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Climate Trends in the Salmon River Basin of British Columbia

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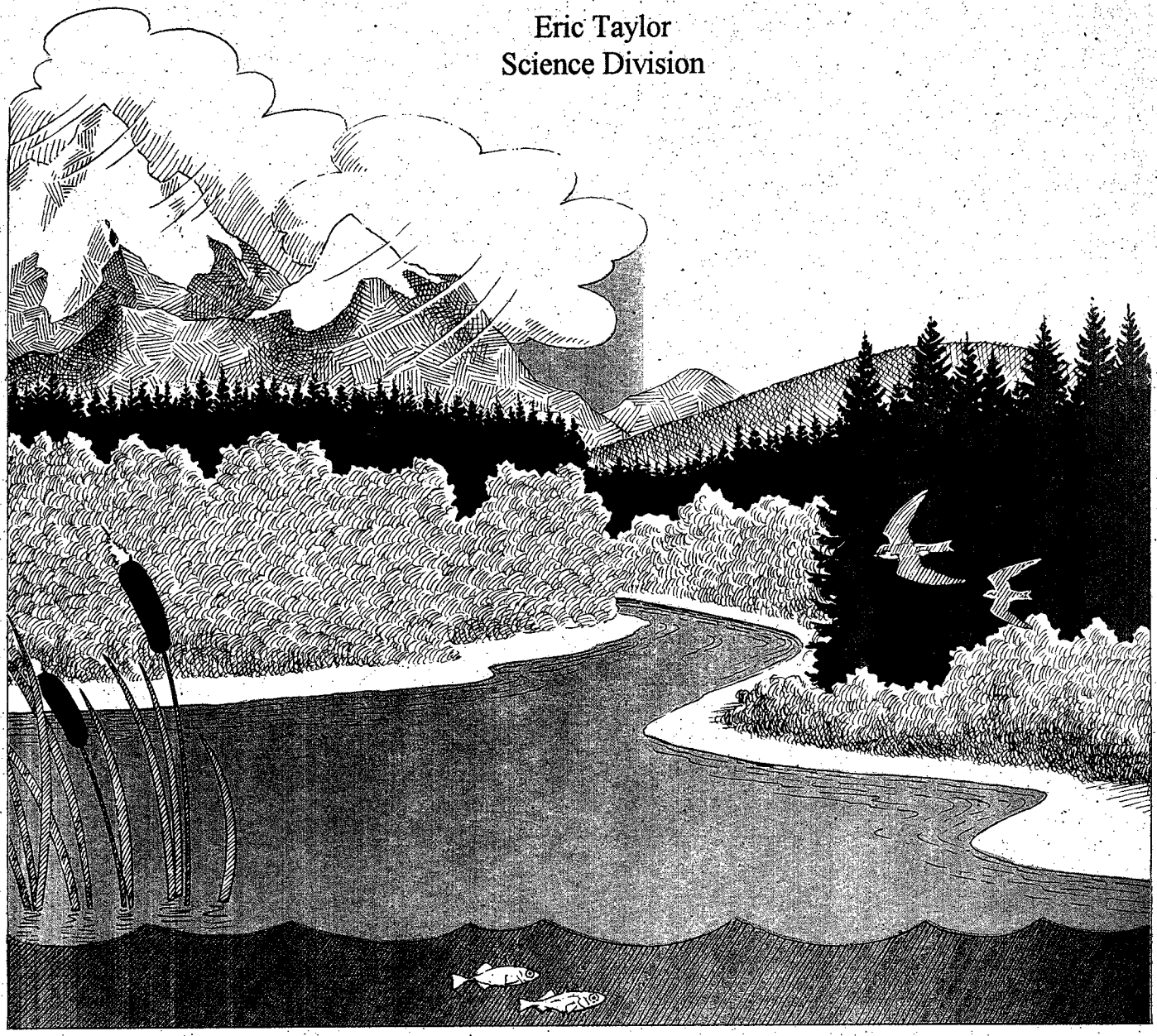
Science Division



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CLIMATE TRENDS IN THE SALMON RIVER BASIN OF BRITISH COLUMBIA

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This paper examines long-term temperature and precipitation trends in the instrumental record of the Salmon River Basin of British Columbia. The climate record of two stations in the basin, Salmon Arm and Westwold, which have operated since 1921, were analysed. Overall annual temperatures have declined at both stations, most noticeably at Salmon Arm, with most of this cooling occurring in spring and autumn. However, winter temperatures have noticeably increased in Westwold. Precipitation trends were inconsistent across the basin. Overall, Salmon Arm precipitation has increased about 15% since the 1920s, with this increase confined to the spring, summer and autumn. Conversely, overall Westwold precipitation has decreased about 10%, due mainly to drier autumns and winters.

1. Introduction

The Salmon River Basin has been selected by the Environmental Conservation Branch of Environment Canada as a pilot project to determine ecosystem objectives. In support of this work, this paper describes climate trends in the basin during this century.

The Salmon River Basin (Figure 1) is in the southern interior of British Columbia in the plateau area between the Coast Range mountains and the Rockies. The Salmon River is a relatively small river about 160 kilometres long. The area of the Salmon River Basin is about 1400 km^2.

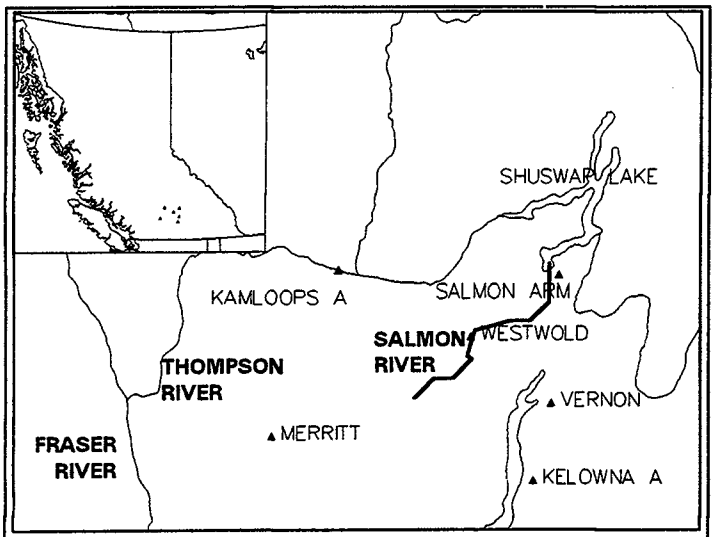

Figure 1. The Salmon River rises about 60 km east-northeast of Merritt in the southern interior of British Columbia. It flows northeastwards through Westwold and into Shuswap Lake near Salmon Arm. The Salmon River Basin extends about 15 km on either side of the river. The six communities on this map are also shown on the inset map of British Columbia.

2. Data

2.1 Selection of Climate Stations in the Salmon River Basin

Two climate stations were analyzed in this study: Salmon Arm, near the outlet of the Salmon River, and Westwold, near the centre of the Salmon River Basin. These two stations have a relatively long and continuous period of record. Other climate sites in the basin were not used due to either the shortness of the climate record or the numerous gaps in the record. All data used in this study were either monthly mean temperature or monthly total precipitation. These data were obtained from the Atmospheric Environment Service National Climate Archive.

2.2 Climatology of Westwold and Salmon Arm

The Westwold climate station is located near the geographical centre of the Salmon River Basin. The terrain surrounding the climate station is moderately treed, level grassland with mountains rising to 1700 metres along the sides of the valley.

The Salmon Arm A climate site is located 4 kilometres

Table 1. Annual temperature and precipitation at Westwold and Salmon Arm, based on 1951-1980 temperature and precipitation records. Statistics are from Canadian Climate Normals, 1951-80, Atmospheric Environment Service.

Climate Element	Westwold	Salmon Arm
Daily maximum temperature (°C)	12.8	12.9
Daily minimum temperature (°C)	-1.1	2.3
Daily mean temperature (°C)	5.9	7.6
Extreme maximum temperature (°C)	39.4	41.1
Extreme minimum temperature (°C)	-45.6	-35.0
Mean annual precipitation (mm)	319.5	533.7
Days with measurable precipitation	111	122

southeast of the southern end of Shuswap Lake near the outlet of the Salmon River. The station is on a grassed portion of a bench 150 metres above the lake. The general terrain surrounding the Salmon Arm site is heavily treed and mountainous. Shuswap Lake likely exerts a moderating influence on the climate of Salmon Arm, which has a daily minimum temperature several degrees higher than Westwold. Salmon Arm also receives about 67% more annual precipitation than Westwold. A comparison of the annual temperature and precipitation at each site is shown in Table 1.

This study analyses trends in temperature or precipitation at Salmon Arm and Westwold. These data may not be homogeneous in time. Homogeneities in climate data can result from the movement of a climate station, changes in vegetation around a site, and changes in the measurement instruments and recording practices. The precipitation time series is particularly vulnerable to movement of a climate station, as precipitation can vary considerably over short distances, particularly in irregular terrain. Homogeneity testing for temperature has been performed for a number of Canadian climate stations. (Gullett 1991). Salmon Arm and Westwold were not among these stations. However, climate data from both sites is routinely quality-controlled prior to entry into the National Climate Archive.

To identify large station movements, station changes as reported by the Climatological Station Catalogue (Atmospheric Environment Service,1989) were examined for Westwold and Salmon Arm.

a) Observations were conducted at Westwold, 50 ° 29'N, 119° 45'W at elevation 617m, from May 1921 to February 1964. The station was then moved 2.5 kilometres to 50°28'N, 119° 43'W, elevation 616m.

b) The Salmon Arm climate record used in this study is a compilation of both Salmon Arm, 50° 42'N, 119° 15'W, elevation 506m, and Salmon Arm A, 50° 41'N, 119° 14'W, elevation 527m. Salmon Arm operated from July 1911 through to July 1982. Salmon Arm A operated from September 1982 to the present.

These station movements are not large but some of the station changes described above could have introduced artificial changes into the climate record. Also, there may have been smaller climate station movements or observing program changes that were not recorded in the Climate Station Catalogue. Since none of the data used from these four climate sites has undergone rigorous homogeneity testing, temperature and precipitation trends may possibly be affected as a result of these station changes. A much more detailed analysis of the station history files would be necessary for a complete assessment of data homogeneity but this is beyond the scope of the present preliminary analysis.

3. Methods.

3.1 Precipitation Measurement Methods

Daily snowfall, the depth of newly fallen snow on the ground, was measured with a snow ruler at both climate sites throughout their history. Liquid precipitation was measured at both Salmon Arm and Westwold using Type A Rain Gauges until

Table 2. Number of months of missing data and methods used to estimate temperature and precipitation values.

Station	Monthly Parameter	Total missing months of data	Number of months estimated by first estimating daily data	Number of months estimated by comparison with nearby stations.
Salmon Arm	Precipitation	10	6	4
	Temperature	2	0	2
Westwold	Precipitation	8	3	5
	Temperature	20	19	1

the 1970s, and Type B Rain Gauges more recently. Type A Rain Gauges used a copper cylinder to collect precipitation, which was subsequently measured by pouring the water into a graduated container. Type B Rain Gauges use a clear plastic graduated cylinder to collect and directly measure the precipitation. The Atmospheric Environment Service estimates the water-equivalent of newly fallen snow by assuming that one centimetre of snowfall is equivalent to one millimetre of liquid water.

3.2 Treatment of Missing Data

A number of months of temperature and precipitation data were missing from the record. These missing monthly data were estimated as follows.

When only five days or less of data were missing in a particular month, these missing daily values were replaced with the average value of the observed daily data for that specific month and year. The monthly temperature (precipitation) values were then estimated by averaging (summing) all of the observed and estimated daily values.

When more than five days of data were missing in a month, the monthly value at a nearby station was used in the estimating procedure. Temperature was estimated by calculating the average difference between the monthly temperature at the station and that at the nearby station for 10 years prior to, and 10 years following the missing event. The missing monthly temperature was estimated by adding this difference to the monthly temperature of the nearby station for the specific month that was missing. Precipitation was estimated by calculating the average ratio between the monthly precipitation at the station and that at the nearby station for 10 years prior to, and 10 years following the missing event. The missing monthly precipitation was estimated by multiplying this ratio by the precipitation at the nearby station that was observed in that month.

This procedure resulted in all missing temperature and precipitation data being estimated for the period of record. Table 2 summarizes the number of months of missing data that were estimated in this study and the method used to do this estimation.

3.3 Period of Climatology Record.

The period of record of each climate station is shown in Table 3. The Salmon Arm record is a compilation of two stations; Salmon Arm (station number 1166945) and Salmon Arm A (station number 1166R45). Westwold (station number 1168880) operated continuously through the period of record.

The common precipitation period of record for the two stations was May 1921 to August 1993. The common period of record for temperature was May 1921 to December 1990. Any comparisons of climate trends made in this study between the sites will refer to this common period.

This study analyses both seasonal and annual climate trends. Seasons are defined as follows:

i) Winter: December, January, February.

Table 3. Period of Record of Monthly Climate Station Data.

	Parameter	Start of record	End of Record
Salmon Arm	Precipitation	Aug, 1911	Aug, 1993
	Temperature	July, 1911	Dec, 1990
Westwold	Precipitation	May, 1921	Sept, 1993
	Temperature	May, 1921	Sept, 1993

ii) Spring: March, April, May.
iii) Summer: June, July, August.
iv) Autumn: September, October, November.

Annual climate data used in this study is based on the January through December period, and so does not coincide exactly with four complete seasons as defined above. Graphs of the annual and seasonal climate data based on mean monthly temperature and total monthly precipitation appear in the Appendix.

Trends in the data were estimated from the changes in the fifteen-year moving average of annual and seasonal temperature and precipitation throughout the period of record.

Table 4. Trends in annual and seasonal temperature at two climate sites in the Salmon River basin from May 1921 to December 1990. Trends are based upon the 15 year moving average of the seasonal and annual temperature time series. Temperature trends based on moving averages that exhibit a cyclical pattern or a visible departure from a linear trend are labeled as "variable".

	Westwold (°C)	Salmon Arm (°C)
Winter	+1.	0.0 (variable
Spring	-0.9 (variable	-0.
Summer	0.	-0.8 (variable
Autumn	-0.	-1.
Annual	-0.2 (variable	-0.8 (variable

4. Results

The appendix contains annual and seasonal graphs of temperature and precipitation at both Salmon Arm and Westwold. These graphs also show the fifteen-year moving average of the annual data. This section summarizes the analysis of these graphs during the common period of record. Trends were obtained using a regression line fitted to the fifteen-year moving average of temperature and precipitation, in order to identify any long term changes in these parameters. The regression line extends for the entire period of record, though it only is meaningful for the domain of the 15 year moving average. This domain is the period 1928-1983 for temperature, and 1928-1985 for precipitation.

4.1 Temperature

4.1.1 Annual temperature.

Table 4 summarizes the seasonal and annual temperature trends during the common period of record for each climate station. These trends are the changes in the regression line fitted to the 15 year moving average. The trends in annual temperature change does not exactly equal the average of the seasonal temperature changes since regression methods were used to estimate each of the trends.

The fifteen year moving averages of annual temperature at both climate stations have an underlying temperature cycle with a period of about 25 years. This cycle begins with a slight temperature rise early in the period of record and peaking around 1938, a temperature decline until about 1950, and another rise until the mid 1960's. Overall, annual temperatures have decreased since the 1920s in the Salmon River basin, declining 0.2 °C at Westwold and 0.8°C at Salmon Arm.

4.1.2 Seasonal Temperature

Temperatures have declined overall during spring and autumn at both climate sites in the basin. However, temperature trends are not as consistent in winter and summer. Winter temperatures have risen noticeably in Westwold, while remaining steady at Salmon Arm. Conversely, summer temperatures have declined in Salmon Arm, while remaining steady at Westwold.

4.2 Precipitation

4.2.1 Annual Precipitation

Table 5 summarizes the seasonal and annual precipitation trends during the common period of record for each climate station. As with temperature, the trends in annual precipitation change do not exactly equal the sum of the seasonal precipitation changes.

Noticeable differences in annual precipitation trends occurred at the two climate sites. At Westwold, the fifteen year moving average suggests the existence of a long-term precipitation cycle with a period of the order of 50 years. No such cycle is evident at Salmon Arm. A regression line based on the fifteen year moving average suggests an overall decrease in precipitation at Westwold of 30 millimetres (about 10%) since the 1920s. Conversely, there was an overall precipitation increase of about 80 millimetres (about 15%) at Salmon Arm since the 1920s. This increase cannot be explained by the relocation of the station in 1982, as most of the increase occurred before the station was moved.

Table 5. Trends in annual and seasonal precipitation at two climate sites in the Salmon River Basin from May 1921 to August 1993 in millimetres of water equivalent. Trends are based upon the fifteen year moving average of the seasonal and annual precipitation time series. Precipitation trends based on moving averages that exhibit a cyclical pattern or a visible departure from a linear trend are labeled as "variable".

	Westwold (mm)	Salmon Arm (mm)
Winter	-25	0
Spring	0 (variable)	+15
Summer	+10	+45
Autumn	-15 (variable)	+20
Annual	- 30 (variable)	+80

4.2.2 Seasonal Precipitation

Seasonal precipitation changes since 1921 have not been consistent at both climate stations. While spring, summer and autumn precipitation has shown overall increases at Salmon Arm, the precipitation changes at Westwold were more varied. Summer precipitation at Westwold has increased about 10 millimetres, (about 10%), and this increase is more evident since the mid 1970s. Winter and autumn precipitation in Westwold has shown an overall decrease of about 20%, while there is little trend in overall spring precipitation.

5. Conclusion

Monthly temperature and precipitation records for the period 1921-1993 at Westwold and Salmon Arm were examined to estimate any climate trends in the Salmon River Basin.

There has been a decrease in annual temperatures in the Salmon River basin as measured at Salmon Arm and Westwold for the common period of record (1922-1990). Seasonally, temperatures have fallen at both sites in spring and autumn. Temperature trends are not as consistent across the basin in winter and summer.

Annual and seasonal precipitation changes are not consistent across the Salmon River Basin since the 1920s. Annual precipitation has decreased at Westwold, while increasing at Salmon Arm. Similar inconsistencies occur on a seasonal basis.

Acknowledgments.

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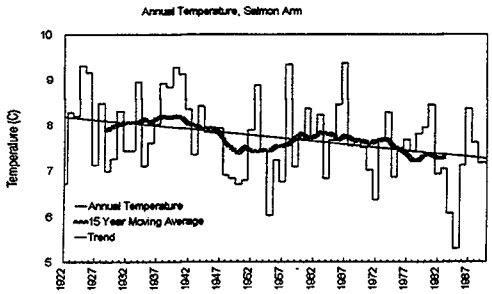
Gullett, D.W., L. Vincent and L.H. Malone, 1991. Homogeneity Testing of Monthly Temperature Series. Atmospheric Environment Service, Internal CCC Report 91-10.

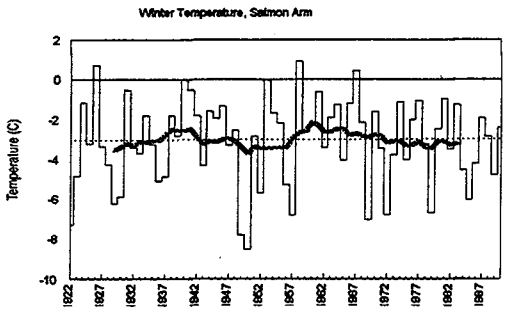
Gullett, D.W. and W.R. Skinner, 1992. The State of Canada's Climate: Temperature Change in Canada 1895-1991. A State of the Environment Report number 92-02.

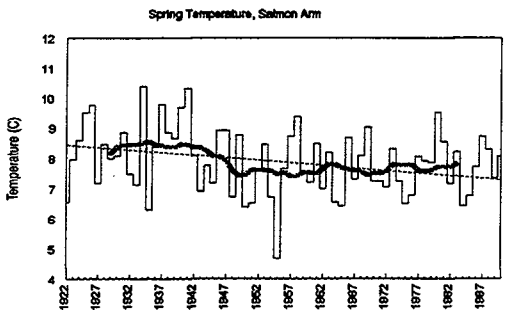
Appendix

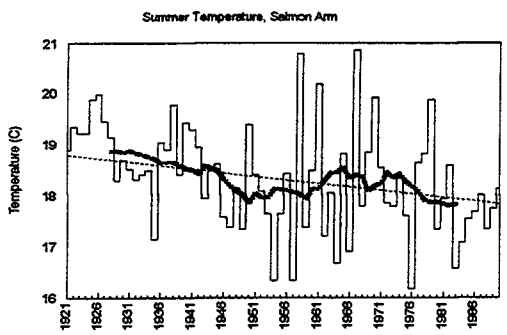
Salmon River Basin Temperature Trends

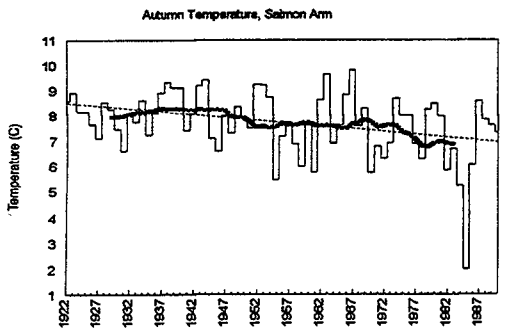
Salmon Arm



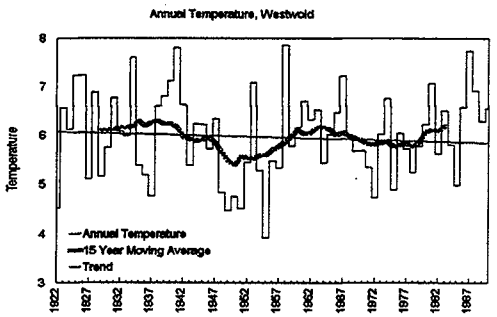


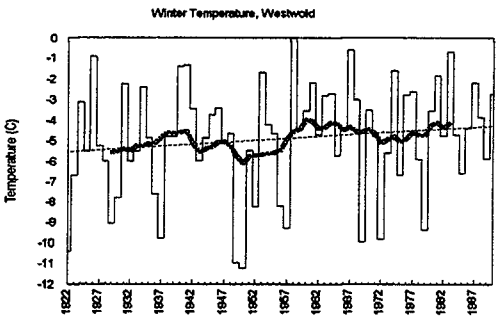


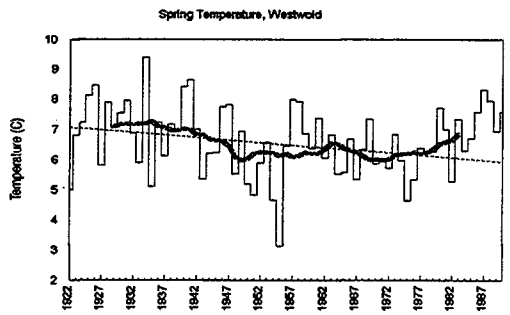


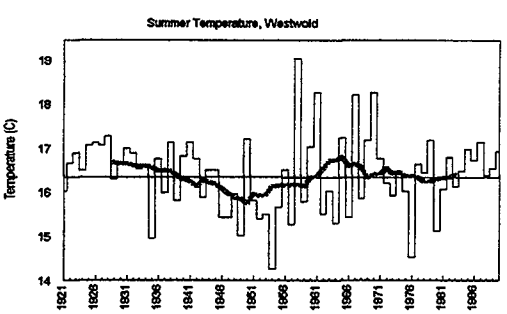


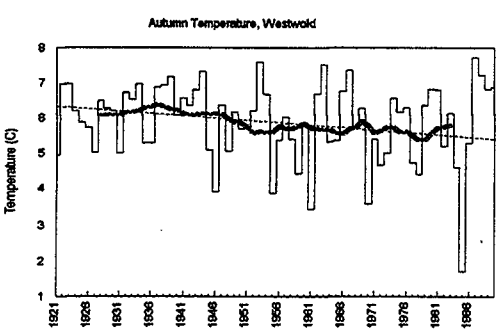
Westwold









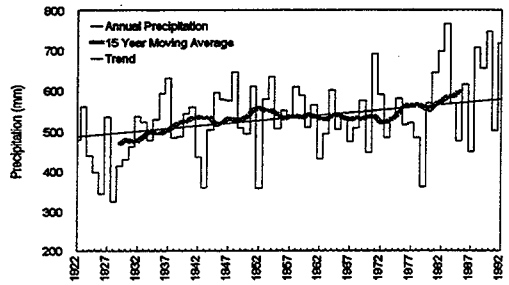


Appendix

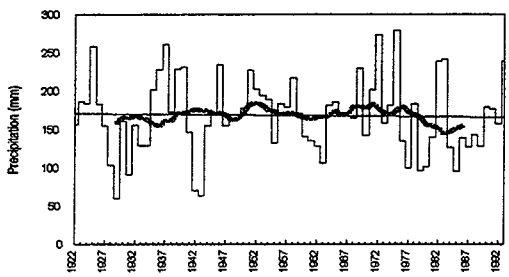
Salmon River Basin Precipitation Trends

Salmon Arm

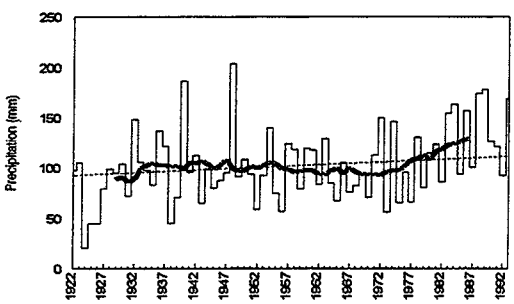
Annual Precipitation, Salmon Arm



Winter Precipitation, Salmon Arm



Spring Precipitation, Salmon Arm



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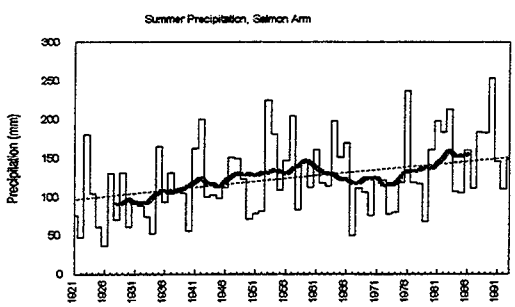
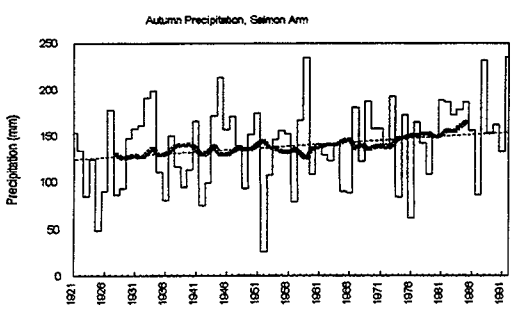
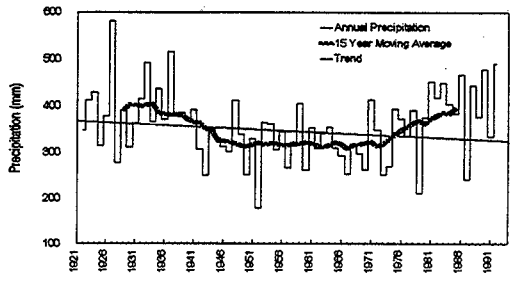


Autumn Precipitation, Salmon Arm

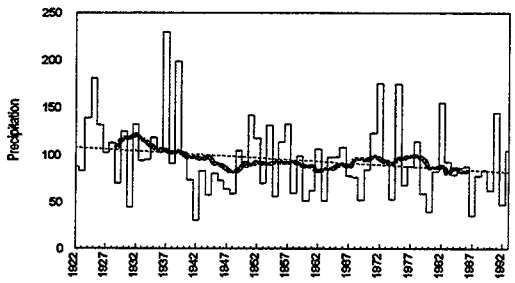


Westwold

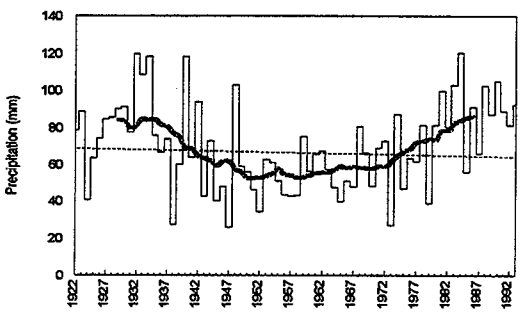
Annual Precipitation, Westwold



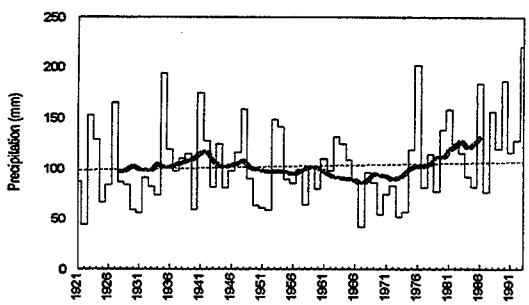
Winter Precipitation, Westwold



Spring Precipitation, Westwold



Summer Precipitation, Westwold



Autumn Precipitation, Westwold