TULAMEEN RIVER WATERSHED OVERVIEW CHANNEL ASSESSMENT

VOLUME 1 TEXT

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2: Holding Creek
3: Podunk Creek
4: Vuich Creek
5: Jim Kelly Creek
6: Champion Creek
7: Britton Creek
8: Lawless Creek
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VOLUME 3: OTTER CREEK AND LOWER TULAMEEN WATERSHED

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Figure 5.0.1 Channel restoration opportunities, Tulameen River watershed

TULAMEEN RIVER WATERSHED
OVERVIEW STREAM CHANNEL ASSESSMENT

1: INTRODUCTION AND OBJECTIVES

The B.C. Ministry of Environment, Lands and Parks has requested M. Miles and Associates Ltd. to determine how historic land use practices have affected stream channel processes in the Tulameen River watershed. This 1,780 km² basin is located in southwestern British Columbia 200 km east of Vancouver *(Figure 1.0.1)*. The original contract specified that this work was to be undertaken on the mainstem channel of both Tulameen River and Otter Creek. This scope was subsequently increased to include twelve of the larger tributaries. Similar analyses were therefore undertaken on Holding, Podunk, Vuich, Jim Kelly, Champion, Britton, Lawless, Olivine, Spearing, Thynne, Granite and Asp Creeks. This overview level assessment was undertaken using existing information and air photograph interpretation. On the basis of this analysis, areas requiring field inspection have been identified and preliminary recommendations on appropriate restoration activities have been prepared.

The physical setting is described in SECTION 2. Physiographic and geological information have been summarized, fish distributions are discussed and land use information has been compiled on the basis of satellite imagery. A detailed review of the available hydrometric data was also undertaken. Studies in British Columbia by *Barrett (1979), Church and Miles (1987)* and *Church (1997)* have shown that there have been significant hydrometric variations over the period of instrumented record. We have therefore examined the historical variation in precipitation, snow accumulation and runoff in the study area to determine if changes in the hydrometric regime are of sufficient magnitude that they could affect stream channel processes and morphology.

A series of four historical air photos spanning the period between 1947 and 1996 have been compiled at a common scale of 1:15,000 for all of the study streams. On the basis of this information, land use impacts and changes in channel morphology over time have been documented in SECTION 3. Priorities for field inspection are summarized in SECTION 4 and mitigation recommendations presented in SECTION 5. Suggestions for future work are discussed in SECTION 6.

2: PHYSICAL SETTING

2.1 PHYSIOGRAPHY, GEOLOGY AND WATERSHED MORPHOMETRY

2.1.1 Physiography

The western portion of the Tulameen watershed is located within the Cascade Mountains, while the eastern portion is situated within the Thompson Plateau.

The Cascade Mountains, which include volcanic cones such as Mount St. Helen's and Mount Baker to the south, are characterized by peaks, high ridges and remnant cirque basins *(Holland, 1976)*. Elevations in the Cascade Mountains typically range from 700 to 2,300 m asl. Stream channels generally have steep gradients and flow in narrow valleys.

The Thompson Plateau is comprised of gently sloping upland areas and deeply incised U-shaped valleys *(Preto, 1979)*. The transition between the plateau and the adjoining mountains is gradual, such that the boundary between the two physiographic units is arbitrary *(Holland, 1976)*. Elevations within the Thompson Plateau typically range between 600 to 1,800 m asl. Streams in the Thompson Plateau frequently have lower gradients and flow in wider valleys in comparison to channels in the Cascade Mountains.

Many of the streams within the Tulameen watershed follow fault boundaries *(Preto, 1979)*. The tributaries within the Cascade Mountains generally flow in an eastward direction, while streams in the Thompson Plateau typically exhibit a north–south alignment.

2.1.2 Bedrock Geology

The Tulameen watershed is located within the Quesnellia Terrane *(Monger, 1989)*. This is a region of complex geology characterized by extensive faulting, uplift, and volcanic intrusions. The Tulameen watershed is approximately bounded by major structural faults on all four sides and Otter Creek, the largest tributary to Tulameen River, follows a north–south trending fault located in the central section of the watershed.

Geologic mapping by *Monger (1989)* indicates that there are five main rock assemblages within the Tulameen watershed *(Figure 2.1.1)*. These assemblages are roughly oriented north-northeast and from the east to west are as follows: Nicola Group, Spences Bridge Group, Nicola Group again, Eagle Plutonic Complex, Pasayten Group, and Ladner Group. There are also several intrusive bodies within the watershed (the Allison Lake Pluton, the Tulameen Complex and Plateau basalts) which have caused local metamorphism and deformation.

The Nicola Group consists of several facies of volcanic rocks ranging from undifferentiated mafics to porphyry pyroclastics and flows associated with ancient volcanic eruptions. These rocks have been deformed and metamorphosed and therefore are potentially erosion prone. Most of Lawless Creek and the lower Tulameen River lie within this Group.

The Spences Bridge Group is comprised of felsic and mafic volcanics, sandstone, shale, and conglomerate. This assemblage is found in the north-central region of the watershed. These rocks are frequently incompetent and erosion prone. Most of Otter Creek and Asp Creek is located within this assemblage.

The Eagle Plutonic Complex is principally composed of granite, granodiorite, diorite, and amphibolite. This assemblage of rocks has undergone little deformation or metamorphism and is therefore very erosion resistant. The mid elevation reaches of Podunk Creek and the upper Tulameen River flow through this Complex.

The Pasayten and Ladner Groups are both comprised of undifferentiated sandstone, conglomerate and argillite. These sedimentary rocks have been weakened by low grade metamorphism and are potentially susceptible to erosion. The headwaters of streams in the southwest corner of the watershed, such as Vuich, Podunk and the upper Tulameen River, flow through these assemblages.

2.1.3 Surficial Geology

Surficial geology mapping *(Fulton, 1962)* indicates that the majority of upland areas in the Tulameen watershed are covered by till that ranges in thickness from 0.5 m to over 9 m. These materials generally reflect the characteristics of the underlying bedrock. Rock and colluvium are exposed within higher elevation areas and along the valley walls of both Otter Creek and the mainstem Tulameen River. The valley bottom areas commonly contain fluvial or glaciofluvial deposits. These include sand and gravel terraces and deltas, as well as ridges and kame complexes associated with relic outwash channels.

Many small and medium-sized kettle lakes are found in the northern portion of the watershed. These lakes are commonly deep and narrow, and are typically oriented north-south along the direction of former ice movement.

2.1.4 Watershed Morphometry

Morphometric data for each of the watersheds investigated in this study are summarized in *Table 2.1.1.* This information has been digitized from 1:20,000 scale TRIM mapping.

Jim Kelly Creek is the smallest watershed having a basin area of 32 km^2 and a main channel length of 12 km. Otter Creek is the largest tributary having a basin area of 672 km^2 and a main channel length of 68 km. The Tulameen River drainage has a total area of 1,780 km^2 and the mainstem river is 84 km long.

Long profiles of the mainstem Tulameen and the investigated tributary channels are shown on *Figure 2.1.2.* An equivalent channel slope has been calculated using the following equation:

$$ES = \left[\frac{n}{\sum s^{-0.5}}\right]^2 \qquad .....(i)$$

Where: ES is the equivalent channel slope (m/m);
n is the number of equal length channel segments (in this case 10); and
s is the slope (in m/m) of the channel segment.

As discussed in *Taylor and Schwartz (1952)* and *Warnock (1982)* this procedure is thought to produce a uniform main channel slope with the same flood travel time as the actual profile. Otter Creek has the lowest equivalent channel slope of 0.005 m/m. Olivine Creek has the highest value of 0.057 m/m. The mainstem Tulameen River has an equivalent slope of 0.009 m/m which is smaller than that of any tributary stream except Otter Creek.

Watershed shape has been calculated on the basis of an index compiled by dividing the main channel length squared by the basin area *(see Warnock, 1982)*. A value of 1 is indicative of a square watershed and higher values are indicative of a more elongate morphometry. Values range from 1.1 (Spearing Creek) to 7.5 for Asp Creek. Values for Otter Creek and the mainstem Tulameen are 6.8 and 3.9, respectively.

2.2 CLIMATOLOGY

2.2.1 Available Data

With the exception of Princeton, there are no active or long term climate stations in the study area. Seven regional stations have therefore been selected to illustrate representative climatic characteristics and to investigate long term trends in precipitation totals. Station locations are shown on *Figure 2.2.1* and the available data is summarized on *Table 2.2.1.* Sites range in elevation between 39 and 1,707 m asl. Hedley and a combination of sites at Princeton *(Princeton combined)* are the longest running stations with 79 and 96 years of record, respectively.

2.2.2 Annual Precipitation

The seasonal precipitation regime is illustrated on *Figure 2.2.2.* These data show that there are significant regional variations in both timing and magnitude.

Data from the Cascade Mountains (such as *Hope*, *Hope Slide* or *Manning Park*) indicate that over 80% of the total annual precipitation is associated with cyclonic activity in the period between September and April. This seasonal variation is much less pronounced at stations in the Thompson Plateau such as *Brookmere*, *Princeton* or *Similkameen Mine*. The monthly precipitation totals at these sites are relatively similar and reflect both cyclonic activity in the fall or winter and convective activity in the summer. Further east at Hedley, the importance of fall or winter cyclonic precipitation decreases and the wettest months occur in the summer.

The compiled data indicate that there are large variations in annual precipitation totals across the study area. Data from *Hope Slide* and *Manning Park* suggest that the average annual precipitation along the western edge of the Tulameen watershed might be in the range of 1,060 to 1,235 mm. This value decreases inland to 580 mm at *Brookmere*, 340 mm at *Princeton* and 316 mm at *Hedley*. Annual precipitation also appears to increase with elevation as *Hedley NP Mine* (elevation 1,707 m) has an 83% higher average value (579 vs. 316 mm) than that reported at *Hedley* (elevation 517 m).

The spatial variability in annual precipitation in the area between the small number of climate stations bordering the Tulameen watershed is unknown. However, biogeoclimatic mapping provides a basis for making an initial estimate. There are five biogeoclimatic zones in the study area *(Figure 2.2.3)*. Analysis of a Ministry of Forests (MOF) compilation of climate data *(Spittlehouse, pers. comm.)* indicates that the probable range in average annual precipitation within each of these biogeoclimatic zones is as follows:

	RANGE IN ANNUAL PRECIPITATION (mm) BY BIOGEOCLIMATIC ZONE				
	Ponderosa Pine – Bunchgrass	Interior Douglas Fir	Montane Spruce	Engelmann Spruce – Subalpine Fir	Alpine Tundra
Minimum	206	276	381	414	623
Mean	338	443	599	1,152	2,258
Maximum	609	1,199	1,088	2,169	3,683

A frequency analysis has been undertaken on the recorded annual precipitation totals *(Table 2.2.2)*. These calculations suggest that the 25 and 100-year return period annual precipitation totals will be approximately 1.5 to 1.6 and 1.7 to 1.9 times the average values listed above.

2.2.3 Seasonal Variation in Temperature

The seasonal variation in temperature at representative regional climate stations is illustrated on *Figure 2.2.4.* Mean annual temperature can be seen to decrease with increasing elevation. Values range from 9.8°C at *Hope*, 5.9°C at *Princeton A*, 4.1°C at *Brookmere* and 2.0°C at *Hedley NP Mine*. Average maximum daily temperatures of over 20°C have been observed throughout the period between May and September. Minimum temperatures occur between November and February and have reached values of -30° to -40°C. From a fisheries perspective, these data suggest that elevated summer water temperatures and deep water winter refuge habitat could be critical or limiting factors for resident fish in small streams.

2.2.4 Extreme 1-Day Rainfall and Precipitation

The seasonal variation in extreme 1-day rainfall and precipitation is illustrated on *Figure 2.2.5.* Maximum 24-hour precipitation values are associated with late fall or winter cyclonic activity in the Cascade Mountains. At low elevation (e.g. *Hope*) the extreme values consist of rainfall events, while at higher elevation sites (e.g *Hope Slide*), there may be a significant snowfall component. The relative importance of spring and summer events increases within the Thompson Plateau. For example, data from *Hedley MP Mine* indicates that the extreme 1-day precipitation events typically occur in May, June or July.

A frequency analysis of annual extreme 1-day precipitation totals *(Table 2.2.3)* indicates that 2-year return period totals decrease from 74 mm at *Hope* to 22 mm at *Princeton* and *Hedley*. Ten-year return period events range from 114 mm at *Hope* to 37 mm at *Hedley* and 100 year values are 164 and 54 mm, respectively. Criteria proposed by *Caine (1980)* suggest that shallow landslides or debris flows will occur in susceptible materials when 24-hour precipitation totals exceed 100 mm.*[1] These results indicate that 1-day precipitation totals having less than 10-year return periods are sufficient to cause slope instabilities in the Cascade Mountains. In contrast, 100-year return period 1-day events in the Thompson Plateau are unlikely to cause slope instabilities.

2.2.5 Short Duration Rainfall Intensities

Short duration rainfall intensity–duration–frequency data from *Hope A* and *Princeton A* are shown on *Figure 2.2.6. Caine's (1980)* criterion for the initiation of shallow landslides or debris flows in susceptible materials has been overlaid. This analysis indicates that 5 minute to 24-hour rainfall intensities having return periods of approximately 3 years exceed Caine's criterion in the

1 *Church and Miles (1987)* found that slope instabilities and debris torrents have occurred with smaller precipitation totals in southwestern BC as a result of wet antecedent conditions or snowmelt.

western portion of the Cascades. In contrast, the data from *Princeton A* indicate that Caine's criteria are exceeded by 3-year return period events over durations of 5 minutes; 5-year events at durations of 60 minutes; 20-year events at a duration of 2 hours and by ≥100-year events lasting 4 hours or more. This pattern reflects the intense, but short duration, convective events which occur in the Thompson Plateau.

2.2.6 Snow Accumulation

There are eight snow course stations located within or adjacent to the Tulameen watershed (see *Figure 2.2.1 and Table 2.2.4*). The seasonal variation in observed snow cover and average maximum water equivalent value is shown on *Figure 2.2.7*. These data, which have not been adjusted for varying periods of record, indicate that maximum snow accumulation and the duration of snow cover are affected by elevation and distance inland. High elevation sites in the cascades, such as Great Bear, report average maximum snow water equivalents of 1,508 mm *(Table 2.2.5)*. This value decreases eastward to 370 mm at Hamilton Hill and 221 mm at Nickel Plate.

2.2.7 Historical Variation in Annual Precipitation

The historical variation in annual precipitation is shown on *Figure 2.2.8*. The period of record is variable and the longest operating station *(Princeton)* is missing data for the period between 1978 and 1992. Annual precipitation data at *Princeton* was therefore correlated with data from *Princeton A* (**r^2** = 0.99) and this relationship has been used to estimate the missing data. The data on *Figure 2.2.8* indicate there has been an unusual number of above average annual precipitation totals in the period since the mid 1970's. The highest value on record occurs in 1990 and has a calculated return period of 10 to >100 years. Three of the five maximum observed annual precipitation values at Hedley and three of the six maximum values at *Princeton* have occurred in the 1990's.

In order to refine this analysis, residual mass curves for the three longest running sites are plotted on *Figure 2.2.9*. In this technique for trend analysis, negative sloping lines represent less than average values and positively sloping lines represent greater than average values. The results indicate that annual total precipitation at *Hope plus Hope A* was generally less than average between the 1940's and the early 1970's and generally greater than average values have occurred in subsequent years.*[1] The data from *Princeton* show a pattern which is similar to that reported for other areas in the province by *Barrett (1979)* and *Church (1997)*. Specifically, annual

1 The data from *Hope* is confounded by the movement of the station from *Hope* to *Hope A* in 1973. This suggests that the post-1973 increase in annual precipitation could have been affected by the change in station location.

precipitation totals were less than normal prior to 1944 and were subsequently greater than average. The magnitude of this change is approximately 20% (i.e. the average annual precipitation increased from 305.8 mm to 364.7 mm). The data from *Hedley* also show a pattern of generally increasing annual precipitation with post-1977 values (393.3 mm) being 36% larger than those which occurred in the earlier part of the century (289.4 mm). Three tests (**Q**, **R**, and **W** statistics, described in *Buishand, 1982*) indicates that there is a 95 to 99% probability that a statistically significant shift in the annual precipitation regime has occurred at both *Princeton* and *Hedley (Table 2.2.6)*.

2.2.8 Historical variation in annual extreme one day precipitation

The historical variation in annual extreme one day precipitation is shown on *Figure 2.2.10*. The available record is again of variable length. Data from *Princeton* has been correlated with *Princeton A* (**r^2** = 0.94) in order to estimate missing data. The data from *Hope plus Hope A* indicate that a sizeable increase in extreme one day totals occurred after the station was moved in 1973. More reliable and longer term records from the nearby station at *Agassiz CDA (1890-1995)* also show a trend of increasing extreme 1-day precipitation and the **Q**, **R**, and **W** statistics indicate there is a 95 to 99% probability that a statistical shift in regime has occurred *(see Hartman and Miles, 1997)*.

Data from *Princeton* indicate that >200-year return period 1-day precipitation totals occurred in 1935 and 1936, a >50-year event occurred in 1949 and a >10-year event occurred in 1986. Pre-1935 events were, in general, smaller than those which occurred in the latter part of the century. The data from *Hedley* is more variable. A >200-year return period event occurred in 1909 and >25-year return period events occurred in 1935 and 1957. Residual mass curves for these three stations are shown on *Figure 2.2.11*. Statistical tests (summarized on *Table 2.2.6*) indicate that there is a 90 to 95% probability of a statistically significant shift in extreme 1-day precipitation regime at *Princeton*. However, the data from *Hedley* do not show a statistically significant shift in regime at the 90% confidence level.

2.2.9 Historical variation in annual maximum snow accumulation

The historical variation in annual maximum snow water equivalents is shown on *Figure 2.2.12*. These data indicate that the maximum recorded snow accumulation generally occurred in 1972 and had a return period of 25 to over 200 years.

In order to extend the period of record, data from *Nickel Plate* has been correlated to observed values at *Missezula Mountain* (**r^2** = 0.74) and data from *Copper Mountain* and *Sunday Summit* have been correlated (**r^2** = 0.79). Residual mass curves from *Brookmere, Copper Mountain* and

Nickel Plate are shown on *Figure 2.2.13* and indicate that there has been a trend towards less than average snow accumulation in the period since the mid to late 1970's. The decrease in average maximum annual snow water equivalents ranges from 26% at *Brookmere* to 31% at *Copper Mountain.* Statistical tests, summarized on *Table 2.2.6*, indicate that these changes are statistically significant at *Brookmere* and *Copper Mountain*, but not at *Nickel Plate*.

2.3 HYDROLOGY

2.3.1 Available Information

Environment Canada has operated thirteen stream gauging stations in the general vicinity of the study area *(Figure 2.3.1)*. As indicated on *Table 2.3.1*, the data is of variable length and there is little information available for basin areas of less than 180 km². *Similkameen River at Princeton* and *Tulameen River at Princeton* are the two longest running sites with 60 and 40 years of record, respectively. Data from *Fraser River at Hope* has also been compiled as previous analyses indicate that the flow regime has undergone systematic variations over the last 86 years. This station therefore provides a long term reference site, albeit from a larger basin, which can be compared to the shorter term data from the Tulameen watershed.

2.3.2 Seasonal Variation in Flow

The seasonal variation in flow is illustrated on *Figure 2.3.2*. Data from *Otter Creek* and *Tulameen River* indicate that spring snowmelt is the dominant hydrological event of the year. The freshet can begin as early as March and persist until late June or July. Mid-summer storms or convective events appear to cause short duration and comparatively small floods on the >250 km² streams shown on *Figure 2.3.2*. However, these processes could cause sizeable flows on smaller tributary watersheds. Streamflows typically recede to very low levels in August, September or early October. Rain or rain-on-snow events can cause sizeable flood flows between October and January, however, late fall and winter discharges are typically very small.

2.3.3 Annual Runoff

Annual runoff values have been summarized on *Table 2.3.2*. This analysis, and data presented in *Coulson et al. (1997)*, indicates that the annual runoff in the study area ranges from approximately 1,000 mm in the Tulameen headwaters to 100 mm/yr in the vicinity of Princeton. The analysis of precipitation data in SECTION 2.2.2 indicates that the average annual precipitation

exceeds 1,000 mm on the Tulameen headwaters and 325 mm at *Princeton.* This suggests that up to 70% of this total is lost to evapotranspiration with the larger losses occurring in the drier and hotter areas within the Thompson Plateau.

2.3.4 Flood Magnitudes

A frequency analysis of annual maximum daily and instantaneous discharges at representative stream gauging sites has been undertaken using the Water Management Branch's computer program "FREQAN" (*Tables 2.3.3 and 2.3.4*). These analyses, and information provided in *Coulson (1997)*, have been used to estimate flood magnitudes at representative sites in the study area *(Table 2.3.5)*.*[1] The results indicate that unit peak flows within watersheds draining the Cascade Mountains are significantly larger than those in the Thompson Plateau. Lake regulation also appears to substantially reduce flood magnitudes on the mainstem of Otter Creek.

2.3.5 Minimum Flows

A frequency analysis of annual minimum flows has been undertaken and the results are summarized on *Table 2.3.6*. These calculations indicate that *Otter Creek below Spearing Creek* (basin area 409 km²) typically goes dry in the summer and the average minimum flow at *Otter Creek at Tulameen* (basin area 673 km²) is only 0.2 m³/s. This corresponds to a unit discharge of 0.0003 m³/s/km². Tributaries to Otter Creek and other streams in the Thompson Plateau can be expected to have similar or even smaller minimum unit flows.

The average minimum flows on Tulameen River increase from 0.4 m³/s *"below Vuich Creek"*, (basin area 256 km²) to 1.3 m³/s at *Coalmont* (basin area 1,370 km²) and 1.9 m³/s at *Princeton* (basin area 1,760 km²). The average minimum unit discharges are 0.0015, 0.0009 and 0.0011 m³/s/km², respectively. The average minimum unit flows on Tulameen River are therefore approximately three times larger than those which occur in Otter Creek or other drier watersheds draining the Thompson Plateau.

2.3.6 Historical Variation in Annual Runoff

The historical variation in annual runoff is illustrated on *Figure 2.3.3* and selected residual mass curves are on shown on *Figure 2.3.4*. This analysis suggests that there has been a substantial

1 These preliminary analyses are appropriate for the purposes of the present report, but should be verified prior to being used for design purposes.

variation in the average annual discharge over the period of instrumented record. The pattern in the residual mass curves for Otter Creek, Tulameen River, Similkameen River and Fraser River is generally similar. The longer term data from Fraser River indicate that the average runoff in the period between 1954 and 1976 is, on average, 16% larger than that which occurred between 1922 and 1953. **Q** and **R** statistics suggests that this change in regime is statistically significant at the 90 to 99% confidence level *(Table 2.2.6)*. The periods of record on Otter Creek, Tulameen River and Similkameen River are of shorter duration and therefore do not include data from the comparatively dry pre-1955 period. Post-1975 flows have been generally less than average, which is similar to what has been observed on Fraser River. Statistical tests indicate that these changes in average flow on Tulameen River, Similkameen River and Otter Creek are generally not significant at the 90% confidence level. The **Q** and **R** statistics indicate that there is a 90% probability of a statistically significant shift in annual flow regime on Tulameen and Similkameen Rivers, respectively. These conflicting results indicate that a longer period of record would be required to determine if the Tulameen watershed has experienced changes in flow regime similar to that which has occurred on Fraser River.

2.3.7 Historical Variation in Annual Maximum Daily Discharge

The historical variation in annual maximum daily discharge is shown on *Figure 2.3.5*. Residual mass curves for the longer term streamflow stations are shown on *Figure 2.3.6*.

Data from Otter Creek indicate that the largest post-1948 flood occurred in 1972 and had a return period of over 50 years at Tulameen. Floods having greater than 10 year return periods occurred in 1949, 1950 and 1954. There are no pre-1948 or post 1985 data on Otter Creek and the size of floods in these periods is therefore unknown.

The flood of 1948 was a sizeable event on *Tulameen River at Coalmont*. However, the period of record is sufficiently short that reliable return periods cannot be calculated. The largest floods in the post-1948 period occurred in 1972 (return period 50 years at *Princeton*) and 1994 (return period 25 years at *"below Vuich Creek"* and approximately 70 years at *Princeton*). Greater than 10-year return period floods also occurred in 1954, 1955, 1989 and 1990. All of these floods are sufficiently large that morphologic change is likely to have occurred, particularly in areas with elevated sediment loadings or cleared riparian areas.

The residual mass curve from *Fraser River At Hope* indicates that the average maximum daily discharge in the period between 1946 and 1974 is 22% larger than the average values observed in the period 1926 to 1945 and 16% larger than the average value between 1975 and 1997. The **R** statistic indicates that there is a 99% probability that there has been a significant shift in the annual maximum daily discharge regime at this station *(Table 2.2.6)*.

The residual mass curves for *Similkameen River at Princeton* has a similar pattern to that from Fraser River. Annual maximum daily flows in the period between 1914 and 1975 are, on average, 21% larger than those which have occurred in the succeeding period. Data from Otter Creek and Tulameen River show more variation and at least part of this is due to the comparatively short length of data which is available. The **R** statistic suggests that there is a 95% probability of a statistical shift in regime on Similkameen River; **Q** and **W** statistics also show a 90 to 95% probability of a significant shift in regime on *Otter Creek at Tulameen*. All other tests are not significant at the 90% confidence limit.

2.3.8 Historical Variation in Annual Minimum Daily Discharge

The historical variation in annual minimum daily discharge is shown on *Figure 2.3.7*. Residual mass curves for the longer term streamflow stations are shown on *Figure 2.3.8*.

The data on *Figure 2.3.7* indicate that annual minimum flows show a general trend toward decreasing value on both Otter Creek and Tulameen River. Extreme minimum events on Tulameen River occurred in 1988 and had calculated return periods of approximately 25 years. The more limited data from Otter Creek suggest that the 1947 and 1980 low flow values had return periods of approximately 50 and 30 years, respectively.

The residual mass curves for data from *Fraser River at Hope (Figure 2.3.8)* show a trend of less than average values between 1912 and 1954, generally greater than average values between 1954 and 1982, and generally less than average values in the subsequent period. Specifically, the average minimum flows in the period between 1954 and 1983 are 26% larger than those observed between 1913 and 1953 and 15% larger than the average values between 1984 and 1997.

The residual mass curves from the Tulameen and Similkameen watersheds have a similar pattern to that from Fraser River. For example, annual minimum flows on *Similkameen River At Princeton* were 10% less than average between 1940 and 1954, 33% greater than average between 1955 and 1973 and 18% less than average in the post 1974 period. Statistical analyses *(Table 2.2.6)* indicate that there is a 90% probability of a shift in regime on *Similkameen River At Princeton)* and a 90 to 95% probability on Otter Creek (**Q** and **W** statistics).

Changes in land use, water extraction and variations in water temperature *(see Constantz and Zellweger, 1995)* could play a role in the post-1975 or 1980 reductions in minimum flows. However, the principal cause is likely to be the generally reduced snow accumulations which have occurred in the post-1975 to 1980 period *(see Figure 2.2.13)*.

2.3.9 Discussion

The data analysis presented in SECTIONS 2.2 and 2.3 suggest that post-1950 annual precipitation and extreme 1-day precipitation totals have been greater than the long term average. In contrast, annual maximum snow accumulations have been decreasing since the mid 1970's or early 1980's. Regional data suggest that annual runoff and maximum daily discharges may also be greater than the long term average during the period between approximately 1950 and 1980. In general, annual runoff, annual maximum daily flows and annual minimum flows have subsequently decreased to average or below average size, despite the greater than average annual precipitation and the occurrence of a number of unusually large flood events.

The potential changes in hydrometric conditions discussed above could have significant impacts on the stream morphology *(see Church, 1997)* and fisheries habitat. Regime equations for gravel bed rivers *(Bray, 1973)* suggest that a 20% increase in the size of the 2-year return period flood would result in a 10% increase in the average channel width. Such changes are likely to be best expressed in alluvial reaches with reduced vegetation cover. Changes in fisheries habitat are likely to be more difficult to assess as persistent variations in streamflow are also expected to affect sediment loads, water temperature, the extent and thickness of the winter ice cover or other biologically important parameters. These analyses suggest that physically or biologically significant changes in stream conditions could have occurred during this century due to climatic variability. It is therefore necessary to discriminate naturally induced changes in channel properties from those which have occurred as a result of local or upstream land use activities.

2.4 FISHERIES RESOURCES AND FISH HABITAT IMPACTS

A Fish and Fish Habitat Overview Assessment was conducted on the Tulameen River watershed in 1996 by IRC Integrated Resource Consultants Inc. *(IRC, 1997)*. This report indicates that rainbow trout occur throughout the Tulameen watershed, except possibly upstream of migration barriers in the upper reaches of Champion, Jim Kelly and Olivine Creeks. Other resident species include longnose dace, sculpins and redside shiners.

The fish habitat assessment concluded that logging, placer mining and flood events have impacted many stream reaches in the Tulameen watershed. From a fisheries perspective, the most severe impacts were observed in Arrastra, Champion, Frenchy and Granite Creeks. The fish habitat in Jim Kelly Creek and the mainstem Tulameen River was also reported to have been impacted, but to a lesser extent. Specifically, natural and road-related landslides combined with extensive bank erosion along cleared riparian areas, resulted in large accumulations of sediment and woody debris. *IRC (1997)* indicates that these activities have substantially degraded fish habitat and caused barriers which are impassable to fish.

2.5 LAND USE ACTIVITIES

2.5.1 Baseline Thematic Mapping

Baseline thematic mapping generated from 1992 satellite imagery of the Tulameen River watershed was obtained from the BC Ministry of Environment Lands and Parks (MOELP). Watershed boundaries were overlain on this map *(Figure 2.5.1)* and the land use statistics were analyzed. Land use in individual tributary watersheds and cumulative downstream totals are summarized on *Tables 2.5.1 and 2.5.2*, respectively.

This analysis indicates that approximately 63% of the Tulameen River watershed is composed of recently logged, selectively logged or young forest. Old forest comprises approximately 29% of the watershed. The widespread distribution of young forest (49%) is thought to be the combined result of extensive, pre-1947, forest fires and historic logging in the Tulameen River watershed. Land use statistics within individual watersheds illustrate the extent of deforestation that has occurred from fire and logging. For example, the Vuich Creek basin is comprised of 20% "old" forest and 66% "young" forest. Jim Kelly, Otter, and Asp Creeks show a similar history. Recent harvesting on Lawless, Olivine, and Spearing Creeks comprises as much as 24% of the total basin area.

Agricultural activity has primarily occurred in the valley bottom areas on Otter Creek and on two of its larger tributaries, Spearing and Thynne Creeks. Some agricultural development has also occurred on the lower Tulameen River. In total, agricultural land use occurs in only 0.6% of the watershed. Rangelands were also identified in the Otter, Granite and Asp Creek watersheds and in the lower section of the Tulameen mainstem. A total of 2.4% of the watershed is estimated to be used for rangeland. Very small areas of mining activity were identified along the Tulameen mainstem and these comprise approximately 0.1% of the watershed area.

The above analyses indicate that logging and fire are likely the most important factors affecting channel stability in the Tulameen watershed. Range and agricultural activity are however expected to be locally important along valley bottom areas within the Thompson Plateau and mining activity could potentially have localized channel impacts. Highway and railway right-of-ways are too small to be portrayed on the baseline thematic mapping. These facilities occur extensively along both Otter Creek and the lower Tulameen River and are expected to have affected channel processes in these areas.

2.5.2 Interior Watershed Assessment Procedure Results

An Interior Watershed Assessment Procedure or IWAP *(Anonymous, 1995)* was prepared on the Tulameen River watershed in 1996/1997 by Middle Fork GIS *(1997)*. The results of the IWAP were based entirely on ARC/INFO GIS data analysis and no air photo interpretation or field work was undertaken to confirm the results.

The IWAP results are summarized on *Table 2.5.3*. This analysis suggests that mass wasting is relatively uncommon and that the issues of greatest concern are surface erosion, lack of riparian buffers and increased peak flows due to forest harvesting. The Level 1 analysis indicates that impacts are likely to be most severe on the Tulameen mainstem and within the Spearing, Otter, Lawless, Granite, Asp and Champion Creek watersheds. All of these areas have sufficiently high IWAP scores (i.e. values scoring greater than 0.5) that a more detailed or Level 2 analysis is justified (see *Page 21; Anon, 1995)*.

It should be noted that the results of the IWAP appear questionable in some cases and a re-evaluation might be justified. For example, a *"SURFACE EROSION"* value of 1.0 was calculated for the Holding Creek basin. The *"SURFACE EROSION"* category is intended to reflect the extent of the road network and stream crossings within the basin. However, no road construction has occurred in the Holding Creek drainage area, so the basin should score 0.0 rather than 1.0.

3: LAND USE IMPACTS AND CHANGES IN CHANNEL MORPHOLOGY

3.1 INTRODUCTION

A stream channel is in equilibrium with the discharge it must carry, the size and calibre of the sediment load and the characteristics of the bed and bank materials. Changes in one or more of these characteristics (through either natural or anthropogenic causes) can be expected to cause a change in the morphometry (i.e. size) or morphology (i.e. the plan form or character) of a river channel.

The analyses in SECTION 2.2 suggest that hydrometric conditions have changed over the period of instrumented record. It is, however, not clear whether the documented variations in the size of flood peaks solely reflects climatic change. Recent studies in the US Pacific Northwest suggest that 25% clearcutting with roads can approximately double the size of flood peaks *(Jones and Grant, 1996)*. *Cheng (1990)* has documented a significant increase in flood magnitude following a fire in the Salmon Arm area. Similar results might be expected to occur in the Tulameen watershed.

Logging or other processes causing deforestation, such as fire, grazing or mining activities have been commonly associated with increased rates of slope instability *(e.g. Rood, 1984; Sidle et al., 1985)*. If the resulting sediments enter the stream channel they can impact both local and down-stream channel processes. Channel morphology, as well as the quantity and size distribution of both the suspended sediment and bed material load, can all be affected. We have previously undertaken a variety of studies in the BC interior *(see M. Miles and Associates Ltd., 1995A; 1995B and 1996)* and these clearly demonstrated that a loss of riparian vegetation results in wider channel widths and accelerated rates of channel shifting. Studies on Coldwater River *(M. Miles and Associates Ltd., 1997)* suggest that riparian vegetation loss due to valley bottom fires on interior streams can result in on-going channel instability which persists for at least fifty years. In addition, flood discharges or anthropogenic impacts appear to cause greater instability on these burned areas in comparison to the effects of similar events in areas with old growth bank vegetation and woody debris in the stream channel.

Given this complexity, an assessment of channel impacts requires a careful review of historical information to identify the areas of changing channel morphology and to determine the factors responsible.

3.2 METHODOLOGY

Changes in channel stability on the mainstem Tulameen River and thirteen basins or sub-basins were assessed on the basis of historical air photo analyses. Air photos from 1947, 1967, 1986, and 1996 were scanned and digitally printed at a common scale of 1:15,000. Reach breaks were identified from the air photos and distances from the stream mouth were determined from 1:20,000 scale TRIM mapping. This information, along with tributary stream names, was transferred to the photo compilations. Changes in land use and channel morphology were then identified and the photo compilations were annotated to show the location of these features. Where required, the photos were stereoscopically viewed under an enlarging mirror stereoscope to confirm the initial air photo interpretation.

3.3 RESULTS

The annotated air photos are presented in Volumes 2 and 3. Addendums 1 to 9, containing the Tulameen River mainstem, Holding Creek, Podunk Creek, Vuich Creek, Jim Kelly Creek, Champion Creek, Britton Creek, Lawless Creek and Olivine Creek are included in Volume 2. Otter Creek, Spearing Creek, Thynne Creek, Granite Creek and Asp Creek, which comprise Addendums 10 to 12, are presented in Volume 3. In addition to the photos, each Addendum contains tables which list the factors predisposing a channel to morphologic change, summarize land use developments and identify sections of impacted stream channel.

A concise summary of stream channel impacts is presented on *Table 3.3.1*. The length and percent of each stream channel which has been impacted has been tabulated. Identified land use activities include fire, flood, anthropogenic or natural slope instability, riparian logging, agricultural clearing, grazing or farming, upstream sediment supply, road/railway construction and mining. In cases where a section of channel has been affected by more than one process only the dominant factor has been listed.

Inspection of *Table 3.3.1* indicates that fire has affected several watersheds, including the Tulameen headwaters, Holding, Podunk, Vuich, Lawless, Thynne and Granite Creeks. This occurred prior to the 1947 photography and the stream channel has been adjusting to this impact over the past 50 years.

Large flood flows have significantly affected nine streams, including Tulameen River and Holding, Podunk, Vuich, Jim Kelly, Champion, Thynne and Granite Creeks. Much of the flood damage occurs in previously burned areas which illustrates the importance of mature riparian vegetation and in-channel woody debris in maintaining channel stability.

Natural landslides have affected Tulameen River and Holding, Vuich, Jim Kelly and Granite Creeks. There again appears to be a frequent correlation between fire history and landslide distribution. Anthropogenic landslides have also affected six streams, including Tulameen River and Champion, Lawless, Thynne, Granite and Asp Creeks. Most slides were associated with road construction, mining activity or irrigation of steep-sided glaciofluvial or glaciolacustrine terraces.

Riparian clearing has affected nine stream channels, including Tulameen River and Podunk, Champion, Britton, Lawless, Olivine, Thynne, Granite and Asp Creeks. The most significant logging-related impacts occur on Lawless Creek with 16.8 km or 63% of the channel being affected. Channel impacts due to the clearing of riparian vegetation for ranching or agriculture is evident on the lower Tulameen River, Champion Creek, Otter Creek, Spearing Creek and Thynne Creek. Otter Creek has been the most severely affected, with 36 km or 53% of the channel being impacted.

The downstream movement of sediment has adversely affected five streams, including sections of Tulameen River and Lawless, Olivine, Spearing and Granite Creeks. Riparian clearing was commonly the principal initial cause of this sediment production.

Road or railway construction has directly affected six streams, including Tulameen River and Jim Kelly, Lawless, Otter, Spearing and Asp Creeks. Railway construction along the Otter Creek Valley has had the most severe impact and has affected 25.3 km or 37% of the channel. Morphologic changes include both channel encroachments and diversions.

Mining has locally affected Tulameen River, Olivine Creek and Granite Creek. Impacts are generally associated with overburden or waste material being pushed into the river channel.

From the context of forest development, the principal impacts are associated with riparian logging, anthropogenic landslides, the downstream movement of sediment and road construction. The total length of affected stream channels is as follows:

IMPACT [1]	LENGTH OF CHANNEL AFFECTED (km)	% OF ALL CHANNELS AFFECTED
Riparian Logging	65.2	18
Anthropogenic Landslides	12.2	3
Downstream Sediment Movement	17.0	5
Road Construction (except Tulameen River & Otter Creek)	7.3	4

Approximately 30% of the 356 km of stream channels investigated in this study have been affected by these processes.

1 This table excludes non-logging related impacts on Otter Creek and lower Tulameen River.

4: PRIORITIES FOR FIELD INSPECTION

Priorities for field inspections to confirm the results of the air photograph studies are compiled in Volumes 2 and 3. This information is summarized on *Table 4.0.1* and on a 1:75,000 scale map *(Figure 4.0.1)*. Stream restoration priority is based on our assessment of the extent of anthropogenic channel morphology impacts. However, site inspections have been recommended in a small number of areas to confirm the impacts due to flood or fire, to investigate natural landslides or to assess sites potentially suitable for fish habitat enhancement or restoration projects.

The priority for site inspections to assess forest development impacts is as follows:

STREAM	LENGTH OF CHANNEL (Km) HAVING MEDIUM OR HIGH PRIORITY FOR SITE INSPECTION DUE TO:				
	Anthropogenic Landslides	Riparian Logging	Downstream Sediment Movement	Road Construction and Bridge Crossings	TOTAL [1]
Tulameen River	7.8	6.7	1.0		15.5
Holding Creek					
Podunk Creek		5.1			5.1
Vuich Creek					
Jim Kelly				0.2	0.2
Champion Creek	2.7	4.2			6.9
Britton Creek		8.9			5.1
Lawless Creek		18.6			18.6
Olivine Creek		3.8			3.8
Otter Creek					
Spearing Creek			3.1		3.1
Thynne Creek		4.5			4.5
Granite Creek	0.9	2.4	7.6	3.0	13.9
Asp Creek	0.6	5.5			6.1

1 This table excludes non-logging related impacts on Otter Creek and lower Tulameen River.

5: RECOMMENDATIONS FOR CHANNEL RESTORATION

River restoration opportunities identified during the air photograph analyses are compiled in Volumes 2 and 3. This information is summarized on *Table 5.0.1* and on a 1:75,000 scale map *(Figure 5.0.1)*. These recommendations address all land use impacts and attempt to priorize restoration work from a watershed perspective. On the basis of this analysis, range and agricultural impacts along Otter Creek and the lower Tulameen River result in the longest length (48 km) of high priority restoration sites. Logging impacts in Lawless Creek result in the second longest length of high priority sites (5.4 km). Other areas with high priorities for restoration include Podunk Creek (3 km), Jim Kelly Creek (0.2 km), Champion Creek (1.7 km), Britton Creek (1.4 km), Olivine Creek (0.5 km), Spearing Creek (2.3 km), Thynne Creek (0.5 km) and Granite Creek (1.2 km).

Preliminary recommendations on appropriate restoration strategies are presented in Volumes 2 and 3. As discussed in *Kellerhals and Miles (1996)* and *Hartman and Miles (1995)*, the principal objective of this proposed work is to restore or expedite the recovery of the processes which are responsible for channel morphology, rather than to try and artificially create specific structures or types of aquatic habitat. Recommendations include:

i) planting, seeding or bioengineering slope instabilities to reduce sediment production and stabilize the slope;

ii) establishing a fenced riparian corridor along the stream channel;

iii) revegetating disturbed areas adjacent to stream crossings;

iv) planting seedlings and live whips or using bioengineering techniques to stabilize eroding channel banks;

v) trial planting of seedlings and live whips or use bioengineering techniques to stabilize higher elevation gravel bars; and

vi) evaluating the risks and benefits of placing large woody debris to provide fisheries habitat in areas where the channel banks were burned or logged.

Construction of valley bottom fencing in grazed areas and the establishment of a riparian corridor is likely to be the single most cost efficient restoration opportunity identified in this study. This work would be beneficial over most of Otter Creek and much of the lower Tulameen River.

Within logged areas it would be desirable to address local slope instabilities and site-specific impacts at bridge crossings. Measures to expedite the establishment or growth of riparian vegetation would provide widespread benefit. Bioengineering techniques for stabilizing eroding banks and unvegetated gravel bars would also be useful. However, experimentation would be needed to determine if this work can be undertaken in a cost efficient and reliable manner.

Finally, it might be desirable to provide woody debris or other structural measures to create fisheries habitat until such time as the stream banks become well vegetated and stable. Studies in Alberta *(Pattenden et al., 1996)* suggest such work is most likely to be successful in laterally and vertically stable streams which are carrying small quantities of bedload. Unfortunately, many sections of channel affected by riparian logging do not have these channel characteristics. On-going monitoring and maintenance may therefore be required to ensure that any placed structures continue to provide useful habitat until such a time as the riparian vegetation re-establishes and begins to supply woody debris to the stream channel.

6: FUTURE WORK

6.1 PREPARATION FOR FUTURE SITE INSPECTIONS AND PRESCRIPTION RECOMMENDATIONS

The present report provides a watershed level evaluation of channel impacts and identifies areas where additional office and field analyses are required. This information will provide a basis for deciding which streams warrant further investigation. The historical air photo compilations from these sites should then be reviewed in more detail to select areas which qualify for FRBC funded stream restoration activities.

Large scale mosaics (such as illustrated on *Figure 6.1.1*) should ideally be prepared for areas where site inspection and restoration work is required. These mosaics would be used as a base for field notes, the presentation of restoration prescriptions and monitoring the project's long term performance.

6.2 COMPLETION OF PHOTO COMPILATIONS IN OTHER HIGH PRIORITY WATERSHEDS

On the basis of data in the *IRC (1997)* IWAP report and discussions with Will Sloan of Tolko Industries in Merritt, it would appear desirable to complete historical air photo analyses similar to those undertaken in the present study for the following streams:

Tributaries to Tulameen River Mainstem

- Skwum;
- Holmes;
- Illal;
- Arrastra;
- Frenchy; and
- Sutter.

Tributaries to Otter Creek

- Manning;
- McPhail;
- Gulliford; and
- Elliot.

6.3 POST-FIRE MONITORING OF LAWLESS CREEK

The 1998 fire in Lawless Creek provides an opportunity to document how interior stream channels respond to an extensive burn and to determine the rate at which channel recovery occurs. The air photo compilation in Volume 2, Addendum 8 provides a basis for assessing pre-fire conditions. It would be desirable to fly both overview (1:20,000) and large scale (≥1:5,000) photos next spring or early summer to document post fire conditions. Ground photos, channel geometry surveys and bed material samples could be obtained to further document baseline conditions. Installation of a gauging station to monitor water quantity and quality would also be desirable. Consideration should be given to obtaining similar information from a nearby, comparable, unburned watershed. It is important to be aware that the expected channel destabilization and post fire recovery will take many decades and that a rigorous monitoring program would need periodic funding over this period.

6.4 EVALUATION OF THIS REPORT

The information presented in this report is somewhat different from what is normally requested in an overview level channel assessment report. It would be very desirable to jointly review the strengths and weaknesses of the present product in order to improve future studies.

7: CERTIFICATION

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February, 1999

PROFESSIONAL PROVINCE OF M. J. MILES BRITISH COLUMBIA GEOSCIENTIST

8: SOURCES OF INFORMATION

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8.2 PERSONAL COMMUNICATIONS

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FIGURES

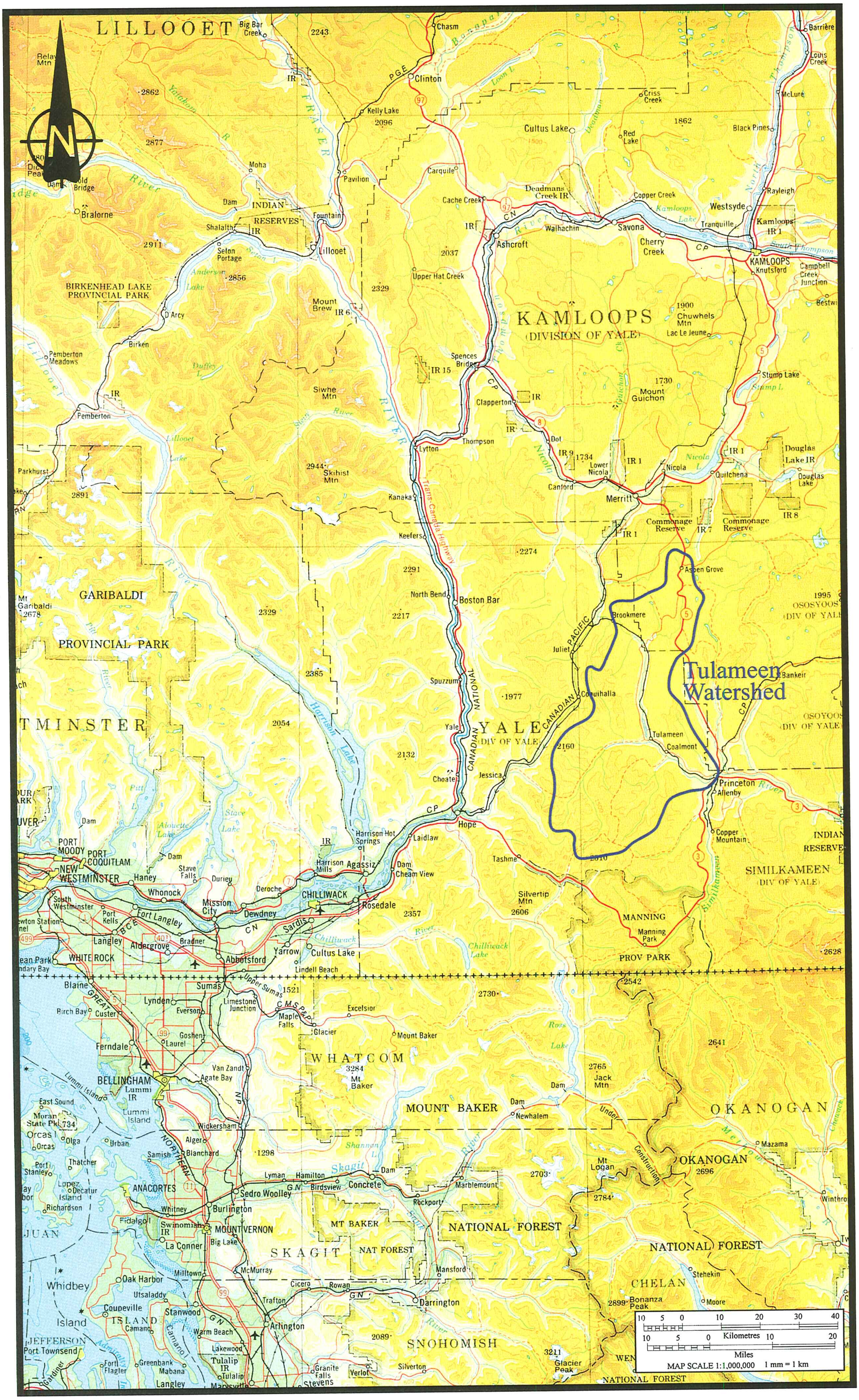
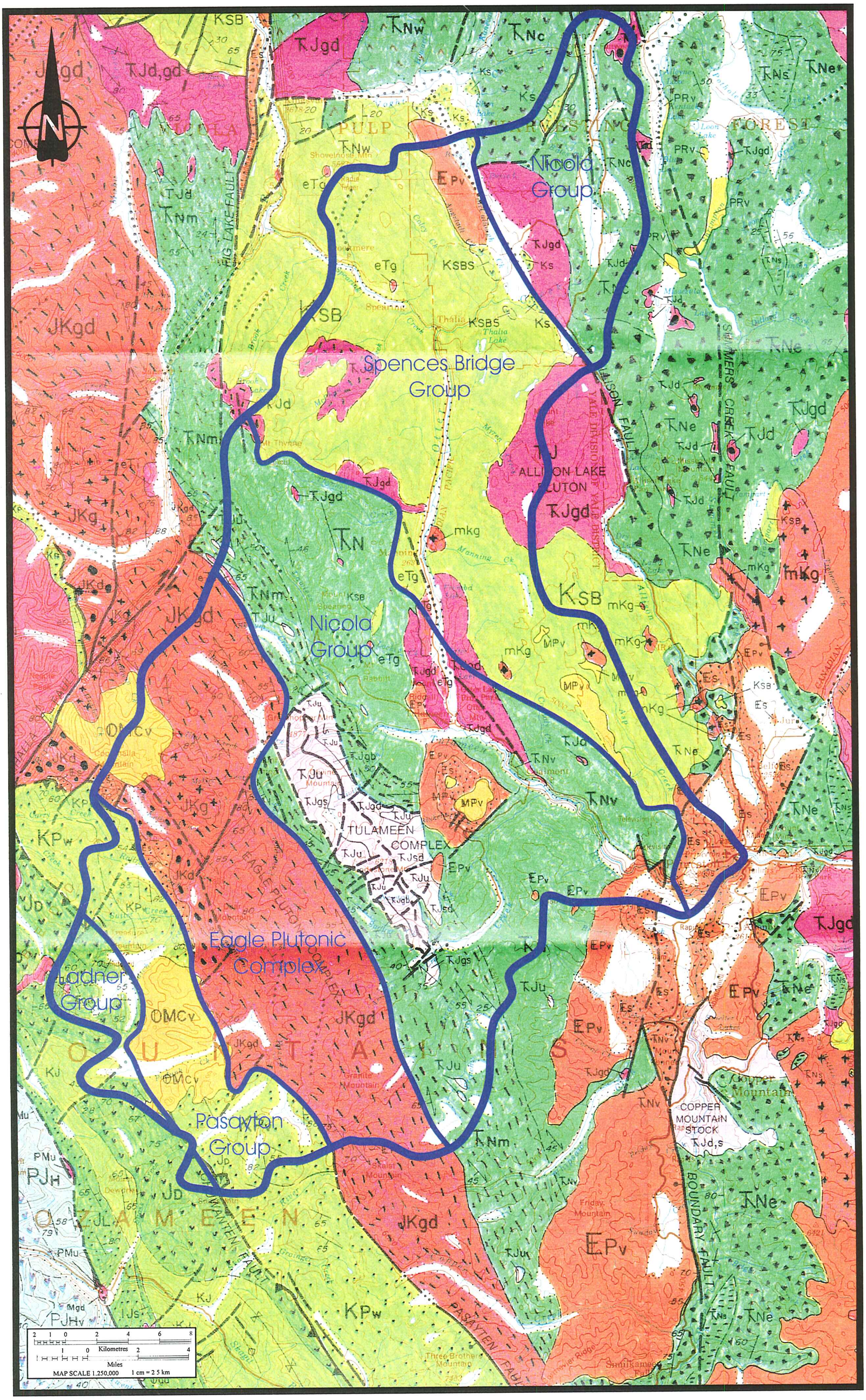


Figure 1.0.1: Location Map.



(Modified from Monger, 1989)

Note: See Section 2.1.2 for a discussion of the identified groups or complexes and for a description of specific map units.

Figure 2.1.1: Bedrock geology in the vicinity of the Tulameen watershed.

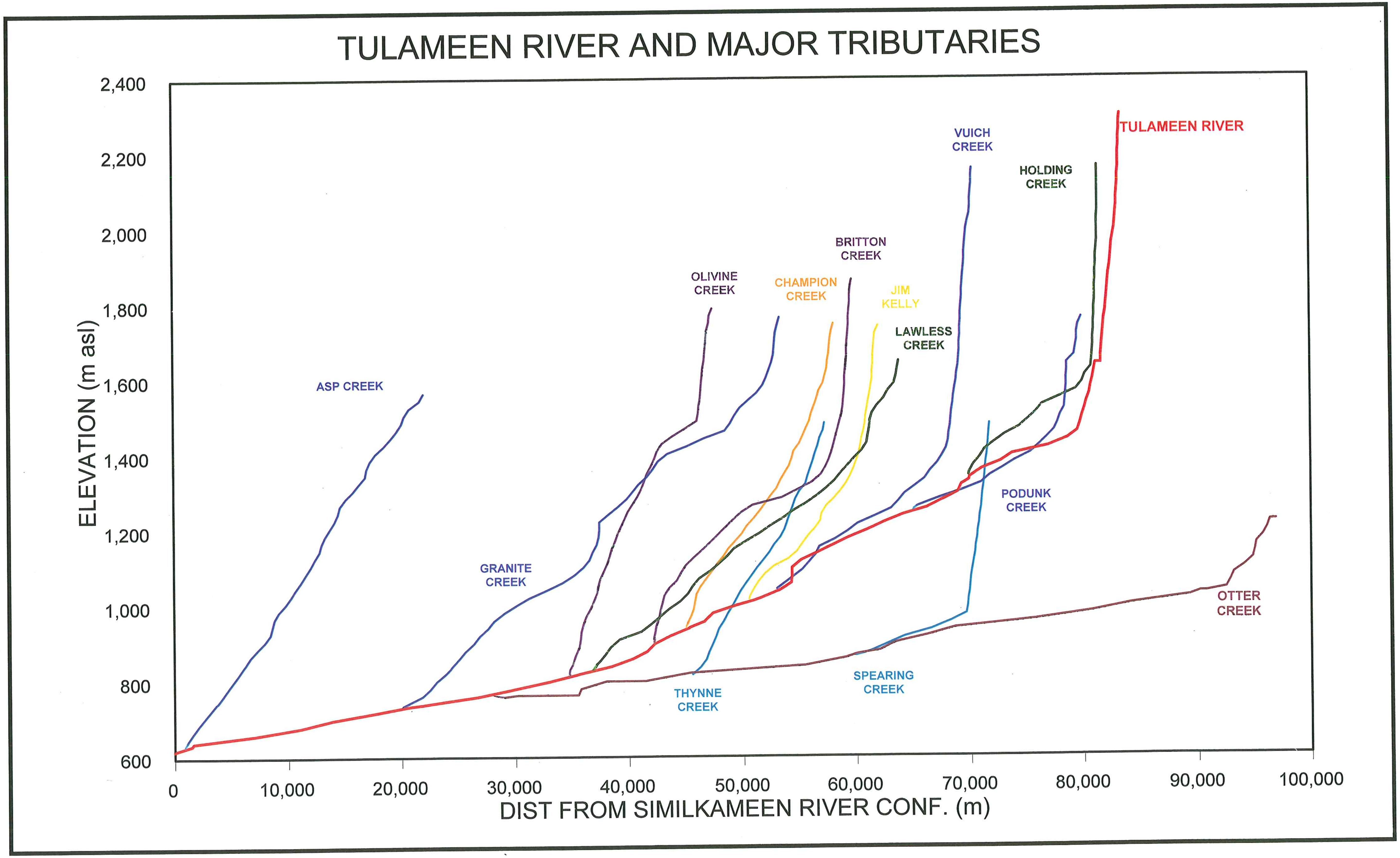


Figure 2.1.2: Long profile of the Tulameen River mainstem and the larger tribututaries

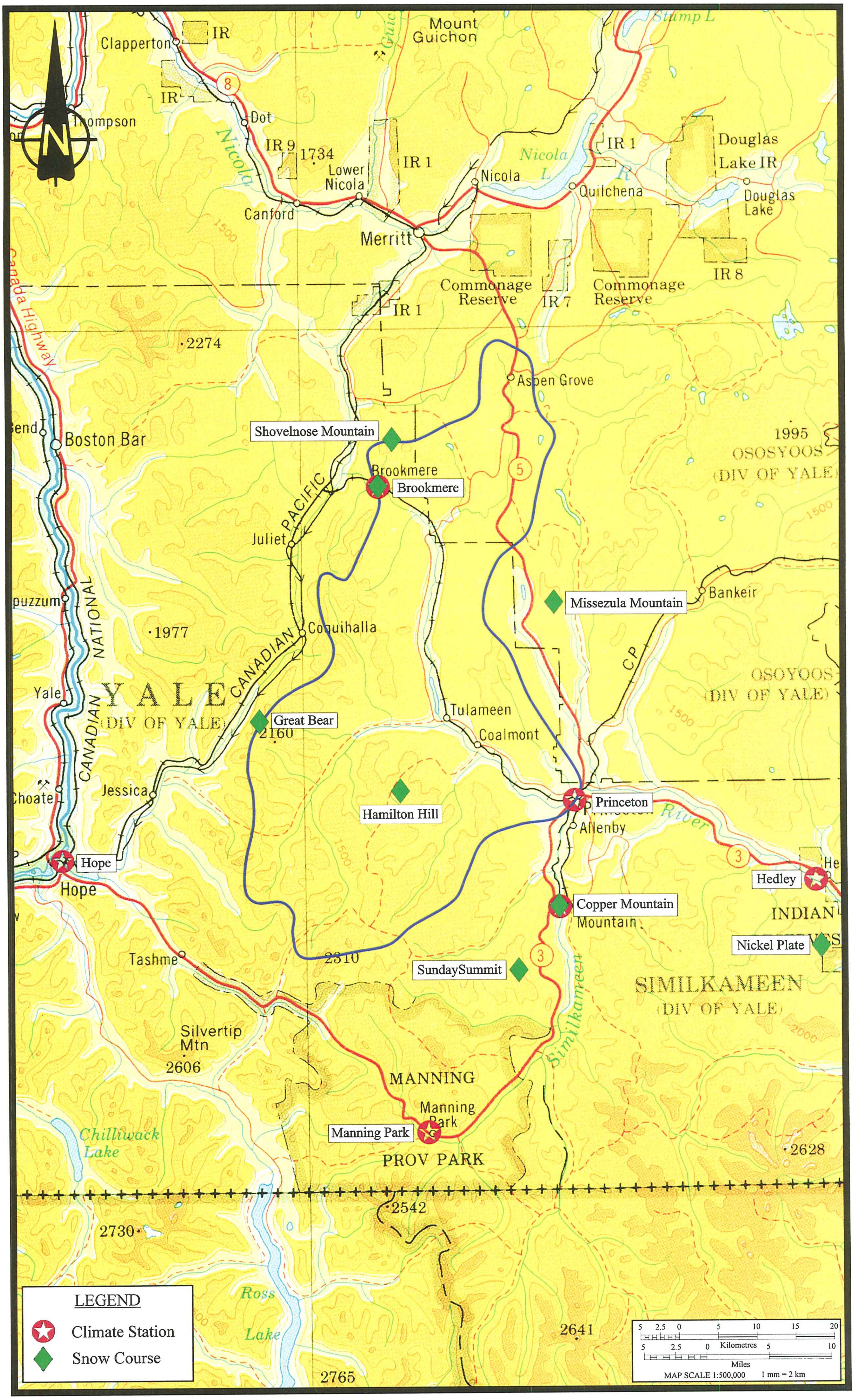
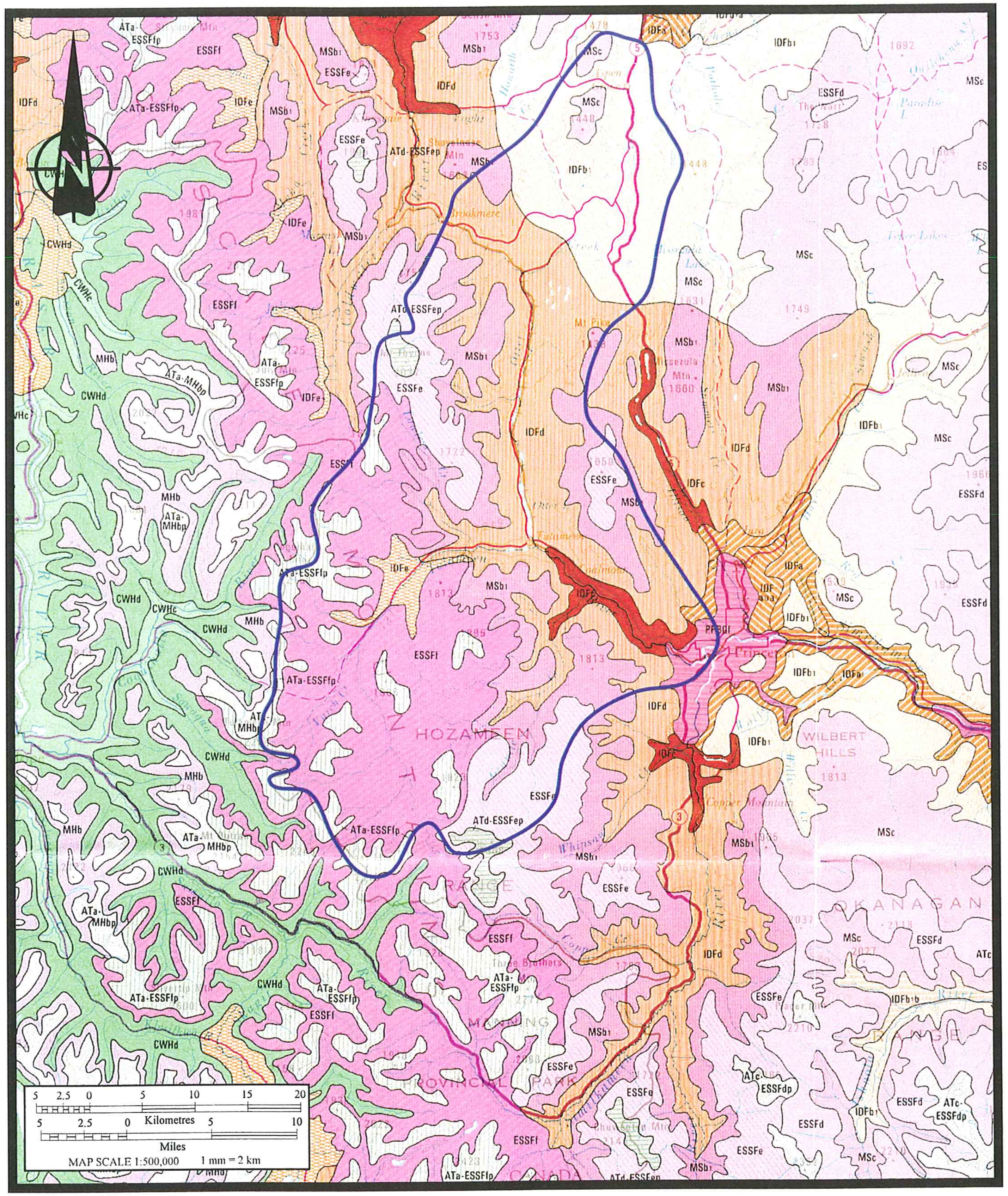


Figure 2.2.1: Location of Climate and Snow Course stations.

Figure 2.2.2: Seasonal Variation in Annual Precipitation

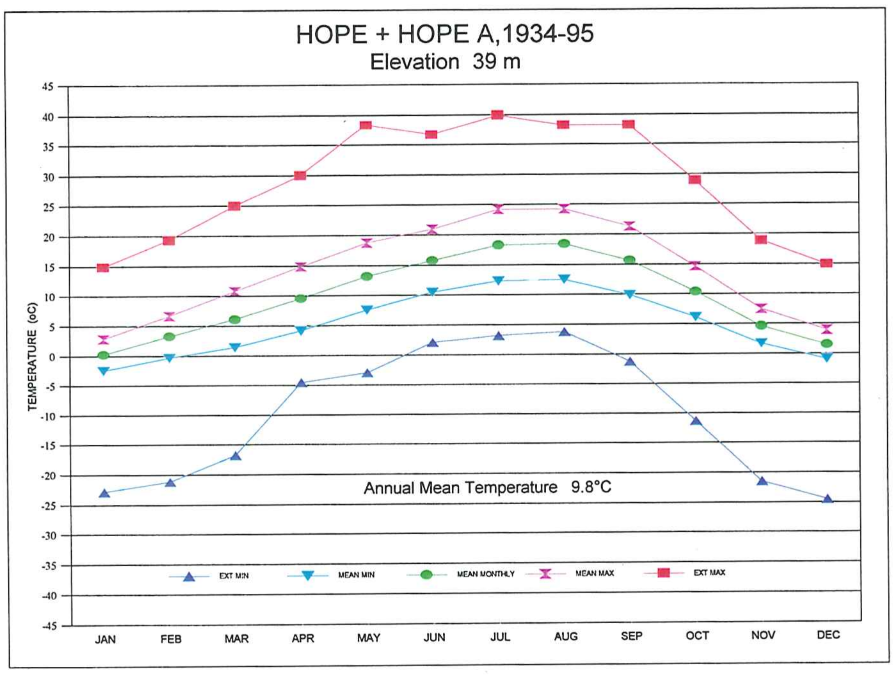


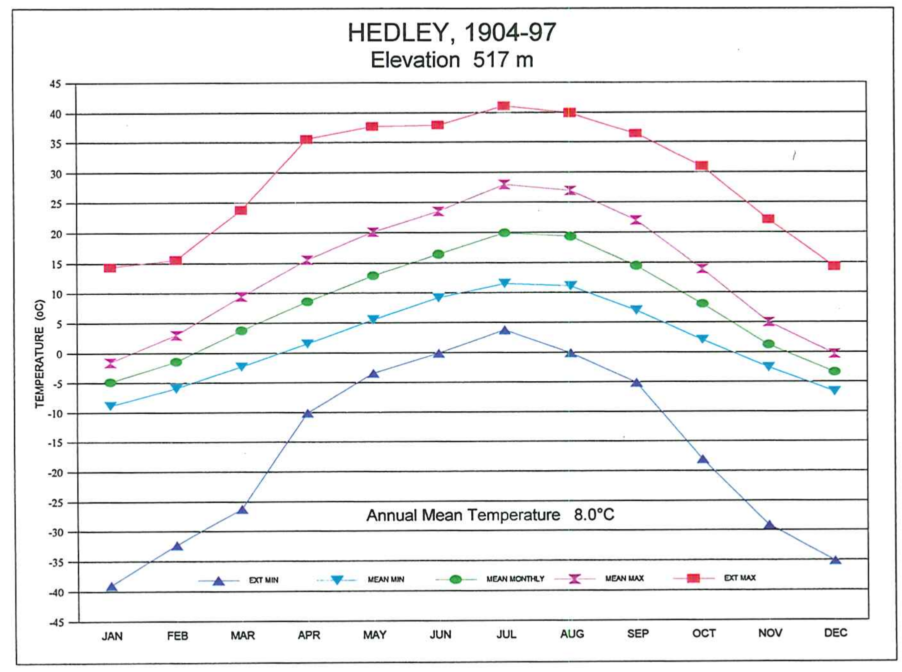
MAPPING UNITS

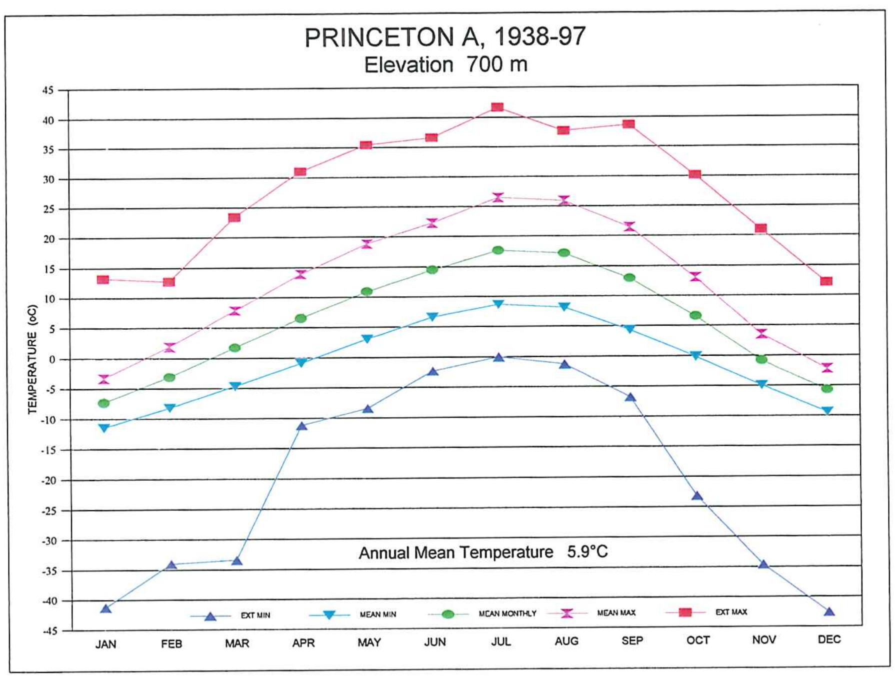
biogeoclimatic zone	*biogeoclimatic subzone*	Map unit	*biogeoclimatic variant*
Alpine Tundra (AT) and Mountain Hemlock (MH)	Coastal Alpine Tundra (ATa) and Maritime Parkland Mountain Hemlock (MHap)	ATa-MHap	
	Coastal Alpine Tundra (ATa) and Subcontinental Parkland Mountain Hemlock (MHbp)	ATa-MHbp	
Alpine Tundra (AT) and Engelmann Spruce - Subalpine Fir (ESSF)	Coastal Alpine Tundra (ATa) and Subcontinental Parkland Engelmann Spruce - Subalpine Fir (ESSFfp)	ATa-ESSFfp	
	Dry Southern Alpine Tundra (ATd) and Dry Southern Parkland Engelmann Spruce - Subalpine Fir (ESSFep)	ATd-ESSFep	
	Very Dry Southern Alpine Tundra (ATc) and Very Dry Southern Parkland Engelmann Spruce - Subalpine Fir (ESSFdp)	ATc-ESSFdp	
Mountain Hemlock (MH)	Maritime Forested Mountain Hemlock (MHa)	MHa1	West Vancouver Island Maritime Forested Mountain Hemlock
		MHa2	East Vancouver Island Maritime Forested Mountain Hemlock
		MHa3	Pacific Ranges Maritime Forested Mountain Hemlock
	Subcontinental Forested Mountain Hemlock (MHb)	MHb	
Engelmann Spruce - Subalpine Fir (ESSF)	Very Dry Southern Forested Engelmann Spruce - Subalpine Fir (ESSFd)	ESSFd	
	Dry Southern Forested Engelmann Spruce - Subalpine Fir (ESSFe)	ESSFe	
	Subcontinental Forested Engelmann Spruce - Subalpine Fir (ESSFf)	ESSFf	
Montane Spruce (MS)	Dry Montane Spruce (MSb)	MSb1	Thompson Plateau Dry Montane Spruce
	Very Dry Southern Montane Spruce (MSc)	MSc	
Interior Douglas-fir (IDF)	Very Dry Submontane Interior Douglas-fir (IDFa)	IDFa	
		IDFa:a	Edaphic Grassland Phase Very Dry Submontane Interior Douglas-fir
		IDFa:b	Southern Exposure Phase Very Dry Submontane Interior Douglas-fir
	Very Dry Montane Interior Douglas-fir (IDFb)	IDFb1	Thompson Plateau Very Dry Montane Interior Douglas-fir
		IDFb1a	Edaphic Grassland Phase Very Dry Montane Interior Douglas-fir
		IDFb1b	Southern Exposure Phase Very Dry Montane Interior Douglas-fir
	Dry Submontane Interior Douglas-fir (IDFc)	IDFc	
	Dry Western Montane Interior Douglas-fir (IDFd)	IDFd	
	Subcontinental Interior Douglas-fir (IDFe)	IDFe	
Ponderosa Pine-Bunchgrass (PPBG)	Very Dry Southern Forested Ponderosa Pine - Bunchgrass (PPBGf)	PPBGf	

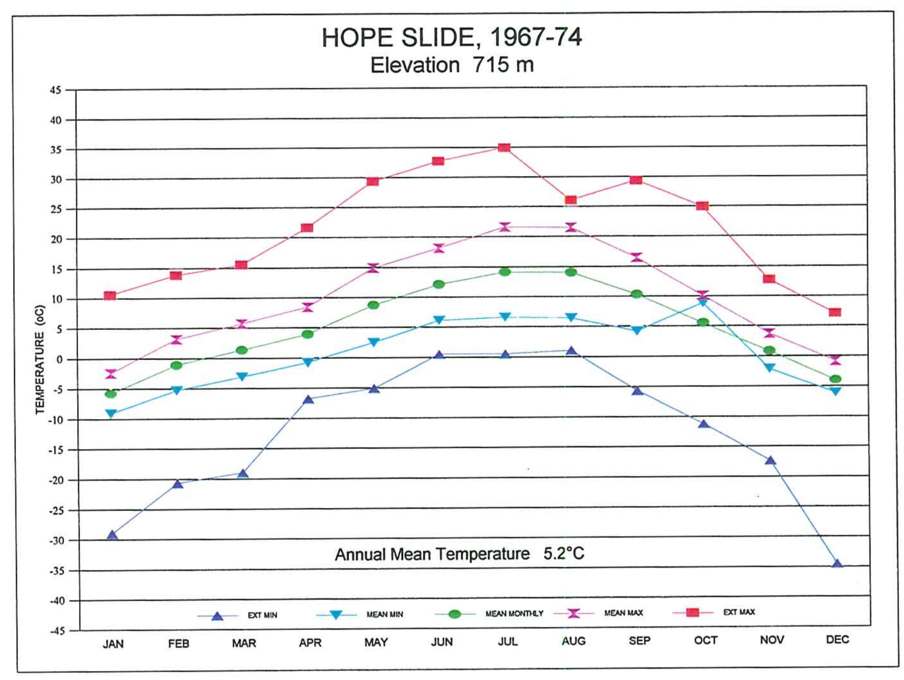
From: Biogeoclimatic Units, Victoria-Vancouver, 1:500,000 NTS Mapsheet 92 S.E., Vancouver Forest Region, Ministry of Forests, 1992.

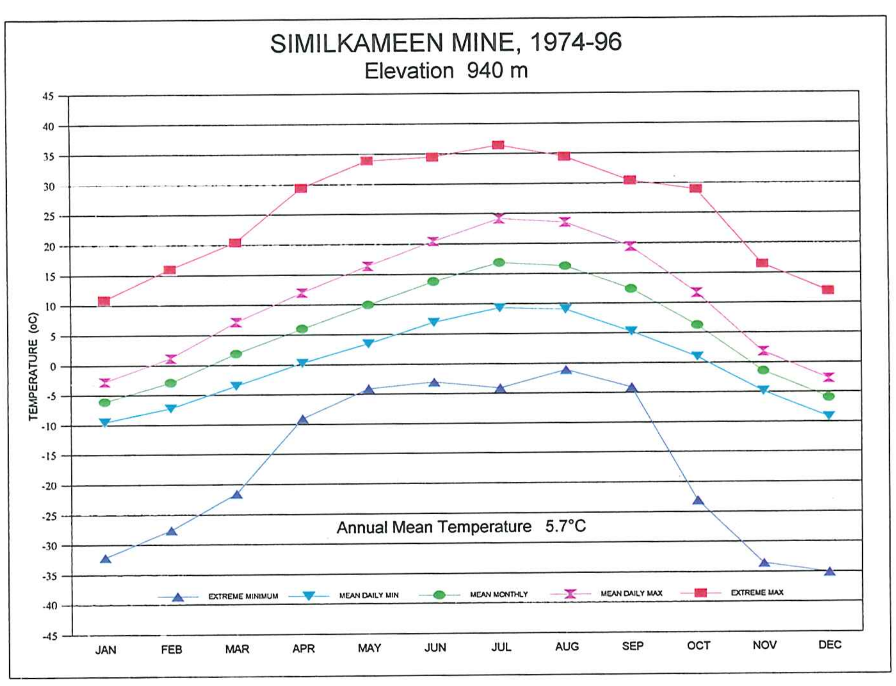
Figure 2.2.3: Biogeoclimatic zonations in the vicinity of the Tulameen watershed.

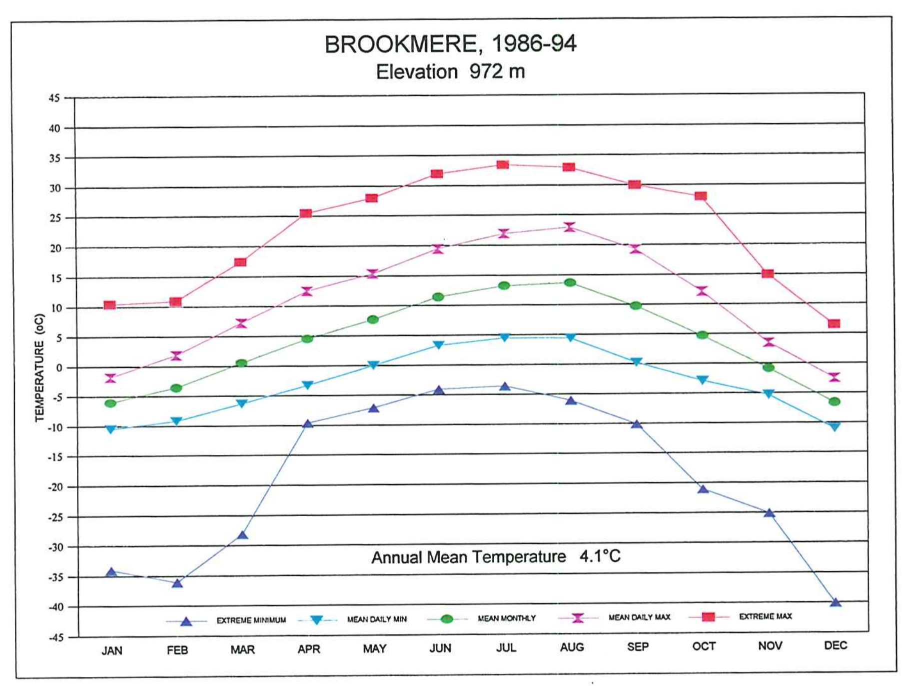


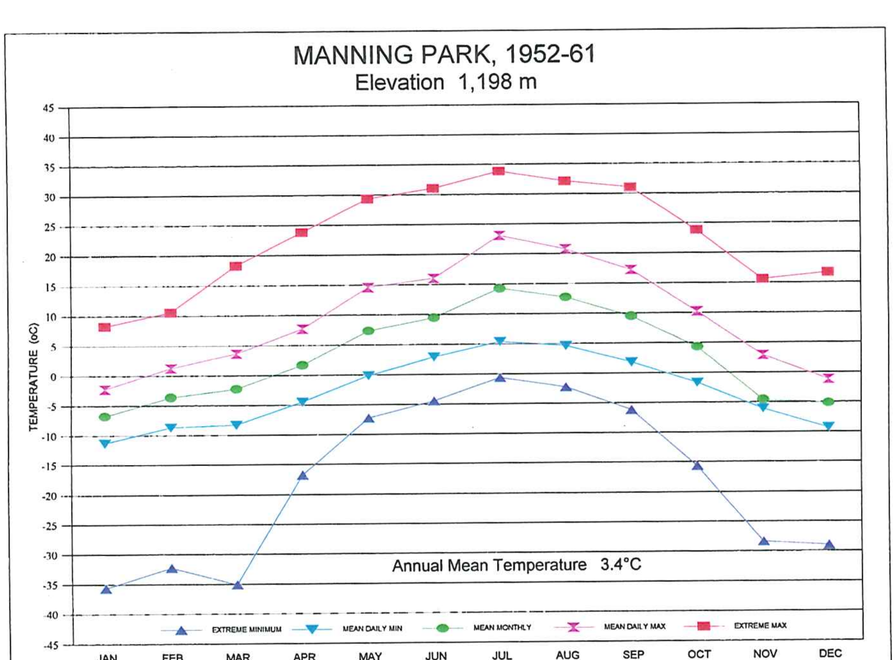












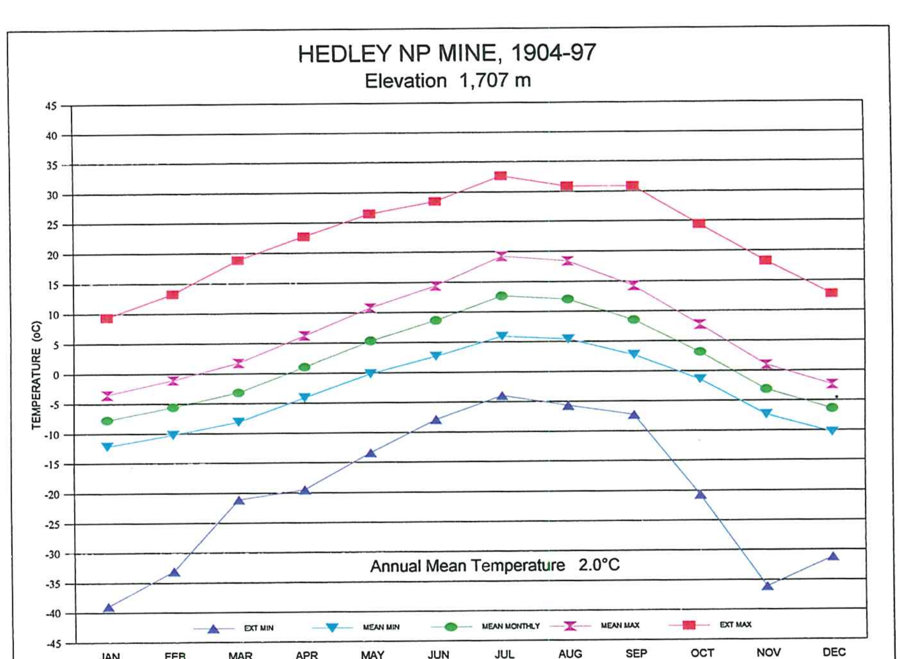


Figure 2.2.4: Seasonal Variation in Temperature.

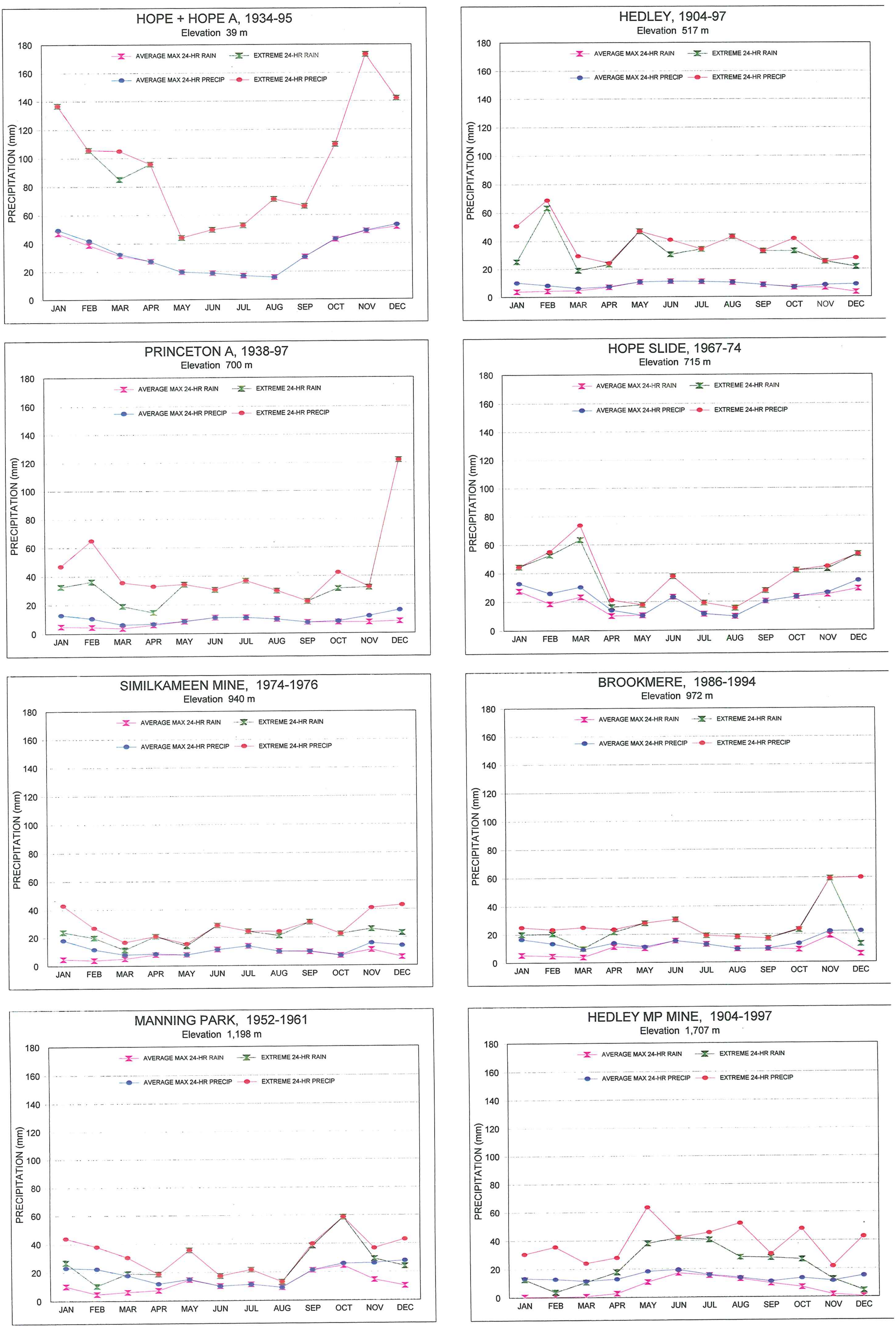
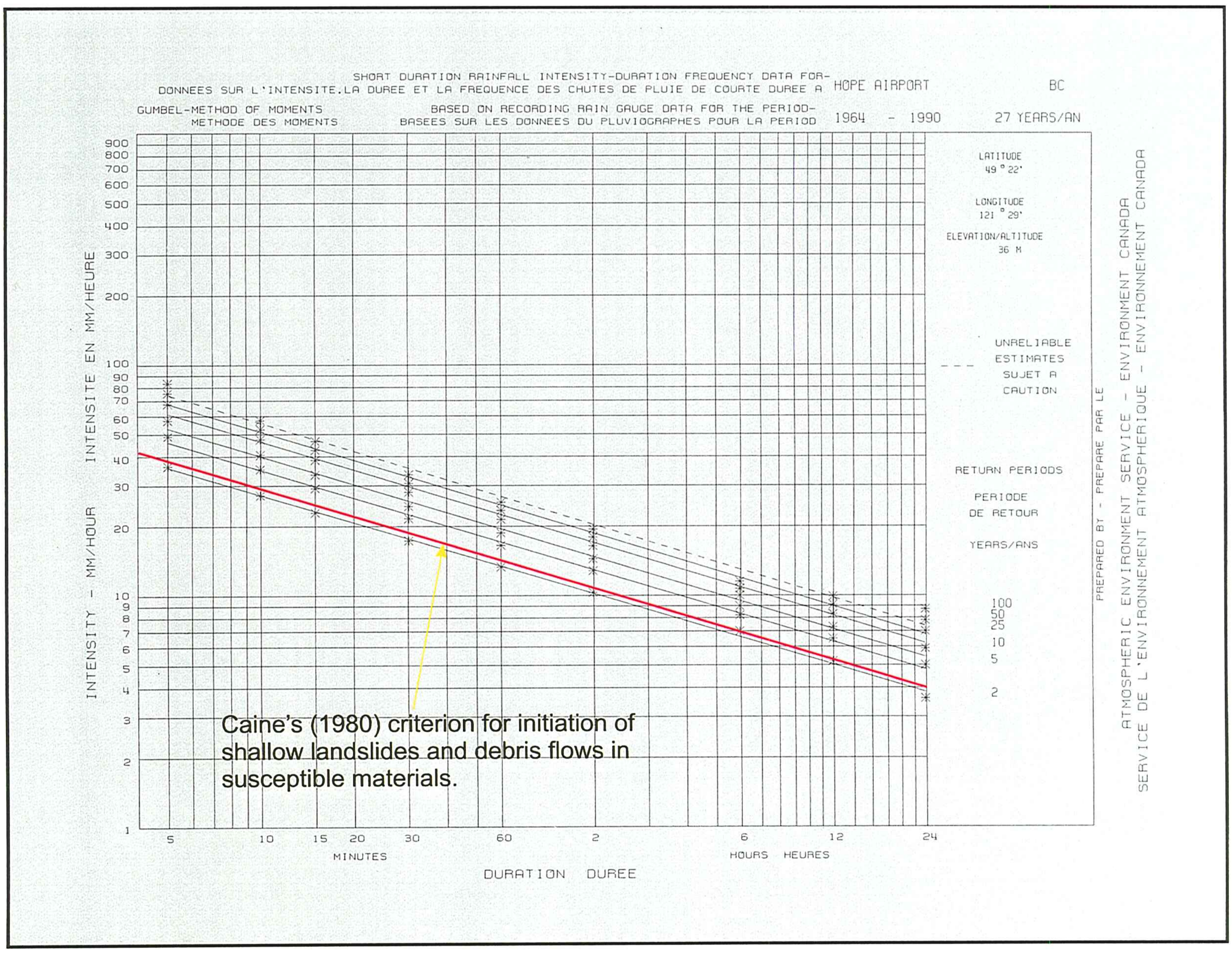


Figure 2.2.5: Seasonal Variation in Extreme 1-Day Rainfall and Precipitation

HOPE A



PRINCETON A

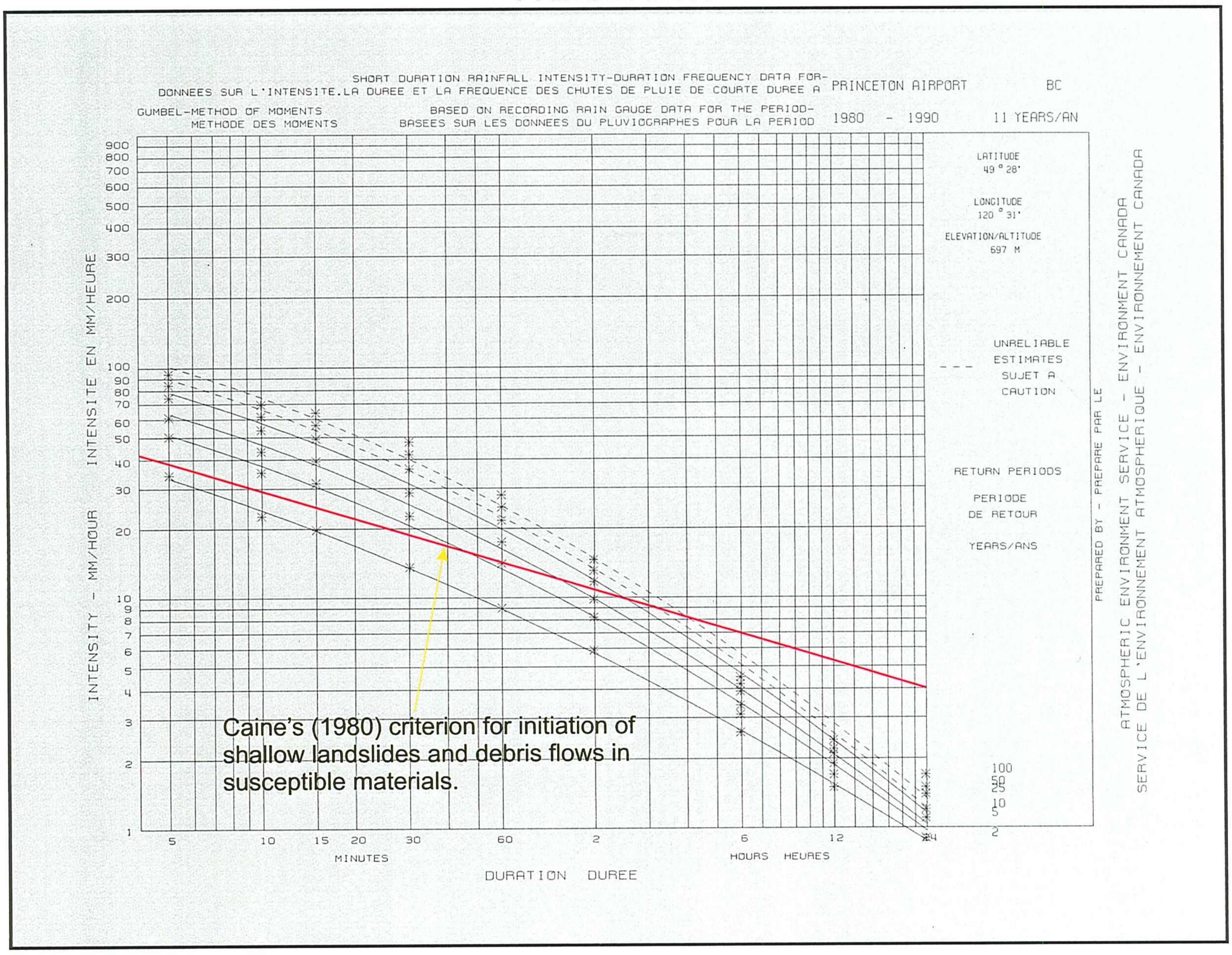


Figure 2.2.6: Short duration rainfall intensity-duration frequency plots for Hope A and Princeton A.

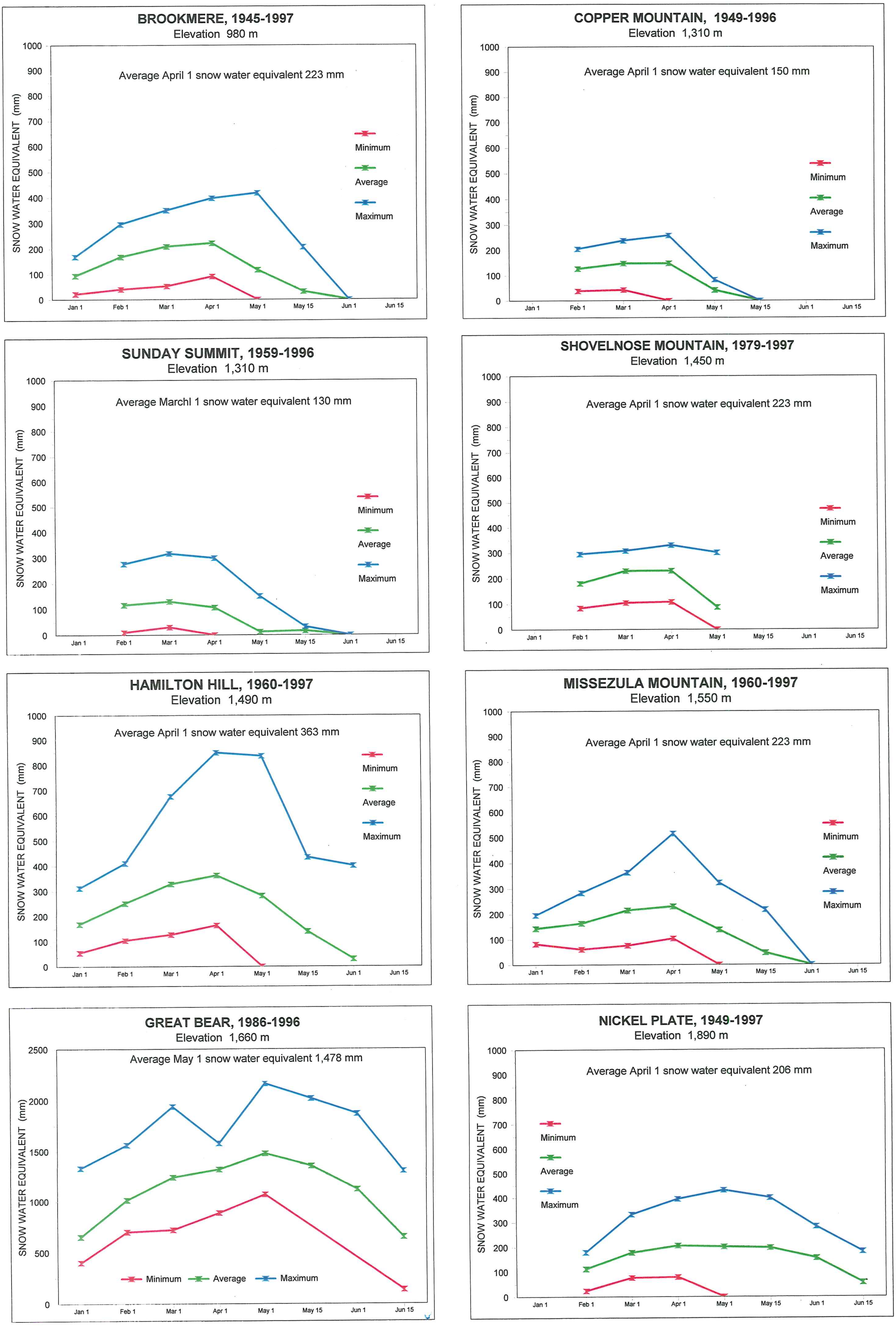
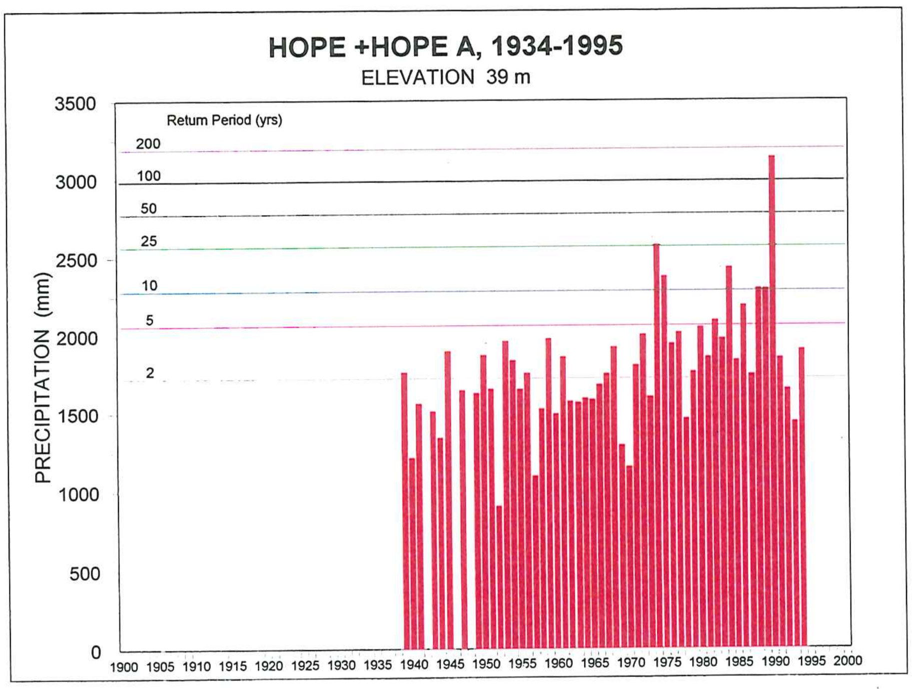
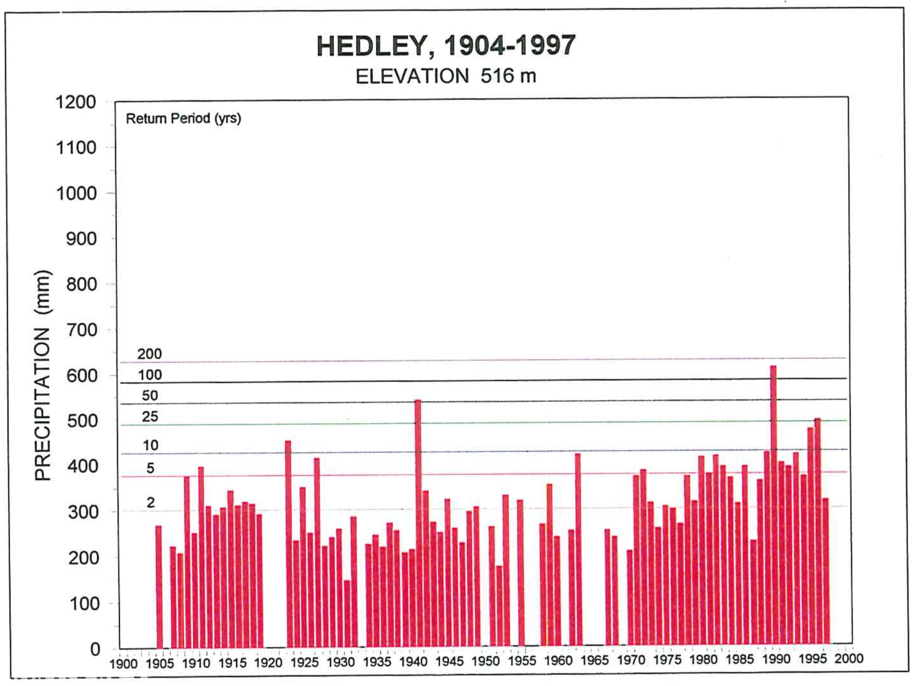
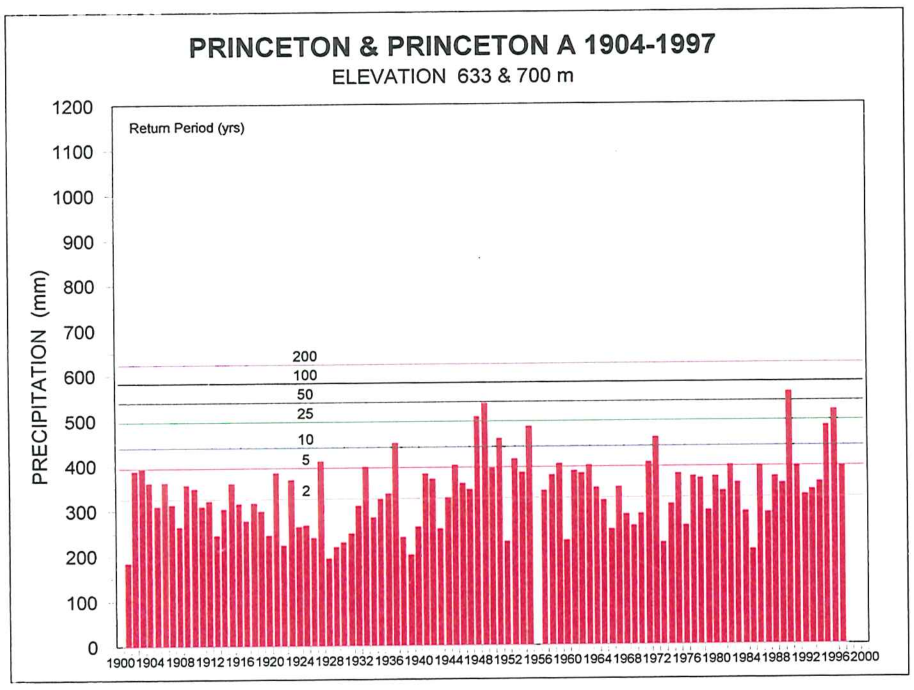
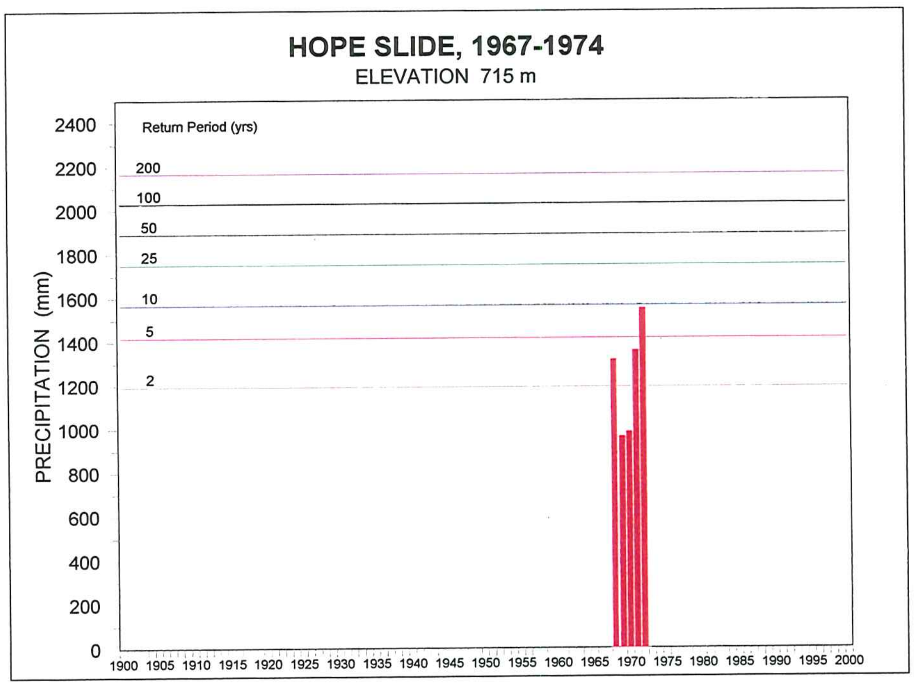


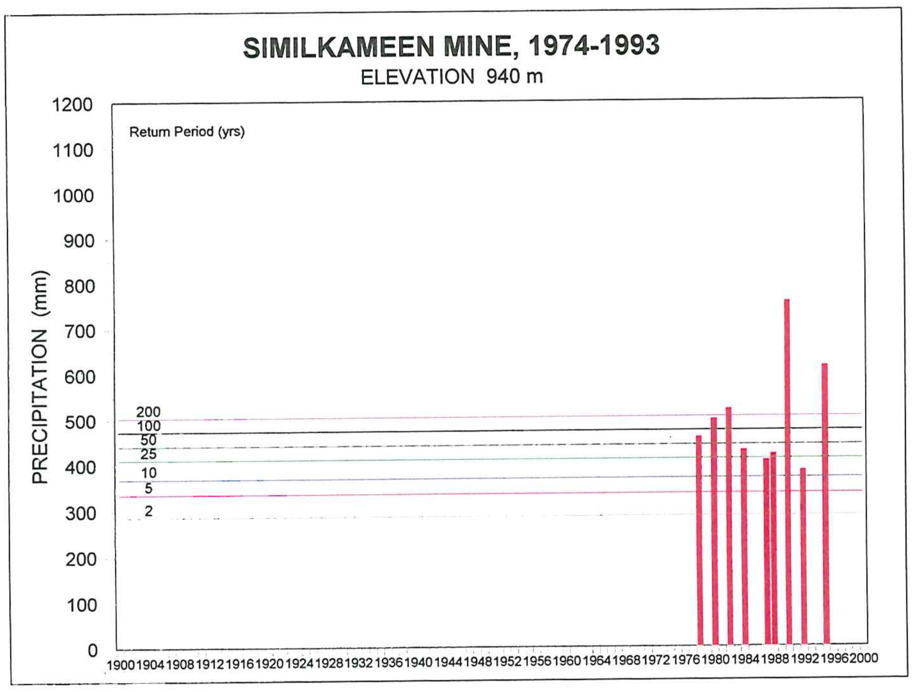
Figure 2.2.7: Seasonal Variation in Snow Cover.

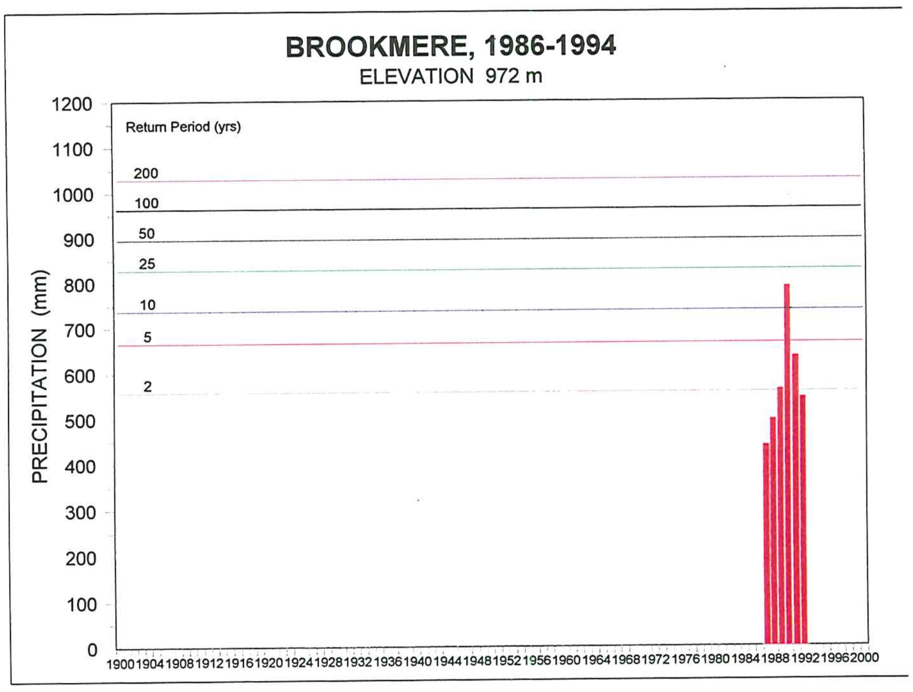


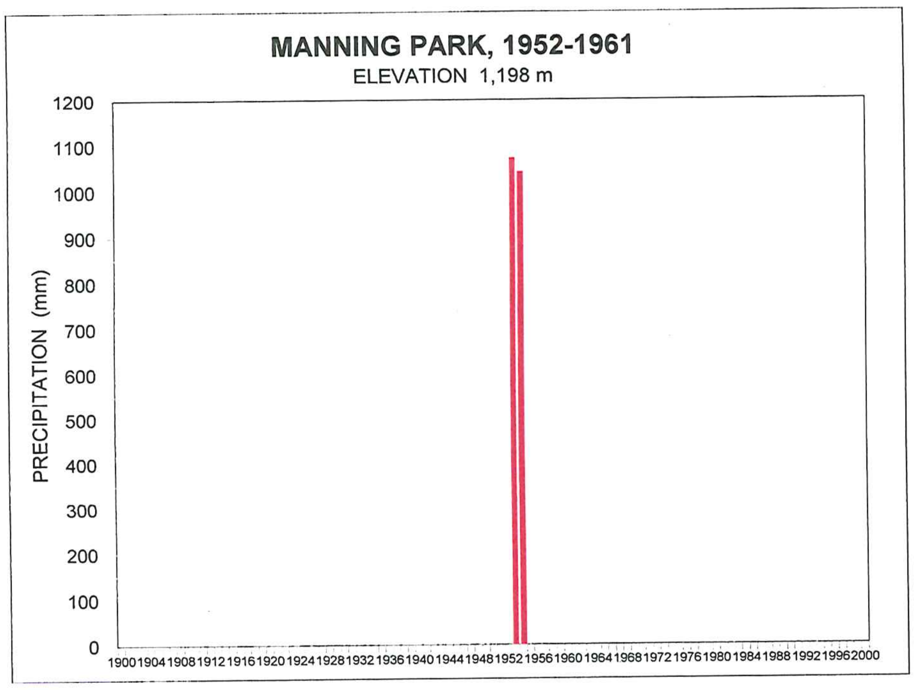












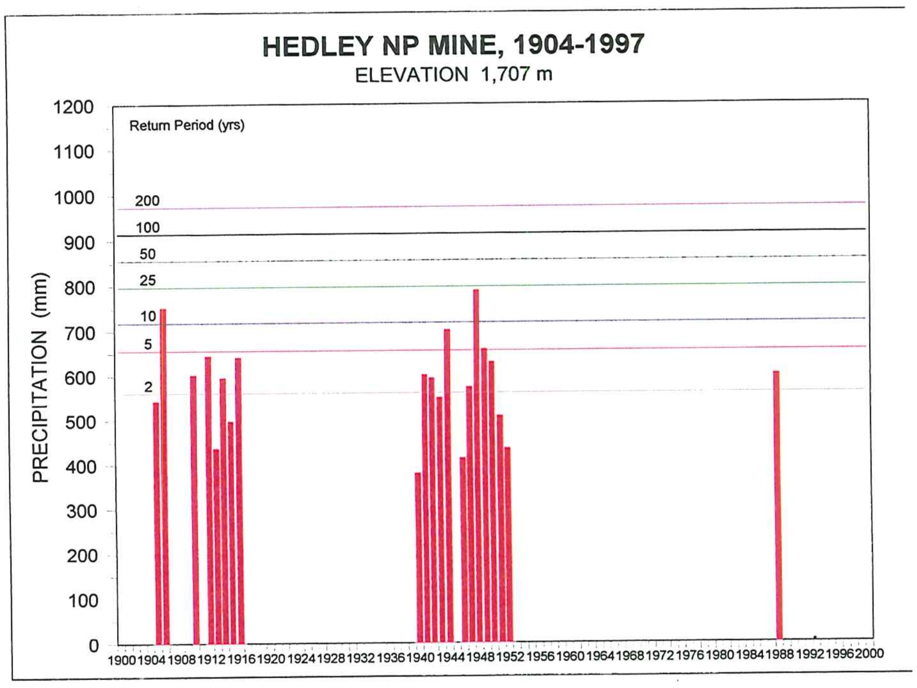


Figure 2.2.8: Historical Variation in Annual Total Precipitation

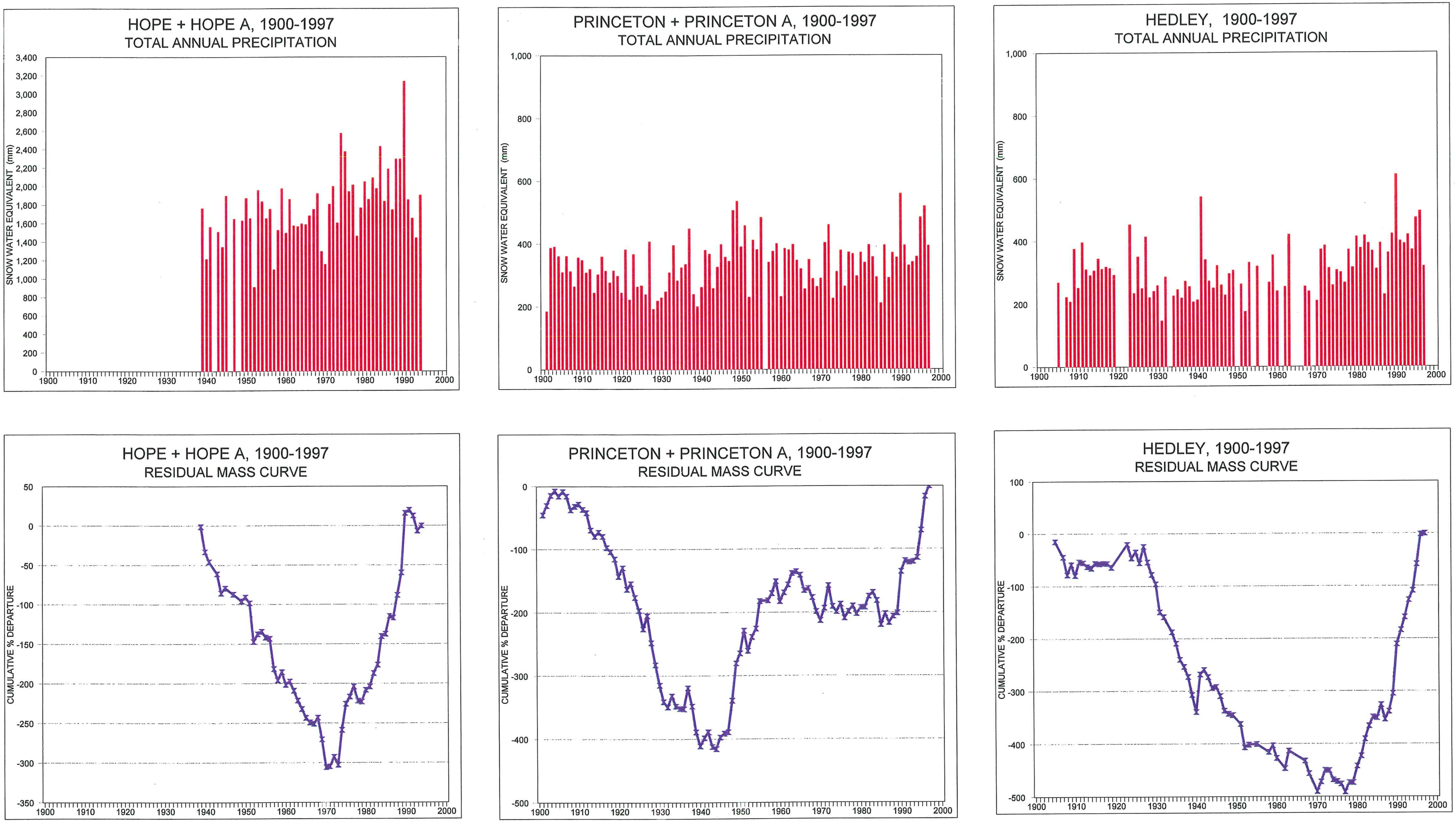


Figure 2.2.9: Residual Mass Curves for Annual Precipitation Totals at Hope, Princeton Combined and Hedley.

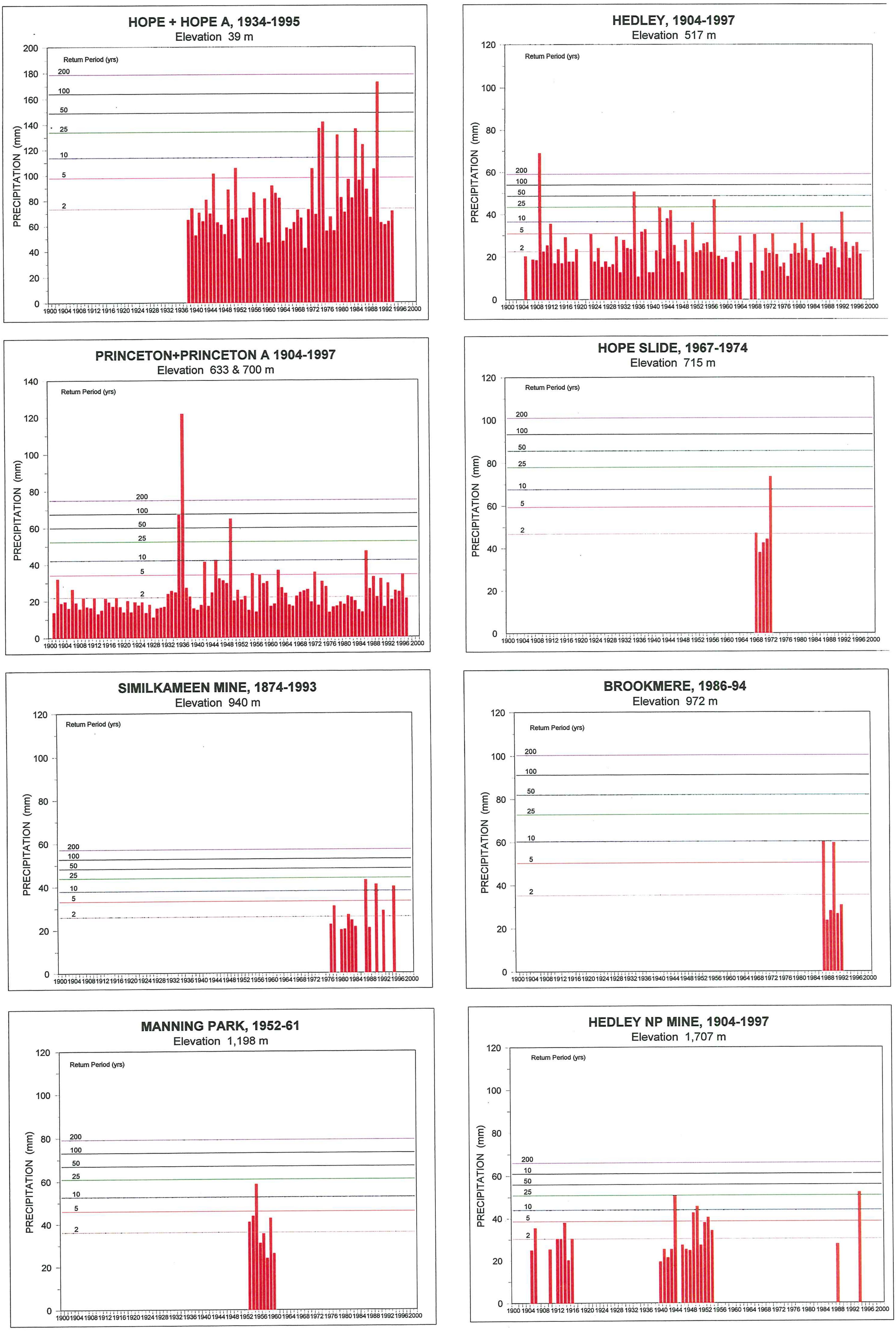


Figure 2.2.10: Historical Variation in Extreme 1-Day Precipitation

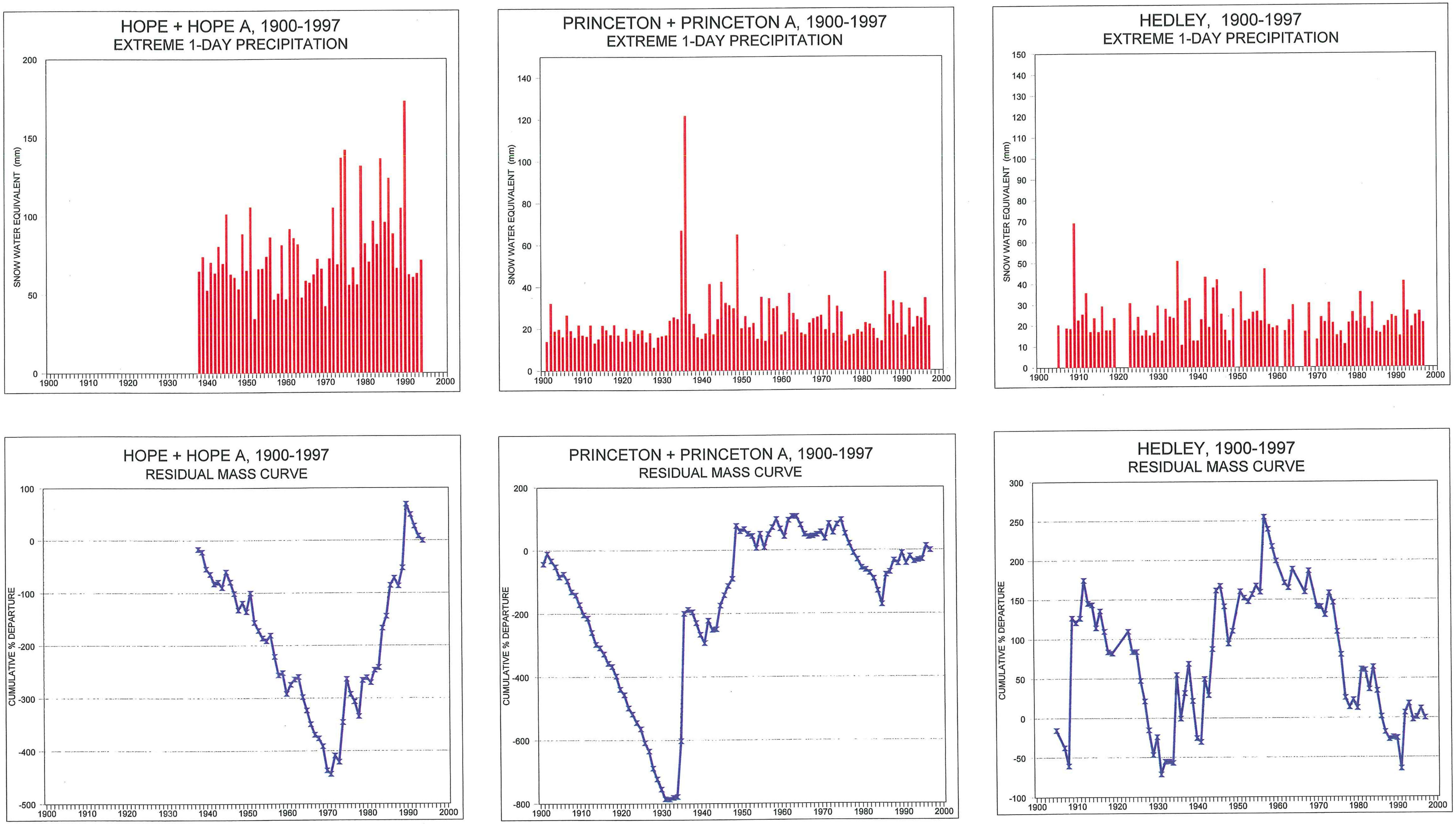


Figure 2.2.11: Residual Mass Curves for Extreme 1-Day Precipitation at Hope, Princeton Combined and Hedley.

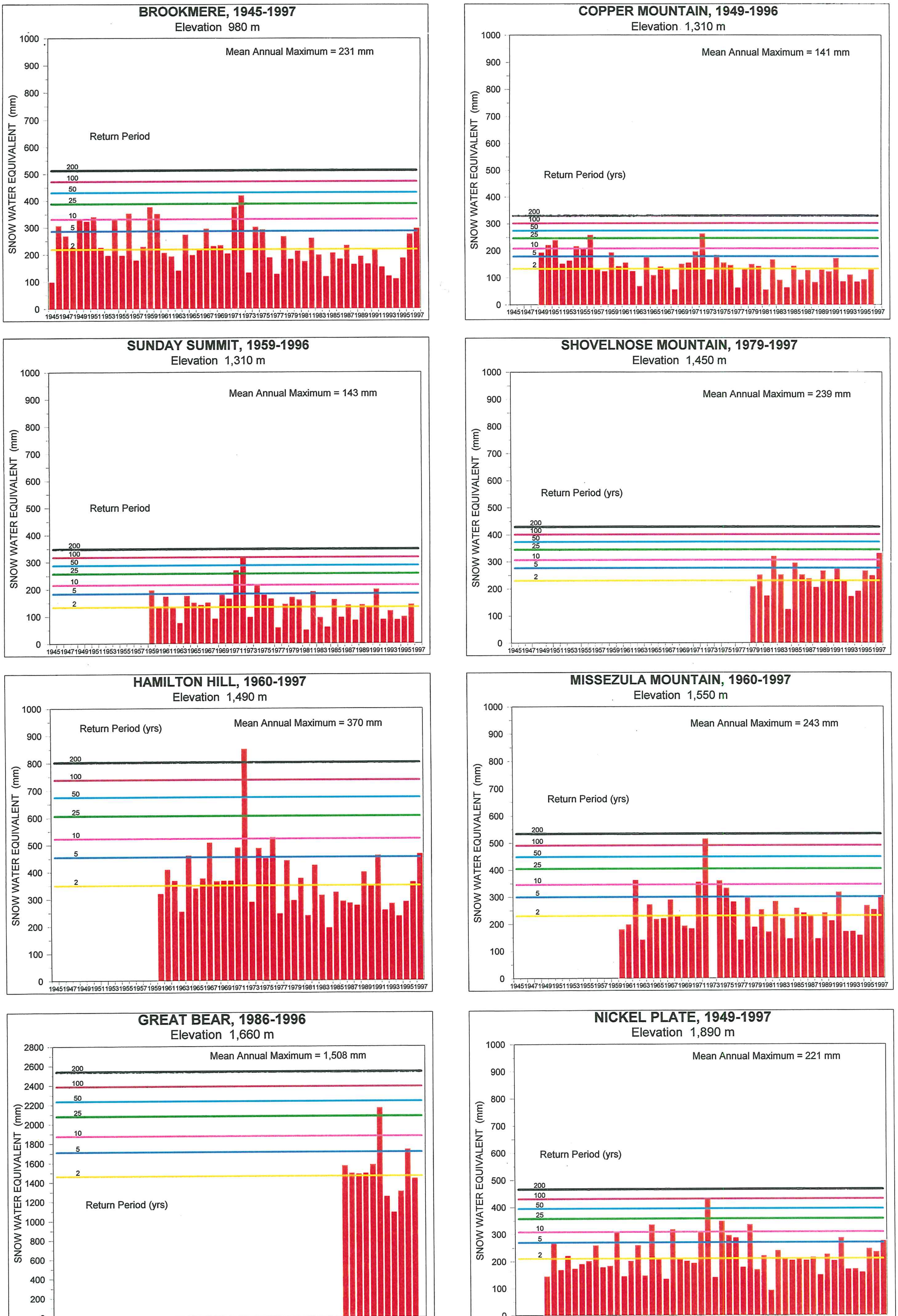


Figure 2.2.12: Historical Variation in Annual Maximum Snow Accumulation.

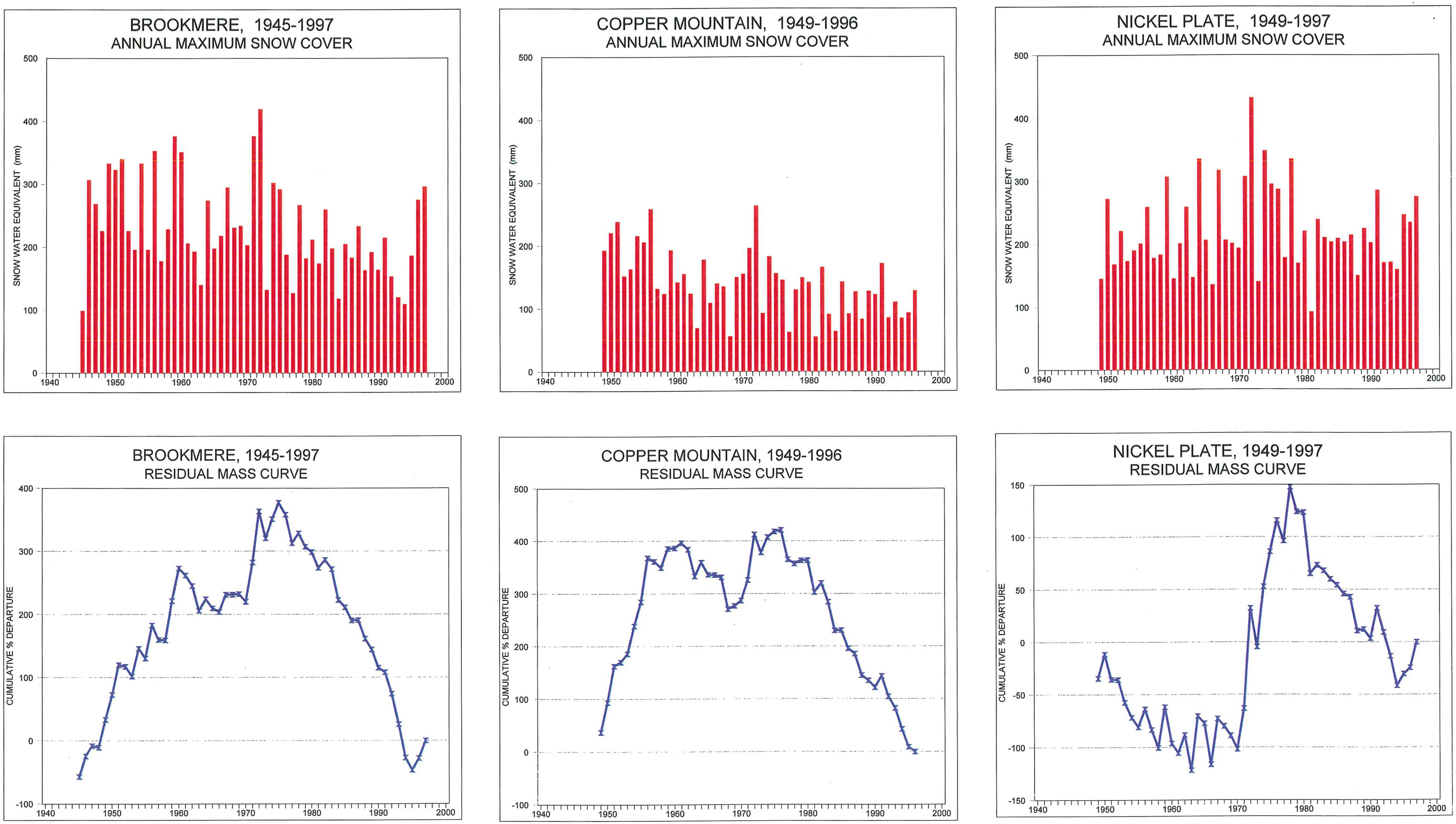


Figure 2.2.13: Residual Mass Curves for Annual Maximum Snow Cover at Brookmere, Copper Mountain and Nickel Plate.

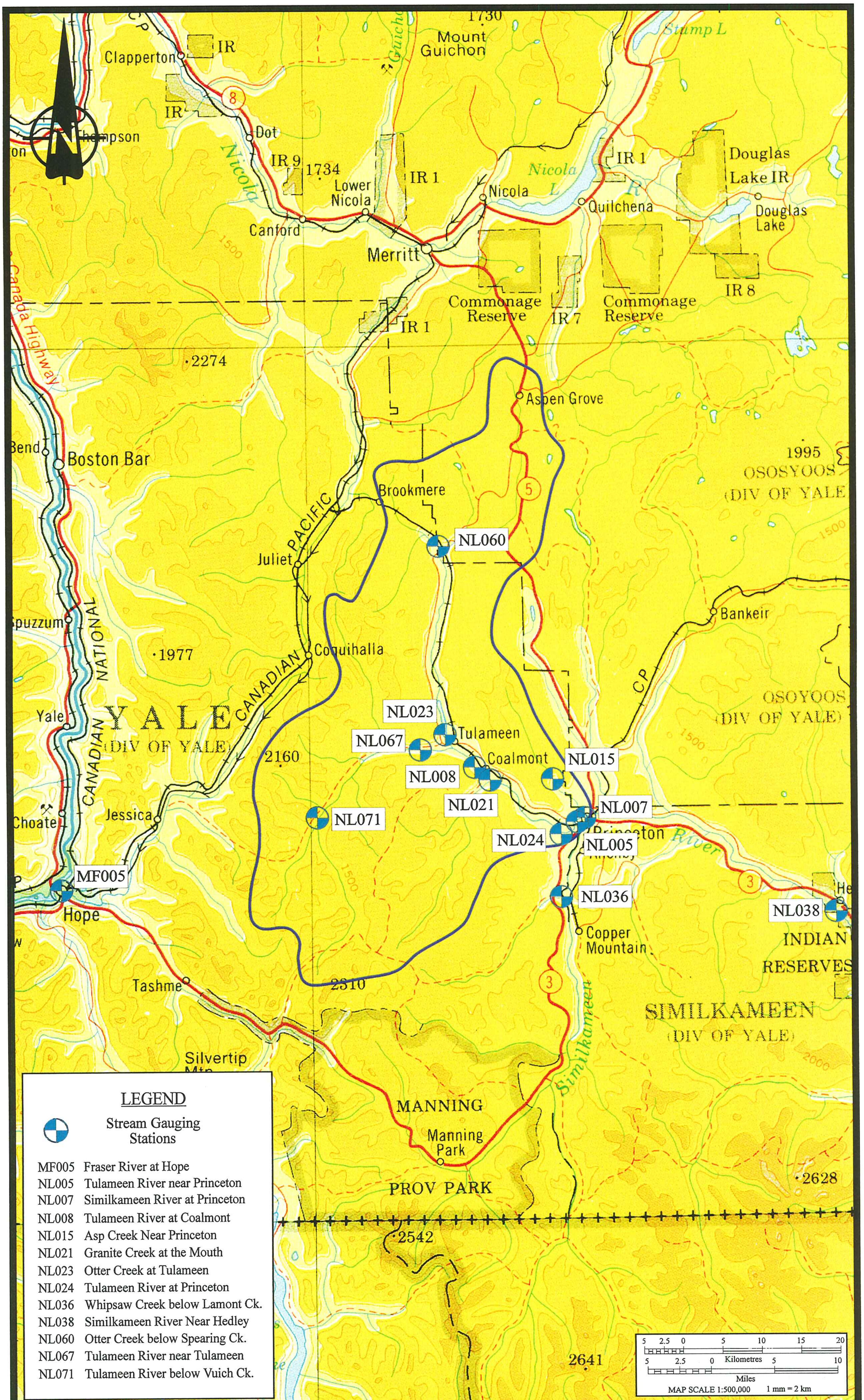


Figure 2.3.1: Location of stream gauging stations.

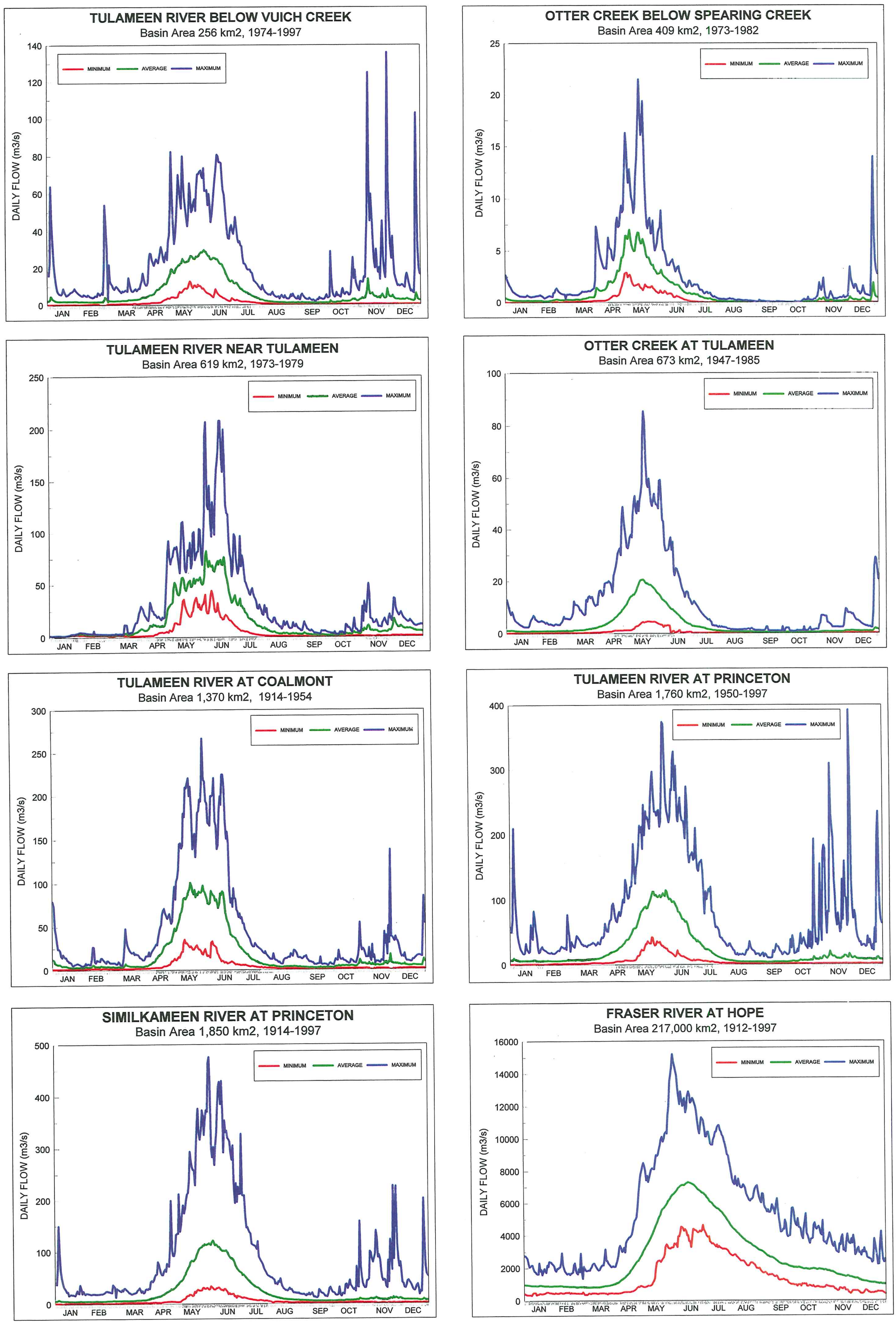


Figure 2.3.2: Seasonal Variation in Discharge.

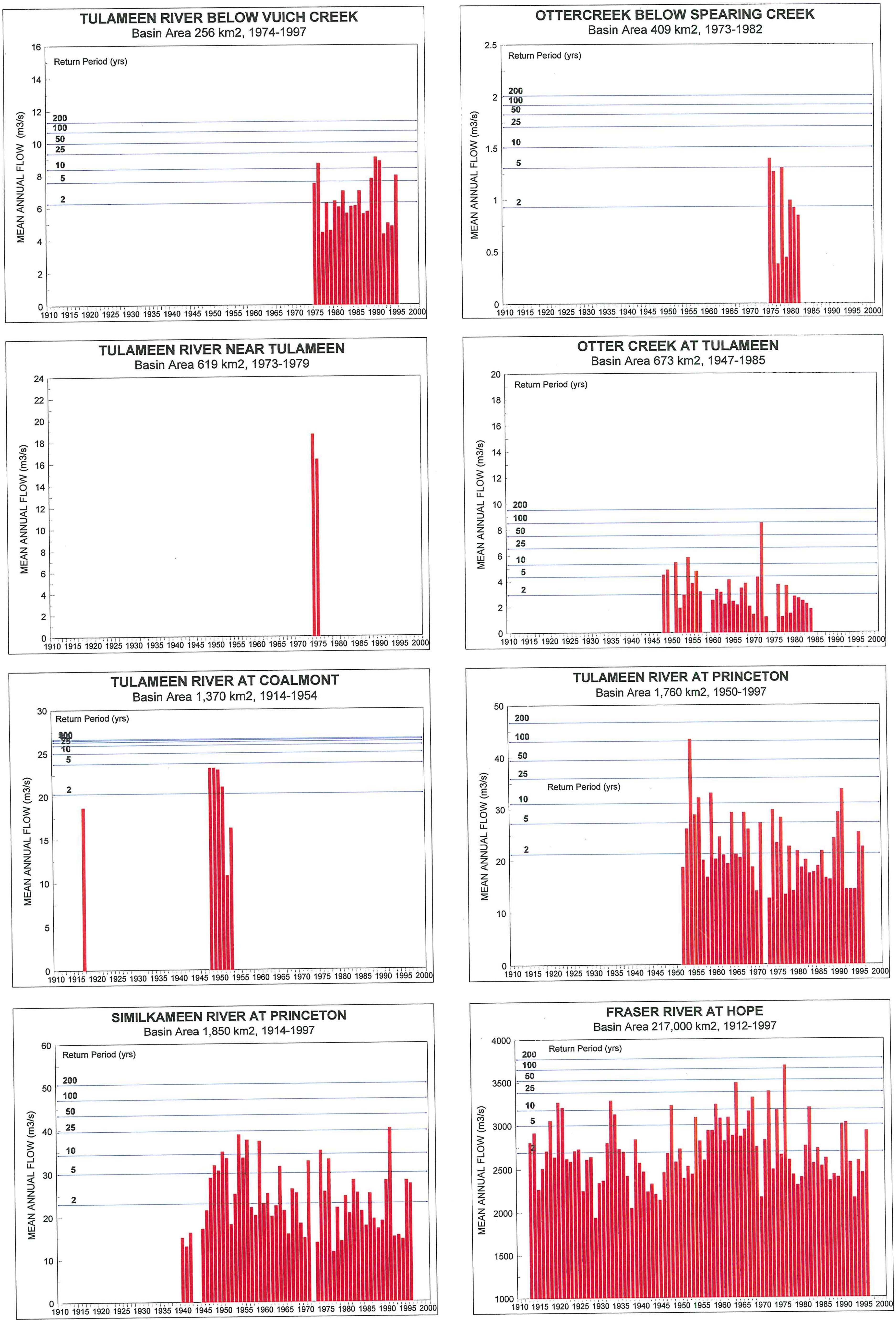


Figure 2.3.3: Historical Variation in Mean Annual Runoff

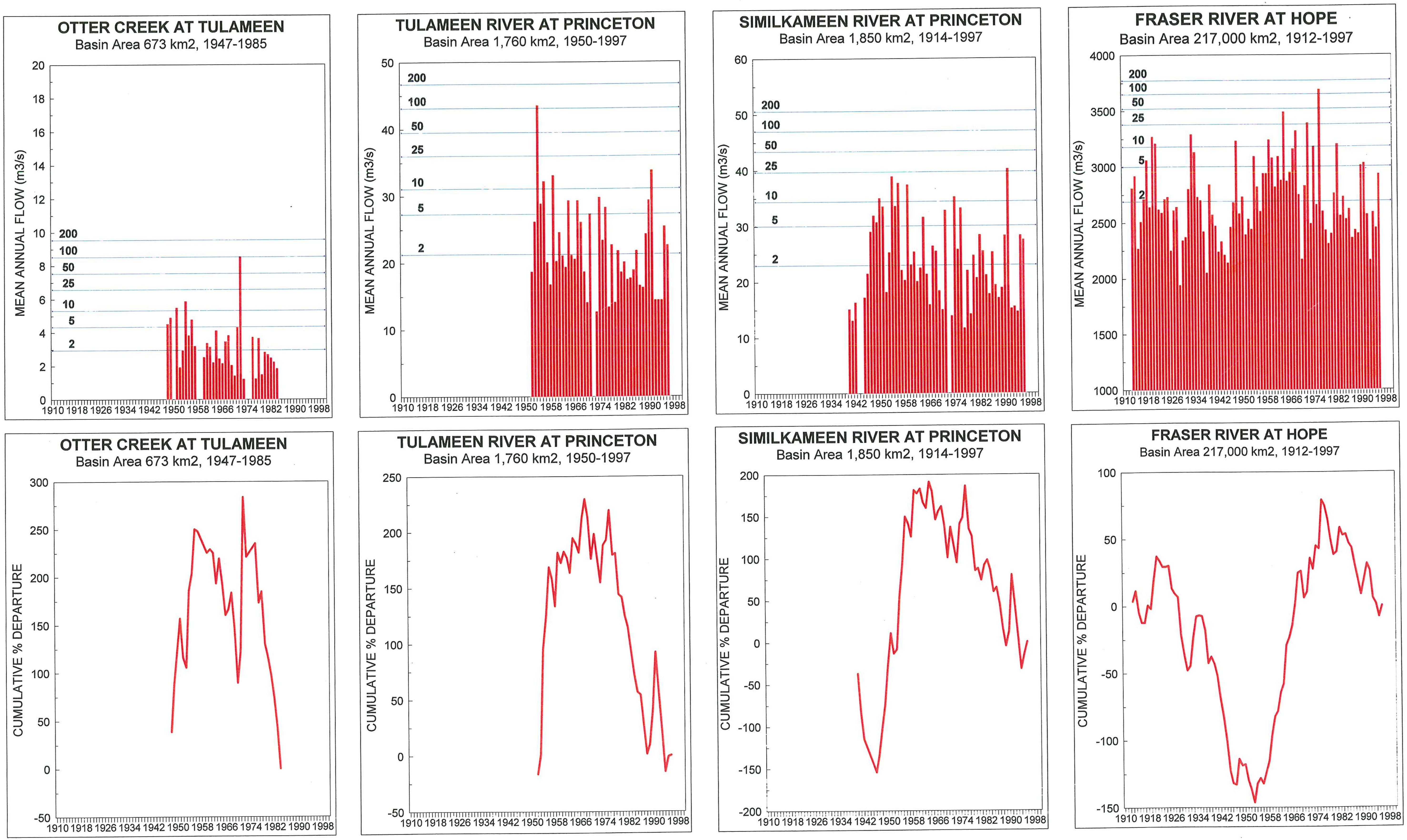


Figure 2.3.4: Residual Mass Curves for Annual Mean Runoff.

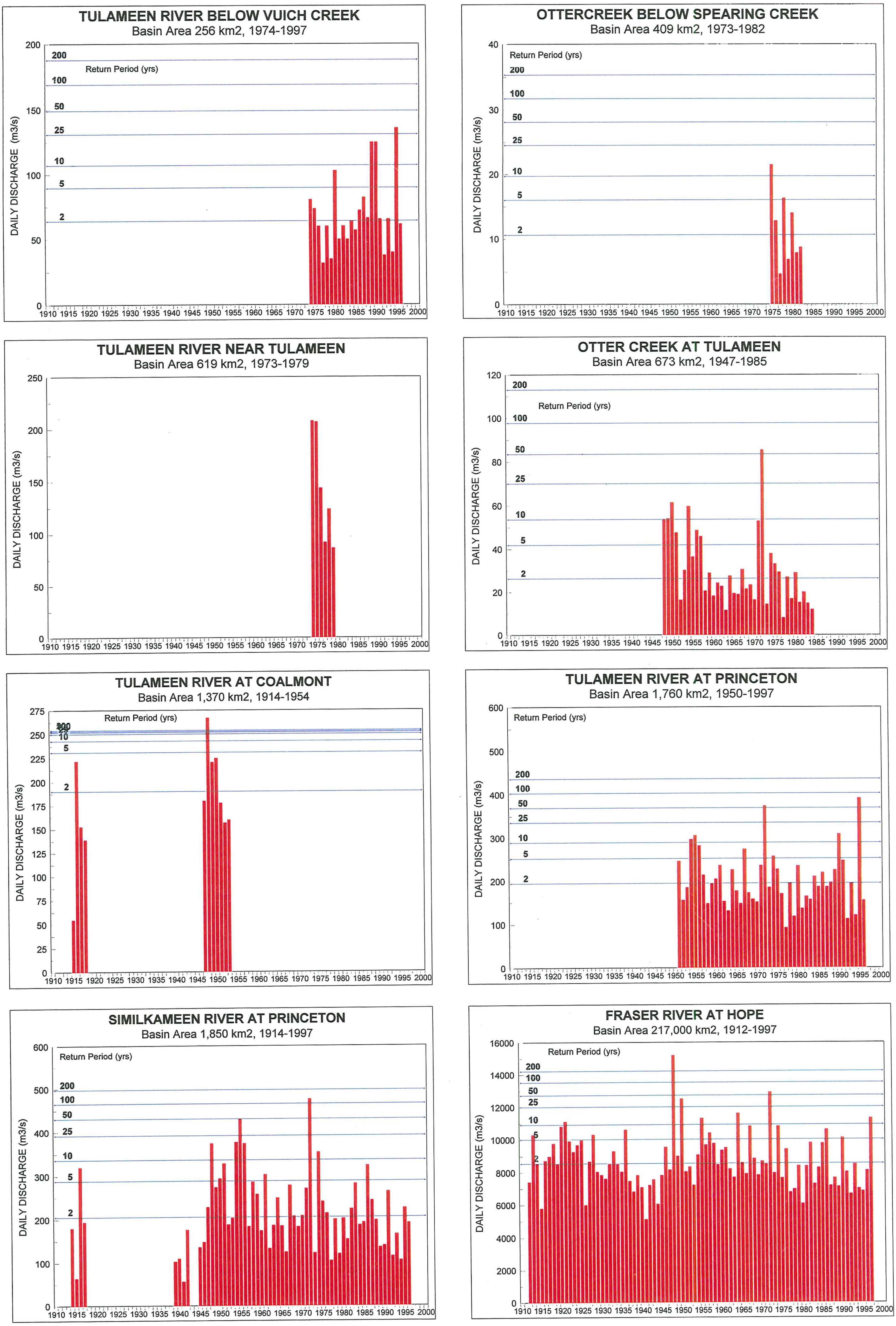


Figure 2.3.5: Historical Variation in Annual Maximum Daily Discharge (m^3/s).

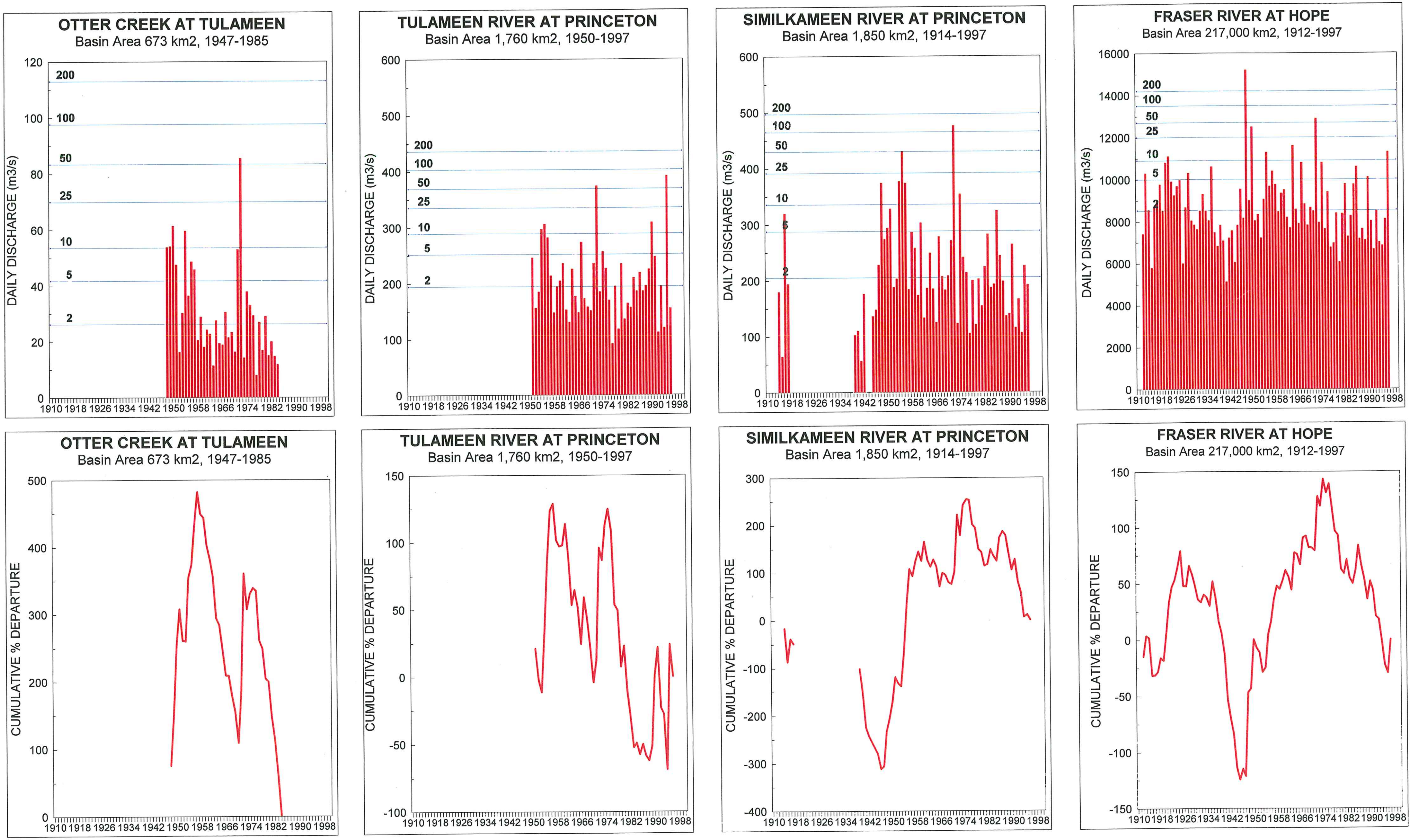


Figure 2.3.6: Residual Mass Curves for Annual Maximum Daily Discharge.

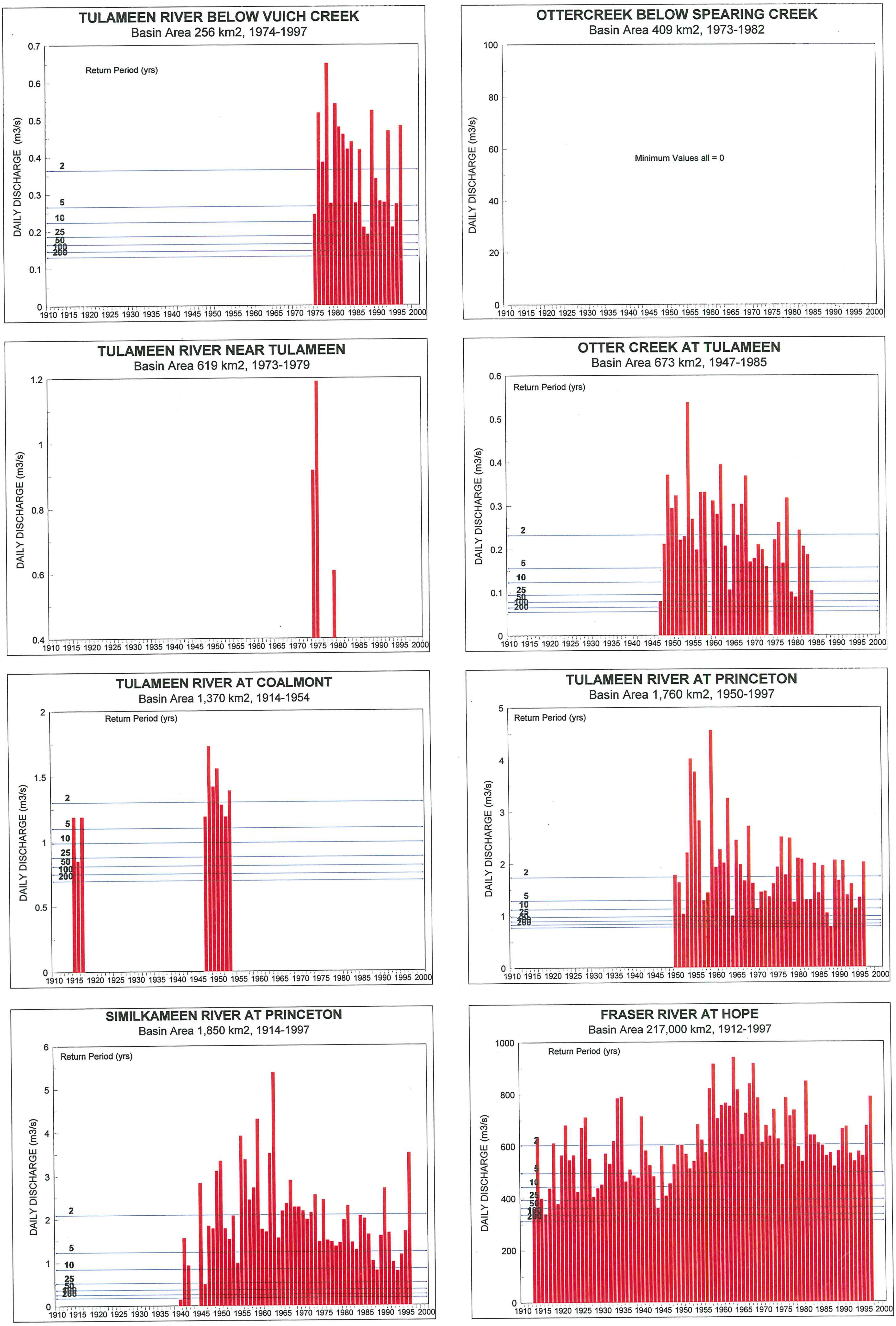


Figure 2.3.7: Historical Variation in Annual Minimum Daily Discharge (m³/s).

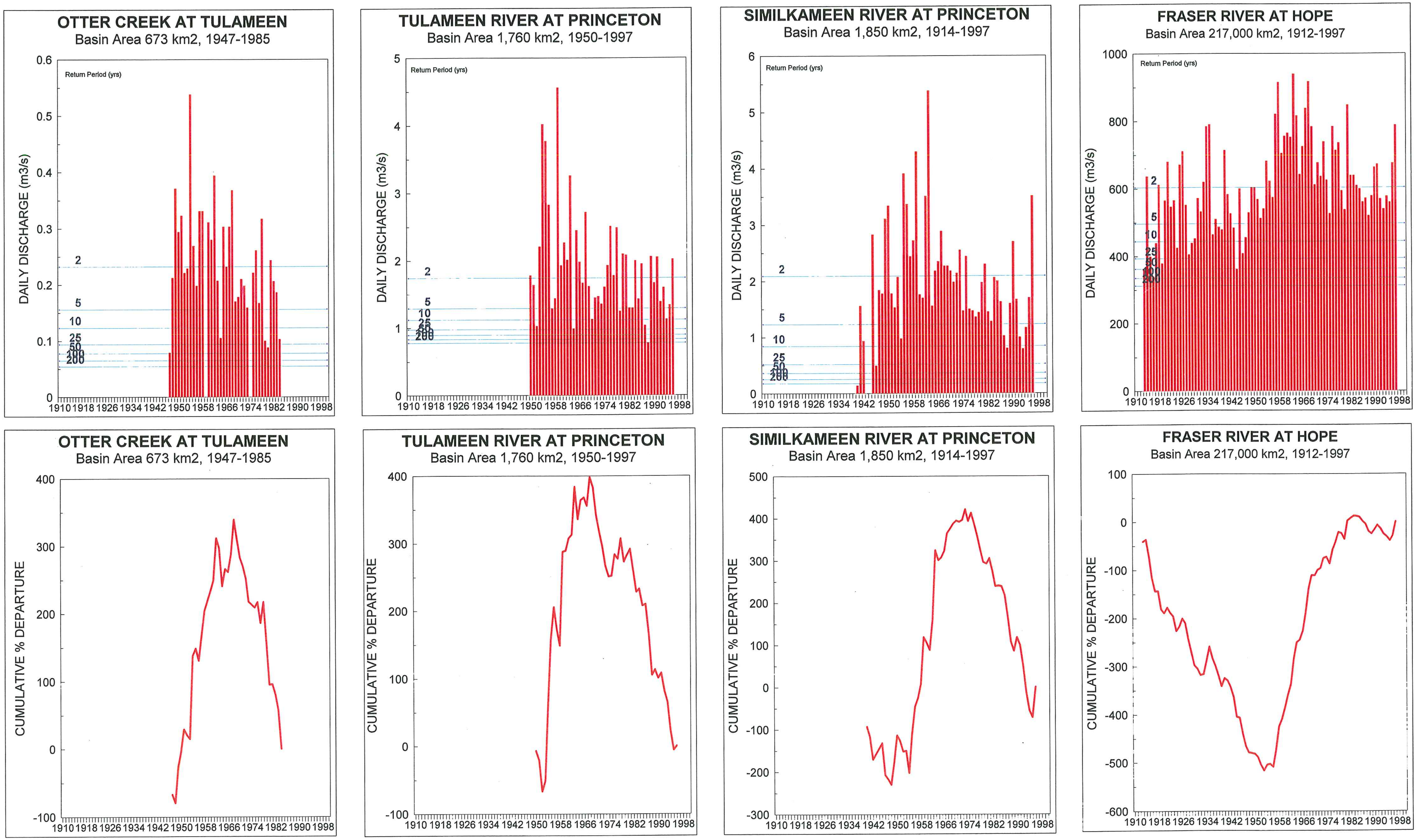


Figure 2.3.8: Residual Mass Curves for Annual Minimum Daily Discharge.

30BCC96028 #091	July 14, 1996 Air Photos	APPROX. SCALE: 1:5,000	M. MILES AND ASSOCIATES LTD. 645 ISLAND ROAD, VICTORIA, BC, V8S 2T7	PROJECT: TULAMEEN RIVER WATERSHED OVERVIEW CHANNEL ASSESSMENT			
		DATE: 8 February 1999					
REFERENCED DRAWING No.	REFERENCED DRAWING DESCRIPTION	DRAWN: S. Moore		TITLE: FIGURE 6.1.1 BRITTON CREEK BETWEEN KM 10 AND 6 EXAMPLE OF 1:5,000 SCALE AIR PHOTO MOSAIC SITE PLAN			
A | Jan 25/99	For Client Review | SM | MM | MM	DESIGNED: S. Moore	Phone: 250-595-0653 Fax: 250-595-7367 email: mmaa@coastnet.com				
		CHECKED: M. Miles	CLIENT: B.C. MINISTRY OF ENVIRONMENT, LANDS AND PARKS	PROJECT No.: MMA 0083	Km. No.: 10 to 6	REV.: A	
REV. | DATE	REVISION | DRAWN | CHECKED | APPROVED	APPROVED: M. Miles			DWG. No.: 0083-1		

TABLES

TABLE 2.1.1: WATERSHED MORPHOMETRIC DATA

WATERSHED	BASIN AREA	MAINSTEM CHANNEL LENGTH	MAXIMUM ELEVATION	MINIMUM ELEVATION	EQUIVALENT CHANNEL SLOPE	WATERSHED SHAPE
	(km^2)	(km)	(m)	(m)	(m/m)	($Length^2$/Area)
Holding Creek	32.8	11.5	2,123	1,340	0.028	4.03
Podunk Creek	47.2	14.7	1,974	1,260	0.020	4.58
Vuich Creek	80.7	17.4	2,285	1,045	0.029	3.75
Jim Kelly Creek	31.9	11.5	2,157	1,018	0.044	4.15
Champion Creek	51.4	12.9	1,880	940	0.054	3.24
Britton Creek	68.5	17.6	1,899	905	0.029	4.52
Lawless Creek	116.3	26.7	1,929	837	0.027	6.13
Olivine Creek	28.7	12.8	1,820	818	0.057	5.71
Otter Creek (at the mouth)	671.6	67.7	1,780	775	0.005	6.82
Spearing Creek	132.6	11.8	1,531	870	0.018	1.05
Thynne Creek	46.3	11.7	1,780	820	0.053	2.96
Granite Creek	266.6	33.4	1,720	730	0.027	4.18
Asp Creek	66.6	22.4	1,601	657	0.045	7.53
Tulameen River At Princeton	1,779.5	83.5	2,309	635	0.009	3.92

NOTE: Data from 1:20,000 TRIM mapping.

TABLE 2.2.1: SUMMARY OF AVAILABLE CLIMATE DATA

STATION NUMBER	STATION NAME	PERIOD OF RECORD	ELEVATION (m asl)	DATA AVAILABLE		
				TEMPERATURE	PRECIPITATION	RATE OF PRECIPITATION
1113540	Hope + Hope A	1934-1995	39	X	X	X
1123360	Hedley	1904-1997	517	X	X	
1126505	Princeton	1893-1942	633	X	X	
1126510	Princeton A	1938-1997	700	X	X	X
1113581	Hope Slide	1967-1974	715	X	X	
1127360	Similkameen Mine	1974-1996	940	X	X	
1121090	Brookmere	1986-1994	972	X	X	
1124890	Manning Park	1952-1961	1198	X	X	
1127358	Similkameen Copper Mountain	1980-1995	1229	X	X	
1123390	Hedley NP Mine	1904-1997	1707	X	X	

Source: Environment Canada, 1997.

TABLE 2.2.2: FREQUENCY ANALYSIS OF ANNUAL TOTAL PRECIP. IN THE VICINITY OF TULMEEN RIVER

AES STATION NAME	PERIOD OF RECORD	YEARS OF RECORD	MEAN VALUE (mm)	STAND. DEV. (mm)	MAXIMUM OBSERVED VALUE			SPECIFIED RETURN PERIOD PRECIPITATION (mm)						
					YEAR	VALUE (mm)	RETURN PERIOD (yrs)	2 YEARS	5 YEARS	10 YEARS	25 YEARS	50 YEARS	100 YEARS	200 YEARS
HOPE + HOPE A	34-75	53	1786.9	381.2	1990	3136.4	167	1724.4	2061.0	2284.5	2566.2	2775.1	2982.9	3189.5
HEDLEY	04-97	79	315.7	85.0	1990	611.7	156	301.8	376.8	426.6	489.4	535.9	582.2	628.3
PRINCETON COMBINED	1893-97	96	337.7	78.0	1990	559.4	69	324.9	393.8	439.5	497.1	539.8	582.3	624.6
HOPE SLIDE	67-74	5	1235.0	252.7	1972	1549.1	9	1193.6	1416.7	1564.8	1751.5	1890.0	2027.7	2164.6
SIMILKAMEEN MINE	74-95	9	295.1	56.7	1990	427.1	36	285.8	335.9	369.1	411.1	442.2	473.1	503.8
BROOKMERE	87-93	6	577.7	122.6	1990	789.3	17	557.6	665.8	737.7	828.3	895.5	962.3	1028.7
MANNING PARK	52-61	2	1057.8	29.3	1953	1072.8	4	1052.9	1078.8	1096.0	1117.6	1133.7	1149.6	1165.5
HEDLEY NP MINE	04-97	21	578.5	107.0	1948	788.1	22	561.0	655.5	718.2	797.2	855.9	914.2	972.2

NOTE: Shaded values exceed twice the period of record and are therefore potentially unreliable

TABLE 2.2.3: FREQUENCY ANALYSIS OF ANNUAL MAX. DAILY PRECIP. IN THE VICINITY OF TULMEEN RIVER

AES STATION NAME	PERIOD OF RECORD	YEARS OF RECORD	MEAN VALUE (mm)	STAND. DEV. (mm)	MAXIMUM OBSERVED VALUE			SPECIFIED RETURN PERIOD PRECIPITATION (mm)						
					YEAR	VALUE (mm)	RETURN PERIOD (yrs)	2 YEARS	5 YEARS	10 YEARS	25 YEARS	50 YEARS	100 YEARS	200 YEARS
HOPE + HOPE A	34-75	57	78.1	27.4	1990	173.1	153	73.6	97.8	113.8	134.0	149.0	163.9	178.8
HEDLEY	04-97	84	24.0	9.5	1909	69.1	767	22.5	30.9	36.5	43.5	48.7	53.9	59.1
PRINCETON COMBINED	1893-97	97	24.3	13.8	1937	121.9	15742	22.0	34.2	42.2	52.4	60.0	67.5	75.0
HOPE SLIDE	67-74	5	49.2	14.1	1972	73.7	17	46.9	59.4	67.6	78.0	85.7	93.4	101.0
SIMILKAMEEN MINE	74-95	12	27.3	8.1	1987	43.0	22	26.0	33.2	37.9	43.9	48.3	52.7	57.1
BROOKMERE	87-93	6	38.1	16.9	1987	60.0	10	35.3	50.3	60.2	72.7	82.0	91.2	100.4
MANNING PARK	52-61	8	38.0	11.2	1955	58.7	20	36.2	46.0	52.6	60.9	67.0	73.1	79.2
HEDLEY NP MINE	04-97	24	31.9	9.3	1994	52.3	31	30.4	38.6	44.0	50.8	55.9	60.9	66.0

NOTE: Shaded values exceed twice the period of record and are therefore potentially unreliable

TABLE 2.2.4: AVAILABLE SNOW SURVEY DATA

STATION NUMBER	DRAINAGE	NAME	ELEVATION (m asl)	STATUS	AVAILABLE DATA		
					START	END	# OF YEARS
1C01	Middle Fraser	Brookmere	980	Active	1945	1997	53
1C29	Middle Fraser	Shovelnose Mountain	1,450	Active	1979	1997	19
1D15	Lower Fraser	Great Bear	1,660	Active	1987	1997	11
2G01	Similkameen	Copper Mountain	1,310	Inactive	1949	1971	48
2G01A	Similkameen	Sunday Summit	1,310	Inactive	1959	1995	38
2G02	Similkameen	Nickel Plate	1,890	Inactive	1949	1986	49
2G05	Similkameen	Missezula Mountain	1,550	Active	1960	1997	37
2G06	Similkameen	Hamilton Hill	1,490	Active	1960	1997	38

Source: *Snow Survey Bulletins*, Ministry of Environment Lands and Parks.

TABLE 2.2.5: FREQUENCY ANALYSIS OF ANNUAL MAXIMUM SNOW ACCUMULATION

AES STATION NAME	PERIOD OF RECORD	YEARS OF RECORD	MEAN VALUE (mm)	STAND DEV	OBSERVED VALUE			SPECIFIED RETURN PERIOD PRECIPITATION (mm)						
					YEAR	VALUE	RETURN PERIOD	2 YEARS	5 YEARS	10 YEARS	25 YEARS	50 YEARS	100 YEARS	200 YEARS
BROOKMERE	1945-92	53	231.5	76.5	1972	419	42	218.9	286.5	331.4	387.9	429.9	471.6	513.1
COPPER MOUNTAIN	1949-96	48	141.2	51.3	1972	264	39	132.8	178.1	208.2	246.1	274.2	302.2	330.0
SUNDAY SUMMIT	1959-96	38	142.7	55.8	1972	317	98	133.5	182.8	215.5	256.8	287.3	317.8	348.0
SHOVELNOSE MTN	1979-97	19	238.8	51.8	1997	331	18	230.4	276.1	306.4	344.6	373.0	401.2	429.3
HAMILTON HILL	1960-97	38	369.7	117.5	1972	851	341	350.4	454.2	523.0	609.9	674.3	738.4	802.1
MISSEZULA MTN	1960-97	37	243.1	79.0	1972	516	150	230.2	299.9	346.3	404.6	447.9	491.0	533.8
GREAT BEAR	1986-96	11	1507.8	280.5	1991	2,166	37	1,461.8	1,709.5	1,873.8	2,081.1	2,234.8	2,387.6	2,539.7
NICKEL PLATE	1949-97	49	221.2	66.7	1972	432	103	210.3	269.2	308.3	357.5	394.1	430.4	466.6

NOTES: Shaded values exceed twice the period of record and are therefore potentially unreliable
Copper Mountain data synthesized from Sunday Summit between 1972 and 1996
Nickel Plate data synthesized from Missezula Mountain between 1986-1997

TABLE 2.2.6: SUMMARY OF STATISTICAL TESTS TO DETECT SHIFTS IN HYDROMETRIC REGIME

PARAMETER	STATION	PROBABILITY (%) OF A STATISTICALLY SIGNIFICANT SHIFT IN REGIME		
		Q STATISTIC	R STATISTIC	W STATISTIC
ANNUAL PRECIPITATION	Hope plus Hope A	99	99	NS @ 90
	Princeton plus Princeton A	99	95	99
	Hedley	99	99	95
EXTREME 1-DAY PRECIPITATION	Hope plus Hope A	99	99	NS @ 90
	Princeton plus Princeton A	95	95	90
	Hedley	NS @ 90	NS @ 90	NS @ 90
ANNUAL MAXIMUM SNOW ACCUMULATION (WE)	Brookmere	99	99	NS @ 90
	Copper Mountain	99	95	90
	Nickel Plate	NS @ 90	NS @ 90	NS @ 90
MEAN ANNUAL RUNOFF	Otter Creek At Tulameen	NS @ 90	NS @ 90	NS @ 90
	Tulameen River At Princeton	90	NS @ 90	NS @ 90
	Similkameen River At Princeton	NS @ 90	90	NS @ 90
	Fraser River At Hope	90	99	NS @ 90
ANNUAL MAXIMUM DAILY DISCHARGE	Otter Creek At Tulameen	95	NS @ 90	90
	Tulameen River At Princeton	NS @ 90	NS @ 90	NS @ 90
	Similkameen River At Princeton	NS @ 90	95	NS @ 90
	Fraser River At Hope	NS @ 90	90	NS @ 90
ANNUAL MINIMUM DAILY DISCHARGE	Otter Creek At Tulameen	95	99	NS @ 90
	Tulameen River At Princeton	95	95	NS @ 90
	Similkameen River At Princeton	90	99	NS @ 90
	Fraser River At Hope	99	99	99

NOTE: Q, R and W statistics are described in *Buishand, (1982)*.

TABLE 2.3.1: SUMMARY OF AVAILABLE DATA AT SELECTED STREAM GAUGING STATIONS

STATION NUMBER 08...	STATION NAME	BASIN AREA (km2)	TYPE OF RECORD	TYPE OF FLOW	PARAMETER	YEARS OF RECORD
NL015	Asp Creek Near Princeton	51.8	12 #; 19-20 #; 60-69 MS	NAT	1	10
					2	-
NL036	Whipsaw Creek below Lamont Ck	185	64 #; 65-97 RC	NAT	1	33
					2	32
NL071	Tulameen River Below Vuich Creek	256	74-97 RC	NAT	1	23
					2	18
NL021	Granite Creek at the Mouth	264	14-15 MS; 73-76 MS; 77 M#; 78 MS; 79 M#	NAT	1	3
					2	-
NL060	Otter Creek Below Spearing Creek	409	73 M#; 74 R#; 75-82 RC	NAT	1	8
					2	8
NL067	Tulameen River Near Tulameen	619	73-75 MC; 76-79 MS	NAT	1	6
					2	-
NL023	Otter Creek at Tulameen	673	12 #; 15-16 #; 47-73 MC; 74 MS; 75 RS; 76-85 RC	REG	1	37
					2	10
NL008	Tulameen River at Coalmont	1,370	14-16 MS; 17-18 MC; 47-54 MC	NAT	1	11
					2	-
NL005	Tulameen River Nr Princeton	NA	19-20 MS	NAT	1	1
					2	-
NL024	Tulameen River at Princeton	1,760	50-51 MS; 52-73 MC; 74-97 RC	REG	1	32
					2	31
NL007	Similkameen River at Princeton	1,850	14-17 MS; 39-42 MC; 43-44 MS; 45-75 MC; 76-97 RC	NAT	1	60
					2	20
NL038	Similkameen River Near Hedley	5,590	65-97 RC	NAT	1	33
					2	31
MF005	Fraser River at Hope	217,000	12-49 MC; 51-97 RC	REG 52	1	86
					2	46

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NOTES:

*	stage only	REV	Data to 19__ have been reviewed	(i)	Data not published
#	miscellaneous measurements	NAT	Natural Flow	1	Daily Flows
M	manual gauge	REG	Regulated Flow with date of regulation if known	2	Instantaneous Flows
R	recording gauge	NA	Not Available	7	Satellite D.C.P.
S	seasonal operation			10	Minimum Flows
C	continuous operation				
	numbers refer to years (e.g. 09 is 1909)				

TABLE 2.3.2: FREQUENCY ANALYSES OF MEAN ANNUAL DISCHARGE

STATION	BASIN AREA (km²)	YEARS OF RECORD	MEAN ANNUAL FLOW (m³/s)		MEAN ANNUAL FLOW (m³/s) FOR A RETURN PERIOD OF:													
			MEAN	STANDARD DEVIATION	2 YEARS		5 YEARS		10 YEARS		25 YEARS		50 YEARS		100 YEARS		200 YEARS	
					m³/s	mm	m³/s	mm	m³/s	mm	m³/s	mm	m³/s	mm	m³/s	mm	m³/s	mm
Asp Creek Near Princeton	52	10	na	na	na		na		na		na		na		na		na	
Whipsaw Creek Below Lamont Lake	185	33	na	na	0.90	153	1.34	229	1.69	288	2.20	375	2.63	449	3.11	531	3.64	621
Tulameen River Below Vuich Creek	256	21	6.414	1.462	6.25	770	7.57	933	8.38	1,033	9.35	1,153	10.00	1,233	10.70	1,319	11.30	1,393
Granite Creek at the Mouth	264	7	na	na	na		na		na		na		na		na		na	
Otter Creek Below Spearing Creek	409	8	0.945	0.384	0.93	72	1.31	101	1.57	121	1.71	132	1.83	141	1.92	148	2.01	155
Tulameen River Near Tulameen	619	2	na	na	na		na		na		na		na		na		na	
Otter Creek at Tulameen	673	32	3.258	1.5545	2.95	138	4.34	204	5.31	249	6.58	309	7.54	354	8.53	400	9.54	447
Tulameen River at Coalmont	1,370	7	19.514	4.6721	20.30	468	23.80	548	25.00	576	25.90	597	26.30	606	26.50	610	26.60	613
Tulameen River at Princeton	1,760	44	22.368	6.594	21.30	382	27.30	490	31.10	558	36.00	645	39.50	708	43.10	773	46.70	837
Similkameen River at Princeton	1,850	54	24.065	7.5579	23.00	392	20.00	341	34.40	587	39.70	677	43.40	740	47.00	802	50.60	863
Fraser River at Hope	217,000	84	2710.5	354.8	2,690	391	3,000	436	3,180	462	3,380	492	3,520	512	3,650	531	3,770	548

NOTE: Return period estimates have been calculated on the basis of the Pearson Type III distributation filled by the Method of Moments
Shaded values exceed twice the period of record and are therefore potentially unreliable

TABLE 2.3.3: FREQUENCY ANALYSES OF ANNUAL MAXIMUM DAILY DISCHARGES

STATION	BASIN AREA (km²)	YEARS OF RECORD	MAXIMUM DAILY DISCHARGE (m³/s)		MAXIMUM DAILY DISCHARGE (m³/s) FOR A RETURN PERIOD OF:						
			MEAN	STANDARD DEVIATION	2 YEARS	5 YEARS	10 YEARS	25 YEARS	50 YEARS	100 YEARS	200 YEARS
Asp Creek Near Princeton	52	10	4.3	4.3	3	5	9	16	24	38	58
Whipsaw Creek Below Lamont Lake	185	33	8.9	4.7	8	12	15	18	21	24	26
Tulameen River Below Vuich Creek	256	23	69.7	28.5	64	90	107	131	149	169	188
Granite Creek at the Mouth	264	7			na	na	na	na	na	na	na
Otter Creek Below Spearing Creek	409	85	11.6	5.6	11	16	20	25	28	32	35
Tulameen River Near Tulameen	619	6	143.7	53.7	na	na	na	na	na	na	na
Otter Creek at Tulameen	673	37	30.7	17.4	26	42	54	70	83	98	113
Tulameen River at Coalmont	1,370	11	177.9	56.6	190	231	243	250	252	253	254
Tulameen River at Princeton	1,760	46	203.4	64.8	194	252	289	335	369	403	436
Similkameen River at Princeton	1,850	60	216.2	88.9	205	288	336	392	430	465	497
Fraser River at Hope	217,000	86	8,706	1,676	8,520	10,000	10,900	12,000	12,700	13,500	14,200

NOTE: Return period estimates have been calculated on the basis of the Pearson Type III distribution filled by the Method of Moments
Shaded values exceed twice the period of record and are therefore potentially unreliable

TABLE 2.3.4: FREQUENCY ANALYSES OF ANNUAL MAXIMUM INSTANTANEOUS DISCHARGES

STATION	BASIN AREA (km²)	YEARS OF RECORD	MAXIMUM INSTANTANEOUS DISCHARGE (m³/s)		MAXIMUM INSTANTANEOUS DISCHARGE (m³/s) FOR A RETURN PERIOD OF:						
			MEAN	STANDARD DEVIATION	2 YEARS	5 YEARS	10 YEARS	25 YEARS	50 YEARS	100 YEARS	200 YEARS
Asp Creek Near Princeton	52	10			na	na	na	na	na	na	na
Whipsaw Creek Below Lamont Lake	185	31	10.8	6.1	9	15	18	24	28	32	37
Tulameen River Below Vuich Creek	256	18	91.4	55.6	75	120	158	218	273	337	412
Granite Creek at the Mouth	264	7	na	na	na	na	na	na	na	na	na
Otter Creek Below Spearing Creek	409	8	13.6	6.6	12	19	23	29	33	38	42
Tulameen River Near Tulameen	619	6	na	na	na	na	na	na	na	na	na
Otter Creek at Tulameen	673	10	21.3	8.3	21	29	33	38	41	44	47
Tulameen River at Coalmont	1,370	7	na	na	na	na	na	na	na	na	na
Tulameen River at Princeton	1,760	22	245.9	127.2	213	312	393	516	623	746	886
Similkameen River at Princeton	1,850	20	219.2	79.8	207	281	329	386	428	468	509
Fraser River at Hope	217,000	46	8845.0	1553.9	8,620	10,000	10,900	12,000	12,800	13,600	14,400

NOTE: Return period estimates have been calculated on the basis of the Pearson Type III distribution filled by the Method of Moments
Shaded values exceed twice the period of record and are therefore potentially unreliable

TABLE 2.3.5: INITIAL FLOOD MAGNITUDE ESTIMATES FOR REPRESENTATIVE LOCATIONS IN THE TULAMEEN RIVER WATERSHED.

	LOCATION	BASIN AREA (km²)	INITIAL ESTIMATE OF MAXIMUM INSTANTANEOUS DISCHARGE (m³/s) FOR VARIOUS RETURN PERIODS						
			2 Year	5 Year	10 Year	25 Year	50 Year	100 Year	200 Year
TULAMEEN RIVER WATERSHED	Tulameen River upstream of Holding Creek confluence	37.0	11	18	23	32	41	50	60
	Holding Creek	32.8	10	15	20	28	36	44	52
	Tulameen River downstream of Holding Creek confluence	69.8	40	72	90	112	147	177	199
	Tulameen River upstream of Podunk Creek confluence	83.8	46	87	91	129	168	203	229
	Podunk Creek	47.2	21	32	42	57	74	92	108
	Tulameen River downstream of Podunk Creek confluence	131.0	56	106	131	157	210	288	341
	Tulameen River upstream of Vuich Creek confluence	173.1	57	113	147	190	260	294	346
	Vuich Creek	80.7	32	48	63	87	110	139	165
	Tulameen River downstream of Vuich Creek confluence	253.8	75	120	158	218	273	337	412
	Tulameen River upstream of Jim Kelly Creek confluence	259.6	78	130	169	247	286	363	428
	Jim Kelly Creek	31.9	9	14	18	25	31	39	47
	Tulameen River downstream of Jim Kelly Creek confluence	291.5	79	131	171	261	292	411	446
	Tulameen River upstream of Champion Creek confluence	319.1	83	140	176	271	313	447	479
	Champion Creek	51.4	15	23	30	40	50	62	74
	Tulameen River downstream of Champion Creek confluence	370.5	83	156	178	296	341	463	519
	Tulameen River upstream of Britton Creek confluence	377.7	87	159	181	302	344	472	529
	Britton Creek	68.5	18	27	36	48	60	75	87
	Tulameen River downstream of Britton Creek confluence	446.2	94	178	187	335	379	491	580
	Tulameen River upstream of Lawless Creek confluence	459.6	97	188	193	345	391	506	597
	Lawless Creek	116.3	21	33	43	57	71	86	103
	Tulameen River downstream of Lawless Creek confluence	575.9	109	213	219	380	432	518	622
	Tulameen River upstream of Olivine Creek confluence	579.3	110	214	220	382	434	521	626
	Olivine Creek	28.7	8	12	16	21	26	32	37
	Tulameen River downstream of Olivine Creek confluence	608.0	112	219	225	395	449	535	638
	Tulameen River upstream of Otter Creek confluence	633.9	117	222	235	399	463	545	640
	Otter Creek	671.6	21	29	33	38	41	44	47
	Tulameen River downstream of Otter Creek confluence	1,305.5	162	248	324	486	561	653	809
	Tulameen River upstream of Granite Creek confluence	1,374.7	173	275	327	495	577	687	825
	Granite Creek	266.6	77	133	173	253	267	387	173
	Tulameen River downstream of Granite Creek confluence	1,641.3	182	295	364	509	607	722	837
	Tulameen River upstream of Asp Creek confluence	1,711.2	188	308	368	513	616	736	856
	Asp Creek	66.6	9	14	18	24	29	35	42
	Tulameen River downstream of Asp Creek confluence	1,777.8	190	302	382	516	622	740	871
	Tulameen River upstream of Similkameen River confluence	1,779.5	213	312	393	516	623	746	886
OTTER CREEK WATERSHED	Otter Creek upstream of Spearing Creek confluence	266.6	0	0	0	0	0	0	0
	Spearing Creek	132.6	0	0	0	0	0	0	0
	Otter Creek downstream of Spearing Creek confluence	399.2	12	19	23	29	33	38	42
	Otter Creek upstream of Thynne Creek confluence	506.8	0	0	0	0	0	0	0
	Thynne Creek	46.3	0	0	0	0	0	0	0
	Otter Creek downstream of Thynne Creek confluence	553.1	0	0	0	0	0	0	0
	Otter Creek upstream of Tulameen River confluence	671.6	21	29	33	38	41	44	47

NOTE: i) These calculations are preliminary estimates which need to be verified prior to being used for design purposes.

ii) Red values are derived from the flood frequency analysis of data collected by the former Water Survey of Canada.

iii) Blue values have been calculated based on procedures recommended in *Coulson et al. (1997).*

iv) Black values have been inferred based on derived regional relationships betweeen unit runoff and basin area (i.e. Creager Equation with values of "c" ranging between 2 and 13 - see Creager, Justin and Hinds, 1948).

TABLE 2.3.6: FREQUENCY ANALYSES OF ANNUAL MINIMUM DAILY DISCHARGES

STATION	BASIN AREA (km²)	YEARS OF RECORD	MINIMUM DAILY DISCHARGE (m^3/s)		MINIMUM DAILY DISCHARGE (m^3/s) FOR A RETURN PERIOD OF:						
			MEAN	STANDARD DEVIATION	2 YEARS	5 YEARS	10 YEARS	25 YEARS	50 YEARS	100 YEARS	200 YEARS
Asp Creek Near Princeton	52	8	0.130	0.007	0.011	0.007	0.004	0.005	0.004	0.003	0.003
Whipsaw Creek Below Lamont Lake	185	32	0.108	0.053	0.098	0.065	0.052	0.041	0.035	0.030	0.027
Tulameen River Below Vuich Creek	256	22	0.380	0.129	0.364	0.266	0.224	0.186	0.164	0.146	0.131
Granite Creek at the Mouth	264	7	na	na	na	na	na	na	na	na	na
Otter Creek Below Spearing Creek	409	8	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Tulameen River Near Tulameen	619	3	0.905	0.291	na	na	na	na	na	na	na
Otter Creek at Tulameen	673	36	0.242	0.097	0.232	0.156	0.123	0.094	0.078	0.065	0.055
Tulameen River at Coalmont	1,370	10	1.299	0.242	1.300	1.100	0.988	0.878	0.809	0.749	0.696
Tulameen River at Princeton	1,760	47	1.908	0.784	1.740	1.290	1.120	0.976	0.896	0.832	0.780
Similkameen River at Princeton	1,850	55	2.040	0.968	2.090	1.230	0.842	0.518	0.361	0.252	0.177
Fraser River at Hope	217,000	85	611.412	134.365	604	496	444	393	362	335	312

NOTE: Return period estimates have been calculated on the basis of the Pearson Type III distribution filled by the Method of Moments
Shaded values exceed twice the period of record and are therefore potentially unreliable

TABLE 2.5.1: LAND USE STATISTICS COMPILED BY WATERSHED.

SUB BASIN	BASIN AREA (km²)	% OF TOTAL WATER-SHED	LAND USE STATISTICS BY WATERSHED																											
			AGRICULTURE		ALPINE		BARREN SURFACES		FRESH WATER		MINING		OLD FOREST		RANGELANDS		RECENTLY BURNED		RECENTLY LOGGED		SELECTIVELY LOGGED		SUBALPINE AVALANCHE CHUTES		URBAN		WETLANDS		YOUNG FOREST	
			AREA (km²)	%	AREA (km²)	%	AREA (km²)	%	AREA (km²)	%	AREA (km²)	%	AREA (km²)	%	AREA (km²)	%	AREA (km²)	%	AREA (km²)	%	AREA (km²)	%	AREA (km²)	%	AREA (km²)	%	AREA (km²)	%	AREA (km²)	%
Holding Creek	32.8	1.8	-	-	1.4	4.3	-	-	-	-	-	-	17.5	53.4	+	+	2.0	6.1	-	-	-	-	0.4	1.2	-	-	0.5	1.5	10.9	33.2
Podunk Creek	47.2	2.7	-	-	0.8	1.8	0.6	1.2	-	-	-	-	25.0	53.0	-	-	2.4	5.1	2.7	5.6	-	-	0.3	0.6	-	-	1.1	2.4	14.3	30.3
Vuich Creek	80.7	4.5	-	-	6.5	8.1	-	-	-	-	-	-	16.0	19.8	-	-	2.0	2.4	0.8	1.0	-	-	1.9	2.4	-	-	0.2	0.3	53.3	66.1
Jim Kelly	31.9	1.8	-	-	7.6	23.8	0.1	0.3	-	-	-	-	3.1	9.8	-	-	-	-	-	-	-	-	2.3	7.3	-	-	0.2	0.7	18.6	58.3
Champion	51.4	2.9	-	-	-	-	-	-	-	-	-	-	30.5	59.3	-	-	-	-	4.1	7.9	-	-	-	-	-	-	-	-	16.8	32.6
Britton Creek	68.5	3.8	-	-	12.7	18.6	0.2	0.3	-	-	-	-	23.7	34.7	-	-	-	-	6.9	10.1	-	-	2.1	3.0	-	-	0.2	0.2	22.8	33.2
Lawless Creek	116.3	6.5	-	-	0.6	0.5	-	-	-	-	-	-	51.1	43.9	-	-	-	-	25.0	21.5	4.0	3.4	-	-	-	-	-	-	35.6	30.6
Olivine Creek	28.7	1.6	-	-	-	-	-	-	-	-	-	-	6.9	24.2	-	-	-	-	6.8	23.6	2.3	7.9	-	-	-	-	-	-	12.7	44.4
Otter Creek	492.7	27.7	7.5	1.5	-	-	0.6	0.1	4.2	0.9	-	-	95.5	19.4	37.1	7.5	0.4	0.1	28.8	5.8	33.7	6.8	-	-	0.4	0.1	14.7	3.0	269.8	54.8
- *Spearing Ck.*	132.6	7.5	0.1	0.1	1.1	0.8	-	-	-	-	-	-	51.5	38.8	-	-	-	-	12.7	9.5	29.2	22.0	-	-	-	-	0.6	0.5	37.6	28.4
- *Thynne Ck.*	46.3	2.6	0.1	0.2	-	-	-	-	-	-	-	-	15.4	33.3	-	-	-	-	3.0	6.5	-	-	-	-	-	-	-	-	27.8	60.0
Granite Creek	266.6	15.0	-	-	-	-	0.4	0.2	-	-	-	-	92.2	34.6	0.5	0.2	0.6	0.2	34.4	12.9	0.8	0.3	-	-	-	-	1.9	0.7	135.8	50.9
Asp Creek	66.6	3.7	0.3	0.4	-	-	-	-	-	-	-	-	10.2	15.3	3.3	5.0	-	-	3.4	5.2	7.5	11.3	-	-	0.5	0.8	-	-	41.4	62.2
Tulameen Mainstem & Residual Sub-basins	317.2	17.8	2.2	0.7	3.4	1.1	1.1	0.3	-		0.1	+	85.4	26.9	2.1	0.7	+	+	17.8	5.6	16.6	5.2	0.6	0.2	3.4	1.1	1.8	0.6	182.5	57.5
TULAMEEN WATERSHED	**1,779.5**	**100.0**	**10.2**	**0.6**	**34.1**	**1.9**	**3.0**	**0.2**	**4.2**	**0.2**	**0.1**	**0.0**	**524.0**	**29.4**	**43.0**	**2.4**	**7.4**	**0.4**	**146.4**	**8.2**	**94.1**	**5.3**	**7.6**	**0.4**	**4.3**	**0.3**	**21.2**	**1.2**	**879.9**	**49.4**

NOTE: *Spearing* and *Thynne Creeks* are tributaries to Otter Creek.
"+" indicates a value of ≤0.05

TABLE 2.5.2: LAND USE STATISTICS COMPILED BY CUMULATIVE UPSTREAM WATERSHED AREA.

SUB BASIN	BASIN AREA (km^2)	% OF TOTAL WATER-SHED	CUMULATIVE UPSTREAM LAND USE STATISTICS																											
			AGRICULTURE		ALPINE		BARREN SURFACES		FRESH WATER		MINING		OLD FOREST		RANGELANDS		RECENTLY BURNED		RECENTLY LOGGED		SELECTIVELY LOGGED		SUBALPINE AVALANCHE CHUTES		URBAN		WETLANDS		YOUNG FOREST	
			AREA (km^2)	%	AREA (km^2)	%	AREA (km^2)	%	AREA (km^2)	%	AREA (km^2)	%	AREA (km^2)	%	AREA (km^2)	%	AREA (km^2)	%	AREA (km^2)	%	AREA (km^2)	%	AREA (km^2)	%	AREA (km^2)	%	AREA (km^2)	%	AREA (km^2)	%
Holding Creek	32.8	1.8	-	-	1.4	0.1	-	-	-	-	-	-	17.5	1.1	+	+	2.0	0.1	-	-	-	-	0.4	+	-	-	0.5	+	10.9	0.6
Podunk Creek	80.0	4.4	-	-	2.2	0.1	0.6	0.1	-	-	-	-	42.5	2.3	+	+	4.4	0.2	2.7	0.1	-	-	0.7	+	-	-	1.6	+	25.2	1.4
Vuich Creek	160.7	9.0	-	-	8.7	0.4	0.6	0.1	-	-	-	-	58.5	3.2	+	+	6.4	0.3	3.5	0.1	-	-	2.6	0.1	-	-	1.8	0.1	78.5	4.4
Jim Kelly Creek	192.6	10.8	-	-	16.3	0.9	0.7	0.1	-	-	-	-	61.6	3.4	+	+	6.4	0.3	3.5	0.1	-	-	4.9	0.2	-	-	2.0	0.1	97.1	5.4
Champion Creek	244.0	13.7	-	-	16.3	0.9	0.7	0.1	-	-	-	-	92.1	5.1	+	+	6.4	0.3	7.6	0.4	-	-	4.9	0.2	-	-	2.0	0.1	113.9	6.4
Britton Creek	312.5	17.5	-	-	29.0	1.6	0.9	0.1	-	-	-	-	115.8	6.5	+	+	6.4	0.3	14.5	0.8	-	-	7.0	0.4	-	-	2.2	0.1	136.7	7.6
Lawless Creek	428.8	24.0	-	-	29.6	1.6	0.9	0.1	-	-	-	-	166.9	9.3	+	+	6.4	0.3	39.5	2.2	4.0	0.2	7.0	0.4	-	-	2.2	0.1	172.3	9.6
Olivine Creek	457.5	25.7	-	-	29.6	1.6	0.9	0.1	-	-	-	-	173.8	9.7	+	+	6.4	0.3	46.3	2.6	6.3	0.3	7.0	0.4	-	-	2.2	0.1	185.0	10.4
Otter Creek	950.2	53.3	7.5	0.4	29.6	1.6	1.5	0.1	4.2	0.2	-	-	269.3	15.1	37.1	2.0	6.8	0.3	75.1	4.2	40.0	2.2	7.0	0.4	0.4	+	16.9	0.9	454.8	25.5
– *Spearing Ck.*	1082.8	60.8	7.6	0.4	30.7	1.7	1.5	0.1	4.2	0.2	-	-	320.8	18.0	37.1	2.0	6.8	0.3	87.8	4.9	69.2	3.8	7.0	0.4	0.4	+	17.5	0.9	492.4	27.6
– *Thynne Ck.*	1129.1	63.4	7.7	0.4	30.7	1.7	1.5	0.1	4.2	0.2	-	-	336.2	18.8	37.1	2.0	6.8	0.3	90.8	5.1	69.2	3.8	7.0	0.4	0.4	+	17.5	0.9	520.2	29.2
Granite Creek	1395.7	78.4	7.7	0.4	30.7	1.7	1.9	0.1	4.2	0.2	-	-	428.4	24.0	37.6	2.1	7.4	0.4	125.2	7.0	70.0	3.9	7.0	0.4	0.4	+	19.4	1.0	656.0	36.8
Asp Creek	1462.3	82.1	8.0	0.4	30.7	1.7	1.9	0.1	4.2	0.2	-	-	438.6	24.6	40.9	2.2	7.4	0.4	128.6	7.2	77.5	4.3	7.0	0.4	0.9	+	19.4	1.0	697.4	39.1
Tulameen Mainstem & Residual Sub-basins	**1779.5**	**100.0**	**10.2**	**0.6**	**34.1**	**1.9**	**3.0**	**0.2**	**4.2**	**0.2**	**0.1**	**0.0**	**524.0**	**29.5**	**43.0**	**2.4**	**7.4**	**0.4**	**146.4**	**8.2**	**94.1**	**5.3**	**7.6**	**0.4**	**4.3**	**0.2**	**21.2**	**1.2**	**879.9**	**49.4**

NOTE: *Spearing* and *Thynne Creeks* are tributaries to Otter Creek.
"+" indicates a value of ≤0.05

TABLE 2.5.3: INTERIOR WATERSHED ASSESSMENT RESULTS FOR THE TULAMEEN WATERSHED

	LEVEL 1 IWAP HAZARD INDICES				LEVEL 2 REQUIRED	ASSESSED IN THIS REPORT
	PEAK FLOW	SURFACE EROSION	RIPARIAN BUFFER	MASS WASTING		
Tulameen River above Holding Creek	0.20	0.85	0.08	0.06	No	Yes
Holding Creek	0.34	1.00	0.00	0.13	No	Yes
Podunk Creek	0.17	0.58	0.11	0.03	No	Yes
Tulameen River above Vuich Creek	0.21	0.72	0.04	0.06	No	Yes
Vuich Creek above Sutter Creek	0.19	0.50	0.00	0.04	No	Yes
Sutter Creek	0.05	0.63	1.00	0.00	Yes	No
Vuich Creek	0.13	0.47	0.21	0.00	No	Yes
Jim Kelly Creek	0.09	0.54	0.00	0.00	No	Yes
Champion Creek	0.56	1.00	0.23	0.19	Yes	Yes
Britton Creek above Illal Creek	0.50	0.72	0.34	0.03	No	Yes
Illal Creek	0.22	0.52	0.48	0.00	No	No
Lawless Creek upstream of Holm Creek	0.47	1.00	0.77	0.18	Yes	Yes
Holm Creek	0.70	1.00	0.81	0.57	Yes	No
Lawless Creek	0.52	1.00	0.75	0.34	Yes	Yes
Tulameen River between Vuich Creek and Otter Creek excluding Lawless Creek	0.41	0.95	0.36	0.09	No	Yes
Otter Creek including Bates Creek	0.44	0.93	0.80	0.00	Yes	Partially
Guliford Creek	0.72	1.00	1.00	0.06	Yes	No
Otter Creek above McCullogh Creek	0.40	1.00	1.00	0.01	Yes	Yes
Spearing Creek above McPhail Creek	0.46	1.00	1.00	0.04	Yes	Yes
Mcphail Creek	0.46	1.00	1.00	0.04	Yes	No
Spearing and McPhail Creeks	0.52	1.00	1.00	0.02	Yes	Partially
Thynne Creek	0.30	0.70	0.27	0.01	No	Yes
Manning Creek	0.74	1.00	1.00	0.01	Yes	No
Elliot Creek	0.44	0.88	1.00	0.00	Yes	No
Otter Creek below McCullogh Creek excluding Mcphail and Spearing Creeks	0.47	1.00	0.87	0.08	Yes	Yes
Granite Creek above Arrastra Creek	0.75	1.00	0.66	0.13	Yes	Yes
Arrastra Creek	0.48	1.00	0.65	0.09	Yes	No
Granite Creek	0.62	1.00	0.52	0.13	Yes	Yes
Asp Creek	0.51	1.00	0.95	0.03	Yes	Yes
Cook Creek	0.57	0.65	0.42	0.00	Yes	No
Tulameen River below Otter Creek excluding Granite Creek	0.47	0.95	0.76	0.06	Yes	Yes

KEY:
- Green — values ≤0.49
- Blue — values between 0.50 and 0.74
- Red — values ≥0.75

NOTE: Hazard indices ≥0.5 (except for Surface Erosion) indicate that a Level 2 IWAP analysis is justified. Summary format and hazard indices are from a report by *Middle Fork GIS, 1997*.

TABLE 3.3.1: SUMMARY OF STREAM CHANNEL IMPACTS

WATERSHED	STREAM CHANNEL LENGTH	LENGTH OF IMPACTED CHANNEL AS A RESULT OF:																		TOTAL LENGTH OF IMPACTED STREAM CHANNEL	
		FIRE		FLOODS		NATURAL LANDSLIDES		ANTHROPOGENIC LANDSLIDES		RIPARIAN LOGGING		RIPARIAN CLEARING FOR FOR GRAZING OR AGRICULTURE		DOWNSTREAM SEDIMENT MOVEMENT		ROAD OR RAILWAY CONSTRUCTION		MINING			
	Km	Km	%	Km	%	Km	%	Km	%	Km	%	Km	%	Km	%	Km	%	Km	%	Km	%
Tulameen River	83.5	12.7	15	6.8	8	5.0	6	4.9	6	13.7	16	14.5	17	3.4	4	10.5	13	2.1	3	73.6	88
Holding Creek	11.5	2.2	19	1.9	17	1.0	9													5.1	44
Podunk Creek	14.7	5.8	39	2.1	14					4.4	30									12.3	84
Vuich Creek	17.4	4.8	28	5.8	33	2.9	17													13.5	78
Jim Kelly Creek	11.5			3.9	34	2.8	24									1.1	10			7.8	68
Champion Creek	12.9			1.0	8			0.2	2	7.2	56	1.6	12							10.0	78
Britton Creek	17.6									8.9	51									8.9	51
Lawless Creek	26.7	1.4	5					3.7	14	16.8	63			1.1	4	2.6	10			25.6	96
Olivine Creek	12.8									6.1	48			1.4	11			2.3	18	9.8	77
Otter Creek	67.7			0.5	1							36.2	53			25.3	37			62.0	92
Spearing Creek	11.8											0.8	7	2.3	19	3.4	29			6.5	55
Thynne Creek	11.7	1.0	9	1.8	15			0.8	7	1.1	9	0.5	4							5.2	44
Granite Creek	33.4	13.4	40	3.0	9	2.9	9	1.0	3	1.4	4			9.0	27	0.2	1	0.7	2	31.6	95
Asp Creek	22.4							1.6	7	5.6	25									7.2	32
TOTAL	**355.6**	**41.3**	**12**	**26.8**	**8**	**14.6**	**4**	**12.2**	**3**	**65.2**	**18**	**53.6**	**15**	**17.2**	**5**	**43.1**	**12**	**5.1**	**1**	**279.1**	**78**

TABLE 4.0.1: SUMMARY OF FIELD INSPECTION PRIORITIES

WATERSHED	CHANNEL LENGTH (km)	PRIORITY LEVEL FOR FIELD INSPECTION	ASSESS SITE CONDITIONS DUE TO: FIRE AND/OR FLOOD HISTORY		NATURAL LANDSLIDES		ANTHROPOGENIC LANDSLIDES		RIPARIAN LOGGING		RIPARIAN CLEARING FOR GRAZING OR AGRICULTURE		DOWNSTREAM SEDIMENT MOVEMENT		ROAD OR RAILWAY CON-STRUCTION		BRIDGE CROSSINGS		MINING		FISH HABITAT RESTORATION OPPORTUNITIES		TOTAL	
			Km	%	Km	%	Km	%	Km	%	Km	%	Km	%	Km	%	Km	%	Km	%	Km	%	Km	%
Tulameen River	83.5	Low	13.8	17	7.1	9	0.4	0					1.6	2							1.7	2	24.6	29
		Medium	4.7	6			6.9	8	1.4	2	0.5	1	0.4	0	12.7	15	0.5	1					27.1	32
		High					0.9	1	5.3	6	9.4	11	0.6	1	7.4	9							23.6	28
Holding Creek	11.5	Low	3.3	29	1.8	16																	5.1	44
		Medium																					0.0	0
		High																					0.0	0
Podunk Creek	14.7	Low	5.2	35																			5.2	35
		Medium	3.0	20					5.1	35													8.1	55
		High																					0.0	0
Vuich Creek	17.4	Low	6.8	39	2.9	17																	9.7	56
		Medium	5.8	33																			5.8	33
		High																					0.0	0
Jim Kelly Creek	11.5	Low			2.8	24											0.9	8					3.7	32
		Medium	3.9	34																			3.9	34
		High															0.2	2					0.2	2
Champion Creek	12.9	Low							1.5	12			1.2	9									2.7	21
		Medium					2.2	17	2.5	19													4.7	36
		High					0.5	4	1.7	13													2.2	17
Britton Creek	17.6	Low																					0.0	0
		Medium							4.2	24													4.2	24
		High							4.7	27													4.7	27
Lawless Creek	26.7	Low	1.4	5	3.7	14			1.9	7													7.0	26
		Medium							5.3	20													5.3	20
		High							13.3	50													13.3	50
Olivine Creek	12.8	Low							3.8	30													3.8	30
		Medium							1.6	13													1.6	13
		High							2.2	17									2.3	18			4.5	35
Otter Creek	67.7	Low									17.0	25			7.1	10							24.1	36
		Medium	0.5	1							15.6	23			4.4	6							20.5	30
		High									6.8	10			13.1	19					1.8	3	21.7	32
Spearing Creek	11.8	Low													3.4	29							3.4	29
		Medium											0.8	7									0.8	7
		High											2.3	19									2.3	19
Thynne Creek	11.7	Low	2.8	24																	0.8	7	3.6	31
		Medium							4.5	38													4.5	38
		High									0.5	4											0.5	4
Granite Creek	33.4	Low	12.4	37	1.4	4			1.6	5							0.2	1					15.6	47
		Medium			1.3	4	0.4	1	2.4	7			7.6	23	3.0	9							14.7	44
		High					0.5	1											0.7	2			1.2	4
Asp Creek	22.4	Low					1.0	4	0.1	0													1.1	5
		Medium					0.6	3	5.5	25													6.1	27
		High																					0.0	0
TOTAL	**355.6**	**Low**	**45.7**	**13**	**19.7**	**6**	**1.4**	**0**	**8.9**	**3**	**17.0**	**5**	**2.8**	**1**	**7.1**	**2**	**1.1**	**0**	**0.0**	**0**	**2.5**	**1**	**106.2**	**30**
		Medium	**17.9**	**5**	**1.3**	**0**	**10.1**	**3**	**32.5**	**9**	**16.1**	**5**	**8.0**	**2**	**20.1**	**6**	**0.5**	**0**	**0.0**	**0**	**0.0**	**0**	**106.5**	**30**
		High	**0.0**	**0**	**0.0**	**0**	**1.9**	**1**	**27.2**	**8**	**16.7**	**5**	**0.6**	**0**	**20.5**	**6**	**0.2**	**0**	**3.0**	**1**	**1.8**	**1**	**71.9**	**20**

TABLE 5.0.1: CHANNEL RESTORATION OPPORTUNITIES

WATERSHED	TOTAL CHANNEL LENGTH (Km)	LENGTH OF STREAM CHANNEL WITH OPPORTUNITIES FOR RESTORATION						TOTAL LENGTH OF STREAM CHANNEL RESTORATION OPPORTUNITIES	
		LOW PRIORITY		MEDIUM PRIORITY		HIGH PRIORITY			
		KM	%	KM	%	KM	%	KM	%
Tulameen River	83.5	24.6	29	25.6	31	24.1	29	74.3	89
Holding Creek	11.5	2.8	24	1.2	10	0.0	0	4.0	35
Podunk Creek	14.7	7.0	48	3.4	23	3.0	20	13.4	91
Vuich Creek	17.4	8.7	50	6.2	36	0.0	0	14.9	86
Jim Kelly Creek	11.5	3.7	32	3.9	34	0.2	2	7.8	68
Champion Creek	12.9	2.7	21	5.2	40	1.7	13	9.6	74
Britton Creek	17.6	0.0	0	7.5	43	1.4	8	8.9	51
Lawless Creek	26.7	11.8	44	9.1	34	5.4	20	26.3	99
Olivine Creek	12.8	3.9	30	3.8	30	0.5	4	8.2	64
Otter Creek	67.7	18.1	27	22.3	33	23.7	35	64.1	95
Spearing Creek	11.8	3.4	29	0.8	7	2.3	19	6.5	55
Thynne Creek	11.7	3.6	31	0.0	0	0.5	4	4.1	35
Granite Creek	33.4	13.8	41	16.5	49	1.2	4	31.5	94
Asp Creek	22.4	0.8	4	6.2	28	0.0	0	7.0	31
TOTAL	**355.6**	**104.9**	**29**	**111.7**	**31**	**64.0**	**18**	**280.6**	**79**