Winter damage to grapevines occurs due to the interaction of a large number of factors. The extent and amount of damage to vines which might be expected during an extremely cold winter depends upon climatic factors, the grape variety planted, soil type, and the level of farm management. The climatic factors contributing to problems of winter damage depend primarily upon extreme winter minimum temperatures, snow cover, wind and early autumn freezes.

In Washington State a threshold temperature of -23°C has been identified as the temperature at which injury to both buds and trunks begins to occur to the more sensitive European grape varieties (Tukey and Clore, 1972). While the mid winter -23°C threshold begins to damage the vines early winter cold can also harm the grapes. Paroschy and Meiring (1978) determined that grape leaves must remain on the vine for three to four weeks after the harvest to permit the build-up of carbohydrate reserves in the storage tissue and natural protective waxes. This accumulation and concentration of carbohydrates and waxes is responsible for the grape plant becoming winter hardy (Paroschy, 1978). A 1955 cold wave enveloped the Okanagan Valley beginning on November 11th and resulted in considerable damage to grapevines as temperatures fell to -17°C at Summerland C.D.A., Penticton Airport and Oliver. This severe arctic outbreak so early in the winter, resulted in a 78% drop in production from the previous year throughout the region.

A temperature of -12°C on or before November 15th has been identified as the temperature which will begin to cause damage to grapevines early in the winter. More severe damage to vines occurs as winter temperatures drop to -20°C. Work done by Meiering et al. (1980) on Gewurtztraminer grapes in Ontario revealed that extensive mechanical damage to phloem and xylem layers of the grapes was observed at -25°C.

The funnelling of wind by the narrow southern interior valleys is responsible for strong and persistent winds during both the growing season and winter months. The Similkameen Valley is oriented east to west near Keremeos, and north to south in the Cawston area, which tends to funnel winds in those directions. Wind is also increased and funnelled north or south within the Okanagan Valley, particularly in the area from Osoyoos to Westbank. Northward in the Kelowna area, a widening of the valley leads to a decrease in wind speeds. Persistent high winds during the growing season may delay grape maturity and increase potassium levels into the phloem and the grape berries (Freeman, Kliewer and Stern, 1982). Winter winds are also an important factor with respect to grape growing. The elevated sloping lands, although milder, are more exposed to high winds and often have their protective snow cover removed as a result of drifting. Damage on these sites is a function of not only winter cold, but also the high winds and lack of snow cover. The grapevines become more exposed to the harmful effects of the drying winter winds and cold temperatures. A lack of snow cover during arctic outbreaks encourages freezing of the soil and subsequent desiccation to the grapevines.

Shelterbelts or windbreaks have been used throughout the world as a means of protecting crops and soil from the detrimental effects of strong winds (World Meteorological Organization, 1964). Areas where winds cause significant problems include much of the Similkameen Valley and sloping lands in the south Okanagan, most particularly the east side of the valley south of Oliver. The main valley from Okanagan Falls to Westbank also experiences high winter winds.

2.5.1 Synoptic Conditions Resulting In Winter Damage To Grapevines

The weather conditions that lead to winter damage of grapevines within the Similkameen and Okanagan Valleys are the result of severe outbreaks of very cold air masses originating in the continental regions of Canada's Arctic. Often the arctic air flowing into the Okanagan is not cold enough to cause damage to perennial crops such as grapevines. On occasion, however, the major dome of the cold air mass flows southward over the province. These severe arctic outbreaks occur as a result of the formation of a strong high pressure ridge just to the west of British Columbia, combined with the formation of a cold and heavy arctic air mass over the Yukon and Alaska. These conditions produce a strong cold northerly flow in the upper air which can bring the arctic front southward through the Okanagan and Similkameen Valleys. After the passage of the arctic front, the cold air often dries and deepens resulting in a further lowering of already severe temperatures. It is during these synoptic situations that most of the winter damage has occurred to vineyards in the study area.

2.5.2 Observations of Recent Winter Damage To The Okanagan and Similkameen Grape Crop

The most recent winter of serious widespread damage to grapevines was that of 1978/79. An arctic front passed south of the region on December 26th. After the passage of the front, a strenghtening of the upper arctic ridge occurred. The result was a deepening of the cold air mass over the region, temperatures lowered and winds from the north increased. Temperatures during December, 1978 fell to -25°C at Keremeos, -25°C at Osoyoos, -26°C at Oliver, - 21°C at Penticton Airport, -23°C at Summerland CDA, and from -22°C to -31°throughout the Kelowna area.

These low temperatures, in combination with strong winds and a light snowpack all contributed to damage to the grapevines. Damage to vines was further compounded by the cool late summer weather conditions and a heavier than usual grape crop, resulting in a late grape harvest. A severe mid November freeze killed grape leaves shortly after harvest and before the vines had the opportunity to become winter hardy (Denby and Vielvoye, 1979). Damage ranged from moderate to severe throughout most areas of the Okanagan and Similkameen. A complex pattern of damage was revealed upon examination of vineyards during the next spring and summer. More than 50% of the vines in the Similkameen Valley were damaged severely. Throughout the southern part of the Okanagan Valley, in areas south of Okanagan Falls more than 50% of vines showed severe winter damage. Although temperatures in the south Okanagan and Similkameen were not as low as in the areas north of Summerland, higher winds and less snow cover associated with sandy soils all contributed to more vine kill in the southern districts. These conditions resulted in a substantial amount of mechanical freeze damage and subsequent dehydration of vine root systems on sandy soils.

In exposed localities as far north as Summerland and Westbank more than 20% of the vines were severely damaged. East Kelowna, a region away from the lake and not exposed to strong winds, despite having temperatures of -26°C, had less damage. The damage to vines was approximately 10% in the East Kelowna area. Table 17 reveals the winter conditions that resulted in most of the observed damage.

Table 17
1978/1979 Winter Conditions

Climate Station	Extreme Winter Minimum Temperature	December 31 Snowpack
Keremeos	-24.5°C	6 cm
Osoyoos	-25.0°C	Trace
Oliver	-25.5°C	0 cm
Penticton Airport	-20.8°C	2 cm
Summerland C.D.A.	-22.5°C	6 cm
Kelowna Airport	-30.5°C	15 cm
Keloka BCMAF	-26.0°C	not measured
Okanagan Centre	-25.5°C	not measured

The winter of 1972/73 also produced considerable damage to grapevines. Overall production was reduced by 577 tonnes from the previous year. Severe early autumn freezes during the period September 17 to 26th, killed grape leaves and prevented grapevines from becoming winter hardy. This was a contributing factor to the most severe damage observed in the Oliver to Osoyoos area (Denby and Vielvoye, 1973).

In 1972, 75% of the grapevines in the Similkameen Valley were damaged. This was attributed to temperatures of -20°C on December 7th, -22°C on January 7th and sparse snow cover. Early autumn freezes that occurred in the Okanagan Valley were not apparent within the Similkameen Valley.

The 1972/73 pattern of grapevine winter damage in the Oliver and Osoyoos area was much different from that experienced in 1978/79. Unlike 1978/79, most damage was observed in areas prone to cold air pooling. The coldest temperature experienced at Oliver was -21°C on January 5th. It is apparent that the major reason for the damage in the south Okanagan was the very early severe freezes that occurred in the mid to late September. Localities experiencing most damage in Summerland to Peachland area, were situated approximately 180 meters (600 ft) above and several kilometers from the lake. Even though temperatures as low as -19°C were observed, the main reason for the damage evident in the following spring was the early autumn freeze in 1972.

The pattern of winter damage in the Kelowna to Westbank area was also not the same as that observed in 1978/79. Most damage during 1972/73 in this area was not in the more exposed localities but in areas having the poorest air drainage (frost pockets). Vines in the Okanagan Mission area, typical of a site with good air drainage, showed the least amount of observed damage. Temperatures fell to -24°C at Kelowna Airport on December 8th and again on January 8th to 10th. Kelowna Pollution Control Centre had extreme minimums which dropped to -19°C on December 8th and January 4th, 6th, and 10th. These temperatures alone cannot account for the winter damage experienced in the grape growing areas around Kelowna. Instead the early autumn freezes, with temperatures from -3°C to -6°C on September 27th injured green canes and did not permit many grapevines in the more freeze prone localities to become winter hardy. The moderately cold winter temperatures, did not cause problems to grapevines but compounded the problem arising from the early autumn freezes.

Prior to 1972, other cold winters have also caused problems to the grape crop. After the very cold winter of 1968/69 overall Okanagan and Similkameen grape production was reduced by 72% from the previous year. Extremely low temperatures were recorded late in December and throughout the month of January. The coldest temperatures were recorded in the Similkameen Valley (-30°C) and in areas away from Okanagan Lake. Within the Kelowna area, Kelowna Airport, some distance from Okanagan Lake, had a temperature as low as -36°C on December 30th. Closer to the lake, Kelowna Bowes Street had an extreme minimum temperature of -29°C on the same date. Kelowna C.D.A., away from the moderating affects of Okanagan lake, had an extreme minimum of -32°C on December 30th. Fortunately, heavy snowpacks served to protect the grape vines in most areas north of Penticton. The amount of snow on the ground at the end of December varied from 5 cm at Keremeos and Osoyoos, to 10 cm in Oliver region, 15 to 18 cm in the Penticton to Summerland area, and 25 to 29 cm in the snowier less windy Kelowna area. Winter damage to vine roots may well have been more severe had it not been for the protection provided by the insulating layer of snow.

The winter of 1949/50 was also severe, reducing production to 42% of the previous year. Mann, Keane and Lapins (1952) observed that the very cold temperatures of from -27°C to -32°C on January 17th, 18th, 24th and 25th, caused considerable problems to the tree fruit industry, throughout the Okanagan Valley. This damage occurred despite substantial amounts of snow cover throughout January 1950. Penticton Airport had 13 cm of snow on the ground on January 31, 1950. Most damage to orchards occurred at the higher elevations away from the moderating affect of Okanagan Lake, in areas of poor air drainage.

An extensive network of climate stations operated in 1971/72 by the British Columbia Ministry of Environment throughout the Okanagan and Similkameen Valleys permitted a more thorough analysis of the spatial variation in winter temperatures. During the winter of 1971/72, the Similkameen Valley experienced extreme winter minimum temperatures that were slightly lower than throughout most of the Okanagan Valley. Temperatures fell to -23°C to -24°C throughout the Similkameen Valley. Within the Okanagan Valley, the data collected during the winter of 1971/72 demonstrated the moderating influence of Okangan Lake. This moderating influence was most pronounced in the Summerland area. The extreme minimum temperatures recorded at Jones Flat and Summerland C.D.A., close to the lake, were approximately -22°C. Faulder, a few kilometres west of Summerland at a higher elevation and further inland, recorded an extreme winter minimum temperature of -27°C.

Much the same pattern of extreme winter minimum temperatures was evident in the Peachland to Kelowna area. Sloping lands next to the lake recorded temperatures from -19°C to -22°C, while as little as one kilometre inland in the lowlands of Mission and Trepanier Creeks, cold air pooling and a lack of moderation by Okanagan lake permitted temperaturs to fall to -25°C to -27°C. Further inland, in areas such as Kelowna Airport, the 1971/72 extreme winter minimum temperature dropped to -30°C. Most areas away from the lake in the Kelowna area, though colder than the sloping lands next to the lake had winter minimums of -24°C to -26°C.

The large open lakes influence the Okanagan Valley's winter climate in two ways. The warmer water directly moderates the air in close proximity to a lake. Also, moisture introduced into the atmosphere from the larger lakes results in the formation of valley cloud, this prevents or hinders additional cooling of the air mass at night.

Extreme minimum temperatures observed during the winter of 1971/72 in the Osoyoos area revealed the tendency for milder temperatures throughout this portion of the valley. This is likely in response to the persistent winds which blow during arctic outbreaks. This mixing affect prevents winter minimum temperatures from falling to extremely low values in the more exposed localities. The sloping valley sides for example recorded extreme winter minimums from -18°C to -21°C, with the most moderate temperatures recorded around Osoyoos. Valley bottom sites north of Osoyoos, prone to cold air pooling, were colder with temperatures falling to -22°c to -24°C. Localities away from the main valley were colder still, with a climate station within the Richter Pass experiencing an extreme winter minimum temperature of -28°C.

2.5.3 Frequency Analysis of Extreme Winter Minimum Temperatures Damaging to Grapevines

The temperature thresholds that have been identified for the purposes of this study are as follows: A temperature of -23°C after November 15th or -12°C before this date has been isolated as the temperatures corresponding to the initiation of damage to grapevines. In addition, moderate to severe damage to grapevines is assumed to correspond to a temperature of -26°C occurring at any time during the winter.

An extreme value analysis (Gumbel, 1960), a statistical technique which permits the determination of the recurrence interval of certain designated temperature extremes, has been applied to climatic data throughout the Okanagan and Similkameen Valleys. This statistical technique has been used to determine the expected frequency of the -26°C critical temperature, and has been based upon the occurrences of historical winter extreme minimum temperatures of -26°C or lower. A separate analysis has been undertaken upon extreme winter minimum temperatures at weather stations throughout the region, to determine the number of occurrences of a temperature of -12°C on or before November 15th, or a temperature of -23°C thereafter. Table 18 shows the expected number of occurrences of these temperature thresholds.

Table 18
Frequency of Extreme Winter Minimum Temperatures Throughout the Okanagan and Similkameen Valleys

Climatic Station	Recurrence Interval of Temperatures Less Than ⁻26°C	Observed Frequency of Occurrences of ⁻12°C Before Nov. 15 or ⁻23°C After Nov. 15
Keremeos	1 winter in 7 yrs.	1 winter in 2 yrs.
Osoyoos	1 winter in 28 yrs.	1 winter in 4 yrs.
Oliver	1 winter in 8 yrs.	1 winter in 3 yrs.
Penticton Airport	1 winter in 27 yrs.	1 winter in 4 yrs.
Summerland C.D.A.	1 winter in 16 yrs.	1 winter in 3 yrs.
Kelowna C.D.A	1 winter in 3 yrs.	1 winter in 2 yrs.
Okanagan Centre	1 winter in 12 yrs.	1 winter in 47 yrs

The Similkameen Valley is colder in winter than most of the Okanagan Valley, as the Similkameen does not have the moderating benefit of any large lakes. The Keremeos weather station has a recurrence interval of a -26°C temperature in one winter every seven to eight years, the -12°C early winter or -23°C mid winter temperature threshold has occurred in twenty-one winters in forty-eight years or approximately 1 winter every 2 years.

Southern sections of the Okanagan Valley, despite being away from the largest lake in the region, generally have the mildest winter temperatures. Osoyoos may expect the least number of occurrences of winter temperatures causing damage to the grape crop. The Oliver climate station is located in a cold, low lying, site reflecting the tendency for a greater number of occurrences of grape damaging winter temperatures. This station is not representative of most of the vineyards around Oliver, as most are located in milder valley side locations. Penticton Airport illustrates the advantage gained by being close to Okanagan Lake in that the number of occurrences of grape damaging winter temperatures is less than the low-lying areas around Oliver.

Summerland C.D.A., above the lake and slightly inland, has recorded an increased number of occurrences of temperatures causing winter damage. The Kelowna area experiences much variation in winter minimum temperatures. An analysis of twenty years of winter temperature data revealed that weather stations in the city and hence near to Okanagan Lake, had temperatures moderated accordingly. The twenty year record revealed seven winters when temperatures to -12°C before November 15 or -23°C after mid November, and only one winter when temperatures fell below -26°C. East Kelowna, away from the lake and 130 metres (430 ft) higher in elevation, had twelve winters with temperatures falling to the -12°/-23°C threshold, and seven out of the twenty winters experienced -26°C or lower (Gumbel analysis predicted a -26°C or colder temperature in one winter out of every three to four years).

Okanagan Centre on Okanagan Lake is at the northern limit of the area covered by the Grape Atlas. A temperature of -26°C has a recurrence interval of once in twelve to thirteen years, and a -12°C early winter or -23°C mid winter temperature has been reached in thirteen winters in forty-six years.