fluctuates due to shorter term seasonal pumping (Suite L_A_1 and L_A_2). Another suite in the west of the Condah WSPA shows a marginally declining trend from 1974 to 1999, with a relatively stable trend thereafter (Suite L_C_1).

References: (1) GHD (2020d), (2) DEECA. (2023).

8.1.4 Paaratte GMA

The Paaratte GMA located in southwest Victoria, east of Warrnambool, is bound in the south by the Bass Strait coastline and in the north by the extent of the Dilwyn Formation from Irrewillipe East to 3 km north of Cobden. The western boundary extends in a line westward from the Cobden region through Nirranda before terminating on the coast west of Port Campbell. The eastern boundary delineates the boundary of the recharge area and aligns with the Fergusons Hill Anticline.

The GMA comprises undulating to hilly terrain and generally slopes downhill to the south. The management area is intended to primarily manage the groundwater resource of the Mepunga/Dilwyn Formation (LTA). PCV Order 2019 defines the depth boundaries pertaining to the target aquifer using contour lines to describe the upper and lower boundaries of the GMA. The PCV therefore primarily relates to confined aquifers.

A regional scale hydrostratigraphic profile in and around the Paaratte GMA is listed in Table 8-8 and key hydrogeological attributes are described in Table 8-9.

Table 8-8 Hydrostratigraphic profile in and around the Paaratte GMA

Geological formation	VAF code	Geological period	Lithology
Gellibrand Marl	UMTD	Upper-Middle to Lower-Middle Tertiary	Clay, silt, siltstone (fractured rock), marl (fractured rock), minor sand.
Clifton Formation ⁽¹⁾	LMTA	Lower-Middle Tertiary	Sand, gravel, limestone (fractured rock), minor clay, occasional coal.
Narrawaturk Marl	LMTD	Lower-Middle to Lower Tertiary	Clay, silt, siltstone (fractured rock), marl (fractured rock), minor sand.
Dilwyn Formation	LTA	Lower Tertiary	Sand, gravel, clay and silt, minor coal.
Cretaceous and Permian Sediments	CPS	Cretaceous and Permian	Sandstone, mudstone siltstone (fractured), sand and minor coal.
Basement rocks	BSE	Basement rocks	Sedimentary (fractured rock): sandstone, siltstone, mudstone, shale. Igneous: includes volcanics, granites, granodiorites.

Source: (GHD, 2020d).

Notes:

The shaded grey cell indicates the confined aquifer VAF layer subject to the Phase B study.

(1) Based on the PCV criteria, the LMTA VAF layer is not indicated to occur within the GMU.

Table 8-9 Paaratte GMA – Key hydrogeological attributes

Attribute	Parameter	Description
Groundwater management	GMU size ⁽¹⁾	1,346 km ²
	PCV Order depth	Defined by the upper and lower contour surfaces of the geological formation as described by Plan No. LEGL./18-090, lodged in the Central Plan Office of DEECA (PCV Order 2018).
	Overlying GMUs	None.
	Underlying GMUs	None.
	Confined aquifers (and VAF code, number) ⁽¹⁾	Mepunga/Dilwyn Formation (LTA, 111). The PCV primarily relates to confined aquifers.
	PCV and derivation ⁽¹⁾	4,606 ML/year (PVC Order 2019). Derivation: Aquifer throughflow analysis.
Groundwater usage	Licensed volume ⁽²⁾	3,159 ML/year (June 2021).
	Licensed use ⁽²⁾	Average (2009-2021): 321 ML/year. Minimum (2020-2021): 281 ML/year. Maximum (2015-2016): 367 ML/year.
Hydrogeological conceptualisation	Recharge areas ⁽³⁾	Recharge to the Dilwyn Formation (LTA) is considered to occur principally via direct infiltration of precipitation into outcropping Dilwyn Formation sediments along the eastern side of the Paaratte GMA.
	Groundwater flow and aquifer/aquitard characteristics ⁽³⁾	There is potential groundwater-surface water interaction in outcrop areas, or GMA margins such as near the Newlingrook GMA.
	Cross border flows	Not applicable.
Groundwater monitoring	Groundwater suite hydrographic classification ⁽¹⁾	For the LTA, a variable long-term trend that fluctuates with long term climatic trends and shorter-term use trends is indicated (Suite L_AA_99).

References: (1) GHD (2020d), (2) DEECA. (2023), (3) SKM. (1998h).

8.1.5 Newlingrook GMA

The Newlingrook GMA is located in southwestern Victoria, east of Port Campbell. The GMA is bound in the east and northwest by outcropping basement rock, in the northeast by the Gellibrand Saddle, the south by Bass Strait and the Princetown syncline-Ferguson Hill anticline basement feature in the west.

The GMA comprises undulating to hilly terrain and manages all formations below the surface, with a primary focus on the groundwater resources of the Pebble Point Formation (LTA).

A regional scale hydrostratigraphic profile in and around the Newlingrook GMA is listed in Table 8-10 and key hydrogeological attributes are described in Table 8-11.

Table 8-10 Hydrostratigraphic profile in and around the Newlingrook GMA

Geological formation	VAF code	Geological period	Lithology
Bridgewater Formation	QA	Quaternary	Sand, gravels, clay, silts.
Hanson Plain Sand	UTAM	Upper Tertiary	Sand.
Port Campbell Limestone ⁽¹⁾	UMTA	Upper-Middle Tertiary	Limestone (fractured rock), sand, gravel, clay, minor coal.
Gellibrand Marl	UMTD	Upper-Middle to Lower-Middle Tertiary	Clay, silt, siltstone (fractured rock), marl (fractured rock), minor sand.

Confined Aquifer Throughflow Assessment – Updated Method and Phase B State-wide Rollout

Geological formation	VAF code	Geological period	Lithology
Clifton Formation ⁽¹⁾	LMTA	Lower-Middle Tertiary	Sand, gravel, limestone (fractured rock), minor clay, occasional coal.
Narrawaturk Marl	LMTD	Lower-Middle to Lower Tertiary	Clay, silt, siltstone (fractured rock), marl (fractured rock), minor sand.
Pebble Point Formation (Dilwyn Formation)	LTA	Lower Tertiary	Sand, gravel, clay and silt, minor coal.
Older Volcanics ⁽²⁾	LTBb	Lower Tertiary	Basalt (fractured rock).
Cretaceous and Permian Sediments	CPS	Cretaceous and Permian	Sandstone, mudstone siltstone (fractured), sand and minor coal.
Basement rocks	BSE	Mesozoic and Palaeozoic	Sedimentary (fractured rock): sandstone, siltstone, mudstone, shale. Igneous: includes volcanics, granites, granodiorites.

Source: (GHD, 2020d).

Notes:

The shaded grey cell indicates the confined aquifer VAF layer subject to the Phase B study.

(1) The UMTA and LMTA are not indicated as confined aquifers in the GMA.

(2) The LTBb VAF layer is not indicated to occur within the GMU.

Table 8-11 Newlingbrook GMA – Key hydrogeological attributes

Attribute	Parameter	Description
Groundwater management	GMU size ⁽¹⁾	448 km ²
	PCV Order depth	All formations below the surface.
	Overlying GMUs	None.
	Underlying GMUs	None.
	Confined aquifers (and VAF code, number) ⁽¹⁾	Pebble Point Formation (LTA, 111). The PCV primarily relates to confined aquifers.
	PCV and derivation ⁽¹⁾	1,977 ML/year (PVC Order 2006). Derivation: Volume of licensed entitlement (inferred).
Groundwater usage	Licensed volume ⁽²⁾	1,958 ML/year (June 2021).
	Licensed use ⁽²⁾	Average (2006-2021): 145 ML/year. Minimum (2010-2011): 8 ML/year. Maximum (2014-2015): 738 ML/year.
Hydrogeological conceptualisation	Recharge areas ⁽¹⁾	Recharge occurs from an estimated 17 % of rainfall which equates to 0.17 m/year.
	Groundwater flow and aquifer/aquitard characteristics	N/a.
	Cross border flows	Not applicable.
Groundwater monitoring	Groundwater suite hydrographic classification ⁽¹⁾	For the LTA, a decreasing long-term trend that fluctuates with the long term climatic trends is indicated (Suite L_Y_3).

References: (1) GHD (2020d), (2) DEECA. (2023).

8.1.6 Gellibrand GMA

The Gellibrand GMA is located in south western Victoria, south of Colac, within the Kawarren groundwater sub-basin. The GMA's borders are shared with the Gerangamete GMA to the north and east, and the Newlingrook GMA occurs nearby to the southwest.

The management area incorporates all formations below ground surface but was intended to primarily manage the groundwater resource of the Dilwyn Formation (LTA). The PCV relates to confined and unconfined aquifers.

A regional scale hydrostratigraphic profile in and around the Gellibrand GMA is listed in Table 8-12 and key hydrogeological attributes are described in Table 8-13.

Table 8-12 Hydrostratigraphic profile in and around the Gellibrand GMA

Geological formation	VAF code	Geological period	Lithology
Bridgewater Formation	QA	Quaternary	Sand, gravels, clay, silts
Port Campbell Limestone	UMTA	Upper-Middle Tertiary	Limestone (fractured rock), sand, gravel, clay, minor coal
Gellibrand Marl	UMTD	Upper-Middle to Lower-Middle Tertiary	Clay, silt, siltstone (fractured rock), marl (fractured rock), minor sand
Clifton Formation ⁽¹⁾	LMTA	Lower-Middle Tertiary	Sand, gravel, limestone (fractured rock), marl (fractured rock), minor sand
Narrawaturk Marl	LMTD	Lower-Middle to Lower Tertiary	Clay, silt, siltstone (fractured rock), marl (fractured rock), minor sand
Dilwyn Formation	LTA	Lower Tertiary	Sand, gravel, clay and silt, minor coal
Older Volcanics ⁽²⁾	LTBb	Lower-Middle Tertiary	Basalt (fractured rock)
Basement Rocks	BSE	Mesozoic and Palaeozoic	Sedimentary (fractured rock): sandstone, siltstone, mudstone, shale. Igneous: includes volcanics, granites, granodiorites

Source: (GHD, 2020d).

Notes:

The shaded grey cells indicate the confined aquifer VAF layers subject to the Phase B study.

(1) The relatively small and narrow area occupied by the LMTA VAF layer in this GMU is not considered sufficient to warrant a throughflow analysis.

(2) The LTBb VAF layer is not indicated to occur within the GMU.

Table 8-13 Gellibrand GMA – Key hydrogeological attributes

Attribute	Parameter	Description
Groundwater management	GMU size ⁽¹⁾	83 km ²
	PCV Order depth	All formations below the surface.
	Overlying GMUs	None.
	Underlying GMUs	None.
	Confined aquifers (and VAF code, number) ⁽¹⁾	Dilwyn Formation (LTA, 111). The PCV relates to confined and unconfined aquifers.
	PCV and derivation ⁽¹⁾	0 ML/year (PVC Order 2006). Derivation: Based on the assumption that all, or most of the LTA throughflow discharges into the Gellibrand River, and that surface water resources of the Gellibrand River are fully allocated.
	Licensed volume ⁽²⁾	0 ML/year (June 2021).

Confined Aquifer Throughflow Assessment – Updated Method and Phase B State-wide Rollout

Attribute	Parameter	Description
Groundwater usage	Licensed use ⁽²⁾	Average: 0 ML/year. Minimum: 0 ML/year. Maximum: 0 ML/year.
Hydrogeological conceptualisation	Recharge areas	N/a.
	Groundwater flow and aquifer/aquitard characteristics ⁽¹⁾	There is an assumption that all, or most of LTA throughflow discharges into the Gellibrand River (i.e., recharge to the LTA is equal to discharge to the Gellibrand River).
	Cross border flows	Not applicable.
Groundwater monitoring	Groundwater suite hydrographic classification ⁽¹⁾	For the LTA, a declining long-term trend that fluctuates with use is indicated (Suite L_Y_3). The groundwater level decline may be due to historic use within the Gellibrand GMA or potentially from groundwater extraction from the Barwon Downs bore field within the Gerangamete GMA.

References: (1) GHD (2020d), (2) DEECA. (2023).

8.1.7 Gerangamete GMA

The Gerangamete GMA consists of a large part of the Barwon Downs Graben located in southwestern Victoria, approximately 75 km southwest of Geelong. The graben is bounded by structural highs, the Barongarook High in the west and the Otway Ranges in the south.

The management area incorporates all formations below ground surface, with the primary focus of the GMA being the groundwater resource of the Eastern View Formation (LTA).

A regional scale hydrostratigraphic profile in and around the Gerangamete GMA is listed in Table 8-14 and key hydrogeological attributes are described in Table 8-15.

Table 8-14 Hydrostratigraphic profile in and around the Gerangamete GMA

Geological formation	VAF code	Geological period	Lithology
Gellibrand Marl	UMTD	Upper-Mid to Lower-Middle Tertiary	Fossiliferous marl and calcareous siltstone.
Clifton Formation ⁽¹⁾	LMTA	Lower-Middle Tertiary	Yellowish white limestone and quartz sand deposited in a littoral to marine environment.
Narrawaturk Marl	LMTD	Lower-Middle to Lower Tertiary	Carbonaceous, fossiliferous, dark grey to brown silty marl with thin sand beds.
Yaugher Volcanics ⁽²⁾	LTBb	Lower-Middle Tertiary	Basalt, tuff, breccia and volcanoclastics.
Dilwyn, Pebble Point and Mepunga formations (Eastern View Formation)	LTA	Lower Tertiary	The Dilwyn and Pebble Point formations contain quartz sands with mudstone, ligneous clays and brown coals. Marginal marine intercalations occur in the Dilwyn Formation.
Basement Rocks	BSE	Mesozoic and Palaeozoic	Sedimentary (fractured rock): sandstone, siltstone, mudstone, shale. Igneous: includes volcanics, granites, granodiorites.

Source: (SKM, 1998i).

Notes:

The shaded grey cell indicates the confined aquifer VAF layer subject to the Phase B study.

(1) The relatively small and narrow area occupied by the LMTA VAF layer in this GMU is not considered sufficient to warrant the throughflow analysis.

(2) The LTBb VAF layer is not indicated to occur within the GMU.

Table 8-15 Gerangamete GMA – Key hydrogeological attributes

Attribute	Parameter	Description
Groundwater management	GMU size ⁽¹⁾	380 km ²
	PCV Order depth	All formations below the surface.
	Overlying GMUs	None.
	Underlying GMUs	None.
	Confined aquifers (and VAF code, number) ⁽³⁾	Eastern View Formation (LTA, 111). The PCV relates to confined and unconfined aquifers.
	PCV and derivation ^(1,3)	239 ML/year (PVC Order 2011). Derivation: The PCV was previously aligned with Barwon Water's groundwater licence, which allowed extraction from the Gerangamete GMA up to 20,000 ML in any one year, 80,000 ML over a consecutive 10-year period and 400,000 ML over a 100-year period. The PCV was reduced to 239 ML on 26 June 2019 as Barwon Water withdrew its licence renewal application for the Barwon Downs borefield until remediation of historical impacts of groundwater pumping is complete under the Section 78 Ministerial Notice. The historical impacts include (in combination with the effects of a drier climate) reduction in flows to Boundary Creek and the subsequent activation of acid sulfate soils in Big Swamp (the Yeodene peat swamp).
Groundwater usage	Licensed volume ⁽²⁾	238 ML/year (June 2021).
	Licensed use ⁽²⁾	Average (2005-2021): 3,524 ML/year. Minimum (2017-2018): 3 ML/year. Maximum (2009-2010): 12,692 ML/year.
Hydrogeological conceptualisation	Recharge areas ⁽¹⁾	The Barongarook High forms the major recharge area for the basin.
	Groundwater flow and aquifer/aquitard characteristics ⁽¹⁾	Dilwyn Formation, Pebble Point Formation and Mepunga formation aquifers (LTA) are treated as a single aquifer system due to the hydraulic continuity between them. This aquifer is approximately 200-300 m in thickness. Groundwater movement in the LTA is restricted primarily by structures in the area.
	Cross border flows	Not applicable.
Groundwater monitoring	Groundwater suite hydrographic classification ⁽³⁾	Historically, observation bores near the Gerangamete production bore field indicated rapid drawdowns and recoveries. Further from the bore field, observation bores exhibited comparatively slower drawdowns and longer recovery times.

References: (1) SKM (1998i), (2) DEECA. (2023), (3) Barwon Water. (2019).

8.1.8 Jan Juc GMA

The Jan Juc GMA is located in southwest of Victoria and includes the townships of Anglesea, Aireys Inlet and Torquay. The western boundary coincides with the Torquay basin boundary (Otway Ranges) and Bass Strait defines the eastern and southern limits. The northern boundary is marked by roads towards the coast including Grossmans Road, Main Road, Grays Road, Thielemanns Road and Wormbete Station Road.

The GMA is split by the following zone and formation criteria:

- Zone 1 - all formations below the surface (unconfined sedimentary plains).
- Zone 2 – Upper Eastern View Formation (confined sedimentary plains).
- Zone 2 – Lower Eastern View Formation confined sedimentary plains).
- Zone 2 – all formations below the surface other than the Lower Eastern View formation and Upper Eastern View formation (unconfined sedimentary plains).

Confined Aquifer Throughflow Assessment – Updated Method and Phase B State-wide Rollout

The primary focus of the GMA is on the groundwater resource of the Eastern View Formation (LTA).

A regional scale hydrostratigraphic profile in and around the Jan Juc GMA is listed in Table 8-16 and key hydrogeological attributes are described in Table 8-17.

Table 8-16 Hydrostratigraphic profile in and around the Jan Jac GMA

Geological formation	VAF code	Geological period	Lithology
Bridgewater Formation	QA	Quaternary	Sand, gravels, clay, silts.
Hanson Plain Sand	UTAM	Upper Tertiary	Sand.
Gellibrand Marl	UMTD	Upper-Middle to Lower-Middle Tertiary	Clay, silt, siltstone (fractured rock), marl (fractured rock), minor sand.
Narrawaturk Marl	LMTD	Lower-Middle to Lower Tertiary	Clay, silt, siltstone (fractured rock), marl (fractured rock), minor sand.
Eastern View Formation	LTA	Lower Tertiary	Sand, gravel, clay, silt, and minor coal.
Cretaceous and Permian Sediments	CPS	Cretaceous and Permian	Sandstone, mudstone siltstone (fractured), sand and minor coal.
Basement Rocks	BSE	Mesozoic and Palaeozoic	Sedimentary (fractured rock): sandstone, siltstone, mudstone, shale. Igneous: includes volcanics, granites, granodiorites.

Source: (GHD, 2020d).

Note:

The shaded grey cell indicates the confined aquifer VAF layers subject to the Phase B study.

Table 8-17 Jan Juc GMA – Key hydrogeological attributes

Attribute	Parameter	Description
Groundwater management	GMU size ⁽¹⁾	290 km ²
	PCV Order depth	Defined by the following zone and formation criteria: <ul style="list-style-type: none"> Zone 1 - all formations below the surface (unconfined sedimentary plains). Zone 2 – Upper Eastern View Formation (confined sedimentary plains). Zone 2 – Lower Eastern View Formation confined sedimentary plains). Zone 2 – all formations below the surface other than the Lower Eastern View formation and Upper Eastern View formation (unconfined sedimentary plains).
	Overlying GMUs	None.
	Underlying GMUs	None.
	Confined aquifers (and VAF code, number) ⁽¹⁾	Eastern View Formation (LTA, 111).
	PCV and derivation ⁽¹⁾	<ul style="list-style-type: none"> Zone 1 – 250 ML/year. Zone 2 (Upper Eastern View Formation) – 4,000 ML/year. Zone 2 (Lower Eastern View Formation) – 10,000 ML/year (35,000 ML/year in any five year period). Zone 2 (all formations below the surface other than the Lower Eastern View formation and Upper Eastern View formation) – 0 ML/year. <p>Total: 14,250 ML/year (in accordance with the Bulk Entitlement (Anglesea) Groundwater Order 2009).</p>

Confined Aquifer Throughflow Assessment – Updated Method and Phase B State-wide Rollout

Attribute	Parameter	Description
		Derivation: Numerical groundwater model impact assessment, incorporating 2006 licensed entitlements and subsequent additional volume application from Barwon Water.
Groundwater usage	Licensed volume ⁽²⁾	14,250 ML/year (June 2021).
	Licensed use ⁽²⁾	Average (2007-2021): 2,801 ML/year. Minimum (2017-2018): 7 ML/year (Alcoa ceased pumping in 2017). Maximum (2011-2012): 7,806 ML/year (both Alcoa and Barwon Water were extracting groundwater).
Hydrogeological conceptualisation	Recharge areas ⁽¹⁾	Recharge is predominantly through rainfall infiltration. Total outcrop area was estimated to be 70 km ² and rainfall for the two outcropping regions was estimated to be 900 mm/year (Lower Eastern View Formation) and 700 mm/year (Upper Eastern View Formation).
	Groundwater flow and aquifer/aquitard characteristic	N/a.
	Cross border flows	Not applicable.
Groundwater monitoring	Groundwater suite hydrographic classification ⁽¹⁾	For the LTA, a declining long-term trend that is highly influenced by use trends is indicated (Suite L_X_2).

References: (1) GHD (2020d), (2) DEECA. (2023).

8.2 Aquifer property data

Aquifer property data collected for the Clifton Formation (LMTA) and Dilwyn, Pebble Point and Mepunga formations (LTA) in the Otway-Torquay GMB is presented in Table 8-18 and Table 8-19, respectively. The statistical analysis of the K (K_h) point data for each of the VAF layers is presented in Table 8-20, including the P20 K, P50 K and P80 K values adopted for the throughflow calculations.

Table 8-18 Otway-Torquay GMB - LMTA properties

Area	Aquifer	K _h (m/d)	K _v (m/d)	T (m ² /d)	S	Reference
Condah WSPA	Clifton Formation	10	N/a	N/a	N/a	SKM (1998j), as cited in GHD (2020).
Condah WSPA	Clifton Formation	3.9	N/a	233	N/a	DELWP (2016), as cited in GHD (2020).
Condah WSPA	Clifton Formation	3-4	Na	143	N/a	Nolan-ITU (2002), as cited in GHD (2020).
Condah WSPA	Clifton Formation	18.2-18.8	N/a	206.6	N/a	Nolan-ITU (2002), as cited in GHD (2020).
Condah WSPA	Clifton Formation	2.5-4	N/a	N/a	7×10 ⁻⁵	SKM (2007), as cited in GHD (2020).
Condah WSPA	Clifton Formation	4.1-5.7	N/a	N/a	N/a	GHD (2020).
Condah WSPA	Clifton Formation	0.5-5.0	N/a	N/a	N/a	GHD (2020).

Confined Aquifer Throughflow Assessment – Updated Method and Phase B State-wide Rollout

Table 8-19 Otway-Torquay GMB - LTA properties

Area	Aquifer	K_h (m/d)	K_v (m/d)	T (m ² /d)	S	Reference
Glenelg WSPA	Dilwyn Formation	43	N/a	868	N/a	DELWP (2016), as cited in GHD (2020).
Glenelg WSPA	Dilwyn Formation	84	N/a	1,086	N/a	SKM (2011), as cited in GHD (2020).
Glenelg WSPA	Dilwyn Formation	17	N/a	224	N/a	SKM (2011), as cited in GHD (2020).
Glenelg WSPA	Dilwyn Formation	34.9	N/a	1,186	N/a	SKM (2011), as cited in GHD (2020).
Glenelg WSPA	Dilwyn Formation	23	N/a	92	N/a	SKM (2011), as cited in GHD (2020).
Portland GMA	Mepunga & Dilwyn formations	5	N/a	700-1,000	1×10^{-4}	SKM (1998k), as cited in GHD (2020).
Portland GMA	Mepunga & Dilwyn formations	9.3	N/a	N/a	N/a	DELWP (2016), as cited in GHD (2020).
Portland GMA	Mepunga & Dilwyn formations	6.9	N/a	N/a	N/a	DELWP (2016), as cited in GHD (2020).
Portland GMA	Mepunga & Dilwyn formations	17.0	N/a	N/a	N/a	DELWP (2016), as cited in GHD (2020).
Portland GMA	Mepunga & Dilwyn formations	13.0	N/a	546	N/a	DELWP (2016), as cited in GHD (2020).
Paaratte GMA	Mepunga & Dilwyn formations	N/a	N/a	400	N/a	DELWP (2016), as cited in GHD (2020).
Paaratte GMA	Mepunga & Dilwyn formations	N/a	N/a	344	N/a	DELWP (2016), as cited in GHD (2020).
Paaratte GMA	Mepunga & Dilwyn formations	11.0	N/a	N/a	N/a	DELWP (2016), as cited in GHD (2020).
Paaratte GMA	Mepunga & Dilwyn formations	3	N/a	N/a	1×10^{-4}	SKM (1998h), as cited in GHD (2020).
Paaratte GMA	Mepunga & Dilwyn formations	2.2	1.2×10^{-6}	363-418	7.3×10^{-5} - 1.11×10^{-4}	SKM (2010d), as cited in GHD (2020).
Paaratte GMA	Mepunga & Dilwyn formations	2.5	1.2×10^{-6}	363-418	7.3×10^{-5} - 1.11×10^{-4}	SKM (2010d), as cited in GHD (2020).
Newlingrook GMA	Pebble Point Formation	22	N/a	N/a	2.2×10^{-3} - 3×10^{-4}	SKM (1998l), as cited in GHD (2020).
Newlingrook GMA	Pebble Point Formation	4	N/a	N/a	2.2×10^{-3} - 3×10^{-4}	SKM (1998l), as cited in GHD (2020).
Newlingrook GMA	Pebble Point Formation	1	N/a	N/a	2.2×10^{-3} - 3×10^{-4}	SKM (1998l), as cited in GHD (2020).
Newlingrook GMA	Pebble Point Formation	16-37	N/a	380-1,390	1×10^{-4}	GHD (2006), as cited in GHD (2020).

Confined Aquifer Throughflow Assessment – Updated Method and Phase B State-wide Rollout

Area	Aquifer	K_h (m/d)	K_v (m/d)	T (m ² /d)	S	Reference
Newlingbrook GMA	Pebble Point Formation	5-30	N/a	380-1,390	1×10^{-4}	GHD (2006), as cited in GHD (2020).
Gellibrand GMA	Dilwyn Formation	1	N/a	N/a	3×10^{-4}	SKM (1998m), as cited in GHD (2020).
Gellibrand GMA	Dilwyn Formation	8	N/a	728	N/a	DELWP (2016), as cited in GHD (2020).
Gellibrand GMA	Dilwyn Formation	10	N/a	1,056	N/a	DELWP (2016), as cited in GHD (2020).
Gellibrand GMA	Dilwyn Formation	N/a	N/a	928	N/a	DELWP (2016), as cited in GHD (2020).
Gellibrand GMA	Dilwyn Formation	N/a	N/a	825	N/a	DELWP (2016), as cited in GHD (2020).
Gellibrand GMA	Dilwyn Formation	38.4	N/a	4,408	N/a	DELWP (2016), as cited in GHD (2020).
Gellibrand GMA	Dilwyn Formation	8.5	N/a	512	N/a	DELWP (2016), as cited in GHD (2020).
Gellibrand GMA	Dilwyn Formation	4.9	N/a	220	N/a	DELWP (2016), as cited in GHD (2020).
Gerangamete GMA	Dilwyn, Pebble Point and Mepunga formations	6	N/a	N/a	2.4×10^{-4}	SKM (1998i).
Jan Jac GMA	Eastern View Formation	1	N/a	N/a	9.4×10^{-4}	GHD (2020).
Jan Jac GMA	UEVF	Average 0.5-1.5 m/d (4.5 m/d over sand layers)	N/a	110	9.4×10^{-4}	GHD (2011), as cited in GHD (2020).
Jan Jac GMA	LEVF	Average 3-5 m/d (30-180 m/d over sand layers)	N/a	300-500	8.5×10^{-4}	
Jan Jac GMA	UEVF	0.5-40 m/d (average 0.5 for UEVF and 4.5 m/d for sand layers)	N/a	110	9.4×10^{-4}	GHD (2019), as cited in GHD (2020).
Jan Jac GMA	Eastern View Formation	2.8	N/a	530	N/a	DELWP (2016), as cited in GHD (2020).
Otway Basin	LTA	4-40	N/a	N/a	N/a	Bush (2009), as cited in SKM (2010d).

Table 8-20 Otway-Torquay GMB – LMTA and LTA K_h statistics

K_h statistical parameter	Value	
	LMTA	LTA
Number of data points	2	26
Minimum	0.5 m/d	1.0 m/d
P20	N/a (3 m/d)	3 m/d
P50	N/a (8 m/d)	8.3 m/d (15 m/d adopted) ⁽¹⁾

K _h statistical parameter	Value	
	LMTA	LTA
Average	7.0 m/d	14.6 m/d
P80	N/a (15 m/d)	22 m/d
Maximum	18.8 m/d	84 m/d
Standard deviation	N/a	18.4

Notes:

The shaded cells indicate the P20 K, P50 K and P80 K values adopted in the gridded throughflow rate analysis.

The inputted K values were rounded to the nearest 0.5 for the throughflow analysis.

N/a: Insufficient K_h point data to inform statistical analysis. In the absence of sufficient K point data, the typical K ranges from pumping tests informed the selection of representative values of P20, P50 and P80 K for adoption in the throughflow assessment. These adopted values are indicated in brackets.

(1) For the LTA P50 K, 15 m/d was adopted in keeping with the average K of the dataset and the expected range for this unit of 4-40 m/d (Bush (2009), as cited in SKM (2010d)).

8.3 Outputs

8.3.1 Glenelg WSPA (abolished)

The Glenelg WSPA (abolished) is designated flow-tubes LMTA ft03 and LTA ft11 (Table 8-1). The predevelopment throughflows for these flow-tubes relies on throughflow outputs from the following cross-sections perpendicular to groundwater flow:

- LMTA ft03: 10 m and 20 m modelled RWL contours.
- LTA ft11: 20 m, 40 m and 60 m modelled RWL contours.

The (P50 K) predevelopment throughflow estimate of each cross-section in the LMTA ft03 and LTA ft11 is reported in Table 8-21. The corresponding average, lower and upper range (P50 K), and lower range minimum (P20 K) predevelopment throughflow estimates for the flow-tubes, and a combined estimate, are also reported. The spatial variability of the calculated throughflow rate within the flow-tubes, and combined, is represented by the SD and CV in Table 8-21.

Table 8-21 Predevelopment throughflow estimates for flow-tubes - LMTA ft03 and LTA ft11

Parameter	Value
LMTA ft03	
P50 K PD throughflow, Cross-section 1 (10 m RWL) (ML/y)	5,689
P50 K PD throughflow, Cross-section 2 (20 m RWL) (ML/y)	2,123
Average (P50 K) PD throughflow (ML/y)	3,906
Lower range (P50 K) PD throughflow (ML/y)	2,123
Upper range (P50 K) PD throughflow (ML/y)	5,689
Lower range minimum (P20 K) PD throughflow (ML/y)	796
SD (ML/y)	2,521
CV (%)	65
Approximate length of flow-tube (km)	25
LTA ft11	
P50 K PD throughflow, Cross-section 1 (20 m RWL) (ML/y)	151,958
P50 K PD throughflow, Cross-section 2 (40 m RWL) (ML/y)	118,993
P50 K PD throughflow, Cross-section 3 (60 m RWL) (ML/y)	63,221
Average (P50 K) PD throughflow (ML/y)	111,390
Lower range (P50 K) PD throughflow (ML/y)	63,221

Confined Aquifer Throughflow Assessment – Updated Method and Phase B State-wide Rollout

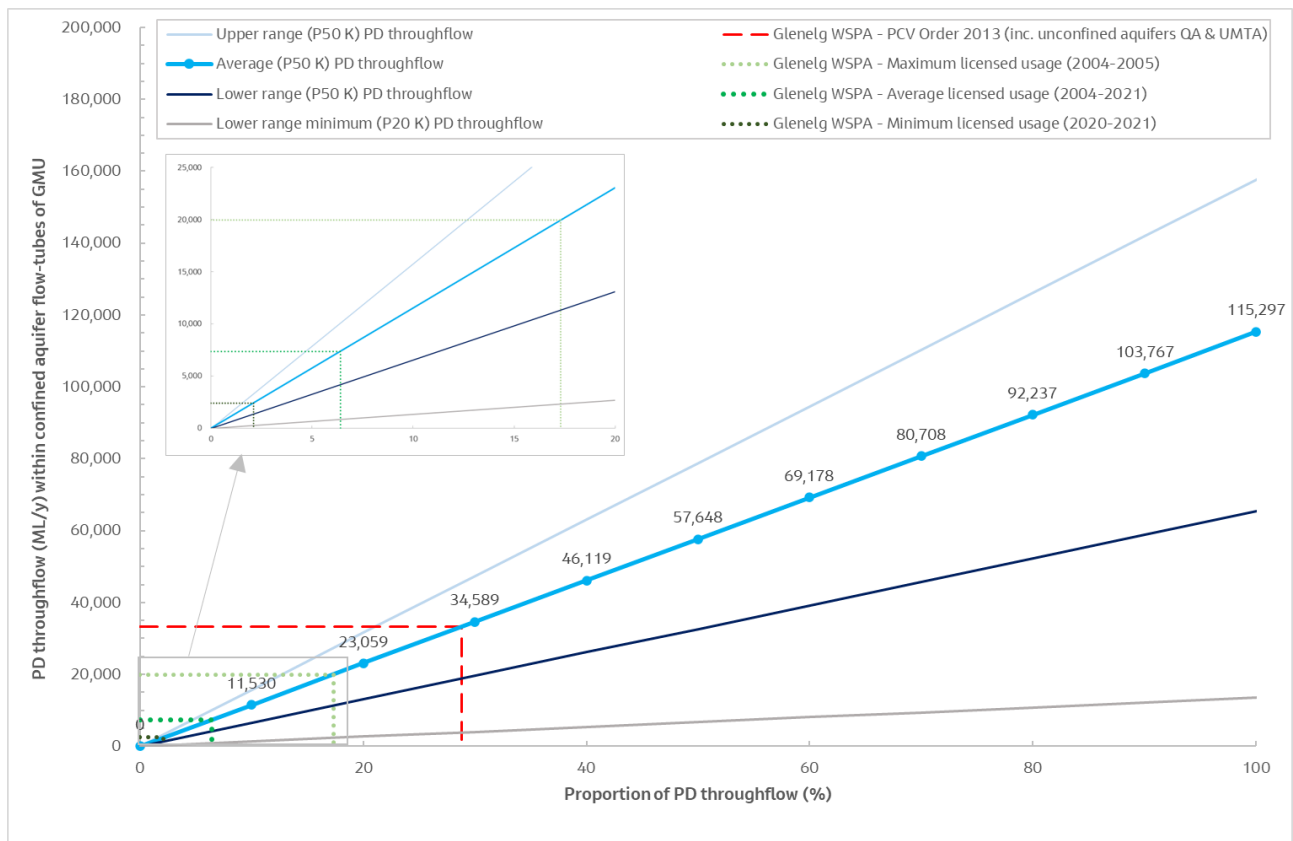
Parameter	Value
Upper range (P50 K) PD throughflow (ML/y)	151,958
Lower range minimum (P20 K) PD throughflow (ML/y)	12,644
SD (ML/y)	23,310
CV (%)	21
Approximate length of flow-tube (km)	115
Combined LMTA ft03 and LTA ft11	
Average (P50 K) PD throughflow (ML/y)	115,297
Lower range (P50 K) PD throughflow (ML/y)	65,344
Upper range (P50 K) PD throughflow (ML/y)	157,647
Lower range minimum (P20 K) PD throughflow (ML/y)	13,440
SD (ML/y)	25,831
CV (%)	22

Note:

All of the cross-sections occur within the GMU boundary.

To assist with contextualising the throughflow outputs, the average, lower and upper range (P50 K) and lower range minimum (P20 K) predevelopment throughflow estimates for combined flow-tubes LMTA ft03 and LTA ft11 are presented in Figure 8-1. For comparison, the Glenelg WSPA PCV (abolished) and minimum, average and maximum licensed usage values are overlaid on the figure.

Figure 8-1 Glenelg WSPA (abolished) - PCV and licensed usage relative to relative to predevelopment throughflow estimates of combined flow-tubes LMTA ft03 and LTA ft11



The throughflow results of the flow-tubes, and their spatial variability, are summarised in Table 8-22 in the context of historic management arrangements and licensed usage in the now abolished Glenelg WSPA, including considerations for assigning a sustainable yield.

Table 8-22 Summary of predevelopment throughflows in context of Glenelg WSPA (abolished)

Flow-tube parameter	Result
Confined VAF layers	LMTA and LTA.
Comparison with WSPA boundary	For both flow-tubes LMTA ft03 and LTA ft 11, a number of UA cells occur to the east of the WSPA. The WSPA represents between approximately 60% of the flow-tube length in the LMTA and the entire length for the LTA.
Flow from, or to, GMUs or UAs	For the LMTA, upgradient flow from an UA to the WSPA is indicated. For the LTA, there is indicated to be cross-border flows.
GMU PD throughflow estimate	All of the flow-tube cross-sections occur within the boundary of the WSPA. The average (P50 K) predevelopment throughflow of the WSPA is therefore estimated to be 115,297 ML/y .
Confined aquifer(s) contributing majority of PD throughflow	Dilwyn Formation (LTA) (97%).
CV (%) and potential factors contributing to spatial variability	CV: 22 %.
PCV (historic) relative to PD throughflow	The historic PCV (33,262 ML/y) represents 29 % of the average (P50 K) predevelopment throughflow (115,297 ML/y) but allowing for spatial variability may be between 21 % and 51 %. The historic PCV represents 247 % of the lower range minimum (P20 K) predevelopment throughflow.
Average licensed usage relative to PD throughflow	The average licensed usage (7,383 ML/y) represents 6 % of the average (P50 K) predevelopment throughflow (115,297 ML/y) but allowing for spatial variability may be between 5 % and 11 %. The average licensed usage represents 55 % of the lower range minimum (P20 K) predevelopment throughflow.
Relative rankings (Appendix B)	Relative reliability ranking: Low; Relative uncertainty ranking: Low; Relative potential for adverse impact on aquifer value(s): Low; Overall GMU ranking: Low-Low.
Considerations for assigning sustainable yield	<ul style="list-style-type: none"> ▪ The unconfined QA aquifer (Bridgewater Formation) formed part of the abolished Glenelg WSPA and is subject to the CDM Smith unconfined aquifer sustainable yield study. The assessment of the overall sustainable yield will therefore need to consider contributions from this unconfined aquifer. ▪ For the LMTA, upgradient flow from an UA to the WSPA is indicated. ▪ Equitable sharing of the groundwater resource due to the potential for cross-border flows in the LTA.

8.3.2 Portland GMA

The Portland GMA is designated flow-tube LTA ft12 (Table 8-1). The predevelopment throughflow estimates for LTA ft12 rely on throughflow outputs from four cross-sections perpendicular to groundwater flow (at 20 m, 40 m, 60 m and 100 m modelled RWL contours).

The (P50 K) predevelopment throughflow estimate of each cross-section in the LTA ft12 is reported in Table 8-23. The corresponding average, lower and upper range (P50 K), and lower range minimum (P20 K) predevelopment throughflow estimates for the flow-tube are also reported. The spatial variability of throughflow within the flow-tube is represented by the SD and CV in Table 8-23.

Table 8-23 Predevelopment throughflow estimates for flow-tube LTA ft12

Parameter	Value
P50 K PD throughflow, Cross-section 1 (20 m RWL) (ML/y)	329,435
P50 K PD throughflow, Cross-section 2 (40 m RWL) (ML/y)	222,400
P50 K PD throughflow, Cross-section 3 (60 m RWL) (ML/y)	134,616

Confined Aquifer Throughflow Assessment – Updated Method and Phase B State-wide Rollout

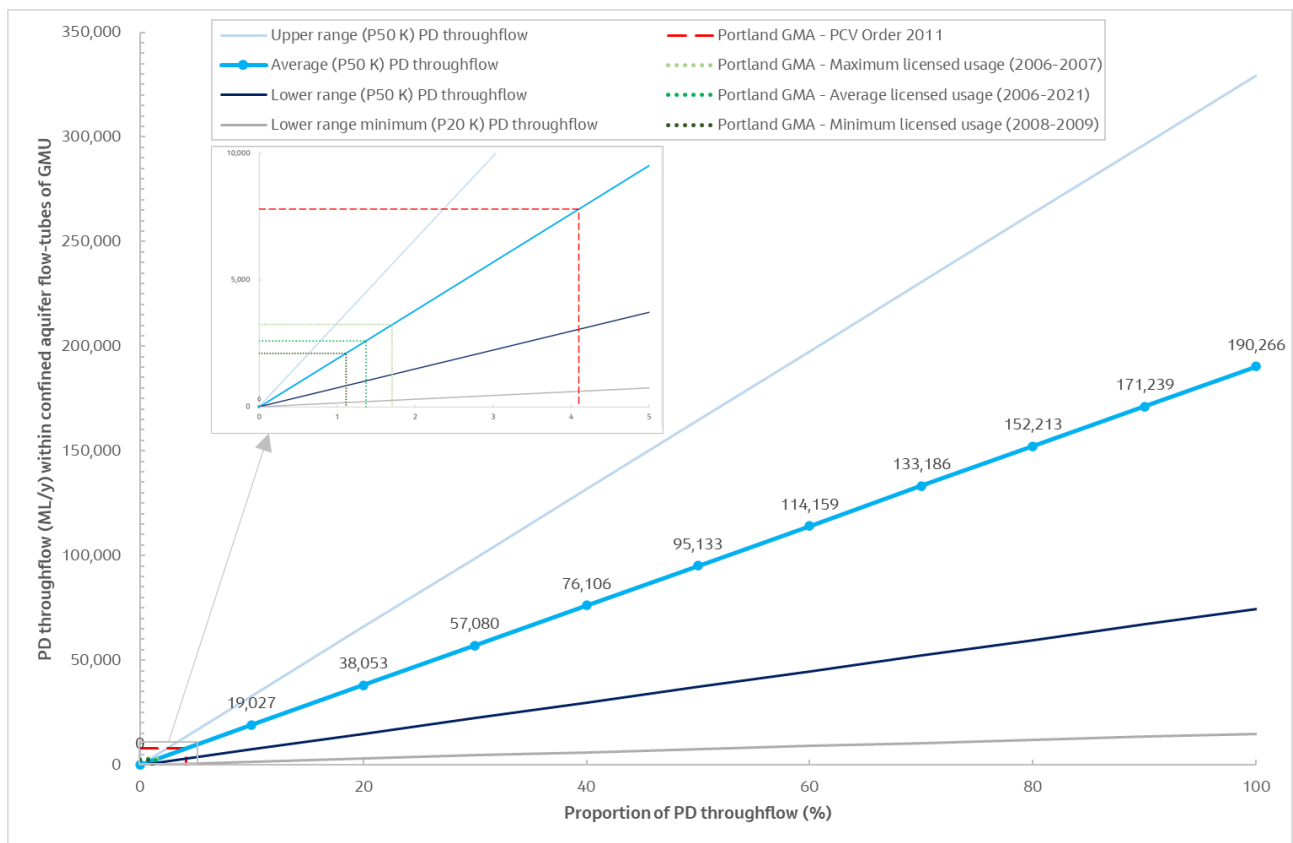
Parameter	Value
P50 K PD throughflow, Cross-section 4 (100 m RWL) (ML/y)	74,613
Average (P50 K) PD throughflow (ML/y)	190,266
Lower range (P50 K) PD throughflow (ML/y)	74,613
Upper range (P50 K) PD throughflow (ML/y)	329,435
Lower range minimum (P20 K) PD throughflow (ML/y)	14,923
SD (ML/y)	97,568
CV (%)	51
Approximate length of flow-tube (km)	65

Note:

All of the cross-sections occur within the GMU boundary, however they include the entire width of the flow-tube, including UA cells in the east.

To assist with contextualising the throughflow outputs, the average, lower and upper range (P50 K) and lower range minimum (P20 K) predevelopment throughflow estimates for flow-tube LTA ft12 are presented in Figure 8-2. For comparison, the Portland GMA PCV and minimum, average and maximum licensed usage values are overlaid on the figure.

Figure 8-2 Portland GMA - PCV and licensed usage relative to predevelopment throughflow estimate of flow-tube LTA ft12



The throughflow results of the flow-tube, and its spatial variability, are summarised in Table 8-24 in the context of management arrangements and licensed usage for the Portland GMA, including considerations for assigning a sustainable yield.

Table 8-24 Summary of predevelopment throughflows in context of Portland GMA

Flow-tube parameter	Result
Confined VAF layers	LTA.
Comparison with GMA boundary	Narrowing of the GMA boundary in the northeast is such that the GMA occupies a proportion of the width of the flow-tube in this area. Where the GMA narrows, the flow-tube is occupied by UA cells. The GMA generally represents the entire length for the flow-tube.
Flow from, or to, GMUs or UAs	Apart from the UA cells in the northeast, the GMA does not receive flow from, or contribute flow to, another GMU or UA.
GMU PD throughflow estimate	All of the flow-tube cross-sections occur within the boundary of the WSPA. The average (P50 K) predevelopment throughflow of the GMA is therefore estimated to be 190,266 ML/y .
CV (%) and potential factors contributing to spatial variability	CV: 51 %.
PCV relative to PD throughflow	The PCV (7,795 ML/y) represents 4 % of the average (P50 K) predevelopment throughflow (190,266 ML/y) but allowing for spatial variability may be between 2 % and 10 %. The PCV represents 52 % of the lower range minimum (P20 K) predevelopment throughflow.
Average licensed usage relative to PD throughflow	The average licensed usage (7,795 ML/y) represents 4 % of the average (P50 K) predevelopment throughflow (190,266 ML/y) but allowing for spatial variability may be between 2 % and 10 %. The average licensed usage represents 52 % of the lower range minimum (P20 K) predevelopment throughflow.
Relative rankings (Appendix B)	Relative reliability ranking: Low; Relative uncertainty ranking: Medium; Relative potential for adverse impact on aquifer value(s): Low; Overall GMU ranking: Medium-Low .
Considerations for assigning sustainable yield	The north-eastern boundary of the GMA boundary does not capture the inferred extent of the flow-tube. These cells to the northeast of the GMA are within an UA.

8.3.3 Condah WSPA

The Condah WSPA is designated flow-tube LMTA ft04 (Table 8-1). The predevelopment throughflows for LMTA ft04 relies on throughflow outputs from six cross-sections perpendicular to groundwater flow (at 15 m, 30 m, 55 m, 80 m, 140 m and 180 m modelled RWL contours).

The (P50 K) predevelopment throughflow estimate of each cross-section in the LMTA ft04 is reported in Table 8-25. The corresponding average, lower and upper range (P50 K), and lower range minimum (P20 K) predevelopment throughflow estimates for the flow-tube are also reported. The spatial variability of throughflow within the flow-tube is represented by the SD and CV in Table 8-25.

Table 8-25 Predevelopment throughflow estimates for flow-tube LMTA ft04

Parameter	Value
P50 K PD throughflow, Cross-section 1 (15 m RWL) (ML/y)	3,443
P50 K PD throughflow, Cross-section 2 (30 m RWL) (ML/y)	3,726
P50 K PD throughflow, Cross-section 3 (55 m RWL) (ML/y) ⁽¹⁾	12,127
P50 K PD throughflow, Cross-section 4 (80 m RWL) (ML/y) ⁽¹⁾	26,104
P50 K PD throughflow, Cross-section 5 (140 m RWL) (ML/y)	13,254
P50 K PD throughflow, Cross-section 6 (180 m RWL) (ML/y)	13,136
Average (P50 K) PD throughflow (ML/y)	11,965
Lower range (P50 K) PD throughflow (ML/y)	3,443
Upper range (P50 K) PD throughflow (ML/y)	26,104
Lower range minimum (P20 K) PD throughflow (ML/y)	1,291
SD (ML/y)	8,288

Confined Aquifer Throughflow Assessment – Updated Method and Phase B State-wide Rollout

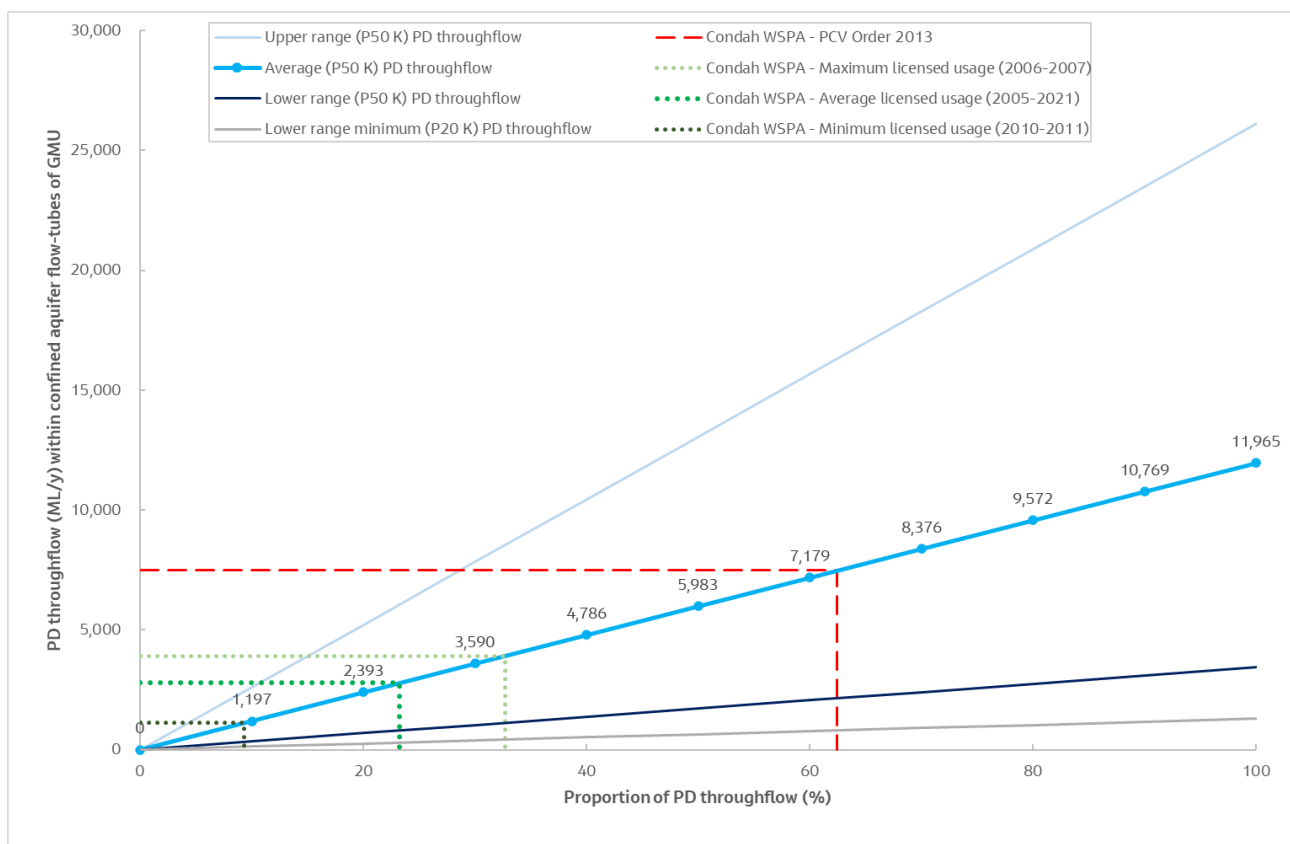
Parameter	Value
CV (%)	69
Approximate length of flow-tube (km)	75

Note:

(1) The cross-sections identified occur within the boundary of the Condah WSPA, however they include the entire width of the flow-tube, including UA cells in the east.

To assist with contextualising the throughflow outputs, the average, lower and upper range (P50 K) and lower range minimum (P20 K) predevelopment throughflow estimates for flow-tube LMTA ft04 are presented in Figure 8-3. For comparison, the Condah WSPA PCV and minimum, average and maximum licensed usage values are overlaid on the figure.

Figure 8-3 Condah WSPA - PCV and licensed usage relative to predevelopment throughflow estimate of flow-tube LMTA ft04



The throughflow results of the flow-tube, and its spatial variability, are summarised in Table 8-26 in the context of management arrangements and licensed usage in the Condah WSPA, including considerations for assigning a sustainable yield.

Table 8-26 Summary of predevelopment throughflows in context of Condah WSPA

Flow-tube parameter	Result
Confined VAF layers	LMTA.
Comparison with WSPA boundary	Apart from the southern boundary of the GMA, the width of the flow tube is partly occupied by UA cells. The GMA represents 40 % of the length of the flow-tube.

Confined Aquifer Throughflow Assessment – Updated Method and Phase B State-wide Rollout

Flow-tube parameter	Result
Flow from, or to, GMUs or UAs	As indicated by the inferred flow-tube, the GMA receives flow from, and contributes flow to UAs.
GMU PD throughflow estimate	The average (P50 K) predevelopment throughflow of the cross-sections within the Condah GMA , is 19,116 ML/y , compared with the that estimated for the entire flow-tube of 11,965 ML/y .
CV (%) and potential factors contributing to spatial variability	CV: 69 %.
PCV relative to PD throughflow	The PCV (7,470 ML/y) represents 62 % of the average (P50 K) predevelopment throughflow (11,965 ML/y) but allowing for spatial variability may be between 29 % and 217 %. The PCV represents 579 % of the lower range minimum (P20 K) predevelopment throughflow.
Average licensed usage relative to PD throughflow	The average licensed usage (2,782 ML/y) represents 23 % of the average (P50 K) predevelopment throughflow (11,965 ML/y) but allowing for spatial variability may be between 11 % and 81 %. The average licensed usage represents 215 % of the lower range minimum (P20 K) predevelopment throughflow.
Relative rankings (Appendix B)	Relative reliability ranking: Medium; Relative uncertainty ranking: Medium; Relative potential for adverse impact on aquifer value(s): Low; Overall GMU ranking: Medium-Low.
Considerations for assigning sustainable yield	<ul style="list-style-type: none"> The eastern boundary of the GMA does not capture the inferred extent of the flow-tube. These cells to the east of the GMA are within an UA. The GMA occupies 40 % of the length of the flow-tube with the GMA receiving flow from, and contributing flow to, UAs.

8.3.4 Paaratte GMA

The Paaratte GMA is designated flow-tube LTA ft14 (Table 8-1). The predevelopment throughflows for LTA ft14 rely on throughflow outputs from three cross-sections perpendicular to groundwater flow (at 30 m, 40 m and 70 m modelled RWL contours).

The (P50 K) predevelopment throughflow estimate of each cross-section in the LTA ft14 is reported in Table 8-27. The corresponding average, lower and upper range (P50 K), and lower range minimum (P20 K) predevelopment throughflow estimates for the flow-tube are also reported. The spatial variability of throughflow within the flow-tube is represented by the SD and CV in Table 8-27.

Table 8-27 Predevelopment throughflow estimates for flow-tube LTA ft14

Parameter	Value
P50 K PD throughflow, Cross-section 1 (30 m RWL) (ML/y)	116,672
P50 K PD throughflow, Cross-section 2 (40 m RWL) (ML/y)	219,736
P50 K PD throughflow, Cross-section 3 (70 m RWL) (ML/y)	102,243
Average (P50 K) PD throughflow (ML/y)	146,217
Lower range (P50 K) PD throughflow (ML/y)	102,243
Upper range (P50 K) PD throughflow (ML/y)	219,736
Lower range minimum (P20 K) PD throughflow (ML/y)	20,449
SD (ML/y)	64,077
CV (%)	44
Approximate length of flow-tube (km)	55

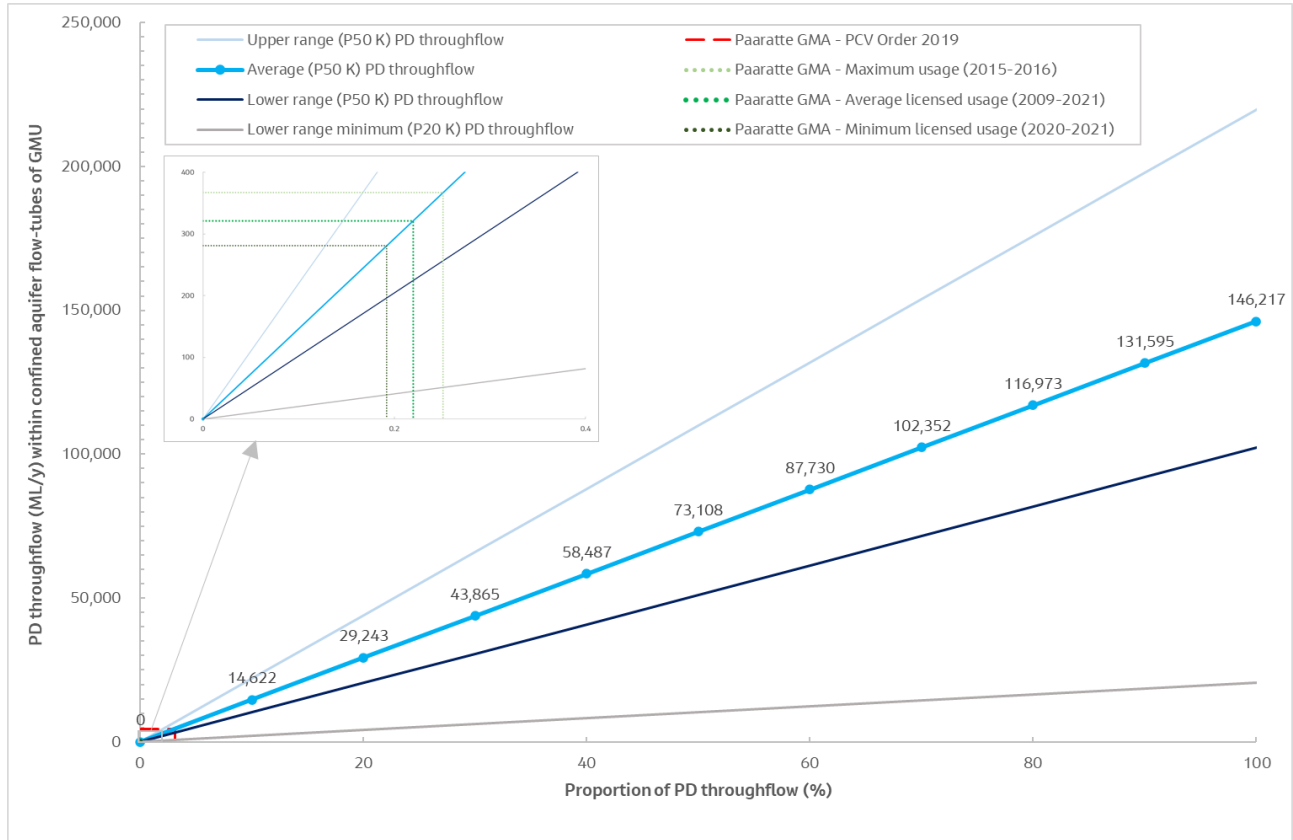
Note:

All of the cross-sections occur within the GMU boundary.

To assist with contextualising the throughflow outputs, the average, lower and upper range (P50 K) and lower range minimum (P20 K) predevelopment throughflow estimates for flow-tube LTA ft14 are presented in

Figure 8-4. For comparison, the Condah WSPA PCV and minimum, average and maximum licensed usage values are overlaid on the figure.

Figure 8-4 Paaratte GMA - PCV and licensed usage relative to predevelopment throughflow estimate of flow-tube LTA ft14



The throughflow results of the flow-tube, and its spatial variability, are summarised in Table 8-28 in the context of management arrangements and licensed usage in the Paaratte GMA, including considerations for assigning a sustainable yield.

Table 8-28 Summary of predevelopment throughflows in context of Paaratte GMA

Flow-tube parameter	Result
Confined VAF layers	LTA.
Comparison with GMA boundary	The GMA boundary generally occupies the entire width and length of the flow-tube, with the exception of a number of UA cells in the north.
Flow from, or to, GMUs or UAs	Apart from the UA cells in the north, the GMA does not receive flow from, or contribute flow to, another GMU or UA.
GMU PD throughflow estimate	All of the flow-tube cross-sections occur within the boundary of the GMA. The average (P50 K) predevelopment throughflow of the GMA is therefore estimated to be 146,217 ML/y .
CV (%) and potential factors contributing to spatial variability	CV: 44 %.
PCV relative to PD throughflow	The PCV (4,606 ML/y) represents 3 % of the average (P50 K) predevelopment throughflow (146,217 ML/y) but allowing for spatial variability may be between 2 % and 5 %. The PCV represents 23 % of the lower range minimum (P20 K) predevelopment throughflow.

Flow-tube parameter	Result
Average licensed usage relative to PD throughflow	The average licensed usage (321 ML/y) represents < 1 % of the average (P50 K) predevelopment throughflow (146,217 ML/y) including allowing for spatial variability. The average licensed usage represents 2 % of the lower range minimum (P20 K) predevelopment throughflow.
Relative rankings (Appendix B)	Relative reliability ranking: Low; Relative uncertainty ranking: Low; Relative potential for adverse impact on aquifer value(s): Low; Overall GMU ranking: Low-Low.
Considerations for assigning sustainable yield	The northern boundary of the GMA boundary does not capture the inferred extent of the flow-tube. These cells to the north of the GMA are within an UA.

8.3.5 Newlingrook GMA

The Newlingrook GMA is designated flow-tube LTA ft15 (Table 8-1). The predevelopment throughflows for LTA ft15 rely on throughflow outputs from one cross-section perpendicular to groundwater flow (at 40 m modelled RWL contours).

The (P50 K) predevelopment throughflow estimate of the cross-section in the LTA ft15 is reported in Table 8-29. The corresponding (adopted) average (P50 K) and the lower range minimum (P20 K) predevelopment throughflow estimates for the flow-tube are also reported. As only one cross-section informs the throughflow assessment, the spatial variability of the throughflow calculation has not been assessed.

Table 8-29 Predevelopment throughflow estimates for flow-tube - LTA ft15

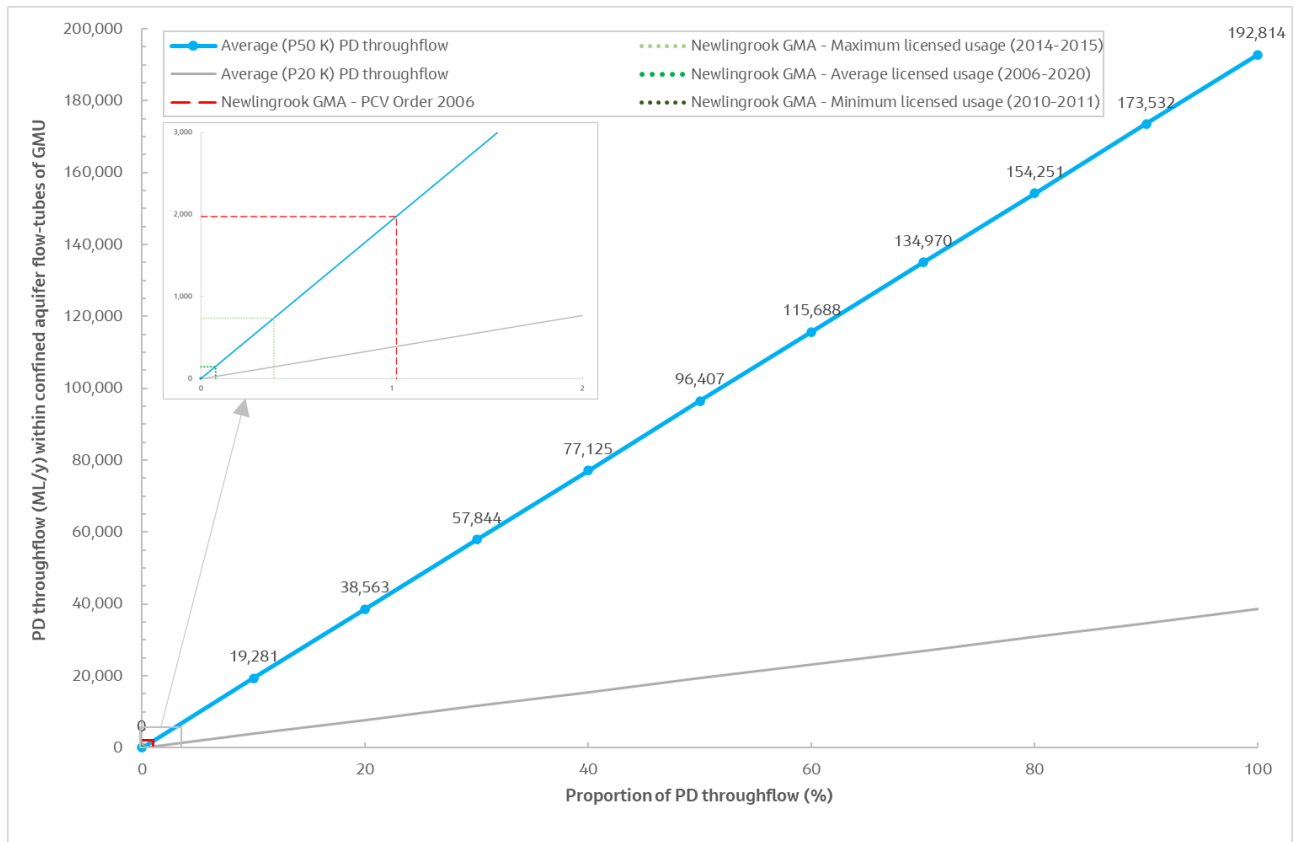
Parameter	Value
P50 K PD throughflow, Cross-section 1 (40 m RWL) (ML/y)	192,814
Adopted average (P50 K) PD throughflow (ML/y)	192,814
Lower range minimum (P20 K) PD throughflow (ML/y)	38,563
Approximate length of flow-tube (km)	15

Note:

The cross-section occurs within the GMU boundary.

To assist with contextualising the throughflow outputs, the average (P50 K) and lower range minimum (P20 K) predevelopment throughflow estimates for flow-tube LTA ft15 are presented in Figure 8-5. For comparison, the Newlingrook GMA PCV and minimum, average and maximum licensed usage values are overlaid on the figure.

Figure 8-5 Newlingrook GMA - PCV and licensed usage relative to predevelopment throughflow estimate of flow-tube LTA ft15



The throughflow results of the flow-tube are summarised in Table 8-30 in the context of management arrangements and licensed usage in the Newlingrook GMA, including considerations for assigning a sustainable yield.

Table 8-30 Summary of predevelopment throughflows in context of Newlingrook GMA

Flow-tube parameter	Result
Confined VAF layers	LTA.
Comparison with GMA boundary	The GMA boundary generally occupies the entire width and length of the flow-tubes.
Flow from, or to, GMUs or UAs	The GMA does not receive flow from, or contribute flow to, another GMU or UA.
GMU PD throughflow estimate	The flow-tube cross-section occurs within the boundary of the GMA. The average (P50 K) predevelopment throughflow of the GMA is therefore estimated to be 192,814 ML/y .
CV (%) and potential factors contributing to spatial variability	CV: N/a (one cross-section was assessed).
PD throughflow relative to PCV	The PCV (1,977 ML/y) represents 1 % of the average (P50 K) predevelopment throughflow (192,814 ML/y). The PCV represents 5 % of the lower range minimum (P20 K) predevelopment throughflow.
PD throughflow relative to average licensed usage	The average licensed usage (145 ML/y) represents < 1 % of the average (P50 K) predevelopment throughflow (192,814 ML/y). The average licensed usage also represents < 1 % of the lower range minimum (P20 K) predevelopment throughflow.
Relative ranking (Appendix B)	Relative reliability ranking: Low; Relative uncertainty ranking: High; Relative potential for adverse impact on aquifer value(s): Low; Overall GMU ranking: High-Low .

Flow-tube parameter	Result
Considerations for assigning sustainable yield	The Dilwyn Formation (LTA) is indicated to be largely thin or absent east of the Gellibrand River and a zonal approach to groundwater management may be required.

8.3.6 Gellibrand GMA

The Gellibrand GMA is designated flow-tube LTA ft16 (Table 8-1). The predevelopment throughflows for LTA ft16 rely on throughflow outputs from one cross-section perpendicular to groundwater flow (at 110 m modelled RWL contours).

The (P50 K) predevelopment throughflow estimate of the cross-section in the LTA ft16 is reported in Table 8-31. The corresponding (adopted) average (P50 K) and the lower range minimum (P20 K) predevelopment throughflow estimates for the flow-tube are also reported. As only one cross-section informs the throughflow assessment, the spatial variability of the throughflow calculation has not been assessed.

Table 8-31 Predevelopment throughflow estimates for flow-tube - LTA ft16

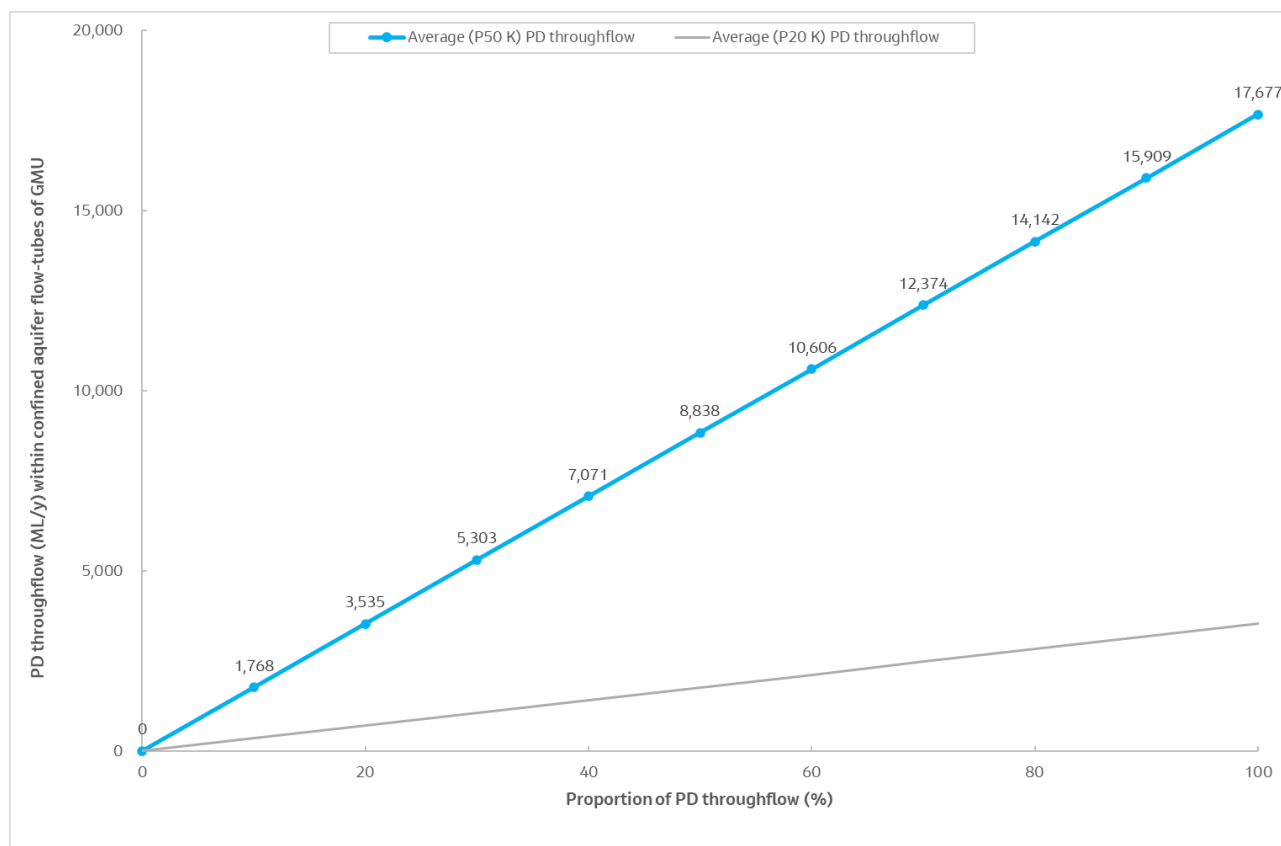
Parameter	Value
P50 K PD throughflow, Cross-section 1 (110 m RWL) (ML/y)	17,677
Adopted average (P50 K) PD throughflow (ML/y)	17,677
Lower range minimum (P20 K) PD throughflow (ML/y)	3,535
Approximate length of flow-tube (km)	5

Note:

The cross-section occurs within the GMU boundary.

To assist with contextualising the throughflow outputs, the average (P50 K) and lower range minimum (P20 K) predevelopment throughflow estimates for flow-tube LTA ft16 are presented in Figure 8-6. As the PCV and minimum, average and maximum licensed usage are 0 ML/y (Table 8-13), these parameters do not display on the figure.

Figure 8-6 Gellibrand GMA - predevelopment throughflow estimate of flow-tube LTA ft16



The throughflow results of the flow-tube is summarised in Table 8-32 in the context of management arrangements and licensed usage in the Gellibrand GMA, including considerations for assigning a sustainable yield.

Table 8-32 Summary of predevelopment throughflows in context of Gellibrand GMA

Flow-tube parameter	Result
Confined VAF layers	LTA.
Comparison with GMA boundary	The GMA boundary mostly occupies the entire width and length of the flow-tube.
Flow from, or to, GMUs or UAs	The GMA does not contribute flow to another GMU or UA. Groundwater flow is however indicated from the recharge area of the Barongarook High (within the Gerangamete GMA) to the Gellibrand GMA. Groundwater flow within the Dilwyn Formation is considered to discharge to Gellibrand River.
GMU PD throughflow estimate	The flow-tube cross-section occurs within the boundary of the GMA. The average (P50 K) predevelopment throughflow of the GMA is therefore estimated to be 17,677 ML/y .
CV (%) and potential factors contributing to spatial variability	CV: N/a (one cross-section was assessed).
PCV relative to PD throughflow	The PCV and licensed usage is 0 ML/y based on the assumption that groundwater in the Dilwyn Formation (LTA) largely discharges into the Gellibrand River which is fully allocated.
Average licensed usage relative to PD throughflow	As above.
Relative rankings (Appendix B)	Relative reliability ranking: Low; Relative uncertainty ranking: High; Relative potential for adverse impact on aquifer value(s): Low; Overall GMU ranking: High-Low .

Flow-tube parameter	Result
Considerations for assigning sustainable yield	Groundwater flow within the Dilwyn Formation is considered to discharge to Gellibrand River which is fully allocated.

8.3.7 Gerangamete GMA

The Gerangamete GMA is designated flow-tube LTA ft31 (Table 8-1). The predevelopment throughflows for LTA ft31 rely on throughflow outputs from two cross-sections perpendicular to groundwater flow (at 90 m and 145 m modelled RWL contours).

The (P50 K) predevelopment throughflow estimate of each cross-section in the LTA ft31 is reported in Table 8-33. The corresponding average, lower and upper range (P50 K), and lower range minimum (P20 K) predevelopment throughflow estimates for the flow-tube are also reported. The spatial variability of throughflow within the flow-tube is represented by the SD and CV in Table 8-33.

Table 8-33 Predevelopment throughflow estimates for flow-tube - LTA ft31

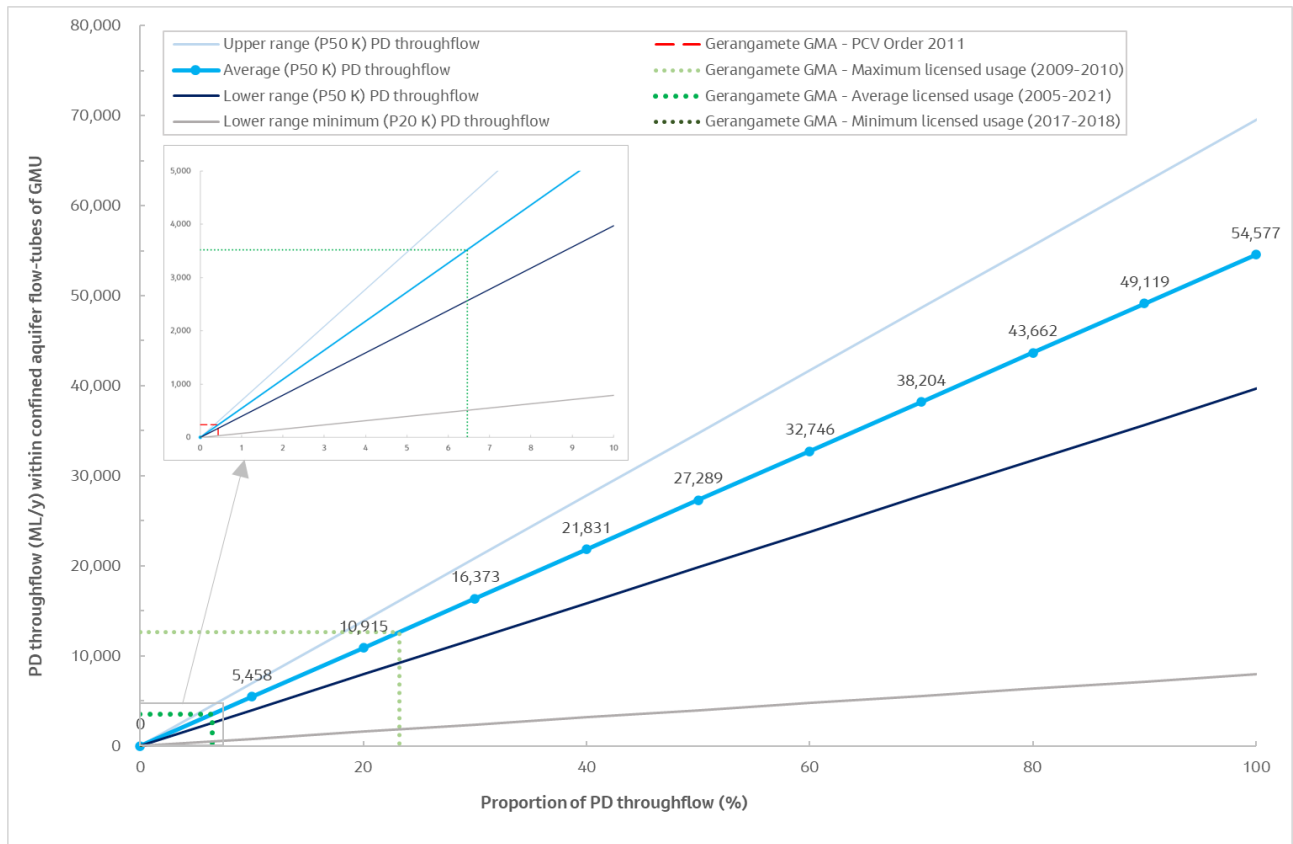
Parameter	Value
P50 K PD throughflow, Cross-section 1 (90 m RWL) (ML/y) ⁽¹⁾	39,652
P50 K PD throughflow, Cross-section 2 (145 m RWL) (ML/y)	69,502
Average (P50 K) PD throughflow (ML/y)	54,577
Lower range (P50 K) PD throughflow (ML/y)	39,652
Upper range (P50 K) PD throughflow (ML/y)	69,502
Lower range minimum (P20 K) PD throughflow (ML/y)	7,930
SD (ML/y)	21,107
CV (%)	39
Approximate length of flow-tube (km)	80

Note:

(1) The cross-section identified occurs within the boundary of the Gerangamete GMA.

To assist with contextualising the throughflow outputs, the average, lower and upper range (P50 K) and lower range minimum (P20 K) predevelopment throughflow estimates for flow-tube LTA ft31 are presented in Figure 8-7. For comparison, the Gerangamete GMA PCV and minimum, average and maximum licensed usage values are overlaid on the figure.

Figure 8-7 Gerangamete GMA - PCV and licensed usage relative to predevelopment throughflow estimate of flow-tube LTA ft31



The throughflow results of the flow-tube, and its spatial variability, are summarised in Table 8-34 in the context of management arrangements and licensed usage in the Portland GMA, including considerations for assigning a sustainable yield.

Table 8-34 Summary of predevelopment throughflows in context of Gerangamete GMA

Flow-tube parameter	Result
Confined VAF layers	LTA.
Comparison with GMA boundary	The GMA generally occupies the entire width of the flow-tube. The GMA occupies approximately 40 % of the flow-tube length with groundwater indicated to flow beyond the northern boundary to the northeast, within an UA.
Flow from, or to, GMUs or UAs	Groundwater is indicated to flow from the northern boundary of the GMA to an UA. Groundwater flow is also indicated from the recharge area of the Barongarook High (within the Gerangamete GMA) to the Gellibrand GMA.
GMU PD throughflow estimate	The average (P50 K) predevelopment throughflow of the cross-sections within the Gerangamete GMA is 39,502 ML/y (one cross-section only), compared with the that estimated for the entire flow-tube of 54,577 ML/y .
CV (%) and potential factors contributing to spatial variability	CV: 39 %. A range of spatially variable processes may be responsible including potential discharge to lake systems along the flow path of the flow-tube.
PD throughflow relative to PCV	The PCV (239 ML/y) represents < 1 % of the average (P50 K) predevelopment throughflow (54,577 ML/y) including allowing for spatial variability. The PCV represents 3 % of the lower range minimum (P20 K) predevelopment throughflow. It is noted that prior to Barwon Water withdrawing its licence renewal application for the Barwon Downs borefield, the PCV for the

Flow-tube parameter	Result
	Gerangamete GMA was substantially higher (i.e., a maximum of 20,000 ML in any one year) (Section 8.1.7).
PD throughflow relative to average licensed usage	The average licensed usage (3,524 ML/y) represents 6 % of the average (P50 K) predevelopment throughflow (54,577 ML/y) but allowing for spatial variability may be between 5 % and 9 %. The average licensed usage represents 44 % of the lower range minimum (P20 K) predevelopment throughflow.
Relative rankings (Appendix B)	Relative reliability ranking: Low; Relative uncertainty ranking: Low; Relative potential for adverse impact on aquifer value(s): Low; Overall GMU ranking: Low-Low.
Considerations for assigning sustainable yield	<ul style="list-style-type: none"> ▪ Potential groundwater flow from the recharge area of the Barongarook High (within the Gerangamete GMA) to the Gellibrand GMA. ▪ Potential groundwater flow beyond the northern boundary of the GMA, to the northeast within an UA and discharge to lake systems.

8.3.8 UA LMTA near Warrnambool

The UA LMTA near Warrnambool (Figure 5-4) is designated flow-tube LMTA ft05 (Table 8-1). The predevelopment throughflows for LMTA ft05 rely on throughflow outputs from one cross-section perpendicular to groundwater flow (at 20 m modelled RWL contours).

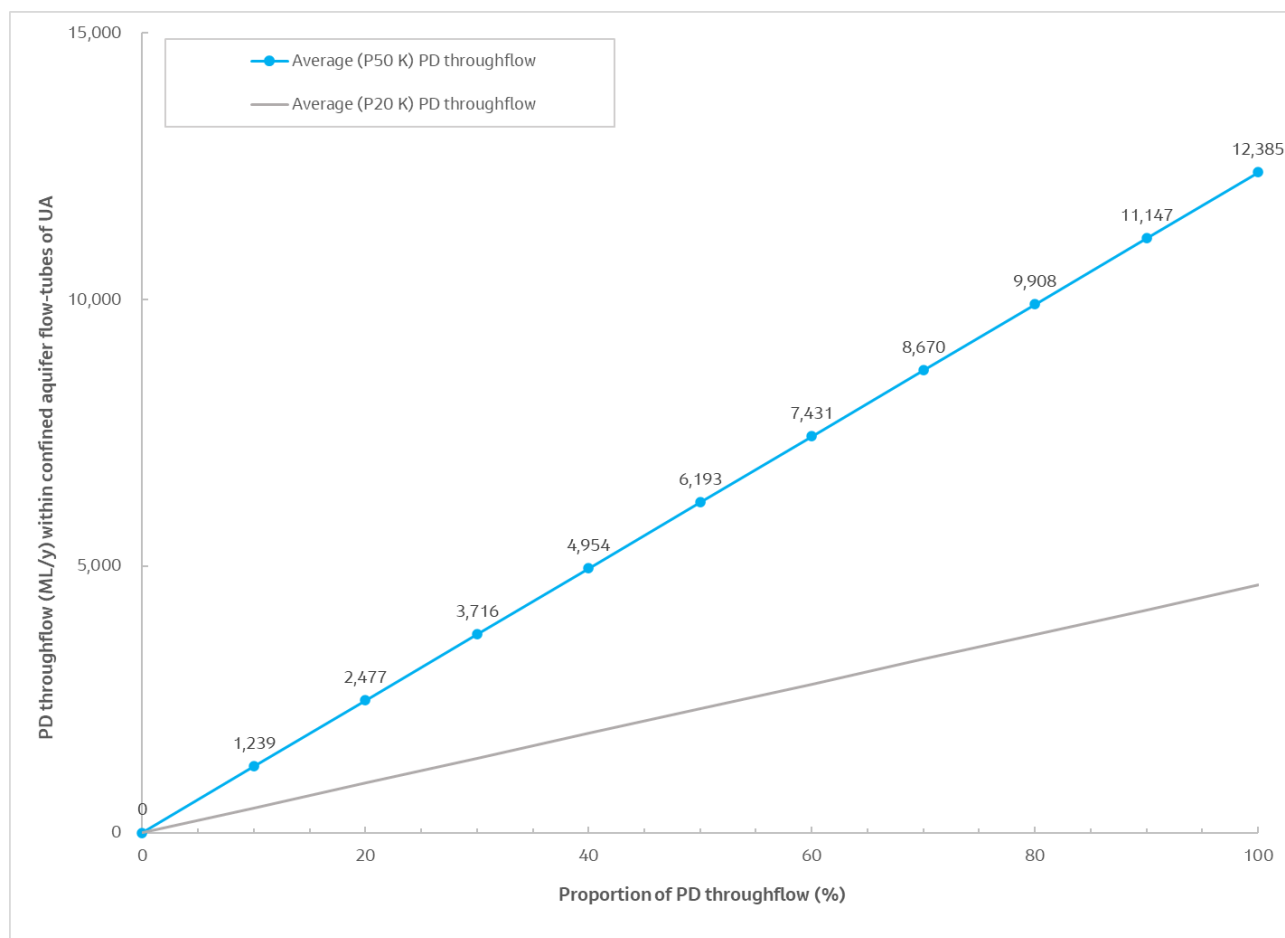
The (P50 K) predevelopment throughflow estimate of the cross-section in the LMTA ft05 is reported in Table 8-35. The corresponding (adopted) average (P50 K) and the lower range minimum (P20 K) predevelopment throughflow estimates for the flow-tube are also reported. As only one cross-section informs the throughflow assessment, the spatial variability of the throughflow calculation has not been assessed.

Table 8-35 Predevelopment throughflow estimates for flow-tube – LMTA ft05

Parameter	Value
P50 K PD throughflow, Cross-section 1 (20 m RWL) (ML/y)	12,385
Adopted (average) (P50 K) PD throughflow (ML/y)	12,385
Lower range minimum (P20 K) PD throughflow (ML/y)	4,644
Approximate length of flow-tube (km)	70

To assist with contextualising the throughflow outputs, the average (P50 K) and lower range minimum (P20 K) predevelopment throughflow estimates for flow-tube LMTA ft05 are presented in Figure 8-8.

Figure 8-8 Predevelopment throughflow estimates of flow-tube LMTA ft05 near Warrnambool



8.3.9 UA LTA north of Colac

The UA LTA north of Colac (Figure 5-6) is designated flow-tube LTA ft32 (Table 8-1). The predevelopment throughflows for LTA ft32 rely on throughflow outputs from two cross-sections perpendicular to groundwater flow (at 100 m and 35 m modelled RWL contours).

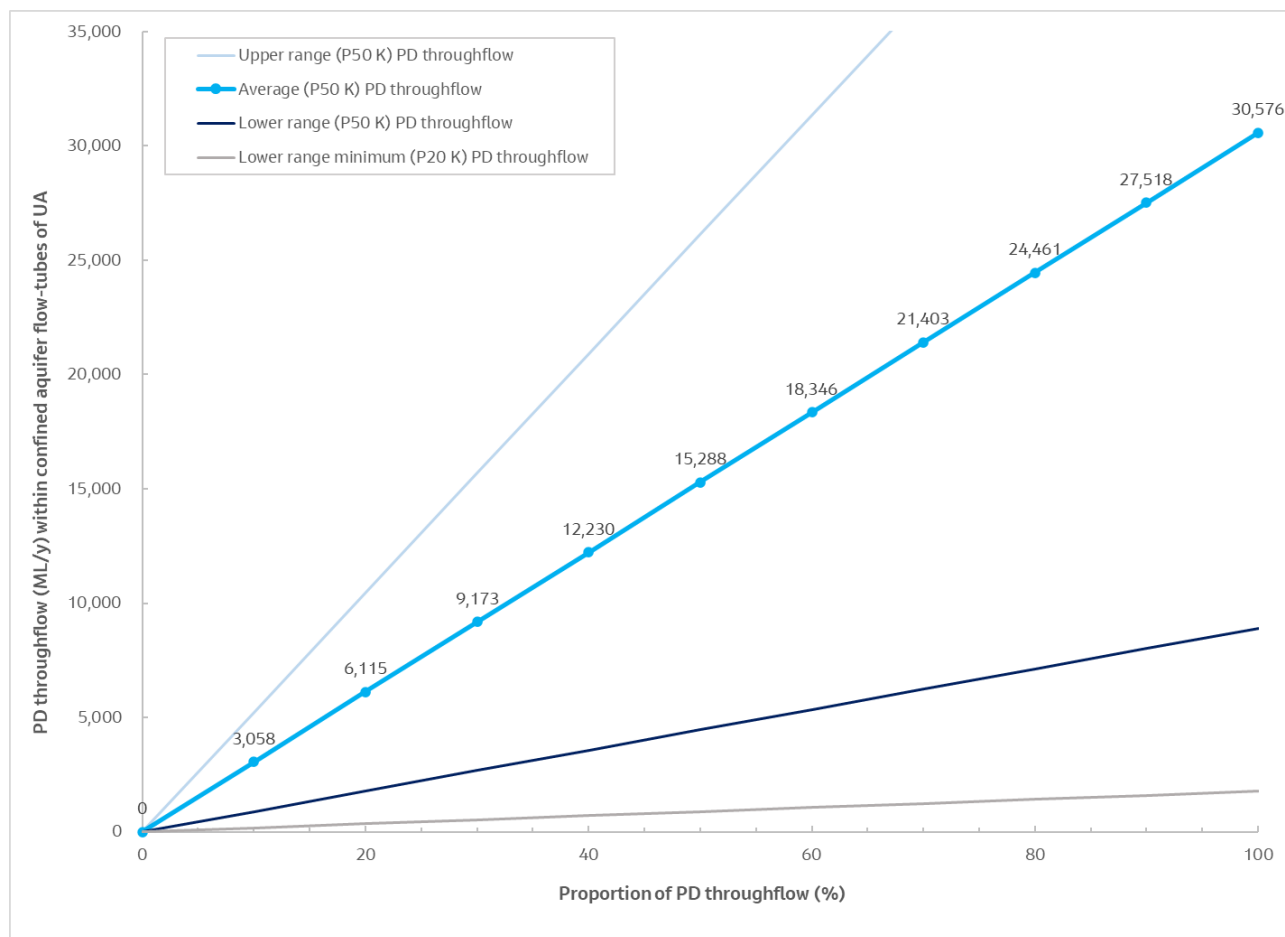
The (P50 K) predevelopment throughflow estimate of each cross-section in the LTA ft32 is reported in Table 8-36. The corresponding average, lower and upper range (P50 K), and lower range minimum (P20 K), predevelopment throughflow estimates for the flow-tube are also reported. The spatial variability of the calculated throughflow rate within the flow-tube is represented by the SD and CV in Table 8-36.

Table 8-36 Predevelopment throughflow estimates for flow-tube – LTA ft32

Parameter	Value
P50 K PD throughflow, Cross-section 1 (100 m RWL) (ML/y)	52,248
P50 K PD throughflow, Cross-section 2 (35 m RWL) (ML/y)	8,904
Average (P50 K) PD throughflow (ML/y)	30,576
Lower range (P50 K) PD throughflow (ML/y)	8,904
Upper range (P50 K) PD throughflow (ML/y)	52,248
Lower range minimum (P20 K) PD throughflow (ML/y)	1,781
SD (ML/y)	30,649
CV (%)	100
Approximate length of flow-tube (km)	100

To assist with contextualising the throughflow outputs, the average, lower and upper range (P50 K) and lower range minimum (P20 K) predevelopment throughflow estimates for flow-tube LTA ft32 are presented in Figure 8-9.

Figure 8-9 Predevelopment throughflow estimates of flow-tube LTA ft32 north of Colac



8.3.10 UA LTA near Warrnambool

The UA LTA near Warrnambool (Figure 5-6) is designated flow-tube LTA ft13 (Table 8-1). The predevelopment throughflows for LTA ft13 rely on throughflow outputs from two cross-sections perpendicular to groundwater flow (at 20 m and 40 m modelled RWL contours).

The (P50 K) predevelopment throughflow estimate of each cross-section in the LTA ft13 is reported in Table 8-37. The corresponding average, lower and upper range (P50 K), and lower range minimum (P20 K), predevelopment throughflow estimates for the flow-tube are also reported. The spatial variability of the calculated throughflow rate within the flow-tube is represented by the SD and CV in Table 8-37.

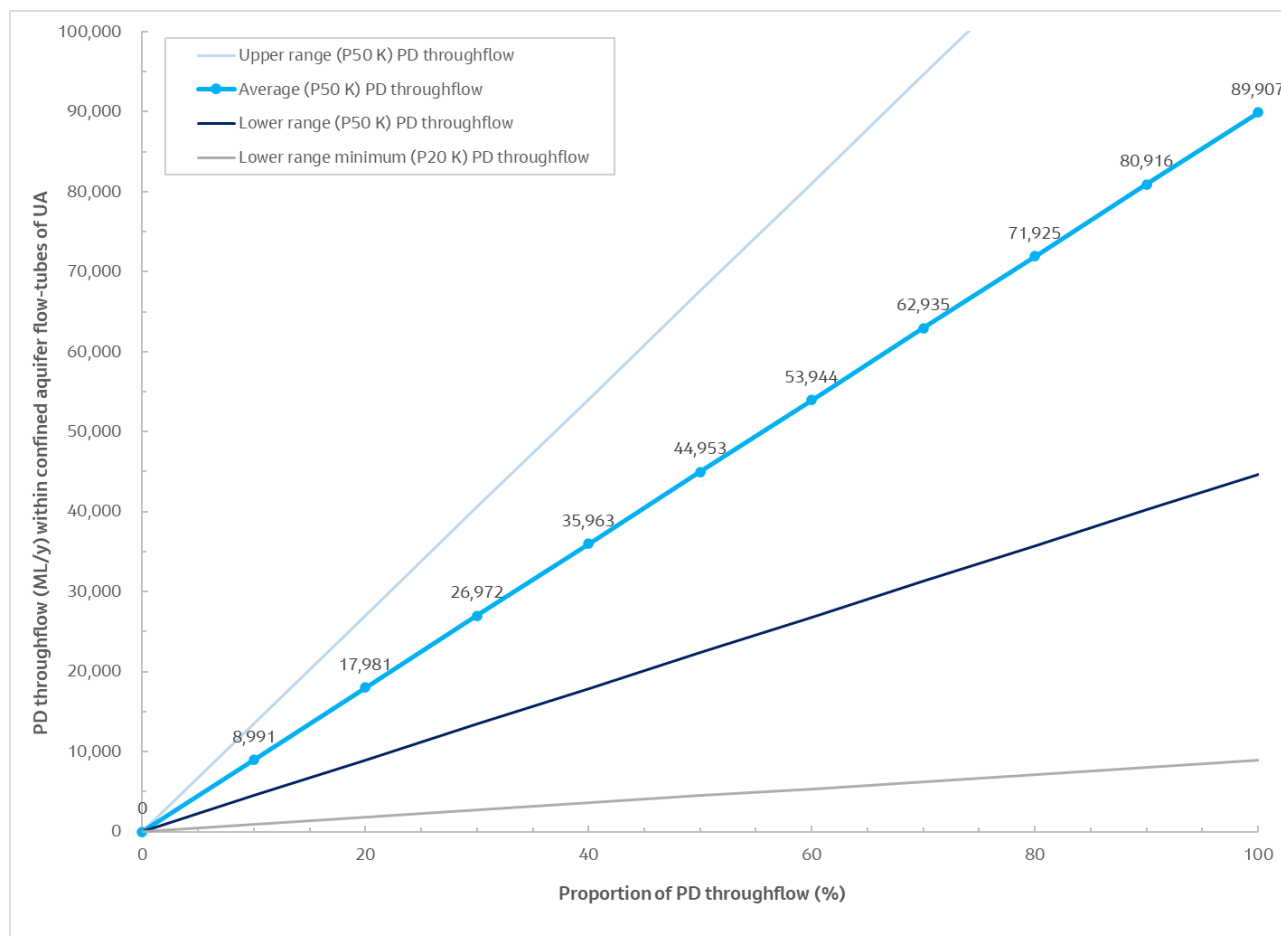
Table 8-37 Predevelopment throughflow estimates for flow-tube - LTA ft13

Parameter	Value
P50 K PD throughflow, Cross-section 1 (20 m RWL) (ML/y)	135,105
P50 K PD throughflow, Cross-section 2 (40 m RWL) (ML/y)	44,708
Average (P50 K) PD throughflow (ML/y)	89,907
Lower range (P50 K) PD throughflow (ML/y)	44,708
Upper range (P50 K) PD throughflow (ML/y)	135,105
Lower range minimum (P20 K) PD throughflow (ML/y)	8,942
SD (ML/y)	63,920

Parameter	Value
CV (%)	71
Approximate length of flow-tube (km)	50

To assist with contextualising the throughflow outputs, the average, lower and upper range (P50 K) and lower range minimum (P20 K) predevelopment throughflow estimates for flow-tube LTA ft13 are presented in Figure 8-10.

Figure 8-10 Predevelopment throughflow estimates of flow-tube LTA ft13 near Warrnambool



8.3.11 UA LTA near Skipton

The UA LTA near Skipton (Figure 5-6) is designated flow-tube LTA ft30 (Table 8-1). The predevelopment throughflows for LTA ft30 rely on throughflow outputs from three cross-sections perpendicular to groundwater flow (at 220 m, 240 m and 265 m modelled RWL contours).

The (P50 K) predevelopment throughflow estimate of each cross-section in the LTA ft30 is reported in Table 8-38. The corresponding average, lower and upper range (P50 K), and lower range minimum (P20 K), predevelopment throughflow estimates for the flow-tube are also reported. The spatial variability of the calculated throughflow rate within the flow-tube is represented by the SD and CV in Table 8-38.

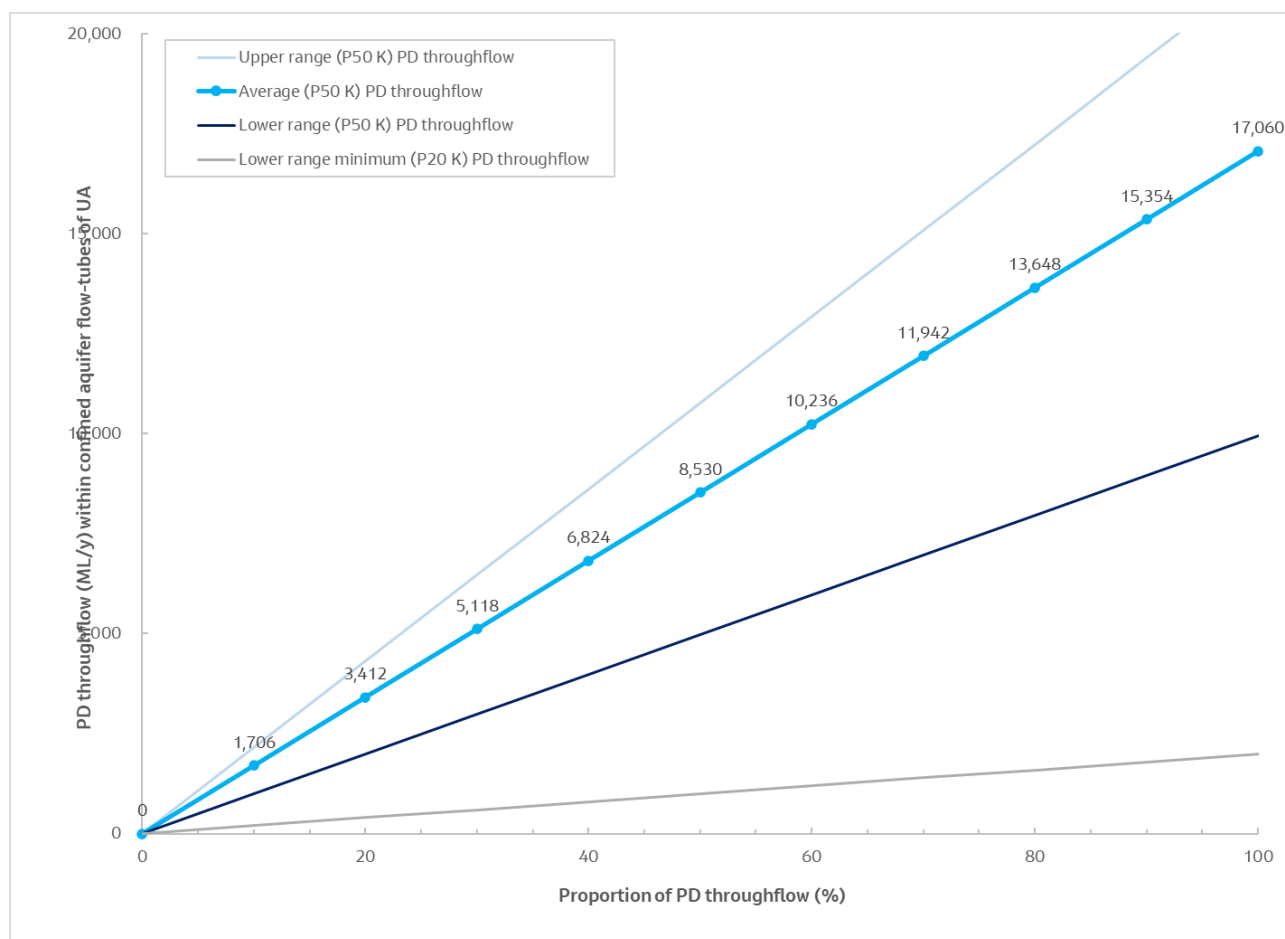
Table 8-38 Predevelopment throughflow estimates for flow-tube - LTA ft30

Parameter	Value
P50 K PD throughflow, Cross-section 1 (220 m RWL) (ML/y)	21,541
P50 K PD throughflow, Cross-section 2 (240 m RWL) (ML/y)	9,939

Parameter	Value
P50 K PD throughflow, Cross-section 3 (265 m RWL) (ML/y)	19,699
Average (P50 K) PD throughflow (ML/y)	17,060
Lower range (P50 K) PD throughflow (ML/y)	9,939
Upper range (P50 K) PD throughflow (ML/y)	21,541
Lower range minimum (P20 K) PD throughflow (ML/y)	1,988
SD (ML/y)	6,235
CV (%)	37
Approximate length of flow-tube (km)	50

To assist with contextualising the throughflow outputs, the average, lower and upper range (P50 K) and lower range minimum (P20 K) predevelopment throughflow estimates for flow-tube LTA ft13 are presented in Figure 8-11.

Figure 8-11 Predevelopment throughflow estimates of flow-tube LTA ft30 near Skipton



8.3.12 Jan Juc GMA

The Jan Juc GMA is designated flow-tube LTA ft17 (Table 8-1). The predevelopment throughflows for LTA ft17 rely on throughflow outputs from one cross-section perpendicular to groundwater flow (at 70 m modelled RWL contour).

The (P50 K) predevelopment throughflow estimate of each cross-section in the LTA ft17 is reported in Table 8-39. The corresponding (adopted) average (P50 K) and the lower range minimum (P20 K) predevelopment

throughflow estimates for the flow-tube are also reported. As only one cross-section informs the throughflow assessment, the spatial variability of the throughflow calculation has not been assessed.

Table 8-39 Predevelopment throughflow estimates for flow-tube - LTA ft17

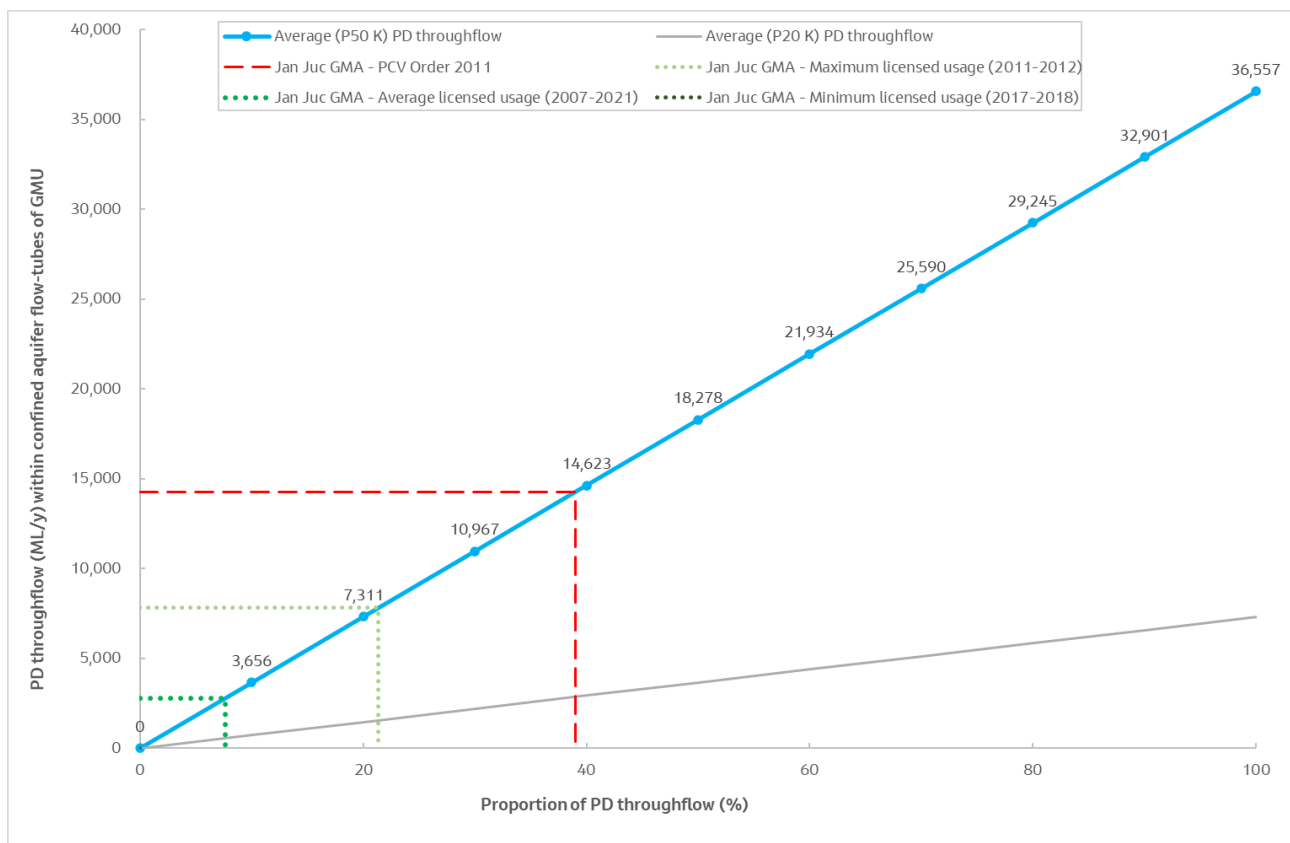
Parameter	Value
P50 K PD throughflow, Cross-section 1 (70 m RWL) (ML/y)	36,557
Adopted (average) (P50 K) PD throughflow (ML/y)	36,557
Lower range minimum (P20 K) PD throughflow (ML/y)	7,311
Approximate length of flow-tube (km)	5

Note:

The cross-section occurs within the GMU boundary.

To assist with contextualising the throughflow outputs, the average (P50 K) and lower range minimum (P20 K) predevelopment throughflow estimates for flow-tube LTA ft17 are presented in Figure 8-12. For comparison, the Jan Juc GMA PCV and minimum, average and maximum licensed usage values are overlaid on the figure.

Figure 8-12 Jan Juc GMA - PCV and licensed usage relative to predevelopment throughflow estimate of flow-tube LTA ft17



The throughflow results of the flow-tube are summarised in Table 8-40 in the context of management arrangements and licensed usage in the Jan Juc GMA, including considerations for assigning a sustainable yield.

Confined Aquifer Throughflow Assessment – Updated Method and Phase B State-wide Rollout

Table 8-40 Summary of predevelopment throughflows in context of Jan Juc GMA

Flow-tube parameter	Result
Confined VAF layers	LTA.
Comparison with GMA boundary	The GMA boundary mostly occupies the entire width and length of the flow-tube.
Flow from, or to, GMUs or UAs	The GMA does not receive flow from, or contribute flow to, another GMU or UA.
GMU PD throughflow estimate	The flow-tube cross-section occurs within the boundary of the GMA. The average (P50 K) predevelopment throughflow of the GMA is therefore estimated to be 36,557 ML/y .
CV (%) and potential factors contributing to spatial variability	CV: N/a (one cross-section was assessed).
PCV relative to PD throughflow	The PCV (14,250 ML/y) represents 39 % of the average (P50 K) predevelopment throughflow (36,557 ML/y). The PCV represents 195 % of the lower range minimum (P20 K) predevelopment throughflow.
Average licensed usage relative to PD throughflow	The average licensed usage (2,801 ML/y) represents 8 % of the average (P50 K) predevelopment throughflow (36,557 ML/y). The average licensed usage represents 38 % of the lower range minimum (P20 K) predevelopment throughflow.
Relative rankings (Appendix B)	Relative reliability ranking: Low; Relative uncertainty ranking: High; Relative potential for adverse impact on aquifer value(s): Low; Overall GMU ranking: High-Low.
Considerations for assigning sustainable yield	None identified.

9. Central GMB – Port Phillip Bay groundwater catchments

The Central GMB is located in southern Victoria and includes the West Port Phillip Bay, East Port Phillip Bay, Westernport and Tarwin groundwater catchments. This chapter concerns the West and East Port Phillip Bay groundwater catchments.

The confined aquifers within the Port Phillip Bay groundwater catchments include:

- Brighton Group/Baxter Sandstone (UTAF) (Figure 5-2).
- Mornington Volcanics (LTBa) (Figure 5-5).
- Werribee Formation (LTA) (Figure 5-6).

The Port Phillip Bay groundwater catchments contain three GMUs that incorporate confined aquifers. Outside of these GMUs the UTAF and LTA are managed as unincorporated areas (Figure 5-2, Figure 5-5 and Figure 5-6). The flow-tubes assigned in the groundwater catchments are listed in Table 9-1.

Table 9-1 Port Phillip Bay groundwater catchments – assigned flow-tubes

Groundwater catchment	GMU or non-GMU	PCV Order depth	Confined VAF layer and flow-tube no.	Aquifer name
West Port Phillip Bay	Cut Paw Paw GMA	All formations below 50 m	LTA ft05	Werribee Formation
	Moorabbin GMA	All formations below surface	LTA ft04	Werribee Formation
	UA between Melbourne and Geelong	N/a	UTAF ft08	N/a
	UA near Werribee	N/a	LTA ft06	N/a
	UA southeast of Geelong	N/a	LTA ft18	N/a
East Port Phillip Bay	Frankston GMA	All formations below surface	UTAF ft03	Brighton Group/Baxter Sandstone
			LTA ft03	Werribee Formation
			LTBa ft04	Mornington Volcanics

Note:

Shaded cell indicates the flow-tube is assigned to a GMU but includes a significant (multiple cells) UA either upgradient or downgradient of the GMU.

9.1 Hydrogeological characterisation

9.1.1 Cut Paw Paw GMA

The Cut Paw Paw GMA is located on the northwest margin of Port Phillip Bay. It is bounded by Princes Highway and Buckley Street to the north, Altona Bay to the south, Maribyrnong and Yarra Rivers to the east, and Laverton Creek to the west. The GMA manages all formations below 50 m, with a primary focus on the confined aquifer within the Werribee Formation (LTA).

A regional scale hydrostratigraphic profile in and around the Cut Paw Paw GMA is listed in Table 9-2 key hydrogeological attributes are described in Table 9-3.

Table 9-2 Hydrostratigraphic profile in and around the Cut Paw Paw GMA

Geological formation	VAF code	Geological period	Lithology
Brighton Group/Baxter Formation	UTAF	Upper Tertiary	Sand, gravel, and clay.

Confined Aquifer Throughflow Assessment – Updated Method and Phase B State-wide Rollout

Geological formation	VAF code	Geological period	Lithology
Fyansford Formation ⁽¹⁾	UMTD	Upper-Middle to Lower-Middle Tertiary	Clay, silt, siltstone, marl (fractured rock), minor sand.
Werribee Formation	LTA	Lower-Middle to Lower Tertiary	Sand, gravel, clay and silt, minor coal.
Mornington Volcanics ⁽²⁾	LTBa	Lower-Middle Tertiary	Basalt.
Basement Rocks	BSE	Mesozoic and Palaeozoic	Sedimentary (fractured rock): sandstone, siltstone, mudstone, shale. Igneous (fractured rock): includes volcanics, granites, granodiorites.

Source: (GHD, 2020a).

Notes:

The shaded grey cell indicates the confined aquifer VAF layer subject to the Phase B study.

(1) The Fyansford Formation (UMTD) is by definition an aquitard layer in the VAF. The minor sands layer in the UMTD cannot be accommodated in this VAF based throughflow analysis and has been excluded.

(2) The LTBa VAF layer is not indicated to occur within the GMU.

Table 9-3 Cut Paw Paw GMA – Key hydrogeological attributes

Attribute	Parameter	Description
Groundwater management	GMU size ⁽¹⁾	57 km ²
	PCV Order depth	All formations below 50 m.
	Overlying GMUs	None.
	Underlying GMUs	None.
	Confined aquifers (and VAF code, number) ⁽¹⁾	Werribee Formation (LTA, 111). The PCV primarily relates to confined aquifers.
	PCV and derivation ⁽¹⁾	3,650 ML/year (PCV Order 2006). Derivation: Combination of throughflow and aquifer storage.
Groundwater usage	Licensed volume ⁽²⁾	523 ML/year (June 2021).
	Licensed use ⁽²⁾	Average (2007-2021): 99 ML/year. Minimum (2015-2016): 12 ML/year. Maximum (2013-2014): 424 ML/year.
Hydrogeological conceptualisation	Recharge areas ⁽¹⁾	Recharge is likely to occur in two different areas. One of the recharge areas is situated in the Bacchus Marsh area, approximately 35-40 km northwest of the GMA. The other potential source of recharge is the overlying Newer Volcanics Basalt that surrounds the margins of the Port Phillip Basin. The expected recharge to the confined Werribee Formation aquifer (LTA) within the GMA is negligible.
	Groundwater flow and aquifer/aquitard characteristics ⁽¹⁾	Groundwater from Cut Paw Paw GMA flows northwest to southeast.
	Cross border flows	Not applicable.
Groundwater monitoring	Groundwater suite hydrographic classification ⁽¹⁾	For the LTA, a relatively stable long-term trend is indicated (Suite L_U_1).

Reference: (1) GHD. (2020a), (2) DEECA. (2023).

9.1.2 Moorabbin GMA

The Moorabbin GMA is situated on the eastern side of Port Phillip Bay and is bounded in the north by the Princes Highway, Clayton Road/Boundary Road in the east and Port Phillip Bay in the south and west. The GMA, comprising flat to undulating terrain, pertains to all formations below the surface but was intended to primarily manage the groundwater resource of the Brighton Group (UTAF) and the sands within the Fyansford Formation (UMTD). A degree of hydraulic connection is recognised with the underlying aquifer systems and therefore all aquifers are considered in the PCV, although deeper formations are utilised to a lesser extent.

A regional scale hydrostratigraphic profile in and around the Moorabbin GMA is listed in Table 9-4 and key hydrogeological attributes are described in Table 9-5.

Table 9-4 Hydrostratigraphic profile in and around the Moorabbin GMA

Geological formation	VAF code	Geological period	Lithology
Undifferentiated Sediments	QA	Quaternary	Sand, gravels, clay and silts.
Brighton Group/Baxter Sandstone	UTAF	Upper Tertiary	Sand, gravel and clay.
Fyansford Formation ⁽¹⁾	UMTD	Upper-Middle to Lower-Middle Tertiary	Clay, silt, siltstone, marl (fractured rock), minor sand.
Werribee Formation	LTA	Lower-Middle to Lower Tertiary	Sand, gravel, clay and silt, minor coal.
Mornington Volcanics ⁽²⁾	LTBa	Lower-Middle Tertiary	Basalt.
Basement Rocks	BSE	Mesozoic and Palaeozoic	Sedimentary (fractured rock): sandstone, siltstone, mudstone, shale. Igneous (fractured rock): includes volcanics, granites, granodiorites.

Source: (GHD, 2020a).

Notes:

The shaded grey cells indicates the confined aquifer VAF layers subject to the Phase B study.

(1) The Fyansford Formation (UMTD) is by definition an aquitard layer in the VAF. The minor sands layer in the UMTD cannot be accommodated in this VAF based throughflow analysis and has been excluded.

(2) The LTBa VAF layer is not indicated to occur within the GMU.

Table 9-5 Moorabbin GMA – Key hydrogeological attributes

Attribute	Parameter	Description
Groundwater management	GMU size ⁽¹⁾	130 km ²
	PCV Order depth	All formations below the surface.
	Overlying GMUs	None.
	Underlying GMUs	None.
	Confined aquifers (and VAF code, number) ⁽¹⁾	Includes all formations below surface but was intended to primarily manage the groundwater resource of the Brighton Group (UTAF, 105) and the sands within the Fyansford Formation (UMTD). The PCV primarily relates to unconfined aquifers. Notably, a degree of hydraulic connection with the underlying aquifer systems is recognised and therefore the GMA also covers the underlying Werribee Formation (LTA). The deeper units are utilised to a lesser extent.
	PCV and derivation ⁽¹⁾	2,700 ML/year (PCV Order 2006). Derivation: Volume of licence entitlement (inferred).

Attribute	Parameter	Description
Groundwater usage	Licensed volume ⁽²⁾	2,624 ML/year (June 2021).
	Licensed use ⁽²⁾	Average (2006-2021): 1,096 ML/year. Minimum (2010-2011): 545 ML/year. Maximum (2006-2007): 1,987 ML/year.
Hydrogeological conceptualisation	Recharge areas	Recharge to the aquifer system occurs from rainfall on the outcropping Brighton Group (UTAF).
	Groundwater flow and aquifer/aquitard characteristics ⁽¹⁾	The Brighton Group (UTAF) is exposed over the entire Moorabbin GMA, whereas the Fyansford Formation (UMTD) is present across the GMA but not exposed, with an approximate thickness of 60-90 m.
	Cross border flows	Not applicable.
Groundwater monitoring	Groundwater suite hydrographic classification ⁽¹⁾	For the LTA, a relatively stable long term trend is indicated (Suite L_U_1).

Reference: (1) GHD. (2020a), (2) DEECA. (2023).

9.1.3 Frankston GMA

The Frankston GMA is located southeast of Melbourne on the eastern margin of Port Phillip Bay. The GMA is bordered by Patterson River/Eumemmerring Creek to the north, Cranbourne and Lyndhurst to the east, the Port Phillip coastline to the west, and extends from Frankston to the intersection of Frankston-Cranbourne Road and the Cranbourne/Lyndhurst boundary to the south.

The GMA manages all formations below the surface, however the primary focus of the PCV is managing the following confined aquifers: Brighton Group/Baxter Formation (UTAF), Werribee Formation (LTA) and Mornington Volcanics (LTBa). Although the deeper units were not initially planned to be included in the PCV, the confined aquifer systems of these units represent reasonable groundwater resources within the GMA and are therefore included in the current study.

A regional scale hydrostratigraphic profile in and around the Frankston GMA is listed in Table 9-6 and key hydrogeological attributes are described in Table 9-7.

Table 9-6 Hydrostratigraphic profile in and around the Frankston GMA

Geological formation	VAF code	Geological period	Lithology
Undifferentiated Sediments	QA	Quaternary	Sand, gravels, clay, silts.
Brighton Group/Baxter Sandstone	UTAF	Upper Tertiary	Sand, gravel and clay.
Fyansford Formation ⁽¹⁾	UMTD	Upper–Middle to Lower–Middle Tertiary	Clay, silt, siltstone, marl (fractured rock), minor sand.
Werribee Formation	LTA	Lower–Middle to Lower Tertiary	Sand, gravel, clay, silt, minor coal.
Mornington Volcanics	LTBa	Lower–Middle Tertiary	Basalt.
Basement Rocks	BSE	Mesozoic and Palaeozoic	Sedimentary (fractured rock): sandstone, siltstone, mudstone, shale. Igneous (fractured rock): includes volcanics, granites, granodiorites

Source: (GHD, 2020a).

Notes:

The shaded grey cells indicate the confined aquifer VAF layers subject to the Phase B study.

(1) The Fyansford Formation (UMTD) is by definition an aquitard layer in the VAF. The minor sands layer in the UMTD cannot be accommodated in this VAF based throughflow analysis and has been excluded.

Table 9-7 Frankston GMA – Key hydrogeological attributes

Attribute	Parameter	Description
Groundwater management	GMU size ⁽¹⁾	140 km ²
	PCV Order depth	All formations below the surface.
	Overlying GMUs	None.
	Underlying GMUs	None.
	Confined aquifers (and VAF code, number) ⁽²⁾	Includes all formation below the surface but was intended to primarily manage the groundwater resource of the Brighton Group aquifer (UTAF, 105). A degree of hydraulic connection with the underlying aquifer systems is recognised and therefore the GMA also covers the underlying Older Volcanics (LTBa, 112), Werribee Formation (LTA, 111) and Palaeozoic basement (BSE, 114). These deeper units are utilised to a lesser extent. The PCV relates to both unconfined and confined aquifers.
	PCV and derivation ⁽²⁾	3,200 ML/year (PCV Order 2006). Derivation: Combination of aquifer recharge and volume of water required to maintain seawater/freshwater interface to control seawater intrusion.
Groundwater usage	Licensed volume ⁽³⁾	2,542 ML/year (June 2021).
	Licensed use ⁽³⁾	Average (2006–2021): 230 ML/year. Minimum (2014–2015): 50 ML/year. Maximum (2019–2020): 686 ML/year.
Hydrogeological conceptualisation	Recharge areas ⁽¹⁾	The GMA's rainfall recharge has been estimated to be 5,426 ML/year, which includes groundwater discharge from the Brighton Group aquifer (UTAF) that occurs across approximately one third of the GMA and contributes to the low-lying areas and wetlands.
	Groundwater flow and aquifer/aquitard characteristics ⁽¹⁾	The Frankston GMA varies from unconfined to semi-confined where Quaternary deposits overly the main aquifer (Brighton Group, UTAF). The Fyansford Formation (UMTD) is comprised of fine grained, low permeability sediments. It's largely known as an aquitard, with leakage to the underlying Older Volcanics (LTBa), Werribee Formation (LTA) and basement rocks (BSE). The Fyansford Formation (UMTD) is recharged via leakage from the overlying Brighton Group sediments (UTAF).
	Cross border flows	Not applicable.
Groundwater monitoring	Groundwater suite hydrographic classification ⁽²⁾	The LTA is indicated to have a relatively stable long-term trend (Suite L_U_1).

References: (1) SKM (1998c), (2) GHD (2020a), (3) DEECA. (2023).

9.2 Aquifer property data

Aquifer property data collected for the Brighton Group/Baxter Sandstone (UTAF), Werribee Formation (LTA) and Mornington Volcanics (LTBa) in the Port Phillip Bay groundwater catchments is presented in Table 9-8, Table 9-9 and Table 9-10, respectively. The statistical analysis of the K (K_n) point data for each of the VAF layers is presented in Table 9-11, including the P20 K, P50 K and P80 K values adopted for the throughflow calculations.

Confined Aquifer Throughflow Assessment – Updated Method and Phase B State-wide Rollout

Table 9-8 Port Phillip Bay groundwater catchments - UTAF properties

Area	Aquifer	K_h (m/d)	K_v (m/d)	T (m ² /d)	S	Reference
Western Port Basin	Brighton Group	<1-5, average 2 m/d (up to 10-50 m/d in coarser layers of aquifer)	N/a	N/a	N/a	SKM (1998c).
Port Phillip CMA	Brighton Group	<0.5	N/a	N/a	4×10 ⁻⁴	Leonard (1992), as cited by GHD (2010a).
Port Phillip CMA	Brighton Group	0.5	N/a	18	N/a	GHD (2010a).
Port Phillip CMA	Baxter Formation	N/a	N/a	50-300	N/a	Thompson (1974), as cited by GHD (2010a).

Table 9-9 Port Phillip Bay groundwater catchments - LTA properties

Area	Aquifer	K_h (m/d)	K_v (m/d)	T (m ² /d)	S	Reference
Frankston GMA	Werribee Formation	N/a	N/a	569	2.59×10 ⁻⁴	DELWP (2016).
Port Phillip Basin	Werribee Formation	5 m/d (representative of entire aquifer), up to 15 m/d	N/a	75-300	2×10 ⁻⁴	Leonard (1992), as cited by SKM (1998b) and Leonard (2006).

Table 9-10 Port Phillip Bay groundwater catchments - LTBa properties

Area	Aquifer	K_h (m/d)	K_v (m/d)	T (m ² /d)	S	Reference
Port Phillip CMA	Mornington Volcanics	5	N/a	1-155	4×10 ⁻⁵ -2×10 ⁻⁴	Leonard (1992), as cited by GHD (2010a).

Table 9-11 Port Phillip Bay groundwater catchments K_h statistics

K_h statistical parameter	Value		
	UTAF ⁽¹⁾	LTA	LTBa ⁽¹⁾
Number of data points	1	1	1
Minimum	<0.5 m/d	N/a	N/a
P20	N/a (1.5 m/d)	N/a (1 m/d)	N/a (2 m/d)
P50	N/a (2.5 m/d)	N/a (5 m/d)	N/a (3.5 m/d)
Average	N/a	5.0 m/d	5.0 m/d
P80	N/a (3.5 m/d)	N/a (12 m/d)	N/a (8 m/d)
Maximum	50 m/d	15 m/d	N/a
Standard deviation	N/a	N/a	N/a

Notes:

The shaded cells indicate the P20 K, P50 K and P80 K values adopted in the gridded throughflow rate analysis.

The inputted K values were rounded to the nearest 0.5 for the throughflow analysis.

N/a: Insufficient K_h point data to inform statistical analysis. In the absence of sufficient K point data, the typical K ranges from pumping tests informed the selection of representative values of P20, P50 and P80 K for adoption in the throughflow assessment. These adopted values are indicated in brackets.

(1) The point K data and ranges were limited for the UTAF and LTBa in the Port Phillip Bay groundwater catchments. Representative values of P20, P50 and P80 K were therefore adopted from the equivalent VAF layer within the Westernport groundwater catchment.

9.3 Outputs

9.3.1 Cut Paw Paw GMA

The Cut Paw Paw GMA is designated flow-tube LTA ft05 (Table 9-1). The predevelopment throughflows for LTA ft05 rely on throughflow outputs from four cross-sections perpendicular to groundwater flow (at 5 m, 20 m, 60 m and 100 m modelled RWL contours).

The (P50 K) predevelopment throughflow estimate of each cross-section in the LTA ft05 is reported in Table 9-12. The corresponding average, lower and upper range (P50 K), and lower range minimum (P20 K) predevelopment throughflow estimates for the flow-tube are also reported. The spatial variability of throughflow within the flow-tube is represented by the SD and CV in Table 9-12.

Table 9-12 Predevelopment throughflow estimates for flow-tube - LTA ft05

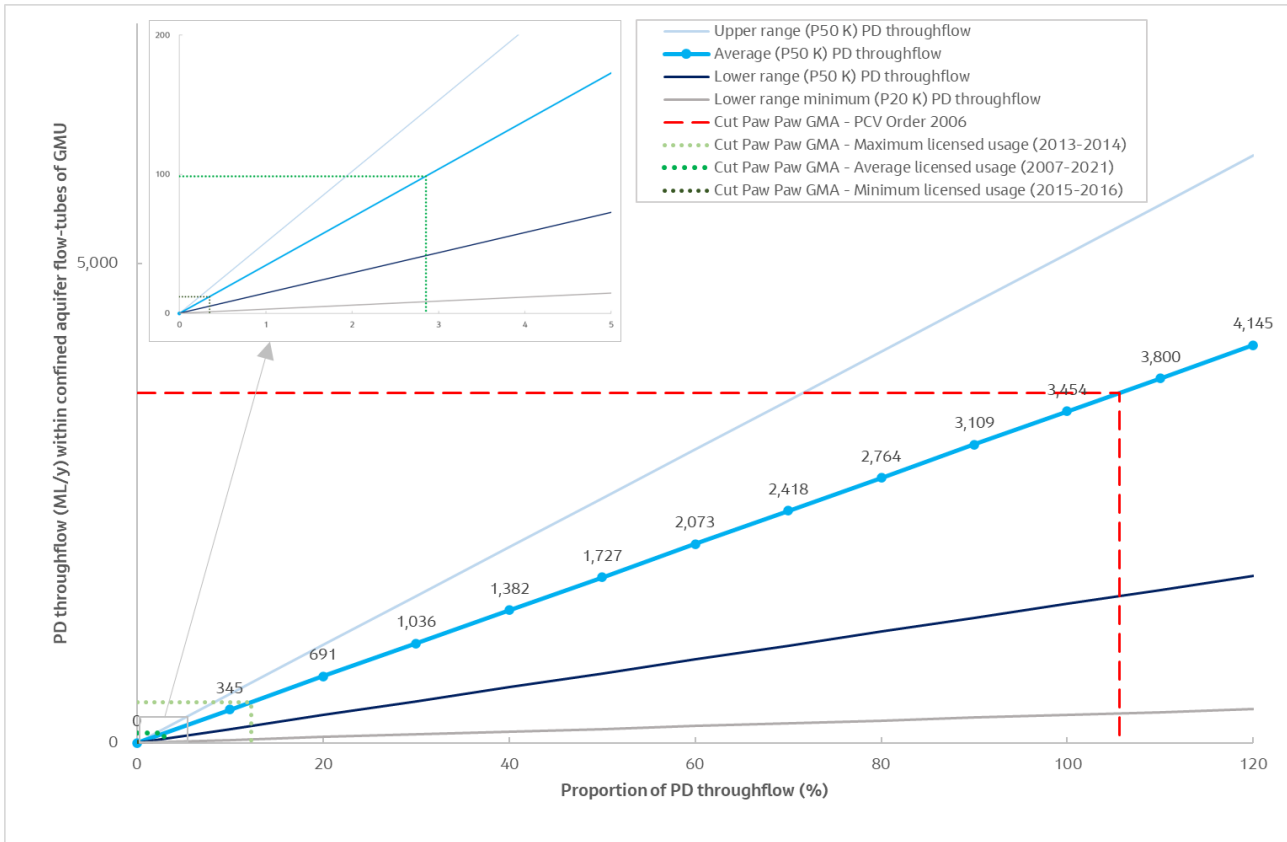
Parameter	Value
P50 K PD throughflow, Cross-section 1 (5 m RWL) (ML/y) ⁽¹⁾	3,120
P50 K PD throughflow, Cross-section 2 (20 m RWL) (ML/y)	4,147
P50 K PD throughflow, Cross-section 3 (60 m RWL) (ML/y)	5,101
P50 K PD throughflow, Cross-section 4 (100 m RWL) (ML/y)	1,450
Average (P50 K) PD throughflow (ML/y)	3,454
Lower range (P50 K) PD throughflow (ML/y)	1,450
Upper range (P50 K) PD throughflow (ML/y)	5,101
Lower range minimum (P20 K) PD throughflow (ML/y)	290
SD (ML/y)	1,562
CV (%)	45
Approximate length of flow-tube (km)	35

Note:

(1) The cross-section identified occurs within the boundary of the Cut Paw Paw GMA.

To assist with contextualising the throughflow outputs, the average, lower and upper range (P50 K) and lower range minimum (P20 K) predevelopment throughflow estimates for flow-tube LTA ft05 are presented in Figure 9-1. For comparison, the Cut Paw Paw PCV and minimum, average and maximum licensed usage values are overlaid on the figure.

Figure 9-1 Cut Paw Paw GMA - PCV and licensed usage relative to predevelopment throughflow estimate of flow-tube LTA ft05



The throughflow results of the flow-tube, and its spatial variability, are summarised in Table 9-13 in the context of management arrangements and licensed usage in the Cut Paw Paw GMA, including considerations for assigning a sustainable yield.

Table 9-13 Summary of predevelopment throughflows in context of Cut Paw Paw GMA

Flow-tube parameter	Result
Confined VAF layers	LTA
Comparison with GMA boundary	The GMA mostly occupies the width of the flow-tube and approximately 30 % of its length.
Flow from, or to, GMUs or UAs	As indicated by the inferred flow-tube, the GMA receives flow from an UA. The GMA does not contribute flow to another GMU or UA.
GMU PD throughflow estimate	The average (P50 K) predevelopment throughflow of the cross-section within the Cut Paw Paw GMA , is 3,120 ML/y (one cross-section only), compared with the that estimated for the entire flow-tube of 3,454 ML/y .
CV (%) and potential factors contributing to spatial variability	CV: 45 %.
PCV relative to PD throughflow	The PCV (3,750 ML/y) represents 106 % of the average (P50 K) predevelopment throughflow (3,454 ML/y) but allowing for spatial variability may be between 72 % and 252 %. The PCV represents 1,2599 % of the lower range minimum (P20 K) predevelopment throughflow.
Average licensed usage relative to PD throughflow	The average licensed usage (99 ML/y) represents 3 % of the average (P50 K) predevelopment throughflow (3,454 ML/y) but allowing for spatial variability may be between 2 % and 7 %. The average licensed usage represents 34 % of the lower range minimum (P20 K) predevelopment throughflow.

Flow-tube parameter	Result
Relative rankings (Appendix B)	Relative reliability ranking: Low; Relative uncertainty ranking: Low; Relative potential for adverse impact on aquifer value(s): Low; Overall GMU ranking: Low-Low.
Considerations for assigning sustainable yield	<ul style="list-style-type: none"> ▪ The GMA occupies 30 % of the length of the flow-tube, with the GMA receiving flow from an UA. ▪ The LTA recharges in areas outside of the GMA. ▪ Potential risks of sea water intrusion from groundwater development.

9.3.2 Moorabbin GMA

The Moorabbin GMA is designated flow-tube LTA ft04 (Table 9-1). The predevelopment throughflows for LTA ft04 rely on throughflow outputs from one cross-section perpendicular to groundwater flow (at 10 m modelled RWL contour).

The (P50 K) predevelopment throughflow estimate of the cross-section in the LTA ft04 is reported in Table 9-14. The corresponding (adopted) average (P50 K) and the lower range minimum (P20 K) predevelopment throughflow estimates for the flow-tube are also reported. As only one cross-section informs the throughflow assessment, the spatial variability of the throughflow calculation has not been assessed.

Table 9-14 Predevelopment throughflow estimates for flow-tube - LTA ft04

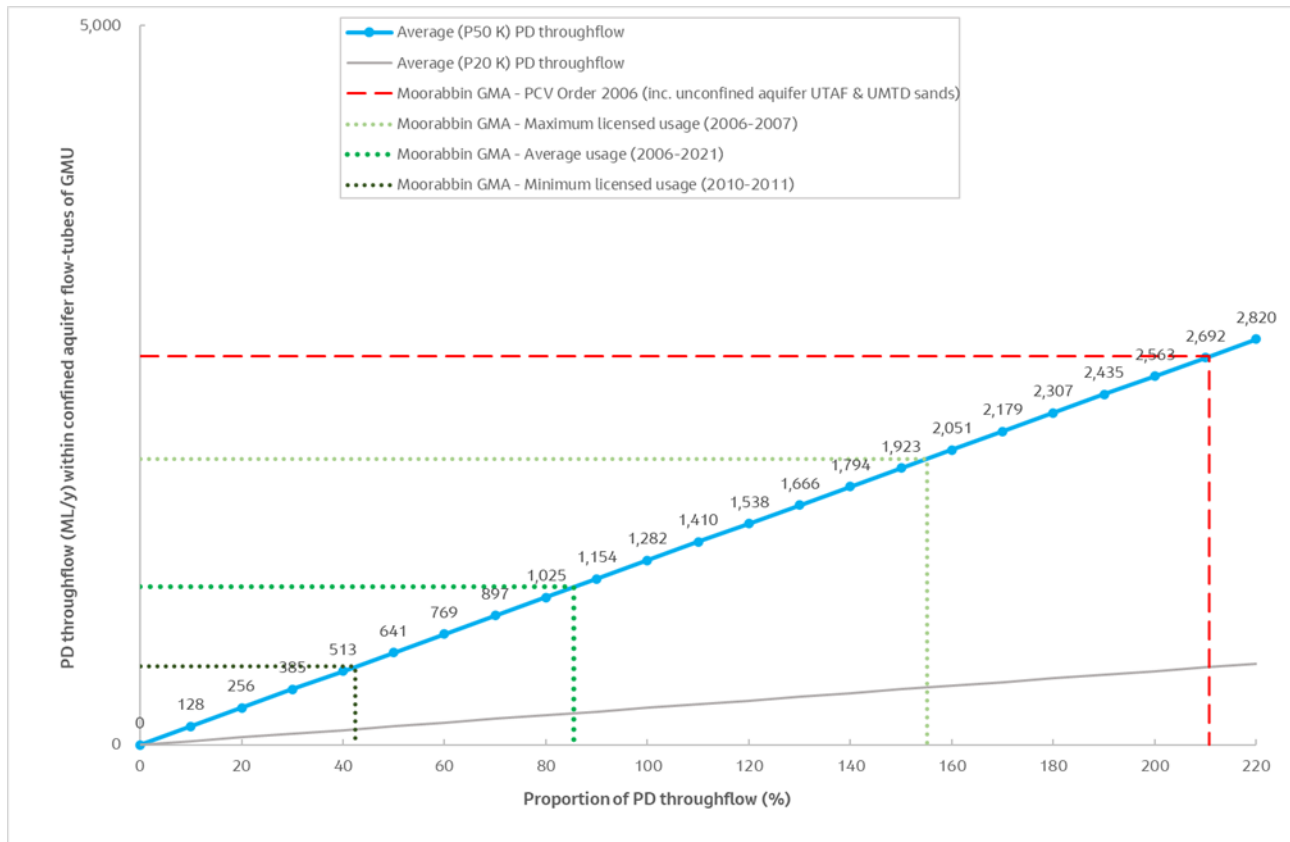
Parameter	Value
P50 K PD throughflow, Cross-section 1 (10 m RWL) (ML/y)	1,282
Adopted (average) (P50 K) PD throughflow (ML/y)	1,282
Lower range minimum (P20 K) PD throughflow (ML/y)	256
Approximate length of flow-tube (km)	10

Note:

The cross-section occurs within the GMU boundary.

To assist with contextualising the throughflow outputs, the average (P50 K) and lower range minimum (P20 K) predevelopment throughflow estimates for flow-tube LTA ft04 are presented in Figure 9-2. For comparison, the Moorabbin GMA PCV and minimum, average and maximum licensed usage values are overlaid on the figure.

Figure 9-2 Moorabbin GMA - PCV and licensed usage relative to predevelopment throughflow estimate of flow-tube LTA ft04



The throughflow results of the flow-tube are summarised in Table 9-15 in the context of management arrangements and licensed usage in the Moorabbin GMA, including considerations for assigning a sustainable yield.

Table 9-15 Summary of predevelopment throughflows in context of Moorabbin GMA

Flow-tube parameter	Result
Confined VAF layers	LTA.
Comparison with GMA boundary	The GMA boundary mostly occupies the entire width and length of the flow-tube.
Flow from, or to, GMUs or UAs	The GMA does not contribute flow to, or receive flow from, another GMU or UA.
GMU PD throughflow estimate	The flow-tube cross-section occurs within the boundary of the GMA. The average (P50 K) predevelopment throughflow of the GMA is therefore estimated to be 1,282 ML/y .
CV (%) and potential factors contributing to spatial variability	CV: N/a (one cross-section was assessed).
PCV relative to PD throughflow	The PCV (2,700 ML/y) represents 211 % of the average (P50 K) predevelopment throughflow (1,282 ML/y). The PCV represents 1,053 % of the lower range minimum (P20 K) predevelopment throughflow.
Average licensed usage relative to PD throughflow	The average licensed usage (1,096 ML/y) represents 86 % of the average (P50 K) predevelopment throughflow (1,282 ML/y). The average licensed usage represents 428 % of the lower range minimum (P20 K) predevelopment throughflow.
Relative rankings (Appendix B)	Relative reliability ranking: Low; Relative uncertainty ranking: High; Relative potential for adverse impact on aquifer value(s): High; Overall GMU ranking: High-High.

Flow-tube parameter	Result
Considerations for assigning sustainable yield	<ul style="list-style-type: none"> ▪ The unconfined UTAF aquifer (Brighton Group) (subject of the CDM Smith unconfined aquifer sustainable yield study) and the sands within the Fyansford Formation (UMTD) form key and well utilised aquifers in the GMA. The assessment of the overall sustainable yield for the Moorabbin GMA will therefore need to consider contributions from these aquifers. ▪ Potential risks of sea water intrusion from groundwater development.

9.3.3 UA UTAF between Melbourne and Geelong

The UA UTAF between Melbourne and Geelong (Figure 5-2) is designated flow-tube UTAF ft08 (Table 9-1). The predevelopment throughflows for UTAF ft08 rely on throughflow outputs from four cross-sections perpendicular to groundwater flow (at 10 m, 30 m, 50 m and 70 m modelled RWL contours).

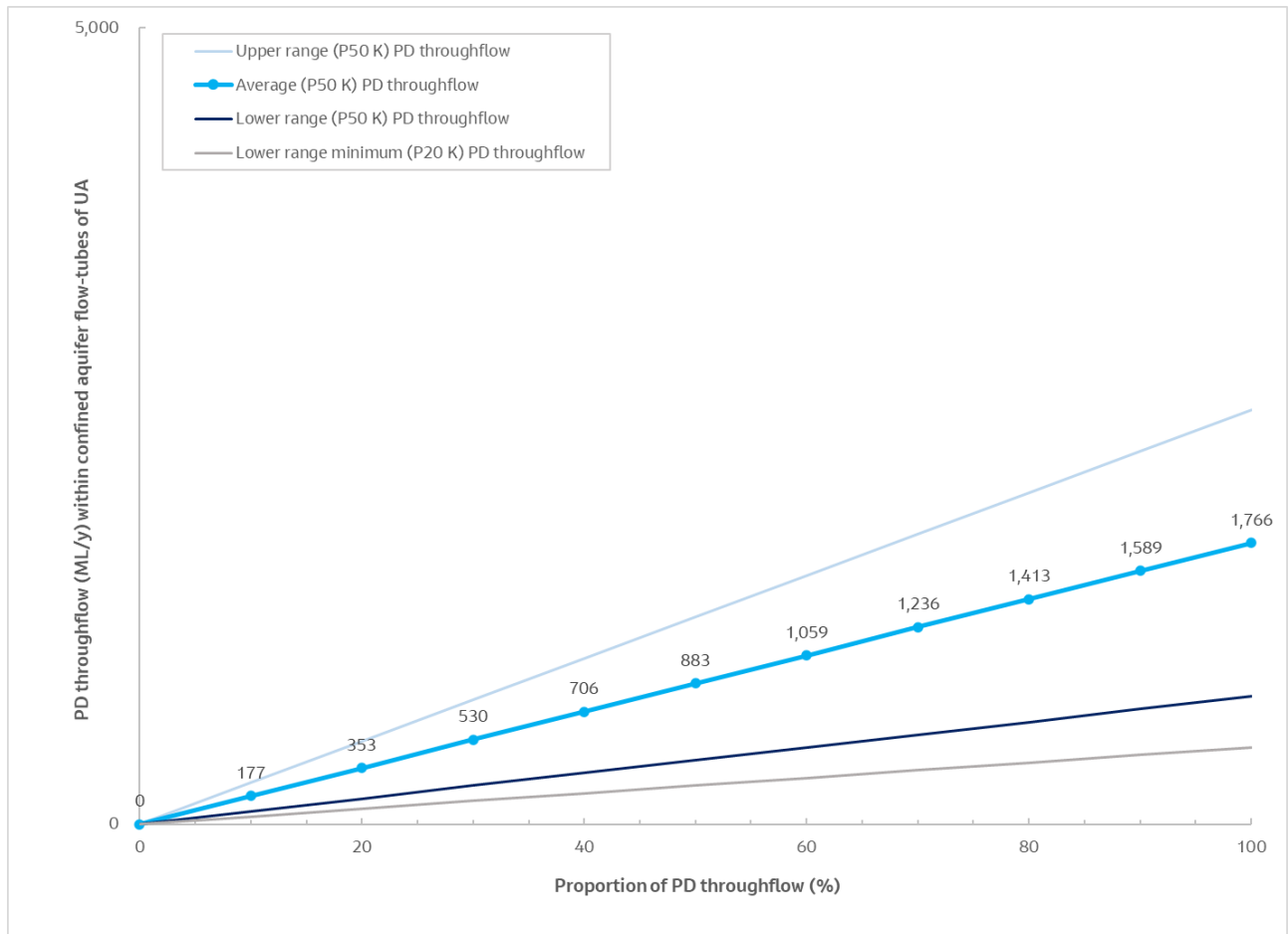
The (P50 K) predevelopment throughflow estimate of each cross-section in the UTAF ft08 is reported in Table 9-16. The corresponding average, lower and upper range (P50 K), and lower range minimum (P20 K), predevelopment throughflow estimates for the flow-tube are also reported. The spatial variability of the calculated throughflow rate within the flow-tube is represented by the SD and CV in Table 9-16.

Table 9-16 Predevelopment throughflow estimates for flow-tube – UTAF ft08

Parameter	Value
P50 K PD throughflow, Cross-section 1 (10 m RWL) (ML/y)	802
P50 K PD throughflow, Cross-section 2 (30 m RWL) (ML/y)	1,344
P50 K PD throughflow, Cross-section 3 (50 m RWL) (ML/y)	2,600
P50 K PD throughflow, Cross-section 4 (70 m RWL) (ML/y)	2,318
Average (P50 K) PD throughflow (ML/y)	1,766
Lower range (P50 K) PD throughflow (ML/y)	802
Upper range (P50 K) PD throughflow (ML/y)	2,600
Lower range minimum (P20 K) PD throughflow (ML/y)	481
SD (ML/y)	838
CV (%)	47
Approximate length of flow-tube (km)	50

To assist with contextualising the throughflow outputs, the average, lower and upper range (P50 K) and lower range minimum (P20 K) predevelopment throughflow estimates for flow-tube UTAF ft08 are presented in Figure 9-3.

Figure 9-3 Predevelopment throughflow estimates of flow-tube UTAF ft08 between Melbourne and Geelong



9.3.4 UA LTA near Werribee

The UA LTA near Werribee (Figure 5-6) is designated flow-tube LTA ft06 (Table 9-1). The predevelopment throughflows for LTA ft06 rely on throughflow outputs from five cross-sections perpendicular to groundwater flow (at 5 m, 20 m, 40 m, 60 m and 95 m modelled RWL contours).

The (P50 K) predevelopment throughflow estimate of each cross-section in the LTA ft06 is reported in Table 9-17. The corresponding average, lower and upper range (P50 K), and lower range minimum (P20 K), predevelopment throughflow estimates for the flow-tube are also reported. The spatial variability of the calculated throughflow rate within the flow-tube is represented by the SD and CV in Table 9-17.

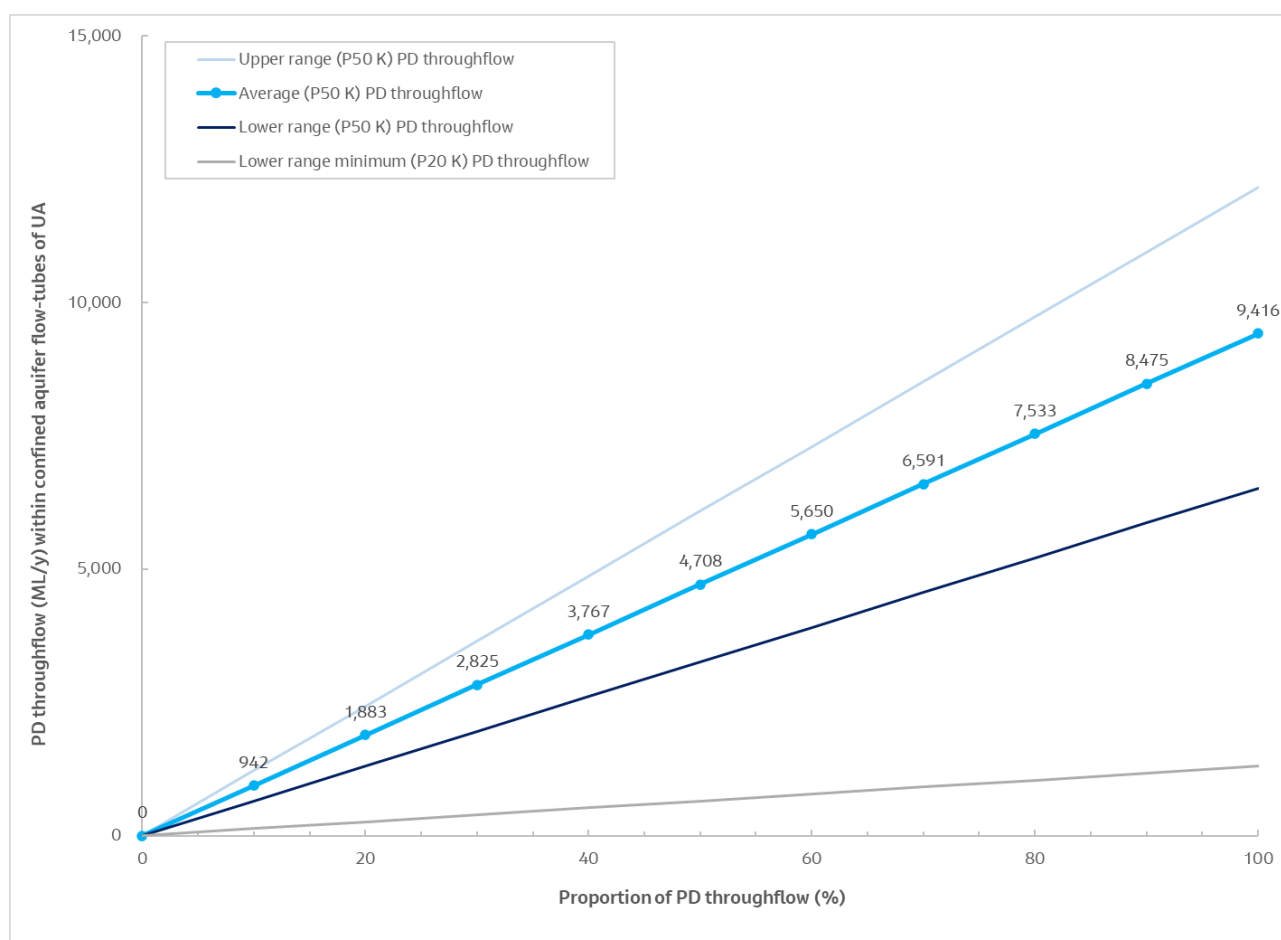
Table 9-17 Predevelopment throughflow estimates for flow-tube – LTA ft06

Parameter	Value
P50 K PD throughflow, Cross-section 1 (5 m RWL) (ML/y)	7,345
P50 K PD throughflow, Cross-section 2 (20 m RWL) (ML/y)	12,160
P50 K PD throughflow, Cross-section 3 (40 m RWL) (ML/y)	11,372
P50 K PD throughflow, Cross-section 4 (60 m RWL) (ML/y)	6,513
P50 K PD throughflow, Cross-section 5 (95 m RWL) (ML/y)	9,693
Average (P50 K) PD throughflow (ML/y)	9,416
Lower range (P50 K) PD throughflow (ML/y)	6,513
Upper range (P50 K) PD throughflow (ML/y)	12,160
Lower range minimum (P20 K) PD throughflow (ML/y)	1,303

Parameter	Value
SD (ML/y)	2,457
CV (%)	26
Approximate length of flow-tube (km)	40

To assist with contextualising the throughflow outputs, the average, lower and upper range (P50 K) and lower range minimum (P20 K) predevelopment throughflow estimates for flow-tube LTA ft06 are presented in Figure 9-4.

Figure 9-4 Predevelopment throughflow estimates of flow-tube LTA ft06 LTA near Werribee



9.3.5 UA LTA southeast of Geelong

The UA LTA southeast of Geelong (Figure 5-6) is designated flow-tube LTA ft18 (Table 9-1). The predevelopment throughflows for LTA ft18 relies on throughflow outputs from one cross-section perpendicular to groundwater flow (at 20 m modelled RWL contour).

The (P50 K) predevelopment throughflow estimate of each cross-section in the LTA ft18 is reported in Table 9-18. The corresponding (adopted) average (P50 K) and the lower range minimum (P20 K) predevelopment throughflow estimates for the flow-tube are also reported. As only one cross-section informs the throughflow assessment, the spatial variability of the throughflow calculation has not been assessed.

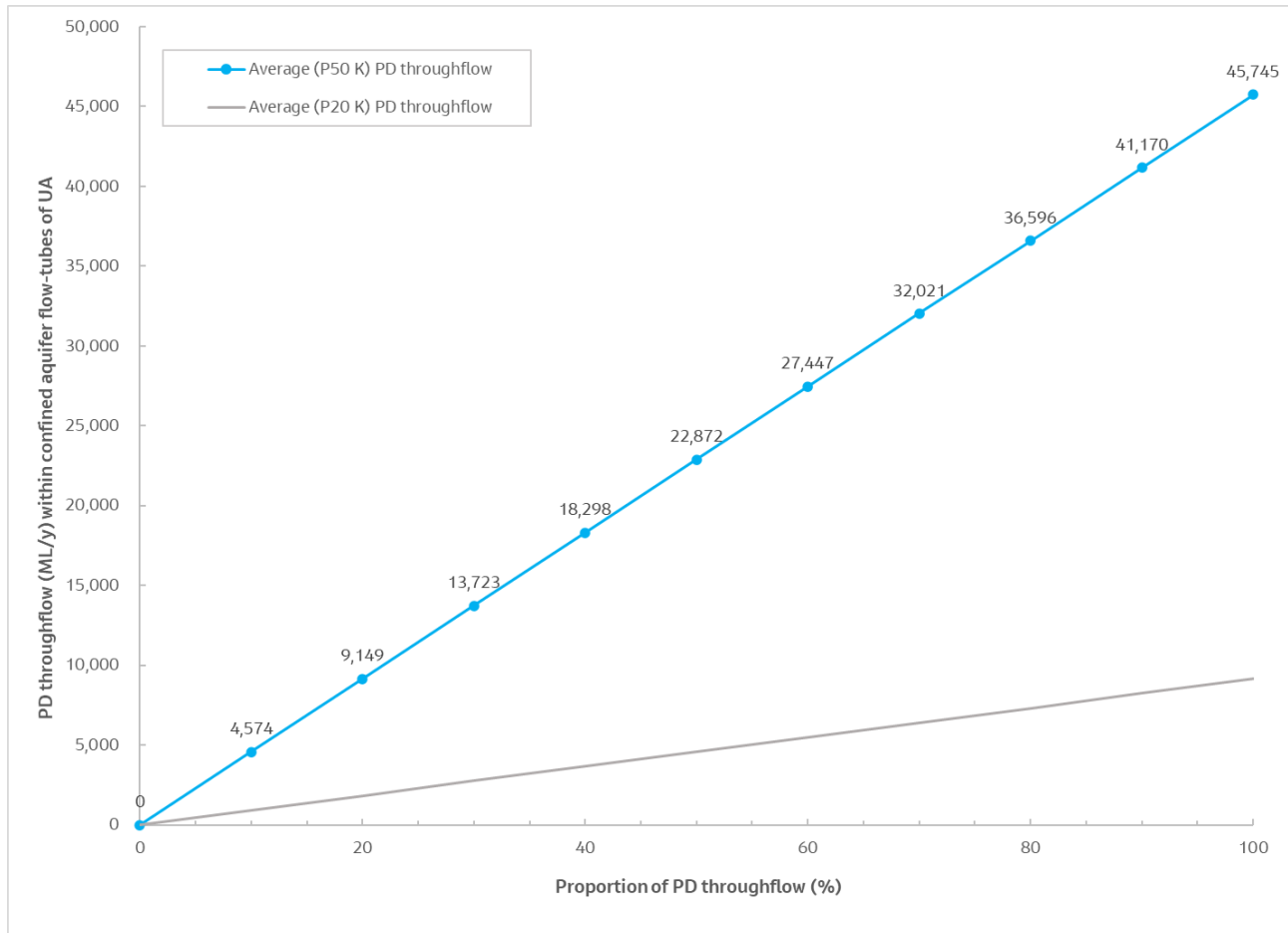
Table 9-18 Predevelopment throughflow estimates for flow-tube - LTA ft18

Parameter	Value
P50 K PD throughflow, Cross-section 1 (20 m RWL) (ML/y)	45,745

Parameter	Value
Adopted (average) (P50 K) PD throughflow (ML/y)	45,745
Lower range minimum (P20 K) PD throughflow (ML/y)	9,149
Approximate length of flow-tube (km)	10

To assist with contextualising the throughflow outputs, the average (P50 K) and lower range minimum (P20 K) predevelopment throughflow estimates for flow-tube LTA ft18 are presented in Figure 9-5.

Figure 9-5 Predevelopment throughflow estimates of flow-tube LTA ft18 LTA southeast of Geelong



9.3.6 Frankston GMA

The Frankston GMA is designated flow-tubes UTAF ft03, LTA ft03 and LTBa ft04 (Table 9-1). The predevelopment throughflows for these flow-tubes rely on throughflow outputs from the following cross-sections perpendicular to groundwater flow:

- UTAF ft03: 5 m and 25 m modelled RWL contours.
- LTA ft03: 5 m and 25 m modelled RWL contours.
- LTBa ft04: 5 m and 25 m modelled RWL contours.

The (P50 K) predevelopment throughflow estimate of each cross-section in the UTAF ft03, LTA ft03 and LTBa ft04 is reported in Table 9-19. The corresponding average, lower and upper range (P50 K), and lower range minimum (P20 K) predevelopment throughflow estimates for the flow-tubes, and a combined estimate, are also reported. The potential variability of throughflow within the flow-tubes, and combined, is represented by the SD and CV in Table 9-19.

Confined Aquifer Throughflow Assessment – Updated Method and Phase B State-wide Rollout

Table 9-19 Predevelopment throughflow estimates for flow-tubes - UTAF ft03, LTA ft03 and LTBa ft04

Parameter	Value
UTAF ft03	
P50 K PD throughflow, Cross-section 1 (5 m RWL) (ML/y)	603
P50 K PD throughflow, Cross-section 2 (25 m RWL) (ML/y)	326
Average (P50 K) PD throughflow (ML/y)	464
Lower range (P50 K) PD throughflow (ML/y)	326
Upper range (P50 K) PD throughflow (ML/y)	603
Lower range minimum (P20 K) PD throughflow (ML/y)	196
SD (ML/y)	196
CV (%)	42
Approximate length of flow-tube (km)	15
LTA ft03	
P50 K PD throughflow, Cross-section 1 (5 m RWL) (ML/y)	3,269
P50 K PD throughflow, Cross-section 2 (25 m RWL) (ML/y)	2,108
Average (P50 K) PD throughflow (ML/y)	2,689
Lower range (P50 K) PD throughflow (ML/y)	2,108
Upper range (P50 K) PD throughflow (ML/y)	3,269
Lower range minimum (P20 K) PD throughflow (ML/y)	422
SD (ML/y)	821
CV (%)	31
Approximate length of flow-tube (km)	15
LTBa ft04	
P50 K PD throughflow, Cross-section 1 (5 m RWL) (ML/y)	36
P50 K PD throughflow, Cross-section 2 (25 m RWL) (ML/y)	88
Average (P50 K) PD throughflow (ML/y)	62
Lower range (P50 K) PD throughflow (ML/y)	36
Upper range (P50 K) PD throughflow (ML/y)	88
Lower range minimum (P20 K) PD throughflow (ML/y)	20
SD (ML/y)	37
CV (%)	60
Approximate length of flow-tube (km)	20
Combined UTAF ft03, LTA ft03 and LTBa ft04	
Average (P50 K) PD throughflow (ML/y)	3,215
Lower range (P50 K) PD throughflow (ML/y)	2,469
Upper range (P50 K) PD throughflow (ML/y)	3,960
Lower range minimum (P20 K) PD throughflow (ML/y)	638
SD (ML/y)	1,054
CV (%)	33

Note:

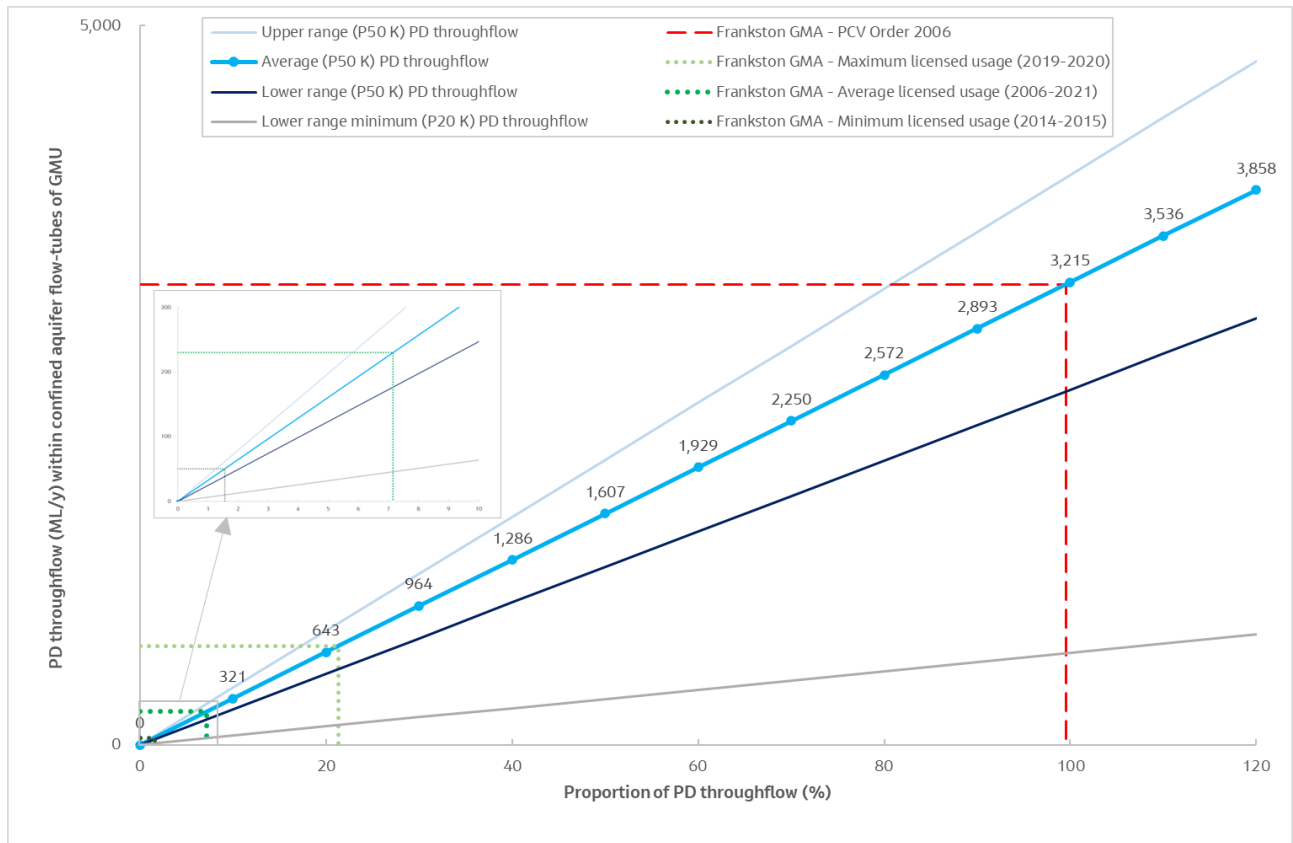
All of the cross-sections occur within the GMU boundary.

To assist with contextualising the throughflow outputs, the average, lower and upper range (P50 K) and lower range minimum (P20 K) predevelopment throughflow estimates for combined flow-tubes UTAF ft03, LTA

Confined Aquifer Throughflow Assessment – Updated Method and Phase B State-wide Rollout

ft03 and LTBa ft04 are presented in Figure 9-6. For comparison, the Frankston GMA PCV and minimum, average and maximum licensed usage values are overlaid on the figure.

Figure 9-6 Frankston GMA - PCV and licensed usage relative to predevelopment throughflow estimates of combined flow-tubes UTAF ft03, LTA ft03 and LTBa ft04



The throughflow results of the flow-tubes, and their spatial variability, are summarised in Table 9-20 in the context of management arrangements and licensed usage in the Frankston GMA, including considerations for assigning a sustainable yield.

Table 9-20 Summary of predevelopment throughflows in context of Frankston GMA

Flow-tube parameter	Result
Confined VAF layers	UTAF, LTA and LTBa.
Comparison with GMA boundary	The GMA boundary mostly occupies the entire width and length of the flow-tubes.
Flow from, or to, GMUs or UAs	The GMA does not contribute flow to, or receive flow from, another GMU or UA.
GMU PD throughflow estimate	All of the flow-tube cross-sections occur within the boundary of the GMA. The average (P50 K) predevelopment throughflow of the GMA is therefore estimated to be 3,215 ML/y .
Confined aquifer(s) contributing majority of PD throughflow	Werribee Formation (LTA) (84 %).
CV (%) and potential factors contributing to spatial variability	CV: 33 %.

Confined Aquifer Throughflow Assessment – Updated Method and Phase B State-wide Rollout

Flow-tube parameter	Result
PCV relative to PD throughflow	The PCV (3,200 ML/y) represents 100 % of the average (P50 K) predevelopment throughflow (3,215 ML/y) but allowing for spatial variability may be between 81 % and 130 %. The PCV represents 502 % of the lower range minimum (P20 K) predevelopment throughflow.
Average licensed usage relative to PD throughflow	The average licensed usage (230 ML/y) represents 7 % of the average (P50 K) predevelopment throughflow (3,215 ML/y) but allowing for spatial variability may be between 6 % and 9 %. The average licensed usage represents 36 % of the lower range minimum (P20 K) predevelopment throughflow.
Relative rankings (Appendix B)	Relative reliability ranking: Low; Relative uncertainty ranking: Low; Relative potential for adverse impact on aquifer value(s): Low; Overall GMU ranking: Low-Low.
Considerations for assigning sustainable yield	<ul style="list-style-type: none"> ▪ The unconfined UTAF aquifer (Brighton Group) (subject of the CDM Smith unconfined aquifer sustainable yield study) and the sands within the Fyansford Formation (UMTD) form key and well utilised aquifers in the GMA. The assessment of the overall sustainable yield for the Frankston GMA will therefore need to consider contributions from these aquifers. ▪ Potential risks of sea water intrusion from groundwater development.

10. Central GMB – Westernport groundwater catchment

The Central GMB is located in southern Victoria and includes the West Port Phillip Bay, East Port Phillip Bay, Westernport and Tarwin groundwater catchments. This chapter concerns the Westernport groundwater catchment.

The confined aquifers within the Westernport groundwater catchment include:

- Brighton Group/Baxter Sandstone (UTAF) (Figure 5-2).
- Sherwood Formation/Yallock Formation and Batesford Limestone (UMTA) (Figure 5-3).
- Mornington Volcanics (LTBa) (Figure 5-5).
- Childers Formation (LTA) (Figure 5-6).

The Westernport groundwater catchment contains two GMUs that incorporate confined aquifers. Outside of these GMUs the UTAF and UMTA are managed as unincorporated areas (Figure 5-2, Figure 5-3, Figure 5-4 and Figure 5-6). The flow-tubes assigned in the groundwater catchment are listed in Table 10-1.

Table 10-1 Westernport groundwater catchment – assigned flow-tubes

Groundwater catchment	GMU or non-GMU	PCV Order depth	Confined VAF layer and flow-tube no.	Aquifer name
Westernport	Koo-Wee-Rup WSPA	All formations below surface	UTAF ft02	Baxter Sandstone
			UMTA ft02	Sherwood Formation/Yallock Formation
			LTBa ft02, ft03	Mornington Volcanics
			LTA ft02	Childers Formation
	Corinella GMA	All formations below surface	UTAF ft01	Brighton Group/Baxter Sandstone
			UMTA ft01	Batesford Limestone
			LTA ft01	Childers Formation
	UA north of Bonbeach	N/a	UTAF ft04	N/a
UA near Hastings	N/a	UMTA ft03	N/a	

10.1 Hydrogeological characterisation

10.1.1 Koo-Wee-Rup WSPA

The Koo-Wee-Rup WSPA covers part of the Tertiary Western Port Basin, a small structurally controlled sedimentary basin. The GMU extends from Berwick to Drouin along the Princes Highway in the north, to Tooradin and Granville in the south. While the management area includes all formations below the surface, it is intended to primarily manage the groundwater resource of the Tertiary Westernport Group which comprises the Baxter (UTAF) and Sherwood and Yallock formations (UMTA). The PCV therefore primarily relates to confined aquifers.

The regional scale hydrostratigraphic profile in and around the Koo-Wee-Rup WSPA is listed in Table 10-2 and key hydrogeological attributes are described in Table 10-3.

Table 10-2 Hydrostratigraphic profile in and around the Koo-Wee-Rup WSPA

Geological formation	VAF code	Geological period	Lithology
Undifferentiated sediments	QA	Quaternary	Sand, gravels, clay, silts. Unconfined.
Baxter Sandstone	UTAF	Upper Tertiary	Sand, gravel and clay. Confined except around margins on basin.
Sherwood Formation/Yallock Formation	UMTA	Upper-Middle Tertiary	Limestone (fractured rock), sand, gravel, clay, minor coal. Confined except around margins on basin.

Confined Aquifer Throughflow Assessment – Updated Method and Phase B State-wide Rollout

Geological formation	VAF code	Geological period	Lithology
Mornington Volcanics	LTBa	Lower Tertiary	Basalt. Confined.
Childers Formation	LTA	Lower Tertiary	Sand, gravel, clay and silt, minor coal. Confined.
Basement rocks	BSE	Mesozoic and Palaeozoic	Sedimentary (fractured rock): sandstone, siltstone, mudstone, shale. Igneous (fractured rock): includes volcanics, granites, granodiorites.

Source: (GHD, 2020a).

Note:

The shaded grey cells indicates the confined aquifer VAF layers subject to the Phase B study.

Table 10-3 Koo-Wee-Rup WSPA – Key hydrogeological attributes

Attribute	Parameter	Description
Groundwater management	GMU size ⁽¹⁾	1,114 km ² .
	PCV Order depth	All formations below surface.
	Overlying GMUs	None.
	Underlying GMUs	None.
	Confined aquifers (and VAF code, number) ⁽¹⁾	Baxter Sandstone (UTAF, 105), Sherwood Formation/Yallock Formation (UMTA, 107), Mornington Volcanics (LTBa, 112), Childers Formation (LTA, 111). The management area is intended to primarily manage the groundwater resources of the UTAF and UMTA. The PCV primarily relates to confined aquifers.
	PCV and derivation ⁽¹⁾	12,915 ML/year (PCV Order 2006). Derivation: Combination of aquifer throughflow and recharge methods.
Groundwater usage	Licensed volume ⁽⁴⁾	12,566 ML/year (June 2021).
	Licensed use ⁽⁴⁾	Average (2004-2021): 3,610 ML/year. Minimum (2011-2012): 1,924 ML/year. Maximum (2006-2007): 6,452 ML/year.
Hydrogeological conceptualisation	Recharge areas ⁽²⁾	Groundwater recharge occurs vertically to the Tertiary aquifers through the overlying Quaternary sediments, as well in areas where the Tertiary sediments outcrop along the edges of the Basin.
	Groundwater flow and aquifer/aquitard characteristics ^(2,3)	The Westernport sequence is generally considered as a single aquifer system, as there is a hydraulic connection between each individual formation. Basaltic clay of the Older Volcanics is considered to form a semi-confining to confining layer between the Westernport sequence and the underlying Older Volcanics/Childers formations. Hydraulic conductivities and individual bore yields within the Westernport sequence are highly variable. With regards to the Baxter Formation (UTAF), the coarsest grained deposits are found in the northwest of the basin near granite outcrops which are likely the source of the sand, and along the Heath Hill Fault in the east. Grain size tends to be finer in the east of the basin which may be related to the source rock (e.g. Silurian siltstone) and/or lower energy fluvial environment at the time of deposition.
	Cross border flows	Not applicable.

Confined Aquifer Throughflow Assessment – Updated Method and Phase B State-wide Rollout

Attribute	Parameter	Description
	Groundwater-surface water interaction ⁽²⁾	There is little evidence of surface water-groundwater interaction, noting that the area has been progressively drained over the last 120 years. It is possible that there is some hydraulic connection between the shallow Quaternary sediments and the lower reaches of the Lang Lang and Bunyip Rivers.
	Saline intrusion ^(1,2)	Salt water intrusion from the coast is a threat to aquifer sustainability.
	Points of groundwater discharge ⁽²⁾	Discharge is generally into Westernport Bay.
Groundwater monitoring	Groundwater suite hydrographic classification ⁽¹⁾	Groundwater levels have largely stabilised to 1990 levels (although below sea level in the main use area) under the PCV. The relevant groundwater suite hydrograph classifications include U_AL_2 (UTAF); M_S_1 and M_S_2 (UMTA); L_S_1 and L_S_2 (LTA).

References: (1) GHD (2020a), (2) SRW (2010), (3) EarthEon (2021), (4) DEECA (2023).

10.1.2 Corinella GMA

The Corinella GMA is located on the south-eastern edge of the Tertiary Westernport Basin. The area covers relatively flat plains that slope to the west. Undulating terrain lies beyond the GMA to the south and west. The GMA governs all formations from the surface and includes three confined aquifers: the Brighton Group/Baxter Sandstone (UTAF), Batesford Limestone (UMTA) and the Childers Formation (LTA). The PCV is intended to primarily manage the LTA.

A regional scale hydrostratigraphic profile in and around the Corinella GMA is listed in Table 10-4 and key hydrogeological attributes are described in Table 10-5.

Table 10-4 Hydrostratigraphic profile in and around the Corinella GMA

Geological formation	VAF code	Geological period	Lithology
Undifferentiated sediments	QA	Quaternary	Sand, gravels, clay, silts.
Brighton Group/Baxter Formation	UTAF	Upper Tertiary	Sand, gravel and clay.
Batesford Limestone	UMTA	Upper-Mid Tertiary	Limestone (fractured rock), sand, gravel, clay, minor coal.
Childers Formation	LTA	Lower-Mid Tertiary	Sand, gravel, clay, silt, and minor coal.
Mornington Volcanics ⁽¹⁾	LTBa	Lower-Mid Tertiary	Basalt.
Basement rocks	BSE	Mesozoic and Palaeozoic	Sedimentary (fractured rock): sandstone, siltstone, mudstone, shale. Igneous (fractured rock): includes volcanics, granites, granodiorites.

Source: (GHD, 2020a).

Notes:

The shaded grey cells indicate the confined aquifer VAF layers subject to the Phase B study.

(1) The LTBa VAF layer is not indicated to occur within the GMU.

Table 10-5 Corinella GMA – Key hydrogeological attributes

Attribute	Parameter	Description
Groundwater management	GMU size ⁽¹⁾	110 km ²
	PCV Order depth	All formations below surface.

Confined Aquifer Throughflow Assessment – Updated Method and Phase B State-wide Rollout

Attribute	Parameter	Description
	Overlying GMUs	None.
	Underlying GMUs	None.
	Confined aquifers (and VAF code, number) ⁽²⁾	Brighton Group/Baxter Formation (UTAF, 105), Batesford Limestone (UMTA, 107) and Childers Formation (LTA, 111). The management area is intended to primarily manage the groundwater resources of the LTA. The PCV primarily relates to confined aquifers.
	PCV and derivation ⁽²⁾	2,550 ML/year (PCV Order 2006). Derivation: Combination of rainfall recharge and aquifer throughflow.
Groundwater usage	Licensed volume ⁽³⁾	662 ML/year (June 2021).
	Licensed use ⁽³⁾	Average (2006-2021): 61 ML/year. Minimum (2020-2021): 14 ML/year. Maximum (2009-2010): 129 ML/year.
Hydrogeological conceptualisation	Recharge areas	N/a.
	Groundwater flow and aquifer/aquitard characteristics ⁽¹⁾	Groundwater is recharged vertically to the Tertiary aquifers in exposed areas around the basin margin and outcrop areas to the north of the Bass River. It is assumed groundwater flows from highland areas to the south and east towards Westernport Bay.
	Cross border flows	Not applicable.
Groundwater monitoring	Groundwater suite hydrographic classification ⁽²⁾	A variable long-term trend that fluctuates with long term climate and use (Suite M_S_88) is indicated for the Middle aquifers (UTAF, UMTA).

References: (1) SKM (1998a), (2) GHD (2020a), (3) DEECA. (2023).

10.2 Aquifer property data

Aquifer property data collected for the Brighton Group/Baxter Sandstone (UTAF), Sherwood Formation/Yallock Formation and Batesford Limestone (UMTA), Mornington Volcanics (LTBa) and Childers Formation (LTA) in the Westernport groundwater catchment is presented in Table 10-6, Table 10-7, Table 10-8 and Table 10-9, respectively. The statistical analysis of the K (K_h) point data for each of the VAF layers is presented in Table 10-10, including the P20 K, P50 K and P80 K values adopted for the throughflow calculations.

Table 10-6 Westernport groundwater catchment - UTAF properties

Area	Aquifer	K_h (m/d)	K_v (m/d)	T (m ² /d)	S	Reference
Port Phillip CMA	Brighton Group/Baxter Formation	0.5	N/a	18	N/a	GHD (2010a).
Port Phillip CMA	Brighton Group	<0.5	N/a	N/a	N/a	Leonard (1992), as cited by GHD (2010a).
Port Phillip CMA	Baxter Formation	N/a	N/a	50-300	N/a	Thompson (1994), as cited by GHD (2010a).
KWR WSPA	Baxter Formation	4.5	N/a	136	0.001	EarthEon (2018), as cited in EarthEon (2021).
KWR WSPA	Baxter Formation	3.5	N/a	21	0.001	EarthEon (2020), as cited in EarthEon (2021).

Confined Aquifer Throughflow Assessment – Updated Method and Phase B State-wide Rollout

Area	Aquifer	K_h (m/d)	K_v (m/d)	T (m ² /d)	S	Reference
KWR WSPA	Baxter Formation	2	N/a	100	2×10^{-4}	Lakey (1980b), as cited in EarthEon (2021).
KWR WSPA	Baxter Formation	1-4	N/a	N/a	N/a	SKM (1998a), as cited in GHD (2020).

Table 10-7 Westernport groundwater catchment - UMTA properties

Area	Aquifer	K_h (m/d)	K_v (m/d)	T (m ² /d)	S	Reference
KWR WSPA	Sherwood Formation	20	N/a	226	N/a	EarthEon (2015), as cited in EarthEon (2021).
KWR WSPA	Sherwood Formation	0.8	N/a	44	2.1×10^{-4}	Lakey (1980b), as cited in EarthEon (2021).
KWR WSPA	Sherwood Formation	1.3	N/a	27	1.9×10^{-4}	Lakey (1980b), as cited in EarthEon (2021).
KWR WSPA	Sherwood Formation	1	N/a	90	2.8×10^{-4}	Lakey (1980b), as cited in EarthEon (2021).
KWR WSPA	Sherwood Formation	2.6	N/a	18	2.4×10^{-4}	Lakey (1980b), as cited in EarthEon (2021).
KWR WSPA	Sherwood Formation	8.5	N/a	85	1.1×10^{-4}	Lakey (1980b), as cited in EarthEon (2021).
KWR WSPA	Sherwood Formation	N/a	N/a	12.5	2.3×10^{-4}	Lakey (1980a), as cited in EarthEon (2021).
KWR WSPA	Sherwood Formation	N/a	N/a	85.3	1.03×10^{-4}	Lakey (1980a), as cited in EarthEon (2021).
KWR WSPA	Sherwood Formation	3.5	N/a	84	2.5×10^{-4}	Lakey (1980b), as cited in EarthEon (2021).
KWR WSPA	Sherwood Formation	5.7	N/a	150	2.7×10^{-4}	Lakey (1980b), as cited in EarthEon (2021).
KWR WSPA	Sherwood Formation	4.8	N/a	100	N/a	Lakey (1980b), as cited in EarthEon (2021).
KWR WSPA	Sherwood Formation	4.6	N/a	191	3.5×10^{-1}	Lakey (1980b), as cited in EarthEon (2021).
KWR WSPA	Sherwood Formation	3-4.8	N/a	191	$0.3-3 \times 10^{-4}$	SKM (1998a), as cited in GHD (2020).
KWR WSPA	Sherwood Formation	1-8.5	N/a	85-90	2×10^{-4}	SKM (1998a), as cited in GHD (2020).
Port Phillip CMA	Batesford Limestone	N/a	N/a	18	N/a	GHD (2010a).

Table 10-8 Westernport groundwater catchment - LTBa properties

Area	Aquifer	K_h (m/d)	K_v (m/d)	T (m ² /d)	S	Reference
KWR WSPA	Older Volcanics	0.4	N/a	3.2	3.9×10^{-5}	GHD (2013), as cited in EarthEon (2021).
KWR WSPA	Older Volcanics	7.2	N/a	57.9	3.5×10^{-4}	SKM (2009a), as cited in EarthEon (2021).

Confined Aquifer Throughflow Assessment – Updated Method and Phase B State-wide Rollout

Area	Aquifer	K_h (m/d)	K_v (m/d)	T (m ² /d)	S	Reference
KWR WSPA	Older Volcanics	27.2	N/a	163	3×10^{-4}	SKM (2009a), as cited in EarthEon (2021).
KWR WSPA	Older Volcanics	3.6	N/a	87	3×10^{-4}	SKM (2009a), as cited in EarthEon (2021).
KWR WSPA	Older Volcanics	2.1	N/a	42	0.17	SKM (2009a), as cited in EarthEon (2021).
KWR WSPA	Older Volcanics	2.9	N/a	41	N/a	Lakey (1980b), as cited in EarthEon (2021).
KWR WSPA	Older Volcanics	2.8	N/a	64	N/a	Lakey (1980b), as cited in EarthEon (2021).
KWR WSPA	Older Volcanics	N/a	N/a	13	N/a	Lakey (1980b), as cited in EarthEon (2021).
KWR WSPA	Older Volcanics	0.1	N/a	2.5	N/a	Lakey (1980b), as cited in EarthEon (2021).
KWR WSPA	Older Volcanics	3.6	N/a	141	N/a	Lakey (1980b), as cited in EarthEon (2021).
KWR WSPA	Older Volcanics	1.3	N/a	34	N/a	Lakey (1980b), as cited in EarthEon (2021).
KWR WSPA	Older Volcanics	8.9	N/a	640	N/a	Lakey (1980b), as cited in EarthEon (2021).
KWR WSPA	Older Volcanics	7.6	N/a	130	N/a	Lakey (1980b), as cited in EarthEon (2021).
KWR WSPA	Older Volcanics	9.4	N/a	496	N/a	Lakey (1980b), as cited in EarthEon (2021).
KWR WSPA	Older Volcanics	2.3	N/a	134	N/a	Lakey (1980b), as cited in EarthEon (2021).
KWR WSPA	Mornington Volcanics	2.9-11.7	N/a	1,500	5×10^{-3} - 5×10^{-4}	SKM (1998a), as cited in GHD (2020).

Table 10-9 Westernport groundwater catchment - LTA properties

Area	Aquifer	K_h (m/d)	K_v (m/d)	T (m ² /d)	S	Reference
KWR WSPA	Childers Formation	3-3.7 m/d	N/a	149	2.5×10^{-4}	SKM (1998a), as cited in GHD (2020)
Port Phillip CMA	N/a	0.1-5, median 0.5	N/a	N/a	N/a	GHD (2010a).
Corinella GMA	Childers Formation	1	N/a	N/a	N/a	SKM (1998a).

Table 10-10 Westernport groundwater catchment K_h statistics

K_h statistical parameter	Value			
	UTAF	UMTA	LTBa	LTA
Number of data points	4	10	14	1
Minimum	<0.5 m/d	0.8 m/d	0.1 m/d	0.1 m/d
P20	N/a (1.5 m/d)	1.2 m/d	1.8 m/d	N/a (0.1 m/d)
P50	N/a (2.5 m/d)	4.1 m/d	3.3 m/d	N/a (0.5 m/d)
Average	2.6 m/d	5.3 m/d	5.7 m/d	0.5 m/d

K _h statistical parameter	Value			
	UTAF	UMTA	LTBa	LTA
P80	N/a (3.5 m/d)	6.3 m/d	8.1 m/d	N/a (4.5 m/d)
Maximum	4.5 m/d	20.0 m/d	27.2 m/d	5.0 m/d
Standard deviation	N/a	5.7	6.91	N/a

Notes:

The shaded cells indicate the P20 K, P50 K and P80 K values adopted in the gridded throughflow rate analysis.

The inputted K values were rounded to the nearest 0.5 for the throughflow analysis.

N/a: Insufficient K_h point data to inform statistical analysis. In the absence of sufficient K point data, the typical K ranges from pumping tests informed the selection of representative values of P20, P50 and P80 K for the throughflow assessments. These adopted values are indicated in brackets.

10.3 Outputs

10.3.1 Koo-Wee-Rup WSPA

The Koo-Wee-Rup WSPA is designated flow-tubes UTAF ft02, UMTA ft02, LTBa ft02, LTBa ft03 and LTA ft02 (Table 10-1). The predevelopment throughflows for these flow-tubes rely on throughflow outputs from the following cross-sections perpendicular to groundwater flow:

- UTAF ft02: 5 m, 15 m and 25 m modelled RWL contours.
- UMTA ft02: 5 m and 15 m modelled RWL contours.
- LTBa ft02: 5 m, 15 m, 25 m and 35 m modelled RWL contours.
- LTBa ft03: 5 m and 20 m modelled RWL contours.
- LTA ft02: 5 m, 15 m and 25 m modelled RWL contours.

The (P50 K) predevelopment throughflow estimate of each cross-section in the UTAF ft02, UMTA ft02, LTBa ft02, LTBa ft03 and LTA ft02 is reported in Table 10-11. The corresponding average, lower and upper range (P50 K), and lower range minimum (P20 K) predevelopment throughflow estimates for the flow-tubes, and a combined estimate, are also reported. The potential variability of throughflow within the flow-tubes, and combined, is represented by the SD and CV in Table 10-11.

Table 10-11 Predevelopment throughflow estimates for flow tubes - UTAF ft02, UMTA ft02, LTBa ft02, LTBa ft03 and LTA ft02

Parameter	Value
UTAF ft02	
P50 K PD throughflow, Cross-section 1 (5 m RWL) (ML/y)	3,726
P50 K PD throughflow, Cross-section 2 (15 m RWL) (ML/y)	5,463
P50 K PD throughflow, Cross-section 3 (25 m RWL) (ML/y)	3,683
Average (P50 K) PD throughflow (ML/y)	4,291
Lower range (P50 K) PD throughflow (ML/y)	3,683
Upper range (P50 K) PD throughflow (ML/y)	5,463
Lower range minimum (P20 K) PD throughflow (ML/y)	2,210
SD (ML/y)	1,016
CV (%)	24
Approximate length of flow-tube (km)	35
UMTA ft02	
P50 K PD throughflow, Cross-section 1 (5 m RWL) (ML/y)	4,067
P50 K PD throughflow, Cross-section 2 (15 m RWL) (ML/y)	3,453
Average (P50 K) PD throughflow (ML/y)	3,760
Lower range (P50 K) PD throughflow (ML/y)	3,453

Confined Aquifer Throughflow Assessment – Updated Method and Phase B State-wide Rollout

Parameter	Value
Upper range (P50 K) PD throughflow (ML/y)	4,067
Lower range minimum (P20 K) PD throughflow (ML/y)	863
SD (ML/y)	434
CV (%)	12
Approximate length of flow-tube (km)	15
LTBa ft02	
P50 K PD throughflow, Cross-section 1 (5 m RWL) (ML/y)	482
P50 K PD throughflow, Cross-section 2 (15 m RWL) (ML/y)	825
P50 K PD throughflow, Cross-section 3 (25 m RWL) (ML/y)	1,229
P50 K PD throughflow, Cross-section 4 (35 m RWL) (ML/y)	921
Average (P50 K) PD throughflow (ML/y)	864
Lower range (P50 K) PD throughflow (ML/y)	482
Upper range (P50 K) PD throughflow (ML/y)	1,229
Lower range minimum (P20 K) PD throughflow (ML/y)	276
SD (ML/y)	242
CV (%)	28
Approximate length of flow-tube (km)	30
LTBa ft03	
P50 K PD throughflow, Cross-section 1 (5 m RWL) (ML/y)	642
P50 K PD throughflow, Cross-section 2 (20 m RWL) (ML/y)	627
Average (P50 K) PD throughflow (ML/y)	634
Lower range (P50 K) PD throughflow (ML/y)	627
Upper range (P50 K) PD throughflow (ML/y)	642
Lower range minimum (P20 K) PD throughflow (ML/y)	358
SD (ML/y)	11
CV (%)	2
Approximate length of flow-tube (km)	10
LTA ft02	
P50 K PD throughflow, Cross-section 1 (5 m RWL) (ML/y)	577
P50 K PD throughflow, Cross-section 2 (15 m RWL) (ML/y)	602
P50 K PD throughflow, Cross-section 3 (25 m RWL) (ML/y)	385
Average (P50 K) PD throughflow (ML/y)	521
Lower range (P50 K) PD throughflow (ML/y)	385
Upper range (P50 K) PD throughflow (ML/y)	602
Lower range minimum (P20 K) PD throughflow (ML/y)	77
SD (ML/y)	18
CV (%)	3
Approximate length of flow-tube (km)	35
Combined UTAF ft02, UMTA ft02, LTBa ft02, LTBa ft03 and LTA ft02	
Average (P50 K) PD throughflow (ML/y)	10,070
Lower range (P50 K) PD throughflow (ML/y)	8,630
Upper range (P50 K) PD throughflow (ML/y)	12,002
Lower range minimum (P20 K) PD throughflow (ML/y)	3,784

Confined Aquifer Throughflow Assessment – Updated Method and Phase B State-wide Rollout

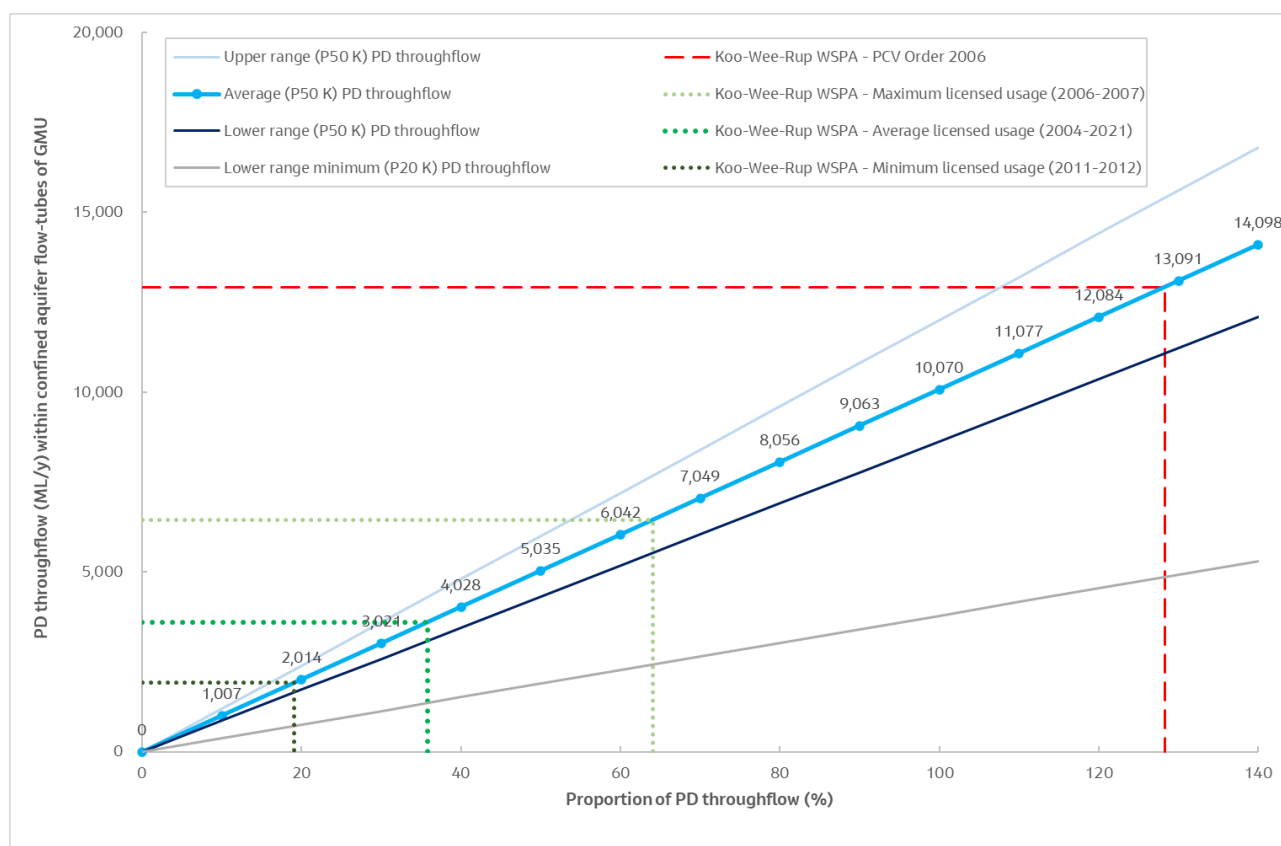
Parameter	Value
SD (ML/y)	1,720
CV (%)	55

Note:

All of the cross-sections occur within the GMU boundary.

To assist with contextualising the throughflow outputs, the average, lower and upper range (P50 K) and lower range minimum (P20 K) predevelopment throughflow estimates for combined flow-tubes UTAF ft02, UMTA ft02, LTBa ft02, LTBa ft03 and LTA ft02 are presented in Figure 10-1. For comparison, the Koo-Wee-Rup WSPA PCV and minimum, average and maximum licensed usage values are overlaid on the figure.

Figure 10-1 Koo-Wee-Rup WSPA - PCV and licensed usage relative to predevelopment throughflow estimates of combined flow-tubes UTAF ft02, UMTA ft02, LTBa ft02, LTBa ft03 and LTA ft02



The throughflow results of the flow-tubes, and their spatial variability, are summarised in Table 10-12 in the context of management arrangements and licensed usage in the Koo-Wee-Rup WSPA, including considerations for assigning a sustainable yield.

Table 10-12 Summary of predevelopment throughflows in context of Koo-Wee-Rup WSPA

Flow-tube parameter	Result
Confined VAF layers	UTAF, UMTA, LTBa and LTA.
Comparison with WSPA boundary	The WSPA boundary generally occupies the entire width and length of the flow-tubes.

Confined Aquifer Throughflow Assessment – Updated Method and Phase B State-wide Rollout

Flow-tube parameter	Result
Flow from, or to, GMUs or UAs	The WSPA does not receive flow from, or contribute flow to, another GMU or UA.
GMU PD throughflow estimate	All of the flow-tube cross-sections occur within the boundary of the WSPA. The average (P50 K) predevelopment throughflow of the WSPA is therefore estimated to be 10,070 ML/y .
Confined aquifer(s) contributing majority of PD throughflow	Boisdale Formation (UTAF) (43%) and Sherwood/Yallock Formation (UMTA) (37%).
CV (%) and potential factors contributing to spatial variability	CV: 17 %. A range of spatially variable processes may be responsible including vertical leakage from the overlying unconfined Quaternary unit.
PCV relative to PD throughflow	The PCV (12,915 ML/y) represents 128 % of the average (P50 K) predevelopment throughflow (10,070 ML/y) but allowing for spatial variability may be between 108 % and 150 %. The PCV represents 341 % of the lower range minimum (P20 K) predevelopment throughflow.
Average licensed usage relative to PD throughflow	The average licensed usage (3,610 ML/y) represents 36 % of the average (P50 K) predevelopment throughflow (10,070 ML/y) but allowing for spatial variability may be between 30 % and 42 %. The average licensed usage represents 95 % of the lower range minimum (P20 K) predevelopment throughflow.
Relative rankings (Appendix B)	Relative reliability ranking: Medium; Relative uncertainty ranking: Low; Relative potential for adverse impact on aquifer value(s): Medium; Overall GMU ranking: Low-Medium.
Considerations for assigning sustainable yield	<ul style="list-style-type: none"> ▪ The overall estimate of sustainable yield for the WSPA will need to consider contributions from the Quaternary undifferentiated sediments, the subject of the CDM Smith unconfined aquifer sustainable yield study. ▪ Groundwater resources may need to be managed on an aquifer by aquifer basis due to: <ul style="list-style-type: none"> - Absence (in particular) of the UMTA in the northeast section of the WSPA. - Variability in throughflow contributions from each confined aquifer. ▪ Regarding the management history of the Koo-Wee-Rup WSPA aquifer systems, it was recognised in the early 1980s that concentrated extraction in the vicinity of Dalmore and Cora Lynn resulted in drawdown in the Westernport Group below sea level resulting in a strong risk of sea water intrusion into the aquifer. Accordingly, a reduction of use occurred through community involvement in a groundwater management plan. Based on the combined average (P50 K) predevelopment throughflow estimate, the aquifer systems may have the capacity for increased extraction, however, the protection of aquifer values (e.g., avoiding groundwater quality degradation by sea water intrusion) may place tighter constraints on the aquifer and result in assigning a lower sustainable yield than indicated by throughflow estimates. ▪ The distribution of use (both licensed and non-licensed) and the whole of aquifer basis of the throughflow estimate should be considered in assessing the sustainable yield.

10.3.2 Corinella GMA

The Corinella GMA is designated flow-tubes UTAF ft01, UMTA ft01 and LTA ft01 (Table 10-1). The predevelopment throughflows for these flow-tubes rely on throughflow outputs from the following cross-sections perpendicular to groundwater flow:

- UTAF ft01: 10 m modelled RWL contour.
- UMTA ft01: 10 m modelled RWL contour.
- LTA ft01: 10 m modelled RWL contour.

The (P50 K) predevelopment throughflow estimate of each cross-section in the UTAF ft01, UMTA ft01 and LTA ft01 is reported in Table 10-13. The corresponding (adopted) average (P50 K) and the lower range minimum (P20 K) predevelopment throughflow estimates for the flow-tubes are also reported. As only one cross-section in the flow-tube informs the throughflow assessment, the spatial variability of the throughflow calculation has not been assessed.

Table 10-13 Predevelopment throughflow estimates for flow tubes - UTAF ft01, UMTA ft01 and LTA ft01

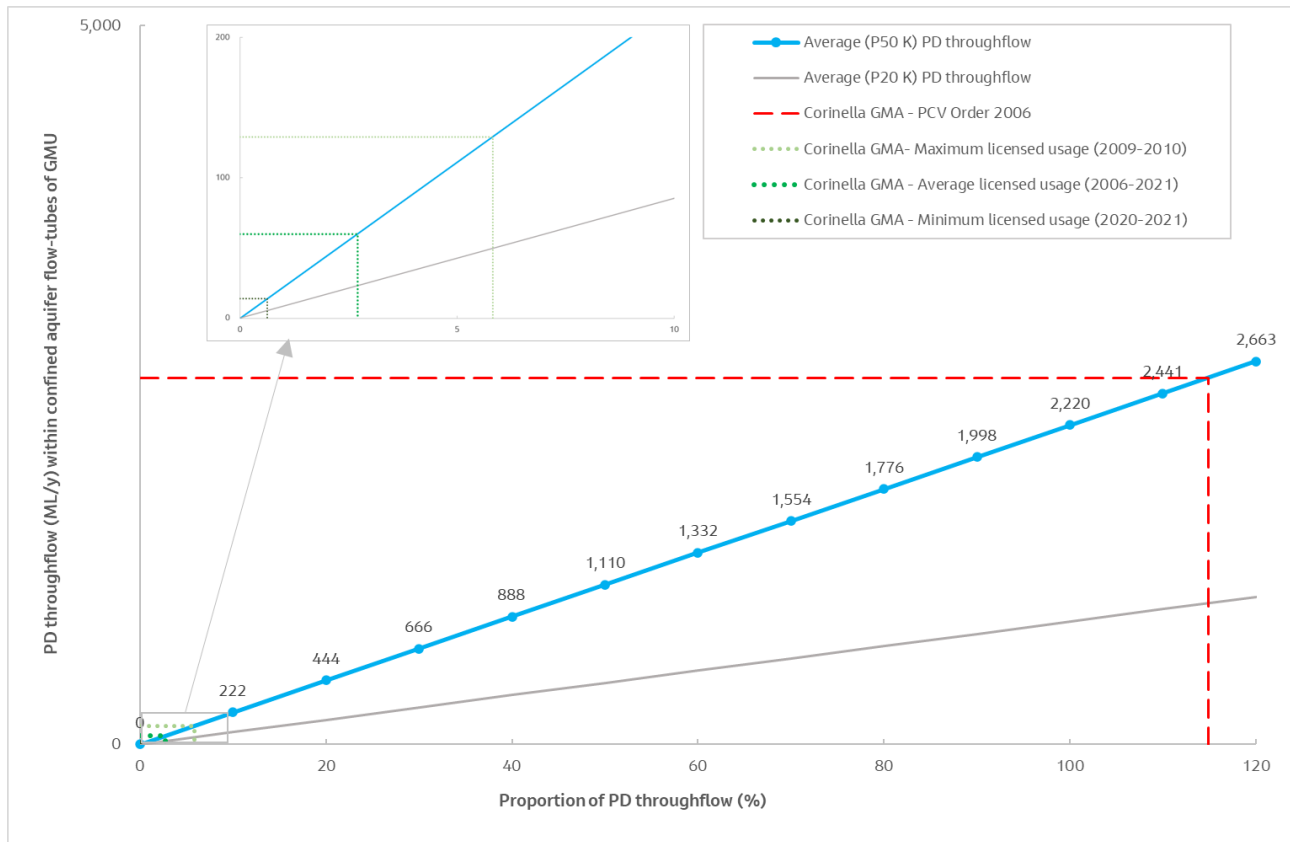
Parameter	Value
UTAF ft01	
P50 K PD throughflow, Cross-section 1 (5 m RWL) (ML/y)	904
Adopted (average) (P50 K) PD throughflow (ML/y)	904
Lower range minimum (P20 K) PD throughflow (ML/y)	542
Approximate length of flow-tube (km)	10
UMTA ft01	
P50 K PD throughflow, Cross-section 1 (5 m RWL) (ML/y)	966
Adopted (average) (P50 K) PD throughflow (ML/y)	966
Lower range minimum (P20 K) PD throughflow (ML/y)	242
Approximate length of flow-tube (km)	10
LTA ft01	
P50 K PD throughflow, Cross-section 1 (5 m RWL) (ML/y)	350
Adopted (average) (P50 K) PD throughflow (ML/y)	350
Lower range minimum (P20 K) PD throughflow (ML/y)	70
Approximate length of flow-tube (km)	10
Combined UTAF ft01, UMTA ft01 and LTA ft01	
Adopted (average) (P50 K) PD throughflow (ML/y)	2,220
Lower range minimum (P20 K) PD throughflow (ML/y)	854

Note:

The cross-section occurs within the GMU boundary.

To assist with contextualising the throughflow outputs, the average (P50 K) and lower range minimum (P20 K) predevelopment throughflow estimates for flow-tubes UTAF ft01, UMTA ft01 and LTA ft01 are presented in Figure 10-2. For comparison, the Corinella GMA PCV and minimum, average and maximum licensed usage values are overlaid on the figure.

Figure 10-2 Corinella GMA - PCV and licensed usage relative to predevelopment throughflow estimates of combined flow-tubes UTAF ft01, UMTA ft01 and LTA ft01



The throughflow results of the flow-tubes are summarised in Table 10-14 in the context of management arrangements and licensed usage in the Corinella GMA, including considerations for assigning a sustainable yield.

Table 10-14 Summary of predevelopment throughflows in context of Corinella GMA

Flow-tube parameter	Result
Confined VAF layers	UTAF, UMTA and LTA.
Comparison with GMA boundary	The GMA boundary mostly occupies the entire width and length of the flow-tubes.
Flow from, or to, GMUs or UAs	The GMA does not contribute flow to, or receive flow from, another GMU or UA.
GMU PD throughflow estimate	The flow-tube cross-sections occur within the boundary of the GMA. The average (P50 K) predevelopment throughflow of the GMA is therefore estimated to be 2,220 ML/y .
CV (%) and potential factors contributing to spatial variability	CV: N/a (one cross-section was assessed in each flow-tube).
PCV relative to PD throughflow	The PCV (2,550 ML/y) represents 115 % of the average (P50 K) predevelopment throughflow (2,220 ML/y). The PCV represents 299 % of the lower range minimum (P20 K) predevelopment throughflow.
Average licensed usage relative to PD throughflow	The average licensed usage (60 ML/y) represents 3 % of the average (P50 K) predevelopment throughflow (2,220 ML/y). The average licensed usage represents 7 % of the lower range minimum (P20 K) predevelopment throughflow.
Relative rankings (Appendix B)	Relative reliability ranking: Low; Relative uncertainty ranking: Medium; Relative potential for adverse impact on aquifer value(s): Low; Overall GMU ranking: Medium-Low.

Flow-tube parameter	Result
Considerations for assigning sustainable yield	Potential risks of sea water intrusion from groundwater development.

10.3.3 UA UTAF north of Bonbeach

The UA UTAF north of Bonbeach (Figure 5-2) is designated flow-tube UTAF ft04 (Table 10-1). The predevelopment throughflows for UTAF ft04 relies on throughflow outputs from one cross-section perpendicular to groundwater flow (at 10 m modelled RWL contour).

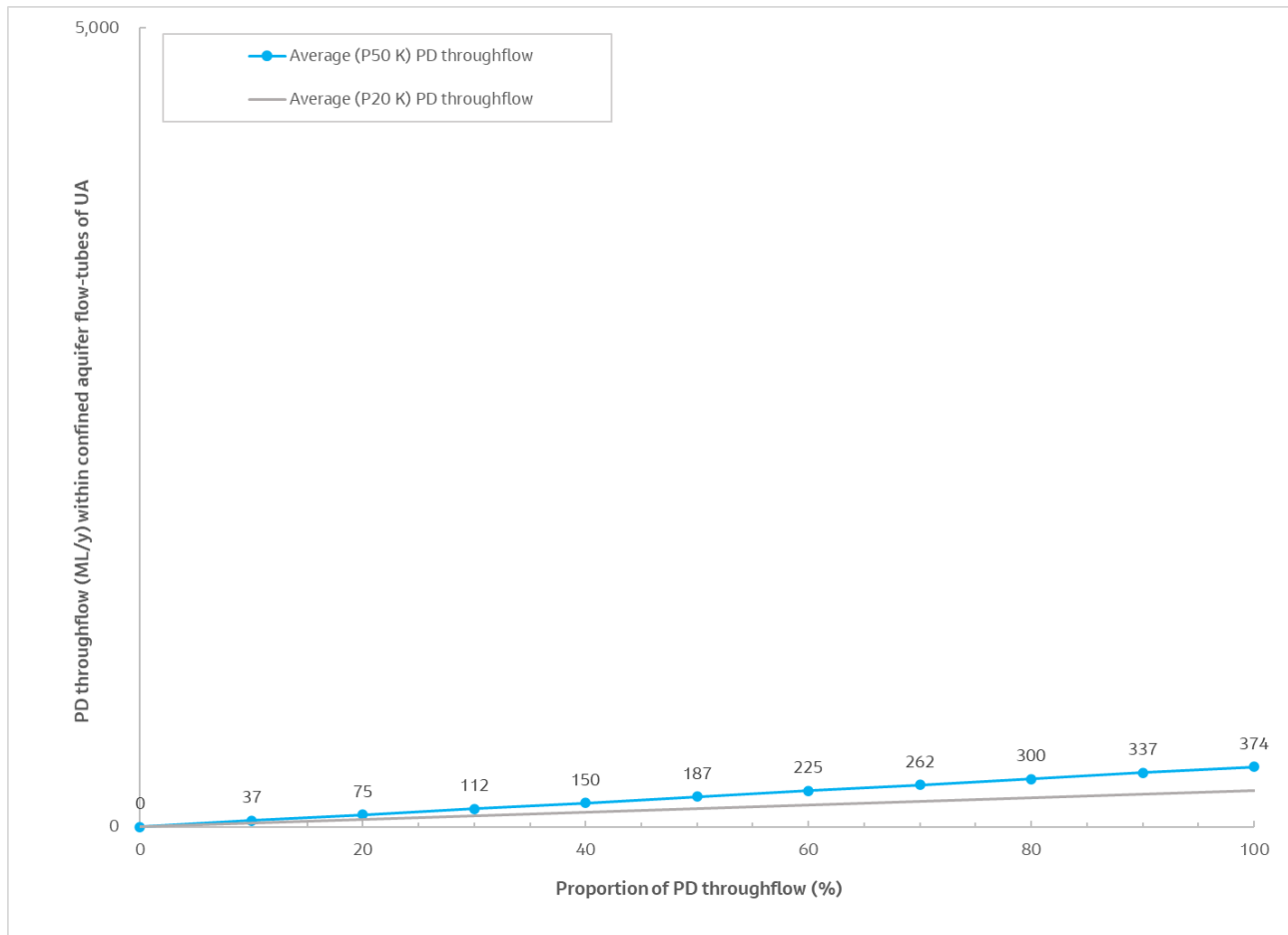
The (P50 K) predevelopment throughflow estimate of the cross-section in UTAF ft04 is reported in Table 10-15. The corresponding (adopted) average (P50 K) and the lower range minimum (P20 K) predevelopment throughflow estimates for the flow-tube are also reported. As only one cross-section informs the throughflow assessment, the spatial variability of the throughflow calculation has not been assessed.

Table 10-15 Predevelopment throughflow estimates for flow tubes – UTAF ft04

Parameter	Value
P50 K PD throughflow, Cross-section 1 (10 m RWL) (ML/y)	374
Average (P50 K) PD throughflow (ML/y)	374
Lower range minimum (P20 K) PD throughflow (ML/y)	225
Approximate length of flow-tube (km)	10

To assist with contextualising the throughflow outputs, the average (P50 K) and lower range minimum (P20 K) predevelopment throughflow estimates for flow-tube UTAF ft04 are presented in Figure 10-3.

Figure 10-3 Predevelopment throughflow estimates of flow-tube UTAF ft04 north of Bonbeach



10.3.4 UA UMTA near Hastings

The UA UMTA near Hastings (Figure 5-3) is designated flow-tube UMTA ft03 (Table 10-1). The predevelopment throughflows for UMTA ft03 rely on throughflow outputs from two cross-sections perpendicular to groundwater flow (at 5 m and 20 m modelled RWL contours).

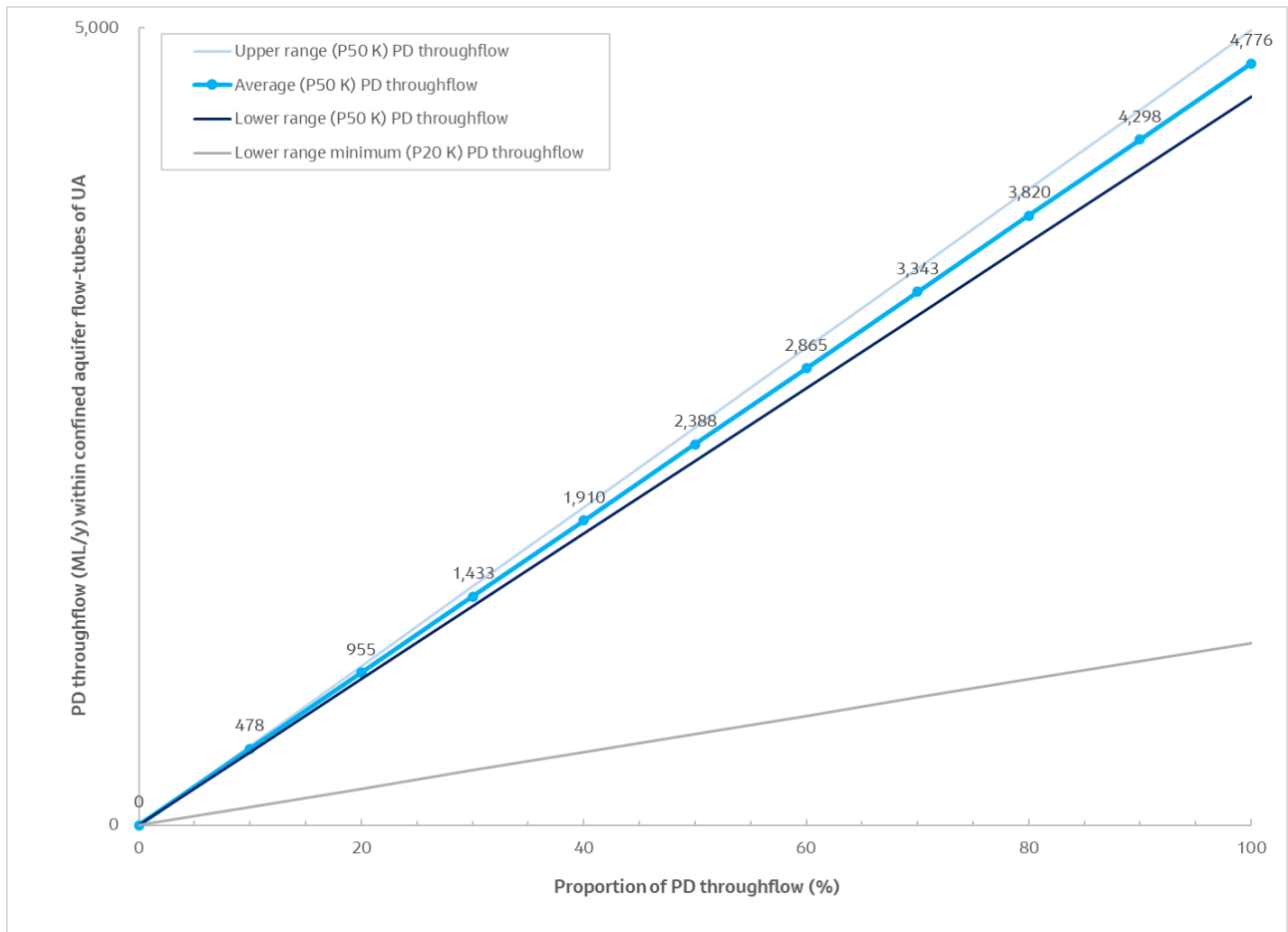
The (P50 K) predevelopment throughflow estimate of each cross-section in UMTA ft03 is reported in Table 10-16. The corresponding average, lower and upper range (P50 K), and lower range minimum (P20 K), predevelopment throughflow estimates for the flow-tube are also reported. The spatial variability of the calculated throughflow rate within the flow-tube is represented by the SD and CV in Table 10-16.

Table 10-16 Predevelopment throughflow estimates for flow tubes – UMTA ft03

Parameter	Value
P50 K PD throughflow, Cross-section 1 (5 m RWL) (ML/y)	4,568
P50 K PD throughflow, Cross-section 2 (20 m RWL) (ML/y)	4,984
Average (P50 K) PD throughflow (ML/y)	4,776
Lower range (P50 K) PD throughflow (ML/y)	4,568
Upper range (P50 K) PD throughflow (ML/y)	4,984
Lower range minimum (P20 K) PD throughflow (ML/y)	1,142
SD (ML/y)	294
CV (%)	6
Approximate length of flow-tube (km)	5

To assist with contextualising the throughflow outputs, the average, lower and upper range (P50 K) and lower range minimum (P20 K) predevelopment throughflow estimates for flow-tube UMTA ft03 are presented in Figure 10-4.

Figure 10-4 Predevelopment throughflow estimates of flow-tube UMTA ft03 near Hastings



11. Gippsland GMB – Moe groundwater catchment & GMA

The Gippsland GMB is located in southeast Victoria and includes the East Gippsland, Central Gippsland, Moe and Seaspray groundwater catchments. This chapter concerns the Moe groundwater catchment.

The confined aquifers within the Moe groundwater catchment include:

- Yarragon Formation (UMTA) (Figure 5-3).
- Thorpdale Volcanics (LTBa) (Figure 5-5).
- Childers Formation (LTA) (Figure 5-6).

The Moe groundwater catchment contains one GMU that incorporates these confined aquifers (Figure 5-3, Figure 5-5 and Figure 5-6). The flow-tubes assigned in the groundwater catchment are listed in Table 11-1.

Table 11-1 Moe groundwater catchment – assigned flow-tubes

Groundwater catchment	GMU or non-GMU	PCV Order depth	Confined VAF layer and flow-tube no.	Aquifer name
Moe	Moe GMA	All formations below 25 m from surface	UMTA ft05	Yarragon Formation
			LTBa ft05	Thorpdale Volcanics
			LTA ft10	Childers Formation

Note:

Shaded cell indicates the flow-tube is assigned to a GMU but includes a significant (multiple cells) UA either upgradient or downgradient of the GMU.

11.1 Hydrogeological characterisation

The Moe GMA is located in the north-western corner of the Gippsland Basin and covers the Moe Swamp sub-basin. 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. To the east a narrow valley leads to the broader Gippsland Basin region.

The aquifers of the Moe Swamp sub-basin are disconnected from the Gippsland Basin as a result of structural compartmentalisation of these areas (Yates et al., 2015).

The GMA governs all formations from 25 to 2,000 m in depth and includes the following four confined aquifers:

- Haunted Hills Gravel (UTQA).
- Yarragon Formation (UMTA).
- Thorpdale Volcanics (LTBa).
- Childers Formation (LTA).

Due to the small occurrence of confined areas of Haunted Hills Gravel (UTQA) in the Moe GMA (partially occupying three gridded cells along the Latrobe River), this VAF layer has been excluded from the throughflow assessment.

A regional scale hydrostratigraphic profile in and around the Moe GMA is listed in Table 11-2 and key hydrogeological attributes are described in Table 11-3.

Table 11-2 Hydrostratigraphic profile in and around the Moe GMA

Geological formation	VAF code	Geological period	Lithology
Haunted Hills Gravel ⁽¹⁾	UTQA	Quaternary	Sand, gravel and clay.
Undifferentiated Upper Tertiary Aquitard	UTD	Upper Tertiary	N/a.
Yarragon Formation	UMTA	Upper Mid-Tertiary	Unconsolidated clay, silt, minor sand and gravel, with coal seams. The Yarragon Formation is an isolated age equivalent unit of the Yallourn Formation.

Confined Aquifer Throughflow Assessment – Updated Method and Phase B State-wide Rollout

Geological formation	VAF code	Geological period	Lithology
Thorpdale Volcanics	LTBa	Lower Tertiary	Basalt; sometimes with inter-bedded sandstone, silcrete, often highly weathered.
Childers Formation	LTA	Lower Tertiary	Interbedded gravel, sand, clay and coal seams.
Basement Rocks	BSE	Mesozoic and Palaeozoic	Sedimentary (fractured rock): sandstone, siltstone, mudstone, shale. Igneous (fractured rock): includes volcanics, granites, granodiorites.

Source: Jacobs, 2014&19 and Yates et al., 2015.

Notes:

The shaded grey cells indicate the confined aquifer VAF layers subject to the Phase B study.

(1) Due to the small occurrence of confined areas of Haunted Hills Gravel (UTQA) in the Moe GMA (GMA partially occupying three gridded cells along the Latrobe River), this VAF layer has been excluded from the throughflow assessment

Table 11-3 Moe GMA – Key hydrogeological attributes

Attribute	Parameter	Description
Groundwater management	GMU size	350 km ² (GIS calculated)
	PCV Order depth	25-2,000 m.
	Overlying GMUs	None.
	Underlying GMUs	None.
	Confined aquifers (and VAF code, number) ⁽¹⁾	Yarragon Formation (UMTA, 107), Thorpdale Volcanics (LTBa, 112), Childers Formation (LTA, 111).
	PCV and derivation ⁽¹⁾	8,200 ML/year (PCV Order 2011). Derivation: Technical (100% recharge minus discharge to rivers).
Groundwater usage	Licensed volume ⁽³⁾	3,762 ML/year (June 2021). Within and in areas surrounding the Moe GMA (i.e., Sandy Creek and Moe Swamp Basin zones), no new entitlements are allowed due to the potential for groundwater extraction to impact upon stream flows.
	Licensed use ⁽³⁾	Average (2004-2021): 826 ML/year. Minimum (2010-2011): 192 ML/year. Maximum (2006-2007): 1,447 ML/year.
Hydrogeological conceptualisation	Recharge areas ^(2,4)	Recharge occurs where the three aquifer units (UMTA, LTBa and LTA) outcrop in the north of the Gippsland Basin, in the south of the basin along the Yarragon Fault, and to west of the basin where the Thorpdale Volcanics (LTBa) outcrop. Recharge is from stream leakage and rainfall infiltration, including leakage from the Latrobe River in the north of the Gippsland Basin.
	Groundwater flow and aquifer/aquitard characteristics ^(2,4)	Due to structural compartmentalisation, the aquifers of the Moe Swamp are disconnected from the Tarwin sub-basin and Gippsland Basin. In general, the flow systems of the Moe Swamp is less complex than the Gippsland Basin, as the sedimentary depositional environments were terrestrial only. The base of the Yarragon Formation (UMTA) consists of sands with coals and clays dominating towards the top of the sequence, confining the basal aquifer. A lateral facies change from sandy to clayey sediments occurs around the Moe monocline, approximately 5 km west of Moe. The Thorpdale Volcanics (LTBa) also forms a significant confined to semiconfined aquifer, with greater reported transmissivity than the Yarragon (UMTA) and Childers (LTA) formations.

Attribute	Parameter	Description
		Artesian conditions occur in the southern and central part of the Moe sub-basin. Low permeability layers are present within the sequence and potentiometric levels tend to increase with depth. Groundwater flow is from the recharge areas towards the centre and towards the east of the basin where groundwater discharges via upwards leakage through the confining beds in the east of the basin, up into the water table aquifer and the Latrobe River. This upward leakage occurs due to elevated basement topography on the Haunted Hills Block and the lateral facies change from sandy to clayey sediments around the Moe Monocline, which restricts groundwater flow eastwards out of the basin and into the Latrobe Valley. Aquifer depressurisation for coal mining and oil and gas development in the Gippsland Basin is not considered to have affected groundwater levels in the Moe Swamp sub-basin, as result of the restricted hydraulic connectivity between the Moe Swamp sub-basin and the Latrobe Valley Depression.
	Cross border flows	Not applicable.
Groundwater monitoring	Groundwater suite hydrographic classification ⁽¹⁾	A declining water level trend since 2005 (L_PP_88) is indicated for the Lower aquifer (LTBa, LTA).

References: (1) Jacobs (2019), (2) Yates et al. (2015), (3) DEECA. (2023), (4) Beverly et al. (2015).

11.2 Aquifer property data

Aquifer property data collected for the Yarragon Formation (UMTA), Thorpdale Volcanics (LTBa) and Childers Formation (LTA) in the Moe groundwater catchment is presented in Table 11-4, Table 11-5 and Table 11-6, respectively. The statistical analysis of the K (K_h) point data for each of the VAF layers is presented in Table 11-7, including the P20 K, P50 K and P80 K values adopted for the throughflow calculations.

Table 11-4 Moe groundwater catchment – UMTA properties

Area	Aquifer	K_h (m/d)	K_v (m/d)	T (m ² /d)	S	Reference
Moe GMA	Yarragon Formation	0.02	0.002	N/a	N/a	Jacobs (2014), as cited in Jacobs (2019).

Table 11-5 Moe groundwater catchment – LTBa properties

Area	Aquifer	K_h (m/d)	K_v (m/d)	T (m ² /d)	S	Reference
Moe GMA	Thorpdale Volcanics	<1-18, average 5.25	0.0125	N/a	N/a	Birch (2003), Hofmann & Cartwright (2013) and Jacobs (2014), as cited in Jacobs (2019).
Leongatha GMA	Thorpdale Volcanics	0.51	0.69	N/a	N/a	GHD (2010b) as cited in Jacobs (2019).
Leongatha GMA	Thorpdale Volcanics	0.625	0.182	N/a	1.0×10^{-5}	GHD (2010b) as cited in Jacobs (2019).

Table 11-6 Moe groundwater catchment – LTA properties

Area	Aquifer	K_h (m/d)	K_v (m/d)	T (m ² /d)	S	Reference
Moe GMA	Childers Formation	Up to 50	0.005	N/a	N/a	Jacobs (2014), as cited in Jacobs (2019).

Area	Aquifer	K_h (m/d)	K_v (m/d)	T (m ² /d)	S	Reference
Leongatha GMA	Childers Formation	2	N/a	N/a	2×10^{-3}	SKM (1998e) as cited in Jacobs (2019).
Leongatha GMA	Childers Formation	0.76	0.03	N/a	N/a	GHD (2010b) as cited in Jacobs (2019).

Table 11-7 Moe groundwater catchment K_h statistics

K_h statistical parameter	Value		
	UMTA ⁽¹⁾	LTBa ⁽¹⁾	LTA ⁽¹⁾
Number of data points	1	2	2
Minimum	N/a	0.51 m/d	0.76 m/d
P20	N/a (1.2 m/d)	N/a (1.8 m/d)	N/a (0.1 m/d)
P50	N/a (4.1 m/d)	N/a (3.3 m/d)	N/a (0.5 m/d)
Average	N/a	5.25 m/d	N/a
P80	N/a (6.3 m/d)	N/a (8.1 m/d)	N/a (4.5 m/d)
Maximum	N/a	18 m/d	50 m/d
Standard deviation	N/a	N/a	N/a

Notes:

The shaded cells indicate the P20 K, P50 K and P80 K values adopted in the gridded throughflow rate analysis.

The inputted K values were rounded to the nearest 0.5 for the throughflow analysis.

N/a: Insufficient K_h point data to inform statistical analysis. In the absence of sufficient K point data, the typical K ranges from pumping tests informed the selection of representative values of P20, P50 and P80 K for the throughflow assessments. These adopted values are indicated in brackets.

(1) The point K data and ranges were limited for the UMTA, LTBa and LTA in the Moe groundwater catchments. Representative values of P20, P50 and P80 K were therefore adopted from the equivalent VAF layer within the Westernport groundwater catchment.

11.3 Outputs

The Moe GMA is designated flow-tubes UMTA ft05, LTBa ft05 and LTA ft10 (Table 11-1). The predevelopment throughflows for these flow-tubes relies on throughflow outputs from the following cross-sections perpendicular to groundwater flow:

- UMTA ft05: 70 m and 90 m modelled RWL contours.
- LTBa ft05: 70 m and 80 m modelled RWL contours.
- LTA ft10: 70 m and 90 m modelled RWL contours.

The (P50 K) predevelopment throughflow estimate of each cross-section in the UMTA ft05, LTBa ft05 and LTA ft10 is reported in Table 11-8. The corresponding average, lower and upper range (P50 K), and lower range minimum (P20 K) predevelopment throughflow estimates for the flow-tubes, and a combined estimate, are also reported. The potential variability of throughflow within the flow-tubes, and combined, is represented by the SD and CV in Table 11-8.

Table 11-8 Predevelopment throughflow estimates for flow tubes – UMTA ft05, LTBa ft05 and LTA ft10

Parameter	Value
UMTA ft05	
P50 K PD throughflow, Cross-section 1 (70 m RWL) (ML/y)	4,787
P50 K PD throughflow, Cross-section 2 (90 m RWL) (ML/y)	3,361
Average (P50 K) PD throughflow (ML/y)	4,074
Lower range (P50 K) PD throughflow (ML/y)	3,361
Upper range (P50 K) PD throughflow (ML/y)	4,787

Confined Aquifer Throughflow Assessment – Updated Method and Phase B State-wide Rollout

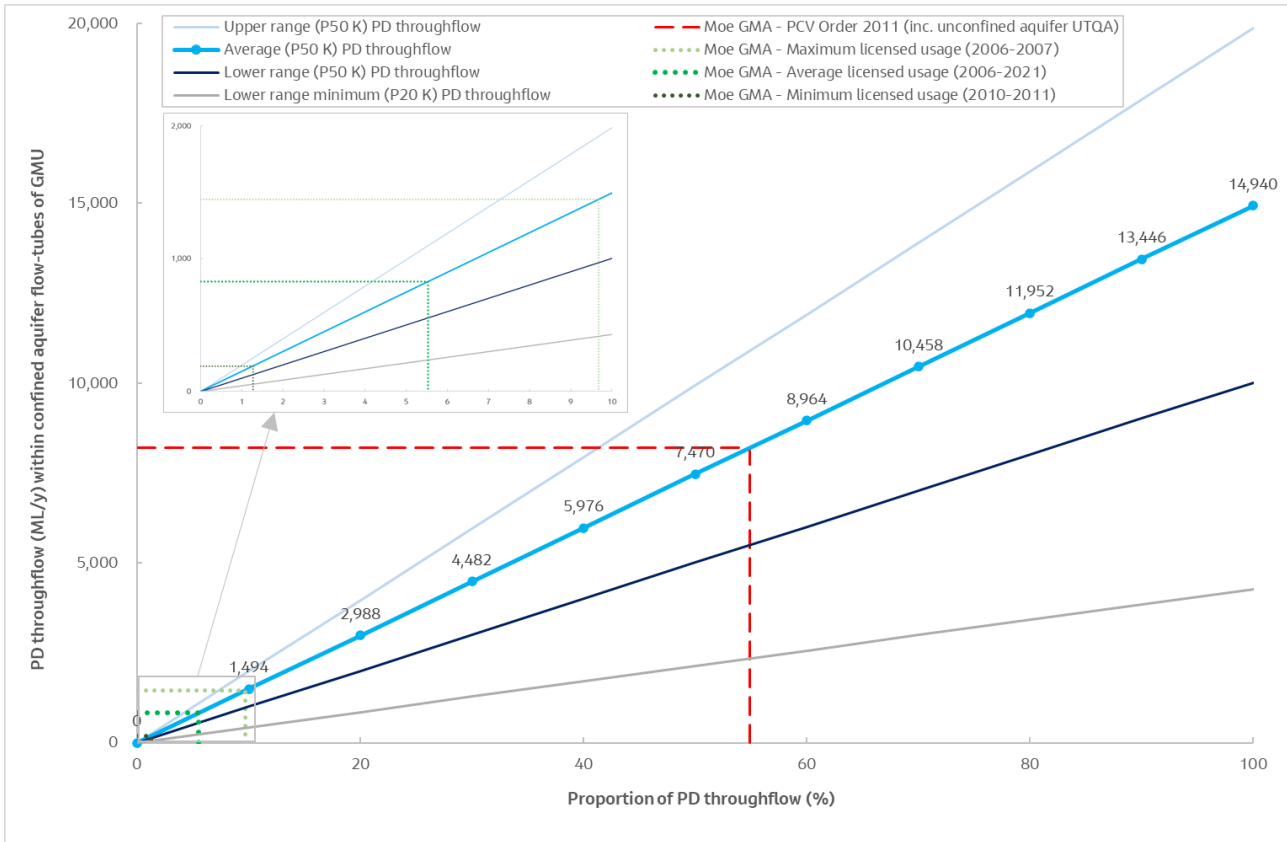
Parameter	Value
Lower range minimum (P20 K) PD throughflow (ML/y)	840
SD (ML/y)	1,009
CV (%)	25
Approximate length of flow-tube (km)	30
LTBa ft05	
P50 K PD throughflow, Cross-section 1 (70 m RWL) (ML/y)	5,658
P50 K PD throughflow, Cross-section 2 (80 m RWL) (ML/y)	12,989
Average (P50 K) PD throughflow (ML/y)	9,323
Lower range (P50 K) PD throughflow (ML/y)	5,658
Upper range (P50 K) PD throughflow (ML/y)	12,989
Lower range minimum (P20 K) PD throughflow (ML/y)	3,233
SD (ML/y)	5,184
CV (%)	56
Approximate length of flow-tube (km)	30
LTA ft10	
P50 K PD throughflow, Cross-section 1 (70 m RWL) (ML/y)	999
P50 K PD throughflow, Cross-section 2 (90 m RWL) (ML/y)	2,086
Average (P50 K) PD throughflow (ML/y)	1,542
Lower range (P50 K) PD throughflow (ML/y)	999
Upper range (P50 K) PD throughflow (ML/y)	2,086
Lower range minimum (P20 K) PD throughflow (ML/y)	200
SD (ML/y)	768
CV (%)	50
Approximate length of flow-tube (km)	35
Combined UMTA ft05, LTBa ft05 and LTA ft10	
Average (P50 K) PD throughflow (ML/y)	14,940
Lower range (P50 K) PD throughflow (ML/y)	10,017
Upper range (P50 K) PD throughflow (ML/y)	19,862
Lower range minimum (P20 K) PD throughflow (ML/y)	4,273
SD (ML/y)	6,962
CV (%)	47

Note:

All of the cross-sections occur within the GMU boundary.

To assist with contextualising the throughflow outputs, the average, lower and upper range (P50 K) and lower range minimum (P20 K) predevelopment throughflow estimates for combined flow-tubes UMTA ft05, LTBa ft05 and LTA ft10 are presented graphically in Figure 11-1. For comparison, the Moe GMA PCV and minimum, average and maximum licensed usage values are overlaid on the figure.

Figure 11-1 Moe GMA – PCV and licensed usage relative to predevelopment throughflow estimates of combined flow-tubes UMTA ft05, LTBa ft05 and LTA ft10



The throughflow results of the flow-tubes, and their spatial variability, are summarised in Table 11-9 in the context of management arrangements and licensed usage for the Moe GMA, including considerations for assigning a sustainable yield.

Table 11-9 Summary of predevelopment throughflows in context of Moe GMA

Flow-tube parameter	Result
Confined VAF layers	UMTA, LTBa and LTA.
Comparison with WSPA boundary	For flow-tubes LTBa ft05 and LTA ft10, a number of UA cells occurring outside the GMA to the east and south (LTBa ft05 only). The GMA boundary generally occupies the entire length of the flow-tubes.
Flow from, or to, GMUs or UAs	The GMA does not receive flow from, or contribute flow to, another GMU or UA.
GMU PD throughflow estimate	All of the flow-tube cross-sections occur within the boundary of the WSPA. The average (P50 K) predevelopment throughflow of the WSPA is therefore estimated to be 14,940 ML/y .
Confined aquifer(s) contributing majority of PD throughflow	Thorpdale Volcanics (LTBa) (62%).
CV (%) and potential factors contributing to spatial variability	CV: 47 %. A range of spatially variable processes may be responsible including upwards leakage from the deeper confined aquifers.
PCV relative to PD throughflow	The PCV (8,200 ML/y) represents 55 % of the average (P50 K) predevelopment throughflow (14,940 ML/y) but allowing for spatial variability may be between 41 % and 82 %. The PCV represents 192 % of the lower range minimum (P20 K) predevelopment throughflow.

Confined Aquifer Throughflow Assessment – Updated Method and Phase B State-wide Rollout

Flow-tube parameter	Result
Average licensed usage relative to PD throughflow	The average licensed usage (826 ML/y) represents 6 % of the average (P50 K) predevelopment throughflow (14,940 ML/y) but allowing for spatial variability may be between 4 % and 8 %. The average licensed usage represents 19 % of the lower range minimum (P20 K) predevelopment throughflow.
Relative rankings (Appendix B)	Relative reliability ranking: Low; Relative uncertainty ranking: Low; Relative potential for adverse impact on aquifer value(s): Low; Overall GMU ranking: Low-Low.
Considerations for assigning sustainable yield	<ul style="list-style-type: none"> ▪ The overall estimate of sustainable yield for the GMA will need to consider contributions from the Haunted Hills Gravel (UTQA), the subject of the CDM Smith unconfined aquifer sustainable yield study. ▪ Groundwater resources may need to be managed on an aquifer by aquifer basis due to variability in throughflow contributions from each confined aquifer. It is noted that the Thorpdale Volcanics (LTBa) is indicated to have comparatively greater transmissivity and throughflow than the Yarragon (UMTA) and Childers (LTA) formations.

12. Gippsland GMB – Central groundwater catchment

The Gippsland GMB is located in southeast Victoria and includes the East Gippsland, Central Gippsland, Moe and Seaspray groundwater catchments. This chapter concerns the Central Gippsland groundwater catchment.

The confined aquifers within the Central groundwater catchment include:

- Boisdale Formation (Wurruk Sand) (UTAF) (Figure 5-2).
- Balook Formation (UMTA) (Figure 5-3).
- M2C aquifer and Seaspray Sand (LMTA) (Figure 5-4).
- Latrobe Group (LTA) (Figure 5-6).

The Central groundwater catchment contains three GMUs that incorporates confined aquifers. Outside of these GMUs the UMTA and LTA are managed as unincorporated areas (Figure 5-2, Figure 5-3, Figure 5-4 and Figure 5-6). The flow-tubes assigned in the groundwater catchment are listed in Table 12-1.

Table 12-1 Central groundwater catchments – assigned flow-tubes

Groundwater catchment	GMU or non-GMU	PCV Order depth	Confined VAF layer and flow-tube no.	Aquifer name
Central Gippsland	Sale WSPA	All formations from 25 to 200 m	UTAF ft07	Boisdale Formation (Wurruk Sand)
	Rosedale GMA	Zone 1 - all formations from 50 to 150 m below surface Zone 2 - all formations from 25 to 350 m below surface Zone 3 - all formations from 200 to 300 m below surface	UMTA ft06	Balook Formation
	Stratford GMA ⁽¹⁾	Zone 1 – all formations below 150 m from the surface Zone 2 - all formations below 350 m from the surface	LMTA ft06	M2C aquifer and Seaspray Sand
			LTA ft08	Latrobe Group
	UA west of Marlo	N/a	LTA ft09	N/a

Notes:

Shaded cell indicates the flow-tube is assigned to a GMU but includes a significant (multiple cells) UA either upgradient or downgradient of the GMU.

(1) Based on the GMU depth criteria ranges, the confined LMTA is allocated to the Stratford GMA.

12.1 Hydrogeological characterisation

12.1.1 Sale WSPA

The Sale WSPA, located in the Gippsland region of eastern Victoria, comprises the high yielding confined Boisdale Formation (Wurruk Sand) aquifer (UTAF). The WSPA has vertical depth limits for the confined aquifer that correspond to 25-200 m. Significant groundwater use occurs in the WSPA for both urban and irrigation supplies.

The regional scale hydrostratigraphic profile in and around the Sale WSPA is listed in Table 12-2 and key hydrogeological attributes are described in Table 12-3.

Table 12-2 Hydrostratigraphic profile in and around the Sale WSPA

Geological formation	VAF code	Geological period	Lithology
Haunted Hills Formation	QA/UTQA	Quaternary-Upper Tertiary	Clay, sandy clay, sand, gravel and clayey sand.

Confined Aquifer Throughflow Assessment – Updated Method and Phase B State-wide Rollout

Geological formation	VAF code	Geological period	Lithology
Nuntin Clay and Jemmy's Point Formation	UTQD	Quaternary-Upper Tertiary	The Nuntin Clay (confining layer of Boisdale Formation) comprise of clays, gravels and fine to coarse grained sands. The Jemmy's Point Formation comprises shelly and sandy marl and calcareous sandstone, overlain by shelly sand and minor gravels.
Boisdale Formation (Wurruk Sand)	UTAF	Upper Tertiary	Fluviatile sand aquifer of medium to coarse grained sands, confined to semi-confined by either the Boisdale Formation (Nuntin Clay Member) or clays within the overlying Haunted Hills Gravel.
Yallourn and Hazelwood formations (absence in and around Sale)	UTD	Upper Tertiary	Yallourn Formation consists of coal seams interbedded with non-marine claystones and mudstone. Hazelwood Formation consists of interbedded brown coal and clay.
Balook Formation (underlying north-western part of GMU)	UMTA	Upper Middle Tertiary	Dominated by fine-grained clay and a thicker upper unit consisting of coarse-grained sand interlayered with thin clay layers.
Seaspray Group (i.e. Gippsland Limestone and the Lakes Entrance Formation) (underlying most of the GMU apart from where Balook Formation occurs in the northwest)	UMTD	Upper Middle Tertiary	Calcareous sedimentary deposits with aquitard properties.
M2C aquifer and Seaspray Sand	LMTA	Lower Middle Tertiary	The Morwell Formation contains a number of sand-dominated aquifers interspersed with brown coal seams, which generally act as aquitards. The intervening aquifers are named locally after their overlying coal seams as M1A Aquifer, M1B Aquifer, M2A Aquifer, M2B Aquifer and M2C Aquifer. The most significant of these aquifers is the basal M2C Aquifer/Seaspray Sand, which is an important regional aquifer. Consequently it has been given its own categorisation (LMTA) in the VAF.
Latrobe Group	LTA	Lower Tertiary	Marine and non-marine siliciclastics that host all the known hydrocarbon occurrences in the offshore region of the Gippsland Basin. The Latrobe Group includes three formations: the Yarram Formation, Carrajung Volcanics, and Traralgon Formation.
Strzelecki Group	BSE	Mesozoic	Low-permeability, non-marine, volcanoclastic-rich sandstones and mudstones.

Source: (Jacobs, 2015).

Note: The shaded grey cell indicates the confined aquifer VAF layer subject to the Phase B study.

Table 12-3 Sale WSPA – Key hydrogeological attributes

Attribute	Parameter	Description
	GMU size	1,738 km ² (GIS calculated).

Confined Aquifer Throughflow Assessment – Updated Method and Phase B State-wide Rollout

Attribute	Parameter	Description
Groundwater management	PCV Order depth	All formations from 25 to 200 m.
	Overlying GMUs	Wa De Lock and Denison GMAs (Quaternary aquifers).
	Underlying GMUs	Rosedale Zone 3 GMA and Stratford Zone 2 GMA.
	Confined aquifers (and VAF code, number) ⁽¹⁾	Boisdale Formation (Wurruk Sand) (UTAF, 105).
	PCV and derivation ⁽¹⁾	21,238 ML/year (PCV Order 2013). Derivation: Inferred to align to volume of licensed use.
Groundwater usage	Licensed volume ⁽⁴⁾	21,203 ML/year (June 2021).
	Licensed use ⁽⁴⁾	Average (2004–2021): 11,029 ML/year. Minimum (2011–2012): 6,324 ML/year. Maximum (2018–2019): 17,867 ML/year.
Hydrogeological conceptualisation	Recharge areas ⁽²⁾	Recharge occurs along the northern margin of the aquifer beneath the alluvial plain of the Thomson and Macalister rivers to the west of Maffra, and along the northern flank of the Baragwanath Anticline to the south of Sale. Lesser amounts of recharge occur from the northern part of the aquifer between Stratford and Paynesville, and from the western part of the aquifer near Rosedale.
	Groundwater flow and aquifer/aquitard characteristics ⁽²⁾	<u>Inter-aquifer connectivity with overlying shallow aquifer</u> – largely an upward groundwater pressure gradient (and potential for upward leakage). During periods of groundwater abstraction, however, water levels in the Boisdale Formation (UTAF) can fall below levels in the upper aquifer system, potentially reversing the vertical flow direction. Numerical groundwater modelling of the Boisdale Aquifer (UTAF) suggests that, despite the presence of the Nuntin Clay separating the water table from the Wurruk Sand, there is still a significant net upward flow to the water table. <u>Inter-aquifer connectivity with underlying aquifer</u> – the Boisdale Aquifer (UTAF) in the Sale region is underlain in the west by the Latrobe Valley Group, grading laterally eastwards into the Balook Formation Aquifer (UMTA) and the Seaspray Group (LMTA). A small number of nested site hydrographs show that historically, there has been an upward gradient from the deeper Latrobe Valley Group/Balook Formation and the Latrobe Group to the Boisdale Formation. However, hydrographs also show that this upwards gradient is decreasing with declining levels in the LTA (Latrobe Group) and the Balook Formation Aquifer (UMTA).
	Cross border flows	Not applicable.
	Points of groundwater discharge ⁽³⁾	Possible discharge to the lake systems.
Groundwater monitoring	Groundwater suite hydrographic classification ⁽¹⁾	Extraction from the Boisdale Formation (UTAF) is contributing (since 1997) to the declining water level trend (suite: M_0_1), having the potential to cause saline intrusion from Lake Wellington.

References: (1) Jacobs (2019), (2) Jacobs (2015), (3) SRW (2021), (4) DEECA (2023).

12.1.2 Rosedale GMA

The Rosedale GMA is located in central Gippsland, underlying the Denison and Wa De Lock GMAs and Sale WSAP (Section 12.1), and overlying the Stratford GMA (Section 12.1.3). The GMA incorporates the Balook Formation (UMTA) and includes three subzones:

- Zone 1 – all formations from 50-150 m.
- Zone 2 – all formations from 25-350 m.
- Zone 3 – all formations from 200-300 m.

A regional scale hydrostratigraphic profile in and around the Rosedale GMA is listed in Table 12-4 and key hydrogeological attributes are described in Table 12-5.

Table 12-4 Hydrostratigraphic profile in and around the Rosedale GMA

Geological formation	VAF code	Geological period	Lithology
Haunted Hills Formation	QA/UTQA	Quaternary-Upper Tertiary	Clay, sandy clay, sand, gravel and clayey sand.
Nuntin Clay and Jemmy's Point Formation	UTQD	Quaternary-Upper Tertiary	The Nuntin Clay (confining layer of Boisdale Formation) comprise of clays, gravels and fine to coarse grained sands. The Jemmy's Point Formation comprises shelly and sandy marl and calcareous sandstone, overlain by shelly sand and minor gravels.
Boisdale Formation (Wurruk Sand)	UTAF	Upper Tertiary	Fluviatile sand aquifer of medium to coarse grained sands, confined to semi-confined by either the Boisdale Formation (Nuntin Clay Member) or clays within the overlying Haunted Hills Gravel.
Yallourn and Hazelwood formations	UTD	Upper Tertiary	Yallourn Formation consists of coal seams interbedded with non-marine claystones and mudstone. Hazelwood Formation consists of interbedded brown coal and clay.
Balook Formation	UMTA	Upper Middle Tertiary	Dominated by fine-grained clay and a thicker upper unit consisting of coarse-grained sand interlayered with thin clay layers.
Seaspray Group (i.e. Gippsland Limestone and the Lakes Entrance Formation) (mostly absent in Rosedale GMA)	UMTD	Upper Middle Tertiary	Calcareous sedimentary deposits with aquitard properties.
M2C aquifer and Seaspray Sand	LMTA	Lower Middle Tertiary	The Morwell Formation contains a number of sand-dominated aquifers interspersed with brown coal seams, which generally act as aquitards. The intervening aquifers are named locally after their overlying coal seams as M1A Aquifer, M1B Aquifer, M2A Aquifer, M2B Aquifer and M2C Aquifer. The most significant of these aquifers is the basal M2C Aquifer/Seaspray Sand, which is an important regional aquifer. Consequently it has been given its own categorisation (LMTA) in the VAF.
Latrobe Group	LTA	Lower Tertiary	Marine and non-marine siliciclastics that host all the known hydrocarbon occurrences in the offshore region of the Gippsland Basin. The Latrobe Group includes three formations: the Yarram Formation, Carrajung Volcanics, and Traralgon Formation.

Confined Aquifer Throughflow Assessment – Updated Method and Phase B State-wide Rollout

Geological formation	VAF code	Geological period	Lithology
Strzelecki Group	BSE	Mesozoic	Low-permeability, non-marine, volcanoclastic-rich sandstones and mudstones.

Source: (Jacobs, 2015).

Note: The shaded grey cell indicates the confined aquifer VAF layer subject to the Phase B study.

Table 12-5 Rosedale GMA – Key hydrogeological attributes

Attribute	Parameter	Description
Groundwater management	GMU size	2,700 km ² (GIS calculated).
	PCV Order depth	Zone 1 (50-150 m), Zone 2 (25- 350 m) and Zone 3 (200-300 m).
	Overlying GMUs	Denison and Wa De Lock GMAs and Sale WSAP.
	Underlying GMUs	Stratford GMA.
	Confined aquifers (and VAF code, number) ⁽¹⁾	Balook Formation (UMTA, 107).
	PCV and derivation ⁽¹⁾	22,372 ML/year (PCV Order 2017). Derivation: Inferred to align to volume of licensed use.
Groundwater usage	Licensed volume ⁽³⁾	22,272 ML/year (June 2021).
	Licensed use ⁽³⁾	Average (2004-2021): 8,828 ML/year. Minimum (2010-2011): 3,117 ML/year. Maximum (2012-2013): 18,923 ML/year.
Hydrogeological conceptualisation	Recharge areas ⁽²⁾	Recharge areas of the Balook Formation (UMTA) are expected to be in the northerly areas where the unit is closer to the surface, receiving downward recharge from overlying aquifers.
	Groundwater flow and aquifer/aquitard characteristics ⁽²⁾	Groundwater is expected to move freely between the Balook Formation (UMTA) and Lower Tertiary Group aquifers. Groundwater flow in its natural state is thought to flow from west to east in the Latrobe Valley Depression. East of the Balook Formation (UMTA), groundwater may partly flow upwards into the Boisdale Formation (UTAF); as a result of change to a less permeable formation. The Latrobe Valley Group is dewatered in the brown coal mines which has created a drawdown cone extending eastwards to Flynn, which impacts the groundwater flow pattern in the western part of the Latrobe Valley. Historically there was an upward gradient from the Latrobe Group aquifers (LTA) to the overlying Balook Formation (UMTA). Aquifer depressurisation has reversed this gradient, so there is now a downward gradient from the Balook Formation (UMTA) to the Latrobe Group aquifers (LTA).
	Cross border flows	Not applicable.
Groundwater monitoring	Groundwater suite hydrographic classification ⁽¹⁾	A long-term declining trend since 1982 (Suite M_O_2) is indicated for the Middle aquifer (UMTA).

References: (1) Jacobs (2019), (2) Jacobs (2015), (3) DEECA (2023).

12.1.3 Stratford GMA

The Stratford GMA is located in central Gippsland, underlying the Denison and Wa De Lock GMAs and Sale WSAP (Section 12.1), and Rosedale GMA (Section 12.1.2). The GMA incorporates the M2C aquifer and Seaspray Sand (LMTA) and Latrobe Group aquifers (LTA). The following two subzones apply:

- Zone 1 – all formations below 150 m from the surface.
- Zone 2 – all formations below 350 m from the surface.

The regional scale hydrostratigraphic profile in and around the Stratford GMA is listed in Table 12-4 and key hydrogeological attributes are described in Table 12-6.

Table 12-6 Hydrostratigraphic profile in and around the Stratford GMA

Geological formation	VAF code	Geological period	Lithology
Haunted Hills Formation	QA/UTQA	Quaternary-Upper Tertiary	Clay, sandy clay, sand, gravel and clayey sand.
Nuntin Clay and Jemmy's Point Formation	UTQD	Quaternary-Upper Tertiary	The Nuntin Clay (confining layer of Boisdale Formation) comprise of clays, gravels and fine to coarse grained sands. The Jemmy's Point Formation comprises shelly and sandy marl and calcareous sandstone, overlain by shelly sand and minor gravels.
Boisdale Formation (Wurruk Sand)	UTAF	Upper Tertiary	Fluviatile sand aquifer of medium to coarse grained sands, confined to semi-confined by either the Boisdale Formation (Nuntin Clay Member) or clays within the overlying Haunted Hills Gravel.
Yallourn and Hazelwood formations	UTD	Upper Tertiary	Yallourn Formation consists of coal seams interbedded with non-marine claystones and mudstone. Hazelwood Formation consists of interbedded brown coal and clay.
Balook Formation	UMTA	Upper Middle Tertiary	Dominated by fine-grained clay and a thicker upper unit consisting of coarse-grained sand interlayered with thin clay layers.
Seaspray Group (i.e. Gippsland Limestone and the Lakes Entrance Formation) (mostly absent in Stratford GMA)	UMTD	Upper Middle Tertiary	Calcareous sedimentary deposits with aquitard properties.
M2C aquifer and Seaspray Sand	LMTA	Lower Middle Tertiary	The Morwell Formation contains a number of sand-dominated aquifers interspersed with brown coal seams, which generally act as aquitards. The intervening aquifers are named locally after their overlying coal seams as M1A Aquifer, M1B Aquifer, M2A Aquifer, M2B Aquifer and M2C Aquifer. The most significant of these aquifers is the basal M2C Aquifer/Seaspray Sand, which is an important regional aquifer. Consequently it has been given its own categorisation (LMTA) in the VAF.
Latrobe Group	LTA	Lower Tertiary	Marine and non-marine siliciclastics that host all the known hydrocarbon occurrences in the offshore region of the Gippsland Basin. The Latrobe Group includes three formations: the Yarram Formation, Carrajung Volcanics, and Traralgon Formation. The Traralgon Formation is the most widespread of the Lower Tertiary units and includes extensive aquifers interbedded with several major brown coal seams. For the purposes of this study,

Confined Aquifer Throughflow Assessment – Updated Method and Phase B State-wide Rollout

Geological formation	VAF code	Geological period	Lithology
			it has been assumed the aquifer component of the LTA is approximately 20% of its overall thickness.
Strzelecki Group	BSE	Mesozoic	Low-permeability, non-marine, volcanoclastic-rich sandstones and mudstones.

Source: (Jacobs, 2015).

Note: The shaded grey cells indicate the confined aquifer VAF layers subject to the Phase B study.

Table 12-7 Stratford GMA – Key hydrogeological attributes

Attribute	Parameter	Description
Groundwater management	GMU size	4,600 km ² (GIS calculated).
	PCV Order depth	Zone 1 (below 150 m from surface), Zone 2 (below 350 m from surface).
	Overlying GMUs	Denison and Wa De Lock GMAs, Sale WSAP and Rosedale GMA.
	Underlying GMUs	None.
	Confined aquifers (and VAF code, number) ⁽¹⁾	M2C aquifer and Seaspray Sand (LMTA, 109) and Latrobe Group (LTA, 111).
	PCV and derivation ⁽¹⁾	27,686 ML/year (PCV Order 2018). Derivation: Inferred to align to volume of licensed use.
Groundwater usage	Licensed volume ⁽³⁾	37,434 ML/year (June 2021).
	Licensed use ⁽³⁾	Average (2004-2021): 22,626 ML/year. Minimum (2004-2005): 17,225 ML/year. Maximum (2009-2010): 27,897 ML/year.
Hydrogeological conceptualisation	Recharge areas ⁽²⁾	Recharge to Latrobe Group aquifers (LTA) is thought to occur through vertical leakage from the Balook Formation (UMTA), in addition to direct infiltration where the Latrobe Group outcrops or is closely connected to the surficial units (along the western and northern basin margins).
	Groundwater flow and aquifer/aquitard characteristics ⁽²⁾	The Traralgon Formation is the most widespread unit of the LTA layer and includes extensive aquifers (thick interbedded sequences of sand and gravel) with several major brown coal seams which can be in excess of 100 m thick and behave as regional aquitards. Groundwater is expected to move freely between the Balook Formation and Lower Tertiary Group aquifers. Historically there was an upward gradient from the Latrobe Group aquifers (LTA) to the overlying Balook Formation aquifer (UMTA). Aquifer depressurisation has reversed this gradient, so there is now a downward gradient from the Balook Formation (UMTA) to Latrobe Group aquifer (LTA).
	Cross border flows	Not applicable.
Groundwater monitoring	Groundwater suite hydrographic classification ^(1,2)	A long-term declining trend since 1978 is indicated for the Lower Latrobe Group aquifers (LTA) (Suite L_O_1). The decline is attributable to offshore gas and oil extraction, dewatering of coal mines and groundwater extraction for irrigation.

References: (1) Jacobs (2019), (2) Jacobs (2015), (3) DEECA (2023).

12.2 Aquifer property data

Aquifer property data collected for the Boisdale Formation (Wurruk Sand) (UTAF), Balook Formation (UMTA), M2C aquifer and Seaspray Sand (LMTA) and Latrobe Group (LTA) in the Central Gippsland groundwater catchment (and neighbouring Seaspray groundwater catchment where relevant) are presented in Table 12-8, Table 12-9, Table 12-10 and Table 12-11, respectively. The statistical analysis of the K (K_h) point data for each of the VAF layers is presented in Table 12-12, including the P20 K, P50 K and P80 K values adopted for the throughflow calculations.

Table 12-8 Central Gippsland groundwater catchment – UTAF properties

Area	Aquifer	K_h (m/d)	K_v (m/d)	T (m ² /d)	S	Reference
Sale WSPA	Boisdale Formation	5	N/a	1,300	5×10^{-4}	SKM (1998f), as cited in Jacobs, 2019.
Sale WSPA	Boisdale Formation (Wurruk Sand)	12.4	0.04	N/a	N/a	GHD (2010b) as cited in Jacobs, 2019.
Sale WSPA	Boisdale Formation	29.9	4.5	N/a	10×10^{-5}	Beverly et al.. (2015) as cited in Jacobs, 2019.
Sale WSPA	Boisdale Formation	24	N/a	N/a	10×10^{-4}	SKM (2008) as cited in Jacobs, 2019.
Giffard WSPA	Boisdale Formation	2.5	N/a	N/a	N/a	Jacobs (2019).

Table 12-9 Central Gippsland groundwater catchment – UMTA properties

Area	Aquifer	K_h (m/d)	K_v (m/d)	T (m ² /d)	S	Reference
Gippsland Basin	Balook Formation	3.53	0.066	N/a	N/a	GHD (2010b) as cited in Jacobs, 2019.
Gippsland Basin	Balook Formation	7.5	0.14	N/a	N/a	GHD (2010b) as cited in Jacobs, 2019.
Gippsland Basin	Balook Formation	16.1	1.202	N/a	1×10^{-5}	Beverly et al.. (2015) as cited in Jacobs (2019).
Gippsland Basin	Balook Formation	6.07	0.627	N/a	1×10^{-5}	Beverly et al.. (2015) as cited in Jacobs (2019).
Gippsland Basin	Balook Formation	2-7	N/a	1,000	N/a	Various sources as cited in Beverly et al.. (2015).
Gippsland Basin	Balook Formation	2-57	N/a	N/a	N/a	Various sources as cited in Beverly et al.. (2015).

Table 12-10 Central Gippsland groundwater catchment – LMTA properties

Area	Aquifer	K_h (m/d)	K_v (m/d)	T (m ² /d)	S	Reference
Yarram WSPA	M1B Aquifer (Latrobe Valley)	0.97	0.13	N/a	N/a	GHD (2010b) as cited in Jacobs, 2019.
Yarram WSPA	Lower M2 Interseam	16.1	1.202	N/a	1×10^{-5}	Beverly et al.. (2015) as cited in Jacobs (2019).
Rosedale GMA	M2C Aquifer / Seaspray Sand	1.63	0.3	N/a	N/a	GHD (2010b) as cited in Jacobs, 2019.
Rosedale GMA	M2C Aquifer / Seaspray Sand	6.119	0.39	N/a	1×10^{-5}	Beverly et al.. (2015) as cited in Jacobs (2019).
Gippsland Basin	M2C Aquifer / Seaspray Sand	6.4×10^{-4} -76.06	N/a	N/a	N/a	Various sources as cited in Beverly et al.. (2015).

Table 12-11 Central Gippsland groundwater catchment – LTA properties (aquifer units only) ⁽¹⁾

Area	Aquifer	K_h (m/d)	K_v (m/d)	T (m ² /d)	S	Reference
Gippsland Basin	Upper Latrobe Group	0.0016-76.06	N/a	N/a	N/a	Various sources as cited in Beverly et al.. (2015).
Gippsland Basin	T1 interseam	0.0016-88.0	N/a	N/a	N/a	Various sources as cited in Beverly et al.. (2015).
Gippsland Basin	T2 interseam	1.6×10^{-7} -88.0	N/a	N/a	N/a	Various sources as cited in Beverly et al.. (2015).
Yarram WSPA	T2 interseam	0.886	0.0957	N/a	1.0×10^{-5}	Beverly et al.. (2015) as cited in Jacobs (2019).

(1) The LTA includes extensive aquifers interbedded with several major brown coal seams. For the purposes of this study, it has been assumed the aquifer component of the LTA is approximately 20% of its overall thickness.

Table 12-12 Central Gippsland groundwater catchment – K_h statistics

K_h statistical parameter	Value			
	UTAF	UMTA	LMTA	LTA (aquifer units only)
Number of data points	5	4	4	1
Minimum	2.5 m/d	2	6.4×10^{-4} m/d	1.6×10^{-7}
P20	4.5 m/d	N/a (2.5 m/d)	N/a (0.1 m/d)	N/a (0.1 m/d)
P50	12.4 m/d	N/a (6 m/d)	N/a (4 m/d)	N/a (1.5 m/d)
Average	14.7 m/d	8.3 m/d	6.2 m/d	N/a
P80	25.2 m/d	N/a (15 m/d)	N/a (10 m/d)	N/a (8 m/d)
Maximum	29.9 m/d	57 m/d	76.1 m/d	88.0
Standard deviation	11.9	N/a	N/a	N/a

Notes:

The shaded cells indicate the P20 K, P50 K and P80 K values adopted in the gridded throughflow rate analysis.

The inputted K values were rounded to the nearest 0.5 for the throughflow rate analysis.

N/a: Insufficient K_h point data to inform statistical analysis. In the absence of sufficient K point data, the typical K ranges from pumping tests informed the selection of representative values of P20, P50 and P80 K for the throughflow assessments. These adopted values are indicated in brackets.

12.3 Outputs

12.3.1 Sale WSPA

The Sale WSPA is designated flow-tube UTAF ft07 (Table 12-1). The predevelopment throughflows for UTAF ft07 rely on throughflow outputs from four cross-sections perpendicular to groundwater flow (at 5 m, 10 m, 20 m and 25 m modelled RWL contours).

The (P50 K) predevelopment throughflow estimate of each cross-section in the UTAF ft07 is reported in Table 12-13. The corresponding average, lower and upper range (P50 K), and lower range minimum (P20 K) predevelopment throughflow estimates for the flow-tube are also reported. The spatial variability of throughflow within the flow-tube is represented by the SD and CV in Table 12-13.

Table 12-13 Predevelopment throughflow estimates for flow-tubes – UTAF ft07

Parameter	Value
P50 K PD throughflow, Cross-section 1 (5 m RWL) (ML/y)	18,796
P50 K PD throughflow, Cross-section 2 (10 m RWL) (ML/y)	25,665

Confined Aquifer Throughflow Assessment – Updated Method and Phase B State-wide Rollout

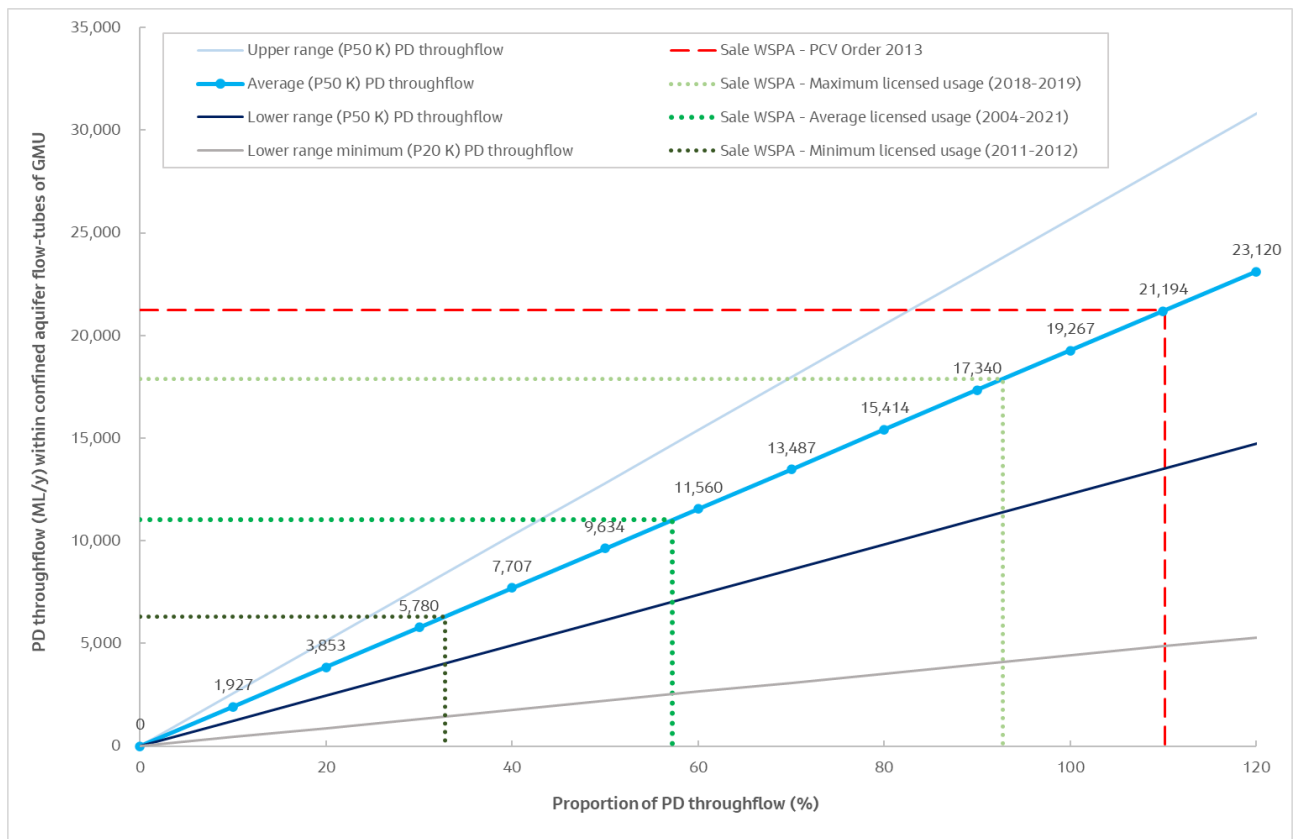
Parameter	Value
P50 K PD throughflow, Cross-section 3 (20 m RWL) (ML/y)	20,325
P50 K PD throughflow, Cross-section 4 (25 m RWL) (ML/y)	12,282
Average (P50 K) PD throughflow (ML/y)	19,267
Lower range (P50 K) PD throughflow (ML/y)	12,282
Upper range (P50 K) PD throughflow (ML/y)	25,665
Lower range minimum (P20 K) PD throughflow (ML/y)	4,422
SD (ML/y)	5,510
CV (%)	29
Approximate length of flow-tube (km)	55

Note:

All of the cross-sections occur within the GMU boundary.

To assist with contextualising the throughflow outputs, the average, lower and upper range (P50 K) and lower range minimum (P20 K) predevelopment throughflow estimates for flow-tube UTAF ft07 are presented in Figure 12-1. For comparison, the Sale WSPA PCV and minimum, average and maximum licensed usage values are overlaid on the figure.

Figure 12-1 Sale WSPA – PCV and licensed usage relative to predevelopment throughflow estimate of flow-tube UTAF ft07



The throughflow results of the flow-tube, and its spatial variability, are summarised in Table 12-14 in the context of management arrangements and licensed usage in the Sale WSPA, including considerations for assigning a sustainable yield.

Table 12-14 Summary of predevelopment throughflows in context of Sale WSPA

Flow-tube parameter	Result
Confined VAF layer	UTAF.
Comparison with WSPA boundary	The WSPA boundary generally occupies the entire width of the flow-tube. The WSPA represents approximately 91% of the flow-tube length. A number of cells within the flow-tube are mapped upgradient of the WSPA. Depending on the depth of the UTAF layer in this area, the cells will belong to either the Rosedale Zone 2 GMA or Wa De Lock GMA.
Flow from, or to, GMUs or UAs	As above, depending on the depth of the UTAF layer upgradient of the WSPA, the management area may receive flow from either the Rosedale Zone 2 GMA or Wa De Lock GMA. The WSPA does not contribute flow to another GMU or UA.
GMU PD throughflow estimate	All of the flow-tube cross-sections occur within the boundary of the WSPA. The average (P50 K) predevelopment throughflow of the WSPA is therefore estimated to be 19,267 ML/y .
CV (%) and potential factors contributing to spatial variability	<p>CV: 29 %.</p> <p>A range of spatially variable processes may be responsible, including:</p> <ul style="list-style-type: none"> ▪ Comparatively higher throughflow are calculated in the upgradient and central sections of the WSPA. A potential cause may be upwards leakage from underlying Balook Formation at the terrestrial-marine facies transition in this area (GHD, 2010). ▪ Diminishing throughflow rates are calculated towards the coastline. Potential cause(s) include: <ul style="list-style-type: none"> - Groundwater discharge to the Gippsland lakes. - Groundwater discharge due to groundwater development and/or offshore oil and gas production in the Gippsland Basin. The steady-state potentiometric surface sourced from the West Gippsland CMA EcoMarkets model (GHD, 2010b), and used in the throughflow calculation, was based on long-term average groundwater levels, hence some data points used to generate these values will post-date groundwater development and/or oil and gas production. ▪ Increasing upwards leakage to the overlying Quaternary aquifer along the flow path (noting this process was not identified in the CHM).
PCV relative to PD throughflow	The PCV (21,238 ML/y) represents 110 % of the average (P50 K) predevelopment throughflow (19,267 ML/y) but allowing for spatial variability may be between 83 % and 173 %. The PCV represents 480 % of the lower range minimum (P20 K) predevelopment throughflow.
Average licensed usage relative to PD throughflow	The average licensed usage (11,029 ML/y) represents 57 % of the average (P50 K) predevelopment throughflow (19,267 ML/y) but allowing for spatial variability may be between 43 % and 90 %. The average licensed usage represents 249 % of the lower range minimum (P20 K) predevelopment throughflow.
Relative rankings (Appendix B)	Relative reliability ranking: Low; Relative uncertainty ranking: Low; Relative potential for adverse impact on aquifer value(s): Medium; Overall GMU ranking: Low-Medium.
Considerations for assigning sustainable yield	<ul style="list-style-type: none"> ▪ Potential for inter-aquifer leakage and stress induced yield augmentation. ▪ Saline intrusion from Lake Wellington.

12.3.2 Rosedale GMA

The Rosedale GMA is designated flow-tube UMTA ft06 (Table 12-1). The predevelopment throughflows for UMTA ft06 rely on throughflow outputs from one cross-section perpendicular to groundwater flow (at 30 m modelled RWL contour).

The (P50 K) predevelopment throughflow estimate of the cross-section in the UMTA ft06 is reported in Table 12-15. The corresponding (adopted) average (P50 K) and the lower range minimum (P20 K) predevelopment throughflow estimates for the flow-tubes are also reported. As only one cross-section informs the throughflow assessment, the spatial variability of the throughflow calculation has not been assessed.

Table 12-15 Predevelopment throughflow estimates for flow-tube – UMTA ft06

Parameter	Value
P50 K PD throughflow, Cross-section 1 (30 m RWL) (ML/y) ⁽¹⁾	98,333
Adopted (average) (P50 K) PD throughflow (ML/y)	98,333
Lower range minimum (P20 K) PD throughflow (ML/y)	40,972
Approximate length of flow-tube (km)	80

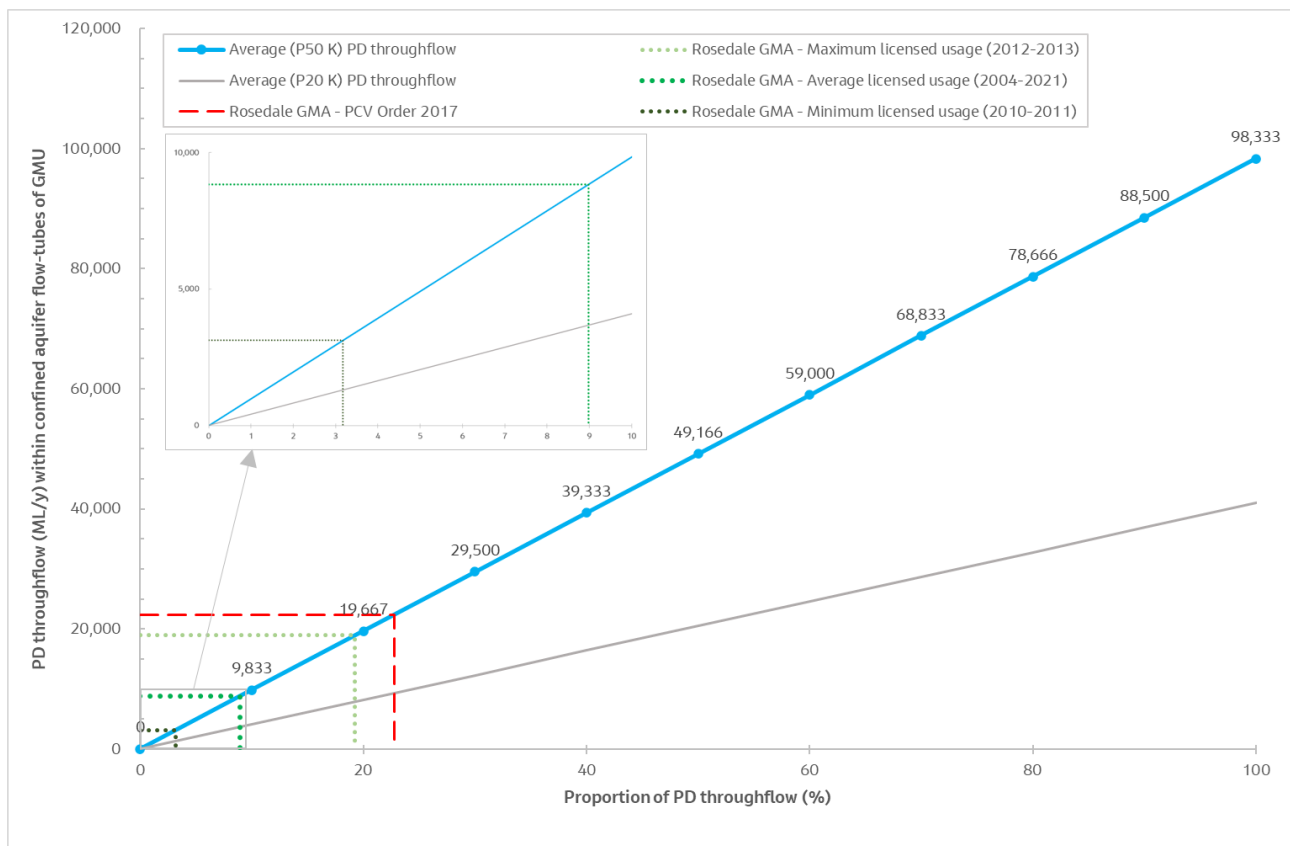
Notes:

The cross-section occurs within the GMU boundary.

(1) Throughflow cross-sections near Yallourn have been excluded from the GMU scale throughflow assessment as the UMTA modelled predevelopment potentiometric surfaces are potentially affected by dewatering. The modelled RWL 30 m AHD contour indicates some level of interference from dewatering, with a heightened H_L/L. Accordingly, the calculated predevelopment throughflow is expected to be an over-estimate.

To assist with contextualising the throughflow outputs, the average (P50 K) and lower range minimum (P20 K) predevelopment throughflow estimates for flow-tube UMTA ft06 are presented in Figure 12-2. For comparison, the Rosedale GMA PCV and minimum, average and maximum licensed usage values are overlaid on the figure.

Figure 12-2 Rosedale GMA – PCV and licensed usage relative to predevelopment throughflow estimate of flow-tube UMTA ft06



The throughflow results of the flow-tube are summarised in Table 12-16 in the context of management arrangements and licensed usage in the Rosedale GMA, including considerations for assigning a sustainable yield.

Table 12-16 Summary of predevelopment throughflows in context of Rosedale GMA

Flow-tube parameter	Result
Confined VAF layers	UMTA.
Comparison with GMA boundary	A number of UA cells in UMTA ft06 occur outside the GMA to the east. The GMA boundary generally occupies the entire length of the flow-tubes.
Flow from, or to, GMUs or UAs	The GMA does not contribute flow to, or receive flow from, another GMU or UA.
GMU PD throughflow estimate	The flow-tube cross-section occurs within the boundary of the GMA. The average (P50 K) predevelopment throughflow of the GMA is therefore estimated to be 98,333 ML/y . As this cross-section relies on a potentiometric surface potentially affected by dewatering, and in turn, a heightened H _L /L, the calculated predevelopment throughflow is expected to be an over-estimate.
CV (%) and potential factors contributing to spatial variability	CV: N/a (one cross-section was assessed).
PCV relative to PD throughflow	The PCV (22,372 ML/y) represents 23 % of the average (P50 K) predevelopment throughflow (98,333 ML/y). The PCV represents 55 % of the lower range minimum (P20 K) predevelopment throughflow.
Average licensed usage relative to PD throughflow	The average licensed usage (8,828 ML/y) represents 9 % of the average (P50 K) predevelopment throughflow (98,333 ML/y). The average licensed usage represents 22 % of the lower range minimum (P20 K) predevelopment throughflow.
Relative rankings (Appendix B)	Relative reliability ranking: Low; Relative uncertainty ranking: High; Relative potential for adverse impact on aquifer value(s): Low (but elevated to Medium due to the inference that the throughflow estimate is likely to be an over-estimate); Overall GMU ranking: High-Medium.
Considerations for assigning sustainable yield	<ul style="list-style-type: none"> ▪ The throughflow estimate is expected to be an over-estimate due to the potential influence of dewatering on the potentiometric surface and H_L/L of the UMTA layer. ▪ Reversal of vertical gradients (from Latrobe Group coal dewatering) and the now downward gradient from the Balook Formation to Latrobe Group aquifer. ▪ Potential for predevelopment throughflow patterns and rates in the Balook Formation to be significantly affected by coal dewatering in the Latrobe Group aquifer.

12.3.3 Stratford GMA

The Stratford GMA is designated flow-tubes LMTA ft06 and LTA ft08 (Table 12-1). The predevelopment throughflows for these flow-tubes rely on throughflow outputs from the following cross-sections perpendicular to groundwater flow:

- LMTA ft06: 15 m, 35 m and 70 m modelled RWL contours.
- LTA ft08: 5 m, 20 m and 30 m modelled RWL contours.

The (P50 K) predevelopment throughflow estimate of each cross-section in the LMTA ft06 and LTA ft08 is reported in Table 12-17. The corresponding average, lower and upper range (P50 K), and lower range minimum (P20 K) predevelopment throughflow estimates for the flow-tubes, and a combined estimate, are also reported. The spatial variability of the calculated throughflow rate within the flow-tubes, and combined, is represented by the SD and CV in Table 12-17.

Table 12-17 Predevelopment throughflow estimates for flow-tubes – LMTA ft06 and LTA ft08

Parameter	Value
LMTA ft06	
P50 K PD throughflow, Cross-section 1 (15 m RWL) (ML/y)	20,192
P50 K PD throughflow, Cross-section 2 (35 m RWL) (ML/y)	35,021
P50 K PD throughflow, Cross-section 3 (70 m RWL) (ML/y)	47,488
Average (P50 K) PD throughflow (ML/y)	34,234
Lower range (P50 K) PD throughflow (ML/y)	20,192

Confined Aquifer Throughflow Assessment – Updated Method and Phase B State-wide Rollout

Parameter	Value
Upper range (P50 K) PD throughflow (ML/y)	47,488
Lower range minimum (P20 K) PD throughflow (ML/y)	505
SD (ML/y)	13,665
CV (%)	40
Approximate length of flow-tube (km)	80
LTA ft08 ^(1,2)	
P50 K PD throughflow, Cross-section 1 (5 m RWL) (ML/y)	1,890
P50 K PD throughflow, Cross-section 2 (20 m RWL) (ML/y)	3,100
P50 K PD throughflow, Cross-section 2 (30 m RWL) (ML/y)	2,928
Average (P50 K) PD throughflow (ML/y)	2,639
Lower range (P50 K) PD throughflow (ML/y)	1,890
Upper range (P50 K) PD throughflow (ML/y)	3,100
Lower range minimum (P20 K) PD throughflow (ML/y)	126
SD (ML/y)	655
CV (%)	25
Approximate length of flow-tube (km)	135
Combined LMTA ft06 and LTA ft08	
Average (P50 K) PD throughflow (ML/y)	36,873
Lower range (P50 K) PD throughflow (ML/y)	22,082
Upper range (P50 K) PD throughflow (ML/y)	50,588
Lower range minimum (P20 K) PD throughflow (ML/y)	631
SD (ML/y)	14,320
CV (%)	39

Notes:

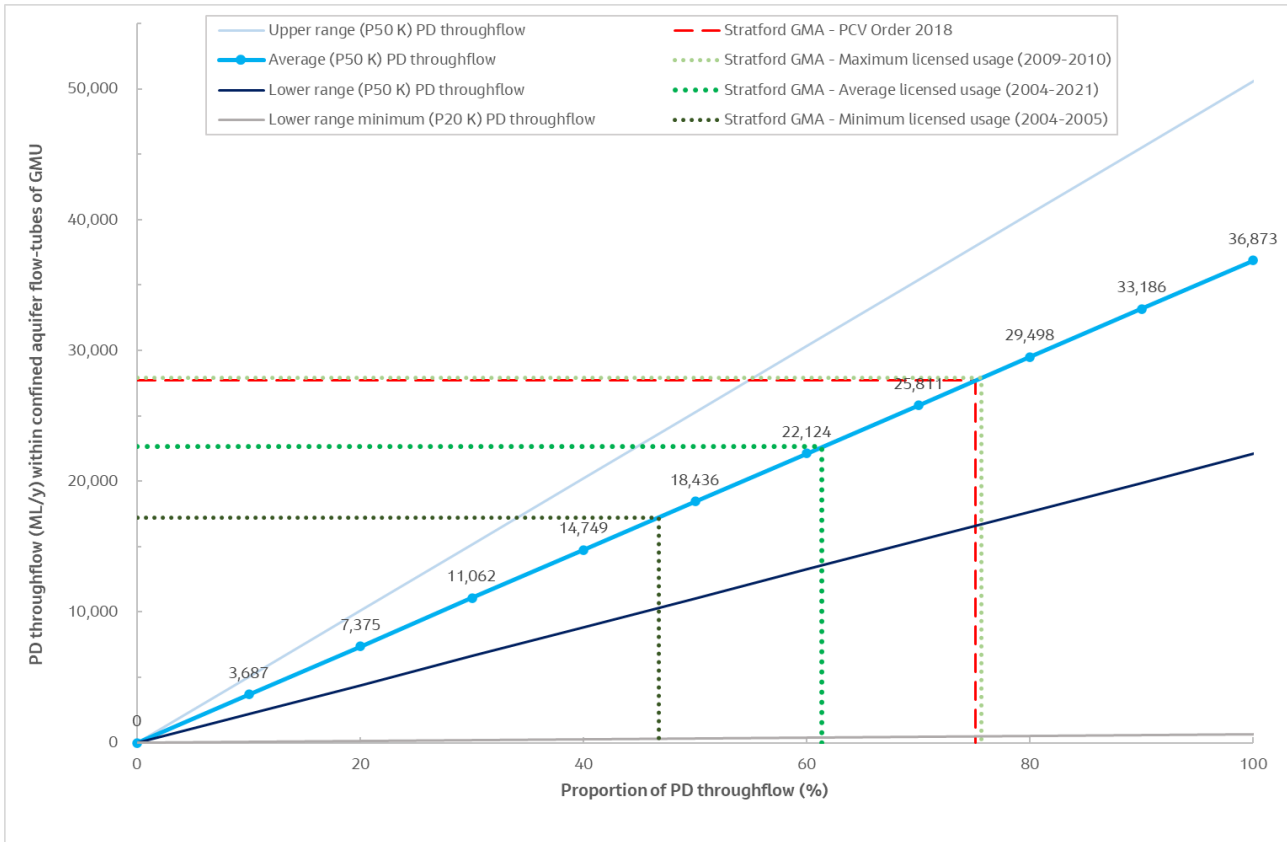
All of the cross-sections occur within the GMU boundary.

(1) Throughflow cross-sections near Yallourn have been excluded from the GMU scale throughflow assessment as the LTA modelled predevelopment potentiometric surfaces are potentially affected by dewatering.

(2) Based on the CHM, it was assumed that the aquifer unit constitutes 20% of the thickness of the LTA VAF layer.

To assist with contextualising the throughflow outputs, the average, lower and upper range (P50 K) and lower range minimum (P20 K) predevelopment throughflow estimates for combined flow-tubes LMTA ft06 and LTA ft08 are presented in Figure 12-3. For comparison, the Stratford PCV and minimum, average and maximum licensed usage values are overlaid on the figure.

Figure 12-3 Stratford GMA – PCV and licensed usage relative to relative to predevelopment throughflow estimates of combined flow-tubes LMTA ft06 and LTA ft08



The throughflow results of the flow-tube, and its spatial variability, are summarised in Table 12-18 in the context of management arrangements and licensed usage in the Stratford GMA, including considerations for assigning a sustainable yield.

Table 12-18 Summary of predevelopment throughflows in context of Stratford GMA

Flow-tube parameter	Result
Confined VAF layer	LMTA and LTA.
Comparison with GMA boundary	The GMA boundary generally occupies the entire width and length of the flow-tubes.
Flow from, or to, GMUs or UAs	The GMA does not receive flow from, or contribute flow to, another GMU or UA.
GMU PD throughflow estimate	All of the flow-tube cross-sections occur within the boundary of the GMA. The average (P50 K) predevelopment throughflow of the WSPA is therefore estimated to be 36,873 ML/y .
CV (%) and potential factors contributing to spatial variability	CV: 39 %. A range of spatially variable processes may be responsible including varying rates (and direction) of inter-aquifer leakage between the Balook Formation and underlying Lower Tertiary units.
PCV relative to PD throughflow	The PCV (27,686 ML/y) represents 75 % of the average (P50 K) predevelopment throughflow (36,873 ML/y) but allowing for spatial variability may be between 55 % and 125 %. The PCV represents 4,389 % of the lower range minimum (P20 K) predevelopment throughflow.
Average licensed usage relative to PD throughflow	The average licensed usage (22,625 ML/y) represents 61 % of the average (P50 K) predevelopment throughflow (36,873 ML/y) but allowing for spatial variability may be between 45 % and 102 %. The average licensed usage represents 3,587 % of the lower range minimum (P20 K) predevelopment throughflow.

Flow-tube parameter	Result
Relative rankings (Appendix B)	Relative reliability ranking: Low; Relative uncertainty ranking: Medium; Relative potential for adverse impact on aquifer value(s): High; Overall GMU ranking: Medium-High.
Considerations for assigning sustainable yield	<ul style="list-style-type: none"> ▪ Potential for stress induced yield augmentation due to the reversal of vertical gradients (from Latrobe Group coal dewatering) and the now downward gradient from the Balook Formation to Latrobe Group aquifer. ▪ Potential for predevelopment throughflow patterns and rates in the Lower Tertiary aquifers to be significantly affected by coal dewatering.

12.3.4 UA west of Marlo

The UA west of Marlo (Figure 5-6) is designated flow-tube LTA ft09 (Table 12-1). The predevelopment throughflows for LTA ft09 rely on throughflow outputs from two cross-sections perpendicular to groundwater flow (at 15 m and 30 m modelled RWL contours).

The (P50 K) predevelopment throughflow estimate of each cross-section in the LTA ft09 is reported in Table 12-19. The corresponding average, lower and upper range (P50 K), and lower range minimum (P20 K), predevelopment throughflow estimates for the flow-tube are also reported. The spatial variability of the calculated throughflow rate within the flow-tube is represented by the SD and CV in Table 12-19.

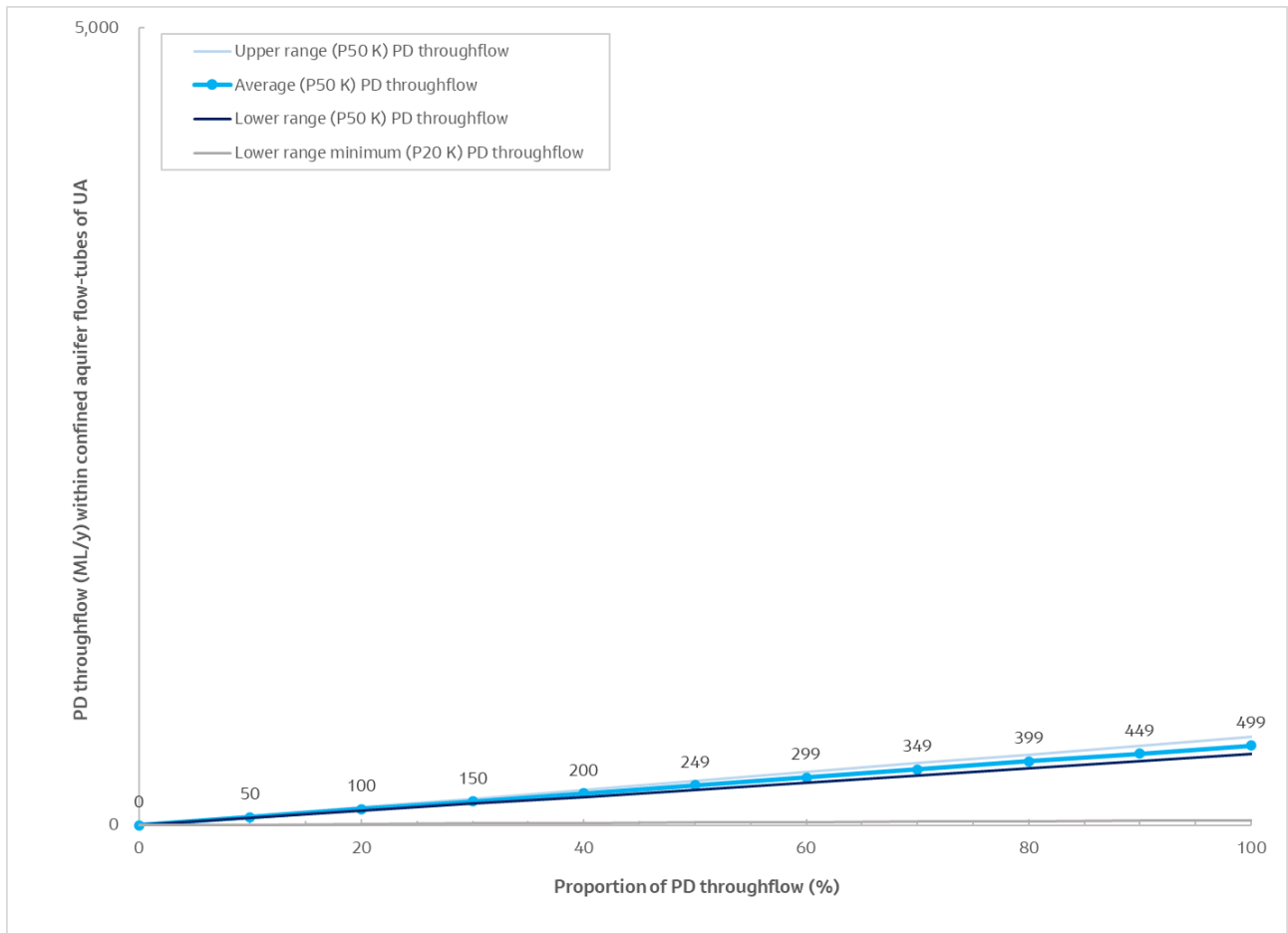
Table 12-19 Predevelopment throughflow estimates for flow-tube - LTA ft09

Parameter	Value
P50 K PD throughflow, Cross-section 1 (15 m RWL) (ML/y) ⁽¹⁾	554
P50 K PD throughflow, Cross-section 2 (30 m RWL) (ML/y) ⁽¹⁾	444
Average (P50 K) PD throughflow (ML/y)	499
Lower range (P50 K) PD throughflow (ML/y)	444
Upper range (P50 K) PD throughflow (ML/y)	554
Lower range minimum (P20 K) PD throughflow (ML/y)	30
SD (ML/y)	78
CV (%)	16
Approximate length of flow-tube (km)	20

(1) Based on the Stratford CHM (Section 12.1.3), it was assumed that the aquifer unit constitutes 20% of the thickness of the LTA VAF layer.

To assist with contextualising the throughflow outputs, the average, lower and upper range (P50 K) and lower range minimum (P20 K) predevelopment throughflow estimates for flow-tube LTA ft09 are presented in Figure 12-4.

Figure 12-4 UA west of Marlo - PCV and licensed usage relative to predevelopment throughflow estimates of flow-tube LTA ft09



13. Gippsland GMB – Seaspray groundwater catchment

The Gippsland GMB is located in southeast Victoria and includes the East Gippsland, Central Gippsland, Moe and Seaspray groundwater catchments. This chapter concerns the Seaspray groundwater catchment.

The confined aquifers within the Seaspray groundwater catchment include:

- Boisdale Formation (Wurruk Sand) (UTAF) (Figure 5-2).
- Balook Formation (UMTA) (Figure 5-3).
- Seaspray Sand (LMTA) (Figure 5-4).
- Latrobe Group (LTA) (Figure 5-6).

The Seaspray groundwater catchment contains two GMUs that incorporates confined aquifers (Table 13-1, and Figure 5-2, Figure 5-3, Figure 5-4 and Figure 5-6). The flow-tubes assigned in the groundwater catchment are listed in Table 13-1.

Table 13-1 Seaspray groundwater catchment - assigned flow-tubes

Groundwater catchment	GMU or non-GMU	PCV Order depth	Confined VAF layer and flow-tube no.	Aquifer name
Seaspray	Giffard GMA	All formations from 50 to 200 m below surface	UTAF ft06	Boisdale Formation (Wurruk Sand)
	Yarram WSPA	Zone 1 – all formations below 200 m Zone 2 – all formations below surface	UTAF (Zone 2 only) ft05	Boisdale Formation (Wurruk Sand)
			UMTA (Zone 2 only) ft04	Balook Formation
			LMTA ft01	Seaspray Sand
			LTA ft07	Latrobe Group

13.1 Hydrogeological characterisation

13.1.1 Giffard GMA

The Giffard GMA, located in the Gippsland region of eastern Victoria, comprises the high yielding confined Boisdale Formation (Wurruk Sand) aquifer (UTAF). The WSPA extends from the region east of Yarram to Loch Sport and has vertical depth limits for the confined aquifer that correspond to 50-200 m. The northern boundary of the GMA is the southern limit of the Baragwanath Anticline, and the coast forms the southern boundary of the GMA.

The management area overlies Yarram Zone 1 WSPA which incorporates the deeper Balook Formation (UMTA), Seaspray Sand (LMTA) and Latrobe Group (LTA) confined aquifers.

The regional scale hydrostratigraphic profile in and around the Giffard GMA is listed in Table 13-2 and key hydrogeological attributes are described in Table 13-3.

Table 13-2 Hydrostratigraphic profile in and around the Giffard GMA

Geological formation	VAF code	Geological period	Lithology
Haunted Hills Formation	QA/UTQA	Quaternary-Upper Tertiary	Clay, sandy clay, sand, gravel and clayey sand

Confined Aquifer Throughflow Assessment – Updated Method and Phase B State-wide Rollout

Geological formation	VAF code	Geological period	Lithology
Nuntin Clay and Jemmy's Point Formation	UTQD	Quaternary-Upper Tertiary	The Nuntin Clay (confining layer of Boisdale Formation) comprise of clays, gravels and fine to coarse grained sands. The Jemmy's Point Formation comprises shelly and sandy marl and calcareous sandstone, overlain by shelly sand and minor gravels.
Boisdale Formation (Wurruk Sand)	UTAF	Upper Tertiary	Fluviatile sand aquifer of medium to coarse grained sands, confined to semi-confined by either the Boisdale Formation (Nuntin Clay Member) or clays within the overlying Haunted Hills Gravel.
Yallourn and Hazelwood formations	UTD	Upper Tertiary	Yallourn Formation consists of coal seams interbedded with non-marine claystones and mudstone. Hazelwood Formation consists of interbedded brown coal and clay.
Balook Formation	UMTA	Upper Middle Tertiary	Dominated by fine-grained clay and a thicker upper unit consisting of coarse-grained sand interlayered with thin clay layers.
Seaspray Group (i.e. Gippsland Limestone and the Lakes Entrance Formation)	UMTD	Upper Middle Tertiary	Calcareous sedimentary deposits with aquitard properties.
Seaspray Sand	LMTA	Lower Middle Tertiary	The sand dominated basal aquifer of the Latrobe Valley Coal Measures is termed the Seaspray Sand. It is an important regional aquifer, and accordingly, has its own categorisation (LMTA) in the VAF.
Latrobe Group	LTA	Lower Tertiary	Marine and non-marine siliciclastics that host all the known hydrocarbon occurrences in the offshore region of the Gippsland Basin. The Latrobe Group includes three formations: the Yarram Formation, Carrajung Volcanics, and Traralgon Formation.
Strzelecki Group	BSE	Mesozoic	Low-permeability, non-marine, volcanoclastic-rich sandstones and mudstones.

Source: (Jacobs, 2015).

Note: The shaded grey cell indicates the confined aquifer VAF layer subject to the Phase B study.

Table 13-3 Giffard GMA – Key hydrogeological attributes

Attribute	Parameter	Description
Groundwater management	GMU size	750 km ² (GIS calculated)
	PCV Order depth	All formations from 50 to 200 m below surface.
	Overlying GMUs	None.
	Underlying GMUs	Yarram Zone 1 WSPA.
	Confined aquifers (and VAF code, number) ⁽¹⁾	Boisdale Formation (UTAF, 105).

Confined Aquifer Throughflow Assessment – Updated Method and Phase B State-wide Rollout

Attribute	Parameter	Description
	PCV and derivation ⁽¹⁾	5,689 ML/year (PCV Order 2017). Derivation: Inferred to align to volume of licensed use.
Groundwater usage	Licensed volume ⁽³⁾	5,689 ML/year (June 2021).
	Licensed use ⁽³⁾	Average (2004–2021): 2,476 ML/year. Minimum (2011–2012): 845 ML/year. Maximum (2018–2019): 5,548 ML/year.
Hydrogeological conceptualisation	Recharge areas ^(1,2)	In the Giffard–Seaspray region, recharge areas for the Boisdale Aquifer (UTAF) are thought to be along the southern flank of the Baragwanath Anticline, to the north of Woodside and Stradbroke and possibly from the Yarram area to the west.
	Groundwater flow and aquifer/aquitard characteristics ^(1,2)	The Boisdale aquifer (UTAF) is confined, and groundwater flow is considered to be in a south-east direction, towards the coast. The historic Zone 1 area (west of Dutson Downs) is isolated from the Boisdale Formation (UTAF) in Latrobe Valley and has its own recharge in the north. The historic Zone 2 (east of Dutson Downs) is connected to the Boisdale Formation (UTAF) in the Sale GMA and is recharged by throughflow from the Sale GMA. For the coastal extent of the Boisdale Aquifer (UTAF), in the Seaspray- Giffard region, there has been little investigation of the vertical movement between aquifers. There is a risk of saline intrusion from excessive pumping.
	Cross border flows	Not applicable.
Groundwater monitoring	Groundwater suite hydrographic classification ⁽¹⁾	Water level trends in the Boisdale Formation (UTAF) were declining between 2003–2008 and stable since 2008 – 2017 (Suite U_AG_1).

References: (1) Jacobs (2019), (2) Jacobs (2015), (3) DEECA (2023).

13.1.2 Yarram WSPA

The Yarram WSPA, in eastern Victoria, is located south of the Strzelecki Ranges and includes the onshore area of the Gippsland Basin. This is a relatively small component of the whole Gippsland Basin but covers an area where groundwater is extracted primarily for irrigating pasture in Yarram and surrounding districts. The Yarram WSPA also incorporates forested areas along the Strzelecki Ranges comprising State Parks and plantation forestry.

The WSPA is located within the Seaspray Depression; a structure bounded by the Baragwanath Anticline to the north and major faulting along its flanks. The structure plunges steeply to the east into Bass Strait.

The management area includes the hydraulically connected aquifers of the Latrobe Group (LTA) and the shallower Balook Formation (UMTA) which are the main sources of water used for irrigation. From Woodside to Golden Beach, the Latrobe Group is much deeper, underlying the Gippsland Limestone (aquitard) and Boisdale Formations. These aquifers are overlain by the shallow unconfined Haunted Hills Formation; a low yielding and generally poorer quality aquifer, typically suitable for stock watering and dairy wash purposes.

While the WSPA was declared to manage groundwater extractions from the Latrobe Group aquifer (LTA) and the Balook Formation (UMTA), it also includes aquifers belonging to the Latrobe Valley Coal Measures (LMTA), and the Boisdale Formation (UTAF) where the aquifer is present outside of the Giffard GMA.

The WSPA includes all formations below surface (Zone 2), except in Zone 1 where it underlies the Giffard GMA (in areas where the UTAF is generally present), and the where the WSPA incorporates all formations below 200 m.

The regional scale hydrostratigraphic profile in and around the Yarram WSPA is listed in Table 13-4 and key hydrogeological attributes are described in Table 13-5.

Confined Aquifer Throughflow Assessment – Updated Method and Phase B State-wide Rollout

Table 13-4 Hydrostratigraphic profile in and around the Yarram WSPA

Geological formation	VAF code	Geological period	Lithology
Haunted Hills Formation	QA/UTQA	Quaternary-Upper Tertiary	Clay, sandy clay, sand, gravel and clayey sand.
Nuntin Clay and Jemmy's Point Formation	UTQD	Quaternary-Upper Tertiary	The Nuntin Clay (confining layer of Boisdale Formation) comprise of clays, gravels and fine to coarse grained sands. The Jemmy's Point Formation comprises shelly and sandy marl and calcareous sandstone, overlain by shelly sand and minor gravels.
Boisdale Formation (Wurruk Sand) ⁽¹⁾	UTAF	Upper Tertiary	Fluviatile sand aquifer of medium to coarse grained sands, confined to semi-confined by either the Boisdale Formation (Nuntin Clay Member) or clays within the overlying Haunted Hills Gravel.
Yallourn and Hazelwood formations	UTD	Upper Tertiary	Yallourn Formation consists of coal seams interbedded with non-marine claystones and mudstone. Hazelwood Formation consists of interbedded brown coal and clay.
Balook Formation	UMTA	Upper Middle Tertiary	Dominated by fine-grained clay and a thicker upper unit consisting of coarse-grained sand interlayered with thin clay layers.
Seaspray Group (i.e. Gippsland Limestone and the Lakes Entrance Formation)	UMTD	Upper Middle Tertiary	Calcareous sedimentary deposits with aquitard properties.
Seaspray Sand	LMTA	Lower Middle Tertiary	The sand dominated basal aquifer of the Latrobe Valley Coal Measures is termed the Seaspray Sand. It is an important regional aquifer, and accordingly, has its own categorisation (LMTA) in the VAF.
Latrobe Group	LTA	Lower Tertiary	Marine and non-marine siliciclastics that host all the known hydrocarbon occurrences in the offshore region of the Gippsland Basin. The Latrobe Group includes three formations: the Yarram Formation, Carrajung Volcanics, and Traralgon Formation. The Traralgon Formation is the most widespread of the Lower Tertiary units and includes extensive aquifers interbedded with several major brown coal seams. For the purposes of this study, it has been assumed the aquifer component of the LTA is approximately 20% of its overall thickness.
Strzelecki Group	BSE	Mesozoic	Low-permeability, non-marine, volcanoclastic-rich sandstones and mudstones.

Source: (Jacobs, 2015).

Notes:

The shaded grey cells indicate the confined aquifer VAF layers subject to the Phase B study.

(1) The UTAF is incorporated in the Giffard GMA where it overlies Yarram Zone 1 WSPA.

Confined Aquifer Throughflow Assessment – Updated Method and Phase B State-wide Rollout

Table 13-5 Yarram WSPA – Key hydrogeological attributes

Attribute	Parameter	Description
Groundwater management	GMU size	2,700 km ² (GIS calculated)
	PCV Order depth	Zone 1 – all formations below 200 m Zone 2 – all formations below surface.
	Overlying GMUs	Giffard GMA (Yarram WSPA in Zone 1).
	Underlying GMUs	None.
	Confined aquifers (and VAF code, number) ⁽¹⁾	Intended to primarily manage the Balook Formation (UMTA, 107) and Latrobe Group (LTA, 111) aquifers. Areas of Boisdale Formation (UTAF, 105) in Yarram (Zone 2) and Latrobe Valley Coal Measures (LMTA, 109) are also included.
	PCV and derivation ⁽¹⁾	25,690 ML/year (PCV Order 2017). Derivation: Inferred to align to volume of licensed use.
Groundwater usage	Licensed volume ⁽³⁾	25,688 ML/year (June 2021).
	Licensed use ⁽³⁾	Average (2004-2021): 11,482 ML/year. Minimum (2011-2012): 6,740 ML/year. Maximum (2018-2019): 16,557 ML/year.
Hydrogeological conceptualisation	Recharge areas ^(1,2)	For the Balook Formation (UMTA), recharge areas are expected to be in the north where the unit is closer to the surface, receiving downward recharge from overlying aquifers. Recharge to Latrobe Group aquifers (LTA) occurs through vertical leakage, from the Balook Formation (UMTA), and through direct infiltration where the Latrobe Group outcrops or is closely connected to the surficial units (along the western and northern basin margins). In the Yarram area, outcropping Lower Tertiary Basalts are likely to be the recharge source for the sub-cropping LTA.
	Groundwater flow and aquifer/aquitard characteristics ^(1,2)	The Traralgon Formation is the most widespread unit of the LTA and includes extensive aquifers (thick interbedded sequences of sand and gravel) with several major brown coal seams which can be in excess of 100 m thick and behave as regional aquitards. In the coastal extent of the Boisdale Aquifer (UTAF) in the Seaspray–Giffard region there has been little investigation of the vertical movement between aquifers. The Boisdale (UTAF) is underlain by the Balook Formation (UMTA) in the western part of the Giffard GMA and there is speculation that there may be hydraulic connection between these aquifers in this region. Lithological analysis demonstrates there is no significant aquitard separating the Balook Aquifer (UMTA) from the underlying LTA in the Yarram region. A degree of hydraulic connection is evidenced by hydrographs that indicate a dampened response in the Balook Formation (UMTA) to groundwater pressure declines in the LTA. Historically there was an upward gradient from the Latrobe Group aquifers (LTA) to the overlying Balook Formation aquifer (UMTA). Aquifer depressurisation has reversed this gradient, so there is now a downward gradient from the Balook aquifer (UMTA) to Latrobe Group aquifer (LTA).
	Cross border flows	Not applicable.
Groundwater monitoring	Groundwater suite hydrographic classification ^(1,2)	In Zone 1, a long-term declining trend since 1985 is indicated for the Lower aquifers (LMTA, LTA) (Suite L_O_2). In Zone 2, a long-term declining trend since 1983 is indicated for the Lower aquifers (LMTA, LTA) (Suite L_O_1). The long-term water level decline is due to a combination of groundwater extraction for offshore oil production and onshore

Attribute	Parameter	Description
		irrigation. Associated risks include seawater intrusion and subsidence. Declining trends observed in the Balook Formation aquifer (UMTA) are likely to be a direct result of Latrobe Group aquifer (LTA) pressure declines, although the response is dampened.

References: (1) Jacobs (2019), (2) Jacobs (2015), (3) DEECA (2023).

13.2 Aquifer property data

Aquifer property data collected for the Boisdale Formation (Wurruk Sand) (UTAF), Balook Formation (UMTA), Seaspray Sand (LMTA) and Latrobe Group (LTA) in the Seaspray groundwater catchment (and neighbouring Central Gippsland groundwater catchment where relevant) are presented in Table 13-6, Table 13-7, Table 13-8 and Table 13-9, respectively. The statistical analysis of the K (K_h) point data for each of the VAF layers is presented in Table 13-10, including the P20 K, P50 K and P80 K values adopted for the throughflow calculations.

Table 13-6 Seaspray groundwater catchment - UTAF properties

Area	Aquifer	K_h (m/d)	K_v (m/d)	T (m^2/d)	S	Reference
Sale WSPA	Boisdale Formation	5	N/a	1,300	5×10^{-4}	SKM (1998f), as cited in Jacobs, 2019.
Sale WSPA	Boisdale Formation (Wurruk Sand)	12.4	0.04	N/a	N/a	GHD (2010b) as cited in Jacobs, 2019.
Sale WSPA	Boisdale Formation	29.9	4.5	N/a	10×10^{-5}	Beverly et al.. (2015) as cited in Jacobs (2019).
Sale WSPA	Boisdale Formation	24	N/a	N/a	10×10^{-4}	SKM (2008) as cited in Jacobs (2019).
Giffard WSPA	Boisdale Formation	2.5	N/a	N/a	N/a	Jacobs (2019).

Table 13-7 Seaspray groundwater catchment - UMTA properties

Area	Aquifer	K_h (m/d)	K_v (m/d)	T (m^2/d)	S	Reference
Gippsland Basin	Balook Formation	3.53	0.066	N/a	N/a	GHD (2010b) as cited in Jacobs, 2019.
Gippsland Basin	Balook Formation	7.5	0.14	N/a	N/a	GHD (2010b) as cited in Jacobs, 2019.
Gippsland Basin	Balook Formation	16.1	1.202	N/a	1×10^{-5}	Beverly et al.. (2015) as cited in Jacobs (2019).
Gippsland Basin	Balook Formation	6.07	0.627	N/a	1×10^{-5}	Beverly et al.. (2015) as cited in Jacobs (2019).
Gippsland Basin	Balook Formation	2-7	N/a	1,000	N/a	Various sources as cited in Beverly et al.. (2015).
Gippsland Basin	Balook Formation	2-57	N/a	N/a	N/a	Various sources as cited in Beverly et al.. (2015).

Table 13-8 Seaspray groundwater catchment - LMTA properties

Area	Aquifer	K_h (m/d)	K_v (m/d)	T (m^2/d)	S	Reference
Yarram WSPA	M1B Aquifer (Latrobe Valley)	0.97	0.13	N/a	N/a	GHD (2010b) as cited in Jacobs, 2019.

Confined Aquifer Throughflow Assessment – Updated Method and Phase B State-wide Rollout

Area	Aquifer	K_h (m/d)	K_v (m/d)	T (m ² /d)	S	Reference
Yarram WSPA	Lower M2 Interseam	16.1	1.202	N/a	1×10^{-5}	Beverly et al.. (2015) as cited in Jacobs (2019).
Rosedale GMA	M2C Aquifer / Seaspray Sand	1.63	0.3	N/a	N/a	GHD (2010b) as cited in Jacobs, 2019.
Rosedale GMA	M2C Aquifer / Seaspray Sand	6.119	0.39	N/a	1×10^{-5}	Beverly et al.. (2015) as cited in Jacobs (2019).
Gippsland Basin	M2C Aquifer / Seaspray Sand	6.4×10^{-4} -76.06	N/a	N/a	N/a	Various sources as cited in Beverly et al.. (2015).

Table 13-9 Seaspray groundwater catchment - LTA properties (aquifer units only) ⁽¹⁾

Area	Aquifer	K_h (m/d)	K_v (m/d)	T (m ² /d)	S	Reference
Gippsland Basin	Upper Latrobe Group	0.0016-76.06	N/a	N/a	N/a	Various sources as cited in Beverly et al.. (2015).
Gippsland Basin	T1 interseam	0.0016-88.0	N/a	N/a	N/a	Various sources as cited in Beverly et al.. (2015).
Gippsland Basin	T2 interseam	1.6×10^{-7} -88.0	N/a	N/a	N/a	Various sources as cited in Beverly et al.. (2015).
Yarram WSPA	T2 interseam	0.886	0.0957	N/a	1.0×10^{-5}	Beverly et al.. (2015) as cited in Jacobs (2019).

(1) The LTA includes extensive aquifers interbedded with several major brown coal seams. For the purposes of this study, it has been assumed the aquifer component of the LTA is approximately 20% of its overall thickness.

Table 13-10 Seaspray groundwater catchment K_h statistics

K_h statistical parameter	Value			
	UTAF	UMTA	LMTA	LTA (aquifer units only)
Number of data points	5	4	4	1
Minimum	2.5 m/d	2	6.4×10^{-4} m/d	1.6×10^{-7}
P20	4.5 m/d	N/a (2.5 m/d)	N/a (0.1 m/d)	N/a (0.1 m/d)
P50	12.4 m/d	N/a (6 m/d)	N/a (4 m/d)	N/a (1.5 m/d)
Average	14.7 m/d	8.3 m/d	6.2 m/d	N/a
P80	25.2 m/d	N/a (15 m/d)	N/a (10 m/d)	N/a (8 m/d)
Maximum	29.9 m/d	57 m/d	76.1 m/d	88.0
Standard deviation	11.9	N/a	N/a	N/a

Notes:

The shaded cells indicate the P20 K, P50 K and P80 K values adopted in the gridded throughflow rate analysis.

The inputted K values were rounded to the nearest 0.5 for the throughflow analysis.

N/a: Insufficient K_h point data to inform statistical analysis. In the absence of sufficient K point data, the typical K ranges from pumping tests informed the selection of representative values of P20, P50 and P80 K for the throughflow assessments. These adopted values are indicated in brackets.

13.3 Outputs

13.3.1 Giffard GMA

The Giffard GMA is designated flow-tube UTAF ft06 (Table 12-1). The predevelopment throughflows for UTAF ft06 rely on throughflow outputs from one cross-section perpendicular to groundwater flow (at 10 m modelled RWL contour).

The (P50 K) predevelopment throughflow estimate of the cross-section in the UTAF ft06 is reported in Table 13-11. The corresponding (adopted) average (P50 K) and the lower range minimum (P20 K) predevelopment throughflow estimates for the flow-tube are also reported. As only one cross-section informs the throughflow assessment, the spatial variability of the throughflow calculation has not been assessed.

Table 13-11 Predevelopment throughflow estimates for flow-tube - UTAF ft06

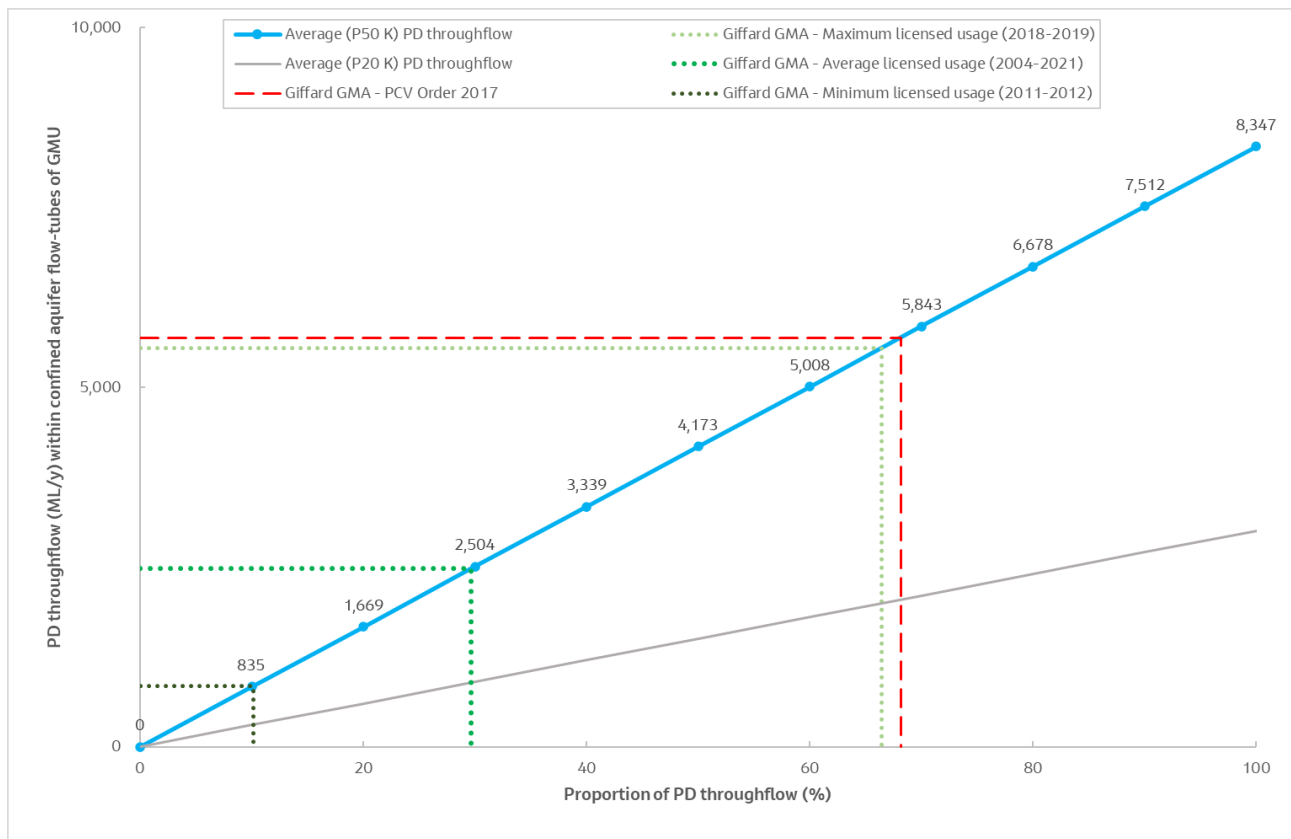
Parameter	Value
P50 K PD throughflow, Cross-section 1 (10 m RWL) (ML/y)	8,347
Adopted (average) (P50 K) PD throughflow (ML/y)	8,347
Lower range (P50 K) PD throughflow (ML/y)	8,347
Upper range (P50 K) PD throughflow (ML/y)	8,347
Lower range minimum (P20 K) PD throughflow (ML/y)	3,005
SD (ML/y)	N/a
CV (%)	N/a
Approximate length of flow-tube (km)	20

Notes:

The cross-section occurs within the GMU boundary.

To assist with contextualising the throughflow outputs, the average (P50 K) and lower range minimum (P20 K) predevelopment throughflow estimates for flow-tube UTAF ft06 are presented in Figure 13-1. For comparison, the Giffard GMA PCV and minimum, average and maximum licensed usage values are overlaid on the figure.

Figure 13-1 Giffard GMA - PCV and licensed usage relative to predevelopment throughflow estimate of flow-tube UTAF ft06



The throughflow results of the flow-tubes are summarised in Table 13-12 in the context of management arrangements and licensed usage in the Giffard GMA, including considerations for assigning a sustainable yield.

Table 13-12 Summary of predevelopment throughflows in context of Giffard GMA

Flow-tube parameter	Result
Confined VAF layers	UTAF.
Comparison with GMA boundary	The GMA boundary generally occupies the entire width and length of the flow-tube.
Flow from, or to, GMUs or UAs	The GMA does not contribute flow to, or receive flow from, another GMU or UA.
GMU PD throughflow estimate	The flow-tube cross-section occurs within the boundary of the GMA. The average (P50 K) predevelopment throughflow of the GMA is therefore estimated to be 8,347 ML/y .
CV (%) and potential factors contributing to spatial variability	CV: N/a (one cross-section was assessed).
PCV relative to PD throughflow	The PCV (5,689 ML/y) represents 68 % of the average (P50 K) predevelopment throughflow (8,347 ML/y). The PCV represents 189 % of the lower range minimum (P20 K) predevelopment throughflow.
Average licensed usage relative to PD throughflow	The average licensed usage (2,475 ML/y) represents 30 % of the average (P50 K) predevelopment throughflow (8,347 ML/y). The average licensed usage represents 82 % of the lower range minimum (P20 K) predevelopment throughflow.
Relative rankings (Appendix B)	Relative reliability ranking: Low; Relative uncertainty ranking: High; Relative potential for adverse impact on aquifer value(s): Low; Overall GMU ranking: High-Low.
Considerations for assigning sustainable yield	<ul style="list-style-type: none"> Potential risks of sea water intrusion from groundwater development.

13.3.2 Yarram WSPA

The Yarram WSPA is designated flow-tubes UTAF ft05, UMTA ft04, LMTA ft01 and LTA ft07 (Table 13-1). The predevelopment throughflows for these flow-tubes rely on throughflow outputs from the following cross-sections perpendicular to groundwater flow:

- UTAF ft05: 10 m, 20 m and 40 m modelled RWL contours.
- UMTA ft04: 5 m, 15 m and 30 m modelled RWL contours.
- LMTA ft01: 10 m, 35 m and 70 m modelled RWL contours.
- LTA ft07: 25 m and 40 m modelled RWL contours.

The (P50 K) predevelopment throughflow estimate of each cross-section in the UTAF ft05, UMTA ft04, LMTA ft01 and LTA ft07 is reported in Table 13-13. The corresponding average, lower and upper range (P50 K), and lower range minimum (P20 K) predevelopment throughflow estimates for the flow-tubes, and a combined estimate, are also reported. The potential variability of throughflow within the flow-tubes, and combined, is represented by the SD and CV in Table 13-13.

Table 13-13 Predevelopment throughflow estimates for flow-tubes - UTAF ft05, UMTA ft04, LMTA ft01 and LTA ft07

Parameter	Value
UTAF ft05	
P50 K PD throughflow, Cross-section 1 (10 m RWL) (ML/y)	2,177
P50 K PD throughflow, Cross-section 2 (20 m RWL) (ML/y)	3,456
P50 K PD throughflow, Cross-section 3 (40 m RWL) (ML/y)	1,980
Average (P50 K) PD throughflow (ML/y)	2,538
Lower range (P50 K) PD throughflow (ML/y)	1,980

Confined Aquifer Throughflow Assessment – Updated Method and Phase B State-wide Rollout

Parameter	Value
Upper range (P50 K) PD throughflow (ML/y)	3,456
Lower range minimum (P20 K) PD throughflow (ML/y)	713
SD (ML/y)	801
CV (%)	32
Approximate length of flow-tube (km)	20
UMTA ft04	
P50 K PD throughflow, Cross-section 1 (5 m RWL) (ML/y)	15,027
P50 K PD throughflow, Cross-section 2 (15 m RWL) (ML/y)	9,790
P50 K PD throughflow, Cross-section 3 (30 m RWL) (ML/y)	26,298
Average (P50 K) PD throughflow (ML/y)	17,038
Lower range (P50 K) PD throughflow (ML/y)	9,790
Upper range (P50 K) PD throughflow (ML/y)	26,298
Lower range minimum (P20 K) PD throughflow (ML/y)	4,079
SD (ML/y)	8,436
CV (%)	50
Approximate length of flow-tube (km)	20
LMTA ft01	
P50 K PD throughflow, Cross-section 1 (10 m RWL) (ML/y)	28,060
P50 K PD throughflow, Cross-section 2 (35 m RWL) (ML/y)	32,390
P50 K PD throughflow, Cross-section 3 (70 m RWL) (ML/y)	34,877
Average (P50 K) PD throughflow (ML/y)	31,776
Lower range (P50 K) PD throughflow (ML/y)	28,060
Upper range (P50 K) PD throughflow (ML/y)	34,877
Lower range minimum (P20 K) PD throughflow (ML/y)	701
SD (ML/y)	3,062
CV (%)	10
Approximate length of flow-tube (km)	30
LTA ft07 ⁽¹⁾	
P50 K PD throughflow, Cross-section 1 (25 m RWL) (ML/y)	3,767
P50 K PD throughflow, Cross-section 2 (40 m RWL) (ML/y)	2,821
Average (P50 K) PD throughflow (ML/y)	3,294
Lower range (P50 K) PD throughflow (ML/y)	2,821
Upper range (P50 K) PD throughflow (ML/y)	3,767
Lower range minimum (P20 K) PD throughflow (ML/y)	188
SD (ML/y)	669
CV (%)	20
Approximate length of flow-tube (km)	40
Combined UTAF ft05, UMTA ft04, LMTA ft01 and LTA ft07	
Average (P50 K) PD throughflow (ML/y)	54,646
Lower range (P50 K) PD throughflow (ML/y)	42,651
Upper range (P50 K) PD throughflow (ML/y)	68,398
Lower range minimum (P20 K) PD throughflow (ML/y)	5,681
SD (ML/y)	12,968

Confined Aquifer Throughflow Assessment – Updated Method and Phase B State-wide Rollout

Parameter	Value
CV (%)	24

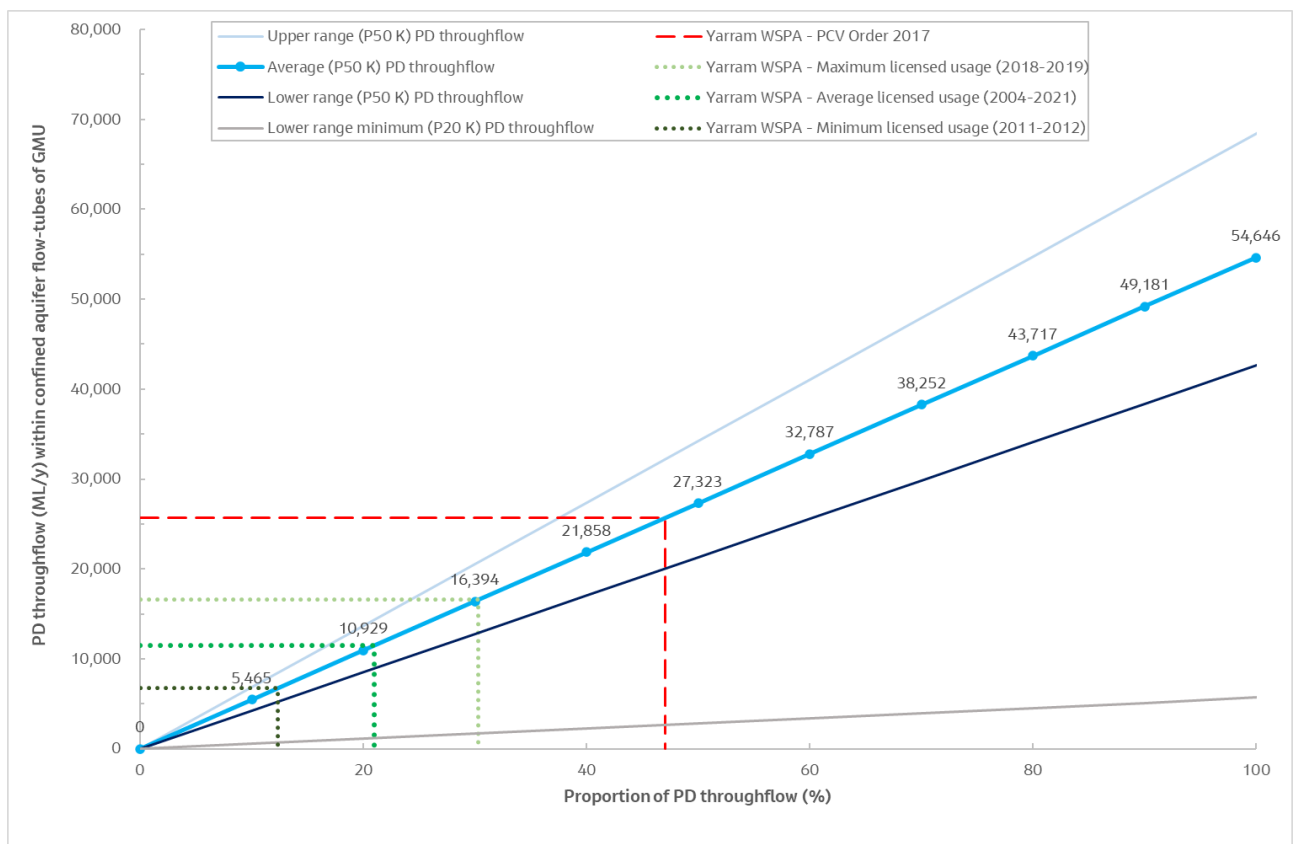
Notes:

The cross-sections occur within the GMU boundary.

(1) Based on the CHM, it was assumed that the aquifer unit constitutes 20% of the thickness of the LTA VAF layer.

To assist with contextualising the throughflow outputs, the average, lower and upper range (P50 K) and lower range minimum (P20 K) predevelopment throughflow estimates for combined flow-tubes UTAF ft05, UMTA ft04, LMTA ft01 and LTA ft07 are presented in Figure 13-2. For comparison, the Yarram WSPA PCV and minimum, average and maximum licensed usage values are overlaid on the figure.

Figure 13-2 Yarram WSPA - PCV and licensed usage relative to predevelopment throughflow estimates of combined flow-tubes UTAF ft05, UMTA ft04, LMTA ft01 and LTA ft07



The throughflow results of the flow-tubes, and their spatial variability, are summarised in Table 13-14 in the context of management arrangements and licensed usage in the Yarram WSPA, including considerations for assigning a sustainable yield.

Table 13-14 Summary of predevelopment throughflows in context of Yarram WSPA

Flow-tube parameter	Result
Confined VAF layer	UTAF, UMTA, LMTA and LTA.
Comparison with WSPA boundary	The WSPA boundary generally occupies the entire width and length of the flow-tubes.
Flow from, or to, GMUs or UAs	The WSPA does not contribute flow to, or receive flow from, another GMU or UA.

Confined Aquifer Throughflow Assessment – Updated Method and Phase B State-wide Rollout

Flow-tube parameter	Result
GMU PD throughflow estimate	All of the flow-tube cross-sections occur within the boundary of the WSPA. The average (P50 K) predevelopment throughflow of the WSPA is therefore estimated to be 54,646 ML/y .
CV (%) and potential factors contributing to spatial variability	CV: 24 %. A range of spatially variable processes may be responsible including upwards leakage from the Latrobe Group aquifers to the overlying Balook Formation.
PCV relative to PD throughflow	The PCV (25,690 ML/y) represents 47 % of the average (P50 K) predevelopment throughflow (54,646 ML/y) but allowing for spatial variability may be between 38 % and 60 %. The PCV represents 454 % of the lower range minimum (P20 K) predevelopment throughflow.
Average licensed usage relative to PD throughflow	The average licensed usage (11,482 ML/y) represents 21 % of the average (P50 K) predevelopment throughflow (54,646 ML/y) but allowing for spatial variability may be between 17 % and 27 %. The average licensed usage represents 202 % of the lower range minimum (P20 K) predevelopment throughflow.
Relative rankings (Appendix B)	Relative reliability ranking: Low; Relative uncertainty ranking: Medium; Relative potential for adverse impact on aquifer value(s): Low; Overall GMU ranking: Medium-Low.
Considerations for assigning sustainable yield	<ul style="list-style-type: none"> ▪ Reversal of hydraulic gradients due to aquifer depressurisation such that there is now a downward gradient from the Balook Formation to Latrobe Group aquifer. ▪ Potential for inter-aquifer leakage and stress induced yield augmentation.

14. Summary of throughflow outputs

The following key outputs of the Phase B study are summarised at the flow-tube scale in Table 14-1:

- Average, lower range and upper range (P50 K) predevelopment throughflow rates and lower range minimum (P20 K) predevelopment throughflow rate.
- Where the flow-tube overlaps with a GMU; relative rankings for reliability, uncertainty and potential for adverse impact on aquifer value(s), and an overall GMU ranking.
- Where the flow-tube overlaps with a GMU; PCV and average licensed usage.

Table 14-1 Summary of flow-tube scale throughflow outputs

GMB	GMU or UA	PCV Order depth	Confined VAF layer and flow-tube no.	Predevelopment throughflow (ML/y) of flow-tube(s)				PCV (ML/y) (and as a proportion (%) of PD average (P50 K) throughflow)	Average licensed usage (ML/y) (and as a proportion (%) of PD average (P50 K) throughflow)	Relative reliability ranking	Relative uncertainty ranking	Relative potential for adverse impact on aquifer value(s) ranking	Overall GMU ranking
				Average (P50 K)	Lower range (P50 K)	Upper range (P50 K)	Lower range minimum (P 20 K)						
Wimmera-Mallee	West Wimmera GMA	Not depth defined ⁽³⁾	UMTA ft07,08 LTA ft21, 22	16,853	8,385	32,611	3,279	57,409 (341)	22,033 (131)	Medium	Medium	Very High	Medium-Very High
	Murrayville GMA	All formations from 70 to 200 m below surface	UMTA ft07	6,646	3,610	13,345	1,313	11,005 (166)	5,408 (81)	Medium	Medium	High	Medium-High
	UA near Salt Lake	N/a	UTAM ft02	316	153	627	38	N/a	N/a	N/a	N/a	N/a	N/a
	UA east and north of Horsham	N/a	LTA ft23	414	169	817	85	N/a	N/a	N/a	N/a	N/a	N/a
	UA between Donald and Robinvale	N/a	LTA ft24	1,304	754	1,888	377	N/a	N/a	N/a	N/a	N/a	N/a
Goulburn-Murray	Mid Loddon GMA	All formations below surface	UTAF ft11 LTA ft26	17,904	9,235	41,272	4,843	34,037 (190)	17,689 (99)	Low	Low	High	Low-High
	UA east of Wycheproof	N/a	UTAF ft12	13,682	6,714	20,650	3,155	N/a	N/a	N/a	N/a	N/a	N/a
	UA near Kerang	N/a	LTA ft25	22,315	18,533	25,666	11,184	N/a	N/a	N/a	N/a	N/a	N/a
	Lower Campaspe Valley WSPA	All formations below surface with an exception ⁽¹⁾	UTAF ft10 LTA ft28	23,983	18,810	28,325	9,879	55,875 (233)	29,689 (124)	Low	Low	Very High	Low-Very High
	UA near Cohuna	N/a	LTA ft27	6,339	2,790	8,774	1,684	N/a	N/a	N/a	N/a	N/a	N/a
	Katunga WSPA	All formations below 25 m from surface	UTAF ft09 LTA ft29	104,905	68,595	143,392	36,177	60,577 (58)	27,785 (26)	Low	Low	Low	Low-Low
Otway-Torquay	Glenelg WSPA (abolished)	All formations below surface	LMTA ft03 LTA ft11	115,297	65,344	157,647	13,440	33,262 (29)	7,383 (6)	Low	Low	Low	Low-Low
	Portland GMA	All formations below 200 m from surface	LTA ft12	190,266	74,613	329,435	14,923	7,795 (4)	7,795 (4)	Low	Medium	Low	Medium-Low
	Condah WSPA	All formations from 70 to 200 m below surface	LMTA ft04	11,965	3,443	26,104	1,291	7,470 (62)	2,782 (23)	Medium	Medium	Low	Medium-Low
	Paaratte GMA	Not depth defined ⁽⁴⁾	LTA ft14	146,217	102,243	219,736	20,449	4,606 (3)	321 (<1)	Low	Low	Low	Low-Low
	Newlingrook GMA	All formations below surface	LTA ft15	192,814	N/a	N/a	38,563	1,977 (1)	145 (<1)	Low	High	Low	High-Low
	Gellibrand GMA	All formations below surface	LTA ft16	17,677	N/a	N/a	3,535	0 (0)	0 (0)	Low	High	Low	High-Low
	Gerangamete GMA	All formations below surface	LTA ft31	54,577	39,652	69,502	7,930	239 (<1)	3,524 (6)	Low	Low	Low	Low-Low
	UA near Warrnambool	N/a	LMTA ft05	12,385	N/a	N/a	4,644	N/a	N/a	N/a	N/a	N/a	N/a
	UA north of Colac	N/a	LTA ft32	30,576	8,904	52,248	1,781	N/a	N/a	N/a	N/a	N/a	N/a

Confined Aquifer Throughflow Assessment – Updated Method and Phase B State-wide Rollout

GMB	GMU or UA	PCV Order depth	Confined VAF layer and flow-tube no.	Predevelopment throughflow (ML/y) of flow-tube(s)				PCV (ML/y) (and as a proportion (%) of PD average (P50 K) throughflow)	Average licensed usage (ML/y) (and as a proportion (%) of PD average (P50 K) throughflow)	Relative reliability ranking	Relative uncertainty ranking	Relative potential for adverse impact on aquifer value(s) ranking	Overall GMU ranking
				Average (P50 K)	Lower range (P50 K)	Upper range (P50 K)	Lower range minimum (P 20 K)						
	UA near Warrnambool	N/a	LTA ft13	89,907	44,708	135,105	8,942	N/a	N/a	N/a	N/a	N/a	N/a
	UA near Skipton	N/a	LTA ft30	17,060	9,939	21,541	1,988	N/a	N/a	N/a	N/a	N/a	N/a
	Jan Juc GMA	Not depth defined ⁽⁵⁾	LTA ft17	36,557	N/a	N/a	7,311	14,250 (39)	2,801 (8)	Low	High	Low	High-Low
Central	Cut Paw Paw GMA	All formations below 50 m	LTA ft05	3,454	1,450	5,101	290	3,750 (106)	99 (3)	Low	Low	Low	Low-Low
	Moorabbin GMA	All formations below surface	LTA ft04	1,282	N/a	N/a	256	2,700 (211)	1,096 (86)	Low	High	High	High-High
	UA between Melbourne and Geelong	N/a	UTAF ft08	1,766	802	2,600	481	N/a	N/a	N/a	N/a	N/a	N/a
	UA near Werribee	N/a	LTA ft06	9,416	6,513	12,160	1,303	N/a	N/a	N/a	N/a	N/a	N/a
	UA southeast of Geelong	N/a	LTA ft18	45,745	N/a	N/a	9,149	N/a	N/a	N/a	N/a	N/a	N/a
	Frankston GMA	All formations below surface	UTAF ft03 LTA ft03 LTBa ft04	3,215	2,469	3,960	638	3,200 (100)	230 (7)	Low	Low	Low	Low-Low
	Koo-Wee-Rup WSPA	All formations below surface	UTAF ft02 UMTA ft02 LTBa ft02, ft03 LTA ft02	10,070	8,630	12,002	3,784	12,915 (128)	3,610 (36)	Medium	Low	Medium	Low-Medium
	Corinella GMA	All formations below surface	UTAF ft01 UMTA ft01 LTA ft01	2,220	N/a	N/a	854	2,550 (115)	60 (3)	Low	Medium	Low	Medium-Low
	UA north of Bonbeach	N/a	UTAF ft04	374	N/a	N/a	225	N/a	N/a	N/a	N/a	N/a	N/a
	UA near Hastings	N/a	UMTA ft03	4,776	4,568	4,984	1,142	N/a	N/a	N/a	N/a	N/a	N/a
Gippsland	Moe GMA	All formations below 25 m from surface	UMTA ft05 LTBa ft05 LTA ft10	14,940	10,017	19,862	4,473	8,200 (55)	826 (6)	Low	Low	Low	Low-Low
	Sale WSPA	All formations from 25 to 200 m	UTAF ft07	19,267	12,282	25,665	4,422	21,238 (110)	11,029 (57)	Low	Low	Medium	Low-Medium
	Rosedale GMA	Zone 1 - all formations from 50 to 150 m below surface Zone 2 - all formations from 25 to 350 m below surface Zone 3 - all formations from 200 to 300 m below surface	UMTA ft06	98,333	N/a	N/a	40,972	22,372 (23)	8,828 (9)	Low	High	Medium	High-Medium

GMB	GMU or UA	PCV Order depth	Confined VAF layer and flow-tube no.	Predevelopment throughflow (ML/y) of flow-tube(s)				PCV (ML/y) (and as a proportion (%) of PD average (P50 K) throughflow)	Average licensed usage (ML/y) (and as a proportion (%) of PD average (P50 K) throughflow)	Relative reliability ranking	Relative uncertainty ranking	Relative potential for adverse impact on aquifer value(s) ranking	Overall GMU ranking
				Average (P50 K)	Lower range (P50 K)	Upper range (P50 K)	Lower range minimum (P 20 K)						
	Stratford GMA ⁽²⁾	Zone 1 – all formations below 150 m from the surface Zone 2 - all formations below 350 m from the surface	LMTA ft06 LTA ft08	36,873	22,082	50,588	631	27,686 (75)	22,625 (61)	Low	Medium	High	Medium-High
	UA west of Marlo	N/a	LTA ft09	499	444	554	30	N/a	N/a	N/a	N/a	N/a	N/a
	Giffard GMA	All formations from 50 to 200 m below surface	UTAF ft06	8,347	N/a	N/a	3,005	5,689 (68)	2,475 (30)	Low	High	Low	High-Low
	Yarram WSPA	Zone 1 – all formations below 200 m Zone 2 – all formations below surface	UTAF (Zone 2 only) ft05 UMTA (Zone 2 only) ft04 LMTA ft01 LTA ft07	54,646	42,651	68,398	5,691	25,690 (47)	11,482 (21)	Low	Medium	Low	Medium-Low

Notes:

Shaded cell indicates the GMU contains one or more flow-tube(s) that includes a significant UA (of multiple cells) either upgradient or downgradient of the GMU. The throughflow results for these GMUs should therefore be considered in the context of the whole flow system. This will have implications for equitable sharing of the groundwater resources between the GMUs, unincorporated areas, and in the case of cross-border flows, South Australia.

(1) The WSPA incorporates all depths below the surface with the exception of all formations from the surface to 25 metres below the surface north of the Waranga West Channel.

(2) Based on the GMU depth criteria ranges, the confined LMTA is allocated to the Stratford GMA.

(3) The West Wimmera GMA PCV Order 2013 is defined by stratigraphic units and includes the Pliocene Sands Aquifer, Tertiary Limestone Aquifer, and Tertiary Confined Sand Aquifer.

(4) The Paaratte GMA PCV Order 2018 is defined by the upper and lower contour surfaces of the geological formation as described by Plan No. LEGL./18-090, lodged in the Central Plan Office of DEECA.

(5) The Jan Jac GMA is defined by stratigraphic units and includes the Upper Eastern View Formation Aquifer and the Lower Eastern View Formation Aquifer. Zone 1 includes all formations below the surface. Zone 2 is managed by formation and includes (i) all formations below the surface other than the Lower and Upper Eastern View Formation, (ii) Upper Eastern View Formation and (iii) Lower Eastern View Formation.

15. Conclusions

As part of the **Phase A** study, an ArcGIS semi-automated tool for calculating predevelopment throughflows of confined aquifers (based on Darcy's equation), and including uncertainty, was developed and trialled in five Pilot areas, on a VAF layer basis. In **Phase B** (the subject of this report), the tool was enhanced and rolled-out to the confined aquifer systems across Victoria. Ultimately, the throughflow outputs generated in this State-wide study will assist DEECA in reviewing sustainable yields for these confined systems.

The **Phase B** study area included the following confined VAF layers within 17 GMAs and 7 WSPAs:

- UTAM.
- UTAF.
- UMTA.
- LMTA.
- LTB.
- LTA.

Areas of confined VAF layers not occupied by a GMU (i.e., within UAs), were also included in the study area.

The **Phase B** roll-out consisted of the following steps:

- Collation of VAF layer based GIS data including top and bottom elevations (to inform the parameter 'b') and modelled predevelopment (or as near to as was available) confined aquifer potentiometric surfaces (to inform the hydraulic gradient parameter 'H_L/L').
- Collation of hydrogeological information of GMUs to enable the interrogation and contextualisation of predevelopment throughflow outputs.
- Collation and interrogation of horizontal conductivity (K) data for each VAF layer at the GMB scale.
- Calculation of predevelopment throughflows (including uncertainty) across the State-wide study area at the following scales:
 - Gridded (5×5 km): using the ArcGIS tool developed in **Phase A**.
 - Flow-tube: based on the development of an ArcGIS Pro tool with the additional capability of automating cross-sectional throughflow calculations at this scale.
- Interrogation of throughflow outputs at the flow-tube scale, and GMU scale, in the context of management arrangements and licensed usage.
- Assignment of the overall ranking of GMUs based on the criteria of relative reliability and uncertainty of the throughflow outputs, and according to the licensed usage, the relative potential for adverse impact on aquifer value(s). The overall rankings can be used by DEECA for decision making purposes in their review of sustainable yields for these confined systems across the State.

The following outputs were generated in **Phase B** and documented in this report:

- Predevelopment or early development throughflow outputs (**average, lower and upper range (P50 K) and lower range minimum (P20 K)**) at the flow-tube and GMU scale, including uncertainty, and in the context of the GMU's PCV and average minimum and maximum licensed usage.
- For GMUs, observations concerning the predevelopment throughflows in the context of management arrangements and usage, their spatial variability, and considerations for assigning a sustainable yield.
- For GMUs, rankings of the relative reliability and uncertainty of the throughflow outputs, and relative potential for adverse impact on aquifer value(s), including an overall ranking.

These outputs should be considered in the context of the study's assumptions, approximations, limitations and exclusions that are listed in this report.

Additionally, the following digital outputs were generated in **Phase B** and provided to DEECA:

- Spatial datasets (as shapefiles):
 - Modelled predevelopment confined aquifer (VAF layer) potentiometric surfaces.
 - Gridded cells that represented the flow-tubes and cross-sections assigned in each VAF layer.
- ArcGIS Pro throughflow calculation tool which allows a project team member (in the Jacobs IT environment) to:

Confined Aquifer Throughflow Assessment – Updated Method and Phase B State-wide Rollout

- Inspect individual cells for input and output data of the throughflow calculation including average RWL, H_L/L and b, TDS, default and adopted K and gridded predevelopment throughflows.
- Create flow-tubes, assign K data and calculate gridded and flow-tube scale predevelopment throughflows.
- Excel files consisting of predevelopment throughflow outputs (and raw data generated in the ArcGIS Pro tool) at the flow-tube and GMU scale, including uncertainty, and in the context of the GMU's PCV and minimum, average and maximum licensed usage values.

The **Phase B** throughflow outputs are summarised for the GMUs in the study area in Table 15-1, in the context of their overall ranking. This information can be used by DEECA for decision making purposes in their review of sustainable yields for these confined systems across the State. As indicated in this report, a practical approach would be to first reduce uncertainty in the throughflow outputs using desktop approaches. Following any updates to the throughflow estimates, and corresponding impact assessment, investment in additional monitoring and assessment can be considered.

Table 15-1 Overall GMU rankings

		Ranking of the relative potential for adverse impact on aquifer value(s) (based on average licenced usage)			
		Low	Medium	High	Very High
Ranking of relative uncertainty of throughflow estimates	Low	Katunga WSPA Glenelg WSPA ⁽¹⁾ Paaratte GMA Gerangamete GMA Cut Paw Paw GMA Frankston GMA Moe GMA	Sale WSPA Koo-Wee-Rup WSPA*	Mid-Loddon GMA	Lower Campaspe Valley WSPA
	Medium	Portland GMA Corinella GMA Yarram WSPA Condah WSPA*	-	Stratford GMA Murrayville GMA*	West Wimmera GMA
	High	Newlingrook GMA Gellibrand GMA Jan Juc GMA Giffard GMA	Rosedale GMA	Moorabbin GMA	-

Notes:

GMUs identified with * are inferred to have a comparatively higher reliability (i.e., medium reliability ranking) than the GMUs in the same cells (i.e., low reliability ranking).

(1) The Glenelg WSPA was abolished in September 2022.

16. References

- Aquade. (2011). *Groundwater - Surface water interaction in the Lower Campaspe Valley WSPA*. Unpublished report held by Goulburn- Murray Water, Tatura, Victoria. Reference DM 3310320.
- Aquaterra. (2010). *Mallee CMA Groundwater Model (EM3) – Transient Calibration Development Report Development Report*. Report prepared for DSE.
- Barwon Water. (2019). *Gerangamete Groundwater Management Area 2018-2019 Report*.
- 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.
- Bush, A.L. (2009). *Physical and chemical hydrogeology of the Otway Basin, southeast Australia* (Doctoral dissertation, University of Melbourne, School of Earth Sciences).
- Cartwright & Weaver. (2005). *Hydrogeochemistry of the Goulburn Valley region of the Murray Basin*.
- CDM Smith. (2018). *Data Mapping – Aquifer Properties & Recharge*. Report prepared for DELWP, September 2018.
- CDM Smith. (2022). *Revision of Groundwater Salinity and Yield Mapping for Victoria 2022*. Prepared for DELWP, 7 September 2022.
- DEECA. (2023). *VWA_GMU-data.xls*. Provided by DEECA. 16 June 2023.
- DELWP. (2016). *Aquifer Properties - Deliverable 2 - Report on FY 2015-2016 Research Activities*.
- DELWP. (2017). *Victorian Water Accounts 2016 – 2017*.
- DELWP. (2020a). *Guidelines for Assessing the Impact of Climate Change on Water Availability in Victoria*. November 2020.
- DELWP. (2020b). *Southern Victoria Long Term Water Resource Assessment, Overview Report*. Final, 2020.
- DELWP. (2021). *Victorian Water Accounts 2019-2020*.
- DELWP. (2022a). *Methodology – Review of Groundwater Sustainable Yields*. Groundwater Assessment and Modelling, Water Resources Strategy Division, Water and Catchments. Internal Report – Draft, April 2022.
- DELWP. (2022b). *Sustainable Yields Project – Salinity Category for SY Assessment outside GMU*. Draft guidance paper.
- DEPI. (2014). *DEPI Northern Victoria Groundwater Model Conceptualisation and Calibration*.
- DJPR. (2021). *HydroSight Study: Estimation of Aquifer Properties and Recharge in Thirteen Selected Groundwater Management Areas*. Draft report.
- DSE. (2012). *Lower Campaspe Valley Water Supply Protection Area, Groundwater Management Plan*.
- DWLBC. (2000). *Mallee Region Groundwater Modelling Report No. 1*.
- DWLBC. (2006). *Mallee PWA – Murrayville WSPA Groundwater Model*.
- EarthEon. (2015). *Hydrogeological Assessment*.
- EarthEon. (2018). *Hydrogeological Assessment, 490 Westernport Road, Lang Lang, Victoria*.
- EarthEon. (2020). *Hydrogeological Assessment, 815 Westernport Rd, Lang Lang*.
- EarthEon. (2021). *Western Port Basin Conceptual Hydrogeological Model*. Report prepared for SRW.

EAS. (2010). *Hydrogeology and Groundwater Salinity Report, Drilling Program, Calperum Station, South Australia*. A report prepared by E.A. Systems Pty Limited for Bureau of Rural Sciences. Report Number 22636.38458.

FedUni. (2015). "Visualising Victoria's Groundwater." (internet data portal). Centre for eResearch and Digital Innovation, Federation University Australia, Mt Helen, Ballarat, Victoria. Retrieved 18 July 2022, from: <https://www.vvg.org.au>.

GHD. (2006). *Report for Newlingrook GMA, Review of Groundwater Resources*.

GHD. (2010a). *Port Phillip CMA Groundwater Flow Modelling Report*. Report prepared for DSE.

GHD. (2010b). *West Gippsland CMA Groundwater Model. Interim steady-state model development report*. Report prepared for DSE.

GHD. (2011). *Report for Anglesea Borefield Project, Hydrogeological Assessment*.

GHD. (2012). *Report on the Development on State-wide 3D Aquifer Surfaces*. Report prepared for the Department of Sustainability & Environment, May 2012.

GHD. (2013). *Applicant: Technical Hydrogeological Assessment to Support Groundwater License*.

GHD. (2018). *Groundwater Condition Reporting – Stage 4*.

GHD. (2019). *Jan Juc GMA Groundwater Resource Appraisal*.

GHD. (2020a). *Collation of information for sustainable yield review Volume 1: Central Region*. Report prepared for DELWP, July 2020.

GHD. (2020b). *Collation of information for sustainable yield review Volume 2: Wimmera-Mallee Region*. Report prepared for DELWP, July 2020.

GHD. (2020c). *Collation of information for sustainable yield review Volume 3: Goulburn-Murray Groundwater Region*. Report prepared for DELWP, July 2020.

GHD. (2020d). *Collation of information for sustainable yield review Volume 4: Otway-Torquay Groundwater Region*. Report prepared for DELWP, July 2020.

GMW Water. (2017). *Groundwater Management Plan for the Katunga Water Supply Protection Area*. August 2017.

GWM Water. (2017). *Murrayville Groundwater Management Area Local Management Plan*. July 2017.

GWM Water. (2019). *West Wimmera Groundwater Management Area Local Management Plan*. 2019.

Hocking et al. (2010a). *North Central CMA Groundwater Model. Transient model development report*.

Hocking et al. (2010b). *Wimmera CMA Groundwater Model. Transient model development report*.

Hocking et al. (2010c). *Goulburn Broken CMA Groundwater Model. Transient model development report*.

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

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

Jacobs. (2015). *Gippsland Region Assessment of Potential Impacts on Water Resources*. Prepared for DELWP in collaboration with the Geological Survey of Victoria.

Jacobs. (2019). *Review of Groundwater Permissible Consumptive Volume (PCV) in Gippsland Region*. Report prepared for DELWP, July 2019.

Jacobs. (2020). *Groundwater Assessment Guidelines - Groundwater Assessment Framework*. Report prepared for DELWP, October 2020.

Jacobs (2022). *Technical Assessment of State-wide Groundwater Sustainable Yields Project – Confined Aquifers Throughflow Assessment – Phase A Pilot Study*. 30 August 2022.

Lahey. (1980a). *Effects of channel deepening*.

Lahey. (1980b). *Unpublished*.

Leonard, J. G., Lahey, R. & Blake, R. (1983). *Hydrogeological investigation and assessment, Barwon Downs Graben, Otway Basin, Victoria*. Department of Minerals & Energy, Victoria GSV UR 1983/054.

Leonard, J. G. (1992). *Port Phillip Region Groundwater Resources – Future Use and Management*. Department of Water Resources, Victoria.

Leonard. (2006). Hydrogeology of the Melbourne Area, *Australian Geomechanics* Vol. 41, No. 3, September 2006.

Macumber, P. (1974). *Groundwater Survey - Calivil Pump Test*. Geological Survey Unpublished Report 1974/53.

Macumber. P. (2007). *Groundwater occurrence and process in the Mid-Loddon WSPA*. Prepared for Goulburn-Murray Water. June 2007.

NGC. (2004). Knowledge gaps for groundwater reform. In: *Proceedings from Workshop 12–13 November 2003*. Canberra, Australia.

Nolan-ITU. (2001). *Campaspe Deep Lead GSPA Groundwater Model*.
[https://www.vgls.vic.gov.au/client/en_AU/VGLS-public/search/detailnonmodal/ent:\\$002f\\$002fSD_ILS\\$002f0\\$002fSD_ILS:160752/one?qu=Groundwater+flow+--+Victoria+--+Campaspe+Region+--+Computer+simulation.&ic=true&ps=300&h=0](https://www.vgls.vic.gov.au/client/en_AU/VGLS-public/search/detailnonmodal/ent:$002f$002fSD_ILS$002f0$002fSD_ILS:160752/one?qu=Groundwater+flow+--+Victoria+--+Campaspe+Region+--+Computer+simulation.&ic=true&ps=300&h=0)

Nolan ITU. (2002). *Condah WSPA Technical Assessment (Part 1)*.

Nolan-ITU. (2003). *Campaspe Valley and Huntly Plain Conceptual Groundwater Model*.

PB. (2010). *Groundwater Resource Appraisal for Southeast Melbourne*.

Prathapar, Lawson and Enever. (1997). *Hydrogeology of the Coleambally Irrigation Area: A Brief Description for Use with a Groundwater Simulation Model*. CSIRO Technical Report 3/97.

Robinson M., et al. (1992). *Ouyen Hydrogeological Map (1:250 000 scale)*. Victorian Rural Water Corporation 1992. Bureau of Mineral Resources, Geology and Geophysics, Canberra, Australia

SKM. (1998a). *Corinella GMA PAV*.

SKM. (1998b). *Cut Paw Paw PAV*.

SKM. (1998c). *Frankston GMA PAV*.

SKM. (1998d). *Permissible Annual Volume Project - the Lang Lang GMA*. Prepared for the Department of Natural Resources and Environment Victoria.

SKM. (1998e). *The Permissible Annual Volume Project – The Leongatha GMA*. Prepared for the Department of Natural Resources and Environment, Victoria.

SKM. (1998f). *The Permissible Annual Volume Project – The Sale GMA*, Department of Natural Resources and Environment, Victoria, 1998.

SKM. (1998g). *Murrayville PAV*.

SKM. (1998h). *Paaratte PAV Project*.

SKM. (1998i). *Gerangamete PAV Project*.

SKM. (1998j). *Condah PAV Project*.

SKM. (1998k). *Portland PAV Project*.

SKM. (1998l). *Newlingbrook PAV Project*.

SKM. (1998m). *Gellibrand PAV Project*.

SKM. (2005). *Gymbowen PAV Project*.

SKM. (2007). *Condah WSPA*.

SKM. (2008). *Sale Groundwater Management Area – Groundwater Resource Appraisal*. Report prepared for Southern Rural Water.

SKM. (2009a). *Application to extract Groundwater for Urban Supply, Hydrogeological Assessment*.

SKM. (2009b). *Glenelg Hopkins CMA Groundwater Model Report, Final model development report*.

SKM. (2010a). *Glenelg Hopkins Groundwater Model Development*. Report prepared for Victorian Government Department of Sustainability and Environment (DSE), May 2010.

SKM. (2010b). *Groundwater Entitlement Volume Methods – Literature Review and Evaluation*. December 2010.

SKM. (2010c). *MDBSY Groundwater Modelling Report – Southern Riverine Plains*.

SKM. (2010d). *LTA Groundwater Resource Appraisal*.

SKM. (2011). *SA-Vic Border Zone Groundwater Investigation*.

SKM & GHD. (2009). *Hydrogeological Mapping of Southern Victoria*. Prepared for Southern Rural Water.

SRW. (2010). *Groundwater Management Plan – Koo Wee Rup Water Supply Protection Area*.

SRW. (2021). *Catchment Statement for Central Gippsland and Moe Groundwater Catchments*. Version 4. May 2021.

Thompson, B. R. (1974). *The geology and hydrogeology of the Western Port Sunlands*. Geological Survey of Victoria Report.

Tickell & Humphrys. (1986). *Groundwater resources and associated problems of the Victorian part of the Riverine Plain*. Geological Survey Report No.84.

Yates, G., Doody, T., Pritchard, J., Walker, K., Karim, F., Carey, H., Wallace, L., Galinec, V. and Sundaram, B. (2015). *Context statement for the Gippsland Basin bioregion. Product 1.1 from the Gippsland Basin Bioregional Assessment*. Department of the Environment, Bureau of Meteorology, CSIRO and Geoscience Australia, Australia.

Appendix A. User guide - ArcGIS Pro throughflow tool

Introduction

This user guide explains how to access and operate the Groundwater Throughflow Tool developed by Jacobs. This document was first published on 19/4/2023 and was updated on 8/6/2023.

Groundwater Throughflow Tool

The Groundwater Throughflow Tool utilises ArcGIS Pro desktop software, Python scripts, an ArcGIS toolbox and an ArcGIS file geodatabase to manipulate and create GIS data. The tool allows a user to calculate groundwater throughflow rates for 5 km × 5 km grids for six confined aquifers across Victoria. The tool allows a user to select grids to create “Flow Tubes” and then within these flow tubes create “Cross-Sections”. When the flow tubes are selected, a user can provide an updated hydraulic conductivity (K) value and recalculate throughflow based on these updated values. The new flow tube grids are then exported to a new dataset where a user can create cross-sections and then export them to an Excel spreadsheet for further analysis.

Terms and acronyms used in tool:

- GW: groundwater.
- “Groundwater throughflow” and “groundwater flux” are used interchangeably.

Getting started

Download the “GW Flux Tool” to a local or network drive location. The new location for the tool should be considered carefully. Once the tool is installed, it should not be moved. The tool and its associated files and folders will take up about 50 MB of disk space.

Python scripts

For the tool to work correctly, the path of the data needs to be hard coded into the Python scripts. To do this, open the Python scripts provided (see Scripts folder) in a code editor (e.g., Microsoft Visual Studio) and replace the file paths with the updated file path of the file geodatabase.

There are two Python files that need to be updated: CreateFlowTube.py and ExportCrossSection.py.

On line 3 of each script, replace the following code:

- Old code:

```
arcpy.env.workspace = r"J:\IE\Projects\03_Southern\IA270700\Spatial\Working\ArcPro\GW Flux Tool - DELWP Package\GW Flux Tool\Data\IA270700_GW_data.gdb"
```

- New code:

```
arcpy.env.workspace = r"*new path on DELWP network*\GW Flux Tool\Data\IA270700_GW_data.gdb"
```

Make sure you save both scripts before closing.

Directory structure

There are several directories housing various information used by the tool. Please make yourself familiar with this directory structure. There is no need to delete or move information within this structure. In doing so, it could affect operation of the tool.

-  .backups
-  Data
-  Exports
-  Index
-  Scripts
-  Toolbox
-  User Guide
-  GW Flux Tool - DELWP Package.aprx

ArcGIS Pro

Users will require access to ArcGIS Pro to be able to use the “GW Flux Tool”. Please ensure you are using version 2.9 to run the tool. A “Basic” ArcGIS Pro licence is all that is required to run the tool.

ArcGIS Pro settings

Please ensure that geoprocessing tools are allowed to overwrite existing datasets. This setting can be modified in Project > Options > Geoprocessing:

Set options for running geoprocessing tools and scripts

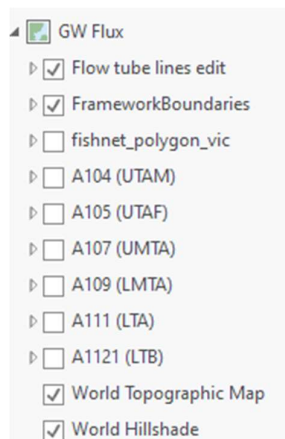
Allow geoprocessing tools to overwrite existing datasets

Groundwater Tools toolbox

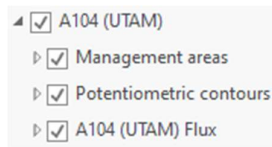
The tools are available in the Groundwater Tools.atbx file in the Toolbox directory. Please ensure that this toolbox is available under the Toolboxes section of your Catalog in ArcGIS Pro. If it is not, you can re-add the toolbox by right-clicking Toolboxes, clicking Add Toolbox and navigating to the Groundwater Tools.atbx file to add it.

Using the Tool

To access the tool, open the “GW Flux Tool” ArcGIS Pro document. You will see a range of layers in the Table of Contents on the left-hand side of the screen. Most of these layers are reference layers only, available to aid a user when selecting Flow Tube and Cross-Section grids. There is one layer called “Flow tube lines edit”, this is designed for a user to create Flow Tube lines to assist with decision making when selecting Flow Tube grids. For more information on creating Flow tube lines and editing data, refer Appendix A: Editing data.



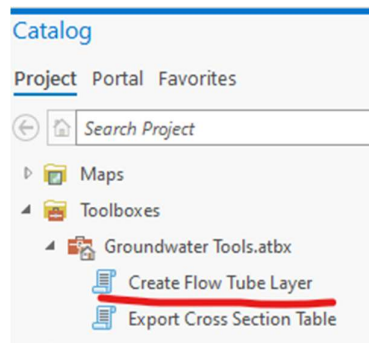
The reference data for each aquifer is stored within a group layer with the aquifer name. For example, all reference data associated with A104 (UTAM) is stored under a group layer of this name. If you expand the group layer by clicking on the triangle to the left of the layer name you will see the data that is held within.



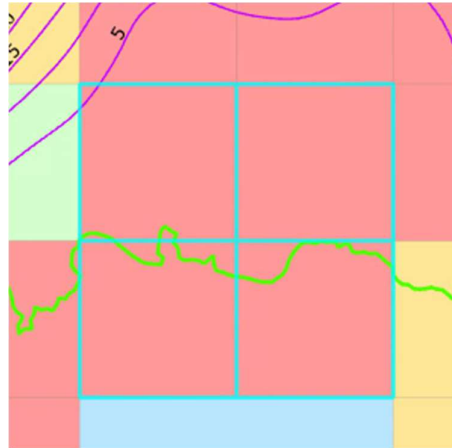
- The Management areas layers display any administrative boundaries relevant to that aquifer
- The Potentiometric contours layers display any potentiometric contours relevant to that aquifer
- The “Flux” layer contains the 5 km × 5 km grids which cover the aquifer. This is the layer that will be used as inputs to the “GW Flux Tool”.

Create Flow Tube Layer

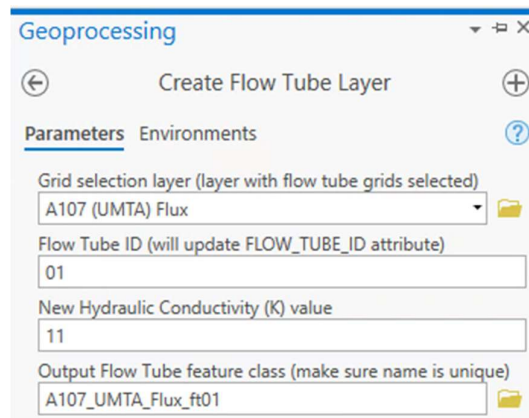
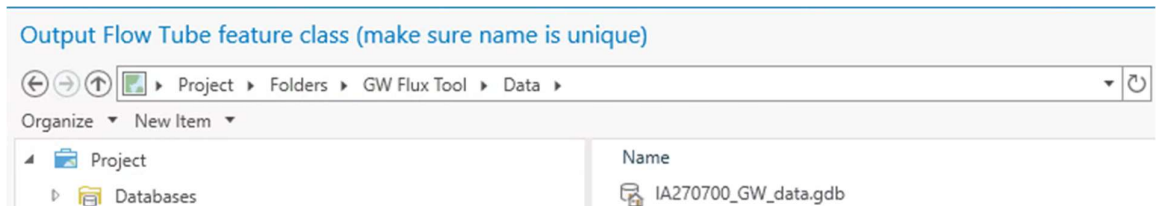
In the Catalog Pane, expand Toolboxes and Groundwater Tools.atbx and double-click on “Create Flow Tube Layer”. (To open the Catalog Pane, go to the View tab on the ribbon and select Catalog Pane.)



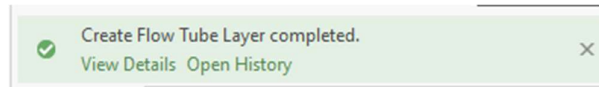
1. Isolate an aquifer group layer by turning it on in the Table of Contents (ToC). For this example, we will use the A107 (UMTA) Flux layer.
2. Zoom to an area of interest by using the mouse wheel or, with the Explore tool selected, holding down the Shift key and the left mouse button to draw a box to zoom to.
3. Select grids that will make up the new Flow Tube layer. Several zoom tools are available under the Map > Selection > Select toolbar on the ribbon, including Rectangle, Line and Polygon select. A Polygon select will allow you to select abstract shapes while the Rectangle tool will allow you to select/deselect single grids (as well as a rectangle). Within each aquifer, flow tubes should not overlap. Each grid cell can only be in one flow tube. To fine tune the flow tube geometry, hold down the shift key and left mouse button to ADD a grid cell to a flow tube, and hold down the control key and left mouse button to REMOVE a grid cell to a flow tube.



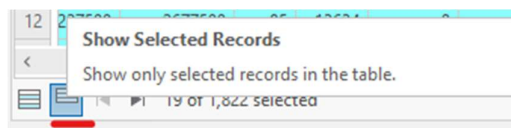
4. Once the Flow Tube grids are selected, go over to the Create Flow Tube Layer tool you opened earlier.
 - a. In the Grid selection layer, drag the layer from the ToC or use the drop-down to select the layer with the grid selection.
 - b. Provide the tool with a Flow Tube ID for the grids selected. This will update the Flow Tube ID attribute within the GIS data.
 - c. Provide a new Hydraulic Conductivity (K) value to be used in the new throughflow calculation.
 - d. Select the File Geodatabase output location and create a new and unique output dataset name for the new Flow Tube Layer. You can use the existing Geodatabase in the Data directory or create a new one if you choose. You can also choose to overwrite an existing dataset if you choose, just don't make sure you overwrite one of the reference layers in your map!



5. When ready, click the "Run" button at the bottom right. Depending on a few variables, the tool could take 1–2 minutes to run. Please note: Do not have the Grid selection layer attribute table open when running the tool, as this will cause the tool to fail.
6. Once the tool has successfully run you will get a message and the new layer will be automatically added to your map



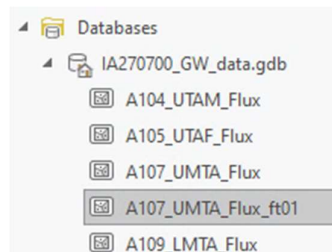
7. To check your K value and throughflow rate has been calculated correctly, you can open the Attribute Table of either the newly created layer, or the source layer. To do this, right-click on the layer in the ToC and select Attribute Table. To filter on selected records only, select the button at the bottom left of the attribute table.



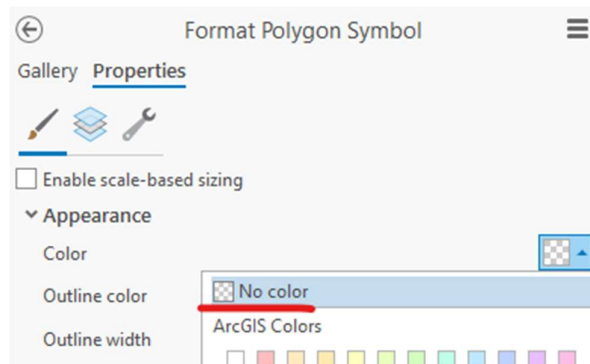
The updated K value will be in the "K_PX" field and the updated throughflow rate will be in the "DARCY_PX" field. The Flow Tube ID you entered will be in the "FLOW_TUBE_ID" field.

Export Cross-Section Table

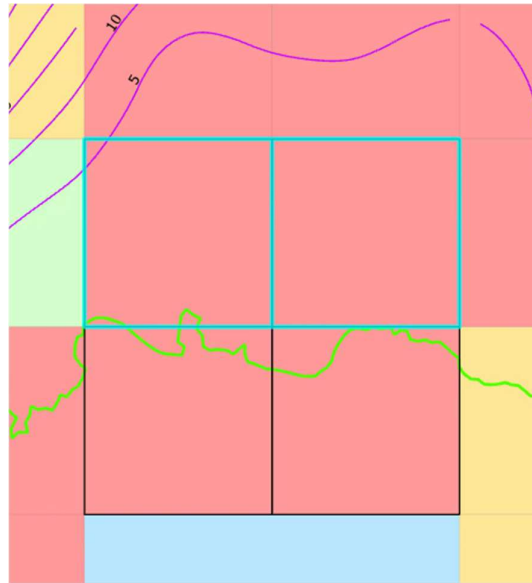
1. Add your newly created Flow Tube Layer to the map. The layer can be found in the File Geodatabase where you saved your dataset in the previous step. The Geodatabase can be accessed in the Databases folder of the Catalog pane. The layer can simply be dragged into your map from this location.



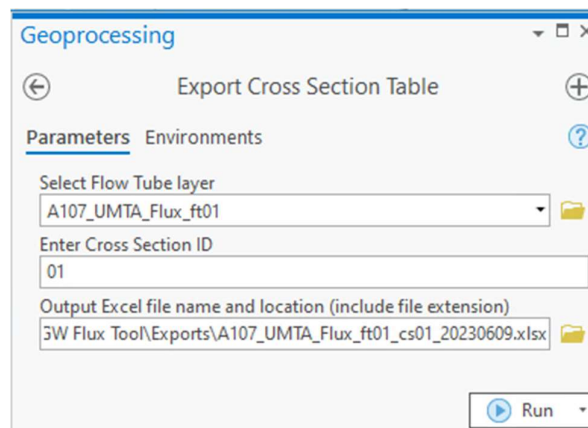
2. In the Toolboxes > Groundwater Tools.atbx, double-click the "Export Cross Section Table" tool.
3. If you need to adjust the fill symbology of the grids so you can see through them, click on the symbol in the ToC and remove the fill in the Symbology properties dialogue that appears.



4. You will need to make a selection on the new Flow Tube Layer to run this tool. This time the selection will be a Cross-Section. A Cross-Section will be more linear in nature, would be approximately parallel to a potentiometric contour, and could look something like the below:



5. Populate the Export Cross-Section Table tool parameters as follows:
 - a. Select the Flow Tube Layer with the Cross-Section selection made.
 - b. Choose a unique Cross-Section ID (this will be updated in the attributes).
 - c. Select a location and name for the output Excel file (provide the file extension). An Export folder in the file directory has been provided for exports of this nature. If you get an error message, please make sure you remove the asterisk at the end of the file path before you run this tool.



6. Once ready, hit the Run button at the bottom right. The tool should take approximately 1 minute to run. Again, please ensure that the attribute table is not open as this will affect the operation of the tool.
7. Once the tool is completed, you will get a successful message. Go to the output location of the Excel file to check the file is there and is complete. Your selected grids should be present and the "CROSS_SECTION_ID" field should be populated with the Cross-Section ID you provided.

To exit the tool, please close ArcGIS Pro. There is no need to save the document, but you can do so if you wish.

Document metadata

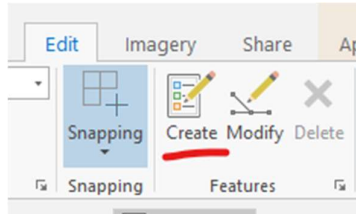
Document version: 1.0

Document last saved: 9/06/2023 10:31:00 AM

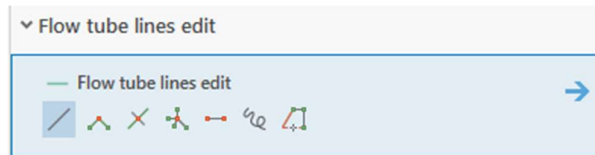
Appendix A

Editing data

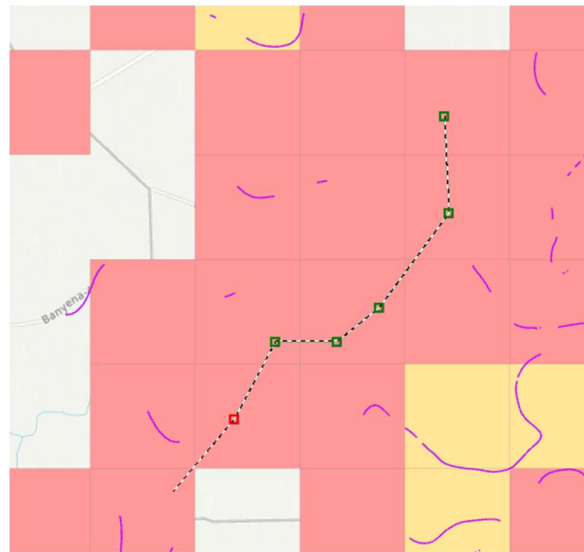
To create Flow Tube lines, select the Edit tab on the toolbar ribbon across the top of the screen. Click on the "Create" button under the Features section which will open a Create Features dialogue.



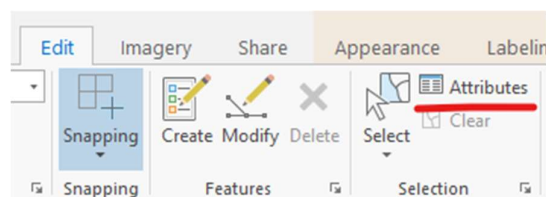
Select the layer where you want to make the edits, in this case the Flow tube lines edit layer. Some digitising tools will appear, allow you to create some features in this layer.



For example, a simple polyline tool can be selected and then a line can be created in the map by using the left mouse button to define the line's vertices. Once the line is complete, you can double-click the left mouse button to complete the line.



Once the features have been digitised, you have the option to update some attributes. Click on the Attributes button in the Selection section of the Edit toolbar.



An attributes dialogue will open allowing you to provide details such as ID, VAF, Name and Description.

<u>Attributes</u>	Geometry
OBJECTID	2
ID	1
VAF	A104
Name	Flow Tube 1
Description	Digitised Flow Tube
Shape.STLength()	72824.90748

There is no need to hit the save button, the data is automatically saved.

Appendix B. Relative rankings and prioritisation of GMUs

B.1 Relative reliability of throughflow estimates

GMB	GMU	VAF layer ⁽¹⁾	No. of K data points in VAF layer within GMB ⁽²⁾	Area of VAF within GMB (km ²)	No. of K data points/1,000 km ² of GMB	Score of areal density of K data	No. of cross-sections within flow-tube	Score of number of cross-sections within flow-tube	Combined score for areal density of K data points and number of cross-sections in flow-tube	Overall ranking of relative reliability	
Wimmera-Mallee	West Wimmera GMA	UTAM	3	10,000	0.3	1	3	2	-	-	
	West Wimmera GMA	UMTA	28	40,030	0.7	1	8	3	-	-	
	West Wimmera GMA	LTA	7	63,000	0.1	1	9	3	-	-	
	West Wimmera GMA	Combined	-	-	-	1	-	3	4	Medium	
Goulburn-Murray	Murrayville GMA	UMTA	28	40,030	0.7	1	6	3	4	Medium	
	Mid Loddon GMA	UTAF	40	20,500	2.0	1	5	3	-	-	
	Mid Loddon GMA	LTA	26	12,600	2.1	1	2	1	-	-	
	Mid Loddon GMA	Combined	-	-	-	1	-	2	3	Low	
	Lower Campaspe Valley WSPA	UTAF	40	20,500	2.0	1	2	1	-	-	
	Lower Campaspe Valley WSPA	LTA	26	12,600	2.1	1	3	2	-	-	
	Lower Campaspe Valley WSPA	Combined	-	-	-	1	-	2	3	Low	
	Katunga WSPA	UTAF	40	20,500	2.0	1	2	1	-	-	
	Katunga WSPA	LTA	26	12,600	2.1	1	3	2	-	-	
	Katunga WSPA	Combined	-	-	-	1	-	2	3	Low	
	Otway-Torquay	Glenelg WSPA (abolished)	LMTA	7	10,400	0.7	1	2	1	-	-
		Glenelg WSPA (abolished)	LTA	32	22,200	1.4	1	3	2	-	-
Glenelg WSPA (abolished)		Combined	-	-	-	1	-	2	3	Low	
Portland GMA		LTA	32	22,200	1.4	1	4	2	3	Low	
Condah WSPA		LMTA	7	10,400	0.7	1	6	3	4	Medium	
Paaratte GMA		LTA	32	22,200	1.4	1	3	2	3	Low	
Newlingrook GMA		LTA	32	22,200	1.4	1	1	1	2	Low	
Gellibrand GMA		LTA	32	22,200	1.4	1	1	1	2	Low	
Gerangamete GMA		LTA	32	22,200	1.4	1	2	1	2	Low	
Central	Jan Juc GMA	LTA	32	22,200	1.4	1	1	1	2	Low	
	Cut Paw Paw GMA	LTA	2	6,600	0.3	1	4	2	3	Low	
	Moorabbin GMA	LTA	2	6,600	0.3	1	1	1	2	Low	
	Frankston GMA	UTAF	4	6,400	0.6	1	2	1	-	-	
	Frankston GMA	LTA	2	6,600	0.3	1	2	1	-	-	
	Frankston GMA	LTBa	1	1,300	0.8	1	2	1	-	-	
	Frankston GMA	Combined	-	-	-	1	-	1	2	Low	
	Koo-Wee-Rup WSPA	UTAF	6	6,400	1	1	3	2	-	-	
	Koo-Wee-Rup WSPA	UMTA	12	1,750	7	2	2	1	-	-	
	Koo-Wee-Rup WSPA	LTBa	15	1,300	12	3	4	2	-	-	
	Koo-Wee-Rup WSPA	LTA	3	6,600	0.5	1	3	2	-	-	
	Koo-Wee-Rup WSPA	Combined	-	-	-	2	-	2	4	Medium	
	Corinella WSPA	UTAF	6	6,400	0.9	1	1	1	-	-	
Corinella WSPA	UMTA	12	1,750	6.9	2	1	1	-	-		
Corinella WSPA	LTA	3	6,600	0.5	1	1	1	-	-		

GMB	GMU	VAF layer ⁽¹⁾	No. of K data points in VAF layer within GMB ⁽²⁾	Area of VAF within GMB (km ²)	No. of K data points/1,000 km ² of GMB	Score of areal density of K data	No. of cross-sections within flow-tube	Score of number of cross-sections within flow-tube	Combined score for areal density of K data points and number of cross-sections in flow-tube	Overall ranking of relative reliability
	<i>Corinella WSPA</i>	<i>Combined</i>	-	-	-	1	-	1	2	<i>Low</i>
Gippsland	Moe GMA	UMTA	1	4,800	0.2	1	2	1	-	-
	Moe GMA	LTBa	3	1,000	3.0	1	2	1	-	-
	Moe GMA	LTA	3	9,500	0.3	1	2	1	-	-
	<i>Moe GMA</i>	<i>Combined</i>	-	-	-	1	-	1	2	<i>Low</i>
	Sale WSPA	UTAF	5	4,300	1.2	1	4	2	3	Low
	Rosedale GMA	UMTA	11	4,800	2.3	1	1	1	2	Low
	Stratford GMA	LMTA	5	3,600	1.4	1	3	2	-	-
	Stratford GMA	LTA	4	9,500	0.4	1	3	2	-	-
	<i>Stratford GMA</i>	<i>Combined</i>	-	-	-	1	-	2	3	<i>Low</i>
	Giffard GMA	UTAF	5	4,300	1.2	1	1	1	2	Low
	Yarram WSPA	UTAF	5	4,300	1.2	1	3	2	-	-
	Yarram WSPA	UMTA	6	4,800	1.3	1	3	2	-	-
	Yarram WSPA	LMTA	5	3,600	1.4	1	3	2	-	-
	Yarram WSPA	LTA	4	9,500	0.4	1	2	1	-	-
	<i>Yarram WSPA</i>	<i>Combined</i>	-	-	-	1	-	2	3	<i>Low</i>

Notes:

(1) Where multiple VAF layers occurred within a flow-tube, each VAF layer was scored separately, and an average was derived for the flow-tube.

(2) Where ranges in K values were available in the database, there were included in the summation of the number of K data points.

B.2 Relative uncertainty of throughflow estimates

GMB	GMU	VAF layer	CV %	Score of CV of flow-tube	Factor difference between P50 K and P20 K	Score of factor difference between adopted P50 K and P20 K of flow-tube	Combined scores for CV and factor difference between P50 K and P20 K	Overall relative uncertainty rating
Wimmera-Mallee	West Wimmera GMA	UTAM	-	-	4.0	2	-	-
	West Wimmera GMA	UMTA	-	-	2.8	2	-	-
	West Wimmera GMA	LTA	-	-	2	2	-	-
	<i>West Wimmera GMA</i>	<i>Combined</i>	51	2	-	2	4	<i>Medium</i>
	Murrayville GMA	UMTA	55	2	2.8	2	4	Medium
Goulburn-Murray	Mid Loddon GMA	UTAF	-	2	2.1	1	-	-
	Mid Loddon GMA	LTA	-	1	1.7	1	-	-
	<i>Mid Loddon GMA</i>	<i>Combined</i>	80	2	-	1	3	<i>Low</i>
	Lower Campaspe Valley WSPA	UTAF	-	1	2.1	2	-	-
	Lower Campaspe Valley WSPA	LTA	-	1	1.7	1	-	-
	<i>Lower Campaspe Valley WSPA</i>	<i>Combined</i>	26	1	-	1.5	2.5	<i>Low</i>
	Katunga WSPA	UTAF	-	1	2.1	2	-	-
	Katunga WSPA	LTA	-	1	1.7	1	-	-
<i>Katunga WSPA</i>	<i>Combined</i>	46	1	-	1.5	2.5	<i>Low</i>	
Otway-Torquay	Glenelg WSPA (abolished)	LMTA	-	2	2.7	2	-	-

Confined Aquifer Throughflow Assessment – Updated Method and Phase B State-wide Rollout

GMB	GMU	VAF layer	CV %	Score of CV of flow-tube	Factor difference between P50 K and P20 K	Score of factor difference between adopted P50 K and P20 K of flow-tube	Combined scores for CV and factor difference between P50 K and P20 K	Overall relative uncertainty rating
	Glenelg WSPA (abolished)	LTA	-	1	5	2	-	-
	<i>Glenelg WSPA (abolished)</i>	<i>Combined</i>	22	1	-	2	3	<i>Low</i>
	Portland GMA	LTA	51	2	5	2	4	<i>Medium</i>
	Condah WSPA	LMTA	69	2	2.7	2	4	<i>Medium</i>
	Paaratte GMA	LTA	44	1	5	2	3	<i>Low</i>
	Newlingrook GMA	LTA	-	3	5	2	5	<i>High</i>
	Gellibrand GMA	LTA	-	3	5	2	5	<i>High</i>
	Gerangamete GMA	LTA	39	1	5	2	3	<i>Low</i>
	Jan Juc GMA	LTA	-	3	5	2	5	<i>High</i>
Central	Cut Paw Paw GMA	LTA	45	1	5	2	3	<i>Low</i>
	Moorabbin GMA	LTA	-	3	5	2	5	<i>High</i>
	Frankston GMA	UTAF	42	1	1.7	1	-	-
	Frankston GMA	LTBa	-	2	1.8	1	-	-
	Frankston GMA	LTA	-	1	5	2	-	-
	<i>Frankston GMA</i>	<i>Combined</i>	33	1	-	1.3	2.3	<i>Low</i>
	Koo-Wee-Rup WSPA	UTAF	-	-	1.7	1	-	-
	Koo-Wee-Rup WSPA	UMTA	-	-	4	2	-	-
	Koo-Wee-Rup WSPA	LTBa	-	-	1.8	1	-	-
	Koo-Wee-Rup WSPA	LTA	-	-	5	2	-	-
	<i>Koo-Wee-Rup WSPA</i>	<i>Combined</i>	17	1	-	1.5	2.5	<i>Low</i>
	Corinella WSPA	UTAF	-	-	1.7	1	-	-
	Corinella WSPA	UMTA	-	-	4	2	-	-
	Corinella WSPA	LTA	-	-	5	2	-	-
<i>Corinella WSPA</i>	<i>Combined</i>	-	3	-	1.7	4.7	<i>Medium</i>	
Gippsland	Moe GMA	UMTA	-	1	4	2	-	-
	Moe GMA	LTBa	-	2	1.8	1	-	-
	Moe GMA	LTA	-	2	5	2	-	-
	<i>Moe GMA</i>	<i>Combined</i>	47	1	-	1.7	2.7	<i>Low</i>
	Sale WSPA	UTAF	29	1	2.8	2	3	<i>Low</i>
	Rosedale GMA	UMTA	-	3	2.4	2	5	<i>High</i>
	Stratford GMA	LMTA	-	1	40	3	-	-
	Stratford GMA	LTA	-	1	15	3	-	-
	<i>Stratford GMA</i>	<i>Combined</i>	39	1	-	3	4	<i>Medium</i>
	Giffard GMA	UTAF	-	3	2.8	2	5	<i>High</i>
	Yarram WSPA	UTAF	-	1	2.8	2	-	-
	Yarram WSPA	UMTA	-	2	2.4	2	-	-
	Yarram WSPA	LMTA	-	1	40	3	-	-
	Yarram WSPA	LTA	-	1	15	3	-	-
<i>Yarram WSPA</i>	<i>Combined</i>	24	1	-	2.5	4	<i>Medium</i>	

B.3 Relative potential for adverse impacts on aquifer value(s)

GMB	GMU	Average licensed usage as a proportion of average (P50 K) PD throughflow (%)	Rating of relative potential for adverse impacts on aquifer value(s)
Wimmera-Mallee	West Wimmera GMA	131	Very High
	Murrayville GMA	81	High
Goulburn-Murray	Mid Loddon GMA	99	High
	Lower Campaspe Valley WSPA	124	Very High
	Katunga WSPA	26	Low
Otway-Torquay	Glenelg WSPA (abolished)	6	Low
	Portland GMA	1	Low
	Condah WSPA	23	Low
	Paaratte GMA	<1	Low
	Newlingrook GMA	<1	Low
	Gellibrand GMA	0	Low
	Gerangamete GMA	6	Low
	Jan Juc GMA	8	Low
Central	Cut Paw Paw GMA	3	Low
	Moorabbin GMA	86	High
	Frankston GMA	7	Low
	Koo-Wee-Rup WSPA	36	Medium
	Corinella WSPA	3	Low
Gippsland	Moe GMA	6	Low
	Sale WSPA	57	Medium
	Rosedale GMA	9	Low
	Stratford GMA	61	High
	Giffard GMA	30	Low
	Yarram WSPA	21	Low

