



Stringybark Creek Reliability of Supply Assessment

Prepared for Melbourne Water

Final

August 2002

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Contents

1. Introduction	1
1.1 Background.....	1
1.2 Purpose	1
1.3 Structure	1
2. The Stringybark Creek Catchment	2
2.1 Catchment Description.....	2
2.2 Climate and Hydrology.....	2
2.3 Water Use.....	4
3. Catchment Modelling.....	5
3.1 Model Description	5
3.2 Model Development	8
4. Security of Supply	10
4.1 Scenarios.....	10
4.2 Results.....	12
4.2.1 Scenario 1	12
4.2.2 Scenario 2	14
4.2.3 Scenario 3	15
4.2.4 Scenario 4	18
4.2.5 Drought Response Plan	22
4.3 Flow Comparison	24
4.4 Summary.....	31
5. Data Collation and Preparation.....	32
5.1 Rainfall.....	32
5.2 Evaporation.....	33
5.3 Streamflow	34
5.4 Diversion Licenses	35
5.5 Farm Dam Volumes	36
6. Derivation of Demands.....	37
6.1 Direct Irrigation.....	37
6.2 Onstream and Offstream Dams.....	39
6.3 Domestic and Stock	40
6.4 Farm Dams	40
6.5 Summary.....	40
7. Derivation of Inflows and Losses.....	41
7.1 Time-lag and Losses.....	41
7.2 Trend Analysis	41
7.3 Infilling and Extension	43
7.4 Transposition	47
8. References	50
Appendices.....	51

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1. Introduction

1.1 Background

Melbourne Water has the responsibility for developing Streamflow Management Plans (SFMPs) under the State Environment Protection Policy of Victoria. Streamflow Management Plans provide a framework by which water can be shared between water users and the environment.

A Streamflow Management Plan is currently being developed for the Stringybark Creek catchment. This creek is located in the Yarra Valley, joining Olinda Creek around Yering just upstream of its confluence with the Yarra River. The catchment is unregulated, and streamflows are impacted on by licensed diversions and the effect of farm dams. Use of water in the catchment has reached a point where it may be stressing environmental health.

1.2 Purpose

To help the Working Group develop the Streamflow Management Plan, Sinclair Knight Merz was engaged to develop a hydrological model of the Stringybark Creek catchment. The model will be used to order the thought processes needed to develop an SFMP. It will assist the Working Group make judgements about flow sharing options, based on the impact to river flows and on the security of supply to private diverters.

This report documents the first stage of a two-stage process. Stage 1 is the development of the hydrological model and some initial scenario modelling. Stage 2 will involve further scenario modelling, as devised by the Working Group during negotiations.

1.3 Structure

The sections in this report have been arranged into two groups to cater for various audiences:

- ❑ Sections 1 to 4 present the findings in a non-technical format. They are aimed at members of the Stringybark Creek Catchment community without expertise in hydrological analysis.
- ❑ Sections 5 to 7 contain a technical description of the methodology used. They provide a transparent and defensible description of how the outcomes were derived.

2. The Stringybark Creek Catchment

2.1 Catchment Description

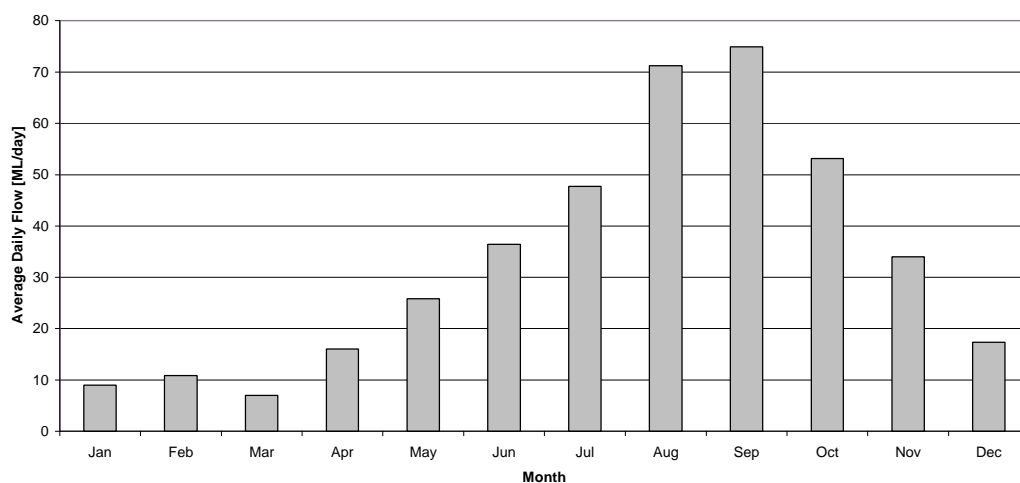
Stringybark Creek begins near Silvan in the Dandenong Ranges. The stream generally flows north, passing through the townships of Wandin North and Gruyere, before turning northwest through the township of Yering. Stringybark Creek joins with Olinda Creek around Yering just upstream of its confluence with the Yarra River. The catchment is unregulated. It provides water for irrigators and stock and domestic users, either through direct diversion or water harvesting in farm dams.

The Stringybark Creek catchment has been divided into five subcatchments for this study. This has been based on the sites at which minimum environmental flows have been recommended (Close and Koster, 2001), and the two main tributaries Little Stringybark Creek and Log Creek. The total catchment has an area of approximately 76 km². Little Stringybark Creek comprises approximately 8.5 km², and Log Creek comprises approximately 16 km². A map of the catchment and subcatchments is shown in Figure 2-2.

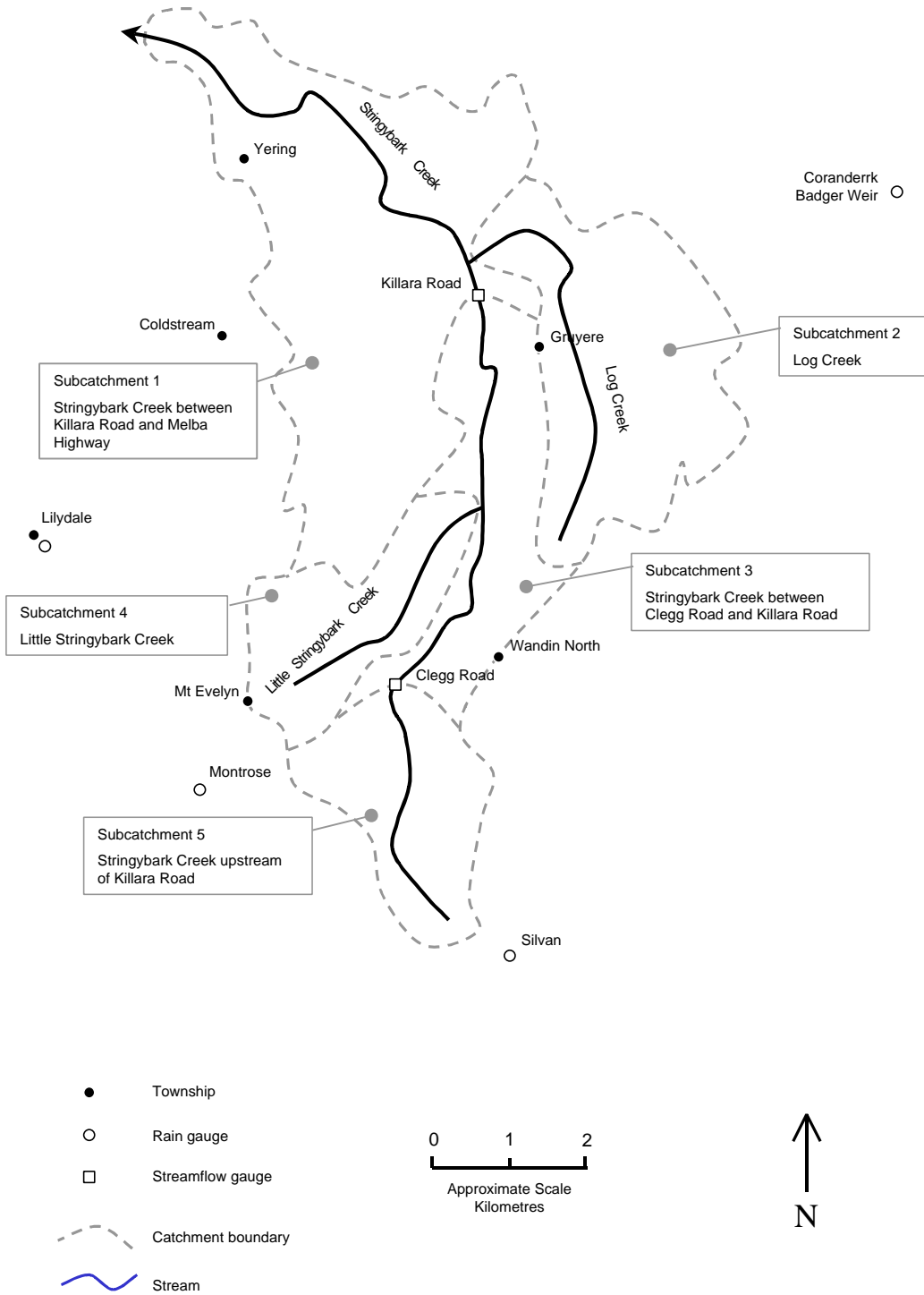
2.2 Climate and Hydrology

The Stringybark Creek catchment has a temperate climate. Average monthly rainfall varies from as low as 54 mm in February to 108 mm in August, with the annual average rainfall being approximately 840 mm. Average evaporation varies from as low as 38 mm in June to 172 mm in January. The annual average evaporation is approximately 1184 mm.

Streamflows are highly seasonal. Average flows are lowest in March at 7 ML/day, and highest in September at 75 ML/day. The average annual flow at the catchment outlet is approximately 12,300 ML/annum. Average daily flows for each month are shown in Figure 2-1.



■ **Figure 2-1 Average daily flows for each month at the catchment outlet.**



■ Figure 2-2 Stringybark Creek catchment.

2.3 Water Use

The majority of water use in the Stringybark Creek catchment is in the upper reaches above Clegg Road. The most common crops grown here are vegetables, orchards, flowers, viticulture and trees. Limited irrigation occurs within the Little Stringybark Creek catchment. Within the Log Creek catchment most of the land is used for viticulture. Downstream of Gruyere cattle grazing is most common, with some viticulture and vegetables.

Farming in the catchment relies on run-of-river flows during summer, onstream and offstream storages, and farm dams. Farm dams are those filled by rainfall runoff rather than water pumped directly from the creek. They comprise small dams used for domestic and stock, as well as larger dams used for irrigation. The total volume of farm dams has been estimated from aerial photographs (refer Section 5.5). A summary of annual licences and estimated farm dam volumes is shown in Table 2-1. Note that where there is more than one usage type for a licence, the licensed volume has been distributed equally among the usage types.

■ **Table 2-1 Annual licences and estimated farm dam volumes in the Stringybark Creek catchment.**

Subcatchment	Licence Volumes (ML)				Farm Dam Volumes (ML)
	Direct Irrigation	Domestic and Stock	Onstream Dam Filling	Offstream Dam Filling	
Stringybark Ck between Killara Rd and Melba Hwy	0	2	0	593	489
Log Creek	0	0	0	194	603
Stringybark Ck between Clegg Rd and Killara Rd	24 ⁽¹⁾	4	0	2	331
Little Stringybark Ck	0	0	0	12	245
Stringybark Ck above Clegg Rd	162 ⁽²⁾	8	44	27	61

Notes:

- (1) Includes 2 ML of licences not currently used.
- (2) Includes 17 ML of licences not currently used.

3. Catchment Modelling

Streamflows are measured at two locations along Stringybark Creek – Clegg Road and Killara Road. These stations are shown in Figure 2-2. These, along with historic diversions and farm dam impacts have been used to build a model of streamflows through the rest of the catchment. This model can be used to test different ways of allocating and managing water licences (refer Section 4). Changes in managing licences can be made in the model and the effect on the streamflows observed.

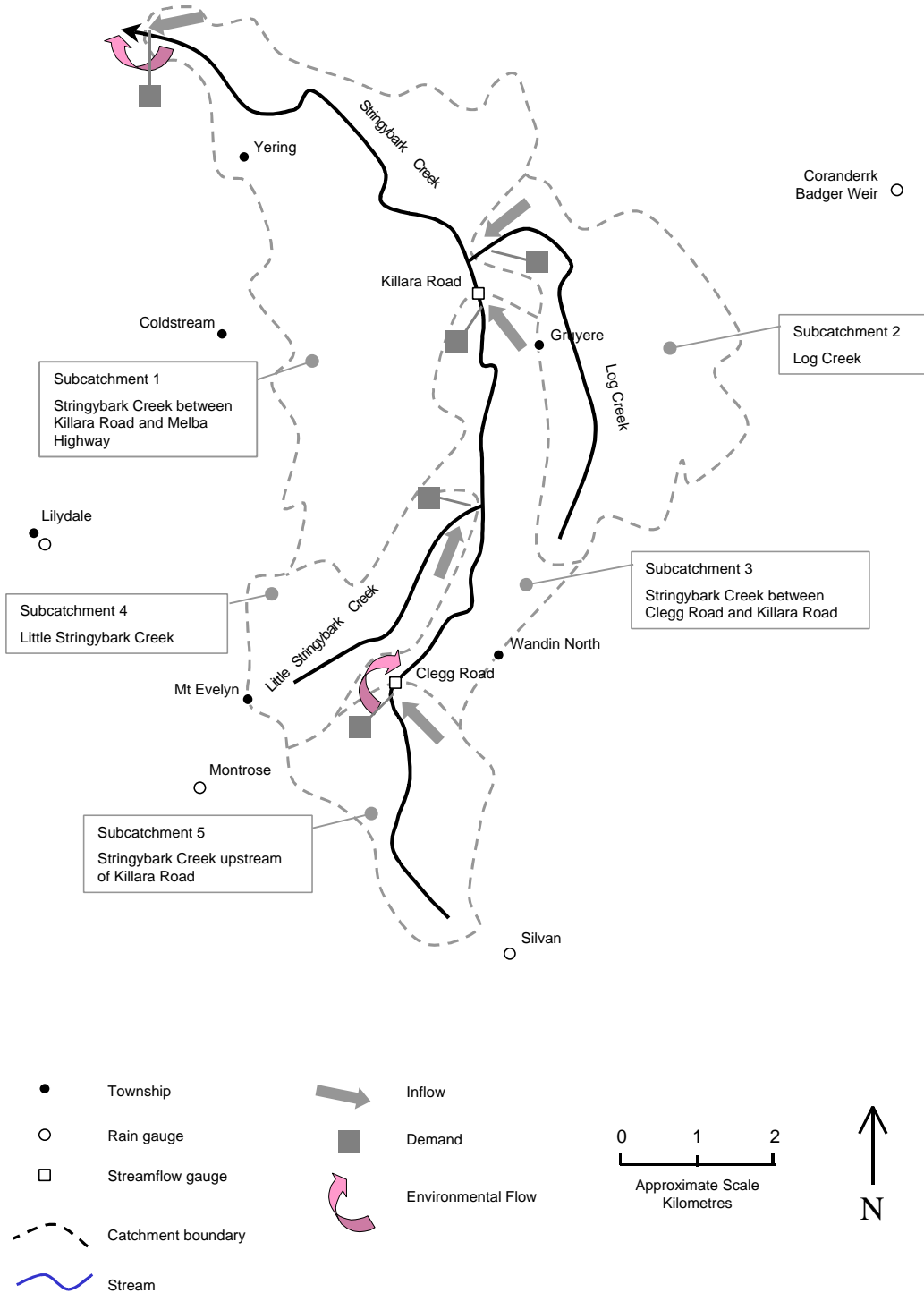
The following sections provide a description of the model and its development.

3.1 Model Description

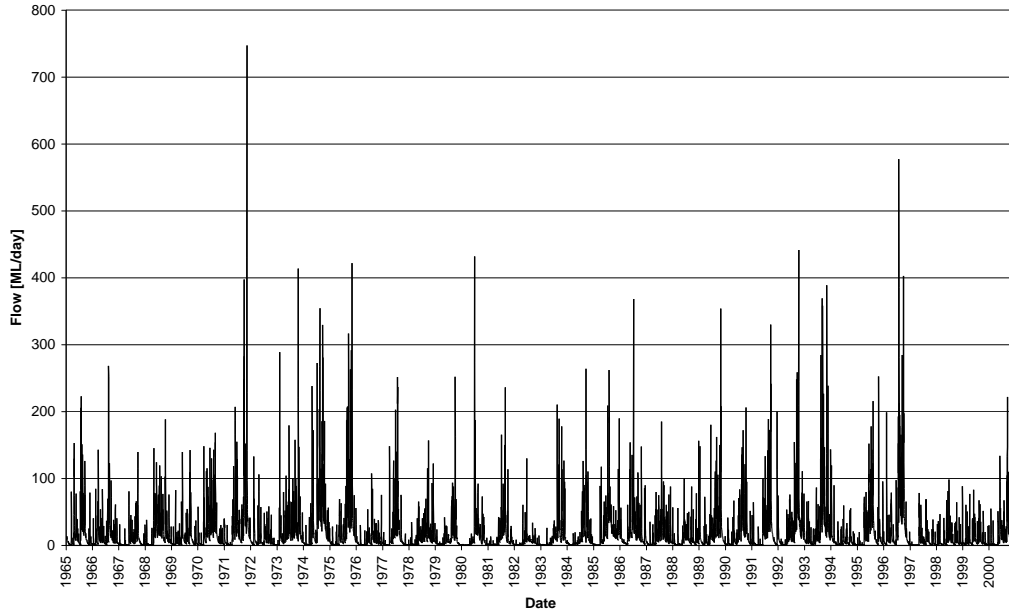
The hydrological model of Stringybark Creek was developed using REALM (Resource Allocation Model), a software package designed for modelling river systems. The model has a number of features:

- ❑ The model represents the catchment as five regions. This means that it is possible to specify different inflows and demands in different subcatchments, as shown in Figure 3-1.
- ❑ The model runs from 1965 to 2000, covering a range of climatic conditions. The results are therefore not biased by a limited number of wet or dry years.
- ❑ The model accounts for different types of water use: (1) Direct irrigation diversions, (2) Domestic and stock, (3) Onstream winterfill dams, (4) Offstream winterfill dams, and (5) Farm dams. Note that the diverter groups shown in Figure 3-1 have been simplified into one demand centre.
- ❑ The demands change from year to year based on how wet or dry it was in each year. The demands can be used to determine reliability of supply.
- ❑ The model can produce results for a constant level of development over the period 1965 to 2000. This means that results are not affected by historic changes in the level of development in the catchment. It enables us to test how different levels of development affect streamflows in the catchment.

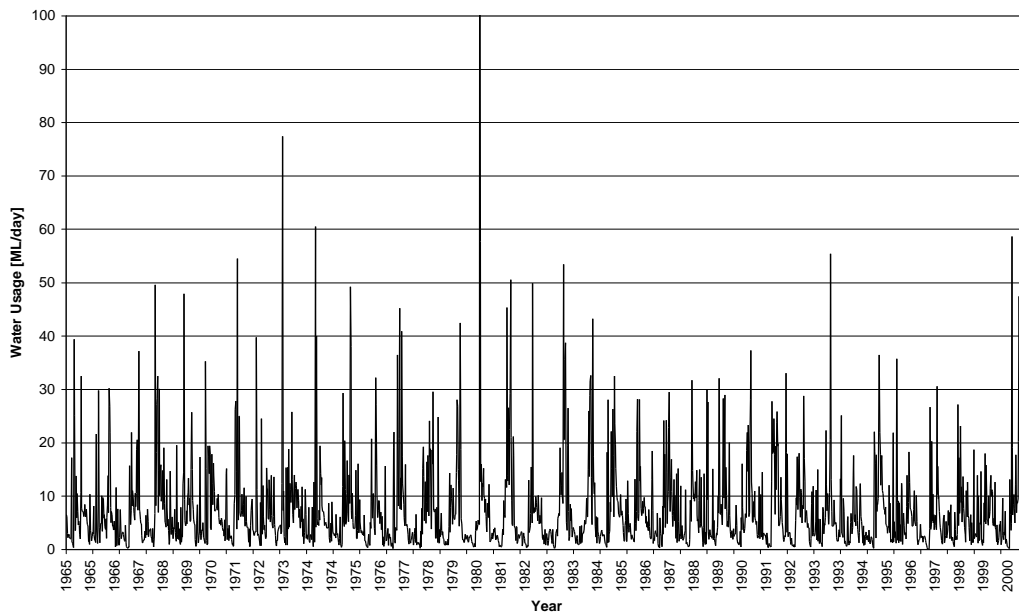
Example streamflows and demands are shown in Figure 3-2 and Figure 3-3.



■ Figure 3-1 Inflows and demands as represented in the Stringybark Creek REALM model.



■ Figure 3-2 Estimated streamflows at Killara Road assuming current level of development conditions from 1965 to 2000.



■ Figure 3-3 Estimated demands (all types) in the Stringybark Creek catchment assuming current level of development conditions from 1965 to 2000.

3.2 Model Development

Several inputs and assumptions were needed to develop the hydrological model. These are summarised below, and described more fully in Sections 5 to 7.

Climatic Data

Rainfall and evaporation data was used to predict streamflows at times when no streamflow gaugings were available. Rainfall and evaporation data was also used to estimate irrigation demands. To prepare the data for use, gauged rainfall and evaporation records were firstly infilled and extended by making comparisons with records at nearby stations. Secondly, the data was checked for the presence of any unexplained trends. Thirdly, the variation in rainfall and evaporation across the catchment was estimated from nearby gauging stations. The main rainfall stations used for this study included those at Lilydale, Coranderrk Badger Weir, Silvan and Montrose.

Additional information on the derivation of climate inputs for the modelling is provided in Section 5.

Water Demands

Water demands were required for each subcatchment. No metered water use data was available, however private diverter licence volumes were known. Licence volumes formed the basis for estimating annual water usage. This assumes the entire licence volume was used. Climatic data was used to estimate seasonal variability.

Water demands were estimated at different levels of development for this project:

- ❑ Historic level of development demands were estimated over the period that gauged flows at Killara Road were available (1979 to 1987). They were based on licences which were active at that time. Historic demands were used to check the calibration of the hydrological model.
- ❑ Current level of development demands were based on those licences which were active in July 2000. Current level of development demands do not account for sleeper licences. They were estimated over the whole model period (1965 to 2000) to determine the current security of supply.
- ❑ Full level of development demands were based on all licenses current in July 2000. Full level of development demands account for both active and sleeper licences. They were estimated over the whole model period (1965 to 2000) to determine the security of supply at full levels of development.

Additional information on the derivation of demands for the modelling is provided in Section 6.

Streamflows

Gauged streamflows at Killara Road were available from 1979 to 1987, but were required to cover the period 1965 to 2000. An analysis was undertaken to determine the relationship between rainfall, evaporation and streamflow using the available gauged data. The relationship was then used to predict streamflows when no gauged streamflow data was available.

Streamflows were also needed to be estimated at the outlet of each subcatchment. A comparison was made between streamflows at the recently installed gauge at Clegg Road in 1999 and 2000, to the predicted streamflows at Killara Road over the same period. The increase in flow between these two locations was then used to predict streamflows at points between these two gauges, and also downstream of Killara Road.

Additional information on the derivation of streamflows is provided in Section 7.

4. Security of Supply

4.1 Scenarios

The Stringybark Creek REALM model was used to assess the security of supply to private diverters for direct irrigation and domestic and stock use. Several scenarios were investigated for this project, which looked at the security of supply at different levels of development, both with and without environmental passing flows in place. The three different demand levels which have been considered (also referred to in Section 3.2) are:

- ❑ Historic level of development demands, estimated over the period that gauged flows at Killara Road were available (1979 to 1987). They were based on licences which were active at that time. Historic demands were used to check the calibration of the hydrological model.
- ❑ Current level of development demands, based on those licences which were active in July 2000. Current level of development demands do not account for sleeper licences. They were estimated over the whole model period (1965 to 2000) to determine the current security of supply.
- ❑ Full level of development demands, based on all licenses current in July 2000. Full level of development demands account for both active and sleeper licences. They were estimated over the whole model period (1965 to 2000) to determine the security of supply at full levels of development.

Table 4-1 contains an outline of the scenarios which have been modelled. The environmental flows implemented in the model (after Close and Koster, 2001) for Scenario 4 are shown in Table 4-2.

■ **Table 4-1 Stringybark Creek REALM scenarios.**

Scenario	Purpose of Scenario	L.O.D. ¹ Demands	Passing Environmental Flows?
1	Calibration of the Stringybark Creek REALM model based on historic catchment conditions.	Historic	No
2	To test reliability of supply to diverters based on the current catchment conditions.	Current	No
3	To test the reliability of supply to diverters based on estimated full level of development conditions.	Full	No
4	To test the reliability of supply to diverters based on estimated full level of development conditions with environmental flows implemented.	Full	Yes

Notes: (1) L.O.D. stands for Level of Development

■ **Table 4-2 Environmental flow recommendations for Stringybark Creek (after Close and Koster, 2001).**

Location	Environmental Flow Recommendation (ML/day)
Clegg Rd, Mt Evelyn	1.5
Melba Highway	4.5

A preliminary assessment was also made of the impact of restrictions specified in the Drought Response Plan (Yarra Catchment) Private Diverters (Melbourne Water, 2001). The DRP currently applies to all water users in the Stringybark Creek catchment. The DRP was not included in the model because its trigger is a function of flow in the Yarra River, which is outside the Stringybark Creek catchment boundary. The impact of the DRP is discussed in Section 4.2.5.

The results of the scenario modelling are presented in the following sections. The results refer to a number of terms which are described below:

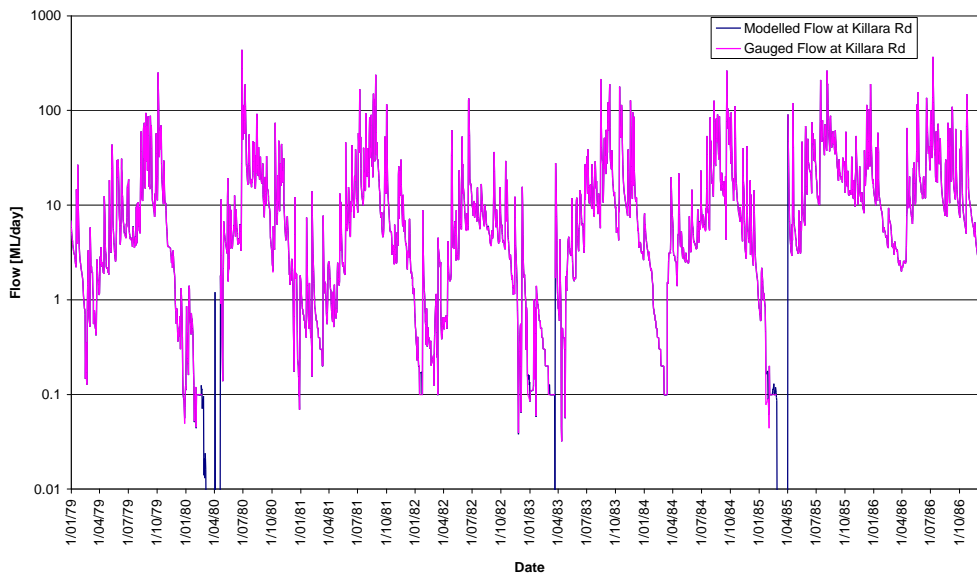
- ❑ *Unrestricted demand* – The demand that would be met given an unlimited supply of water.
- ❑ *Demand met* – The demand that can be met based on how much water is available. If there are environmental flow provisions in a catchment, the water available to meet demands is determined after environmental flows have been met.
- ❑ *Shortfall* – The difference between the demand met and the unrestricted demand.

4.2 Results

4.2.1 Scenario 1

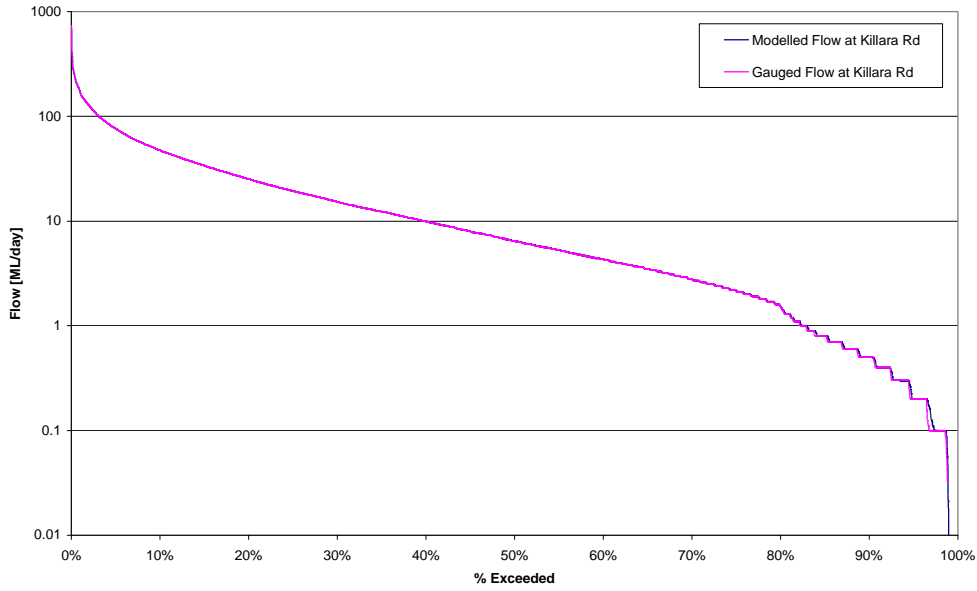
Calibration

The model was calibrated to gauged flows at two points in the Stringybark Creek catchment. Outflows from the upper Stringybark subcatchment correspond to the Clegg Road streamflow gauge, and outflows from the middle Stringybark correspond to the Killara Road streamflow gauge (Figure 3-1). A comparison of the gauged and modelled flows at these points over the concurrent period of record shows very good results (Figure 4-1 to Figure 4-3). The differences between gauged and modelled flows at Clegg Road are because the inflows above Clegg Road have been predicted from flows at Killara Road which has slightly different flow characteristics.

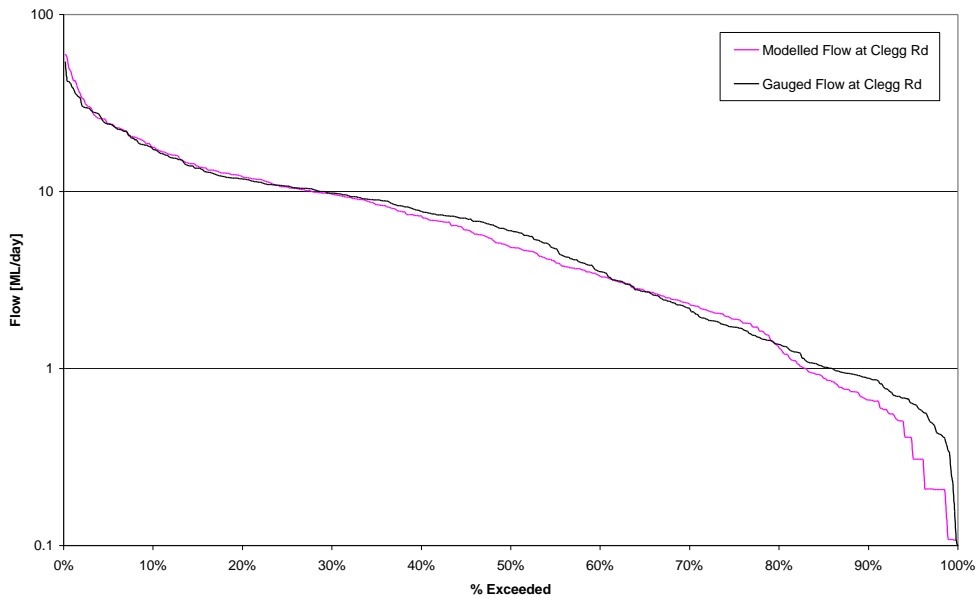


NB: flow scale is shown in the logarithmic domain

■ **Figure 4-1 Time series of gauged and modelled flows at Killara Road.**



■ Figure 4-2 Flow duration curves of gauged and modelled flows at Killara Road.



■ Figure 4-3 Flow duration curves of gauged and modelled flows at Clegg Road.

4.2.2 Scenario 2

Current level of development (no environmental flows)

Scenario 2 presents the reliability of supply at current levels of development with no environmental flows. The results for Scenario 2 are shown in Table 4-3, which provides the number and duration of shortfalls (when demands cannot be fully met) in each Stringybark Creek subcatchment. The results show that unrestricted demands in all subcatchments can be met in all years (ie. there are no demand shortfalls). In Little Stringybark Creek and Log Creek this is also the case because there are no summer diversions.

■ **Table 4-3 Number and duration of shortfalls by subcatchment under Scenario 2**

Subcatchment	Total number of years of shortfalls	Average shortfall duration (weeks)	Range in shortfall durations (weeks)
Upper Stringybark	0	0	N/A
Middle Stringybark	0	0	N/A
Lower Stringybark	0	0	N/A

Note: There are no summer diversions in Little Stringybark Creek and Log Creek.

4.2.3 Scenario 3

Full level of development (no environmental flows)

Scenario 3 demonstrates the impact of moving from current to full levels of development. The results for Scenario 3 are shown in Table 4-4, Figure 4-4 and Figure 4-5.

Table 4-4 provides the number and duration of shortfalls in each subcatchment. Under Scenario 3, the unrestricted demand in the upper and middle Stringybark subcatchments cannot be fully met in 13 and 10 years respectively. There are no shortfalls in the lower Stringybark Creek catchment because the direct diverter demands are very small there (refer Table 2-1).

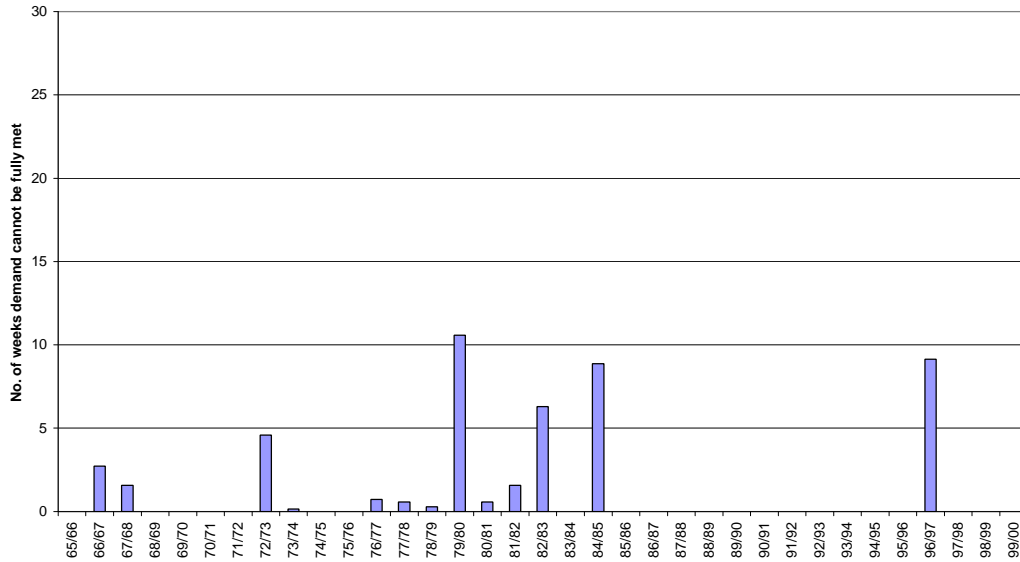
■ **Table 4-4 Number and duration of shortfalls by subcatchment under Scenario 3**

Subcatchment	Total number of years when demands cannot be fully met	Average shortfall duration (weeks)	Range in shortfall durations (weeks)
Upper Stringybark	13	4	1 to 11
Middle Stringybark	10	2	1 to 6
Lower Stringybark	0	0	N/A

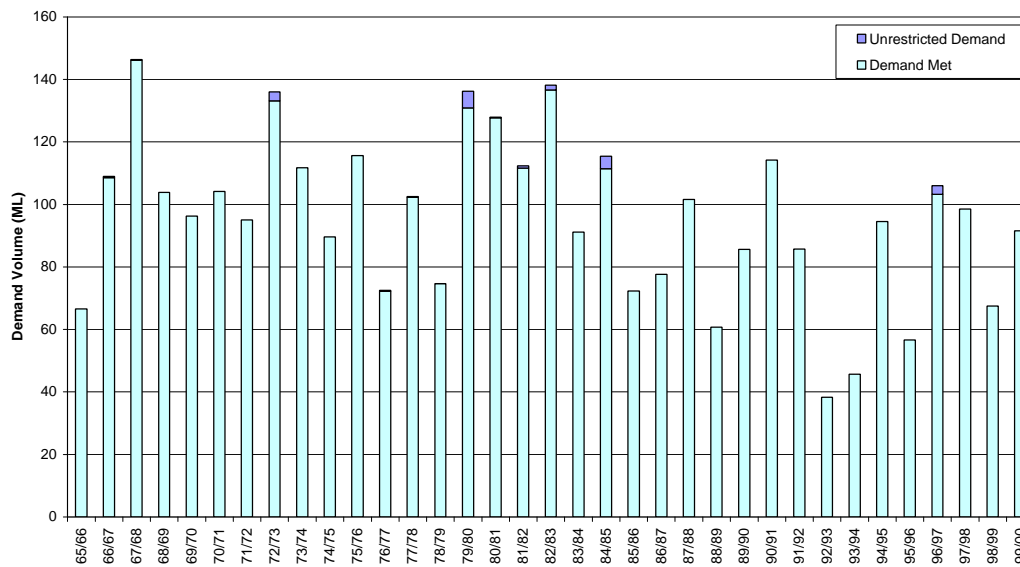
Note: There are no summer diversions in Little Stringybark Creek and Log Creek.

Figure 4-4 and Figure 4-6 illustrate the number of weeks in each year where demands cannot be fully met. Figure 4-5 and Figure 4-7 compare the unrestricted demands in each year to the demand met.

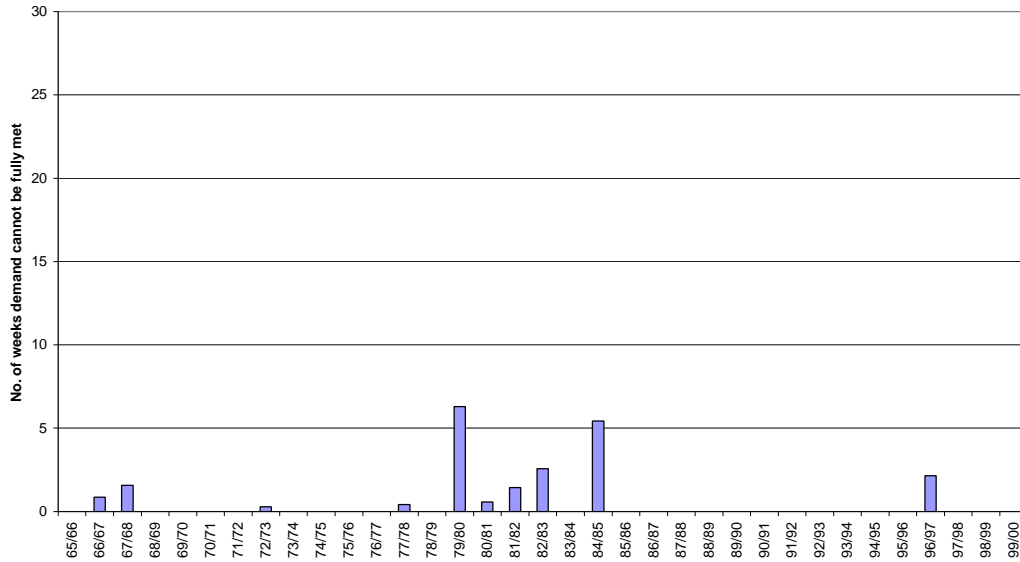
Compared to Scenario 2, the results for Scenario 3 show a significant increase in the number of years in which shortfalls occur, however the shortfall volume is small in relation to the total demand. This suggests that demand reduction strategies could eliminate these shortfalls. Note that the reliability of supply for diverters in the lower Stringybark subcatchment is not affected by the increase from current to full level of development.



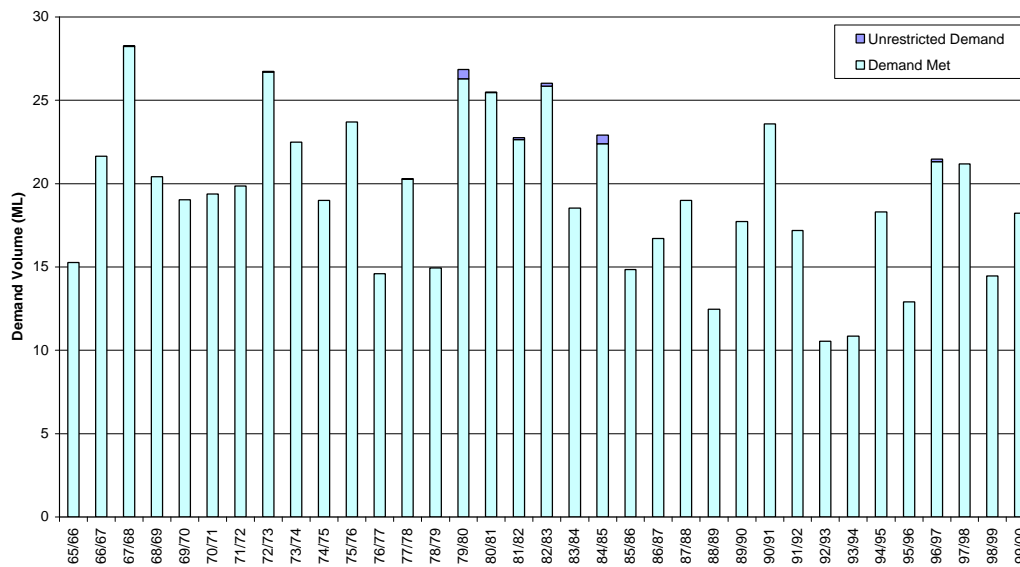
■ Figure 4-4 Number of weeks where demand cannot be fully met in the upper Stringybark subcatchment under Scenario 3



■ Figure 4-5 A comparison of the unrestricted demand and the demand met in the upper Stringybark subcatchment under Scenario 3



■ Figure 4-6 Number of weeks where demand cannot be fully met in the middle Stringybark subcatchment under Scenario 3



■ Figure 4-7 A comparison of the unrestricted demand and the demand met in the middle Stringybark subcatchment under Scenario 3

4.2.4 Scenario 4

Full level of development (with environmental flows implemented)

Scenario 4 demonstrates the impact of implementing environmental flows at full levels of development. The results for Scenario 4 are shown in Table 4-5, and Figure 4-8 to Figure 4-13.

Table 4-5 provides the number and duration of shortfalls in each subcatchment. Under Scenario 4, the unrestricted demands in the upper, middle and lower Stringybark subcatchments cannot be met in all years (ie. there is a shortfall in demands).

■ **Table 4-5 Number and duration of shortfalls by subcatchment under Scenario 4**

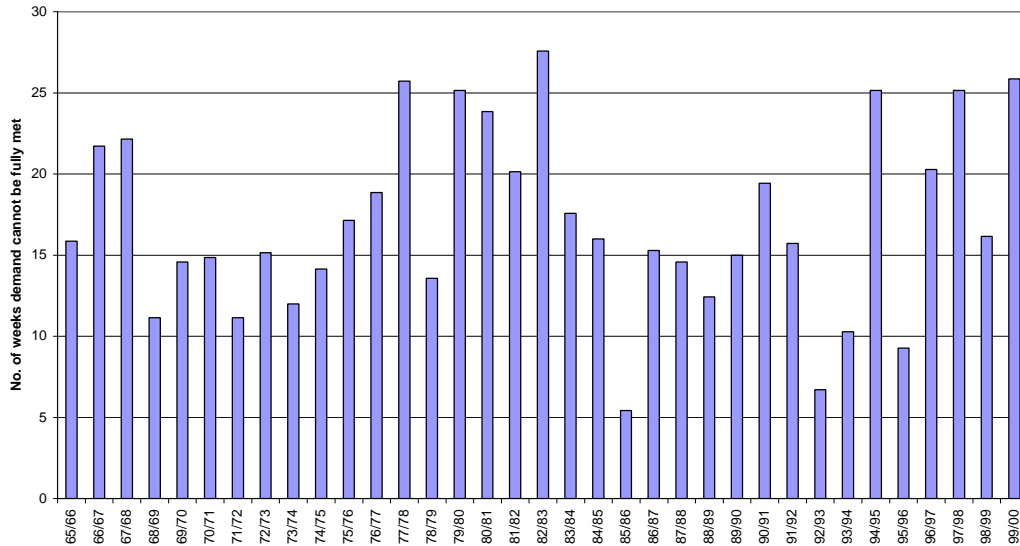
Subcatchment	Total number of years demand cannot be fully met	Average shortfall duration (weeks)	Range in shortfall durations (weeks)
Upper Stringybark	35	17	1 to 28
Middle Stringybark	35	16	1 to 27
Lower Stringybark	35	16	1 to 27

Note: There are no summer diversions in Little Stringybark Creek and Log Creek.

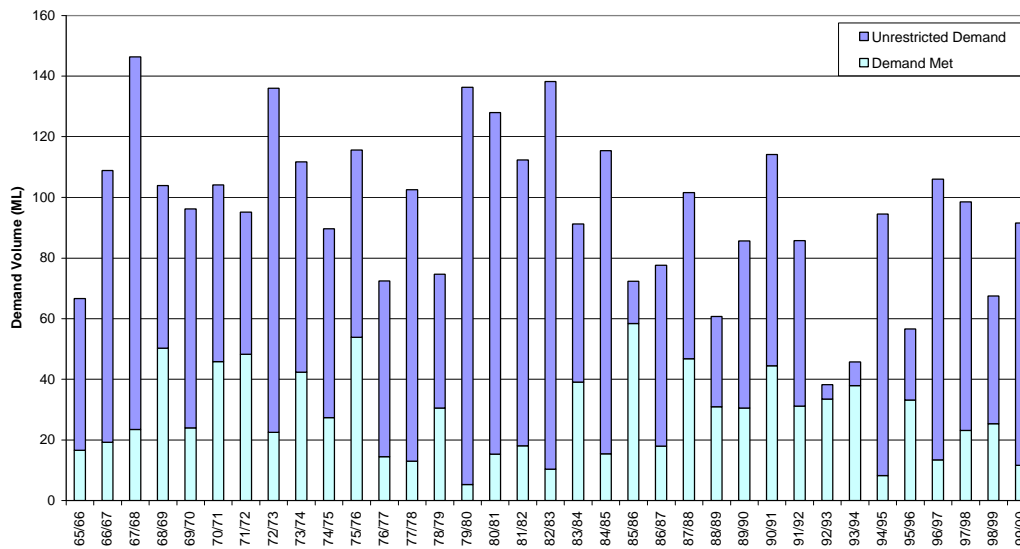
Figure 4-8, Figure 4-10 and Figure 4-12 illustrate the number of weeks in each year where demands cannot be fully met. Figure 4-9, Figure 4-11 and Figure 4-13 compare the unrestricted demands in each year to the demand met. The results show that with the introduction of environmental flow recommendations under full development conditions:

- ❑ In the upper Stringybark subcatchment demands cannot be fully met in all years between 1965 and 2000. The demand met in many of these years is significantly lower than the unrestricted demand.
- ❑ In the middle Stringybark subcatchment demands cannot be fully met in all years between 1965 and 2000. Again the demand met in most of these years is substantially lower than the unrestricted demand.
- ❑ In the lower Stringybark subcatchment demands cannot be fully met in all years between 1965 and 2000. The demand met in most of these years is closer to the unrestricted demand.

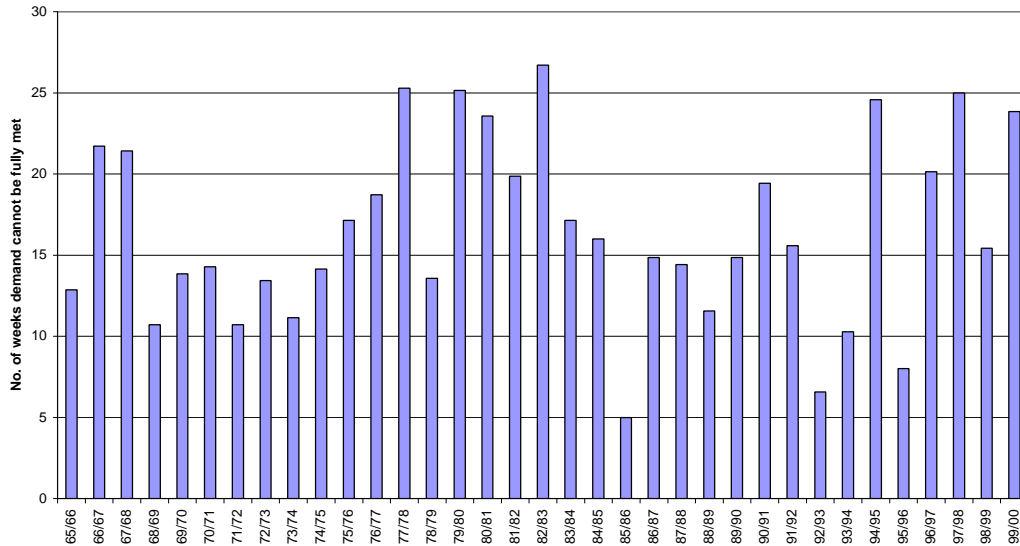
By comparison with Scenarios 2 and 3, the results for Scenario 4 show a significant increase in the number of years in which demands cannot be fully met, and the shortfall volumes are large in relation to the total demand. This is because the streamflows drop below the environmental flows of 1.5 ML/day at Clegg Road and 4.5 ML/day at Melba Highway in each year. Referring to Section 4.3, streamflows are less than the environmental flow (ie the environmental flow cannot be met) for 15% of the time at Clegg Road, and 28% of the time at Melba Highway. This comparison also demonstrates that the reliability of supply for diverters upstream of Clegg Road is more strongly influence by the environmental flow at Melba Highway than the environmental flow at Clegg Road.



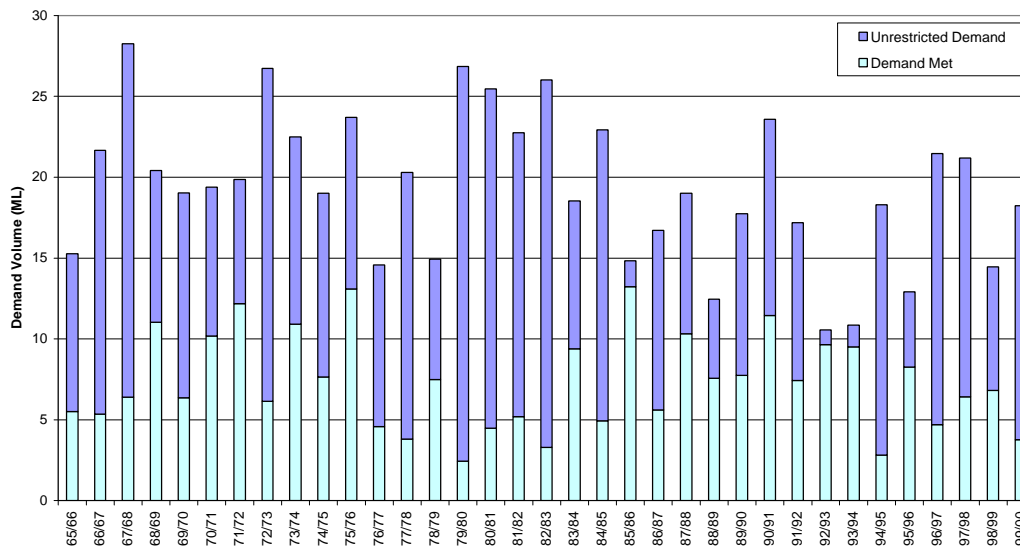
■ Figure 4-8 Number of weeks where demand cannot be fully met in the Upper Stringybark subcatchment under Scenario 4



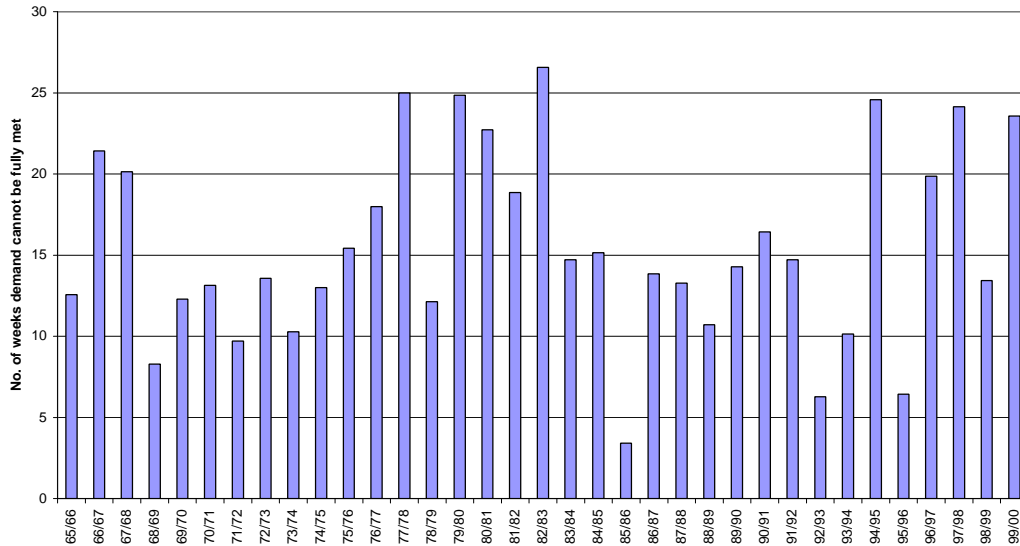
■ Figure 4-9 A comparison of the unrestricted demand and the demand met in the Upper Stringybark subcatchment under Scenario 4



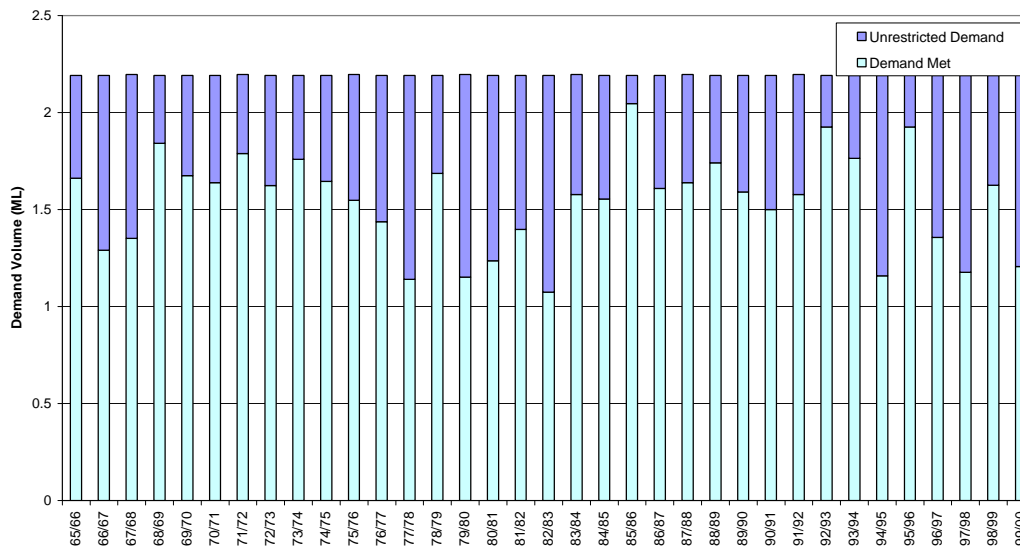
■ Figure 4-10 Number of weeks where demands cannot be fully met in the Middle Stringybark subcatchment under Scenario 4



■ Figure 4-11 A comparison of the unrestricted demand and the demand met in the Middle Stringybark subcatchment under Scenario 4



■ Figure 4-12 Number of weeks where demands cannot be fully met in the Lower Stringybark subcatchment under Scenario 4



■ Figure 4-13 A comparison of the unrestricted demand and the demand met in the Lower Stringybark subcatchment under Scenario 4

4.2.5 Drought Response Plan

The *Drought Response Plan (Yarra Catchment) Private Diversions* (Melbourne Water, 2001) provides three restriction levels for private diverters based on flows in the Yarra River at Warrandyte (Table 4-6). Since implementation of the Drought Response Plan (DRP) in 1998, Level 2 restrictions have been enacted four times (*Pers comm*, Melbourne Water).

■ **Table 4-6 Private diverter restrictions (after Melbourne Water, 2001)**

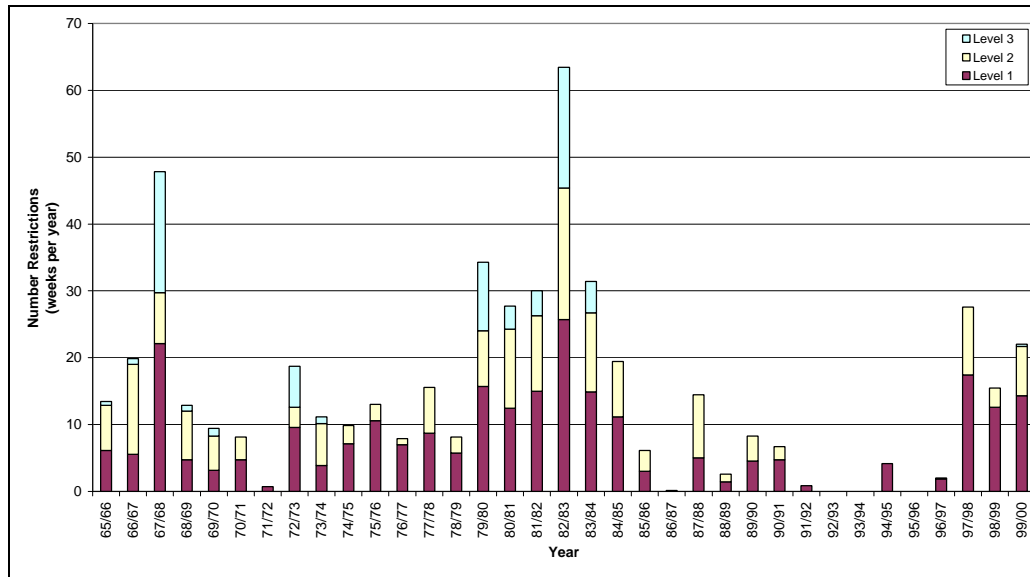
Restriction Level	Warrandyte Flow (7 day rolling average, ML/day)	Summary of Restrictions Specified in DRP (please see the DRP for the complete descriptions)
1	375	Diverters to implement drought contingency plans or otherwise conserve water.
2	300	<p><u>Direct Diverters:</u> Pumping limited to a maximum of 8 hours/day, with diverters split into two groups taking water on alternate days of the week. Commercial flower growers and nurseries are able to take water every day over a four hour period. Golf Courses must reduce usage by 30% of normal usage levels.</p> <p><u>Direct Diverters – onstream:</u> No restrictions if water held >50% entitlement. If water held 20-50% entitlement, use is allowed provided environmental flow maintained. If water held <20% entitlement then Direct Diverter restrictions apply.</p> <p><u>Domestic and Stock:</u> Diversions are banned where alternative supplies exist.</p> <p><u>Winterfill:</u> No restrictions provided water is drawn from reserves of stored water.</p> <p><u>Industrial:</u> Usage must be reduced by 20% of normal usage levels.</p>
3	200	<p><u>Direct Diverters:</u> Pumping limited to a maximum of 2 hours/day for annual crops and 4 hours/day for perennial crops, with diverters split into two groups taking water on alternate days of the week. Commercial flower growers and nurseries are able to take water every day over for a period not exceeding one hour. Golf Courses must reduce usage by 80% of normal usage levels.</p> <p><u>Direct Diverters – onstream:</u> No restrictions if water held >50% entitlement. If water held 20-50% entitlement, use is allowed provided environmental flow maintained. If water held <20% entitlement then Direct Diverter restrictions apply.</p> <p><u>Domestic and Stock:</u> Diversions are banned where alternative supplies exist.</p> <p><u>Winterfill:</u> No restrictions provided water is drawn from reserves of stored water.</p> <p><u>Industrial:</u> Usage must be reduced by 70% of normal usage levels.</p>

These restrictions have not been included in the scenario modelling as an estimate of flows in the Yarra River at Warrandyte at current and future levels of development is not available. The number of restrictions that would occur in each year based on the historic streamflow data from the Yarra River at Warrandyte is provided in Figure 4-14.

Minimum passing flows from the Upper Yarra Reservoir commenced in January 1993, which explains why the frequency in the number of estimated restrictions is greater prior

to 1993 than in the following years. Due to changes in operation of the Upper Yarra Reservoir, the pre-1993 restriction levels and frequency of restrictions shown in Figure 4-14 are not representative of current conditions in the Yarra River.

If desired, a current and future level of development series of flows at Warrandyte could be estimated as part of Stage 2 of this project and the restriction policy included in future scenario modelling.



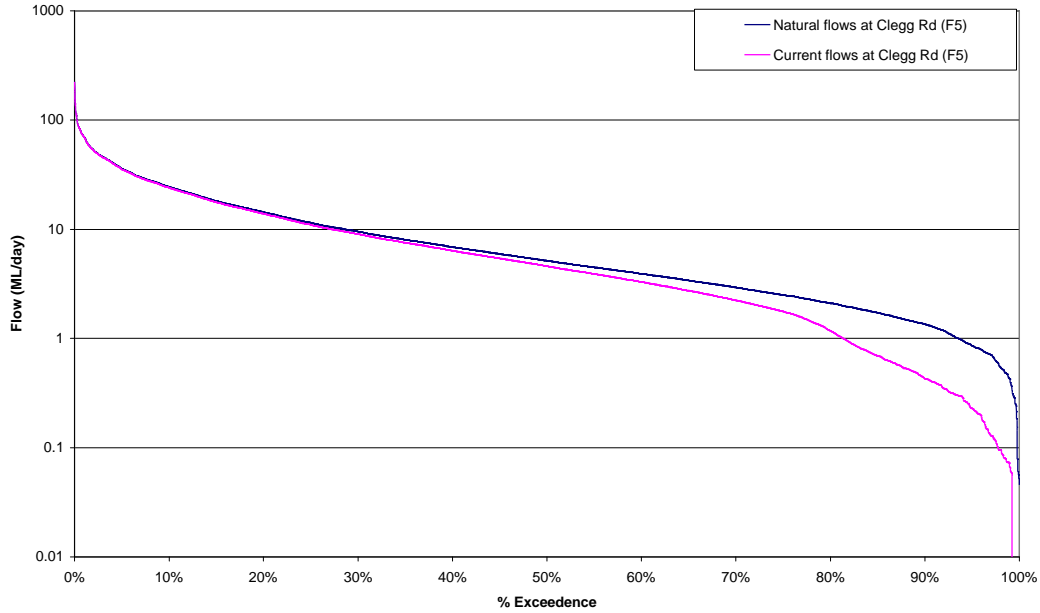
■ Figure 4-14 Number of restrictions (weeks per year) that would have been implemented historically based on Yarra River at Warrandyte flows and the Drought Response Plan for Yarra Catchment private diverters

4.3 Flow Comparison

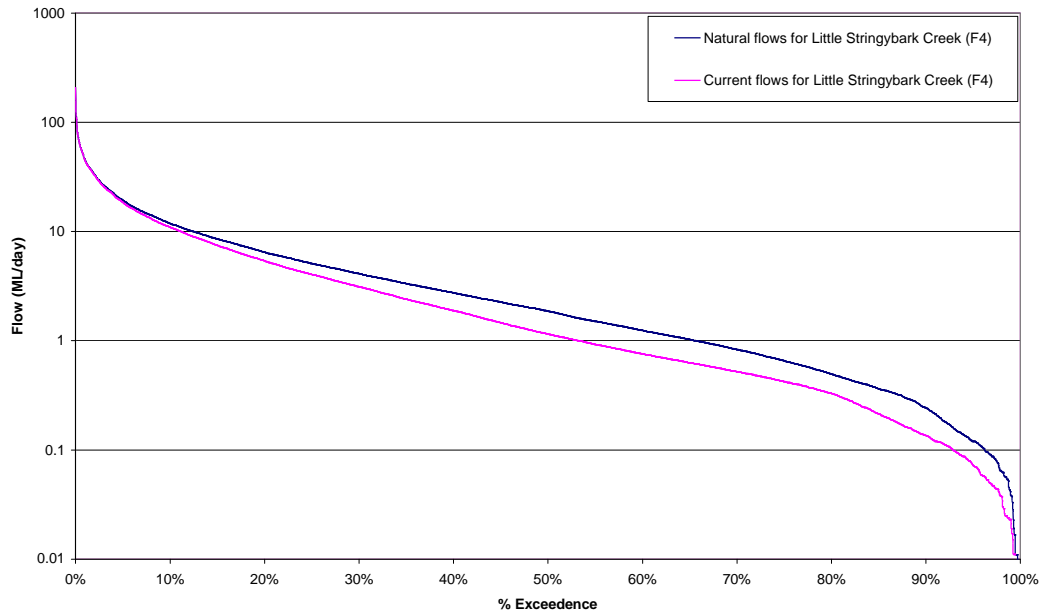
Figure 4-15 to Figure 4-19 compare flows under natural and current level of development conditions (Scenario 2). It can be seen that estimated flows in all subcatchments have been reduced due to diversions.

Figure 4-20 to Figure 4-24 compare flows under natural conditions to flows under full level of development conditions both with and without environmental flows implemented (Scenarios 3 and 4). As shown, flows in the upper, middle and lower Stringybark Creek subcatchments are further reduced below the natural flow conditions due to the potential increase in diversions. Implementing environmental flows does not effect flows above the 58th, 64th, and 67th percentiles in the upper, middle and lower subcatchments respectively. The environmental flows do however lessen the impact of diversions on lower flows.

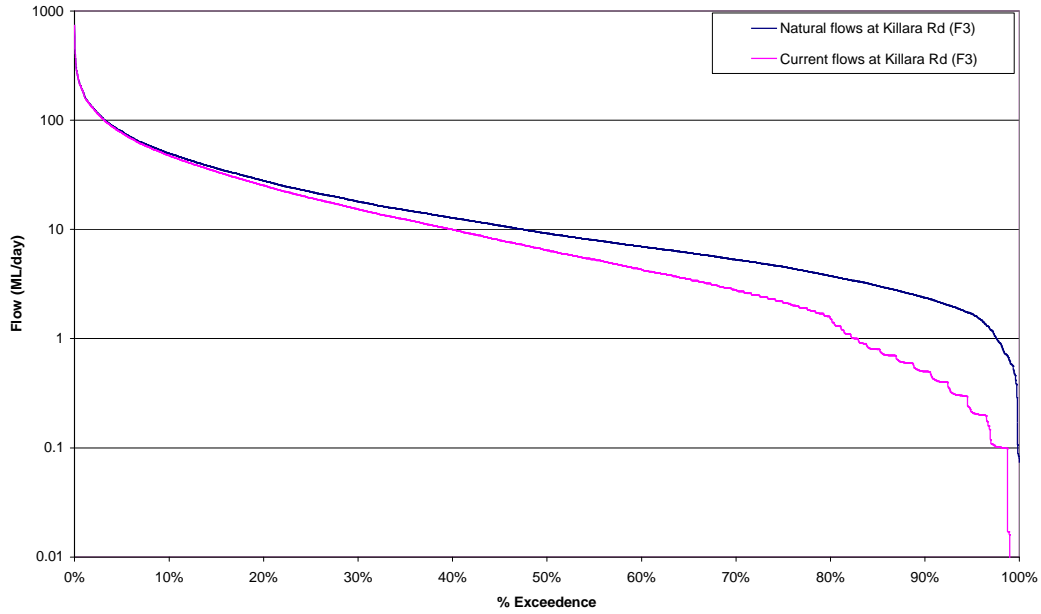
Because there are minimal licensed diversions on the tributaries Little Stringybark Creek and Log Creek, the flows here do not change between current and full levels of development, or with the implementation of the environmental flow recommendations (Figure 4-21 and Figure 4-23).



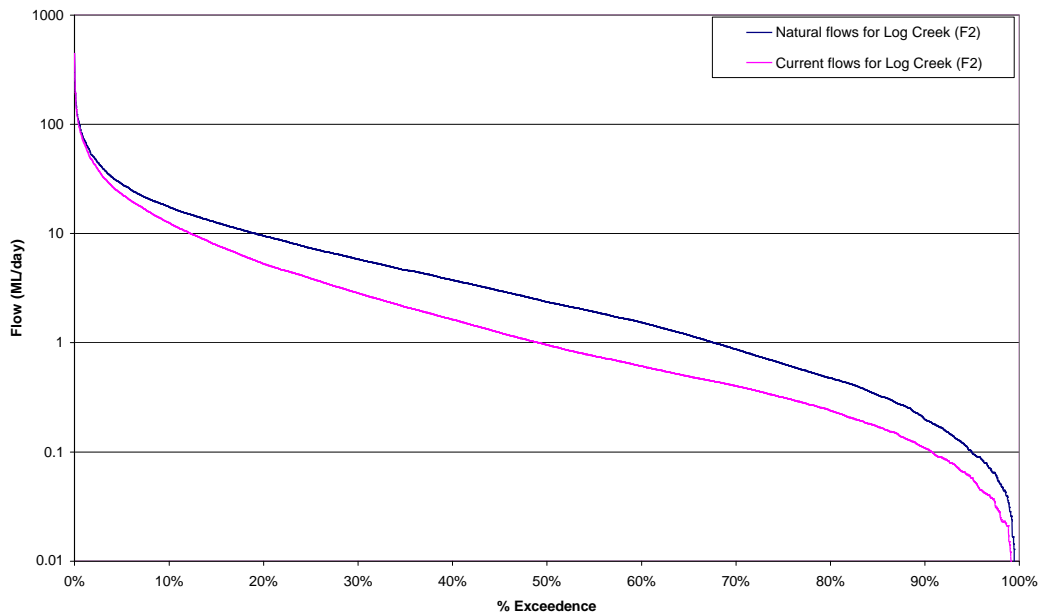
■ **Figure 4-15 Upper Stringybark Creek Subcatchment flow duration curves under natural and current conditions**



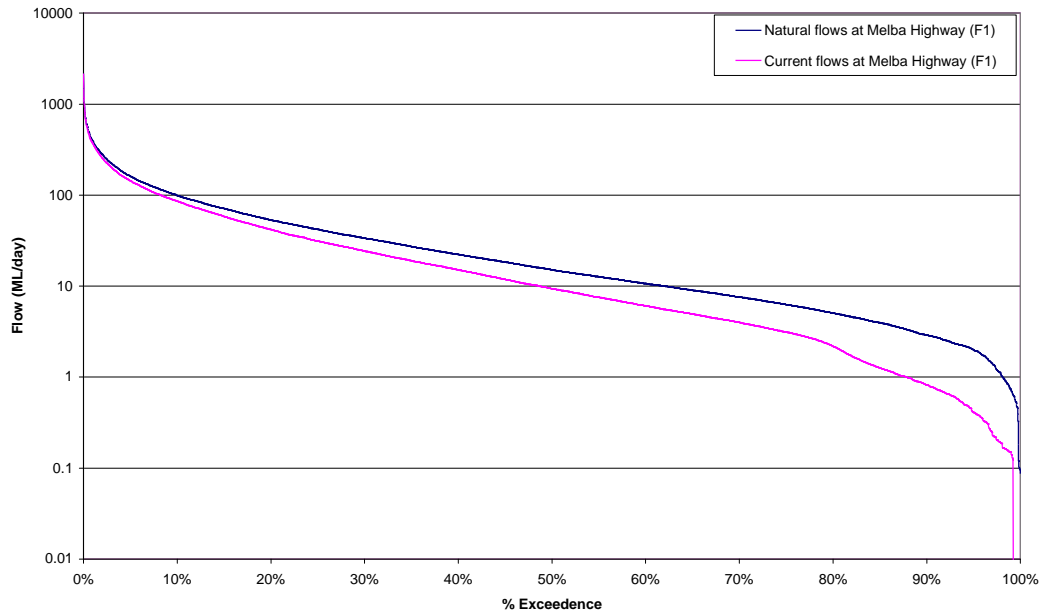
■ **Figure 4-16 Little Stringybark Creek Subcatchment flow duration curves under natural and current conditions**



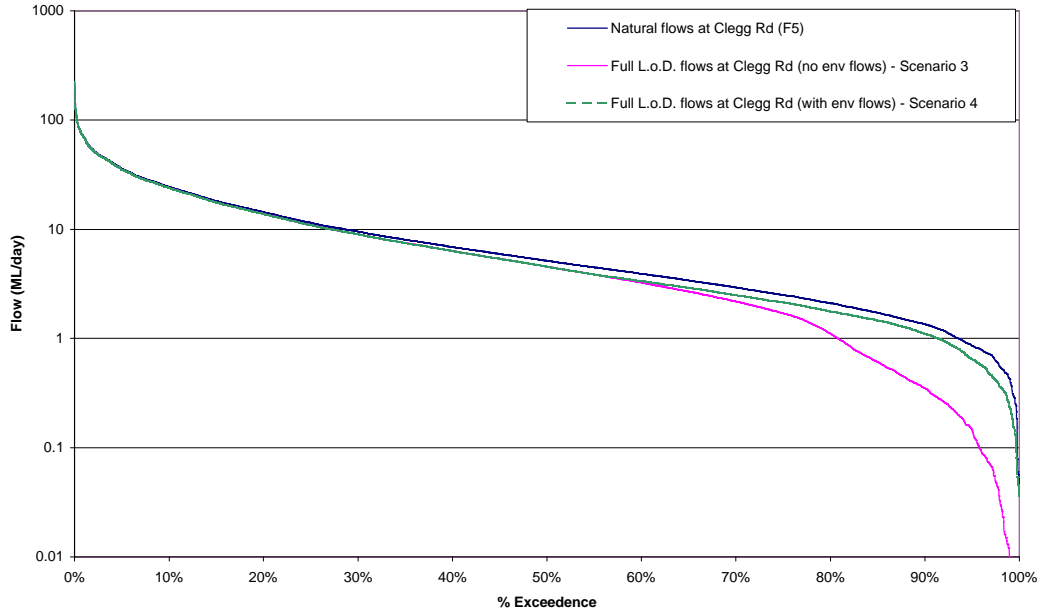
■ Figure 4-17 Middle Stringybark Creek Subcatchment flow duration curves under natural and current conditions



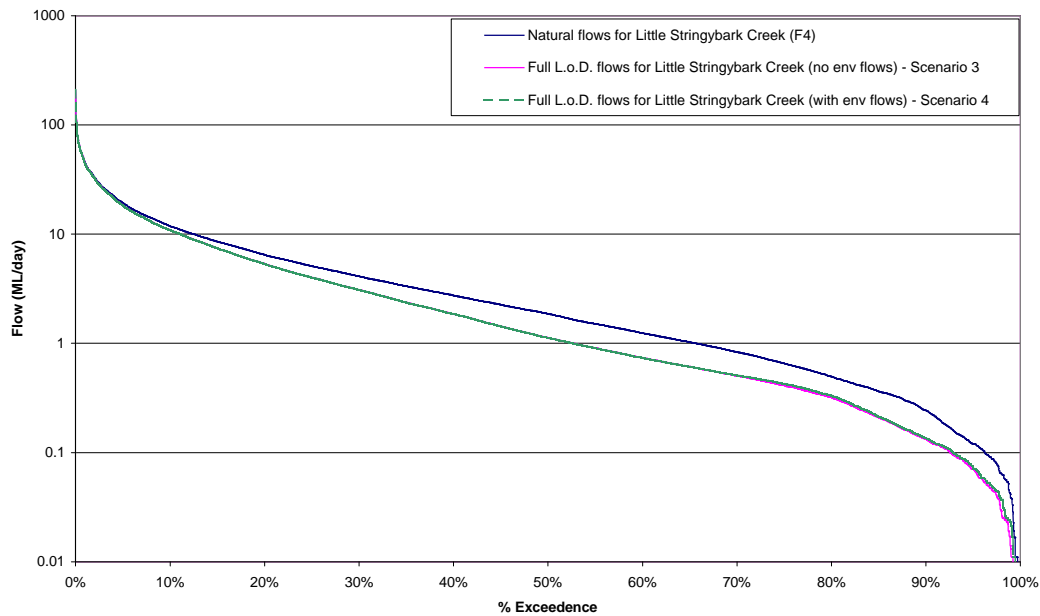
■ Figure 4-18 Log Creek Subcatchment flow duration curves under natural and current conditions



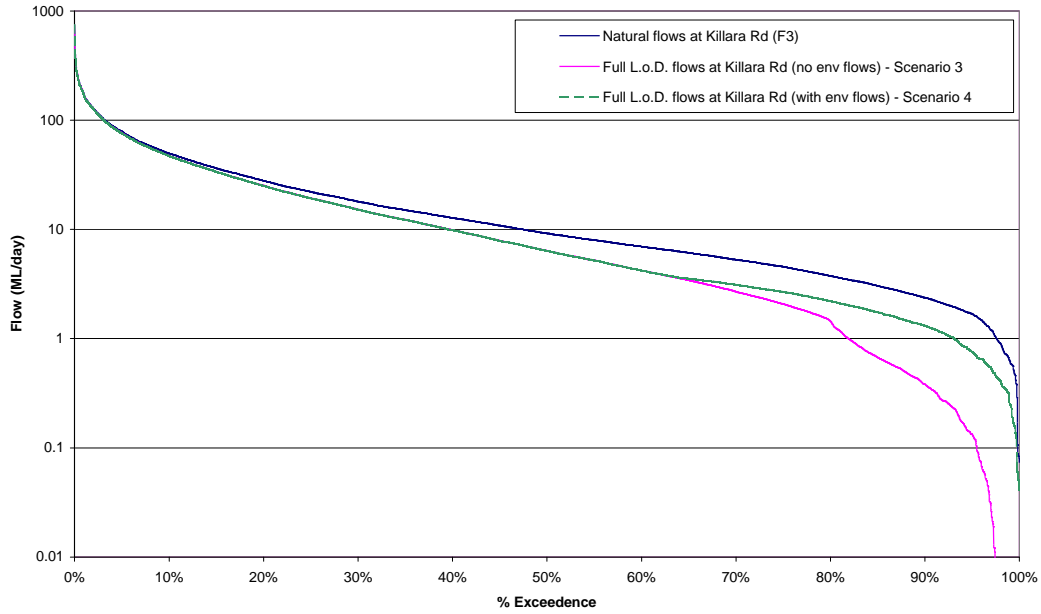
■ Figure 4-19 Lower Stringybark Creek Subcatchment flow duration curves under natural and current conditions



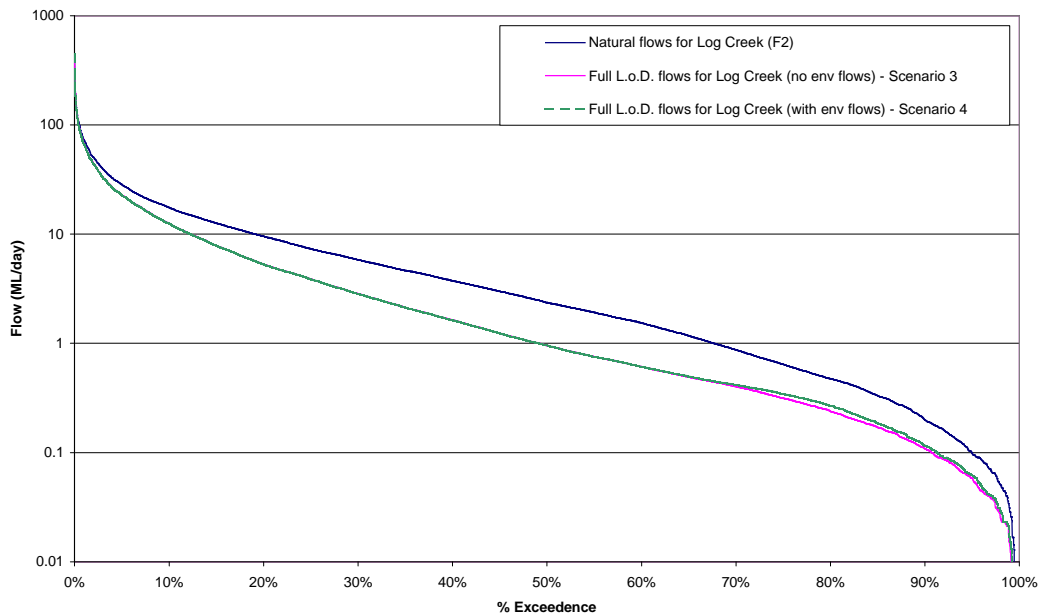
■ Figure 4-20 Upper Stringybark Creek Subcatchment flow duration curves under natural and full level of development conditions



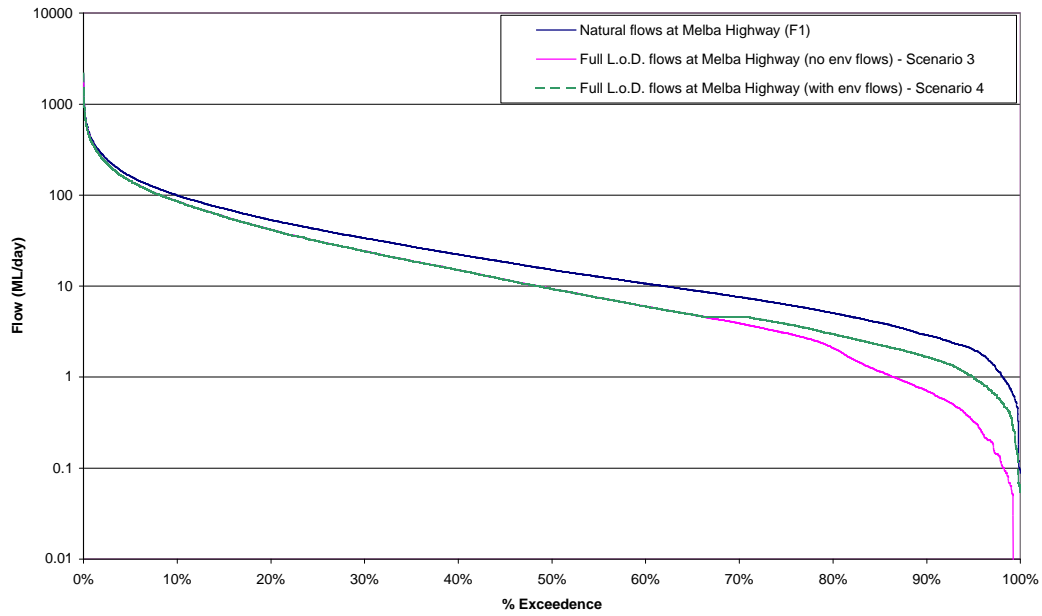
■ Figure 4-21 Little Stringybark Creek Subcatchment flow duration curves under natural and full level of development conditions



■ Figure 4-22 Middle Stringybark Creek Subcatchment flow duration curves under natural and full level of development conditions



■ Figure 4-23 Log Creek Subcatchment flow duration curves under natural and full level of development conditions



■ Figure 4-24 Lower Stringybark Creek Subcatchment flow duration curves under natural and full level of development conditions

4.4 Summary

Four different scenarios have been modelled for the Stringybark Creek catchment, the results for which have been presented in the preceding sections. Table 4-7 summarises the results of each scenario.

■ **Table 4-7 Summary of scenario modelling results**

Scenario	Purpose of Scenario	Total number of years demands cannot be met			Average duration demands cannot be met (weeks)			Environmental Flow Compliance
		Upper Stringy-bark	Middle Stringy-bark	Lower Stringy-bark	Upper Stringy-bark	Middle Stringy-bark	Lower Stringy-bark	
2	To test reliability of supply to diverters based on the current catchment conditions.	-	-	-	-	-	-	N/A
3	To test the reliability of supply to diverters based on estimated full level of development conditions.	13	10	-	4	2	-	N/A
4	To test the reliability of supply to diverters based on estimated full level of development conditions with environmental flows implemented.	35	35	35	17	16	16	85% Clegg Rd 72% Melba Hwy

Note: There are no summer diversions in Little Stringybark Creek and Log Creek.

Under current level of development conditions, and with no environmental flows specified, it is predicted that all demands can be fully met for all sub-catchments.

Under full level of development conditions, and if no environmental flows are implemented, demands in the upper, middle and lower Stringybark subcatchments cannot be fully met in 13 and 10 and 0 years out of 35 respectively. If environmental flows are then implemented, these demands cannot be met in all 35 years.

In order to meet the environmental flow recommendations there is a significant impact on the ability for demands to be met, especially in the upper and middle Stringybark subcatchments under full level of development conditions. This impact may be lessened by implementing demand reduction strategies.

5. Data Collation and Preparation

5.1 Rainfall

Rainfall data was required from 1965 to 2000 to estimate irrigation demands, farm dam impacts, and to estimate streamflows in the absence of gaugings. Although significant periods of recorded rainfall data near Stringybark Creek catchment are available, some records contained missing data and periods where the measurement was accumulated over several days. It was also necessary to check the data for the presence of any unexplained trends. All rainfall data was obtained from the Bureau of Meteorology. The preparation of rainfall data is described below.

Location of Rainfall Gauges

The four key rainfall gauges used in this study are shown in Figure 2-1.

Disaggregation

The method used to disaggregate accumulated periods was that proposed by Porter and Ladson (1993), which assumes the influence of nearby stations is inversely proportional to their distance from the gauge for which the accumulated data is to be disaggregated (the focal gauge). This safeguards against the uncertainty of using data from a single station. As the time required for this procedure is large, an automated procedure has been developed.

Infilling of Missing Data

An automated procedure has also been developed for the process of infilling missing data. This procedure calculates the correlation between the focal and nearby gauges. The gauge with the highest correlation that has data concurrent with the missing period is used for infilling. The hyetograph of the selected nearby station is adjusted by the ratio of the concurrent mean annual rainfalls of the two stations and used to infill the missing period. A summary of the rainfall data is contained in Table 5-1.

■ **Table 5-1 Rainfall gauging station details.**

Rainfall Station	Location	Period of Record Available	Proportion missing
086066	Lilydale	1885 – 2000	4.1%
086219	Coranderrk Badger Weir	1879 – 2000	29.7%
086106	Silvan	1920 – 2000	1.1%
086076	Montrose	1918 – 2000	30.4%

Removal of Trend

The rainfall data sets were checked for stationarity (i.e. absence of trend) by plotting a double mass curve of each annual data series against a nearby known “high quality” rainfall gauge, as identified by the Bureau of Meteorology. Upon analysis it was found that none of the data sets required de-trending.

Estimation of Rainfall over a Catchment

The total rainfall over a catchment is likely to be best represented by a combination of nearby rainfall gauges rather than just one site. A weighting method was used for each sub-catchment (1 to 5), whereby data sets were weighted according to their proximity to the centroid of the subcatchment. The relative influence of nearby gauging stations for each subcatchment is shown in Table 5-2.

■ **Table 5-2 Weighting of rainfall stations for each subcatchment.**

Rainfall Station	Subcatchment				
	1	2	3	4	5
086076	–	–	84%	–	50%
086219	14%	72%	16%	–	–
086066	86%	28%	–	62%	–
086106	–	–	–	38%	50%

5.2 Evaporation

Evaporation data was required from 1965 to 2000 to estimate irrigation demands, farm dam impacts, and to estimate streamflows in the absence gaugings. Although significant recorded data near Stringybark Creek catchment is available, it does not extend from 1965 to 2000, and contains missing data and periods where the measurement was accumulated over several days. It was also necessary to check the data for the presence of any unexplained trends. All evaporation data was obtained from the Bureau of Meteorology. The preparation of evaporation data is described below.

Location of Evaporation Gauges

Evaporation data was taken from gauging station 086104 at Scoresby Research Institute.

Disaggregation

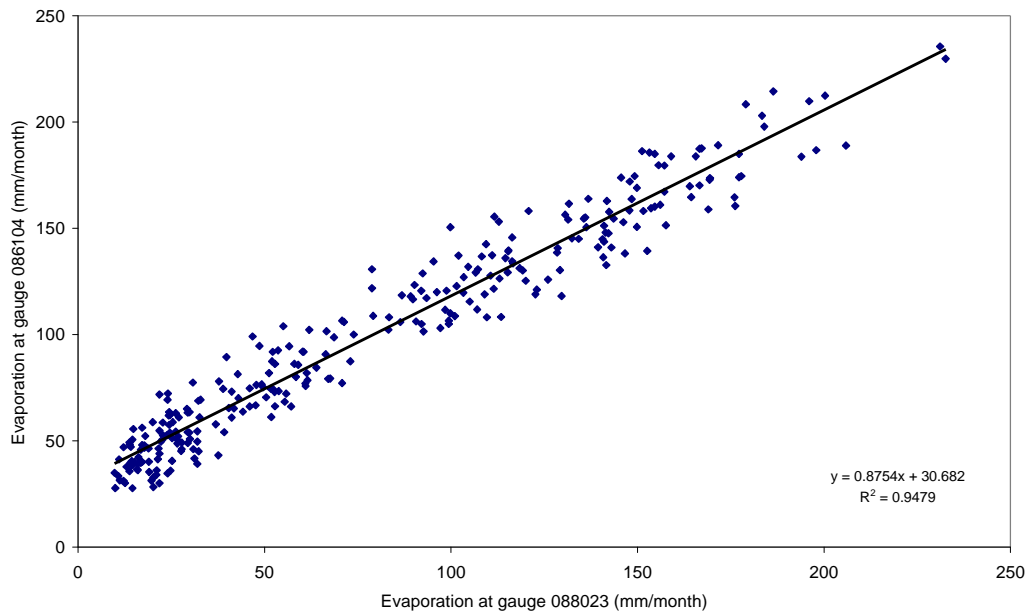
Disaggregation of the evaporation data was undertaken in the same way as the rainfall data.

Infilling and Extension of Missing Data

The evaporation data was infilled and extended based on a monthly correlation with gauge 088023 at Eildon. A summary of the evaporation data is contained in Table 5-3. The correlation is shown in Figure 5-1.

■ **Table 5-3 Evaporation gauging station details.**

Rainfall Station	Location	Period of Record Available	Proportion missing
086104	Scoresby	1965-1994	4.8%



■ **Figure 5-1 Correlation used to extend the evaporation data.**

Estimation of Evaporation over a Catchment

For each sub-catchment within the Stringybark Creek catchment, the ratio of mean annual point potential evaporation at the centre of the sub-catchment to that at evaporation gauging station 086104 was used to adjust the daily evaporation data for each sub-catchment. The mean annual evaporation was obtained from the Bureau of Meteorology. The adjustments used are shown in Table 5-4.

■ **Table 5-4 Weighting of evaporation stations for each sub-catchment.**

Subcatchment	Factor
1	0.98
2	0.96
3	0.99
4	0.99
5	0.99

5.3 Streamflow

Melbourne Water supplied streamflows at two gauges within the Stringybark Creek catchment as shown on Figure 2-2:

- ❑ 229657 Stringybark Creek at Killara Road (1/03/1979 to 30/06/1986)
- ❑ 229401 Stringybark Creek at Clegg Road (10/07/1999 to date)

Both records contained periods of missing data. The quality of data at each gauge is good, however flows at Killara Road are controlled by the volume which can pass through the culvert immediately downstream of the gauge.

5.4 Diversion Licenses

Diversion licenses were provided by Melbourne Water. The licenses were divided into the five sub-catchments used in the REALM model. The reach to which each diverter was assigned for modelling purposes is shown in Table 5-5.

■ **Table 5-5 Assignment of Diversers to Reaches**

Subcatchment	Licence Type	Licence Volume (ML/yr)	Status
Stringybark Creek between Killara Road and Melba Highway	Domestic & Stock	2	Active
	Off-Stream Dam Filling	190	Active
	Off-Stream Dam Filling	30	Active
	Off-Stream Dam Filling	15	Active
	Off-Stream Dam Filling	42	Active
	Off-Stream Dam Filling	38	Active
	Off-Stream Dam Filling	87	Active
	Off-Stream Dam Filling	46	Active
	Off-Stream Dam Filling	2	Active
	Off-Stream Dam Filling	98	Active
	Off-Stream Dam Filling	45	Active
Log Creek	Off-Stream Dam Filling	74	Active
	Off-Stream Dam Filling	55	Active
	Off-Stream Dam Filling	65	Active
Stringybark Creek between Clegg Road and Killara Road	Domestic & Stock	2	Active
	Irrigation	12	Active
	Irrigation	10	Active
	Off-Stream Dam Filling	2	Active
	Domestic, Stock & Irrigation	4*	Inactive
Little Stringybark Creek	Off-Stream Dam Filling	3	Active
	Off-Stream Dam Filling	9	Inactive
Stringybark Creek above Clegg Road	Domestic & Stock	2	Cancelled ¹
	Domestic, Stock & Irrigation	4*	Active
	Domestic, Stock & Irrigation	4*	Active
	Domestic, Stock & On-stream Dam Filling	4*	Active
	Irrigation	7	Active
	On-stream Dam Filling	18	Active
	Irrigation	7	Active
	Irrigation	3	Active
	Irrigation	15	Active
	Irrigation	7	Active
	Irrigation	12	Active
	On-stream Dam Filling	7	Active
	Irrigation	7	Active
	Irrigation	7	Active
Irrigation	5	Active	

Subcatchment	Licence Type	Licence Volume (ML/yr)	Status
Stringybark Creek above Clegg Road	Irrigation	3	Active
	Irrigation	7	Active
	Irrigation	10	Active
	Irrigation	7	Active
	Irrigation	9	Active
	Irrigation	4	Active
	Irrigation	5	Active
	On-stream Dam Filling	7	Active
	On-Stream Dam Filling	10	Active
	Off-Stream Dam Filling	8	Active
	Off-Stream Dam Filling	14	Active
	Off-Stream Dam Filling	1	Active
	Off-Stream Dam Filling	4	Active
	Irrigation	7	Inactive ²
	Irrigation	4	Inactive
	Irrigation	4	Inactive
	Irrigation	4	Inactive
	Irrigation	7	Inactive
Irrigation	7	Inactive ³	
Irrigation	10	Inactive	

Notes:

(1) Being cancelled (Jan 2001), (2) Inactive post 1981, (3) Inactive post 1970 except 1982 drought, (*) Licensed volume distributed equally among corresponding licence types

5.5 Farm Dam Volumes

Farm dam volumes for each subcatchment were supplied by EGIS. The dam volumes had been estimated from their surface area as shown on aerial photographs, using the relationship derived by Good and McMurray (1997):

$$V \text{ (ML)} = \frac{A(\text{km}^2)^{1.4}}{22727}$$

■ Equation 1

6. Derivation of Demands

Demand time series at different levels of development were required for this project:

- ❑ Historic demands were required to assist in the calculation of inflows, and as input to the REALM calibration run. Historic licensed demands were taken to be licenses active over the period of gauged flows at Killara Road (1979 to 1987).
- ❑ Current level of development demands were required as input to the REALM scenario runs. Current licensed demands were taken to be licenses active in July 2000.
- ❑ Full level of development demands were also required as input to the REALM scenario runs. The full level of development demands were calculated by assuming that both active and inactive licence volumes were fully utilised.

At each level of development, the following types of demands were estimated:

- ❑ Direct irrigation
- ❑ Domestic and stock
- ❑ On-stream winterfill
- ❑ Off-stream winterfill
- ❑ Farm dams

There were no commercial and industrial demands within the Stringybark catchment. The derivation of each type of demand is described below.

6.1 Direct Irrigation

Direct irrigation demands were estimated using the PRIDE irrigation demand model (Erlanger et al., 1992). This model uses daily rainfall and evaporation, crop area and weekly crop factors for each crop type to estimate crop water requirements in a given region.

Direct irrigation demands were required in subcatchments 3 and 5 as summarised in Table 6-1.

■ **Table 6-1: Summary of direct irrigation licences.**

Reach	Description	Total Licensed Volume [ML/yr]		
		Historic	Current	Full
1	Stringybark Ck between Killara Rd and Melba Highway	0	0	0
2	Log Creek	0	0	0
3	Stringybark Ck between Clegg Rd and Killara Rd	22	22	24
4	Little Stringybark Creek	0	0	0
5	Stringybark Ck above Clegg Rd	123	119	136

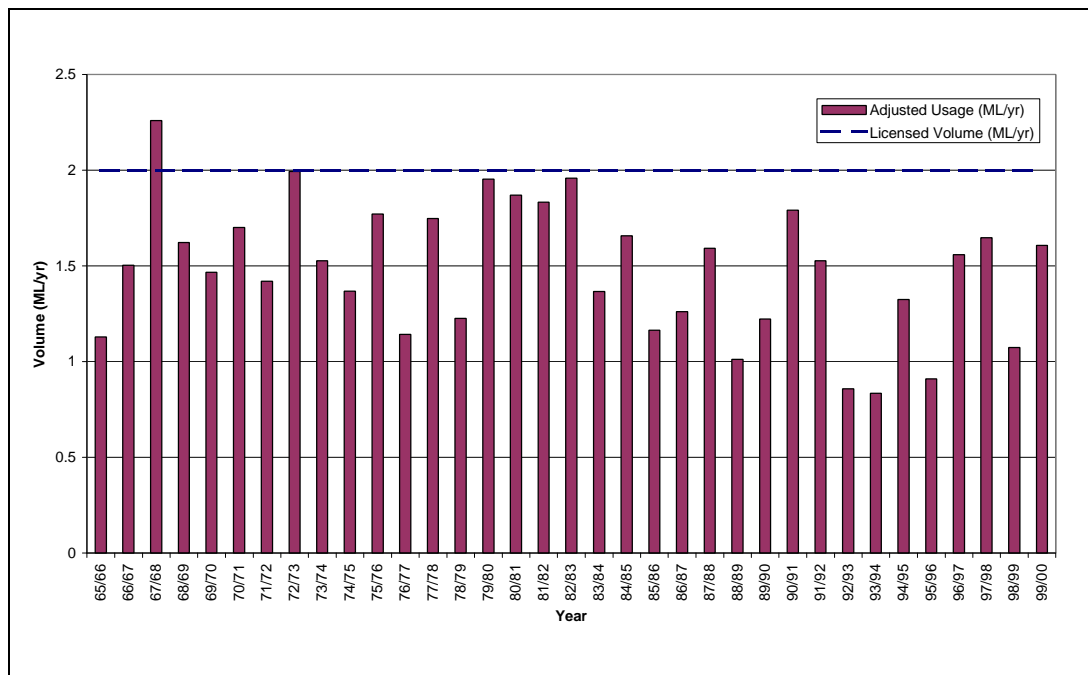
Note: Historic demands were assumed constant over the period 1979 to 1987.

The overall water demand was modelled using five categories of crop type:

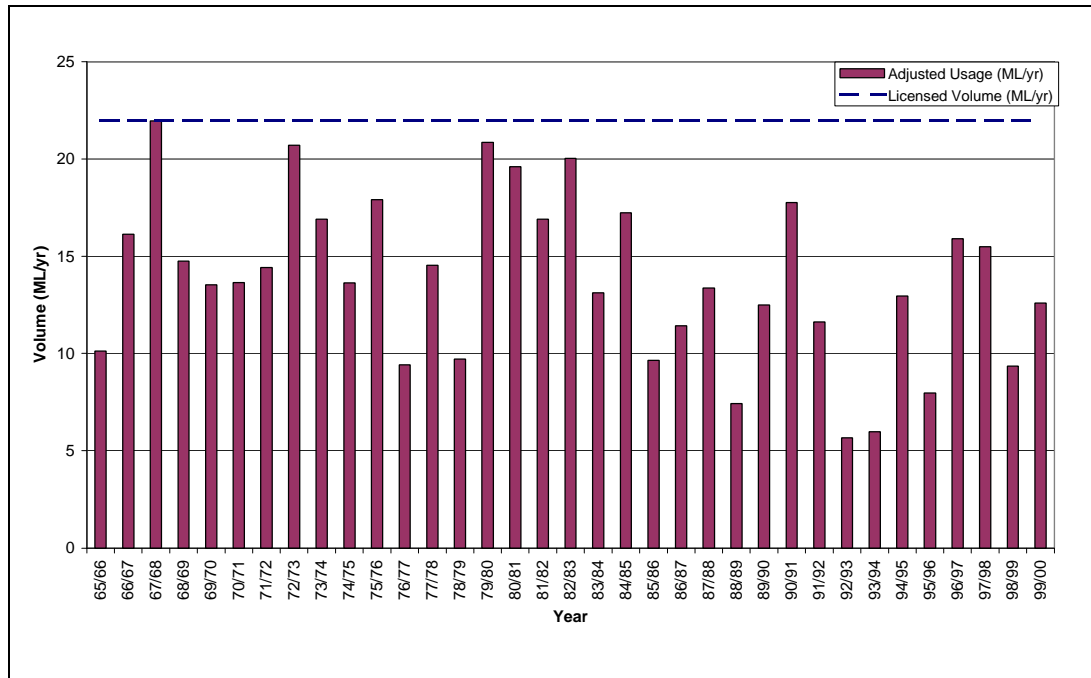
- ❑ Year round crops (eg nurseries)
- ❑ Orchards
- ❑ Summer crops (eg berries, vegetables, and flowers)
- ❑ Vines
- ❑ Perennial pasture

Crop types were well documented in the licence database provided by Melbourne Water. Where there was insufficient information on the crop type irrigated, it was assumed to be a summer crop.

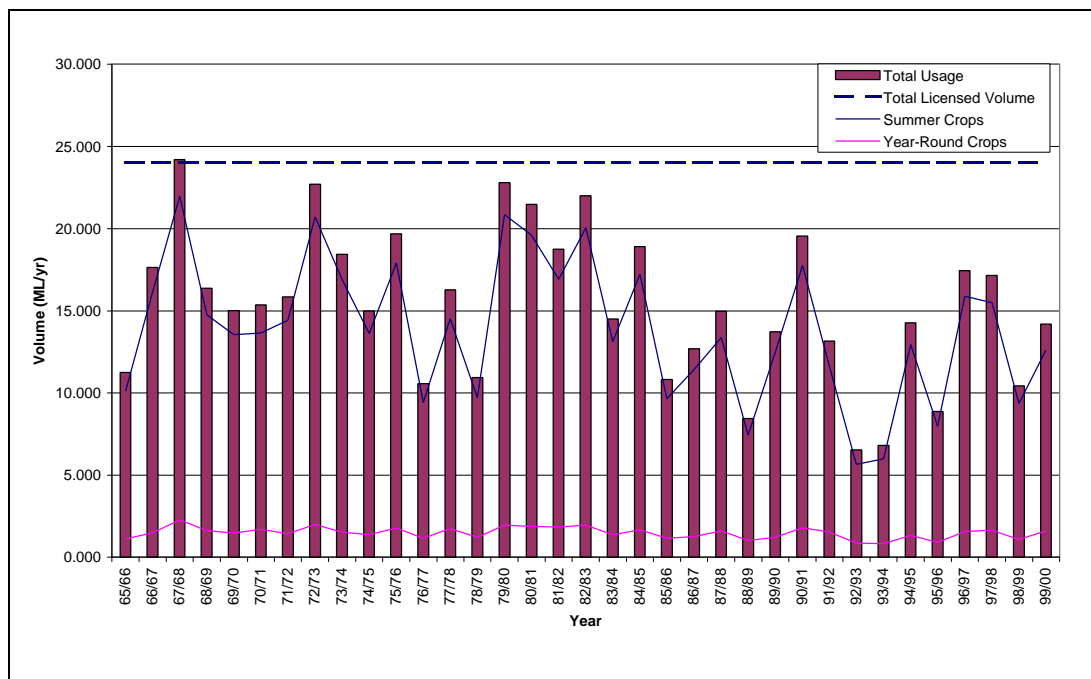
The PRIDE model was calibrated for each subcatchment by adjusting the crop area such that the maximum demand over an irrigation season was approximately equal to the total licence volume for each crop. If the demand in one irrigation season was substantially greater than all other years this value was allowed to exceed the total licence volume. This process is illustrated in Figure 6-1 and Figure 6-2, which show the calibration for each crop type in subcatchment 3 (year-round and summer crops only) at full level of development. The total irrigation demand in the subcatchment is equal to the sum of the estimated demand for each crop type. Calibration plots for each crop type and the sum of all crops in each reach can be found in Appendix A.



■ **Figure 6-1 Subcatchment 3 water usage for year-round crops at full level of development.**



■ Figure 6-2 Subcatchment 3 water usage for summer crops at full level of development.



■ Figure 6-3 Subcatchment 3 total water usage at full level of development.

6.2 Onstream and Offstream Dams

Demands to fill onstream and offstream storages were derived on the assumption that licence holders would only divert during the winterfill period (May to October inclusive).

It was also assumed that licence holders diverted one hundred percent of their licence volume each year. The diversion pattern over winter was calculated from the proportion of streamflow that occurred on average in each of the winterfill months at Killara Road (229657).

6.3 Domestic and Stock

Domestic and stock demands were assumed to be equal to the diversion licence volume. The rate of extraction was assumed to be constant throughout the year.

6.4 Farm Dams

For this study the hydrologic impact of farm dams in each sub-catchment was modelled individually using the Tool for Estimating Dam Impacts (TEDI). The model inputs for each sub-catchment were:

- ❑ Partial natural inflows (historic flows adjusted for some diversions as per Equation 4)
- ❑ Monthly rainfall and evaporation data

Other model inputs which had been derived in the previous farm dam impact study (Egis 2002) were:

- ❑ The number and volume of farm dams in each catchment
- ❑ The threshold dam volume between stock and domestic and irrigation dams (threshold volume = 10 ML).
- ❑ Irrigation demand patterns and annual demand volumes.
- ❑ Stock and domestic demands and annual demand volumes.
- ❑ The proportion of farm dam volume withdrawn each year as annual demand (demand factor = 2).
- ❑ Farm dam size distribution.
- ❑ Upstream catchment area for farm dams of 5 ML and 100 ML in size.

For each sub-catchment, the monthly time series of farm dam impacts were disaggregated uniformly over the month.

6.5 Summary

Five daily demand data sets were derived for input into REALM at historic, current and full levels of development. For the relevant subcatchment (denoted in brackets) these series were:

- ❑ Total direct irrigation of the five modelled crop types (3, 5)
- ❑ Total on-stream extractions of the five modelled crop types (5)
- ❑ Offstream dam extractions (all reaches – 1, 2, 3, 4 and 5)
- ❑ Extractions for domestic and stock (1, 3, 5)
- ❑ Farm dam impacts (all reaches – 1, 2, 3, 4 and 5)

7. Derivation of Inflows and Losses

Natural streamflows were derived for each sub-catchment based on adjustments made to gauged streamflows. There are two streamflow gauges within the Stringybark Creek catchment:

- 229657 Stringybark Creek at Killara Road (1/03/1979 to 30/06/1986)
- 229401 Stringybark Creek at Clegg Road (10/07/1999 to date)

Before the gauged streamflows at Killara Road could be used, it was necessary to check the data for any unexplained trend, infill missing periods, and extend the data to cover the period 1965 to 2000. Streamflows at Killara Road (gauge 229657) were then extended using the modified AWBM rainfall runoff model (refer Section 7.3 below), and transposed to other locations in the catchment.

7.1 Time-lag and Losses

The significance of travel times and losses due to seepage and evaporation could not be adequately investigated using the gauged data on Stringybark Creek because concurrent streamflow data was not available. These aspects were therefore investigated for the adjacent Olinda Creek which did contain concurrent streamflow data, with the intention of applying any outcomes to the Stringybark Creek catchment.

The analysis of streamflows along Olinda Creek did not identify any time-lag or losses along its reach. These outcomes were therefore assumed to apply to Stringybark Creek catchment, and are consistent with the short stream length and hydrogeological conditions.

7.2 Trend Analysis

The Generalised Additive Model (GAM) was used to assess trends in the streamflow data with time. GAM is a parametric technique that adequately accounts for problems associated with missing data, serial correlation, non-linear influences, and the effects of other variables on the value of the dependant variable.

A previous study investigating the impact of farm dams in the Stringybark Creek catchment (EGIS, 2002) identified a time trend in the streamflows at Killara Road, and the data was de-trended accordingly. However, when the de-trended flows were compared to those predicted by the AWBM rainfall-runoff model developed for that study, it appeared that the de-trending had resulted in an over-correction during low flow periods. While this may have not been critical for assessing farm dam impacts, it is important for the purposes of this study.

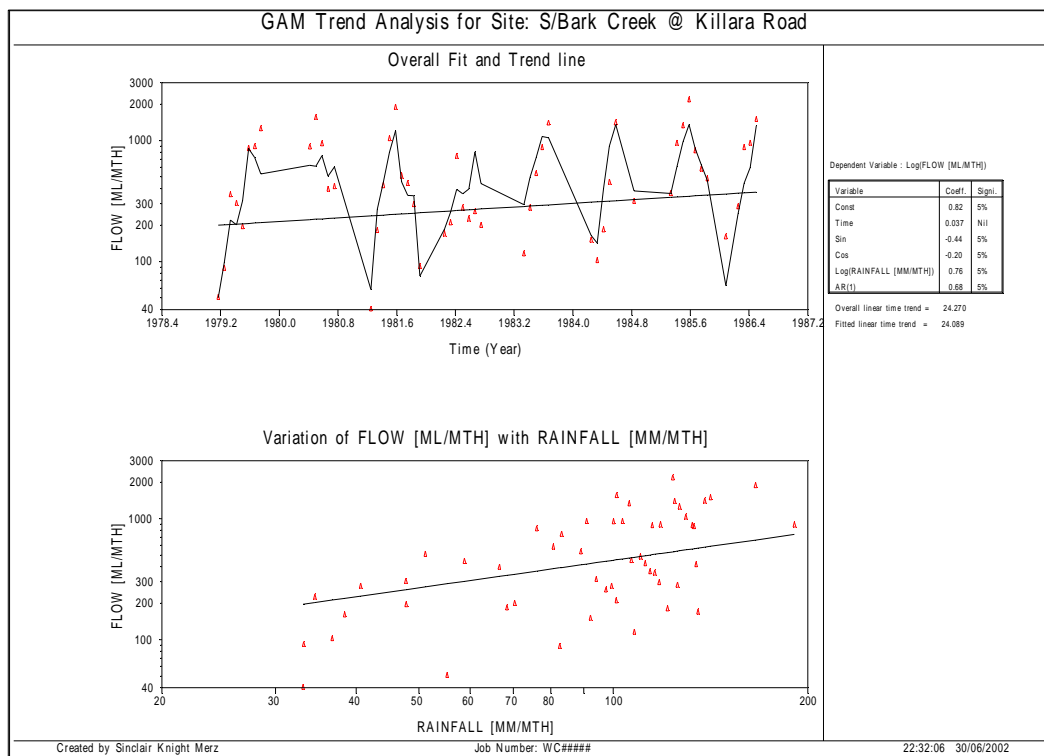
The trend analysis was therefore repeated, using the same variables as the previous study, which included gauged streamflows at Killara Road, rainfall and seasonality. The difference was that a logarithmic transform was applied to the streamflow and rainfall data, to increase the sensitivity of the model to low flows. A linear time trend was fitted to the data. The form of the model was:

$$\text{Log}(\text{Flow}) = b_1 + b_2 * \text{Log}(\text{Rain}) + b_3 * (\cos(\text{season})) + b_4 * (\sin(\text{season})) + b_5 * t + \text{AR}[1] + e$$

■ Equation 2

where: Flow = Total monthly flow [ML]
 Rain = Monthly rainfall, derived from the average of rainfalls weighted to be representative of subcatchments 3, 4 and 5 [mm]
 Season = Month of the year
 t = Time
 AR[1] = Lag 1 auto-regressive term
 ε = Model residual
 b1, b2...b6 = Model coefficients

Figure 7-1 shows the linear time trend fitted to the gauged flows at Killara Road. The significance of the trend line is dependent on the amount of scatter of the data and the gradient. The analysis did identify a rising trend in streamflows, however it was not considered to be statistically significant at the 10% level, and therefore the gauged flows were not de-trended.



■ Figure 7-1 The linear time trend fitted to gauged flows at Killara Rd (gauge 229657).

7.3 Infilling and Extension

The streamflow data was infilled and extended by fitting the AWBM model on a daily time-step. Examination of the simulated flows indicated that the model consistently overestimated low flow conditions in the catchment. While the overall volume associated with this modelled bias is small, it is of considerable importance to evaluating streamflows during stressed conditions. In order to correct this deficiency an additional term was introduced to simulate the decrease in contributions from sub-surface stores during dry conditions. This decrease in baseflow contribution was assumed to occur for streamflows less than 1.5 ML/day and was found to be around 45% of the flow (Equation 3).

$$\text{If } Q_{AWBM} < Q_T \text{ then } Q_{est} = (1 - LF) * Q_{AWBM}$$

■ Equation 3

Where:

- Q_{AWBM} = flow estimate from AWBM rainfall runoff model
- Q_T = streamflow threshold below which additional loss function applies
- Q_{est} = revised flow estimate based on additional losses
- LF = loss factor (a value between 0 and 1).

The results of the modified AWBM model are displayed in Table 7-1 and Figure 7-2 to Figure 7-6. Table 7-1 shows the goodness of fit statistics. Figure 7-2 displays flow duration curves of the observed and estimated data, while Figure 7-3 to Figure 7-6 compare the data in time series plots. Figure 7-7 compares the cumulative flows of observed and estimated data over time. Note that all calibration plots have estimated data removed from periods corresponding to missing observed data.

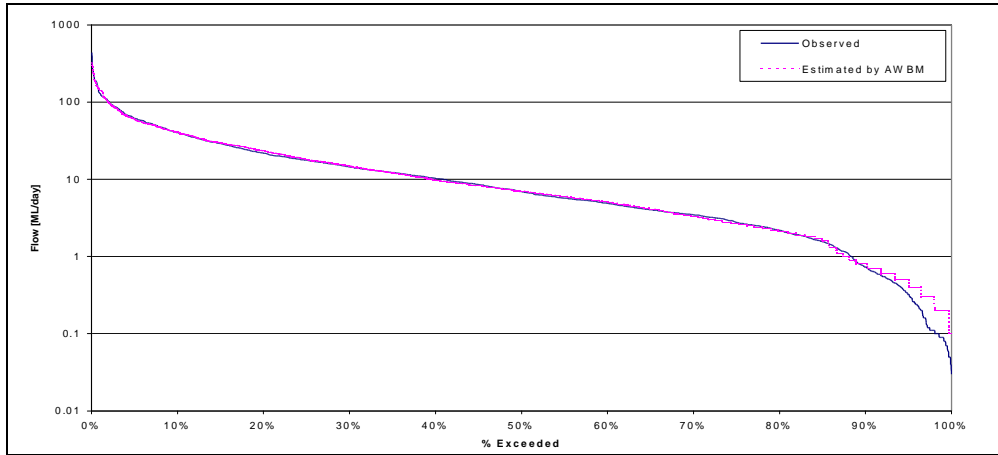
■ **Table 7-1 Goodness of fit statistics for calibration of the modified AWBM model to gauged flows at Killara Road.**

Goodness of Fit Measures	Value
Comparison of mean	Observed: 16.15 ML/day Estimated: 16.15 ML/day
Comparison of standard deviation	Observed: 27.55 ML/day Estimated: 26.91 ML/day
Coefficient of Determination (R ²)	Unadjusted for timing: 0.17 Adjusted for timing: 0.61
Standard Error (SE)	Unadjusted for timing: 24.6 Adjusted for timing: 16.9

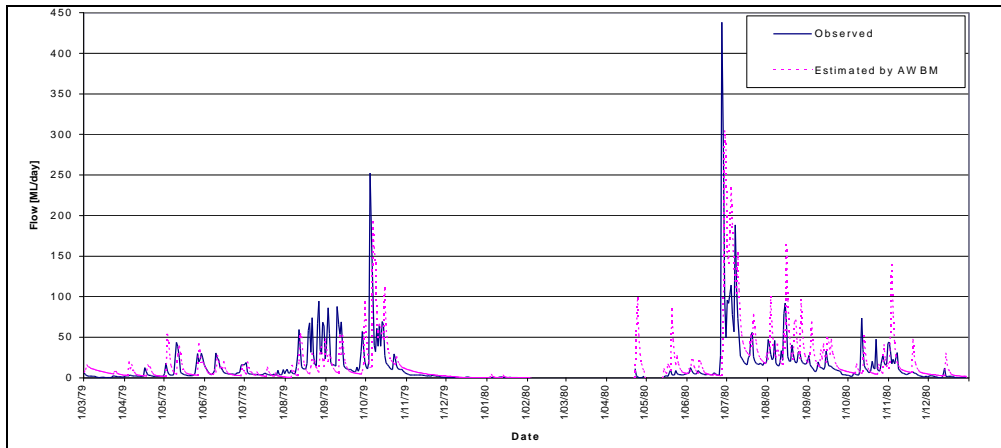
Note: The model consistently had a timing delay of two days, therefore the coefficient of determination has been reported on the raw model output, and the adjusted model output.

Comparisons were also made on a monthly basis with the AWBM model fitted as part of the previous study investigating the impact of farm dams (EGIS, 2000). The results from this study agree well with those from the previous study, as illustrated in Figure 7-8 to Figure 7-10.

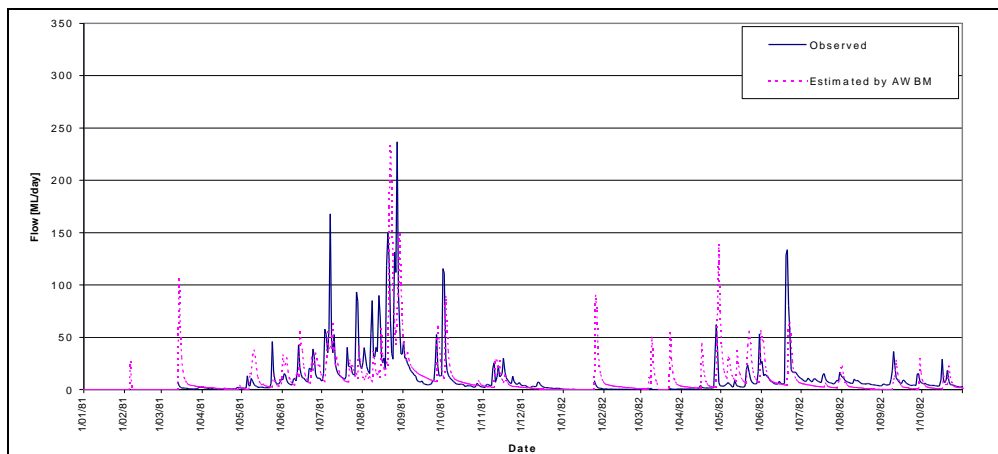
Results of the modified AWBM model



■ Figure 7-2: Flow Duration Curves of Observed and Estimated Daily Flows at Killara Road Gauge (1/03/1979 – 30/06/1986)

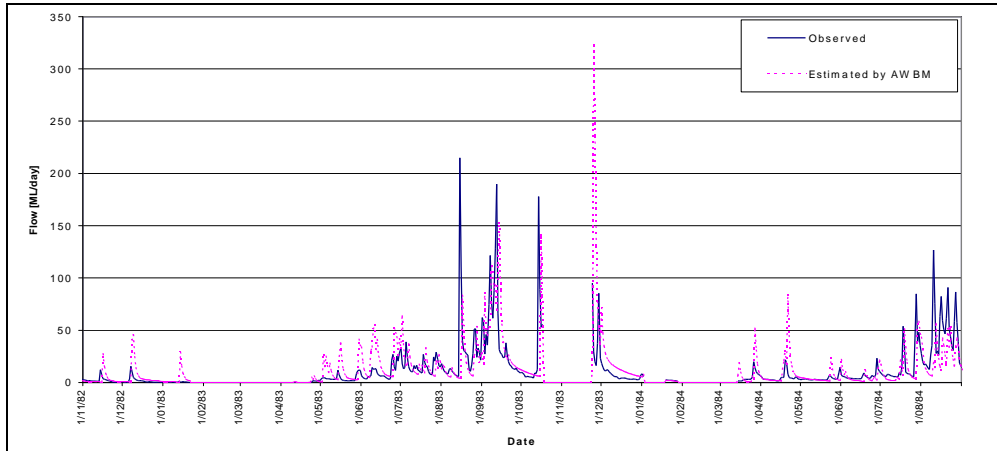


■ Figure 7-3 Time Series Plots of Observed and Estimated Daily Flows at Killara Road Gauge (1/03/1979 to 31/12/1980)

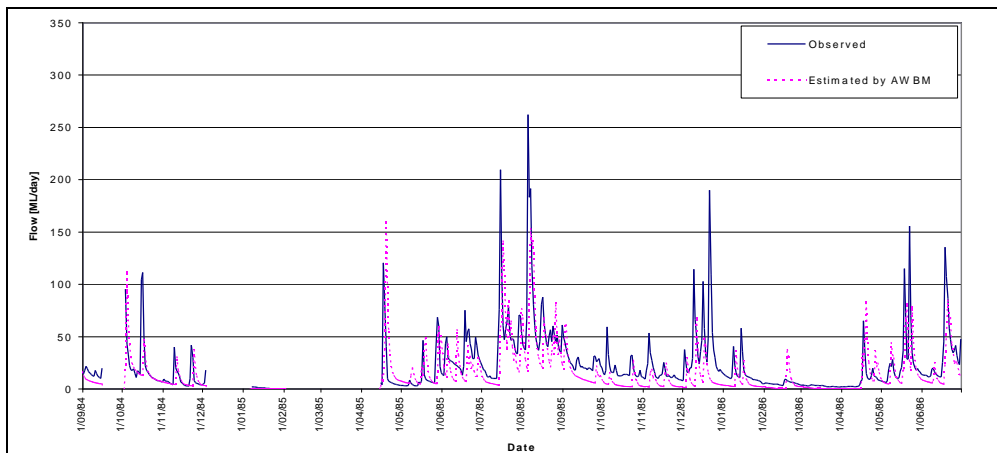


■ Figure 7-4 Time Series Plots of Observed and Estimated Daily Flows at Killara Road Gauge (1/01/1981 to 31/10/1982)

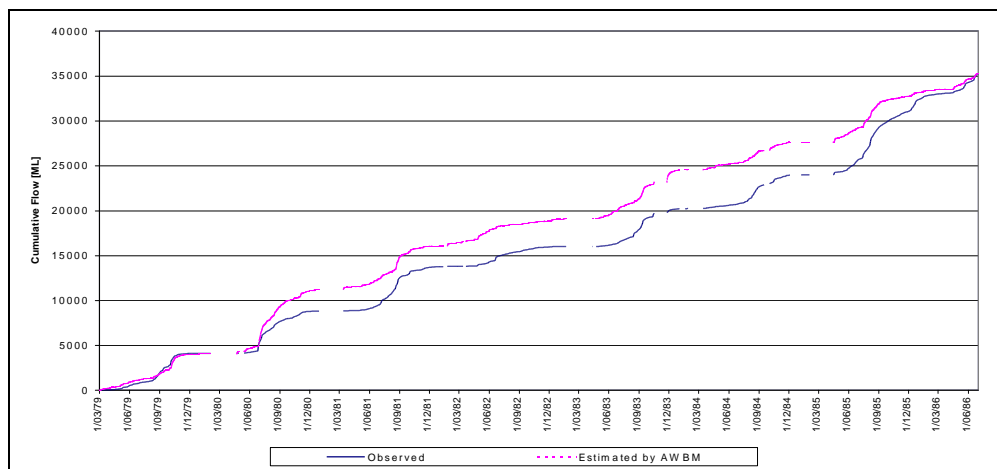
Results of the modified AWBM model



■ Figure 7-5 Time Series Plots of Observed and Estimated Daily Flows at Killara Road Gauge (1/11/1982 to 31/08/1984)

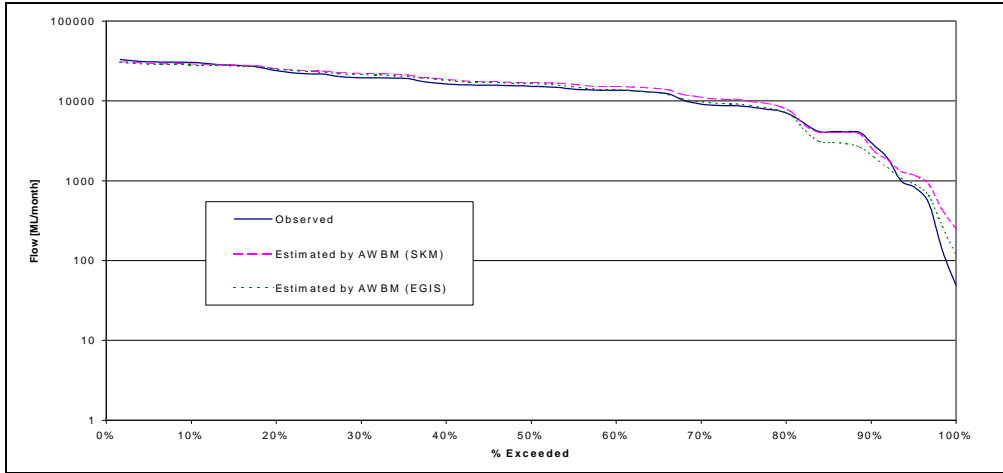


■ Figure 7-6 Time Series Plots of Observed and Estimated Daily Flows at Killara Road Gauge (1/09/1984 to 30/06/1986)

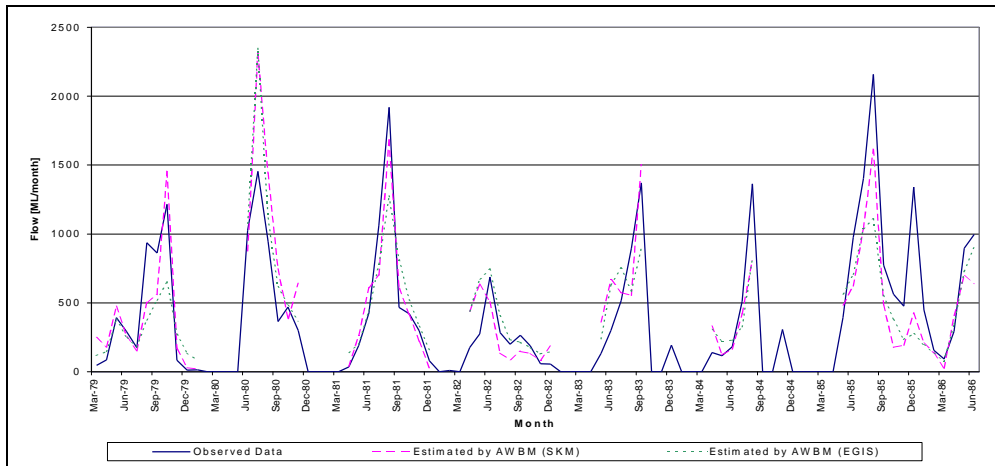


■ Figure 7-7 Mass Curves of Observed and Estimated Flow at Killara Road Gauge

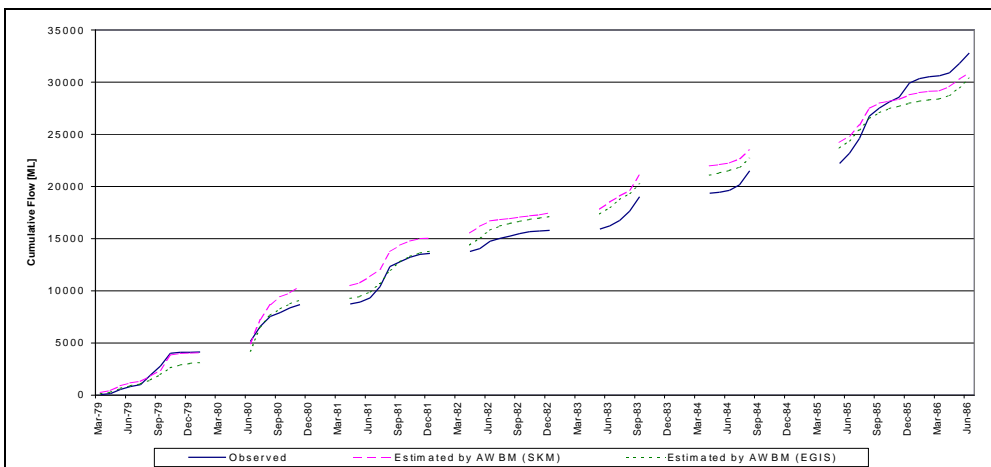
Monthly comparison with previous study (Egis, 2002)



■ Figure 7-8 Flow Duration Curves of Observed and Estimated Monthly Flows by SKM and EGIS at Killara Road Gauge (March 1979 to December 1980)



■ Figure 7-9 Time Series Plots of Observed and Estimated Monthly Flows by SKM and EGIS at Killara Road Gauge (March 1979 to December 1980)



■ Figure 7-10 Mass Curves of Observed and Estimated Monthly Flows by SKM and EGIS at Killara Road Gauge

The parameters used for the calibration and a brief description of their function in the model are shown in Table 7-2. The climatic input was rainfall recorded at Silvan (gauge 086106) and the mean monthly evaporation estimated for subcatchment 3 as derived from the evaporation recorded at Scoresby Research Institute (gauge 086104).

■ **Table 7-2 Parameters used in the modified AWBM.**

Variable	Description	Value
Capacity Storage 1	Depth of the hypothetical storage 1	10 mm
Capacity Storage 2	Depth of the hypothetical storage 2	300 mm
Capacity Storage 3	Depth of the hypothetical storage 3	750 mm
Partial Area factor 1	The proportion of the catchment that storage 1 covers	0.25
Partial Area factor 2	The proportion of the catchment that storage 2 covers	0.4
Partial Area factor 3	The proportion of the catchment that storage 3 covers	0.35
BFI	The proportion of the overflow which becomes groundwater when the storage overflows	0.35
K _{base}	Baseflow regression constant; influences rate at which groundwater is fed into streams.	0.95
K _s	Surface regression constant; influences length of time required for water in a stream to reach the catchment outlet.	0.51
LF	Loss factor ¹	0.45%
Q _T	Streamflow threshold below which low flow loss applies ¹	1.5 ML/d

(1) The modified AWBM model refers to the additional loss function which was required to model rainfall-runoff for low flows in the Stringybark Creek catchment.

7.4 Transposition

Streamflows at Killara Road were adjusted to derive inflows for each subcatchment in the REALM model. The adjustment was based on using a transposition relationship.

Trial Method

A regional transposition relationship was recently derived as part of the Hoddles Creek Streamflow Management Plan using mean annual flows (SKM, 2000). However, in that study the regional transposition relationship was found to be inaccurate during low flows. As a result, a transposition relationship specific to Hoddles Creek was developed for that study.

Based on the nature of the problems encountered during the Hoddles Creek study, a new regional transposition relationship was derived for use in this study using a range of low and high flows (percentiles) rather than mean annual flows. This is called a percentile transposition relationship, and accounted for the seasonal variability of flows throughout the year in a way that would not have been captured using mean annual flows.

Partial natural flows were calculated by adding all historic upstream diversions, except the impact of on-stream and farm dams, back to flows at the gauge:

$$Partial\ Natural\ Flow = Historic\ Flow + Off-stream\ Dam\ Diversions + Domestic\ and\ Stock\ Demands + Direct\ Irrigation\ Diversions$$

■ **Equation 4**

The new transposition relationship was tested by transposing the partial natural streamflows at Killara Road to subcatchment 5, and comparing them to the partial natural streamflows at Clegg Road (gauge 229401). However, the result of this comparison found the new regional transposition relationship to still be inaccurate.

Adopted Method

To overcome the inaccuracies of applying regional data to the Stringybark Creek catchment, a percentile transposition relationship was derived for Stringybark Creek, making use of the gauged streamflows at Clegg Road (available from 10/7/1999 to 31/12/2000) and the estimated streamflows at Killara Road. Because the streamflows at Killara Road were estimated from the AWBM rainfall runoff model over this period, no attempt was made to compare the *timing* of flows. However because the AWBM model predicted the *distribution* of streamflows very well (refer Section 7.3), it was considered appropriate to compare flow percentiles.

Firstly, the percentile transposition relationship was derived using partial natural flows at Killara Road and at Clegg Road. A comparison of partial natural flow percentiles demonstrated that for the lowest 60% of daily flows, there was no increase in the partial natural flow between Clegg Road and Killara Road. This would result in no inflows being predicted between Clegg Road and the catchment outlet for 60% of the time, which was assumed to be unlikely.

It was therefore chosen to recalculate the percentiles using full natural flows (accounting for onstream and farm dams as well as the other licensed diversions shown in Equation 4):

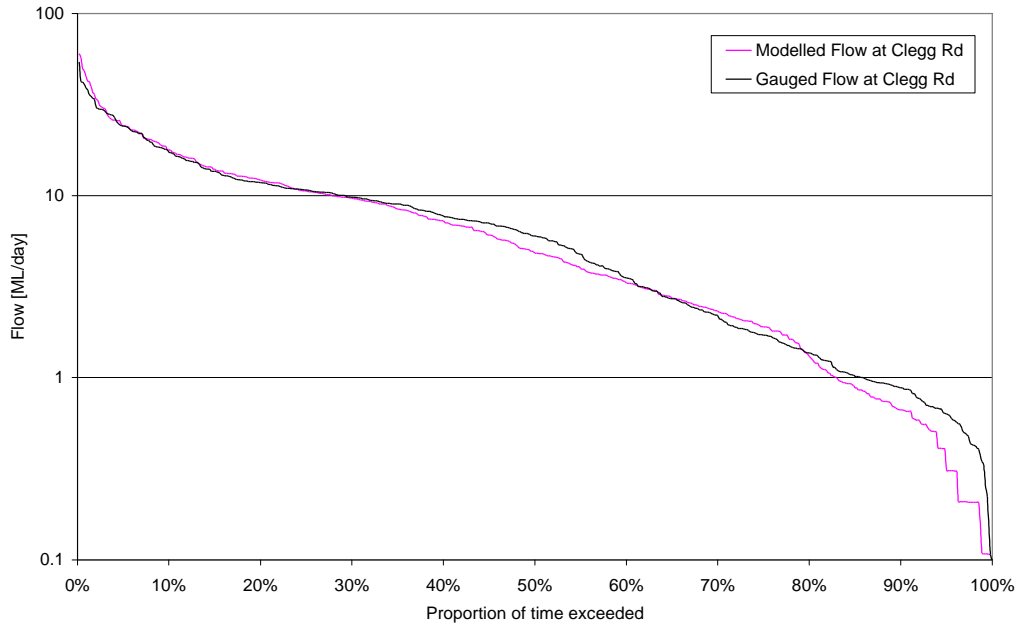
$$\text{Full Natural Flow} = \text{Historic Flow} + \text{Off-stream Dam Diversions} + \text{Domestic and Stock Demands} + \text{Direct Irrigation Diversions} + \text{On-stream Dam Impacts} + \text{Farm Dam Impacts}$$

■ **Equation 5**

On-stream dam impacts for subcatchment 5 were derived in the same manner as offstream dams (Section 6.2), and farm dam impacts were estimated using TEDI (Section 6.4). These impacts were added to partial natural flows to derive full natural flows. The percentile transposition relationship was re-derived using the full natural flows, and a new series of transposition factors were calculated for application to natural flows throughout the catchment.

To check the final transposition relationship, the flow duration curve of estimated streamflows after diversions are taken out and the gauged streamflows at Clegg Road were compared. The comparison, shown in Figure 7-11, shows good agreement between the gauged and estimated flows.

To apply the transposition relationship, inflows for the model sub-catchments representing inter-station areas were determined by estimating the proportion of flow for the total catchment area and then subtracting the proportion of flow estimated at the upstream sites. The proportion of flow estimated for the inter-station area (transposition factor) was then multiplied by the natural gauged flow at Killara Road to derive the required inflow series. Table 7-3 details the methodology adopted for the five sub-catchments and the relevant transposition factors.



■ Figure 7-11 Comparison of the flow duration curve between the gauged and estimated flows at Clegg Road.

■ Table 7-3 Method adopted to transpose concurrent flows.

Inflow	Method of Estimating Concurrent Flow	Transposition Factor	Area (km ²)
F5	Proportion of flow estimated directly for F5 catchment	$\left(\frac{A_5}{A_{229657}}\right)^m$	A ₅ = 8.6
F4	Proportion of flow estimated for total catchment above F4 minus proportion of flow estimated directly for F5	$\left(\frac{A_4 + A_5}{A_{229657}}\right)^m - \left(\frac{A_5}{A_{229657}}\right)^m$	A ₄ = 8.5
F3	Gauged 229657 flow minus F5 and F4 Inflows	$1 - \left(\frac{A_4 + A_5}{A_{229657}}\right)^m - \left(\frac{A_5}{A_{229657}}\right)^m$	A ₃ = 11.9
F2	Proportion of flow estimated for total catchment above F2 minus proportion of flow estimated for total catchment above F3	$\left(\frac{A_2 + A_3 + A_4 + A_5}{A_{229657}}\right)^m - 1$	A ₂ = 15.9
F1	Proportion of flow estimated for total catchment minus proportion of flow estimated for total catchment above F2	$\left(\frac{A_1 + A_2 + A_3 + A_4 + A_5}{A_{229657}}\right)^m - \left(\frac{A_2 + A_3 + A_4 + A_5}{A_{229657}}\right)^m$	A ₁ = 31.3

Notes: (1) m is the slope of the percentile flow versus area relationship, specific to each percentile flow, (2) A₁, A₂, ..., A₅ are sub-catchment areas for that inflow point, (3) A₂₂₉₆₅₇ is the catchment area of the Killara Road gauge = 29 km²

8. References

Close, P. and Koster, W. (2001). *An Assessment of Environmental Flow Requirements for the Olinda Creek Catchment*. Report prepared for Melbourne Water by the Department of Natural Resources and Environment, July 2001.

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Erlanger, P.D., Poulton, D.C. and Weinmann, P.E. (1992). *Development and Application of an Irrigation Demand Model Based on Crop Factors*. Conference on Engineering in Agriculture 1992, Albury, Australia. IEAust. Nat. Conf. Publication No. 92/11: 923-298

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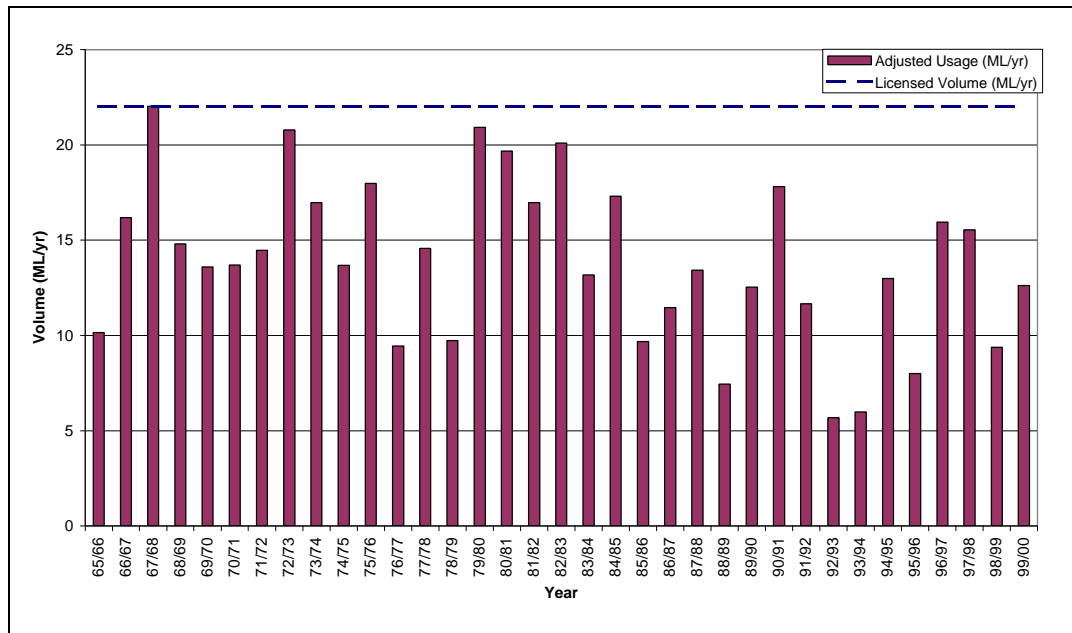
Sinclair Knight Merz (2000) *Streamflow Management Plan for Hoddles Creek – Estimation of Streamflow and Demands Data and Development of REALM Model*.

Appendices

Appendix A PRIDE Calibration Plots

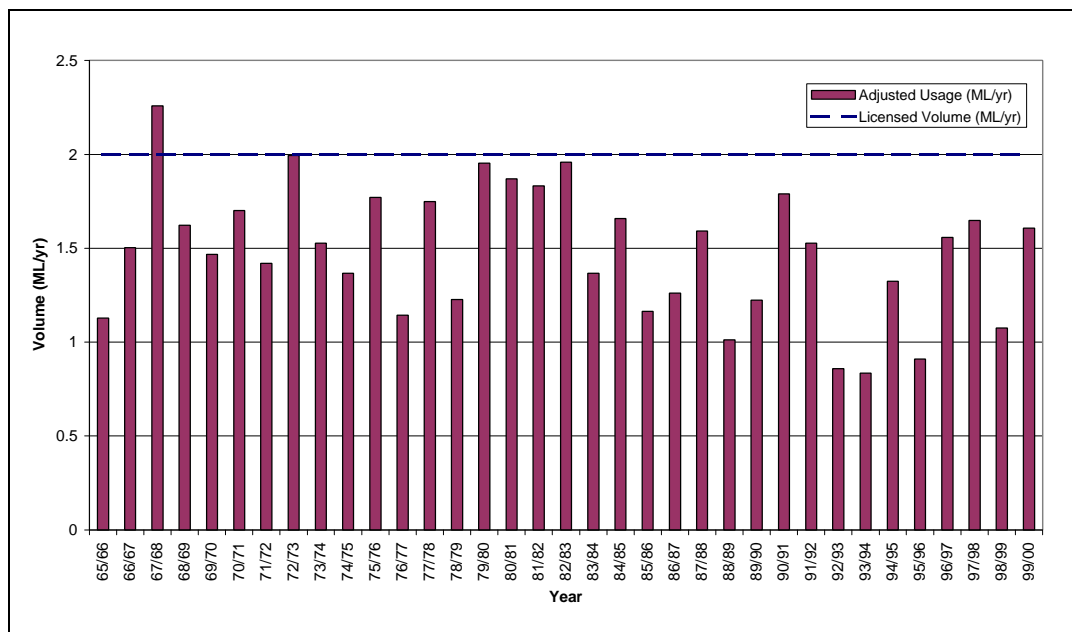
Subcatchment 3 - Diverters from Stringybark Creek between Clegg and Killara Roads

Current and Historic Levels of Development

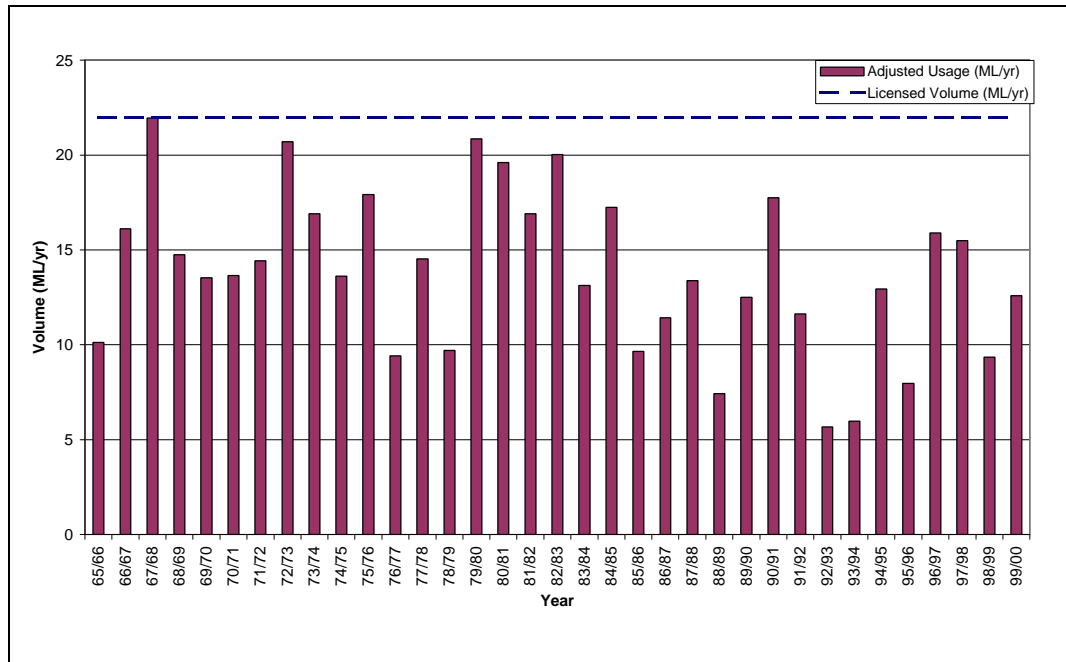


■ Figure 8-1 Subcatchment 3 Total (summer crops only) Demands at Current and Historic Levels of Development

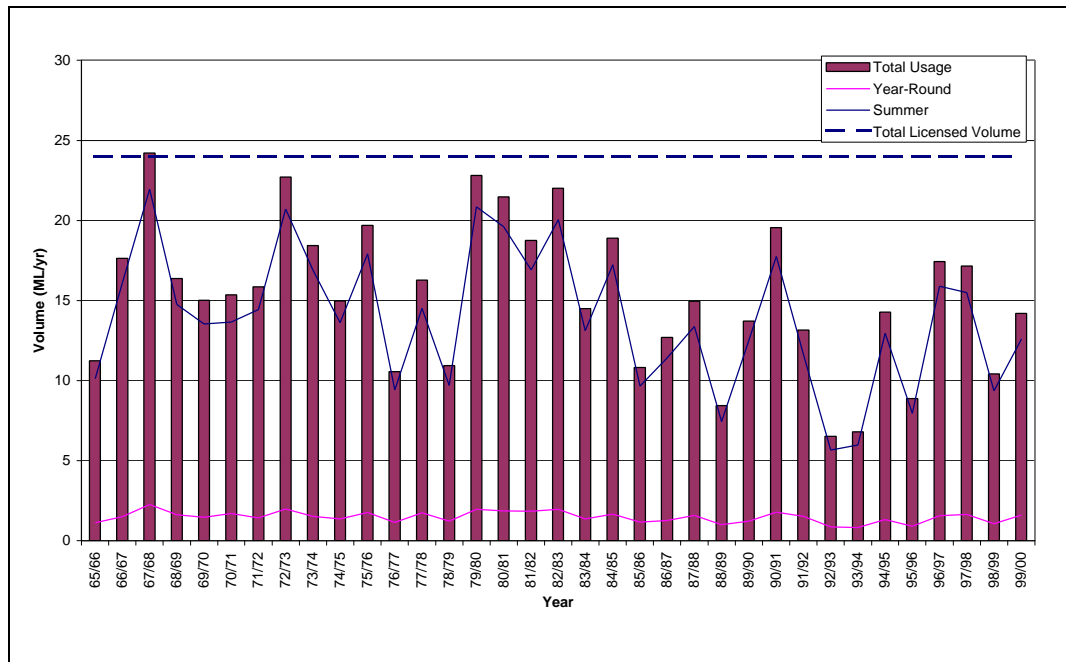
Full Level of Development



■ Figure 8-2 Subcatchment 3 Year-Round Crops Usage at Full Level of Development



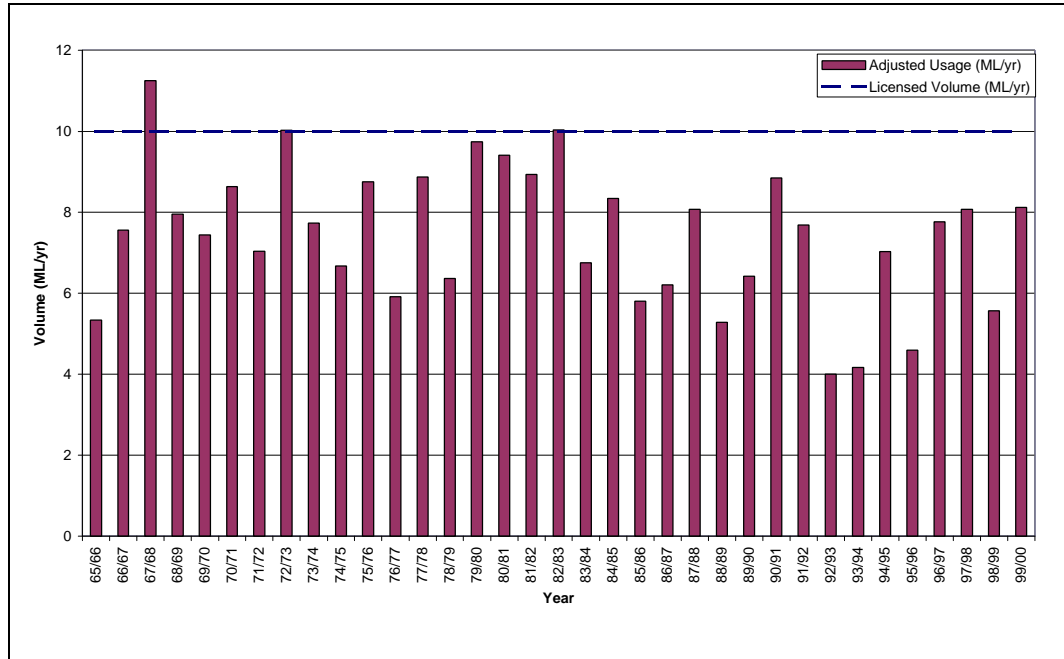
■ Figure 8-3 Subcatchment 3 Summer Crops Usage at Full Level of Development



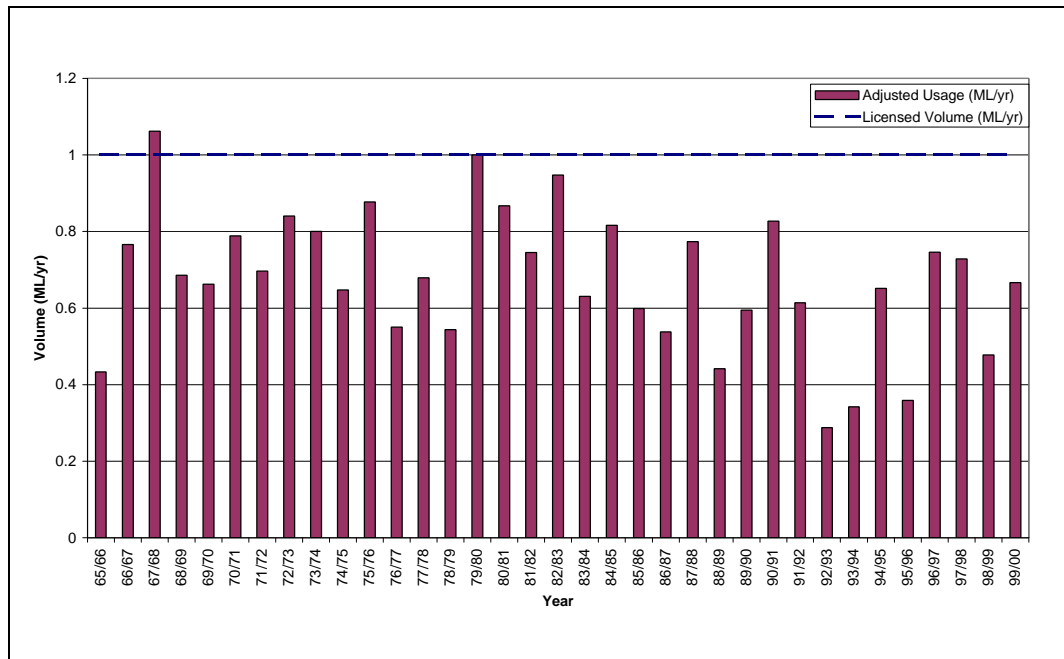
■ Figure 8-4 Subcatchment 3 Total Demands at Full Level of Development

Subcatchment 5 - Diverters from Stringybark Creek above Clegg Road

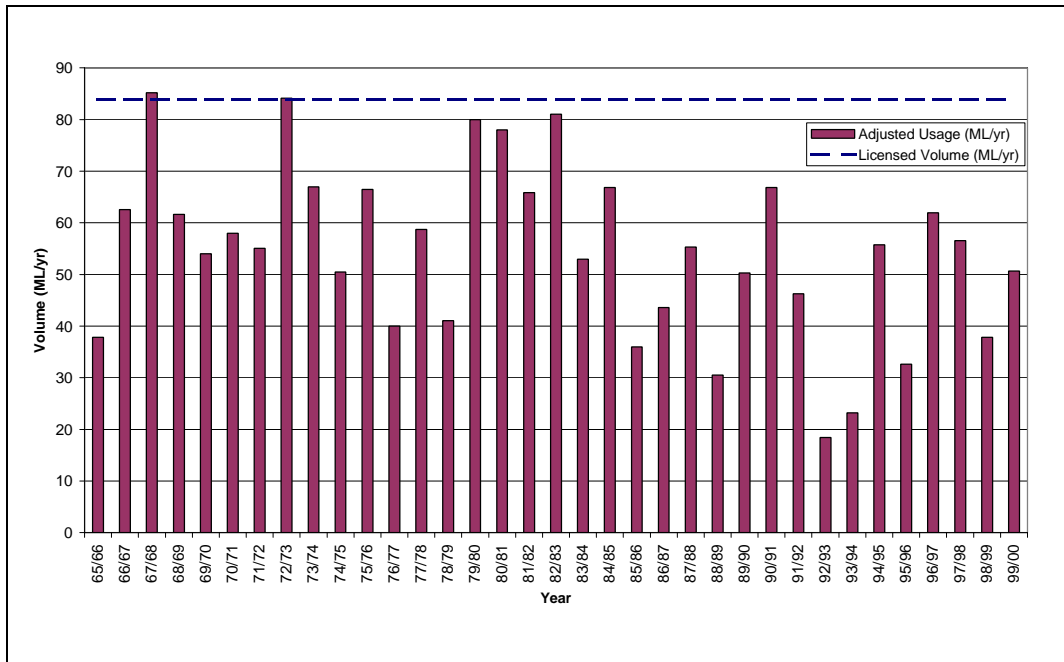
Current Level of Development



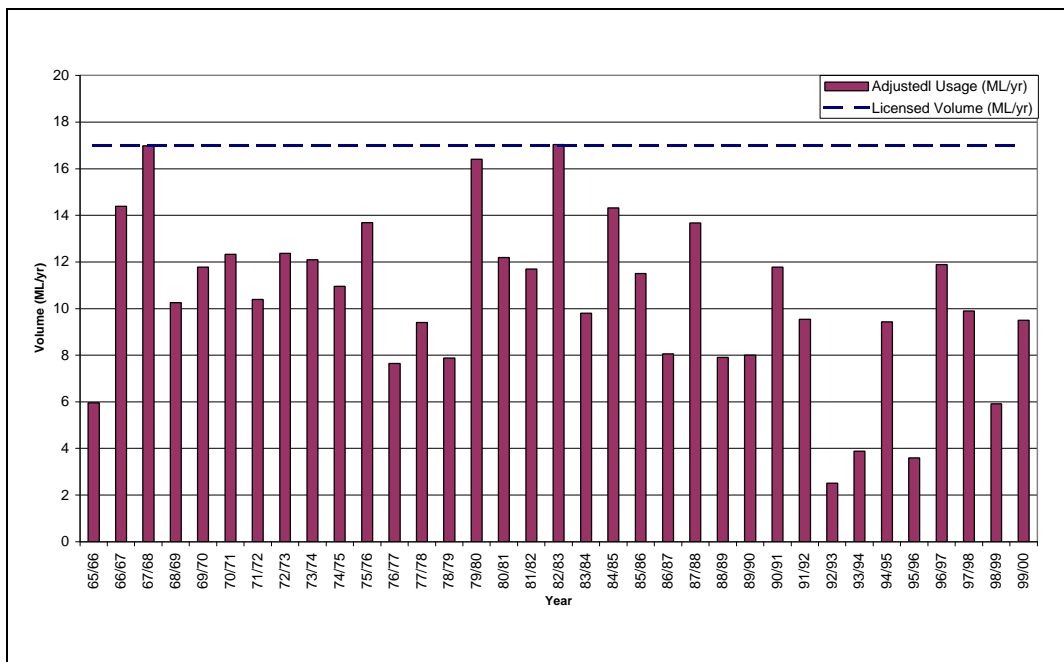
■ Figure 8-5 Subcatchment 5 Year-Round Crops Usage at Current Level of Development



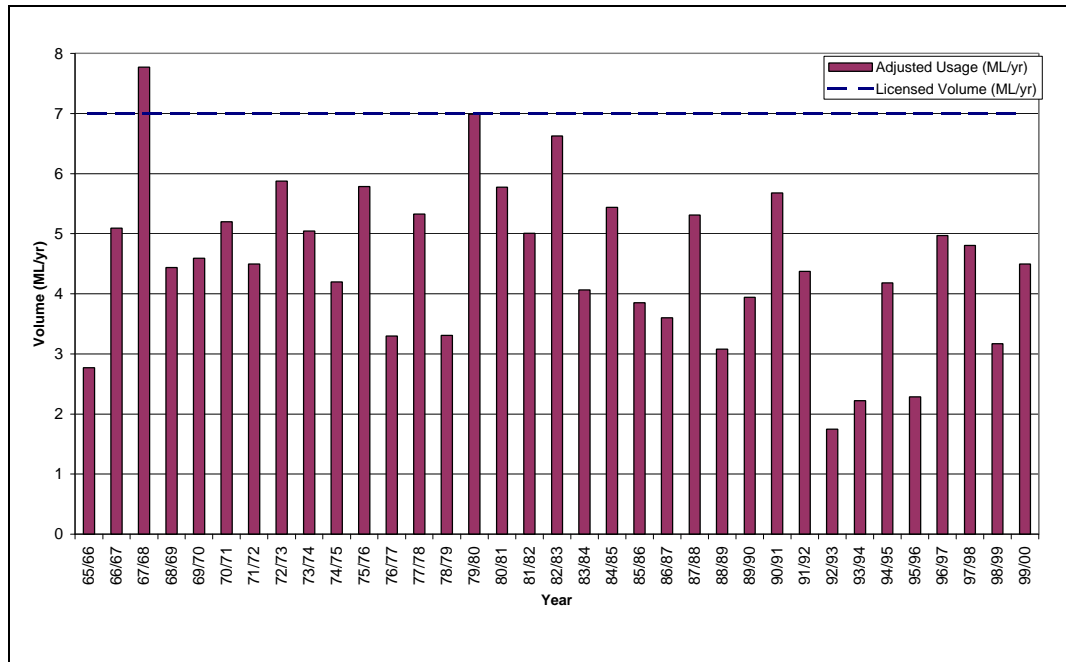
■ Figure 8-6 Subcatchment 5 Orchards Usage at Current Level of Development



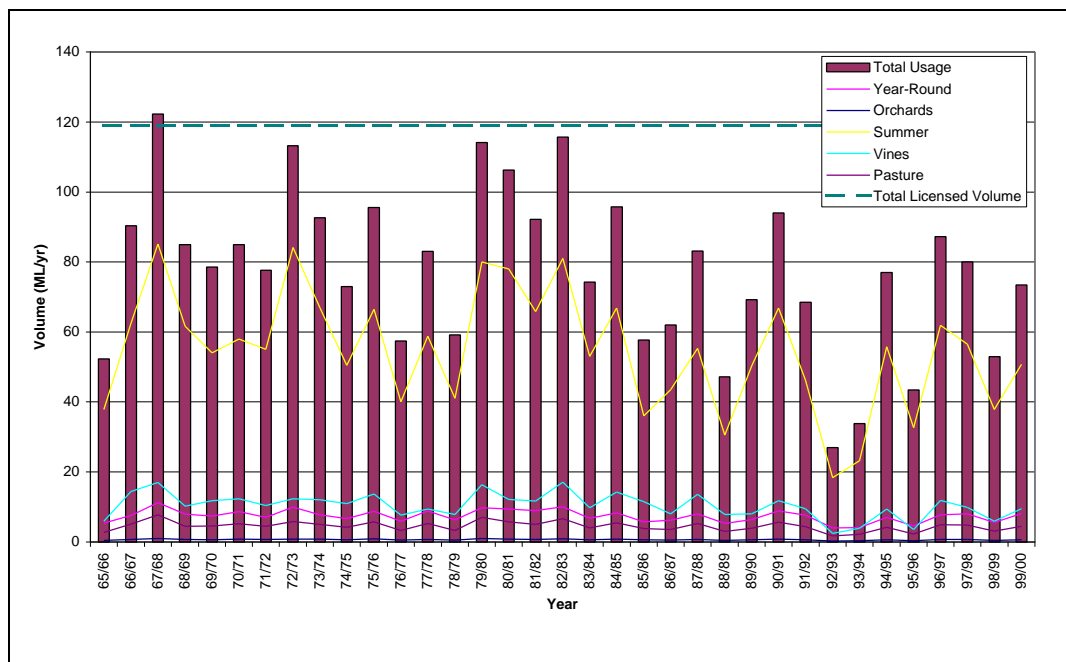
■ Figure 8-7 Subcatchment 5 Summer Crops Usage at Current Level of Development



■ Figure 8-8 Subcatchment 5 Vines Usage at Current Level of Development

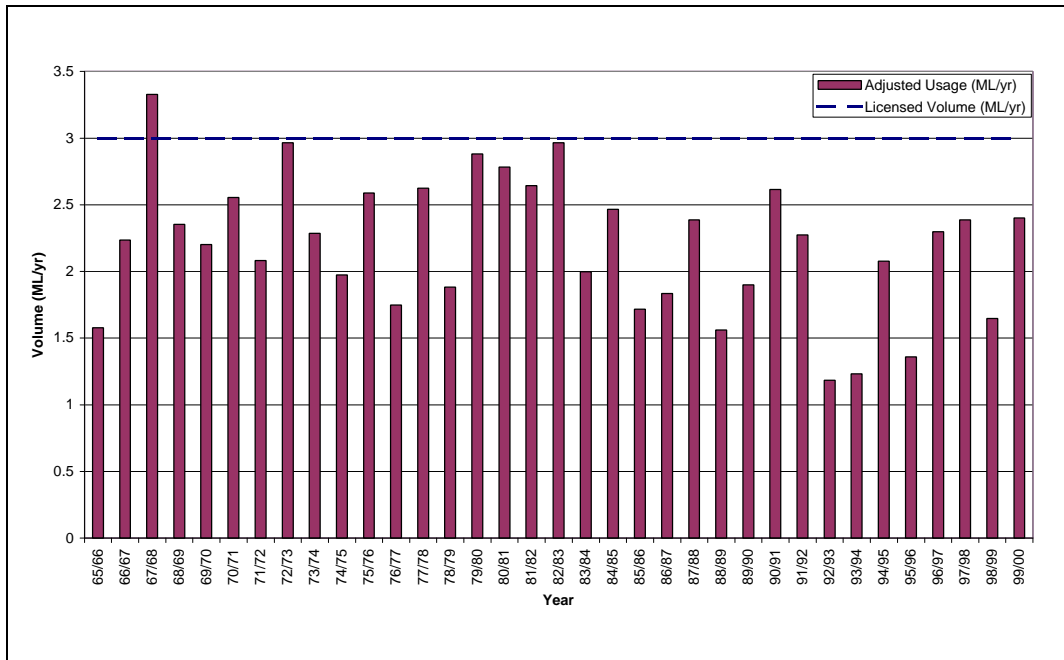


■ Figure 8-9 Subcatchment 5 Pastures Usage at Current Level of Development

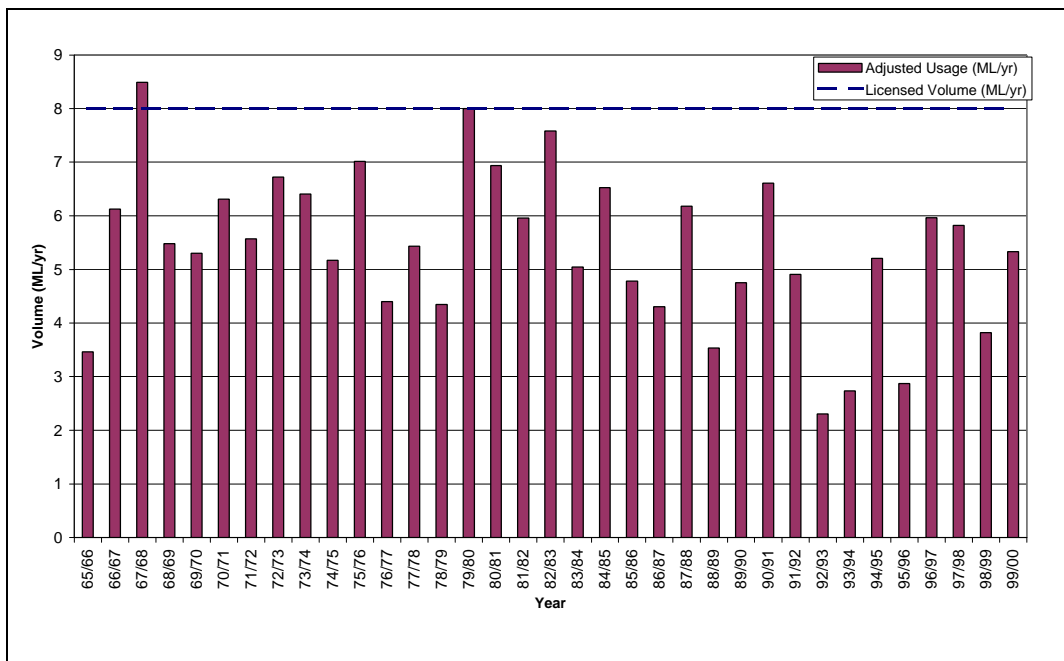


■ Figure 8-10 Subcatchment 5 Total Demands at Current Level of Development

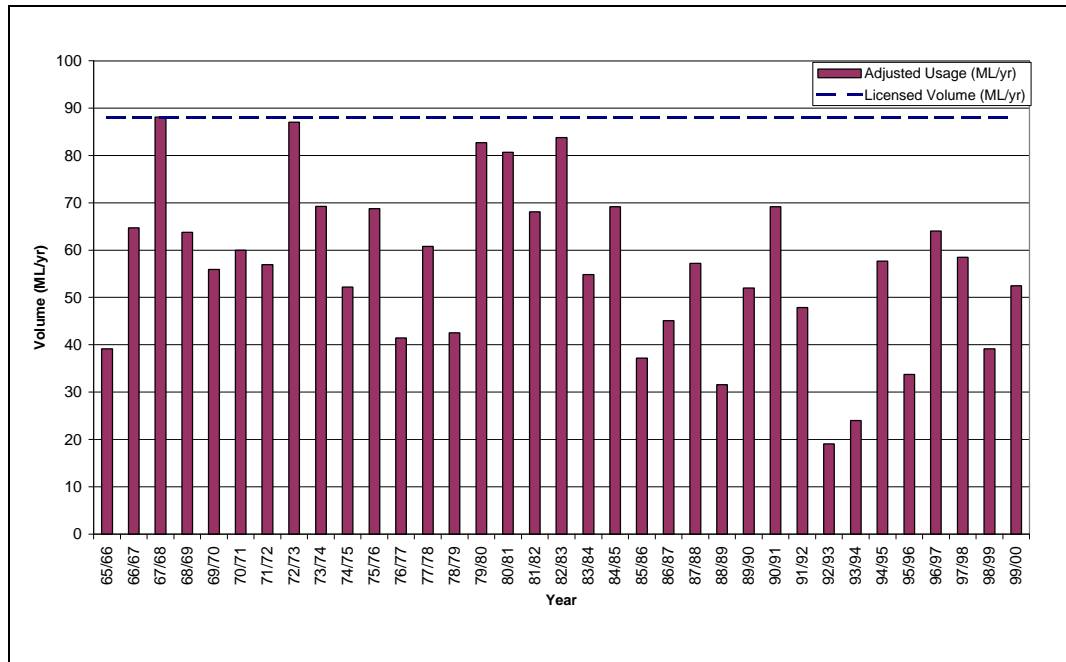
Historic Level of Development



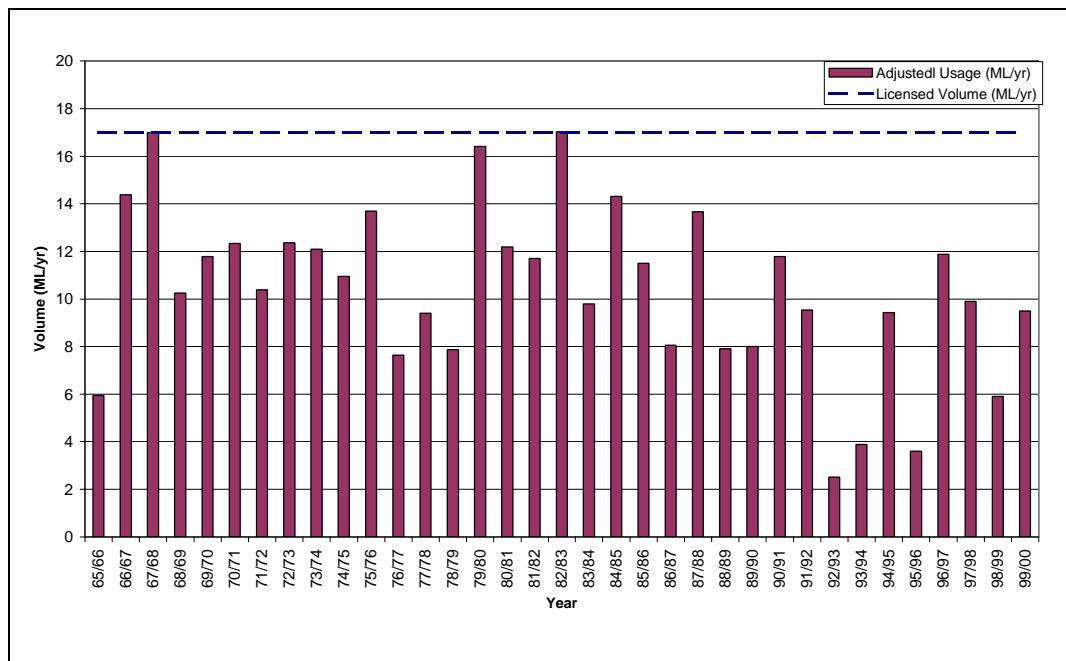
■ **Figure 8-11 Subcatchment 5 Year-Round Crops Usage at Historic Level of Development**



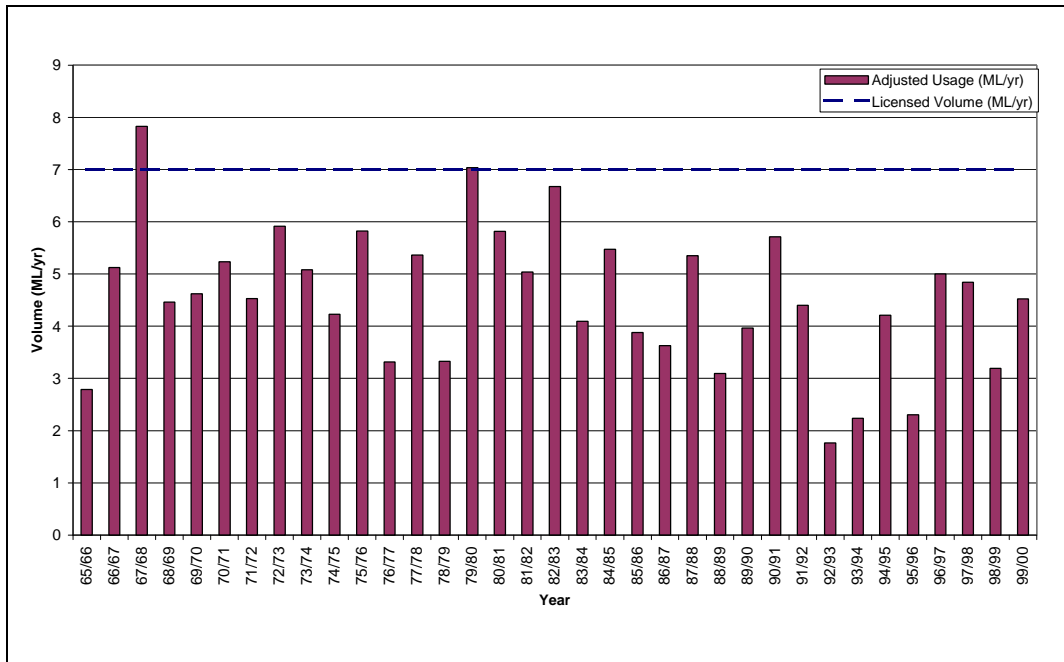
■ **Figure 8-12 Subcatchment 5 Orchards Usage at Historic Level of Development**



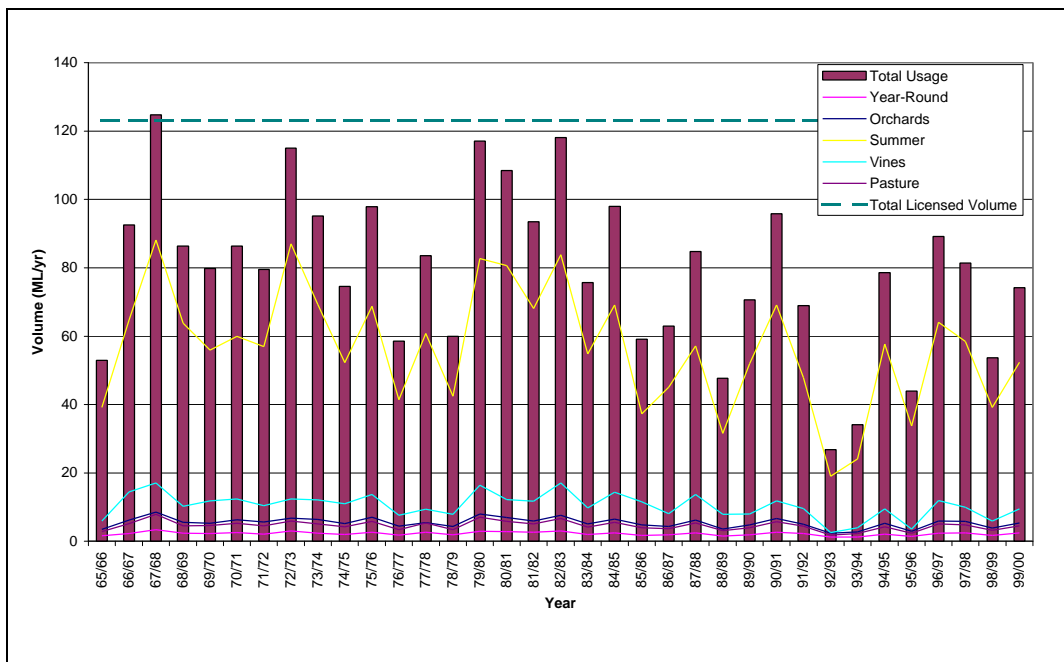
■ Figure 8-13 Subcatchment 5 Summer Crops Usage at Historic Level of Development



■ Figure 8-14 Subcatchment 5 Vines Usage at Historic Level of Development

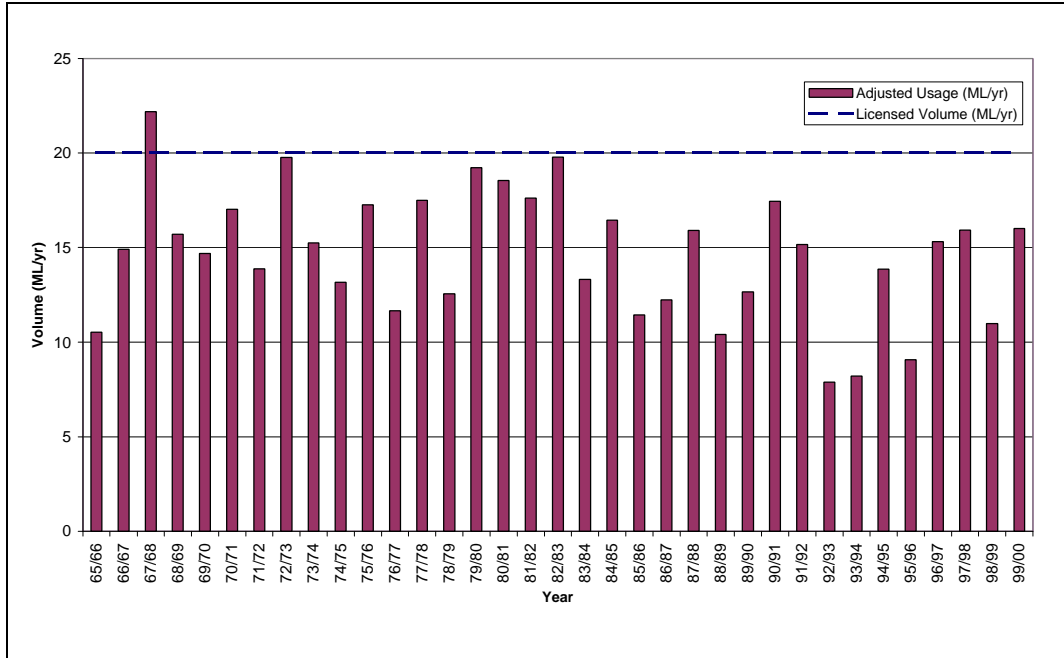


■ Figure 8-15 Subcatchment 5 Pastures Usage at Historic Level of Development

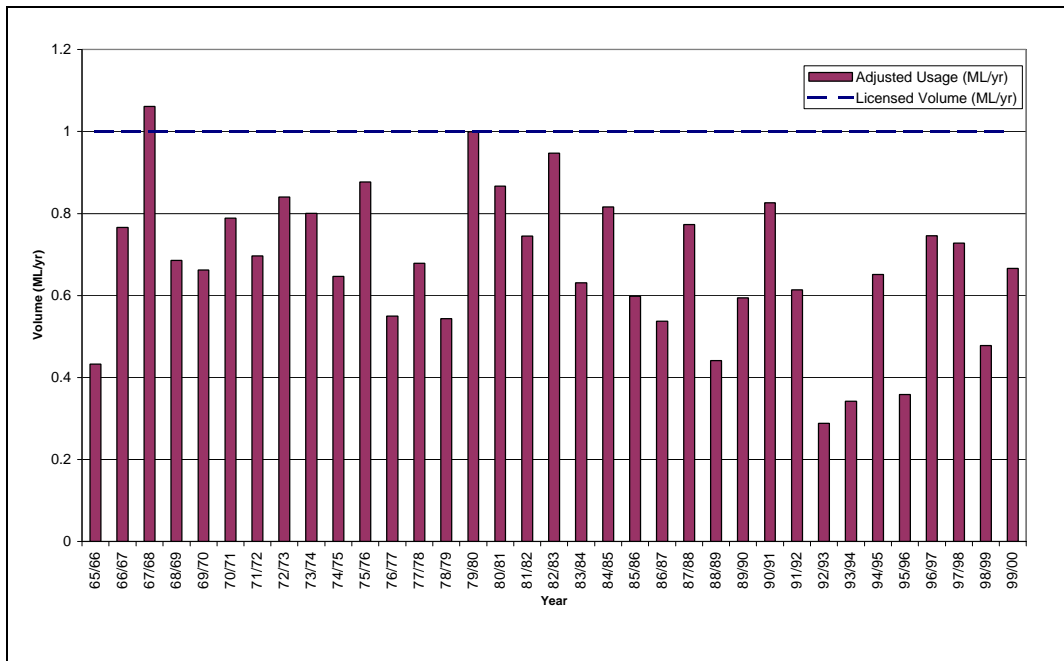


■ Figure 8-16 Subcatchment 5 Total Demands at Historic Level of Development

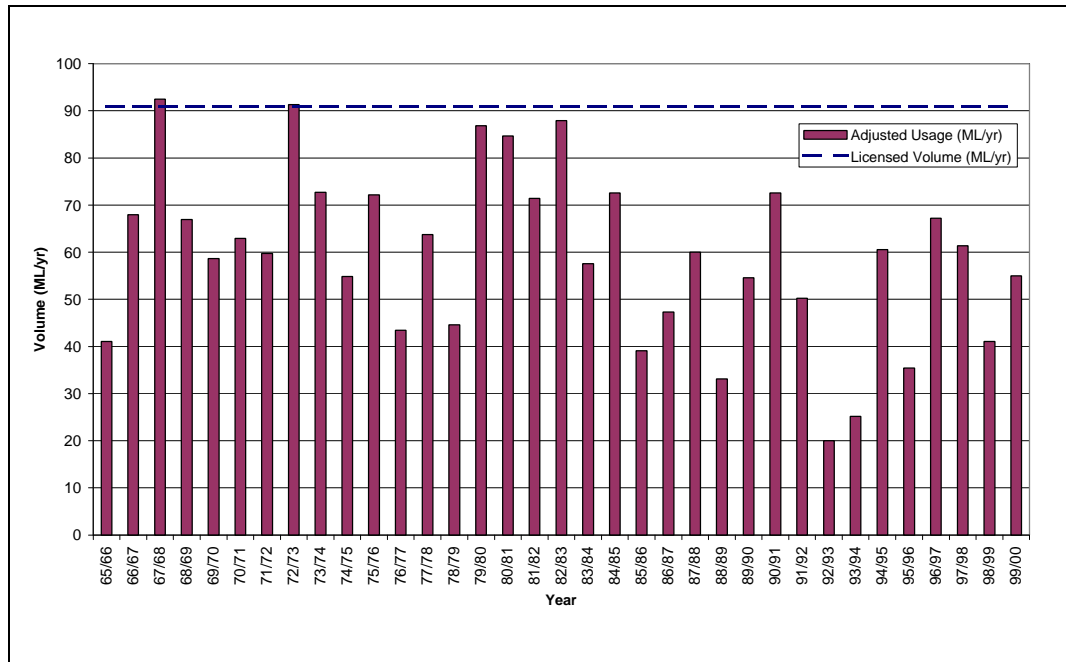
Full Level of Development



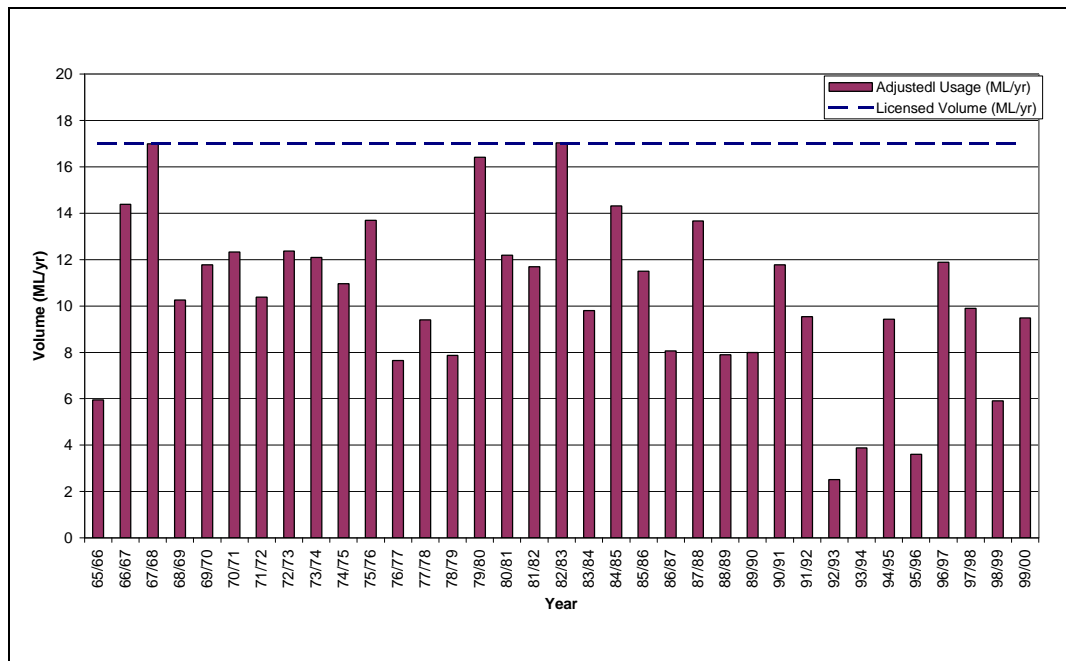
■ Figure 8-17 Subcatchment 5 Year-Round Crops Usage at Full Level of Development



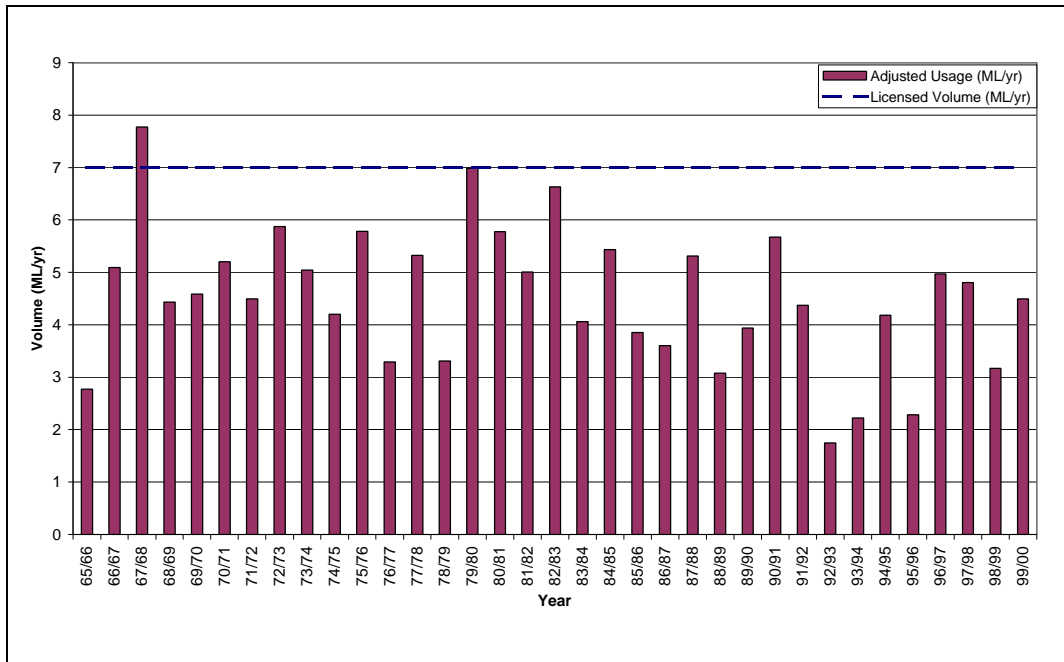
■ Figure 8-18 Subcatchment 5 Orchards Usage at Full Level of Development



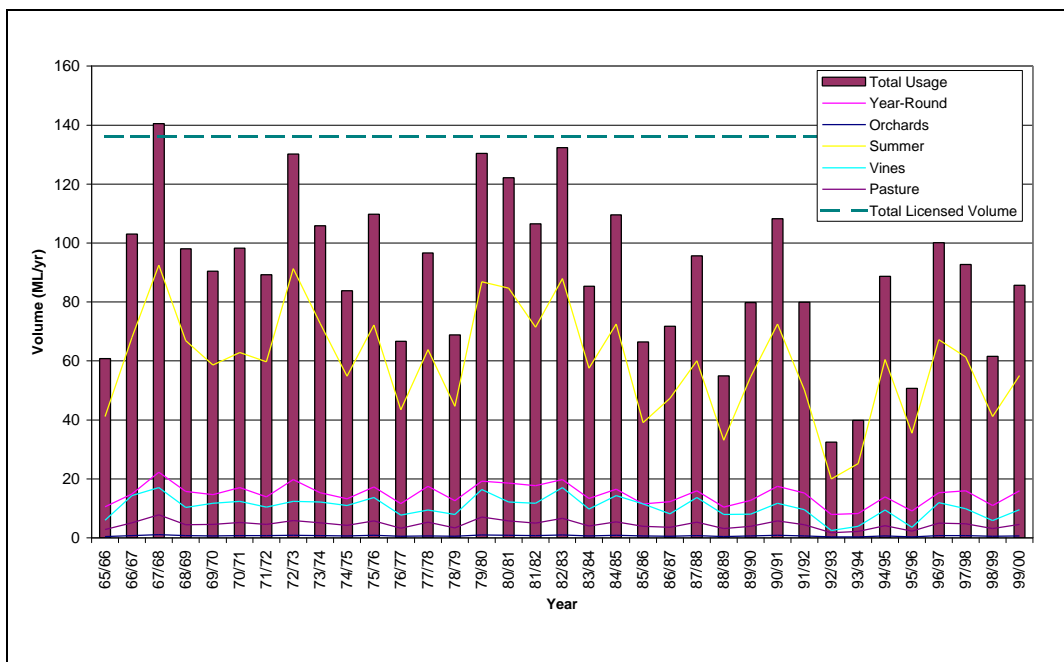
■ Figure 8-19 Subcatchment 5 Summer Crops Usage at Full Level of Development



■ Figure 8-20 Subcatchment 5 Vines Usage at Full Level of Development



■ Figure 8-21 Subcatchment 5 Pastures Usage at Full Level of Development



■ Figure 8-22 Subcatchment 5 Total Demands at Full Level of Development