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Hydrology and Water Use for Salmon Streams in the Thompson River Watershed, British Columbia

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1995

Canadian Manuscript Report of Fisheries and Aquatic Sciences No. 2297

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HYDROLOGY AND WATER USE FOR SALMON STREAMS IN THE THOMPSON RIVER WATERSHED, BRITISH COLUMBIA

by

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Cat. No. Fs 97-4/2297E ISSN 0706-6473

Correct citation for this publication:

Rood, K.M., and R.E. Hamilton. 1995. Hydrology and water use for salmon streams in the Thompson River Watershed, British Columbia. Can. Manuscr. Rep. Fish. Aquat. Sci. 2297: 164 pp.

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ABSTRACT

The Fraser River Action Plan (FRAP) is developing plans for environmentally sustainable salmon production in streams of the Fraser River watershed. This report focuses on the Thompson River watershed, which includes three Habitat Management Areas (HMA): the South Thompson-Shuswap, the North Thompson, and the Thompson-Nicola HMAs. The Thompson River is a major tributary of the Fraser River. The watershed drains plateau, highland, and mountain regions to the east of the Fraser River. Hydrology and water use in eighty salmon streams and reaches of the Thompson River are discussed.

The hydrologic regimes and the effects of human development on the regimes are emphasized. Ten indices use hydrologic, water use, and land use data to rank habitat sensitivity of the streams. Some indices express the level of human activity. Some express the state of the stream and its ability to resist change. The most useful indices reflect summer water use, compare low and peak flows to mean flow, and indicate the extent of forest harvesting in the watersheds. The most sensitive streams are those that are most affected by human activity and those naturally sensitive to human impact.

Forest harvesting and agricultural activities have the greatest potential impact on stream flows. There are some water withdrawals for urban and industrial use, but amounts are small compared to irrigation use and stream flows. In the North Thompson HMA, the most important issues affecting stream flows are developing water storage, managing forest harvest rates, and controlling sediment and erosion. Several northern watersheds have had 20 to 40% of the area logged. In the south, summer flows are low on many small streams. In southern watersheds, licenced water demands can reduce summer stream flows.

Streams in the Thompson-Nicola HMA have large basins and considerable water storage available, so large water demands do not affect summer flows. Some streams have low flow problems in the summer. Several watersheds have had 20 to 40% of the area logged.

South Thompson-Shuswap streams usually have smaller drainage basins, limited storage, and large potential water demands. On many small and medium-sized streams, potential water demand accounts for more than 50% of summer low flows. In addition, some small streams have low summer flows. Several watersheds have more than 20% of their area logged, and some large, older clear-cut areas cause stream flow problems. Development of water storage, riparian zone management and erosion control are important issues in the HMA.

The report recommends improving stream flow measurement, monitoring and controlling water use, and developing water management plans for the most sensitive streams. Stream flow requirements of fish should be better studied. The report also recommends distributing proposed forest harvesting over the various tributary basins, to maintain flow regimes. These measures will allow more accurate prediction of the impacts of harvesting on hydrology.

RÉSUMÉ

Le Plan d'action pour le Fraser (FRAP) vise la production de saumon, dans une perspective de développement durable, dans les cours d'eau du bassin hydrographique du Fraser. Le présent rapport porte sur le bassin de la Thompson, qui couvre trois zones de gestion de l'habitat (ZGH): la ZGH Thompson sud-Shuswap, la ZGH Thompson nord et la ZGH Thompson-Nicola. La rivière Thompson est un des principaux affluents du Fraser. Son bassin draine les régions de plateaux, de hautes terres et de montagnes situées à l'est du fleuve. Ce rapport examine l'hydrologie et l'utilisation de l'eau sur quatre-vingts rivières à saumon et sur le cours de la Thompson elle-même.

Les travaux mettent l'accent sur les régimes hydrologiques et les effets de l'activité humaine sur ces régimes. Dix indices font appel aux données sur l'hydrologie, l'utilisation de l'eau et l'utilisation des terres pour classer les cours d'eau selon la vulnérabilité de leurs habitats. Certains indices expriment le niveau de l'activité humaine; d'autres indiquent l'état du cours d'eau et son aptitude à résister au changement. Les indices les plus utiles reflètent l'utilisation de l'eau en été, comparent les débits minimaux et maximaux au débit moyen, et indiquent l'ampleur de l'exploitation forestière dans les bassins versants. Les cours d'eau les plus vulnérables sont ceux qui sont les plus affectés par l'activité humaine et ceux qui sont naturellement sensibles à l'impact de cette activité.

Ce sont l'exploitation forestière et les activités agricoles qui ont le plus fort impact potentiel sur les débits. Quelques ponctions sont faites à des fins d'utilisation urbaine ou industrielle, mais elles sont faibles par rapport aux volumes prélevés pour l'irrigation et aux débits des cours d'eau. Dans la ZGH Thompson nord, les plus importantes questions touchant les débits sont le développement du stockage de l'eau, la gestion des taux d'exploitation des forêts et la lutte contre la sédimentation et l'érosion. Dans certains bassins du nord, 20 à 40 % de la superficie est exploitée par la foresterie. Dans le sud, les débits sont faibles en été sur de nombreux petits cours d'eau. Dans les bassins du sud, les permis d'utilisation de l'eau peuvent réduire les débits en été.

Les cours d'eau de la ZGH Thompson-Nicola possèdent de vastes bassins et une capacité considérable de stockage de l'eau, de sorte que les fortes demandes d'eau n'affectent pas les débits estivaux. Certains cours d'eau ont des problèmes à l'étiage en été. Dans plusieurs bassins, 20 à 40 % de la superficie est exploitée par la foresterie.

Dans la ZGH Thompson sud-Shuswap, les cours d'eau ont généralement des bassins plus petits, une capacité limitée de stockage et une forte demande potentielle. Sur de nombreux cours d'eau de taille petite ou moyenne, la demande potentielle d'eau représente plus de 50 % des débits à l'étiage estival. De plus, certaines petites rivières ont des débits faibles en été. Dans plusieurs bassins, plus de 20 % de la superficie est en coupe, et la présence de certaines vastes zones de coupes à blanc anciennes cause des problèmes de débit. Le développement du stockage de l'eau, la gestion des zones riveraines et la lutte contre l'érosion constituent des questions importantes dans la ZGH.

Le rapport recommande d'améliorer les mesures du débit, de surveiller et de régir l'utilisation de l'eau, et d'élaborer des plans de gestion de l'eau pour les cours d'eau les plus vulnérables. Il est nécessaire de mieux étudier les besoins du poisson en matière de débit. Le rapport recommande aussi de répartir les projets d'exploitation forestière sur les divers bassins tributaires et de maintenir les débits. Ces mesures permettront de prédire plus précisément les impacts de l'exploitation forestière sur l'hydrologie.

FOREWORD

This report was commissioned by the Fraser River Action Plan (FRAP). It contains hydrology and land use information that will be useful in reviewing salmon habitat quality and assessing habitat sensitivity.

The Hell's Gate landslide in 1913 decimated sockeye and pink stocks from the upper Fraser River. Habitat degradation and marine exploitation rates have affected some salmon stocks as well. Measures to rebuild salmon stocks began several decades ago, and the stocks have been rebuilding slowly. Stock rebuilding became a higher priority after the signing of the 1985 Canada-U.S.A. Pacific Salmon Treaty. Canada's Green Plan recognizes the importance of good habitat quality in rebuilding stocks. The Department of Fisheries and Oceans incorporated habitat considerations in the Fraser River Green Plan initiative in 1990. This program is now called the Fraser River Action Plan. One of its goals is developing and maintaining sustainable fisheries resources in the Fraser River Basin.

Under FRAP, the Department of Fisheries and Oceans is developing an integrated fisheries resource management plan for the entire Fraser River Basin. The plan provides direction to governments and stakeholders for conserving and restoring habitat and rebuilding salmon stocks. The basin was divided into fifteen Habitat Management Areas (HMAs), based on major river systems and salmon stocks. Within each HMA, the status of salmon habitat, stocks, and habitat restoration and protection priorities will be defined. This information will be used to establish a database and the framework for discussing sustainable development, to which Canada is committed.

Sustainable development is based on two principles: maintaining ecological diversity and maximizing the net economic benefits of the resource. Specific goals are incorporated into Habitat Management Plans and associated DFO decisions and activities. These goals are:

1) **Avoiding irreversible man-made changes to fish producing habitats.**
Habitat alterations that reduce fish production capacity will be avoided if they cannot be reversed within one human generation.

2) **Maintaining the genetic diversity of fish stocks.**
No fish stock will be written off arbitrarily, and small or remnant stocks will be conserved and rebuilt wherever possible.

3) **Maintaining the physical and biological diversity of fish habitats.**
Habitat diversity encourages genetic diversity, alternate life history strategies, and the capacity to survive natural variation in environmental conditions.

4) **Providing a net gain in the productive capacity by habitat management.**
Natural and self-sustaining methods of increasing productive capacity are preferred to those that require human intervention and maintenance.

5) **Maximizing the value of commercial, sport, and aboriginal fisheries.**
Competing uses of the fisheries resources will be quantified by considering tangible and intangible market and extra-market values.

6) **Maximizing the non-consumptive values of fishery resources.**
Intangible and cultural values of the fishery resources will be considered when allocating fishery resources.

7) **Distributing fishery net benefits in a fair and equitable manner.**
Local communities should help make decisions about habitat conservation and restoration, stock enhancement, distribution of benefits, and cost-sharing arrangements.

This report is intended to contribute to effective land use planning. In turn, this should protect and manage aquatic habitat successfully and result in sustainable development.

1.0 INTRODUCTION

1.1 Purpose of the Study

The Fraser River Environmentally Sustainable Development Task Force, of the Department of Fisheries and Oceans, is developing plans for environmentally sustainable salmon production. Planning is based on sixteen sub-basins -- called Habitat Management Areas (HMA) -- of the Fraser River watershed. The study area for this report -- the Thompson River watershed -- includes three habitat management areas (Figure 1). These are the South Thompson - Shuswap, North Thompson, and Thompson - Nicola.

In 1991, the Task Force contracted Sigma Engineering Ltd to compile biophysical and resource use data and assess habitat sensitivity within the Thompson River HMA's. Our study utilizes this resource use data, regional hydrological analysis, and water licence summaries to classify, in more detail, the sensitivity of salmon streams in the Thompson River basin to land and water use. The indices used for classification are general and should be applicable to other Habitat Management Areas within the Fraser Basin.

1.2 Scope of the Study

The study focuses on the salmon streams within the Thompson River Basin listed in the Stream Information Summary System (SISS). The SISS includes 29 streams in the North Thompson HMA, 43 streams in the South Thompson - Shuswap HMA and 8 streams in the Nicola - Thompson HMA, for a total of 80 salmon streams. The total includes several different reaches of major rivers, such as the South Thompson River. Information available prior to 1992 has been summarized in this report.

The following tasks were completed to meet the objectives of this report:

- Review Water Survey of Canada gauging stations in the Thompson River basin and calculate flow characteristics for those salmon streams with gauging records;
- Utilize natural or "naturalized" gauging records to regionalize hydrologic characteristics and predict flows on ungauged salmon streams;
- Prepare summaries of water utilization for each of the salmon streams in the study region from Water Mangement Branch records;
- Develop stream sensitivity indices, based on hydrologic characteristics and water utilization, that may be generalized to other parts of the Fraser watershed; and
- Rank and discuss sensitive streams and discuss technical or management solutions.

The main task was predicting flow characteristics for the 80 salmon streams. The quality of information varied greatly from stream to stream and our approach focussed on predicting "natural" flow characteristics that permitted comparison and ranking of streams within the study area. Predicted flows are not necessarily the best estimate for any individual stream and should not be used for design of structures or evaluation of projects without further, detailed study of that particular stream.

1.3 Report Structure

Tables and figures have been prepared separately for each Habitat Management Area so they may be removed for inclusion in other reports, which the Department of Fisheries & Oceans may wish to produce.

Background information discussed by Sigma Engineering Ltd is not repeated in this report and data taken from their volumes has not been reviewed or verified. References to Sigma's data, tables or figures in the text should be understood to refer to the appropriate Sigma Engineering Ltd report, listed in Chapter 7, "References".

1.4 Acknowledgements

Funding for this project was provided by the federal Department of Fisheries and Oceans through the Fraser River Action Plan, a Green Plan initiative. A number of individuals provided an overall perspective on land and water use and hydrology, as well as information on the salmon streams. We would like to thank Lidia Jaremovic, Gordon Kosakoski, Buryl Kurtz, Tim Panko, George Neilsen, Mel Sheng, Otto Langer, and John Patterson of the Department of Fisheries and Oceans.

2.0 FLOW CHARACTERISTICS OF THE SALMON STREAMS

2.1 Hydrometric Data in the Thompson Basin

The Water Survey of Canada is the prime agency collecting and reporting discharge data in British Columbia. Gauging stations in the Thompson River watershed are described in *Surface Water Data Reference Index: Canada 1988* published by Environment Canada. There are roughly 400 active and abandoned stream gauging stations in the Thompson River watershed. Many of the abandoned stations operated briefly during the early part of this century. Their records are too short to calculate reliable flow statistics and it is unclear if they reflect the contemporary hydrologic regime, because of changes in water demand, water utilization, and climate. Roughly 50 gauging stations were active during the 1980's and have continuous, or nearly-continous flow records (Figure 1).

Twenty-three of the salmon streams, have continuous, or near-continuous, records of daily discharge during the 1980's. These records were used to calculate mean annual flows, annual floods, monthly discharges and 7 day low flows for the streams. At all of these stations, measured flows are affected by upstream storage and extraction of water, and calculated flow characteristics, particularly low flows, differ from the natural flow expected in the absence of water or land use. On some streams, water use is small in comparison to flows and the recorded flows are a reasonable estimate of natural flows; however, on many salmon streams, regulation and extraction affect the natural flow regime.

Fifty-seven of the salmon streams have no gauging records or, have older, or too brief, records that are not suitable for calculating flow characteristics. At these ungauged streams, mean flow statistics were estimated from equations developed from a regional analysis of Water Survey of Canada gauging records (Appendix E). The mean annual flows, annual floods, monthly flows, and 7 day low flows predicted for the ungauged salmon streams represent the regime that would occur in the absence of upstream water or land use.

The flow characteristics calculated from gauging records and from regional analysis are not equivalent. In order to compare ungauged and gauged streams, and use the data in the same indices, the flow characteristics on the gauged stream were adjusted to represent the "natural" regime in the stream; the regime that would occur in the absence of all regulation or extraction. Natural flows were estimated by adding potential water extractions, as calculated from summaries of water licences, to the flow recorded at the gauge. The suitability of this approach varies from stream to stream. Where extractions occur with only limited storage, the procedure provides acceptable estimates of the natural flow regime; where storage volumes are a significant proportion of the total licenced withdrawals, the procedure over-estimates the natural flow regime.

2.1.1 Other Sources of Hydrometric Data

The Water Management Branch of the Ministry of Environment operates some gauging stations whose data are reported by the Water Survey of Canada, collects miscellaneous measurements on streams with licenced extractions, and carries out occasional (regional) data collection programs during droughts. Their drought measurement programs (Anon 1986, Nyhof 1987, Richards 1977) focus on measuring minimum flows during the summer. Measurements on the salmon streams were used to corroborate regional estimates of low flows.

2.1.2 Reference Point for Flow Characteristics

Water licences were summarized for the total watershed upstream of the mouth of salmon streams. On ungauged streams, flow estimates were calculated for the mouth of the stream to correspond with the water licence summaries.

The Water Survey of Canada report their data for a specific point on the stream which may be near the mouth of the stream, or a considerable distance upstream. The sites are generally chosen for accessibility and for their suitability as gauging sites, rather than other criteria, and licensed water extractions may exist downstream as well as upstream of the gauge site. In most cases, the gauging site is near the mouth of the stream, and the recorded flows may be assumed to also describe flows at the mouth. If a major tributary enters between the gauge and the mouth, or if the gauge is well upstream of the mouth, the flows recorded at the gauge will not reflect those at the mouth and reported flow characteristics at the mouth were estimated by regional relationships.

2.2 Gauged Salmon Streams

Flow characteristics calculated for gauged salmon streams are shown shaded in Tables 2, 3 and 4. Adjustments to the flows reported by the Water Survey of Canada are discussed in Section 2.2.2. Table 1 provides definitions of the flow characteristics used in this report. More detailed descriptions follow in Sections 2.2.3 and 2.4.

Unadjusted flows of the gauged streams are also of interest. These are reported in Appendices A, B and C and discussed in Section 2.3.

2.2.1 Period of Record for Calculating Flow Characteristics

In British Columbia, there is a consistent pattern of declining annual flows in the late 1940's and 1950's and above average annual flows in the 1960's and 1970's (Barrett 1979). Mean annual flows, as well as other flow characteristics, vary from decade to decade and it is important, when comparing records at different stations, to limit flow data to a common period, so that variation between gauges reflects the character of the particular station rather than differences in the period of record. We have adopted 1980-89 (inclusive) as our standard period for analysis. Flow characteristics are stable and homogeneous, and are similar to those from long-term records. As well, this period includes several moderate droughts and has the greatest number of operating Water Survey of Canada gauges.

2.2.2 Adjustments for Regulation of Water Survey of Canada Flow Records

At many of the Water Survey of Canada stations in the Thompson Basin, recorded flows are affected by some form of upstream regulation, including water extractions for domestic and irrigation use, diversions to other watersheds, or major storage projects. Where the regulation consists of licensed water extractions, with limited storage (Tables 5, 6 and 7) the observed flows are "naturalized" by adding licenced water extractions obtained from summaries provided by the Water Management Branch (Section 4.2). These naturalized flows are close to the natural regime, but may vary because of differences between actual and licenced water use upstream of the gauge, flow enhancement by releases from small storage projects or return flows from irrigation diversions.

No reservoirs in the Thompson River basin have the capacity to significantly alter mean annual flows, but mean annual flows in some salmon streams may be reduced by licenced consumption. In the Nicola River watershed, the total licenced irrigation extractions are roughly 10% of the annual flow volume. In Duteau Creek, the total annual diversion of water out of the basin by the Vernon Irrigation District amounts to roughly 50% of the annual flow volume.

The Nicola Lake and Duteau Creek reservoirs, as well as a number of other reservoirs, alter the natural pattern of monthly flow and affect maximum and, particularly, minimum flows. In some instances, instream flows are based on conservation releases, rather than reflecting the difference between extractions and available natural flows. In these circumstances, natural flows estimated as the sum of licenced extractions and recorded flows are likely to over-estimate the "true" natural regime. Salmon streams with storage volumes approaching the licenced volume of irrigation extractions may be identified in Tables 5, 6 and 7.

It is possible to adjust flow records to reflect natural circumstances, but only if regulation is imposed by one large reservoir and suitable data are available. Inflows, which represent natural flows, may be calculated under certain special circumstances -- releases are measured, daily (or monthly) water levels are recorded and the reservoir elevation-storage curve is known. This procedure was not carried out as only a few salmon streams, in the Thompson watershed, had sufficient gauging records.

It is more common for the total storage to consist of a number of small, independently-operated, reservoirs. Where the volume of total storage is small compared to irrigation extractions (Tables 5, 6, and 7), it is reasonable to ignore the contribution of storage to low flows, and naturalized flows may be estimated with summaries of licenced extractions. On streams with a large volume of total storage compared to minimum monthly flows, naturalized flows, estimated from licenced extractions, will overestimate true natural flows because some diversions are compensated by releases from storage.

2.2.3 Annual Flow Characteristics

The historic period for the **mean annual flow** is 1980 to 1989, inclusive (see Table 1 for defintions). No adjustments were made for the effect of regulation, except on Duteau Creek, where the Vernon Irrigation District operates a major diversion. Adjustments were taken from Rood (1989).

The historic period for the **mean annual flood** is 1980 to 1989, inclusive. No adjustments were made for the effect of regulation, though it is recognized that reservoirs on the Nicola, Bonaparte and Shuswap Rivers and on Duteau Creek affect flood flows.

2.2.4 Seasonal Flow Characteristics

The water year was divided into two seasons: summer (May 1 to October 31) and winter (November 1 to April 30). This division was chosen to include all irrigation within one season and to separate low flow estimates into two distinct seasons. Summer low flows are affected by storage and release of water, irrigation diversion and domestic and waterworks withdrawals. Winter low flows are more nearly natural, and are only affected by storage and release of water (in a few circumstances) and domestic and waterworks withdrawals.

Tables 2, 3 and 4 report mean August and September flows for the gauged streams. Measured flows were adjusted to naturalized flows by adding potential licenced demands for each month, following the procedures in Section 2.2.2.

Summer and winter 7 day low flows were extracted from Water Survey of Canada records, covering 1980 to 1989, and mean seasonal seven-day low flows calculated as an average of all observations and reported on Tables 2, 3 and 4. The mean low flows do not necessarily correspond with the two-year return seven-day low flows. This occurs because the mean low flow is affected by extreme seven-day low flows occurring within the period of record.

Summer 7 day low flows were naturalized by adding the calculated potential demand for September, as these flows typically occur in September or October. This is a crude adjustment as low flows may occur during periods of limited or no irrigation and the adjustment will over-estimate the natural flows that would occur. Winter 7 day low flows were not adjusted in any fashion.

2.3 Measured Flows on the Gauged Salmon Streams

In addition to naturalized flows, the recorded flows on the gauged salmon streams are of interest. The long records permit calculation of more detailed flow characteristics than on the ungauged streams, such as mean annual hydrographs (Appendix A), seasonal distributions of annual 7 day low flows (Appendix B) and 7-day low flow frequency curves (Appendix C). Mean annual hydrographs, seasonal distributions and 7-day low flow frequency curves are based on all available, complete years of data at the gauge sites, rather than 1980-89 -- in order to best estimate the flow characteristics at the gauge -- and are not adjusted for upstream storage or water use.

The mean annual hydrographs, included as Appendix A, are calculated from all available complete, continuous years of record at the gauge. All years were used because these gave the best representation of the annual pattern of flow.

Appendix B shows the distribution, by month, of the annual 7-day low flows, based on the longest continuous period of record at each gauging station. The longer period of record was used in order to provide sufficient data for stable patterns of low flow occurrence. 7-day low flow frequency curves for these records are included in Appendix C.

Appendix D includes estimates of floods with various return periods. These were calculated with the CFA-88 program, prepared by the Water Survey of Canada, as adapted for micro-computers. Floods of 5, 10, 50 and 100 year return periods are reported as multiples of the mean annual flood.

2.4 Ungauged Salmon Streams

The Thompson River basin includes a number of physiographic and climatic regions, each with a different characteristic hydrologic regime. Distinct flow regimes occur in the Plateau, Highlands and Mountain regions of the Thompson River Basin, with, typically, the lowest unit seven-day flows on the Thompson and Fraser Plateaus and the highest in the Monashee, Cariboo and Cascade Mountains. The differences between the regions are greater than the effect of regulation.

2.4.1 Estimation of Flow Characteristics

Regionalization focussed on predicting mean August and September flows and seasonal mean 7-day low flows for ungauged salmon streams: mean annual flows and mean annual floods were predicted by Sigma Engineering Ltd. Equations, relating flow and physiographic characteristics at gauging stations with natural or "naturalized" records, were developed (Appendix E). These equations, along with the physiographic characteristics of the ungauged basins, were used to estimate the flows reported on Tables 2, 3 and 4. Where measurements by the Water Survey of Canada and Water Management Branch were available these were used to adjust some predicted flows. The reported flows are estimates of natural flows that would be recorded without extractions, storage or land uses that alter the hydrologic regime.

Data and analytic procedures are described in Appendix E to this report. Estimated flows were compared with miscellaneous records collected by the Water Management Branch and short-term records reported by the Water Survey of Canada and adjusted where required.

2.4.2 Flow Characteristics of Ungauged Streams

Sigma (1991) calculated unit mean annual flows for streams with (suitable) Water Survey of Canada records and estimated **mean annual flows** at ungauged salmon streams, or those with inadequate records, by transferring unit mean annual flows from nearby gauged streams. Their mean annual flows, which do not refer to a common period of record, are recorded on Tables 2, 3 and 4. These flows are not adjusted for regulation or extractions, but, in most circumstances, adequately represent natural flows as extractions are generally small compared to mean annual flows.

Sigma also calculated unit mean annual floods for streams with (suitable) Water Survey of Canada gauges. **Mean annual floods** were estimated at ungauged salmon streams, or those with inadequate records, by transferring from unit mean annual floods from nearby gauged streams. Their mean annual floods, which do not refer to a common period of record, are recorded on Tables 2, 3 and 4. These flows are not adjusted for upstream regulation.

Mean August and September flows were estimated by the equations described in Appendix E and represent natural flows, based on the 1980-1989 period. **Mean summer and winter seven-day flows** were estimated from the equations described in Appendix E and are natural flows based on the 1980-1989 period.

2.4.3 Limitation of Flow Characteristics Estimated from Regional Analysis

The Water Survey of Canada network imposes some limitations on the regional analysis. Gauging sites are often chosen where there is a stable control on the channel and these locations, which are often bedrock, are also sites where sub-surface flow is forced to the surface. During droughts there may be flow at the Water Survey of Canada gauge when upstream or downstream reaches record no surface flow. Regionalization of the Water Survey records may overestimate 7 day low flows.

Second, minimum flows are affected by surficial geology and other factors that are not explicitly incorporated into regional analyses. Unusual geology, or other factors, may produce much greater or much lesser flows than predicted.

Finally, the measured winter and summer daily flows at the Water Survey of Canada gauges, which are incorporated in the regional analysis, are derived by different procedures. In summer, daily flows are calculated by applying a rating curve to a continuous stage record. In winter, under ice cover, flow is measured every three or four weeks and estimated, or interpolated, between the dates of measurements using such factors as air temperature, and measurements at nearby gauges. Regionalization of the measured winter low flows may be of lower accuracy than summer low flows.

3.0 LAND USE

3.1 Logging

Sigma interpreted forest and logging land use within the study basins from 1:250,000 Landsat imagery and estimated the following parameters:

- Non-Forested Areas (includes exposed bedrock, icefields, treeless biogeoclimatic zones, etc). Measured with a dot-grid.
- Percent De-Forested Area: Visually estimated from the Landsat imagery, includes all logged areas as well as burned areas.
- Percent Recent Logging: Visually estimated from the Landsat imagery, includes those cutblocks with no evidence of vegetation. Age of these blocks are unknown.

The quality of these data are unknown but may not be very high. Three and seven metre green-up times for typical stands, by biogeoclimatic zone are also reported. Tables 2, 3 and 4 report areas of recent and total logging.

3.2 The Effect of Logging on Hydrology

Haul and skidder road construction increases runoff from the road surface and increases the rapidity of runoff. Ditching along roads concentrates water, generally into fewer channels, and intercepts subsurface flow, increasing the speed of flow to drainage channels. The removal of trees severely reduces or eliminates transpiration, in the short-term. Tree removal also increases air movement and changes soil temperature, but the overall effect is to reduce evapotranspiration from the soil. In British Columbia, tree harvesting also affects the distribution of snow and the timing of its melt.

3.2.1 Forest Harvesting and Streamflow Quantities

All well-designed experiments show increased water yield as a response to forest removal, and the increase is generally proportional to the amount of canopy removed (Bosch and Hewlett 1982). The increased flow of water results from increased storage of water in the soil as the result of reduced transpiration following the removal of forest cover. Increases are observed during the low flow season and also during the wet, or high flow season, particularly early in the season when soil storage differences are greatest between the forested and clearcut areas.

Clearcut logging in Camp Creek near Penticton, B.C., following Pine Beetle infestation, produced results similar to those recorded in experiments from the western and southeastern United States. Both annual and monthly water yields increased in the clearcut stream with the greatest increases recorded in the low flow months of August and September (Cheng 1990).

3.2.2 Forest Harvesting and Flood Flows

Many studies have demonstrated increased storm volumes and peak flows following forest removal, though there are few results appropriate to the Interior of British Columbia. Cheng (1990) found increased, and earlier, peak flows in Camp Creek after clearcutting of 30% of the basin area. His finding of a 20% greater, and two weeks earlier, flood peak are roughly comparable with studies in other snowmelt-dominated systems.

The Ministry of Forests has prepared guidelines for the Kootenay Lake Forest District to control rate of cut in such a manner as to minimize changes to the annual hydrograph in snowmelt-dominated hydrographs. Changes to the freshet hydrograph are minimized by distributing the cut over a range of elevations and aspects and by controlling the maximum "clearcut equivalent area" – a factor applied to the cut block area that changes with re-generation and the proportion cut in the block – within the watershed. Maximum allowable clearcut equivalent areas vary with basin type, but range from 25% to 35%.

3.2.3 Forest Harvesting and Sedimentation

Watershed disturbance during forest harvesting often causes increased fine (suspended) and coarse (bedload) sediment delivery to streams, through erosion of roads and cut-banks, soil disturbance or landsliding. Elevated suspended sediment loads and deposition of this material on fans or in low-gradient sections of streams may have greater impact than changes in the hydrologic regime resulting from logging.

The relative importance of various erosion processes, and the various forestry activities, to the total sediment budget of a disturbed watershed depend on the precipitation regime, character of the watershed, soils and logging practices. Details may only be resolved after extremely detailed study. However, a general appreciation of the nature of sediment sources and sediment delivery processes may be obtained from aerial photographs and reconnaissance studies.

3.3 Agricultural Land Use

Sigma reports agricultural land use, as measured from 1:50,000 manuscript maps showing ALR boundaries, agricultural land use, land tenure and B.C.L.I. land capability (Talisman 1979). These maps were derived from interpretation of 1976 and 1977 air photographs and were used by Talisman to provide 1990 and 2010 projections of "improved farmland", which consists of cultivated or cropped land and improved pasture. As defined by Talisman, the improved pasture includes all areas where native vegetation was removed and pasture mix planted and does not include unconverted rangeland used for cattle grazing. Both the cultivated land and the improved pasture may be irrigated. Tables 2, 3 and 4 report the estimated 1990 improved farmland.

Sigma also includes total areas of cropland and total irrigated areas (broken into flood and sprinkler irrigation) for the Agricultural subdivisions lying within the Thompson Drainage. These data may be used to approximately estimate the irrigated land in various portions of the study area (Section 4.2.2).

3.4 Physiography

The following parameters were used to describe each of the watersheds:

- **Drainage Area:** Sigma extracted drainage areas upstream of stream gauging sites from Water Survey of Canada publications and drainage areas above the mouths of salmon streams from SISS records (measured from 1:50,000 NTS maps). The two sources are not always consistent and in some instances the drainage area reported by the Water Survey of Canada is greater than the reported basin area above the stream mouth. The data have not been corrected as the differences amount to only a few percent of the total basin area and are of the size of typical measurement errors.

- **Relief:** Defined as the difference between the maximum and minimum elevations in the basin, measured from 1:250,000 topographic maps.

- **Surface Area of Lakes:** The surface area of lakes and reservoirs within each drainage was estimated with a dot grid on 1:250,000 maps.

4.0 WATER LICENCES

The Water Rights Branch of the Ministry of Environment maintains a computerized data base of water licences in British Columbia. Summaries (by licence type) were produced for all salmon streams, as well as streams with long-term Water Survey of Canada gauging stations.

4.1 Classification of Water Licences

Figure 2 reproduces the water licence classification system used by the Water Management Branch. Water licences are classified into consumptive and non-consumptive uses and further classified by the type of user. Computer-generated summaries, obtained from the Water Rights Branch, Victoria, utilize the main classification on Figure 2, as well as providing more detail on the type of user, producing a total of 73 sub-categories (including non-consumptive uses).

4.1.1 Consumptive Licences

The computer-generated classification provides more detail than is required so we have reported consumptive licenced extractions from the salmon streams (Tables 2, 3 and 4), under the categories of Domestic, Waterworks, Irrigation and Industrial. Pulp Mills, Land Improvement and Mining licences, which are classified separately by the Water Management Branch, are included under our Industrial category as there are few of these licences in the Thompson River basin. Tables 2, 3 and 4 report the sum of all licences, of each type, above the mouth of the salmon stream.

4.1.2 Non-Consumptive Licences

Non-consumptive water use includes Power Generation, Storage (nonpower and power) and Conservation. Conservation licences are totalled and summarized on Tables 2, 3 and 4. Nearly all the storage licences are non-power licences; Sigma discusses the few small and large hydro projects in the various HMAs.

The total non-power storage licences in each salmon stream are listed on Tables 5, 6 and 7. The total includes all storage for domestic, waterworks, irrigation, industrial and conservation licences; though, in most streams, the vast majority of the licences are for irrigation.

Tables 5, 6 and 7 also compare the irrigation licences to the non-power storage in each salmon stream. Storage affects discharge by being accumulated during the spring freshet and released during low flows, or during the irrigation season. In many watersheds, licenced storage volumes are matched to some irrigation licences, and the net reduction in low flows resulting from diversion for irrigation is, theoretically, less than the total licenced irrigation diversion. This does not work in practice as the upstream storage facilities trap incoming flows during low flows as well as high flows -- reducing downstream flows in addition to extractions -- and leaky dams and evaporative and transmission losses reduce the storage quantity available to compensate for licenced extractions.

4.2 Licenced Versus Actual Water Use

4.2.1 Domestic and Waterworks Licences

Domestic use is only partly consumptive. In summer, although a large portion of the domestic use is for watering of lawns and gardens some of this water re-enters the stream as return flow.

Waterworks are also only partly consumptive; but in organized areas, water may be diverted out of the basin and return flows may not end up in the same stream, producing a true loss to streamflow. Typically, waterworks are licenced for amounts well in excess of actual extractions. Because licence-holders for large waterworks projects pay a fee based on actual water use, rather than the licenced amount, records are available of the annual volumes of water extracted from streams. We have not obtained these records because waterworks and domestic extractions in salmon streams in the Thompson Basin are mostly insignificant when compared to irrigation use or to streamflow.

4.2.2 Irrigation Licences

A certain percentage of the water diverted for irrigation reenters the stream as return flow. When flood irrigation (by ditches and flumes) was prevalent it was assumed that roughly 30% of the diverted volume returned to the stream. Sprinkler and drip/trickle irrigation are expected to produce considerably less return flow and these are now the dominant methods of irrigating.

Water applied to the land on a particular day will cause return flow some days, weeks or months later. The Okanagan report assumes about 12% of the annual return flow occurs in September and 9% in October; and also allows for a small percentage (about 4% per month) through the winter months. Return flow in August and September may reduce the impact of irrigation diversions in those months if the flow is returning to a reach of the stream supporting fish.

Actual irrigation demand can be estimated from the area of irrigated land and a calculated or estimated water duy. Areas of irrigated land in salmon streams in the Thompson Basin can be estimated from the "Improved farmland" reported for each basin and the percentage of improved farmland that is irrigated within each agricultural census district (Table 3.3.1: Sigma Engineering Ltd). The portion of improved farmland that is irrigated varies over the Thompson watershed: in the northern (or north-eastern) basin less of the land is irrigated; some crops are grown without irrigation and probably less "improved pasture" is irrigated. The percent irrigated is very approximate because of variations within census areas and uncertainties in the census data.

The duty -- the water needed for the irrigation season expressed as a depth -- is used to calculate the total amount of water needed for irrigation. However, the theoretical duty and the actual amount applied can be very different, as a result of farming practices and, as well, the duty varies with location and elevation and from year to year. Year-to-year variations are significant: from 1975 to 1988, duty in the Vernon Irrigation District varied from 31 to 48 cm (Rood 1989), with the greatest amount required during low flow, dry years. In dry years the actual extraction approaches the licenced volume.

Irrigation demand can be estimated following the above procedure; however, we prefer to use the water licence summaries, for several reasons. First, the improved farmland is shown as "zero" in a number of salmon streams that have irrigation licences (Tables 2, 3, and 4). This may result from non-use of licences, diversion of water to farms out of the basin, or inaccuracies in estimating improved farmland. Second, the irrigated portion of improved farmland is only roughly known for the individual salmon streams and, third, duty is only known for a few basins with detailed studies. Finally, the water licences represent, as discussed in the next section, a potential maximum demand on the salmon streams and provide a comparable standard of comparison from stream to stream.

4.3 Calculation of Licenced Demand

Calculation of licenced demand has the advantage of providing a consistent measure of demand from each stream and, in many instances, the licenced amount may be close to actual use: extractions are greatest in dry years and overuse of some licences may compensate for licences that are only partly used, or not used at all.

The demand calculated from the total licenced amounts is the maximum potential demand that may be exerted on the stream, if all licences were fully utilized. Some streams are fully recorded and the calculated demand will not increase: on other streams additional licences may be issued. (Those salmon streams with reserve notices or restrictions, issued by the Water Management Branch, are shown on Tables 8, 9, and 10.)

The water licences summarized on Tables 2, 3, and 4 are expressed in various units, ranging from acre-feet for irrigation licences, to gallons/day for waterworks and domestic licences and ft^3/s for conservation licences. Licenced amounts expressed as a discharge were converted to litres per second (L/s) using appropriate conversion factors: 1 L/s is equivalent (approximately) to 19,000 imperial gallons/day; 1 L/s is equivalent (approximately) to .035 ft^3/s.

Licensed amounts expressed as a volume (ac-ft) were converted to cubic decametres (dam^3), where 1 dam^3 is equivalent (approximately) to 0.81 ac-ft. In any time period, the total demand is calculated by adding the demand from waterworks, domestic and industrial licences, which are assumed to be constant throughout the year, to the irrigation demand. Irrigation volumes are assumed to be distributed in the Thompson River Basin as follows: May (15%), June (25%), July (25%), August (25%) and September (10%). (These percentages were used in the Okanagan Basin Report (1974) and correspond reasonably well with the seasonal distribution of water use by the Vernon Irrigation District (Rood 1989).) Monthly irrigation volumes (in dam^3) were converted to discharges (L/s) by multiplying by 10^6, and dividing by the number of seconds in the month.

The total demand varies from month to month as a result of irrigation extractions. Tables 2, 3 and 4 present calculated licenced total demand, in L/s, for August, September and February. These months were chosen because August and September are months when low flows commonly occur during the irrigation season and February is the winter month with the minimum monthly discharge.

5. SENSITIVITY INDICES FOR THE SALMON STREAMS

Tables 8, 9 and 10 present the sensitivity indices calculated for salmon streams in the Thompson River watershed. It was felt that the most useful indices for assessing habitat sensitivity would indicate the magnitude of water use during low flows in summer, compare the magnitude of low flows to mean flows, compare peak flows to mean flows and indicate the extent of logging in the watershed.

The indices are expressed as percentages, except for peak flows, which are expressed as a ratio of the mean annual flow. The use of percentages and ratios permits easy comparison of streams of different watershed areas and allows ranking of the streams. The most senstive streams were identified as those with the most extreme indices or those whose indices exceeded some critical value. On Tables 8, 9 and 10 the most sensitive streams are shaded: the rationale for selecting the most sensitive streams is discussed separately for each index in the following sections.

5.1 Summer Water Demand

Indices 1, 2, 3 and 4 express potential demand in August and September as a percentage of various measures of low flow. Indices 1 and 2 compare potential water demand to mean 7-day summer low flows, which typically occur between early August and mid-October. The 7-day low flows used in calculating the indices are "naturalized" or are estimates of the natural low flow and, consequently, the indices indicate the percentage of the available low flow that could, potentially, be required to meet water demand. Indices 1 and 2 represent extreme demands that may occur during the irrigation season. Indices 3 and 4 compare potential demand in August and September to average flows in these months and are a measure of typical or normal portion of streamflows devoted to irrigation during the late summer.

Large values of Indices 1 through 4 indicate streams with great potential demand, primarily from irrigation, on summer low flows. On Tables 8, 9 and 10, those streams whose indices are the top 25% of the values are shaded.

The potential water demand is calculated from the total licences and almost certainly over-estimates the actual water use. The indices also do not account for storage and release in the watershed. Also, small errors in measurement or calculation of 7 day low flows can make large differences in the value of the indices.

5.2 Summer and Winter 7 day Low Flows

Indices 5 and 6 compare seasonal 7 day low flows to mean annual flow, expressing the 7 day low flows as a percentage of mean flow. Actual 7 day low flows -- as opposed to naturalized streamflows -- were used in the indices so that the indices reflected current conditions in streams with licenced demand and those without licenced demand. The 7 day low flows used in calculating the indices are the recorded low flows on gauged streams, prior to adjustment to reflect upstream storage and diversion of waters, and, on ungauged streams, with licenced demand, the predicted natural flows were adjusted to actual flows by subtracting the (September) potential water demand. Low values of the indices indicate streams with large water demand or steep recession curves during summer drought.

On Tables 8, 9 and 10, those streams whose indices are in the lowest 25% of the values are shaded. Most of the streams with low indices have small drainage basins and some have licenced demand while others are unaffected by diversion or storage. Typically, smaller streams have more extreme response to drought and, on the Thompson Plateau and Quesnel Highlands, measurements by the Water Management Branch indicate that drainage basins up to 100, or more, km^2 may have zero discharge during moderate droughts.

5.3 Peak Flows

Index 7 compares the mean annual flood to mean annual flow, expressing the mean annual flood as a ratio of the mean annual flow. Higher values of the index indicate streams with a greater range of flow, and, possibly, lower channel stability. This ratio does not vary greatly from stream to stream, partly because both mean annual floods and mean annual flows are estimated for the ungauged streams, from unit flows on the gauged streams (Sigma 1991). Consequently, ratios on the ungauged streams are the same as those on the gauged streams, and there is no correction for variation of unit annual flood with basin area. (Larger basins have lower unit values because of storm coverage effects.) On Tables 8, 9 and 10, streams with values of 10 or more for Index 7 are shaded.

Large values of the index may not indicate unstable streams because stability is also affected by the materials in the streambed and the gradient of the stream. Neither of these variables are included in the index.

Extreme floods also affect channel stability. Appendix D lists the ratios of floods of various return periods to mean annual flood for gauged salmon streams in the Thompson River basin.

5.4 Logging

Indices 8 and 9 express the area of logging as a percentage of total basin area. Index 8 calculates the percentage of the watershed that has been recently logged (no vegetative cover visible on Landsat images); Index 9 the percentage of total logging (all visible cutblocks or disturbance on Landsat images). It is assumed that the "recent logging" includes all areas with limited or no hydrologic recovery following clearcutting. Some blocks included in the total logging may not have reached 3 m green-up and full hydrologic recovery, though the percentage that have not recovered or the clearcut equivalency of the older logging are not known.

Recent harvesting covering more than 20% of the watershed leads to changes in the annual hydrograph and, possibly, changes in the sediment regime of the stream. Those streams with recent logging greater than 20% of the basin area are shaded on Tables 8, 9, and 10. The Ministry of Forests often uses limits of 25 to 35% clearcut equivalent area to minimize changes to the hydrologic regime. We have selected a slightly lower value to compensate for the contribution from older logging and also to clearly indicate those streams where changes in the hydrologic regime may be initiated with further cutting.

Total basin area was used rather than forested area for several reasons. The effect on the hydrologic regime depends on the portion of the total basin whose hydrologic response is altered. If the forested area is only a small portion of the basin area, clearing a large percentage of the forest will have an undetectable influence on the hydrologic regime. Also, the Ministry of Forests uses total basin area in calculating these indices and we have followed their practice.

5.5 Sensitive Streams -- North Thompson HMA

The streams that are shaded on Table 8, which are identified as sensitive as a result of high water demand, low flows, high peak flows or recent logging covering more than 20% of the basin, are summarized in the table on the following page.

The sensitive streams are roughly divided into streams in the southern half of the HMA, where licenced withdrawals affect low flows, and streams in the northern half of the watershed where large portions of the basins have been clearcut.

Mahood River is the only large stream with potential water demands that are a significant portion of low flows. The potential demand results mostly from irrigation licences and the total irrigation licences are large compared to the improved farmland of 35.09 km^2 within the basin. The difference suggests that either the irrigated land is underestimated, or that potential water use exceeds actual water use (Section 6.2).

Water Demand	Low Flows	Peak Flows	Logging
Louis Creek	Christian Creek	E. Barriere River	Mann Creek
Christian Creek	McTaggart Creek	Haggard Creek	Brookfield Ck
Lemieux Creek	Tumtum Creek	Fennell Creek	Mahood River
McTaggart Creek	Lion Creek	Mann Creek	Raft River
Mann Creek	Goose Creek		Mad River
Mahood River	Cedar Creek		Unnamed Ck (04-4210)
Reg Christie Ck	Cook Creek		Unnamed Creek (04-4600)
			Lion Creek
			Finn Creek
			Goose Creek

Of the moderate-sized streams, Louis Creek has by far the greatest potential water demand, amounting to 50% of the flow in average years (see Figure A.2) and much greater percentages during droughts. There is very little licenced storage on Louis Creek. Lemieux Creek (Figure A.3) and Mann Creek have moderate potential demands, mostly resulting from irrigation. Dry creek bed has been observed along Lemieux Creek (Voysey 1990) which seems to result from a combination of local extractions and exchange of surface waters with subsurface flow and groundwater. The Water Survey of Canada gauge near the mouth always recorded surface flows during the 1980s. On Mann and Lemieux Creeks roughly 50% of the total irrigation extractions have an associated storage licence. Note that Mann Creek has no improved farmland (Table 2).

Of the smaller streams, Christian and McTaggart Creeks have potential water demands in excess of typical low flows (Table 8). In Christian Creek, the calculated demand exceeds the estimated 7 day low flow, though the demand is partly compensated by storage (Table 5). Inspection of gauging records from the 1960's on Christian Creek indicates unusually high summer flows for such a small, regulated basin, which may result from groundwater discharge from Heffley Lake which is poised above the head of the basin. Recent flow measurements by the Water Management Branch showed no flow in the upper creek during the 1985 drought. Despite uncertainty conceming flows, demand is large in Christian Creek compared to 7-day low flows.

On McTaggart Creek, measurements by the Water Management Branch (Anonymous 1986) indicate minimum flows of 3 L/s during the 1985 drought, which represent flows that remain after irrigation and other extractions. While there is uncertainty about the total available flow, it seems likely that potential demand is as least as great as, and probably exceeds, typical low flows.

A moderate potential demand, resulting from irrigation licences, is exerted on flows in Reg Christie Creek. 7 day low flows estimated for this creek are partly confirmed by seasonal Water Survey of Canada records from the mid-1920's. There is no storage development on this creek and it is unknown if the water licences are actively used.

It is mostly streams with small watersheds that have extreme low flow indices, including Christian and McTaggart Creeks. Most of the other creeks that were identified as sensitive are not affected by regulation or extraction and are in the northermost part of the North Thompson HMA, north of Avola.

Creeks with high ratios of of peak to mean flows are mostly in the upper Barriere watershed and drain the high elevations of the Dunn Peak Range. Large ratios of peak flows to mean flows are based on measurements from the Water Survey of Canada gauge in Harper Creek watershed, which may over-estimate peak flows in Haggard and Fennell Creeks.

Most of the streams with high proportions of recent logging in their basin lie in the northem half of the North Thompson HMA. These streams include several streams that were previously identified as sensitive because of low flows, water demand or peak flows such as Mann Creek, Mahood River, Mad River, Lion Creek and Goose Creek. All basins in the North Thompson HMA, with the exception of Tumtum Creek, Blue River and Albreda River, have percentages of total logging ranging from 20 to 44%.

5.6 Sensitive Streams -- South Thompson - Shuswap HMA

The streams that are shaded on Table 9, which are identified as sensitive as a result of high water demand, low flows, high peak flows or recent logging covering 20% of the basin, are summarized in the table on the following page.

The Salmon River is the only large stream with potential water demands that are a significant portion of summer low flows (Figures A.9 and A.10). A section of the stream at Westwold experiences no surface flow during parts of the summer though surface flows are always recorded at gauge sites along the river. Roughly 25% of the total licenced irrigation removal is compensated for by storage licences (Table 6).

Potential water demand constitutes a large portion of streamflow on many of the salmon streams with small and moderate-sized basins. The streams identified in the table, on the following page, all have potential demands in excess of 50% of the estimated average summer (natural) 7 day low flows and potential demand is a much larger portion of low flow during droughts. Licensed storage is very limited in these streams except for Chase Creek and Sinmax Creek where roughly one-half of the total irrigation licences are compensated by attached storage licences (Table 6). Note that a number of other streams have potential water demands that exceed 50% of low flows under some circumstances.

Water Demand	Low Flows	Peak Flows	Logging
Chase Creek	Chase Creek	Chase Creek	Duteau Creek
Huihill Creek	Hunakwa Creek	Reienecker Creek	
Sinmax Creek	Hunakwa Creek		
Salmon River	Canoe Creek		
Canoe Creek	Blurton Creek		
Trinity Creek	Fortune Creek		
Bessette Creek	Trinity Creek		
Duteau Creek	Kingfisher Creek		
Harris Creek	Danforth Creek		
	Ireland Creek		

Duteau and Bessette Creeks are a slightly different case (Figure A.14). Storage licences in Duteau Creek are sufficient to compensate for irrigation extractions by the Vernon Irrigation District; however, flows are diverted out of the basin and operation of the reservoir system, which controls flows in the upper watershed, for supply of irrigation and domestic water severely limits downstream flows in Duteau Creek, particularly in late summer and winter. Additional demand on Bessette Creek, which is only partly compensated by storage licences, reduces downstream flows.

It is mostly streams with small and moderate-sized watersheds that have extreme low flow indices, including some streams with high potential licenced demand. Many of the winter 7 day low flows in these small watersheds are predicted to be very small, with many only a few percent of the mean annual flow.

Only Chase and Reienecker Creeks are identified as sensitive to peak flows. This may result, in part, from the methods used by Sigma to estimate mean annual flows and mean annual floods.

Only Duteau Creek in the South Thompson - Shuswap HMA has over 20% of its basin recently logged. Most of the basins, however, have greater than 20% total logging and some have over 40% total logging (Table 9).

5.7 Sensitive Streams -- Thompson - Nicola HMA

Classification of indices in Table 10 identified the following streams as sensitive as a result of high water demands, low flows, high peak flows or recent logging covering more than 20% of the basins.

Water Demand	Low Flows	Peak Flows	Logging
Nicola River	Spius Creek	Coldwater River	Maka Creek
Spahomin Creek	Maka Creek		Bonaparte River
Bonaparte River	Coldwater River		
Deadman River			
Coldwater River			

Most of the salmon streams with large potential summer water demands are moderately large or large basins with developed storage. Storage licences compensate for a large, but variable portion of the irrigation licences in these basins (Table 7) and in the Nicola and Deadman Rivers water is released from storage for fisheries purposes to maintain minimum flows. Licenced storage on the Nicola River compensates for all or nearly all of the total irrigation licences and on the other streams, storage licences attached to irrigation licences and other licenced storage compensates for roughly half to two-thirds of the potential water demand. In these circumstances, our calculated indices may not describe water use because of difficulties in estimating natural flows in streams where low flows are controlled by storage.

Streams with extreme low flow indices include Spius and Maka Creeks and the Coldwater River, where summer low flows are predicted to be approximately 10% of mean annual flows. Both Spahomin Creek and Coldwater River have few irrigation licences with associated storage, large potential demands and extreme low flows. Neither of these creeks are restricted by the Water Management Branch for further licencing.

Coldwater River has a relatively high ratio of peak flow to mean annual flow. Maka Creek and Bonaparte River have recent logging covering more than 20% of their basin area. Percentages of total logging in Nicola, Spius, Coldwater and Bonaparte River and Maka Creek range from 26 to 40% (Table 10).

6.0 TECHNICAL AND MANAGEMENT OPTIONS FOR THE SALMON STREAMS

6.1 Introduction

Section 5.5, 5.6 and 5.7 identify the most sensitive salmon streams in the North Thompson, South Thompson - Shuswap and Thompson - Nicola HMA's. Many of these streams have been the subject of studies and reports, have been, or currently are, managed in one fashion or another to benefit salmon, or are a source of on-going concern to Fisheries & Oceans Canada. As part of our study, we reviewed existing reports and studies, discussed various issues with Fisheries & Oceans personnel, and summarized management and technical options for some of the sensitive salmon streams in the following sections.

Our discussions are not comprehensive appraisals of the various senstive salmon streams but rather summarize previous studies or personal communications from knowledgeable individuals familiar with the streams. Comments are not included for all sensitive streams. Information was kindly supplied by Mr. G. Kosakoski, Mr. B. Kurtz, Mr. T. Panko, Mr. G. Neilsen and Mr. M. Sheng of Fisheries & Oceans Canada. For many of the streams we have further distilled the available information into recommendations for management of individual streams. The recommendations are in no particular order and the streams are not listed in priority order. In some instances, we felt there was insufficient information to develop general recommendations and these were not included for all streams. We would recommend further study and investigation of all sensitive salmon streams, particularly those with no restrictions on water licencing.

As well as the specific discussion of individual streams in the following sections a number of general recommendations arise from this study that apply to management of the Habitat Management Areas as well as the individual streams. These include legislative, policy and technical issues. Instream flow needs for fish are not addressed in existing legislation and changes are required to ensure that these needs are considered during licencing of waters in salmon streams.

This report estimated flows for all salmon streams from gauging records and regional analysis. Some additional hydrologic studies are warranted for the sensitive streams. On ungauged streams, estimated flows, particularly low flows, should be confirmed by measurement programs, perhaps in conjunction with the Water Management Branch and the Water Survey of Canada. On gauged streams, further analysis of additional gauging records on tributaries or the upper mainstem is warranted, where these are available.

There are other gaps in technical knowledge which limit our ability to adequately manage, and priorize, the sensitive, and other, salmon streams. These include:

1. Groundwater wells on the floodplain of some streams directly reduce instream discharges but the quantities withdrawn are often not known, the wells are unlicenced and not incorporated into the total water demand on the stream. Licencing of groundwater extractions would provide a mechanism for including this demand into water budgets.

2. The relationship between actual and licenced withdrawals, for various licence types, is not known. Regular and effective monitoring of withdrawals is required to establish the demand on sensitive systems. Demand varies from year-to-year, based on a number of

factors, and management of streams requires some knowledge of the annual variation of demand.

3. The Water Management Branch classifies streams and restricts further water use in some streams. The restricted streams do not always seem to correspond to those with large potential demands, e.g. the Coldwater River. Fisheries & Oceans Canada should review the basis for decisions on restricting or not restricting water use and participate in revising the list of reserved streams.

4. Instream flow needs for fish, or other uses, have not been established for the sensitive salmon streams. When instream flow requirements are better known, it is easier to assess and manage the licenced demands.

In preparing management plans, and priorizing streams, the differences between the three Habitat Management Areas should be considered. The Thompson - Nicola salmon streams have large basins and, often, considerable quantities of storage, which provides opportunities for reservoir management to benefit fish. The South Thompson - Shuswap salmon streams tend to have smaller basins, limited storage, and very large potential water demands. Storage development, riparian zone management, and erosion control are important issues. Also, large, older clearcut areas cause problems in some basins. Few streams in the North Thompson have large potential water demands, particularly when compared to the other two Habitat Management Areas. Storage development on some streams, managing rates of clearcutting, and sediment and erosion control are important issues.

The sensitive streams identified in Sections 5.5, 5.6 and 5.7 include those where a considerable portion of typical summer flows are potentially utilized by licenced demand, principally irrigation, and are under the greatest threat from water use. Further water withdrawals from these stream systems – even with compensating storage – should be opposed until actual licenced demand is established and water management options for the stream system are reviewed. There are also a number of streams, particularly those with small basins, that are relatively unaffected by licenced demand but have very low 7 day flows in relation to mean annual discharge. Withdrawals from these systems should be opposed until streamflows are confirmed and water management options reviewed.

Salmon streams with a potential licenced demand that is lower than the sensitive streams but greater than zero are under a moderate, and possibly increasing, threat from water use. On these streams the potential for future increased water demand should be examined and instream flows assessed. If demand is expected to increase, minimum flow agreements, or restrictive licencing, may be used to maintain instream flows and storage opportunities in the basin should be investigated. Storage opportunities may either supplement existing flows or meet future demand.

Some of the salmon streams have insignificant or zero licenced demand and are not likely to experience increased agricultural or water supply demand in the future. The basins of many of these streams are logged and alterations to the hydrologic, and sediment, regimes or channel morphology will result from this source. Alterations to the hydrologic regime may be managed by controlling the rate of clearcutting. Changes to the sediment regime are not so easily controlled and individual sources may alter downstream suspended sediment concentrations.

Management or technical options may also be used to improve those streams with the greatest potential water demands. In those basins with only limited storage, additional reservoirs may be used to supplement minimum flows in the stream. Agreements on minimum flows, instream flow needs and investigation of losses along the channel should precede any storage investigations.

In basins with significant storage development it may also be possible to improve minimum flows. In some instance, typical operating procedures for reservoirs may be altered to provide more water during critical periods, particularly if these occur during the winter. A detailed study is required of inflow to the reservoirs and the operating regime as well as defining instream flow needs (see Rood 1989). Fisheries & Oceans Canada may participate in developing extra storage, or improving existing storage, to provide additional water for release during minimum instream flows. In both instances, it should be ensured that some contractual relationship clearly spells out the reservoir operator's obligations.

6.1 North Thompson HMA

Louis Creek: There is a long standing problem with low flows in Louis Creek. Considerable discussion has taken place in the past between DFO and the Water Management Branch, regarding storage development, but without any definite resolution. There are several active and discontinued WSC stations in and around the watershed as well as a number of miscellaneous flow measurements, but no detailed hydrologic study has been completed.

Clearing and road building near Todd Mountain is apparently resulting in high turbidity. Riparian habitat in a lower section of the creek is being degraded by clearing and uncontrolled livestock access (M. Sheng, SEP).

1. A detailed hydrologic study, including a review of storage options on Eileen and McGilvery Lakes, should be completed so that instream flow alternatives can be assessed.
2. A policy for protection and development of riparian vegetation should be developed.
3. Sources of sediment should be investigated and appropriate action taken.

Barriere River: Leonie Creek, entering the river just above Barriere, is a source of silt which may be preventing the use of the lower two miles of the river by fish. The silt source is an old slide, possibly caused by road building or logging, which continues to remain active.

1. The silt source on Leonie Creek should be examined to determine if remedial action is feassible.

Lemieux Creek: There has been no detailed study of the hydrology or instream flow requirements. The creek at times goes dry, because of subsurface flow, near the mouth and in another reach approximately 6 km upstream, which can prevent or delay upstream migration.

There is potential for storage development on Taweel Lake and Fish & Wildlife (Kamloops) have applied for a storage licence.

1. A detailed hydrological study should be completed to determine the feasibility of storage development on Taweel Lake and improvement of instream flows.

2. Pursue joint-funded MOELP/DFO flow storage on Taweel Lake to improve low flows.

Joseph Creek: Coho spawning area below Dunn Lake is limited and there is a proposal by SEP to develop a spawning channel along the edge of Dunn Lake (M. Sheng).

1. The proposal to develop a spawning channel along the edge of Dunn Lake should be given further consideration.

Clearwater River: There are few problems with the river because it is in Wells Grey Park. There is also a recreational corridor between the town of Clearwater and the park in which there is some logging but it is rigorously controlled. The river is also under reserved (no licencing) status.

Mahood River: Only the lower river below Mahood Lake is used by salmon. There are several large licences (which may not be used) and most of the water licences are above the lake and may not have much effect on downstream low flow (T. Panko).

1. The water licences on Mahood River should be reviewed to determine whether they are being used and whether they affect fish habitat. Unused licences should be cancelled.

Brookfield Creek: Debris and siltation, that may come from two old sawmill operations, now closed, may be limiting the use of this stream by salmon (T. Panko).

Finn Creek: Logging is on hold while a hydrological study by DFO and the Forest Service is completed. There is the possibility for development (by SEP) of several side channels near the mouth, below the highway, where there seems to be a good groundwater supply. There is also a land reserve for a hatchery but no plans for immediate development.

1. Enhancement possibilities on Finn Creek should be reviewed before the forestry studies are completed so plans for the future can be integrated.

6.2 South Thompson - Shuswap HMA

Chase Creek: Only the lower end of the creek near the mouth is utilized by salmon. The Chase Riffle, at the mouth of Chase Creek, is the main chinook spawning area in the South Thompson. Sediment concentration and channel instability provide some concern, but are not a high priority for remedial action.

1. Channel stability in the chinook spawning area should be examined. Siltation of the gravels may be a negative factor, gravel recruitment may be positive.

Sinmax Creek: Sediment may be added to the creek from the base of a spoil pile at an old silver mine. This erosion was first reported in 1976 and may still be active (G. Neilsen). Low flow problems have been reported but have not been studied (G. Kosakoski).

1. Low flow problems should be studied in detail.

Hiuihill Creek: DFO and the Ministry of Forests have assessed the impacts of past logging and studied the potential impacts of proposed logging. Increased flood levels and erosion resulting from logging, road building, land clearing and agriculture have been reported (R. Erenko, Ministry of Forests). Sediment sources have been identified and are currently monitored.

1. Cooperate with monitoring of erosion sources. Special erosion control measures may be feasible.

Scotch Creek: The large area of recent and past logging in the basin is considered the main cause of increased channel erosion and sedimentation, particularly on the fan (B. Kurtz). DFO has requested a hydrologic assessment of past logging and proposed logging in the watershed (B. Kurtz).

1. A joint hydrologic study (MOF, MOE, DFO) should be completed before additional logging is approved.

2. Any proposed channelization in the lower reches by MOTH, or others, should be carefully assessed.

Eagle River: Agriculture and linear development in the reach downstream of Perry River has alienated some off-channel rearing habitat (B. Kurtz). Logging is considered to have produced problems in some tributaries, particularly South Pass Creek (G. Kosakoski).

Salmon River: The Salmon River has a high irrigation demand and discharge varies along its length due to bedrock outcrops which control the interchange of water between surface and subsurface flows. A reach of the river near Westwold goes dry in the summer while there is surface flow in the upstream and downstream channel. This may have occurred in the natural river but it is aggravated by withdrawals. Losses of water in this reach should be studied before any effort to mitigate the impact of irrigation is undertaken.

Groundwater wells in the valley must also affect river flow. Other problems include high water temperatures during low flow periods, erosion of stream banks, and consequent sedimentation, by livestock and clearing of riparian vegetation.

1. An effort should be made to expedite the legislation required for licensing of wells.
2. Storage opportunities should be reviewed.
3. A policy for the protection of riparian vegetation should be developed.

Shuswap River above Mabel Lake: The BC Hydro station at Shuswap Falls, originally built about 1910, causes fish stranding downstream of the dam and prevents upstream migration. The small head pond not only requires frequent dredging and flushing but it does not adequately buffer flows released from the Sugar Lake reservoir. If the plant suddenly shuts down because of lightning, or some other cause, the flow in the river below the station can be severely reduced for a short period of time. In the past there has been an informal arrangement with the station manager whereby the pond level is carefully controlled to minimize the effect of the shutdown. A revised operating order was issued by B.C. Hydro in 1991.

A few years ago, SEP investigated the possibility of a fishway around the dam to rehabilitate the upper river as there is a natural route that could be utilized for the fishway channel (G. Nielsen).

1. Agreements with B.C. Hydro respecting their operation should be strengthened and formalized.
2. The fishway proposal should be reconsidered.

Bessette Creek: In 1975, a joint committee, consisting of representatives from federal and provincial agencies, developed a water licence management plan for Bessette Creek and its tributaries ("Bessette Creek Watershed Committee Report", August 8, 1975). The plan established several zones, with alternative licensing procedures for each zone. It recognized both instream and off stream uses of water by use of restrictive clauses in new licences. The plan was followed for some time and was particularly helpful in expediting processing of licence applications. It seems to have been abandoned at some point, possibly because of changes of personnel in the government agencies.

1. The 1975 water licence management plan should be reviewed, updated, and reactivated. It may provide a suitable procedure for licence review on other streams.

2. Previous studies of instream flow needs should be reviewed and updated as necessary.

Duteau Creek: The Vemon Irrigation District (VID), provides water for irrigation and the City of Vemon, and controls flows in Duteau Creek through storage reservoirs in the upper watershed and operation of the Headgates diversion structure, immediately above WSC station (08LC006) on Duteau Creek. (Duteau Creek is included in the water management plan mentioned under "Bessette Creek").

The Vemon Irrigation District has several first priority licences which give them almost total control over the creek. Negotiations concerning instream flows were not particularly successful until 1977 when, under Agriculture and Rural Development Agreement (ARDA), a joint storage facility was developed in Grizzly Swamp. A licence for 1000 acre-feet of storage was issued to DFO for conservation purposes. According to the ARDA agreement this water was to be used for enhancement of the fisheries resource. As the stored water has to be released through the VID diversion structure, an agreement was drafted to arrange for the releases and for division of maintenance costs for the Grizzly Swamp reservoir. This agreement has never been signed by the VID and they have not requested payment of any of the annual maintenance and operating costs. The VID may not be releasing any more water into Duteau Creek for fish then they ever have. They claim that the DFO storage water only partially supports previous water releases into the creek and that there is no extra water for enhancement.

On February 16, 1989 there was a meeting between DFO and VID at which it was agreed that a new set of operating procedures for the reservoirs would be prepared to provide better control of the storage and releases for instream flows. The new procedures were drafted by DFO and sent to the WMB on January 9, 1990 for review and further development. Mr. Robin McNeil of the Water Management Branch (Victoria) is still reviewing the new procedures.

It has been reported that the hydrology has been affected by recent logging, especially in some of the tributaries above the reservoirs (B. Kurtz).

1. DFO should follow up on the resolutions made at the meeting of February 16, 1989 and complete some form of agreement with the Vemon Irrigation District.

2. Previous studies of instream flow needs should be reviewed and updated as necessary.

3. Rood (1989) provided a number of recommendations concerning data collection, technical studies and storage development as well as reservoir operation. These should be considered.

6.3 Thompson - Nicola HMA

Thompson River: Some side channels above Spences Bridge, used by pink salmon, go dry at times (G. Neilsen). Salmon Enhancement Program has reviewed some of these channels.

1. Modification to some side channels may ensure a more reliable flow of water. Further study would be required.

Nicola River: Studies of the Nicola River include a Strategic Water Management Plan (Anon 1983) and a report on instream flow requirements (Kosakoski and Hamilton 1982). In the late 1980's, a new dam, partly paid for by DFO, was constructed at the outlet of Nicola Lake for the joint benefit of the farmers, ranchers and fisheries. Unfortunately, the potential benefits have been limited by two problems: dredging of the channel at the lake outlet has not been completed, and the constraints, possibly not completely warranted, on maximum lake levels. A joint committee, comprising DFO, WMB and Fish & Wildlfie, meets once or twice a year to plan operations for the ensuing year.

Several years ago, DFO installed Finnegan screens on several irrigation ditch intakes, on an experimental basis. Many of these screens have since been removed or the ranchers have switched to sprinkler irrigation. It would be useful to summarize the results of that experiment as it relates to flood irrigation techniques. An assessment of screens for sprinkler intakes would also be useful.

A ground water spawning channel is proposed for the Indian Reserve, about 4 km downstream of Merritt and SEP is considering other sites along the river.

1. The joint management committee should continue to meet every year to plan the reservoir operation. it should also solve the problems of dredging and maximum reservoir levels.

2. Review screening specifications, in light of changing irrigation techniques.

3. Review the proposals and recommendations in the strategic plan and revitalize if appropriate.

Bonaparte River: Several studies have been completed, including an Environmental Management Plan (Anon 1986), and Lovdahl (1991) and Hamilton (1991) report on a storage proposal for Bonaparte Lake. The proposal to develop storage on Bonaparte Lake appears to be mutually beneficial to irrigators and fisheries. A joint management agreement would be necessary. Specific recommendations for the storage development are given in the two 1991 reports. SEP is involved in the detailed planning of the project. There is some concern over resident trout in Bonaparte Lake and their migration past the proposed new dam. Other recommendations in the two reports are:

1. Review water licences and actual water use.

2. Study the possibility of storage development in other lakes.

3. Review fisheries resource maintenance flow requirements for the fall and winter.

4. Develop a policy for the protection of riparian vegetation.

The Bonaparte Lake Dam is scheduled for construction in 1992.

Deadman River: A report prepared in 1974 by DFO contains recommendations for instream flows and reservoir management. In the late 1970's, a new dam was completed at Snohoosh Lake under ARDA to jointly benefit agriculture and fisheries and a legal agreement was entered into by DFO and the Deadman Creek Improvement District. Under the terms of the agreement DFO pays for a part of the operating and maintenance costs in return for provision of certain instream flows. DFO does not have a water licence, but the licence issued to the district contains a clause guaranteeing instream flow.

There have been various changes to the river and, possibly, to land and water use in the valley since the 1974 report. The Indian Band operates a SEP hatchery and at least one major obstacle to upstream migration has been eliminated.

In 1991 a groundwater fed channel for coho (utilizing the existing hatchery outflow) was built on the upper limit of the indian reserve (M. Sheng).

There appears to be a need to modify the flow control on the river to better accomodate steelhead. Fish and Wildlife have storage licences on Tsintsunko lake and another lake in the Criss Creek drainage which might be developed. A suggestion has also been made that water could be pumped to the lower Deadman River from the Thompson River. Either of these alternatives would provide water to the Reserve and permit release of water stored in the Snohoosh Reservoir for instream flows.

Streambank improvements (riprap and planting), funded by SEP and the Habitat Conservation Fund (HCF) have been completed at several sites, including Docksteader's farm, where livestock watering was a problem.

1. A check should be made, from time to time, that the terms of the legal agreement are being fulfilled.

2. Reservoir management should be reviewed annually.

3. Recommendations made in the 1986 management plan should receive serious consideration.

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TABLES

Table 1: Definitions of Flow characteristics

Annual flood - Maximum or "peak" daily flow of the year.

Annual flow - Average of the daily flows between January 1 and December 31 for a particular year.

Annual 7 day low flow - The lowest average flow for 7 consecutive days between January 1 and December 31. Same as "7 day mean low" used in Appendix C.

Daily flow - Average flow for the period midnight to midnight.

Mean annual flood - Average of the annual floods for a stated historic period.

Mean annual flow - Average of the annual flows for a stated historic period.

Mean annual 7 day low flow - Average of the 7 day low flows for a stated historic period.

Mean August flow - Average of the August flows for a stated historic period.

Mean September flow - Average of the September flows for a stated historic period.

Mean summer 7 day low flow - Average of the summer 7 day low flows for a stated historic period.

Mean winter 7 day low flow - Average of the winter 7 day low flows for a stated historic period.

Naturalized flow - Measured flows, adjusted with upstream water licences, to represent the flows that would occur in the absence of regulation and extraction.

Summer 7 day low flow - The lowest average flow for 7 consecutive days between May 1 and October 31.

Water demand - Sum of all the consumptive uses upstream of a reference point, as estimated from water licences.

Winter 7 day low flow - The average flow for 7 consecutive days between November 1 and April 30.

Unit flow - The flow at a reference point, usually a Water Survey of Canada station, divided by the basin area above that reference point.

Table 2: North Thompson Habitat Management Area -- Salmon Streams

Stream Name	WSC Gauge No.	Basin Area (mouth) (km2)	Logged Area Recent (km2)	Logged Area Older (km2)	Improved Farmland (1990) (km2)	Total Water Licenses: Domestic (g/day)	Irrigation (ac-ft)	Waterworks (g/day)	Industrial (g/day)	Conservation (cfs)	Licensed Demand (L/s): Aug	Sept	Feb	Naturalized Flows in the Salmon Streams (m3/s): Mean Annual	Mean Flood	Mean Monthly Aug	Mean Monthly Sept	Mean 7 day Low Summer	Mean 7 day Low Winter
N. Thompson R		20742	2511.9	2211.1	91.55	-	-	-	-	-	-	-	-	420.0	1890	406.08	270	205	76
Louis Creek	LB072	526	32.1	77.1	6.59	32,000	4,703	122,000	182,996	0.6	552	332	1	2.7	23.4	1.76	1.34	1.05	0.57
Christian Ck		19	1.9	5.6	0.33	3,500	950	0	500	0.6	111	67	0	0.1	0.9	0.11	0.07	0.07	0.003
Barriere R	LB020	1151	113.8	225.7	1.63	70,500	2,710	2,002,500	24,000	0	326	199	9	14.1	94.9	7.58	5.32	3.85	2.62
E. Barriere R.		318	36.5	59	0	45,500	313	2,500	500	0	37	22	0	3.9	41.0	1.31	0.97	0.68	0.42
Haggard Ck		92	13.7	13.7	0	4,500	32	0	0	0	4	2	0	1.1	19.0	0.45	0.36	0.2	0.14
Fennell Ck		110	5.5	22	0	500	0	0	0	0	0	0	0	1.4	27.2	0.34	0.36	0.15	0.12
Lemieux Ck	LB078	454	45.4	45.4	1.68	11,000	921	0	1,182,103	0	113	70	5	2.9	22.1	1.74	1.12	0.78	0.58
Joseph Ck		259	25.5	34.6	0.27	7,000	800	5,000	0	1.07	94	56	0	6.4	53.4	3.43	2.94	1.87	0.79
Dunn Ck		105	2.5	19.2	0.27	500	272	0	0	0.07	32	19	0	2.6	21.6	1.41	1.27	0.69	0.33
McTaggart Ck		21	0	7.4	0.27	500	231	0	0	0	27	16	0	0.1	1.0	0.06	0.04	0.03	0.01
Mann Ck	LB050	295	72.7	29.1	0	9,000	731	40,000	27,500	0	86	52	0	3.0	29.8	1.37	1.20	0.60	0.33
Clearwater R	LA001	10551	1315.7	804	36.79	123,800	10,921	2,270,000	161,986	10.3	1289	778	11	220.0	966.0	290.3	78.3	50.38	22.4
Brookfield Ck		92	18.3	4.6	0.8	0	52	10,000	30,000	0	6	4	0	1.7	15.5	0.42	0.34	0.19	0.14
Mahood R	LA008	4915	1228.7	737.2	35.09	86,300	9,332	4,060,000	124,486	0.3	1111	674	19	33.7	166.0	24.6	16.6	12	7
Raft R		764	189.3	113.6	0.63	2,500	879	0	1,500	0	103	62	0	15.2	116.6	4.42	3.75	2	1.1
Reg Christie Ck		76	11.3	3.8	0	1,000	342	0	0	0	40	24	0	1.5	10.8	0.50	0.42	0.22	0.15

1. Shading indicates gauged salmon streams.
2. Logged areas, improved farmland, mean annual flows and mean annual flood from Sigma (1991).
3. Total water licences for each salmon stream expressed in imperial units, as provided by Water Management Branch.
4. Reference for all data in table is the mouth of the salmon stream.
5. Licenced demands (L/s) calculated from total water licences as described in body of report.
6. Naturalized flows are estimates of those that would occur in the absence of all upstream regulation and water extractions.

Table 2: Continued

Stream Name	WSC Gauge No.	Basin Area (mouth) (km2)	Logged Area Recent (km2)	Logged Area Older (km2)	Improved Farmland (1990) (km2)	Lic Total Water Licences Domes-tic (g/day)	Irrig-ation (ac-ft)	Water-works (g/day)	Indus-trial (g/day)	Conser-vation (cfs)	Licensed Demand (L/s) Aug	Sept	Feb	Naturalized Flows in the Salmon Streams (m3/s) Mean Annual	Mean Flood	Mean Monthly Aug	Mean Monthly Sept	Mean 7 day Low Summer	Mean 7 day Low Winter
Mad R		227	45.4	45.4	0	0	0	0	0	0	0	0	0	4.5	42.2	0.98	0.74	0.49	0.31
Unnamed Ck (04-4210)		11	4	0	0	0	0	0	0	0	0	0	0	0.2	2.0	0.07	0.06	0.025	0.023
Avola Ck		5	0	2.1	0	0	0	45,000	0	0	0	0	0	0.1	0.9	0.03	0.03	0.011	0.011
Unnamed Ck (04-4600)		10	2.4	0	0	0	0	0	0	0	0	0	0	0.2	1.9	0.06	0.06	0.02	0.02
Tumtum Ck		24	2.4	1.2	0	0	0	0	0	0	0	0	0	0.5	4.5	0.10	0.08	0.035	0.033
Lion Ck		46	9.3	9.3	0	0	0	0	0	10	0	0	0	0.9	8.6	0.17	0.14	0.069	0.061
Finn Ck		134	33.4	13.4	0	500	0	0	0	2.7	0	0	0	4.7	39.1	1.19	1.01	0.58	0.32
Goose Ck		9	2.2	1.8	0	0	0	0	0	0	0	0	0	0.3	2.6	0.02	0.014	0.005	0.008
Blue R	LB038	275	19.2	22	0	0	0	200,000	5,000	0	1	1	1	9.7	80.3	7.21	4.93	3.17	1.21
Cedar Ck		11	1.1	1.7	0	1,000	11	0	0	0	1	1	0	0.4	3.2	0.07	0.066	0.025	0.023
Cook Ck		11	1.1	1.7	0	1,000	0	0	0	0	0	0	0	0.4	3.2	0.09	0.09	0.034	0.028
Albreda R		406	28.5	32.5	0	500	0	0	1,000	0	0	0	0	14.3	118.6	3.37	2.68	1.89	0.87

1. Shading indicates gauged salmon streams.
2. Logged areas, improved farmland, mean annual flows and mean annual flood from Sigma (1991).
3. Total water licences for each salmon stream expressed in imperial units, as provided by Water Management Branch.
4. Reference for all data in table is the mouth of the salmon stream.
5. Licenced demands (L/s) calculated from total water licences as described in body of report.
6. Naturalized flows are estimates of those that would occur in the absence of all upstream regulation and water extractions.

Table 3: South Thompson - Shuswap Habitat Management Area -- Salmon Streams

Stream Name	WSC Gauge No.	Basin Area (mouth) (km2)	Logged Area Recent (km2)	Logged Area Older (km2)	Improved Farmland (1990) (km2)	Total Water Licenses: Domestic (g/day)	Irrigation (ac-ft)	Waterworks (g/day)	Industrial (g/day)	Conservation (cfs)	Licensed Demand (L/s): Aug	Sept	Feb	Naturalized Flows in the Salmon Streams (m3/s): Mean Annual	Mean Flood	Mean Monthly Aug	Mean Monthly Sept	Mean 7-day Flow Summer	Mean 7-day Flow Winter
S. Thompson R (lower mainstem)	LE031	17311	1644.5	2830.4										311.0	930.0	397	242		62.20
Chase Ck		297	17.8	41.6	3.64	22,100	2,559	6,000	716,298	0	303	183	3	1.4	13.5	0.68	0.50	0.30	0.10
S. Thompson R (upper mainstem)		15209	1455.5	2428.8	299.55									17.8	71.3		–		
Adams R	LD001	3323	205	397.1	6.53	46,000	3,553	52,000	1,449,209	2	423	258	7	74.1	230.0	110.42	73.96	46.12	22.60
Hiuihill Ck		110	11	21.9	0.97	3,500	1,068	0	936,209	0	129	79	4	1.4	11.1	0.30	0.21	0.15	0.10
Nikwikwaia Ck		97	11.7	22.3	0	–	–	–	–	–	0	0	0	1.2	9.8	0.25	0.16	0.13	0.08
Adams R (upper -- above Adams Lake)		3087	179	343.8	5.51												–		
Sinmax Ck		191	28.6	38.2	5.51	8,000	1,897	0	47,500	0	222	133	0	0.8	3.0	0.63	0.39	0.30	0.20
Momich R		477	27.3	61.9	0	–	–	–	–	–	0	0	0	21.1	152.2	5.30	4.50	3.58	1.90
Cayenne Ck		368	22.1	51.5	0	–	–	–	–	–	0	0	0	16.3	117.4	4.10	3.50	2.74	1.52
Scotch Ck		611	61	183.2	0.54	1,500	203	0	0	0	24	14	0	7.7	61.7	5.40	4.40	3.59	1.94
Onyx Ck		57	5.7	17.3	2.15	6,000	543	0	0	0	64	38	0	1.0	9.6	0.27	0.18	0.13	0.09
Ross Ck		106	10.6	31.7	0	0	535	0	0	0	63	38	0	1.9	17.8	0.60	0.51	0.24	0.15
Seymour R	LE027	807	40.3	96.8	0.27	5,000	26	0	0	0	3	2	0	35.7	257.4	32.50	25.60	11.70	6.70
McNomee Ck		68	3.4	23.7	0	–	–	–	–	–	0	0	0	3.0	21.7	0.83	0.76	0.38	0.21
Hunakwa Ck		35	0	8.8	0	–	–	–	–	–	0	0	0	0.9	7.0	0.21	0.18	0.08	0.07

1. Shading indicates gauged salmon streams.
2. Logged areas, improved farmland, mean annual flows and mean annual flood from Sigma (1991).
3. Total water licences for each salmon stream expressed in imperial units, as provided by Water Management Branch.
4. Reference for all data in table is the mouth of the salmon stream.
5. Licenced demands (L/s) calculated from total water licences as described in body of report.
6. Naturalized flows are estimates of those that would occur in the absence of all upstream regulation and water extractions.

Table 3: Continued

Stream Name	WSC Gauge No.	Basin Area (mouth) (km2)	Logged Area Recent (km2)	Logged Area Older (km2)	Improved Farmland (1990) (km2)	Total Water Licenses Domestic (g/day)	Irrigation (ac-ft)	Waterworks (g/day)	Industrial (g/day)	Conservation (cfs)	Licensed Demand (L/s) Aug	Sept	Feb	Naturalized Flows in the Salmon Streams (m3/s) Mean Annual	Mean Flood	Mean Monthly Aug	Mean Monthly Sept	Mean 7-day Flow Summer	Mean 7-day Flow Winter
Anstey R		238	23.8	59.4	0	0	0	0	0	0	0	0	0	10.5	75.9	3.26	2.81	1.76	0.74
Eagle R	LE024	1246	158.1	154.6	10.8	42,000	2,306	18,500	5,543,685	10	294	186	25	37.7	236.0	30.79	23.89	18.25	10.34
Owlhead Ck		24	0.5	3	0.65	2,000	62	0	0	0	7	4	0	1.0	6.0	0.27	0.26	0.11	0.07
Perry R		438	43.8	65.7	0	0	0	0	0	0	0	0	0	19.4	139.7	8.15	7.07	4.85	1.66
South Pass Ck		31	1.6	9.2	0	0	0	0	0	0	0	0	0	1.3	9.0	0.60	0.60	0.26	0.14
Relenecker Ck		53	2.6	15.8	0	0	0	0	0	0	0	0	0	1.0	9.6	0.30	0.25	0.13	0.09
Tappen Ck		131	6	36.2	5.98	49,000	1,002	0	308,428	10	119	72	2	0.3	0.8	0.45	0.34	0.20	0.15
Salmon R	LE021	1501	161.4	439.1	88.1	132,750	19,562	40,000	40,879	0	2290	1374	1	4.6	28.6	3.90	3.15	2.58	1.50
Bolean Ck	LE094	221	33.2	55.4	2.16	8,000	705	0	0	0	83	50	0	1.1	7.9	0.39	0.46	0.17	0.11
Canoe Ck		80	1.6	18.3	12.07	17,500	296	2,233,000	4,446	0	45	31	10	0.2	1.0	0.13	0.09	0.04	0.05
Shuswap R	LC002	5415	674.6	770.5	?	313,350	49,100	12,011,402	2,951,682	1.38	5813	3514	67	101.0	420.3	78.32	56.51	45.75	37.91
Shuswap R	LC018	1372	115.5	203.4	116.28									18.6	93.2	65.30	50.10		
(Mabel Lake to Mara Lake)																			
Johnson Ck		22	1.1	3.2	0.32	3,500	171	0	0	0	20	12	0	0.9	6.4	0.28	0.27	0.11	0.07
Blurton Ck		24	1.2	7.2	0.27	8,500	270	0	5,000	0	32	19	0	1.0	7.0	0.25	0.23	0.10	0.07
Fortune Ck		151	3	12.1	60.98	13,250	799	2,544,000	29,403	0	105	67	11	1.2	10.0	0.25	0.20	0.13	0.10
Trinity Ck		195	13.7	15.6	2.72	7,000	1,632	0	3,000	0	191	115	0	2.0	8.5	0.41	0.33	0.25	0.10

1. Shading indicates gauged salmon streams.
2. Logged areas, improved farmland, mean annual flows and mean annual flood from Sigma (1991).
3. Total water licences for each salmon stream expressed in imperial units, as provided by Water Management Branch.
4. Reference for all data in table is the mouth of the salmon stream.
5. Licenced demands (L/s) calculated from total water licences as described in body of report.
6. Naturalized flows are estimates of those that would occur in the absence of all upstream regulation and water extractions.

Table 3: Continued

Stream Name	WSC Gauge No.	Basin Area (mouth) (km2)	Logged Area Recent (km2)	Logged Area Older (km2)	Improved Farmland (1990) (km2)	Total Water Licenses: Domestic (g/day)	Irrigation (ac-ft)	Waterworks (g/day)	Industrial (g/day)	Conservation (cfs)	Licensed Demand (L/s): Aug	Sept	Feb	Naturalized Flows in the Salmon Streams (m3/s): Mean Annual	Mean Flood	Mean Monthly Aug	Mean Monthly Sept	Mean 7-day Flow Summer	Mean 7-day Flow Winter
Kingfisher Ck		192	17.7	49.4	0	500	38	0	53,855	0	5	3	0	8.1	55.7	1.42	1.15	0.72	0.39
Danforth Ck		29	1.5	8.8	0	–	–	–	–	–	0	0	0	1.2	8.4	0.15	0.13	0.06	0.05
Shuswap River	LC019	4029	556	565.3	56.83														
Noisy Ck		59	5.8	17.6	0	0	0	0	0	0	0	0	0	2.5	17.1	0.64	0.58	0.29	0.17
Wap Ck		354	35.4	53.1	0	0	0	0	0	0	0	0	0	14.9	102.7	6.11	5.31	3.52	1.28
Tsuius Ck		210	20.9	31.5	0	–	–	–	–	–	0	0	0	8.8	60.9	2.34	1.98	1.23	0.57
Ireland Ck		104	8.3	12.5	0.8	2,500	680	0	2,500	0	80	48	0	4.4	30.2	0.50	0.40	0.23	0.16
Bessette Ck	LC039	795	109.5	78.5	39.24	49,600	30,939	2,537,901	148,164	1.38	3633	2184	12	4.5	34.3	5.56	4.40	3.30	0.95
Creighton Ck		154	15.4	23.1	10.96	12,000	1,733	0	1,000	0	203	122	0	0.9	7.8	0.59	0.45	0.28	0.20
Duteau Ck	LC006	217	54.3	21.7	11.73	9,000	18,329	2,537,901	40,164	1.38	2156	1298	11	1.2	11.0	0.69	0.41	0.30	0.23
Harris Ck		212	21.2	10.6	0	0	8,000	0	2,000	0	936	562	0	1.2	10.7	1.39	1.11	0.71	0.39

1. Shading indicates gauged salmon streams.
2. Logged areas, improved farmland, mean annual flows and mean annual flood from Sigma (1991).
3. Total water licences for each salmon stream expressed in imperial units, as provided by Water Management Branch.
4. Reference for all data in table is the mouth of the salmon stream.
5. Licenced demands (L/s) calculated from total water licences as described in body of report.
6. Naturalized flows are estimates of those that would occur in the absence of all upstream regulation and water extractions.

Table 4: Thompson - Nicola Habitat Management Area -- Salmon Streams

Stream Name	WSC Gauge No.	Basin Area (mouth) (km2)	Logged Area Recent (km2)	Logged Area Older (km2)	Improved Farmland (1990) (km2)	Total Water Licences Domes-tic (g/day)	Total Water Licences Irrig-ation (ac-ft)	Total Water Licences Water-works (g/day)	Total Water Licences Indus-trial (g/day)	Total Water Licences Conser-vation (cfs)	Licensed Demand (L/s) August	Licensed Demand (L/s) Sept	Licensed Demand (L/s) March	Naturalized Flows in the Salmon Streams (m3/s) Mean Annual	Mean Flood	Mean Monthly Aug	Mean Monthly Sept	Mean 7 day Low Summer	Mean 7 day Low Winter
Thompson R	LF051	55665	2313.4	2909.3	150.4									759	2650	981.00	444.00		
Nicola R	LG006	7227	727.1	1180.9	60.7	222,400	72,669	2,342,203	12,898,501	408.6	8572	5170	68	22.7	180	15.92	11.02	9.51	5.06
Spius Ck	LG008	780	138.9	95.2	1.4	6,500	1,664	0	0	0	195	117	0	9.33	80.9	1.84	1.41	0.97	1.56
Maka Ck		217	54.2	10.8	0	-	-	-	-	-	0	0	0	2.6	22.5	0.51	0.39	0.24	0.43
Coldwater R	LG010	915	45.7	274.5	9.5	40,350	5,804	2,000,703	3,000	3	688	416	9	7.42	74.3	1.92	1.43	1.06	1.37
Spahomin Ck	LG060	237	11.9	11.9	4.4	500	4,405	0	20,000	237	516	309	0	0.62	3.77	1.03	0.40	0.38	0.09
Bonaparte R	LF002	5390	1078.1	1078.1	27.4	108,900	30,238	2,696,262	4,157,290	0	3569	2154	31	4.51	20.8	8.12	4.57	3.66	1.00
Deadman R	LF027	1497	149.7	299.5	6.9	32,001	11,436	0	5,000	11.1	1338	803	0	2.85	24	2.98	2.16	1.46	0.49

1. Shading indicates gauged salmon streams.
2. Logged areas, improved farmland, mean annual flows and mean annual flood from Sigma (1991).
3. Total water licences for each salmon stream expressed in imperial units, as provided by Water Management Branch.
4. Reference for all data in table is the mouth of the salmon stream.
5. Licenced demands (L/s) calculated from total water licences as described in body of report.
6. Naturalized flows are estimates of those that would occur in the absence of all upstream regulation and water extractions.

Table 5: Storage -- North Thompson HMA

Stream Name	Total Non-Power Storage (ac-ft)	Total Irrigation Licences (ac-ft)	Percent with Storage (%)
Louis Ck	600	4703	13
Christian Ck	600	950	63
Barriere R	1047.5	2710	39
E. Barriere R	0	313	0
Haggard Ck	0	32	0
Fennell Ck	0	0	-
Lemieux Ck	225	921	24
Joseph Ck	12	800	2
Dunn Ck	0	272	0
McTaggart Ck	0	231	0
Mann Ck	502	731	69
Clearwater R	5384.2	10921	49
Brookfield Ck	0	52	0
Mahood R	5357	9332	57
Raft R	120	879	14
Reg Christie Ck	0	342	0

Table 5: Storage -- North Thompson HMA

Stream Name	Total Non-Power Storage (ac-ft)	Total Irrigation Licences (ac-ft)	Percent with Storage (%)
Mad R	0	0	-
Unnamed Ck	0	0	-
Avola Ck	0	0	-
Unnamed Ck	0	0	-
Tumtum Ck	0	0	-
Lion Ck	0	0	-
Finn Ck	0	0	-
Goose Ck	0	0	-
Blue R	0	0	-
Cedar Ck	0	11	0
Cook Ck	0	0	-
Albreda R	1	0	-
TOTAL	7,892	22,018	36

1. "Non-power" includes all storage for domestic, waterworks, industrial, irrigation or conservation licences.
2. Irrigation licences for each salmon stream from Table 2.
3. Percent with storage calculated by dividing non-power storage by total irrigation licences for each salmon stream.
4. "TOTAL" only counts licences in each basin once.

Table 6: Storage -- South Thompson-Shuswap HMA

Stream Name	Total Non-power Storage (ac-ft)	Total Irrigation Licences (ac-ft)	Percent with Storage (%)
Chase Ck	1,156	2,559	45
Adams R	1,139	3,553	32
Hiuihill Ck	8	1,068	1
Nikwikwaia Ck	-	0	-
Sinmax Ck	1,066	1,897	56
Momich R	-	0	-
Cayenne Ck	-	0	-
Scotch Ck	0	203	0
Onyx Ck	0	543	0
Ross Ck	0	535	0
Seymour R	0	26	0
McNomee Ck	-	0	-
Hunakwa Ck	-	0	-

Table 6: Storage -- South Thompson-Shuswap HMA

Stream Name	Total Non-power Storage (ac-ft)	Total Irrigation Licences (ac-ft)	Percent with Storage (%)
Anstey R	-	0	-
Eagle R	3	2,306	0
Owlhead Ck	0	62	0
Perry R	0	0	-
South Pass Ck	-	0	-
Reienecker Ck	-	0	-
Tappen Ck	0	1,002	0
Salmon R	4,377	19,562	22
Bolean Ck	16	705	2
Canoe Ck	35	296	12
Shuswap R	30,643	49,100	62
Johnson Ck	0	172	0
Blurton Ck	0	270	0
Fortune Ck	1,023	799	128
Trinity Ck	5	1,632	0

Table 6: Storage -- South Thompson-Shuswap HMA

Stream Name	Total Non-power Storage (ac-ft)	Total Irrigation Licences (ac-ft)	Percent with Storage (%)
Kingfisher Ck	0	38	0
Danforth Creek	-	0	-
Noisy Ck	0	0	-
Wap Ck	0	0	-
Tsuius Ck	-	0	-
Ireland Ck	480	680	71
Bessette Ck	28,776	30,939	93
Creighton Ck	115	1,733	7
Duteau Ck	26,795	18,329	146
Harris Ck	0	8,000	0
TOTAL	37,353	79,685	47

1. "Non-power" includes all storage for domestic, waterworks, industrial, irrigation or conservation licences.
2. Irrigation licences for each salmon stream from Table 3.
3. Percent with storage calculated by dividing non-power storage by total irrigation licences for each salmon stream.
4. "TOTAL" only counts licences in each basin once.

Table 7: Storage -- Thompson-Nicola HMA

Stream Name	Total Non-Power Storage (ac-ft)	Total Irrigation Licences (ac-ft)	Percent with Storage (%)
Nicola River	73,260	72,669	101
Spius Creek	110	1,664	7
Maka Creek	0	0	-
Coldwater River	1,679	5,804	29
Spahomin Ck.	1,668	4,405	38
Bonaparte River	7,395	30,238	24
Deadman River	7,120	11,436	62
TOTAL	87,775	114,343	77

1. "Non-power" includes all storage for domestic, waterworks, industrial or conservation licences.
2. Irrigation licences for each salmon stream from Table 4.
3. Percent with storage calculated by dividing non-power storag by total irrigation licences for each salmon stream.
4. "TOTAL" only counts licences in each basin once.

Table 8: Sensitivity Indices -- North Thompson HMA

Stream Name	Status	SUMMER WATER USE Index 1 Aug Use/ Sum Q7L2	Index 2 Sept Use/ Sum Q7L2	Index 3 Aug Use/ mean Aug	Index 4 Sept Use/ mean Sept	LOW FLOWS Index 5 Sum Q7L2/ QAA	Index 6 Win Q7L2/ QAA	PEAK FLOWS Index 7 Q2/ QAA	LOGGING Index 8 Recent/ Basin	Index 9 Total/ Basin
N. Thompson R		-	-	-	-	49	18	5	12	23
Louis Creek	FR	52	32	31	25	26	21	9	6	21
Christian Ck	FR	164	99	98	99	1	3	9	10	39
Barriere R		8	5	4	4	26	19	7	10	29
E. Barriere R.		5	3	3	2	17	11	10	11	30
Haggard Ck		2	1	1	1	17	12	17	15	30
Fennell Ck		0	0	0	0	11	9	20	5	25
Lemieux Ck		14	9	6	6	24	20	8	10	20
Joseph Ck		5	3	3	2	28	12	8	10	23
Dunn Ck		5	3	2	2	26	13	8	2	21
McTaggart Ck	PWS	103	62	47	45	9	9	9	0	35
Mann Ck		14	9	6	4	18	11	10	25	35
Clearwater R	RES	3	2	0	1	23	10	4	12	20
Brookfield Ck		3	2	1	1	11	8	9	20	25
Mahood R		10	6	5	4	33	21	5	25	40
Raft R		5	3	2	2	13	7	8	25	40
Reg Christie Ck		18	11	8	6	13	10	7	15	20

1. Status refers to restrictions noted by the Water Management Branch: FR, fully recorded with exceptions for storage; RES, reserved, no licencing; PWS, possible water shortages.
2. Aug and Sept Use are total demands in these months; Sum and Win Q7L2 are summer and winter mean 7 day low flows; mean Aug and and Sept are mean August and September monthly flows; QAA is mean annual flow; Q2 is the mean annual flood; Recent and Total are recent and total logging areas in the basin; Basin is basin area above the mouth.
3. Indices expressed as percentages except 7, which is a direct ratio.
4. Shading indicates salmon streams with most extreme values for the various indices. The most extreme 25% are shown for Indices 1 to 6; values of Index 7 exceeding 10 are shaded; and values of Index 8 exceeding 20% are shaded.

Table 8: Continued

		SUMMER WATER USE				LOW FLOWS		PEAK FLOWS	LOGGING	
Stream Name	Status	Index 1 Aug Use/ Sum Q7L2	Index 2 Sept Use/ Sum Q7L2	Index 3 Aug Use/ mean Aug	Index 4 Sept Use/ mean Sept	Index 5 Sum Q7L2/ QAA	Index 6 Win Q7L2/ QAA	Index 7 Q2/ QAA	Index 8 Recent/ Basin	Index 9 Total/ Basin
Mad R		0	0	0	0	11	7	9	20	40
Unnamed Ck (04-4210)		0	0	0	0	11	11	9	36	36
Avola Ck		2	2	1	1	11	11	9	0	42
Unnamed Ck (04-4600)		0	0	0	0	10	10	9	24	24
Tumtum Ck		0	0	0	0	7	7	9	10	15
Lion Ck		0	0	0	0	8	7	9	20	40
Finn Ck		0	0	0	0	12	7	8	25	35
Goose Ck		0	0	0	0	2	3	8	24	44
Blue R		0	0	0	0	33	12	8	7	15
Cedar Ck		5	3	2	1	6	6	8	10	25
Cook Ck		0	0	0	0	9	7	8	10	25
Albreda R		0	0	0	0	13	6	8	7	15

no licencing; PWS, possible water shortages.

2. Aug and Sept Use are total demands in these months; Sum and Win Q7L2 are summer and winter mean 7 day low flows; mean Aug and and Sept are mean August and September monthly flows; QAA is mean annual flow; Q2 is the mean annual flood; Recent and Total are recent and total logging areas in the basin; Basin is basin area above the mouth.
3. Indices expressed as percentages except 7, which is a direct ratio.
4. Shading indicates salmon streams with most extreme values for the various indices. The most extreme 25% are shown for Indices 1 to 6; values of Index 7 exceeding 10 are shaded; and values of Index 8 exceeding 20% are shaded.

Table 9: Sensitivity Indices -- South Thompson - Shuswap HMA

		SUMMER WATER USE				LOW FLOWS		PEAK FLOW	LOGGING	
Stream Name	Status	Index 1 Aug Use/ Sum Q7L2	Index 2 Sept Use/ Sum Q7L2	Index 3 Aug Use/ mean Aug	Index 4 Sept Use/ mean Sept	Index 5 Sum Q7L2/ QAA	Index 6 Win Q7L2/ QAA	Index 7 Q2/ QAA	Index 8 Recent/ Basin	Index 9 Total/ Basin
S. Thompson R (lower mainstem)								3	9	26
Chase Ck	RES	101	61	44	36	8	7	10	6	20
S. Thompson R (upper mainstem)								4	10	26
Adams R	RES	1	1	0	0	62	30	3	6	18
Hiuihill Ck	RES	86	53	43	38	5	7	8	10	30
Nikwikwaia Ck		0	0	0	0	11	7	8	12	35
Adams R (upper -- above Adams Lake)	RES								6	17
Sinmax Ck	FR	74	44	35	34	21	25	4	15	35
Momich R		0	0	0	0	17	9	7	6	19
Cayenne Ck		0	0	0	0	17	9	7	6	20
Scotch Ck		1	0	0	0	46	25	8	10	40
Onyx Ck		49	29	24	21	9	9	9	10	40
Ross Ck		26	16	10	7	10	8	9	10	40
Seymour R		0	0	0	0	33	19	7	5	17
McNomee Ck		0	0	0	0	13	7	7	5	40
Hunakwa Ck		0	0	0	0	9	8	8	0	25

1. Status refers to restrictions noted by the Water Management Branch: FR, fully recorded with exceptions for storage; RES, reserved, no licencing; PWS, possible water shortages.
2. Aug and Sept Use are total demands in these months; Sum and Win Q7L2 are summer and winter mean 7 day low flows; mean Aug and and Sept are mean August and September monthly flows; QAA is mean annual flow; Q2 is the mean annual flood; Recent and Total are recent and total logging areas in the basin; Basin is basin area above the mouth.
3. Indices expressed as percentages except 7, which is a direct ratio.
4. Shading indicates salmon streams with most extreme values for the various indices. The most extreme 25% are shown for Indices 1 to 6; values of Index 7 exceeding 10 are shaded; and values of Index 8 exceeding 20% are shaded.

Table 9: Sensitivity Indices -- South Thompson - Shuswap HMA

Stream Name	Status	SUMMER WATER USE Index 1 Aug Use/ Sum Q7L2	Index 2 Sept Use/ Sum Q7L2	Index 3 Aug Use/ mean Aug	Index 4 Sept Use/ mean Sept	LOW FLOWS Index 5 Sum Q7L2/ QAA	Index 6 Win Q7L2/ QAA	PEAK FLOW Index 7 Q2/ QAA	LOGGING Index 8 Recent/ Basin	Index 9 Total/ Basin
Anstey R		0	0	0	0	17	7	7	10	35
Eagle R		2	1	1	1	48	27	6	13	25
Owlhead Ck		7	4	3	2	10	7	6	2	15
Perry R		0	0	0	0	25	9	7	10	25
South Pass Ck		0	0	0	0	20	11	7	5	35
Relenecker Ck		0	0	0	0	13	9	10	5	35
Tappen Ck		59	36	26	21	43	50	3	5	32
Salmon R	RES	89	53	59	44	26	33	6	11	40
Bolean Ck	RES	49	29	21	11	11	10	7	15	40
Canoe Ck	RES	114	79	34	34	4	25	5	2	25
Shuswap R		13	8	7	6	42	38	4	12	27
Shuswap R (Mabel Lake to Mara Lake)								5	8	23
Johnson Ck		18	11	7	4	11	8	7	5	20
Blurton Ck		32	19	13	8	8	7	7	5	35
Fortune Ck		82	53	41	34	5	8	8	2	10
Trinity Ck		75	45	46	34	7	5	4	7	15

1. Status refers to restrictions noted by the Water Management Branch: FR, fully recorded with exceptions for storage; RES, reserved, no licencing; PWS, possible water shortages.
2. Aug and Sept Use are total demands in these months; Sum and Win Q7L2 are summer and winter mean 7 day low flows; mean Aug and and Sept are mean August and September monthly flows; QAA is mean annual flow; Q2 is the mean annual flood; Recent and Total are recent and total logging areas in the basin; Basin is basin area above the mouth.
3. Indices expressed as percentages except 7, which is a direct ratio.
4. Shading indicates salmon streams with most extreme values for the various indices. The most extreme 25% are shown for Indices 1 to 6; values of Index 7 exceeding 10 are shaded; and values of Index 8 exceeding 20% are shaded.

Table 9: Sensitivity Indices -- South Thompson - Shuswap HMA

Stream Name	Status	SUMMER WATER USE				LOW FLOWS		PEAK FLOW	LOGGING	
		Index 1 Aug Use/ Sum Q7L2	Index 2 Sept Use/ Sum Q7L2	Index 3 Aug Use/ mean Aug	Index 4 Sept Use/ mean Sept	Index 5 Sum Q7L2/ QAA	Index 6 Win Q7L2/ QAA	Index 7 Q2/ QAA	Index 8 Recent/ Basin	Index 9 Total/ Basin
Kingfisher Ck		1	0	0	0	9	5	7	9	35
Danforth Ck		0	0	0	0	5	4	7	5	36
Shuswap River									14	28
Noisy Ck		0	0	0	0	12	7	7	10	40
Wap Ck		0	0	0	0	24	9	7	10	25
Tsuius Ck		0	0	0	0	14	6	7	10	25
Ireland Ck		35	21	16	12	4	4	7	8	20
Bessette Ck		110	66	65	50	25	21	8	14	24
Creighton Ck		74	44	35	27	18	23	9	10	25
Duteau Ck		719	433	312	317	15	8	9	25	35
Harris Ck		132	79	67	51	12	33	9	10	15

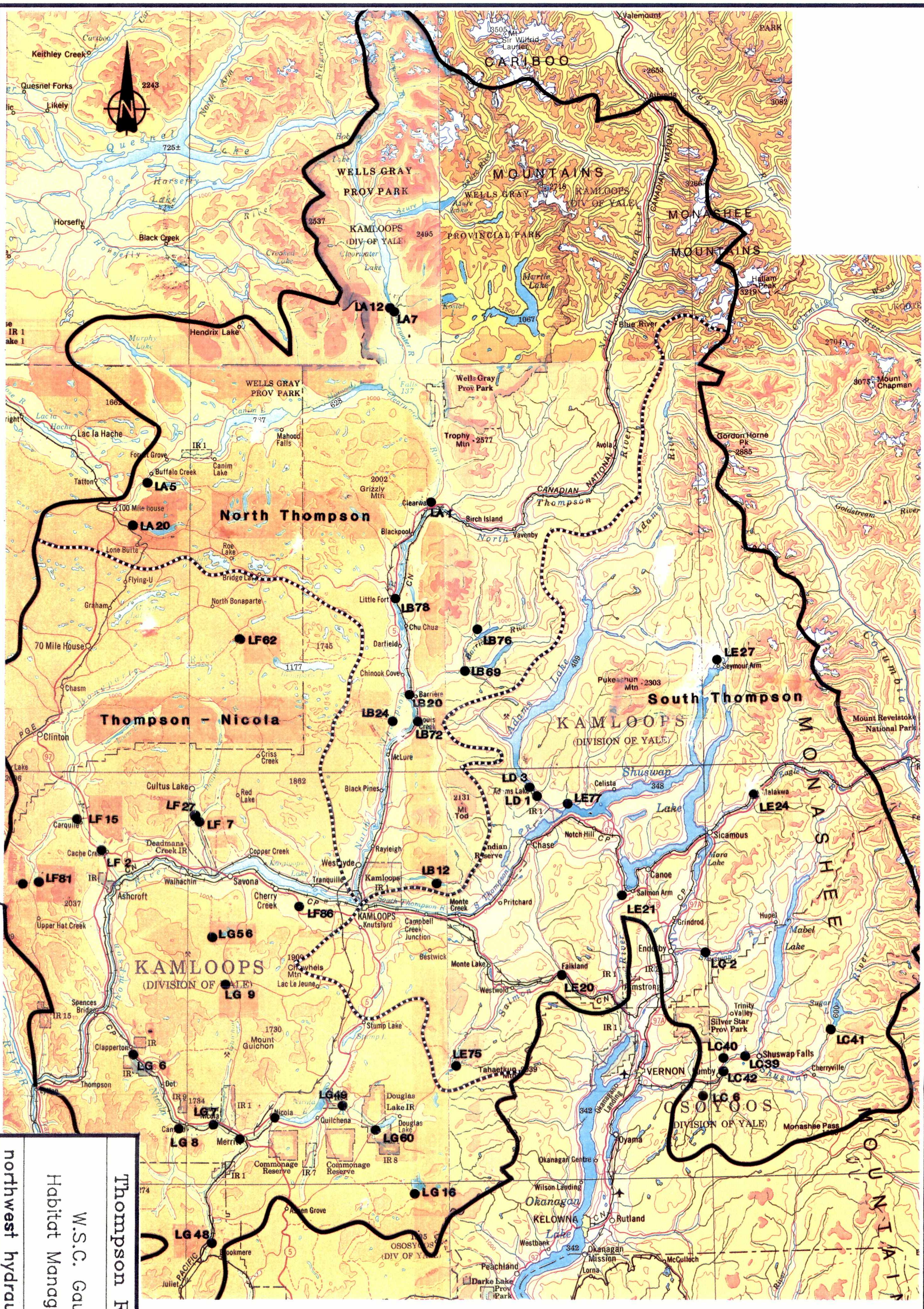
1. Status refers to restrictions noted by the Water Management Branch: FR, fully recorded with exceptions for storage; RES, reserved, no licencing; PWS, possible water shortages.
2. Aug and Sept Use are total demands in these months; Sum and Win Q7L2 are summer and winter mean 7 day low flows; mean Aug and and Sept are mean August and September monthly flows; QAA is mean annual flow; Q2 is the mean annual flood; Recent and Total are recent and total logging areas in the basin; Basin is basin area above the mouth.
3. Indices expressed as percentages except 7, which is a direct ratio.
4. Shading indicates salmon streams with most extreme values for the various indices. The most extreme 25% are shown for Indices 1 to 6; values of Index 7 exceeding 10 are shaded; and values of Index 8 exceeding 20% are shaded.

Table 10: Sensitivity Indices -- Nicola - Thompson HMA

		SUMMER WATER USE				LOW FLOWS		PEAK FLOW	LOGGING	
Stream Name	Status	Index 1 Aug Use/ Sum Q7L2	Index 2 Sept Use/ Sum Q7L2	Index 3 Aug Use/ mean Aug	Index 4 Sept Use/ mean Sept	Index 5 Sum Q7L2/ QAA	Index 6 Win Q7L2/ QAA	Index 7 Q2/ QAA	Index 8 Recent/ Basin	Index 9 Total/ Basin
Thompson R								3	4	9
Nicola R	FR	90	54	54	47	19	22	8	10	26
Spius Ck	FR	20	12	11	8	9	17	9	18	30
Maka Ck		0	0	0	0	9	17	9	25	30
Coldwater R		65	39	36	29	9	18	10	5	35
Spahomin Ck		136	81	50	77	11	15	6	5	10
Bonaparte R	FR	98	59	44	47	33	22	5	20	40
Deadman R	FR	91	55	45	37	23	17	8	10	0

1. Status refers to restrictions noted by the Water Management Branch: FR, fully recorded with exceptions for storage; RES, reserved, no licencing; PWS, possible water shortages.
2. Aug and Sept Use are total demands in these months; Sum and Win Q7L2 are summer and winter mean 7 day low flows; mean Aug and and Sept are mean Augu Table 8: Sensitivity Indices -- North Thompson HMA
are recent and total logging areas in the basin; Basin is basin area above the mouth.
3. Indices expressed as percentages except 7, which is a direct ratio.
4. Shading indicates salmon streams with most extreme values for the various indices. The most extreme 25% are shown for Indices 1 to 6 values of Index 7 exceeding 10 are shaded; and values of Index 8 exceeding 20% are shaded.

FIGURES



Thompson River Basin

W.S.C. Gauges and Habitat Management Areas

northwest hydraulic consultants

FIGURE 2: Classification of British Columbia Water Licences

No.	USE CLASS	DESCRIPTION (uses included)	UNITS
	CONSUMPTIVE		
1	Waterworks	- conveyed by local authority (municipality, regional or improvement district) - conveyed by others (individual, utility, Indian band)	gallons/day gallons/year
2	Domestic use		gallons/day
3	Pulpmills		cubic feet/second
4	Industrial	- processing (sawmills, food, manufacturing, etc.) - cooling - enterprise (hotels, motels, restaurants, etc.) - ponds - watering - bottling for sale - commercial bulk export - mineral water sold in containers and used in bathing pools - all other industrial uses	any
5	Irrigation	- conveyed by local authority (municipal) - private agricultural use	acre-feet
6	Land improvement	e.g. draining property, creating ponds	any
7	Mining	- hydraulic, washing coal, processing ore, placer	any
	NON-CONSUMPTIVE		
8	Power generation	- residential, commercial, general	cubic feet/second
9	Storage - nonpower		acre-feet
10	Storage - power		acre-feet
11	Conservation	- storage (e.g. waterfowl habitat enhancement) - use of water (e.g. hatchery) - construction of works in and around a stream (e.g. fish culture, fish ponds, personal)	any

APPENDIX A

MEAN ANNUAL HYDROGRAPHS

A. MEAN ANNUAL HYDROGRAPHS

1. Each hydrograph was plotted using the longest continuous set of daily flow records.

2. The historic period used to plot the curve is shown in brackets after the station number.

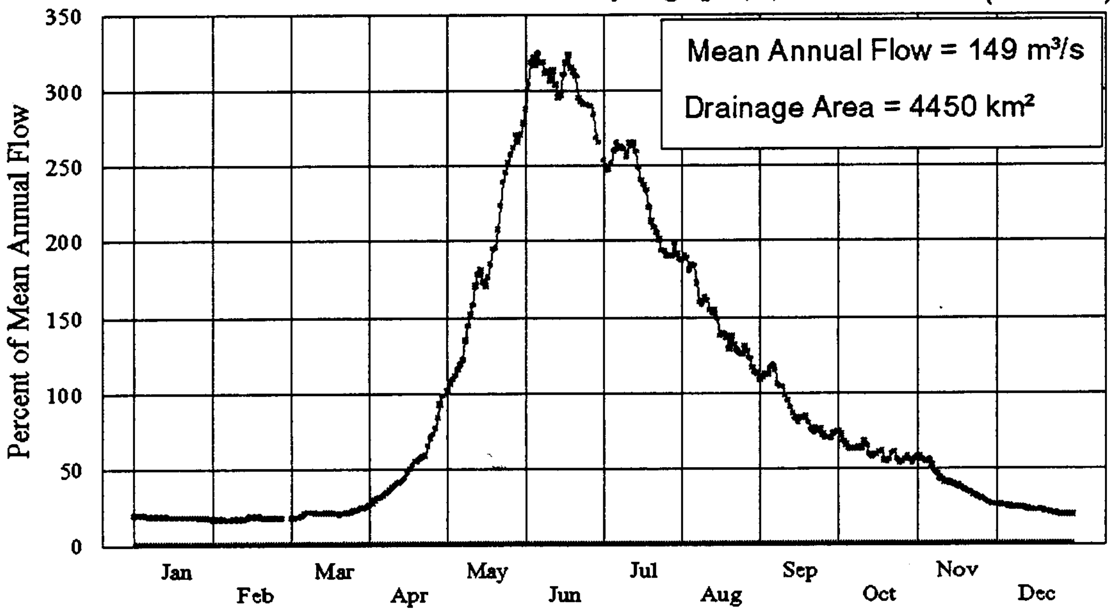
3. The vertical axis shows the flow as a percentage of the mean annual flow. The flow for a particular time of year can be calculated by multiplying the corresponding percentage value by the mean annual flow. For example, the peak flow is generally 400% to 500% of the mean annual flow.

4. The irrigation demand in the watershed, above the station, is shown if it is greater than about 3% of the mean annual flow.

5. Plotting of the hydrographs as a percentage of the mean annual flow allows easier comparison between them. For example, the hydrograph for the Shuswap River (08LC002), p. A11, shows the August flow averages about 70% of the mean annual flow, whereas the hydrograph for Fortune Creek shows the August flow averages about 20% of the mean annual flow; this indicates that the August flow for Fortune Creek is likely to be more of a problem for fisheries, especially as the irrigation demand is also relatively higher.

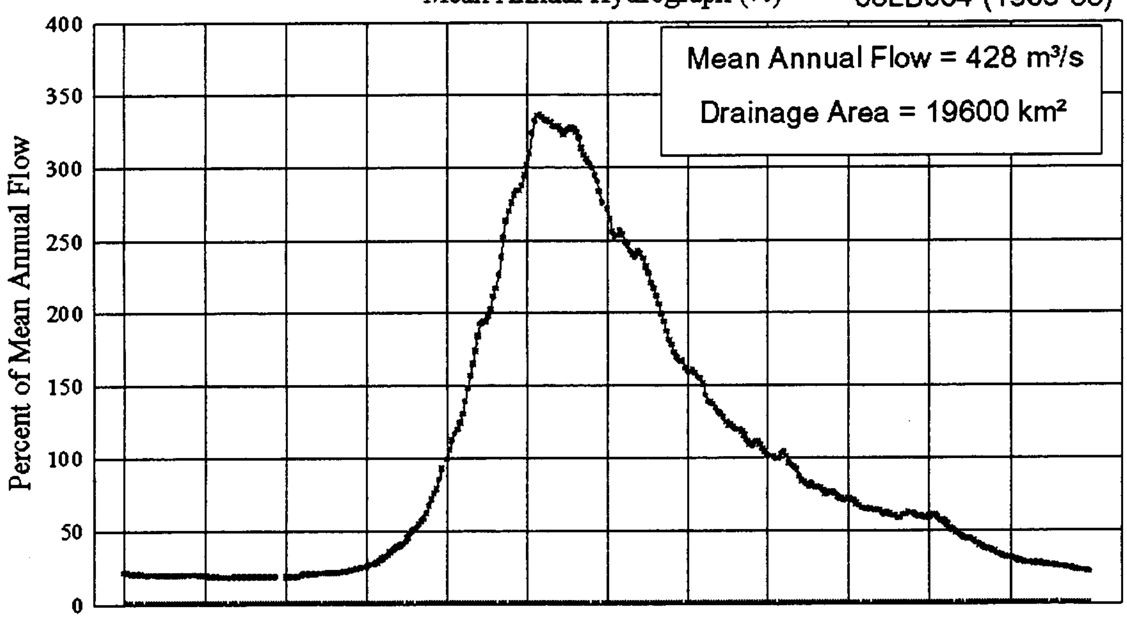
N. Thompson River

Mean Annual Hydrograph (%) 08LB047 (1961-88)

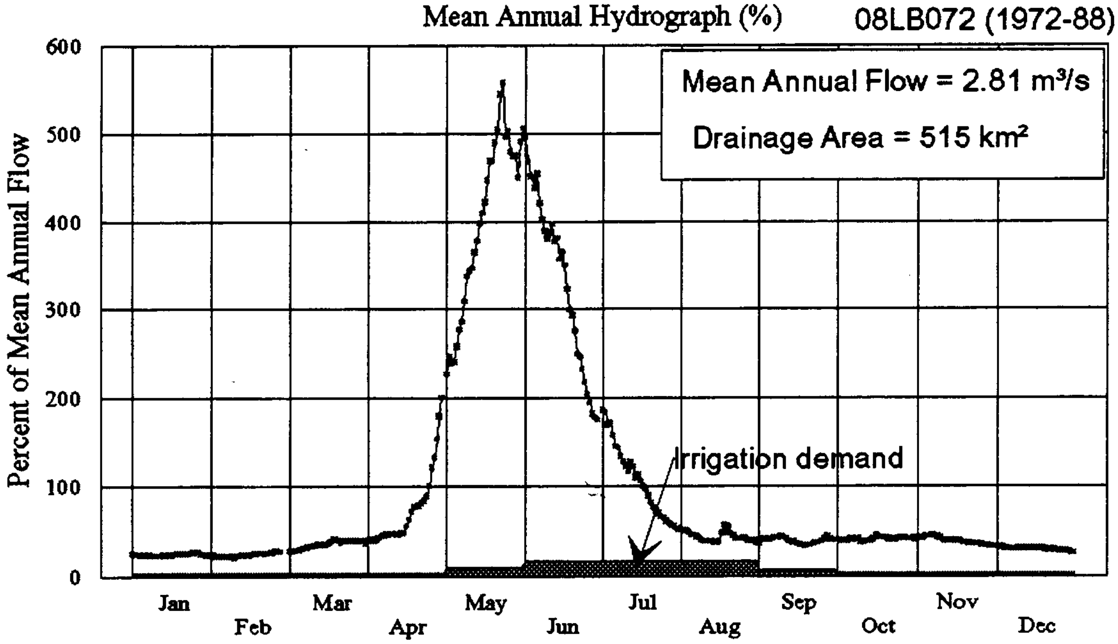


N. Thompson River

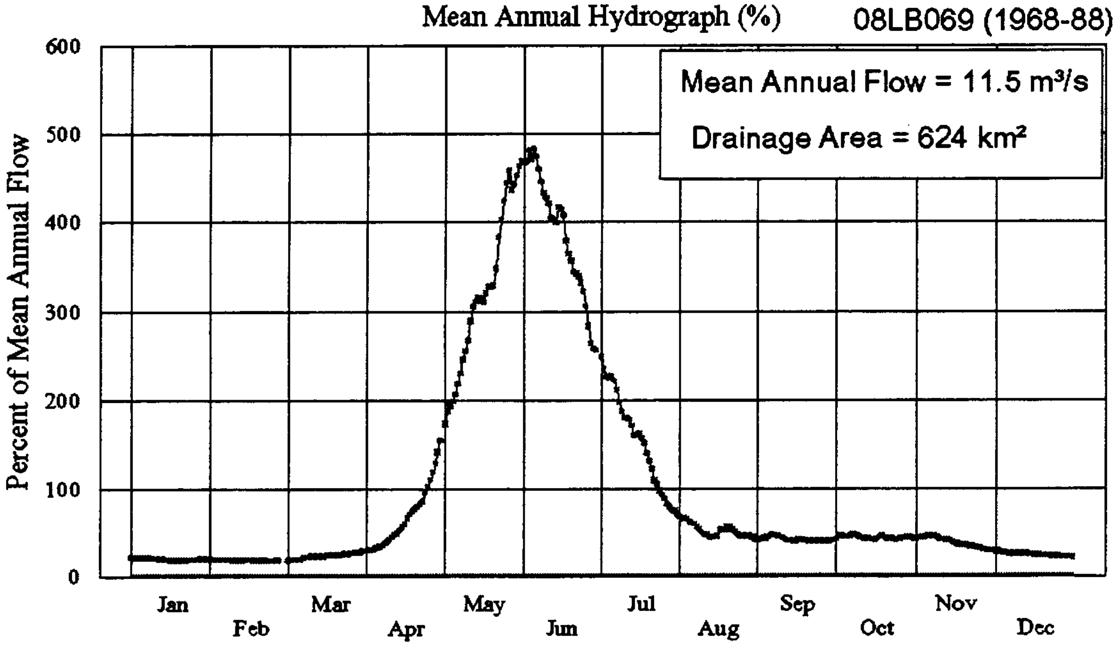
Mean Annual Hydrograph (%) 08LB064 (1959-88)



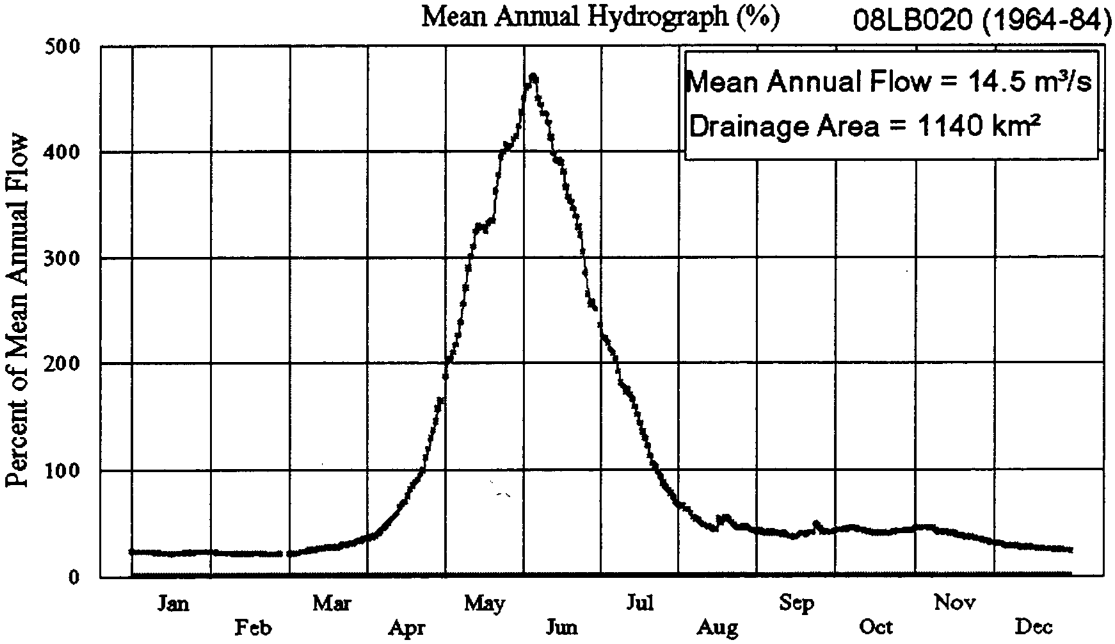
Louis Creek



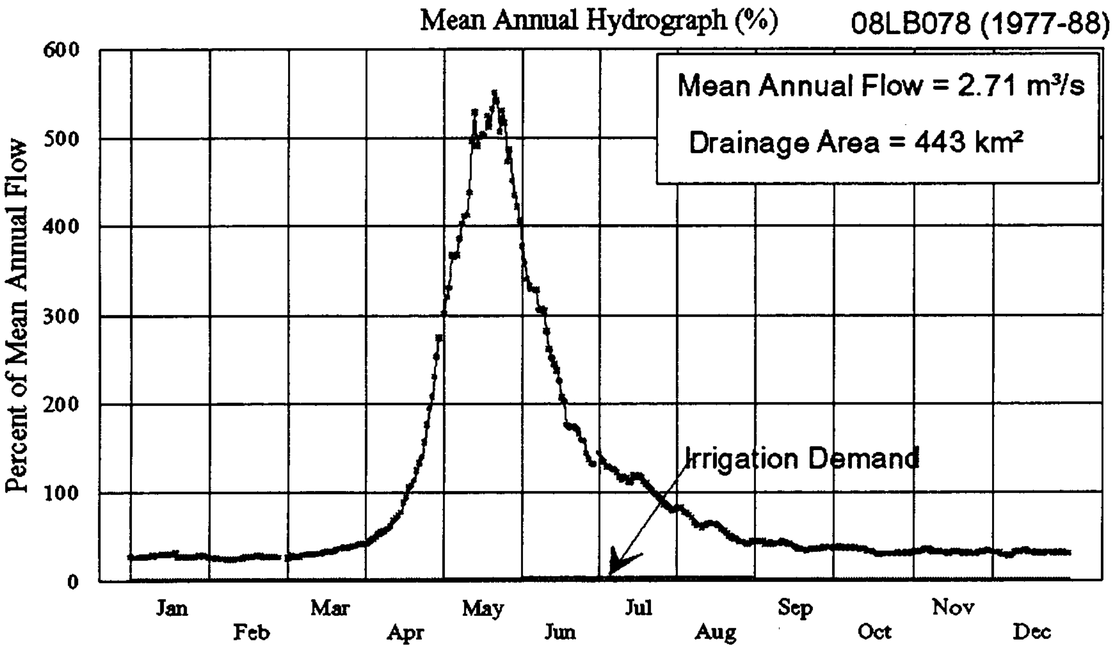
Barriere River



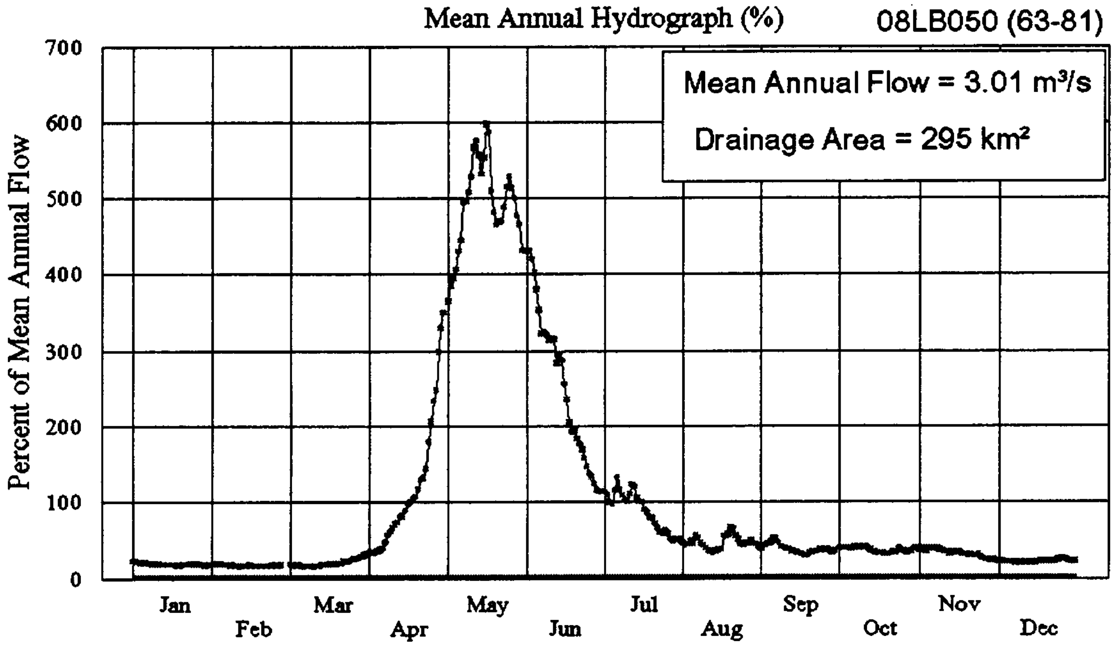
Barriere River



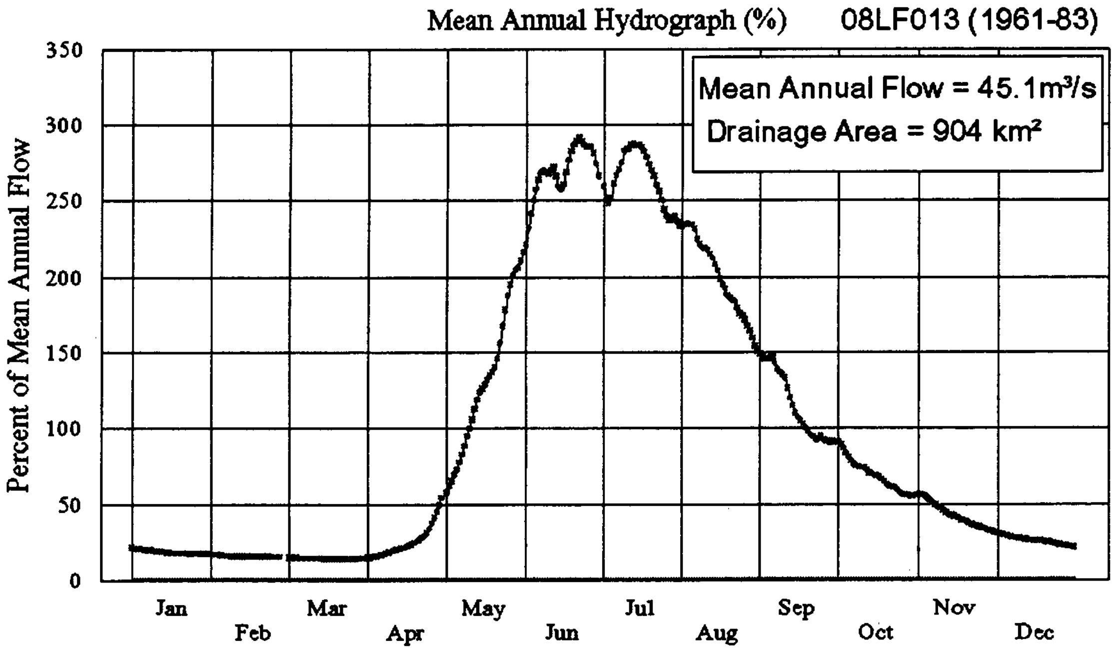
Lemieux Creek

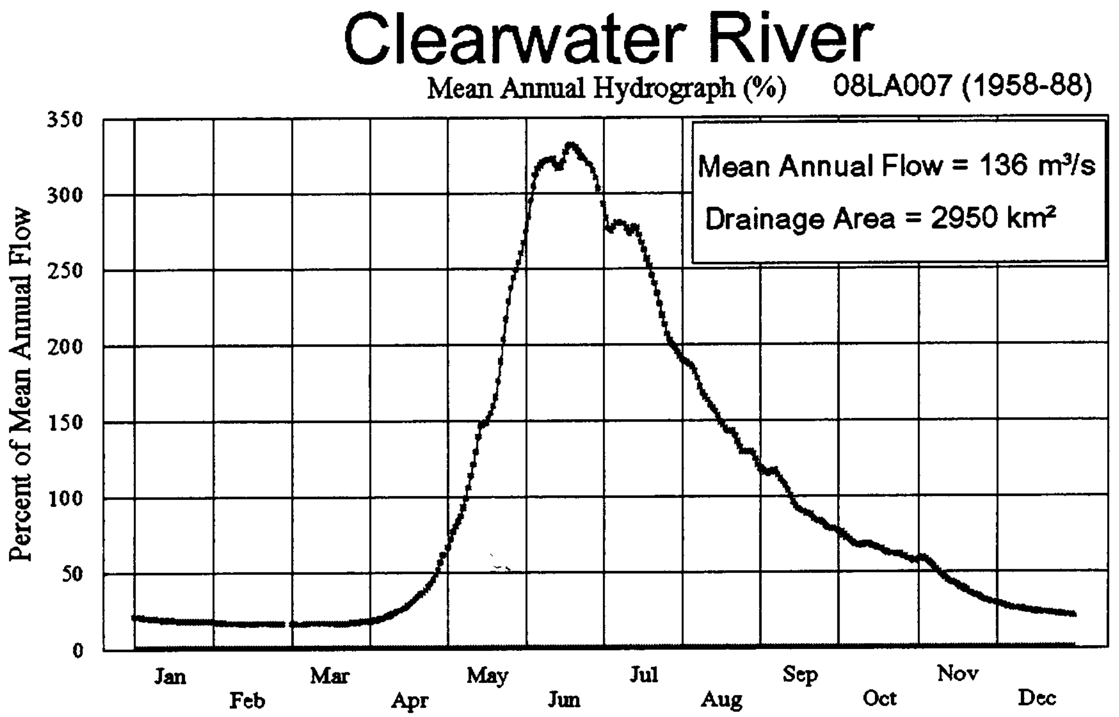


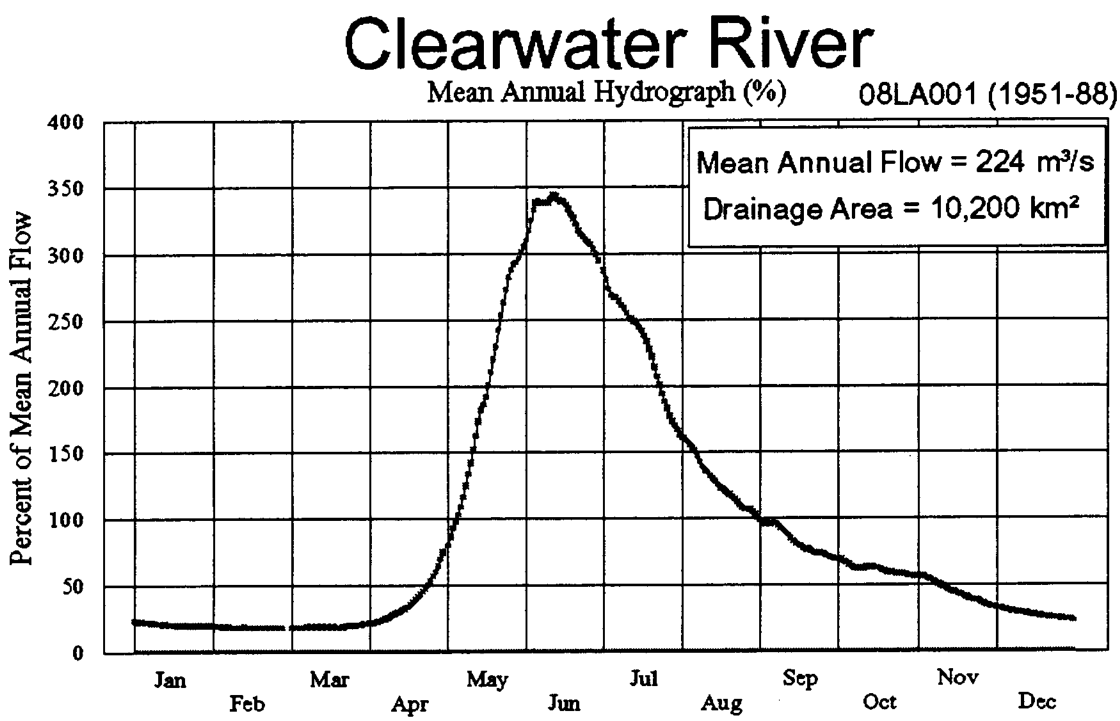
Mann Creek



Clearwater River

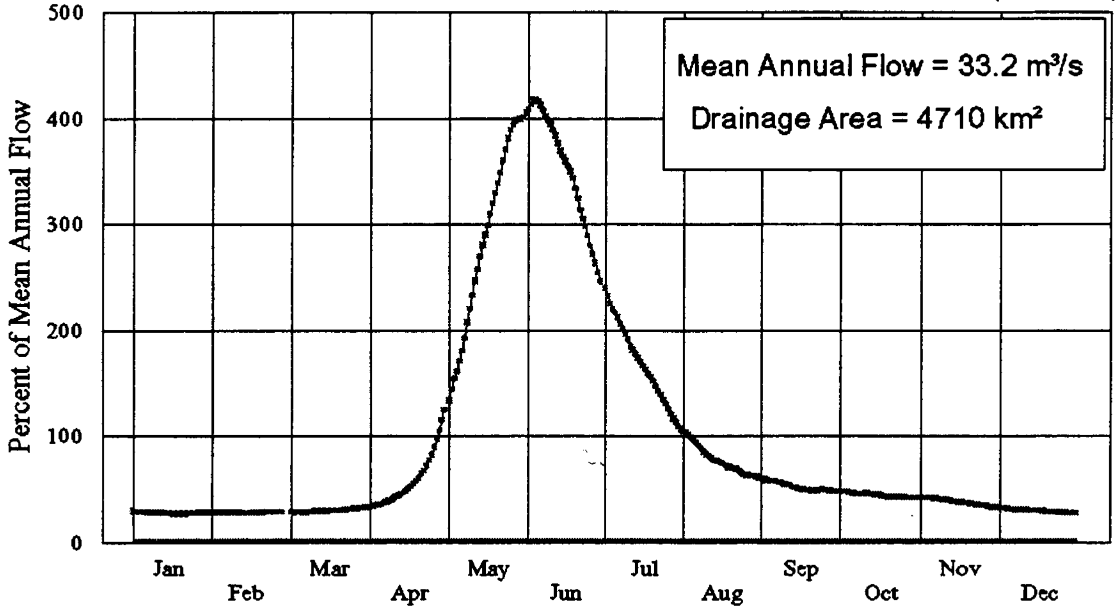



Clearwater River
Mean Annual Hydrograph (%)
08LA007 (1958-88)
Mean Annual Flow = 136 m³/s
Drainage Area = 2950 km²
Percent of Mean Annual Flow
0
50
100
150
200
250
300
350
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec


Clearwater River
Mean Annual Hydrograph (%)
08LA001 (1951-88)
Mean Annual Flow = 224 m³/s
Drainage Area = 10,200 km²
Percent of Mean Annual Flow
0
50
100
150
200
250
300
350
400
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

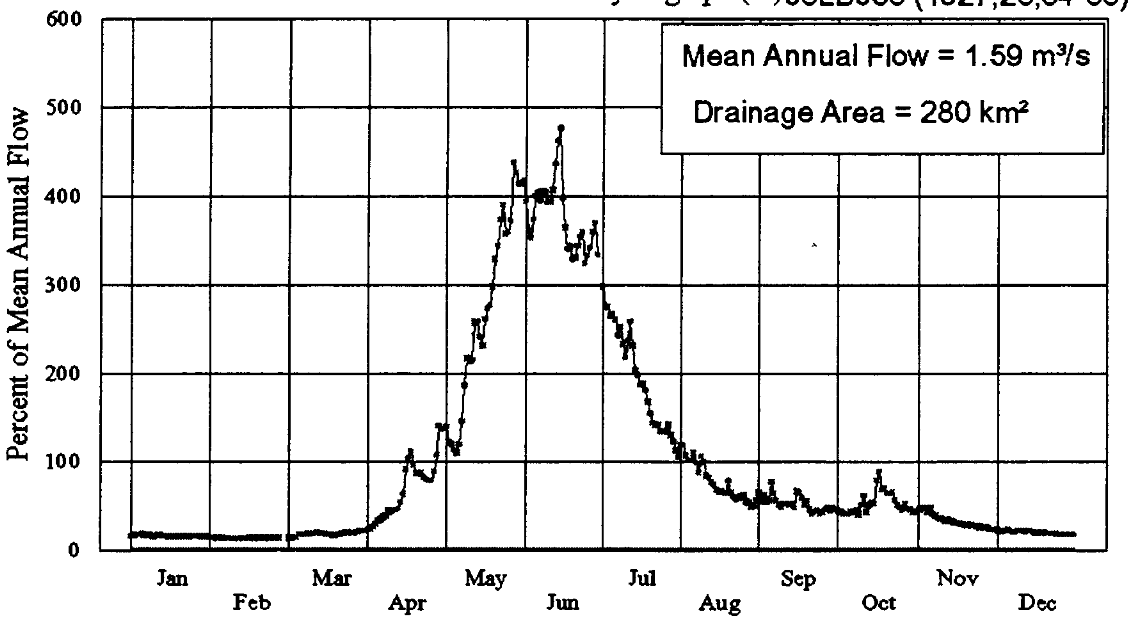
Mahood River

Mean Annual Hydrograph (%) 08LA008 (1961-84)



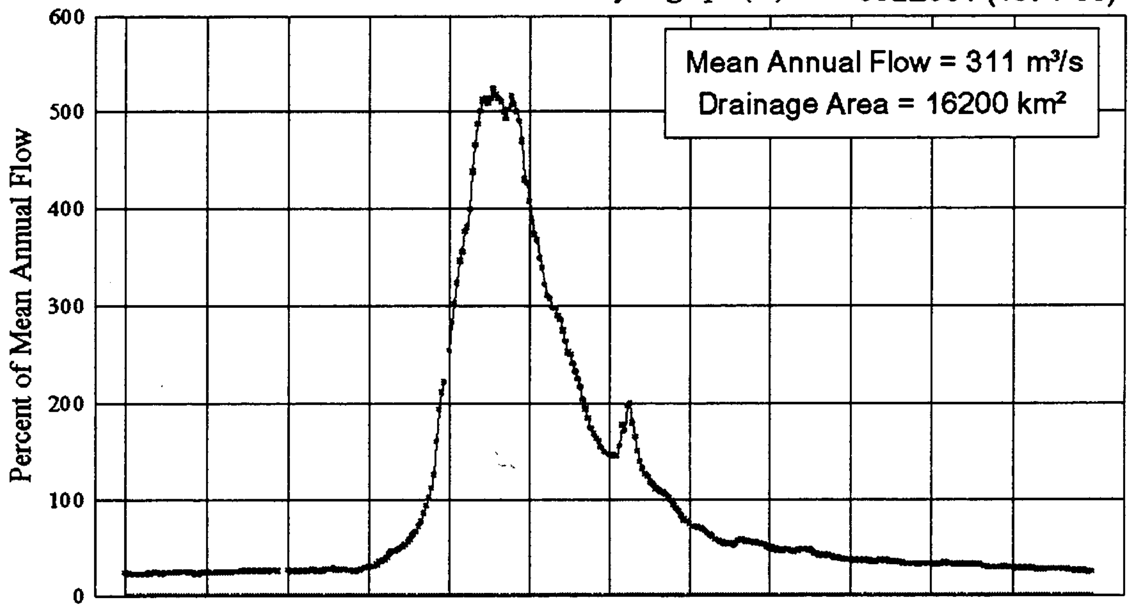
Blue River

Mean Annual Hydrograph (%) 08LB038 (1927,28,84-88)



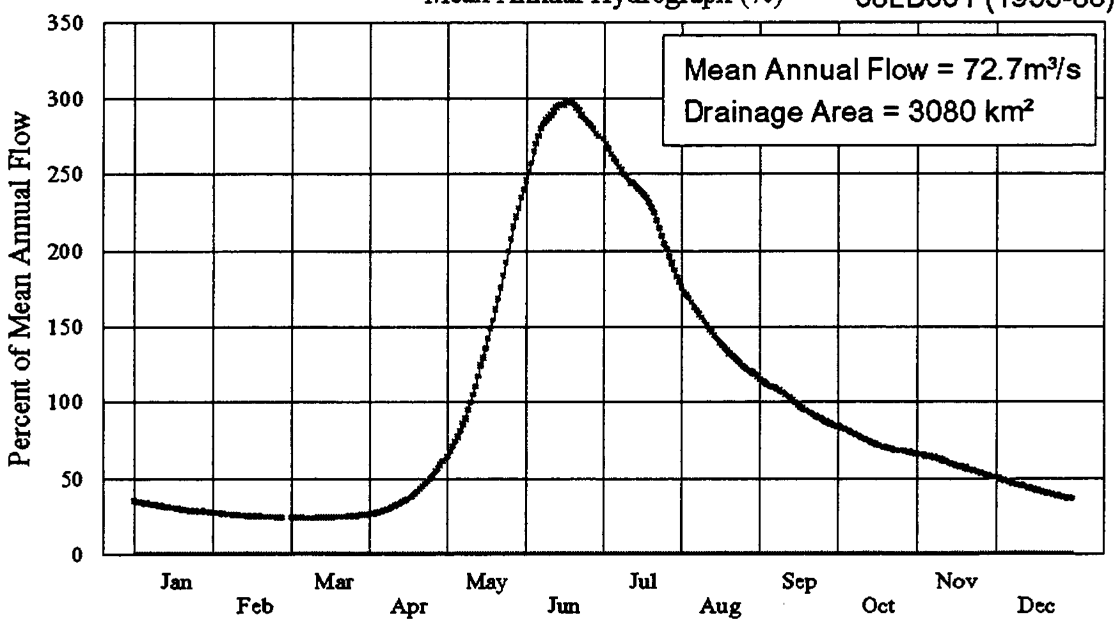
South Thompson River

Mean Annual Hydrograph (%) 08LE031 (1971-88)

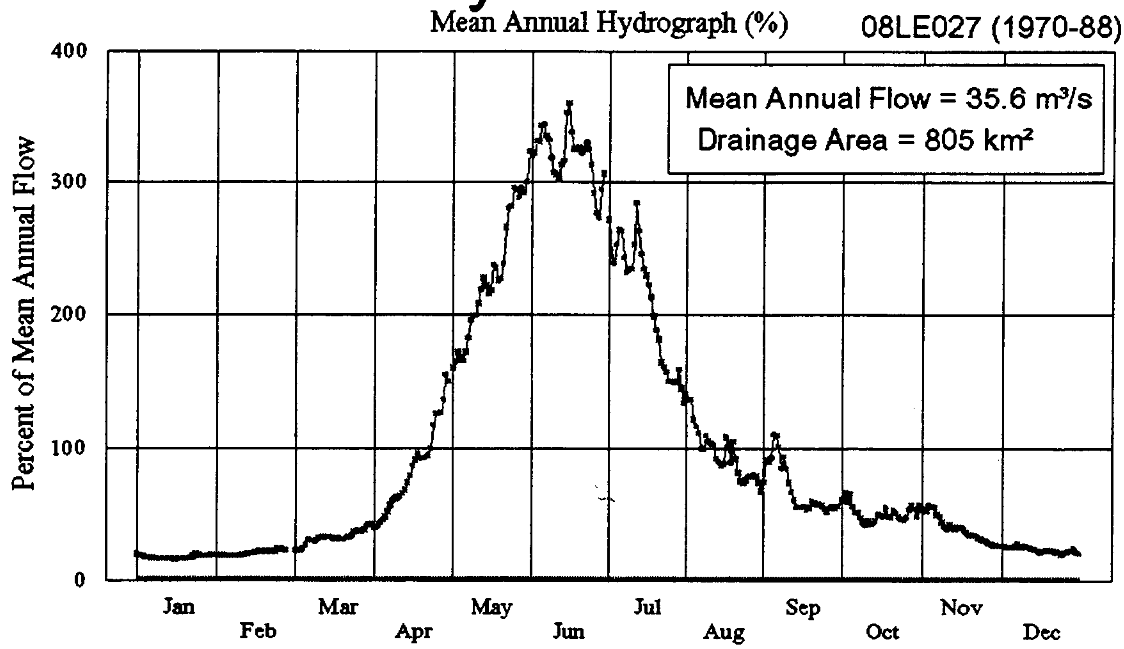


Adams River

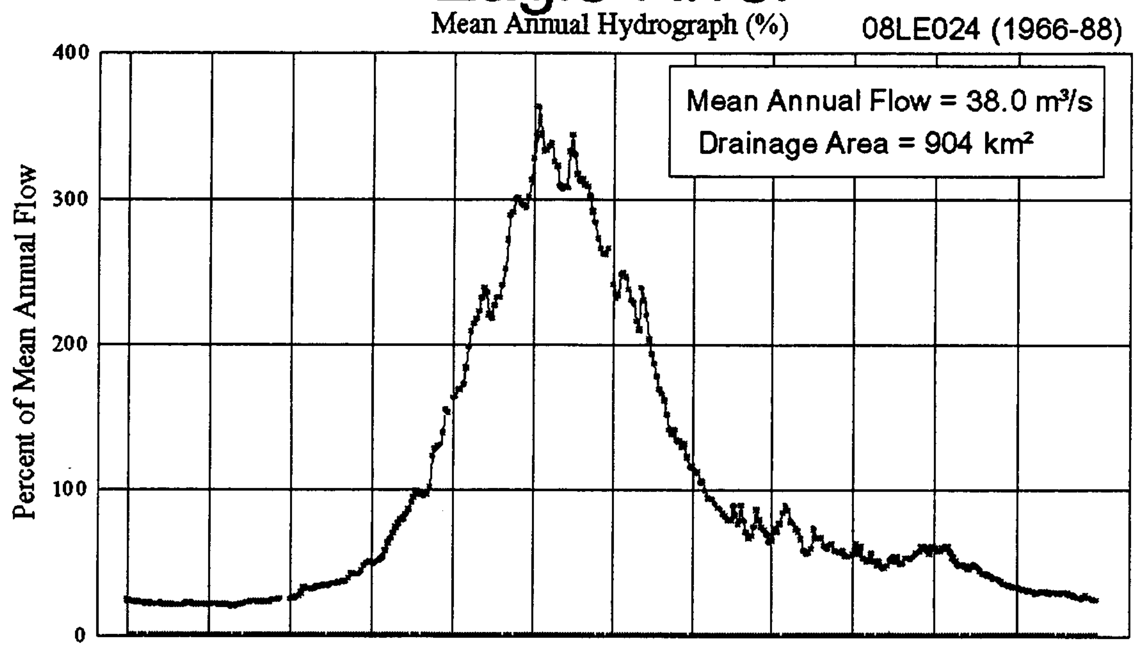
Mean Annual Hydrograph (%) 08LD001 (1953-88)

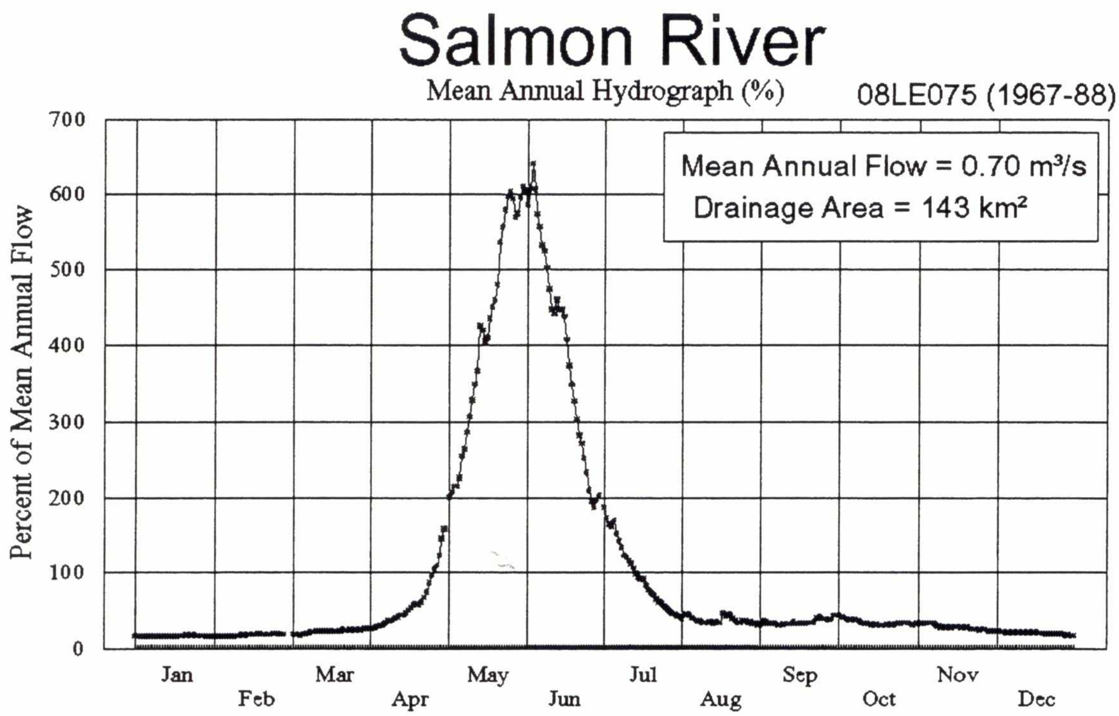


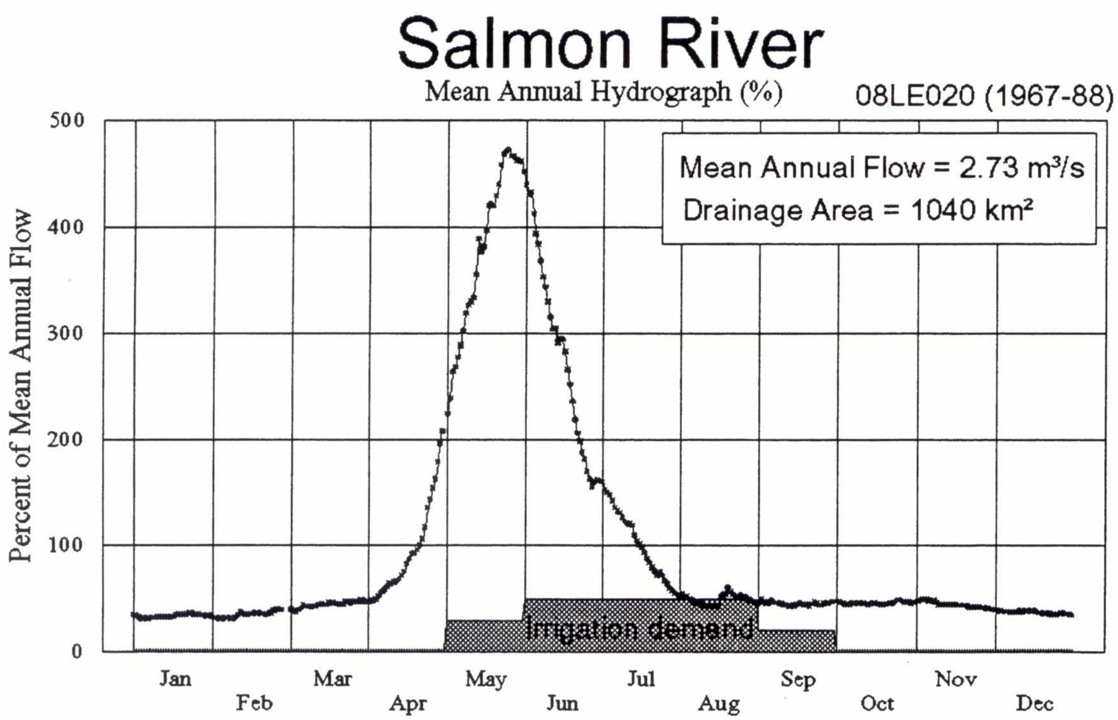
Seymour River



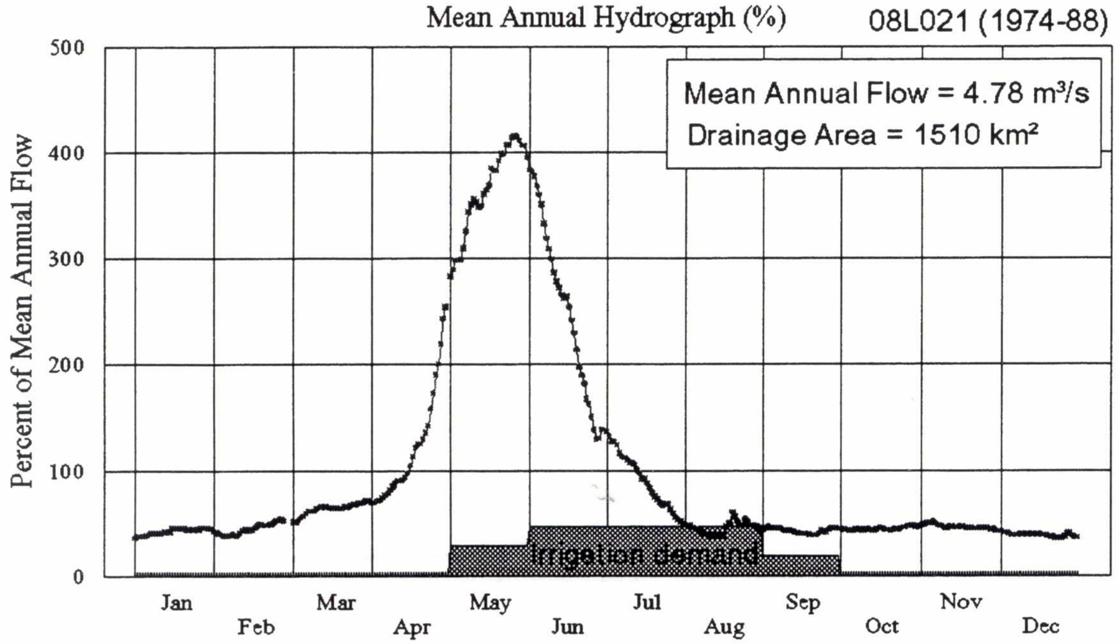
Eagle River



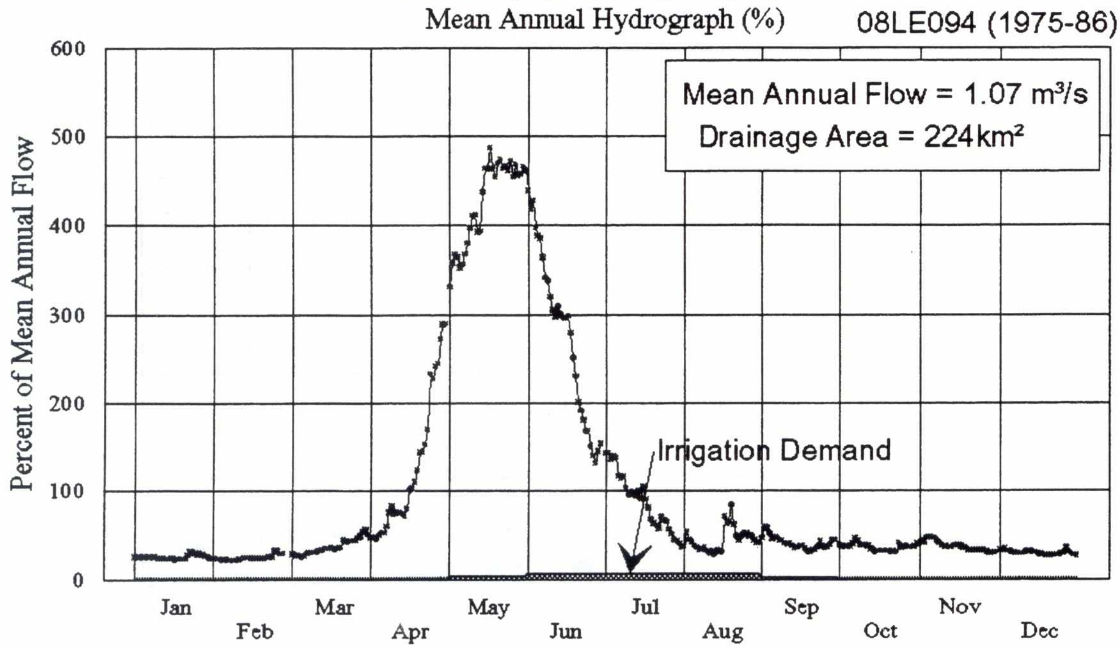

Salmon River
Mean Annual Hydrograph (%)
08LE075 (1967-88)
Mean Annual Flow = 0.70 m³/s
Drainage Area = 143 km²
Percent of Mean Annual Flow
700
600
500
400
300
200
100
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec


Salmon River
Mean Annual Hydrograph (%)
08LE020 (1967-88)
Mean Annual Flow = 2.73 m³/s
Drainage Area = 1040 km²
Percent of Mean Annual Flow
500
400
300
200
100
0
Irrigation demand
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

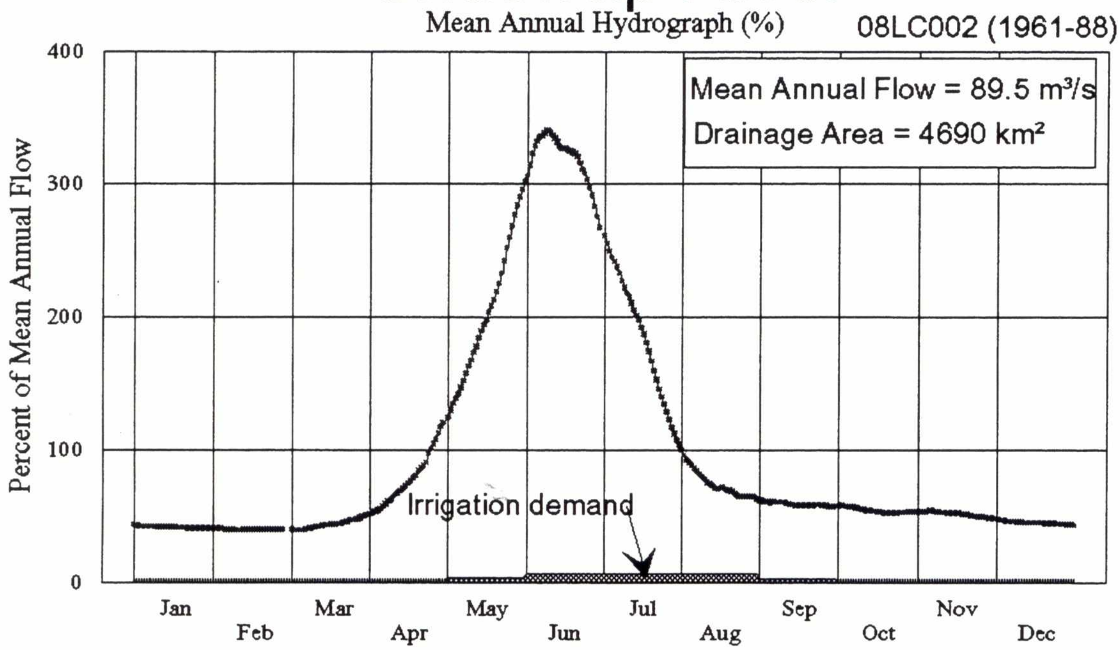
Salmon River



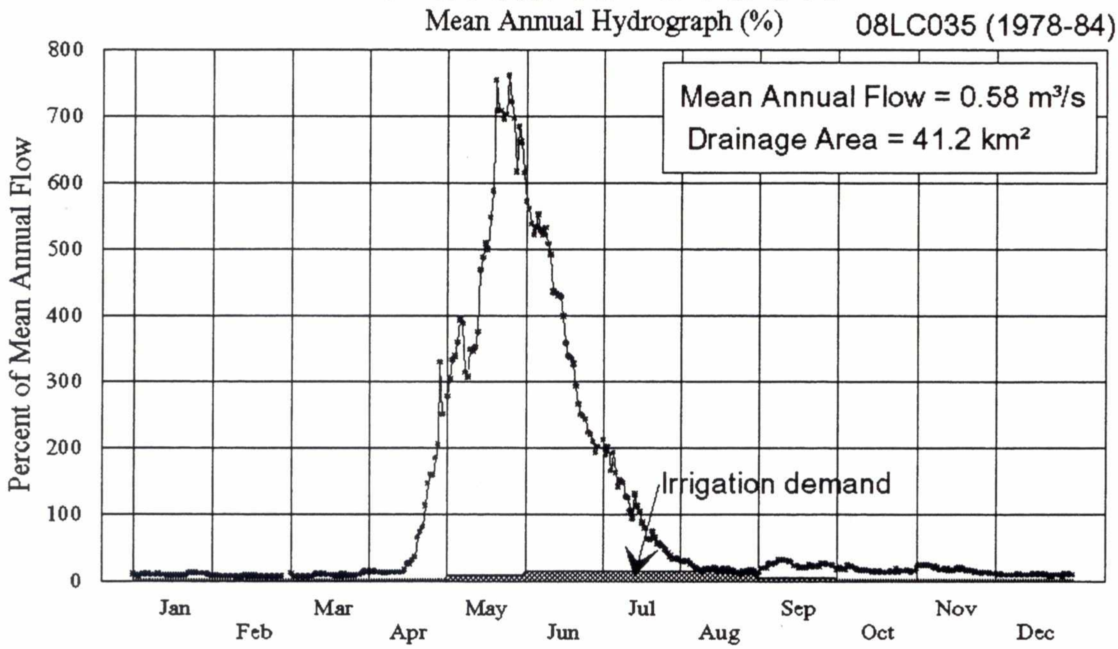
Bolean Creek

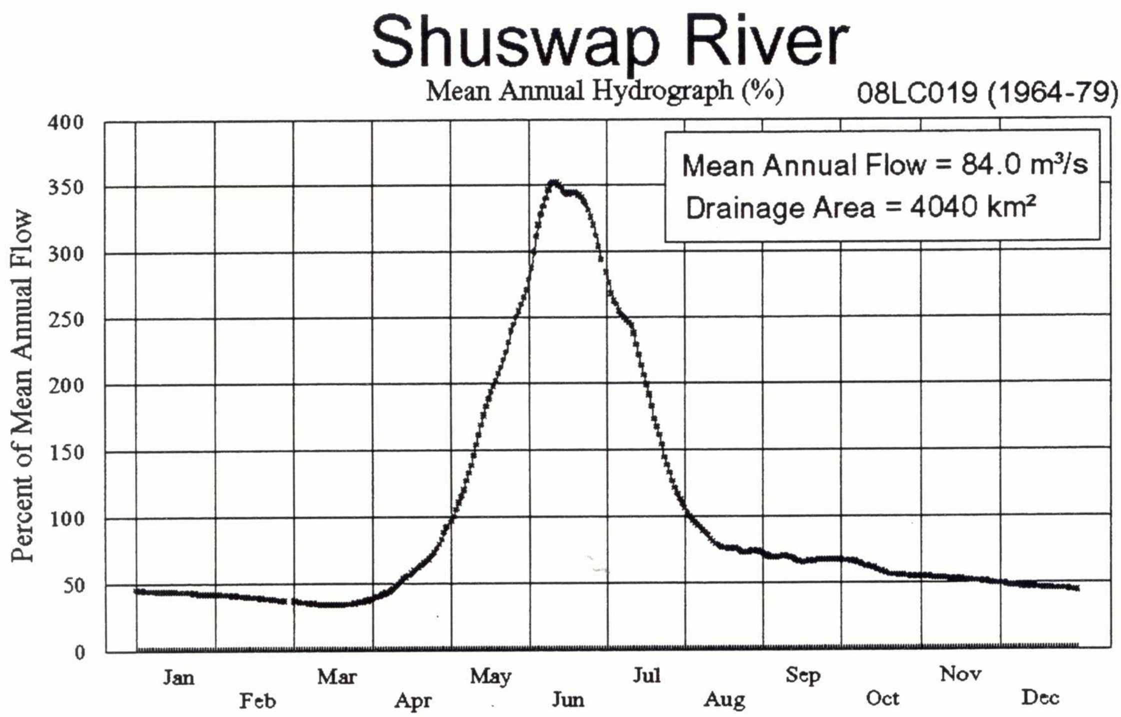


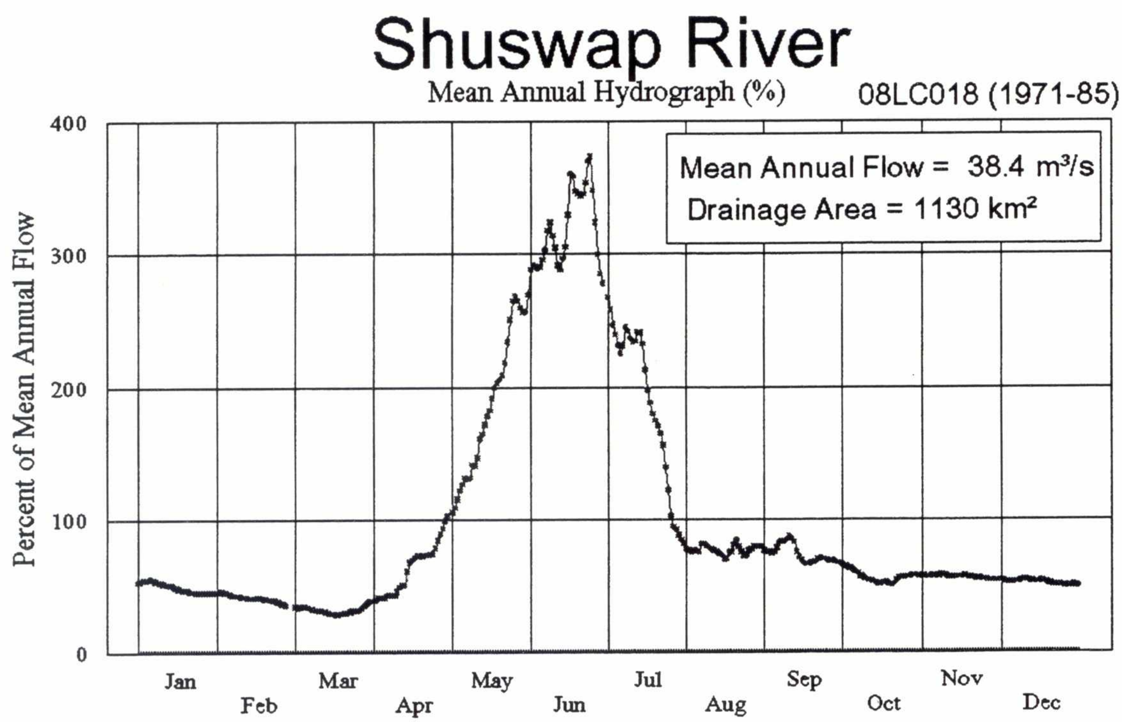
Shuswap River

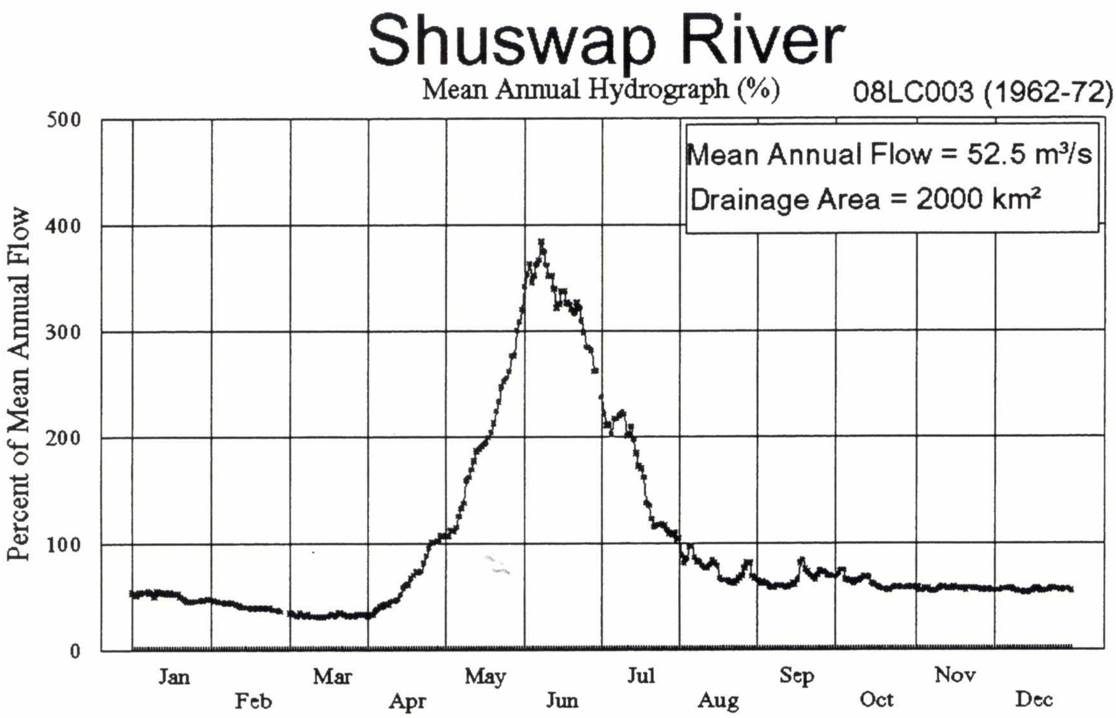


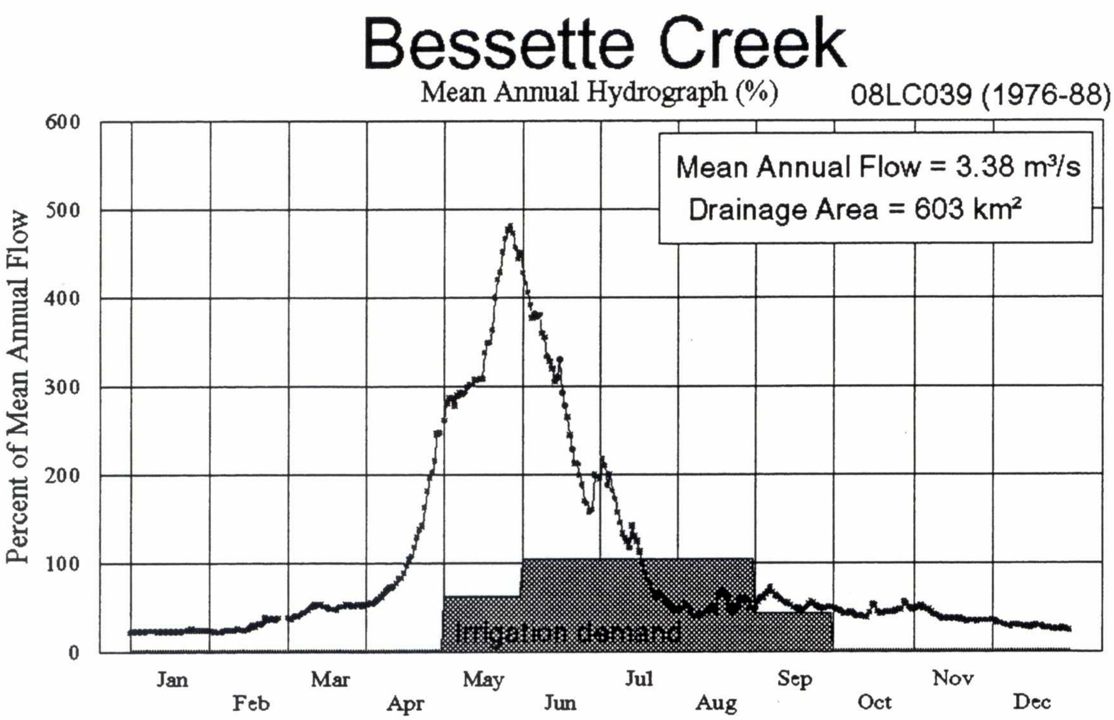
Fortune Creek

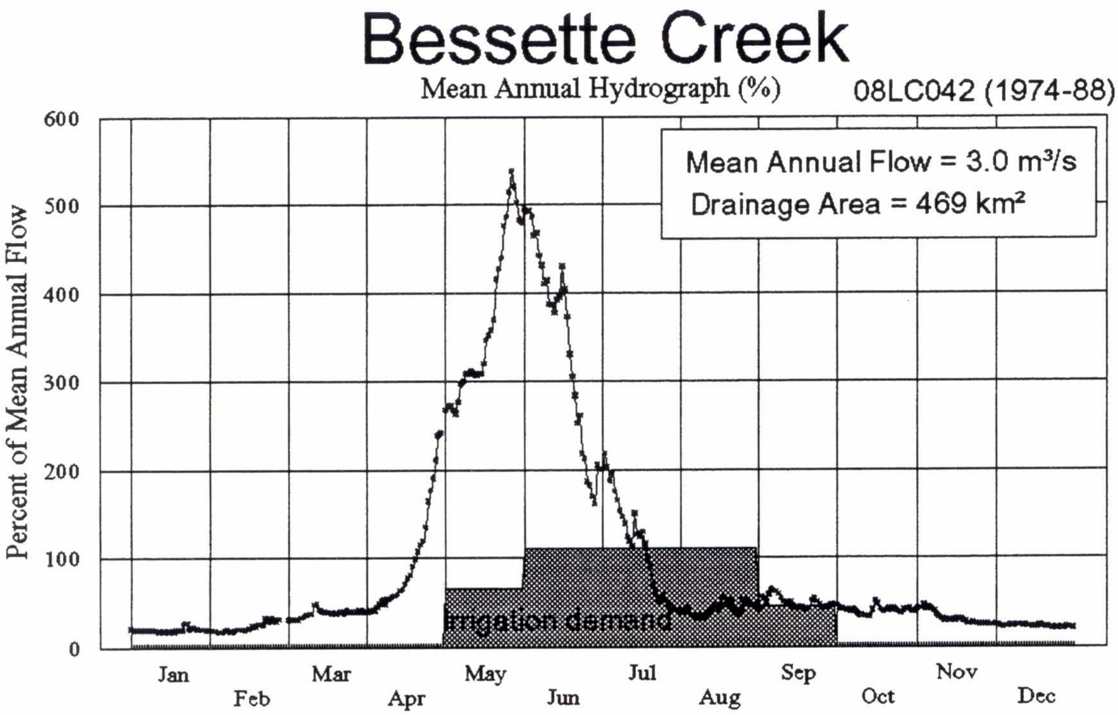


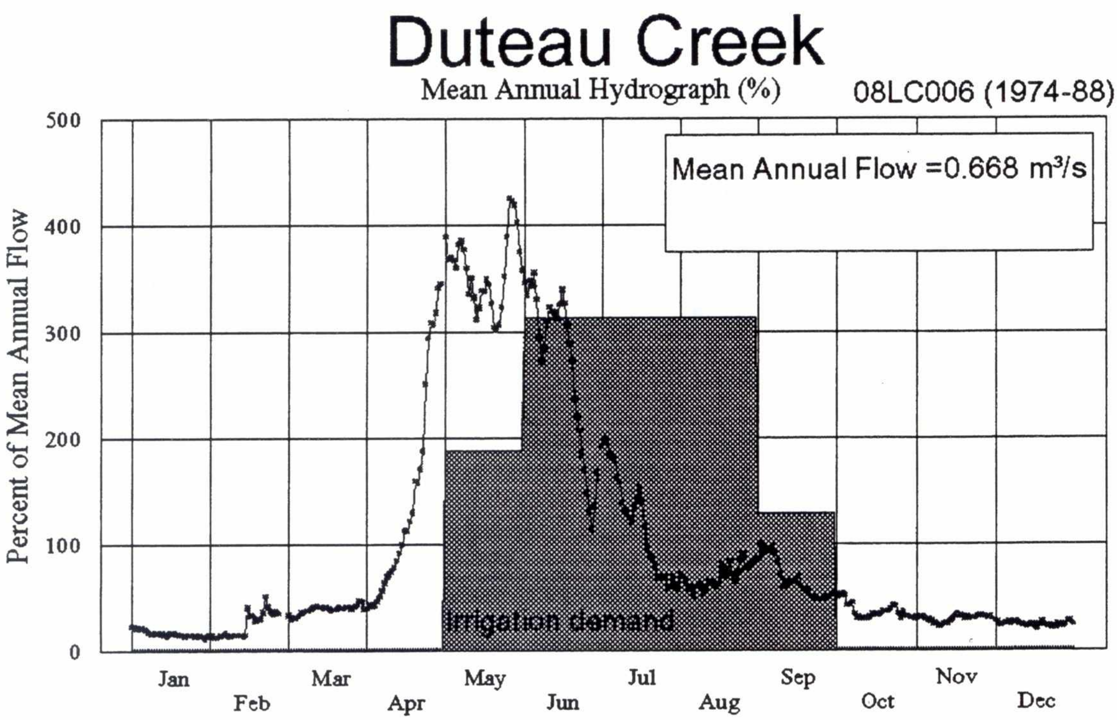

Shuswap River
Mean Annual Hydrograph (%)
08LC019 (1964-79)
Mean Annual Flow = 84.0 m³/s
Drainage Area = 4040 km²
Percent of Mean Annual Flow
400
350
300
250
200
150
100
50
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

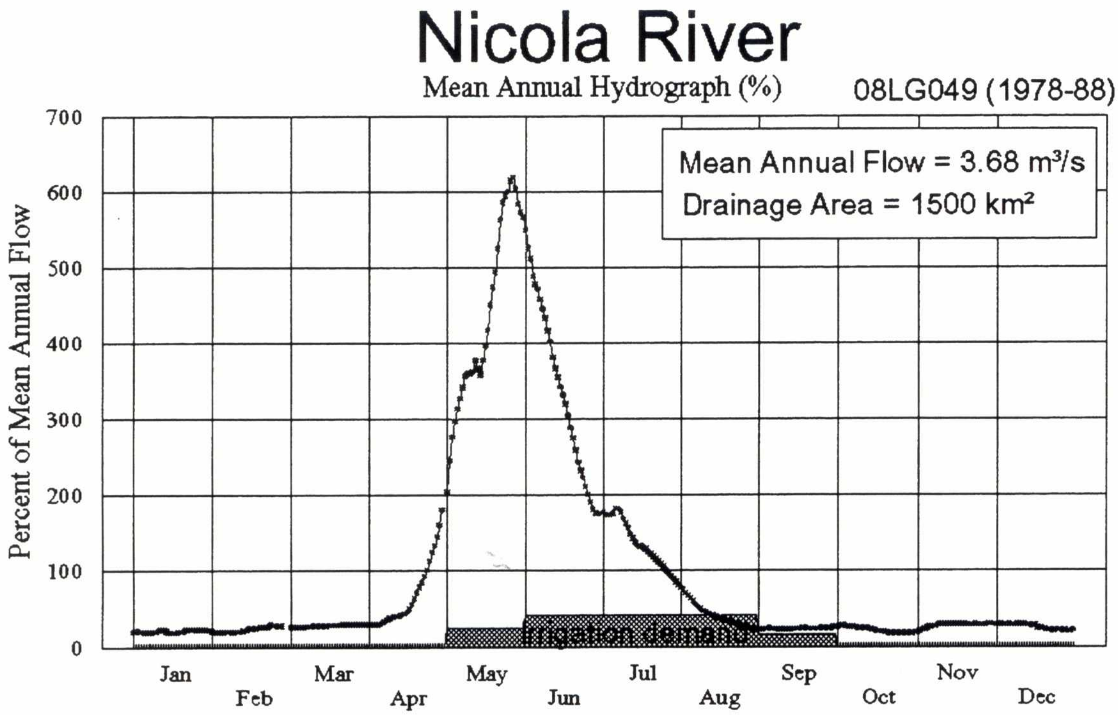

Shuswap River
Mean Annual Hydrograph (%)
08LC018 (1971-85)
Mean Annual Flow = 38.4 m³/s
Drainage Area = 1130 km²
Percent of Mean Annual Flow
400
300
200
100
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

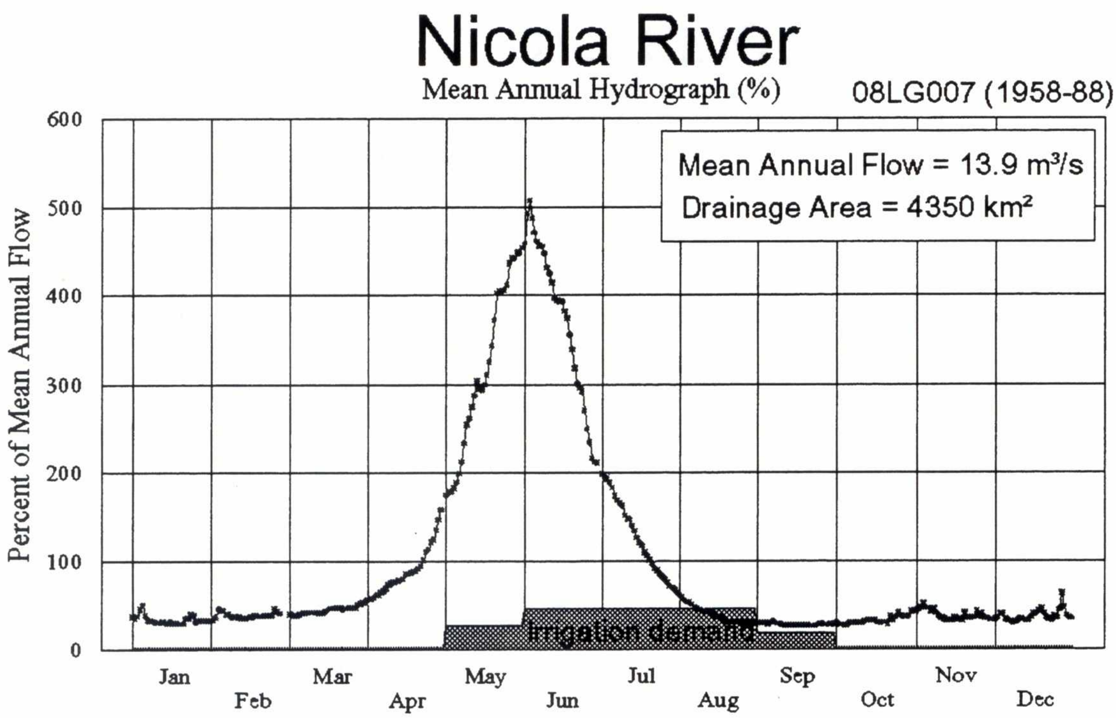

Shuswap River
Mean Annual Hydrograph (%)
08LC003 (1962-72)
Mean Annual Flow = 52.5 m³/s
Drainage Area = 2000 km²
Percent of Mean Annual Flow
500
400
300
200
100
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec


Bessette Creek
Mean Annual Hydrograph (%)
08LC039 (1976-88)
Mean Annual Flow = 3.38 m³/s
Drainage Area = 603 km²
Percent of Mean Annual Flow
600
500
400
300
200
100
0
Irrigation demand
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec


Bessette Creek
Mean Annual Hydrograph (%)
08LC042 (1974-88)
Mean Annual Flow = 3.0 m³/s
Drainage Area = 469 km²
Percent of Mean Annual Flow
600
500
400
300
200
100
0
Irrigation demand
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

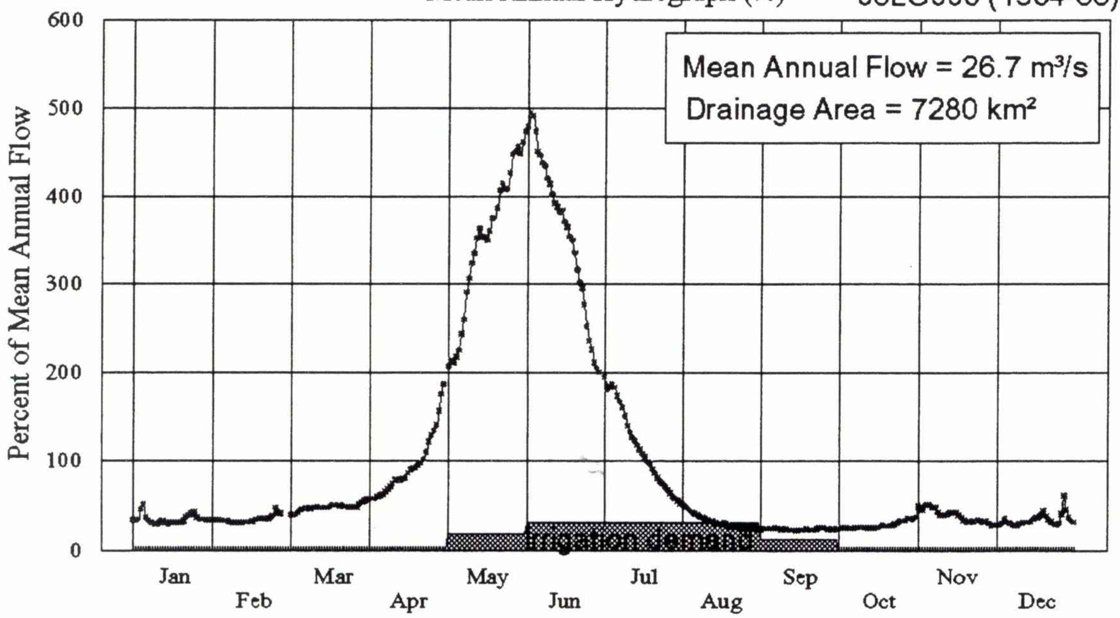

Duteau Creek
Mean Annual Hydrograph (%)
08LC006 (1974-88)
Mean Annual Flow =0.668 m³/s
Percent of Mean Annual Flow
500
400
300
200
100
0
Irrigation demand
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec


Nicola River
Mean Annual Hydrograph (%)
08LG049 (1978-88)
Mean Annual Flow = 3.68 m³/s
Drainage Area = 1500 km²
Percent of Mean Annual Flow
700
600
500
400
300
200
100
0
Irrigation demand
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec


Nicola River
Mean Annual Hydrograph (%)
08LG007 (1958-88)
Mean Annual Flow = 13.9 m³/s
Drainage Area = 4350 km²
Percent of Mean Annual Flow
600
500
400
300
200
100
0
Irrigation demand
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

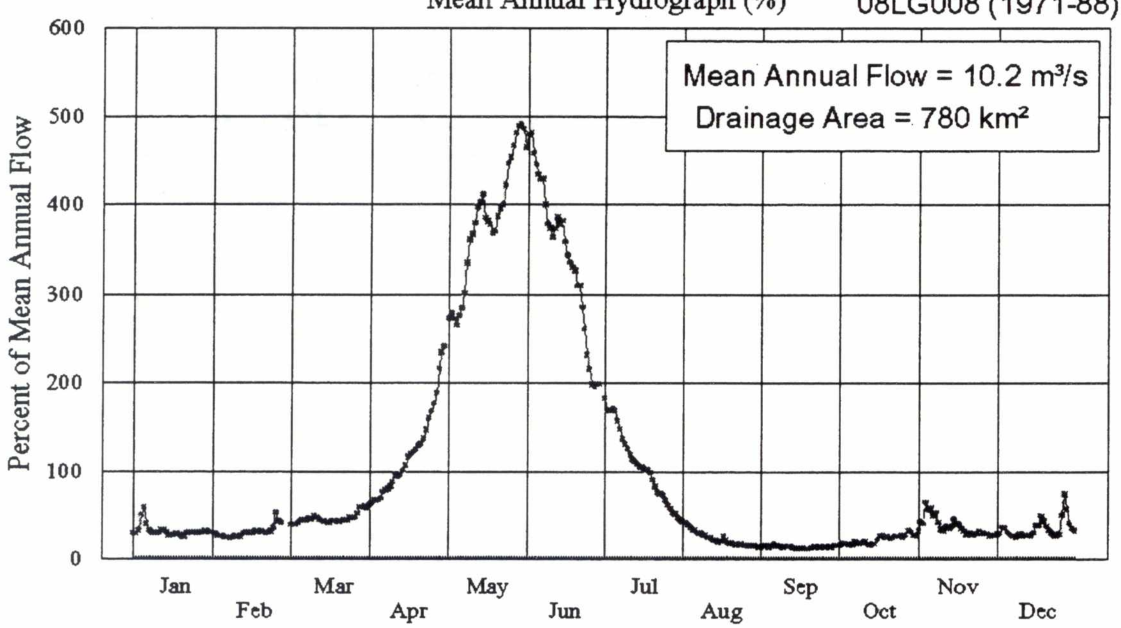
Nicola River

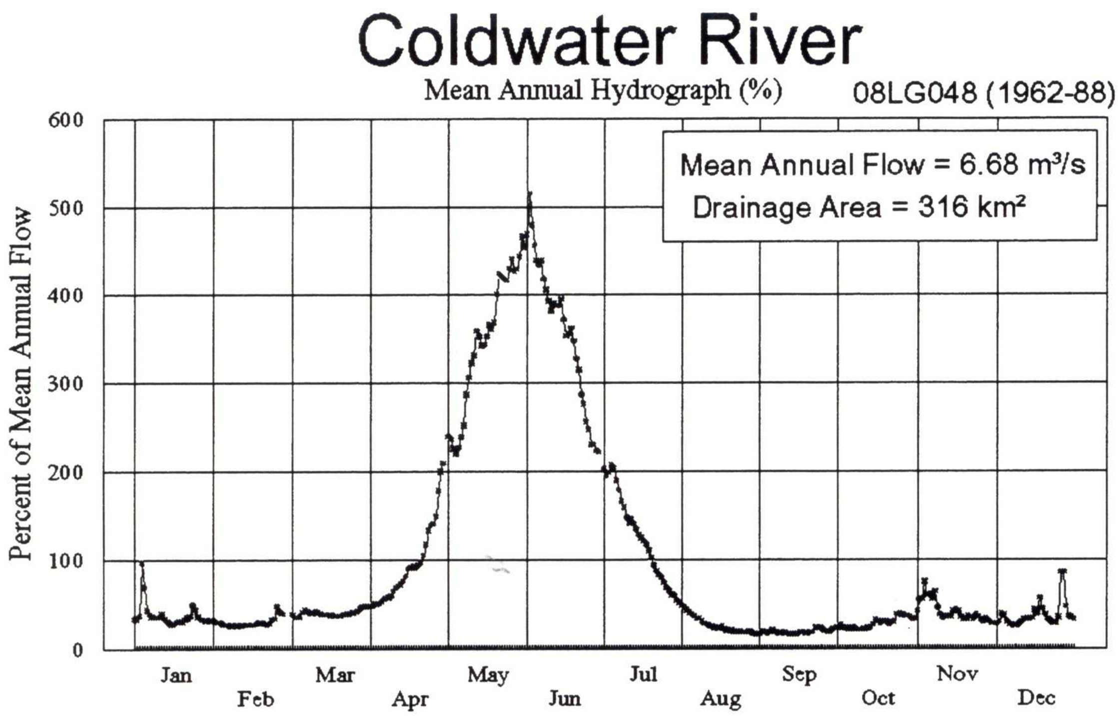
Mean Annual Hydrograph (%) 08LG006 (1964-88)

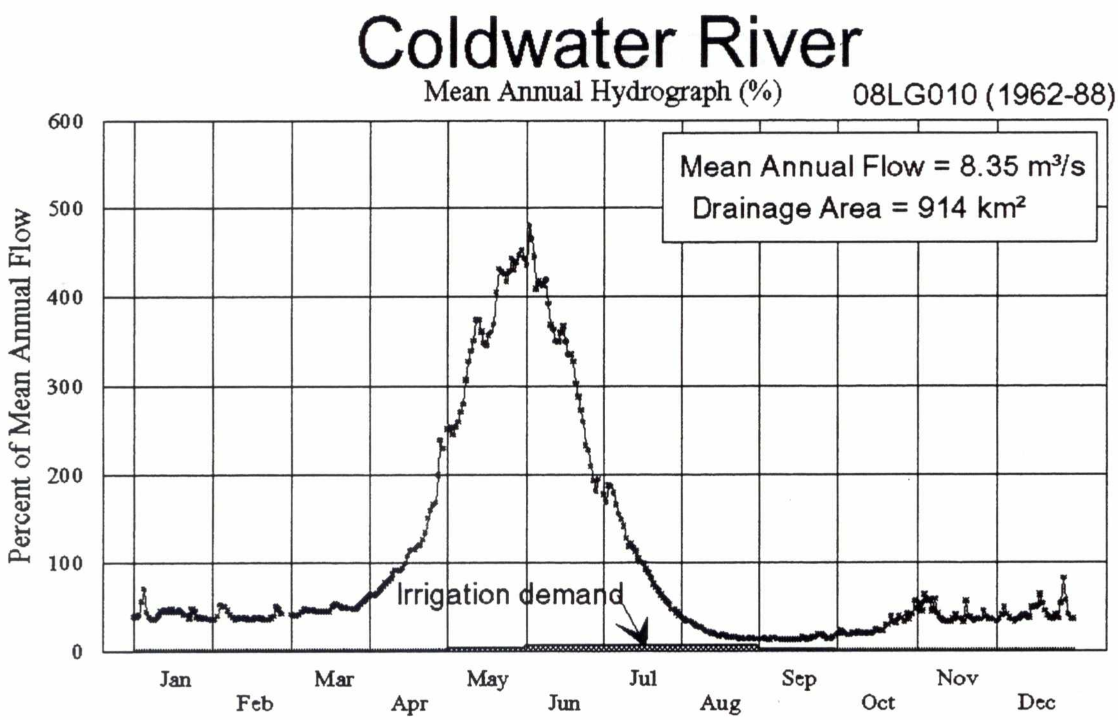


Spius Creek

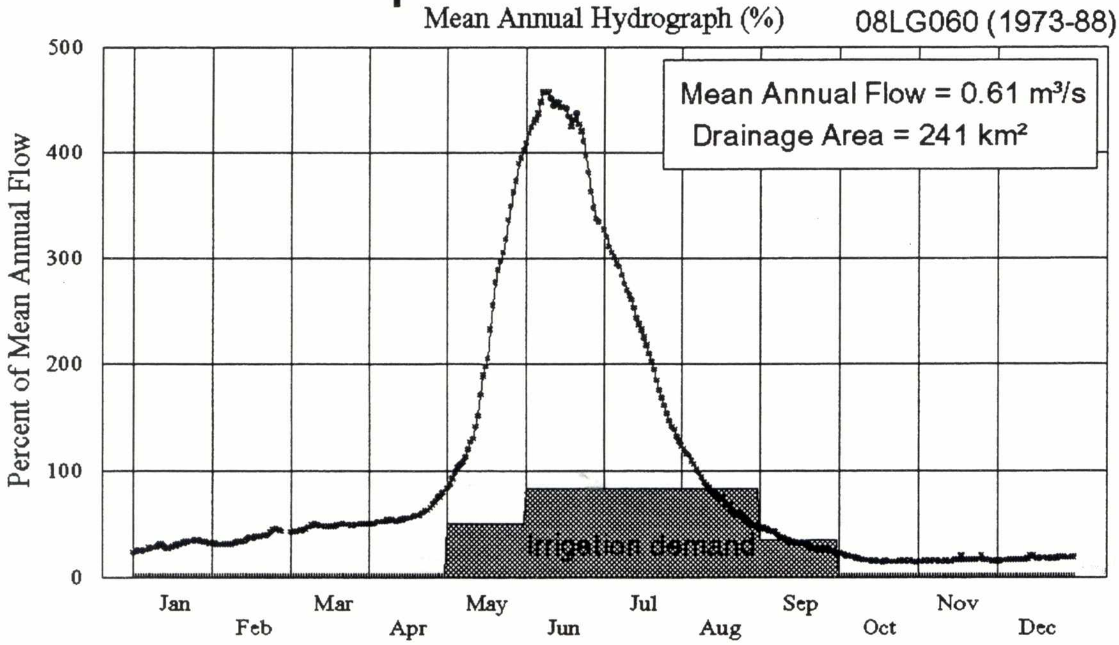
Mean Annual Hydrograph (%) 08LG008 (1971-88)



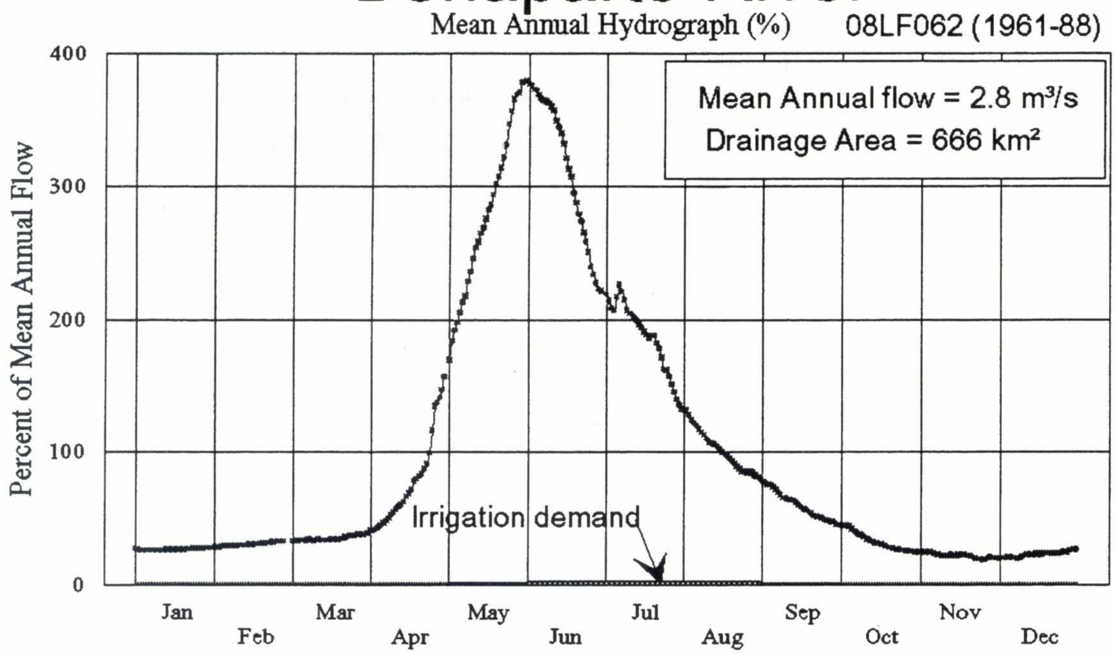

Coldwater River
Mean Annual Hydrograph (%)
08LG048 (1962-88)
Mean Annual Flow = 6.68 m³/s
Drainage Area = 316 km²
Percent of Mean Annual Flow
600
500
400
300
200
100
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec


Coldwater River
Mean Annual Hydrograph (%)
08LG010 (1962-88)
Mean Annual Flow = 8.35 m³/s
Drainage Area = 914 km²
Irrigation demand
Percent of Mean Annual Flow
600
500
400
300
200
100
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

Spahomin Creek

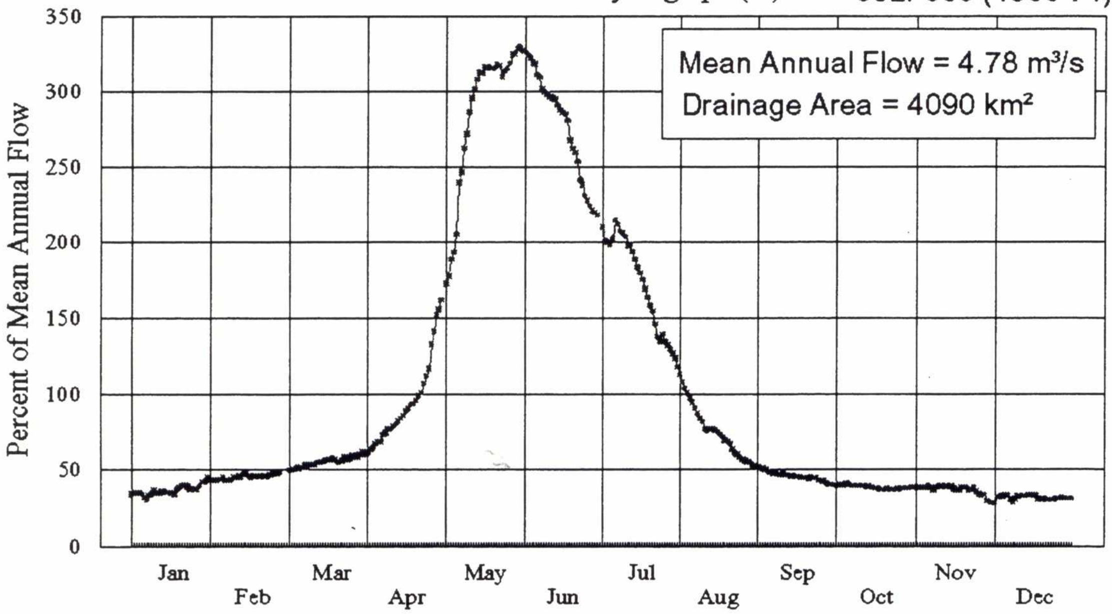


Bonaparte River



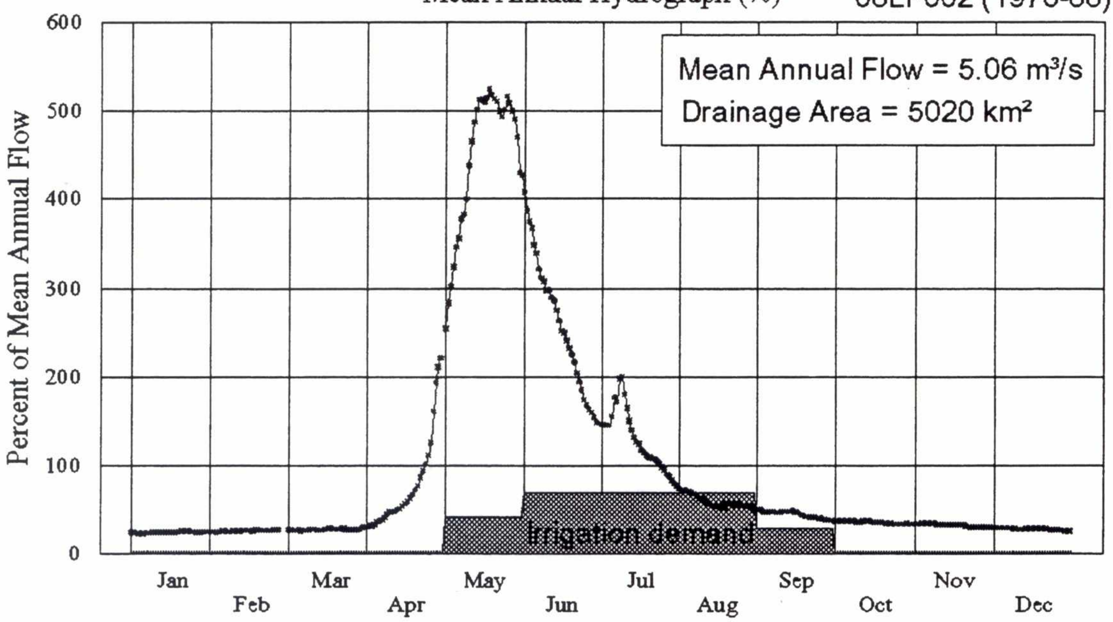
Bonaparte River

Mean Annual Hydrograph (%) 08LF060 (1966-74)

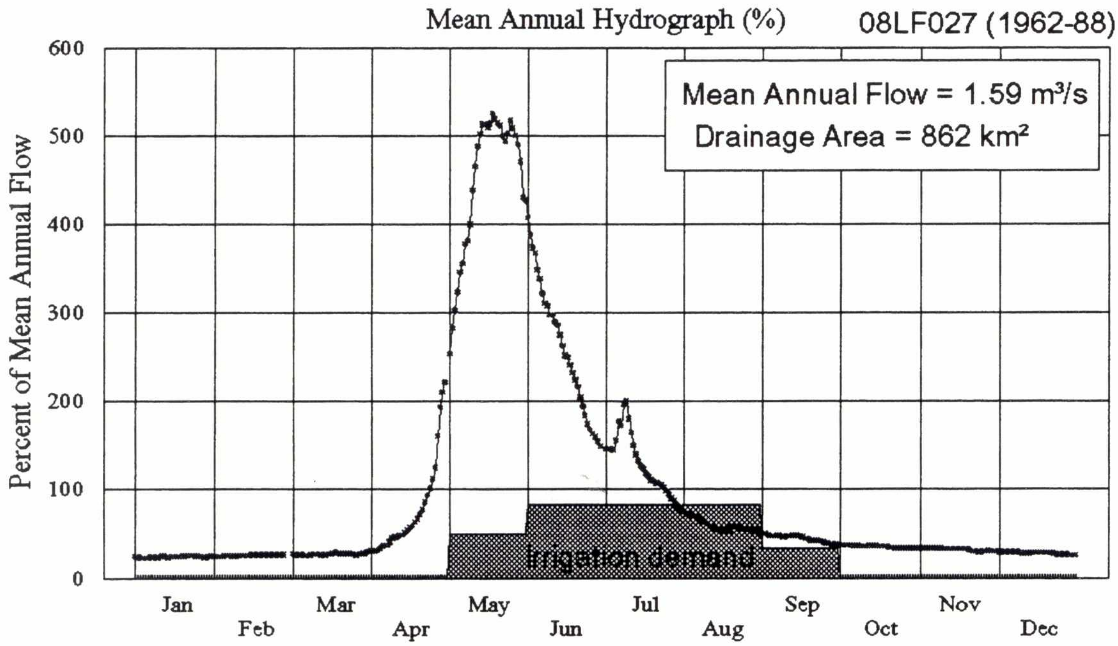


Bonaparte River

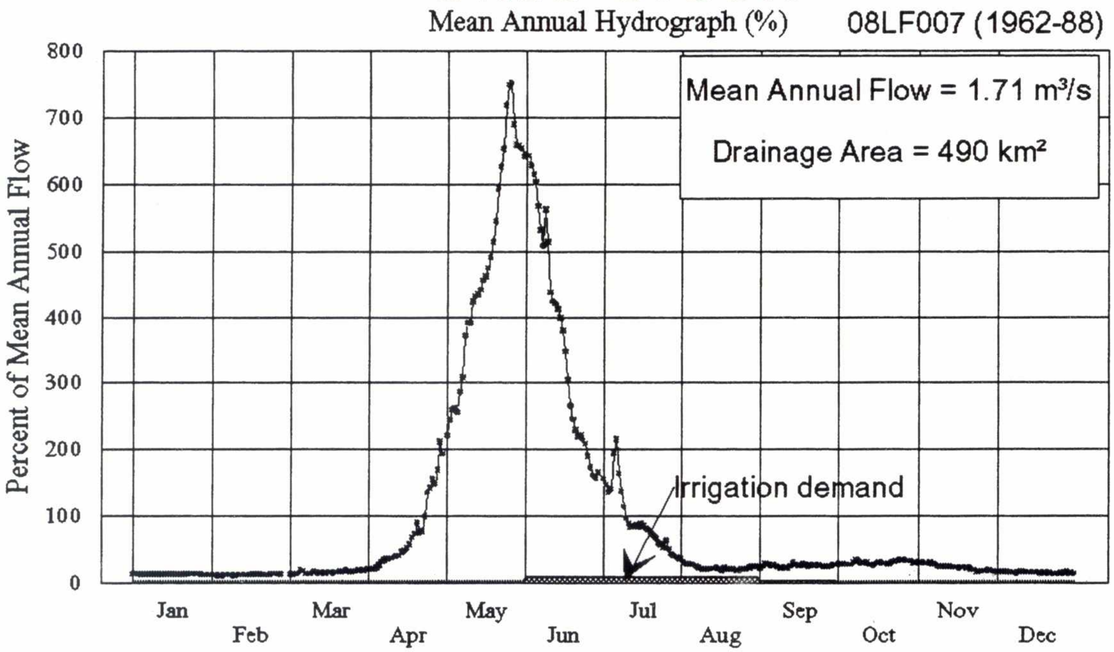
Mean Annual Hydrograph (%) 08LF002 (1976-88)



Deadman River



Criss Creek



APPENDIX B

DISTRIBUTION, BY MONTH, OF ANNUAL 7 DAY LOW FLOWS

B. DISTRIBUTION, BY MONTH, OF ANNUAL 7 DAY LOW FLOWS

1. The Y axis for each small graph is in percent.

2. Each small graph shows the distribution, month by month, of the "annual 7 day low flows" for one Water Survey of Canada (WSC) station.

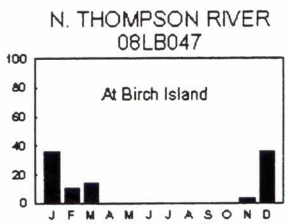
3. Only those years having complete daily data for the whole year were used to calculate the 7 day low flows.

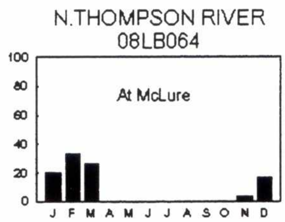
4. Only those stations with 15 or more years of complete annual data were used, with one exception (Lemieux Creek, with 12 years of complete data).

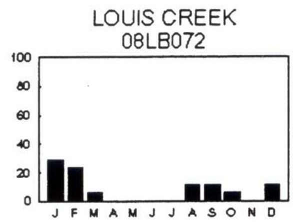
5. The "Annual 7 day low flow" was calculated using daily flow values taken directly from WSC data, without correction for diversions or storage.

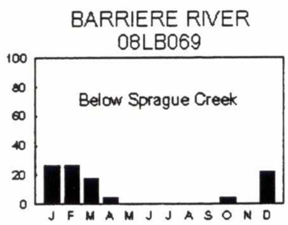
NORTH THOMPSON HMA

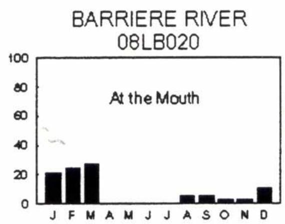
Distribution, by Month , of Annual 7Day Low Flows (In Percent)

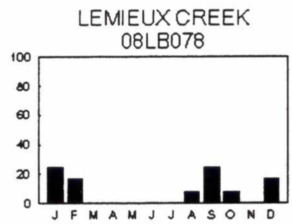


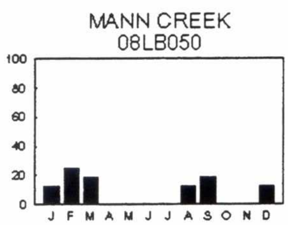


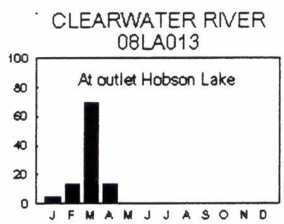


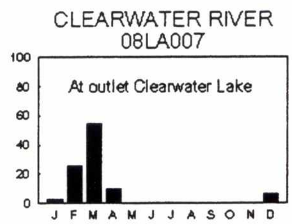


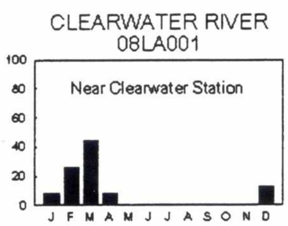


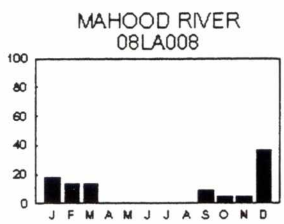








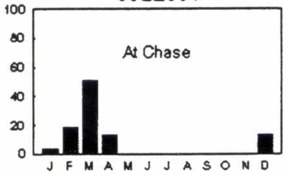




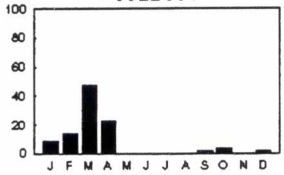
SOUTH THOMPSON - SHUSWAP HMA

Distribution, by Month , of Annual 7Day Low Flows (In Percent)

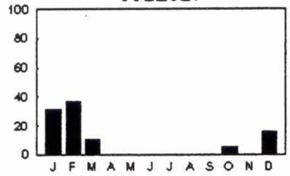
SOUTH THOMPSON RIVER
08LE031



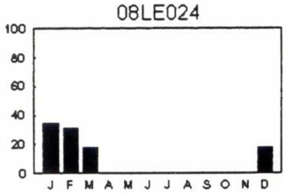
ADAMS RIVER
08LD001



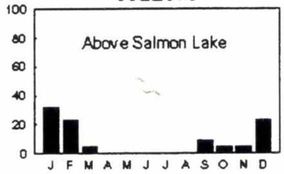
SEYMOUR RIVER
08LE027



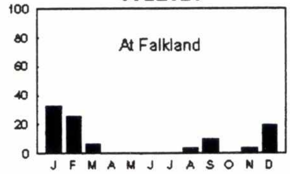
EAGLE RIVER
08LE024



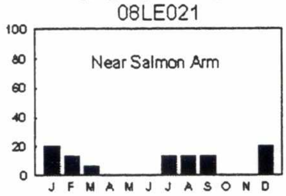
SALMON RIVER
08LE075



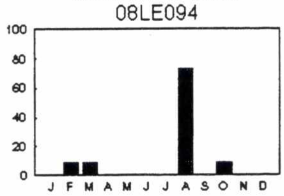
SALMON RIVER
08LE020



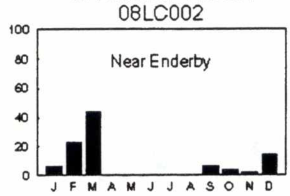
SALMON RIVER
08LE021



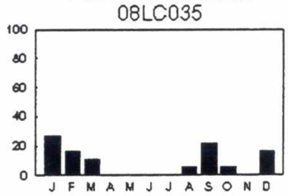
BOLEAN CREEK
08LE094



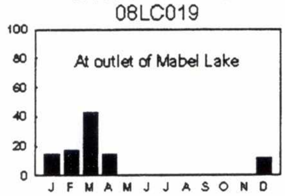
SHUSWAP RIVER
08LC002



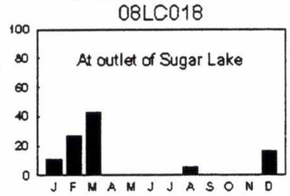
FORTUNE CREEK
08LC035



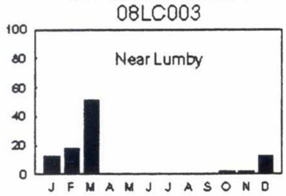
SHUSWAP RIVER
08LC019



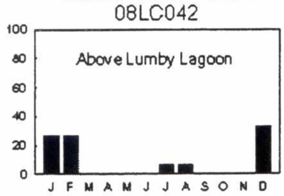
SHUSWAP RIVER
08LC018



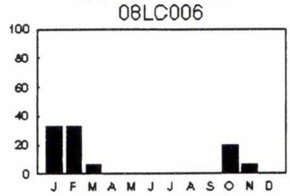
SHUSWAP RIVER
08LC003



BESSETTE CREEK
08LC042

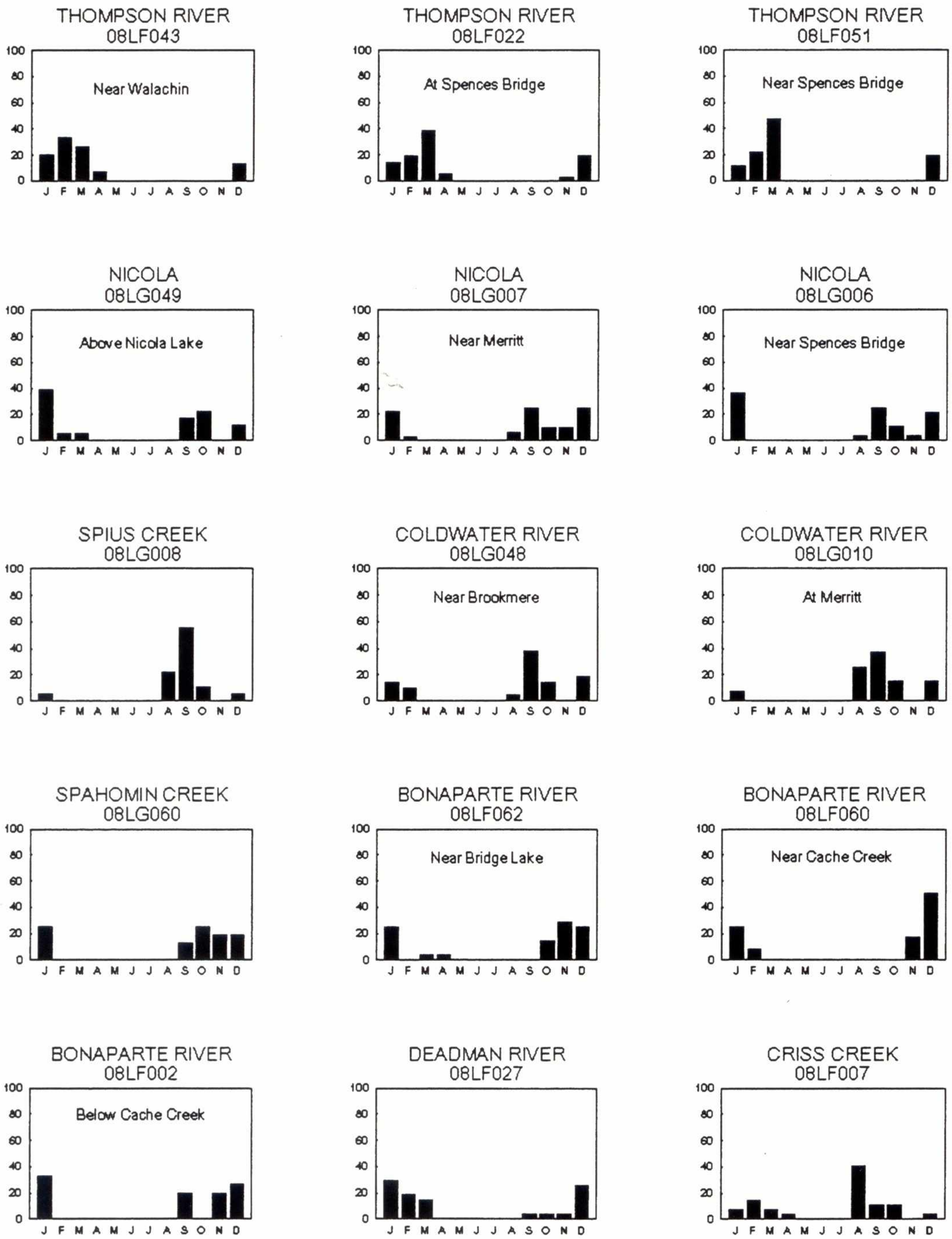


DUTEAU CREEK
08LC006



THOMPSON - NICOLA HMA

Distribution, by Month , of Annual 7Day Low Flows (In Percent)



APPENDIX C

7-DAY LOW FLOW FREQUENCY CURVES

C. 7-DAY LOW FLOW FREQUENCY CURVES

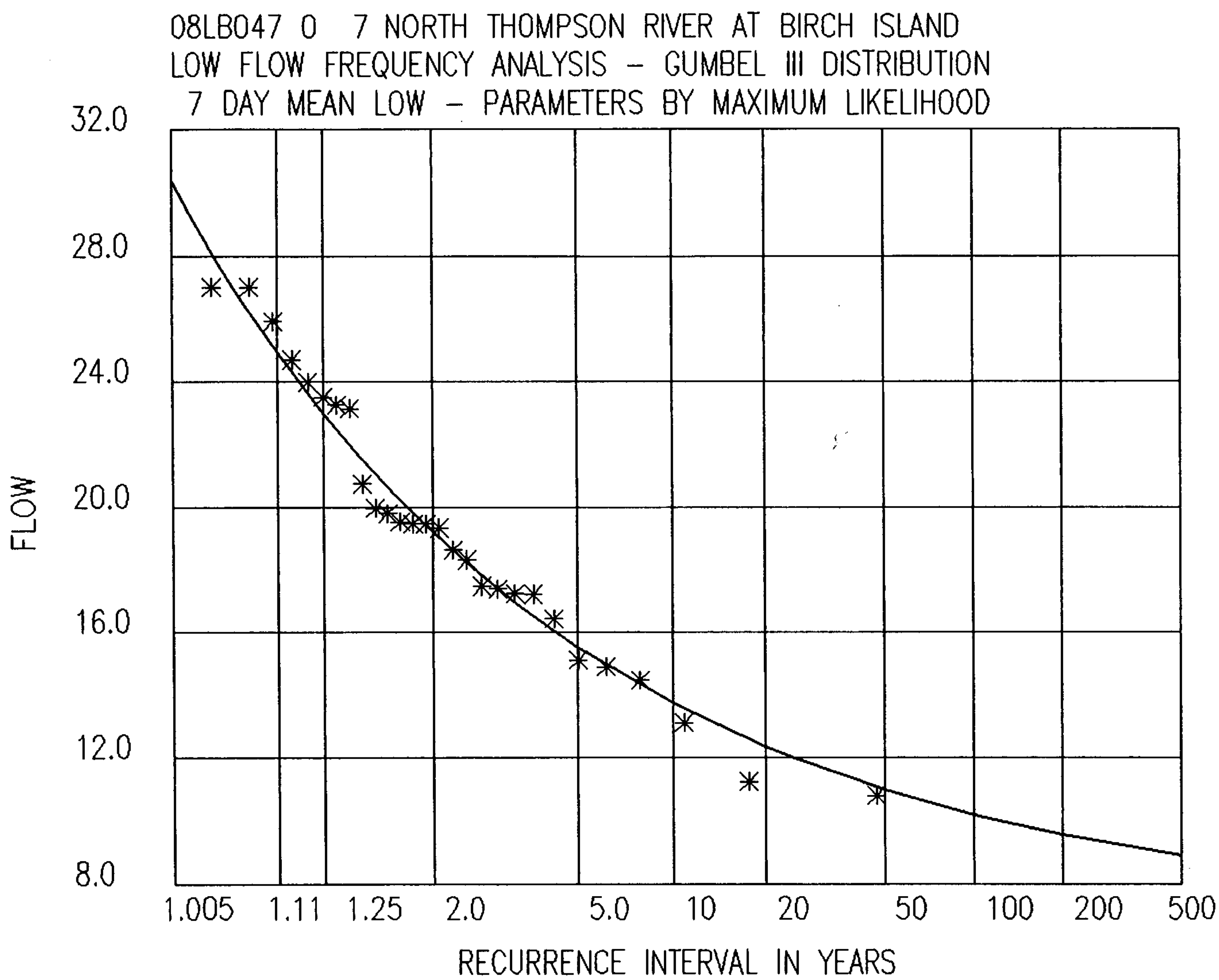
1. Flow is in cubic metres per second.

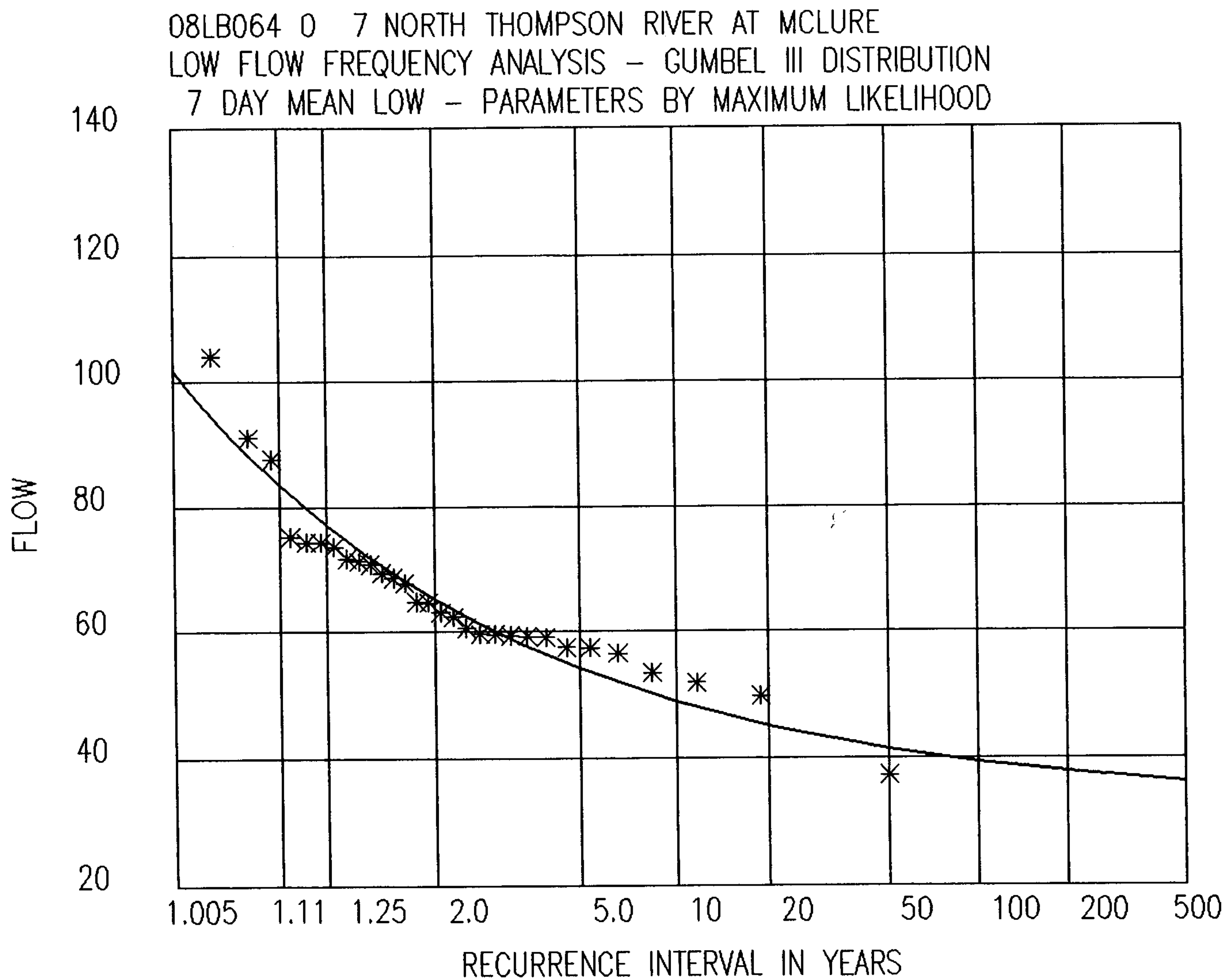
2. "Seven Day Mean Low" is the lowest average flow for 7 consecutive days between January 1 and December 31.

3. Each data point on a graph represents the "Seven Day Mean Low" for one year. All the complete years of daily data were used in the analysis.

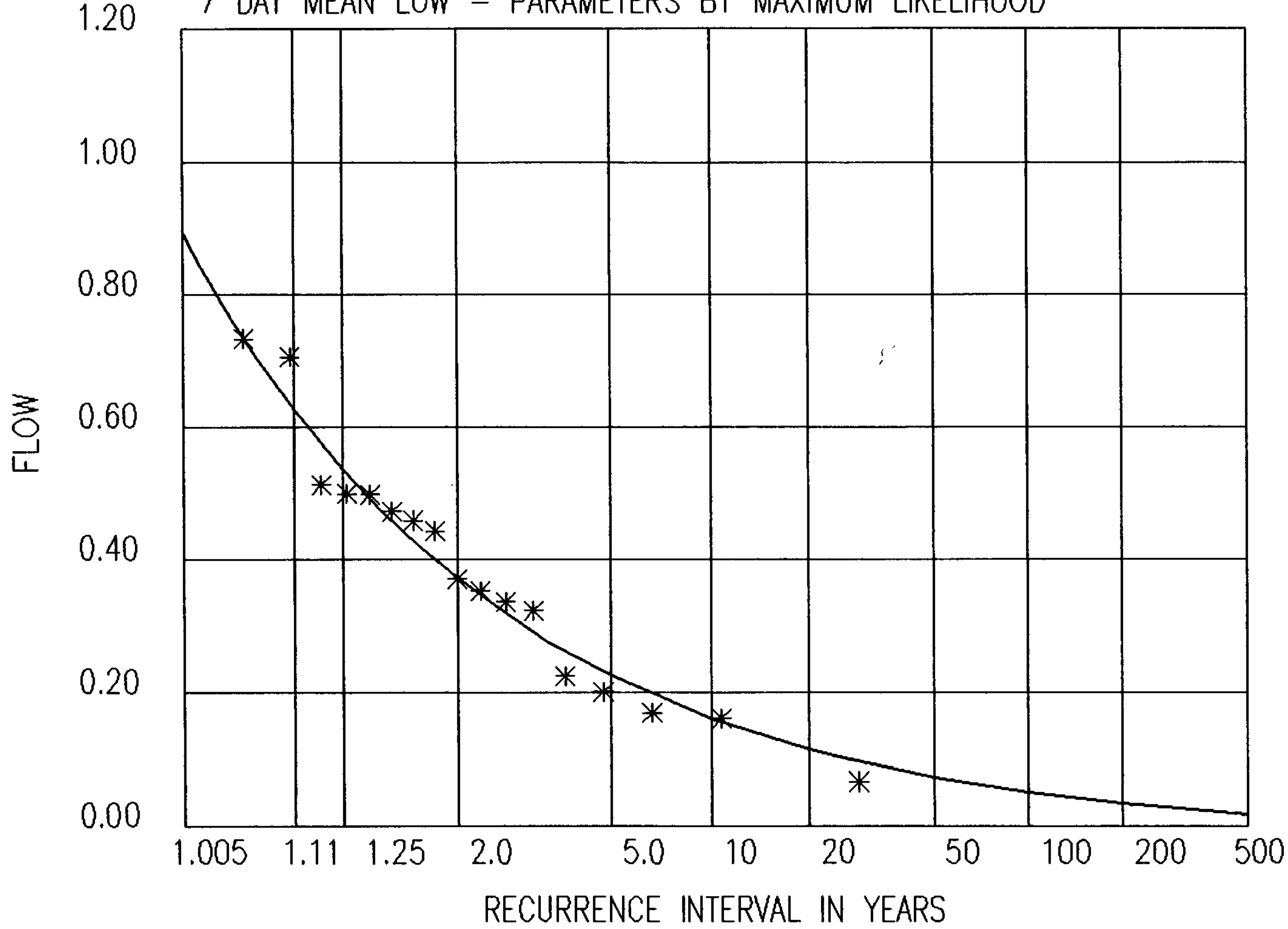
4. "Gumbel 111 distribution", also known as Gumbel's limited distribution of smallest values, is the equation of the curve fitting the data points.

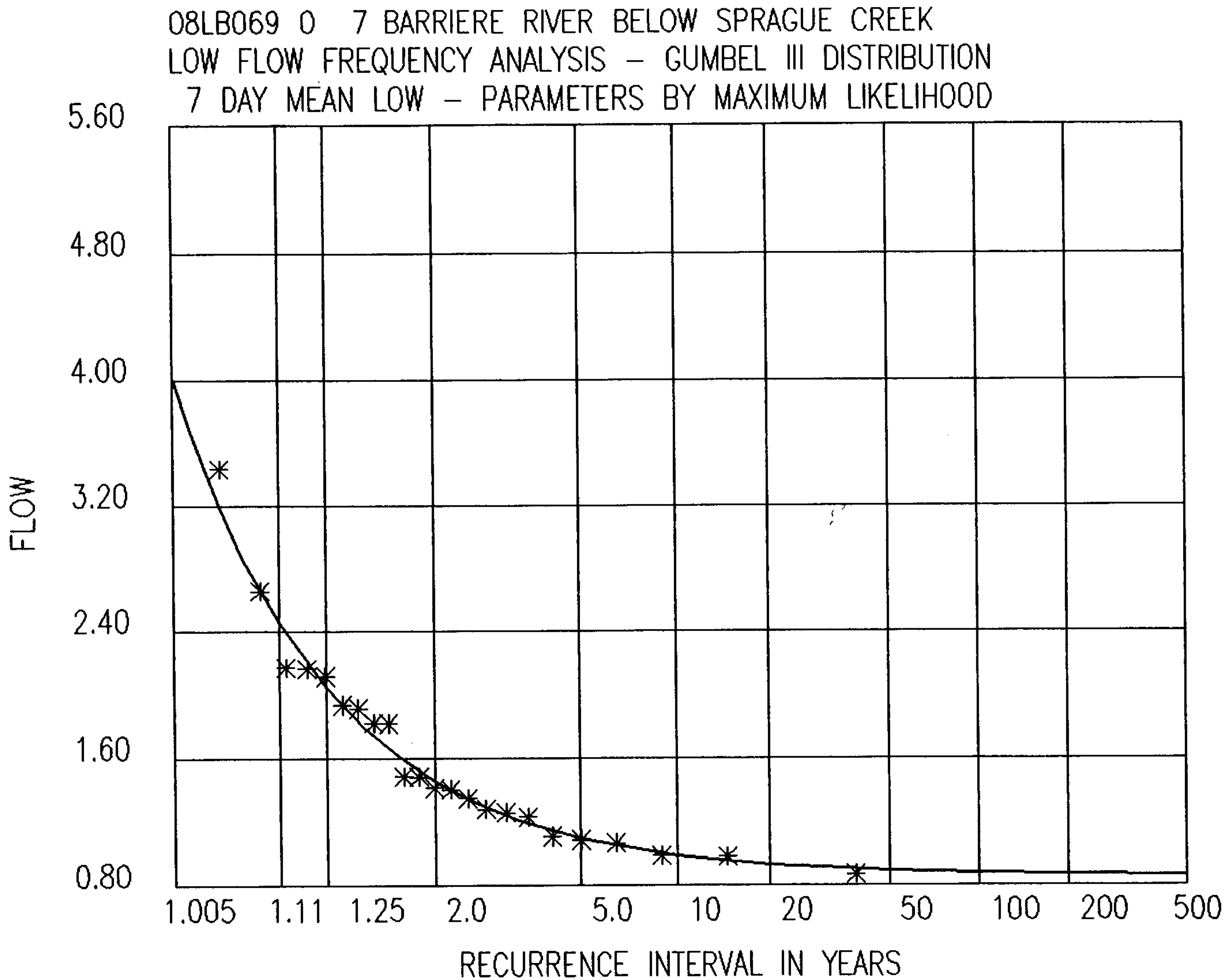
5. "Maximum likelihood" is a statistical technique used to fit a curve to data points; it is generally superior to the more common least squares technique.

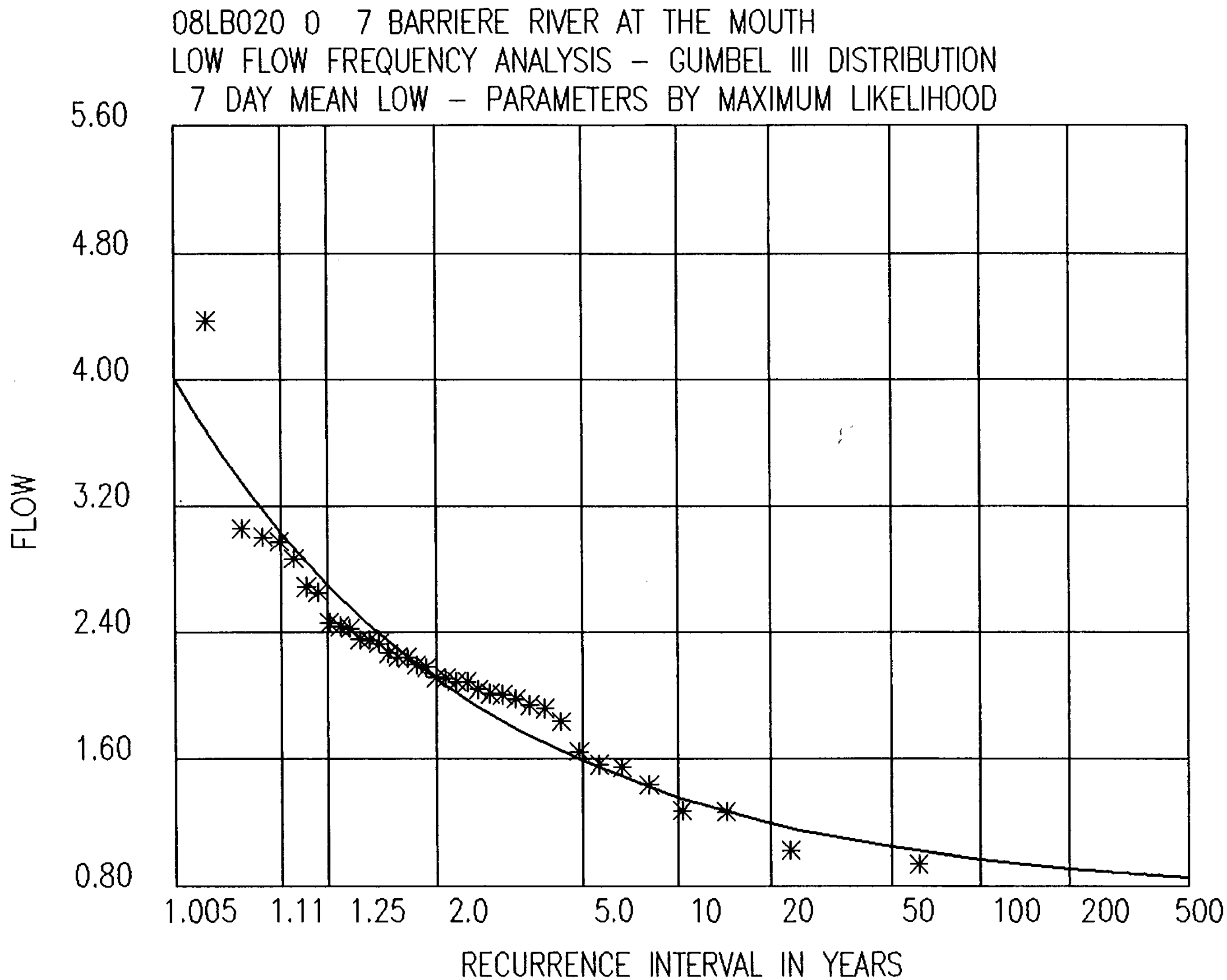

08LB047 0 7 NORTH THOMPSON RIVER AT BIRCH ISLAND
LOW FLOW FREQUENCY ANALYSIS - GUMBEL III DISTRIBUTION
7 DAY MEAN LOW - PARAMETERS BY MAXIMUM LIKELIHOOD
FLOW
32.0
28.0
24.0
20.0
16.0
12.0
8.0
1.005
1.11
1.25
2.0
5.0
10
20
50
100
200
500
RECURRENCE INTERVAL IN YEARS


08LB064 0 7 NORTH THOMPSON RIVER AT MCLURE
LOW FLOW FREQUENCY ANALYSIS - GUMBEL III DISTRIBUTION
7 DAY MEAN LOW - PARAMETERS BY MAXIMUM LIKELIHOOD
FLOW
140
120
100
80
60
40
20
1.005
1.11
1.25
2.0
5.0
10
20
50
100
200
500
RECURRENCE INTERVAL IN YEARS

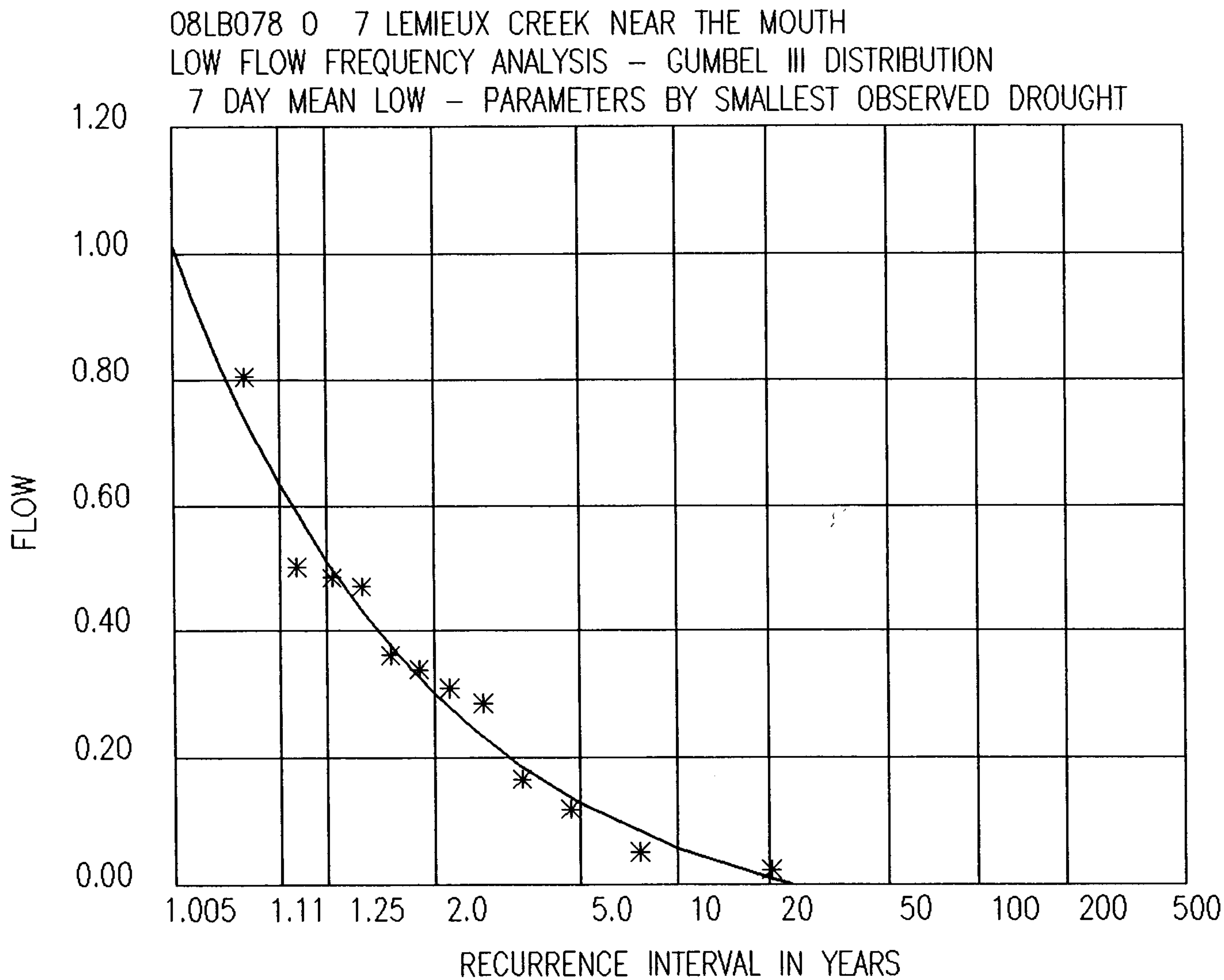
08LB072 0 7 LOUIS CREEK AT THE MOUTH
LOW FLOW FREQUENCY ANALYSIS - GUMBEL III DISTRIBUTION
7 DAY MEAN LOW - PARAMETERS BY MAXIMUM LIKELIHOOD

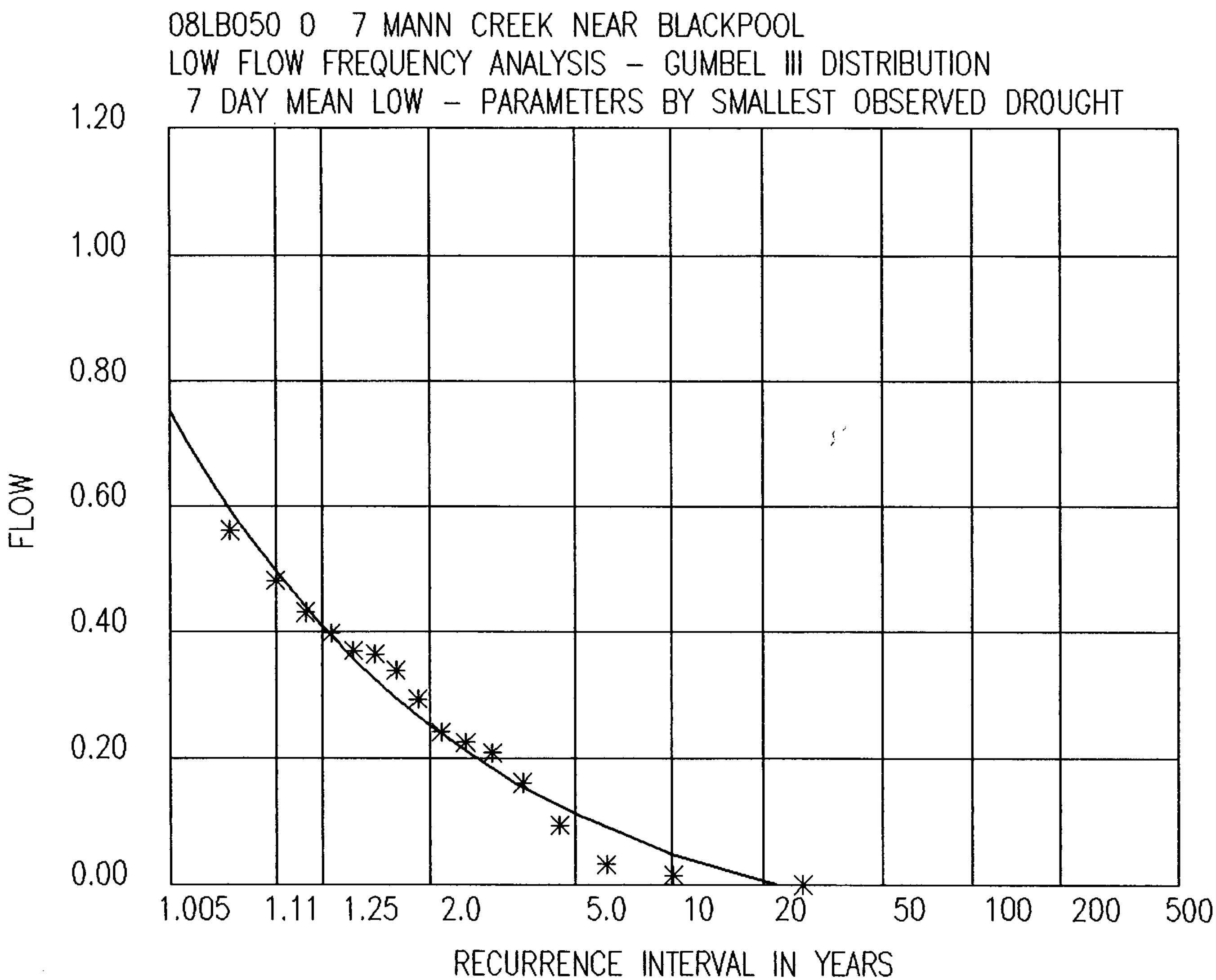



08LB069 0 7 BARRIERE RIVER BELOW SPRAGUE CREEK
LOW FLOW FREQUENCY ANALYSIS – GUMBEL III DISTRIBUTION
7 DAY MEAN LOW – PARAMETERS BY MAXIMUM LIKELIHOOD
FLOW
5.60
4.80
4.00
3.20
2.40
1.60
0.80
1.005
1.11
1.25
2.0
5.0
10
20
50
100
200
500
RECURRENCE INTERVAL IN YEARS

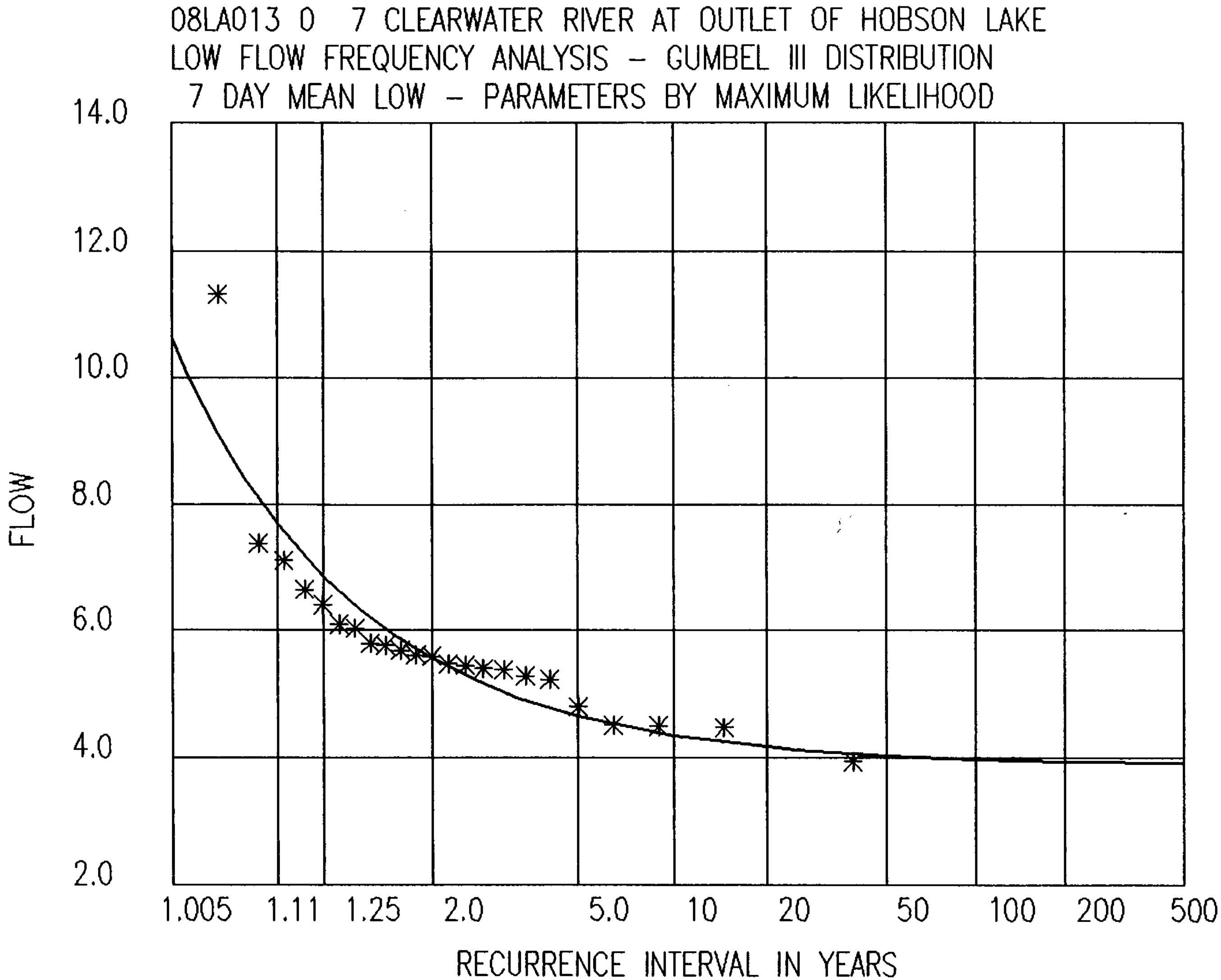


08LB020 0 7 BARRIERE RIVER AT THE MOUTH
LOW FLOW FREQUENCY ANALYSIS - GUMBEL III DISTRIBUTION
7 DAY MEAN LOW - PARAMETERS BY MAXIMUM LIKELIHOOD
FLOW
5.60
4.80
4.00
3.20
2.40
1.60
0.80
1.005
1.11
1.25
2.0
5.0
10
20
50
100
200
500
RECURRENCE INTERVAL IN YEARS

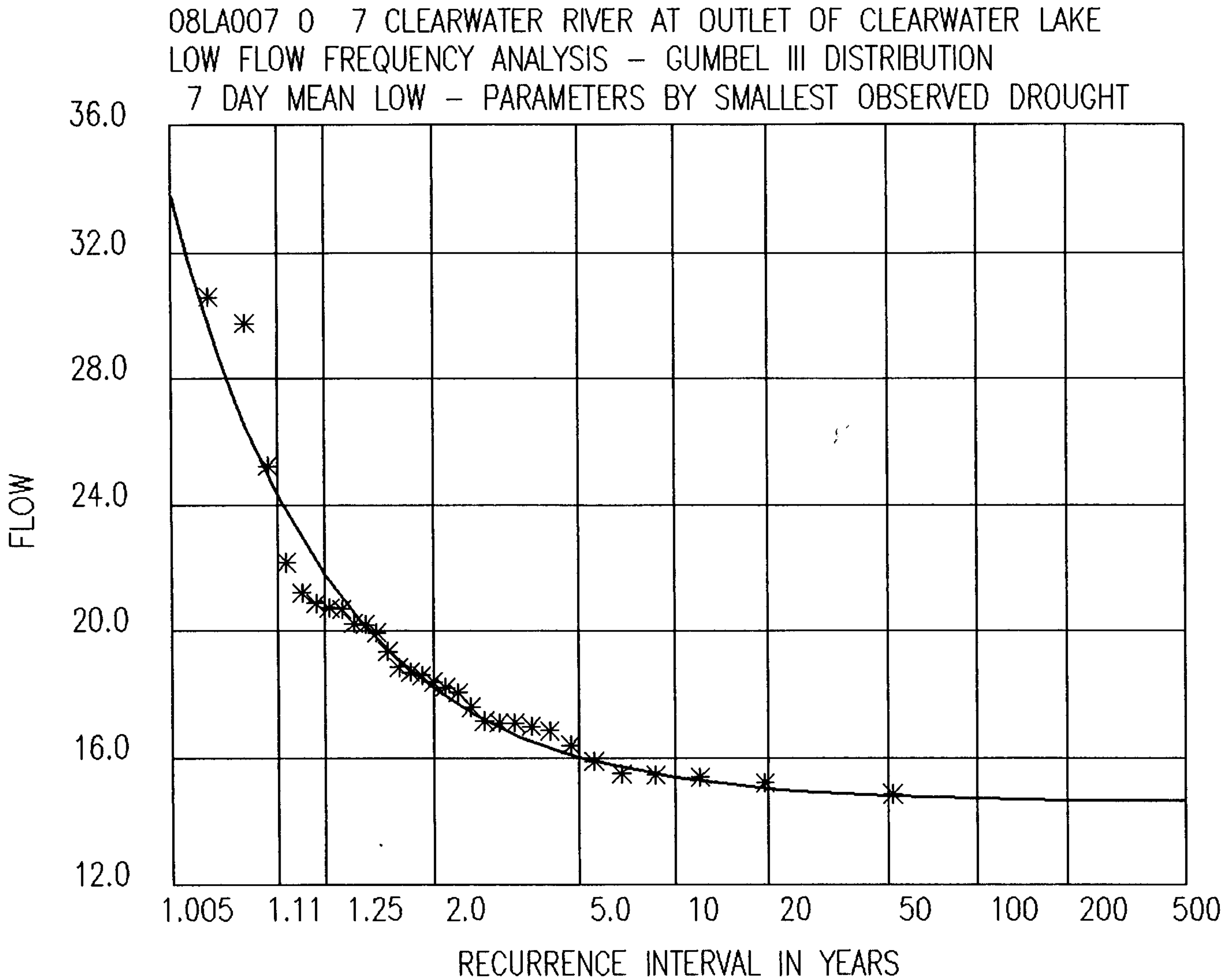

08LB078 0 7 LEMIEUX CREEK NEAR THE MOUTH
LOW FLOW FREQUENCY ANALYSIS - GUMBEL III DISTRIBUTION
7 DAY MEAN LOW - PARAMETERS BY SMALLEST OBSERVED DROUGHT
FLOW
1.20
1.00
0.80
0.60
0.40
0.20
0.00
1.005
1.11
1.25
2.0
5.0
10
20
50
100
200
500
RECURRENCE INTERVAL IN YEARS



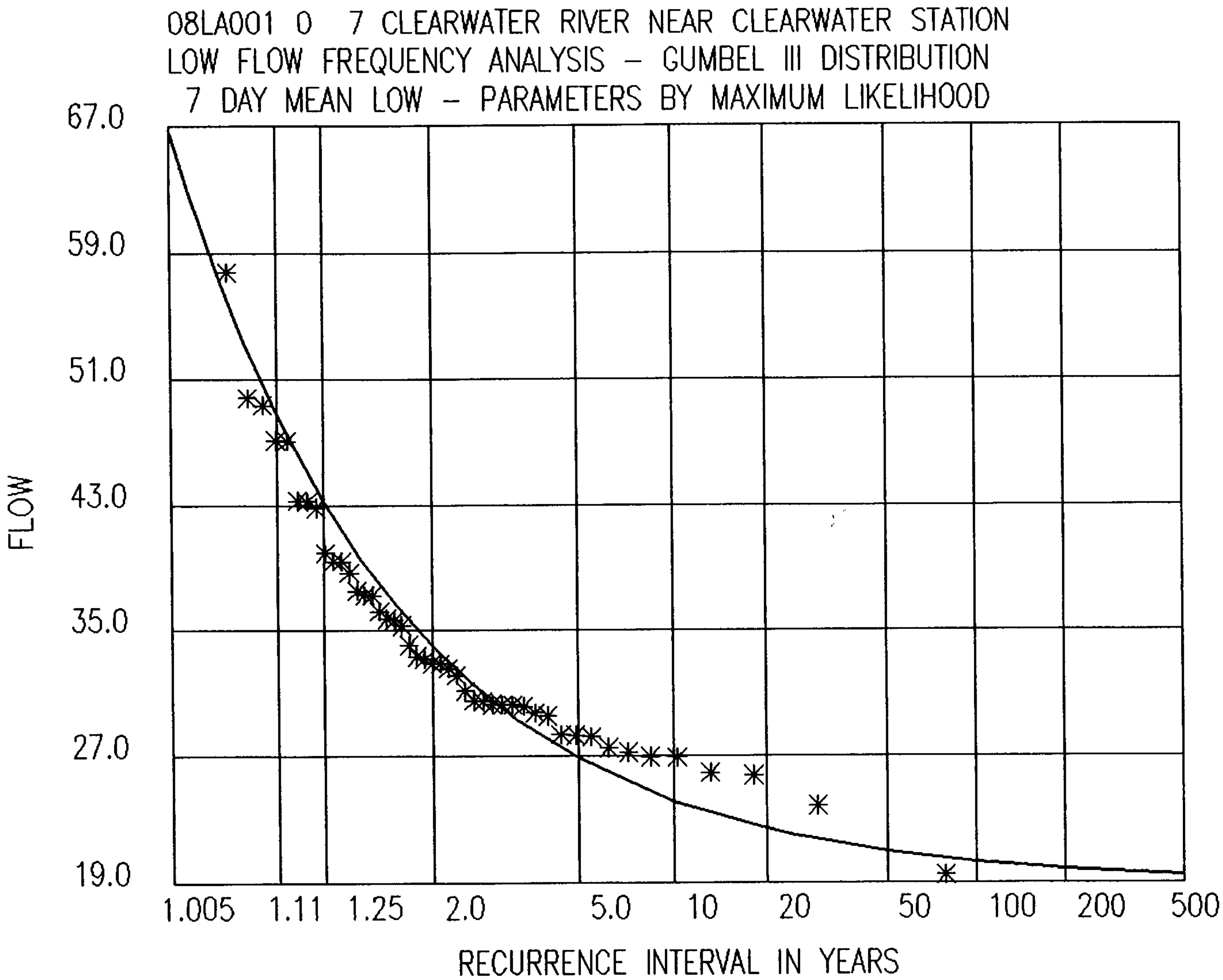
08LB050 0 7 MANN CREEK NEAR BLACKPOOL
LOW FLOW FREQUENCY ANALYSIS - GUMBEL III DISTRIBUTION
7 DAY MEAN LOW - PARAMETERS BY SMALLEST OBSERVED DROUGHT
1.20
1.00
0.80
0.60
0.40
0.20
0.00
FLOW
1.005
1.11
1.25
2.0
5.0
10
20
50
100
200
500
RECURRENCE INTERVAL IN YEARS



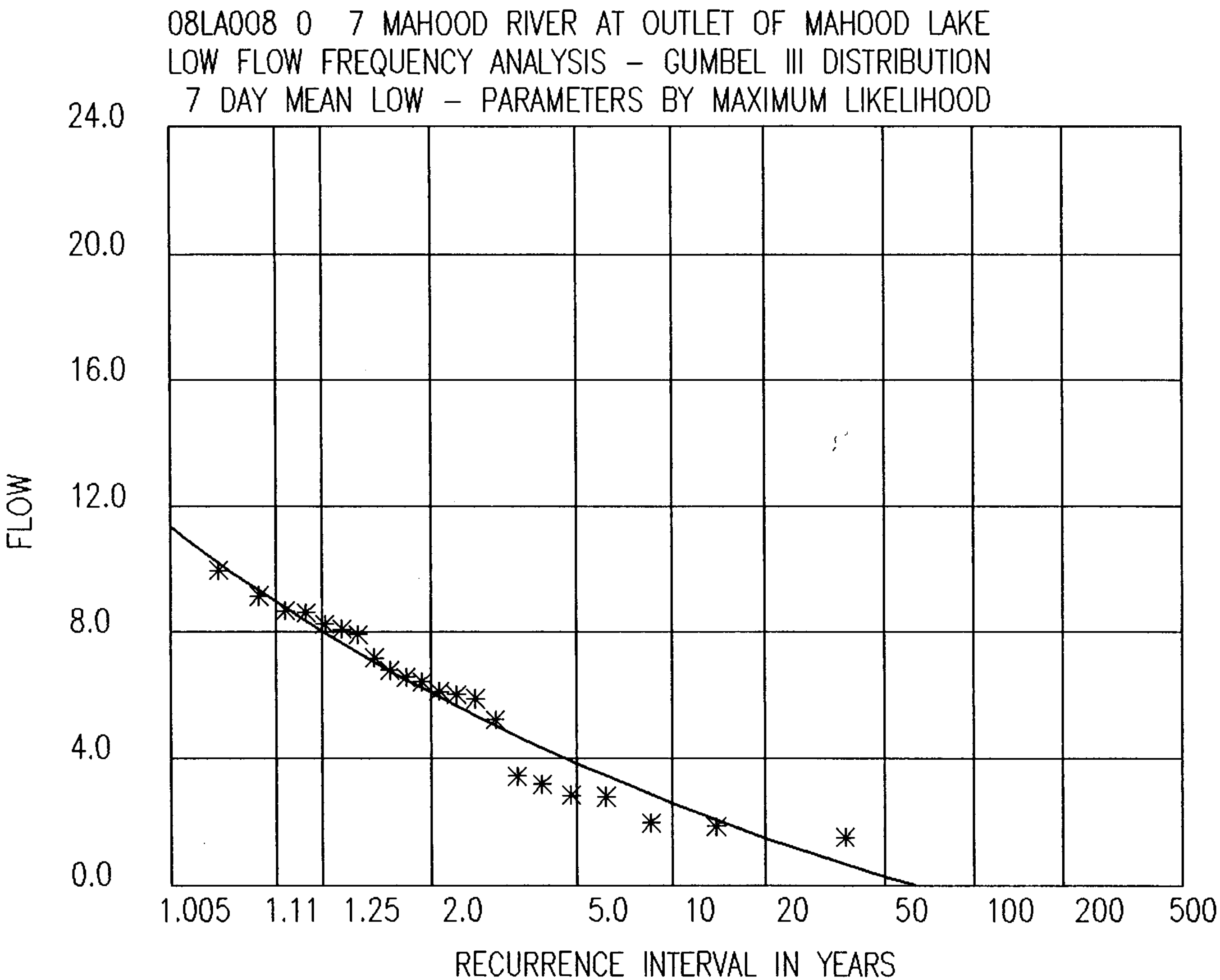
08LA013 0 7 CLEARWATER RIVER AT OUTLET OF HOBSON LAKE
LOW FLOW FREQUENCY ANALYSIS - GUMBEL III DISTRIBUTION
7 DAY MEAN LOW - PARAMETERS BY MAXIMUM LIKELIHOOD
FLOW
14.0
12.0
10.0
8.0
6.0
4.0
2.0
1.005
1.11
1.25
2.0
5.0
10
20
50
100
200
500
RECURRENCE INTERVAL IN YEARS

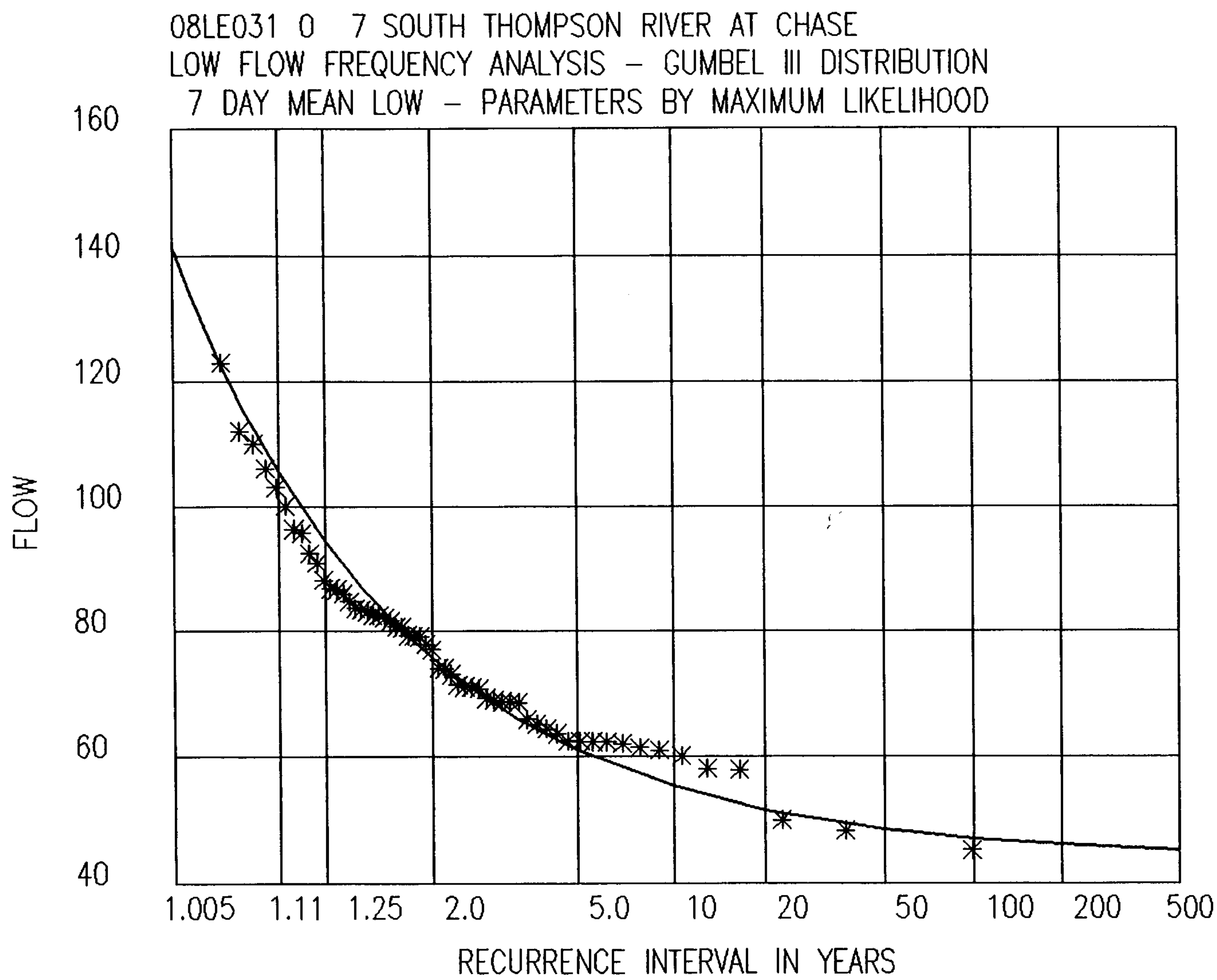


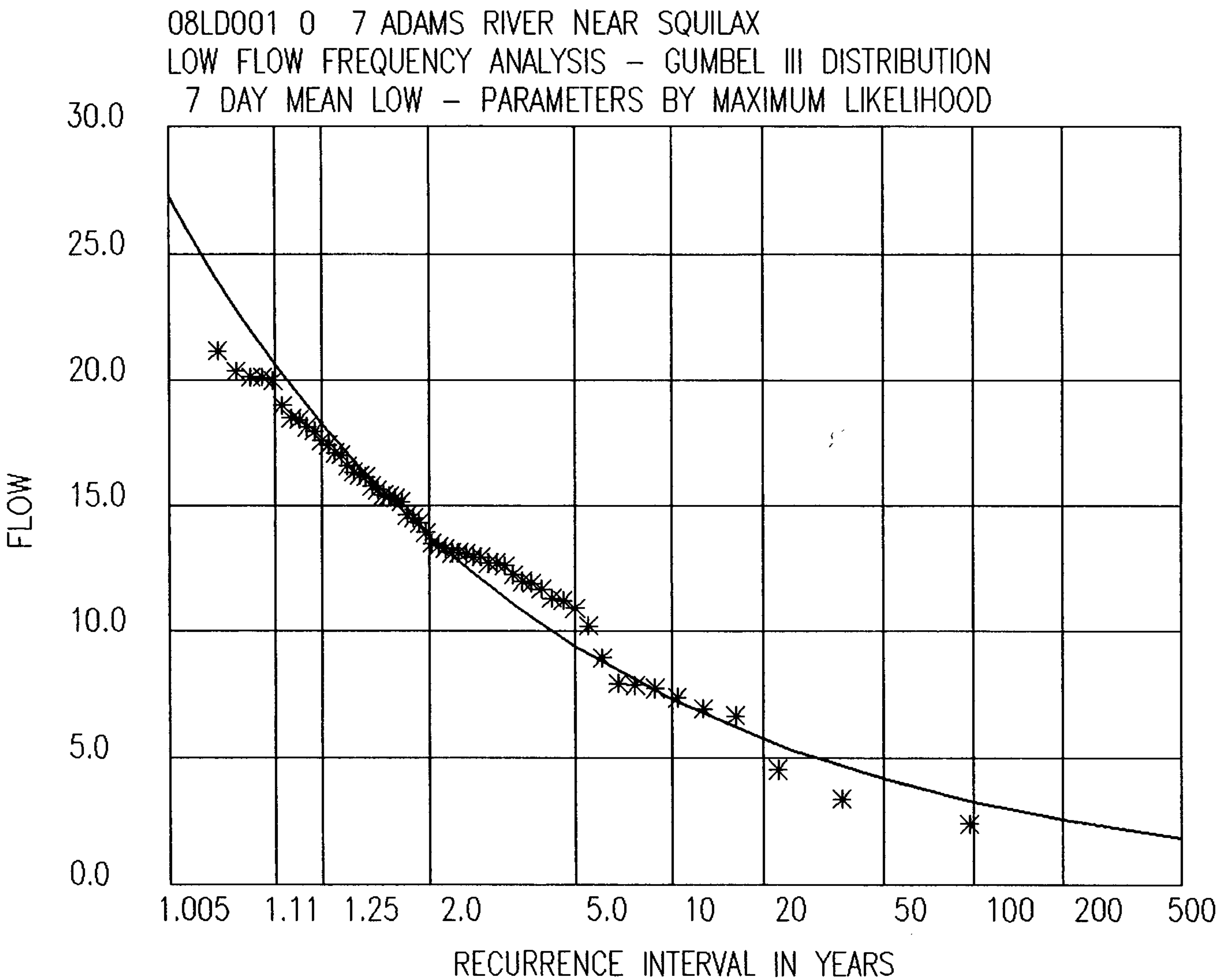
08LA007 0 7 CLEARWATER RIVER AT OUTLET OF CLEARWATER LAKE
LOW FLOW FREQUENCY ANALYSIS – GUMBEL III DISTRIBUTION
7 DAY MEAN LOW – PARAMETERS BY SMALLEST OBSERVED DROUGHT
FLOW
36.0
32.0
28.0
24.0
20.0
16.0
12.0
1.005
1.11
1.25
2.0
5.0
10
20
50
100
200
500
RECURRENCE INTERVAL IN YEARS

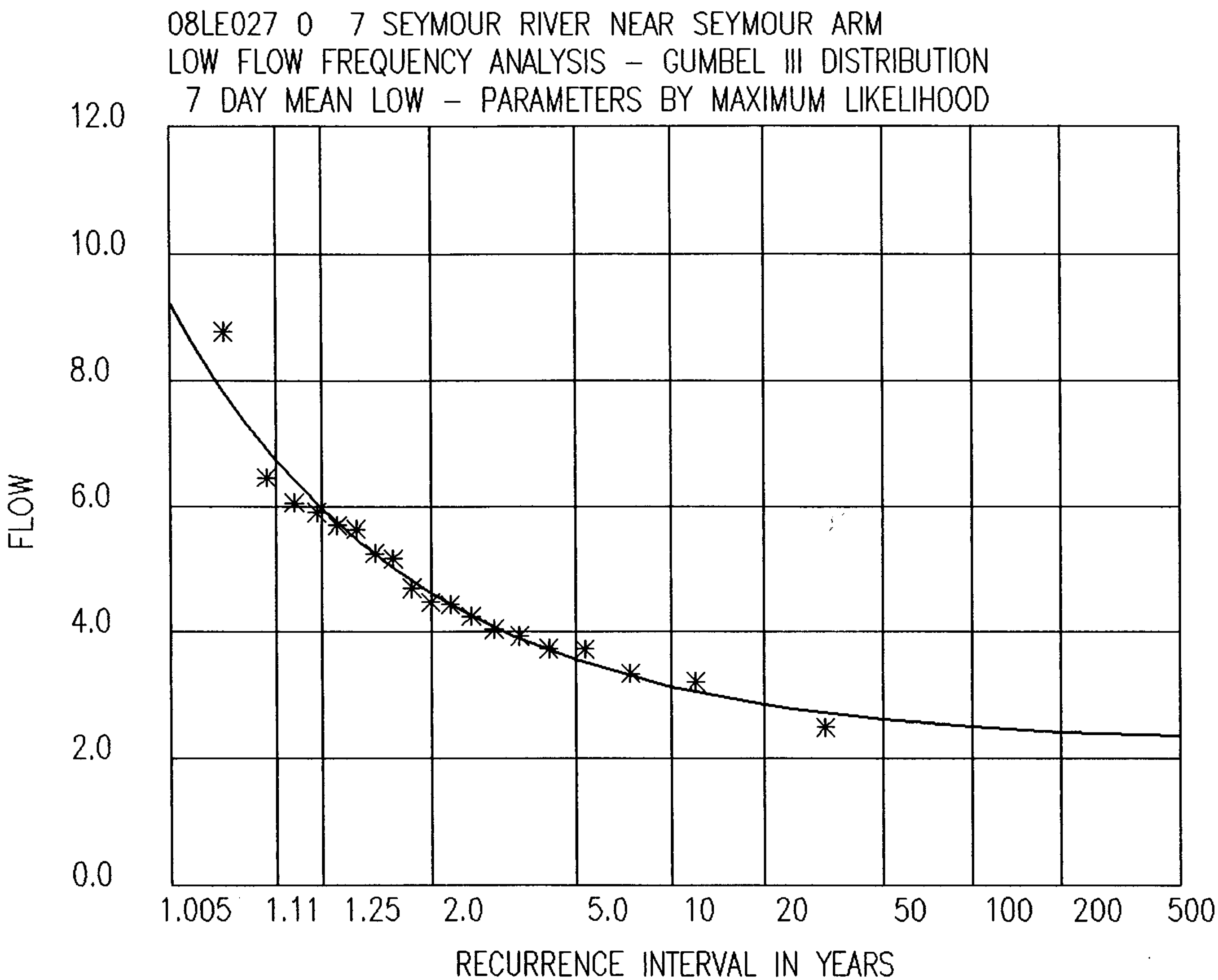


08LA001 0 7 CLEARWATER RIVER NEAR CLEARWATER STATION
LOW FLOW FREQUENCY ANALYSIS – GUMBEL III DISTRIBUTION
7 DAY MEAN LOW – PARAMETERS BY MAXIMUM LIKELIHOOD
67.0
59.0
51.0
43.0
35.0
27.0
19.0
FLOW
1.005
1.11
1.25
2.0
5.0
10
20
50
100
200
500
RECURRENCE INTERVAL IN YEARS

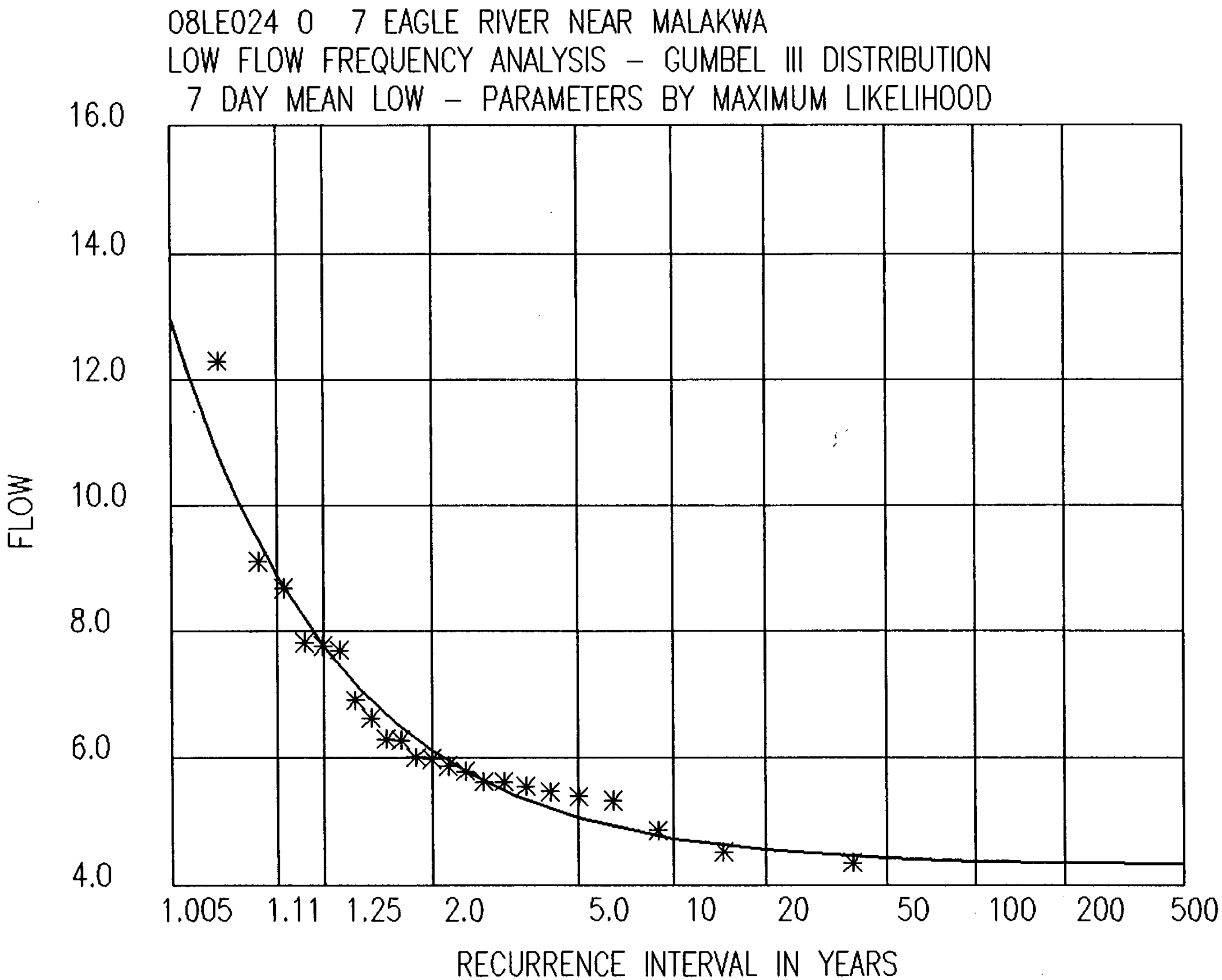

08LA008 0 7 MAHOOD RIVER AT OUTLET OF MAHOOD LAKE
LOW FLOW FREQUENCY ANALYSIS - GUMBEL III DISTRIBUTION
7 DAY MEAN LOW - PARAMETERS BY MAXIMUM LIKELIHOOD
24.0
20.0
16.0
12.0
8.0
4.0
0.0
FLOW
1.005
1.11
1.25
2.0
5.0
10
20
50
100
200
500
RECURRENCE INTERVAL IN YEARS


08LE031 0 7 SOUTH THOMPSON RIVER AT CHASE
LOW FLOW FREQUENCY ANALYSIS – GUMBEL III DISTRIBUTION
7 DAY MEAN LOW – PARAMETERS BY MAXIMUM LIKELIHOOD
160
140
120
100
80
60
40
FLOW
1.005
1.11
1.25
2.0
5.0
10
20
50
100
200
500
RECURRENCE INTERVAL IN YEARS

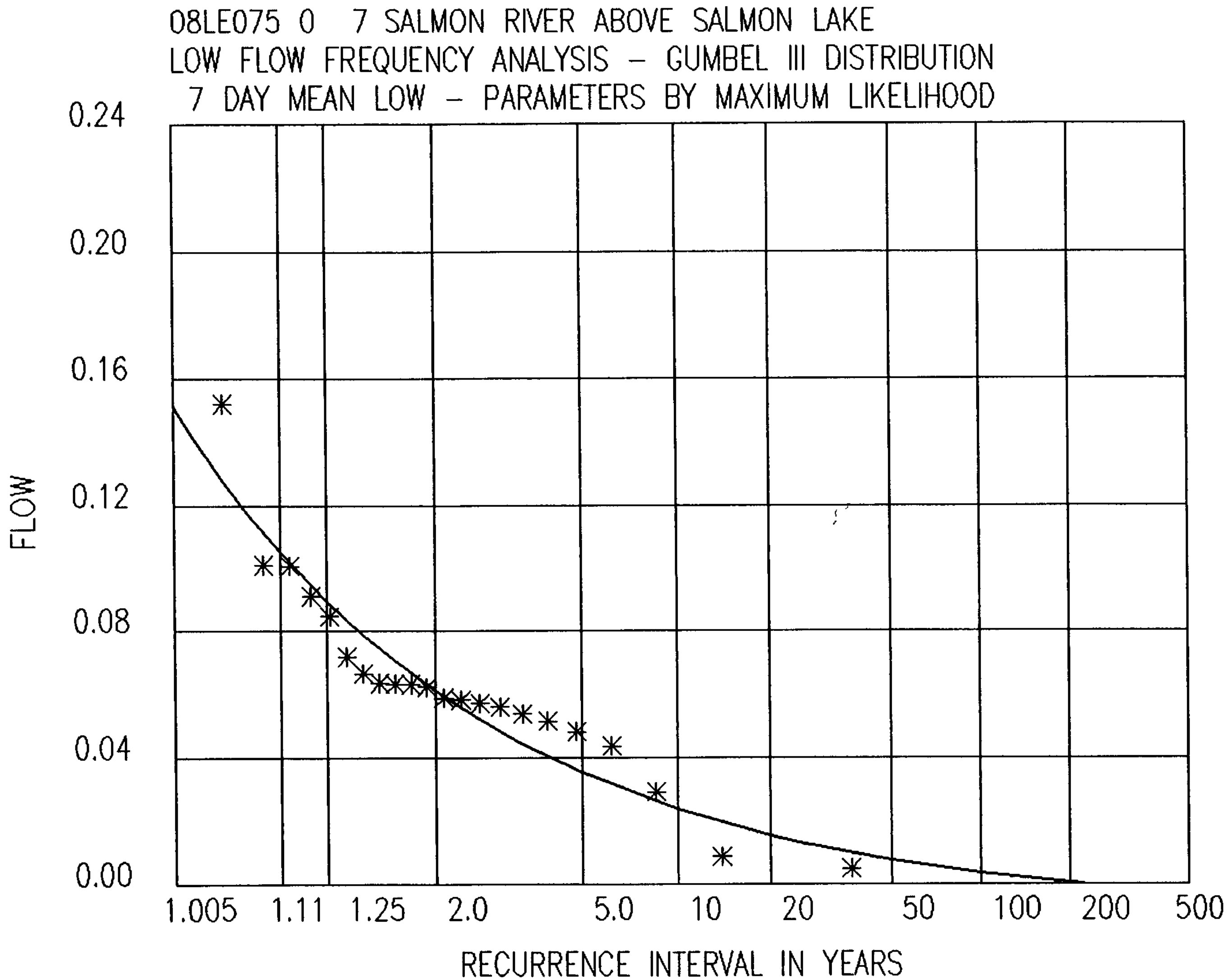

08LD001 0 7 ADAMS RIVER NEAR SQUILAX
LOW FLOW FREQUENCY ANALYSIS - GUMBEL III DISTRIBUTION
7 DAY MEAN LOW - PARAMETERS BY MAXIMUM LIKELIHOOD
FLOW
30.0
25.0
20.0
15.0
10.0
5.0
0.0
1.005
1.11
1.25
2.0
5.0
10
20
50
100
200
500
RECURRENCE INTERVAL IN YEARS



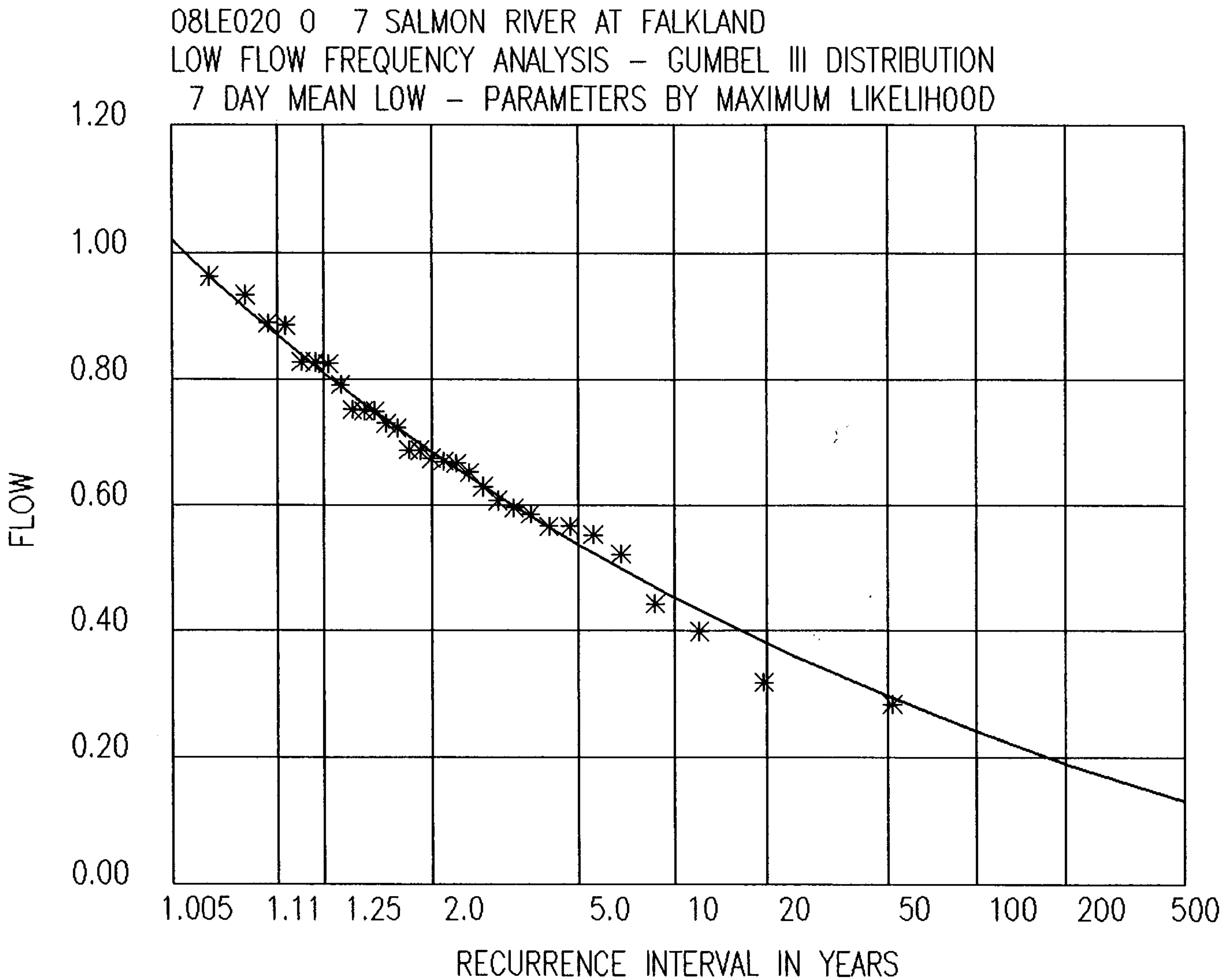
08LE027 0 7 SEYMOUR RIVER NEAR SEYMOUR ARM
LOW FLOW FREQUENCY ANALYSIS - GUMBEL III DISTRIBUTION
7 DAY MEAN LOW - PARAMETERS BY MAXIMUM LIKELIHOOD
FLOW
12.0
10.0
8.0
6.0
4.0
2.0
0.0
1.005
1.11
1.25
2.0
5.0
10
20
50
100
200
500
RECURRENCE INTERVAL IN YEARS

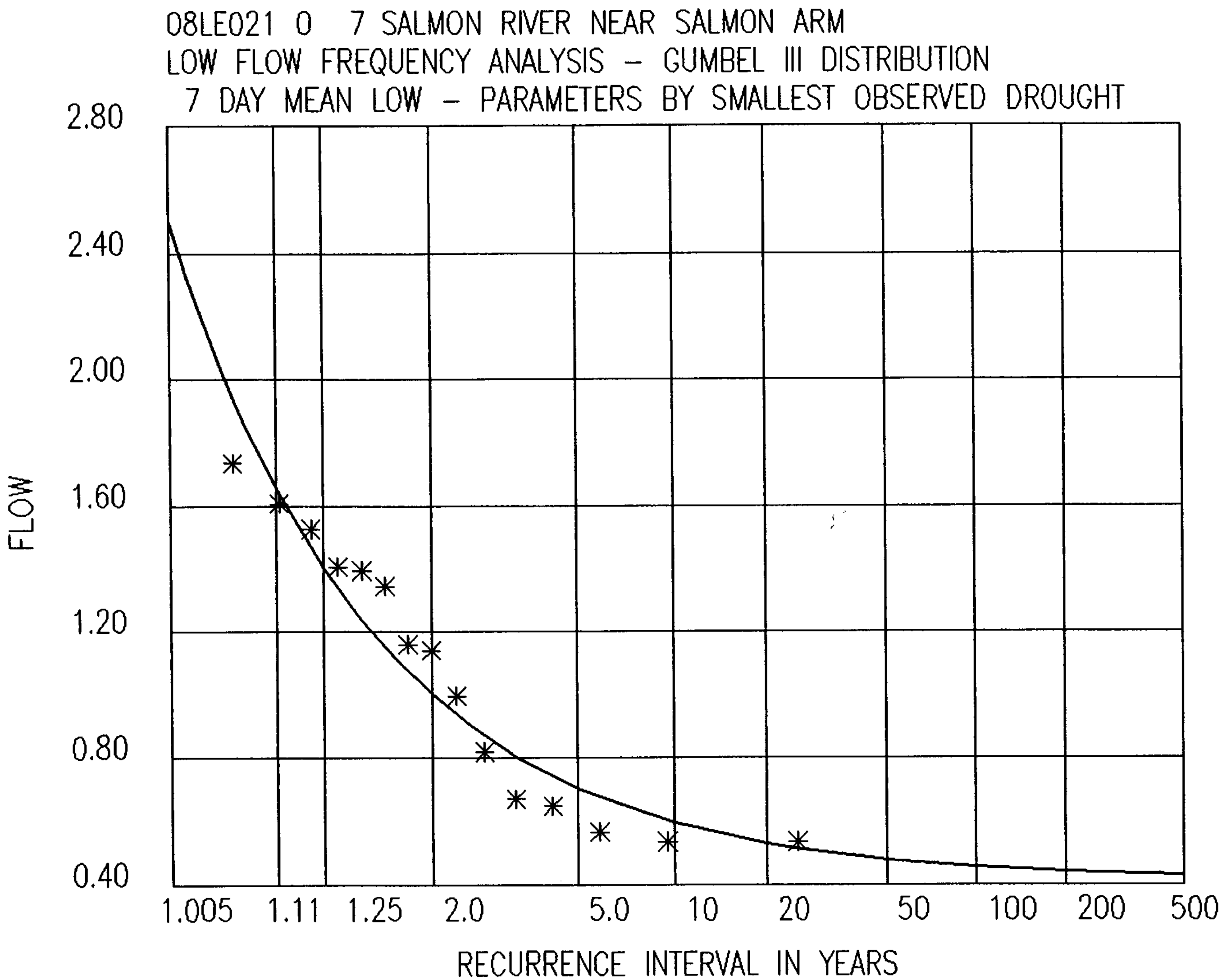


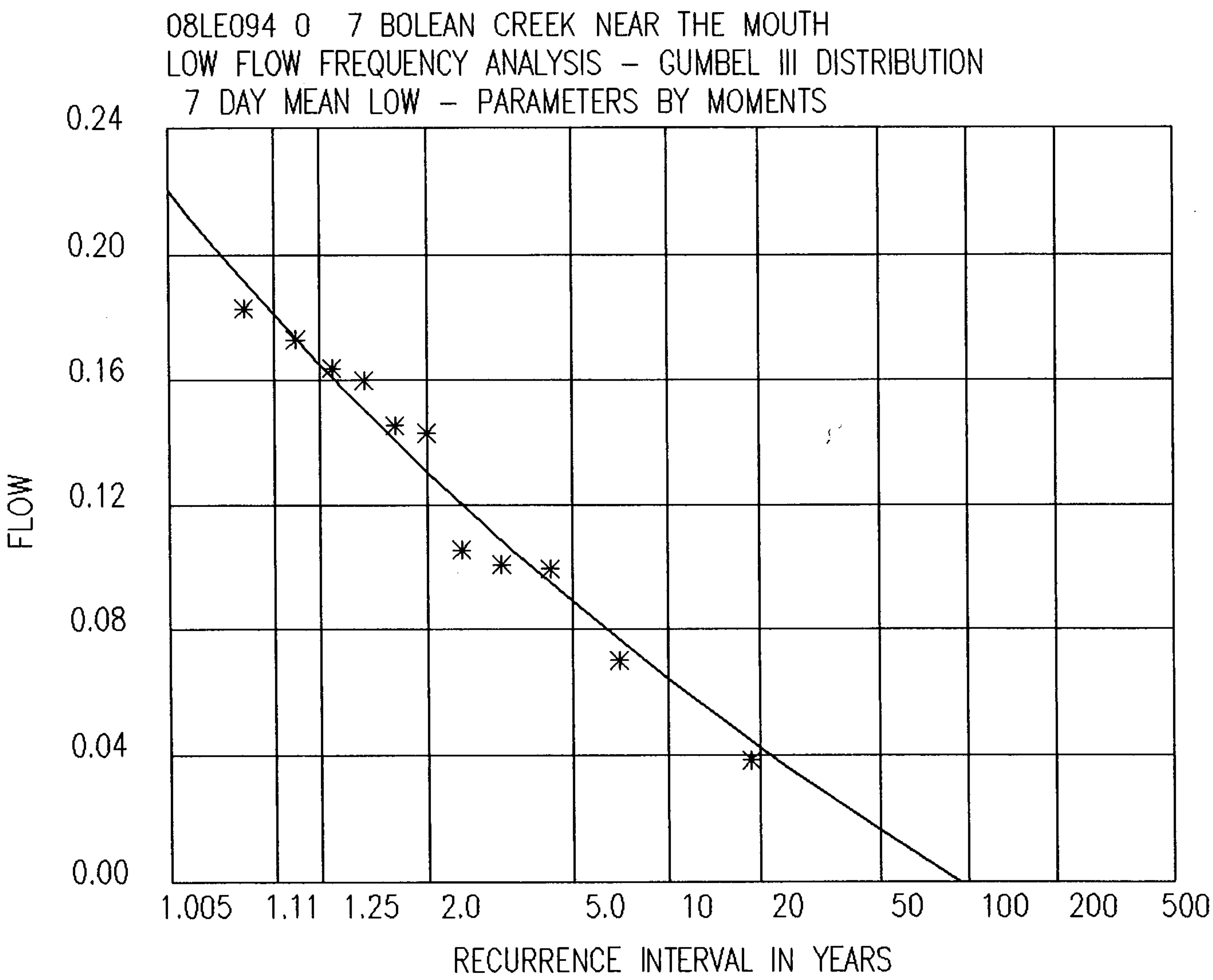
08LE024 0 7 EAGLE RIVER NEAR MALAKWA
LOW FLOW FREQUENCY ANALYSIS - GUMBEL III DISTRIBUTION
7 DAY MEAN LOW - PARAMETERS BY MAXIMUM LIKELIHOOD
FLOW
16.0
14.0
12.0
10.0
8.0
6.0
4.0
1.005
1.11
1.25
2.0
5.0
10
20
50
100
200
500
RECURRENCE INTERVAL IN YEARS

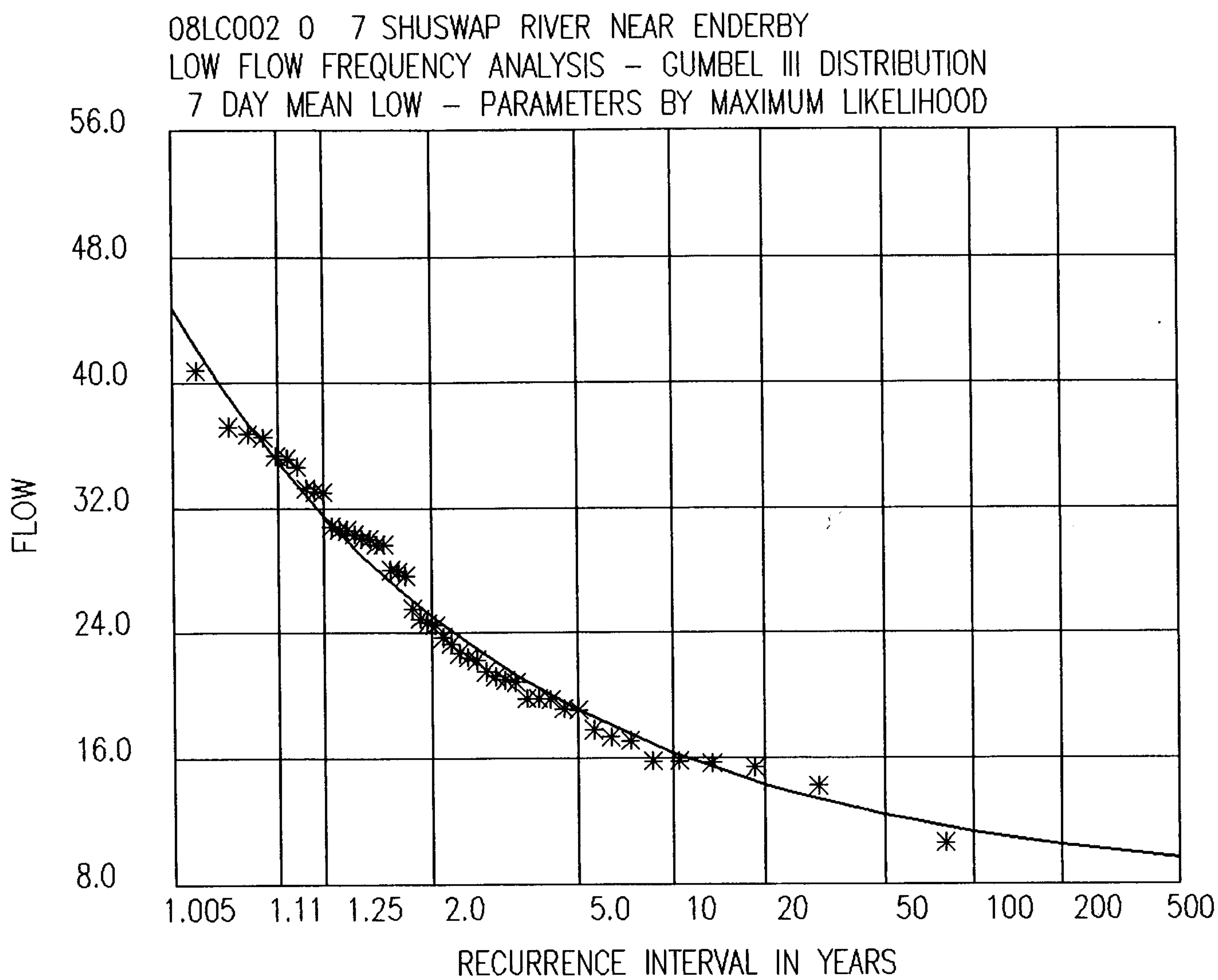


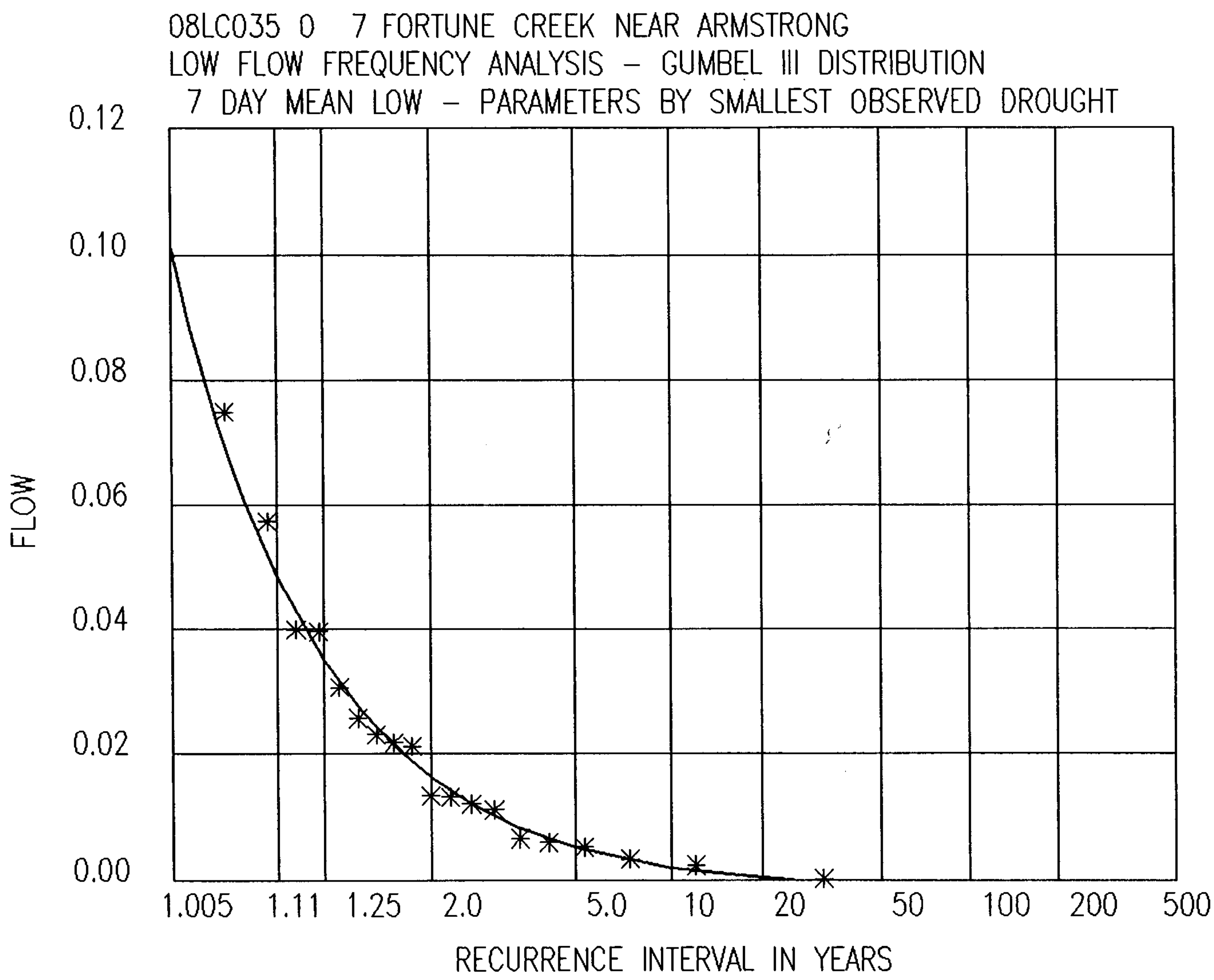
08LE075 0 7 SALMON RIVER ABOVE SALMON LAKE
LOW FLOW FREQUENCY ANALYSIS - GUMBEL III DISTRIBUTION
7 DAY MEAN LOW - PARAMETERS BY MAXIMUM LIKELIHOOD
FLOW
0.24
0.20
0.16
0.12
0.08
0.04
0.00
1.005
1.11
1.25
2.0
5.0
10
20
50
100
200
500
RECURRENCE INTERVAL IN YEARS


08LE020 0 7 SALMON RIVER AT FALKLAND
LOW FLOW FREQUENCY ANALYSIS - GUMBEL III DISTRIBUTION
7 DAY MEAN LOW - PARAMETERS BY MAXIMUM LIKELIHOOD
1.20
1.00
0.80
0.60
0.40
0.20
0.00
FLOW
1.005
1.11
1.25
2.0
5.0
10
20
50
100
200
500
RECURRENCE INTERVAL IN YEARS

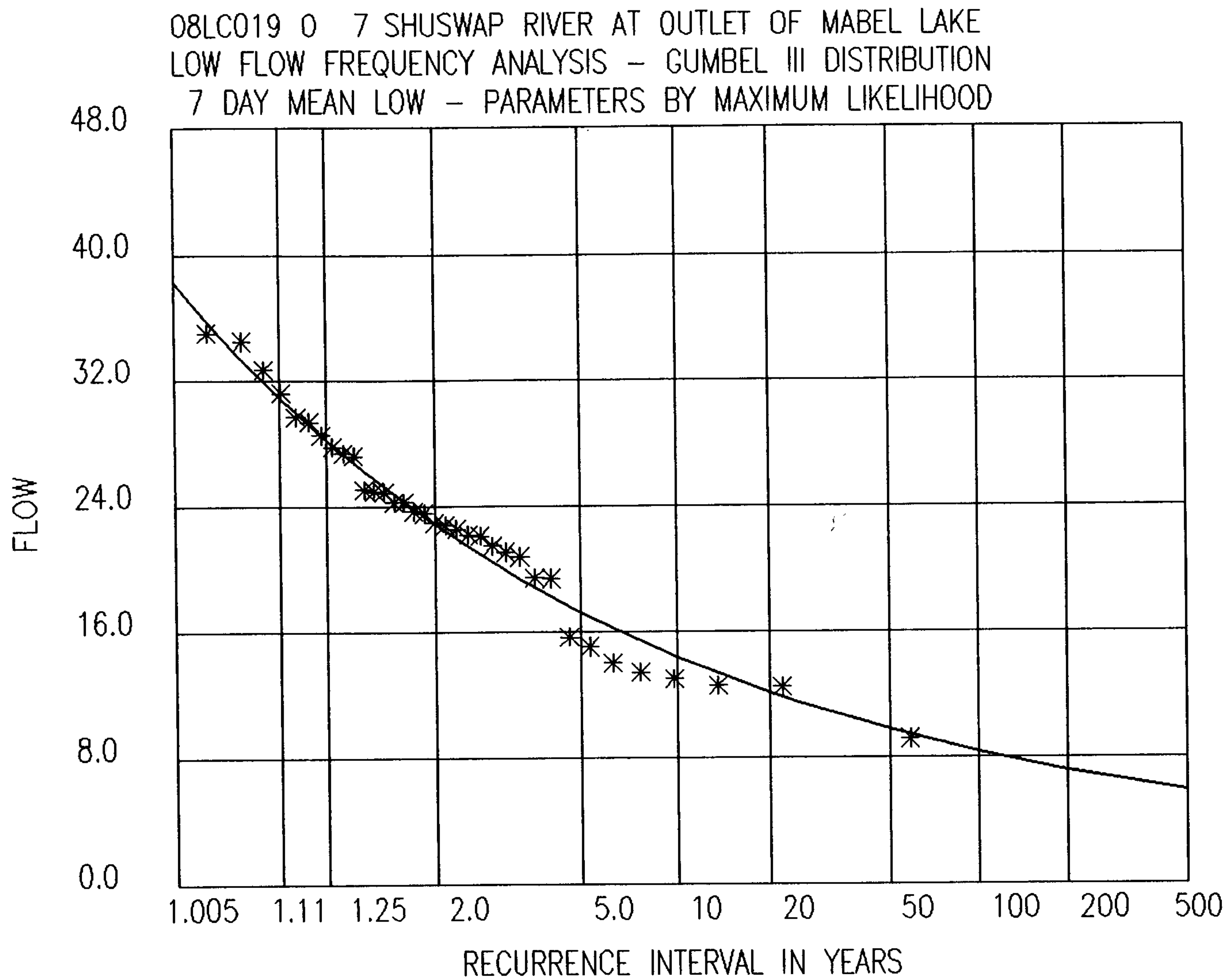

08LE021 0 7 SALMON RIVER NEAR SALMON ARM
LOW FLOW FREQUENCY ANALYSIS - GUMBEL III DISTRIBUTION
7 DAY MEAN LOW - PARAMETERS BY SMALLEST OBSERVED DROUGHT
FLOW
2.80
2.40
2.00
1.60
1.20
0.80
0.40
1.005
1.11
1.25
2.0
5.0
10
20
50
100
200
500
RECURRENCE INTERVAL IN YEARS


08LE094 0 7 BOLEAN CREEK NEAR THE MOUTH
LOW FLOW FREQUENCY ANALYSIS - GUMBEL III DISTRIBUTION
7 DAY MEAN LOW - PARAMETERS BY MOMENTS
FLOW
0.24
0.20
0.16
0.12
0.08
0.04
0.00
1.005
1.11
1.25
2.0
5.0
10
20
50
100
200
500
RECURRENCE INTERVAL IN YEARS

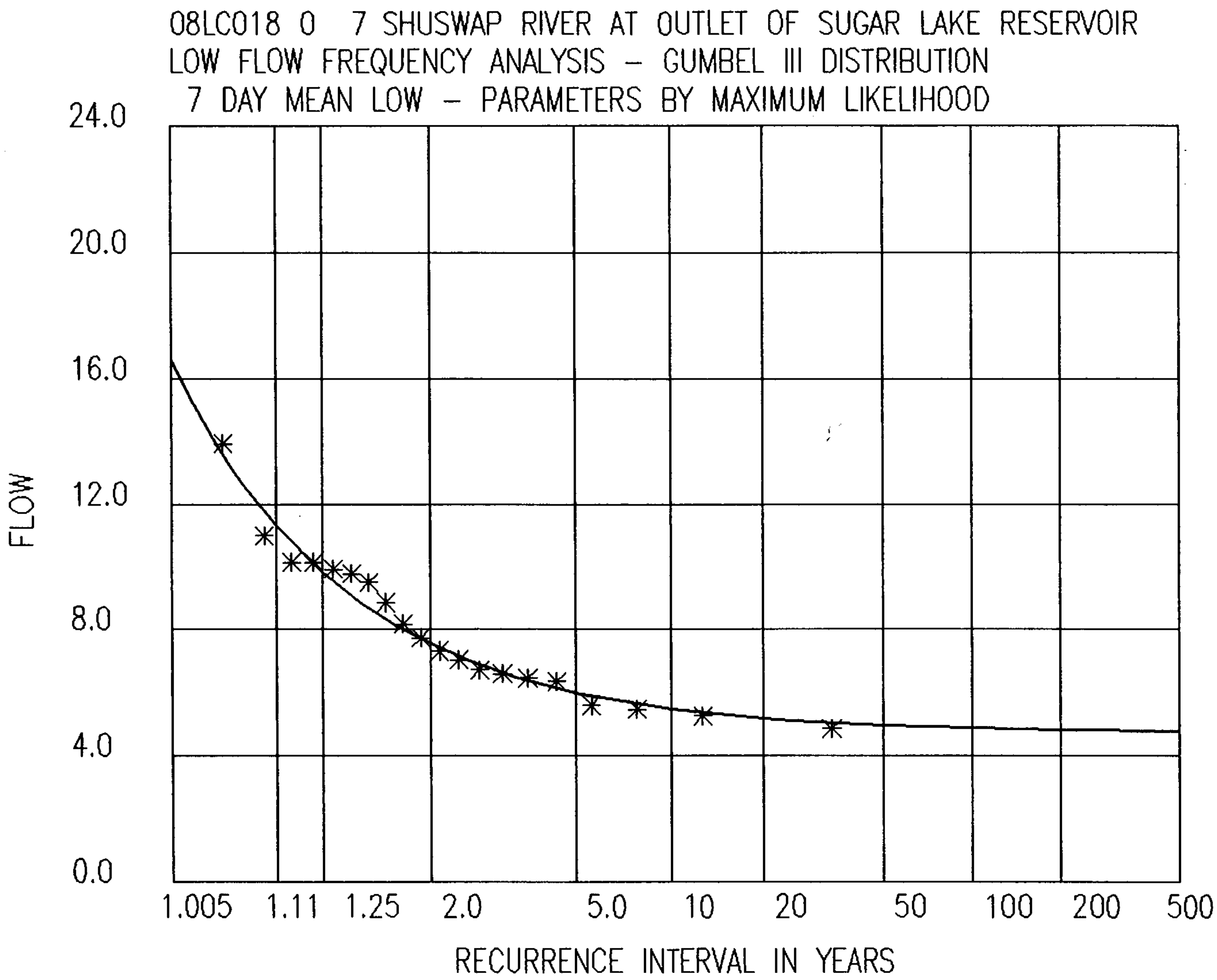

08LC002 0 7 SHUSWAP RIVER NEAR ENDERBY
LOW FLOW FREQUENCY ANALYSIS - GUMBEL III DISTRIBUTION
7 DAY MEAN LOW - PARAMETERS BY MAXIMUM LIKELIHOOD
FLOW
56.0
48.0
40.0
32.0
24.0
16.0
8.0
1.005
1.11
1.25
2.0
5.0
10
20
50
100
200
500
RECURRENCE INTERVAL IN YEARS

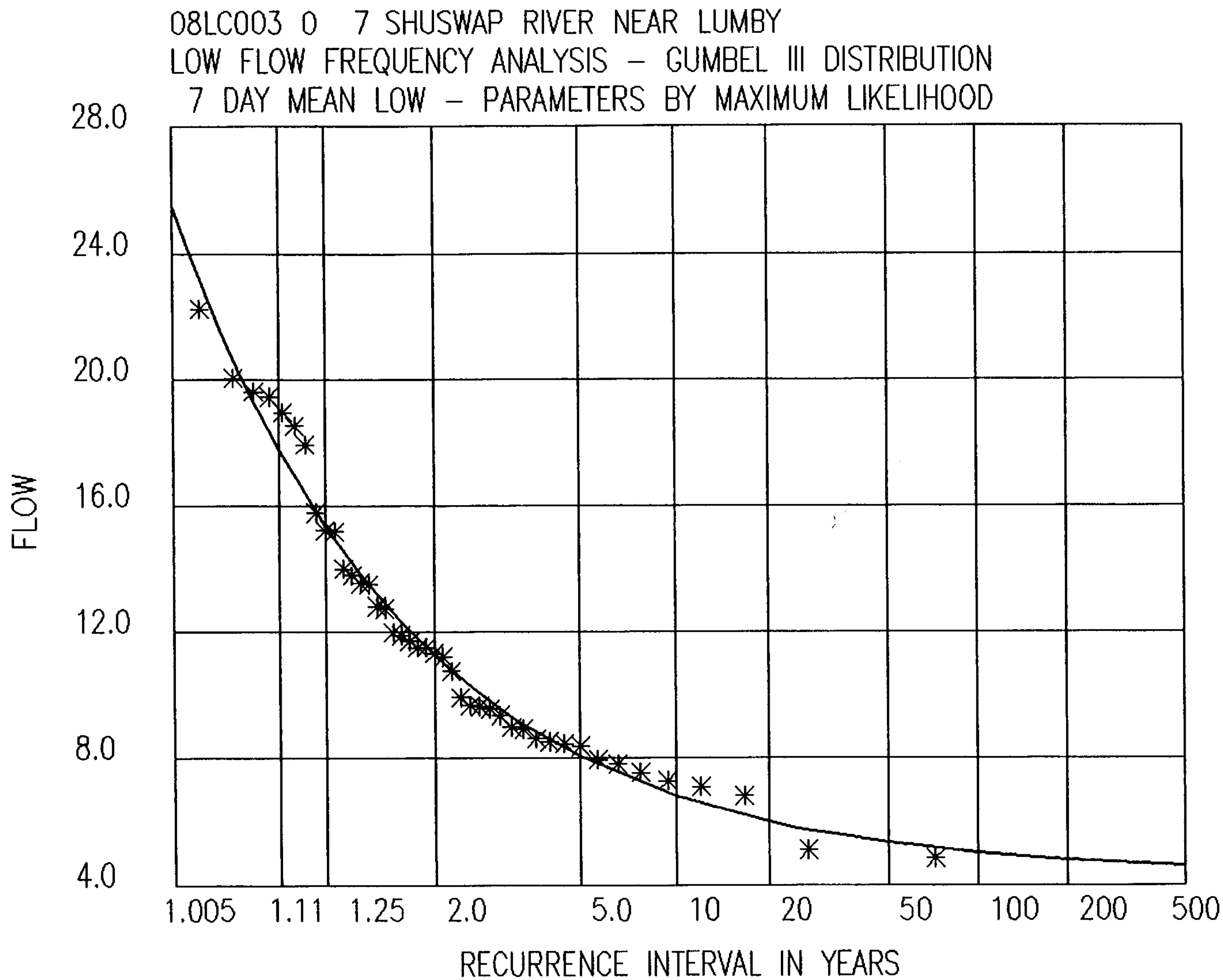


08LC035 0 7 FORTUNE CREEK NEAR ARMSTRONG
LOW FLOW FREQUENCY ANALYSIS – GUMBEL III DISTRIBUTION
7 DAY MEAN LOW – PARAMETERS BY SMALLEST OBSERVED DROUGHT
FLOW
0.12
0.10
0.08
0.06
0.04
0.02
0.00
1.005
1.11
1.25
2.0
5.0
10
20
50
100
200
500
RECURRENCE INTERVAL IN YEARS

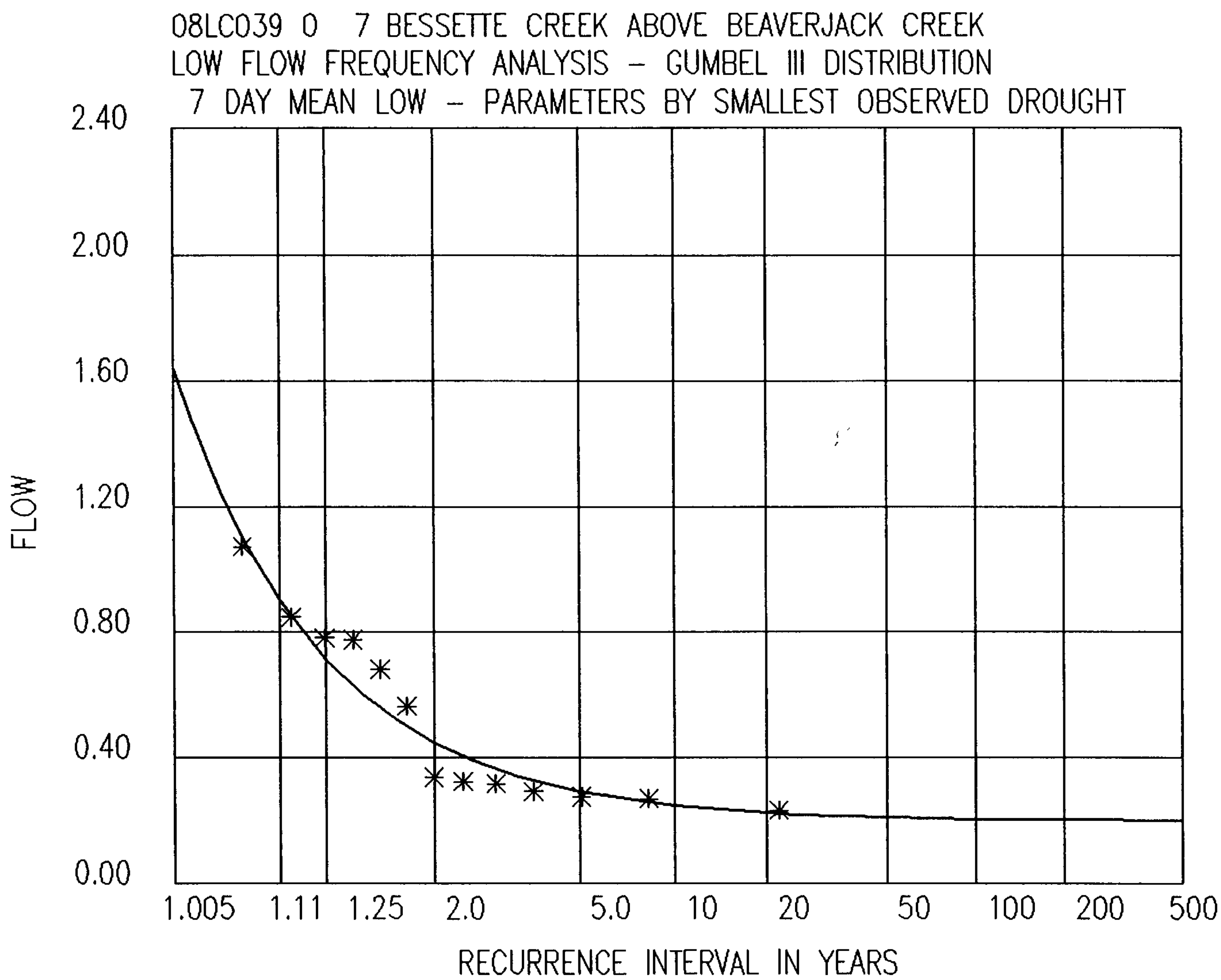


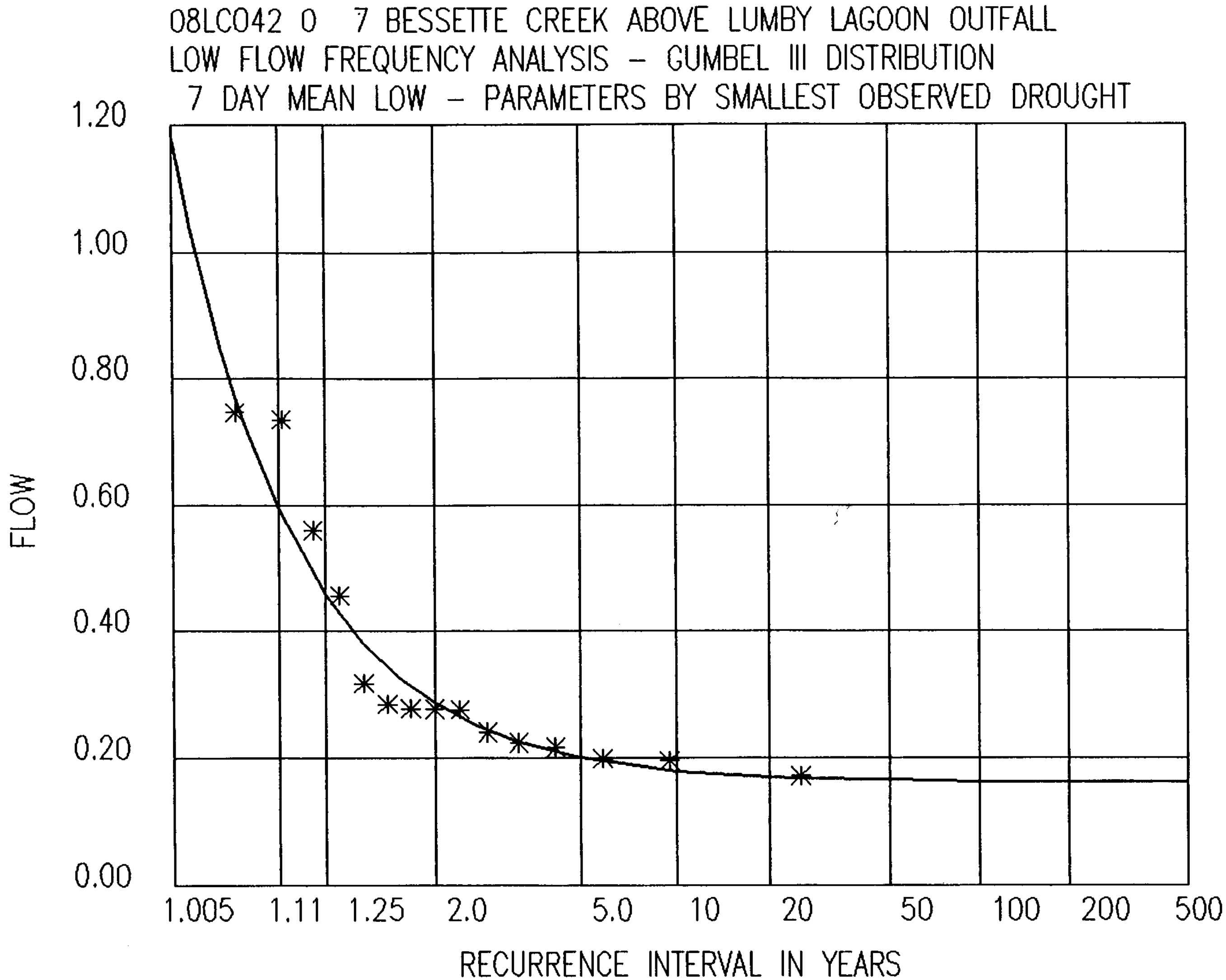
08LC019 0 7 SHUSWAP RIVER AT OUTLET OF MABEL LAKE
LOW FLOW FREQUENCY ANALYSIS - GUMBEL III DISTRIBUTION
7 DAY MEAN LOW - PARAMETERS BY MAXIMUM LIKELIHOOD
FLOW
48.0
40.0
32.0
24.0
16.0
8.0
0.0
1.005
1.11
1.25
2.0
5.0
10
20
50
100
200
500
RECURRENCE INTERVAL IN YEARS


08LC018 0 7 SHUSWAP RIVER AT OUTLET OF SUGAR LAKE RESERVOIR
LOW FLOW FREQUENCY ANALYSIS - GUMBEL III DISTRIBUTION
7 DAY MEAN LOW - PARAMETERS BY MAXIMUM LIKELIHOOD
FLOW
24.0
20.0
16.0
12.0
8.0
4.0
0.0
1.005
1.11
1.25
2.0
5.0
10
20
50
100
200
500
RECURRENCE INTERVAL IN YEARS

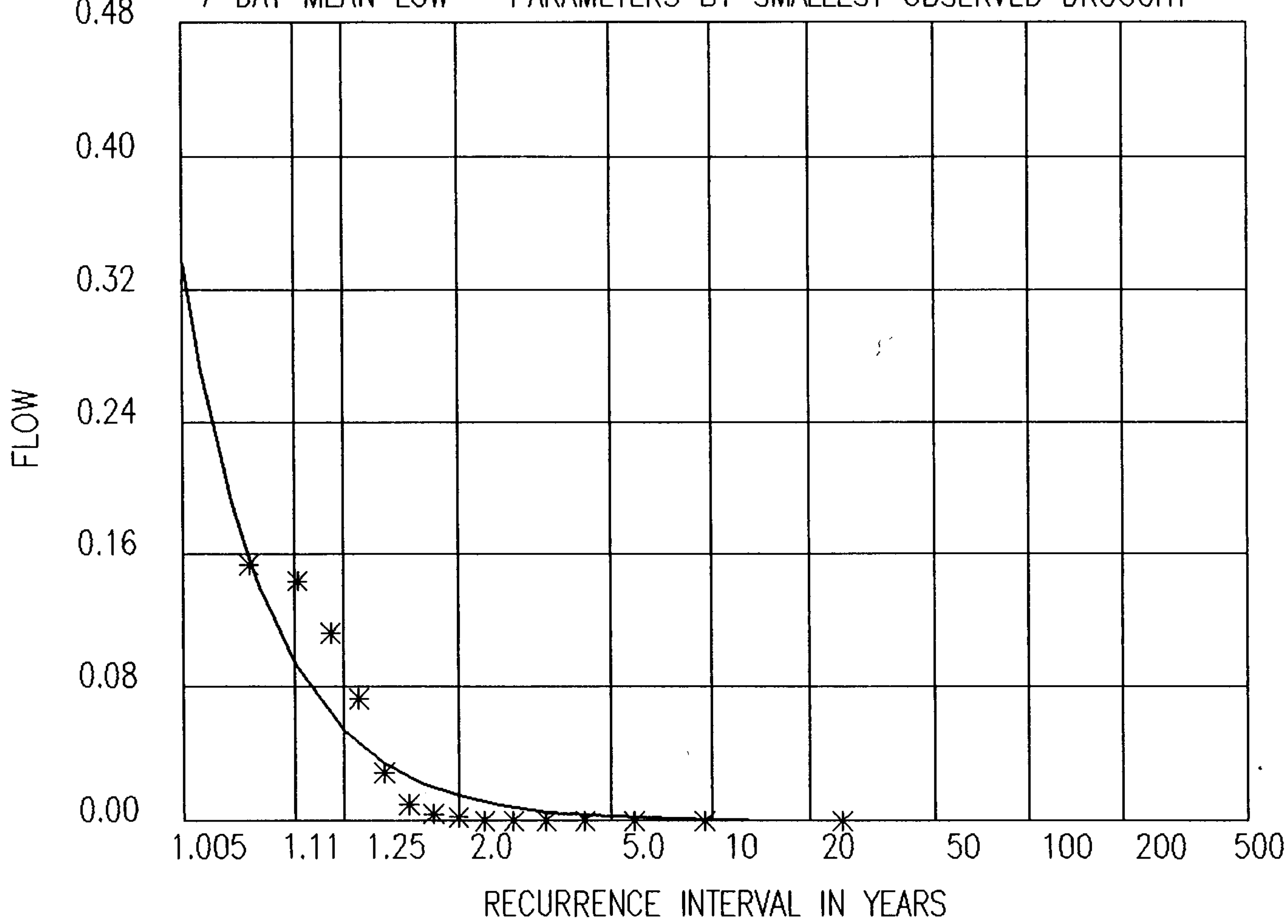


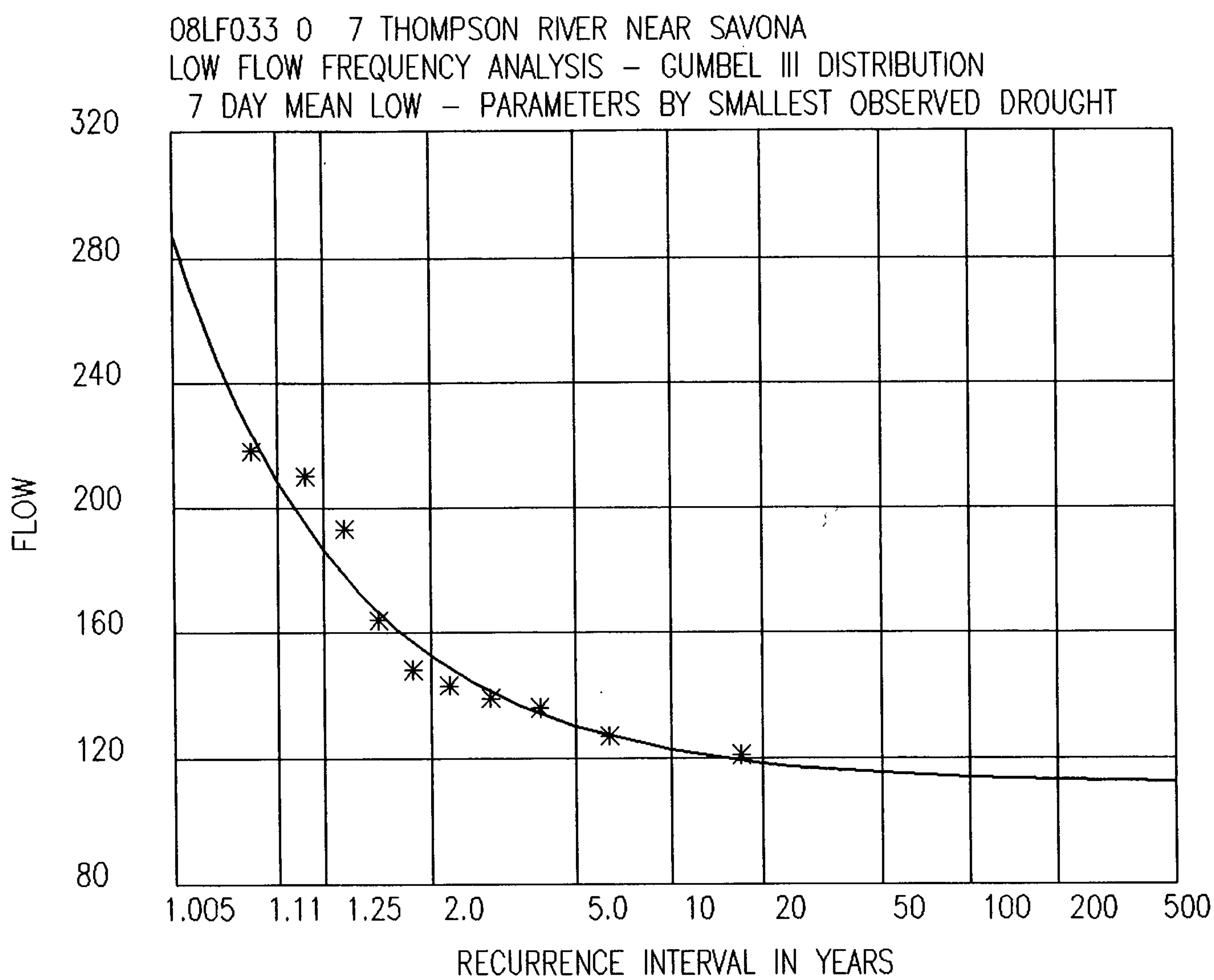
08LC003 0 7 SHUSWAP RIVER NEAR LUMBY
LOW FLOW FREQUENCY ANALYSIS – GUMBEL III DISTRIBUTION
7 DAY MEAN LOW – PARAMETERS BY MAXIMUM LIKELIHOOD
28.0
24.0
20.0
16.0
12.0
8.0
4.0
FLOW
1.005
1.11
1.25
2.0
5.0
10
20
50
100
200
500
RECURRENCE INTERVAL IN YEARS


08LC039 0 7 BESSETTE CREEK ABOVE BEAVERJACK CREEK
LOW FLOW FREQUENCY ANALYSIS - GUMBEL III DISTRIBUTION
7 DAY MEAN LOW - PARAMETERS BY SMALLEST OBSERVED DROUGHT
FLOW
2.40
2.00
1.60
1.20
0.80
0.40
0.00
1.005
1.11
1.25
2.0
5.0
10
20
50
100
200
500
RECURRENCE INTERVAL IN YEARS

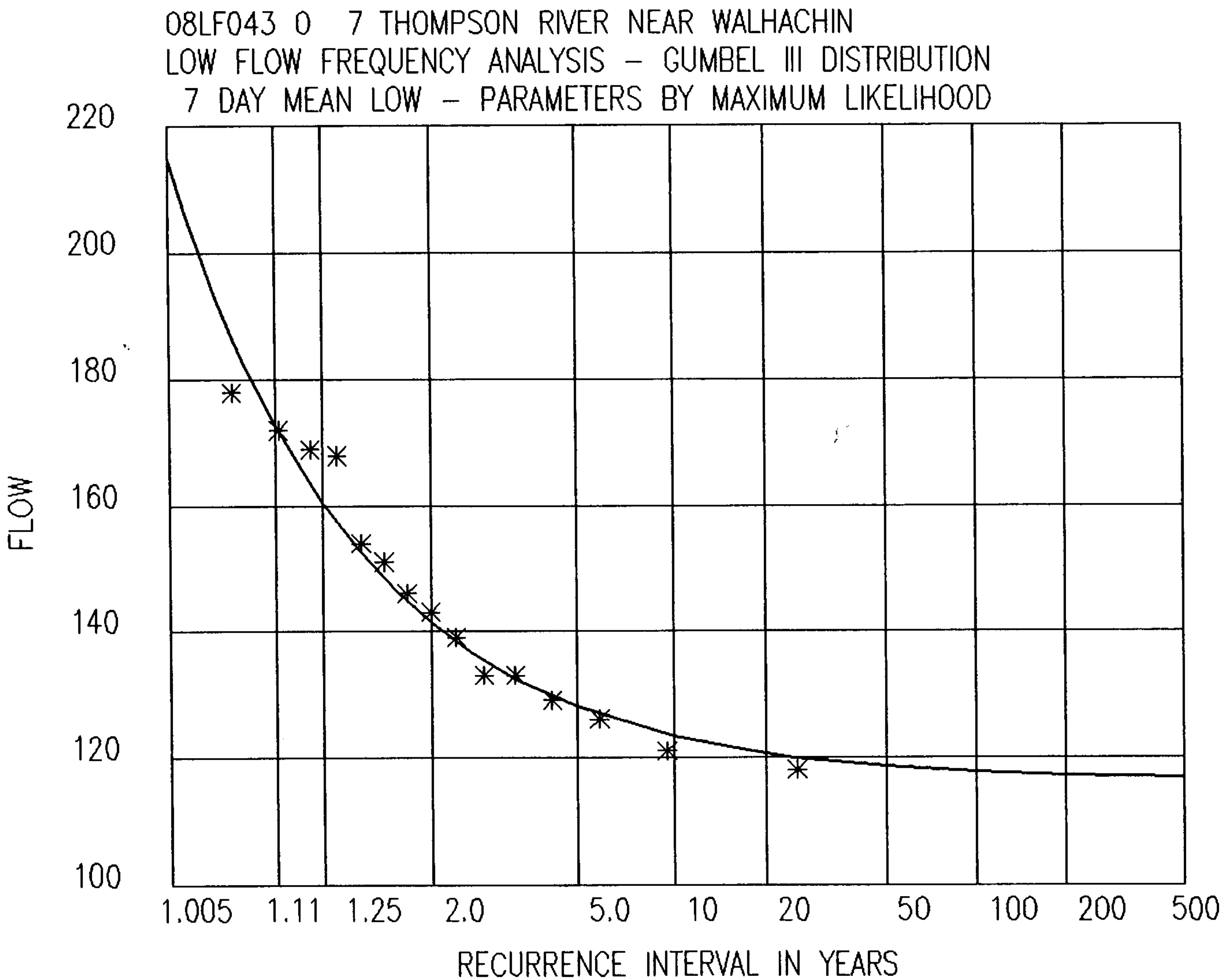

08LC042 0 7 BESSETTE CREEK ABOVE LUMBY LAGOON OUTFALL
LOW FLOW FREQUENCY ANALYSIS - GUMBEL III DISTRIBUTION
7 DAY MEAN LOW - PARAMETERS BY SMALLEST OBSERVED DROUGHT
FLOW
1.20
1.00
0.80
0.60
0.40
0.20
0.00
1.005
1.11
1.25
2.0
5.0
10
20
50
100
200
500
RECURRENCE INTERVAL IN YEARS

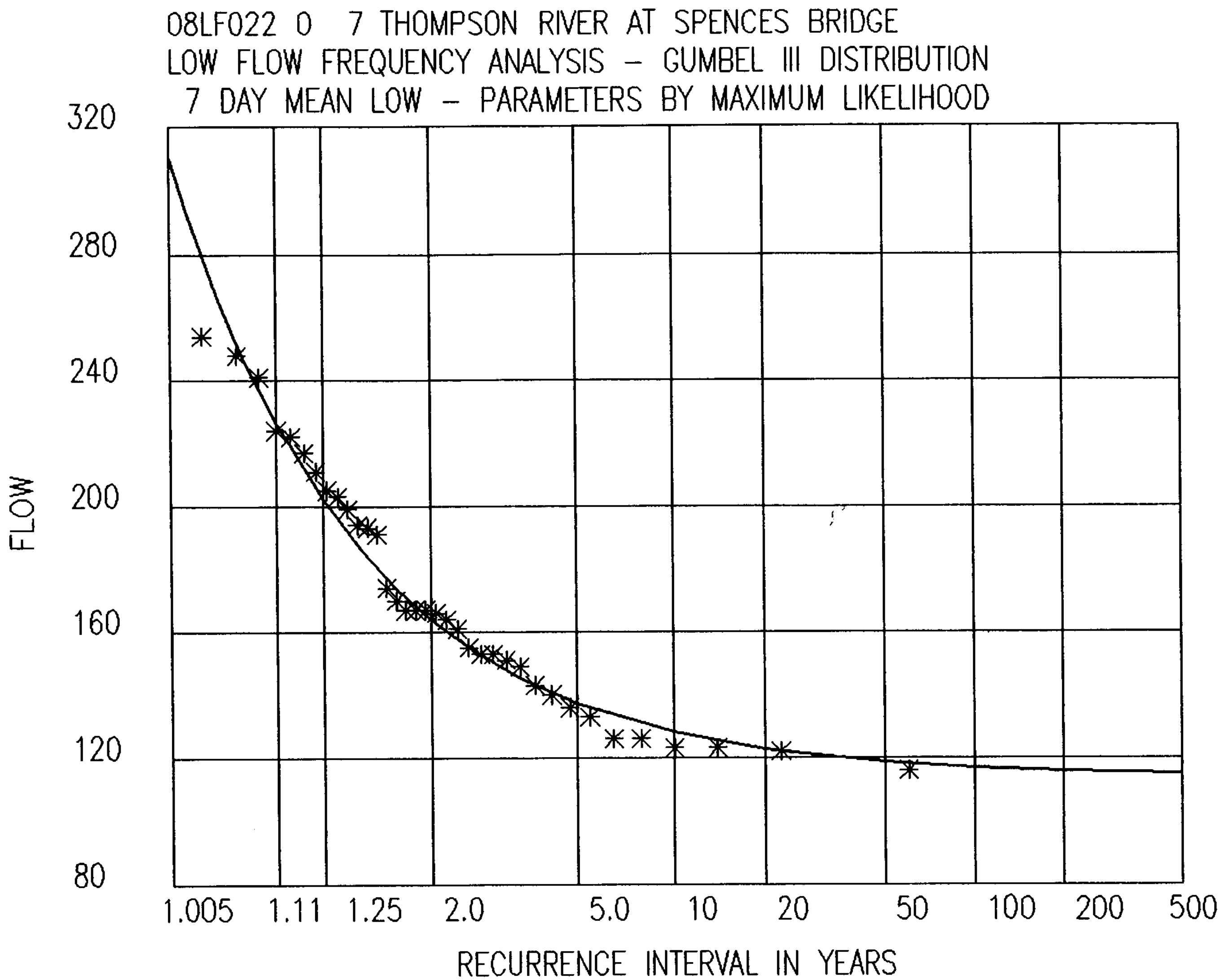
08LC006 0 7 DUTEAU CREEK NEAR LAVINGTON
LOW FLOW FREQUENCY ANALYSIS – GUMBEL III DISTRIBUTION
7 DAY MEAN LOW – PARAMETERS BY SMALLEST OBSERVED DROUGHT

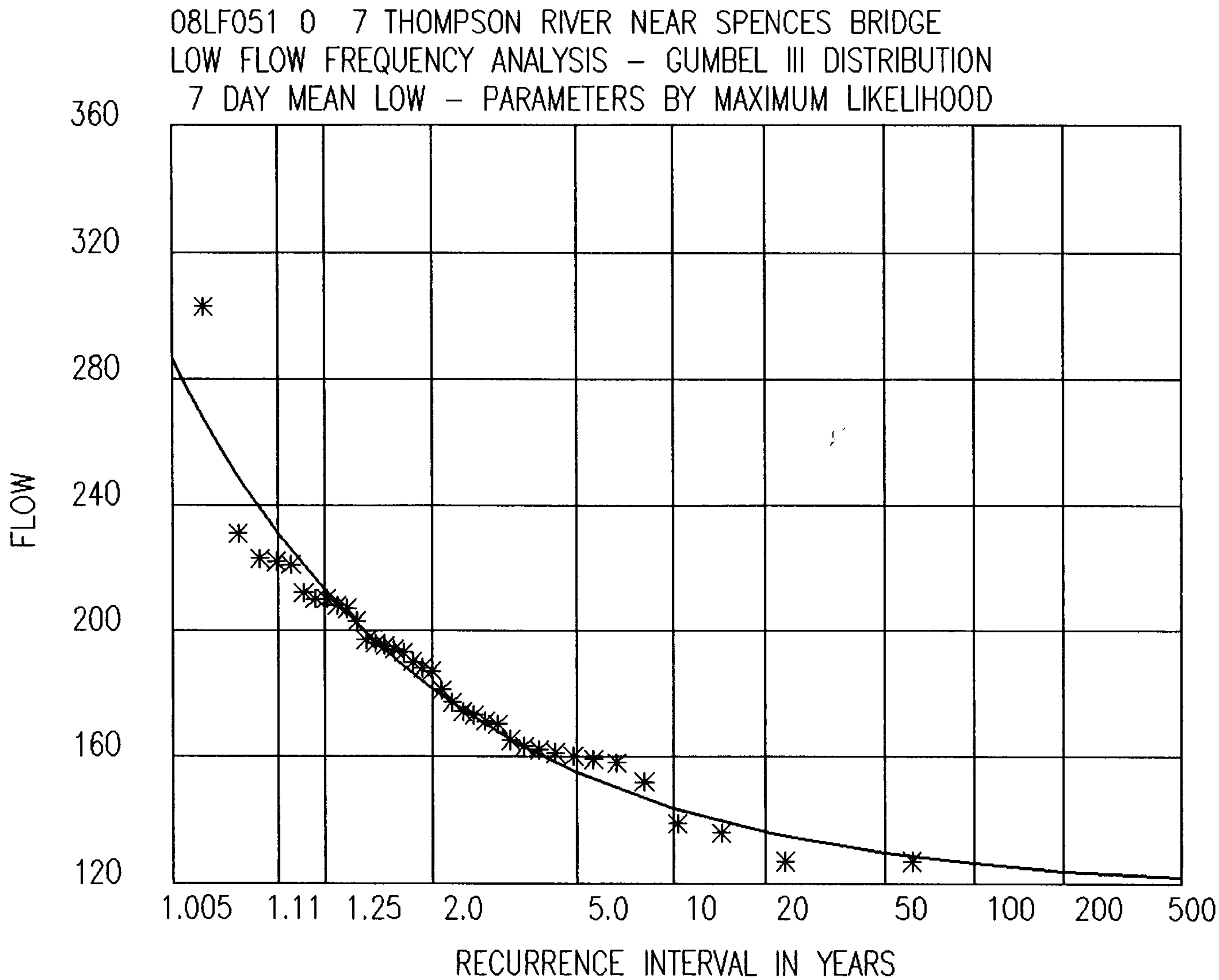




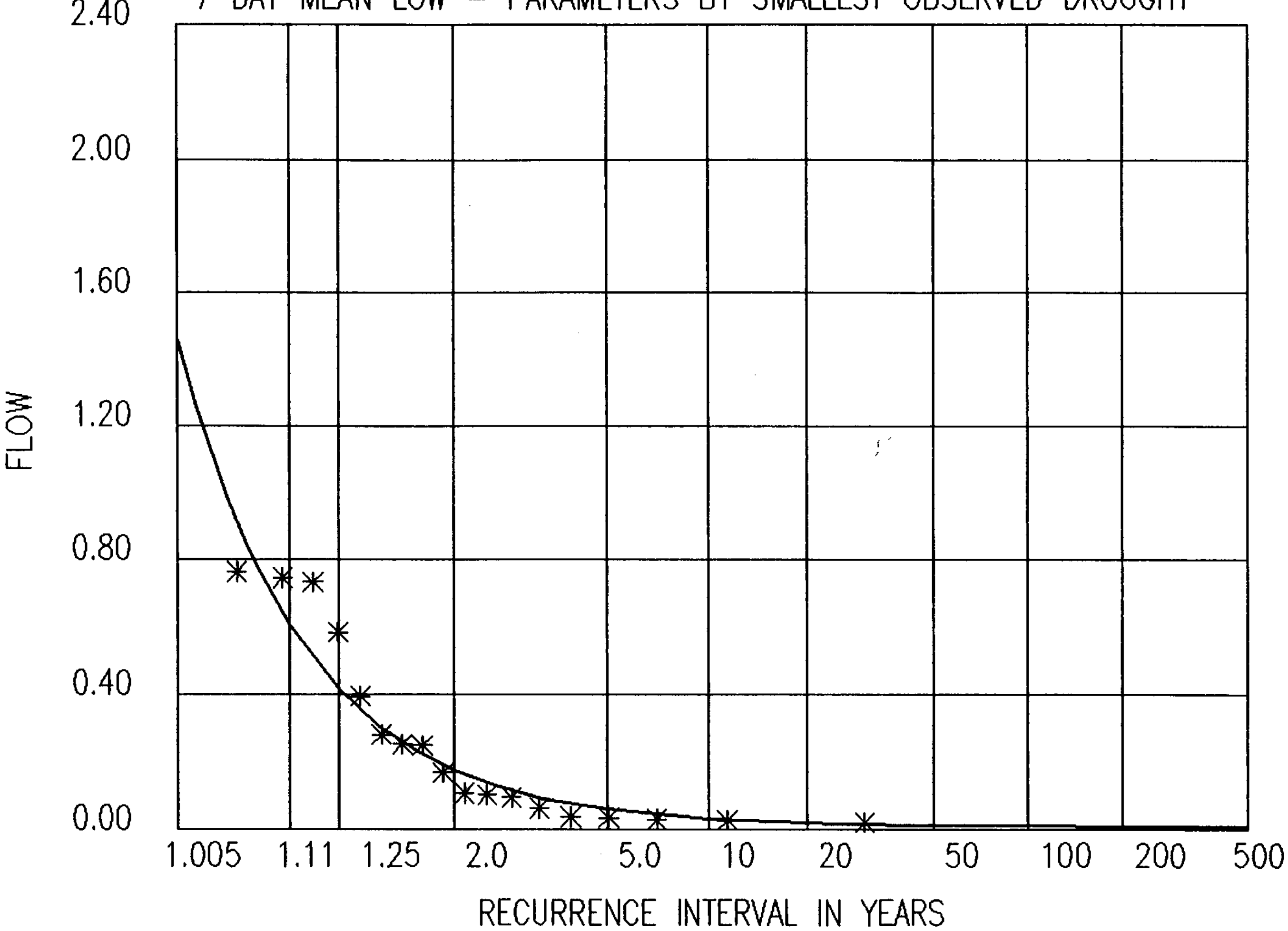
08LF033 0 7 THOMPSON RIVER NEAR SAVONA
LOW FLOW FREQUENCY ANALYSIS – GUMBEL III DISTRIBUTION
7 DAY MEAN LOW – PARAMETERS BY SMALLEST OBSERVED DROUGHT
FLOW
320
280
240
200
160
120
80
1.005
1.11
1.25
2.0
5.0
10
20
50
100
200
500
RECURRENCE INTERVAL IN YEARS

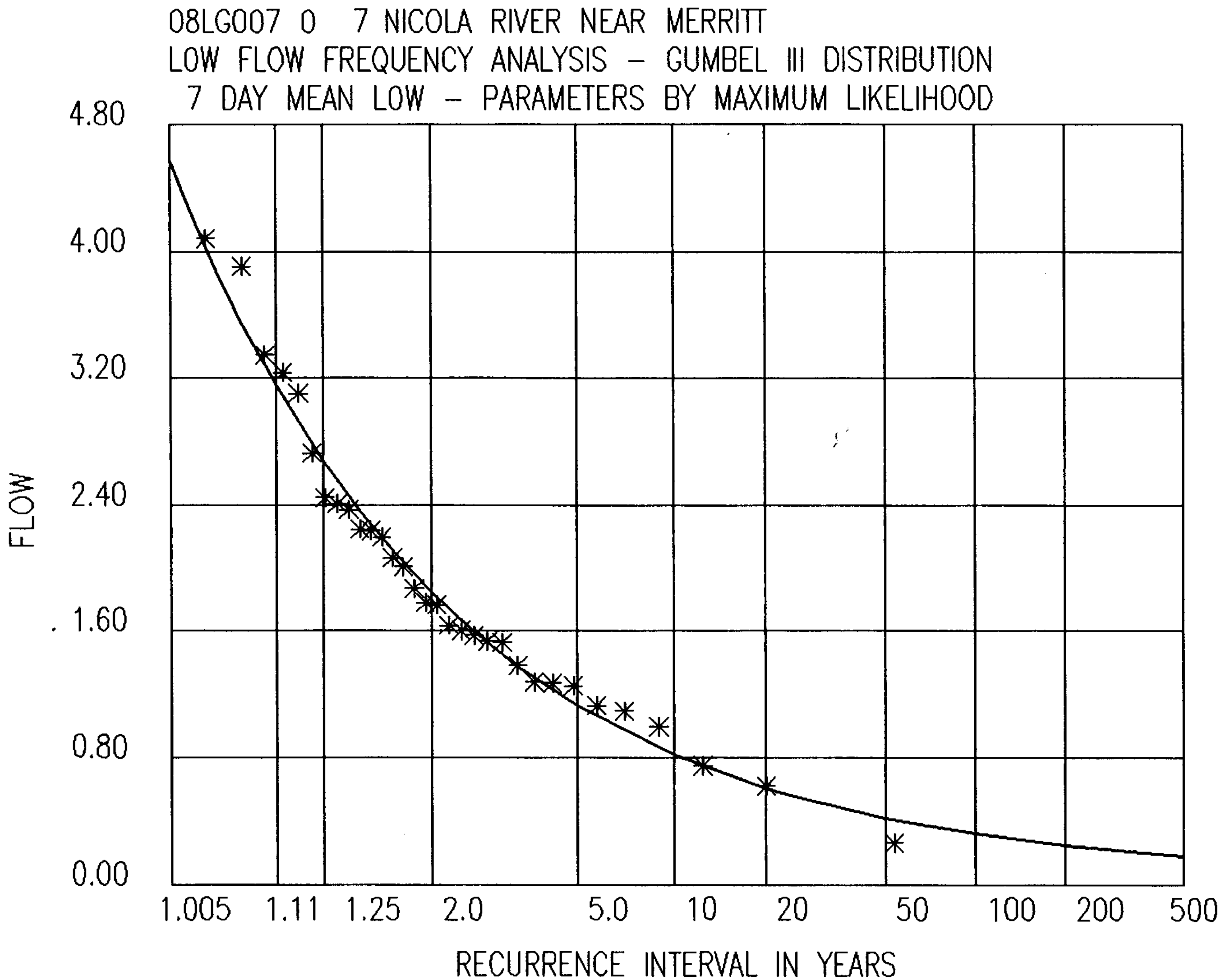

08LF043 0 7 THOMPSON RIVER NEAR WALHACHIN
LOW FLOW FREQUENCY ANALYSIS - GUMBEL III DISTRIBUTION
7 DAY MEAN LOW - PARAMETERS BY MAXIMUM LIKELIHOOD
FLOW
220
200
180
160
140
120
100
1.005
1.11
1.25
2.0
5.0
10
20
50
100
200
500
RECURRENCE INTERVAL IN YEARS

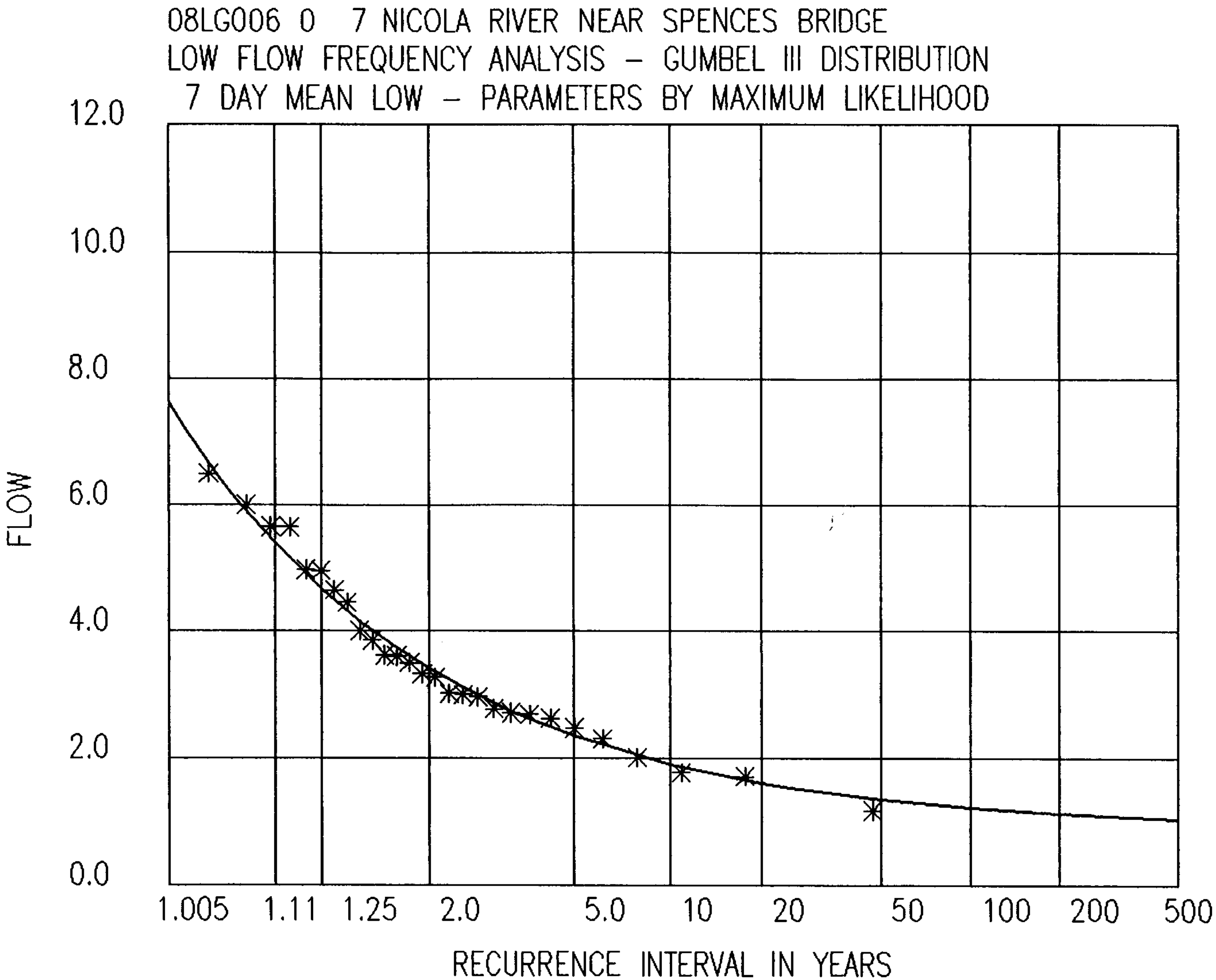

08LF022 0 7 THOMPSON RIVER AT SPENCES BRIDGE
LOW FLOW FREQUENCY ANALYSIS - GUMBEL III DISTRIBUTION
7 DAY MEAN LOW - PARAMETERS BY MAXIMUM LIKELIHOOD
FLOW
320
280
240
200
160
120
80
1.005
1.11
1.25
2.0
5.0
10
20
50
100
200
500
RECURRENCE INTERVAL IN YEARS

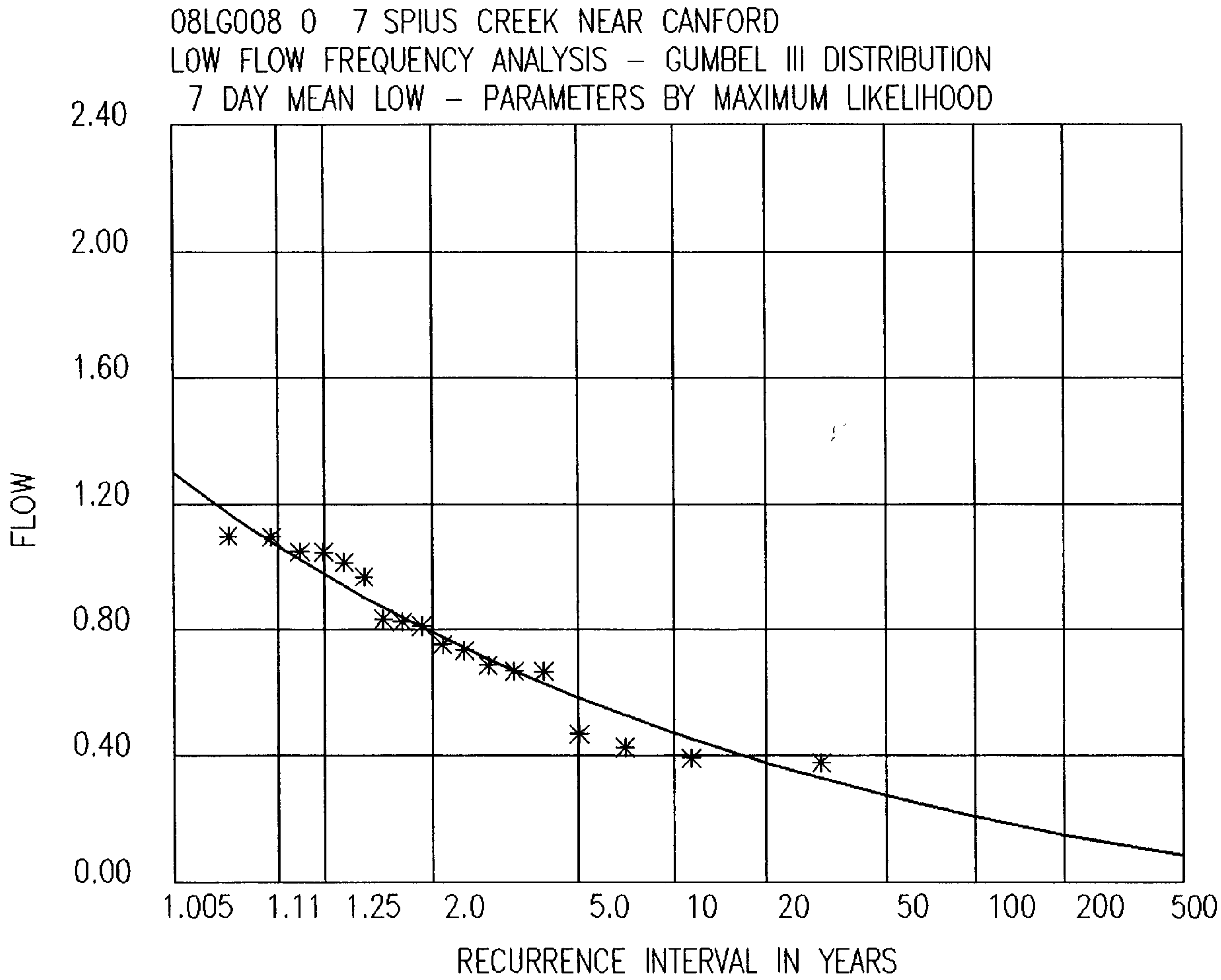

08LF051 0 7 THOMPSON RIVER NEAR SPENCES BRIDGE
LOW FLOW FREQUENCY ANALYSIS - GUMBEL III DISTRIBUTION
7 DAY MEAN LOW - PARAMETERS BY MAXIMUM LIKELIHOOD
FLOW
360
320
280
240
200
160
120
1.005
1.11
1.25
2.0
5.0
10
20
50
100
200
500
RECURRENCE INTERVAL IN YEARS

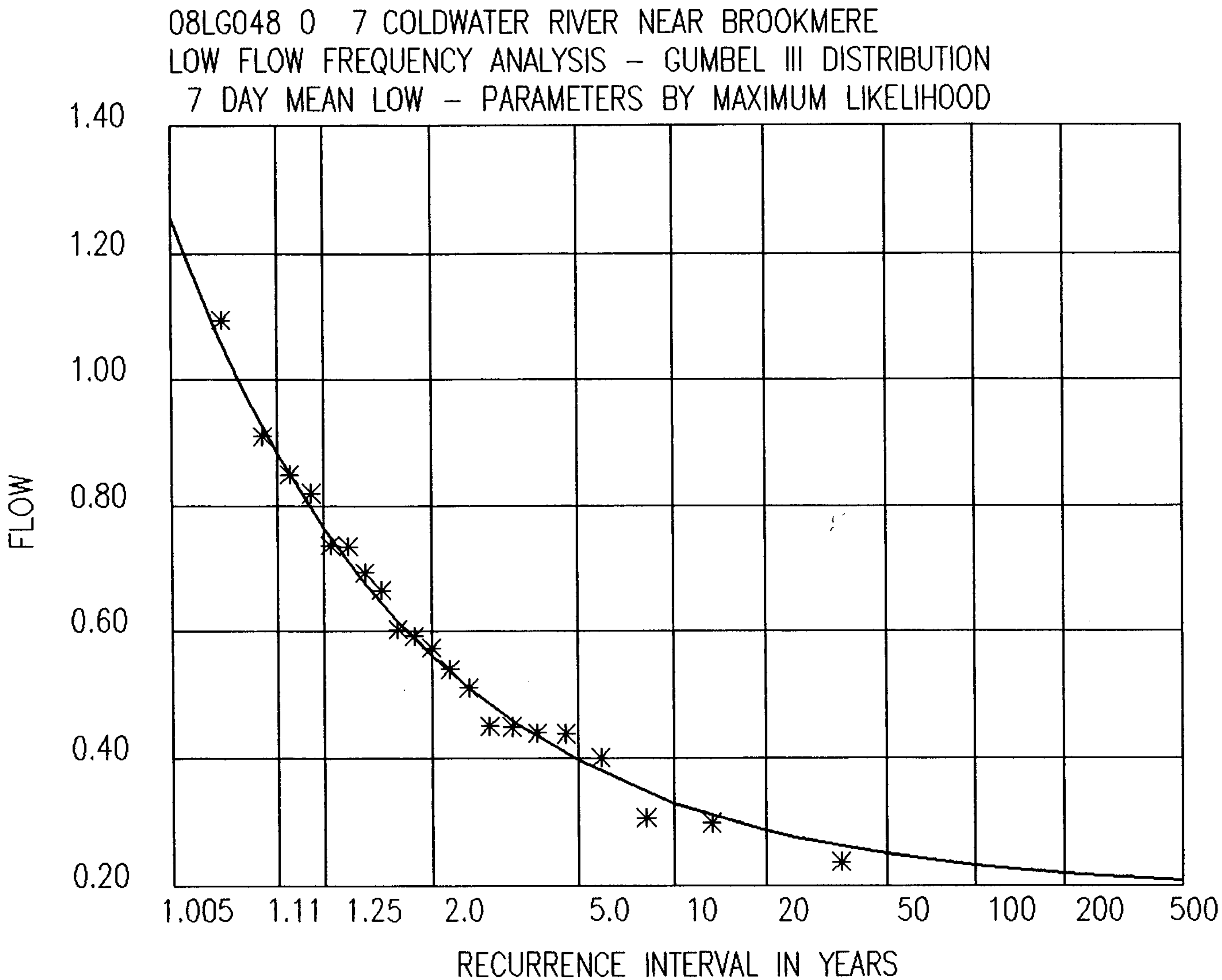
08LG049 0 7 NICOLA RIVER ABOVE NICOLA LAKE
LOW FLOW FREQUENCY ANALYSIS – GUMBEL III DISTRIBUTION
7 DAY MEAN LOW – PARAMETERS BY SMALLEST OBSERVED DROUGHT

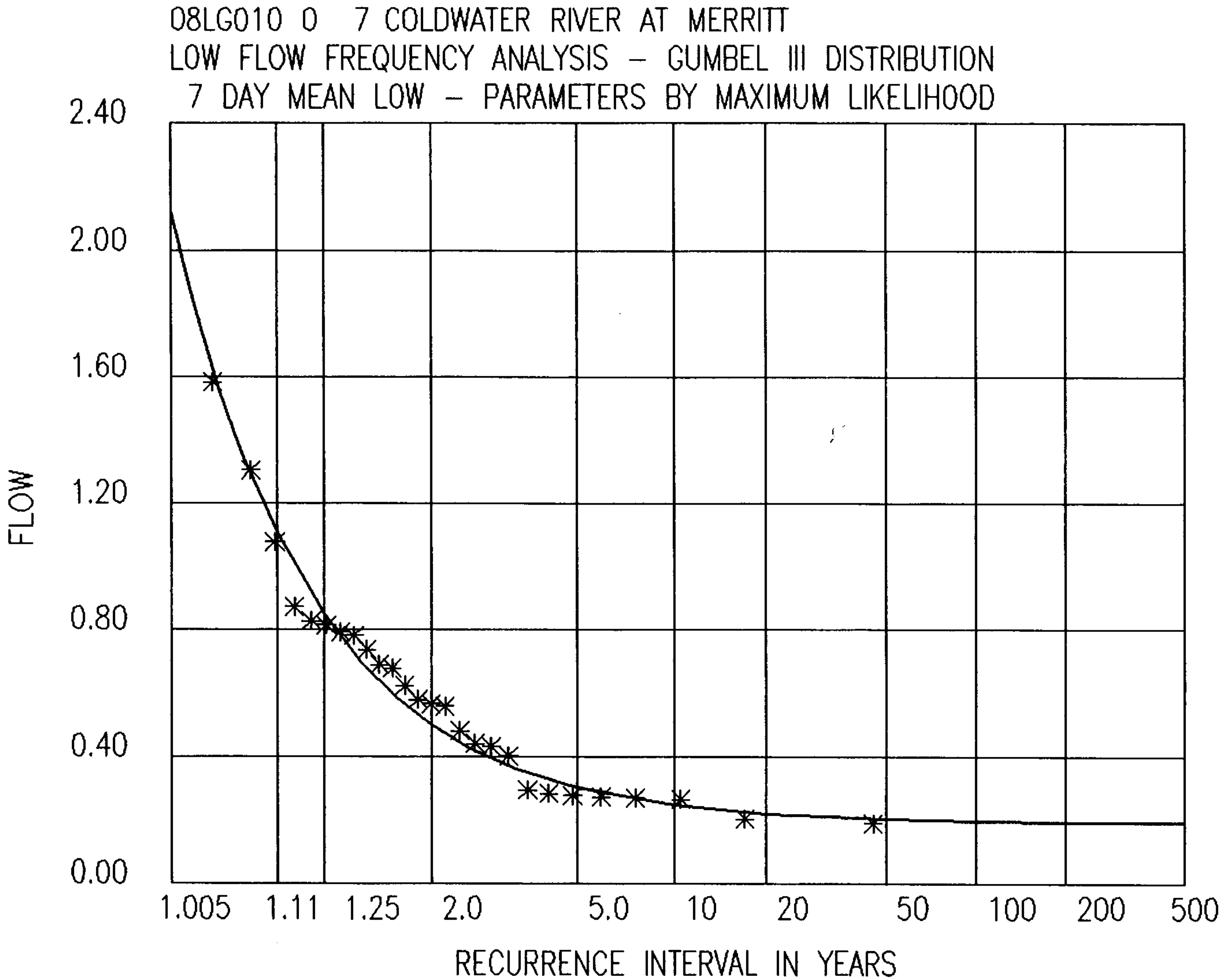


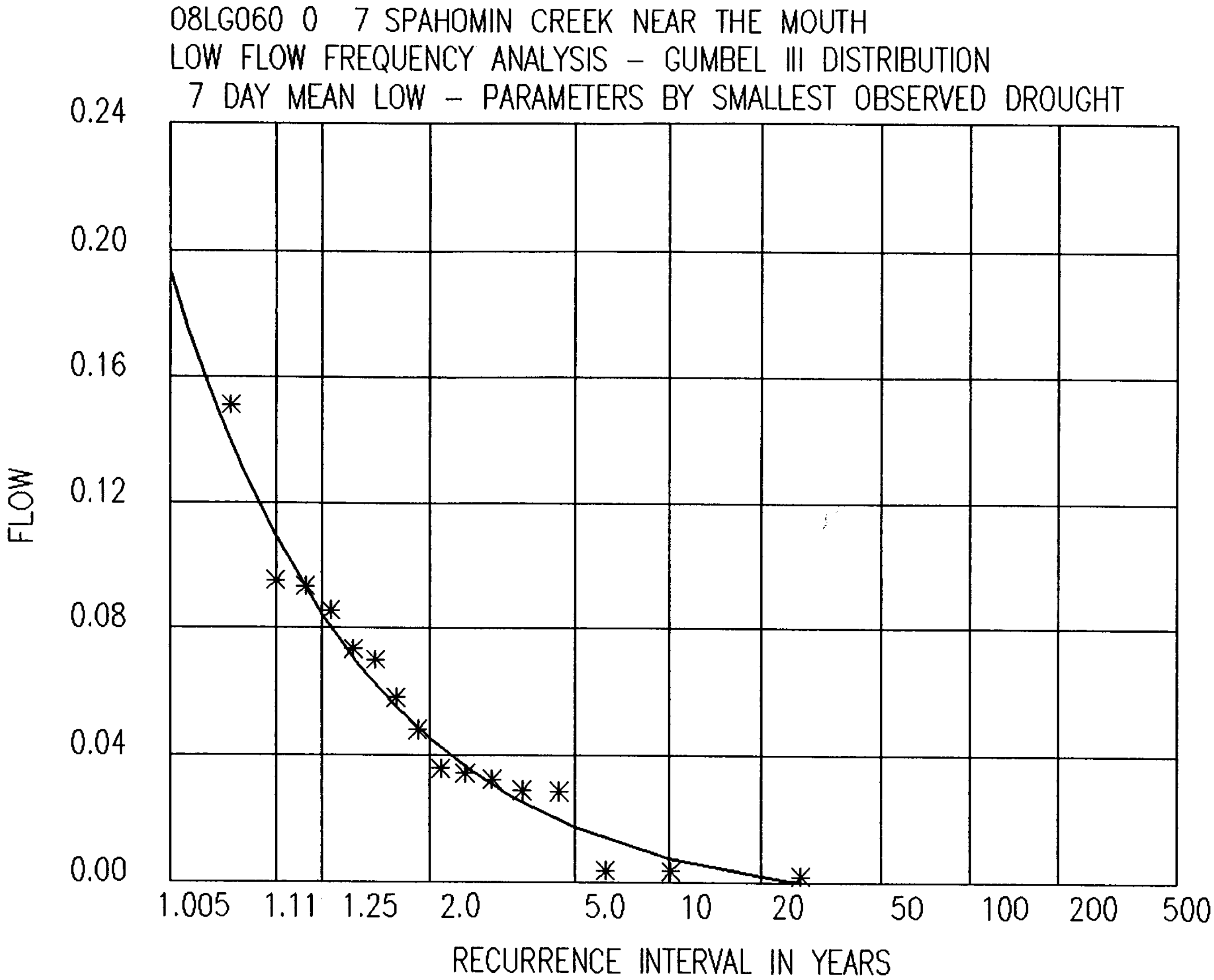

08LG007 0 7 NICOLA RIVER NEAR MERRITT
LOW FLOW FREQUENCY ANALYSIS - GUMBEL III DISTRIBUTION
7 DAY MEAN LOW - PARAMETERS BY MAXIMUM LIKELIHOOD
FLOW
4.80
4.00
3.20
2.40
1.60
0.80
0.00
1.005
1.11
1.25
2.0
5.0
10
20
50
100
200
500
RECURRENCE INTERVAL IN YEARS


08LG006 0 7 NICOLA RIVER NEAR SPENCES BRIDGE
LOW FLOW FREQUENCY ANALYSIS - GUMBEL III DISTRIBUTION
7 DAY MEAN LOW - PARAMETERS BY MAXIMUM LIKELIHOOD
FLOW
12.0
10.0
8.0
6.0
4.0
2.0
0.0
1.005
1.11
1.25
2.0
5.0
10
20
50
100
200
500
RECURRENCE INTERVAL IN YEARS

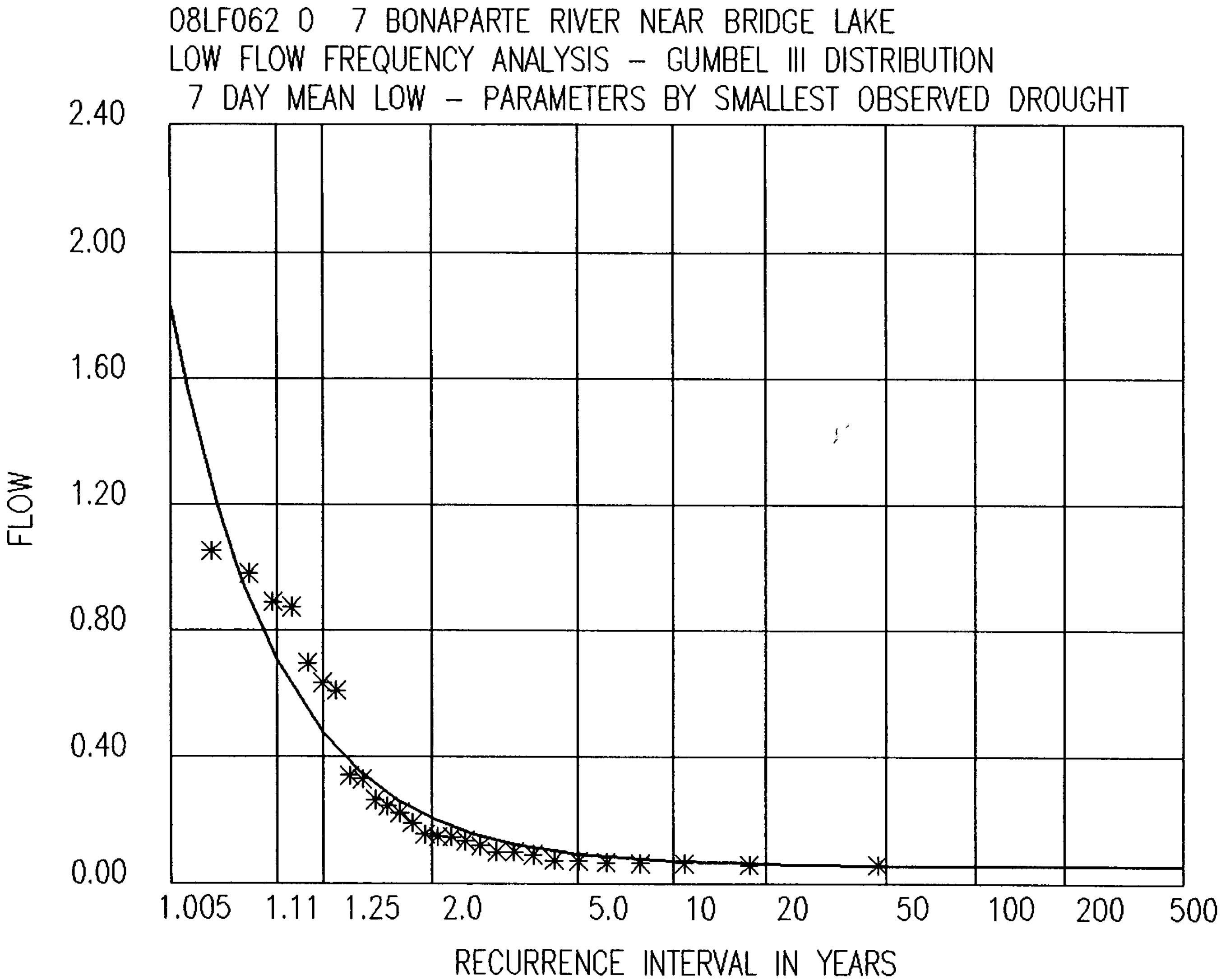

08LG008 0 7 SPIUS CREEK NEAR CANFORD
LOW FLOW FREQUENCY ANALYSIS - GUMBEL III DISTRIBUTION
7 DAY MEAN LOW - PARAMETERS BY MAXIMUM LIKELIHOOD
FLOW
2.40
2.00
1.60
1.20
0.80
0.40
0.00
1.005
1.11
1.25
2.0
5.0
10
20
50
100
200
500
RECURRENCE INTERVAL IN YEARS

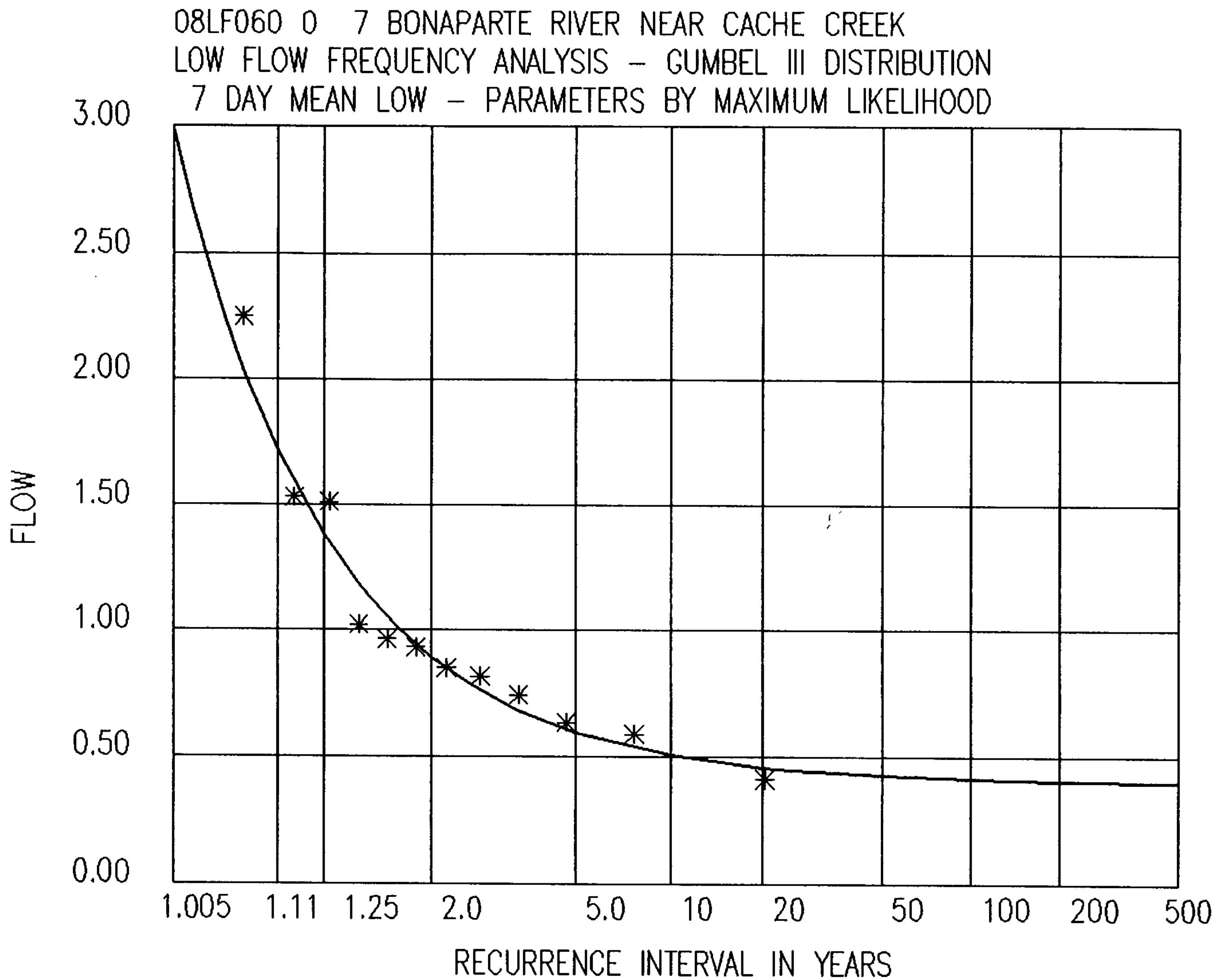

08LG048 0 7 COLDWATER RIVER NEAR BROOKMERE
LOW FLOW FREQUENCY ANALYSIS - GUMBEL III DISTRIBUTION
7 DAY MEAN LOW - PARAMETERS BY MAXIMUM LIKELIHOOD
FLOW
1.40
1.20
1.00
0.80
0.60
0.40
0.20
1.005
1.11
1.25
2.0
5.0
10
20
50
100
200
500
RECURRENCE INTERVAL IN YEARS

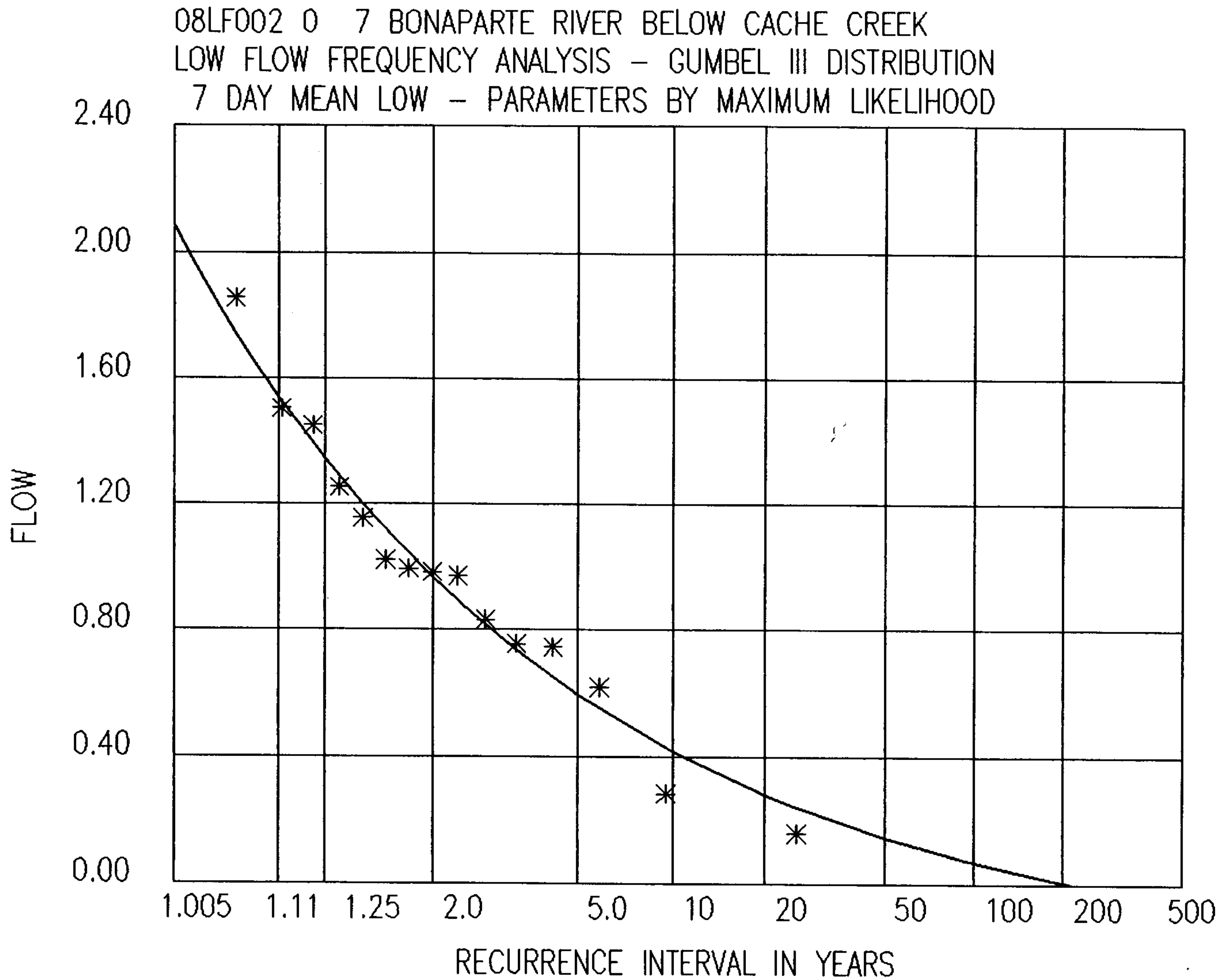

08LG010 0 7 COLDWATER RIVER AT MERRITT
LOW FLOW FREQUENCY ANALYSIS – GUMBEL III DISTRIBUTION
7 DAY MEAN LOW – PARAMETERS BY MAXIMUM LIKELIHOOD
FLOW
2.40
2.00
1.60
1.20
0.80
0.40
0.00
1.005
1.11
1.25
2.0
5.0
10
20
50
100
200
500
RECURRENCE INTERVAL IN YEARS

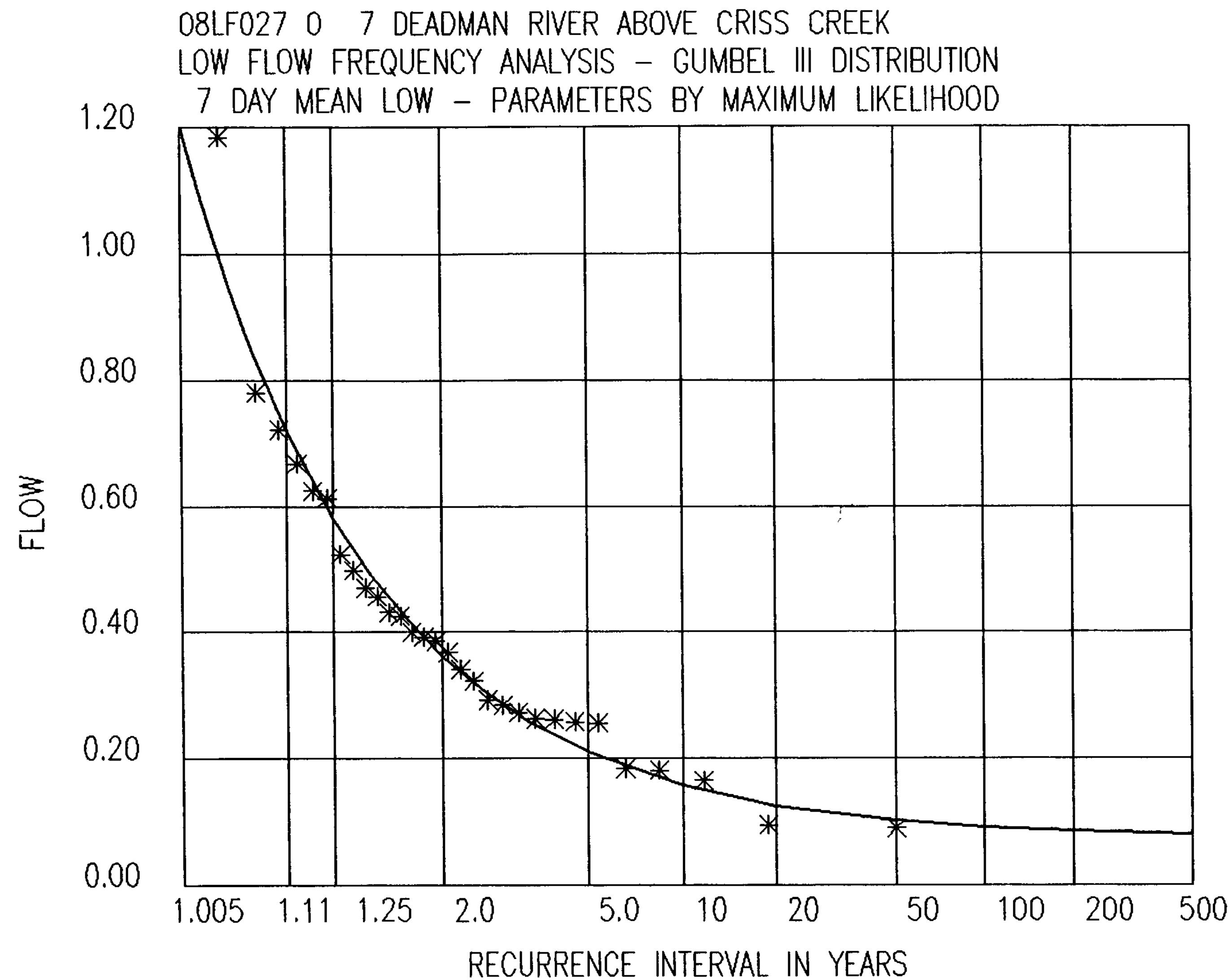


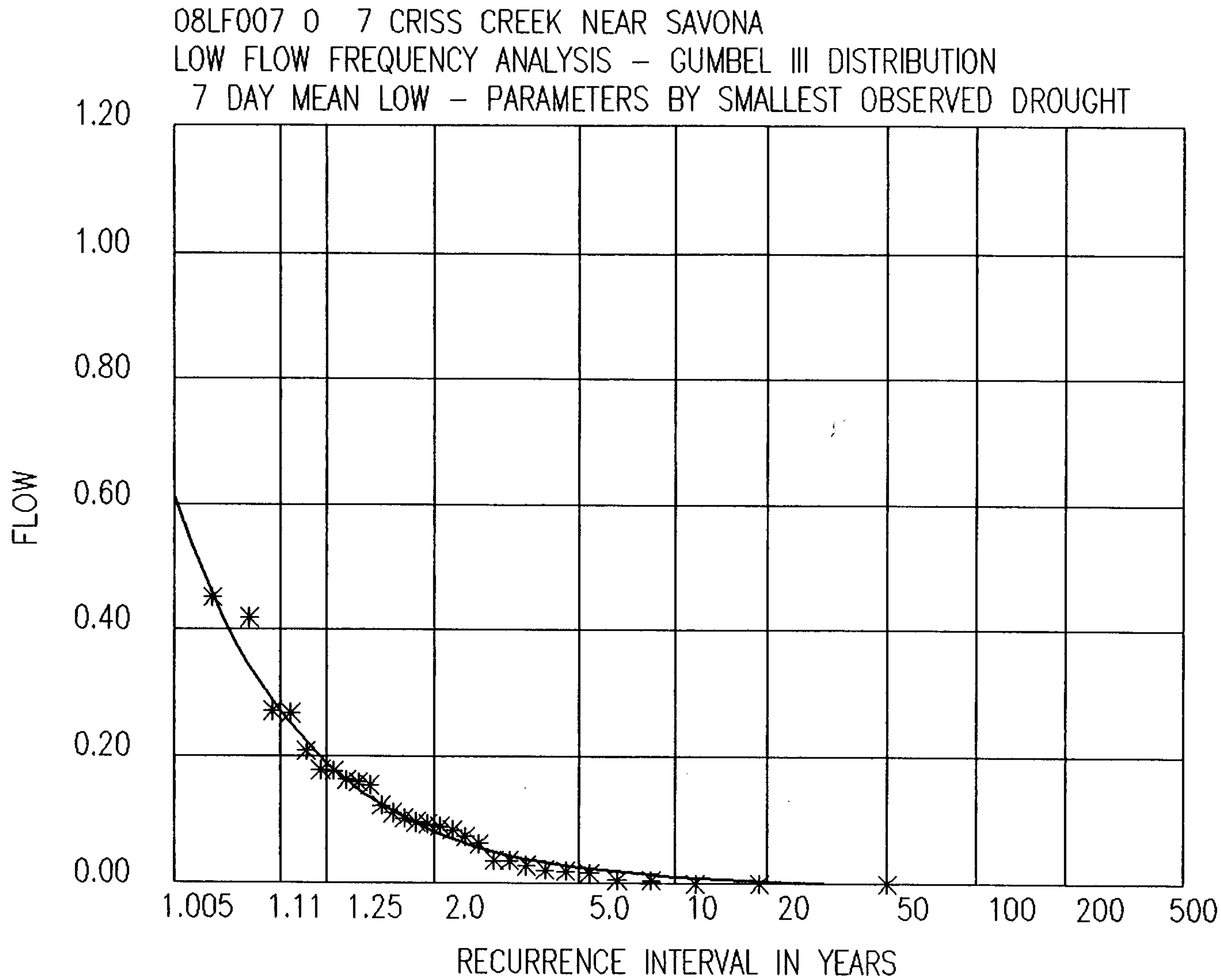
08LG060 0 7 SPAHOMIN CREEK NEAR THE MOUTH
LOW FLOW FREQUENCY ANALYSIS - GUMBEL III DISTRIBUTION
7 DAY MEAN LOW - PARAMETERS BY SMALLEST OBSERVED DROUGHT
FLOW
0.24
0.20
0.16
0.12
0.08
0.04
0.00
1.005
1.11
1.25
2.0
5.0
10
20
50
100
200
500
RECURRENCE INTERVAL IN YEARS


08LF062 0 7 BONAPARTE RIVER NEAR BRIDGE LAKE
LOW FLOW FREQUENCY ANALYSIS - GUMBEL III DISTRIBUTION
7 DAY MEAN LOW - PARAMETERS BY SMALLEST OBSERVED DROUGHT
FLOW
2.40
2.00
1.60
1.20
0.80
0.40
0.00
1.005
1.11
1.25
2.0
5.0
10
20
50
100
200
500
RECURRENCE INTERVAL IN YEARS


08LF060 0 7 BONAPARTE RIVER NEAR CACHE CREEK
LOW FLOW FREQUENCY ANALYSIS - GUMBEL III DISTRIBUTION
7 DAY MEAN LOW - PARAMETERS BY MAXIMUM LIKELIHOOD
FLOW
3.00
2.50
2.00
1.50
1.00
0.50
0.00
1.005
1.11
1.25
2.0
5.0
10
20
50
100
200
500
RECURRENCE INTERVAL IN YEARS


08LF002 0 7 BONAPARTE RIVER BELOW CACHE CREEK
LOW FLOW FREQUENCY ANALYSIS – GUMBEL III DISTRIBUTION
7 DAY MEAN LOW – PARAMETERS BY MAXIMUM LIKELIHOOD
FLOW
2.40
2.00
1.60
1.20
0.80
0.40
0.00
1.005
1.11
1.25
2.0
5.0
10
20
50
100
200
500
RECURRENCE INTERVAL IN YEARS


08LF027 0 7 DEADMAN RIVER ABOVE CRISS CREEK
LOW FLOW FREQUENCY ANALYSIS - GUMBEL III DISTRIBUTION
7 DAY MEAN LOW - PARAMETERS BY MAXIMUM LIKELIHOOD
1.20
1.00
0.80
0.60
0.40
0.20
0.00
FLOW
1.005
1.11
1.25
2.0
5.0
10
20
50
100
200
500
RECURRENCE INTERVAL IN YEARS


08LF007 0 7 CRISS CREEK NEAR SAVONA
LOW FLOW FREQUENCY ANALYSIS – GUMBEL III DISTRIBUTION
7 DAY MEAN LOW – PARAMETERS BY SMALLEST OBSERVED DROUGHT
FLOW
1.20
1.00
0.80
0.60
0.40
0.20
0.00
1.005
1.11
1.25
2.0
5.0
10
20
50
100
200
500
RECURRENCE INTERVAL IN YEARS

APPENDIX D

MEAN ANNUAL AND GREATER FLOODS IN THE SALMON STREAMS

D. MEAN ANNUAL AND GREATER FLOODS IN THE SALMON STREAMS

Table D1 presents mean annual floods and the ratio of 10, 20, 50 and 100-year return period floods to mean annual flood for those salmon streams with gauging records of ten years or more. Calculations are based on the most recent, continuous period of record, including records from 1990, at each station.

The magnitude of the reported floods are calculated from the CFA-88 program, as an average of the floods predicted, for the given return periods, by the lognormal, log-Pearson III, and Wakeby distributions applied to the annual flood flows.

No adjustment to the reported annual flood flows is included for the effect of storage and regulation.

Table D1: Ratios of n-year floods to mean annual floods for the salmon streams.

Stream	Gauge No.	Years Record	Mean Annual Flood (m3/s)	Ratio to Mean Annual Flood at return periods of			
				10 yr	20 yr	50 yr	100 yr
Clearwater R at Clearwater Stn	08LA001	32	941	1.30	1.41	1.55	1.66
Clearwater R at outlet of Clearwater L	08LA007	32	622	1.32	1.43	1.58	1.69
Mahood R at outlet of Mahood L	08LA008	17	140	1.50	1.70	1.96	2.17
Barriere R at the mouth	08LB020	48	92	1.34	1.45	1.59	1.68
N Thompson R at Birch Island	08LB047	31	706	1.28	1.37	1.47	1.54
Mann Creek near Blackpool	08LB050	19	27	1.83	2.30	2.97	3.55
N Thompson R at McLure	08LB064	32	1820	1.25	1.35	1.47	1.57
Louis Creek near the mouth	08LB072	20	25	1.47	1.62	1.78	1.90
Lemieux Ck near the mouth	08LB078	14	18	2.12	2.69	3.54	4.29
Shuswap R near Enderby	08LC002	54	361	1.34	1.48	1.66	1.81
Shuswap R at outlet of Sugar Lk	08LC018	13	192	1.46	1.61	1.78	1.89
Shuswap R at outlet of Mabel Lk	08LC019	35	325	1.38	1.54	1.76	1.94
Bessette Ck above Beaverjack Ck	08LC039	19	26	1.45	1.64	1.92	2.16
Adams R near Squilax	08LD001	41	242	1.26	1.36	1.49	1.58
Salmon River at Falkland	08LE020	39	17	1.92	2.33	2.89	3.34
Salmon River near Salmon Arm	08LE021	26	29	1.45	1.60	1.76	1.88
Eagle R near Malakwa	08LE024	25	212	1.34	1.49	1.70	1.88
Seymour R near Seymour Arm	08LE027	21	207	1.30	1.45	1.66	1.84
Salmon River above Salmon Lake	08LE078	25	7.4	1.52	1.70	1.95	2.13

Table D1: Continued

Stream	Gauge No.	Years Record	Mean Annual Flood (m3/s)	Ratio to Mean Annual Flood at return periods of 10 yr	20 yr	50 yr	100 yr
Bonaparte R below Cache Creek	08LF002	19	25	2.29	2.81	3.48	3.98
Nicola R near Spences Bridge	08LF006	33	186	1.42	1.59	1.82	1.99
Criss Ck near Savona	08LF007	29	20	1.64	2.18	2.70	3.13
Deadman R above Criss Ck	08LF027	29	10	2.57	3.61	5.63	7.91
Spahomin Ck near the mouth	08LF060	19	3.9	1.63	1.86	2.17	2.40
Bonaparte R near Bridge Lk	08LF062	30	12	1.94	2.33	2.91	3.45
Spius Ck near Canford	08LG008	21	84	1.69	1.82	2.08	2.26
Coldwater R at Merritt	08LG010	30	70	1.45	1.63	1.87	2.05
Coldwater R near Brookmere	08LG048	25	59	1.48	1.66	1.90	2.06

1. Mean annual floods and ratios calculated for mean daily flows.
2. Mean annual floods and 10, 20, 50 and 100 year return period floods calculated with the CFA-88 program and the reported values are the average of values calculated assuming lognormal, log-Pearson III and Wakeby distributions.

APPENDIX E

REGIONAL HYDROLOGY OF THE THOMPSON RIVER WATERSHED

E. REGIONAL HYDROLOGY OF THE THOMPSON RIVER WATERSHED

E.1 Introduction

Regional hydrologic analysis predicts the flow characteristics of ungauged watersheds from relationships between flow characteristics, climate and hydrology developed in watershed with gauging stations. The simplest and best relationships occur within regions that are reasonably homogeneous with respect to flow-generating mechanisms, climate and physiography.

The Thompson watershed contains at least three physiographic regions: plateau, consisting of the Thompson and Fraser Plateaux; highlands, consisting of the Quesnel, Shuswap and Okanagan Highlands; and mountains, including the Cariboo, Monashee and Cascade Mountains. The regions are named and described in Holland (1976). Sigma Engineering (Figure 2.1) maps the various regions. Most of the ungauged salmon streams lie in the highlands with the remainder in one of the mountain regions. Almost all the salmon streams on the plateaux are gauged.

Our focus was on predicting August and September mean monthly flows and summer and winter 7 day low flows, as described in Chapter 2 of the main text.

E.2 Water Survey of Canada Records

E.2.1 Criteria for Selecting Gauging Records

The general criteria for selecting gauging records for correlation or regression analysis with climate and physiographic data are:

1. All stations should have a complete or nearly complete record of flows during a common base period. In this report our base period is 1980 to 1989, inclusive;
2. The length of the base period should be at least 10 years, though some compromise is necessary between long base periods and the number of stations available for inclusion in the analysis;
3. Drainage areas at the gauging sites should exceed 100 km^2 and be less than several thousand km^2. The lower limit avoids local anomalies, the upper limit avoids artificially high correlations induced by including large drainage areas that encompass most of the region;
4. The records should all be independent. Where there are multiple records on one stream, only one record should be used or the records should be subtracted to produce flow estimates for the independent portions of the total basin area; and
5. There should be no upstream regulation, water use, or diversion out of the basin.

The above list is ideal; the following section discusses relaxing these criteria to provide sufficient stations for an adequate statistical analysis.

E.2.2 Water Survey of Canada Records in the Highlands

Table E1 lists the Water Survey of Canada stations in the Highlands region that were selected for analysis. These stations do not all meet the criteria discussed in Section E.2.1. Stations smaller than 100 km^2 are included in the analysis and the maximum size is restricted to 1,000 km^2. Smaller drainage basins were included because the majority of the ungauged salmon streams have small watersheds. Spahats Creek, which is missing 1980, was included but several stations missing two or three years in the 1980's were excluded. Spahats and Vance, both of which have seasonal records, were included. As well, we have also included Mann Creek, which has only limited records in the 1980's but was included because it has a long and consistent record which should provide suitable average values.

Many of the watersheds have upstream regulation and extraction. Records were adjusted following the procedures outlined in Chapter 2 of the report, utilizing summaries of water licences obtained from the Water Management Branch.

Independence of the records is a more serious issue. Three stations lie in the Barriere River watershed (08LB020, 08LB069, 08LB076). Harper Creek is an upstream tributary that is reasonably independent of the other stations: however, the station below Sprague Creek includes roughly 60% of the drainage area of the station at the mouth. The two records were subtracted to produce an independent record for the lower Barriere River basins. This produces negative flows, during various periods, in the fall and winter and, as a result, accurate 7 day low flows can not be calculated for the lower Barriere River, downstream of Sprague Creek. However, moderately accurate mean monthly flows in August and September can be calculated for the lower Barriere River and this artificial station was used in part of the analysis.

E.3 Climate and Physiographic Data

Physiographic and climate variables that are related to flow characteristics are listed on Table E.2. The physiographic variables collected for the watersheds of the selected gauging stations are: drainage basin area, maximum and minimum elevations, and the area of lakes. Elevation range was calculated from the minimum and maximum elevations.

May to September precipitation was calculated from manuscript maps (1:125,000) prepared by the Climatology Unit of the Waste Management Branch. Basin areas were superimposed on these maps and the areas lying between individual isohyets was estimated. Average seasonal precipitation was calculated from an areally-weighted average of the contour mid-points and are reported to the nearest 25 mm.

E.4 Regression analysis of flow characteristics and physiography and climate

E.4.1 Procedures

The following procedures were used in developing regression models for each of the streamflow variables:

1. Bi-variate correlations between the independent variables and the chosen flow characteristic -- both logarithmic transformed and non-transformed -- were used to identify those variables significantly correlated with the flow characteristic. (R^2 must exceed 0.55 for a significant correlation with 11 cases.);

2. A correlation matrix was prepared for the significant independent variables. Intercorrelated independent variables produce little improvement in the explanation level of multiple regression models.

3. The multi-variate relationship with the highest r^2 and the lowest standard error, for each flow characteristic, was determined.

4. The selected relationship was used to predict flow characteristics at ungauged salmon streams.

E.4.2 Mean Monthly Flows

Basin area was significantly correlated and maximum elevation and elevation range were almost significantly correlated with mean August and September flows. Other variables exhibited near-zero or zero correlation. Maximum elevation and elevation range are inter-correlated and maximum elevation was dropped in favour of elevation range. Correlations were stronger with logarithmically-transformed variables and a logarithmic transform was used in developing multiple regression equations.

Constant and coefficients for the preferred regression equations, relating the logarithms of mean August and September flows to the logarithms of basin area and elevation range, are described in the following table. Standard errors of these equations, expressed in logarithms in the table, are equivalent to percent standard errors of, roughly, +60%, -40%. Similar percent standard errors occurred during a regional analysis of Vancouver Island (Rood 1988).

Month	Constant	Basin Area	Elev. Range	r^2	SE_y	N
August	-10.771	0.863	2.409	0.89	0.228	11
Sept	-11.747	0.797	2.688	0.91	0.205	11

E.4.3 Seven Day Low Flows

Basin area was significantly correlated and maximum elevation and elevation range were almost significantly correlated with mean summer and winter 7 day low flows. Other variables exhibited near-zero or zero correlation. Maximum elevation and elevation range are inter-correlated and maximum elevation was dropped in favour of elevation range. Correlations were stronger with logarithmically-transformed variables.

The constant, and coefficients for the preferred regression equations, relating the logarithms of summer and winter mean 7 day low flows to the logarithms of basin area and elevation range, are described in the following table. Standard errors of these equations, expressed in logarithms in the table, are equivalent to percent standard errors of, roughly, +60%, -40%.

Period	Constant	Basin Area	Elev. Range	r^2	SE_y	N
Summer	-11.914	0.980	2.565	0.92	0.231	10
Winter	-8.750	0.860	1.716	0.95	0.148	9

E.5 Predicting Flow Characteristics in Ungauged Salmon Streams

The preferred equations from Sections E.4.2 and E.4.3 were used to predict mean monthly and mean 7 day low flows for the ungauged salmon streams. Where no gauging records exist on the salmon stream the predicted flows are reported in Tables 2 and 3. For those salmon streams with short-term records collected by the Water Survey of Canada or low flow measurements by the Water Management Branch, the predicted values were compared to the measured values. If the predicted values differed greatly from the measured values, generally, the measured values were accepted, or an average of the two sets of values were included on Tables 2 and 3.

The data set used to develop the regression equations mostly includes basins from the southern portion of the North Thompson HMA, including some basins lying partly on the Fraser Plateau. The equations provide reasonable predictions for ungauged salmon streams lying in this part of the Thompson watershed and, likely, poorer predictions for salmon streams in the more distant portions of the South Thompson - Shuswap HMA.

Table E1: Gauging Stations in the Quesnel Highlands with Natural or near-natural flow and records during most of the 1980's.

Station	Gauge No.	Basin Area (km2)	Period of Record	Comments
Lemieux Ck near the mouth	08LB078	443	77-87MC; 86-90RC	
Barriere R below Sprague Ck	08LB069	624	64-66MC; 67MS; 68-73MC 74-82RC; 83-84MC; 85-90RC	
Barriere R at the mouth	08LB020	1140	52-58MC; 63-90MC	
Harper Ck near the mouth	08LB076	168	73-90RC	
Louis Ck at the mouth	08LB072	515	71-86MC; 87-90RC	
Fish Trap Ck near Mclure	08LB024	135	70-90RC	
Paul Ck at Pinantan Lk	08LB012	55.7	77-90MC	
Mann Creek near Blackpool	08LB050	295	60-62MS; 63-66MC; 67-68MS; 69-74MC; 75MS; 76-81MC	old record
Spahats Ck near the mouth	08LA021	52.5	81-90MS	missing 1980
Corning Ck near Squilax	08LE077	26.2	79MS; 80-90RC	
Vance Ck below Deafies Ck	08LC040	73.3	70-77MS; 78-90MC	

1. R refers to recording gauges, M to manual; C to continuous records, S to seasonal.

Table E2: Physiography, Climate and Flow Characteristics for Water Survey of Canada stations in the Highlands Region

Station	Basin Area (km2)	Lake Area (km2)	Elevation in Basin (ft) Max	Min	Range	May-Sept Precip (mm)	Mean 7 day Low Flows Summer (m3/s)	Winter (m3/s)	Mean Monthly Flows August (m3/s)	September (m3/s)
Lemieux Ck near the mouth	443	19.1	5500	1400	4100	160	1.00	0.53	2.23	1.39
Barriere R below Sprague Ck	624	6.6	7500	1800	5700	225	2.98	1.87	5.36	4.21
Lower Barriere River	516	14	5500	1400	4100	180			1.74	1.15
Harper Ck near the mouth	168	0.01	8640	2600	6040	250	1.26	0.62	2.10	1.83
Louis Ck at the mouth	515	0.7	7000	1400	5600	175	1.03	0.57	1.57	1.37
Fish Trap Ck near Mclure	135	1.6	5000	2000	3000	160	0.21	0.14	0.43	0.32
Paul Ck at Pinantan Lk	55.7	1	5000	2500	2500	150	0.02	0.04	0.06	0.04
Mann Creek near Blackpool	295	1.6	5500	1400	4100	225	0.60	0.33	1.37	1.20
Spahats Ck near mouth	52.5	0.3	8460	2500	5960	325	0.43		1.18	0.97
Corning Ck near Squilax	26.2	0.01	5500	1300	4200	350	0.03	0.04	0.08	0.08
Vance Ck below Deafies Ck	73.3	0.01	5700	2300	3400	400	0.14	0.08	0.29	0.20