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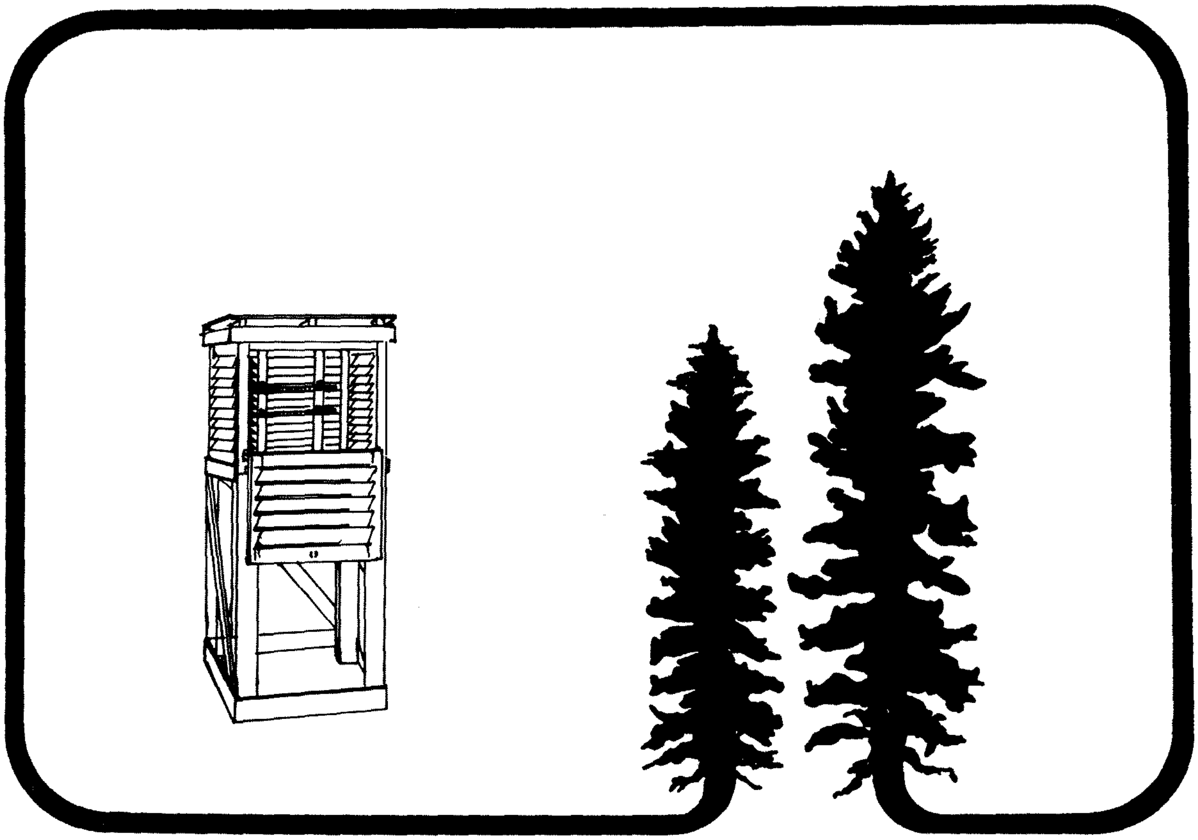
Climatic networks

Proceedings of the workshop and annual meeting of the Alberta Climatological Association April 1978



compiled by J.M. Powell

Northern Forest Research Centre • Edmonton, Alberta • Information Report NOR-X-209

CLIMATIC NETWORKS:

PROCEEDINGS OF THE WORKSHOP AND ANNUAL MEETING SPONSORED BY THE ALBERTA CLIMATOLOGICAL ASSOCIATION

APRIL 13, 1978
ATMOSPHERIC ENVIRONMENT CENTRE
EDMONTON, ALBERTA

COMPILED BY

J.M. POWELL

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FOREWORD

This is the second workshop and annual meeting sponsored by the Alberta Climatological Association or its predecessor the Alberta Climatological Committee, which was formed in 1967. The intent of the association in holding these workshops and annual meetings is to encourage the interchange and dissemination of climatic information between all interested agencies and individuals in Alberta. The proceedings of the first workshop, which looked at the theme "Applications of Climatology," have been published (Powell 1977). The theme "Climatic Networks" was selected for the second workshop because the executive of the association felt that it would be topical. We were aware of in-service discussions taking place within the Atmospheric Environment Service, which has a responsibility to maintain climatological and other meteorological networks. Other user agencies in Alberta were also very much concerned with climatic networks; presently several are considering establishing new, probably short-term networks or are evaluating existing networks as a means to provide them with the necessary background climatic information to help make resource and management decisions.

In his welcoming address, Mr. G.H. Legg, Regional Director, Western Region, Atmospheric Environment Service,outlined the development of climatology in Canada from the early years when Mr. A.J. Connor was the Dominion Climatologist to the present. He paid tribute to Mr. and Mrs. Owen of Edmonton who acted as "provincial agents" before the development of the regional organization in the early 1950's and noted that great credit was due to the numerous volunteer climatological observers who had worked so diligently through the years to develop the valuable statistical data base that permits us to delineate climatic regions and establish the climate of so many locations. He also suggested that much credit goes to regional personnel in the Observational Systems Division for their work in recruiting, training, and particularly motivating the volunteer observers, since this is becoming more and more difficult in our mobile society where people do not wish to be tied to a program seven days a week.

These proceedings contain the six papers presented at the morning workshop, one in summary form, and the summaries of 18 agency, institution, and committee reports presented to the annual meeting in the afternoon. Also included is the text of a presentation by Horace Wilson on orographic precipitation, and an outline of the other topics discussed at the annual meeting. Publication of these proceedings was made possible by the allocation of funds by the Northern Forest Research Centre, Canadian Forestry Service, Edmonton, and the Western Region, Atmospheric Environment Service, Edmonton. To the latter the association is also indebted for meeting facilities. Special thanks are due to Mrs. P. Logan, Scientific Editor, Northern Forest Research Centre, for her assistance in editing and seeing these proceedings through to publication. Lastly, a sincere thanks to the association executive, speakers, and all participants for their individual interest and collective enthusiasm that made the workshop and annual meeting a success.

John M. Powell, Chairman

Powell, J.M. (Ed.). 1977. Applications of climatology: Proceedings of the workshop and annual meeting sponsored by the Alberta Climatological Committee. Fish. Environ. Can., Can. For. Serv., North. For. Res. Cent. Edmonton, Alta. Inf. Rep. NOR-X-193. 137 pp.

CONTENTS

W O R K S H O P

C L I M A T I C   N E T W O R K S

NATIONAL STANDARDS IN WEATHER OBSERVING NETWORKS

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ABSTRACT

The development of standards related to weather observing networks and their application have been important to the operation of national meteorological services. The direction and ongoing coordination for such standards have come mainly from the World Meteorological Organization (WMO). This international body serves as the umbrella agency which formulates standards and encourages their adoption by national meteorological services.

Standards related to weather observing networks may be categorized in terms of network planning and design, instruments and instrument systems, observations and codes and quality control.

The Network Standards Division of the Atmospheric Environment Service (AES) shoulders responsibility for the establishment of standards for AES observational systems. The challenges of the future in the area of standards development concern automatic observing systems, remote sensing systems and air quality monitoring systems.

The benefits of standardization of weather-observing systems are perhaps most apparent at the international level. The adoption of national standards in the establishment of regional or subregional observational networks is dependent on the specific user requirements for data, promulgation of guidelines on national standards and economics.

The development of standards related to weather-observing networks and their application have been important to the establishment and operation of national meteorological services. Because weather data constitute the fundamental source for the provision of meteorological services, it is essential that meteorological agencies obtain adequate and accurate observations. This paper briefly reviews the historical development of standards for meteorological observing networks, examines the concept of standards, and looks at the application of standards in the data acquisition systems of the Atmospheric Environment Service.

During the nineteenth century there was an enormous expansion of industry, commerce and international trade which the Industrial Revolution had spawned. The need for rapid collection and dissemination of weather data became more significant especially for maritime transportation. Precise, reliable and regular information on weather was required for the safety and efficiency of marine transportation. Consequently, the First International Meteorological Conference took place in Brussels in August, 1853 to examine maritime meteorological problems. The conference adopted a standard form of ship's log and a set of standard instructions for the observations taken on board ocean-going vessels. The log had 24 columns for recording elements which included pressure, wet and dry bulb temperatures, speed and direction of wind, amount, form and direction of clouds, and sea temperature at the surface and at depth. While the Brussels conference was an encouraging beginning for international marine meteorological cooperation and standardization, the larger aspects of international meteorological standardization remained. Meteorology had already taken on a new importance as a result of increasing demands for collection of data on climate and weather for different practical purposes. There was an increasing need for the development of techniques for the rapid collection and dissemination of observations. National economies required the development of a network of meteorological stations and the perfecting of methods of observation (World Meteorological Organization 1976). As a result of increasing needs of the international community for meteorological data, the first International Meteorological Congress was held in Vienna in 1873. One of its first acts was to arrange for the preparation of standardized instructions and procedures for meteorological observations on land, standardization of meteorological instruments, and the preparation of a telegraphic figure code (World Meteorological Organization 1973). Looking back, that standardization effort took place over a century ago.

The Vienna Congress of 1873 served as the preparatory phase of organized international meteorology. The International Meteorological Organization was formed in 1891 and gave way to the World Meteorological Organization (WMO) in 1951. One of the stated objectives of the WMO is "to promote standardization of meteorological and related observations and ensure the uniform publication of observations and statistics". The international community which is dedicated to progress in meteorology has unwaveringly pursued the objectives of the WMO. The underlying principle that work in international meteorology be carried out by countries on a voluntary basis has been adhered to in an exemplary fashion. Many groups and agencies outside the sphere of meteorology are largely unaware of the tremendous voluntary efforts which a government expends with efficiency and economy in the interests of international meteorology. The Atmospheric Environment Service (AES) is certainly no exception. In the area of standards it has assumed responsibility for "the development, design, and establishment of standards and procedures for the meteorological data acquisition systems. These data are constantly being evaluated against international, national and provincial requirements for data and the availability of instruments and equipment to accomplish the task more efficiently and economically. An extensive program for the quality control of data for publication, archiving, and consultation purposes is maintained using technical and computer methods". (Environment Canada 1975).

The term standards is often used in a very loose sense and as a result, the meaning of the term in national weather observing systems is not always readily apparent. It has been difficult to get international agreement on a definition of standards. However, the International Organization for Standardization has put forward a generally accepted definition. A part of that definition follows:

> A Standard is the result of a particular standardization effort, approved by a recognized authority. It may take the form of i) a document containing a set of conditions to be fulfilled, ii) a fundamental unit or physical constant, iii) an object for physical comparison .
>
> Standardization is the process of formulating and applying rules for an orderly approach to scientific activity for the benefit and with the cooperation of all concerned, and in particular, for the promotion of optimum overall economy taking due account of functional conditions and safety requirements . . . . It is based on the results of science, techniques and experience. It determines not only the basis for present but also for future development and it should keep pace with progress . . . . (Leggett 1970)

Specifications, methods and procedures are subsets of a particular standard. With reference to the above and for purposes herein, the term "standard" is used to refer to a document prepared and sanctioned by AES which contains a set of conditions to be fulfilled in the AES data acquisition networks.

Standards related to weather-observing networks may be categorized in terms of network planning and design, instruments and instrument systems, observations and codes and quality control. The Network Standards Division of the Atmospheric Environment Service is responsible for the establishment of standards for AES observational systems.

The AES operates or shares in the operation of approximately 30 different types of networks, some of which report current conditions (real-time), and others which report on a daily, weekly or monthly basis (non-real-time). The AES document "Planning of Meteorological Observational Networks" sets forth the network policy and objectives of AES with respect to the different observing systems. The standards relating to network planning and design, which include station spacing, siting and exposure criteria for some of these networks, stem from those promulgated by the WMO. Refinements of these criteria are incorporated into the standards as experience and research shed new light on optimum network designs.

In the past, meteorological instrumentation was fairly well standardized because instruments were specially manufactured for a national meteorological service according to service specifications. The Campbell-Stokes sunshine recorder was developed almost a hundred years ago and it continues to be used in many observing networks around the world as the standard instrument for measuring sunshine. In some instances, a meteorological organization would design and fabricate its own instruments for the national network. A case in point is the AES mercury station barometer, which is both designed and assembled by the Canadian meteorological service. The AES has an inventory of approved standard instruments for use in its regular observing networks. However, this traditional method of instrumenting networks is changing. National meteorological services and other agencies are increasingly incorporating commercially available meteorological instruments into their weather-observing networks. As the availability and scope of meteorological sensors and sytems from a variety of companies expand, there is a pressing need for the standardization of instrument parameter definitions and of instrument test procedures. If each manufacturer of meteorological instruments would use nationally accepted standard tests to establish performance characteristics for his equipment, then the confusion and misunderstanding existing between manufacturer and users could be minimized. Standard tests can become the mechanism by which necessary information about available meteorological sensors and systems is acquired. Then the task of evaluating the suitability of equipment to adequately fulfill the measurement requirement would be greatly aided. The American Meteorological Society took the initiative on the instrumentation standards question some time ago, but the need to support the development of these standards in Canada should be pursued (Lamb and Pharo 1967).

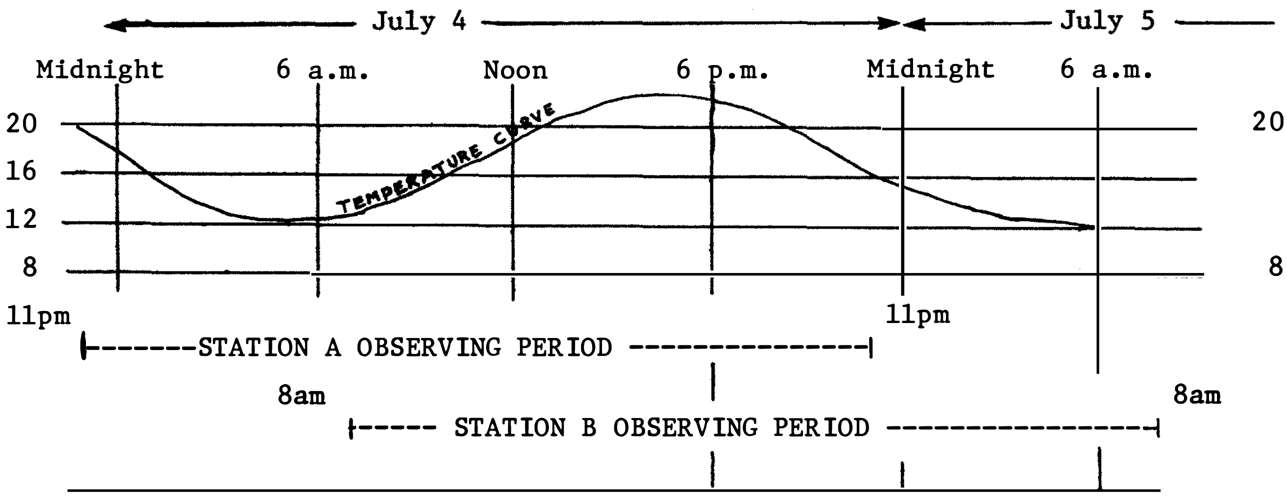
Standards relating to the reading, recording and reporting of weather observations and their coding constitute some of the most visible aspects of standards application in weather-observing networks. National standards for observing or measuring weather parameters in most cases follow directly from the WMO recommended standards. Included in these standards are the parameters to be observed or measured, the accuracies required, times of observation and format specifications, including coding. The hourly weather report is interesting to reflect upon because it was originally conceived about 40 years ago as the Airways Weather Code primarily to meet the needs of the aviation industry in North America, but has, through time, grown in usefulness to the point where it is the main source of weather data for a multitude of users. The earth is divided into time zones and Canada is overlaid with 7 of them. Consequently, the times when observations are taken may create problems for users of data. For the timing of observations, standard times are fixed by WMO and the official times adopted by the country concerned should be as close as possible to the standard times.

This is not always practical. Canadian principal climatological stations use hourly data to make observations for each "climatological day," which is the 24-hour period ending 0600 GMT. On the other hand, ordinary climatological stations (the volunteer stations) make two readings per day at approximately 8 a.m. and 8 p.m. Unless these distinctions are known, seeming inconsistencies arise when comparing data between the two types of stations (Fig. 1). Comparing U.S. data to Canadian data is further complicated because the U.S. National Weather Service equivalent to our principal climatological stations bases its climatological day on the local calendar day.

The AES Network Standards Division is also responsible for the final quality control of all surface weather data and upper air data prior to placing the data into the national climatological archive. Quality control criteria which are imposed on surface meteorological data for the flagging of suspect data include check for excessive values, check for interparameter consistency, mathematical check, and check for unreasonable changes of the parameter in space and time. The quality control process is a vital part of insuring that data published in official AES publications and accumulated in the archives is as complete and error-free as possible.

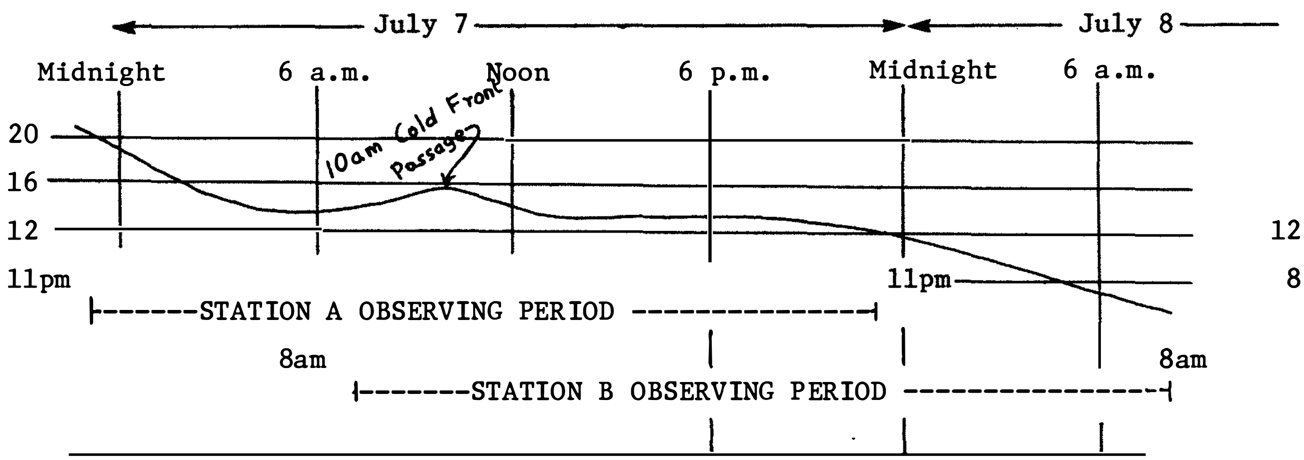
In conclusion, the use of standards should not be seen as a deterrent to adapting a weather-observing network to meet changing needs; rather, it is the means whereby accurate and complete weather data are made available in a consistent format so that they are useful to a maximum number of users. Certainly data collection systems cannot be static. They must be continuously reassessed in light of changing international, national and regional needs. The WMO has shown its responsiveness to changing needs through its formulation of plans and standards for background air pollution monitoring, global water-quality monitoring and a program to standardize the use of automatic weather-observing stations by arranging for a study comparing different available automatic observing systems. In recent years, there have been significant changes in the objectives for which meteorological observations are required. At the national level it is incumbent on the AES as the national service agency in meteorology to continue to be responsive to the changing needs of groups dealing with weather activities. The establishment of Private Aviation Weather Reporting Stations (PAWRS) is an example of a new network required by aviation at airports with limited facilities. The standards of weather observations at these stations are the same as those for the regular hourly weather reporting network. However, the data not archived by the AES, mainly because of the irregular observing times. There is a growing need for weather data at a local or regional level which is sometimes not fulfilled by the existing national observing network. This need can often be satisfied through special arrangements between AES and the agency concerned, once the mutual benefits have been identified. The aspect of economics has not been considered here. It is recognized, however, that the economic factor is of supreme importance in establishing and operating data acquisition networks. When methods of

(i)



Maximum temperature for Station A for July 4 is 18°C.
Maximum temperature for Station B for July 4 is 18°C.

(ii)



Maximum temperature for Station A for July 7 is 20°C.
Maximum temperature for Station B for July 7 is 16°C.

FIGURE 1

The effect of different observing times on recording the maximum temperature at two Alberta weather stations which are located close to each other and assuming that both stations experience the same air temperatures. Station B is an ordinary (volunteer) climatological station where readings are taken twice a day - at 8 a.m. and 8 p.m. Station A is a principal climatological station (usually a synoptic weather station) where the climatological day is from 0601 GMT to 0600 GMT the following day. Note that in the normal case (i) the maximum temperatures are the same, but in changing weather conditions, as in example (ii), the results can be quite different.

obtaining required data are examined, the overriding factor is usually the availability of funds. In the AES observational systems, the application of national standards plays a very important part in the provision of accurate and complete weather data. Other agencies within Canada operating or contemplating operating weather-observing networks are encouraged to adopt AES standards, especially if their observed data are intended for inclusion in AES publications.

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AN OBJECTIVE APPROACH TO CLIMATIC NETWORK PLANNING

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ABSTRACT

In order to maximize the benefits derived from the limited resources available to support climatological networks, it is necessary to re-evaluate our network standards and to devote a considerable effort to network planning. Some of the factors which must be considered in preparing a rational network plan are considered in this paper.

Carried to the ultimate, the rationalization of the network design process could result in a highly objective plan for the evolution of a network which would provide a near maximum return for whatever resources are invested. Even allowing for a significant degree of subjectivity in assigning weights to the various factors considered in arriving at the design network, this sort of rational approach should result in significant improvements over the existing network.

A number of factors which should be evaluated in designing a climatological network are examined for a specific area, the province of Alberta. These include known climatological variability, land use and economic factors, topography, and existing networks. A sample network design is produced based on an evaluation of these factors as they are published in the Atlas of Alberta.

Network requirements for climatology and those for a typical operational activity are examined with points of similarity and differences enumerated so that dual-purpose stations might be identified and separated from stations which would be used primarily for operational purposes.

INTRODUCTION

The existing Atmospheric Environment Service (AES) climatological networks in Alberta have developed on long-standing network design criteria. These are based primarily on spacing limits, e.g., the 40-km spacing between Precipitation-Temperature stations. Stations were also to be "representative of the area." In later years, there have been modifications taking into account population density or the size (population) of urban centres. There has been, as well, the unstated criterion that it be possible to recruit a (volunteer) observer.

This paper proposes an alternative philosophy in climatological network design. The gross features of our climate have been identified fairly well using the existing networks. Now we can afford to re-examine our networks so that the data they provide might permit us to obtain greater definition in our climatic picture in order to better meet the needs of the area and of the nation as a whole. Observer requirements should have less influence than formerly with the development of electronic data recording equipment. The rationale behind these proposals is that the network design criteria should reflect the social and economic needs of the area, the physical relationships between climate and topography and also the gradients of the important climatological parameters as they have been determined from existing data. They should also reflect the need for baseline data required in environmental impact studies.

REQUIREMENTS

1. Network design should take into account climatic and topographic variability, with denser networks where these variabilities are greater.

2. Network density should reflect the economic and aggregate social needs of the areas, as measured by the annual value of climate-sensitive production and population density. Recognition should be given to the potential development of new industries and activities in each area.

3. Network design should take into account existing stations, especially those with long complete records and a reputation for accuracy, and those with extensive observing programs.

4. Greater use should be made of climatic studies or projects using dense networks or transects incorporating existing continuous stations plus special stations operated for fixed terms. These special stations should be automated to the maximum possible extent. These studies or projects could determine small-scale gradients and variability in data-sparse areas as related to the long term continuing stations.

5. The network should comply with standards established by the user or publisher.

BASIC NETWORK--PRECIPITATION AND TEMPERATURE--ALBERTA

The network should be designed to provide coverage at least equivalent to the existing AES standard for Ordinary Climatological Stations (Precipitation and Temperature) when averaged over the southern, more densely populated half of the province. A reduced coverage sufficient to meet the needs of the less populated northern half of the province and at least equal to the minimum AES standard for northern areas should be established in the north half of Alberta.

The following comments on climatological, topographical, and economic factors are based on maps in the Atlas of Alberta, published in 1969. Appendix 1 lists the significant maps.

1. Two areas in the southern half of Alberta can be identified as having relatively low population density, weak gradients of the climatological parameters and few outstanding topographical features. These are the areas south and east of Foremost (excluding the Cypress Hills) and the area bounded on the south by the Trans-Canada Highway through Medicine Hat to Brooks, thence by a line northward through Drumheller to Stettler and northeastward to Provost. Station density in these areas could be relatively low.

2. Between and west of these areas the productivity in agriculture, forest products, oil and gas, construction, water supply and hydroelectric power, recreation, etc. is high and the population density is relatively high. Climatological and topographical gradients are generally strong, with a majority of isopleths running from north or northwest, to south or southeast. The irrigated areas are particularly productive agricultural areas and strongly affected by climate. Station density should be high.

3. In central Alberta, economic activity is moderately high and more uniform from east to west, but dropping off in the foothills and mountains where forestry and recreation become the main activities. Fossil fuel extraction is important but less weather-sensitive. Population densities are fairly high throughout this area except in the mountains. Climatic gradients are generally weaker than in the south. Topography is relatively weak east of Edson, but the foothills and mountains span approximately 240 km (150 miles) with numerous ranges of hills and mountains on a line from Edson through Jasper to the continental divide. Climatological data in the latter area are limited, and the area is denoted on many of the climatological maps as having "insufficient data." Station density should be greater than average.

4. The upper portion of the Peace River basin in Alberta and the lower portions of its major tributaries have moderately well developed agriculture and forestry industries and a major coal development. Station density should be average.

5. In the lower Peace, a resource railway, some irregular agricultural development and existing oil and gas pipelines with a potential for further pipeline, forestry and agricultural development require that a medium density network be designed in that area. Station density should be average.

6. A transportation corridor provided by the Athabasca River and development of the Alberta Oil Sands dictate the design of a medium density network along a line from Lac La Biche, Alberta to Fort Smith, N.W.T. Station density should be above average in the oil sands assessment. Slightly below average would suffice elsewhere in this area.

7. That area of northern Alberta lying between the Peace and Athabasca rivers is sparsely populated, with very limited economic development and apparently limited potential for development. Most climatological parameters have weak gradients so far as can be determined from the limited data available (which consist mostly of summer reports from the Forestry lookout towers). A sparse network will meet the essential requirements for this area. The existing network is biased to hilltop sites but otherwise adequate in the summer months. It should be strengthened by the addition of storage or recording precipitation gauges and wind-temperature recorders at a limited number of lookout towers in order to extend their record through the winter months.

8. Representative stations should be maintained in all of the cities. Specifically, this would require the establishment of a high quality Precipitation-Temperature station plus wind at Lloydminster, where urban growth may be having an effect on the local climate. The data from the station in the valley at Red Deer should be studied to ensure that it is representative of the valley portion of the city. Comparison of this station with Red Deer Airport (Penhold) and other nearby stations on the surrounding "plain" might then establish the effects of the valley and changes brought about by urban growth. The stations at the other smaller cities should be examined from the point of view of their representation of the city climate.

9. Sufficient networks of Precipitation-Temperature stations should operate in the metropolitan areas of Calgary and Edmonton to establish local variations which may be important in the design of municipal services, e.g. storm drainage. These networks should also be sufficient to detect the gross features of any climatic change brought about by urban growth and development. Existing networks in these cities are nearly adequate.

A SAMPLE SOLUTION TO THE NETWORK DESIGN PROBLEM FOR ALBERTA

One possible solution to the network design problem for Alberta is shown in Figure 1. Assuming that topography, specifically elevation above the mean sea level, is a major factor in determining climatological variations in Alberta, climatological observing stations are arranged in a series of transects parallel to the topographic and climatological gradients (i.e., perpendicular to the isopleths of elevation or climatological parameters). Some should be sited at ridges or valleys in order to establish or confirm relationships between climatology and topography. This should permit the extraction of more climatological detail from a given quantity of data. In Alberta most of these transects will run in an east-west direction.

A few widely spaced north-south transects are designed to establish latitudinal relationships and to tie in the east-west transects. Fortuitously, the needs identified by the economic and social patterns in the northern half of the province will be substantially satisfied by two of these transects.

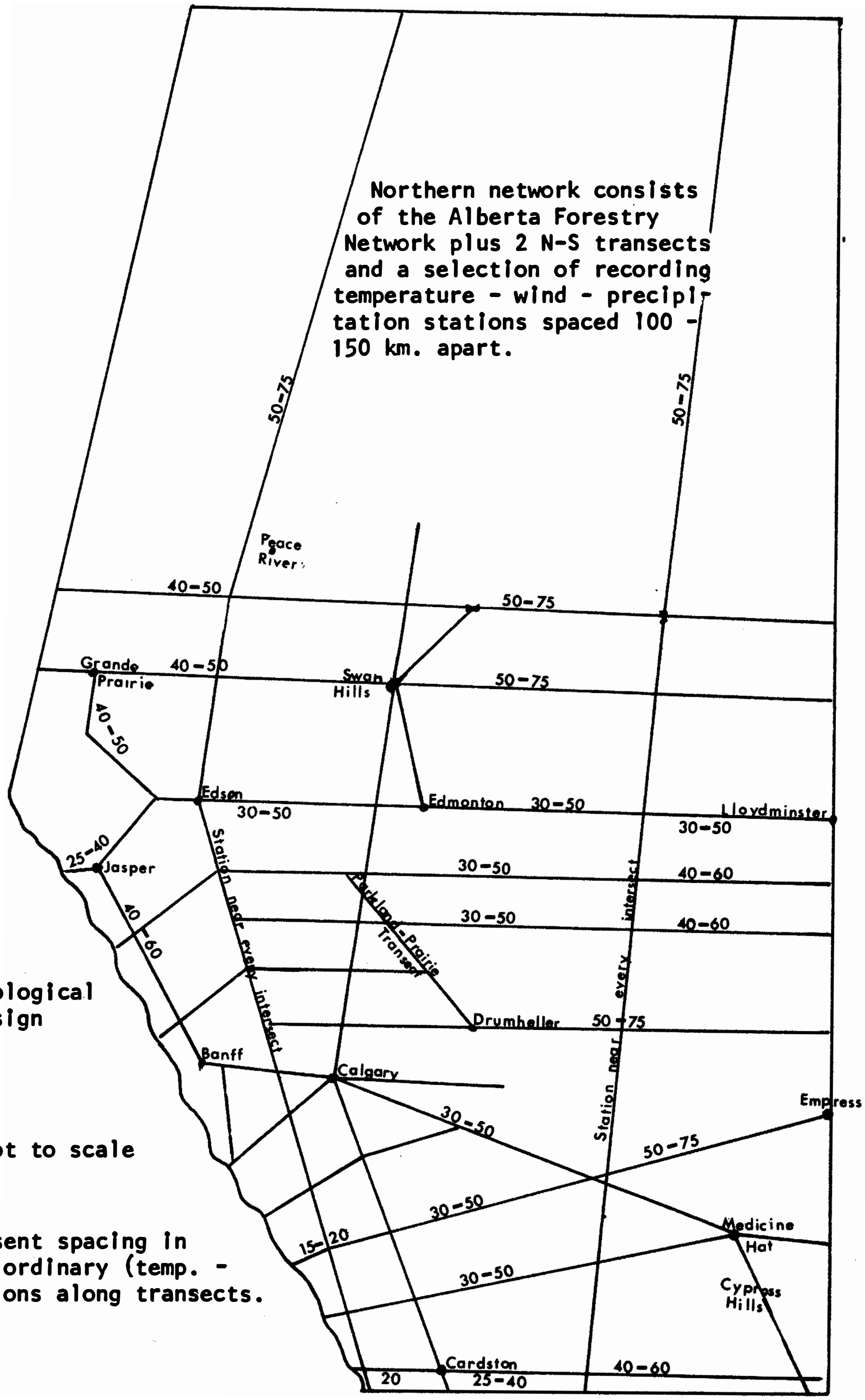

FIGURE 1.

Sample Climatological Network Design

Schematic - not to scale

Figures represent spacing in kilometres of ordinary (temp. - precip.) stations along transects.

The number of long transects and station spacing along the transects are based on an examination of such factors as agricultural production, forest production, forest resources, population density, hydrology, irrigation areas, recreation and hydrocarbon deposits. The location of the transects has been fitted to the existing network insofar as this was possible. Special purpose transects are shown in areas of special interest. These include the Cypress Hills, the Swan Hills, a prairie-to-parkland transition and the Eastern Rockies watershed.

Stations measuring precipitation only should usually be established solely for the purpose of identifying the variability of precipitation in a particular area. Therefore, they should be established in groups around representative Precipitation-Temperature stations with 10-20 km separation from the central station and each other. The number of these small-scale precipitation networks would depend on the variability of precipitation in time and space as determined from the existing data. Exceptions to these general standards would be: stations located in areas where the Precipitation-Temperature network is sparse, recording precipitation stations operated primarily for hydrological studies, and stations which are expected to expand to a full Precipitation-Temperature program at a later date.

At Calgary and Edmonton there is a requirement for two or three stations in the valleys and a number of stations on the surrounding plains within 16 km of the city centres, selected to represent different slopes, aspects, elevations and land use. These are required to determine variability of precipitation and to determine urban climate effects.

CLIMATOLOGICAL NETWORK REQUIREMENTS VS OPERATIONAL REQUIREMENTS

Virtually any collection of meteorological data could probably be used one way or another in delineating some feature of the climate or microclimate of the area where it is gathered. However, much of the data gathered on an operational basis in support of specialized activities may overlap or otherwise exceed the time and space densities required to meet the requirements in climatology, while lacking the permanency, accuracy or siting requirements of the climatologist. Conversely, stations or data which are essential in determining features of the climate of a given region may not be directly and operationally useful to any other particular activity. A hypothetical example of the former might be a dense network of precipitation stations which would be required to permit scheduling of irrigation using a water balance method over a large irrigation area in southern Alberta. The extreme variability, in time and space, of convective precipitation would dictate a station every 3 or 5 km, reporting daily during the growing season, to permit optimum utilization of the available water. Such a network might choke a climatological data processing system with superfluous data. On the other hand, a small selection of stations or groups of stations from such a network, recorded year-round over a period of years, could provide useful information on the spatial variability of precipitation.

The requirements of the irrigation user might be listed as:

1. A dense network-spacing 3-8 km or less.

2. Complete coverage of arable, irrigable lands.

3. Precipitation data required from early spring to the end of the growing season only.

4. Precipitation measurements taken at sites chosen to be as representative as possible of the surrounding arable land.

5. Current data, plus a starting soil moisture value, are essential. Long, homogeneous records are not required.

The requirements of the climatologist might be:

1. A broad-scale network of reliable, accurate, homogeneous year-round, long-lived stations, each representative of a large surrounding area.

2. Selected-small scale networks comprising a few stations perhaps similar in spacing to the water user's network described above, but including the full range of elevations and landforms in the area. These small networks serve the purpose of developing topo-climatological relationships which would, hopefully, be transposable to similar areas in the surrounding region.

3. Daily or more frequent readings are usually essential, but real-time reporting is not usually required.

From these requirements, it can be seen that in this example, only a fraction of the total number of stations in one network are directly applicable to the other.

APPENDIX 1

The following maps in the "Atlas of Alberta"--prepared by the Government of Alberta and the University of Alberta, 1969, published by the University of Alberta Press, were considered in the preparation of this paper:

Page 14
- Growing degree days
- Heating degree days
- Mean annual temperature range

Page 15
- (Date of) last spring frost (mean)
- (Date of) first fall frost (mean)
- (Mean) frost-free period
- (Number of) winter days with maximum above 40°F
- (Number of) summer days with maximum above 80°F

Page 16	-	Precipitation--various--9 maps
Page 17	-	Precipitation
	-	One day rainfall--5 and 25 year return periods
	-	Precipitation extreme--mean 24 hours
	-	Thunderstorms, hail--frequency
Page 18	-	Hours of sunshine
Page 19	-	9 maps of water demand, surplus and deficiency
Page 25	-	Water use
Page 29	-	Vegetation
Page 34	-	Soils
Page 35	-	Land resources
Page 53	-	Population--urban and rural distribution
Page 67	-	Land use
Page 71	-	Agricultural products sales
Page 89	-	Forest productivity (potential)
Page 91	-	Forest products
Page 102	-	Refineries and pipelines (needs updating)
Page 128	-	Recreation

CLIMATIC NETWORKS FOR FORESTRY PURPOSES

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ABSTRACT

A forest is a complex ecological system upon which climate can have both direct and indirect effects. Some of the problems of obtaining representative climatological data for a forest environment, and the standards and types of climatological stations and networks required are discussed. Examples are given of various forest climate networks at the macro-, meso-, and microscale in Alberta, and the varying needs of the different forest disciplines for climatic information.

INTRODUCTION

A forest is a complex ecological system upon which climate can have both direct and indirect effects. There are six environmental variables that directly affect the status or rate of the physiological processes of the forest: light, heat, water, oxygen, carbon dioxide, and mineral nutrients. All other environmental or site variables are indirect because they regulate either the absolute amount or the rate (quality and or quantity) of supply of one or more of these six primary growth factors. Examples of some indirect variables would be elevation, aspect, topography, soil texture, soil depth, water table, and permafrost. The forest environment is an atmosphere-plant-soil continuum of atmospheric and lithic components in which physical quantities, especially water, nutrients, energy, and carbon dioxide, are continually being transferred in the continuum; however, it also has a biotic component. The organisms in this forest community all interact and can either directly or indirectly affect both the survival and growth of the individual tree in the community or ecosystem. This effect will also change with location, time, and treatment.

A knowledge of the distribution of meteorological parameters within a forest stand is therefore very important. In a forest the climatic stratification is so clearly discernable that one can speak of a climate of the forest litter, ground flora, undergrowth, trunk space, etc. In the forest every layer shows different sources and sinks of heat and moisture; thus, in any climate study of a forest stand ideally each layer should be measured. From a practical point of view the most important ecoclimatic regions of the forest are the crown space, the air layer near the ground, and the upper layer of the forest soil. The first two layers are connected with the two active surfaces in a forest--the canopy surface and forest floor, although depending on the density of the forest, several active surfaces may be present in the trunk layer. The atmospheric variables in the forest will undergo large and rapid changes in time, but not as great as in the open; however, these changes require sampling over time and different sampling intervals because of different rates of change. As Munn (1970) has indicated, it may be convenient but not at all relevant to use data from stations set up in an open-grassed area in physiological investigations of adjacent forests. In forest climatology we have to consider the whole range of climate from the general conditions over a country to the particular microconditions of a spore on a plant leaf or an insect under the bark of a tree.

The spatial, temporal, and treatment-induced variability of the factors have always made it difficult to conduct detailed investigations of the forest physical environment, and this is compounded by the problems inherent in the measurement processes themselves. Basically there are three problems associated with the measurement of the physical environment: 1) indirect measurement of the variables by instruments or other procedures, 2) quantity of measurements required, and 3) the differing measurement requirements of the variables used to describe the forest environment. Federer (1974) indicated that some 63 variables could be considered for the description of the changes in the physical environment because of a relatively simple forest treatment; however, not all have to be measured, although in fact the most important changes may not be measurable.

SOME RECOGNIZED STANDARDS FOR CLIMATOLOGICAL STATIONS, INCLUDING FIRE WEATHER

With that brief introduction to the forest ecosystem, an environment in which it is probably more difficult than in any other to obtain representative meteorological data, I wish to turn to some recognized "standards". In its Guide to Agricultural Meteorological Practices (1968) under the heading "Agrometeorological observations in forest areas" the World Meteorological Organization states the following:

> Two types of observational stations are generally necessary:
>
> (a) Standard climatological stations, to measure the climate of areas in which forests grow;
> (b) Forest stations, to measure climates within or near a forest.
>
> *Standard climatological stations*
>
> Standard climatological stations in forest areas should be similar in exposure to those in other agricultural areas, so that they may form part of the same homogeneous network. In theory this may be accomplished in two ways:
>
> (a) If the forest has a compact canopy with a relatively smooth top, by exposing the instruments above that canopy in the same manner as the instruments at other agrometeorological stations are exposed above a short grass surface; and

(b) By locating the instruments in a grass-covered clearing in the forest area, the clearing to be large enough for the influence of the forest to be negligibly small, i.e. large enough for the data observed therein not to be significantly different from what would be obtained in a much larger clearing.

In practice the first method would rarely be suitable because of the rough and porous nature of most forest canopies. The second method is preferred.

It remains to be determined how large the minimum acceptable size of clearing should be. This will depend on the height of the surrounding forest. Current information suggests that the diameter of the clearing should be at least 10 times, preferably 20 times the tree-height of the surrounding forest.

Much forest land is topographically rough. Care should be taken, when selecting a station site, to avoid hollows and, generally, any areas where the ground surface is concave. A slight convexity of surface is preferable.

Forest stations

Macroclimatic observations inside, or close to the borders of forests are required for the understanding of many forest processes or for planning and co-ordinating operations related to these processes. The siting of instruments for such observations, and the selection of meteorological elements to be observed will depend on which processes are of interest.

Growth of forest trees is related more closely to the air temperature in the crown space than to that two metres above ground in the trunk space. In practice, observations made somewhat above the crowns rather than inside the crown should give values more representative of an area.

Standards for location of fire weather stations in North America are provided by Turner and Lawson (1978) and Fischer and Hardy (1976); both indicate that they should conform as much as possible to standards for climatological stations. Fischer and Hardy (1976) state that fire-weather stations should be on level ground where there is only a low vegetative cover and situated where they will receive full sun for the greatest possible number of hours per day during the fire season. If a station is located on a slope, a south or west exposure is required to meet fire-danger rating standards (Deeming et al. 1972). Sites with distinct changes in topography, such as gullies, peaks, and ridges, should be avoided. The sites should otherwise approximate those selected for the standard climatological station to give long-term operation, relatively unchanged exposure, program and quality of observations, and representative records for the site area for at least 10 years (World Meteorological Organization 1960). Referring to a fenced area with mown grass or cropped natural vegetation, Turner and Lawson (1978) state that "when located in a logged area, the enclosure should be cleared of logs and branches". Fischer (1973) indicates that a ground cover of coniferous needles or a bed of gravel would provide an acceptable substitute in areas where a well-clipped cover of natural vegetation is lacking and cannot be maintained without irrigation around a fire-weather station. Another publication (Fischer and Hardy 1976) recommends that brush and trees be kept down within a 6-m radius of the station.

GUIDELINES FOR CLIMATE NETWORKS

The Guide to Climatological Practices (World Meteorological Organization 1960) states under "Networks" that "ideally, the number of stations at which any particular climatic element is observed should be large enough to permit a complete analysis to be made, without resorting to doubtful hypotheses, of the geographical distribution of mean values, frequencies, extremes and other characteristics of this element". Further, in order to determine gradients of the various climatic elements in the vicinity of large-and small-scale geographic boundaries, such as large lakeshores, mountain ranges, and valley bottoms, it is necessary to establish networks of chains of ordinary climatological stations at distances of 2-10 km between individual stations perpendicular to such geographic features. Other stations in a direction parallel to such boundaries may be as much as 25-50 km apart, depending on the circumstances. Networks of this density should work equally well in forested areas.

The Guide to Agricultural Meteorological Practices (World Meteorological Organization 1963) states that under ideal conditions, a network of stations should cover all aspects of variation of climate and soil and each type of agricultural, horticultural, or forestry activity. Later it states that a reasonable aim is to have one observer for every 50 km^2, and that marginal areas of agriculture and silviculture will often deserve special attention in order to determine the boundary of the region where an individual crop can be grown successfully or a specific agricultural or silvicultural procedure is profitable. It is also important in such marginal areas to ascertain the frequency and the typical geographical distribution of the main weather hazards.

Gandin (1970) provides a review of some of the methods of establishing networks and the density required for the various elements. He describes three groups of basic station networks, the elements they should observe, and the admissable distances between stations for flat areas. In mountainous areas the density may have to be twice as great; he also noted that network requirements differ greatly from region to region. The need for data in one season may be greater than in other seasons, which could affect the density or operation of the network. He stresses the need to have reference stations in any network for studying long-term climatic changes, for correcting data from other stations, and for analysis of the representativeness of individual stations. Canada has few designated reference or bench mark stations, and up to 1968 only one in Alberta at the Ellerslie farm of the University of Alberta (Potter 1968).

Guidelines for the administration and expansion of the ordinary (daily temperature and precipitation), precipitation, and supplementary climatological (evaporation, rate-of-rainfall, soil temperature, bright sunshine, and wind) networks in Canada are given by Potter (1968). These include suggested separation distances between stations and the annual rate at which the various networks should be expanded. These guidelines might not be current, for over the last few years there has been a decrease in the number of ordinary and precipitation stations.

Corbett (1967) states that the best locations for a group of stations can be determined only by operating a dense network long enough to provide data for making a selection. Once the relationship between the density of the observational network and accuracy of areal rainfall determinations (or other variables) is known, the network can be scaled down to achieve the desired degree of accuracy. However, economic considerations may be a limiting factor! The purpose of the network is the primary consideration in determining the relevant density or scale of sampling. In his textbook Biometeorological Methods, Munn (1970) states that a network may be required for one of three reasons: a) to obtain areal mean values, b) to interpolate between observing points for subsequent correlation with biological variables or for provision of information on local climate, or c) to predict the behavior of environmental variables, using empirical methods or physical models that require knowledge of initial conditions.

Turner and Lawson (1978) discuss fire-weather station networks and indicate that the fire-danger index values can be expected to be highly reliable within a radius of about 40 km over flat terrain, but at distances greater than 160 km, weather conditions are usually so different that the index is generally unreliable. From a 10-year study of index values and fire statistics in British Columbia, Lawson (1977) concluded that useful values were obtained about fire activity for as far as 100 km away. Turner and Lawson (1978) feel that until suitable automatic fire weather stations are available, stations will be located where people can attend them daily and on time, whether the stations cover a large area for a regional network or a few square kilometres for a particular operating area. Often differences in elevation can be far more significant than distance alone, especially in mountainous terrain. Supplementary fire weather stations are often necessary, differing from the regular stations only in their permanence, number of parameters measured, or measurement at infrequent intervals. Such supplementary stations are often required in locations where a fire weather index is to be used.

King and Furman (1976) estimated the density of fire-danger stations necessary to measure the "average worst" fire danger conditions, based on the Burning Index in the U.S. National Fire Danger Rating System (Deeming et al. 1972), for six relatively homogeneous fire-climate regions (after Schroeder and Buck 1970). The resulting spacings provide approximate guidelines for planning fire-danger station network densities. Furman (1975) further employed a method to group existing fire-weather stations based on an analysis of the similarity of sequences of six fire climate elements over a fire season, to determine if there is duplication in monitoring fire climate and if so, to what degree. This method can help a fire manager streamline a fire-weather station network for reasons of economy with least impact on his ability to monitor the fire danger.

FORESTRY CLIMATIC NETWORKS

Macronetworks

Forestry depends on the regular climatological network of the Atmospheric Environment Service (AES) in the forest and fringe agricultural areas. In spite of all the climatological stations in the AES network we have very limited data and observations from the forest land environment, exclusive of the daily observations from fire weather stations during the fire season and the odd valley-bottom station.

Fortunately in Alberta the AES network has been greatly augmented in the forested zone by the Alberta Forest Service (AFS) network of fire-weather stations at lookout and ranger stations; some of the latter have been operated year-round for short periods. Without this network of daily summer recording stations, which saw great expansion in the early 1960's, the network in the forested area of Alberta would be very sparse. The present network consists of about 180 forest-fire-weather stations, which are used by the AFS to augment the AES network to provide greater detail for such items as the surface weather charts. Data from the fire-weather network are used to monitor fire-weather conditions and to produce fire-danger ratings. The hazard-rating maps are used to help deploy the protection teams and equipment for potential fire-fighting needs to combat fires. The daily lightning occurrence maps are also used for fire detection surveys. The climatic network is also used by the AFS for other purposes. In Saskatchewan, unfortunately, the information from the fire-weather lookout stations is employed only for fire-weather forecasting; the irregular observations, often taken only at midday, do not find their way into the _Monthly Record of Meteorological Observations in Canada_ published by the AES. These fire-weather stations are of little use for other forestry purposes or for resource management in general unless daily climatic parameters are recorded. However, the farsightedness of the AFS in upgrading its fire-weather stations and network density in the early 1960's has allowed their use for other climatological purposes; many were listed in the 1941-1970 _Canadian Normals_ for temperature and precipitation (Environment Canada 1975 a, b). Recently many of the AFS stations were used as part of a network of over 300 stations to develop a summer climatic classification for the forested areas of the three prairie provinces based on the 1961-70 period to assist resource management (Powell and MacIver 1977). The AFS is using an earlier phase of the classification system to develop a seedling planting schedule. The forest climate classification will also be useful for other forestry management purposes and research, such as stand establishment studies, tree provenance trials, hydrological studies, site and productivity classifications, delineating hazard areas for disease and insect organisms, and fire protection.

Meso- and Micronetworks--general

Climatology is concerned with studies of local and regional climate on a micro-, meso- and macroscale. Thus, besides the normal climatological network or fire climate network at the macroscale, other more intensive networks are required at the meso- and microscale for a wide range of forestry or forest-related studies. The scales represented by the terms micro-, meso-, macroclimatology and other terms such as topoclimatology or agrotopoclimatology have been variously defined (Geiger 1951, 1965; Huschke 1959; MacHattie and Schnelle 1974; Schroeder 1961; Tepper 1959; Thornthwaite 1953; and others).

Mesoclimatology is concerned with the climate of small places or areas, which the Glossary of Meteorology (Huschke 1959) states may not be climatically representative of the general region, but "may include topographic or landscape features from a few acres to a few square miles, such as a small valley, a forest clearing, a beach, a village site".

Microclimatology is mainly concerned with the distribution of temperature, humidity, wind, etc. with height above ground surface up to a few decametres, and of temperature and moisture content of the soil layers below ground surface down to a depth of a few metres (World Meteorological Organization 1960). The large diurnal variations and pronounced vertical gradients close to the surface decrease rapidly as one moves away from the surface. At any particular instant these factors, which are largely determined by the slope of the ground, the character of the soil, and the nature, extent, and stage of growth of any vegetative cover, vary rapidly with time and place.

Generally meso- and microclimatic networks consist of 8-10 recording points located around a basic climatological station that are operated for a few months or years. The observations in the meso- or microclimatic networks are compared with observations at the standard climatological stations. The networks of stations established to assess the broader features of the meso- and microclimate must be based on simple climate equipment that allows standardization of observation conditions and comparison with the regular climatological stations. Depending on the need, these stations may not be at the standard height of regular stations, but sufficient stations in the mesoclimate network should be at standard height to enable a comparison with regular climatological stations to be made. Conditons near the ground and within a plant cover differ from those at 2 m above ground. For instance, temperature within plants can be 1-2°C higher than at the 2-m level, which for a 5-month growing season will give 200-300°C higher degree-day sum than at the 2-m level. This is equal to a displacement of approximately 1° latitude southward. In microclimatic studies, the closer one approaches the smaller end of the scale, the more do standard meteorological instruments of the type used in microclimate become inadequate for the work; therefore, special instruments, conditions of observation, and routines have to be adopted (World Meteorological Organization 1963).

There may also be a need in certain studies to carry out surveys of the meso- or microclimate of an area by using mobile or portable equipment of small size and sufficient sensitivity to establish the climate regime. These mobile surveys should be linked to regular climatological stations or other stations in a network. Such mobile surveys are very useful in establishing topoclimatic variations in an area and the representativeness of stations. Examples of such techniques used in Alberta, several for forestry purposes, can be found in a number of reports (Hayter 1972 ; Longley and Louis-Byne 1967; MacIver 1970; MacIver *et al*. 1975; Powell 1974).

Examples of some forestry-related meso- and microclimatic networks in our area follow.

Forestry-related meso- and microclimatic networks

A number of mesoclimatic stations were established for 2 years in the Columbia River valley near Invermere, including a transect of stations across and along a tributary valley, Francis Creek, for comparison with observations at Invermere in the main valley. Among other things, the transect of stations was used to show the buildup and dissipation of summer temperature inversions in the tributary valley under three air mass conditions (Powell 1970, Fig. 7). MacHattie (1966, 1968, 1970) employed a similar transect and other stations in the lower Kananaskis valley to investigate the summer temperature, relative humidity, and wind conditions. During the last 7 years a series of mesoclimatic networks was employed on different forest harvesting compartments on the North Western Pulp and Power lease area near Hinton, where 10-20 satellite stations were established for comparison with several base climate stations. Not all the satellite climate stations were operated at the same time, and they were used to sample different aspects, slopes, and size of cut in the area for comparison with the base climate station. At base stations, air temperature, humidity, precipitation, radiation, wind, and soil temperature were regularly recorded, and for shorter periods, soil moisture and evaporation. At the satellites, temperature, humidity, precipitation, and soil temperature were regularly recorded, and other parameters at selected stations or at irregular intervals. In addition, on some cutblocks microclimate networks were established to record local variations for certain climate parameters. Throughout the Hinton area additional precipitation stations, both standard gauge and recording gauge,were employed to provide a denser network of precipitation sampling points. This dense network, which included the regular climatological stations reporting to the AES and data from the Tri Creeks and Cache Percotte Experimental Watersheds, was used to produce seasonal and storm maps in support of forest hydrology studies (Hillman *et al.* 1978). Examples of other dense precipitation networks in support of forest hydrology studies are found in the Marmot Creek basin (Storr and Ferguson 1972). This experimental basin also has a dense grid network of snow survey sampling points and a series of snow courses (Storr and Golding 1974).

Other microclimatic studies in forestry may include several related discipline areas. For forest regeneration and seedling growth studies it is the microclimate close to the ground, both of the air and soil layers, that is relevant. In forest entomology it is often the habitat niche conditions which are important, or a combination of climatic parameters that restrict the insect to a particular zone of the forest environment. In forest pathological investigations different climatic parameters can affect the pathogen at different stages. For example, a single spore stage requires favorable atmospheric climatic conditions for sporulation, release, dispersal, and deposition; suitable climatic conditions are then required for germination, followed by penetration and colonization of the host before sporulation starts again to repeat the cycle. A dense microclimate network was used to follow the conditions necessary for the dispersal of pine stem rust spores from cankers under different forest canopy closures (Powell 1969) and to show relationships between spore release and different climatic parameters (Powell 1972). The conclusion from these examples is that the design of networks depends on the objectives of the study, and thus on the climatic elements to be monitored. It is hoped that all the micro- or mesoclimatic networks needed to answer a particular forestry requirement will be able to tie into an existing climatological station or macroclimatic network in each forest region having a different climatic regime.

CONCLUDING REMARKS

Historically, macroclimatological or meteorological information has been used mainly by the forester in the fire protection area. Other forestry disciplines have been using more and more climatological information, as indicated by the hazard zones developed for insect (Safranyik et al. 1974) and disease problems (Charlton 1963), or the use of special forecasts for preventing infection of forest nursery stock by rust fungi.

Recently, Tikkala (1976) indicated some of the areas in forestry where meteorology should be of interest to foresters; these included reforestation of lands that have been denuded through one means or another, logging planning, engineering requirements, recreation planning both winter and summer, and insect and disease management in the forest environment. He indicated that one of the keys to expanding cooperation with meteorologists in forestry-related weather operations is the use of the fire-weather stations on a year-round basis, at multiple purpose locations and with broad-scale analysis of data. At the same conference, Lamb (1976) stressed the need for better sampling of the forest and rangeland environment both diurnally and through the year. He also noted that we are not effectively utilizing existing climatological data, and that the users, or potential users of information, have not accepted or identified their own responsibilities for effective use of climatological resources. It is hoped that the needs of the forester for climatic information will be provided by our present and future climatological networks, or that he can use special climate stations for his purpose and tie into the network.

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METEOROLOGICAL DATA NEEDED IN SOIL CONSERVATION STUDIES IN ALBERTA

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ABSTRACT

Three deficiencies in Alberta meteorological data currently hinder progress in improving soil conservation efforts. The first is information on rainfall intensities. The Alberta Hail Studies program has provided data which suggest that intensities for short periods are much greater than those so far recorded by Atmospheric Environment Service stations. Application of the Universal Soil Loss Equation requires more precise information about our rainfall in order to arrive at realistic values for R, the rainfall factor in the equation. A second deficiency in my opinion is one of failure to communicate information which is currently being gathered relating to precipitation. Continuous cropping is less likely to result in soil losses than summer fallowing, but farmers on thin black, dark brown and brown soils face a quandary every spring: Is there enough subsoil moisture to warrant seeding a new crop on last year's stubble? I believe that a good computer-produced map, based on precipitation data as a percent of normal from August 15 through to April 30 for <u>all</u> reporting stations, and published in the daily papers would be a great help in answering the question. Finally, the third gap in our knowledge relates to wind directions and velocities in parts of Alberta where wind erosion is occurring almost every year and farmers are failing to do an adequate job of strip farming to stop it. The area where more detailed data are especially needed is south of Highway 12 (Lacombe-Coronation) and east of Highway 2 to the east and southern boundaries of the province.

Erosion of soil occurs at an accelerated rate when man moves into an area and removes the protective cover of grass or forest. The amount of erosion is of course related to climatic factors, particularly those relating to wind and rain.

In Alberta the farming of prairie lands in southern Alberta led to serious wind erosion problems which reached a climax in the 'dirty thirties' (Toogood 1971), during a period of extended drought. The problem of wind erosion has still not been solved on many southern Alberta farms, as indicated by the annual occurrence of dust storms and the filling-in of roadside and irrigation ditches with drifted soil. The Chinook belt of southwestern Alberta has naturally been an area of major concern, with its high wind velocities coupled with large areas of unprotected and dry cultivated fields.

Water erosion in Alberta has been recognized as a problem (Toogood and Newton 1955; Toogood 1963; and Alberta Environment Conservation Authority 1976). The problem is not as serious as in areas of higher precipitation, and for that reason tends to be neglected. Spring runoff poses a special kind of water erosion which has not received much attention, the attitude apparently being that we cannot hope to control the soil's moisture and temperature, the amount of snowfall, and the rate at which it melts in the spring. Runoff resulting from intensive rains in summer has been studied intensively in the U.S.A., and much attention has been focussed recently on the Universal Soil Loss Equation (USLE). A recent publication (Soil Conservation Society of America 1976) reports the proceedings of a 3-day meeting devoted entirely to the USLE and its application.

The equation is as follows: $A = RKSLCP$

where:
- A = tons of soil lost per acre per annum:
- R = rainfall factor
- K = soil erodibility factor
- SL = slope percent and length factors
- C = factor for cropping system used and
- P = factor for practices of soil conservation applied.

The rainfall factor is the one that is of concern to us at this meeting and I would like to draw your attention to the deficiencies we find in data from the Atmospheric Environment Service (AES). First, I wish to comment on rainfall intensity data. Research has shown very little correlation between amount of erosion and total annual precipitation or even 24-hour rainfall. The highest correlation in the U.S.A. was found to be with the 30-minute intensity data and my opinion is that in Alberta, if we had enough data to prove it, it would be with 15-minute intensity data. As you are well aware our very intense rainfalls do not last for many minutes.

That our AES data on rainfall intensities are inadequate was suggested to me by Alberta Hail Studies Records. The AES in the Camrose-Drumheller-Calgary region had, in the 1969-72 period, four recording rain gauges. The heaviest 30-minute rainfalls reported in '69, '70, '71 and '72 were as follows:

AES Station	'69	'70	'71	'72
Calgary	7.9 mm	-	8.4 mm	20.8 mm
Forestburg	8.9	14.0 mm	9.1	11.7
Lacombe	-	14.5	31.0	17.0
Red Deer	25.4	11.9	-	5.6

Meanwhile, farmers in the area, reporting to Alberta Hail Studies on their hail report cards following each storm, filled in blanks stating amount of precipitation and duration of storms, for those same years. Even allowing for some inaccuracies on the part of the farmers in measurement of rainfall and estimates of duration, their data, which follow, contrast with the above AES data:

No. of farmers in the 4-year period who reported	
Over 63.5 mm in 30 minutes	8
50.8 - 63.5 " " " "	11
38.1 - 50.8 " " " "	62
25.4 - 38.1 " " " "	281

Even the long-term record data for the AES stations named do not reach the intensities reported by the farmers:

Calgary	(26 yr of data)	30.5 mm	record 30-minute precipitation
Forestburg	(8" " ")	40.6 "	" " "
Lacombe	(8" " ")	31.0 "	" " "
Red Deer	(11 " " ")	25.4 "	" " "

It seems obvious that a much denser network of recording gauges is needed by the AES to measure adequately the intensities of our summer rainfalls. Such data must be obtained if we want to use the USLE for Alberta conditions.

A second inadequacy of AES data relating to the USLE relates to the C factor, the cropping practice. It is a well-established fact that erosion, both wind and water, is minimized by crop cover. The use of summerfallow inevitably encourages erosion. Continuous cropping is therefore a means of reducing erosion losses and farmers have been urged to adopt the practice. Many years of experience, however, leave farmers convinced that fallowing is necessary, to conserve moisture and for other reasons. In the drier regions of the province they can be persuaded to "stubble-in", or crop continuously, only when good reserves of subsoil moisture are present in early May. Now this is where the AES could render some valuable assistance which it is not currently giving.

It is a problem of communication that needs to be tackled. Mr. C. Gietz of Alberta Agriculture and the Data Processing Centre have shown that computer-based maps of Alberta can be prepared quickly showing accumulated totals of precipitation. Maps that have been prepared to date have been based on only a few (about 40) selected AES stations and thus their value is somewhat questionable. What we need are maps, updated every week, based on cumulative precipitation since, say, last August 1, based on <u>all</u> the reporting stations (in agricultural Alberta at least), and <u>published</u> in the daily and weekly newspapers. Such maps would be a valuable guide to farmers in assessing moisture reserves on hand at seeding time.

The final need which I think merits attention by meteorologists concerns wind erosion. In the Lethbridge-Ft. Macleod area the problem of wind erosion is well recognized. Further north, however, in the Vulcan, Strathmore, Beiseker and Drumheller areas in particular there is wind erosion each year and farmers aren't doing much about it. I believe that more data on wind speed and direction need to be collected throughout the area of the province east of Highway 2 and south of Highway 12. These data would provide our Soil Conservation people with valuable information and a better data base, both for use in extension work among farmers and as a base for research work.

In summary, therefore, here are my three suggestions as to our needs from meteorologists for soil conservation work:

1. Greater density of the network of recording rain gauges.

2. Published cumulative precipitation maps of the province, especially in April, for the preceding 8 months.

3. More data on wind speed and direction.

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CLIMATOLOGICAL REQUIREMENTS FOR A REGIONAL HYDROLOGIST

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ABSTRACT

A regional hydrologist needs to know the actual climatology of a region as well as the daily, weekly, monthly, seasonal and yearly meteorological data that make the final climate.

Of concern are trends, probabilities, forecasts, credibility and availability of temperatures, precipitation, sunshine, radiation, humidity, etc.

Micronetworks are an important need of the regional user. Some of the effects of climate on the design, economics and overall justification of many segments of our regional planning are illustrated.

INTRODUCTION

Climate by definition is average weather. Although we know that weather is variable, we usually consider that the climate of an area stays constant. In most situations, because of a very slow change process in any aspect of climate, it seems reasonable to consider climate as static.

Climatic needs for a region, as considered in this paper, include the long-term parameters as well as the on-going inputs on a day-to-day or "now" basis.

CLIMATE ON A LONG-TERM BASIS

Demands of a regional hydrologist involve precipitation--amounts, intensities and return periods; temperatures--as related to length of growing season, crop limitations and construction industry controls; and sunshine and radiation (net)--as related to cropping, water use and growing season.

The major demands on a hydrologist are related to runoff amounts, timing and their probabilites. Structure design and economic and physical feasibilities are dictated by precipitation amounts, etc.

The available information on return-period rainfall intensities is in the author's opinion so valuable that efforts should be made to improve its reliability. The complexity of Alberta climate is very evident when one tries to evaluate the expected flood peaks, whether caused by snow, snow and rain, or rain.

CLIMATE AND WATER USE

Imposed on the above requirements is the need for water demand values. These may be agricultural (major use in Lethbridge area), industrial, municipal and recreational. Climatic factors of temperature, humidity, radiation and sunshine are essential for determination of this much-requested input to basin planning. The actual measurement on an area by area basis is costly and time-consuming, thereby warranting less accurate but acceptable empirical determinations.

Usually the most accurate empirical method is the one that includes on-site measurements of more of the factors affecting the complexity of water use, especially in agriculture. Therefore, on a regional basis the data collection network should be such to serve such specifics as above. There is a need to evaluate the representativeness of each meteorological factor on an area basis and design the networks accordingly. To illustrate: radiation can be measured at a site for a specific number of square kilometers. Precipitation should be evaluated for its purpose as related to density.

Accuracy of precipitation data on an areal basis improves as the density of gauges increases. There is, however, a point of economics, even physical limitations, that must be acknowledged. In the extreme a solid network of gauges would measure accurately the area rainfall. However, none of the rain would enter the hydrologic cycle in a normal or natural pattern. Somewhere between no rain gauges and total coverage by rain gauges lies the desirable. Experience in a region has emphasized the interaction of water demand and gauge density. As the demand for this renewable resource has intensified so also has the need for more accurate precipitation networks and their input to rainfall intensities, runoff amounts and timing.

To illustrate: runoff forecasting in the Peace River Basin prior to construction of the Portage Mountain Dam was essentially concerned with flooding of lands and danger to life along the banks of the Peace River. However, with the construction of the huge power complex on the Peace River came an economic need to better forecast runoff. The need is emphasized in the estimate that a 1% improvement in spring flood inflow forecasts on the Peace River would result in an additional saving of $1 million in the operation of the dam (1966 dollars) (World Meteorological Organization 1966).

The same can be said for agricultural use in the retention of runoff waters for diversion to farms during the growing season in the south part of the province. As the demand in this use area increases so also does the need to regulate and manage storage for the maximum use of available runoff water.

Although this country has not really felt the impact of water shortages, the possibility is on the horizon. Areas in the U.S.A., and I am sure in other countries of the world, have the amounts of land they can plant each year dictated by the yearly spring snow survey. In other words, some years a farmer is told he can plant 80% of his land according to water available on the watershed, and that is what he plants. This illustrates the need for intensifying the measurement of "now" inputs to climate.

CLIMATIC TRENDS

Basin planning involves much climatic input to final decisions on land use, development proposals and economics of planning. Climatic indicators, whether 100% accurate or not, must be used to determine feasibilities for irrigated agriculture development, industrial complexes and urban development.

There is, in my opinion, a pressing need for more trend analysis and more thought given to the compiling of information required for this type of evaluation. It appears that in some areas there is data available (e.g., temperature readings), but to analyze this information requires much time-consuming calculation. The format for data should be such that trend analysis could be made with little cost to the local planner or user. To illustrate the need for trend data, I would like to discuss the Oldman River Basin (Fig. 1) and to some extent to the rest of the province.

Major settlement of Alberta occurred in the first part of this century (1901-1911) when there occurred a fairly good precipitation pattern. In the 1930's (a long, dry spell) many farms failed, and based on this period irrigation projects in the province were designed to meet such a drought. There are indications that in the 1890's there was even a more serious drought. Should irrigation in Alberta be designed to meet 1930 or 1890 drought conditions, or are the wetter conditions in the 1960's indicative of a trend? An analysis, for example, of precipitation at Cardston indicates a trend of increase of 2.5 cm in 25 years. If this continues, what of the presently anticipated demand by irrigated agriculture on water supplies?

Along with precipitation is the possible trend of temperature--is it real or imagined? In our work with evapotranspiration (consumptive use) of water by plants, we have utilized a method of determining length of growing season proposed by J.R.H. Noble (1970). The method utilizes a plot of the mean monthly minimum temperatures at the middle of each month with a smooth curve joining the points. An approximate mean daily minimum temperature can then be ascertained for any day coming under the curve. Using 0°C frost data, the first and last frosts for each meteorological station were ascertained and located on the graph. The mean daily minimum temperature was read from the graph for these points. Two degrees were subtracted from this temperature, and the new temperature was then located on the graph, this point being the last or first killing frost (see Fig. 2). The assumption was that the difference between the mean daily temperature and 0°C or -2°C is, in spring or fall, a simple multiple of the standard deviation of the daily minimum temperature on a given date.

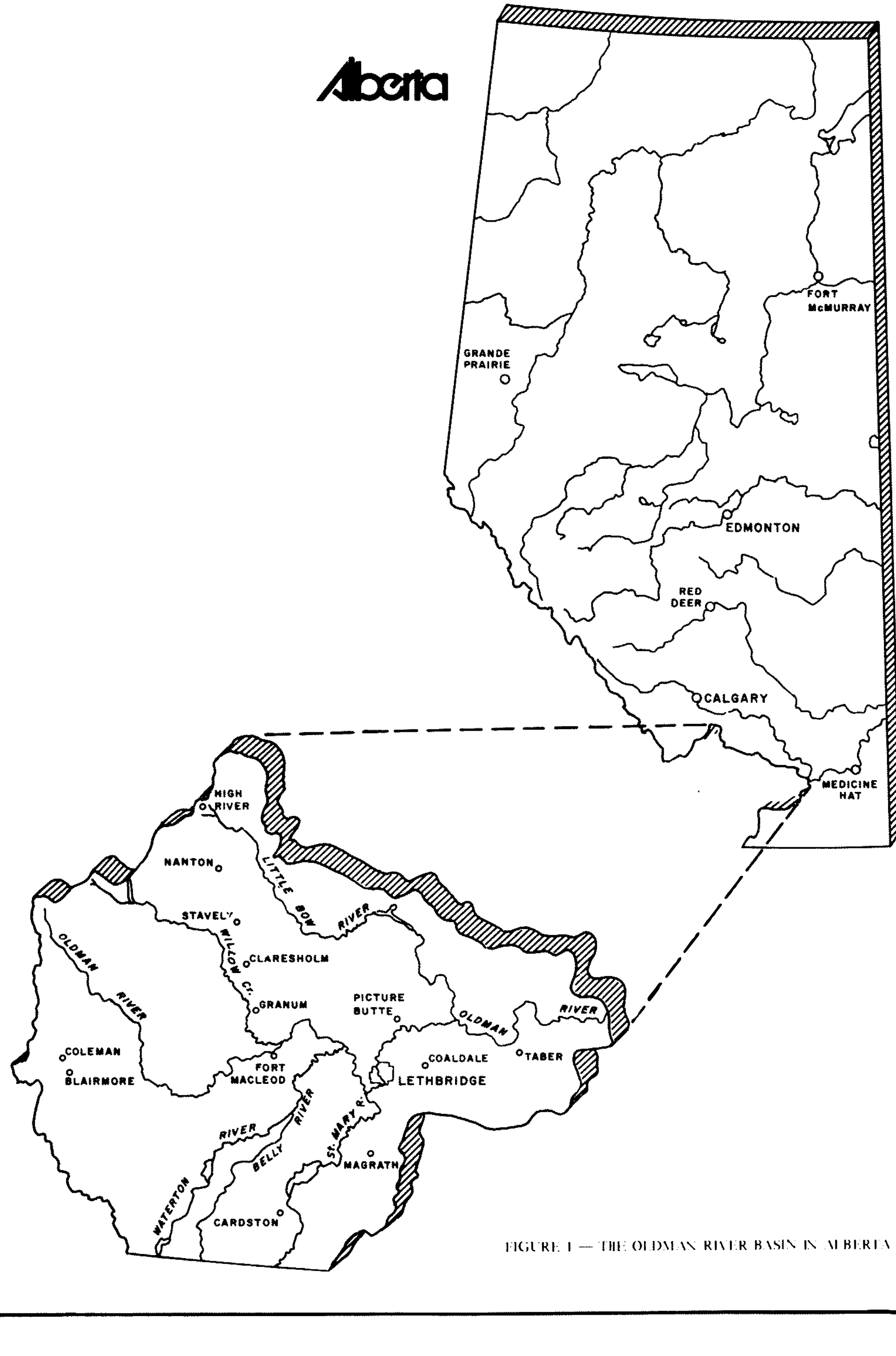


FIGURE 1 — THE OLDMAN RIVER BASIN IN ALBERTA

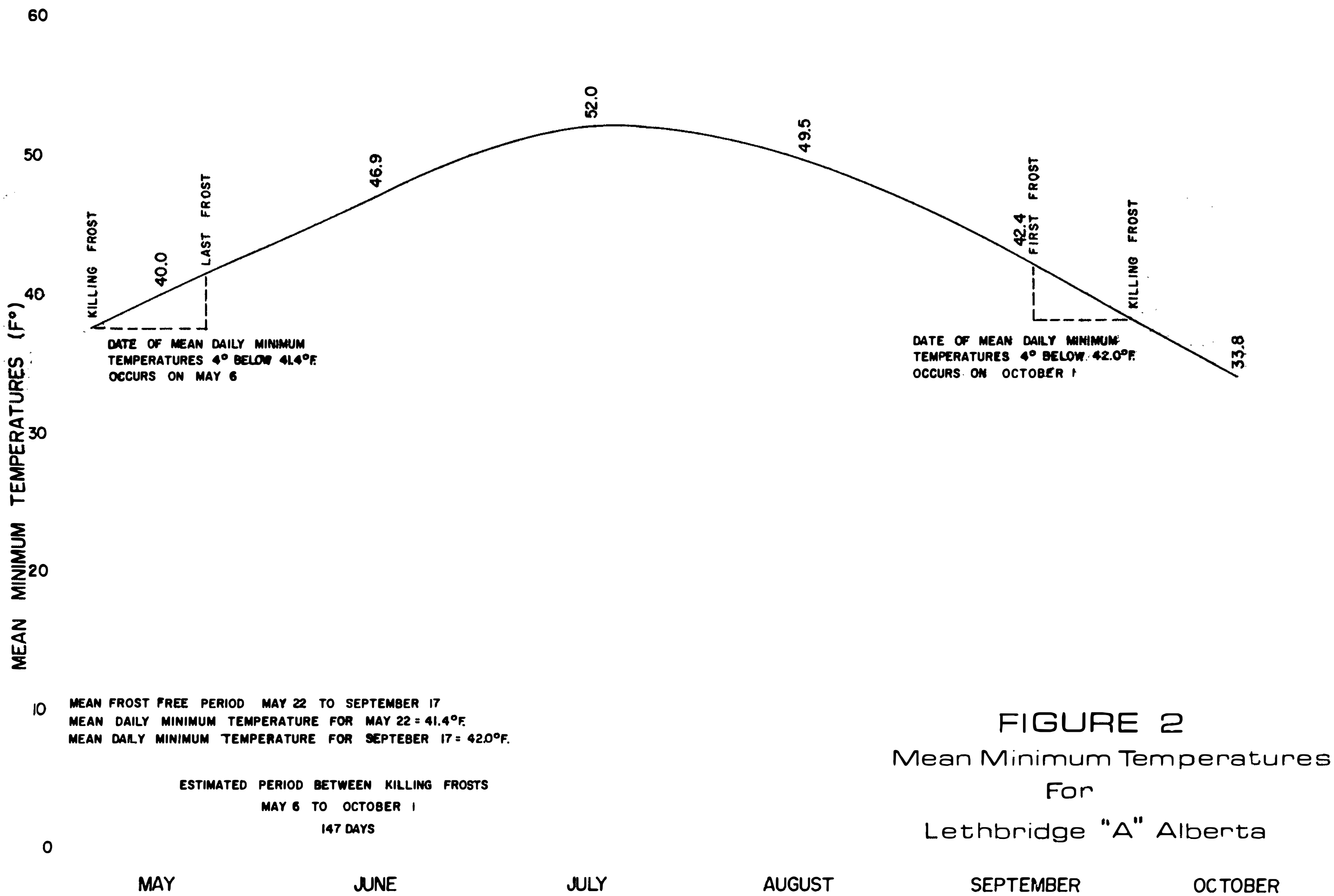


FIGURE 2
Mean Minimum Temperatures
For
Lethbridge "A" Alberta

Whether there is a trend or not cannot be said, but in the original analysis using meteorological data for the years 1931-1960 we established lengths of growing season for the active reporting stations in Alberta. This year, using data for the period 1941-1970 (an including additional stations), we replotted and reassessed our growing seasons.

Some decreased, some increased and a few remained the same. Most of the major stations in southern Alberta had a shortening of the growing season. To illustrate: Carway 7 days, Cardston 5 days, Lethbridge 1 day, Medicine Hat 2 days and Pincher Creek 2 days. Manyberries gained 1 day, while next door Foremost lost 1 day. The general indication was a decreasing length of growing season, or a cooler climate.

In an attempt to check the possibilities of this occurring, we ran a moving mean on mean monthly temperatures for stations available from Atmospheric Environment Service. Stations checked were Calgary, Lethbridge, Medicine Hat and Fort MacLeod.

Generally, there is an increasing negative slope to the trend line of stations, specifically in September, and a definite negative slope for annual temperatures.

I agree with one leading hydrologist (World Meteorological Organization 1966) who has suggested that the design of long-term water resource projects take into account climatic trends and cycles. This, in his estimation, is the most serious problem facing today's water planner.

Some scientists (Winkless and Browning 1976) in the eastern U.S.A. have estimated that a drop of 1°C in mean annual temperature is equivalent to a move 300 miles north. If there is a trend, then we ask "for how long? What effect on population, irrigation developments, agriculture in general, etc.?"

If, as we are noting in our work, the drop is essentially concentrated in September, then what crops will be affected? Specialty crops requiring a long growing season could be affected, whereas wheat perhaps would not feel the change for many decades.

These and other questions are becoming more and more important as the pressure for an intensified agricultural base in southern Alberta increases.

CLIMATE AND MICROCLIMATE

A rating was made recently of the suitability of proposed irrigation developments in the Oldman River Basin. Included in the assessment was climate, which included temperature (heat units), length of growing season and precipitation (growing season).

Of interest was the effect of actual station location on the climatic assessment. For example: Fort MacLeod has a longer growing season than Taber, Lethbridge and Medicine Hat, raising the question of station location at Fort MacLeod. For two stations at Vauxhall, approximately 5 miles apart, we calculated one to have a growing season of 145 days and the other 150 days. For Edmonton International, Edmonton Industrial and Namao, the length of growing season was 130, 151 and 148 days in that order. As a matter of interest, Edmonton Industrial gained 13 days from our initial assessment. Station microclimate needs assessing.

CLIMATIC DATA COLLECTION AND STORAGE

It is the author's opinion that the feasibility of establishing a meteorological network based on selected provincial parks should be investigated. The opportunity to obtain long-term records of many meteorological factors without the eventual intrusion of urban development seems to be available from such a network. Many of the provincial parks are maintained on a year-round basis, thereby offering the added feature of complete years of records. Along with this, many parks have radio contact with urban centers if immediate storm data are needed.

The number of existing (Fig. 3) and proposed provincial parks makes the establishment of the proposed network appear feasible.

In southern Alberta use could be made of some of the existing provincial parks (Fig. 4) to provide climatic data were no meteorological stations exist; for example, Elkwater, Writing-On-Stone, Police-Outpost, Chain Lakes and others. The representativeness of each location for the area would have to be assessed before establishing a station. The value to users would justify, if necessary, some monetary renumeration.

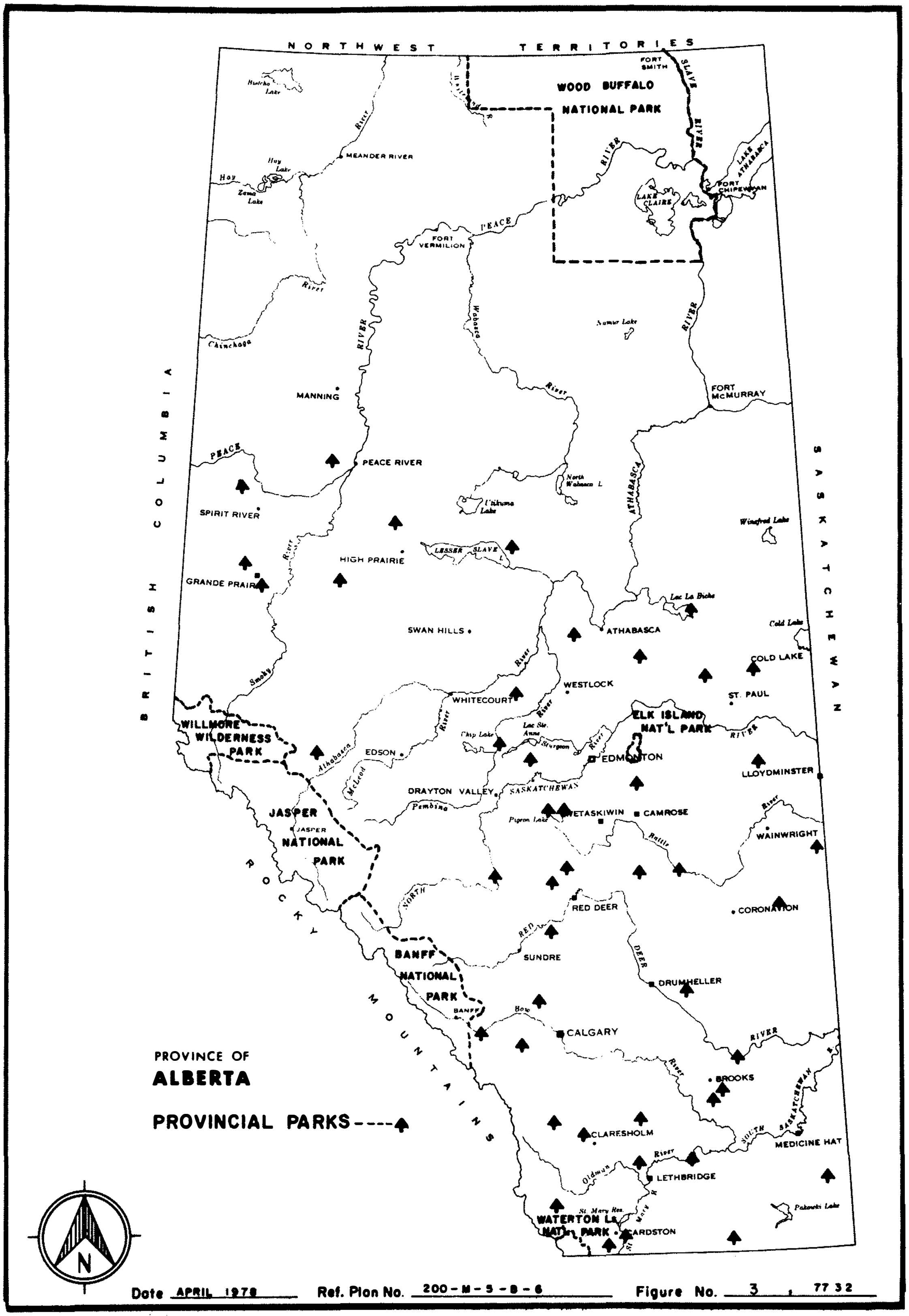
The author would also like to see a policy of retaining original data sheets until a check can be made on the recorded data. To illustrate: at one location where data was compiled by two different services there was an instance of precipitation differences. Table 1 illustrates the recorded data; it appears that June 15 may be the day needing a second check.

Table 1 also illustrates the difference between "readers" in crediting rainfall to a day. There appears to be variability in recording between Technical Services (Alberta Environment) readers, as well as between services. Fig. 5 is included to show the relationship of the stations listed in Table 1.

SUMMARY

1. Networks should be evaluated more on a microscale basis than they are at present to include the needs of regional users.

2. Trends are essential assessments necessary for the most beneficial evaluation of long-term water development projects.


NORTHWEST TERRITORIES
WOOD BUFFALO NATIONAL PARK
FORT SMITH
SLAVE RIVER
LAKE ATHABASCA
FORT CHIPEWYAN
LAKE CLAIRE
MEANDER RIVER
PEACE
FORT VERMILION
FORT McMURRAY
MANNING
PEACE RIVER
SPIRIT RIVER
HIGH PRAIRIE
LESSER SLAVE L
GRANDE PRAIRIE
SWAN HILLS
ATHABASCA
COLD LAKE
WESTLOCK
ST. PAUL
WHITECOURT
ELK ISLAND NAT'L PARK
WILLMORE WILDERNESS PARK
EDSON
EDMONTON
LLOYDMINSTER
DRAYTON VALLEY
SASKATCHEWAN
WETASKIWIN
CAMROSE
WAINWRIGHT
JASPER NATIONAL PARK
JASPER
RED DEER
CORONATION
SUNDRE
DRUMHELLER
BANFF NATIONAL PARK
BANFF
CALGARY
BROOKS
CLARESHOLM
MEDICINE HAT
LETHBRIDGE
WATERTON L. NAT'L PARK
CARDSTON
BRITISH COLUMBIA
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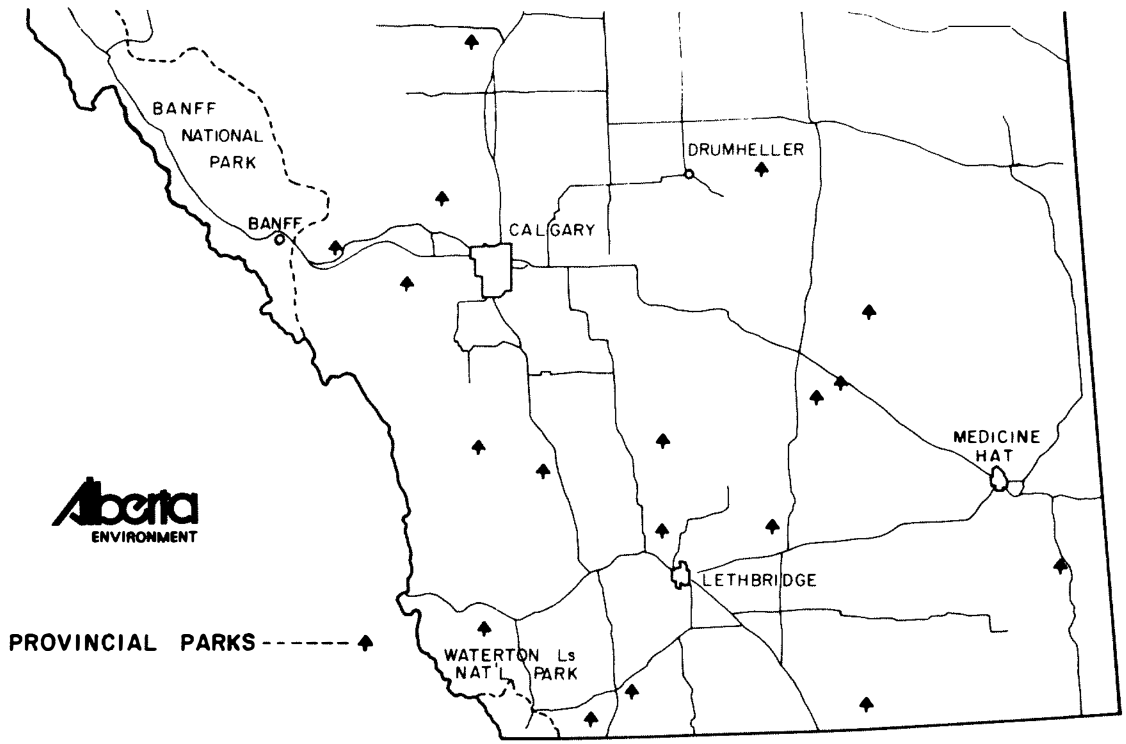

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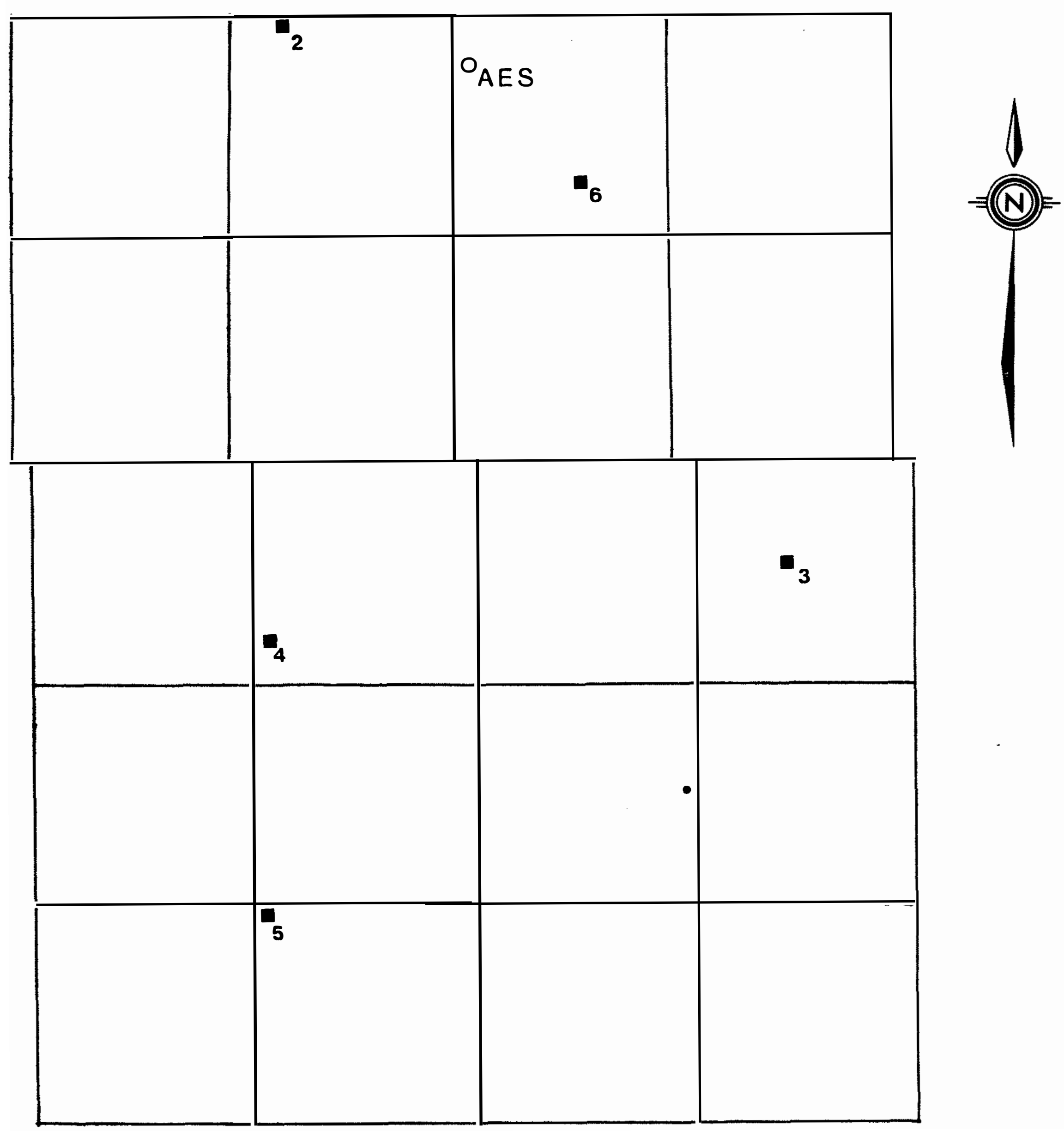
TABLE I

STORM OF JUNE 12 - 21, 1975

DAY	TECHNICAL SERVICES SITES					A. E. S.
	#2	#3	#4	#5	#6	
12						0.04
13	0.41	0.45	0.31		0.02	0.24
14			0.19	0.30	0.27	
15		0.09		0.09		2.64
16	0.50	0.38	0.43	0.42	0.30	0.58
17	0.30	0.28			0.25	0.65
18	0.74		0.44	0.28	0.55	0.95
19	1.47	2.14	0.88	1.44	0.84	3.61
20	1.40	1.62	0.99	1.90	2.12	0.23
21			1.03	0.87	0.17	
TOTALS	4.82	4.96	4.27	5.30	4.52	8.94
MONTH TOTALS	5.18	5.40	4.75	5.84	4.88	9.32

Location Plan of Precipitation Stations



■ Study Site

Each Square represents a section of land.

Figure 5

3. The microclimate and regional representativeness of stations are important to understand when making regional assessments.

4. The value of establishing more complete weather stations on a more comprehensive grid at locations with a long life expectancy should be considered.

5. Data reports from stations should be retained and where possible evaluated for accuracy.

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DATA REQUIREMENTS FOR AIR POLLUTION STUDIES FROM CLIMATOLOGICAL NETWORKS

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SUMMARY

Private consulting firms do a significant portion of the industry-related air pollution work in Alberta. This report on the climatology-related concerns of air pollution workers assumes that the type of work done by INTERA and the opinions of the INTERA staff are representative of the industry in general. The staff working at INTERA over the last four years includes meteorologists, chemical engineers and climatologists. Specific requirements in air pollution studies conducted over that four-year period were primarily wind speed frequency, wind direction frequency, daily and seasonal temperature variation, cloud cover and precipitation. The Atmospheric Environment Service (AES) STAR program for stability class history has also been used. These data parameters were used the most, but this situation is not static and future work may require data from additional parameters.

In terms of changes to a network system that would be beneficial to air pollution work, the topics were divided into the categories of station density, data collection parameters and data synthesis and reporting. Station density should not be increased substantially, as site-specific meteorological work is required for individual studies and is correlated with regional information.

Data collection parameters could be increased. First, the existing stations could collect regional information on mixing heights by releasing one or two minisondes per day, in lieu of the pibal releases to collect temperature and wind profiles. Additional information on stability classes from temperature data at three points on low towers could be considered. Solar flux is important in atmospheric mixing but to date is unwieldy and is not generally used.

Data synthesis and reporting are an area of major concern. Data analysis delays often restrict the use of regional data collected in the same year as the field study. Reducing data reduction time would be of very great benefit to atmospheric studies. Errors in data also have been a source of delay and cost. It is strongly recommended that efforts should be placed upon improving data quality and especially turn-around time rather than expansion of the number of sites or the number of parameters measured at each site, except for the addition of mixing heights.

ALBERTA CLIMATOLOGICAL ASSOCIATION

ANNUAL MEETING

REPORTS

CHAIRMAN'S REPORT

John M. Powell

During the past year the Alberta Climatological Association has held three meetings. The first, in March 1977, was our Annual Meeting and Workshop, the proceedings of which have been published. In fact, we have recently begun distributing the second printing of these proceedings; to date some 500 copies have been distributed.

The other two meetings were special meetings arranged at short notice, both very well attended by members and others from the Edmonton area. On May 5, 1977, Gordon McKay, Director, Meteorological Applications Branch, Atmospheric Environment Service, Fisheries and Environment Canada, spoke on "How will climatic change affect Alberta". On March 16, 1978, Morley Thomas, Director-General, Central Services Directorate, Atmospheric Environment Service, Fisheries and Environment Canada, spoke on "Some interesting aspects of the climate of Canada". It is hoped that similar meetings can be arranged when other persons with an interesting climatological message visit our area. If any of you know of planned visits by such persons please let the Executive know in good time so that they can be invited to speak to the Association if appropriate.

The Executive of four members whom you elected at the last meeting have had several half-day meetings. Among other topics that they have dealt with, you instructed them to pay special attention to two items: 1) preparing for a similar workshop for this year which I hope was adequately accomplished by our session this morning, and 2) formulating new goals for discussion and possible approval at this meeting. A constitution incorporating these goals, membership and an executive will be put before you this afternoon and we will welcome discussion and comment on this item.

Last year we found the item "Agency Reports" to be most useful in setting the scene of activity in climatology and related areas in Alberta. Again this year we have invited various agencies or postsecondary educational institutions to present brief reports either up-dating earlier reports or introducing a new report. In these reports we have asked them to indicate climatic networks, studies in progress and publications, in this way we hope the information will prove useful to a wider audience. If any of you are from agencies, and I use agencies in a wide sense to include institutions, corporations and companies, that haven't reported, I invite you to do so today or to submit material for the proceedings, as we wish to make this listing as complete as possible. Again, if any agency can assist with the cost of printing the proceedings this year, it would be much appreciated.

It is my privilege at this time to acknowledge the assistance the association has received during the past year. First I would like to thank the Northern Forest Research Centre of the Canadian Forestry Service, Fisheries and

Environment Canada for publishing and distributing the proceedings of our last workshop and annual meeting. They also provided the facilities for that meeting and for one of the special meetings. The facilities for the other special meeting were kindly supplied by the Meteorology Division, Department of Geography, University of Alberta. Today I would like to thank the Western Region of the Atmospheric Environment Service for the facilities and tour of their building, which includes the Alberta and Arctic Weather Centres, and especially thank Ben Janz for the local arrangements. Our Secretary, Elliot Kerr, prepared and distributed the brochure for our meeting today, and I would also like to acknowledge the work of the cover artist. Alberta Environment kindly funded the production and distribution of the brochure. I should like to thank the following groups who provided material for display for our meeting today: Alberta Agriculture; Alberta Environment; Alberta Remote Sensing Centre, Alberta Environment; Alberta Research Council; Atmospheric Environment Service, Fisheries and Environment Canada; Northern Forest Research Centre, Fisheries and Environment Canada; and the Alberta Centre, Canadian Meteorological and Oceanographic Society. I would also like to record my appreciation to the other members of this year's Executive, Conrad Gietz, Ben Janz and Elliot Kerr, who have worked hard with me to promote and improve the role of the Alberta Climatological Association.

In closing I would like to quote from a letter from Gordon McKay, Director, Meteorological Applications Branch, Atmospheric Environment Service, Fisheries and Environment Canada received after our workshop last year:

> The activities of the Alberta Climatological Committee are impressive. ... The workshop program gives testimony to the vigour of climatology in Alberta which is no doubt due to the Committee itself.
>
> Those who have made the Committee such a success merit not just congratulations, but the gratitude of the meteorological community. They also merit recognition by Canadians in general for it is the public that benefits substantially from the application of meteorological information.

You will note that the constitution document to be discussed later today states "The aims of the Association shall be to promote the study and development of climatology in Alberta for the public benefit..." we should always keep this in mind, whether we are generators or users of climatological information.

SECRETARY'S REPORT

W. Elliot Kerr

The general membership was asked whether they wanted the minutes of the executive meetings circulated during the year. A vote indicated that it wasn't necessary to circulate the executive meeting minutes.

Special thanks was extended to Virgilio T. DaSilva of Alberta Environment for his artistic drafting of the 1977 and 1978 workshop brochure.

The executive will welcome comments on the format of the next workshop to be held in 1979.

I have very much enjoyed my term as secretary of the Alberta Climatological Association (A.C.A.) and feel that the Association has grown in numbers and strengthened in purpose. However, I strongly believe that this momentum will soon be lost, unless we formalize our relationship with each of the member agencies. Then, and only then, the A.C.A. can put forth meaningful proposals and be able to receive monetary support to accomplish them. The days of begging our member agencies to financially support our proposals and recommendations are nearing an end. This, along with depending on the executive to carry out the majority of the proposals, is not the best approach.

If the Association is to enjoy a meaningful future, it should be organized in such a manner that it could contract various individuals and/or consultants to attain the goals of the organization. This can be accomplished by creating a trust fund, establishing an agency membership fee, an individual membership fee (to cover the cost of publishing conference proceedings) and of course registering with Alberta Consumer and Corporate Affairs. The latter move would enable the A.C.A. to become eligible for grants from both the federal and provincial governments.

I realize that this would be a very large step for our relatively young organization; however, I see it as our only method of survival.

ALBERTA AGRICULTURE--UPDATE SUMMARY 1978

Conrad W. Gietz

Supervisor, Agrometeorology
Alberta Agriculture
Edmonton

One area of emphasis continues to be providing meteorological information and advice for department staff in applied research and extension. This includes information relevant to production and markets on a routine basis, and to assist planning of emergency measures to meet special situations such as last year's drought. Extension information was provided to producers directly by a variety of means. General moisture information was supplied with soil test results to assist interpretation.

ALBERTA FOREST SERVICE CLIMATIC NETWORK, REPORT FOR 1978

S.D. Rothfels

Alberta Forest Service
Alberta Energy and Natural Resources
Edmonton

The climatic network for forestry operations is used primarily by the Forest Protection Branch of the Forest Service. The Fire Control section of this branch utilizes the network data in operational resource and logistical allocation in preparation for and in the combat of forest fires. Other uses include Timber Management planners who may use the climatic network in decisions relating to clear-cutting practices, timber blowdowns, et cetera. As well, many times network data may be included in data submitted for Land Use Assessments--as an example forestry vs. agriculture or recreation. Fish and Wildlife workers have also made use of the data from the climatic network in their project work. And last though not least, the historical data of the forestry climatic network has been supplied to other government agencies, public groups and miscellaneous planners where such data is of use.

Data from the climatic network is collected from about 180 lookouts and ranger stations located throughout the forested area of the province. The collection of this data is made twice daily during the fire season by radio and teletype. Historically, the climatic data collected from 1965 to the present can be assumed to be of high quality. The data from the period of 1959 to 1964 is of good, but slightly lower quality than the subsequent period due to less precise instrumentation. As well, records from sporadic fire years are available for the period preceding 1959, such as data for the years 1914, 1926 and 1931. "Antique" records from the Nordegg Ranger Station, for example, are housed in the Provincial Archives of Alberta.

The historical record of the Forest Service climatic network is made available to the public and interested parties through the Monthly Record of Meteorological Observations in Canada compiled by Environment Canada and Climate of Alberta compiled jointly by Alberta Environment and Environment Canada. As well, a library microfiche record is in the process of being set up. The Forest Service continues a program of publication of pertinent climatic forestry variables.

REFERENCE

Alberta Energy and Natural Resources. 1978. Alberta Forest Service Fire-Weather Observing Network for 1978 fire-season: lookouts, ranger stations, AES stations, parks, reserves, settlements, and private stations. For. Serv., 15 p. (mimeo).

CLIMATOLOGY PROGRAM
RESOURCE APPRAISAL GROUP
RESOURCE EVALUATION AND PLANNING DIVISION (R.E.A.P.)
ALBERTA ENERGY AND NATURAL RESOURCES

K. Leggat and C. Van Waas
Alberta Energy and Natural Resources, Edmonton

The Resource Appraisal Group is responsible for resource evaluation, determination of resource suitability, and coordination of data needs for government resource planning agencies. The main role of the group is to act as a multidisciplinary team in the description and evaluation of the character and potential of natural land systems in specific study areas. The resulting ecological (biophysical) reports are implemented by the Resource Planning Branch as the basis for initial stages of the land use planning process. The Resource Appraisal is supported by the Land Classification Group, whose input is a terrain analysis base, and the Resource Inventory Group, which is geared to supply information on present forest cover and forage availability.

A deficiency of climatic description and evaluation in ecological (biophysical) reports has affected their overall value as planning documents. The capability of the Resource Appraisal Group to strengthen this weakness has been achieved through initiation of the Climatology Program.

There are two major functions assigned to the Climatology Unit, a short description of each follows:

1. Contribution to ecological (biophysical) reports

It is the responsibility of the Climatology Unit to conduct a search for climatic data and literature relevant to the study area. For most areas in Alberta detailed climatic information relevant to land use planning is greatly lacking. Available data are employed along with vegetation to classify the land surface at the region level (Lacate 1969). Data and literature are also used to evaluate capability for land uses such as agriculture, outdoor recreation, forestry and wildlife.

2. Topoclimatic Mapping and Evaluation

It has long been apparent that for wise management of public lands site-specific climatological information must be available. To allow the definition of local climates and classification of these climates, a high density climatological network is required.

A typical network operated by R.E.A.P. in a defined study area will have a density of approximately 1 temperature station per 300 km^2, and 1 precipitation station per 150 km^2. These stations are not evenly distributed as there are concentrations to document climatic transition zones and topographic effects on local climates. Other parameters will be measured depending on their importance to the study.

A topoclimatic network will be equipped with monthly recording devices. Data collection will be year-round for 3 or 4 years, after which time data are tied into adjacent A.E.S. stations to approach long-term statistics. These data would then be utilized for topoclimatic mapping and as input for climatic classification of suitability for various land uses.

A steering committee will act to indentify clients and define study areas requiring this type of detailed topoclimatic mapping and analysis. The present focus is toward agrotopoclimatic mapping and classification of the High Level - La Crete area of the Lower Peace River Region.

This type of program has operated in British Columbia for 13 years and has successfully demonstrated a need for and usefulness of such a program in Alberta. Although the attention in this write-up has focussed on the needs of government planning agencies, other concerns for the program may include environmental protection and land management economics.

REFERENCE

Lacate, D.S. 1969. Guidelines for Bio-Physical Land Classification. Can. For. Serv., Publ. No. 1264, Ottawa.

ALBERTA ENVIRONMENT
ENVIRONMENTAL PROTECTION SERVICES REPORT FOR 1978

R.P. Angle
Air Quality Control Branch
Environmental Protection Services
Alberta Environment, Edmonton

1. Follow-up to 1977 Annual Report

Eppley pyranometers for the measurement of global solar radiation and ultraviolet radiation were installed and operated on the roof of Oxbridge Place in downtown Edmonton to gather data in support of photochemical pollution research. The global solar radiation data will likely be available through the publications of the Solar and Wind Energy Research Program (SWERP).

Further to the Sour Gas Industry Air Monitoring Directive, site documentation of continuous air monitoring stations has been received and is on file for reference. A site inspection program was initiated to ensure that all sites conform to the standard siting criteria.

2. Research Projects Funded

(a) Plume Diffusion Over Downwind Two-dimensional Hills: A Wind Tunnel Study, D.J. Wilson, Department of Mechanical Engineering, University of Alberta.

(b) A Study of the Stability of the Atmospheric Boundary Layer as Revealed by an Acoustic Sounder and its Relation to Pollution Levels in Calgary, T. Mathews and R.B. Hicks, Department of Physics, University of Calgary.

The above two reports are available in the Alberta Environment Library.

(c) Climatic Change as it Affects Alberta and the Other Prairie Provinces, R.W. Longley, Professor Emeritus, University of Alberta.

Copies available from the Research Secretariat, 12th floor, Oxbridge Place, 9820 - 106 Street, Edmonton.

(d) A Tabulation and Analysis of Solar Radiation Data for Alberta, J.E. Hay.

Available from Publications, Alberta Research Council, 11315 - 87 Avenue, Edmonton, price $2.00.

3. Precipitation Quality Monitoring Program (PQMP)

Objective: To monitor the chemical characteristics of rain and snowfall in Alberta.

Purpose:

1. To detect any significant changes that may occur as a result of:

    (a) industrialization
    (b) long-range transport of air pollutants into the province.

2. To provide a historical data base that may be used to:

    (a) specify the ultimate fate of pollutants
    (b) determine the long term effects on soil and water bodies especially in regard to potential acidification.

Relation to Other Programs:

The Air Quality and Inter-environmental Research Branch of the Atmospheric Environment Service of Environment Canada is currently operating a nation-wide program known as CANSAP (the Canadian Network for Sampling Precipitation). There are five stations in Alberta: Fort McMurray, Edson, Rocky Mountain House, Coronation, and Lethbridge. The program went into operation in April 1977, but is firmly committed only until April 1979.

The Alberta Environment program will supplement CANSAP, giving finer space resolution and ensuring continuity into the future.

Because rain is an efficient scavenging agent for pollutants, the chemical composition of rain provides an alternative measure of air quality. Thus the precipitation monitoring program complements Alberta Environment's existing air quality monitoring program.

AOSERP is operating a similar program for northeast Alberta.

Station Location:

The six stations will be located in the following regions: Edmonton, Calgary, Red Deer, Whitecourt, Medicine Hat, and Grande Prairie.

Equipment: The Sangamo Type A Precipitation Collector, an all-weather air pollution sampler that automatically separates wet and dry fall-out.

Analysis:

1. Wet samples (rain, snow, other hydrometeors will be analyzed monthly by the Pollution Control Lab for:

    (a) pH
    (b) specific conductance

(c) net titratable acidity
(d) sulphates
(e) nitrates and nitrites
(f) phosphates
(g) the ammonium ion
(h) the chloride ion
(i) the metal ions, sodium, potassium, calcium and magnesium

2. Dry samples will be shipped to the lab monthly but three such samples will be pooled (by season; winter--December, January, February; spring--March, April, May; summer--June, July August; autumn--September, October, November) for the purpose of analysis. These seasonal samples will be analyzed in the first instance for the same constituents as in the wet samples, and then for the following metals: aluminum, beryllium, cadmium, chromium, cobalt, copper, iron, lead, manganese, magnesium, molybdenum, nickel, silver, vanadium, and zinc.

4. Air Pollution Meteorological Station

An air pollution meteorological station was established in the Restricted Development Area to the southwest of Edmonton. A monostatic acoustic radar is operated continuously. Supporting measurements include: wind speed and direction at 10 m, atmospheric pressure, surface temperature, temperature difference over 7 m, incoming radiation, outgoing radiation, net radiation. During mid-season months, temperature and wind profiles are determined three times each weekday using a balloon borne minisonde tracked by a single optical theodolite. Turbulence measurements are also made using a bivane and electronically calculating the standard deviations (sigmas) of the elevation and azimuth angle fluctuations.

5. Other

The Research Secretariat sponsored a symposium on environmental research with regard to sulphur, held at the University of Alberta, November 17 and 18, 1977. Copies of Proceedings of Alberta Sulphur Gas Research Workshop III may be obtained from the Research Secretariat.

FLOW FORECASTING BRANCH--ALBERTA ENVIRONMENT

W.K. Kuhnke
Flow Forecasting Branch
Alberta Environment
Edmonton

The Flow Forecasting Branch is responsible for river forecasting in Alberta. River forecasting includes flood forecasting and water supply forecasting. Both types of forecast depend heavily on the climatic data available from the eastern slopes of the Rocky Mountains. At present, most of the weather data used for flood forecasting is provided by the Alberta Forest Service network of lookout towers.

The Branch feels that the data presently available from the East Slopes is insufficient to produce the best possible forecasts and therefore is planning a major expansion of the climatic gauge network in these areas. The expansion program is a long-term project and primarily involves automatic precipitation gauges with appropriate telemetry to communicate the data on a real-time basis.

The Branch is involved in computer simulation of watershed response to rainfall and snowmelt for the purposes of developing accurate and reliable procedures for flood and water supply forecasting.

The Branch is also cooperating with the Hail Studies group of the Atmospheric Sciences Division of Alberta Research Council on a pilot project measuring rainfall over large areas using the weather radar at Penhold.

CLIMATOLOGICAL NETWORKS MAINTAINED BY THE ATMOSPHERIC SCIENCES DIVISION, ALBERTA RESEARCH COUNCIL, AND BY THE ALBERTA HAIL PROJECT

G. Lunn
Atmospheric Sciences Division
Alberta Research Council
Edmonton

The Alberta Hail Project and the Atmospheric Sciences Division individually and co-maintain the following networks.

PRECIPITATION NETWORKS

There has been a reduction in network coverage area from previous years (G. Lunn and L. Wojtiw 1977) of 6500 km^2 to 31 700 km^2 (Fig. 1). There were approximately 530 volunteer stations, each supplied with a wedge-type raingauge and sanded hailpads. In addition, 130 stations, in a dense network of 930 km^2 (Fig. 2), were similarly supplied. Data from these networks includes daily rainfall accumulations, 0800 to 0800, size distributions of hailstones measured from the pads, and other storm data as noted on hailcard reporting forms. There are approximately 65 000 hailcard reporting forms mailed to farmers throughout Alberta. Rain and hail data is collected within these networks from June 1 to September 10 each year.

Within this dense network, three microdense networks were operated in 1977. These are labelled "A", "B", and "H" (Fig. 2). These staff run networks consisted of 26 and 16 hailpads and raingauges in two 0.6 km^2 areas and 18 hailpads on an 8-km long line. Within the former two microdense networks, hailcubes, anemometers, hygrothermographs and five tipping bucket raingauges were maintained. Anemometer and hygrothermograph sites were supported in other parts of the dense network as well (Fig. 2).

Data from these networks is used in the development of crop-damage, hailstorm parameter models and as a tool towards evaluation of the seedling experiment. Networks of varying densities allow the researcher to investigate the meso- and microscale variability of various climatic elements, especially those heavily influenced by varying stages of hailstorm life history.

Areal accumulations of rainfall have been determined (Barge *et al.* 1978) using weather radar data from Penhold and raingauge data from the surface networks. The great advantage of using weather radar data is its view of the spatial variability of precipitation patterns over basins or sub-basins.

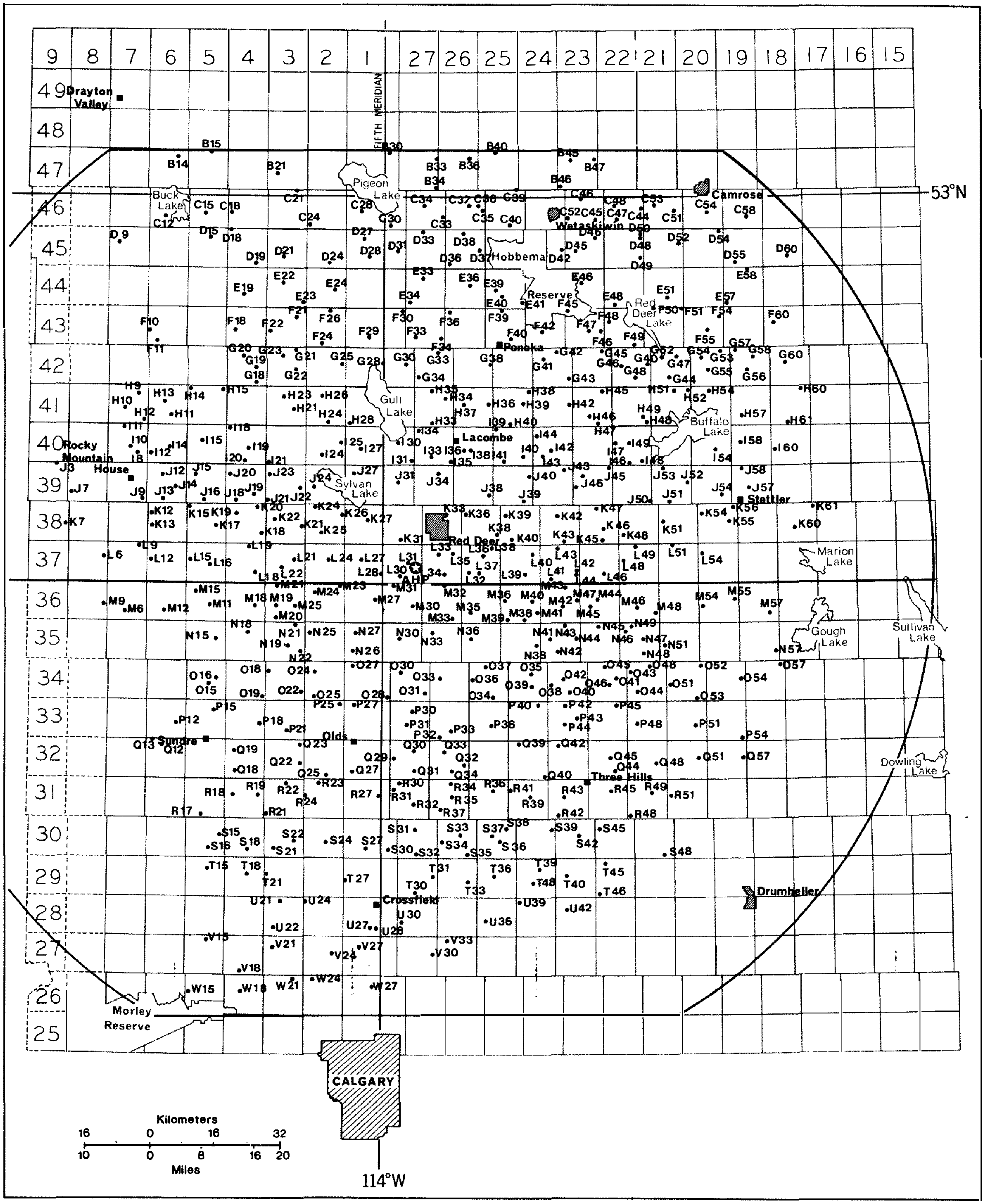

Figure 1. Precipitation network

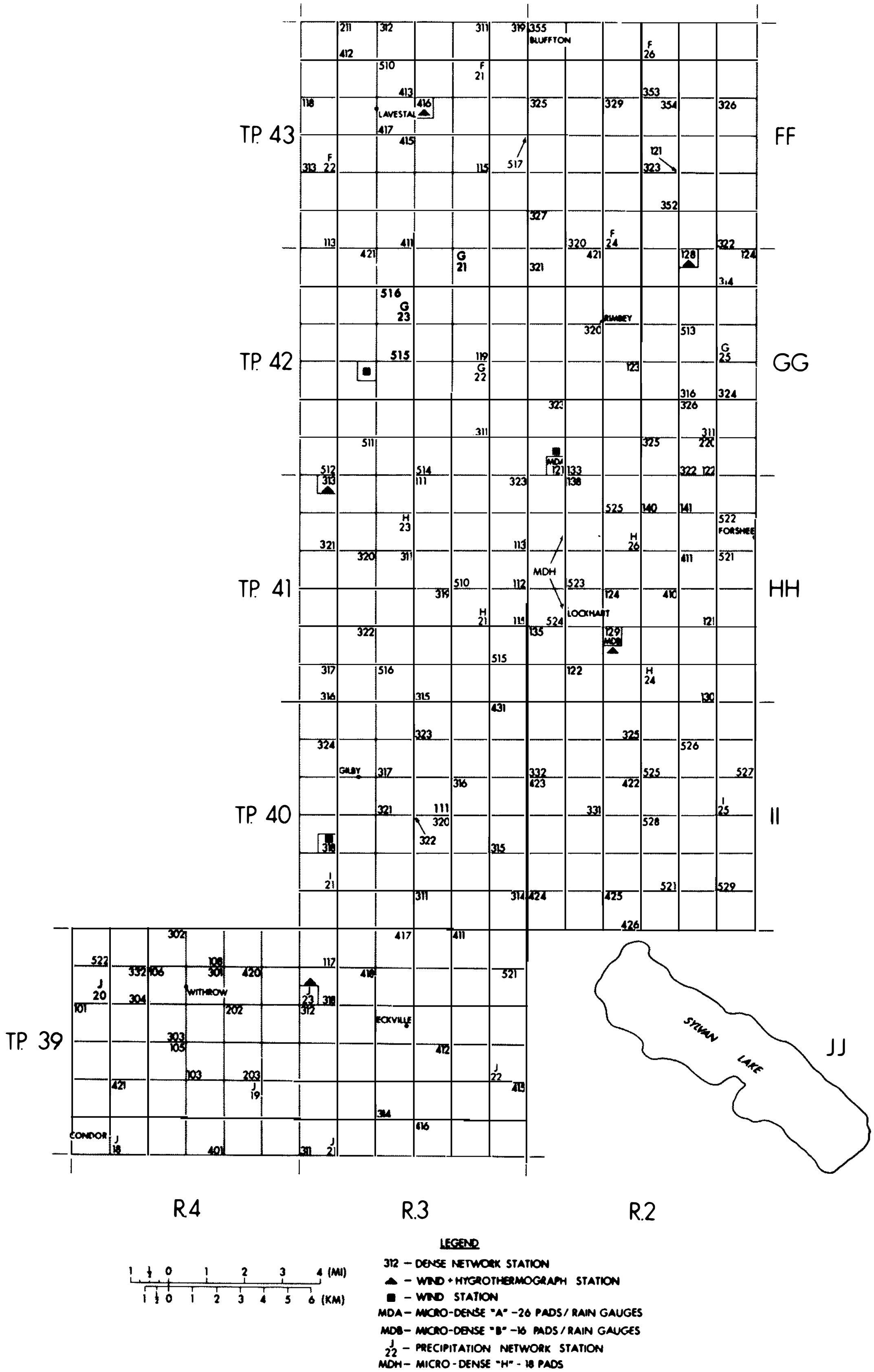

Figure 2. Dense hailpad network

Upper air data is collected from four staff operated stations during the summer field project. These are 1) Red Deer Airport, 2) Rocky Mountain House Airport, 3) University of Calgary, 4) Mobile Rawinsonde or MORAS. In August and September 1977 data were collected to measure the effects of the Rocky Mountain barrier on atmospheric stability. The experimental days required southwesterly 500 mb flow, with no significant short-wave perturbations, and southeasterly surface flow.

Radiosonde releases were performed throughout the chosen days from the four project stations. This data was augmented with piball releases, aircraft soundings, traverses, and chaff releases. Final results are not presently available.

In October of 1977, we hosted a five-day international workshop on hailfall measurements at Banff. Hail researchers from Canada, the United States, France, Italy, Switzerland and Argentina attended. The main purpose of the workshop was to pool ideas and to set international standards for network design, and the measurement, collection and reporting of hail data. A calibration lab was held which tested the various materials used as hailpads. An additional benefit from this workshop was the formation of an internal organization of hail researchers called Circle International Grêle, for the free flow of information concerning hail measurement problems and advances. Results of this workshop will be published in the first 1978 issue of Atmosphere-Ocean (Vol. 16, No. 1). A second workshop is planned to be held in France.

The author gratefully acknowledges the financial support of the Alberta Weather Modification Board.

BIBLIOGRAPHY

Barge, B.L., R.G. Humphries, S.J. Mah, and W.K. Kuhnke. 1978. Precipitation measurements by weather radar in central Alberta -- Applications to hydrology. Paper presented at the Seventh Symposium of the Water Studies Institute on Applied Prairie Hydrology. Saskatoon, Saskatchewan, 9-11 May.

Deibert, R.J. (ed.). 1978. Alberta Hail Project field program 1977. Alberta Weather Modif. Board, Rep. No. 6, March. 92 pp.

Lunn, G. and L. Wojtiw. 1977. Climatological related hail research at the Alberta Hail Project. Pages 97-102 *in* Powell, J.M. (ed.) Applications of climatology: Proceedings of the workshop and annual meeting sponsored by the Alberta Climatological Committee. Fish. Environ. Can., Can. For. Serv., North. For. Res. Cent., Edmonton, Alberta. Inf. Rep. NOR-X-193. 137 pp.

Renick, J.H. 1977. A bibliography of research on Alberta hailstorms and their modification. Alberta Weather Modif. Board, Rep. No. 5, Alberta Agric., Three Hills, Alberta, October. 21 pp.

RESEARCH COUNCIL OF ALBERTA
SOLAR AND WIND ENERGY RESEARCH PROGRAM

Robert Grauman
Alberta Research Council
14605 - 118 Avenue, Edmonton

Last year at the Alberta Climatological Association Workshop, Dr. T. Rachuk presented a paper entitled "Climatological Aspects of Wind and Solar Energy". Since that time, the Solar and Wind Energy Research Program, or SWERP, under the Alberta Research Council, has been started with Energy Resources Research Fund, or ERRF funding. Dr. T. Rachuk is the Department Head of this program. One of the functions of SWERP will be to take an inventory of the solar and wind energy available to the citizens of Alberta.

In order to supplement the solar and wind data being collected by the Atmospheric Environment Service and other agencies, we will be establishing up to fifteen automatic climatological stations in Alberta over the next three years. We have chosen the MATER or Magnetic Tape Event Recorder system developed by Atmospheric Environment Service for our prime data collection system. The first six installations will be made at Pincher Creek, Lethbridge, Calgary, Rocky Mountain House, Coronation and Fort McMurray, and these installations will begin upon receipt of the MATERs from the manufacturer. In addition, a prototype station will be installed at our One Hundred Eighteenth Avenue Building site. This station will be used as a test bed for new installation techniques, new sensors, and repaired equipment, and therefore will not provide a continuous record.

The MATER is a cassette tape based system that records data by making unique sets of marks on magnetic tape. The array of sensors we propose include the Atmospheric Environment Service type 45B anemometer, an electronic thermometer, and six solar radiation sensors. The solar radiation sensors will consist of a net radiometer, a diffusograph and four Kipp and Zonen CM4 pyranometers mounted on the horizontal, south face, west face and east face of a cube. Due to the number of sensors in the array, two MATERs will be required at each site. One will be mounted on the anemometer tower, and will record wind speed and direction, and atmospheric temperature. This station will be solar powered, probably for less capital cost than the cost of laying an AC line for power. The other MATER will record the solar radiation parameters and will be placed in a silo, using the techniques pioneered by AOSERP. It too, will be solar powered, although radiation integrators take considerably more power than the rest of the MATER system.

In order to increase the data return and reduce maintenance, mounts for the pyranometers are being designed, in co-operation with Atmospheric Environment Service, that will decrease problems with snow, frost, rain and dew on the sensor bulbs. Early tests indicate that the technique will be successful, and if this is so, it will allow use of pyranometers in remote unmanned sites.

The data collected by the MATER will be decoded by a computer based system. The computer will make a sophisticated analysis of the raw data, allowing in depth quality assurance. The data will be archived on nine track IBM magnetic tape. Atmospheric Environment Service is procuring this decoder now, and it is hoped that SWERP will be following with an identical order shortly.

AGRICULTURE CANADA RESEARCH STATION,BEAVERLODGE

W.G. Bailey
Research Station, Agriculture Canada,
Box 29, Beaverlodge, Alberta

Under present technology, there are approximately 11 million ha of potential agricultural land in northwestern Canada. Of this, approximately 9 million ha are in the British Columbia-Alberta Peace Block. Of this latter, only 2 million ha are currently in agricultural production. Faced with a potential four- to fivefold increase in the Peace region's land area for foodstuff production, the research thrust at the Beaverlodge Research Station and its substations at Prince George, British Columbia, and Fort Vermilion, Alberta is in the development of the technology for wise management of present and future agricultural land.

Climatological research pursuits at Beaverlodge thus can be seen to fall into three areas. The first is a planned upgrading of the quality and frequency of meteorological observations at Beaverlodge during 1978. This is to include hourly integrated observations of air temperature and humidity, wind direction and speed, precipitation, soil temperature, soil heat flux density and the flux densities of global solar, reflected solar, diffuse solar, longwave, net and photosynthetically active radiation. This data will be used to supplement ongoing research programs in plant breeding, physiology and pathology, weed science, apiculture and rangeland ecology.

The second area of climatological research is in the promotion of maps of the spatial and temporal distributions of the climatic resources for agriculture in northwestern Canada. Under the auspices of the Land Evaluation Program, co-operative research has been underway on this since 1977 with the British Columbia Ministry of the Environment.

The last area of Beaverlodge's climatological research program is in the planned undertaking of specific micrometeorological investigations related to agriculture. These are to include studies of the radiation, energy and water balance of agricultural surfaces both on level and sloping terrain; investigations of environmental stress on plant physiological responses, such as stomatal behaviour; and analysis of the microclimatological ramifications of land clearing for agriculture.

AGRICULTURE CANADA RESEARCH STATION LETHBRIDGE

Dr. W. Haufe reported that they hope to appoint a meteorologist to the staff this year.

Recent publication:

Hobbs, E.H. 1977. The agricultural climate of the Lethbridge area, 1902-1976. Agric. Can., Res. Stn., Lethbridge, Alta. LRS Mimeo 3. 14 p.

AGRICULTURE CANADA--SOIL SURVEY, EDMONTON

W.W. Pettapiece
Agriculture Canada--Soil Survey
14605 - 118 Avenue, Edmonton

The Soil Capability for Agriculture (under the C.L.I.) uses climate as a primary criterion - specifically frost-free period and precipitation. Recent studies of crop yield data by T.W. Peters have shown that, for the same frost-free period and precipitation, there is a marked increase in yield as one goes from north to south in the province. Obviously there is another aspect of climate which needs to be taken into account. The present feeling is that it is related to total accumulated heat units, and the idea is being explored further.

A paper published on these findings is:

Peters, T.W. 1977. Relationships of yield data to agroclimates, soil capability classification and soils of Alberta. Can. J. Soil Sci. 57:341-347.

ATMOSPHERIC ENVIRONMENT SERVICE
FISHERIES & ENVIRONMENT CANADA
WESTERN REGIONAL HEADQUARTERS
EDMONTON, ALBERTA

J.T. Kotylak

Items of interest to climatology which occurred in 1977 follow:

1. Climatological Station Status:

During 1977, the number of ordinary climatological stations in Alberta decreased by 9, leaving a total of 370 stations. The number of sunshine stations was decreased by two. One station was added to each of the Fischer Porter network, Snow Survey network, and the Nipher Snow Gauge network.

2. Digital Electronic Maximum - Minimum Thermometer:

A request by Atmospheric Environment Service (AES) Headquarters in Downsview has gone out to companies to submit proposals for the development and production of a self-contained digital maximum and minimum thermometer suitable for replacing the Stevenson Screen and glass thermometers currently in use at our climatological stations. An observer would read an electronic display of maximum and minimum temperatures from the unit each day. This equipment should increase voluntary observing for the climatology network.

3. Climatological MATER Program:

Field testing of the MATER was initiated. The MATER (Magnetic Tape Event Recorder) is an unmanned climatological station which can record temperature, wind, liquid precipitation, radiation and sunshine data on cassette tape. The tape is later retrieved and decoded at a Regional centre. The MATER is not yet an approved standard AES instrument and a series of malfunctions required occasional repairs during the field testing phase. This system would reduce our dependence on observers at remote locations and enhance the network in remote areas.

4. Quality Control of Climatological Data:

Plans were formulated to automate the quality control of climatological data taken by the ordinary climatological network. Preliminary quality control of data to date has been performed manually at Regional Office. The automation will not affect station observing procedures. A direct benefit of the automation process will be availability of data much sooner than before and in computer accessible form (mag tape).

5. Metrication:

The conversion to metric instruments in the meteorological observing networks continued according to plan. About one-quarter of the ordinary climatological stations have been converted. The tipping bucket rain gauge bridges underwent conversion late in 1977.

6. The Climatology Section was organizationally transferred from the Alberta Weather Centre to the Scientific Services Unit. This took place with the move of the Regional Headquarters from downtown Edmonton and of the Arctic and Alberta Weather Centres from the International Airport to a new building in South Edmonton.

7. New Publications:

   a. The Climate of the Contiguous Mountain Parks: Banff, Jasper, Yoho, Kootenay, by B. Janz and D. Storr prepared for PARKS CANADA by the AES. Project Rep. No. 30. 1977.

ALBERTA OIL SANDS ENVIRONMENTAL RESEARCH PROGRAM (AOSERP)

B. Janz

Atmospheric Environment Service
Fisheries and Environment Canada
6325 - 103 St., Edmonton

1. A description of the network collecting data of a climatological nature in the Oil Sands area was described last year.

2. New Publications:

   a. Physical Climatology of the Oil Sands Area--R.W. Longley and B. Janz. (available in two months).

   b. Air System Data Directory--AOSERP (available in two months)

3. Other Data:

   a. Monthly Summary--for 9 stations in AOSERP area.

      - Temperature
      - Precipitation
      - Wind

   b. Snow Survey--12 stations

   c. Tall Tower--(Hourly Basis)

      - Wind (3 levels)
      - Temperature (5 levels)

   d. Minisonde--Twice Daily since January 1, 1978.

NORTHERN FOREST RESEARCH CENTRE: 1977 STUDIES IN ALBERTA WITH CLIMATOLOGICAL INPUT, OTHER THAN HYDROLOGY

John M. Powell
Northern Forest Research Centre
Fisheries and Environment Canada, Edmonton

Following is a brief update of the report presented to the Alberta Climatological Committee Annual Meeting last year.

1. Climatic zonation for the forested areas of the Prairie Provinces.

This study using daily temperature and precipitation data for May to September for the years 1961-1970 has been completed; nearly 200 stations in Alberta were used. A separate study of the precipitation climatology of the Eastern Slopes was also carried out.

Powell, J.M. and D.C. MacIver. 1977. A summer climate classification for the forested area of the Prairie Provinces using factor analysis. Fish. Environ. Can., North. For. Res. Cent., Edmonton, Alta. Inf. Rep. NOR-X-177. 51 pp.

Powell, J.M. and D.C. MacIver. 1978. Maps of selected climatic parameters for the Prairie Provinces, May to September 1961-1970. Fish. Environ. Can., North. For. Res. Cent., Edmonton, Alta. Inf. Rep. NOR-X-206. 31 pp.

Powell, J.M. 1978. Climatic classification of the Prairie Provinces of Canada. In Essays of Meteorology and Climatology: in honor of Richmond W. Longley. Univ. Alberta, Dep. Geography (in press).

Powell, J.M. 1977. Precipitation climatology of the Eastern Slopes area of Alberta. Pages 187-204 in Swanson, R.H. and P.A. Logan (compilers). Alberta Watershed Research Symposium Proceedings, 1977. Fish. Environ. Can., North. For. Res. Cent., Edmonton, Alta. Inf. Rep. NOR-X-176. 342 pp.

2. Climate of clear-cut forested areas in the Hinton area.

Field data for this study was completed in 1977. Meso- and micro-climate networks were run in two areas near Obed Lookout. Data from the 7 years of data has been extracted and analysis started. Four years of precipitation data were employed for a hydrometeorological report.

Powell, J.M. and D.C. MacIver. 1976. Summer climate of the Hinton-Edson area, west-central Alberta, 1961-1970. Fish. Environ. Can., North. For. Res. Cent., Edmonton, Alta. Inf. Rep. NOR-X-149. 43 pp.

Hillman, G.R., J.M. Powell, and R.L. Rothwell. 1978. Hydrometeorology of the Hinton-Edson area, Alberta, 1972-1975. Fish. Environ. Can., North. For. Res. Cent., Edmonton, Alta. Inf. Rep. NOR-X-202. 170 pp.

3. Effect of microclimate of clear-cut areas on pine and spruce seedling growth.

Field sampling for the study was completed in 1977. Extraction of some of the microclimate data is completed and analysis is underway.

4. Biogeoclimatic ecosystem classification of the Province of Alberta.

Macroclimatic data along with vegetational and soil characteristics were used to provisionally recognize nine biogeoclimatic zones.

5. Analysis and synthesis of forest insect and disease survey historical data and information.

Summaries have been prepared for 25 common defoliator insects giving records of infestations. Interrelationships between weather (moisture deficiencies and heat unit summaries) and insect population trends are being investigated.

6. Preplanting conditioning of containerized conifer seedlings and field performance.

Container seedlings which have received different preplanting treatments were planted on two plots 70 km south of Grande Prairie. Two climate stations were established to follow the microclimatic conditions to relate to seedling growth performance. In 1977 the stations were operated from May to mid-October and included daily temperature, precipitation, wind recording, and soil temperatures and air temperatures near the ground.

Zalasky, H. 1977. Bibliography of frost damage in tree nurseries. Fish. Environ. Can., North. For. Res. Cent., Edmonton, Alta. Inf. Rep. NOR-X-190.

7. Fire behavior in boreal forest fuels.

Related to improving the Fire Weather Index. Studies on four forest types near Slave Lake to develop fire spread and intensity tables for important fuel types within the region. In past years 6 climate stations, 4 in forest and 2 in open, have been operated for parts of summer; in 1977 a pair of stations was operated in jack pine type in association with fire behavior study. A paper on moisture variations on conifer foliage is in preparation.

8. Fire management systems and guidelines.

Two publications relating to the Fire Weather Index were published:

Kiil, A.D., R.S. Miyagawa and D. Quintilio. 1977. Calibration and performance of the Canadian Fire Weather Index in Alberta. Fish. Environ. Can., Can. For. Serv., North. For. Res. Cent., Edmonton, Alta. Inf. Rep. NOR-X-173.

Kiil, A.D. 1977. Overwinter monitoring of the Drought Code is recommended. Fish. Environ. Can., North. For. Res. Cent., Edmonton, Alta. For. Rep. 5(2):8.

9. Evaluation of the role of fire in forest and intermingled vegetation in the prairie provinces, Rocky Mountains and far north.

Available climatological data has been assembled for the Nahanni Park area. A climate station was operated in the summer at Henry House in Jasper National Park in conjunction with a prescribed fire study.

10. Effects of atmospheric effluents on forest soils.

Two reports on effects of atmospheric sulphur depositions on rainfall, lodgepole pine foliage and soils were published:

Baker, J. 1977. Nutrient levels in rainfall, lodgepole pine foliage and soils surrounding two sulphur gas extraction plants in Strachan, Alberta. Fish. Environ. Can., North. For. Res. Cent., Edmonton, Alta. Inf. Rep. NOR-X-194.

Baker, J. 1977. Observations on nutrient levels in rainfall, lodgepole pine foliage and soils surrounding two sulphur gas extraction plants in Strachan, Alberta. Pages 125-140 in Proc. of Alberta Sulphur Gas Research Workshop III. Res. Secretariat, Alta. Environ. & Alta. Dep. Pedology, Univ. of Alberta.

11. AOSERP: Effects of air pollution on vegetation.

Biomonitoring network includes sampling of precipitation to determine influence of polluted precipitation on the availability of soil nutrients in selected soils.

STUDIES USING CLIMATE DATA COLLECTED BY HYDROLOGY SECTION, NORTHERN FOREST RESEARCH CENTRE

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Climate data are gathered by the Hydrology Section of the Northern Forest Research Centre for research projects carried out by the section. Following is a brief update of the report presented to the Alberta Climatological Committee Workshop, March 4, 1977.

1. The James River Study. As reported last year, 1976 saw the completion of the 4-year study of snow accumulation and melt in 10 replications of 10 opening sizes. In the spring of 1977, 14 closely spaced openings of 1 tree height (H) diameter were snow surveyed along with three replications of opening sizes 0H (i.e., control), 1/4H, 1/2H, 3/4H, and 1H of the main study. Results of the main study plus first-year results of the snow survey in the closely spaced 1H openings have been reported by Golding (1977a).

Baseline data on temperature, humidity, and wind were gathered at four stations as in past years.

2. The study of snowpack evaporation during chinooks has been reported by Golding (1977b).

3. Chemical water quality analysis was continued on rain water samples collected at Marmot Creek experimental watershed.

4. Marmot Creek intensive snow survey was carried out in March 1977 as has been the case since 1969. Effect of the Cabin Creek harvest on snow accumulation has been reported (Golding 1977a).

5. Snow courses were measured in the spring of 1977 at Streeter Basin experimental watershed. Comparison was made of snow accumulation in natural openings, small artifical openings, and treed areas and reported by Golding (1977a).

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Golding, D.L. 1977a. Watershed treatment to alter snow accumulation and melt rates. Pages 237-255 in Alberta Watershed Research Program Symposium Proceedings, 1977. Fish. Environ. Can., North. For. Res. Cent. Inf. Rep. NOR-X-176.

Golding, D.L. 1977b. Snowpack evaporation during chinooks along the East Slopes of the Rocky Mountains. Pages 251-254 in Proceedings, Second Conference on Hydrometeorology, Oct. 25-27, 1977, Toronto. Am. Meteorol. Soc., Boston, Mass.

RECENT ACTIVITIES IN CLIMATOLOGY AND METEOROLOGY AT THE UNIVERSITY OF ALBERTA

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1. Summary

"Climatic change as it affects Alberta and the other Prairie Provinces", prepared by Professor Longley in June, 1977 under the sponsorship of the Research Secretariat of Alberta Environment has been well received and widely distributed.

A book entitled "Essays in Meteorology and Climatology: In Honour of Richmond W. Longley" is in final printing stages. The book contains 21 papers, primarily on Canadian climatology, by colleagues and former students of Professor Longley. It was edited by Professor Reinelt and is being published by the Department of Geography.

The book "Truelove Lowland, Devon Island, Canada: A High Arctic Ecosystem", edited by Professor L.C. Bliss of the Department of Botany and published by the University of Alberta Press, appeared in 1977. It summarized all field and laboratory studies of one of the two terrestrial productivity projects of the Canadian Committee of the IBP. The book contains a chapter on micrometeorological studies of Truelove Lowland in addition to articles on permafrost and energy budgets.

The final report on a microclimatological study in a forest of *Pinus banksiana* on a steep slope near Richardson Fire Tower in northern Alberta by the Departments of Botany and Geography is in preparation. An article on forest canopy modelling was published in 1977 by Mehlenbacher and Whitfield.

Analyses of the remains of a 100-year-old white spruce from near Edmonton by John Gray and Peter Thompson of the Department of Physics have shown that $^{18}O/^{16}O$ ratios in cellulose appear to be excellent indicators of mean annual temperature. Work is continuing with a 2000-year-old Sequoia from California and with other Canadian trees.

Infra-red weather satellite imagery was used to investigate the thermal characteristics of the surface and lower atmospheric levels in the western Arctic by Professor Reinelt and B.C. Green. They found complex structures that led to intensification of small-scale lows, persistent inversions, and land-sea breezes. D. Oracheski completed a report on satellite data analyses of time and space changes in clouds associated with frontal systems moving from the Gulf of Alaska to the Prairie Provinces.

An analysis of spatial variability in hailfalls using sparse and dense networks of hailpads in central Alberta was completed by L. Wojtiw and Professor Lozowski. R. D'Amours and E.P. Lozowski showed that the assumption of steady-state conditions in numerical modelling of hailstone growth is inadequate.

Dr. H. Sandhu, under the direction of Professor Charlton, has reported on the results of analyses of $^{18}O/^{16}O$ ratios in liquid and solid precipitation and in vapour at widely-spaced locations in Alberta. The study showed that stable isotopes are useful tracers in the study of graupel and hail formation.

Analyses of soil temperature measurements under oil spills were described in "Reclamation of Agricultural Soils after Oil Spills", a report to the Agricultural Research Trust and the Environmental Research Trust by staff members of the Department of Soil Science. S. Cohen, under the supervision of Professor S.I. Smith, completed a field study of energy and water budget components within and below fallow and 5 vegetated plots at the Ellerslie Research Station.

A simple atmospheric radiation model for the prediction of hourly daytime mixing heights was developed by R.B. Thomson and tested by means of minisonde observations at Edmonton and Mildred Lake.

A numerical study of large-scale blocking ridges in the atmosphere by L. Diehl showed that such ridges can form as the result of unstable growth of long waves.

Seasonal and annual mean temperature and precipitation data for 8 Alberta stations with long and complete records were subjected to spectral analyses by A. Lachapelle. Minor, but apparently significant maxima were found at periods of about 5 years, especially in fall temperature data.

2. Public Lectures on Climatic Change

The Institute of Earth and Planetary Physics of the University of Alberta continued its series of public lectures on climatic change in 1977. The following presentations were heard:

"Climate and the Changing Sun" by Dr. John A. Eddy, National Center for Atmospheric Research, Boulder. (March 28)

"Do Solar Variations Affect the Weather?" by Colin O. Hines, Professor of Physics, University of Toronto. (October 6)

"Geographical Patterns of Climatic Change Since 1000 B.C." by Dr. T.M.L. Wigley, Climatic Research Unit, University of East Anglia, Norwich. (December 8)

Dr. J.L. Honsaker of the Department of Geography presented a paper entitled "The Little Ice Age" on January 30, 1978.

3. Reports and Publications

(a) Articles

Caiazza, R., and K.D. Hage, 1977: Nutrients in the precipitation of central Alberta, Canada. Proc. Second Conference on Hydrometeorology, Oct. 25-27, Toronto. Amer. Meteorol. Soc., pp. 150-155

Courtin, G.M., and C.L. Labine, 1977: Microclimatological studies on Truelove Lowland. In Truelove Lowland, Devon Island, Canada: A High Arctic Ecosystem, (L.C. Bliss, ed.) University of Alberta Press, Edmonton, 73-106.

Gray, J. and P. Thompson, 1976: Climatic information from $^{18}O/^{16}O$ ratios of cellulose in tree rings. Nature 262 (5568), 481-482.

Gray, J. and P. Thompson, 1977: Climatic significance of $^{18}O/^{16}O$ ratios in tree rings. Advances in Mass Spectrometry, 7.

Hage, K.D., 1977: Research in urban climatology at the University of Alberta. Climatological Bulletin, 22, 25-29.

Longley, R.W., 1977: Climatic change as it affects Alberta and the other Prairie Provinces. Research Secretariat, Alberta Environment, 33 pp.

Lozowski, E.P., 1977: Comments on "The hailpad calibration for Italian hail damage documentation". J. Appl. Meteorol., 16(6), 668.

Mehlenbacher, L.A. and D.W.A. Whitfield, 1977: Modelling thermal eddy diffusivity at canopy height. Boundary-Layer Meteorology, 12(2), 153-170.

Thompson, P. and J. Gray, 1977: Determination of $^{18}O/^{16}O$ ratios and compounds containing C.H.O. Int. J. Applied Radiation and Isotopes, 28, 411-415.

(b) M.Sc. Theses (1977)

Cohen, S.: Land use change on micro-climate in central Alberta: an energy balance study.

D'Amours, R.: A numerical model for heat transfers during hailstone icing.

Diehl, L.: Dynamics of baroclinic waves and blocking ridge development.

Green, B.: An investigation of thermal fields and secondary circulations in the Canadian western Arctic.

Lachapelle, P.A.: Modern spectral methods with applications to Alberta climatic data.

Oracheski, D.: Influence of the Cordillera on crossing frontal cloud bands.

Sandhu, H.S.: Interpreting the oxygen-18/oxygen-16 variations in some samples of vapour, rain, hail and snow from Alberta.

Thomson, R.B.: An operational mixing depth model for northern Alberta.

Wojtiw, L.: An initial assessment of the representativeness and accuracy of Alberta hailpad data.

A REVIEW OF CLIMATOLOGICAL RESEARCH AT THE UNIVERSITY OF CALGARY 1977-78

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The Department of Geography at the University of Calgary is primarily responsible for climatological research in the institution. Departments such as Physics and Chemical and Mechanical Engineering are involved in projects that have a fair amount of climatological content.

The first part of this report will discuss climatological efforts within the Geography Department. The second part deals with work in other areas of the University.

Climatology in the Department of Geography

The research in Calgary's urban heat island and airshed reported previously (Nkemdirim and Rhodes 1977) is continuing. Four publications (Nkemdirim 1977 a and b, Nkemdirim et al. 1977, and Nkemdirim and Truch 1978) describe the major characteristics of the surficial pattern of the heat island. These include (a) the presence of a double maxima in the diurnal pattern of the island, (b) the role of topography and wind in the evolution of that pattern, and (c) the seasonal variability in the strength of the island. In a presentation Nkemdirim (1977c) argued that a coaxial technique of the type employed in hydrology can be useful for estimating the strength of urban heat islands in Calgary.

Results of the work on the airshed which was to have been published this year are not complete. Consequently, publication has been postponed to 1979. However, some preliminary results are available. These include (a) data on the mean depth of the boundary layer and its diurnal and seasonal variability, (b) a confirmation of the structure of the temperature field at various levels in the urban atmosphere up to 300 m previously identified by Nkemdirim (1976), (c) the effect of chinooks on air pollution levels in the city (Nkemdirim and Leggat 1978), (d) a confirmation of pollutant stratification in the urban airshed at night and early morning, and (e) the presence of a homogeneous pollution profile during the day.

Because all our research in urban climate in Calgary points to the significant influence of regional topography on that climate, we conducted an experiment on Calgary's Spy Hill to examine the influence of topography on atmospheric dispersion in an area in which such a control is very pronounced. The results of that experiment (Nkemdirim and Benjamin 1978) revealed that a small hill could generate a wake effect extending beyond four times its height. The effect of reduced ventilation on the concentration of matter in the cavity was also observed. These results feed directly into the development of a topographically inspired model of the heat island.

There are two other related experiments. In the first experiment now completed (Nkemdirim 1978), cooling rates over grass (summer) and snow (winter) were compared under similar sky, wind and humidity conditions. It was found that the rates over snow were twice as high as their grass equivalent. However, the atmosphere during the cooling period was more disturbed (turbulent) over grass. None of this is new, but the experiment did enable us to index differential cooling rates during the two seasons. The second experiment, again an energy budget one, will be undertaken in the fall. It will attempt to isolate and quantify the effect of topography on the accumulation of heat in the urban atmosphere during the warming phase and on energy dissipation during cooling.

This summer, we are conducting an investigation on urban rainfall in Calgary. We hope to be able to isolate the effect of position, topography, orientation, air quality, storm type and synoptic conditions on the spatial variability of rainfall and its intensity in the city and surrounding country. To this end we have placed twenty standard rain gauges and five tipping bucket gauges within the city -- a density of better than one gauge per 20 km^2. We are also hoping to supplement this network with radar data from the Alberta Hail Project.

Analysis of past records from several stations in and around Calgary is being undertaken to verify if (a) there has been a trend in city precipitation which could parallel the enhanced heat island intensity observed in the course of the past decade, and (b) Calgary's urban complex has any effect on the rainfall regime downwind of the city.

Dr. S.A. Harris is continuing his research on permafrost. He has developed a numerical method to explain the areal distribution of the phenomenon in Western Canada.

Finally, the author of this report is preparing a book on the climate of Calgary in partnership with Canadian Western Natural Gas Company. The book is scheduled for printing next year.

Climatology in other Departments

Drs. Mathews and Hicks of the Department of Physics are still involved in boundary layer work based on acoustics. Their report (Mathews and Hicks 1977) shows that acoustics can be used to (a) monitor the size and variability of the convective layer in Calgary, and (b) study the form and motion of chinook waves in the area. They correlated the inception and decay of the overnight inversion with sunrise and sunset. They also showed that a good correlation exists between chinook events and air pollution. There are now three sounders in operation in the city -- at the University, the Stampede ground, and Mount Royal College. A fourth and more powerful sounder is planned for the airstrip at Suffield.

Dr. Gerry Smith of the Department of Mechanical Engineering is working on solar energy and its use in homes. The experimental facility which is housed at the University Weather Station is still being developed. It is hoped that future reports will include information on progress in that endeavour.

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Nkemdirim, L.C. 1977b. Research in Urban Climatology at the University of Calgary. McGill Univ., Dep. Geogr., Climatol. Bull. 22:19-23.

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Nkemdirim, L.C. and K. Leggat. 1978. The effect of chinook weather on urban heat islands and air pollution. Water, Air and Soil Pollution 9:53-67.

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Nkemdirim, L.C. and P. Truch. 1978. Variability of temperature fields in Calgary, Alberta. Atmos. Environ. 12:809-824.

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UNIVERSITY OF LETHBRIDGE, DEPARTMENT OF GEOGRAPHY

R.J. Fletcher

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Our most recent publication was Climate of Arctic Canada in Maps, R. Fletcher and G.S. Young, Occas. Publ. No. 13, Boreal Inst. North. Stud., Univ. Alberta, 48 pp. 1976.

Just accepted for publication in American Scientist is "The Causes of Glaciation without Tears: a Review and Suggested Model," by C.B. Beaty.

Research in progress: 1. Synoptic Precipitation Climatology of Southern Alberta--R.J. Fletcher. 2. Analysis of Climatic Anomalies in Arctic Canada--R.J. Fletcher.

ALBERTA AGROMETEOROLOGY ADVISORY COMMITTEE REPORT

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This is one of fifteen Advisory Committees which report to the Minister of the Alberta Department of Agriculture. The general functions of Advisory Committees are:

1. The Advisory Committees in reporting to the Minister shall:

   (a) seek consultation with governments and other agencies on matters of policy and programs relating to

      i) production, processing and marketing of agricultural products
      ii) agricultural research and
      iii) socio-economic issues.

   (b) recommend on such matters within their sphere of agricultural interest and in particular agricultural research.

2. The Advisory Committees may:

   (a) review and summarize annual results of agricultural research,
   (b) identify needs, review and make recommendations on publications.

The current officers of the Agrometeorology Advisory Committee are:

Chairman:	D.H. Laverty	- Alberta Agriculture
Secretary:	C.W. Gietz	- Alberta Agriculture
Directors:	B. Janz	- Atmospheric Environment Service
	W.O. Haufe	- Agriculture Canada

The Committee was established in 1975, with primary objectives to improve communication among climatologists and agrologists, and to promote greater use of climate information in managing agricultural production.

A workshop was held in 1976 featuring requested papers on current work in Alberta on Agrometeorology. Copies of the proceedings of this workshop are available from the secretary.

At the 1977 annual meeting, Dr. Haufe presented a paper entitled "An Approach to Problems in Agrometeorology". This paper presented specific guidelines for attacking climate-related agriculture production problems through phases of research and development, technology transfer and application in practical management of the production system. These guidelines have been circulated to the other Advisory Committees for review and implementation.

The current objective of the Committee is to define the important climate problems in various fields of agriculture and to determine the meteorological inputs that are required for user applications in production. Cost, reliability and automation of field plot instruments for recording climate parameters are currently hampering collection of climate data at numerous remote sites. Some standard evaluation of climate instrumentation would be valuable in this regard.

Erosion, development of energy resources and water for irrigation development are areas which are critically affected by climate and significant to future agricultural production. Methods of accumulating relevant climatic data for these areas will need to be developed to ensure continued development of agricultural production for relatively large sections of Alberta.

ON OROGRAPHIC PRECIPITATION

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INTRODUCTION

That precipitation tends to increase with height in hilly or mountainous country has been known in western Canada as early as the beginning of the fur trade. For the ranges of hills in the plains area, a typical rate of increase with height is 30 $cm \cdot km^{-1} \cdot yr^{-1}$. However, in the mountains to the west, the data from neighboring stations show rates as low as zero and as high as 220 $cm \cdot km^{-1} \cdot yr^{-1}$. This wide variation suggests the need for information on the physical factors that combine to produce the observed patterns of precipitation over hills and mountains.

Unfortunately, most of the literature on this subject that is readily available is descriptive in nature, and it is difficult to find papers which deal with physical factors. Although there are a few which give explanations of some of the processes, the writer has not been able to find any which could be considered adequate generally in this respect. The present offering is aimed at reducing that deficiency.

The factors to be considered include the characteristics of air flow over barriers, precipitable water, evaporation from falling precipitation, and shielding by barriers upstream.

AIRFLOW THEORY

The development of theory for the flow of air over mountain barriers began in Europe in the 1930's. It immediately became evident that the problem being tackled was beset by severe mathematical difficulties. The first major contribution was that of Queney (1), in which he gave a summary of results from more than 10 years of study. This was followed by a series of papers by Scorer beginning with Scorer (2). A good review of the early literature was contributed by Corby (3). Recently, Klemp and Lilly (4) have published a more advanced treatment. The following material has been gleaned from those papers, and consists of pieces of theory which are applicable to orographic precipitation.

SIMPLE IRROTATIONAL FLOW

As a starter, attention is given to two-dimensional flow over a long narrow ridge for the simplest possible set of conditions. The ridge has a maximum height of 500 m, and is oriented N-S. The wind is in the positive x-direction, or from the west and denoted by U. As surface friction is ignored, U is the geostrophic wind. The lapse rate is adiabatic. There is no vertical shear in the undisturbed flow upstream, but where the barrier imposes curvature, there is vertical shear such that the y-component of vorticity retains a zero value throughout the pattern of flow.

The profile of the ridge in the xz-plane is given by:

$$\zeta = a^2 b(a^2 + x^2)^{-1} \quad (1)$$

where: ζ is the height,
b, the height of the crest, and
a represents the width.

The streamline pattern over such a barrier is described by:

$$\zeta = ab(a + z)[(a + z)^2 + x^2]^{-1} \quad (2)$$

where: z is the height of a streamline in the undisturbed flow, and
ζ, the displacement for z in the disturbed flow.

Table 1 shows the variation of ζ with z and x with a = 5 km and b = 0.5 km.

Table 1. The variation of ζ with x and z

x(km)	z(km)	0	1	2	3	4	5
0		0.50	0.42	0.36	0.31	0.28	0.25
1		.48	.40	.35	.31	.27	.25
2		.43	.37	.33	.29	.26	.24
3		.37	.33	.30	.27	.25	.23
4		.30	.29	.27	.25	.23	.22
5		.25	.25	.24	.22	.21	.20
6		.20	.21	.21	.20	.19	.18
7		.17	.18	.18	.18	.17	.17
8		.14	.15	.16	.16	.15	.15
9		.12	.13	.13	.14	.14	.14
10		.10	.11	.12	.12	.12	.13

The values under z = 0 represent the surface profile and those for x = 0 show the decrease of amplitude with height.

It may be noted that the variation of amplitude with height depends on ba^{-1}. The disturbance decreases with height rapidly over a narrow ridge but more slowly over a wide ridge.

Also, the wind varies inversely with the separation of streamlines because of the requirement for mass continuity. Thus maximum values of u occur over the crest. With a narrow ridge, the value of u may equal 2U at x = 0 and z = 0, as an extreme.

From Table 1 it may be seen that the maximum slope of streamlines occurs near where $x = \pm 3.5$ km. Thus the maximum vertical velocities ought to occur near that distance upwind from the crest, or just above the level of $z = b/2$.

However, if the cloud base or condensation level (CL) is well above the surface, the zone of maximum precipitation is shifted downwind because of the horizontal component of motion of falling precipitation. For example, if the CL is at z = 1500 m and the terminal velocity of the raindrops is 3 $m \cdot sec^{-1}$, the time of descent is between 333 and 500 sec, or about 8 min. With U = 30 $km \cdot h^{-1}$, the horizontal motion is about 4 km. This would transfer the maximum zone to the crest or beyond. As a typical fall speed for snowflakes is 1 $m \cdot sec^{-1}$, the corresponding transfer is 12 km, which would locate the maximum zone well down the lee slope.

This suggests that the precipitation from convective activity ought to be maximum near the crest of low ridges and that the variation with height because of this factor would be small on the average.

STATIC STABILITY

With $\partial\theta/\partial z > 0$, where θ is the potential temperature for dry air, and the wet bulb potential temperature for saturated air, the streamline pattern may be described by:

$$\zeta = (\rho o \rho^{-1})^{1/2} U o U^{-1} \; (a \cos \ell z - x \sin \ell z) ab[(a + z)^2 + x^2]^{-1} \quad (3)$$

where: ρo and Uo are surface values of density and wind,
$\ell = sU^{-1}$, and
$s = (g\Theta^{-1}\partial\Theta/\partial z)^{1/2}$

The density and trigonometric terms are from Queney, the wind term from Scorer, and the denominator has been borrowed from (2). Because many small terms were omitted in its derivation, (3) may be regarded as an approximation of real behavior.

The amplitude of maximum ζ depends on the density, wind, and denominator terms. As an example, at the tropopause at z = 10 km, the amplitude is increased by a factor of 1.6 by density, decreased by 0.4 by typical shear, and by 0.1 for 0 = 0.5 km and a = 5 km.

The trigonometric term imposes periodicity. In the horizontal, there is a wavelength of $2\pi U s^{-1}$, and the wave amplitude decreases rapidly away from the crest, particularly in the upstream direction. In the vertical, the pattern of waves is repeated at intervals of

$2\pi Us^{-1}$. With $U = 30$ km·h^{-1} and $s = 36$ rad·h^{-1}, representing normal lapse rate, the wavelength is 5.2 km.

Diagrams representing (3) may be seen in the reference pages. In them it is evident that the pattern upstream is much the same as indicated by Table 1, particularly at lower levels. Thus, the factor of airmass stability is of minor importance with regard to dynamic lift upstream from a low barrier, and the pattern of precipitation would be much the same as with simple irrotational flow.

HIGH BARRIERS

In this section, consideration is given to flow with $\partial\theta/\partial z > 0$ and $b > 400$ m.

For such a climb a significant amount of energy must be expended to do work against static stability, which opposes vertical displacements:

$$dw/dt = d(w^2/2)/dz = -s\zeta \qquad (4)$$

where: w is the vertical velocity

It is assumed that the flow is in hydrostatic balance, so that $dw/dt = \rho^{-1}\partial p/\partial z - g = 0$

For convenience, attention is limited to the behavior of a surface parcel in front of the barrier.

With $U^2/2$ as the only initial source of energy, $\Delta(w^2/2) = -\Delta(u^2/2)$. From (4), the maximum climb is given by $(U^2/2) = s^2\zeta^2/2$, or $\zeta = s^{-1}U$. With $U = 30$ km·h^{-1}, and $s = 36$ rad·h^{-1}, $s^{-1}U = 833$ m. With $b > 833$ m, the flow is halted in front of the barrier.

Where it is stopped, there is an anomaly of pressure represented by $\Delta p = \rho U^2/2$. Until some mechanism provides relief, the blockage moves upstream. Where the flow is decelerating $d(u^2/2)/dx = -\rho^{-1}\partial p/\partial x$. That brings the Coriolis accelerations into play, $dv/dt = f(U - u)$, and $du/dt = fv$. The first turns the parcel northward, and the second at a later stage turns it to the right, and these enable the parcel to make the climb.

The northward motion across the isobars of the prevailing pressure gradient results in the energy conversion,

$$dv/dt = d(v^2/2)/dy = -\rho^{-1}\partial p/\partial y = fU$$
$$\text{or } \Delta(v^2/2) = -\rho^{-1}\Delta p = fU\Delta y \qquad (5)$$

This conversion provides the energy for the climb against the opposing static stability. From (4),

$$\Delta(w^2/2) = -s^2\zeta^2/2 \quad (6)$$

Then, $fU\Delta y = s^2\zeta^2/2$ (7)

and $fUv = s^2\zeta w$ (8)

This relationship is significant with regard to the location of the maximum values of w and precipitation. The ratio, wv^{-1} decreases with increasing ζ.

Unfortunately, little attention has been given in the literature to the characteristics of flow on the windward side of a major barrier, although the lee side has been treated in many papers. Solutions are made available routinely as products of numerical weather prediction, but the interactions among the forces involved are not displayed in those products.

For present purposes, it is convenient to assume a sinusoidal variation of v, $v = -V \sin ft$. Then,

$$w = -fUV(s^2\zeta)^{-1} \sin ft \quad (9)$$

with $ft = 0$ at $x = 0$ at the crest

Table 2 gives a set of values for $U = 30$ km·h^{-1}, $b = 2$ km, and $s = 36$ rad·h^{-1}, and $V \approx U$.

Table 2. The variation of y, ζ, v, and w with ft

ft(deg)	y(km)	ζ(km)	v(km hr^{-1})	w(km hr^{-1})
-180	0	0.0	0	0.0
-160	6	0.34	10.2	0.36
-140	25	0.67	19.2	0.33
-120	54	0.98	26.1	0.31
-100	90	1.26	29.4	0.27
- 80	126	1.50	29.4	0.23
- 60	162	1.70	26.1	0.18
- 40	191	1.84	19.2	0.12
- 20	209	1.93	10.2	0.06
00	216	2.00	0.0	0.00

The interval of time for this motion is $\Delta t = \pi f^{-1} = 8$ h. If the mean value of u = U for the 8 hours, the vertical motion begins 240 km upstream from the crest. If the CL = 670 m, precipitation would begin about 200 km upstream and quickly reach a maximum rate, then decrease toward the crest. Roughly, the maximum rate would occur 6U from the crest, numerically.

This applies to the behavior of a surface parcel. Because U increases ordinarily with height, the deviation to the left also decreases with height. Also, as the vertical shear tends to vary with U so that $U^{-1}\partial U/\partial z = z(8.4\text{ km})^{-1}$ on the average, the contributions to precipitation from higher levels tend to reach maximum values farther upstream. Because precipitable water ordinarily decreases with height, the location of the maximum zone with stable air depends mainly on the contribution from lower levels.

With $\partial\theta/\partial z$ near zero, the maximum is located where the barrier slope is steepest.

These considerations suggest a broad belt of maximum precipitation between the steepest slope and the location of the climatological mean value of 6U upstream from the crest of the barrier.

PRECIPITABLE WATER

Another significant factor is the variation of precipitable water with height. For the preparation of the following table, it has been assumed that the air is initially saturated with a wet-adiabatic lapse rate, and a temperature at 1000 mb is 12°C. The slope S of the barrier is uniform. It has been assumed that the flow at 400 mb remains undisturbed and that the convergence in the xz-plane is uniform. The values in the precipitation column are the amounts released by condensation, ignoring retention in the form of cloud.

Table 3. The variation of precipitation with lift

lift (mb)	pcpn (cm)
1000-950	0.28
950-900	0.25
900-850	0.22
850-800	0.18
800-750	0.15
750-700	0.12

To obtain rates in the form of amounts per day, the figures in the second column may be multipled by 24 SU, where S is given by

$$S = (\text{distance for rise of 50 mb})^{-1}$$

Obviously the actual rate can be very high with strong winds and a steep slope.

Again, for high barriers, the heaviest precipitation occurs during the early stages of lift.

SHIELDING

Table 3 may also be used to estimate the effect of shielding by an upstream barrier. As a first approximation the upstream barrier gets all of the precipitation from the lift up to the level of its crest. The higher barrier gets what is left.

As an example, the height of the crest of the coastal mountains of British Columbia varies around 850 mb, and that of the Rockies, around 700 mb. For equal slopes, the ratio of rates would be 0.74:0.46 according to the table. Again as a rough approximation, the Rockies would receive no orographic precipitation below the 850-mb level.

Also, there would be a rapid increase of precipitation with height near 850 mb on the windward slope of the Rockies.

Allowing for 1 g/kg of condensation retained in cloud and assuming that precipitation persists past the crest to the CL on the lee side, the orographic precipitation would be zero roughly 50 mbs below the level of its crest.

EVAPORATION FROM RAINDROPS

The standard reference on this subject appears to be Kinzer and Gunn (5). In that paper, they present pertinent theory as well as results from experimental work.

The rate of evaporation from a raindrop falling at its terminal velocity depends mainly on its diameter and the ambient relative humidity, and to a lesser degree on ambient temperature. In Table 4 are given values of m^{-1} dm/dt, where m is the mass, for T = 10°C. D = diameter and V = terminal velocity.

Table 4. Evaporation rate (fraction of m lost min^{-1})

D(cm)	V(m min^{-1})	m(μ gm)	RH 10%	50%	90%
0.01	16	0.52	1.0	1.0	1.0
0.05	124	65	0.84	0.48	0.12
0.10	242	524	0.30	0.17	0.035
0.20	389	4190	0.12	0.07	0.013
0.30	484	14140	0.08	0.04	0.009

Evidently, a drizzle droplet 0.01 cm in diameter would persist less than one minute with RH < 95%. With heavy rain, D = 0.3 cm typically, and the loss rate is nearly negligible. However, for light rain with D = 0.1 cm and RH = 50%, one third would be lost while falling 500 m.

It may be noted that the rate increases as the drop descends, because of decreasing D and RH.

These variations indicate that precipitation would tend to increase significantly with height, because of evaporation from raindrops, particularly in dry climates, and where heavy rain is infrequent.

In the cold season, although the evaporation rate from a snow flake is relatively slow, the settling speed is also slow. Although the writer has not been able to find values for snow flakes that are comparable to those in Table 4, accumulations ought to increase with height to some degree.

ASPECT

The discussion so far has been limited to behavior in front of a barrier oriented N-S with respect to U from the west. The major barriers in British Columbia vary between N-S and NW-SE orientations and the dominant direction of flow during the year is WNW. This departure from the assumption of normal incidence does not appear to be a serious matter with respect to the implications indicated by basic theoretical conditions.

However, it must be borne in mind that much of the precipitation from a travelling cyclone occurs where the winds at lower levels have a strong southerly component, and at mid-tropospheric levels, a significant component across the track from the right.

This factor appears to be significant with regard to precipitation patterns in British Columbia, such as near Nelson where there are mountains to the north and low-lying interior of the State of Washington to the south. Another is the wet area just N and NE of Vancouver, which is open to flow from Puget Sound to the South.

CONCLUSIONS

These theoretical considerations suggest the following conclusions as first approximations:

1. Dynamic lift over a low ridge increases precipitation at higher elevations on the ridge but also to some degree in the immediate vicinity. This appears to be a minor factor with regard to the rate of increase with height.

2. Evaporation from precipitation in unsaturated air would be expected to result in a significant rate of increase with height generally, without regard for slope. A linear relationship appears to be appropriate for ridges less than 500 m in height, but would decrease in applicability with crest height greater than 500 m.

3. With a high barrier, an adiabatic lapse rate, and a uniform windward slope, precipitation tends to decrease with height above the condensation level.

4. With a high barrier and an adiabatic lapse rate, the rate of precipitation tends to vary with the steepness of slope.

5. With a high barrier and stable air, the maximum rate tends to occur roughly 6 hours of wind travel time upstream from the crest and to decrease from there to zero at the crest, with respect to large-scale behavior.

6. Shielding by upstream barriers is significant with respect to the orographic component of precipitation. It also is a major factor with regard to the variation of precipitation with height.

7. The resultant climatological pattern of precipitation depends on various combinations of these factors as well as on aspect.

ACKNOWLEDGMENTS

Dr. Keith Hage and Dr. Erhard Reinelt of the University of Alberta have been kind enough to review this paper. They have commented on the lack of reference to a number of important field studies which have dealt with individual factors. Because time does not permit adequate consultation of them, they are listed here for the benefit of those who may wish to pursue the subject further.

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OTHER ITEMS OF BUSINESS--ANNUAL MEETING

W.E. Kerr, Secretary

A. OLD BUSINESS

1. ALBERTA HYDROMETEOROLOGICAL DATA SOURCES AND THE INVENTORY OF UNPUBLISHED DATA:

Mr. Brian McGee, a private information science consultant gave a brief outline of his proposal to identify data sources and unpublished data.

This proposal is as follows:

Overview

A need has been recognized by end users of Alberta hydrological and meteorological data for the identification of sources and unpublished source documents. Computer processible files with the capability of producing directories to these sources have been proposed to attain this goal. What follows is a solicited proposal related to the implementation of such an information system to be maintained by the Alberta Climatological Association.

Objective

To establish within the association:

1. The capability of identifying, encoding and maintaining computer processible citations to sources and source documents.

2. The capability of producing for publication or special projects directories to these sources.

Methodology

1. Determine citation criteria and formats for source and unpublished source documents.

2. Identify responsibility centers for the encoding of entries.

3. Process entries, producing pilot directories for evaluation.

4. Evaluation (a) In terms of satisfying end user requirements.
   (b) In terms of requisite support levels to be supplied by Alberta Climatological Association.

5. Revise steps 1 to 3 where necessary.

6. Produce and distribute publications.

The services provided under this proposal are advisory and project-management related. For each of these steps, and there are many detailed steps within these six, the responsable personnel will be supplied with examples, advice and case histories. In the mechanics of encoding and processing the entries rigorous guidelines of quality control will be developed.

Time/Task

September 1978 is an acceptable target for the production and evaluation of the pilot directories referred to above. This would allow for preparation of the final products to coincide with the end of the calendar year.

Costs

As a general rule it costs $12 to process each citation described in a source identification computer-processible file; 80% of this cost is labor, both intellectual and clerical. Only 20% is computer cost. Since it is understood that the labor will be supplied free and the computer runs at less than commercial rates, the Alberta Climatological Association may produce a product at less than $2.00 an entry.

A discussion followed with several members questioning whether we required a study of this much detail. Keith Hage recommended that only quality controlled data be published or that the type of data should be indicated in such an inventory. Mention was made of a recent inventory completed by Mr. McGee for the Alberta Treasury Bureau of Statistics entitled "Alberta Land Related Data Bases Inventory and Index". Several persons present agreed to sound out their agency concerning the need for such an inventory, and it was recommended that each agency representative interested in the project should contact Elliot Kerr or the Executive with their proposals. The new Executive would then decide what action to follow.

2. ALBERTA CLIMATOLOGICAL ASSOCIATION PROPOSED GOALS

The executive proposed the following goals and constitution to the membership present at the 1978 annual meeting:

ALBERTA CLIMATOLIGICAL ASSOCIATION CONSTITUTION

1. The group shall be known as the Alberta Climatological Association.

2. The aims of the Association shall be to promote the study and development of climatology in Alberta for the public benefit, and in furtherance of this object and no other purposes the Association shall:

(i) facilitate the ongoing exchange and dissemination of climatological information;

(ii) promote the publication of Alberta climatic information and data where needs exist;

(iii) identify the climatological needs of various users and explore ways of meeting these needs;

(iv) provide avenues of contact and co-operation between climatologists themselves and between climatologists and workers in other disciplines;

(v) promote these aims by any other appropriate means.

3. Membership shall be open to anyone interested in furthering the aims of the Association and in participating in its activities. Application for membership shall be submitted to the Secretary for approval by the Association's Executive and confirmation by the Annual General Meeting.

4. The Association's Executive shall consist of four officers. The Executive shall have the power to co-opt one or two additional members as appropriate for specific purposes.

5. The Officers of the Executive shall be:

(i) Chairman;

(ii) Secretary;

(iii) two Directors

Each officer shall be elected for a period of two years, two officers retiring each year. Immediate re-election for one further two-year period shall be permitted.

6. Election of officers of the Executive shall take place at the Annual General Meeting. The agenda of the Annual General Meeting shall be circulated to the membership of the Association at least four weeks beforehand and nominations to the Executive invited.

7. The functions of the Association's Executive shall include:

(i) administering the Association's affairs, and acting on its behalf between meetings;

(ii) organizing meetings;

(iii) calling an Annual General Meeting and any Extraordinary General Meetings that may be deemed necessary.

8. This Constitution can be changed only by a two-thirds majority of those present and voting at an Annual General Meeting, and provided that the membership has been notified of the proposed changes at least four weeks in advance of the Annual General Meeting.

After some discussion, Don Laverty moved that we adopt the proposed goals as our constitution. This motion was seconded by Joe Kotylak. A majority voted in favor, nobody voted against the motion, 4 persons abstained.

B. NEW BUSINESS

1. A. Laycock moved and J. Kotylak seconded that the agency reports should continue to be written and/or presented annually. This motion was carried by all those present.

2. E.Kerr commented that items of new business and recommendations should whenever possible be submitted in writing to the executive at least 1 month prior to the annual meeting.

C. ELECTION OF OFFICERS

The executive stepped down and Richmond Longley was asked to chair the meeting for the election of officers. Don Laverty recorded the proceedings.

Chairman--John Powell was nominated. It was moved and seconded that nominations cease. John indicated that he would serve for 1 year only as chairman. The motion was carried by all those present.

Secretary--Elliot Kerr was nominated; however, he declined to run. Ron Whistance-Smith was nominated and seconded to run. Keith Leggat was nominated and seconded to run. It was moved and seconded that nominations cease and the two candidates were asked to leave the room for a show of hands vote. Keith Leggat was voted the new secretary of the A.C.A. for a 2-year term.

Directors--Ron Whistance-Smith, Elliot Kerr and Ben Janz were nominated and seconded to run as director. E. Kerr and B. Janz indicated they would only stand for a 1-year term. It was moved and seconded that nominations cease and the three candidates left the room for a show of hands vote. Ron Whistance-Smith and Ben Janz were voted the new directors of the A.C.A.; Ron for a 2-year term and Ben for a 1-year term.

The new 1978 A.C.A. executive is as follows:

Chairman--John M. Powell 435-7333 (7210)

(1-year term)
Northern Forest Research Centre
Fisheries and Environment Canada
5320 - 122 Street
Edmonton, Alberta
T6H 3S5

Secretary--Keith Leggat 427-8515

(2-year term)
Alberta Energy and Natural Resources
3 rd Floor, North Tower, Petroleum Plaza
9945 - 108 Street
Edmonton, Alberta
T5K 2C9

Directors--Ron Whistance-Smith 432-4760

(2-year
University of Alberta, Dept. of Geography
Henry Marshall Tory Building
Edmonton, Alberta
T6G 2H4

Ben Janz 437-1250

(1-year term)
Atmospheric Environment
Fisheries and Environment Canada
6325 - 103 Street
Edmonton, Alberta
T6H 5H6

Recognition was extended to Elliot Kerr and John Powell for their services to the association in the past 2 years, and to Conrad Gietz and Ben Janz for their role on the Executive during the past year.

The annual A.C.A. meeting was adjourned at 4:30 p.m.

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