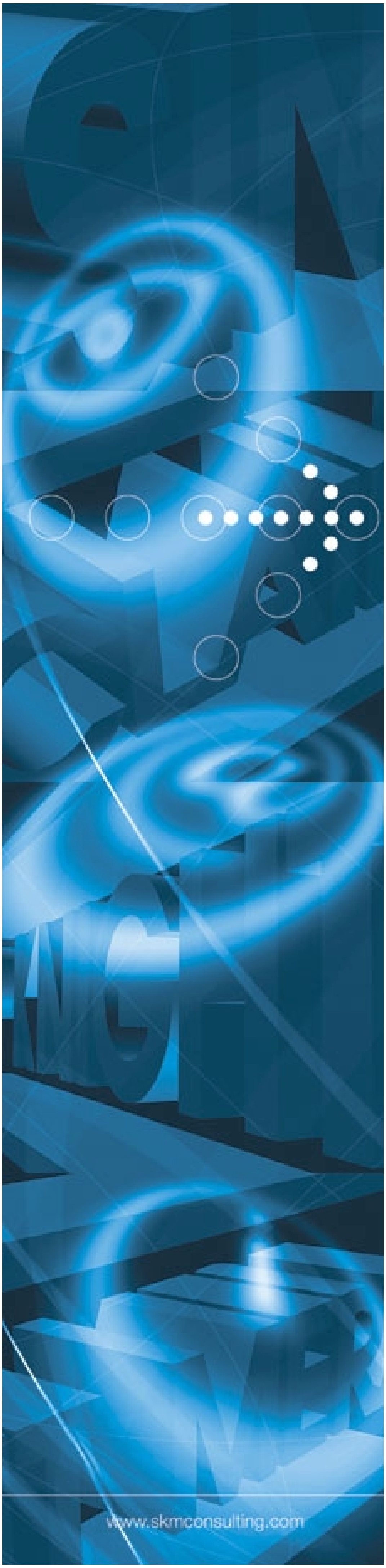

Estimation of streamflow and demand data and development of a REALM model for Olinda Creek Catchment

Report prepared for Melbourne Water

Final 2

July 2002

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Contents

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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 for the Olinda Creek catchment is currently being developed. This creek is located in the Yarra Valley. It joins Stringybark Creek around Yering just upstream of its confluence with the Yarra River. The catchment is unregulated and licensed diversions, discharges from the Lilydale Sewerage Treatment Plant (STP) and the effect of farm dams have impacted streamflows in the catchment. Use of water has reached a point where it may be stressing environmental health.

1.2 Purpose

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

This report is the first 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 Project 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 Olinda Creek Catchment community without expertise in hydrological analysis.

- Sections 5 to 8 contain a technical description of the methodology used. They provide a transparent and defensible description of how the outcomes were derived.

2. The Olinda Creek Catchment

2.1 Catchment Description

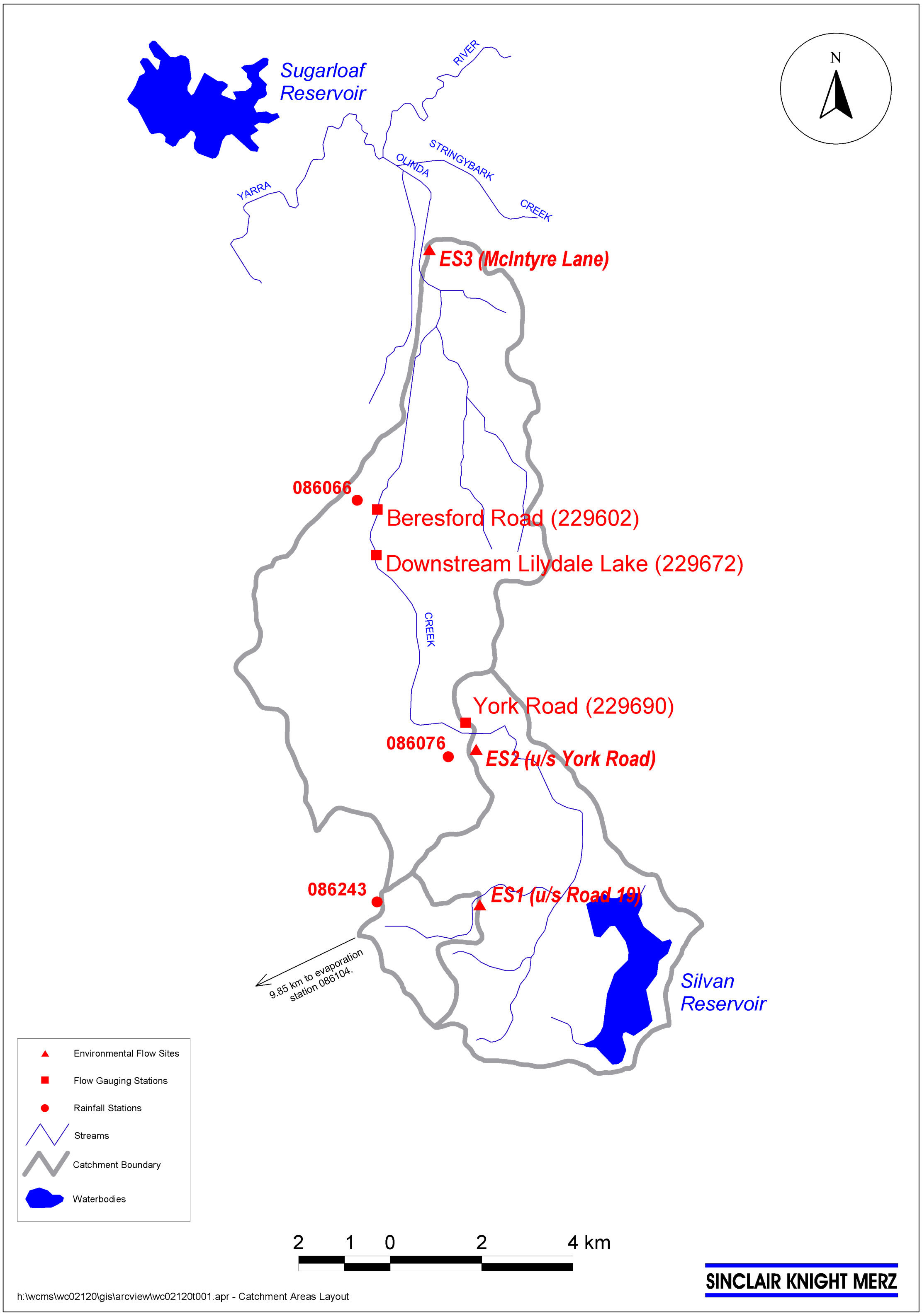
Olinda Creek begins near Kalorama in the Dandenong Ranges. The stream generally flows north and the central and uppermost reaches of the catchment are urbanised, containing the townships of Lilydale, Kalorama and Coldstream West. The catchment is long and narrow and has a total area of approximately 83 km². A map of the catchment is shown in Figure 2-1.

The catchment provides water for irrigators, stock and domestic users, and a small number of commercial and industrial users, either through direct diversion or water harvesting in farm dams. The catchment is unregulated, however there are two significant water storages within the catchment. Silvan Reservoir in the upper reaches does not collect water from the catchment and releases a constant passing flow of 2 ML/day (Pers comm, Steve Nicol, Melbourne Water). Lilydale Lake is a recreational water body in the lower reaches of the catchment, and is operated so that the outflows essentially equal the inflows (Close and Koster, 2001). Downstream of Lilydale, the Lilydale Sewerage Treatment Plant (STP) discharges treated effluent to Olinda Creek.

The Olinda Creek catchment has been divided into three subcatchments for this study, based on the sites at which minimum environmental flows have been recommended (Close and Koster, 2001). The subcatchments are described in Table 2.1 and shown in Figure 2-1. The Lower Subcatchment is the larger and most urbanised of the three, and the downstream reach of Olinda Creek is relatively straight and channelised before the confluence with the Yarra River. The Middle Subcatchment contains Silvan Reservoir, which is surrounded by a restricted public access catchment reserve. The Upper Subcatchment is partially urbanised and the headwaters of the catchment are in the Dandenong Ranges National Park (Close and Koster, 2001). The Lilydale STP discharges into the Lower Subcatchment, below Beresford Road.

- **Table 2.1 – Olinda Creek subcatchment descriptions**

Subcatchment	Description	Area (km^2)
Upper	From top of Olinda Creek Catchment to the bridge on Road 19, off Olinda Creek Road, Kalorama (Environmental Flow Site 1)	4.4
Middle	Downstream of Environmental Flow Site 1 to the York Road bridge, Mt Evelyn (Environmental Flow Site 2)	29.5
Lower	Downstream of Environmental Flow Site 2 to the bridge on McIntyre Lane, Coldstream Killara Rd. (Environmental Flow Site 3)	49.3

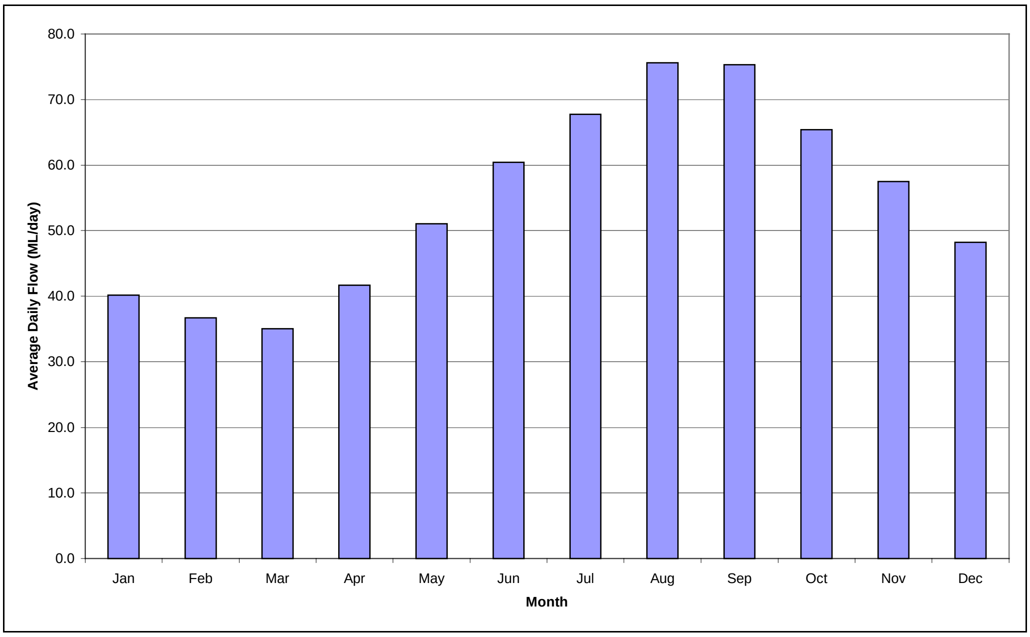


■ **Figure 2-1 Olinda Creek Catchment**

2.2 Climate and Hydrology

The Olinda Creek catchment has a temperate climate. Average monthly rainfall varies from as low as 57 mm in February to 112 mm in September, with the annual average being approximately 1,100 mm. Average evaporation varies from as low as 39 mm in June to 175 mm in January. The annual average evaporation is approximately 1,200 mm.

Streamflows in the catchment are seasonal and the daily average flows are lowest in March at 35 ML/day, and highest in August at 76 ML/day. The average annual flow at the downstream point of the study area is approximately 20,600 ML/annum, of which the Lilydale STP contributes around 13%. Average daily flows for each month at the downstream point of the catchment (Olinda Creek at McIntyre Lane) are shown in Figure 2-2.



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

2.3 Water Use

The majority of water use in the Olinda Creek catchment is in the middle and lower reaches. The most common crops grown are pasture, vegetables, berries, orchards, flowers, viticulture and trees.

Farming in the catchment relies on run-of-river flows during summer, onstream and offstream storages, and farm dams. Farm dams are those dams filled primarily by rainfall runoff rather than by water pumped directly form the Olinda Creek. The total volume of farm dams has been estimated from aerial photographs (Egis, 2002). Farm dams are used to store water for both stock and domestic use and irrigation. More detailed information on estimating the volume of farm dams is provided in Section 5.5. A summary of annual licences and estimated farm dam volumes is provided in Table 2-2.

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

Subcatchment	**Number of Licence Holders**	**Licence Volumes (ML)**						**Unlicensed Farm Dam Volumes (ML)**
		Direct Irrigation	**Domestic & Stock (D&S)**	**D&S and Irrigation**	**Onstream Dam Filling**	**Offstream Dam Filling**	**Commercial or Industrial**	
Upper	28	75	22	16	12	92	-	-
Middle	28	182	20	11	11	46	50	8
Lower	11	207	2	4	-	12	5	117
TOTAL	**67**	**464**	**44**	**31**	**23**	**150**	**55**	**125**

3. Catchment Modelling

Streamflows are measured at three locations on Olinda Creek – York Road, downstream of Lilydale Lake and at Beresford Road. These stations are shown in Figure 2-1. This, along with farm dam impacts and any historic streamflow diversions or releases, can be 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. Changes in managing licences can be made in the model and the effect on the streamflows observed.

3.1 Model Description

The Olinda Creek hydrological model simulates daily streamflows and daily water use throughout the catchment. The model was developed using REALM, a software package designed for modelling river systems.

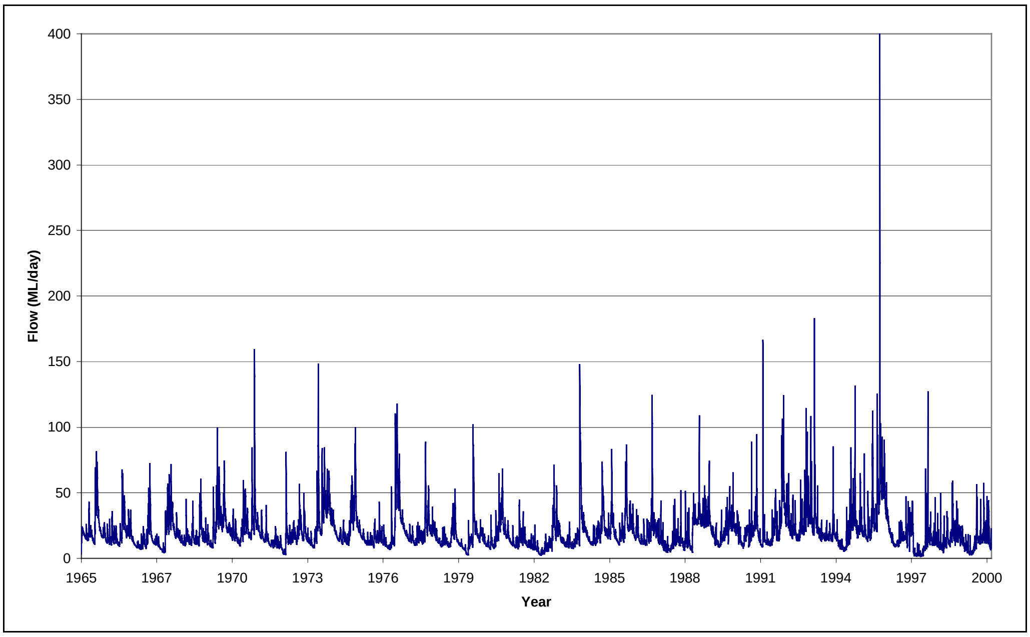
The model has a number of features:

- ☐ The catchment has been broken into three regions, as shown in Figure 2-1. This means that it is possible to specify different inflows and extractions in different subcatchments.

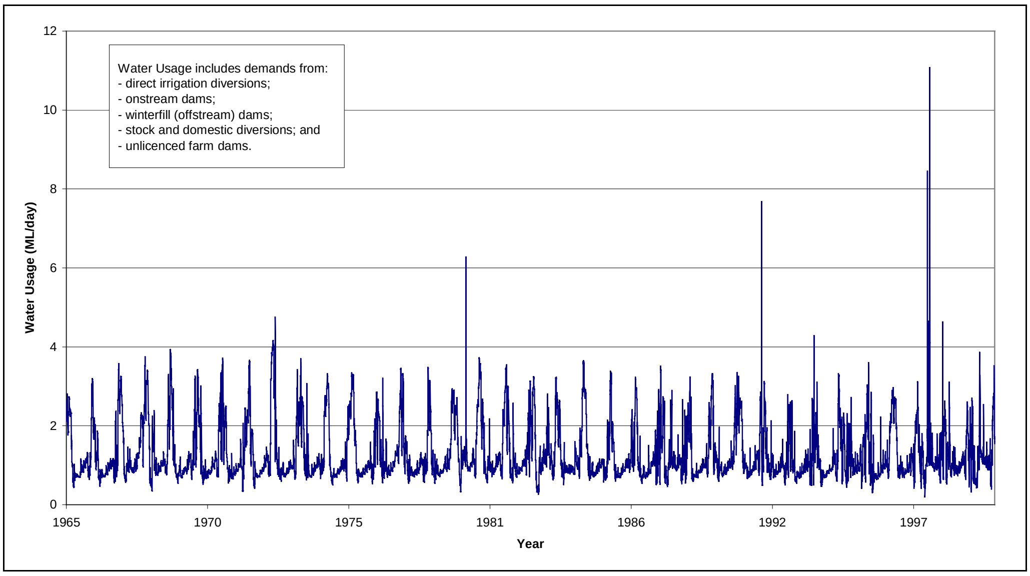
- ☐ The model runs from 1965 to 2000, thereby covering a range of climatic conditions. The results are therefore not biased by a limited number of wet or dry years.

- ☐ The model inputs were derived based on a constant level of irrigation development over the period 1965 to 2000, with changes from year to year based on how wet or dry it was in each particular year. This means that results are not affected by historic changes in the level of development in the catchment, and enables us to test, at a statistically significant level, how different levels of irrigation development impact on streamflows in the catchment.

- ☐ The model estimates daily streamflows and water usage for each subcatchment, between 1965 and 2000. The water usage data can be used to determine reliability of supply. Example outputs are provided in Figure 3-1 and Figure 3-2.



- **Figure 3-1 Estimated streamflows at York Road assuming current level of development conditions from 1965 to 2000**



- **Figure 3-2 Estimated water usage in the Olinda 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 8.

Climatic Data

In times when streamflows are not monitored, rainfall and evaporation data was used to predict streamflow. It was also used to estimate irrigation demands. Firstly, rainfall or evaporation records were infilled and extended by making comparisons with records at nearby stations. It was then necessary to check this data for the presence of any unexplained trends, which can change how much rainfall or evaporation is measured at a particular station and does not reflect the actual rainfall that occurred. Secondly, the variation in rainfall and evaporation across the catchment was estimated from nearby stations. The main rainfall stations used for this study included those at Lilydale, Montrose, Mount Dandenong, Olinda and Silvan. The main evaporation stations used for this study include those at Scoresby and Eildon. . These stations are shown in Figure 2-1.

Additional information on the derivation of climate inputs for the modelling is provided in Section 5.1 and 5.2.

Derivation of Demands

The demand types in the Olinda Creek catchment include direct diversion (irrigation, stock and domestic, commercial and industrial) from the creek, onstream and offstream storages, and farm dams.

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 that the entire licence volume is used. Climatic data was used to estimate seasonal variability. The impact of farm dams on streamflows was based on a prior investigation undertaken by Egis (2002).

Additional information on the derivation of demands can be found in Section 6.

Streamflows

Gauged streamflows at York Road were available from 1987 to 2000, 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. This relationship was then used to predict streamflows when no gauged streamflow data were available. The extended and infilled streamflow record at York Road was then used to estimate streamflows at other points in the Olinda Creek catchment.

Additional information on the infilling of missing streamflow data, extending the available period of streamflow record to cover the period from 1965 to 2000, and estimating streamflows at other points in the catchment are provided in Section 7.

4. Security of Supply

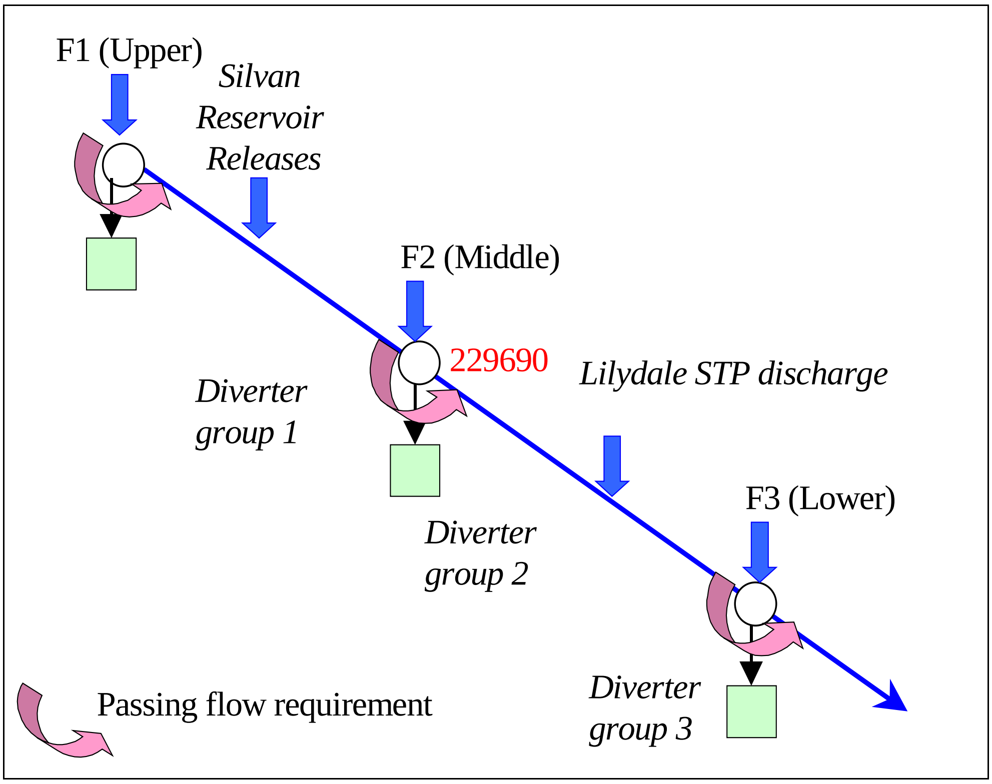
The Resource Allocation Model (REALM) was chosen as a planning tool to assess the security of supply under current and future demand and discharge scenarios. REALM is an excellent tool for evaluating changes in the operation of streamflow and water supply systems as it has a high degree of flexibility and is able to simulate complex operating rules.

REALM inputs include climate, streamflow, demand, discharges and characteristics of the streamflow system, such as any requirements to pass environmental flows at particular stream locations. A daily time step REALM model has been developed for the Olinda Creek catchment and used to simulate the demand, discharge and streamflow over the climatic period from 1965 to 2000 under a variety of scenarios (Section 4.1).

The model was calibrated using historic demands, streamflows, discharges from Lilydale STP and releases from Silvan Reservoir. The assessment of the reliability of supply for diverters was based on current and full level of development demands. The current level of development scenarios investigate the streamflows and reliability of supply that would occur over the climatic period 1965 to 2000 if demands are constant at current levels of development. The full level of development scenarios investigate the streamflows and reliability of supply that would occur over the climatic period 1965 to 2000 if demands are constant at estimated full levels of development.

A schematic of the Olinda Creek REALM, showing the various inflows, discharges and demands in the catchment, is illustrated in Figure 4-1. The diverter groups shown in the schematic have been simplified into one demand centre, however in the actual REALM system they have been broken down into five separate demand groups:

- Direct irrigation diversions;
- Domestic and stock (including commercial and industrial);
- Onstream dams;
- Offstream winterfill dams; and
- Farm dams.



- **Figure 4-1 Schematic of Olinda Creek REALM**

4.1 Scenarios

A number of scenarios have been investigated for this project and these are described in Table 4-1. The environmental flow recommendations that are implemented in Scenarios 4 and 5 are described in detail in Table 4-2.

- **Table 4-1 Olinda Creek REALM scenarios**

Scenario	Purpose of Scenario	L.O.D.[1] Demands	L.O.D. STP Discharges	Passing Environmental Flows?
1	Calibration of the Olinda Creek REALM model based on historic catchment conditions.	Historic	Historic	No
2	To test reliability of supply to diverters based on the current catchment conditions.	Current	Current	No
3	To test the reliability of supply to diverters based on estimated full level of development conditions.	Full	Full	No
4	To test the reliability of supply to diverters based on estimated full level of development conditions with environmental flows implemented.	Full	Full	Yes
5	To assess the impact on reliability of supply to diverters and on meeting the specified environmental flow recommendations in the Lower Subcatchment if Lilydale STP discharges remain at the current L.O.D. discharges.	Full	Current	Yes

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

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

Environmental Flow Site	Description	Environmental Flow Recommendation (ML/day)
Environmental Flow Site 1	Upstream of bridge on Road 19, off Olinda Creek Road, Kalorama	2
Environmental Flow Site 2 (compliance point)	Upstream of bridge on York Road, Mt Evelyn	6
Environmental Flow Site 3	Downstream of bridge on McIntyre Lane, Coldstream	15

For each scenario the reliability of supply for water users was examined. A preliminary assessment is also made of the impact of restrictions specified in the Drought Response Plan (Yarra Catchment) Private Diverters (Melbourne Water, 2001) on water users in the catchment. The DRP was however not included in the model as its trigger is a function of flow in the Yarra River, which is not available at current and future levels of development. This is discussed further in Section 4.2.6.

The following terms are used throughout the results section (Section 4.2) and brief explanations are provided:

- ☐ 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.

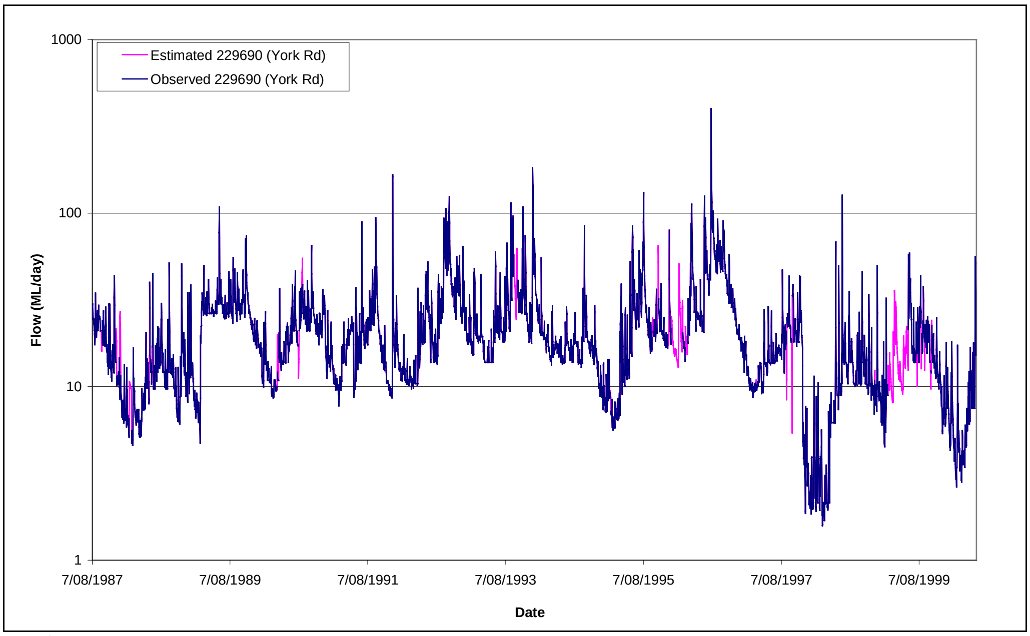
4.2 Results

4.2.1 Scenario 1

Calibration

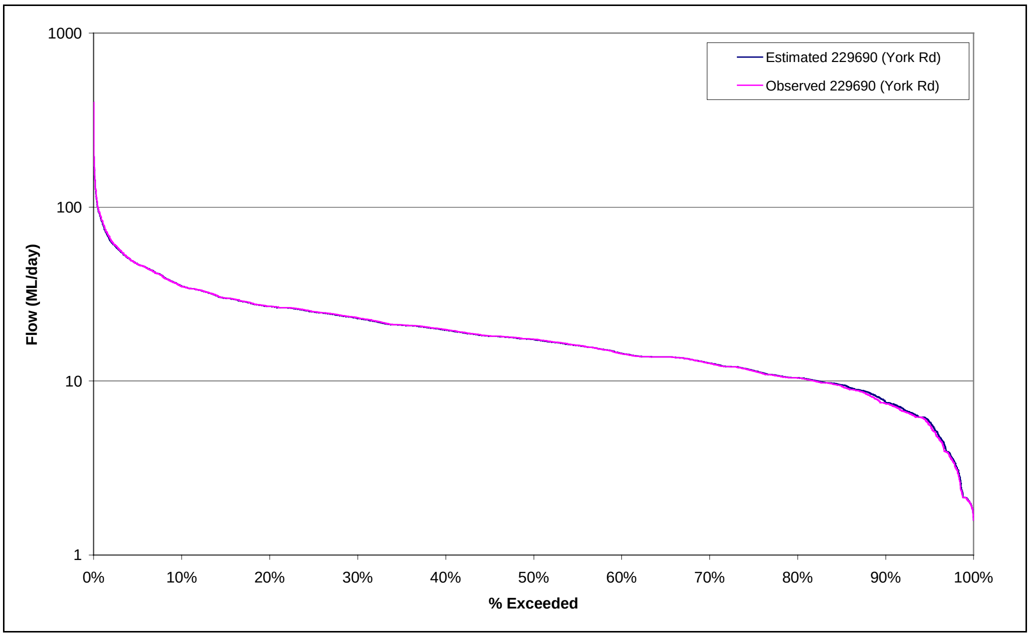
There is one calibration point in the Olinda Creek Catchment. The outflow from the Middle Subcatchment (F2) corresponds to the Olinda Creek at York Rd (229690) flow gauging station (Figure 1). A comparison of the gauged and modelled flows at this point over the concurrent period of record shows very good results (Figure 4-2 and Figure 4-3).

A shortfall is the difference in the unrestricted demand (ie the demand that would be met if there was an unlimited supply of water) and the demand met. Under historic conditions, six minor shortfalls were found to occur in five different years in the Upper Subcatchment, lasting from one up to 23 days. As the historic and current conditions have been modelled using the same data in the Upper Subcatchment the plots showing the number of weeks of shortfalls and the demand met versus the unrestricted demand is provided in the results for Scenario 2 (Section 4.2.2).



NB: flow scale is shown in the logarithmic domain

- **Figure 4-2 Time series of gauged and modelled flows at York Road (229690)**



- **Figure 4-3 Flow duration curves of gauged and modelled flows at York Road (229690)**

4.2.2 Scenario 2

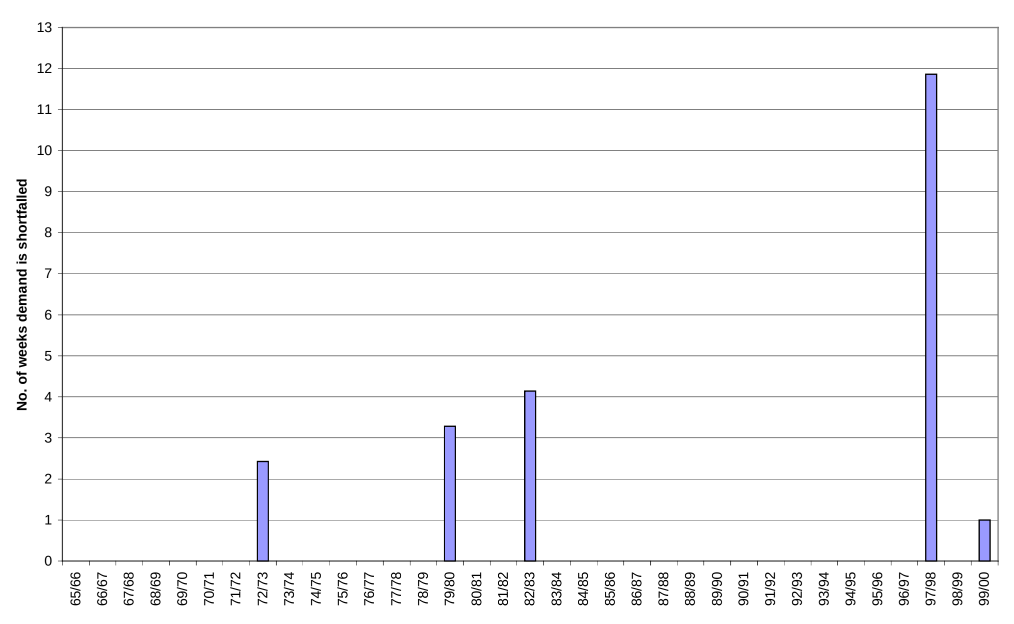
Current level of development, no environmental flows

Under Scenario 2, the unrestricted demand in the Upper Subcatchment cannot be met in all years (ie. there is a shortfall in demands). There are no demand shortfalls in the Middle or Lower subcatchments. Table 4-3 provides the number and duration of shortfalls in each subcatchment under Scenario 4.

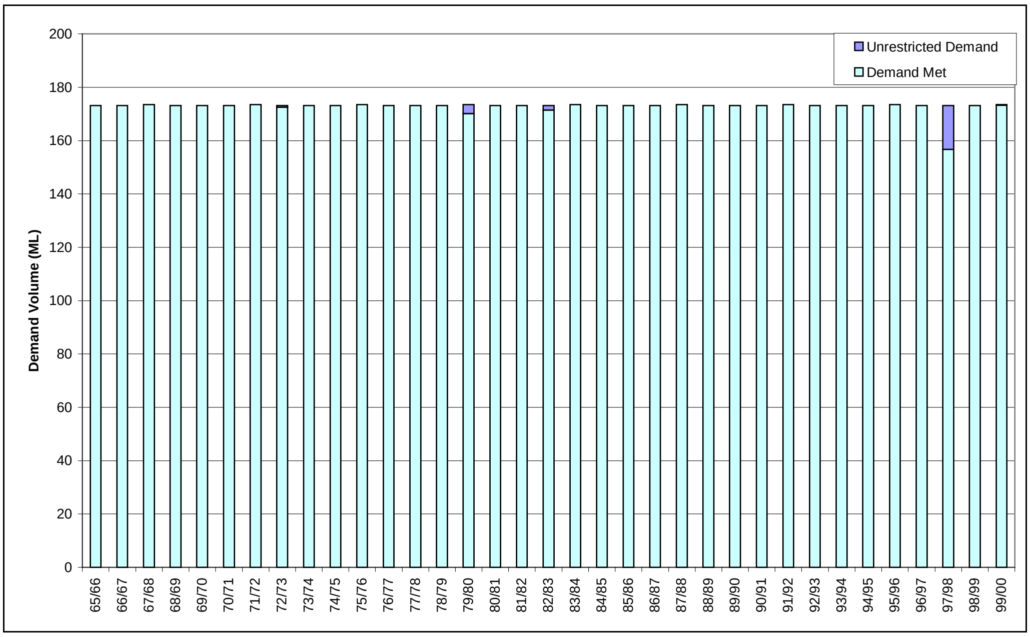
- **Table 4-3 Number and duration of shortfalls by subcatchment under Scenario 2**

Subcatchment	Total number of years of shortfalls	Average shortfall duration (days)	Range in shortfall durations (days)
Upper (F1)	5	6	1 to 23
Middle (F2)	0	0	N/A
Lower (F3)	0	0	N/A

Figure 4-4 illustrates the number of weeks in each year where demands cannot be fully met and Figure 4-5 compares the unrestricted demands in each year to the demand met for the Upper Subcatchment. Under the current level of development, only minor shortfalls occur in the Upper Subcatchment.



- **Figure 4-4 Number of weeks where demands cannot be fully met in the Upper Subcatchment (F1) under Scenario 2**



- **Figure 4-5 A comparison of the unrestricted demand and the demand met in the Upper Subcatchment (F1) under Scenario 2**

4.2.3 Scenario 3

Full level of development (no environmental flows and STP discharges at design capacity)

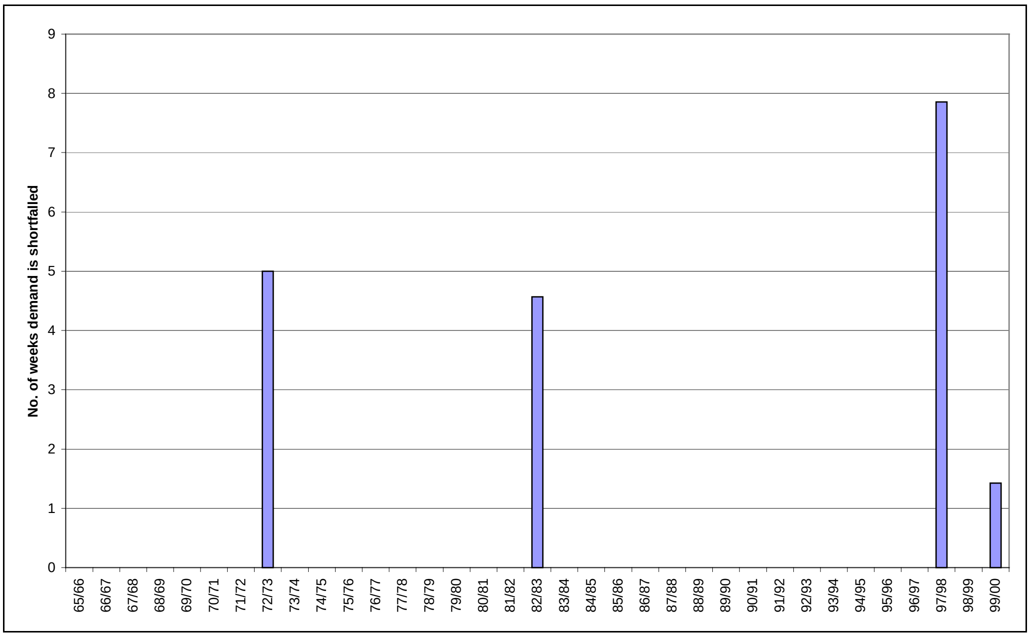
Under Scenario 3, the unrestricted demand in the Upper Subcatchment cannot be met in all years (ie. there is a shortfall in demands). There are no demand shortfalls in the Middle or Lower subcatchments. Table 4-4 provides the number and duration of shortfalls in each subcatchment under Scenario 4.

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

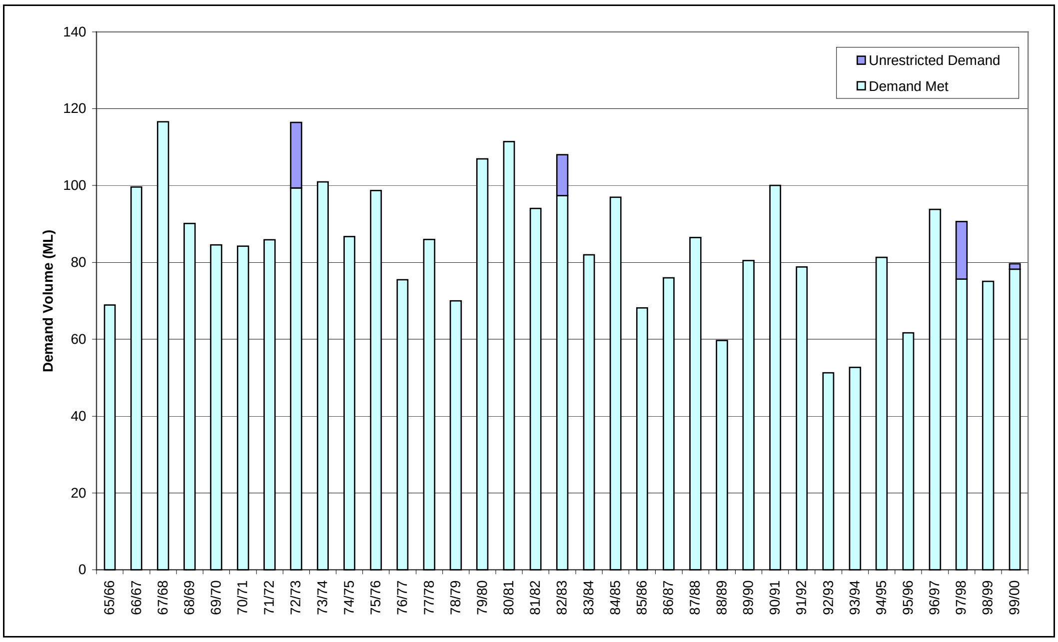
Subcatchment	Total number of years of shortfalls	Average shortfall duration (days)	Range in shortfall durations (days)
Upper (F1)	4	11	1 to 32
Middle (F2)	0	0	N/A
Lower (F3)	0	0	N/A

Figure 4-6 illustrates the number of weeks in each year where demands are shortfalled. Shortfalls are found to occur in only in the Upper Subcatchment in four of the years between 1965 and 2000. Figure 4-7 compares the unrestricted demands in each year to the demand met for the Upper Subcatchment.

The demand met in the Upper Subcatchment over the four years where shortfalls occur is only marginally lower than the unrestricted demand. The reliability of supply for diverters in the Middle and Lower subcatchments is not effected by increases in the level of development, from current to full, under this scenario.



■ Figure 4-6 Number of weeks where demands cannot be fully met in the Upper Subcatchment (F1) under Scenario 3



- **Figure 4-7 A comparison of the unrestricted demand and the demand met in the Upper Subcatchment (F1) under Scenario 3**

4.2.4 Scenario 4

Full level of development (with environmental flows implemented and STP discharges at design capacity)

Under Scenario 4, the unrestricted demand in the Upper and Middle subcatchments cannot be met in all years (ie. there is a shortfall in demands). There are no demand shortfalls in the Lower Subcatchment. Table 4-5 provides the number and duration of shortfalls in each subcatchment under Scenario 4.

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

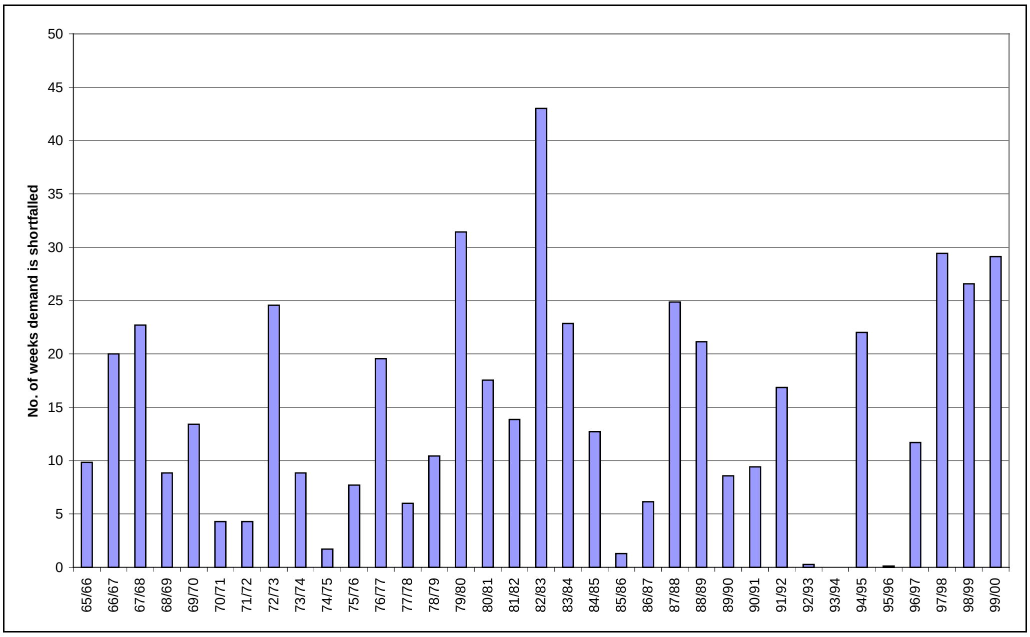
Subcatchment	Total number of years of shortfalls	Average shortfall duration (days)	Range of shortfall durations (days)
Upper (F1)	34	11	1 to 118
Middle (F2)	11	9	1 to 54
Lower (F3)	1	7	7(1)

Notes: (1) Only one shortfall period of seven days was recorded.

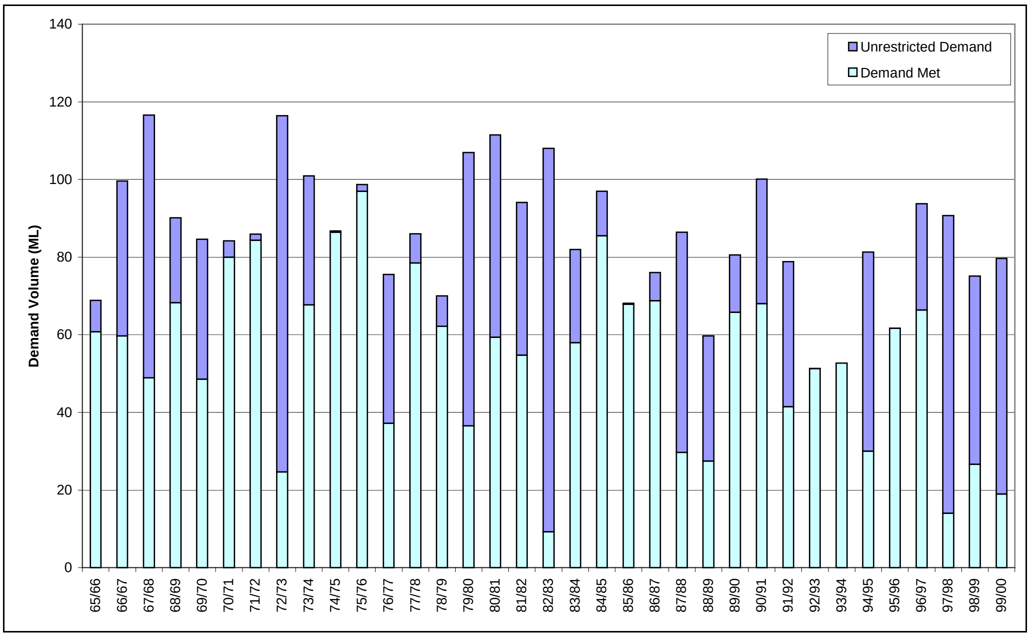
Figure 4-8 illustrates the number of weeks in each year where demands cannot be fully met and Figure 4-9 compares the unrestricted demands in each year to the demand met for the Upper Subcatchment. With the introduction of environmental flow recommendations in the Upper Subcatchment under full development conditions, diverters are shortfalled in 34 out of the 35 years between 1965 and 2000. The demand met in many of these years (for example 1972/73, 1982/83 and 1997/98) is significantly lower than the unrestricted demand.

Figure 4-10 illustrates the number of weeks in each year where demands cannot be fully met and Figure 4-11 compares the unrestricted demands in each year to the demand met for the Middle Subcatchment. With the introduction of environmental flow recommendations in the Middle Subcatchment under full development conditions, diverters are shortfalled in 11 of the years between 1965 and 2000. The demand met in most of these shortfall years is close to the unrestricted demand, excluding the years of 1972/73, 1982/83 and 1997/98, where the demand met is substantially lower than the unrestricted demand.

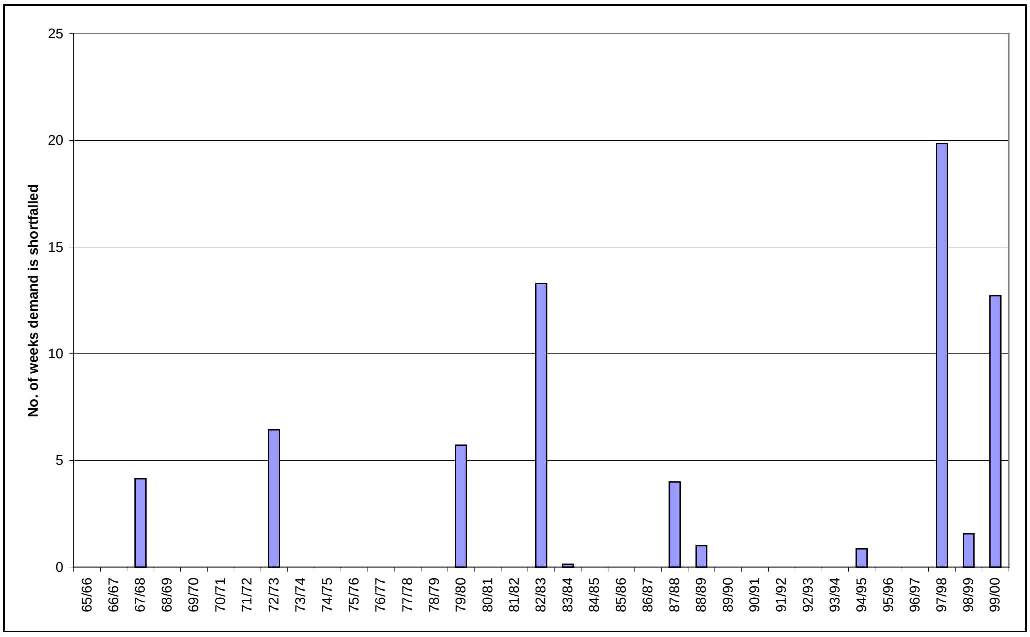
Figure 4-12 illustrates the number of weeks in each year where demands cannot be fully met and Figure 4-13 compares the unrestricted demands in each year to the demand met for the Lower Subcatchment. With the introduction of environmental flow recommendations in the Lower Subcatchment under full development conditions, diverters are shortfalled in only one of the years (1997/98) between 1965 and 2000. The demand met is only marginally lower than the unrestricted demand in this year.



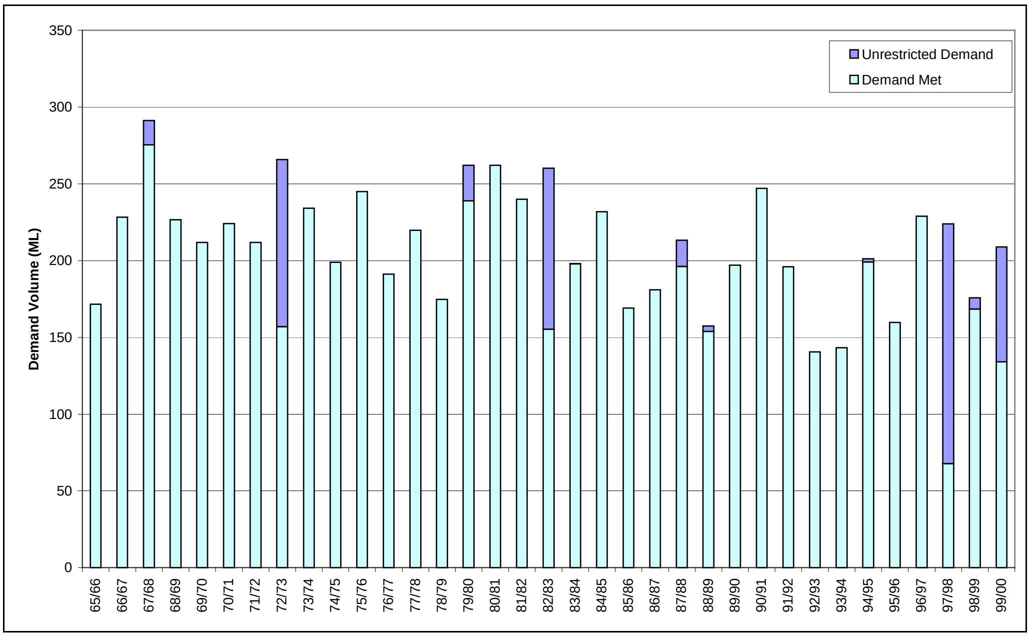
- **Figure 4-8 Number of weeks where demands cannot be fully met in the Upper Subcatchment (F1) under Scenario 4**



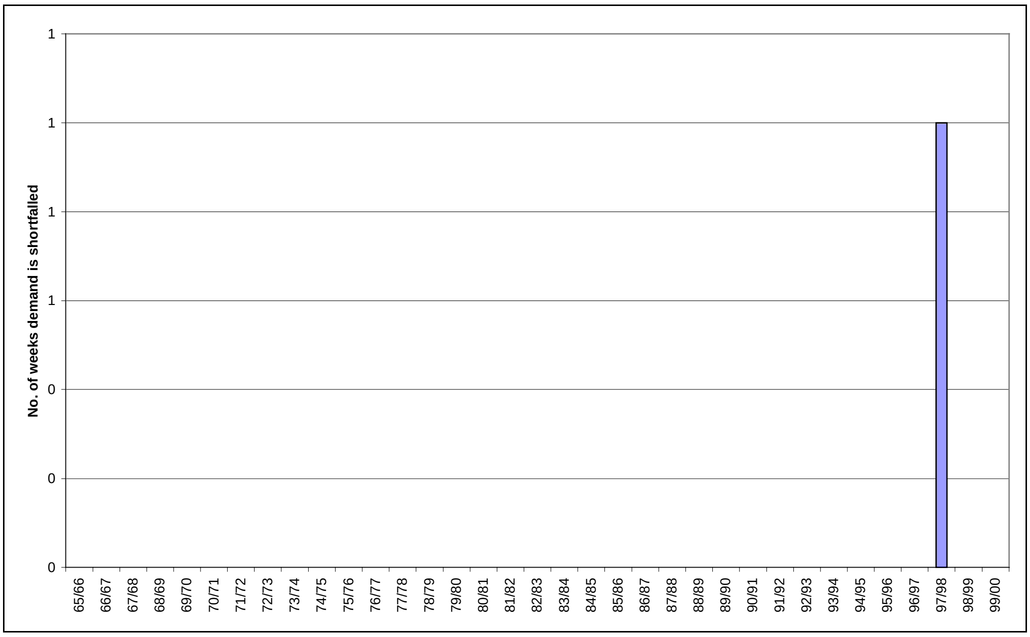
- **Figure 4-9 A comparison of the unrestricted demand and the demand met in the Upper Subcatchment (F1) under Scenario 4**



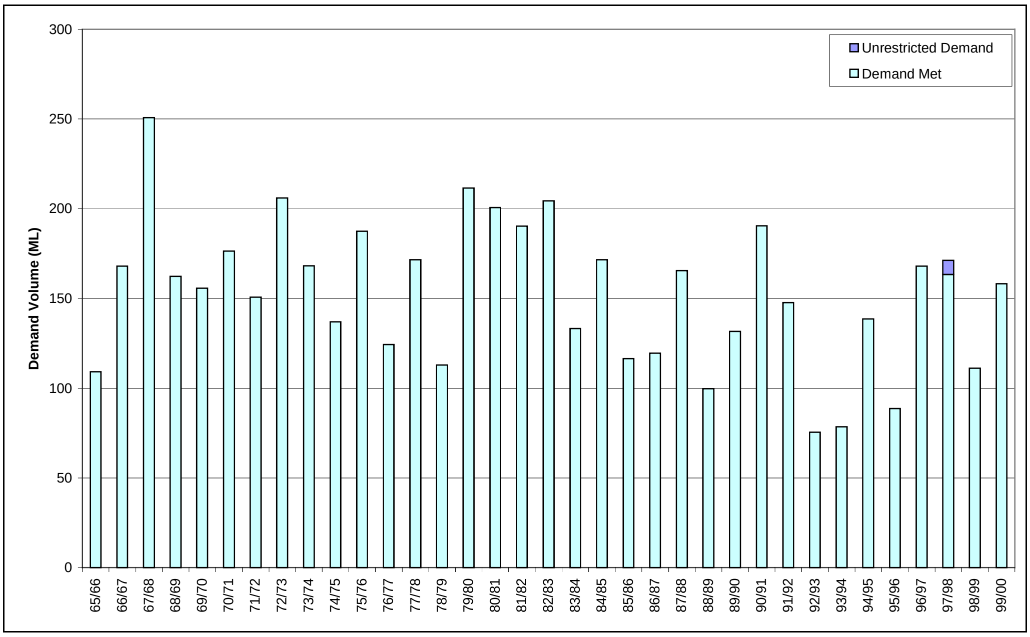
- **Figure 4-10 Number of weeks where demands cannot be fully met in the Middle Subcatchment (F2) under Scenario 4**



- **Figure 4-11 A comparison of the unrestricted demand and the demand met in the Middle Subcatchment (F2) under Scenario 4**



- **Figure 4-12 Number of weeks where demands cannot be fully met in the Lower Subcatchment (F3) under Scenario 4**



- **Figure 4-13 A comparison of the unrestricted demand and the demand met in the Lower Subcatchment (F3) under Scenario 4**

Environmental flow recommendations at the sites specified in Table 4-2 are implemented under Scenario 4. The environmental flow recommendations are not able to be met 100% of the time, with streamflows falling below the specified environmental flow 13% and 3% of the time in the Upper and Middle subcatchments respectively. In the Lower Subcatchment the environmental flow recommendation of 15 ML/day can be met on all days over the 1965 to 2000 period due to increased discharges from the Lilydale STP.

4.2.5 Scenario 5

Full level of development (with environmental flows implemented and STP discharges at current capacity)

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

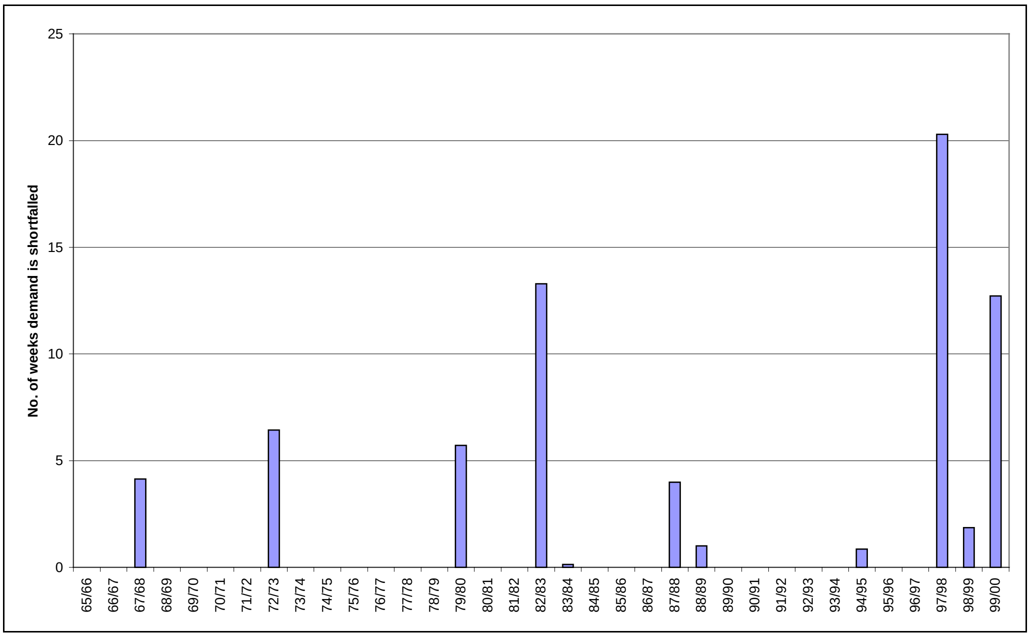
- **Table 4-6 Number and duration of shortfalls by subcatchment under Scenario 4**

Subcatchment	Total number of years of shortfalls	Average shortfall duration (days)	Range in shortfall durations (days)
Upper (F1)	34	11	1 to 118
Middle (F2)	11	9	1 to 59
Lower (F3)	6	9	1 to 46

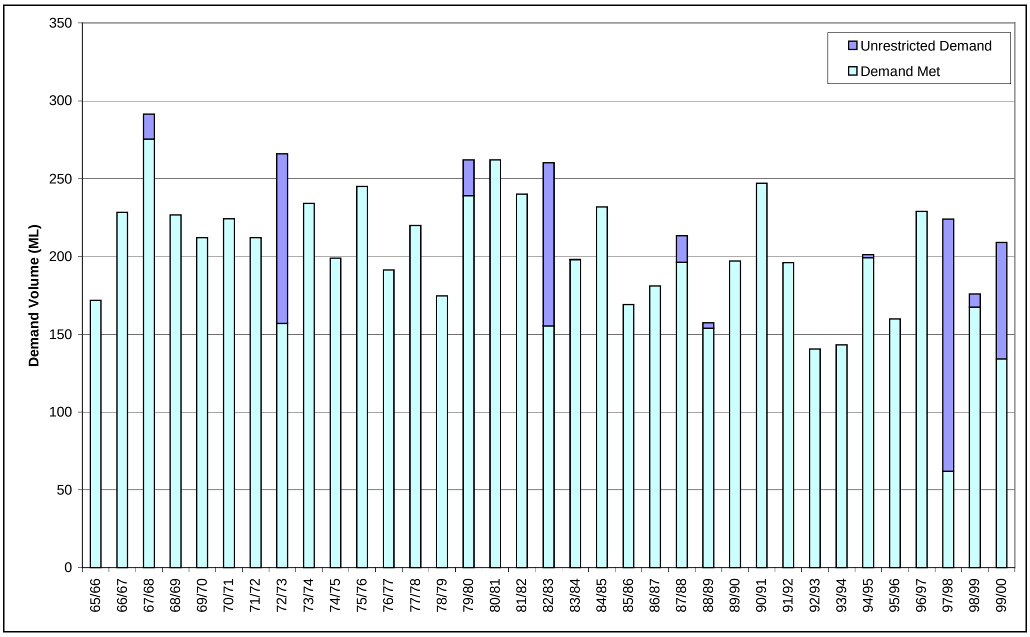
The shortfalls for the Upper Subcatchment under Scenario 5 are the same as under Scenario 4. In the Middle Subcatchment the shortfall duration range is slightly greater, which reflects the need to pass flows from this catchment to satisfy environmental flows in the Lower Subcatchment under Scenario 5. Figure 4-14 illustrates the number of weeks in each year where demands cannot be fully met and Figure 4-15 compares the unrestricted demands in each year to the demand met for the Middle Subcatchment.

Figure 4-16 illustrates the number of weeks in each year where demands cannot be fully met and Figure 4-17 compares the unrestricted demands in each year to the demand met for the Lower Subcatchment.

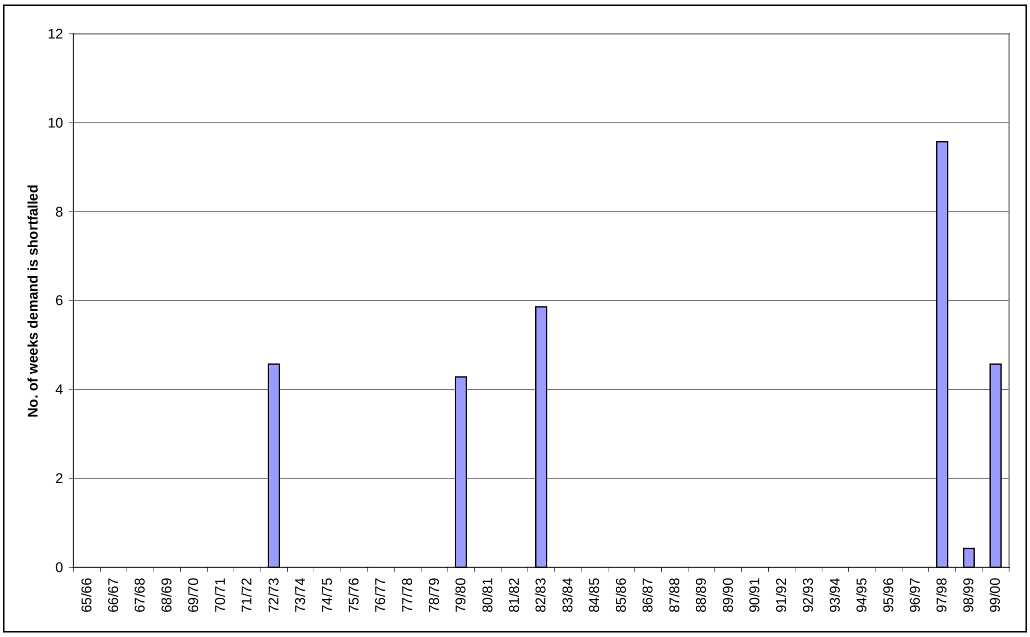
By maintaining the discharges from the Lilydale STP at current level of development discharges and increasing the diversions to full level of development with the implementation of environmental flow recommendations in the Lower Subcatchment, diverters are shortfalled in 6 of the years between 1965 and 2000. The demand met in three of these shortfall years (1972/73, 1982/83 and 1997/98) is significantly lower than the unrestricted demand.



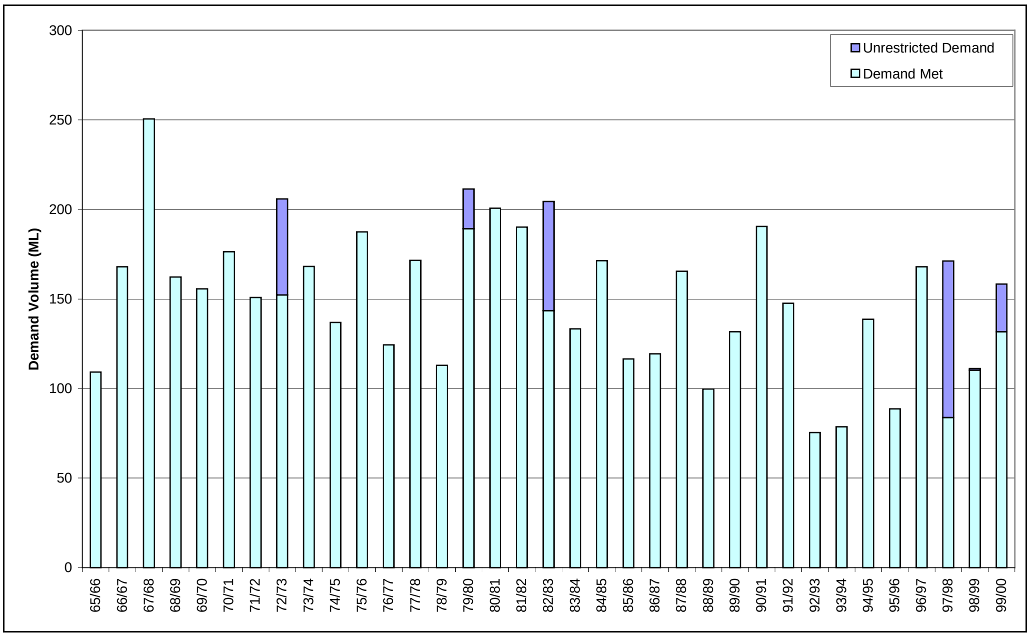
- **Figure 4-14 Number of weeks where demands cannot be fully met in the Middle Subcatchment (F2) under Scenario 5**



- **Figure 4-15 A comparison of the unrestricted demand and the demand met in the Middle Subcatchment (F2) under Scenario 5**



- **Figure 4-16 Number of weeks where demands cannot be fully met in the Lower Subcatchment (F3) under Scenario 5**



- **Figure 4-17 A comparison of the unrestricted demand and the demand met in the Lower Subcatchment (F3) under Scenario 5**

Environmental flow recommendations at the sites specified in Table 4-2 are implemented under Scenario 5, however the discharges from the Lilydale STP are kept at the current level of development, whilst diversions from the catchment are at full level of development. The environmental flow recommendations are not able to be met 100% of the time in any of the subcatchments, with streamflows falling below the specified environmental flow 13%, 3% and 1% of the time in the Upper, Middle and Lower subcatchments respectively.

4.2.6 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 4-7). Since implementation of the Drought Response Plan (DRP) in 1998, Level 2 restrictions have been enacted four times (*Pers comm*, Melbourne Water).

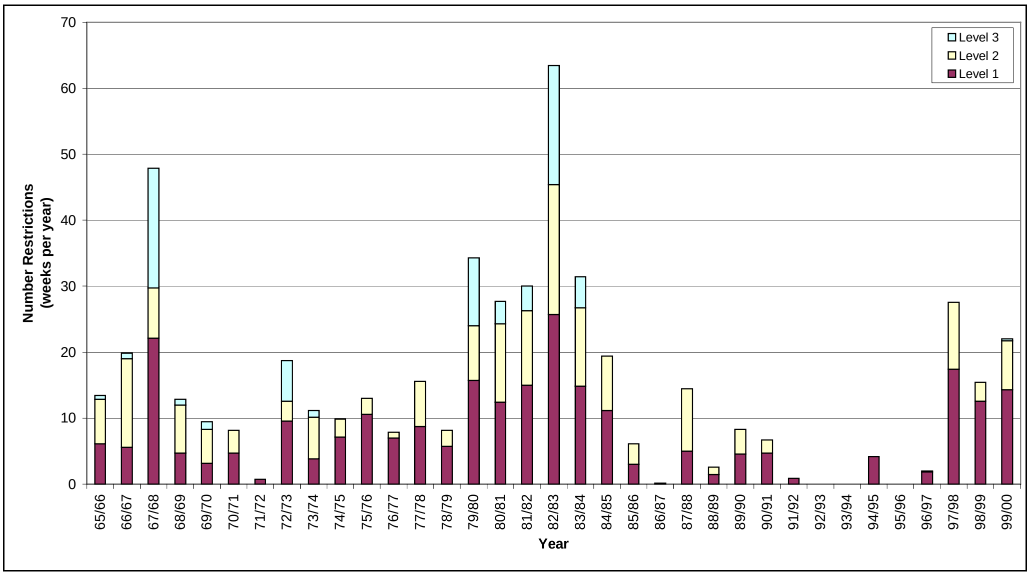
- **Table 4-7 Private diverter restrictions (after Melbourne Water, 2001)**

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	<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% cf normal usage levels. <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. <u>Domestic and Stock</u>: Diversions are banned where alternative supplies exist. <u>Winterfill</u>: No restrictions provided water is drawn from reserves of stored water. <u>Industrial</u>: Usage must be reduced by 20% cf normal usage levels.
3	200	<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% cf normal usage levels. <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. <u>Domestic and Stock</u>: Diversions are banned where alternative supplies exist. <u>Winterfill</u>: No restrictions provided water is drawn from reserves of stored water. <u>Industrial</u>: Usage must be reduced by 70% cf normal usage levels.

These restrictions have not been included in the scenario modelling as as estimate of Yarra River flow 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 4-18.

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 in the pre-1993 period 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 4-18 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 4-18 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

Under current level of development conditions (Scenario 2), estimated flows in the Upper Subcatchment have been reduced due to diversions. This is demonstrated in Figure 4-19, which shows *flow duration curves* for flows under natural and current level of development conditions in the Upper Subcatchment.

A flow duration curve is generated by taking the time series of flow data and ordering it from the largest flow to the smallest flow and plotting this against the rank (ie the largest flow is given a rank of 1, the second largest flow is given a rank of 2 and so on until the smallest flow is given a rank). This rank is expressed as a percentage and labelled as the “% Exceedence” on the flow duration curves and represents the proportion of the time when a flow at a particular magnitude is exceeded. The ordered flow data is plotted on a logarithmic scale to enable the differences in very low flows to be observed. Flow duration curves are excellent for comparing how flows at particular magnitudes have been impacted by different development conditions.

Figure 4-19 shows that in the Upper Subcatchment flows over all ranges were higher under natural conditions than under current level of development conditions. For example the flows that are exceeded 50% of the time (% Exceedence = 50%) under natural conditions were around 3 ML/day. However, under the current level of development conditions, the flows that are exceeded 50% of the time have been reduced to around 2 ML/day.

In the Middle and Lower Subcatchments flows under current conditions are higher than natural due to releases from Silvan Reservoir and Lilydale STP discharges (Figure 4-20 and Figure 4-21).

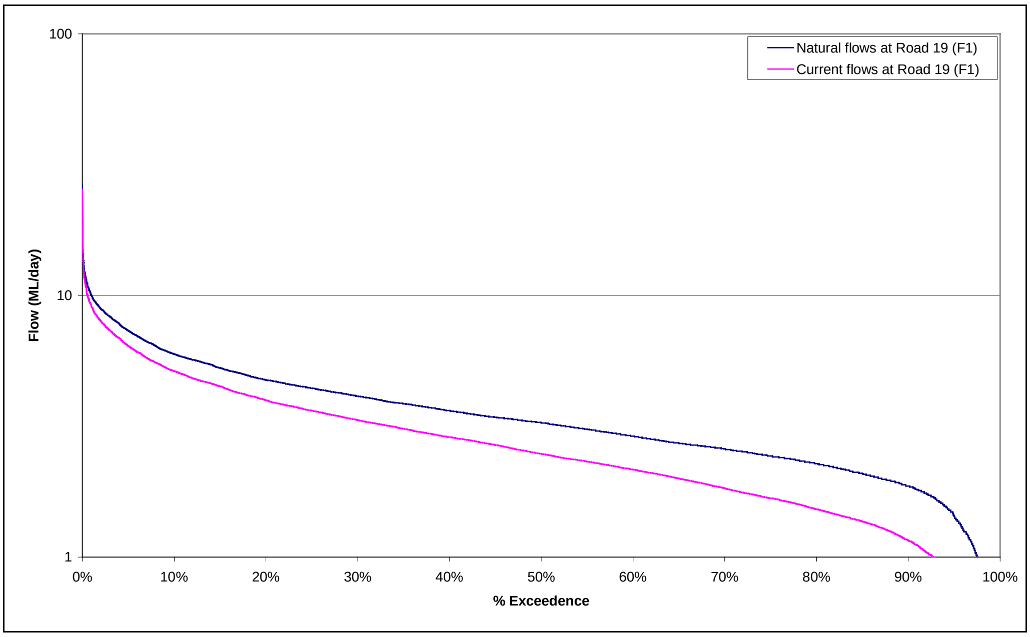
Under full level of development conditions without environmental flows implemented (Scenario 3) the flows in the Upper Subcatchment (Figure 4-22) are reduced even further below the natural flow conditions.

With the implementation of environmental flow recommendations in Scenario 4 and Scenario 5, flows in the Upper Subcatchment that are exceeded 70% of the time are reduced by a similar amount as under Scenario 3.

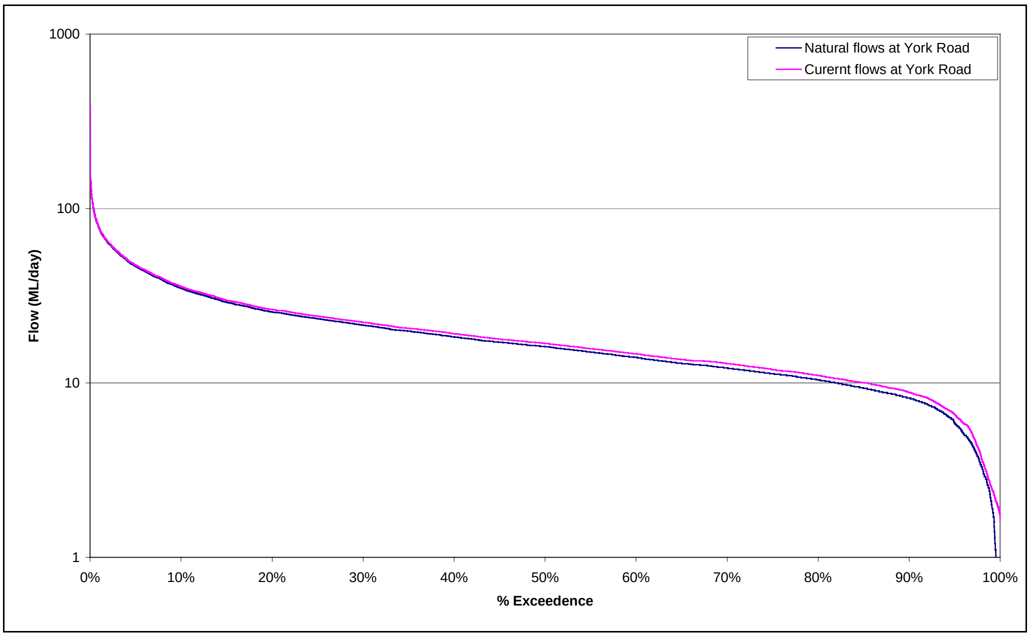
For flows that are lower than the flow exceeded 70% of the time (ie low flows), the implementation of environmental flows results in a lessening impact when compared to natural (hence the straight line in the flow duration curves for Scenario 4 and Scenario 5). For flows that are exceeded around 85% of the time, the flows under Scenario 4 and Scenario 5 are equal to the natural flow duration curve.

Under full level of development conditions without environmental flows implemented (Scenario 3), the flows in the Middle Subcatchment (Figure 4-23) are approximately equal to natural. With environmental flows implemented (Scenario 4 and Scenario 5) flows exceed the natural flows. These higher flows are due to releases from Silvan Reservoir exceeding diversion levels in the catchment at this point.

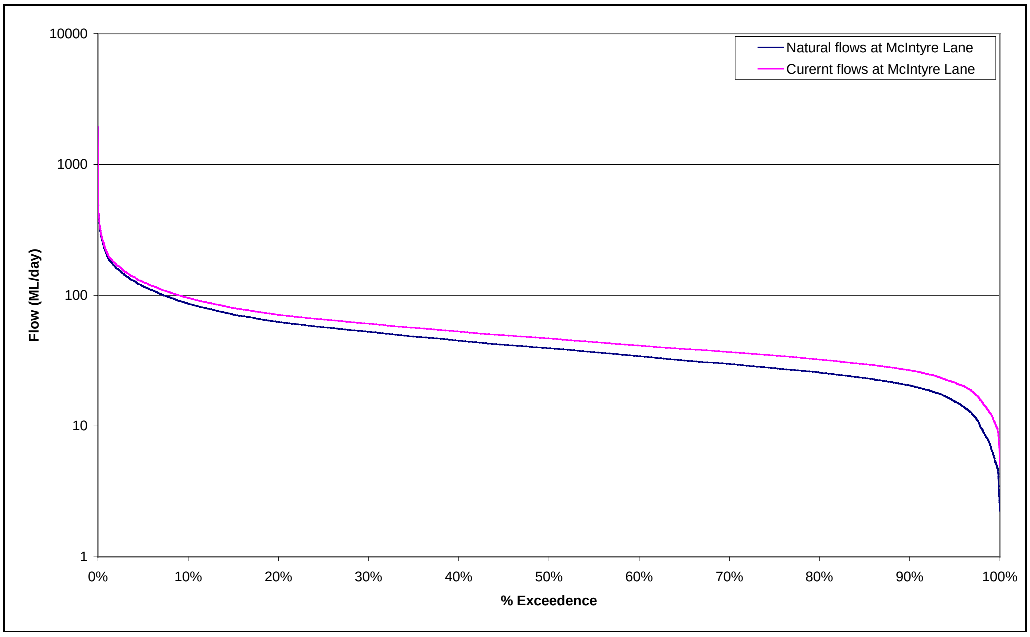
Under full level of development conditions the flows in the Lower Subcatchment (Figure 4-24) are higher than natural flows under all scenarios. Flows under Scenario 3 and Scenario 4 are approximately equal, hence the introduction of environmental flow recommendations at full level of development diversions does not impact on streamflow conditions. Under full level of development diversions with the discharge from the Lilydale STP at current discharge levels, there is a reduction in flows, however the streamflows are still above natural conditions.



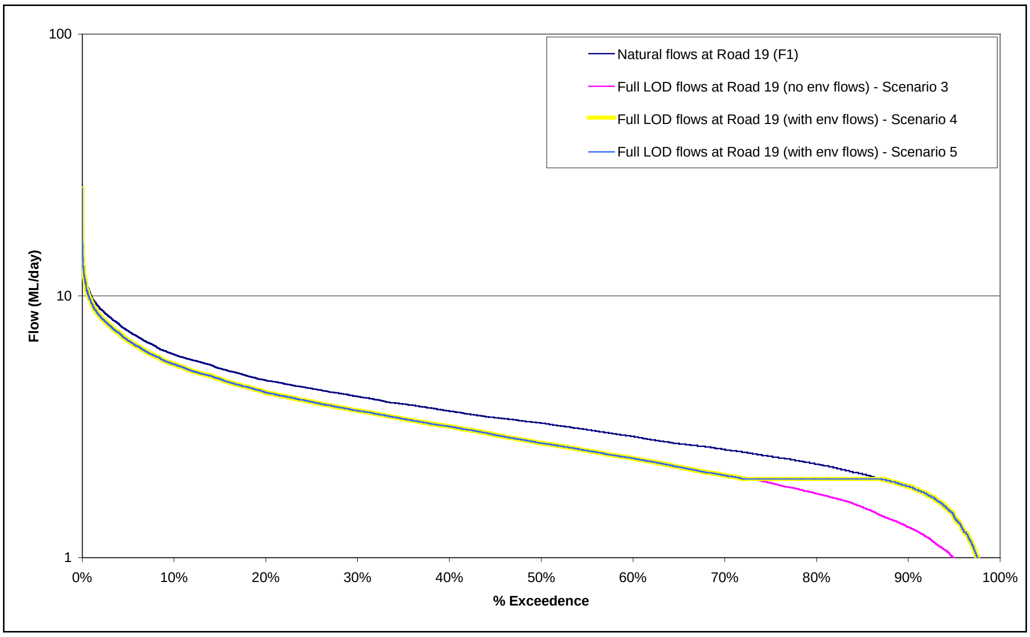
- **Figure 4-19 Upper Subcatchment flow duration curves under natural and current conditions**



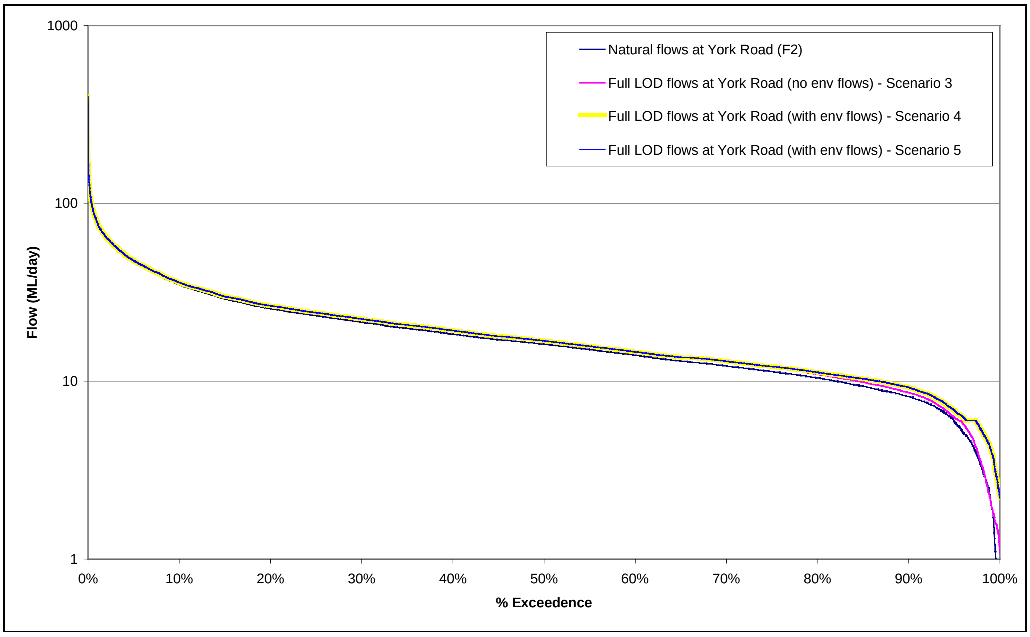
- **Figure 4-20 Middle Subcatchment flow duration curves under natural and current conditions**



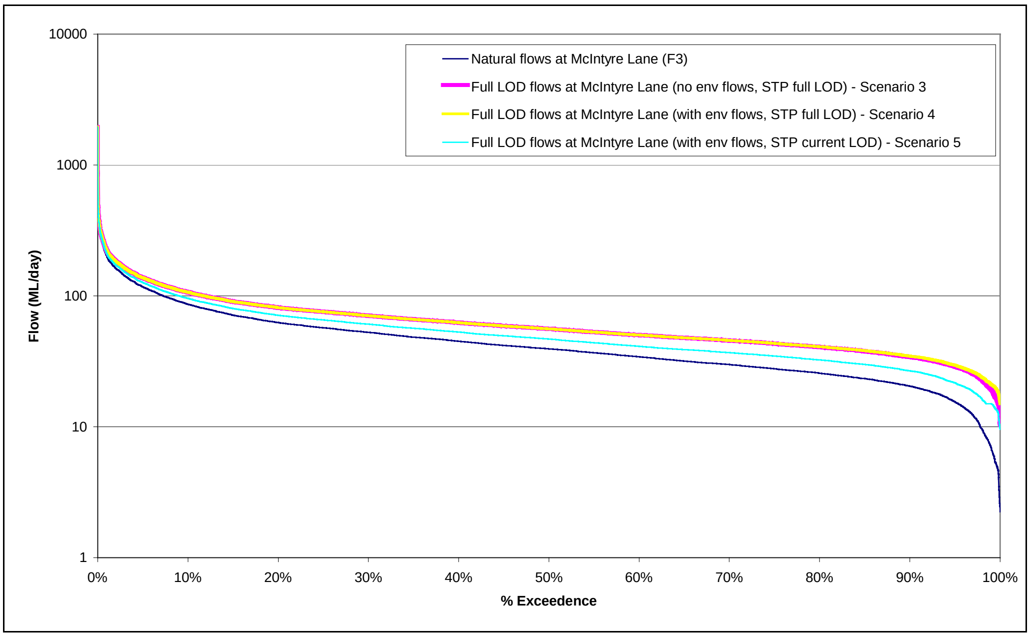
- **Figure 4-21 Lower Subcatchment flow duration curves under natural and current conditions**



- **Figure 4-22 Upper Subcatchment flow duration curves under natural and full level of development conditions**



- **Figure 4-23 Middle Subcatchment flow duration curves under natural and full level of development conditions**



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

4.4 Summary

Five different scenarios have been modelled for the Olinda Creek catchment, the results for which have been presented in the preceding sections. Table 4-8 summarises the results of each scenario.

Under full level of development conditions with environmental flows specified, the diverters in the Upper Subcatchment experience demand shortfalls in 34 out of 35 years, compared with four out of 35 years if environmental flows are not implemented. In the Middle and Lower subcatchments, diverters experience demand shortfalls in ten and four years out of 35 respectively, compared to no demand shortfalls if environmental flows are not implemented.

In general the environmental flow recommendations can be achieved, however there is a significant impact on the ability for demands to be met, especially in the Upper Subcatchment under full level of development conditions.

Streamflows in the Olinda Creek catchment under current levels of development are in fact greater in the Middle and Lower subcatchments, due to releases from Silvan Reservoir and discharges from Lilydale STP. There is significant reduction in flows, especially in the low flow range, in the Upper Subcatchment.

Under full level of development conditions (with environmental flows implemented), further reductions in streamflows will occur in the Upper Subcatchment, and significant reductions compared to natural are estimated in the Middle Subcatchment. Due to increased discharges from the Lilydale STP, streamflows at the lower end of the Olinda Creek catchment will approximate natural flow conditions.

- **Table 4-8 Summary of scenario modelling results**

Scenario	Purpose of Scenario	Total number of years of shortfalls			Average shortfall duration (days)			Environmental Flow Compliance
		Upper	Middle	Lower	Upper	Middle	Lower	
1	Calibration of the Olinda Creek REALM model based on historic catchment conditions.	5	-	-	6	-	-	N/A
2	To test reliability of supply to diverters based on the current catchment conditions.	5	-	-	6	-	-	N/A
3	To test the reliability of supply to diverters based on estimated full level of development conditions.	4	-	-	11	-	-	N/A
4	To test the reliability of supply to diverters based on estimated full level of development conditions with environmental flows implemented.	34	11	1	11	9	7	87% Upper, 97% Middle, 100% Lower
5	To assess the impact on reliability of supply to diverters and on meeting the specified environmental flow recommendations in the Lower Subcatchment if Lilydale STP discharges remain at the current L.O.D. discharges.	34	11	6	11	9	9	87% Upper, 97% Middle, 99% Lower

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 recorded streamflow. Although significant periods of recorded rainfall data near Olinda 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**

Station Number	Location	Period of Record Available	Proportion Missing
086066	Lilydale	1965-2000	4.1%
086076	Montrose	1965-2000	40.5%
086243	Mount Dandenong GTV9	1968-1986	0.5%
086252	Olinda Laurel Crt	1967-1994	4.9%

A number of the rainfall stations that were to be used in the analysis contained records that did not cover the entire modelling period (1965-2000). As such, the records for these stations were extended using linear regression with a nearby rainfall station that did cover the required period. The correlation between the data sets was verified by checking the coefficient of determination (or R^2 value) for each regression. An R^2 value of 1 indicates perfect correlation, while in general, an R^2 value of greater than 0.8 indicates a strong relationship between two data sets. The regression analysis was based on concurrent annual data sets, and then the relationship between the data sets was extended to the missing daily data for the rainfall station of interest. Table 5-2 outlines the periods where regression was required. It also shows the stations used for each regression analysis and the R^2 values in each case.

- **Table 5-2 Regression Analysis**

Station of Interest	Period of Regression	Station used for Regression	R^2 value
086243	1965-1968, 1987-2000	086076	0.88
086252	1965-1967	086106	0.85
086252	1994-2000	086359	0.86

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 (Yan Yean, 086131), 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 subcatchment, whereby data sets were weighted according to their proximity to the centroid of the subcatchment. The relative influence of nearby rainfall stations for each subcatchment is shown in Table 5-3.

- **Table 5-3 Weighting of rainfall stations for each subcatchment.**

Rainfall Station	Subcatchment		
	Upper	Middle	Lower
086066	-	-	72%
086076	-	56%	28%
086243	88%	-	-
086252	12%	44%	-

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 recorded data. Although significant recorded data near Olinda 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. 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 (refer Figure 2-1). A summary of the evaporation data used in this study is contained in Table 5-4.

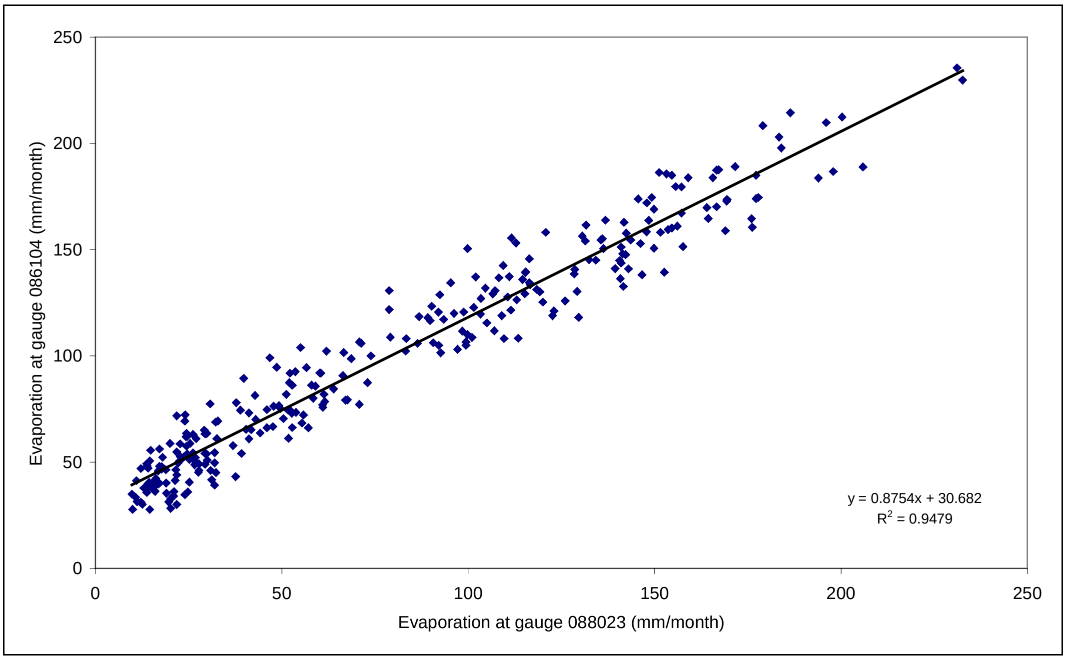
- **Table 5-4 Evaporation gauging station details.**

Rainfall Station	Location	Period of Record Available	Proportion missing
086104	Scoresby	1965-1994	4.8%
088023	Lake Eildon	1970-2000	2.8%

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. The correlation is shown in Figure 5-1. The monthly regression was converted to daily by dividing the intercept by 30.4 and then applying it to daily data.



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

Estimation of Evaporation over a Catchment

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

- **Table 5-5 Weighting of evaporation stations for each subcatchment.**

Subcatchment	Factor
Upper	0.99
Middle	0.99
Lower	1.01

5.3 Streamflow

There are three streamflow gauging stations in the catchment (Table 5-6), with various periods of missing data at all three sites and differing levels of data quality. Of note are four years of erroneous flow data at the Olinda Creek at Beresford Rd site (229602) between January 1991 and March 1995. There is also a period of three months of flow data at the Olinda Creek site downstream of Lilydale Lake (229672) between June 2000 and September 2000, where the gauge appears to be reading incorrectly.

- **Table 5-6 Streamflow gauging stations in the Olinda Creek Catchment**

Station ID	Station Name	Period of Available Record	Proportion of missing or erroneous data
229690	Olinda Creek at York Rd, Mt Evelyn	August 1987 to date	6%
229672	Olinda Creek downstream of Lilydale Lake	November 1990 to date	5%
229602	Olinda Creek at Beresford Rd, Lilydale	December 1977 to February 1999	28%

5.4 Diversion Licenses

Diversion license information was provided by Melbourne Water. The licenses were divided into the three subcatchments used in the REALM model, as shown in Table 5-7.

5.5 Farm Dam Volumes

Farm dam volumes for the Olinda Creek catchment 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):

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

Equation 1

■ **Table 5-7 Assignment of diverters to subcatchments**

Subcatchment	Typical usage / purpose	Licensed volume (ML/yr)	Status
Upper Catchment Olinda Creek upstream of Road 19	Domestic & Stock	2	Active
	Domestic & Stock	2	Active
	Domestic & Stock	2	Active
	Domestic & Stock	2	Active
	Domestic & Stock	2	Active
	Domestic & Stock	2	Active
	Domestic & Stock	2	Active
	Domestic & Stock	2	Active
	Domestic & Stock	2	Active
	Domestic & Stock	2	Active
	Domestic & Stock	2	Active
	Domestic & Stock, and irrigation	4	Active
	Domestic & Stock, and irrigation	4	Inactive
	Domestic & Stock, and irrigation	4	Inactive
	Domestic & Stock, and irrigation	4	Inactive
	Irrigation	14	Active
	Irrigation	5	Active
	Irrigation	12	Active
	Irrigation	2	Active
	Irrigation	14	Inactive
	Irrigation	5	Inactive
	Irrigation	10	Inactive
	Irrigation	12	Inactive
	Irrigation	1	Inactive
	Off-Stream Dam Filling	25	Active
	Off-Stream Dam Filling	17	Active
	Off-Stream Dam Filling	50	Active
	On-Stream Dam Filling	12	Active
Middle Subcatchment: Olinda Creek between Road 19 and York Road	Domestic & Stock	2	Active
	Domestic & Stock	2	Active
	Domestic & Stock	2	Active
	Domestic & Stock	2	Active
	Domestic & Stock	2	Active
	Domestic & Stock	2	Active
	Domestic & Stock	2	Active
	Domestic & Stock	2	Inactive
	Domestic & Stock	4	Inactive
	Domestic & Stock, and irrigation	4	Active
	Domestic, Stock & irrigation	7	Inactive
	Industrial	50	Inactive
	Irrigation	13	Active
	Irrigation	25	Active
	Irrigation	13	Active
	Irrigation	45	Active
	Irrigation	2	Active
	Irrigation	12	Active
	Irrigation	15	Active
	Irrigation	7	Active
	Irrigation	2	Active
	Irrigation	18	Inactive
	Irrigation	7	Inactive
	Irrigation	5	Inactive
	Irrigation	18	Inactive
	Off-Stream Dam Filling	19	Active
	Off-Stream Dam Filling	27	Active
	On-Stream Dam Filling	11	Active

Subcatchment	Typical usage / purpose	Licensed volume (ML/yr)	Status
Upper Catchment Olinda Creek upstream of Road 19	Commercial	5	Active
	Domestic & Stock	2	Active
	Domestic & Stock, and irrigation	4	Active
	Irrigation	25	Active
	Irrigation	25	Active
	Irrigation	60	Active
	Irrigation	50	Active
	Irrigation	18	Active
	Irrigation	4	Active
	Irrigation	25	Inactive
	Off-Stream Dam Filling	12	Active

6. Derivation of Demands

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

- <u>Historic demands</u> 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 York Road (1987 to 2000).
- <u>Current level of development demands</u> were required as input to the REALM scenario runs. Current level of development demands were based on the results of the diverter survey conducted in June 200 by Melbourne Water. The current demands were adopted as historic for the Olinda Creek catchment.
- <u>Full level of development demands</u> 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 (including commercial and industrial);
- On-stream;
- Off-stream winterfill; and
- Farm dams.

There is one commercial licence and one industrial licence within the Olinda Creek 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 estimated for all subcatchments, as summarised in Table 6-1.

Table 6-1: Summary of direct irrigation licences.

Reach	Description	Total Licensed Volume (ML/yr)		
		Historic	Current	Full
LD1 (Upper)	Diverters from Olinda Creek (or tributaries) upstream of Road 19	35	35	83
LD2 (Middle)	Diverters from Olinda Creek (or tributaries) between Road 19 and York Road	136	136	184
LD3 (Lower)	Diverters from Olinda Creek (or tributaries) between York Road McIntyre Lane	182	182	207

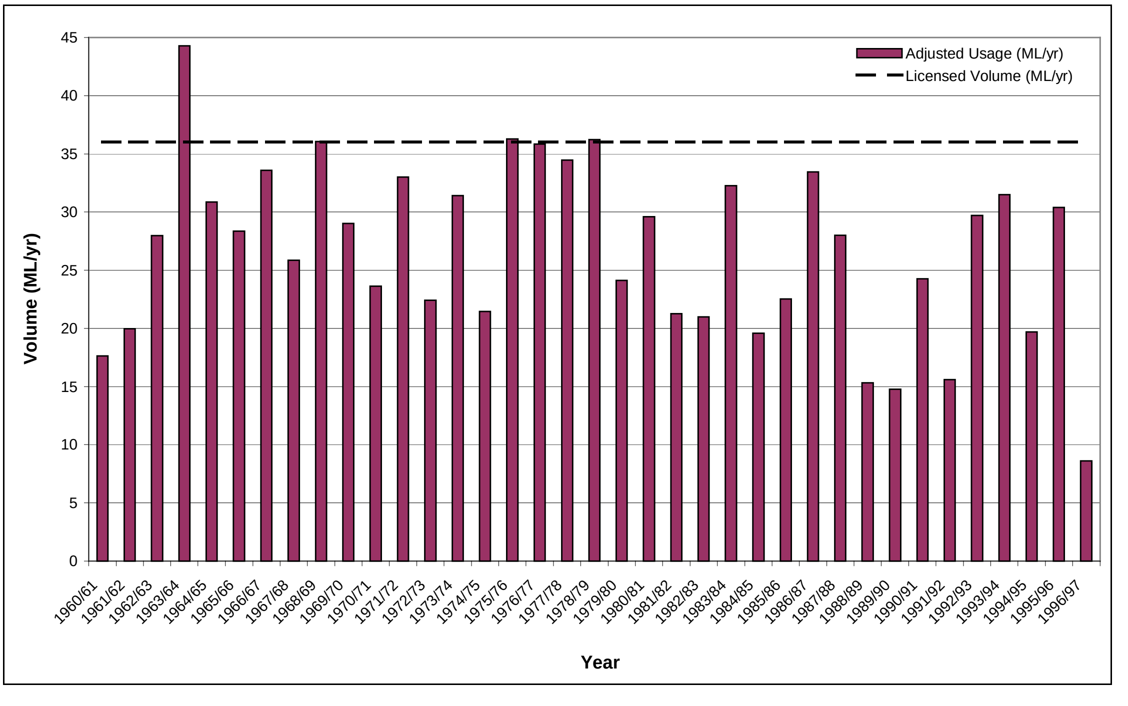
Note: Historic crop areas were assumed constant over the period 1987 to 2000.

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

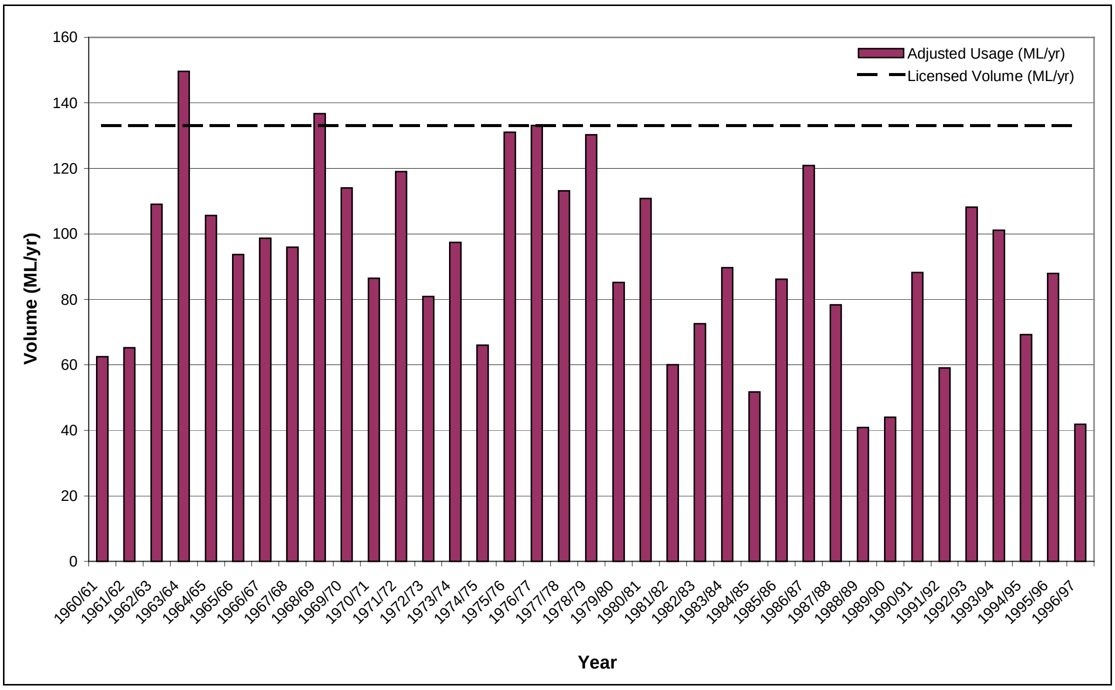
- ❑ Year round crops (eg nurseries);
- ❑ Orchards;
- ❑ Summer crops (eg berries, vegetables, and flowers);
- ❑ Vines; and
- ❑ Perennial pasture.

Crop types were documented in the licence database provided by Melbourne Water (based on diverter survey results from June 2000). Where there was insufficient information on the crop type irrigated, it was assumed to be a summer crop.

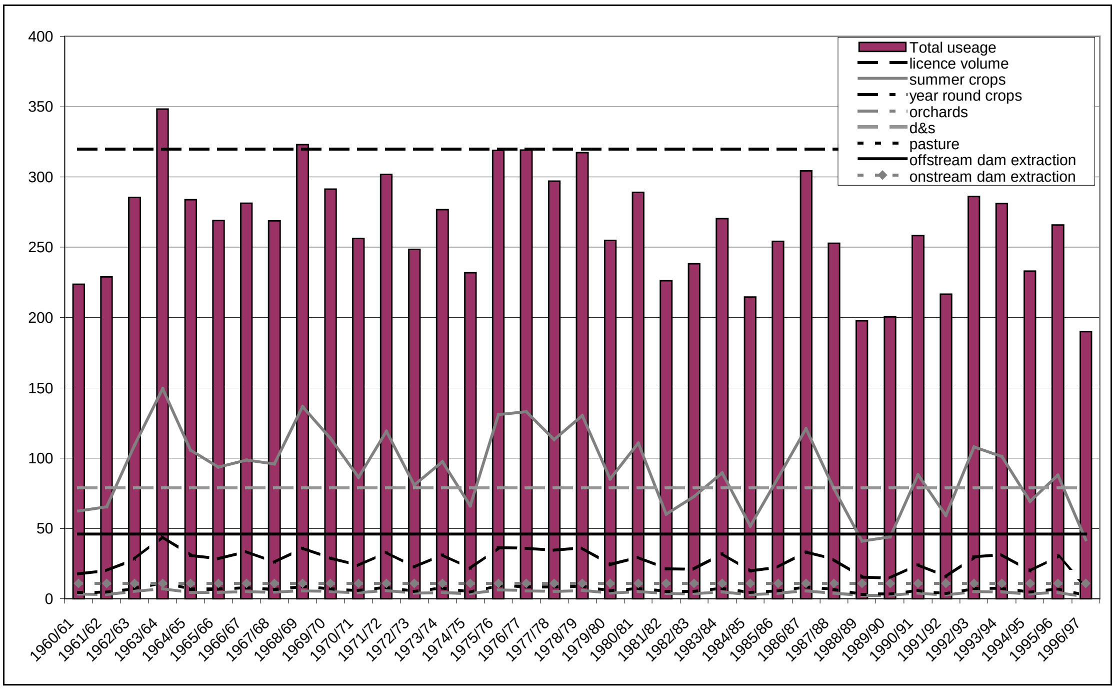
The PRIDE model was calibrated for each subcatchment by adjusting the crop area such that the maximum demand over an irrigation season was approximately equal to the total licence volume for each crop. If the demand in a particular irrigation season was substantially greater than all other years this 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 Middle Subcatchment (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 (Figure 6-3). Calibration plots for each crop type and the sum of all crops in each reach can be found in Appendix A.



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



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



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

6.2 Offstream Dams

Winterfill (offstream dam) demands were derived on the assumption that licence holders would only divert during winter (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 in each subcatchment was based on the proportion of streamflow that occurred in each of the winterfill months.

6.3 Onstream Dams

Onstream dam demands were derived on the assumption that licence holders would only divert during winter (May to October inclusive), ie that all summer flows were passed. It was also assumed that licence holders diverted one hundred percent of their licence volume each year. The diversion pattern over winter in each subcatchment was based on the proportion of streamflow that occurred in each of the winterfill months.

6.4 Domestic and Stock

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

6.5 Farm Dams

For this study the hydrologic impact of farm dams in each subcatchment was modelled individually using the Tool for Estimating Dam Impacts (TEDI). The model inputs for each subcatchment were the partial natural inflows (historic flows adjusted for onstream, offstream, domestic and stock, and direct irrigation diversions, and releases from Silvan Reservoir).

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

- The number and volume of farm dams in the Olinda Creek catchment;
- The threshold dam volume between stock and domestic and irrigation dams (threshold volume = 15 ML);
- Irrigation demand patterns and annual demand volumes;
- Stock and domestic demands and annual demand volumes;
- Monthly rainfall and evaporation data;
- The proportion of farm dam volume withdrawn each year as annual demand (demand factor = 1);
- Farm dam size distribution; and
- Upstream catchment area for farm dams of 5 ML and 100 ML in size.

The Egis (2002) TEDI model was adjusted based on the area of each subcatchment and the volume of farm dams within each subcatchment. No other changes were made to the model. For each subcatchment, the monthly time series of farm dam impacts were disaggregated to daily based on the pattern of the partial natural inflow.

6.6 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 (1, 2 & 3);
- ❑ Onstream dam extractions (1 & 2);
- ❑ Offstream dam extractions (1, 2 & 3);
- ❑ Extractions for domestic and stock, including commercial and industrial (1, 2 & 3); and
- ❑ Farm dam impacts (2 & 3).

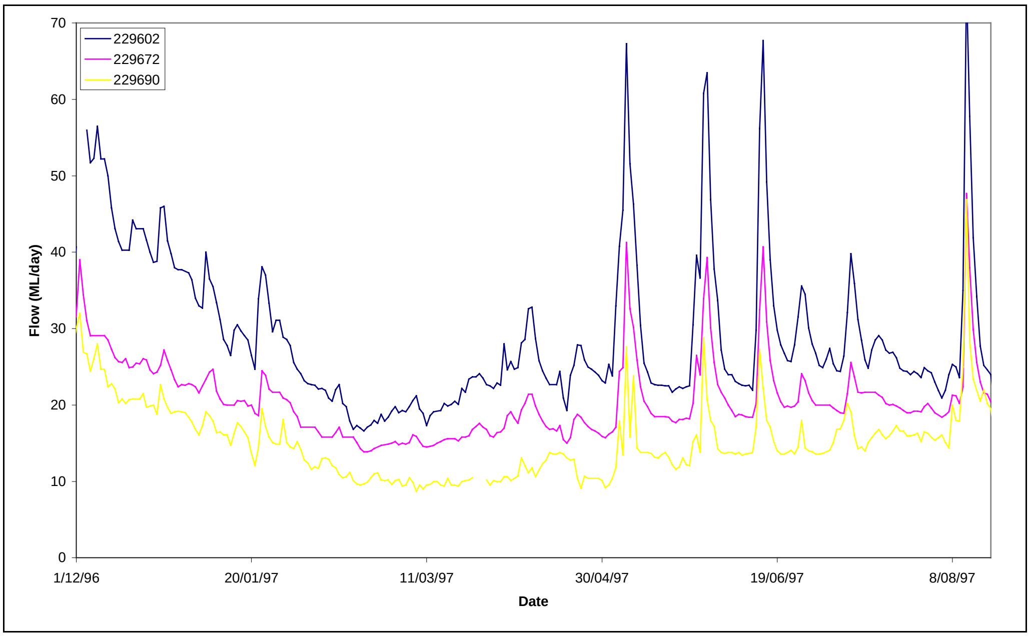
7. Derivation of Inflows and Losses

Natural streamflows were derived for each subcatchment based on adjustments made to gauged streamflows. There are three streamflow gauges within the Olinda Creek catchment (Table 5-6).

Before the gauged streamflows at York 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 York Road (gauge 229690) were then extended using the modified AWBM rainfall runoff model (refer Section 7.3), and transposed to other locations in the catchment.

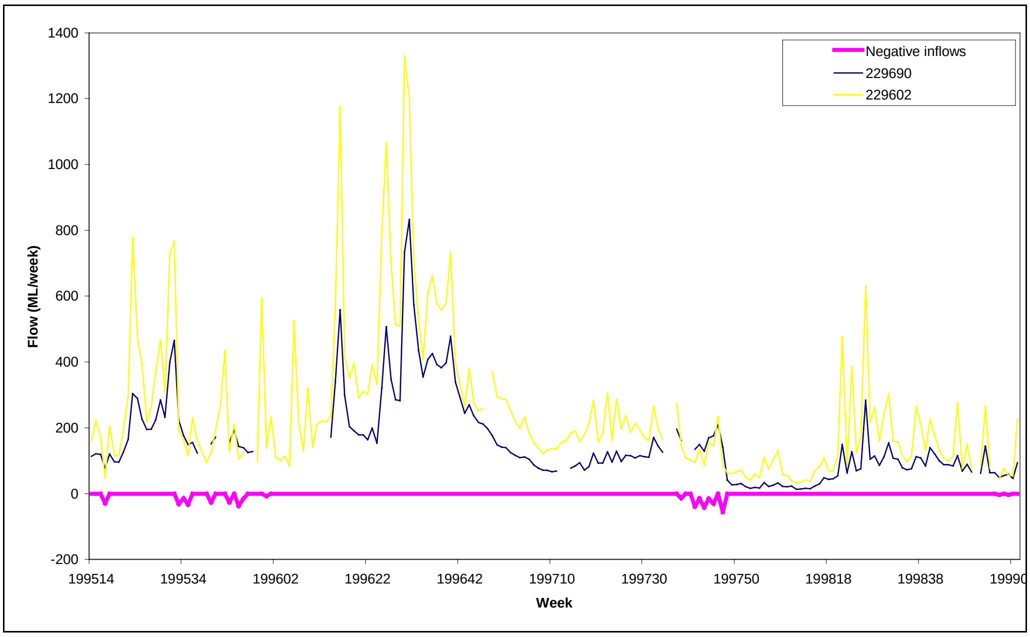
7.1 Time-lag and Losses

To investigate the occurrence of time lag and losses on streamflow in the Olinda Creek catchment, a comparison between the York Road (229690), Beresford Road (229602) and Olinda Creek downstream of Lilydale Lake (229672) sites was made over the concurrent period of available record. Figure 7-1 illustrates the flows at the three gauging sites over a short period of record. The flow hydrograph peaks generally occur on the same day, with some instances of a delay of no more than one day. However, the occurrence of a delay in the flows is not consistent across the entire concurrent period of record or at particular flow ranges. Hence the system has been modelled without any time-lag component.



- **Figure 7-1 Hydrograph peaks**

Losses in streamflow were investigated over the period of concurrent data at the York Road and Beresford Road sites. The period of record was truncated to only four years between 1995 and 1999, due to erroneous gauge data at Beresford Road from 1991 to 1995. Daily streamflows were aggregated to weekly values and the Beresford Road flows were subtracted from the York Road flows. Negative values are due to either a loss or a gauging error. Figure 7-2 illustrates the weekly flows at Beresford Road and York Road and the negative inflows that occurred over the concurrent period of record.



- **Figure 7-2 Losses occurring in Olinda Creek**

No negative inflows occurred over the low flow period, suggesting that no true losses occurred. The negative inflows that did occur tended to be in a particular range of flows, but did not consistently occur over the entire period. Due to the nature of the negative inflows that were observed over the limited period of concurrent data, it is believed that they are as a result of differences in the relative accuracy of the rating tables between the upstream and downstream gauges. Hence there were no losses incorporated into the Olinda Creek model.

7.2 Trend Analysis

A previous study investigating the impact of farm dams in the Olinda Creek catchment (Egis, 2002) identified no statistically significant long-term trend in the streamflow data. Hence, it was not necessary to adjust the streamflow records for trend.

7.3 Infilling and Extension

As part of the impact of farm dams study Egis infilled and extended the gauge data at York Road (229690) using the AWBM model. Unfortunately this data did not cover the entire period of record required for this study and the goodness of fit of the estimated data, was not satisfactory for the use in a daily model. This is of particular importance if the data is required in low flow analyses. Hence, the parameters and calibration used by Egis (2002) could not be used in this investigation.

Streamflow data at the York Road gauge (229690) 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, particularly the length of low flow spells. In order to correct this, an additional term was introduced to AWBM 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 6.5 ML/day and was found to be around 55% of the flow (**Equation 2**).

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

Equation 2

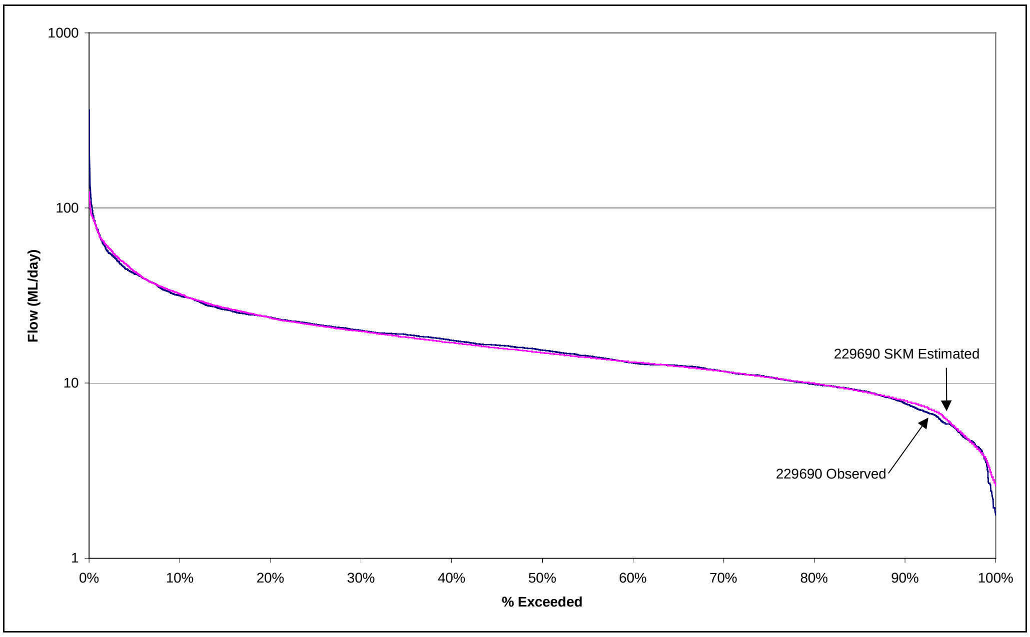
Where:
Q_{AWBM} = flow estimate from AWBM rainfall runoff model
Q_T = streamflow threshold below which additional loss function applies
Q_{est} = revised flow estimate based on additional losses
LF = loss factor (a value between 0 and 1)

The results of the AWBM runs are displayed in Figure 7-3 to Figure 7-8. Figure 7-3 displays flow duration curves of the observed and estimated data, while Figure 7-4 to Figure 7-8 compare the data in time series plots. Figure 7-9 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. The goodness of fit of the estimated data to the gauged data at 229690 is provided in Table 7-1.

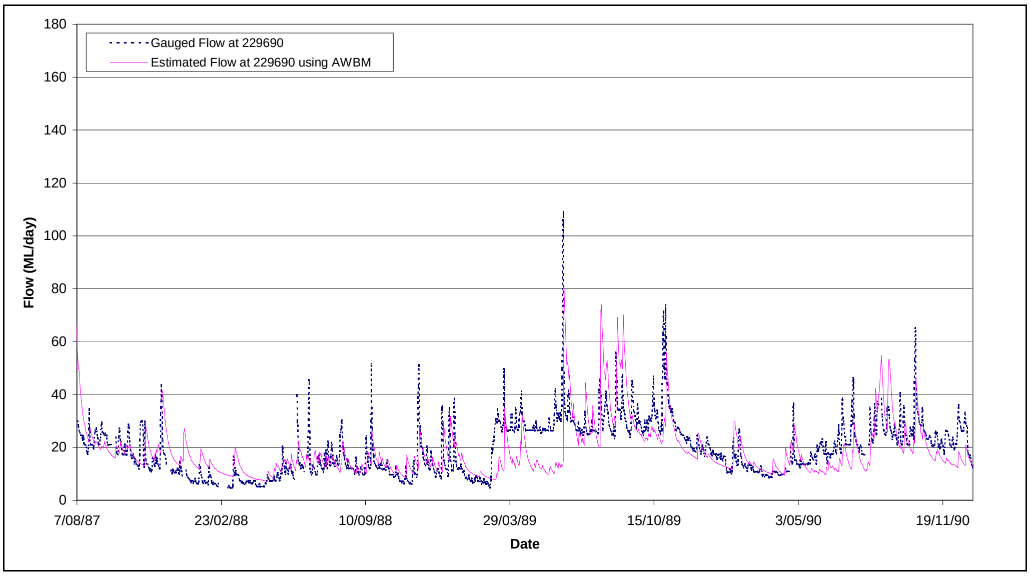
- **Table 7-1 Goodness of fit of observed versus AWBM estimated data at York Road (229690)**

Goodness of Fit Measures	Value
Coefficient of Determination (R^2)	0.52
Standard Error (SE)	9.873

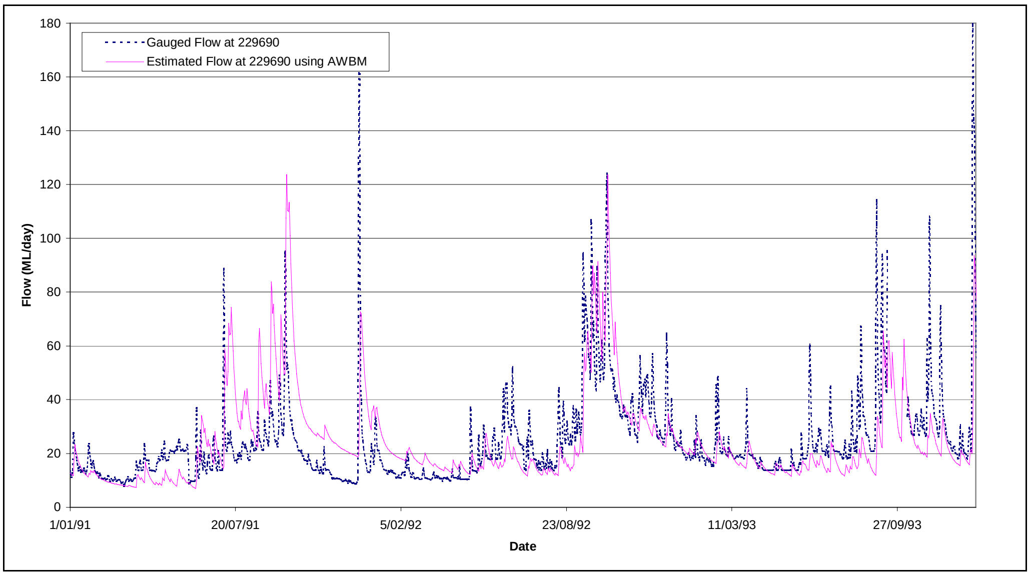
Comparisons were also made on a monthly basis with the AWBM model fitted as part of the previous study investigating the impact of farm dams (EGIS, 2002) and are presented in Figure 7-10 to Figure 7-12.



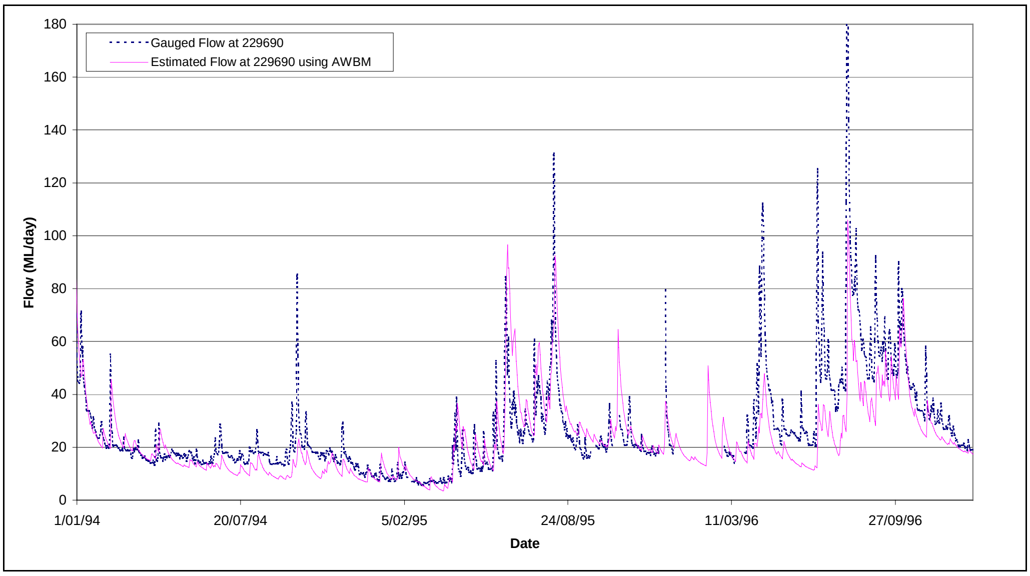
- **Figure 7-3: Flow duration curves of observed and estimated daily flows at York Road site, 229690**



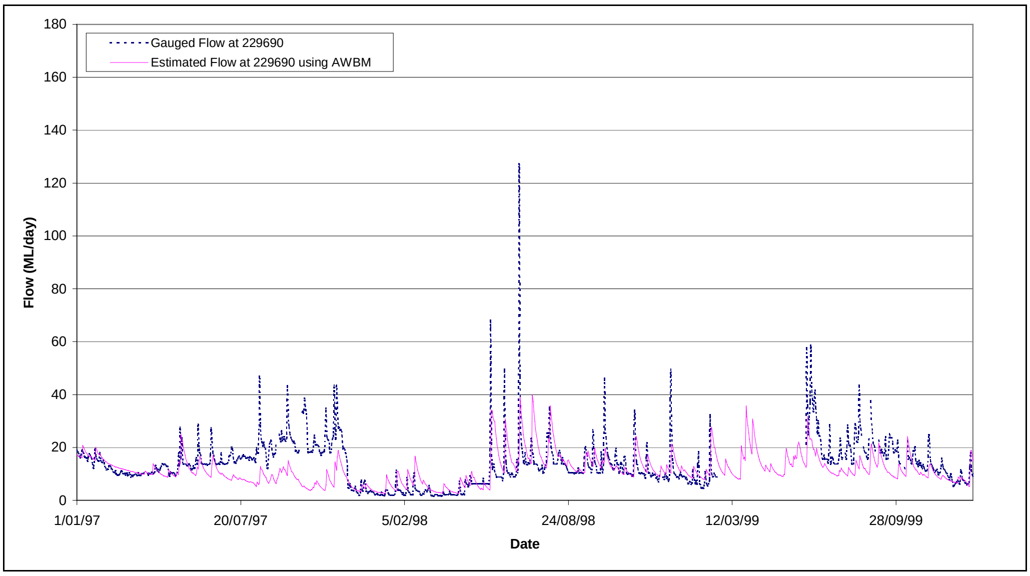
- **Figure 7-4 Time Series of observed and estimated daily flows at York Road site, 229690 (7/8/87 to 31/12/1990)**



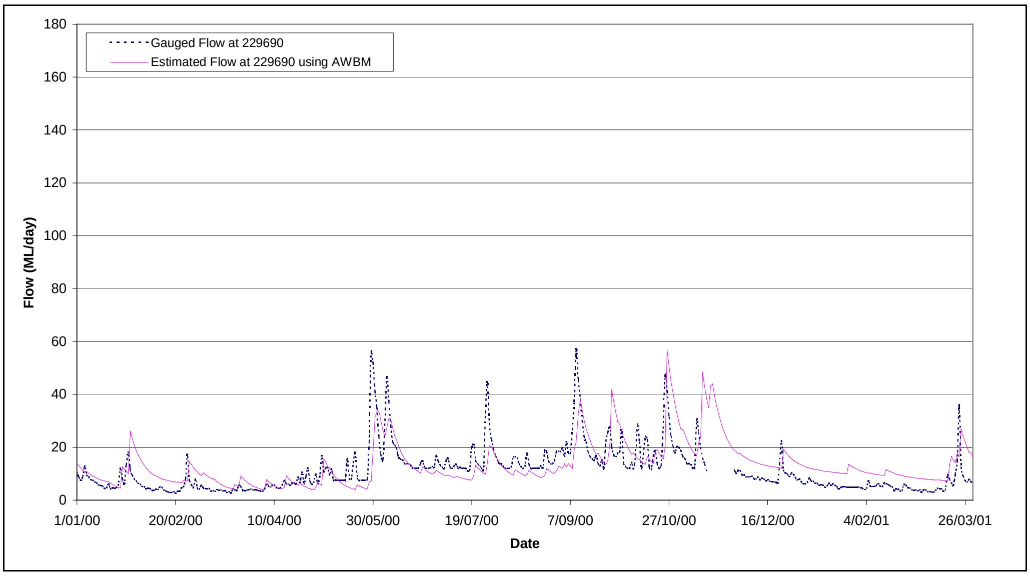
- **Figure 7-5 Time Series of observed and estimated daily flows at York Road site, 229690 (1/01/1991 to 31/12/1993)**



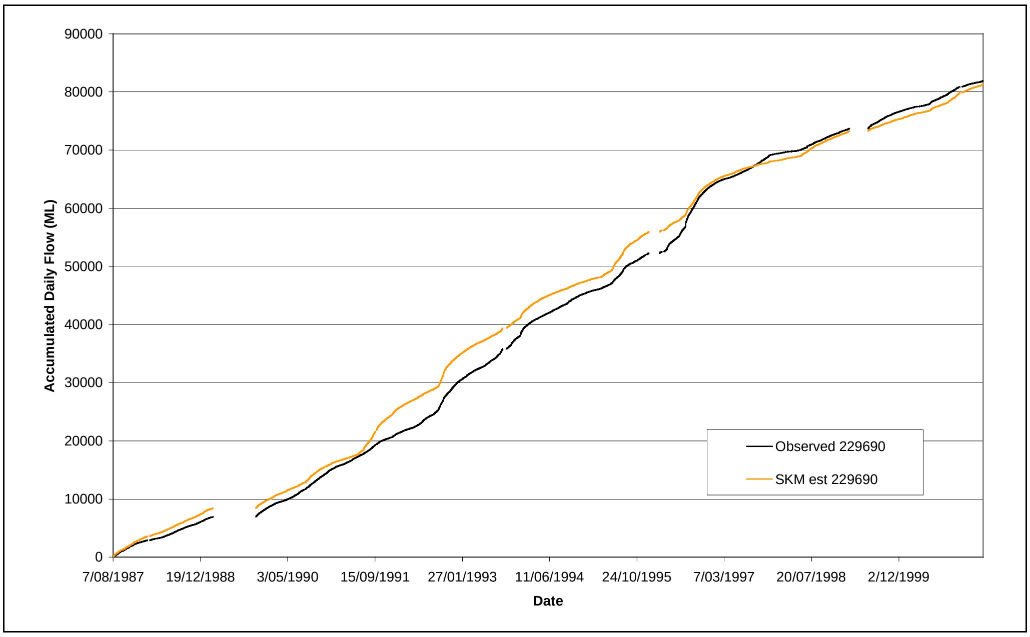
- **Figure 7-6 Time Series Plots of observed and estimated daily flows at York Road site, 229690 (1/01/1994 to 31/12/1996)**



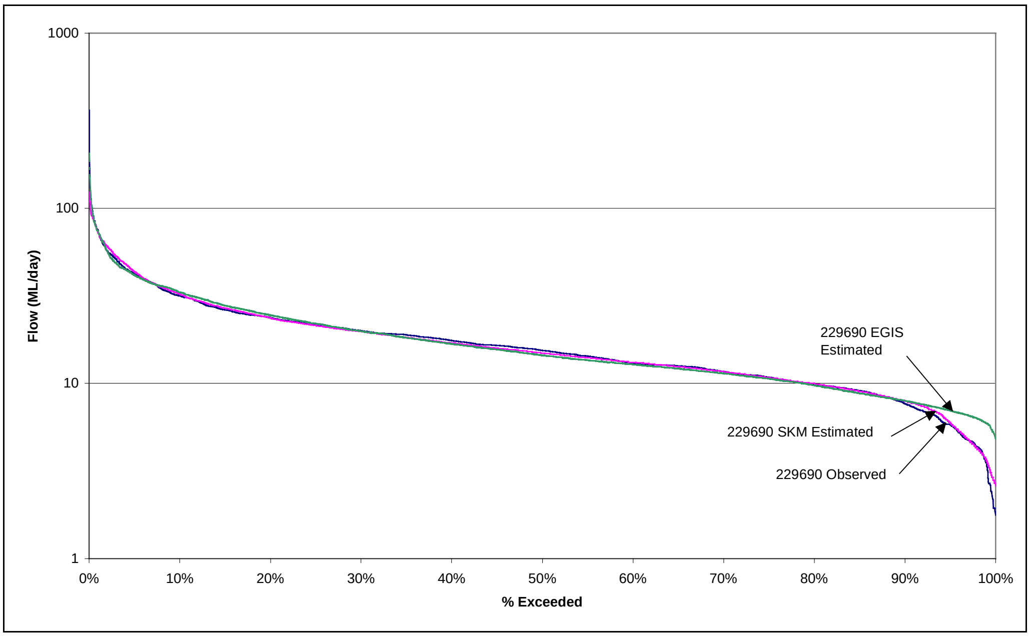
■ **Figure 7-7 Time Series Plots of observed and estimated daily flows at York Road site, 229690 (1/01/1997 to 31/12/1999)**



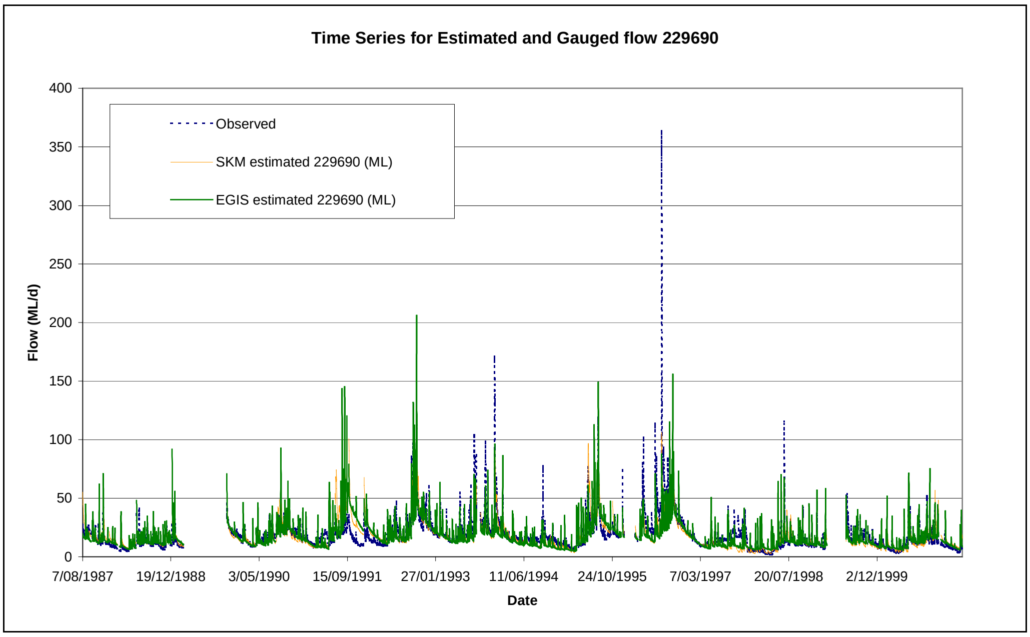
■ **Figure 7-8 Time Series Plots of observed and estimated daily flows at York Road site, 229690 (1/01/2000 to 30/03/2001)**



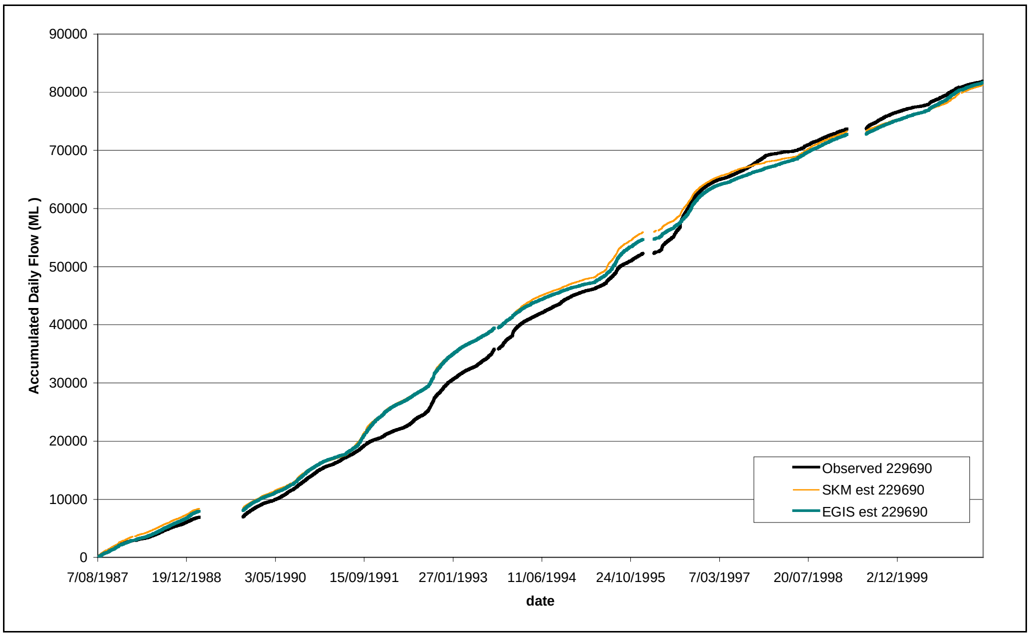
- **Figure 7-9 Mass Curves of observed and estimated flow at York Road Gauge, 229690**



- **Figure 7-10 Flow duration curves of observed and estimated monthly flows by SKM and EGIS at York Road Gauge (August 1987 to March 2001)**



- **Figure 7-11 Time series plots of observed and estimated monthly flows by SKM and EGIS at York Road gauge (August 1987 to March 2001)**



- **Figure 7-12 Mass curves of observed and estimated daily flows by SKM and EGIS at York Road gauge (August 1987 to March 2001)**

The values of variables used for the calibration and a brief description of their function in the model are provided in Table 7-2. The climatic input was rainfall recorded at Lilydale (gauge 086066) and the mean monthly evaporation recorded at Scoresby Research Institute (gauge 086104).

- **Table 7-2 Variables used in modified AWBM(1)**

Variable	Description	Value
Capacity Storage 1	Depth of the hypothetical storage 1	0
Capacity Storage 2	Depth of the hypothetical storage 2	24
Capacity Storage 3	Depth of the hypothetical storage 3	145
Partial Area factor 1	The proportion of the catchment that storage 1 covers	0.2
Partial Area factor 2	The proportion of the catchment that storage 2 covers	0.1
Partial Area factor 3	The proportion of the catchment that storage 3 covers	0.7
BFI	The proportion of the overflow which becomes groundwater when the storage overflows	0.6
K_{base}	Baseflow regression constant; influences rate at which groundwater is fed into streams.	0.993
K_s	Surface regression constant; influences length of time required for water in a stream to reach the catchment outlet.	0.15
LF	Loss Factor(2)	0.45
Q_T	Streamflow threshold in ML below which loss applies(2)	6.5

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

(2) Additional variables added to the AWBM model.

7.4 Transposition of Streamflows

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.

Based on the nature of the difficulties 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, which accounts for the seasonal variability of flows throughout the year in a way that would not have been captured using mean annual 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 flow at the relevant gauge to derive the required inflow series. Table 7-3 details the methodology adopted and the relevant transposition factors.

■ Table 7-3 Method adopted to transpose concurrent flows

Inflow	Method of Estimating Concurrent Flow	Transposition Factor	Area (km^2)
F1	Proportion of flow estimated directly for F1 catchment	$\left(\frac{A_1}{A_{229690}}\right)^m$	$A_1 = 4.43$
Lower F3	Proportion of flow estimated for total Olinda catchment minus proportion of flow estimated for total catchment above Beresford Rd gauge (229602)	$\left(\frac{A_1 + A_2 + A_3}{A_{229602}}\right)^m - 1$	$A_{\text{Lower F3}} = 28.9$

Notes:

(1) m is the slope of the percentile flow versus area relationship, specific to each percentile flow,
(2) A_1, A_2, A_3 are subcatchment areas for that inflow point,
(3) A_{229690} is the catchment area of the York Road gauge = 33.9 km^2,
(4) A_{229602} is the catchment area of the Beresford Road gauge = 52.5 km^2

7.5 Lilydale STP discharges

The Lilydale STP discharges treated effluent to Olinda Creek downstream of Lilydale, and commenced operations in 1968. The plant was upgraded in May 1998, which increased the design capacity from 4.5 ML/day to 30 ML/day.

Historic, current and future levels of development discharges were required for inputs into the REALM scenario modelling.

Historic daily discharges from the Lilydale STP were available from 1/07/1998 to 31/10/2001 and the annual discharge for each year was available from 1987/88 to 1996/97. There was also limited monthly discharge data available from hard copy records kept at the STP. Melbourne Water and Yarra Valley Water provided this information, which is summarised in Table 7-4.

■ Table 7-4 Lilydale STP discharge data

Date	Average Daily Discharge (ML/day)	Annual Discharge (ML/yr)	Average Daily Discharge (ML/day)	Data Supplier
Oct-1975	-	-	1.5	Yarra Valley Water
Jul-1975	-	-	2.0	Yarra Valley Water
Jan-1986	-	-	4.2	Yarra Valley Water
Jul-1986	-	-	6.7	Yarra Valley Water
Jan-1990	-	-	5.3	Yarra Valley Water
Jul-1990	-	-	8.9	Yarra Valley Water
1987/1988	5.6	2,043	-	Yarra Valley Water
1988/1989	7.1	2,594	-	Yarra Valley Water
1989/1990	7.2	2,630	-	Yarra Valley Water
1990/1991	8.0	2,922	-	Yarra Valley Water
1991/1992	8.6	3,154	-	Melbourne Water
1992/1993	7.5	2,719	-	Melbourne Water
1993/1994	7.6	2,756	-	Melbourne Water
1994/1995	7.1	2,580	-	Melbourne Water
1995/1996	7.8	2,835	-	Melbourne Water
1996/1997	7.4	2,705	-	Melbourne Water
1997/1998	6.2	2,262	-	Melbourne Water
1998/1999	7.2	2,619	-	Melbourne Water
1999/2000	7.5	2,754	-	Melbourne Water
2000/2001	7.7	2,794	-	Melbourne Water

NB: daily discharge records between 1/07/1997 and 31/03/2001 were provided by Melbourne Water

The daily STP discharges between 1998/99 and 2000/01 were strongly correlated with rainfall. This correlation may be due to rainfall infiltrating the sewerage system. Discharges from the STP are seasonal, with the highest discharges occurring during the months of June, July and August, and the lowest during the months of December, January and February.

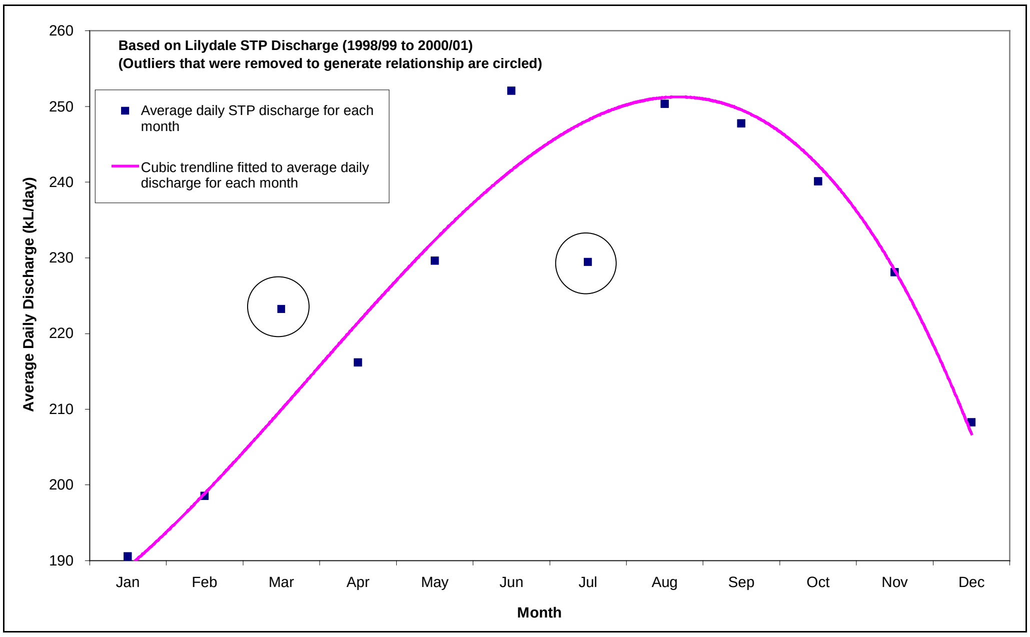
In order to generate the required REALM model inputs, the trend in average monthly discharge for each month of the year over the period of available daily discharge was investigated. The trendline derived is illustrated in Figure 7-13 and takes the form of:

$$Q_n = -0.1675*(Month_n)^3 + 1.7016*(Month_n)^2 + 5.7805*(Month_n) + 181.83 \quad (R^2 = 0.9)$$

Equation 3

Where: Q_n = average monthly discharge in $month_n$
$n = 1, 2, 3.......12$
(ie $Month_1$ (January) = 1; $Month_{12}$ (December) = 12)

Equation 3 could then be used to estimate the pattern of average daily discharge for each month of the year (Table 7-5).



■ **Figure 7-13 Trendline fitted to the average monthly STP discharge based on the daily discharge data from July 1998 to October 2001**

■ Table 7-5 Pattern of average monthly STP discharges

Month	**Historic Ave Daily Discharge (July 1998 to October 2001) (ML/month)**	**Estimated Ave Daily Discharge (based on cubic relationship,** Equation 3**) (ML/month)**	**Pattern of distribution for annual discharge (ratio of estimate for Month$_n$ to TOTAL Estimated)**
January	191	189	7.0%
February	199	199	7.3%
March (removed as outlier)	223	210	7.7%
April	216	221	8.1%
May	230	232	8.5%
June	252	242	8.9%
July (removed as outlier)	229	248	9.1%
August	250	251	9.2%
September	248	250	9.2%
October	240	242	8.9%
November	228	228	8.4%
December	208	207	7.6%
TOTAL Annual Discharge	2,714	2,720	100%

The pattern of discharge can be applied to an annual discharge value in order to get the average daily discharge for each month of that year. These estimates provide a uniform distribution of daily discharges across each month, or a *base* monthly discharge.

In order to introduce the within month variability observed in the three years of actual daily discharge data, a relationship was investigated between the difference in the *base* monthly uniform daily discharge and *actual* daily discharge. These differences in values are called the *residuals*, which were shifted so that there were no negative values in the time series, called the *shifted residuals*. Examples of the actual daily discharge, base monthly uniform daily discharge, and the corresponding residuals and shifted residuals are provided in Table 7-6.

■ Table 7-6 Example calculations of residuals and shifted residuals

Date	***Actual* Daily Discharge (kL/day)**	***Base* Uniform Daily Discharge for Month (kL/day)**	***Residual*** (ie difference in *Actual* & *Base*) **(kL/day)**	***Shifted Residual*** (ie. moved up so that there are no zero values) **(kL/day)**
23/07/1998	5898	6015	-117	2871
24/07/1998	3027	6015	-2988	0
25/07/1998	6339	6015	324	3312
26/07/1998	6333	6015	318	3306
27/07/1998	5892	6015	-123	2865
28/07/1998	6924	6015	909	3897
29/07/1998	7460	6015	1445	4433
30/07/1998	10422	6015	4407	7395
31/07/1998	4485	6015	-1530	1458
1/08/1998	8207	6088	2119	5107
2/08/1998	11882	6088	5794	8782
3/08/1998	8354	6088	2266	5254
4/08/1998	7892	6088	1804	4792
5/08/1998	7350	6088	1262	4250

The *shifted residuals* were found to correlate well with rainfall and soil moisture on a weekly basis (**Equation 4**), and the resulting relationship could then be used to generate a weekly time series of estimated *shifted residuals* for each week over the period 1965 to 2000, based on rainfall and evaporation records.

Shifted Residual (kL/week) = 312*(RAIN) + 4.1*(SOIL) + 28594 ($R^2 = 0.5$)

Equation 4

where: Discharge = Total weekly discharge [ML/week]
Rain = Weekly rainfall at Lilydale gauge 086066
Soil = soil moisture

The soil moisture capacity was estimated using a simplified ‘bucket’ model approach where the soil moisture content at time step ‘n’ is equal to the soil moisture content at time step ‘n-1’ plus rainfall less evaporation (**Equation 5**). The initial soil moisture content was set at 100, with minimum and maximum ranges at any time step of zero and 200 respectively.

$$SOIL_n = SOIL_{n-1} + RAIN_{086066} - EVAP_{086104}$$

Equation 5

Although the goodness of fit of **Equation 4** is average, the estimated time series of *shifted residuals* is adequate for the intended purpose, ie introducing variability to the base pattern derived using **Equation 3**. The weekly estimated *shifted residuals* were disaggregated uniformly to daily values and then shifted downwards to ensure a distribution of negatives and positives similar to that of the *residuals* generated from the actual daily discharge data.

Determining the historic STP discharge time series

For the derivation of historic STP discharges from 1965 to 2000, the *base* daily discharge was derived by applying the pattern in Table 7-5 to the available annual discharge values over time. The STP was commissioned in 1968, hence there were no discharges prior to 1/01/1968.

Between 1968 and 1975 the base pattern was assumed to be the same over all years and was derived from the estimated annual discharge for 1975. This annual discharge was estimated from the supplied average daily discharges for the months of October 1975 and July 1975 (the values were averaged and then multiplied by 365 days to get the annual discharge).

For the years between 1975 and 1987 the annual discharge was determined by linear interpolation between the estimated annual discharge for 1975 and the actual annual discharge for 1987/88. These annual discharges were then used to derive the base pattern in each year.

From 1987/88 to 1997/98 actual annual discharge values were available to derive the base pattern in each year.

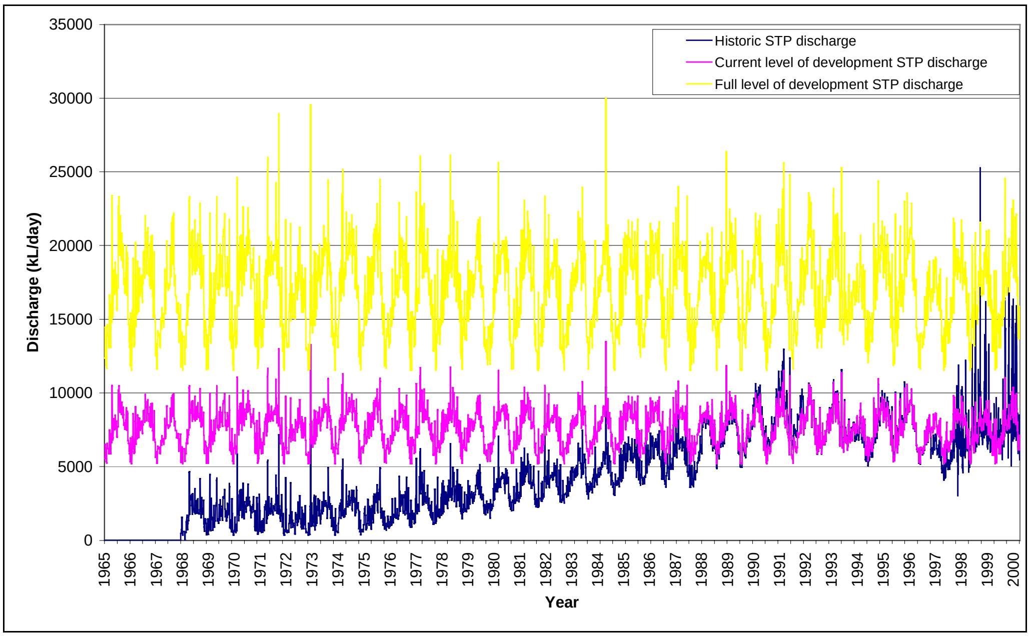
The estimated *residuals* were then added to the base pattern in each year from January 1965 to June 1998 to derive the estimated historic daily discharge time series (Figure 7-14). The actual daily discharge data was used in the period from July 1998 to December 2000.

Determining the current level of development STP discharge time series

The *base* daily discharge to determine the current level of development STP discharges was derived from annual discharge for 2000/01 of 7,655 ML/annum by applying the pattern in Table 7-5. The estimated *residuals* were then added to this repeating *base* daily discharge pattern from 1965 to 2000 to generate the current level of development discharge time series (Figure 7-14).

Determining the full level of development STP discharge time series

The full level of development discharge time series (Figure 7-14) was generated by factoring the current level of development discharge time series, such that the maximum daily discharge value over the 1965 to 2000 period was equal to 30,000 kL/day, the design capacity of the current STP. The full level of development discharge time series was approximately 2.2 times the current level of development discharge time series.



- **Figure 7-14 Historic, current and full levels of development daily discharges for the Lilydale Sewerage Treatment Plant**

7.6 Inflow methodologies

7.6.1 Derivation of F1 Inflow

Inflow to the Upper Subcatchment, F1, was determined by transposing natural flows at the York Road gauge (229690) using a regional transposition relationship (Section 7.4). The method for deriving natural flows at 229690 is described in the Section 7.6.2.

$$F1 = \text{Transposed}\ (229690_{\text{NATURAL}})$$

Equation 6

7.6.2 Derivation of F2 Inflow

The downstream point of the Middle Subcatchment, F2, corresponds to the York Road gauging station (229690). The infilled and extended gauge data (as described in Section 7.3) is not representative of flows under natural conditions.

It was necessary to add back historic diversions and farm dam impacts (as described in Section 6) to the gauged flow in order to generate natural flows. Conversely, releases from Silvan Reservoir, which are constant at 2 ML/day (*Pers comm* Steve Nicol, Melbourne Water), and were therefore subtracted from the infilled and extended gauge data.

$$F2 = 229690_{GAUGE} - R_{SILVAN} + D_{HISTORIC} + FD - F1$$

Equation 7

Where: 229690_{GAUGE} = gauge flows at York Road (229690);
R_{SILVAN} = releases from Silvan Reservoir;
$D_{HISTORIC}$ = estimated historic diversions; and
FD = estimated farm dam impact.

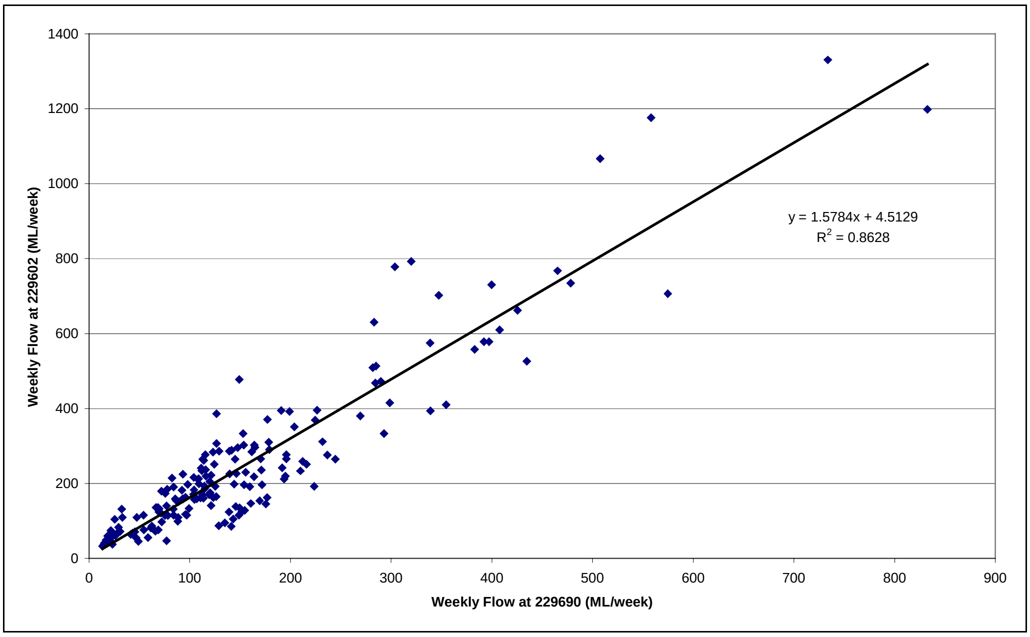
Once diversions and reservoir release effects from gauged streamflow records were considered, the natural flow time series was transposed to get the inflow for the F1 catchment. The F2 inflow was therefore equal to the natural flow at 229690 minus the F1 inflow. The transposition method is described in Section 7.4.

7.6.3 Derivation of F3 Inflow

Flows entering the Lower Subcatchment, F3, are gauged at the York Road site (229690) and there is another streamflow gauge midway down this subcatchment at the Lilydale site (229602). The area between these two gauges is predominantly urbanised, however below the Lilydale gauge the subcatchment is predominantly rural. As such the inflow for F3 was determined in a two step process.

Step 1: inflows between York Road and Beresford Road

- The inflow into the urbanised area (ie between 229690 and 229602) was determined by calculating the inter-station flow. However, the recorded data at the Lilydale gauge (229602) does not cover the required period from 1965 to 2000.
- To infill missing periods of data and extend the time series to cover the required period of record a weekly regression between gauged flow at 229690 and 229602 was developed (Figure 7-15).



- **Figure 7-15 Regression between weekly flow at 229690 and 229602**

- ❑ The infilled and extended gauge data at 229690 could then be used to infill and extend the gauge data at 229602. The following equation was applied to obtain weekly flows at the Lilydale station:

$$Q_{229603} = 1.5784 \times Q_{229690}$$

Equation 8

- ❑ The estimated weekly flows at Lilydale station (229602) were then disaggregated to daily using the pattern of flows at York Road (229690).
- ❑ In order to then obtain natural flows at Beresford Road (229602), releases from Silvan Reservoir were subtracted and historic demands for the 229602 catchment were added. This “partial” natural flow series was then input into the TEDI model and the farm dam impacts for the 229602 catchment were derived and added back to get natural flow at 229602.
- ❑ The natural flow determined at 229690 (refer Section 7.6.2) was then subtracted from the natural flow at 229602 to obtain the inter-station flow between 229690 and 229602.

$$Q_{\mathrm{INTERSTATION}} = 229602_{\mathrm{NATURAL}} - 229690_{\mathrm{NATURAL}}$$

Equation 9

Step 2: inflows downstream of Beresford Road to McIntyre Lane

- ❑ The inflow below Beresford Road (229602) was determined by transposing the partial natural flow at 229602 using the transposition relationship described in Section 7.4.
- ❑ A partial natural flow series for the whole catchment (F1 + F2 + F3) could then be derived and input into the TEDI model to determine the farm dam impact for the combined subcatchments.
- ❑ This impact time series was then used to calculate the farm dam impact in the portion of the Lower Subcatchment below Beresford Road, which could then be

added to the transposed partial natural time series for this section of the subcatchment.

It was not necessary to consider the discharges from the Lilydale STP in deriving the inflow to F3, as the STP discharges to Olinda Creek downstream of the Beresford Road gauge.

The total inflow to F3 was then determined by adding the inter-station flow between York Road and Beresford Road to the natural inflow downstream of Beresford Road.

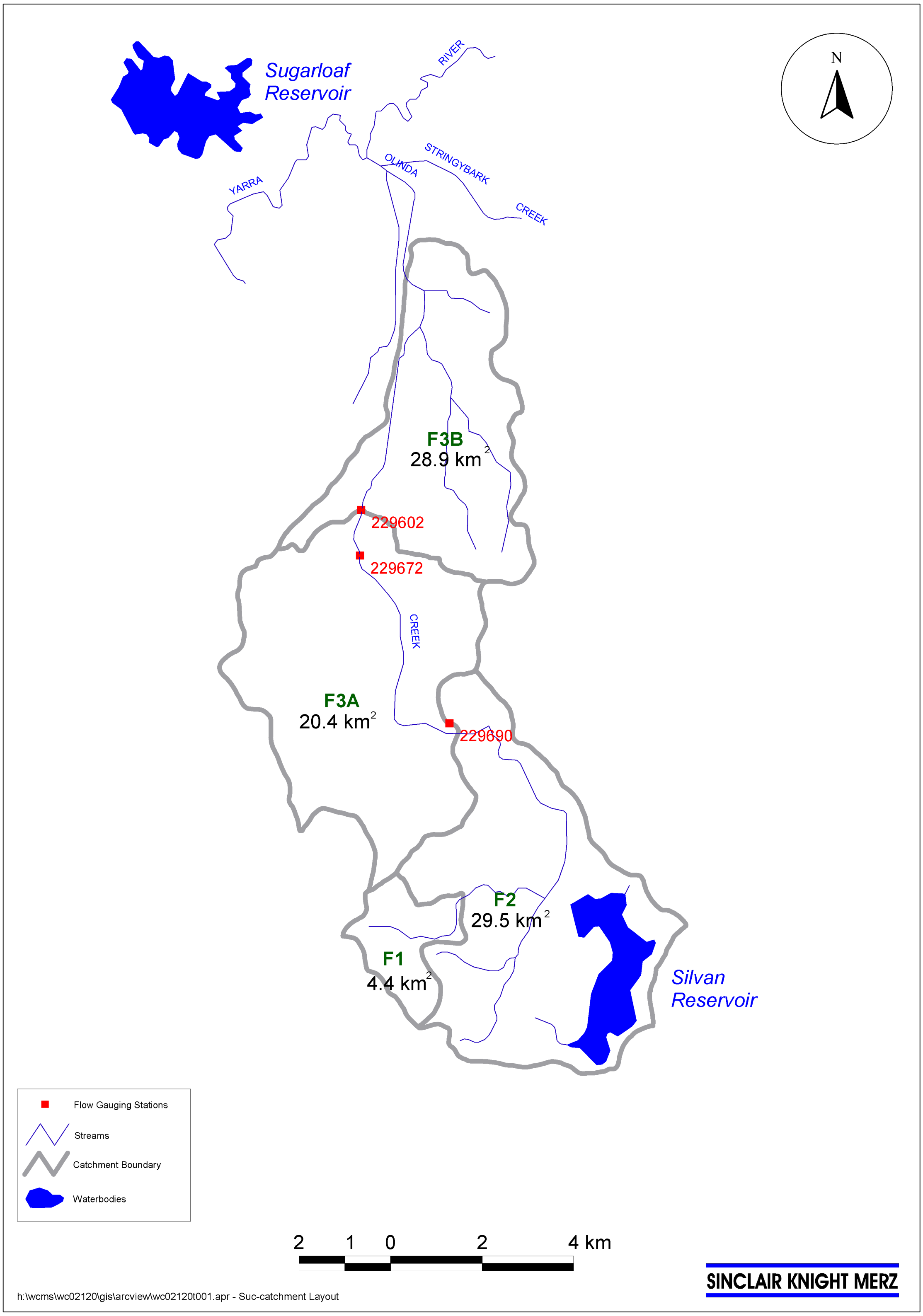
$$F3 = Q_{INTERSTATION} + \text{Transposed}\ (229602_{NATURAL})$$

Equation 10

This methodology provides adequate consideration of the impact that urbanisation has on streamflow, ie the greater impervious area associated with urbanisation leads to greater runoff or greater flow per unit area. Table 7-7 provides the calculated flow per unit for Olinda Creek subcatchments and demonstrates the higher flow per unit area in the urbanised portion of the catchment between York Road and Beresford Road. The subcatchments labelled in Table 7-7 are illustrated in Figure 7-16.

- **Table 7-7 Flow per unit area in each subcatchment**

Subcatchment Area	Flow per Unit Area (ML/km^2)
229690 natural (F1 + F2)	214
Inter-station between 229602 and 229690 (F3A) (URBAN)	243
F3	219
Downstream 229602 (F3B)	201



- **Figure 7-16 Olinda Creek subcatchments**

8. References

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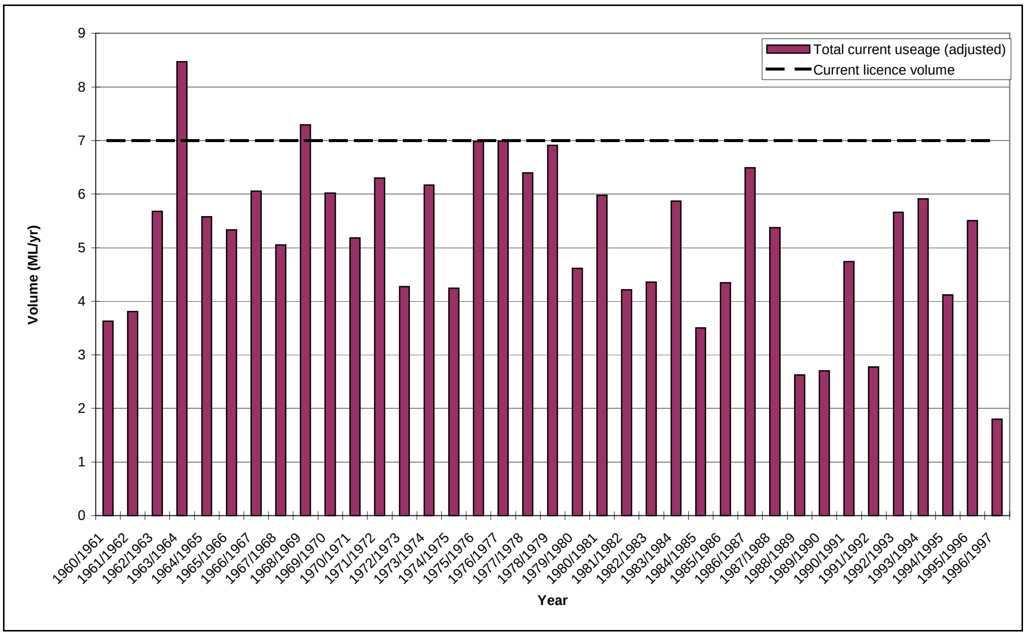
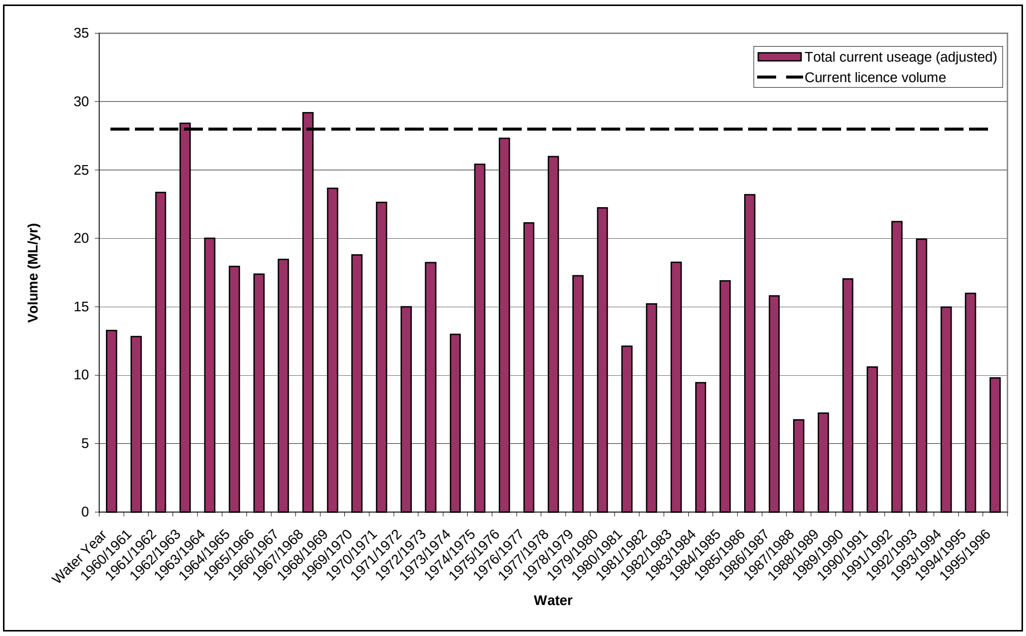
Appendix A Pride Calibration Plots

Upper Subcatchment – Diverters between top of catchment and Road 19

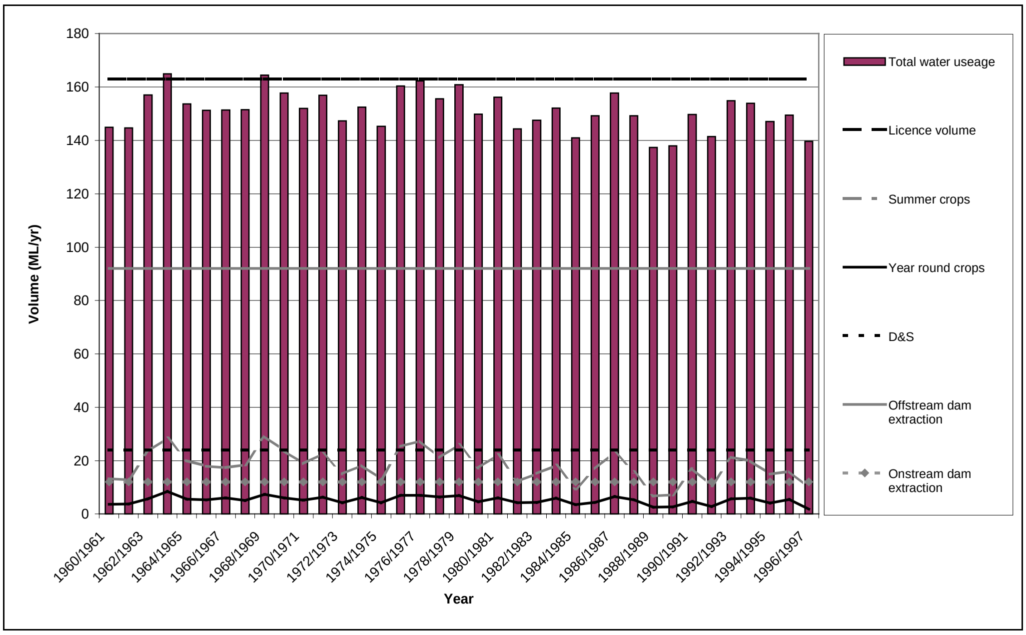
Current and Historic Levels of Development



- **Figure A-17 Upper Subcatchment Year-Round Crops Usage at Current Level of Development**

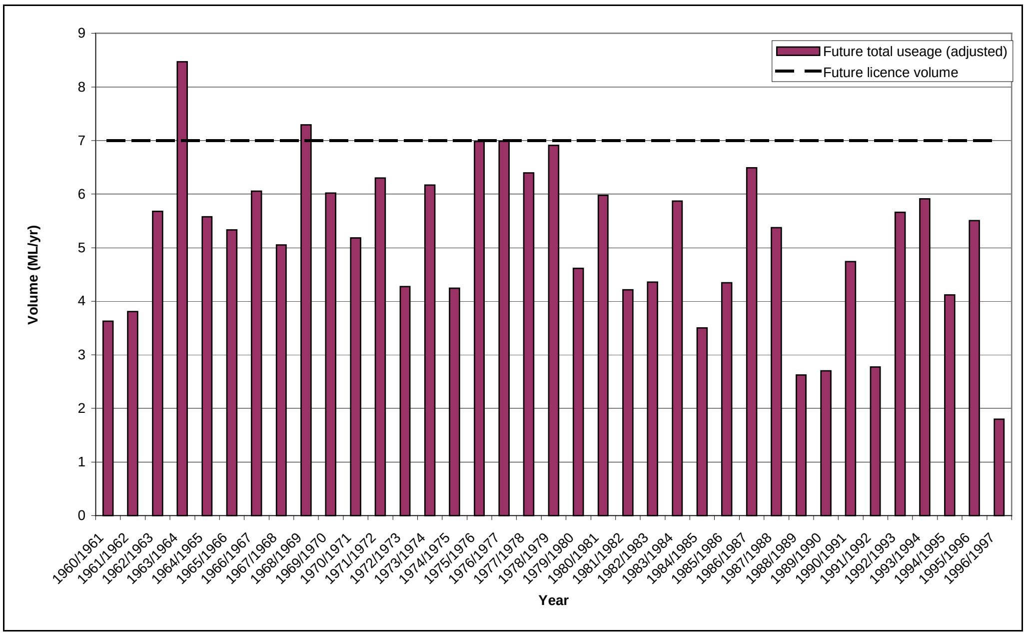


- **Figure A-18 Upper Subcatchment Summer Crops Usage at Current Level of Development**

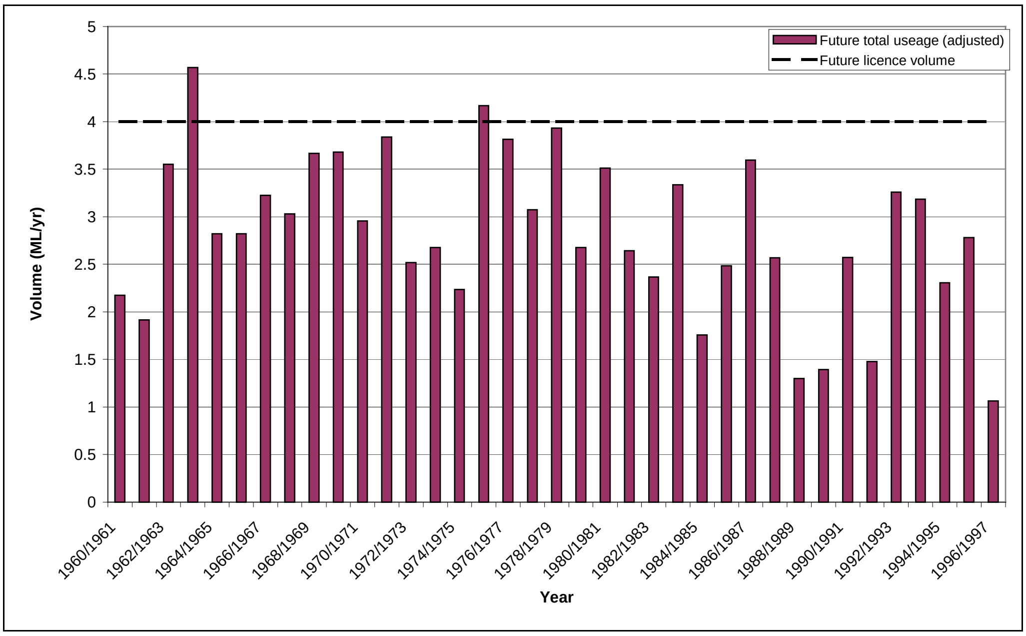


- **Figure A-19 Upper Subcatchment Total Demands at Current Level of Development**

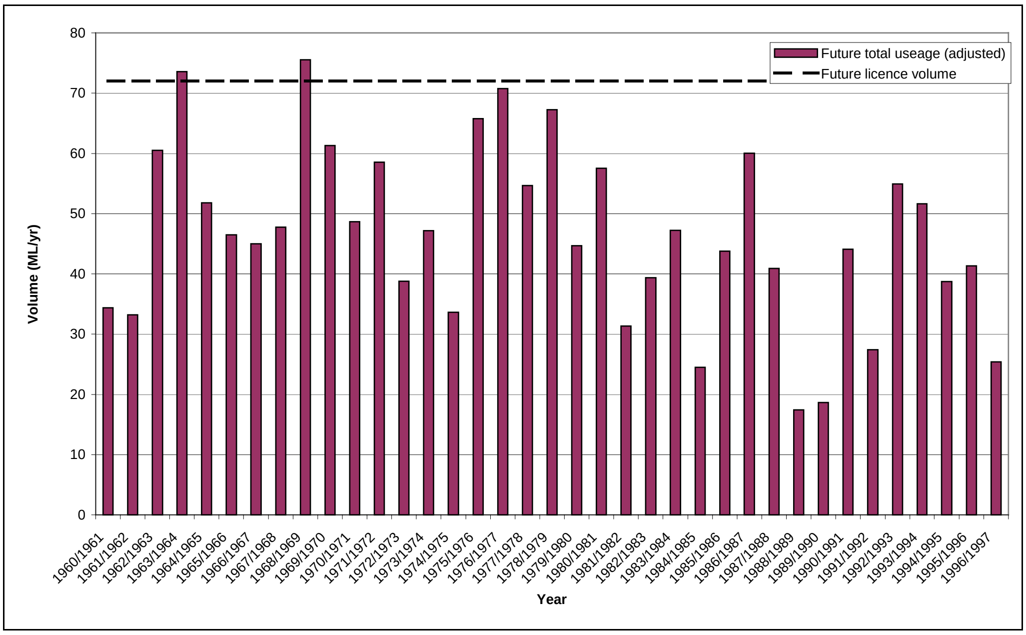
Full Level of Development



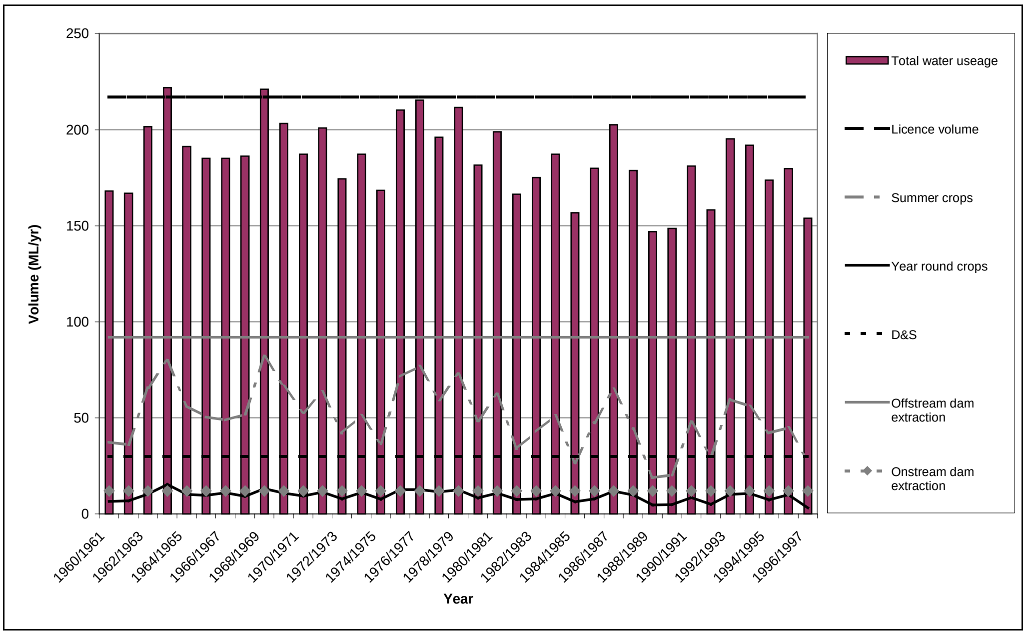
- **Figure A-20 Upper Subcatchment Year-Round Crops Usage at Full Level of Development**



- **Figure A-21 Upper Subcatchment Orchard Usage at Full Level of Development**



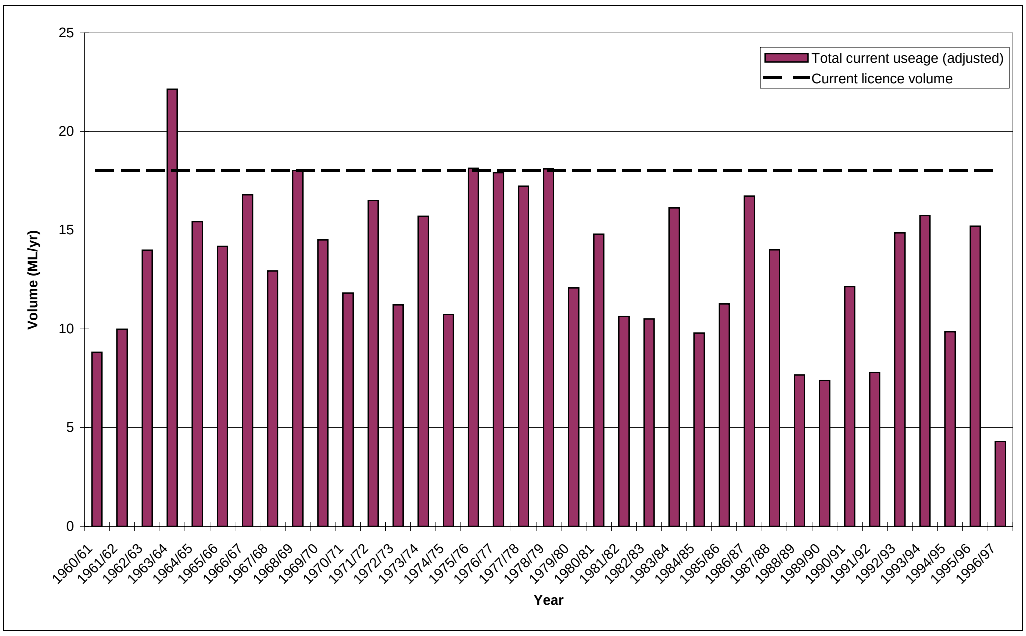
■ **Figure A-22 Upper Subcatchment Summer Crops Usage at Full Level of Development**



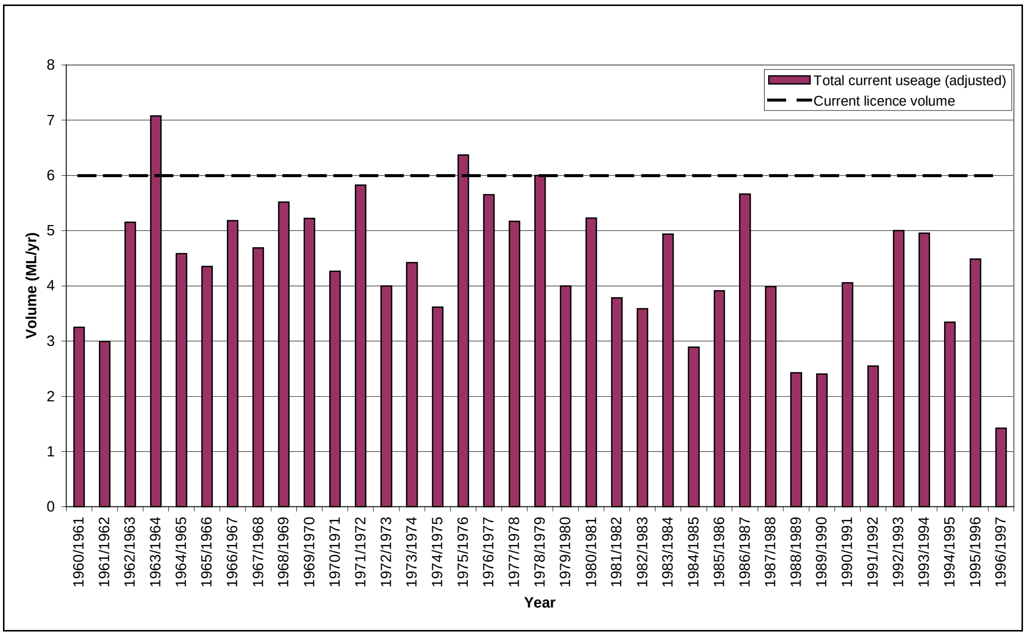
■ **Figure A-23 Upper Subcatchment Total Demands at Full Level of Development**

Middle Subcatchment - Diverters from Olinda Creek downstream of Road 19 and upstream of the bridge on York Road, Mt Evelyn.

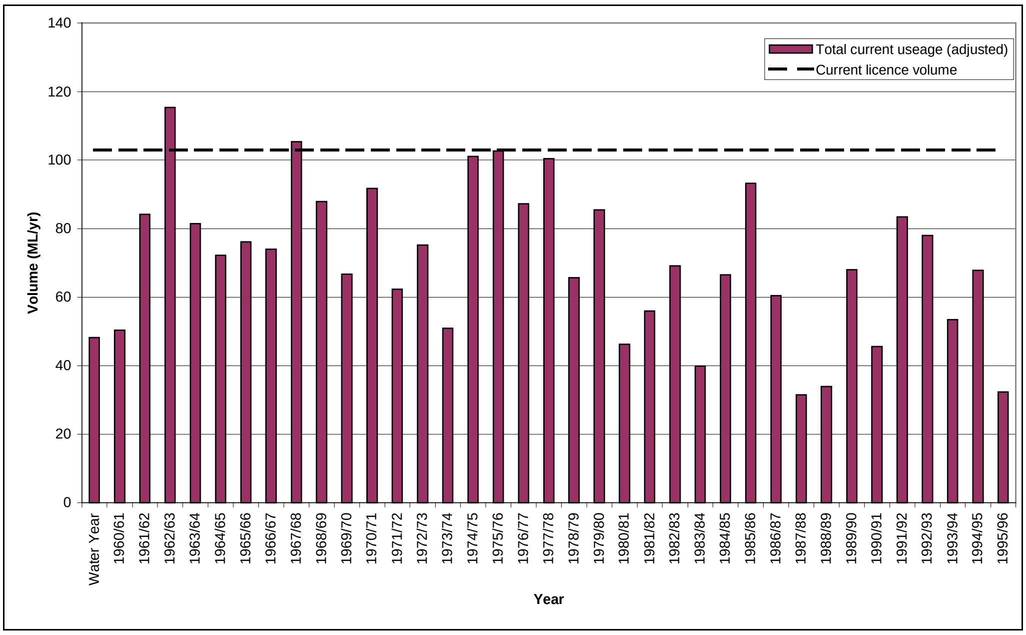
Current Level of Development



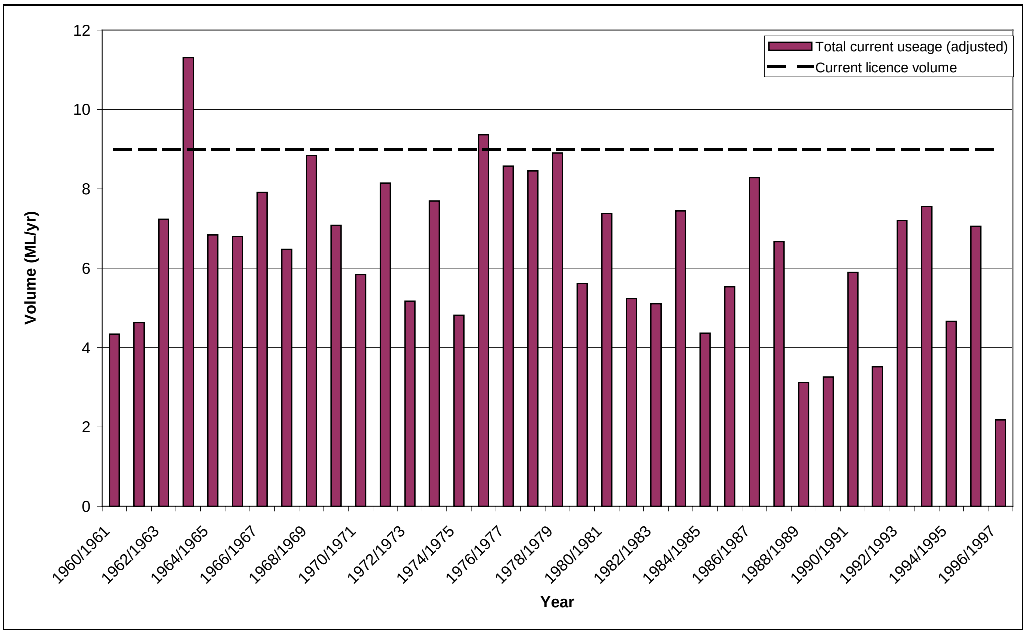
- **Figure A-24 Middle Subcatchment Year-Round Crops Usage at Current Level of Development**



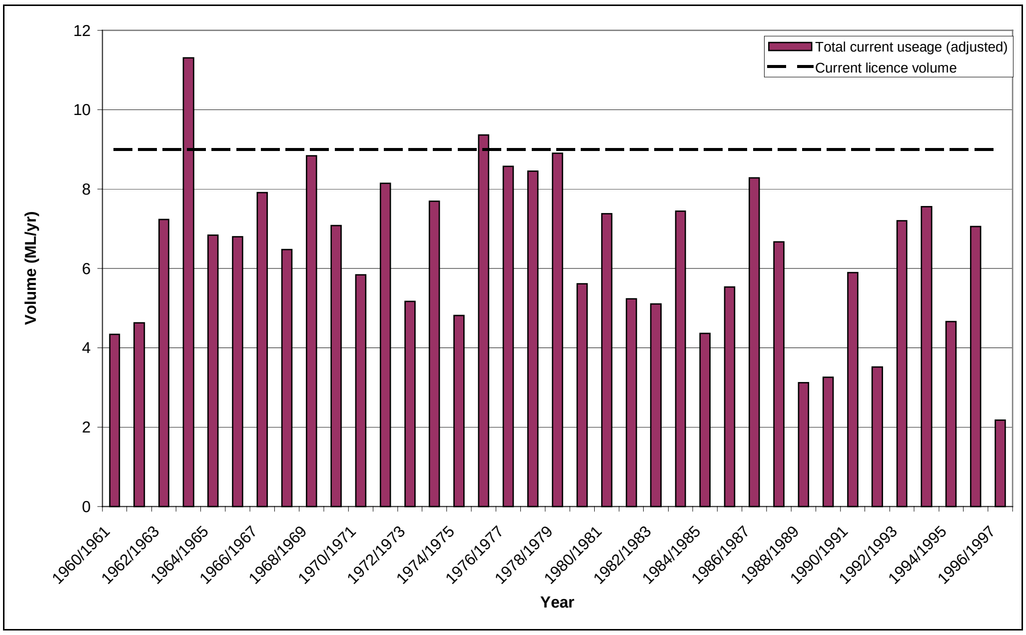
- **Figure A-25 Middle Subcatchment Orchards Usage at Current Level of Development**



- **Figure A-26 Middle Subcatchment Summer Crops Usage at Current Level of Development**

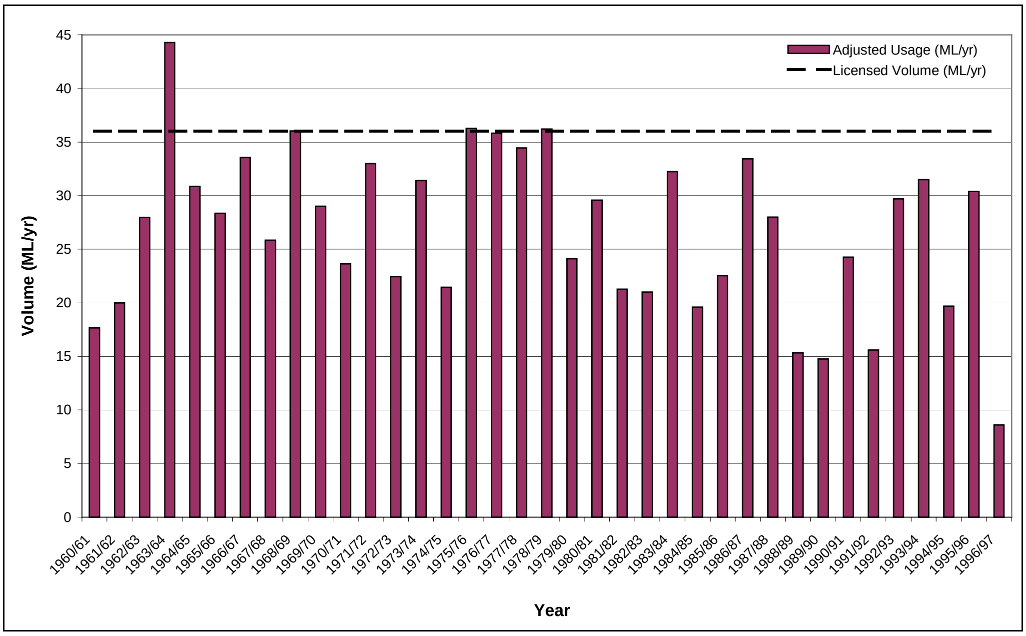


- **Figure A-27 Middle Subcatchment Pastures Usage at Current Level of Development**

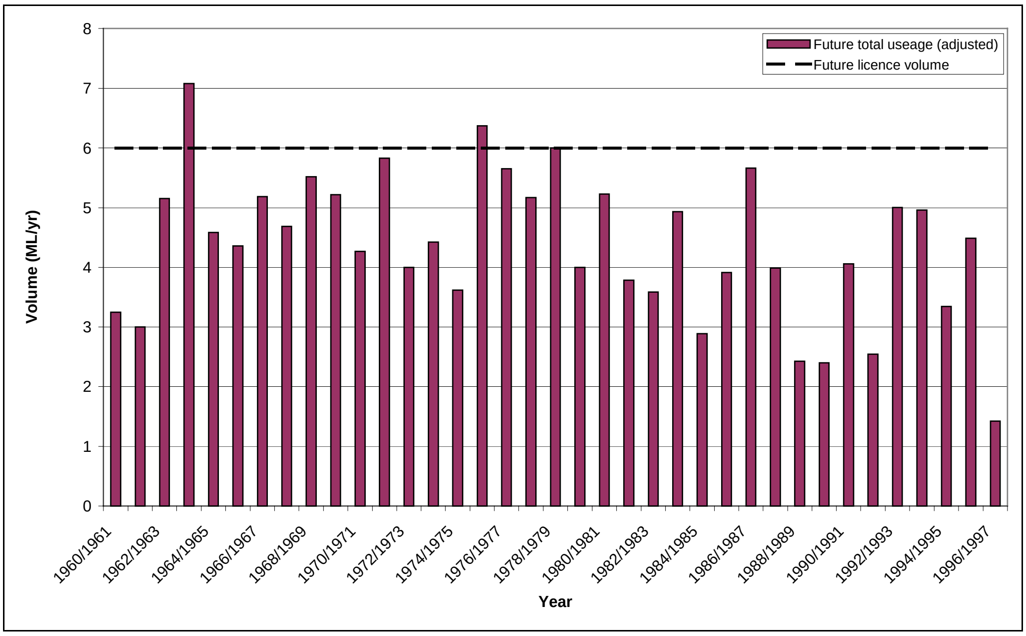


- **Figure A-28 Middle Subcatchment Total Demands at Current Level of Development**

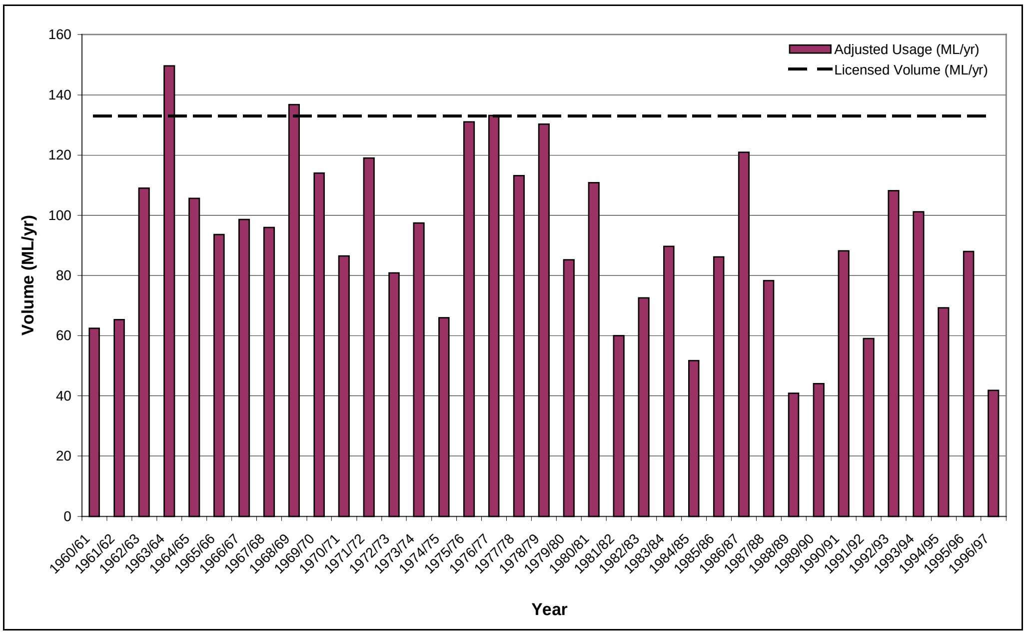
Full Level of Development



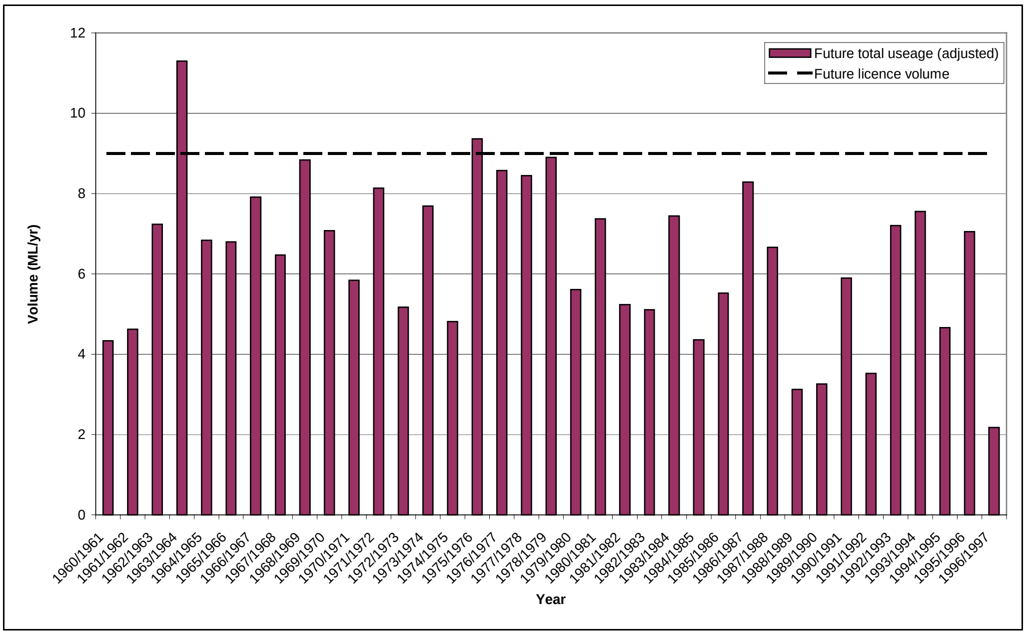
- **Figure A-29 Middle Subcatchment Year-Round Crops Usage at Full Level of Development**



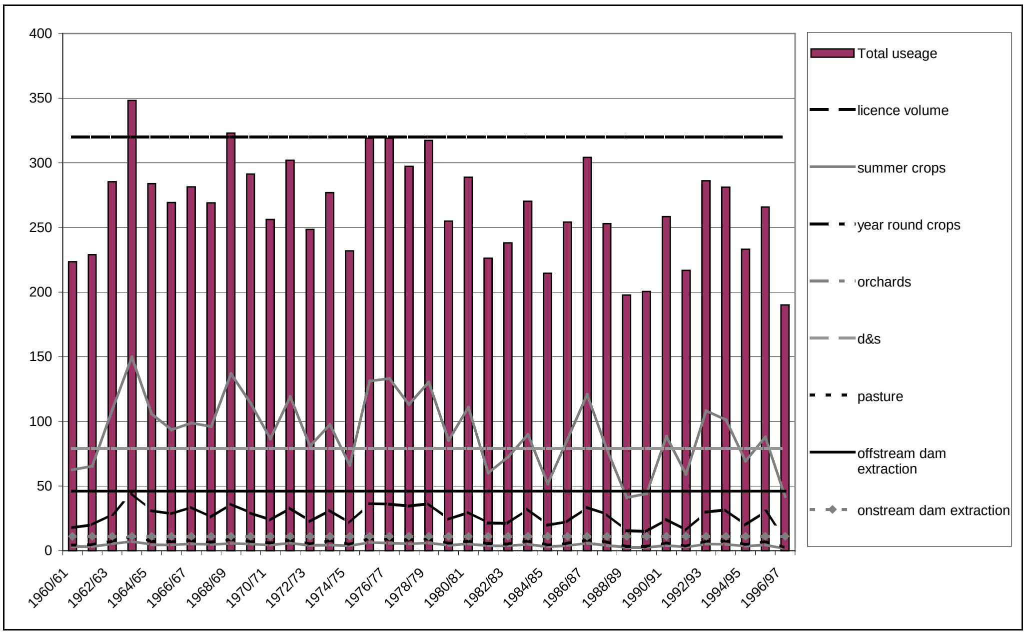
- **Figure A-30 Middle Subcatchment Orchards Usage at Full Level of Development**



■ Figure A-31 Middle Subcatchment Summer Crops Usage at Full Level of Development



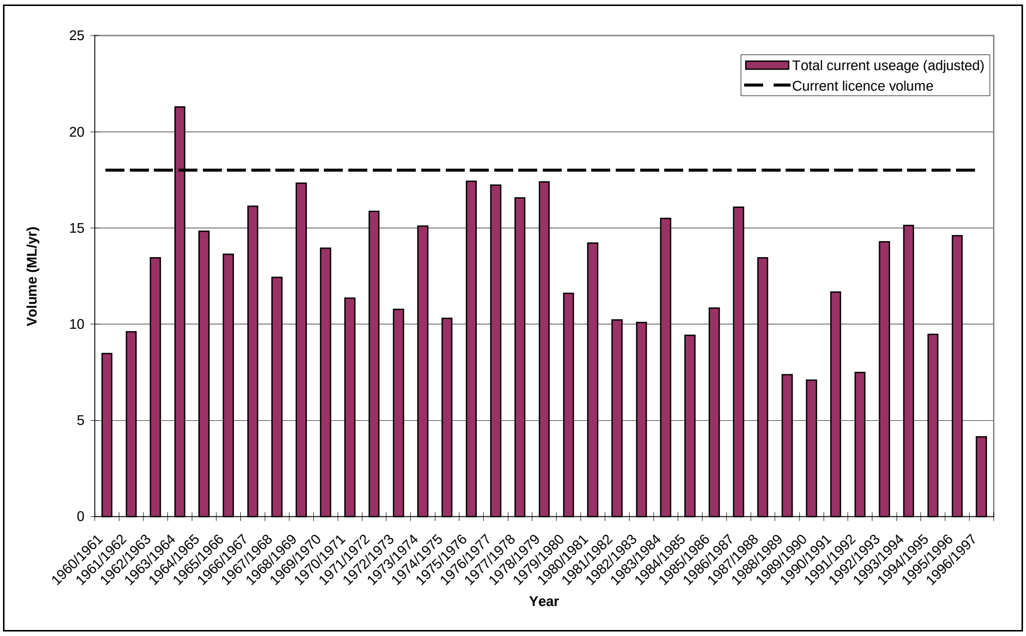
■ Figure A-32 Middle Subcatchment Pastures Usage at Full Level of Development



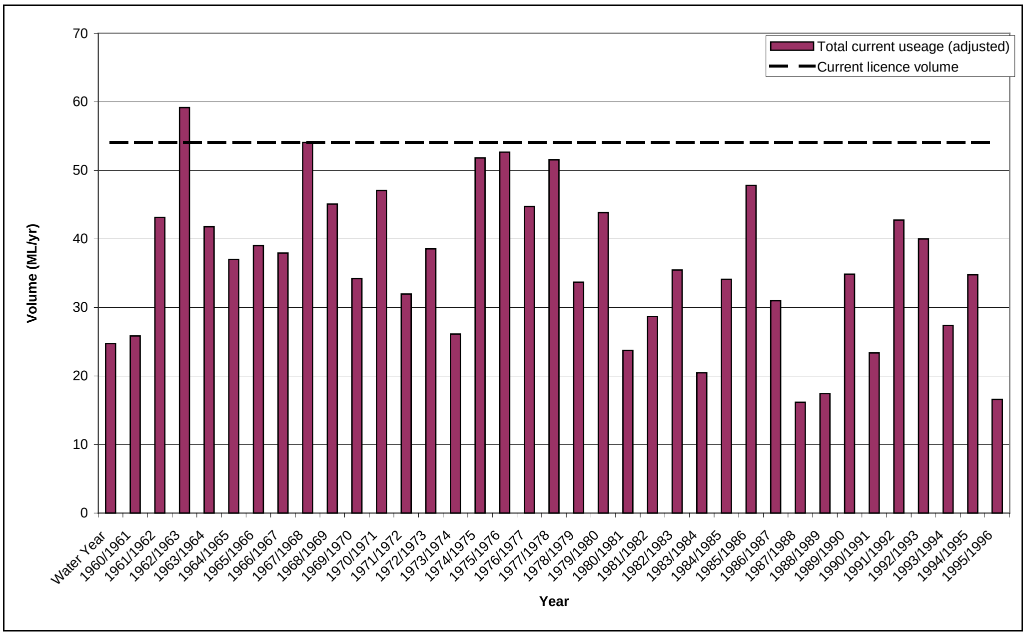
- **Figure A-33 Middle Subcatchment Total Demands at Full Level of Development**

Lower Subcatchment - Diverters from Olinda Creek downstream of the York Road bridge, Mt Evelyn and upstream of the McIntyre Lane bridge

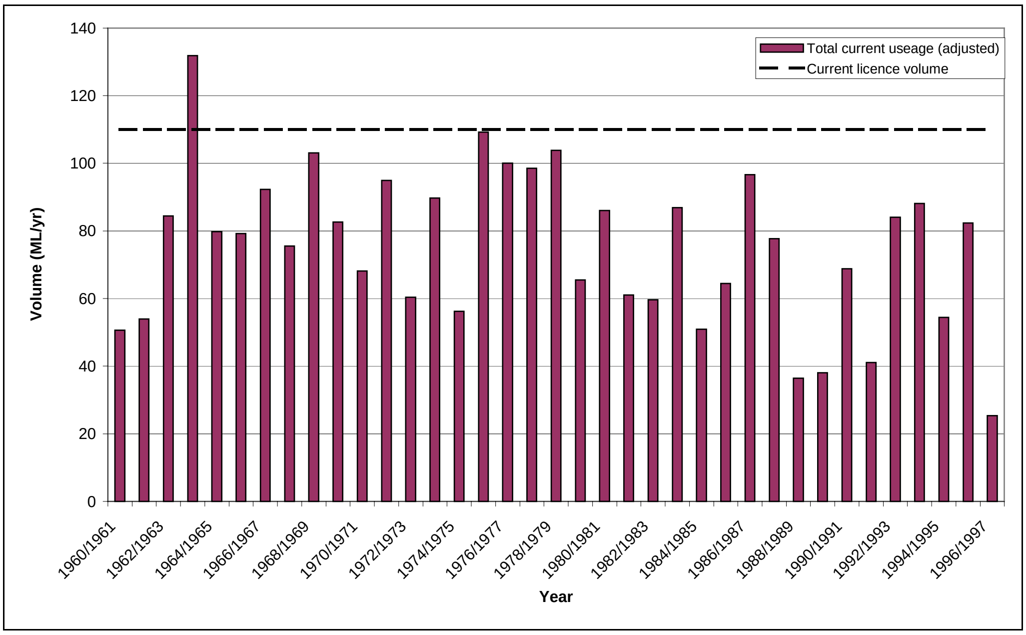
Current Level of Development



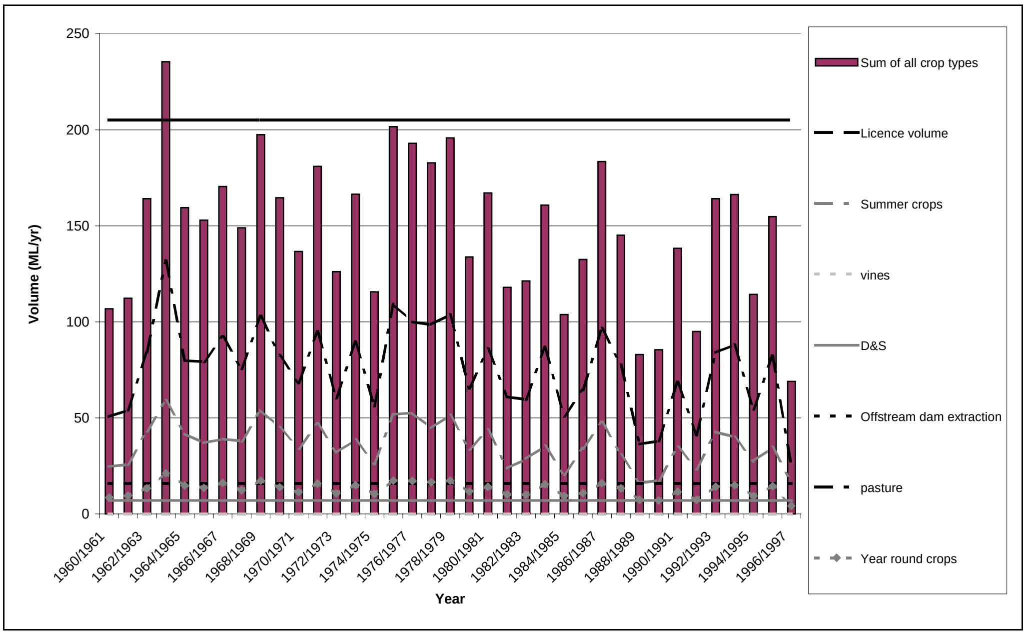
- **Figure A-34 Lower Subcatchment Year Round Usage at Current Level of Development**



- **Figure A-35 Lower Subcatchment Summer Crops Usage at Current Level of Development**

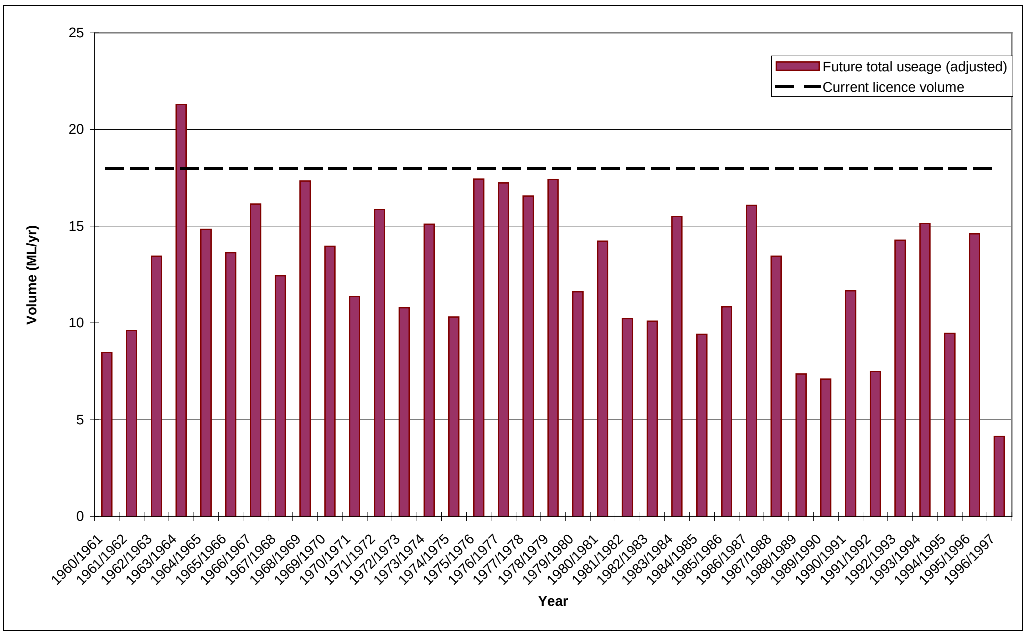


- **Figure A-36 Lower Subcatchment Pasture Usage at Current Level of Development**

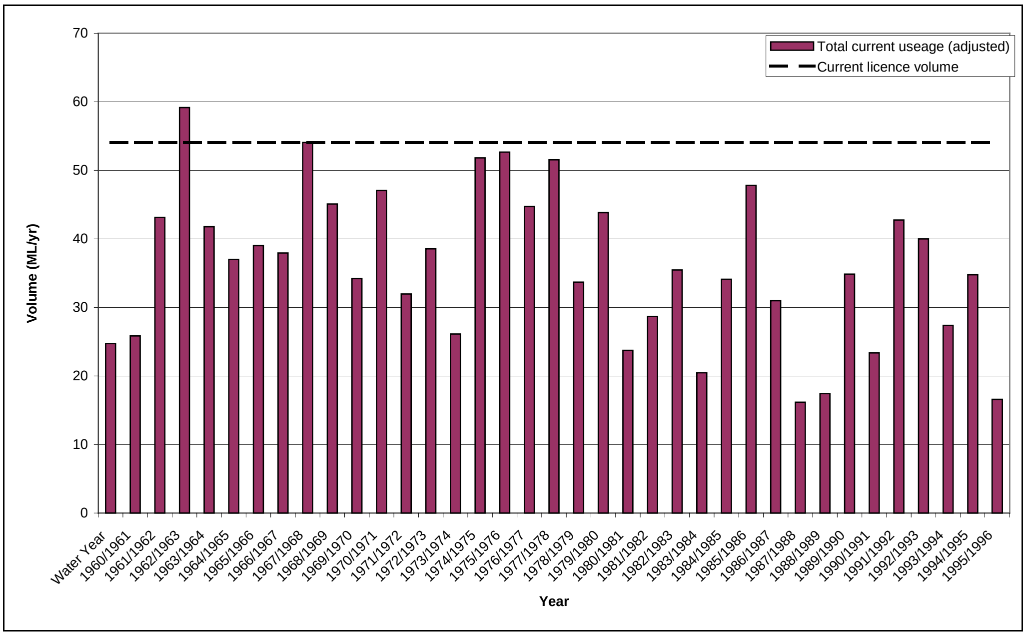


- **Figure A-37 Lower Subcatchment Total Demands at Current Level of Development**

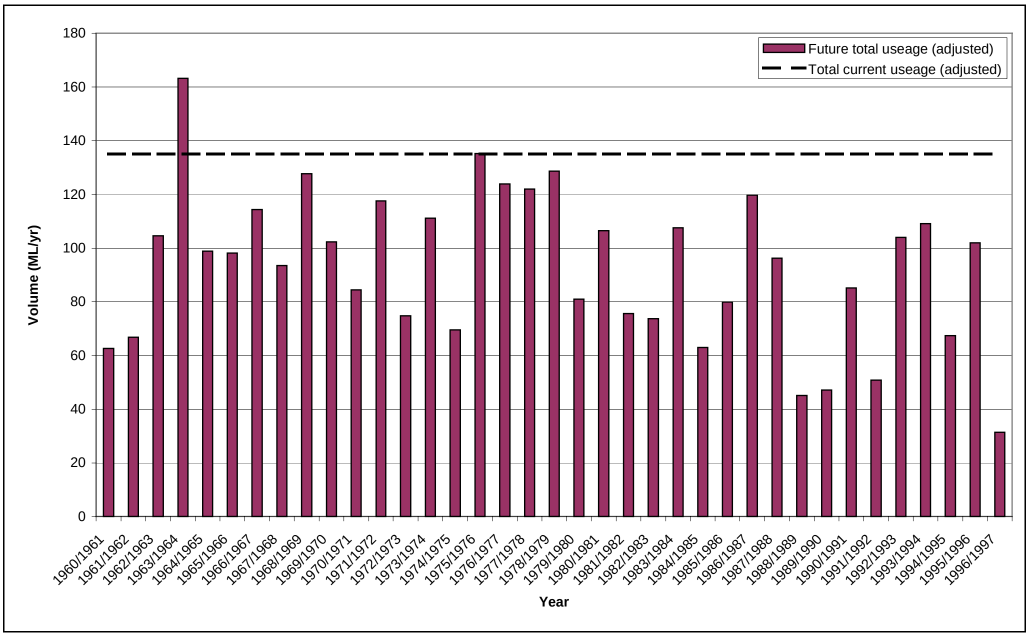
Full Level of Development



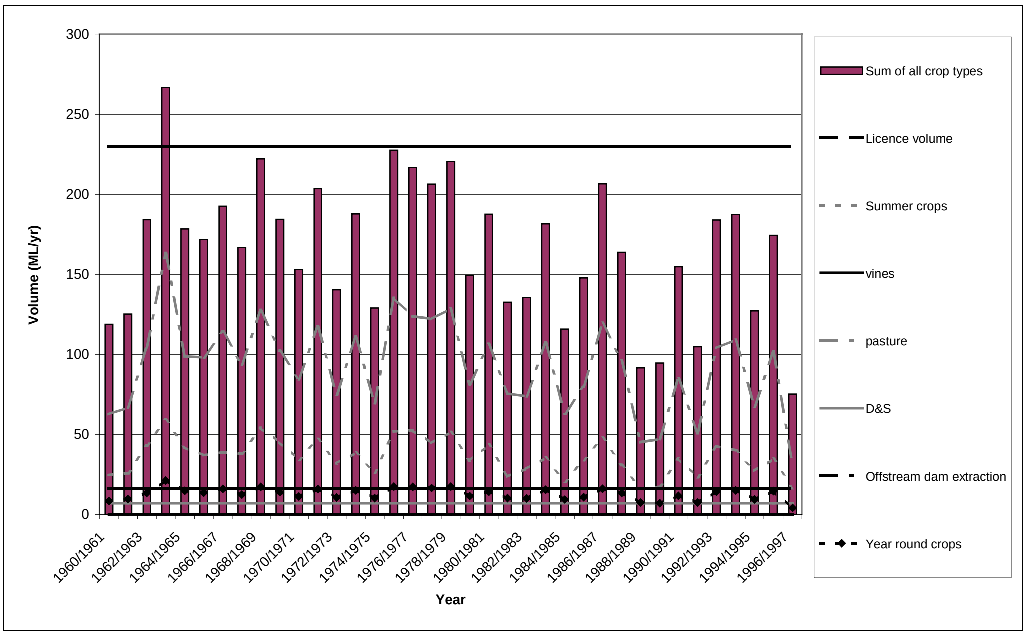
- **Figure A-38 Lower Subcatchment Year Round Usage at Full Level of Development**



- **Figure A-39 Lower Subcatchment Summer Crops Usage at Full Level of Development**



- **Figure A-40 Lower Subcatchment Pasture Crops Usage at Full Level of Development**



- **Figure A-41 Lower Subcatchment Total Demands at Full Level of Development**