Melbourne Water

Assessment of Farm Dam impact on the Plenty River Catchment

Final 1

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SINCLAIR KNIGHT MERZ

Sinclair Knight Merz Pty Limited
ACN 001 024 095
ABN 37 001 024 095
590 Orrong Road
Armadale VIC 3143
PO Box 2500
Malvern VIC 3144
Australia
Telephone: +61 3 9248 3100
Facsimile: +61 3 9248 3364

Executive Summary

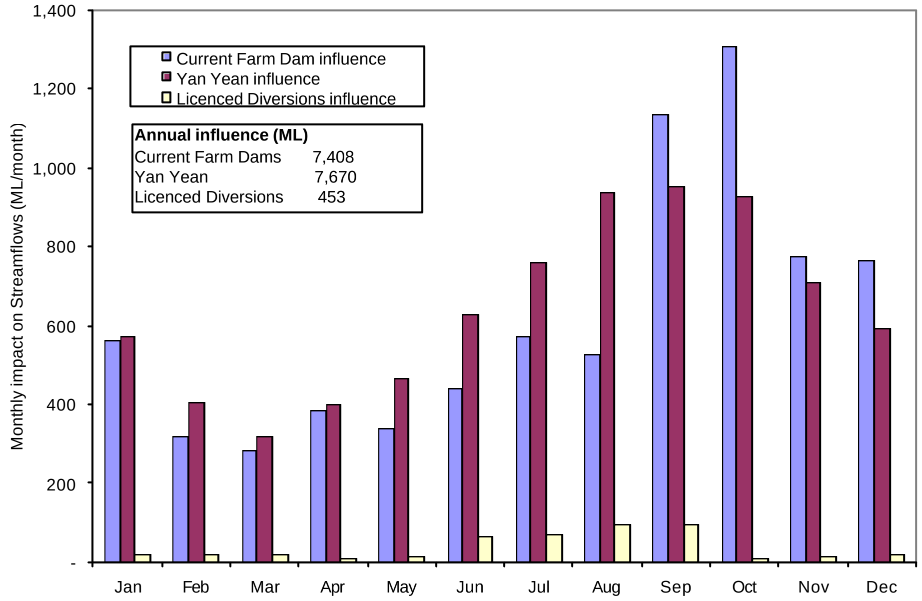
Melbourne Water is required, under the State Environment Policy, to develop Streamflow Management Plans (SFMP) for unregulated catchments, which includes the Plenty River. The primary objective of a Stream Flow Management Plan is to have agreed and equitable management of take-and-use licences, which considered all demands on the water resource and ensures there are sufficient flows to maintain the long-term environmental health of river systems. To assist in this process, Sinclair Knight Merz (SKM) was engaged by Melbourne Water to undertake a study into the impact of farm dams on streamflow in the Plenty River catchment. The consideration of unlicensed diversions harvested by catchment dams in conjunction with licensed diversions provides a sound basis for development of the flow sharing rules required in a SFMP. The term “catchment dams” is used here to denote dams which harvest rainfall runoff but which are not located on a waterway. The use of water from other types of dams (e.g. off-stream and on-stream dams) are accounted for in the licensed diversions.

The effect of catchment dams on seasonal streamflow is not well understood, however it is considered that they can potentially have a significant impact. Several regions in Victoria, as well as further afield, are experiencing a rapid increase in high value intensive agricultural developments relying on new dams for their water supply. There is widespread concern over the impacts these new dams could be having on existing water entitlements and environmental flows, particularly in unregulated catchments, but there is little information available to inform catchment and water resource management agencies on how to respond to this trend.

For this reason, SKM developed a modelling tool known as the Tool for Estimating Dam Impacts (TEDI; SKM,2000; Neal et al., 2000; Nathan et al., 2000). This is a water balance simulation model specifically written to determine the impact of catchment dams. The model uses climate conditions (historical records of rainfall and evaporation) and data on known diversions to estimate natural streamflow conditions. In the case of Plenty River, the Natural streamflow can be calculated as

Natural Streamflow = Gauged Streamflow
Plus Licensed diversions
Plus Toorourrong inflow (0.2 ML/d passing flow)
Minus Treatment plant discharge
Plus Farm dam impacts

This process allows the effect of each diversion type to be assessed individually. The following bar chart shows the monthly reduction to natural flow caused by each catchment dams, licensed diversions and diversions to Yan Yean. This chart clearly shows that catchment dams cause a significant reduction to streamflow, especially in the later half of the year.



In the Plenty River catchment:

- The current total volume of farm dams in the Plenty River catchment is 3565 ML, which represents 15% of the mean annual flow (23880 ML).
- For each additional ML of farm dam there is a 2.2 ML decrease in mean annual flow
- Catchment dams have a larger impact on streamflow compared to licensed diverters in the catchment. The main alterations to the natural flow regime occur due to the impact of farm dams and diversions to Yan Yean.
- The current level of development in the Plenty River has reduced high flow by approximately 1590 ML/year, median flow by 420 ML/year, and low flow by 115 ML/year.

Contents

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1. Introduction

Melbourne Water is required, under the State Environment Policy, to develop Streamflow Management Plans (SFMP) for unregulated catchments, which includes the Plenty River. To assist in this process, Sinclair Knight Merz was engaged by Melbourne Water to undertake a study into the impact of farm dams on streamflow in the Plenty River catchment. The consideration of unlicensed diversions harvested by catchment dams in conjunction with licensed diversions provides a sound basis for development of the flow sharing rules required in a SFMP. The term "catchment dams" is used here to denote dams which harvest rainfall runoff but which are not located on a waterway. The use of water from other types of dams (e.g. off-stream and on-stream dams) are accounted for in the licensed diversions.

The Plenty River system is located north of Melbourne and drains a catchment of 351 km^2. The upper parts of the Plenty River catchment include an area of State Forest and also the Toorourrong Reservoir. Downstream of the Toorourrong Reservoir the River flows through a floodplain until Mernda, and then passes a section in a relatively natural state followed by areas of high urbanisation. The Toorourrong Reservoir passes water into an off-stream storage, Yan Yean Reservoir, via an aqueduct. The catchment for Yan Yean, although part of the Plenty River catchment, does not contribute to the downstream flow.

The effect of catchment dams on seasonal streamflow is not well understood, however it is considered that they can potentially have a significant impact. Several regions in Victoria, as well as further afield, are experiencing a rapid increase in high value intensive agricultural developments relying on new dams for their water supply. There is widespread concern over the impacts these new dams could be having on existing water entitlements and environmental flows, particularly in unregulated catchments, but there is little information available to inform catchment and water resource management agencies on how to respond to this trend.

The modelling tool which is to be used as the basis for this study is known as the Tool for Estimating Dam Impacts (TEDI; SKM,2000; Neal et al., 2000; Nathan et al., 2000). This is a water balance simulation model specifically written to determine the impact of catchment dams.

This report includes:

- Trend analyses on historical streamflows to remove the historical impact of catchment dam development thereby ensuring the analysis is undertaken on a stationary streamflow series, with no statistically significant trend
- A description of the water balance model used to estimate the impact of catchment dams and a summary of the overall methodology
- Results of the water balance modelling, including the present and potential future impacts of catchment dams on the natural flow regime.

2. Overview of Catchment Dam Modelling

The TEDI model is a computer-based model that was developed by Sinclair Knight Merz for the Murray Darling Basin Commission, with the specific intention of modelling the impact of catchment dams (SKM, 2000).

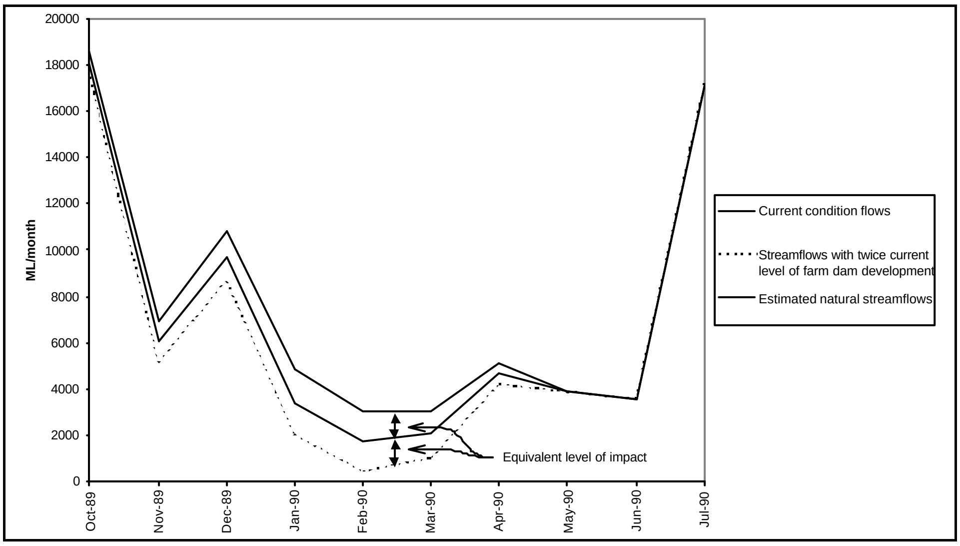
TEDI can be used to:

- determine the impact of continued catchment dam development on the current flow regime; and,
- ascertain the impact of the existing level of catchment dam development on the natural flow regime.

The impacts of additional catchment dams are assessed by gradually introducing hypothetical dams into the study catchment and calculating a water balance (based on a monthly time step) on individual dams. The outflows from each individual dam are summed and then added to the residual catchment flow (ie. the fraction of total flows unaffected by dams) to provide an estimate of the total flow leaving the catchment. Additional catchment dams are randomly selected from the current size distribution of dams in each catchment.

The impact of current levels of development on *natural flows* is estimated by adding the current volume of catchment dams in each catchment to the existing "current condition" flows and evaluating the impacts of this scenario using the water balance simulation model (that is, the model is used to simulate twice the current level of catchment dam development). The magnitude of the reduction in streamflow caused by these additional dams is then *added* to the streamflow time series representing current conditions to estimate natural flows prior to the influence of catchment dams. This is represented diagrammatically in Figure 2-1.

■ **Figure 2-1 Method used to estimate natural flows**

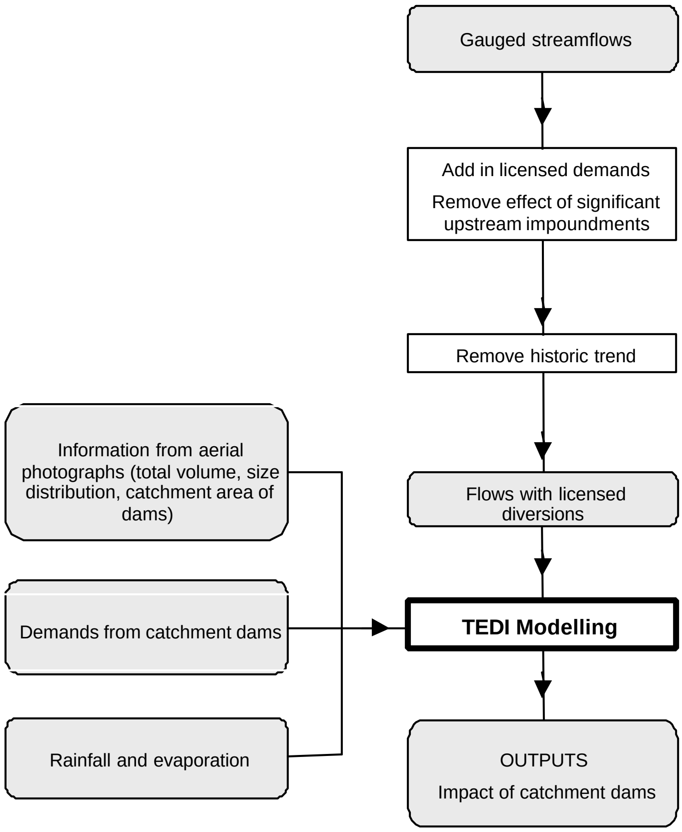


2.1 Summary of Modelling Approach

A schematic of the modelling approach used is shown in Figure 2-2. This figure illustrates the sequence of the main tasks undertaken to identify catchment dam impacts, and reference to the report section that describes the task.

In brief, observed streamflows are assembled for the site of interest. The streamflows are corrected for the influence of consumptive demands and for upstream impoundments. They are then analysed for trend due to the influence of catchment dam development and detrended as appropriate. Information on the number, size and catchment area of dams is determined from aerial photographs and the annual cycle of demands extracted from the catchment dams are also estimated. Rainfall and evaporation data required for water balance computations are prepared and are used in conjunction with the other inputs for simulation of dam impacts using the TEDI model. The impacts of catchment dams are then characterised in a number of different ways.

■ **Figure 2-2 Schematic of modelling approach**



3. Derivation of Model Inputs

The TEDI model requires the following inputs:

- Streamflows;
- Rainfall and evaporation;
- The volume of catchment dams;
- The distribution of dam sizes;
- The catchment area of dams; and,
- Information regarding demands from catchment dams.

Each of these topics is discussed in more detail in the following sections.

3.1 Streamflows

The streamflow data used in the TEDI model consisted of the observed streamflows adjusted for:

- trend removal (where necessary);
- the impact of historic licensed diversions; and
- the influence of upstream impoundments.

Streamflow data was also infilled and extended where required. The resulting streamflow data was the best estimate of flow influenced only by catchment dam development.

The observed streamflows were analysed for any trend that might skew results. The following sections describe:

- The unadjusted (observed) streamflow data;
- The impact of licensed diversions;
- The impact of significant upstream impoundments; and
- The historical trend analysis.

3.1.1 Observed Streamflows

There are three sites on the Plenty River where streamflow data is available

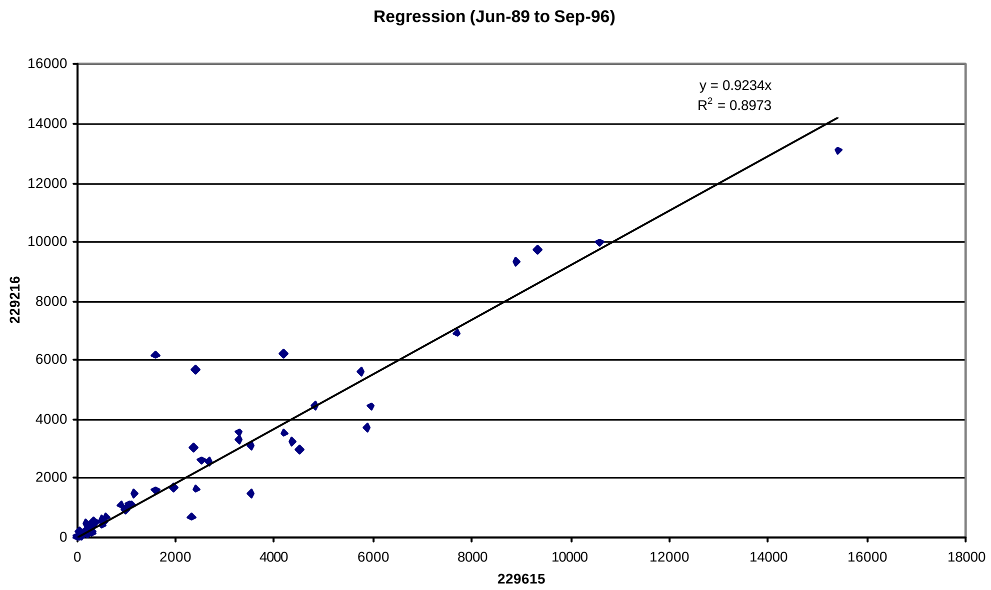
- Plenty River at Lower Plenty (SI No. 229614)
- Plenty River at Mernda (SI No. 229216)
- Plenty River at Greensborough (SI No. 229615)

It is preferable to use a gauging station that encompasses a large portion of the total Plenty River Catchment. For this reason, the Mernda station was not used. Both Lower Plenty and Greensborough stations are located at the lower end of the catchment. However, the Lower Plenty gauge was affected over the period 1991 – 1997 by bridge constructions, causing unreliable stage data, limited measurements and unsettled control[1]. For this reason, the streamflow at Greensborough was used in this study, with reliable recorded data from June 1989 to May 2000. A less accurate data set extending back to 1981 was also supplied by Melbourne water and included in the TEDI analysis to provide the maximum period of record.

[1] Information provided through correspondence with Thiess Services 18/12/2000

The period of record contained sections of missing data, and thus infilling was required. The only extended period of missing data was between 30/11/90 and 8/1/91, though other missing data was present over shorter periods. A correlation between the Greensborough and Mernda stations was found by plotting both the time series and a linear regression (of monthly data over the period June 1989 to September 1996 as shown in Figure 3-1) between the two sites, however this correlation was only apparent up until June 1997. After this time (as the flow patterns differed markedly and there was little missing data after June 1997) infilling was achieved by linear interpolation. Infilling was performed on a daily time step and the daily streamflow data was aggregated to produce monthly streamflow.

■ **Figure 3-1 Regression between gauges 229615 and 219216**



There was poor correlation between the gauges at low flows, particularly when zero flows occurred at Mernda. It was therefore identified that when flows at Mernda were zero, the corresponding flow at Greensborough was 1.88ML/day on average. The minimum flow at Greensborough was therefore set to 1.88ML/day. Using the regression developed previously, if flow at Mernda dropped below 1.74 ML/day, Greensborough was assumed to have a constant flow of 1.88 ML/day.

3.1.2 Historic Extractions by Licensed Diverters

An estimate of historic licensed diversions is required in order to adjust the gauged flow and obtain a flow series influenced only by catchment dams. Information on the distribution of irrigation demands across the year is also required for input to the TEDI model. This data is used to determine a pattern of extraction from the larger catchment dams.

Six types of licensed demands were identified:

- Irrigation;
- On-stream dams (those dams located on defined waterways);
- Off-stream dams (those dams supplied by pumping or diverting water from waterways);
- Stock and domestic;
- Industrial; and
- Commercial.

Ideally, actual recorded consumption by licensed diverters should be added back to the gauged streamflow to obtain a flow series unaffected by licensed diversions. Unfortunately this data does not exist for Plenty River. In addition, no estimates from irrigation demand estimation modelling were available. Therefore, it was assumed conservatively that historical extractions by licensed diverters were equal to their licensed volume each year, except in recent years where survey data is available.

To add the licensed volume back to flow for each year, both the total annual volume of extraction and the pattern applied to that volume must be defined. Current licensed volumes for the Plenty River catchment, as provided by Melbourne Water, are shown in Table 3-1. Surveys of diverters in the Plenty Catchment indicated that in recent years the volume diverted has significantly reduced. Therefore, the demands were divided into two periods, historical and current. It is assumed that historically (prior to 1995) the volume diverted is equal to the licence volume. Demands over the past five years, or current usage, takes into account survey details.

- **Table 3-1 Summary of Licenses (ML/yr)**

	Domestic and stock	Commercial	Winterfill	Direct Irrigators	Total
Licence	8	4	335	106	453
Current Usage	8	4	261	35	308

As Diamond Creek is the adjacent catchment, it is adequate to assume similar crop types and hence irrigation patterns. The pattern applied to the licensed direct irrigation volume was extracted from information on Diamond Creek provided by Melbourne Water as part of a previous study (SKM 2000b). The irrigation pattern is shown in Table 3-2. This same pattern was applied to irrigation extractions from larger catchment dams in the TEDI model. The demand patterns applied to the other types of licensed demands are shown in Table 3-3, and are the same as those used for the Diamond Creek catchment.

- **Table 3-2 Monthly Proportion of Demands (%)**

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Irrigation	0.18	0.19	0.19	0.06	0.01	0.00	0.00	0.01	0.03	0.07	0.11	0.16

- **Table 3-3 Estimated Monthly Usage of License Allocation (%)**

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Stock&Domestic	11.7	11.7	10.0	7.9	6.7	6.2	6.3	6.2	6.5	7.4	8.4	11.0
Off/On Stream Dam filling	0.0	0.0	0.0	0.0	10.0	10.0	15.0	15.0	20.0	20.0	5.0	5.0

3.1.3 Upstream Impoundments

Toorourrong Reservoir is located on the Plenty River East Branch and has a capacity of 273 ML. Water is transported from this Reservoir to Yan Yean Reservoir via an aqueduct. A base flow of 0.2 ML is passed daily into the Plenty River, along with occasional spills once the Reservoir fills. The influence of Toorourrong must be removed from the gauged flow data at Greensborough.

Melbourne Water provided the estimated streamflow into the Toorourrong Reservoir. It is assumed that this streamflow is all passed via the aqueduct to Yan Yean Reservoir apart from the 0.2 ML/d passing flow. Although this is an approximation, no data is available reflecting the volume or time of spills, effect of evaporation or other such variables. Discussion with Melbourne Water indicates that Toorourrong Reservoir rarely spills, and thus this assumption is considered appropriate.

3.1.4 Treatment Plant Discharge

The outfall from the Whittlesea (Cades Rd) Treatment plant must be subtracted from the gauged streamflow data. Discharge from the treatment plant commenced in March 1989 and since this time discharge volumes have steadily increased.

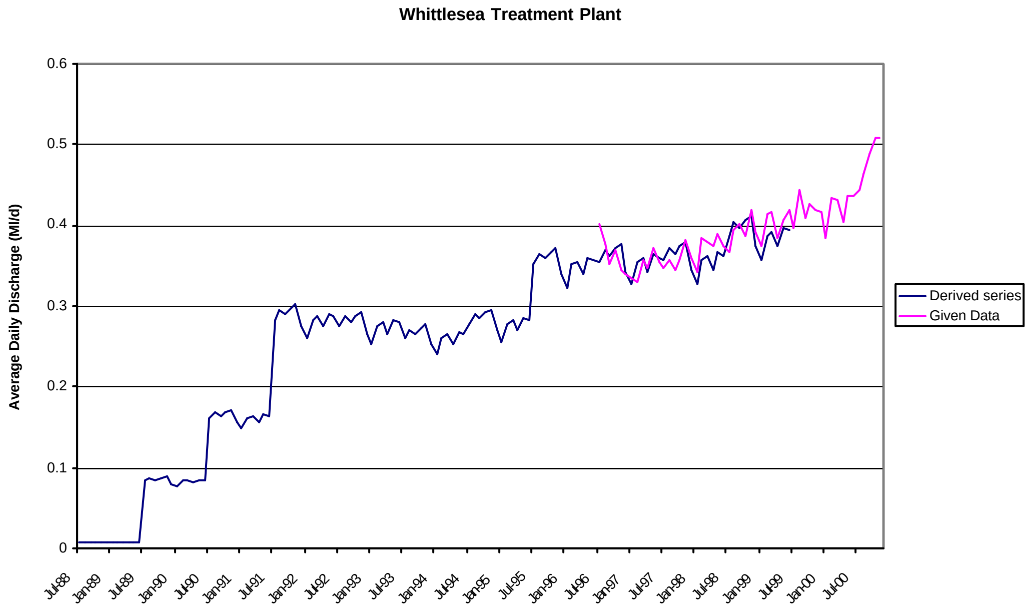
Melbourne Water provided monthly outflow rates over the period of July 1996 to November 2000. The average monthly discharges were calculated and the percentage of annual discharge per month found. This was used to define an annual discharge pattern as shown in Table 3-4.

■ **Table 3-4 Monthly discharge as percentage of total annual discharge**

	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
%Annual	8.28	8.61	8.45	8.68	8.79	8.00	7.62	8.28	8.39	8.00	8.49	8.40

The flow pattern was applied to the total annual outflow data provided for previous years in order to obtain a time series of discharge over the total period. Both the derived pattern and the given monthly flow rates are shown in Figure 3-2.

■ **Figure 3-2 Time series for discharge from Whittlesea Treatment Plant**



3.1.5 Adjusted Streamflow

The Adjusted streamflow to be imputed into TEDI was calculated from the gauged streamflow as follows:

Adjusted Streamflow =	Gauged Streamflow	
	Plus	Licensed diversions
	Plus	Toorourrong inflow (0.2 ML/d passing flow)
	Minus	Treatment plant discharge

3.1.6 Historical Trend Analysis

For the assessment of catchment dam impacts it is desirable to analyse a stationary streamflow series that contains no significant trends over time. Time trends in recorded streamflow data often arise from influences such as proliferation of catchment dams, increased water demands and urbanisation. This section describes how the streamflow records were analysed for stationarity.

The analysis of trends in the streamflow data was undertaken using a Generalised Additive Model (GAM). This is a powerful quasi-parametric statistical test that is able to overcome many of the practical problems with real hydrologic data sets. It was felt that Toorourrong Reservoir has a large impact on flows, so its influence, as well as the effect of upstream demands and discharges were removed before analysis.

Trend analyses were undertaken on monthly flows, with variability being explained as a function of time, season and rainfall. Results are reported according to the statistical significance of the trend being investigated under the following three categories:

- statistically significant at the 5% level of significance (highly significant trend);
- statistically significant at the 10% level of significance (moderately significant trend); and,
- not statistically significant (no trend).

It should be noted that the GAM analysis was only performed on the more recent data set (the period 1989 – 1999) as this is the more reliable data.

In summary, there have been no statistically significant trends in monthly streamflow in the Plenty River catchment over the period of streamflow. Full results are given in Appendix A.

3.2 Volume of catchment dams

Previous experience in the identification of current catchment dam development has shown that the most effective means of estimating volumes of catchment dams is from aerial photographs. Other sources of reference which have been found to be less suitable than aerial photographs include:

- Orthophotomaps
  These are of poorer quality than aerial photographs, are sporadically located, and based on photographs taken in the 1970's.

- Satellite imagery
  The location of catchment dams indicated by satellite imagery has not been verified by other means. In addition, the accuracy of satellite imagery is limited by the pixel size used to record the images. The cost of high resolution satellite imagery currently prohibits its use for studies of catchment dams

- Council development approvals
  Development approval is not required by all local councils. Records that are available provide only incomplete information because many dams are constructed without development approval, even when required.

Aerial photographs were obtained for the catchment, and using these the surface area of each catchment dam was digitised. The corresponding dam volumes were then calculated using the volume – surface area relationship derived by Good and McMurray (1997):

- $$V = A^{1.4} / 22727$$ **Equation 1**

where V is the storage volume in megalitres and A is the surface area in metres squared.

Dams identified from aerial photographs included on-stream dams, off-stream dams and catchment dams. Both on-stream and off-stream storages were assumed to hold water licenses, and the means by which these are considered is described in Section 3.1. The TEDI model was used to determine the impact of catchment dams that comprise the third category. Table 3.5 summarises the total volume of catchment dams identified from aerial photography, and this volume as a proportion of mean annual flow. Based on this information, the impact of catchment dam development was modelled up to a dam volume of 30% of mean annual flow. It is seen that the total volume of farm dams in the catchment is 3565 ML, which represents 15% of the mean annual flow (23880 ML).

■ **Table 3.5: Current and future volumes of catchment dams**

Catchment	Total volume of existing catchment dams (ML)	Volume of existing catchment dams as a proportion of MAF* (%)	Assumed future level of catchment dam development (ML)
Plenty River	3565	15%	7165

*calculated from derived natural flow data

When digitising catchment dams from aerial photographs it was necessary to make a number of assumptions. It was assumed that no farm dams would exist in the residential, developed region or Epping and thus this area was not digitised. The same is the case for areas of State Forest.

It should be noted that the aerial photos used to identify dams in this catchment were of a greater resolution than those used in other Melbourne Water catchments, and so may have resulted in more small dams being identified.

3.3 Distribution of Dam Sizes

The catchment dams identified on the aerial photographs were used to derive a distribution of dam sizes for input into the TEDI model. This is shown in Figure 3-3.

■ **Figure 3-3 Distribution of catchment dam sizes**

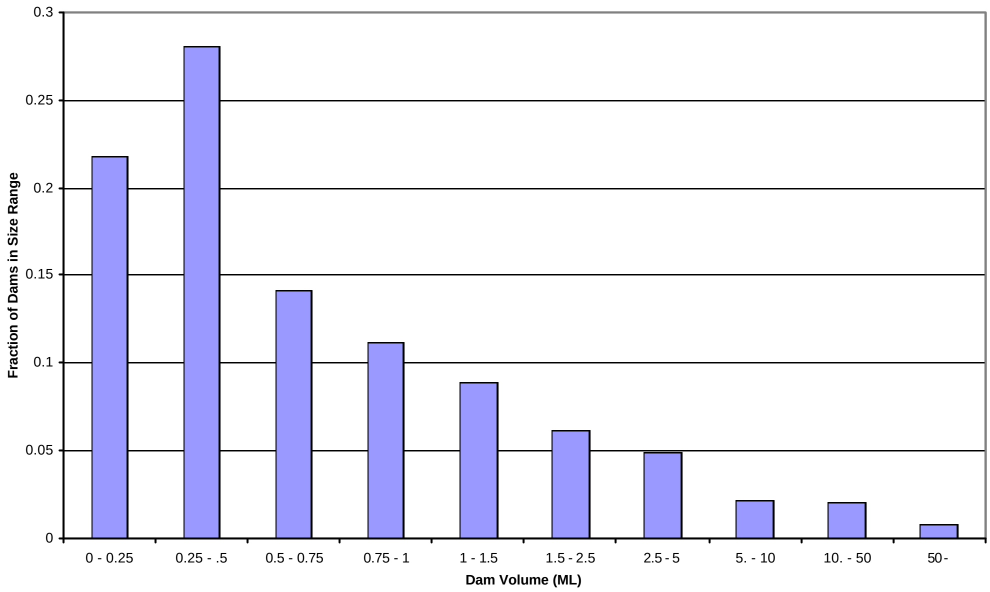


Table 3-6 further clarifies the number of dams in each size range.

■ **Table 3-6 Farm Dam distribution**

Total no. dams	<5ML	5 – 10 ML	10 – 20 ML	20 – 50 ML	50 – 100 ML	100 – 200 ML	> 200 ML
1503	1428	33	16	14	6	5	1

3.4 Catchment Areas of Catchment Dams

The TEDI model uses a linear relationship to relate dam size to catchment area. This relationship is defined by the catchment area of a 5ML and 100ML dam. While this is perhaps a simplistic assumption, the effort required to determine and incorporate a spatially explicit, non-linear relationship is very significant and is not suited to the scope of this investigation.

As adopted for Sinclair Knight Merz (2000), the contributing catchment areas of 5 ML and 100 ML dams were based on a line of best fit between the collective results for all catchments investigated in that project. These are 0.35 km^2 and 1.37 km^2 respectively.

3.5 Demands from Catchment Dams

When estimating the extraction from catchment dams a distinction was made between dams used for stock and domestic purposes and those used for irrigation purposes. All dams less than 5 ML were assumed to be for stock and domestic use, while all dams greater in size were assumed to be used for irrigation. The selection of this arbitrary 5 ML dam size is based on landholder surveys in the Lal Lal catchment in Western Victoria.

Stock and domestic demands were assumed to be uniform throughout the year, while demands from larger dams were set to follow an irrigation pattern based on the historical estimates derived for the licensed irrigation diversions (refer to Section 3.1.2)

The annual demands from each catchment dam used for irrigation was estimated by multiplying the capacity of the dam by a demand factor, corresponding to the number of times a dam would fill and empty in a year. Available evidence indicates that generally demand factors vary between one and three, with a factor of two being most common (ICAM/SKM, 1999; Good, 1992; SKM, 1999). Results have been presented using a demand factor of two for irrigation dams, while an irrigation factor of one was used for domestic and stock dams.

3.6 Rainfall and Evaporation

The TEDI model estimates the volumetric net evaporation by multiplying the net depth of rainfall and evaporation by the water surface area of the catchment dam. The surface area was derived from the storage volume of the catchment dam using a surface area-volume relationship derived by Good and McMurray (1997):

- $A = 1294\ V^{0.714}$ **Equation** 2

Where A is the surface area in m^2 and V is the storage volume in ML.

Monthly district rainfall was used as input to the TEDI model. This is preferable to using the nearest individual station, as district rainfall data is assumed to be stationary as it is comprised of the combined records of many stations. To ensure that the district rainfall data is representative, it was adjusted by the ratio of the long-term average rainfall at the centroid of the study catchment to the average district rainfall. The district used was 086 and the values were adjusted according to records from the gauge 086131.

Average monthly potential evaporation was extracted from GIS coverages produced by the Bureau of Meteorology.

The data used is summarised in Table 3-7

- **Table 3-7 Climate Data Input to the TEDI Model**

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainfall (mm)	51.5	45.1	54.5	67.6	76.5	60.5	73.2	81.8	72.4	78.3	68.7	67.2
Point Potential Evap (mm)	217.5	187.8	152.3	97.9	45.6	30.9	35.8	53.8	84.8	134.0	169.9	181.8

3.7 Reduction in Gauged Catchment Area

The total catchment area for the Plenty River Catchment is 351 km^2. However, Yan Yean's local catchment does not contribute to the flow at the Greensborough gauge. The catchment area of Yan Yean, 22.5 km^2, was therefore subtracted from the total area and the reduced area (an area of 328.5 km^2) was used in the analysis.

4. Results

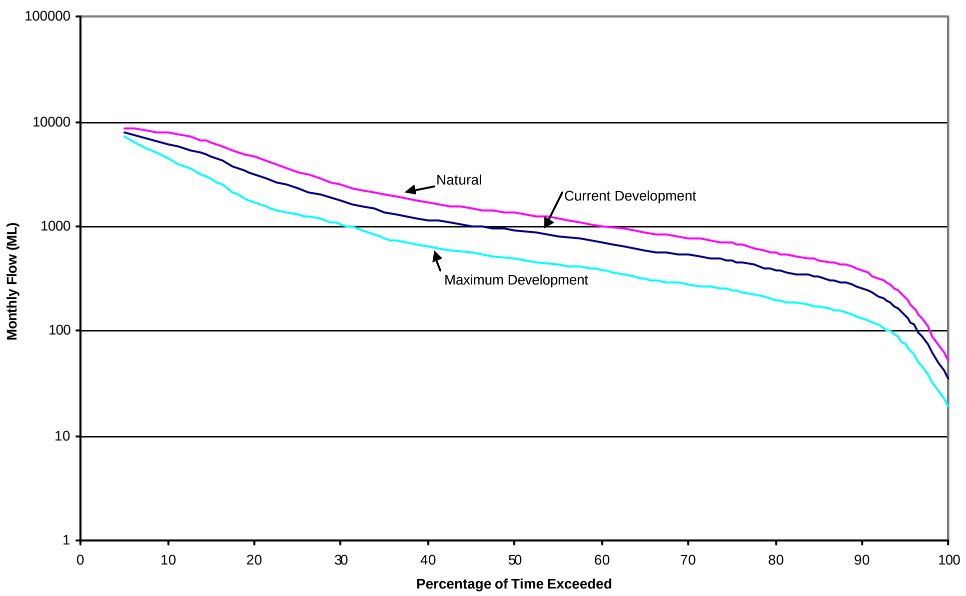
The impacts of catchment dams on streamflows were assessed using a number of diagnostic plots. These plots aid in the interpretation of these impacts on a range of flow characteristics, such as reductions in mean monthly flow and reductions in high and low flows. As described in Section 3, results are shown for a demand factor of two for irrigation purposes and one for domestic and stock, and for levels of development up to a total catchment dam storage volume of 30% of the mean annual flow over the simulation period.

All results presented in this report can be derived from the TEDI program, which is freely available from the Department of Natural Resources and Environment.

The time series of natural, current and predicted future conditions are shown in Appendix B. The time series show that current levels of catchment dam development already has a significant impact on the streamflow throughout the period investigated. As expected, future developments further reduce the streamflow, this being more apparent over summer months.

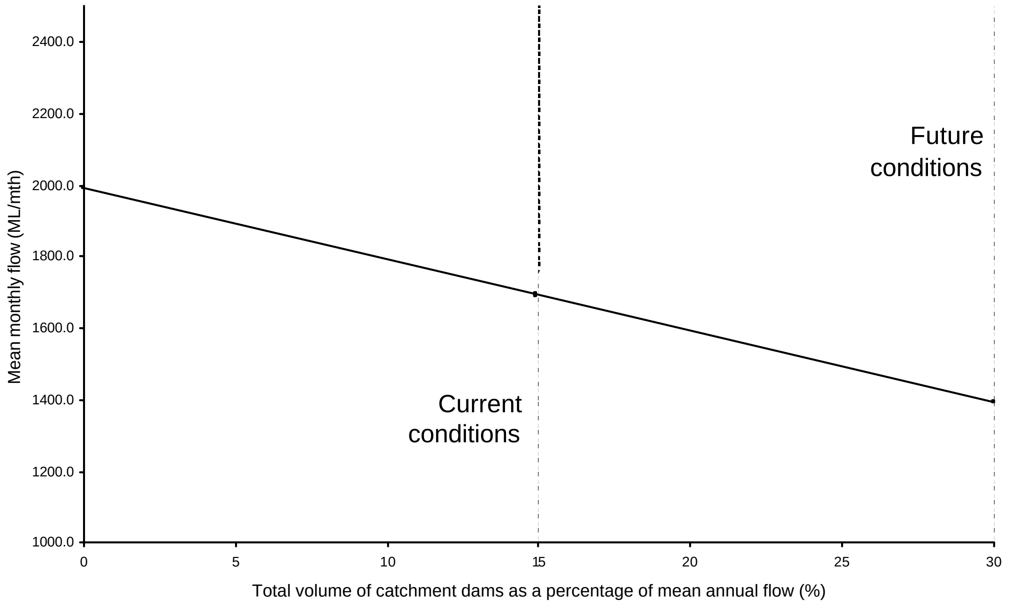
Flow duration curves for natural conditions relative to current conditions and assumed future development are shown in Figure 4-1. This plot shows that at current levels of catchment dam development it is estimated that the 90% exceedance flow would decrease by around 31% relative to natural conditions. If future development resulted in the volume of catchment dams increasing to 30% of mean annual flow, the 90% exceedance flow is estimated to decrease by 64%. The effect of future development on the 10% exceedance flow is a reduction of 42%. The key thing to note about Figure 4-1 is that the whole range of flows is effected, not just low flow periods.

■ **Figure 4-1 Flow duration curves under natural, current and future conditions in the Plenty River catchment**



The current and potential impact of catchment dams on mean monthly flow in the Plenty River Catchment is shown in Figure 4-2. Figure 4-2 illustrates, for example, that when catchment dam storage increases from the current level of development by a further 3600 ML (or to 30% of mean annual flow), the mean monthly flow decreases from 1695 ML to around 1395 ML.

■ **Figure 4-2 Impact of catchment dams on mean monthly flow in the Plenty River catchment**



The impact of catchment dam development on selected current flow exceedance percentiles is shown in Figure 4-3. In this figure, Q_{10} denotes the (high) flow that is exceeded only 10% of the time, Q_{50} is the median flow, and Q_{90} denotes the (low) flow that is exceeded 90% of the time. Impacts are characterised as non-dimensional ratio between flows with additional catchment dam development compared to flows under current conditions. The figure shows that under current conditions, catchment dams significantly effect low, median and high flows.

■ **Figure 4-3 Impact of catchment dams on selected exceedance percentiles in the Plenty River catchment**

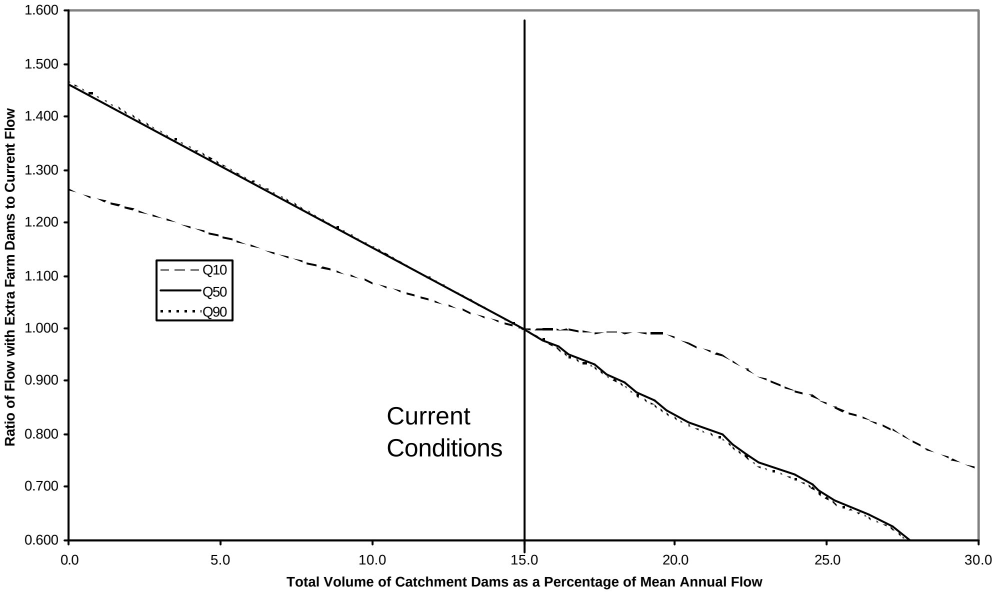


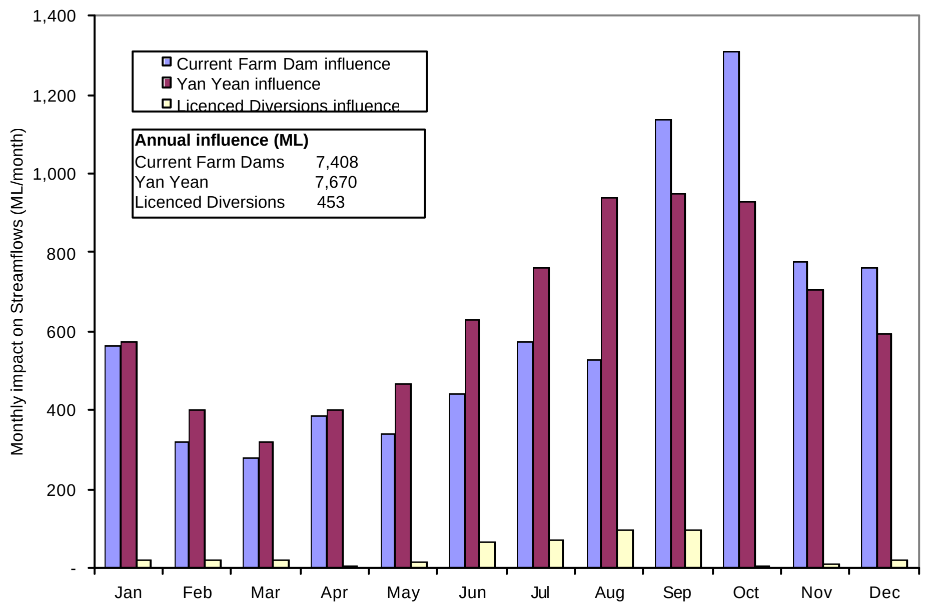
Table 4-1 shows the annual reduction in flow for every megalitre of catchment dam development. Results would indicate that the Plenty River catchment is most affected by the presence of catchment dams in times of higher flow.

■ **Table 4-1 Average impact on annual streamflow (in ML) for each additional ML of catchment dam development**

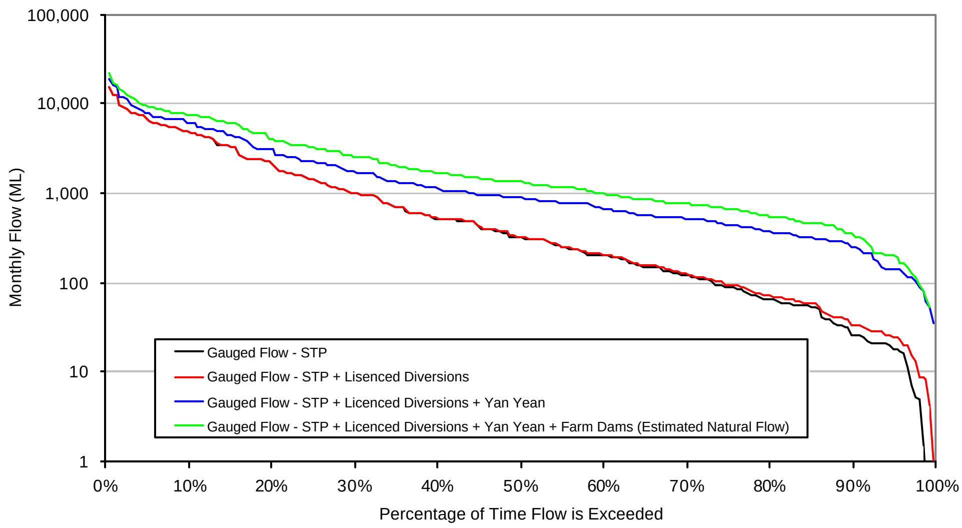
Q_{90}	Q_{50}	Q_{10}	Mean
0.4	1.4	5.7	2.1

A comparison of the influence of various demands in the catchment demonstrates the large influence of catchment dams. Figure 4-4 and Figure 4-5 both show this comparison. Figure 4-4 presents a bar chart that allows the monthly impact on streamflow to be easily compared. It is seen that the current level of farm dams reduces monthly flow by a similar magnitude to that of Yan Yean diversions. Similarly, Figure 4-5 shows that Licensed demands and the Treatment Plant have little effect on the flow regime, with main changes occurring due to Yan Yean diversions and Farm Dam impacts.

- **Figure 4-4 Comparison of monthly impact of Catchment dams and Licensed demands on streamflows**



- **Figure 4-5 Flow duration curve demonstrating the effect of diversion type.**



5. Conclusions

In the Plenty River catchment:

- For each additional ML of farm dam there is a 2.2 ML decrease in mean annual flow
- Catchment dams have a larger impact on streamflow compared to licensed diverters in the catchment. The main alterations to the natural flow regime occur due to the impact of farm dams and diversions to Yan Yean.
- The current level of development in the Plenty River has reduced high flow by approximately 1590 ML/year, median flow by 420 ML/year and low flow by 115 ML/year.

It should be noted that results will differ for other catchments. For example, if a catchment has moderate levels of winter inflow (when the dams are filling) but a significant baseflow component year round, it may be more effected by catchment dams in the winter months than the summer months. The nature of the demands from catchment dams i.e. predominantly stock and domestic or predominantly irrigation, also influences the months most affected by catchment dams. Therefore direct extrapolation of results from one catchment to another should be avoided.

6. References

Good, R.K. (November, 1993) The Impact of the Development on Streamflow in the Marne River, Engineering and Water Supply Department, Report 92/93.

Integrated Catchment Assessment and Management (ICAM) Centre, The Australian National University (ANU), Sinclair Knight Merz (SKM) (May 1999*) Impacts and implication of Farm Dams on Catchment Yield*, prepared for the Murray Darling Basin Commission, Natural Resource Management Strategy, Project R7028

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

Sinclair Knight Merz (2000b): *The Impact of Farm Dams on Hoddles Creek and Diamond Creek Catchments* prepared for Melbourne Water.

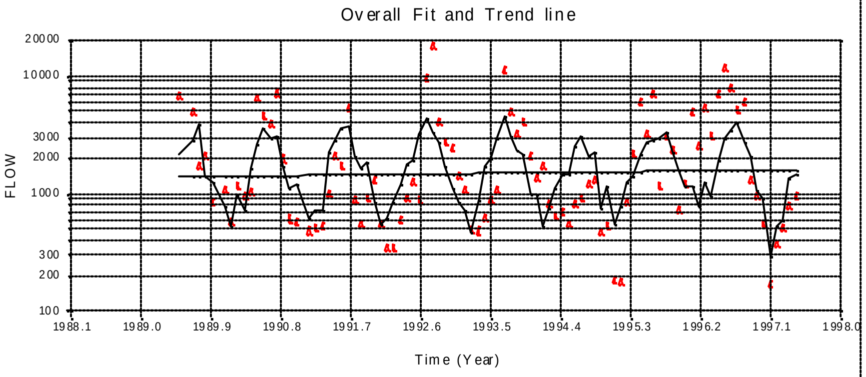
Sinclair Knight Merz (May 2000): User Manual, Tool for Estimating Farm Dam Impacts (TEDI) prepared for the Department of Natural Resources and Environment (Victoria), Environment Australia and Melbourne Water, Project WC01240.100.

Sinclair Knight Merz (August 1999*) Impact of Farm Dams on Streamflow Yield in the Hawkesbury-Nepean Basin* prepared for the Department of Land and Water Conservation.

Appendix A GAM Trend Analysis Results

GAM Trend Analysis for Site: Plenty River @ Greensborough

Overall Fit and Trend line



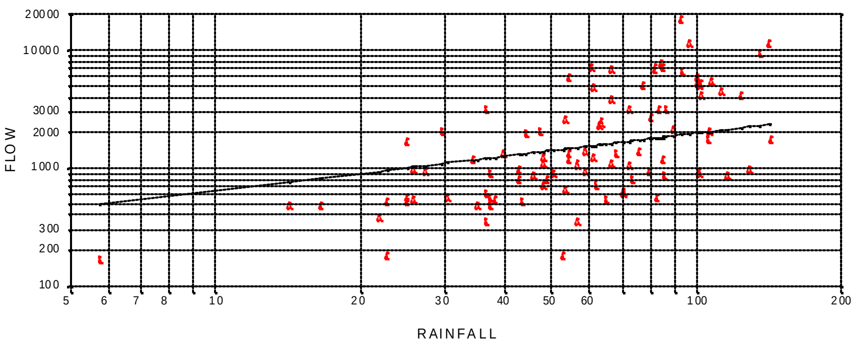
Dependent Variable : Log(FLOW)

Variable	Coeff.	Signi.
Const	2.3	5%
Time	0.0078	Nil
Sin	-0.29	5%
Cos	-.013	Nil
Log(RAINFALL)	0.49	5%
AR(1)	0.57	5%

Overall linear time trend = 26.676

Fitted linear time trend = 26.665

Variation of FLOW with RAINFALL



Job Number: WC01640

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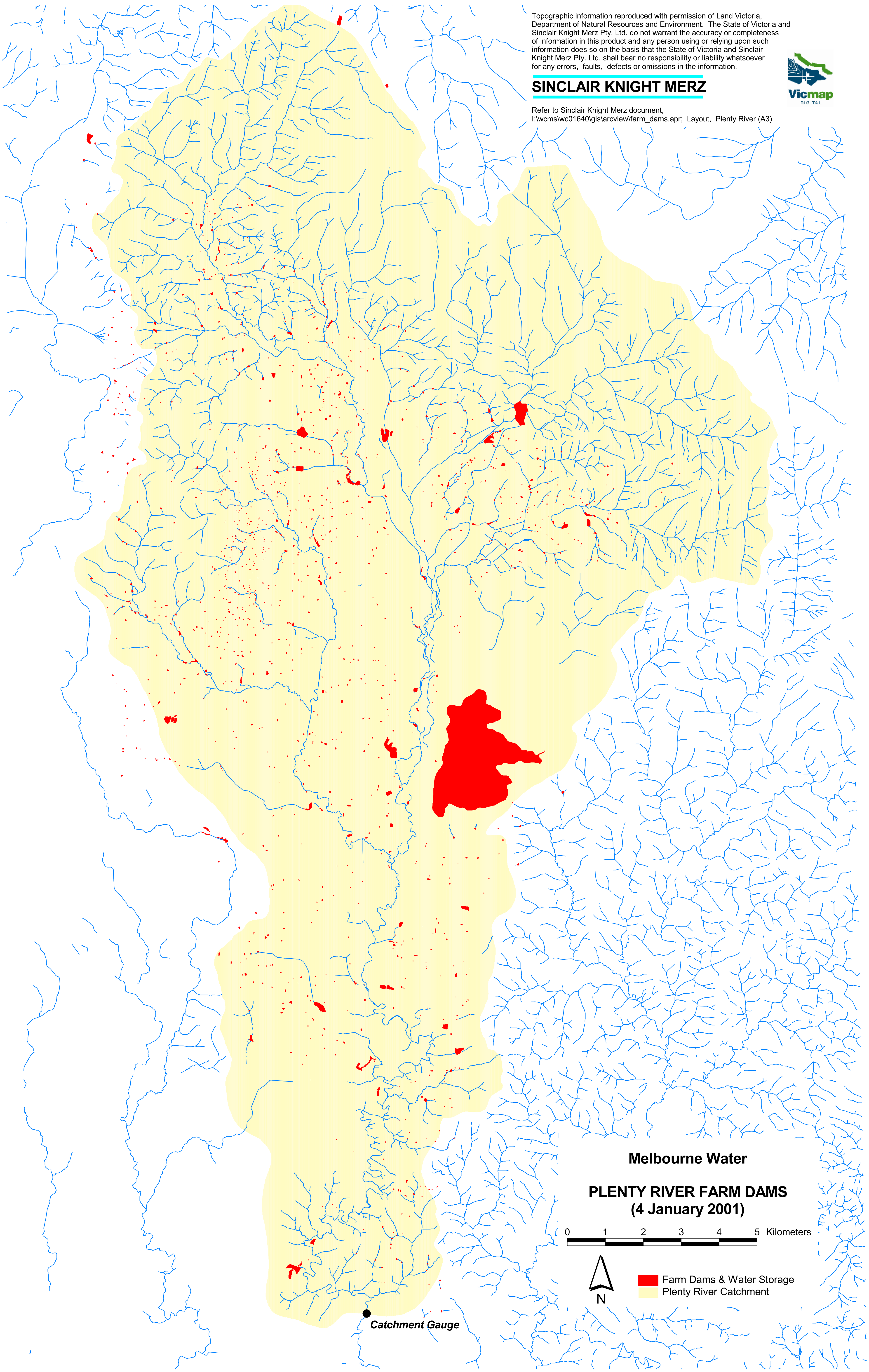
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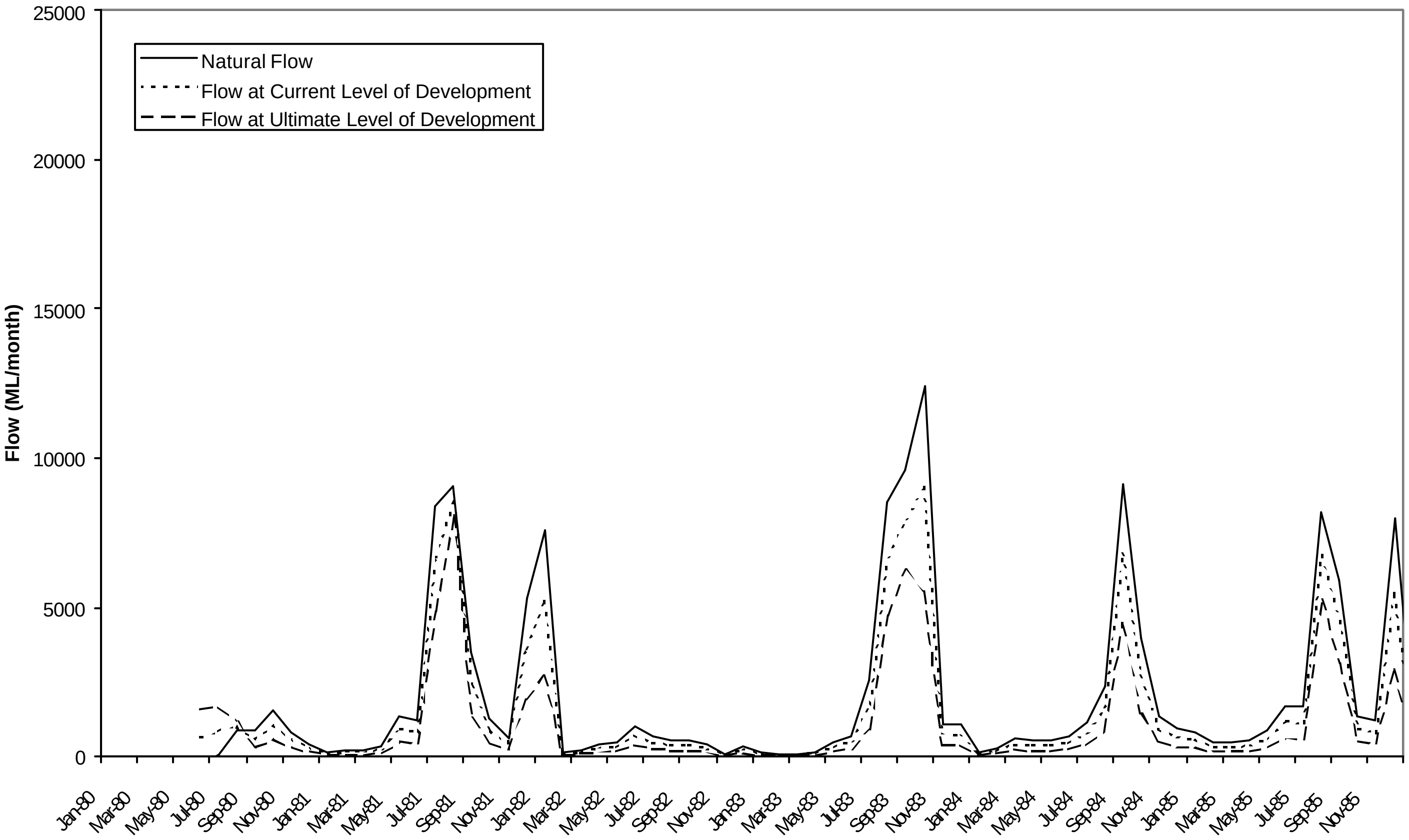
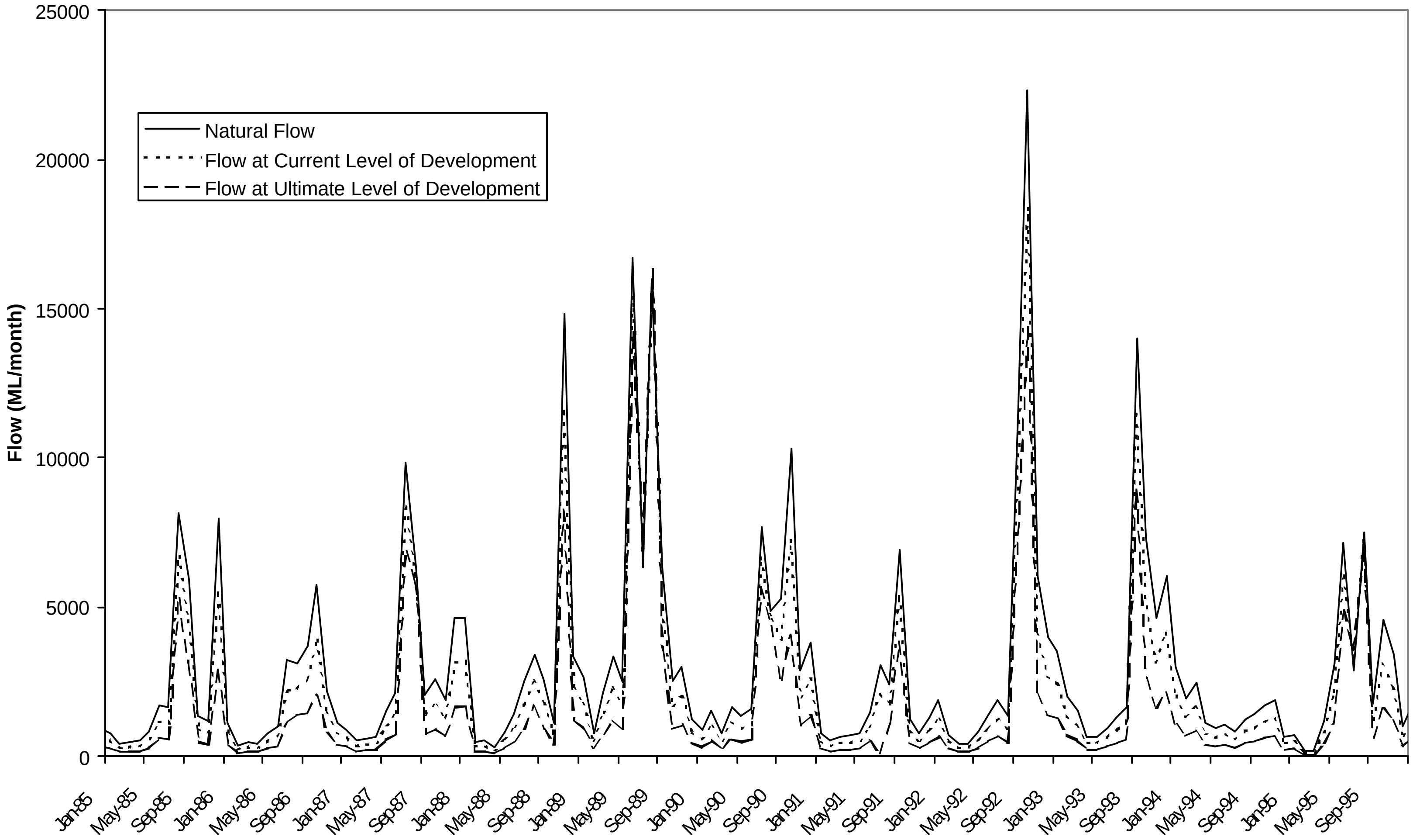
SINCLAIR KNIGHT MERZ
Vicmap
Refer to Sinclair Knight Merz document, I:\wcms\wc01640\gis\arcview\farm_dams.apr; Layout, Plenty River (A3)
Melbourne Water
PLENTY RIVER FARM DAMS
(4 January 2001)
0 1 2 3 4 5 Kilometers
N
Farm Dams & Water Storage
Plenty River Catchment
Catchment Gauge

Appendix C Time Series





25000
20000
15000
10000
5000
0
Flow (ML/month)
Natural Flow
Flow at Current Level of Development
Flow at Ultimate Level of Development
Jan-85
May-85
Sep-85
Jan-86
May-86
Sep-86
Jan-87
May-87
Sep-87
Jan-88
May-88
Sep-88
Jan-89
May-89
Sep-89
Jan-90
May-90
Sep-90
Jan-91
May-91
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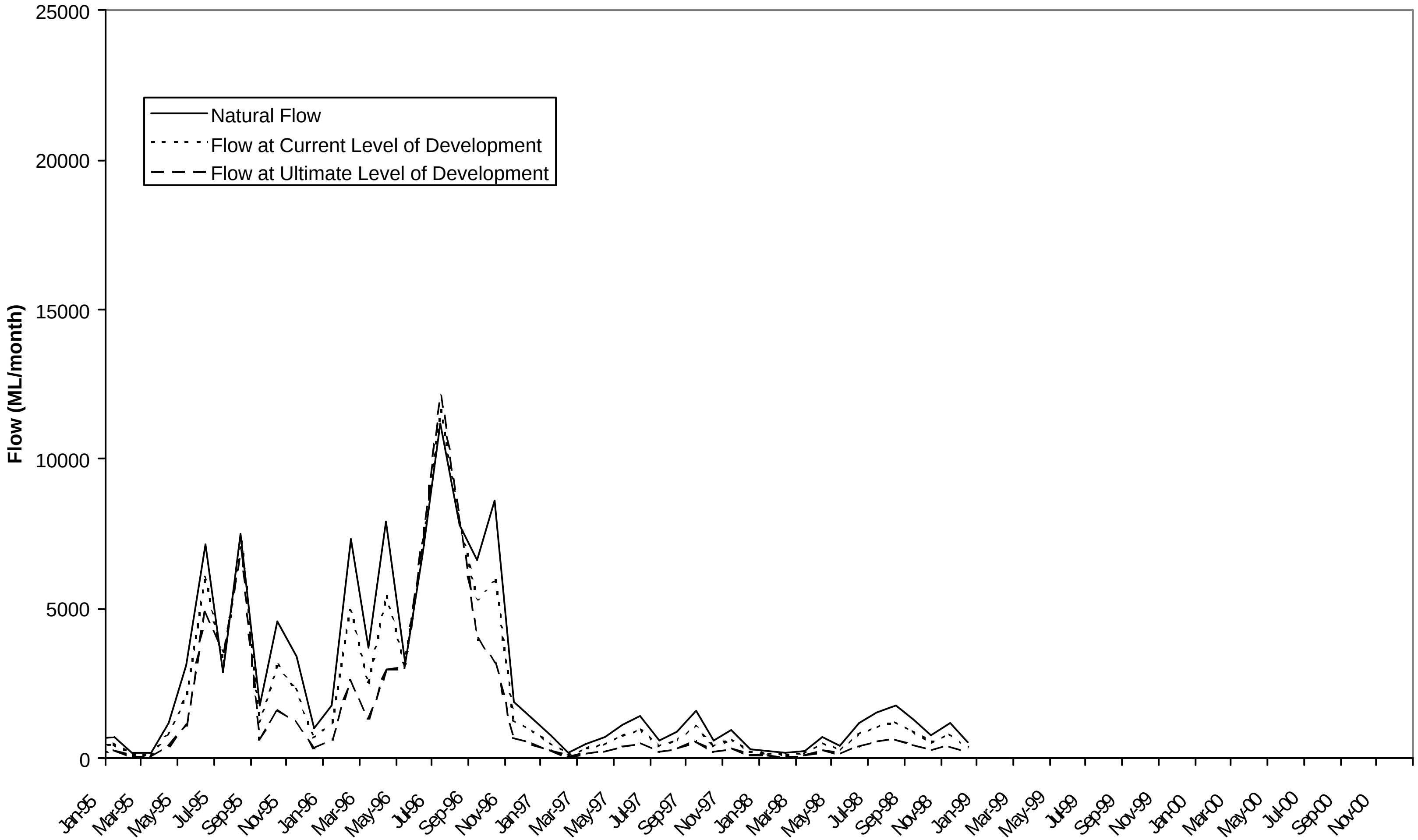
Jan-95
May-95
Sep-95


Flow (ML/month)
25000
20000
15000
10000
5000
0
Natural Flow
Flow at Current Level of Development
Flow at Ultimate Level of Development
Jan-95
Mar-95
May-95
Jul-95
Sep-95
Nov-95
Jan-96
Mar-96
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