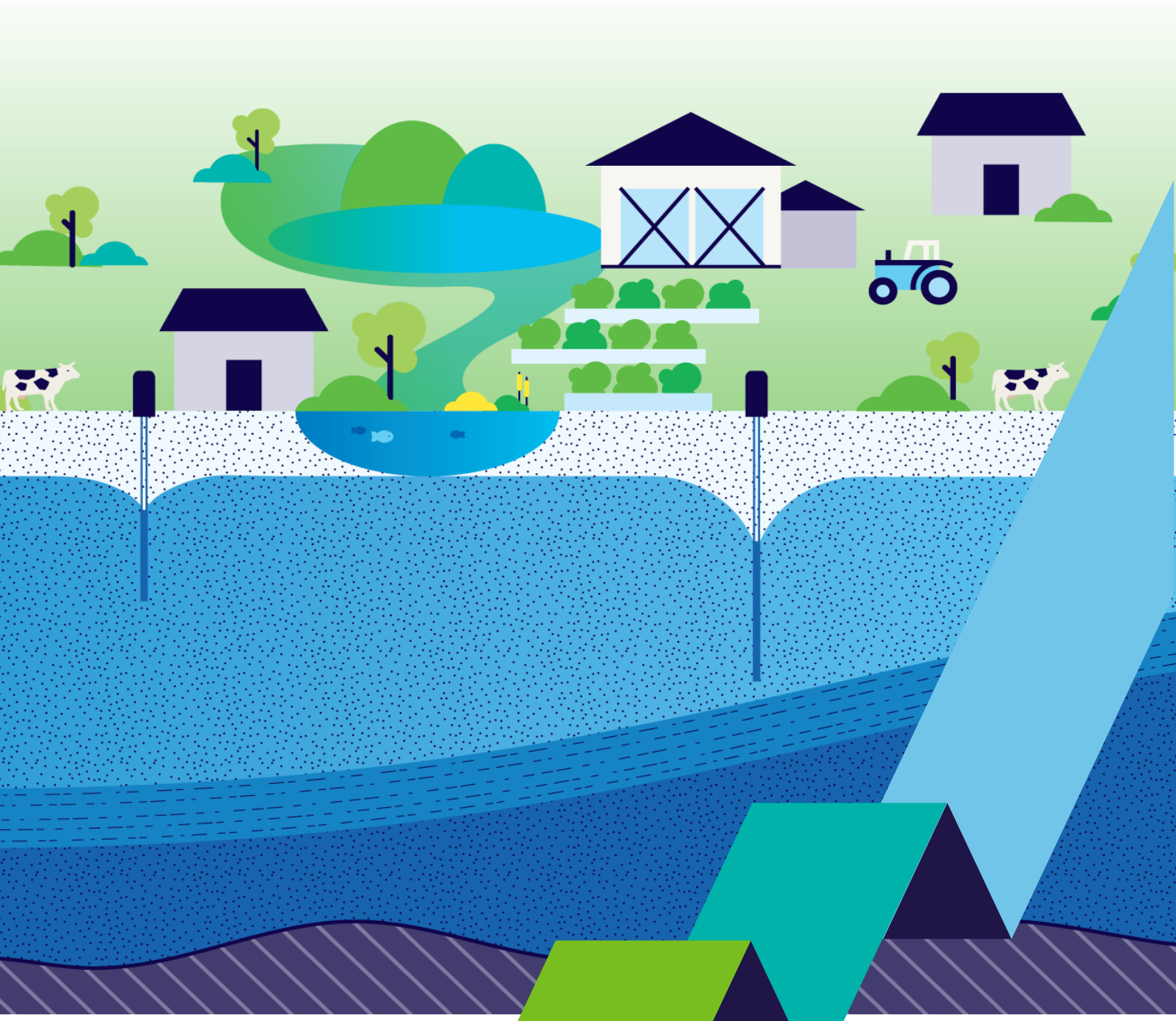
GROUNDWATER SUSTANABLE YIELD ASSESSMENT: METHODOLOGY REPORT

Part 5 Sustainable Yields Synthesis paper – Confined Aquifers Synthesis Approach (DEECA)



VICTORIA State Government | Energy, Environment and Climate Action

Acknowledgements

The Sustainable Yield Assessment for Victoria was undertaken by DEECA in collaboration with Southern Rural Water, Goulburn–Murray Water, Grampians Wimmera Mallee Water, and Lower Murray Water corporations.

A technical advisory panel provided specialist advice in the development of the assessment method. The panel comprised specialists from Deakin University (Prof. Wendy Timms), Jacobs (Dr Richard Evans) and HydroGeoLogic (Mr Hugh Middlemis).

The assessment was completed with contributions from external industry specialists, who developed the technical details of the methodology and carried out assessments of groundwater resources. These included Jacobs Pty Ltd, GHD Pty Ltd, CDM Smith Pty Ltd, HARC Pty Ltd and Monash University (Dr Tim Peterson).

Authors

Groundwater Assessment and Modelling team, Water Resources Strategy, Department of Energy, Environment and Climate Action. 8 Nicolson Street, East Melbourne 3002.

Editor

Scientel Pty Ltd, 8 Latrobe Street, Melbourne 3000

We acknowledge and respect Victorian Traditional Owners as the original custodians of Victoria's land and waters, their unique ability to care for Country and deep spiritual connection to it.

We honour Elders past and present whose knowledge and wisdom has ensured the continuation of culture and traditional practices.

DEECA is committed to genuinely partnering with Victorian Traditional Owners and Victoria's Aboriginal community to progress their aspirations.

ISBN 978-1-76176-767-8 (pdf/online/MS word)

Disclaimer

This publication may be of assistance to you but the State of Victoria and its employees do not guarantee that the publication is without flaw of any kind or is wholly appropriate for your particular purposes and therefore disclaims all liability for any error, loss or other consequence which may arise from you relying on any information in this publication.

Accessibility

To receive this document in an alternative format, phone the Customer Service Centre on 136 186, email customer.service@delwp.vic.gov.au, or contact National Relay Service on 133 677. Available at DEECA website (www.deeca.vic.gov.au), https://www.water.vic.gov.au/water-sources/groundwater/groundwater-management-2030/sustainable-yield-assessment/?a=777719.

Contents

Contents **1**

List of Figures **1**

List of Tables **1**

About this report **3**

1. Purpose **4**

2. Background **5**

3. Sustainable Yield Synthesis Approach **5**

3.1. GMU Scale 5

Step 1: Drawdown-Use Assessment 5

Step 2: Throughflow Flux Assessment 7

Step 3: Synthesised Results 9

3.2. UAs Scale 12

References **13**

List of Figures

Figure 1. Synthesis flowchart for confined and unconfined outputs 4
Figure 2. Schematic flowchart of the proposed SY synthesis approach 5
Figure 3: A general table format indicating a relationship between groundwater use and drawdown for Sale WSPA, Representative Suite M_O_1 (Part 3) 6
Figure 4: A general graph format indicating a relationship between throughflow flux and proportion of predevelopment flux for Sale WSPA (Part 2) 8
Figure 5: A visual representation of proportion of predevelopment throughflow flux-use relationship (GHD Pty Ltd, 2024) and drawdown-use relationship (GHD Pty Ltd, 2024) based on the synthesised information for the Sale WSPA, Representative Suite M_O_1 12

List of Tables

Table 1. The estimated drawdown with uncertainty bands for PCV, licensed entitlement and licensed usages for the Sale WSPA, Representative Suite M_O_1, for volumes of different uses 7
Table 2. The values of groundwater volume with uncertainty bands for DEECA sustainability metrics for the Sale WSPA, Representative Suite M_O_1 7
Table 3. The values of proportion of predevelopment flux for PCV, licensed entitlement and licensed usages for the Sale WSPA 9
Table 4 The values of proportion of predevelopment flux with uncertainty bands for the DEECA sustainability metrics (5- and 10m drawdowns) for the Sale WSPA 9
Table 5. The values of drawdown and proportion of predevelopment flux for PCV, licensed entitlement and licensed usages for the Sale WSPA, Representative Suite M_O_1 9

Table 6. The values of groundwater volume and proportion of predevelopment flux with uncertainty bands for the DEECA sustainability metrics (5- and 10m drawdowns) for the Sale WSPA, Representative Suite M_O_1 10
Table 7. The compilation of synthesised results in a consolidated format for the Sale WSPA, Representative Suite M_O_1 11
Table 8. Throughflow volume for the LTA-NW1 UA - Wimmera Mallee 12

About this report

This report outlines the technical approach and methodology of the Sustainable Yield (SY) project. The Victorian Department of Energy, Environment, and Climate Action (DEECA) developed the methodology in partnership with:

- Contractors Jacobs, GHD Pty Ltd and CDM Smith, who were responsible for developing the technical aspects of the methodology and conducting assessments of groundwater resources.
- Representatives from Southern Rural Water Corporation, Goulburn-Murray Rural Water Corporation, Grampians Wimmera Mallee Rural Water Corporation, and the DEECA Environmental Waterways and Water Licensing Policy teams, who possessed extensive experience and expertise in water and groundwater resource management and policy, and offered advice on technical, management and policy aspects of the project.
- A technical review panel, consisting of 3 subject matter experts in groundwater assessment and modelling, who provided expert peer review of the methodologies.

The methodology was developed in stages so that assessments could be undertaken in parallel with the methodology refinement. This enabled DEECA to meet the project completion date of June 2024. The methodology is described and reported in 8 parts:

- Part 1: Methodology overview
- Part 2: Confined aquifers – throughflow method (report by (Jacobs, 2024))
- Part 3: Confined aquifers – drawdown-use method (report by (GHD Pty Ltd, 2024))
- Part 4: Unconfined aquifers – recharge estimation and drawdown-use methods (report by (CDM Smith, 2025))
- Part 5: Sustainable Yield synthesis paper – confined aquifers synthesis approach (DEECA) (this report)
- Part 6: Sustainable Yield synthesis paper – semi-confined aquifers mapping approach (DEECA)
- Part 7: Sustainable Yield synthesis paper – semi-confined aquifers synthesis approach (DEECA)
- Part 8: Sustainable Yield synthesis paper – Mapping, Boundaries, and Naming Conventions for Confined Aquifer UAs (DEECA)

Part 1, the methodology overview provides context for the project by discussing its drivers, current resources and understanding, expected outcomes, objectives, outputs, scope, and principles for the proposed approach to the methodology.

Parts 2 to 8 of the methodology provide additional details of the methods. Parts 2 to 4 were developed and reported on by the contractors, and parts 5 to 8 were developed by DEECA.

This paper presents Part 5 of the Methodology Report.

1. Purpose

This document, Part 5 Sustainable Yield Synthesis – Confined aquifers, presents the approach applied to synthesise the outputs of confined aquifer assessments included in Part 2 Confined Aquifers – Throughflow Method (Jacobs, 2024) and Part 3 Confined aquifers – Drawdown/Use Method (GHD Pty Ltd, 2024).

The synthesised information will be used for sustainable yield recommendations by DEECA. A synthesis concept (shown in **Figure 1**) was presented in the Part 1 Methodology report.

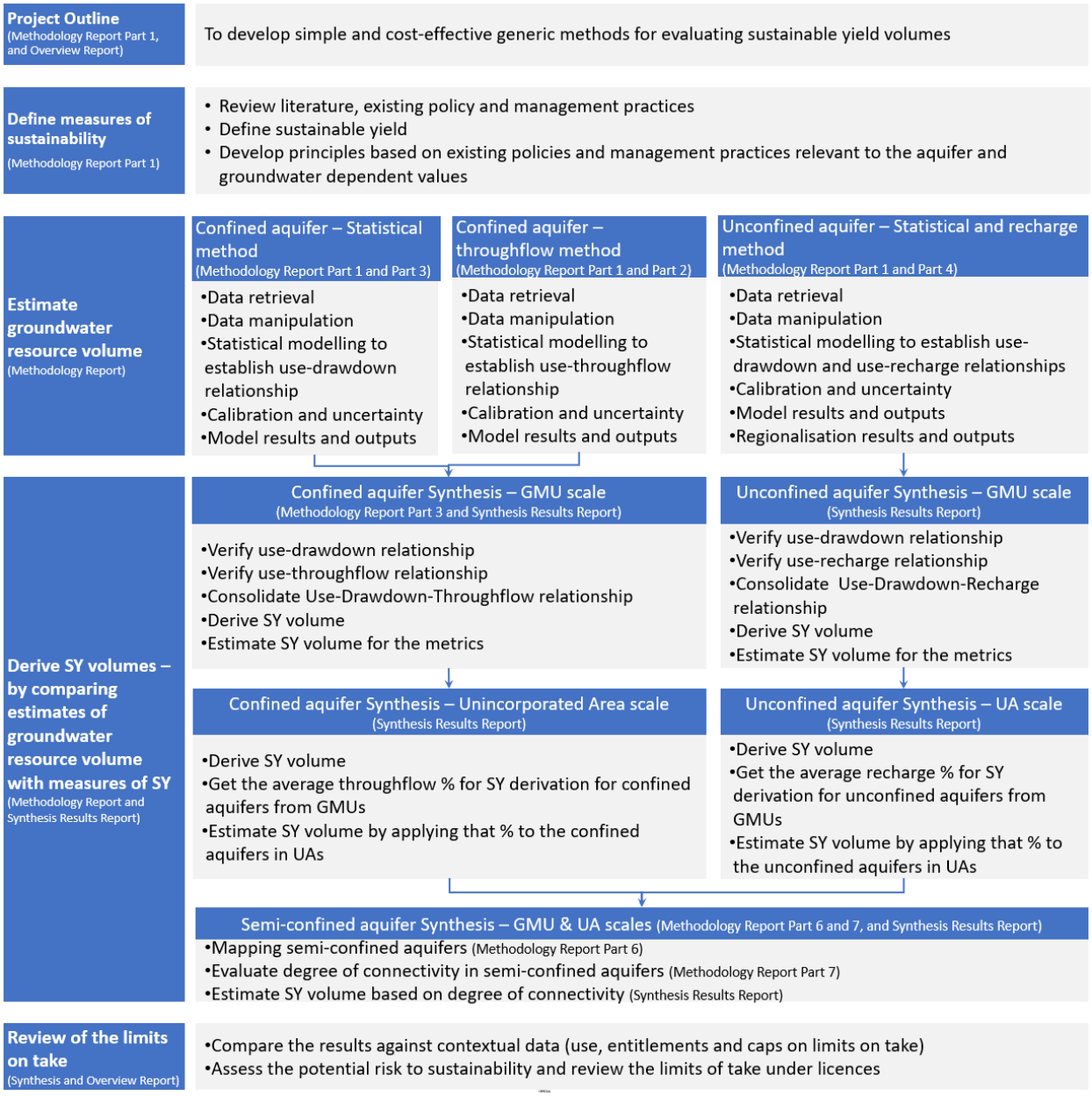


Figure 1. Synthesis flowchart for confined and unconfined outputs

2. Background

DEECA conducted assessments of confined aquifers under the SY project (Part 1) using GIS-based throughflow flux calculations (Jacobs, 2024) and Transfer Function Noise (TFN)-based use-drawdown modelling (GHD Pty Ltd, 2024) approaches. Details of these assessments can be found in Part 2 (Jacobs, 2024) and Part 3 (GHD Pty Ltd, 2024) of the DEECA SY project. The outputs of these assessments cannot directly be used to recommend sustainable volumes for a Groundwater Management Unit (GMU). An approach was investigated to synthesise the outputs from these two assessments and recommend sustainable yield volumes on GMU and Unincorporated Area (UA) scales. The following sections describe the approach and its application to the Sale Water Supply Protection Area (WSPA) and the LTA-NW3 UA - Wimmera Mallee, in the context of the case study. The synthesised results are presented in both tabulated and graphical formats.

This report is specifically designed to demonstrate the development of an approach for synthesising the Drawdown-Use and Throughflow Flux Assessments. This approach has been applied to a single GMU as an example, illustrating how the methodology integrates both assessment results. The same approach has been implemented across all confined GMUs in the state, with the results presented in the SY Synthesis Results Report.

3. Sustainable Yield Synthesis Approach

3.1. GMU Scale

Figure 2 shows a schematic flowchart of the proposed SY synthesis approach for the GMU scale. It shows a three-step approach for synthesising the outputs of throughflow flux (Part 2) and drawdown-use (Part 3) assessments for confined aquifers at the GMU scale.

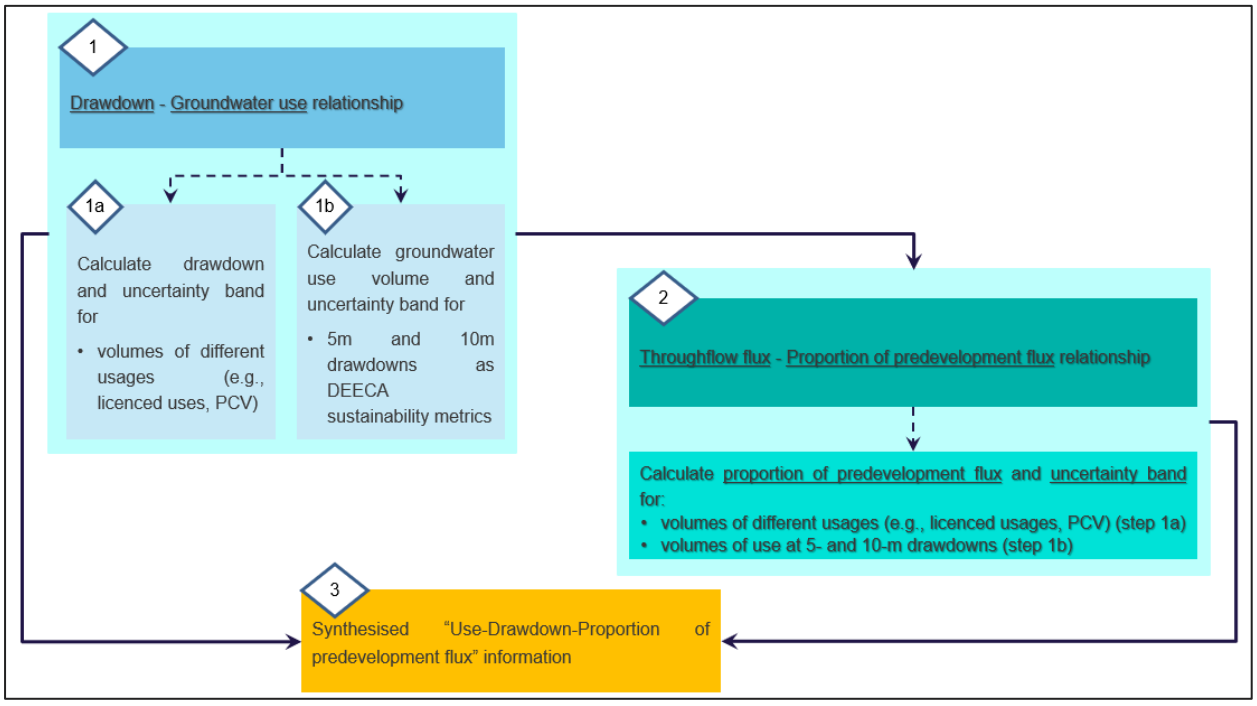


Figure 2. **Schematic flowchart of the proposed SY synthesis approach**

Step 1: Drawdown-Use Assessment

First step represents the output of drawdown-use assessment which is based on a relationship between drawdown and groundwater use. The relationship is presented with a table and a linear equation along with uncertainty bands for each GMU in this assessment. A general table format is shown in representing

groundwater drawdowns over 20 years with uncertainty bands for Sale WSPA for various groundwater uses.

Table 125 Relationship of Suite drawdown to GMU extraction for Sale WSPA Suite M_O_1

Volume (ML/year) for whole of GMU based on two yearly average annual extraction	Based on model prediction of Suite M_O_1 annual recovered levels
	Drawdown over 20 years (m) (lower limit to upper limit based on 95% prediction interval band)
30,000	22.6 (18.4 - 23.7)
28,000	21 (17 - 22.1)
26,000	19.4 (15.6 - 20.5)
24,000	17.8 (14.2 - 18.9)
22,000	16.2 (12.8 - 17.3)
20,000	14.6 (11.4 - 15.7)
18,000	13 (10 - 14.1)
16,000	11.4 (8.6 - 12.5)
14,000	9.8 (7.2 - 10.9)
12,000	8.2 (5.8 - 9.3)
10,000	6.6 (4.4 - 7.7)
8,000	5 (3 - 6.1)
6,000	3.4 (1.6 - 4.5)
4,000	1.8 (0.2 - 2.9)
2,000	0.2 (-1.2 - 1.3)
0	-1.4 (-2.6 - -0.3)

Figure 3: A general table format indicating a relationship between groundwater use and drawdown for Sale WSPA, Representative Suite M_O_1 (Part 3)

The following equations were extracted from drawdown-use assessment for Sale WSPA, representative Suite M_O_1:

$$h \propto 0.0008 \times Q - 1.4016 \quad (2)$$

$$h \propto 0.0008 \times Q - 0.2796 \quad (3)$$

$$h \propto 0.0007 \times Q - 2.6347 \quad (4)$$

where h is drawdown (m), and Q is volume (groundwater use) (ML/year). The relationship between drawdown and use is represented by equation 2 and the upper and lower uncertainty bands are represented by equations 3 and 4.

Step 1a

Step 1a in **Figure 2** involves estimating drawdowns and uncertainty bands for volumes of different uses (e.g., licensed usages, licensed entitlement, and Permissible Consumptive Volume (PCV)). Table 1 shows the estimated drawdown for these uses with lower and upper uncertainty bands based on the above equations (Equations 2-4).

Table 1. The estimated drawdown with uncertainty bands for PCV, licensed entitlement and licensed usages for the Sale WSPA, Representative Suite M_O_1, for volumes of different uses

Volume		Drawdown (m)
Type	Volume (ML/yr)	
Min licensed usage (2011-2012)	6,324	3.66 [4.78 – 1.79] *
Avg licensed usage (2004-2021)	11,029	7.42 [8.54 – 5.09]
Max licensed usage (2018-2019)	17,867	12.89 [14.01 – 9.87]
Licensed entitlement (2016-2017)	21,218	15.56 [16.88 – 12.21]
PCV (Order 2013)	21,238	15.59 [16.71 – 12.23]

*Denotes the lower and upper uncertainty band

Step 1b

The inverse of the Equations 2-4 was used to calculate the volumes of groundwater and uncertainty bands for DEECA sustainability metrics (5m and 10m drawdowns) (step 1b). Table 2 presents the estimated groundwater volumes for these metrics.

Table 2. The values of groundwater volume with uncertainty bands for DEECA sustainability metrics for the Sale WSPA, Representative Suite M_O_1

Drawdown (m)	Volume (ML/yr)
5.0	8,002 [6,600 – 10,907] *
10.0	14,252 [12,850 – 18,050]

*denotes the lower and upper uncertainty band

Step 2: Throughflow Flux Assessment

The throughflow flux assessment is based on a GIS tool that calculates predevelopment gridded throughflow rates (based on Darcy's equation) across a GMU and throughflow flux on a GMU scale. The GMU scale flux is presented as a relationship between throughflow fluxes and proportions of predevelopment throughflow flux. An illustration of the relationship is shown as a graph and a linear equation along with uncertainty bands for each GMU. **Figure 4** shows a general graph format representing throughflow flux and proportion of predevelopment flux with uncertainty bands for Sale WSPA.

Figure 12-1 Sale WSPA – PCV and licensed usage relative to predevelopment throughflow estimate of flow-tube UTAF ft07

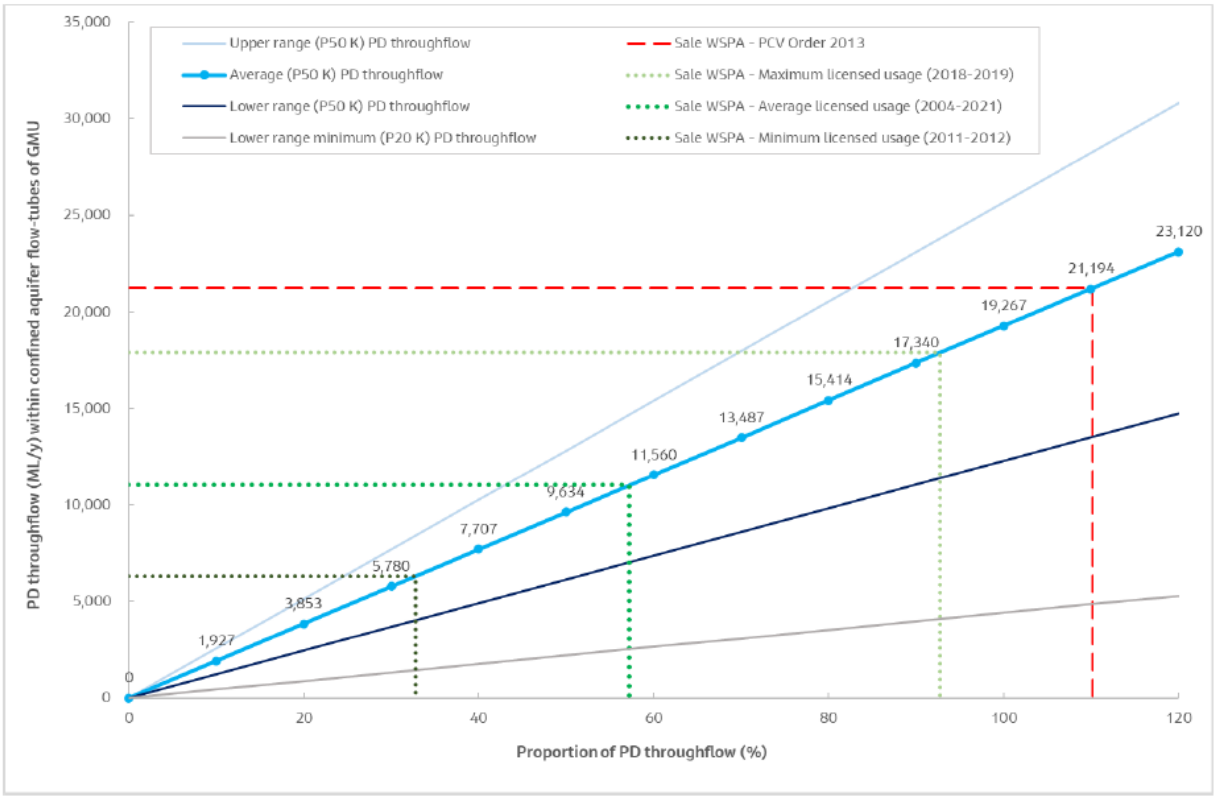


Figure 4: A general graph format indicating a relationship between throughflow flux and proportion of predevelopment flux for Sale WSPA (Part 2)

The following equations were extracted from throughflow flux assessment for Sale WSPA, representative Suite M_O_1:

$$P \propto 0.0052 \times Q \quad (6)$$

$$P \propto 0.0081 \times Q \quad (7)$$

$$P \propto 0.0039 \times Q \quad (8)$$

where *P* is proportion of predevelopment flux (%), *Q* is volume (throughflow flux) (ML/year). The relationship between throughflow flux and proportion of predevelopment flux is represented by equation 6 and the upper and lower uncertainty bands are represented by equations 7 and 8. These equations were used to calculate proportion of predevelopment flux and the uncertainty bands for different volumes shown in **Table 1** and **Table 2** (e.g., PCV, licensed usages, volumes at 5 and 10 m drawdowns). **Table 3** and **Table 4** present the estimated proportion of predevelopment flux.

Table 3. The values of proportion of predevelopment flux for PCV, licensed entitlement and licensed usages for the Sale WSPA

Volume		Proportion of predevelopment flux (%)
Type	Volume (ML/yr)	
Min licensed usage (2011-2012)	6,324	32 [25 - 51]
Avg licensed usage (2004-2021)	11,029	57 [43 - 90]
Max licensed usage (2018-2019)	17,867	93 [70 - 145]
Licensed entitlement (2016-2017)	21,218	110 [83 - 173]
PCV (Order 2013)	21,238	110 [83 - 173]

Table 4 The values of proportion of predevelopment flux with uncertainty bands for the DEECA sustainability metrics (5- and 10m drawdowns) for the Sale WSPA

Drawdown (m)	Proportion of predevelopment flux (%)
5.0	42 [31 - 65]
10.0	74 [56 - 116]

Step 3: Synthesised Results

In step 3, the results of steps 1 and 2 are combined in order to have consolidated results. **Table** 5 and **Table 6** present the synthesised results for volumes of different uses (e.g., licensed usages, licensed entitlement, and PCV) and DEECA sustainability metrics (5m and 10m drawdowns). Table 7 presents a compilation of synthesised results in a consolidated format.

Table 5. The values of drawdown and proportion of predevelopment flux for PCV, licensed entitlement and licensed usages for the Sale WSPA, Representative Suite M_O_1

Volume		Drawdown (m)	Proportion of predevelopment flux (%)
Type	Volume (ML/yr)		
Min licensed usage (2011-2012)	6,324	3.66 [4.78 – 1.79]	32 [25 - 51]
Avg licensed usage (2004-2021)	11,029	7.42 [8.54 – 5.09]	57 [43 - 90]
Max licensed usage (2018-2019)	17,867	12.89 [14.01 – 9.87]	93 [70 - 145]
Licensed entitlement (2016-2017)	21,218	15.56 [16.88 – 12.21]	110 [83 - 173]
PCV (Order 2013)	21,238	15.59 [16.71 – 12.23]	110 [83 - 173]

Table 6. The values of groundwater volume and proportion of predevelopment flux with uncertainty bands for the DEECA sustainability metrics (5- and 10m drawdowns) for the Sale WSPA, Representative Suite M_O_1

Drawdown (m)	Volume (ML/yr)	Proportion of predevelopment flux (%)
5.0	8,002 [6,600 – 10,907]	42 [31 - 65]
10.0	14,252 [12,850 – 18,050]	74 [56 - 116]

The synthesised information is also presented in the format of a graph for visualisation. **Figure 5** shows a visual representation of proportion of predevelopment throughflow flux-use relationship (Jacobs, 2024) and drawdown-use relationship (GHD Pty Ltd, 2024) based on the synthesised information for the Sale WSPA, Representative Suite M_O_1.

Table 7. The compilation of synthesised results in a consolidated format for the Sale WSPA, Representative Suite M_O_1

Assessment area	GMU		Sale WSPA
	Representative Suite		M_O_1
	Aquifer		Boisdale Formation (UTAF, 105)
	Water system depth boundary (metres below natural surface)		All formations between 25 m and 200 m below surface
Context	Permissible Consumptive Volume (ML/yr)		21,238
	Licensed entitlement (ML/yr)		21,203
	Licensed average use (ML/yr)		11,029
Synthesis results	Use at average volume	Drawdown (m) [lower band–upper band]	7.42 (8.54–5.09)
		Proportion of throughflow flux (%) [lower band–upper band]	57 (43–90)
	Use at Permissible Consumptive Volume	Drawdown (m) [lower band–upper band]	15.59 (16.71–12.23)
		Proportion of throughflow flux (%) [lower band–upper band]	110 (83–173)
	Use at 10 m drawdown	Volume (ML/yr) [lower band–upper band]	14,252 (12,850–18,050)
		Proportion of throughflow flux (%) [lower band–upper band]	74 (56–116)

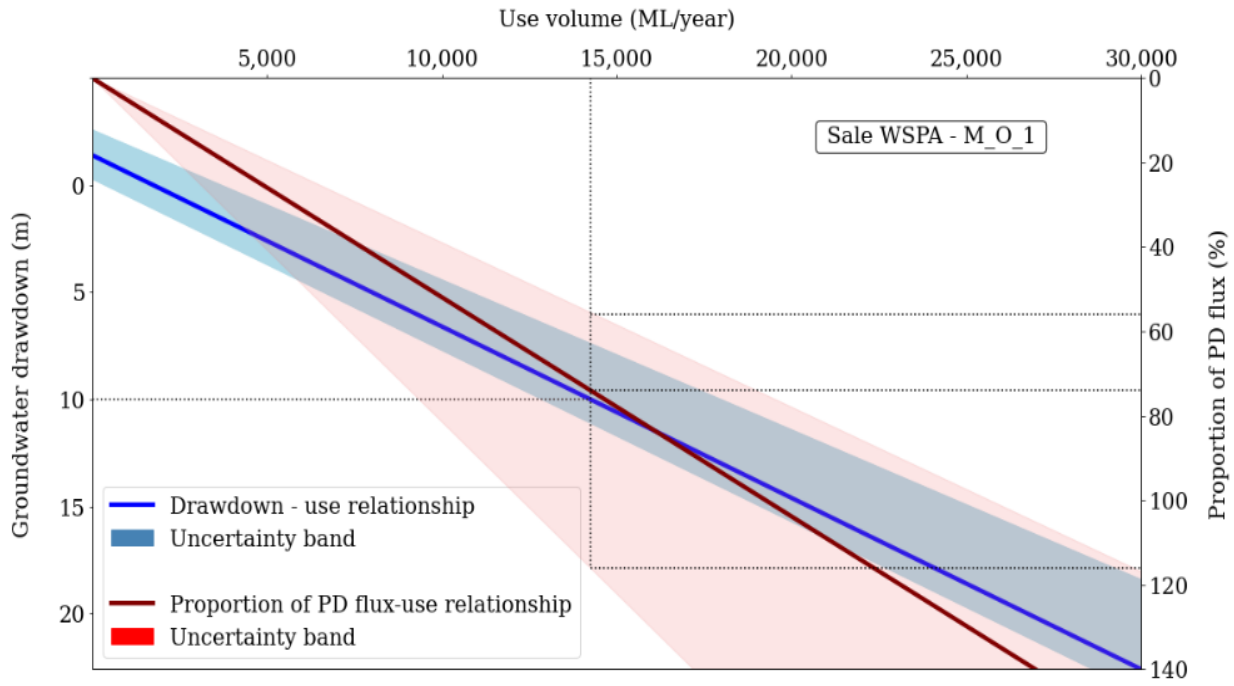


Figure 5: A visual representation of proportion of predevelopment throughflow flux-use relationship (GHD Pty Ltd, 2024) and drawdown-use relationship (GHD Pty Ltd, 2024) based on the synthesised information for the Sale WSPA, Representative Suite M_O_1

3.2. UAs Scale

Since UAs are not modelled to obtain use-drawdown relationships, only throughflow flux results are available. **Table 8** shows the throughflow volume for the LTA-NW1 UA – Wimmera Mallee.

Table 8. Throughflow volume for the LTA-NW1 UA - Wimmera Mallee

Assessment area	Unincorporated Area	LTA-NW1
	Aquifer	LTA
Context	Licensed entitlement (ML/yr)	0
	Licensed average use (ML/yr)	0
Synthesis results	Pre-development throughflow flux (ML/yr)	2,670

References

CDM Smith. (2025). *Review Of Groundwater Sustainable Yield: Unconfined and Semi-confined Aquifers.* Melbourne: CDM Smith.

GHD Pty Ltd. (2024). *Technical Assessment of State Wide Groundwater Sustainable Yields Confined Aquifers :Stage 2 (Statewide) report.* Melbourne: GHD Ltd Pty.

Jacobs. (2024). *Confined Aquifer Throughflow Assessment - Updated Methof and Phase B State-wide Rollout.* Melbourne: Jacobs.