Regional Flood Estimation Method for the Mt Lofty Ranges

by

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Abstract

A regional flood estimation procedure has been developed by correlation analysis of peak flood flows at gauged sites against measured basin characteristics in catchments of the Mt Lofty Ranges near Adelaide in South Australia. From various topographic and meteorological characteristics of the catchments, eleven independent variables were selected for the analysis. Dependent variables were avoided. Sets of equations have been developed for average recurrence intervals of 2 to 200 years. These equations depending on availability and suitability of data, can be used to estimate flood frequency curves at any ungauged site for appropriate catchments in the region of analysis. SAS computer statistical package was used to obtain regression coefficients for all the derived equations.

In the study undertaken, the LPIII distribution was found to perform the best from the ten distribution types analysed to represent the frequency distribution of flood flows. The goodness of fit of the distribution to the peak flow series has been assessed using the 'difference test' and 'chi-square test'. The distribution types were ranked according to the test values. A homogeneity test following Langbein's theory, was applied to the region, but this proved to be unsatisfactory. Further testing was undertaken using cluster analysis.

The hydrometric archiving system, HYDSYS was used extensively for the analysis of flood flows. Twenty two catchments were selected as being suitable for the analysis. The streamflow records and some catchment characteristics information were obtained from Engineering and Water Supply Department of South Australia. Analysis of peak flows was carried out for both annual and partial series. A revised analysis has been made for annual series by discarding low and zero values from the data set. A flood frequency analysis computer program was modified to discard low values and adjust the probability accordingly.

The results were compared to those of the probabilistic rational method for the region and it was found that the proposed regional method provided an improved estimation of flood frequency at ungauged sites.

ERRATA

pg xii The following item should be included in the Notation list

AAR *Average Annual Rainfall*

pg 14 Section 2.2 2nd paragraph 5th sentence should read

"..from any developed model *are* somewhat suspect".

pg 24 Table 2.4
The AAR column should have the units of *mm*

pg 25 Table 2.4 cont'd
The AAR column should have the units of *mm*

pg 45 Sect3.5 2nd para 2nd sentence should read

"The figure shows that the *catchments* are...."

Declaration

I declare that this thesis does not contain any material which has been accepted for the award of any degree in any university and, to the best of my knowledge and belief, it does not contain any material previously published or written by another person except where due reference has been made in the text of the thesis. I also declare that I have no objection to the thesis being made available for photocopying and loan, if accepted for the award of the degree.

(Shirin Akter)

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Notation

A = Drainage Area

AEP = Average Exceedance Probability

ARI = Average Recurrence Interval

Cv = Coefficient of Variation

D = Number of Farm Dams

EWS = Engineering and Water Supply Department

F = Percent Forest

FTIII = Fisher Tippett Type III

G = Gumbel

Iv = Index of Variability

JP = Final Prediction Error

La = Percent Lake

LG = Log Gumbel

LN = Log Normal

LP = Log Potter

LPIII = Log Pearson Type III

MSE = Mean Square Error

N = Normal

P = Potter

PT3 = Pearson Type III

PTN = Power Transform Normal

R = Average Annual Rainfall

R^2 = Coefficient of Determination

Ru = Percent Rural

S = Basin Slope

SE = Standard Error

Sh = Basin shape

Sk = Coefficient of Skewness

SSE = Error Sum of Squares

U = Percent Urbanisation

Chapter 1

Introduction

1.1 General

In hydrology, "Flood Estimation" refers to the specification of a design flood regardless of the method used to derive the required estimate. Peak flood flow estimations are required in the design of flood control projects, flood plain mapping, planning and designing of all kinds of water resource development projects such as bridges, dams, reservoir spillways as well as storm drainage, and highway drainage. There are many available methods which are currently used in practice, but improved methods are needed that are reliable, and easily applicable to schemes of all sizes.

Projects based on a "design flood" require an estimate of the magnitude and frequency of flood peaks at the site of the structure. The magnitude of a design flood is estimated for a particular frequency of occurrence, expressed as the "return period" of the flood. The return period can also be expressed as average exceedance probability (AEP) where frequency analysis is based on annual series data or average recurrence interval (ARI) where frequency analysis is based on partial series data. ARI is defined as the average interval between years in which a given discharge is exceeded, whether once or more than once (IE.Aust, 1987). A flood peak of recurrence interval of 50 years (Q_{50}), represents the peak discharge that has an average probability of occurrence of once in 50 years, although it may occur more frequently in any 50 year period.

There are two methods available for estimating floods on ungauged catchments (Boyd, 1978 & Heiler et al., 1974) as follows :

(i) Rainfall based procedures
(ii) Runoff based procedures

Firstly the rainfall based procedures produce an estimate for the design flood by using runoff producing rainstorms and applying some type of rainfall-runoff relationship. This procedure assumes that past meteorological conditions are representative of those which will occur in the future (Victorov, 1971). This method has the advantage that usually rainfall records are longer than stream flow records but are subjected to uncertainties in the converting models.

Secondly the runoff based procedures develop a flood frequency distribution from the series of maximum flood peaks using stream flow records directly. For ungauged catchments regional flood frequency methods require calculated relationships for estimation of peak flows. They assume that the meteorological events and watershed characteristics which determine runoff remain essentially unchanged (Victorov, 1971).

The flood frequency method could be considered the most reliable method when a long period of record is available to establish the appropriate probability distribution.

The necessity of analysing flood flows is universally accepted since the analyses govern the planning and design of projects that are susceptible to flood damage. There are many techniques which have been developed for flood estimation for ungauged areas but there is no single method which is universally accepted for flood frequency analysis.

Many hydrologic design problems occur at sites where stream flow data are unavailable. At these ungauged locations, it is necessary to use either an uncalibrated estimation method or an empirical equation that is based on a regionalisation of peak flows estimated from available gauged data (Shrader, 1981). Usually empirical equations are developed by regressing observed peak flows.

Regional flood estimation techniques are recommended for use in Australia for a number of states (IE.Aust, 1987). These methods have the advantage that they produce estimates of flood magnitudes for ungauged catchments. Using regional methods, information concerning flood peaks in a catchment can be inferred from other catchments of similar characteristics which are consistent with the available peak flow records over a large area. It is usually assumed that there is no change in the nature of the factors causing floods when estimating flood flows using past records. The recorded data are considered as a sample of a common statistical population (Dalrymple, 1960).

The purpose of the regional analysis undertaken, is to develop a relationship between observed flood flows and catchment characteristics which possibly could be used in ungauged catchments for estimating or predicting the magnitude of flood events. The method which gives the best fit to the data for the range of design flood flows is presumably the most reliable method for use.

1.2 Objectives

The aim of the project is to develop a better method for flood estimation of peak flows which could also be applied in any ungauged site for catchments similar to those of Mt Lofty Ranges. The regional flood frequency study consists of two parts. The first part is the development of basic frequency curves representing the relation between peak flood flows and annual exceedance probability or average recurrence interval. The second part is the development of the relationship between the peak flood flows and different physical and topographic characteristics of the drainage basins to enable estimates of flood flows at any point in the region.

A number of criteria need to be satisfied by the method:

1. Accuracy and reliability;
2. Applicability to the region being examined;
3. The ability to be applied in an easy and timely way; and
4. The method should use data that is readily available.

To obtain a method to satisfy the above criteria the following strategy was adopted :

A: Examination of information such as:

1. The availability, adequacy and accuracy of observational data;
2. The homogeneity and stationarity of records;
3. The occurrence and nature of outliers; and
4. The selection of the appropriate plotting position.

B: Analyses of probability distributions of data including:

1. The method of parameter estimation to be used; and
2. The selection of the most appropriate distribution type.

C: To develop a regional relationship taking into account of:

1. The applicability of the developed regression equations at ungauged sites;
2. The relationship between the catchment characteristics; and
3. Comparison with alternative methods of flood estimation.

1.3 Flood Frequency Analysis

The purpose of this section is to provide a brief introduction to some practical aspects of flood frequency analysis.

The first approach of predicting the magnitude and frequency of flood values is to fit an appropriate probability distribution to the observed data. There are many probability distribution types available that can be fitted to an observed dataset but the distribution type which gives the best fit to the data and is appropriate should be selected for the frequency analysis. The probability distribution model can be used to predict flood flows of any ARI at ungauged sites.

Among the probability distributions described in the literature, the one adopted in this study is Log Pearson Type III distribution which is recommended by the research carried out in U.S.A (Singh, 1987) and also recommended for Australian conditions (McMahon et al., 1980, IE.Aust, 1987). This distribution type has been widely used before in different studies and has proved to be applicable in most cases. It has been found especially suitable for flood frequency analysis (Phien et al., 1984).

The most difficult area associated with the practical application of probability distributions is the method of fitting the distribution to the data. In this study, ten probability distribution types are taken and LPIII is chosen for the flood frequency analysis, which is discussed latter (Chapter 4).

When analysing the flood frequency of peak flood values, four main characteristics are relevant:

- appropriate treatment of outliers and adjustment of probability;
- homogeneity of the region;
- the appropriate probability distribution type; and
- fitting of the distribution to the observed values.

1.4 Regionalisation

Regionalisation is a procedure to extend the known stream flows to regions where no stream flow records exist. Regional analysis is concerned with extending hydrological records in space as distinct from extending them in time (Taylor et al., 1976). Regionalisation, which allows the basins to be treated in groups, has been used extensively throughout the world. Using a regionalisation technique, the frequency curves for ungauged catchments can be developed where limited physical catchment characteristics are available.

A good definition of regionalisation can be cited from Potter et al. (1971): "Regionalisation is a simple process in that short-record catchment statistics are adjusted with respect to the statistics of a nearby long-record catchment according to the degree of correlation between the annual floods for each year of record for the two catchments. If there is no correlation there is no adjustment." Regional analysis can be carried out only under the condition that the stations subjected to the study belong to the same homogeneous region. Under these circumstances, regional frequency analysis can be used in catchments where records are short or unavailable.

There are a number of disadvantages in regionalisation (NERC, 1975). It is a simple matter to group the data into regions, but there may be difficulty in assigning a new catchment to a particular region. Any rules for defining regions could be arbitrary. This could be especially severe if two adjoining regional equations were to give widely different estimates for the mean annual flood for a particular catchment. Secondly, some of the regions may have records from few gauging stations which would make it difficult to estimate the regression equation for that region.

Two broad categories of regionalisation procedures have been widely used (Kirby et al., 1987):

- the index flood method introduced by Dalrymple (1960); and
- the multiple regression approach introduced by Benson (1962).

The index flood method of regionalisation expresses the flood frequency curve at any site in a homogeneous region as the product of an index flood at the site and a dimensionless regional frequency curve. The index flood approximates the mean annual flood at the site. The multiple regression method of regionalisation uses individual flood frequency analyses of flood records at each site to fit regression equations which can be written in the form (Kirby et al., 1987) :

$$\log Q_t = \log a + b \log A + c \log R + \dots\dots\dots\dots + l \log Cv$$

Details of this method have been described in Chap 5.

The regionalisation procedure therefore can be divided into two steps:

- an analysis of each gauging station record to develop a flood frequency curve for each station and
- combining these flood frequency curves so that a resulting frequency curve can be applied throughout the region which is called "the regional frequency curve".

Chapter 2

Data Selection

2.1 General

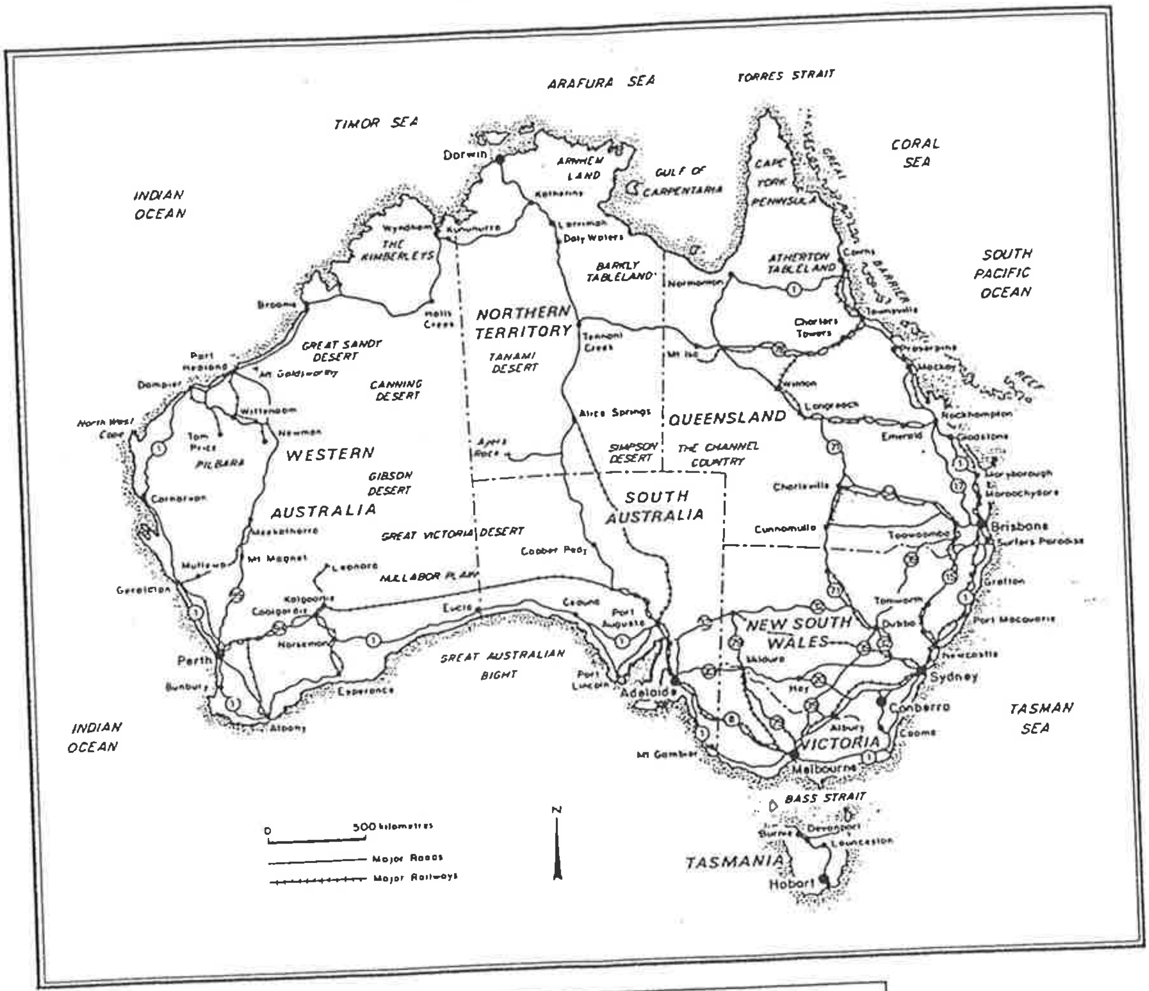
It is logically assumed that past records are the best indicator of the probability of the future occurrence of a flow of a given magnitude. The accuracy of any flood magnitude estimation method depends upon the availability of good data records. The vital element in the design flood procedure is a sufficient length of stream flow records as the reliability of flood frequency estimates are directly related to the length of the records. A long record of stream flow is desirable to have a confident estimate of flood flow for any given ARI.

A regional flood estimation study has been undertaken in Mt Lofty Ranges in Adelaide, South Australia (Figure 2.1). The location of all the catchments for the Mt Lofty Ranges are shown in Figure 2.2. The numbers in catchment areas represent catchment-no in Table 2.1. Twenty two stations have been selected for the analysis. For the convenience of readers all catchments in the Mt Lofty Ranges are listed in Table 2.1.

The Engineering and Water Supply Department of South Australia supplied the stream flow data necessary for this research. Among the 40 stations, 22 were found suitable for the analysis in terms of data availability. Many of these stations were excluded because of discontinuous records. Little Para River, South Para River and Gawler River were excluded from the analysis as stream flows were affected by the reservoirs in the catchments though they are quite important catchments with long records.

Burra Creek, Wakefield River, Hill River and Hutt River fall outside the Mt Lofty Ranges and land cover information was unavailable. So these catchments were discarded from the analysis. A separate analysis could be carried out by forming another group with the catchments that fall outside of the Mt Lofty Ranges. As only four catchments were available which were spread over a wide area, it was decided to concentrate on the catchments in Mt Lofty Ranges only.

It is important in data collection that hydrometric stations are maintained, the gauge height is measured as accurately as possible and the rating table for high flows be established from as many high flow gaugings as possible.



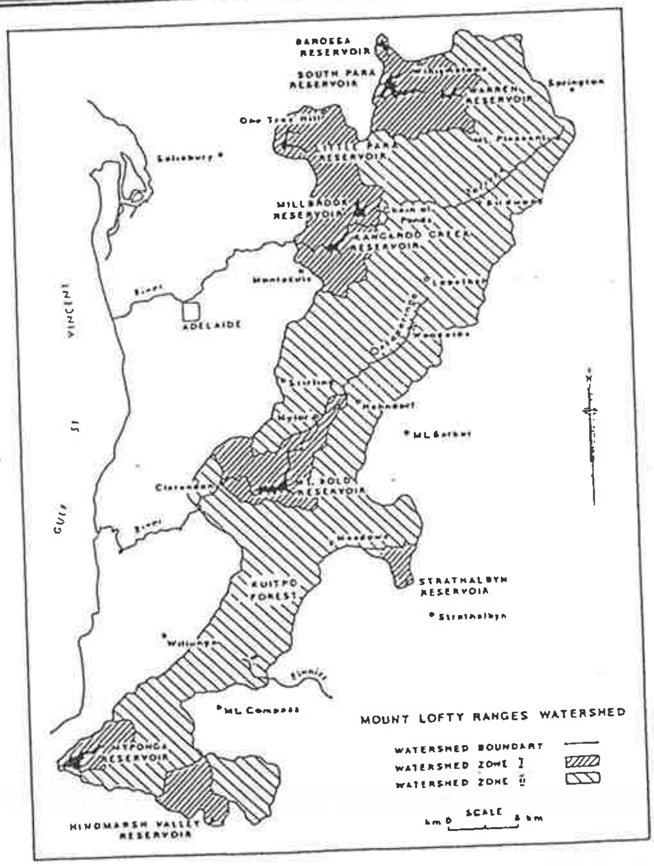


Figure 2.1 Map of Australia (above) and Mt Lofty Ranges Watershed in Adelaide (below).

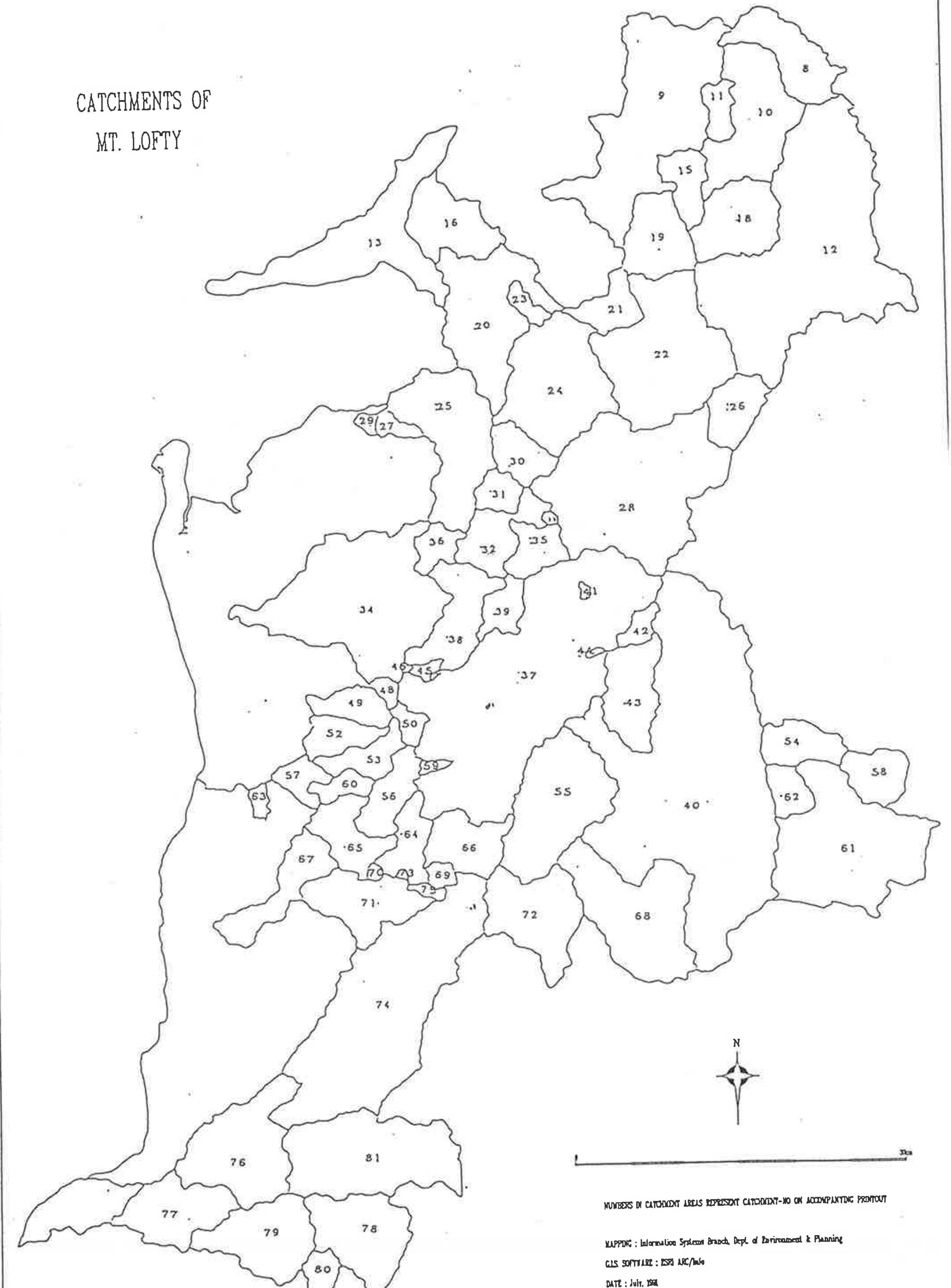


Figure 2.2 Catchments of Mt Lofty Ranges.

TABLE 2.1

List of Catchments in Mt lofty Ranges (EWS)
The Catchments with '*' sign are adopted in this study.

No of Catchment	Name of Catchment	No of Catchment	Name of Catchment
9	North Para Yaldara *	10	North Para Penrice *
12	Marne River *	13	Victoria Park
15	Tanunda Creek	16	Gawler Riv. junction
18	North Para Mt.McKenzie *	19	Jacob Creek
20	South Para South-East Gawler	21	Victoria Creek
22	Warren	23	Barossa Reservoir
24	South Para	25	Little Para
26	Torrens Mt Pleasant *	27	Little Para U/S Fault
28	Torrens Gumeracha	29	Carisbrooke
30	Kersbrook Creek	31	Millbrook
32	Kangaroo Creek	34	Torrens Riv Holbrooks Rd
35	Cudlee Creek	36	Torrens Gorge
37	Onkaparinga River *	38	Sixth Creek *
39	Lenswood Creek *	40	Bremer River *
41	Juers Creek	42	Inverbrackie Creek *
43	Dawesley Creek *	44	Kerber Creek
45	Cox Creek	46	Vince
47	Sutton	48	First Creek *
49	Brownhill Creek	50	Aldgate Creek *
51	Callasch	52	Minno Creek
53	Sturt Creek *	54	Preamimma Creek U/S
55	Mt Barker Creek *	56	Scott Creek *
57	Sturt River	58	Preamimma Creek D/S
59	Lesley Creek	60	Chambers Creek
61	Rocky Gully Creek	62	Dry Creek
63	Happy Valley Reservoir	64	Mt Bold
65	Onkaparinga Clarendon	66	Echunga Creek *
67	Onkaparinga Noarlunga	68	Rodwell and Red Creek.
69	Jupiter Creek	70	D/S Mt. Bold
71	Baker Gully *	72	Angas River *

73	Burntout Creek	74	Finniss River *
75	Dashwood Gully *	76	Myponga River *
77	Myponga Reservoir	78	Currency Creek *
79	Hindmarsh River *	80	Hindmarsh Valley Reservoir
81	Tookayerta Creek		

2.2 Quality of Records

The climate in South Australia is such that there is a natural tendency for streams to have either long periods of 'no flow' or 'low base flow'. For some gauging stations, observed peak flow values are very low such as for Sturt River and First Creek these values tend to reduce the accuracy of the developed model. In the case of First Creek, for 13 years of record the peak flow values varies from 0.11 to 2.8 m^3/s, but in one other year the peak value is 10.14 m^3/s because a bush fire destroyed all vegetation in that year. This station is included in the analysis because of the need to include as many stations as possible.

The basis of the entire procedure is to develop a flood frequency model which will be able to approximate the true peak discharge at any ARI which partly depends on the availability of length of records. A sufficient length of record is required to obtain the desired degree of accuracy of the model. The range of record length of the gauging stations used in this study is 9 to 20 years. Periods of record are listed in Table 2.2. With a maximum of 20 years of record, peak discharges above the 20 year ARI from any developed model is somewhat suspect. Even to estimate the 20 year ARI discharge, a much longer record is needed than that which is available now.

Missing records or discontinuous data could possibly change the statistics of a particular station's record and it is quite possible that a significant event could have occurred during the missing period. The stream flow data has been carefully checked and the stations adopted in this study have continuous flow records.

In HYDSYS (Heweston and Daniell, 1988), a routine called Hypeaks, examines the flow record to select the annual, partial and monthly values and plots LPIII distribution for these series. Zero flows would have an effect on the statistical distribution ie logarithmic mean, standard deviation, and skew coefficient which are the essential parameters for LPIII distribution. Most of the stations used in this study contain a number of low values, some values are almost zero such as for Inverbrackie Creek 0.01 m^3/s and for Torrens River 0.04 m^3/s which have been used in the analysis. Therefore logarithms of these low values can distort the analysis. In the case of First Creek, the logarithmic mean is negative (-0.93) and coefficient of variation is (-5.67) because of extremely low values. Zero and low flows can be adjusted according to IE.Aust (1987) but there is no scope to adjust the probability of low values in HYDSYS. In this study, the regional regression method has been carried out with the values of LPIII distribution analysed by HYDSYS and also a revised analysis has been done by discarding extremely low values when necessary using WS06 computer package. Details have been described in Chapter 5.

However the model was tested excluding the First Creek station and no significant difference was noticed, therefore it was decided to use this particular station in the analysis.

TABLE 2.2

List of catchments adopted for analysis with length of records

Station No	Station Name	Location of Catchments	Period of Record	Area (km^2)
426503	Angas River	Angas Weir	31.1.69 - 7.4.89	59.6
426504	Finniss River	4 km east of Yundi	6.3.69 - 15.12.89	191
426529	Marne River	U/S Cambrai	30.4.73 - 30.5.89	239
426530	Currency Creek	Near Higgins	6.6.72 - 8.6.89	56.9
426533	Bremer River	Near Hartley	11.5.73 - 13.12.89	473
426557	Mt Barker Creek	D/S Mt Barker	24.4.79 - 8.8.89	85.9
426558	Dawesley Creek	Dawesley	1.6.78 - 8.8.89	40.1
501500	Hindmarsh River	Hindmarsh Valley. Res. intake weir	7.3.69 - 4.4.90	55.5
502502	Myponga River	U/S Dam and Rd bridge	20.4.78 - 2.8.90	76.5
503502	Scott Creek	Scott Bottom	27.3.69 -28.3.90	26.8
503503	Baker Gully	4.5 km wnw Kangarilla	11.4.69 - 26.6.89	48.7
503504	Onkaparinga River	At Houlgrave	17.4.73 - 11.10.90	321
503506	Echunga Creek	U/S Mt Bold Reservoir	22.3.73 - 15.3.90	34.2
503507	Lenswood Creek	At Lenswood	18.5.72 - 22.6 89	16.5
503508	Inverbrackie Creek	At Craigbank	17.5.72 - 16.10. 90	8.38
503509	Aldgate River	Aldgate Railway St.	13.7.72 - 22.6.89	7.80
504512	Torrens River	Mt Pleasant	2.5.73 - 19.7.90	25.8
504517	First Creek	Waterfall Gully	7.10.76 - 19.6.90	5.01
504518	Sturt River	U/S Minno Ck junc.	8.12.77 - 17.4.90	19.4
504523	Sixth Creek	Castambul	10.11.77 - 14.8.89	43.6
505504	North Para River	Turretfield	22.5.72 - 26.7.90	708
505517	North Para River	Penrice	22.6.77 - 24.7.90	118

2.3 Catchment Area

There is some doubt about including large areas as well as small areas in groups for the same analysis. Baron et al.(1980) have taken 100 km^2 as the upper limit of 'small' though it is difficult to specify the threshold catchment area between small and large. It was reported in this paper that hydrological characteristics of small catchments exhibit greater variability than those of large catchments. Also small catchments are relatively homogeneous in physical characteristics and rainfall is more uniform than over large catchments. In this study, the range of catchment areas undertaken is 5.01 km^2 to 708 km^2 (Table 2.2). It can be clearly seen that there is a large variation of area whereas most of the catchments are small. Table 2.3 has been compiled showing catchment size and number of years of record.

The effect of storages, number of farm dams, non-uniformity of rainfall intensity on large catchments compared to small ones, has been discussed extensively in the paper of Baron et al. (1980). It may be better to treat small and large catchments as separate populations with their own relationships developed but because of scarcity of data all of them have been considered as one group in this study. Past studies have taken gauging stations from a homogeneous region as one group (NERC, 1975), which encourages the grouping of the Mt Lofty Ranges catchments as a single data base.

One method to test the differences between the two types of catchments is to separate the areas into both small and large population groups and to compare it with the mixed population but to carry out this sufficient data is needed, which is not available. In the range 500 to 750 km^2 there is only one catchment and between 300 to 500 km^2 there are two catchments as shown in Table 2.3. Therefore with only with three stations falling in the large category, it is considered there is an insufficient number of catchments for separate analysis of small and large catchments.

TABLE 2.3

Number of Years of Record

Catchment Area (km^2)

	0 - 5	5 - 10	10 - 15	15 - 20	> 20	
0 - 20			First Creek Sturt River	Lenswood Creek Inverbrackie Creek Aldgate Creek		5
20 - 50		Dawesley Creek	Sixth Creek	Scott Creek Baker Gully Echunga Creek Torrens River		6
50 - 100		Mt Barker Creek	Myponga River	Angas River Currency Creek Hindmarsh River		5
100 - 300			North Para River	Finniss River Marne River		3
300 - 500			Bremer River	Onkaparinga River		2
500 - 750				North Para River		1
		2	6	14		22

2.4 Catchment Description

Twenty two catchments have been initially selected for this study. All of them are in the Mt Lofty Ranges. According to land use categories, these catchments may be divided into three areas (Laut et al., 1977): the very intensively used lands adjacent to Adelaide, the intensive grazing lands of Fleurieu Peninsula and the eastern plateau, and the arable farming and grazing areas of the remainder of the province.

The intensive land use areas in the Adelaide region include the urban areas, horticulture, farms etc. Further east and south, mixed livestock grazing dominates the pattern of rural land use. Farm dams are widely used to irrigate small areas of pastures. In the remainder of the province, grazing of sheep and some beef cattle occur through 90% of the region, while cereal cultivation and livestock grazing are practised on the plains and the lower ridges.

Most of the catchment characteristics have been derived from Glatz (1985) and EWS Report No. 26 (1986).

Angas River : Situated in lower Murray River basin, a low woodland, mostly rural area. Land use is mainly sheep and cattle grazing. Most of the catchments are filled with scattered trees and a small portion with dense ridges on quartzite and schist land.

Finniss River : Lower Murray River catchment with land use varying from forestry to dairy farming and mixed agriculture. Permian fluvioglacial sands in valley floors where there is mainly woodland and shrubland - vegetation type.

Soils are deep to moderately deep, with rock outcrops on ridges. Slope and crests with woodland and open forest.

Marne River : Lower Murray River catchment with land use of sheep grazing and cropping. Consists of structurally controlled ridges with steep slopes of metasiltstone, greywacke and phyllite with odorata low woodland vegetation cover.

Currency Creek : Lower Murray River catchment with land use varying from sheep and cattle grazing to dairy farming. All areas are used for livestock grazing. Ridges on greywacke, and remnants of Tableland with open scrub. Soils are deep to moderately deep and are imperfectly drained.

Bremer River : An undulating plain on tillite, with areas of colcrete merging into alluvial fans, situated in lower Murray River basin. The upland consists of structurally controlled ridges with steep slopes. Livestock grazing and rotational cereal cropping are the dominant land uses.

Mt Barker Creek : Situated in lower Murray River Basin. Sheep grazing, dairy farming are dominant land uses, whereas a little portion is urbanised. Ridges on meta-siltstone, slate and phyllite soils.

Dawesley Creek : Lower Murray River catchment with mainly sheep grazing and dairy farming land uses. Ridges on phyllite and schist with minor quartzite.

Hindmarsh River : Situated in Fleurieu Peninsula basin, with sheep and cattle grazing and dairy farming land uses. Both pastures and crops are used for grazing. A series of low dissected ridges with a cover of open parkland over sown pastures and cereal crops.

Myponga River : Situated in Myponga River basin where dairy farming is dominant land use. An undulating plainland with soil type varying with silt and sands overlain by limestone at western boundary to slate and tillite along northern catchment boundary.

Scott Creek : Onkaparinga River basin catchment with mainly cattle grazing and hobby farming land uses. Predominantly dense natural scrub with steep sided slopes and remnants of open scrubby Tableland.

Baker Gully : Onkaparinga River basin catchment with livestock grazing. Predominantly dense to medium natural scrub with several small pockets of pine plantation and some dairying properties. Tertiary sands and clays in western region. Steep slopes with a portion of scrubby Tableland.

Onkaparinga River : Onkaparinga River basin catchment. Common land uses are grazing dairying, poultry farming, market gardening, orchards and afforestation. Ridges on siltstone and slate soil type and remnants of scrubby Tableland.

Echunga Creek : Situated in Onkaparinga River basin with mixed farming land use. There are small pockets of pine forest plantation and some areas of dairy farming. Tertiary sands along eastern and southern boundaries while siltstone and slate are main soil type. Predominantly medium natural scrub on generally rolling hills.

Lenswood Creek : An undulating catchment situated in Onkaparinga River basin, predominantly used for intensive horticulture, mainly apple orchards.

Inverbrackie Creek : An undulating upland mainly plain with occasionally hills. The main land use is sheep and cattle grazing, also some plantation and vineyards.

Aldgate River : An undulating to hilly high parkland, Onkaparinga River basin catchment with urbanised land and proterozoic slate type soil.

Torrens River : An undulating upland plain, Torrens River basin catchment with palaezoic metamorphosed siltstone soil type. Sheep and cattle grazing is main land use with some pine plantation and vineyards.

First Creek : An undulating land in Torrens River basin. Land use is mainly natural vegetation. Proterozoic siltstone and quartzite soil type.

Sturt River : An urbanised land situated in Torrens River basin. Ridges on phyllite and slate with quartzite and a portion is Tableland with open scrub.

Sixth Creek : Torrens River basin catchment, with forested hills and ridges on siltstone, phyllite and minor quartzite. Main land uses are sheep and cattle grazing, orchards etc.

North Para River : Gawler River basin catchment, among the catchments, one in Penrice and other one in Turretfield. Land uses in both catchment are mainly sheep and cattle grazing with some vineyards and cropping. Relatively plain land siltstone soil with minor granite in south.

The topographic and meteorological characteristics of the catchments are listed in Table 2.4.

TABLE 2.4

Topographic Characteristics of the Catchments

Station No	Station Name	Area (km^2)	A.A.R * (m)	Length (km)	Slope (m/km)	Fall (m)	N.F.D **	Forest (%)	Urban (%)	Rural (%)	Lakes (%)	Basin Shape ##
426503	Angas River	59.6	780	17.5	15.714	275	430	4.16	0.5	95.09	.24	0.294
426504	Finniss River	191	900	33	4.40	145	1185	20.05	0.19	79.47	0.27	0.173
426529	Marne River	239	540	37.5	8.267	310	695	0.47	0.01	99.45	0.07	0.157
426530	Currency Creek	56.9	850	16.5	13.03	215	470	4.62	0	95.16	0.22	0.29
426533	Bremer River	473	520	50	9.34	467	1640	1.4	1.63	95.97	0.25	0.106
426557	Mt Barker Creek	85.9	751	18	7.22	130	575	3.89	3.67	92.26	0.12	0.21
426558	Dawesley Creek	40.1	670	12.75	14.51	185	215	0.04	0.53	96.96	0.58	0.32
501500	Hindmarsh River	55.5	830	17	20.176	343	330	14.27	0	85.67	0.06	0.31
502502	Myponga River	76.5	840	16.5	6.18	102	560	7.07	0	92.81	0.12	0.216
503502	Scott Creek	26.8	900	11	22.73	250	175	42.55	0.72	56.6	0.03	0.41
503503	Baker Gully	48.7	740	15	15.2	228	276	11.49	0.06	88.18	0.10	0.31
503504	Onkaparinga River	321	980	44	6.136	270	2320	11.52	7.24	80.83	0.27	0.137
503506	Echunga Creek	34.2	800	12.5	14	175	220	19.02	0.67	79.72	0.54	0.365
503507	Lenswood Creek	16.5	1030	6	27.5	165	190	16.71	0.18	82.92	0.18	0.364

TABLE 2.4 (Continued)

Station No	Station Name	Area (km^2)	A.A.R * (m)	Length (km)	Slope (m/km)	Fall (m)	N.F.D **	Forest (%)	Urban (%)	Rural (%)	Lakes (%)	Basin Shape ##
503508	Inverbrackie Creek	8.38	750	5.75	12	69	69	0.12	0	99.66	0.22	0.686
503509	Aldgate River	7.80	1100	3.5	57.143	200	7	11.18	56.22	31.97	0.20	0.45
504512	Torrens River	25.8	680	8.5	9.17	78	165	1.94	0	97.64	0.42	0.33
504517	First Creek	5.01	1100	3.5	82.86	290	10	92.82	4.35	2.84	0	0.7
504518	Sturt River	19.4	990	10	28	280	93	48.5	5.92	45.06	0.04	0.515
504523	Sixth Creek	43.6	970	15.75	26.03	410	227	51.64	0.37	47.95	0.04	0.361
505504	North Para River	708	580	78.5	4.94	388	1570	3.98	1.14	94.35	0.19	0.111
505517	North Para River	118	600	25	6.4	160	510	0.105	0	99.73	0.155	0.212

Note :

* A.A.R = Average Annual Rainfall measured from 1:100,000 Isoheytal map.

** N.F.D = No. of Farm Dams measured from 1:50,000 Topographic map.

Basin Shape = Length / Area.

Chapter 3

Development of Procedures

3.1 General

The estimation of flood magnitudes of a given return period are required for planning and design of various river basin projects. The principal of analysing flood magnitude on a probability basis is now universally accepted. Important steps in the regional flood frequency approach are:

- The selection and extraction of the appropriate flood events to be analysed from the continuous record of stream flow at each station and calculation of the probability of each event;
- The establishment of an average recurrence interval of the design event which a structure should be able to accommodate satisfactorily;
- The selection of outliers, low and high, which might have considerable effect on ultimate analysis; and
- The problem to define the boundaries of the homogeneous region and adoption of a method testing whether the catchments considered fall in the same regional population or whether some of them should be excluded from the region.

3.2 Selection of Data Series

In the analysis of flood frequency data, flood data can be listed by one of the two approaches, either "Annual Flood Series" or "Partial Flood Series". It is possible to transform average recurrence intervals in the partial series to those in the annual series (Langbein, 1949). In this study both types of series have been considered in the analysis and an effort was made to find the best one. It was found that the annual series gave a better correlation between observed flood data and estimated flood data from the developed model at each ARI although the partial series appears to be more attractive as it gives the prospect to utilise a greater and more relevant data base (Chapter 6, Table 6.1).

3.2.1 Annual Flood Series

The annual flood series is an array of values consisting of the highest peak flow event in each year, a very simple statistical treatment of flood peaks. The annual series provides more satisfactory results for the more infrequent floods while there is a possibility of misleading results for the more frequent events. One objection in using annual series is that it uses only one flood in each year while the second highest flood in a given year may outrank many other annual flood peaks, especially in Australian rivers, where a great variability in stream flow is observed.

The use of annual series has one advantage in that there is usually no dependency between successive flood peaks, therefore the peaks can be considered independent of each other, except on the change from one year to another. The annual series method was regarded as the best method among the statistical methods for flood estimates in the 1950s, while now partial series is gaining popularity by eliminating the disadvantages of the annual series.

3.2.2 Partial Flood Series

The partial series is an array of all flood values exceeding some arbitrary base level regardless of any given time period or year in which they occur, which resolves the objection noted under annual series. In a partial series there may be a number of values from one year, while there may be no values at all from other years when the base level is not reached. For a short length of record, this series can extract the maximum amount of information from the data. One objection in using partial series is that the floods listed may not be fully independent events ie the occurrence of one flood is dependent on the previous one. The partial series faces other difficulties (Potter et el, 1971), Such as :

- Most of the published methods use the annual series because they have been developed for longer records which then can not be directly applied to partial series and also because of simplicity of analysis; and
- The theoretical frequency distribution which is normally applied to flood analysis generally only applies to the annual series.

To define the partial series properly, the two criteria needed to be defined are the base discharge and independency of the peaks.

3.2.2.1 Selection of Base Period

To develop a partial series the selection of a base discharge q_0 called the threshold is undertaken, so that peaks exceeding this value can be considered in the series. There is a large dispute about choosing the base discharge which is discussed in detail in IE.Aust (1987). McDermott and Pilgrim (1982) showed in their paper that when K is considered equal to N, where K is the no of peaks exceeding threshold and N is the no of years, the data gives the best fitting for LPIII. For Australia it is recommended that the value of the base discharge should be such that the ratio of K to N is lower (IE.Aust, 1987), which is followed in this study. As there is no specific accepted method to select base discharge, the bias in selection can affect the statistical parameters of the series (Laurenson, 1987). The threshold selected can be modified as more data becomes available although changes in the threshold are not desirable once selected.

Figure 3.1 shows the sketch of the process. The time t is measured from t_0. The peaks exceeding the base discharge (over q_0) are indicated by their magnitudes as shown. Values to include are q_1, q_2, q_3, q_4, q_5 and q_i, while q_{i-1} should be excluded from analysis as it is under the base discharge.

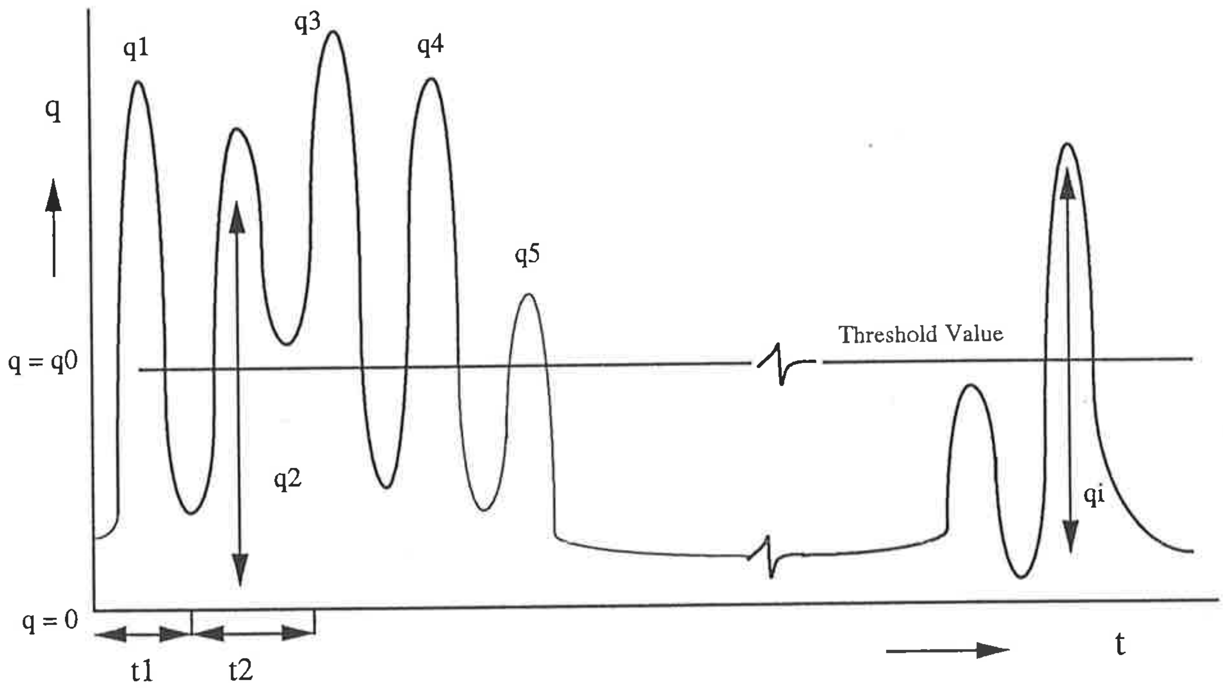


Figure 3.1 Stream flow hydrograph for a time interval (0,t)

3.2.2.2 Criteria for Independence of Flood Peaks

One of the drawbacks of the partial series approach is that successive items in the series may not be independent as successive peak magnitudes are sometimes correlated. The dependency of partial peak magnitude depends on the time between successive peaks. IE.Aust (1987) recommended that the flood peaks should be separated by a time of (5+lnA) days, where A is the catchment area in square miles, with the additional requirement that intermediate flows should drop to below 75% of the lower of the two separate flood peaks. This may only be suitable for catchments larger than 1000 km^2 (IE.Aust, 1987). The above two criteria were not possible to follow completely in this study as all of the catchments used in this analysis are smaller than 1000 km^2.

The independency was checked by plotting flood peaks for each station against time and the independent peaks were sorted out using subjective judgement. From Figure 3.1 peak q_3 is dependent on q_2, while all other peaks are independent.

3.2.2.3 Relationship between Annual Series and Partial Series

To avoid the problems associated with the use of partial series, Langbein (1949) developed a relationship between partial series and annual series. The probability of occurrence of a flood equal to or greater than magnitude m can be defined by (Langbein, 1949):

$$P = \frac{m}{nN}$$

where,

N = total no. of years of record

n = average no. of floods per year

m = order of magnitude beginning with the highest

In annual flood series,

$$n = 1, \qquad P = \frac{m}{N}$$

In a partial duration series it is not necessary to define n, since the equation:

$$Pn = \varepsilon$$

The equation defines the annual expectancy of recurrence of a flood that is equal to or greater than magnitude m.

Hence in this case $\frac{m}{N} = \varepsilon$

Or the probability of any flood is

$$P = \frac{\varepsilon}{n}$$

and the complementary probability of a flood equal to or less than magnitude m is $(1 - \varepsilon / n)$.

Accordingly, the probability of a flood of magnitude m being a maximum of the n floods in a year will be :

$$P = (1 - \varepsilon / n)^n = e^{-\varepsilon}$$

Where, P represents the probability of a flood of magnitude m, being an annual flood, and ε represents its expectancy, m/n among all floods in the partial series.

From this relationship the recurrence intervals of partial series can be transferred to those of annual series. The following table shows comparative values of recurrence intervals by the two methods (Langbein, 1949):

Average Recurrence Interval in years

Partial Series	Annual Series
0.50	1.16
1.00	1.58
1.45	2.00
2.00	2.54
5.00	5.52
10.0	10.5
20.0	20.5
50.0	50.5
100	100.5

3.3 Plotting Position

For the purpose of estimating the flood frequency distribution, there is a need to calculate the probability plotting position to plot flood peaks against recurrence interval or exceedance probability. The analysis of flood data starts by arranging the flood peaks according to their magnitude, where the flood of the highest peak flow in the group of N years flood is rank 1 and so on.

In flood frequency analysis, the plotting position is the probability of a flood. The reciprocal of probability is expressed in terms of years which is called the return period or recurrence interval or its reciprocal exceedance probability (Zhang, 1982). The term ARI can be defined as an average interval of time within which the magnitude of the event will be equalled or exceeded once. A flood having a ARI of 50 years has a 2 percent chance of occurring in any year and similarly a flood with a ARI of 100 years has a 1 percent chance of occurring in any year.

Plotting positions have been widely used in hydrologic frequency analysis for different purposes such as to estimate the magnitude of hydrologic events and its corresponding probability of occurrence, to detect outliers, to fit distributions to data and to assess the adequacy of the fit (Nguyen et al., 1989). A probability plotting position formula which can be applied to all of the flood data available is needed. Plotting of recorded data relates peak flows to frequency of occurrence.

A number of plotting position formulae have been proposed and used in hydrologic practice. Among them the most widely used is the Hazen and Weibull formula. Many of the formulae are simply an extension of the Weibull formula. The Weibull rule was known to be unbiased in terms of probability for systematic records only, while it was found to be biased in case of non uniform distributions, especially for positive skewed distributions (Cunnane, 1978). If the objective of the probability plot is to obtain an unbiased probability estimate corresponding to a particular value, then the Weibull formula is the mostly favoured. This formula is widely accepted because (Cunnane, 1978) :

- it has a theoretical interpretation; and
- it satisfies Gumbel's plotting postulates which are assumed to be necessary conditions.

Gumbel (1947) stated four prerequisites to be satisfied by any plotting position formula. These were :

1. The plotting position must be such that all observations can be plotted.

2. The return period of a value equal to or larger than, the largest observation and the return period of a value equal to or smaller than, the smallest observation should converge towards N, the number of the observations.
3. The observations should be equally spaced on the frequency scale, that is the difference between the plotting positions of the (m+1)th and the m'th observation should be a function of n only and independent of m.
4. The plotting position ought to be analytically simple and have an intuitive meaning.

But Cunnane (1978) expressed doubt concerning Gumbel's plotting position postulates. The criteria that requires the largest value in a sample of size N to be plotted at return period N does not seem to take into account the facts of statistical theory (Cunnane, 1978).

According to Nguyen et al. (1989) it is preferable to develop a specific plotting position formula for each particular distribution. In addition, the unbiased plotting position formulae introduced by Cunnane (1978) have been found to be suitable for various hydrologic frequency analyses.

Nguyen et al. (1989) suggested a simple unbiased plotting position formula which can provide a better approximation of the exact probabilities than those given by several existing plotting formulae. Hirsch and Stedinger (1986) introduce some plotting formulae which consider bias in probability and bias in discharge, where bias in probability is independent of the distribution but bias in discharge depends on the distribution. Five different plotting position formulas based on traditional rules and exceedance rules were used in this paper and the methods were compared in terms of their effects on flood frequency estimation by the curve fitting method.

The plotting position is relatively unbiased in terms of discharge rather than in terms of probability.

The general formula for plotting position (pp) of an observed flood in terms of exceedance probability can be written as (IE.Aust, 1987) :

$$pp = \frac{m - \alpha}{N + 1 + 2\alpha}$$

where,

m = Rank of the flood in the series. (ie rank of the highest peak is 1)

N = Number of years of record

α = A constant

For the best 'goodness of fit' different values of α are considered. The values of α adopted are listed as follows :

TABLE 3.1

Plotting Position Formulae (Cunnane, 1978)

Proponent Name	**Plotting Position Probability**	**Value of α in** $pp = \frac{m-\alpha}{N+1+2\alpha}$
Blom Formula	$\frac{m - 3/8}{N + 1/4}$	3/8
Weibull Formula	$\frac{m}{N + 1}$	0
Hazen Formula	$\frac{m - .5}{N}$	0.5
Beard Formula	$\frac{m - .31}{N + .38}$	0.31
Chegodayev Formula	$\frac{m - .3}{N + .4}$	0.3
Gringorten Formula	$\frac{m - .44}{N + .12}$	0.44
Cunnane Formula	$\frac{m - .4}{N + .2}$	0.4

The above formulae have been tested for the annual and partial series. Cunnane formula ($\alpha = 0.4$) is the best for the partial series. Although the Weibull formula ($\alpha = 0$) gives the better result for LPIII, LN, LG, LP in the annual series than the Cunnane formula. In this study the Cunnane formula has taken for both annual and partial series for uniformity. In case of the monthly series it gives almost the same result as the partial series. In Table 3.2 and 3.3 a comparison of plotting position formulae is shown from the 'goodness of fit' test for both annual and partial series. Details of the 'goodness of fit' test are described in Chapter 4.

TABLE 3.2

Comparison of goodness of fit results for different plotting position for LPIII
(Partial Series, Difference test only)

Station No	$P = \frac{m - .4}{N + .2}$ Cunnane Formula	$P = \frac{m}{N + 1}$ Weibull Formula	$P = \frac{m - .3}{N + .4}$ Chegodayev Formula
426503	1.807	2.634	1.979
426504	1.933	2.461	2.114
426529	0.528	0.579	0.544
426530	0.455	0.592	0.505
426533	1.226	1.134	1.184
426557	0.687	1.076	0.795
426558	0.974	1.426	1.097
501500	1.558	1.5223	1.472
502502	0.182	0.187	0.176
503502	0.745	0.985	0.819
503503	1.734	1.734	1.683
503504	0.710	0.916	0.779
503506	0.581	0.757	0.645
503507	1.442	1.754	1.558
503508	1.584	1.779	1.677
503509	1.273	1.509	1.371
504512	0.997	0.985	0.996
504517	3.250	3.841	3.410
504518	0.766	0.846	0.786
504523	1.295	2.003	1.471
505504	2.305	3.223	2.686
505517	4.310	5.002	1.351

TABLE 3.3

Comparison of goodness of fit results for different plotting position for LPIII
(Annual Series, Difference test only)

Station No	$P = \frac{m - .4}{N + .2}$ Cunnane Formula	$P = \frac{m}{N + 1}$ Weibull Formula	$P = \frac{m - .3}{N + .4}$ Chegodayev Formula
426503	11.348	11.254	12.936
426504	3.01	3.414	3.112
426529	17.592	15.763	17.107
426530	3.963	3.427	3.792
426533	4.595	3.841	4.395
426557	2.132	1.997	2.088
426558	4.229	4.479	4.299
501500	2.283	1.856	2.113
502502	1.572	1.568	1.565
503502	3.405	3.42	3.406
503503	3.241	3.042	3.079
503504	1.715	1.81	1.597
503506	2.531	2.462	2.515
503507	2.625	3.022	2.780
503508	7.716	7.294	7.60
503509	1.734	2.041	1.849
504512	12.103	9.868	11.432
504517	6.319	7.636	6.702
504518	1.605	1.647	1.615
504523	1.646	2.245	1.786
505504	9.192	9.443	9.325
505517	13.984	13.677	13.905

3.4 Outliers

In flood frequency analysis the term "outlier" is used to indicate the events that depart significantly from the trend of the other observed flood data in the sample. The outliers can simply be detected as the points that fall outside of the 5% and 95% confidence limits. In Figure 3.2, there are two outliers that fall outside the confidence band though they are very close to the confidence limit curve. The existence of outliers can have an impact on the computed flood frequency curve and therefore the outliers need to be examined. If the outliers are simply discarded from the data set, the results of the estimation might be distorted. On the other hand if the sample is analysed using suitable statistical methods, the results of the estimation could be biased. So the retention, modification or deletion of outliers can affect the statistical parameters computed from the data. All procedures for treating outliers ultimately require judgement involving both mathematical and hydrological considerations (IE.Aust, 1987).

From a statistical point of view, there may be two causes for the presence of outliers. Firstly it may be because of violation of some external factors such as personal negligence or gross error of measurement which may cause some unreasonably high or low observations. The second cause can be that some outliers may result entirely from the fact that all observations in the sample arise from a long tailed distribution (Siyi, 1987).

However to make an objective judgement, in this study an outlier test has been carried out. The procedures and equations for high and low outliers given in IE.Aust (1987), were used in the development of a program to test for outliers and to adjust the probability accordingly. Procedures for this testing were added to the WS06 package (Kopittke et al., 1976a) which was compiled on an IBM Compatible, running under MS-DOS (Appendix E). No outlier was found for the stations used for flood frequency analysis. Although in LPIII plotting for some stations some events fell outside of the 5% and 95% confidence limits but these were close to the 5% and 95% confidence curve. It was decided to use all data as normal flood events. There is no provision in HYDSYS to adjust the outliers and this would be a good addition to this package.

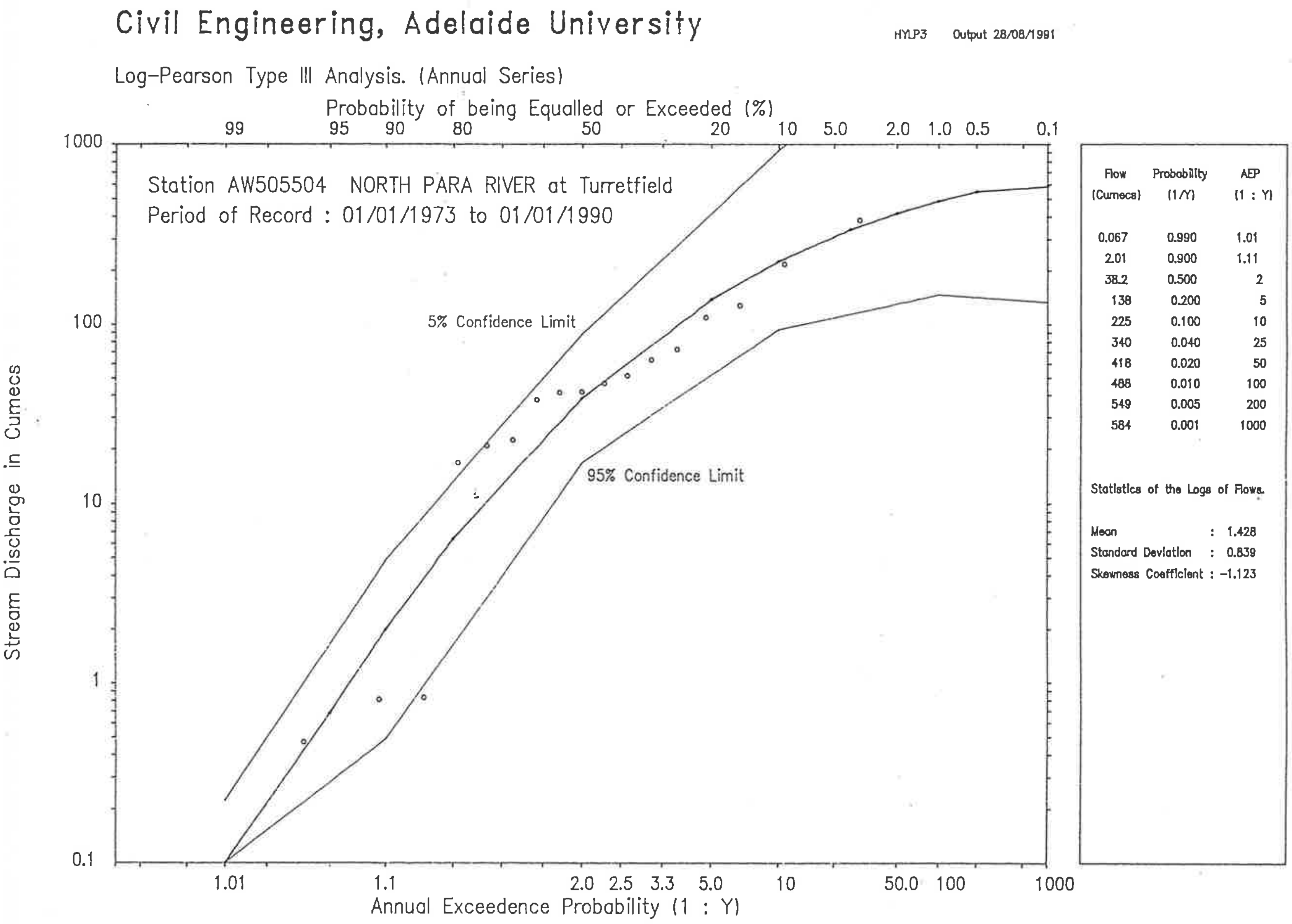


Figure 3.2 LPIII analysis for station AW505504 (Annual Series)

3.5 Homogeneity of Region

A prerequisite of the regional flood frequency analysis approach is the identification of the regions that are homogeneous with respect to the flood frequency behaviour of the watershed (Wiltshire, 1986). Accurate flood estimates are possible if the underlying flood frequency distributions are similar at all sites in the region. A requirement to test for the homogeneity of the region is therefore necessary.

There are two requirements for the successful identification of a homogeneous region as suggested by Wiltshire et al. (1986) :

- a method of quantifying regional homogeneity; and
- a method of grouping hydrologically similar basins into homogeneous regions.

Wiltshire (1986) applied a procedure to the basins of Britain by grouping them into five groups based on basin area, average rainfall and urban fraction. Four of these groups were homogeneous with respect to the coefficient of variation of the annual maximum flood series.

There are various methods for grouping basins into homogeneous regions but it is better to identify the region by either flood statistics or basin characteristics rather than by geographical space. When using geographical space, regions are assumed to be homogeneous in terms of their hydrological response but this cannot be guaranteed as neighbouring basins can be physically different. Not withstanding this, regions can be grouped as proposed by Wiltshire (1986) :

- by factor analysis which forms groups of basins having similar basin characteristics but with only qualitative judgements regarding their homogeneity of flood response;
- by cluster analysis which forms groups of basins characterised by specific mean annual flood and coefficient of variation; and
- by discriminant analysis which forms groups of basins having a similar flood response.

The results by applying such multivariate techniques depends on the manner in which the technique is used. Cluster and factor analysis are both sensitive to the scaling of the data. The best way of defining a region is to group the basins together which are hydrologically similar and then to interpret the groups in terms of basin characteristics. This procedure was followed for the British basins using cluster analysis to group the basins together having similar Cvs and specific mean annual floods. Discriminant analysis was then applied to differentiate between the clusters on the basis of basin characteristics (Wiltshire et al. 1986). In this analysis the specific mean annual flood describes the spatial intensity of the average maximum flood and Cv represents the year to year variability of the annual maxima.

Lack of homogeneity is a common practical problem in flood frequency analysis. The catchment characteristics can be totally changed during the period of records. Some aspects noted include construction of farm dams, storage levees and improvement of hydraulic capacity of channels. Even the change of the nature of land use, such as different farming practice, reafforestation, urbanisation, and soil conservation work is very common. In a few cases it is possible to adjust the recorded values according to the different type of change. However these aspects indicate that the estimation of design floods for a static environmental condition should be carried out with caution.

In this study, a homogeneity test has been undertaken with 22 stations in the Mt Lofty Ranges using the Langbein's homogeneity test (Dalrymple, 1960). The data for each station has been tabulated in Table 3.4. The ARI (column 9) has been determined using the discharge value equal to the average flood ratio multiplied by the mean annual flood ($Q_{2.33}$). The average flood ratio is obtained by averaging the ratio of the 10 ARI year flood (Q_{10}) to the mean annual flood or 2.33 ARI year flood ($Q_{2.33}$). The values of Q_{10} and $Q_{2.33}$ are obtained from LPIII curve (Appendix D). The adjusted period of record (column 10), is the number of years of actual record plus one half the number of years the record was extended. The lower limit and upper limit have been tabulated in Table 3.5. These values have been taken from the paper by Gumbel (1942). Details can be found in Dalrymple (1960).

The ARI (Column 9) has been plotted against effective length of record (Column 10) as shown in Figure 3.3. The figure shows that the regions are not quite homogeneous. Two points fall outside the upper limit, while there are four points that would fall outside the LPIII graphs. These four points result from the stations in Table 3.4 where the ARI greater than 1000 in column 8. For Myponga, Scott, Echunga and Inverbrackie Creeks, Q_{1000} values are respectively 17.3, 17.1, 23.5 and 13.1 m^3/s and the Q100 values are 16.9, 16.6, 23.2, and 13.1 m^3/s. The LPIII curves for these stations are extremely flat for the higher ARIs. From the above discussion, it is therefore difficult to develop a grouping for these stations.

Another alternative method that has been applied is a multivariate technique such as cluster analysis, to form groups of catchments or to identify objectively homogeneous hydrological regions characterised by specific mean annual flood (Q_{MAF}) and coefficient of variation (Cv) as shown in Figure 3.4. Q_{MAF} describes the spatial intensity of the mean annual maximum flood (Wiltshire et al., 1986). It can be defined as the ratio of Qmean to area. In this study, Q_{100} has been taken for cluster analysis. The Cv of a flood series is a measure of flood variability from year to year and is related to the steepness of the flood frequency curve. Other forms of cluster analysis have also been tried. These include, Cv plotted against a dimensionless flood (Q_{SP}) which was obtained by dividing the annual maximum flood by the mean annual flood (Q_{100}/Qmean), and Sk plotted against Q_{MAF}. Cv vs Q_{MAF} gave the best result.

The Figure 3.4 shows three groups in each graph, while one falls in the third group, two or three fall in the second group and the rest of the data falls in the first group. Grouping in cluster analysis is not uniform and as the third and second groups contain only one and two stations respectively, the whole region was considered as one homogeneous group.

The cluster analysis was undertaken using the Cluster Procedure in the SAS statistical package on an IBM - PC compatible.

TABLE 3.4

Data for homogeneity test

Station Name	Station Number	Drainage Area (Km2)	Length of Record (Years)	Mean Annual Flood (Q2.33) (Cumecs)	10-Years Flood (Q10) (Cumecs)	Ratio (Q10/Q2.33)	Q2.33*2.5 (Cumecs)	T for Q of Column 8 (ARI) (Years)	Period of Record Adjusted (Years)
1	2	3	4	5	6	7	8	9	10
Angas River	426503	59.6	19	14	37.7	2.693	35.00	8	23
Finniss River	426504	191	19	48	88.7	1.848	120.00	25	31.5
Marne River	426529	239	16	18	59	3.278	45.00	7	19.5
Currency River	426530	56.9	16	12	26	2.167	30.00	19	25.5
Bremer River	426533	473	15	49	118	2.408	122.50	10	20
Mt Barker Ck	426557	85.9	9	22	48.4	2.200	55.00	40	29
Dawesley Ck	426558	40.1	10	11	36.6	3.327	27.50	6	13
Hindmarsh River	501500	55.5	20	17	36.3	2.135	42.50	16	28
Myponga River	502502	76.5	11	10	15.1	1.510	25.00	>1000	>500
Scott Creek	503502	26.8	20	8.9	14.3	1.607	22.25	>1000	>500
Baker Gully	503503	48.7	19	12	28.3	2.358	30.00	12	25
Onkaparinga River	503504	321	16	89	191	2.146	222.50	15	23.5
Echunga Ck	503506	34.2	16	13	20.6	1.585	32.50	>1000	>500
Lenswood Ck	503507	16.5	16	10.5	28.2	2.686	26.25	8	20
Inverbrackie Ck	503508	8.38	17	7.3	12.6	1.726	18.25	>1000	>500
Aldgate River	503509	7.8	16	7.5	14.4	1.920	18.75	18	25
Torrens River	504512	25.8	16	9	34.1	3.789	22.50	9	20.5
First Ck	504517	5.01	13	0.92	3.43	3.728	2.30	5	15.5
Sturt River	504518	19.4	12	6.2	11.1	1.790	15.50	45	34.5
Sixth River	504523	43.6	11	18.5	47.7	2.578	46.25	9	15.5
North Para River	505504	708	17	50	225	4.500	125.00	4.5	19.3
North Para River	505517	118	12	29.5	81	2.746	73.75	9	16.5
Average Ratio --						2.5			

TABLE 3.5

Column headed TL and Tu respectively give the lower and upper limits of the chart for homogeneity test

n (Years)	y	$\frac{6.33}{\sqrt{n}} = 2\sigma$	Lower limit		Upper limit	
			y - 2σ	TL	y + 2σ	Tu
5	2.25	2.83	-0.58	1.2	5.08	160
10	2.25	2.0	0.25	1.85	4.25	70
20	2.25	1.42	0.83	2.8	3.67	40
30	2.25	1.16	1.09	3.52	3.41	31
40	2.25	1.0	1.25	4.01	3.25	26.3
50	2.25	0.9	1.35	4.4	3.15	24
100	2.25	0.63	1.62	5.6	2.88	18
200	2.25	0.45	1.80	6.5	2.70	15.5
500	2.25	0.28	1.97	7.7	2.53	13
1000	2.25	0.2	2.05	8.3	2.45	12

(See Appendix B for the equations)

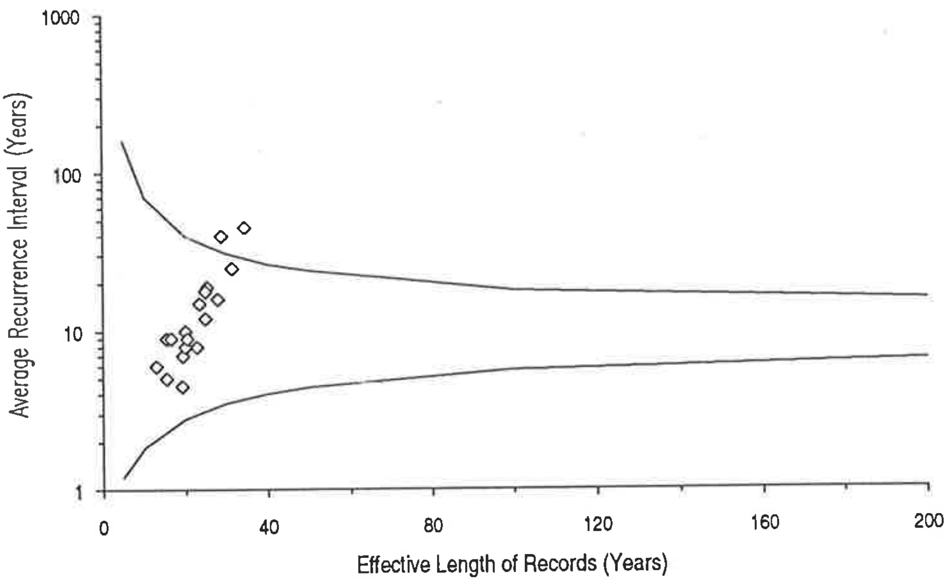


Figure 3.3 Homogeneity test chart

WARD'S MINIMUM VARIANCE CLUSTER ANALYSIS

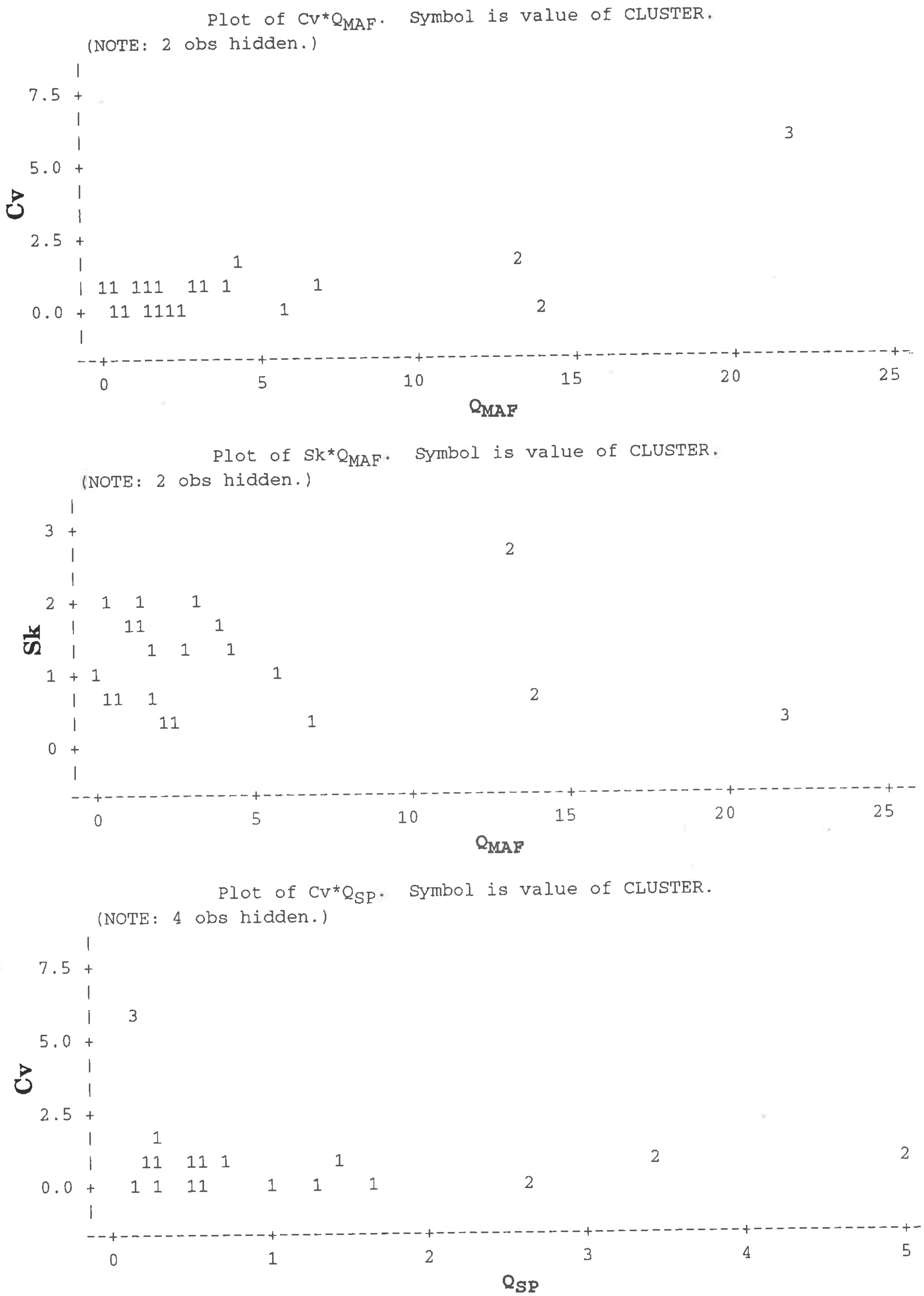


Figure 3.4 Cluster analysis for homogeneity test

Geographical regions in the Mt Lofty Ranges exhibit a poor degree of homogeneity with respect to flood frequency curves as tested by two different methods. Although it is quite possible that the resulting solution in terms of basin groupings may not be unique ie different basin characteristics may produce a statistically significant result. Regional homogeneity requires that catchments be similar with respect to various factors such as topography, geology, rainfall intensity, rainfall seasonality and flood producing weather patterns (Boyd, 1978).

In the UK flood studies report (NERC, 1975) the British Isles was divided into two geographical regions, while in the beginning Britain and Ireland were considered as one homogeneous area without any statistical testing of the hydrological uniformity of the regions. The regions can be selected on the basis of general geographical similarity. It was decided to keep Mt Lofty Ranges catchments as one group according to geographical similarity as there were insufficient stations to divide the catchments into different groups although the cluster analysis has shown three groups.

Chapter 4

Flood Frequency Analysis

4.1 General

When sufficient stream flow data is available in catchments, an appropriate regional flood estimation method can be developed which then can be applied to ungauged catchments. Flood frequency estimation methods can be used when sufficient data is available.

In the regional flood frequency method used in this study, the appropriate flood events are selected and extracted from the continuous record of stream flow at each station to calculate the probability of each flow event. A frequency distribution is then fitted to the data for each catchment. The parameters of the fitted distribution are then empirically related to the catchment characteristics. These can then be applied to estimating the design floods for all ungauged catchments in the same region. The frequency distribution relates the magnitude of an event to its return period. It can be expressed either by a mathematical equation or by a plotted curve. The curves or equations are based on different factors such as catchment area, stream length, stream slope and other climatic and physiographic factors such as mean annual rainfall, %forest, %urban, %rural and soil type.

When only short term records are available and there is a need to extrapolate these records, it is advantageous to assume specific mathematical forms of frequency distributions for the hydrologic data (Bell, 1969). Distributions can be represented by a straight line through the scatter points on special graph paper such as log-normal, semi-log, extreme probability or 'Gumbel' paper.

Regional flood frequency studies have been used to obtain regional estimates for some time. The Index flood method of regional flood frequency analysis has been one of the most popular and widely used methods of providing flood information at ungauged catchments since it was first described by Dalrymple (1960). The method of multiple regression described by Benson and Riggs has been used widely (Potter et al., 1971, IE.Aust, 1987).

4.2 WSO6 Frequency Analysis

4.2.1 Introduction

The computer program WS06 for frequency analysis has been used for fitting the distribution to the flood data of selected series for each station. The WS06 package calculates the statistics of normal and logarithmically transformed data including arithmetic mean, standard deviation, coefficient of skewness, probability for the chosen plotting position and average recurrence interval, average exceedance probability and magnitude of flow for each distribution type (Kopittke et al., 1976). A test for outliers has been developed and added to this program which prints the value of the lowest and highest outlier that is considered in the analysis. If any flood data falls outside this outlier limit, provision is made to adjust the probability in the program using the equations described in Australian Rainfall and Runoff (IE.Aust, 1987).

Split analysis which is required for the consistency and accuracy test of flood data is included in the program. Three tests for accuracy and two tests for consistency are available. To determine the best distribution type, WS06 - Frequency Analysis uses a 'goodness of fit' test which includes the difference test, modified difference test, chi - square test and modified chi - square test. The 'goodness of fit' test allows the selection of the best distribution type according to the best fitting of the flood data.

Several probability functions can be used for flood frequency analysis. There is no particular probability function which is universally accepted, because of the different regional watershed conditions and climatological factors. However for Australian conditions Australian Rainfall and Runoff (IE.Aust, 1987) recommends the LPIII distribution. McMahon et al. (1981) analysed 172 Australian streams and suggested that the LPIII distribution is the most appropriate for estimation of extreme flood discharges.

The important criteria in selecting the probability function are (Chong et al., 1983):

- It should be a theoretically based function; and
- It should extract the maximum information from the data available.

In this study, ten probability functions were examined to determine the best frequency distribution for the 22 catchments. Eight distribution types were selected for comparison of results (Table 4.1). The distribution types Power Transform Normal and Normal are discarded from final selection. The plotting position is selected according to the IE.Aust (1987) recommendation.

4.2.2 Distribution Undertaken in the Analysis

The following ten different distribution types were fitted to the flood data for each station :

1. Pearson Type III (PT3)
2. Log Pearson Type III (LPIII)
3. Normal (N)
4. Log Normal (LN)
5. Gumbel (G)

6. Potter (P)
7. Log Gumbel (LG)
8. Log Potter (LP)
9. Power Transform Normal (PTN)
10. Fisher Tippett Type III (FTIII)

To estimate the distribution parameters, four main methods are available (Singh, 1986) :

- Method of moments;
- Maximum likelihood method;
- Least square method; and
- Graphical method.

The graphical method relies on the plotting of the observed maximum flood flows on various probability papers to determine the best fitted distribution type to the plotted flood values. The analytical methods rely on computing statistical parameters of the flood series including mean, standard deviation and skew coefficient. The method of moments and maximum likelihood method are the most popular techniques for estimating the function parameters with a computer. In this study, the method of moments is used for the analysis of the probability function. In the method of moments, the sample mean, standard deviation and skew coefficient are used as estimates of the corresponding distribution parameters.

Fitting of the distribution to the data by the method of moments follows the equation (Kopittke et al., 1976b):

$$X(T) = \bar{X} + K(T)\,S \tag{4.1}$$

where,

$\bar{x}$ = mean of peak discharge data

S = standard deviation of data

K(T) = frequency factor for return period T

X(T) = discharge at return period T

The equation 4.1 can be considered as the basis for all the distributions.

The brief description of the distributions are given below (Kopittke et al., 1976b) :

Pearson Type III : This distribution may be regarded as a form of the gamma distribution and uses a three parameter function. The values of K(T) are determined from the exceedance probability and the coefficient of skewness.

Log Pearson Type III : Estimation for this distribution is carried out in the logarithmic domain (base 10) because the distribution is much easier to define in the logarithmic values. The procedure used in practice for this method is to fit a Pearson Type III distribution to the logarithms of the original values. This is a three parameter distribution.

Normal distribution : This method uses a two parameter function and the values of K(T) are determined from exceedance probability. In the Normal distribution the expression is :

$$X(T) = \mu + \sigma K(T) \qquad 4.2$$

where,

σ = standard deviation

μ = mean of data

Log Normal distribution : The Log Normal distribution applies the frequency factor to the logarithms (base 10) of the data. This is a two parameter distribution and a special case of LPIII when the coefficient of skewness is zero.

Gumbel distribution : This is a two parameter Fisher Tippett Extreme value distribution. In the Gumbel distribution the expression is :

$$K(T) = -\frac{\sqrt{6}}{\pi}\left[A + \ln\left(\ln.\frac{T}{T-1}\right)\right]$$

where,

A = Euler's Constant.

The Log Gumbel applies the frequency factor to the logarithms of the data.

Potter distribution : This distribution method is similar to the Gumbel with a correction factor which allows for the number of years of data. For greater than 100 years, the two distributions are nearly identical. The expression is :

$$K(T) = -\frac{\sqrt{6}}{\pi}\left[A + \ln\left(\ln.\frac{T}{T-1}\right)\right](1.2 - 0.002N)$$

The log Potter applies the frequency factor to the logarithms of the data.

Fisher Tippett Type III distribution : This method uses a three parameter Fisher Tippett Extreme Value function which has an upper bound. This is also known as the Weibull distribution.

In the case of the log distributions a usual practice is to calculate the sampling variance or standard error in the log domain and to add some multiple of this quantity to the estimate in the log domain. This is represented in the real domain by the multiplication of the estimate by some factor (NERC, 1975).

4.2.3 Goodness of Fit Test

Fitting of a frequency distribution to flood data for the purpose of estimating floods at different average recurrence interval or annual exceedance probability is a widely used technique. However the main difficulty arises in choosing the appropriate frequency distribution, especially when a number of distribution types fit the flood data equally well. In practice, the choice of distribution for the flood frequency analysis at a site is not easy. The form of the distribution chosen is dependent not only on the method of estimation but also on the choice of 'goodness of fit' index. The numerical measure of 'goodness of fit' is referred to as a 'goodness of fit' index. Therefore the 'goodness of fit' index is useful in discriminating between different distributions for the same application.

Goodness of fit indices have been carried out for 10 distributions on the data for the 22 stations. The tests which have been used to determine the 'goodness of fit' of the distribution to the plotted data are the (Kopittke et al., 1976a) :

- Difference test;
- Modified Difference test;
- Chi - square test; and
- Modified Chi - square test.

For the best 'goodness of fit' greater emphasis is placed on the Difference test and Chi - square test. Because the Modified Difference test uses the bottom half of the flood data and the Modified Chi - square test uses the bottom 80% of the distribution, they are given less attention or importance in choosing the best distribution type. Split record testing was not performed as sufficient length of records of data were not available to carry out this particular test.

In the fitting of a distribution type to the flood data, the 'goodness of fit' test is essential though it is not a sufficient criteria to select the method that will give the best estimation of flood frequencies.

Difference test : The Difference test compares each data element in the ranked series with the theoretical value for the same rank. The summation of the absolute value of the difference is then divided by the mean annual maximum peak discharge.

$$D = \Sigma\left|X_i - X_{i'}\right| / \overline{X}$$

where,

x_i = ith observed value of the flow

$x_{i'}$ = ith theoretical value of the flow for the same rank of $x_{i'}$

$\overline{X}$ = mean of observed flows

The modified difference test follows the same procedure for the difference test as described above but it uses only top half of the ranked data in the analysis. This test is usually performed in addition to the difference test.

Chi - square test : Chi - square test compares the observed and expected frequencies of data points in five equally probability ranges which set the degrees of freedom at 2 for the two parameter distribution and 1 for the three parameter distribution.

The test statistic is :

$$\chi_c^2 = \sum_{i=1}^{k} (O_i - E_i)^2 / E_i$$

where,

k = no of class intervals

O_i = observed no of observations in the ith class interval

E_i = expected no of observations in the ith class interval

The modified Chi - square test is used on the bottom 80% of distribution of ranked data.

4.2.4 Results of Analysis

The 'goodness of fit' test results are shown in Table 4.1. The numbers indicate their position from 'goodness of fit' test. The lower the sum the better. A comparison of results of the ten distributions is given below :

- Log Pearson Type III gives the best fit to the partial series;
- Pearson Type III provides the best fit to the annual series;
- The three parameter distributions fit the data more closely than the two parameter distributions;

- Pearson Type III, Log Pearson Type III, Fisher Tippett Type III, Log Normal distributions fit the data well.
- Normal, Log Gumbel, Log Potter, Gumbel, Potter distributions are poorly fitted to the data.

As LPIII gives a reasonably good fit to both series, it has been selected for the flood frequency analysis. The LPIII distribution is fitted to the logarithms of the flood data. The natural data is first transformed to logarithms and then the statistical parameters (logarithmic mean, standard deviation and skew coefficient) are computed. Other reasons for the selection of the LPIII from the ten distributions are :

- It is the most commonly used distribution type. Computer programs are available for analysis and plotting of data for this particular distribution such as in HYDSYS.
- For Australian condition, it has been proven to be the preferable distribution by different researchers (IE.Aust, 1987, McMahon et al., 1980).

Although it does not give the best results for the annual series data, to be consistent and for the reasons described above, it has been chosen for the regional flood frequency analysis.

TABLE 4.1

Frequency distribution of probability functions

Station No	Partial Series								Annual Series							
	P III	**LP III**	**LN**	**G**	**P**	**LG**	**LP**	**FT**	**P III**	**LP III**	**LN**	**G**	**P**	**LG**	**LP**	**FT**
426503	5	2	4	7	8	1	3	1	2	3	6	4	5	7	8	1
426504	5	1	4	8	7	2	3	6	5	7	2	1	8	3	4	6
426529	5	3	1	4	8	2	7	6	3	5	6	1	4	7	8	2
426530	4	1	5	2	6	8	7	3	1	4	6	5	3	7	8	2
426533	7	3	6	2	8	1	4	5	4	5	6	3	2	7	8	1
426557	4	1	6	7	8	2	5	3	4	5	6	2	1	7	8	3
426558	5	2	6	7	8	3	1	4	2	5	6	1	4	7	8	2
501500	6	2	4	3	8	7	5	1	6	3	5	2	1	7	8	4
502502	2	3	4	7	5	8	6	1	1	2	6	5	3	4	7	8
503502	5	2	7	6	8	1	3	4	1	5	6	4	3	7	8	2
503503	6	5	4	3	8	2	1	7	4	2	3	1	7	5	8	6
503504	2	3	4	1	8	6	7	5	3	4	2	1	7	5	8	6
503506	5	4	1	8	6	2	7	3	2	5	7	1	4	6	8	3
503507	4	1	6	8	7	2	3	5	1	3	2	4	6	5	7	1
503508	6	4	2	8	7	5	1	3	2	5	6	3	4	7	8	1
503509	4	1	6	8	7	3	2	5	4	3	5	6	8	1	2	4
504512	7	6	5	8	1	3	2	4	4	5	6	3	1	7	8	2
504517	5	1	6	7	8	2	3	4	5	1	3	7	8	2	4	6
504518	5	2	1	7	8	3	6	4	3	6	1	2	5	7	8	4
504523	4	1	6	8	7	2	3	5	4	3	6	7	8	2	1	5
505504	5	1	4	7	8	2	3	6	1	3	6	4	5	7	8	2
505517	5	1	4	6	8	3	2	7	3	1	2	5	6	7	8	4
SUM	106	50	96	132	157	70	84	92	65	85	104	72	103	124	153	75

NOTE:

Distribution Type

P III = Pearson type 3
LPIII = Log Pearson type III
LN = Log Normal
G = Gumbel
P = Potter
LG = Log Gumbel
LP = Log Potter
FT = Fisher Tippett type III

4.3 HYDSYS - Computer Package

HYDSYS - a time series data management system is a system for the storage, editing, retrieval and analysis of time series data and related information (Heweston and Daniell, 1988 & HYDSYS, 1990). It runs on IBM PC and compatible microcomputers. Flow data records for each station were obtained on floppy disk from the Engineering and Water Supply Department of South Australia. Information on the data availability and quality was extracted from the HYDSYS archive.

The flow records for all the stations have been analysed using HYDSYS programs. Each station has a database of peak flow values updated by HYPEAKS, a routine program under HYDSYS, which extracts annual, partial and monthly series of peaks in a form suitable for importing into the SERIES and PEAKTIME databases. The databases are used by HYPL3 to perform a LPIII analysis (Heweston and Daniell, 1988 & HYDSYS, 1990). The partial series has been extracted by looking at QMIN and TMIN in the station description databases. According to IE.Aust (1987) the base discharge or QMIN should be selected such that at least N peaks can be extracted from the whole records where N is the no of years of record. The best results are obtained when K = N (IE.Aust, 1987). Therefore QMIN was selected such that the value of K is between N and 2N.

Independent peaks are extracted by selecting TMIN. TMIN is selected on the basis that it is greater than the maximum time separation between the independent peaks. Peaks which exceed QMIN and are spaced TMIN apart or more are considered as independent events and are entered into the series file. When multiple peaks are spaced less than TMIN apart only the highest peak is taken. HYPEAKS ensures that there are the same number of monthly and partial peaks as there are annual peaks as well. This is achieved by discarding excess partial and monthly peaks.

The LPIII analyses are performed using the program HYPL3 according to the method described in IE.Aust (1987) for annual, partial and monthly series. The analysis assumes one peak for each year of record. In cases where peaks have been deleted for some reason, or in cases of zero peaks for annual or partial series, a correction is applied as described in IE.Aust (1987) section 10.7.2.

The LPIII results for both partial and annual series are listed in Table 4.2 and Table 4.3. Most of the stations showed similar values at the ARI of 100 and 200 year for the annual series data, which shows that extrapolations beyond the ARI of 100 years is unreliable due to the short length of records on which the analysis is based.

TABLE 4.2

Peak Discharges at different Average Recurrence Interval (Annual Series) Extracted from LPIII analysis

Station No	Station Name	Average Recurrence Interval in Years							Skew Coefficient	Coefficient of Variation
		2	5	10	25	50	100	200		
426503	Angas River	11.8	2	37.7	62.2	88	122	167	0.636	0.317
426504	Finniss River	41.9	70	88.7	112	128	143	158	-0.539	0.182
426529	Marne River	14.1	43.6	59	70.2	74.6	77	78.2	-1.907	1.171
426530	Currency Creek	9.45	19.8	26	32.5	36.2	39.1	41.4	-1.221	0.569
426533	Bremer River	40.9	93.9	118	136	143	147	149	-1.837	0.504
426557	Mt Barker Creek	20.7	40.6	48.4	53.5	55.3	56.3	56.8	-1.937	0.529
426558	Dawesley Creek	9.39	25.8	36.6	47.7	53.8	58.4	61.8	-1.391	0.889
501500	Hindmarsh River	14.9	27.2	36.3	48.6	58.1	67.7	77.5	-0.363	0.286
502502	Myponga River	10.1	13.7	15.1	16.2	16.6	16.9	17.1	-1.598	0.25
503502	Scott Creek	7.77	12.4	14.3	15.7	16.3	16.6	16.9	-1.686	0.475
503503	Baker Gully	9.88	20.2	28.3	39.7	48.8	58.1	67.9	-0.403	0.406
503504	Onkaparinga River	79	145	191	248	289	327	364	-0.635	0.19
503506	Echunga Creek	11.5	18.2	20.6	22.2	22.9	23.2	23.4	-1.86	0.422
503507	Lenswood Creek	8.99	19.5	28.2	41	51.6	62.8	74.8	-0.358	0.454
503508	Inverbrackie Creek	6.42	11.5	12.6	13	13.1	13.1	13.1	-2.576	1.422
503509	Aldgate River	6.77	10.9	14.4	19.9	24.9	30.7	37.5	0.598	0.269
504512	Torrens River	6.73	22.6	34.1	46.3	53.2	58.3	62.1	-1.428	1.395
504517	First Creek	0.765	2.2	3.93	7.5	11.5	17.1	24.8	0.265	-5.67
504518	Sturt River	5.72	9.16	11.1	13.1	14.4	15.4	16.3	-0.95	0.412
504523	Sixth Creek	16.6	32.5	47.7	73.9	99.4	131	171	0.468	0.262
505504	North Para River	38.2	138	225	340	418	488	549	-1.123	0.587
505517	North Para River	24.1	61	81	97.6	105	110	113	-1.672	0.623

Note: Cv = Coefficeint of variation = $\frac{Sx}{m}$

where, Sx = Logarithmic Standard Deviation of the series
m = Logarithmic Mean of the series

TABLE 4.3

Peak Discharges at different Average Recurrence Interval (Partial Series) extracted from LPIII Analysis

Station No	Station Name	Average Recurrence Interval in Years							Skew Coefficient	Coefficient of Variation
		2	5	10	25	50	100	200		
426503	Angas River	18.3	30.6	42.4	62.9	83.2	108.8	141	0.995	0.187
426504	Finniss River	40.9	59.4	77.6	109	141	181.4	233	1.688	0.106
426529	Marne River	27.5	32.8	37.1	43.2	48.4	54.1	60.4	1.481	0.057
426530	Currency Creek	14.9	18.7	21.1	24.2	26.4	28.7	31	0.216	0.096
426533	Bremer River	57.1	81.4	98.7	122	140	159	179	0.194	0.101
426557	Mt Barker Creek	23.6	34.7	43.7	57.1	68.7	81.9	96.8	0.675	0.133
426558	Dawesley Creek	16.3	25.7	34	47.4	60	74.9	92.9	0.859	0.174
501500	Hindmarsh River	21.2	29.3	35.5	44.4	51.8	60	68.8	0.634	0.117
502502	Myponga River	12	12.9	13.3	13.8	14.2	14.5	14.7	-0.167	0.034
503502	Scott Creek	8.6	11.1	13.1	16.1	18.6	21.4	24.6	1.184	0.124
503503	Baker Gully	17	24.2	30	38.4	45.6	53.6	62.6	0.675	0.137
503504	Onkaparinga River	123.2	166	195	233	261	291	321	0.179	0.072
503506	Echunga Creek	13.3	17.7	21.2	26.2	30.5	35.2	40.4	0.898	0.119
503507	Lenswood Creek	11.7	18.6	25.1	36.4	47.4	61.3	78.7	1.142	0.197
503508	Inverbrackie Creek	7	10.5	13.7	18.7	23.4	29.1	35.8	1.033	0.218
503509	Aldgate River	7.8	11.1	14.2	19.5	24.5	30.7	38.4	1.513	0.178
504512	Torrens River	17.1	21.4	24.1	27.5	30	32.5	35	0.159	0.091
504517	First Creek	1.4	2.4	3.7	6.75	10.7	17	27	2.252	1.196
504518	Sturt River	7	9	10.7	13.3	15.6	18.3	21.3	1.476	0.134
504523	Sixth Creek	18	31	45	71.8	101	141	197	1.446	0.192
505504	North Para River	65.3	114	168	272	389	551	778	1.478	0.139
505517	North Para River	23.7	40.3	64.8	127	217	375	655	2.839	0.185

4.4 Checking Results of WS06 with those of HYDSYS

LPIII curves were drawn using HYLP3, a routine program under HYDSYS archive. The peak flow values at different recurrence interval ranges from 2 years to 200 years obtained from HYLP3 are compared with those obtained from WS06 flood frequency analysis. Both of the computer packages give similar flood frequency analysis for LPIII distribution for both annual and partial series. WS06 also provides the analyses of other distribution types which was not possible to check against HYDSYS as HYDSYS has provision of analysing only for the LPIII distribution.

4.5 Relationship between 10, 25, 50, and 100 Year ARI Peak Flows

An effort has been made to establish a relationship between the 25, 50 and 100 year ARI discharges with the 10-year ARI discharge to calculate 25, 50, and 100 year ARI peak flows from 10-year ARI peak flow quickly for ungauged catchments. Table 4.4 shows the relationship for annual series and Table 4.5 for partial series. The results from Table 4.5 are summarised below:

$$Q_{25} = Q_{10} * 1.4$$

$$Q_{50} = Q_{10} * 1.7$$

$$Q_{100} = Q_{10} * 2.2$$

TABLE 4.4

Annual series discharges from flood frequency analysis(LPIII distribution)

Station No.	10 - Year Flood (Q10) (Cumecs)	25 - Year Flood (Q25) (Cumecs)	50 - Year Flood (Q50) (Cumecs)	100 - Year Flood (Q100) (Cumecs)	Ratio (Q25/Q10)	Ratio (Q50/Q10)	Ratio (Q100/Q10)	Q10*1.31 Calculated (Q25) (Cumecs)	Q10*1.55 Calculated (Q50) (Cumecs)	Q10*1.81 Calculated (Q100) (Cumecs)
426503	37.7	62.2	88	122	1.65	2.33	3.24	49.39	58.44	68.24
426504	88.7	112	128	143	1.26	1.44	1.61	116.20	137.49	160.55
426529	59	70.2	74.6	77	1.19	1.26	1.31	77.29	91.45	106.79
426530	26	32.5	36.2	39.1	1.25	1.39	1.50	34.06	40.30	47.06
426533	118	136	143	147	1.15	1.21	1.25	154.58	182.90	213.58
426557	48.4	53.5	55.3	56.3	1.11	1.14	1.16	63.40	75.02	87.60
426558	36.6	47.7	53.8	58.4	1.30	1.47	1.60	47.95	56.73	66.25
501500	36.3	48.6	58.1	67.7	1.34	1.60	1.87	47.55	56.27	65.70
502502	15.1	16.2	16.6	16.9	1.07	1.10	1.12	19.78	23.41	27.33
503502	14.3	15.7	16.3	16.6	1.10	1.14	1.16	18.73	22.17	25.88
503503	28.3	39.7	48.8	58.1	1.40	1.72	2.05	37.07	43.87	51.22
503504	191	248	289	327	1.30	1.51	1.71	250.21	296.05	345.71
503506	20.6	22.2	22.9	23.2	1.08	1.11	1.13	26.99	31.93	37.29
503507	28.2	41	51.6	62.8	1.45	1.83	2.23	36.94	43.71	51.04
503508	12.6	13	13.1	13.1	1.03	1.04	1.04	16.51	19.53	22.81
503509	14.4	19.9	24.9	30.7	1.38	1.73	2.13	18.86	22.32	26.06
504512	34.1	46.3	53.2	58.3	1.36	1.56	1.71	44.67	52.86	61.72
504517	3.93	7.5	11.5	17.1	1.91	2.93	4.35	5.15	6.09	7.11
504518	11.1	13.1	14.4	15.4	1.18	1.30	1.39	14.54	17.21	20.09
504523	47.7	73.9	99.4	131	1.55	2.08	2.75	62.49	73.94	86.34
505504	225	340	418	488	1.51	1.86	2.17	294.75	348.75	407.25
505517	81	97.6	105	110	1.20	1.30	1.36	106.11	125.55	146.61
Average Ratio					1.31	1.55	1.81			

TABLE 4.5

Partial series discharges from flood frequency analysis(LPIII distribution)

Station No.	10 - Year Flood (Q10) (Cumecs)	25 - Year Flood (Q25) (Cumecs)	50 - Year Flood (Q50) (Cumecs)	100 - Year Flood (Q100) (Cumecs)	Ratio (Q25/Q10)	Ratio (Q50/Q10)	Ratio (Q100/Q10)	Q10*1.36 Calculated (Q25) (Cumecs)	Q10*1.73 Calculated (Q50) (Cumecs)	Q10*2.24 Calculated (Q100) (Cumecs)
426503	42.4	62.9	83.2	108.8	1.48	1.96	2.57	57.66	73.35	94.98
426504	77.6	109	141	181.4	1.40	1.82	2.34	105.54	134.25	173.82
426529	37.1	43.2	48.4	54.1	1.16	1.30	1.46	50.46	64.18	83.10
426530	21.1	24.2	26.4	28.7	1.15	1.25	1.36	28.70	36.50	47.26
426533	98.7	122	140	159	1.24	1.42	1.61	134.23	170.75	221.09
426557	43.7	57.1	68.7	81.9	1.31	1.57	1.87	59.43	75.60	97.89
426558	34	47.4	60	74.9	1.39	1.76	2.20	46.24	58.82	76.16
501500	35.5	44.4	51.8	60	1.25	1.46	1.69	48.28	61.42	79.52
502502	13.3	13.8	14.2	14.5	1.04	1.07	1.09	18.09	23.01	29.79
503502	13.1	16.1	18.6	21.4	1.23	1.42	1.63	17.82	22.66	29.34
503503	30	38.4	45.6	53.6	1.28	1.52	1.79	40.80	51.90	67.20
503504	195	233	261	291	1.19	1.34	1.49	265.20	337.35	436.80
503506	21.2	26.2	30.5	35.2	1.24	1.44	1.66	28.83	36.68	47.49
503507	25.1	36.4	47.4	61.3	1.45	1.89	2.44	34.14	43.42	56.22
503508	13.7	18.7	23.4	29.1	1.36	1.71	2.12	18.63	23.70	30.69
503509	14.2	19.5	24.5	30.7	1.37	1.73	2.16	19.31	24.57	31.81
504512	24.1	27.5	30	32.5	1.14	1.24	1.35	32.78	41.69	53.98
504517	3.7	6.75	10.7	17	1.82	2.89	4.59	5.03	6.40	8.29
504518	10.7	13.3	15.6	18.3	1.24	1.46	1.71	14.55	18.51	23.97
504523	45	71.8	101	141	1.60	2.24	3.13	61.20	77.85	100.80
505504	168	272	389	551	1.62	2.32	3.28	228.48	290.64	376.32
505517	64.8	127	217	375	1.96	3.35	5.79	88.13	112.10	145.15
Average Ratio					1.36	1.73	2.24			

Chapter 5

Estimation of Flood Peaks from Catchment Characteristics

5.1 Introduction

To estimate flood flows on an ungauged site, the regional flood flow analysis is a widely used method. Regional regression methods are developed using correlation analysis of peak flood flows at gauged sites against measured basin characteristics. This correlation analysis can be carried out either by using statistical correlation techniques or by using graphical methods.

Results of the multiple correlation technique can be represented either in the form of equations or in entirely graphical form, such as a set of curves covering all the necessary relations. Graphical methods have been used in many regional studies. It is the simplest method of applying the results to the ungauged catchments. In most of the studies it is found that the peak flows are strongly correlated with drainage area.

In this study, a relationship has been established between flood peaks and catchment characteristics in the Mt Lofty Ranges. Previous investigations in South Australia have been limited and based on the probabilistic rational method (EWS Report No. 26, 1986), relating mean annual flood to catchment area and rainfall intensity. In this study many characteristics of the catchment, physical and meteorological, which could influence the flood flows have been considered. A set of equations have been derived from which the flood at a given recurrence interval can be deduced. Although the estimation by use of an indirect method is less reliable than those based on the direct analysis of records at a site, it is the best available method for ungauged sites.

In this study, regression analysis has been carried out for both annual and partial series. The coefficient of variation (Cv) and the skew coefficient (Sk) have been included in the analysis to enhance the equations. When the number of years of record at a site is not very long then any additional information about the flood regime that can be added through the catchment characteristics can be of benefit.

After establishing a regression model which gives an adequate fit to the data, it is necessary to check the validity of the model before it is used in practice. Data splitting or cross validation can be an effective method of evaluating a regression model. A duplex data splitting* algorithm has been described in Snee (1977) can be useful. In this study, due to scarcity of data, it was not possible to carry out a splitting test. All of the stations have been used in regression model and tested on 3 other stations.

It might be possible for the developed model to give a good fit to the known data and a poor prediction of new data. To have a very good model, a large data base of flow records is required to develop and test the model, particularly if a large number of predictor variables are used.

5.2 Choice of Catchment Characteristics

The choice of catchment characteristics to be used in the regression analysis has been made by careful consideration of the factors which could contribute most in determining the size of flood peaks.

After precipitation reaches the ground in any form, physical characteristics of the basin are responsible to convert it to runoff. Although meteorological factors such as temperature, wind and evaporation may have effects on the runoff, it is generally controlled by topographic characteristics of the basin. Among these characteristics some are stable such as area, stream length, stream slope, while others such as % forest, % urbanisation are variable.

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* Data splitting : The reasonable way to proceed is to split the data into half by two sets. The first set of data is called estimation data which is used to estimate the model coefficient and the second half or remaining data is called prediction data which is used to measure the prediction accuracy of the model (Snee, 1977).

A set of hydrologic factors which are completely independent are preferable, but this is not always possible. Drainage area appears to be the most important variable. Higher peak flows generally occur from larger areas as the volume of rain that falls on it, is larger than from smaller catchments. Most of the other variables that are chosen may be related or dependent on drainage area except rainfall which is a climatic factor. The magnitude of rainfall can be considered as independent of the catchment but average rainfall intensity varies with the size of the drainage area and rainfall intensity distribution varies with the topography of the basin.

A strong correlation has been found between the area and length of a basin and therefore length is not considered in the regression analysis in this study. The interdependent factors in multiple regression analysis can lead to invalid and illogical relationships. There is some degree of mutual interdependence existing between climatic and topographic factors and the topographic factors are also interrelated (Benson, 1964). Because of their interdependence, it is sufficient to consider only one or two factors instead of many, for a good correlation analysis.

In this study, eight regression equations have been evaluated using different variables for a range of average recurrence intervals including 2, 5, 10, 25, 50, 100, and 200 years. Some variables have not been considered because of unavailability or the fact that they are difficult to collect such as soil type index, soil moisture and other soil characteristics. The interpretation of the regression coefficients might be simpler when the independent variables are uncorrelated.

5.2.1 Topographic Characteristics

The most influential factor in determining the size of flood peaks, from the topographic characteristics was the drainage area of the basin. The other factors which have been used in the regression analysis are : slope of the basin, shape of the basin, %forest, %urban, %rural and %lakes. Fall across the catchment is another factor which is highly correlated with area and has not been included in the analysis.

Drainage area : The catchment areas of the region used in this study were available from the report by Glatz (1985) in km^2. The range of catchment areas in this study vary from First Creek at 5.01 km^2 to North Para River at 708 km^2. Because there are many artificial storages such as farm dams in the drainage area, it is possible that a large portion of area is non contributing to the flood peak upto a particular average recurrence interval.

The drainage area, as expected, was found to be very significant and the most important variable affecting the peak discharge.

Length of basin : The length of a basin can be defined as the longest straight line that may be drawn from the outlet to the watershed boundary or the length of the longest watercourse in the basin, The latter definition has been adopted in this study. The length was measured by opisometer from 1:50000 topographic map prepared by "The Department of Lands". To measure the length is quite difficult especially where meandering of rivers is extreme. Maps of the same area, but having different scale or dates, show varying degrees of meandering and there is no consistent ratios to convert stream lengths from one map scale to another. Lengths from this study have been measured from the same scale map but from different editions. Generally the water flows over the flood plain in a shorter path than that followed by water within the main river channel, hence an effective length is somewhat shorter than the meander length and varies with the stage (Benson, 1964).

Length and drainage area are highly correlated and although the length is not used in regression analysis it was measured to calculate the slope of the basin.

Mean channel slope : Channel slope appears to be the next most important variable to drainage area in estimating peak discharge. There is no unique or universally accepted way of evaluating slope. Some hydrologists have used the total drop from the head of the longest watercourse to the catchment outlet which is called 'average area slope' (Sa), which is used in the analysis. Some studies have used 'equal area slope' (Se) while others have used segments of the main channel, such as the lower three-quarters (Bernard et al., 1960). Some studies have used '85-10 percent slope' method (slope between 85 and 10 percent above the gauged outlet) in order to evaluate slope along the main channel (Benson, 1964). The simplest method of expressing slope of the basin is to divide the difference in elevation between the upper and lower end of the channel by the length of the channel.

In this study the slope has been taken as ratio of the change of altitude and length. Where length is measured along the longest watercourse.

Change in Altitude : The change in altitude or fall is a factor which has no direct influence on flood peaks. There are some factors which are not easily evaluated but may vary with fall, so the fall acts as a surrogate of their combined effect (Benson, 1964). Because of these other related factors the fall might show some relation to the variation in flood peaks.

In this study, fall has not been used in regression equation, but it has been calculated to evaluate slope. The fall has been calculated from the difference of the contour value at the head of the longest watercourse and at the gauging point for each catchment. The contour interval was 10 meters for the topographic map of scale 1:50,000.

Basin shape : The basin shape is determined from the ratio of length and area (L/A). The basin shape is not significantly related to the peak flows when compared with drainage area and length. In the regression analysis if both area and length are used, then shape does not add any further information as area and length provide the measure of shape of the basin. In the regression analysis of this study, basin shape has been used instead of length. Shape factor (L/A^2) which is a measure of shape could also be used as a factor. From this investigation basin shape was found to be more significant than the shape factor which was then discarded.

Land cover : The land cover for each catchment such as %forest, %rural, %urbanisation, %lakes was collected from The Department of Environment and Planning. Softwood, hardwood and natural vegetation were included in the %forest, while orchards, vineyards, non irrigated and irrigated crops, and pasture are included in the %rural factor. The land cover has been expressed in percentage area. It should be noted that both the character and areal extent of land use varies with time.

Studies have shown that urbanisation increases the peak discharge, by a significant amount (Knee, 1990), whereas certainly there is a relationship between amount of forest cover on the catchment and the peak rate of discharge. It was however, decided that urbanisation and forestry are the more likely land use classes to affect floods.

Artificial or natural storages can effectively reduce the rate of peak discharge. Such storages include lakes, ponds, swamps and reservoirs and are expressed as %lake or the surface area of water as a percentage of the total area. The number of lakes, ponds, reservoirs can be measured from maps whereas the size or volume of storages can vary with the seasons of year and from year to year. Their extent depends on the publication data of the map and on the mapping standard.

5.2.2 Meteorological Characteristics

Besides the physical characteristics, the meteorological characteristics are also considered in predicting the peak discharge. There are a number of meteorological characteristics such as average annual rainfall, intensity, number of rain days, temperature and evaporation that could be considered. In this study only average annual rainfall has been considered.

Average annual rainfall : Rainfall is the meteorological factor from which runoff results. Precipitation varies during individual storms, from year to year and from place to place. The average annual rainfall has been preferred in the regression equation as a measure of rainfall.

Average annual rainfall for each drainage basin has been determined from the isohyetal map prepared by the EWS at a scale of 1:100,000. The average annual rainfall values were estimated at the centre of each drainage basin.

Other variables : The number of farm dams, the coefficient of skewness and the coefficient of variation were also considered in predicting the peak discharge. Among these the number of farm dams has a good correlation with the peak discharge and it seems to have a considerable influence on the flood flows. The number of farm dams therefore was considered as one of the factors affecting flood occurrence although the actual numbers were difficult to obtain. The number of farm dams were determined using the 1:50,000 topographic map series. The extent of farm dams depended on when the map was made.

The number of farm dams has increased significantly each year because of the increased population, new farms, and extension of existing farms. Most of the available maps were published in 1980 or before that period. It was therefore difficult to get a count of the correct number of farm dams. The method to get the best count of farm dams would be from recent photography of the catchment areas. This was not done in this research work. For this study, the number of farm dams have been assessed from two different editions of maps. From the rate of increase in each year a rough estimation of farm dams at the end of 1990 has been made. The coefficient of variation and the coefficient of skewness are estimated from the analysis of maximum flood values.

TABLE 5.1

Range of catchment variables used in this study

Catchment characteristics	Unit	Maximum	Minimum
Area (A)	km^2	708	5.01
Avg. Annual Rainfall (R)	mm	1100	520
Length (L)	km	78.5	3.5
Slope (S)	m/km	82.9	4.4
Fall (Fa)	m	467	69
No. of Farm Dams (D)		2320	7
%Forest (F)	%	92.8	0.04
%Urban (U)	%	56.2	0
%Rural (Ru)	%	99.7	2.84
%Lakes (La)	%	1.35	0
Basin Shape (Sh)	km^{-1}	0.7	0.106

Note : As log values used in regression analysis, the zero values of U has been replaced by small amount such as .001 to eliminate logs of zero.

5.3 Regression Analysis of Flood Quantiles with Catchment Characteristics

In this section the equation relating the flood quantiles to the catchment characteristics is described. The method used to derive the relationship is multiple linear regression. Multiple linear regression is an expression of simple regression to fit a straight line to the experimental data. The general equation that has been adopted in this study which includes all statistically significant variables is in the form :

$$Q_T = a\, A^b\, R^c\, S^d\, D^e\, Sh^f\, F^g\, U^h\, Ru^i\, La^j\, Sk^k\, Cv^l \qquad 5.1$$

where a is the regression constant, b,c,d,e,f,g,h,i,j,k,l are the regression coefficients and T is the recurrence interval.

Q_T = Predicted peak discharge at recurrence interval, T

A = Catchment Area (km^2)

R = Average Annual Rainfall (mm)

S = Basin Slope (m/km)

D = Number of Farm Dams

Sh = Basin Shape (Le/A)

F = Percent Forest (%)

U = Percent Urbanisation (%)

Ru = Percent Rural (%)

La = Percent Lake (%)

Sk = Coefficient of Skewness

Cv = Coefficient of Variation

The parameters described above are the independent variables used in the analysis. The dependent variable used in each regression was the flood peak discharge of a specified return period of 2, 5, 10, 25, 50, 100, and 200 years. The flood peak discharges were calculated by fitting the LPIII distribution to both the annual series and partial series. The LPIII frequency curves have been drawn using HYDSYS.

The multiple regression method provides a set of equations for calculating the peak discharges at different recurrence intervals using appropriate topographic and meteorological variables for the ungauged catchments. The best equation is the one containing the maximum number of independent variables although other equations can be used depending on the availability and reliability of the independent variables. If the specified return period for design is not given for the derived equation, the design flood peak can be obtained by calculating the flood frequency curve for the particular ungauged catchment. The desired peak value at a certain recurrence interval can be derived from the curve.

In hydrological analyses, the logarithms of the variables are often used in the regression equation. From various studies it is known that peak flow discharges are linearly related to the basin characteristics if the logarithms of each are used (Dalrymple, 1960, Acreman, 1985). Therefore, discharges at each recurrence interval and the basin characteristics are transformed to the logarithms before the calculations are performed.

To make the above non linear equation into linear form, the following equation can be written,

$$\text{Log } Q_T = \text{Log } a + b \text{ Log } A + c \text{ Log } R + d \text{ Log } s + \ldots + l \text{ Log } Cv. \qquad 5.2$$

Both the multiple regression analysis and the correlation analysis have been carried out using the software package SAS, a suite of statistical computer programs (SAS, 1988).

The first question after fitting a regression is "how good is it ?" There are several ways of describing the goodness of fit of the regression equation. It can be described by the coefficient of determination (R^2), the standard error of the regression (SE), or the prediction error (PE).

The strength of the relationship between the flood peaks and the various independent variables is measured by the standard error of estimate. This represents the degree to which the variation in flood peaks may be explained or alternatively how well the peak discharges estimated from the regression equation approximate the observed peak discharges used in the regression analysis.

As a measure of the association of the variables, the standard error of the regression (SE) was used. The standard error SE is defined as the square root of the ratio of the residual (actual values minus estimated values) to the calculated value. It was computed as a percentage of the calculated LPIII values as follows :

$$SE\,(\%) = 100 * \left\{ \frac{[\,(Q_{LP3} - Q_{est})\,/\,Q_{LP3}\,]^2}{N} \right\}^{0.5} \qquad 5.3$$

where,

N = number of observations

Q_{est} = estimated discharge from regression equation

Q_{LP3} = calculated discharge from LPIII distribution

The set of regression equations from SAS output for the different variables at different recurrence intervals are listed in Table 5.2 for the annual series and Table 5.3 for the partial series. The eight equations that have been derived using different combinations of independent variables are listed below :

Name of Method	Independent variables
Method 1	A
Method 2	A, S
Method 3	A, R, S
Method 4	A, Sk, Cv
Method 5	A, S, Sh
Method 6	A, R, S, D, Sh
Method 7	A, S, Sh, F, U, Ru, La
Method 8	A, R, S, D, Sh, F, U, Ru, La, Sk, Cv

Multiple regression is a purely statistical technique, although care has been taken in choosing independent variables on hydrologic grounds. There is a problem in using the regression equation in the estimation of a peak discharge at a given site when the values of the independent variables are outside the range of values used in the regression analysis. Extrapolation beyond the observed range of the independent variables can be considered to be risky and the applicability of the derived equations beyond the range of these values is unknown.

The regression equation is also not applicable to rivers which are affected significantly by regulation, diversions, and dams. The peak discharge at any site can be computed using the derived equations. The prediction ability of the regression equations can be improved by dividing the study area into hydrologic regions in which the basin characteristics in each region are similar.

The main advantage of the multiple regression method is that individual flood frequency distributions can be obtained for each catchment. The computed flood peaks for different recurrence intervals from the regression equations are listed in Table 5.4 for the annual series and Table 5.5 for the partial series.

TABLE 5.2

Regression Equations (Annual Series)

Recurrence Interval, T in Years	Number of Stations	Independent Variables Included	Log a	a	b	c	d	e	f	g	h	i	j	k	l	Observed Values for stat.426503 (Cumecs)	Computed Values (Cumecs)	Residual Values	Standard error (%)
2 ——	426503	A	0.01789	1.0421	0.61793											11.8	13.03	-1.23	2.22
		A, S	0.5241	3.3427	0.4963	-0.2603											12.41	-0.61	1.10
		A, R, S	-2.9061	0.001241	0.5653	1.1882	-0.3802										11.99	-0.19	0.35
		A, Sk, Cv	0.1096	1.287064	0.485	0.139	-0.4993										15.57	-3.77	6.82
		A, S, Sh	0.55943	3.626018	0.3911	-0.2614	-0.2697										12.15	-0.35	0.63
		A, R, S, D, Sh	-2.7814	0.001654	0.32464	1.0772	-0.289	0.12705	-0.367								12.43	-0.63	1.13
		A, S, Sh, F, U, Ru, La	-0.338	0.459198	0.45546	-0.11883	0.1011	0.0567	0.0797	0.49736	0.0884						16.40	-4.60	8.31
		A, R, S, D, Sh, F, U, Ru, La, Sk, Cv	-2.3962	0.004016	0.521	0.8254	-0.1827	0.00324	0.1846	-0.0833	0.0606	0.2854	0.0258	-0.102	-0.276		17.55	-5.75	10.39
5 ——		A	0.2512	1.7832	0.66817											24.4	27.38	-2.98	2.60
		A, S	0.6298	4.263831	0.5772	-0.1947											26.40	-2.00	1.75
		A, R, S	-0.184	0.654636	0.5936	0.2818	-0.2231										26.19	-1.79	1.56
		A, Sk, Cv	0.2817	1.912934	0.62	0.03565	-0.1888										29.49	-5.09	4.45
		A, S, Sh	0.6897	4.894406	0.399	-0.1965	-0.457										25.47	-1.07	0.93
		A, R, S, D, Sh	-0.184	0.654636	0.3344	0.2123	-0.1744	0.0683	-0.5285								26.01	-1.61	1.40
		A, S, Sh, F, U, Ru, La	0.041	1.099006	0.569	0.02345	-0.0063	-0.0177	0.0528	0.2698	0.114						33.01	-8.61	7.53
		A, R, S, D, Sh, F, U, Ru, La, Sk, Cv	-3.4037	0.000395	0.81218	1.0767	-0.152	-0.155	0.203	-0.0773	0.07165	0.6151	0.0466	-0.321	0.1999		34.42	-10.02	8.75
10 ——		A	0.37894	2.392985	0.6667											37.7	36.52	1.18	0.67
		A, S	0.5078	3.219586	0.636	-0.066											36.07	1.63	0.92
		A, R, S	-0.0434	0.904899	0.64685	0.19095	-0.08556										35.88	1.82	1.03
		A, Sk, Cv	0.3601	2.291395	0.663	-0.1126	-0.0815										39.76	-2.06	1.17
		A, S, Sh	0.5772	3.777461	0.429	-0.0683	-0.53										34.59	3.11	1.76
		A, R, S, D, Sh	0.0978	1.252564	0.3861	0.1381	-0.0535	0.0452	-0.5772								35.08	2.62	1.48
		A, S, Sh, F, U, Ru, La	0.1409	1.383248	0.66	0.1543	0.00032	-0.025	0.0375	0.1382	0.159						44.13	-6.43	3.63
		A, R, S, D, Sh, F, U, Ru, La, Sk, Cv	-3.5438	0.000286	0.93124	1.1152	-0.1286	-0.2033	0.26905	-0.075	0.0774	0.6882	0.0683	-0.495	0.3465		47.41	-9.71	5.49
25 ——		A	0.52577	3.3556	0.6464											62.2	47.13	15.07	5.17
		A, S	0.2966	1.9797	0.7014	0.1178											48.17	14.03	4.81
		A, R, S	-0.52482	0.2987	0.71796	0.2845	0.08915										47.78	14.42	4.94
		A, Sk, Cv	0.446	2.7925	0.689	-0.3171	0.0045										53.60	8.60	2.95
		A, S, Sh	0.373	2.3605	0.474	0.1156	-0.5832										46.00	16.20	5.55
		A, R, S, D, Sh	-0.3878	0.4094	0.4676	0.2497	0.10426	0.0217	-0.5964								46.11	16.09	5.52

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TABLE 5.2 (Continued)

Regression Equations (Annual Series)

Recurrence Interval, T in Years	Number of Stations	Independent Variables Included	Log a	a	b	c	d	e	f	g	h	i	j	k	l	Observed Values for stat.426503 (Cumecs)	Computed Values (Cumecs)	Residual Values	Standard error (%)
		A, S, Sh, F, U, Ru, La	0.2085	1.6162	0.7714	0.32055	0.05	-0.0175	0.02086	-0.0095	0.2215						57.76	4.44	1.52
		A, R, S, D, Sh, F, U, Ru, La, Sk, Cv	-3.3989	0.0004	1.0348	1.0857	-0.103	-0.2357	0.3772	-0.0747	0.0837	0.7053	0.0955	-0.7092	0.4421		65.61	-3.41	1.17
50 —		A	0.6282	4.2482	0.6236											88	54.36	33.64	8.15
		A, S	0.131	1.3521	0.743	0.2557											57.00	31.00	7.51
		A, R, S	-1.05627	0.0878	0.7668	0.41127	0.2142										56.33	31.67	7.67
		A, Sk, Cv	0.507	3.2137	0.6953	-0.464	0.0476										64.36	23.64	5.73
		A, S, Sh	0.2093	1.6192	0.5098	0.25336	-0.5975										54.38	33.62	8.15
		A, R, S, D, Sh	-0.9268	0.1184	0.532	0.3884	0.2186	0.0069	-0.5857								54.00	34.00	8.24
		A, S, Sh, F, U, Ru, La	0.2314	1.7037	0.8501	0.4395	0.1084	-0.0078	0.0108	-0.1038	0.266						67.66	20.34	4.93
		A, R, S, D, Sh, F, U, Ru, La, Sk, Cv	-3.1415	0.0007	1.0894	1.0236	-0.0836	-0.2465	0.4691	-0.07614	0.0883	0.6897	0.1134	-0.8554	0.47503		80.43	7.57	1.83
100 —		A	0.72314	5.2862	0.5986											122	61.07	60.93	10.65
		A, S	-0.03406	0.9246	0.7804	0.3894											65.66	56.34	9.85
		A, R, S	-1.62756	0.0236	0.8125	0.55196	0.3337										64.62	57.38	10.03
		A, Sk, Cv	0.563	3.6559	0.6966	-0.604	0.0826										75.35	46.65	8.15
		A, S, Sh	0.04604	1.1118	0.5418	0.387	-0.6115										62.56	59.44	10.39
		A, R, S, D, Sh	-1.50608	0.0312	0.594	0.5413	0.3273	-0.0081	-0.5735								61.54	60.46	10.57
		A, S, Sh, F, U, Ru, La	0.2486	1.7726	0.9198	0.5513	0.1598	0.00227	0.00173	-0.1922	0.3062						77.07	44.93	7.85
		A, R, S, D, Sh, F, U, Ru, La, Sk, Cv	-2.7633	0.0017	1.1228	0.9302	-0.0656	-0.2484	0.5458	-0.0798	0.0921	0.6517	0.12816	-0.9896	0.4843		96.01	25.99	4.54
200 —		A	0.81473	6.5272	0.57175											167	67.57	99.43	12.69
		A, S	-0.195	0.6383	0.8142	0.5192											74.42	92.58	11.82
		A, R, S	-2.2297	0.0059	0.85516	0.70482	0.4481										72.92	94.08	12.01
		A, Sk, Cv	0.6183	4.1524	0.6934	-0.736	0.1099										86.94	80.06	10.22
		A, S, Sh	-0.1147	0.7679	0.5752	0.517	-0.6125										70.91	96.09	12.27
		A, R, S, D, Sh	-2.1185	0.0076	0.6567	0.7059	0.4317	-0.0221	-0.5492								69.09	97.91	12.50
		A, S, Sh, F, U, Ru, La	0.2588	1.8147	0.986	0.657	0.2184	0.0133	-0.0062	-0.2725	0.3433						86.52	80.48	10.27
		A, R, S, D, Sh, F, U, Ru, La, Sk, Cv	-2.3159	0.0048	1.1455	0.8177	-0.0479	-0.244	0.6236	-0.084	0.0957	0.6019	0.1409	-1.11276	0.4783		112.90	54.10	6.91

NOTE:
A : Basin Area
R : Average Annual Rainfall
S : Basin Slope
D : Number of Farm Dams
Sh : Basin Shape
F : % Forest
U : % Urban
Ru : % Rural
La : %Lake
Sk : Coefficient of Skewness
Cv : Coefficient of Variation
a,b,c,d,e,f,g,h,i,j,k,l : Regression Coefficients

TABLE 5.3

Regression Equations (Partial Series)

Recurrence Interval,T in Years	Number of Stations	Independent Variables Included	Log a	a	b	c	d	e	f	g	h	i	j	k	l	Observed Values for stat. 426504 (Cumecs)	Computed Values (Cumecs)	Residual values	Standard error (%)
2 ——	426504	A	0.133	1.358313	0.633											40.9	37.75	3.15	1.64
		A, S	0.4884	3.078931	0.55	-0.183											41.65	-0.75	0.39
		A, R, S	-1.3604	0.043611	0.5846	0.6404	-0.2474										50.80	-9.90	5.16
		A, Sk, Cv	0.1105	1.289734	0.5847	-0.0911	-0.1111										34.02	6.88	3.59
		A, S, Sh	0.5585	3.618262	0.3387	-0.185	-0.535										41.69	-0.79	0.41
		A,R, S, D, Sh	-1.1404	0.072377	0.16543	0.479	-0.12014	0.17753	-0.7243								47.07	-6.17	3.21
		A, S, Sh, F, U, Ru, La	-0.2437	0.570558	0.5285	0.07756	-0.0522	0.04054	0.03784	0.324	0.182						38.82	2.08	1.09
		A, R, S, D, Sh, F, U, Ru, La, Sk, Cv	-5.197	6.35E-06	0.9513	1.6062	-0.0217	-0.2875	0.0373	-0.0147	0.0085	0.7077	0.064	-0.1737	0.4401		40.45	0.45	0.24
5 ——		A	0.2987	1.989299	0.6277											59.4	53.77	5.63	2.02
		A, S	0.4967	3.13834	0.58	-0.1018											56.83	2.57	0.92
		A, R, S	-1.1051	0.078505	0.6124	0.555	-0.158										67.51	-8.11	2.91
		A, Sk, Cv	0.3424	2.139885	0.6387	-0.0671	0.0805										50.77	8.63	3.10
		A, S, Sh	0.546	3.515604	0.434	-0.1033	-0.3746										56.87	2.53	0.91
		A,R, S, D, Sh	-0.9367	0.115691	0.29	0.4215	-0.051	0.15	-0.533								63.34	-3.94	1.42
		A, S, Sh, F, U, Ru, La	-0.08525	0.821769	0.6794	0.1403	0.2467	0.0149	0.0505	0.255	0.203						52.31	7.09	2.54
		A, R, S, D, Sh, F, U, Ru, La, Sk, Cv	-5.751	1.77E-06	1.029	1.8292	-0.027	-0.328	-0.02223	-0.0177	0.00681	0.85	0.0559	-0.1665	0.7446		60.59	-1.19	0.43
10 ——		A	0.4162	2.607354	0.6198											77.6	67.61	9.99	2.75
		A, S	0.501	3.169567	0.5994	-0.0436											69.23	8.37	2.30
		A, R, S	-0.8778	0.132495	0.6271	0.4776	-0.0918										80.30	-2.70	0.74
		A, Sk, Cv	0.5033	3.186398	0.6785	-0.0245	0.221										67.66	9.94	2.73
		A, S, Sh	0.5313	3.3986	0.5093	-0.0445	-0.231										69.26	8.34	2.29
		A,R, S, D, Sh	-0.7771	0.167071	0.4343	0.398	-0.0277	0.0894	-0.3182								77.29	0.31	0.09
		A, S, Sh, F, U, Ru, La	0.10165	1.263718	0.7864	0.1641	0.468	-0.0092	0.058	0.1733	0.2067						63.45	14.15	3.89
		A, R, S, D, Sh, F, U, Ru, La, Sk, Cv	-6.1561	6.98E-07	1.0867	2.019	-0.0535	-0.37	-0.0886	-0.0225	0.0003	0.922	0.0487	-0.135	0.9577		82.64	-5.04	1.39
25 ——		A	0.5692	3.708515	0.6057											109	89.29	19.71	3.85
		A, S	0.4994	3.157912	0.6225	0.036											87.58	21.42	4.19
		A, R, S	-0.5956	0.253746	0.64451	0.3793	-0.0024										98.51	10.49	2.05
		A, Sk, Cv	0.7114	5.145173	0.7296	0.0423	0.4064										97.52	11.48	2.25
		A, S, Sh	0.5065	3.209963	0.6013	0.0357	-0.0542										87.58	21.42	4.19
		A,R, S, D, Sh	-0.594	0.254683	0.6421	0.3856	-0.0088	-0.009	-0.0234								98.86	10.14	1.98

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TABLE 5.3 (Continued)

Regression Equations (Partial Series)

Recurrence Interval,T in Years	Number of Stations	Independent Variables Included	Log a	a	b	c	d	e	f	g	h	i	j	k	l	Observed Values for stat. 426504 (Cumecs)	Computed Values (Cumecs)	Residual values	Standard error (%)
		A, S, Sh, F, U, Ru, La	0.3932	2.472863	0.9141	0.1845	0.729	-0.043	0.0653	0.044	0.2052						80.30	28.70	5.61
		A, R, S, D, Sh, F, U, Ru, La, Sk, Cv	-6.708	1.96E-07	1.15	2.291	-0.096	-0.4227	-0.216	-0.03166	-0.012	0.9875	0.0384	-0.08	1.225		124.51	-15.51	3.03
50 —		A	0.6813	4.80065	0.595											141	109.27	31.73	4.80
		A, S	0.5038	3.190068	0.6374	0.09123											103.87	37.13	5.61
		A, R, S	-0.3583	0.438228	0.655	0.299	0.0611										113.97	27.03	4.09
		A, Sk, Cv	0.8626	7.28786	0.7685	0.1007	0.5441										128.29	12.71	1.92
		A, S, Sh	0.4922	3.10599	0.672	0.0916	0.0887										103.87	37.13	5.61
		A,R, S, D, Sh	-0.4405	0.36266	0.815	0.3803	-0.0073	-0.952	0.2233								118.60	22.40	3.39
		A, S, Sh, F, U, Ru, La	0.64222	4.387529	1.01	0.189	0.9273	-0.0701	0.07	-0.0645	0.201						95.48	45.52	6.88
		A, R, S, D, Sh, F, U, Ru, La, Sk, Cv	-7.098	7.98E-08	1.196	2.4976	-0.138	-0.4653	-0.3165	-0.0393	-0.023	1.0232	0.0313	-0.03	1.42		170.88	-29.88	4.52
100 —		A	0.7922	6.197264	0.5832											181.4	132.59	48.81	5.74
		A, S	0.5066	3.210702	0.652	0.147											122.41	58.99	6.93
		A, R, S	-0.128	0.744732	0.6645	0.22	0.12 46										131.04	50.36	5.92
		A, Sk, Cv	1.1012	12.62409	0.8071	0.1615	0.6813										168.11	13.29	1.56
		A, S, Sh	0.476	2.992265	0.743	0.1477	0.2336										122.35	59.05	6.94
		A,R, S, D, Sh	-0.2974	0.504197	0.9935	0.3805	-0.009	-0.186	0.478								141.68	39.72	4.67
		A, S, Sh, F, U, Ru, La	0.8976	7.899507	1.102	0.1911	1.123	-0.098	0.0744	-0.1762	0.1943						112.77	68.63	8.07
		A, R, S, D, Sh, F, U, Ru, La, Sk, Cv	-7.5187	3.03E-08	1.243	2.717	-0.1825	-0.51	-0.42	-0.048	-0.035	1.056	0.023	0.024	1.6125		233.99	-52.59	6.18
200 —		A	0.901	7.361594	0.5716											233	160.26	72.74	6.66
		A, S	0.505	3.198895	0.667	0.2036											143.42	89.58	8.20
		A, R, S	0.1092	1.285879	0.6746	0.1371	0.1897										149.66	83.34	7.63
		A, Sk, Cv	1.158	14.38799	0.846	0.226	0.8183										219.94	13.06	1.20
		A, S, Sh	0.4553	2.852988	0.815	0.205	0.3795										143.32	89.68	8.21
		A,R, S, D, Sh	-0.1507	0.706806	1.1786	0.381	-0.0124	-0.2814	0.7387								168.42	64.58	5.91
		A, S, Sh, F, U, Ru, La	1.155	14.28894	1.1953	0.193	1.316	-0.1261	0.0785	-0.291	0.1866						132.46	100.54	9.20
		A, R, S, D, Sh, F, U, Ru, La, Sk, Cv	-7.9402	1.15E-08	1.291	2.938	-0.228	-0.556	-0.53	-0.0566	-0.0475	1.0855	0.0145	0.0805	1.805		320.55	-87.55	8.01

NOTE: A : Basin Area
R : Average Annual Rainfall
S : Basin Slope
D : Number of Farm Dams
Sh : Basin Shape
F : % Forest
U : % Urban
Ru : % Rural
L : %Lake
Sk : Coefficient of Skewness
Cv : Coefficient of Variation
a,b,c,d,e,f,g,h,i,j,k,l : Regression Coefficients

TABLE 5.4

Note : For each station upper values are from flood frequency analysis and lower values are from multiple regression analysis (Annual Series)
Median residual : Median of ratios of the two flow values (in m^3/s) at each average recurrence interval

Station No.	Station Name	Average Recurrence Interval in Years							Median Residual
		2	5	10	25	50	100	200	
426503	Angas River	11.8	24.4	37.7	62.2	88	122	167	0.996
	—	17.5	34.4	47.4	65.6	80.4	96	112.9	
426504	Finniss River	41.9	70	88.7	112	128	143	158	0.94
	—	38.9	67.6	90	120.9	144.4	168.3	193.1	
426529	Marne River	14.1	43.6	59	70.2	74.6	77	78.2	0.817
	—	15.5	51.1	71.9	88.8	95.5	98.9	100	
426530	Currency Creek	9.45	19.8	26	32.5	36.2	39.1	41.4	0.821
	—	11.8	25.1	32.4	39.5	43.4	46.3	48.5	
426533	Bremer River	40.9	93.9	118	136	143	147	149	1.067
	—	31.5	79.6	107.1	132.1	144.7	154.3	161.7	
426557	Mt Barker Creek	20.7	40.6	48.4	53.5	55.3	56.3	56.8	1.068
	—	19.1	38.2	45.8	50.7	52.2	52.5	52.3	
426558	Dawesley Creek	9.39	25.8	36.6	47.7	53.8	58.4	61.8	0.715
	—	13.7	35.2	48.9	64.1	74.3	83.6	92.3	
501500	Hindmarsh River	14.9	27.2	36.3	48.6	58.1	67.7	77.5	0.957
	—	12.4	24.9	35.7	52.3	66.7	82.7	100.8	
502502	Myponga River	10.1	13.7	15.1	16.2	16.6	16.9	17.1	0.64
	—	17.1	23.3	24.8	25.3	25.1	24.7	24.3	
503502	Scott Creek	7.77	12.4	14.3	15.7	16.3	16.6	16.9	1.149
	—	7.2	10.9	12.3	13.4	13.9	14.3	14.6	
503503	Baker Gully	9.88	20.2	28.3	39.7	48.8	58.1	67.9	0.688
	—	11.6	26.6	39.6	59.5	76.7	95.6	116.8	
503504	Onkaparinga River	79	145	191	248	289	327	364	1.134
	—	63	121	164.8	222.6	264.8	305.6	346	
503506	Echunga Creek	11.5	18.2	20.6	22.2	22.9	23.2	23.4	0.995
	—	10.3	16.9	19.9	22.6	24.2	25.3	26.3	
503507	Lenswood Creek	8.99	19.5	28.2	41	51.6	62.8	74.8	1.09
	—	8.1	17.4	25.4	37.5	47.8	58.9	71	
503508	Inverbrackie Ck	6.42	11.5	12.6	13	13.1	13.1	13.1	1.115
	—	4.6	9.7	11.5	12.5	12.8	12.8	12.6	
503509	Aldgate River	6.77	10.9	14.4	19.9	24.9	30.7	37.5	1.045
	—	6.4	10.5	14	19.2	23.9	29.2	35.3	
504512	Torrens River	6.73	22.6	34.1	46.3	53.2	58.3	62.1	1.512
	—	6	16.8	23.2	29.3	32.3	34.5	35.9	
504517	First Creek	0.765	2.2	3.93	7.5	11.5	17.1	24.8	0.871
	—	1.3	2.4	4.3	8.2	12.5	18.6	26.8	
504518	Sturt River	5.72	9.16	11.1	13.1	14.4	15.4	16.3	0.675
	—	7.7	12.4	15.4	19.2	22.1	25.1	28.2	
504523	Sixth Creek	16.6	32.5	47.7	73.9	99.4	131	171	2.107
	—	11.5	18.6	24.8	34.5	43	52.5	63.6	
505504	North Para River	38.2	138	225	340	418	488	549	1.016
	—	44.5	151.6	234	329.3	388.2	436	474.9	
505517	North Para River	24.1	61	81	97.6	105	110	113	1.571
	—	18.1	40.2	50.8	59.6	63.8	67	69.5	
	Average Median Residual								1.045

TABLE 5.5

Note : For each station upper values are from flood frequency analysis and lower values are from multiple regression analysis (Partial Series)
Median Residual : Median of ratios of the two flow values (in cumecs) at each average recurrence interval

Station No	Station Name	Average Recurrence Interval in Years							Median Residual
		2	5	10	25	50	100	200	
426503	Angas River	18.3	30.6	42.4	62.9	83.2	108.8	141	0.85
	----------	23.1	37.4	50.9	73.6	95.6	122.9	157.2	
426504	Finniss River	40.9	59.4	77.6	109	141	181.4	233	0.876
	----------	40.45	60.6	82.6	124.5	170.9	234	320.6	
426529	Marne River	27.5	32.8	37.1	43.2	48.4	54.1	60.4	1.095
	----------	21.8	26.6	31.4	39.3	47.03	56.2	67.3	
426530	Currency Creek	14.9	18.7	21.1	24.2	26.4	28.7	31	0.566
	----------	23.15	30.95	36.3	43.4	48.9	54.6	60.5	
426533	Bremer River	57.1	81.4	98.7	122	140	159	179	0.948
	----------	60	86.5	104.9	129.3	147.8	166.7	186.4	
426557	Mt Barker Creek	23.6	34.7	43.7	57.1	68.7	81.9	96.8	0.864
	----------	24.92	37.4	48.5	66.1	82.5	102.1	125.5	
426558	Dawesley Creek	16.3	25.7	34	47.4	60	74.9	92.9	0.949
	----------	17.35	26.6	35.2	49.4	63.1	80	100.7	
501500	Hindmarsh River	21.2	29.3	35.5	44.4	51.8	60	68.8	1.047
	----------	18.2	25.8	32.4	42.5	51.6	62.3	74.9	
502502	Myponga River	12	12.9	13.3	13.8	14.2	14.5	14.7	0.812
	----------	17.9	18.02	17.6	17	16.5	15.9	15.3	
503502	Scott Creek	8.6	11.1	13.1	16.1	18.6	21.4	24.6	0.993
	----------	8.4	11.11	13.24	16.3	18.9	21.8	24.9	
503503	Baker Gully	17	24.2	30	38.4	45.6	53.6	62.6	0.988
	----------	16.11	23.3	29.5	38.9	47.3	57.1	68.5	
503504	Onkaparinga River	123.2	166	195	233	261	291	321	1.504
	----------	80.8	110.5	130	155.5	174.3	193.8	213.1	
503506	Echunga Creek	13.3	17.7	21.2	26.2	30.5	35.2	40.4	1.047
	----------	13.2	17.6	20.8	25.2	28.7	32.4	36.4	
503507	Lenswood Creek	11.7	18.6	25.1	36.4	47.4	61.3	78.7	1.014
	----------	11.6	18.3	24.7	35.83	46.7	60.4	77.6	
503508	Inverbrackie Ck	7	10.5	13.7	18.7	23.4	29.1	35.8	0.968
	----------	6.56	9.96	13.35	19.2	25.2	32.9	42.7	
503509	Aldgate River	7.8	11.1	14.2	19.5	24.5	30.7	38.4	0.964
	----------	7.97	11.4	14.7	20.3	25.5	32.1	40.2	
504512	Torrens River	17.1	21.4	24.1	27.5	30	32.5	35	1.614
	----------	11.55	14.1	15.5	17.1	18.1	19	19.8	
504517	First Creek	1.4	2.4	3.7	6.75	10.7	17	27	0.935
	----------	1.45	2.5	3.9	7.22	11.6	18.6	30.1	
504518	Sturt River	7	9	10.7	13.3	15.6	18.3	21.3	0.935
	----------	7.6	10	11.8	14.5	16.6	18.9	21.5	
504523	Sixth Creek	18	31	45	71.8	101	141	197	1.603
	----------	14.6	22.6	30.6	44.5	58.6	76.7	100	
505504	North Para River	65.3	114	168	272	389	551	778	0.843
	----------	80.3	136.7	199.4	320.2	455.6	644.5	910.4	
505517	North Para River	23.7	40.3	64.8	127	217	375	655	1.257
	----------	23.7	40.1	60.8	106	162.9	250.3	385.8	
	Average Median Residual								1.03

5.4 Results of Regression Analysis

The most important variable has been found to be the drainage area which was expected. Eight regression equations with different combinations of catchment variables have been evaluated and an effort has been made to find the best combination for estimating flood flows. The correlation matrix is obtained as part of the regression computations. The correlation matrix expresses the degree of correlation among the independent variables and between the dependent variables and each of the independent variables. Table 5.6 shows a simple correlation matrix between Q_{10} (10-year ARI peak discharge) and the independent variables. The 10-year ARI flood was chosen as it might be closely related to floods of higher return periods.

Length is highly correlated with area (0.99) therefore length was excluded from the regression analysis, shape (length/area) used instead. Also fall has not been used in the equation because of its effect is included in the slope variable. The number of farm dams has a high correlation with other catchment variables and also the percent of rural.

The correlation matrix also shows some nonsense relationship such as the average annual rainfall related to Q_{10} by negative (-0.54) correlation that means as average annual rainfall increases, Q_{10} decreases. Also slope shows same relationship (-0.74) ie as slope increases, Q_{10} decreases. Hydrologically these type of relationships are impossible and these relationships appear because of interrelationship with drainage area.

TABLE 5.6

Correlation Matrix of Catchment Characteristics with Q_{10}

	Q_{10}	Area	Avg. Ann. Rainfall	Length	Slope	Fall	No of farm dams	Shape	% Forest	% Urban	% Rural	% Lake	Sk	Cv
Q_{10}	1													
Area	.899	1												
Avg. Ann. Rainfall	-.54	-.62	1											
Length	.88	.99	-.62	1										
Slope	-.74	-.8	.62	-.79	1									
Fall	.29	.37	-.05	.40	.24	1								
No of farm dams	.83	.92	-.55	.92	-.86	.18	1							
Shape	-.89	-.97	.59	-.92	.77	-.30	-.86	1						
% Forest	-.29	-.21	.71	-.20	.44	.34	-.21	.22	1					
% Urban	.002	.06	.38	-.09	.36	.40	-.25	.014	.41	1				
% Rural	.59	.54	-.55	.54	-.72	-.23	.69	-.51	-.5	-.44	1			
% Lake	.42	.26	-.36	.21	-.5	-.42	.34	-.32	-.53	-.13	.66	1		
Sk	.14	.25	-.62	.26	-.52	-.37	.28	-.23	-.61	-.24	.51	.38	1	
Cv	-.42	-.38	-.20	.37	.29	-.15	-.44	.38	-.27	-.13	-.497	-.29	.14	1
Standard Deviation	.42	.57	.09	.35	.33	.22	.63	.23	.91	1.17	.34	.43	.3	.34
Mean	1.54	1.74	2.9	1.18	1.13	2.32	2.44	-.55	.69	-.58	1.83	-.88	-.02	-.28

Benson (1964) described that for the same size of drainage area, larger slopes will produce larger floods which is partially supported in this study. From Table 5.2 and Table 5.3, it can be seen that the exponent of slopes are negative for the lower recurrence intervals whereas positive for the higher ones. For method 8, the exponent of slope is negative for all recurrence intervals while for method 7 it is positive for all recurrence intervals. Again it can be explained as the effect of interrelationship between the catchment variables. It is also quite possible that some important variable is not included because of the unavailability of data or the importance has not been recognised.

Eight equations have been developed for the Mt Lofty Ranges to predict the flood flows. Each variable used in the regression equations has been selected to explain some of the spatial variation in peak discharge estimate.

The variables that are used in the regression equation represent the best possible combination of the catchment variables to explain the peak flows. The model is applicable only to hydrologically similar areas, with those characteristics of physiography, geology, vegetation, elevation, and average annual rainfall that are used in the regression analysis.

The mean square error (Appendix C) has been plotted against ARI for both annual and partial series as shown in Figure 5.1 and Figure 5.2. Significantly better results are shown for method 8 and method 4 while the other equations give similar results. The residual values have been plotted against ARI for both annual and partial series (Figure 5.3 and Figure 5.4). The standard error has also been plotted against ARI for both annual and partial series as shown in Figure 5.5 and Figure 5.6. In both cases method 8 and then method 4 give much better result.

The coefficient of variation has been plotted against area for both series in Figure 5.7 and Figure 5.8 where the points show much more scatter for the annual series.

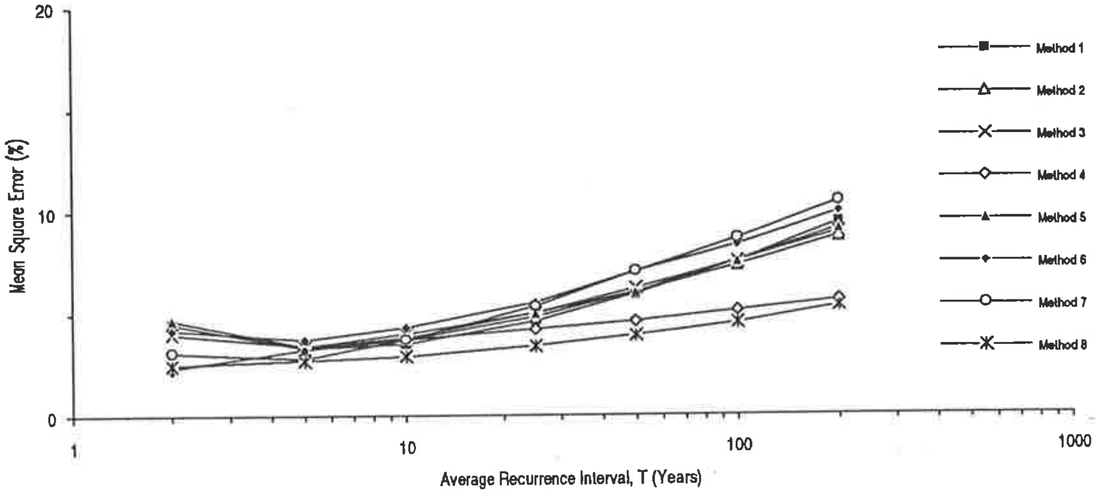

Figure 5.1 Mean Square Error in percent plotted against Average Recurrence Interval for Annual Series.

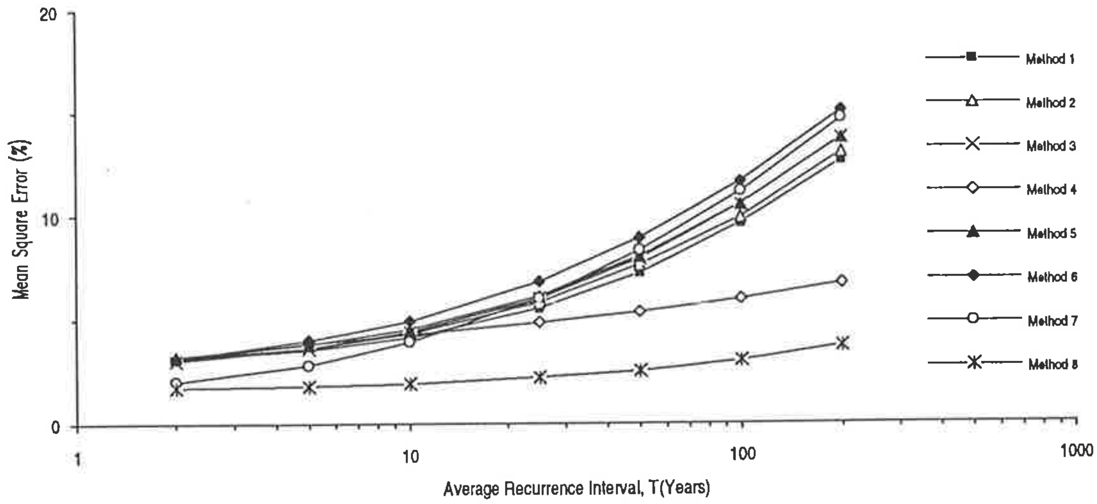

Figure 5.2 Mean Square Error in percent plotted against Average Recurrence Interval for Partial Series.

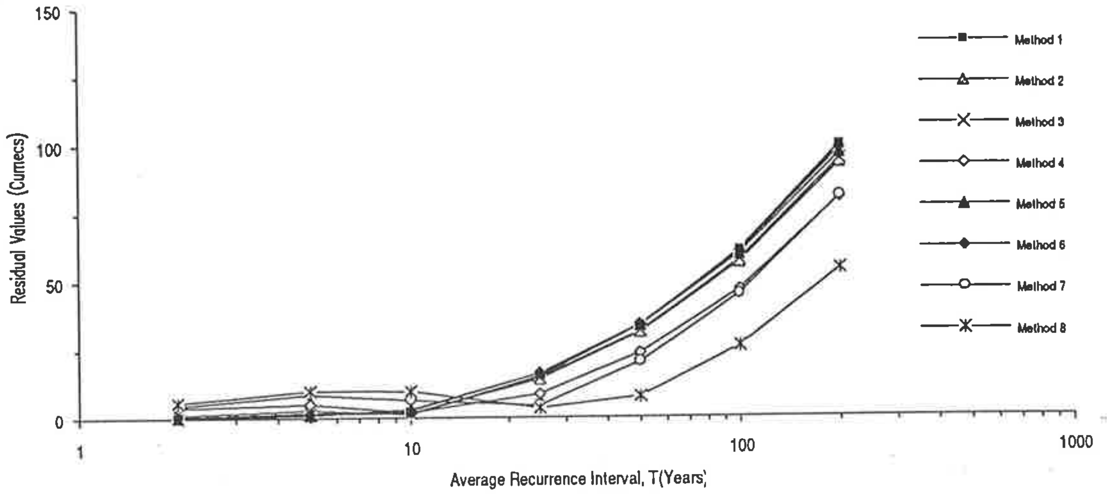

Figure 5.3 Residual Values plotted against Average Recurrence Interval for Annual Series (From Table 5.2).

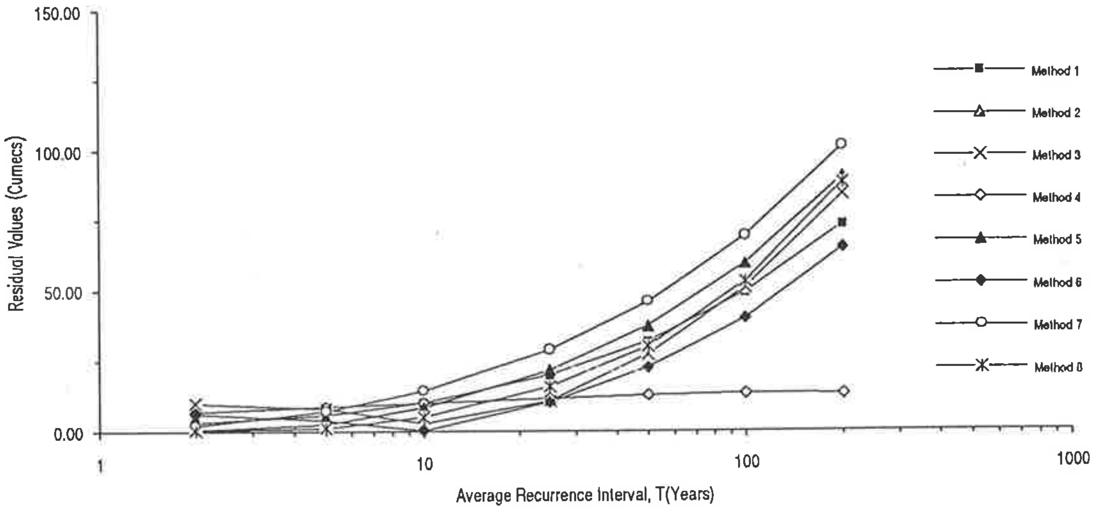

Figure 5.4 Residual values plotted against Average Recurrence Interval for Partial Series (From Table 5.3).

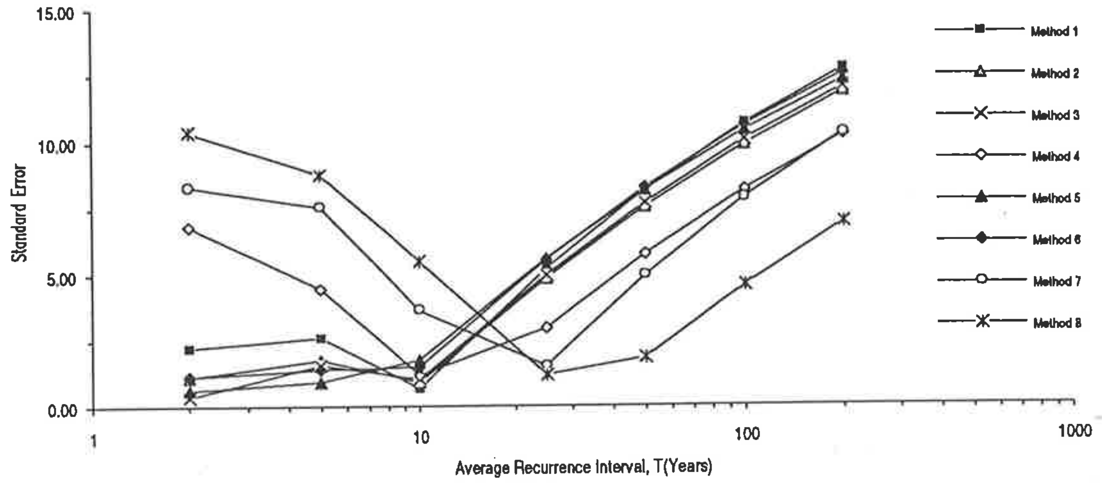

Figure 5.5 Standard Error plotted against Average Recurrence Interval for Annual Series (From Table 5.2).

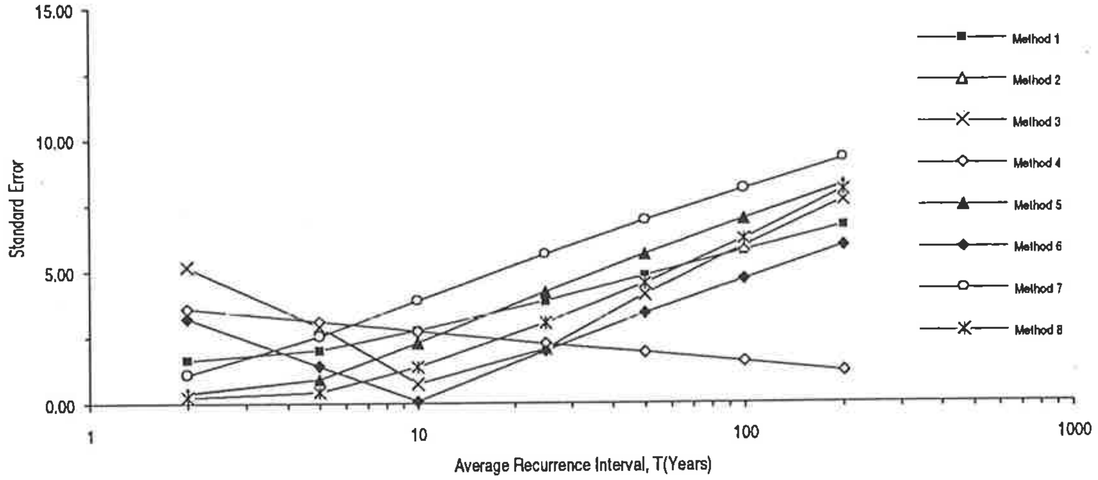

Figure 5.6 Standard Error plotted against Average Recurrence Interval for Partial Series (From Table 5.3).

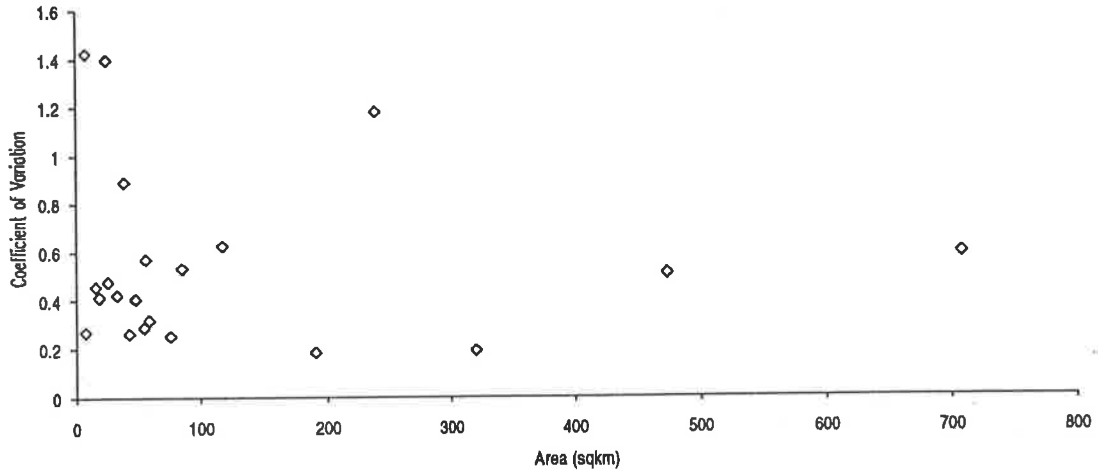

Figure 5.7 Coefficient of Variation plotted against Area for Annual Series.

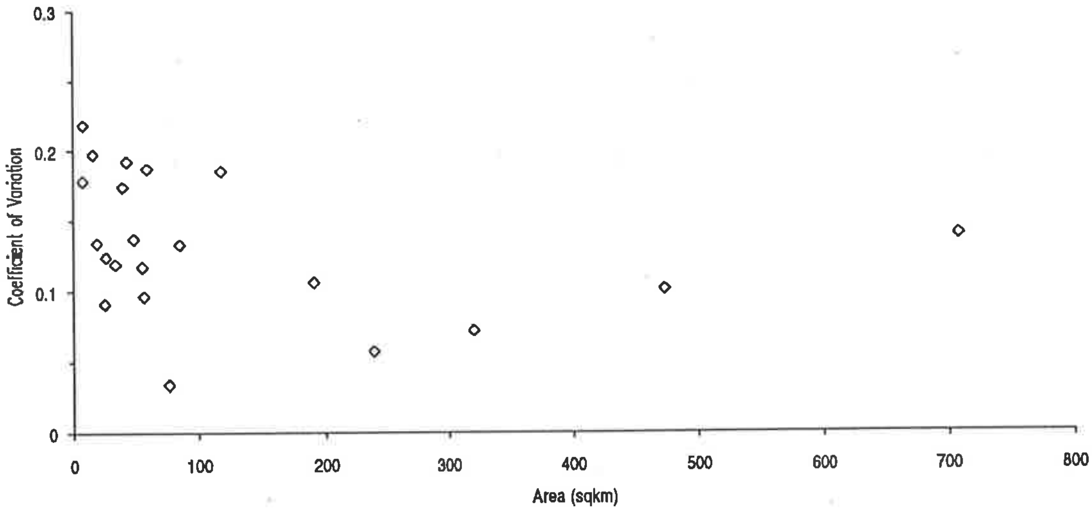

Figure 5.8 Coefficient of Variation plotted against Area for Partial Series.

5.5 Interrelationships between major Catchment Parameters

Many geomorphological variables that describe the physical form of the catchments have been found to be strongly correlated with area. The best correlation with area has been found to be stream length. An analysis was undertaken to derive interrelationships between major catchment parameters. Such as :

$$L = a\,A^{b}$$
$$S = a\,A^{b}$$
$$S = a\,L^{b}$$

where,

L = main stream length (km)

S = main stream slope (m/km)

A = catchment area (km^2)

The following relationships have been found by analysing 22 catchments in Mt Lofty Ranges :

Expression	Standard error
$L = 1.33\,A^{0.61}$	.021
$S = 88\,A^{-0.47}$	.079
$S = 104\,L^{-0.75}$	.129

In comparison to a previous study on Mt Lofty Ranges (EWS Report No. 26, 1986) there is very little difference in the exponent of A (.67 in length-area and -.42 in slope-area relationship in the EWS Report), whereas greater difference has been found in slope-length relationship. Past investigations have found that the mainstream length is a function of area to a power of approximately 0.6, which is strongly supported by this study.

Length and slope have been plotted against catchments area on log-log paper in Figure 5.9 and Figure 5.10. From those figures it can be easily seen that the stronger relationship exists between length and area compared to slope and area. In the slope vs area and length vs slope curve the points are much more scattered than the length vs area curve.

The correlation coefficient was -.79 for the slope-length relationship and -.8 for the slope-area relationship. These coefficients can be compared with the correlation coefficient of .99 for the length-area relation, which shows little scatter and followed the statement given in (McDermott and Pilgrim, 1982) that a high correlation exists between stream length and catchment area and to a lesser degree between stream slope and area or stream length.

Gary (1961) reported in his paper that the slope of the main stream can be inversely related to the parameters of length and area as a simple power equation. In this study significant agreement was found with the above statement.

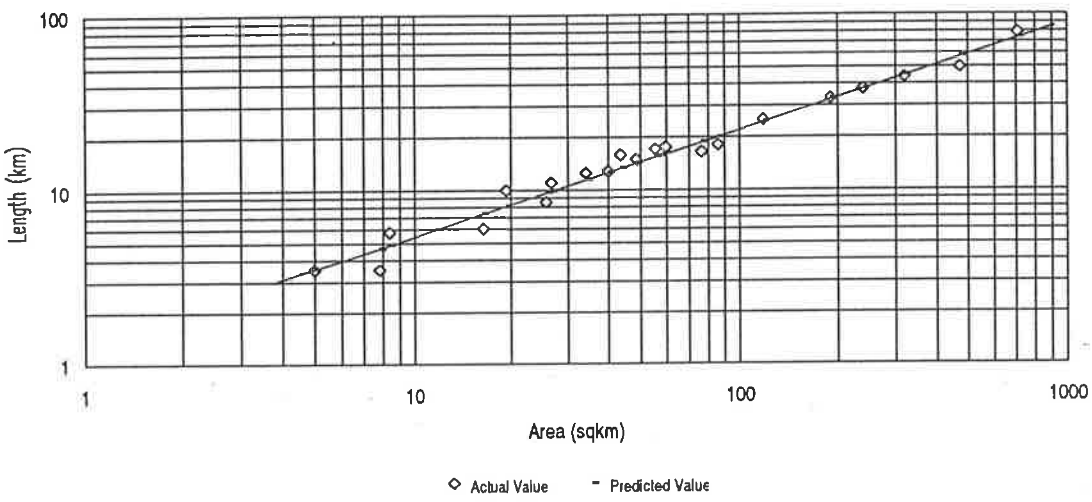

Figure 5.9 Length (km) plotted against Area (km^2).

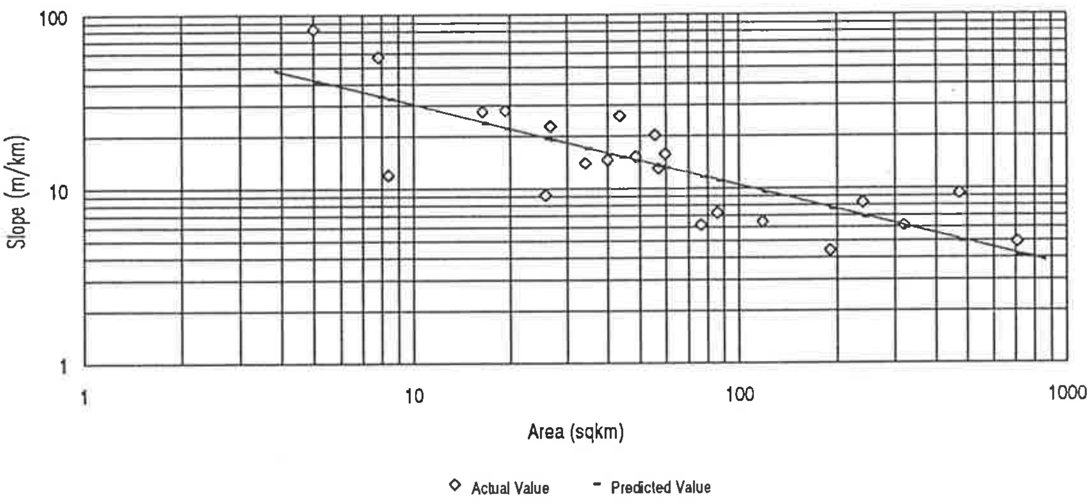

Figure 5.10 Slope (m/km) plotted against Area (km^2).

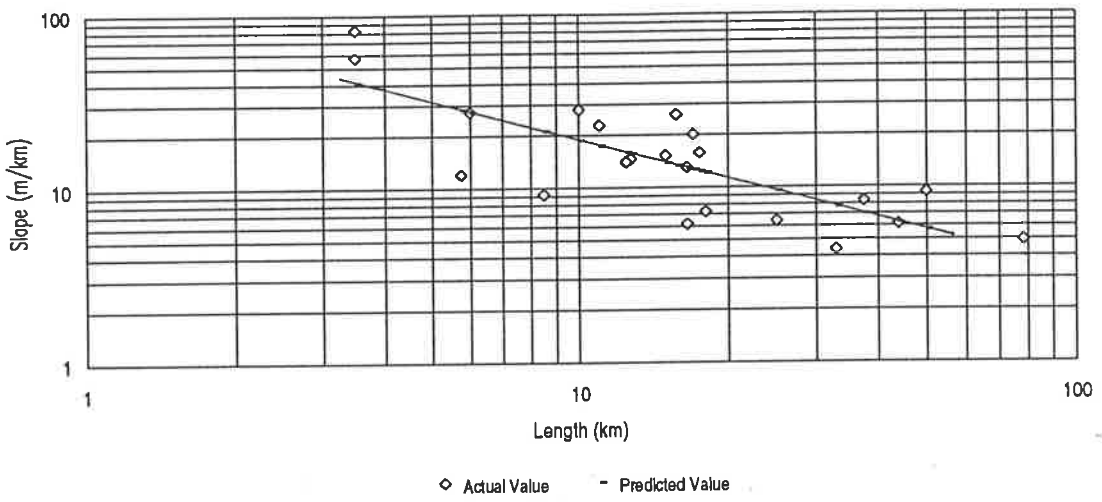

Figure 5.11 Slope (m/km) plotted against Length (km).

5.6 Graphs of Regression Coefficients

Regression coefficients have been plotted against the average recurrence interval for both annual and partial series. The graphs are shown in Figures 5.12 to 5.15. The values of each coefficient vary uniformly with the average recurrence interval over the range 2 to 200 years. The variation among the coefficients is not consistent over the range of ARI. When one coefficient increases another decreases. The partial series gives better graphs than annual series.

For the annual series results three graphs have been plotted. Figure 5.12 for method 1 using only the regression coefficient for catchment area. Figure 5.13 for method 6 which has 5 independent variables and Figure 5.14 for method 8 which has 11 independent variables. Figure 5.12 shows that the coefficients are reasonably consistent with the values ranging from .5 to .74. For method 8 a larger variation in the area coefficient is observed ranging from .52 to 1.14. Similar results are observed for the partial series. With the addition of each independent variable to drainage area, the coefficient of area (b) increases (Table 5.2 and 5.3). The coefficient is positive throughout and shows the direct relationship between discharge and area.

Another important coefficient is for the average annual rainfall, where the positive value throughout all recurrence intervals shows the existence of a direct relationship with peak flow values. The coefficient for shape gives negative values throughout the range of ARI which indicates an inverse relationship with the peak discharge.

Slope is the most important factor after drainage area. But in this study slope coefficient is negative for a range (2 to 25 years) of ARI. The negative values are not reasonable as peak discharge should increase with the increasing slope.

Coefficient of %urban gives positive values throughout which was expected as discharge increases as urbanised area increases but %lakes also gives positive value which was not expected as storage causes a reduction in flood peaks. The %forest coefficient is almost negative throughout which is reasonable. The %rural coefficient is positive for a range of recurrence intervals because as more land is changed from forest to rural, peak flows become higher.

In the case of the number of farm dams, method 8 gives negative values which was expected but method 6 gives positive values which is not reasonable. It would be expected that an increase in the number of farm dams would reduce the flood peaks. The variation of coefficients of all catchment variables is uniform throughout all the recurrence intervals.

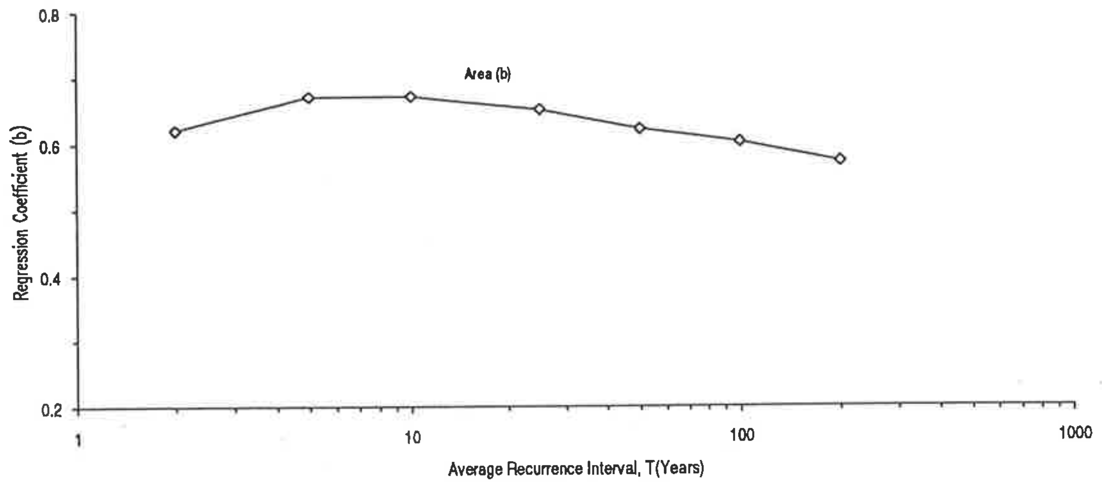

Figure 5.12 Regression Coefficient (b) plotted against Average Recurrence Interval for Annual Series (from method 1).

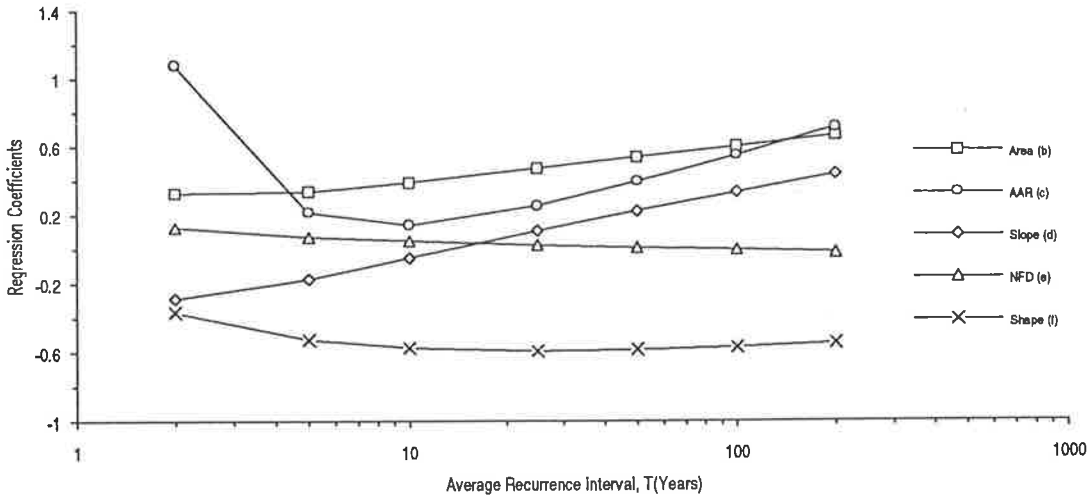

Figure 5.13 Regression Coefficients for five independent variables plotted against Average Recurrence Interval for Annual Series(from method 6).

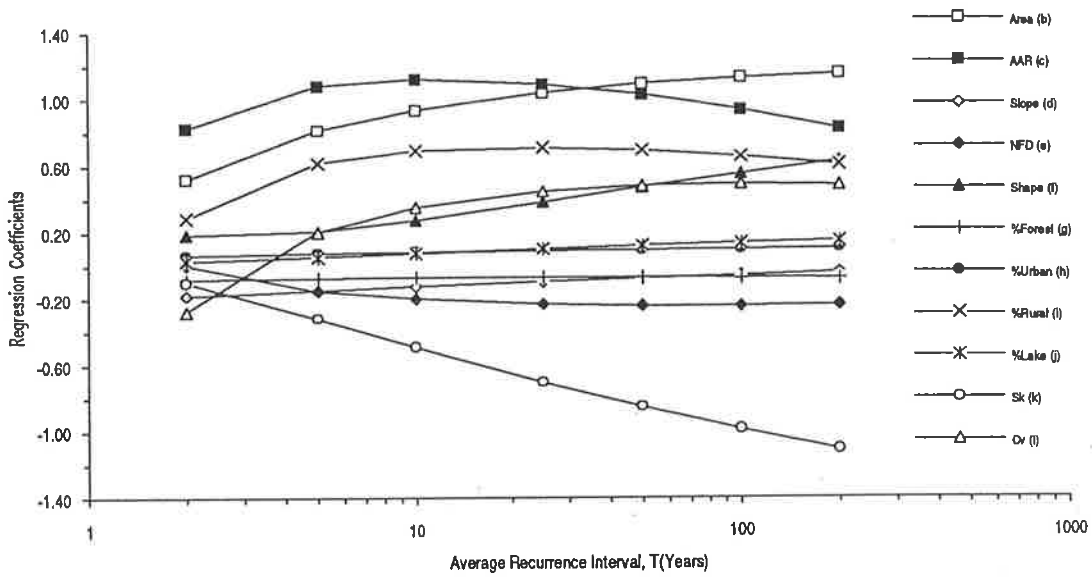

Figure 5.14 Regression Coefficients for all independent variables plotted against Average Recurrence Interval for Annual Series (from method 8).

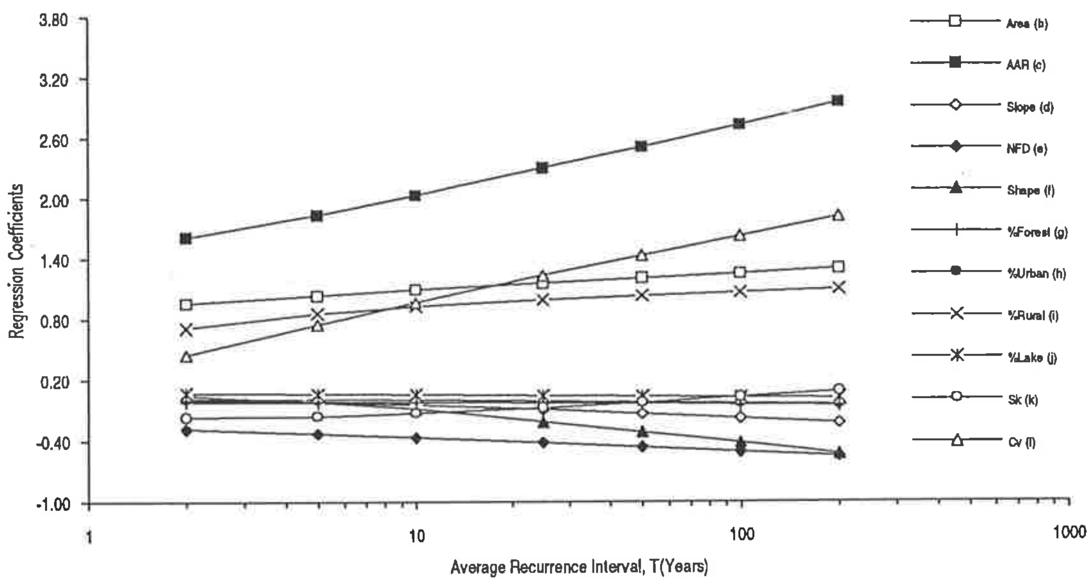

Figure 5.15 Regression Coefficients for all independent variables plotted against Average Recurrence Interval for Partial Series (from method 8).

5.7 Revision of Regression Analysis

In case of annual series, some problem may arise in fitting a frequency distribution to the data set if it contains a number of low or zero values, which usually occur in small, arid-region streams. The problems that may happened can be listed as (Benson et al., 1969) :

- Commonly used distributions do not fit such a set of data.
- If a logarithmic transformation of the data is being used, logarithms of zero flows are not useable in a computation.

In the Adelaide Hill's Catchment area most of the stations contain zero and low values. Twelve stations out of twenty two contain a number of low values less than 1.0 m^3/s. For annual flood series, the peak flood values of the stations which have very flat LPIII curves, have been checked. For those stations, very low values especially values less than 1.0 m^3/s and those that fall beyond 5% and 95% confidence limit curve were discarded. In this study most of the LPIII curves have negative skew values. These stations usually have low outliers. Because of the modification most of the stations show better values while Marne River, Currency Creek, and Myponga River do not show any improvement.

In this study, the procedure as described in IE.Aust (1987) has been followed to modify the frequency distribution of annual series data. In this study, the WS06 - Computer program has been modified which discards the low values from the data set and adjusts the probability accordingly. From the adjusted exceedance probability (%) peak discharges at different recurrence interval have been calculated by plotting on probability graph paper.

Table 5.7 shows the revised set of regression equations for the average recurrence interval 2 to 200 years where Index of variability (Iv) has been used instead of coefficient of variation (Cv) and Table 5.8 shows the revised results for annual series data. In Figure 5.16 the revised mean square error has been plotted against average recurrence interval. In Figure 5.17 a comparison of the graphs of annual, partial and revised annual series are shown. From this graph it can be clearly seen that revised annual series gives a higher mean square error than the annual series, which was not expected. Because of the modification, the length of record decreases as many stations contain a number of low values. Probably the graph represents the importance of length of record in regional regression analysis.

TABLE 5.7

Revised Regression Equations (Annual Series)

Recurrence Interval, T In Years	Independent Variables Included	Log a	a	b	c	d	e	f	g	h	i	j	k	l
2------	A	-0.0102	0.9768	0.6329										
	A, S	0.3554	2.2667	0.5451	-0.188									
	A, R, S	-2.937	0.0012	0.6113	1.141	-0.303								
	A, Sk, Iv	-0.5203	0.6960	-0.0903	-0.79									
	A, S, Sh	0.4288	2.6841	0.3266	-0.1902	-0.5597								
	A, R, S, D, Sh	-2.743	0.0018	0.2435	1.013	-0.2051	0.137	-0.6722						
	A, S, Sh, F, U, Ru, La	-0.4512	0.3538	0.3926	-0.0423	-0.2087	0.0666	0.0693	0.4754	0.0998				
	A, R, S, D, Sh, F, U, Ru, La, Sk, Iv	-6.248	5.65E-07	0.702	1.957	-0.0687	-0.1783	-0.198	-0.0448	0.0455	0.5886	0.0325	-0.051	0.3452
5------	A	0.2537	1.7935	0.6417										
	A, S	0.462	2.8973	0.592	-0.107									
	A, R, S	-1.798	0.0159	0.6372	0.783	-0.186								
	A, Sk, Iv	0.1364	1.3690	0.6702	-0.1	-0.085								
	A, S, Sh	0.5236	3.3389	0.4072	-0.1088	-0.473								
	A, R, S, D, Sh	-1.622	0.0239	0.302	0.661	-0.0911	0.1324	-0.5983						
	A, S, Sh, F, U, Ru, La	-0.1326	0.7369	0.5463	0.0674	-0.05	0.0331	0.0504	0.311	0.1328				
	A, R, S, D, Sh, F, U, Ru, La, Sk, Iv	-5.254	5.57E-06	0.8446	1.984	-0.185	-0.2743	0.1316	-0.0422	0.0527	0.5555	0.0736	-0.0453	1.1682
10------	A	0.3973	2.4963	0.6386										
	A, S	0.5266	3.3620	0.6075	-0.0665									
	A, R, S	-1.188	0.0649	0.642	0.594	-0.1265								
	A, Sk, Iv	0.4777	3.0040	0.651	-0.112	0.278								
	A, S, Sh	0.5682	3.7000	0.4836	-0.068	-0.3175								
	A, R, S, D, Sh	-1.082	0.0828	0.4415	0.5273	-0.0761	0.0703	-0.375						
	A, S, Sh, F, U, Ru, La	0.1221	1.3246	0.6972	0.1175	0.2274	0.0035	0.046	0.184	0.168				
	A, R, S, D, Sh, F, U, Ru, La, Sk, Iv	-5.279	5.26E-06	1.0625	2.22	-0.269	-0.3814	0.5221	-0.0617	0.057	0.5222	0.1064	-0.0512	1.64
25-----	A	0.5834	3.8318	0.6115										
	A, S	0.5836	3.8335	0.6115	-0.00012									
	A, R, S	-0.628	0.2355	0.636	0.4196	-0.0425								
	A, Sk, Iv	0.8855	7.6825	0.605	-0.1211	0.6806								
	A, S, Sh	0.6041	4.0188	0.5506	-0.0007	-0.156								
	A, R, S, D, Sh	-0.5986	0.2520	0.5831	0.4156	-0.0426	0.00004	-0.1345						

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TABLE 5.7 (Continued)

Revised Regression Equations (Annual Series)

Recurrence Interval, T In Years	Independent Variables Included	Log a	a	b	c	d	e	f	g	h	i	j	k	l
	A, S, Sh, F, U, Ru, La	0.4864	3.0648	0.8742	0.186	0.5816	-0.0336	0.0412	-0.0026	0.226				
	A, R, S, D, Sh, F, U, Ru, La, Sk, Iv	-5.558	2.77E-06	1.264	2.545	-0.2997	-0.446	0.903	-0.104	0.0594	0.408	0.15	-0.0665	2.0536
50 -----	A	0.71	5.1286	0.5924										
	A, S	0.626	4.2267	0.613	0.0432									
	A, R, S	-0.084	0.8241	0.627	0.246	0.0184								
	A, Sk, Iv	1.1754	14.9761	0.5721	-0.128	0.977								
	A, S, Sh	0.6258	4.2247	0.6131	0.0432	0.0013								
	A, R, S, D, Sh	-0.1398	0.7248	0.738	0.316	-0.0423	-0.0844	0.1195						
	A, S, Sh, F, U, Ru, La	0.7937	6.2187	1.02	0.22	0.89	-0.068	0.0404	-0.1547	0.2632				
	A, R, S, D, Sh, F, U, Ru, La, Sk, Iv	-5.704	1.98E-06	1.455	2.787	-0.352	-0.522	1.248	-0.139	0.063	0.32	0.178	-0.08	2.374
100 ----	A	0.8193	6.5963	0.5753										
	A, S	0.658	4.5499	0.6141	0.083									
	A, R, S	0.407	2.5527	0.6191	0.087	0.0741								
	A, Sk, Iv	1.428	26.7917	0.5422	-0.1306	1.234								
	A, S, Sh	0.642	4.3853	0.663	0.0834	0.1246								
	A, R, S, D, Sh	0.2774	1.8941	0.873	0.225	-0.0425	-0.1623	0.332						
	A, S, Sh, F, U, Ru, La	1.0486	11.1841	1.1484	0.261	1.1524	-0.0994	0.0386	-0.2893	0.3				
	A, R, S, D, Sh, F, U, Ru, La, Sk, Iv	-5.915	1.22E-06	1.6487	3.028	-0.3922	-0.602	1.584	-0.1693	0.064	0.2486	0.2102	-0.0867	2.663
200 ----	A	0.9356	8.6218	0.553										
	A, S	0.687	4.8641	0.6123	0.128									
	A, R, S	0.8951	7.8542	0.6082	-0.0721	0.135								
	A, Sk, Iv	1.6963	49.6935	0.506	-0.1333	1.504								
	A, S, Sh	0.6503	4.4699	0.7215	0.129	0.2796								
	A, R, S, D, Sh	0.6738	4.7185	1.04	0.149	-0.0503	-0.2581	0.5988						
	A, S, Sh, F, U, Ru, La	1.376	23.7684	1.289	0.286	1.458	-0.1334	0.038	-0.4524	0.3373				
	A, R, S, D, Sh, F, U, Ru, La, Sk, Iv	-6.0515	8.88E-07	1.843	3.262	-0.443	-0.676	1.936	-0.204	0.066	0.1446	0.2396	-0.0974	2.94

A : Basin Area
R : Average Annual Rainfall
S : Basin Slope
D : Number of Farm Dams
Sh : Basin Shape
F : % Forest
U : % Urban
Ru : % Rural
L : %Lake
Sk : Coefficient of Skewness
Iv : Index of Variability
a,b,c,d,e,f,g,h,i,j,k,l : Regression Coefficients

TABLE 5.8

Revised annual series excluding extremely low flows.

Note : For each station upper values are from flood frequency analysis and lower values are from multiple regression analysis (Annual Series)

Station No.	Station Name	Average Recurrence Interval in Years 2	5	10	25	50	100	200	Sk	Iv
426503	Angas River	11	23.5	36	60	86	118	160	0.636	0.352
	---------------	14.7	28.9	40	55.7	68.8	82.7	97.7		
426504	Finniss River	41.9	70	88.7	112	128	143	158	-0.539	0.291
	---------------	34	60	80.4	104.7	124.9	145.1	167.5		
426529	Marne River	17	32	40	46	50	52.5	54.5	-1.436	0.415
	---------------	19.1	39.9	57.1	78.6	99.3	121.6	147.2		
426530	Currency Creek	9.6	18.5	24.8	31	35	38.5	42	-0.953	0.391
	---------------	14.3	29.7	42.7	61.5	77.4	95.4	115		
426533	Bremer River	42.5	85	104	122	130	137	140.9	-1.547	0.481
	---------------	33.9	76.9	109.6	151.3	186.7	223.3	261.6		
426557	Mt Barker Creek	20	34.5	44	56	65	72	80	-0.595	0.293
	---------------	18.8	31.3	38.4	45.7	50.9	54.7	58.5		
426558	Dawesley Creek	10.5	19.5	29	46	64	86	115	0.813	0.295
	---------------	11.1	20.1	28.5	44	59.8	78.6	103.2		
501500	Hindmarsh River	14.9	27.2	36.3	48.6	58.1	67.7	77.5	-0.363	0.33
	---------------	11.6	19.9	25.3	31.9	36.6	41	45.2		
502502	Myponga River	10.1	13.7	15.1	16.2	16.6	16.9	17.1	-1.598	0.236
	---------------	14.4	19.6	21.4	22.7	22.9	22.9	22.6		
503502	Scott Creek	7.6	12	14	15.6	16.5	17.1	17.5	-1.320	0.281
	---------------	6.7	10.8	12.9	15.1	16.4	17.4	18.4		
503503	Baker Gully	9.88	20.2	28.3	39.7	48.8	58.1	67.9	-0.403	0.393
	---------------	10.6	22.4	31.5	42.3	51.3	60.4	69.8		
503504	Onkaparinga River	79	145	191	248	289	327	364	-0.635	0.353
	---------------	68.1	130.2	184.9	265.9	336.8	411.8	499.4		
503506	Echunga Creek	10.2	16.4	21	27.5	33	38	44	-0.018	0.244
	---------------	10.6	16.8	21.2	27.3	32.1	36.3	41.2		
503507	Lenswood Creek	8.99	19.5	28.2	41	51.6	62.8	74.8	-0.358	0.422
	---------------	9.9	20.2	27	36.6	42.9	48.8	54.1		
503508	Inverbrackie Ck	4.9	9.5	13.5	19.3	25	31	39.2	0.233	0.306
	---------------	4.1	8.5	13	20.6	29.1	39.3	53.4		
503509	Aldgate River	6.77	10.9	14.4	19.9	24.9	30.7	37.5	0.598	0.23
	---------------	6.5	10.7	14.3	19.9	25.2	31.4	38.6		
504512	Torrens River	8.6	17.7	24	30.8	36.2	42	47	-0.587	0.334
	---------------	6.7	13.3	17.8	23.2	27.5	31.8	36.2		
504517	First Creek	0.8	2.1	3.6	7.2	12	18.5	30.5	0.964	0.426
	---------------	0.86	2.2	3.7	7.3	11.9	18.2	29.5		
504518	Sturt River	5.72	9.16	11.1	13.1	14.4	15.4	16.3	0.085	0.293
	---------------	7.7	13.9	19.3	27.2	34.6	42.1	51.5		
504523	Sixth Creek	16.6	32.5	47.7	73.9	99.4	131	171	0.468	0.327
	---------------	10.4	18.8	25.3	34.6	42.2	50	59		
505504	North Para River	41	103	185	300	450	640	920	0.65	0.388
	---------------	52.6	113.7	170.4	237.2	305.9	379.9	468.3		
505517	North Para River	17.8	44	78	150	250	400	630	1.013	0.416
	---------------	16.2	37.1	58.7	92.8	131	177.1	239		

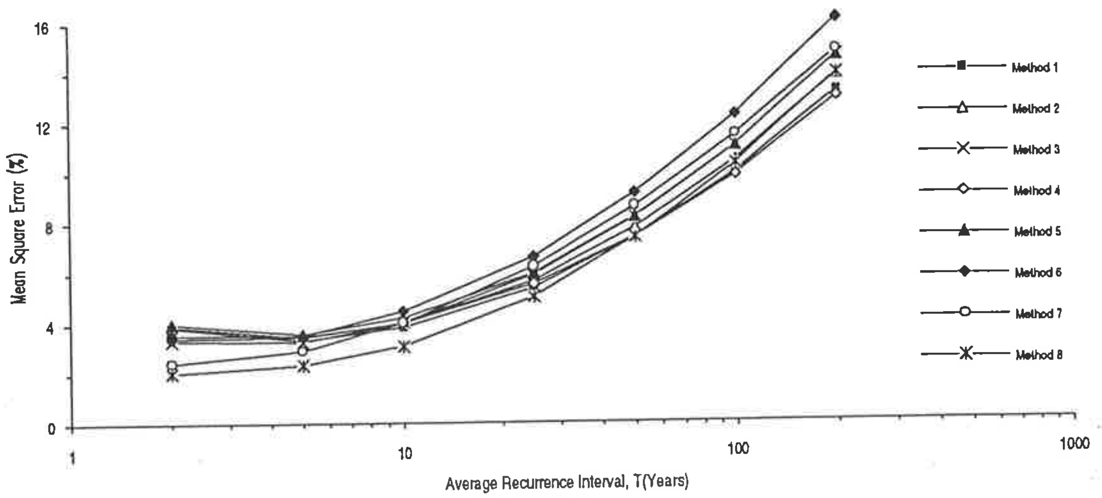

Figure 5.16 Mean Square Error in percent plotted against Average Recurrence Interval for Revised Annual Series.

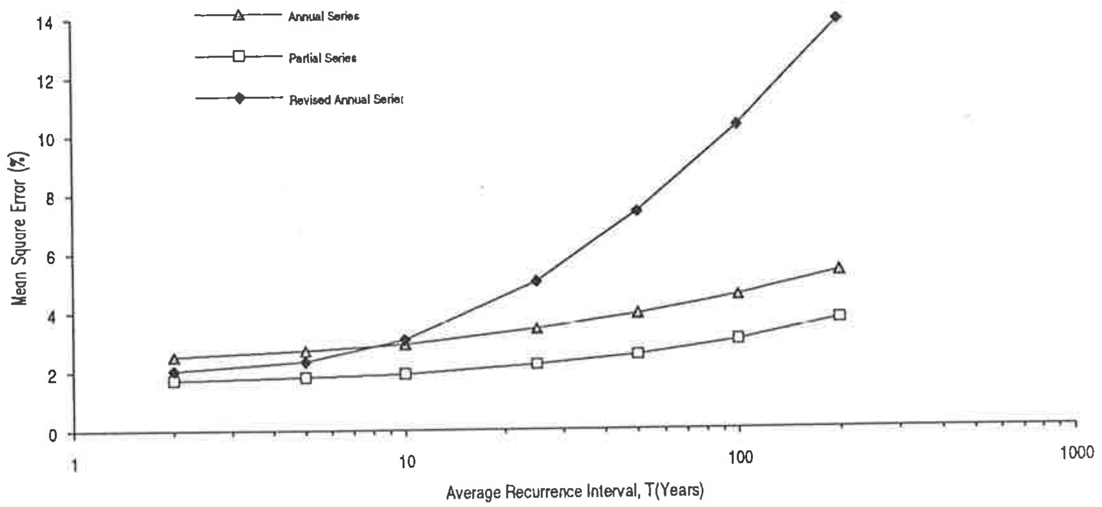

Figure 5.17 Mean Square Error in percent plotted against Average Recurrence Interval for Annual, Partial, and Revised Annual Series.

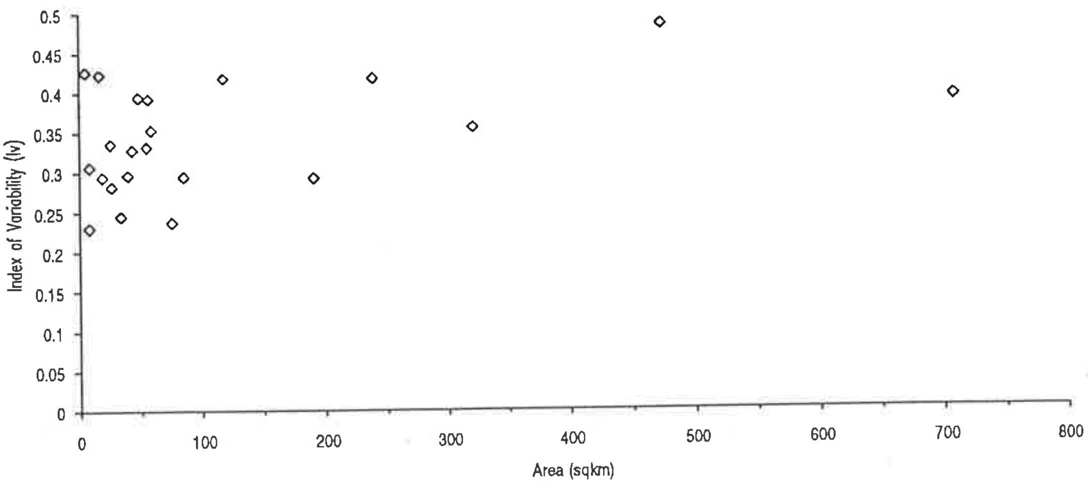

Figure 5.18 Index of Variability plotted against Area for Revised Annual Series.

5.8 Concluding Remarks on Regression Analysis

Eight multiple regression equations have been developed with various combinations of independent variables for average recurrence intervals 2, 5, 10, 25, 50, 100, and 200 years to estimate the flood frequency based on peak discharge for the respective recurrence interval. The stations used in the analysis vary in size of catchment area from 5.01 km^2 to 708 km^2, but because of the scarcity of data all have been considered as one group.

The validity of the regression equations was tested on three stations in the Mt Lofty Ranges (Little Para River, South Para River and Gawler River) though it might be not reliable as these stations are affected by a number of reservoirs within their respective catchment areas. The prediction of flood flows for Gawler River were quite good while for Little Para and South Para River, a large variation from observed flood frequency value has been noticed. Method 1, Method 3, Method 4, Method 6, and Method 8 gave reliable results while Method 4 and 8 were always the best.

The relationships obtained between area and length, area and slope support previous studies. The coefficient of variation has been plotted against area. The points are fairly scattered throughout the whole range, and do not seem to follow any pattern. By comparing coefficient of determination (R^2) and mean square error (MSE) the following conclusions can be drawn :

- The regression equation with all variables (method 8) and method 4 give the best estimation procedure for all recurrence intervals from 2 years to 1000 years. R^2

and MSE are significantly less in comparison to the other methods while all methods give a close prediction at the lower recurrence interval.

- The average median residuals from Table 5.4 and Table 5.5 are 1.05 for the annual series and 1.04 for the partial series, which are small and support the reliability of the evaluated models.
- Coefficient of variation and coefficient of skewness appears to be significant factors in predicting flood flows.
- In some cases, drainage area only is able to give satisfactory results rather than using two or more catchment variables. The %forest seems to have a significant effect on the estimation of the peak flow values.
- The equations give a closer prediction for medium catchments with reasonable slope (10 to 30 m/km) while for large catchments with steep slopes the equations appear to overestimate the peak flows.
- The variation of regression coefficients is uniform throughout all the ARI considered.
- For the stations with extremely low peak flows, Gumbel and Fisher Tippett type III distributions seem to be better than LPIII. When using log based distributions, the logarithm of low values can distort the distribution.

It has been difficult to classify the different catchments as belonging to a particular region. The estimated peak flows depend on many factors and vary from one catchment to an other.

The regression model is not applicable to any stream which is affected by diversions, dams, reservoirs, or any kind of regulation. The equations are applicable of course only in South Australia and more particularly to the coastal ranges and Fleurieu Peninsula.

The range of MSE from low to high recurrence interval is .07 to .151 calculated from the log values of independent variables. The model predicts flow values with a good degree of accuracy when compared to the evaluated flood frequency curves.

Chapter 6

Reliability of Procedure

6.1 General

It is difficult to assess the accuracy of the procedure because inaccuracies can result from different sources. The inaccuracies could be from data errors, measurement errors, inappropriate frequency analysis and inappropriate regionalisation procedures. It is considered to be useful to discuss the errors separately so that the user can subjectively assess the accuracy of the flood magnitude predicted. One major advantage of regional flood frequency analysis is that a combination of all the records from all stations in a hydrologically homogeneous region will reduce the sampling errors considerably.

6.2 Stream flow Data Error

All peak flow data are subject to some measurement inaccuracies which may have significant effect on the determination of the flood flow frequency. In all of the literature on flood frequency analysis, it is assumed that peak flood values are measured without significant error. But in reality, at a gauging station the very large discharges are not measured but the higher flows are estimated by extending the rating curve or by estimated measurements. Therefore these flood values could be subjected to larger errors than those that are gauged directly.

The EWS maintains gauging stations on various creeks, streams and rivers in South Australia. River stage heights are continuously recorded at the gauging stations. The stage is converted to discharge using a rating curve (stage vs discharge curve).

High outliers may occur due to errors in extrapolation. The characteristics of the storm which are responsible for outliers or high values can be analysed to determine whether the outlier is genuine or is caused by inaccuracy in the extrapolation.

Because the likely stream flow data errors could be quite large at the top end of the curve, then it is likely that they will affect the shape of the frequency curves and the derived regional relationships.

Chong et al. (1987) demonstrated the measurement effect on the results of flood frequency analysis in their paper. The effect of small measurement errors are negligible and can be neglected in absence of outliers. The presence of measurement error can invalidate the results of the regional flood frequency analysis.

6.3 Measurement Error

In this study, many of the geomorphological measures which are used in the analysis have considerable uncertainty in their measured values. Parameters such as length, slope, fall, number of farm dams, and basin shape are measured from 1:50000 topographic maps and the average annual rainfall is measured from a 1:100000 isohyetal map which has been developed from station information of varying length of records. There is a every possibility of error in measuring these parameters and difficulty in assessing the quality of measurement of these parameters.

Stream length for a given catchment is the best example. There must be some differences between stream length measured in the field and those measured from maps as a result of smoothing of sinuosities and problems in identifying stream sources. McDermott and Pilgrim found a maximum variation of 80% in measured stream length for a given watershed when examining the effect of map scale on lengths of several hundred streams (Pilgrim, 1986). Baron et al. (1980) reported that different map scales can cause differences of measured length of greater than 50% while variation of 10% is common in individual measurement of lengths from a map. In Australia, scales of generally available maps vary from 1:25000 to

1:250000. The effect of differing sinuosities shown at a different scale has received much less attention and very little information is available on the magnitude of resulting differences in stream lengths measured on different scale maps (Pilgrim, 1986).

Stream slope depends on the inverse of the length and is a function of map scale. Both fall and basin shape also depend on map measurements. Areas of small watersheds have also been found to vary by at least 10% with different scale maps (Pilgrim, 1986). These variations are random rather than systematic.

In the case of measuring the number of farm dams, it can be considered as an estimated value. Recent maps on the Mt Lofty Ranges are unavailable. Some of them having a last edition date of 1974. In this study, the number of farm dams have been determined from old maps and the numbers are calculated for 1990 from the estimated growth in other catchments which is not entirely reliable. There are possibilities of uncertainty in %forest, %urbanisation, %rural and %lakes which are also measured from maps (from the Environment and Planning Department of South Australia). The errors which result from these catchment parameters perhaps could influence the relationship between flood flows and the catchment characteristics.

6.4 Errors in Frequency Analysis

Floods are a random phenomenon with the magnitude of the T-year flood depending upon the underlying probability distribution of flood events and the values of the distribution parameters.

In this study the LPIII distribution has been chosen to represent the distribution of flood flows for Mt Lofty Ranges. A distribution is assumed or chosen in accordance with some criterion of best fit to the observed flood series. The goodness of fit of the distribution to the flood series has been assessed by the 'Difference test' and the 'Chi - square test'. The distribution type was ranked according to the values obtained from those tests. Sometimes it is difficult to assess the best distribution type because some distributions give good results in the difference test while they gave poor results for the chi - square test and vice versa. There is a possibility of bias occurring when assessing the goodness of fit.

The estimation of the peak flow could be subject to measurement errors, the magnitude of which depends upon the measured peak flows and on the length of record. To reduce the sampling errors longer lengths of record of peak flows series are needed. The length of record used in the frequency analysis has a significant effect on the accuracy of the derived frequency curves. There is some uncertainty associated with assigning recurrence intervals to the recorded data and the degree of uncertainty depends on the length of record period being analysed (Taylor et al, 1976).

If very long records were available it would be expected that the predicted flood peaks at a particular frequency or return period would be quite reliable. The shorter the period of record the greater the uncertainty in the recurrence intervals assigned to a particular flow event. In this study, the maximum length of record available is 20 years and the range of record length is from 9 to 20 years. These are considered to be very short lengths of flood peak populations and rather unreliable for the higher return periods. This can be easily proved from the observed and predicted flood values listed in Table 5.2 and Table 5.3 in Chapter 5. From Table 6.1 in Section 6.5 it is shown that best correlation between the regression analysis flows and the frequency analysis flows was found for Q_{10} and Q_{25}.

6.5 Errors in the Regionalisation Procedure

Any major local variation in climate and geology within a particular region could result in a considerable difference between the observed values and predicted values from the regional relationship. The precision of the regression equations for estimating flood values can be judged by the correlation between the observed and predicted values, listed below in Table 6.1.

TABLE 6.1

Correlation between peak flows from Flood Frequency analysis and Multiple Regression analysis

	Correlation Coefficients						
	Q2	Q5	Q10	Q25	Q50	Q100	Q200
Annual Series	.965	.969	.977	.981	.979	.972	.961
Partial Series	.931	.935	.94	.95	.953	.947	.928

In this study, the annual series gives better correlations than the partial series which was not expected.

6.6 Comparisons with Other Regional Studies

The only way to test the reliability of any model is to compare it with the other methods. The EWS made an investigation on the Adelaide Hill's catchments based on the probabilistic rational method (EWS Report No 86/26). The results obtained from the regression analysis have been compared with those from the probabilistic rational method. The regression method proved much better than the rational method although it used a smaller length of record than that of this study. The values and the percentage differences are listed in Table 6.2.

The graph of flood peak flows vs average recurrence interval from observed, regional regression analysis and probabilistic rational method for two catchments, Marne River and Scott Creek, are shown in Figure 6.1. The graph shows that rational method departs significantly from the observed curve whereas the regression curve is close to the observed curve. The regression equation can improve the estimates of flood frequency at an ungauged site compared to the probabilistic rational method.

TABLE 6.2

Comparison of results between regional regression analysis and probabilistic rational method for partial series (EWS Rep. No. 86/26).

Name of Station	Name of Method	Q10	% Diff.	Q50	% Diff.	Q100	% Diff.
Finniss River	Observed value	77.6		141		181	
	Regression Value	82.6	6.44	171	21.2	234	29
	Rational Value	58.9	24.2	88.4	37.3	106	41.2
Marne River	Observed value	37.1		48.4		54.1	
	Regression Value	31.4	15.4	47	2.83	56.2	3.88
	Rational Value	50.6	36.3	83.1	71.7	103	90.5
Bremer River	Observed value	98.7		140		159	
	Regression Value	105	6.28	148	5.57	166	4.84
	Rational Value	72.9	26.2	121	13.5	152	4.36
Hindmarsh River	Observed value	35.5		51.8		60	
	Regression Value	32.4	8.73	51.6	0.39	62.3	3.83
	Rational Value	25.8	27.2	41.7	19.5	51.6	13.9
Scott Creek	Observed value	13.1		18.6		21.4	
	Regression Value	13.2	1.07	18.9	1.61	21.8	1.87
	Rational Value	18.1	38.2	29.3	57.7	36.4	70.3
Baker Gully	Observed value	30		45.6		53.6	
	Regression Value	29.5	1.67	47.3	3.73	57.1	6.53
	Rational Value	25.2	15.9	41.2	9.61	51.3	4.24
Onkaparinga River	Observed value	195		261		291	
	Regression Value	130	33.3	174	33.2	194	33.4
	Rational Value	76.2	60.9	119	54.2	146	49.6
Echunga Creek	Observed value	21.2		30.5		35.2	
	Regression Value	20.8	1.89	28.7	5.9	32.4	7.95
	Rational Value	20.3	4.39	32.9	8.03	41.1	16.6
Lenswood Creek	Observed value	25.1		47.4		61.3	
	Regression Value	24.7	1.59	46.7	1.48	60.4	1.47
	Rational Value	13.5	46.1	21.8	54	29.9	51.1

TABLE 6.2 (Continued)

Inverbrackie Creek	Observed value	13.7		23.4		29.1	
	Regression Value	13.3	2.55	25.2	7.69	32.9	13.1
	Rational Value	8.92	34.9	14.8	36.7	18.5	36.3
Aldgate River	Observed value	14.2		24.5		30.7	
	Regression Value	14.7	3.52	25.5	4.08	32.1	4.56
	Rational Value	8.5	40.1	13.7	44	17	44.7
Torrens River	Observed value	24.1		30		32.5	
	Regression Value	15.5	35.7	18.1	39.7	19	41.5
	Rational Value	16.7	30.9	26.9	10.2	33.3	2.58

Note : % Difference = (Observed - regression or rational) * 100/ Observed value

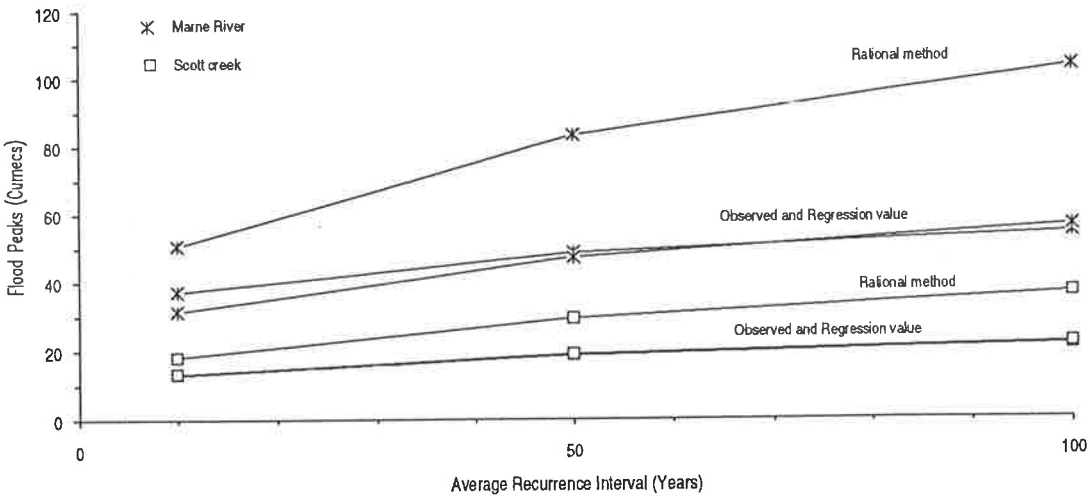

Figure 6.1 Comparative curves of flood peaks vs average recurrence interval from observed value, regression analysis and rational method.

Chapter 7

Conclusions and Recommendation

The objective of this study was to develop an improved method for flood flow estimation. A relationship was developed between observed peak flows and catchment characteristics which possibly could be used in ungauged catchments for estimating or predicting the magnitude of flood events. Eight multiple regression equations have been developed with various combination of independent variables for ARI 2, 5, 10, 25, 50, 100, and 200 to estimate the peak flows for the respective recurrence interval.

After performing two homogeneity tests, it was decided to consider all stations in Mt Lofty Ranges as one homogeneous group. An outlier test was also performed. A program was developed to test outliers and added to the WS06 - computer package (Kopittke et al., 1976a). No outlier was found for the stations used in the frequency analysis, but many low flow values were discarded.

From the flood frequency analysis the LPIII distribution was found to be the best among the ten probability distribution types. The LPIII gives the best fit for the partial series and the Pearson Type 3 gives the best fit for the annual series. As the LPIII gives reasonably good fit for both series, it was chosen as the distribution for the flood frequency analysis. For the stations with extremely low values, Gumbel and Fisher Tippett Type III distributions seem to be better than the LPIII distribution. For log based distributions, the logarithm of low values can distort the distribution.

A strong correlation was found between two major catchment parameters, area and length. Therefore length was discarded from the regression analysis. The length is a function of area to a power of approximately 0.6 which supports a past investigation (EWS Report No, 1986). The number of farm dams has a high correlation with other catchment variables but most significantly with the percentage of rural catchment.

The most important variable was found to be the drainage area. Eight regression equations with different combinations of catchment variables have been evaluated and an effort has been made to find the best combination for estimating flood flows. Method 4 which includes area, Sk, and Cv and method 8 which includes eleven independent variables, as shown in Table 5.2 have the least mean square errors and are considered to be the best methods for predicting flood flows at ungauged sites. All methods give closer prediction at lower recurrence intervals. The %forest seems to have a significant effect on the estimation of the peak flow values. The coefficient of variation and the coefficient of skewness appear to be significant factors in predicting flood flows.

It could be recommended that by analysing further stations a contour map of Sk and Cv could be drawn. The regression equations with the variables of area, Sk and Cv are an extremely simple set of equations and using these equations, flood peak flows at different ARIs can be determined with less effort and time at an ungauged site.

A detailed study of soil class could also be valuable in this type of regional flood estimation, as the infiltration index of soil can be considered important when estimating the magnitude of peak flows.

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Glossary

The terms used in this study include definitions taken from USWRC (1976) and IE.Aust (1987) are listed below :

Annual Flood : The maximum instantaneous peak discharge in each year of record.

Annual Flood Series : A list of annual flood peak flows.

Array : A list of data in order of magnitude ; in flood frequency analysis it is customary to list the largest value first.

Average Recurrence Interval (ARI) : The ARI is the average interval between years in which a given discharge is exceeded, whether once or more than once. This is different from the ARI for the partial series, which is the average interval between exceedances of the given discharge.

Coefficient of Skewness or Skew Coefficient : A numerical measure or index of the lack of symmetry in a frequency distribution. Function of the third moment of magnitudes about their mean, a measure of asymmetry.

Coefficient of Variation : The coefficient of variation is a dimensionless measure of variability.

Confidence Limits : Confidence intervals give the range within which the actual population is expected to lie with a selected level of probability. The confidence limits enclose the confidence interval.

Distribution : Function describing the relative frequency with which events of various magnitudes occur.

Exceedance Probability : The probability that a random event will exceed a specified magnitude in a given time period, usually one year unless otherwise indicated.

Expected Probability : The average of the true probabilities of all magnitude estimates for any specified flood frequency that might be made from successive samples of a specified size.

Homogeneity : Records from the same populations.

Index of Variability (Iv) : The standard deviation of the logarithms of actual peak discharges.

Method of Moments : A standard statistical computation for estimating the moment of a distribution from the data of a sample.

Outlier : Outliers (extreme events) are data points which depart significantly from the trend of the remaining observed data.

Parameter : A characteristic descriptor, such as a mean or standard deviation.

Partial Flood Series : A partial flood series consists of all independent floods with peak discharges above a selected base value, regardless of the number of such floods occurring each year.

Percent Chance : A probability multiplied by 100.

Plotting Position : The value of the annual exceedance probability (AEP) or average recurrence interval (ARI) used for plotting is known as the "plotting position".

Standard Deviation : A measure of the dispersion or precision of a series of statistical values such as precipitation or streamflow. It is the square root of the sum of squares of the deviations from the arithmetic mean divided by the number of values or events in the series.

Standard Error : An estimate of the standard deviation of a statistic. Often calculated from a single set of observations. Calculated like the standard deviation but differing from it in meaning.

Appendix A

Station Summary Report

Station Description : AW426503 Angas River at Angas Weir

Latitude : 35 : 14

Longitude : 138 : 51

Maximum Gauging Height (m) : 10.16

Maximum Gauged Flow (m^3/s) : 0.263

Period of Record :

Continuous Record : 29.05.1964 - 04.03.1969 (a)

04.03.1969 - 26.03.1981 (b)

26.03.1981 (c)

Details :

Stage : Electroflow, L & S F Type Float Operated and L & S/ Aus1 A Type Float Operated for Continuous Record a, b, and c

Control : Sharp Stepped Weir

Measuring Facility :

Quality of Record : Poor Fair and Good for Continuous Record a, b, and c

Use : Stream Gauging

Site : Natural Watercourse

Frequency : Continuous Analogue

Water Quality : Comprehensive

Remarks :

Station Description : AW426504 Finniss River 4 km East of Yundi

Latitude : 35 : 20

Longitude : 138 : 40

Maximum Gauging Height (m) : 1.065

Maximum Gauged Flow (m^3/s) : 0.062

Period of Record :

Continuous Record :	08.06.1965 - 06.03.1969	(a)
	06.03.1969 - 03.02.1975	(b)
	03.02.1975	(c)

Details :

Stage : Electroflow, L & S F Type Float Operated and L & S/ Aus1 A Type Float Operated for Continuous Record a, b, and c

Control : Sharp Stepped Weir

Measuring Facility : Traveller

Quality of Record : Poor Fair and Good for Continuous Record a, b, and c

Use : Stream Gauging

Site : Natural Watercourse

Frequency : Continuous Analogue

Water Quality : Comprehensive

Remarks :

Station Description : AW426529 Marne River at U / S Cambrai

Latitude : 34 : 41

Longitude : 139 : 14

Maximum Gauging Height (m) : 1.935

Maximum Gauged Flow (m^3/s) : 4.21

Period of Record :

Continuous Record : 06.12.1972 - 03.07.1989

Details :

Stage : L & S/ Aus1 A Type Float Operated

Control : Stable Natural

Measuring Facility :

Quality of Record : Good

Use : Stream Gauging

Site : Natural Watercourse

Frequency : Continuous Analogue

Water Quality : Comprehensive

Remarks : Discontinued

Station Description : AW426530 Currency Creek at Near Higgins

Latitude : 35 : 27

Longitude : 138 : 42

Maximum Gauging Height (m) : 1.374

Maximum Gauged Flow (m^3/s) : 0.63

Period of Record :

Continuous Record : 06.06.1972 -

End of Data : 08.06.1989

Details :

Stage : L & S/ Aus1 A Type Float Operated

Control : Triangular Vee Weir

Measuring Facility : Traveller

Quality of Record : Good

Use : Stream Gauging

Site : Natural Watercourse

Frequency : Continuous Analogue

Water Quality : Comprehensive

Remarks :

Station Description : AW426533 Bremer River at Near Hartley

Latitude : 35 : 13

Longitude : 139 : 0

Maximum Gauging Height (m) : 1.148

Maximum Gauged Flow (m^3/s) : 0.07

Period of Record :

Continuous Record : 11.05.1973 -

End of Data : 13.12.1989

Details :

Stage : L & S/ Aus1 A Type Float Operated

Control : Triangular Vee Weir

Measuring Facility : Traveller

Quality of Record : Good

Use : Stream Gauging

Site : Natural Watercourse

Frequency : Continuous Analogue

Water Quality : Comprehensive

Remarks :

Station Description : AW426557 Mt Barker Creek at D / S Mt Barker

Latitude : 35 : 5

Longitude : 138 : 55

Maximum Gauging Height (m) : 2.41

Maximum Gauged Flow (m^3/s) : 20.58

Period of Record :

Continuous Record : 24.04.1979 -

End of Data : 08.08.1989

Details :

Stage : L & S/ Aus1 A Type Float Operated

Control : Triangular Vee Weir

Measuring Facility : Traveller

Quality of Record : Good

Use : Stream Gauging

Site : Natural Watercourse

Frequency : Continuous Analogue

Water Quality : Comprehensive

Remarks :

Station Description : AW426558 Dawesley Creek at Dawesley

Latitude : 35 : 2

Longitude : 138 : 57

Maximum Gauging Height (m) : 1.892

Maximum Gauged Flow (m^3/s) : 11.08

Period of Record :

Continuous Record : 01.06.1978

End of Data : 08.08.1989

Details :

Stage : L & S/ Aus1 A Type Float Operated

Control : Triangular Vee Weir

Measuring Facility : Traveller

Quality of Record : Good

Use : Stream Gauging

Site : Natural Watercourse

Frequency : Continuous Analogue

Water Quality : Comprehensive

Remarks :

Station Description : AW501500 Hindmarsh River at Hindmarsh Valley Res Intake Weir

Latitude : 35 : 28

Longitude : 138 : 35

Maximum Gauging Height (m) : 1.751

Maximum Gauged Flow (m^3/s) : 2.6

Period of Record :

Continuous Record : 22.07.1964 - 26.01.1968 (a)

07.03.1969 - 18.10.1977 (b)

18.10.1977 - (c)

1989 - (d)

End of Data : 04.04.1990

Details :

Stage : Electroflow, L & S F Type Float Operated, L & S / Aus1 A Type Float Operated, and SDS Torrens Solid State Logger for Continuous Record a, b, c and d

Control : Sharp Stepped Weir

Measuring Facility :

Quality of Record : Poor, Fair and Good for Continuous Record a, b, and c

Use : Stream Gauging

Site : Natural Watercourse

Frequency : Continuous Analogue

Water Quality : Comprehensive

Remarks :

Station Description : AW502502 Myponga River at U / S Dam and Road Bridge

Latitude : 35 : 23

Longitude : 138 : 29

Maximum Gauging Height (m) : 3.374

Maximum Gauged Flow (m^3/s) : 13.4

Period of Record :

Continuous Record : 20.04.1978 -

End of Data : 02.08.1990

Details :

Stage : Differential Pressure Transducer and L & S Type A

Control : Triangular Vee Weir

Measuring Facility :

Quality of Record : Good

Use : Stream Gauging

Site : Natural Watercourse

Frequency : Continuous Analogue

Water Quality : Comprehensive

Remarks :

Station Description : AW503502 Scott Creek at Scott Bottom

Latitude : 35 : 06

Longitude : 138 : 41

Maximum Gauging Height (m) : 2.229

Maximum Gauged Flow (m^3/s) : 9.16

Period of Record :

Continuous Record :	28.05.1964 - 31.12.1964	(a)
	31.12.1964 - 02.04.1969	(b)
	27.03.1969 - 24.11.1976	(c)
	26.11.1976 -	(d)
	1989 -	(e)

End of Data : 28.03.1990

Details :

Stage : Electroflow, Bristol, L & S F Type Float Operated, L & S / Aus1 A Type Float Operated, and SDS Torrens Solid State Logger for Continuous Record a, b, c and d

Control : Sharp Stepped Weir

Measuring Facility :

Quality of Record : Poor, Poor, Fair and Good for Continuous Record a, b, c, and d

Use : Stream Gauging

Site : Natural Watercourse

Frequency : Continuous Analogue

Water Quality : Comprehensive

Remarks : Telemark

Station Description: AW503503 Baker Gully at 4.5 km WNW Kangarilla

Latitude : 35 : 8

Longitude : 138 : 36

Maximum Gauging Height (m) : 2.011

Maximum Gauged Flow (m^3/s) : 4.2

Period of Record :

Continuous Record : 11.04.1969 - 18.11.1976 (a)

18.11.1976 - 26.06.1989 (b)

End of Data : 26.06.1989

Details :

Stage : L & S F Type Float Operated, and L & S / Aus1 A Type Float Operated for Continuous Record a, and b

Control : Sharp Stepped Weir

Measuring Facility :

Quality of Record : Fair and Good for Continuous Record a and b

Use : Stream Gauging

Site : Natural Watercourse

Frequency : Continuous Analogue

Water Quality : Comprehensive

Remarks : Discontinued

Station Description : AW503504 Onkaparinga River at At Houlgrave

Latitude : 35 : 5

Longitude : 138 : 43

Maximum Gauging Height (m) : 6.701

Maximum Gauged Flow (m^3/s) : 184.43

Period of Record :

Continuous Record : 17.04.1973 - (a)

1989 - (b)

Details :

Stage : L & S / Aus1 A Type Float Operated, and SDS Torrens Solid State Logger for Continuous Record a, and b

Control : Triangular Vee Weir

Measuring Facility : Traveller

Quality of Record : Good

Use : Stream Gauging

Site : Natural Watercourse

Frequency : Continuous Analogue

Water Quality : Comprehensive

Remarks : Telemark

Station Description : AW503506 Echunga Creek at U / S Mt Bold Res.

Latitude : 35 : 7

Longitude : 138 : 44

Maximum Gauging Height (m) : 2.775

Maximum Gauged Flow (m^3/s) : 18.82

Period of Record :

Continuous Record : 22.03.1973 - 17.09.1976 (a)

17.09.1976 - (b)

1989 - (c)

End of Data : 15.03.1990

Details :

Stage : L & S F Type Float Operated, L & S / Aus1 A Type Float Operated, and SDS Torrens Solid State Logger for Continuous Record a, b, and c

Control : Sharp Combination Weir

Measuring Facility : Traveller

Quality of Record : Fair and Good for Continuous record a and b

Use : Stream Gauging

Site : Natural Watercourse

Frequency : Continuous Analogue

Water Quality : Comprehensive

Remarks :

Station Description : AW503507 Lenswood creek at lenswood

Latitude : 34 : 58

Longitude : 138 : 51

Maximum Gauging Height (m) : 2.107

Maximum Gauged Flow (m^3/s) : 8.24

Period of Record :

Continuous Record : 18.05.1972 - 22.06.1989

End of Data : 22.06.1989

Details :

Stage : L & S / Aus1 A Type Float Operated

Control : Triangular Vee Weir

Measuring Facility : Traveller

Quality of Record : good

Use : Stream Gauging

Site : Natural Watercourse

Frequency : Continuous Analogue

Water Quality : Comprehensive

Remarks : Discontinued

Station Description : AW503508 Inverbrackie Creek at Craigbank

Latitude : 34 : 57

Longitude : 138 : 57

Maximum Gauging Height (m) : 0.948

Maximum Gauged Flow (m^3/s) : 4.79

Period of Record :

Continuous Record : 17.05.1972 -

End of Data : 16.10.1990

Details :

Stage : L & S / Aus1 A Type Float Operated

Control : Stable Natural

Measuring Facility : Traveller

Quality of Record : Good

Use : Stream Gauging

Site : Natural Watercourse

Frequency : Continuous Analogue

Water Quality : Comprehensive

Remarks : Pluviometer at station

Station Description : AW503509 Aldgate Creek at Aldgate Rly. Station

Latitude : 35 : 2

Longitude : 138 : 44

Maximum Gauging Height (m) : 2.132

Maximum Gauged Flow (m^3/s) : 8.19

Period of Record :

Continuous Record : 13.07.1972 - 22.06.1989

End of Data : 22.06.1989

Details :

Stage : L & S / Aus1 A Type Float Operated

Control : Stable Natural

Measuring Facility : Traveller

Quality of Record : Good

Use : Stream Gauging

Site : Natural Watercourse

Frequency : Continuous Analogue

Water Quality : Comprehensive

Remarks : Discontinued

Station Description : AW504512 Torrens River at Mt Pleasant

Latitude : 34 : 47

Longitude : 139 : 2

Maximum Gauging Height (m) : 1.965

Maximum Gauged Flow (m^3/s) : 13.0

Period of Record :

Continuous Record : 02.05.1973 - (a)

1989 - (b)

End of Data : 19.07.1990

Details :

Stage : L & S / Aus1 A Type Float Operated, and SDS Torrens Solid State Logger for Continuous Record a, and b

Control : Stable Natural

Measuring Facility : Traveller

Quality of Record : Good

Use : Stream Gauging

Site : Natural Watercourse

Frequency : Continuous Analogue

Water Quality : Comprehensive

Remarks : Telemark, Pluviometer at Station

Station Description : AW504517 First Creek at Waterfall Gully

Latitude : 34 : 58

Longitude : 138 : 41

Maximum Gauging Height (m) : 1.382

Maximum Gauged Flow (m^3/s) : 1.21

Period of Record :

Continuous Record : 07.10.1976 -

End of Data : 19.06.1990

Details :

Stage : L & S / Aus1 A Type Float Operated

Control : Triangular Vee Weir

Measuring Facility :

Quality of Record : Good

Use : Stream Gauging

Site : Natural Watercourse

Frequency : Continuous Analogue

Water Quality : Comprehensive

Remarks :

Station Description : AW504518 Sturt River at U / S Minno Ck Junction

Latitude : 35 : 4

Longitude : 138 : 57

Maximum Gauging Height (m) : 1.818

Maximum Gauged Flow (m^3/s) : 9.46

Period of Record :

Continuous Record : 08.12.1977 -

End of Data : 17.04.1990

Details :

Stage : Differential Pressure Transducer and L & S type A

Control : Triangular Vee Weir

Measuring Facility :

Quality of Record : Fair

Use : Stream Gauging

Site : Natural Watercourse

Frequency : Continuous Analogue

Water Quality : Comprehensive

Remarks :

Station Description : AW504523 Sixth Creek at Castambul

Latitude : 34 : 53

Longitude : 138 : 45

Maximum Gauging Height (m) : 2.611

Maximum Gauged Flow (m^3/s) : 23.08

Period of Record :

Continuous Record : 10.11.1977 - 14.08.1989

End of Data : 14.08.1989

Details :

Stage : L & S / Aus1 A Type Float Operated

Control : Triangular Vee Weir

Measuring Facility : Traveller

Quality of Record : Good

Use : Stream Gauging

Site : Natural Watercourse

Frequency : Continuous Analogue

Water Quality : Comprehensive

Remarks : Discontinued

Station Description : AW505504 North Para River at Turretfield

Latitude : 34 : 34

Longitude : 138 : 46

Maximum Gauging Height (m) : 4.470

Maximum Gauged Flow (m^3/s) : 74.6

Period of Record :

Continuous Record : 22.05.1972 - 24.06.1976 (a)

24.06.1976 - (b)

1989 - (c)

Details :

Stage : L & S F Type Float Operated, L & S / Aus1 A Type Float Operated, and SDS Torrens Solid State Logger for Continuous Record a, b, and c

Control : Sharp Combination Weir

Measuring Facility : Traveller

Quality of Record : Fair and Good for Continuous Record a and b

Use : Stream Gauging

Site : Natural Watercourse

Frequency : Continuous Analogue

Water Quality : Comprehensive

Remarks : Telemark and Pluviometer at Station

Station Description : AW505517 North Para River at Penrice

Latitude : 34 : 28

Longitude : 139 : 4

Maximum Gauging Height (m) : 2.130

Maximum Gauged Flow (m^3/s) : 19.035

Period of Record :

Continuous Record : 22.06.1977 - (a)

1989 - (b)

End of Data : 24.07.1990

Details :

Stage : Differential Pressure Transducer and L & S Type A and SDS Torrens Solid State Logger for Continuous Record a, and b

Control : Triangular Vee Weir

Measuring Facility : Traveller

Quality of Record : Good

Use : Stream Gauging

Site : Natural Watercourse

Frequency : Continuous Analogue

Water Quality : Comprehensive

Remarks : Telemark and Pluviometer at Station

Appendix B

B.1 Homogeneity Test

Equations for the homogeneity test are taken from Dalrymple (1960) :

The standard deviation of the reduced variate y, of the Gumbel distribution is equal to :

$$\sigma_y = \frac{e^y}{\sqrt{n}}\sqrt{\frac{1}{T-1}}$$

T = recurrence interval

n = number of years of record

y = function of the recurrence interval T

Which means a large number of different but homogeneous records, each n years long, probably two thirds of the estimates of the T - years flood will be within of their most probable value of T. It was decided to make the test on the 10 - year flood because this is the longest recurrence interval for which most records will give dependable estimates. The following calculations are derived , where

T = 10 years

y = 2.25 years

$e^y = 9.49$

$$2\sigma_y = \frac{2e^y}{\sqrt{n}}\sqrt{\frac{1}{T-1}}$$

$$2e^y\sqrt{\frac{1}{T-1}} = 2 * 9.49 * \sqrt{\frac{1}{9}}$$

$$= 6.33$$

The Table 3.5 (Chapter 3) gives values of upper and lower limit for the homogeneity test chart taken from Gumbel (1942).

The output from SAS for cluster analysis has been given next.

B.2 Output from Cluster Analysis

STATION	AREA	MAR	LENGTH	SLOPE	FALL	NFD	Q100	Q50	Q10
ANGAS RIVER	59.60	491	17.50	15.714	275	430	108.8	83.2	42.4
FINNISS RIVER	191.00	912	33.00	4.400	145	1185	181.4	141.0	77.6
MARNE RIVER	239.00	288	37.50	8.267	310	695	54.1	48.4	37.1
CURRENCY CK	56.90	488	16.50	13.030	215	470	28.7	26.4	21.1
BREMER RIVER	473.00	376	50.00	9.340	467	1640	159.3	140.1	98.7
MT BARKER CK	85.90	751	18.00	7.220	130	575	81.9	68.7	43.7
DAWESLEY CK	40.10	674	12.75	14.510	185	215	74.9	60.0	34.0

Q5	Q2	SK	CV	QMEAN	QMAF	QSP
30.6	18.3	0.636	0.317	109.945	1.8447	0.98959
59.4	40.9	0.539	0.182	109.945	0.5756	1.64992
32.8	27.5	1.907	1.171	109.945	0.4600	0.49206
18.7	14.9	1.221	0.569	109.945	1.9322	0.26104
81.4	57.1	1.837	0.504	109.945	0.2324	1.44891
34.7	23.6	1.937	0.529	109.945	1.2799	0.74492
25.7	16.3	1.391	0.889	109.945	2.7418	0.68125

STATION	AREA	MAR	LENGTH	SLOPE	FALL	NFD	Q100	Q50	Q10
HINDMARSH RIVER	55.50	830	17.00	20.176	343	330	60.0	51.8	35.5
MYPONGA RIVER	76.50	768	16.50	6.180	102	560	14.5	14.2	13.3
SCOTT CK	26.80	809	11.00	22.727	250	175	21.4	18.6	13.1
BAKER GULLY	48.70	740	15.00	15.200	228	276	53.6	45.6	30.0
ONKAPARINGA RIVER	321.0	952	44.00	6.136	270	2320	290.6	261.2	195.0
ECHUNGA CK	34.20	787	12.50	14.000	175	220	35.2	30.5	21.2
LENSWOOD CK	16.50	1049	6.00	27.500	165	190	61.3	47.4	25.1

Q5	Q2	SK	CV	QMEAN	QMAF	QSP
29.3	21.2	0.363	0.286	109.945	1.9810	0.54573

12.9	12.0	1.598	0.250	109.945	1.4372	0.13188
11.1	8.6	1.686	0.475	109.945	4.1024	0.19464
24.2	17.0	0.403	0.406	109.945	2.2576	0.48752
166.0	123.2	0.635	0.190	109.945	0.3425	2.6431
17.7	13.3	1.860	0.422	109.945	3.2148	0.32016
18.6	11.7	0.358	0.454	109.945	6.6633	0.55755

STATION	AREA	MAR	LENGTH	SLOPE	FALL	NFD	Q100	Q50	Q10
INVERBRACKIE CK	8.38	832	5.75	12.000	69	69	29.1	23.4	13.7
ALDGATE RIVER	7.80	1175	3.50	57.143	200	7	30.7	24.5	14.2
TORRENS RIVER	25.80	677	8.50	9.170	78	165	32.5	30.0	24.1
FIRST CREEK	5.01	1018	3.50	82.860	290	10	17.0	10.7	3.7
STURT RIVER	19.40	711	10.00	28.000	280	93	18.3	15.6	10.7
SIXTH RIVER	43.60	840	15.75	26.030	410	227	141.4	101.1	45.0
NORTH PARA RIVER	708.00	446	78.50	4.940	388	1570	549.1	388.3	168.4
NORTH PARA RIVER	118.00	503	25.00	6.400	160	510	375.0	217.0	64.8
							======		
							2418.8		

Q5	Q2	SK	CV	QMEAN	QMAF	QSP
10.5	7.0	2.576	1.422	109.945	13.1199	0.26468
11.1	7.8	0.598	0.269	109.945	14.0955	0.27923
21.4	17.1	1.428	1.395	109.945	4.2614	0.29560
2.4	1.4	0.265	5.670	109.945	21.9451	0.15462
9.0	7.0	0.950	0.412	109.945	5.6673	0.16645
31.0	18.0	0.468	0.262	109.945	2.5217	1.28610
115.0	65.7	1.123	0.587	109.945	0.1553	4.99432
40.3	23.7	1.672	0.623	109.945	0.9317	3.41080

Ward's Minimum Variance Cluster Analysis

Eigenvalues of the Covariance Matrix (For plot of Cv^*Q_{MAF})

	Eigenvalue	Difference	Proportion	Cumulative
1	30.5962	30.0245	0.981655	0.98166
2	0.5718	.	0.018345	1.00000

Root-Mean-Square Total-Sample Standard Deviation = 3.947657

Root-Mean-Square Distance Between Observations = 7.895313

NCL	Clusters	Joined	FREQ	SPRSQ	RSQ	ERSQ	CCC	PSF	PST2
15	CL16	OB22	3	0.00024	0.999	.	.	946.3	3.1
14	CL19	CL21	4	0.00030	0.999	.	.	738.1	11.9
13	OB7	OB13	2	0.00034	0.999	.	.	640.0	.
12	CL17	CL18	5	0.00041	0.998	.	.	573.8	7.8
11	OB10	OB17	2	0.00067	0.998	.	.	488.3	.
10	OB14	OB19	2	0.00076	0.997	.	.	442.1	.
9	CL14	OB3	5	0.00081	0.996	.	.	423.6	6.9
8	OB15	OB16	2	0.00174	0.994	.	.	357.4	.
7	CL12	CL13	7	0.00184	0.993	.	.	332.1	8.6
5	CL11	CL10	4	0.00640	0.984	.	.	262.4	9.0
4	CL7	CL6	15	0.01610	0.968	0.9448	1.931	181.2	32.8
3	CL4	CL5	19	0.06672	0.901	0.8995	0.065	86.7	37.4
2	CL8	OB18	3	0.09451	0.807	0.7626	0.943	83.5	54.2
1	CL3	CL2	22	0.80673	0.000	0.0000	0.000	.	83.5

Eigenvalues of the Covariance Matrix (For plot of Sk^*Q_{MAF})

	Eigenvalue	Difference	Proportion	Cumulative
1	29.8622	29.4272	0.985643	0.98564
2	0.4350	.	0.014357	1.00000

Root-Mean-Square Total-Sample Standard Deviation = 3.892121

Root-Mean-Square Distance Between Observations = 7.784241

NCL	Clusters Joined		FREQ	SPRSQ	RSQ	ERSQ	CCC	PSF	PST2
15	CL16	OB	3	0.00020	0.999	.	.	821.6	1.8
14	OB7	OB13	2	0.00035	0.999	.	.	642.5	.
13	CL17	CL19	4	0.00036	0.999	.	.	528.2	8.0
11	CL13	OB4	5	0.00077	0.998	.	.	440.2	4.7
10	OB14	OB19	2	0.00106	0.996	.	.	374.5	.
9	CL21	CL15	5	0.00146	0.995	.	.	322.7	12.4
8	CL14	CL18	4	0.00228	0.993	.	.	272.2	10.9
7	OB15	OB16	2	0.00382	0.989	.	.	222.4	.
6	CL12	CL9	8	0.00386	0.985	.	.	210.4	10.2
5	CL11	CL8	9	0.01088	0.974	.	.	160.1	19.2
4	CL5	CL6	17	0.02978	0.944	0.9476	-0.215	101.8	21.3
3	CL4	CL10	19	0.05496	0.889	0.9026	-0.476	76.4	18.0
2	CL7	OB18	3	0.07467	0.815	0.7655	1.075	87.9	19.5
1	CL3	CL2	22	0.81473	0.000	0.0000	0.000	.	87.9

Eigenvalues of the Covariance Matrix (For plot of Cv^*Q_{SP})

	Eigenvalue	Difference	Proportion	Cumulative
1	1.69724	0.569360	0.600768	0.60077
2	1.12788		0.399232	1.00000

Root-Mean-Square Total-Sample Standard Deviation = 1.18851

Root-Mean-Square Distance Between Observations = 2.377021

NCL	Clusters Joined		FREQ	SPRSQ	RSQ	ERSQ	CCC	PSF	PST2
15	CL17	CL20	4	0.00025	0.999	.	.	498.8	2.0
14	OB5	OB20	2	0.00072	0.998	.	.	357.5	.
13	OB6	CL16	4	0.00086	0.997	.	.	290.6	5.7
12	OB3	OB7	2	0.00097	0.996	.	.	255.5	.
11	CL15	CL18	6	0.00101	0.995	.	.	240.3	5.9

10	OB2	CL14	3	0.00135	0.994	.	.	224.4	1.9
9	OB1	CL13	5	0.00236	0.992	.	.	195.0	6.1
8	CL12	CL21	4	0.00400	0.988	.	.	161.1	8.1
7	OB12	OB22	2	0.00655	0.981	.	.	130.4	.
6	CL9	CL11	11	0.00888	0.972	.	.	112.4	15.3
5	CL6	CL8	15	0.03327	0.939	.	.	65.5	22.7
4	CL7	OB21	3	0.04386	0.895	0.8225	3.120	51.2	6.7
3	CL5	CL10	18	0.04890	0.846	0.7333	3.744	52.3	14.4
2	CL3	CL4	21	0.41239	0.434	0.5025	-0.976	15.3	51.0
1	CL2	OB18	22	0.43389	0.000	0.0000	0.000	.	15.3

Appendix C

Regression Analysis

Regression analysis is the analysis of the relationship between one variable and another set of variables. The relationship is expressed as an equation that predicts a dependent variable (or response variable) from a function of independent variables (or regressor variables) and parameters. The equation for the ith observation might be (SAS, 1988).

$$Yi = \beta_0 + \beta_1 X_i + \varepsilon_i$$

Where, Yi is the dependent variables, Xi is a independent variables, β_0 and β_1 are unknown parameters to be estimated, and ε_i is an error term.

The coefficient of determination (R^2), the error sum of squares (SSE), the mean square error (MSE) and the final prediction error or the estimated mean square error of prediction (JP) for each model are listed in Table C.1, Table C.2 and Table C.3. The above statistics are defined below :

1.The error sum of squares (SSE) = $\Sigma (Yi - \beta_0 - \beta_1 X_i)^2$

2. The coefficient of determination (R^2) = $1 - \dfrac{SSE}{SST_i}$

R^2 is an indicator of how much of the variation in the data is explained by the model. where,

> SST_0 = the uncorrected total sum of squares for the mean for the dependent variables.
>
> SST_1 = the total sum of squares corrected for the mean for the dependent variables.

i = 1 if there is an intercept, 0 otherwise.

3. The mean square error (MSE) = $\dfrac{SSE}{(n-p)}$

where,

n = the number of observations.

p = the number of parameters including the intercept.

4. The final prediction error (JP) = $\dfrac{MSE(n+p)}{n}$

TABLE C.1

Results of regression procedure from statistical package SAS (Annual series).

Recurrence Interval	Independent Variables	R^2	SSE	MSE	JP
2	A	.741	.91	.045	.049
	A, S	.76	.85	.045	.051
	A, R, S	.801	.694	.04	.045
	A, S, Sh	.76	.844	.047	.055
	A, Sk, Cv	.88	.42	.023	.027
	A, R, S, D, Sh	.806	.68	.042	.054
	A, S, Sh, F, U, Ru, L	.876	.434	.031	.042
	A,R,S,D,Sh,F,U,Ru,L,Sk,Cv	.93	.25	.025	.038
5	A	.82	.66	.033	.036
	A, S	.83	.62	.033	.037
	A, R, S	.833	.617	.034	.04
	A, S, Sh	.834	.612	.034	.04
	A, Sk, Cv	.841	.587	.033	.038
	A, R, S, D, Sh	.84	.60	.037	.048

TABLE C.1 (Continued)

Recurrence Interval	Independent Variables	R^2	SSE	MSE	JP
	A, S, Sh, F, U, Ru, L	.891	.40	.028	.039
	A,R,S,D,Sh,F,U,Ru,L,Sk,Cv	.924	.277	.027	.043
10	A	.81	.71	.035	.039
	A, S	.81	.71	.037	.04
	A, R, S	.811	.703	.04	.046
	A, S, Sh	.815	.69	.038	.045
	A, Sk, Cv	.821	.665	.037	.044
	A, R, S, D, Sh	.82	.68	.043	.054
	A, S, Sh, F, U, Ru, L	.861	.52	.037	.051
	A,R,S,D,Sh,F,U,Ru,L,Sk,Cv	.92	.296	.029	.046
25	A	.735	.93	.046	.051
	A, S	.76	.92	.048	.055
	A, R, S	.76	.91	.05	.06
	A, S, Sh	.762	.896	.05	.06
	A, Sk, Cv	.8	.756	.042	.05
	A, R, S, D, Sh	.764	.89	.055	.07
	A, S, Sh, F, U, Ru, L	.8	.751	.053	.073
	A,R,S,D,Sh,F,U,Ru,L,Sk,Cv	.91	.34	.034	.052
50	A	.69	1.18	.059	.065
	A, S	.704	1.13	.06	.07
	A, R, S	.71	1.11	.062	.073
	A, S, Sh	.71	1.11	.06	.073
	A, Sk, Cv	.783	.83	.046	.054
	A, R, S, D, Sh	.715	1.09	.07	.087
	A, S, Sh, F, U, Ru, L	.75	.96	.07	.094
	A,R,S,D,Sh,F,U,Ru,L,Sk,Cv	.9	.39	.039	.06
100	A	.62	1.51	.075	.082
	A, S	.65	1.38	.073	.083

TABLE C.1 (Continued)

Recurrence Interval	Independent Variables	R^2	SSE	MSE	JP
	A, R, S	.66	1.35	.075	.088
	A, S, Sh	.65	1.36	.075	.09
	A, Sk, Cv	.77	.913	.051	.06
	A, R, S, D, Sh	.66	1.32	.083	.105
	A, S, Sh, F, U, Ru, L	.695	1.2	.086	.117
	A,R,S,D,Sh,F,U,Ru,L,Sk,Cv	.88	.45	.045	.07
200	A	.54	1.89	.094	.103
	A, S	.595	1.66	.087	.099
	A, R, S	.61	1.61	.089	.106
	A, S, Sh	.6	1.64	.091	.107
	A, Sk, Cv	.755	1.0	.056	.066
	A, R, S, D, Sh	.613	1.59	.099	.126
	A, S, Sh, F, U, Ru, L	.644	1.46	.104	.142
	A,R,S,D,Sh,F,U,Ru,L,Sk,Cv	.87	.534	.053	.08

TABLE C.2

Results of regression procedure from statistical package SAS (Partial series).

Recurrence Interval	Independent Variables	R^2	SSE	MSE	JP
2	A	.815	.62	.031	.034
	A, S	.823	.591	.031	.035
	A, R, S	.836	.546	.03	.036
	A, S, Sh	.828	.573	.032	.037
	A, Sk, Cv	.832	.56	.031	.037
	A, R, S, D, Sh	.848	.505	.031	.04

TABLE C.2 (Continued)

Recurrence Interval	Independent Variables	R^2	SSE	MSE	JP
	A, S, Sh, F, U, Ru, L	.914	.284	.02	.028
	A,R,S,D,Sh,F,U,Ru,L,Sk,Cv	.947	.175	.0175	.027
5	A	.792	.701	.035	.038
	A, S	.795	.693	.036	.041
	A, R, S	.804	.66	.036	.043
	A, S, Sh	.797	.684	.038	.045
	A, Sk, Cv	.795	.692	.038	.045
	A, R, S, D, Sh	.812	.634	.04	.05
	A, S, Sh, F, U, Ru, L	.883	.395	.028	.038
	A,R,S,D,Sh,F,U,Ru,L,Sk,Cv	.946	.182	.018	.028
10	A	.761	.82	.041	.044
	A, S	.761	.82	.043	.049
	A, R, S	.77	.791	.044	.052
	A, S, Sh	.762	.813	.045	.053
	A, Sk, Cv	.775	.771	.043	.051
	A, R, S, D, Sh	.771	.783	.049	.062
	A, S, Sh, F, U, Ru, L	.841	.543	.039	.053
	A,R,S,D,Sh,F,U,Ru,L,Sk,Cv	.944	.193	.019	.03
25	A	.693	1.104	.055	.06
	A, S	.693	1.103	.058	.066
	A, R, S	.697	1.08	.06	.0714
	A, S, Sh	.693	1.103	.061	.072
	A, Sk, Cv	.76	.872	.048	.057
	A, R, S, D, Sh	.697	1.087	.068	.086
	A, S, Sh, F, U, Ru, L	.766	.842	.06	.082
	A,R,S,D,Sh,F,U,Ru,L,Sk,Cv	.939	.219	.022	.034
50	A	.624	1.45	.072	.079
	A, S	.626	1.44	.076	.086
	A, R, S	.628	1.43	.079	.094

TABLE C.2 (Continued)

Recurrence Interval	Independent Variables	R^2	SSE	MSE	JP
	A, S, Sh	.626	1.44	.08	.094
	A, Sk, Cv	.75	.961	.053	.063
	A, R, S, D, Sh	.63	1.42	.089	.113
	A, S, Sh, F, U, Ru, L	.699	1.156	.083	.112
	A,R,S,D,Sh,F,U,Ru,L,Sk,Cv	.934	.253	.025	.04
100	A	.55	1.91	.096	.104
	A, S	.55	1.89	.099	.113
	A, R, S	.552	1.89	.105	.124
	A, S, Sh	.552	1.89	.105	.124
	A, Sk, Cv	.75	1.07	.06	.07
	A, R, S, D, Sh	.56	1.86	.116	.148
	A, S, Sh, F, U, Ru, L	.632	1.55	.111	.151
	A,R,S,D,Sh,F,U,Ru,L,Sk,Cv	.928	.304	.03	.046
200	A	.47	2.51	.126	.137
	A, S	.476	2.48	.13	.148
	A, R, S	.476	2.477	.137	.162
	A, S, Sh	.478	2.47	.137	.162
	A, Sk, Cv	.744	1.21	.067	.08
	A, R, S, D, Sh	.492	2.4	.15	.191
	A, S, Sh, F, U, Ru, L	.568	2.04	.146	.199
	A,R,S,D,Sh,F,U,Ru,L,Sk,Cv	.921	.373	.037	.057

TABLE C.3

Results of regression procedure from statistical package SAS
(Revised Annual series).

Recurrence Interval	Independent Variables	R^2	SSE	MSE	JP
2	A	.779	.768	.038	.042
	A, S	.788	.738	.039	.044
	A, R, S	.829	.596	.033	.039
	A, S, Sh	.794	.719	.04	.047
	A, Sk, Iv	.824	.614	.034	.04
	A, R, S, D, Sh	.84	.565	.0353	.045
	A, S, Sh, F, U, Ru, L	.904	.333	.024	.032
	A,R,S,D,Sh,F,U,Ru,L,Sk,Cv	.942	.203	.0203	.0313
5	A	.808	.662	.033	.036
	A, S	.811	.653	.034	.039
	A, R, S	.831	.586	.0325	.0384
	A, S, Sh	.815	.64	.035	.042
	A, Sk, Iv	.82	.621	.0345	.041
	A, R, S, D, Sh	.84	.56	.035	.045
	A, S, Sh, F, U, Ru, L	.883	.403	.029	.04
	A,R,S,D,Sh,F,U,Ru,L,Sk,Cv	.933	.233	.0233	.036
10	A	.784	.763	.038	.042
	A, S	.785	.759	.04	.045
	A, R, S	.796	.721	.04	.047
	A, S, Sh	.787	.753	.042	.049
	A, Sk, Iv	.796	.72	.04	.047
	A, R, S, D, Sh	.8	.712	.044	.057
	A, S, Sh, F, U, Ru, L	.841	.56	.04	.055
	A,R,S,D,Sh,F,U,Ru,L,Sk,Cv	.913	.306	.031	.047

TABLE C.3 (Continued)

Recurrence Interval	Independent Variables	R^2	SSE	MSE	JP
25	A	.703	1.07	.0536	.0585
	A, S	.703	1.072	.056	.064
	A, R, S	.708	1.053	.0585	.07
	A, S, Sh	.703	1.07	.06	.07
	A, Sk, Iv	.727	.986	.055	.065
	A, R, S, D, Sh	.71	1.05	.066	.084
	A, S, Sh, F, U, Ru, L	.76	.87	.062	.084
	A,R,S,D,Sh,F,U,Ru,L,Sk,Cv	.862	.5	.05	.077
50	A	.618	1.47	.074	.08
	A, S	.618	1.47	.0774	.088
	A, R, S	.62	1.464	.081	.096
	A, S, Sh	.62	1.47	.082	.096
	A, Sk, Iv	.656	1.32	.074	.087
	A, R, S, D, Sh	.622	1.46	.091	.116
	A, S, Sh, F, U, Ru, L	.69	1.2	.086	.117
	A,R,S,D,Sh,F,U,Ru,L,Sk,Cv	.81	.735	.073	.114
100	A	.531	1.98	.099	.108
	A, S	.532	1.977	.104	.118
	A, R, S	.533	1.98	.11	.13
	A, S, Sh	.533	1.976	.11	.13
	A, Sk, Iv	.582	1.76	.099	.116
	A, R, S, D, Sh	.538	1.955	.122	.155
	A, S, Sh, F, U, Ru, L	.622	1.6	.114	.155
	A,R,S,D,Sh,F,U,Ru,L,Sk,Cv	.757	1.03	.103	.159
200	A	.44	2.63	.132	.144
	A, S	.443	2.62	.138	.157
	A, R, S	.443	2.62	.145	.172
	A, S, Sh	.444	2.615	.145	.172
	A, Sk, Iv	.51	2.32	.129	.152

TABLE C.3(Continued)

Recurrence Interval	Independent Variables	R^2	SSE	MSE	JP
	A, R, S, D, Sh	.456	2.56	.16	.204
	A, S, Sh, F, U, Ru, L	.561	2.06	.147	.201
	A,R,S,D,Sh,F,U,Ru,L,Sk,Cv	.706	1.38	.138	.214

From Table C.1 and Table C.2 it can be clearly distinguished that method 7 gives significantly less SSE with high coefficient of determination for all average recurrence interval from 2 years to 200 years (calculations are from log values).

Appendix D

Log Pearson Type III Analysis

The outline of LPIII analysis can be arranged in the following steps :

- Transformation of the list of n flood magnitude either annual or partial data events Y1, Y2 ....Yn to the list of corresponding logarithmic magnitude X1, X2 ....Xn.

- Computation of the arithmetic mean of the logarithms.

$$M = \frac{\sum X}{n}$$

- Computation of the standard deviation of the logarithms.

$$S = \sqrt{\frac{\sum (X - M)^2}{n - 1}}$$

- Computation of the coefficient of skewness.

$$g = \frac{n\sum (X - M)^2}{(n - 1)(n - 2)s^3}$$

- Computation of the logarithms of discharges at each selected recurrence interval.

$$\text{Log } Q = M + KS$$

The value K is from the table in WS06 - Computer Program.

- Computation of antilog of Q (as Log Q is the logarithm of discharge) to get flood discharge Q.

The frequency curve can be drawn by plotting Q against each average recurrence interval and drawing continuous line through the plotted points. In this study, the LPIII curves are drawn easily by using HYDSYS.

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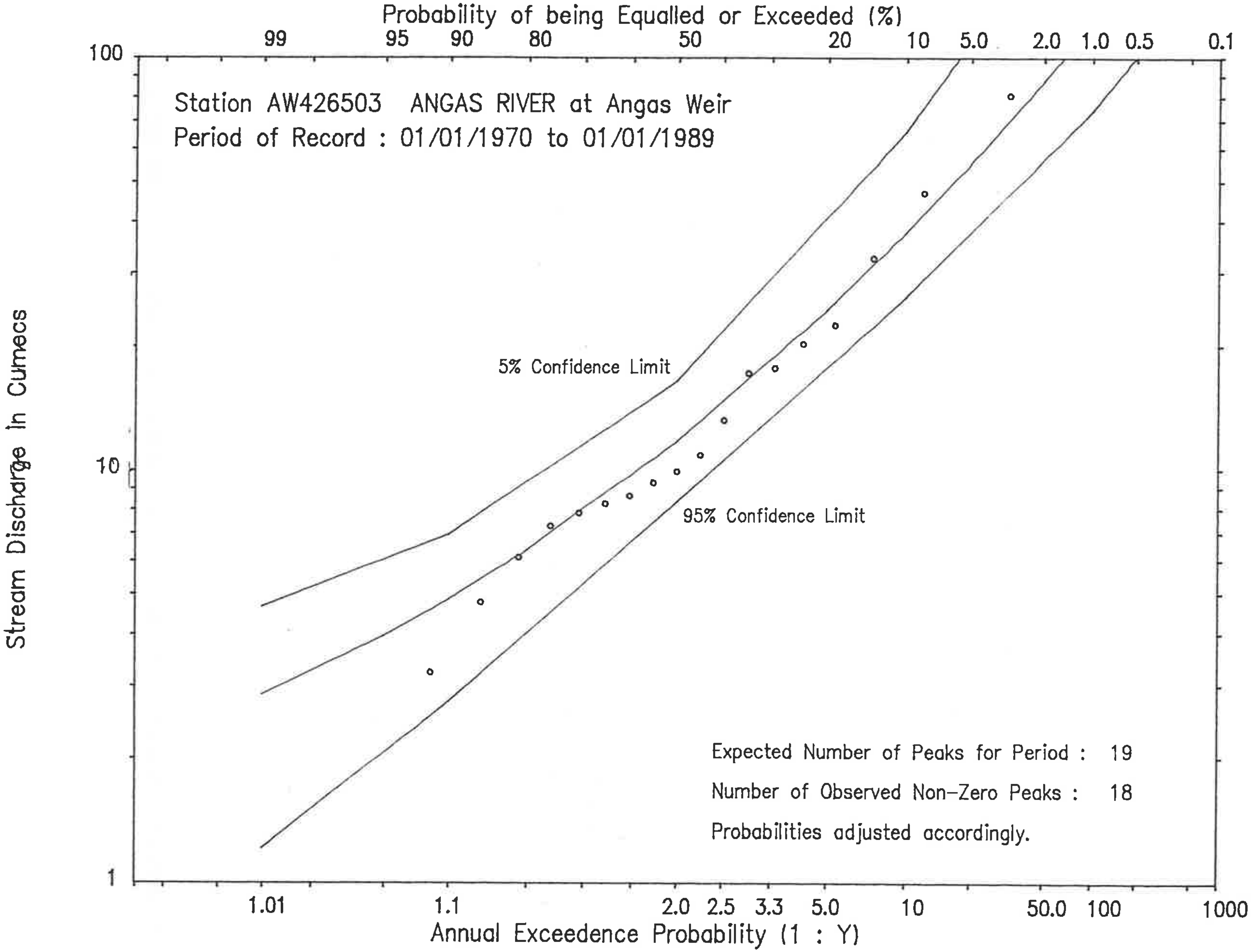
HYLP3 Output 26/05/1992

Log-Pearson Type III Analysis. (Annual Series)



Flow (Cumecs)	Probability (1/Y)	AEP (1 : Y)
2.85	0.990	1.01
4.87	0.900	1.11
11.8	0.500	2
24.4	0.200	5
37.7	0.100	10
62.2	0.040	25
88.0	0.020	50
122	0.010	100
167	0.005	200
331	0.001	1000

Statistics of the Logs of Flows.

Mean : 1.108

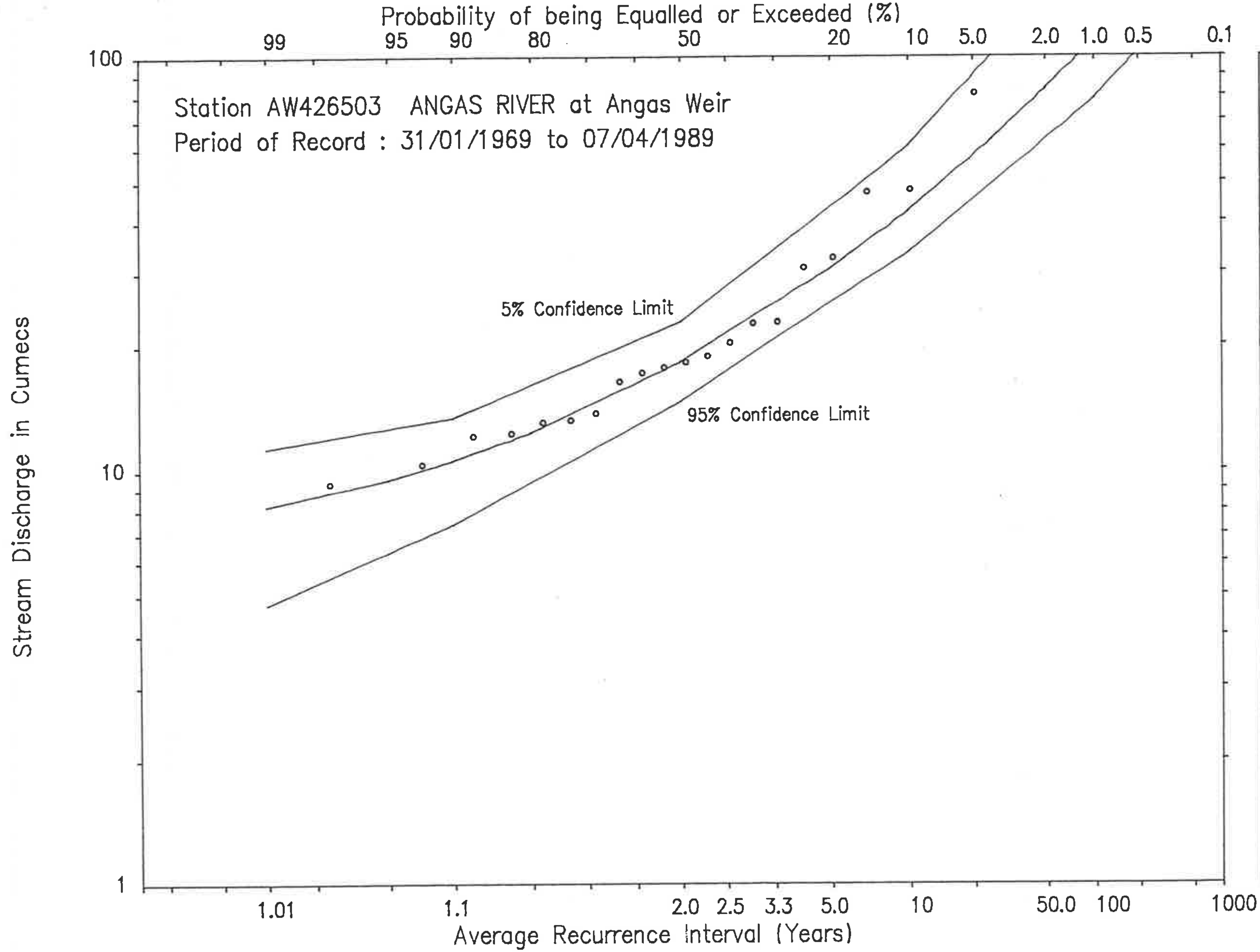
Standard Deviation : 0.352

Skewness Coefficient : 0.636

Civil Engineering, Adelaide University

HYLP3 Output 26/05/1992

Log–Pearson Type III Analysis. (Partial Series)



Flow (Cumecs)	Probability (1/Yp)	ARI (Yp yrs)
8.20	0.990	1.01
10.6	0.900	1.11
18.3	0.500	2
30.6	0.200	5
42.4	0.100	10
62.9	0.040	25
83.2	0.020	50
109	0.010	100
141	0.005	200
253	0.001	1000

Statistics of the Logs of Flows.

Mean : 1.302
Standard Deviation : 0.243
Skewness Coefficient : 0.995

Series Extraction Parameters

TMin : 7200.00
QMin : 9.00

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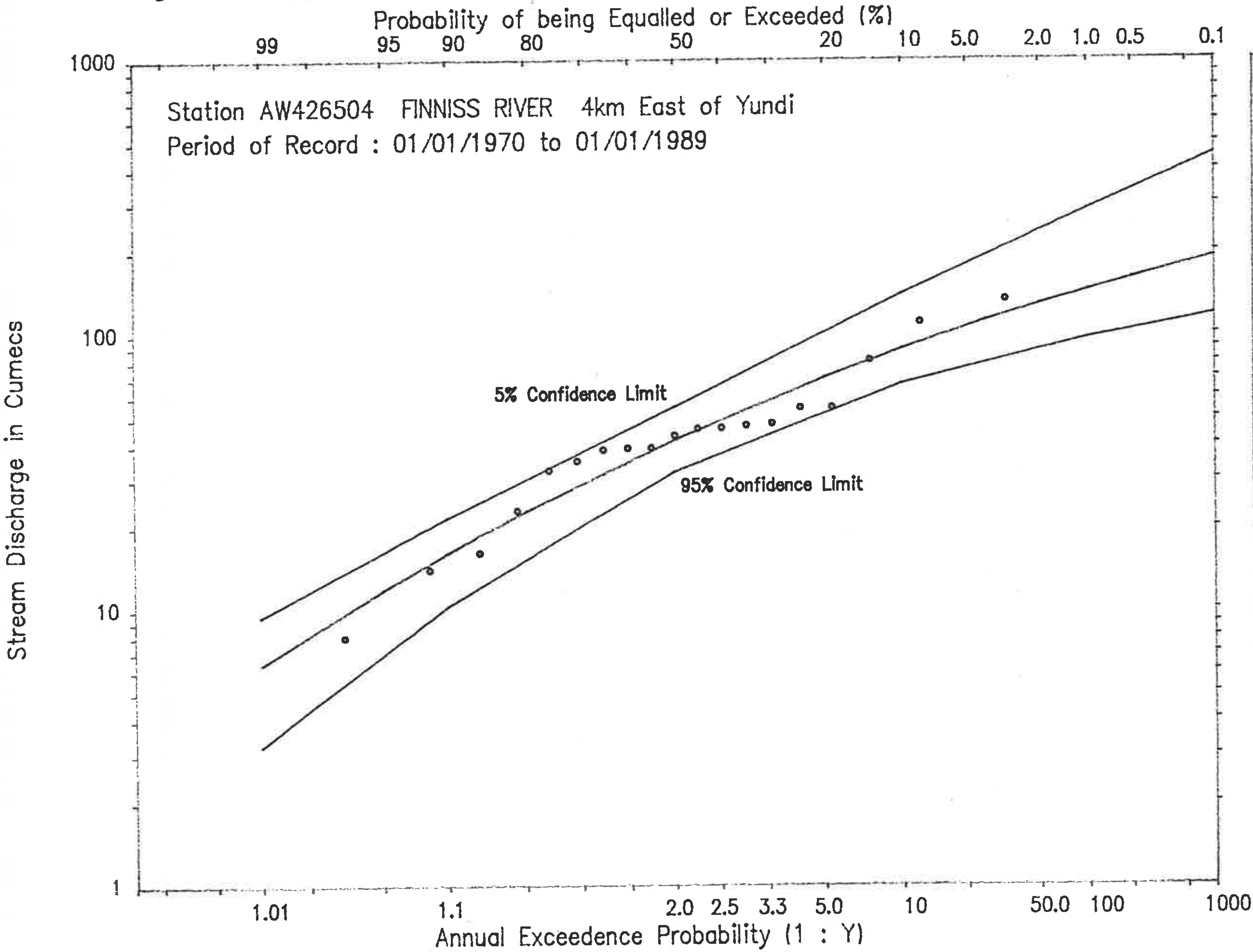
HYLP3 Output 27/02/1991

Log-Pearson Type III Analysis. (Annual Series)



Flow (Cumecs)	Probability (1/Y)	AEP (1 : Y)
6.40	0.990	1.01
16.2	0.900	1.11
41.9	0.500	2
70.0	0.200	5
88.7	0.100	10
112	0.040	25
128	0.020	50
143	0.010	100
158	0.005	200
190	0.001	1000

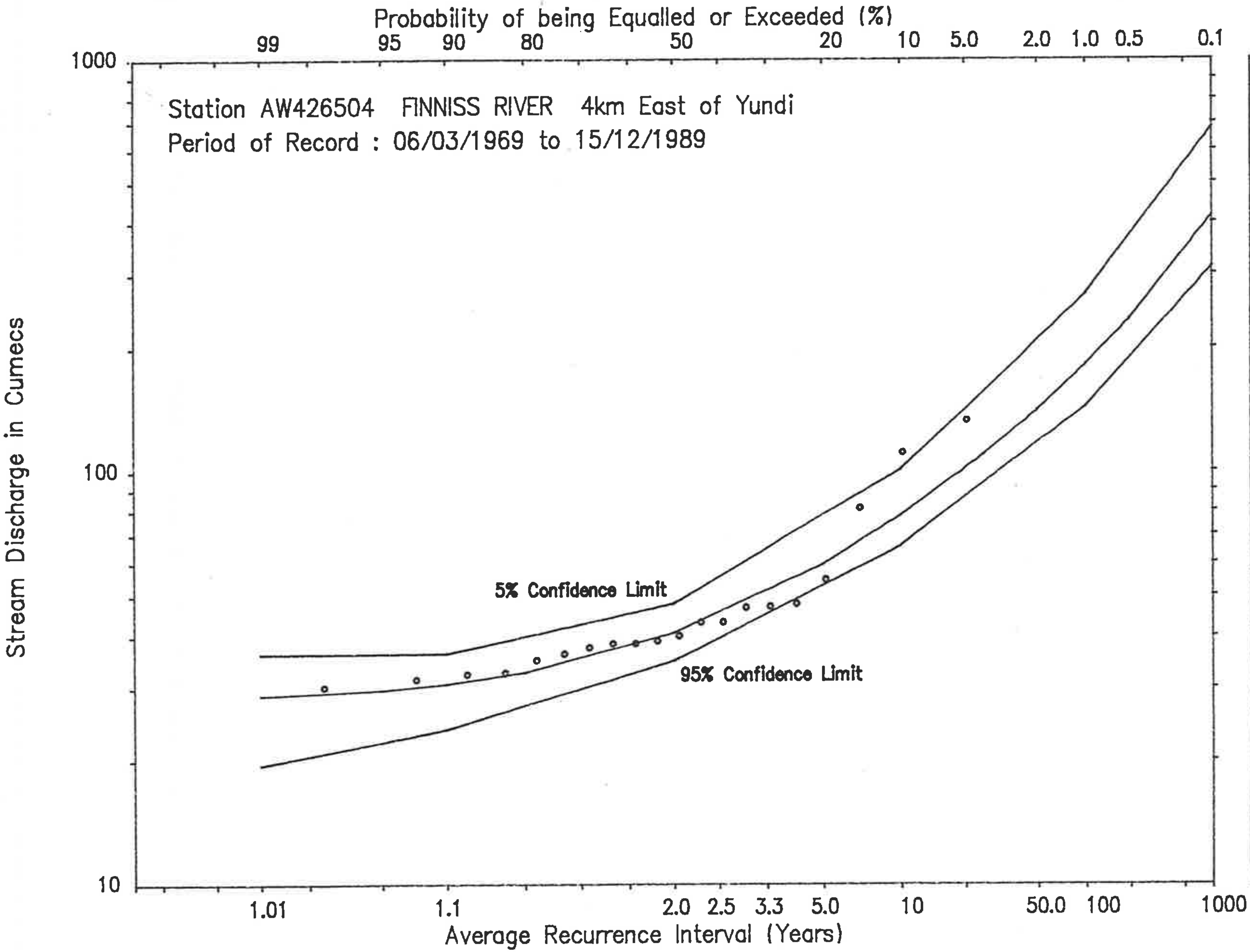
Statistics of the Logs of Flows.

Mean	:	1.596
Standard Deviation	:	0.291
Skewness Coefficient	:	-0.539

Civil Engineering, Adelaide University

rYLP3 Output 12/02/1992

Log-Pearson Type III Analysis. (Partial Series)



Flow (Cumecs)	Probability (1/Yp)	ARI (Yp yrs)
28.7	0.990	1.01
30.8	0.900	1.11
40.9	0.500	2
58.4	0.200	5
77.6	0.100	10
109	0.040	25
141	0.020	50
181	0.010	100
233	0.005	200
415	0.001	1000

Statistics of the Logs of Flows.

Mean : 1.658
Standard Deviation : 0.175
Skewness Coefficient : 1.688

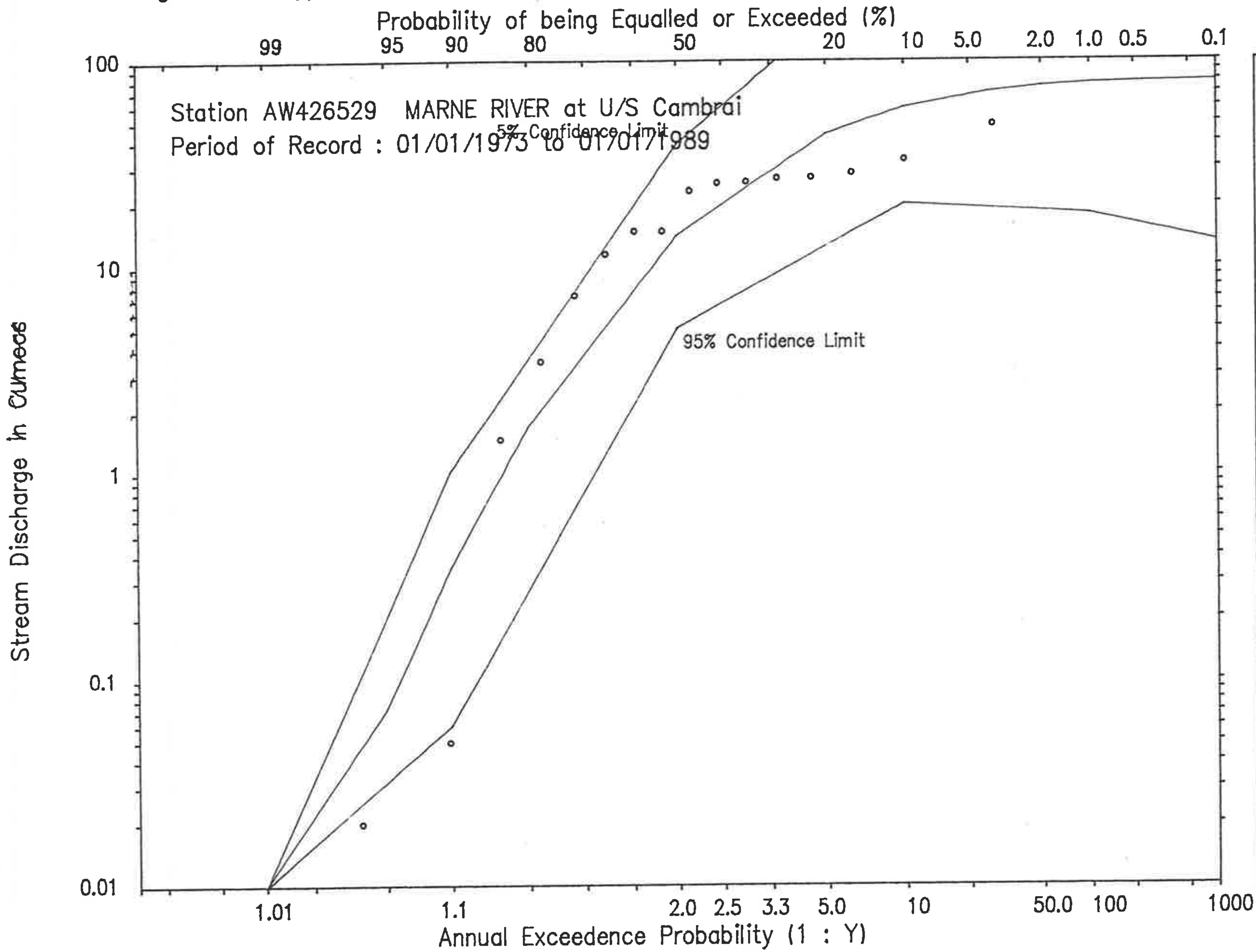
Series Extraction Parameters

TMin : 11520.00
QMin : 30.00

Civil Engineering, Adelaide University

HYLP3 Output 26/05/1992

Log-Pearson Type III Analysis. (Annual Series)



Flow (Cumecs)	Probability (1/Y)	AEP (1 : Y)
0.002	0.990	1.01
0.350	0.900	1.11
14.1	0.500	2
43.6	0.200	5
59.0	0.100	10
70.2	0.040	25
74.6	0.020	50
77.0	0.010	100
78.2	0.005	200
79.3	0.001	1000

Statistics of the Logs of Flows.

Mean : 0.853

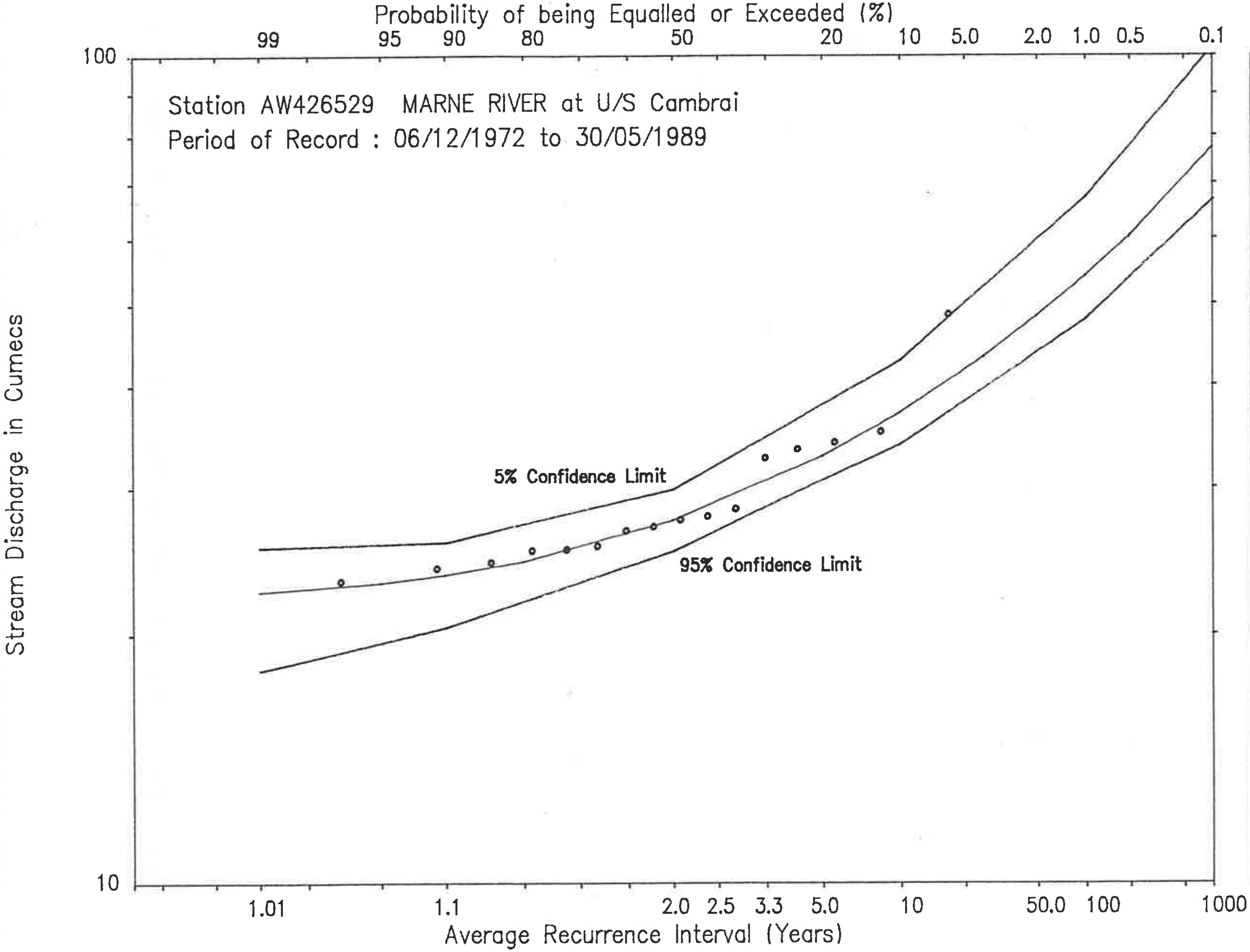
Standard Deviation : 0.999

Skewness Coefficient : -1.907

Civil Engineering, Adelaide University

HYLP3 Output 12/02/1992

Log–Pearson Type III Analysis. (Partial Series)



Flow (Cumecs)	Probability (1/Yp)	ARI (Yp yrs)
22.6	0.990	1.01
23.6	0.900	1.11
27.5	0.500	2
32.8	0.200	5
37.1	0.100	10
43.2	0.040	25
48.4	0.020	50
54.1	0.010	100
60.4	0.005	200
77.6	0.001	1000

Statistics of the Logs of Flows.

Mean : 1.458

Standard Deviation : 0.083

Skewness Coefficient : 1.481

Series Extraction Parameters

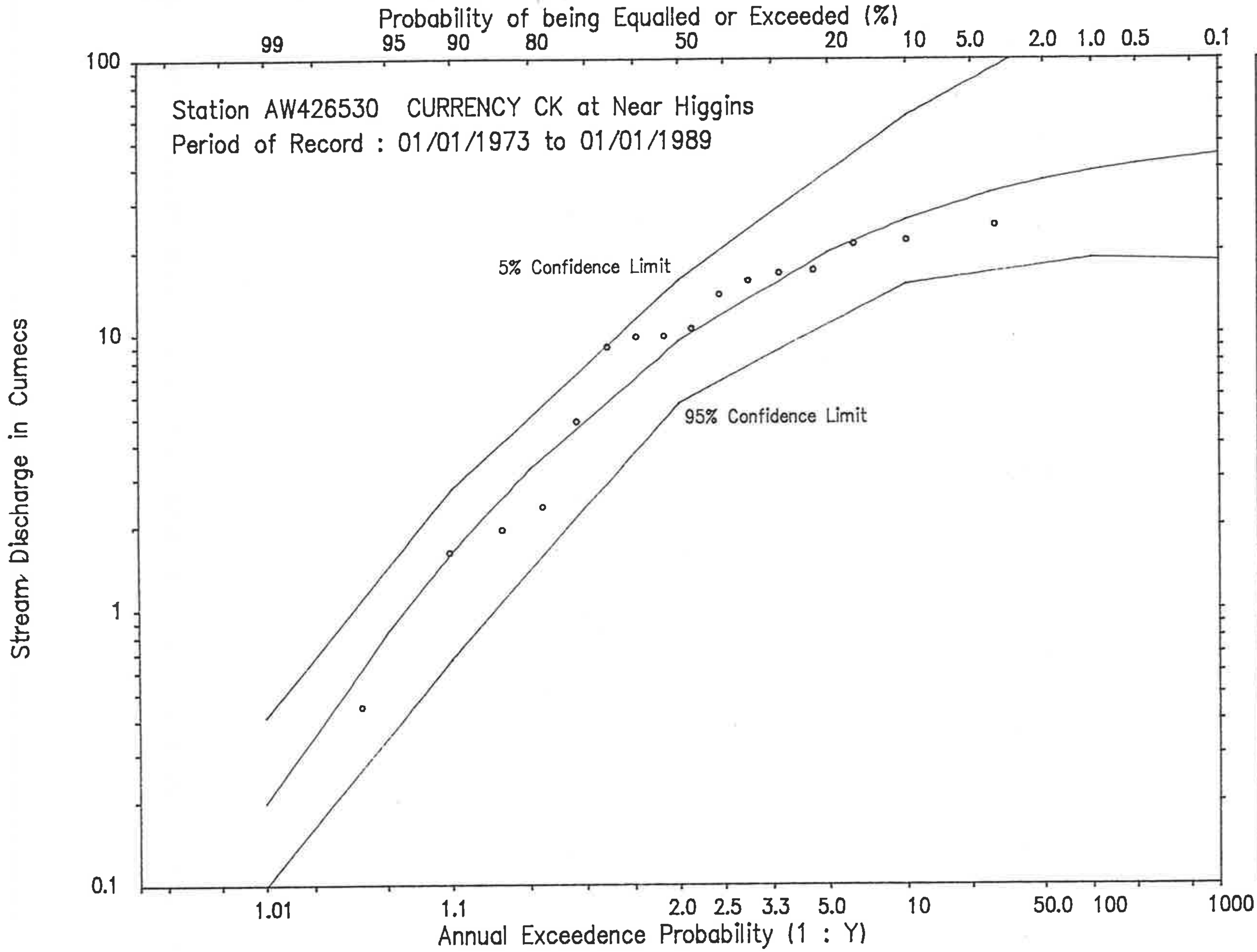
TMin : 10080.00

QMin : 14.00

Civil Engineering, Adelaide University

HYLP3 Output 26/05/1992

Log-Pearson Type III Analysis. (Annual Series)



Flow (Cumecs)	Probability (1/Y)	AEP (1 : Y)
0.199	0.990	1.01
1.61	0.900	1.11
9.45	0.500	2
19.8	0.200	5
26.0	0.100	10
32.5	0.040	25
36.2	0.020	50
39.1	0.010	100
41.4	0.005	200
45.1	0.001	1000

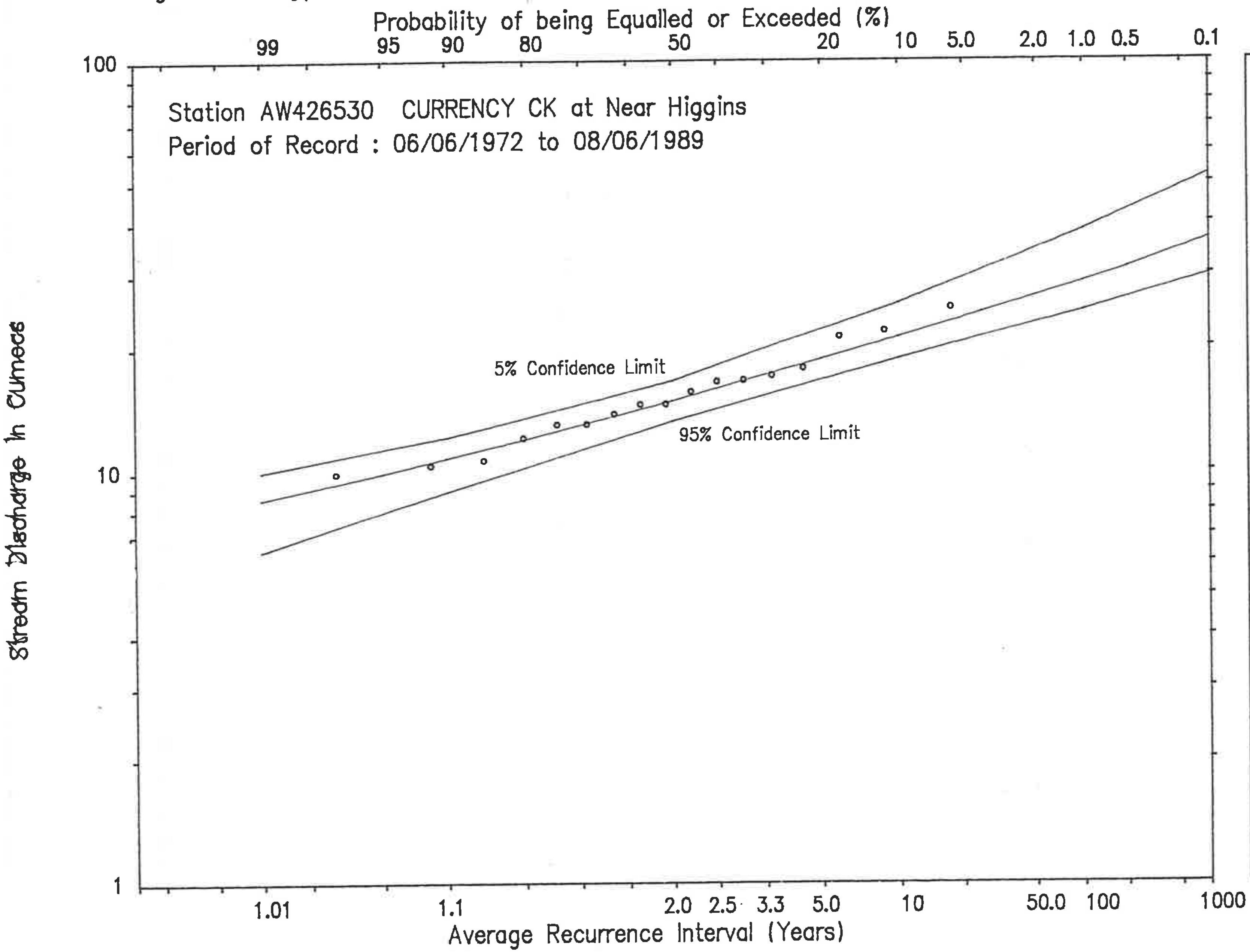
Statistics of the Logs of Flows.

Mean : 0.876
Standard Deviation : 0.499
Skewness Coefficient : -1.221

Civil Engineering, Adelaide University

HYLP3 Output 26/05/1992

Log-Pearson Type III Analysis. (Partial Series)



Flow (Cumecs)	Probability (1/Yp)	ARI (Yp yrs)
8.58	0.990	1.01
10.9	0.900	1.11
14.9	0.500	2
18.7	0.200	5
21.1	0.100	10
24.2	0.040	25
26.4	0.020	50
28.7	0.010	100
31.0	0.005	200
36.4	0.001	1000

Statistics of the Logs of Flows.

Mean : 1.178
Standard Deviation : 0.113
Skewness Coefficient : 0.216

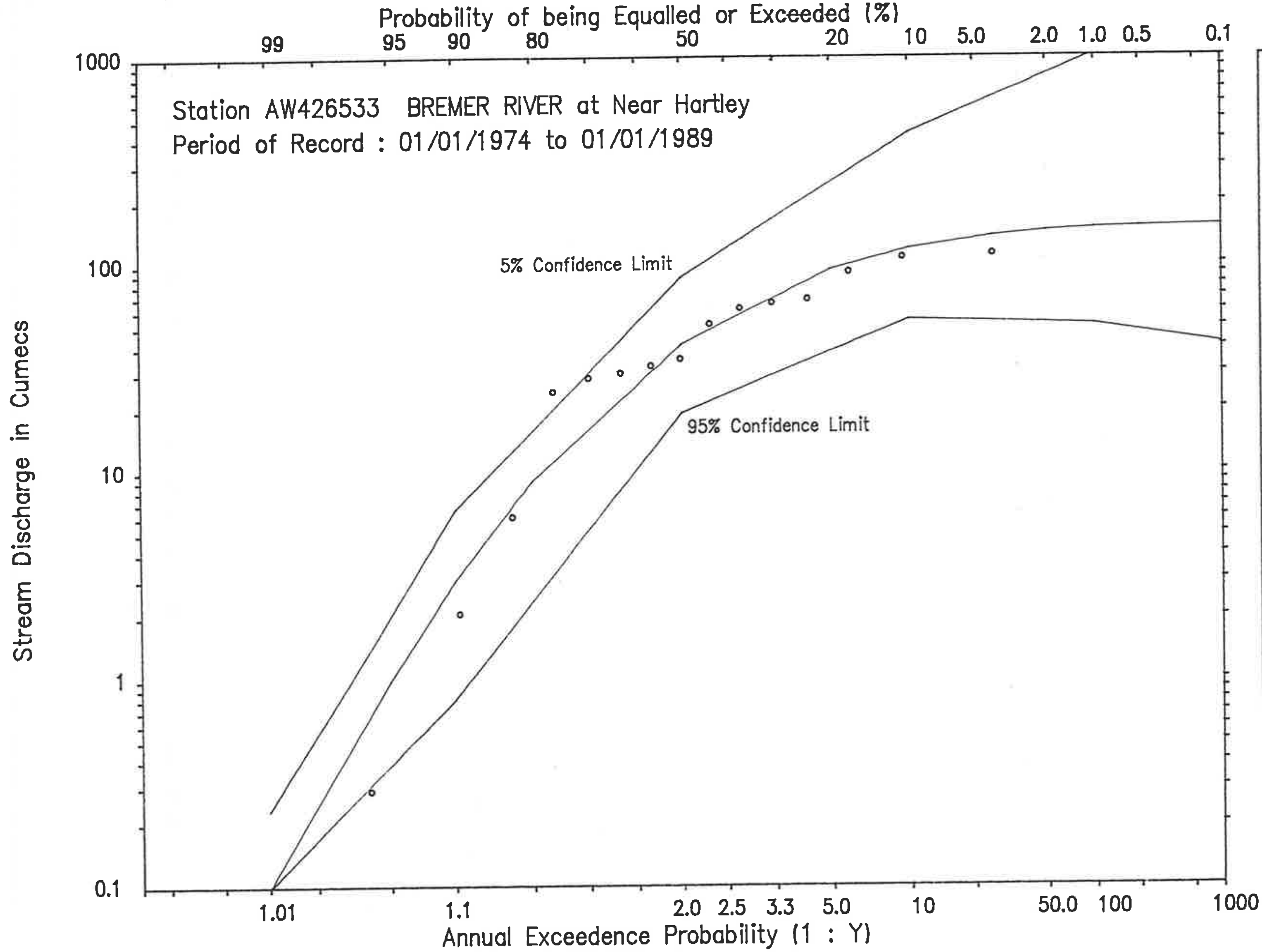
Series Extraction Parameters

TMin : 4320.00
QMin : 9.00

Civil Engineering, Adelaide University

HYLP3 Output 26/05/1992

Log-Pearson Type III Analysis. (Annual Series)



Flow (Cumecs)	Probability (1/Y)	AEP (1 : Y)
0.081	0.990	1.01
2.98	0.900	1.11
40.9	0.500	2
93.9	0.200	5
118	0.100	10
136	0.040	25
143	0.020	50
147	0.010	100
149	0.005	200
152	0.001	1000

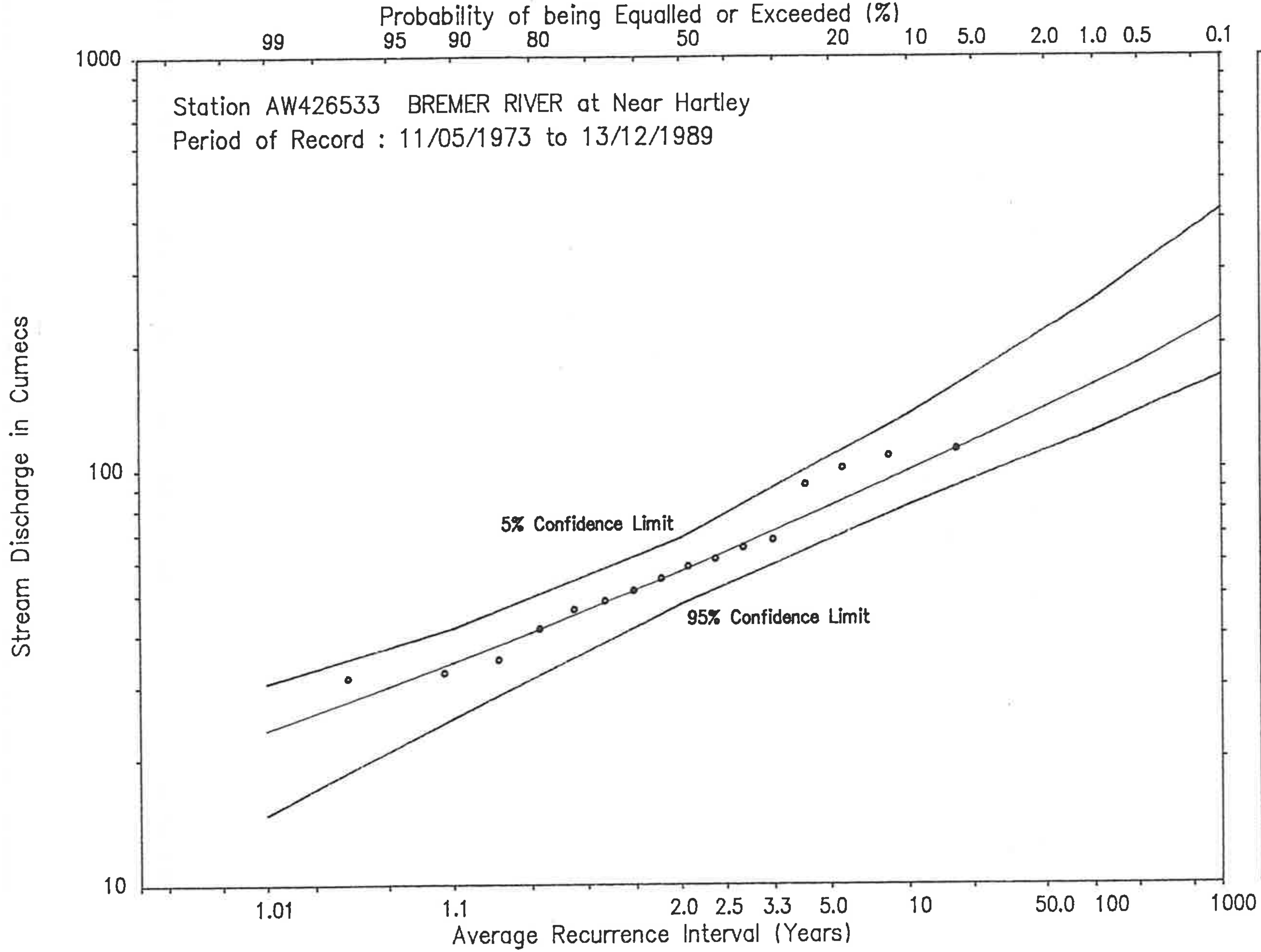
Statistics of the Logs of Flows.

Mean : 1.408
Standard Deviation : 0.710
Skewness Coefficient : -1.837

Civil Engineering, Adelaide University

HYLP3 Output 12/02/1992

Log-Pearson Type III Analysis. (Partial Series)



Flow (Cumecs)	Probability (1/Yp)	ARI (Yp yrs)
23.6	0.990	1.01
34.5	0.900	1.11
57.1	0.500	2
81.4	0.200	5
98.7	0.100	10
122	0.040	25
140	0.020	50
159	0.010	100
179	0.005	200
231	0.001	1000

Statistics of the Logs of Flows.

Mean : 1.762
Standard Deviation : 0.178
Skewness Coefficient : 0.194

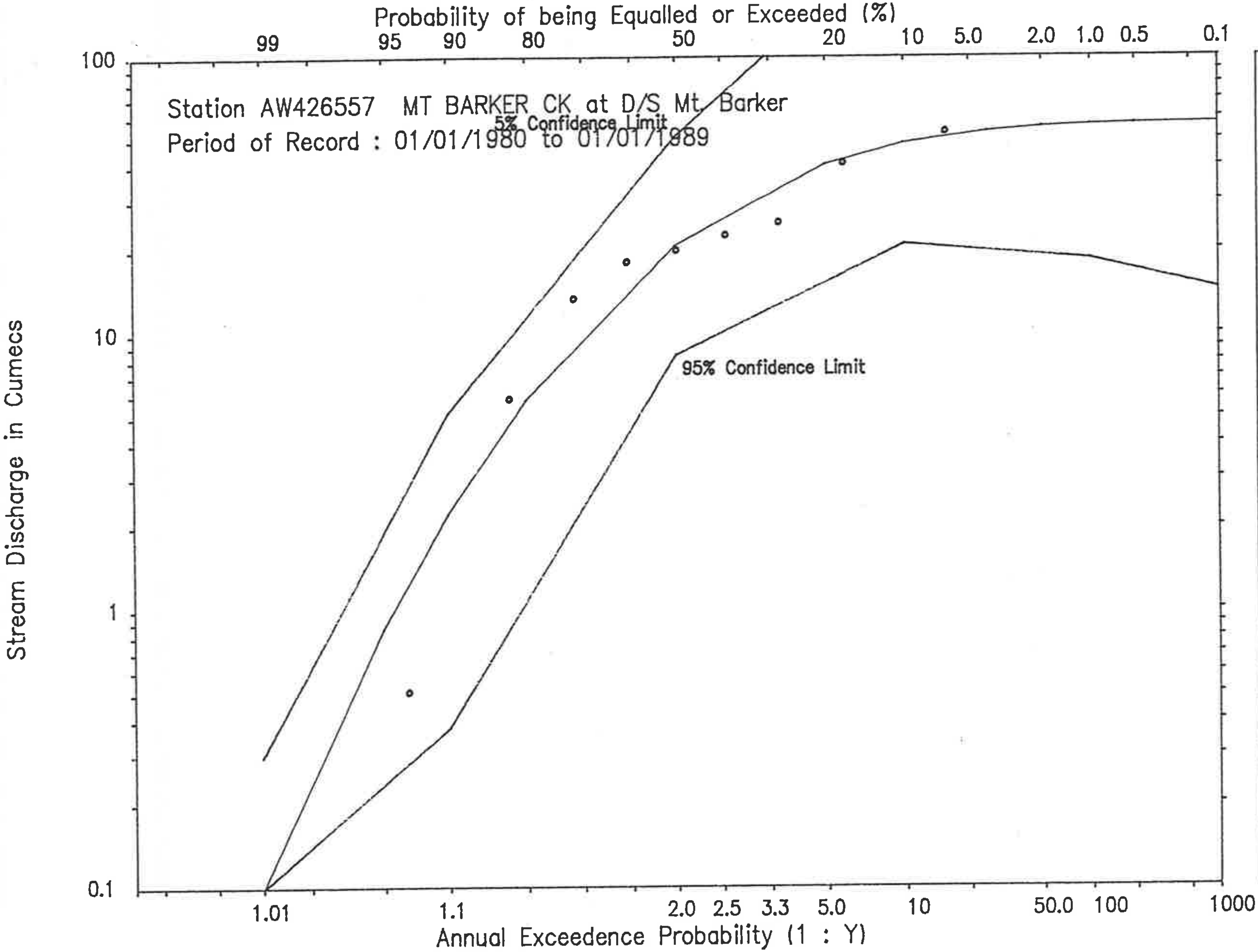
Series Extraction Parameters

TMin : 11520.00
QMin : 25.00

Civil Engineering, Adelaide University

HYLP3 Output 12/02/1992

Log-Pearson Type III Analysis. (Annual Series)



Flow (Cumecs)	Probability (1/Y)	AEP (1 : Y)
0.097	0.990	1.01
2.24	0.900	1.11
20.7	0.500	2
40.6	0.200	5
48.4	0.100	10
53.5	0.040	25
55.3	0.020	50
56.3	0.010	100
56.8	0.005	200
57.2	0.001	1000

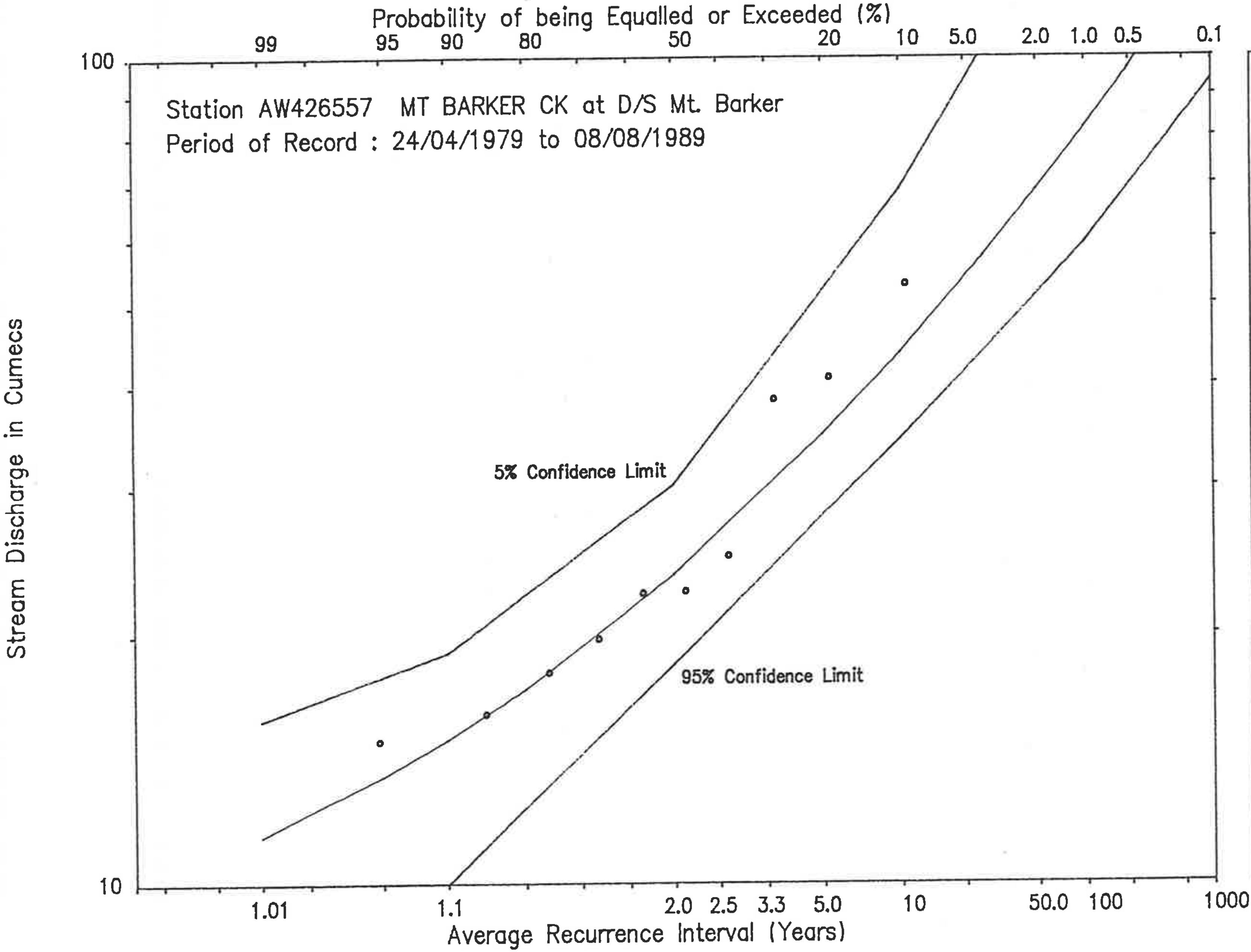
Statistics of the Logs of Flows.

Mean	: 1.137
Standard Deviation	: 0.602
Skewness Coefficient	: -1.937

Civil Engineering, Adelaide University

rHYLP3 Output 12/02/1992

Log-Pearson Type III Analysis. (Partial Series)



Flow (Cumecs)	Probability (1/Yp)	ARI (Yp yrs)
11.4	0.990	1.01
15.0	0.900	1.11
23.6	0.500	2
34.7	0.200	5
43.7	0.100	10
57.1	0.040	25
68.7	0.020	50
81.9	0.010	100
96.8	0.005	200
140	0.001	1000

Statistics of the Logs of Flows.

Mean	:	1.394
Standard Deviation	:	0.185
Skewness Coefficient	:	0.675

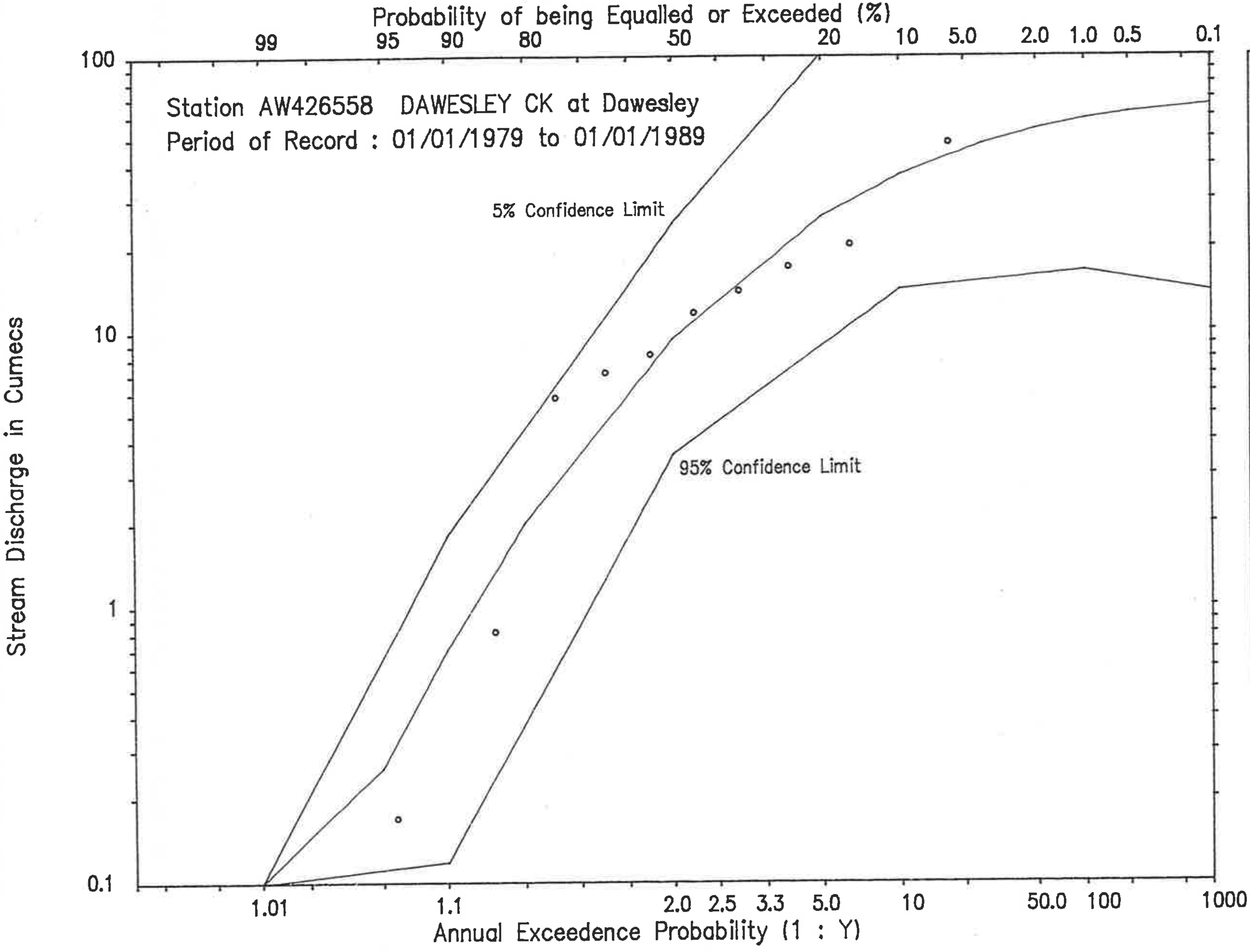
Series Extraction Parameters

TMin	:	8640.00
QMin	:	14.00

Civil Engineering, Adelaide University

HYLP3 Output 26/05/1992

Log-Pearson Type III Analysis. (Annual Series)



Flow (Cumecs)	Probability (1/Y)	AEP (1 : Y)
0.029	0.990	1.01
0.703	0.900	1.11
9.39	0.500	2
25.8	0.200	5
36.6	0.100	10
47.7	0.040	25
53.8	0.020	50
58.4	0.010	100
61.8	0.005	200
66.1	0.001	1000

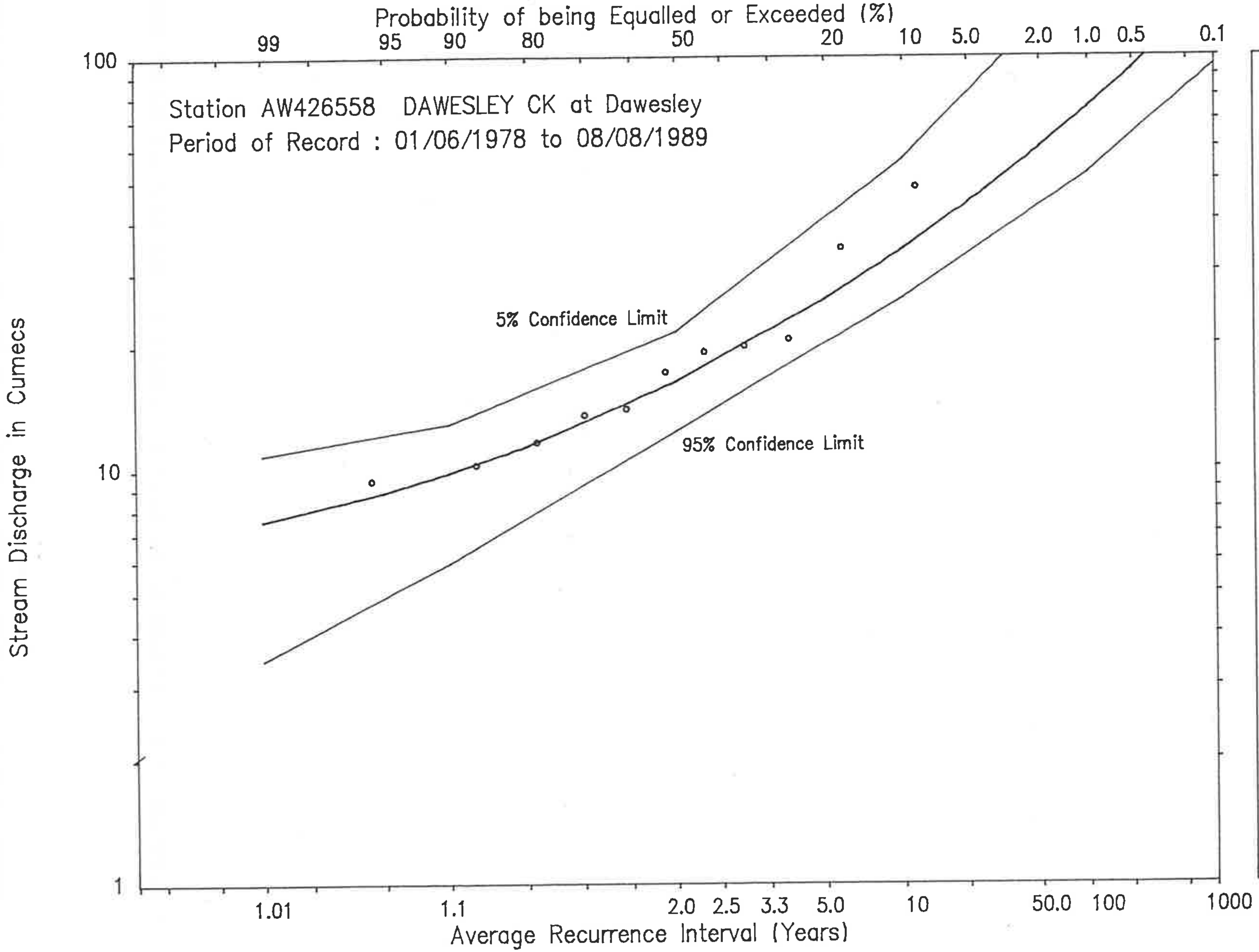
Statistics of the Logs of Flows.

Mean : 0.811
Standard Deviation : 0.721
Skewness Coefficient : -1.391

Civil Engineering, Adelaide University

HYLP3 Output 26/05/1992

Log-Pearson Type III Analysis. (Partial Series)



Flow (Cumecs)	Probability (1/Yp)	ARI (Yp yrs)
7.55	0.990	1.01
9.85	0.900	1.11
16.3	0.500	2
25.7	0.200	5
34.0	0.100	10
47.4	0.040	25
59.9	0.020	50
74.9	0.010	100
92.9	0.005	200
150	0.001	1000

Statistics of the Logs of Flows.

Mean : 1.242
Standard Deviation : 0.216
Skewness Coefficient : 0.859

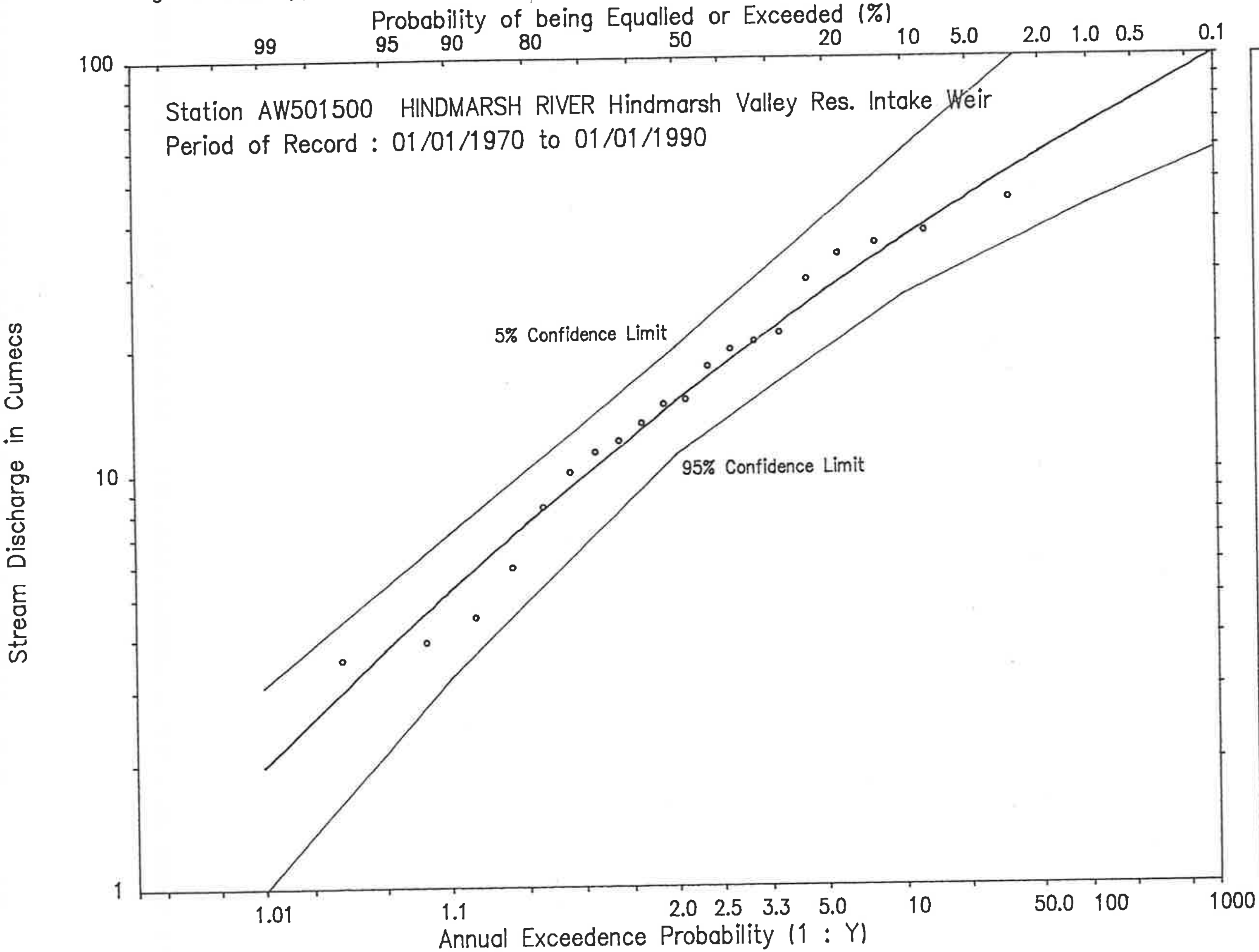
Series Extraction Parameters

TMin : 8640.00
QMin : 8.00

Civil Engineering, Adelaide University

HYLP3 Output 26/05/1992

Log-Pearson Type III Analysis. (Annual Series)



Flow (Cumecs)	Probability (1/Y)	AEP (1 : Y)
1.99	0.990	1.01
5.23	0.900	1.11
14.9	0.500	2
27.2	0.200	5
36.3	0.100	10
48.6	0.040	25
58.1	0.020	50
67.7	0.010	100
77.5	0.005	200
101	0.001	1000

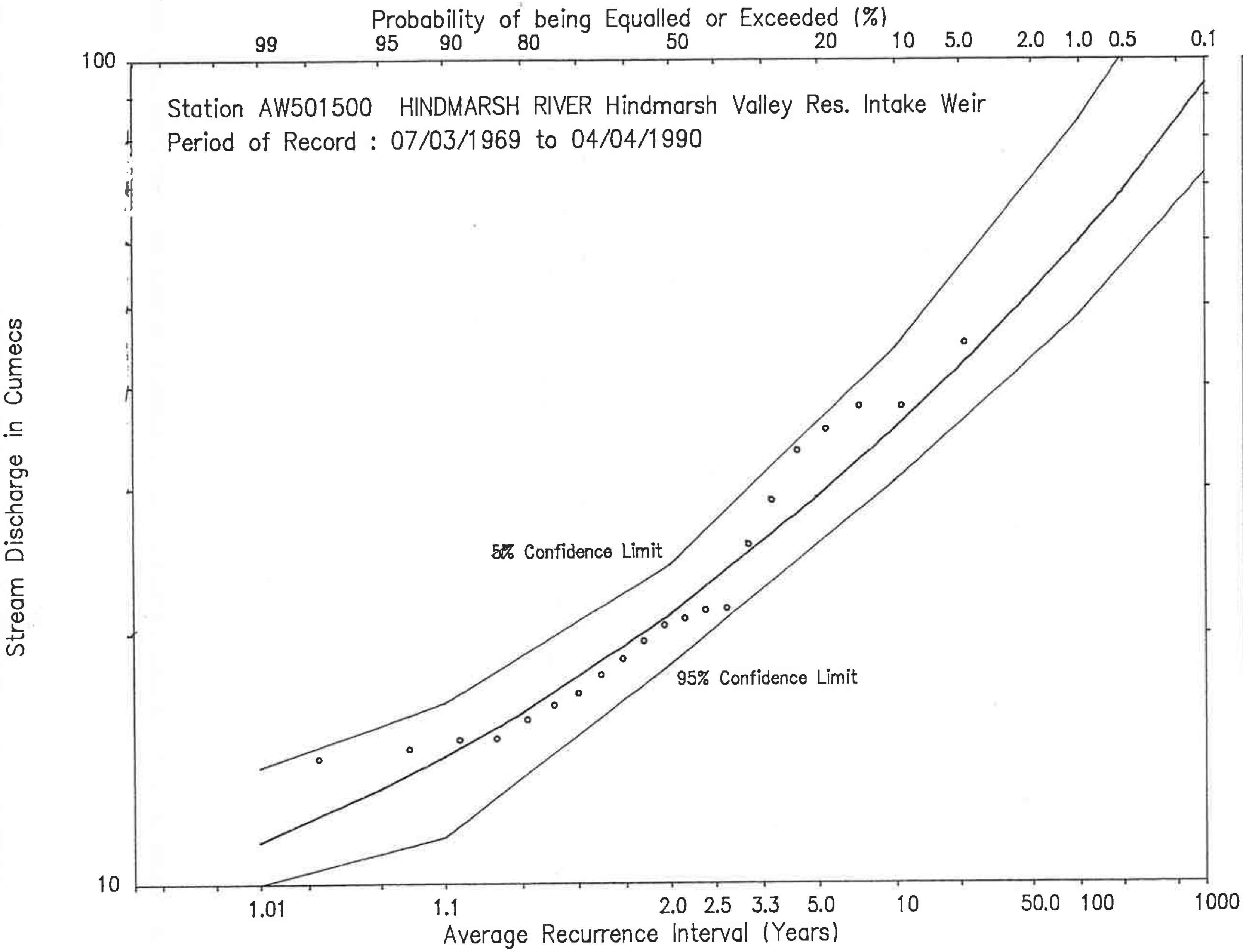
Statistics of the Logs of Flows.

Mean : 1.152
Standard Deviation : 0.330
Skewness Coefficient : -0.363

Civil Engineering, Adelaide University

HYLP3 Output 26/05/1992

Log-Pearson Type III Analysis. (Partial Series)



Flow (Cumecs)	Probability (1/Yp)	ARI (Yp yrs)
11.2	0.990	1.01
14.3	0.900	1.11
21.2	0.500	2
29.3	0.200	5
35.5	0.100	10
44.4	0.040	25
51.8	0.020	50
59.9	0.010	100
68.8	0.005	200
93.4	0.001	1000

Statistics of the Logs of Flows.

Mean	:	1.342
Standard Deviation	:	0.157
Skewness Coefficient	:	0.634

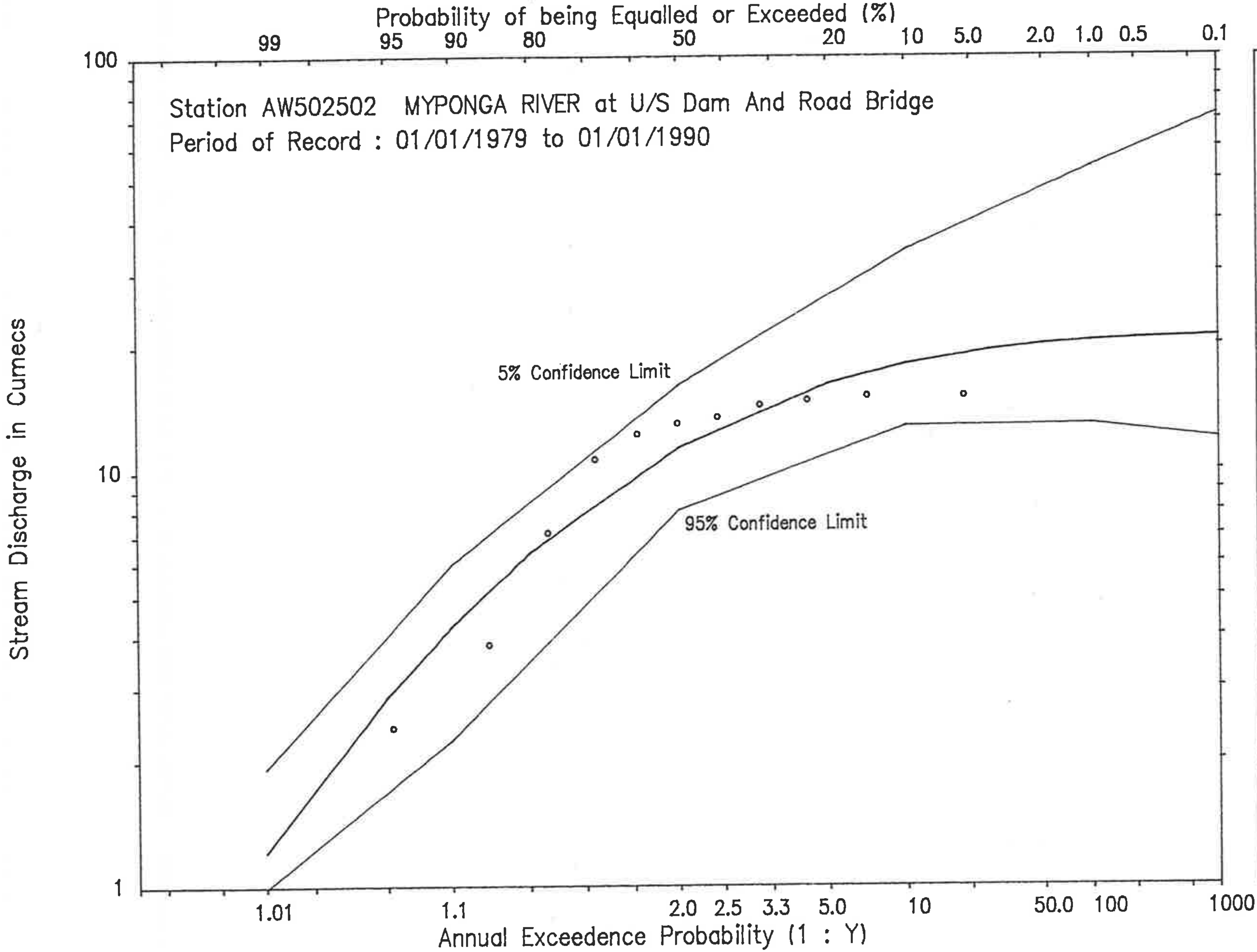
Series Extraction Parameters

TMin	:	7200.00
QMin	:	14.00

Civil Engineering, Adelaide University

HYLP3 Output 26/05/1992

Log-Pearson Type III Analysis. (Annual Series)



Flow (Cumecs)	Probability (1/Y)	AEP (1 : Y)
1.22	0.990	1.01
4.26	0.900	1.11
11.4	0.500	2
16.1	0.200	5
18.0	0.100	10
19.4	0.040	25
20.0	0.020	50
20.4	0.010	100
20.7	0.005	200
21.0	0.001	1000

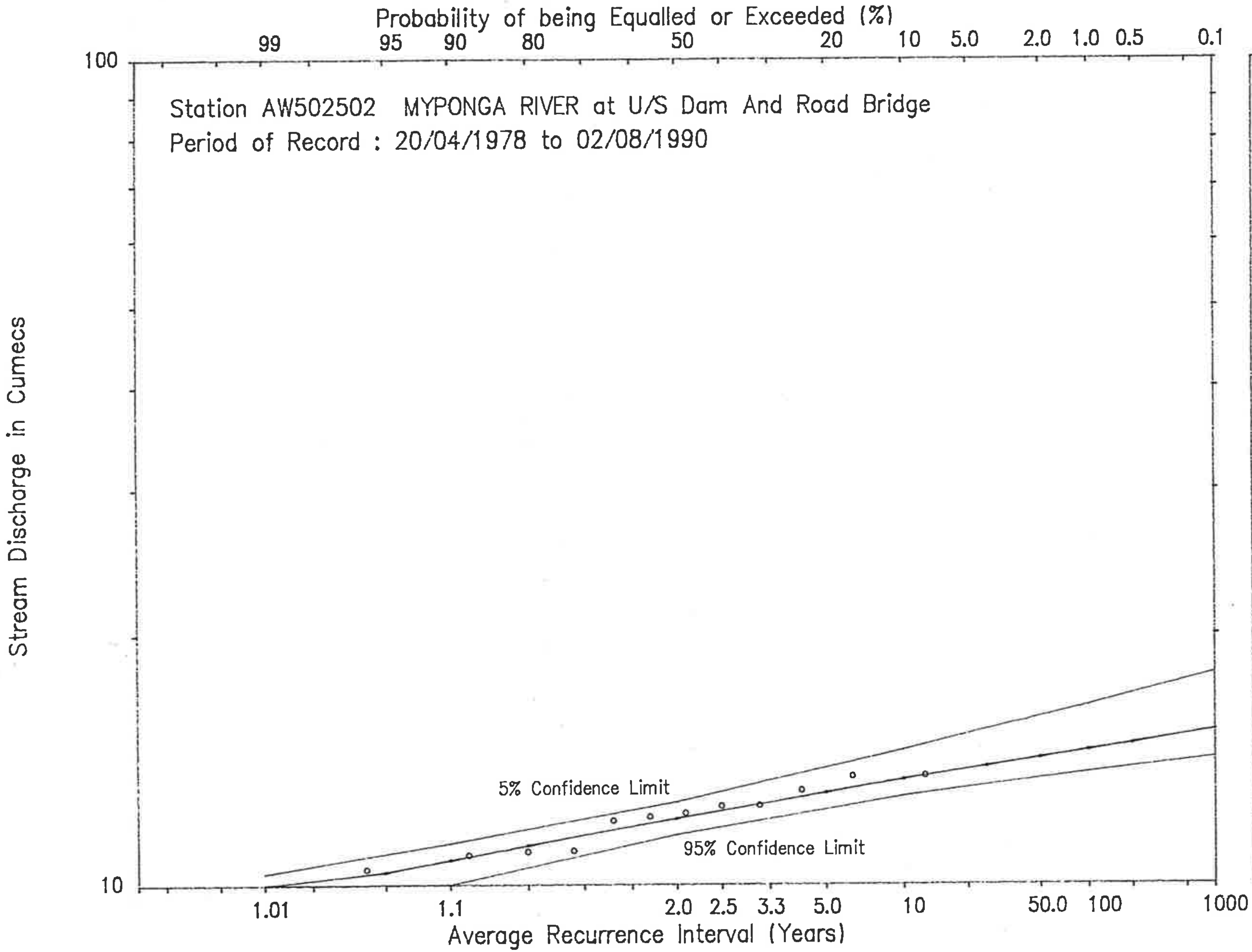
Statistics of the Logs of Flows.

Mean : 0.988
Standard Deviation : 0.270
Skewness Coefficient : -1.604

Civil Engineering, Adelaide University

hYLP3 Output 29/08/1991

Log-Pearson Type III Analysis. (Partial Series)



Flow (Cumecs)	Probability (1/Yp)	ARI (Yp yrs)
9.70	0.990	1.01
10.7	0.900	1.11
12.0	0.500	2
12.9	0.200	5
13.3	0.100	10
13.8	0.040	25
14.2	0.020	50
14.5	0.010	100
14.7	0.005	200
15.3	0.001	1000

Statistics of the Logs of Flows.

Mean : 1.078
Standard Deviation : 0.037
Skewness Coefficient : -0.167

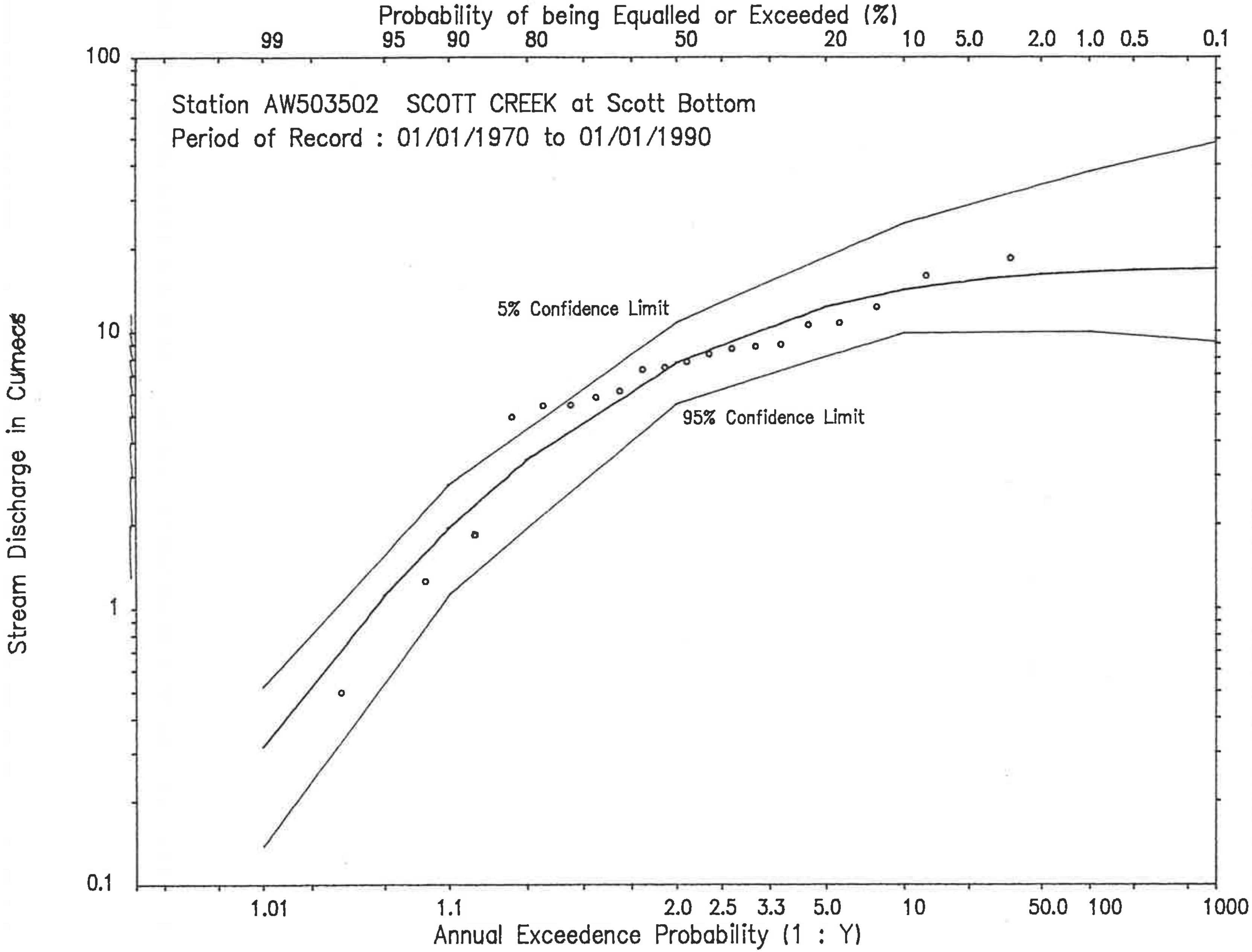
Series Extraction Parameters

TMin : 5760.00
QMin : 10.00

Civil Engineering, Adelaide University

HYLP3 Output 26/05/1992

Log-Pearson Type III Analysis. (Annual Series)



Flow (Cumecs)	Probability (1/Y)	AEP (1 : Y)
0.318	0.990	1.01
1.96	0.900	1.11
7.73	0.500	2
12.3	0.200	5
14.2	0.100	10
15.5	0.040	25
16.1	0.020	50
16.4	0.010	100
16.7	0.005	200
16.9	0.001	1000

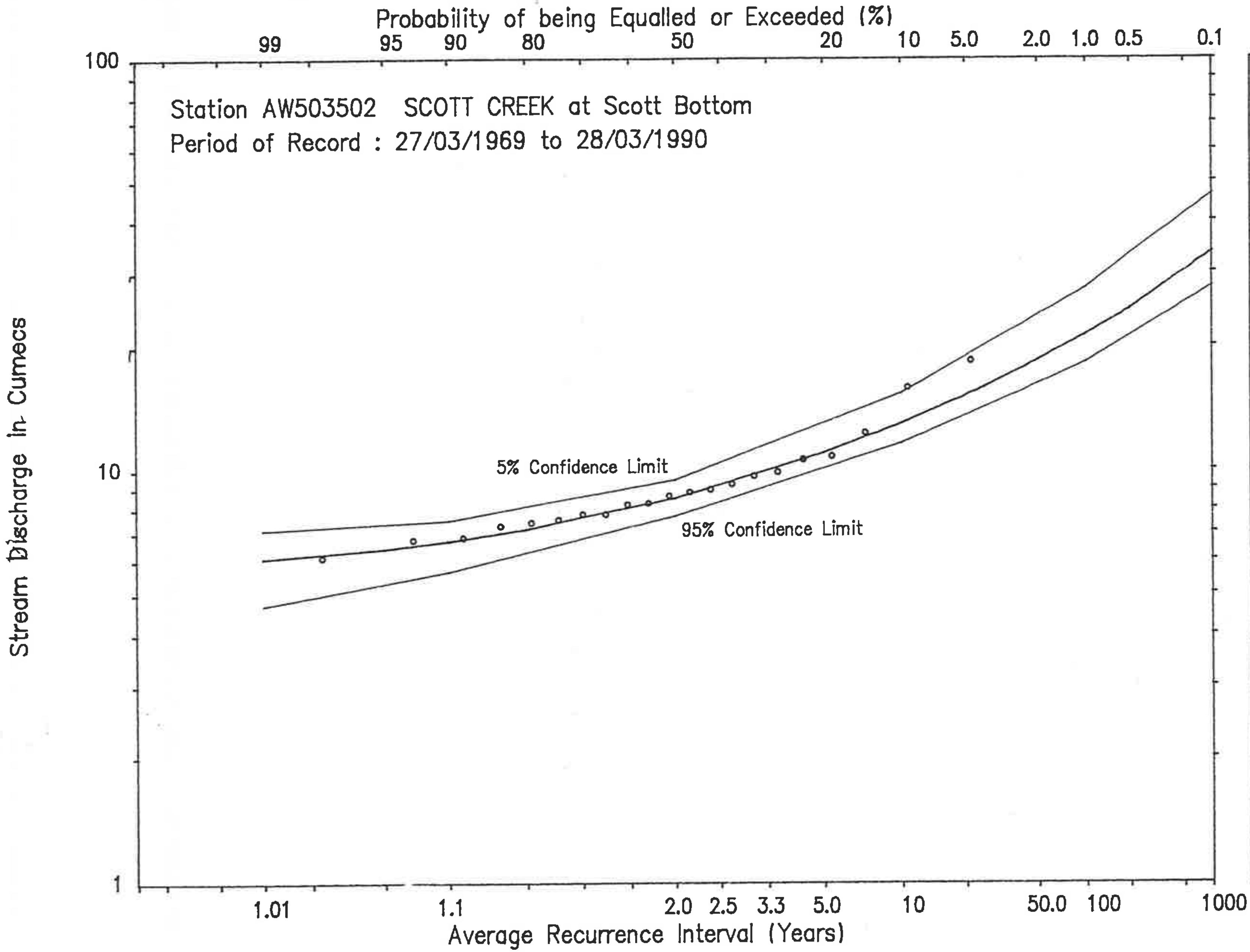
Statistics of the Logs of Flows.

Mean : 0.788
Standard Deviation : 0.374
Skewness Coefficient : -1.693

Civil Engineering, Adelaide University

HYLP3 Output 26/05/1992

Log-Pearson Type III Analysis. (Partial Series)



Flow (Cumecs)	Probability (1/Yp)	ARI (Yp yrs)
6.10	0.990	1.01
6.72	0.900	1.11
8.54	0.500	2
11.0	0.200	5
13.0	0.100	10
15.9	0.040	25
18.4	0.020	50
21.3	0.010	100
24.5	0.005	200
33.6	0.001	1000

Statistics of the Logs of Flows.

Mean	:	0.955
Standard Deviation	:	0.118
Skewness Coefficient	:	1.222

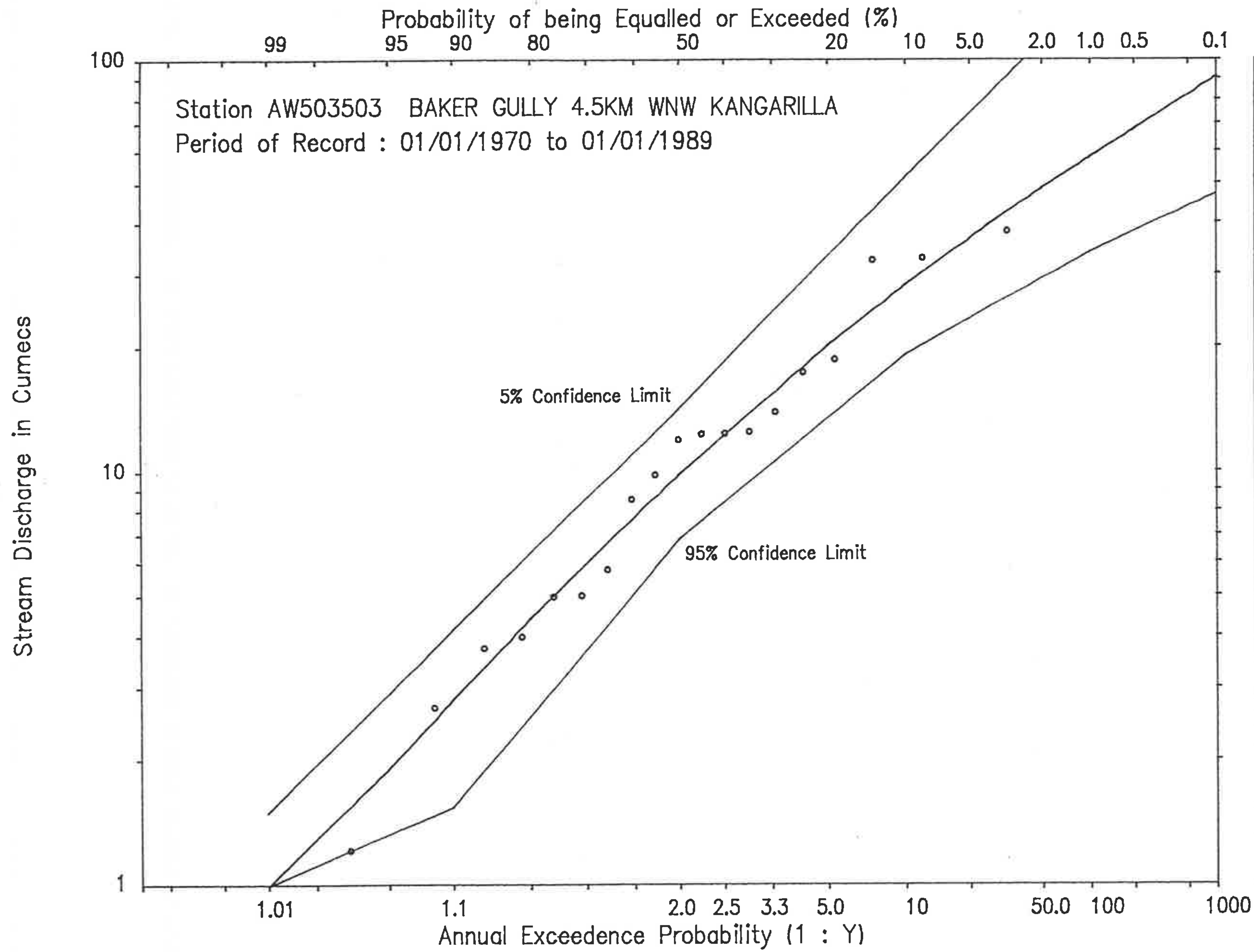
Series Extraction Parameters

TMin	:	5760.00
QMin	:	6.00

Civil Engineering, Adelaide University

HYLP3 Output 26/05/1992

Log-Pearson Type III Analysis. (Annual Series)



Flow (Cumecs)	Probability (1/Y)	AEP (1 : Y)
0.874	0.990	1.01
2.83	0.900	1.11
9.88	0.500	2
20.2	0.200	5
28.3	0.100	10
39.7	0.040	25
48.8	0.020	50
58.1	0.010	100
67.9	0.005	200
91.3	0.001	1000

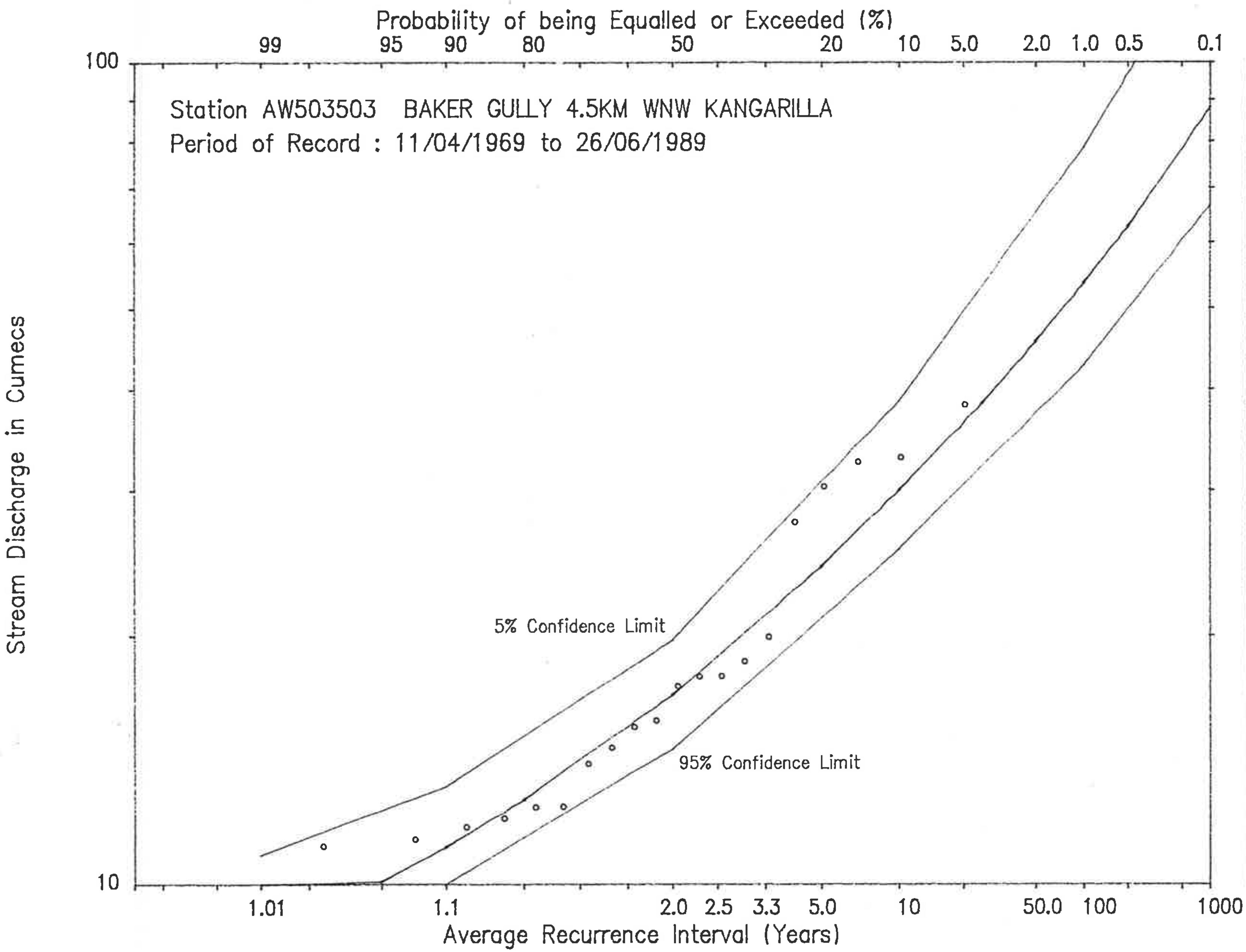
Statistics of the Logs of Flows.

Mean	:	0.969
Standard Deviation	:	0.393
Skewness Coefficient	:	-0.403

Civil Engineering, Adelaide University

HYLP3 Output 29/08/1991

Log-Pearson Type III Analysis. (Partial Series)



Flow (Cumecs)	Probability (1/Yp)	ARI (Yp yrs)
8.62	0.990	1.01
11.1	0.900	1.11
17.0	0.500	2
24.2	0.200	5
30.0	0.100	10
38.4	0.040	25
45.6	0.020	50
53.6	0.010	100
62.6	0.005	200
88.1	0.001	1000

Statistics of the Logs of Flows.

Mean : 1.248
Standard Deviation : 0.171
Skewness Coefficient : 0.675

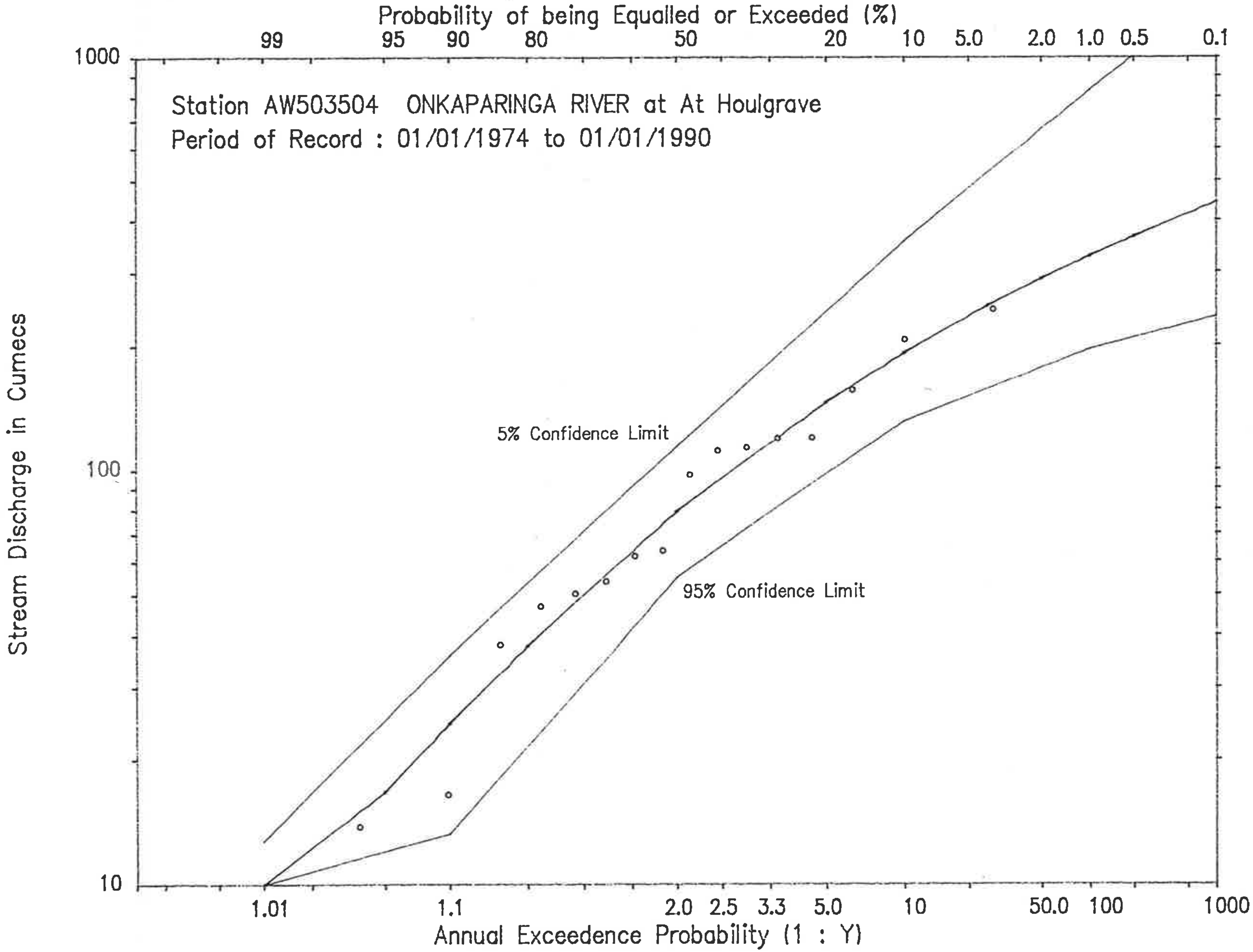
Series Extraction Parameters

TMin : 8640.00
QMin : 10.00

Civil Engineering, Adelaide University

HYLP3 Output 29/08/1991

Log-Pearson Type III Analysis. (Annual Series)



Flow (Cumecs)	Probability (1/Y)	AEP (1 : Y)
7.58	0.990	1.01
24.6	0.900	1.11
79.0	0.500	2
145	0.200	5
191	0.100	10
248	0.040	25
289	0.020	50
327	0.010	100
364	0.005	200
442	0.001	1000

Statistics of the Logs of Flows.

Mean : 1.860

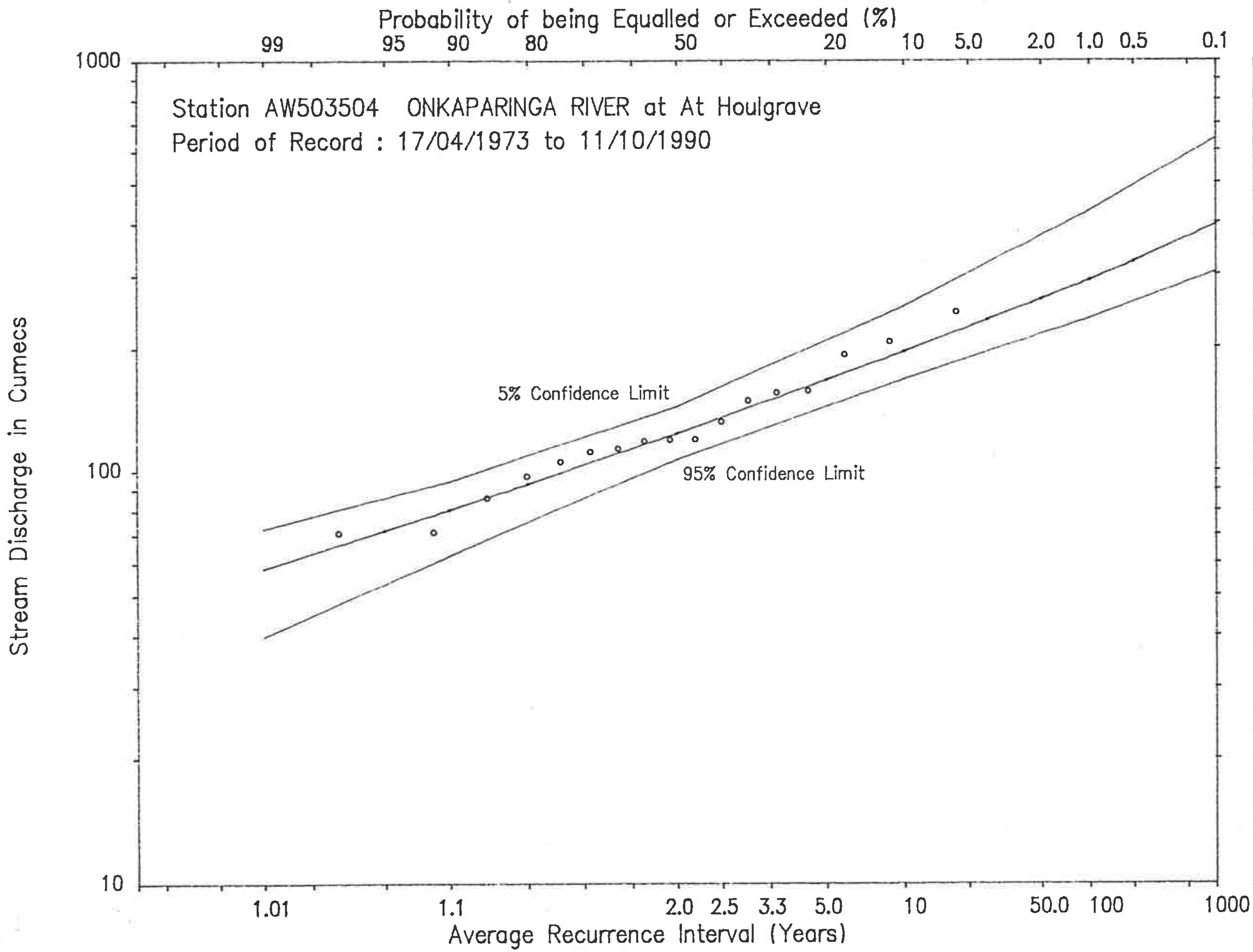
Standard Deviation : 0.353

Skewness Coefficient : -0.635

Civil Engineering, Adelaide University

HYLP3 Output 29/08/1991

Log-Pearson Type III Analysis. (Partial Series)



Flow (Cumecs)	Probability (1/Yp)	ARI (Yp yrs)
58.3	0.990	1.01
80.5	0.900	1.11
123	0.500	2
166	0.200	5
195	0.100	10
233	0.040	25
261	0.020	50
291	0.010	100
321	0.005	200
395	0.001	1000

Statistics of the Logs of Flows.

Mean	:	2.095
Standard Deviation	:	0.150
Skewness Coefficient	:	0.179

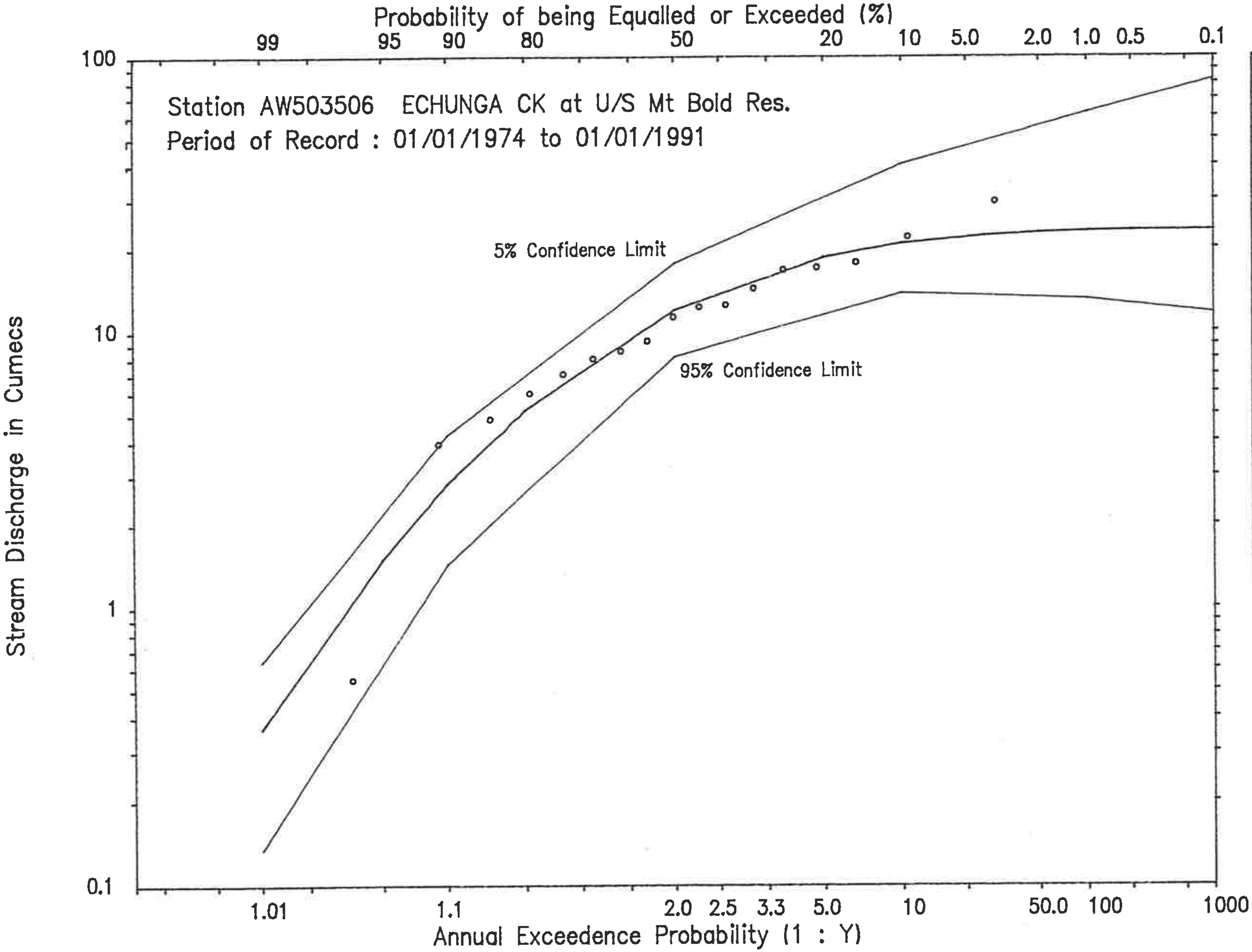
Series Extraction Parameters

TMin	:	10080.00
QMin	:	50.00

Civil Engineering, Adelaide University

HYLP3 Output 28/05/1992

Log-Pearson Type III Analysis. (Annual Series)



Flow (Cumecs)	Probability (1/Y)	AEP (1 : Y)
0.365	0.990	1.01
2.81	0.900	1.11
12.0	0.500	2
18.6	0.200	5
20.8	0.100	10
22.2	0.040	25
22.7	0.020	50
23.0	0.010	100
23.1	0.005	200
23.2	0.001	1000

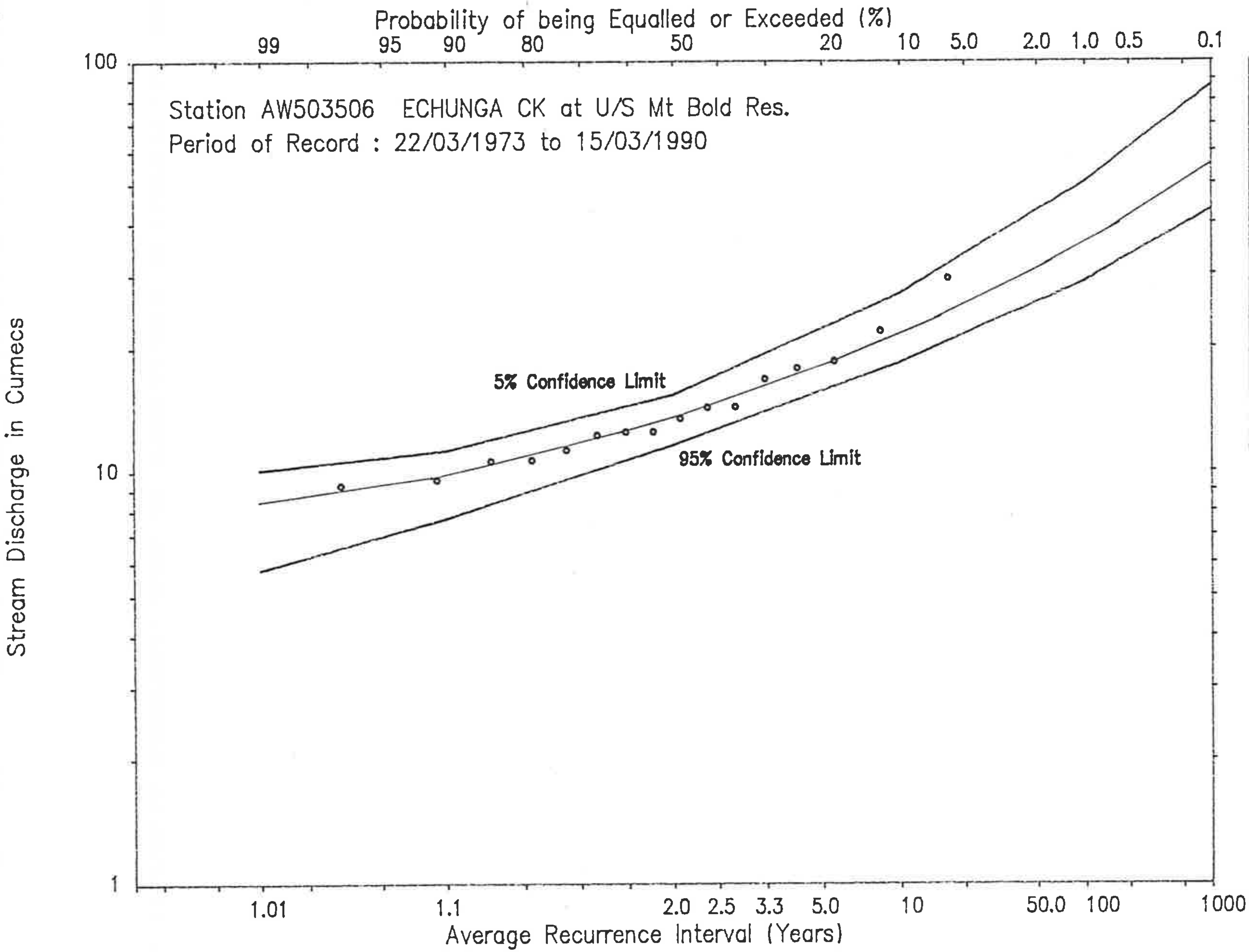
Statistics of the Logs of Flows.

Mean : 0.961
Standard Deviation : 0.392
Skewness Coefficient : -1.935

Civil Engineering, Adelaide University

HYLP3 Output 28/08/1991

Log-Pearson Type III Analysis. (Partial Series)



Flow (Cumecs)	Probability (1/Yp)	ARI (Yp yrs)
8.29	0.990	1.01
9.73	0.900	1.11
13.3	0.500	2
17.7	0.200	5
21.2	0.100	10
26.2	0.040	25
30.5	0.020	50
35.2	0.010	100
40.4	0.005	200
55.1	0.001	1000

Statistics of the Logs of Flows.

Mean	:	1.144
Standard Deviation	:	0.136
Skewness Coefficient	:	0.898

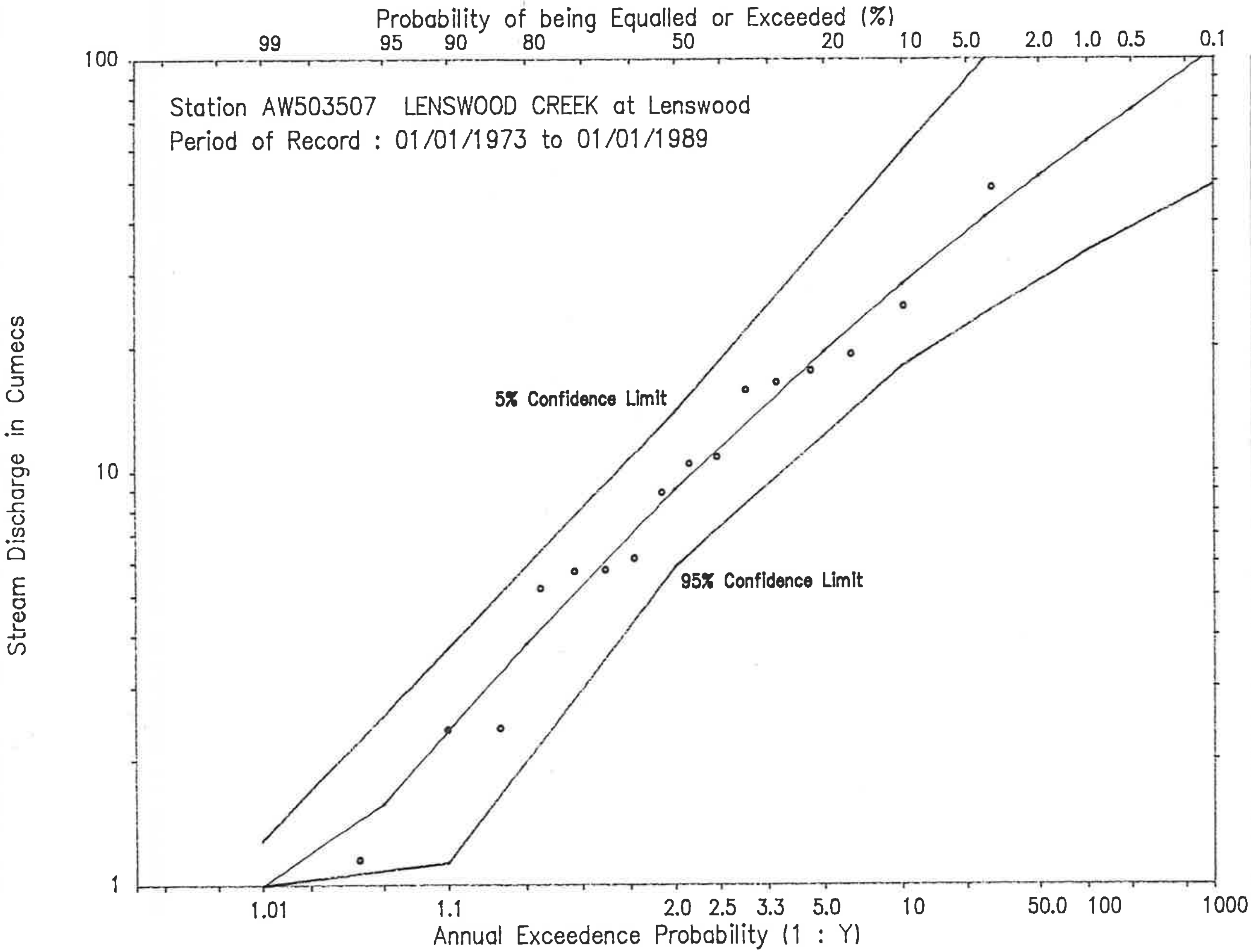
Series Extraction Parameters

TMin	:	5760.00
QMin	:	8.00

Civil Engineering, Adelaide University

HYLP3 Output 28/08/1991

Log-Pearson Type III Analysis. (Annual Series)



Flow (Cumecs)	Probability (1/Y)	AEP (1 : Y)
0.688	0.990	1.01
2.37	0.900	1.11
8.99	0.500	2
19.5	0.200	5
28.2	0.100	10
41.0	0.040	25
51.6	0.020	50
62.8	0.010	100
74.8	0.005	200
105	0.001	1000

Statistics of the Logs of Flows.

Mean : 0.929

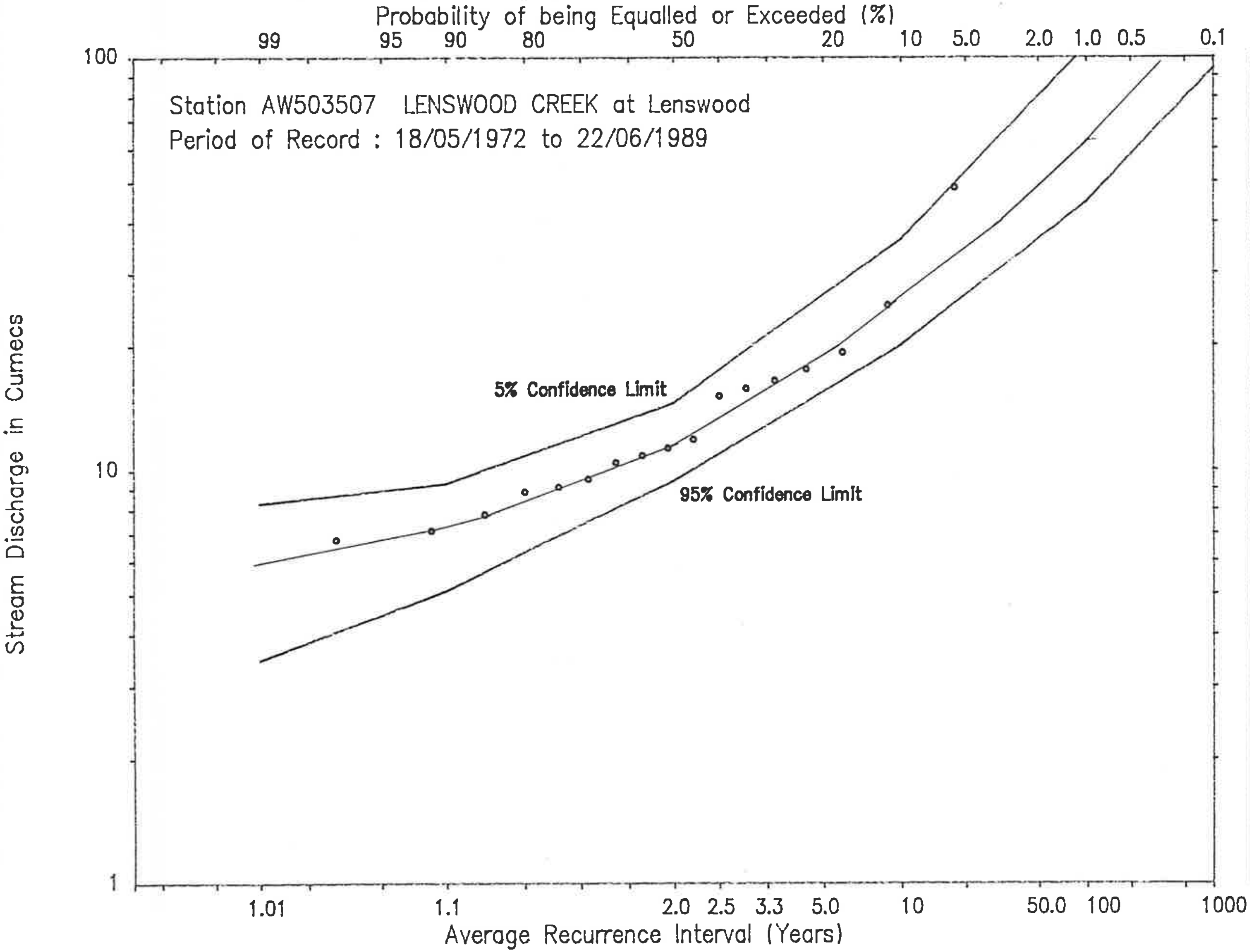
Standard Deviation : 0.422

Skewness Coefficient : -0.358

Civil Engineering, Adelaide University

HYLP3 Output 28/08/1991

Log-Pearson Type III Analysis. (Partial Series)



Flow (Cumecs)	Probability (1/Yp)	ARI (Yp yrs)
6.07	0.990	1.01
7.38	0.900	1.11
11.7	0.500	2
18.6	0.200	5
25.1	0.100	10
36.4	0.040	25
47.4	0.020	50
61.3	0.010	100
78.7	0.005	200
138	0.001	1000

Statistics of the Logs of Flows.

Mean : 1.108
Standard Deviation : 0.218
Skewness Coefficient : 1.142

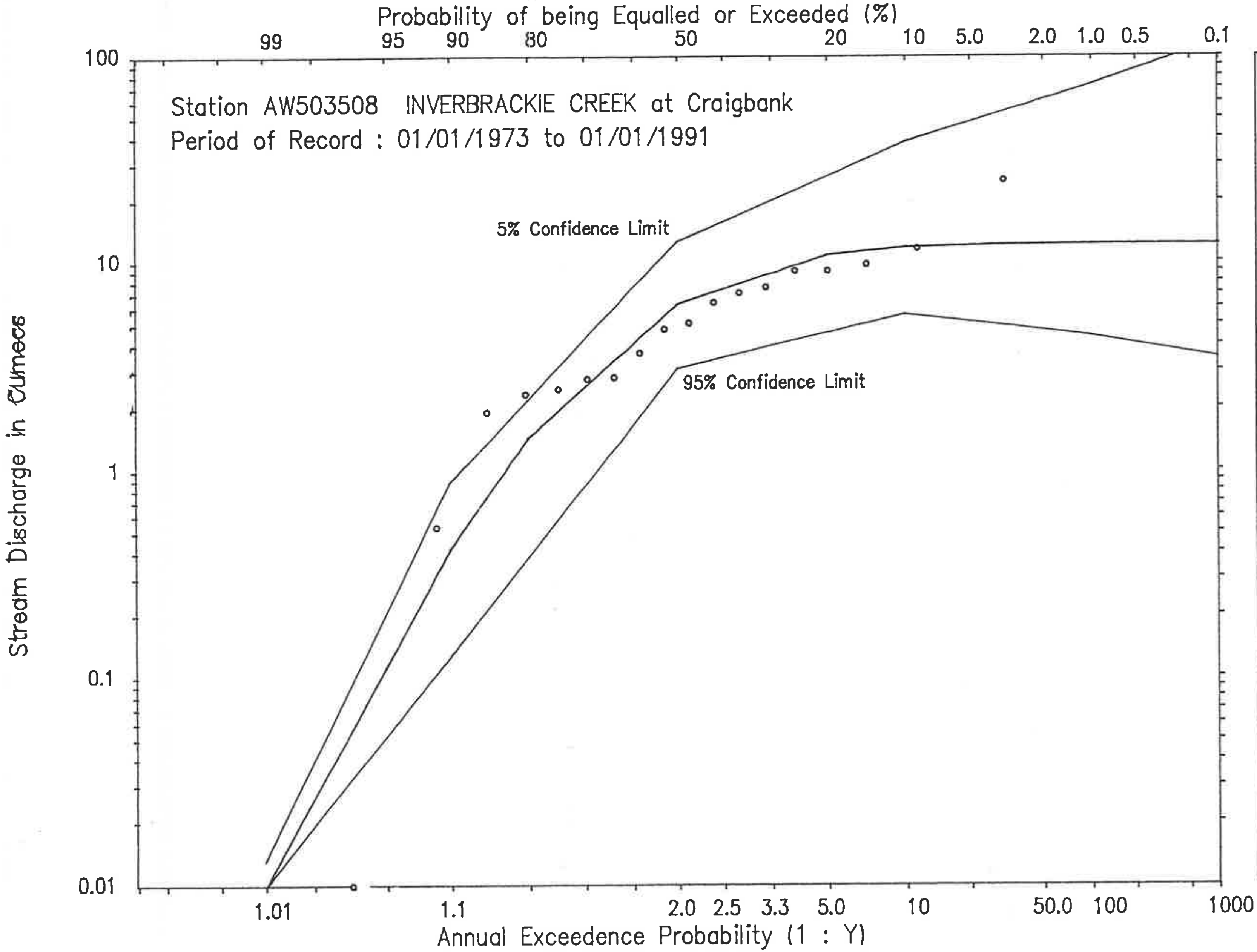
Series Extraction Parameters

TMin : 5760.00
QMin : 6.00

Civil Engineering, Adelaide University

HYLP3 Output 26/05/1992

Log-Pearson Type III Analysis. (Annual Series)



Flow (Cumecs)	Probability (1/Y)	AEP (1 : Y)
0.005	0.990	1.01
0.417	0.900	1.11
6.25	0.500	2
10.8	0.200	5
11.8	0.100	10
12.1	0.040	25
12.2	0.020	50
12.2	0.010	100
12.2	0.005	200
12.3	0.001	1000

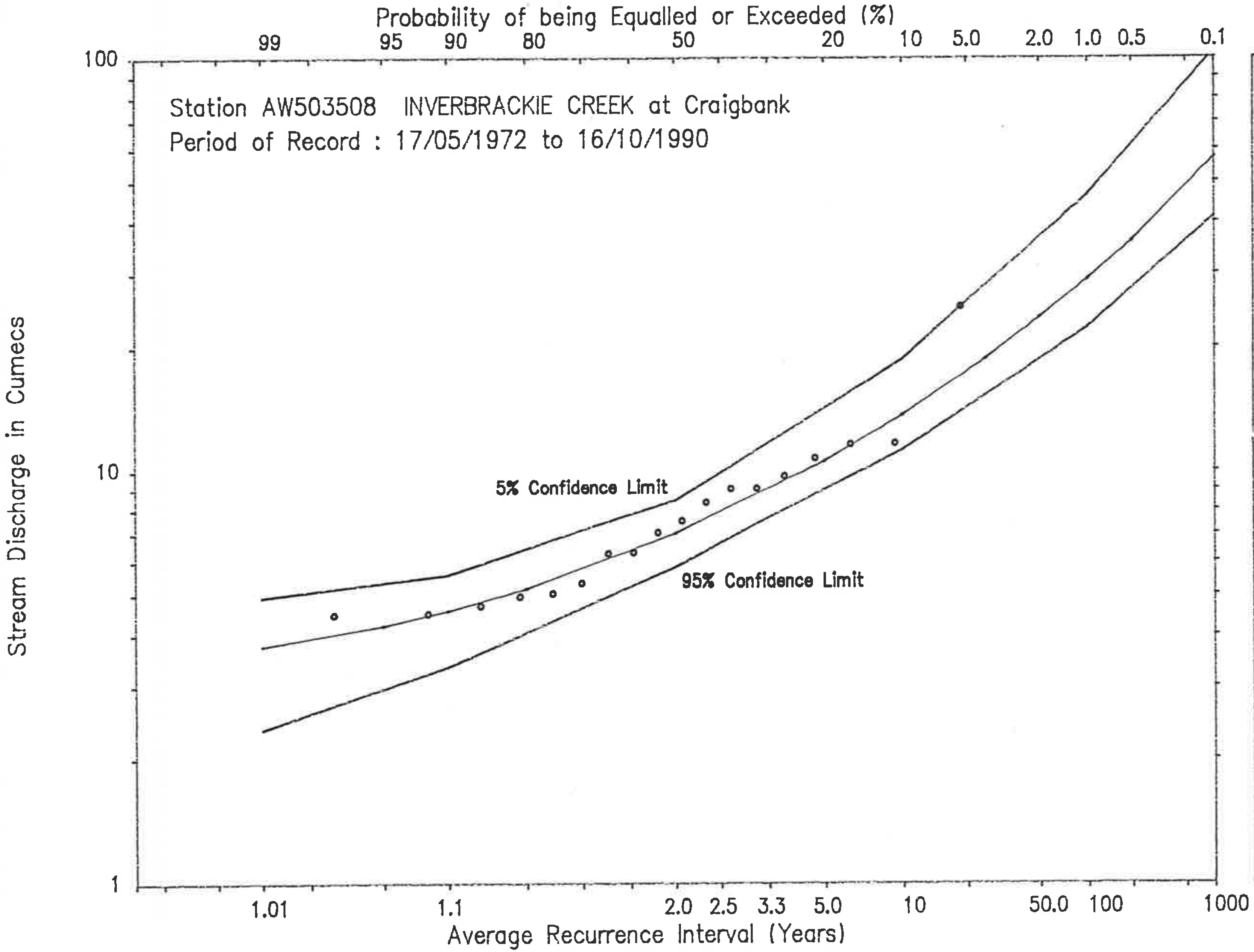
Statistics of the Logs of Flows.

Mean : 0.526
Standard Deviation : 0.732
Skewness Coefficient : -2.608

Civil Engineering, Adelaide University

HYLP3 Output 28/08/1991

Log-Pearson Type III Analysis. (Partial Series)



Flow (Cumecs)	Probability (1/Yp)	ARI (Yp yrs)
3.77	0.990	1.01
4.59	0.900	1.11
7.00	0.500	2
10.5	0.200	5
13.7	0.100	10
18.7	0.040	25
23.4	0.020	50
29.1	0.010	100
35.8	0.005	200
57.3	0.001	1000

Statistics of the Logs of Flows.

Mean : 0.878
Standard Deviation : 0.192
Skewness Coefficient : 1.033

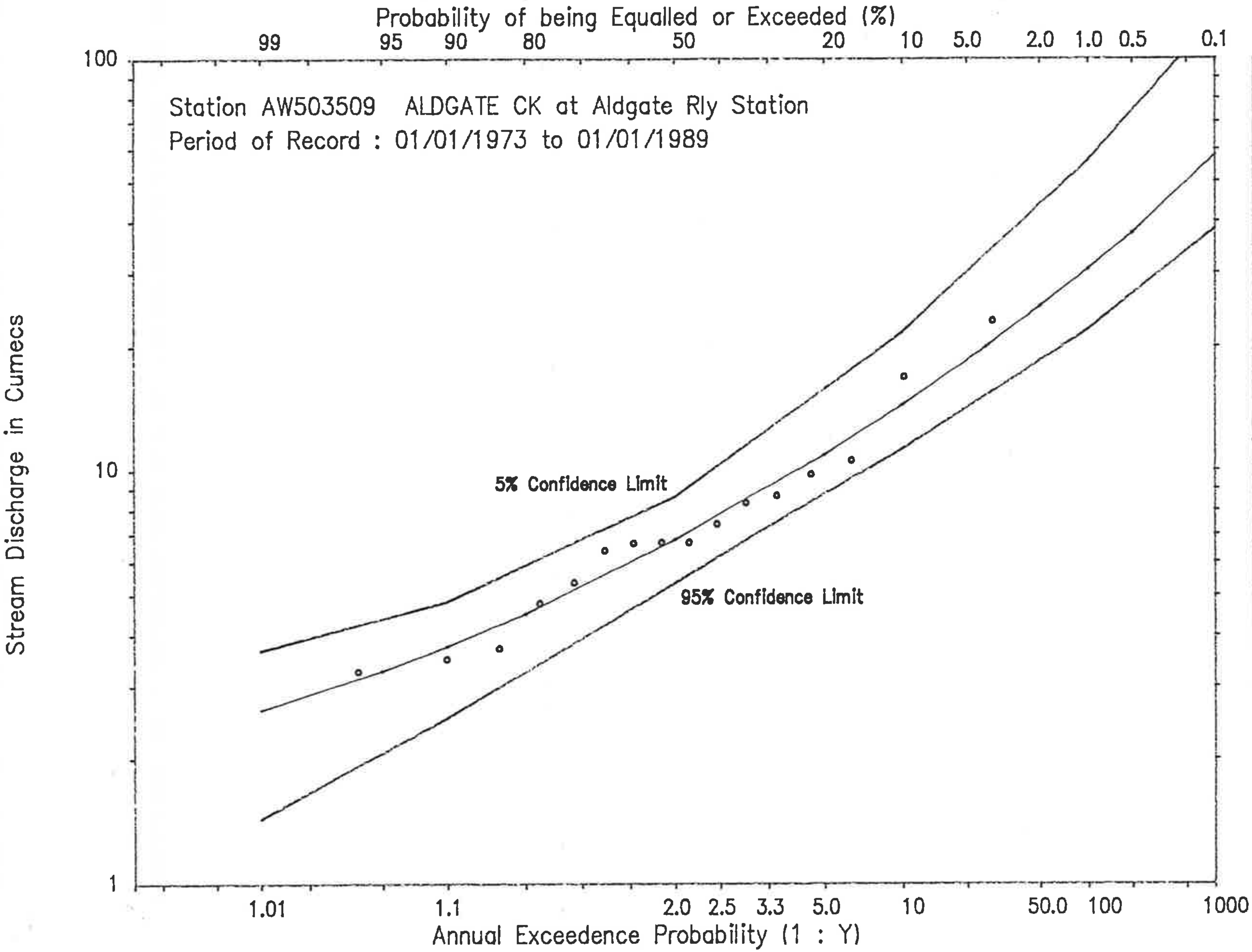
Series Extraction Parameters

TMin : 4320.00
QMin : 4.00

Civil Engineering, Adelaide University

HYLP3 Output 28/08/1991

Log-Pearson Type III Analysis. (Annual Series)



Flow (Cumecs)	Probability (1/Y)	AEP (1 : Y)
2.63	0.990	1.01
3.78	0.900	1.11
6.77	0.500	2
10.9	0.200	5
14.4	0.100	10
19.9	0.040	25
24.9	0.020	50
30.7	0.010	100
37.5	0.005	200
58.1	0.001	1000

Statistics of the Logs of Flows.

Mean : 0.853

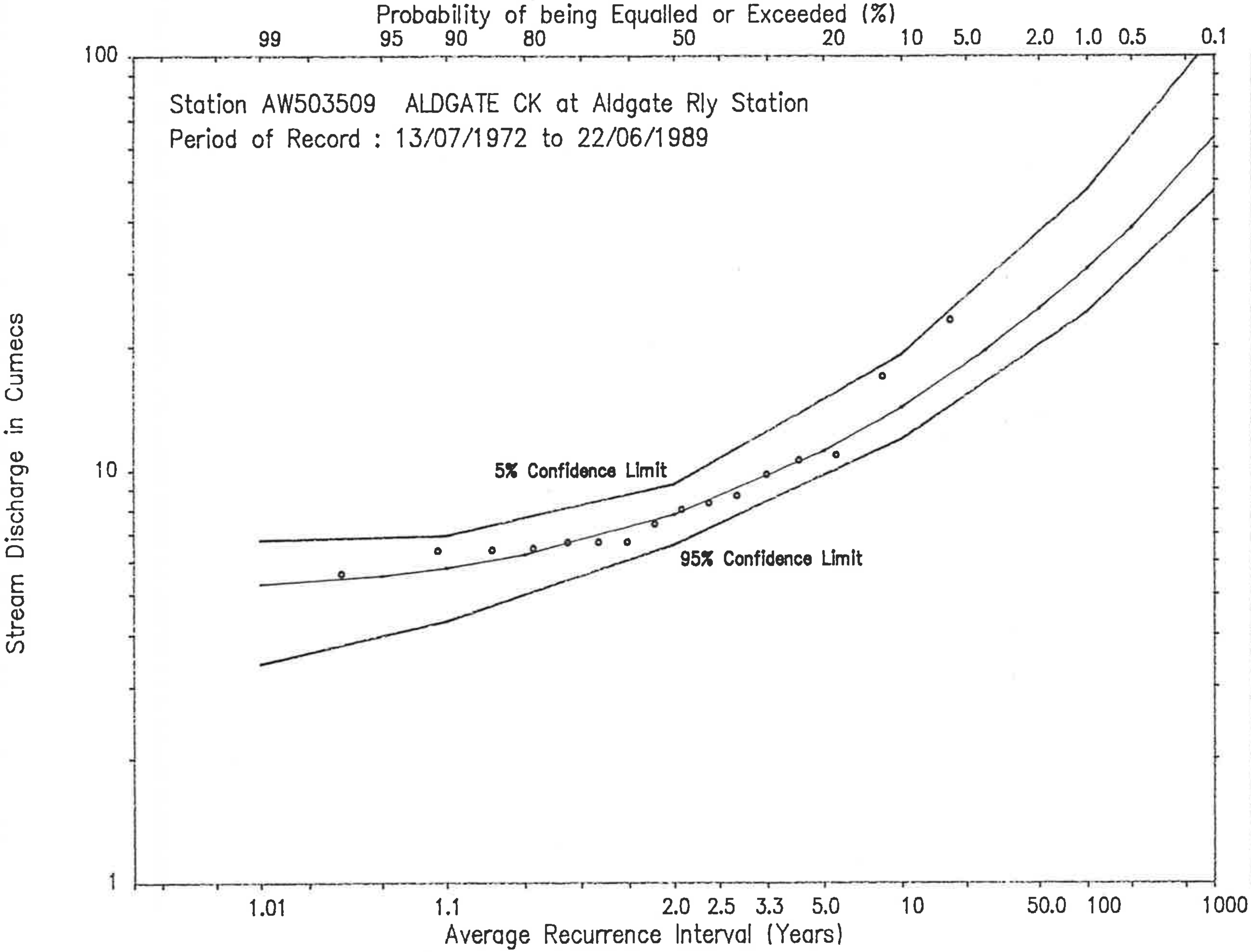
Standard Deviation : 0.230

Skewness Coefficient : 0.598

Civil Engineering, Adelaide University

HYLP3 Output 28/08/1991

Log-Pearson Type III Analysis. (Partial Series)



Flow (Cumecs)	Probability (1/Yp)	ARI (Yp yrs)
5.30	0.990	1.01
5.80	0.900	1.11
7.80	0.500	2
11.1	0.200	5
14.2	0.100	10
19.5	0.040	25
24.5	0.020	50
30.7	0.010	100
38.4	0.005	200
63.8	0.001	1000

Statistics of the Logs of Flows.

Mean : 0.932
Standard Deviation : 0.166
Skewness Coefficient : 1.513

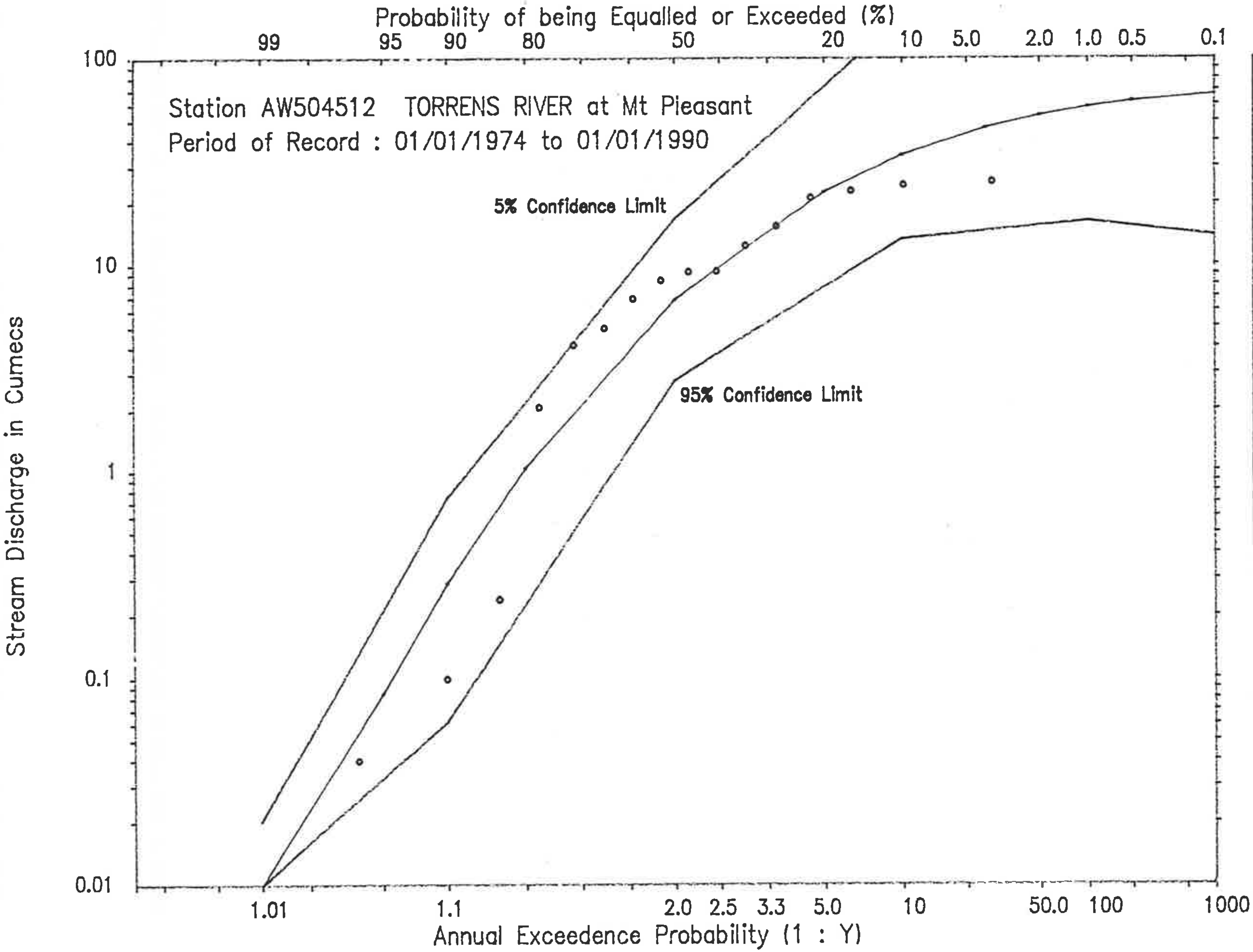
Series Extraction Parameters

TMin : 4320.00
QMin : 5.00

Civil Engineering, Adelaide University

HYLP3 Output 28/08/1991

Log-Pearson Type III Analysis. (Annual Series)



Flow (Cumecs)	Probability (1/Y)	AEP (1 : Y)
0.006	0.990	1.01
0.287	0.900	1.11
6.73	0.500	2
22.6	0.200	5
34.1	0.100	10
46.3	0.040	25
53.2	0.020	50
58.3	0.010	100
62.1	0.005	200
68.8	0.001	1000

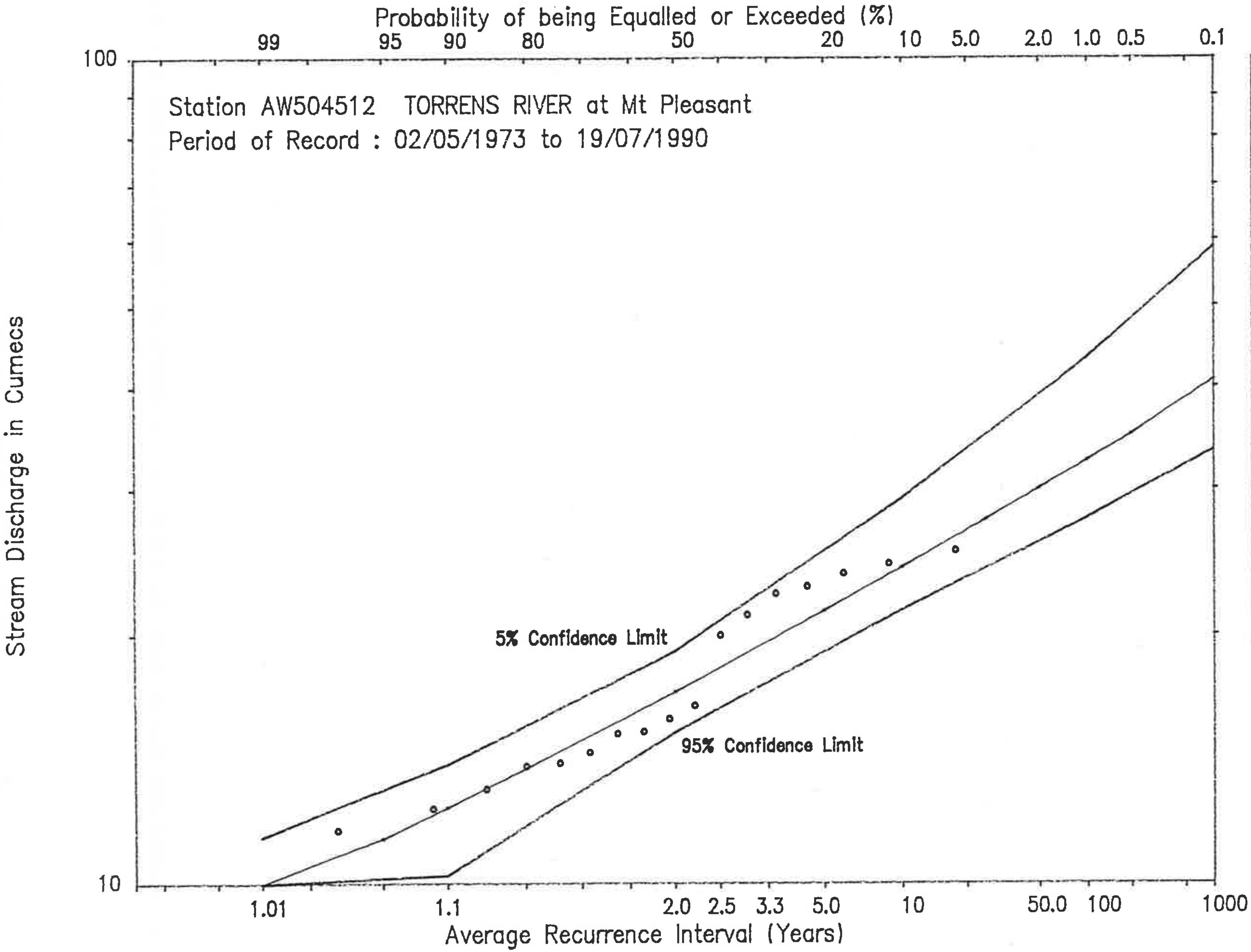
Statistics of the Logs of Flows.

Mean : 0.627
Standard Deviation : 0.875
Skewness Coefficient : -1.428

Civil Engineering, Adelaide University

HYLP3 Output 28/08/1991

Log-Pearson Type III Analysis. (Partial Series)



Flow (Cumecs)	Probability (1/Yp)	ARI (Yp yrs)
9.68	0.990	1.01
12.4	0.900	1.11
17.1	0.500	2
21.4	0.200	5
24.1	0.100	10
27.5	0.040	25
30.0	0.020	50
32.5	0.010	100
35.0	0.005	200
40.8	0.001	1000

Statistics of the Logs of Flows.

Mean : 1.235
Standard Deviation : 0.113
Skewness Coefficient : 0.159

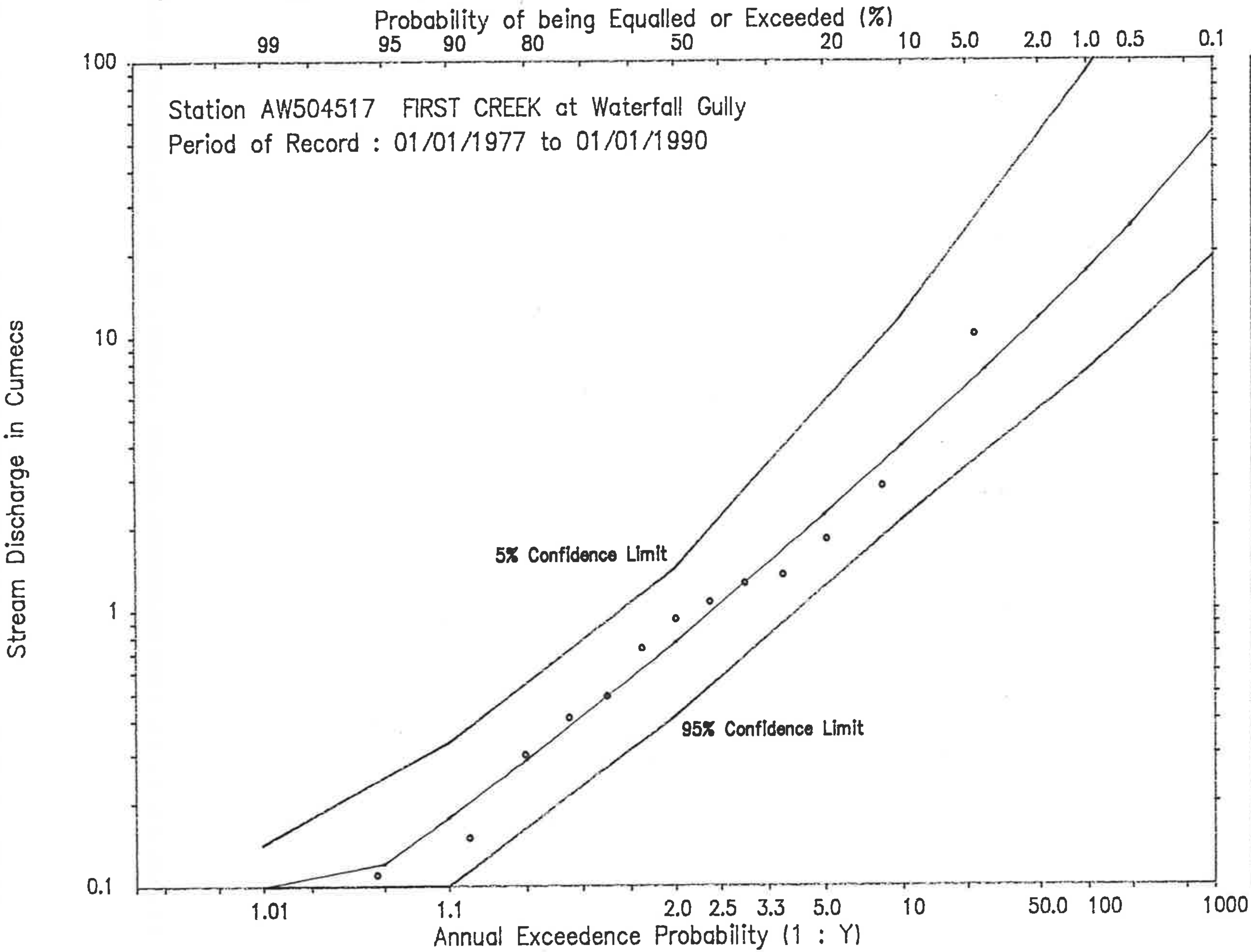
Series Extraction Parameters

TMin : 5760.00
QMin : 9.00

Civil Engineering, Adelaide University

rHYLP3 Output 28/08/1991

Log-Pearson Type III Analysis. (Annual Series)



Flow (Cumecs)	Probability (1/Y)	AEP (1 : Y)
0.061	0.990	1.01
0.177	0.900	1.11
0.765	0.500	2
2.20	0.200	5
3.93	0.100	10
7.50	0.040	25
11.5	0.020	50
17.1	0.010	100
24.8	0.005	200
54.3	0.001	1000

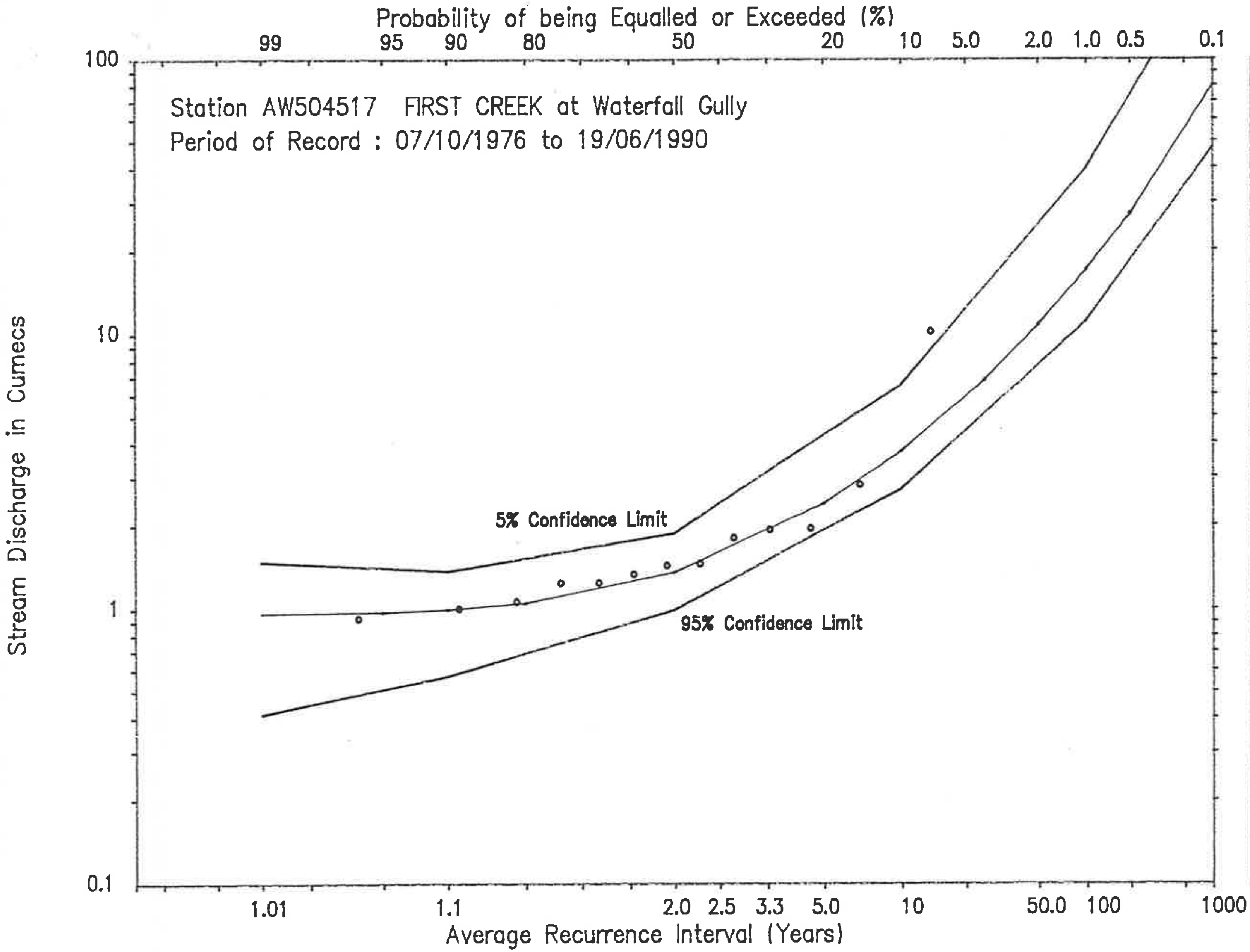
Statistics of the Logs of Flows.

Mean : -0.093
Standard Deviation : 0.527
Skewness Coefficient : 0.265

Civil Engineering, Adelaide University

HYLP3 Output 28/08/1991

Log-Pearson Type III Analysis. (Partial Series)



Flow (Cumecs)	Probability (1/Yp)	ARI (Yp yrs)
0.969	0.990	1.01
1.00	0.900	1.11
1.36	0.500	2
2.38	0.200	5
3.71	0.100	10
6.75	0.040	25
10.7	0.020	50
17.0	0.010	100
27.0	0.005	200
80.4	0.001	1000

Statistics of the Logs of Flows.

Mean : 0.225
Standard Deviation : 0.269
Skewness Coefficient : 2.252

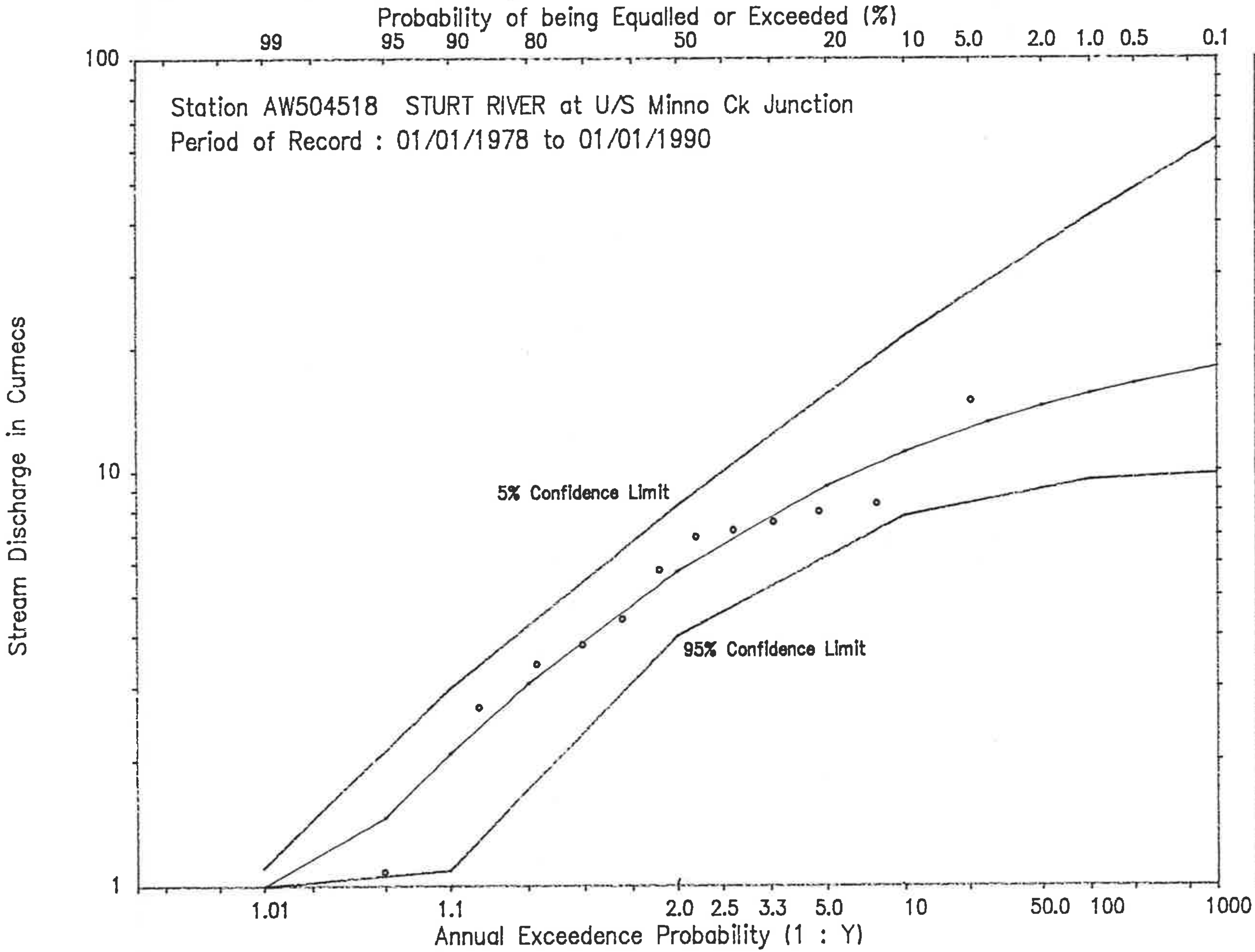
Series Extraction Parameters

TMin : 2880.00
QMin : 0.75

Civil Engineering, Adelaide University

HYLP3 Output 28/08/1991

Log-Pearson Type III Analysis. (Annual Series)



Flow (Cumecs)	Probability (1/Y)	AEP (1 : Y)
0.683	0.990	1.01
2.08	0.900	1.11
5.72	0.500	2
9.16	0.200	5
11.1	0.100	10
13.1	0.040	25
14.4	0.020	50
15.4	0.010	100
16.3	0.005	200
17.9	0.001	1000

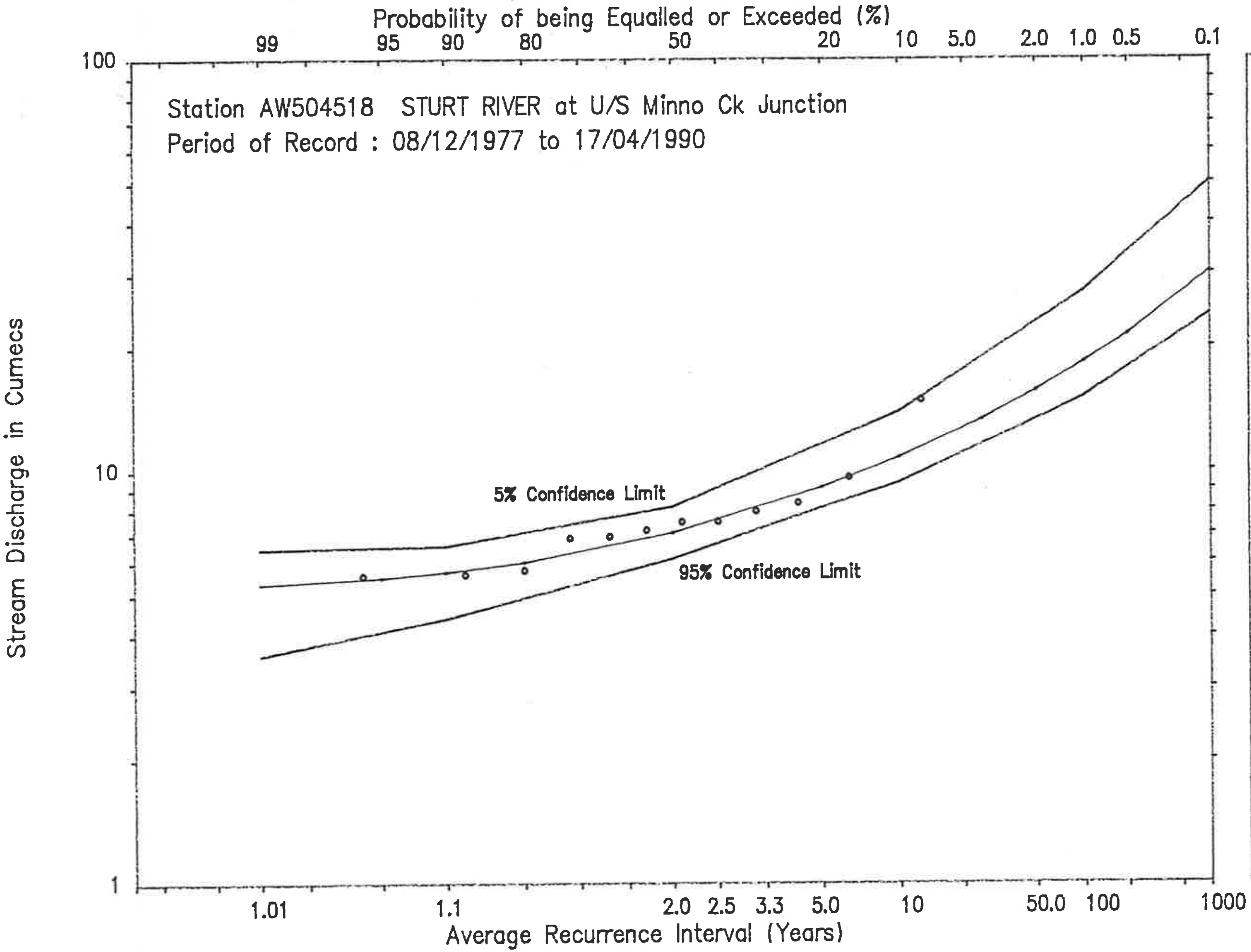
Statistics of the Logs of Flows.

Mean : 0.711
Standard Deviation : 0.293
Skewness Coefficient : -0.950

Civil Engineering, Adelaide University

HYLP3 Output 28/08/1991

Log-Pearson Type III Analysis. (Partial Series)



Flow (Cumecs)	Probability (1/Yp)	ARI (Yp yrs)
5.34	0.990	1.01
5.70	0.900	1.11
7.05	0.500	2
9.04	0.200	5
10.7	0.100	10
13.3	0.040	25
15.6	0.020	50
18.3	0.010	100
21.3	0.005	200
30.3	0.001	1000

Statistics of the Logs of Flows.

Mean	:	0.875
Standard Deviation	:	0.117
Skewness Coefficient	:	1.476

Series Extraction Parameters

TMin	:	4320.00
QMin	:	5.00

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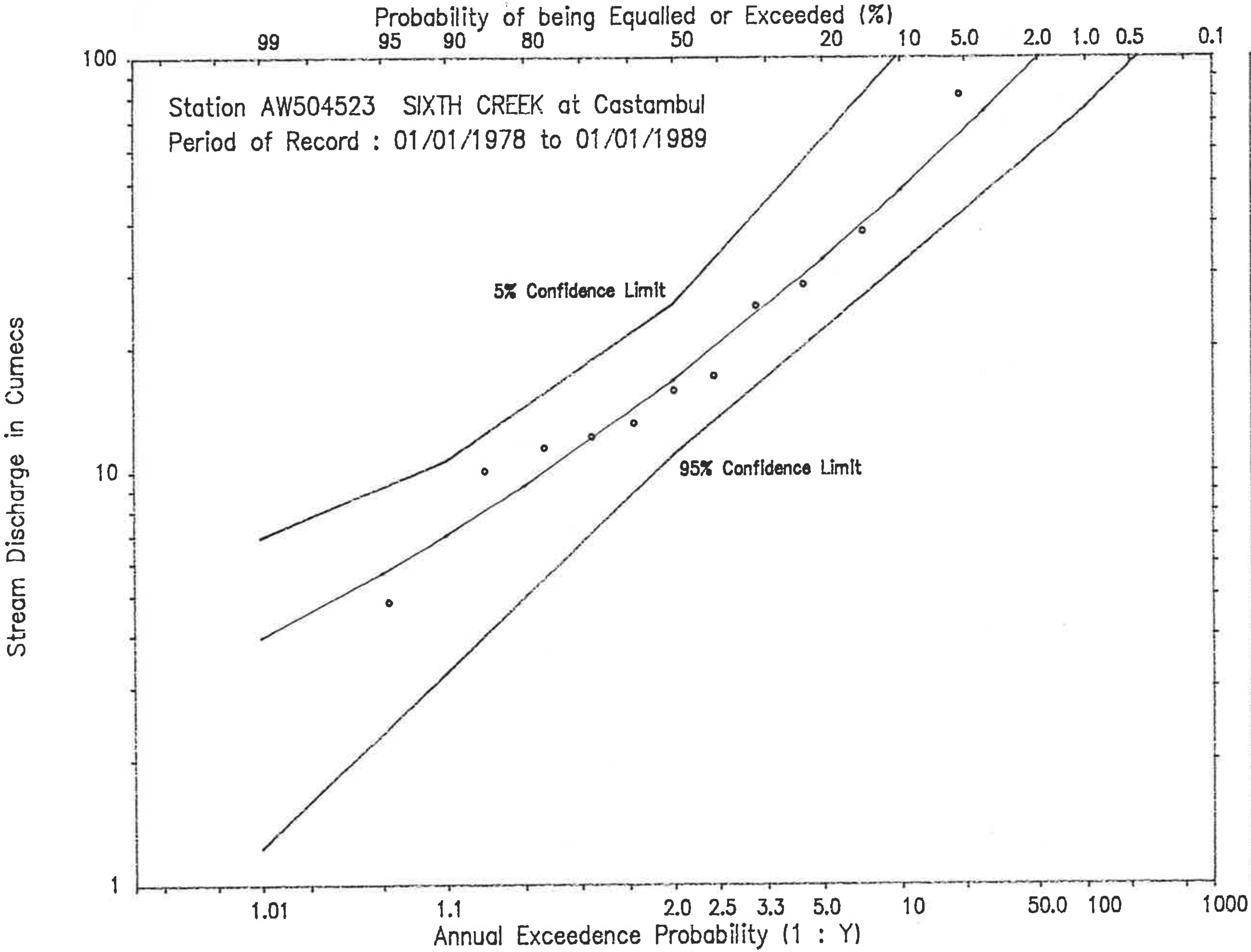
HYLP3 Output 28/08/1991

Log-Pearson Type III Analysis. (Annual Series)



Flow (Cumecs)	Probability (1/Y)	AEP (1 : Y)
3.97	0.990	1.01
7.03	0.900	1.11
16.6	0.500	2
32.5	0.200	5
47.7	0.100	10
73.9	0.040	25
99.4	0.020	50
131	0.010	100
171	0.005	200
301	0.001	1000

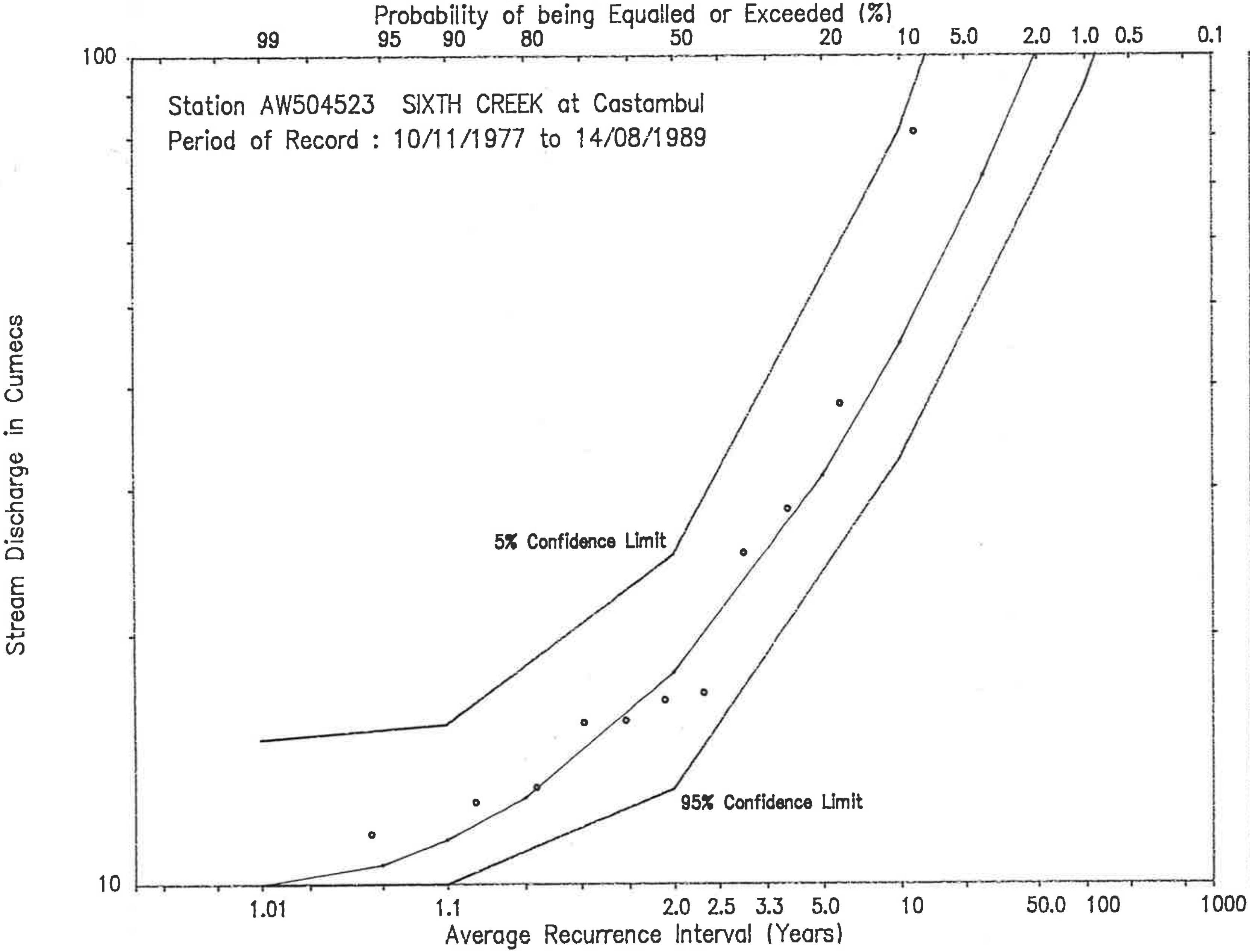
Statistics of the Logs of Flows.

Mean : 1.247
Standard Deviation : 0.327
Skewness Coefficient : 0.468

Civil Engineering, Adelaide University

HYLP3 Output 28/08/1991

Log–Pearson Type III Analysis. (Partial Series)



Flow (Cumecs)	Probability (1/Yp)	ARI (Yp yrs)
9.73	0.990	1.01
11.3	0.900	1.11
18.0	0.500	2
31.0	0.200	5
45.0	0.100	10
71.8	0.040	25
101	0.020	50
141	0.010	100
197	0.005	200
419	0.001	1000

Statistics of the Logs of Flows.

Mean : 1.315
Standard Deviation : 0.253
Skewness Coefficient : 1.446

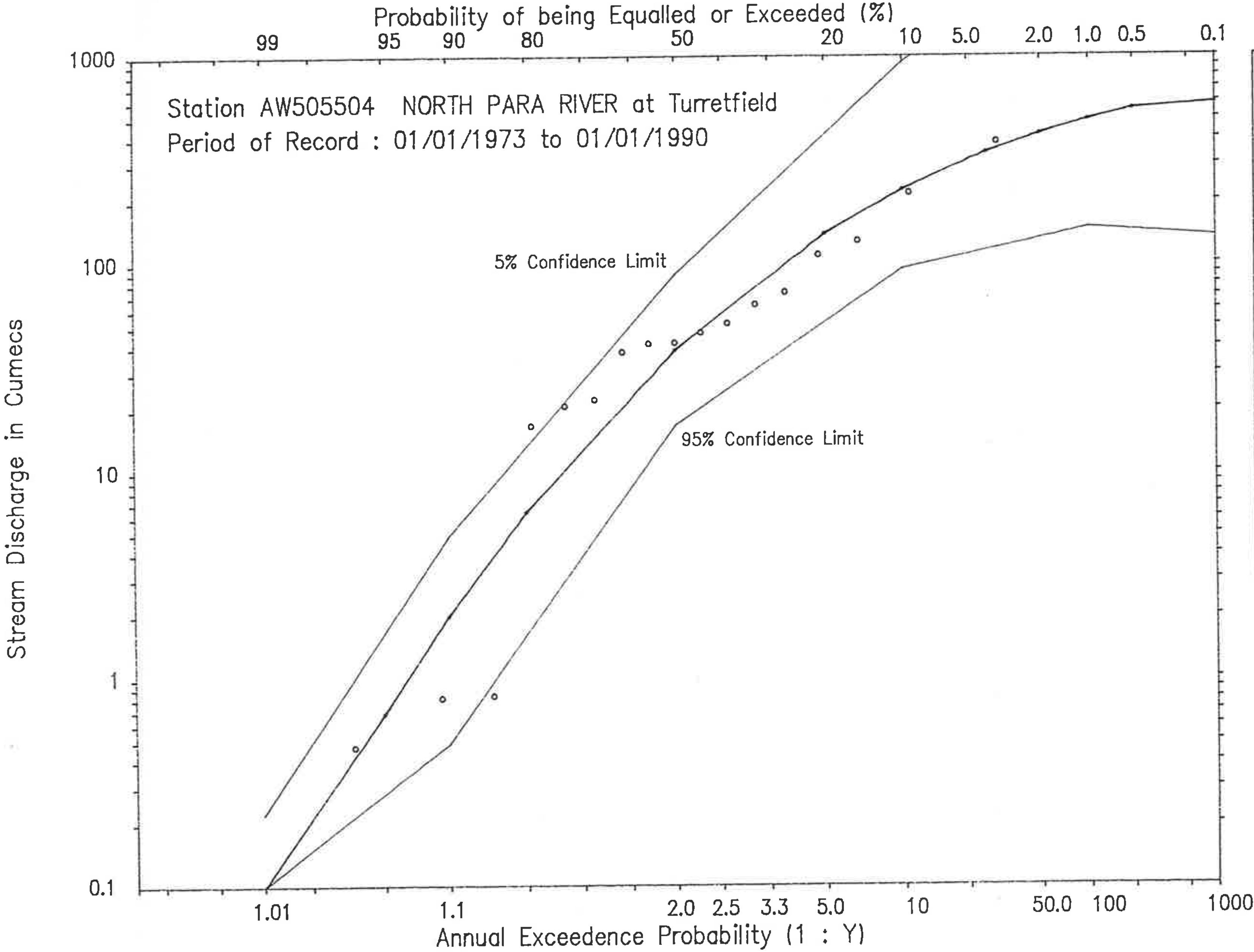
Series Extraction Parameters

TMin : 7200.00
QMin : 11.00

Civil Engineering, Adelaide University

HYLP3 Output 28/08/1991

Log-Pearson Type III Analysis. (Annual Series)



Flow (Cumecs)	Probability (1/Y)	AEP (1 : Y)
0.067	0.990	1.01
2.01	0.900	1.11
38.2	0.500	2
138	0.200	5
225	0.100	10
340	0.040	25
418	0.020	50
488	0.010	100
549	0.005	200
584	0.001	1000

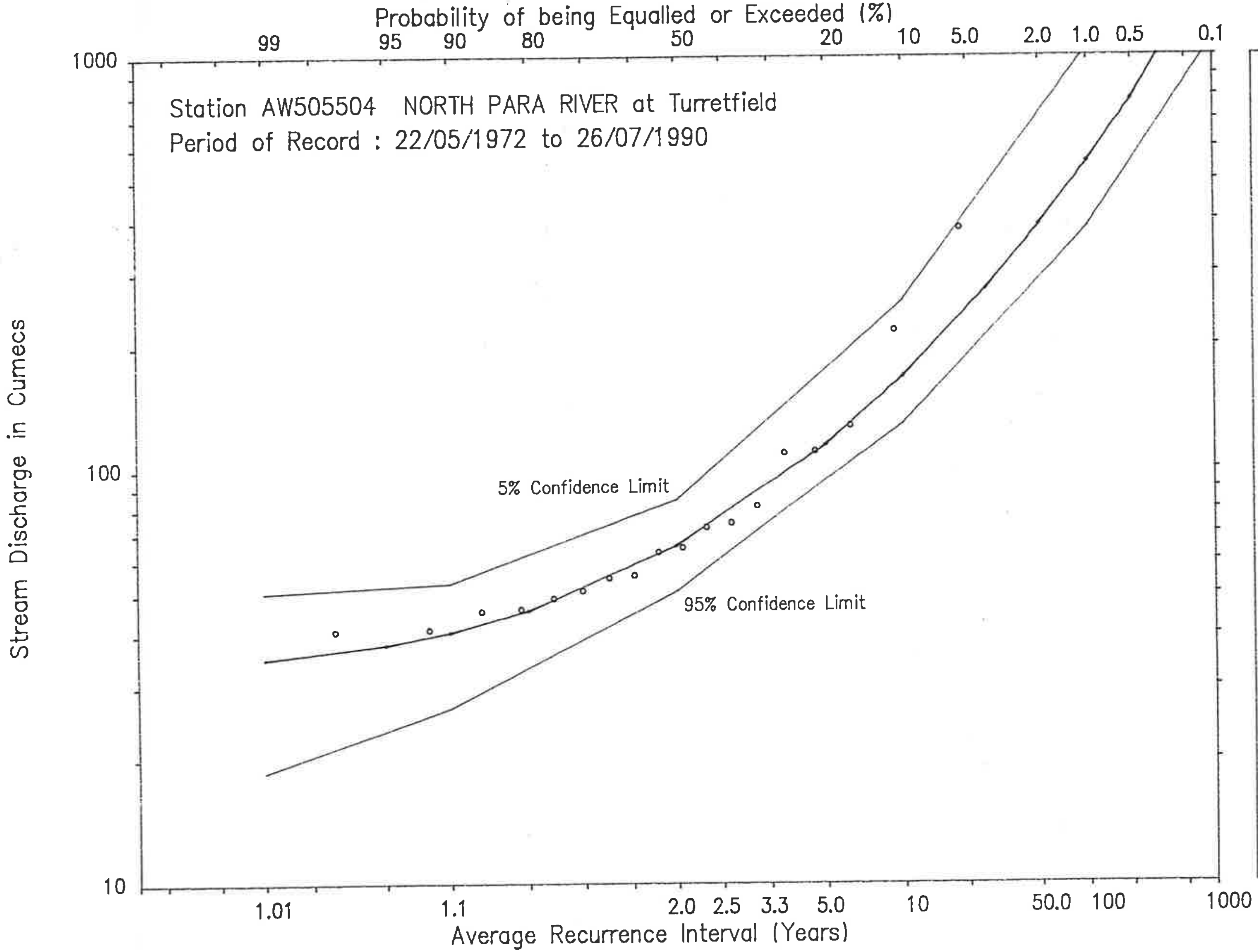
Statistics of the Logs of Flows.

Mean	:	1.428
Standard Deviation	:	0.839
Skewness Coefficient	:	-1.123

Civil Engineering, Adelaide University

HYLP3 Output 28/08/1991

Log-Pearson Type III Analysis. (Partial Series)



Flow (Cumecs)	Probability (1/Yp)	ARI (Yp yrs)
35.1	0.990	1.01
40.7	0.900	1.11
65.3	0.500	2
114	0.200	5
168	0.100	10
272	0.040	25
389	0.020	50
551	0.010	100
778	0.005	200
1708	0.001	1000

Statistics of the Logs of Flows.

Mean : 1.877
Standard Deviation : 0.261
Skewness Coefficient : 1.478

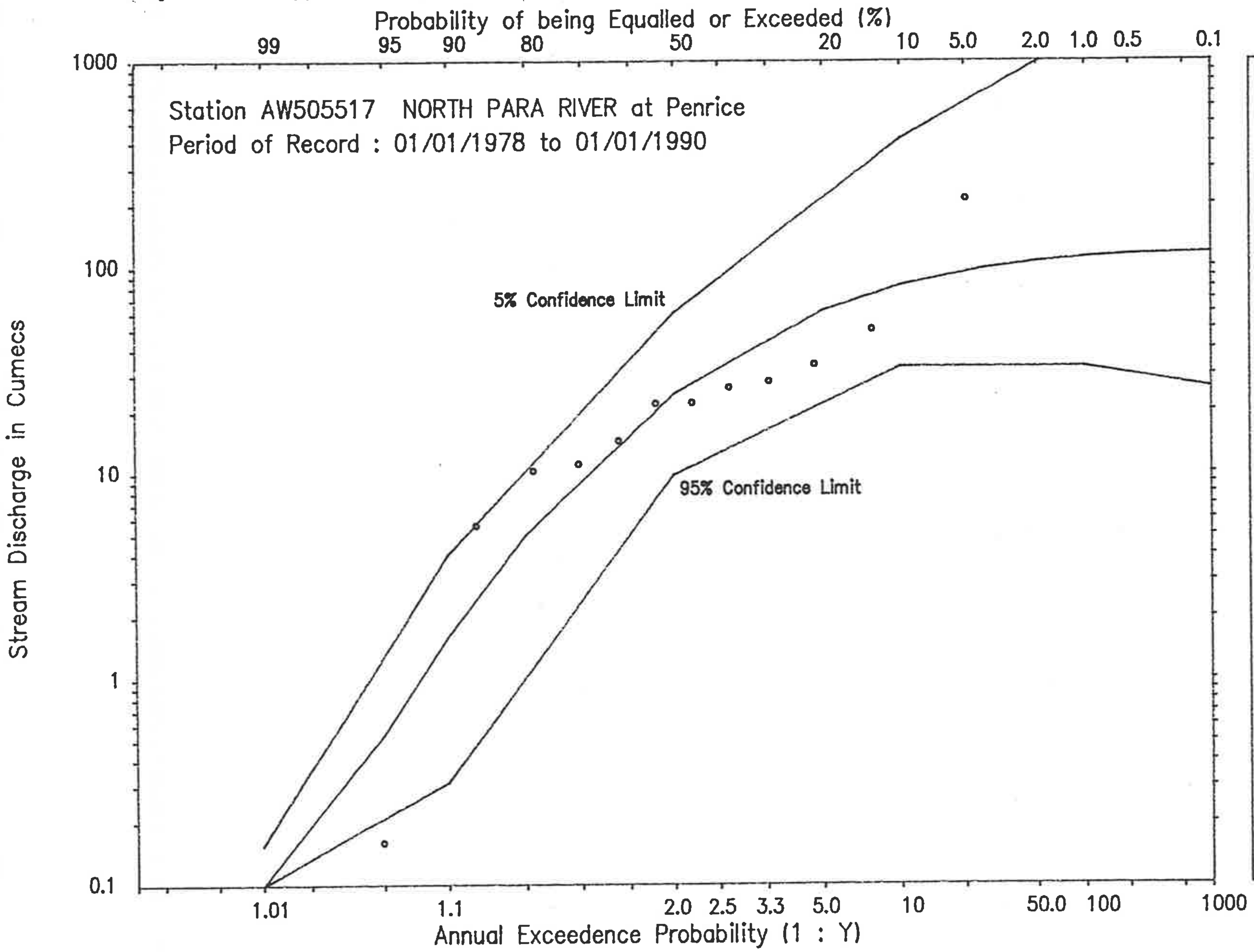
Series Extraction Parameters

TMin : 11520.00
QMin : 35.00

Civil Engineering, Adelaide University

HYLP3 Output 02/05/1991

Log-Pearson Type III Analysis. (Annual Series)



Flow (Cumecs)	Probability (1/Y)	AEP (1 : Y)
0.046	0.990	1.01
1.61	0.900	1.11
24.1	0.500	2
61.0	0.200	5
81.0	0.100	10
97.6	0.040	25
105	0.020	50
110	0.010	100
113	0.005	200
116	0.001	1000

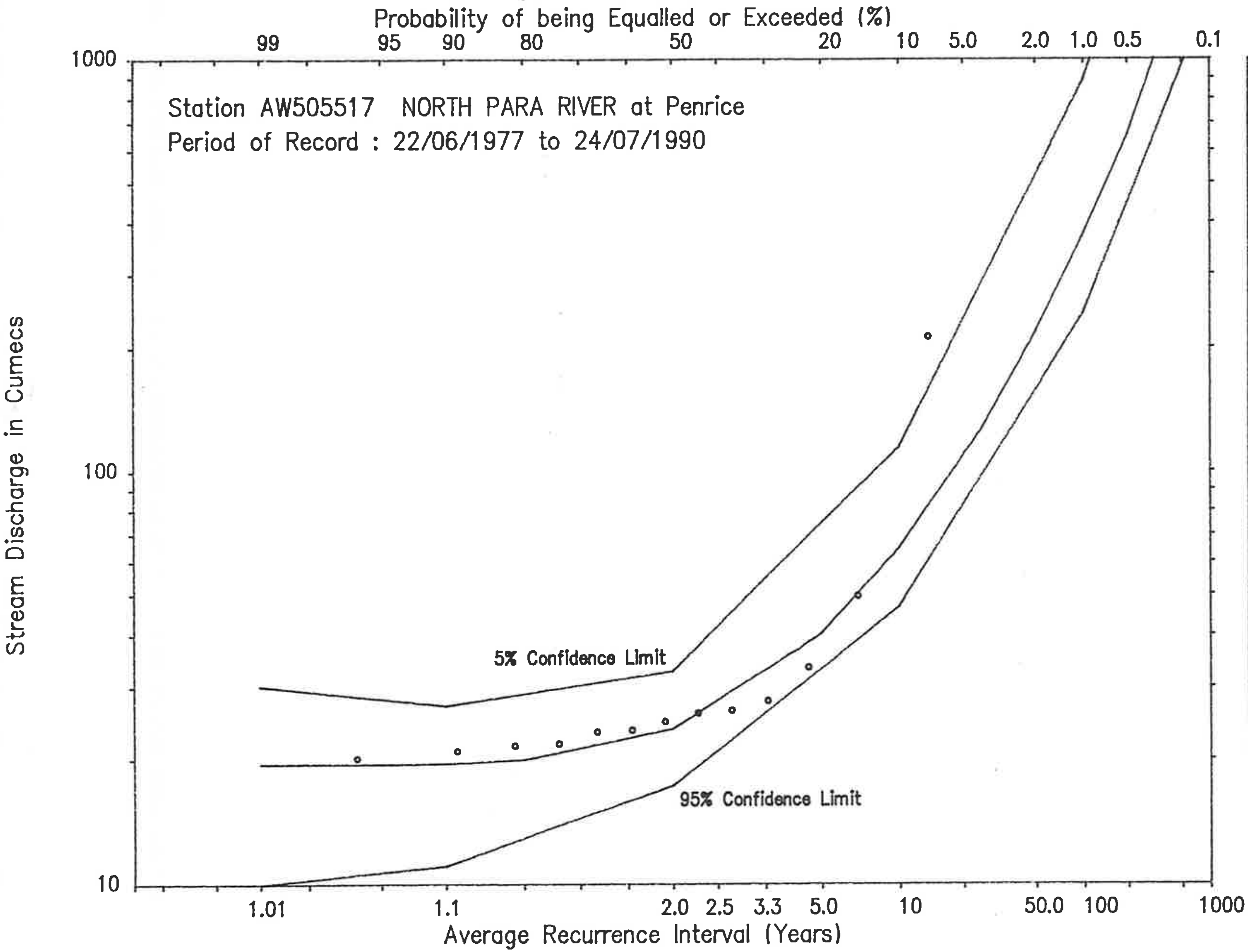
Statistics of the Logs of Flows.

Mean : 1.186
Standard Deviation : 0.739
Skewness Coefficient : -1.672

Civil Engineering, Adelaide University

HYLP3 Output 02/05/1991

Log-Pearson Type III Analysis. (Partial Series)



Flow (Cumecs)	Probability (1/Yp)	ARI (Yp yrs)
19.4	0.990	1.01
19.6	0.900	1.11
23.7	0.500	2
40.3	0.200	5
64.8	0.100	10
127	0.040	25
217	0.020	50
375	0.010	100
655	0.005	200
2451	0.001	1000

Statistics of the Logs of Flows.

Mean	:	1.482
Standard Deviation	:	0.274
Skewness Coefficient	:	2.839

Series Extraction Parameters

TMin	:	8640.00
QMin	:	15.00

Appendix E

WS06 - Computer Program

WS06 - Computer program has been modified to perform an outlier test to detect low and high outliers from the flood flow data series. The procedure in developing the low and high outlier equations has been followed as described in IE.Aust (1987).

In the modified WS06 - Computer package, provision has been made to discard extremely low or zero values as chosen by the user and then to adjust the probability accordingly. The program has been provided on a floppy disk, and is available from the Civil Engineering Department, University of Adelaide. The results from one station has been given next as an example of the output.

UNIVERSITY OF ADELAIDE PROGRAM WSO6

DATA AND STATISTICS OF FULL RECORD

503508 INVERBRACKIE CREEK 4.6.92

ANNUAL SERIES CUMECS

INPUT DATA :-

NUMBER OF EVENTS = 15

MAGNITUDE OF EVENTS :

9.01	7.50	2.34	7.03	5.04
2.47	11.58	24.87	9.69	1.92
4.72	6.31	9.02	3.64	2.79

ADJUSTING PROBABILITY FACTOR(n/N) = .882

MAGNITUDE OF LOW VALUES :

0.53 0.01

STATISTICS OF NORMAL DATA

MEAN = 7.2

STANDARD DEVIATION = 5.7

COEFFICIENT OF SKEWNESS = 2.222

STANDARD ERROR COEFF OF SKEW = 0.580

STATISTICS OF LOGS OF DATA

LOGARITHMIC MEAN = 0.754

LOGARITHMIC STANDARD DEVIATION = 0.306

COEFF OF SKEWNESS OF LOGARITHMS = 0.233

GEOMETRIC MEAN = 5.7

STANDARD ERROR COEFF OF SKEW = 0.580

TEST OF OUTLIERS

VALUE OF LOW OUTLIER = 1.076

VALUE OF HIGH OUTLIER = 38.516

NO OUTLIERS ARE FOUND IN THIS DATA SET

ORDERED VALUES WITH CORRESPONDING RANK AND PROBABILITY

NOTE: P = 100*(M- .40)/(N+ .20), HIGHEST VALUE HAS RANK M = 1.

FOR ANNUAL SERIES ADJUSTED PROBABILITY P=P*Pn, WHERE Pn=n/N

RANK	MAGNITUDE	P	RANK	MAGNITUDE	P	RANK	MAGNITUDE	P
1	24.87	3.5	2	11.58	9.3	3	9.69	15.1
4	9.02	20.9	5	9.01	26.7	6	7.50	32.5
7	7.03	38.3	8	6.31	44.1	9	5.04	49.9
10	4.72	55.7	11	3.64	61.5	12	2.79	67.3
13	2.47	73.1	14	2.34	78.9	15	1.92	84.8

PEARSON TYPE III DISTRIBUTION FITTED TO FULL RECORD

RECURRENCE INTERVAL(YRS.),	EXCEEDANCE PROBABILITY(%)	MAGNITUDE
1.01	99.00	2.0
1.05	95.00	2.2
1.11	90.00	2.4
1.25	80.00	2.9
2.00	50.00	5.3
5.00	20.00	10.5
10.00	10.00	14.6
25.00	4.00	20.1
50.00	2.00	24.3
100.00	1.00	28.5
200.00	0.50	32.8
1000.00	0.10	42.8
10000.00	0.01	57.2

LOG-PEARSON TYPE III DISTRIBUTION FITTED TO FULL RECORD

RECURRENCE INTERVAL (YRS)	EXCEEDANCE PROBABILITY (%)	MAGNITUDE CUMECS	ADJUSTED EXPRO(P=P*Pn %)
1.01	99.00	1.2	87.35
1.05	95.00	1.9	83.82
1.11	90.00	2.3	79.41
1.25	80.00	3.1	70.59
2.00	50.00	5.5	44.12
5.00	20.00	10.2	17.65
10.00	10.00	14.2	8.82
25.00	4.00	20.6	3.53
50.00	2.00	26.3	1.76
100.00	1.00	32.9	0.88
200.00	0.50	0.6	0.44
1000.00	0.10	63.2	0.09
10000.00	0.01	111.2	0 .01

NORMAL DISTRIBUTION FITTED TO FULL RECORD

RECURRENCE INTERVAL(YRS.)	EXCEEDANCE PROBABILITY(%)	MAGNITUDE
1.01	99.00	-6.2
1.05	95.00	-2.3
1.11	90.00	-.2
1.25	80.00	2.4
2.00	50.00	7.2
5.00	20.00	12.0
10.00	10.00	14.6
25.00	4.00	17.3
50.00	2.00	19.0
100.00	1.00	20.6

200.00	0.50	22.0
1000.00	0.10	24.9
10000.00	0.01	28.6

LOG-NORMAL DISTRIBUTION FITTED TO FULL RECORD

RECURRENCE INTERVAL(YRS.)	EXCEEDANCE PROBABILITY(%)	MAGNITUDE
1.01	99.00	1.1
1.05	95.00	1.8
1.11	90.00	2.3
1.25	80.00	3.1
2.00	50.00	5.7
5.00	20.00	10.3
10.00	10.00	14.0
25.00	4.00	19.5
50.00	2.00	24.1
100.00	1.00	29.2
200.00	0.50	34.8
1000.00	0.10	50.0
10000.00	0.01	77.8

GUMBEL DISTRIBUTION FITTED TO FULL RECORD

RECURRENCE INTERVAL (YRS)	EXCEEDANCE PROBABILITY (%)	MAGNITUDE	
		POTTER	GUMBEL
1.01	99.00	-4.	-2.
1.05	95.00	-2.	0.
1.11	90.00	0.	1.
1.25	80.00	2.	2.
2.00	50.00	6.	6.
5.00	20.00	12.	11.
10.00	10.00	16.	15.
25.00	4.00	21.	19.

50.00	2.00	25.	22.
100.00	1.00	28.	25.
200.00	0.50	32.	28.
1000.00	0.10	40.	36.
10000.00	0.01	52.	46.

LOG-GUMBEL DISTRIBUTION FITTED TO FULL RECORD

RECURRENCE INTERVAL (YRS)	EXCEEDANCE PROBABILITY (%)	MAGNITUDE	
		POTTER	GUMBEL
1.01	99.00	1.	2.
1.05	95.00	2.	2.
1.11	90.00	2.	3.
1.25	80.00	3.	3.
2.00	50.00	5.	5.
5.00	20.00	10.	9.
10.00	10.00	17.	14.
25.00	4.00	31.	24.
50.00	2.00	48.	35.
100.00	1.00	75.	52.
200.00	0.50	118.	76.
1000.00	0.10	331.	183.
10000.00	0.01	1453.	649.

POWER TRANSFORMED NORMAL DISTRIBUTION FITTED TO FULL RECORD

RECURRENCE INTERVAL(YRS.)	EXCEEDANCE PROBABILITY(%)	MAGNITUDE
1.01	99.00	1.3
1.05	95.00	1.9
1.11	90.00	2.4
1.25	80.00	3.1
2.00	50.00	5.5
5.00	20.00	10.1

10.00	10.00	14.3
25.00	4.00	21.1
50.00	2.00	27.5
100.00	1.00	35.2
200.00	0.50	44.5
1000.00	0.10	74.2
10000.00	0.01	147.1

FISHER-TIPPETT TYPE III DISTRIBUTION FITTED TO FULL RECORD

RECURRENCE INTERVAL(YRS.)	EXCEEDANCE PROBABILITY(%)	MAGNITUDE
1.01	99.00	1.9
.05	95.00	2.0
1.11	90.00	2.3
1.25	80.00	2.9
2.00	50.00	5.3
5.00	20.00	10.5
10.00	10.00	14.5
25.00	4.00	20.0
50.00	2.00	24.3
100.00	1.00	28.5
200.00	0.50	32.9
1000.00	0.10	43.1
10000.00	0.01	57.6

RESULTS OF GOODNESS OF FIT TEST

TEST NO. / DISTRIBUTION TYPE	1	2	3	4
PEARSON	1.9481	1.5572	3.3333	3.0000
LOG-PEARSON	2.2941	1.8062	3.3333	3.0000

NORMAL	4.3931	2.8238	3.3333	3.0000
LOG-NORMAL	2.3725	1.9186	3.3333	3.0000
GUMBEL	2.5995	1.8719	0.6667	0.6667
POTTER	3.3269	2.0244	7.3333	4.3333
LOG-GUMBEL	2.2339	1.5065	3.3333	3.0000
LOG-POTTER	3.4858	2.8519	5.3333	5.0000
P.T.NORMAL	2.3336	1.8110	3.3333	3.0000
FISHER-TIPPETT	1.8995	1.5596	2.6667	2.3333

TEST NO.	TEST TYPE	TEST EVALUATION
1	DIFFERENCE TEST	SMALLEST = BEST
2	MODIFIED DIFFERENCE TEST (BOTTOM HALF OF DATA)	SMALLEST = BEST
3	CHI-SQUARED TEST	SMALLEST = BEST
4	MODIFIED CHI-SQUARED TEST (BOTTOM 80% OF DISTRIBUTION)	SMALLEST = BEST