A GEOMORPHOLOGIC APPROACH FOR DETERMINING FLOOD - FREQUENCIES IN THE SOUTHERN YUKON

by

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A thesis submitted to the Faculty of Graduate Studies of the University of Manitoba in partial fulfillment of the requirements of the degree of

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For Tony and Hellen

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ABSTRACT

This thesis examines the fluvial geomorphology of the southern Yukon with the intent of deriving a flood model which can be used to predict floods in this sub-arctic region. Thirty-six watersheds were chosen for investigation. Initially, a large variable set describing watershed geomorphology and climate was compiled. The selection of these variables was based on intuition and their success in other flood studies. In addition, flood-frequency analyses of the streams' historic streamflow records yielded values of their mean annual floods and their two, five, ten and twenty year floods. With the aid of a statistical multiple regression technique, a set of equations was derived that related flood discharges for different return periods to the variables describing watershed climate and geomorphology. These equations are:

$$QMA = 0.0044\ TCHL^{0.76}\ PRECIP^{1.38}\ NASP^{0.26}\ HYPI^{0.85}$$

$$Q20/QMA = 4.75\ TCHL^{0.12}\ PRECIP^{-0.35}$$

$$Q10/QMA = 3.86\ TCHL^{0.08}\ PRECIP^{-0.29}$$

$$Q5/QMA = 2.32\ TCHL^{0.04}\ PRECIP^{-0.18}$$

$$Q2/QMA = 0.78\ TCHL^{-0.01}\ PRECIP^{0.06}$$

Where;
- QMA = Mean Annual Flood
- Q20 = Twenty Year Flood
- Q10 = Ten Year Flood
- Q5 = Five Year Flood
- Q2 = Two Year Flood
- TCHL = Total Channel Length
- PRECIP = Mean Annual Precipitation
- NASP = Normalized Aspect
- HYPI = Hypsometric Integral

The above equations form a simple flood model which can be easily applied to ungauged streams in southern Yukon.

The significance of the variables total channel length, mean annnual precipitation, normalized aspect and

the hypsometric integral to the hydrology of southern Yukon are discussed. The reasons advanced for the importance of these variables to northern hydrology are: total channel length measures watershed size and the rapidity of streamflow response to water inputs; mean annual precipitation measures the amount of water input available for runoff; normalized aspect measures the north-south orientation of a watershed and is accounting for local differences in precipitation and snowmelt in mountainous terrain; and hypsometric integral measures the potential energy available to a watershed's runoff response processes.

The overall framework of the flood model is conceptually acceptable and its successfull application to a test watershed (Dale Creek) augurs well for its operational use in the southern Yukon.

1 INTRODUCTION

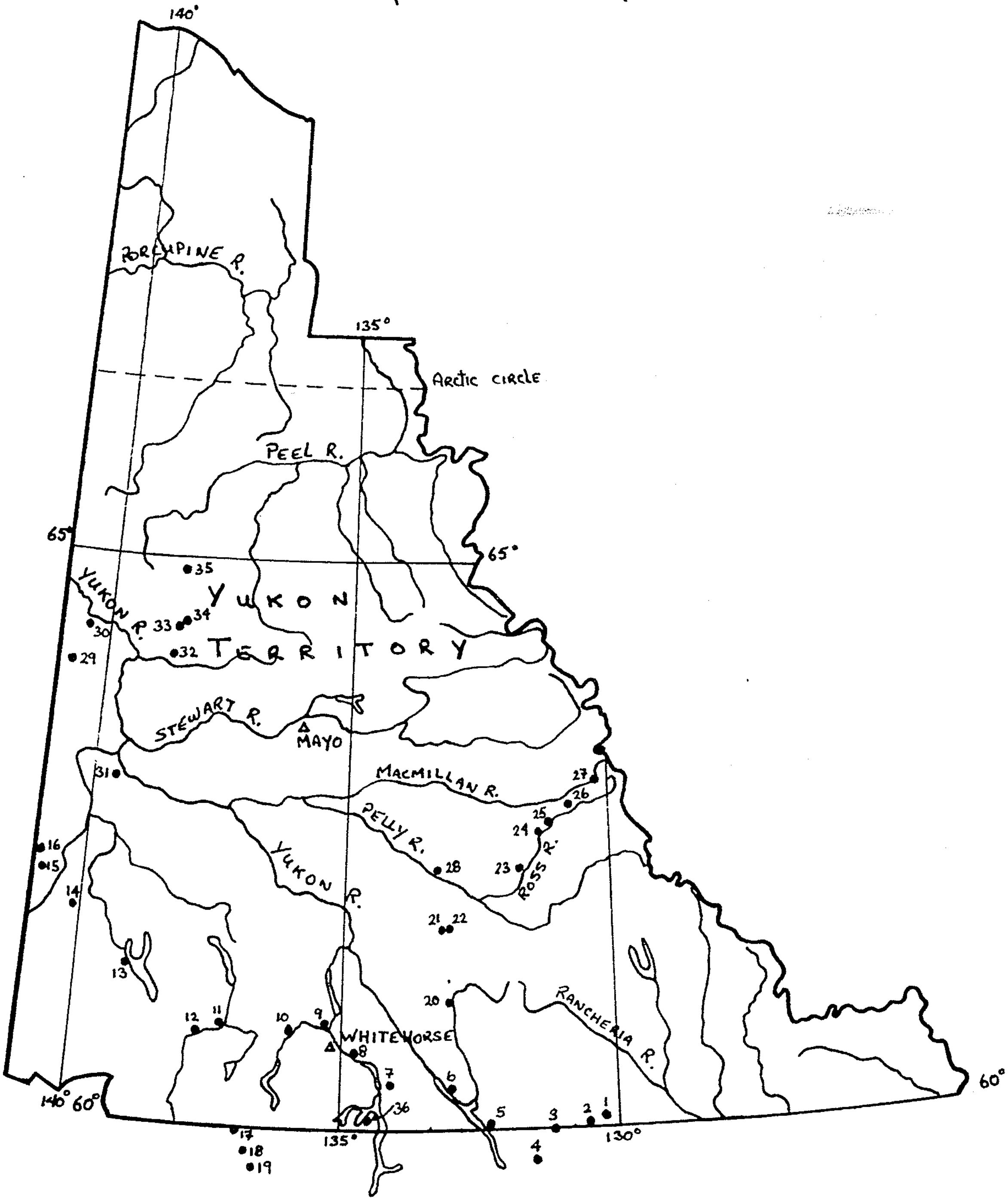
If resource development in Yukon Territory is to proceed in concert with optimum conservation of the natural environment, then the potential impact which specific ventures (e.g. placer mining), will have on their immediate surroundings must be studied. If not, unforeseen consequences of development could result in ecological disasters, which would be magnified by the fragile nature of the northern environment. An integral part of any such impact study is the assessment of the region's waters in terms of both quality and quantity. Where high streamflows are concerned, a long history of recorded flows is the primary requirement necessary to ensure adequate protection of life and environment. In the North a history of recorded flows is rarely available and, therefore, some other means of evaluating flood potential must be found. This thesis investigates the fluvial geomorphology of the southern Yukon with the intent of deriving a flood model which can be simply, and easily applied to the streams of this sub-arctic region.

The region chosen for study is the entire drainage area of the Yukon River, upstream of its crossing at the Alaska - Yukon border. Also included are the following headwater drainages of the Mackenzie River system viz.: Big Creek, Spencer Creek and Freer Creek which are tributaries of the Rancheria River in southeastern Yukon; Unnamed Creek a tributary of the Peel River in west-central Yukon; and Dale Creek a tributary of the Tsichu River in west-central N.W.T.. A rough description of this region is that part of Yukon Territory lying south of the sixty-fifth parallel, herein refered to as the southern Yukon, and encompassing an area of aproximately 200,000 square kilometers (Fig.1.1).

In all, a total of thirty-six streams, with catchment areas ranging in size from 10 to 250 square kilometers, were included in this study. The selection of the streams for the study was based on two criteria: (1) that each stream havea minimum of four years of recorded streamflows; and (2) topographic map coverage at the 1:50,000 scale. The 1:50,000 scale was deemed necessary to

Fig. 1.1 Map of Study Area: Southern Yukon

A numbered listing of the study streams is presented in Appendix 1.



accurately measure the relevant parameters describing watershed morphometry.

Chapter 2 presents a brief review of the methods used to predict floods on ungauged streams, concentrating on the methods predominating in northern hydrologic investigations. The choice of the morphometric and climatic indices used to characterize a watershed in this study, their methods of measurement, and their relative importance based on other flood studies are described in Chapter 3. In Section 3.4, a correlation analysis is used to investigate for redundancy among the morphometric indices. In Chapter 4, flood frequency analysis of the study streams provide estimates of their mean annual flood and the largest floods expected in two, five, ten and twenty years. In Chapter 5, the significant physiographic and climatic variables are related to the flood levels by a stepwise regression technique in an effort to derive predictive equations which can be applied to remote streams.

1.1 DESCRIPTION OF THE STUDY AREA; SOUTHERN YUKON

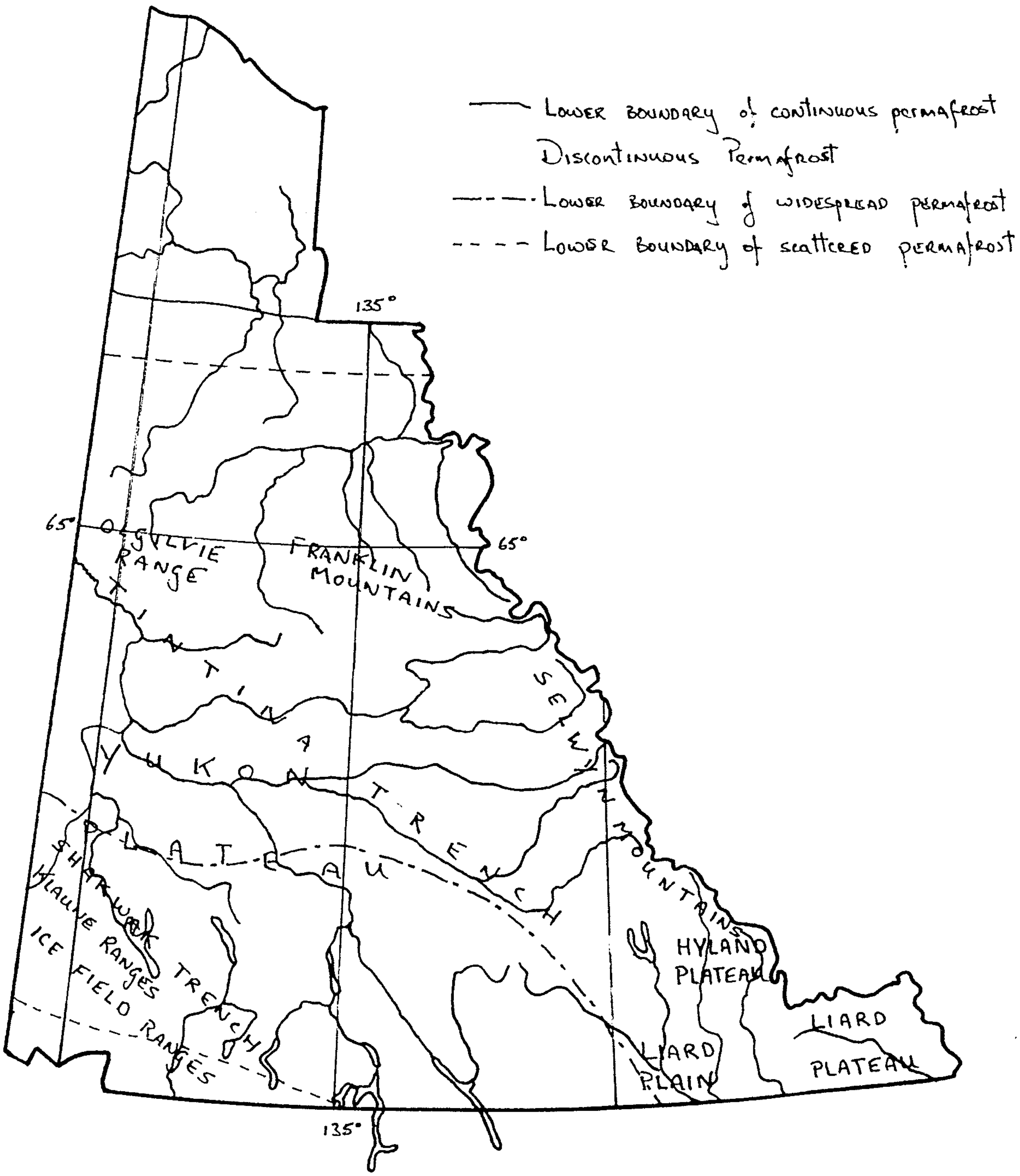
Southern Yukon Territory has a diverse physiography. The Yukon Plateau, a physiographic unit of the Cordillera described by Bostock (1948,& 1970) comprises most of the study area. This plateau has a varied topography - generally less than 1,800 meters elevation -

interrupted by individual mountains, plus large persistent valleys. The most impressive of these are the Tintina and Shakwak Trenches which trend northwest for distances of over 500 kilometers, and whose widths range from 1 to 25 kilometers, with floors of uniform elevation. The plateau is bounded on the north and east by the Ogilvie, Wernecke and Selwyn Mountains, and on the southwest by the St. Elias Mountains and the Kluane and Boundary Ranges (Fig 1.1).

The effects of glaciation, both continental and alpine, can be seen in the physiography and surficial geology of much of the southern Yukon. The limits of glaciation during the Pleistocene are shown in Figure 1.2. There is a definite contrast in surface features and sediments between the areas covered by glacial ice and the unglaciated areas in the northwest of the study region. Bostock (1970, p.22) succinctly describes both of these areas:

> "Large unglaciated areas cover most of northwestern Yukon and give an indication of the character of the plateaux of the Cordillera before Pleistocene glaciation. There the topography is sculptured by the normal processes of sub-aerial erosion at northern latitudes. The classic area is that around Klondike River in Yukon Plateau where relief is 2,000 to 3,000 feet, and the metamorphic rocks are much the same as in the adjoining glaciated areas. The unglaciated plateau area is composed of long ridges spreading from a central divide, separated by closely spaced small creeks that merge into larger streams, the valleys gradually widening. The gradients are even and uninterrupted by rapids and lakes. The valleys are V-shaped with sides flaring upwards and diminishing in steepness until the broad, rounded ridges of the uplands are reached. These may be broken in places by

Fig. 1.2 Physiography and Permafrost : Southern Yukon



castle-like outcrops on or near their summits. The general drainage is dendritic among smaller streams, but a few larger streams are straight, following some linear structural feature. Persistent bedrock terraces along many of the larger valleys are mantled by variable thicknesses of gravel, sand, and soil, and follow more gentle gradients than the present streams. In places stream reversal and capture are apparent. Lakes are generally lacking; a few ponds occur due to ice pushing on the valley flats, to damming of the rivers by lava flows; oxbow lakes occur along the larger rivers.

"Glacial ice covered the Cordillera with the exception of the area referred to above and some minor areas. In many ranges only the highest peaks projected above the ice, which left its imprint on the topography as both erosional and depositional features. Conspicuous in the mountains are cirques, aretes, and horns, and along the valley sides ice-margin channels have been cut in bedrock, kame terraces, and moraines. On the valley floors are a host of features mainly formed of surficial materials: pitted till, outwash plains and terraces, drumlin fields, simple and compound eskers, lake terraces and all manner of fluvial-glacial features.

"Great U-shaped valleys furrow the country, most impressive where filled with lakes ..... A belt of long lakes stretches along the western or dry side of the Interior System from Kluane Lake in Yukon Territory to Taseko Lakes in British Columbia. Another zone lies on the eastern side, on the relatively wet western slopes of the mountains from Mayo Lake in the north to Shuswap and Kootenay Lakes in the south."

The climate of the southern Yukon can be described as continental sub-arctic, that is, marked variability day to day and year to year both in temperature and precipitation. Winters are long and cold, and summers are short and cool (Table 1.1). Summer days are long with daylight periods lasting up to 22 hours and temperatures reaching the mid twenties. Table 1.1 presents mean monthly temperatures, and mean monthly precipitation and snowfall for Mayo and Whitehorse.

Table 1.1 Mean monthly temperatures, amounts of precipitation and snowfall and prevailing wind directions for Mayo and Whitehorse.

MAYO

	JAN	FEB	MAR	APR	MAY	JUNE
Temperature	-29.0	-19.9	-11.7	-0.4	7.5	13.4
Precipitation	17.5	16.4	10.3	8.6	19.5	35.3
Snowfall	18.7	17.9	10.8	7.5	2.1	0

	JULY	AUG	SEPT	OCT	NOV	DEC
Temperature	15.2	12.6	6.5	-2.3	-15.2	-24.5
Precipitation	51.7	41.5	30.3	28.3	24.4	22.5
Snowfall	0	0.1	2.7	20.7	25.5	24.5

WHITEHORSE

	JAN	FEB	MAR	APR	MAY	JUNE
Temperature	-20.7	-13.2	-8.2	0.3	6.7	12.0
Precipitation	17.7	13.3	13.5	9.5	12.9	30.7
Snowfall	21.3	15.2	16.4	10.5	2.9	0.9

	JULY	AUG	SEPT	OCT	NOV	DEC
Temperature	14.1	12.5	7.5	0.6	-8.8	-16.6
Precipitation	33.9	37.9	30.3	21.5	19.8	20.2
Snowfall	0	0.8	4.5	16.1	23.8	24.2

Mayo, about 300 kilometers north of Whitehorse, experiences slightly colder winters and warmer summers. Mayo is wetter, although Whitehorse receives slightly more snowfall in the spring.

Southern Yukon Territory lies within the discontinuous permafrost zone (Fig. 1.2). Many factors, other than climate, affect the distribution of permafrost within the discontinuous zone (e.g., elevation, aspect, vegetation cover, physical properties of sediments, winter snow cover, surface water and groundwater). Along the southern border of Yukon Territory permafrost consists of small isolated patches a few meters to tens of meters thick, but becomes more widespread and thicker northwards as mean annual temperature decreases (Brown, 1974; and Hughes, 1974). Perennially frozen ground has a variety of effects on the region's streams. These include: increasing the proportion of surface flow to total runoff; retarding bank erosion in the spring, a period of high streamflows; and adding to the relative importance of block slumping as a channel forming process.

Treeline generally extends to 1200 metres elevation throughout the region, although this can vary markedly depending on local climate, steepness of slopes, aspect, etc.. The vegetation is similar in type to that in the interior of British Columbia. Summarizing a study of the vegetation and soil complexes along reaches of the

Pelly, Ross, Teslin, and Liard Rivers, Lavkulich (1973,p.108) reported that:

> "Throughout each of the river reaches it can be seen that the dominant vegetation on the unstable portions of the river consists mainly of willow, balsam poplar, and whitespruce, whereas more stable areas contain black spruce, aspen, and lodgepole pine. Also on the more stable sections of the river reach, the major soil developed is a Brunisol or Podzol depending on type of material, whereas on the unstable sections a Regosol tends to be dominant."

The flow regime of the streams is characterized by an annual spring flood induced by snowmelt, followed by progressively declining summer streamflows which are punctuated by occasional rain-storm floods. Although the latter floods may be very severe, the spring freshet is generally the major hydrological event of the year. By late autumn streamflow has declined to a very low level and on most small streams has ceased entirely. Groundwater flow continues in many locations throughout the winter forming icings where the water surfaces. Along the streams, in regions that sustain a deep winter snowpack, icings are ecologically significant. They support the overwintering of wildlife by providing relatively snowfree corridors which facilitates foraging on the riparian vegetation (Gill and Kershaw, 1979). Another aspect of the hydrology of these streams is the marked diurnal fluctuations in streamflows during the spring and early summer, due to diurnal fluctations in the rate of snowmelt.

2 REVIEW OF TECHNIQUES OF FLOOD PREDICTION

Preparatory to this investigation, a brief review of the methods of flood prediction is presented. This review, where possible, will concentrate by way of examples on those methods used in northern Canada and Alaska. Most flood prediction techniques are controversial simply because they attempt to anticipate nature. This controversy is magnified when these techniques are applied to remote regions, where the adequate base line data needed for model verification are rarely available . Under this circumstance it is best to apply all reasonable methods to the problem on hand given the economic constraints of the situation. Although this may not decrease the uncertainty of a decision, it would certainly provide a greater insight into the range of floods that may be expected.

2.1 EARLY FLOOD FORMULAE

The first formulae proposed for the prediction of floods were of necessity both simple and general in nature, because of a lack of flood data. The equation, $Q = C A^n$, is a good example of these early formulae where: Q is flood discharge; A is drainage basin area; C is a runoff coefficient; and n a constant. The values of the constants C, and n, being based on a regional judgement. This type of formula was easily derived by plotting the maximum floods on record for the streams of a region against their drainage areas on logarithm paper. A line was then drawn that averages, or envelops, the plotted points, this line having the above general equation where n is the slope and C an intercept. However, the exact significance of the flood event predicted remained in doubt, since there was not a return period or frequency factor associated with it. Examples of the above formulae can be found in most highway and railroad design manuals.

2.2 PHYSICALLY BASED MODELS

Some of the earlier empirical formulae included parameters that measured precipitation and perhaps the most successful of these was the rational formula:

$$Q = C\ i\ A \qquad .....(2.1)$$

where, Q = flood discharge.
i = rainfall intensity.
A = drainage area.
C = runoff coefficient.

The rational formula was based on the premise that if a uniform rainfall of intensity i fell on an impervious watershed of size A, then flood discharge (Q) would increase until all portions of the drainage basin were contributing to runoff, whereupon, streamflow would become constant. A point of note here, is the definition for the time of concentration of a drainage basin, i.e. the time required for discharge to become constant, or for runoff from the most distant part of the watershed to reach the outlet.

Actual runoff is far more complicated than the rational formula indicates. Rainfall intensity is seldom the same over an area of appreciable size or for any substantial period of time during the same storm. If a uniform intensity of rainfall, having a duration equal to the time of concentration were to occur on all parts of the basin, the rate of runoff would vary in any case because of differences in physiography, surficial geology and antecedent moisture conditions. These limitations have resulted in a consensus of opinion among hydrologists that the rational formula should be restricted to use on small basins less than one square kilometer in size (Dalrymple, 1964).

Church (1971), in a study of the streams along the route of the Mackenzie Valley Pipeline, attempted to overcome this restriction to the use of the rational formula by weighting the coefficient C, according to basin area:

$$C = 2^{(7.413 - \log A)} \qquad \text{.....(2.2)}$$

However, Church cautioned that the procedure overestimated floods for basins of moderate size and underestimated them for some large basins, but at most by a factor of two.

The Water Resources Division, Indian and Northern Affairs, Whitehorse, currently employs a computer model based on the rational formula but modified by kinematic wave theory. Developed by Eagleson (1970) and applied to the Yukon by Howard and Associates (1974), essentially what this flood model does is derive a solution for the modified rational equation:

$$Q = 645\ A\ Ar\ i \qquad \text{.....(2.3)}$$

where, Q = flood discharge (cfs.).
A = drainage area (sq. mi.).
Ar = ratio of runoff contributing area to total drainage area.
i = rainfall intensity (in./hr.).
645 = the conversion factor to cfs..

An explanation of the calculus of the kinematic wave model is given in Appendix A.

Implicit in the solution of the kinematic wave model are the assumptions that: storm duration equals or exceeds a basin's time of concentration and that storm duration and rainfall intensity are independent of each other. Both of these assumptions are contrary to hydrologic theory and practise. Many large floods are caused by short high intensity rain storms. Considering the causes of precipitation (frontal and non-frontal cyclonic cooling, orographic cooling, and convective cooling) there is definitely a correlation between rainfall intensity and duration. For example, Eagleson (1970) states:

> "Nonfrontal cyclonic precipitation of extratropical origin produces rains (or snows) of moderate intensities but of fairly long duration.....(p. 160)
>
> "Cyclonic cooling of the frontal variety......When the front is a warm front,....the lifting and cooling of the air is gradual thus producing moderate rainfall rates, often of quite long duration.....(p. 160).
> "If the front is a cold front.....the resulting weather may be tumultuous, with short-duration pelting rains and high winds (p. 161).
>
> When moist winds blow upslope, the air will expand and cool at the lower presure corresponding to the higher elevations.......Of particular interest is what is known as the 'rain shadow' or deficiency in rainfall which may occur on the lee side of the slope because of a removal of most of the moisture by high mountains (p.161).
>
> "Convective precipitation is of very short duration, seldom more than 1 hr, but the intensities are so high that total precipitation may amount to 3 to 4 in."(p. 161).

Aside from these criticisms, the kinematic wave model still cannot escape the limitations of the rational formula and therefore, predictions from this model should be treated with the utmost of caution.

2.2 STATISTICALLY BASED MODELS

Perhaps the most promising methods of assessing the flood potential on a remote stream are those utilizing statistics. Not only does statistics provide a means of reducing a mass of data to a few meaningful parameters, but it also offers versatility in the approach chosen for analysis. Given an array of floods, the mean or some other measure of central tendency, such as the median or mode can be found. The dispersion of the floods around the mean, the variance, can also be measured. Futhermore, statistics such as the skewness,kurtosis and serial correlation which describe other aspects of the array can be measured . Apart from these individual statistics the distribution of the floods can be modelled by a density function that defines the relative frequency of occurrence of the individual floods. This function can be modified to a cumulative distribution function which yields the probability or the return period for a flood.

The oldest, and still a widely prevalent, statistical technique is the index flood method which analyzes the historic flood record for all the streams of a homogenous region. Statistical tests, which test for an expected range in flood ratios (i.e., the ten year return period flood divided by the mean annual flood), are used to determine the homogeneity of a hydrologic region. Usually this analysis involves annual maximum floods. For each stream in a region the annual floods are ranked in terms of magnitude, and return periods assigned from one of the many formulae which are available. These data are then plotted on suitable graph paper from which representative floods are extracted - commonly the mean annual flood, and the five, ten, twenty, fifty,and one hundred year return period floods. These representative floods are then standardized by division by a standard measure, either the basin's mean annual flood or drainage area. The regional mean for each stadardized return period flood is calculated, which when plotted on logarithm paper yields the regional flood frequency curve. All that is then needed for the application of the curve to a remote watershed is the value of the standard measure. This method is somewhat rigid in application, in that it does not allow for local variations which may occur because of differences in climate, physiography and geology. Today, sets of regional flood frequency curves can be found for many regions of the world; e.g., Berwick, Childers and Kuentzel (1964); and Dalrymple (1960).

A statistical regression analysis offers a more powerful approach than the index flood method, in that it can account for local differences in hydrologic regime. By relating a dependent variable to one or more independent variables, a regression analysis explains the variation in the dependent variable in terms of the other variables and permits predictions of the dependent variable when the independent variables are known (Benson, 1962a). Generally, there are two forms of the regression method employed in hydrology, the difference lying in the choice of the independent variables. The first method utilizes variables describing climate and stream channel dimensions, while the second uses climate coupled with drainage basin characteristics. Each of these methods usually derives a series of equations relating specific flood levels to the independent variables.

Initiated by the early work of Leopold and Maddock (1953), a number of investigators have proposed sets of regression equations to estimate floods at ungauged drainage basins from channel geometry measurements. Hedman (1970) and Fields (1975) used measurements based on channel depositional features such as longitudinal and point bars. Scott and Kunckler (1976) and Hedman and Kastner (1977) used measurements at the active channel level, while Emmett (1972 & 1975), Riggs (1974), Lowham (1976), Riggs and Harenburg (1972) and Harenburg (1980) used measurements of channel geometry at the bankfull stage. In a recent study Osterkamp and Hedman (1982) classified streams in the Missouri River Basin on the basis of their channel sediments, and related flood levels for the streams in each class to their active channel width and slope in the following way:

For channels with a low silt-clay bed	$Q2 = 0.065\ W^{0.80}\ G^{-0.69}$
For channels with sand bed, silt banks	$Q2 = 0.56\ W^{0.95}\ G^{-0.34}$
For cannels with sand bed, sand banks	$Q2 = 0.13\ W^{1.02}\ G^{-0.42}$
For channels with gravel beds	$Q2 = 1.9\ W^{1.15}$
For channels with cobble bed	$Q2 = 0.14\ W^{1.39}\ G^{-0.34}$

where, Q2 = two year flood.
W = active-channel width.
G = channel gradient.

One major drawback of this method of flood modelling is the accurate field determination of the streamflow level from which channel geometry measurements are to be taken. This applies to measurements taken at the active channel level or the bankfull or dominant discharge stage. For Yukon streams it is often difficult to delimit precisely bankfull stage as it is not at all apparent from bank line or vegetation evidence.

Another problem with the channel geometry method concerns the assignment of a return period to floods at the bankfull stage. Questions that are often asked include the following: Do bankfull stage floods have a common return period for the streams within a region? If bankfull floods do not have a common return period, then what factors do control a stream channel's hydraulic geometry? Can these factors be readily assessed and applied to the measurement of channel geometry for the streams within a region? These questions must be answered if the channel geometry method of flood modelling is to be applied.

Wolman and Leopold (1957) suggested a common return period for bankfull stage discharges of from 1 - 2 years and this was supported by Dury (1973), who showed that for U.S. rivers bankfull stage could be equated with a return period of 1.58 years. Similarly, other researchers have indicated that bankfull floods tend to a common return period (McGilchrist and Woodyer, 1968; Nixon, 1959; Riggs, 1974; and Woodyer, 1968).

On the other hand, Hey (1975) presents data showing that at upstream sites on the River Wye bankfull discharge occurs more frequently than at downstream sites. Kilpatrick and Barnes (1964) also note that variations occur in the frequency of bankfull discharge from stream to stream and suggest that channel slope is the cause for this variation. The greater entrenchment of steep sloped streams as compared with mild sloped streams results in a greater channel capacity for the steep sloped streams and thus bankfull discharges occur less frequently. Kennedy (1972) and Williams (1978) have also noted the variation of return periods for bankfull discharge.

The above debate is well illlustrated by Alberta's rivers.

"The fact that return periods for bankfull flow in Albertan rivers appear to be considerably longer than in most other rivers for which data have been reported is indisputable."(Kellerhals and Church, 1980, p.1131).

However, the cause of this phenomenon has prompted considerable debate between researchers. Smith (1979) reasons that ice-scour activity during spring flooding is the cause of the oversized channels, while Kellerhals and Church suggest that relatively recent entrenchment of some large Albertan rivers may be the cause. They also note that flood stages due to ice jams and over bottom-fast ice are ignored in flood frequency calculations, but if they were included, these high stages would lower the return period of the bankfull stage.

For Yukon streams it would be an oversimplification to assume a constant return period for bankfull flows. Considering the importance of other processes which affect a stream channel's hydraulic geometry in the North (e.g. freeze up activity, snowmelt flooding and the presence of permafrost.), it is doubtful whether the return period assigned to bankfull discharges in more temperate regions is applicable here. Certainly, the mean return period for bankfull discharge on Yukon streams may approximate two years. However, when applying the channel geometry method of flood-frequency estimation to Yukon streams the range, or variation, of bankfull returns around the mean bankfull return period must also be known. Otherwise the unilateral application of a mean bankfull discharge return period could result in the overestimation, or underestimation of an ungauged stream's flood-frequency relationship. Not only is this because of the diverse physiography and climate of the region, but it is also because of the many variations in channel hydraulic geometry which occur along a stream.

A similar, but flexible method of flood prediction uses watershed morphologic and climatic characteristics, measured from base maps, in a regression analysis. Benson (1962a) suggested that this method had a great potential for application to remote areas. Since an early study by Benson (1962b), numerous studies have adopted this technique and the following is a brief, but by no meams complete, account of these flood studies. Instead of presenting the complete equation sets for each study, only the equations derived for the mean annual or two year flood are shown.

Benson (1962b) in a study of New England watersheds derived the following equation:

$$Qma = 3.4\ A^{1.0}\ S^{0.35}\ St^{-0.28}\ T^{0.35}\ O^{0.85} \quad \text{.....(2.11)}$$

where, Qma = mean annual flood.
A = drainage area.
S = stream slope.
St = a storage index.
T = mean number of degrees below zero.
O = an orographic factor.

The Natural Environmental Research Council (1975) in the most extensive flood studies to date, encompassing earlier work by Cole (1966),Nash and Shaw (1966), and Rodda (1967), derived the follwing regression equations for the British Isles:

$$Qma = C\ AREA^{0.95}\ STMFRQ^{0.27}\ S1085^{0.16}\ SOIL^{1.23}\ RSMD^{1.03}\ (1+LAKE)^{-0.85} \quad .....(2.12)$$

The constant C depending on the region. For:

Northern Scotland	0.0186
East Anglia	0.0153
South Coast	0.0234
Southwest England	0.0315
Central Region	0.0213
Ireland	0.0172

and for the Thames, Lee, and Essex areas the appropriate equation is:

$$Qma = 0.302\ AREA^{0.70}\ STMFRQ^{0.52}\ (1+URBAN)^{2.5} \quad .....(2.13)$$

where, Qma = mean annual flood.
AREA = drainage area.
STMFRQ = stream frequency.
S1085 = slope.
SOIL = a soil index.
RSMD = rainfall minus soil moisture deficit.
LAKE = percentage area of lakes.
URBAN = percentage of urban areas.

The Inland Waters Directorate (1978) for the rivers of southern Yukon Territory derived the following equation:

$$Qma = 0.28\ A^{0.82}\ ELEV^{3.13}\ ALS^{-0.18}\ AGL^{0.25}\ BHNW^{0.82}\ SENW^{-1.87}\ SEW^{-0.50} \quad .....(2.14)$$

where, Qma = mean annual flood.
A = drainage area.
ELEV = elevation of the watershed.
ALSW = percentage area of lakes and swamps.
AGL = percentage area of glaciers.
BHNW = barrier height northwest.
SENW = shield effect to the northwest.
SEW = shield effect to the west.

Lamke (1979) in a flood study of Alaskan streams south of the Yukon River derived sets of equations for two distinct hydrologic regions. The equation for Region 1, is:

$$Q2 = 11.76\ A^{0.80}\ P^{0.52}\ (T+1)^{0.19}\ (St+1)^{-0.26} \quad \text{.....(2.15)}$$

where, Q2 = the flood with a two year return period.
A = drainage area.
P = mean annual precipitation.
T = mean minimum January temperature.
St = pecentage area of lakes and swamps.

Leith (1976) in a study of British Columbia watersheds derived the following equation:

$$Qma/A = 10.4 + 0.32\ NPOSI - 0.0017\ ELEV - 0.0013\ DSNW - 0.06\ RAFOR + 0.91\ RASWP + 0.000076\ SEW \quad \text{..(2.16)}$$

where, Qma = mean annual flood.
NPOSI = the grid coordinate, similar to longitude.
ELEV = elevation.
DSNW = distance to the sea in the northwest.
RAFOR = percentage of forest.
RASWP = percentage of swamp.
SEW = shield effect to the east.

Thackur and Lindeijer (1973, & 1974) derived two equations for Mackenzie River tributary basins. For watersheds with drainage areas less than ten thousand square miles:

$$Qma = 0.00007\ DA + 0.00026\ MEE - 0.94\ RL + 2.04 \quad \ldots\ldots (2.17)$$

and for watersheds greater than ten thouasand square miles:

$$Qma = 0.00048\ MEE + 1.37\ RL - 0.054\ HYI + 4.78 \quad \ldots\ldots (2.18)$$

where, Qma = mean annual flood.
DA = drainage area.
MEE = mean elevation.
RL = length ratio.
HYI = hypsometric integral.

The above investigations and the many more published studies not included here, emphasize the potential ascribed to this type of modeling technique for the prediction of flood levels on ungauged streams. The variety of independent variables used in the regression models are also of note - their choice being governed by individual intuition and availability of source material. The selection of the independent variables for this investigation is the topic of the next chapter.

APPENDIX A

THE KINEMATIC WAVE MODEL

The Water Resources Division, Indian and Northern Affairs, Whitehorse, currently employs a computer model based on the rational formula but modified by kinematic wave theory. Developed by Eagleson (1970) and applied to the Yukon by Howard and Associates (1974), essentially what this flood model does is derive a solution for the modified rational equation:

$$Q = 645\ A\ Ar\ i \qquad \ldots\ldots(2.3)$$

where, Q = flood discharge (cfs.).
A = drainage area (sq. mi.).
Ar = ratio of runoff contributing area to total drainage area.
i = rainfall intensity (in./hr.).
645 = the conversion factor to cfs..

Where the mathematics become rigorous is in the assignment of a return period to the computed flow. This is achieved by the use of a probability function $P(Q)$ i.e. the product of two exponential distributions describing storm duration and rainfall intensity. It is assumed that duration and intensity are independent events.

The probability density function for intensity $f(i)$, is given by:

$$f(i) = be^{-bi} \qquad \text{.....(2.4)}$$

where, b = 1/average storm intensity.

The probability density function for duration $f(t)$, is given by

$$f(t) = le^{-lt} \qquad \text{.....(2.5)}$$

where, l = 1/average storm duration.

The integral of the product of these two functions yields the probability of events of duration greater than t, and intensity greater than i:

$$P(Q) = l\ b \int_{i}^{\infty} \int_{t}^{\infty} e^{-lt\ -bi} dt\ di \qquad \text{.....(2.6)}$$

The lower limits of integration indicate the conditions of minimum duration and intensity. The condition for minimum intensity is the peak flood discharge divided by contributing area. The time of concentration (tw) for the watershed is the condition for minimum storm duration. Substituting these lower limits into equation 2.7 yields:

$$P(Q) = l\ b \int_{Q/645 A_r}^{\infty} \int_{t_w}^{\infty} e^{-lt\ -bi} dt\ di \qquad \text{.....(2.7)}$$

From kinematic wave theory the time of concentration for the watershed tw, can be expressed as the sum of the time of concentration for the catchment tc, and the time of concentration for the stream ts, these two components having the following solutions:

$$tw = tc + ts = (a/i)^{0.5} + (b/i)^{0.33} \quad .....(2.8)$$

where a is the catchment coefficient:

$$a = \{0.919\ Nc\ Ar\ Ac\} / \{Sc^{0.5}\ L\};$$

and b is the stream coefficient:

$$b = \{0.130\ P\ Ns^2\} / \{Ss\ Ar\ Ac\}.$$

where, Nc = the Manning's n for the catchment.
Ns = the Manning's n for the stream.
L = the length of the stream.
Sc = the slope of the catchment.
Ss = the slope of the stream.
and 0.914 and 0.130 are conversion factors.

Thus the double integral reduces to:

$$P(Q) = 1\ b \int_{Q/645 Ar}^{\infty} e^{[-1\{(a/i)^{0.5} + (b/i)^{0.33}\} - bi]} di \quad ...(2.9)$$

which can be solved empirically.

Knowing the number of storms per year, St, and the runoff coefficients, Ra and Re, which account for antecedent moisture conditions and losses to evapotranspiration respectively, the return period T, in years can be calculated from:

$$T = 1 / \{P(Q)\ St\ Ra\ Re\} \quad .....(2.10)$$

3 WATERSHED CHARACTERISTICS

Many variables describing significant elements of watershed morphometry have been proposed in fluvial geomorphologic studies. A variety of purposes, scales and environments of individual investigations have governed the choice of a particular morphologic variable set (e.g. Benson, 1962b; Carlston, 1963; I.W.D., 1978; Lambke, 1978; Leith, 1976; Nash and Shaw, 1966; N.E.R.C., 1975; Rodda, 1969; Thomas and Benson, 1970; and Thaker and Lindeijer, 1973). These studies have shown that clear relationships exist between watershed morphometry and streamflow. However,the exact significance of individual measures remains in some doubt. One reason for this may be the disproportionate effect a morphometric variable has under various flow conditions i.e. <u>a variable may exercise an influence over high flows but not over mean or low flows.</u>

Gray (1965) distinguishes five general factors which have been successfully applied in statistical streamflow studies: Size and shape of the drainage basin; density and distribution of the channel network; general land slope; size, slope and condition of the stream channels; and surface storage. These categories acted as a guideline in the selection of the morphometric variables for this study. The choice of a variable was based both on theory and on its success as a flood predictor in previous studies. Another reason for the inclusion of a morphometric variable was its ease of measurement from widely available reference material.

3.1 MORPHOMETRY

The morphometric data were derived from 1:50,000 scale National Topographic System mapsheets; this scale being the largest scale available with coverage of the instrumented drainage basins. The perimeter of each basin was outlined and the latitude and longitude of the basin mouth recorded. The mouth of the drainage basin was defined by the location of the gauging station. The following is a listing of the morphometric variables which were selected for analysis. The description of an individual variable includes: the variable's name and abbreviation; the unit of measure; where it was used previously; and the method of measurement or derivation.

3.1a Watershed location

The latitude (LAT) and longitude (LONG) at the mouth of the drainage basin serve to locate the position of the watershed. Both of these variables were measured to the nearest one hundredth of a degree to facilitate computer manipulation. Thakur and Lindeijer (1974, p.355) used longitude and latitude as variables in a flood regression analysis of Mackenzie River tributaries and on the basis of the significance of longitude in the analysis concluded that:

> "On an equivalent area basin, the flood magnitudes of east side Mackenzie tributaries appear to be lower than those on the west side, making the eastern side of the Mackenzie a safer route for pipelines."

The elevation (ELEV in meters asl.) at the basin mouth serves to locate the vertical position of the watershed. The elevation at the basin mouth is not the only measure of the vertical location of a drainage basin. Another variable which describes the distribution of drainage basin area around a basin's mean altitude, the hypsometric coefficient (described later on in this chapter), is also included in this study. When considered together these two variables were thought to adequately describe the vertical position of a watershed.

3.1b Watershed size

The area of the drainage basin (AREA in sq. kilometers) is perhaps the physiographic characteristic most widely applied in flood studies. A simple relation between area (A) and an index of streamflow (Q) has been employed for the prediction of discharge for a number of years. Such relations have usually been expressed in the form $Q = c\,A^b$, where c and b, are constants, the exponent b being generally in the range of 0.5 to 1.0. The drainage area was measured using a polar planimeter. The measurements were repeated four times and the mean computed. Three other watershed surface area measures were also computed relative to drainage area, area above treeline, area of lake and swamp plus area of glacier. These variables are described in section 3.1d.

The rank (RANK) of the main stream at the basin mouth was determined by the Strahler (1952) ordering method. This method of numbering stream segments proceeds from the head-most tributaries termed first order streams. Two first order streams combine to form a second order stream; two second order streams combine to form a third order stream and so on. Rank has been used with limited success in streamflow studies but is included here as a quick measure of watershed magnitude.

The perimeter (PER in kilometers) is the length of the drainage divide of the watershed measured with an opisometer. It is often difficult to delimit precisely, especially in low lying and marshy areas. Also, subsurface drainage may not necessarily correspond with the surface drainage area. Perimeter has a high correlation with drainage basin area and, therefore, it is not usually found as an individual measure in streamflow studies, but it has been combined with area to form a basin shape index, as discussed later.

The maximum basin length (BAL in kilometers) measured in a straight line from the basin mouth to the furthest point on the drainage divide defines the maximum length of the basin. It was measured with a ruler. Maximum basin length is another variable that is highly correlated with basin area and, therefore, it is not usually found as an individual measure in streamflow studies. It has been, however, combined with basin area and relief to form measures of basin shape and gradient, respectively.

3.1c Watershed shape

Basin shape has proved an elusive morphometric characteristic to measure. Since Horton (1932) defined the basin form factor (BSH1), calculated by dividing basin area by the square of maximum basin length ($BSH1 = AREA/BAL^2$), there have been many attempts to quantify basin shape. These have included: a circularity ratio, the comparison of basin area with the area of a circle of equal perimeter (Miller,1953)); and an elongation ratio, the comparison of the diameter of a circle with the same area as the basin to the basin's length (Schumm 1956). The above measures are arguably unrealistic because the average basin is pear-shaped rather than circular and so a lemniscate ratio has been proposed by Chorley, Malm and Pogorzelski (1957). Many other shape ratios have also been proposed. Another measure of basin shape (BSH2) was included because it simply expresses the square of the perimeter divided by the basin area (BSH2 = PER^2/ AREA), a measure of basin circularity (Miller, 1953).

3.1d <u>Watershed surface cover and storage</u>

The area above treeline (ATR) is expressed as a percent of the total basin area. The predominant vegetation cover below treeline on the watersheds studied is forest.

> "In the Plynlimon catchment comparison of the peak discharges from the Severn with two thirds forest cover are generally lower than those from the Wye under mountain grassland. In general, if other watershed characteristics are constant the pattern of streamflow from forested areas should show less difference between peak and low flows than is the case for a watershed covered by other forms of vegetation." (Gregory and Walling, 1973, p. 291)

Area above treeline was also used successfully as a predictive variable by Thakur and Lindiejer (1973 & 1974) in their flood study of the Mackenzie River tributary basins.

The area of lake and marsh (ALM) is expressed as a percent of the basin area and is considered to be a non-contributing area of the watershed as far as peak flows are concerned. For this reason, the percentage area of lake and marsh has been included in many flood studies as a measure of watershed storage, e.g. Benson (1962b) and N.E.R.C. (1975).

The area of glacier and perennial snowpack (AGL) is also expressed as a percent of basin area. The glacier cover and perennial snowpack cover are a continuous source of runoff during the summer months. This variable proved to be an important predictor of flood flows for the rivers in the southern Yukon (I.W.D., 1978).

The above three area measures were computed relative to drainage basin area, with the aid of a random dot overlay (density of 4 points per sq. kilometer at the 1:50,000 scale) after a method proposed by Haan and Johnson (1966).

3.1e Stream channel network

The main channel length (STL in kilometers) is measured with an opisometer from the mouth of the basin, along the stream and following the route of highest order tributaries to the stream terminus. Morisawa (1968) related stream length (L) to mean annual flow (Q) for 96 watersheds in six different physiographic areas of the eastern United

States. She found significant relationships for five of the regions having the general form: $Q = a L^b$. The exponent b was in the range 1.5 to 2.0 .

The total channel length (TCHL in kilometers) is the cumulative length of all streams present in a basin, i.e. the total length of the blue-line network outlined on a 1:50,000 map. The morphometric literature advances three methods for delimiting total channel length from topographic maps viz.: the blue-line network; contour crenulation; and mesh length extension. For hydrologic purposes Goudie (1981) recommends the blue line network be used for delimiting total channel length, while Gregory and Walling (1973, p.48) state:

> "Where the network density is to be used in relation to the contemporary processes operating in the basin, the blue line method is most appropriate in Britain, but elsewhere depends upon map convention."

The blue line network, although dependent on map convention, was used as the basis for delimiting channel network in this study. Total channel length was measured with an opisometer. Total channel length is highly correlated with basin area and, in some cases, may replace area as the strongest measure of watershed size (Gregory and Walling, 1973).

The drainage density (DRD in kilometers^{-1}) is defined as the total channel length of the drainage net divided by basin area (DRD = TCHL/ AREA). Drainage density, first proposed by Horton (1932), has been touted as the most valuable single index in relation to streamflow, in that it reflects precipitation intensity modified by local variations in rock type, soil type, and land use. Sokolov (1969,in Gregory and Walling, 1973, p.272) argued that:

> "Drainage density is certain to be the most important factor characterizing the conditions of flood flow formation .... Nature itself creates a drainage network of a density necessary for outflow of water excess from a watershed surface."

The stream frequency (STF in 1/sq. kilometers) is the ratio of total number of stream segments of all orders present in a basin to drainage area (STF = total no. of stream segments/ AREA). Introduced by Horton (1945), stream frequency is a simple index of network extent. Stream frequency is highly correlated with drainage density and, because, it is a simpler measure to calculate, stream frequency is sometimes substituted for drainage density in streamflow studies (e.g. N.E.R.C.,1975).

The bifurcation ratio (BIRA) is the ratio of the number of first order streams to the number of second order streams in a basin. Single measures of the bifurcation ratio are recommended by Gardiner (1975) for stream flow studies, as opposed to other measures such as the weighted mean bifurcation ratio proposed by Schumm (1956). Considering the small size of the drainage basins in this study BIRA was adopted as the most representative measure of their bifurcation ratio.

3.1f Watershed relief and stream slope

Numerous investigators have noted the importance of relief as a morphometric variable in flood studies.

> "With increasing relief, steepness of hillslopes and higher stream gradients, time of concentration of runoff decreases. Thus all other conditions being equal, the greater the relief of a basin the greater the rate of hydrograph rise."(Patton and Baker, 1976, p.942).

Basin relief (REL in meters) is defined as the maximum elevation on the drainage divide minus the elevation at the basin mouth (Strahler, 1952). Two other measures of basin relief were also calculated: (1) The relief ratio (RELRA) defined as the basin relief divided by maximum basin length (RELRA = REL/ BAL); and (2) the ruggedness number (RUGNO) defined as the drainage density times the basin relief divided by one thousand (RUGNO = DRD * REL/ 1000) (Strahler 1958). Patton and Baker (1976) found that ruggedness number was an important morphometric variable in distinguishing between regions prone to flash floods and those with less severe streamflow regimes. However, the utility of the ruggedness number is somewhat restricted by the fact that a single value can represent a variety of conditions i.e. basins with high drainage densities and low relief can have the same ruggedness value as basins with high relief and low network densities.

It has been long recognized that the profile of a stream tends to be concave upwards and this fact has resulted in many proposed measures for stream slope. Two measures of mainstream slope were used in this study. The first measure is main channel slope (SLOPE) defined by dividing the difference in elevation between the stream terminus and its mouth, by the length of the main channel (Horton, 1932). This measure, although a simple and useful index, can give the same value for a variety of stream profiles.

In order to exclude the highest and lowest gradients, the second measure defines mainstream slope between the ten and eighty-five percentiles of mainstream length. Benson (1959) found that these percentiles gave the best prediction of mean annual flood. N.E.R.C. (1975) also found that these percentiles gave the best measure but, unlike Benson, who defines mainstream length as that along the main channel between the basin mouth and divide, N.E.R.C. defined mainstream length as the length of the main channel depicted by the blue line network on topographic maps. Benson's measure of slope when extended to the divide closely aproximates the measure proposed by Horton above. Therefore, the second measure of channel slope (S1085), used in this study, was defined as the difference in elevation betweeen the ten and eighty-five percentiles of main channel length, as depicted by the blue line network, divided by the main channel length between these two percentiles.

3.1g Watershed aspect

The aspect (ASP) is the direction of the main channel looking downstream from the drainage divide. The aspect of a basin was determined with a protractor, the angle being measured in degrees from True North. Aspect has met with limited success in flood studies but is included here because of the marked differences in geomorphology and climate between north and south facing drainage basins.

> "It is a common observation that snow on a south-facing slope melts faster than snow on a north-facing slope, the reason being that the orientation of the slope affects the amount of direct beam solar radiation the area receives." (Male and Gray, 1981, p.365).

In order to account for this phenomenon, two transformations of aspect were tried and resulted in the normalized direction variables NASP and CASP2. The variable NASP is symmetric about a north-south line and is defined as follows:

for $1 < \text{ASPect} < 180$, $\text{NASP} = \text{ASP}/180$;

and for $180 < \text{ASPect} < 359$, $\text{NASP} = (360 - \text{ASP})/180$.

CASP2 is defined as the cosine of aspect plus two ($\text{CASP2} = \cos(\text{ASP}) + 2$). Two is added to the cosine of aspect in order that CASP2 will lie in the range of one to three otherwise, log transformations would be undefined for negative values. Besides the obvious difference of a cosine function there is another more subtle difference between these two variables. NASP does not distinguish between east facing watersheds and west facing watersheds whereas CASP2 does.

Both of the normalized direction variables were then combined with relief ratio and slope defining the following variables GRADA, GRADB, GRADE, and GRADF, termed gradient vectors for this study.

GRADA = NASP/ RELRA, GRADB = NASP/ SLOPE,

GRADE = CASP2/ RELRA and GRADF = CASP2/ SLOPE.

Since the snowmelt flood is the dominant annual event on Yukon streams, measures of a drainage basin's orientation in three dimensions were thought necessary, because the amount of solar radiation incident on a drainage basin affects the timing and rate of snowmelt. The gradient vectors were therefore derived to express a watershed's aspect and gradient simultaneously.

3.1h Watershed hypsometry

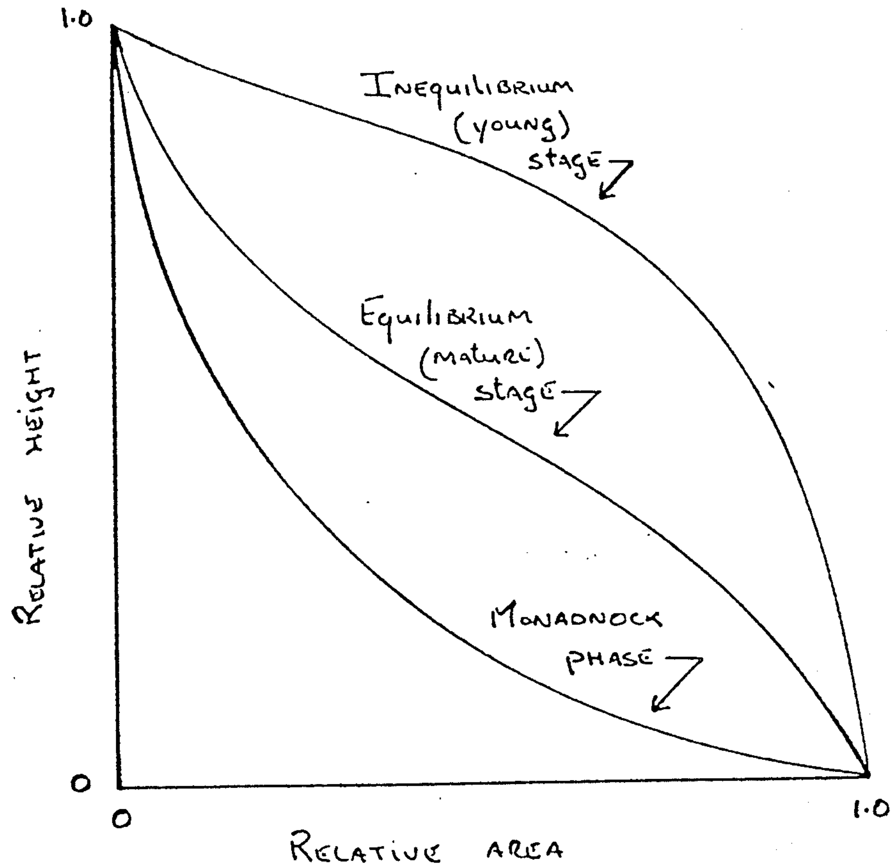
Hypsometry offers a conceptually attractive alternative for expressing overall relief aspects of a watershed. Hypsometry is the basin area-altitude relationship found by measuring the area within specified contour intervals (the 100 m. or 500 ft. contour intervals depending on map convention) and summed to give a cumulative frequency curve. The area between the contour intervals was determined from a random dot overlay (density of four dots per square kilometer at a 1:50,000 map scale) after a method proposed by Haan and Johnson (1966). Two measures of hypsometry are used in this study. The hypsometric integral (HYPI) is the area below the frequency curve expressed in percent. The hypsometric coefficient (HYPC) is the percent of area above the mean altitude of the watershed (Strahler, 1952b).

The hypsometric analysis of a drainage basin was developed in its modern form by Langbein (1947). Strahler (1952b) applied hypsometric analysis to small watersheds and suggested that the shape of the hypsometric curve indicated the stage of geomorphic development of the basin. The typical stages of basin evolution according to Strahler are illustrated in Fig. 3.1

> "From the standpoint of hypsometric analysis the development of a drainage basin in a normal fluvial cycle seems to consist of two major parts only. (1) An inequilibrium stage of early development, in which slope transformations are taking place rapidly as the drainage system is expanded and ramified. (2) An equilibrium stage in which a stable hypsometric curve is developed and maintained in a steady state as relief slowly diminishes. The monadnock phase with abnormally low hypsometric integral when it does occur can be regarded as transitory because removal of the monadnock will result in restoration of the curve to the equilibrium form.....The hypsometric curve of the equilibrium stage is an expression of the attainment of a steady state in the processes of erosion and transportation within the fluvial system and its contributing slopes" (Strahler, 1952b, p.1130).

Strahler's classification of hypsometric curves with its emphasis on fluvial activity is regarded by many geomorphologists as unrealistic. In Canada drainage basins have undergone countless episodes of fluvial, glacial and

Fig. 3.1 Characteristic curves of erosion cycle :



periglacial activity. Many of the basins of this study have recently been glaciated, and their overall shape (U-shaped cross-section) and host of surface features (moraines, eskers, kame terraces, kettles, outwash plains) are the result of glacial and periglacial activity. The valley bottoms, for the most part are still covered by till, outwash deposits and lacustrine deposits. This supports the supposition that recent fluvial activity has done little in the way of modifying the overall shape of these basins as expressed by their hypsometric curves. It is more likely then, that a hypsometric curve reflects the combined glacial, periglacial and fluvial history of a watershed.

Also of note are the inherent generic connotations of Strahler's classification of hypsometric curves i.e. equilibrium or mature stage of development, inequilibrium or youthful stage of development, and the monadnock state denoting an abnormal phase of drainage basin development. Contrary to Strahler's inference that a low integral basin reflected an abnormal state, the study basins with low hypsometric integral are fairly typical of small, U-shaped upland valleys which have been recently scoured by alpine glaciers e.g. Dale Creek (Fig. 5.3), and Mule Creek (Appendix 2 Fig.14). For these reasons, 'typical' hypsometric curve shapes for this study are denoted by the terms low, medium and high integral curves.

A broad range of hypsometric curve shapes are attained by the basins of this study (Appendix 2, Figs. 1 to 36). For example, a high integral curve is exemplified by Benson Creek, a medium integral curve by Bacon Creek, and a low integral curve by Enger Creek.

Hypsometric analysis is not one of the more popular investigative techniques of hydrology although its use has been suggested where precipitation, evaporation or snowcover vary with altitude. In the past a major drawback of a hypsometric analysis has been its tedious and time-consuming nature. However, this has now been remedied by the methods proposed by Haan and Johnson (1966) and Pike and Wilson (1971) for rapidly determining the hypsometric integral. The relevance of hypsometry to northern resource management should not be overlooked. Besides its apparent application to hydrology, hypsometry accurately reflects the activity of a stream within its basin. Its analysis, therefore, provides a good appraisal of the potential long term hazard posed by the erosional activity of a stream. The role of hypsometry with regard to streamflow is examined in the light of this study's findings in Chapter 5.

The values for the morphometric variables for each watershed are presented in Appendix 1.

3.2 CLIMATE

Other flood studies have shown the importance of including indices that describe prevailing climatic conditions e.g. I.W.D. (1978), Lamke (1978), Nash and Shaw (1970), N.E.R.C. (1975) and Thomas and Benson (1972). Although an individual flood is influenced by the rainfall directly associated with it, the flood of a given return period is probably better related to the prevailing precipitation characteristics (Benson,1962a). Experience with other flood studies has shown that mean annual rainfall (Nash and Shaw, 1970; and N.E.R.C.,1975) and mean annual precipitation have had good success in flood models in areas where snowmelt is prevalent (Lamke, 1978; I.W.D., 1978; and Thomas and Benson, 1970).

Two variables depicting the climate of a basin were selected for this study. They are mean annual precipitation (PRECIP in cms.), and average storm intensity (INTENS in cms./day). The values of the variables for each basin were taken from Isohyet maps prepared by the Water Resources Div., Indian and Northern Affairs, Whitehorse, for the period 1959 to 1973. The values of the climatic variables for each watershed are also presented in Appendix 1.

3.3 CORRELATION ANALYSIS OF THE MORPHOMETRIC AND CLIMATIC VARIABLES

The following average statistics were computed for the basins of this study. The average channel length of the first order streams is 1.4 kilometers, for second order streams it is 2.4 kilometers, and for third order streams it is 4.5 kilometers. The average bifurcation ratio between first and second order streams is 3.9 and between second and third order streams is 4.0. This implies that on the average for every kilometer of third order stream channel in the southern Yukon there are 2.1 kilometers of second order stream channels and 4.9 kilometers of first order stream channels as depicted on 1:50,000 maps (i.e. a 1:2:5 ratio).

A perusal of the pair-wise correlation matrix in Appendix 3 shows that high correlations exist between variables that express similar dimensions of a drainage basin. Variables related to the size of a watershed show the highest intercorrelations (Table 3.1).

Table 3.1

Correlation matrix

	AREA	PER	STL	BAL	TCHL
Basin AREA	1.00				
Basin PERimeter	0.94	1.00			
Main STream Length	0.88	0.87	1.00		
BAsin Length	0.93	0.97	0.91	1.00	
Total CHannel Length	0.88	0.84	0.84	0.85	1.00
RANK of main channel	0.70	0.71	0.63	0.71	0.77

The variables measuring basin relief are not as well correlated as one would suppose (Table 3.2).

Table 3.2

Correlation Matrix

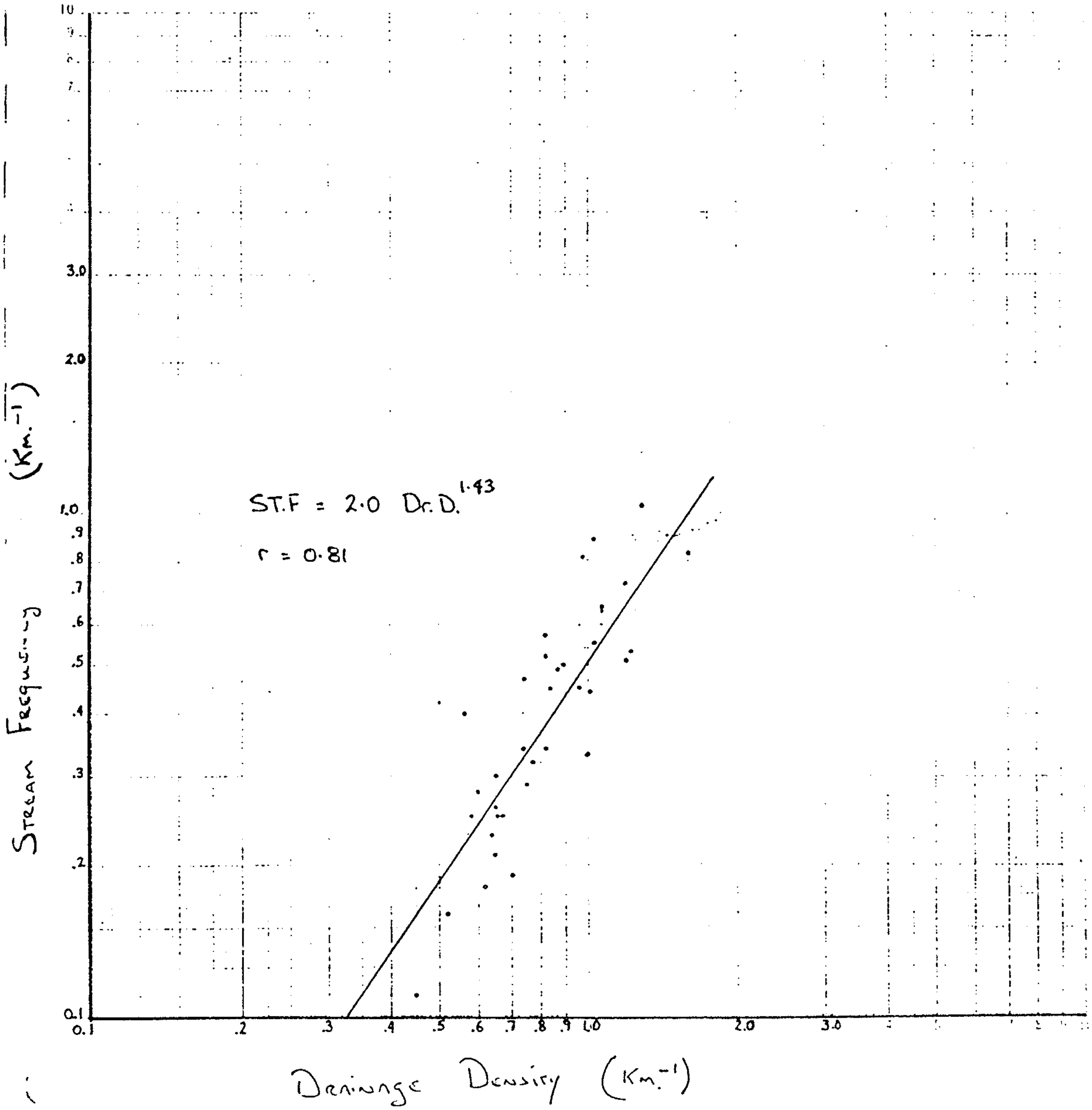
	REL	RELRA	REGNO	SLOPE	S1085	HYPI
Basin RELief	1.00					
RELief RAtio	0.28	1.00				
RUGgedness NO.	0.65	0.22	1.00			
Channel SLOPE	0.37	0.89	0.27	1.00		
Slope,10 & 85%	0.33	0.88	0.23	0.96	1.00	
HYPsometric Integral	0.20	0.27	0.18	0.44	0.38	1.00
HYPsometric Coef.	0.17	0.32	0.05	0.47	0.41	0.92

Of note are the are the high correlations between the two slope measures and relief ratio, suggesting that only one of these variables need to be incorporated in a regression analysis. Also the two measures of basin hypsometry are poorly correlated with the other relief measures, which emphasizes that a special property of watershed relief is expressed by the hypsometric measures.

An interesting relationship is provided by the relation between stream frequency and drainage density. Although each of these indices measures distinct aspects of a basin's stream network (two basins may have the same drainage density but different stream frequencies or vice versa), Melton (1958) suggested that the range of natural variations in a relation of the two was quite small. A least squares regression analysis determined the following equation (Fig. 3.2.):

$$STF = 2.0\ DRD^{1.43} \quad : r = 0.81$$

Fig. 3·2 Regression of stream frequency on drainage density.



This implies that as basin morphology becomes increasingly fine-textured in southern Yukon, stream frequency and drainage density to the power of 1.43 increase proportionately, their ratio always approaching the value 2.0. In other words, an increase in the total length of the drainage network is due to a simultaneous increase in the length and number of the channels.

Perhaps the most interesting correlations are those between the climatic and morphometric variables (Table 3.3). Mean annual precipitation shows a fair correlation with elevation, implying an orographic effect. A description of the orographic effect along the Canol Road, which is a north trending traverse through the study area, is given by Wahl (1981):

> "In this area, the mountainous terrain also complicates the climate pattern. As a general statement, precipitation increases with increased elevations, and temperatures decrease with increased elevation. In the winter however, the temperature pattern reverses with temperatures generally lower in the valley floors and warmer up the mountain slopes."

Table 3.3

Correlation Matrix

	ELEV	LAT	DRD	STF	PRECIP
Basin ELEVation	1.00				
LATitude	-0.05	1.00			
DRainage Density	0.13	0.26	1.00		
STream Frequency	-0.07	0.22	0.83	1.00	
Mean Annual PRECIPitation	0.49	-0.06	0.32	0.32	1.00
Average Storm INTENSity	0.18	0.47	0.30	0.29	0.46

Average storm intensity's highest correlation is with latitude, where a decrease in storm intensity occurs with increased latitude. This phenomenon is readily verified from the monthly storm intensity maps constructed by Veruschuren and Meheriuk (1973), which show a decrease in storm intensity with increased distance from the ocean.

Both of the climatic variables are very weakly correlated with the other morphometric variables including drainage density and stream frequency. For many of the world's climatic regions drainage density has been shown to be highly correlated with amount of precipitation and rain intensity. The general consensus of opinion is that drainage density reflects precipitation intensity and that local variations can be explained by other basin characteristics such as rock type, soil and land use (Gregory and Walling, 1976). However, the dominance of the winter climate in the study region is responsible for additional channel forming processes (e.g. freeze-up, break-up and snowmelt flooding, and processes related to permafrost such as, block slumping and bottom-fast ice). Since the snowmelt flood is the dominant annual event on Yukon streams, it is not that suprising that mean annual precipitation and average storm intensity are not highly correlated with drainage density and stream frequency.

4 FLOOD-FREQUENCY ANALYSIS

Flood-frequency analysis originated with the consideration of economics in the development of rivers and their floodplains. In its simplest form, the analysis involves the compilation of recorded streamflow statistics, from which the floods of interest are extracted, ranked and fitted to a frequency distribution (Benson, 1962a).. Although this seems a straight forward procedure, flood frequency analysis since its inception in the 1930's, has been plagued by a considerable amount of controversy, which primarily surrounds two issues of concern: (1) The treatment of the flood data prior to analysis; and (2) the plotting and fitting of a curve to the flood series.

The questions commonly debated concerning the preparation of the flood data prior to analysis are:

1. Should floods be separated into causative categories, i.e. snowmelt events versus rainstorm events?

2. Should records be lengthened by correlation analysis and missing floods estimated?

3. Is the time period of recorded flood data representative of the future period of concern?

4. What importance should be given to the very large floods in a short period of record?

Consistant answers to these questions are lacking and more often than not the hydrologist is advised to use his judgement when questions of this nature occur.

The wide differences of opinion among hydrologists concerning the methodology of flood frequency analysis stems mainly from lack of flood data. This lack of specific data creates doubt as to the true statistical nature of a flood series. Controversy centres around the following questions.

1. What is the most suitable method for determining the plotting positions of the floods in a series?

2. Is the graphical fitting of a curve to the flood series plotted on a frequency-magnitude graph preferable to the mathematical fitting of a frequency relationship?

3. If a mathematical fitting is preferred, then, which mathematical method or statistical distribution should be applied?

The hydrological literature on flood frequency analysis abounds with arguments both for and against the selection of a particular approach.

This results in difficulties in how best to judge between the various methods. Indeed;

> "what we must face up to is the realization that there are a number of methods of fitting flood data that are virtually on a par, even though this may mean they are equally poor....From among these we might as well choose one and use it as a basic method "(Benson, 1972, p.29).

4.1 METHODS OF ANALYSIS

The streamflow data for the thirty-six streams of this study were gleaned from the records of the Water Resources Div., Indian and Northern Affairs, Whitehorse. The data covered the years 1975 to 1982. The subsequent analysis of this data involved preparation of an annual series of maximum floods for each stream, and the fitting of a frequency distribution to the annual series. The following are definitions of the hydrological terms used in the flood-frequency analysis of Yukon streams.

FLOOD is any relatively high streamflow in a year as measured by a gauge or discharge quantity. Its magnitude is measured as the maximum instantaneous discharge associated with the flood event.

RECURRENCE INTERVAL is the average interval of time during which a given magnitude flood will be equalled or exceeded once only.

MEAN ANNUAL FLOOD (QMA) is the flood which has a recurrence interval of 2.33 years. On average once every 2.33 years the highest flood of the year will exceed the mean annual flood.

TWO YEAR FLOOD (Q2) is the flood which will be equalled, or exceeded on average once every two years. Similarly, FIVE YEAR FLOOD (Q5), TEN YEAR FLOOD (Q10) and TWENTY YEAR FLOOD (Q20) are the floods which are equaled or exceeded on average once every five, ten and twenty years respectively.

4.2 PREPARATION OF ANNUAL FLOOD SERIES

An annual series of maximum floods was prepared for each of the thirty-six streams, with each stream having a minimum of four consecutive years of record. The historical periods of recorded flows for the streams of this study are listed in Table 4.1. A five year minimum period was the standard used by the Natural Environmental Research Council (1975) in their study of floods in the British Isles. Thakur and Lindeijer (1973, & 1974) used four years of recorded streamflows as a minimum criterion for evaluating the fifty and one hundred year floods for Mackenzie River tributaries. Although the study streams had a minimum of four years of recorded streamflows, it became immediately apparent that the highest annual flood levels for some of the streams were not recorded. There were apparently two reasons for this. Either the annual flood occurred in the early spring and the recorder site was not operational at this time, or the gauge was destroyed by the flood. In many of these cases, a minimum flood level was estimated by the water survey crews upon inspection of the site, and this level was used as a standard for comparison in later analysis.

TABLE 4.1. HISTORICAL STREAM FLOW SUMMARY.

Name of stream	Historical stream flow record 1975	76	77	78	79	80	81	82.
Spencer Creek				C	C	C	C	C
Freer Creek					R	R	R	R
Partridge Creek				R	R	R	R	R
Logjam Creek				C	C	C	C	C
Strawberry Creek					C	C	C	C
Deadman Creek				C	C	C	C	C
Judas Creek					C	C	C	C
Wolf Creek					C	C	C	C
Unnamed Creek					R	R	C	C
Stoney Creek					C	C	C	C
Marshall Creek				C	C	C	C	C
Bear Creek		C	C	C	C	C	C	C
Burwash Creek				R	R	R	R	R
Long's Creek		C	R	R	R	R	R	R
Dry Creek		C	C	C	C	C	C	C
Enger Creek					R	R	R	R
Stanley Creek			C	C	C	C	C	C
Mule Creek			C	R	R	R	R	C
Stonehouse Creek			C	C	C	C	C	C
Murphy Creek			R	R	R	R		
Groundhog creek			C	C	C	C		
Bacon Creek			C	C	C	C		
180 Mile Creek	C	C	C	C	C	C	C	C
Twin Creek #1				R	R	R	C	R
Riddel Creek	C	C	C	C	C	C	C	C
Boulder Creek			C	C	C	C	C	C
South MacMillan River #2	C	C	C	C	C	C	R	R
Vangorda Creek		R	R	R	R	R	R	R
Benson Creek	C	C	C					
Wolf Creek	C	C	C	C	C	C	C	C
Grizzly Creek	C	C	C	C	C	C	C	C
Unnamed Creek			C	C	C	C	C	C
Big Gold Creek					R	R	R	R
Clinton Creek				R	R	R	R	R
Thistle Creek					R	R	R	R
Big Thing Creek				R	R	C		

(C) Crest gauge station.
(R) Water level recorder station.

A circumstance which must be considered before-hand, however, is the nature of the flood data. There are two types of streamflow recording stations operated by the Water Resoures Div., Indian and Northern Affairs. These are: (1) Stations with continuous water-level recorders; and (2) crest-gauge stations. Out of necessity most of the stations are of the latter type. Each station is visited by Water Resouces Div. personnel every two or three weeks. At this time the stream is metered and the water level recorded. At the crest-gauge stations any intervening high water mark is also noted. The type of stream flow recording station is also listed in Table 4.1. The resulting flow data for the streams with crest-gauges is, therefore, a series of discontinuous flow records. This nature of the recorded stream flows had a bearing on the method chosen for estimating the missing flood data.

Also relevant to the subject of the recorded streamflow data is the definition of the rating curve. There is a paucity of information on the simultaneous measurement of high stream flows and their corresponding water levels, a common occurrence where only a few years of recorded flows are available. As a result the upper tail of the rating curves for the streams are not as well defined as their lower reaches. Therefore, this fact should be kept in mind when converting to discharge from the rating curve.

Egginton (1978) has cautioned that the presence of bottom-fast ice can result in overestimation of the breakup flood, which usually is the highest annual flood event experienced by the study streams. However, my own observations on Dale Creek and 180 Mile Creek have shown that the opposite condition can occur. While metering these streams, a thin veneer of ice was noted which coated the gravel-boulder bed during the high flows of the spring freshet. This ice film reduces the bed roughness thus causing increased flow velocities within the stream channel. Preliminary estimates using the Manning Formula suggest a decrease in the Manning's 'n' for flows within channels experiencing this condition as high as an order of magnitude. Therefore, if the stage-discharge relationship as defined for ice-free conditions is used, underestimation of the breakup flood is also possible.

The simplest method of estimating missing floods begins with the identification of a nearby stream of similar regime with a history of recorded flows that covers the period of missing floods. Correlation of the common period of record provides a relationship from which the missing floods can be estimated. Usually this method involves the correlation of the maximum annual floods. However, the short period of record for the streams of this study dictated the need for correlation of another criterion of streamflow in order to determine the missing floods. N.E.R.C. (1975) employed a correlation of maximum monthly flows between streams in Britain to obtain estimates of missing flood data. Again, the nature of the recorded flow data for the study streams precluded an analysis of this type. Instead, high flow series consisting of the highest four or five recorded flows in a year, were constructed for the common period of record for the stream with missing data and for a nearby stream considered to have a similar streamflow regime and a good historical flow record (Benson,1962b). The data pairs were then plotted on a graph and visually inspected. If a strong correlation was apparent a least squares regression analysis was employed to define a relationship which could be used to estimate the missing flood data. The high flow series, the scatter diagram, the relationship developed and the estimated flood statistics for the affected creeks are presented in Appendix 4.

4.3 THE FLOOD-FREQUENCY RELATIONSHIP FOR THE STREAMS

The flood-frequency analysis began by arranging the annual maximum floods for each stream, both recorded and estimated, in order of magnitude. The largest flood in a series is assigned the rank of one ,the second largest the rank of two, etc.. A recurrence inteval (T) for the individual floods in a series was calculated by applying the Weibull formula:

$$T = (N + 1) / M \quad .....(4.1)$$

where N, is the number of years of record and M, is the rank of the flood.

The ranked floods were then plotted on logarithm-probability paper to conform with present D.I.A.N.A., Y. T. practise. A gently curving line was fitted to the plotted data and extrapolated to the 20 year return period. It is doubtful whether a more rigorous graphical treatment is necessary in view of the short periods of recorded streamflows involved in the study.

The flood-frequency relationships provided estimates of the mean annual flood, the two year flood, the five year flood, the ten year flood and the twenty year flood for each of the study streams (Appendix 5).

5 ESTIMATION OF FLOODS FROM WATERSHED CHARACTERISTICS

Previous flood studies have made use of multiple regression analysis to develop relationships between specific flood levels and characteristics of physiography and climate (I.W.D.,1978, Lamke,1978, N.E.R.C.,1975, Thakur and Lindeijer,1973, and Thomas and Benson,1972). These studies have proposed a relationship having the general form:

$$Y = 10^{b0} X_1^{b1} X_2^{b2} X_3^{b3} \ldots \quad \ldots (5.1)$$

A logarithmic transform of equation 5.1 yields the linear equation:

$$Y = b0 + b1 X_1 + b2 X_2 + b3 X_3 + \ldots \quad \ldots (5.2)$$

Equation 5.2 can be derived by a multiple regression analysis where: Y is the dependent variable - a flood of a specified recurrence inteval; X_1, X_2, X_3,..... are the independent variables - variables describing physiography and climate; b0 is an intercept; and b1, b2, b3,.....are the regression coefficients.

In most studies a set of regression equations are derived for floods of several recurrence intervals. In this study regression equations are computed for the mean annual, two year, five year, ten year and twenty year floods. Herein lies the advantage of a regression type model. A comparison with another flood prediction model, the index flood method, will help to clarify what is meant by this last statement.

The index flood method is perhaps the most commonly used flood assessment technique. This method applies a regional frequency curve, i.e. the average shape of all frequency curves computed for the instrumented basins of a 'homogeneous region' to an ungauged basin. Its position is fixed on a suitable graph by estimating the size of a particular flood for the ungauged stream - this usually being the mean annual flood. This flood estimate is determined from a regional relationship with drainage area. The underlying rigidity of the index flood method implies a uniform dependence between the floods of specific recurrence intervals spanning all watersheds of a region.

"It is probable that different factors may be acting at the separate flood levels or that the same factors may have varying effects at different levels. The multiple correlation method, when used independently at specific flood levels allows complete flexibility and does not require making assumptions about the relation between the floods of different recurrence intervals." (Benson, p.20,1962a).

The diverse physiography and geology of the southern Yukon Territory, coupled with the variations in local climate, which in some cases can be quite marked over short distances, reflect a potential for a variety of flood regimes. A flood prediction model based on a regression analysis offers an approach which is adaptable to the potential local variations in watershed form and process.

5.1 REGRESSION ANALYSIS

The BMD step-wise regression program was used for the regression analysis (BMD Package, 1977). This program initially constructs a pair-wise correlation matrix for both independent and dependent variables. The independent variable with the highest correlation with the dependent variable is selected as the initial entrant in the regression. The program then adds, or deletes variables at subsequent steps on the basis of their F ratio statistic. The BMD package also provides for transformation of input data.

All the variables were transformed prior to analysis by taking their common logarithms. Area above treeline, area of lake and marsh and area of glacier often have values of zero, therefore, for these variables the logarithm of one plus the variable was used. Also, two was added to the cosine of aspect in order that the variable CASP2 would have a range between one and three (as explained before).

5.2 RESULTS OF THE REGRESSION ANALYSES

The results of the multiple regression analysis for the mean annual, two year, five year, ten year, and twenty year floods are presented in Tables 5.1 to 5.5. The derived equations are:

$$QMA = 10^{-15.8}\ TCHL^{0.67}\ PRECIP^{1.35}\ NASP^{0.25}\ HYPI^{0.81}\ LAT^{7.6} \quad ..(5.3)$$

$$Q2 = 10^{-16.5}\ TCHL^{0.66}\ PRECIP^{1.40}\ NASP^{0.25}\ HYPI^{0.82}\ LAT^{7.75} \quad ..(5.4)$$

$$Q5 = 10^{-13.9}\ TCHL^{0.72}\ PRECIP^{1.17}\ NASP^{0.25}\ HYPI^{0.79}\ LAT^{6.73} \quad ..(5.5)$$

$$Q10 = 10^{-1.77}\ TCHL^{0.84}\ PRECIP^{1.09}\ NASP^{0.25}\ HYPI^{0.83} \quad .....(5.6)$$

$$Q20 = 10^{-1.68}\ TCHL^{0.88}\ PRECIP^{1.04}\ NASP^{0.25}\ HYPI^{0.83} \quad .....(5.7)$$

TABLE 5.1 RESULTS OF THE REGRESSION ANALYSIS:

MEAN ANNUAL FLOOD

STEP	VAR. NAME	COEF.	F RATIO	F TO REMOVE	R	R^2	SEE	CONST.
1	TCHL	0.75	22.06	22.06	0.63	0.39	0.31	$10^{-0.53}$
2	TCHL	0.79	24.01	35.07	0.73	0.59	0.26	$10^{-2.66}$
	PRECIP	1.26		16.14				
3	TCHL	0.72	20.97	32.40	0.81	0.66	0.24	$10^{-2.51}$
	PRECIP	1.31		20.21				
	NASP	0.26		6.65				
4	TCHL	0.76	20.41	42.08	0.85	0.72	0.22	$10^{-2.36}$
	PRECIP	1.38		26.45				
	NASP	0.25		7.66				
	HYPI	0.85		6.99				
5	TCHL	0.67	19.63	33.50	0.88	0.77	0.20	$10^{-15.8}$
	PRECIP	1.35		28.58				
	NASP	0.25		8.41				
	HYPI	0.81		7.33				
	LAT	7.60		5.27				

COEFF. is the regression coefficient. F RATIO is the F statistic for the regression equation. F TO REMOVE is the F statistic of the independent variables entered. R is the multiple correlation coefficient. R^2 is the coefficient of determination. SEE is the standard error of estimate. CONST. is the intercept.

The regression variables are:

TCHL = Total channel length.
PRECIP = Mean annual precipitation.
NASP = Normalized aspect.
HYPI = Hypsometric integral.
LAT = Latitude.

TABLE 5.2 RESULTS OF THE REGRESSION ANALYSIS:

TWO YEAR FLOOD

STEP	VAR. NAME	COEF.	F RATIO	F TO REMOVE	R	R^2	SEE	CONST.
1	TCHL	0.74	20.48	20.48	0.61	0.38	0.32	$10^{-0.6}$
2	TCHL	0.77	23.82	33.54	0.77	0.59	0.26	$10^{-2.8}$
	PRECIP	1.32		17.32				
3	TCHL	0.71	20.74	30.81	0.81	0.66	0.24	$10^{-2.6}$
	PRECIP	1.36		21.59				
	NASP	0.26		6.56				
4	TCHL	0.75	20.26	40.22	0.85	0.72	0.22	$10^{-2.5}$
	PRECIP	1.44		28.21				
	NASP	0.26		7.56				
	HYPI	0.86		7.06				
5	TCHL	0.66	19.59	31.85	0.87	0.77	0.21	$10^{-16.5}$
	PRECIP	1.40		30.63				
	NASP	0.25		8.33				
	HYPI	0.82		7.43				
	LAT	7.75		5.40				

COEFF. is the regression coefficient. F RATIO is the F statistic for the regression equation. F TO REMOVE is the F statistic of the independent variables entered. R is the multiple correlation coefficient. R^2 is the coefficient of determination. SEE is the standard error of estimate. CONST. is the intercept.

The regression variables are:

TCHL = Total channel length.
PRECIP = Mean annual precipitation.
NASP = Normalized aspect.
HYPI = Hypsometric integral.
LAT = Latitude.

TABLE 5.3 RESULTS OF THE REGRESSION ANALYSIS:

FIVE YEAR FLOOD

STEP	VAR. NAME	COEF.	F RATIO	F TO REMOVE	R	R^2	SEE	CONST.
1	TCHL	0.80	27.89	27.89	0.67	0.45	0.29	$10^{-0.45}$
2	TCHL	0.83	24.73	40.10	0.77	0.60	0.25	$10^{-2.27}$
	PRECIP	1.08		12.30				
3	TCHL	0.76	21.45	37.48	0.82	0.67	0.23	$10^{-2.13}$
	PRECIP	1.13		15.53				
	NASP	0.25		6.56				
4	TCHL	0.80	20.66	47.94	0.85	0.73	0.22	$10^{-2.00}$
	PRECIP	1.20		20.44				
	NASP	0.25		7.51				
	HYPI	0.82		6.73				
5	TCHL	0.72	18.99	38.44	0.87	0.76	0.21	$10^{-13.87}$
	PRECIP	1.17		21.33				
	NASP	0.25		7.99				
	HYPI	0.79		6.88				
	LAT	6.73		4.09				

COEFF. is the regression coefficient. F RATIO is the F statistic for the regression equation. F TO REMOVE is the F statistic of the independent variables entered. R is the multiple correlation coefficient. R^2 is the coefficient of determination. SEE is the standard error of estimate. CONST. is the intercept.

The regression variables are:

TCHL = Total channel length.
PRECIP = Mean annual precipitation.
NASP = Normalized aspect.
HYPI = Hypsometric integral.
LAT = Latitude.

TABLE 5.4 RESULTS OF THE REGRESSION ANALYSIS:

TEN YEAR FLOOD

STEP	VAR. NAME	COEF.	F RATIO	F TO REMOVE	R	R^2	SEE	CONST.
1	TCHL	0.84	32.23	32.23	0.70	0.49	0.29	$10^{-0.42}$
2	TCHL	0.87	25.30	43.41	0.78	0.61	0.26	$10^{-2.06}$
	PRECIP	0.97		9.91				
3	TCHL	0.80	21.80	40.79	0.82	0.67	0.24	$10^{-1.91}$
	PRECIP	1.02		12.58				
	NASP	0.25		6.48				
4	TCHL	0.84		52.14	0.85	0.73	0.22	$10^{-1.77}$
	PRECIP	1.09		16.83				
	NASP	0.25		7.40				
	HYPI	0.83		6.84				

COEFF. is the regression coefficient. F RATIO is the F statistic for the regression equation. F TO REMOVE is the F statistic of the independent variables entered. R is the multiple correlation coefficient. R^2 is the coefficient of determination. SEE is the standard error of estimate. CONST. is the intercept.

The regression variables are:

TCHL = Total channel length.
PRECIP = Mean annual precipitation.
NASP = Normalized aspect.
HYPI = Hypsometric integral.

TABLE 5.5 RESULTS OF THE REGRESSION ANALYSIS:

TWENTY YEAR FLOOD

STEP	VAR. NAME	COEF.	F RATIO	F TO REMOVE	R	R^2	SEE	CONST.
1	TCHL	0.88	36.00	36.00	0.72	0.51	0.28	$10^{-0.40}$
2	TCHL	0.91	26.63	47.03	0.79	0.62	0.26	$10^{-1.96}$
	PRECIP	0.93		8.89				
3	TCHL	0.84	22.47	44.21	0.82	0.68	0.24	$10^{-1.82}$
	PRECIP	0.97		11.19				
	NASP	0.25		6.03				
4	TCHL	0.88	21.51	56.03	0.86	0.74	0.22	$10^{-1.68}$
	PRECIP	1.04		15.00				
	NASP	0.25		6.88				
	HYPI	0.83		6.68				

COEFF. is the regression coefficient. F RATIO is the F statistic for the regression equation. F TO REMOVE is the F statistic of the independent variables entered. R is the multiple correlation coefficient. R^2 is the coefficient of determination. SEE is the standard error of estimate. CONST. is the intercept.

The regression variables are:

TCHL = Total channel length.

PRECIP = Mean annual precipitation.

NASP = Normalized aspect.

HYPI = Hypsometric integral.

There are many similarities between the equations. In all cases total channel length (TCHL) is the first variable entered into the regression equations, followed in order, by mean annual precipitation (PRECIP), normalized aspect (NASP) and hypsometric integral (HYPI). The correlation cofficient and the standard error of estimate increase and decrease, respectively, at aproximately the same rate in each step of equation derivation. Latitude enters as the fifth variable in all cases. However, in equations 5.6 and 5.7 the F TO ENTER statistic for latitude is less than four and, therefore, is not entered into these equations.

Although the multiple correlation coefficients for equations 5.3 to 5.7 are significant (R = 0.86 approx.), their standard errors of estimate are 0.21 on average. This implies that, in about two thirds of the predictions from this set of equations, the actual value will be in the range of -38% to +62%. The 95% confidence limits for a prediction are -63% to +168%. Consequently, predictions from these equations are fairly rough estimates of the true flood regime. However, judgement as to the effectiveness of the equations depends on their utilization and the availability of other flood estimation methods.

5.3 THE FLOOD MODEL

Since latitude was the fifth variable selected by the step-wise regression procedure it deserves consideration in the analysis. Latitude, as noted earlier, showed a fair negative correlation with average storm rainfall intensity. In addition, increased latitude results in decreases of mean monthly winter temperatures as well as increases in permafrost distribution. For these reasons latitude should not be overlooked as an important variable in subsequent flood investigations in the Yukon. It may even provide a basis for subdivision of the territory into hydrologic regions in the future, if the stream gauging network is expanded. In this study latitude proved to be the last variable entered successfully into the regression equations. It is interesting to note the sensitivity of latitude in terms of its exponent relative to the other variables of equations 5.3, 5.4, and 5.5. Indeed, the slight improvement to the predictions attributed to the inclusion of latitude does not merit this amount of sensitivity. For this reason latitude was deleted from further analysis. The exclusion of latitude results in the following set of equations having only four independent variables.

$$QMA = 0.0044\ TCHL^{0.76}\ PRECIP^{1.38}\ NASP^{0.26}\ HYPI^{0.85} \quad \ldots(5.8)$$

$$Q2 = 0.0034\ TCHL^{0.75}\ PRECIP^{1.44}\ NASP^{0.26}\ HYPI^{0.86} \quad \ldots(5.9)$$

$$Q5 = 0.0102\ TCHL^{0.80}\ PRECIP^{1.20}\ NASP^{0.25}\ HYPI^{0.82} \quad ..(5.10)$$

$$Q10 = 0.0170\ TCHL^{0.84}\ PRECIP^{1.09}\ NASP^{0.25}\ HYPI^{0.83} \quad \ldots(5.6)$$

$$Q20 = 0.0209\ TCHL^{0.88}\ PRECIP^{1.03}\ NASP^{0.25}\ HYPI^{0.83} \quad \ldots(5.7)$$

The above set of equations prove very interesting from the point of view of their exponents (i.e. regression coefficients). As the flood levels increase, the exponent for total channel length increases and that of mean annual precipitation decreases. Meanwhile, not unexpectededly, the exponents for normalized aspect and hypsometric integral remain relatively unchanged. Given the unvarying nature of the two parameters NASP and HYPI, in order to present simpler formulae and calculations, methods of flood-ratioing are attempted. For example, the flood ratio of the twenty year flood relative to the mean annual flood (QMA) is:

$$\frac{Q20}{QMA} = \frac{0.0209\ TCHL^{0.88}\ PRECIP^{1.03}\ NASP^{0.25}\ HYPI^{0.83}}{0.0044\ TCHL^{0.76}\ PRECIP^{1.38}\ NASP^{0.26}\ HYPI^{0.85}} \quad ..(5.11)$$

Assuming that the differences in NASP and HYPI reflected by their exponents are sufficiently small it follows that:

$$\frac{Q20}{QMA} = 4.75\ TCHL^{0.12}\ PRECIP^{-0.35}\ ; \quad \ldots.(5.12)$$

and likewise it follows that:

$$\frac{Q10}{QMA} = 3.86\ TCHL^{0.08}\ PRECIP^{-0.29}\ ; \qquad \text{....(5.13)}$$

$$\frac{Q5}{QMA} = 2.32\ TCHL^{0.04}\ PRECIP^{-0.18}\ ; \qquad \text{....(5.14)}$$

$$\frac{Q2}{QMA} = 0.78\ TCHL^{-0.01}\ PRECIP^{0.06}\ ; \qquad \text{....(5.15)}$$

The flood ratio equations (5.12 to 5.15) with equation 5.8 now form a simpler flood model. A later section of this chapter will outline the application of the model to a test watershed. Before discussing the significance of total channel length, mean annual precipitation, normalized aspect and the hypsometric integral to northern hydrology, caution should be advised when inferences are made concerning the role of variables in regression equations. It is possible that a variable included in a regression analysis may not be related causally to the dependent variable, but instead, may be associated with a variable not even considered in the analysis.

5.4 THE ROLE OF THE INDEPENDENT REGRESSION VARIABLES IN THE FLOOD MODEL

The flood ratio equations imply that there are considerable differences in the roles of the independent variables as far as flooding is concerned in the southern Yukon. The overall flood regime of a stream is a function of the four variables; total channel length (TCHL); mean annual precipitation (PRECIP); normalized aspect (NASP); and the hypsometric integral (HYPI). However, the differences in severity between floods of specific recurrence intervals are attributable to changes in total channel length and mean annual precipitation only. In other words, TCHL and PRECIP express the dynamic nature of a watershed, while NASP and HYPI express the relative fixed geomorphologic state of the watershed.

The response of northern drainage basins to water inputs must be understood if the significance of the variables, total channel length, mean annual precipitation, normalized aspect and hypsometric integral are to be ascertained. A brief discussion of the evolution of drainage basin response models to precipitation inputs is presented by Gregory and Walling (1973) and is recapitulated in the following account.

Horton (1945) provided an important conceptual view of the drainage basin known as the overland flow model. Two basic mechanisms of water supply to the stream channel network are visualized by this model – overland flow and base flow. Rain falling on the drainage basin would initially infiltrate the soil and gradually reach the the ground water table. Below this, water is stored and released forming the base flow component of stream flow. The maximum rate at which water can infiltrate the soil is the soil's infiltration capacity. If rainfall intensity exceeded infiltration capacity water would at first be retained on the surface and would fill hollows and small depressions, after which it would begin to flow overland as sheetflow until it reached the channel network which provides the surface runoff component of streamflow.

The overland flow model became the basis for streamflow estimation techniques such as the rational formula and unit hydrograph theory. These in turn, envisaged that all of a basin's drainage area would contribute to stream runoff. However, problems were encountered in separating flood hydrographs into the two components of base flow and overland flow. Field work reveals that overland flow is not often experienced except in arid and arctic regions. Even for arid regions, it may be typical but its temporal frequency is low. Also field observations reveal that precipitation intensity seldom exceeds infiltration capacity; and water flow can not only occur below the surface, but also above the ground water table. This evidence led to the postulation of the throughflow model. Several types of throughflow have since been distinguished:

> "Some authorities have referred to throughflow as the flow that occurs in the soil horizons, especially above relatively impermeable layers such as the junction of the A and B horizons; and to interflow as the lateral flow that occurs in the aeration zone above the level of permanent saturation but below the A and B soil horizons. Others (for example, Jamieson and Amerman, 1969) referred to quick return flow in the soil layers, delayed return flow in the aeration zone, and prolonged return flow from the saturation zone. Necessarily, the location and extent of subsurface flow will reflect local conditions and particularly the presence of impeding layers in the profile below the surface. In practise a distinction between several types is a convenient simplification of the complex continuum which exists in reality." (Gregory and Walling, 1973, p.29).

The throughflow model has been recently modified by the realization of the dynamic nature of the drainage basin and its stream network. Thus concepts of Unit Source Areas and Partial and Variable Source Areas have been proposed. These methods recognise that the simultaneous generation of surface runoff over an entire drainage basin is improbable during most rainfall events. Instead, they suggest that surface runoff is generated from a small proportion of the total drainage basin area. Recent studies in temperate regions have shown that a major portion of storm runoff is produced by surface flow and 'return flow' (upslope throughflow emerging at the surface), from quickly saturated zones proximate to stream channels and at the foot of slopes (Anderson and Burt, 1978; Dunne and Black, 1970; Carson and Sutton, 1971;and Hewlett and Hibbert, 1967). With continued rainfall the saturated areas expand. Also, depending on antecedent soil moisture conditions, the areas that contribute to runoff may vary from one rainfall event to another. Thus the partial areas contributing to surface runoff are dynamic.

Snowmelt is of paramount importance to the runoff regime of northern watersheds. To reiterate, the predominant annual event in the Yukon watersheds is the spring snowmelt flood. Therefore, concepts which attempt to describe the runoff regime in these drainage basins must account for the snowmelt process. This involves successfully describing such processes as: the state, ripening and ablation of the winter snow pack; the movement of melt water (and incident rainfall) in and through the snowpack; and the effect of permafrost and seasonal frost combined with antecedent soil moisture conditions.

The 'ripening' and subsequent ablation of a snowpack are complex processes and are best described by considering the sources of energy for these processes. The term 'ripening' refers to the process whereby a snowpack approaches a saturated condition and a temperature of 0^{o}c.. The amount of energy absorbed by a snowpack depends on many factors, but of prime concern are the albedo (reflectivity of the snow surface), and the density of the pack. Since snowmelt is a thermodynamic process it can be described by the following equation:

$$Q_s = Q_r + Q_a + Q_{wv} + Q_s + Q_p \quad .....(5.16)$$

The energy available for snowmelt Q_s, being derived from: (1) the net all-wave radiation flux, Q_r; (2) conduction and convective transfer of sensible heat from the overlying air, Q_a; (3) condensation of water vapour from the overlying air, Q_{wv}; (4) conduction from the underlying soil, Q_s; and (5) heat supplied by incident rainfall, Q_r.

While evaluation of the individual components of equation 5.16 can calculate snowmelt at a point, the energy-equation technique is generally far too complex to apply over an entire watershed (Gray and Male, 1981). This is because the effect of variations in elevation, slope, aspect and vegetation cover on the melt factors (e.g. net radiation flux, air temperature, wind and humidity), are hard to adequately assess over the whole basin. However, other indicators of the energy available for snowmelt have been proposed and by far the most successfully applied of these is air temperature, there being two main reasons for this. First, air temperature data is widely available; and second, estimates of snowmelt from air temperature indices agree well with results obtained from detailed analysis of the terms in the energy equation over an entire watershed (U.S. Army Corps of Engineers, 1956).

"In general, air temperature is a good index of the energy available for melt in areas covered by dense forest vegetation. In this situation the long-wave radiation exchange between the vegetation canopy and the snow, which is a function of the temperature diffrences between the two surfaces, is the most important energy flux. ....In contrast, temperature is not as reliable an index for open areas because short-wave radiation, sensible and latent heat fluxes (none directly related to temperature), can exhibit wide variations depending on weather conditions (Male and Gray, 1981, p. 417).

Usually, the ripening of the winter snow pack is a relatively rapid process. In the Yukon watersheds the snow pack generally attains its maximum water equivalent in early to mid May, with snowmelt ensuing in late May and early June and lasting from two to four weeks (D.I.A.N.A. snow course records, unpub.).

The movement of snowmelt runoff (and incident rainfall), from a snowpack to a stream involves the continuous interaction of many different types of flow. These include: the slow downward percolation of melt water from the snow surface to the ground; flow along the ground surface, either in a `slush' layer or in drainage channels; and flow through the ground (Male and Gray, 1981). Generally, until a snowpack becomes isothermal at 0^{o}c. any water introduced to the pack will refreeze, thereby accelerating the ripening process. However, when the temperature of the pack does reach 0^{o}c. snowmelt commences and melt water slowly percolates downwards from the snow surface. Surface melt water can also flow down through the pack in isolated channels of coarse-grained snow which act as drains or preferred paths for meltwater, although the formation of these channels is often associated with rain on snow (Gerdel, 1954; in Male and Gray, 1981). The presence of relatively impermeable, high density layers within the pack also affects the downward movement of melt water. Water may accumulate above these layers, forming a saturated layer within the snowpack. If these layers are sloped, lateral flow may occur along them for short distances until a drain or percolation zone is reached (Gerdel, 1948; and Langham, 1974).

A 'slush' (saturated) zone may occur at the snow-ground surface with the accumulation of sufficient melt water (Colbeck 1974, and 1978)). Colbeck (1974) developed the basic theory for flow in this zone and suggests that it is relatively rapid when compared to the downward percolation of water through the pack. The rate of lateral fow in the slush layer depends on the rate of inflow, the permeability and structure of the snow in the slush layer, and the ground surface slope and roughness. In summary, a melting snowpack can be simply conceived as consisting of two distinct zones; a slush layer at the snow-ground surface which is fed by an overlying, unsaturated melting snow cover.

Another factor which influences the lateral movement of melt water on the ground surface is the combination of frozen ground and the moisture content of the soil. During the snowmelt period Yukon watersheds are invariably underlain by frozen ground. Whether frozen ground is impermeable to melt water very much depends on its structure, temperature and moisture content before it was frozen. A variety of ground infiltration conditions have been noted in the literature (Male and Gray, 1981). These range from the impermeable surface presented by a well moistened frozen soil to the initial, relatively permeable condition of a dry frozen soil.

As seasonal frost thaws during the summer, a Yukon watersheds response to precipitation can be expected to gradually approach the dynamic Partial and Varying area models. However:

> "the presence of permafrost at shallow depth inhibits the deep infitration of water, and encourages immediate runoff of a high proportion of input water once the active layer becomes wet." (Church, 1974 p.11).

The active layer refers to the thermally active layer that blankets permanently frozen ground - the zone of seasonal freeze and thaw activity. Permafrost, nevertheless, should not be considered as impermeable to water flow. Williams and Van Eggerton (1973) have proposed that permafrost areas have a low but finite permeability which is confirmed by the many:

> "instances of developed water supplies, springs, and artesian aquifiers in permafrost basins." (Newbury, 1974, p.32).

5.4a TOTAL CHANNEL LENGTH (TCHL)

The importance of total channel length lies in the fact that the more extensive the channel network, the more rapid and larger will be the basin's flood response to water input. Recent studies, in more temperate regions than this study, have shown that a major part of storm runoff is produced by overland flow and return flow from quickly saturated areas bordering the stream channels. Therefore, the amount of water which can rapidly reach the stream should intrinsically, reflect the size of the channel network. Other flood studies have shown that watershed area was the most important independent variable. However, considering that a large part of a watershed's area does not contribute directly to surface runoff, it may be that total channel length is a better measure of the runoff contributing areas of a watershed.

Gregory and Walling (1968) have shown that, for two small watersheds in southeast Devon, stream discharge was related to the square of total channel length. Weyman (1970) surmised that if only the surface runoff component of streamflow is considered, then discharge may be directly proportional to total channel length. This is an interesting conjecture especially when applied to northern watersheds underlain by seasonal frost and permafrost. The presence of frozen ground may effectively restrict the downward movement of water through the soil and promote surface flow (plus return flow in the active layer during the summer). Many researchers (e.g. Ambler (1974), Anderson (1974), Marsh and Woo (1981), and Newbury (1974)) have reported high rates of surface runoff from both snowmelt and rainfall on arctic and sub-arctic watersheds. If surface runoff is the major mechanism of water supply to northern streams, stream discharge should then be directly proportional to total channel length. This assertion is favourably supported by the flood equations (5.8, 5.12, 5.13, 5.14, & 5.15) derived by the regression analysis. The exponents for total channel length in the equations are less than unity, but the overall trend of the exponent approaches unity with increased flood levels thus implying that as surface flow becomes more dominant, the more severe is the flood. In terms of the overall framework of the flood equations, the fact that TCHL is the dominant variable is encouraging since a stream channel network is a naturally adjusting system which reflects prevailing climatic conditions modified to a certain extent by underlying geologic structure.

5.4b MEAN ANNUAL PRECIPITATION (PRECIP)

Obviously, the amount of water available will also affect the flood response of a stream and an average measure of this amount is provided by mean annual precipitation. As flood levels increase the exponent for mean annual precipitation gradually decreases approaching unity for the twenty year flood (equations 5.6 to 5.10). This may suggest that mean annual precipitation is more closely related to floods of the mean annual range than to larger ones. This may be due to the increasing significance of other factors that affect the magnitude of the larger floods such as the rate of snowmelt and antecedent soil moisture conditions.

5.4c NORMALIZED ASPECT (NASP)

Establishing the significance of normalized aspect is probably best approached from the standpoint of how it affects the mean annual flood in equation 5.8. Normalized aspect measures the north-south orientation of a basin. It does not however, distinguish between east facing and west facing basins. In addition, it should be pointed out that the value of normalized aspect cannot equal zero. Therefore, a watershed's aspect cannot be true north, it can, however, be very close - one degree east or west of north being the limit. If the other independent variables in equation 5.8 are held constant and normalized aspect is allowed to vary, then the effect of normalized aspect on the mean annual flood can be assessed. This is easily accomplished with the aid of Figure 5.1.

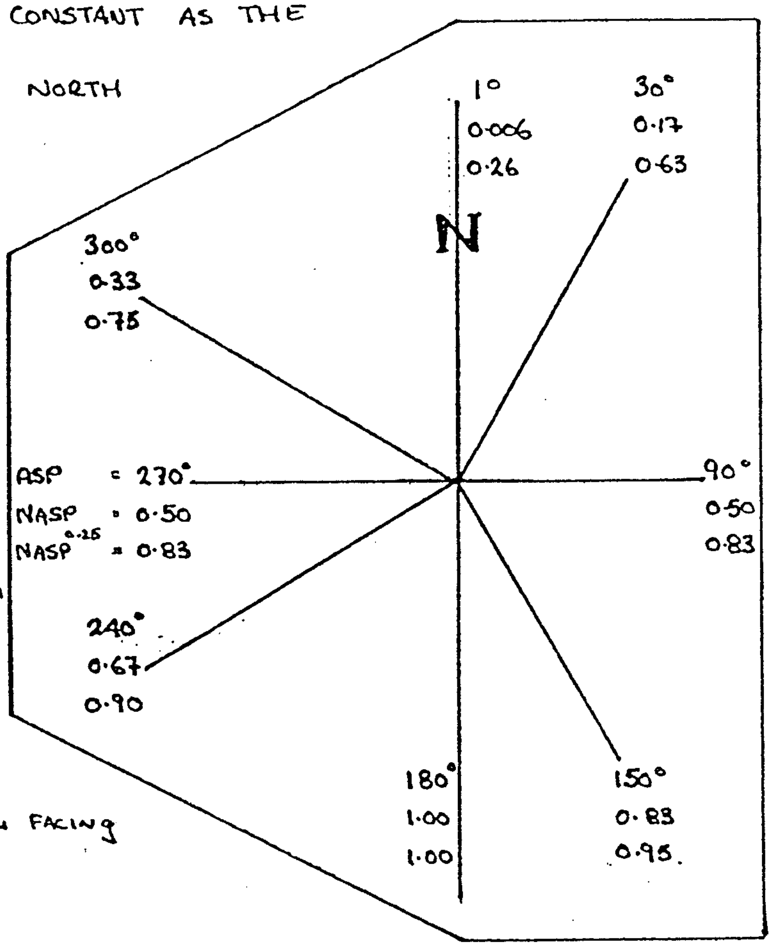
Fig. 5.1 THE EFFECT OF NASP ON MEAN ANNUAL FLOOD.

THE MEAN ANNUAL FLOOD IS DETERMINED FROM

$$Q_{MA} = 0.0044\ TCHL^{0.76}\ PRECIP^{1.38}\ NASP^{0.25}\ HYPI^{0.85} \quad \ldots (8)$$

IF TCHL, PRECIP, AND HYPI REMAIN CONSTANT AS THE WATERSHED ROTATES FROM SOUTH TO NORTH

THEN $Q_{MA} = C\left(NASP^{0.25}\right)$



FOR A WATERSHED FACING SOUTH

$Q_{MA} = C\,(1.0)$

FOR A WATERSHED FACING W.S.W.

$Q_{MA} = C\,(0.90)$

= 10% LESS THAN Q_{MA} FOR A SOUTH FACING WATERSHED.

FOR A WATERSHED FACING N.N.E

$Q_{MA} = C\,(0.63)$

= 37% LESS THAN Q_{MA} FOR A SOUTH FACING WATERSHED.

THEREFORE THE EFFECT OF NASP IS TO REDUCE THE POTENTIAL LEVEL OF THE Q_{MA} FOR WATERSHEDS WITH NORTHERLY ASPECTS

Examination of this diagram illustrates the effect that the variable has on mean annual flood. The more southerly a watershed's aspect, the greater the flood hazard associated with its stream.

A possible interpretation for the role of normalized aspect in the flood model might lie with the low sun angle experienced in the sub-arctic during the snowmelt period, i.e. south facing watersheds receive more hours of direct sunlight and present a greater angle of incidence to incoming solar radiation than do their shadowed northern counterparts. Therefore, southern facing basins should sustain relatively warmer climates and more rapid snowmelt activity.

Another plausible explanation for the role of normalized aspect unfolds when the northwest to southeast trend of the mountain ranges of the southern Yukon Territory are considered. The southern slopes of these ranges generally experience wetter conditions because of greater orographic precipitation from incursions of moist Pacific air masses, as compared with the more sheltered northern facing slopes and leeward regions of the interior. The northwestward variation in the average number of storms per day and the average amount of precipitation per storm from the Gulf of Alaska to Norman Wells are shown by monthly isohyet maps constructed by Veruschuren and Meheriuk (1973). These isohyets closely conform to the topography of the coast and mountain ranges. Therefore these maps support this conjecture that normalized aspect reflects an important phenomenon of the hydrology of the southern Yukon.

5.4d HYPSOMETRIC INTEGRAL (HYPI)

The role of hypsometric integral is very similar to that of the variable normalized aspect in equation 5.8. Once again, by holding the other independent variables of equation 5.8 constant and by varying the hypsometric integral the effect on mean annual flood can be determined. The hypsometric integral for a basin can realistically be assumed to range between 0.15 and 0.65. Thus, $HYPI^{0.85}$ will range between 0.20 and 0.70. The effect that hypsometric integral has on the magnitude of the mean annual flood is clear. The larger a basin's hypsometric integral the greater, or more severe, are the floods. This is noteworthy from the point of view of the erosional capacity of a stream network. A basin with high hypsometric integral (i.e. a high integral basin) has considerably more work to do in terms of erosion and transportation of material than a low integral basin. However, this disparity is somewhat compensated for by the greater flood potential that exists on high integral basins as expressed by the flood model.

The importance of hypsometric integral as a hydrologic variable has remained vague. MacDonald and Lewis (1973, p.12) suggest that:

> "hypsometry can play an important role in determining the form of a rivers hydrograph when snowmelt is a major component of total runoff. A 'mature' basin can be expected to have a flatter hydrograph than the 'monadnock' or 'youthfull' types. In these last two types a large proportion of the total area lies within a narrow elevation range and, assuming no interference from other factors, maximum rates of snowmelt will occur at the same time over most of the basin."

This same premise could reasonably be applied to rainfall activity, changes in soil mantle and vegetation cover with altitude, their effect, however, on hydrograph shape may be different. The general consensus of opinion is that hypsometry reflects a number of processes that vary with altitude (McDonald and Lewis, 1973).

Although these are valid conjectures concerning the influence which hypsometry has on streamflow, they do not account for the precise nature of the relationship between the hypsometric integral and floods, as expressed by the flood model. Why does a basin with a high hypsometric integral experience a greater or more severe flood regime than a basin with a low hypsometric integral? It is hypothesized that the hypsometric integral is a measure of the relative potential energy available to a watershed's runoff response processes to water imput in the same way that stream slope is a measure of the energy available for flow within the stream channel. In order to explain this hypothesis it is necessary to distinguish physically between a drainage basin with a high hypsometric integral and a basin with a low hypsometric integral. On a high integral basin the majority of the drainage area is concentrated in the upper reaches of the basin, whereas most of the drainage area of a low integral basin lies within its lower altitudes. During the snowmelt period on a high integral basin a perched or hanging water table may gradually form in the saturated layer of the snowpack on the valley side slopes. The large head available to flow in this slush layer may then feed and promote the rapid expansion of down-slope saturated zones within the snowpack proximate to the stream channels. Thus the surface flow (and shallow return flow, if the active layer is thawing), from these zones would be tremendously enhanced. This same premise may also apply to the infrequent high intensity rain storm event. Perched saturated zones forming in the active layer on the valley side slopes thus promoting the rapid growth of downslope saturated zones near the stream channels from which surface flow is derived. Therefore, a high integral basin would realize a rapid response to snowmelt and rainfall resulting in high flood levels.

Alternatively, a basin with most of its drainage area concentrated in its lower reaches would have a vastly diminished potential head available for the charging of saturated zones in the valley bottoms. Further-more, a low integral basin has a greater potential for wetlands than does a high integral basin. The correlation coefficient between hypsometric integral and area of lake and marsh is -0.58. Therefore, a low integral basin has a greater storage capacity and thus a muting effect on its flood waters. The above is a hypothesized account of why the hypsometric integral is an important hydrological variable in the flood model.

The purely conjectural nature of this discussion concerning the importance of the variables: total channel length; mean annual precipitation; normalized aspect; and hypsometric integral to northern hydrology must be stressed. The reasons elucidated for their importance in the regression equations, although plausible, are still unsubstantiated. The opinions expressed are subject to the need for further research, without which this theorizing will remain speculative. My own observations and deductions are sufficiently encouraging for me to form the firm opinion that such additional research is warranted.

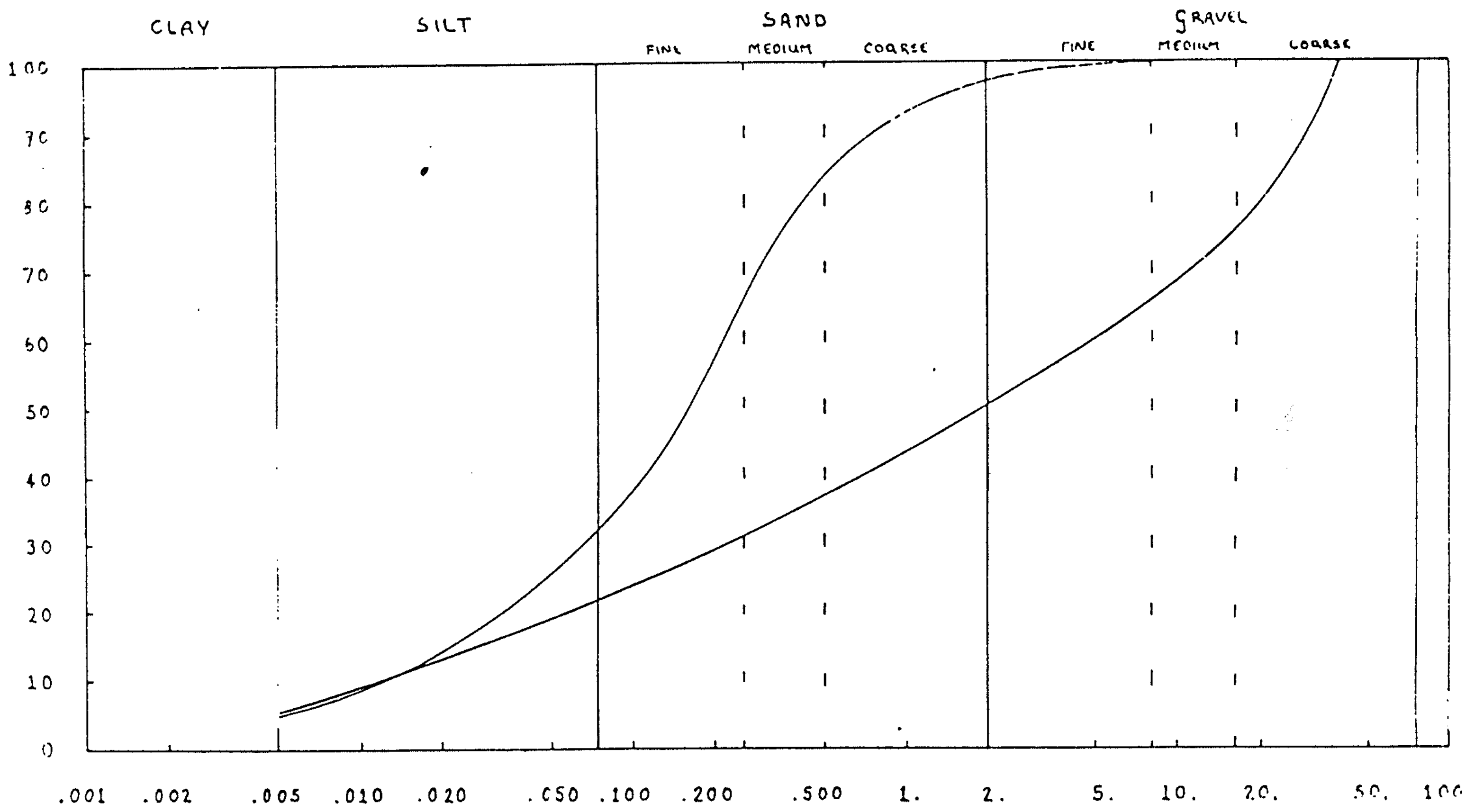
5.5 DALE CREEK: A TEST OF THE FLOOD MODEL

A suggested procedure for using the proposed flood model to estimate flood discharges is afforded by its application to Dale Creek. Since Dale Creek was not included in the regression analyses and has one of the longest records of streamflow (albeit only six years), the results from the regression model can be compared to its historical annual maximum floods series.

Dale Creek is a tributary of the Tsichu River, located in the Selwyn Mountains at the Yukon - Northwest Territories border (Long. 130^{o} 05′, Lat. 63^{o} 16′). The streamflow recording station on Dale Creek at aproximately 1460 m.asl defines a watershed of some 13.1 sq.km. with a relief of 860 m..The stream flows to the east through a broad U-shaped valley which opens onto the MacKenzie Barrens - a high and vast sub-arctic tundra plateau. A lush alpine meadow, dotted with a few ponds and wetlands occupies the floor and lower slopes of Dale Valley grading upwards to high talus slopes. Thirteen rock glaciers ribboning the south-facing valley side wall have been identified by Kershaw (1978).

Flowing between well defined overhanging banks, Dale Creek in its lower course, exhibits typical pool and riffle development, interspersed by relatively steeper, straight reaches of deep and rapid flow. The banks of Dale Creek are stable even though there is a high percentage of sand and silt in the bank material (Fig. 5.2,). This stability is attributable to the presence of permafrost that affords protection along the bank face. The bed material ranges in size from coarse sand to boulders and is comprised mainly of mudstones, greywackes and fine grained felsites, the felsite being weathered to a striking orange sheen. Some crumbly marblized limestone breccia is also present in the bed material.

Fig. 5.2 Dale Creek Size-Distribution Curves for Two Samples of Bank Material.



A meteorology station, operative since 1974 lies some 8 km. to the east of Dale Creek at the Tsichu River airstrip. Preliminary estimates of the climate by Kershaw and Gill (1979) show a mean January temperature of $-19.4^{\circ}c.$ and a mean June temperature of $6.7^{\circ}c.$. A mean annual precipitation greater than 76 cm. occurs, of which the snowfall is greater than 343 cm..

To recapitulate the proposed flood model is:

$$QMA = 0.0044\ TCHL^{0.76}\ PRECIP^{1.38}\ NASP^{0.26}\ HYPI^{0.85} \quad \text{...(5.8)}$$

$$\frac{Q20}{QMA} = 4.75\ TCHL^{0.12}\ PRECIP^{-0.35} \quad \text{....(5.12)}$$

$$\frac{Q10}{QMA} = 3.86\ TCHL^{0.08}\ PRECIP^{-0.29} \quad \text{.....(5.13)}$$

$$\frac{Q5}{QMA} = 2.32\ TCHL^{0.04}\ PRECIP^{-0.18} \quad \text{......(5.14)}$$

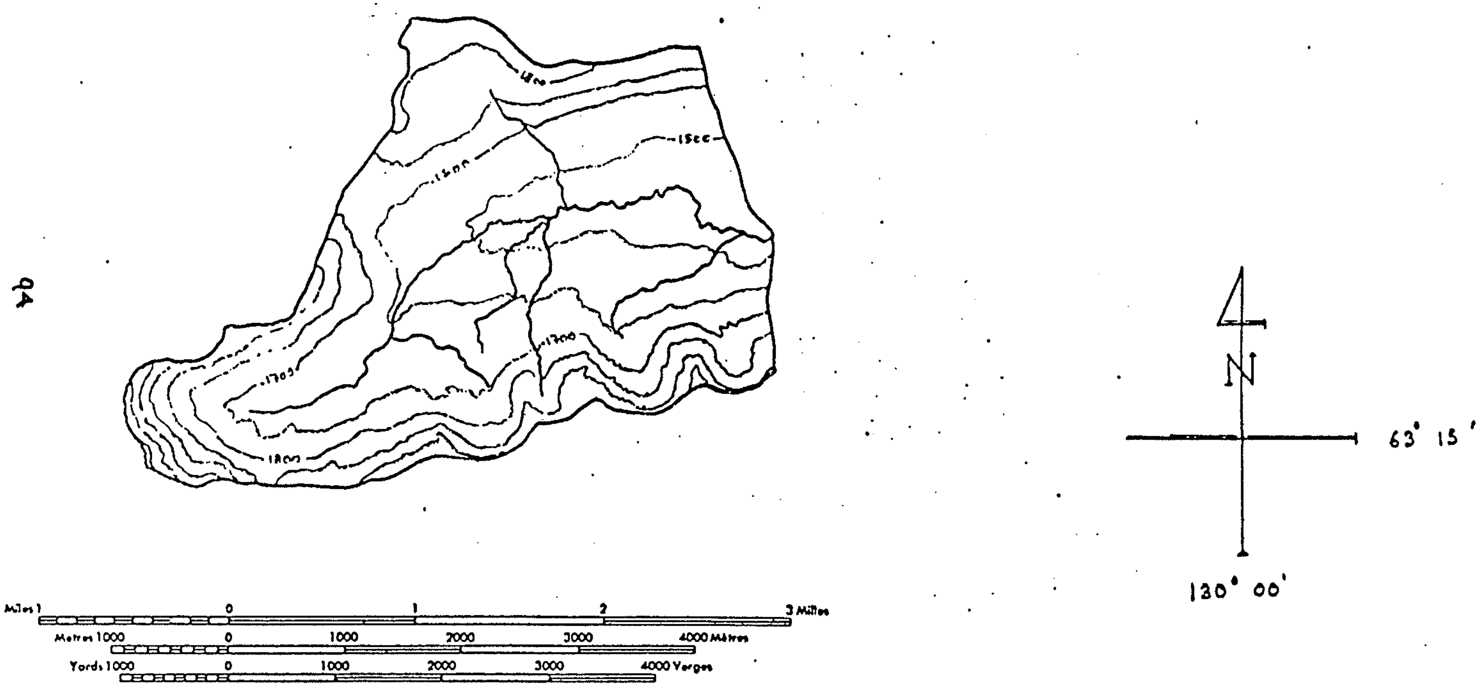
$$\frac{Q2}{QMA} = 0.78\ TCHL^{-0.01}\ PRECIP^{0.06} \quad \text{......(5.15)}$$

In order to evaluate the model as it applies to Dale Creek the values of the three independent variables, total channel length, normalized aspect and the hypsometric integral were measured from the 1:50,000 N.T.S. map sheets (Fig. 5.3a and b). These values are:

TCHL = 13.0 km.

$$NASP = (ASP)/180 = 70/180 = 0.39$$

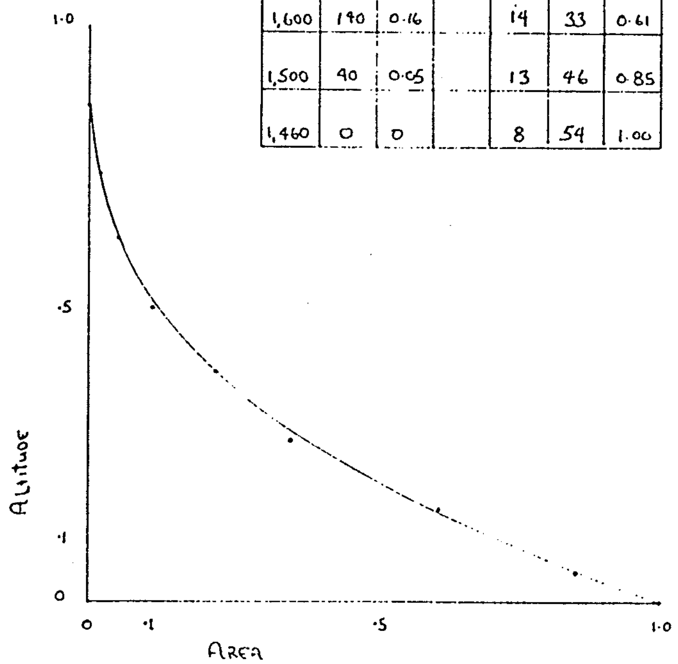
Fig. 5.3a.



Dale Creek.

Fig. 5.36. Dale Creek; Calculation of Hypsometric Integral

Elev.	Elev.-h	Elev.-h / Rel.		#	Σ#	Σ# / Tot.
2,320	860	1.00		0	0	0
2,300	840	0.98		0	0	0
2,200	740	0.86		0	0	0
2,100	640	0.74		1	1	0.02
2,000	540	0.63		2	3	0.05
1,900	440	0.51		3	6	0.11
1,800	340	0.40		6	12	0.22
1,700	240	0.28		7	19	0.35
1,600	140	0.16		14	33	0.61
1,500	40	0.05		13	46	0.85
1,460	0	0		8	54	1.00



Hypsometric Integral = 0·25

$$HYPI = 0.25 ; \text{(Fig 5.3)}$$

The value for mean annual precipitation was derived from recorded precipitation data at Tsichu River from 1974 to 1982.

$$PRECIP = 80 \text{ cm.}$$

The values for total channel length, annual precipation, normalized aspect, and hypsometric integral can now be substituted into the equations of the flood model and the flood levels computed.

$$QMA = 0.0044\,(13.0)^{0.76}\,(80.0)^{1.38}\,(0.39)^{0.26}\,(0.25)^{0.85}$$
$$= 3.15 \text{ cumecs.}$$

The flood ratios yield:

$$Q20/QMA = 4.75\,(13.0)^{0.12}\,(80.0)^{-0.35}$$
$$= 1.39$$
$$\text{therefore, } Q20 = 1.39(QMA)$$
$$= 4.40 \text{ cumecs.;}$$

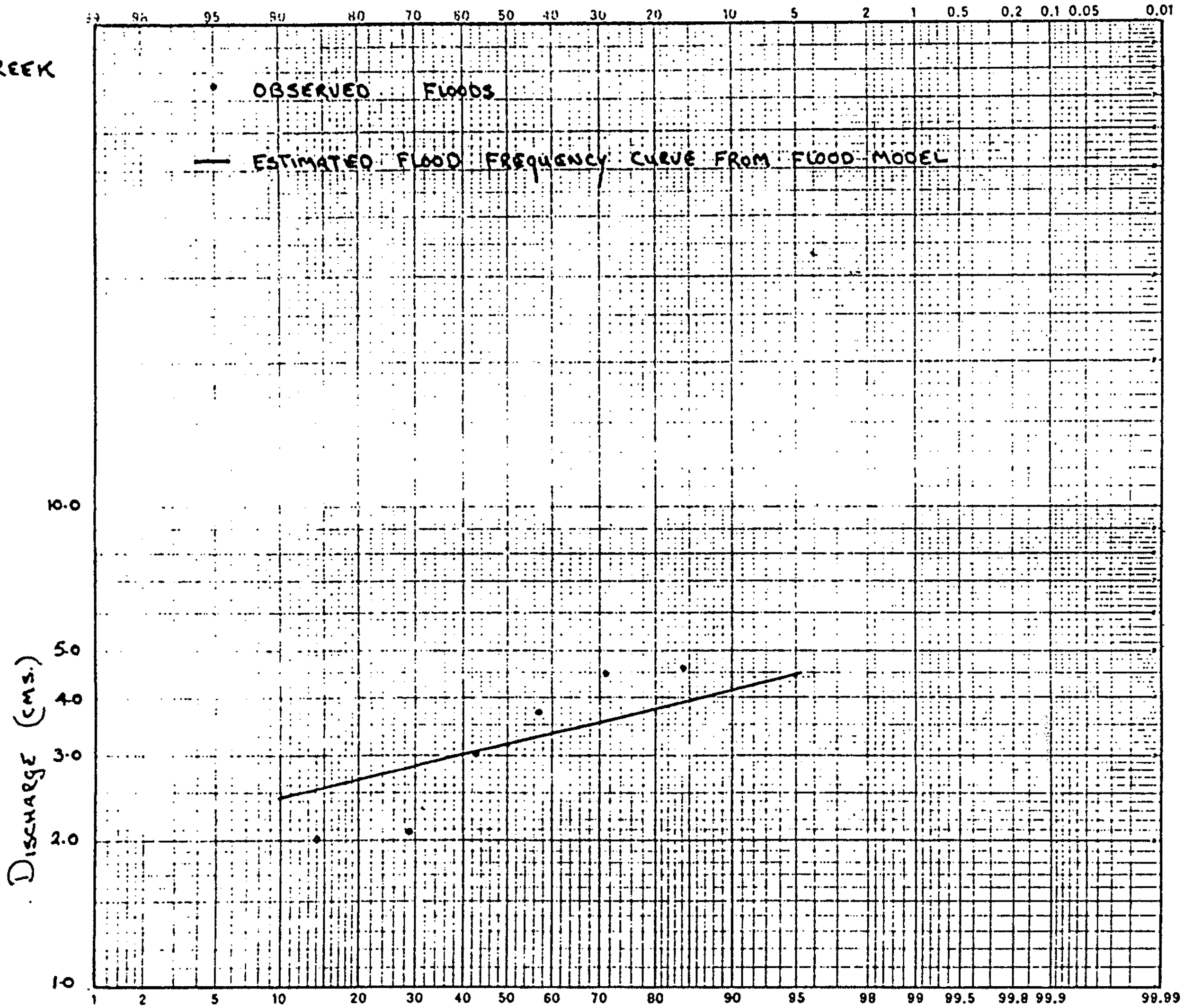
$$Q10/QMA = 3.85\,(13.0)^{0.08}\,(80.0)^{-0.29}$$
$$= 1.32(QMA)$$
$$\text{therefore, } Q10 = 4.2 \text{ cumecs.;}$$

$$Q5/QMA = 2.32\,(13.0)^{0.04}\,(80.0)^{-0.18}$$
$$= 1.17(QMA)$$
$$\text{therefore, } Q5 = 3.7 \text{ cumecs.; and}$$

$$Q2/QMA = 0.78\,(13.0)^{-0.01}\,(80.0)^{0.06}$$
$$= 0.99(QMA)$$
$$\text{therefore, } Q2 = 3.1 \text{ cumecs}$$

The computed discharges are plotted on log-probability paper (Fig. 5.4). Also included are the recorded annual floods.

Fig. 5.4 Dale Creek



At this point it must be noted that prior to proceeding on any discussion of the comparison between the observed and the predicted flood discharges there is an important factor which must be considered. The highest flow metered on Dale Creek is 3.0 cumecs. whereas the highest recorded stage equates with a flow of 4.6 cumecs., this figure being extrapolated from the stage-discharge curve. However, the good definition of the stage-discharge curve for flows less than 3.0 cumecs. suggests that the error involved in the extrapolation of flows from the higher recorded stages may be small. Definition of the upper tail of the stage-discharge relationship is a common problem experienced in the use of flow data from recently established stream gauging stations (this being previously discussed in Chapter 4, sec.2).

In Fig. 5.4 the predicted flows closely conform to the flood frequency curve derived from the historic flood series. However, this comparison should not be construed as the definitive test of the model. Since the flood model does work in this instance, its application to other streams in the southern Yukon does look promising. As yet it is not possible to apply the model to other streams with a long history of recorded flows for comparison purposes, mainly because there are no others at this present time, except for those streams used to derive the model.

To test the model on streams in other parts of the country is not necessarily a valid option either, because this will not test its effectiveness in the region it was designed to cover. Therefore, time and use will be the ultimate judge of the effectiveness of the model.

5.6 CONCLUSION

A flood model (equations 5.8, 5.12, 5.13, 5.14 and 5.15), which can be easily and quickly applied (in the field if need be), has been derived to estimate flood-frequencies for ungauged streams in the southern Yukon.

The flood model is composed of four variables. These are: total channel length (TCHL); mean annual precipitation (PRECIP); normalized aspect (NASP); and the hypsometric integral (HYPI). The suggested reasons for why these variables are important to the hydrology of the southern Yukon are summerized in the following statements.

TCHL measures the relative size of a watershed and the quickness of its stream networks response to snowmelt and rainfall activity.

PRECIP measures the amount of water available for streamflow.

NASP measures the north-south aspect of a watershed. It is hypothesized that watersheds facing south experience higher flood regimes because of prevailing weather patterns and greater snowmelt rates than do their shadowed northern counterparts.

HYPI measures a watersheds area-altitude distribution. It is hypothesized that HYPI is a relative measure of the potential energy available to a watersheds runoff response processes to snowmelt and rainfall activity.

The overall framework of the flood model is conceptually acceptable. The two variables TCHL and PRECIP express the dynamic hydrological aspects of a watershed, while NASP and HYPI measure its relatively stable geomorphologic state. The succesful application of the flood model to a test watershed (Dale Creek) augurs well for its operational use in the southern Yukon.

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APPENDIX 1

VARIABLE LISTING

LIST OF PREDICTED VALUES, RESIDUALS, AND VARIABLES
NOTE - NEGATIVE CASE NUMBER DENOTES A CASE WITH MISSING VALUES.
THE NUMBER OF STANDARD DEVIATIONS FROM THE MEAN IS DENOTED BY UP TO 3 ASTERISKS TO THE RIGHT
OF EACH RESIDUAL OR VARIABLE.
MISSING VALUES AND VALUES OUT OF RANGE ARE DENOTED
BY VALUES GREATER THAN OR EQUAL TO 0.2127E 38 IN ABSOLUTE VALUE.
MISSING VALUES ARE DENOTED BY MORE THAN THREE ASTERISKS.

CASE NO.	LABEL	PREDICTED	RESIDUAL		WEIGHT	VARIABLES 80 LQMA	3 LONG	4 LAT	5 RANK	6 ELEV	7 AREA
1	SPENCER	1.271	-0.1574		1.000	1.114	130.2	60.13	4.000	868.0	155.6
2	FREER	0.6266	0.1216		1.000	0.7482	130.5	60.07	3.000	899.0	45.60
3	PARTRIDG	0.8848	0.1831E-01		1.000	0.9031	131.2	59.97	3.000	883.0	61.70
4	LOGJAM	0.9428	-0.1946		1.000	0.7482	131.5	59.50	4.000	848.0	88.20
5	STRAWBER	0.4884	-0.4124E-01		1.000	0.4472	132.3	60.08	3.000	731.0	62.90
6	DEADMAN	0.9884	0.2020		1.000	1.190	133.1	60.33	4.000	687.0	220.7
7	JUDAS	0.5925	0.7030E-01		1.000	0.6628	134.1	60.38	4.000	746.0	183.1
8	WOLF	0.6825	-0.8044E-01		1.000	0.6021	134.9	60.60	4.000	716.0	173.1
9	GRAVELWA	-0.2013	-0.3363	*	1.000	-0.5376	135.3	60.82	2.000	731.0	25.80
10	STONY	0.3004	0.4203E-01		1.000	0.3424	136.0	60.80	3.000	716.0	36.60
11	MARSHAL	0.8573	-0.1583		1.000	0.6990	137.3	60.85	4.000	670.0	221.6
12	BEAR	0.4462	0.1101		1.000	0.5563	137.7	60.80	3.000	641.0	71.60
13	BURWASH	0.8763	-0.1215E-02		1.000	0.8751	139.2	61.40	4.000	868.0	166.8
14	LONG'S	0.9770	0.3241	*	1.000	1.301	140.2	61.85	4.000	685.0	112.7
15	DRY	0.8522	0.5150E-02		1.000	0.8573	140.7	62.17	4.000	685.0	137.2
16	ENGER	0.2418	0.1895		1.000	0.4314	140.8	62.30	4.000	716.0	67.20
17	STANLEY	1.012	-0.2088E-01		1.000	0.9912	136.8	59.93	4.000	868.0	75.10
18	MULE	0.6052	-0.2435	*	1.000	0.3617	136.6	59.78	3.000	868.0	22.40
19	STONEHOU	0.5512	0.1812		1.000	0.7324	136.5	59.63	2.000	944.0	10.90
20	MURPHY	0.8766	0.3409	*	1.000	1.217	133.0	61.63	3.000	792.0	112.9
21	GROUNDHO	0.8473	0.1070		1.000	0.9542	133.0	61.30	3.000	1097.	66.60
22	BACON	0.8323	0.1219		1.000	0.9542	133.0	61.78	3.000	1050.	61.50
23	150 MILE	0.9665	-0.5802E-01		1.000	0.9085	131.7	62.30	3.000	808.0	80.80
24	TWIN	0.9076	-0.2263	*	1.000	0.6812	131.3	62.62	3.000	1480.	45.10
25	RIDDELL	0.9881	0.1486		1.000	1.137	131.1	62.68	4.000	910.0	53.00
26	BOULDER	1.198	0.1075		1.000	1.305	130.8	62.87	4.000	910.0	85.40
27	MAC 2	1.529	-0.1746		1.000	1.354	130.2	63.10	4.000	1100.	183.3
28	VANGORDA	0.8239	-0.2557	*	1.000	0.5682	133.4	62.23	4.000	696.0	87.70
29	BIG GOLD	0.9947	-0.3319	*	1.000	0.6628	140.8	64.03	4.000	716.0	49.40
30	CLINTON	1.371	-0.3497	*	1.000	1.021	140.6	64.40	4.000	320.0	209.7
31	THISTLE	1.086	0.3121	*	1.000	1.398	139.5	63.07	5.000	381.0	208.2

32	BENSON	1.226	0.2291 *	1.000	1.455	138.5	64.17	4.000	686.0	88.10
33	WOLF DEM	1.039	0.1517	1.000	1.190	138.4	64.37	3.000	868.0	67.60
34	GRIZZLY	0.7668	0.7829E-01	1.000	0.8451	138.3	64.40	3.000	929.0	33.30
35	UNNAMED	1.307	-0.1459	1.000	1.161	138.3	64.95	4.000	899.0	222.0
36	BIG THIN	0.3662	-0.8742E-01	1.000	0.2788	134.5	60.07	3.000	671.0	35.70

ACH ASTERISK REPRESENTS ONE STANDARD DEVIATION

IST OF PREDICTED VALUES, RESIDUALS, AND VARIABLES (CONTINUED)

CASE NO.	LABEL	8 PER	VARIABLES 9 STL	10 BAL	11 TCHL	12 REL	13 ASP	14 CASP	15 BSH1	16 BSH2
1	SPENCER	59.60	25.60	21.50	127.0	1165.	111.0	-0.3584	0.3400	22.83
2	FREER	29.00	11.00	10.80	40.70	1128.	3.000	0.9986	0.3900	18.44
3	PARTRIDG	42.60	18.50	15.40	45.80	1195.	162.0	-0.9511	0.2600	29.41
4	LOGJAM	42.80	17.60	14.50	74.00	1043.	182.0	-0.9994	0.4200	20.77
5	STRAWBER	32.30	14.00	10.60	33.00	802.0	251.0	-0.3256	0.5600	16.48
6	DEADMAN	70.00	30.10	23.70	143.8	1206.	180.0	-0.9999	0.3900	22.20
7	JUDAS	65.70	32.30	23.30	122.9	942.0	240.0	-0.5000	0.3400	23.57
8	WOLF	75.50	42.60	28.30	130.2	1372.	66.00	0.4067	0.2200	32.93
9	GRAVELWA	21.00	9.500	8.200	18.00	970.0	4.000	0.9976	0.3800	17.09
10	STONY	30.50	14.00	12.90	22.10	1255:	158.0	-0.9272	0.2200	25.42
11	MARSHAL	69.00	28.50	22.50	129.0	1346.	153.0	-0.8910	0.4500	21.48
12	BEAR	42.00	21.00	16.10	47.20	1020.	162.0	-0.9511	0.2800	31.12
13	BURWASH	69.80	27.30	22.80	178.8	1890.	48.00	0.6691	0.3200	29.21
14	LONG'S	51.00	25.50	16.30	72.50	930.0	175.0	-0.9962	0.4200	23.09
15	DRY	73.00	13.00	21.00	120.0	945.0	73.00	0.2924	0.3100	38.84
16	ENGER	39.50	14.10	12.00	37.40	731.0	343.0	0.9563	0.4700	23.22
17	STANLEY	40.00	18.00	15.00	78.40	1128.	275.0	0.8720E-01	0.3300	21.30
18	MULE	18.70	5.500	6.400	27.00	1097.	64.00	0.4384	0.5500	15.61
19	STONEHOU	15.00	7.800	5.800	11.70	625.0	58.00	0.5299	0.3200	20.64
20	MURPHY	53.00	19.20	16.60	51.00	1143.	70.00	0.3420	0.4100	24.89
21	GROUNDHO	36.00	13.50	12.60	41.50	899.0	283.0	0.2250	0.4200	19.46
22	BACON	36.50	14.70	14.70	40.00	1250.	90.00	0.0	0.2800	21.66
23	180 MILE	49.40	13.00	14.10	80.50	1189.	116.0	-0.4384	0.4100	30.20
24	TWIN	38.50	16.80	11.00	46.00	797.0	171.0	-0.9877	0.3700	32.87
25	RIDDELL	38.20	15.00	13.80	63.10	1197.	112.0	-0.3746	0.2800	27.53
26	BOULDER	40.20	17.30	14.60	137.4	680.0	335.0	0.9063	0.4000	18.92
27	MAC 2	72.50	38.00	22.50	175.3	1111.	217.0	-0.7986	0.3600	28.68
28	VANGORDA	48.50	19.50	16.00	67.10	1376.	248.0	-0.3746	0.3400	26.82
29	BIG GOLD	30.20	10.50	10.00	48.60	660.0	185.0	-0.9962	0.4900	18.46
30	CLINTON	66.50	27.30	24.30	168.9	956.0	103.0	-0.2250	0.3600	21.09
31	THISTLE	66.00	30.50	23.30	269.0	1107.	273.0	0.5230E-01	0.3800	20.92
32	BENSON	52.60	23.00	19.10	105.8	1234.	169.0	-0.9816	0.2400	31.40
33	WOLF DEM	42.00	15.60	14.10	69.70	1265.	74.00	0.2756	0.3400	26.09
34	GRIZZLY	30.00	9.000	11.00	21.80	1234.	108.0	-0.3090	0.2800	27.03
35	UNNAMED	72.00	40.00	24.60	179.4	838.0	46.00	0.6947	0.3700	23.35
36	BIG THIN	25.80	8.100	9.100	26.50	1534.	98.00	-0.1392	0.4300	18.65

IST OF PREDICTED VALUES, RESIDUALS, AND VARIABLES (CONTINUED)

CASE NO.	LABEL	17 DRD	VARIABLES 18 STF	19 RELRA	20 SLOPE	21 BIRA	22 HYPI	23 HYPC	24 GRAD1	25 GRAD2
1	SPENCER	0.8200	0.5200	0.5420E-01	0.3330E-01	4.710	0.4100	0.2400	-0.1940E-01	-0.1190E-01

2	FREER	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3	PARTRIDG	0.7400	0.4700	0.7760E-01	0.2720E-01	4.600	0.3800	0.2400	-0.7760E-01	-0.2590E-01
4	LOGJAM	0.8400	0.4500	0.7190E-01	0.3490E-01	4.290	0.3800	0.2900	-0.7190E-01	-0.3490E-01
5	STRAWBER	0.5200	0.1600	0.7560E-01	0.2500E-01	2.000	0.4100	0.3200	-0.2460E-01	-0.8100E-02
6	DEADMAN	0.6500	0.2100	0.5090E-01	0.2420E-01	4.500	0.4100	0.2900	-0.5090E-01	-0.2420E-01
7	JUDAS	0.6700	0.2500	0.4040E-01	0.1040E-01	4.120	0.3000	0.1800	-0.2020E-01	-0.5200E-02
8	WOLF	0.7500	0.2900	0.4850E-01	0.2150E-01	3.700	0.4300	0.4100	0.1970E-01	0.8700E-02
9	GRAVELWA	0.7000	0.1900	0.1183	0.9150E-01	4.000	0.4600	0.4900	0.1180	0.9130E-01
10	STONY	0.6000	0.2700	0.9730E-01	0.7290E-01	3.500	0.5100	0.6200	-0.9020E-01	-0.6760E-01
11	MARSHAL	0.5800	0.2500	0.6060E-01	0.3210E-01	3.330	0.4500	0.4500	-0.5400E-01	-0.2860E-01
12	BEAR	0.6600	0.2500	0.6330E-01	0.2170E-01	3.250	0.3200	0.1100	-0.6020E-01	-0.2060E-01
13	BURWASH	1.070	0.6500	0.8290E-01	0.3520E-01	3.730	0.3400	0.1500	0.5550E-01	0.2360E-01
14	LONG'S	0.6400	0.2300	0.5700E-01	0.2330E-01	4.750	0.3700	0.3100	-0.5680E-01	-0.2320E-01
15	DRY	0.8700	0.4900	0.4500E-01	0.2340E-01	4.730	0.1800	0.6000E-01	0.1320E-01	0.6800E-02
16	ENGER	0.5600	0.4000	0.6100E-01	0.6500E-02	3.800	0.1700	0.7000E-01	0.5830E-01	0.6200E-02
17	STANLEY	1.040	0.8900	0.7520E-01	0.4400E-01	4.250	0.5000	0.5500	0.6600E-02	0.3800E-02
18	MULE	1.210	0.5400	0.1715	0.8310E-01	2.670	0.3200	0.2600	0.7520E-01	0.3640E-01
19	STONEHOU	1.070	0.6400	0.1080	0.4100E-01	6.000	0.5100	0.4500	0.5720E-01	0.2170E-01
20	MURPHY	0.4500	0.1100	0.6890E-01	0.3810E-01	3.000	0.4900	0.4800	0.2360E-01	0.1300E-01
21	GROUNDHO	0.6200	0.1800	0.7140E-01	0.3840E-01	4.500	0.4800	0.4500	0.1610E-01	0.8600E-02
22	BACON	0.6500	0.2600	0.8500E-01	0.4460E-01	6.500	0.4200	0.4400	0.0	0.0
23	180 MILE	1.000	0.3300	0.8430E-01	0.5280E-01	4.200	0.3500	0.2400	-0.3700E-01	-0.9600E-02
24	TWIN	1.020	0.4400	0.7250E-01	0.3510E-01	2.800	0.3200	0.1600	-0.7160E-01	-0.3470E-01
25	RIDDELL	1.190	0.7200	0.8670E-01	0.5330E-01	4.830	0.3500	0.1600	-0.3280E-01	-0.2000E-01
26	BOULDER	1.610	0.8300	0.4660E-01	0.2310E-01	4.580	0.4600	0.4300	0.4220E-01	0.2090E-01
27	MAC 2	0.9600	0.4500	0.4940E-01	0.1660E-01	5.670	0.4500	0.4300	-0.3950E-01	-0.1330E-01
28	VANGORDA	0.7700	0.3200	0.8600E-01	0.5000E-01	3.170	0.4200	0.2500	-0.3220E-01	-0.1870E-01
29	BIG GOLD	0.9800	0.8100	0.6600E-01	0.4060E-01	3.110	0.4300	0.3000	-0.6570E-01	-0.4040E-01
30	CLINTON	0.8100	0.5700	0.3930E-01	0.2010E-01	3.440	0.3800	0.2200	-0.8800E-02	-0.4500E-02
1	THISTLE	1.290	1.040	0.4750E-01	0.2800E-01	4.420	0.4000	0.2600	0.2500E-02	0.1500E-02
	BENSON	1.200	0.5100	0.6460E-01	0.3710E-01	1.730	0.6300	0.7300	-0.6340E-01	-0.3640E-01
	WOLF DEM	1.030	0.5500	0.8970E-01	0.4400E-01	6.200	0.4500	0.4000	0.2470E-01	0.1210E-01
	GRIZZLY	0.6500	0.3000	0.1122	0.7110E-01	3.500	0.4400	0.3100	-0.3470E-01	0.1150E-01
3	UNNAMED	0.8100	0.3400	0.3410E-01	0.9100E-02	3.730	0.5200	0.4200	0.2370E-01	0.6300E-02
36	BIG THIN	0.7400	0.3400	0.1686	0.1468	2.670	0.6300	0.6900	-0.2350E-01	-0.2040E-01

LIST OF PREDICTED VALUES, RESIDUALS; AND VARIABLES (CONTINUED)

CASE NO.	LABEL	VARIABLES 26 ATR	27 ALM	28 AGL	29 PRECIP	30 INTENS	31 Q2	32 QMA	33 Q5	34 Q10
1	SPENCER	0.3400	0.2000E-01	0.0	68.60	0.3800	11.80	13.00	19.00	24.00
2	FREER	0.7500	0.2000E-01	0.0	68.60	0.3900	5.200	5.600	7.700	9.600
3	PARTRIDG	0.2300	0.2000E-01	0.0	58.40	0.3900	7.800	8.000	9.000	9.600
4	LOGJAM	0.2900	0.2000E-01	0.0	52.10	0.3600	5.100	5.600	8.800	12.50
5	STRAWBER	0.6000E-01	0.3000E-01	0.0	35.60	0.3200	2.500	2.800	4.000	5.200
6	DEADMAN	0.1700	0.2000E-01	0.0	35.60	0.3400	13.00	15.50	28.50	43.00
7	JUDAS	0.9000E-01	0.3000E-01	0.0	25.40	0.3100	4.000	4.600	8.400	13.00
8	WOLF	0.6600	0.6000E-01	0.0	25.40	0.3100	3.500	4.000	6.000	8.100
9	GRAVELWA	0.4200	0.2000E-01	0.0	24.10	0.3200	0.2600	0.2900	0.4400	0.5800
10	STONY	0.7000	0.2000E-01	0.0	24.10	0.3300	1.800	2.200	4.000	5.600
11	MARSHAL	0.3600	0.2000E-01	0.0	27.90	0.3900	4.500	5.000	7.300	9.400
12	BEAR	0.5000E-01	0.1000E 00	0.0	27.90	0.4100	3.200	3.600	5.100	6.200
13	BURWASH	0.5500	0.2000E-01	0.2000E-01	34.30	0.4800	6.500	7.500	12.50	18.00
14	LONG'S	0.1700	0.2000E-01	0.0	45.70	0.5600	19.50	20.00	23.50	26.00
15	DRY	0.3000E-01	0.1900	0.0	50.80	0.5600	6.100	7.200	14.00	22.00
16	ENGER	0.4000E-01	0.1400	0.0	43.20	0.5300	2.500	2.700	3.400	3.700
17	STANLEY	0.9500	0.2000E-01	0.2000E-01	53.30	0.3900	8.800	9.800	15.70	21.50

18 MULE	0.9100	0.2000E-01	0.1200	63.50	0.4100	2.200	2.300	3.000	3.600
19 STONEHOU	1.000	0.7000E-01	0.0	68.60	0.4200	5.000	5.400	6.600	7.600
20 MURPHY	0.3400	0.2000E-01	0.0	47.00	0.3800	15.00	16.50	23.00	29.00
21 GROUNDHO	0.5800	0.2000E-01	0.0	50.80	0.3800	8.200	9.000	12.70	16.00
22 BACON	0.7400	0.2000E-01	0.0	50.80	0.3800	8.200	9.000	12.80	16.00
23 180 MILE	0.2200	0.2000E-01	0.0	45.70	0.4200	7.500	8.100	10.00	11.00
24 TWIN	0.5000E-01	0.5000E-01	0.0	52.10	0.5300	4.400	4.800	6.400	8.000
25 RIDDELL	0.2000	0.4000E-01	0.0	52.10	0.5300	12.80	13.70	17.50	21.00
26 BOULDER	0.1000E 00	0.8000E-01	0.0	55.90	0.5600	19.00	20.20	26.00	31.00
27 MAC 2	0.6900	0.5000E-01	0.1000E-01	62.20	0.6400	20.00	22.60	30.00	37.50
28 VANGORDA	0.2300	0.2000E-01	0.0	35.60	0.3200	3.200	3.700	5.800	8.000
29 BIG GOLD	0.1800	0.2000E-01	0.0	43.20	0.4200	4.300	4.600	6.100	7.400
30 CLINTON	0.6000E-01	0.2000E-01	0.0	50.80	0.6200	9.800	10.50	14.50	19.00
31 THISTLE	0.2000E-01	0.2000E-01	0.0	27.90	0.3600	22.50	25.00	36.00	45.00
32 BENSON	0.7400	0.2000E-01	0.0	34.30	0.3400	26.00	28.50	41.00	54.00
33 WOLF DEM	0.8900	0.2000E-01	0.0	43.20	0.3900	14.00	15.50	23.50	29.00
34 GRIZZLY	0.9500	0.2000E-01	0.0	45.70	0.4200	6.400	7.000	10.00	13.00
35 UNNAMED	0.9400	0.1000E-01	0.0	40.60	0.4800	12.60	14.50	23.50	32.50
36 BIG THIN	0.4700	0.2000E-01	0.0	25.40	0.3300	1.800	1.900	2.850	3.800

ɪST OF PREDICTED VALUES, RESIDUALS, AND VARIABLES (CONTINUED)

CASE NO. LABEL	VARIABLES 35 G20	36 S1085	37 NASP	38 CASP2	39 GRADA	40 GRADB	41 GRADE	42 GRADF	43 RUGN
1 SPENCER	29.50	0.2130E-01	0.6167	1.642	11.38	18.52	30.29	49.30	0.9553
2 FREER	11.50	0.3750E-01	0.1667E-01	2.999	0.1596	0.2732	28.72	49.16	1.004
3 PARTRIDG	10.20	0.1530E-01	0.9000	1.049	11.60	33.09	13.52	38.56	0.8843
4 LOGJAM	16.50	0.3220E-01	0.9889	1.001	13.75	28.33	13.92	28.67	0.8761
5 STRAWBER	6.800	0.2490E-01	0.6056	1.674	8.010	24.22	22.15	66.98	0.4170
6 DEADMAN	60.00	0.2030E-01	1.000	1.000	19.65	41.32	19.65	41.33	0.7839
7 JUDAS	18.00	0.8200E-02	0.6667	1.500	16.50	64.10	37.13	144.2	0.6311
8 WOLF	10.20	0.1690E-01	0.3667	2.407	7.560	17.05	49.62	111.9	1.029
9 GRAVELWA	0.7400	0.9170E-01	0.2222E-01	2.998	0.1878	0.2429	25.34	32.76	0.6790
10 STONY	6.200	0.6690E-01	0.8778	1:073	9.021	12.04	11.03	14.72	0.7530
11 MARSHAL	11.80	0.3060E-01	0.8500	1.109	14.03	26.48	18.30	34.55	0.7807
12 BEAR	7.200	0.1660E-01	0.9000	1.049	14.22	41.47	16.57	48.34	0.6732
13 BURWASH	24.50	0.3750E-01	0.2667	2.669	3.217	7.576	32.20	75.83	2.022
14 LONG'S	28.00	0.1710E-01	0.9722	1.004	17.06	41.73	17.61	43.08	0.5952
15 DRY	33.00	0.2180E-01	0.4056	2.292	9.012	17.33	50.94	97.97	0.8221
16 ENGER	3.900	0.6800E-02	0.9444E-01	2.956	1.548	14.53	48.46	454.8	0.4094
17 STANLEY	28.00	0.3630E-01	0.4722	2.087	6.280	10.73	27.76	47.44	1.173
18 MULE	4.300	0.8310E-01	0.3556	2.438	2.073	4.279	14.22	29.34	1.327
19 STONEHOU	8.600	0.4190E-01	0.3222	2.530	2.984	7.859	23.42	61.70	0.6687
20 MURPHY	35.00	0.3180E-01	0.3889	2.342	5.644	10.21	33.99	61.47	0.5143
21 GROUNDHO	19.50	0.2260E-01	0.4278	2.225	5.991	11.14	31.16	57.94	0.5574
22 BACON	19.50	0.2370E-01	0.5000	2.000	5.882	11.21	23.53	44.84	0.8125
23 180 MILE	11.80	0.5690E-01	0.6444	1.562	7.645	12.21	18.52	29.58	1.189
24 TWIN	9.800	0.4000E-01	0.9500	1.012	13.10	27.07	13.96	28.84	0.8129
25 RIDDELL	24.50	0.3430E-01	0.6222	1.625	7.177	11.67	18.75	30.50	1.424
26 BOULDER	36.00	0.2740E-01	0:1389	2.906	2.980	6.013	62.37	125.8	1.095
27 MAC 2	46.00	0.7900E-02	0.7944	1.201	16.08	47.86	24.32	72.37	1.067
28 VANGORDA	10.70	0.4580E-01	0.6222	1.625	7.235	12.44	18.90	32.51	1.060
29 BIG GOLD	8.700	0.3320E-01	0.9722	1.004	14.73	23.95	15.21	24.72	0.6468
30 CLINTON	24.50	0.1670E-01	0.5722	1.775	14.56	28.47	45.17	88.31	0.7744
31 THISTLE	55.00	0.2210E-01	0.4833	2.052	10.18	17.26	43.21	73.30	1.428
32 BENSON	67.00	0.3790E-01	0.9389	1.018	14.53	25.31	15.76	27.45	1.481
33 WOLF DEM	36.00	0.3910E-01	0.4111	2.276	4.583	9.343	25.37	51.72	1.303

34	GRIZZLY	16.40	0.7980E-01	0.6000	1.691	5.348	8.439	15.07	23.78	0.8021
35	UNNAMED	43.00	0.6500E-02	0.2556	2.695	7.494	28.08	79.02	296.1	0.6788
36	BIG THIN	4.800	0.1371	0.5444	1.861	3.229	3.709	11.04	12.68	1.135

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LIST OF PREDICTED VALUES, RESIDUALS, AND VARIABLES (CONTINUED)

CASE NO.	LABEL	44 LNASP	45 LCASP2	46 LGRADA	47 LGRADB	48 LGRADE	49 LGRADF	50 LRUGN	51 LLONG	52 LLAT
1	SPENCER	-0.2099	0.2153	1.056	1.268	1.481	1.693	-0.1986E-01	2.115	1.779
2	FREER	-1.778	0.4769	-0.7969	-0.5635	1.458	1.692	0.1699E-02	2.116	1.779
3	PARTRIDG	-0.4576E-01	0.2073E-01	1.064	1.520	1.131	1.586	-0.5340E-01	2.118	1.778
4	LOGJAM	-0.4853E-02	0.2604E-03	1.138	1.452	1.144	1.457	-0.5744E-01	2.119	1.775
5	STRAWBER	-0.2178	0.2239	0.9036	1.384	1.345	1.826	-0.3798	2.122	1.779
6	DEADMAN	0.0	0.4307E-04	1.293	1.616	1.293	1.616	-0.1057	2.124	1.781
7	JUDAS	-0.1761	0.1761	1.218	1.807	1.570	2.159	-0.1999	2.128	1.781
8	WOLF	-0.4357	0.3814	0.8785	1.232	1.696	2.049	0.1242E-01	2.130	1.782
9	GRAVELWA	-1.653	0.4768	-0.7262	-0.6146	1.404	1.515	-0.1681	2.131	1.784
10	STONY	-0.5662E-01	0.3052E-01	0.9553	1.081	1.042	1.168	-0.1232	2.134	1.784
11	MARSHAL	-0.7058E-01	0.4493E-01	1.147	1.423	1.262	1.538	-0.1075	2.138	1.784
12	BEAR	-0.4576E-01	0.2073E-01	1.153	1.618	1.219	1.684	-0.1719	2.139	1.784
13	BURWASH	-0.5740	0.4264	0.5074	0.8794	1.508	1.880	0.3058	2.144	1.788
14	LONG'S	-0.1223E-01	0.1647E-02	1.232	1.620	1.246	1.634	-0.2253	2.147	1.791
15	DRY	-0.3919	0.3603	0.9548	1.239	1.707	1.991	-0.8505E-01	2.148	1.794
16	ENGER	-1.025	0.4707	0.1898	1.162	1.685	2.658	-0.3879	2.149	1.794
17	STANLEY	-0.3259	0.3196	0.7979	1.031	1.443	1.676	0.6934E-01	2.136	1.778
18	MULE	-0.4491	0.3871	0.3166	0.6313	1.153	1.468	0.1230	2.135	1.777
19	STONEHOU	-0.4918	0.4031	0.4747	0.8954	1.370	1.790	-0.1747	2.135	1.775
20	MURPHY	-0.4102	0.3696	0.7516	1.009	1.531	1.789	-0.2887	2.124	1.790
21	GROUNDHO	-0.3688	0.3473	0.7775	1.047	1.494	1.763	-0.2538	2.124	1.787
22	BACON	-0.3010	0.3010	0.7696	1.050	1.372	1.652	-0.9018E-01	2.124	1.791
23	180 MILE	-0.1908	0.1936	0.8834	1.087	1.268	1.471	0.7518E-01	2.120	1.794
24	TWIN	-0.2228E-01	0.5309E-02	1.117	1.432	1.145	1.460	-0.8994E-01	2.118	1.797
25	RIDDELL	-0.2061	0.2110	0.8559	1.067	1.273	1.484	0.1536	2.118	1.797
26	BOULDER	-0.8573	0.4633	0.4743	0.7791	1.795	2.100	0.3933E-01	2.117	1.798
27	MAC 2	-0.9994E-01	0.7969E-01	1.206	1.680	1.386	1.860	0.2799E-01	2.115	1.800
28	VANGORDA	-0.2061	0.2110	0.8594	1.095	1.276	1.512	0.2511E-01	2.125	1.794
29	BIG GOLD	-0.1223E-01	0.1647E-02	1.168	1.379	1.182	1.393	-0.1892	2.149	1.806
30	CLINTON	-0.2424	0.2492	1.163	1.454	1.655	1.946	-0.1111	2.148	1.809
31	THISTLE	-0.3158	0.3122	1.008	1.237	1.636	1.865	0.1547	2.144	1.800
32	BENSON	-0.2739E-01	0.7918E-02	1.162	1.403	1.198	1.439	0.1705	2.142	1.807
33	WOLF DEM	-0.3860	0.3571	0.6612	0.9705	1.404	1.714	0.1149	2.141	1.809
34	GRIZZLY	-0.2218	0.2281	0.7282	0.9263	1.178	1.376	-0.9577E-01	2.141	1.809
35	UNNAMED	-0.5925	0.4305	0.8747	1.448	1.898	2.471	-0.1683	2.141	1.813
36	BIG THIN	-0.2640	0.2697	0.5091	0.5692	1.043	1.103	0.5506E-01	2.129	1.779

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LIST OF PREDICTED VALUES, RESIDUALS, AND VARIABLES (CONTINUED)

CASE NO.	LABEL	53 LRANK	54 LS1085	55 LELEV	56 LAREA	57 LPER	58 LSTL	59 LBAL	60 LTCHL	61 LREL
1	SPENCER	0.6021	-1.672	2.939	2.192	1.775	1.408	1.332	2.104	3.066
2	FREER	0.4771	-1.426	2.954	1.659	1.462	1.041	1.033	1.610	3.052
3	PARTRIDG	0.4771	-1.815	2.946	1.790	1.629	1.267	1.188	1.661	3.077
4	LOGJAM	0.6021	-1.492	2.928	1.945	1.631	1.246	1.161	1.869	3.018
5	STRAWBER	0.4771	-1.604	2.864	1.799	1.509	1.146	1.025	1.519	2.904

6	DEADMAN	0.6021	-1.693	2.837	2.344	1.845	1.479	1.375	2.158	3.081
7	JUDAS	0.6021	-2.086	2.873	2.263	1.818	1.509	1.367	2.090	2.974
8	WOLF	0.6021	-1.772	2.855	2.238	1.878	1.629	1.452	2.115	3.137
9	GRAVELWA	0.3010	-1.038	2.864	1.412	1.322	0.9777	0.9138	1.255	2.987
10	STONY	0.4771	-1.175	2.855	1.563	1.484	1.146	1.111	1.344	3.099
11	MARSHAL	0.6021	-1.514	2.826	2.346	1.839	1.455	1.352	2.111	3.129
12	BEAR	0.4771	-1.780	2.807	1.855	1.623	1.322	1.207	1.674	3.009
13	BURWASH	0.6021	-1.426	2.939	2.222	1.844	1.436	1.358	2.252	3.276
14	LONG'S	0.6021	-1.767	2.836	2.052	1.708	1.407	1.212	1.860	2.968
15	DRY	0.6021	-1.662	2.836	2.137	1.863	1.114	1.322	2.079	2.975
16	ENGER	0.6021	-2.167	2.855	1.827	1.597	1.149	1.079	1.573	2.864
17	STANLEY	0.6021	-1.440	2.939	1.876	1.602	1.255	1.176	1.894	3.052
18	MULE	0.4771	-1.080	2.939	1.350	1.272	0.7404	0.8062	1.431	3.040
19	STONEHOU	0.3010	-1.378	2.975	1.037	1.176	0.8921	0.7634	1.068	2.796
20	MURPHY	0.4771	-1.498	2.899	2.053	1.724	1.283	1.220	1.708	3.058
21	GROUNDHO	0.4771	-1.646	3.040	1.823	1.556	1.130	1.100	1.618	2.954
22	BACON	0.4771	-1.625	3.021	1.789	1.562	1.167	1.167	1.602	3.097
23	180 MILE	0.4771	-1.245	2.907	1.907	1.694	1.114	1.149	1.906	3.075
24	TWIN	0.4771	-1.398	3.170	1.654	1.585	1.225	1.041	1.663	2.901
25	RIDDELL	0.6021	-1.465	2.959	1.724	1.582	1.176	1.140	1.800	3.078
26	BOULDER	0.6021	-1.562	2.959	1.931	1.604	1.238	1.164	2.138	2.833
27	MAC 2	0.6021	-2.102	3.041	2.263	1.860	1.580	1.352	2.244	3.046
28	VANGORDA	0.6021	-1.339	2.836	1.943	1.686	1.290	1.204	1.827	3.139
29	BIG GOLD	0.6021	-1.479	2.855	1.694	1.480	1.021	1.000	1.687	2.820
30	CLINTON	0.6021	-1.777	2.505	2.322	1.823	1.436	1.386	2.228	2.980
31	THISTLE	0.6990	-1.656	2.581	2.318	1.820	1.484	1.367	2.428	3.044
32	BENSON	0.6021	-1.421	2.836	1.945	1.721	1.362	1.281	2.024	3.091
33	WOLF DEM	0.4771	-1.408	2.939	1.830	1.623	1.193	1.149	1.843	3.102
34	GRIZZLY	0.4771	-1.098	2.968	1.522	1.477	0.9542	1.041	1.338	3.091
35	UNNAMED	0.6021	-2.187	2.954	2.346	1.857	1.602	1.391	2.254	2.923
36	BIG THIN	0.4771	-0.8630	2.827	1.553	1.412	0.9085	0.9590	1.423	3.186

LIST OF PREDICTED VALUES, RESIDUALS, AND VARIABLES (CONTINUED)

CASE NO.	LABEL	VARIABLES 62 LASP	63 LBSH1	64 LBSH2	65 LDRD	66 LSTF	67 LRELRA	68 LSLOPE	69 LBIRA	70 LHYPI
1	SPENCER	2.045	-0.4685	1.359	-0.8619E-01	-0.2840	-1.266	-1.478	0.6730	-0.3872
2	FREER	0.4771	-0.4089	1.266	-0.5061E-01	-0.3010	-0.9813	-1.215	0.5315	-0.2757
3	PARTRIDG	2.210	-0.5850	1.468	-0.1308	-0.3279	-1.110	-1.565	0.6628	-0.4202
4	LOGJAM	2.260	-0.3768	1.317	-0.7572E-01	-0.3468	-1.143	-1.457	0.6325	-0.4202
5	STRAWBER	2.400	-0.2518	1.217	-0.2840	-0.7959	-1.121	-1.602	0.3010	-0.3872
6	DEADMAN	2.255	-0.4089	1.346	-0.1871	-0.6778	-1.293	-1.616	0.6532	-0.3872
7	JUDAS	2.380	-0.4685	1.372	-0.1739	-0.6021	-1.394	-1.983	0.6149	-0.5229
8	WOLF	1.820	-0.6576	1.518	-0.1249	-0.5376	-1.314	-1.668	0.5682	-0.3665
9	GRAVELWA	0.6021	-0.4202	1.233	-0.1549	-0.7212	-0.9270	-1.039	0.6021	-0.3372
10	STONY	2.199	-0.6576	1.405	-0.2218	-0.5686	-1.012	-1.137	0.5441	-0.2924
11	MARSHAL	2.185	-0.3468	1.332	-0.2366	-0.6021	-1.218	-1.493	0.5224	-0.3468
12	BEAR	2.210	-0.5528	1.493	-0.1805	-0.6021	-1.199	-1.664	0.5119	-0.4948
13	BURWASH	1.681	-0.4948	1.466	0.2938E-01	-0.1871	-1.081	-1.453	0.5717	-0.4685
14	LONG'S	2.243	-0.3768	1.363	-0.1938	-0.6383	-1.244	-1.633	0.6767	-0.4318
15	DRY	1.863	-0.5086	1.589	-0.6048E-01	-0.3098	-1.347	-1.631	0.6749	-0.7447
16	ENGER	2.535	-0.3279	1.366	-0.2518	-0.3979	-1.215	-2.187	0.5798	-0.7696
17	STANLEY	2.439	-0.4815	1.328	0.1703E-01	-0.5061E-01	-1.124	-1.357	0.6284	-0.3010
18	MULE	1.806	-0.2596	1.193	0.8279E-01	-0.2676	-0.7657	-1.080	0.4265	-0.4948
19	STONEHOU	1.763	-0.4948	1.315	0.2938E-01	-0.1938	-0.9666	-1.387	0.7782	-0.2924
20	MURPHY	1.845	-0.3872	1.396	-0.3468	-0.9586	-1.162	-1.419	0.4771	-0.3098
21	GROUNDHO	2.452	-0.3768	1.289	-0.2076	-0.7447	-1.146	-1.416	0.6532	-0.3188

6

22	BACON	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
23	180 MILE	2.064	-0.3872	1.480	0.0	-0.4815	-1.074	-1.277	0.6232	-0.4559
24	TWIN	2.233	-0.4318	1.517	0.8600E-02	-0.3565	-1.140	-1.455	0.4472	-0.4948
25	RIDDELL	2.049	-0.5528	1.440	0.7555E-01	-0.1427	-1.062	-1.273	0.6839	-0.4559
26	BOULDER	2.525	-0.3979	1.277	0.2068	-0.8092E-01	-1.332	-1.636	0.6609	-0.3372
27	MAC 2	2.336	-0.4437	1.458	-0.1773E-01	-0.3468	-1.306	-1.780	0.7536	-0.3468
28	VANGORDA	2.394	-0.4685	1.428	-0.1135	-0.4948	-1.066	-1.301	0.5011	-0.3768
29	BIG GOLD	2.267	-0.3098	1.266	-0.8774E-02	-0.9152E-01	-1.180	-1.391	0.4928	-0.3665
30	CLINTON	2.013	-0.4437	1.324	-0.9152E-01	-0.2441	-1.406	-1.697	0.5366	-0.4202
31	THISTLE	2.436	-0.4202	1.321	0.1106	0.1703E-01	-1.323	-1.553	0.6454	-0.3979
32	BENSON	2.228	-0.6198	1.497	0.7918E-01	-0.2924	-1.190	-1.431	0.2380	-0.2007
33	WOLF DEM	1.869	-0.4685	1.416	0.1284E-01	-0.2596	-1.047	-1.357	0.7924	-0.3468
34	GRIZZLY	2.033	-0.5528	1.432	-0.1871	-0.5229	-0.9500	-1.148	0.5441	-0.3565
35	UNNAMED	1.663	-0.4318	1.368	-0.9152E-01	-0.4685	-1.467	-2.041	0.5717	-0.2840
36	BIG THIN	1.991	-0.3665	1.271	-0.1308	-0.4685	-0.7731	-0.8333	0.4265	-0.2007

LIST OF PREDICTED VALUES, RESIDUALS, AND VARIABLES (CONTINUED)

CASE			VARIABLES							
NO.	LABEL	71 LHYPC	72 LGRAD1	73 LGRAD2	74 LATR	75 LALM	76 LAGL	77 LPRECIP	78 LINTENS	79 LQ2
1	SPENCER	-0.6198	-0.8508E-02	-0.5199E-02	0.1271	0.8600E-02	0.0	1.836	-0.4202	1.072
2	FREER	-0.2366	0.4313E-01	0.2567E-01	0.2430	0.8600E-02	0.0	1.836	-0.4089	0.7160
3	PARTRIDG	-0.6198	-0.3508E-01	-0.1140E-01	0.8990E-01	0.8600E-02	0.0	1.766	-0.4089	0.8921
4	LOGJAM	-0.5376	-0.3241E-01	-0.1543E-01	0.1106	0.8600E-02	0.0	1.717	-0.4437	0.7076
5	STRAWBER	-0.4948	-0.1082E-01	-0.3532E-02	0.2531E-01	0.1284E-01	0.0	1.551	-0.4948	0.3979
6	DEADMAN	-0.5376	-0.2269E-01	-0.1064E-01	0.6819E-01	0.8600E-02	0.0	1.551	-0.4685	1.114
7	JUDAS	-0.7447	-0.8863E-02	-0.2264E-02	0.3743E-01	0.1284E-01	0.0	1.405	-0.5086	0.6021
8	WOLF	-0.3872	0.8472E-02	0.3762E-02	0.2201	0.2531E-01	0.0	1.405	-0.5086	0.5441
9	GRAVELWA	-0.3098	0.4844E-01	0.3794E-01	0.1523	0.8600E-02	0.0	1.382	-0.4948	-0.5850
10	STONY	-0.2076	-0.4105E-01	-0.3040E-01	0.2304	0.8600E-02	0.0	1.382	-0.4815	0.2553
11	MARSHAL	-0.3468	-0.2411E-01	-0.1260E-01	0.1335	0.8600E-02	0.0	1.446	-0.4089	0.6532
12	BEAR	-0.9586	-0.2696E-01	-0.9040E-02	0.2119E-01	0.4139E-01	0.0	1.446	-0.3872	0.5051
13	BURWASH	-0.8239	0.2346E-01	0.1013E-01	0.1903	0.8600E-02	0.8600E-02	1.535	-0.3188	0.8129
14	LONG'S	-0.5086	-0.2540E-01	-0.1019E-01	0.6819E-01	0.8600E-02	0.0	1.660	-0.2518	1.290
15	DRY	-1.222	0.5695E-02	0.2943E-02	0.1284E-01	0.7555E-01	0.0	1.706	-0.2518	0.7853
16	ENGER	-1.155	0.2461E-01	0.2684E-02	0.1703E-01	0.5690E-01	0.0	1.635	-0.2757	0.3979
17	STANLEY	-0.2596	0.2857E-02	0.1647E-02	0.2900	0.8600E-02	0.8600E-02	1.727	-0.4089	0.9445
18	MULE	-0.5850	0.3149E-01	0.1553E-01	0.2810	0.8600E-02	0.4922E-01	1.803	-0.3872	0.3424
19	STONEHOU	-0.3468	0.2416E-01	0.9323E-02	0.3010	0.2938E-01	0.0	1.836	-0.3768	0.6990
20	MURPHY	-0.3188	0.1013E-01	0.5609E-02	0.1271	0.8600E-02	0.0	1.672	-0.4202	1.176
21	GROUNDHO	-0.3468	0.6936E-02	0.3719E-02	0.1987	0.8600E-02	0.0	1.706	-0.4202	0.9138
22	BACON	-0.3565	0.0	0.0	0.2405	0.8600E-02	0.0	1.706	-0.4202	0.9138
23	180 MILE	-0.6198	-0.1637E-01	-0.4189E-02	0.8636E-01	0.8600E-02	0.0	1.660	-0.3768	0.8751
24	TWIN	-0.7959	-0.3226E-01	-0.1534E-01	0.2119E-01	0.2119E-01	0.0	1.717	-0.2757	0.6435
25	RIDDELL	-0.7959	-0.1448E-01	-0.8774E-02	0.7918E-01	0.1703E-01	0.0	1.717	-0.2757	1.107
26	BOULDER	-0.3665	0.1795E-01	0.8983E-02	0.4139E-01	0.3342E-01	0.0	1.747	-0.2518	1.279
27	MAC 2	-0.3665	-0.1750E-01	-0.5815E-02	0.2279	0.2119E-01	0.4321E-02	1.794	-0.1938	1.301
28	VANGORDA	-0.6021	-0.1421E-01	-0.8198E-02	0.8990E-01	0.8600E-02	0.0	1.551	-0.4948	0.5051
29	BIG GOLD	-0.5229	-0.2951E-01	-0.1791E-01	0.7188E-01	0.8600E-02	0.0	1.635	-0.3768	0.6335
30	CLINTON	-0.6576	-0.3839E-02	-0.1959E-02	0.2531E-01	0.8600E-02	0.0	1.706	-0.2076	0.9912
31	THISTLE	-0.5850	0.1084E-02	0.6506E-03	0.8600E-02	0.8600E-02	0.0	1.446	-0.4437	1.352
32	BENSON	-0.1367	-0.2845E-01	-0.1610E-01	0.2405	0.8600E-02	0.0	1.535	-0.4685	1.415
33	WOLF DEM	-0.3979	0.1060E-01	0.5223E-02	0.2765	0.8600E-02	0.0	1.635	-0.4089	1.146
34	GRIZZLY	-0.5086	-0.1534E-01	0.4966E-02	0.2900	0.8600E-02	0.0	1.660	-0.3768	0.8062
35	UNNAMED	-0.3768	0.1017E-01	0.2727E-02	0.2878	0.4321E-02	0.0	1.609	-0.3188	1.100
36	BIG THIN	-0.1612	-0.1033E-01	-0.8951E-02	0.1673	0.8600E-02	0.0	1.405	-0.4815	0.2553

PAGE 19 BMDP YUKON ;REGRESSION ANALYSIS

LIST OF PREDICTED VALUES, RESIDUALS, AND VARIABLES (CONTINUED)

CASE NO.	LABEL	81 LG5	82 LQ10	83 LQ20
1	SPENCER	1.279	1.380	1.470
2	FREER	0.8865	0.9823	1.061
3	PARTRIDG	0.9542	0.9823	1.009
4	LOGJAM	0.9445	1.097	1.217
5	STRAWBER	0.6021	0.7160	0.8325
6	DEADMAN	1.455	1.633	1.778
7	JUDAS	0.9243	1.114	1.255
8	WOLF	0.7782	0.9085	1.009
9	GRAVELWA	-0.3565	-0.2366	-0.1308
10	STONY	0.6021	0.7482	0.7924
11	MARSHAL	0.8633	0.9731	1.072
12	BEAR	0.7076	0.7924	0.8573
13	BURWASH	1.097	1.255	1.389
14	LONG'S	1.371	1.415	1.447
15	DRY	1.146	1.342	1.519
16	ENGER	0.5315	0.5682	0.5911
17	STANLEY	1.196	1.332	1.447
18	MULE	0.4771	0.5563	0.6335
19	STONEHOU	0.8195	0.8808	0.9345
20	MURPHY	1.362	1.462	1.544
21	GROUNDHO	1.104	1.204	1.290
22	BACON	1.107	1.204	1.290
23	180 MILE	1.000	1.041	1.072
24	TWIN	0.8062	0.9031	0.9912
25	RIDDELL	1.243	1.322	1.389
26	BOULDER	1.415	1.491	1.556
27	MAC 2	1.477	1.574	1.663
28	VANGORDA	0.7634	0.9031	1.029
29	BIG GOLD	0.7853	0.8692	0.9395
30	CLINTON	1.161	1.279	1.389
31	THISTLE	1.556	1.653	1.740
32	BENSON	1.613	1.732	1.826
33	WOLF DEM	1.371	1.462	1.556
34	GRIZZLY	1.000	1.114	1.215
35	UNNAMED	1.371	1.512	1.633
36	BIG THIN	0.4548	0.5798	0.6812

NUMBER OF INTEGER WORDS OF STORAGE USED IN PRECEDING PROBLEM 7362
CPU TIME USED 13.808 SECONDS

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BMDP2R - STEPWISE REGRESSION

JULY 3, 1984 AT 17:01:40

PROGRAM CONTROL INFORMATION

NO MORE CONTROL LANGUAGE.

LIST OF PREDICTED VALUES, RESIDUALS, AND VARIABLES (CONTINUED)

CASE NO.	LABEL	VARIABLES 81 LQ5	82 LQ10	83 LQ20
1	SPENCER	1.279	1.380	1.470
2	FREER	0.8865	0.9823	1.061
3	PARTRIDG	0.9542	0.9823	1.009
4	LOGJAM	0.9445	1.097	1.217
5	STRAWBER	0.6021	0.7160	0.8325
6	DEADMAN	1.455	1.633	1.778
7	JUDAS	0.9243	1.114	1.255
8	WOLF	0.7782	0.9085	1.009
9	GRAVELWA	-0.3565	-0.2366	-0.1308
10	STONY	0.6021	0.7482	0.7924
11	MARSHAL	0.8633	0.9731	1.072
12	BEAR	0.7076	0.7924	0.8573
13	BURWASH	1.097	1.255	1.389
14	LONG'S	1.371	1.415	1.447
15	DRY	1.146	1.342	1.519
16	ENGER	0.5315	0.5682	0.5911
17	STANLEY	1.196	1.332	1.447
18	MULE	0.4771	0.5563	0.6335
19	STONEHOU	0.8195	0.8808	0.9345
20	MURPHY	1.362	1.462	1.544
21	GROUNDHO	1.104	1.204	1.290
22	BACON	1.107	1.204	1.290
23	180 MILE	1.000	1.041	1.072
24	TWIN	0.8062	0.9031	0.9912
25	RIDDELL	1.243	1.322	1.389
26	BOULDER	1.415	1.491	1.556
27	MAC 2	1.477	1.574	1.663
28	VANGORDA	0.7634	0.9031	1.029
29	BIG GOLD	0.7853	0.8692	0.9395
30	CLINTON	1.161	1.279	1.389
31	THISTLE	1.556	1.653	1.740
32	BENSON	1.613	1.732	1.826
33	WOLF DEM	1.371	1.462	1.556
34	GRIZZLY	1.000	1.114	1.215
35	UNNAMED	1.371	1.512	1.633
36	BIG THIN	0.4548	0.5798	0.6812

NUMBER OF INTEGER WORDS OF STORAGE USED IN PRECEDING PROBLEM 7362
CPU TIME USED 13.808 SECONDS

PAGE 20 BMDP

BMDP2R - STEPWISE REGRESSION

JULY 3, 1984 AT 17:01:40

PROGRAM CONTROL INFORMATION

NO MORE CONTROL LANGUAGE.

APPENDIX 2

HYPSOMETRY

Fig 1.

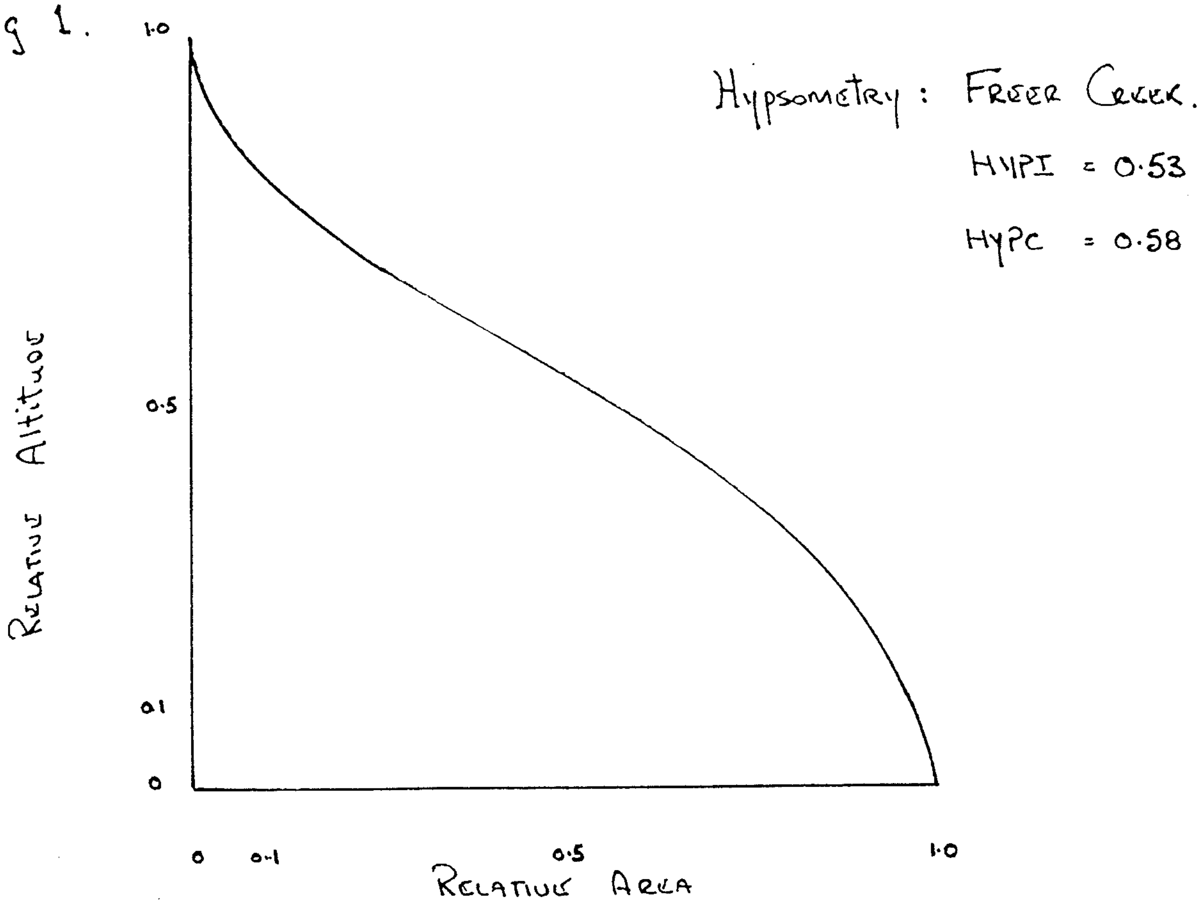

Hypsometry: Freer Creek.
HYPI = 0.53
HYPC = 0.58
Relative Altitude
1.0
0.5
0.1
0
0
0.1
0.5
1.0
Relative Area

Fig 2.

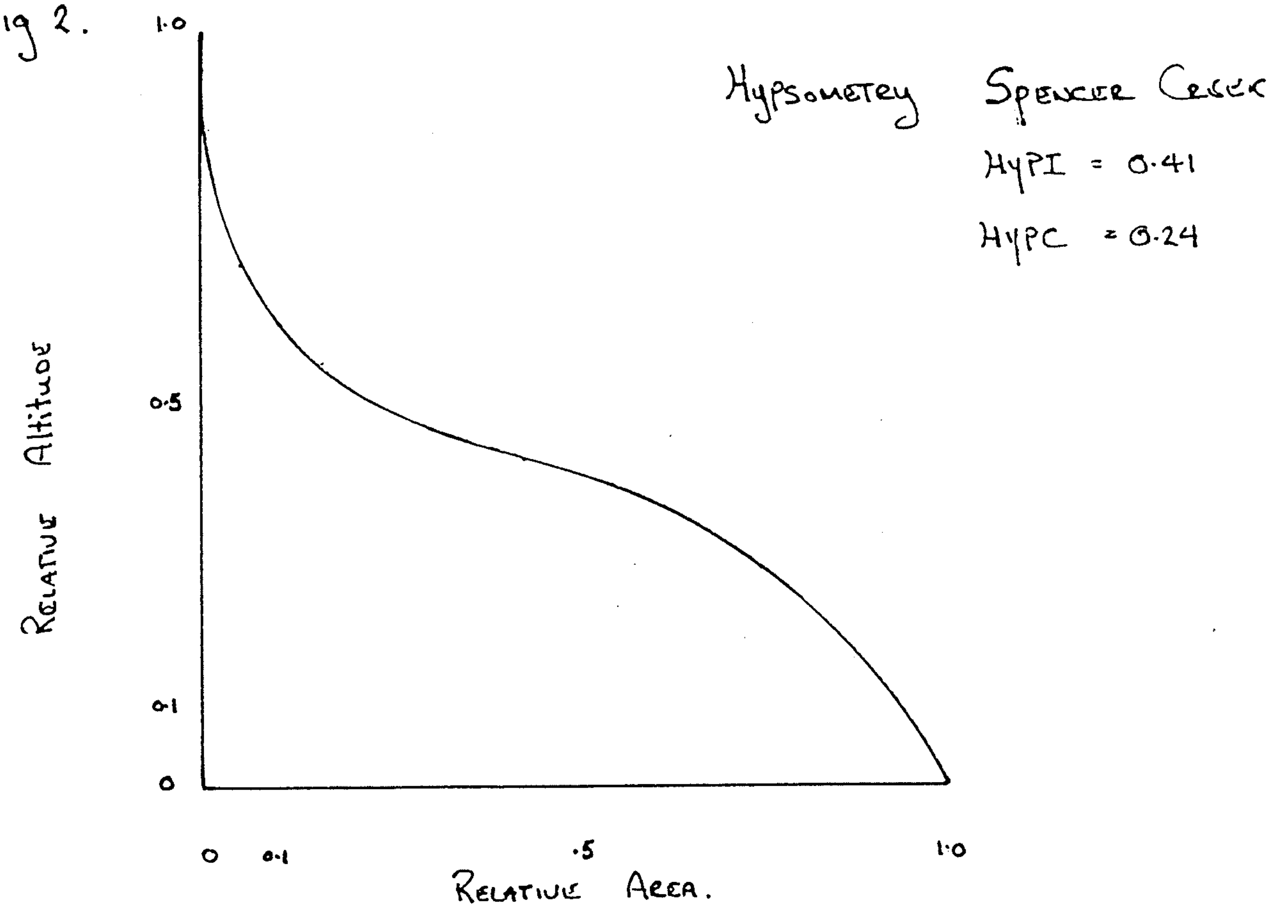
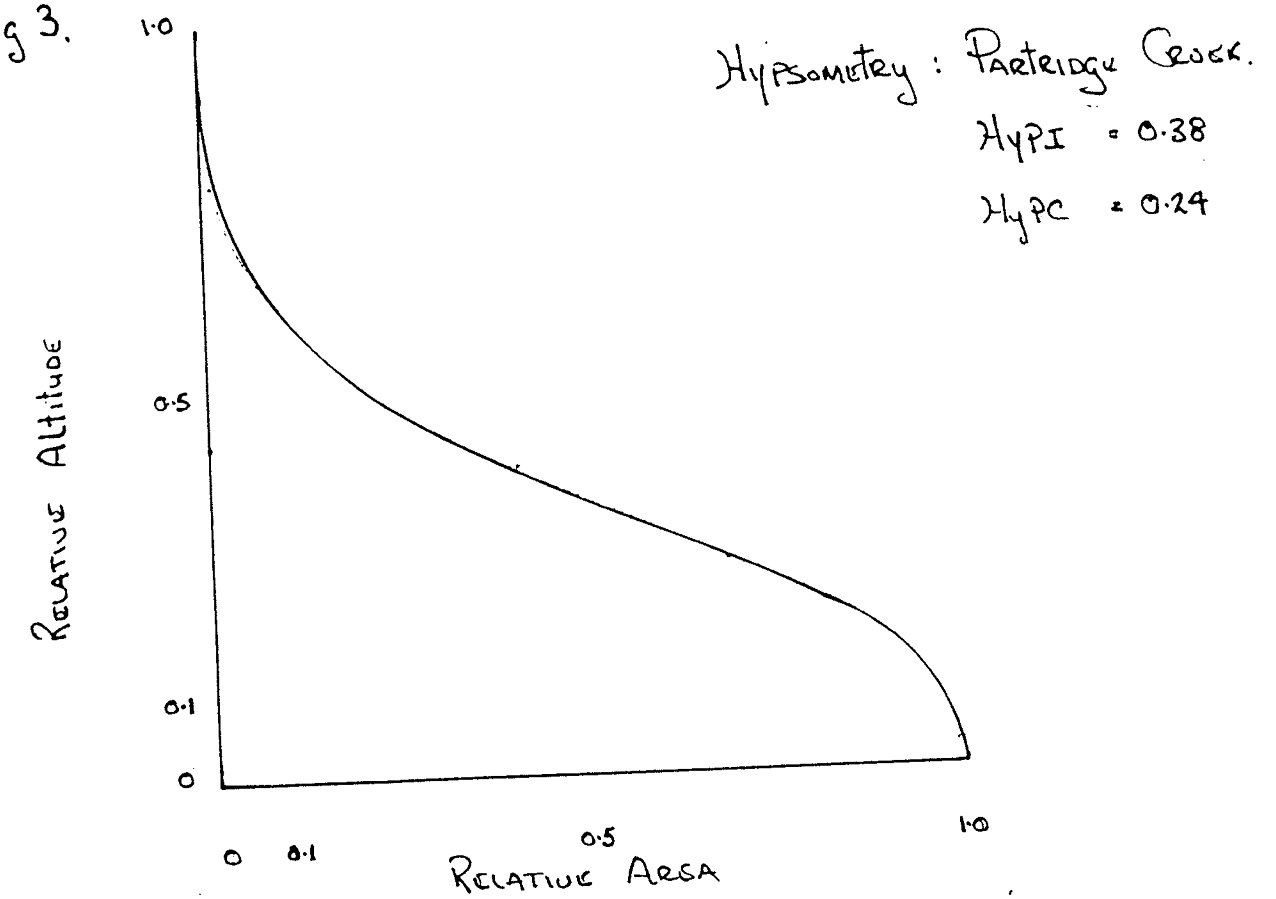
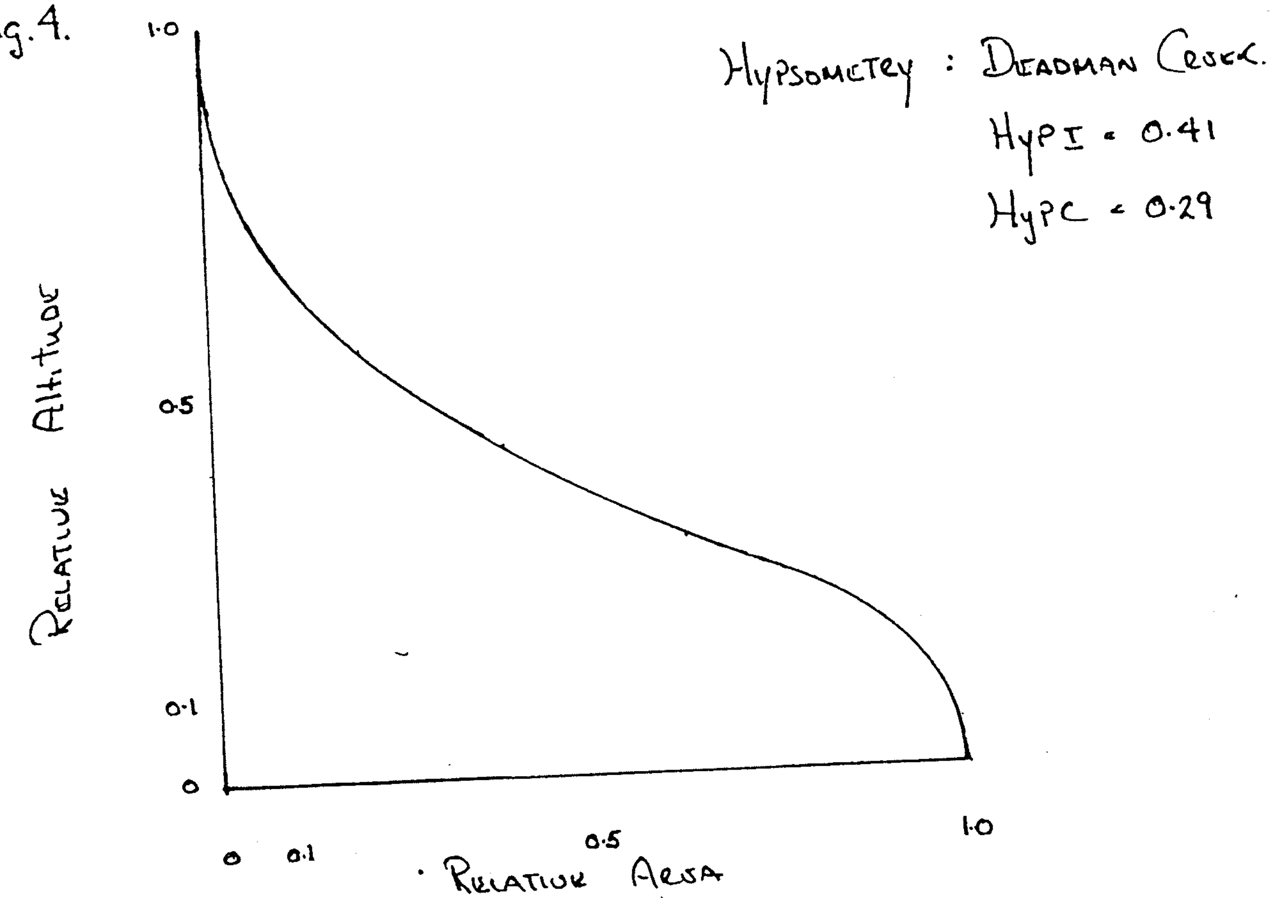

Hypsometry Spencer Creek.
HYPI = 0.41
HYPC = 0.24
Relative Altitude
1.0
0.5
0.1
0
0
0.1
.5
1.0
Relative Area.

Fig 3.



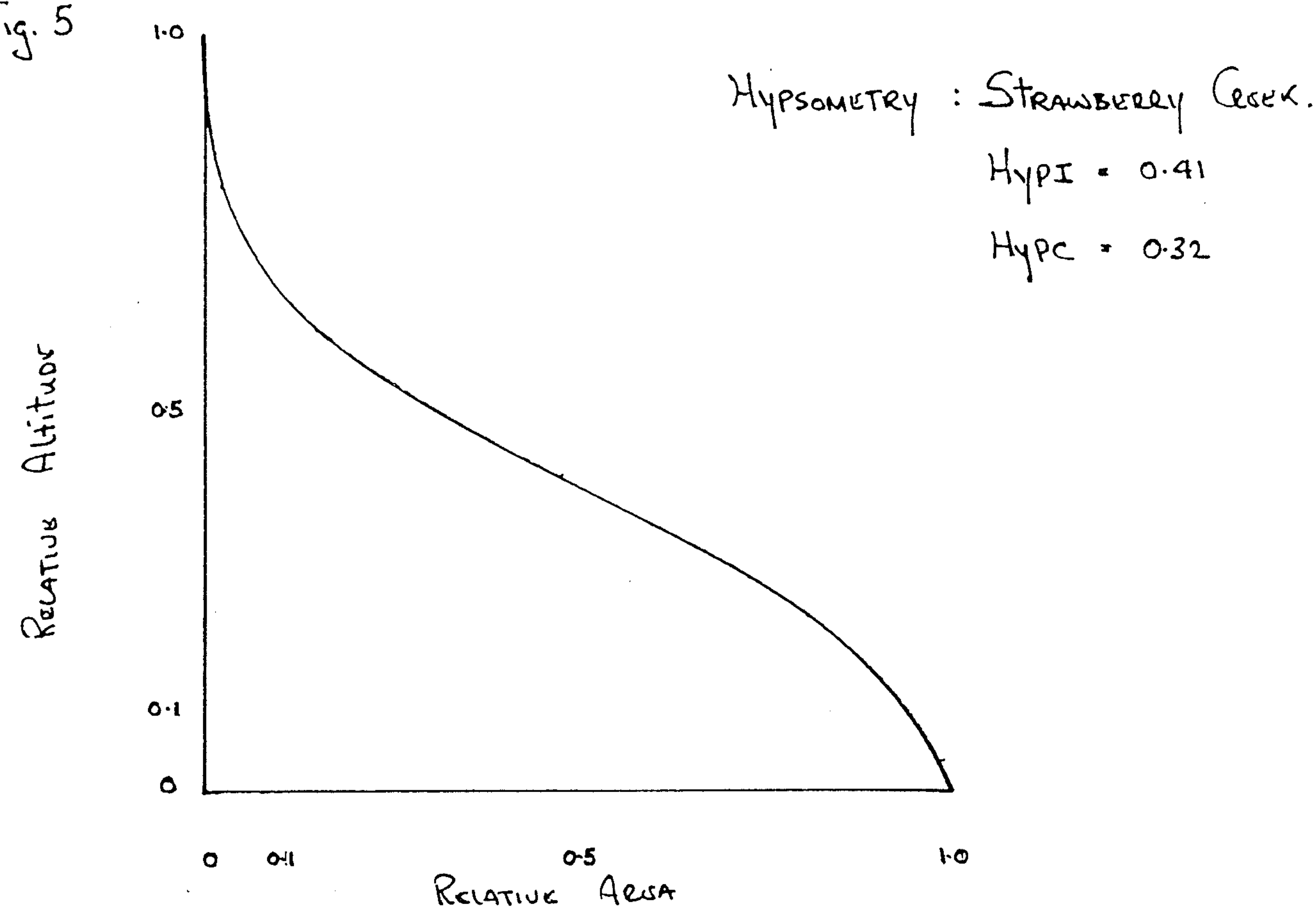
Hypsometry : Partridge Creek.
HypI = 0.38
HypC = 0.24
1.0
0.5
0.1
0
Relative Altitude
0
0.1
0.5
1.0
Relative Area

Fig. 4.



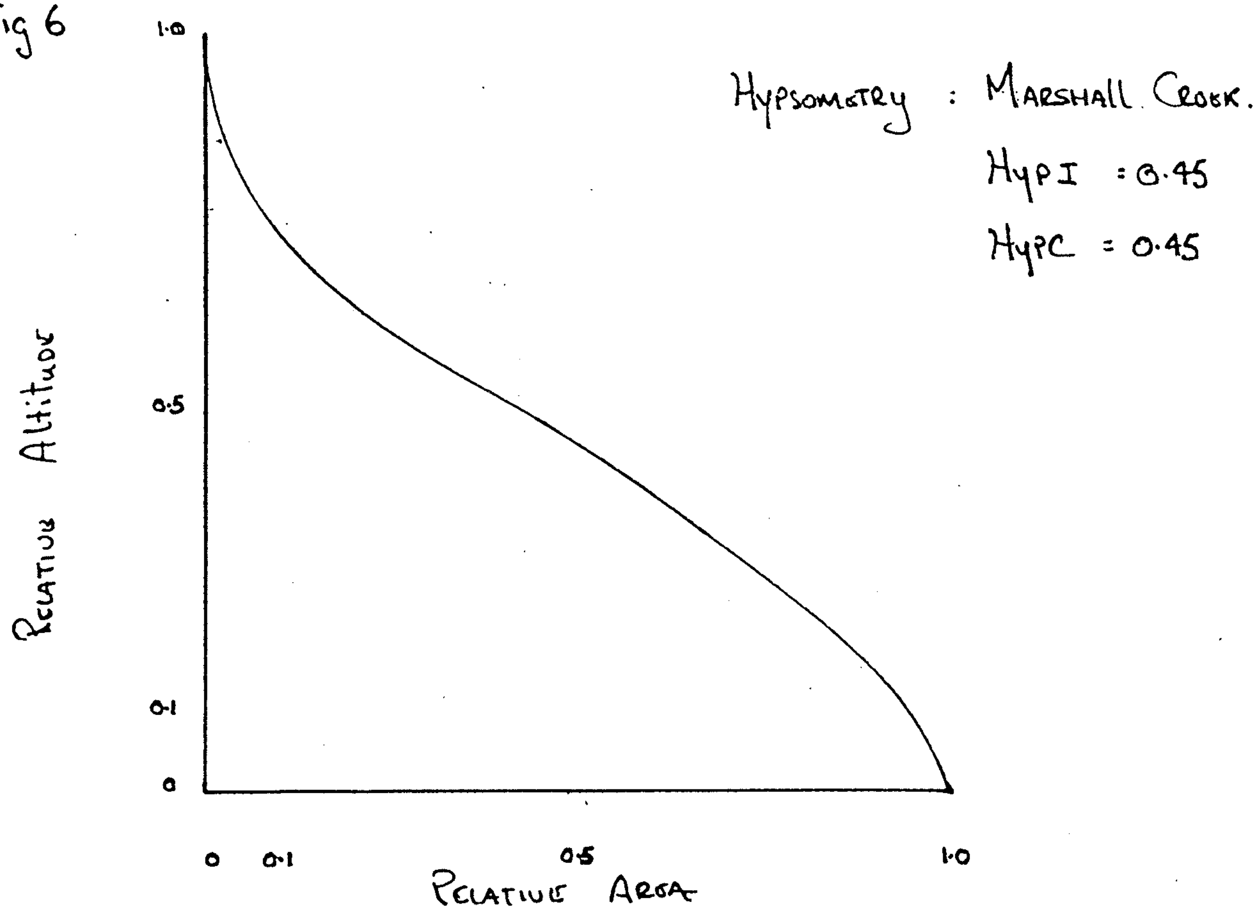
Hypsometry : Deadman Creek.
HypI = 0.41
HypC = 0.29
1.0
0.5
0.1
0
Relative Altitude
0
0.1
0.5
1.0
Relative Area

Fig. 5



Hypsometry : Strawberry Creek.
HypI = 0.41
HypC = 0.32
Relative Altitude
1.0
0.5
0.1
0
0
0.1
0.5
1.0
Relative Area

Fig 6



Hypsometry : Marshall Creek.
HypI = 0.45
HypC = 0.45
Relative Altitude
1.0
0.5
0.1
0
0
0.1
0.5
1.0
Relative Area

Fig 7

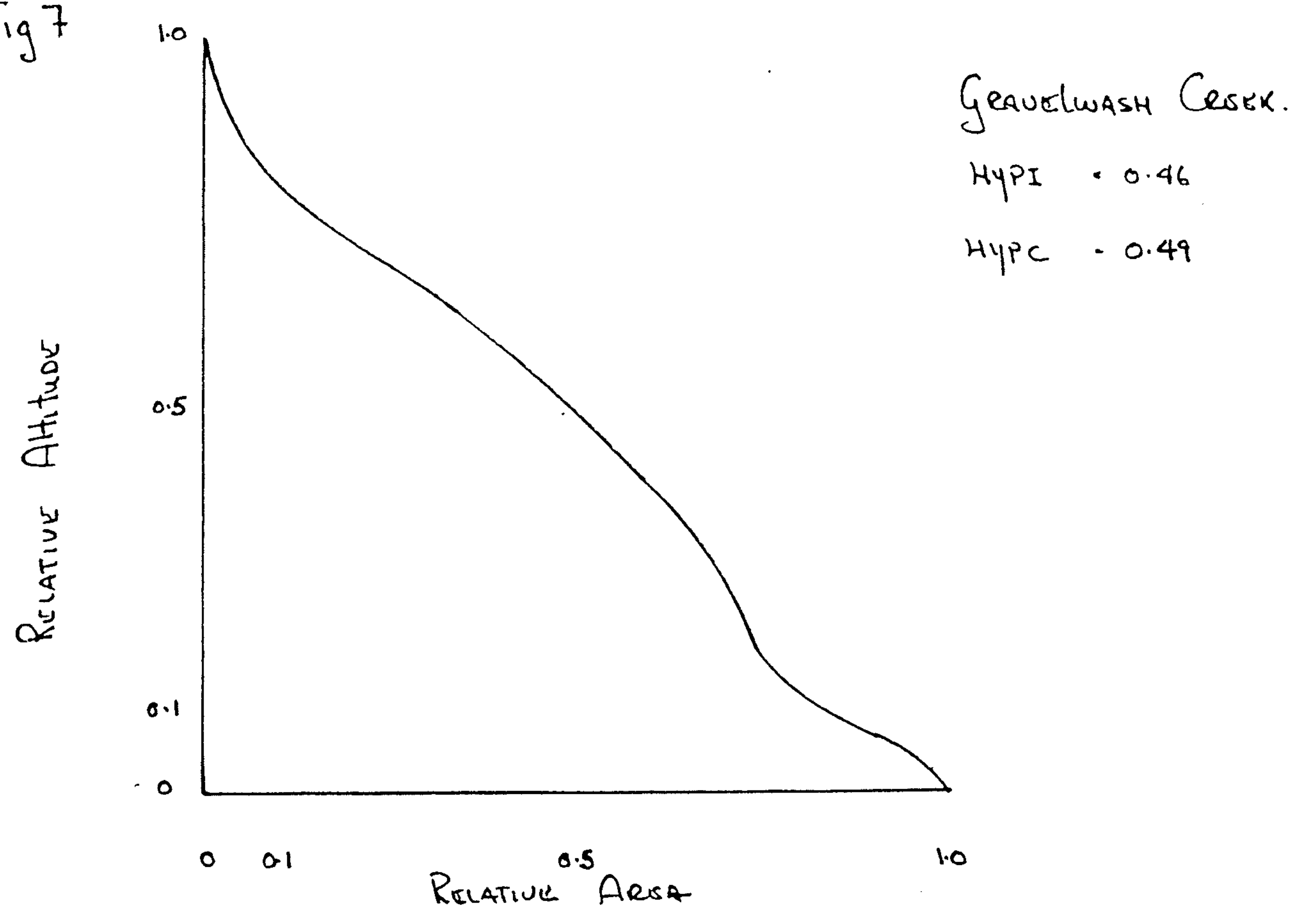

1.0
0.5
0.1
0
Relative Altitude
0
0.1
0.5
1.0
Relative Area
Gravelwash Creek.
HYPI = 0.46
HYPC = 0.49

Fig 8

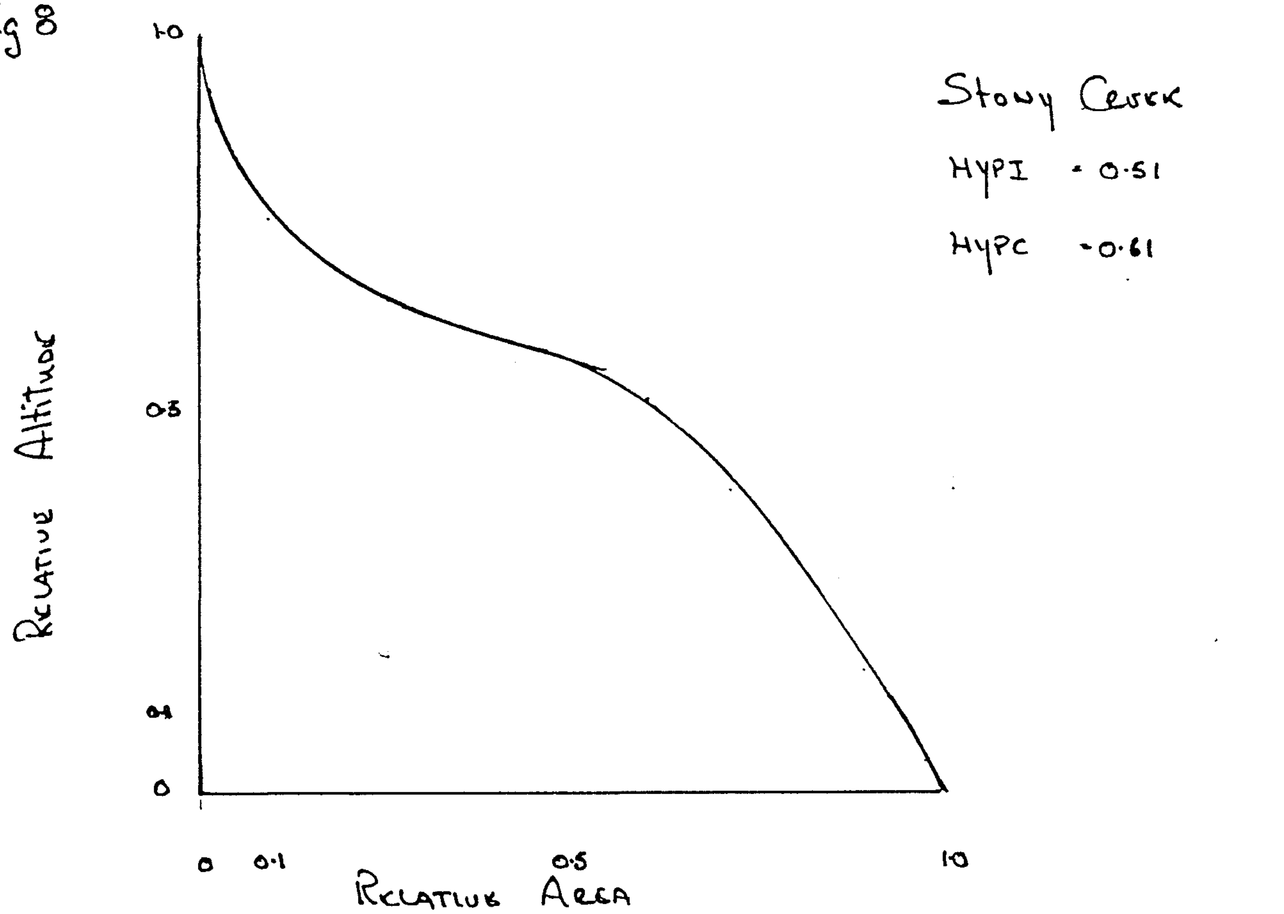

1.0
0.5
0.1
0
Relative Altitude
0
0.1
0.5
1.0
Relative Area
Stony Creek
HYPI = 0.51
HYPC = 0.61

Fig. 9

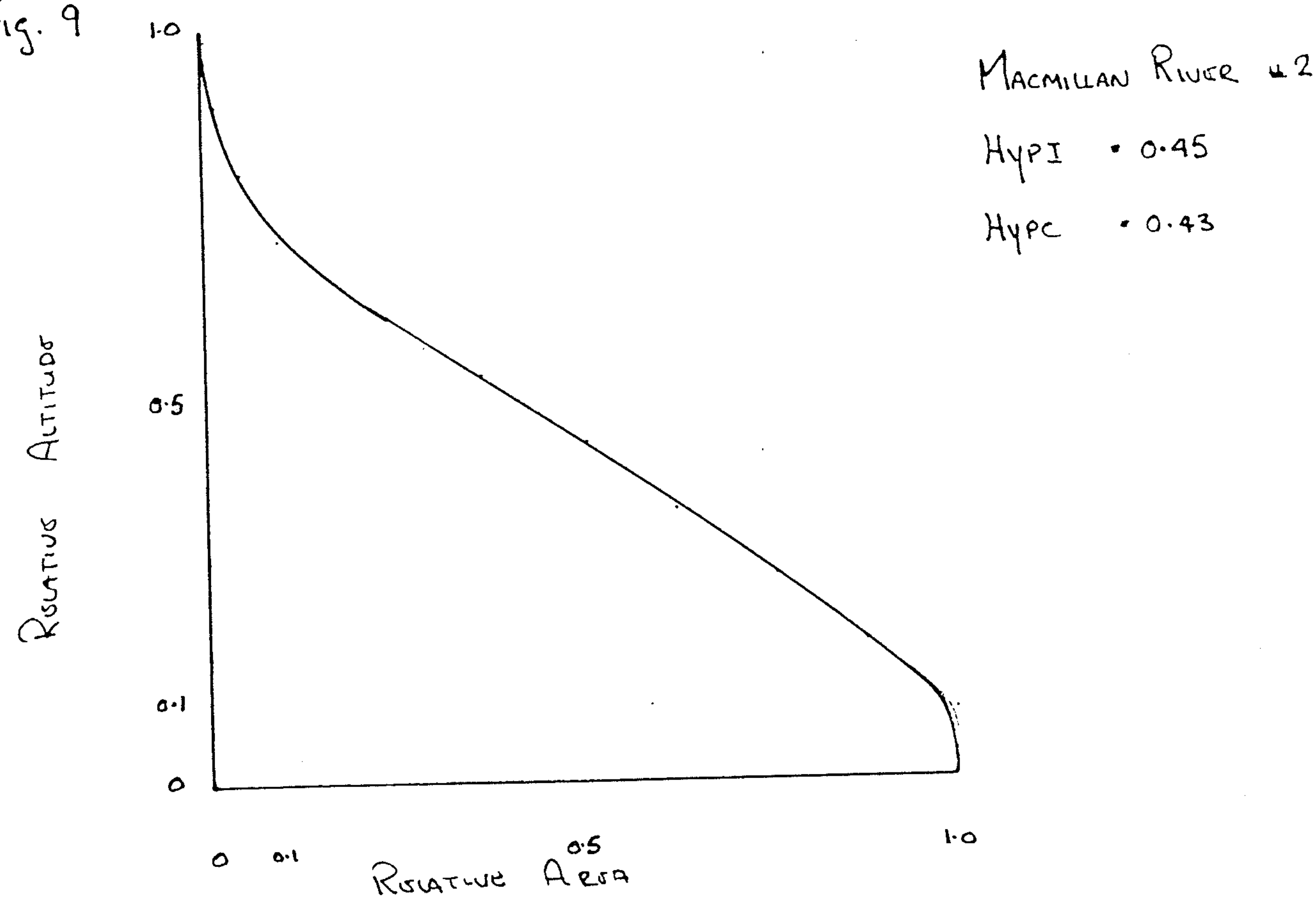

1.0
0.5
0.1
0
Relative Altitude
0
0.1
0.5
1.0
Relative Area
Macmillan River #2
HypI = 0.45
HypC = 0.43

Fig 10

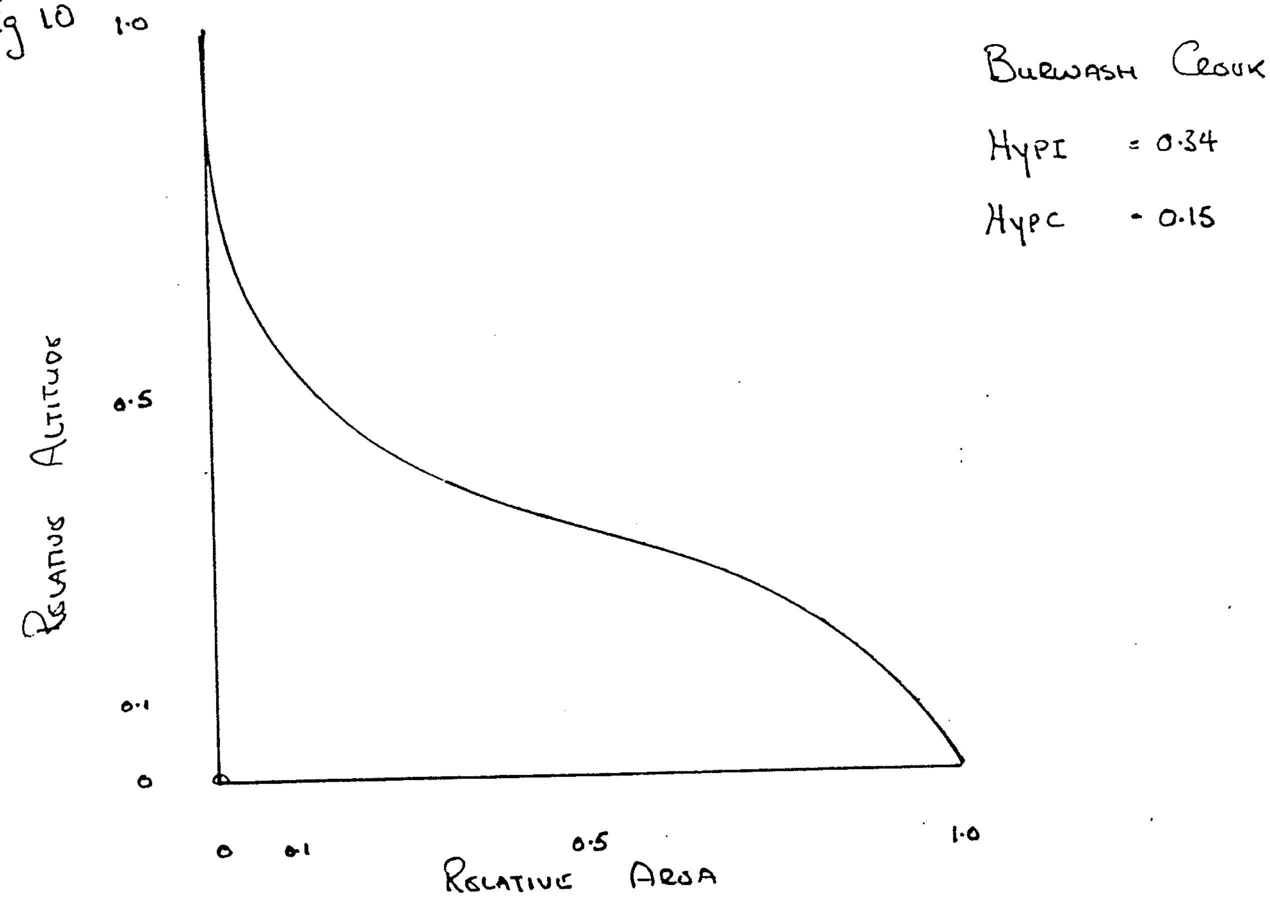

1.0
0.5
0.1
0
Relative Altitude
0
0.1
0.5
1.0
Relative Area
Burwash Creek
HypI = 0.34
HypC = 0.15

Fig. 11.

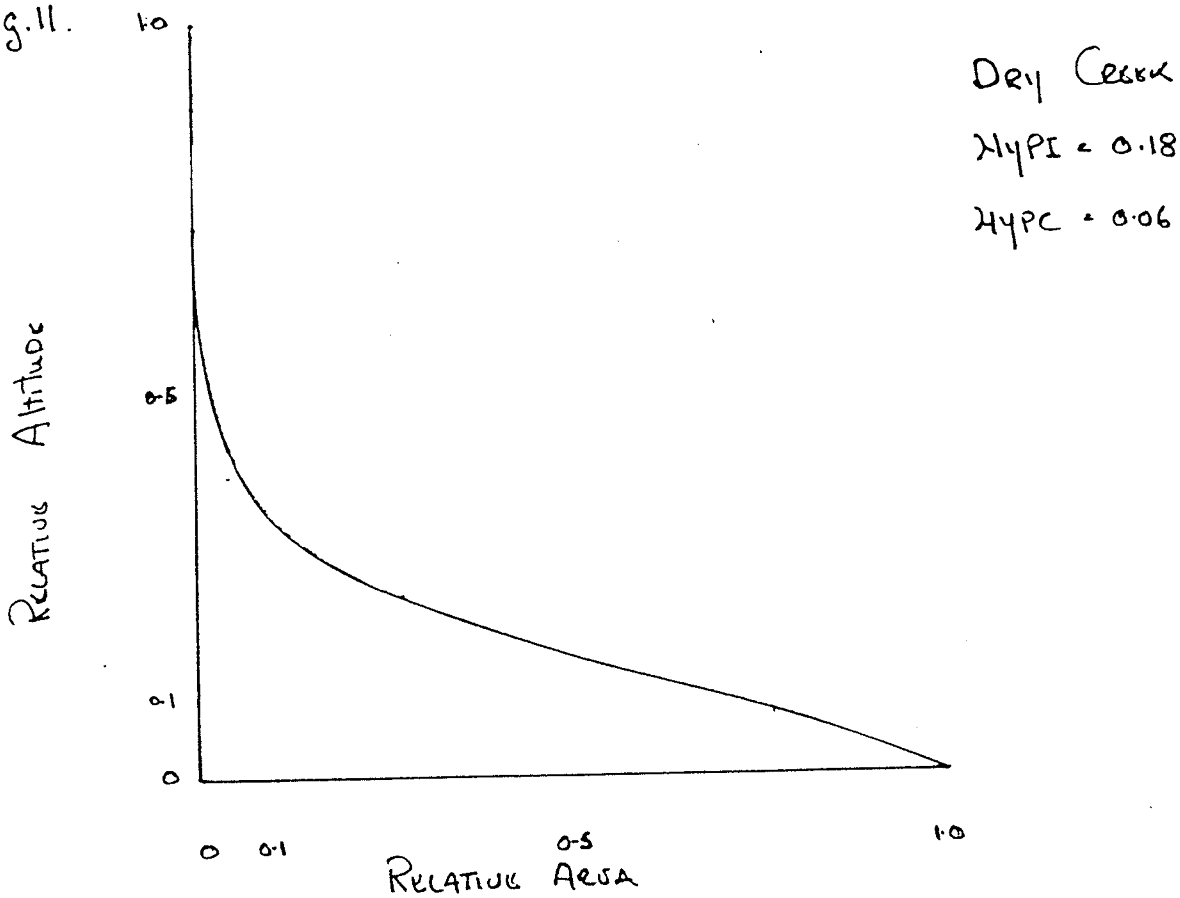

1.0
0.5
0.1
0
Relative Altitude
0
0.1
0.5
1.0
Relative Area
Dry Creek
HypI = 0.18
HypC = 0.06

Fig. 12

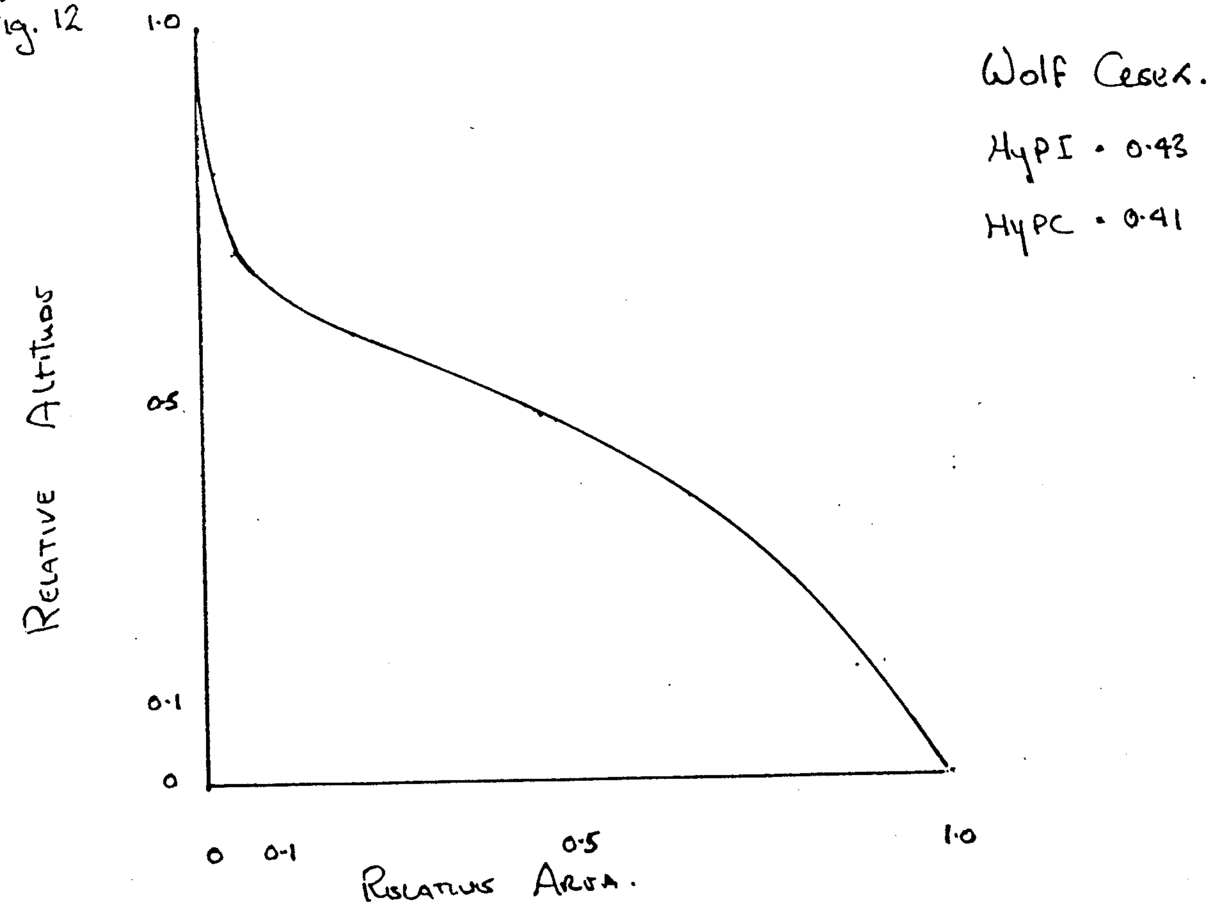
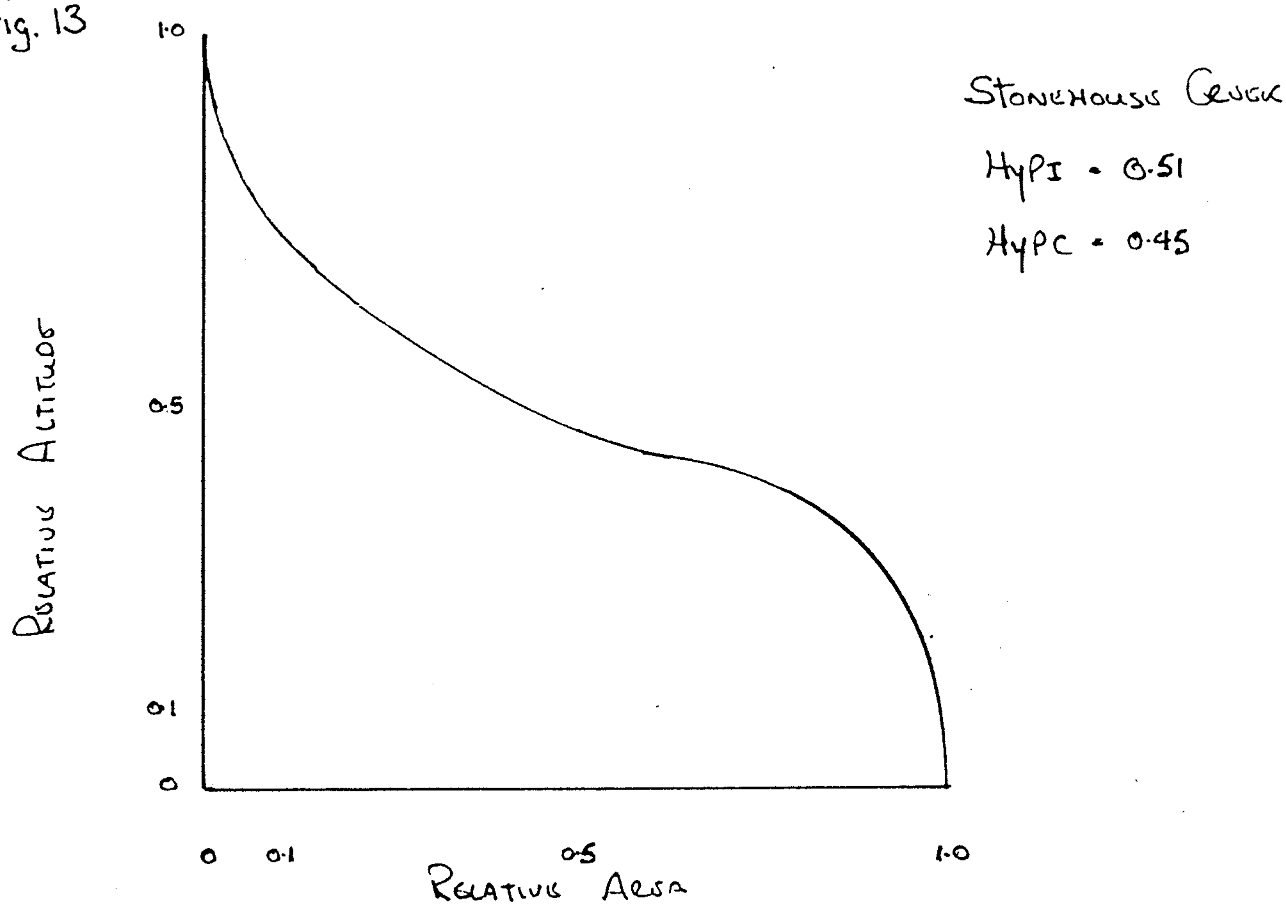
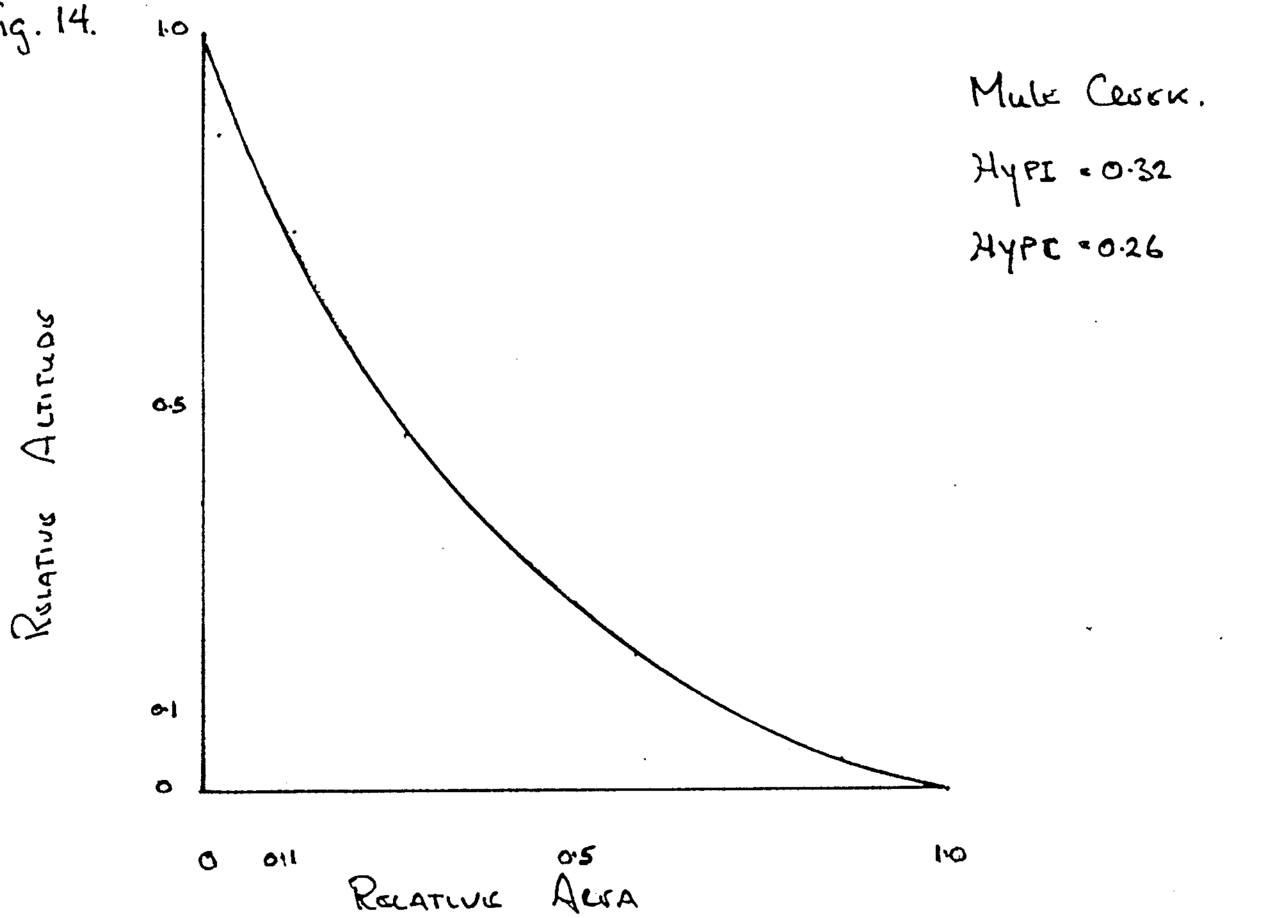

1.0
0.5
0.1
0
Relative Altitude
0
0.1
0.5
1.0
Relative Area.
Wolf Creek.
HypI = 0.43
HypC = 0.41

Fig. 13



1.0
0.5
0.1
0
0
0.1
0.5
1.0
Relative Altitude
Relative Area
Stonehouse Creek
HypI = 0.51
HypC = 0.45

Fig. 14.



1.0
0.5
0.1
0
0
0.1
0.5
1.0
Relative Altitude
Relative Area
Mule Creek.
HypI = 0.32
HypC = 0.26

Fig. 15.

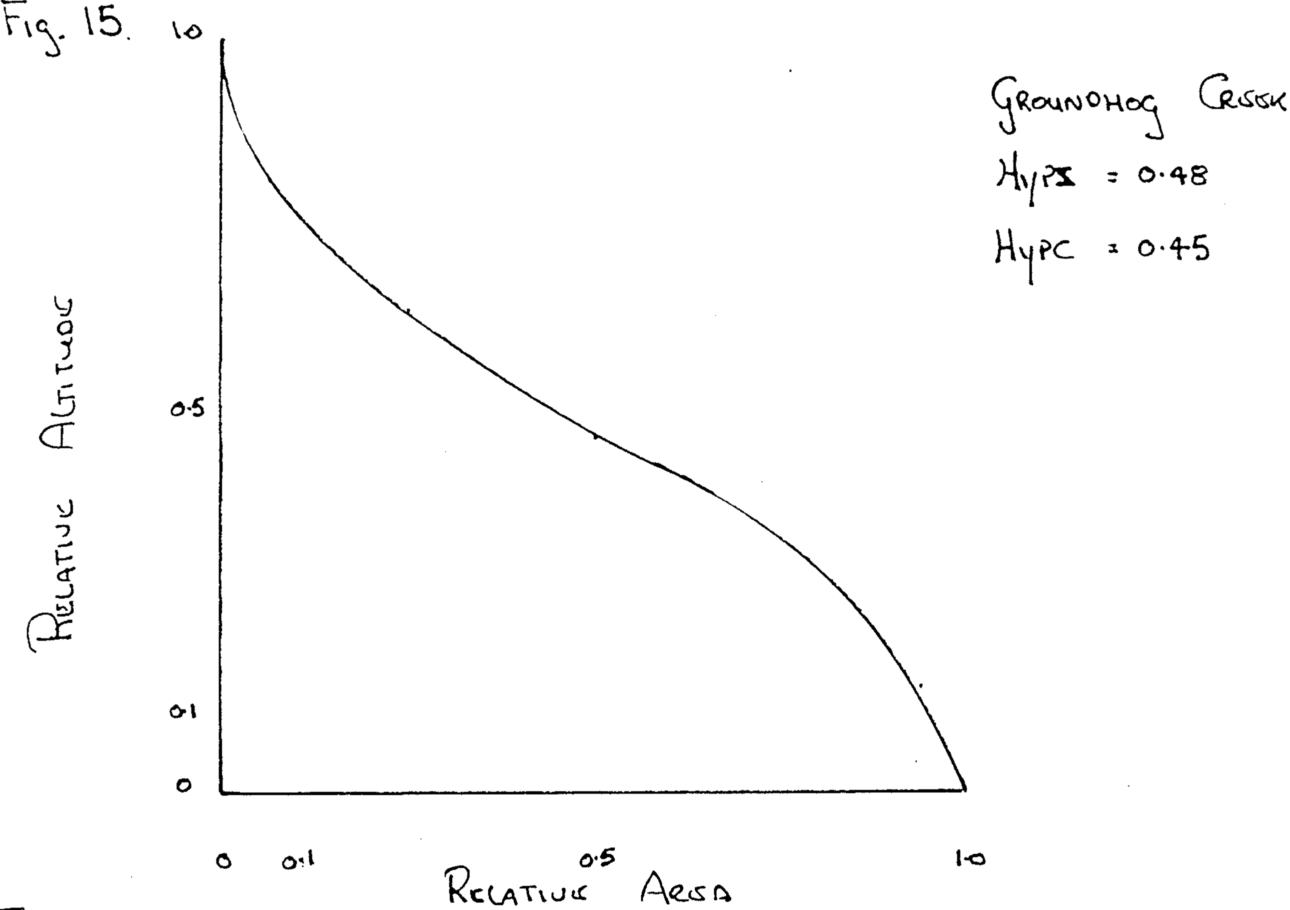

1.0
0.5
0.1
0
Relative Altitude
0
0.1
0.5
1.0
Relative Area
Groundhog Creek
HypI = 0.48
HypC = 0.45

Fig. 16.

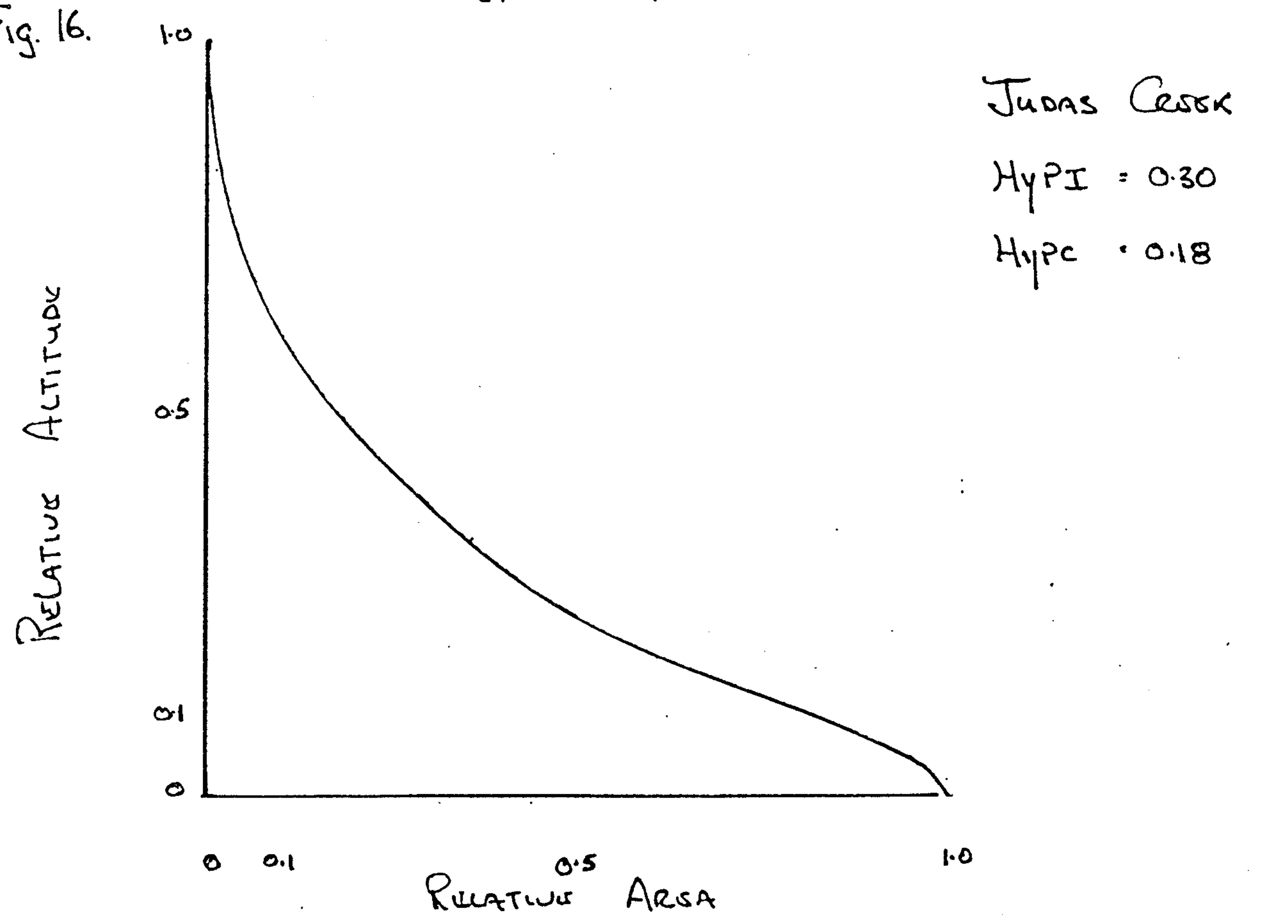
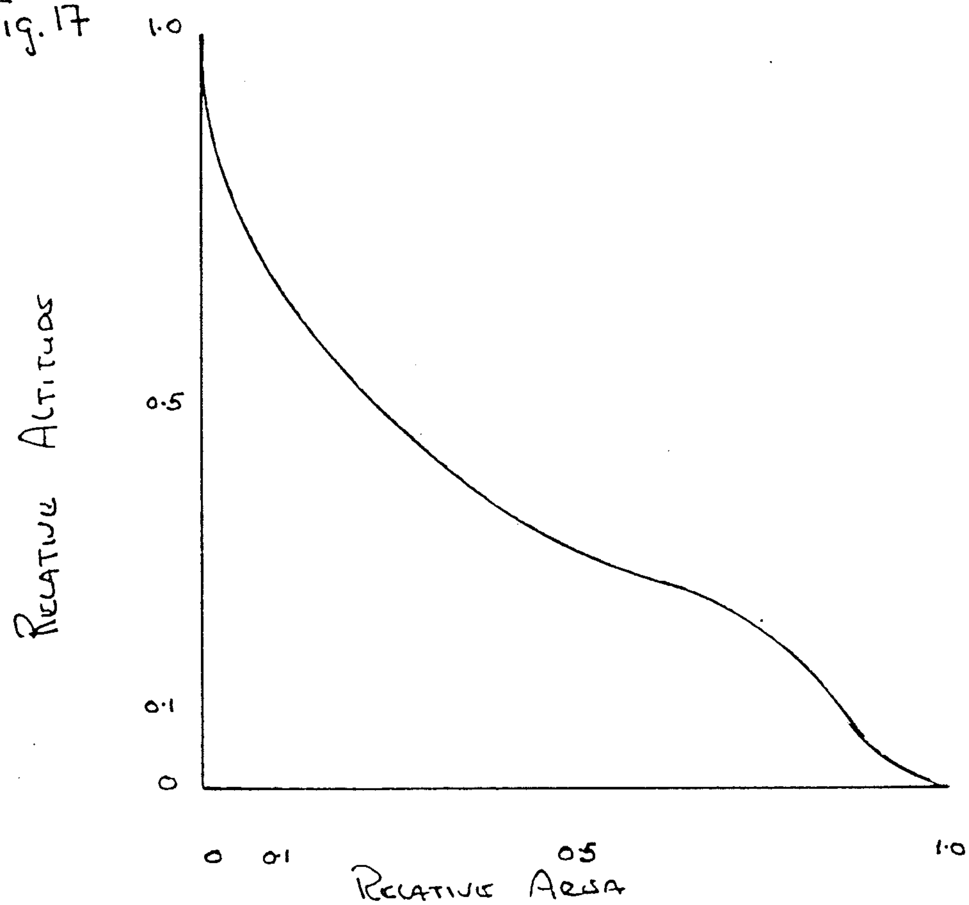

1.0
0.5
0.1
0
Relative Altitude
0
0.1
0.5
1.0
Relative Area
Judas Creek
HypI = 0.30
HypC = 0.18

Fig. 17

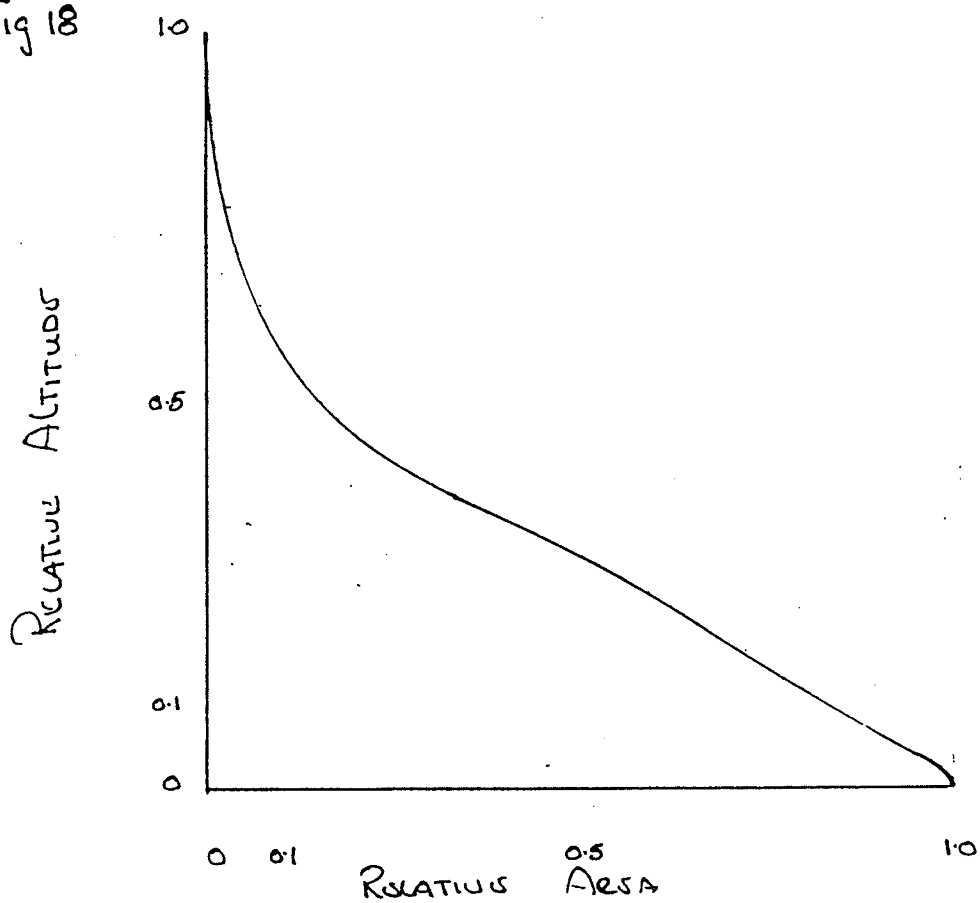


180 Mile Creek

HypI = 0.35

HypC = 0.24

Fig 18

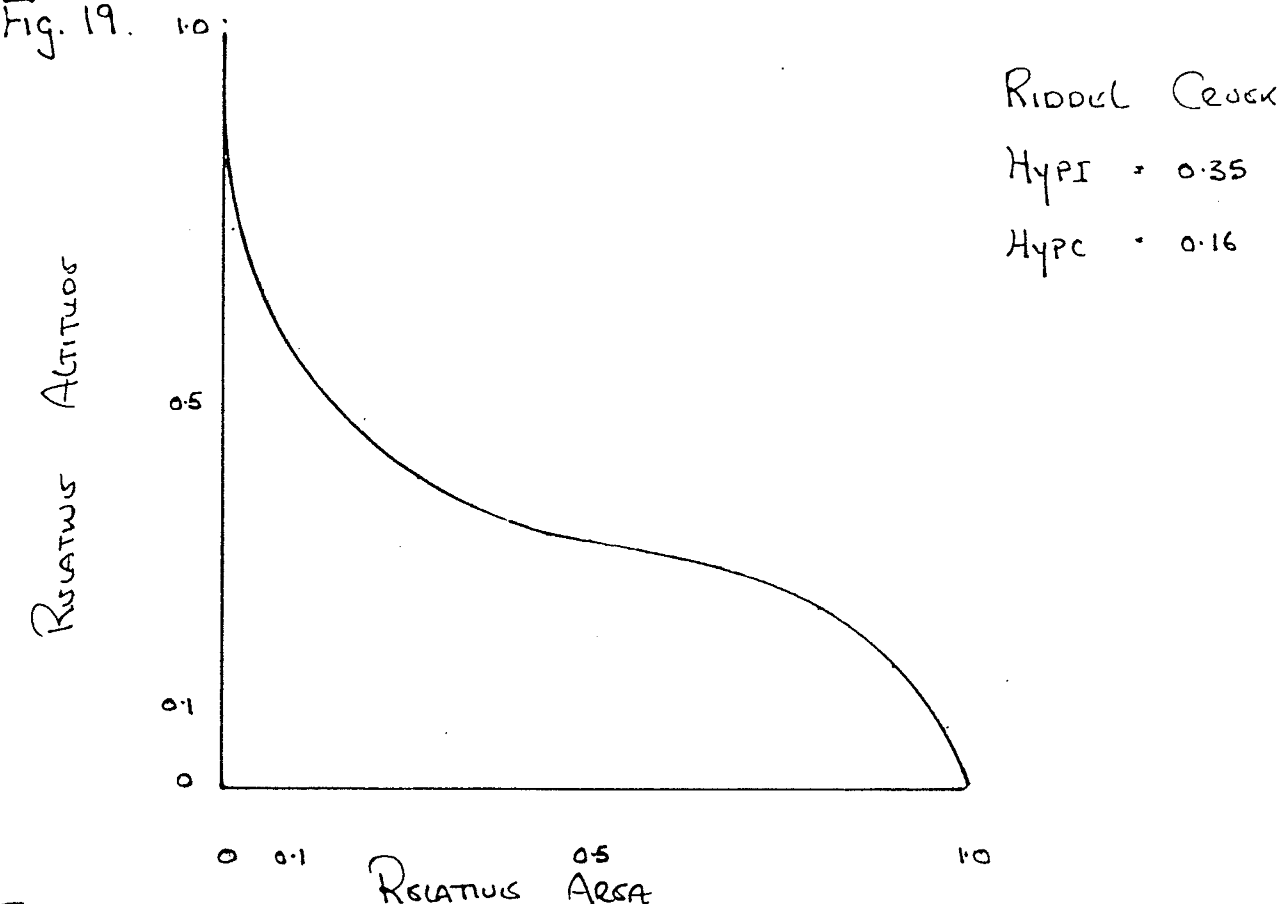


Twin Creek

HypI = 0.32

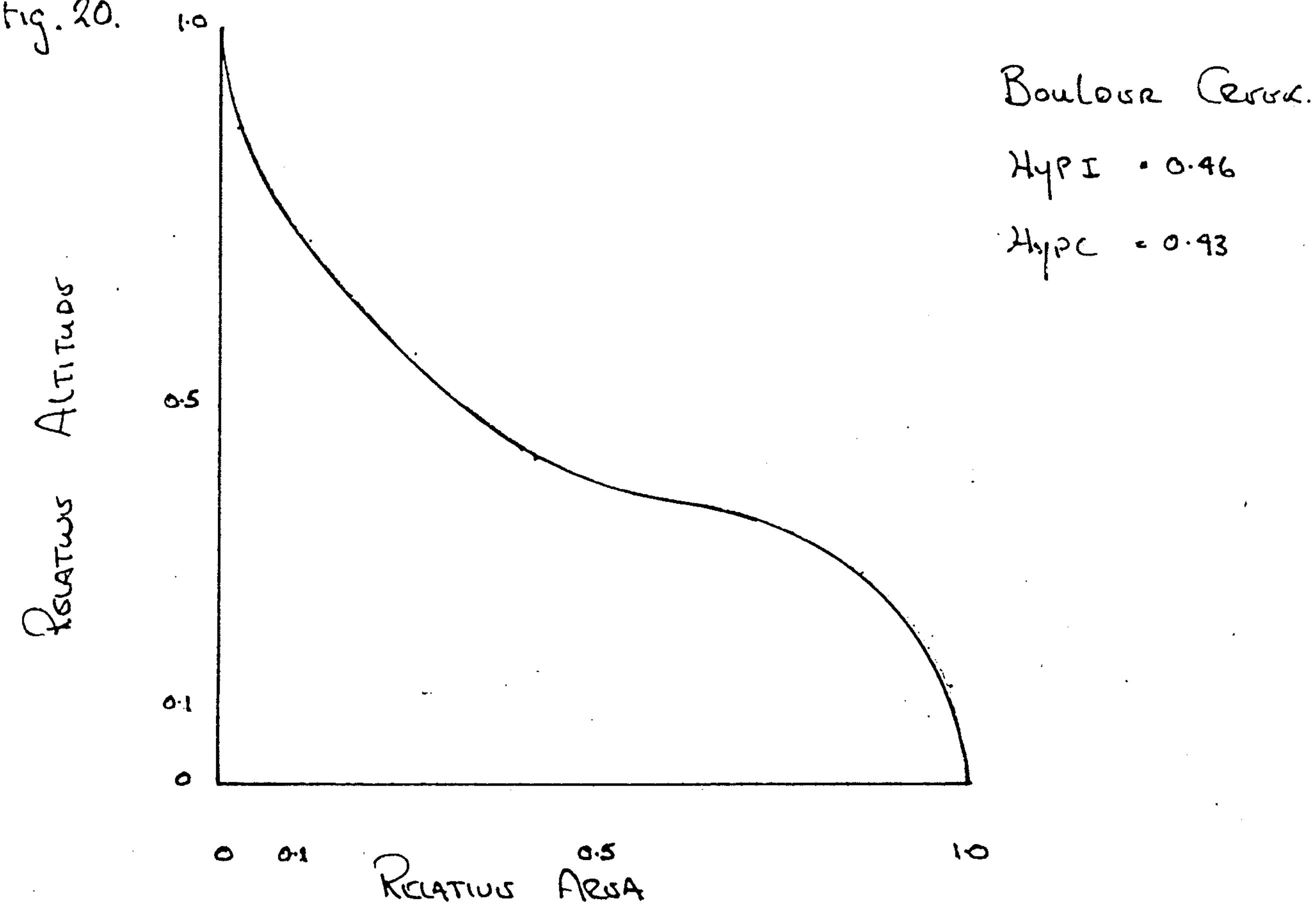
HypC = 0.16

Fig. 19.



1.0
0.5
0.1
0
Relative Altitude
0
0.1
0.5
1.0
Relative Area
Riddel Creek
HypI = 0.35
HypC = 0.16

Fig. 20.



1.0
0.5
0.1
0
Relative Altitude
0
0.1
0.5
1.0
Relative Area
Boulder Creek.
HypI = 0.46
HypC = 0.93

Fig. 21

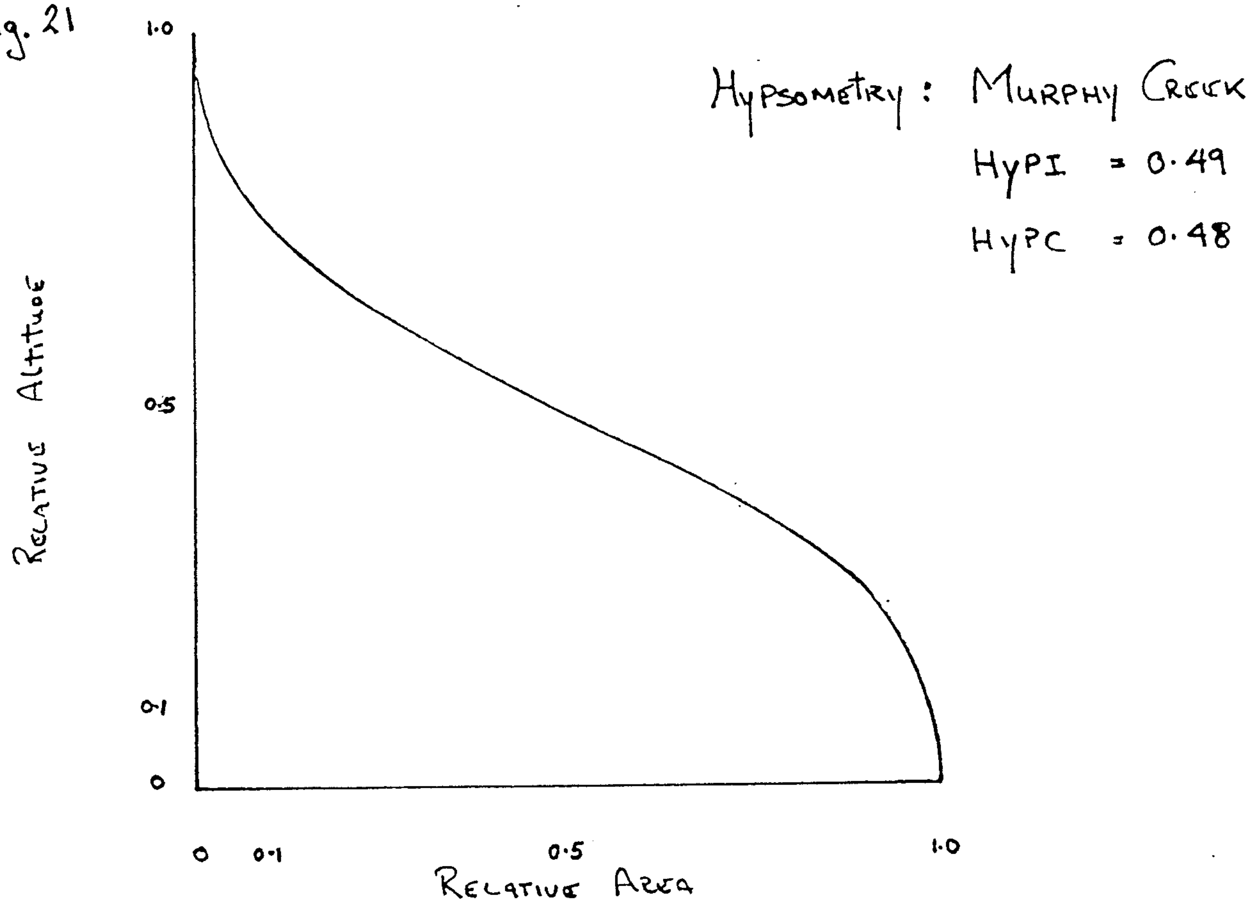

Hypsometry: Murphy Creek
HypI = 0.49
HypC = 0.48
1.0
0.5
0.1
0
Relative Altitude
0
0.1
0.5
1.0
Relative Area

Fig. 22

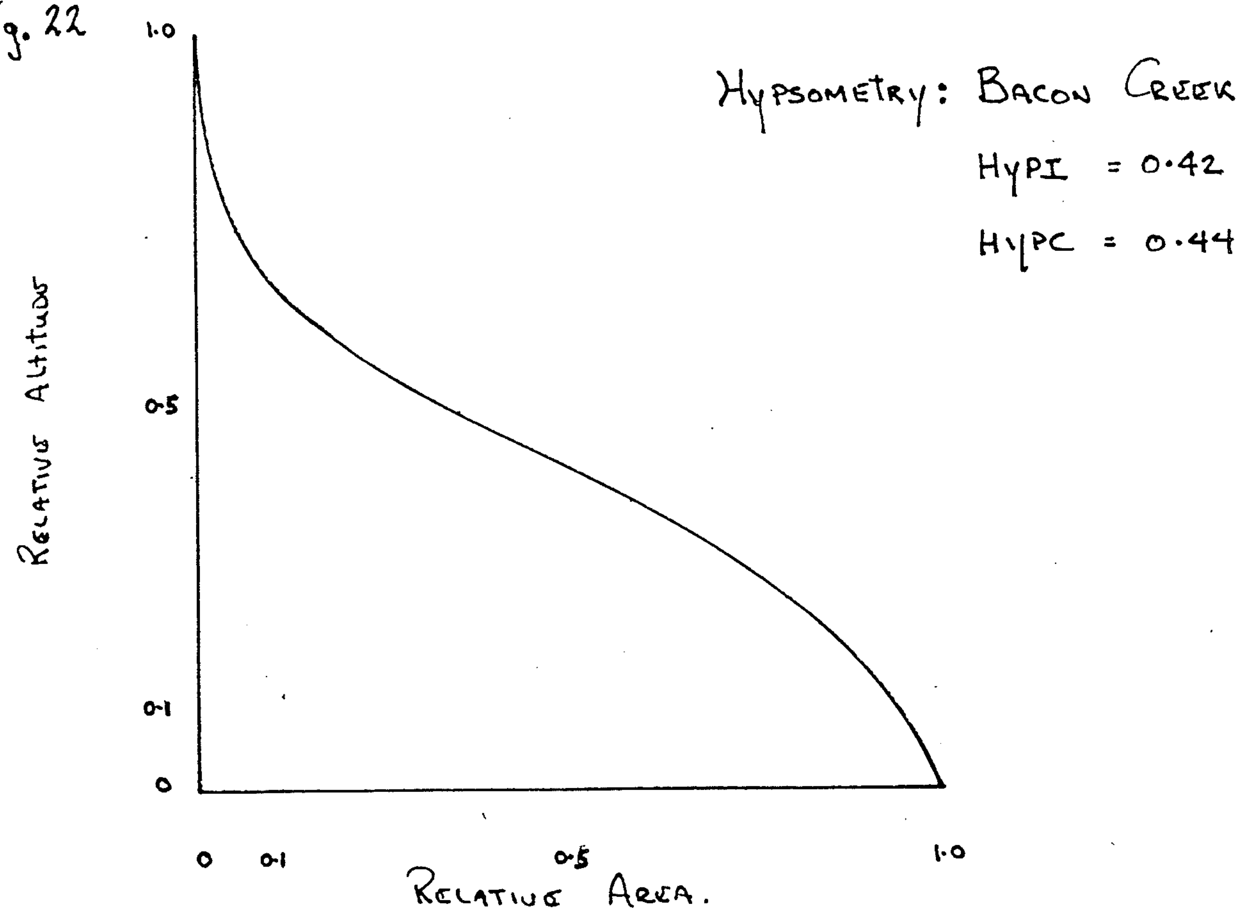

Hypsometry: Bacon Creek
HypI = 0.42
HypC = 0.44
1.0
0.5
0.1
0
Relative Altitude
0
0.1
0.5
1.0
Relative Area.

Fig. 23

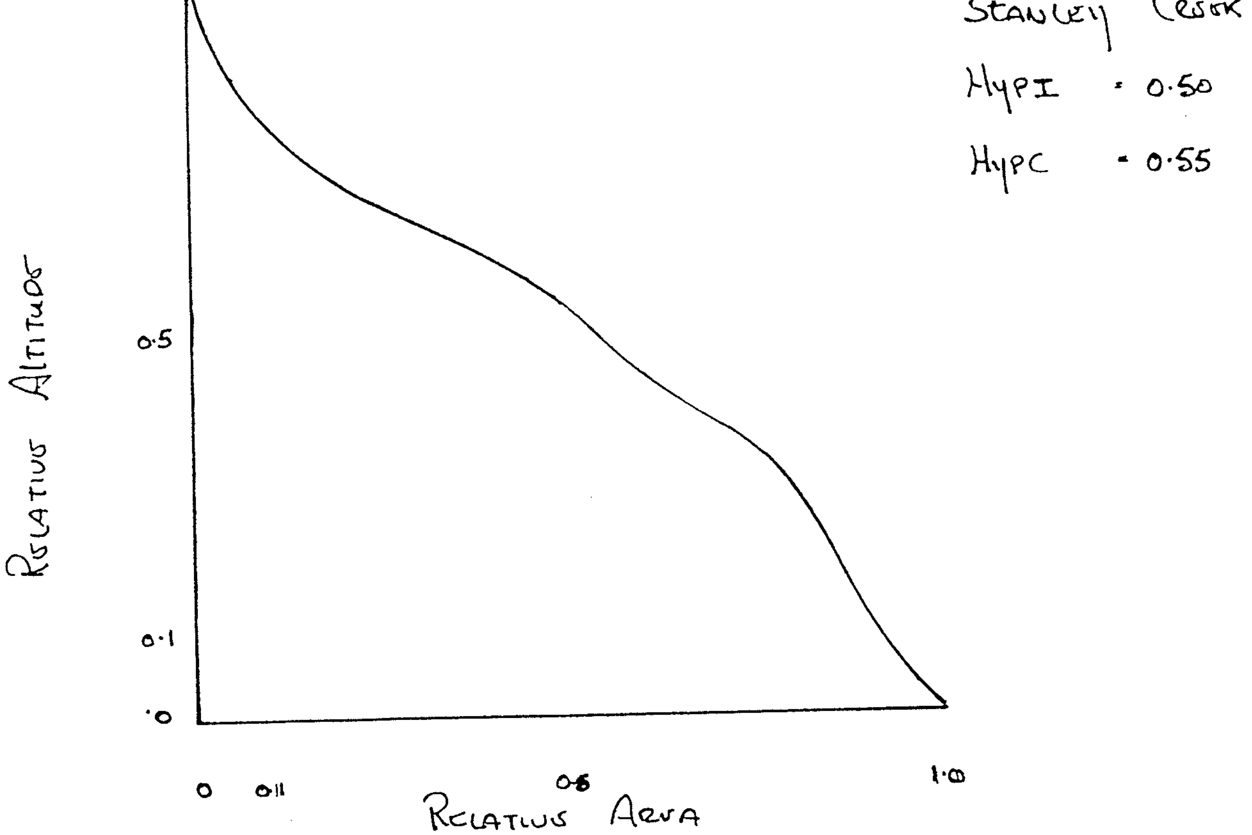

Stanley Creek
HypI = 0.50
HypC = 0.55
Relative Altitude
1.0
0.5
0.1
0
0
0.11
0.5
1.0
Relative Area

Fig. 24.

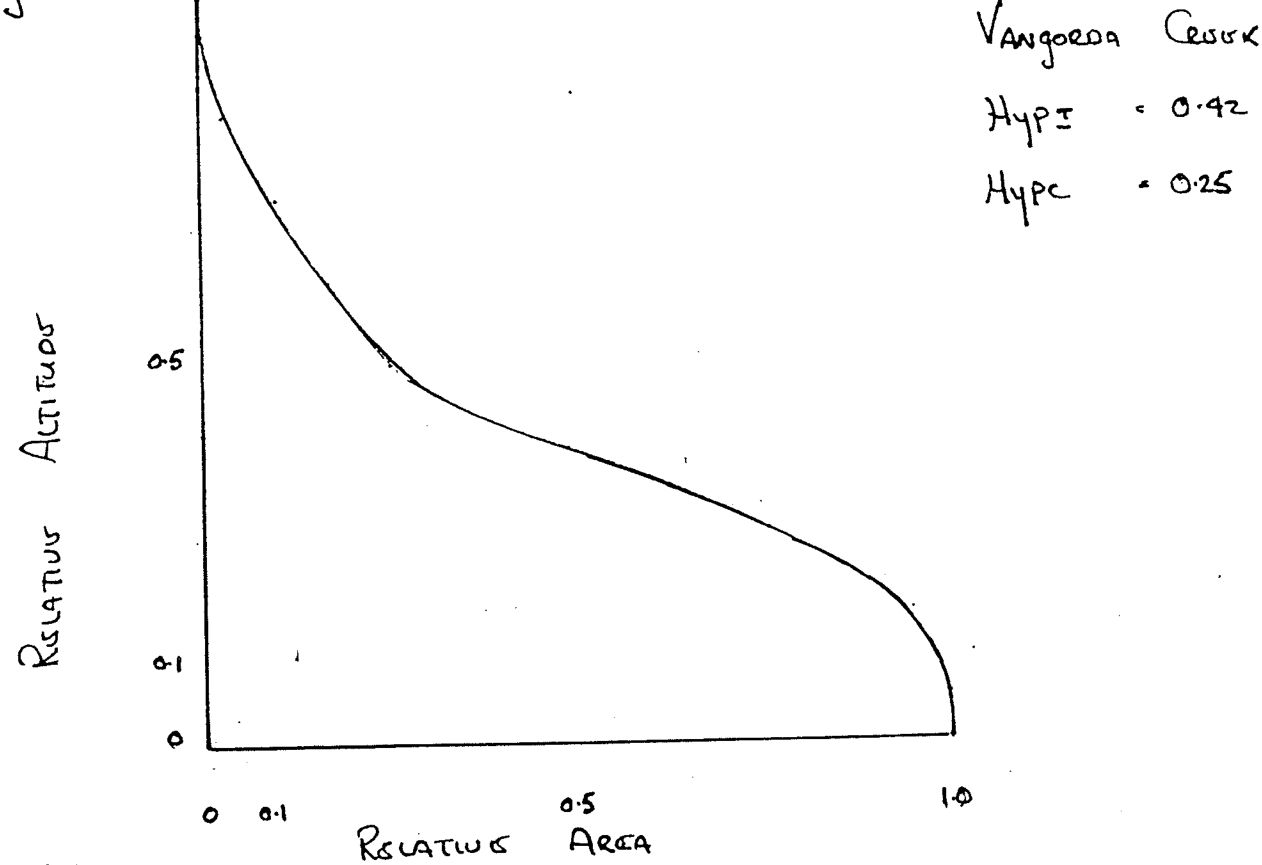

Vangorda Creek
HypI = 0.42
HypC = 0.25
Relative Altitude
1.0
0.5
0.1
0
0
0.1
0.5
1.0
Relative Area

Fig. 25

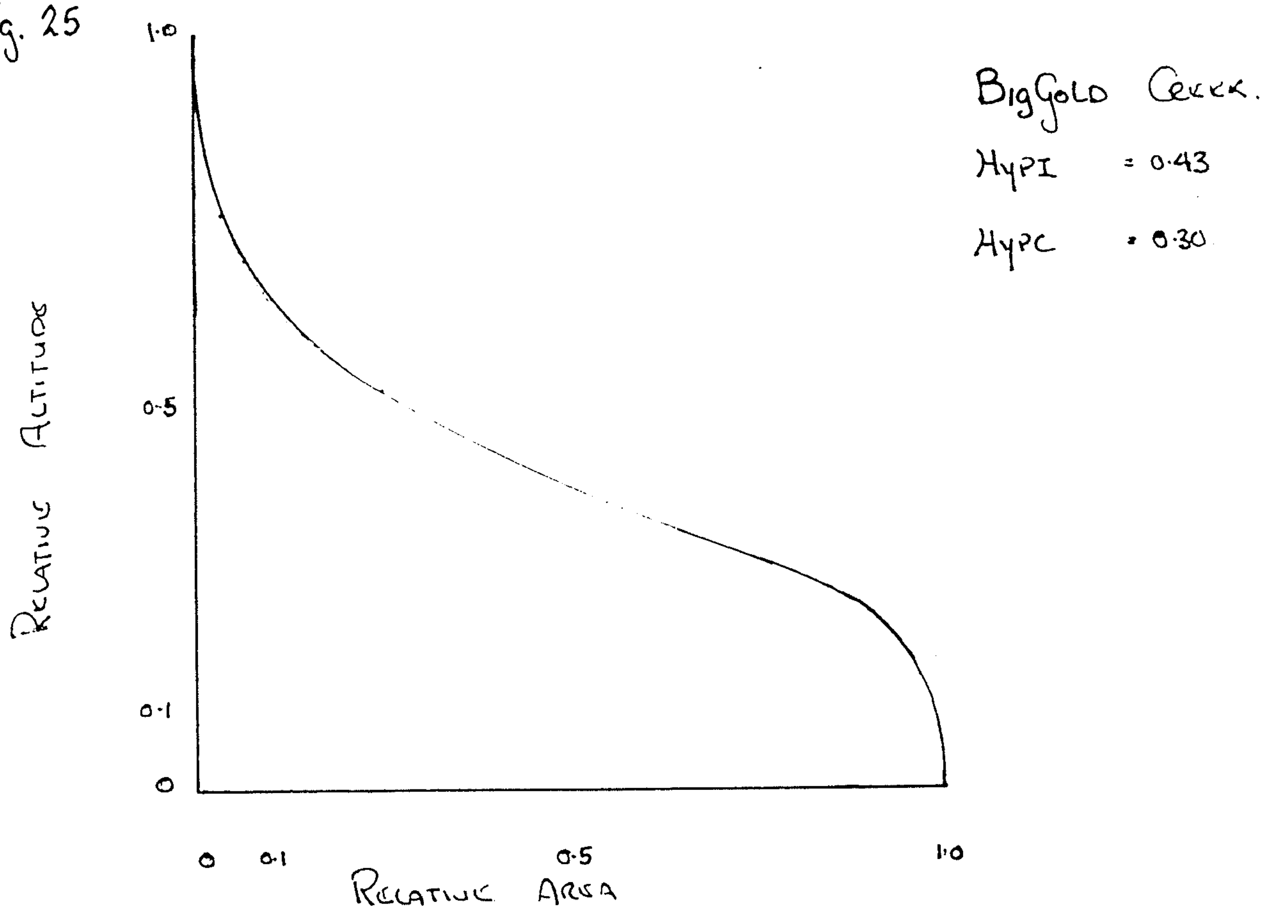

1.0
0.5
0.1
0
Relative Altitude
0
0.1
0.5
1.0
Relative Area
Big Gold Creek.
HypI = 0.43
HypC = 0.30

Fig. 26

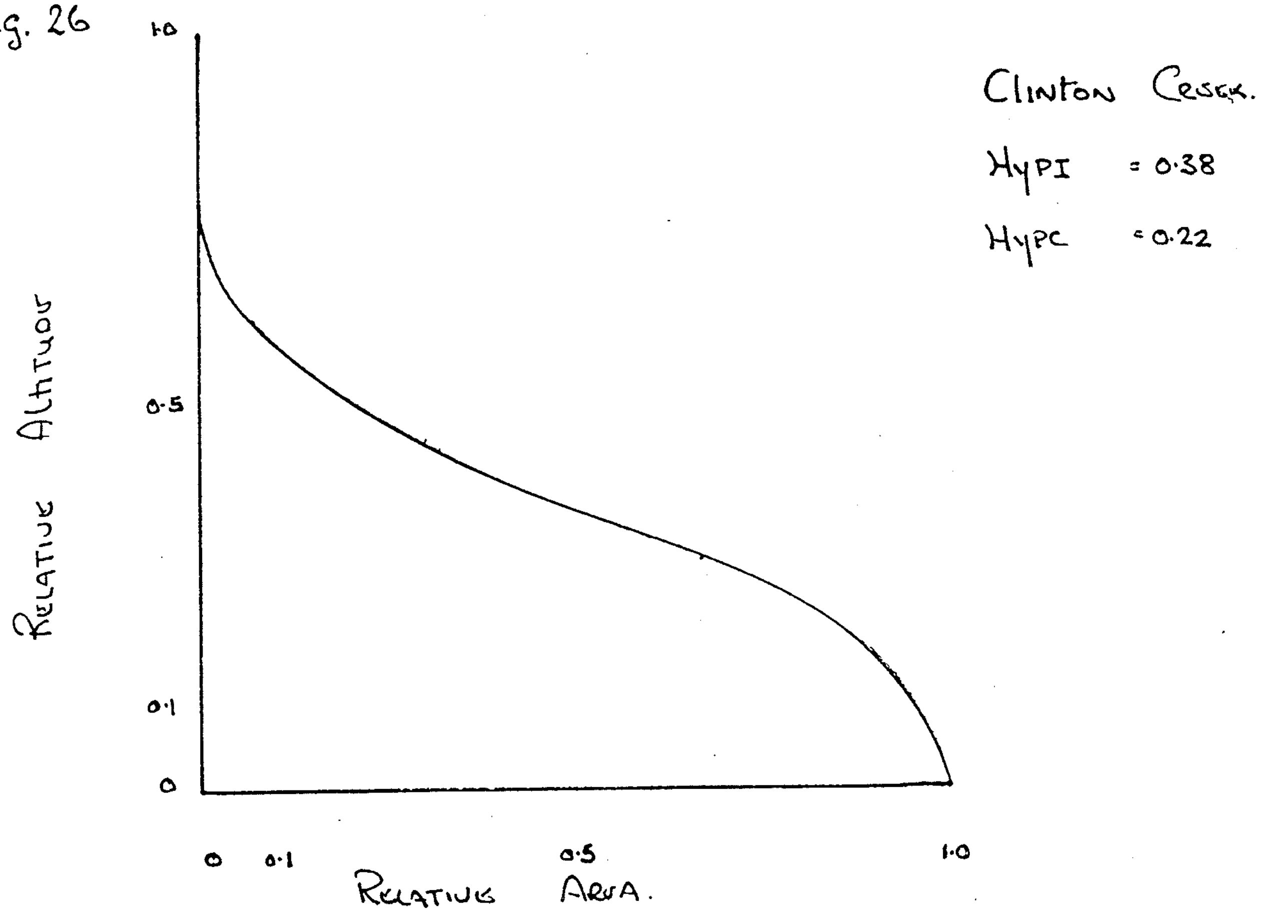

1.0
0.5
0.1
0
Relative Altitude
0
0.1
0.5
1.0
Relative Area.
Clinton Creek.
HypI = 0.38
HypC = 0.22

Fig. 27

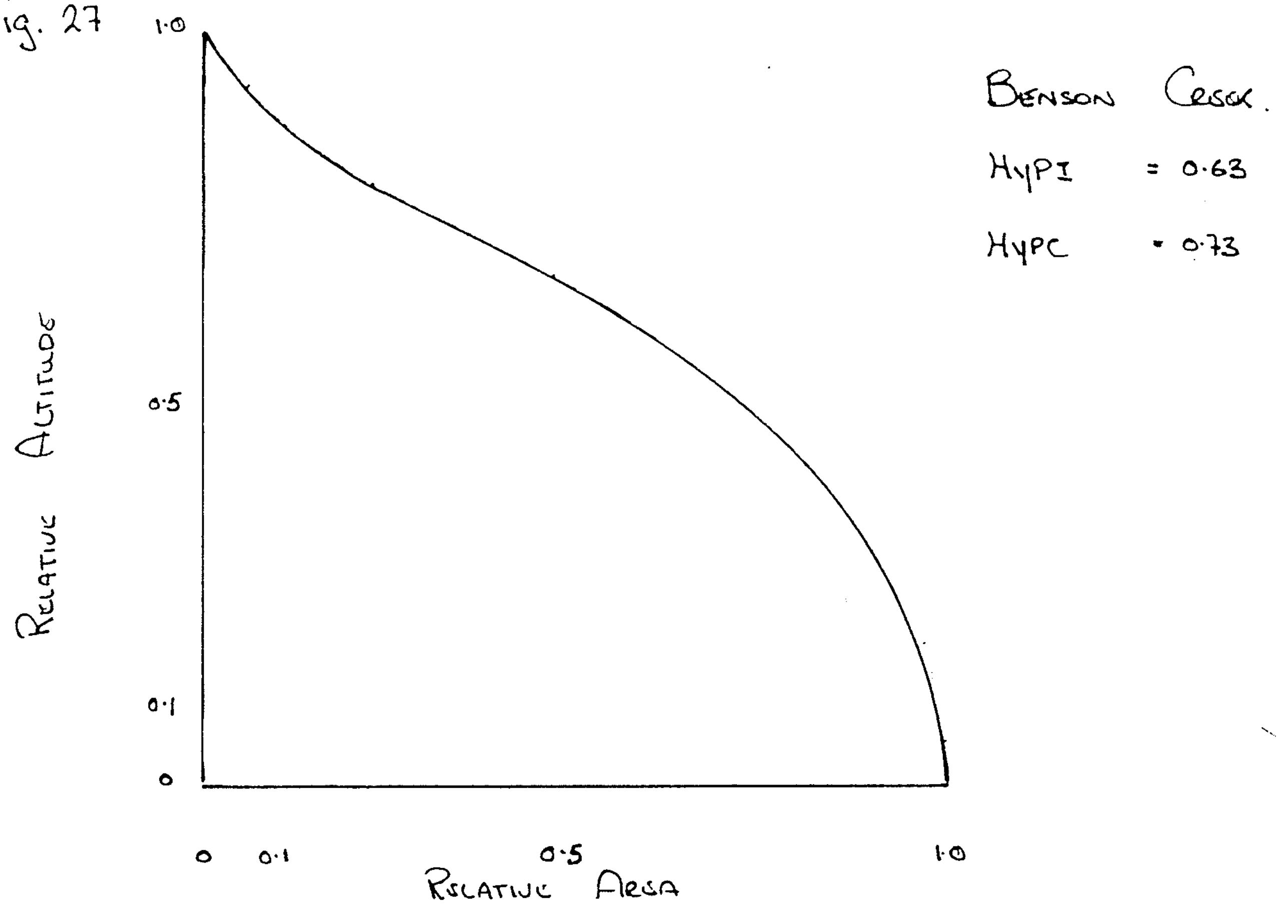

1.0
0.5
0.1
0
0
0.1
0.5
1.0
Relative Altitude
Relative Area
Benson Creek.
HypI = 0.63
HypC = 0.73

Fig. 28

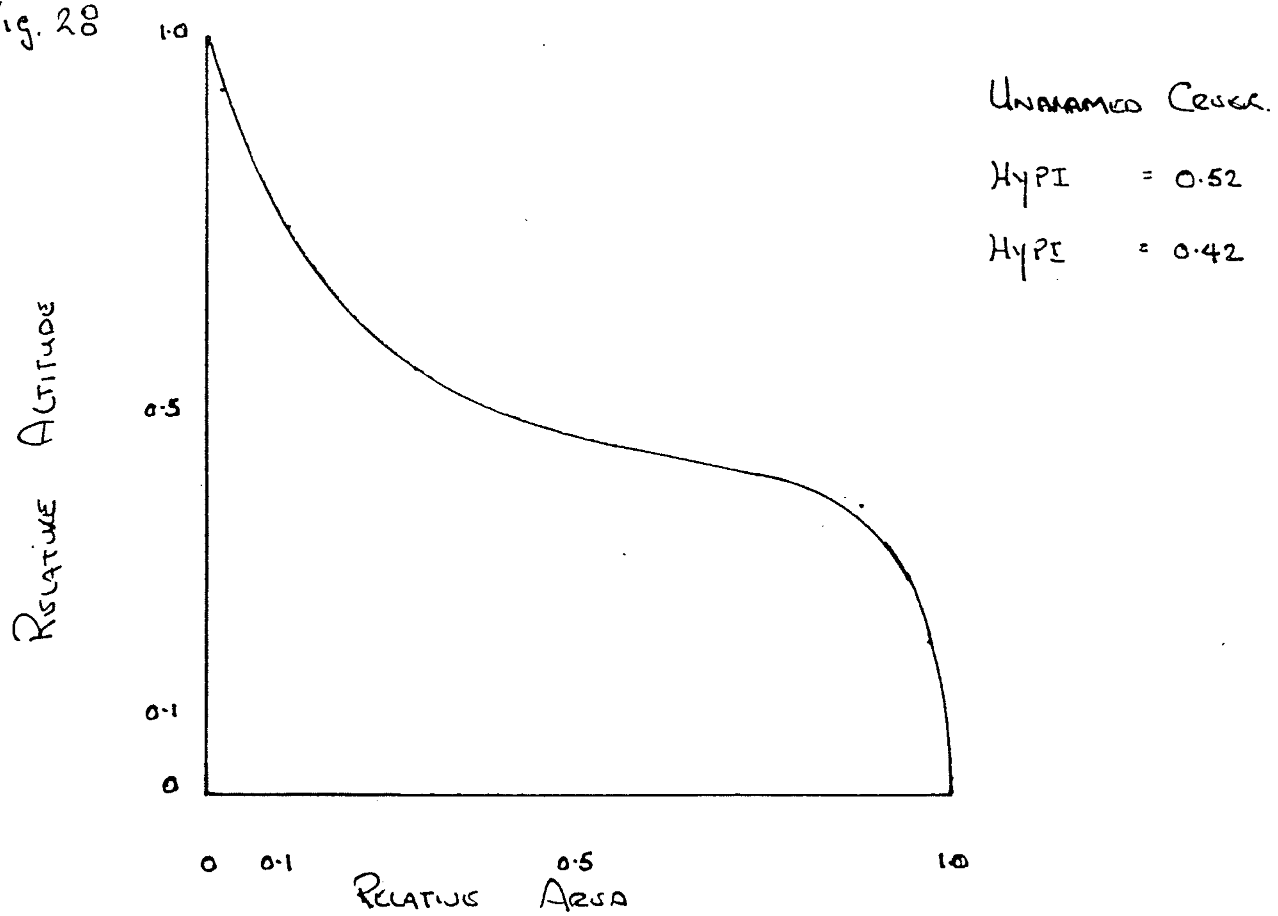

1.0
0.5
0.1
0
0
0.1
0.5
1.0
Relative Altitude
Relative Area
Unnamed Creek.
HypI = 0.52
HypI = 0.42

Fig. 29

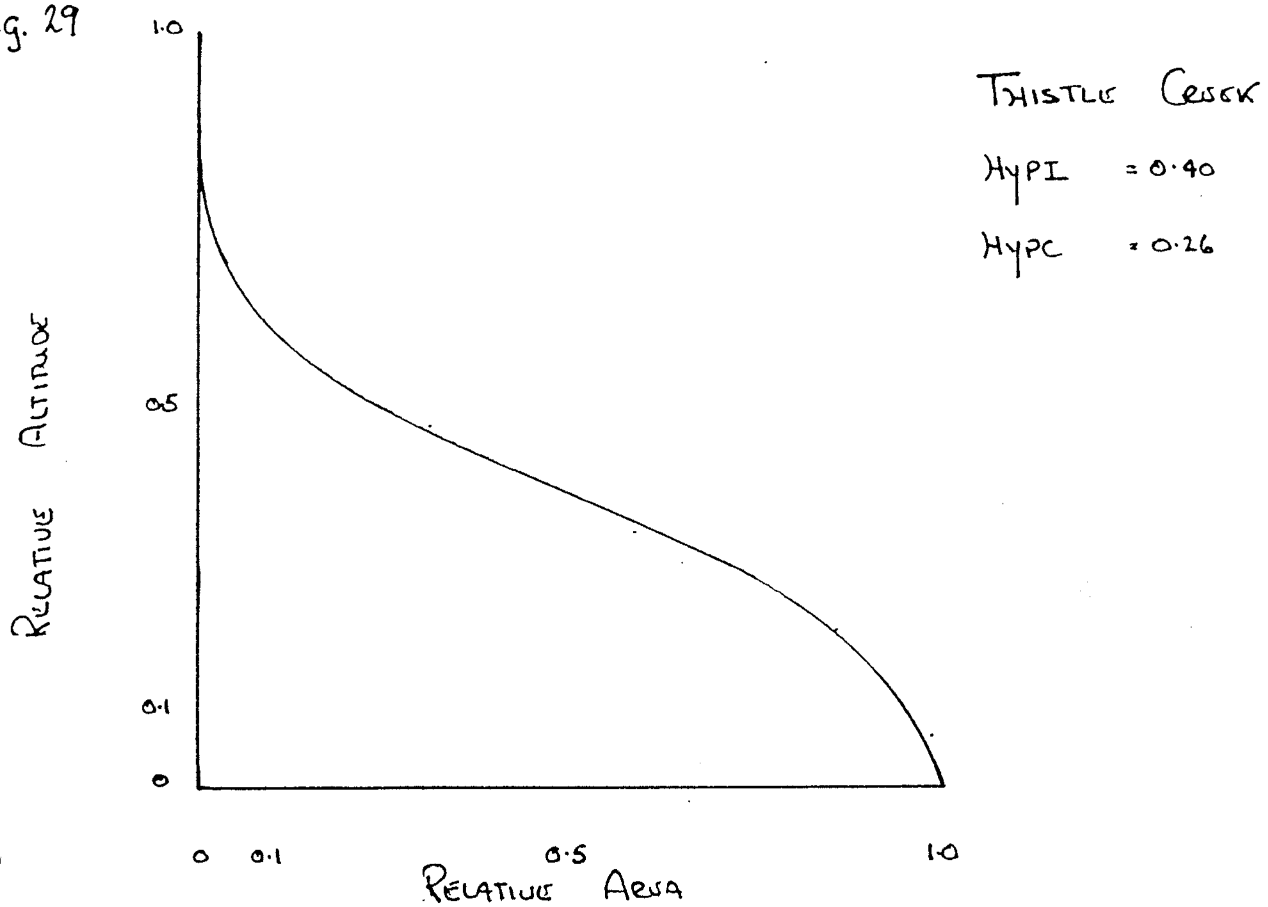

1.0
0.5
0.1
0
Relative Altitude
0
0.1
0.5
1.0
Relative Area
Thistle Creek
HypI = 0.40
HypC = 0.26

Fig. 30

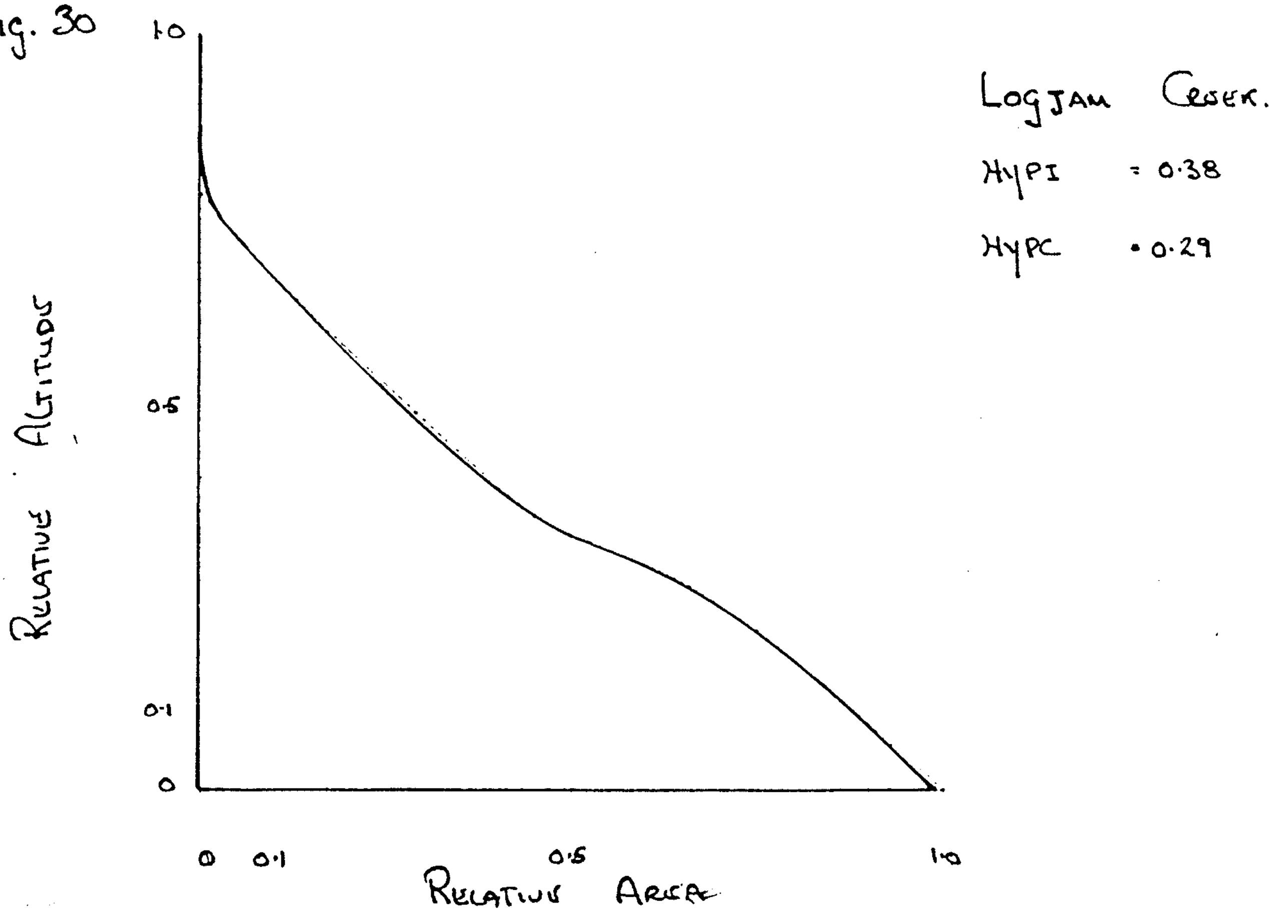
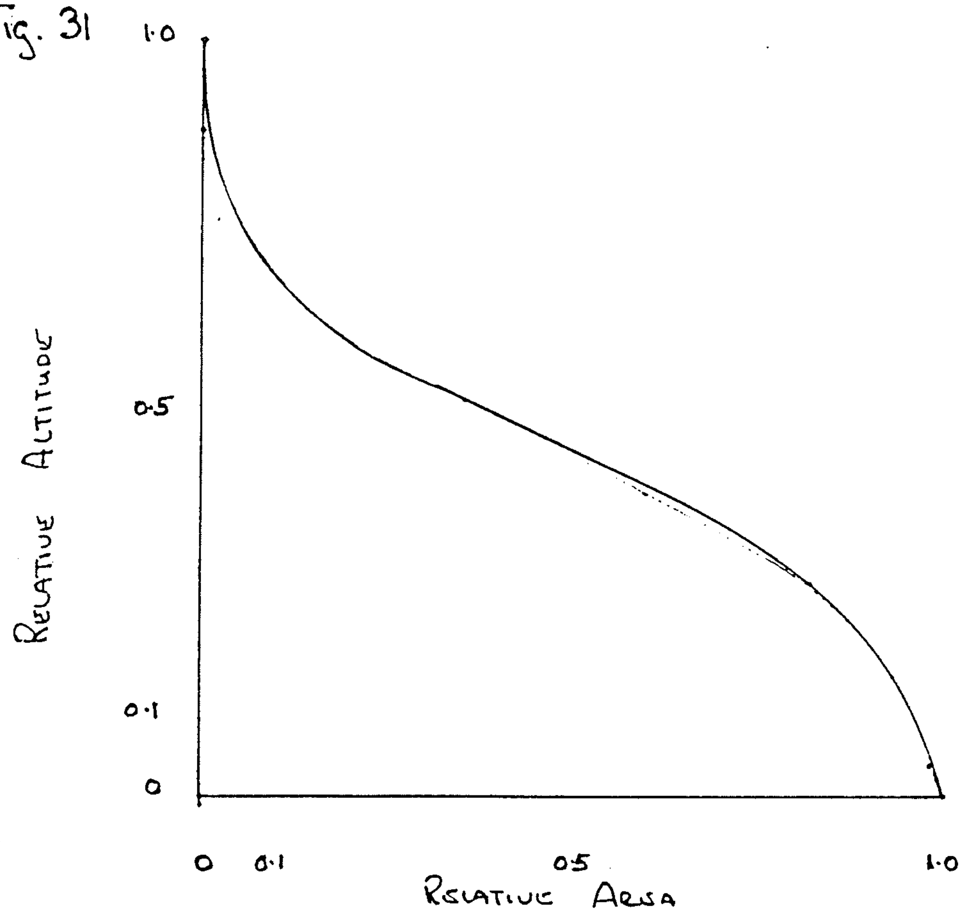

1.0
0.5
0.1
0
Relative Altitude
0
0.1
0.5
1.0
Relative Area
Logjam Creek.
HypI = 0.38
HypC = 0.29

Fig. 31

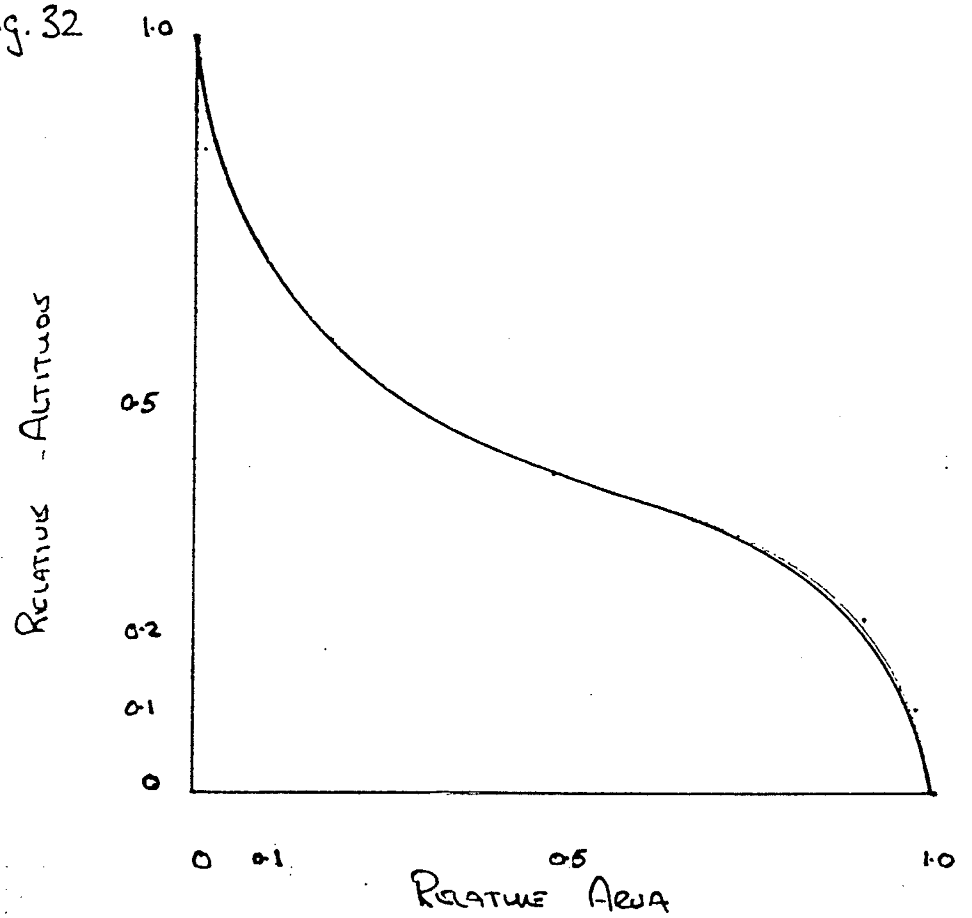


Wolf Creek

HypI = 0.45

HypC = 0.40

Fig. 32



Grizzly Creek

HypI 0.44

HypC 0.33

Fig 33.

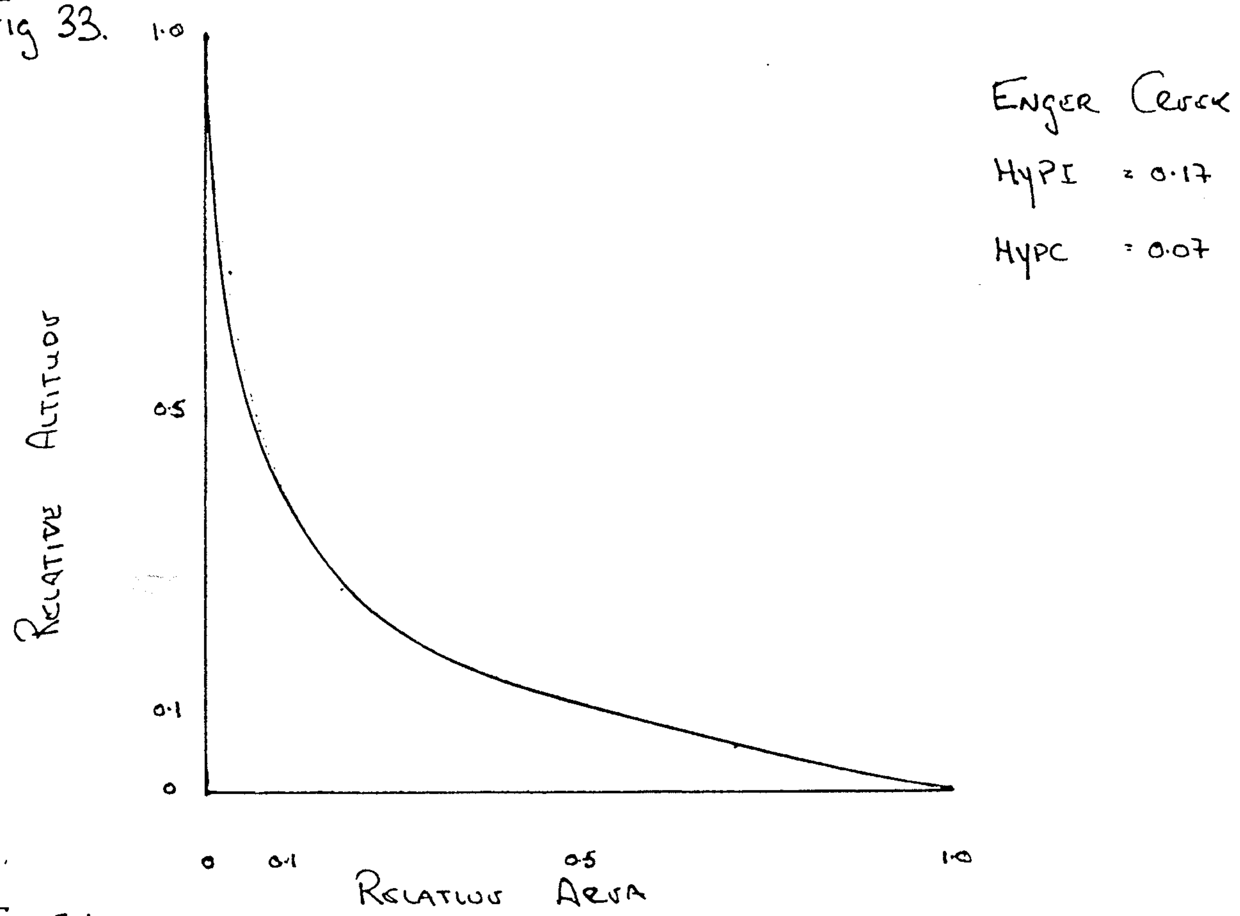

1.0
0.5
0.1
0
Relative Altitude
0
0.1
0.5
1.0
Relative Area
Enger Creek
HypI = 0.17
HypC = 0.07

Fig 34

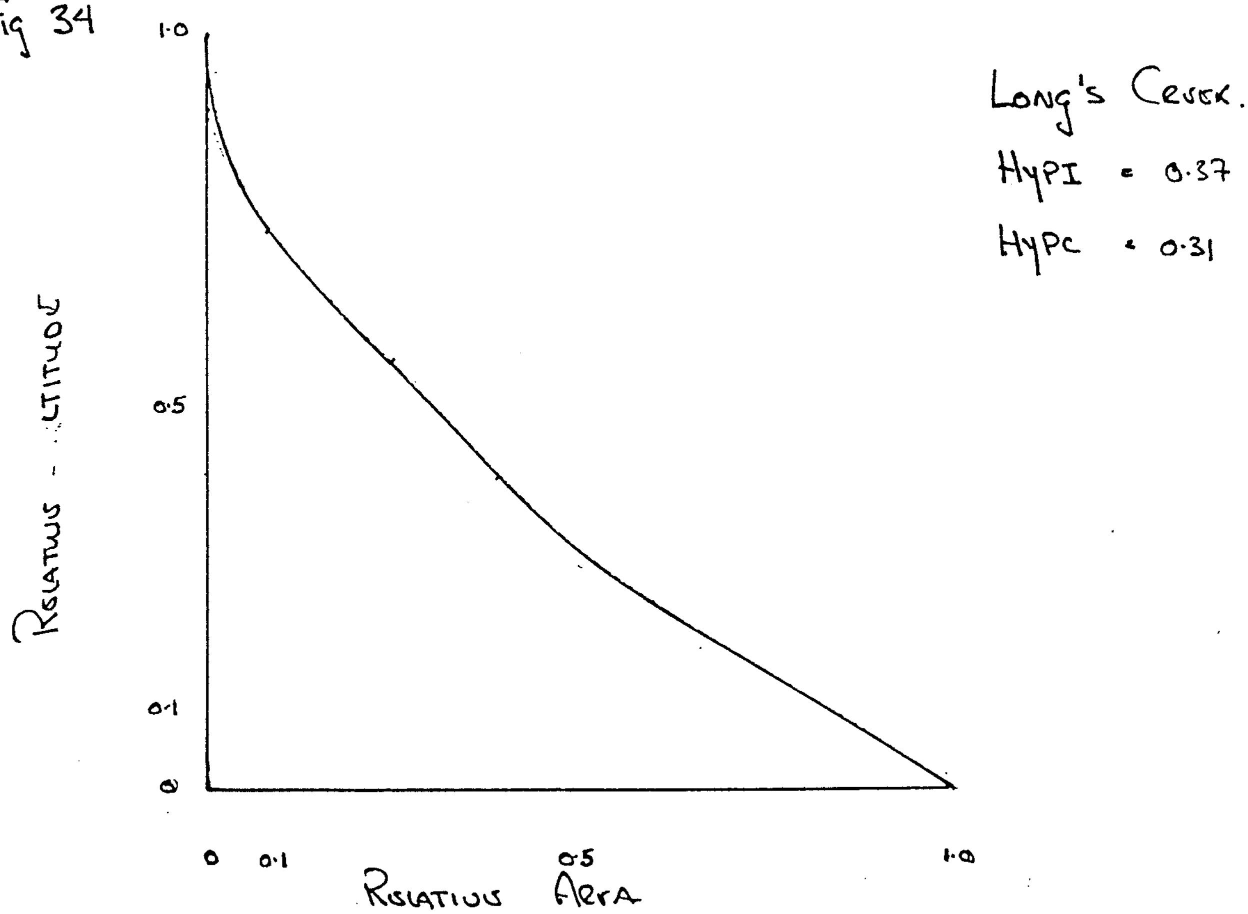

1.0
0.5
0.1
0
Relative Altitude
0
0.1
0.5
1.0
Relative Area
Long's Creek.
HypI = 0.37
HypC = 0.31

Fig 35.

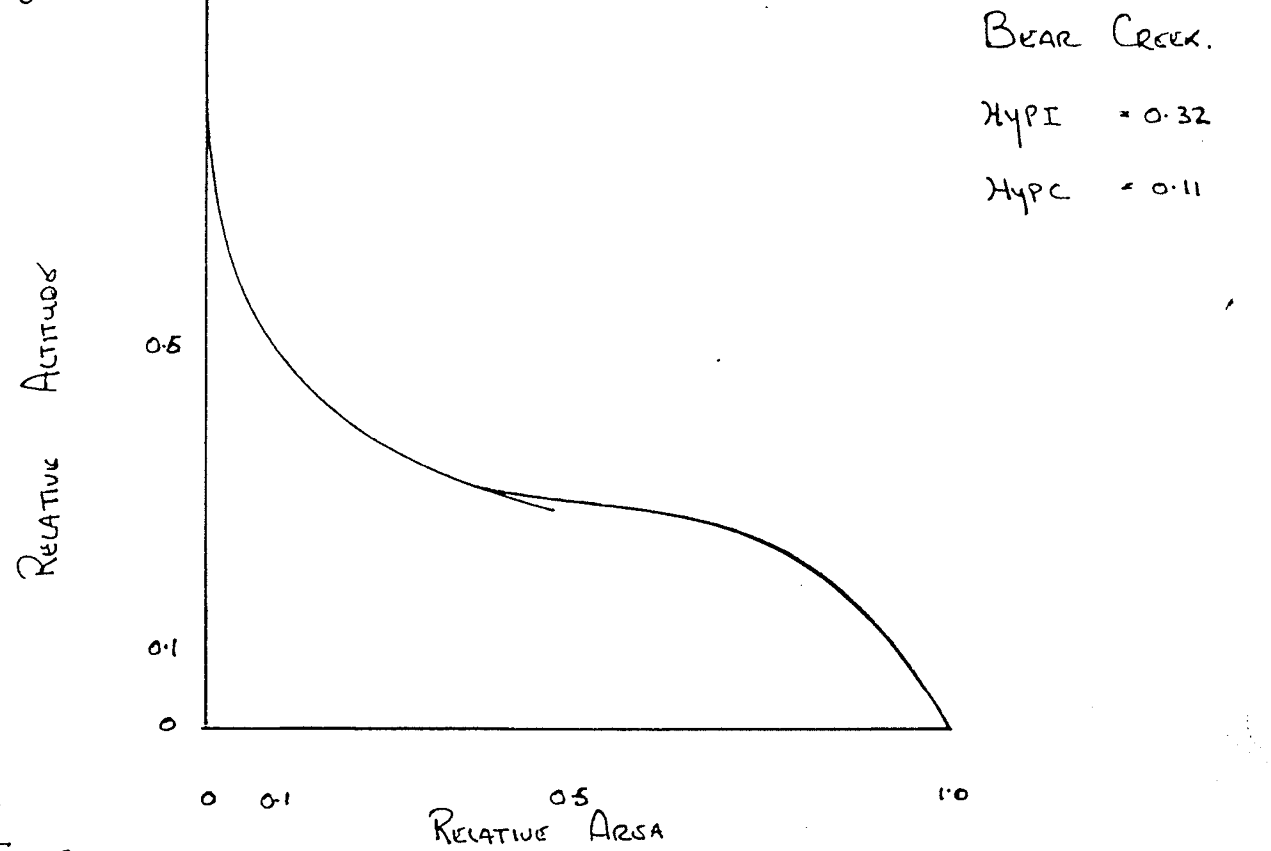
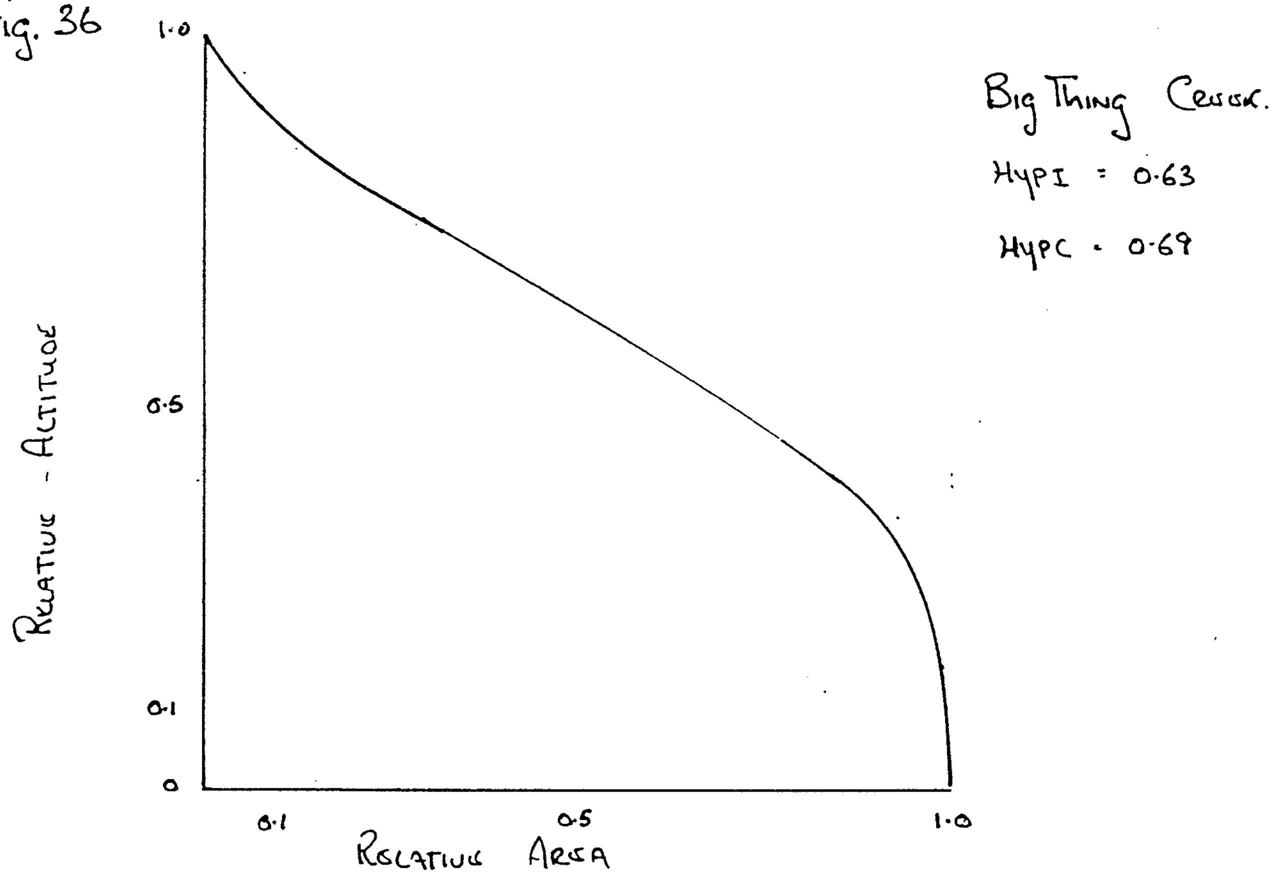

Bear Creek.
HypI = 0.32
HypC = 0.11
1.0
0.5
0.1
0
Relative Altitude
0
0.1
0.5
1.0
Relative Area

Fig. 36


Big Thing Creek.
HypI = 0.63
HypC = 0.69
1.0
0.5
0.1
0
Relative - Altitude
0.1
0.5
1.0
Relative Area

APPENDIX 3

CORRELATION MATRIX

VARIABLE NO.	NAME	MEAN	STANDARD DEVIATION	COEFFICIENT OF VARIATION	SKEWNESS	KURTOSIS	SMALLEST VALUE	LARGEST VALUE	SMALLEST STD SCORE	LARGEST STD SCORE
3	LONG	135.3199	3.5249	0.026048	0.1000	-1.4433	130.2000	140.8000	-1.4525	1.5547
4	LAT	61.7043	1.6001	0.025932	0.4437	-1.0624	59.5000	64.9500	-1.3776	2.0284
5	RANK	3.5278	0.6540	0.185400	-0.3970	-0.3246	2.0000	5.0000	-2.3359	2.2510
6	ELEV	807.5811	198.9479	0.246350	0.5664	2.5998	320.0000	1480.0000	-2.4508	3.3799
7	AREA	100.8082	65.2968	0.647733	0.6366	-1.0260	10.9000	222.0000	-1.3769	1.8560
8	PER	46.8027	17.3940	0.371645	0.1382	-1.1965	15.0000	75.5000	-1.8284	1.6498
9	STL	19.6360	9.4069	0.479062	0.7311	-0.3255	5.5000	42.6000	-1.5027	2.4412
10	BAL	16.0694	5.7551	0.358139	0.2283	-0.9963	5.8000	28.3000	-1.7844	2.1252
11	TCHL	84.7249	59.8141	0.705980	0.9795	0.4174	11.7000	268.0000	-1.2209	3.0641
12	REL	1090.5535	257.5488	0.236163	0.4903	0.8917	625.0000	1890.0000	-1.8076	3.1041
13	ASP	150.1665	88.9317	0.592221	0.3993	-0.7395	3.0000	343.0000	-1.6548	2.1683
14	CASP	-0.1570	0.6739	-4.291791	0.2006	-1.3090	-0.9999	0.9986	-1.2508	1.7148
15	BSH1	0.3647	0.0819	0.224617	0.3327	-0.1772	0.2200	0.5600	-1.7666	2.3837
16	BSH2	24.2126	5.3792	0.222166	0.5883	-0.2733	15.6100	38.8400	-1.5992	2.7192
17	DRD	0.8517	0.2523	0.296227	0.7997	0.3500	0.4500	1.6100	-1.5921	3.0058
18	STF	0.4375	0.2233	0.510440	0.7983	-0.0470	0.1100	1.0400	-1.4665	2.6980
19	RELRA	0.0760	0.0314	0.413489	1.3667	1.9634	0.0341	0.1715	-1.3335	3.0382
20	SLOPE	0.0406	0.0269	0.662242	1.8868	4.6591	0.0065	0.1468	-1.2682	3.9521
21	BIRA	3.9828	1.0797	0.271098	0.3027	-0.0822	1.7300	6.5000	-2.0864	2.3314
22	HYPI	0.4167	0.0980	0.235221	-0.2578	0.6272	0.1700	0.6300	-2.5168	2.1767
23	HYPC	0.3456	0.1672	0.483719	0.3645	-0.5577	0.0600	0.7300	-1.7084	2.3000
24	GRAD1	-0.0082	0.0523	-6.398036	0.5487	-0.4971	-0.0902	0.1180	-1.5694	2.4139
25	GRAD2	-0.0032	0.0292	-9.154758	0.8355	1.7347	-0.0676	0.0913	-2.2043	3.2339
26	ATR	0.4214	0.3284	0.779307	0.3766	-1.3819	0.0200	1.0000	-1.2223	1.7620
27	ALM	0.0369	0.0376	1.018590	2.5679	6.4865	0.0100	0.1900	-0.7160	4.0673
28	AGL	0.0047	0.0204	4.309862	5.0608	25.6125	0.0	0.1200	-0.2320	5.6642
29	PRECIP	44.3443	13.4997	0.304429	0.0977	-1.0465	24.1000	68.6000	-1.4996	1.7968
30	INTENS	0.4194	0.0914	0.217833	0.8311	-0.4266	0.3100	0.6400	-1.1978	2.4139
31	Q2	8.5822	6.4984	0.757191	0.9872	0.0191	0.2600	26.0000	-1.2807	2.6803
32	QMA	9.4497	7.1111	0.752520	0.9790	0.0168	0.2900	28.5000	-1.2881	2.6790
33	Q5	13.5719	10.0585	0.741127	0.9443	0.0160	0.4400	41.0000	-1.3056	2.7268
34	Q10	17.5105	13.1211	0.749330	0.9765	0.1511	0.5800	54.0000	-1.2903	2.7810
35	Q20	21.8649	16.7432	0.765756	0.9884	0.1638	0.7400	67.0000	-1.2617	2.6957
36	S1085	0.0358	0.0271	0.755770	1.8159	3.6373	0.0065	0.1371	-1.0831	3.7405
37	NASP	0.5713	0.2886	0.505252	-0.1389	-1.0107	0.0167	1.0000	-1.9215	1.4852
38	CASP2	1.8430	0.6739	0.365656	0.2006	-1.3090	1.0001	2.9986	-1.2507	1.7149
39	GRADA	8.7396	5.2500	0.600720	0.2024	-1.0988	0.1596	19.6464	-1.6343	2.0775
40	GRADB	19.5989	14.4564	0.737613	1.0371	0.7181	0.2429	64.1026	-1.3389	3.0785
41	GRADE	27.6718	15.5715	0.562724	1.3842	1.5840	11.0257	79.0234	-1.0690	3.2978

42	GRADF	70.9064	82.9824	1.170309	3.2729	11.2914	12.6757	454.8154	-0.7017	4.6264
43	RUGN	0.9240	0.3414	0.369443	0.9619	1.0158	0.4094	2.0223	-1.5076	3.2171
44	LNASP	-0.3525	0.4095	-1.161925	-2.0936	4.2954	-1.7762	0.0	-3.4811	0.8606
45	LCASP2	0.2354	0.1671	0.709704	-0.1624	-1.4428	0.0000	0.4769	-1.4088	1.4456
46	LGRADA	0.7980	0.4717	0.591075	-1.9443	3.9423	-0.7969	1.2933	-3.3813	1.0501
47	LGRADB	1.1198	0.5126	0.457745	-1.8933	4.1829	-0.6146	1.8069	-3.3237	1.3403
48	LGRADE	1.3858	0.2175	0.156977	0.4434	-0.7139	1.0424	1.8978	-1.5787	2.3531
49	LGRADF	1.7077	0.3193	0.186986	0.8441	1.0406	1.1030	2.6578	-1.8938	2.9755
50	LRUGN	-0.0616	0.1562	-2.534565	0.0205	-0.3719	-0.3879	0.3058	-2.0893	2.3530
51	LLONG	2.1312	0.0113	0.005304	0.0766	-1.4496	2.1146	2.1486	-1.4684	1.5387
52	LLAT	1.7902	0.0112	0.006259	0.4133	-1.0953	1.7745	1.8126	-1.3970	2.0002
53	LRANK	0.5394	0.0875	0.162216	-0.9023	0.6064	0.3010	0.6990	-2.7245	1.8231
54	LS1085	-1.5487	0.3079	-0.198791	-0.1295	-0.1618	-2.1871	-0.8630	-2.0733	2.2275
55	LELEV	2.8934	0.1157	0.039976	-1.0617	3.1558	2.5051	3.1703	-3.3564	2.3939
56	LAREA	1.9035	0.3176	0.166846	-0.4484	-0.2230	1.0374	2.3464	-2.7270	1.3944
57	LPER	1.6374	0.1787	0.109131	-0.5569	-0.3118	1.1761	1.8779	-2.5815	1.3464
58	LSTL	1.2440	0.2133	0.171468	-0.1728	-0.6047	0.7404	1.6294	-2.3612	1.8066
59	LBAL	1.1763	0.1683	0.143095	-0.4727	-0.3803	0.7634	1.4518	-2.4530	1.6364
60	LTCHL	1.8166	0.3292	0.181239	-0.2103	-0.8419	1.0682	2.4281	-2.2731	1.8575
61	LREL	3.0257	0.1045	0.034544	-0.2874	-0.0900	2.7959	3.2765	-2.1987	2.3993
62	LASP	2.0480	0.4426	0.216129	-2.0690	4.7859	0.4771	2.5353	-3.5489	1.1009
63	LBSH1	-0.4489	0.0994	-0.221372	-0.2332	-0.3964	-0.6576	-0.2518	-2.1002	1.9832
64	LBSH2	1.3739	0.0945	0.068776	0.1623	-0.7594	1.1934	1.5893	-1.9106	2.2788
65	LDRD	-0.0873	0.1245	-1.426311	0.1668	-0.6318	-0.3468	0.2068	-2.0835	2.3619
66	LSTF	-0.4148	0.2284	-0.550485	-0.1861	-0.6397	-0.9586	0.0170	-2.3811	1.8912
67	LRELRA	-1.1504	0.1640	-0.142535	0.3256	-0.2251	-1.4672	-0.7657	-1.9320	2.3461
68	LSLOPE	-1.4723	0.2752	-0.186907	-0.3169	0.4347	-2.1871	-0.8333	-2.5975	2.3222
69	LBIRA	0.5837	0.1245	0.213207	-0.5608	0.4632	0.2380	0.8129	-2.7776	1.8415
70	LHYPI	-0.3941	0.1180	-0.299482	-1.3521	2.6096	-0.7696	-0.2007	-3.1811	1.6390
71	LHYPC	-0.5227	0.2547	-0.487371	-0.8915	0.4795	-1.2218	-0.1367	-2.7445	1.5153
72	LGRAD1	-0.0041	0.0226	-5.461819	0.4532	-0.6371	-0.0411	0.0484	-1.6328	2.3258
73	LGRAD2	-0.0016	0.0126	-8.034419	0.7031	1.4821	-0.0304	0.0379	-2.2898	3.1380
74	LATR	0.1417	0.0989	0.698180	0.1981	-1.4888	0.0086	0.3010	-1.3453	1.6114
75	LALM	0.0155	0.0151	0.972718	2.4786	5.9488	0.0043	0.0755	-0.7413	3.9848
76	LAGL	0.0020	0.0084	4.257874	5.0211	25.2879	0.0	0.0492	-0.2349	5.6478
77	LPRECIP	1.6257	0.1404	0.086345	-0.3325	-1.1142	1.3820	1.8363	-1.7363	1.5001
78	LINTENS	-0.3866	0.0895	-0.231389	-0.5486	-0.8185	-0.5086	-0.1938	-1.3642	2.1551
79	LQ2	0.7933	0.3979	0.501516	-0.9769	1.8689	-0.5850	1.4150	-3.4643	1.5624
80	LQMA	0.8366	0.3959	0.473241	-0.9850	1.8979	-0.5376	1.4548	-3.4709	1.5615
81	LQ5	0.9963	0.3923	0.393718	-0.9741	1.7885	-0.3565	1.6128	-3.4488	1.5715
82	LQ10	1.1041	0.3958	0.358451	-0.9316	1.5517	-0.2366	1.7324	-3.3875	1.5875
83	LQ20	1.1941	0.4036	0.338006	-0.8535	1.1669	-0.1308	1.8261	-3.2825	1.5657

NOTE - KURTOSIS VALUES GREATER THAN ZERO INDICATE A DISTRIBUTION WITH HEAVIER TAILS THAN NORMAL DISTRIBUTION.

PAGE 4 BMDP YUKON ; REGRESSION ANALYSIS

CORRELATION MATRIX

		LONG 3	LAT 4	RANK 5	ELEV 6	AREA 7	PER 8	STL 9	BAL 10	TCHL 11	REL 12
LONG	3	1.0000									
LAT	4	0.4045	1.0000								
RANK	5	0.2335	0.3051	1.0000							
ELEV	6	-0.5255	-0.0491	-0.3674	1.0000						

AREA	7	0.1557	0.1985	0.6986	-0.3666	1.0000					
PER	8	0.1353	0.2539	0.7116	-0.2758	0.9368	1.0000				
STL	9	0.0346	0.1857	0.6307	-0.1864	0.8789	0.8720	1.0000			
BAL	10	0.1272	0.2172	0.7065	-0.3343	0.9338	0.9691	0.9146	1.0000		
TCHL	11	0.1671	0.3331	0.7713	-0.3304	0.8850	0.8446	0.7882	0.8471	1.0000	
REL	12	-0.0542	-0.1330	0.1100	-0.1204	0.1832	0.2709	0.1875	0.3057	0.1726	1.0000
ASP	13	-0.0526	0.0415	0.4381	-0.0445	0.0713	0.0527	0.0989	0.0395	0.1440	-0.3353
CASP	14	0.1034	-0.0014	-0.1894	0.0321	-0.1038	-0.1457	-0.1629	-0.1394	0.0094	-0.0769
BSH1	15	0.0053	-0.1259	-0.0105	-0.0506	-0.0497	-0.2212	-0.2562	-0.3369	-0.1049	-0.3601
BSH2	16	0.0736	0.2651	0.1604	0.1403	0.1653	0.4669	0.2815	0.4016	0.1776	0.2684
DRD	17	-0.0284	0.2618	0.2508	0.1296	-0.0710	-0.0542	-0.0589	-0.0550	0.3358	-0.0752
STF	18	0.1905	0.2227	0.4142	-0.0763	0.0035	-0.0220	-0.0489	-0.0007	0.3765	-0.0979
RELRA	19	-0.0962	-0.3383	-0.6327	0.1593	-0.7030	-0.7473	-0.7093	-0.7414	-0.6419	0.2816
SLOPE	20	-0.1111	-0.2281	-0.5021	0.0247	-0.5693	-0.6103	-0.6090	-0.5871	-0.5031	0.3679
BIRA	21	-0.1331	0.0111	-0.0268	0.2424	0.0782	0.0884	0.0793	0.0937	0.1337	-0.0708
HYPI	22	-0.1800	0.0216	-0.2258	0.0295	-0.1245	-0.2218	-0.0066	-0.1207	-0.0850	0.1989
HYPC	23	-0.1410	-0.0783	-0.2732	0.0402	-0.1978	-0.2687	-0.0858	-0.1808	-0.1820	0.1663
GRAD1	24	0.0901	-0.1046	-0.2602	0.0245	-0.1160	-0.1910	-0.1892	-0.1877	-0.0273	-0.0813
GRAD2	25	0.0077	-0.0975	-0.3504	0.0588	-0.1348	-0.2015	-0.1956	-0.1981	-0.0577	-0.0658
ATR	26	0.0429	0.0035	-0.3454	0.3296	-0.2316	-0.2568	-0.0916	-0.1865	-0.2003	0.2486
ALM	27	0.2368	0.0129	0.0790	-0.0273	-0.0422	0.1090	-0.1015	0.0221	-0.0167	-0.3482
AGL	28	0.0836	-0.2268	-0.0853	0.0888	-0.1672	-0.2253	-0.2078	-0.2397	-0.1001	0.0966
PRECIP	29	-0.3444	-0.0602	-0.1373	0.4898	-0.2363	-0.2266	-0.2696	-0.2749	-0.1464	-0.3167
INTENS	30	0.1725	0.4709	0.2537	0.1760	0.1722	0.2276	0.1169	0.1242	0.2681	-0.3003
Q2	31	0.0167	0.4839	0.4684	-0.0642	0.3793	0.4002	0.4105	0.3986	0.5586	-0.0161
GMA	32	0.0162	0.4861	0.4789	-0.0647	0.4058	0.4255	0.4316	0.4229	0.5816	-0.0032
Q5	33	0.0497	0.4758	0.5150	-0.0946	0.4792	0.4939	0.4712	0.4927	0.6348	0.0391
Q10	34	0.0667	0.4539	0.5351	-0.1116	0.5260	0.5393	0.4956	0.5376	0.6591	0.0642
Q20	35	0.0839	0.4360	0.5454	-0.1231	0.5615	0.5741	0.5076	0.5688	0.6759	0.0805
S1085	36	-0.0215	-0.1685	-0.5024	0.0049	-0.5491	-0.5853	-0.6014	-0.5833	-0.4729	0.3263
NASP	37	-0.0606	0.0062	0.2095	-0.0201	0.1173	0.1603	0.1765	0.1502	0.0072	0.0597
CASP2	38	0.1034	-0.0014	-0.1894	0.0321	-0.1038	-0.1457	-0.1629	-0.1394	0.0094	-0.0769
GRADA	39	0.0353	0.1125	0.4651	-0.1796	0.5202	0.5221	0.5294	0.5150	0.3754	-0.0868
GRADB	40	0.0029	0.0331	0.3794	-0.0989	0.5229	0.5178	0.6022	0.5072	0.3445	-0.1946
GRADE	41	0.2076	0.3307	0.3850	-0.1496	0.5063	0.4819	0.4566	0.4907	0.5535	-0.2820
GRADF	42	0.2929	0.2295	0.2800	-0.0778	0.2591	0.2436	0.2704	0.2143	0.2074	-0.3493
RUGN	43	-0.0006	0.1211	0.2887	0.0001	0.0837	0.1680	0.0977	0.1816	0.3889	0.6489
LNASP	44	0.0347	0.0928	0.2923	-0.0280	0.2106	0.2701	0.2380	0.2564	0.1313	0.1239
LCASP2	45	0.0918	0.0084	-0.1771	0.0141	-0.0865	-0.1256	-0.1599	-0.1169	0.0258	-0.0357
LGRADA	46	0.0809	0.2033	0.4892	-0.1030	0.4555	0.5111	0.4725	0.4985	0.3648	0.0036
LGRADB	47	0.1304	0.1960	0.5073	-0.0786	0.4874	0.5399	0.5323	0.5146	0.3690	-0.1152
LGRADE	48	0.1806	0.2724	0.3744	-0.1596	0.5247	0.5032	0.4537	0.5085	0.5636	-0.2528
LGRADF	49	0.2129	0.2000	0.3467	-0.0828	0.4671	0.4546	0.4656	0.4361	0.4375	-0.3626
LRUGN	50	-0.0718	0.1151	0.2713	0.0219	0.0816	0.1629	0.1013	0.1889	0.3799	0.6292
LLONG	51	0.9999	0.4012	0.2293	-0.5257	0.1541	0.1330	0.0340	0.1258	0.1643	-0.0512
LLAT	52	0.4031	0.9999	0.3064	-0.0482	0.1988	0.2557	0.1858	0.2181	0.3336	-0.1314
LRANK	53	0.2020	0.3080	0.9913	-0.3285	0.6795	0.7097	0.6174	0.7009	0.7313	0.1401
LS1085	54	-0.0682	-0.1803	-0.4957	0.0488	-0.5996	-0.6070	-0.6754	-0.6033	-0.4845	0.3370
LELEV	55	-0.5304	-0.1393	-0.3944	0.9643	-0.4155	-0.3102	-0.2247	-0.3682	-0.4092	-0.0671
LAREA	56	0.0864	0.2440	0.7747	-0.3312	0.9345	0.9496	0.8472	0.9345	0.8358	0.2241
LPER	57	0.0884	0.2974	0.7441	-0.2509	0.8859	0.9753	0.8376	0.9447	0.8003	0.2785
LSTL	58	0.0036	0.2062	0.6664	-0.1904	0.8590	0.8804	0.9632	0.9167	0.7719	0.1862
LBAL	59	0.0845	0.2595	0.7299	-0.3057	0.8879	0.9538	0.8719	0.9767	0.8070	0.3207
LTCHL	60	0.0794	0.3317	0.8390	-0.2649	0.8765	0.9015	0.7998	0.8865	0.9319	0.2022
LREL	61	-0.0940	-0.1348	0.1128	-0.1377	0.1972	0.2865	0.2031	0.3268	0.1670	0.9847
LASP	62	0.0447	0.1310	0.4716	-0.0450	0.1748	0.2062	0.1931	0.1844	0.1895	-0.1537
LBSH1	63	-0.0071	-0.0968	0.0081	-0.0318	-0.0080	-0.1841	-0.2349	-0.3089	-0.0575	-0.3641
LBSH2	64	0.0652	0.2883	0.1866	0.1389	0.1964	0.4892	0.3253	0.4329	0.1988	0.2929
LDRD	65	-0.0111	0.2575	0.2456	0.1430	-0.0632	-0.0361	-0.0433	-0.0374	0.3362	-0.0374
LSTF	66	0.1824	0.2347	0.3893	-0.0108	-0.0197	-0.0143	-0.0495	0.0013	0.3372	-0.0505

LRELRA	67	-0.1462	-0.3527	-0.6771	0.2261	-0.7842	-0.7956	-0.7648	-0.7936	-0.7214	0.2991
LSLOPE	68	-0.1913	-0.2270	-0.5099	0.1046	-0.5945	-0.6038	-0.6374	-0.5770	-0.4920	0.3990
LBIRA	69	-0.1234	-0.0156	0.0190	0.2070	0.1274	0.1288	0.1097	0.1323	0.1672	-0.0649
LHYPI	70	-0.2510	0.0038	-0.2268	0.0576	-0.0899	-0.2058	0.0427	-0.0934	-0.0526	0.2157
LHYPC	71	-0.2446	-0.0755	-0.2657	0.0804	-0.1337	-0.2531	-0.0079	-0.1527	-0.1261	0.1533
LGRAD1	72	0.0931	-0.0968	-0.2484	0.0217	-0.1039	-0.1783	-0.1798	-0.1755	-0.0154	-0.0794
LGRAD2	73	0.0093	-0.0930	-0.3414	0.0597	-0.1262	-0.1918	-0.1886	-0.1897	-0.0489	-0.0657
LATR	74	0.0076	-0.0186	-0.3482	0.3327	-0.2275	-0.2493	-0.0843	-0.1782	-0.2061	0.2918
LALM	75	0.2289	0.0102	0.0754	-0.0211	-0.0460	0.1041	-0.0984	0.0191	-0.0189	-0.3526
LAGL	76	0.0844	-0.2274	-0.0826	0.0906	-0.1651	-0.2224	-0.2050	-0.2370	-0.0968	0.1008
LPRECIP	77	-0.3008	0.0259	-0.0929	0.4911	-0.2204	-0.1961	-0.2665	-0.2593	-0.1335	-0.3257
LINTENS	78	0.1859	0.4699	0.2325	0.2037	0.1415	0.1959	0.0775	0.0898	0.2430	-0.3018
LQ2	79	-0.0298	0.4365	0.5240	0.0577	0.4324	0.4776	0.4194	0.4617	0.5444	0.0134
LQMA	80	-0.0270	0.4378	0.5343	0.0531	0.4515	0.4989	0.4374	0.4834	0.5599	0.0237
LQ5	81	-0.0049	0.4287	0.5717	0.0241	0.5079	0.5576	0.4759	0.5450	0.6034	0.0665
LQ10	82	0.0039	0.4160	0.5945	0.0070	0.5454	0.5953	0.5021	0.5849	0.6302	0.0952
LQ20	83	0.0109	0.4084	0.6070	-0.0030	0.5732	0.6217	0.5165	0.6101	0.6503	0.1131

		ASP 13	CASP 14	BSH1 15	BSH2 16	DRD 17	STF 18	RELRA 19	SLOPE 20	BIRA 21	HYPI 22
ASP	13	1.0000									
CASP	14	-0.2442	1.0000								
BSH1	15	0.2288	0.1265	1.0000							
BSH2	16	-0.1262	-0.2556	-0.6377	1.0000						
DRD	17	0.0784	0.1933	-0.0495	0.0232	1.0000					
STF	18	0.1787	0.1618	-0.0442	-0.0732	0.8256	1.0000				
RELRA	19	-0.3805	0.1882	0.1849	-0.3325	0.0434	-0.0650	1.0000			
SLOPE	20	-0.3799	0.1067	0.0748	-0.2963	0.0165	-0.0684	0.8929	1.0000		
BIRA	21	-0.0447	0.1416	-0.2822	0.0519	0.1366	0.1822	-0.1806	-0.2204	1.0000	
HYPI	22	-0.1809	0.0053	-0.1353	-0.3258	0.0694	-0.0131	0.2706	0.4415	-0.1491	1.0000
HYPC	23	-0.1524	0.0887	-0.1023	-0.3295	0.0065	-0.0910	0.3158	0.4684	-0.1207	0.9229
GRAD1	24	-0.3259	0.9502	0.2065	-0.3415	0.1858	0.1316	0.2654	0.1436	0.1394	-0.0064
GRAD2	25	-0.3839	0.8502	0.1637	-0.3002	0.1354	0.0419	0.2756	0.1736	0.1453	-0.0018
ATR	26	-0.4237	0.2962	-0.2478	-0.1231	0.0977	0.0235	0.4291	0.3291	0.1734	0.5637
ALM	27	0.1613	0.2310	-0.0869	0.4457	0.0466	0.0667	-0.2413	-0.3132	0.1322	-0.5831
AGL	28	-0.1455	0.1801	0.3530	-0.2469	0.2906	0.1617	0.5054	0.2519	-0.1825	-0.1595
PRECIP	29	-0.0909	0.1572	0.1154	-0.0974	0.3229	0.3237	0.0695	-0.1184	0.3754	-0.0748
INTENS	30	0.0732	0.0672	0.0588	0.2413	0.3027	0.2954	-0.3140	-0.3575	0.2531	-0.3856
Q2	31	0.2046	-0.1192	-0.1573	0.1289	0.4306	0.3342	-0.4421	-0.3479	0.2385	0.2509
QMA	32	0.2006	-0.1171	-0.1640	0.1392	0.4245	0.3295	-0.4533	-0.3558	0.2400	0.2524
Q5	33	0.1765	-0.1052	-0.1848	0.1599	0.3959	0.3141	-0.4811	-0.3688	0.2276	0.2470
Q10	34	0.1571	-0.1068	-0.1986	0.1794	0.3643	0.2878	-0.4964	-0.3756	0.2003	0.2357
Q20	35	0.1358	-0.0992	-0.2007	0.1959	0.3365	0.2684	-0.5048	-0.3808	0.1890	0.2100
S1085	36	-0.3474	0.1061	0.1109	-0.2452	0.0555	-0.0747	0.8761	0.9650	-0.3021	0.3821
NASP	37	0.2405	-0.9914	-0.1146	0.2614	-0.1684	-0.1404	-0.2056	-0.1382	-0.1305	-0.0109
CASP2	38	-0.2442	1.0000	0.1265	-0.2556	0.1933	0.1618	0.1882	0.1067	0.1416	0.0053
GRADA	39	0.2761	-0.8437	-0.0952	0.2612	-0.1604	-0.1068	-0.5798	-0.4755	-0.0314	-0.1348
GRADB	40	0.3165	-0.6374	-0.0501	0.2299	-0.2478	-0.2233	-0.5948	-0.5933	0.0317	-0.2673
GRADE	41	0.0622	0.6220	-0.0156	0.0343	0.1586	0.1771	-0.5473	-0.4918	0.1447	-0.1451
GRADF	42	C.2727	0.4645	0.1494	0.0034	-0.1166	-0.0127	-0.3789	-0.4772	0.0378	-0.3636
RUGN	43	-0.1796	0.1041	-0.2623	0.2254	0.6856	0.5608	0.2169	0.2276	0.0323	0.1241
LNASP	44	0.2820	-0.8387	-0.1398	0.3242	-0.0885	-0.0479	-0.2268	-0.1929	-0.0278	-0.0647
LCASP2	45	-0.2419	0.9884	0.1123	-0.2449	0.1831	0.1644	0.1999	0.1285	0.1598	0.0057
LGRADA	46	0.3630	-0.7733	-0.1650	0.3776	-0.0800	-0.0153	-0.5334	-0.4624	0.0242	-0.1477
LGRADB	47	0.4455	-0.6656	-0.0995	0.3746	-0.1362	-0.0527	-0.6174	-0.6352	0.0512	-0.2962
LGRADE	48	0.0704	0.6614	-0.0083	0.0202	0.1338	0.1832	-0.5762	-0.5407	0.2275	-0.1939
LGRADF	49	0.2269	0.5243	0.0784	0.0573	-0.0094	0.0629	-0.5957	-0.7050	0.2015	-0.3896
LRUGN	50	-0.2162	0.0399	-0.3288	0.2418	0.7059	0.5633	0.2241	0.2730	0.0889	0.1787

LONG	51	-0. 0543	0. 1040	0. 0037	0. 0721	-0. 0307	0. 1867	-0. 0919	-0. 1070	-0. 1347	-0. 1759
LAT	52	0. 0446	-0. 0014	-0. 1265	0. 2688	0. 2610	0. 2209	-0. 3402	-0. 2292	0. 0124	0. 0172
RANK	53	0. 4412	-0. 2254	-0. 0055	0. 1886	0. 2139	0. 3655	-0. 6220	-0. 4965	-0. 0602	-0. 2326
S1085	54	-0. 3525	0. 0386	0. 0490	-0. 1886	0. 1746	0. 0439	0. 8019	0. 8667	-0. 2648	0. 3752
ELEV	55	-0. 0707	0 0618	-0. 0468	0. 1237	0. 0773	-0. 1422	0. 2144	0. 0674	0. 2426	0. 0607
AREA	56	0. 2035	-0 1708	-0. 0671	0. 2692	-0. 0945	-0. 0215	-0. 7791	-0. 6174	0. 0379	-0. 1835
PER	57	0. 1534	-0. 2171	-0. 2285	0. 4908	-0. 0777	-0. 0327	-0. 7857	-0. 6282	0. 0624	-0. 2337
STL	58	0. 2039	-0 2432	-0. 2963	0. 3344	-0. 0834	-0. 0408	-0. 8064	-0. 6805	0. 0957	-0. 0474
BAL	59	0. 1242	-0. 2052	-0. 3553	0. 4419	-0. 0835	-0. 0180	-0. 7803	-0. 6012	0. 0958	-0. 1343
TCHL	60	0. 1992	-0. 1065	-0. 1014	0. 2858	0. 2800	0. 2919	-0. 7281	-0. 5808	0. 0983	-0. 1531
REL	61	-0. 3331	-0. 1267	-0. 3771	0. 2791	-0. 1190	-0. 1464	0. 2624	0. 3631	-0. 0632	0. 1955
ASP	62	0. 8200	-0. 5163	0. 0721	0. 1257	0. 0401	0. 1267	-0. 3791	-0. 3845	-0. 0012	-0. 2136
BSH1	63	0. 2251	0. 1472	0. 9891	-0. 6308	-0. 0301	-0. 0193	0. 1476	0. 0574	-0. 2155	-0. 1393
BSH2	64	-0. 1005	-0. 2831	-0. 6722	0. 9922	0. 0015	-0. 0762	-0. 3652	-0. 3216	0. 0893	-0. 2975
DRD	65	0. 0085	0. 1563	-0. 0958	0. 0691	0. 9851	0. 8293	0. 0608	0. 0377	0. 1646	0. 0600
STF	66	0. 0976	0. 1188	-0. 1174	0. 0299	0. 8249	0. 9581	-0. 0196	-0. 0474	0. 2013	-0. 0585
RELRA	67	-0. 3398	0. 1296	0. 1254	-0. 2763	0. 0090	-0. 0756	0. 9680	0. 8482	-0. 1390	0. 2631
SLOPE	68	-0. 4101	-0. 0084	-0. 0228	-0. 2152	0. 1221	0. 0269	0. 8126	0. 8961	-0. 1368	0. 4555
BIRA	69	-0. 0358	0. 1643	-0. 2702	0. 0507	0. 1049	0. 1846	-0. 2083	-0. 2256	0. 9790	-0. 2146
HYPI	70	-0. 1894	-0. 0591	-0. 1299	-0. 3569	0. 0817	-0. 0096	0. 2452	0. 4024	-0. 1030	0. 9750
HYPC	71	-0. 1496	0. 0237	-0. 0309	-0. 4423	0. 0251	-0. 0833	0. 2867	0. 4137	-0. 0473	0. 9316
GRAD1	72	-0. 3191	0. 9538	0. 2068	-0. 3378	0. 1876	0. 1353	0. 2558	0. 1349	0. 1461	-0. 0092
GRAD2	73	-0. 3781	0. 8537	0. 1660	-0. 2960	0. 1384	0. 0462	0. 2681	0. 1629	0. 1511	-0. 0080
ATR	74	-0. 4385	0. 2806	-0. 2507	-0. 1267	0. 0765	-0. 0055	0. 4396	0. 3542	0. 1685	0. 5890
ALM	75	0. 1671	0. 2299	-0. 0888	0. 4438	0. 0515	0. 0684	-0. 2416	-0. 3162	0. 1334	-0. 5806
AGL	76	-0. 1443	0. 1811	0. 3508	-0. 2452	0. 2924	0. 1654	0. 5038	0. 2506	-0. 1809	-0. 1588
PRECIP	77	-0. 0484	0. 1333	0. 1403	-0. 0646	0. 3153	0. 3191	0. 0209	-0. 1684	0. 3656	-0. 1118
INTENS	78	0. 0537	0. 0803	0. 0675	0. 2366	0. 3174	0. 3177	-0. 2916	-0. 3508	0. 2616	-0. 3899
Q2	79	0. 2073	-0. 1861	-0. 1783	0. 2309	0. 3636	0. 3541	-0. 5246	-0. 4929	0. 3200	0. 1084
QMA	80	0. 2078	-0. 1884	-0. 1935	0. 2454	0. 3548	0. 3456	-0. 5403	-0. 5035	0. 3213	0. 1070
Q5	81	0. 1971	-0. 1883	-0. 2274	0. 2696	0. 3289	0. 3255	-0. 5678	-0. 5061	0. 3142	0. 1076
LQ10	82	0. 1842	-0. 1896	-0. 2457	0. 2812	0. 3103	0. 3080	-0. 5803	-0. 5013	0. 2956	0. 1114
LQ20	83	0. 1684	-0. 1796	-0. 2434	0. 2838	0. 2991	0. 2967	-0. 5841	-0. 4963	0. 2806	0. 1076

		HYPC 23	GRAD1 24	GRAD2 25	ATR 26	ALM 27	AGL 28	PRECIP 29	INTENS 30	Q2 31	QMA 32
HYPC	23	1. 0000									
GRAD1	24	0. 0884	1. 0000								
GRAD2	25	0. 0607	0. 9373	1. 0000							
ATR	26	0. 5972	0. 3115	0. 2859	1. 0000						
ALM	27	-0. 4405	0. 1585	0. 0741	-0. 3293	1. 0000					
AGL	28	-0. 0776	0. 3024	0. 2559	0. 3183	-0. 0963	1. 0000				
PRECIP	29	-0. 0958	0. 1998	0. 1933	0. 2238	0. 0831	0. 2553	1. 0000			
INTENS	30	-0. 3807	0. 0315	-0. 0008	-0. 1901	0. 4150	0. 0260	0. 4555	1. 0000		
Q2	31	0. 1846	-0. 1384	-0. 1270	0. 0104	-0. 1385	-0. 1488	0. 1733	0. 3165	1. 0000	
QMA	32	0. 1842	-0. 1363	-0. 1274	0. 0198	-0. 1347	-0. 1497	0. 1595	0. 3044	0. 9983	1. 0000
Q5	33	0. 1763	-0. 1255	-0. 1266	0. 0389	-0. 1224	-0. 1512	0. 1010	0. 2386	0. 9709	0. 9819
Q10	34	0. 1658	-0. 1247	-0. 1303	0. 0439	-0. 1039	-0. 1476	0. 0622	0. 2016	0. 9307	0. 9479
Q20	35	0. 1405	-0. 1152	-0. 1228	0. 0428	-0. 0773	-0. 1418	0. 0388	0. 1820	0. 8845	0. 9066
S1085	36	0. 4066	0. 1355	0. 1767	0. 3002	-0. 2580	0. 2819	-0. 1870	-0. 3277	-0. 3649	-0. 3716
NASP	37	-0. 0959	-0. 9459	-0. 8615	-0. 2804	-0. 2161	-0. 1543	-0. 1482	-0. 0562	0. 1437	0. 1424
CASP2	38	0. 0887	0. 9502	0. 8502	0. 2962	0. 2310	0. 1801	0. 1572	0. 0672	-0. 1192	-0. 1171
GRADA	39	-0. 2167	-0. 7761	-0. 6972	-0. 4121	-0. 0949	-0. 2370	-0. 1569	0. 1105	0. 3159	0. 3234
GRADB	40	-0. 3154	-0. 5711	-0. 4925	-0. 3875	0. 0300	-0. 1917	-0. 1676	0. 1454	0. 2081	0. 2163
GRADE	41	-0. 1364	0. 4762	0. 3689	-0. 0564	0. 3484	-0. 1403	0. 0105	0. 3206	0. 2240	0. 2357
GRADF	42	-0. 2813	0. 3408	0. 1743	-0. 1134	0. 4552	-0. 0904	-0. 0410	0. 3007	-0. 0178	-0. 0099
RUGN	43	0. 0545	0. 1098	0. 0773	0. 2397	-0. 2048	0. 3157	0. 0151	0. 0343	0. 3152	0. 3210
LNASP	44	-0. 1786	-0. 8757	-0. 8565	-0. 1848	-0. 1437	-0. 0445	-0. 1240	-0. 0015	0. 1934	0. 1963

CASP2	45	0.0744	0.9284	0.8319	0.3051	0.2067	0.1861	0.1569	0.0482	-0.1180	-0.1150
GRADA	46	-0.2621	-0.8322	-0.8238	-0.3041	-0.0367	-0.1771	-0.1383	0.1200	0.3217	0.3288
LGRADB	47	-0.3833	-0.7307	-0.7541	-0.3362	0.1027	-0.1633	-0.1101	0.2036	0.2833	0.2910
LGRADE	48	-0.1750	0.5575	0.4651	-0.0771	0.3497	-0.1573	0.0540	0.3000	0.2426	0.2550
LGRADF	49	-0.3473	0.4360	0.3231	-0.1430	0.4573	-0.1077	0.0644	0.3539	0.1449	0.1552
LRUGN	50	0.1066	0.0498	0.0443	0.2717	-0.2234	0.2968	0.0653	0.0225	0.3151	0.3208
LLONG	51	-0.1367	0.0909	0.0087	0.0474	0.2335	0.0855	-0.3494	0.1655	0.0136	0.0132
LLAT	52	-0.0813	-0.1049	-0.0980	-0.0020	0.0167	-0.2289	-0.0626	0.4730	0.4845	0.4866
LRANK	53	-0.2754	-0.3061	-0.3969	-0.3407	0.0707	-0.0697	-0.1221	0.2609	0.4484	0.4583
LS1085	54	0.3784	0.0852	0.1390	0.2796	-0.3035	0.2521	-0.0767	-0.3653	-0.2920	-0.3020
LELEV	55	0.0926	0.0525	0.0821	0.3902	-0.0125	0.1056	0.4471	0.0659	-0.1077	-0.1080
LAREA	56	-0.2361	-0.2193	-0.2282	-0.3492	-0.0088	-0.2519	-0.2445	0.1800	0.4327	0.4535
LPER	57	-0.2822	-0.2865	-0.2877	-0.3302	0.0820	-0.3002	-0.2354	0.2234	0.4352	0.4564
LSTL	58	-0.1293	-0.2876	-0.2893	-0.2212	-0.0838	-0.3489	-0.2721	0.1314	0.4624	0.4802
LBAL	59	-0.1891	-0.2759	-0.2744	-0.2518	0.0180	-0.3255	-0.2765	0.1389	0.4400	0.4613
LTCHL	60	-0.2319	-0.1508	-0.1747	-0.2839	0.0023	-0.1351	-0.1085	0.2856	0.5612	0.5798
LREL	61	0.1772	-0.1203	-0.0795	0.2419	-0.3685	0.1006	-0.3058	-0.3235	0.0161	0.0293
LASP	62	-0.2510	-0.6318	-0.7014	-0.3587	0.1204	-0.0813	-0.1005	0.1201	0.2495	0.2481
LBSH1	63	-0.1235	0.2294	0.1968	-0.2658	-0.0868	0.2994	0.1474	0.1054	-0.1177	-0.1234
BSH2	64	-0.3168	-0.3768	-0.3392	-0.1092	0.3913	-0.2958	-0.1051	0.2382	0.1671	0.1774
DRD	65	-0.0150	0.1634	0.1223	0.1377	0.0291	0.2878	0.3385	0.2997	0.3817	0.3777
STF	66	-0.1298	0.0912	-0.0032	0.0812	0.1169	0.1856	0.3804	0.3555	0.2572	0.2524
RELRA	67	0.3080	0.2063	0.2305	0.4131	-0.2534	0.3983	0.0882	-0.3490	-0.4421	-0.4555
SLOPE	68	0.4481	0.0577	0.1301	0.3512	-0.4051	0.2380	0.0205	-0.3815	-0.2398	-0.2499
BIRA	69	-0.1933	0.1533	0.1647	0.1127	0.1440	-0.1863	0.3498	0.2746	0.1713	0.1728
HYPI	70	0.8599	-0.0513	-0.0103	0.5407	-0.6966	-0.1337	-0.0568	-0.3968	0.2532	0.2533
HYPC	71	0.9404	0.0459	0.0653	0.5984	-0.6509	-0.0368	-0.0388	-0.4097	0.2145	0.2119
GRAD1	72	0.0828	0.9996	0.9347	0.3106	0.1623	0.3001	0.2010	0.0363	-0.1297	-0.1273
GRAD2	73	0.0518	0.9381	0.9997	0.2850	0.0793	0.2572	0.2002	0.0062	-0.1199	-0.1201
ATR	74	0.6229	0.2993	0.2765	0.9965	-0.3635	0.3056	0.2101	-0.2141	0.0076	0.0166
ALM	75	-0.4398	0.1579	0.0733	-0.3296	0.9997	-0.0974	0.0841	0.4164	-0.1380	-0.1344
AGL	76	-0.0770	0.3033	0.2566	0.3209	-0.0970	0.9999	0.2556	0.0282	-0.1476	-0.1483
PRECIP	77	-0.1413	0.1593	0.1542	0.1890	0.0875	0.2313	0.9884	0.4984	0.2128	0.1990
INTENS	78	-0.3918	0.0419	0.0077	-0.1652	0.4092	0.0434	0.4869	0.9950	0.3098	0.2969
Q2	79	-0.0051	-0.2519	-0.2710	0.0202	-0.0942	-0.1610	0.3595	0.3845	0.8682	0.8685
QMA	80	-0.0056	-0.2564	-0.2778	0.0223	-0.0883	-0.1700	0.3413	0.3755	0.8665	0.8688
Q5	81	0.0007	-0.2609	-0.2883	0.0299	-0.0786	-0.1843	0.2784	0.3323	0.8490	0.8569
Q10	82	0.0064	-0.2622	-0.2902	0.0334	-0.0766	-0.1896	0.2356	0.3020	0.8265	0.8382
Q20	83	0.0005	-0.2488	-0.2728	0.0332	-0.0722	-0.1865	0.2107	0.2830	0.8036	0.8182

		Q5 33	Q10 34	Q20 35	S1085 36	NASP 37	CASP2 38	GRADA 39	GRADB 40	GRADE 41	GRADF 42
Q5	33	1.0000									
Q10	34	0.9904	1.0000								
Q20	35	0.9685	0.9934	1.0000							
S1085	36	-0.3791	-0.3802	-0.3806	1.0000						
NASP	37	0.1370	0.1426	0.1379	-0.1299	1.0000					
CASP2	38	-0.1052	-0.1068	-0.0991	0.1061	-0.9914	1.0000				
GRADA	39	0.3438	0.3672	0.3776	-0.4635	0.8549	-0.8437	1.0000			
GRADB	40	0.2299	0.2520	0.2649	-0.5730	0.6381	-0.6374	0.8717	1.0000		
GRADE	41	0.2748	0.2932	0.3121	-0.4611	-0.5959	0.6220	-0.2043	-0.0185	1.0000	
GRADF	42	0.0103	0.0225	0.0351	-0.4298	-0.4477	0.4645	-0.1922	0.1044	0.7098	1.0000
RUGN	43	0.3332	0.3295	0.3226	0.2271	-0.0973	0.1041	-0.1795	-0.2971	-0.0787	-0.2812
NASP	44	0.2019	0.2077	0.2070	-0.1632	0.8633	-0.8387	0.7289	0.5407	-0.3939	-0.3363
CASP2	45	-0.1011	-0.1029	-0.0943	0.1226	-0.9862	0.9884	-0.8452	-0.6460	0.6155	0.4295
GRADA	46	0.3464	0.3594	0.3641	-0.4278	0.8018	-0.7733	0.8331	0.6863	-0.1159	-0.1383
GRADB	47	0.3060	0.3190	0.3254	-0.5869	0.6981	-0.6656	0.7937	0.7740	0.0197	0.1328
GRADE	48	0.2932	0.3092	0.3275	-0.5261	-0.6442	0.6614	-0.2150	-0.0260	0.9628	0.6629

GRADF	49	0.1793	0.1918	0.2076	-0.6687	-0.5026	0.5243	-0.1030	0.2110	0.8588	0.8692
RUGN	50	0.3330	0.3294	0.3231	0.2604	-0.0385	0.0399	-0.1247	-0.2764	-0.1064	-0.3690
LONG	51	0.0472	0.0646	0.0820	-0.0171	-0.0611	0.1040	0.0331	0.0012	0.2055	0.2904
LAT	52	0.4758	0.4536	0.4354	-0.1698	0.0060	-0.0014	0.1124	0.0327	0.3304	0.2295
RANK	53	0.4939	0.5147	0.5255	-0.5027	0.2446	-0.2254	0.4774	0.3917	0.3575	0.2707
S1085	54	-0.3113	-0.3179	-0.3238	0.8967	-0.0516	0.0386	-0.4295	-0.6674	-0.5641	-0.6506
ELEV	55	-0.1323	-0.1447	-0.1538	0.0441	-0.0488	0.0618	-0.2371	-0.1294	-0.1746	-0.0642
AREA	56	0.5140	0.5497	0.5753	-0.6175	0.1794	-0.1708	0.5434	0.5315	0.4761	0.2536
PER	57	0.5152	0.5513	0.5775	-0.6160	0.2262	-0.2171	0.5507	0.5283	0.4369	0.2330
STL	58	0.5163	0.5360	0.5432	-0.6819	0.2525	-0.2432	0.5863	0.6226	0.4137	0.2416
BAL	59	0.5237	0.5613	0.5859	-0.6103	0.2097	-0.2052	0.5395	0.5142	0.4457	0.1955
TCHL	60	0.6302	0.6553	0.6723	-0.5695	0.1236	-0.1065	0.4764	0.4292	0.5036	0.1882
REL	61	0.0725	0.0970	0.1122	0.3081	0.1016	-0.1267	-0.0350	-0.1502	-0.3022	-0.3790
ASP	62	0.2350	0.2229	0.2079	-0.3308	0.5367	-0.5163	0.4913	0.4356	-0.0629	0.1174
BSH1	63	-0.1414	-0.1547	-0.1555	0.0907	-0.1363	0.1472	-0.0873	-0.0376	0.0188	0.1570
BSH2	64	0.1959	0.2119	0.2241	-0.2758	0.2875	-0.2831	0.2883	0.2580	0.0304	0.0206
DRD	65	0.3567	0.3317	0.3110	0.0680	-0.1335	0.1563	-0.1270	-0.2205	0.1202	-0.1447
STF	66	0.2377	0.2166	0.2033	-0.0490	-0.1018	0.1188	-0.0886	-0.1884	0.1385	0.0187
RELRA	67	-0.4921	-0.5151	-0.5305	0.8229	-0.1502	0.1296	-0.5759	-0.6237	-0.6503	-0.4420
SLOPE	68	-0.2695	-0.2850	-0.2981	0.8504	-0.0156	-0.0084	-0.3936	-0.6371	-0.6229	-0.7479
BIRA	69	0.1631	0.1392	0.1320	-0.3038	-0.1546	0.1643	-0.0335	0.0354	0.1938	0.0758
HYPI	70	0.2396	0.2212	0.1908	0.3411	0.0520	-0.0591	-0.0721	-0.2167	-0.1928	-0.4616
HYPC	71	0.1910	0.1684	0.1348	0.3538	-0.0293	0.0237	-0.1429	-0.2538	-0.1723	-0.3818
GRAD1	72	-0.1157	-0.1147	-0.1048	0.1269	-0.9490	0.9538	-0.7747	-0.5687	0.4886	0.3475
GRAD2	73	-0.1192	-0.1230	-0.1154	0.1663	-0.8642	0.8537	-0.6963	-0.4888	0.3784	0.1820
ATR	74	0.0335	0.0378	0.0354	0.3175	-0.2667	0.2806	-0.4073	-0.3943	-0.0830	-0.1432
ALM	75	-0.1242	-0.1069	-0.0815	-0.2605	-0.2153	0.2299	-0.0948	0.0330	0.3463	0.4558
AGL	76	-0.1495	-0.1457	-0.1397	0.2806	-0.1553	0.1811	-0.2374	-0.1917	-0.1397	-0.0905
PRECIP	77	0.1431	0.1055	0.0834	-0.2277	-0.1173	0.1333	-0.1294	-0.1525	0.0265	-0.0121
INTENS	78	0.2311	0.1923	0.1714	-0.3220	-0.0652	0.0803	0.0813	0.1094	0.3096	0.2985
Q2	79	0.8559	0.8281	0.7971	-0.5308	0.2216	-0.1861	0.3713	0.2615	0.2380	0.0063
QMA	80	0.8621	0.8383	0.8104	-0.5400	0.2242	-0.1884	0.3800	0.2697	0.2478	0.0098
Q5	81	0.8730	0.8650	0.8494	-0.5395	0.2262	-0.1883	0.4013	0.2878	0.2767	0.0100
Q10	82	0.8694	0.8733	0.8670	-0.5314	0.2284	-0.1896	0.4175	0.3027	0.2925	0.0020
Q20	83	0.8609	0.8740	0.8757	-0.5227	0.2188	-0.1796	0.4215	0.3083	0.3076	-0.0047

		RUGN 43	LNASP 44	LCASP2 45	LGRADA 46	LGRADB 47	LGRADE 48	LGRADF 49	LRUGN 50	LLONG 51	LLAT 52
RUGN	43	1.0000									
LNASP	44	0.0088	1.0000								
LCASP2	45	0.1266	-0.7789	1.0000							
LGRADA	46	-0.0652	0.9404	-0.7237	1.0000						
LGRADB	47	-0.1669	0.8449	-0.6321	0.9484	1.0000					
LGRADE	48	-0.0607	-0.4419	0.6651	-0.1581	-0.0198	1.0000				
LGRADF	49	-0.2130	-0.3337	0.5075	-0.0623	0.1909	0.8829	1.0000			
LRUGN	50	0.9725	0.0413	0.0650	-0.0354	-0.1716	-0.1046	-0.2944	1.0000		
LLONG	51	-0.0007	0.0353	0.0927	0.0801	0.1289	0.1783	0.2101	-0.0717	1.0000	
LLAT	52	0.1215	0.0925	0.0084	0.2034	0.1960	0.2731	0.2003	0.1149	0.3998	1.0000
LRANK	53	0.2805	0.3309	-0.2105	0.5182	0.5354	0.3390	0.3250	0.2642	0.1977	0.3093
LS1085	54	0.3198	-0.1005	0.0549	-0.3742	-0.5894	-0.5799	-0.7885	0.3528	-0.0642	-0.1808
LELEV	55	-0.0043	-0.0634	0.0380	-0.1552	-0.1220	-0.1879	-0.0945	0.0091	-0.5298	-0.1387
LAREA	56	0.1037	0.2571	-0.1520	0.5083	0.5358	0.5014	0.4508	0.0906	0.0837	0.2458
LPER	57	0.1572	0.3157	-0.1962	0.5543	0.5770	0.4567	0.4186	0.1494	0.0855	0.2999
LSTL	58	0.0811	0.2872	-0.2419	0.5328	0.5837	0.4287	0.4420	0.0753	0.0021	0.2075
LBAL	59	0.1711	0.2924	-0.1831	0.5328	0.5403	0.4641	0.3966	0.1765	0.0825	0.2613
LTCHL	60	0.3681	0.2224	-0.0911	0.4647	0.4671	0.5188	0.4169	0.3679	0.0759	0.3328
LREL	61	0.6052	0.1452	-0.0801	0.0297	-0.0994	-0.2705	-0.3877	0.6066	-0.0910	-0.1333
LASP	62	-0.0893	0.7339	-0.4727	0.7615	0.7878	-0.0938	0.0760	-0.1107	0.0439	0.1330

LBSH1	63	-0.2527	-0.1646	0.1334	-0.1737	-0.1099	0.0356	0.1044	-0.3124	-0.0091	-0.0972
LBSH2	64	0.2244	0.3528	-0.2709	0.4108	0.4109	0.0184	0.0653	0.2404	0.0638	0.2919
LDRD	65	0.7116	-0.0701	0.1488	-0.0693	-0.1318	0.0959	-0.0438	0.7449	-0.0136	0.2560
LSTF	66	0.5961	-0.0330	0.1157	-0.0142	-0.0351	0.1203	0.0466	0.6185	0.1781	0.2321
LRELRA	67	0.2095	-0.2073	0.1364	-0.5277	-0.6177	-0.6490	-0.6543	0.2050	-0.1422	-0.3538
LSLOPE	68	0.3241	-0.0856	0.0182	-0.3671	-0.6053	-0.6207	-0.8523	0.3811	-0.1876	-0.2274
LBIRA	69	0.0076	-0.0647	0.1779	0.0045	0.0333	0.2683	0.2296	0.0698	-0.1251	-0.0140
LHYPI	70	0.1413	-0.0050	-0.0528	-0.0911	-0.2569	-0.2285	-0.4335	0.2034	-0.2467	-0.0005
LHYPC	71	0.0512	-0.0997	0.0202	-0.1854	-0.3238	-0.1988	-0.3814	0.1156	-0.2401	-0.0792
LGRAD1	72	0.1125	-0.8661	0.9352	-0.8199	-0.7179	0.5712	0.4477	0.0517	0.0939	-0.0970
LGRAD2	73	0.0801	-0.8495	0.8373	-0.8147	-0.7427	0.4758	0.3354	0.0462	0.0102	-0.0935
LATR	74	0.2515	-0.1837	0.2885	-0.3084	-0.3507	-0.1013	-0.1764	0.2840	0.0121	-0.0239
LALM	75	-0.2052	-0.1433	0.2051	-0.0366	0.1045	0.3481	0.4589	-0.2239	0.2256	0.0140
LAGL	76	0.3207	-0.0445	0.1872	-0.1768	-0.1629	-0.1558	-0.1065	0.3009	0.0863	-0.2295
LPRECIP	77	0.0105	-0.0750	0.1349	-0.0822	-0.0496	0.0667	0.0872	0.0494	-0.3061	0.0238
LINTENS	78	0.0453	-0.0058	0.0594	0.1061	0.1898	0.2866	0.3432	0.0308	0.1789	0.4719
LQ2	79	0.2809	0.3657	-0.1601	0.4938	0.4716	0.2591	0.2042	0.2890	-0.0337	0.4363
LQMA	80	0.2818	0.3708	-0.1618	0.5035	0.4806	0.2693	0.2112	0.2895	-0.0308	0.4377
LQ5	81	0.2928	0.3804	-0.1589	0.5236	0.4925	0.2970	0.2196	0.3017	-0.0082	0.4285
LQ10	82	0.2989	0.3853	-0.1590	0.5343	0.4963	0.3119	0.2198	0.3091	0.0008	0.4157
LQ20	83	0.3042	0.3802	-0.1453	0.5335	0.4913	0.3292	0.2250	0.3149	0.0081	0.4080

		LRANK 53	LS1085 54	LELEV 55	LAREA 56	LPER 57	LSTL 58	LBAL 59	LTCHL 60	LREL 61	LASP 62
LRANK	53	1.0000									
LS1085	54	-0.4967	1.0000								
LELEV	55	-0.3511	0.0777	1.0000							
LAREA	56	0.7829	-0.6330	-0.3650	1.0000						
LPER	57	0.7581	-0.6149	-0.2862	0.9695	1.0000					
LSTL	58	0.6604	-0.6947	-0.2349	0.8923	0.8925	1.0000				
LBAL	59	0.7383	-0.6071	-0.3353	0.9553	0.9744	0.9225	1.0000			
LTCHL	60	0.8329	-0.5429	-0.3188	0.9271	0.9088	0.8303	0.8930	1.0000		
LREL	61	0.1467	0.3169	-0.0885	0.2507	0.3041	0.2057	0.3512	0.2122	1.0000	
LASP	62	0.4976	-0.3200	-0.0786	0.2832	0.2911	0.2797	0.2519	0.2701	-0.1552	1.0000
LBSH1	63	0.0079	0.0269	-0.0387	-0.0281	-0.1902	-0.2645	-0.3221	-0.0549	-0.3814	0.0539
LBSH2	64	0.2148	-0.2211	0.1216	0.3013	0.5216	0.3879	0.4806	0.3083	0.3036	0.1597
LDRD	65	0.2082	0.1764	0.0857	-0.0968	-0.0679	-0.0782	-0.0735	0.2833	-0.0786	-0.0086
LSTF	66	0.3525	0.0334	-0.0747	-0.0503	-0.0318	-0.0571	-0.0222	0.2752	-0.1002	0.0856
LRELRA	67	-0.6642	0.8253	0.2880	-0.8200	-0.8058	-0.8153	-0.8022	-0.7811	0.2773	-0.3572
LSLOPE	68	-0.5049	0.9483	0.1328	-0.6153	-0.6048	-0.6597	-0.5713	-0.5391	0.4013	-0.3752
LBIRA	69	-0.0154	-0.2809	0.2061	0.0841	0.1030	0.1236	0.1346	0.1317	-0.0571	-0.0174
LHYPI	70	-0.2340	0.3744	0.0757	-0.1536	-0.2147	0.0040	-0.1081	-0.1192	0.2165	-0.2010
LHYPC	71	-0.2714	0.3650	0.1165	-0.1944	-0.2689	-0.0638	-0.1718	-0.1846	0.1680	-0.2195
LGRAD1	72	-0.2938	0.0758	0.0489	-0.2063	-0.2736	-0.2784	-0.2639	-0.1378	-0.1187	-0.6181
LGRAD2	73	-0.3873	0.1283	0.0823	-0.2187	-0.2780	-0.2827	-0.2662	-0.1645	-0.0799	-0.6903
LATR	74	-0.3416	0.2981	0.4000	-0.3374	-0.3196	-0.2109	-0.2398	-0.2804	0.2849	-0.3734
LALM	75	0.0668	-0.3059	-0.0073	-0.0136	0.0771	-0.0814	0.0141	-0.0008	-0.3739	0.1246
LAGL	76	-0.0671	0.2512	0.1074	-0.2492	-0.2973	-0.3456	-0.3225	-0.1317	0.1041	-0.0806
LPRECIP	77	-0.0711	-0.1040	0.4450	-0.2023	-0.1880	-0.2517	-0.2447	-0.0721	-0.3160	-0.0374
LINTENS	78	0.2414	-0.3449	0.0979	0.1499	0.1950	0.0953	0.1076	0.2622	-0.3282	0.1094
LQ2	79	0.5383	-0.4020	0.0055	0.5044	0.5279	0.4883	0.5140	0.6131	0.0332	0.3775
LQMA	80	0.5483	-0.4098	0.0022	0.5223	0.5476	0.5069	0.5353	0.6273	0.0437	0.3800
LQ5	81	0.5859	-0.4120	-0.0206	0.5763	0.6019	0.5461	0.5957	0.6713	0.0880	0.3754
LQ10	82	0.6085	-0.4071	-0.0354	0.6094	0.6342	0.5699	0.6320	0.6976	0.1169	0.3655
LQ20	83	0.6200	-0.4010	-0.0452	0.6325	0.6548	0.5806	0.6526	0.7172	0.1343	0.3495

LBSH1 LBSH2 LDRD LSTF LRELRA LSLOPE LBIRA LHYPI LHYPC LGRAD1

		63	64	65	66	67	68	69	70	71	72
L3SH1	63	1 0000									
LBSH2	64	-0.6585	1.0000								
LDRD	65	-0.0716	0.0466	1.0000							
LSTF	66	-0.0939	0.0248	0.8597	1.0000						
LRELRA	67	0.0886	-0.3003	0.0243	-0.0417	1.0000					
LSLOPE	68	-0.0402	-0.2402	0.1412	0.0162	0.8420	1.0000				
LBIRA	69	-0.1955	0.0911	0.1354	0.1993	-0.1747	-0.1584	1.0000			
LHYPI	70	-0.1319	-0.3221	0.0735	-0.0684	0.2494	0.4710	-0.1599	1.0000		
LHYPC	71	-0.0477	-0.4164	0.0040	-0.1428	0.2842	0.4548	-0.1107	0.9384	1.0000	
LGRAD1	72	0.2305	-0.3725	0.1644	0.0932	0.1950	0.0483	0.1592	-0.0541	0.0414	1.0000
LGRAD2	73	0.1998	-0.3345	0.1249	0.0007	0.2218	0.1192	0.1699	-0.0164	0.0576	0.9363
LATR	74	-0.2688	-0.1111	0.1170	0.0528	0.4283	0.3798	0.1097	0.5684	0.6269	0.2979
LALM	75	-0.0889	0.3902	0.0330	0.1183	-0.2528	-0.4080	0.1447	-0.6925	-0.6480	0.1616
LAGL	76	0.2976	-0.2938	0.2899	0.1889	0.3974	0.2372	-0.1845	-0.1329	-0.0365	0.3011
LPRECIP	77	0.1744	-0.0698	0.3272	0.3697	0.0490	-0.0193	0.3373	-0.0935	-0.0807	0.1621
LINTENS	78	0.1155	0.2345	0.3141	0.3763	-0.3198	-0.3622	0.2846	-0.4002	-0.4192	0.0466
LQ2	79	-0.1327	0.2798	0.3345	0.3113	-0.5069	-0.3341	0.2727	0.1315	0.0560	-0.2370
LQMA	80	-0.1477	0.2947	0.3264	0.3023	-0.5221	-0.3433	0.2748	0.1297	0.0530	-0.2414
LQ5	81	-0.1797	0.3177	0.3045	0.2818	-0.5559	-0.3512	0.2716	0.1250	0.0470	-0.2453
LQ10	82	-0.1970	0.3270	0.2896	0.2648	-0.5747	-0.3510	0.2559	0.1263	0.0460	-0.2463
LQ20	83	-0.1928	0.3258	0.2821	0.2538	-0.5848	-0.3493	0.2419	0.1214	0.0377	-0.2325

		LGRAD2 73	LATR 74	LALM 75	LAGL 76	LPRECIP 77	LINTENS 78	LQ2 79	LQMA 80	LQ5 81	LQ10 82
LGRAD2	73	1.0000									
LATR	74	0.2748	1.0000								
LALM	75	0.0786	-0.3638	1.0000							
LAGL	76	0.2580	0.3082	-0.0982	1.0000						
LPRECIP	77	0.1627	0.1735	0.0876	0.2318	1.0000					
LINTENS	78	0.0151	-0.1904	0.4104	0.0456	0.5326	1.0000				
LQ2	79	-0.2564	0.0103	-0.0944	-0.1591	0.4181	0.3981	1.0000			
LQMA	80	-0.2633	0.0124	-0.0887	-0.1680	0.3999	0.3879	0.9991	1.0000		
LQ5	81	-0.2742	0.0200	-0.0805	-0.1819	0.3369	0.3411	0.9843	0.9903	1.0000	
LQ10	82	-0.2764	0.0240	-0.0794	-0.1870	0.2932	0.3071	0.9626	0.9718	0.9948	1.0000
LQ20	83	-0.2590	0.0236	-0.0756	-0.1837	0.2685	0.2853	0.9403	0.9514	0.9836	0.9964

		LQ20 83
LQ20	83	1.0000

REGRESSION TITLE. . . . . .
YUKON ;REGRESSION ANALYSIS

STEPPING ALGORITHM. . . . . F
MAXIMUM NUMBER OF STEPS 166
DEPENDENT VARIABLE. . . . . 80 LQMA
MINIMUM ACCEPTABLE F TO ENTER 4.000, 4.000
MAXIMUM ACCEPTABLE F TO REMOVE. 3.900, 3.900
MINIMUM ACCEPTABLE TOLERANCE. 0.01000
SUBSCRIPTS OF THE INDEPENDENT VARIABLES 51 52 53 55 56 57 58 59 60 61 62 63 64 65 66 67

APPENDIX 4

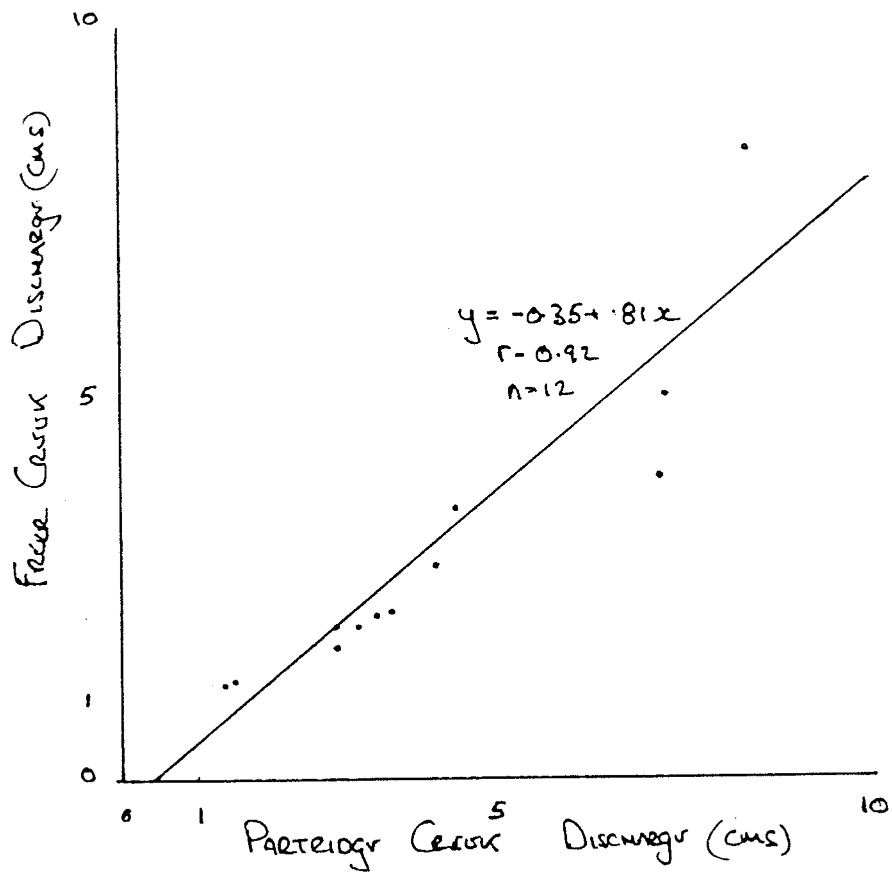
ESTIMATES OF MISSING FLOODS

ESTIMATED MISSING FLOW DATA FOR FREER CREEK

DISCHARGE DATA USED IN REGRESSION ANALYSIS

FREER CREEK	RANK	PARTRIDGE CREEK
8.33	1	8.36
5.09	2	7.28
3.98	3	7.20
3.56	4	4.47
2.86	5	4.20
2.21	6	3.60
2.17	7	3.40
2.02	8	3.15
1.99	9	2.88
1.74	10	2.87
1.32	11	1.48
1.28	12	1.37

SCATTER DIAGRAM



ESTIMATED MAXIMUM INSTANTANEOUS DISCHARGE FOR FREER CREEK.

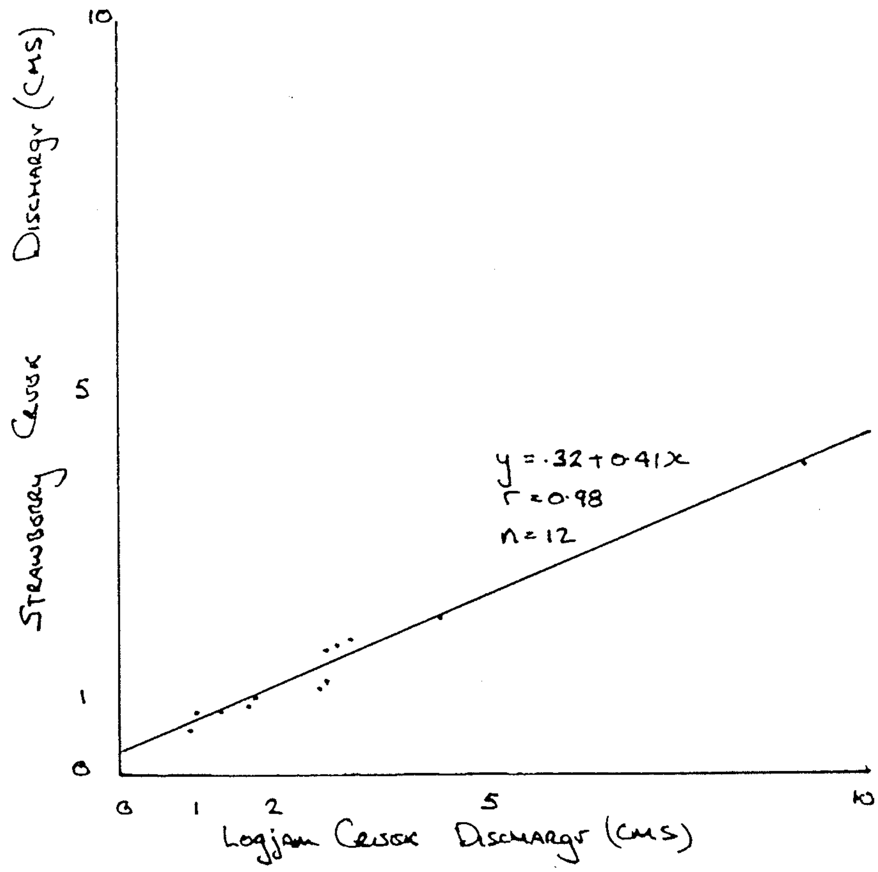
YEAR	EST. MAX INST DISCH. FREER CREEK C.M.S	MAX INST DISCH. PARTRIDGE CREEK C.M.S.
1978	5.90	7.67

Estimated Missing Flow Data for Strawberry Creek.

Discharge data used in regression analysis

Strawberry Creek	Rank	Logjam Creek
4.07	1	9.16
2.07	2	4.31
1.80	3	3.08
1.72	4	2.92
1.70	5	2.79
1.24	6	2.76
1.18	7	2.68
1.05	8	1.82
0.95	9	1.77
0.87	10	1.36
0.87	11	1.02
0.62	12	0.96

Scatter Diagram



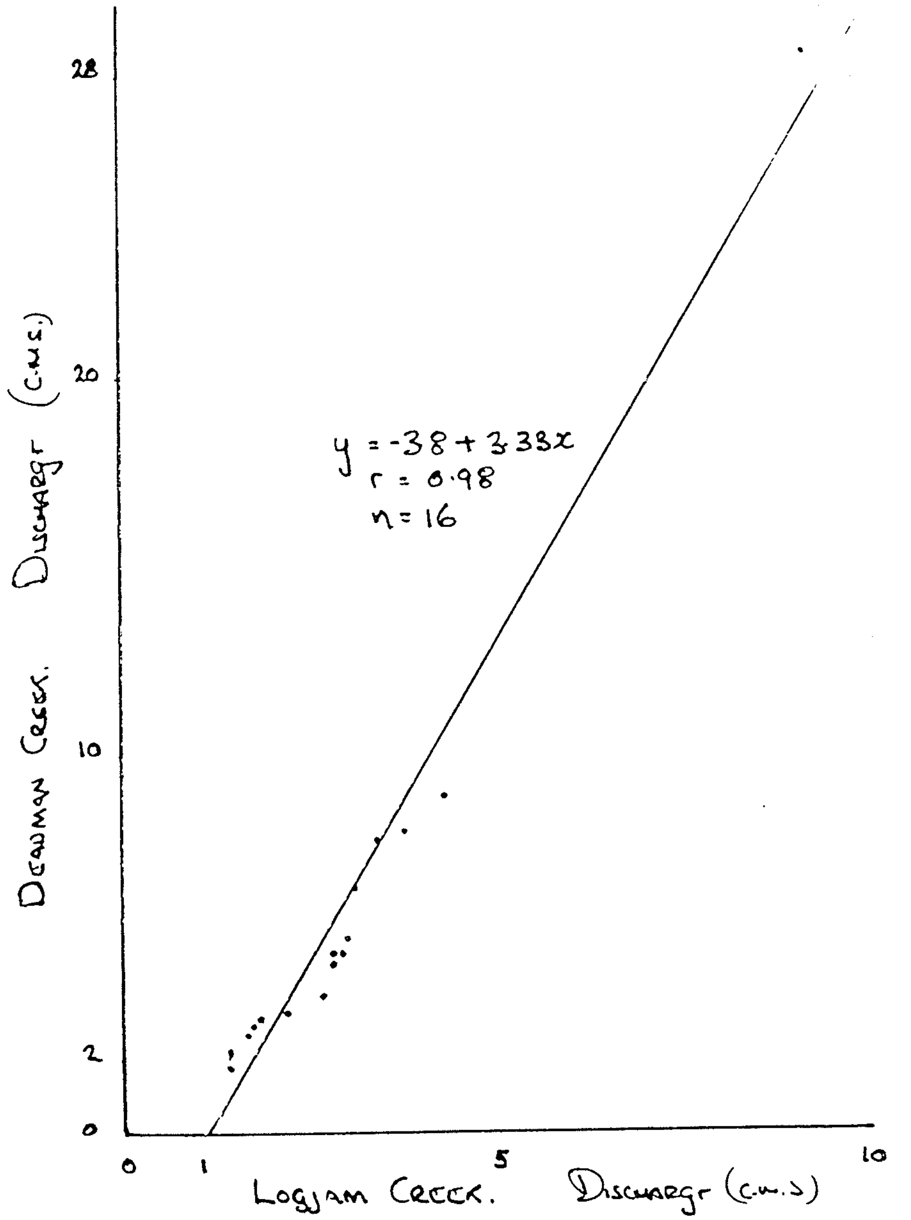
Estimated Maximum Instantaneous Discharge Strawberry Creek.

Year	Est. Max Inst Disch Strawberry Creek. CM.S.	Max Inst Disch Logjam Creek CM.S
1978	1.90	3.75
1980	2.40	4.92
1981	3.50	7.8
1982	2.0	4.01

ESTIMATED MISSING FLOW DATA FOR DEADMAN CREEK.

DISCHARGE DATA USED IN REGRESSION ANALYSIS

DEADMAN CREEK	RANK	LOGJAM CREEK
28.56	1	9.16
8.92	2	4.31
7.97	3	3.75
7.80	4	3.37
6.53	5	3.08
5.15	6	3.01
4.68	7	2.92
4.67	8	2.79
4.26	9	2.76
3.56	10	2.68
3.19	11	2.18
3.06	12	1.82
2.91	13	1.77
2.59	14	1.66
2.34	15	1.40
1.71	16	1.36



ESTIMATED MAXIMUM INSTANTANEOUS DISCHARGE FOR DEADMAN CREEK.

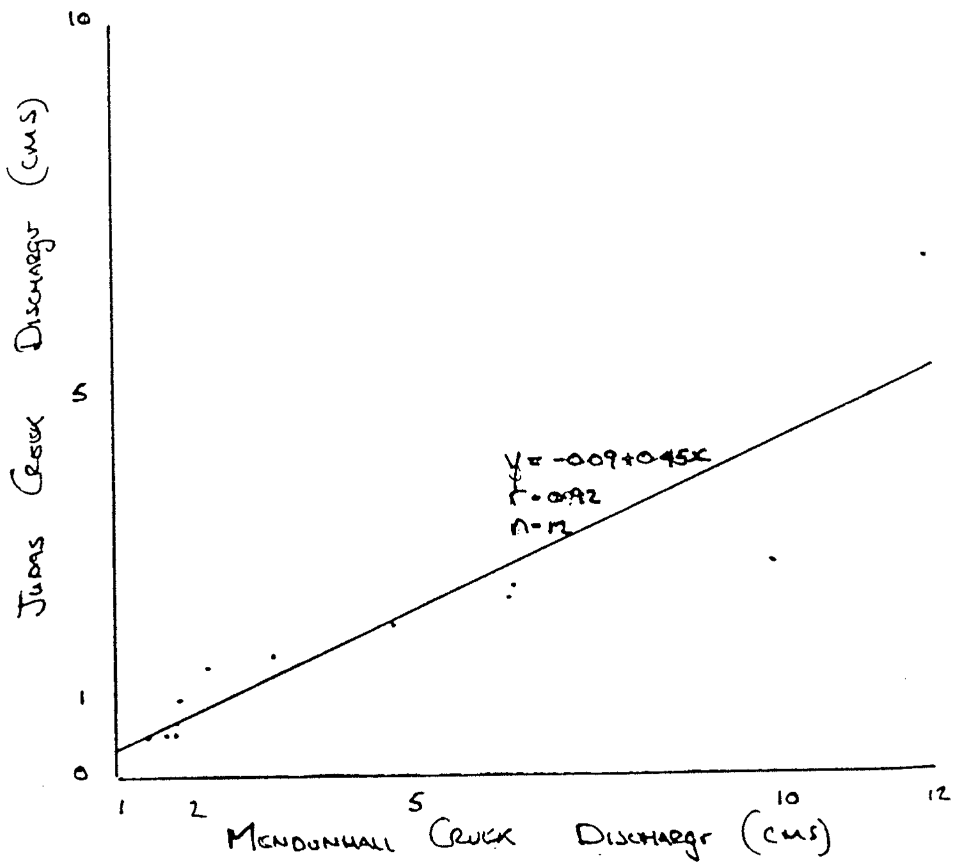
YEAR	EST. MAX INST DISCH DEADMAN CREEK C.M.S	MAX INST DISCH LOGJAM CREEK C.M.S
1978	8.7	3.75
1980	12.6	4.92
1981	22.2	7.80

Estimated missing flow data for Judas Creek.

Discharge data used in regression analysis

Judas Creek	Rank	Mendenhall Creek
6.77	1	11.86
2.81	2	9.79
2.50	3	6.37
2.35	4	6.31
2.02	5	4.71
1.63	6	3.13
1.45	7	2.20
1.01	8	1.86
0.71	9	1.79
0.57	10	1.79
0.56	11	1.68
0.54	12	1.47

Scatter Diagram



Estimated Maximum Instantaneous Discharge for Judas Creek.

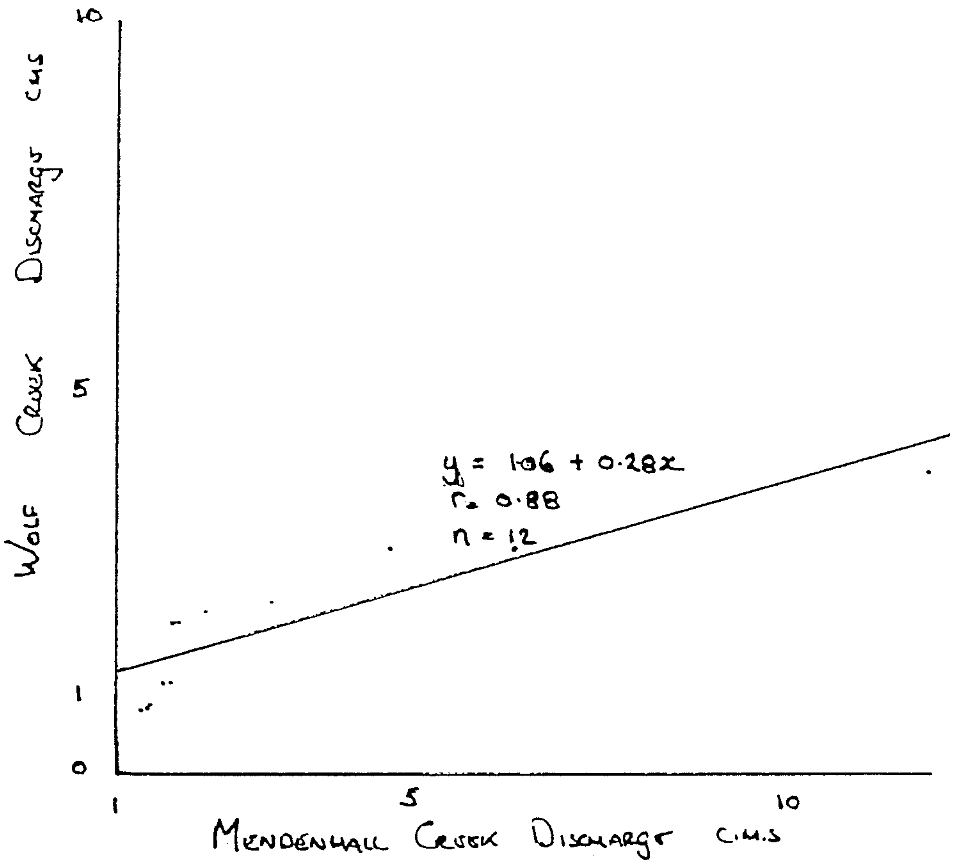
Year	Est. Max Inst. Disch. Judas Creek cms.	Max Inst Disch Mendenhall Creek cms.
1976	7.5	16.4
1977	9.6	21.2
1978	2.4	5.6

Estimated missing flow data for Wolf Creek.

Discharge data used in regression analysis

Wolf Creek	Rank	Mendenhall Creek
3.98	1	11.86
3.02	2	6.37
2.99	3	4.71
2.30	4	3.13
2.18	5	2.20
2.06	6	1.85
2.04	7	1.79
1.25	8	1.79
1.24	9	1.68
0.94	10	1.47
0.92	11	1.43
0.89	12	1.36

Scatter Diagram



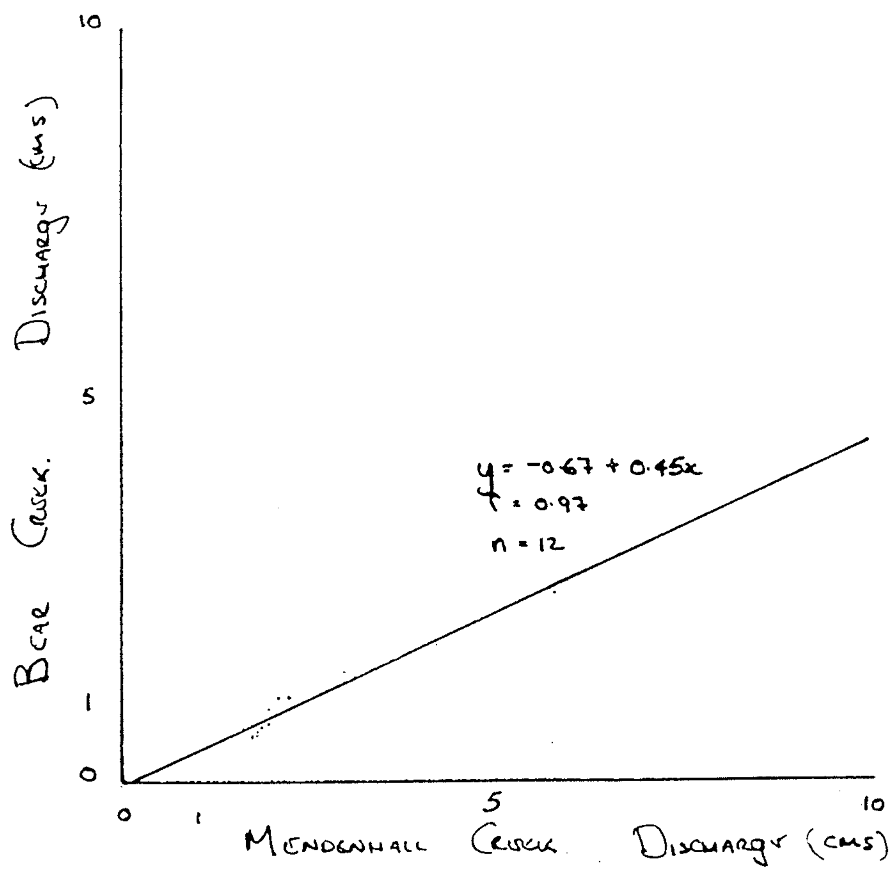
Year	Est. Max. Inst. Disch Wolf Creek cms	Max Inst. Disch Mendenhall Creek. cms
1978	2.6	5.57
1980	3.8	9.79
1981	2.8	6.31
1977	7.0	21.3
1976	5.7	16.5

Estimated missing flow data for Bear Creek.

Discharge data used in Regression analysis

Bear Creek	Rank	Mendenhall Creek
2.46	1	5.79
1.82	2	4.17
1.49	3	2.96
1.11	4	2.20
1.07	5	2.09
0.96	6	1.95
0.75	7	1.94
0.67	8	1.85
0.65	9	1.79
0.60	10	1.78
0.58	11	1.69
0.57	12	1.68

Scatter Diagram

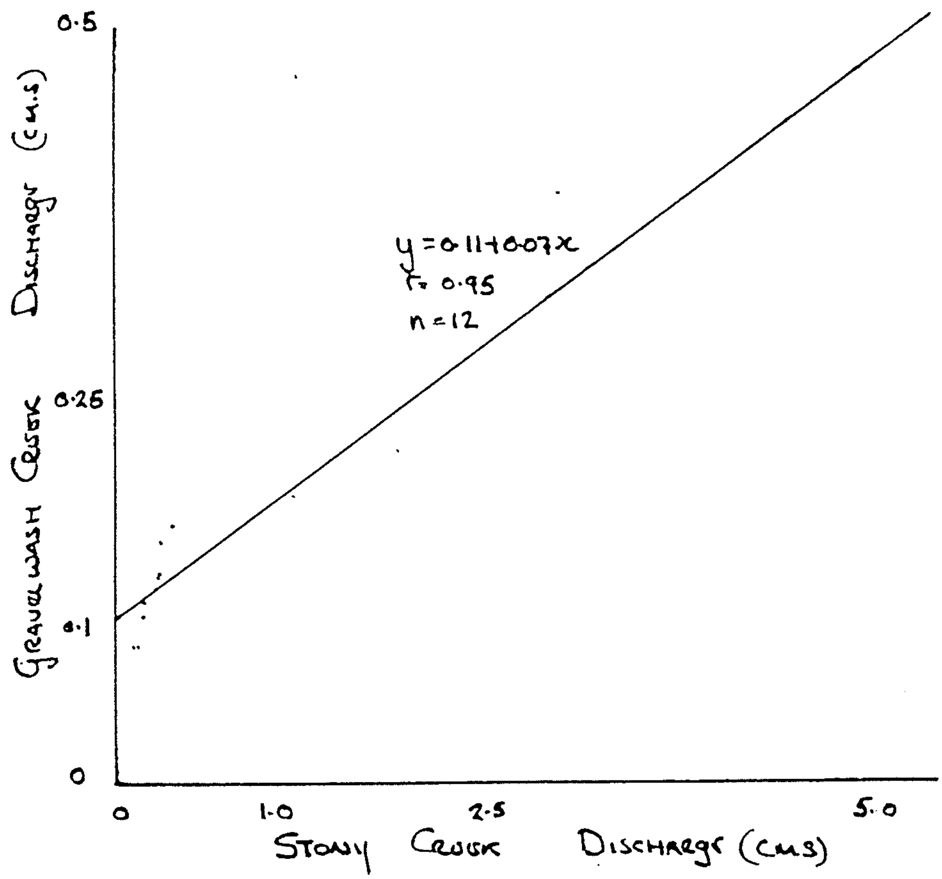


Year	Est Max Inst Disch Bear Creek C.M.S	Max Inst Disch Mendenhall Creek C.M.S
1978	2.4	5.57
1979	5.3	11.86
1980	4.4	9.79
1981	2.79	6.31

ESTIMATED MISSING FLOW DATA FOR GRAVELWASH CREEK.

Discharge data used in Regression analysis		
Gravelwash Creek	Rank	Stony Creek
0.34	1	2.98
0.22	2	1.91
0.19	3	1.21
0.17	4	0.39
0.16	5	0.30
0.14	6	0.29
0.14	7	0.28
0.13	8	0.27
0.12	9	0.18
0.11	10	0.17
0.09	11	0.16
0.09	12	0.15

SCATTER DIAGRAM



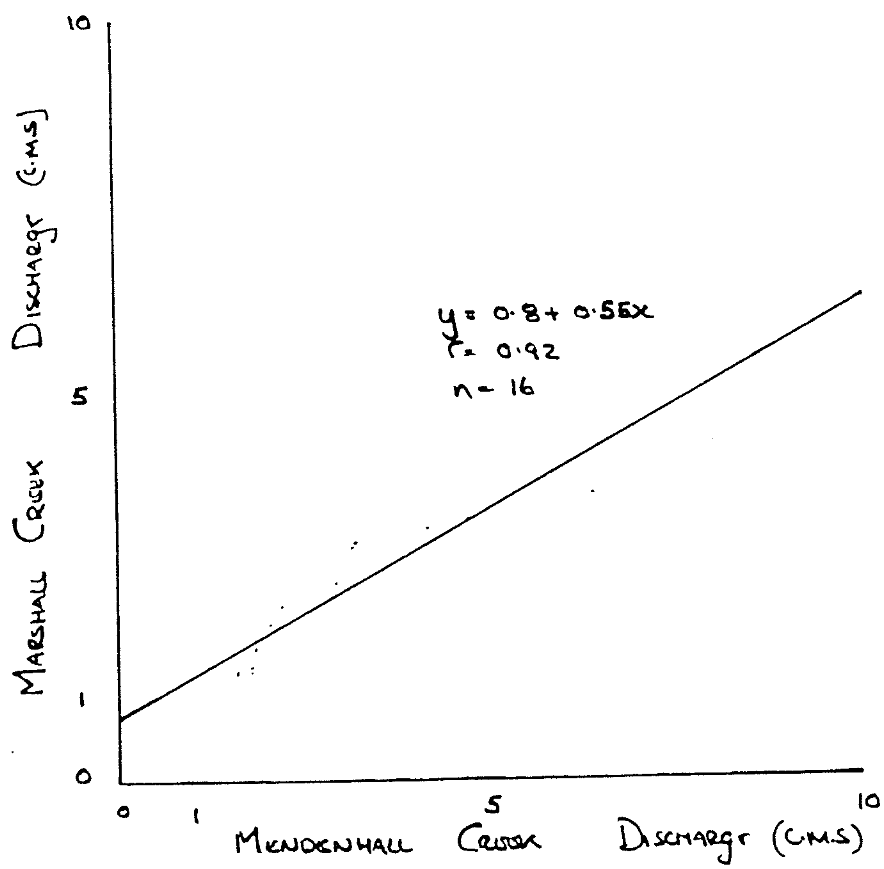
Year	Estimated Max Inst. Disch. Gravelwash Creek C.M.S	Max Inst. Disch Stony Creek. C.M.S.
1978	0.25	1.90
1981	0.42	4.22
1982	0.14	0.41

Estimated missing flow data for Marshall Creek

Discharge data used in regression analysis (cms)

Marshall Creek	Rank	Mendenhall Creek
3.76	1	6.37
3.41	2	4.71
3.3	3	4.17
3.12	4	3.20
3.07	5	3.13
2.59	6	2.96
2.31	7	2.20
2.02	8	2.09
1.93	9	1.95
1.87	10	1.94
1.84	11	1.85
1.71	12	1.85
1.48	13	1.79
1.43	14	1.79
1.41	15	1.69
1.39	16	1.68

Scatter Diagram.

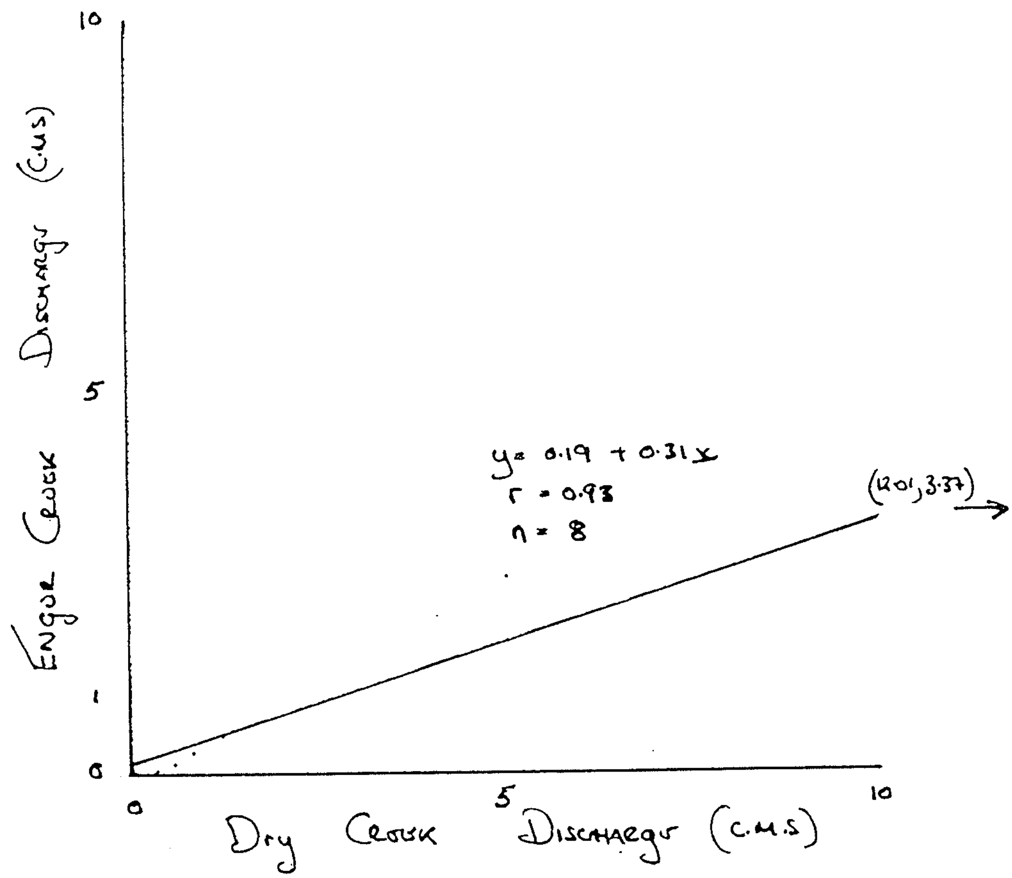


Year	Est. Max. Inst. Disch Marshall Creek cms.	Max Inst Disch Mendenhall Creek (c.m.s)
1978	3.86	5.57
1979	7.32	11.86
1980	6.18	9.79
1981	4.27	6.31

ESTIMATED MISSING flow DATA for ENGER CREEK.

DISCHARGE DATA USED IN REGRESSION ANALYSIS		
ENGER CREEK	RANK	DRY CREEK
3.37	1	12.01
2.62	2	5.01
2.04	3	4.09
0.48	4	1.20
0.30	5	0.79
0.13	6	0.58
0.06	7	0.55
0.03	8	0.32

SCATTER DIAGRAM



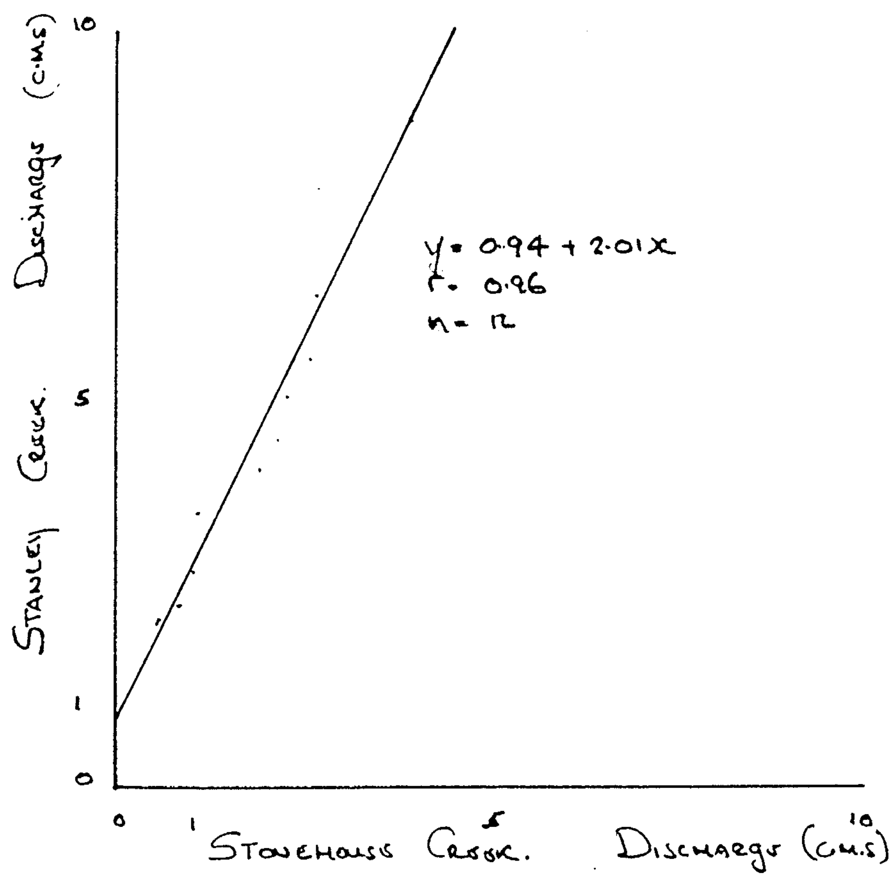
YEAR	EST MAX INST. DISCH. ENGER CREEK. C.M.S	MAX INST DISCH. DRY CREEK C.M.S
1978	3.0	9.24

ESTIMATED MISSING FLOW DATA FOR STANLEY CREEK.

DISCHARGE DATA USED IN REGRESSION ANALYSIS

Stanley Creek	Rank	Stonehouse Creek
8.79	1	3.95
7.92	2	2.71
6.47	3	2.66
5.66	4	2.60
5.13	5	2.27
4.56	6	2.18
4.20	7	1.88
3.60	8	1.06
2.86	9	1.01
2.38	10	0.83
2.1[illegible]	11	0.53
2.13	12	0.52

SCATTER DIAGRAM



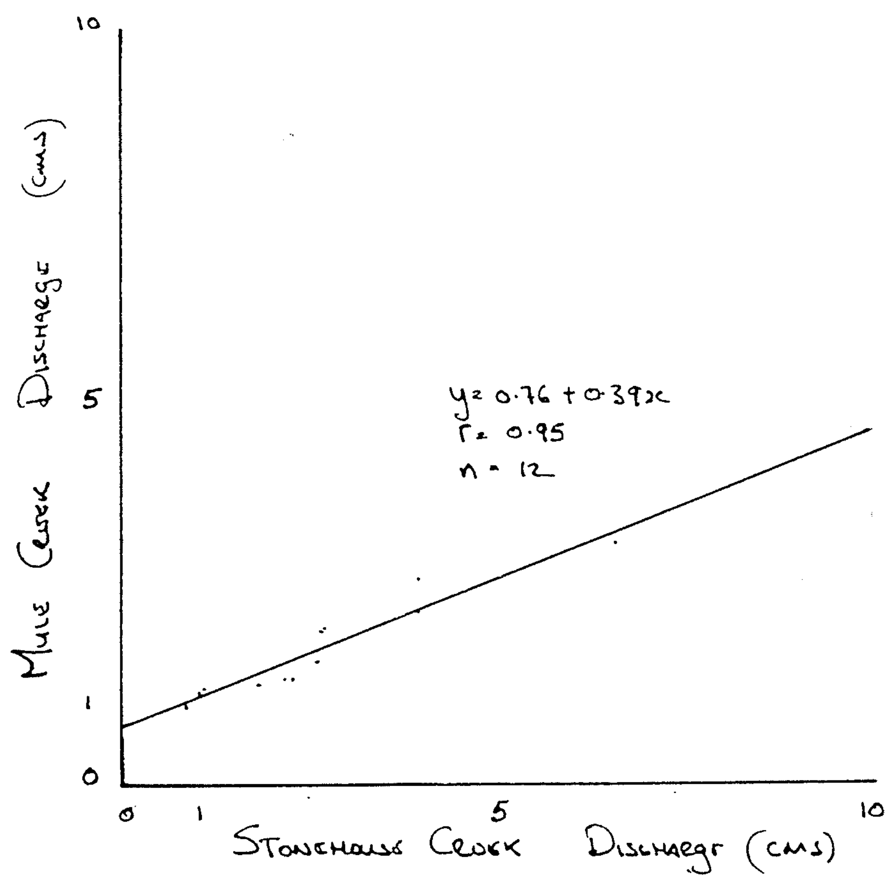
YEAR	EST. MAX. INST. DISCH STANLEY CREEK CMS	MAX INST DISCH. STONEHOUSE CREEK.
1978	8.9	3.95
1980	14.2	6.59
1981	8.9	3.96

Estimated missing flow data for Mule Creek.

Discharge data used in regression analysis

Mule Creek	Rank	Stonehouse Creek
3.16	1	6.59
2.70	2	3.95
2.24	3	3.95
2.05	4	2.71
2.01	5	2.66
1.60	6	2.60
1.38	7	2.27
1.36	8	2.18
1.30	9	1.88
1.28	10	1.06
1.23	11	1.01
1.06	12	0.83

Scatter Diagram.



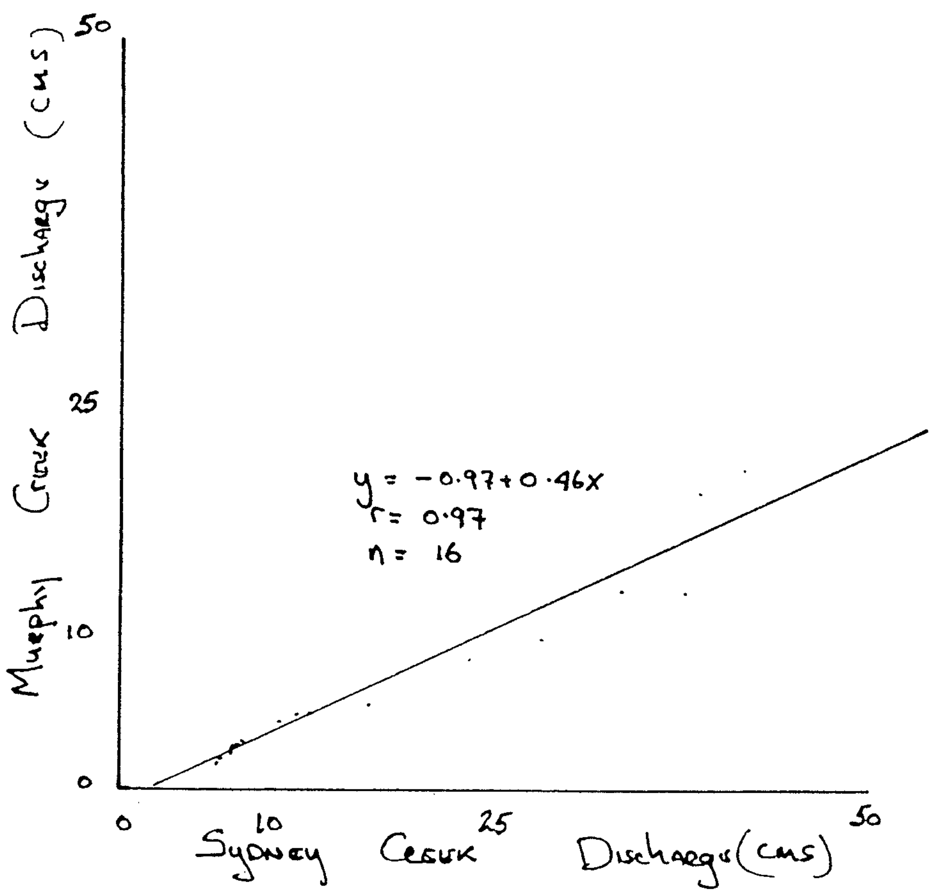
Year	Est. Max Inst Disch Mule Creek CMS	Max. Inst. Disch. Stonehouse Creek. (CMS
1981	2.3	3.96

Estimated Missing Flow Data for Murphy Creek.

Discharge data used in regression analysis

Murphy Creek	Rank	Sydney Creek
21.20	1	41.95
19.86	2	38.92
13.32	3	37.81
12.87	4	33.47
10.18	5	28.21
8.81	6	23.36
5.68	7	16.67
5.09	8	12.79
5.02	9	11.74
4.64	10	10.61
3.34	11	8.27
3.25	12	7.95
2.89	13	7.63
2.53	14	7.56
2.09	15	6.77
1.88	16	6.62

Scatter Diagram



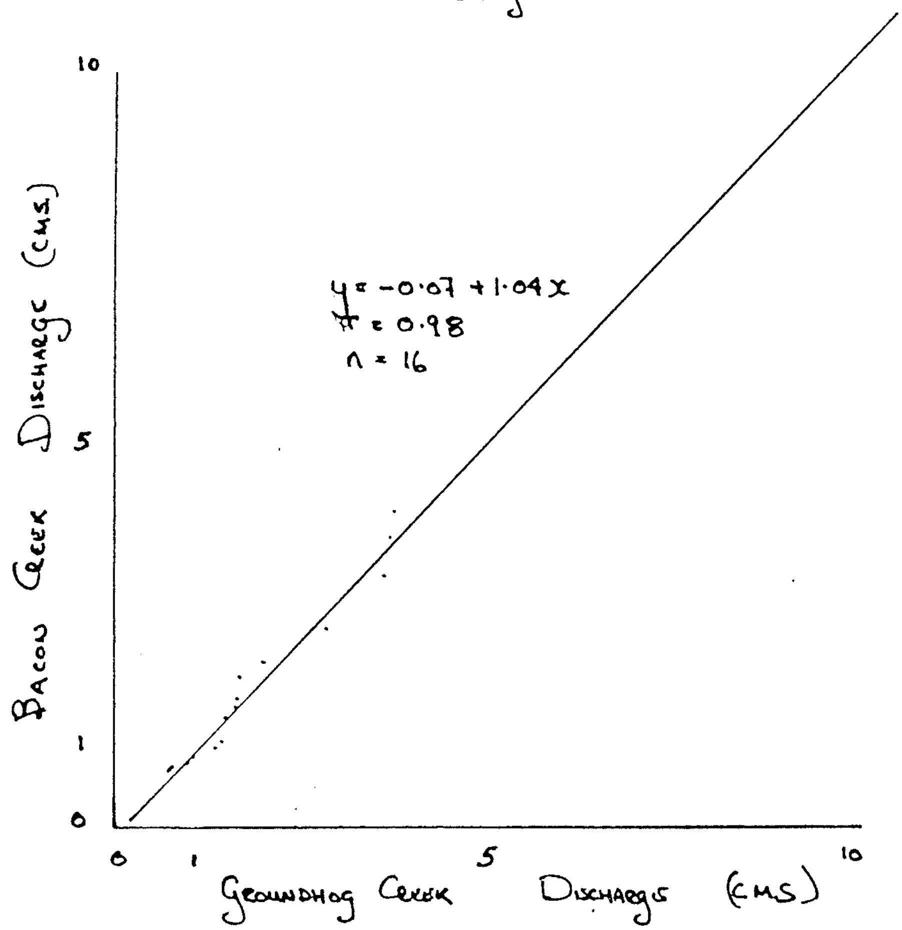
Year	Est. Max Inst. Disch. Murphy Creek (C.M.S.)	Max Inst. Disch. Sydney Creek. (CMS)
1976	18.7	42.72

ESTIMATED MISSING FLOOD DATA : BACON CREEK

DISCHARGE DATA USED IN REGRESSION ANALYSIS

BACON CREEK	RANK	GROUNDHOG CREEK
4.13	1	3.71
3.83	2	3.65
3.33	3	3.59
2.63	4	2.82
2.19	5	1.98
1.99	6	1.66
1.71	7	1.61
1.61	8	1.59
1.45	9	1.44
1.12	10	1.42
1.05	11	1.36
0.91	12	1.04
0.89	13	0.94
0.81	14	0.75
0.78	15	0.71
0.69	16	0.69

SCATTER DIAGRAM



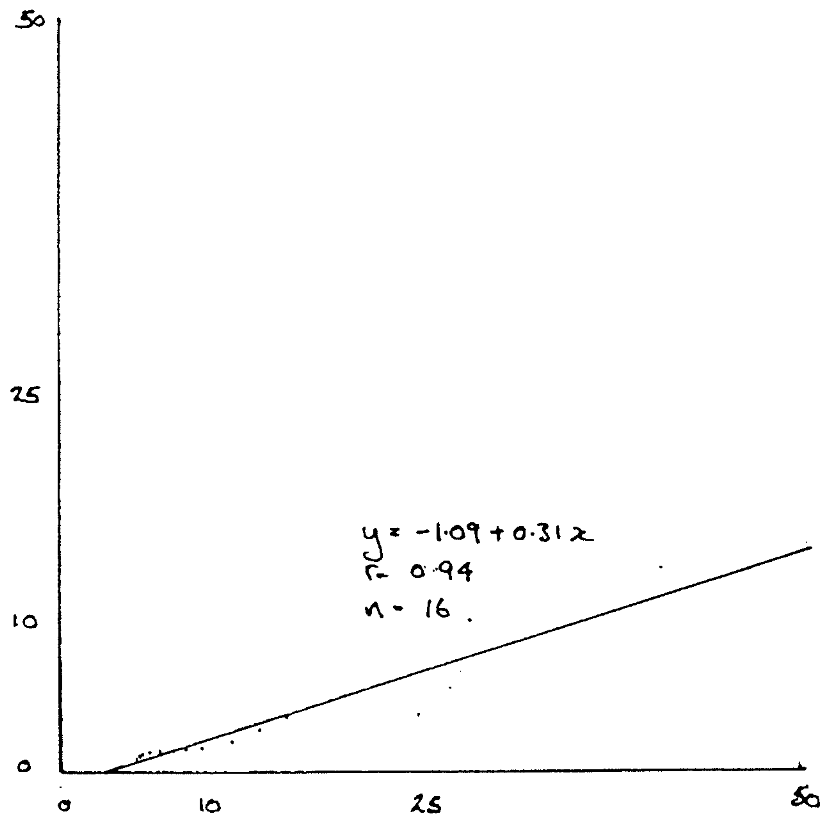
YEAR	EST. MAX INST. DISCH. BACON CREEK CMS.	MAX INST DISCH GROUNDHOG CREEK CMS.
1976	7.0	6.8
1977	6.6	6.41
1978	14.0	13.44
1979	5.6	5.46
1980	10.3	9.97

ESTIMATED MISSING FLOW DATA FOR GROUNDHOG CREEK

DISCHARGE DATA USED IN REGRESSION ANALYSIS

GROUNDHOG CREEK	RANK	ROSE RIVER
13.44	1	40.10
9.97	2	27.54
6.41	3	26.94
5.44	4	26.35
3.65	5	24.10
3.59	6	15.11
2.82	7	13.41
1.98	8	11.48
1.66	9	9.48
1.59	10	8.38
1.44	11	7.56
1.42	12	6.42
1.36	13	5.93
1.08	14	5.43
1.04	15	5.41
0.94	16	5.10

SCATTER DIAGRAM



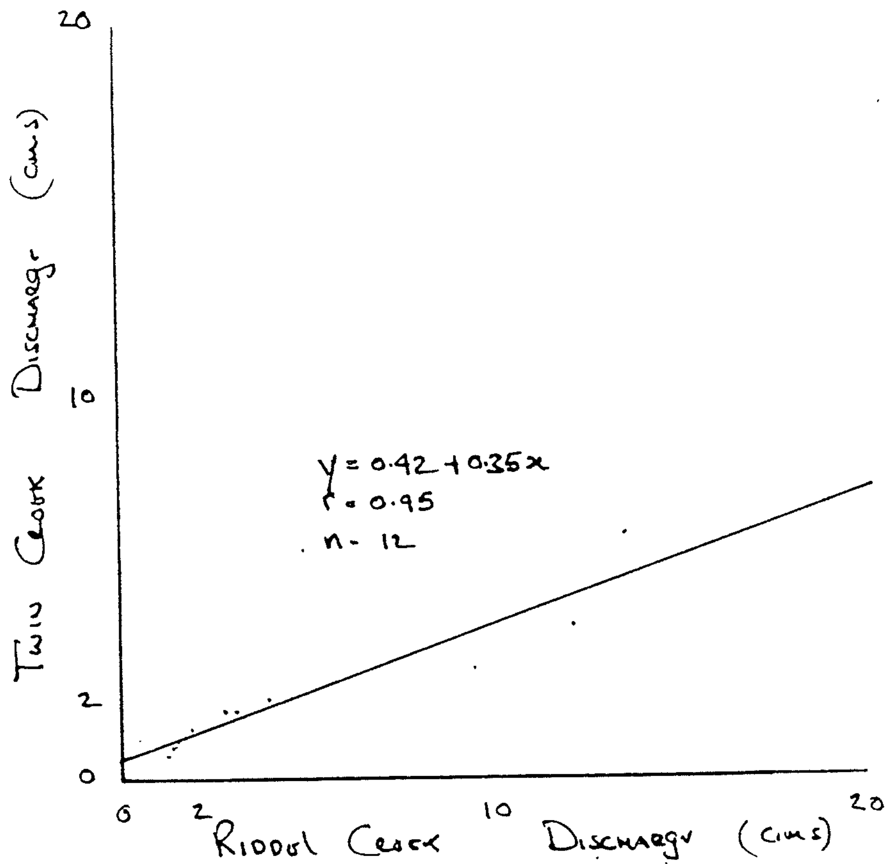
YEAR	EST. MAX INST. DISCH. GROUNDHOG CREEK CMS	MAX INST DISCH ROSE RIVER CMS
1976	6.8	25.20

ESTIMATED MISSING FLOW DATA FOR TWIN CREEK

SCATTER DIAGRAM.

DISCHARGE DATA USED IN REGRESSION ANALYSIS

TWIN CREEK	RANK	RIDDEL CREEK
6.38	1	13.60
3.97	2	12.18
2.85	3	9.58
2.10	4	3.97
1.77	5	3.06
1.76	6	2.82
1.28	7	1.90
1.05	8	1.79
0.96	9	1.57
0.84	10	1.49
0.78	11	1.44
0.63	12	1.27



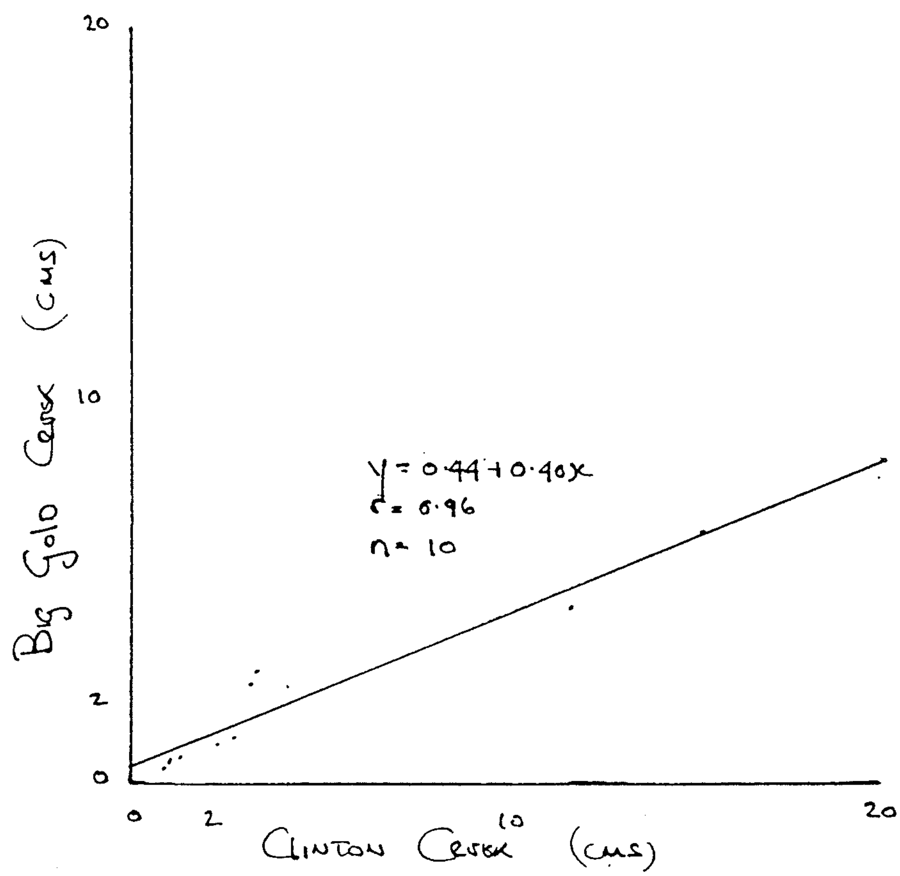
YEAR	EST. MAX INST. DISCH.	MAX INST DISCH
1979	5.01	13.00
1981	4.16	10.59

Estimated missing flow data for Big Gold Creek.

Discharge data used in Regression Analysis

Big Gold Creek	Rank	Clinton Creek
6.6	1	15.25
4.61	2	11.80
4.97	3	3.27
2.58	4	3.17
1.25	5	2.78
1.03	6	2.30
0.67	7	1.24
0.58	8	1.04
0.57	9	1.03
0.47	10	0.87

Scatter Diagram

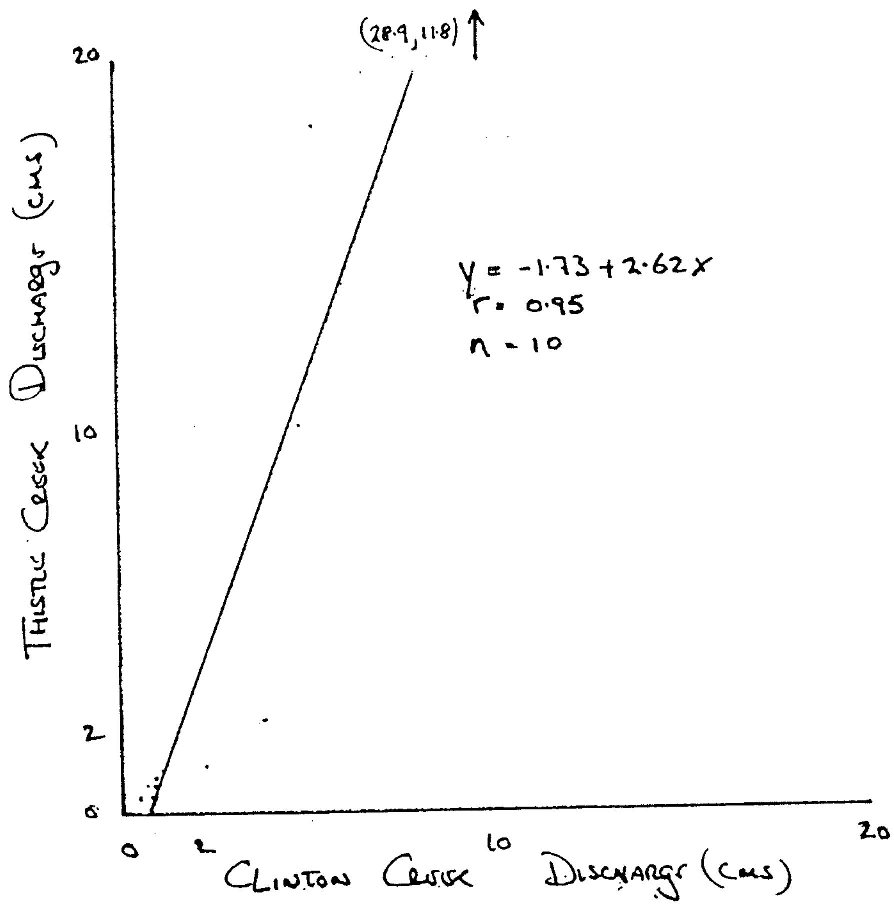


Year	Est. Max Inst. Disch. Big Gold Creek C.M.S	Max Inst Disch. Clinton Creek C.M.S
1978	4.1	9.36
1980	2.5	5.15
1982	4.4	10.0

Estimated missing flow data for Thistle Creek

Discharge data used in Regression analysis		
Thistle Creek	Rank	Clinton Creek
28.86	1	11.80
18.20	2	5.16
10.23	3	4.84
2.46	4	3.80
1.27	5	2.17
1.21	6	1.03
0.99	7	0.82
0.85	8	0.82
0.49	9	0.66
0.47	10	0.25

Scatter Diagram



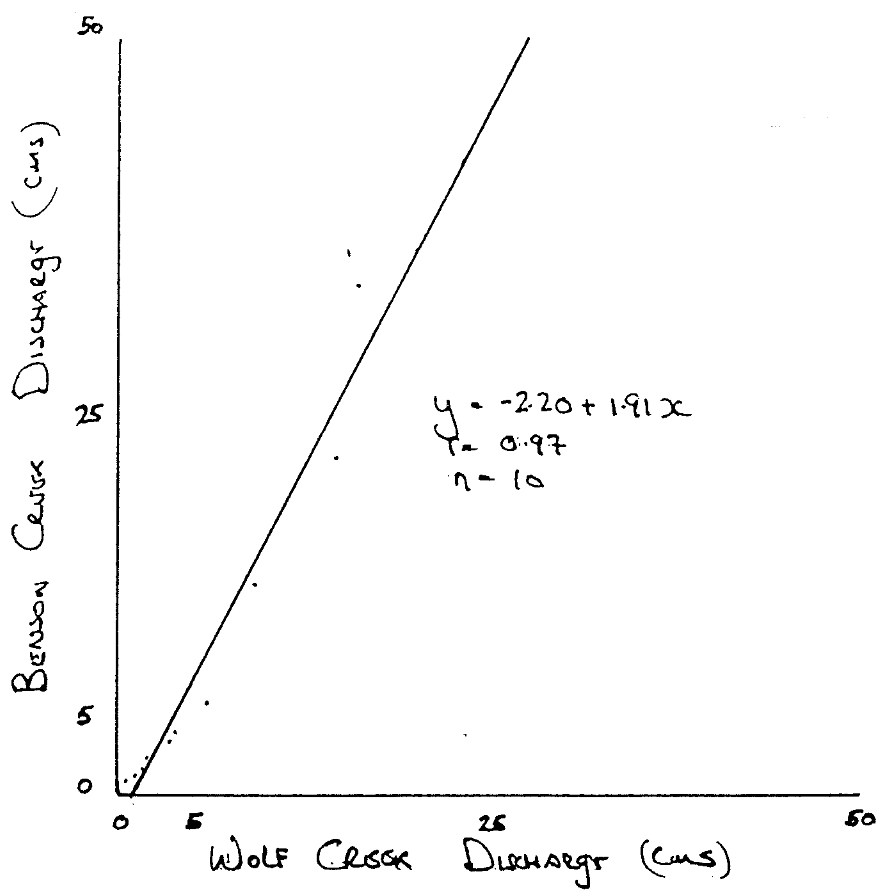
Year	Est. Max. Inst. Disch Thistle Creek C.M.S	Max Inst. Disch. Clinton Creek C.M.S
1978	22.8	9.36
1979	38.2	15.25

Estimated missing flow data for Benson Creek

Discharge data used in regression analysis

Benson Creek	Rank	Wolf Creek
33.6	1	16.1
22.3	2	14.6
13.9	3	9.1
6.1	4	6.0
4.1	5	3.8
3.5	6	3.5
2.4	7	1.9
1.7	8	1.6
1.2	9	1.3
0.9	10	0.6

Scatter Diagram



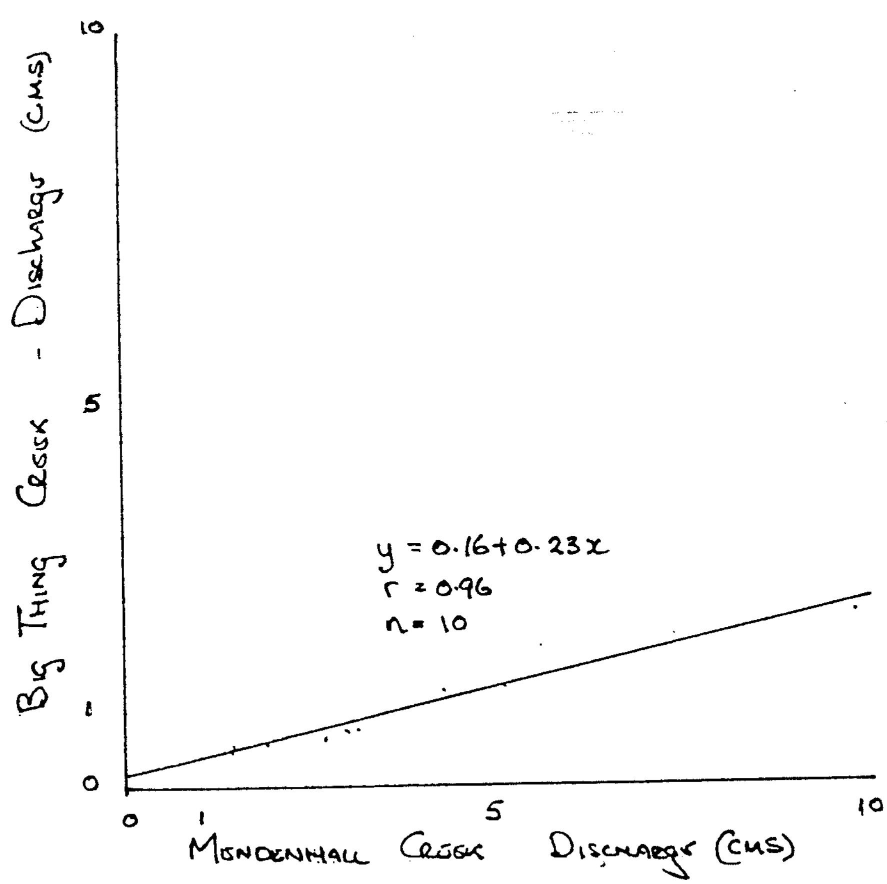
Year	Est. Max Inst Disch. Benson Creek cms.	Max Inst Disch. Wolf Creek cms.
1977	26.6	15.1
1978	26.6	15.1
1979	40.6	22.4
1980	12.4	7.6
1981	48.9	26.8

ESTIMATED MISSING FLOW DATA FOR BIG THING CREEK

SCATTER DIAGRAM

DISCHARGE DATA USED IN REGRESSION ANALYSIS

BIG THING CREEK	RANK	MENDENHALL CREEK
2.26	1	9.79
1.85	2	5.57
1.28	3	5.11
1.27	4	4.29
0.76	5	3.12
0.74	6	2.99
0.65	7	2.70
0.57	8	1.79
0.55	9	1.45
0.48	10	1.44



YEAR	EST. MAX INST. DISCH BIG THING CREEK C.M.S	MAX INST DISCH. MENDENHALL CREEK C.M.S.
1979	2.89	11.86
1981	1.61	6.31

APPENDIX 5

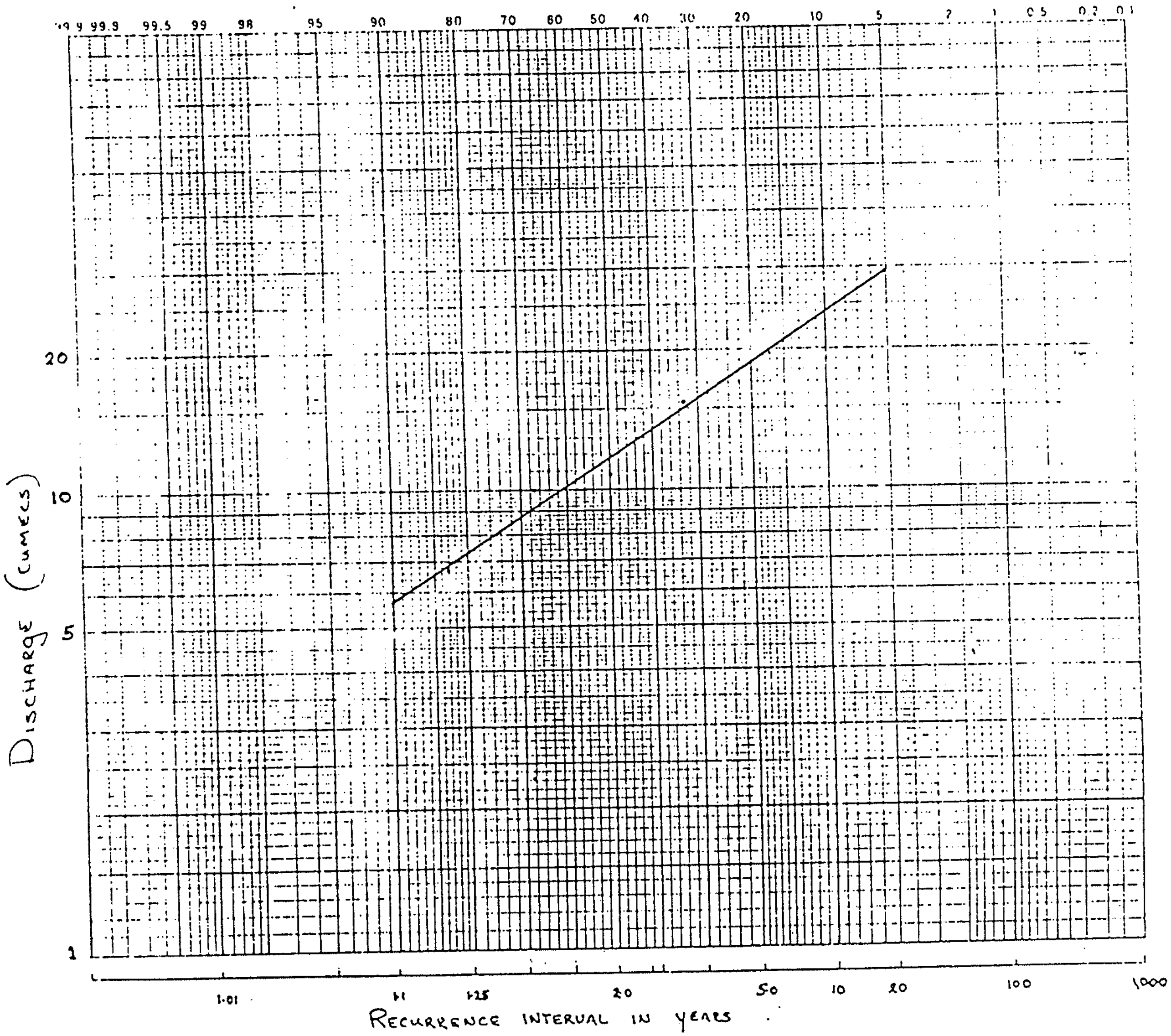
FLOOD-FREQUENCY CURVES

MAXIMUM INSTANTANEOUS DISCHARGE DATA : SPENCER CREEK

RANK.	YEAR.	MAX. INST. DISCH. C.M.S.	RETURN PERIOD. YEARS.
1	1979	19.6	6
2	1981	15.5	3
3	1982	10.9	2
4	1980	10.0	1.5
5	1978	6.7	1.2

*ESTIMATED.

	DISCHARGE . C.M.S.
2 YEAR FLOOD.	11.8
MEAN ANNUAL FLOOD	13.0
5 YEAR FLOOD.	19.0
10 YEAR FLOOD.	24.0
20 YEAR FLOOD.	29.5



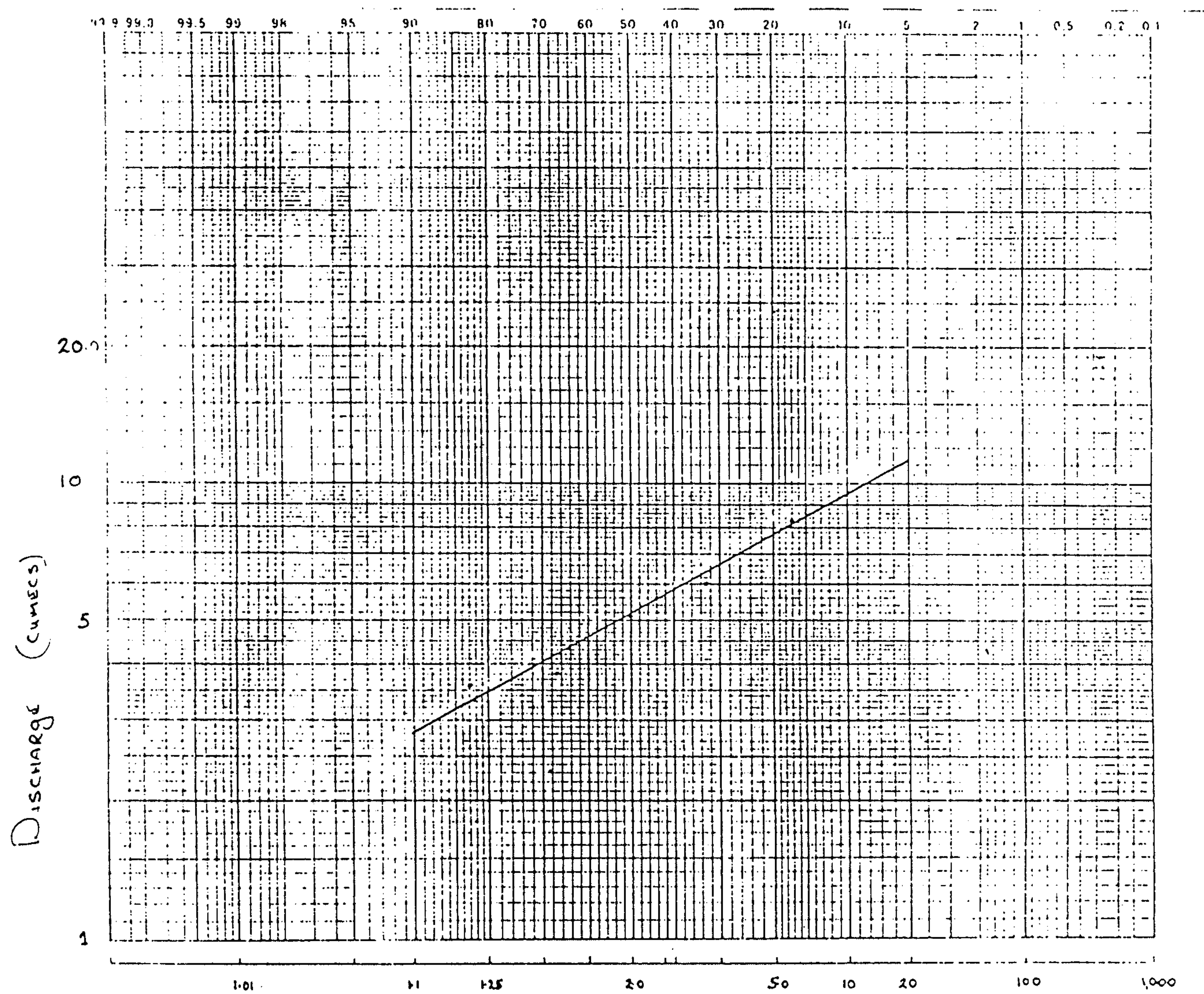
Spencer Creek

Maximum Instantaneous Discharge Data: Freer Creek.

Rank.	Year.	Max. Inst. Disch. c.m.s.	Return Period. years.
1	1980	8.3	6.0
2	1978	6.0	3.0
3	1979	5.1	2.0
4	1982	3.8	1.5
5	1981	3.6	1.2

*Estimated.

	Discharge. c.m.s.
2 year flood.	5.2
Mean annual flood	5.6
5 year flood.	7.7
10 year flood.	9.6
20 year flood.	11.5



Recurrence interval in years

Freer Creek

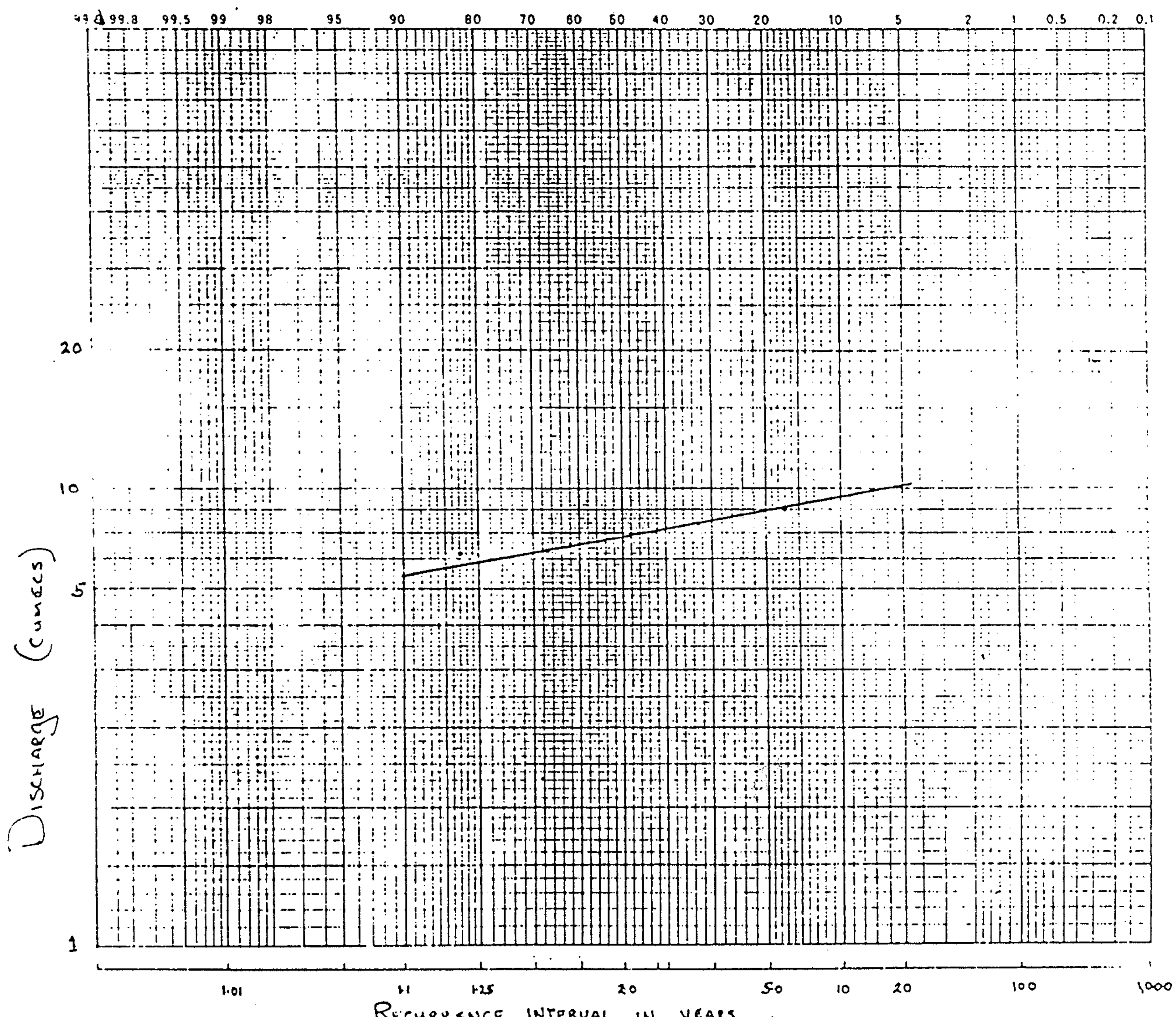
4

Maximum Instantaneous Discharge Data : Partridge Creek

Rank.	Year.	Max. Inst. Disch. C.M.S.	Return Period. Years.
1	1982	9.0	6.0
2	1979	8.4	3.0
3	1978	7.7	2.0
4	1981	7.3	1.5
5	1980	7.2	1.2

*Estimated.

	Discharge. C.M.S.
2 year flood.	7.8
Mean annual flood	8.0
5 year flood.	9.0
10 year flood.	9.6
20 year flood.	10.2



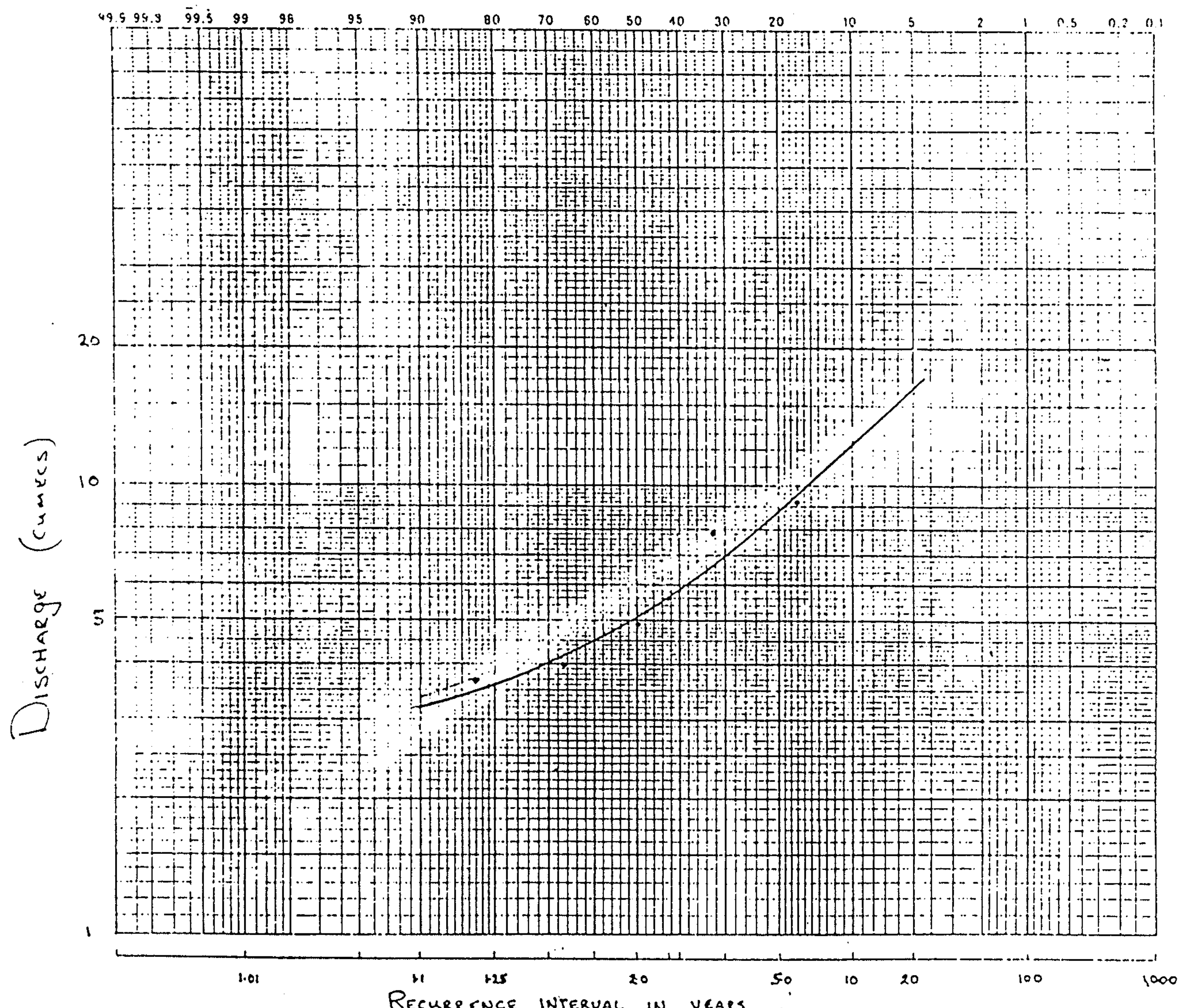
PARTRIDGE CREEK

Maximum Instantaneous Discharge Data: Logjam Creek

Rank.	Year.	Max. Inst. Disch. C.M.S.	Return Period. Years.
1	1979	9.2	6.0
2	1981	7.8	3.0
3	1980	4.9	2.0
4	1982	4.0	1.5
5	1981	3.7	1.2

* Estimated.

	Discharge. C.M.S.
2 year flood.	5.1
Mean annual flood	5.6
5 year flood.	8.8
10 year flood.	12.5
20 year flood.	16.5



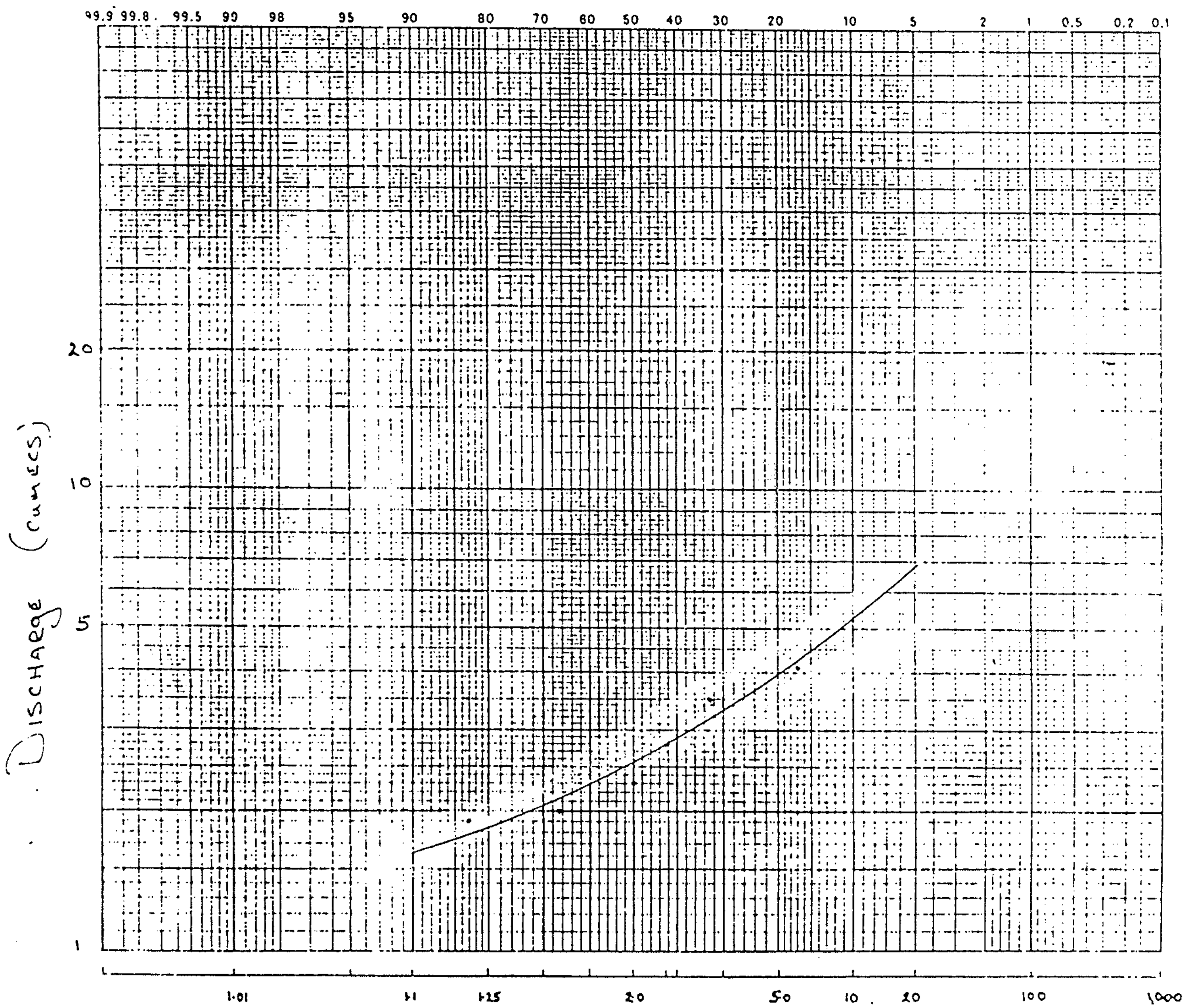
Logjam Creek

Maximum Instantaneous Discharge Data: Strawberry Creek

Rank.	Year.	Max. Inst. Disch. c.m.s.	Return Period. years.
1	1979	4.1	6.0
2	1981	3.5 *	3.0
3	1980	2.3	2.0
4	1982	2.0 *	1.5
5	1978	1.9 *	1.2

*Estimated.

	Discharge. c.m.s.
2 year flood.	2.5
Mean annual flood.	2.8
5 year flood.	4.0
10 year flood.	5.2
20 year flood.	6.8



Recurrence interval in years

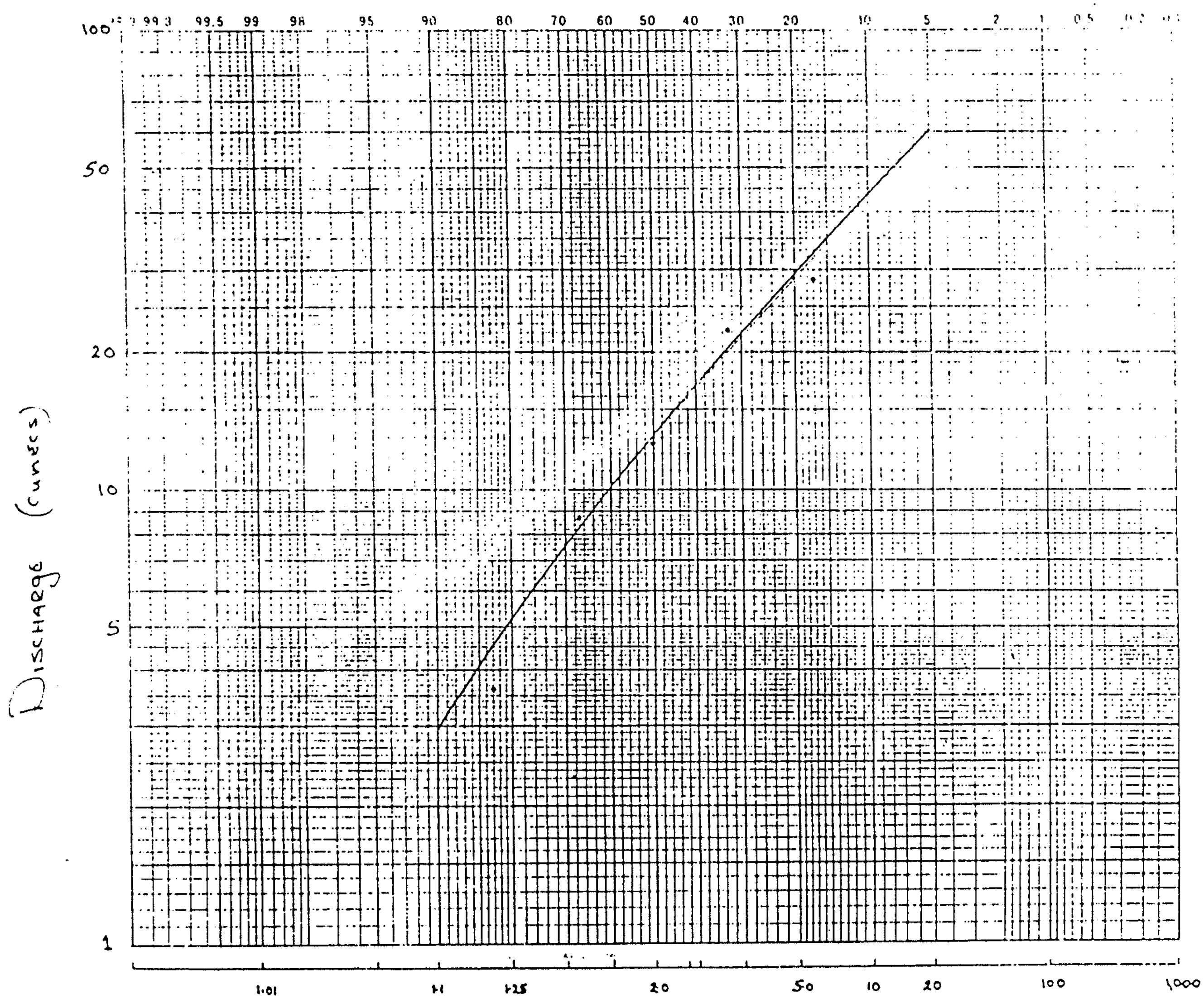
Strawberry Creek

Maximum Instantaneous Discharge Data: Deadman Creek

Rank.	Year.	Max. Inst. Disch. c.m.s.	Return Period. years.
1	1979	28.6	6.0
2	1981	22.2	3.0
3	1980	12.6	2.0
4	1978	8.7	1.5
5	1982	3.6	1.2

*Estimated.

	Discharge. c.m.s.
2 year flood.	13.0
Mean annual flood.	15.5
5 year flood.	28.5
10 year flood.	43.0
20 year flood.	60.0



RECURRENCE INTERVAL IN YEARS

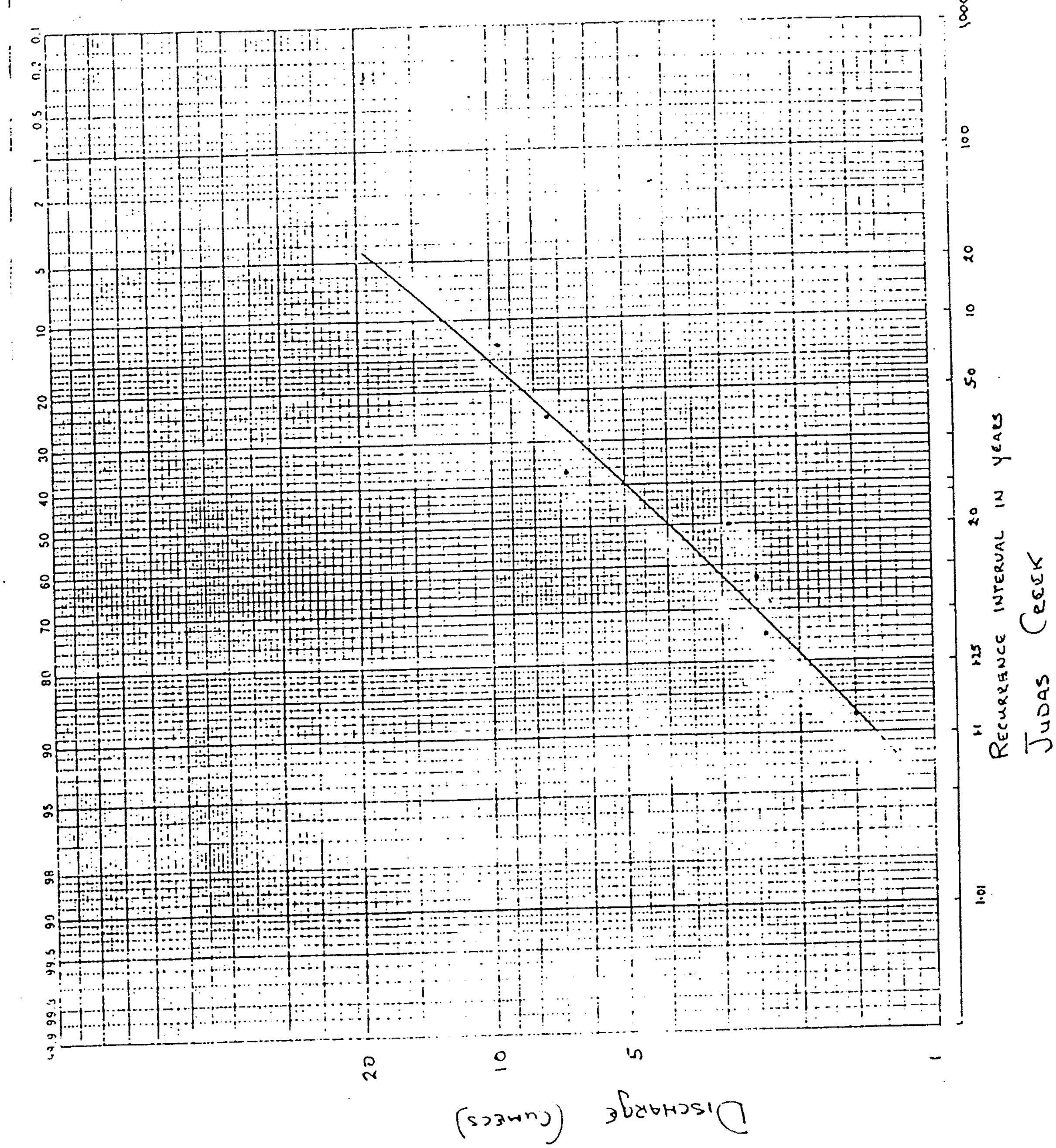
DEADMAN CREEK

Maximum Instantaneous Discharge Data: Judas Creek

Rank.	Year.	Max. Inst. Disch. C.M.S.	Return Period. Years.
1	1977	9.6 *	8
2	1976	7.5 *	4.0
3	1981	6.8	2.67
4	1979	2.8	2.0
5	1980	2.5	1.6
6	1978	2.4 *	1.33
7	1982	1.5	1.14

* Estimated.

	Discharge. C.M.S.
2 year flood.	4.0
Mean annual flood	4.6
5 year flood.	8.4
10 year flood.	113.0
20 year flood.	18.0

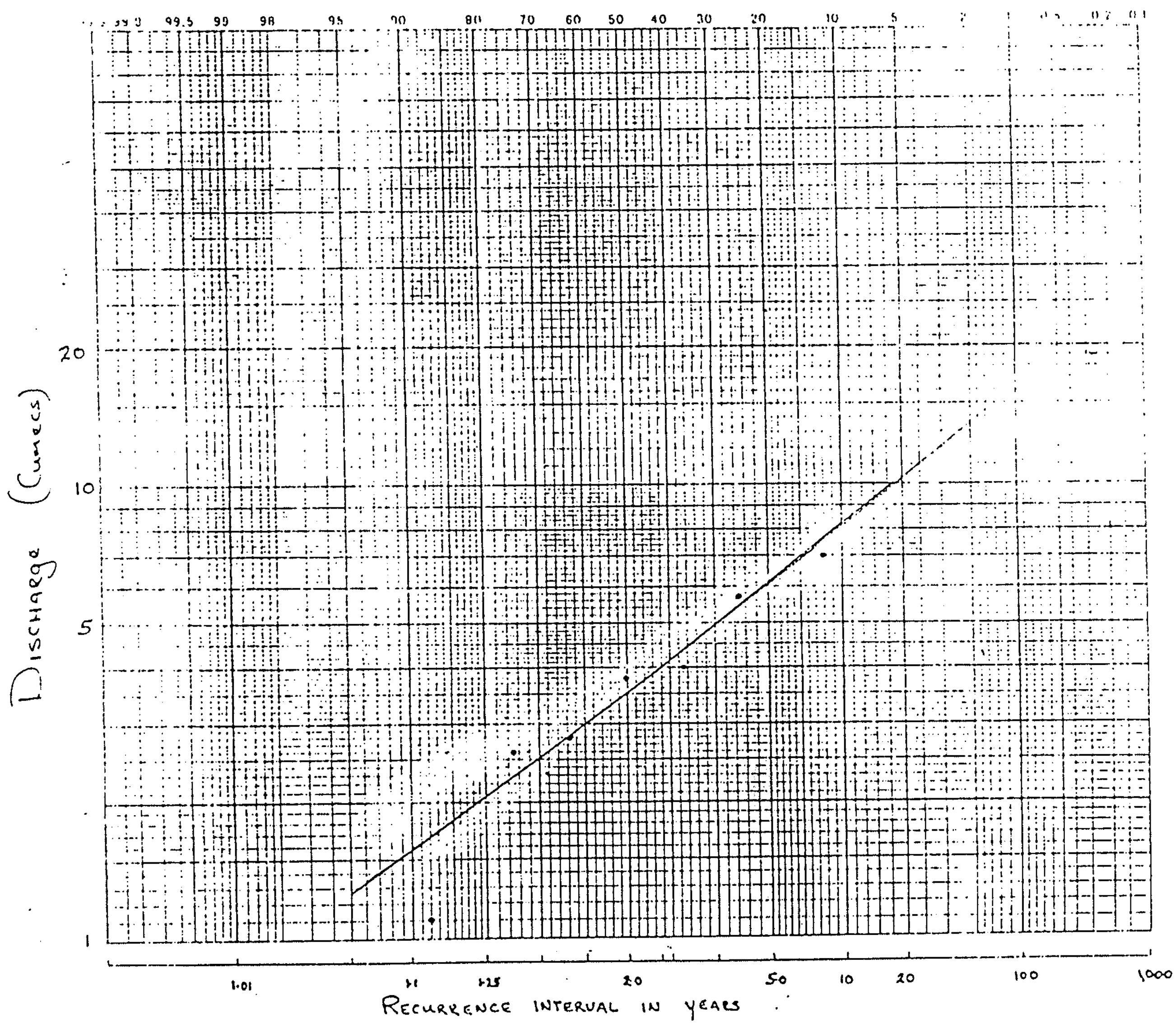

Recurrence Interval in Years
Judas Creek
Discharge (cumecs)
1.01
1.1
1.25
2.0
5.0
10
20
100
1000
20
10
5
1
99.9
99.5
99
98
95
90
80
70
60
50
40
30
20
10
5
2
1
0.5
0.2
0.1

Maximum Instantaneous Discharge Data: Wolf Creek

Rank.	Year.	Max. Inst. Disch. c.m.s.	Return Period. years.
1	1977	7.0 *	8.0
2	1976	5.7 *	4.0
3	1979	4.0	2.67
4	1980	3.8 *	2.0
5	1981	2.8 *	1.6
6	1978	2.6	1.33
7	1982	1.1	1.14

* Estimated.

	Discharge. c.m.s.
2 year flood.	3.5
Mean annual flood	4.0
5 year flood.	6.0
10 year flood.	8.1
20 year flood.	10.2



99.5
99
98
95
90
80
70
60
50
40
30
20
10
5
Discharge (Cumecs)
20
10
5
1
1·01
1·25
2·0
5·0
10
20
100
1000
Recurrence interval in years

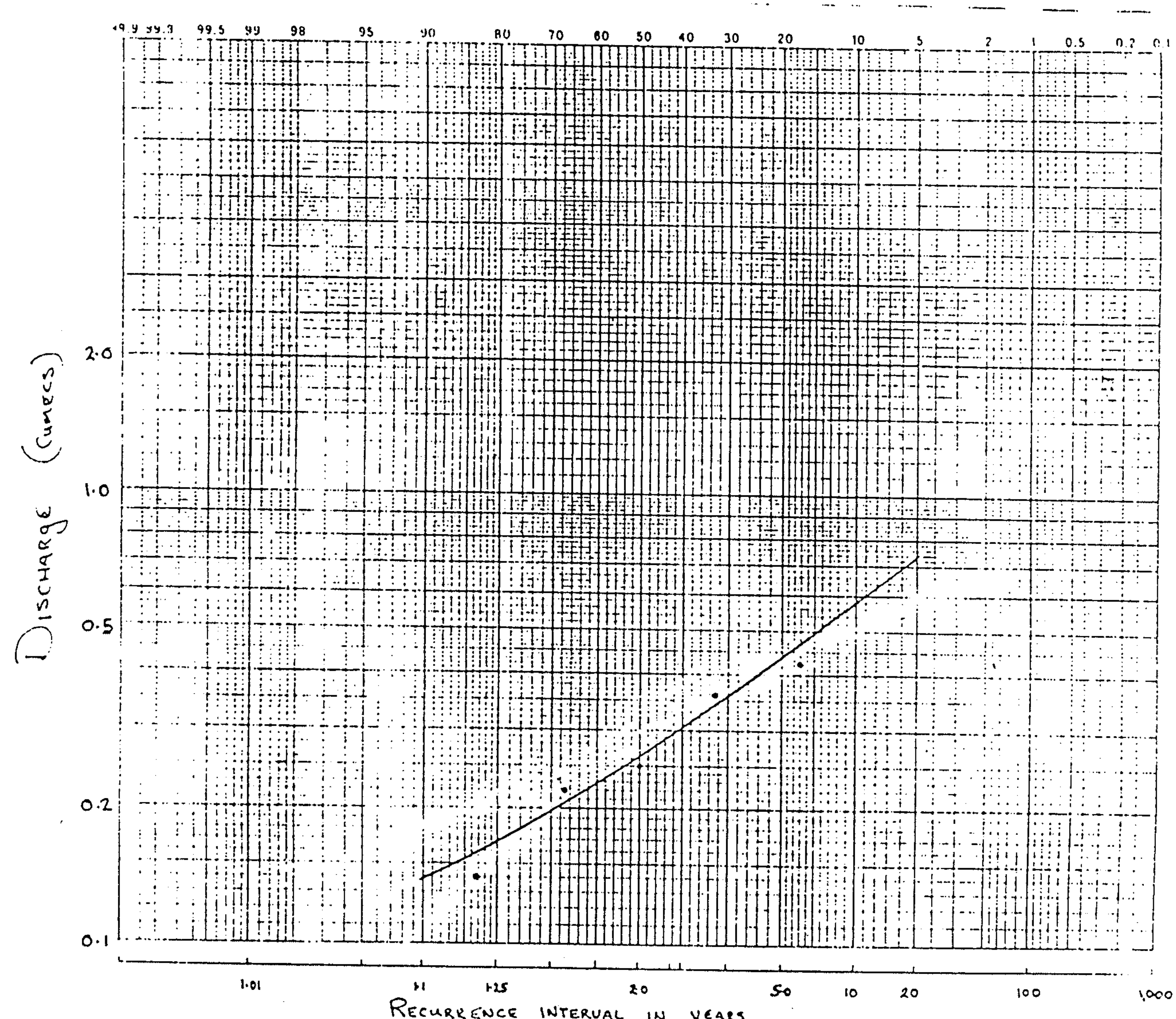
Wolf Creek

Maximum Instantaneous Discharge Data: Gravelwash Creek

Rank.	Year.	Max. Inst. Disch. c.m.s.	Return Period. years.
1	1981	0.42	6.0
2	1980	0.36	3.0
3	1978	0.25	2.0
4	1979	0.22	1.5
5	1982	0.14	1.2

* Estimated.

	Discharge. c.m.s.
2 year flood.	0.26
Mean annual flood	0.29
5 year flood.	0.44
10 year flood.	0 58
20 year flood.	C.74



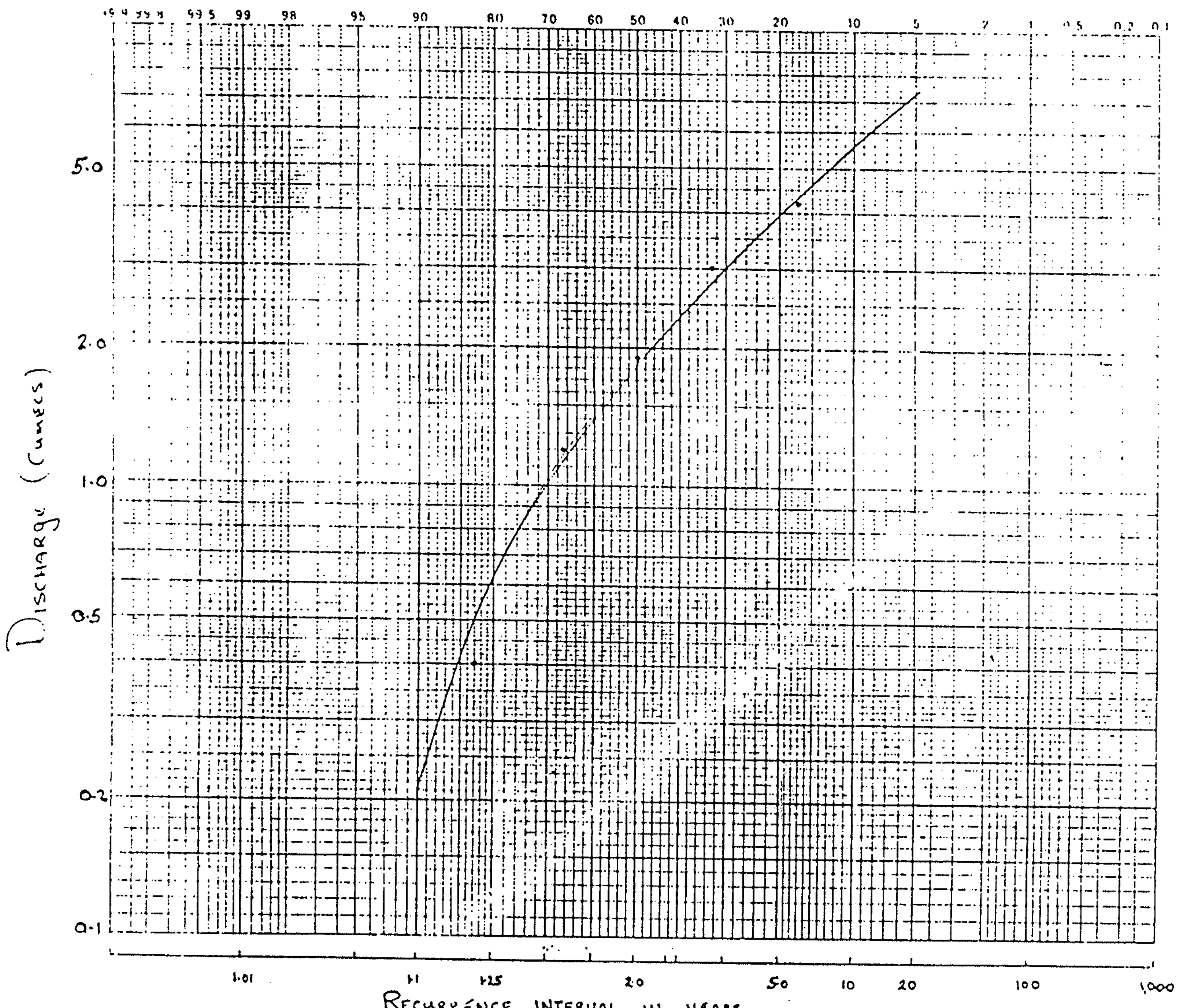
Gravelwash Creek

Maximum Instantaneous Discharge Data : Stony Creek

Rank.	Year.	Max. Inst. Disch. C.M.S.	Return Period. Years.
1	1981	4.2	6
2	1979	3.0	3
3	1978	1.9	2
4	1980	1.2	1.5
5	1982	0.4	1.2

*Estimated.

	Discharge. C.M.S.
2 year flood.	1.8
Mean annual flood.	2.2
5 year flood.	4.0
10 year flood.	5.6
20 year flood.	6.2


99.5
99
98
95
90
80
70
60
50
40
30
20
10
5
2
1
0.5
0.2
0.1
Discharge (Cumecs)
5.0
2.0
1.0
0.5
0.2
0.1
1.01
1.1
1.25
2.0
5.0
10
20
100
1,000
Recurrence interval in years

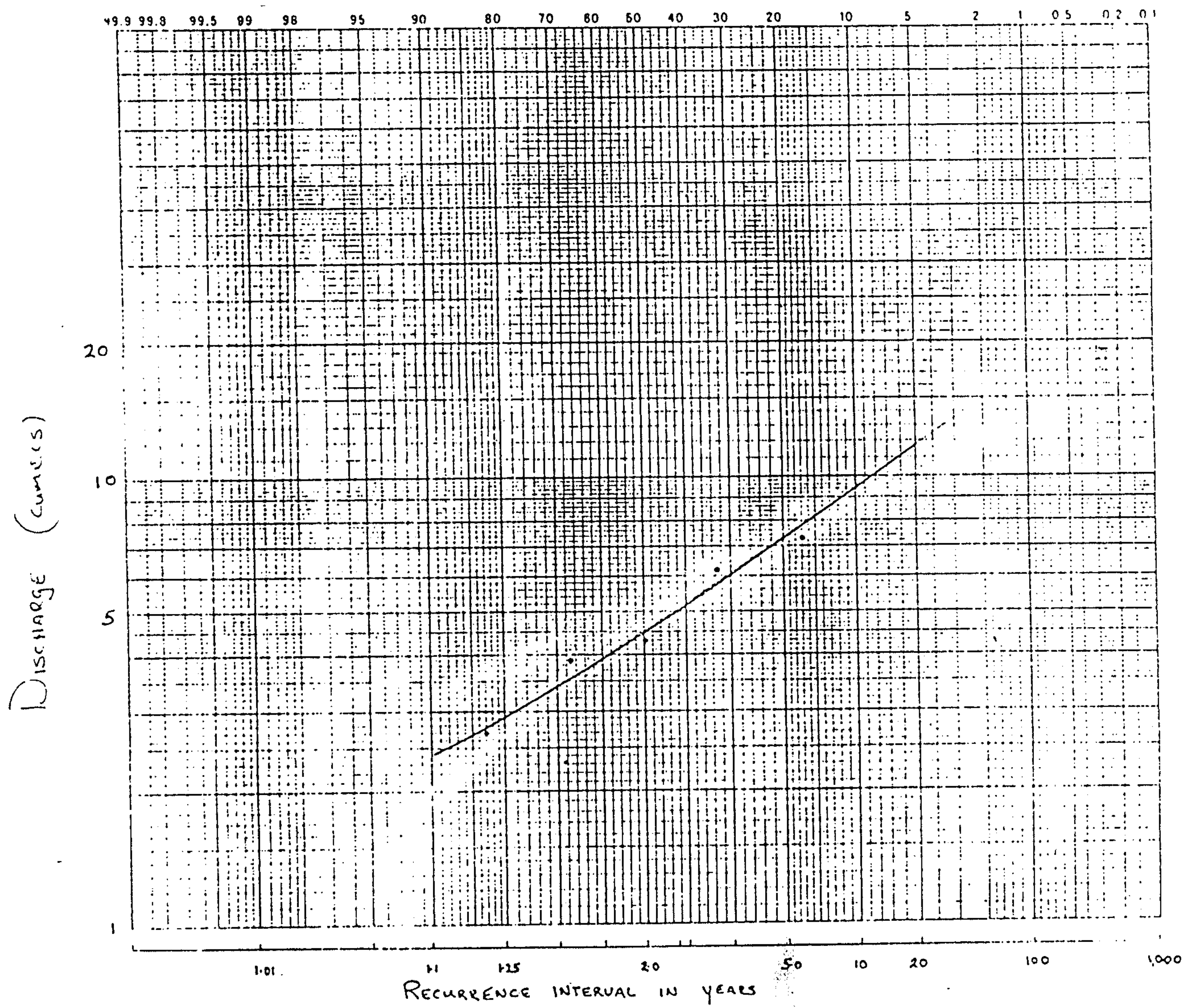
Stony Creek

Maximum Instantaneous Discharge Data : Marshall Creek

Rank.	Year.	Max. Inst. Disch. c.m.s.	Return Period. years.
1	1979	7.3	6
2	1980	6.2	3
3	1981	4.3	2
4	1978	3.9	1.5
5	1982	2.7	1.2

*Estimated.

	Discharge . c.m.s.
2 year flood.	4.5
Mean annual flood	5.0
5 year flood.	7.3
10 year flood.	9.4
20 year flood.	11.8



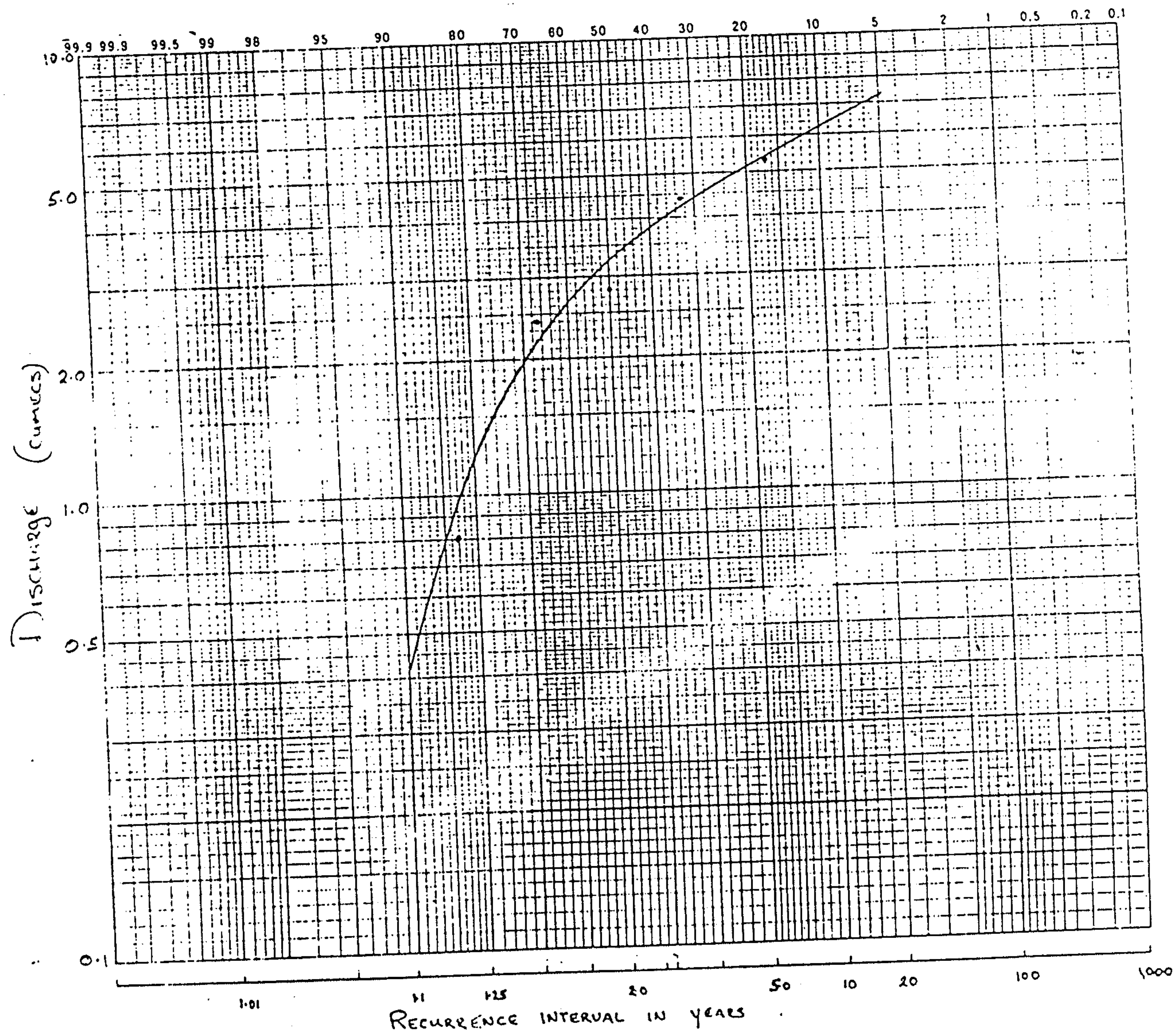
Marshall Creek

Maximum Instantaneous Discharge Data: Bear Creek

Rank.	Year.	Max. Inst. Disch. C.M.S.	Return Period. Years.
1	1979	5.3	6.0
2	1980	4.4	3.0
3	1981	2.8	2.0
4	1978	2.4	1.5
5	1982	0.8	1.2

*Estimated.

	Discharge. C.M.S.
2 year flood.	3.2
Mean annual flood.	3.6
5 year flood.	5.1
10 year flood.	6.2
20 year flood.	7.2



99.9 99.9 99.5 99 98 95 90 80 70 60 50 40 30 20 10 5 2 1 0.5 0.2 0.1
10.0
5.0
2.0
1.0
0.5
0.1
Discharge (cumecs)
1.01
1.1
1.25
2.0
5.0
10
20
100
1000
Recurrence interval in years

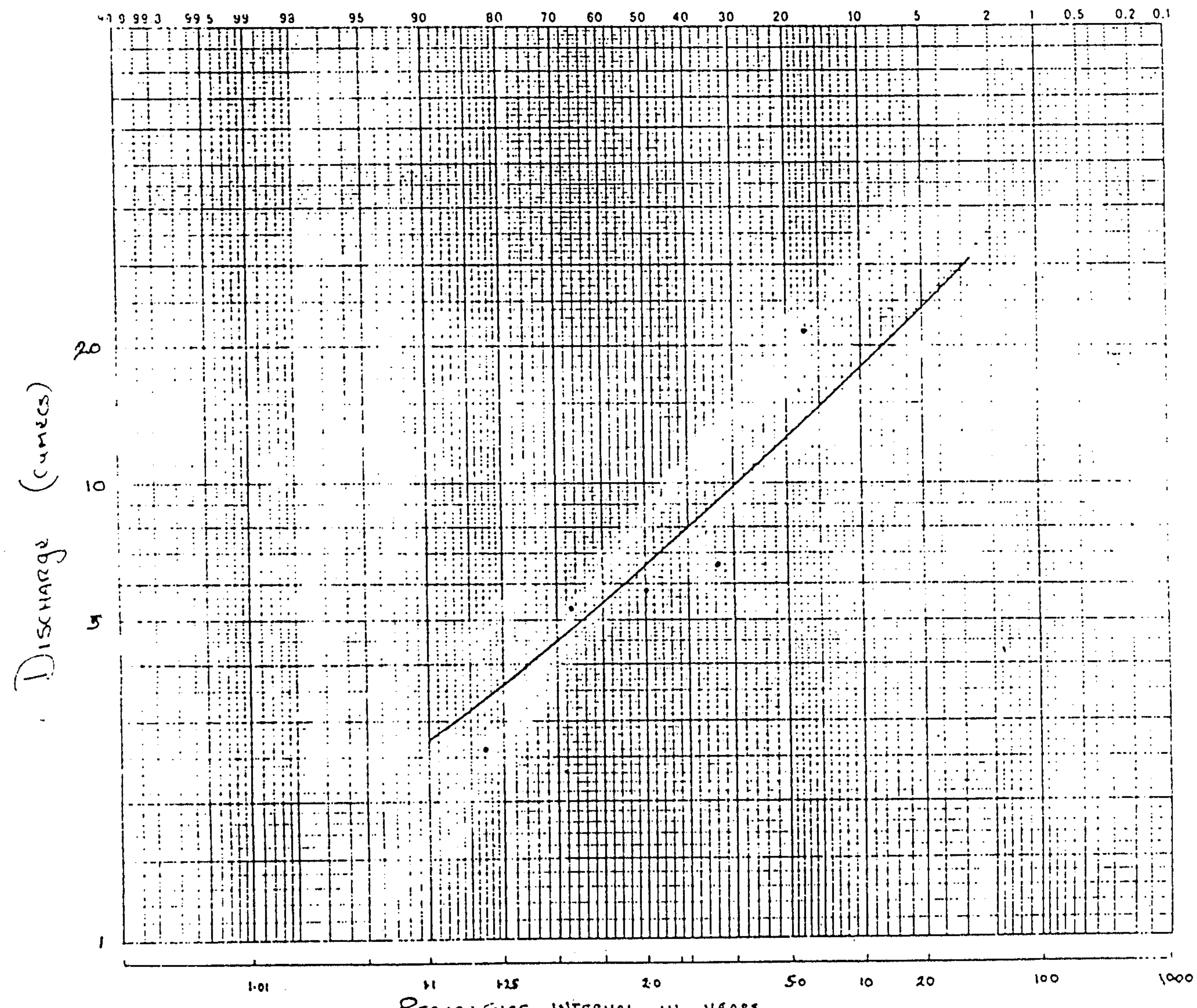
Bear Creek

Maximum Instantaneous Discharge Data : Burwash Creek

Rank.	Year.	Max. Inst. Disch. C.M.S.	Return Period. Years.
1	1978	21.5	6.0
2	1981	6.6	3.0
3	1979	5.8	2.0
4	1980	5.3	1.5
5	1982	2.6	1.2

*Estimated.

	Discharge. C.M.S.
2 year flood.	6.5
Mean annual flood	7.5
5 year flood.	12.5
10 year flood.	18.0
20 year flood.	24.5



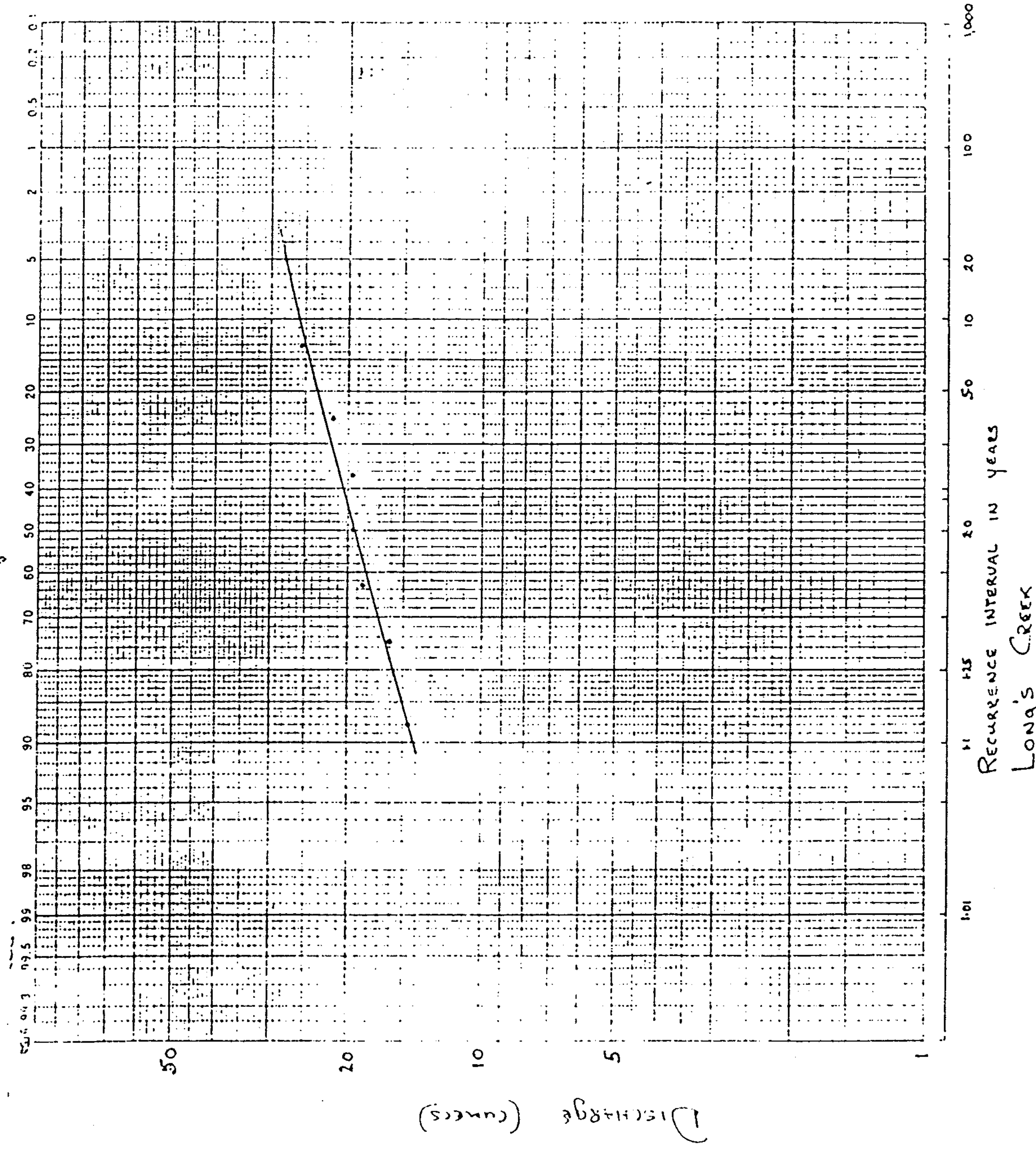
Burwash Creek

MAXIMUM INSTANTANEOUS DISCHARGE DATA : LONG'S CREEK.

RANK.	YEAR.	MAX. INST. DISCH. C.M.S.	RETURN PERIOD. YEARS.
1	1976	25.5	8.0
2	1982	21.7	4.0
3	1977	19.7	2.67
4	1978	19.7	2.0
5	1979	18.5	1.6
6	1981	16.0	1.33
7	1980	15.8	1.14

* ESTIMATED.

	DISCHARGE . C.M.S.
2 YEAR FLOOD.	19.5
MEAN ANNUAL FLOOD.	20.0
5 YEAR FLOOD.	23.5
10 YEAR FLOOD.	26.0
20 YEAR FLOOD.	28.0


Recurrence Interval in Years
Long's Creek
Discharge (cumecs)

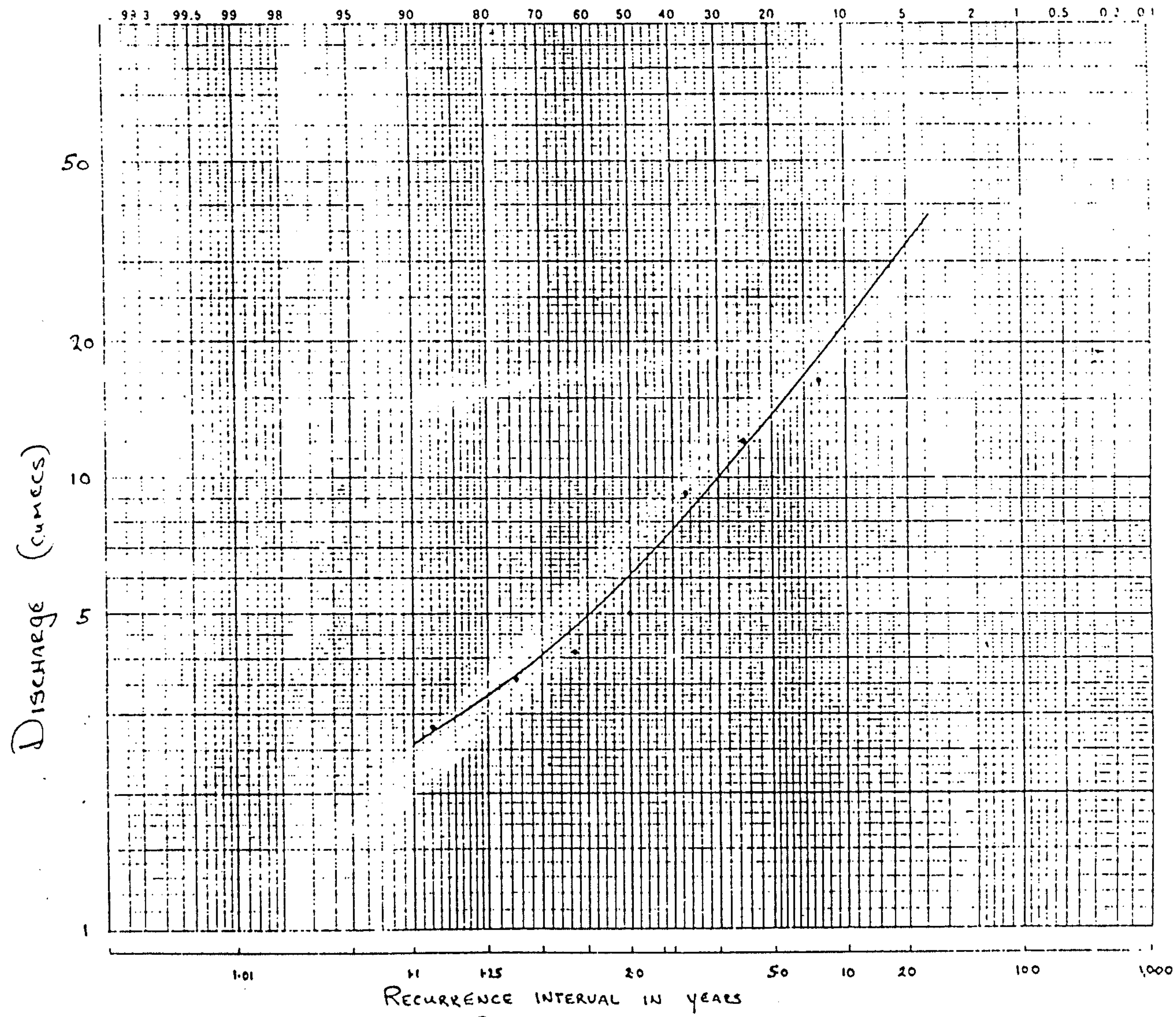
Maximum Instantaneous Discharge Data : Dry Creek

Rank.	Year.	Max. Inst. Disch. C.M.S.	Return Period. Years.
1	1977	16.4	8
2	1979	12.0	4
3	1978	9.2	2.67
4	1980	5.0	2.0
5	1981	4.1	1.6
6	1982	3.6	1.33
7	1976	2.8	1.14

*Estimated.

	Discharge . c.m.s.
2 year flood.	6.1
Mean annual flood	7.2
5 year flood.	14.0
10 year flood.	22.0
20 year flood.	33.0

30


99.5 99 98 95 90 80 70 60 50 40 30 20 10 5 2 1 0.5
50
20
10
5
1
Discharge (cumecs)
1.01 1.1 1.25 2.0 5.0 10 20 100 1,000
Recurrence interval in years

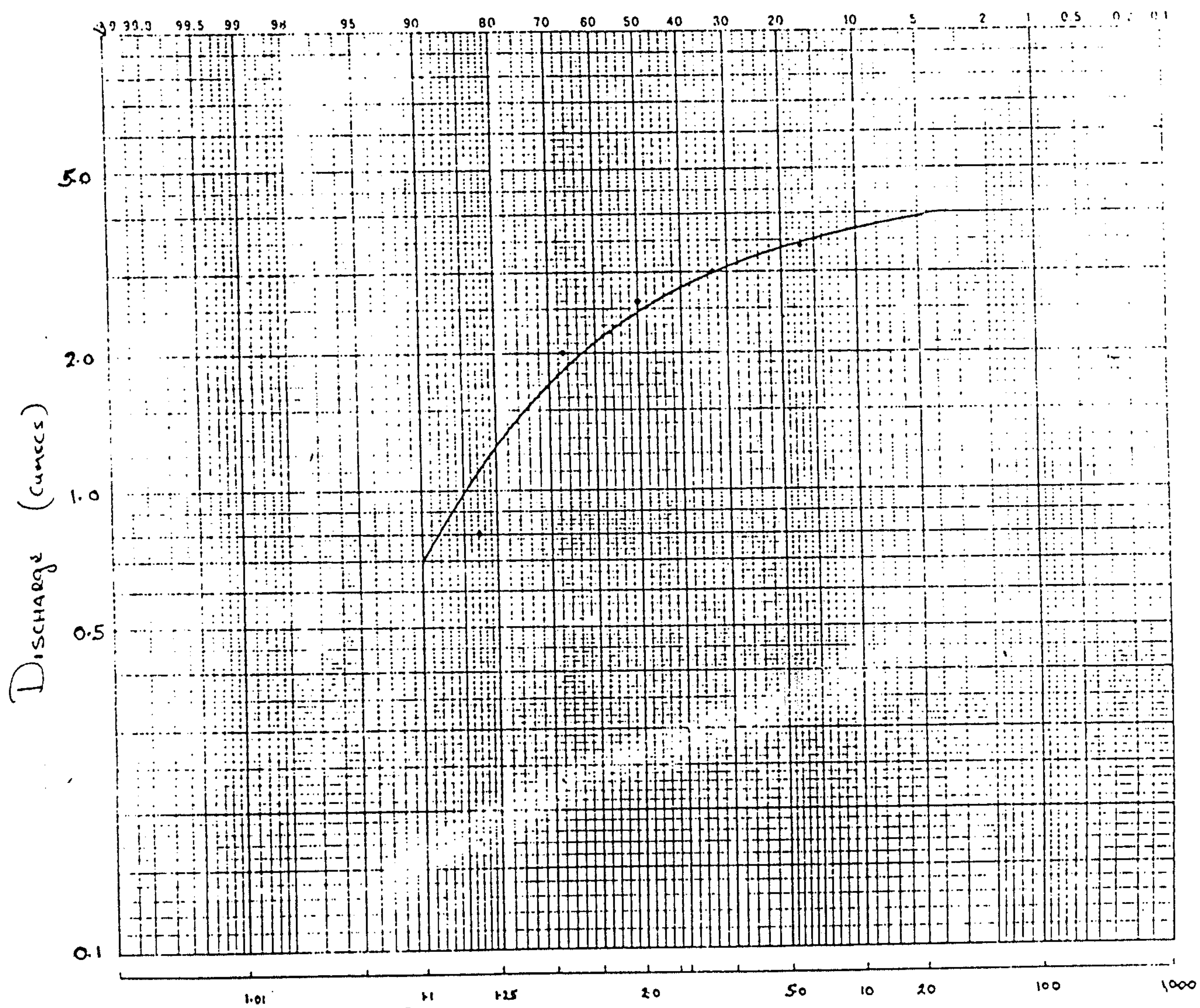
Dry Creek

Maximum Instantaneous Discharge Data: Engur Creek

Rank.	Year.	Max. Inst. Disch. C.M.S.	Return Period. years.
1	1979	3.4	6.0
2	1978	3.0	3.0
3	1981	2.6	2.0
4	1980	2.0	1.5
5	1982	0.4	1.2

* Estimated.

	Discharge . C.M.S.
2 year flood.	2.5
Mean annual flood	2.7
5 year flood.	3.4
10 year flood.	3.7
20 year flood.	3.9



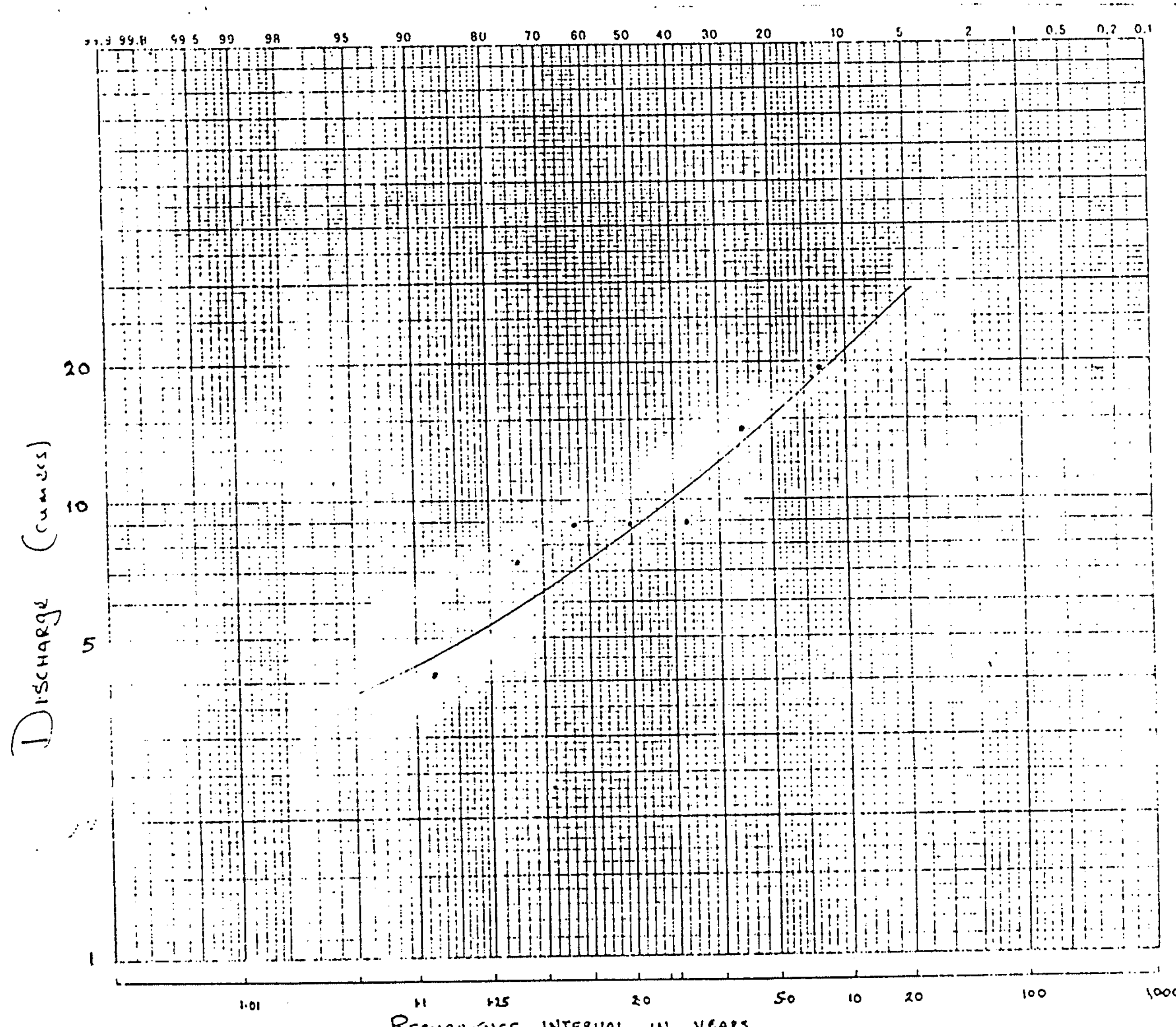
Recurrence interval in years
Enger Creek

Maximum Instantaneous Discharge Data: Standley Creek

Rank.	Year.	Max. Inst. Disch. c.m.s.	Return Period. years.
1	1977	19.2	8.0
2	1980	14.2 *	4.0
3	1981	8.9	2.67
4	1978	8.9	2.0
5	1979	8.8	1.6
6	1976	7.3	1.33
7	1982	4.1	1.14

* Estimated.

	Discharge. c.m.s.
2 year flood.	8.8
Mean annual flood	9.8
5 year flood.	15.7
10 year flood.	21.5
20 year flood.	28.0



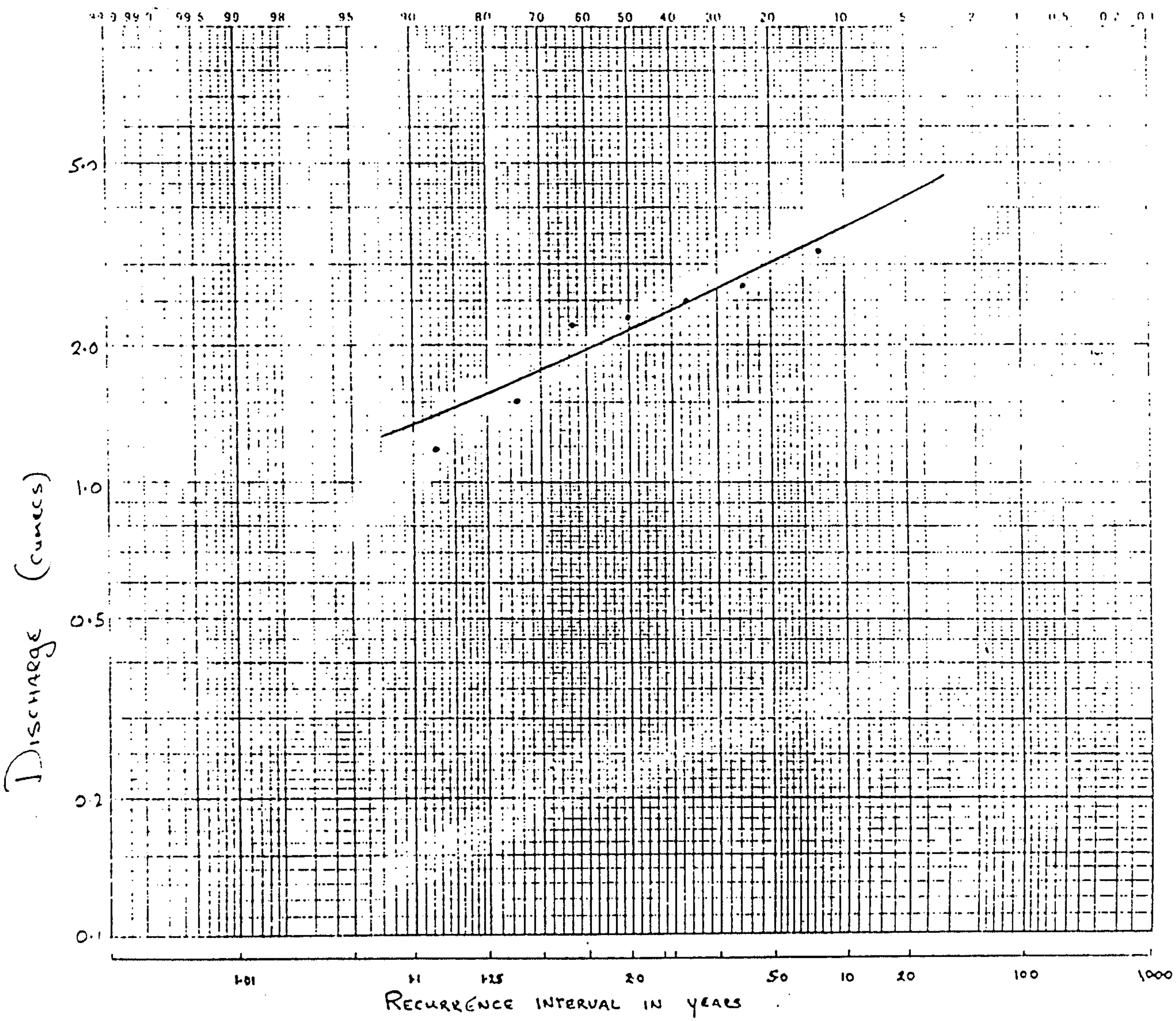
Stanley Creek.

Maximum Instantaneous Discharge Data: Mull Creek.

Rank.	Year.	Max. Inst. Disch. c.m.s.	Return Period. years.
1	1980	3.2	8.0
2	1978	2.7	4.0
3	1977	2.5	2.67
4	1981	2.3	2.0
5	1979	2.2	1.6
6	1976	1.5	1.33
7	1982	1.3	1.14

*Estimated.

	Discharge. c.m.s.
2 year flood.	2.2
Mean annual flood	2.3
5 year flood,	3.0
10 year flood.	3.6
20 year flood.	4.3


Discharge (cumecs)
5.0
2.0
1.0
0.5
0.2
0.1
1.01
1.1
1.25
2.0
5.0
10
20
100
1000
Recurrence interval in years

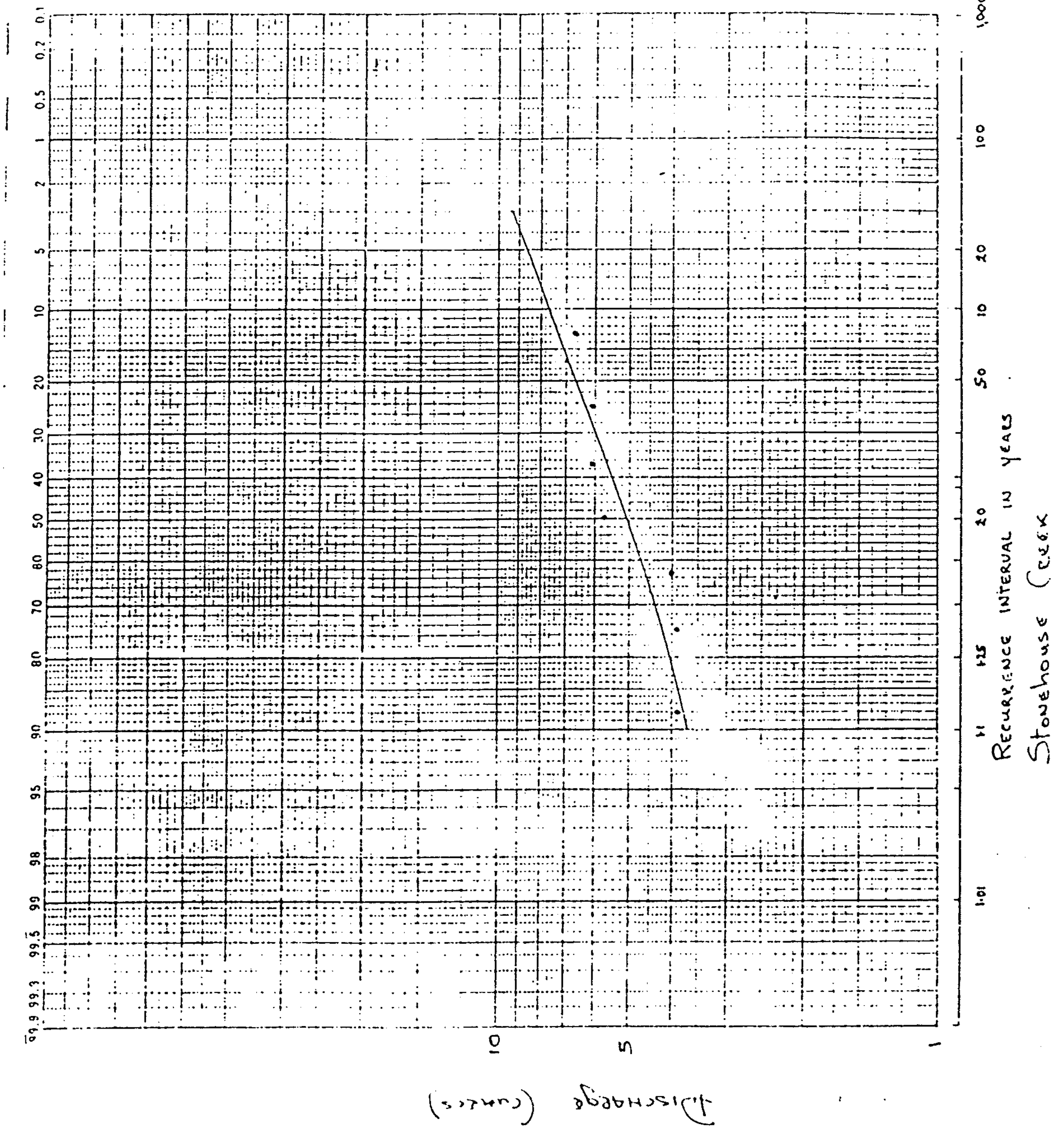
Mule Creek

Maximum Instantaneous Discharge Data: Stonehouse Creek.

Rank.	Year.	Max. Inst. Disch. c.m.s.	Return Period. years.
[illegible]	[illegible]		8.0
[illegible]	[illegible]		4.0
[illegible]	82	6.1	2.67
4	77	5.7	2.0
[illegible]	81	4.0	1.6
[illegible]	978	3.90	1.33
7	1979	3.90	1.14

*Estimated.

	Discharge. c.m.s.
2 year flood.	5.0
Mean annual flood	5.4
5 year flood.	6.6
10 year flood.	7.6
20 year flood.	8.6



Recurrence Interval in Years
Stonehouse Creek
Discharge (cumecs)

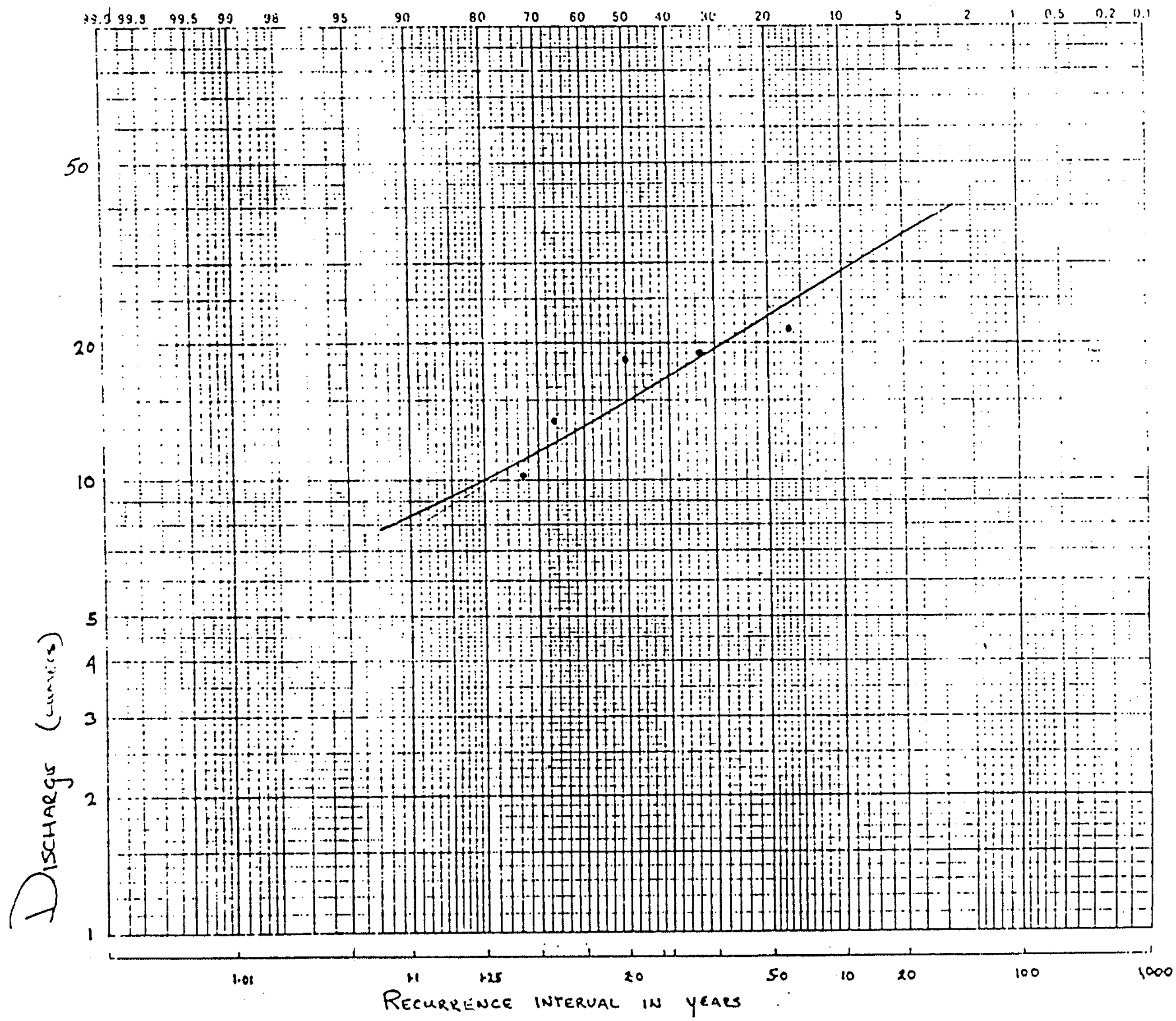
Fig.

Maximum Instantaneous Discharge Data: Murphy Creek

Rank.	Year.	Max. Inst. Disch. c.m.s.	Return Period. years.
1	1979	21.2	6.0
2	1980	19.9	3.0
3	1976	18.7 *	2.0
4	1978	13.3	1.5
5	1977	10.2	1.2

* Estimated.

	Discharge. c.m.s.
2 year flood.	15.0
Mean annual flood.	16.5
5 year flood.	23.0
10 year flood.	29.0
20 year flood.	35.0



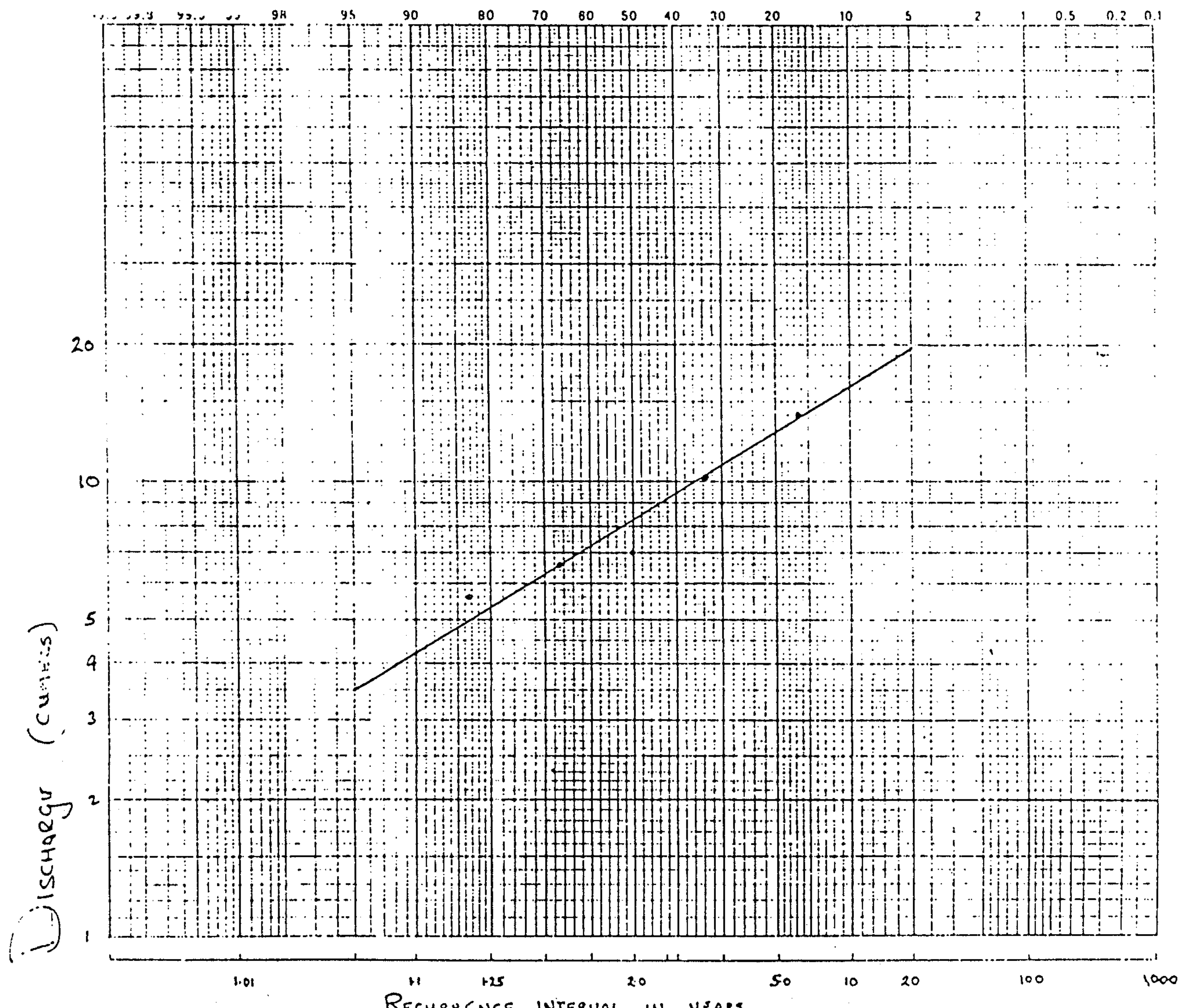
Murphy Creek

Maximum Instantaneous Discharge Data : Bacon Creek

Rank.	Year.	Max. Inst. Disch. c.m.s.	Return Period. years.
1	1978	14.0	6.0
2	1980	10.3	3.0
3	1976	7.0	2.0
4	1977	6.6	1.5
5	1979	5.6	1.2

* Estimated.

	Discharge. c.m.s.
2 year flood.	8.2
Mean annual flood	9.0
5 year flood.	12.8
10 year flood.	16.0
20 year flood.	19.5


98
95
90
80
70
60
50
40
30
20
10
5
2
1
0.5
0.2
0.1
20
10
5
4
3
2
1
Discharge (cumecs)
1.01
1.1
1.25
2.0
5.0
10
20
100
1000
Recurrence interval in years

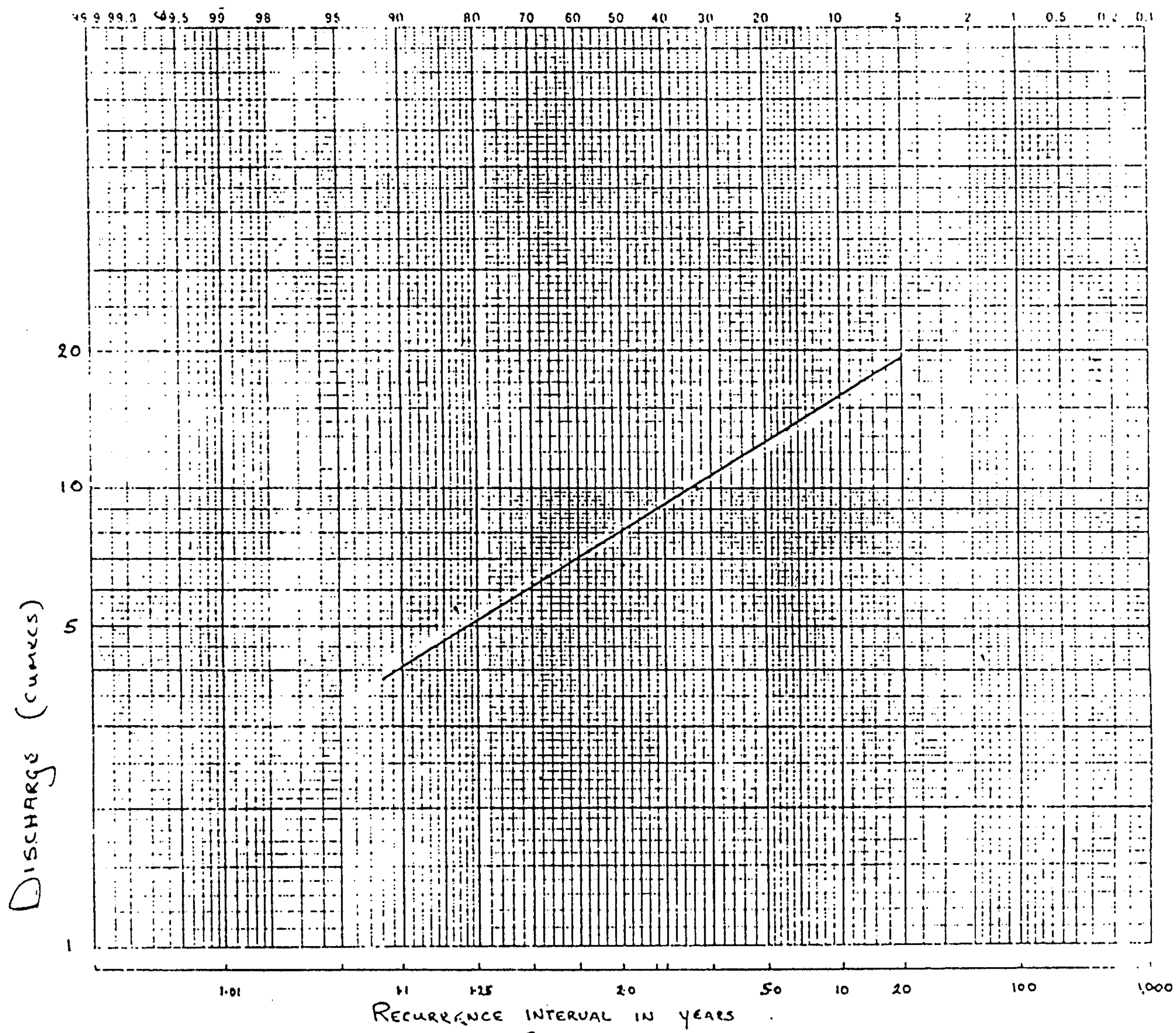
Bacon Creek

Maximum Instantaneous Discharge Data: Groundhog Creek

Rank.	Year.	Max. Inst. Disch. C.M.S.	Return Period. Years.
1	1978	13.4	6.0
2	1980	10.0	3.0
3	1976	6.8	2.0
4	1977	6.4	1.5
5	1979	5.5	1.2

* Estimated.

	Discharge. C.M.S.
2 year flood.	8.2
Mean annual flood	9.0
5 year flood.	12.7
10 year flood.	16.0
20 year flood.	19.5



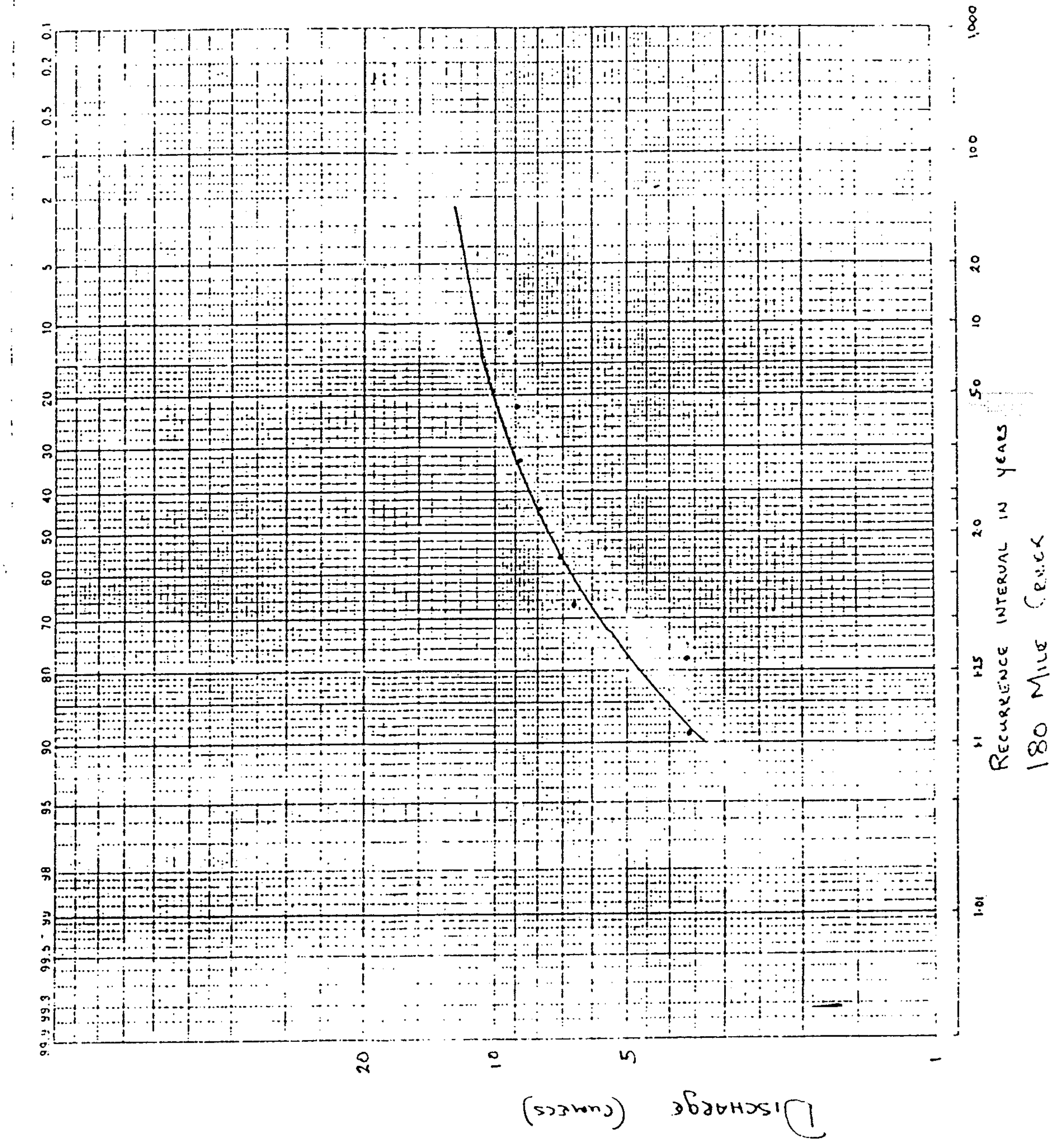
Groundhog Creek

Maximum Instantaneous Discharge Data: 180 Mile Creek

Rank.	Year.	Max. Inst. Disch. c.m.s.	Return Period. years.
1	1981	9.2	9.0
2	1979	8.9	4.5
3	1977	8.8	3.0
4	1982	7.9	2.25
5	1976	7.1	1.8
6	1980	6.6	1.5
7	1975	3.6	1.29
8	1978	3.6	1.13

*Estimated.

	Discharge. c.m.s.
2 year flood.	7.5
Mean annual flood	8.1
5 year flood.	10.0
10 year flood.	11.0
20 year flood.	11.8



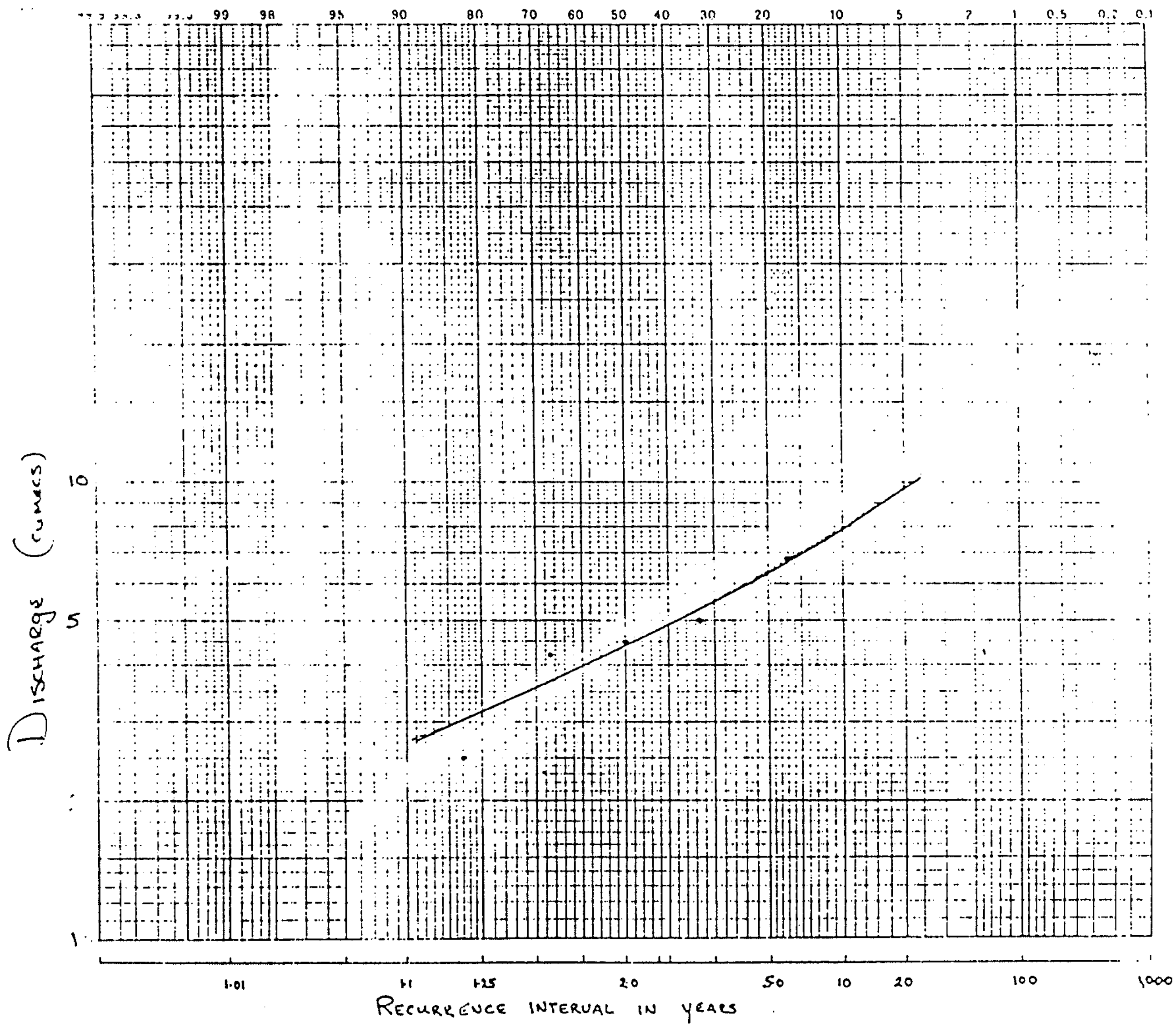
Recurrence Interval in Years
180 Mile Creek
Discharge (cumecs)
20
10
5
1

Maximum Instantaneous Discharge Data : Twin Creek

Rank.	Year.	Max. Inst. Disch. C.M.S.	Return Period. Years.
1	1978	6·8	6.0
2	1977	5.0	3.0
3	1982	4·5	2.0
4	1981	4.2	1·5
5	1980	2·5	1.2

*Estimated.

	Discharge. C.M.S.
2 year flood.	4.4
Mean annual flood.	4.8
5 year flood.	6.4
10 year flood.	8.0
20 year flood.	9.8


99
98
95
90
80
70
60
50
40
30
20
10
5
2
1
0.5
0.1
Discharge (cumecs)
10
5
1
1.01
1.1
1.25
2.0
5.0
10
20
100
1000
Recurrence interval in years

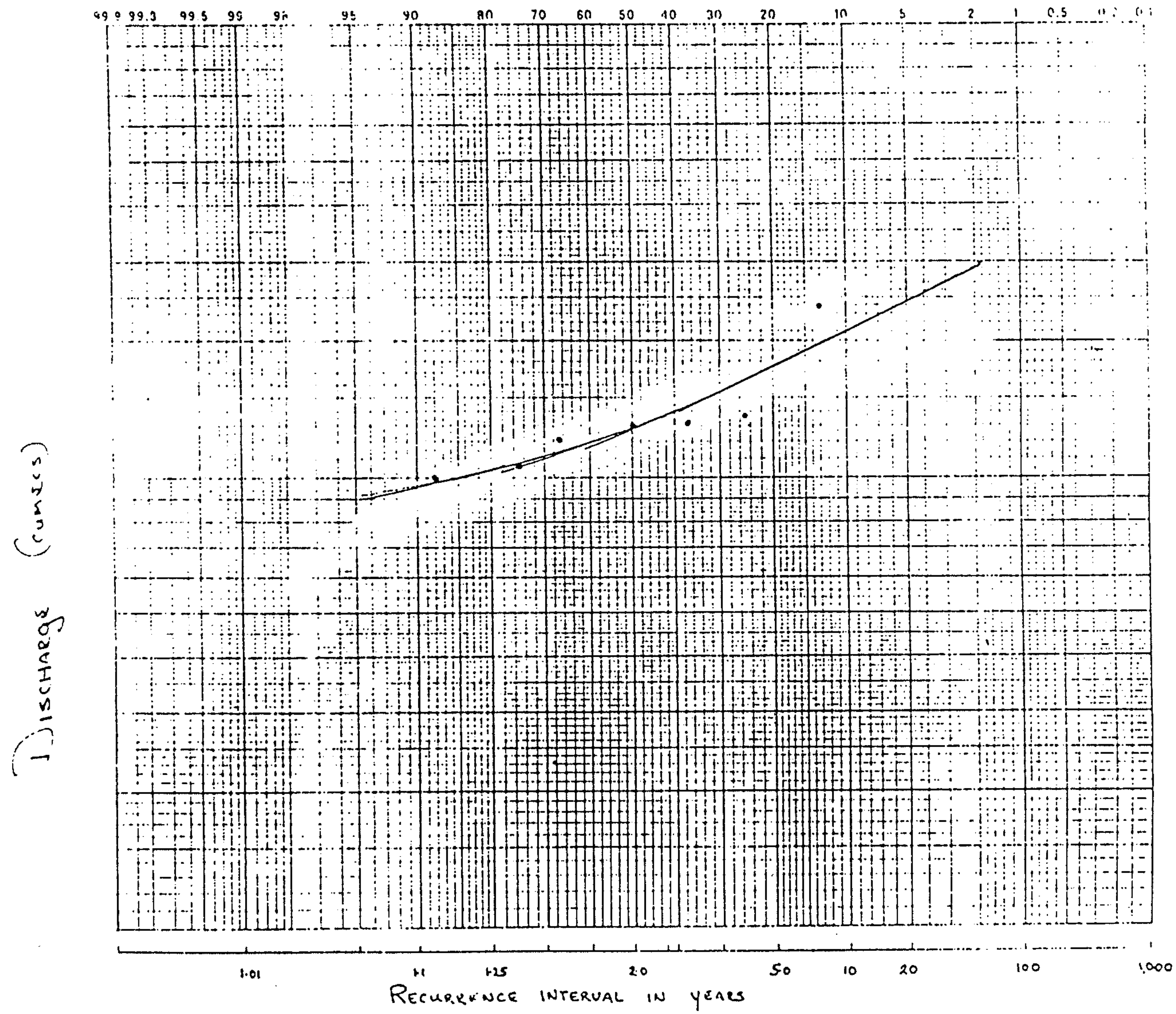
Twin Creek

MAXIMUM INSTANTANEOUS DISCHARGE DATA: RIDDELL CREEK

RANK.	YEAR.	MAX. INST. DISCH. C.M.S.	RETURN PERIOD. YEARS.
1	1977	23.8	8.0
2	1978	13.6	4.0
3	1982	13.1	2.67
4	1979	13.0	2.0
5	1980	12.2	1.6
6	1981	10.6	1.33
7	1976	10.0	1.14

*ESTIMATED.

	DISCHARGE . C.M.S.
2 YEAR FLOOD.	12.8
MEAN ANNUAL FLOOD	13.7
5 YEAR FLOOD.	17.5
10 YEAR FLOOD.	21.0
20 YEAR FLOOD.	24.5



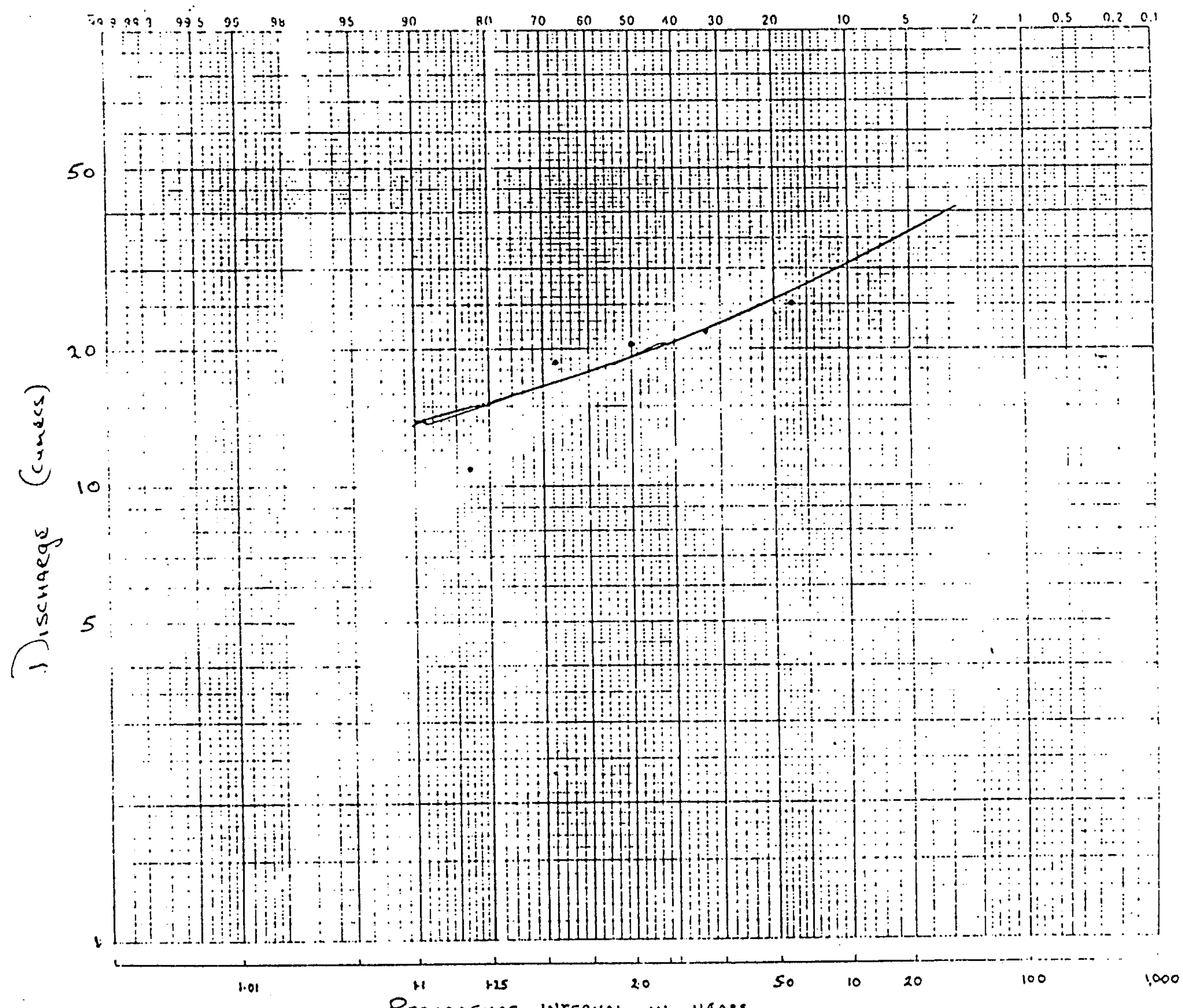
Riddel Creek

Maximum Instantaneous Discharge Data: Boulder Creek

Rank.	Year.	Max. Inst. Disch. c.m.s.	Return Period. years.
1	1980	25.1	6.0
2	1979	21.9	3.0
3	1982	20.5	2.0
4	1978	18.8	1.5
5	1981	10.9	1.2

*Estimated.

	Discharge. c.m.s.
2 year flood.	19.0
Mean annual flood.	20.2
5 year flood.	26.0
10 year flood.	31.0
20 year flood.	36.0



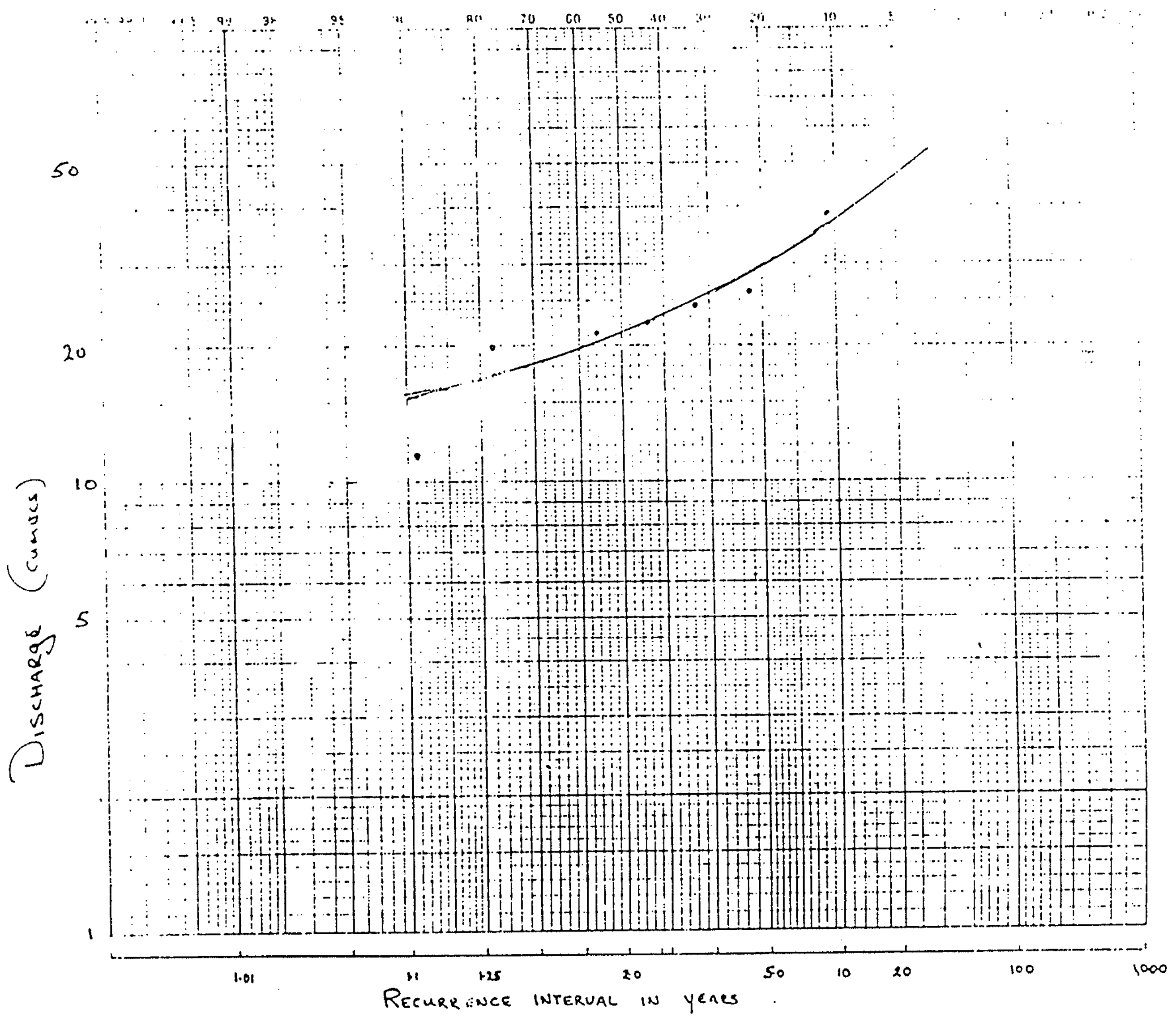
Boulder Creek

Maximum Instantaneous Discharge Data : South McMillan River *:

Rank.	Year.	Max. Inst. Disch. C.M.S.	Return Period. Years.
1	1975	38.5	9.0
2	1978	26.1	4.5
3	1982	24.5	3.0
4	1977	22.1	2.25
5	1979	21.2	1.8
6	1981	20.1	1.5
7	1976	19.9	1.29
8	1980	11.4	1.13

*Estimated.

	Discharge. C.M.S.
2 year flood.	21.0
Mean annual flood	22.6
5 year flood.	30.0
10 year flood.	37.5
20 year flood.	47.0



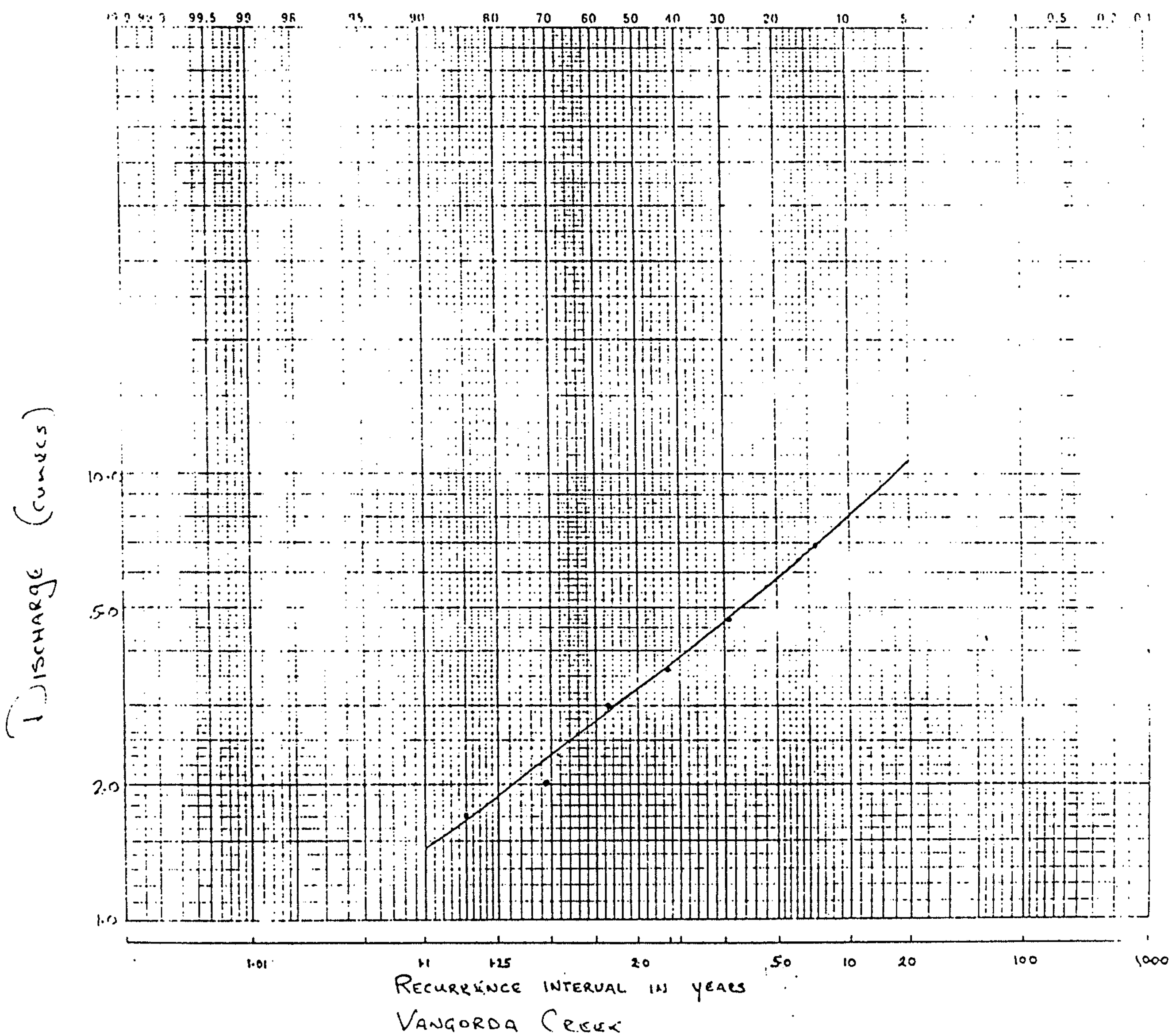
South Macmillan River No. 2

MAXIMUM INSTANTANEOUS DISCHARGE DATA: VANGORDA CREEK

RANK.	YEAR.	MAX. INST. DISCH. C.M.S.	RETURN PERIOD. YEARS.
1	1982	6.90	7
2	1980	4.7	3.5
3	1977	3.6	2.33
4	1979	3.0	1.75
5	1978	2.0	1.4
6	1981	1.7	1.17

* ESTIMATED.

	DISCHARGE. C.M.S.
2 YEAR FLOOD.	3.2
MEAN ANNUAL FLOOD	3.7
5 YEAR FLOOD.	5.8
10 YEAR FLOOD.	8.0
20 YEAR FLOOD.	10.7

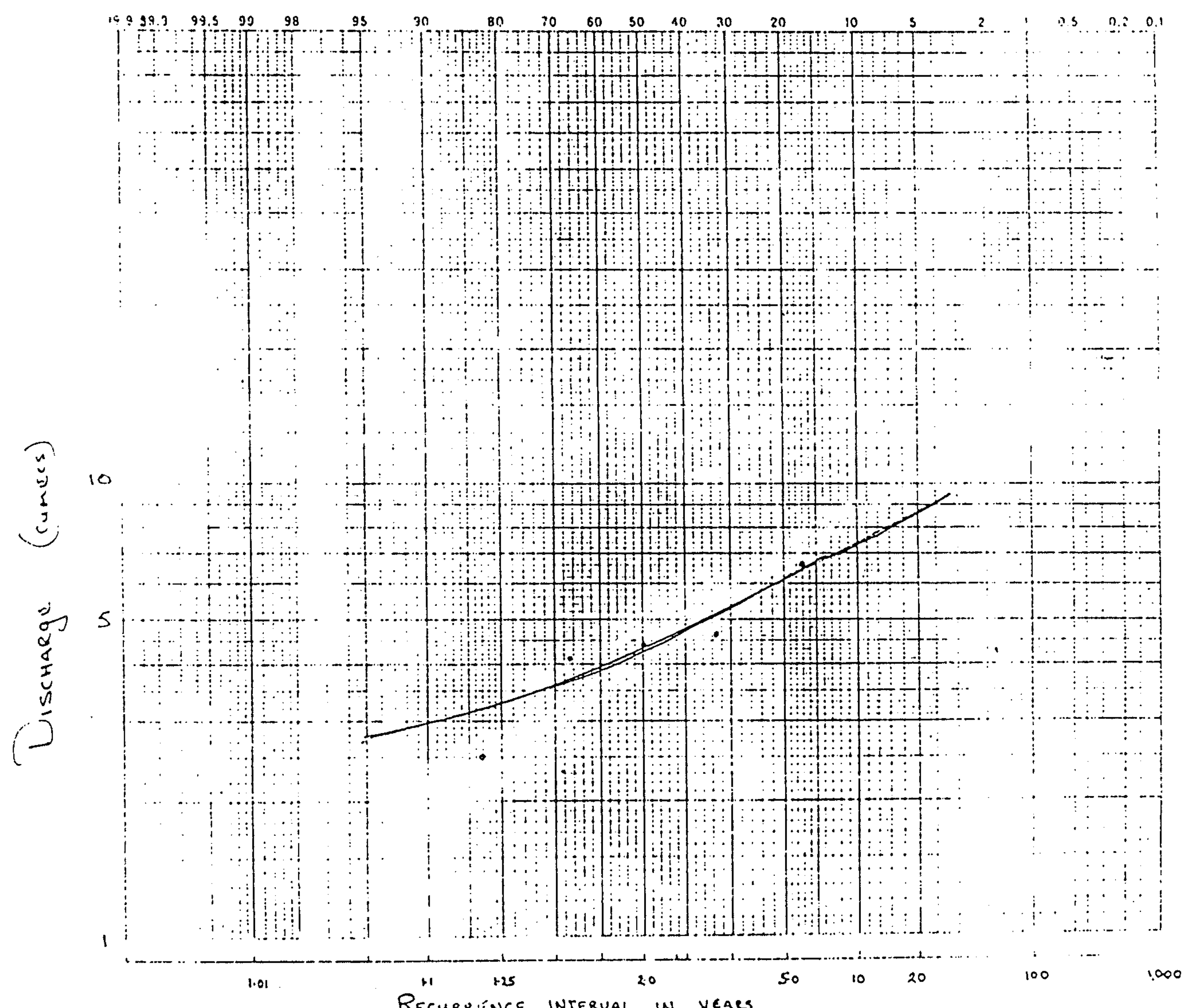

99.5
99
98
95
90
80
70
60
50
40
30
20
10
5
1
0.5
10.0
5.0
2.0
1.0
Discharge (cumecs)
1.01
1.1
1.25
2.0
5.0
10
20
100
1000
Recurrence interval in years
Vangorda Creek

Maximum Instantaneous Discharge Data: Big Gold Creek

Rank.	Year.	Max. Inst. Disch. C.M.S.	Return Period. Years.
1	1981	6.6	6.0
2	1979	4.6	3.0
3	1978	4.4 * (14.? [illegible])	2.0
4	1980	4.1 *	1.5
5	1982	2.5 *	1.2

* Estimated.

	Discharge. C.M.S.
2 year flood.	4.3
Mean annual flood.	4.6
5 year flood.	6.1
10 year flood.	7.4
20 year flood.	8.7



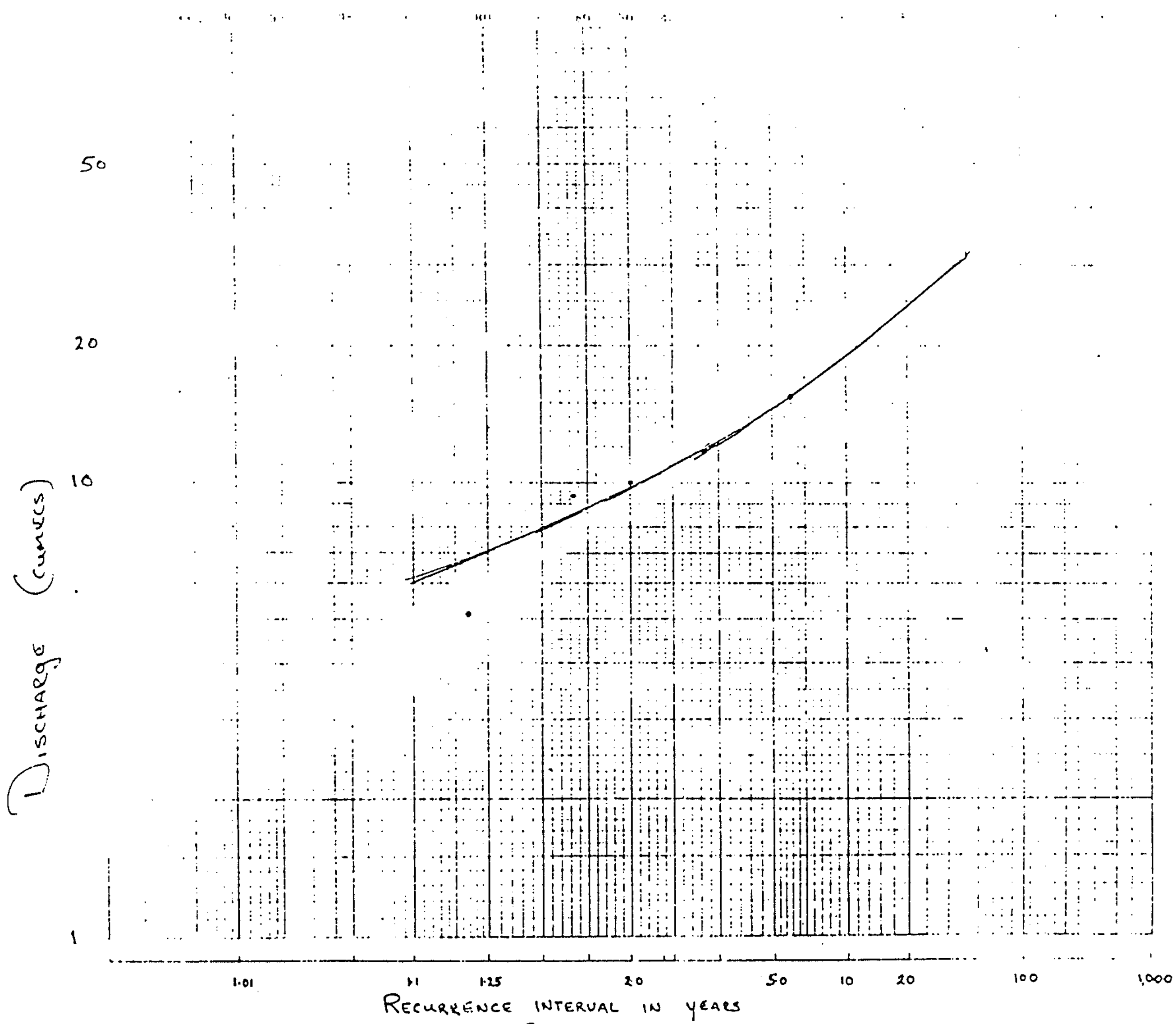
Ria Gold Creek

Maximum Instantaneous Discharge Data : Clinton Creek

Rank.	Year.	Max. Inst. Disch. C.M.S.	Return Period. Years.
1	1979	15.2	6.0
2	1981	11.8	3.0
3	1982	10.0	2.0
4	1978	9.4	1.5
5	1980	5.1	1.2

* Estimated.

	Discharge . C.M.S.
2 year flood.	9.8
Mean annual flood	10.5
5 year flood.	14.5
10 year flood	19.0
20 year flood.	24.5



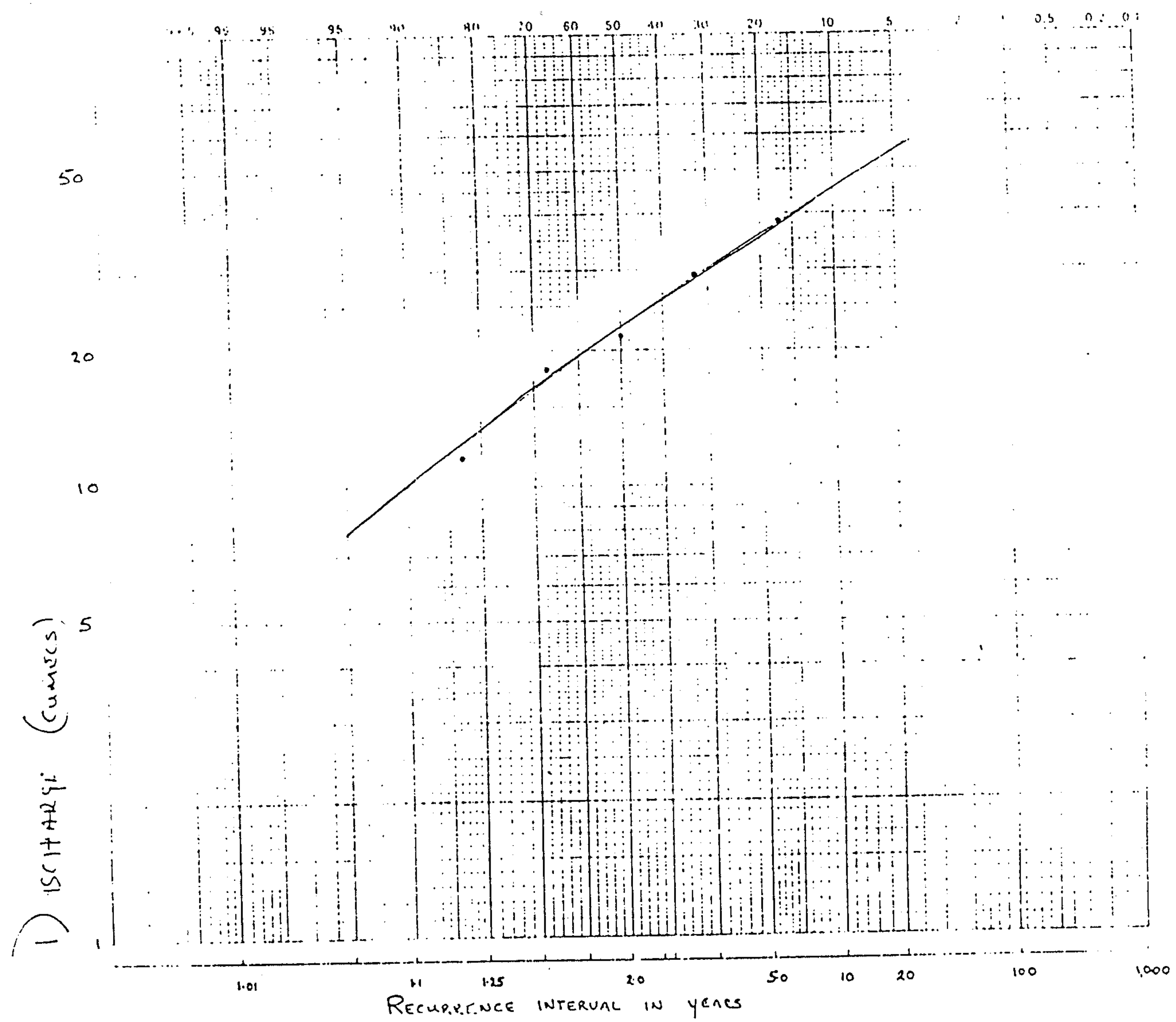
Clinton Creek

Maximum Instantaneous Discharge Data: Thistle Creek

Rank.	Year.	Max. Inst. Disch. C.M.S.	Return Period. Years.
1	1979	38.2	6.0
2	1980	28.9	3.0
3	1978	29.8	2.0
4	1981	18.2	1.5
5	1982	11.5	1.2

*Estimated.

	Discharge. C.M.S.
2 year flood.	22.5
Mean annual flood.	25.0
5 year flood.	36.0
10 year flood.	45.0
20 year flood.	55.0



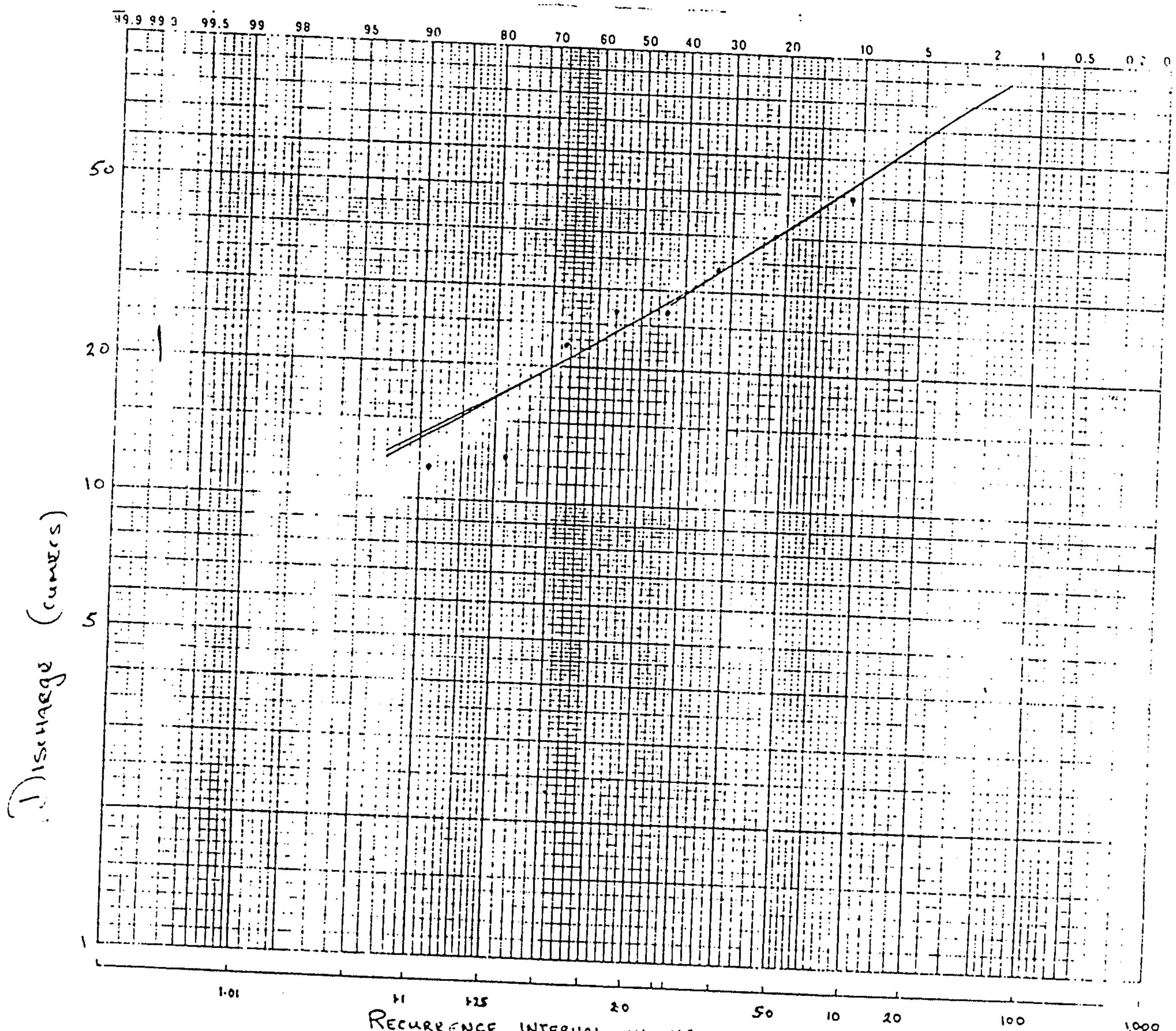
Thistle Creek

Maximum Instantaneous Discharge Data: Benson Creek

Rank.	Year.	Max. Inst. Disch. c.m.s.	Return Period. years.
1	1981	49.1	9.0
2	1979	40.6	4.5
3	1976	33.6	3.0
4	1977	26.6	2.25
5	1978	26.6	1.8
6	1975	22.3	1.5
7	1980	12.4	1.29
8	1982	11.8	1.13

*Estimated.

	Discharge. c.m.s.
2 year flood.	26.0
Mean annual flood.	28.5
5 year flood.	41.0
10 year flood.	54.0
20 year flood.	67.0



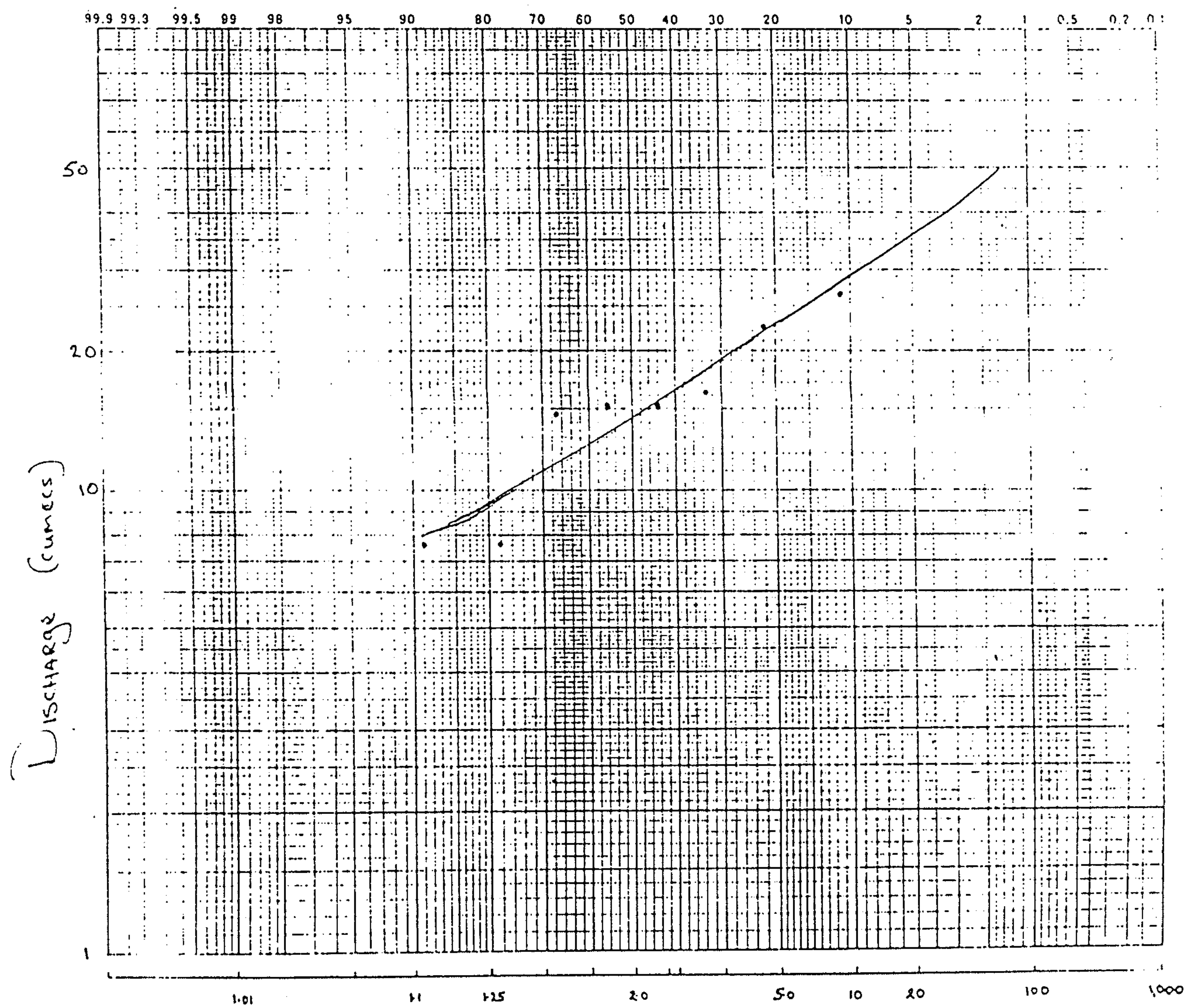
Benson Creek

Maximum Instantaneous Discharge Data : Wolf Creek

Rank.	Year.	Max. Inst. Disch. C.M.S.	Return Period. Years.
1	1981	26.8	9.0
2	1979	22.4	4.5
3	1975	16.1	3.0
4	1977	15.1	2.25
5	1978	15.1	1.8
6	1976	14.6	1.5
7	1980	7.6	1.29
8	1982	7.3	1.13

*Estimated.

	Discharge. C.M.S.
2 year flood.	14.0
Mean annual flood	15.5
5 year flood.	23.5
10 year flood.	29.0
20 year flood.	36.0



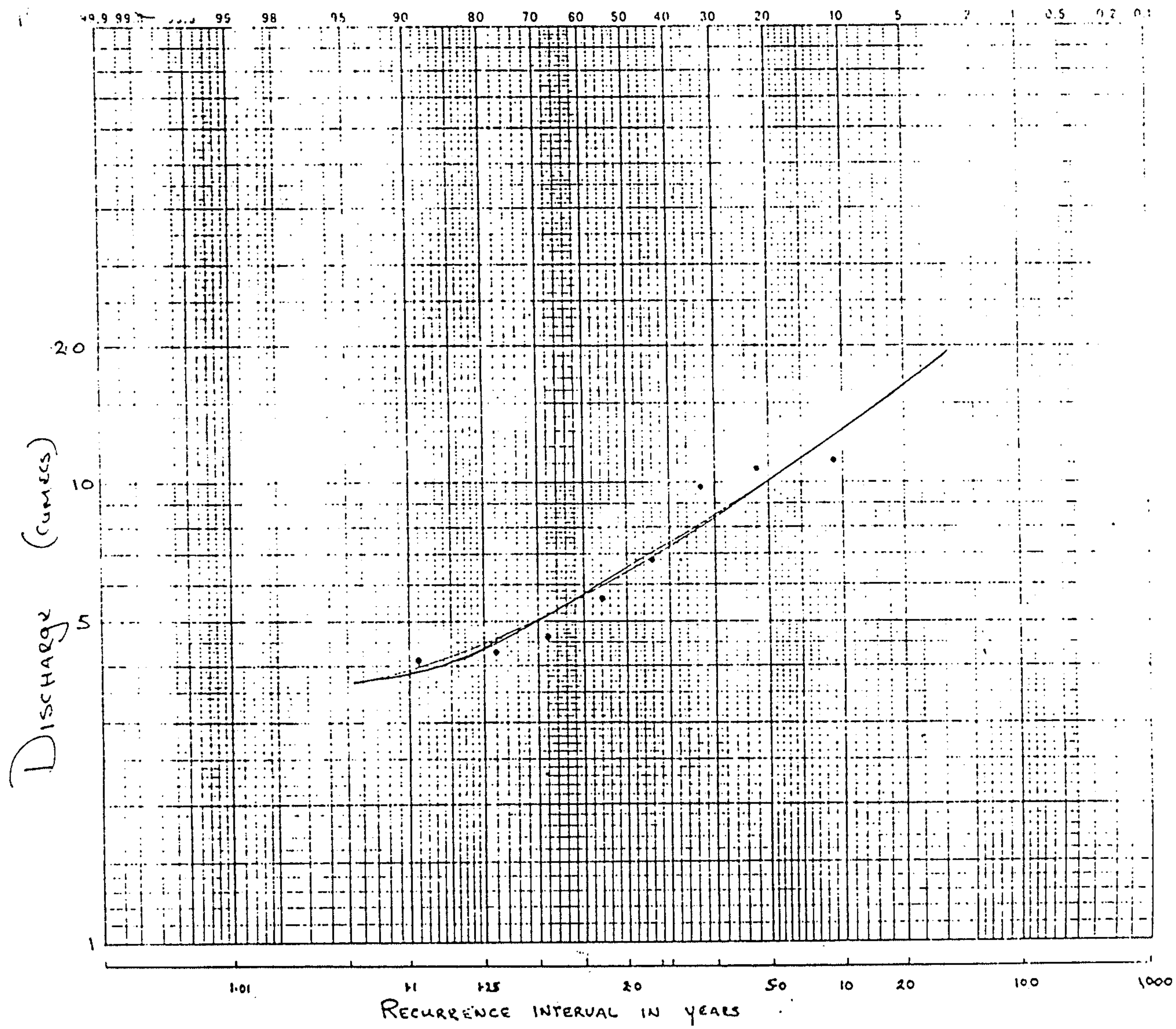
Recurrence Interval in Years
Wolf Creek

Maximum Instantaneous Discharge Data: Grizzly Creek

Rank.	Year.	Max. Inst. Disch. C.M.S.	Return Period. years.
1	1980	11.1	9
2	1981	10.7	4.5
3	1982	9.8	3.0
4	1975	6.8	2.25
5	1976	5.6	1.8
6	1978	4.6	1.5
7	1979	4.3	1.29
8	1977	4.1	1.11

* Estimated.

	Discharge. c.m.s.
2 year flood.	6.4
Mean annual flood	7.0
5 year flood.	10.0
10 year flood.	13.0
20 year flood.	16.4



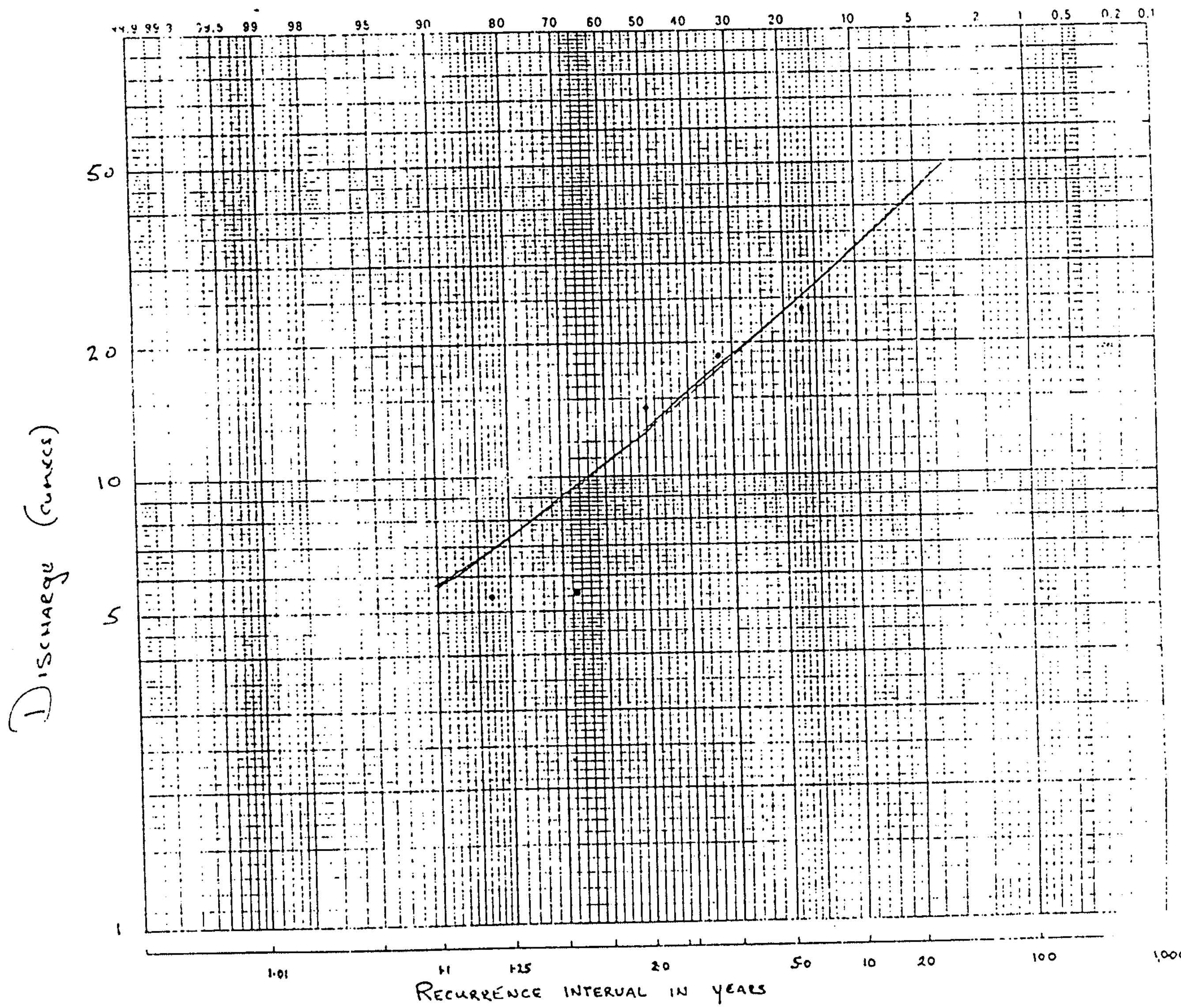
Grizzly Creek

Maximum Instantaneous Discharge Data: Unnamed Creek

Rank	Year	Max. Inst. Disch. C.M.S.	Return Period. Years.
1	1981	23.8	6.0
2	1979	18.7	3.0
3	1982	14.2	2.0
4	1982	5.5	1.5
5	1978	5.4	1.2

*Estimated.

	Discharge. C.M.S.
2 year flood.	12.6
Mean annual flood	14.5
5 year flood.	23.5
10 year flood.	32.5
20 year flood.	43.0



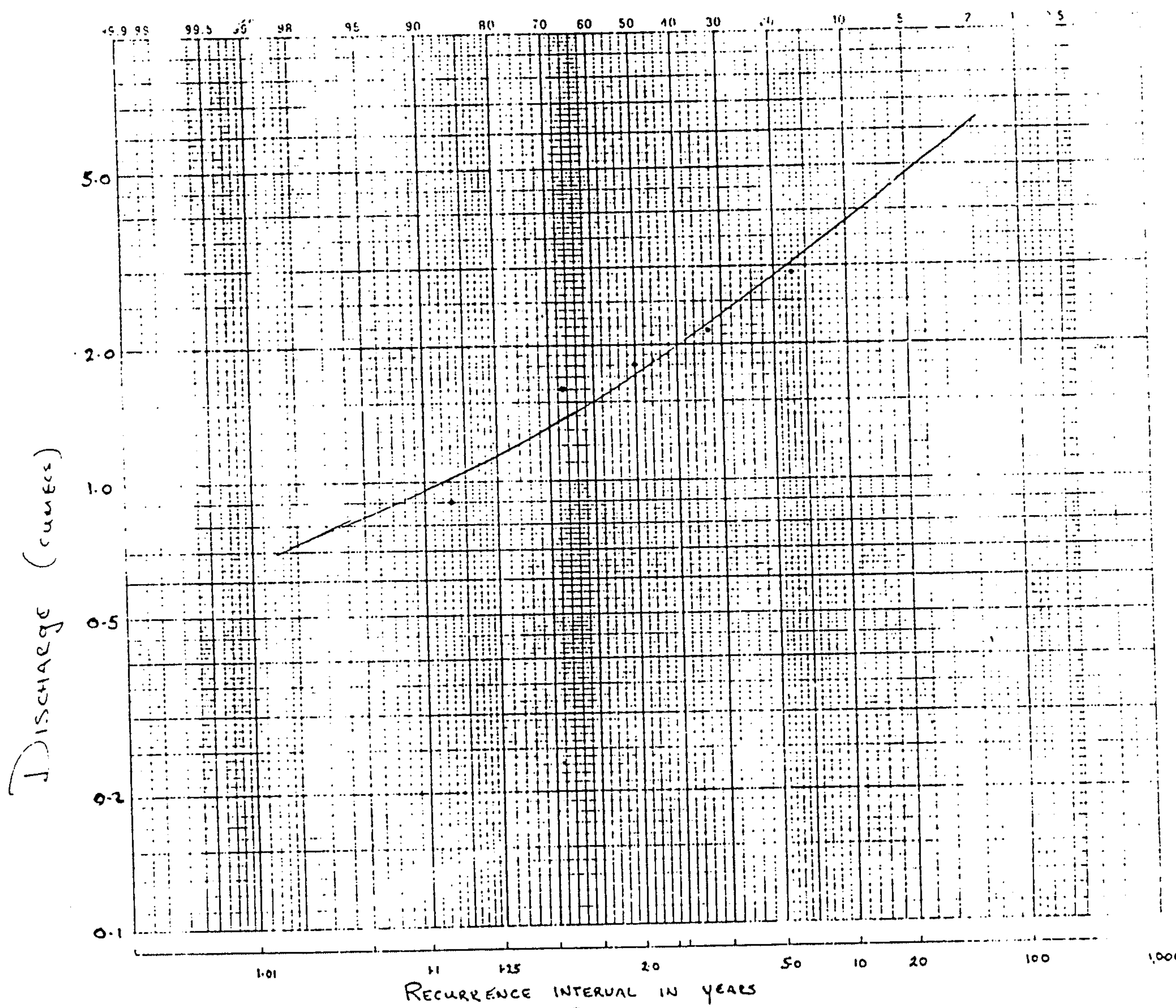
Unnamed Creek

Maximum Instantaneous Discharge Data: Big Thing Creek

Rank.	Year.	Max. Inst. Disch. C.M.S.	Return Period. Years.
1	1979	2.9	6.0
2	1980	2.3	3.0
3	1978	1.8	2.0
4	1981	1.6	1.5
5	1982	0.9	1.2

* Estimated.

	Discharge. c.m.s.
2 year flood.	1.8
Mean annual flood	1.9
5 year flood.	2.85
10 year flood.	3.8
20 year flood.	4.8



Big Thing Creek