Melbourne Water
July 2000

The Impact of Farm Dams on Hoddles Creek and Diamond Creek Catchments

Final Report 2

FINAL 2

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Document History and Status

Issue	Rev.	Issued To	Qty	Date	Reviewed	Approved
DRAFT	1	Steve Nicol (Melbourne Water)	1	3/5/00	B Neal	R Nathan
FINAL	1	Steve Nicol (Melbourne Water)	1	6/6/00	K.Austin	R.Nathan
FINAL	2	Steve Nicol (Melbourne Water)	2 hardcopies 2 softcopies (MS Word & PDF) CD-ROM of project files	14/7/00	K.Austin	B. Neal

Printed:	14 July 2000 8:24 AM
Last Saved:	24 July 2000 1:26 A7/P7
File Name:	I:\WCMS\WC01374\REP00_05.01\final2\r01kaaf2.doc
Project Manager:	Kate Austin
Name of Organisation:	Melbourne Water
Name of Project:	The Impact of Farm Dams on the Hoddles Creek and Diamond Creek Catchments
Name of Document:	Final Report 2
Document Version:	FINAL 2
Project Number:	WC01374

1. Introduction

The development of Streamflow Management Plans for the Diamond and Hoddles Creek catchments is required to provide an equitable share of resources between licensed diverters and the environment. In conjunction with the licensed impacts on flow, it is also desirable to have an estimate of the effect on yield of the unlicensed diversions made by farm dams. Sinclair Knight Merz has recently carried out a range of projects estimating the impact of farm (or catchment) dams.

The effect of farm (catchment) dams on seasonal streamflows 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 a water balance simulation model, developed in response to the shortcomings identified in the historical trend analysis approach (ICAM/SKM, 1999). This computer simulation program, specifically written to determine the impact of catchment dams, is known as the Tool for Estimating Dam Impacts (TEDI).

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 (Section 3).
- A description of the water balance model used to estimate the impact of catchment dams and a summary of the overall methodology (Section 4).
- Results of the water balance modelling, including the present and potential future impacts of catchment dams on the natural flow regime. A sensitivity analysis to model parameters is also presented, designed to guide further development of the model (Section 5).

2. Overview of Catchment Dam Modelling

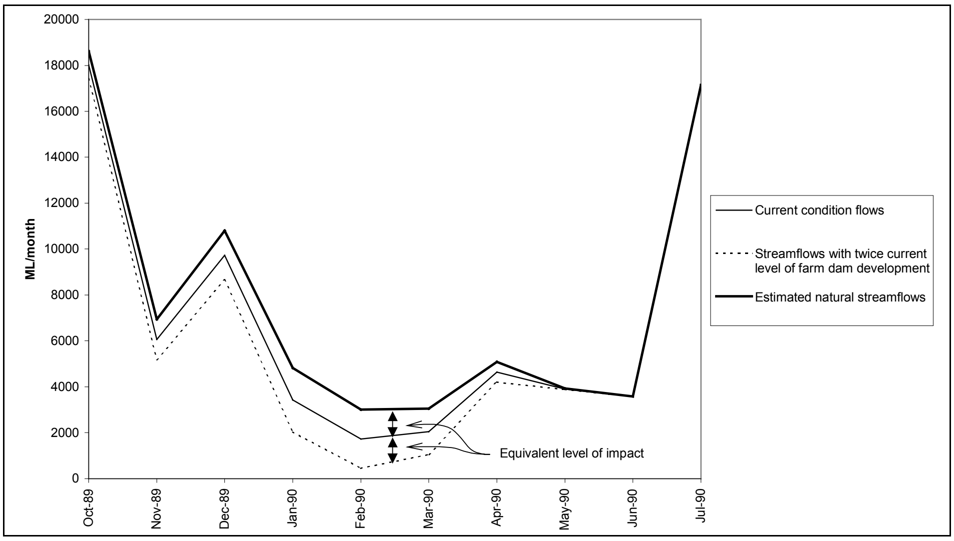
The TEDI model is a computer-based model that was recently developed by Sinclair Knight Merz for the Murray Darling Basin Commission, with the specific intention of modelling the impact of catchment dams (ICAM/SKM, 1999). TEDI can be used to:

- ❑ 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

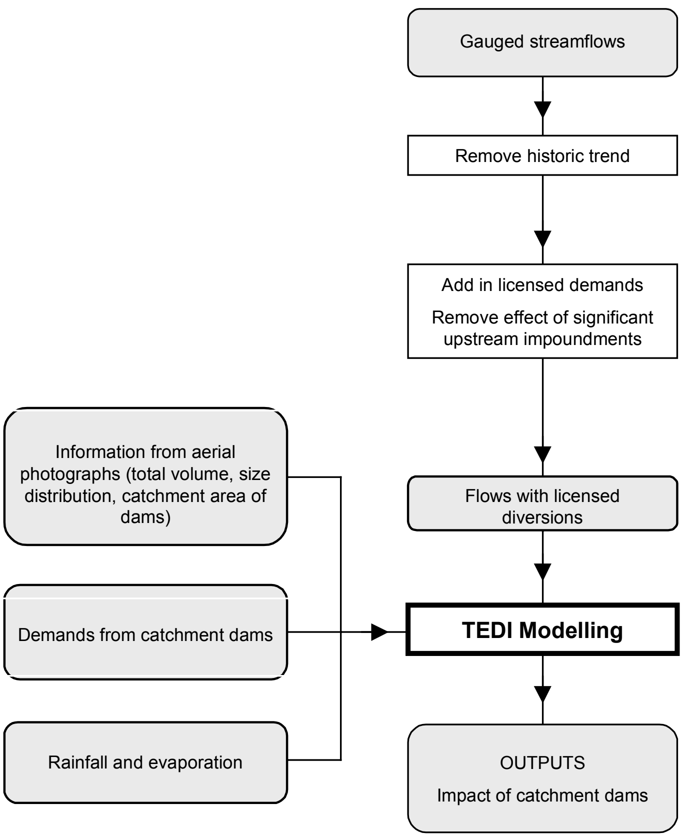


2.1 Summary of Modelling Approach

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 each site. They are then analysed for trend due to the influence of catchment dam development and detrended as appropriate. The streamflows are then corrected for the influence of consumptive demands and for upstream impoundments. 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:

- monthly adjusted streamflows;
- monthly rainfall and evaporation;
- the total volume of catchment dams in the catchment;
- the distribution of dam sizes;
- the relationship between dams size and catchment area of dams; and,
- information regarding the size and pattern of demands from catchment dams.

Each of these topics are 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:

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

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

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

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

3.1.1 Observed Streamflows

Gauged streamflow data is available for Hoddles Creek at Warburton Highway (229224), but only for the period from 3/4/1998 to date. The adjacent Little Yarra River catchment however has a good quality streamflow record for streamflow gauge 229214, covering the entire period of interest (1963 to 1970, daily read; 1970 to date, continuously recorded). A weekly regression equation was developed for the concurrent period to enable the extension of the gauged flow at Hoddles Creek using the flow in the Little Yarra.

Gauged streamflow is available at Diamond Creek at Eltham (stream gauge 229618) for the period 6 February 1980 to date. The stream gauge has a daily read, continuous record. The daily stream flow data was aggregated to produce monthly streamflow. Data was also obtained at gauge 229223 (Diamond Creek at Diamond Creek) for checking purposes.

Table 3.1: Summary of streamflow data

Gauge name	Gauge number	Period of record used
Hoddles Creek @ Warburton Highway	229224	3/4/98 - date
Diamond Creek @ Eltham	229618	6/2/1980 - date
Diamond Creek @ Diamond Creek	229223	6/2/1976 – 9/1/1993

3.1.2 Historical Trend Analyses

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 from each of the chosen sites 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.

Trend analyses were undertaken in each catchment on monthly flows, with variability being explained as a function of time, season and rainfall. A summary of the results of the GAM modelling is shown in Table 3.2, while full results are given in Appendix A -. 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).

Table 3.2: Trend analysis results

Catchment	Significance of Monthly Streamflow Trend
Hoddles Creek	Not Significant
Diamond Creek	Significant (5%)

These results show that there have been no statistically significant trends in monthly streamflow in the Hoddles Creek catchment over the period of extended streamflow.

However, the results of the trend analysis of Diamond Creek show that there is a statistically significant trend in monthly flow from February 1980 to date. As shown by the GAM plot in Appendix A, there is an increasing trend from 1980 to 1990, and then a decreasing trend from 1990 onward. To determine the validity of the resulting trend, an analysis was carried out using streamflow 229223 (Diamond Creek at Diamond Creek), an upstream gauge. The upstream gauge 229223 showed a similar result to stream gauge 223618 indicating that the trend observed at 229618 was a valid trend not caused by a local impact on streamflow measurement. It is possible that the trend reflects land use change or else changes in the level of upstream extractions. It should be noted that the nature of the GAM analysis ensures that the trend is not due to climatic trends.

As data at 229223 ended in September 1993 it was not possible to demonstrate that the decreasing trend in the latter part of 229618 record was regionally correct. Given this trend pattern and no real indication which part of the flow record is correct , the decision was made to note this phenomenon but not to de-trend the gauged data.

3.1.3 Historic Extractions by Licensed Diverters

An estimate of historic extractions by licensed diverters is required in order to adjust the gauged flow to be influenced only by catchment dams. Information on the distribution of 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;
- ❑ off-stream dams;
- ❑ stock and domestic;
- ❑ stock, domestic and commercial,
- ❑ power generation.

Because of different levels of data availability, two different methods were used to derive the historic licensed diversions for Hoddles Creek and Diamond Creek.

3.1.3.1 Hoddles Creek Historic Licensed Diversions

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 Hoddles Creek.

However, a recent attempt has been made to estimate historic licensed demands as part of the Streamflow Management Plan project (refer to Sinclair Knight Merz, 2000a for methodology). This was done by calibrating the irrigation demand estimation model PRIDE to recent survey data, and making assumptions based on advice from Melbourne Water and communications with landholders as to the nature of land use historically. These land use changes were entered into the PRIDE model and a best estimate of historical consumption by licensed diverters was made.

This estimate of historical licensed demand was added back to the time series of gauged data at 229224 prior to TEDI modelling.

3.1.3.2 Diamond Creek Historic Licensed Diversions

Similar to Hoddles Creek, no recorded consumption data was available for licensed diverters on Hoddles Creek. In addition, no PRIDE modelling has been carried out in this catchment to assist with the estimation of historical extractions. Therefore it was assumed (conservatively) that historical extractions by licensed diverters was equal to their licensed volume each year. This is the same assumption as applied to catchments in (Sinclair Knight Merz, 2000b).

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 Diamond Creek catchment were provided by Melbourne Water, as shown in Table 3.3. As a comparison the licensed volumes for Hoddles Creek are also listed in the table, but it should be noted that they were not applied as part of this study.

Table 3.3: Summary of Licenses (ML/yr)

Catchment	Direct Irrigation	On-stream Dams	Off-stream Dams	Stock & Domestic	Stock & Domestic & Commercial	Power Generation
Hoddles Creek	419	59	15	16	20	2
Diamond Creek	269	0	279	24	0	0

The pattern applied to the licensed direct irrigation volume for Diamond Creek is as listed in **Error! Reference source not found.**, and is the same as the pattern applied to irrigation extractions from larger catchment dams in the TEDI model. The demand pattern applied to the other types of licensed demand are shown in Table 3.4, and are as defined in Sinclair Knight Merz (2000b).

Table 3.4: Estimated Monthly Usage of License Allocation

Month	Type of License	
	Domestic & Stock	Off Stream Dam Filling
January	11.7%	0.0%
February	11.7%	0.0%
March	10.0%	0.0%
April	7.9%	0.0%
May	6.7%	10.0%
June	6.2%	10.0%
July	6.3%	15.0%
August	6.2%	15.0%
September	6.5%	20.0%
October	7.4%	20.0%
November	8.4%	5.0%
December	11.0%	5.0%

3.1.4 Upstream Impoundments

There are no upstream impoundments on Hoddles Creek, however Running Creek Reservoir is a significant upstream impoundment in the Diamond Creek catchment.

Information available for Running Creek Reservoir consisted of:

- inflows from 1964 to 1982, estimated by Melbourne Water based on a water balance model; and
- outflows recorded approximately 1.6 km downstream of the reservoir at gauge 229217 (Running Creek at Arthur's Creek) from 1964 to 1982.

The impact of the dam on streamflows was estimated by subtracting outflows from inflows. The concurrent period of estimated inflows and recorded outflows extended from October 1964 to April 1978. This did not allow direct substitution into the streamflow series for Diamond Creek. Average monthly values were therefore derived from the historic data and substituted back into the gauged streamflows.

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 each of the catchments, 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 5% of mean annual flow.

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)
Hoddles Creek	96	1.4%*	349
Diamond Creek	740	1.9%*	1970

*calculated from derived natural flow data

When digitising catchment dams from aerial photographs it was necessary to make a number of assumptions. These assumptions are within the level of accuracy for this project and are discussed below:

1. A number of catchment dams were detected on the aerial photographs, but were too small to be digitised as a distinct shape. These dams were grouped into two categories, assumed to have an average surface area of 40 m^2 and 75 m^2 respectively.

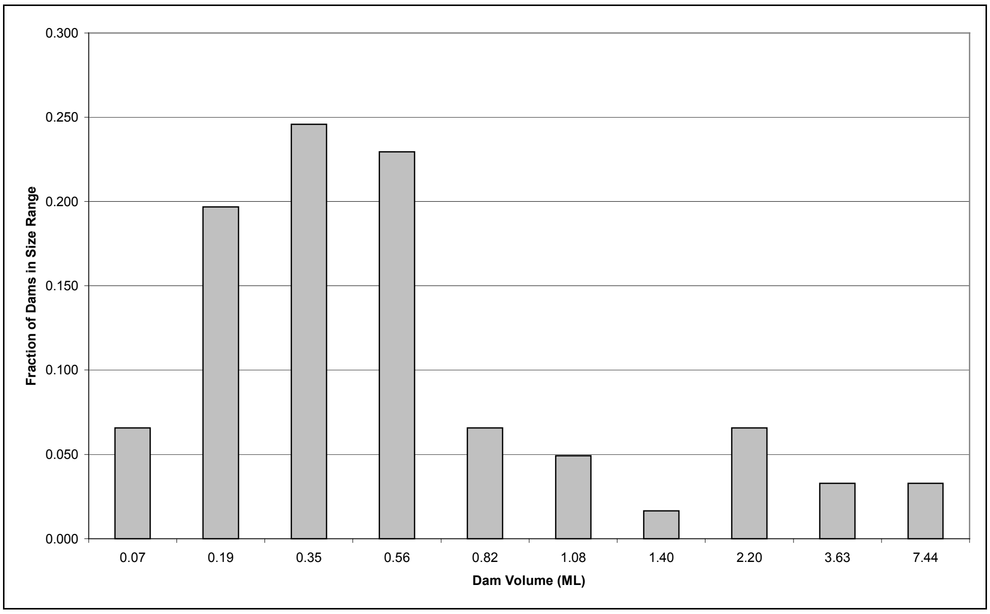
2. Aerial photographs were unable to be obtained for a portion of the Diamond Creek catchment. An inspection of the distribution of dams across the catchment indicated that virtually no or very few dams would be expected to occur in this northern portion of the catchment.

3.3 Distribution of Dam Sizes

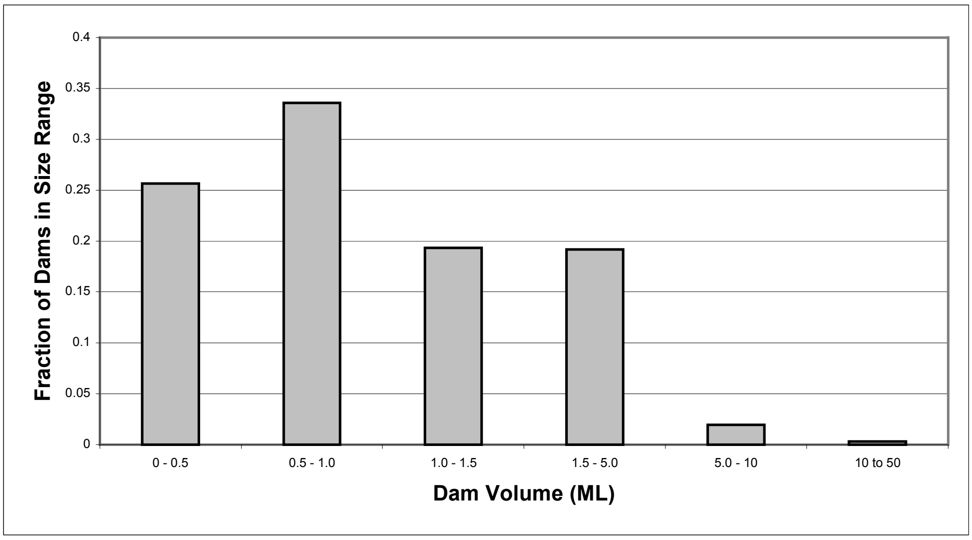
The catchment dams identified on the aerial photographs were used to derive a distribution of dam sizes for input into the TEDI model. This is shown in Figure 3.1.

Figure 3.1: Distribution of catchment dam sizes

Hoddles Creek



Diamond Creek



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 5 ML and a 100 ML dam. This is necessarily a crude assumption that potentially will be improved upon in the future.

As adopted for Sinclair Knight Merz (2000b), 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 Section 3.1.3).

The pattern adopted for the Hoddles Creek catchment was extracted from the current level of development demand derived in catchment LD8 (licensed diverters upstream of Wombat Creek), as described in Sinclair Knight Merz (2000a). The pattern adopted for Diamond Creek was extracted from the spreadsheet provided by Melbourne Water.

Both patterns are shown in Table 3.6.

Table 3.6: Monthly Proportion of Irrigation Demands

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Hoddles	0.35	0.27	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.04	0.24
Diamond	0.18	0.19	0.19	0.06	0.01	0.00	0.00	0.01	0.03	0.07	0.10	0.16

The annual demand from each catchment dam 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 the most common (ICAM/SKM [1999], Good [1992], SKM [1999]). Results have been presented for both catchments using a demand factor of two.

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. To ensure the rainfall data was 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.

Average monthly point potential evaporation was extracted from GIS coverages produced by the Bureau of Meteorology. To save time the evaporation series derived for the Woori Yallock catchment as part of Sinclair Knight Merz (2000b) was applied to the Hoddles Creek catchment. Average monthly values were extracted for the Diamond Creek catchment. The data used is summarised in Table 3.7.

Table 3.7: Climatic Data Input to the TEDI Model

	RAINFALL (mm)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Hoddles	70.4	69.7	78.6	98.3	111.7	105.0	107.6	117.2	115.7	121.1	102.9	90.8
Diamond	52.0	29.0	53.0	58.0	72.0	83.0	77.0	85.0	83.0	83.0	66.0	68.0
	POINT POTENTIAL EVAPORATION (mm)											
Hoddles	176.1	147.8	117.1	74.7	47.6	32.5	35.6	49.9	71.0	105.1	130.6	158.4
Diamond	212.6	183.7	146.8	97.0	44.8	31.5	36.4	53.3	84.9	132.1	163.7	175.5

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, and for levels of development up to a total catchment dam storage volume in each catchment of 5% 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.

4.1 Results for Hoddles Creek

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 that the 90% exceedance flow would decrease by 11% relative to natural conditions. If future development resulted in the volume of catchment dams increasing to 5% of mean annual flow, the 90% exceedance flow is estimated to decrease by 51%.

The current and potential impact of catchment dams on mean monthly flow in the Hoddles Creek 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 253 ML (or about 4% of mean annual flow), the mean monthly flow decreases from 581 ML to around 540 ML for a demand factor of two.

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 a non-dimensional ratio between flows with additional catchment dam development compared to flows under current conditions.

Figure 4.1: Flow duration curves under natural, current and future conditions in the Hoddles Creek catchment

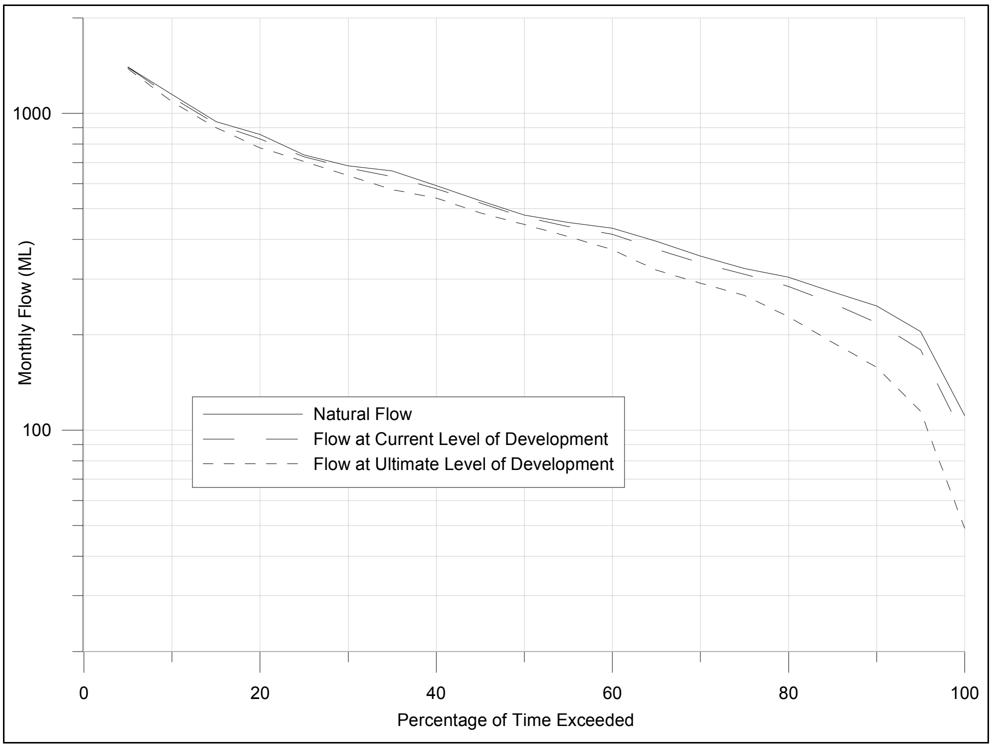


Figure 4.2: Impact of catchment dams on mean monthly flow in the Hoddles Creek catchment

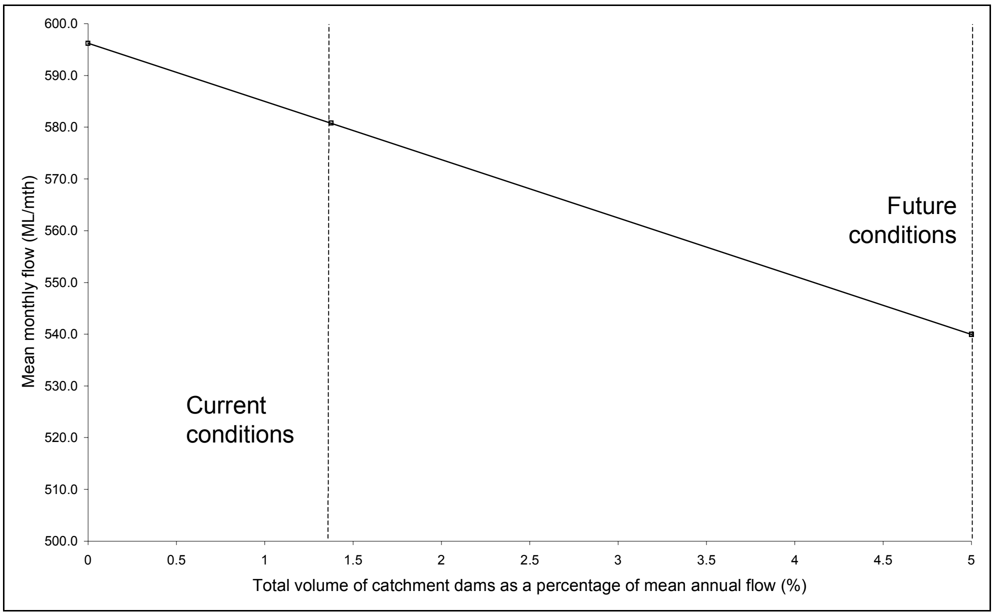
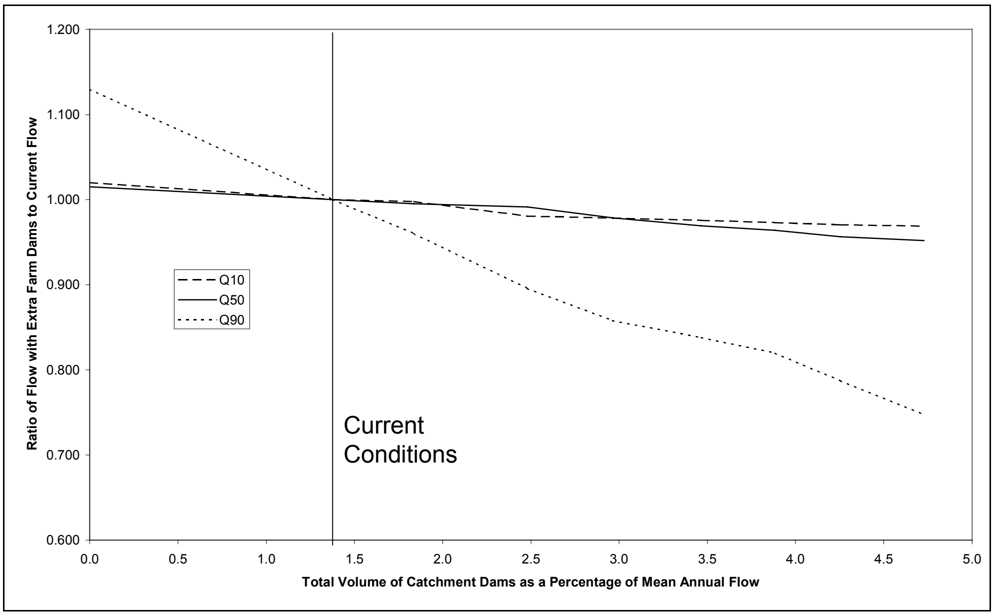


Figure 4.3: Impact of catchment dams on selected exceedance percentiles in the Hoddles Creek catchment



4.2 Results for Diamond Creek

Flow-duration curves for natural conditions relative to current conditions and assumed future development are shown in Figure 4.5. This plot shows that at current levels of catchment dam development it is estimated that the 90% exceedance flow would decrease by around 14% relative to natural conditions. If future development resulted in the volume of catchment dams increasing to 5% of mean annual flow, the 90% exceedance flow is estimated to decrease by 40%. The effect of future development on the 10% exceedance flow is a reduction of 12%.

The current and potential impact of catchment dams on mean monthly flow in the Diamond Creek catchment is shown in Figure 4.5. Figure 4.5 illustrates, for example, that when catchment dam storage increases from the current level of development by a further 1250 ML (or about 5% of mean annual flow), the mean monthly flow decreases from 2100 ML to around 1800 ML.

The impact of catchment dam development on selected current flow exceedance percentiles is shown in Figure 4.6. 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 a non-dimensional ratio between flows with additional catchment dam development compared to flows under current conditions.

The impact of catchment dams on monthly flow and the corresponding magnitude of licensed demands are shown in Figure 4.7.

Figure 4.4: Flow duration curves under natural, current and future conditions in the Diamond Creek catchment

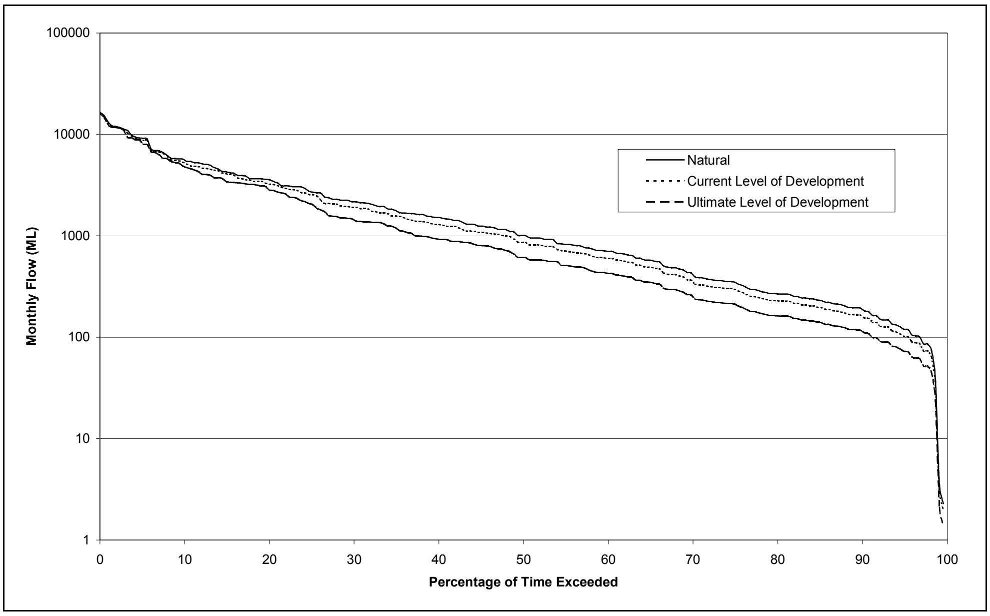


Figure 4.5: Impact of catchment dams on mean monthly flow in the Diamond Creek catchment

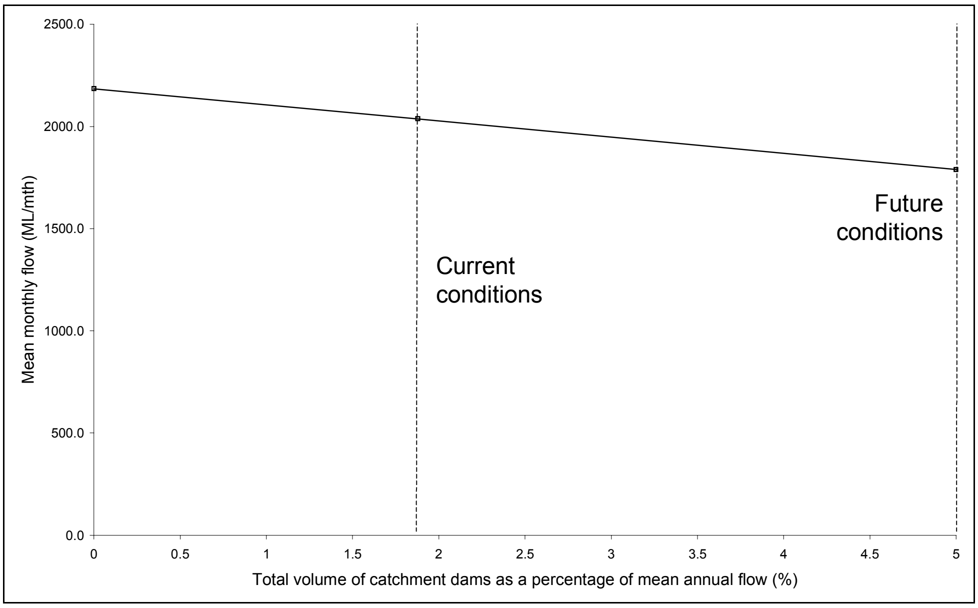
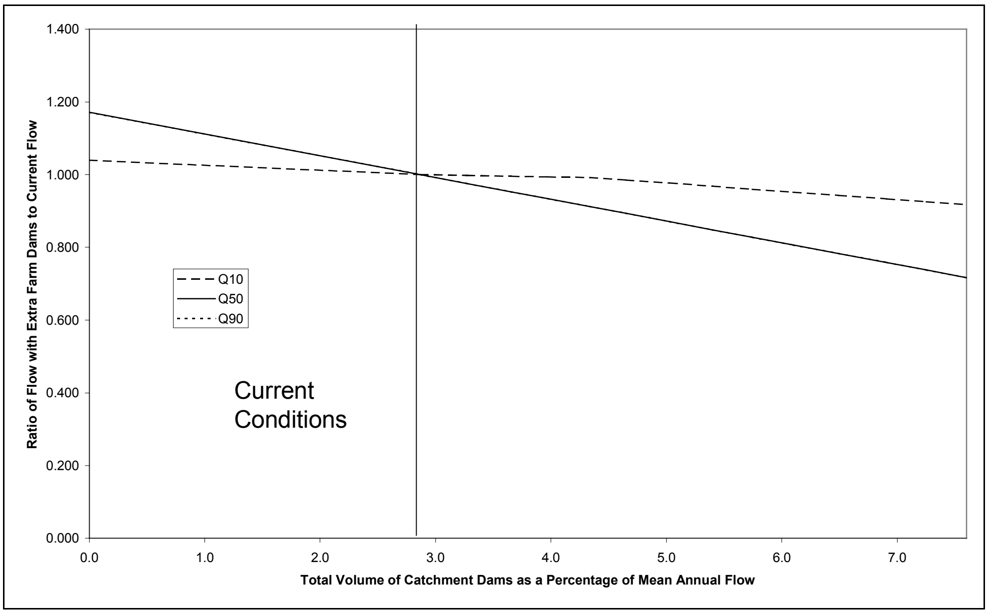
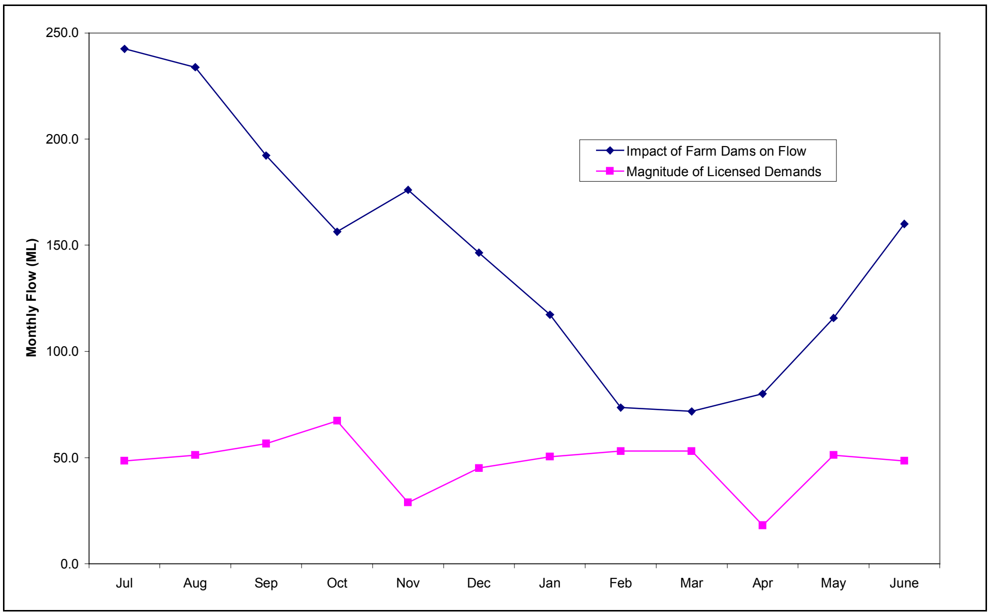


Figure 4.6: Impact of catchment dams on selected exceedance percentiles in the Diamond Creek catchment



*Note that the Q_{90} line plots on top of Q_{50} line.

Figure 4.7: Impact of Farm Dams on Monthly Flow Compared with the Magnitude of Licensed Demands in the Diamond Creek Catchment



4.3 Comparison of Results

The impacts of current level of development demands on high and low flows are summarised in Table 4.1.

Table 4.1: Impact of Current Development on the Natural Q_{90} and Q_{10} Flow(1,2,3)

Catchment	Natural Q_{90} Flow (ML/mth)	Current Q_{90} Flow (ML/mth)	Reduction in Q_{90} Flow (%)
Hoddles Creek	246.3	218.0	11.5
Diamond Creek	193.3	165	14.7
Catchment	**Natural Q_{50} Flow (ML/mth)**	**Current Q_{50} Flow (ML/mth)**	**Reduction in Q_{50} Flow (%)**
Hoddles Creek	477.1	470.0	1.5
Diamond Creek	1005.1	858	14.7
Catchment	**Natural Q_{10} Flow (ML/mth)**	**Current Q_{10} Flow (ML/mth)**	**Reduction in Q_{10} Flow (%)**
Hoddles Creek	1145.7	1123.0	2.0
Diamond Creek	5537.8	5327.0	3.8

(1) Q_{90} is the flow exceeded 90% of the time, i.e. a low flow.
(2) Q_{50} is the flow exceeded 50% of the time, i.e. the median flow
(3) Q_{10} is the flow exceeded 10% of the time, i.e. a high flow

Table 4.2 shows that for Hoddles Creek for every megalitre of catchment dam development, the 90th percentile flow is reduced by 2.1 ML per year, and for Diamond Creek for every megalitre of catchment dam development, the 90th percentile flow is reduced by 4.0 ML per year.

Table 4.2: Average impact on annual streamflow (in ML) for each ML of catchment dam development

Catchment	Q_{90}	Q_{50}	Q_{10}	Mean
Hoddles Creek	2.1	1.1	-	2.0
Diamond Creek	2.4	2.4	4.0	2.4

4.4 Conclusions

The results from the Diamond Creek catchment demonstrate an impact on both low and higher flows. The impact of increased development on the high flows is quite significant . In the Diamond Creek catchment:

- for each additional ML of farm dam there is a 2.4 ML decrease in mean annual flow.

- catchment dams have a larger impact on streamflow compared to licensed diverters in the catchment.
- The current level of development in Diamond Creek has reduced high flow by approximately 200 ML/year , median flow by 150 ML/year and low flow by 30 ML/year.

In the Hoddles Creek catchment:

- for each additional ML of farm dam there is a 2.0 ML decrease in mean annual flow.
- The current level of development in Hoddles Creek has reduced high flow by approximately 20 ML/year , median flow by 10 ML/year and low flow by 30 ML/year.

In the Hoddles Creek catchment the results demonstrate that catchment dams impact on both low and median flows. In *percentage terms* these impacts are shown in Table 4.1, with the percentage reduction in low flows being much greater than for median flows. Corresponding to this, the *magnitude* by which streamflows are reduced is greater for low flows than for median flows, as is seen in Table 4.2. Hence it can be concluded that the Hoddles Creek catchment is most affected by the presence of catchment dams in times of low flow.

It should be noted that this is not always the case 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.

5. References

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

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

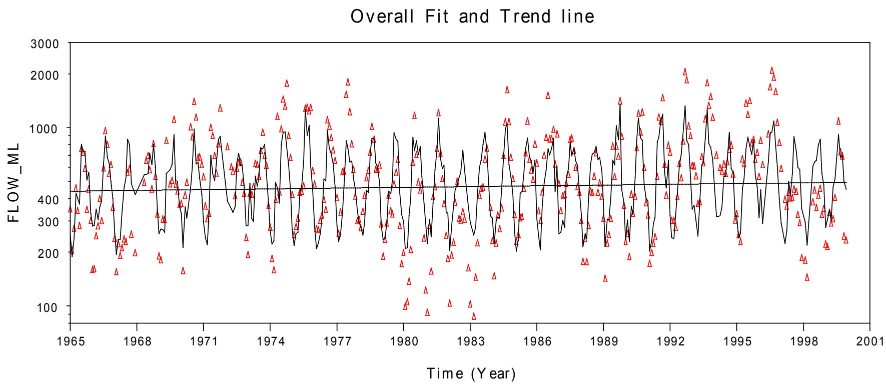
Sinclair Knight Merz (August 1999) *Impact of Farm Dams on Streamflow Yield in the Hawkesbury-Nepean Basin* prepared for Department of Land and Water Conservation.

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): Farm Dam Impacts Study Stage 1 – TEDI Modelling – Impact of Farm Dams in Five Catchments

Appendix A - GAM Trend Analysis Results

GAM Trend Analysis for Site: Hoddles Ck

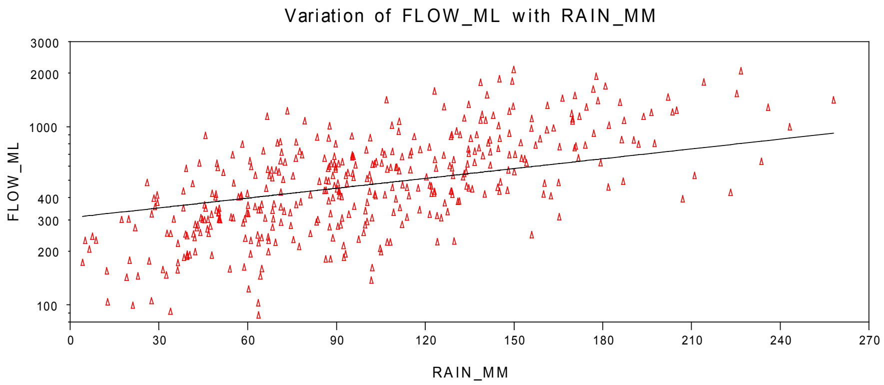


Dependent Variable : Log(FLOW_ML)

Variable	Coeff.	Signi.
Const	2.5	5%
Time	0.0014	Nil
Sin	-0.21	5%
Cos	-.034	5%
RAIN_MM	0.0018	5%
AR(1)	0.78	5%

Overall linear time trend = 1.513

Fitted linear time trend = 1.512



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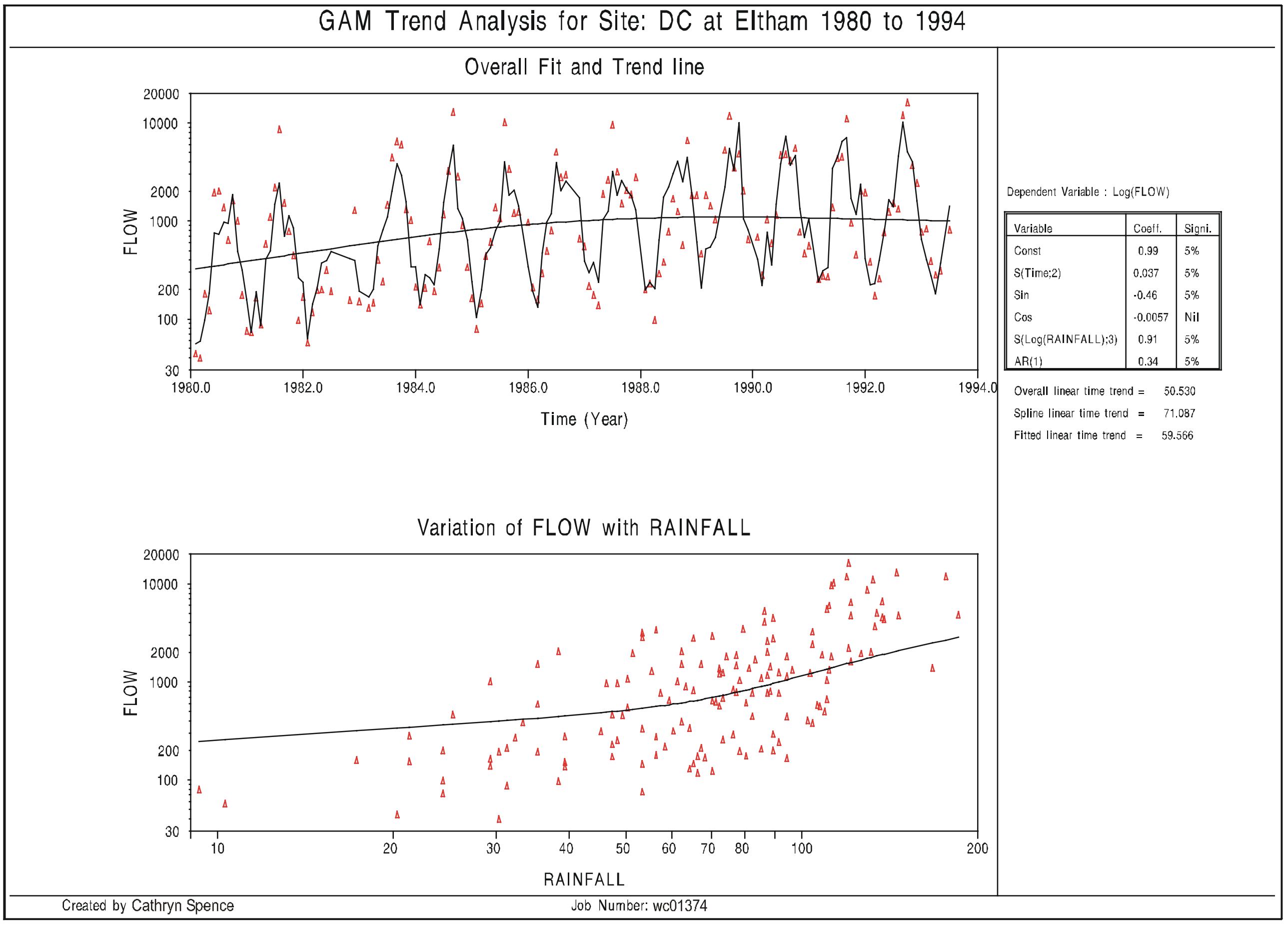

Variable	Coeff.	Signi.
Const	0.99	5%
S(Time;2)	0.037	5%
Sin	-0.46	5%
Cos	-0.0057	Nil
S(Log(RAINFALL);3)	0.91	5%
AR(1)	0.34	5%