Appendix C Victorian hydrological regions for sizing rainwater tanks

Contents

C.1 Introduction

Household rainwater tanks provide an opportunity to reduce mains potable water use by storing collected roof runoff and using it for applications such as toilet flushing and garden watering.

There are no quantitative performance targets in any of Victoria's local government or state authority policies and guidelines controlling the use of rainwater tanks. However, it can be inferred from the various policies and guidelines that a performance target for rainwater tanks (or any other form of rainwater and stormwater harvesting, storage and reuse scheme) is to provide a 'reliable' supply of suitable quality water to meet the demand requirements of a stipulated preferred 'end-use' (e.g. toilet flushing).

Variables include the area of a roof directed into a tank, quantity and nature of the demand, rainfall pattern and the required reliability. Reliability is defined as the percentage of demand that can be met using collected rainwater. Where reliability is less than 100% (i.e. roof runoff cannot meet 100% of demand), an additional water source, such as mains water, will be required to meet a proportion of demand.

This Appendix presents a simple design procedure for sizing rainwater tanks to meet a range of reliabilities for toilet-flushing reuse across Victoria. The procedure is based on developing sizing curves for a reference site (Melbourne) and then adjusting the tank size for other areas in the state depending on location and Mean Annual Rainfall (MAR).

Three tank-sizing regions within Victoria have been defined and show the relationship between MAR and required tank size in each region. These regions are different to those determined to size stormwater treatment measures (see Appendix A) as different aspects of rainfall patterns are important for treatment measures than for reuse applications.

C.2 Methodology

After initial consideration of possible design approaches, the following approach was used to determine hydrologic regions and sizing curves for rainwater tanks throughout Victoria:

1. determine a water reuse application (i.e. toilet flushing) and estimate demand magnitude and distribution (see Section C.3).
2. establish Melbourne tank sizing curves (relating tank size and reuse 'reliability') for a range of reuse demands (see Section C.4).
3. determine the size of tank required at locations around Victoria to achieve an equivalent reliability at certain reference points on the Melbourne tank sizing curves (see Section C.5).
4. define Tank Sizing Regions within Victoria for which the tank size required to achieve the same reliability as a given tank in Melbourne can be predicted based on MAR (see Section C.6).
5. develop rainwater tank sizing curves for each region (see Section C.7).

C.3 Determining reuse application

Water consumption 'per household' varies depending on house type and location although consumption figures 'per person' were found to be less influenced by these factors. Typical water consumption figures for residential areas expressed on a per capita basis are summarised in Figure C.3.1. These consumption rates are for dwellings with water efficient fittings and appliances. Consumption of water for toilet flushing has reduced significantly since the mandatory introduction of dual flush toilets in.

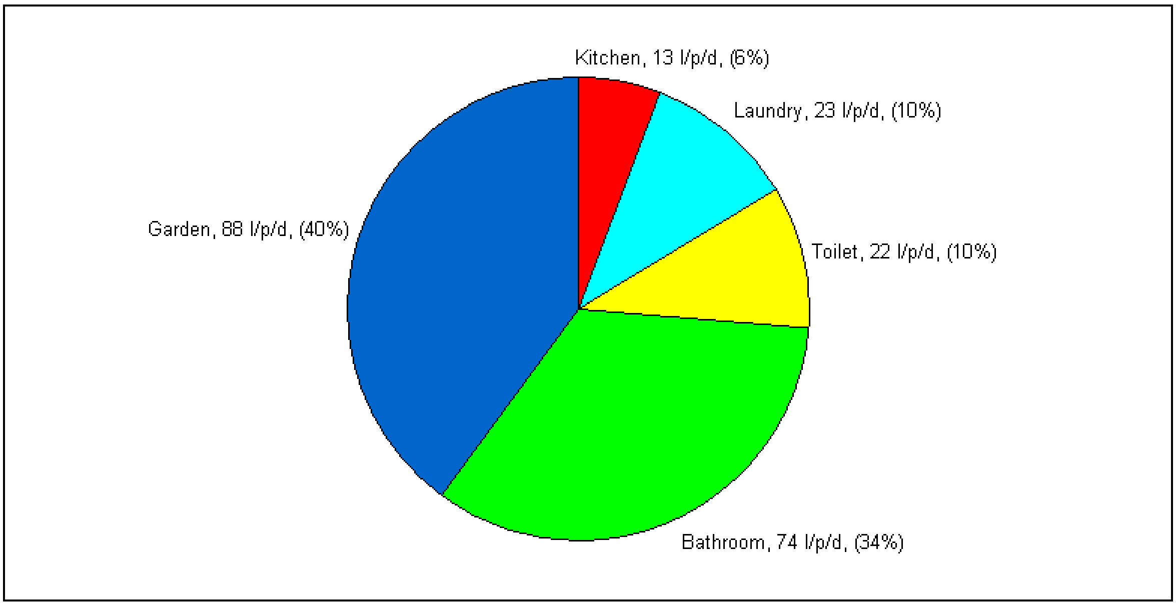

Figure C.3.1 Typical household water use in Victoria (assuming water efficient fittings and appliances) (Coomes Consulting Group 2002, Water Resources Strategy Committee 2001).

Rainwater tanks can be used to supply any one of these uses or combinations of them. The most obvious water uses for rainwater are toilet and garden as they do not require treatment to potable standards. Replacement of mains potable water for toilet flushing is considered to be the more effective of the two because of its consistent demand pattern and thus a higher reliability of water supply can be achieved for a given tank size. Although having a higher water demand, water usage for garden watering is seasonal and the demand pattern is 'out-of-phase' with the supply pattern (i.e. high garden watering demand occurs during low rainfall) and thus requires a larger rainwater tank storage to achieve comparable reductions in potable water usage compared with toilet flushing.

After toilet flushing and garden watering, the next most appropriate use of rainwater is in the laundry (e.g. washing, cold tap). Supplementing the supply for hot water is also an effective option. Hot water usage constitutes about 40% of a household indoor usage. The quality of roof water contained in hot water systems can often be improved through pasteurisation, pressure in the pump and instantaneous heat differentials between the rainwater tank and a hot water service.

Toilet flushing has been selected as the reuse application for this procedure as it is applicable to all types of residential development and the level of use can be predicted with a reasonable degree of certainty. The demand is assumed to be 22 L/person per day (from Figure C.3.1) which represents a 6/3 toilet system.

C.4 Melbourne rainwater tank sizing curves

The Model for Urban Stormwater Improvement Conceptualisation (MUSIC) (Cooperative Research Centre for Catchment Hydrology 2002) was used to establish the curves in Figure C.4.1, which relate reuse reliabilities to tank sizes using Melbourne rainfall data. The simulation period was between January 1980 and December 1989, covering the dry period in 1982/83. Figure C.4.2 shows the MUSIC model set-up.

All units in Figure C.4.1 are dimensionless and so the curves can be used for any sized roof. The four curves relate to a range of occupancy densities that would be expected in Victoria. The curve for a 1.5 person/100 m^2 roof represents low density housing such as a large house in a rural area. In comparison, a 4.5 person/100 m^2 roof represents a much higher density such as an inner city apartment. Figure C.4.1 shows that the lowest occupancy density corresponds to the highest reliability for a given tank size. Reliability increases as tank size increases up to where either 100% of reuse demand is met or 100% of rainwater collected is being used.

Reduction in mains potable water use can be determined by multiplying the reuse demand by the reliability. For example, a 1 kL rainwater tank at a Melbourne house with a 208 m^2 roof and five occupants (i.e. 2.4 people/100 m^2 roof) would provide a reliability of 86% (from Figure C.4.1). The toilet flushing demand is:

22 L/person per day (from Figure C.3.1) $\times$ 5 people $\times$ 365 days = 40.2 kL/year

The reduction in mains potable water is therefore:

40.2 kL/year $\times$ 86% = 35.0 kL/year.

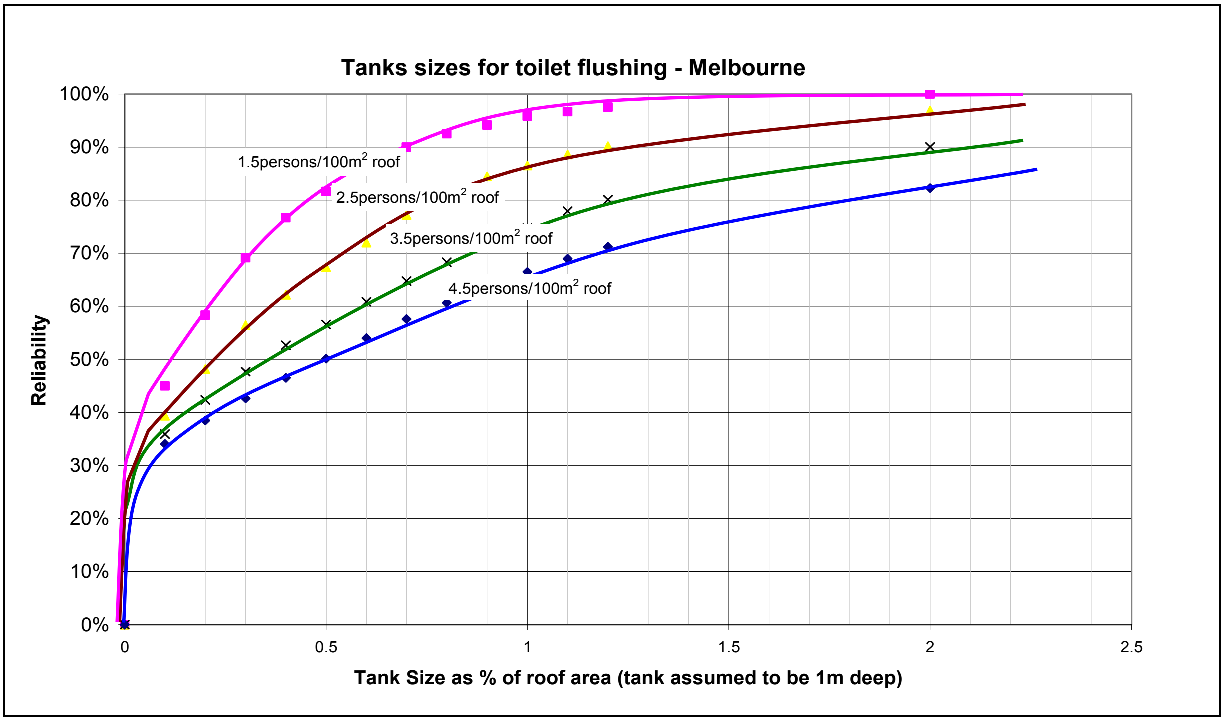

Figure C.4.1 Typical reliabilities for tanks used for toilet flushing reuse in Melbourne.

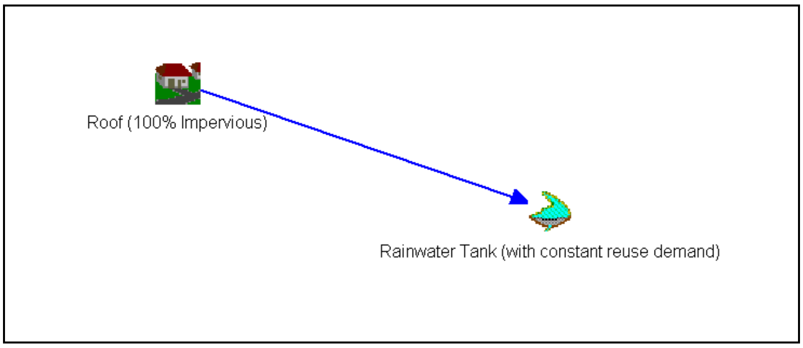

Figure C.4.2 MUSIC Model setup.

C.5 Determining tank sizing regions

Rainwater *tank sizing region*s were determined using data from 45 pluviographic stations throughout Victoria. Fifteen of these are concentrated around the Melbourne/Geelong metropolitan region. The additional stations around Melbourne were considered important because of expected development activity. There are more available data for this region which enables a finer representation of the climatic factors. These stations and their Bureau of Meteorology rainfall district are shown in Table C.5.1 below.

Table C.5.1 Pluviographic stations and Bureau of Meteorology (BOM) districts

BOM district	Stations
Wimmera South	Horsham Tottington Wartook
North Mallee	Mildura
South Mallee	Hopetoun
Lower North	Cobram Kerang
Upper North	Bendigo Tatura Dookie
Lower North-east	Dartmouth
Upper North-east	Bright Hume Reservoir Omeo
East Gippsland	Buchan Sarsfield East Combienbar Genoa Wroxham
West Central	Laverton Melton Werribee Geelong North Little River
East Central	Melbourne Airport Bundoora Essendon Airport Melbourne Croydon Upwey Narre Warren North Dandenong Carrum Downs Koo Wee Rup

Figures C.5.1 and C.5.2 show the distribution of the stations according to their longitude and latitude bearings. The selected pluviographic stations are reasonably well distributed across Victoria and provide sufficient coverage of the state and the metropolitan region. The MAR for the sites selected ranges from 290 mm to 1900 mm, covering the range of rainfall volumes experienced across the state.

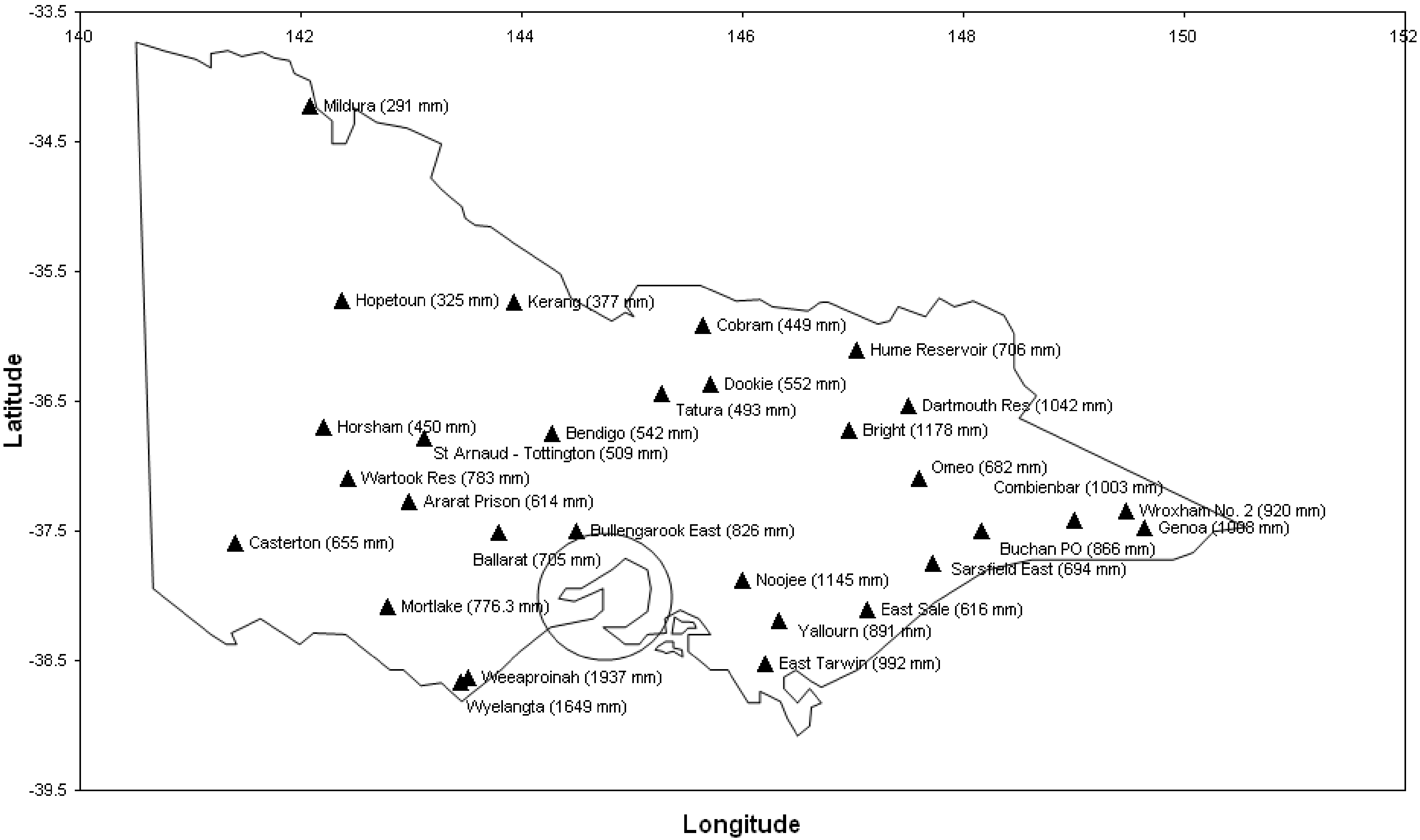

Figure C.5.1 Location of pluviographic stations in Greater Victoria used in defining tank sizing regions.

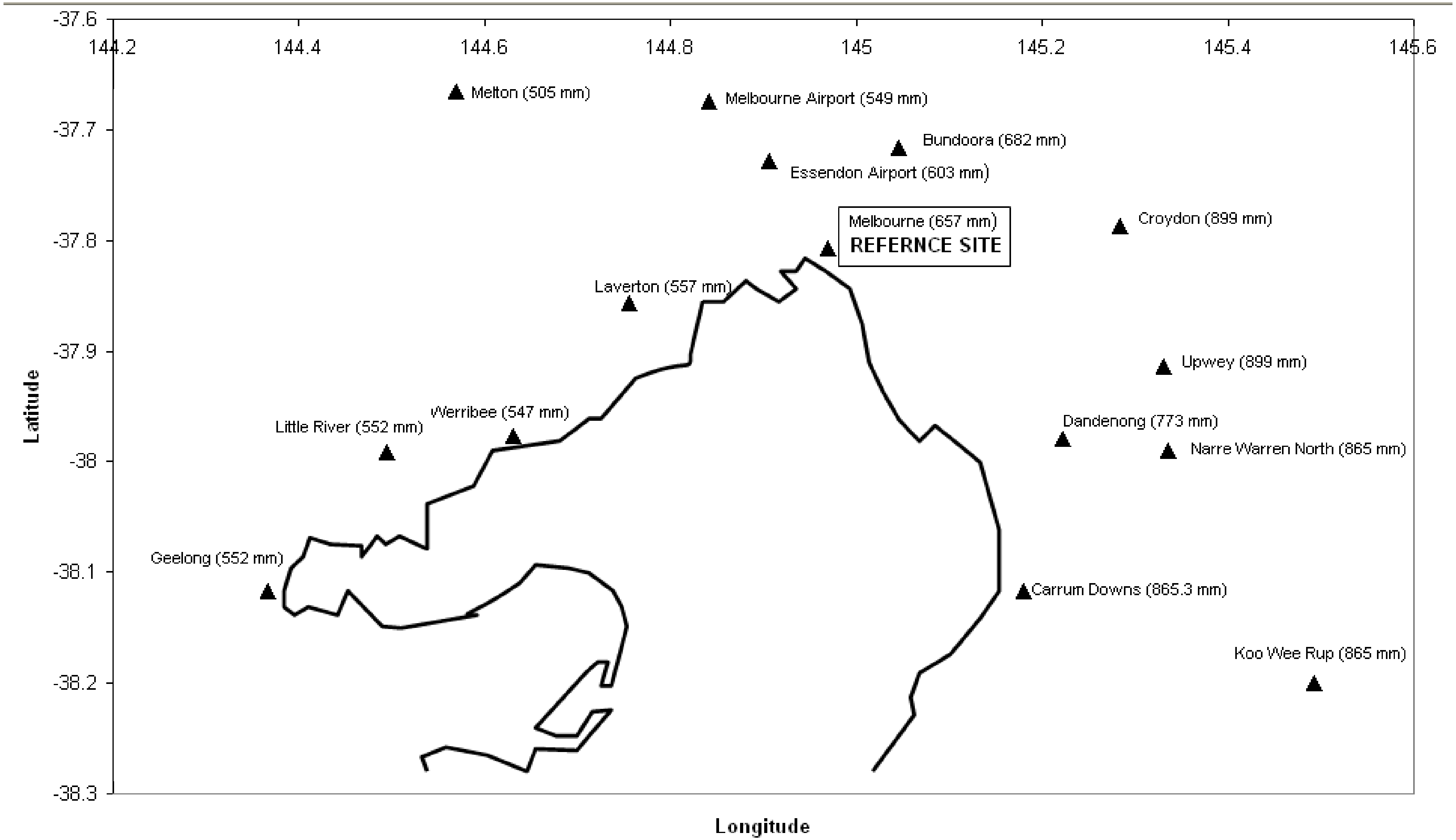

Figure C.5.2 Location of pluviograph stations in Melbourne/Geelong metropolitan region used to determine tank sizing regions.

For each of the 45 pluviographic stations in Victoria, MUSIC modelling was undertaken to determine the tank size required to achieve the same reliability as a series of reference points on the Melbourne tank sizing curves. These reference points are marked on Figure C.5.3 and are listed in Table C.5.2.

Initially, reference points relating to Melbourne 0.5 kL, 1.0 kL, 1.5 kL and 2.0 kL tanks with a 100 m^2 roof area were selected. At several other pluviographic stations in northern Victoria with low MAR, the reliabilities of 1.5 kL and 2.0 kL tanks could not be achieved; therefore, smaller tanks were modelled including 0.2 kL, 0.4 kL and 0.75 kL tanks (with 100 m^2 of roof contributing). For the lowest reuse demand (i.e. 1.5 people/100 m^2 roof), reference points corresponding to 1.5 kL and 2.0 kL were not included as there was a minimal increase in reliability achieved for tanks larger than 1 kL (i.e. it is not thought to be feasible to double tank size to increase reliability by 6%).

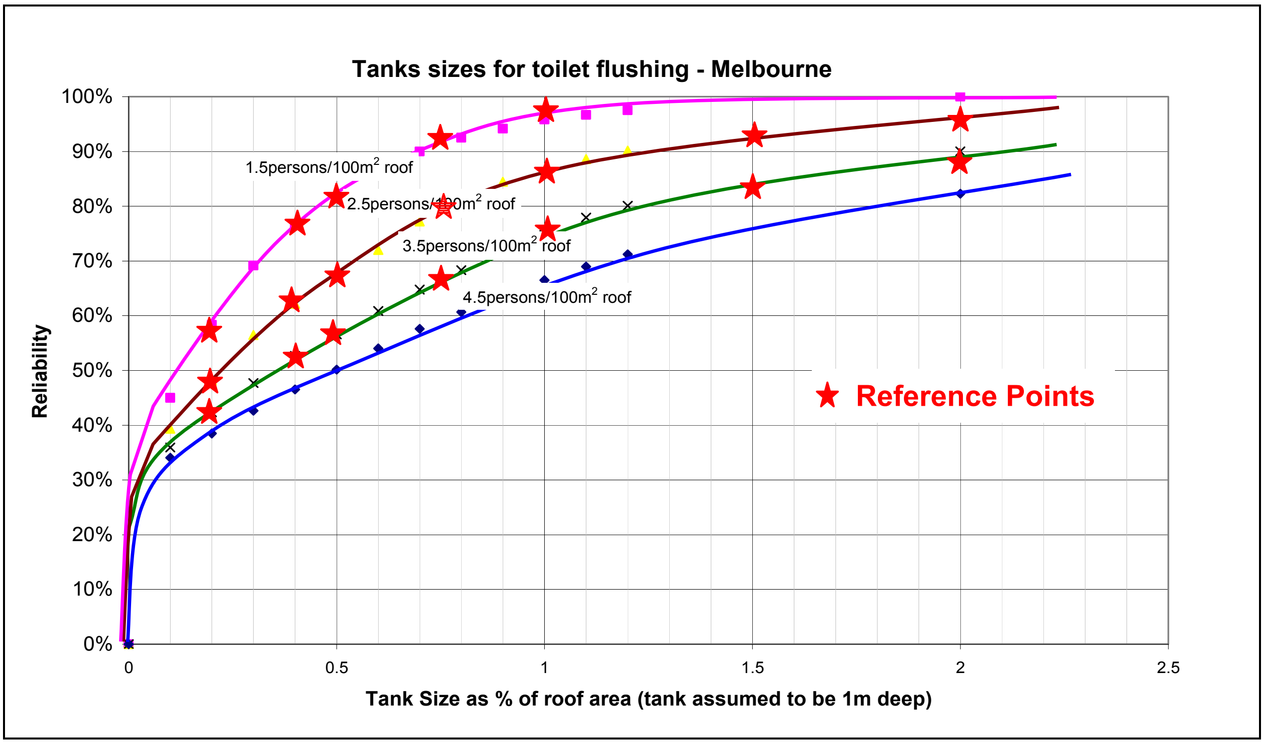

Figure C.5.3 Chart showing 'reference points' (stars) on Melbourne rainwater tank sizing curves.

Table C.5.2 List of reference points on the Melbourne tank sizing curves in Figure C.3.6 (stars)

No.	Equivalent Melbourne tank size (kL)	Demand (people/ 100 m^2 roof)	Reliability
1	0.2	1.5	58
2	0.2	2.4	48
3	0.2	3.5	42
4	0.4	1.5	77
5	0.4	2.4	62
6	0.4	3.5	53
7	0.5	1.5	82
8	0.5	2.4	67
9	0.5	3.5	57
10	0.75	1.5	90
11	0.75	2.4	80
12	0.75	3.5	67
13	1	1.5	94
14	1	2.4	87
15	1	3.5	75
16	1.5	2.4	93
17	1.5	3.5	84
18	2	2.4	97
19	2	3.5	90

The required tank size at each pluviographic station for each of these reference points is shown in Table C.5.3. Initially, the required tank size was plotted against MAR using a demand of 2.4 people with a 1 kL tank for 100m^2 of roof area (reference point no. 14) for all 45 pluviographic stations (Figure C.5.4). Although there is a definite negative correlation between required tank size andMAR,there is a ‘large spread’ in the data. The dotted lines in Figure C.5.4 show a range that is about 40% from the line of best fit.

Table C.5.3 Required tank sizes for reference station across Victoria

Melbourne																
Occupancy: [1]	*3.5*	*2.4*	*1.5*	*3.5*	*2.4*	*1.5*	*3.5*	*2.4*	*1.5*	*3.5*	*2.4*	*1.5*	*3.5*	*2.4*	*1.5*	*3.5*
Reliability (%):	*42*	*48*	*58*	*53*	*62*	*77*	*57*	*67*	*82*	*67*	*80*	*90*	*75*	*87*	*96*	*85*
Tank volume: [2]	0.20	0.20	0.20	0.40	0.40	0.40	0.50	0.50	0.50	0.75	0.75	0.75	1.00	1.00	1.00	1.50
	Equivalent Tank Size [2] (% roof area) for same reliability as Melbourne															
Northern Region																
Mildura	1.03	0.79	0.67	1.68	1.38	1.50	2.02	1.70	1.50	3.25	2.55	2.10	4.90	4.00	2.80	
Hopetoun	0.82	0.64	0.54	1.37	1.23	1.25	1.68	1.65	1.70	3.30	3.70	3.70	6.20	6.65	5.80	
Kerang	0.65	0.57	0.52	1.08	0.98	1.05	1.25	1.21	1.25	2.02	2.10	2.60	3.50	3.70	3.30	
Cobram	0.67	0.58	0.52	1.05	0.96	1.00	1.20	1.15	1.15	1.80	1.85	1.80	2.55	2.60	2.10	
Wodonga	0.58	0.46	0.45	0.75	0.71	0.73	0.84	0.85	0.82	1.23	1.35	1.23	1.60	1.77	1.35	
Tatura	0.76	0.58	0.53	1.04	0.95	1.05	1.15	1.18	1.25	1.90	2.00	2.05	2.90	2.90	2.30	
Dookie	0.57	0.45	0.44	0.78	0.73	0.80	1.18	1.18	1.28	1.29	1.50	1.60	2.90	2.90	2.30	
Southen Region																
Ararat							0.81	0.62	0.66				1.46	1.35	1.25	1.93
Ballarat							0.76	0.50	0.73				1.73	1.18	1.33	2.87
Weearrionah							0.10	0.20	0.25				0.35	0.50	0.45	0.60
Wyelangta							0.35	0.38	0.38				0.75	0.74	0.65	1.09
Noojee							0.23	0.29	0.36				0.65	0.69	0.85	0.88
Yallourn							0.35	0.38	0.42				0.68	0.78	0.80	0.84
East Tarwin							0.32	0.36	0.41				0.71	0.77	0.82	1.50
Bullengarook							0.43	0.42	0.49				0.87	0.95	1.10	1.40
Buchan							0.43	0.45	0.49				0.86	0.88	0.90	1.22
East Sale							0.65	0.62	0.57				1.28	1.25	1.05	1.88
Sarsfield East							0.63	0.62	0.67				1.16	1.25	4.00	1.82
Wroxham							0.46	0.46	0.46				0.90	0.90	0.90	1.32
Genoa							0.39	0.40	0.43				0.86	0.90	0.85	1.22
Combienbar							0.54	0.53	0.53				1.05	1.02	1.05	1.42
Geelong							0.58	0.57	0.62				1.32	1.41	1.50	2.30
Little River							0.72	0.66	0.66				1.66	1.45	1.30	3.05
Melbourne							0.54	0.53	0.55				1.10	1.08	1.15	1.62
Laverton							0.60	0.56	0.60				1.33	1.25	1.25	2.10
Melton							0.82	0.71	0.72				2.07	1.63	1.65	3.17
Bundoora							0.47	0.47	0.49				1.00	1.05	1.05	1.35
Essendon							0.57	0.56	0.59				1.19	1.24	1.30	1.95
Upwey							0.90	0.33	0.38				0.65	0.78	0.30	1.00
Croydon							0.22	0.40	0.35				0.60	0.94	0.70	0.81
Narre Warren							0.40	0.43	0.48				0.81	0.90	1.20	1.25
Carrum							0.37	0.40	0.44				0.85	0.94	1.10	1.25
Koo Wee Rup							0.40	0.44	0.46				0.77	0.84	0.93	1.15
Central																
Dartmouth							0.57	0.57	0.65				1.11	1.18	1.32	1.55
Bright							0.57	0.51	0.64				1.11	0.97	1.30	1.28
Omeo							0.75	0.70	0.70				1.68	1.55	2.00	2.53
Wartook							0.49	0.54	0.65				1.07	1.20	1.40	1.58
Horsham							0.78	0.75	0.80				1.60	1.56	1.60	2.55
Tottington							0.88	0.83	0.84				1.88	1.81	1.80	3.00
Bendigo							0.74	0.82	0.76				1.47	1.50	1.55	2.40

[1] people per 100m ^{2} roof
[2] percent of roof area (assuming tank is 1m deep)

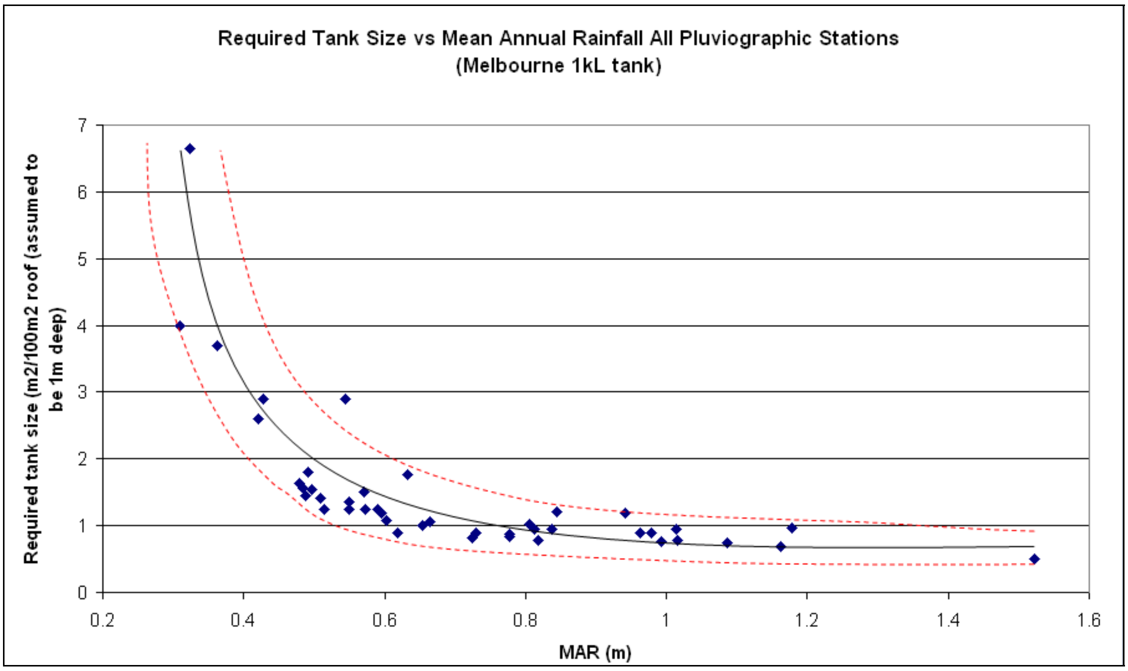

Figure C.5.4 Chart showing required tank size for all pluviographic stations (2.4 people/100 m2 roof; tank 1% catchment area).

An assessment was subsequently undertaken to see if a better correlation could be achieved using the nine regions derived for sizing stormwater treatment devices (see Appendix A).

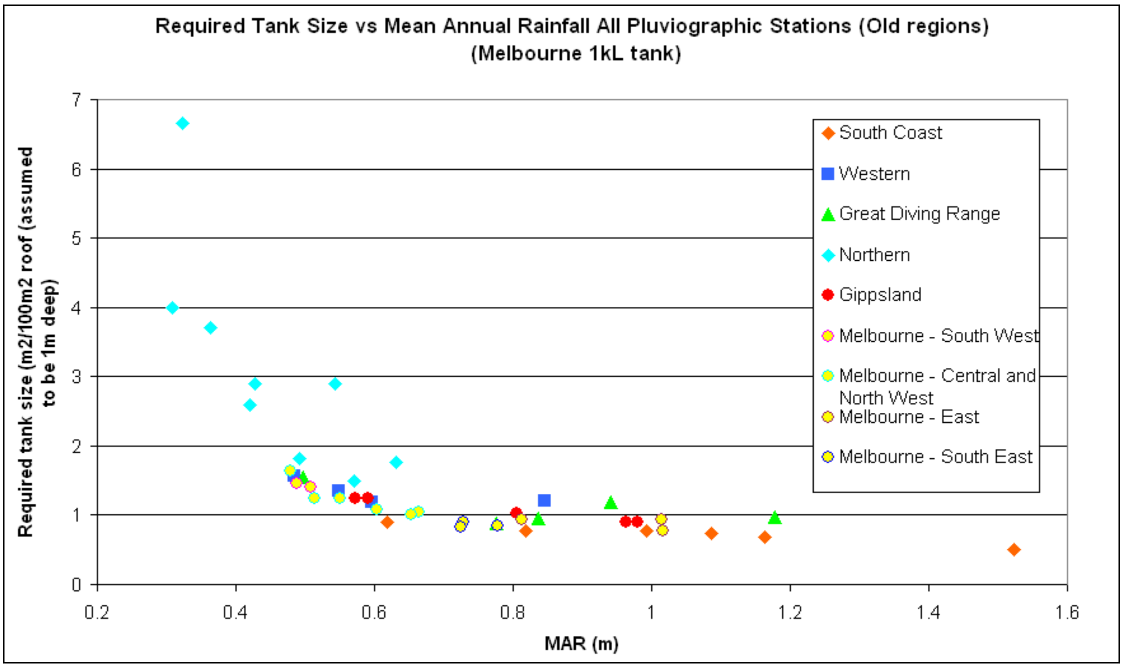

Figure C.5.5 Chart showing required tank size for all stations divided into the hydrologic regions used for sizing stormwater treatment devices.

There appears to be a better correlation within each of the nine regions in Figure C.5.5 than within the entire data set. It was determined, however, that a better correlation can be achieved using different tank sizing regions to those used for treatment device sizing

(Appendix A). Three tank sizing regions were defined: northern, central and southern (Figure C.5.69). Boundaries of the tank sizing regions were determined to represent the results of the analysis and to be aligned so that they do not dissect major urban areas (Figure C.5.7). The pluviographic stations within each hydrologic region are shown in Table C.5.5.4.

The difference between the regions used for sizing rainwater tanks andthose used for sizing stormwater treatment devices may be attributed to the different aspects of rainfall distribution that are relevant to the two applications. The performance of stormwater treatment devices depends on a finer time scale than rainwater tanks.

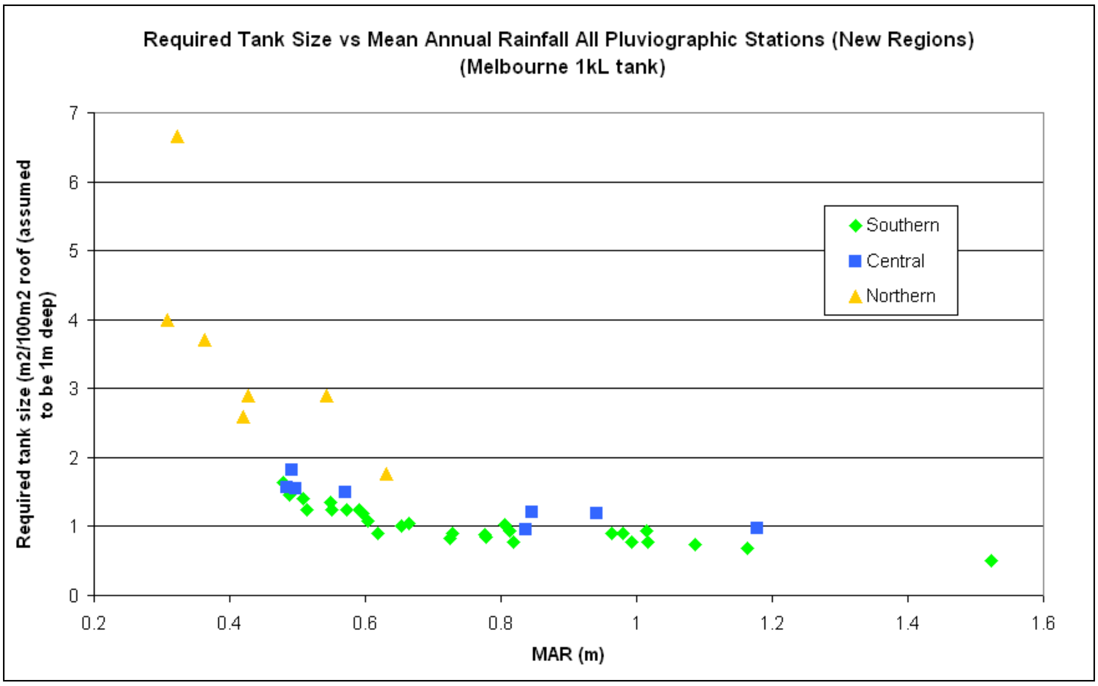

Figure C.5.6 Chart showing required tank size using three hydrologic regions within Victoria.

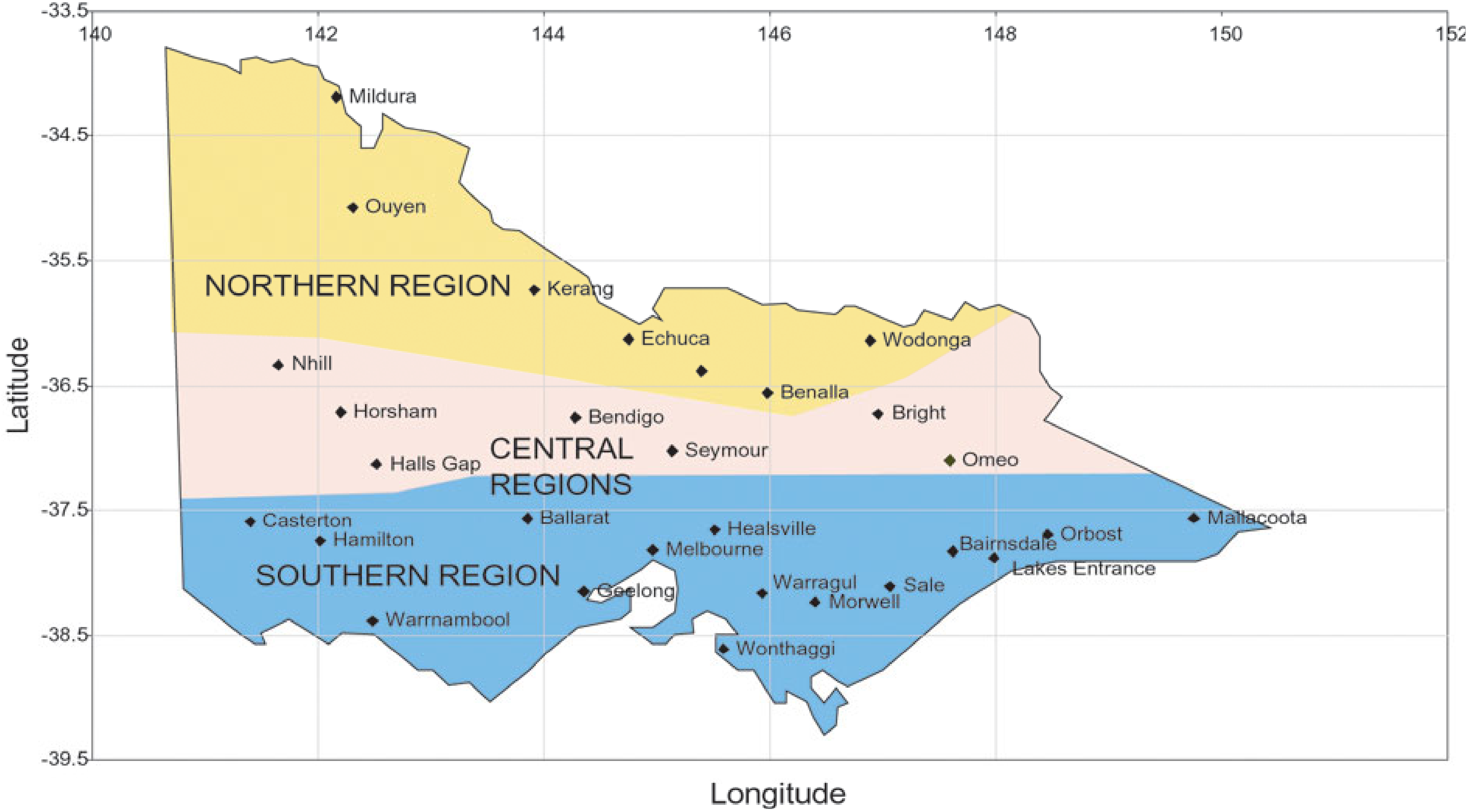

Figure C.5.7 Victorian rainwater tank sizing regions.

Table C.5.4 Pluviographic stations within each hydrologic region

Region	Stations
Northern	Mildura
	Hopetoun
	Kerang
	Cobram
	Hume Reservoir (Wodonga)
	Tatura
	Dookie
Central	Horsham
	Wartook Reservoir
	Tottington
	Darmouth Reservoir
	Bright
	Omeo
	Bendigo

Region	Stations	
Southern	Ararat	Geelong North
	Ballarat	Little River
	Bullengarook	Werribee
	Buchan	Melbourne Airport
	Casterton	Laverton
	Mortlake	Melton
	Weearproinah	Bundoora
	Wyelangta	Essendon Airport
	Noojee	Upwey
	Yallourn	Croydon
	East Tarwin	Narre Warren
	East Sale	North
	Sarsfield East	Carrum
	Combienbar	Dandenong
	Wroxham	Koo Wee Rup
	Genoa	Melbourne

C.6 Determining tank sizing curves

C.6.1 Northern region

For the seven pluviographic stations within the northern region, the tank size required to achieve the same reliability as the reference points described in Section C.5 were plotted against MAR. A curve could be plotted through all the data points relating to a each Melbourne tank size (see Table C.6.1 and Figure C.6.1).

Table C.6.1 Table showing which reference points make up each curve on Figure C.6.1

No.	Equivalent Melbourne tank size (kL)	Demand (people/100 m^2 roof)	Reliability
CURVE 1			
1	0.2	1.5	58
2	0.2	2.4	48
3	0.2	3.5	42
CURVE 2			
4	0.4	1.5	77
5	0.4	2.4	62
6	0.4	3.5	53
CURVE 3			
7	0.5	1.5	82
8	0.5	2.4	67
9	0.5	3.5	57
CURVE 4			
10	0.75	1.5	90
11	0.75	2.4	80
12	0.75	3.5	67
CURVE 5			
13	1	1.5	94
14	1	2.4	87
15	1	3.5	75

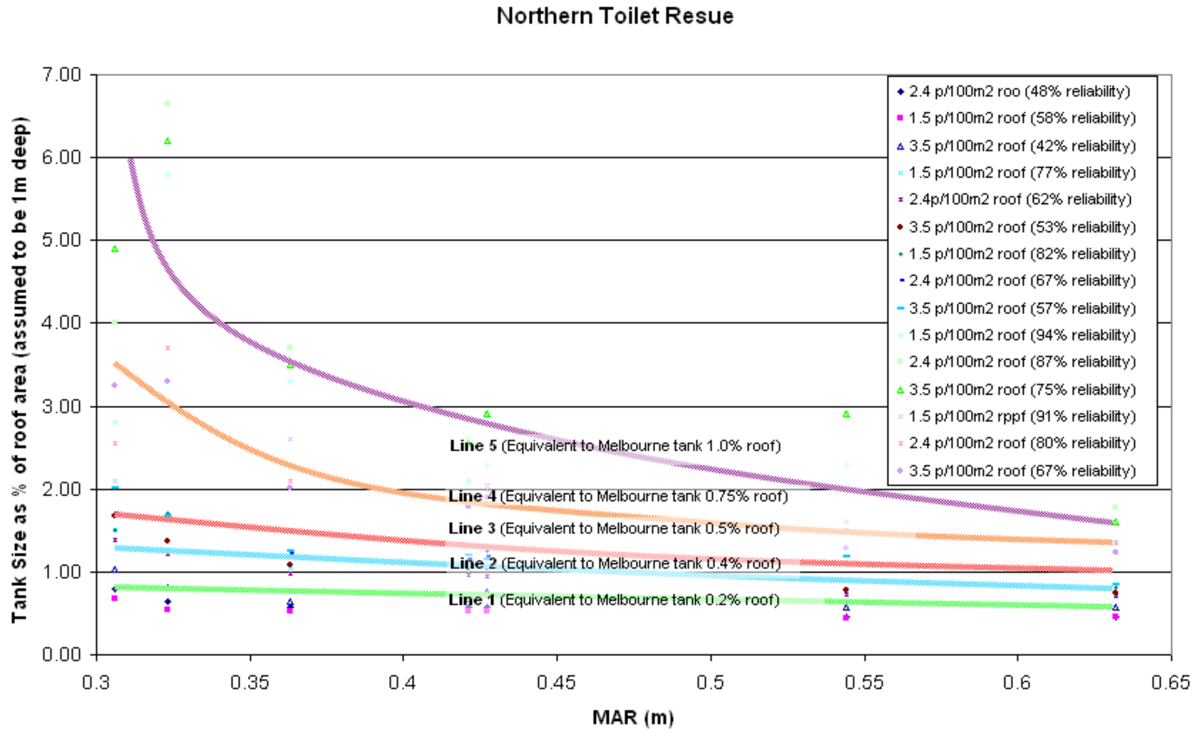

Figure C.6.1 Northern tank sizing region chart.

C.6.2 Central region

For the seven pluviographic stations within the central region, the tank size required to achieve the same reliability as the reference points described in Section 5 were plotted against MAR. A curve could be plotted through all the data points relating to each Melbourne tank size (Table C.6.2 and Figure C.6.2).

Table C.6.2 Table showing which reference points make up each curve on Figure C.6.2

No.	Equivalent Melbourne tank size (kL)	Demand (people/100m^2 roof)	Reliability
CURVE 1			
7	0.5	1.5	82
8	0.5	2.4	67
9	0.5	3.5	57
CURVE 2			
13	1	1.5	94
14	1	2.4	87
15	1	3.5	75
CURVE 3			
16	1.5	2.4	93
17	1.5	3.5	84
CURVE 4			
18	2	2.4	97
19	2	3.5	90

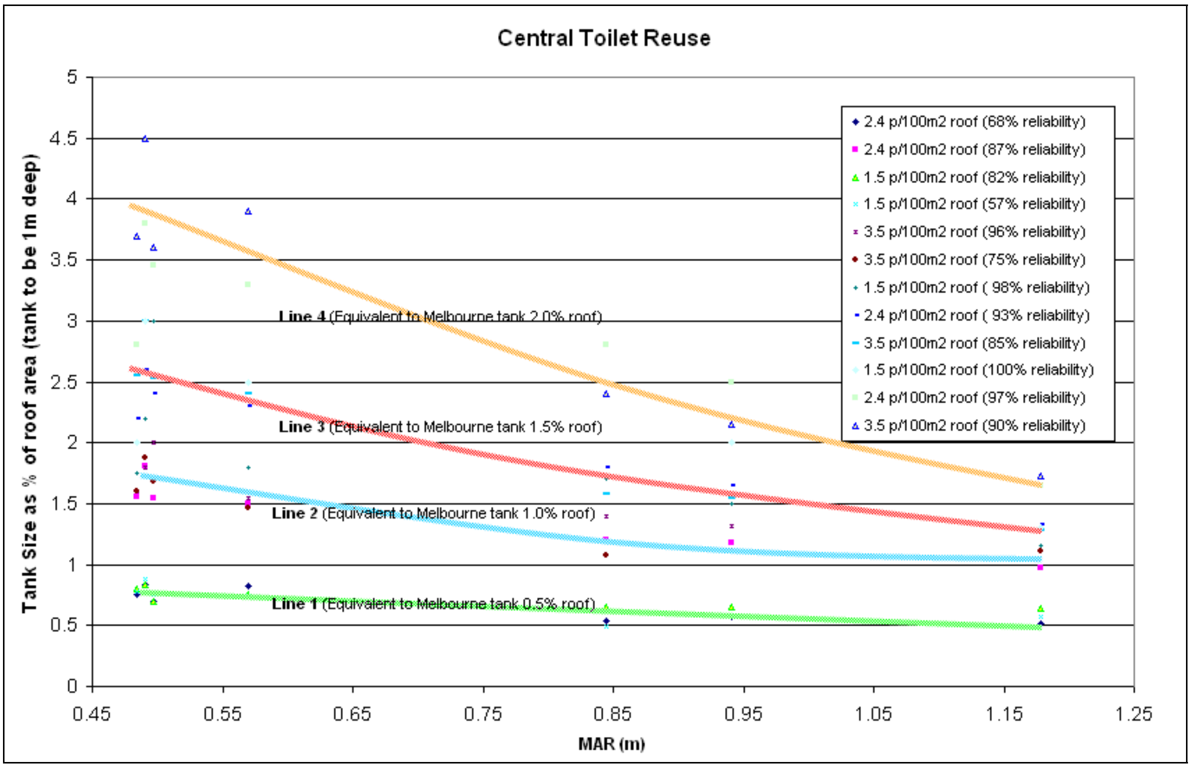

Figure C.6.2 Central tank sizing region chart.

C.6.3 Southern region

For the 31 pluviographic stations within the southern region, the tank size required to achieve the same reliabilities as the reference points described in Section C.5 were plotted againstMAR. A curve could be plotted through all the data points relating to a each Melbourne tank size (Table C.6.3 and Figure C.6.3).

Table C.6.3 Table showing which reference points that make up each curve on Figure C.6.3

No.	Equivalent Melbourne tank size (kL)	Demand (people/100 m^2 roof)	Reliability
CURVE 1			
7	0.5	1.5	82
8	0.5	2.4	67
9	0.5	3.5	57
CURVE 2			
13	1	1.5	94
14	1	2.4	87
15	1	3.5	75
CURVE 3			
16	1.5	2.4	93
17	1.5	3.5	84
CURVE 4			
18	2	2.4	97
19	2	3.5	90

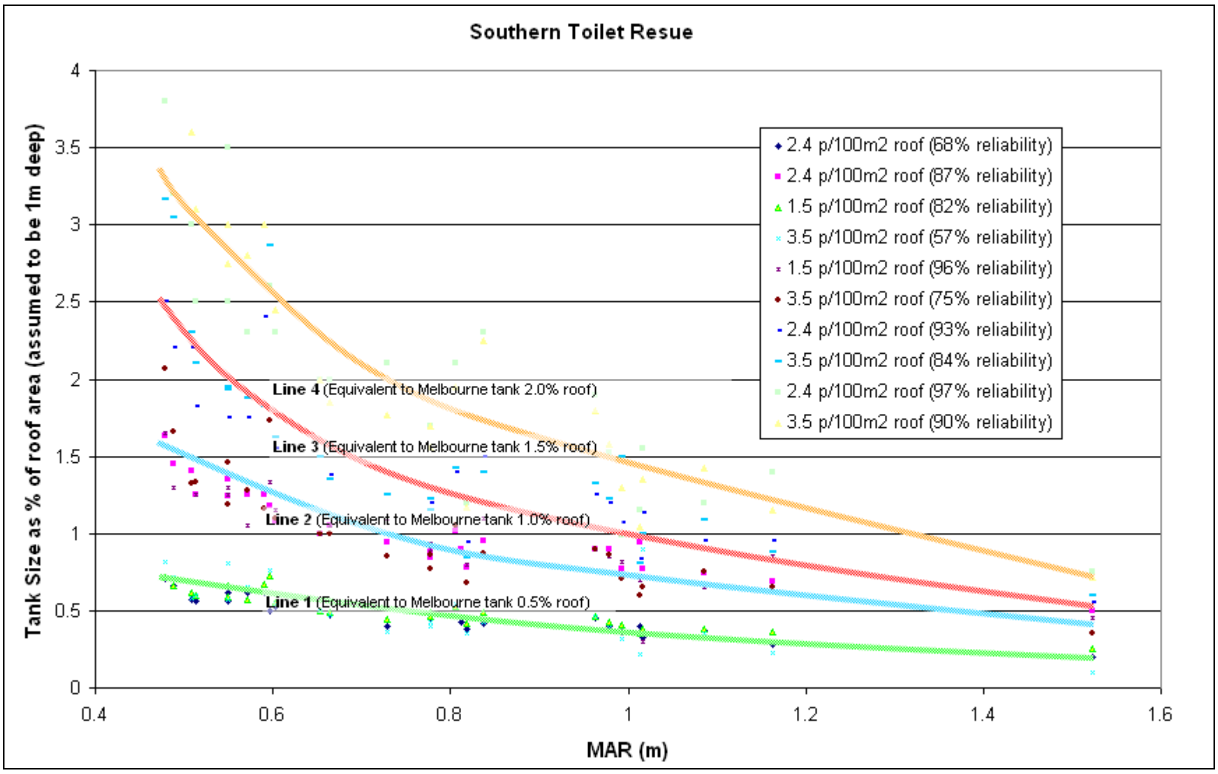

Figure C.6.3 Southern tank sizing region chart.

C.7 Recommended tank sizing curves

The curves in Figures C.7.1 to C.7.3 are the tank sizing curves recommended for the three regions in Victoria (as defined in Figure C.5.7) and used in Chapter 12 of this Manual.

C.7.1 Northern region

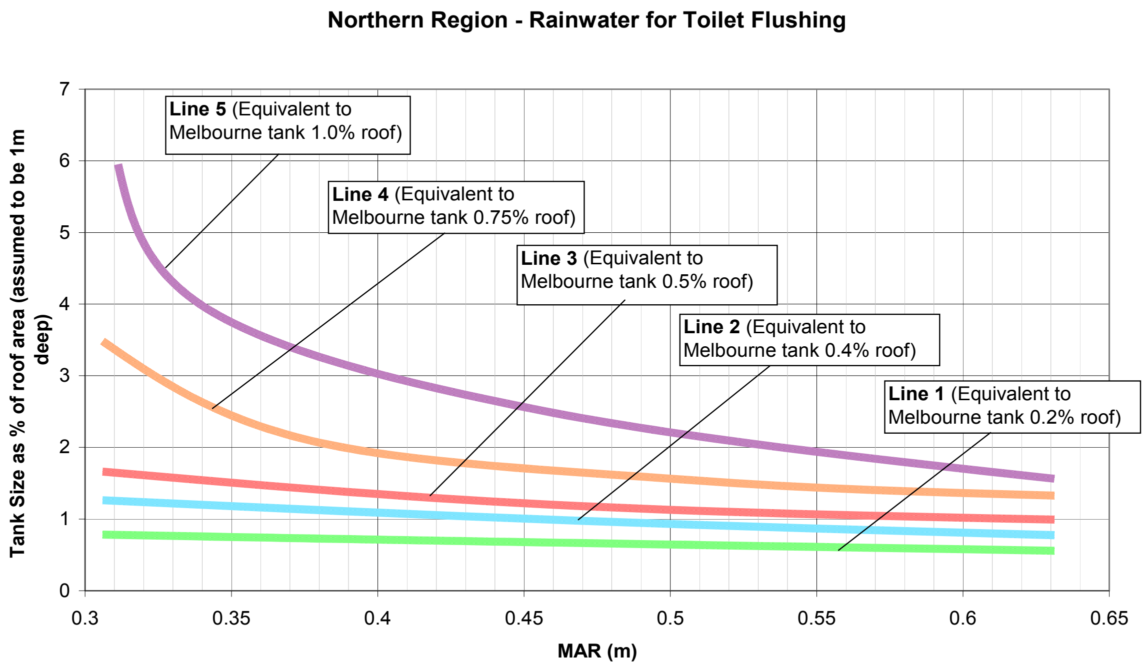

Figure C.7.1 Northern region tank sizing curves.

C.7.2 Central region

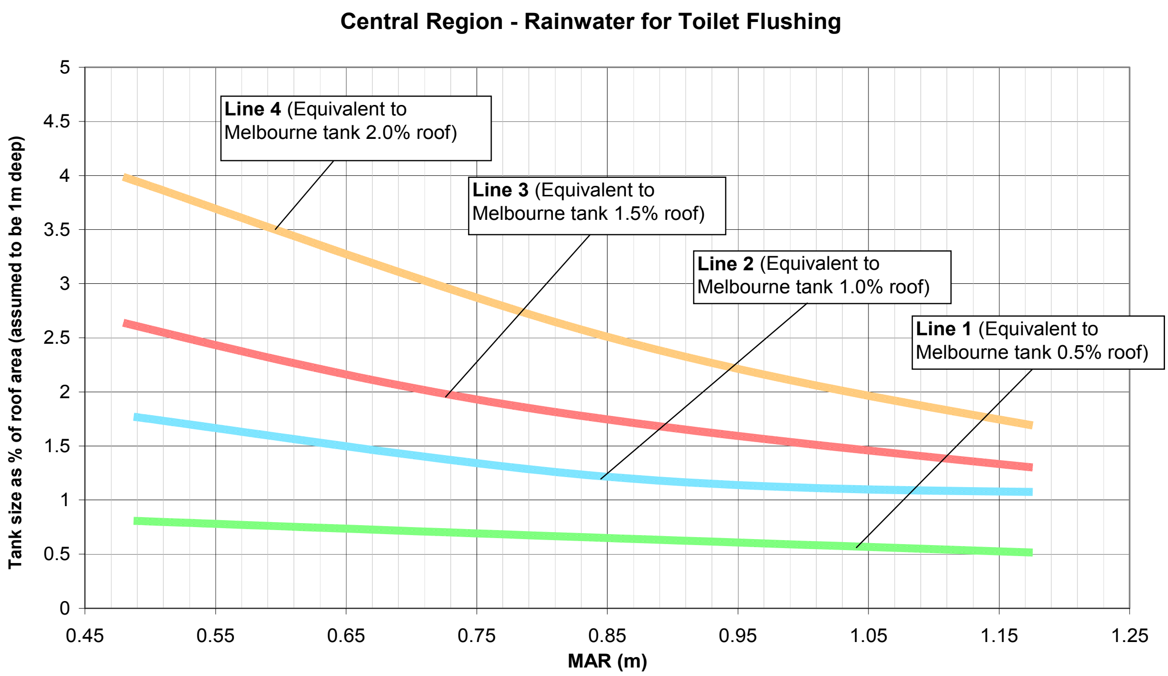

Figure C.7.2 Central region tank sizing curves.

C.7.3 Southern region

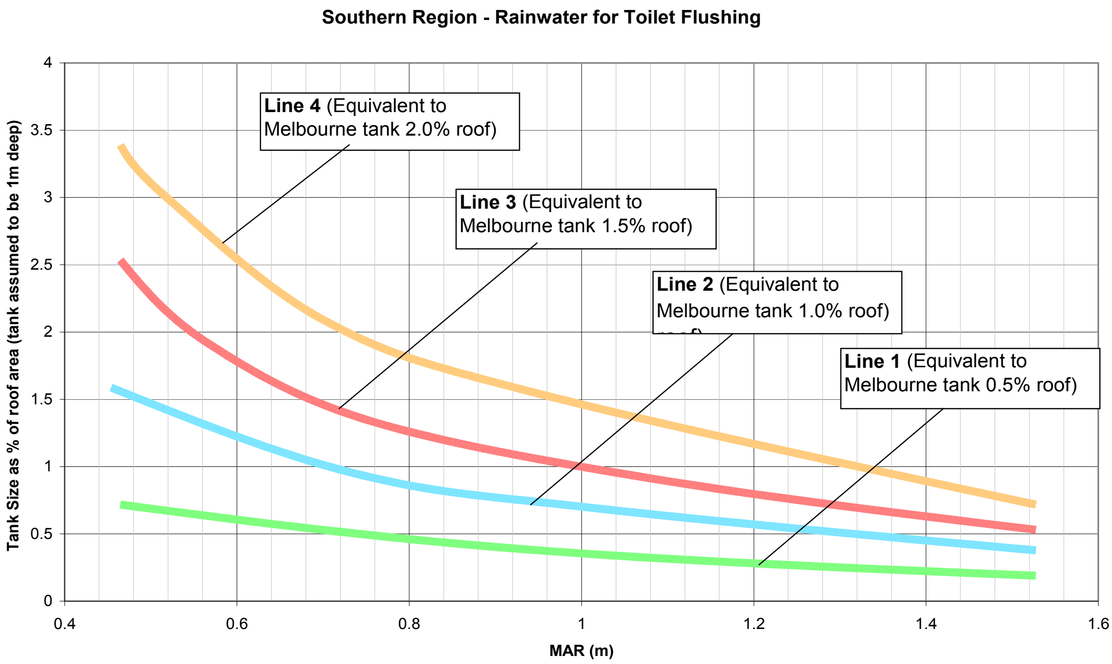

Figure C.7.3 Southern region tank sizing curves.

C.8 Example of the use of tank sizing equations

A family of three who live near Warrnambool Airport wish to collect rainwater to supplement at least 80% of their toilet flushing.

The MAR at Warrnambool Airport is 903 mm (i.e. 0.903 m). The area of roof available to collect water is about 125 m^2 (the occupancy density is therefore 2.4 people/100 m^2 roof).

1 Determine what size tank at the reference site will achieve an 80% saving in toilet water used (i.e. 80% reliability). If the following inputs are applied to the curve in Figure C.4.1 at:

- 2.4 people/100 m^2 of roof
- 80% reliability

interpolation from the curve gives a required tank size of 0.7% of the roof area (and 1 m deep). Therefore, a tank size of $0.007 \times 125 \times 1.0 = 0.9$ kL is required for the reference site.

2 Adjust the required tank size from the reference site to Warrnambool. If the values in Figure C.7.3 (Southern region) are applied with a tank size of 0.7% of roof area and MAR of 0.90 m, interpolation between Lines 1 and 2 with a rainfall of 0.90 m gives a tank size of 0.6% of roof area (1 m deep).

Therefore, required tank size $= 0.006 \times 125 \times 1.0 = 0.75$ kL.

By way of comparison, if the family were in Horsham (450 mm MAR) the required tank size is calculated using Figure C.7.2 and is equivalent to 1.25% of roof area (1 m deep) which equates to a tank size of 1.6 kL.

C.9 Summary

A simple procedure for sizing rainwater tanks is proposed here. This procedure is based on defining three tank sizing regions within Victoria. More details of its application are presented in Chapter 12 of this Manual..

Three regional curves for estimating tank sizes are the result of pooling modelling results for relevant reference pluviographic stations (45 stations). To ensure a systematic application of the procedures, estimates of tank sizes should exclusively use the regional curves provided rather than values derived from a single station, irrespective of the proximity of the site in question to a reference pluviographic station. This would avoid situations where practitioners get to choose between the adjustment factor computed from the regional approach and that derived for the reference pluviographic station of close proximity to the site in question.

C.10 References

Coomes Consulting Group. (2002). Integrated Water Management Epping North Report. Report for Urban and Regional Land Corporation

Water Resources Strategy Committee. (2001). Water Resources Strategy for the Melbourne Area, 2001, Discussion Starter: Stage 1 in Developing a Water Resource Strategy for the Greater Melbourne Area.