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REPORT

Pacific & Yukon Region

Criteria for Maintaining Stations in the British Columbia Climate Network

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CRITERIA FOR MAINTAINING STATIONS IN THE BRITISH COLUMBIA CLIMATE NETWORK

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Summary -

Criteria for maintaining AES climate stations in British Columbia must be developed in order to maximize the utilization of resources. The purpose of this paper is to develop a set of criteria for the maintenance of such stations. Using this station-by-station methodology, the value of each climate station to the AES could be determined and an overall Regional plan for the climate network could be developed.

The criteria utilizes the *Ecoclimatic Regions* developed by the Canadian Wildlife Service, 1989[1] and includes parameters such as elevation variability, population proximity, suitability for climate change detection work, probable future reliability, length of historical record, quality of data, dependability, instrumentation and economic importance. The proximity to the next station was judged to be a prime factor in the maintenance of the climate network and is therefore given special consideration.

The criteria were applied to some stations from the AES climate network and from other agencies. Due to the current and future economic realities, the AES may want to investigate the incorporation of stations from other networks to supplement the AES network.

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[1] *Report of the Ecoregions Working Group of the Canada Committee on Ecological Land Classification, 1989* - Canadian Wildlife Service, Sustainable Development Branch, Ecological Land Classification Series, No.23.

Background

A climate network is an essential and necessary part of the AES mandate "to ensure the safety and well being of all Canadians by providing high quality atmospheric information and advice...". The AES Regions have been delegated the authority to acquire climate data in several ways; by recruitment of volunteers, by cooperative arrangements with other agencies, by contract, by agreements with other government departments, by operating stations themselves. The purpose of a climate network is "...to provide a reliable data base for the study of all aspects of climate."[2] Although it is desirable to incorporate as many of the data collection platforms from other sources as possible, it is recognised there are particular and specific requirements these agencies may have that may not be consistent with the AES purposes.

There have been past efforts (Johnstone, 1986 for example), at rationalizing the basic federal climate network in British Columbia. Most have attempted to do this in a scientific or mathematical manner. This would appear to be a reasonable approach as the AES is an organization based in science. However, past attempts have not been entirely successful due, in part, to this scientific approach. It is the author's opinion that any distribution of climate stations must also be based on subjective considerations. Elements such as the quality of data, willingness of the observer to participate and some indication of 'site permanence', among others, are some of the "non-scientific" factors that need to be considered.

This paper endeavours to incorporate some of these subjective factors in climate station network maintenance. However, it must be noted that a review of previous literature on the subject has indicated there have been past attempts to incorporate subjective criteria into climate network planning (Western Region 1979, AES Policy on the Distribution of Climate Stations 1985). The later of these was found by the Climate Planning Board to be "scientifically unacceptable". The finding was accepted by ADMA.

Current B.C. Network

Past efforts have focused on network density rather than the placement of stations which will, in effect, dictate the density. In the past, the "availability of observers willing to take climate observations has been the dominant factor in

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[2] *Guidelines on the Selection of Reference Climatological Stations (RCSs) From the Existing Climatological Station Network*, WMO, July 1986.

determining the distribution of the climate network in Canada"[3]. In the current and future economic realities, the Pacific Region must review this approach to climate observations. It is reasonable to assume that with increasing economic development, population growth and public awareness of climate issues, there will be increased pressure on the Region to expand the climate network. This is in addition to financial pressures that demand a decrease in the network. Clearly, a station-by-station review of the network is required.

As of February, 1993, the AES climate network in BC consisted of 550 stations. The network relies heavily on volunteers.

The WMO minimum climate network density for mountainous terrain stipulates 41 precipitation stations per 10 000km^2. Johnstone (1986) applied this criteria to produce an assessment of the surplus/deficits of the network at that time. It is recommended the criteria in this study be applied to the current B.C. climate network and compared to the aforementioned WMO criteria. It must also be determined if the Pacific Region can afford to meet the WMO density.

Criteria for Maintaining Stations in the British Columbia Climate Network

This paper attempts to address the subjective as well as the objective factors for climate station maintenance. In consultation with AES staff, it was determined that, in addition to objective factors such as length of station record and the proximity to the next station, a measure of subjective factors such as the probable timeframe a station will exist would be useful. It is recognized that to include this type of factor is to introduce a level of subjectivity into the methodology. However, this is a necessary and essential part of any climate network as these factors play a large role in determining the usefulness of the network.

The findings of the Ecoregions Working Group published in 1989 has been used to formulate the methodology. The goal of this group was to "...attempt to describe the roles and influences that climate has had in molding the patterns and inherent qualities of our ecosystems." The study was initiated on the premise that climate is the primary factor in shaping the ecosystem of a region. Like regions are defined by the role climate has in sustaining the ecosystem and their elements such as soils and vegetation (*Appendix 1*). Within a large area, mesoscale differences in climate will be evident. However, in general, similar ecosystems will develop in the same area as a function of climate.

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[3] An Evaluation of the AES Daily Precipitation Network, AES internal document, AMC SP 90/14.

In consultation with AES staff the proximity to another climate network site was judged to be of primary importance in the maintenance of the climate network. A site that is many kilometres from another site is more valuable to the network than one which is in an area that is saturated with sites. In addition, it is more difficult to find an observer in a remote location. Therefore, after the following procedure is completed, a 'P' factor or Proximity factor is applied. This factor is the relationship of the distance between the site being evaluated and the next closest site. The value of 'P' is determined directly from the graph in *Figure 1*. The shape of this graph shows that the closer a station is to another, the lower the 'P' factor and therefore, the more the station value score (described below) will be reduced. It was determined, in consultation with AES staff, that a distance of 50km would represent a 1:1 relationship. Thus, on the graph, 50km is given a 'P' value of 1.0 meaning the station value score is not decreased nor increased. A distance greater than 50km will indicate the increasing importance of the station to the network and 'P' will increase accordingly.

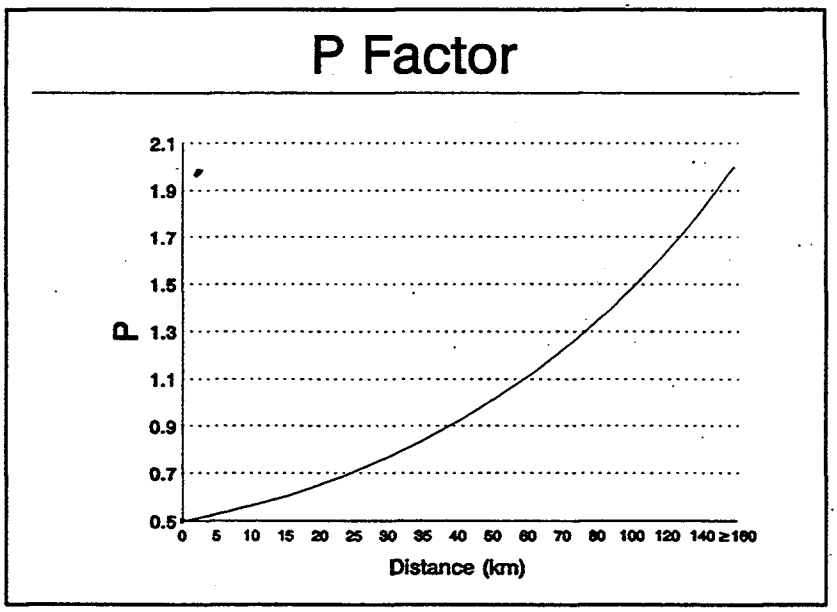


FIGURE 1 - Determination of 'P' Value

The methodology used to develop the maintenance criteria is as follows; a numerical value is determined for each of the following network factors by various methods described below. This value is then multiplied by a weight (*Table 1*) assigned to each network factor. These weightings have been determined in consultation with Climate Services staff and are an initial definition that will be adjusted as the system is refined. This product is then multiplied by the aforementioned 'P' factor. The resulting value is termed the ***station value score***. As the value of a station will depend heavily on the proximity to another station, the 'P'

factor will not allow each station to be taken in isolation. The station value scores are then ranked and the resulting list is to be used as a guide by AES staff for the maintenance of stations in the BC climate network. Therefore, it is recommended this procedure be applied to 5 or more stations at a time as it is used to evaluate stations against one another.

Determination of Weight Values -

Through consultation with AES staff, weights for each of the 9 factors were determined and are summarized below;

Criteria	Weight
Elevation Variability	0.16
Client needs/Population Proximity	0.12
Climate Change Detection	0.11
Probable Timeframe (Agency/Entity)	0.05
Length of Record	0.17
Quality of Data	0.17
Dependability	0.05
Economic Importance	0.10
Instrumentation	0.07
Total:	1.00

Table 1 - Network Factors and Weighting

An evaluation of the B.C. climate program has identified the following as essential and necessary requirements for the maintenance of stations in the BC climate network (all the following are compiled in *Appendix 2*);

Elevation Variability (*Weight = 0.16*):

British Columbia is a very geographically diverse province. In order to state the elevation variability of the province, the previously defined Ecoclimatic Regions are used. These Regions allow the province to be divided into 15 geographically and climatically similar areas. The determination of the variation in elevation within a Region is achieved by assigning a value to the difference between the lowest and highest points in that Region. The higher the variability, the higher the value.

Client Needs/Population Proximity (*Weight = 0.12*):

The requirement for climate data in and surrounding urban centres is great. Public demand is usually greater than in non-urban areas and the scientific

demand for data is substantial. As demand will usually increase with proximity to increased population, the value is based on these factors. However, data may be in demand precisely due to a station's isolation (eg; BC Hydro, MOT etc.) as there are no other methods available to obtain the data required. Opportunities to obtain observers are also usually greater in areas of greater population density. The isolation of a station is accounted for in the previously mentioned 'P' factor.

Climate Change Detection (*Weight = 0.11*):

The prospect of a warmer climate due to the Greenhouse Effect has captured both the media's and the public's attention. Canada has made a commitment to climate change detection. In order to place a numerical value on the benefit of a climate site to climate change detection, the following factors for each station must be considered; the size of the representative area, the length of site record, the continuity of the historical record, the proximity to another long-term climate site, non-urbanization and an estimate of future non-urbanization, the permanence of the site, accuracy of the instrumentation (is the site using current technology), the parameters currently measured and potential for future additional parameters. In this factor, a climate reference station will automatically receive the highest value based on it's length of record.

Probable Timeframe (Agency/Individual) (*Weight = 0.05*):

It is an advantage to choose a location and observer that will continue to operate the site uninterrupted over a long period of time. To obtain a measure of the probable timeframe a station will operate is a very difficult task. There are many factors that may occur to force the closure of the station. To quantify this parameter, the following must be taken into account; does the observer have a stake in the data(eg: for business purposes), is an agency or individual administering the site, a measure of the observer's enthusiasm (is it a hobby or part of employment etc), is the location on the edge of a population centre and therefore likely to be affected by future urbanization?

Length of Record (*Weight = 0.17*):

The length of data record is an important element in a climate network. A lengthy record is valuable in detecting climate change and in defining the climate of the region. It is a common practice to combine the records of stations that have moved a short distance and whose elevation is similar. This method may be used in the present criteria. The method uses the graph shown on the next page. The length of station record is found on the graph and the number of corresponding points is given on the 'Y' axis. The shape of the

graph illustrates the relative lack of importance a short length of record carries. A station that has only been in existence for 5 years or less will not have a long enough record to provide a useful definition of the local climate. In this case it will be given a value of 4 or less points. The points increase dramatically from 4 at 5 years to reach 8 at 10 years due to the increasing length of record and past experience that stations that have operated for approximately 10 years have a tendency to operate for many more. The maximum 10 points is given to a station with a length of record of 30 or more years (the WMO standard for climatological data).

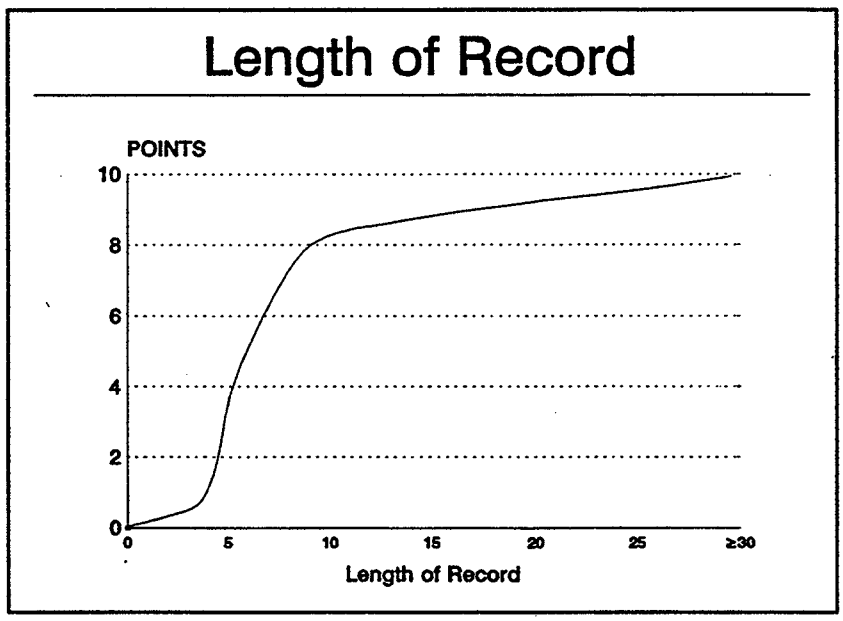


FIGURE 2 - Length of Record

Quality of Data (*Weight = 0.17*)

The quality of the data is a very important factor. Past data has been quality controlled therefore only the quality of the current data is evaluated. There are many factors that may affect the quality of climate data. These include; non-interest of the observer, lack of training, and defective instrumentation.

Dependability (*Weight = 0.05*):

Frequent delinquent stations are well known and are easily identified.

Economic Importance (*Weight = 0.10*):

The climate of an area may influence many economic sectors, such as agriculture, forestry and tourism, and fishing. The effect of climate on the economy of a region will vary depending on whether the region relies heavily on those sectors that are largely climate dependent.

Instrumentation (*Weight = 0.07*)

When ranking stations, a site which has more equipment should be more valuable to the network than one which records only temperature.

Federal Priorities for Data

There are agreements, conventions and other priorities the federal government has committed to that require climate data. The Environmental Assessment and Review Process (EARP), federal/provincial agreements as well as international agreements such as the Columbia River treaty all are examples of these. Therefore federal priorities for data are not included in the current climate network planning criteria as it is assumed these stations must remain open. However, this does not preclude another agency from funding these stations if necessary.

Application of Criteria and Discussion -

The criteria were applied to 6 stations in the B.C. climate network, *Appendix 3*. These sites are then ranked in ascending order for further review by AES staff. Therefore, the procedure establishes an order for which to review the climate network. The results are summarized below:

Station	Station Value Score
Armstrong North	3.34
Blind Channel	3.76
Eagle Bay	4.58
Baldonnel	4.82
Minaker River	6.47
Bella Coola	10.95

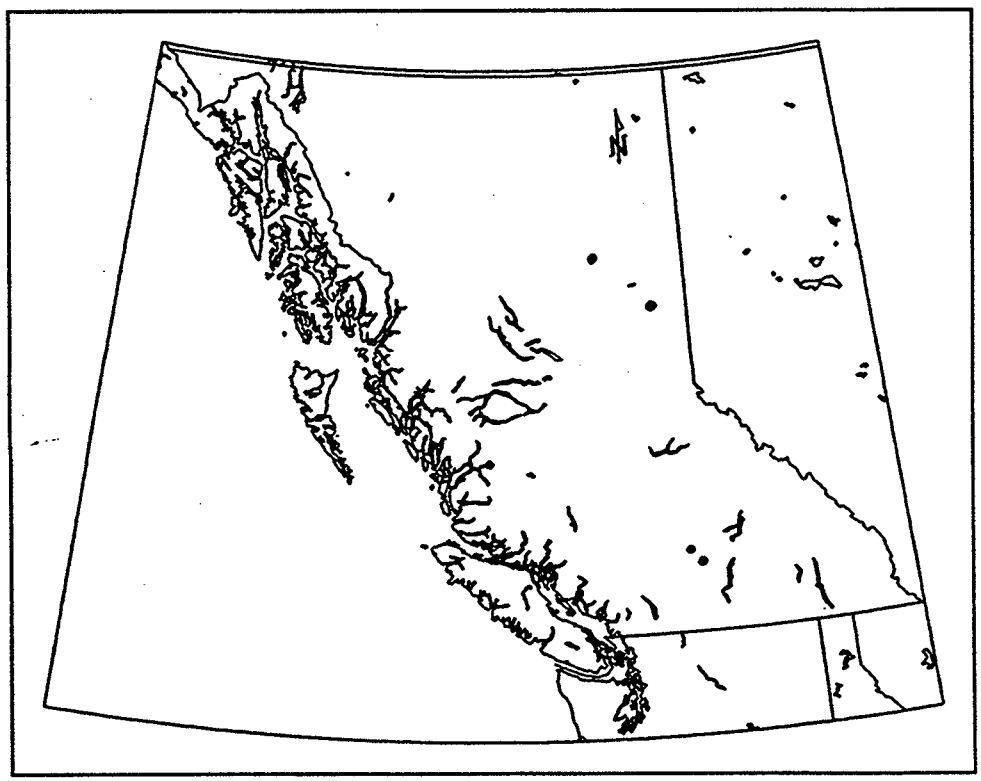


FIGURE 3 - Location of Sample Stations

The following is an example of how the criteria has been applied to achieve the values on page 7 using Appendix 2.

Using **Bella Coola** (ID #1060840) for the example, the steps are outlined below;

1. ELEVATION VARIABILITY - (Weight = .16) The elevation in this Ecoclimatic Zone ranges from near sea level to the height of Mt. Waddington, an elevation difference of approximately 4000 meters. Therefore, using Appendix 2, the difference is greater than 3000 meters and a value of **10** is recorded.

2. CLIENT NEEDS/POPULATION PROXIMITY - (Weight = .12) As the population of Bella Coola is less than 20,000 (approximately 1000) the following calculation must be conducted;

$$\frac{\text{Population of Current Town}}{(\text{Distance to closest town greater than current population})^2}$$

For Bella Coola, performing this calculation results in a value of less than 2.0. Using the table in Appendix 2, we determine this score to have a value of **2**.

3. CLIMATE CHANGE DETECTION - (Weight = .11) As this station is representative of a large area and, more importantly, has a long climate record, as well as very little possibility of future urbanization, a value of **10** is recorded.

4. PROBABLE TIMEFRAME (Agency/Entity) - (Weight = .05) The probable timeframe for this station is based on the length of current station record and the lengthy past record. The score assigned to this factor corresponds to one year of future record to a maximum of 10. ie: if the station is expected to remain for only 6 more years, a score of 6 is recorded. Based on Bella Coola's lengthy record, it is unlikely it will be closed within 10 years. Therefore, a score of **10** is recorded.

5. LENGTH OF RECORD - (Weight = .17) Bella Coola has an extremely long record and is therefore given a value of **10.0** from the graph on page 7.

6. QUALITY OF DATA - (Weight = .17) As previously mentioned, this is the quality of current data, that there are no breaks in the record and no station movements for the period of record. Bella Coola is given a **9**.

7. DEPENDABILITY - (Weight = .05) In consultation with AES staff, the dependability of data from Bella Coola is rated as high or **10** points.

8. ECONOMIC IMPORTANCE - (Weight = .10) The area surrounding Bella Coola is very dependent on the forest industry and therefore would be affected by climate change. This factor is judged high yielding a score of **9** points.

9. INSTRUMENTATION - (Weight = 0.07)
Again, using Appendix 2, the two pieces of equipment at Bella Coola are awarded a score of **5**.

Therefore, multiplying each value by the stated weight yields a total of **8.42**. This value is then multiplied by the 'P' factor taken from the graph on page 4, in this case, 'P' = **1.30**. This yields a *station value score* of **10.95** for Bella Coola. This station value score would then be ranked against all other station value scores in the area under consideration.

Conclusion and Recommendations

Due to the current and future economic realities, the AES Pacific Region cannot afford to maintain an unrationalized or haphazard climate network. Through application of the climate network maintenance criteria, AES can work toward realizing a more rational and logical British Columbia climate station network.

Recommendations - The criteria for climate station network maintenance in British Columbia be adopted as Pacific Regional policy.

- The criteria be applied to all current BC climate network stations with the result compared to the WMO minimum criteria for mountainous regions of 41 stations per 10,000km^2.

- All sites identified by the criteria as candidates for closure be reviewed by the Superintendent of Climate Services and Data Acquisition staff.

- Sites be identified for station openings.

- An overall strategy for the BC climate network be developed.

REFERENCES

Atmospheric Environment Service, "Policy on the Distribution of Stations in the Basic Federal Climate Network", AMC SP #90/14, AMC Meeting, 28/9/85.

Atmospheric Environment Service, "An Evaluation of the AES Daily Precipitation Network", AES internal document, AMC SP #90/14, AMC Meeting, 28/9/85.

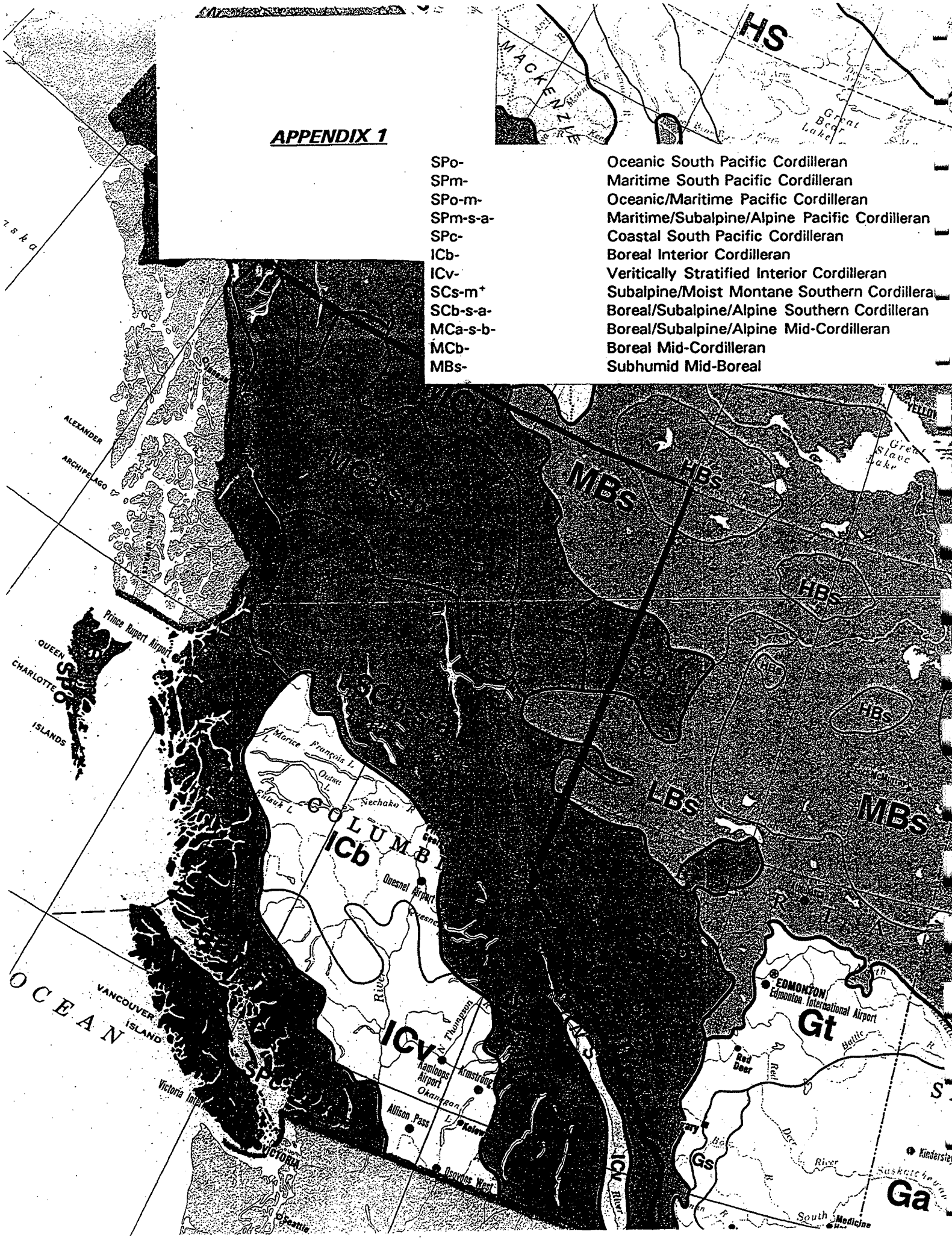
Canadian Wildlife Service, "Report of the Ecoregions Working Group of the Canada Committee on Ecological Land Classification", Sustainable Development Branch, Ecological Land Classification Series, No.23, 1989.

Gandin, L.S., 1970, "The Planning of Meteorological Station Networks", WMO Technical note #111

Johnstone, K., 1986, "An Analysis of the British Columbia Climate Network", AES Internal Report.

WMO, "Guide to Climatological Practices", 1983, WMO Technical Note #100.

WMO, "Guidelines on the Selection of Reference Climatological Stations (RCSs) From the Existing Climatological Station Network", 1986, WMO/TD No.130, WCP-116.


APPENDIX 1
SPo- Oceanic South Pacific Cordilleran
SPm- Maritime South Pacific Cordilleran
SPo-m- Oceanic/Maritime Pacific Cordilleran
SPm-s-a- Maritime/Subalpine/Alpine Pacific Cordilleran
SPc- Coastal South Pacific Cordilleran
ICb- Boreal Interior Cordilleran
ICv- Veritically Stratified Interior Cordilleran
SCs-m+ Subalpine/Moist Montane Southern Cordillera
SCb-s-a- Boreal/Subalpine/Alpine Southern Cordilleran
MCa-s-b- Boreal/Subalpine/Alpine Mid-Cordilleran
MCb- Boreal Mid-Cordilleran
MBs- Subhumid Mid-Boreal
HS
MBs
HBs
LBs
ICb
ICv
SPo
SPm
Gt
Gs
Ga
ALEXANDER ARCHIPELAGO
QUEEN CHARLOTTE ISLANDS
Prince Rupert Airport
VANCOUVER ISLAND
OCEAN
Victoria Int.
VICTORIA
Seattle
Quesnel Airport
Kamloops Airport
Armstrong
Okanagan
Allison Pass
Osoyoos West
EDMONTON
Edmonton International Airport
Red Deer
Medicine
Great Slave Lake
Great Bear Lake
MACKENZIE

APPENDIX 2

BC CLIMATE NETWORK FACTORS

ELEVATION VARIABILITY -

0 - 500m:	1.0 points
500m - 1000m:	3.5
1000m - 2000m:	7.0
2000m - 3000m:	9.0
>3000m	10.0

CLIENT NEEDS/POPULATION PROXIMITY - If the population of the town in which the station being evaluated is ≥20,000, the site is automatically awarded a score of 10. The following formula is used for all sites less than 20,000 population;

$$\frac{\text{Population of Current Town}}{(\text{Distance to closest town with population greater than current population})^2}$$

This value is then compared to the following to obtain the indicated score;

	-	≥25	=	10
12	-	24.9	=	8
5	-	11.9	=	6
2.1	-	4.9	=	3
	-	≤2	=	2

CLIMATE CHANGE DETECTION -

Factors; representative of a large area, length of record, quality of historical data (ie: are there gaps?), proximity to another long-term climate site, non-urbanization and estimate of future non-urbanization, possible timeframe of site (chances of it being there for a long time), accuracy of instrumentation, parameters measured.

Climate reference stations will automatically receive a score of 10.

Using a scale of 1-5, Climate Change Detection is given;

1 = 1.0
2 = 3.0
3 = 6.0
4 = 7.5
5 = 10.0

PROBABLE TIMEFRAME - Factors; does the observer have a stake in the data (eg: for business purposes), is an agency/individual administering the site, a measure of enthusiasm (is it a hobby, part of employment etc),
One point is given for each year of expected future operation up to a maximum of 10.

QUALITY OF DATA - This refers primarily to the accuracy of the recent data which carries a maximum of 7. A maximum of 2 is awarded for the continuity of the data and 1 for no significant movement or station equipment changes for the period of record.

DEPENDABILITY - An estimate of the number of years of future observations. One point is recorded for every future year estimated to a maximum of 10.

ECONOMIC IMPORTANCE - Is the primary economic activity largely dependent on the weather/climate and it's variability? Factors such as; Agriculture, Forestry, Tourism, Fishing.
Does climate variability have an impact on the local economy?

Agriculture = 10 Weather/climate has a very direct effect on the agriculture of an area.

Tourism = 10 Weather/climate also has a very direct effect on the tourism of an area.

Forestry = 9 The forest industry is also affected by weather/climate although not to the same extent as the previous two.

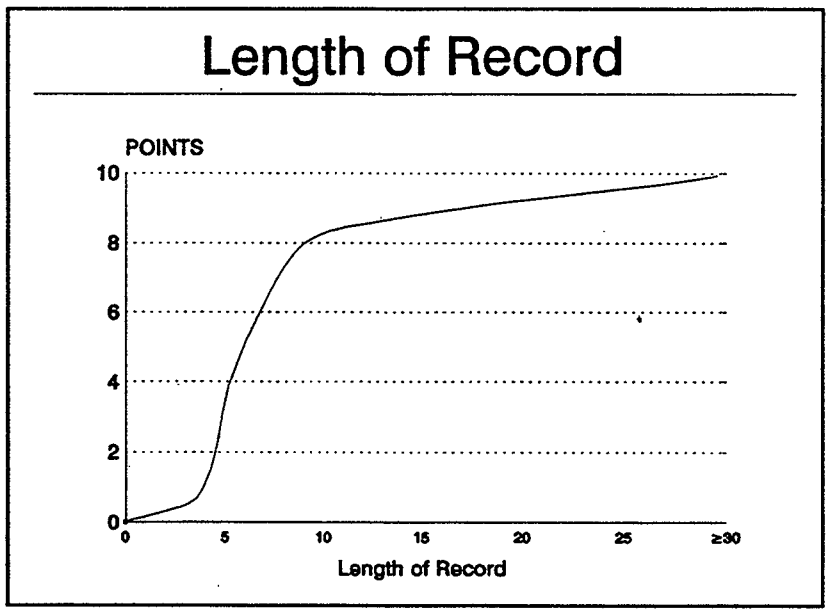
Mining = 4 Mining will only slightly be affected by the weather. This primarily applies to open-pit mining.

Pulp & Paper = 8 The pulp & paper industry uses large amounts of water in manufacturing process.

Fishing = 8 This includes all types of fishing; sport, commercial, freshwater and saltwater. If the climate warms, the oceanic foodchain will change with different species appearing off the BC coast as is seen during El Niño years.

INSTRUMENTATION - Two and one half points are given for each piece of equipment on site to a maximum of 10.

LENGTH OF RECORD - The ratings used for the length of record of a station is taken directly from the following graph;



APPENDIX 3

SAMPLE DATA

FACTOR	WEIGHTING	Armstrong North 1160485 Points	Weighted Valu
Elevation Variability	0.16	9	1.44
Client Needs/Population Proximity	0.12	10	1.2
Climate Change Detection	0.11	3	0.33
Probable Timeframe (Agency/Individual)	0.05	5	0.25
Length of Record	0.17	9.3	1.58
Quality of Data	0.17	1	0.17
Dependability	0.05	2	0.1
Economic Importance	0.1	10	1
Instrumentation	0.07	5	0.35
	1	Total =	6.42
		P factor =	0.52
		Station Value Score =	3.34

FACTOR	WEIGHTING	Blind Channel 1020855 Points	Weighted Valu
Elevation Variability	0.16	3.5	0.56
Client Needs/Population Proximity	0.12	2	0.24
Climate Change Detection	0.11	9	0.99
Probable Timeframe (Agency/Individual)	0.05	5	0.25
Length of Record	0.17	10	1.70
Quality of Data	0.17	8	1.36
Dependability	0.05	8	0.4
Economic Importance	0.1	8	0.8
Instrumentation	0.07	2.5	0.175
	1	Total =	6.48
		P factor =	0.58
		Station Value Score =	3.76

FACTOR	WEIGHTING	Eagle Bay 1162580 *Points*	*Weighted Valu*
Elevation Variability	0.16	9	1.44
Client Needs/Population Proximity	0.12	2	0.24
Climate Change Detection	0.11	10	1.1
Probable Timeframe (Agency/Individual)	0.05	10	0.5
Length of Record	0.17	10	1.70
Quality of Data	0.17	8	1.36
Dependability	0.05	8	0.4
Economic Importance	0.1	8	0.8
Instrumentation	0.07	5	0.35
	1	Total =	7.89
		P factor =	0.58
		Station Value Score =	4.58

FACTOR	WEIGHTING	Baldonnel 1180585 *Points*	*Weighted Valu*
Elevation Variability	0.16	1	0.16
Client Needs/Population Proximity	0.12	2	0.24
Climate Change Detection	0.11	10	1.1
Probable Timeframe (Agency/Individual)	0.05	10	0.5
Length of Record	0.17	10	1.70
Quality of Data	0.17	10	1.7
Dependability	0.05	10	0.5
Economic Importance	0.1	9.5	0.95
Instrumentation	0.07	5	0.35
	1	Total =	7.20
		P factor =	0.67
		Station Value Score =	4.82

FACTOR	WEIGHTING	Minaker River 1195165 Points	Weighted Valu
Elevation Variability	0.16	7	1.12
Client Needs/Population Proximity	0.12	2	0.24
Climate Change Detection	0.11	6	0.66
Probable Timeframe (Agency/Individual)	0.05	5	0.25
Length of Record	0.17	7.9	1.34
Quality of Data	0.17	1	0.17
Dependability	0.05	8	0.4
Economic Importance	0.1	9	0.9
Instrumentation	0.07	5	0.35
	1	Total =	5.43
		P factor =	1.19
		Station Value Score =	6.47

FACTOR	WEIGHTING	Bella Coola 1060840 Points	Weighted Valu
Elevation Variability	0.16	10	1.6
Client Needs/Population Proximity	0.12	2	0.24
Climate Change Detection	0.11	10	1.1
Probable Timeframe (Agency/Individual)	0.05	10	0.5
Length of Record	0.17	10	1.70
Quality of Data	0.17	9	1.53
Dependability	0.05	10	0.5
Economic Importance	0.1	9	0.9
Instrumentation	0.07	5	0.35
	1	Total =	8.42
		P factor =	1.3
		Station Value Score	10.95